Jubba Environmental and Socioeconomic Studies

VOLUME II: ENVIRONMENTAL STUDIES

JESS *Jubba Environmental and Socioeconomic Studies*

Daraasaadka Dooxada Jubba

A project of • Ministry of National Planning and Jubba Valley Development • United States Agency for International Development • Associates in Rural Development, Inc.

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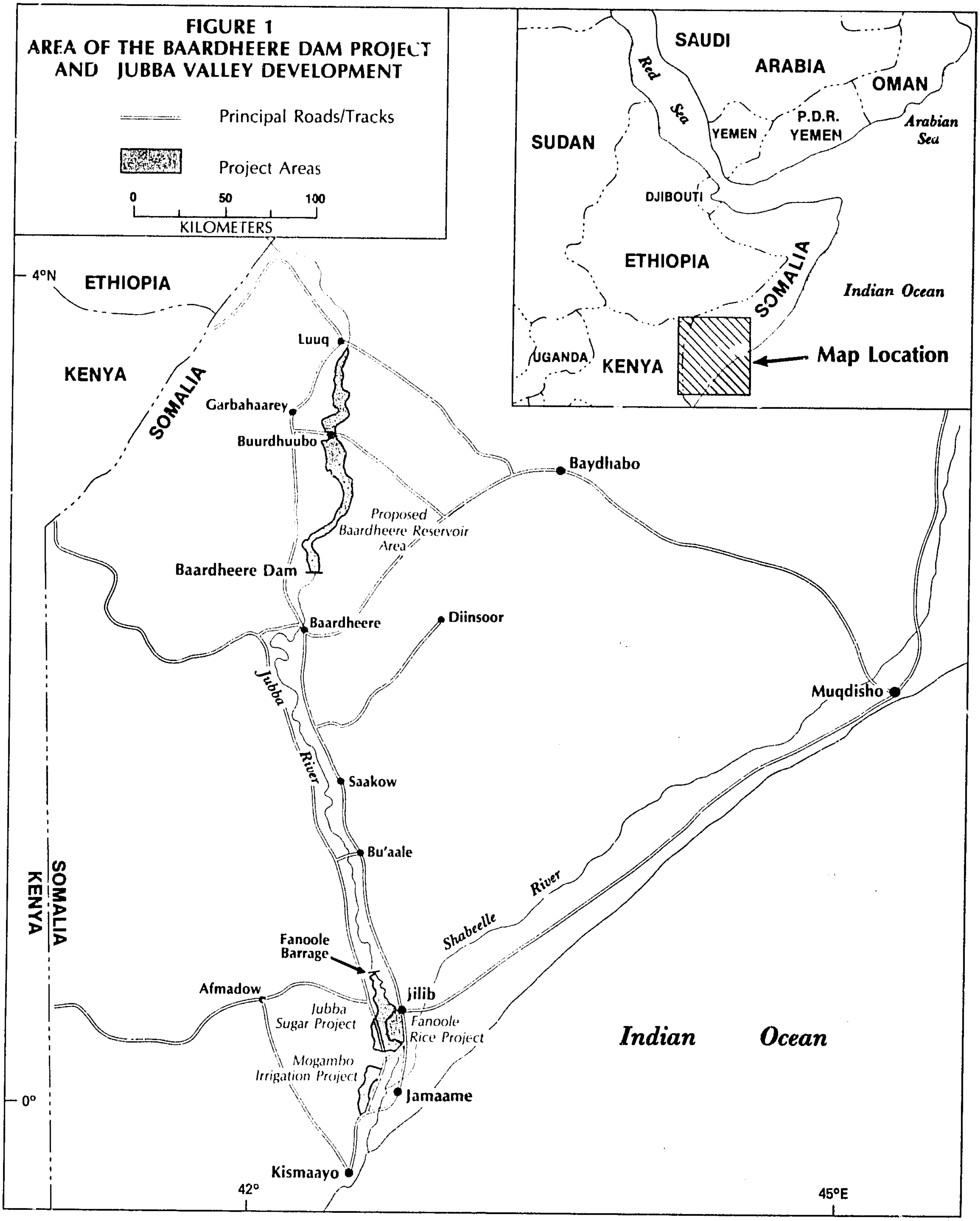
FIGURE 1
AREA OF THE BAARDHEERE DAM PROJECT
AND JUBBA VALLEY DEVELOPMENT
Principal Roads/Tracks
Project Areas
0
50
100
KILOMETERS
SAUDI
ARABIA
OMAN
Red Sea
YEMEN
P.D.R.
YEMEN
Arabian Sea
SUDAN
DJIBOUTI
ETHIOPIA
SOMALIA
Indian Ocean
UGANDA
KENYA
Map Location
4°N
ETHIOPIA
KENYA
SOMALIA
Luuq
Garbahaarey
Buurdhuubo
Baydhabo
Proposed
Baardheere Reservoir
Area
Baardheere Dam
Baardheere
Diinsoor
Jubba
River
Muqdisho
Saakow
Bu'aale
SOMALIA
KENYA
Shabeelle River
Fanoole
Barrage
Afmadow
Jilib
Jubba
Sugar Project
Fanoole
Rice Project
Indian Ocean
Mogambo
Irrigation Project
0°
Jamaame
Kismaayo
42°
45°E

Jubba Environmental and Socioeconomic Studies (JESS) were part of the Jubba Development Analytical Studies Project (JuDAS), implemented in southern Somalia by the U.S. Agency for International Development (USAID) and Ministry of National Planning and Jubba Valley Development (MNPJVD) of the Government of the Somali Democratic Republic (GSDR). Associates in Rural Development, Inc. (ARD), of Burlington, Vermont, provided technical assistance and project management for JESS under USAID contract number AFR-0134-C-00-5047-00. The JuDAS Project also included a soils and land-use classification project, completed in 1987 by the U.S. Bureau of Reclamation (USBR), and a long-term training component administered by USAID. In addition, the Board on Science and Technology for International Development (BOSTID) of the National Academy of Sciences (NAS) provided advisory services to USAID and MNPJVD under JuDAS.

JESS began in September 1985 and ended in March 1989 with publication of this final report. It was carried out as a three-phase project to collect environmental and socioeconomic data in Somalia's Jubba Valley—the site of proposed development of a large hydroelectric dam with the following characteristics:

Specifications of Proposed Buardheere Dam and Reservoir[1]

Installed generating capacity	105 mw
Dam height	75 m
Dam length	609 m
Elevation at dam crest	144 masl
Reservoir water level	
min. normal operation (at penstocks)	128 masl
max. normal operation	142 masl
max. exceptional (flood)	148 masl
max. normal fluctuation[2]	14 m
Reservoir characteristics[3]	
length	160 km
surface area	310 km^2
volume	3,400 million m^3
Discharge[4]	
annual monthly mean	152 cumecs
max. operation	203 cumecs
design flood	750 cumecs
Average residence time for inflows during max. normal operation	191 days

1. Values are approximate, based on preliminary design (ELC 1985).
2. Drawdown in typical year is 7 m. *3. Approximated for 142 masl.*
4. Information updated by AHT (personal communications, 1988).

Complementary to construction of the dam, various plans are being prepared for subsequent development of irrigated agriculture in the middle and lower Jubba Valley. Numerous environmental and socioeconomic changes will occur with dam construction, filling of the reservoir, infrastructural enhancement, and intensification of agriculture.

The JuDAS Project had two major purposes:

- **to gather necessary information on soils/land use and socioeconomic and environmental factors to be incorporated into a master planning process for Jubba Valley development; and**
- **to provide MNPJVD with technical support and training.**

As one of its objectives was to assist Jubba Valley development, JESS continuously supplied results from its socioeconomic and environmental studies to a master planning team assigned to MNPJVD. The team was financed by the German Agency for Technical Cooperation (GTZ) and staffed through Agrar- und HydroTechnik, GMbH (AHT). JESS also provided practical, informal training for its Somali counterparts and served in an advisory capacity to USAID and MNPJVD on long-term training. The three phases of JESS are described below.

Phase I was a six-month period from September 1985 to March 1986 that was used to review and assemble data from existing literature, studies, and ongoing programs in the project area. Based on information gaps and an overview of the area, JESS prepared a work plan to conduct appropriate baseline and problem-specific studies concerning environmental and socioeconomic conditions in the Valley.

Phase II lasted for 24 months, from April 1986 to March 1988, and focused on intensive field data collection, including two longer-term baseline studies (on socioeconomics and terrestrial ecology) and various separate short-term investigations on a variety of environmental and socioeconomic factors relevant to Jubba Valley development.

Phase III, from April 1988 to March 1989, consisted of data analysis, synthesis, interpretation of research results and report writing. This phase culminated in the present comprehensive final report which presents pertinent research findings, and recommendations for enhancing the positive effects and avoiding or mitigating negative impacts of dam construction and operation, as well as development of the Jubba Valley.

The main vehicle for NAS/BOSTID's interaction with the JESS team, USAID and MNPJVD, was a series of workshops/technical advisory meetings. The first workshop, which was held in Somalia at the end of January 1986 and included a field trip to the Jubba Valley, was organized to give direct input to the design of JESS Phase II studies. This workshop was followed up with a two-day meeting in April at ARD's offices in Burlington, Vermont with the panel reviewing the JESS draft Phase II work plan. Beginning in late September 1986, a one-week workshop was held in Kenya to visit water development projects in the Athi and Tana River basins, to review and discuss lessons learned and avoid problems which could occur in similar developments in the Jubba Valley. A final workshop was held in Coolfont, West Virginia in May 1987, and was used to review progress of JESS research, after more than a year of field activities. In late 1988 and early 1989, panel members also reviewed earlier drafts of final reports on longer-term research included in these volumes. During implementation of JESS, the following scientists participated on NAS's Jubba Valley Advisory Panel:

Thayer Scudder, Ph.D. (Chairman), Director, Institute for Development and Anthropology, California Institute of Technology

Claudia Carr, Ph.D., Professor, Department of Conservation and Resource Studies, University of California

Lee Cassanelli, Ph.D., Associate Professor of History, University of Pennsylvania

Charles W. Howe, Ph.D., Professor of Economics, University of Colorado

John M. Hunter, Ph.D., Professor of Community Health Sciences & Professor of Geography, Michigan State University

Walter J. Lusigi, Ph.D., United Nations Educational, Scientific and Cultural Organization, Nairobi

Peter Rogers, Ph.D., Professor, Division of Applied Sciences, Harvard University

Berekat H. Selassi, Ph.D., Professor, Howard University & Georgetown University

Michael Dow, Ph.D., Associate Director, BOSTID

Jeffrey A. Gritzner, Ph.D., Senior Program Officer, BOSTID

Susan M. Piarulli, Program Assistant, BOSTID

The environmental studies proposed in the Phase II work plan were oriented around a longer-term effort, *Terrestrial Ecology Baseline Studies* (TEBS), due to a shift in focus to the study of vegetation and land-use changes in riverine and floodplain areas associated with the Jubba River. JESS' tropical ecologist led the TEBS effort with support from various consultants in forestry, botany, wildlife management, and remote sensing.

The longer-term *Socioeconomic Baseline Studies* (SEBS) were planned around a comprehensive household/family survey of randomly selected villages and towns in the Jubba Valley. The survey covered many aspects, such as a demographic profile, family resources management and allocation, health and nutrition, social services, land tenure, and resources-use rights. SEBS later had an additional special emphasis through a *Women's Baseline Study* (WBS), used to assess issues related to the role of women in development. A separate initiative was also undertaken for a brief survey to assess marketing and price structures for agricultural commodities. These studies were directed by JESS anthropologists and the JESS socioeconomist.

Thirty short-term environmental and socioeconomic investigations were also carried out during Phase II to fill gaps in the technical information for scientifically narrow areas. Reports emanating from these studies and project-management reporting are listed on the following page. It should be understood that JESS short-term consultants worked, in most cases, in isolation from each other and produced certain findings and recommendations that were not comparable. While JESS has reproduced the findings and recommendations of each of these scientists as reported, Volume I (*Executive Report*) and reports based on JESS longer-term studies (TEBS and SEBS) represent the most comprehensive assessment of the overall JESS effort: these reports consider and, in most cases, summarize the findings of other investigations.

With the final design and specifications of the proposed Baardheere Dam and development projects for the Jubba Valley still undergoing study and revision, the need for JESS environmental and socioeconomic assessments was more generic. The flexibility and responsiveness of USAID project management and ARD's field team permitted various studies to be revised or rescheduled based on the realities of an evolving development project.

Complete List of JESS Reports.

Phase I Review and Phase II Work Plan for the JESS Project; July 1986. Report No. 1.

Bibliography for the JESS Project; July 1986. Report No. 2.

JESS Manpower and Training Assessment; Richard Z. Donovan; July 1986. Report No. 3.

Jubba Environmental and Socioeconomic Studies First Annual Report; November 1986. Report No. 4.

JESS Interim Report on Health Impacts of Design Alternatives for Proposed Baardheere Dam; William R. Jobin; November 1986. Report No. 5.

JESS Interim Report on Health Consequences of Design Criteria for Water Supply and Sanitation in New and Resettled Communities; William R. Jobin; November 1986. Report No. 6.

JESS Consultancy Report on Water Quality and Public Health Engineering; William R. Jobin; November 1986. Report No. 7.

JESS Interim Report on Cultural Heritage Sites in Proposed Baardheere Reservoir Area; Steven A. Brandt; November 1986. Report No. 8.

Interim Report on Vegetation Survey of the Jubba Valley; Christopher F. Hemming; October 1986 Report No. 9.

JESS Phase I Design Studies; William R. Jobin, Peter A. Bloch, James C. Riddell, Curt R. Schneider and James F. Ruff; July 1986 Report No. 10.

JESS Second Consultancy Report on Water Quality and Public Health Engineering; William R. Jobin; January 1987. Report No. 11.

JESS Fisheries Consultancy I Report; Earl K. Meredith; June 1987. Report No. 12.

JESS Interim Report on Aerial Photography Interpretation; Eric Trump; June 1987. Report No. 13.

JESS Preliminary Report on Aerial Survey of the Jubba River; R. Murray Watson; June 1987 Report No. 14.

JESS Third Consultancy Report on Water Quality and Public Health Engineering; William R. Jobin; July 1987. Report No. 15.

JESS Working Paper: Pre-construction Concerns with the Baardheere Dam; R. E. Tillman; November 1987. Report No. 16.

JESS Interim Report: Riverine Forests of the Jubba Valley, Issues and Recommendations for Conservation; Ian Deshmukh; November 1987. Report No. 17.

JESS Interim Report: Mapping Jess Research Results; Paul Dulin; October 1987. Report No. 18.

JESS Interim Report: Survey of Palearctic Migrant Birds in Somalia's Middle and Lower Jubba Valley; David Pearson; October 1987. Report No.19.

JESS Interim Report: Long-term Environmental and Socioeconomic Monitoring; Paul Dulin; October 1987. Report No. 20.

JESS Report on Water Balance and Sediment Transport in the Jubba River Watershed; Donald Alford; August 1987. Report No. 21.

JESS Interim Report: Data Management and Analysis; Leonard A. Malczynski; November 1987. Report No. 22.

JESS Interim Report: Vegetation Survey of Baardheere Reservoir Zone; Christopher F. Hemming; August 1987. Report No. 23.

Jubba *Environmental and Socioeconomic Studies: Second Annual Report;* December 1987. Report No. 24.

JESS Interim Report: Second Survey of Palearctic Migrant Birds in Somalia's Middle and Lower Jubba Valley; David Pearson; December 1987. Report No. 25.

JESS Report on Cultural Heritage Survey of the Proposed Baardheere Reservoir; Steven A. Brandt and Thomas H. Gresham, with contributions from Robert Benson, Nanny Carder, and James Ellison; June 1988. Report No. 26.

JESS Report on Forestry in the Jubba Valley; T. J. Synnott; March 1988. Report No. 27.

JESS Report on Biological Limnology of the Jubba River; Steven G. Njuguna and Francis M. Muthuri; March 1988. Report No. 28.

JESS Report on Malaria Endemicity in the Lower Jubba Region; Marian Warsame Yusuf; April 1988. Report No. 29.

Phase II Report and Phase III Work Plan; March 1988. Report No. 30.

JESS Report on Land Tenure Dynamics in the Jubba Valley; James C. Riddell; May 1988. Report No. 31.

JESS Report on Fisheries; Earl K. Meredith; June 1988. Report No. 32.

JESS Report on Pastoral Economy and Seasonal Livestock Movements in the Jubba Valley; Jorg Janzen; August 1988 Report No. 33..

JESS Report on Land Tenure in the Middle Jubba Valley: Issues and Policy Recommendations; Catherine Besteman and Michael Roth; August 1988. Report No. 34.

JESS Report on Economic History of the Lower Jubba: Implications for Development Planning; Ken Menkhaus; August 1988. Report No. 35.

JESS Summary Report on Bilharzia and Distribution of Bulinus Abyssinicus *in the Jubba Valley;* Ralph Klumpp; August 1988. Report No. 36. (Included in *JESS Report No 39.)*

JESS Report On Aerial Resource and Land-use Surveys in the Jubba Valley; Murray Watson and Jennifer Nimmo; May 1988. Report No. 37.

JESS Report on Upper Jubba Watershed Performance; Tom Hart; August 1988. Report No.38.

JESS Report on Water Quality and Public Health Aspects; William Jobin; August 1988. Report No. 39.

Throughout the life of the project, JESS cooperated with other projects and ministries, often exchanging data at informal and formal levels. Such exchanges always took place with full knowledge of MPNJVD and USAID. The following descriptions illustrate the wide range of contacts established during the project.

Land Tenure Center (LTC) of the University of Wisconsin — From the outset, JESS encouraged a close working relationship with two LTC researchers engaged in land tenure assessments in middle Jubba Valley. JESS assisted with logistics, personnel, and advice, and received considerable support in terms of data collection. LTC researchers routinely visited JESS team members and participated in some team meetings to exchange information whenever they returned to Muqdisho from their fieldwork. The JESS team made attempts to visit LTC field sites in the Jubba Valley whenever their activities were in proximity to those sites. As a result of this close liaison, LTC produced a report on land-tenure issues in the Jubba Valley for JESS.

Settlement and Resource Systems Analysis (SARSA) — JESS established close working relationships with the SARSA team. This one-year project studied rural-urban linkages within an approximate 100 km around Kismaayo. Several joint team meetings were held, data were freely exchanged, and both teams made an effort to coordinate their work and standardize data collection to avoid overlapping efforts.

Livestock Marketing and Health (LMH) Project — While it was not necessary to hold joint team meetings, JESS and LMH freely exchanged data on livestock practices in the Jubba Valley. Members of both teams routinely attended consultant debriefings of common interest.

Central Rangelands Development Project (CRDP) — While JESS and CRDP had different geographic venues of interest, information on numerous shared sectoral and technical activities was commonly exchanged between them. Terrestrial ecologists from both teams pooled their resources at times for taxonomic assistance, and the social scientists compared survey techniques. To a limited degree, the projects provided each other with assistance in logistics.

British Forestry Project — The JESS ecologist had numerous meetings with members of the British Forestry Project concerning vegetation and land-use mapping.

World Concern — JESS had two unique experiences with World Concern. During the floods in May 1987, World Concern asked JESS to assist with rescue operations near Luuq. Refugee fields had been severely flooded, and many irrigation pumps were underwater. JESS responded with a loan of a boat and two boat pilots, which enabled World Concern to rescue a majority of refugee irrigation pumps before they rusted beyond repair. In a second instance, World Concern volunteered to perform an anemia survey in Jilib after JESS was forced to cancel a similar study with the Refugee Health Unit (RHU) of the National Refugee Commission. Under this agreement, JESS loaned World Concern hemoglobin spectrophotometers that had been purchased for the RHU study in exchange for the data collected between March and September 1988.

Halcrow-Fox Associates (HFA) — HFA conducted a study for MNPJVD concerning resettlement of the population currently situated in the area of the proposed reservoir. JESS was HFA's first contact in Somalia concerning information and logistic support. During 1987 and early 1988, a very close working relationship developed between the two groups. Incoming HFA consultants were routinely briefed by the team before the onset of their fieldwork. With the permission of MPNJVD, HFA relied heavily on JESS equipment for its fieldwork.

World Bank — One of the principal objectives of JESS is to make its research results available to potential donors in order to meet requirements for financial and development plans. JESS provided considerable assistance to a World Bank preappraisal mission for the Baardheere Dam regarding environmental and resettlement issues, organized and implemented a field trip to the reservoir area for the World Bank team and provided liaison between MNPJVD and the bank in terms of archaeology studies. Copies of all JESS reports have been continuously supplied to the Bank during all phases of the project.

United Nations High Commissioner for Refugees (UNHCR) — JESS held several meetings with resettlement teams from UNHCR. Reports and field notes were made available to these teams as well as remote sensing products developed during JESS.

Somali Academy of Science (SOMAC) — In its studies on archaeology and land tenure, JESS worked with counterparts in an attempt to encourage wider participation of Somali scientists.

National University of Somalia (NUS) — JESS utilized expertise from the faculties of medicine and chemistry to conduct studies in epidemiology, water quality, limnology, and land tenure. JESS was instrumental in arranging the turnover of a USBR atomic-absorption spectrophotometer and other laboratory equipment to NUS before the end of the JuDAS project.

Ministry of Health (MOH) — JESS worked closely with MOH in planning and implementing epidemiology surveys in the lower Jubba Valley. MOH supervisors and technicians conducted this study with JESS financing, logistics, and technical assistance.

World Health Organization (WHO) — JESS also worked closely with WHO officials in planning and implementing the epidemiology surveys. Based on this liaison, surveys were conducted under standards endorsed by WHO. Reports on study results were presented to WHO at an individual debriefing.

Ministry of Fish and Marine Resources (MFMR) — JESS maintained a close relationship with MFMR throughout its studies in Phase II. Personnel from this ministry used JESS boats and equipment to conduct freshwater fisheries research in two Somali rivers and assist fishery cooperatives, one on each river.

Baardheere Dam Technical Committee — The JESS team leader was a member of this committee at the invitation of the Baardheere Dam Project.

Agrar- und HydroTechnik — According to USAID's JuDAS project paper and the scope of work in ARD's technical assistance contract, the purpose of JESS was to generate environmental and socioeconomic information necessary for the creation of a master plan for Jubba Valley development. MNPJVD has overall authority for coordination of the master plan, while GTZ is financing technical assistance through the AHT master planning team. JESS and master planning efforts were to be coordinated in a timely manner by MNPJVD. However, JESS and master plan schedules were *not* in synchronization. Because these projects were funded, negotiated, designed, and planned by different donors, their schedules were not coordinated.

JESS' Phase II began in April 1986 and ended in March 1988. Outputs of that phase were to be used by master planners for preparation of *Master Plan Volume 1: Present Stage of Development*, but this volume was released in December 1987.

AHT's *Master Plan Volume 2: Regional Development Strategy* was released in July 1988. It briefly defines a series of alternative development projects for the Jubba Valley. While AHT took advantage of JESS' Phase II baseline information, analyses of baseline studies data were not completed until the end of Phase III, with the release of the preliminary drafts of the JESS final report in August 1988. AHT's *Master Plan Volume 3: Jubba Valley Development Investment Program* was originally scheduled for release in December 1988, before the planned presentation of the JESS final report.

With these timing and scheduling constraints, JESS staff had to open informal channels of information exchange with the AHT master planning team. Throughout Phase II, USAID, MNPJVD, AHT, and a wide audience of reviewers were kept informed of JESS activities and research results through the release of timely interim reports prepared by consultants and long-term JESS staff. In addition, 28 monthly reports, prepared during the implementation of Phases I and II, were widely distributed in Somalia and elsewhere. SEBS data bases and other research materials, including aerial photographs, water-quality sampling data, field-trip notes, vegetation maps and the results of aerial censuses, were turned over to the master planning team as a matter of course. Various debriefings were presented by JESS consultants after completing their short-term investigations. JESS/AHT interteam meetings, and informal one-on-one collaboration between JESS staff and AHT consultants were mutually beneficial to both teams' efforts in data collection.

As intended in the design of JESS, information collected during Phase II was processed and analyzed during Phase III. Full reports were prepared for both of the longer-term baseline studies (SEBS and TEBS). These, in combination with the group of short-term, intermittent investigation reports, complete JESS' contribution of environmental and socioeconomic studies relative to proposed development in Jubba Valley development. Recommendations are included for enhancement of the beneficial aspects and mitigation and/or avoidance of negative impacts associated with proposed developments, while guidelines for environmental and socioeconomic monitoring take into account the inherent limitations of Somalia's sociopolitical and economic constraints.

This final report was prepared from direct analyses of JESS research and reviews of other data and literature relevant to Jubba Valley development. The ***Executive Report (Volume I)*** synthesizes available information concerning the environmental and socioeconomic implications of construction of the Baardheere Dam and subsequent development of the Jubba Valley. All other JESS reports on long-term baseline studies and short-term investigations are annexed to the *Executive Report:* **Volume II (Environmental Studies), Volume III (Socioeconomic Studies),** and **Volume IV (Bibliography).**

Copies of research materials, including principal data bases and code books, tabular data, field maps, site descriptions, photographic slides, and aerial photographs, were prepared and transferred to the five *JESS Data Repositories*—MNPJVD, USAID/Somalia, USAID/REDSO/ESA, USAID/Washington, and ARD/Burlington. A list of repository materials is included in Volume IV.

As of 31 March 1989, the JESS technical assistance team included:

- *Robert "Gus" Tillman*, Ph.D.—team leader, environmental assessment;
- *Kathryn Craven*, Ph.D.—socioeconomics;
- *Ian Deshmukh*, Ph.D.—ecology, vegetation, and wildlife;
- *James Merryman*, Ph.D.—anthropology;
- *Nancy Merryman*, Ph.D.—women's issues, administrative coordination;
- *Marie Tillman*—data center coordination, bibliographer; and
- *Robert Ondrusek*—information management.

Two personnel changes occurred during the three and one-half years of the project. Dr. E. Drannon Buskirk served as team leader from November 1985 until February 1987, when Dr. Tillman assumed this role. Mr. Richard Donovan was ARD's home-office project manager from the inception of the project until May 1987. Mr. Paul Dulin then managed JESS until completion of the contract and coordinated the preparation of the final report.

Throughout the life of the project, ARD home-office staff participated in various aspects of project management, administration, technical assistance and logistics. Dr. George Burrill, ARD's president, maintained overall management responsibility for the contract. Mr. Richard Hart, the firm's business manager, provided administrative coordination. Mr. Kevin Fitzcharles assisted with project management, hiring consultants, and handling logistics. Mr. Ross Bryant and Mr. Ted O'Shaughnessy supervised procurement. Dr. Alfred Waldstein provided intermittent technical assistance in the preparation of the SEBS final report. Star Albright and Clair Dunn were responsible for editorial production of the final report.

For USAID/Somalia, Sally Patton was project manager from the inception of JuDAS until July 1987. Weston Fisher then managed the project until its completion. Both gave generously of their time and were instrumental in the implementation of this complex project.

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A	A.A.P.G.	American Association of Petroleum Geologists
	ACMRR	Advisory Committee of Experts on Marine Resources Research
	ADC	Agricultural Development Corporation
	AETFAT	Association pour l'Etude Taxonomique de la Flore d'Afrique Tropicale
	AFIS	Administrazione Fiduciaria Italiana della Somalia
	AHT	Agrar-und HydroTechnik, GMbH
	AID	U.S. Agency for International Development
	AIDS	acquired immune deficiency syndrome
	AIRD	Associates for International Resources and Development
	ARD	Associates in Rural Development, Inc.
	ARIS	Aerial Resource Inventory System
	ARTEMIS	African Real-Time Environmental Monitoring using Imaging Satellites
	ASCE	American Society of Civil Engineers
	ASD	Air Survey and Development, Inc.
	ASEAN	Association of Southeast Asian Nations
	ASGA	Association des Services Geologiques Africains
	AVHRR	Advanced Very High Resolution Radiometer
B	B.P.	before present (present being 1952, when radiocarbon dating became commercially available)
	BDP	Baardheere Dam Project
	BFPS	British Forestry Project, Somalia
	BMZ	Bundesministerium fuer Wirtschaftliche Zusammenarbeit
	BNA	Blue Nile Associates
	BOSTID	Board on Science and Technology for International Development
C	ca.	*circa* (approximately)
	CAS	catch assessment survey
	CDA	Cooperation for Development in Africa
	CEC	Commission of the European Communities
	CIFA	Committee for Inland Fisheries of Africa
	CILSS	Comite Permanent Interetats de Lutte contre la Secheresse dans le Sahel
	CISP	Comitato Internazionale per lo Sviluppo dei Popolo
	CITES	Convention on International Trade in Endangered Species
	CPCA	Comite des Peches Continentales pour l'Afrique (FAO)
	CPUE	catch per unit of (fishing) effort
	CRDP	Central Rangelands Development Project
	cumecs	cubic meters per second
	CV	coefficient of variation
	CWS	Church World Services

D	D.V.W.K.	German Association for Water Resources and Land Improvement
	DAP	disodium ammonium phosphate
	DC	district commissioner
	DLWR	Department of Land and Water Resources
E	EC	electrical conductivity
	EC25	electrical conductivity at 25°C.
	EEC	European Economic Community
	EIFAC	European Inland Fisheries Advisory Commission
	ELC	Electroconsult
	EMRO	Eastern Mediterranean Regional Office (WHO)
	ENC	Ente Nazionale Commercio
	ERDAS	Earth Resources Data Analysis Systems, Inc.
	ERP	European Recovery Programme
	ERS	Economic Research Service
F	FAO	Food and Agriculture Organization of the United Nations
	FBS	fish biology sampling
	FEWSD	Food Early Warning System Department
	FR	Forest Reserve
	FSP	fish sampling program
G	GDP	Gross Domestic Product
	GJV	Greater Jubba Valley
	gm	gram
	gn	gill net
	GNP	gross national product
	GOE	Government of Ethiopia
	GSDR	Government of the Somali Democratic Republic
	GTZ	German Agency for Technical Cooperation
H	ha	hectare
	hl	hook line
	HMSO	Her Majesty's Stationery Office
	hn	hoop net
I	IBRD	International Bank for Reconstruction and Development (World Bank)
	ICA	International Center for Aquaculture
	ICE	Instituto Nazionale per Il Commercio Estero
	ICOLD	International Commission on Large Dams
	ICRAF	International Council for Research in Agroforestry
	ICTA	Instituto Ciencia y Tecnología Agrícolas (Guatemala) (Institute of Agricultural Science and Technology)
	IDC	International Development Corporation
	IFAD	International Fund for Agricultural Development

	IFO	Institut fuer Wirtschaftforschung
	IIASA	International Institute for Applied Systems Analysis
	IIED	International Institute for Environment and Development
	IIIC	International Irrigation Information Centre
	ILCA	International Livestock Center for Africa
	ILO	International Labour Office
	IMF	International Monetary Fund
	IPAL	Integrated Project on Arid Lands
	IPM	Integrated Pest Management
	ISNAR	International Service for National Agricultural Research
	ITC	International Institute for Aerial Survey and Earth Sciences
	ITE	Institute of Terrestrial Ecology
	IUCN	International Union for Conservation of Nature and Natural Resources
	IWR	Institute for Water Resources
J	JASPA	Jobs and Skills Programme for Africa
	JESS	Jubba Environmental and Socioeconomic Studies
	JSP	Juba Sugar Project
	JuDAS	Jubba De' opment Analytical Studies
K	KFW	Kreditanstalt fur Wiederaufbau, German Aid Funding Organization
	kph	knots per hour
	KREMU	Kenya Rangeland Ecological Monitoring Unit
L	LDC	less developed countries
	ln	natural logarithm
	LRDC	Land Resources Development Centre (now part of TDRI, Tropical Resources Development Institute)
	LSA	Later Stone Age
	LSU	Land System Units
	LWR	Department of Land and Water Resources, Ministry of Agriculture
M	MAB	Man and the Biosphere Programme
	MARC	Monitoring and Assessment Research Centre
	MARS	Market Study
	masl	meters above sea level
	maxcpue	maximum catch per unit of effort
	MCC	Mennonite Central Committee
	mcm	million cubic meters
	mcpue	mean catch per unit of effort
	MEI	morphoredaphic index
	MFMR	Ministry of Fisheries and Marine Resources
	mincpue	minimum catch per unit of effort
	MIP	Mogambo Irrigation Project

MJVD	Ministry of Jubba Valley Development
MMP	Sir Malcolm MacDonald and Partners, Ltd.
MNPJVD	Ministry of National Planning and Jubba Valley Development (formerly MJVD)
MOA	Minister of Agriculture
MOH	Ministry of Health
MSA	Middle Stone Age
MSY	maximum sustainable yield

N

n.d.	no date
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NERC	Natural Environment Research Council
NES	National Environment Secretariat
NESDIS	National Environmental, Satellite, Data and Information Service
NHWL	Normal High Water Level in Reservoir
NLITH	number of lithics found in a density sample
NOAA AVHRR	National Oceanic and Atmospheric Administration, Advanced Very High Resolution Radiometry
NRA	National Range Agency
NTTCP	National Tsetse and *Trypanosomiasis* Control Project
NUS	National University of Somalia

O

OAS	Organization of American States
ODA	Overseas Development Administration
ODI	Overseas Development Institute
ODU	Overseas Development Unit
OECD	Organization for Economic Cooperation
OEF	Overseas Education Fund
OMVG	Organization pour la Mise en Valeur du Fleuve Gambie
ORS	oral rehydration salts
ORT	oral rehydration therapy

P

PA18	Piper 18 (Super Cub) airplane
pET	potential evapotranspiration
PHC	Primary Health Care
PPC	Bureau for Program and Policy Coordination
ppm	parts per million
PVO	Private and Voluntary Organizations

R

r^2	coefficient of determination in regression analysis
RAO	Regional Agricultural Officer
REDSO	Regional Economic Development Services Offices
RGS	river gauging stations
RMR	Resource Management and Research, Ltd.

S	SAIS	Studio Architetti Ingegneri Specializzati
	SAREC	Swedish Agency for Research Cooperation with Developing Countries
	SCOPE	Scientific Committee on Problems of the Environment
	SDR	Somali Democratic Republic
	SEBS	Socioeconomic Baseline Studies (of JESS)
	SES	Somali Ecological Society
	SG	specific gravity
	SIATSA	Tropical Agricultural Research Services
	SIDA	Swedish International Development Agency
	SLR	single lens reflex camera
	SMP	Somali Marine Projects
	SOGREAH	Societe Grenobloise d'Etudes et d'Applications Hydroliques
	SOMAC	Somalia Academy of Arts and Sciences
	SRC	Synergic Resources Corporation
	SRCS	Somali Red Crescent Society
	SRP	Somalia Research Project (University College of London)
	SRS	Southern Rangelands Survey
	SSh	Somali shillings
	SWDO	Somali Women's Democratic Organization
T	t	metric ton, metric tonne
	TAMS	Tippetts-Abbett-McCarthy-Stratton
	TARDA	Tana and Athi River Development Authority
	TDS	total dissolved solids
	TEBS	Terrestrial Ecology Baseline Studies (of JESS)
	TLU	Tropical Livestock Unit
	TSS	total suspended sediment
	TVA	Tennessee Valley Authority
U	UN	United Nations
	UNCTAD	United Nations Conference on Trade and Development
	UNDP	United Nations Development Programme
	UNEP	United Nations Environment Programme
	UNESCO	United Nations Educational, Scientific, and Cultural Organization
	UNHCR	United Nations High Commission for Refugees
	UNICEF	United Nations Children's Fund
	UNIDO	United Nations Industrial Development Organization
	USAID	U.S. Agency for International Development
	USBR	U.S. Bureau of Reclamation
	USDA	U.S. Department of Agriculture
	USEPA	U.S. Environmental Protection Agency
	USGPO	U.S. Government Printing Office

V	VITA	Volunteers for International Technical Assistance, Inc.
W	WASH	Water and Sanitation for Health Project
	WBS	Women's Baseline Study
	WDA	Water Development Agency
	WHO	World Health Organization
	WWF	World Wide Fund for Nature (formerly World Wildlife Fund)
Y	YMCA	Young Men's Christian Association

Throughout this report scientific units follow standard international practice. For example, kg km^{-2} $year^{-1}$ means kilograms per square kilometer per year.

The International Monetary Fund calculated the average official exchange rate for 1987 at 105.6 SSh to the U.S. dollar. The purchasing power parity during the same period, however, was just over 166 SSh to the U.S. dollar.

The following glossary of standard Somali place names and terms used in JESS reports represents a close approximation to Somali pronunciation and orthography. Words in *parentheses* are alternate spellings that are commonly seen, but which JESS feels are non-standard. The spelling of "Jubba" is an obvious example—by far, the most commonly encountered spelling of the river has only one "b," but based on the most common Somali pronunciation of this word, the double "b" spelling is considered standard. Words appearing in *square brackets* indicate another, different Somali or foreign name for the same place. For example, the most common Somali name for the capital is not Muqdisho, Mogadishu, or Mogadiscio, but Xamar (pronounced "hamar").

Place Names

Afgoove
Afmadow
Arbay Cabdi
Baardheere (Bardera, Bardere, Bardhere)
Badhaadhe
Banta
Baraawe (Brava, Barawe)
Baydhabo (Baidoa)
Beledul Kariim
Bidi
Birbiriso
Bu'aale [mistakenly identified on some maps as Dujuuma]
Buulo Maamow
Buur Fuule
Buurdhuubo (Burdubo)
Cabdulle Kakane
Canjeel
Cusbooley
Deex — grazing area between lower Jubba River and the coast
Demo
Dhacar — grazing area in lower Jubba, west of the river
Dhesheeg Radiile
Dhoobey — grazing area east of lower Middle Jubba
Dhesheeg Waamo (Deshek Uamo)
Dujuuma
Faafxadhuun
Fanoole
Fuuma
Gaduudey
Garbahaarey
Golweyn
Gomeeni Yare
Goob Weyn
Gunneyso
Hakaka
Haraawe
Hiloshiid
Hombooy
Honqorre
Hurufle
Iskandariya [Alessandria]
Jabbi
Jamaame [Margherita]
Jilib (Gelib)
Jowarri — grazing area east of upper Middle Jubba and bay
Kalaanje
Kaytooy
Kismaayo (Kismayo, Chisimaio, Kismayu)
Kumbareera
Kumtiire
Kuudka
Libaanga
Libooye
Luuq (Luq, Luk, Lugh, Lugh Ferrandi, Lugh Ganane)
Madiina
Mana Moofa
Manaane
Mardha
Mareerey
Maykoreebe
Mogambo
Mokomane
Moofa
Muqdisho (Mogadishu, Mogadisho, Mogadiscio) [Xamar]
Nafta Quur

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Nasiib Buundo
Nyiireey
Qalaaliyo
Qoraxey
Saakow (Saacow, Sakow)
Sarenley
Sarsaar
Shabeelle
Shangaani
Tansaaniya
Turdho
Wandiid — grazing area east of Saakow; east of Banaada
Webi Jubba (Uebi Juba) [Ganaane] — Jubba River
Xagar Buulo
Yontooy

Houses
aqal - portable nomad hut
baraako - rectangular with tin roof
cariish - rectangular wattle or mud and wattle
hoori - portable nomad hut
mundul - round wattle or mud and wattle
sar - cement or cement-brick house

Measures and Storage
boosto — about 1/24 of a hectare
darab — about 1/4 of a hectare
kintaal — quintal or about 100 kilograms
shood — 1/4 of a suus or .62 to .75 kilograms
suus — 2.5 to 3.0 kilograms
teneg — large ghee tin

Physical Features
bakool — white soils
ceel — well
degaan — "home areas" of pastoralists
dhasheeg (deshek, desheek, dhasheeg) — depression
dhoobey — dark/black clay soils
doonk — inland rainfed soil
dooy — red clay soil
gosha — of the forest
haro — lake
hilo — watering place
jiimo — riverbank
shiid — stone
tog, togga (tug, toog) — seasonal stream
war — manmade pond
webi — river

Politics
beel — subdistrict
guddi — committee
guddoomiye — chairman
madaxweyne — president
nabadoon — peacemaker
sheikh — Islamic religious leader
tuulo — village
xaafad — neighborhood

Seasons
gu' — big rains (April to June)
xagaa — dry season (June to September)
deyr — small rains (October to November)
jiilaal — very dry season (December to February)

Terrestrial Ecology Baseline Studies

prepared by
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This report includes and combines information from *JESS Reports No. 9* – "Interim Report on Vegetation Survey of the Jubba Valley," Christopher F. Hemming, October 1986; *No. 17* – "JESS Interim Report: Riverine Forest of the Jubba Valley, Issues and Recommendations for Conservation," Ian Deshmukh, November 1987; and *No. 23* – "JESS Interim Report: Vegetation Survey of Baardheere Reservoir Zone," Christopher F. Hemming, August 1987. Associates in Rural Development, Burlington, Vermont. Unless otherwise noted, all photographs in this report are by the author.

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This report presents findings of the Terrestrial Ecology Baseline Studies (TEBS) of Jubba Environmental and Socioeconomic Studies (JESS). Long-term studies by the JESS ecologist are incorporated with information from aerial surveys conducted by Resource Management and Research (RMR), a JESS subcontractor, and several JESS short-term consultants. Most analysis is directed at determining the implications of development, particularly construction of Baardheere Dam, on biological resources in the Jubba Valley.

Acknowledgements

A project the scope and length of JESS inevitably depends upon, and is supported by, a large number of people.

USAID project managers for JESS in Somalia were Sally Patton (1985-1987) and Weston Fisher (1987-1989). Both were exemplary in their support and enthusiasm for the project and ARD project staff.

At Ministry of Jubba Valley Development/Ministry of National Planning and Jubba Valley Development (MJVD/MNPJVD), the project was overseen by Minister Habib and a succession of project managers including Cali Warsame Aden, Aweys Xaji Yusuf, Cabdi Cali Macalin, Yasiin Cusman Nur, and Cabdiraxman Islow Maxdalle. Also at the Ministry, JESS collaborated with the master planning team whose technical assistance was provided by Agrar-und Hydrotechnik, GMbH (AHT).

The core TEBS fieldwork team comprised Cabdulqaadir Xaji Ibrahim ("Saab'), Axmed Shariif Ibrahim, Cabdikriin Xasan Nur, and Yusuf Cabdullahi Madhiinba ("Makalangow"). We were usually fed by Cusman Macalin and driven by Maxamed Hared or Cabdulle Gurey. These people, and all JESS staff, performed well beyond the call of duty.

The following provided professional advice and encouragement. Among short-term JESS consultants, Christopher Hemming provided crucial collaboration in initiating TEBS ground surveys, in identifying plants in the field, and liaising with the Kew and Nairobi herbaria. At those herbaria, Mr. J. Gillett and Miss Christine Kabuye, respectively, provided rapid identifications. ARD consultants, Timothy Synnott and David Pearson, worked closely with TEBS. Professor Warfa and Tom Thurow (National University); Denis Herlocker and Peter Kuchar (Central Rangelands Development Project); Maxamed Cabdiraxman and Giles Leigh-Brown (National Tsetse and Trypanosomiasis Control Project); Neil Bird, Rod Bowen, and Gus Carty (British Forestry Project, Somalia); and Michael Madany (World Concern) all provided helpful technical discussion. TEBS is grateful to the Somalia Research Project for making various drafts and reports available. Murray Watson (RMR) collaborated closely on his aerial surveys and provided numerous insights into Somali ecology.

The long-term JESS team: Kathryn Craven, Jim and Nancy Merryman, and Gus and Marie Tillman, were a joy to work with. We were also blessed with a fine group of short-term consultants and excellent support from ARD home-office staff.

People of the Jubba Valley were always hospitable and generous with their time. This report is dedicated to them and the TEBS field crew.

I. EXECUTIVE SUMMARY

The Jubba Environmental and Socioeconomic Studies (JESS) investigated conditions in the Jubba Valley of southern Somalia (see Figure 1 at the front of this volume). Projections from that baseline information were intended to elucidate changes likely to occur as a result of construction of a high dam near Baardheere and related developments. In particular, JESS was required to suggest ways of mitigating adverse impacts, enhancing potentially good impacts, and to draw up a program for future environmental and socioeconomic monitoring.

This report contains an analysis of the Terrestrial Ecology Baseline Studies (TEBS) section of the JESS project. Human use of biological resources is examined from the perspectives of land use, forestry, rangelands, and biological conservation. TEBS activities are used as the basis for a future monitoring program of terrestrial ecology.

A multi-level approach to data collection was adopted using aerial photography at various scales, low-level aerial censuses, and ground monitoring sites. In this report, these different methods are integrated to present an overview of the Jubba Valley environment. However, basic data from the different methods can be found in JESS data repositories in Somalia, Kenya, and the United States.

The JESS study area covered the three administrative regions of Gedo, Middle Jubba, and Lower Jubba. However, TEBS concentrated on three "impact zones" which will be most affected by construction of the dam and related developments:

- the inundation area behind the dam;
- the Jubba floodplain downstream of the dam; and
- a "river-dependent zone" extending 30 km east and west of the floodplain.

It was assumed that biological resources outside this 35,000 km^2 area would be minimally changed by expected developments in the Jubba Valley.

Particular emphasis was placed on describing and explaining ecological differences between the floodplain and river-dependent zone. Environments similar to the river-dependent zone are widespread in southern Somalia, but floodplain ecology is unique since the Jubba is Somalia's only perennial river.

The floodplain will be altered immediately when Baardheere Dam is closed. Upper reaches will be permanently inundated, while downstream areas will no longer flood extensively and, as a result, will be less naturally fertile. Production systems, particularly floodplain agriculture and livestock forage production, will be negatively impacted by these changes. Although terrestrial productivity in the reservoir area will undoubtedly decrease, at least in the first instance, it seems likely that parts of the drawdown area may have potential for both agriculture and forage production. To make optimum use of hydrological resources during the transition to more sophisticated agricultural systems, the following recommendations are made:

- *Feasibility of controlled floods to maintain floodplain production systems should be assessed.*
- *Potential of the reservoir drawdown zone as a productive resource should be assessed and incorporated into land-use planning and dam operating schedules.*

These recommendations do not require that the dam be delayed since investigations can be carried out during construction. Proposed dam designs do not preclude release of a controlled flood.

Recent Land-use Changes

Comparison of aerial photography of riverside land from 1960, 1983-1984, and 1987 shows two major trends: denser vegetation types (particularly riverine forest) have declined markedly, and many floodplain farms previously dependent on flooding and rainfall have been converted to pumped irrigation. Changes in land use between 1960 and 1983-1984 were relatively slow, but the accelerated rate over the last few years suggests that all riverside land will be farmed by the end of this century. This trend indicates that Jubba Valley planners must take action before the dam is completed if they want to influence the development of land-use patterns.

Vegetation

Vegetation of the Jubba Valley comprises mainly deciduous bushlands of various densities. In the river-dependent zone, this pattern results from the interaction over centuries among climate, soils, and grazing and browsing patterns of wild and domestic large mammals. Until relatively recently, much of the floodplain was covered by evergreen riverine forest. More than 50 percent of the floodplain has now been cleared for agriculture. Most remaining native vegetation has been degraded by human influences such as fires, felling, livestock grazing, and abandonment of fields. Only 900 ha of forest remained in 1987—most of it in small patches threatened by agricultural expansion.

Closure of the dam will lead to sudden loss of terrestrial vegetation in the inundation area and gradual degradation of floodplain vegetation downstream as flooding is either eliminated, or substantially reduced in frequency and extent. Downstream vegetation will also be influenced by development activities increasing the area under irrigation.

Forestry

Review of human use of wood from native vegetation indicates that most is used for fuel. Conservative estimates of wood biomass in TEBS study area exceed 30 million tonnes, while annual production exceeds 400,000 tonnes. However, detailed inventory is needed for accurate estimation. If people were evenly spread throughout the area, sustainable wood production would be adequate for their current needs. However, most of the population is close to the river and most wood in the river-dependent zone is beyond a reasonable collecting distance on foot. TEBS analyses suggest that, taking population distribution into account, demand for wood is matched by sustainable supply in Baardheere and Saakow Districts, but falls short in Jilib, Jamaame, and Kismaayo Districts. In riverine areas of Garbahaarey and Luuq Districts, severe shortages of fuelwood occur due to high population density refugee camps. Only in Bu'aale District does wood production exceed demand.

In the future, demand for wood will increase due to natural population growth, resettlement, and immigration. Resettled populations will include long-term inhabitants of the inundation area and, possibly, some refugees. People entering the area will include dam construction workers and their associates and new settlers attracted by opportunities in the Jubba Valley. However, supply of wood will decrease due to inundation and conversion of floodplain land from native vegetation to agriculture.

Planners should address this predicted shortfall of wood supplies. Options include more widespread collection from and effective management of the river-dependent zone, planting of trees, and increasing the efficiency of wood use so that per capita consumption decreases. Current and planned projects within the forestry department of the National Range Agency (NRA) address tree-planting and increased efficiency, but are weak in optimizing use of native vegetation. TEBS recommendations for the forestry sector include the following:

- *NRA forestry activities in the study area should be strengthened to increase tree planting and more effectively regulate use of vegetation for fuelwood.*
- *Better information on forest inventory and tree and shrub growth rates is urgently needed if optimal use of vegetation is to be practiced.*
- *The area to be inundated by Baardheere Dam should be cleared of woody vegetation and the wood used to supply fuel needs of construction workers and their associates.*
- *Where reservoir area people are resettled, land clearance procedures should include using as much as possible of the cleared wood for construction and clearance.*
- *To meet continuing fuel and construction needs, people should be resettled at low population density, in areas where their forestry needs can be met locally.*

Rangelands

The pastoral sector is economically vital to Somalia, including the Jubba Valley. Sustainable use of range resources is, therefore, an essential component of planning.

The Jubba River and its floodplain attract large numbers of livestock, particularly during the jiilaal dry season between December and April. TEBS analyses of range resources and consumption by livestock show that overall there is an approximate balance between supply and demand for forage in years of average and above-average rainfall. There is, however, local degradation of range resources in some areas, particularly in Lower Jubba. In drought years there is probably a shortage of forage which is acute in the inundation area and to the north. Since some good grazing areas will be lost by inundation, a redistribution of livestock is likely when the dam is closed. Adequate forage resources to support increased livestock exist at present in some parts of Middle Jubba. However, these areas have high infestation with tsetse flies.

It is clear that access to the river for drinking and floodplain forage are essential to support Jubba Valley livestock during jiilaal. Besides range vegetation, livestock also rely on crop residues produced in the floodplain and river-dependent zone. Clearance of floodplain land for agriculture will decrease range resources and increase the need for crop residues. To deal with these developments, TEBS recommendations for the range sector include the following:

- *Agricultural development should take place in such a way that suitable crop residues are available to livestock.*
- *Maintenance of livestock watering points along the Jubba River should be an integral part of floodplain development.*

Conservation and Wildlife

Biological conservation prospects in the study area are limited. Wildlife densities are low, except for some pest species. Opportunities for self-financing conservation areas through tourism are minimal. Conservation activities should, therefore, focus on maintenance of biological diversity and national heritage. Financial and technical support from donors is essential.

Any worthwhile and feasible conservation projects related to Jubba Valley development should concentrate on wetlands, which are rare in Somalia. In particular, swamps of the lower Shabeelle and remnants of Jubba riverine forests should be given the highest priority for establishment of protected areas. Conservation recommendations from TEBS include the following:

- *External funding and technical assistance should be sought to support a coherent conservation program in Somalia.*
- *Shoonto and Barako Madow forest reserves should be given increased protection immediately. Future management options depend on external funding, but should take account of a proposed management plan and the additional measures suggested in this report.*
- *Appropriate areas in the lower Shabeelle Swamps should be conserved for their wildlife populations, because of the scarcity of such wetlands in Somalia, and because of their importance in downstream flood control.*

Other issues of importance to conservation policy in the study area presented in the body of the report include previous proposals for conservation areas, control of pests (including cropping of crocodiles), tsetse eradication proposals and their effect on wildlife, and biological diversity of floodplain vegetation.

Monitoring

Most TEBS monitoring proposals are designed as continuations of TEBS studies, but at reduced intensity. The recommendations assume that the MNPJVD or similar body will establish a monitoring unit to coordinate both environmental and socioeconomic monitoring activities (Tillman 1989). This unit would undertake some field work, but would also commission and collect information from contractors and other agencies.

Specific monitoring activities proposed by TEBS include:

- *Improved collection of rainfall data*—Current rainfall records are inadequate as a basis for planning agricultural and range management activities, and estimating likely effects of drought.
- *Periodic updating of the status of vegetation monitoring sites*—Aerial photographs will show changes in vegetation structure and land use, and ground sites will indicate changes in species composition and biological diversity.
- *Vegetation and soil monitoring of the reservoir drawdown zone*—Developments in this area may include opportunities for seasonal agriculture and livestock forage production.
- *Periodic low level aerial censuses*—These can be used to highlight changes in farming patterns, livestock and wildlife populations, land clearance and enclosure, rural structures, and water sources.

Effective use of JESS-based monitoring data will require a trained and motivated group of scientists and technicians who can communicate with planners and policymakers. Collecting monitoring data is not worthwhile unless it is analyzed and interpreted in a useful way.

II. INTRODUCTION

Wise use of biological resources is an essential component of development planning. Since a basic requirement of JESS was to provide baseline information useful to planners, ecological surveys were essential. This report describes terrestrial biological resources and their current use by the human population of the Jubba Valley. The consequences of proposed developments on terrestrial ecosystems, most importantly the construction of a high dam on the Jubba River north of Baardheere, are assessed. Impacts on aquatic ecology are discussed in other JESS reports contained in this volume: Biological Limnology of the Jubba River (Njuguna and Muthuri 1988); Fisheries in the Jubba River (Meredith 1988); Water Balance and Sediment Transport in the Jubba River Watershed (Alford 1987); and Water Quality and Public Health Aspects of Proposed Dam and Development in Jubba Valley (Jobin 1988).

Experience with large dam projects elsewhere in Africa shows that major changes are inevitable. Obviously some land upstream of a dam is inundated and lost as a terrestrial ecosystem. More subtle environmental changes occur downstream of a dam as a result of reduced flooding irrespective of other human interventions. Since one purpose of Baardheere Dam is to increase land under irrigation, major land-use changes will occur, further impacting floodplain ecology. Such changes are clearly of scientific interest. From a development perspective, it is the interaction between people and ecosystems that is crucial. This report is primarily concerned, therefore, with how people and their use of biological resources will be influenced by changes in terrestrial ecology.

Numerous recent reviews which consider impacts of dams and related developments on terrestrial ecology point to issues concerning vegetation change, redistribution of range and forest resources and loss of biological conservation value (*e.g.*, Adams and Hughes 1986; Roggeri 1985; Scudder 1988; Goldsmith and Hildyard 1986).

The most immediate vegetation change is loss of terrestrial plants from the inundation area. For example, the proposed Kogoufoulbe Dam in Senegal would flood 3,600 ha of riverine forest (University of Michigan 1985). Downstream effects also indicate an impoverishment of riverine forests on, for example, the Tana River in Kenya (Hughes 1985). Such forest loss has obvious consequences for human supplies of forest products, including fuelwood. These forests are often of great significance for biological conservation. Throughout Africa, river valleys are usually settled and farmed leaving only remnants of native forest. Besides endemic plant species, these forest remnants may also contain endemic wildlife. Thus loss of these ecosystems can result in loss of genetic diversity. For example, the Tana River forests house two threatened endemic primate subspecies (Adams and Hughes 1986). Loss of remaining forests on the Tana would undoubtedly cause extinction of these animals in the wild.

Increase in irrigation potential following dam construction leads to clearance of additional forest land for cultivation. Similar losses may occur in rangeland production, either through flooding upstream of a dam or changed hydrology downstream. The Kafue Flats in Zambia, for example, have been adversely affected by both these processes (Scudder 1988). Eastern sections have been permanently inundated by Kariba Dam while upstream portions are less productive because of reduced floods caused by Itezhitezhi Dam.

However, all impacts on human use of biological resources are not negative (Scudder 1988 gives many examples). Wood harvested from inundation areas may be used for construction or fuel. New grazing or agricultural lands may be created in the drawdown zone of the impoundment. Prevention of unpredictable flooding can save millions of dollars (U.S.) in damage to crops, houses, and rural infrastructure. Controlled releases from a dam can make management of downstream lands more predictable than in a pre-dam situation. More intensive agriculture resulting from irrigation can potentially decrease pressure on areas of prime conservation value.

JESS, including TEBS, attempts to give a balanced view of likely losses and potential gains following construction of Baardheere Dam. In particular, recommendations are directed at mitigating adverse effects and enhancing potential gains.

Terrestrial ecology in southern Somalia was little studied until the 1980s. Two important ecological surveys were carried out in the first half of the decade for the Ministry of Livestock, Forestry, and Range. The Southern Rangeland Survey (SRS) (Watson and Nimmo 1985) was the last in a series of three surveys covering the whole country. A combination of satellite imagery, low level aerial reconnaissance, sample aerial census, and ground monitoring sites was used to establish land-system units. These units were described in detail in terms of vegetation, larger wildlife species, livestock, and human resources. Aerial census and vegetation data from SRS, in conjunction with newly commissioned aerial photography and ground surveys, were used by the National Tsetse and Trypanosomiasis Control Project (NTTCP) in preparation of a land-use survey of southern Somalia from the northernmost part of the Shabeelle River to the border with Kenya (LRDC 1985). This survey provides some detail about lower reaches of the Jubba, but places more emphasis on the Shabeelle.

These recent surveys did not focus on the Jubba Valley specifically, or the consequences of construction of a dam on the Jubba River and related developments. However, they provide an up-to-date account of terrestrial ecology over the extensive rangelands surrounding the Jubba floodplain. The existence of these surveys enabled TEBS to concentrate on the Jubba floodplain and adjacent drylands. It is these areas that will change most after closure of the dam. As soon became apparent to JESS, ecological and sociological changes are rapid close to the river, but much slower elsewhere.

TEBS collected and integrated information from a variety of sources. Aerial photography, sample aerial censuses, and ground studies were combined to assess the resource base, how it is used, how it is changing now, and how it is likely to change when the dam is completed. This report was prepared by the TEBS ecologist, but it incorporates work by several JESS consultants. Aerial photography and aerial census were conducted by RMR (Watson and Nimmo 1988). Vegetation surveys were a collaborative effort with Christopher Hemming (1986; 1987—presented in this report as Appendix I); some of the aerial photointerpretation was carried out by Eric Trump (1987). Timothy Synnott (1988) served as a forestry consultant. JESS also collaborated with, and partially supported, the Somalia Research Project (SRP) of University College, London. This three-month expedition conducted ecological and land-use surveys in riverine forests of Middle Jubba. SRP also focused on issues of biological conservation in these forests, producing a management plan for two forest reserves as part of its final report (Madgwick 1988).

TEBS surveys were designed to complement existing and ongoing work in such a way that likely impacts of Baardheere Dam and related developments in the Jubba Valley could be assessed. As emphasized in the ARD project proposal (1985), precise predictions of change are usually not possible. Nevertheless, it was expected that "best estimates" of probable changes could be made and presented in a way useful to planners.

Long-term TEBS field research comprised aerial surveys (photography and censuses) conducted by RMR and ground studies of vegetation and land-use monitoring sites. Both low-level aerial censuses and ground visits were conducted in different seasons to give an idea of annual cycles of land-use, vegetation quantity and quality, and livestock and wildlife occupancy. Spatially, the study area was divided into three distinct impact zones: the inundation area behind the proposed dam, the floodplain downstream of the dam, and the river-dependent zone east and west of (but close to) the floodplain.

For this report results of aerial and ground surveys are combined to give assessments of land use, vegetation, forestry, range resources, and biological conservation. This sectoral approach is appropriate for most development planning activities. Others may wish to see raw data so that different combinations and interpretations can be made. For these people, uninterpreted data sets from aerial and ground studies can be found in the data repositories described at the end of this section and in JESS Final Report, Volume IV, Bibliography.

Basic descriptive material in this report is contained in Sections III to VI. Section III is a broad view of the Jubba Valley including a brief account of socioeconomic conditions. Section IV defines the TEBS study area and its subdivisions. The overall approach to the studies is also described.

Section V concerns land-use changes between 1960 and 1987 which were derived from interpretation of aerial photographs with emphasis on riverside land. Seasonal changes were analyzed from sample aerial censuses conducted in 1987. Section VI describes vegetation in TEBS study area. Vegetation structure, species composition and diversity, and vegetation dynamics are considered. Contrasts between floodplain and river-dependent zone vegetation are emphasized. Sections V and VI present basic information and conclusions relating to future change, but without recommendations relating to planning. Recommendations pertaining to information presented in these sections concern use of biological resources and monitoring which are covered in subsequent sections.

Sections VII to IX are more development-oriented since they deal with human interactions with biological resources. Human use of vegetation as forest products and rangelands is detailed in Section VII. Quantitative assessments are made of forestry and range resources and related to estimates of production and consumption of fuelwood and livestock forage. Section VIII concerns biological conservation. Wildlife populations, plant communities, and protected areas are discussed in the context of conservation prospects in Somalia. Related issues such as tourism, hunting, harvesting, crop protection, beekeeping, and plans to eradicate tsetse fly are considered.

While Sections III to VIII deal with biological resources from a sectoral viewpoint, Sections IX and X combine conclusions from these sectoral analyses. In Section IX an attempt is made to give an overview of how floodplain environments will change after construction of Baardheere Dam. Section X presents proposals for environmental monitoring drawn from conclusions in other sections. Most TEBS studies were designed as potential bases for future monitoring. Priority monitoring activities and approaches are given in this last section.

Conclusions relating to development activities, notably the Baardheere Dam, are given in appropriate sections along with recommendations to mitigate adverse impacts or enhance development opportunities. Most recommendations are at the level of advice to planners as required of JESS, rather than comprising project proposals.

Basic research data such as tables, computer diskettes, descriptions of monitoring sites, aerial photographs, and manuscript maps are housed in five data repositories: MNPJVD, USAID/Somalia, USAID/REDSO East Africa (Nairobi), USAID/Washington, and ARD. At each of these locations a *TEBS Data Guide* describes how to use the contents relevant to this volume.

A. Physical Geography

1. Landform, Geology, and Soils

The JESS study area is defined as the three administrative regions of Gedo, Middle Jubba, and Lower Jubba (see Map 1; further elaboration is given in Section IV.A). Geological maps are presented in Watson and Nimmo (1985) and LRDC (1985). Much of Gedo Region comprises limestone hills, terraces and plateaus dating from Jurassic and Cretaceous periods (65 to 190 million years ago). Local variations include gypsums, basalts, sandstones, and shales. From north of Saakow to Bu'aale, a zone of Pre-Cambrian (570 million years ago) basement granitic gneisses and schists crosses the area east-west. Most of the study area is flatter than that underlaid by limestone, but this formation also contains granite inselbergs characteristic of part of Bay Region. South of Bu'aale are extensive alluvial plains of clays and marls deposited under oceanic condition in recent times (two million years ago). The coastal strip comprises mobile sand dunes to the seaward side and stabilized dunes inland. Around Kismaayo and southward is a region of recent coralline limestones.

Differences in elevation in most of the study area are minor. Following the river southward, the disputed Somalia/Ethiopia border is at 200 m, Luuq at 150 m, the dam site at 100 m, Bu'aale at 40 m, Jilib at 20 m, and Jamaame at 10 m above mean sea level (masl). Local relief can be substantially greater in northern limestone areas, but only exceeds 500 m in a region north of Baardheere and 50 km west of the Jubba river. South of Baardheere, 200 m is not exceeded and most land is virtually flat except for occasional inselbergs north of Saakow.

Soils vary in a sequence related to geological formations (USBR 1987). North of Baardheere soils are often rocky or stony. Finer deposits are sometimes associated with togga (seasonal streams) and depressions containing gypseous soils (Appendix I). In flatter areas of southern sections of the limestone hills and plateaus, vertisols are the predominant soil type as they are in the marine plain. The intermediate zone of basement gneisses and schists has patches of somewhat lighter soils than other non-riverine areas. The surface consists of sand-loams to sand-clays. Gravel layers sometimes occur leading to better drained soils than the surrounding vertisols. All these soils are neutral to alkaline and have low levels of organic matter, nitrogen, and available phosphate (LRDC 1985).

The Jubba River presents a major departure from this overall pattern. A complex mixture of recent alluvial deposits creates a floodplain ranging from less than 100 m to almost 15 km in width. The physiography and gross soil features of floodplain environments are described in Section IV.A.

2. Climate and Hydrology

Rainfall is the most important climatic variable affecting biological resources in low-lying tropical dry to semi-arid areas, such as the Jubba Valley. Unfortunately, rainfall records are poor. Too few stations and too many gaps in data mean that only a coarse picture can be drawn of relationships between biological and climatic phenomena. Watson and Nimmo (1985) present the most extensive and critical rainfall data set for the study area. Within TEBS study area (see below), only three stations (Luuq, Baardheere, and Kismaayo) have more than 30 years of data. Figure 2 shows rainfall for eight stations with the longest records. Other stations have operated for brief or sporadic periods at Diinsoor, Doolow, Yontooy, Saakow, and Bu'aale.

Most of the study area demonstrates the bimodal pattern of rainfall typical of equatorial East Africa. The main rainy season (gu') is from April to June followed by a moderate dry season (xagaa) from July to October. A minor and erratic rainy season (deyr) occurs in November and December followed by an intense dry season (jiilaal) from January to early April. This pattern is modified near the coast where xagaa showers follow gu' until October, but deyr rain is slight. Xagaa rains are usually said to penetrate approximately 50 km inland, but heavy showers occurred as far north as Baardheere in August 1987 and 1988 In 1987 Saakow and Bu'aale received significant xagaa rainfall of 51 mm and 103 mm, respectively, in August and September.

Between Doolow and Jilib mean annual rainfall increases in a southerly direction from around 200 mm to more than 700 mm at Mareerey (Figure 2). South of Jilib rainfall declines to 450 mm at Jamaame and 350 mm at Kismaayo. Mean annual

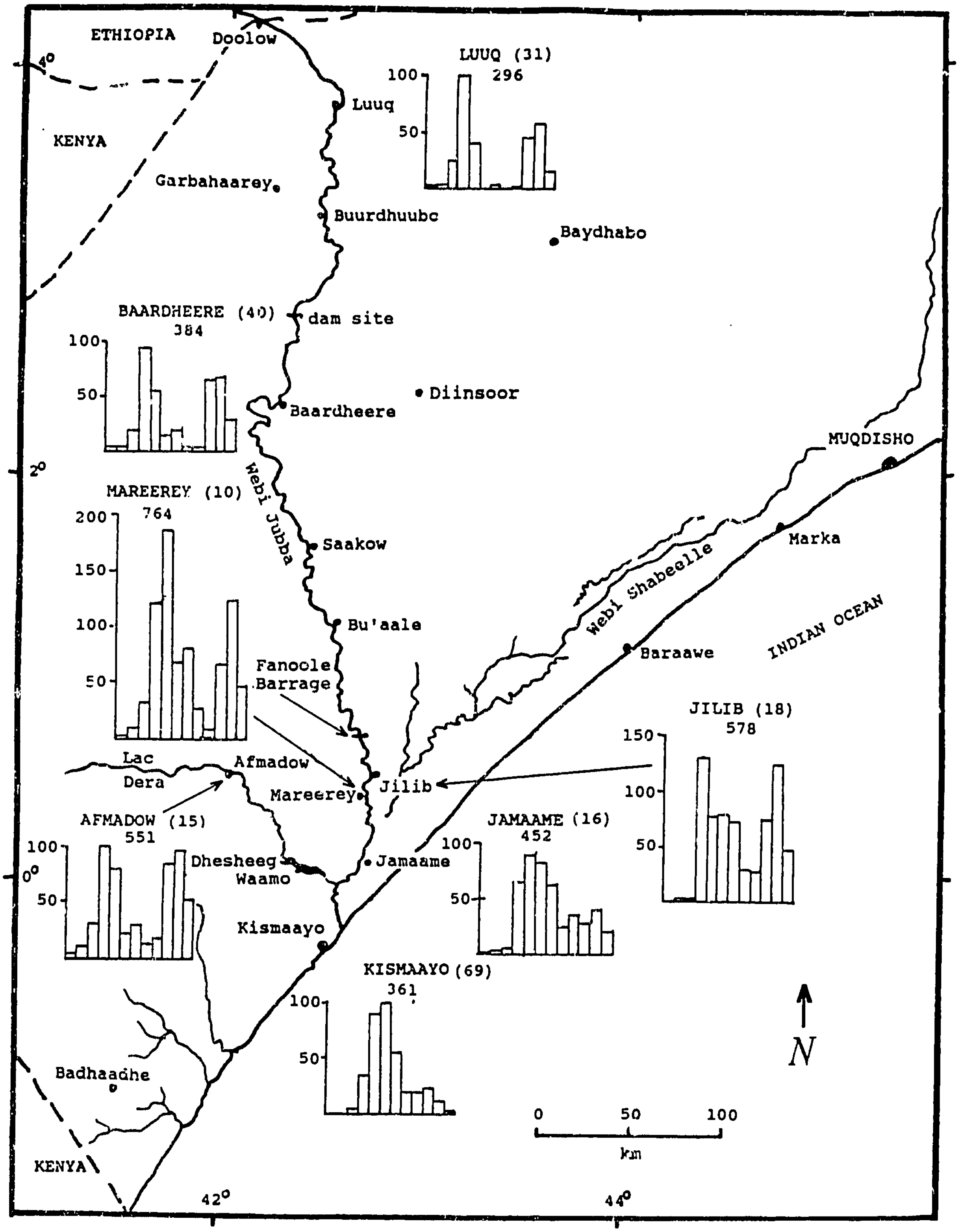

Figure 2. Rainfall map of southern Somalia. Rainfall charts have annual total beneath station name and number of years of records in parentheses. (Data from Watson & Nimmo 1985 and Food Early Warning System, Ministy of Agriculture.)

rainfall for each river section of TEBS study area (see Section IV.A; Map 1) has been approximated by examination of all available rainfall records and isohyet maps in Watson and Nimmo (1985), LRDC (1985), and AHT (1988).

River Section	Mean Annual Rainfall (mm)
I	300
II	350
III	400
IV	450
V	550
VI	650
VII/VIII	450

Information given above implies predictable rainfall patterns. As in other semi-arid areas, mean monthly or annual rainfall for the Jubba Valley are statistical abstractions rather than predictions of what happens in a given month or year. The extent of temporal variation can be examined by comparing annual monthly means with those experienced during the study period or by plotting long-term records of mean annual rainfall as presented by Watson and Nimmo (1985).

Mean monthly rainfall (where records exist) is close to 1986 and 1987 data in only 16 out of 50 comparable records (Figure 3). Monthly patterns in 1986 and 1987 are erratic with xagaa rains tending to be well above average and substantial as far north as Saakow. Gu' rains in 1987 were very late at most stations. Deyr rains varied greatly spatially and from year to year during the study period as expected with the short rainy season in equatorial East Africa. Even seasonality is not very distinct in particular years with the exception of jiilaal being dry. Comparisons of seasonal rainfall at two stations (Baardheere and Jilib; Table 1) show substantial geographical variations, also. In 1987 gu' at Baardheere was above average, but deyr in 1986 and 1987 below average. At Jilib, gu' was good in 1986, but poor in 1987 and deyr poor in both years. However, xagaa rain at Jilib was high in 1986 and extremely high in 1987.

Overall, it seems that annual rainfall during the study period was close to average at Jilib, but low at Baardheere and Mareerey. Gu' and xagaa rains combined were good, but temporal and spatial distributions unusual. Deyr rains were poor, which probably emphasized the harshness of the succeeding jiilaal seasons. Lateness of gu' in 1987 further exacerbated jiilaal that year.

Table 1. Comparison of long-term seasonal rainfall (mm) at two meteorological stations in the study area with records for the JESS field study years of 1986 and 1987.

	SEASONS*			
	Gu' (Apr-July)	Xagaa (Aug-Sept)	Deyr (Oct-Dec)	Year
Baardheere				
long-term	182	11	161	384
1986	no data	(0)**	49	inc.
1987	209	0	102	312
Jilib				
long-term	357	36	182	586
1986	438	53	120	598
1987	309	178	107	597

Seasons defined by drop in monthly rainfall total from long-term records rather than colloquial definition.

***August record missing; July and September both zero.*

Analysis of data for this century from all meteorological stations in southern Somalia suggests that a ten-year cycle in mean annual rainfall is superimposed upon a forty-year cycle (Watson and Nimmo 1985). Successive fluctuations are not of equal magnitude in either proposed cycle, but the region is predicted to be entering low rainfall phases in both cycles during the late 1980s. Unfortunately, the data base is too weak to predict such events with confidence. Even if future data confirm the proposed cycles, rainfall in a particular year or season cannot be predicted. Nevertheless, successful policymaking and planning must take into account the fact that large fluctuations in rainfall occur. Average rainfall is not an adequate planning tool. Strategic plans must allow for the large fluctuations in rainfall characteristic of semi-arid areas and develop means of dealing with wet and dry years. Given the importance of rainfall to crop and forage production, even when irrigated systems are developed, an effective rainfall monitoring system is a high priority (see Section X).

Other commonly measured meteorological variables serve to emphasize the significance of low rainfall. Temperature and wind speed are high and cloud cover low most of the year. These factors all increase evapotranspiration, leading to severe water deficits throughout the study area. Mean annual temperatures at Luuq, Baardheere, Jilib, and Kismaayo are 30.5, 28.2, 27.6, and 26.2 °C, respectively. The coolest months are July and August (monthly means 28.3, 26.8, 25.5, and 25.3 °C, same stations) and February and March the hottest (33.4, 30.8, 29.1, and 27.9°C). Mean annual wind speeds

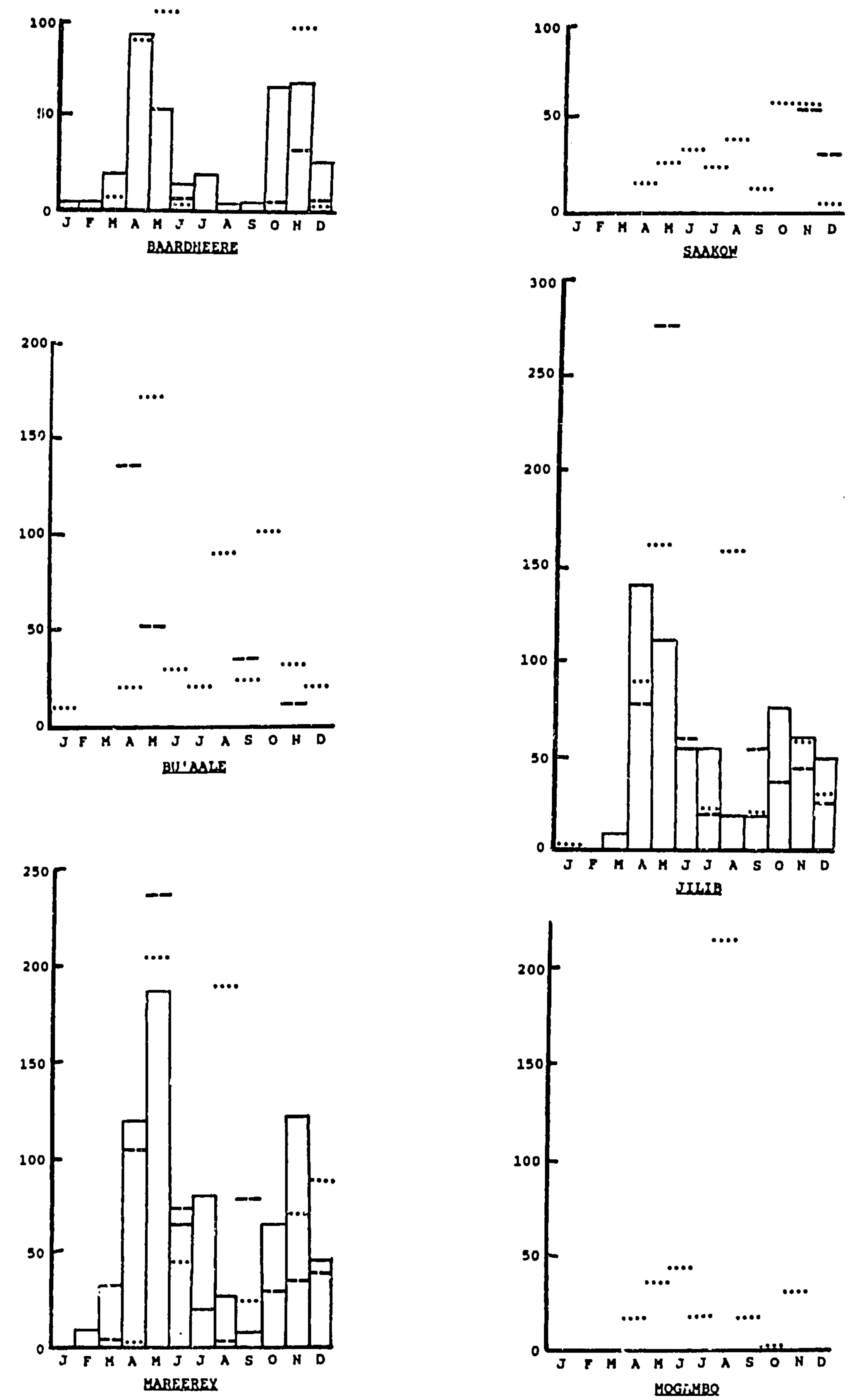

Figure 3. Comparison of long-term means (vertical bars) of monthly rainfall with rainfall received during JESS fieldwork years 1986 and 1987 (dashed and dotted horizontals respectively; 1986 records incomplete). Bu'aale, Mogambo, and Saakow are new stations with no long-term means. (Data from Food Early Warning System, Ministry of Agriculture.

are 1.0, 2.8, 1.1, and 5.4 m second $^{-1}$ for the same stations and mean daily sunshine hours 10.6 at Luuq and 8.2 at Jilib. These factors combine to produce a potential evapotranspiration rate in excess of 2,000 mm year^{-1} over most of southern Somalia (Watson and Nimmo 1985; AHT 1988).

The most important hydrological feature of the study area is the Jubba River. This river is the only "perennially" flowing water body in Somalia to reach the Indian Ocean. Even the Jubba bed is occasionally dry in late jiilaal, but subsurface flow continues. Within the floodplain, soil and available water are altered considerably. More than 90 percent of river water flows from the highlands of southern Ethiopia. Discharge is bimodal more or less coinciding with rainfall seasons in southern Somalia. However, highest river flows occur on average during deyr season, although overbank flooding can occur in both wet seasons. Average annual total flow at Luuq is 6,200 km^3. Extensive floods occur at discharges above 700 m^3 second^{-1}. Recent floods of sufficient magnitude to cause serious economic damage occurred in 1977, 1981, and 1985 (AHT 1988a). The study period was marked by a large gu' flood in 1987 which inundated most of the floodplain. This flood was the most extensive since 1977. During other seasons of 1986 and 1987, overbank flooding was negligible. Relationships between river discharge and extent of flooding are poorly understood as the river bed morphology and floodplain micro-topography have not been determined.

Within Somalia several togga flow into the Jubba during the rains. Most of these are confined to areas north of Saakow. West of the river and south of Fanoole Barrage are several drainage features associated with the Jubba. Webi Yaro (or Little Jubba) used to carry water most of the time, but parts are now dry much of the year as a result of hydrological changes caused by Fanoole Barrage. Sections of this stream are now used as the main irrigation canal for Jubba Sugar Project. The Shabeelle River, further west, flows temporarily with Jubba water during high flows and overbank floods.

South of these channels is Dhesheeg Waamo, a periodically large body of water (60 km^2). This *dhesheeg* (a water-holding depression) receives water from Lac Dera, a seasonal channel flowing from north and west. This small catchment may also receive subsurface flow from Mount Kenya via the Ewaso Nyiro and Lorian Swamps in eastern Kenya (LRDC 1985). During high floods, as in May 1987, Dhesheeg Waamo is filled from the Jubba. Prior to that flood, the dhesheeg bed was dry and the water-table several meters below ground-level. Local reports indicate that this dhesheeg was last dry in 1977, before the last major Jubba flood. These observations indicate the importance of Jubba water for maintaining the water regime of Dhesheeg Waamo.

East of Jilib the Shabeelle River ends in a series of swamps. At times of high flow, Shabeelle water may enter the Jubba along togga and by surface flooding. These swamps are important natural flood protection for parts of Lower Jubba. They are also wildlife areas worthy of protection and important dry season grazing areas for livestock.

Surface hydrology south of Fanoole Barrage and floodplain hydrology along the whole river are complex. It is important that the other water bodies and special nature of the floodplain be taken into account when planning developments on the Jubba following construction of Baardheere Dam.

B. Socioeconomic Environment

A full account of human activities in the Jubba Valley is given in Volume III, Part A of the JESS Final Report, Socioeconomic Baseline Studies (Craven, Merryman, and Merryman 1989). Virtually all biotic communities of the study area are substantially modified by human activities. For centuries people have herded livestock, grown crops, and hunted wildlife in the Jubba Valley. More recently humans have altered local surface hydrology by construction of flood bunds and Fanoole Barrage on the Jubba River. A brief account of human influences and activities as necessary background to this report follows.

JESS Socioeconomic Baseline Studies (SEBS) divides the study area geographically into three socioeconomic regions north to south—upper, middle, and lower Jubba. These correspond to TEBS River Sections I to III, IV and V, and VI to VIII, respectively (see Section IV). Most of riverine upper Jubba is characterized by a dynamic system of smallholder agriculture. Irrigation has spread rapidly along the floodplains from initial foci at Luuq, Buurdhubo, and Baardheere. All-weather roads connect these centers to Muqdisho. However, upper Jubba also encompasses a section of the river with poorer communications than any other. The riverine gorge, from the dam site to a few kilometers south of Buurdhubo, has no roads. Much of the gorge can be reached only on foot or by boat. Nevertheless 3,000 people are estimated to live there, their floodplain farming being dependent on rainfall and river flood seasons (Craven, Merryman, and Merryman 1989).

SEBS middle Jubba region also has poor communication. Tracks exist from Baardheere to Fanoole Barrage on both sides of the river, but they are cut seasonally by rain and river flooding, sometimes for several months. More complex floodplain physiography in this area allows more diverse farming systems using levee land and dhesheegs.

Larger-scale irrigation is found in much of SEBS lower Jubba region. Private banana plantations and three state farms—Fanoole Rice Project, Jubba Sugar Project, and Mogambo Irrigation Project—take up 22,000 ha of floodplain land. Smallholder cultivation, with and without irrigation, also occurs, although many subsistence farmers now have to cope with poorer land and altered hydrology as a result of the plantations.

Against this geographical background, SEBS identifies a set of "socio-ecological sectors": agricultural riverine, agricultural non-riverine or agropastoral, nomadic pastoral, and urban. These divisions are not clear-cut but form a convenient classification for socioeconomic analysis. A particular household may fall entirely within one sector, while another household may divide its time or family members between all sectors.

Riverine agriculture is that confined to the Jubba floodplain. It relies on a mixture of rainfall, flooding, and riverine groundwater to enhance agricultural production (see Section IX). In years with overbank flooding, flood recession agriculture is practiced, particularly in dhesheegs. In contrast, non-riverine agriculture outside the floodplain is entirely rainfed. This sector is most common in Baardheere and Saakow Districts where a combination of adequate rainfall and favorable soils allows sorghum to be grown in most gu' and some deyr seasons. Rainfed farms are usually owned by people who are also riverine farmers or agropastoralists.

The agropastoral sector is steadily increasing in the Jubba Valley and other parts of Somalia where crops can be grown. Livestock may be kept in the vicinity of farms, or may undertake longer migrations in search of forage with part of the family. Crops are grown both as human food and livestock fodder. True nomadism, where the whole family undergoes long seasonal migrations with their livestock, is becoming rarer. Nevertheless, camel-keepers in particular move over great distances, sometimes encompassing the length of the Jubba Valley (Janzen 1988). Most livestock undergo substantial seasonal migrations which preclude all or part of many households from contributing to other production sectors.

The urban sector, involved in commerce, trade, administration, and, to a small extent, manufacture, has strong links with the rural economy. Most urbanites own farms and/or livestock. These links amply demonstrate the diversification of most household economies. In a drought-prone country such as Somalia, and with the added vagary of floods for many Jubba residents, diversification reduces risk of total loss of production at a particular time. In a drought, rainfed farming fails, but some production in floodplain areas may be possible. Livestock can be moved to areas less drought-stricken, or most may survive a short drought. However, a prolonged drought may force surviving livestock to rely on whatever crop production is possible in riverine areas. Flooding may destroy a season of floodplain crops, but non-riverine farms and livestock insure against total loss of family income. Similarly, an urban income in a household provides a cushion against reduced rural production.

Planners need to take account of these flexible household strategies. Interventions which reduce this flexibility will put people at risk during times of environmental and economic stress.

A. Definition and Subdivision of TEBS Study Area

The overall JESS study area is defined as the 120,000 km^2 comprising the administrative regions of Gedo, Middle Jubba, and Lower Jubba (Map 1). However, for purposes of terrestrial ecological studies, a smaller area adjacent to the Jubba River was delineated for two reasons. First, the recent Southern Rangeland Survey (Watson and Nimmo 1985) provides extensive coverage of biological resources which could not be improved within the scope of JESS. Second, the focus of JESS studies is to describe areas likely to be affected by building of Baardheere Dam and related developments. With these facts in mind, it was clear that three distinct terrestrial environments called for detailed study:

- the river and its floodplain;
- the area to be inundated behind the dam; and
- areas east and west of the river and floodplain which are in easy reach for people and livestock.

The third area is defined as being within 30 km of the floodplain and is called the river-dependent zone. Thirty kilometers is a maximum distance that people or livestock are expected to move during routine day-to-day activities. An extension of floodplain in the southwest is added to include Dhesheeg Waamo and its dependent hinterland.

Map 1 shows the position of these areas and further subdivision of TEBS study area north to south into eight river sections. Boundaries of these sections reflect changes in the nature of river and floodplain, some of which are natural and others partially defined by human interventions. These river sections are described in Table 2 and referred to throughout this volume. Although geographically distinct in the floodplain, River Sections VII and VIII are usually combined in analyses because of their small size. These sections are combined as VII/VIII in all analyses of the river-dependent zone. Map 1 shows how river sections relate to administrative boundaries. TEBS river sections correspond closely with Jubba Master Plan "socio-geographic" units (AHT 1988)—River Section III approximates to unit 1; River Sections IV and V to unit 2; River Section VI to units 3 and 4a; section VII/VIII to unit 4b. River sections I and II are not included in the core master planning area.

Table 2. Description of floodplain river sections depicted in Map 1.

River Section	DESCRIPTION
I	North of inundation area to Somalia/Ethiopia border; river bed only slightly incised with broad flat floodplain
II	Inundation area of Baardheere Dam; includes floodplain and other land below 142 m contour. River incised in limestones forming distinct gorge in southern stretch; narrow flat floodplain.
III	Dam site southward to near Barow Diinle village. Gorge at dam site gradually widens and surrounding land flattens; river weakly incised forming flat floodplain several hundred meters wide.
IV	Stretching southward to just south of Bu'aale; broad floodplain (c. 2 km) becomes differentiated into levees and dhesheegs for the first time. This section marks the transition between limestone landscape and marine plains in the river-dependent zone.
V	The river meanders extensively; imperceptibly incised in marine plain with well developed levees and numerous dhesheegs.
VI	Fanoole Barrage is the northern boundary; to the south floodplain is broad (up to 15 km) and physiography complex. Levees and dhesheegs less distinct and mixed with flatter and heterogeneous sediments formed by complex of old river channels and confluence of Shabeelle sediments.
VII/VIII	From just north of equator river is weakly incised and floodplain narrows. Course changes southwest behind coastal dunes before breaking through dune ridge (VIII) and entering Indian Ocean at Goob Weyn.

The Jubba floodplain is further subdivided in terms of physiography and sediment type as presented in the AHT (1984) set of photographic maps. With some consolidation of units to improve sampling rigor, these units are updated in the JESS map series prepared by Watson and Nimmo (1988). These floodplain land types are as follows:

- *Undifferentiated alluvia*—In northern sections the floodplain is narrow and relatively flat and uniform; no subdivisions have been made.
- *Levees*—Distinct raised levees with coarse sediments are formed along the river (al-

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luvial fans of seasonal togga are included in this unit).

- *Dhesheegs*—Behind the levees, depressions in the floodplain with fine-textured water-holding sediments are common. They periodically fill with water from river flooding and from drainage of surrounding land. Some are former river channels (oxbows).
- *Flat alluvia*—Some areas of fine alluvium do not form depressions, but are flat and have (relatively) rapid surface drainage.
- *Heterogeneous alluvia*—In southern sections, floodplain physiography is complex with mixed sediment types due to old river channels and former confluence of Jubba and Shabeelle rivers.
- *Swamps—Some areas are permanently inundated with water.*
- *Irrigated estates*—Floodplain physiography is obscured by land leveling for cultivation of rice (Fanoole and Mogambo state farms), sugar (Jubba Sugar Project), and bananas.

The area under each land type in each river section is given in Table 3.

Table 3. Area (km^2) under each floodplain physiographic land type[1] by river zone (data from Watson and Nimmo 1988).

RIVER SECTION	LAND TYPES					
	Undif	Levee	Dhesheeg	Flat	Heterog	Irrig
I	93					
II	270[2]					
III	65					
IV		48	92			
V		37	110			
VI		90	189[3]	97	213	93
VII		20	24	74	76	127
VIII		11	3	24	29	
Total	428	206	418	195	318	220[4]

Undif = undifferentiated alluvia;
Heterog = heterogeneous alluvia;
Irrig = Irrigated estates.

[1] *Swamps consolidated for all sections = 17 km^2.*
[2] *Includes all inundation area behind Baardheere Dam.*
[3] *Includes Dhesheeg Waamo (112 km^2).*
[4] *Greater area under irrigation than reported by AHT (1988) due to updating by Watson and Nimmo (1988).*

B. Approach to TEBS Studies

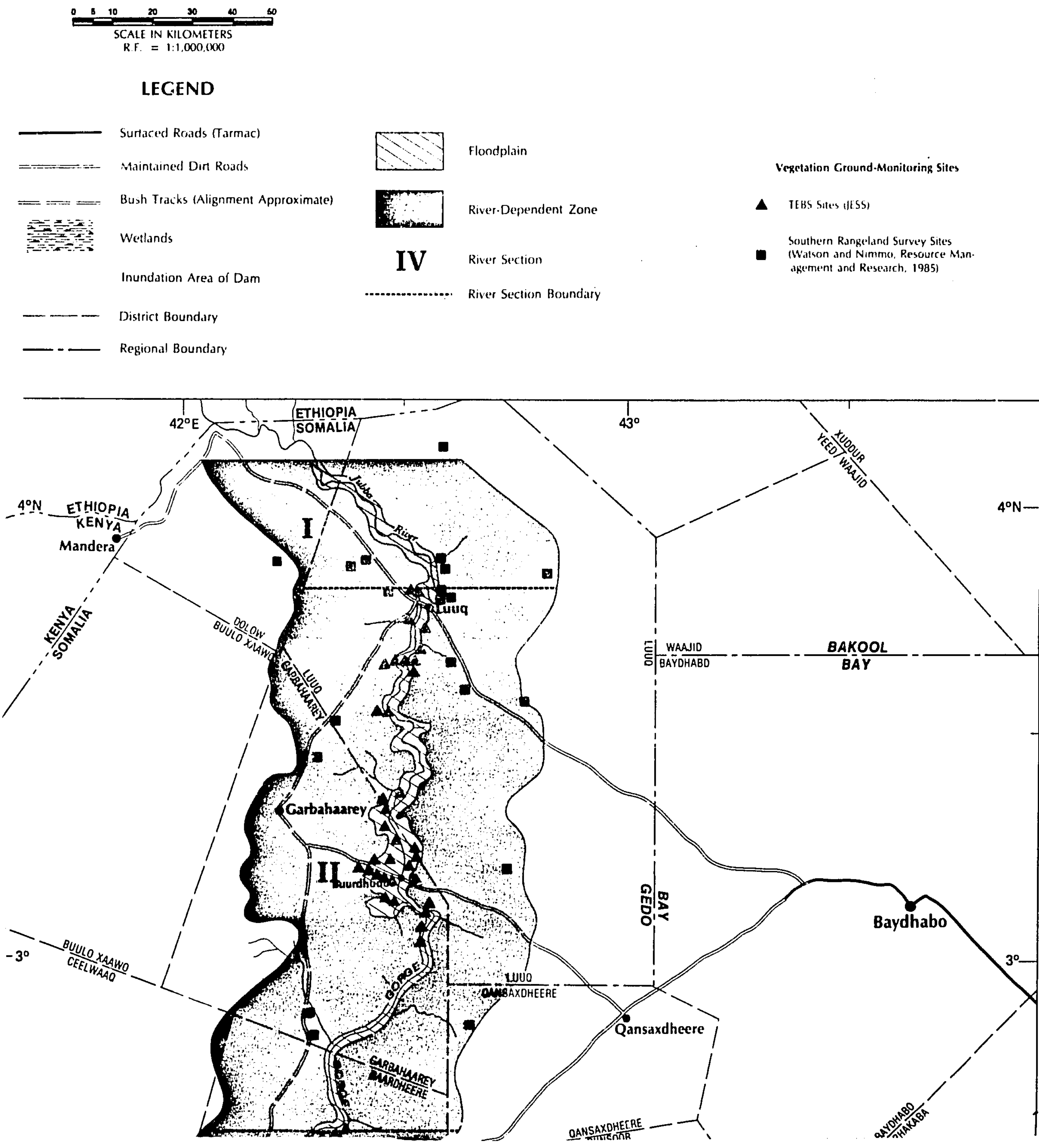
The design and execution of TEBS studies is summarized by ARD (1988). Field and analytical methods are described in relevant sections and appendices in this volume and in Watson and Nimmo (1988). A multi-level approach including aerial photography at various scales, low-level aerial census, and ground studies was used to determine land-use and vegetation patterns. All three approaches are combined to produce a quantitative analysis of vegetation and its use for wood and livestock forage.

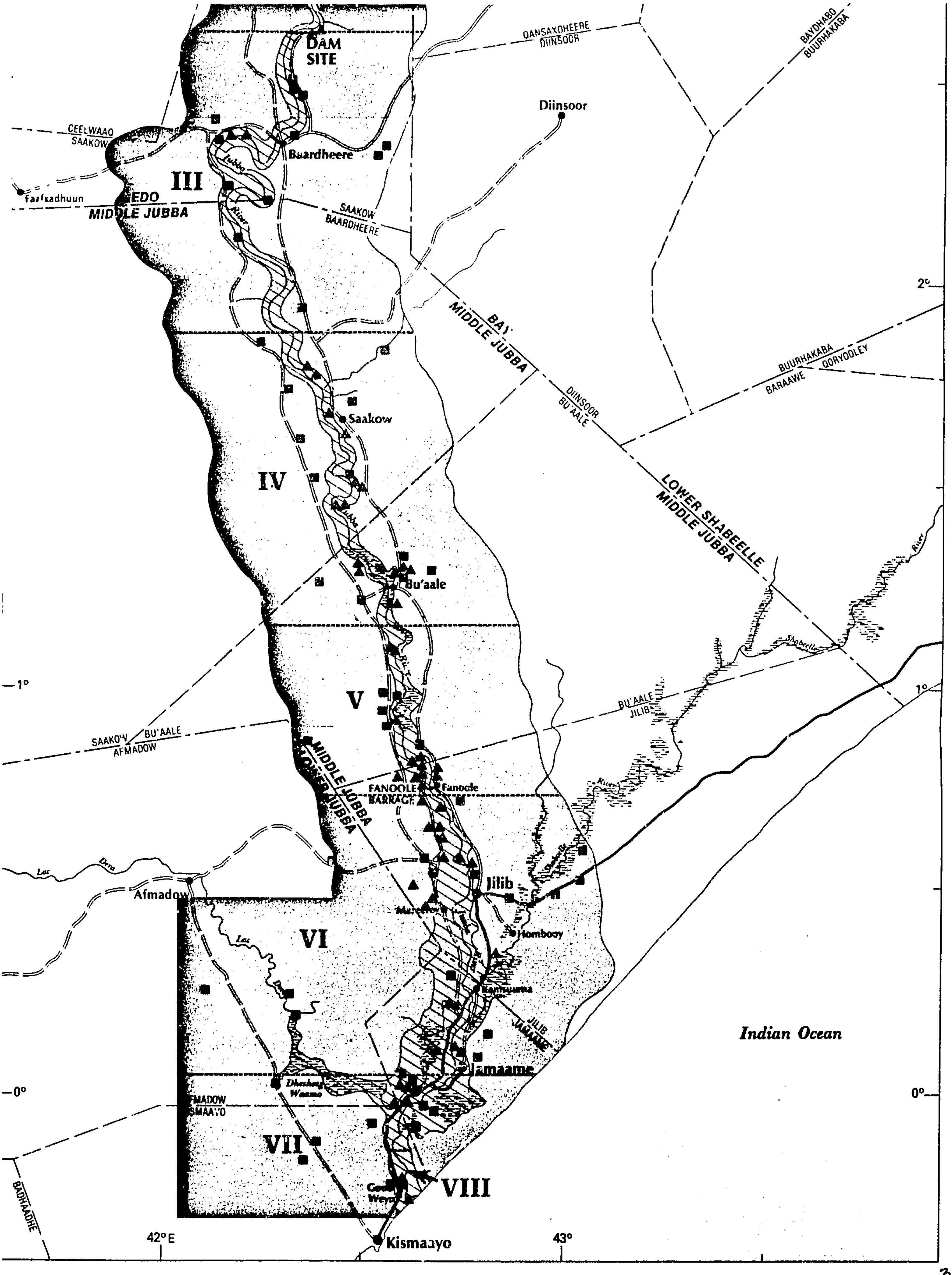
Aerial photography included previous coverage in 1960 (mosaics c. 1:60,000) and 1983-1984 (stereoscopic prints 1: 30,000; mosaics at 1:50,000). JESS commissioned 1:10,000 stereoscopic photographs of the strip stretching 1.5 to 2 km either side of the river and 590 sample 1:1,000 photographs distributed in a stratified random fashion throughout TEBS study area.

Low-level aerial censuses were performed three times in 1987 (26 January to 3 February, 28 March to 13 April, 29 July to 26 August). These censuses estimated livestock and larger wildlife density and distribution, land use, and various cultural features. Sampling intensity in the floodplain and proposed inundation area was approximately 10 percent; in the river-dependent zone, three percent. This work is fully described in Watson and Nimmo (1988).

Ground monitoring sites were established in TEBS study area. Vegetation was described and seasonal visits were made. A major focus of this study was to elucidate the differences between floodplain and river-dependent zone sites.

TEBS MAP #1
TEBS STUDY AREA




DAM SITE
Baardheere
Diinsoor
QANSAXDHEERE
DIINSOOR
BAYDHABO
BUURHAKABA
CEELWAAQ
SAAKOW
III
MIDDLE JUBBA
SAAKOW
BAARDHEERE
BAY
MIDDLE JUBBA
BUURHAKABA
QORYOOLEY
BARAAWE
DIINSOOR
BU'AALE
Saakow
IV
LOWER SHABEELLE
MIDDLE JUBBA
Bu'aale
V
BU'AALE
JILIB
SAAKOW
BU'AALE
AFMADOW
MIDDLE JUBBA
LOWER JUBBA
FANOOLE BARRAGE
Fanoole
Jilib
Afmadow
VI
Hombooy
JILIB
JAMAAME
Indian Ocean
Jamaame
VII
VIII
Kismaayo
42° E
43°
2°
1°
0°
−1°
−0°
BADHAADHE
Jubba
River
Shabeelle

This section concentrates on land-use changes in the Jubba floodplain. Two time-scales are considered. Aerial photo interpretation is used to assess changes from 1960 to 1987. Seasonal dynamics are reviewed from low-level aerial censuses carried out during 1987. The section closes with a qualitative assessment of likely land-use changes before and after closure of Baardheere Dam.

The study concentrates on changes of importance from a development perspective. Major topics addressed include:

- where major changes are occurring;
- the nature of those changes;
- rates of change and projections from them; and
- effects of closure of Baardheere Dam.

Recommendations from this section relate mainly to future monitoring requirements which are dealt with in Section X. However, several important conclusions of relevance to planners are included in Section V.C.

Land-use changes in the upper catchment of Jubba tributaries in Ethiopia are a related issue of great significance to planning for the Baardheere Dam. Removal of vegetation from these highlands will undoubtedly increase sediment loads in the river and lead to a shortening of the effective life of the dam. Abstraction of water for irrigation in Ethiopia will affect the quality and quantity of water reaching Somalia. Unfortunately, it was not possible for JESS to conduct ground studies in the upper catchment. However, an experimental water balance modeling exercise was commissioned by JESS and is contained in this volume (Hart 1989). Suggestions for future monitoring of the upper catchment are also included in that report.

Several land-use studies which include TEBS study area have been conducted in southern Somalia during the last 30 years. Comparability and methodologies of those studies are exhaustively reviewed in LRDC (1985). All of these studies, except AHT (1984), cover much larger areas than TEBS and consequently have a low level of resolution for the Jubba River and its floodplain. From their own work and that of FAO/Lockwood (1967), LRDC compared land use in 1960 and 1983-1984 for several land-use categories. Of interest to JESS are LRDC "land regions" in Middle and Lower Jubba presented in Table 4. Notable trends in some areas include decline in denser vegetation types and increase of cultivation.

Table 4. Comparison of land-use types in 1960 and 1984 based on LRDC (1985). Vegetation types are roughly comparable with those of Section VA in this report.

LAND REGION[1]	DISTRIBUTION OF LAND-USE TYPES (% by area)					
	Crop cycle[2]		Dense vegetation		Open vegetation	
	1960	**1984**	**1960**	**1984**	**1960**	**1984**
Lower Jubba Floodplain	17	33	62	34	13	24
Marine Plain	<1	<1	89	96	10	3
Lac Dera Plain	0	<1	86	35	14	61

[1] *Land Regions within JESS study area: Lower Jubba Floodplain is south of Fanoole Barrage; Marine Plain is west of Lower Jubba Floodplain as far south as Dhesheeg Waamo and east of Lower Jubba Floodplain as far south as the Shabeelle floodplain; Lac Dera Plain is west of the Jubba floodplain between Bu'aale and Fanoole Barrage.*

[2] *Crop cycle includes currently cultivated, seasonally fallow, and recently adandoned land.*

All JESS and AHT studies indicate that the most important effects of building Baardheere Dam will occur in the Jubba floodplain. Developments since 1983 have been rapid in this area. In contrast, the river-dependent zone, stretching 30 km west and east of the floodplain, has undergone only minor changes as illustrated in Table 5. Data in this table are taken from low-level aerial censuses performed in late jiilaal 1984 and 1987. The first (Watson and Nimmo 1985), is an approximately two-percent sample for the Southern Rangeland Survey and the second, a three-percent sample, was commissioned by JESS (Watson and Nimmo 1988). The same observer and land-use classification was used in both surveys. However, the strata used differ as explained in the footnote to Table 5. This difference leads to limitations in their comparability. Despite this inconsistency, changes in rainfed cropping between 1984 and 1987 seem slight.

The main conclusion from Table 5 is that rainfed cultivation is concentrated on land adjacent to River

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Section III (between Baardheere and Bu'aale), particularly to the east of the floodplain. This information agrees with reports of AHT (1984; 1988) and LRDC (1985). It is possible that there may have been a decrease of rainfed farming north of Baardheere and some increase south of the Fanoole Barrage during this period.

Table 5. A comparison of the percentage of land under rainfed cultivation in the river-dependent zone east and west of the Jubba floodplain.

RIVER SECTION	WEST		EAST	
	1984	1987	1984	1987
I	3.0	0.0	0.0	0.0
II	0.9	0.2	0.6	0.4
III	6.2	4.7	12.0	14.0
IV	7.0	0.2	7.1	4.3
V	0.2	0.0	1.0	0.0
VI	0.0	0.2	0.2	3.5
VII/VIII	0.1	0.3	0.8	1.9

Note: 1987 data are consolidated estimates for land 30 km west and east of floodplain. 1984 data are consolidated from several strata which fall partially within these 30 km bands, but many of which stretch considerably further. There is also some overlap of 1984 strata between river sections.

No attempt is made in this section to describe the farming and pastoral land-use systems employed in the Jubba Valley. A brief account is given in Section III.B and more detail can be found in Craven, Merryman, and Merryman (1989); AHT (1984; 1988); LRDC (1985); Watson and Nimmo (1985). Rangelands are discussed in Section VII.D.

A. Land-use Changes between 1960 and 1987

In order to describe changes in land use and vegetation in TEBS study area, the following maps were used:

- Trump's (1987) interpretation for JESS of 1960 aerial photomosaics at approximately 1:60,000. These maps cover the riverine area from just north of Saakow town to the Indian Ocean.
- AHT (1984) photomaps of land use, vegetation, and physiography of the Jubba floodplain at 1:50,000 based on 1983-1984 photography at 1:30,000. This interpretation begins just south of the proposed Baardheere Dam site and ends at the ocean.
- Trump's (1987) interpretation of 1987 1:10,000 photography of the riverine strip, mapped at 1:50,000, commissioned by JESS. The length of the river from Doolow to the ocean is covered, but restricted to a width of approximately 2 km each side of the river.

Because of different areas covered, variable quality of photographs, resolution of interpretations, and inconsistencies in interpretation, a straightforward comparison of areas under different land uses was not made. To do so would involve extensive re-interpretation and repetition of several months' work, but probably have little effect on conclusions.

Review of these maps showed that most changes occurred in the floodplain, particularly close to the river where forest is rapidly disappearing (Deshmukh 1987; presented in this report as Appendix J) and pumped irrigation is rapidly spreading (Watson and Nimmo 1988). Therefore, a comparison was carried out of length of various land types adjacent to the river (separately for east and west banks) by planimetry. The resolution of all three interpretations is such that the river-edge land type invariably stretches some distance inland, usually for several hundred meters. As a result, measurement of land-use categories along the river edge supplies good information about floodplain land use where the floodplain is narrow.

Table 6. Comparison of length of riverside land under cultivation derived from planimetry with area of floodplain under cultivation from a 10-percent aerial strip census.

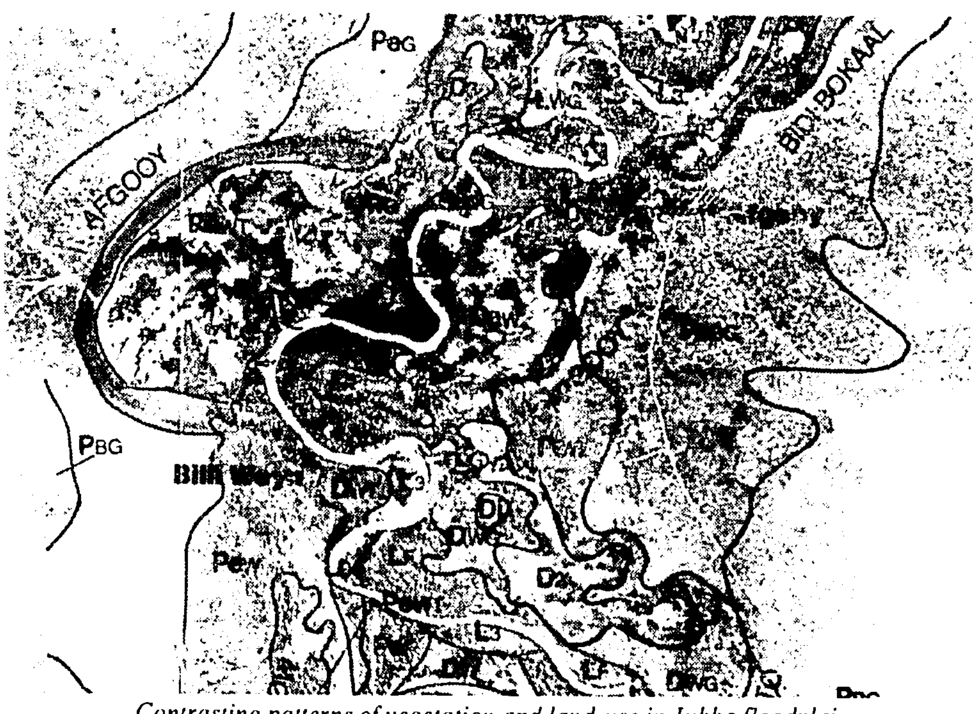
RIVER SECTION	PERCENT LENGTH	PERCENT AREA
I	58	25
II	48	18
III	54	39
IV	49	36
V	53	23
VI	94	53
VI/VIII	78	54

However, the strip adjacent to the river is not necessarily representative of the floodplain as a whole, particularly in wider sections. Table 6 compares percentage of river length under cultivation from this study with percentage of floodplain area cultivated, derived from a 10-percent aerial census conducted in the same season (Watson and Nimmo 1988). As expected, riverside land is used more intensely than the whole floodplain, but the trends in proportion of land cultivated between river sections are similar in both studies indicating that mapping of riverside land use is a good indicator, but not a precise estimate, of floodplain land use.

To simplify and clarify analysis, land types in the various interpretations were consolidated into five categories:

- denser woody vegetation including all types with greater than 20 percent woody cover such as bushlands, woodlands, thickets, and forests (see Section VI.B.3);
- more open vegetation types with less than 20 percent woody cover including grasslands and wooded and bushed grasslands;
- floodplain cropping without pumped irrigation, including flood recession and unirrigated farms;
- floodplain areas with pumped irrigation including riverside smallholdings and estates downstream of Fanoole Barrage; and
- other land types, a minor category including denuded areas around refugee camps, burned areas, and areas not interpretable due to cloud or poor photography.

Several limitations should be considered when reading results of the analysis in the next section. The 1960 interpretation is based entirely on large-scale photomosaics some of which are of poor quality (see the large percentage of "other" land types—actually uninterpretable areas—in the southern river sections of Figure 5). In contrast, the 1983-1984 and 1987 interpretations had access to the original stereoscopic photographic prints. However, errors in these interpretations remain in the view of this author. In the 1984 sheets, woody vegetation cover is usually underestimated, placing many bushlands and woodlands into bushed grassland and wooded grassland categories, respectively. These errors are corrected by the author using appropriate photographs and maps in this analysis for riverside vegetation to make interpretations consistent. Both previous interpretations tend to underestimate smallholder irrigation. These errors have also been partially corrected, although some underestimation and inconsistencies may remain. Large irrigated estates (Jubba Sugar, Fanoole Rice, and Mogambo) are underestimated



Contrasting patterns of vegetation and land-use in Jubba floodplain and surrounding river-dependent zone. (AHT)

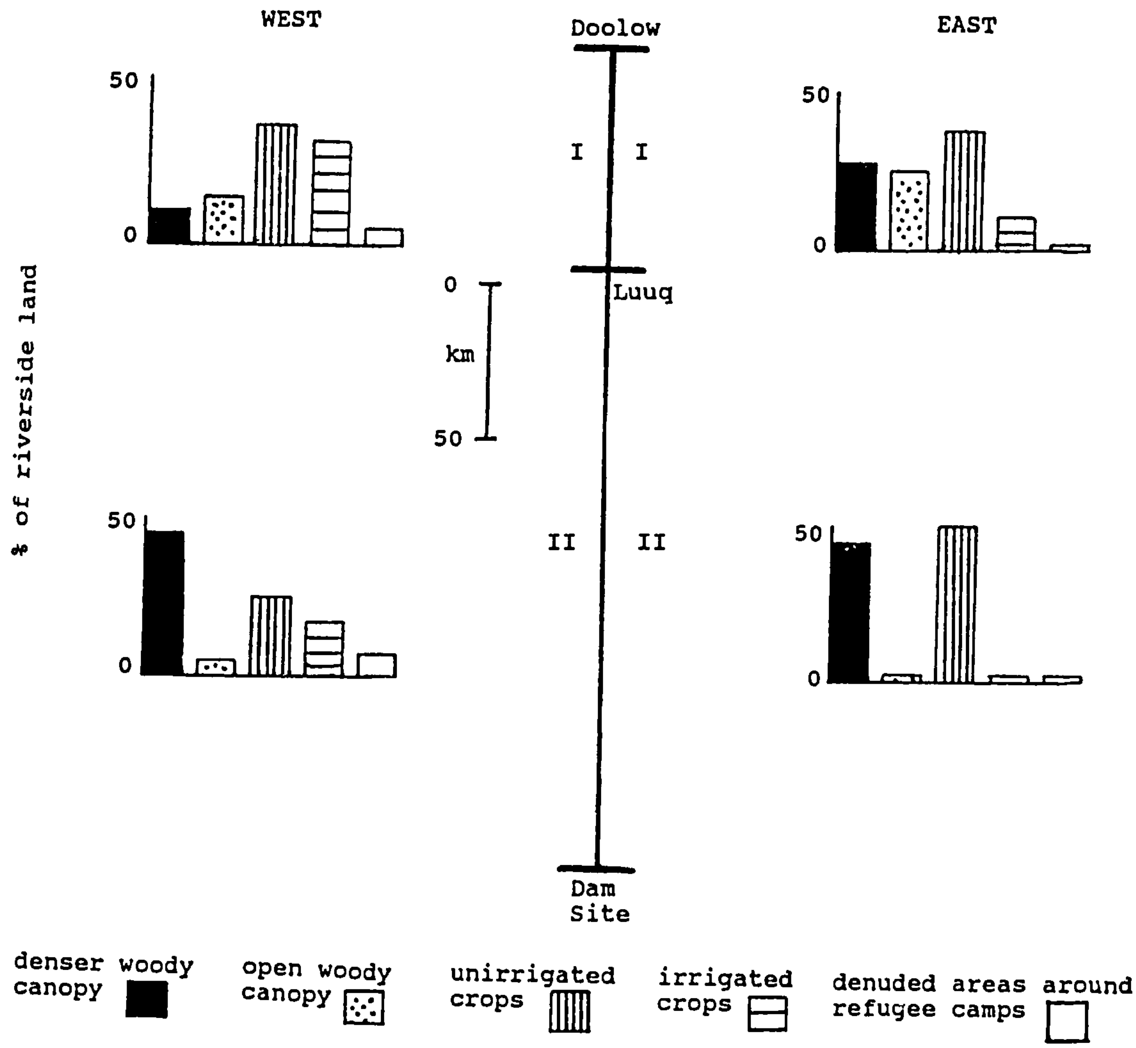


Figure 4. Percentage of riverside (east and west) under TEBS land-use types in River Sections I and II. See text for description of land-use types. Length of river sections to scale.

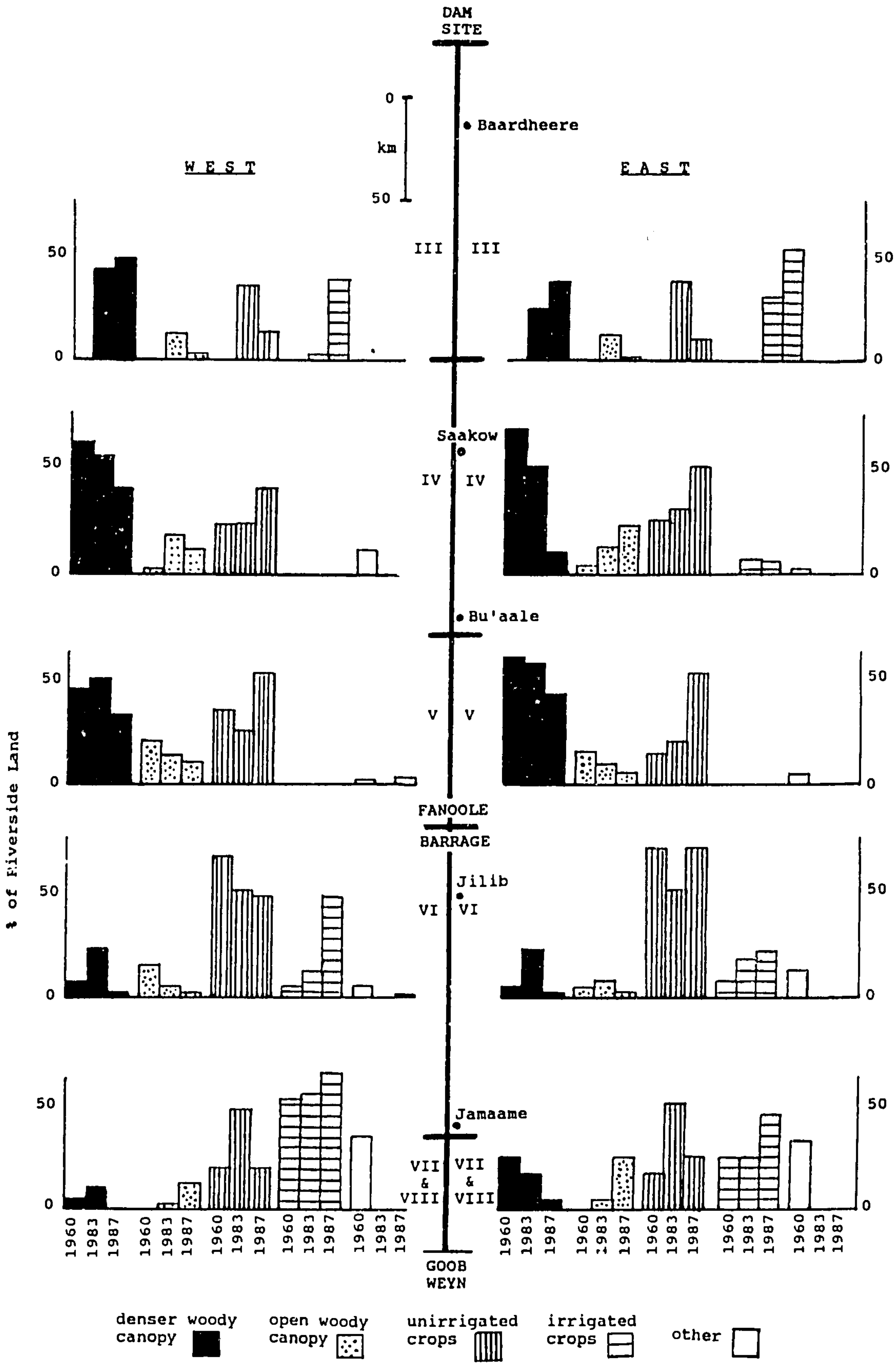


Figure 5. Distribution of riverside land (percent by length) under various land-use types in TEBS River Sections III to VIII derived from interpretation of aerial photographs taken in 1960, 1983-84, and 1987. See text for description of land-use types. Length of river sections to scale (along the river; Section VI includes eastern link around Mombassa Island).

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because many fields are not next to the river and are, therefore, excluded from the area of this analysis.

In River Sections II and III, where the river cuts through limestone plateaus and hills, in some stretches there is no floodplain on one or the other side of the river. Farming is not possible alongside the river here, and the slopes are usually bushland. As a result the proportion of cultivable land in such stretches is less than in other areas. Finally, smallholder irrigation cannot be distinguished on the 1960 photomosaics. Presumably, there was much less than in 1983, or at present. Growth of smallholder irrigation, particularly in Gedo, is reported as a recent phenomenon (AHT 1984; 1988). Access to these areas has been made easier in the last decade by improved roads to Baardheere and Buurdhubo.

An additional analysis of area under dhesheeg cultivation between Saakow town and Fanoole Barrage was made because of the importance of this type of agriculture in Middle Jubba (AHT 1984; 1988). Dhesheegs are often at some distance from the river edge and are underestimated by the methods described above.

The results of this study are summarized in Figures 4 and 5 and Tables 7 and 8. Figure 4 does not compare temporal changes since only the 1987 photo interpretation covers River Sections I and II.

Nevertheless, the data are of interest because of the paucity of prior information for the area to be inundated by Baardheere Dam and the floodplain north of Luuq town. Between Doolow and Luuq the floodplain attains greater width (1 to 3 km) than it does in downstream reaches between Luuq and Saakow. Most of this floodplain is farmed. Irrigation is particularly common on the west side. Grasslands are more common here than in most downstream areas. Most woody vegetation has been cleared for cropping or, around refugee camps, for fuelwood.

In River Section II (inundation area) approximately half the floodplain adjacent to the river is farmed, irrigation again being more common to the west. The remainder of this area is mostly under denser vegetation with little open vegetation.

Figure 5 compares land-use categories for the years 1960, 1983-1984 (arbitrarily set at 1983), and 1987. An overall trend towards increased agriculture is clear, with irrigation predominating around Baardheere and south of Jilib. Most of this change has occurred in recent years. Indeed, total changes between 1960 and 1983 are usually much smaller than those between 1983 and 1987. An exception is development of the Jubba Sugar and Fanoole Rice projects, but these changes do not show up fully in this analysis for reasons explained above. Between Saakow and Fanoole Barrage changes in the first period are very slight; in some cases it seems that agriculture may have experienced a decline. In northern sections (Baardheere to Fanoole Barrage) spread of agriculture (unirrigated and/or irrigated) has been greater on the east side of the river which has better communications and more towns creating markets for produce. South of Jilib almost 90 percent of the riverside land was farmed as early as 1960.

Table 7 illustrates these trends by showing rates of change. The pace of development has accelerated enormously in the last few years. Overall, the average annual loss of vegetation and gain of farmland increased tenfold in 1983 to 1987 compared with 1960 to 1983. During the first period, increase of farmland was at 3 km $year^{-1}$, accelerating to 28 km $year^{-1}$ during the second period. At the present rate of change, all riverside land will be cultivated by the end of the century. Around Baardheere and in the south, farmland has been converted to irrigation, while in the middle sections vegetation has been cleared for unirrigated farms. The increase in denser woody vegetation between 1983 and 1987 around Baardheere seems to have been at the expense of open vegetation types. This trend may reflect the move to irrigation. Open vegetation is maintained by fires escaping from field preparation (see Section VI.D). Such practices are much reduced or absent in irrigated agriculture.

A similar pattern can be seen in the extension of dhesheeg farming between Saakow and Fanoole Barrage (Table 8). Cultivation increased slowly to almost double between 1960 and 1983. A greatly accelerated pace led to an equal increase during the next four years.

Farming of dhesheegs is a complex affair depending on time and degree of flooding as well as socioeconomic factors. For example, 4 km^2 of dhesheeg farmed in 1987 was submerged in 1983. However, the remaining dhesheeg land added to cultivation during this period was all at the expense of vegetation. Most of this clearance for dhesheeg farming has been in the stretch of river between

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Table 7. Land-use changes along the Jubba River between 1960 and 1987, based on aerial photograph interpretation.[†]

[†]Changes are expressed as kilometers or percent of riverside land by length (sum of east and west banks), by river sections north to south.

RIVER SECTION	LAND TYPE	1960-1983** TOTAL CHANGE km	1960-1983** TOTAL CHANGE PERCENT	1960-1983** CHANGE km PER YEAR	1983-1987 TOTAL CHANGE km	1983-1987 TOTAL CHANGE PERCENT	1983-1987 CHANGE km PER YEAR
III	Denser veg				+22	+7	+5.5
	Open veg				-29	-10	-7.3
	Unirrigated				-75	-25	-18.8
	Irrigated				+82	+27	+20.5
IV	Denser veg	-30	-12	-1.3	-44	-17	-11.0
	Open veg	+31	+12	+1.4	*		
	Unirrigated	-4	-2	-0.2	+47	+18	+11.8
	Irrigated	+10	+4	+0.4	-2	-1	-0.5
V	Denser veg	+6	+3	+0.3	-28	-16	-7.0
	Open veg	-9	-5	-0.4	-9	-5	-2.3
	Unirrigated	+7	+4	+0.3	+35	+19	-8.8
	Irrigated	*			*		
VI	Denser veg	+46	+15	+2.0	-49	-16	-12.3
	Open veg	-10	-3	-0.4	-12	-4	-3.0
	Unirrigated	-52	-17	-2.2	+20	+7	+5.0
	Irrigated	+19	+6	+0.8	+36	+12	+9.0
VII/VIII	Denser veg	*			-10	-9	-2.5
	Open veg	+4	+4	+0.2	+16	+14	+4.0
	Unirrigated	+34	+30	+1.5	-28	-25	-7.0
	Irrigated	*			+21	+18	+5.3
TOTAL	Denser veg	+22	+2	+0.9	-109	-10	-27.3
	Open veg	+16	-2	+0.7	-34	-3	-8.5
	Unirrigated	-15	-2	-0.7	-1	*	-0.3
	Irrigated	+29	+3	+1.3	+137	+12	+36.3

* *indicates negligible amount*

** *1960 maps do not cover River Section III.*

Note: Arithmetic discrepancies are due to the "other" land use category (see text) and small variations in lengths measured by planimetry.

Table 8. Changes in land use of dhesheegs in Middle Jubba between 1960 and 1987 based on interpretation of aerial photography. Areas under cultivation in each year and changes between years are given.

AREA OF DHESHEEGS CULTIVATED (km^2)

RIVER STRETCH	1960	1983	1987
Saakow-Bu'aale	9.1	19.5	27.6
Bu'aale-Fanoole Barrage	26.2	43.4	68.0
Total	35.3	62.9	95.6

RATE OF CHANGE IN AREA CULTIVATED ($km^2\ year^{-1}$)

RIVER STRETCH	1960-83	1983-87
Saakow-Bu'aale	0.4	2.0
Bu'aale-Fanoole Barrage	0.8	6.1
Total	1.2	8.1

Bu'aale and Fanoole Barrage putting extreme pressure on the few remnants of riverine forest (Appendix J).

Data presented in this section show gross changes over several years or annual arithmetic average rates of change as though these figures represent uniform trends. This assumption of steady change may be reasonable for the short period between 1983 and 1987, but must be viewed with caution for 1960 to 1983. During these 23 years, fluctuations in land use probably occurred with changes in socioeconomic climate, drought cycles, and river flooding patterns. For example, two patches of dhesheeg (1 km^2) went out of production between 1960 and 1983, although greater increases occurred elsewhere. Nevertheless, the overall conclusion, that change was slow during the first period and more rapid recently, is significant.

B. Seasonal Changes in Land Use

This section reports on results of low-level aerial censuses conducted for JESS by RMR in 1987 (Watson and Nimmo 1988). The censuses were in late January to early February (mid-jiilaal), early April (late jiilaal) and August (mid-xagaa). These periods were chosen primarily to quantify livestock numbers and distribution rather than agricultural land uses. The first census covered the floodplain only, while the second and third covered the floodplain and river-dependent zone.

To get a picture of a "typical year" in the Jubba Valley requires data from many years to assess the effects of drought and flood cycles. Even such a thorough study would be of limited value because of rapid changes in land use described above. Representation of such a typical year would be a statistical abstraction, and could mislead rather than clarify. Therefore, the following account describes events in jiilaal and xagaa 1987 and cannot be generalized to other seasons and years without further information. These seasons are put in temporal context in Section III.B. Briefly, the jiilaal was harsh because of poor deyr rain in 1986 and extremely late arrival of the gu'. Shortly after onset of gu' rain, the largest river flood since 1977 occurred. Thus, the period studied experienced a prolonged dry season and a major flood.

Watson and Nimmo (1988) present a full set of tables and maps for land-use categories and diagrams for the sample strata. These strata can be combined in various ways. Figures 6 and 7 show different aggregations of strata in the floodplain. Figure 6 divides the floodplain north to south into river sections (as in Figures 4 and 5). The general pattern is similar to Figures 4 and 5, albeit dealing with land areas rather than river lengths. Furthermore, this analysis distinguishes flood recession farming, enclosed and cleared land, burned areas, and flooded areas.

From a low-flying aircraft it is not always possible to distinguish areas from which water has just receded, so underestimation of flood recession farming may occur. However, the consistent methods used produce results indicative of changes between seasons. Flood recession agriculture is at a low level throughout, except between Bu'aale and Fanoole Barrage. Most dhesheegs were dry in jiilaal, precluding this type of farming. After the flood, both riverbank and dhesheeg cultivation increased, the latter markedly in some river sections. However, large areas remained under water, limiting the extent of flood recession agriculture. These results emphasize the opportunistic nature of this form of agriculture. Some dhesheegs hold water for many years and planting follows the declining water level throughout. Others dry quickly and may be farmed as dry land most of the time.

Clearing and burning of land reached a peak in late jiilaal as land was prepared for cultivation. Fires are set to clean fields, but often escape into surrounding rangelands. The peak of fires in River Section V agrees with TEBS ground observations. Note that cultivated area drops in xagaa despite the previous clearing of land. Reduced cropping was caused by the flood between the second and third censuses, which devastated crops in most areas. Ground studies indicate that many sharecroppers' pumps were withdrawn in River Section II following inundation (TEBS field notes). Flood waters covered nearly all the floodplain initially, but had receded by the time of the xagaa census. Nevertheless, 20 to 40 percent of land was still inundated in lower river sections.

Figure 7 presents the same floodplain data, but divided into physiographic categories of undifferentiated sediments (River Sections I to III) and levees; dhesheegs; flat, free-draining sediments; and heterogeneous sediments in River Sections IV to VIII (see Section IV.B). The same patterns are evident overall. Note that flood-recession agriculture in depressions is not restricted to the fine-

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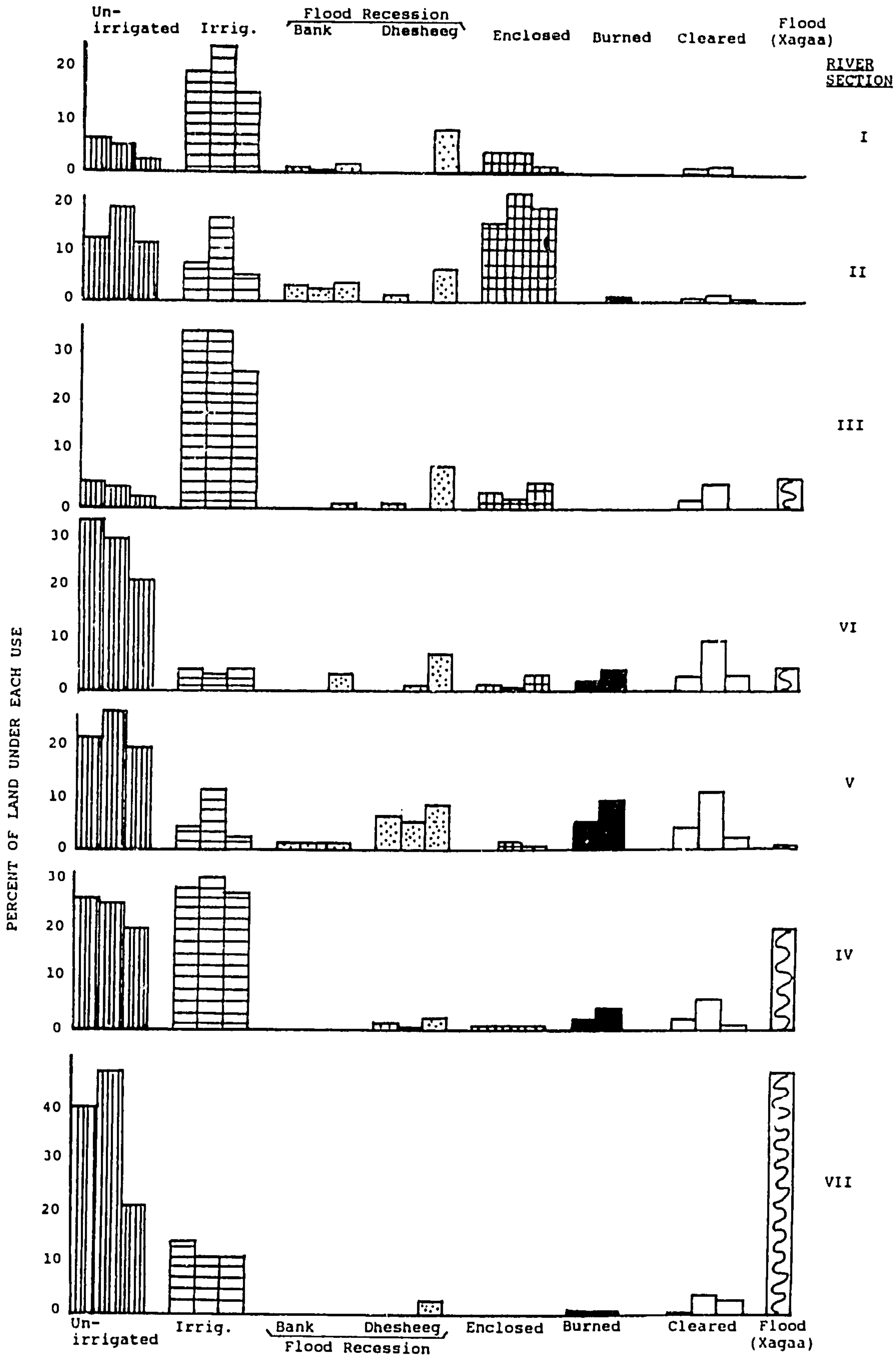

Figure 6. Percentage of floodplain area in each river section under various land uses excluding rangeland. In each case, the first column is for mid-jiilaal, the second column for late jiilaal, and the third column for mid-xagaa under each land use in 1987. Burning was only seen in the first two censuses and flooding only in the last. Data from 10-percent aerial strip census (Watson & Nimmo 1988).

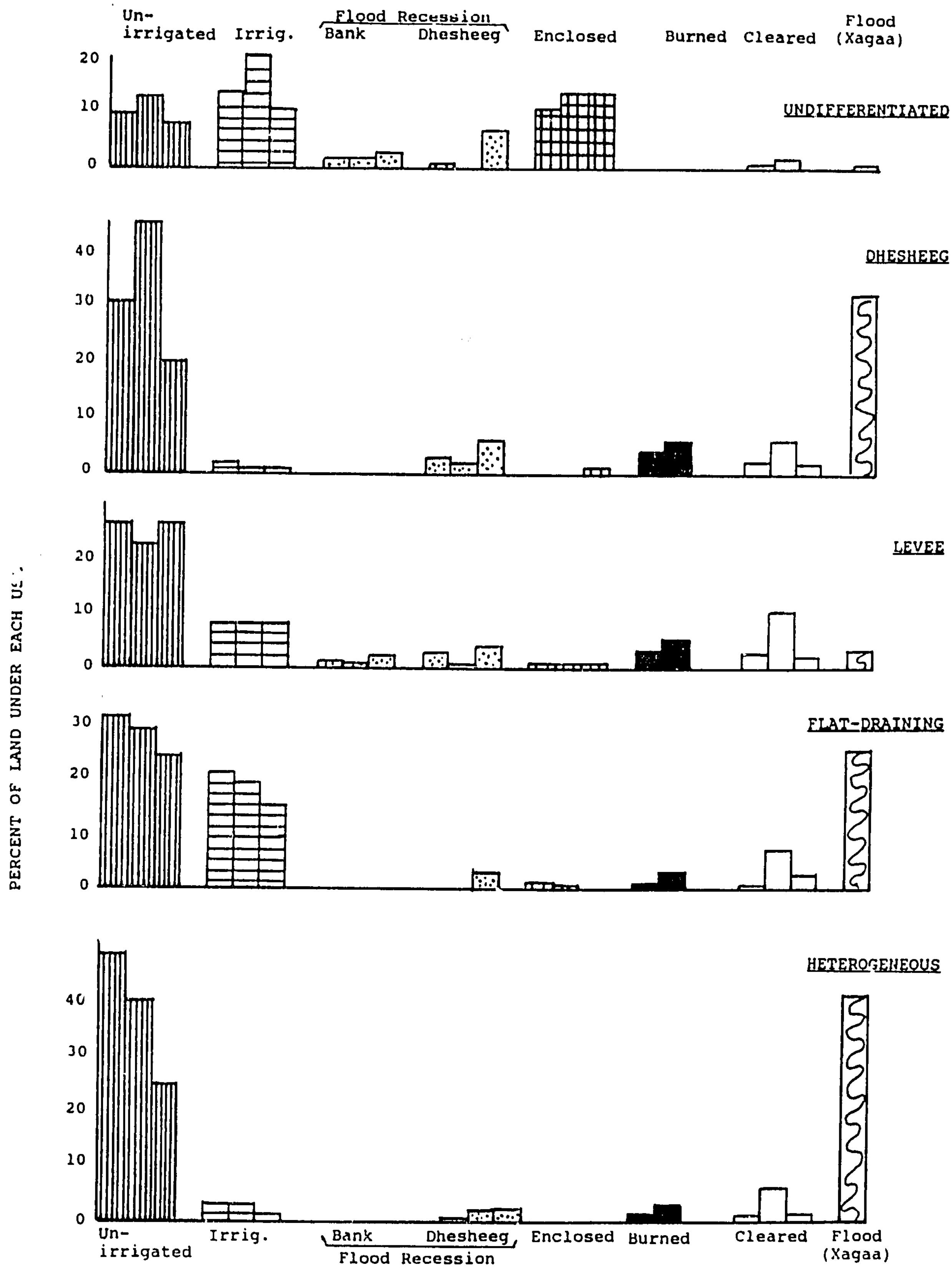

Figure 7. Percentage of floodplain area divided by land physiographic types (see text) under various land uses, excluding rangeland. In each case the first column is for mid-jiilaal, the second column for late jiilaal, and the third column for mid-xagaa under each land use in 1987. Burning was only in the first two census and flooding only in the last. The irrigated estates category, which had approximately 80 percent of land under irrigation in each season, is omitted. Data from 10-percent aerial strip census (Watson & Nimmo 1988).

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grained sediments of classic dhesheegs, but that suitable depressions occur in other land types after a flood, even on the generally coarse sediments of levees. Again, the opportunistic nature of this land-use is emphasized. The only increase in unirrigated agriculture following the flood (as shown in Figure 7) is on levees. These areas drain quickly and crops are planted rapidly and continuously as water recedes exposing more land. Levees also show the greatest proportion of cleared land in the jiilaal in anticipation of cultivation.

Enclosure of land is most common in the floodplain of River Section II (Figure 7). Ground studies show that both croplands and pastures are enclosed. Further downstream, enclosures are virtually absent from most land types. In dhesheegs, the traditional farming pattern makes permanent delineation impractical. As water recedes due to evaporation and infiltration, farmers who have traditional possession of a sector of a dhesheeg perimeter plant that sector continually following the water level down towards the center of the dhesheeg. These activities produce a radial pattern of field plots and a concentric pattern of crop maturity. Most water loss from dhesheegs is by evaporation since clay soils severely impede infiltration.

Table 9. Seasonal change in land-use in river-dependent zone of TEBS study area based on aerial census in 1987 (percent of total land under each use).

REGION	RAINFED FARM		CLEARED		BURNED		ENCLOSED	
	A	B	A	B	A	B	A	B
Northern limestone								
close to river	4 9	5 6	0.2	0.2	0	0	2.5	2.2
far from river	1 8	2 7	0.1	0.1	0	0	1.7	1.8
Southern Marine Plain								
close to river	2.2	2.1	0.2	0.2	0.8	0	0.2	0.5
far from river	0.3	0.7	*	*	*	0	0.1	0.1

A = late jiilaal season B = xagaa season.

Seasonal changes in land use outside the floodplain are shown in Table 9. This table splits the river-dependent zone east-west into areas close to (0 to 15 km) and more distant from (15 to 30 km) the floodplain. North to south, the area is further divided into northern limestones and southern marine plains (see Section III.A). This transition occurs between Saakow and Bu'aale. As already indicated, the river-dependent zone is mainly rangeland with little agriculture. As expected, rainfed farms are more extensive following the gu', although changes are slight. Most farming and enclosure of land is found in areas closer to the floodplain and north of the marine plains. Of note is the small amount of burning in these rangeland areas. It seems that pastoralists rarely set fires in the study area. This observation may be due in part to a shortage of grass fuel in some parts of the river-dependent zone (see Section VII.D)

C. Conclusions

Changes of land use in the Jubba floodplain have increased markedly in recent years. Between 1983 and 1987 two trends are apparent:

- rapid decline of denser vegetation types;and
- conversion of dryland or flood-recession farms to pumped irrigation.

These recent changes have occurred, on average, at 10 times the annual rate estimated between 1960 and 1983. At the rate of agricultural expansion operating between 1983 and 1987, all riverside land will be farmed before the end of the century. The rapidity of these changes makes planning difficult. Development in the floodplain is occurring irrespective of whether plans exist or are implemented. If present trends continue most of the remaining vegetated riverside land will be cultivated and planning options reduced before the dam is closed. Because of rapidity of change, JESS baseline studies cannot be regarded as a definitive statement applicable after dam construction.

Effective monitoring to continually update information before decisions are taken is crucial. The proposed JESS monitoring program will enable important changes to be tracked. Training of technicians and planners to use monitoring information should be a high priority (see Section X: Craven, Merryman, and Merryman 1989; Tillman 1989).

Land-use changes are not uniform throughout the valley. Outside the floodplain such changes are slight. Within the floodplain there has been a marked change from unirrigated and flood recession agriculture to smallholder, pumped irrigation north of Luuq and in Baardheere District. Between Bu'aale and Fanoole, unirrigated agriculture has expanded at the expense of vegetation cover.

Filling of Baardheere Dam will take 5,000 to 10,000 ha of riverine land out of agricultural production. Approximately one-third of this land is irrigated. A further 5,000 ha is enclosed, partly as grazing reserve. In the years of dam construction, these land uses will probably increase, along with more investment in irrigation. Most of this land will be permanently inundated after the dam is closed. In the short-term, after the dam is operational, drawdown agriculture may be possible in restricted areas of suitable soil around the reservoir perimeter, particularly in the narrow floodplain south of Luuq. Over time riverine sediment may be deposited in other parts of the drawdown area, extending agricultural potential. Whether such land could be used effectively, and the rate at which deposition will occur, are unknown. *The possibility of using the drawdown area for agriculture, and monitoring the situation around the reservoir, should be incorporated into the master plan.*

After closure of the dam, floods will be less frequent and less extreme. Current projections suggest flooding at intervals of approximately five years. Most floods will occur in unprotected areas in Lower Jubba (AHT 1988). At other times, river level will be more or less constant precluding flood-recession agriculture. At present, it seems that most farming in the floodplain is not flood-recession farming (Figures 7 and 8), although there is likely to be significant variation from year to year. Even when land is not flooded or irrigated by pumps, seasonal river flood waves raise the water table adjacent to the river enhancing soil moisture for crops (Besteman and Roth 1988). The significance of this factor for crop production is unknown, but its important effect on vegetation is clear (see Sections VI, VII, and IX). When land is flooded, riverine sediments and water rich in dissolved chemicals increase soil fertility. In the absence of floods, crop yields will eventually decline unless fertilizers are added.

It must be emphasized that the dam will have a major beneficial effect by reducing large economic losses caused by destructive floods and subsequent temporary loss of submerged land. In the absence of floods, cropping will become much more predictable provided sufficient inputs of water by irrigation are supplied and soil fertility is maintained. Thus, substantial benefits from the dam will be realized if rational economic development occurs.

The adverse effects of reduced flooding will be felt most severely between Saakow and Fanoole Barrage where pumped irrigation is rare. Construction of an all-weather road between Jilib and Bu'aale may open this area to development of pumped irrigation. At present, poor communication and a largely subsistence economy limit the feasibility of using pumps. Nevertheless, some farmers in this area will suffer declining productivity as dhesheeg and riverbank cultivation become less effective. *A phased change from assisted dhesheeg farming to pumped irrigation as suggested by AHT (1986) may be the best approach to alleviate these problems (see Section IX).*

Recommendations from this section primarily concern future monitoring activities, which are discussed in Section X.

VI. VEGETATION OF THE JUBBA VALLEY

This section describes vegetation types in the Jubba Valley in terms of structural types, species composition, diversity, and dynamics. The term "natural" vegetation is avoided since human activities significantly modify most plant communities. No recommendations are included, since those relevant to vegetation are dealt with in all subsequent sections. However, conclusions and effects of closure of Baardheere Dam are included as Section VI.E. Much of the section is primarily of interest to ecologists, but the conclusions are of direct relevance to any development-oriented reader.

Particular emphasis is placed on vegetation in the floodplain and how it differs from rainfed vegetation in the river-dependent zone. Most non-floodplain plant communities and species in TEBS study area are widespread in southern Somalia, eastern Kenya, and other regions. However, the floodplain communities are very unusual within Somalia, since the Jubba is the only perennial river. Similar plant communities probably occur on the Shabeelle river, but are of limited extent due to more intensive agricultural development. In addition to species composition, differences in vegetation structure, diversity, and seasonal patterns are apparent.

Historically, it seems that much of the floodplain was forested in river sections IV to VIII. Restricted forests probably occurred in more northerly sections since forest trees can be found all along the river. *Acacia* woodlands now represent the densest vegetation in these sections. As recently as 1960, south of Saakow, almost 100 km^2 was under closed forest, but less than 10 km^2 remained along the whole river length by 1987 (Appendix J). The forest remnants are of much interest ecologically and from a conservation perspective (see Sections VI.C.3 and VIII). Such evergreen lowland forests usually occur in the tropics when annual rainfall exceeds 1,000 mm. That they occur on the Jubba in semi-arid conditions clearly indicates the importance of riverine flooding and groundwater for floodplain vegetation.

The distribution of land under native vegetation, as opposed to agriculture, in various parts of the study area is given in Table 10. As noted in Section V much of the floodplain is now cultivated (approximately one-half), whereas non-floodplain lands remain predominantly as rangelands. Enclosure of uncultivated land for range reserve or other purposes is only important in northern floodplains.

Table 10. Total area of land and percentage under native vegetation cover in the study area by river section comparing floodplain (FP) and river-dependent zone west (W) and east (E) of floodplain. Enclosed areas are without agriculture but under native vegetation cover. Data from aerial censuses (Watson and Nimmo 1988).

RIVER SECTION	TYPE	TOTAL AREA (km^2)	% OPEN[1]	% ENCLOSED
I	FP	93	66.6	6.2
	W	1,058	97.5	1.8
	E	1,058	98.2	1.4
II	FP	270	54.6	17.7
	W	4,045	98.5	1.2
	E	4,045	97.5	1.8
III	FP	65	54.8	2.7
	W	3,095	94.2	1.5
	E	3,095	78.9	4.7
IV	FP	140	56.3	<1.0
	W	1,860	99.0	<1.0
	E	1,860	95.1	<1.0
V	FP	147	66.7	<1.0
	W	1,430	100.0	0.0
	E	1,430	100.0	0.0
VI	FP	695	42.3	0.0
	W	4,769	99.8	0.0
	E	2,142	95.1	0.0
VII/VIII	FP	346	35.4	0.0
	W	2,081	99.0	0.0
	E	398	97.2	<1.0
TOTAL Study Area	FP	1,766	47.6	3.0
	W	18,338	98.3	<1.0
	E	14,298	93.1	1.6

[1] *"Open" is all land not actively mananged; non-floodplain percentages are mean of late-jiilaal and xagaa censuses 1987. Floodplain is mean of early- and late-jiilaal and xagaa censuses 1987, except for river sections III, IV, VI, and VII/VIII; in these sections substantial land was flooded in xagaa and mean of two jiilaal censuses is given.*

A. Other Studies and the JESS Approach

Recent resource surveys have mapped various attributes of vegetation in the study area. LRDC (1985) provides a vegetation and land-use map based upon 1983-1984 aerial photography at 1:500,000. From the same photography, AHT (1984) produced a detailed vegetation and land-use map based upon floodplain physiography (1:50,000; see Sections IV and V). For the Southern Rangeland Survey, Watson and Nimmo (1985) subdivided the area into "land-system units" mapped at 1:250,000, which are partly based upon vegetation characteristics; they also produced a 1:1,000,000 map of structural vegetation types. For JESS, Trump (1987) has mapped vegetation and land use at 1:50,000 of a strip 2 km either side of the Jubba. All these maps are available (see annotations in References section) and are more or less compatible. Therefore, no attempt is made in this volume to produce another vegetation map.

JESS studies of terrestrial vegetation avoid repeating other recent work, but attempt to integrate these previous efforts. A multilevel approach is used, combining aerial photography, aerial census, and ground monitoring sites. The main objectives are as follows:

- to determine how floodplain vegetation differs from non-floodplain vegetation;
- to determine how vegetation is used by the human population (covered mainly in Sections V and VII);
- to quantify the area covered by different vegetation types now and in the recent past (see also Section V and Appendix J);
- to establish a basis for vegetation monitoring (see Section X); and
- to predict likely effects of Baardheere Dam.

B. Vegetation Monitoring Sites

The Southern Rangeland Survey (Watson and Nimmo 1985) established 626 ground monitoring sites in southern Somalia. These sites cover the area fairly uniformly (subject to accessibility), but give no special emphasis to the Jubba floodplain. One hundred and fifty-five of these monitoring sites fall in TEBS study area (see Map 1; note that most sites are paired, only one location is shown), but only 18 are in the floodplain (Table 11). Detailed descriptions of vegetation structure and species composition, surface soil characteristics, range condition, and other features were recorded and photographed at Southern Rangeland Survey sites.

TEBS could not improve on this broad coverage of non-floodplain rangelands. Therefore, emphasis on new monitoring sites was for the following purposes:

- Ground sites were established for long-term and seasonal monitoring in the Jubba floodplain and nearby non-floodplain sites downstream of the dam site. Seasonal monitoring was carried out to elucidate special features of floodplain vegetation and land use.
- Ground sites were established in the poorly studied inundation area to describe vegetation which will be lost. Sites above maximum water-level and in the drawdown zone were also set up for future monitoring.
- A large number (595) of large-scale (1:1,000) vertical aerial photographic monitoring sites were established throughout the study area. These photographs represent a stratified random sample and can be used for making quantitative statements about vegetation types as well as being a valuable long-term monitoring tool.

1. Ground Monitoring Sites

Ninety TEBS ground-monitoring sites were established, distributed as shown in Table 11 and Map 1. Sites were chosen to cover the main vegetation and physiographic types identified by the AHT (1984) vegetation map. To represent all 36 of these vegetation types in a statistically valid manner would require many hundreds of samples. From the outset, it was decided that a more useful approach entailed

Table 11. Distribution of vegetation monitoring sites in the study area by river sections. The types of site are discussed in the text; SRS = Southern Rangeland Survey; FP = floodplain; W = 0 to 30 km west of floodplain; E= 0 to 30km east of floodplain.

River	JESS GROUND			JESS PHOTO			SRS		
Section	FP	W	E	FP	W	E	FP	W	E
I	0	0	0	13	14	18	0	8	14
II*	23	10	3	49	51	21	0	12	10
III	2	0	0	23	16	19	4	6	12
IV	9	0	7	40	25	22	2	12	12
V	9	2	1	34	10	16	2	8	2
VI	11	6	2	69	16	16	7	6	14
VII & VIII	3	2	0	63	14	11	3	17	4
TOTAL	57	20	13	291	146	123	18	69	68

** River Section II includes all inundation area up to 142 masl contour and is not all strictly floodplain.*

seasonal visits to a limited number of sites to obtain insights into vegetation use and dynamics. Given the rapid change in vegetation (Section V; Appendix J), statistically comprehensive descriptions of disappearing sites were deemed to be of less value than examining fewer representative sites in greater detail. Aerial photography was relied upon for a more complete and statistically valid approach (AHT 1984; Trump 1987; Section VI.B.2).

Table 12. Distribution of JESS vegetation monitoring sites in the floodplain in relation to physiographic classification (see Section IV.2).

PHYSIOGRAPHIC TYPE	GROUND SITES	PHOTO SITES
undifferentiated alluvia	11	56
levees	11	90
dhesheegs	12	51
flat free-draining alluvia	5	27
heterogeneous alluvia*	3	55
togga	4	12

** underrepresented in ground samples; heavily farmed such that 30 percent of photo samples are termed "mixed" due to lack of vegetation uniformity caused by high level of human activity.*

A typical ground monitoring site is a 20 m x 20 m square although other configurations were used (see Appendix A). Within that square all woody plants above 1 m in height were identified and measured on the first visit for basal diameter, crown diameter, crown depth, and height. Herbaceous vegetation cover was estimated seasonally for grasses, forbs, and dwarf shrubs using a point-frame technique. Standing crop of herbaceous plants was also estimated seasonally by harvesting samples and oven-drying (see Appendix A). Phenological condition (degree and timing of leaf, flower, and fruit) and degree of grazing or browsing were noted for more common species. Other observations, including a complete species list of plants in the vicinity of each site, land-use features, surface soil characteristics, and ethnobotanical information, are described in Appendices A and I.

Although no ground monitoring sites are in the floodplain of River Section I, the vegetation there has been comprehensively described by Wieland (1984) and Wieland and Werger (1985).

2. Photographic Monitoring Sites

Vertical aerial photographs of approximate scale 1:1,000 were taken for analysis of vegetation structure. Each nine-by-nine print covers approximately 5.3 ha. The central 15 x 15 cm portion (equivalent to 2.25 ha) was used for analysis to avoid distortion towards the edge of the photographs. Sampling was on a stratified random basis (the technique employed is described in Appendix B and Watson and Nimmo 1988). Floodplain strata are given in Table 12. For the river-dependent zone, stratification was with respect to distance from the river and river sections. The overall distribution of these photographs is shown in Table 11. Precise locations are given on RMR map series in the JESS Data Repository at USAID/Somalia.

Vegetation was analyzed in two ways. First, a dot grid was used to estimate cover of woody plants. Second, crown diameter was estimated for a random sample of trees and bushes on each photograph (see Appendix B).

3. Vegetation Classification

A system of classification was required that is compatible with the two monitoring site techniques and with previous work (particularly Watson and Nimmo 1985; LRDC 1985; AHT 1984; Trump 1987). In general, it is convenient to describe different vegetation types in gross structural terms such as grassland, bushland, or forest, rather than by species composition. As a second step floristics can be added, where appropriate, to give more information, such as *Sporobolus helvolus* grassland or *Acacia-Terminalia* woodland.

The most widely used structural classification in East Africa was devised by Pratt, Greenway, and Gwynne (given in its fullest form in Pratt and Gwynne 1977). This system was used in preparing Jubba vegetation and land-use maps of AHT (1984) and Trump (1987). Although the system has its weaknesses, the general descriptors are well known to East African ecologists and verbal descriptions are, therefore, widely understood. The system is based on percentage cover of ground by crowns of shrubs and trees. Such a system has the advantage of being applicable in ground studies and aerial photographs. Weaknesses of the basic system are its lack of categories between 20 percent and 100 percent woody cover, and the lack of emphasis given to the status of the herb layer. For JESS studies a modified version of the system has been devised which is briefly described in Table 13 and fully explained in Appendix C. TEBS data bases can be used to generate other cover categories if desired. For TEBS ground sites, the low-shrub layer (woody plants <2 m which normally do not grow taller) and herbaceous layer are described separately for more detail. Thus, TEBS ground site 3 is an "open bush-

Table 13. Classification of vegetation types in the Jubba Valley using structural criteria. (See Appendix C for more detail).

Step 1: Is woody canopy cover (2 m height) greater than 2 percent? (If not go to steps 2 and 3 directly).

% Woody Cover	Canopy < 5 m High	Canopy > 5 m High
2 - 19	sparse bushland or bushed grassland[1]	sparse woodland wooded grassland[1]
20 - 39	open bushland	open woodland
40 - 59	medium bushland	medium woodland
60 - 79	dense bushland	dense woodland
80 +	thicket bushland	forest

Step 2: If woody cover is less than 2 percent consider low-shrub cover (woody plants 2 m high) using % woody cover categories as in step 1 (2 to 19 percent sparse low-shrub layer, etc.)

Step 3: Herbaceous cover is measured using a point-frame and recording number of "hits"[2].

0 - 49 hits	negligible herb layer
50 - 99 hits	sparse herb layer
100- 249 hits	medium herb layer
250+ hits	dense herb layer

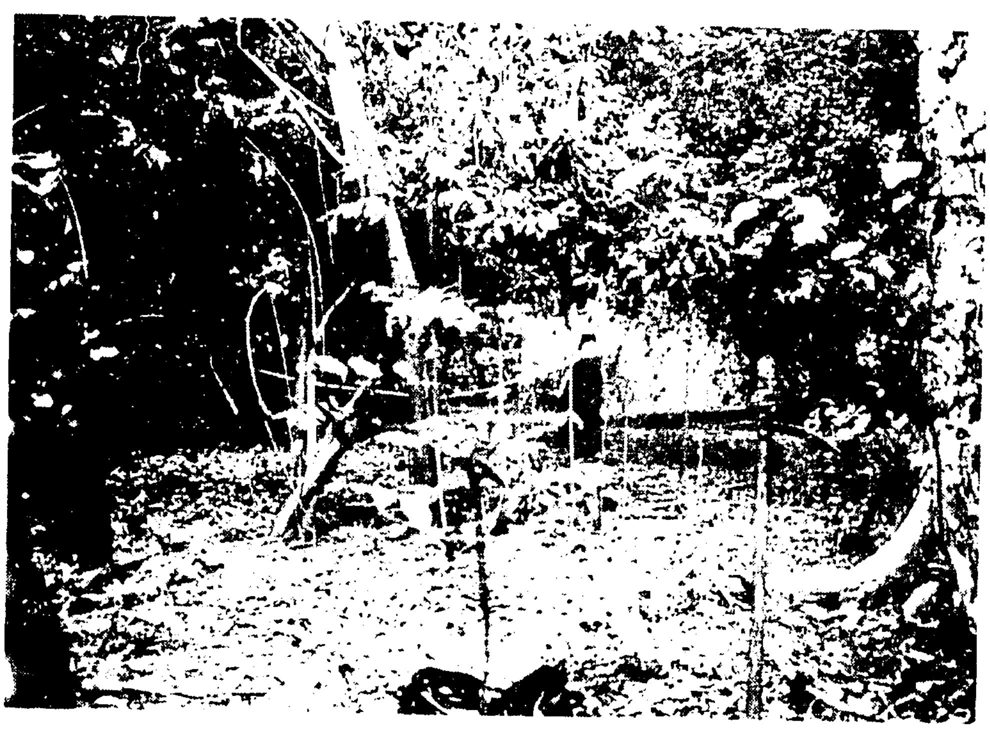
Step 4: If woody and low shrub cover are 2 percent and herbaceous cover negligible, site is classified as barren land.

[1] *"bushed" and "wooded grassland" replace "sparse" categories when herb layer exceeds "negligible"*

[2] *"hits", see Appendix C*

land with open low-shrub layer and sparse herbaceous layer"; site 25 is a "medium bushland with an open low-shrub layer and dense herbaceous layer." This classification of low-growing vegetation for each site is included in JESS data bases for ground sites. Because low-shrub and herbaceous cover are less easily defined for photographic monitoring sites, only tree and bush cover are used as descriptors in most cases.

Figure 8 shows the proportion of structural vegetation types in TEBS study area based on aerial photograph sites. Since these sites are a stratified random sample, they are regarded as representative, although total sample area is small (0.77 percent of floodplain; 0.04 percent of river-dependent zone). Combining this table with the information in Table 10, area under each vegetation type can be calculated. Table 14 compares the randomly chosen photographic sites with the subjectively chosen ground sites. Grasslands, particularly in the floodplain (including wooded and bushed grasslands), seem overrepresented in the ground sample. However, it is possible that grasslands are underrepresented in the photographic samples for two reasons. First, the aerial photographs were commissioned to avoid farms and emphasize vegetation. Many floodplain grasslands may have been correct-



Evergreen tall forest once covered much of the Jubba floodplain.

ly assessed as "abandoned" or "fallow" cultivation and avoided by the pilot/photographer using his census land-use classification (Watson and Nimmo 1988). These two land-use categories comprise 30 percent of total land in the floodplain. Second is a matter of scale: a 20 m x 20 m ground plot may be placed in a grassy section of a patchy area, some of which is relatively open and some of which has denser woody vegetation. A 5-ha photograph will sample this diversity to give an overall picture of a larger area. Photo interpretations of the whole area suggest that floodplain grasslands are under-represented in the aerial photograph monitoring sites. For example, 20 percent of riverside vegetation was "open" in 1987 (Section V) compared with 7.5 percent for the whole floodplain from the monitoring photographs.

Figure 8 compares percentage of vegetation types in floodplain and river-dependent zones. The frequency distributions are strikingly similar. This similarity is a secondary feature resulting from human activity reducing woody vegetation in the floodplain. Overall, bushlands of various densities dominate both floodplain (61 percent) and non-floodplain (71 percent) vegetation (Figure 8). However, the floodplain carries more tall vegetation with 24 percent under woodlands and forest compared with 13 percent outside the floodplain.

Figure 9 is a breakdown of vegetation types by river section. In the floodplain, frequency of denser

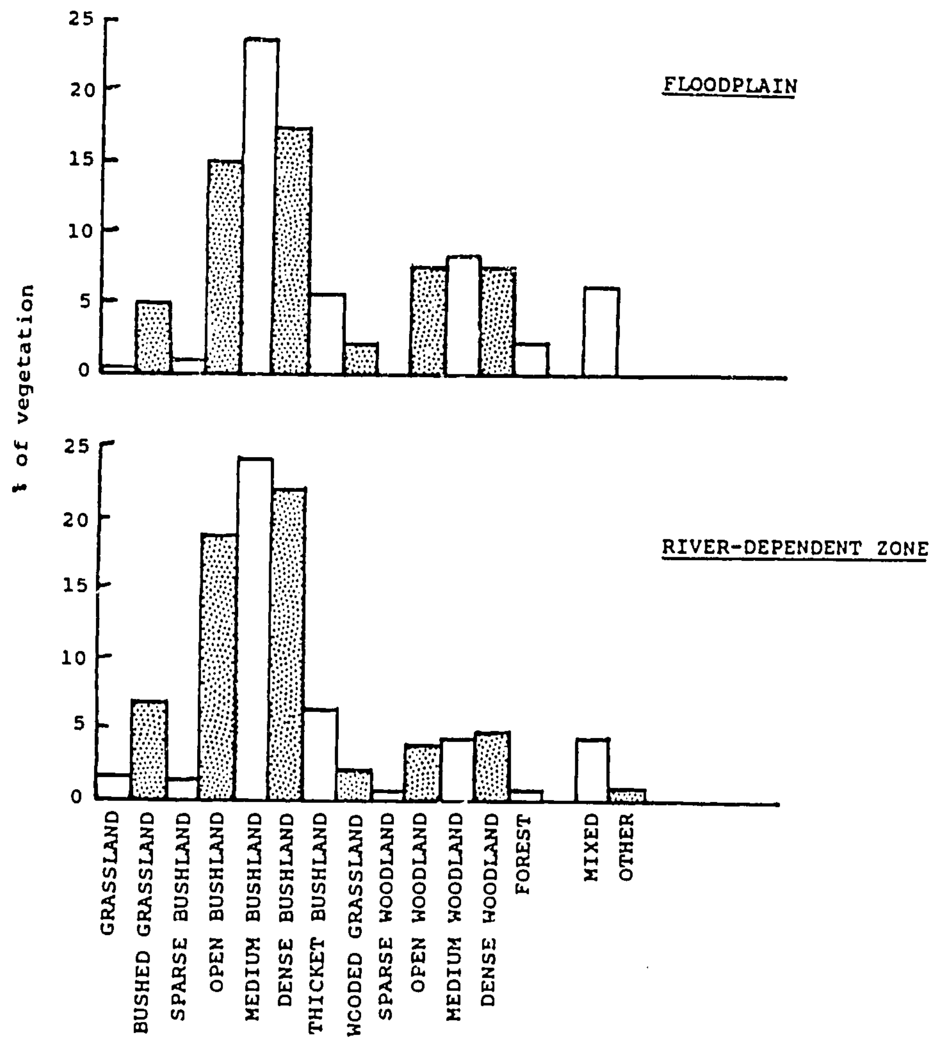


Figure 8. Comparison of percentage of vegetation in TEBS structural categories in the Jubba floodplain and river-dependent zone by river section.

Table 14. Number of TEBS monitoring sites established by ground studies and aerial photography classified by structural composition of vegetation.

	FLOODPLAIN		RIVER-DEPENDENT ZONE	
VEGETATION TYPE	GROUND	PHOTO	GROUND	PHOTO
Forest	9	3	1	1
Dense Woodland	2	23	1	13
Medium Woodland	0	25	0	11
Open Woodland	2	14	0	10
Wooded Grassland	2	7	1	5
Thicket bushland	7	17	7	18
Dense Bushland	3	54	3	60
Medium Bushland	3	76	8	65
Open Bushland	3	48	12	51
Sparse Bushland	1	2	3	2
Bushed Grassland	5	16	11	19
Open Low-shrubland	1	-	0	-
Sparse Low-shrubland	0	-	2	-
Grassland (short)	6	1	-	4
Grassland (tall)	2	-	0	-
Mixed	-	20	-	11

Note: Some photographs could not be classified in this scheme.

vegetation tends to increase in a southerly direction. Open bushlands and open woodlands are common in northern sections, but denser bushlands (including thickets), denser woodlands, and forests assume greater importance further south. Bushed and wooded grasslands do not show consistent trends because they are closely linked with farming activities which vary in intensity in different river sections. In many sections of the floodplain, but reaching a peak of almost 20 percent in VII and VIII, the mixed category indicates that farming intensity is so high that areas of vegetation large enough to fill a monitoring photograph are difficult to find.

In the river-dependent zone, density and height of plants also increase in a southerly direction as expected given the north-south rainfall gradient. River Sections I and II are predominantly open bushlands, with few dense bushlands, thickets, or woodlands. Medium and dense bushlands are common in southerly sections and woodlands more common than in the north.

Comparisons of floodplain and river-dependent zones for each river section generally do not show great differences. Woodlands are more common in the floodplain except for River Sections VII and VIII. In these southern sections, the floodplain is heavily farmed with high human and livestock densities. These factors combine to maintain a relatively degraded woody vegetation.

Overall, differences between floodplain and river-dependent vegetation structure by proportion are not striking. However, larger differences are apparent when "patch size" is taken into account. Perusal of 1983-1984 aerial photomosaics at 1:30,000 shows clearly that while many different vegetation types occur in a few square kilometers of floodplain, forming a complex mosaic, non-floodplain areas carry monotonously similar vegetation over many square kilometers. Another difference is the transition from one vegetation type to another. In the floodplain, transitions are often abrupt between quite dissimilar types such as forest, grassland, and thicket mainly as a result of human activity. Outside the floodplain, transitions are usually gradual and sequential with, for example, bushed grassland grading into open bushland, to medium bushland. Landscapes are further differentiated because of the much higher incidence of farmland in the floodplain.

C. Distribution of Plant Species

The previous section demonstrates that vegetation structure is similar when the floodplain is compared with the river-dependent zone. When species composition is examined, differences are more striking. A comparison of species occurring on and around TEBS ground monitoring sites reveals that 131 species were found only in the floodplain and 121 species only in non-floodplain sites from a total of 313 species recorded (Appendix D). No attempt was made to make a comprehensive plant collection from TEBS study area. Most plants identified were found on or close to ground monitoring sites. A full accounting would produce many more species. For example, in the 1,700 km^2 Kora Reserve comprising riverine and dry bush communities on the Tana River, Kenya, over 700 species have been recorded (Kabuye *et al.* 1986). Table 15 lists the most abundant species found on TEBS monitoring sites throughout the study area. Although a few species are common to both floodplain and non-floodplain sites they are usually much more abundant in one or the other. For example, *Acacia zanzibarica* is predominantly a floodplain species in this area, while *A. reficiens* is dominant in the river-dependent zone. Separation of herbaceous species between floodplain and river-dependent zone is less distinct than trees and shrubs, but performance of these

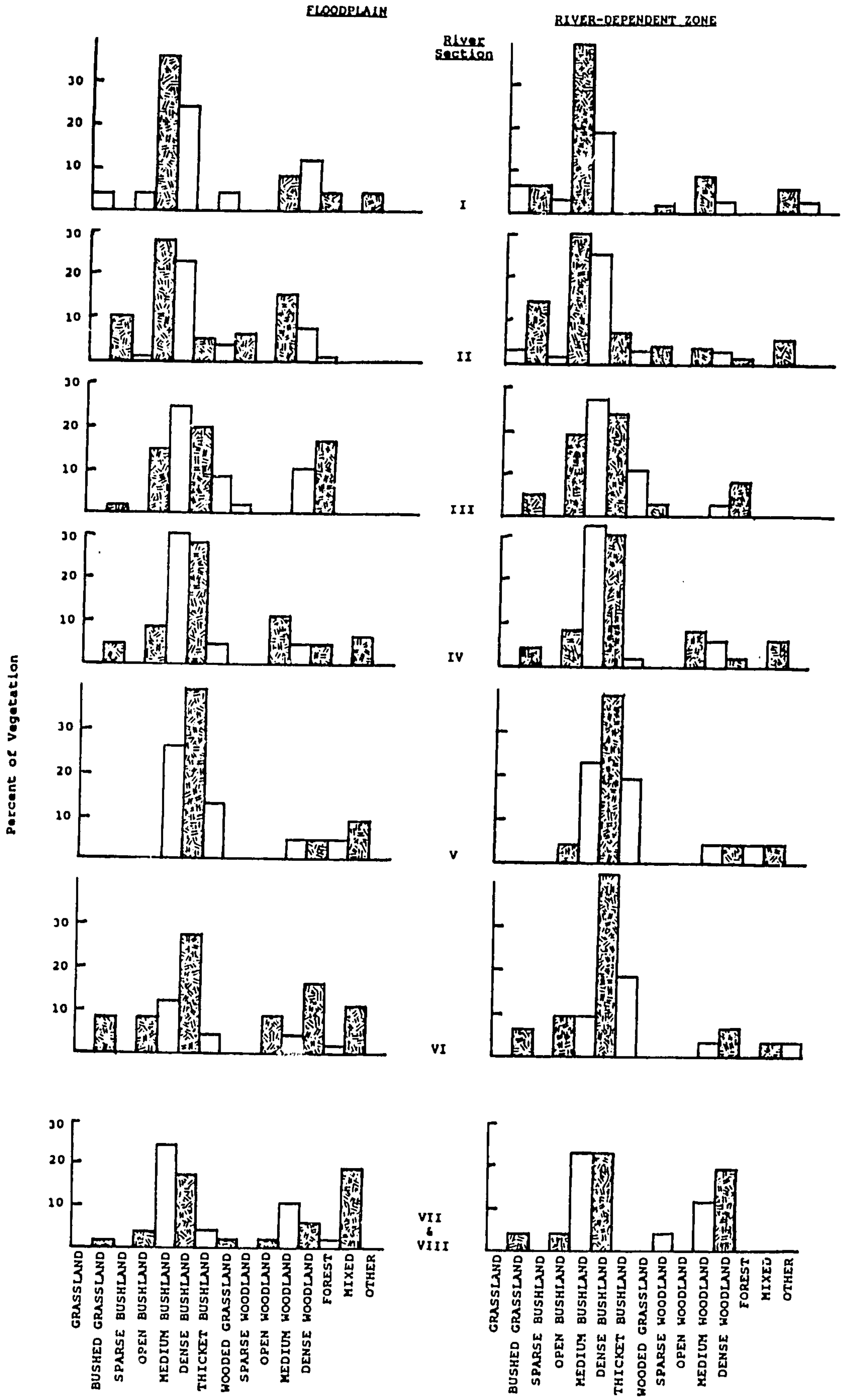


Figure 9. Composition of vegetation by structural types comparing floodplain with river-dependent zone by river section.

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species is markedly different in the two environments (see Section VI.D).

Table 15. Comparison of the most abundant species in TEBS monitoring sites in and out of the Jubba floodplain.

FLOODPLAIN | RIVER-DEPENDENT ZONE

TREES AND SHRUBS

(species constituting more than 1.5 percent of total number of individuals)

SPECIES	% OF PLANTS	SPECIES	% OF PLANTS
Phyllanthus somalensis	24.5	*Acacia reficiens*	14.5
Acacia zanzibarica	10.3	*Commiphora* spp.[1]	7.6
Thespesia danis	8.7	*Acacia horrida*	5.6
Terminalia brevipes	7.8	*Grewia tenax*	4.0
Dichrostachys cinerea	6.3	*Premna resinosa*	3.9
Flueggea virosa	3.5	*Anisotes trisulcus*	3.8
Acalypha fruticosa	2.7	*Acacia zanzibarica*	3.7
Cordia goetzii	2.5	*Cordia sinensis*	3.5
Rinorea elliptica	2.1	*Acacia nubica*	2.5
Adenopodia rotundifolia	2.1	*Cadaba* spp.[1]	2.3
Hyphaene sp.	2.1	*Dobera glabra*	2.3
Acacia nilotica	1.6	*Combretum hereroense*	2.0
Acacia reficiens	1.5	*Acacia bussei*	1.9
Cephalocroton cordofanus	1.5	*Thespesia danis*	1.8
Lecaniodiscus fraxinifolius	1.5	*Terminalia* spp.[1]	1.8
		Euphorbia cuneata	1.7
		Acacia senegal	1.6
		Combretum contractum	1.6
TOTAL	77.2	TOTAL	66.1

HERBACEOUS LAYER

(species with score of 20 or more)

SPECIES		SCORE[2]	SPECIES		SCORE
Sporobolus helvolus	G[3]	147	*Sporobolus helvolus*	G	54
Cenchrus ciliaris	G	31	*Aerva persica*	F	40
Enicostemma axillare	F	30	*Eragrostis cilanensis*	G	34
Eriochloa meyerana	G	29	*Solanum* spp[1]	DS/F	34
Echinochloa haploclada	G	25	*Aristida* spp.[1]	G	30
Sorghum arudinaceum	G	25	*Dactlyoctenium scindicum*	G	28
Solanum spp.[1]	DS/F	24	*Cenchrus ciliaris*	G	25
Echinochloa colona	G	24	*Cadaba glandulosa*	DS	23
Commelina spp.[1]	F	22	*Commelina* spp.[1]	F	22
Indigofera schimperi	DS	21	*Enteropogon* sp.	G	20
			Sporobolus sp.	G	20
TOTAL		378	TOTAL		330
(maximum possible		1,034)	(maximum possible		1,073)

[1] *represents several unidentified species.*
[2] *score is derived from index of abundance described in Appendix A.*
[3] *G = grass; F = forb; DS = dwarf shrub.*

As described in Section VI.C.2, non-floodplain lands are predominantly dry bushlands, whereas the floodplain vegetation is a mosaic of forest patches, woodlands, bushlands, thickets, and grasslands. Human effects outside the floodplain are mainly through extensive livestock grazing and browsing and fuelwood collection, while in the floodplain intensive agricultural activities are the primary cause of present day structural vegetation types. Floodplain species composition is greatly altered by human activities. Periodic flooding and varied soil types also have major effects on which species are present.

For the purpose of an outline description of species composition of plant communities, the study area is divided into broad ecological zones. Outside the floodplain, a north-south division separates major environments in terms of geology and rainfall (Section III). Major geological types are northern limestone hills and plateaus, southern marine plains, and coastal dunes. In the floodplain, major divisions are related to physiographic types such as levees and dhesheegs, which in turn vary somewhat in a north-south direction.

1. Floodplain Species

Where woodlands remain, acacias dominate the floodplain north of Baardheere. Between Doolow and Luuq, the dominant species is *Acacia tortilis* (Wieland and Werger 1985). In the inundation area, *A. zanzibarica* often forms closed stands. Along the river edge forest trees including *Tamarix aphylla*, *Salvadora persica*, *Hyphaene* sp., and occasional *Acacia eliator* and *Ficus* sp. occur.

Further south, non-forest communities are variable, depending on land-use and/or hydrology and soil. Among woody species *Acacia zanzibarica*, *A. nilotica*, *Thespesia danis*, *Terminalia brevipes*, *Dichrostachys cinerea*, and *Phyllanthus somalensis* grow on most physiographic categories. However, there is some differentiation when surface soil texture is taken into account. On heavy clays fringing dhesheegs and along some togga *T. brevipes* often forms a dense thicket. In contrast, *P. somalensis* and *D. cinerea* are more common on coarser soils. *A. nilotica* is especially common on the clays of heterogeneous alluvia south of Jilib. *Adenopodia rotundifolia* is a locally dominant tree in some woodlands on free-draining alluvia south of Fanoole Barrage.

Perennial grasses dominate in most open communities. As shown in Table 15, *Sporobolus helvolus* is strongly dominant, with five other grasses in almost equal secondary roles (although any one may be abundant at a particular site). The most

Contrasting vegetation and rangeland conditions in floodplain (above) and river-dependent zone (below).

common dwarf-shrubs are *Indigofera schimperi* and *Rhynchosia minima*. *Enicostemma axillare* is a common and persistent evergreen forb. Other common annuals include *Tragia plucknetii*, *Commelina* spp. and *Ipomoea* spp.. Most grasslands have a low-shrub layer commonly including *Phyllanthus somalensis*, *Terminalia brevipes* and *Ormocarpum kirkii*.

Of note are occasional tall grasslands (>2 m). Where groundwater is readily available, such as at the river edge, or in lower-lying dhesheegs, *Panicum maximum*, *Eriochloa meyerana*, *Saccharum spontaneum*, and to a lesser extent *Echinochloa haplochlada* and *Sorghum arudinaceum*, form tall dense swards in excess of 10 t ha^{-1} dry matter. In the absence of groundwater, such communities maintain less than half this standing crop under local rainfall conditions (Deshmukh 1984; see also Section VII). These communities demonstrate the significance of local groundwater even to herbaceous plants. This fact should not be overlooked when considering the potential importance of groundwater for floodplain field crops.

2. Non-Floodplain Species

Non-floodplain communities have been described in Watson and Nimmo (1985), LRDC (1985), and TEBS monitoring site data bases. Northern limestones support *Acacia-Commiphora* bushlands similar to those occurring elsewhere in semi-arid East Africa. Dominant species of trees and shrubs are *A. horrida*, *A. reficiens*, and several *Commiphora* species. *A horrida* is more common on stony and rocky soils around the inundation area along with *Euphorbia cuneata*, *Boswellia* spp., *Caesalpinia erianthera*, and several bushy species of *Solanum*. On finer limestone soils south of Baardheere, *A. reficiens* is by far the most abundant species with *A. bussei*, *A. nubica*, *A. etbaica* being common, but fewer *Commiphora* are present. *Dobera glabra* is also common south of the dam site particularly on clay soils.

On the marine plains, *A. reficiens* is abundant. *A. bussei* is found in more northerly areas and *A. drepanolobium* further south. In higher rainfall river sections, species more common in the floodplain such as *A. zanzibarica* and *A. nilotica* are also found. *Cephalocroton cordofanus* and *Premna resinosa* are important in the low-shrub layer.

Other species frequently encountered throughout the river-dependent zone include several species of *Terminalia*, *Cordia sinensis*, *Grewia tenax*, *G. villosa*, *Anisotes trisulcus*, *Combretum hereroense*, and *Acacia senegal*.

The coastal dunes around the estuary are dominated by *A. tortilis* woodlands where these have not been felled. *A. senegal* is also common. The understory is dominated by *Cordia somalensis* shrubs.

Plants in the herb layer probably vary geographically in the river-dependent zone. Grass density is much lower than in the floodplain, allowing dwarf shrubs and forbs to become more abundant. However, detailed description and generalization are difficult because many grasses and most forbs are short-lived following rain. Thus species found in identifiable condition depend on when a site is visited.

In the north, herbaceous vegetation is usually sparse. Common grasses include *Aristida* spp., *Eragrostis cilianensis*, and *Tetrapogon cenchriformis*. Dwarf shrubs include several species of *Barleria* and *Indigofera*. The marine plain carries denser grass cover of *Sporobolus helvolus*, *Cenchrus ciliaris*, *Eragrostis ciliaris*, *Setaria* spp., Dactyloctenium spp., and *Sporobolus* spp.. *Indigofera* spp. are predominant dwarf shrubs along with *Rhynchosia* spp. and *Seddera bagshawei*, but few *Barleria*. Throughout the river-dependent zone, *Cadaba glandulosa* is an abundant low shrub, while *Commelina* spp., *Senra incana*, *Aerva* spp., *Heliotropium* spp., and *Tribulus terrestris* are common forbs.

3. Jubba Forests

Much of the Jubba floodplain was once clothed with an evergreen forest 20 to 30 m tall. Only remnants of this forest remain. The conservation status of Jubba forests is discussed in Section VIII, Appendix J, and Madgwick (1988). Most of this former forest land has been cleared for agriculture, although some reverts to other vegetation types if farming is abandoned (Section VI.D). In 1960 more than 10,000 ha of forest remained, but by 1987 less than 900 ha survived (Deshmukh 1987). Isolated forest trees or small clumps remain scattered throughout most other floodplain vegetation types. Species composition of the remaining forest fragments is variable. Two forest reserves at Shoonto and Barako Madow have been studied in detail by Madgwick (1988). Six TEBS ground monitoring sites were set up in other riverine forests. Table 16 lists forest tree species. This list includes only species characteristic of closed forest. SRP lists many more species found in open woodland, forest edge, and bushland communities found in the forest reserves. Of note is the longer TEBS species list obtained from more widespread forests than SRP. Ten to twelve species had not been collected previously in Somalia and one is new to science. Many newly recorded species may be restricted to the Jubba within Somalia (see Section VIII). In addition to species listed, SRP noted another 11 identified species and 16 unidentified species in the forests, which were not common on their enumerated plots.

The tallest trees (> 25 m) emerge from the canopy and include *Ficus sycomorus* and the acacias. Taller canopy species include *Afzelia quanzensis*, *Mimusops fruticosa*, *Cordia goetzii*, *Spirostachys venenifera*, *Cola* sp., and *Hyphaene* sp.. Common smaller trees and lianes are *Camptolepis ramiflora*, *Garcinia livingstonei*, *Hunteria zeylanica*, *Drypetes natalensis*, *Rinorea elliptica*, *Lecaniodiscus fraxinifolius*, *Saba comorensis*, and *Thespesia danis*. *Acalypha fruticosa*, *T. danis*, *and Flueggea virosa* are common in the shrub understory.

Madgwick (1988) suggests that riverine forests can be split into several soil/hydrological types with characteristic species. Typical river-edge species are *Ficus* spp., *Diospyros cornii*, *Thespesia danis*, *Hunteria zeylanica*, and *Camptolepis ramiflora*. The mid-levee is indicated by *Acacia* sp. and *Afzelia quanzensis*, while the dhesheeg edge has a dense growth of *C. ramiflora* and *Trichila emetica* saplings with scattered taller *Garcinia livingstonei*, *Mimusops fruticosa*, and *Lawsonia inermis* trees. Similar generalizations cannot be made readily about TEBS forest sites because of their wide geographical separation and higher level of human disturbance.

A few patches of forest occur outside of, but close to the floodplain according to the AHT (1984) vegetation maps. TEBS site 54, 20 km north of Jilib, may comprise the only remaining example. A section of Shoonto forest shown above the floodplain by the AHT maps (Appendix J) shows signs of flooding (Madgwick personal communication). The forest of site 54 is semi-deciduous and noticeably less lush than those in the floodplain. The trees are deep-rooting and may obtain groundwater (but no flooding) by runoff from higher ground or lateral penetration of riverine water-table beneath the dry surface soil. Common species found at this site includes *Newtonia erlangeri*, *Albizia anthelmintica*, *Lecaniodiscus fraxinifolius*, *Dobera loranthifolia*, and *Balanites aegyptica*.

Table 16. Species of woody plants (trees, shrubs, lianes) found on Somali Research Project (SRP; Madgwick 1988) and TEBS vegetation sites in riverine forests. SRP sites are in Shoonto and Barako Madow forest reserves.

FAMILY	SRP	JESS (additional species)
Anonaceae		*Monanthotaxis fornicata*
Violaceae		*Rinorea elliptica*#
Lythraceae	*Lawsonia inermis**	
Combretaceae		*Combretum illiarii* ?
Guttiferae	*Garcinia livingstonei**	
Sterculiaceae		*Cola* new species#
Malvaceae	*Thespesia danis**	
Malphigiaceae	*Acridocarpus* sp.	
Euphorbiaceae	*Antidesma venosum*	*Spirostachys venenifera*
		Acalypha fruticosa
		Drypetes natalensis#
		Flueggea virosa
Caesalpinaceae	*Afzelia quanzenzis*	
Mimosaceae	*Acacia* sp.	*Acacia elatior*#
		Acacia rovumae#
		Acacia circummarginata
		Acacia sp. af *macalusoi*#
Papilionaceae		(*Baphia* sp. ??)[1]#
Moraceae	*Ficus sycomorus**	
	F. scasselati	
Simaroubaceae	*Harrisonia abyssinica**	
Meliaceae	*Trichila emetica*	
Sapindaceae	*Camptolepis ramiflora**	
	*Lecaniodiscus fraxinifolius**	*Lepisanthes senegalensis*#
Anacardiaceae	*Sorindeia madagascarensis**	
Ebeniaceae	*Diospyros cornii**	
Sapotaceae	*Mimusops fruticosa**	
	Pachystela brevipes#	
Oleacae		*Olea* sp. af *capensis*#
Apocynaceae	*Hunteria zeylanica*	*Landolphia* sp. #
		Saba comorensis
		Pleiocarpa pycnantha ?#
Rubiaceae		*Polysphaeria multiflora*
		Pavetta transjubensis
Boraginaceae	*Cordia goetzii* *[2]	*Cordia ravae* ? [2]
Bignonaceae	*Kigelia africana*	
Palmae	*Hyphaene* sp.*	
	Phoenix sp.*	

*? = uncertain identification; * = also found on JESS sites; # = new record for Somalia*

[1] *Baphia may be mistaken for Cola new species*
[2] *Cordia ravae ? on JESS plots may be C. goetzii*

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4. Species Diversity

Species diversity is usually defined as the number of species (in a given area) combined in some way with the relative importance of each species. The simplest approximation is species richness–the number of species. Diversity can be measured at the level of sample plots (local diversity) or whole landscapes (for example, the Jubba floodplain). Species diversity is of theoretical interest to ecologists and has more recently assumed importance to conservationists and some development agencies (see Section VIII).

Plant species diversity is generally less in the Jubba floodplain than in the river-dependent zone. This statement remains true whether looking at sample plots or landscape. A plot of riverine forest generally has fewer plant species than a nearby plot of dry bushland. Mean number of woody species in non-floodplain sites is 8.3; in floodplain sites, 5.6, a highly significant difference (t-test; $p < 0.002$). When diversity indices are used, taking into account relative abundance, the difference is even greater. At the plot level, differences in herbaceous species are not significantly different (mean of 6.4 species outside, 6.2 inside floodplain).

Probable reasons for lower species diversity in the floodplain include the following: First, plants must be specialized to survive periodic flooding; most species of plants in the lowland Somali flora are adapted to semi-arid conditions. Second, Jubba riverine flora is limited in geographic extent and is not close to many other similar environments. Since plant species richness is thought to be closely related to total area of a vegetation type and neighboring similar sites as sources of colonization, then non-floodplain sites are expected to have developed a richer flora.

D. Vegetation Dynamics

The natural dynamics of floodplain vegetation are connected with changes in the hydrological regime. As the river changes course, new banks and levees are formed creating new habitats for riverine forest trees. At the same time, existing forests may be swept away if blocking the new channel, or forests may slowly degrade to less dense communities if they become more distant from the river. Under present river-flow conditions, such changes take decades or centuries. For example, no significant changes in the course of the river occurred between 1960 and 1987. When the river is regulated by Baardheere Dam, it will slowly change course in response to the new hydrological regime. Significant changes will take centuries because of the low energy inherent in the regulated river (Alford 1987).

Much more rapid changes in vegetation result from current human activities. Clearance of forests in the floodplain has produced a patchwork of vegetation types described above. Removal of vegetation is not a one-way process, however. Some cleared patches are never farmed, while others are farmed and then abandoned. Abandonment usually results from flooding or changing socioeconomic conditions, rather than reflecting shifting cultivation. Abandoned land becomes revegetated. The resulting vegetation types are varied.

Grasslands usually form in areas regularly burned or heavily grazed. Most TEBS ground monitoring sites in floodplain grasslands are maintained in this manner. Fires are commonly set in jiilaal to clean fields prior to sowing crops. These fires escape into surrounding vegetation preventing establishment of most woody species. Five TEBS ground sites were burned in this way between January and April 1987 (see also Section V). Whether maintained by fire or grazing, most of these grasslands are dominated by *Sporobolus helvolus*. In some cases, a low shrub cover of one or more of *Phyllanthus somalensis*, *Terminalia brevipes*, *Indigofera schimperi*, and *Thespesia danis* develops between fires. Tall grasslands (> 2 m) occurred on two sites subjected to seasonal burning. In a dhesheeg near Kaytooy, a uniform stand of *Eriochloa meyerana* (site 21) was present while on a levee near Madhooka, *Panicum maximum* (up to 3.5 m) and *Echinochloa haploclada* were co-dominant (site 14). Fires occasionally cause a marked change in herbaceous species composition. At site 22 near Mareerey, *Sporobolus helvolus* virtually disappeared from a sward of *Sporobolus helvolus* and *Panicum infestum*, while the latter species became dominant. At a non-floodplain site nearby, *S. helvolus*, *Cymbopogon caesius*, and *Enteropogon* sp. nov (JESS 198; site 35) were replaced by grasses *Paspalidium desertorum* and *Urochloa rudis*. However, at a pair of non-floodplain sites north of Mareerey, fire did not alter the dominance of *S. helvolus*. With such a diversity of responses, it is not possible to generalize about the effects of fire on herbaceous species composition in this area. In all cases, particularly in the floodplain, rapid grass regrowth followed rain.

In the absence of fire or grazing, woody vegetation reestablishes. Site 12, on the edge of a dhesheeg north of Fanoole Barrage, was farmed until the barrage and its bunds eliminated floods in 1977. Since then a 4 m tall thicket of *Dichrostachys cinerea* has developed. Site 37, west of Baardheere is on the edge of a floodplain cultivated about 10 years earlier. Since abandonment a 4 m tall stand of *Acacia reficiens* trees has developed with an understory of *Acalypha fruticosa* shrubs. Site 38 north of Saakow is a levee that was cleared of *A. zanzibarica* woodland four years previously and planted with sesame for one season. Since abandonment, a low bush (2 to 3 m high) cover has reestablished. *A. zanzibarica* is abundant, but other species, including *Flueggea virosa, Spirostachys venenifera*, and *Acalypha fruticosa* are more typical of disturbed riverine forest.

In general, several vegetation types may develop following forest clearance. Where fires are frequent or grazing regular and heavy in the jiilaal, *S. helvolus* grasslands are common. With less disturbance *A. zanzibarica* woodlands are found close to the river and *A. reficiens* woodlands towards the edge of the floodplain.

An important question for conservation is whether riverine forest could regenerate on previously cleared land if left undisturbed. Observations to date are inadequate for a firm answer since the level of disturbance (fire, grazing, wood-cutting) is too high around most abandoned farm sites. Without these disturbances forest regeneration is highly probable. However, creating disturbance-free conditions is difficult, thus emphasizing the conservation status of the few remaining forest remnants (see Section VIII).

Bushlands outside the floodplain seem to have undergone a gradual thinning of woody vegetation. Between 1960 and 1983, LRDC (1985) notes an increase in open bushlands at the expense of denser types in TEBS study area (see Section V). However, these changes are slight and inconsistent from area to area (with increase in bush in some parts of the Shabeelle). Since burning is relatively infrequent and human population low, livestock are the main cause of change in the river-dependent zone under present conditions. It is probable that drought cycles affect the intensity of use, and no unidirectional trends are likely unless there are consistent trends in livestock populations or climate. In general, the river-dependent zone remains well wooded. When elephants were numerous in the area they probably played an important role in periodically opening up denser vegetation.

Shorter-term effects include periodic flooding from the river and the seasonal rainfall cycle. One major river flood occurred during JESS studies, in late May 1987. Most of the floodplain was inundated temporarily and some parts for much longer. Floodwaters covered vegetation and farmland. In the latter case, where floodwaters remained, new areas were brought into cultivation that were dry, or where flood recession could be practiced. Four JESS monitoring sites on formerly abandoned farmland were converted back to agriculture. Although the net area under cultivation in the subsequent xagaa declined due to persistent flood waters (Figure 6), the spatial pattern changed. For example, fallow land in the floodplain declined from 410 km^2 in late jiilaal to 120 km^2 in xagaa (Watson and Nimmo 1988).

Floodwaters caused remarkably little persistent change to TEBS ground monitoring sites. Some sites were visited the following August, but many could not be reached until jiilaal 1988 due to road conditions and persistent water. In some areas, dense stands of *Phyllanthus somalensis* developed shortly after the flood, but these died back during the following jiilaal. Flooding did not lead to significant establishment of forest tree seedlings as has been hypothesized for the Tana River (Hughes 1985). However, the JESS observations are short-term. It remains possible that intermittent flooding has significant effects on forest regeneration.

In the long-term, changes in river course mean that vegetation once subject to occasional flooding and a high water-table become so far removed from the river that river water has little or no influence on plants. Hydrologically, such sites are similar to those in the river-dependent zone, although the soils remain geologically recent alluvia. Two TEBS sites on old levees (sites 4 and 33) reveal that although many species presently occur in floodplain sites closer to the river, vegetation structure, standing crop, and phenology more closely resemble the river-dependent zone than typical floodplain sites in the same area. These observations are of significance when possible effects of the Baardheere Dam are considered (see Section VI.E).

Seasonal Changes

Seasonal changes in activity of plants (phenology) were studied to determine temporal patterns and differences between floodplain and river-dependent zones. A scoring system was used for woody plants at ground monitoring sites to account for the degree of leaf (buds/young, mature, senescent), flowering, and fruiting. In the herbaceous layer a point-frame method recorded the proportions of green and brown grasses, forbs, and dwarf shrubs. These methods are described in Appendix A. Assessment of phenology is important in understanding seasonal availability of human and livestock forage. Productivity of vegetation is also likely to be affected since a plant remaining green throughout the year is likely to be more productive than one that is seasonally dormant.

Seasonality of trees and bushes is marked (Figure 10). As expected, full leafing follows gu' rains. By early jiilaal, floodplain trees and bushes maintain a markedly higher level of young and mature leaves than those outside the floodplain. By late jiilaal this difference is less pronounced. In both types of environment, leaf buds and young leaves begin to appear in late jiilaal well in advance of the onset of gu'. Flowering and fruiting are more prolific in the floodplain and follow gu' or deyr rains. Total phenological activity is consistently higher in the floodplain. Differences between floodplain and river-dependent zone plants would be more marked, if evergreen forests had not been replaced with secondary growth of deciduous and semi-deciduous plants which lose their leaves in dry seasons. Variations in this pattern are expected from year to year. For example, floodplain fruiting was much less pronounced in January 1988 than in January 1987. This difference was apparent in cultivars (papaya and mango) and wild plants. It may be that the 1987 flood upset reproductive phenology of some woody plants.

In the herbaceous layer, phenological patterns clearly distinguish floodplain and river-dependent zones. Overall, herbaceous plants maintain greater cover and remain green longer in floodplain habitats than outside the floodplain (Figure 11). Cover and standing crop of floodplain grasses is often twice that of nearby non-floodplain sites. Implications of this observation are discussed further in Section VII. Grass cover is much higher in the floodplain at all times. Most floodplain dominants are perennial whereas annuals are common in the river-dependent zone. As a result grass cover withers quickly with little green material remaining by early jiilaal and little change in green or brown material between

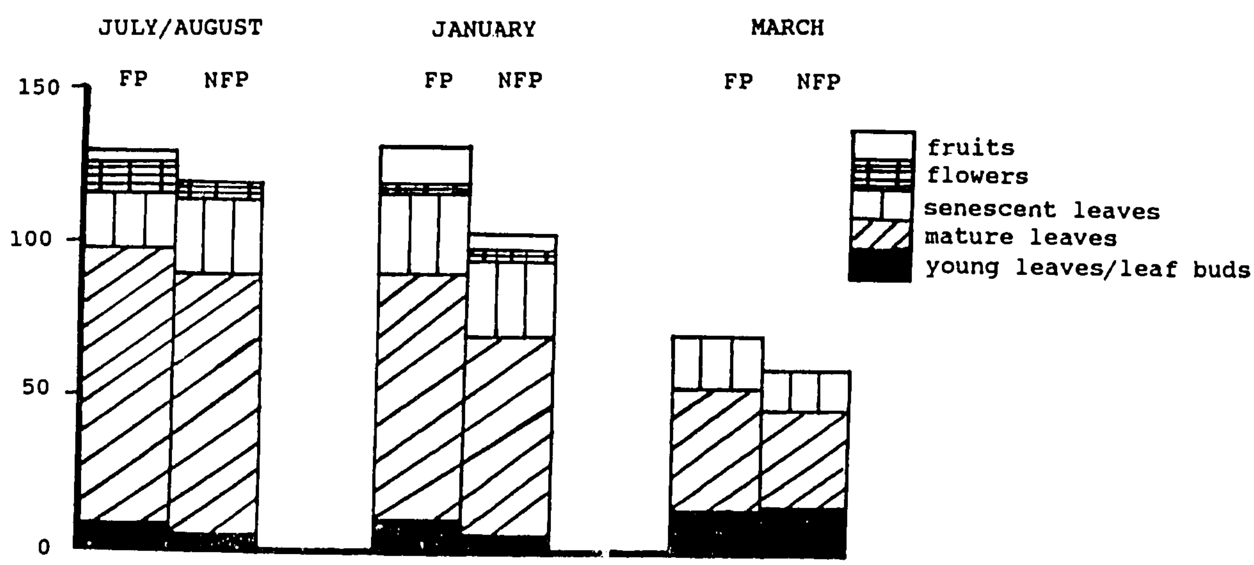

Figure 10. Comparison of phenological patterns during xagaa 1986 and jiilaal 1987 in trees and bushes of the floodplain (FP) and river-dependent zone (NFP) ground monitoring sites. Scoring system is described in Appendix

early and late jiilaal. In contrast, floodplain grass cover declines steadily through the dry season largely due to grazing. Most forbs are short-lived annuals which decline rapidly in dry seasons (Figure 11b). Higher forb cover in non-floodplain habitats is probably a reflection of lower grass cover which allows forbs greater access to light. Dwarf shrubs have greater cover in the floodplain and many persist through dry seasons as woody stems (Figure 11c).

E. Conclusions

Vegetation of the Jubba floodplain is markedly different from that of the surrounding semi-arid river-dependent zone. The difference is primarily due to greater soil water due to surface floods, lateral penetration of river water to the water table of the floodplain, and high nutrient content of river water (see Section IX). Secondary effects include the higher fertility of recent alluvial soils and

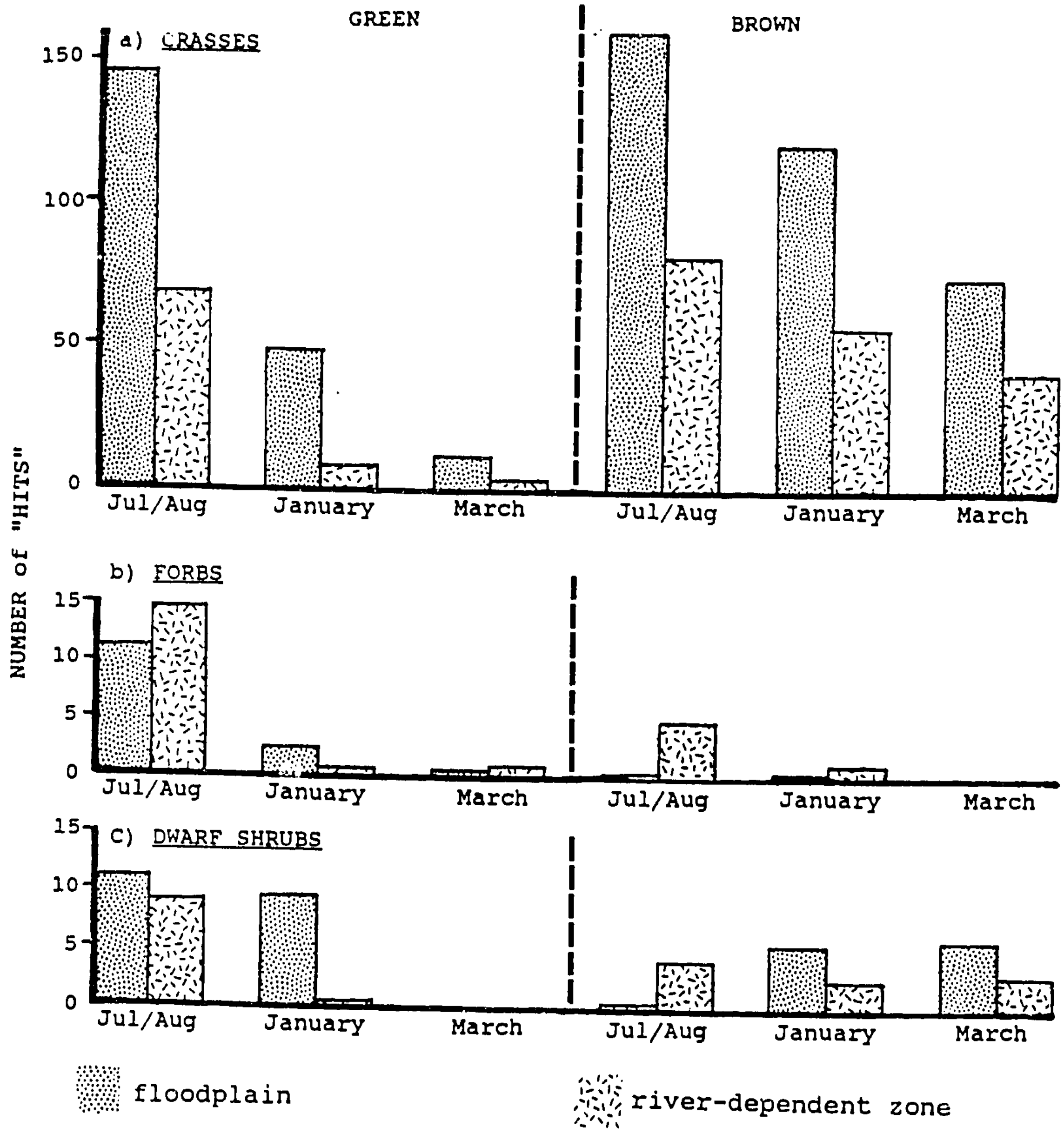

Figure 11. Comparison of herbaceous layer phenology by growth-form (grass, forb, dwarf shrub), condition (green, brown), and environment in ground monitoring sites. Note difference in scale of grasses compared with other plants. Scoring system is described in Appendix A.

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microtopography, (*e.g.*, levees, dhesheegs) caused by river deposition and erosion patterns.

When human influences were small, much of the floodplain was covered by tall evergreen forest. Under rainfed, lowland equatorial conditions, such a community occurs where rainfall exceeds 1,000 mm, twice the precipitation found in some forest areas on the Jubba. The high biomass and primary production of evergreen forests is reflected in secondary communities (*e.g.*, grasslands, bushlands) resulting from forest clearance. Grassland standing crop at floodplain sites is two to 20 times that of nearby non-floodplain sites. These effects are presumably of great importance in unirrigated crop production in the floodplain (see Section IX).

Human activity has changed floodplain vegetation into a mosaic of grasslands, bushlands, woodlands, and small forest patches similar to the river-dependent zone in terms of structure. However, species composition remains very different.

Under present conditions, floodplain vegetation represents an important human resource due to its high standing crop and production, and proximity to permanent water. Fruits, many of which are eaten by people or livestock, and green forage are more abundant than in the river-dependent zone.

Construction of Baardheere Dam will change floodplain vegetation in several ways. First, agricultural development will decrease land under native vegetation. Second, a large area of floodplain vegetation behind the dam will be inundated permanently, or most of the time. Third, downstream floodplain hydrology will change.

Remaining forest remnants between Bu'aale and Fanoole Barrage probably represent the best unused agricultural land in the study area. Construction of a planned all-weather road between Jilib and Bu'aale will make this area much more accessible. As a result, the few forest remnants, which may represent the only natural plant communities along the river, are threatened. Urgent conservation measures are needed to protect remaining forests (see Section VIII).

As the reservoir fills, most floodplain vegetation and large areas of non-floodplain vegetation between the dam site and Luuq will be inundated. Loss of non-floodplain vegetation will be of little significance as similar plant communities cover vast areas outside the inundation area. Much floodplain vegetation is already degraded; losses as a human resource are discussed in Sections VII and VIII.

New vegetation communities will develop in the drawdown zone. Tne nature of this vegetation is impossible to predict with current information, since it will depend upon reservoir operations, soil characteristics, human activity, and species available to colonize. Most species around what will be the reservoir edge are adapted to semi-arid conditions. These plants will not survive in the drawdown zone. Rocky soils characterizing much of the drawdown area may remain almost barren unless fine alluvial sediments are deposited upon them. These soils are not necessarily infertile, however. Increased moisture availability may allow flood-tolerant woody species to grow even on coarse soils. On finer-textured soils, grasslands will probably develop on land exposed long enough by dam operating schedules. Thickets could develop in some areas where slopes, soils, and periods of exposure and inundation are suitable relative to rainfall seasons. This unpredictability emphasizes the importance of planning and monitoring if development potential of the drawdown zone is to be realized.

Downstream vegetation modification due to hydrological changes is difficult to predict without a knowledge of dam operating procedures and current floodplain hydrology. River flow releases from the dam will produce a more or less constant river level with fewer floods. Lack of knowledge of Jubba sedimentology makes it difficult to predict to what extent the river will cut down into its bed as a result of reduced sediment load. Reduced flooding and sediment deposition will lead to a gradual reduction in soil fertility which will affect plant communities in unknown ways. Predictions for the Tana River in eastern Kenya suggest a lowered floodplain water table and less lateral penetration of river water (Hughes 1984; 1985). Similar effects on the Jubba would reduce the area capable of supporting forest and resource availability from floodplain vegetation. Unirrigated agriculture would probably decline in productivity due to this reduction in groundwater.

Overall, floodplain vegetation downstream will degrade slowly to less tall and more open types due to both hydrological change and increased human activity. Hydrological effects will be most pronounced further from the river, but anthropogenic change is more likely closer to the river where irrigation is most readily practiced. Monitoring and careful planning are needed to properly manage floodplain vegetation. Outside the floodplain, vegetation change is likely to be less critical, particularly as distance from the floodplain increases, unless livestock forage and access to water is seriously reduced by developments in floodplain agriculture (see Section VII).

Recommendations relating to vegetation concern human use, conservation, and monitoring which are dealt with in subsequent sections.

This section presents an assessment of current use of wild plants in TEBS study area. Three sectors are considered: use of wood (forestry), other "forest products" (ethnobotany), and livestock graze and browse (range). Information from ground studies, aerial photograph monitoring sites, aerial census, and data from other relevant studies are combined to give "best estimates" of current forest and range resources.

Although treated separately, the major topics of forestry and range are closely interrelated. Changes in forest resources may have positive or negative impacts on range resources. For example, a thinning of woody vegetation reduces forest resources and forage for browsing livestock. However, if reduction in woody cover leads to greater grass growth, grazing resources are improved. Overall reduction in floodplain vegetation, as documented in Section V, has negative impacts on forest and range resources.

A. Forestry: Wood Resources

Forestry in TEBS includes human use of wood and patterns of exploitation and management of forest products. Such wood comes from wild plants or from plantations. Plantations contribute a negligible amount quantitatively to wood production and consumption in the study area (Synnott 1988). Most wood consumed in the Jubba Valley is used for fuel or construction.

Much of the forestry discussion concerns methods used to derive quantitative estimates of wood biomass and growth rates. Detailed discussion is needed because these methods were developed specifically for TEBS. Readers with limited interest in these technical issues are referred to the tables summarizing results. Discussion of forestry as a human resource resumes in Section VII.A.3.

Assessment of forest resources requires the following information:

- volume or weight (biomass) of wood per unit area of land and its distribution relative to vegetation type;
- annual wood production in each vegetation type; and
- rate of use of wood by human populations.

1. Wood Biomass

Accurate estimation of wood biomass requires that a sample of trees and shrubs from a known area be measured, then felled, and their dry weight determined. Measurement of various dimensions of plants are then related to dry weight of wood. Such an approach is very specialized, expensive in time and labor, and is beyond the scope of JESS. However, studies elsewhere in Somalia (Bird 1988) and Kenya (Westem *et al.* 1981; Epp *et al.* 1982; Herlocker unpublished) indicate that crown dimensions of trees and bushes are statistically useful predictors of wood biomass for "bush" communities in East Africa.

Various relationships between plant dimensions and dry mass of wood are examined in Appendix F. From that discussion the most appropriate relationships have been selected, and biomass for each vegetation ground monitoring site calculated. These monitoring sites are then grouped by vegetation types described in Section VI.B.3 and best estimates of biomass in each vegetation type calculated (Table 17). Also shown are the earlier JESS estimates of wood biomass of some vegetation types by Synnott (1988) which were based on data from other areas and discussions with workers in

Table 17. Best estimates of woody biomass ($t\ ha^{-1}$) of JESS structural vegetation types based on predictive equations from other studies (see Appendix F). Also given are earlier "guesstimates" for JESS by Synnott (1988).

VEGETATION TYPE	RANGE OF BEST ESTIMATES	MEDIAN ESTIMATES	SYNNOTT
forest	35-225	130	30-200
dense woodland	12- 75	45	
medium woodland		20[1]	10- 25
open woodland	3- 13	8	
sparse woodland & wooded grassland	2- 3	3	
bushland thicket	19- 33	26	6- 12
dense bushland	7- 12	10	
medium bushland	4- 7	6	3- 9
open bushland	3- 5	4	
sparse bushland & bushed grassland	1- 2	2	1- 5
mixed[2]		5[3]	

[1] *no JESS ground sites, estimate interpolated.*
[2] *mixed refers to vegetation monitoring photographs that have a mixture of vegetation types (see Section VI)*
[3] *no JESS ground sites, estimate arbitrary (see Appendix F).*

Somalia. Synnott's "guesstimates" are remarkably similar to the calculated values.

The most accurate work on wood biomass in East Africa was done by the British Forestry Project, Somalia (BFPS) in Bay Region. They estimated "open bushland" as supporting approximately 5 t ha^{-1} (Bird personal communication), which corresponds well with Table 17. All results presented in this section must be viewed with caution as they are extrapolated from other areas and vegetation types. It is not possible, therefore, to determine their accuracy or precision for the Jubba Valley. Nevertheless, they are the best estimates available until study area specific forest inventory is conducted. The TEBS approach is to produce reasonable, but conservative estimates of wood biomass as a precaution against overexploitation in the future.

Next, the area of land occupied by each vegetation type was used to estimate total wood biomass and biomass per unit area for each river section (Table 18). These areas were calculated from information concerning "open" areas (*i.e.*, uncultivated) in Table 10 and proportions under different vegetation types (based on a random sample of aerial photographs) in Figure 9. Enclosed, unfarmed areas were not included, since the status of their woody vegetation is unknown. Thus, there will be some underestimate of wood stocks in the restricted areas where enclosure is commonly practiced. Significant enclosure is confined mainly to the floodplain in River Section II. Ground studies indicate that enclosed land here is mainly grassland. These areas will be inundated after Baardheere Dam is closed and are only relevant for future planning purposes if wood in the reservoir area is cleared as recommended by TEBS (Section VII.C.1).

Biomass over the whole TEBS study area exceeds 30 million tonnes. However, most of this wood is in the extensive rangelands (river-dependent zone) and not in the floodplain where human population is concentrated (Table 18). Because of extensive farmlands, wood biomass per unit area is usually less in the floodplain as a whole than outside ("Total biomass" column). However, when areas under native vegetation (*i.e.*, unfarmed and unenclosed) alone are considered, biomass is generally greater in floodplain lands ("Study area" column). Note that biomass of the rainfed river-dependent zone generally increases in a southerly direction between River Sections I and V reflecting increased rainfall. Lower wood biomass in both floodplain and river-dependent zone in River Sections VI and VII/VIII probably indicates overexploitation by the denser human populations in these areas (see Synnott 1988).

These TEBS biomass estimates are substantially lower than those given in the Southern Rangeland Survey (Watson and Nimmo 1985). For example, usable wood for fuel was estimated at 14 to 18 t ha^{-1} for areas in the river-dependent zone between Buurdhuubo and Jilib in that study compared with 6 to 18 t ha^{-1} total wood biomass (equivalent to 4 to 11 t ha^{-1} of usable wood) in the present study. Reasons for this discrepancy are discussed in Appendix F.

Table 18. Summary of woody biomass estimates by river sections comparing floodplain (FP) and river-dependent zone (NFP).

RIVER SECTION		TOTAL BIOMASS (t x 10^6)	STUDY AREA (t ha^{-1})	VEGETATED AREA (t ha^{-1})
I	FP	0.06	6.1	9.2
	NFP	1.01	4.8	4.9
II	FP	0.11	4.1	7.6
	NFP	4.82	6.0	6.0
III	FP	0.06	9.1	15.1
	NFP	6.43	10.4	12.0
IV	FP	0.08	5.7	10.1
	NFP	3.24	8.7	9.0
V	FP	0.17	11.8	17.8
	NFP	5.17	18.1	18.1
VI	FP	0.29	4.1	9.8
	NFP	9.17	13.3	13.5
VII/VIII	FP	0.13	3.8	10.8
	NFP	1.55	6.3	6.3

Distribution of biomass by vegetation types is shown in Figure 12. This figure can usefully be compared with Figure 9, where the proportion of land under each vegetation type is shown. Due to their greater biomass per unit area (Table 17), woodlands assume greater importance in Figure 12. In the floodplain, woodland and forest often contain more biomass than bushlands. However, bushlands are the major wood resource in the river-dependent zone. Of note is the significance of thickets in more southerly areas. Because of their low biomass per unit area, bushed and wooded grasslands together with sparse bushlands and sparse woodlands make negligible contribution to total biomass.

2. Production of Wood

Information on annual production of wood in East Africa is almost non-existent. Such information is

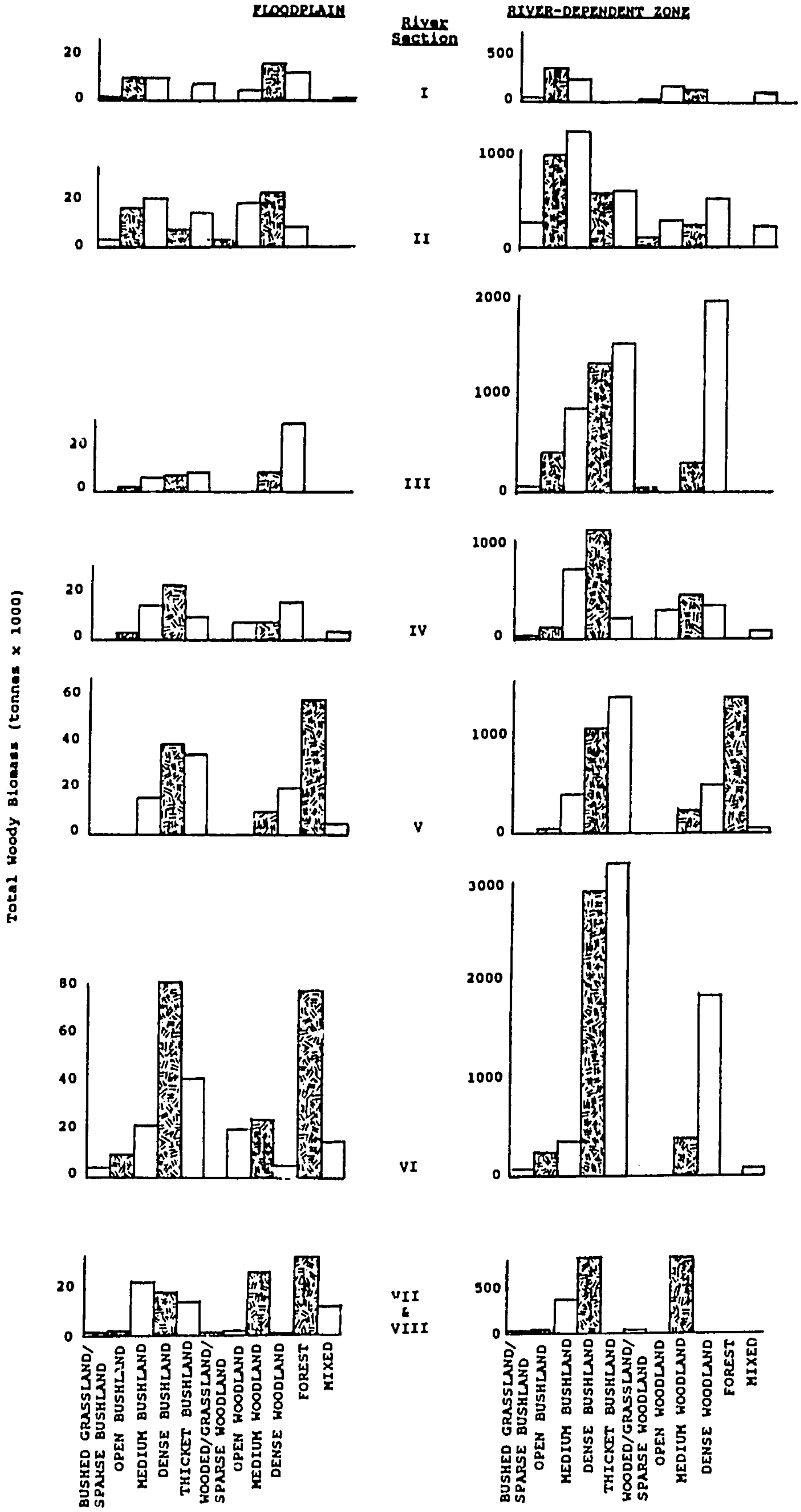

Figure 12. Distribution of total wood biomass by vegetation types in the floodplain and river-dependent zones by river sections. Note subdivisions on river-dependent ordinate are 20 times larger than those for floodplain.

essential to accurately estimate levels of sustainable offtake of wood. Limited data exist relating production of woody vegetation to its biomass. This information is reviewed in Appendix F. Table 19 lists conservative estimates of usable wood production for the TEBS vegetation types. Usable wood is defined as all branch and stem wood having a diameter greater than 2 cm. Smaller wood is little used for fuel or construction except in situations of extreme scarcity. Less conservative estimates of wood production might double the values in Table 19 and Table 20 (see Appendix F).

Table 19. Estimates of annual production of usable[1] wood by vegetation types.

VEGETATION TYPE	USABLE WOOD PRODUCTION ($t\ ha^{-1}\ year^{-1}$)
Forest	0.60
Dense woodland	0.43
Medium woodland	0.28
Thicket bushland	0.34
Open woodland/dense bushland	0.14
Medium bushland/mixed[2]	0.09
Open bushland/bushed and wooded grassland	0.05

[1] *"usable" wood is suitable for fuel; see text and Appendix F.*
[2] *mixed refers to vegetation monitoring photographs which have a mixture of vegetation types; see Section VI.*

No allowance has been made for potential higher production of floodplain vegetation (see Section VI, and specifically VI.A.3), since no predictive data exist on wood production in such environments. An indication of production potential in the floodplain is given by three JESS ground monitoring sites on which bush has regenerated following abandonment of cultivation. These sites had an average annual wood production for each unit of biomass of two to three times that estimated for purely rainfed areas (see Appendix F).

Table 20 extrapolates wood production estimates to the TEBS study area. Total production exceeds 400,000 tonnes per year. Spatial differences in production are similar to those of biomass (Table 18). Because of vegetation types, production per unit area of native vegetation is usually greater in the floodplain than in the river-dependent zone. However, because of extensive cultivation, each hectare of floodplain land overall produces less wood than an equivalent hectare of non-floodplain land. As stated above, no allowance has been made for a greater rate of production in the floodplain due to enhanced water and nutrient supply.

Table 20. Estimates of production of usable[1] wood biomass comparing floodplain (FP) and river-dependent zone (NFP) by river section.

River Section		Total Biomass ($t\ year^{-1}$)	Biomass per unit Area ($t\ km^{-2}\ year^{-1}$) All Land	Vegetated Area
I	FP	780	8.4	12.5
	NFP	15,540	7.3	7.5
II	FP	1,580	5.9	10.7
	NFP	69,684	8.6	8.8
III	FP	700	10.8	19.4
	NFP	82,050	13.2	15.3
IV	FP	1,070	7.6	13.5
	NFP	44,800	12.0	12.4
V	FP	1,810	12.3	18.5
	NFP	55,980	19.6	19.6
VI	FP	3,370	4.8	11.5
	NFP	118,460	17.1	17.4
VII/VII	FP	1,540	4.5	12.5
	NFP	22,280	9.0	9.1

[1] *"usable" wood is suitable for fuel; see text and Appendix F.*

3. Human Use of Wood

People in the Jubba Valley use wood mainly for fuel and house construction. By far the greatest demand is for fuel (Synnott 1988). Although specific estimates of fuel use in the study area have not been made, it is generally agreed that per capita consumption is approximately one tonne per year in settled Somali populations (Synnott 1988). A similar figure is also widely applicable in Kenya (Western *et al.* 1981). Traditional riverine farmers along the Tana in Kenya have an annual per capita fuelwood consumption of 1.2 t, while those in irrigation schemes consumed less than 500 kg (Hughes 1985). Reduced fuelwood use in the irrigation schemes reflects extreme scarcity of fuelwood around these more densely settled areas rather than a conscious effort to conserve supplies.

House construction uses much less wood; *munduls* (round houses) use 3 to 6 t and rectangular houses up to 10 t (TEBS data). Since houses last up to 30 years and usually contain several people, annual per capita wood consumption must be low. From studies elsewhere, Synnott (1988) suggests that less than 0.1 t $capita^{-1}\ year^{-1}$ is consumed for construction of fixed houses. Since enclosure of land by the settled population is a relatively rare phenomenon, the use of thorn bushes for fences is likely to be negligible.

Features relating to wood extraction were recorded in JESS aerial censuses (Watson and Nimmo 1988). Data are indicative of the level of activity, rather than being strictly quantitative. Wood exploitation features, including charcoal kilns, tree cutting, construction poles, and firewood stacks are far more common in the floodplain (0.74 features km^{-2}) than in the river-dependent zone (0.03 features km^{-2}).

Wood consumption by nomads is less easy to quantify, yet nomads make up 30 percent of the population in Gedo, Middle Jubba, and Lower Jubba Regions (AHT 1988). In Marsabit District, Kenya, Lusigi (1984) reports that fuelwood consumption is less than 0.1 t $capita^{-1}$ $year^{-1}$, because the sample population subsists largely on milk and does little cooking. In contrast, the same population used almost 1 t $capita^{-1}$ $year^{-1}$ of thorn bush to construct *bomas* (livestock corrals) to protect stock against predators and raiders. Jubba nomads seem to consume considerably more grain than those in Marsabit. According to SEBS, more than 40 percent of nomads in the Jubba Valley eat grain, and therefore cook daily. Thus, fuelwood consumption is likely to be higher than in Marsabit. Both the author and JESS forestry consultant, Timothy Synnott (who has worked in both areas), believe that construction of corrals is less common than in Marsabit. Pressures from predatory wildlife and livestock raiders are probably less than in northern Kenya. Density for the TEBS study area is 0.4 km^{2} corrals in use and 4.1 km^{2} abandoned (Watson and Nimmo 1988). Maximum density of corrals in use (3 km^{-2}) is found during jiilaal in what will be the inundation area north of Baardheere Dam and along the coastal dunes.

In the absence of more precise local data, it is assumed that annual per capita wood consumption approximates to one tonne for the whole population. Population density for Baardheere, Saakow, Bu'aale, Jilib, Jamaame, and Kismaayo Districts is 13 km^{-2} (AHT 1988). Rural, non-nomadic population averages 6 km^{-2} in these districts ranging from 3 km^{-2} in Bu'aale to 33 km^{-2} in Jamaame. However, population is distinctly concentrated near to the river. According to AHT (1988), density of settled rural people within 15 km of the river averages 44 km^{-2}. By District, 28 (Baardheere), 18 (Saakow), 19 (Bu'aale), 37 (Jilib), 48 (Jamaame), and 77 (Kismaayo) people occupy each square kilometer close to the river.

Comparing this rate of wood consumption and population density with usable wood production (Table 20), it appears that overall wood offtake is more or less matched by supply. However, riverine population density is such that demand for wood outstrips sustainable supply except in Bu'aale District (approximately equivalent to River Section V). If usable wood production is twice that listed, to give a less conservative estimate (see Appendix F), then demand for wood is about equal to sustainable supply in Baardheere and Saakow, but falls far short in Jilib, Jamaame, and Kismaayo Districts.

At present, wood supplies may appear greater than can be sustained in the future for several reasons. First, wood production in the floodplain is undoubtedly greater than in the purely rainfed river-dependent zone. However, as more floodplain is cleared for agriculture, this extra, but unquantified production will be diminished. Second, the accelerated rate of clearance for agriculture (see Section V), potentially produces much felled wood. In areas without wood shortage, much of this wood is burned *in situ*, but smaller poles and firewood are presumably collected. Third, wood resources in non-agricultural areas are being degraded. Such effects are obvious around the refugee camps in Gedo and the densely settled areas south of Jilib. It is possible that similar degradation is occurring, or is about to occur, in other areas. The overall picture of a healthy woody vegetation resource (Synnott 1988; AHT 1988) may be correct now, but degradation may be imminent under present conditions or with accelerated development.

Refugee camps present an acute forestry problem. Camps in Gedo house some 100,000 people (Watson 1988, personal communication), compared with a regional non-refugee population of approximately 250,000 (Watson and Nimmo 1985). Refugee camps are sited close together in two clusters (around Luuq and Buurdhubo) leading to exceptionally high local population densities for a semi-arid area. As a result, land around refugee camps is completely denuded of woody vegetation. As long as these populations remain at high density, it is impossible to support their fuelwood needs by local wood collection.

Most camps will be wholly or partly flooded by Baardheere Dam. Most refugees will, therefore, be moved before the dam is closed. If new camps are established their fuel needs should be supplied by the authorities in the same way as food and water.

Use of wood in construction of typical houses.

Collecting vernacular plant names in devastated vegetation around Horseed refugee camp.

Wood should be collected from more distant rangelands away from population centers, transported to the camps, and distributed to the refugees. If refugees are to be resettled among the general population, their wood needs should be an important determinant of resettlement sites and resultant population density should be taken into account.

4. Forestry Activities in the Jubba Valley

Plantations and other activities of the forestry department of the National Range Agency (NRA) have been reviewed by Synnott (1988) and AHT (1988). The latter study also outlines some activities due to start in the near future. These findings are briefly summarized in this section.

The Forestry Department of the NRA (Ministry of Livestock, Forestry and Range) has a forest officer and a nursery in each district. Facilities and level of activity vary greatly between districts. The best nurseries are in Luuq (as part of Gedo Community Forest Project), Bu'aale, and Jamaame. Most NRA nurseries limit activities to supplying trees to local people with emphasis on the annual National Tree Planting Day. With the exception of Luuq, extension services are minimal.

Forest officers are responsible for enforcing forest law. The most important law for protection of forest resources is that which restricts fuelwood collection to dead wood. While such a law cannot be enforced rigorously among subsistence wood collectors, people are aware of it and modify their activities accordingly (Synnott 1988). District forest officers are also responsible for protection of any forest reserves in their area.

Some private voluntary organizations (PVOs) also have nurseries and give or sell trees for local planting. World Concern in Jilib has experimented successfully with planting a wide variety of local and exotic species. An indication of World Concern's success is that they are able to sell seedlings while most other nurseries give them away. Church World Services and the Japanese Volunteer Service have nurseries near Luuq. Swedish Church Relief, which is involved in primary health care in Middle Jubba, also distributes seedlings.

In summary, tree planting is an established activity in some parts of the Jubba Valley. With improved facilities such plantings could become much more widespread.

The Forestry Sector Support and Training project, administered by the Food and Agriculture Organization of the United Nations (FAO) was due to begin in 1988. This project hopes to strengthen national forestry and wildlife management capabilities. Of particular interest is the regional component which will be established in Lower and Middle Jubba. Specific objectives relating to these regions are:

- Provision of forestry and wildlife development teams in Middle and Lower Jubba Regions, to provide technical assistance to local groups wishing to become involved in community village forestry, agroforestry activities, and wildlife resource management.
- Assessment of community needs with respect to forestry and wildlife in Middle and Lower Jubba Regions and an examination of the associated constraints in order to develop the regional forestry sector.
- Development of policies and related legislation designed to provide for the optimum management of forest and wildlife resources....formulation of model regional management plans for the forest and wildlife resources of the Middle and Lower Jubba Regions. (UNDP 1988)

This project should lead to a greatly improved forestry sector in Middle and Lower Jubba. The thrust for enhancing supplies of forest products is firmly on tree planting. More emphasis on management of wild vegetation would be welcome. Nevertheless, this project represents a potentially important step forward in environmental management of the study area.

B. Other Forest Resources and Ethnobotany

In addition to wood, plant communities supply many other needs of local people. Although such uses may be quantitatively small, they are often qualitatively important. Many of these items can be replaced by manufactured goods. However, supply of such goods in Somalia is often limited and the ability of most rural communities to buy such items severely restricted. Loss of some of these forest products, notably medicinal plants, could be seriously detrimental to local people who lack access to alternative health care. Reduction in wild fruit consumption due to reduction in forest cover may also adversely affect dietary balance.

During visits to ground monitoring sites, TEBS interviewed local people about their use of wild plants. A list of vernacular names of plants has also been collected (Appendices E and I). JESS data on ethnobotany are neither comprehensive nor systematic, since they were collected incidentally at monitoring sites when informants were available. More detailed information on materials used for house construction in Jilib district, use of forest plants in Bu'aale District, and medicinal plants in Lower Jubba is given by Madany (1988), Maunder (1988), and SOMAC/SAREC (1983), respectively.

In summary, TEBS recorded 196 uses of wild plants: 32 as human food, 55 as livestock fodder, 40 as building material, 33 as utensils, 24 as medicines, 12 miscellaneous. Two hundred and sixty-six vernacular names were noted: 191 species had a single local name, 53 had two names, 17 had three names, 5 had four names. All this information is recorded in JESS data repositories (see Section II).

Section VII.A treats all wood as equivalent, independent of species. In reality, certain species are favored for different uses. Virtually all species can be used for firewood, although some species are preferred. Where wood is scarce, land close to settlements is stripped of all wood, as around refugee camps in Gedo. In better stocked areas, subsistence and commercial wood collectors pick denser species, particularly of *Acacia* and *Terminalia.*

Charcoal production and consumption are low in the Jubba Valley. The favored species, *Acacia bussei*, is relatively uncommon in the area (Table 15). Most commercial supplies of charcoal in southern Somalia come from Bay Region where the species is common. Secondary species used by a charcoal producer near Bu'aale include *Acacia reficiens*, *A. tortilis*, *A. nilotica*, and *Terminalia* spp. This producer, who markets about 40 sacks per month from an area in excess of 50 km^2 (equivalent to about 0.1 t km^{-2}), reports that no one else is involved in commercial charcoal production between Saakow and Jilib. He claims that he collects only dead wood, and that the resource has not diminished in his 11 years of operation (TEBS interview, 30 August 1987).

Species used in construction depend upon the type of structure. Large forest trees such as *Mimusops fruticosa* and *Acacia elatior* are used for canoes. *Ficus sycomorus* is favored for sawtimber for the construction of doors and some furniture. For house construction major support poles are *Terminalia* spp. Small wood infill comprises most of the walls. Many species are used including *Cordia sinensis*, *Flueggea virosa*, *Thespesia danis*, *Phyllanthus somalensis*, *Combretum hereroense*, *Terminalia brevipes*, *Lawsonia inermis*, and *Adenopodia rotundifolia*. More detailed information concerning house construction in Jilib District is given by Madany (1988). He lists 20 species and gives more specific uses. In areas where wood is abundant, such as between Bu'aale and Fanoole Barrage, larger sticks (2 to 5 cm diameter) are used in walls. In areas where wood is less easily obtained, smaller poles are used. In villages close to Baardheere and in the refugee camps in Gedo, average stick size is little more than 1 cm diameter. Maunder (1988) lists 15 species used for large timber, 22 species used in carpentry, 10 species with edible fruits, eight species producing usable fibers, and nine medicinal species from forests in Bu'aale District.

Many species used in building come from the floodplain. Their supply will diminish as more land is farmed. Residents of Jilib District, where most riverine vegetation has been depleted, now travel 15 to 20 km to obtain polewood (Madany 1988). Sawtimber has become scarce in much of the study area following removal of riverine forest (Synnott 1988).

Some wild plant foods undoubtedly comprise useful dietary supplements (see also Craven, Merryman, and Merryman 1989). Twenty species of wild fruits are commonly eaten. A few, such as *Grewia villosa* and *Cordia sinensis*, are collected and sold in markets. Several forbs are used in making sauces, particularly in dry seasons when other foods may be scarce. Other foods incidentally foraged include nectar from *Anisotes trisulcus* and gums from several *Acacia* species and *Dichrostachys cinerea.* Nomads collect gum on a commercial scale (Janzen 1988).

Two important drought foods are grain from wild *Sorghum arudinaceum* and tubers of the water lily *Nymphaea lotus*. Wild sorghum is restricted to the floodplain in TEBS study area and water lilies to standing or slow-flowing water. Distribution of both species will be affected by closure of Baardheere Dam. Increased cultivation will decrease wild grasses. Downstream abundance of water lilies may decrease because of reduced flooding of dhesheegs, but Baardheere Reservoir will provide extensive new habitat. It is hoped that

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agricultural development made possible by the dam will reduce needs for these drought survival foods.

Among TEBS records of medicinal plant species, seven were used for wounds including snake and crocodile bites, six for gastric disorders, six for headaches and fevers, four for veterinary purposes, and two for skin problems. More specifically, crushed bark extract of an unidentified *Commiphora* species is used to treat cholera and an extract of *Melhania ovata* to treat hepatitis. SOMAC/SAREC (1983) collected 52 species of medicinal plants between Jilib and Kismaayo. Their report details symptoms, preparation of medicine, and dosage.

Utensils made from wild plants include tooth "brushes," furniture, canoes, mats, sticks and tool hafts, beehives, containers, pestles and mortars, dye, rope, pillow stuffing, and koranic boards. Some plants are used for poisons and others in magic. Trees are also important for shade in villages, fields, and rangelands.

C. Conclusions and Recommendations for the Forestry Sector

The analysis of forest resources presented in this section is heavily dependent on information collected in other parts of East Africa. Much of this data is of questionable accuracy, particularly when extrapolated to areas other than that in which it was collected (see Appendix F). Biomass estimates may be moderately robust, but reliable information on growth rates is minimal. Yet it is growth rates that determine the level of optimal offtake. Information on the presumed higher growth rates of trees and shrubs in the Jubba floodplain would be especially valuable for planning forestry activities in the Jubba Valley.

Recommendation: *Better information on forest inventory and tree and shrub growth rates is urgently needed for optimal use of vegetation.*

These research needs are not peculiar to the study area, but are common to vast areas of Africa. Continued degradation of bush cover in many areas serves to emphasize the necessity of improved information on forest resources.

As population in the study area increases, overall demand for wood will increase unless substitutes are introduced. Overall wood production in the three administrative regions is currently adequate to support the present population according to the TEBS analysis. However, human population is not evenly spread, but concentrated close to the Jubba River. As a result, wood removal is greater than production in some areas and likely to become so soon in others as population increases, unless wood collection is more evenly spread than at present.

Fuelwood use is, by far, the greatest consumer of wood. However, wood requirements for construction are important as are many other forest products used for human food, livestock fodder, medicines, utensils, and myriad other things. Many of these minor forest products can be replaced by manufactured items. However, the financial ability of rural people in the Jubba Valley to make such purchases is small.

It is clear that widespread wood shortage is likely to occur as development in the Jubba Valley proceeds unless action is taken soon. Either supplies of wood need to be increased in a sustainable manner, or per capita demand for wood should be decreased.

Increasing supply presents two options which can be applied together: planting trees and management of existing forestry resources.

1. Planting Trees

This remedy seems obvious, but as Bowen (1988) aptly states:

> There is a marked reluctance . . . to accept the reality that rainfed (and almost certainly irrigated) block plantations will never be capable of meeting more than a small fraction of the country's need for fuelwood . . .

Based on biomass growth rates of native species used in this report, each person would require 2 to 10 ha to meet the estimated annual demand. Faster growing species and irrigation would obviously reduce the required plantation size, but not sufficiently to make plantations a sensible substitute for wood collection from rangelands. Plantations, particularly in the context of areas planted and maintained by smallholders, can make a valuable contribution to environmental conservation. Such plantings are often multi-purpose providing erosion control, shade, wind breaks, fodder, edible fruit, and some domestic wood needs. As such, they should be encouraged along the lines of models provided by the Gedo Community Forest Project (see Bowen 1988 for a recent appraisal).

In its three years of operation, this project has established six nurseries, 70 ha of unirrigated and 20 ha of irrigated plantation, 160 km of on-farm windbreaks, species trials; planted over 200,000 amenity trees; protected 100 ha of degraded land for rehabilitation; and trained nine NRA staff, 22 farmers, and 17 villagers. In this low rainfall area rainfed plantations seem to be of limited value, but irrigated cooperative block plantations can be successful sources of income through sales of poles and fodder. A demand for on-farm trees has been created with windbreaks being particularly popular. Alley cropping also occurs to some extent. The essential components of provision of trees, demonstration of their value, and extension services were greatly enhanced by well-trained and motivated staff (Bowen 1988).

The FAO Forestry Sector Support and Training Project (UNDP 1988) will provide a suitable framework in Middle and Lower Jubba Regions to develop new institutional and extension networks for better management of forest resources. This project should also be the focus of forestry research in the study area. Tree planting is covered well by the project, but too little emphasis is placed on management of local vegetation. In Gedo, continuity of the Community Forest Project should be encouraged in Luuq. The planned Baardheere Experimental Farm (MNPJVD) may provide a suitable site in southern Gedo.

2. Management of Existing Forestry Resources

Wild plants can supply the needs of an expanding population if wood collection is spread over a sufficiently large area. Forestry legislation, by specifying that only dead wood can be collected, helps to spread the load. Such legislation cannot be applied rigorously, nor should it be, except in plantations, but it is a rational basis for maintaining forest resources. People living at subsistence level will always have to collect wood within a few kilometers of their homes. However, people in the cash economy (in urban areas, and cash farmers) may increasingly be prepared to buy fuelwood. In such a situation, commercial fuelwood collection should be regulated in such a way that wood is brought from areas further from population centers (*i.e.*, from the river-dependent zone and further afield). Floodplain areas not being farmed may have significantly greater tree growth rates than purely rainfed areas. Such a possibility should be investigated with a view to exploiting such resources in a sustainable manner.

Experience elsewhere suggests that native bushlands can produce wood more effectively in semi-arid areas than much promoted exotic plantations. In Senegal, for example, local *Acacia seyal* bush produced up to 4 m^3 ha^{-1} $year^{-1}$ of wood (eight times the expected rate) compared to 3 m^3 ha^{-1} $year^{-1}$ by introduced *Eucalyptus camaldulensis*. Initial project assumptions were that this exotic would produce at 20 times the rate of *A. seyal* (Gibson and Muller 1985). The *Acacia* bushlands were managed such that 500 ha blocks were clear-cut for charcoal on a 20-year rotation. Regeneration is by growth of new shoots from cut stumps. Similar management practices should be investigated in Somalia.

Recommendation: *NRA forestry activities in the study area should be strengthened to increase tree planting and more effectively regulate use of vegetation for fuelwood.*

Recommendation: *Research into management techniques for semi-arid bushlands is needed to prevent unplanned resource degradation.*

Reducing wood demand, as an alternative to increasing supply, means either increasing the efficiency with which fuelwood is used, or providing alternative energy sources. Such approaches will require subsidy, initially at least, if people living at subsistence or low income are to be influenced. Efficiency of energy consumption can be increased by using fuel-efficient stoves. At present, most cooking in rural areas of the Jubba Valley is done on open fires. Simple stove prototypes made from local materials are claimed to reduce wood consumption by 20 to 40 percent (Bowen 1988). Dissemination of such stoves needs effective demonstration and very low purchase price or simple construction from local materials. The efficiency of charcoal production can be increased by improving kiln construction. It seems that kiln efficiency has decreased recently in Bay Region, further increasing pressure on fuelwood resources in that area (Bird 1988).

If affluence and communications improve, new fuels may replace wood to some extent. Kerosene is one short-term possibility, particularly in urban areas. In the longer-term, electricity from Baardheere Dam may play a significant role. However, such substitutions will not be rapid. Management of forest resources to ensure sustained production must remain the highest priority in rural energy policy.

Recommendation: *MNPJVD should consider an overall energy conservation and development project for the Jubba Valley.*

Such a project would need components of research, development, and demonstration of appropriate renewable energy or energy saving techniques. The essential first step is an energy needs assessment so that time is not wasted on inappropriate technologies or nonexistent needs. Since women perform virtually all fuelwood collection and cooking, a successful project of this sort should focus on women.

Closure of Baardheere Dam and related developments will have a substantial impact on forestry. Several factors will combine to increase pressure on forest resources downstream of the dam. Population density around the reservoir will probably be less than that currently inhabiting the floodplain to be inundated. Reduced population density will result from resettlement of reservoir area residents and resettlement or repatriation of refugees. It is unlikely that new populations will be attracted to most of the reservoir perimeter. Rainfall is too low and most soils unsuitable for agriculture and most of the fertile floodplain will be lost (see Section IX). Fishing as a common activity is unlikely to develop since the market for freshwater fish is minimal in Somalia. Fewer livestock will be able to rely on riverine forage than previously (Section VII.E).

Two population groups that will increase local density immediately are the people resettled from the reservoir area, currently estimated at 12,000 to 15,000 individuals (Craven, Merryman, and Merryman 1989) and construction crews with their associates at the dam site and around Baardheere town. In terms of forest resources, the best place to resettle the reservoir area population is the area between Bu'aale and Fanoole Barrage (TEBS River Section V). This is the only riverine area where conservative estimates of wood production suggest that supply exceeds demand. It is also the river section including priority areas for biological conservation. A dispersed settlement pattern is best for sustained wood exploitation.

Land clearance for agriculture should be carried out in such a way that wood is not wasted. New settlers will have a high demand for building wood which could be met by cleared timber. According to data presented in this section, even if as little as 25 percent of wood biomass is suitable for construction, one munduul could be built for every 2 ha of floodplain cleared. Much of the remaining wood is suitable for other purposes, including fuel. However, an additional 15,000 people would nearly double the riverine population in Bu'aale District (currently 19,000; AHT 1988) and press hard on forest resources. Saakow District has the next lowest riverine density, but is also low on wood stocks (Table 18; approximately River Section IV). The issue of resettlement serves to highlight the problems of increasing population density in regions of restricted wood supply.

Recommendation: *Where reservoir area people are resettled, land clearance procedures should include using as much of the cleared wood for construction and fuel as feasible.*

Recommendation: *To meet continuing fuel and construction needs, resettled people should be established at low population density in areas where their forestry needs can be met locally.*

Refugee camps in Gedo will be flooded entirely in the Buurdhuubo area and partially around Luuq when Baardheere Dam is closed. Some refugees are currently being repatriated; others may be resettled among the Jubba Valley populace. For this latter group the same guidelines for resettlement contained in the last two recommendations should be followed. It is also possible that new camps will be established. If vegetation degradation similar to that around the existing camps is to be avoided, a different approach to supply of building materials and fuelwood is required. Refugee support organizations should treat wood supply in a similar manner to other basic needs such as food, water, and health care.

Recommendation: *If refugees in Gedo are to be rehoused in new camps, fuel and construction wood should be supplied to the occupants, rather than expecting refugees to collect inadequate wood supplies themselves from the area around the camps.*

Wood should be collected widely from the river-dependent zone so that no one area is degraded and trucked to the camps for distribution.

Up to 4,000 people are expected to move into the Baardheere area temporarily as dam construction proceeds (Tillman 1987). Unless other arrangements are made, their requirements for wood will probably be similar to those for local residents. Such a population might be present for four to five years with a consequent extra fuel demand of 16,000 to 20,000 t of wood. The area to be inundated contains perhaps 50,000 t of usable fuelwood. Thus, clearance of this area could supply fuel needs for construction camps. However, such clearance is unlikely to be economical compared with prices and quality of locally harvested wood. Clearance of wood from the reservoir area and its local use should, therefore, be incorporated into plans for dam construction. It may be necessary to subsidize clearance.

Cutting of wood from the inundation area is not a simple procedure. Areas above the high water level should not be cleared; otherwise erosion of exposed soil may cause siltation in the reservoir. Cut wood should not be left on the ground even if it has no economic value. Any loose material will float down to the dam and may clog the turbines. These factors, and the need to supply construction workers and their associates with fuel, dictate that wood removal should begin soon after dam contracts have been negotiated, and that clearance be properly supervised.

Recommendation: *The area to be inundated by Baardheere Dam should be cleared of woody vegetation and the wood used to supply fuel needs of construction workers and their associates.*

It is unlikely that most wood will be of sufficient quality to make careful extraction for use other than fuel worthwhile. Some of the floodplain woodlands will, however, have timber suitable for construction. The fuelwood and selected construction wood could easily be floated down to the dam site or Baardheere town for storage and subsequent use. Since the wood will be used over several years, measures to protect it from decay may be advantageous. Fuelwood could be converted to charcoal for better storage. Other types of wood could be treated with waste oil from vehicles and irrigation pumps. The latter are especially common in the Baardheere area.

The present land law encourages forest destruction. Registration of agricultural land requires that "improvements" be made within a year (Besteman and Roth 1988; Craven, Merryman, and Merryman 1989). In this context, improvement means clearing of vegetation as a prelude to cultivation. In practice, registrants often clear their whole plot, but cultivate only small sections. Such practices call for amendment and proper administration of land law if forest resources are to be wisely used.

Recommendation: *Land law should be amended so that clearance without agricultural development is not regarded as land improvement. Unplanned commercial exploitation of forest resources in Middle Jubba should be prohibited.*

An all-weather road is planned from Jilib to Baardheere. The initial construction, from Jilib to Bu'aale is planned for 1989. This road will make the substantial vegetation resources between Fanoole Barrage and Bu'aale town accessible to agricultural development and extraction of forest resources. Such developments should be strongly discouraged except within the planning framework for Jubba Valley Development. Wood resources in this area should be used sustainably for local populations and their future development. This area also contains forest reserves which are a high priority for conservation (Section VIII). Construction of this road make protection measures for these reserves even more urgent. It will be necessary to increase the number of locally recruited NRA forest guards. This action is compatible with recommendations for protection of forest reserves given in Section VIII.

D. Range Resources and Their Use

The pastoral sector is the backbone of Somalia's economy both internally and with respect to foreign earnings. Sustainable use of range resources is, therefore, a vital component of Jubba Valley development.

Recent surveys suggest that range resources are not overused in southern Somalia, although degradation is apparent in restricted areas (Watson and Nimmo 1985; LRDC 1985). This conclusion contrasts with earlier estimates that much of the area has an overabundance of livestock and a degraded range resource (FAO/Lockwood 1967 and FAO 1981; cited by Watson and Nimmo 1985).

For the greater JESS study area, Gedo, Middle Jubba, and Lower Jubba Regions, Watson and Nimmo's (1985) conclusions seem appropriate. They agree with similar studies in northern Kenya. These surveys recognize that the Jubba and Shabeelle floodplains attract large concentrations of livestock in dry seasons. JESS terrestrial ecology studies and TEBS study area were designed to

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elucidate range resources and their use in the Jubba floodplain and the area near the floodplain (*i.e.*, river-dependent zone). They do not attempt to cover the three Jubba regions because of recent comprehensive assessments by Watson and Nimmo (1985).

Results are summarized in Figure 13, which compares forage yield (total amount of forage per hectare) with food requirement of livestock in each river section. Derivation of these estimates is described in subsequent sections. In practice perhaps half of total forage yield is available to large herbivores.

The river-dependent zone approximates the pattern expected in extensive East African rangelands (Deshmukh 1986a). Forage increases with rainfall between River Sections I and VI. On average, less than 30 percent of forage is consumed by large herbivores. Camels are more significant consumers in drier areas, and cattle in wetter.

Floodplain forage/livestock relationships are quite distinct. Average consumption is around 50 percent of forage according to Figure 13. If it assumed that only 50 percent of forage can be consumed sustainably (as suggested above and elaborated in Appendix G), then it seems that the floodplain is fully utilized. Because much land is cultivated, forage yield of wild plants shows no trend in relation to rainfall. In some river sections, it is likely that range resources are inadequate and agricultural by-products support the livestock population for a crucial few weeks in jiilaal. Another feature of note is the substantial proportion of forage consumed by hippopotamuses in some river sections. Other species of wildlife have a negligible effect on range resources.

Relationships in Figure 13 assume a year of average rainfall. In years of low rainfall, production of herbaceous forage (graze) is sharply reduced (see Figure 14), yet livestock demand remains the same, at least temporarily. In a prolonged drought more livestock are slaughtered, or die from natural causes, but livestock populations fluctuate less than does production of forage. Floodplain resources, including crop residues, are even more vital in such years. Fortunately, floodplain graze seems more resilient to "overgrazing" than that in the river-dependent zone which may have been degraded by long-term overuse (TEBS ground monitoring site data).

1. Range Resource Assessment

Data from ground monitoring sites, sample large-scale aerial photography, and aerial census are combined with studies from elsewhere to produce "best estimates" of forage availability and livestock offtake. Appendix G should be consulted to understand limitations of these methods.

Forage is divided into "graze" (herbaceous layer; grasses, forbs, and dwarf shrubs) and "browse" (leaves, buds, fruit, and young twigs of bushes and trees). Herbaceous forage was assessed directly at ground monitoring sites by harvesting (Appendix A). Forage yield is defined as dry weight per unit area of standing crop of graze or browse available at the end of a growing season and before a noticeable amount has been consumed (Deshmukh in press). This quantity is regarded as a maximum estimate of forage available to large herbivores. In practice, much less is usually available due to consumption by other organisms, inaccessibility, trampling, fire, and other factors (see Section VII.D.4).

Forage yield of herbaceous vegetation in semi-arid areas is usually closely correlated with rainfall. Figure 14 illustrates this generalization by comparing a relationship for East and southern African rangelands with the Jubba Valley. Of particular note is much higher forage yield in the floodplain compared with the river-dependent zone. Floodplain sites produce more forage than the general prediction, attributable to high fertility caused by groundwater and nutrients from the river. Groundwater is implicated because there was no overbank flood in the season when most data were collected (further discussion in Section IX).

Non-floodplain sites, particularly in drier northern areas, produce less forage than the general prediction (Figure 14). This finding may indicate that herbaceous vegetation in the river-dependent zone is degraded. Supporting evidence is as follows. First, bare ground is evident at many ground sites after gu' rains and before the area is grazed. In the north, many sites had negligible herbage (the proportion of such sites is factored into Figure 13, but not Figure 14; see Appendix G). Second, herbaceous cover is independent of woody canopy cover. In more productive situations, herbaceous cover decreases as woody cover increases due to competition for soil water (*e.g.*, Wijngaarden 1985). Third, herbaceous forage is abundant in some areas (such as thickets) inaccessible to livestock while surrounding land has poor grass cover.

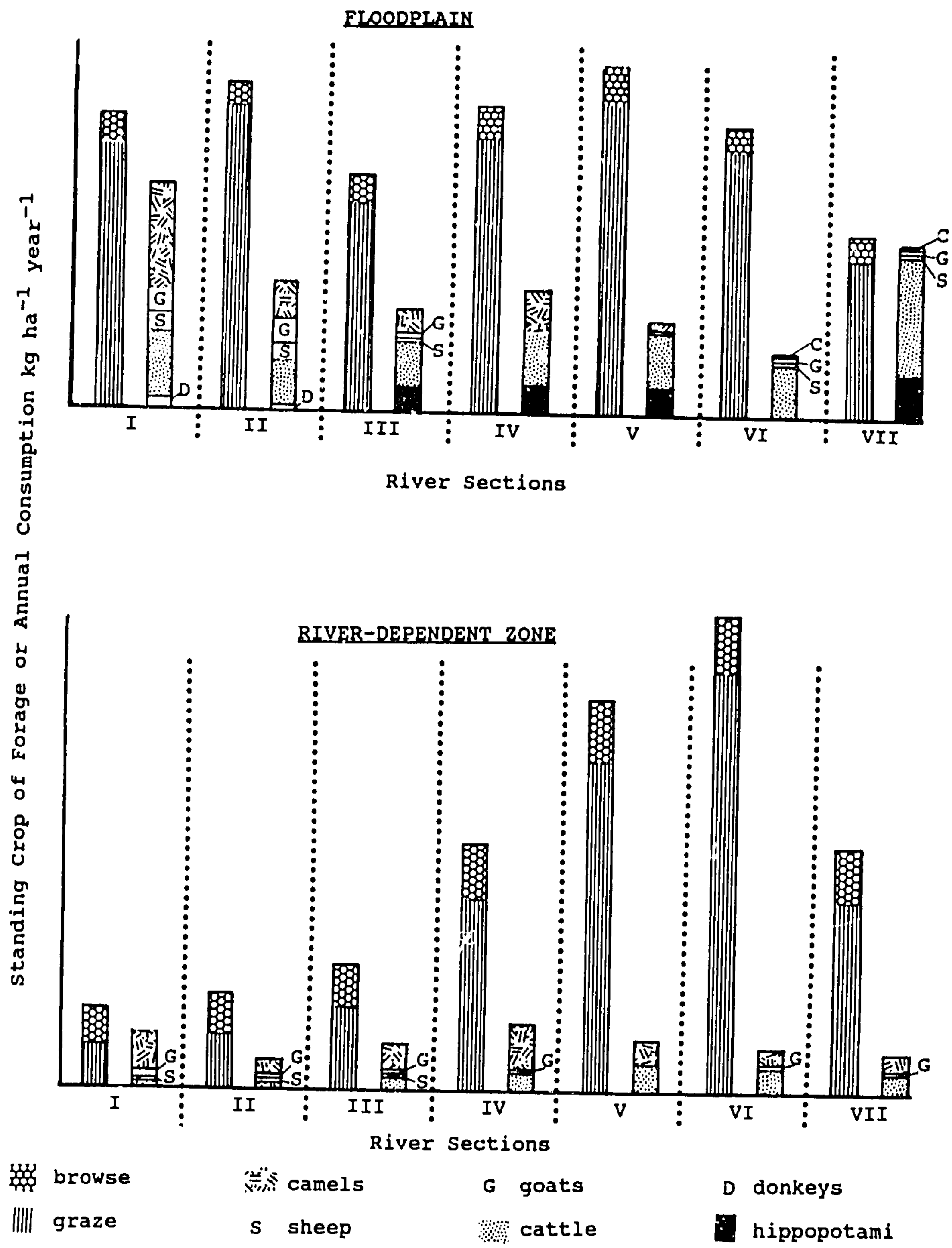

Figure 13. Estimates of total forage yield and its consumption by large herbivores in each river section in the floodplain and river-dependent zone.

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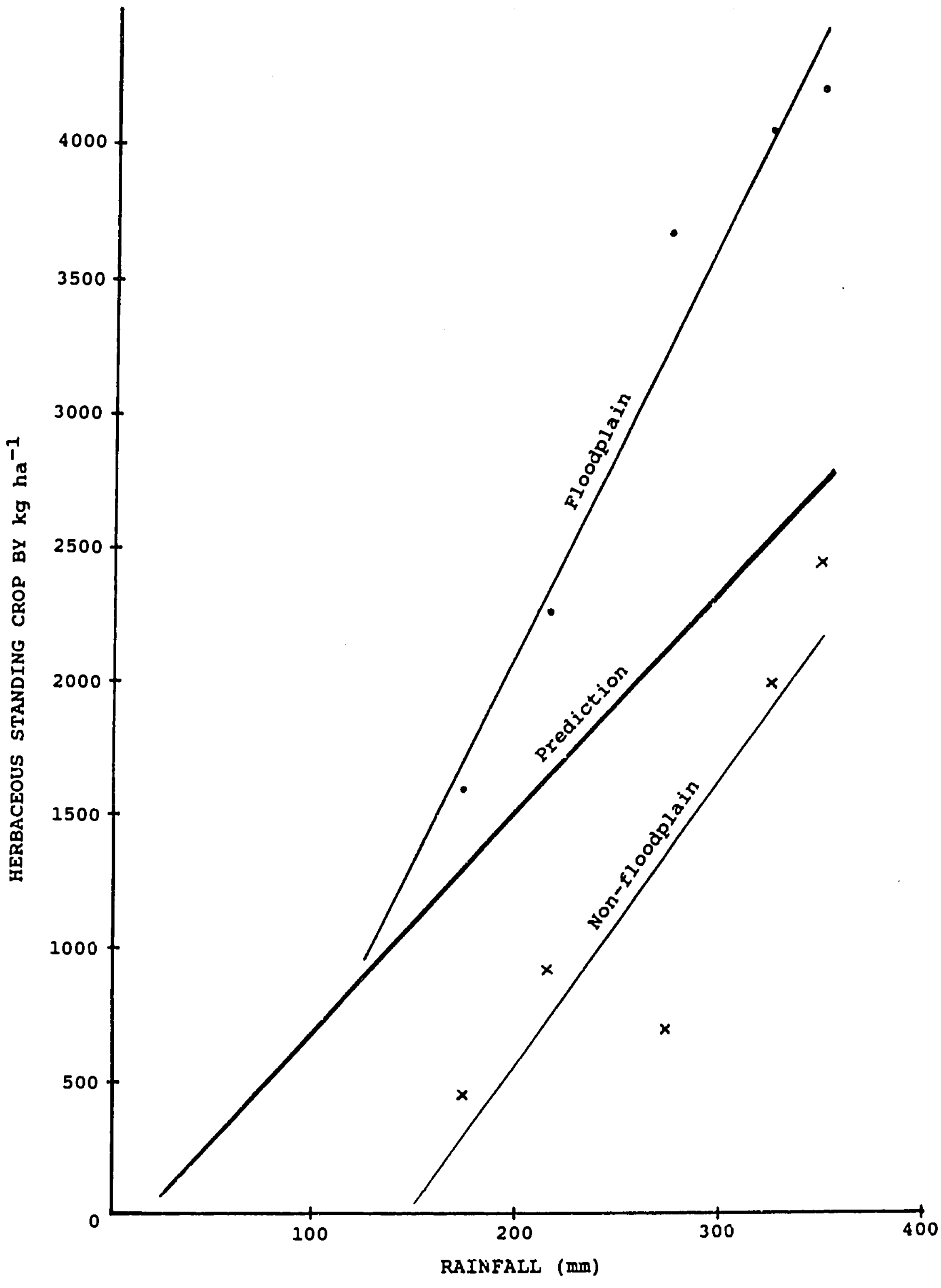

Figure 14. Peak herbaceous standing crop (forage yield) related to rainfall in the Jubba floodplain and river-dependent zone and a general relationship for eastern and southern Africa (see Appendix G).

It is likely that the river-dependent zone, at least in more northern stretches, has been overgrazed in the past, leading to a current situation of low productivity. Proximity to the river, with its seasonally large concentrations of livestock, may be the cause of degradation in these less resilient areas. Most of these TEBS ground sites are close to the floodplain and may not represent the whole river-dependent zone. However, aerial censuses show a fairly uniform livestock biomass throughout the river-dependent zone, indicating that grazing pressure is probably uniform too (Watson and Nimmo 1988).

Forage yield of browse is estimated from a relationship devised by Ecosystems (1985). Data come from Marsabit District in northern Kenya, a semi-arid area with vegetation similar to non-floodplain areas of southern Somalia. The regression model combines rainfall and percentage woody canopy cover to predict browse yield (see Appendix G). Direct effect of amount of rainfall is much less important in this model than that for graze yield. However, canopy cover in uncleared areas is also related to rainfall (*e.g.*, Figure 9) reinforcing the overall importance of rainfall in semi-arid areas. No data are available on the likely greater production of browse by individual plants in floodplain environments. A conservative assumption of no extra floodplain production has been adopted. As with forest production, it is better to underestimate rather than overestimate resources for planning purposes.

Table 21. Total forage yield from browse (foliage) in JESS vegetation types.

Vegetation type	Forage yield (kg ha^{-1} year^{-1})
Forest[1]	990
Dense woodland[1]	840
Medium woodland	560
Open woodland	320
Sparse woodland/wooded grassland	160
Thicket bushland	920
Dense bushland	720
Medium bushland	530
Open bushland	330
Sparse bushland/bushed grassland	120
Mixed	780

[1] *Browse from these categories for reasons of "quality", tsetse fly infestation, and height are regarded unavailable to livestock (see Appendix G).*

Estimates of forage yield for TEBS study area (Figure 13) take into account rainfall in each river section (Section III.A.2), area under each vegetation type, and land use in a similar way to the forestry estimates (see Appendix G). Estimates of browse for each vegetation type are given in Table 21 and are discussed further in Appendix G.

2. Livestock Populations and Consumption of Forage

Estimates of livestock populations and biomass are based on three aerial censuses conducted for JESS by RMR (Watson and Nimmo 1988). Censuses were conducted in mid-jiilaal (January/February), late jiilaal (March/April), and mid-xagaa (July/August) 1987. The first census covered only the floodplain. but the others included the entire TEBS study area. The xagaa census is regarded as "wet season" as it reflects livestock distribution shortly after gu' rains. Relatively little livestock concentration in the floodplain seems to occur in late xagaa compared with jiilaal. Xagaa rain and lower seasonal evapotranspiration than in jiilaal allow most nomadic stock to remain outside the floodplain. Negligible grazing was apparent in floodplain ground monitoring sites towards the end of xagaa (TEBS data).

As with forage production, livestock biomass in East African rangelands is usually related to rainfall. Figure 15 compares such a relationship for 10 areas (seven pastoral districts in Kenya; three non-riverine regions in southern Somalia) with data for the Jubba. Jubba administrative regions are in accord with the general relationship as is the TEBS study area as a whole, although livestock occupancy of Middle and Lower Shabeelle Regions is substantially higher (see Map 1 for location of regions).

When TEBS study area is considered, most sections of the river-dependent zone are somewhat higher in biomass than the general relationship in both wet and dry seasons. Overuse of the river-dependent zone in some sections, as suggested above, is supported by this higher than "normal" livestock biomass (Section VII.D.1). Lower biomass in River Sections V and VI is probably related to tsetse infestation (V and VI) and large state farms occupying much land and excluding livestock (VI). More startling than the situation in the river-dependent zone is livestock biomass in all floodplain sections (Figure 15). These biomass estimates bear no direct relationship to rainfall and are exceptionally high particularly in the dry season. They leave no doubt as to the importance of maintaining livestock access to the river and its floodplain.

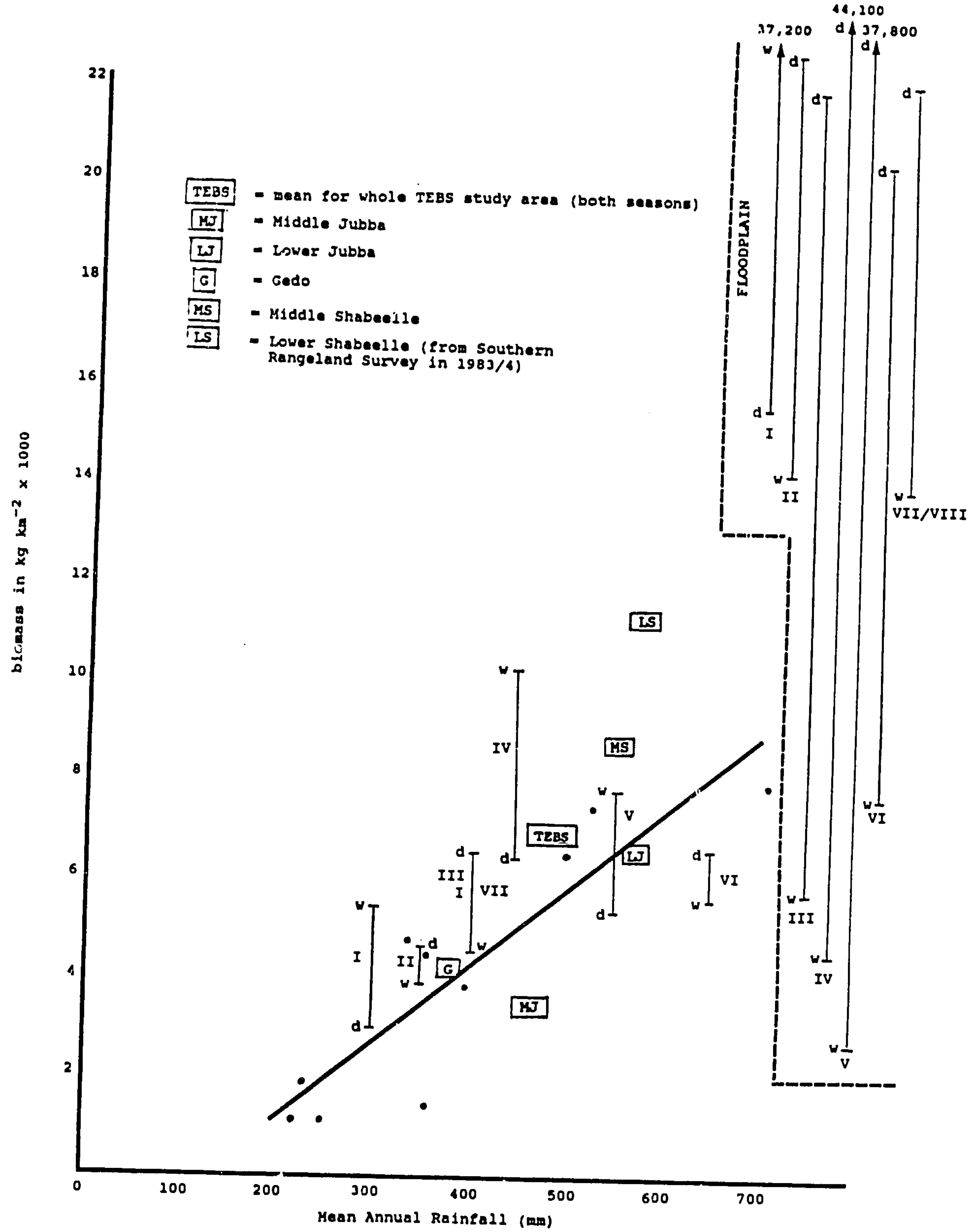

Figure 15. Relationships between mean annual rainfall and biomass of livestock in eastern Africa. Solid line and filled dots represent a regression analysis of seven pastoral districts in Kenya and three non-riverine regions of southern Somalia. Vertical bars in the body of the graph are wet (w) and dry (d) season censuses for TEBS river-dependent zone. The separate section to the right of the graph is for floodplain by river section (Roman numerals). (Data from Coe, Cumming, and Phillipson 1976; Ecosystems 1985; Lusigi 1984; Watson 1972; Watson and Nimmo 1985; Watson and Nimmo 1988.)

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A more detailed account of livestock density is afforded by examination of Figure 16. Higher floodplain biomass is seen in all species in most river sections. The exception is camels in River Sections V to VIII. In these higher rainfall areas, non-floodplain areas have equal (V) or greater (VI and VII) peak biomass than the floodplain. Cattle, sheep, and donkeys are the most floodplain dependent species. These species are at greater density in the floodplain for virtually all seasons and river sections. Sheep and donkeys are more common in River Sections I to IV, but have almost negligible biomass elsewhere.

Most species show greater floodplain biomass in late jiilaal than in other seasons in most river sections. Spectacular increases include camels in River Section IV and cattle in River Section V. Very high biomass and forage consumption (Figures 13 and 15) in River Section I, particularly in xagaa suggest that this area is seriously overstocked. A similar situation is the floodplain of river sections VII and VIII (Figure 13). These anomalies may be an artifact of sampling times. It is possible that high biomass is not maintained for long periods as is assumed in annual consumption estimates (see below). It is also reported that some animals in River Section I move seasonally across the border to Ethiopia (Janzen 1988).

A closer look at where highest floodplain concentrations of livestock occur is provided by data on individual strata. These data are best examined on map sheets of Watson and Nimmo (1988). High floodplain density of camels in early jiilaal in River Section II results from large numbers drinking at or in the river. Presumably many of these animals would move away after watering. Similar river concentrations of camels occurred in late jiilaal in River Sections III and IV. In the latter section, the other camel concentration was in dhesheegs.

In River Section V, cattle were concentrated in dhesheegs with virtually no livestock on levees. These levees remain the most forested along the river and, therefore, devoid of graze, but with high tsetse populations, whereas dhesheegs are often cleared and partly farmed or grassed. Dhesheegs are also favored by cattle in River Section VI, which has lowest cattle density on the sugar estates. Cleared but unplanted sections of Mugambo and Fanoole rice schemes also have large cattle populations. By xagaa, many animals have moved to levees, probably because free drainage of soils makes them more attractive after the rains and the extensive flooding that year. In River Section VII, heterogeneous alluvia are favored, particularly earlier in jiilaal. These areas are a complex of farms in use and under fallow with a mixture of palatable grasses and attractive *Acacia nilotica* browse.

Overall, seasonal changes in floodplain livestock biomass are compensated by movements into and out of the adjacent river-dependent zone. Total biomass of TEBS study area increases by only 8 percent when wet and dry seasons are compared, indicating that net movements into the area are small compared with redistribution within. However, when species are considered, camel biomass remains constant, whereas cattle and sheep increase by around 20 percent, in the dry season. Movements of livestock are covered in more detail elsewhere in JESS (Janzen 1988; Watson and Nimmo 1988; Craven, Merryman, and Merryman 1989) and by LRDC (1985).

Annual consumption of forage by livestock (and hippopotamuses) is calculated using daily food intake relative to body mass and population estimates of each species in various sections of the study area (see Appendix G). To project from daily intake rates to annual consumption in a particular area it is necessary to know the number of days that area is occupied by a particular mixture of livestock species. For computation purposes, it is assumed that both mid- and late-jiilaal censuses of livestock biomass are maintained for 60 days each, and xagaa for the remainder of the year in floodplain sections. Since there is no mid-jiilaal census in the river-dependent zone, late-jiilaal densities are applied for 120 days and xagaa estimates for the remaining 245 days. This procedure may be responsible for anomalies such as calculated overstocking in River Sections I and VII (Figure 13). Short of conducting more censuses, it is not possible to determine the magnitude of this type of error.

3. Comparison of Forage Yield and Livestock Consumption: The Problem of Carrying Capacity

A simple comparison of forage yield and its consumption by livestock gives a first approximation of range carrying capacity (Figure 15). However, such simplicity is confounded by food selection and quality (browse or graze, palatable or unpalatable); seasonal movements, water sources, and forage availability (has all the food been consumed in the place needed even if there is plenty elsewhere); and

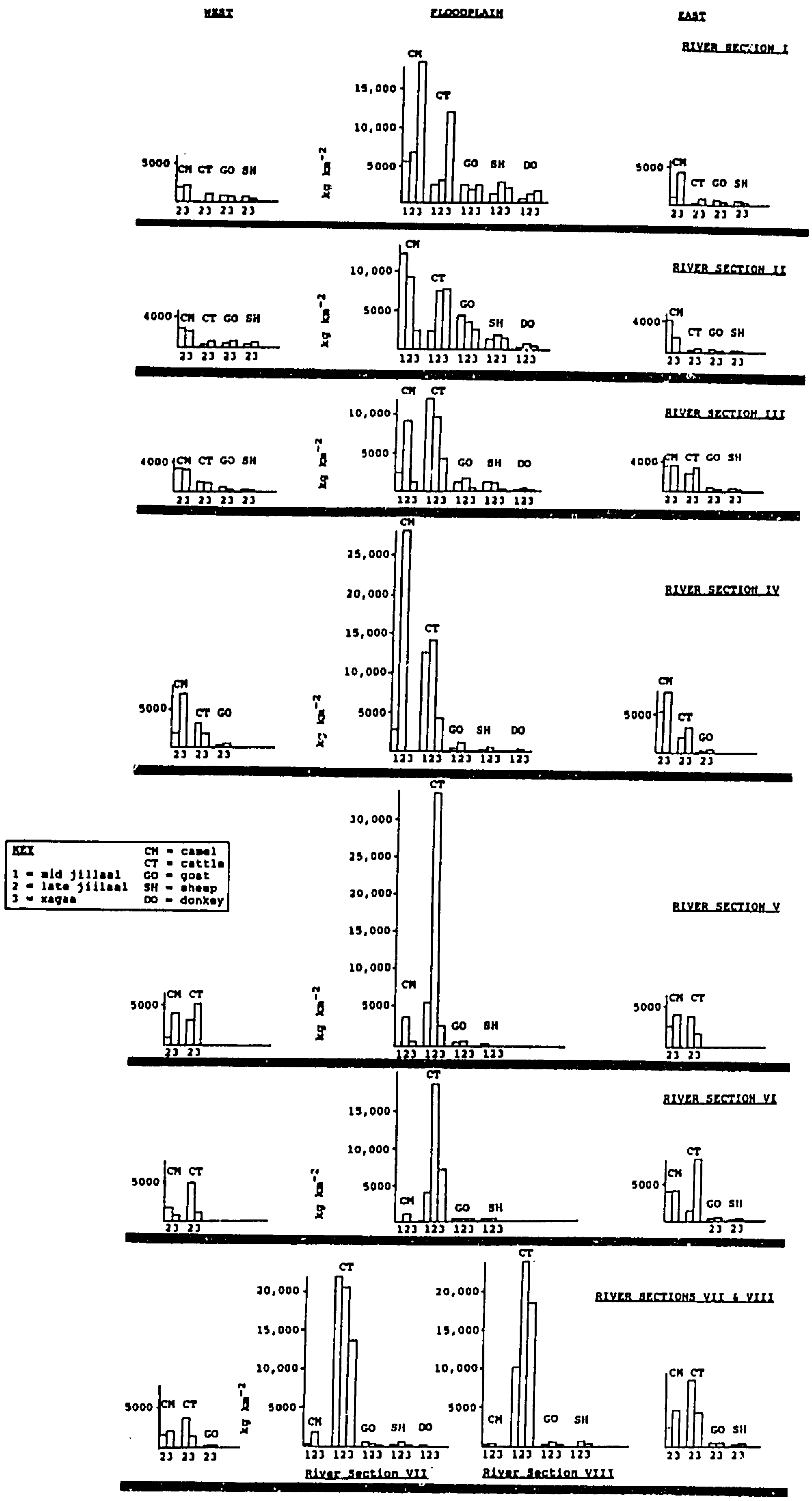


Figure 16. Livestock biomass by species, season, river section, and floodplain versus river-dependent zone for TEBS study area in 1987. (Watson and Nimmo 1988.)

longer-term drought cycles. No satisfactory scientific method has been devised for estimating optimal livestock production and range management for nomadic pastoral systems of Africa. The nomads themselves know far more than any short-term study can achieve. However, steadily increasing human population, accompanied by slower net increases in livestock biomass and loss of former grazing lands, puts increasing pressure on range resources. These problems are perhaps tacitly acknowledged by gradual shifts in pastoral strategy, notably towards agropastoralism (Craven, Merryman, and Merryman 1989). Such limitations should be borne in mind while reading the following account.

Analysis of forage consumption, detailed in Appendix G, proceeds as follows. Cattle, donkeys, and sheep are considered grazers; camels and goats, browsers. It is well known that all species consume at least some graze and browse, but this simplification is an initial step in analyzing food availability. The method avoids the necessity of defining precisely the relative proportions of graze and browse consumed by each species. Such information is not available for the study area.

First, browse available to goats is compared with their annual food requirement. Because of their small stature, it is assumed that only 25 percent of total browse is available. Any browse not consumed by goats is then available to camels who have access to an additional 25 percent of browse higher in trees and shrubs (*i.e.*, 50 percent of total browse is reachable by camels). Any browse not consumed by goats and camels is potentially available to other livestock. If browse consumption exceeds browsable forage, then the shortfall must be made up from graze. If there is an excess of browse, it may be used by grazers. A similar computation is made for forage available to grazers (as half of forage yield) and their consumption. Any excess of graze is then available to browsers. Using this approach the overall balance between forage available and that consumed can be examined (details, assumptions, and references in Appendix G).

Table 22 summarizes results of the analysis. Taking a year of average rainfall, available forage exceeds livestock demand in most areas. Of note is the relative shortage of browse, particularly in northern sections where camels are most abundant. The proportion of graze consumed by camels in the study area is unknown, but data from elsewhere show that sufficient graze can be consumed to validate the assumptions behind Table 22. Watson and Nimmo (1985) suggest 20 percent for southern Somalia. However, in Marsabit, northern Kenya, dwarf shrubs (considered here as graze) make up almost 50 percent of camel diet and herbaceous plants a further 20 percent (Lusigi 1984). Overall, the only shortfalls in forage occur in the river-dependent zone of River Section I and the floodplain of River Sections VII/VIII. A possible cause of these anomalies relating to timing of censuses is discussed in the previous section. More than enough forage remains in the river-dependent zone of River Section VII/VIII to supply the deficit in the floodplain. It may be that movements of livestock (particularly cattle) make use of the river-dependent zone. Overstocking remains a possibility in River Section I since this area experienced five to 10 times the jiilaal livestock mortality per unit of surviving biomass as other river sections in 1987 (Watson and Nimmo 1988).

Table 22. Analysis of balance between available forage and forage demand by livestock comparing floodplain and river-dependent zone by river sections. "Normal year" where graze and browse are accounted for separately is for average rainfall. "Drought" is for a dry year and only overall balance is presented (see Appendix G).

		BALANCE (kg ha^{-1} $year^{-1}$) "NORMAL YEAR"			DROUGHT
River Section		Browse	Graze	Overall	Overall
I	FP	-1,087	+1,230	+143	-3[illegible]0
	NFP	-232	+82	-150	-282
II	FP	-513	+808	+295	-474
	NFP	+12	+66	+74	-112
III	FP	-82	+474	+392	+232
	NFP	-51	+223	+172	+25
IV	FP	-202	+774	+572	+538
	NFP	-161	+717	+556	+232
V	FP	+136	+856	+992	+255
	NFP	+57	+1,328	+1,385	+793
VI	FP	+85	+615	+700	+274
	NFP	+121	+1,863	+1,984	+1,183
VII/VIII	FP	+63	-1,205	-1,142	-1,368
	NFP	+95	+769	+864	+534

In a drought year (see Table 22, right column, and Appendix G), graze production is much reduced leading to forage deficits in all parts of River Sections I and II and very small surpluses in most other areas. Bearing in mind factors presented in the next section, it seems likely that mortality of livestock will be high in drought years, as in most nomadic pastoral systems.

4. Factors Influencing Forage Use by Livestock

All graze and browse is not equally palatable. Some plant species are unpalatable or even poisonous. Table 23 gives palatability ratings for the most abundant species in TEBS study area. Many dominant trees and bushes are of rather low palatability. *Acacia reficiens*, the most abundant species of all, is regarded as unpalatable in Marsabit District, Kenya (Lusigi 1984). However, there is no doubt that it is browsed in TEBS ground monitoring sites during jiilaal, even though it is not favored. Most abundant floodplain grasses are palatable. They maintain a high standing crop into the dry season and are completely grazed down at many sites.

Temporal and spatial factors also affect availability and quality of forage. Cattle need to drink at least every two to three days, limiting the distance they can travel from water. The Jubba is by far the most important water source in the study area during jiilaal. In this season, herbaceous forage in the river-dependent zone is low in quantity and quality (Figure 13) relative to the floodplain. Therefore, cattle are virtually restricted to the floodplain during late jiilaal in more northerly areas, as illustrated in Figure 15. Similar factors affect browse availability. Although camels can wander for many days without water and, therefore, gather forage from a wide area, quality and quantity of browse are much reduced in jiilaal, particularly in the river-dependent zone. Since most common trees and shrubs are deciduous, browse is poor in dry seasons. Browsers are forced to eat younger twigs or leaf and fruit litter from the ground. Thus, although there may be a positive forage balance overall, spatial and temporal factors will always reduce the amount that can be consumed in reality.

*Table 23. Palatability ratings of most abundant plants on JESS ground monitoring sites.**

FLOODPLAIN		RIVER-DEPENDENT ZONE	
Trees and shrubs			
Acacia zanzibarica	LP	*Acacia reficiens*	LP
A. nilotica	P	*Commiphora* spp.	P
Terminalia brevipes	P	*A. horrida*	P
Thespesia danis	U	*A. zanzibarica*	LP
Dichrostachys cinerea	HP	*Grewia tenax*	LP
Lecaniodiscus fraxinifolius	?	*Cordia sinensis*	P
Phyllanthus somalensis	U	*A. nubica*	LP/UP
Acacia reficiens	LP	*A. bussei*	LP
Salvadora persica	P	*Anisotes trisulcus*	P
Spirostachys venenifera	U	*Combretum hereroense*	LP?
Herbaceous layer			
Sporobolus helvolus	HP	*Sporobolus helvolus*	HP
Cenchrus ciliaris	P	*Aerva persica*	U
Enicostemma axillare	U	*Eragrostis cilianensis*	HP
Eriochloa meyerana	?	*Aristida* sp.	LP
Echinochloa haploclada	P	*Dactyloctenium*	
Sorghum arudinaceum	HP	*scindicum*	P
Echinochloa colona	P	*Cenchrus ciliaris*	P
Commelina spp.	P	*Cadaba* spp.	U
Indigofera schimperi	P	*Commelina* spp.	P
Heliotropium aegyptiacum	U	*Enteropogon* sp.	P
		Sporobolus sp.	P

HP = highly palatable; P = palatable; LP = low palatability; U = unpalatable; ? = unknown palatability.
Source: From Herlocker & Kuchar (1986) or Jubba Valley residents
**Abundance based on canopy cover, not number of plants as in Table 15; species restricted to forests are omitted.*

Wild herbivores also consume graze and browse. Densities and distribution of terrestrial wildlife are such that they are unlikely to have a noticeable impact on livestock forage (Section VIII). However, the amphibious hippopotamus is a significant floodplain grazer in River Sections IV to VII (Figure 13). Extrapolation from sample census data suggest that hippopotamuses account for 40 percent of floodplain forage consumption in River Sections V and VII/VIII. However, total aerial counts, which probably give a better estimate of hippopotamus numbers, suggest a maximum of 25 percent of floodplain forage consumption in River Section V (Watson and Nimmo 1988; Appendix G; Figure 13). Where hippopotamus density is high, control programs, as suggested in Section VIII, may be as beneficial to pastoralists as to farmers.

Fires also consume forage, often removing all herbaceous vegetation and causing trees and bushes to shed leaves. Where fires are frequent, woody cover is gradually reduced, thereby reducing browse production, but potentially increasing graze production. During the JESS study period, fires were most frequent in the floodplain during jiilaal and relatively unimportant in the river-dependent zone. Fires are usually set during field preparation, but often escape into surrounding rangelands. Occurrence of fires is documented in Section V and in Watson and Nimmo (1988). Loss of vegetation by burning is probably of marginal significance to overall forage balance. Most fires are in River Sections V and VI, which have the greatest positive balance (Table 22).

Another important restriction on forage availability is the presence of biting flies which spread livestock diseases. Of particular importance in riverine areas are tsetse flies and the trypanosomiases they transmit. Distribution of tsetse is shown in Map 2. Cattle are badly affected, yet are largely dependent on floodplain habitats. Camels are also sensitive, but less restricted to the floodplain. LRDC (1985) reports that trypanosomiases account for 22, eight, and two percent of recorded deaths in cattle, sheep, and goats, respectively, in the riverine areas. Heavier trypanosomiasis-related mortality occurs during droughts when animals suffer nutritional stress. Infestations are at their worst in wet seasons and decline during jiilaal.

These facts help to explain livestock movements inferred from Figure 16. In River Section III southward, cattle move out of the floodplain in xagaa into the tsetse-free river-dependent zone. Tsetse are thought to be absent north of Baardheere. As a result, cattle are able to remain in the floodplain through xagaa in River Sections I and II. In fact, cattle density was higher during the wet season in these sections than in the dry season (Figure 16). Heaviest tsetse infestations occur in floodplain lands south of Saakow (LRDC 1985). Some grassland TEBS ground monitoring sites remain ungrazed throughout the year, reportedly due to extreme tsetse infestation. Because of forage availability, livestock must use the floodplain during jiilaal. To alleviate effects of disease, herders vaccinate their livestock when occupying tsetse-infested areas. Other livestock diseases such as anthrax, rinderpest, and hoof-and-mouth occur, often more so in the floodplain, but their effects have not been quantified (see LRDC 1985; Watson and Nimmo 1985; AHT 1988).

Factors affecting forage availability discussed above all effectively reduce carrying capacity of the study area. In contrast, the availability of crop residues provides an additional and nutritious food source for livestock. Sorghum and maize produce three to four times as much stover as grain (AHT 1988; Hubbel personal communication). Since grain production averages about 1 t ha^{-1} $year^{-1}$ (AHT 1988), these croplands produce as much potential livestock fodder (3 to 4 t ha^{-1}) as a hectare of rangeland (compare Figure 14). Sorghum and maize stover can be grazed in fields or collected and stored or transported more easily than wild grasses. Beans and sesame also produce consumable residues, but at a lower rate than grain crops. Rice straw is a potential fodder, but is not made available at the state farms of Fanoole and Mogambo.

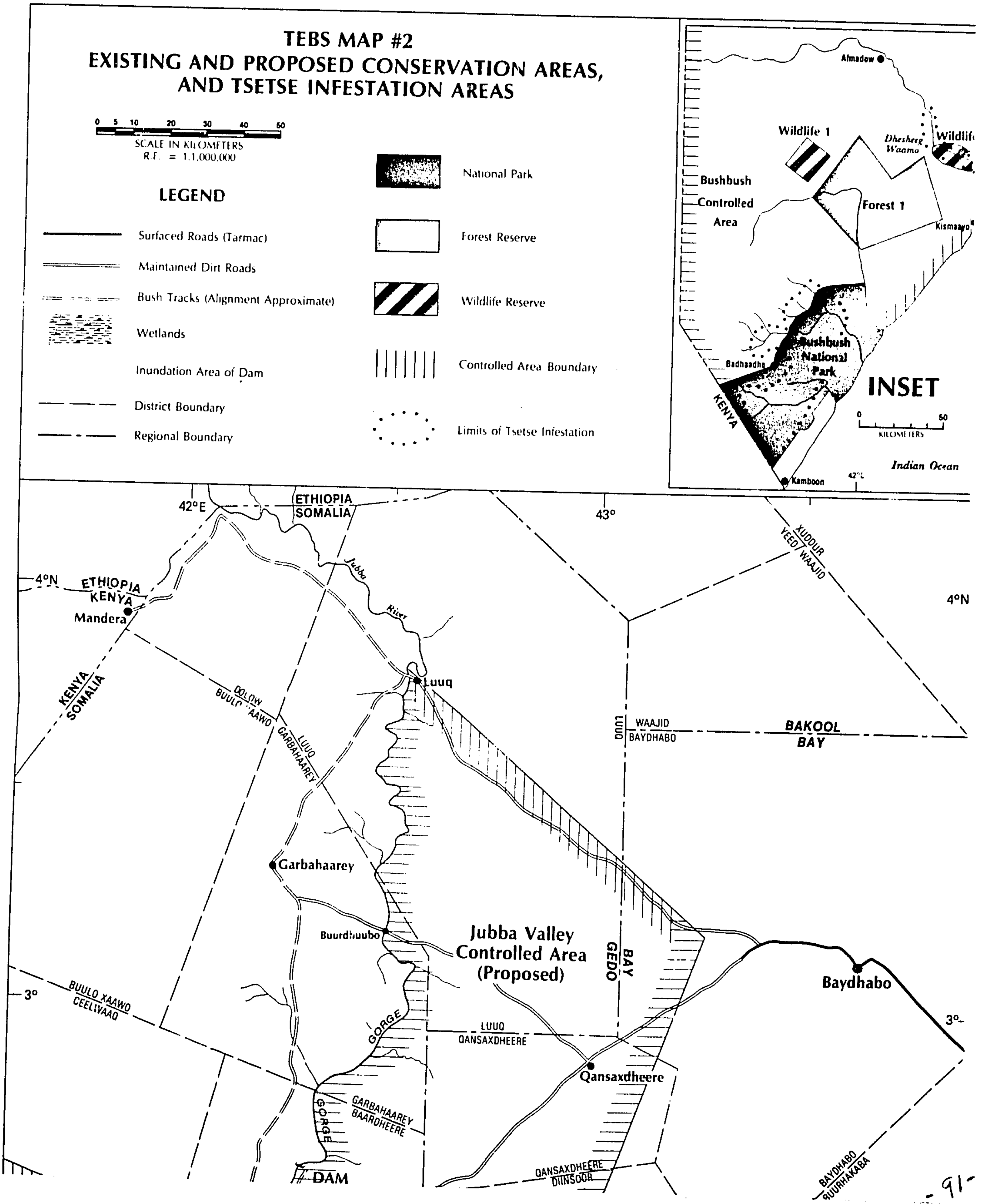
The Ministry of Agriculture estimates 71,000 t, 97,000 t, and 58,000 t of maize and sorghum residues are produced in Gedo, Middle Jubba, and Lower Jubba respectively (AHT 1988). Most of this production is in the floodplain, although significant rainfed sorghum farming occurs in the river-dependent zone of River Sections III and IV. Assuming, for illustrative purposes, that all production does occur in the floodplain, then approximately 1 t ha^{-1} of crop residues is available throughout the whole floodplain using the Ministry of Agriculture production statistics. On a smaller geographical scale, MMP (1987) calculates that in a proposed smallholder development at Hombooy (Middle Jubba Region), 6000 ha of mixed croplands will produce 12,000 t of crop residues each year. This estimate is compatible with extrapolation from the Ministry of Agriculture data. Comparing this estimate with forage balance indicates the potential importance of crop residues to the livestock economy.

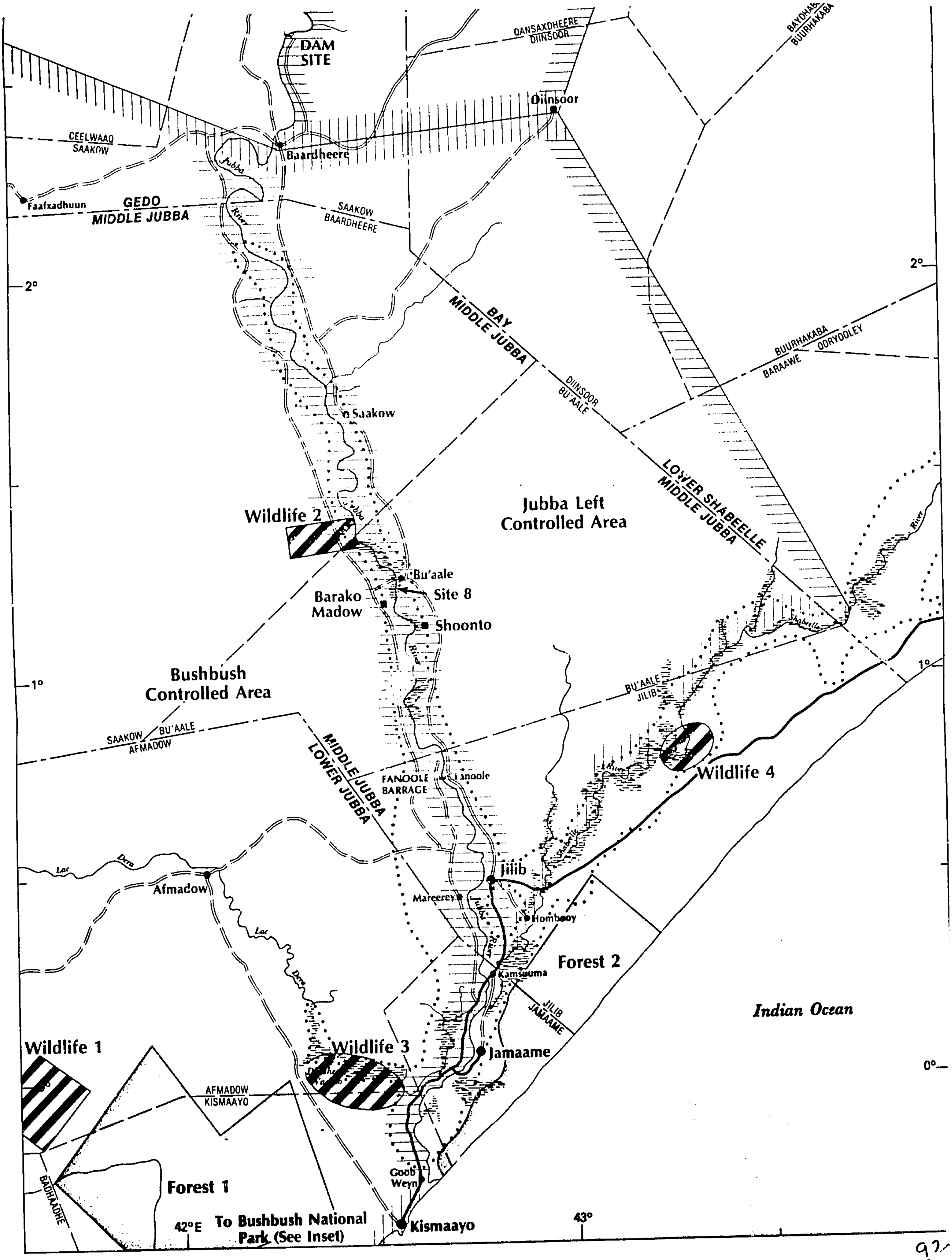
Aerial censuses reveal that about 20 percent of cattle, 10 percent of sheep, seven percent of goats, and seven percent of camels foraged in current or fallow croplands throughout the TEBS study area late in the dry season (Watson and Nimmo 1988). Only cattle (two percent overall) were seen feeding on crop residues transported from the fields. However, about 30 percent of cattle were eating such residues during late jiilaal in River Section I. Watson and Nimmo (1985) regard the livestock/crop residue relationship to be relatively poorly developed in the Jubba Valley compared to the Shabeelle Valley. This point is illustrated by extremely high livestock biomass maintained in the Shabeelle administrative regions (Figure 15). Clearly there is potential to increase livestock production in the Jubba if herders and farmers become more closely integrated.

E. Conclusions and Recommendations for the Range Sector

Rangeland is the most extensive land use in the study area. Range and livestock development are, therefore, crucial to the future of the Jubba Valley. Overall, it appears that the TEBS study area sup-

TEBS MAP #2
EXISTING AND PROPOSED CONSERVATION AREAS, AND TSETSE INFESTATION AREAS





DAM SITE
QANSAXDHEERE
DIINSOOR
BAYDHABA
BUURHAKABA
Diinsoor
CEELWAAQ
SAAKOW
Baardheere
Jubba
Faafxadhuun
GEDO
MIDDLE JUBBA
SAAKOW
BAARDHEERE
River
2°
BAY
MIDDLE JUBBA
BUURHAKABA
QORYOOLEY
BARAAWE
DIINSOOR
BU'AALE
Saakow
LOWER SHABEELLE
MIDDLE JUBBA
Wildlife 2
Jubba Left
Controlled Area
Bu'aale
Site 8
Barako
Madow
Shoonto
River
Shabeelle
Bushbush
Controlled Area
1°
BU'AALE
JILIB
SAAKOW
BU'AALE
AFMADOW
MIDDLE JUBBA
LOWER JUBBA
FANOOLE
BARRAGE
Fanoole
Wildlife 4
Lac
Dera
Afmadow
Jilib
Mareerey
Hombooy
Forest 2
Kamsuuma
JILIB
JAMAAME
Indian Ocean
Wildlife 1
Wildlife 3
Jamaame
0°
AFMADOW
KISMAAYO
BADHAADHE
Forest 1
Goob
Weyn
42°E
To Bushbush National
Park (See Inset)
Kismaayo
43°

ports a higher biomass of livestock than the greater JESS study area. This difference is attributable to the river as a permanent source of water and availability of dry season forage in the floodplain.

Models of forage production and consumption indicate that most rangelands are not overstocked in years of average rainfall. However, it appears that parts of the river-dependent zone are somewhat degraded. In contrast, floodplain grasslands show great resilience to flood, fire, and grazing. In drought years forage resources are pressed hard and livestock losses are inevitable. Crop residues, produced mainly in the floodplain, provide an important source of fodder alleviating seasonal and drought stresses. During stress periods additional forage is also made available by cutting the higher branches from palatable trees and bushes which livestock could not reach otherwise.

The most important immediate effect on range resources of closing Baardheere Dam will be loss of rangelands in the inundation area. At present this area supports 22,600 kg km^{-2} of livestock in jiilaal. Approximately half this biomass comprises cattle and sheep which are restricted to the floodplain during this season and much of the year. Relative to TEBS study area, approximately seven percent of sheep and goats and two percent of cattle and camel biomass occur in the inundation zone. Approximately 24 million kilograms of annual forage yield will be lost. Presumably, most livestock will leave the area since rangelands around the inundation zone will be a poor source of forage initially, at least, compared with the lost floodplain. Since more northerly areas already seem overstocked, it is likely that most movement will be southward. River Sections IV to VI could absorb the extra animals without greatly altering forage balance. However, stresses will be greater in drought years. Also, animals moved will be exposed to greater health hazards since tsetse is absent from River Section II, but prevalent to the south. Livestock mortality per unit of living biomass was similar in River Sections II, IV, and VI during jiilaal 1987, but twice as high in River Section V (Watson and Nimmo 1988), suggesting that increased health risk will be a real phenomenon in some areas.

The reservoir drawdown zone may become a seasonally usable rangeland. Soil types in this zone are not known quantitatively. Much of the area is stony or rocky, but there are also stretches of finer soil (Appendix I). Over time, fine riverine sediments may be deposited in the drawdown zone. If that happens, seasonal grasslands will probably develop, providing a good dry season grazing resource. It may be possible to enhance establishment of palatable grasslands by seeding. Drawdown agriculture is another possibility (Sections V and IX) which would produce livestock fodder as a by-product. Until the reservoir edge and drawdown zone are demarcated, it is not possible to predict the potential of such developments. However, the reservoir perimeter should be as much a focus of development planning as downstream areas (see Section IX).

Tsetse may become established around the reservoir even though they are thought to be absent now. Tsetse distribution is closely linked to air temperature and humidity (Rogers 1979). A large body of water will decrease air temperature and increase humidity, thereby improving conditions for flies. If bush increases around the perimeter of the reservoir due to increased soil moisture, fly habitat will be further improved. These possibilities should be borne in mind as part of the country's tsetse eradication program.

If the drawdown zone becomes a focus for livestock, crocodile populations will probably become a serious threat to people and animals. Crocodile control programs may be desirable (see Section VIII).

Downstream of the dam, agricultural development will reduce floodplain rangelands. Given the crucial nature of these rangelands as a dry season resource, greater integration of livestock and agriculture will be required to maintain livestock production. Some new rangelands may become usable if tsetse eradication is successful in compensating somewhat for losses of land to agriculture.

Recommendation: *Agricultural development should take place in such a way that suitable crop residues are available to livestock.*

At present such a situation is found to some extent among subsistence farmers and small-holders. In the large state farms on the Jubba, crop residues are not made available to livestock. Great potential exists to enhance the livestock economy if proper integration is allowed to develop and is encouraged. Such processes of integration depend on appropriate farming systems and sociological interactions. Planning to optimize such developments is difficult. Farming systems should be developed that

Dhesheep and river livestock watering points will need to be maintained.

94'

allow grazing and/or collection of crop residues of suitable crop species. However, the sociological interactions are unpredictable with present information. An important requirement will be local government officials who are skilled in resolving conflicts between pastoralists and farmers.

As suggested in other sections, floodplain vegetation will be degraded as a result of reduced flooding, groundwater, and nutrients supplied by the river. Similar developments will occur in unirrigated or unfertilized floodplain agriculture. Potential loss of production is illustrated by Figure 14. Comparison of the floodplain regression with that predicted for typical rainfed areas in East and southern Africa suggests a 20 to 50 percent reduction in herbaceous forage yield may occur. The floodplain regression omits tall grasslands in particularly favorable sites which yield up to 20 t ha^{-1} $year^{-1}$. These effects can be countered in the agricultural sector by irrigation and artificial fertilizers, but range production will decrease. Use of crop residues to feed livestock will become yet more important.

Another effect of increased floodplain agriculture on livestock will be reduced access to the river and dhesheeg watering points. Allocation of land should be managed in such a way that conflicts between farmers and herders concerning access to drinking water are minimized. One possibility is to use some dhesheegs specifically for livestock watering, leaving levees free for agricultural development. According to Janzen (1988) herders prefer dhesheegs to the river for watering. Since dhesheeg flooding will be reduced or absent after the dam closure, selected dhesheegs could be filled with water by cutting channels from the river, as is now the case at Dhesheeg Radiile near Bu'aale, or by employing pumps. Major watering points are mapped by Janzen (1988), LRDC (1985), and Watson and Nimmo (1985; 1988). Decisions as to which watering points are to be maintained or developed need to be worked out at the local level between farmers, herders, new projects, and government officials, rather than being imposed as an overall plan for the whole river.

Recommendation: *Maintenance of livestock watering-points along the Jubba River should be an integral part of floodplain development. The possibility of using selected dhesheegs for this purpose should be investigated.*

Dhesheeg Waamo presents a special problem. Although its hydrology is poorly understood, it fills when the Jubba has large floods, as in 1987. At other times, its waters are topped up from the Lac Dera catchment and possibly by underground flow from the Lorian Swamps in Kenya. In the absence of Jubba waters the dhesheeg dries up, as in jiilaal 1987 when the water-table was several meters below ground (TEBS field observations). Dhesheeg Waamo is an important part of the jiilaal livestock concentration area in Afmadow District (LRDC 1985; Peter Little personal communication). JESS estimated 30,000 kg km^{-2} of livestock in Waamo during mid- and late-jiilaal censuses and 12,000 kg km^{-2} during xagaa, indicating high and relatively persistent occupation of Waamo (Watson and Nimmo 1988). After dam construction Dhesheeg Waamo will receive less water from the Jubba, possibly none at all, resulting in detrimental effects on forage and water availability for livestock. Yet there will be excess water in the river every few years which will probably cause costly floods in farmlands of Lower Jubba (AHT 1988). It may be possible to have controlled diversion of water from the river to Dhesheeg Waamo, particularly when excess water has to be released from Baardheere Dam. AHT (1988) predicts that such releases will occur approximately in one year out of five. It is not known how often Dhesheeg Waamo floods from the Jubba in the pre-dam situation. Therefore, without further investigation it is not possible to predict how effective a five-year flood would be in maintaining this wetland ecosystem. The Italian administration opened two channels (Far Waamo and Farta Mogambo) between the Jubba and Waamo to divert Jubba floods from banana plantations downstream (LRDC 1985). Although not noticeably effective at present, it is possible that these channels could form the basis of an enhanced diversion scheme.

Recommendation: *The possibility of diverting post-dam flood waters into Dhesheeg Waamo should be investigated to maintain forage and water requirements for livestock in Afmadow District.*

River-dependent zone rangelands are degraded in northern river sections such that herbaceous forage yield is smaller than its potential. The possibility of rehabilitating these areas should be considered. Initially, a small project using livestock exclosures would be adequate to demonstrate whether, and to what extent, natural regeneration is possible. If successful, the project could be extended to larger areas, perhaps by attempting to introduce grazing rotation schemes. However, such schemes are notoriously difficult to enforce and administer in pastoral nomadic settings. To have any hope of success, such a project would require good extension, demonstration, and local participation components. The Central Rangelands Project of the Somali National Range Agency has met with some success in similar endeavors, but only with massive financial input.

Recommendation: *The possibility of rehabilitating herbage yields in the river-dependent zone should be investigated.*

Long-term trends in livestock populations between 1952 and 1984 in southern Somalia were assessed by Watson and Nimmo (1985). They concluded that cattle numbers had increased, that sheep had probably increased, but that trends in other species were difficult to discern given the weakness of early data. Increase in total livestock biomass is highly probable and may even have doubled during the period. Watson and Nimmo (1985) attribute these changes to an increase in mean annual rainfall from 1959 to 1983 as part of a 40-year cycle, and land-use changes. They warn that the mid-1980s may see the beginning of a rainfall decline if the 40-year cycle is verified.

Most trends in livestock biomass between 1983-1984 and 1987 are too small to discern given the different sampling strategy of the two sets of surveys. However, it seems that sheep numbers have increased since the 35,000 km^2 TEBS study area is estimated to contain more in jiilaal 1987 than 117,000 km^2 of Gedo, Middle Jubba, and Lower Jubba in jiilaal 1984 (Watson and Nimmo 1985; 1988). Much of the extra sheep production is in River Sections I and II. Sheep numbers may, therefore, decline again after construction of the dam. It is of interest to understand the significance of increase in sheep numbers so that suitable measures can be taken to counter negative impacts of the dam.

VIII. CONSERVATION AND WILDLIFE

Recently, biological conservation in tropical countries has been promoted as a necessary part of economic development. The "World Conservation Strategy" was an important international document setting the scene for this decade (International Union for the Conservation of Nature and Natural Resources; IUCN 1980). The central hypothesis is that maintenance of natural ecosystems is essential for sustained economic development. As the decade proceeds, the increasing rate of species loss has shifted specific attention to conservation of biological diversity. These concerns have sufficient political impact to affect policies of major development agencies such as the World Bank and USAID. Many agencies now require that environmental effects of development projects be assessed and areas of conservation importance be protected. Recent U.S. government legislation specifically draws attention to protection of tropical forests and "biodiversity" in USAID-funded projects.

Two quotations from a respected African ecologist and conservationist are especially relevant to conservation issues in the study area.

> African ecosystems are not as fragile and vulnerable as is popularly believed...But current accelerated rates of change leave little room for complacency regarding the identification of real rather than perceived conservation priorities.
>
> Biotic diversity is not linked to the distribution of elephants, rhino....The massive investment campaigns directed at these species does more for the souls of donors and the egos of the elephant experts than ...for biotic diversity, which is centered on less exciting communities of.....wetlands, lakes and rivers. (Huntley 1988).

Indeed, the major conservation opportunities in southern Somalia are concerned with river-related ecosystems such as the Jubba forests, Shabeelle Swamps, and the seasonal river complex of Bushbush, rather than the vast rangelands that dominate the area. It is rangelands that are resilient, as suggested in Huntley's first statement. Wetlands are also resilient if protected from major hydrological interventions such as dams or draining for agriculture. Both the Jubba forests and the Shabeelle Swamps may be affected by dam developments in the near future.

This section considers the status of terrestrial large mammal populations and demonstrates that most are at such low densities that effective conservation measures cannot be taken in the Somali context. Aquatic wildlife, specifically crocodile and hippopotamus, are of pest status in some areas and should be controlled. Related issues such as subsistence hunting, tsetse control, wildlife as pests, effects of Baardheere Dam, and tourist potential are discussed. All these issues demonstrate the need for more effective environmental and conservation policy in Somalia.

Historical transitions in awareness about biological conservation from hunters to natural historians to scientific ecologists to politicians and policymakers have left a tangled web of ill-defined terms such as: wildlife, game, wildlands, biodiversity, and genetic diversity. For the purposes of addressing a development-oriented audience, rather than a biological one, "wildlife" will be used to refer to non-domestic mammals, birds, and reptiles. "Biological diversity" or "diversity" will refer to the number of species in a given area or community. "Biological conservation" or "conservation" refers to maintenance of species or groups of species (communities) in their natural environment. Other confusing terms will be kept to a minimum and defined where used.

Most of this volume has referred to TEBS study area (Section IV). When "study area" is used alone in this section it will mean the wider JESS study area, the administrative regions of Gedo, Middle Jubba, and Lower Jubba (Map 1). Scientific names of animals not given in tables, but reported from the study area are presented in Appendix II.

A. Conservation Prospects in Somalia

Somalia has missed the opportunity to create large and effective wildlife conservation areas. Wildlife densities are now low compared with other countries in the region which have a system of functioning reserves. In Somalia, significant economic returns from biological conservation cannot be expected in the foreseeable future. A country which struggles to supply basic human needs to its population cannot be expected to finance large-scale conservation measures. However, these conditions do not preclude the possibility of developing an effective conservation policy with support from external donors.

At present, biological conservation activities come under the Ministry of Livestock, Forestry, and Range. Matters relating to vegetation are mainly within the National Range Agency (NRA), while the Wildlife Department is directly under the Ministry. Range, forest, and wildlife reserves are provided for under Somali law. This structure is not ideal for conservation activities. The Ministry's basic remit is exploitation of natural resources through livestock production and forest products, rather than environmental conservation and protection of diversity. The need for a separate government body to oversee environmental and conservation activities has been expressed frequently, most recently at the National Workshop on Desertification and the Environment in Somalia (March 1988). Such a body would formulate a coherent environmental policy including a national conservation strategy.

Given the paucity of larger wildlife, funding, and skilled people, conservation in Somalia should be carefully prioritized. Large tracts of land need not be separated as pure conservation areas. Protection and management of smaller, carefully selected reserves will be much more effective. Terms such as "national park" and "biosphere reserve" are not used here because they have specific international meanings which may not be directly applicable to conservation management in Somalia. Appropriate designations should be decided as part of a national system of conservation areas rather than determined by the specific situation in the Jubba Valley.

In determining conservation priorities for Somalia, particular attention should be paid to:

- endemic species;
- rare species, internationally;
- rare species, of restricted distribution within Somalia; and
- plant and animal communities which are unusual, especially diverse or rapidly diminishing in extent.

Conservation sites should be selected and managed in ways that seek optimal balances between rural populations and conservation objectives.

Recommendation: *External funding and technical assistance should be sought to support a coherent conservation program in Somalia.*

Substantial economic benefits from conservation cannot be expected in the near-term. Tourism is almost nonexistent in Somalia and could only be developed slowly. Potential attractions compared with neighboring Kenya are limited. More specialized tourists interested in birds, vegetation, a unique culture, or getting away from other tourists might be attracted to Somalia, but such people will not have a significant impact on foreign exchange earnings. Massive investment in improving communications infrastructure and tourist facilities would be required to attempt to attract large numbers of people. Cost effectiveness of such investments could not be guaranteed.

Extractive use of wildlife is also limited in scope except for proposed cropping of crocodiles (see Section VII.B.2). Game hunting can be lucrative, but would need to be carefully controlled. Animals especially attractive to hunters, such as elephant, rhinoceros, buffalo, lion, and leopard are all rare in Somalia. Subsistence hunting will undoubtedly continue to provide a useful supply of protein to rural populations. Such hunting cannot be controlled effectively over large areas, but it may be appropriate to restrict the species killed, or prevent hunting entirely in more limited areas of special conservation value.

Commercial game cropping or ranching as a means of supplying meat to local or export markets is not feasible in Somalia. Animal populations are too sparse for commercial operations to compete in price with meat from livestock. Local religion and taste dictate stringent selection of species and slaughter techniques which are difficult to operate in the field. Game meat for export would be far too expensive and is unlikely to meet foreign hygiene requirements if slaughtered in the bush.

B. Wildlife Populations

1. Large Terrestrial Animals

Seasonal aerial censuses of TEBS study area show that domestic livestock dominates large mammal biomass. Terrestrial wildlife numbers (large mammals and ostrich) and biomass are low throughout the census area (Table 24). The more common species, such as lesser kudu and gerenuk, are largely independent of surface water and do not, therefore, rely on the river. Other abundant species, such as warthog, bushpig, and baboon are ubiquitous and achieve pest status in many areas.

Table 24. Biomass (liveweight) and population estimates of domestic and wild large animals in the TEBS study area. Data from aerial census March-April 1987 - DRY; July-August 1988 - WET (Watson and Nimmo 1988).

SPECIES	BIOMASS (kg km^{-2})		POPULATION	
	DRY	WET	DRY	WET
Domestic				
camel	2,945	3,078	335,000	350,000
cattle	3,040	2,503	584,000	481,000
goat	374	341	718,000	655,000
sheep	237	195	455,000	374,000
donkey	42	21	10,000	5,000
TOTAL	6,638	6,138		
Wildlife[1]				
gerenuk	5.7	17.3	7,850	23,730
waterbuck	0.6	0.5	190	160
lesser kudu	16.7	33.0	14,460	28,500
oryx	0.7	3.8	260	1,460
ostrich	0.7	0.2	300	90
giraffe	47.4	68.3	2,050	2,950
warthog	4.0	7.3	3,990	7,200
bush pig	0.9	2.8	870	2,780
elephant[2]	56.8	0.0	780	0
elephant skeleton			2,990	4,300
baboon troop	12.5	15.4	430	530
vervet troop	0.3	0.0	60	0
TOTAL	146.3	148.6		

[1] *wet season estimates included small numbers of duiker (310), reedbuck (50), oribi, (100) and honey badger (80), which have a negligible effect on total biomass.*

[2] *elephant estimates result from a single sighting of six animals in one stratum.*

The Jubba River and floodplain are not significant dry season concentration areas for larger wildlife. Predominance of livestock, ever-increasing agricultural activity, and poaching have led to elimination of much riverine wildlife. Highest jiilaal floodplain densities of wild herbivores were in dhesheegs of River Sections V and VII which had approximately 1,100 kg km^{-2} of terrestrial larger mammals. Most of this biomass comprises warthogs and baboons. The same areas had 78,000 kg km^{-2} and 23,000 kg km^{-2} of domestic stock, respectively (Watson and Nimmo 1988). Note that elephant population estimates are not reliable, as they result from a single sighting in one stratum. The far greater number of elephant skeletons over living animals indicates the impact of poaching. Average large wildlife biomass is less than 150 kg km^{-2}. By comparison, a typical conservation area with similar rainfall in other East African countries has approximately 3,500 kg km^{-2} of wildlife (Deshmukh in press). A floodplain area would support even higher biomass.

Outside the floodplain, larger wildlife are more common in the wet season (Tables 24 and 25). Biomass estimates for the dry season are severely skewed by a single occurrence of elephants. However, population estimates show large numbers of gerenuk, lesser kudu, and oryx moving into TEBS study area after the rains. Presumably, these species are further east and west during jiilaal, clearly demonstrating their independence of the Jubba. Highest large mammal densities in the river-dependent zone were found in the distant marine plains 12 to 30 km from the floodplain west of the river in Sections V, VI, and VII/VIII. Biomass above 1,000 kg km^{-2} was found south and west of Dhesheeg Waamo in xagaa (1,050 kg km^{-2}), west of River Section V in jiilaal (1,430 kg km^{-2}) and in lower Shabeelle floodplain in jiilaal (1,290 kg km^{-2}).

Geographical distribution of larger wildlife populations in TEBS study area is shown in Table 25. A striking feature is the paucity of animals in floodplains of river sections north of Fanoole Barrage. Only warthog and baboon were seen. Most species are at higher density in southern sections, probably reflecting higher rainfall in these areas. Gerenuk and lesser kudu are common throughout most of the river-dependent zone, but giraffe are concentrated in the south. Oryx and elephant are rare, with small herds of the latter entering TEBS study area sporadically.

Trends in large animal populations south of Bu'aale can be approximated by comparing aerial census data from jiilaal 1976 (Abel and Kille 1976), 1984 (Watson and Nimmo 1985), and 1987 (Watson and Nimmo 1988). Different sampling techniques and strata were used in these studies. Thus, comparisons are merely indicative. Lesser kudu and gerenuk populations are similar; giraffe and oryx are significantly reduced; and elephants are virtually eliminated. Abel and Kille (1976) also saw rhinoceros which are now probably extinct in TEBS study area. These trends are confirmed by interviews with Jubba Valley residents. Elephants are rarely seen, although they were common 20 years ago. The only JESS ground sighting was a small herd at Dhesheeg Radiile in jiilaal 1987, which

Table 25. Geographical distribution of population estimates of larger wildlife comparing floodplain (FP) and river-dependent zone (NFP) by river section north to south. Estimates are the higher observed in late jiilaal (unmarked) or xagaa (*) censuses (Watson and Nimmo 1988).

River Section		GER	WAT	KUD	ORX	OST	GIR	WART	PIG	ELE	BAB	VERV
I	FP	0	0	0	0	0	0	0	0	0	0	0
	NFP	1,280*	0	100*	0	0	0	230*	0	0	0	0
II	FP	0	0	0	0	0	0	320	0	0	56*	0
	NFP	9,260*	0	220*	400*	0	0	610	0	0	180*	0
III	FP	0	0	0	0	0	0	110*	0	0	10	0
	NFP	1,760*	0	2460*	580*	0	0	690*	0	0	40	0
IV	FP	0	60	0	0	0	0	110*	0	0	20	0
	NFP	2,750*	0	2,920*	0	0	0	2,280*	0	0	110*	0
V	FP	0	0	0	0	0	0	80*	0	0	40	8
	NFP	1,150*	0	4,930	260	0	490	480*	0	790†	100*	0
VI	FP	360	0	420	0	0	0	930	670	0	40	0
	NFP	3,980	0	9,200*	480*	112	1,650*	1,660*	160*	0	90	0
VII/VIII	FP	290	160*	280*	0	190	0	1,000	1,340*	0	30*	0
	NFP	4,850*	0	2,530	0	0	1,300*	410	1,210*	0	0	0

GER = gerenuk; WAT = waterbuck; KUD = lesser kudu; ORX = oryx; OST = ostrich; GIR = giraffe; WART = warthog; PIG = bushpig; ELE = elephant; BAB = troop of baboons; VERV = troop of vervet monkeys.

Note: Neither columns nor rows can be added for total estimate since data are composite of two censuses.
† elephant estimates result from a single sighting in one stratum.

was subsequently shot. As recently as the early 1980s, a herd of 250 destroyed 100 ha of cane at Jubba Sugar. However, most informants have seen no elephants for several years.

Table 26 lists larger mammals not encountered during aerial census, but seen by JESS field teams and by the Somalia Research Project (SRP). No quantitative statements can be made beyond the observation that dikdik are very common. From the conservation perspective, six of these species are rare in Somalia and dibatag is endemic to the Horn of Africa. Most of these sightings were in, or close to, the floodplain. Species which have been recorded in the past (Whittaker *et al.* 1985), but were not seen during JESS, include black rhinoceros, plains and Grevy's zebra, and Grant's and Soemmering's gazelles. Presumably these species are now very rare or absent from TEBS study area.

Somalia has 12 endemic species of larger mammals (Whittaker *et al.* 1985). Of these, only Hunter's hartebeest has its center of distribution in the study area (Clauser *et al.* 1969). As noted above, Soemmering's gazelle was previously reported in the study area and dibatag were occasionally reported during JESS surveys.

Construction of Baardheere Dam will have little effect on larger wildlife. Populations in the inundation area are negligible except for the ubiquitous warthogs and baboons (Table 25; FP River Section II). Depending on development of vegetation around the reservoir perimeter, wildlife habitat may

Table 26. Larger mammals seen during ground visits to the Jubba Valley by JESS and by Somalia Research Project (Varty 1988a).

COMMON NAME	SCIENTIFIC NAME
greater bushbaby	*Galago crassicaudatus*[1]
lesser bushbaby	*G. senegalensis*
blue monkey	*Cercopithecus mitis*[1]
Kirk's dikdik	*Madoqua kirki*
Guenther's dikdik	*M. guentheri*
Salt's dikdik	*M. saltiana*
Red forest duiker	*Cephalophus natalensis*[1]
dibatag	*Ammodorcus clarkei*[2]
Cape buffalo	*Syncerus caffer*[1]
lion	*Panthera leo*
leopard	*P. pardus*[1]
caracal	*Felis caracal*
African wild cat	*F. sylvestris*
large-spotted genet	*Genetta tigrina*[1]
common genet	*G. genetta*
African civet	*Viverra civetta*[1]
spotted hyaena	*Crocuta crocuta*
striped hyaena	*Hyaena hyaena*
bat-eared fox	*Otocyon megalotis*
black-backed jackal	*Canis mesomelas*
aardvaark	*Orycteropus afer*
porcupine	*Hystrix cristata*

[1] Of limited distribution and probably rare within Somalia;
[2] Endemic to Horn of Africa (Whittaker et al. 1985).

increase, particularly if human population is reduced by resettlement. Downstream of the dam wildlife habitat will decrease, but as detailed above, the floodplain is no longer an important dry season refuge.

2. Large Aquatic Animals

Crocodile and hippopotamus are abundant in the river and some dhesheegs and swamps. Despite being confined to the vicinity of the river, their combined biomass exceeds threefold that of all other larger wildlife throughout the TEBS area. Population size and density were estimated in the sample aerial censuses and during total aerial surveys of the river (Watson and Nimmo 1988). Five-hundred and eighty-seven hippopotamuses and 1,537 crocodiles were seen during a total count in jiilaal 1987. Hippopotamus were evident in all river sections from III south, but reached highest density in Section V. Crocodiles were seen in all sections with most in Sections IV, V, and VI. Allowing for sampling procedures in the various surveys, the Jubba is probably home to 3,000 to 6,000 hippopotamuses and 40,000 to 150,000 crocodiles (Watson and Nimmo 1988). Crocodile density is exceptionally high.

After filling of the reservoir behind Baardheere Dam, a large new water body will lead to an increase in populations of crocodile and hippopotamus. Fish populations undergo a rapid increase behind new dams, creating a large food supply for crocodiles. Although some currently favored basking and nesting sites on sand banks will disappear, the large lake perimeter will provide many new ones. The extent of increase in hippopotamus populations is more difficult to predict. Suitable herbaceous forage may be relatively scarce around the reservoir in the early years (see Section VII.E)

Freshwater turtles and their nests were also seen during aerial surveys and fisheries studies. They remain unidentified.

3. Smaller Wildlife

Birds in Middle and Lower Jubba were assessed by JESS and, in forests between Bu'aale and Fanoole Barrage, by Somali Research Project. Smaller mammals of the Jubba forests were also studied by SRP.

JESS studies concentrated on birds which breed in Europe and Asia, but spend the northern winter in Africa (palearctic migrants). Distribution of these

Crocodiles are significant predators of people and livestock.

birds is well-known in breeding grounds and wintering grounds in Kenya and to the south. However, migration routes and possible wintering grounds in the Horn of Africa are poorly known. JESS ornithologist David Pearson conducted surveys in March and November 1987. His main objective was to discover whether the Jubba Valley is a significant wintering ground and whether large numbers of migrants use the valley as a route to wintering grounds further south. In addition, likely impacts of developments linked with Baardheere Dam were assessed.

Pearson's reports (1987a; 1987b) should be consulted for details. Approximately 20,000 migrant wading birds were estimated to be in the valley south of Jilib in November, primarily around irrigated rice schemes. The most numerous species were wood sandpiper (*Tringa glareola*) and ruff (*Philomacus pugnax*). Little stint (*Calidris minuta*), together with wood sandpiper, were common in March, but further north in dhesheegs between Bu'aale and Fanoole Barrage. African waders were also well represented in both surveys. Although some wader habitat in dhesheegs may be lost after construction of Baardheere Dam, it is likely that new habitat far in excess of that lost will be created by the reservoir and new irrigation works.

Marine mud-flats in Kismaayo are feeding grounds for 4,000 additional waders. This area is an important feeding-ground in a regional context. Although not currently threatened, activities in Kismaayo should be monitored to ensure that these mud-flats remain intact.

Nineteen species of migrant land birds were recorded in both March and November, although species composition differed somewhat. It is unclear to what extent these birds are dependent on evergreen floodplain habitats. In March, when conditions were very dry, many were found in dry bushlands of the river-dependent zone. However, in November these birds were more concentrated in the evergreen vegetation.

Five new records of bird species for Somalia were recorded during these brief surveys indicating the paucity of previous studies. Overall, Pearson (1987a; 1987b) concluded that palearctic migratory birds were unlikely to be adversely affected by construction of Baardheere Dam.

Bird studies by SRP were concentrated in forest reserves at Shoonto and Barako Madow (Wood 1988). Thirty-eight species were caught in the forests and a further 72 species recorded in or adjacent to the reserves. Of the 38 species, Pearson (1987a) observed five in non-forest, but riverine habitats. Thirteen SRP species are considered rare, or very restricted in distribution within Somalia. Eleven species are regarded as likely to be lost to Somalia if the remaining riverine forest is lost (Table 27). A further 13 species are vulnerable (Wood 1988).

Table 27. Birds and mammals from Shoonto and Barako Madow forests that are rare, or of restricted distribution, in Somalia (Wood 1988; Varty 1988a). Mammal species are in addition to those in Table 26.

COMMON NAME	SCIENTIFIC NAME
BIRDS	
Pel's fishing owl	*Scotopelia peli*
Brown-hooded kingfisher	*Halcyon albiventris*
Eastern bearded scrub robin	*Cercotrichus quadrivirgata*
Red-capped robin chat	*Cossypha natalensis*
Black-headed apalis	*Apalis melanocephala*
Ashy flycatcher	*Muscicapa caerulescens*
Black-throated wattle-eye	*Platysteira peltata*
Little yellow flycatcher	*Erythrocercus holochlorus*
Crested flycatcher	*Trochocercus cyanomelas*
Olive sunbird	*Nectarinia olivacea*
Dark-backed weaver	*Ploceus bicolor*
BATS	
Parisi's slit-faced bat	*Nycteris parisii*[1]
Commerson's leaf-nosed bat	*Hipposideros commersoni*
Eisentraut's bat	*Pipistrellus eisentrauti*[1]
House bat	*Scotoecus albigula*

[1] *very rare internationally*

In addition to larger mammals listed in Tables 24 and 26, SRP recorded eight species of bats, two species of mongoose, and seven species of rodent in riverine forests at Shoonto and Barako Madow (Varty 1988a). Thirty-two mammal species were recorded from the forests and a further nine species from adjacent areas. Of these, and in addition to those listed in Table 26, four species can be regarded as being rare or of restricted distribution within Somalia (Varty 1988a). Two bat species are thought to be very rare internationally.

Sixteen species of rodents and two species of shrew are reported as possible endemics in Somalia or neighboring areas of Kenya (Whittaker *et al.* 1985). Of these, only the Somali shrew is reported from the Jubba and its status as an endemic is no longer viable

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following collection in Ethiopia, Sudan, and the Arabian peninsula (Varty 1988a).

Literature surveys show that 29 species of amphibians and 127 species of reptiles are recorded in southern Somalia (Whittaker *et al.* 1985). Of these, one amphibian and 29 of the reptiles are endemic to Somalia, but none restricted to the study area. Information on numbers and distribution is inadequate to assess the conservation status of these animals.

Little is known of terrestrial invertebrates in the study area. Nineteen species of butterflies were recorded by SRP, but no other specific studies are known. Riverine habitats of the Tana river in Kenya are particularly rich in arthropod species (Collins *et al.* 1986). Three-hundred and fourteen species of ground dwellers were found on river beaches and floodplain, 75 percent of which are absent from the adjacent non-floodplain dry bush in the dry season. Several species were new to science. Given its isolation from similar rivers, the Jubba is also likely to have endemic arthropods. Collins *et al.* (1986) consider that river regulation has adverse effects on some arthropods. Many of the 78 species restricted to open sand banks may not survive if these habitats become vegetated as a result of a more constant river level. Similar effects on the Jubba are likely after construction of Baardheere Dam when fluctuations in water level will be reduced.

4. Relationships Between Wildlife and Local People

Inhabitants of the study area interact with wildlife on a daily basis. Some interactions are beneficial to humans, such as consuming animals or their products. Others are detrimental. Many wild animals are pests to crops. Some are predators of people or their livestock. Many other species are encountered more or less frequently, but their relationship with people is neutral.

It is unlikely that rural subsistence farmers and pastoralists are directly responsible for the dramatic decline in some larger wildlife species. Most slaughter is the result of poaching, defined here as killing wild animals for non-subsistence trade in wildlife products. However, increased farming along the river has undoubtedly reduced habitat for some wildlife species. Opening up riverside lands also increases livestock occupancy, thereby increasing competition for forage. Reduction of large predators may be more linked to subsistence farmers, because less wildlife will force predators to switch to livestock, and farmers are more likely to eliminate these predators.

Hunting for food is widespread in the study area, but is a dominant means of subsistence for relatively few people. Non-hunters also benefit by the purchase of game meat. More than 80 percent of SEBS respondents claimed that they never eat game; only four to seven percent eat hunted meat often (daily/weekly). More than 15 percent of riverine farmers and nomads eat game occasionally, whereas urban consumption is negligible.

It is likely that hunting and consumption of game is underreported since hunting is technically illegal in most of the study area (see Map 2). Douthwaite (1985) found increasing reluctance to answer questions about hunting south of Saakow. In Dhoobley, near the dam site, half of the men questioned (10 respondents) had hunted in the previous week. For all respondents, game was the last meat eaten. Between Baardheere and Saakow almost 60 percent (37 questioned) ate game, but only one man admitted to hunting. For five, the last meat consumed was game. South of Saakow to Fanoole Barrage, all those questioned denied hunting or eating wild animals. However, other surveys indicate that hunting remains common in the southern districts. In Douthwaite's (1987) survey lesser kudu was the preferred prey (64 percent), followed by gerenuk and dibatag (each 11 percent), giraffe (7 percent), and bushbuck and waterbuck (4 percent).

SRP administered a questionnaire to hunters in five villages in Bu'aale District (Varty 1988a). Both riverine forest and dry bush species are taken with emphasis on riverine habitats during dry seasons. Lesser kudu, dikdik, and gerenuk are most common prey in the bush and red forest duiker, bushbuck, and waterbuck in riverine areas. Most villagers use traps or bow and arrow. They also buy game meat from "shifta" (non-locals with firearms), who are also said to be responsible for most poaching in the area.

Although reliable quantitative data are lacking, it is probable that hunted meat is an important dietary supplement for Jubba residents. Low protein consumption by farmers and dry-season shortages of grain in some years accentuate the significance of wildlife as a food source.

Wildlife as a nuisance to most rural people is perhaps a more common experience than as food. Crocodiles are important predators of people and livestock throughout the area. Quantitative data are not available, but people in most villages speak of recent crocodile attacks. Given the extremely high crocodile population, such predation is to be expected. Although at low density, lion and spotted hyena are also cited as attackers of livestock.

The most common terrestrial large mammal species habitually found in the floodplain—warthogs and baboons—together with amphibious hippopotamuses, are important crop pests. These species are always cited when farmers are questioned. Other recognized pests are porcupine, bushpigs, waterbuck, bushbuck, vervet monkeys, and various rodents. *Quelea* birds are serious pests of rice and sorghum, but do not attack maize, the main subsistence crop in the riverine area. Other birds are not generally regarded as pests, although sacred ibis (*Threskiornis aethiopica*) occasionally attack sesame.

At present, activities of the Wildlife Department are largely directed at protecting wildlife from poaching and hunting. Such a role induces conflict rather than cooperation with rural people. Control of wildlife that is a genuine threat to people or their economic activities is a necessary activity of any wildlife department. A more forceful wildlife control policy should be adopted, directed particularly at ubiquitous pest species such as hippopotamus and warthog. Even more urgent is a crocodile control program to reduce human predation. Crocodile skins have a high monetary value. Provision of controlled concessions to harvest crocodiles could provide the Wildlife Department with a substantial income. Since crocodile and hippopotamus populations will increase in the reservoir behind Baardheere Dam, properly managed cropping will not seriously endanger the populations. To enable legal international trade in the skins, IUCN clearance is required since Nile crocodile are included in the Convention on International Trade in Endangered Species (CITES). Such a program would need good regulatory and management skills. It may be preferable to offer a concession to a reputable wildlife management company since local expertise in wildlife biology and skin preparation is lacking. Research into breeding biology of crocodiles on the Jubba is an essential prerequisite to a cropping program.

Recommendation: *A crocodile cropping program should be introduced and methods of preparation and marketing of skins be investigated.*

Recommendation: *The Wildlife Department should more effectively control crop pests, concentrating on those species with large populations.*

Honey production is a significant economic activity involving wild animals. Traditional beekeeping is widespread in the Jubba and Shabeelle floodplains (Douthwaite 1985). Honey-hunting is also carried out, but to a lesser extent. Beekeeping is only practiced by sedentary farmers, but nomads also hunt "wild" honey. In 1983 more than 35,000 hives were thought to be in use along the Jubba. Income from sale of honey ranged between 330 and 10,000 SSh per year per beekeeper An estimated 150,000 l of honey was produced, with a total value of 7 million SSh (Douthwaite 1985). The price of honey has risen from 50 SSh in 1983 to 200 SSh in 1986 (Varty 1988b). Beekeeping is a secondary activity of farmers. As such, it provides a substantial source of income for many individuals.

Most hives are placed in large forest trees close to villages, but occasionally hives may be as much as a six-hour walk from home. Beekeepers may own as many as 100 hives, the median number being 30. Hollowed logs are used as hives. Colonization rates by bees range from 50 to 100 percent and each produces approximately 5 to 10 l per year (Douthwaite 1985). In 1983 beekeeping was increasing markedly, particularly in forest areas. Agricultural areas are less favorable due to a shortage of suitable trees and theft. However, honey production is said to have declined in several villages recently, apparently as a result of poor flowering of important pollen species (SEBS field notes). This change may reflect natural flowering patterns which respond to floods and droughts, but it could be a trend caused by agricultural expansion in the floodplain and loss of wild plants.

Beekeeping should be encouraged in the study area, perhaps with external assistance. Patterson (undated), prepared a project proposal which could be implemented in the Jubba Valley. He suggests investigation of hive types under Somali conditions to determine the most appropriate that can be constructed with local materials. The project would emphasize demonstration of improved beekeeping techniques and equipment.

A possible threat to honey production is a plan to eradicate tsetse fly in the Jubba using insecticide spraying (see also Section VIII.D). Experiments and surveys of effects of spraying on bees in the

Shabeelle were conducted in 1983 and 1984 (Douthwaite 1985). In 1983, bee mortality, hive desertion, and consequent economic loss were substantial. In 1984, losses were reduced because of the season and time of day that spraying was executed. Future spraying should be programmed to minimize bee losses and compensation should be paid for lost honey production. If necessary, re-introduction of bees to sprayed areas should be carried out.

Recommendation: *Honey production should be encouraged and further developed. Steps should be taken to minimize the effects of tsetse eradication on bee populations.*

C. Vegetation Resources and Conservation

Most of the study area is vegetated by dry bush rangelands. These areas have been livestock grazing and browsing areas for centuries. Vegetation is not seriously degraded over most of this area, although gradually increasing livestock and human populations may lead to problems in the future. No special conservation measures are proposed beyond those relating to forestry and range management.

Of more concern is the Jubba floodplain. Although most of the forest has gone, vegetation communities remain significantly different in species composition from non-floodplain lands (Section VI; Appendix D). Of 313 plant species recorded in JESS surveys, 131 were restricted to the floodplain. Many of these 131 species are known to occur in habitats away from TEBS study area, but their distribution in Somalia and East Africa can only be ascertained by a study of herbarium records. Such a study was not possible during JESS because identifications were not complete until the end of the project. JESS plant collections were primarily monitoring site-based and do not claim to be comprehensive. Even so, many new records for Somalia were found (see Table 16).

Further research to determine the wider distribution of Jubba floodplain plants is worthwhile. J. Gillett (personal communication) suggests that three species (*Cola* sp. nov., *Pavetta tranjubensis*, *Acacia maculusoi*) may be confined entirely to the Jubba; two species (*Camptolepis ramiflora*, *Adenopodium rotundifolium*) are very rare elsewhere; and a further six species (*Rinorea elliptica*, *Harrisonia abyssinica*, *Lepisanthes senegalensis*, *Polysphaeria mutliflora*, *Spirostachys venenifera*, *Drypetes natalensis*) may be restricted within Somalia to the Jubba. Gillett emphasizes that herbarium records need checking to verify this list. An appropriate research project would be to check herbarium records at the East African Herbarium (Kenya National Museums), the Royal Botanic Gardens (Kew, U.K.), and the herbarium in Florence, Italy. Additional fieldwork may then be desirable to assess the distribution of species which appear to be of restricted to the Jubba floodplain. International conservation bodies such as IUCN or World Wide Fund for Nature (WWF) are appropriate bodies for financial support.

Recommendation: *External funds should be sought to support a research project into the distribution of Jubba floodplain plant species.*

Species diversity at the level of study plots is generally lower in the floodplain than in nearby dry bushlands (Section VI). However, this fact does not reduce conservation value of riverine habitats because they greatly increase the diversity of the study area as a whole. Many floodplain species are rare or of restricted distribution in Somalia, thereby increasing their conservation status.

Terrestrial vegetation in the floodplain between Baardheere Dam site and Luuq town will be lost entirely. Most of the inundation area surveyed by JESS comprises secondary woodlands, bushlands, and grasslands interspersed with croplands. One species of sedge (*Cyperus* sp. nov; JESS collection number 279), apparently new to science, was collected on the eastern floodplain south of Luuq adjacent to TEBS ground monitoring site 64. The species may occur in other areas, since the Jubba floodplain remains poorly collected. It is possible that this plant will find new habitats around the edge of the reservoir. Although the species is unlikely to have any special economic value or aesthetic appeal, it could easily be salvaged and propagated elsewhere as its precise location is known. A project to conserve this sedge could be combined with other proposals concerning vegetation conservation. Distribution could be clarified if field work is required by the floodplain species distribution project recommended above. If salvage proves desirable, the sedge could be transplanted to Shoonto forest reserve. This reserve has relatively diverse floodplain physiography and a suitable habitat could probably be found. Costs involved in this salvage operation are very low.

Recommendation: *Action should be taken, in conjunction with other proposals concerning vegetation conservation, to protect the new sedge species found in JESS surveys.*

Downstream of the dam, floodplain vegetation is expected to undergo gradual impoverishment due to changes in hydrology and land use described in previous sections. Land-use changes are already rapid and measures are urgently needed to conserve the remaining forest patches in particular.

Conservation of Riverine Forests

Riverine forest along the Jubba declined from 9,350 ha in 1960 to 900 ha early in 1987. New forest clearance has occurred since then leaving a few small remnants (Appendix J). Even less forest remains on the Shabeelle, where the last few hectares are conserved in Balcad Nature Reserve. Jubba forests are of great conservation value as they contain many plant species previously unrecorded in Somalia (Table 16). Biogeographically, they represent the northernmost sections of East African lowland and coastal forests. The nearest comparable riverine forests are on the Tana river 400 km southwest, in Kenya. These lowland forests are threatened by loss or degradation throughout the East African region, thereby accentuating the international case for conserving forest on the Jubba (Douthwaite 1987; Madgwick 1988). Woody vegetation of seasonal rivers in Bushbush is probably different in structure and species composition to Jubba forests (Madgwick 1988; Kuchar and Mwendwa 1982). The Bushbush vegetation is equally worthy of conservation as discussed in Section VIII.D. The so-called Boni forest, straddling the southern Somali-Kenyan border, seems to be a mixture of woodlands, bushlands, and thickets (Kuchar and Mwendwa 1982; Abel 1976).

Madgwick (1988) compares species composition in Barako Madow and Shoonto forests (Map 2; Figure 17) with those of Tana forests. She concludes that Tana forests are more diverse because of a more dynamic river system. However, JESS collections from different forest patches significantly increase the number of common larger woody plants in the Jubba forests. Of the additional JESS species in Table 16, only six of the 18 are recorded by Hughes (1985) for the Tana forests. (The six species are *Flueggea virosa, Drypetes natalensis, Spirostachys venenifera, Acacia elatior, Lepisanthes senegalensis,* and *Polysphaeria multiflora.*)

Until recently, it was thought that Jubba forests contained several species of endemic trees (see discussion in Kuchar 1988). However, taxonomic revisions indicate that most of these plants belong to well-known and widespread species. One of these species, *Camptolepis ramiflora* (absent from Tana forests) remains of interest since it is previously known as a rare plant of the Tanzanian coast. JESS has collected what appears to be a new species of *Cola* (site 8; JESS collection number 242), thus reopening the possibility of Jubba endemics.

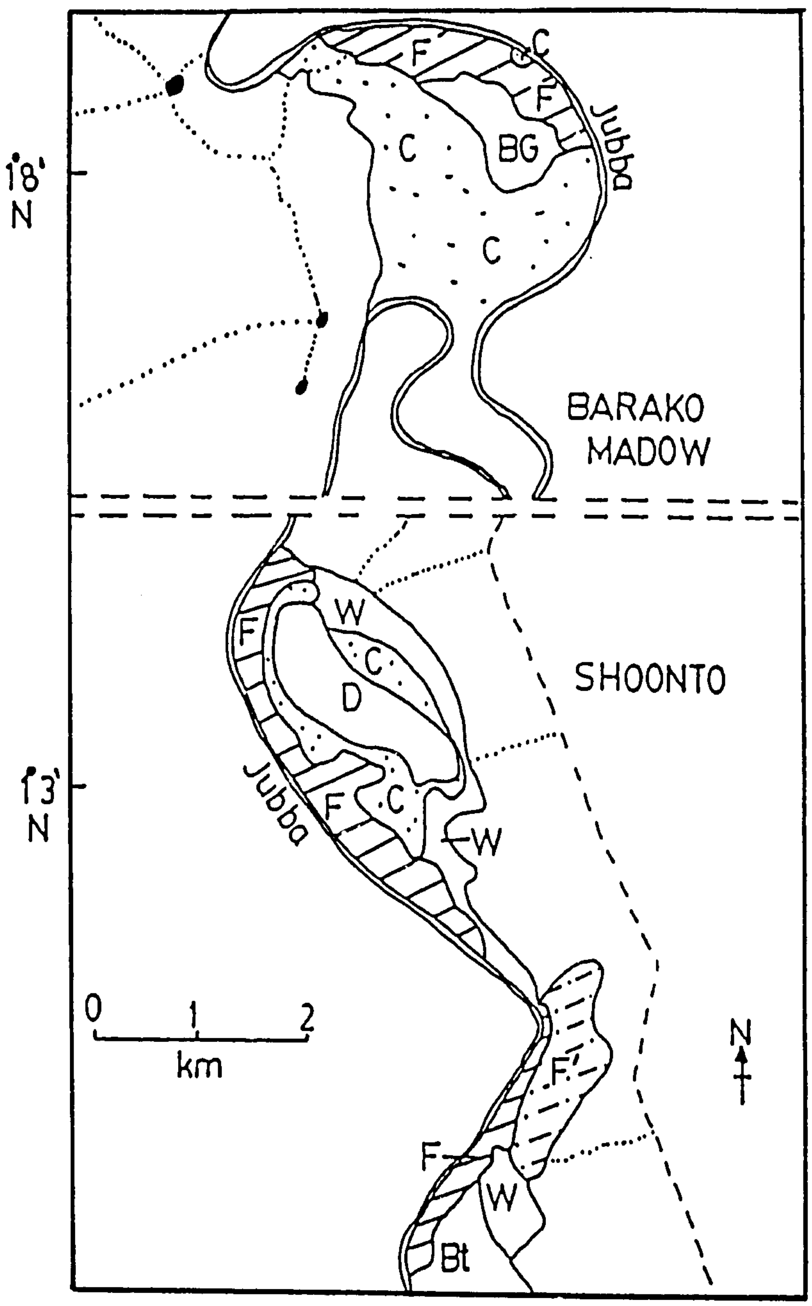
Effects of Baardhhere Dam on these forests are discussed at length by Deshmukh (Appendix J), Synnott (1988), and Madgwick (1988). Although they disagree over details, these authors agree that survival prospects for the forests are good, if they are properly protected.

The two largest remaining blocks of forest are already designated as forest reserves (see Map 2; Figure 17). Some effort has been made at demarcation and various management proposals have been put forward by SRP (Madgwick and Wood 1988) and the Somali Ecological Society (unpublished document). These proposals call for external funding. Such funding may soon be recommended by the World Bank as part of its proposed system of loans to the Baardheere Dam Project.

These forest reserves should be the focus of riverine forest conservation on the Jubba. The following measures should be undertaken as soon as possible:

- checking of boundary markers;
- prevention of any agricultural land registration in the reserves; and
- hiring of extra guards from neighboring villages to prevent cutting of trees and hunting.

Other conservation measures, variously proposed by Deshmukh (Appendix J), Madgwick and Wood (1988), and the Somali Ecological Society could then be assessed when external funding is available. Vegetation alone dictates that these reserves are worthy of protection. However, they also contain many animal species which will benefit from conservation activities. Long-term survival of larger rare animal species is questionable in such small protected areas, but this is no argument against making the attempt, since the vegetation at least will remain long beyond any normal planning horizon.



KEY
F = floodplain
F'= forest above floodplain
W = woodland
BG = bushed grassland
Bt = thicket bushland
C = crops
D = open water in dhesheeg

Figure 17. Vegetation and land use in and around Barako Madow and Shoonto forest (Deshmukh 1987)

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Future actions to be considered should include the following:

- The reserves should be zoned so that the best forest areas are completely protected, while some minor extractive use is permitted in less pristine areas.
- Trees should be planted from other Jubba forests in degraded areas of the reserves to increase survival prospects of plants native to the area, but not presently in the reserves. In particular, propagation of the new *Cola* species should be attempted, followed by other species from the "JESS additional list" of Table 16.
- River profiles should be assessed to determine whether Shoonto dhesheeg will flood from the river when Baardheere Dam is completed. If not, a channel or pumping system should be used to flood the dhesheeg as it is an important site for wading birds. Addition of water to the dhesheeg may alleviate the expected impoverishing effects on vegetation of altered hydrology after the dam is built.
- The periodic flood recession cultivators using Shoonto dhesheeg should be compensated for their loss of occasional farmland.

Administration of these reserves should be incorporated into the activities of the new FAO-executed forestry project in the NRA which will be active in the area (see Section VII.A.4). The Somali Ecological Society is also interested in playing a role in Jubba forest conservation and has experience at managing a nature reserve on the Shabeelle. The society can provide voluntary expertise and labor and help to publicize the reserves. Legal recognition is currently being sought which would enable the society to obtain and manage funds from external donors. If sufficient funds are available, the Somali government should consider turning these forest reserves into a "demonstration project" in conservation management with assistance from the Somali Ecological Society and the FAO project. The reserves will be accessible to visitors when the proposed all-weather road from Jilib is complete. Management techniques for protection and restoration of ecosystems, integration of conservation into rural development, research, and education could all be incorporated into plans for the reserves.

An additional nature reserve should be designated, at least temporarily, encompassing JESS ground monitoring site number 8 (Map 2). This small area (10 to 20 ha) of forest is completely undisturbed, despite being within walking distance of Bu'aale town. The area is probably too small for permanent protection, but it contains six species on the JESS list of Table 16, including the new *Cola* sp. and three other new Somali records. Local informants indicate that the area may already be an informal reserve, since it is favored as a meeting place for important events. This reserve would serve as a source of seed for attempted propagation of species absent in Shoonto and Barako Madow forests. Other species on the list should be sought from forest remnants around Kaytooy.

Recommendation: *Shoonto and Barako Madow forest reserves should be given increased protection immediately. Future management options depend on external funding, but should take account of the proposed SRP management plan and the additional measures suggested in this report.*

D. Conservation Proposals for JESS Study Area

Numerous recent missions from World Bank, WWF, and IUCN have excited interest in biological conservation in Somalia. In July 1988, a World Bank consultant specifically looked at wildlife conservation measures that might be appropriate in relation to construction of Baardheere Dam. One possibly relevant World Bank policy is that of "compensatory wildlands." Where World Bank projects take over "wildlands," a suitable and similar area, at least equal in size, is to be set aside for conservation. Unfortunately, the definition of wildlands ("natural land and water areas in a state virtually unmodified by human activity"; Goodland 1988) excludes most of Africa outside parts of the rainforest and montane zones. The Jubba reservoir area is substantially modified both in the floodplain and surrounding bushlands by agricultural and pastoral activities. Indeed, virtually all savanna conservation areas throughout Africa are excluded by the World Bank definition of wildlands. Thus the policy is not strictly applicable to the Baardheere Dam Project. However, the principle, of relating conservation activities to development projects is a good one. For example, World Bank interest in conserving Shoonto and Barako Madow forests is an appropriate response to Baardheere Dam construction.

Various conservation areas have been declared or proposed in Gedo, Middle Jubba, and Lower Jubba (Map 2). These are already in existence (although the exact legal status is unclear in most cases), but are barely recognized on the ground.

1. Bushbush Controlled Area and Jubba Left Controlled Area.

These vast areas cover most of Middle and Lower Jubba Regions. Regulations covering "Controlled Areas" (Article 9; chapter 1: Book 1. Fauna [Hunting] Conservation) include:

> . . . no person shall . . . hunt any game animal without a Game Licence for such animal ...obtained from the Minister . . .

At present no licenses are being issued as a result of a hunting ban, although occasionally hunting by foreign dignitaries is permitted.

Such regulations are unenforceable in practice over such large areas with low density of animals. Unenforceable regulations bring the law into disrepute. Periodic campaigns against poachers may be worthwhile, but measures against subsistence hunters are not. Since poaching is illegal in all areas, these "Controlled Areas" should be abandoned. The concept of smaller controlled areas may be useful when and if a national conservation strategy is enacted. JESS and related studies indicate that the only Somali-endemic large mammal inhabiting these areas is the dibatag. Previous surveys indicate that a few Soemmering's gazelle may remain. However, the distributional center of these animals where any conservation effort should be directed, is northwest of the Shabeelle.

Recommendation: *Bushbush and Jubba Left Controlled Areas should be abandoned.*

2. Bushbush National Park/Game Reserve

Although reportedly now designated as a national park, Bushbush (Map 2) does not meet international requirements for such designation since it contains people; nor are funds currently available to manage the area as a national park. Conservation funds currently being sought by the Wildlife Department to protect this area should take the following remarks into account. Proposals to formalize national park status are ill-advised.

Bushbush has long been recognized as a prime candidate for conservation in southern Somalia. The area is diverse in landscape, vegetation, and fauna. Watson and Nimmo (1985) show a fine-grained pattern of more than 10 different land systems. Vegetation is varied including wooded thickets, strips of riverine forest, marshlands, and grasslands (LRDC 1985). In 1984-1985 biomass of larger terrestrial wildlife was high, with much of the area supporting more than 1,000 kg km^{-2} and local concentrations exceeding 5,000 kg km^{-2} (Watson and Nimmo 1985). Species included gerenuk, duiker, Hunter's antelope, lesser kudu, giraffe, and elephant. In 1975 topi, bushbuck, buffalo, and rhinoceros were also seen (Abel and Kille 1976). Hunter's antelope is endemic to the Somali/Kenyan border.

Incursions by livestock are limited by tsetse infestation. Across the Kenya border is the Boni National Reserve enhancing the conservation potential of Bushbush. Abel (1976) proposed a management plan for the area as a national park. Permanent residents include coastal people involved in fishing, trade and farming, inland cultivators, and subsistence hunters. Abel (1976) considered that the hunters " . . . (are) not at all harmful . . . " and illustrated their conservation ethic by adding " . . . they have allowed the rhinoceros population to remain at quite high densities." (Since 1976, rhinoceros numbers have declined sharply primarily as a result of poaching, not subsistence hunting.) He then states that "the park will mean the end of this culture" and "Other areas where they can continue their traditional way of life do not exist."

Combining these statements makes it illogical to suggest moving these subsistence hunters. Their activities are compatible with conservation. However, protective measures should be enhanced by preventing land registration for cultivation, reinforcing anti-poaching activities, and preventing attempts at tsetse eradication in a suitably defined conservation area. These management activities should be carried out by local people with some external monitoring to ensure that mutually agreed objectives are pursued. Such proposals require a minimum of funding which should be sought from external sources.

Recommendation: *Efforts should be made to protect the Bushbush area intact with local populations integrated into management proposals.*

3. Barako Madow and Shoonto Forest Reserves

These two reserves, including recommendations for conservation, are dealt with in Section VIII.C. Two other forest reserves in Middle Jubba reportedly in existence are Nus Duuniya and Kaytooy. Unfortunately, forest in these areas is practically gone. Had effective measures been taken sooner, Kaytooy would have been especially worthy of protection.

4. Other Proposed Conservation Areas.
Abel and Kille (1976) outlined several areas of conservation potential as forest or wildlife reserves (Map 2). Of these, Wildlife 1 and 2 have little to offer from the biodiversity standpoint. Wildlife 3, Dhesheeg Waamo, while an important perennial to semi-perennial wetland, is heavily used by pastoralists and those practicing flood-recession agriculture. For these reasons and those discussed in Section VIII.B.1, additional wildlife areas should not be designated, with the exception of the Shabeelle Swamps (Wildlife Area 4; exact position to be determined). Conservation of these swamps is desirable as much for their wetland/vegetation status as their wildlife. In addition, these swamps are an important natural flood protection device. They absorb Shabeelle flood peaks and reduce flooding downstream. Suitable area should be selected bearing these criteria in mind. Hydrological considerations will need to be taken into account when planning conservations measures. Watson (personal communication) points out that the swamps are slowly drying and that wildlife is much reduced and human use intensifying. A dam on the Shabeelle has recently been completed in Ethiopia. Since flood peaks in Somalia will probably be reduced, the future hydrological status of these swamps is unclear. Monitoring of river releases from Ethiopia may be required to assess the future of the swamps.

According to LRDC (1985), extensive swamps exist southwest of Guudo Ferry at Madax Maroodi, Baar Madax, and Balli Weyne. These areas appear to have good wildlife populations (Watson and Nimmo 1985; Parker 1987). Human population density is thought to be low, although the northern edge is important for livestock in dry seasons. To the south, pastoral use is restricted by dense woody vegetation (LRDC 1985). A conservation project is already planned and about to be funded for swamps higher on the Shabeelle northwest of Haaway (Wildlife Department 1988). However, this project is poorly conceived and should not be used as a model for other areas in Somalia. Complex zonation of permitted land use and related proposals make this project unworkable with foreseeable management and extension services. A recent World Bank consultant (Blower, personal communication) proposes that areas in the lower Shabeelle Swamps be conserved to compensate for land lost behind Baardheere Dam. He emphasizes the need for competent assessment of boundaries and management proposals. Since such expertise and experience is not available locally, he proposes that WWF be contracted to carry out such work. These proposals are worthy of support.

Recommendation: *Appropriate areas in the lower Shabeelle Swamps should be conserved for their wildlife populations, for the scarcity of such wetlands in Somalia, and because of their importance in downstream flood control.*

Planned forest reserves are referred to by Abel and Kille (1976), but are not discussed. Area "Forest 1" (Map 2) appears unexceptional in vegetation according to recent maps (Watson and Nimmo 1985; LRDC 1985). A better prospect may be *Acacia tortilis* woodlands on the coastal dunes (Forest 2, Map 2). Protection of this area (currently commercially exploited for firewood), would help to prevent sand dune erosion, which is an increasing problem along the coast.

A recently proposed Jubba Valley Controlled Area (Map 2) is not worthy of consideration for reasons given above in discussion of the other Controlled Areas.

The new FAO project on forest and wildlife support in Lower and Middle Jubba (UNDP 1988) should be the best umbrella for conservation activities in the study area. Bushbush, Jubba forests, and other possible reserves would have a local institutional framework with multilateral donor support.

Recommendation: *Future conservation activities in the study area should be administered within the framework of the FAO/NRA Forestry Sector Support and Training Project.*

Tsetse Control and Conservation
National policy is to eradicate tsetse flies and, therefore, most trypanosomiases in Somalia. Distribution of flies is limited to the Jubba and Shabeelle riverine areas and a distinct population in the southwest corner of Somalia along the coast and Kenyan border (Map 2). Eradication of tsetse will increase livestock production in these areas, but have potentially detrimental effects on biological diversity. Specific problems relating to beekeeping have been mentioned (Section VIII.B.4).

Other wildlife may also be adversely affected. Insecticides used in spraying operations kill insects other than tsetse and may, therefore, affect insectivorous animals. Monitoring feeding behavior of insectivorous bats and a bird (little bee-eater; *Merops pusillus*) in the Shabeelle suggests that effects on their insect prey are not great (Douthwaite 1985). Fish mortality can also occur, but again adverse effects seem to be small or temporary in the Shabeelle (Douthwaite 1985). However, as Wood (1988) points out, to small and isolated populations of fish- and insect-eating birds, a temporary effect on food supply may lead to local extinction. Small conservation areas such as the Jubba forests are particularly vulnerable to such effects.

Since it is not certain whether tsetse eradication from the Somali riverine systems is feasible, conservation areas should be the last to be treated. Such treatment should then go ahead only if eradication is proving entirely successful. The least harmful techniques available should be used in eradicating tsetse from these areas. Such techniques will be apparent from experimental work being carried out by National Tsetse and Trypanosomiasis Control Project (NTTCP) and from Douthwaite (1986).

Bushbush as a conservation area presents a somewhat different situation with respect to tsetse. Jubba and Shabeelle fly populations are isolated from others in East Africa and benefits of eradication could be permanent (Map 2). The fly population of Bushbush is contiguous with coastal and Tana River tsetse in Kenya (LRDC 1985). Therefore, the southeast corner of Somalia will be continually re-infested from Kenya. Rather than treating this fact as a problem, it should be grasped as a conservation opportunity. Protection of wildlife and vegetation from encroachment by livestock in Bushbush will be more secure if tsetse remain in this restricted area. Tsetse control using the new and very effective pheromone traps could protect livestock in southeastern Somalia outside the Bushbush conservation area. These traps are currently being used successfully in a German Agency for Technical Cooperation (GTZ) supported project in southern Somalia.

Recommendation: *Tsetse fly eradication efforts should be restricted to the Jubba and Shabeelle systems and not be attempted in the Bushbush area adjacent to the Kenya border.*

E. Conclusions

Limited wildlife, financial, and human resources dictate that Somalia should adopt a restricted program of biological conservation. Most of southern Somalia will inevitably remain as rangeland with the higher potential areas increasingly devoted to agriculture. Nevertheless, a well-conceived and carefully executed conservation strategy would be beneficial.

Section VIII.A lists criteria that should be applied when selecting conservation areas. The proposals for the JESS study area listed in preceding sections were written with these criteria in mind.

Endemic species. The major center of Somali faunal endemism is well to the north and east of the study area. Of the larger mammals, only Hunter's antelope is relevant and could be suitably protected in the proposed Bushbush conservation area. Information on smaller animals is inadequate to recommend conservation measures. Reserves in Bushbush, Jubba forests, and Shabeelle Swamps will protect some of the species dependent on riverine and wetland habitats. Smaller species of dry bushlands are presumably not threatened unless these environments become seriously degraded by increases in livestock populations. The proposed reserves will help to protect the only known endemic riverine plants.

Rare species, internationally. The much-publicized campaigns to protect elephant and rhinoceros are of limited interest to Somalia. Rhinoceros is close to extinction in the country and only remnant elephant populations remain. Conservation efforts directed at these species will be far more effective in other countries. Two rare bat species (Table 27) will have at least part of their range protected in the Jubba forest reserves. Crocodiles are listed as "vulnerable" by the IUCN. However, Jubba populations are extremely high, and will increase after construction of Baardheere Dam. A controlled cropping program is recommended.

Rare species, or species of restricted distribution in Somalia. Several mammals, birds, and plants are restricted to riverine habitats on the Jubba. Some of these will probably be lost as a result of agricultural development. It is hoped that as the conservation areas recommended here are more effectively managed, they will become refuges for some of these species.

Diverse, unusual, and diminishing communities. Most of the study area is dry bushland supporting a high diversity of plant life. These areas are not presently threatened, except in small localized areas around settlements and watering points. Conservation areas proposed here will protect the last remnants of riverine communities. In addition, Bushbush contains dryland bushed and wooded thickets which are underrepresented in conservation areas in East Africa.

IX. FLOODPLAIN ENVIRONMENTS

Throughout preceding sections of this report the distinctive nature of the Jubba floodplain has been emphasized. This section brings together some of that information to suggest why floodplain ecology is different to surrounding areas and to suggest what changes may occur after closure of Baardheere Dam.

Several observations made earlier in the report show floodplain vegetation is different than that of the river-dependent zone. They include:

- the floodplain supports closed evergreen forest which would not normally occur unless rainfall was twice that of the Jubba Valley;
- floodplain grasslands are much more productive than is normal in the Jubba Valley rainfall regime;
- phenological activities of floodplain plants indicate a more prolonged growing season than outside the floodplain; and
- vegetation on old levees which are now far from the river and no longer flood are more like the river-dependent zone in biomass and phenology.

These features indicate that the floodplain is a more productive environment that the river-dependent zone. High production of floodplain vegetation is not an abstract ecological phenomenon since it results in greater wood and forage production for human use. This higher production could result from several factors:

- surface flooding enhances soil moisture;
- lateral infiltration of riverine water enhances soil moisture;
- sediments deposited from flood water increase soil nutrients; and/or
- flood water is rich in dissolved nutrients.

It is likely that these features combine to produce fertile floodplains. However, the relative contribution made by each factor is unknown. The role of surface flooding is obvious, but cannot account for enhanced production in non-flood years. For example, forage yield of monitoring site grasses in 1986, a non-flood year, was similar to that in 1987 when monitoring sites were flooded.

Lateral penetration of water from the river is more difficult to demonstrate, but is significant. Jubba farmers state that levee crops obtain water by infiltration from the river and subsequent capillary rise (Besteman and Roth 1988). Aerial observation of flooded dhesheegs in June 1987 showed that many contained rather clear water in contrast to the highly turbid water of the river and surface flooded areas (JESS field notes). It is likely that clear water entered dhesheegs by lateral infiltration from the river. Some clear water may have been from rainfall runoff, but rainfall in gu' 1987 was less than in 1986 when the same dhesheegs remained dry. Direct evidence of lateral infiltration is available for the Tana River in eastern Kenya. Hughes (1985) shows that the riverine water table penetrates laterally under levees and beyond for considerable distances even during low river flows. She estimates that three to seven percent of river volume is lost due to evapotranspiration and seepage to the floodplain.

JESS studies show that flood water is rich in plant nutrients. Jobin (1988) demonstrated high concentrations of important plant nutrients. Dissolved phosphorus and nitrogen were 4 mg l^{-1} and 5 mg l^{-1}, respectively, during the 1987 flood compared with less than 1 mg l^{-1} during other seasons. Suspended sediment during the flood contained almost 4 mg kg^{-1} of phosphorus and 1 mg kg^{-1} of nitrogen compared with negligible amounts at other times.

Crop production reflects the fact that herbaceous wild plants in the floodplain are more productive than would be the case in a purely rainfed area. It is for this reason that floodplain agriculture has been distinguished from rainfed areas in the river-dependent zone throughout this report. This approach contrasts with that of AHT (1988) and Watson and Nimmo (1988) who refer to all areas not irrigated or undergoing flood recession agriculture as being rainfed.

Implications Resulting from Baardheere Dam

Effects on floodplains will differ in stretches upstream and downstream of the dam site. While some immediate results are obvious, such as inundation of reservoir area floodplains and reduced downstream flooding, others are difficult to predict.

Baardheere Dam will prevent devastating floods,
but will also eliminate current floodplain grazing from the reservoir area.

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Downstream of the dam it appears that occasional flooding of limited extent will continue (AHT 1988). Much of this flooding will be in Lower Jubba, but the highest frequency of flood-recession agriculture, particularly in dhesheegs, is in Middle Jubba (Section V). In other words, the projected flood regime remains damaging to areas where floods are economically most severe, but eliminates floods where the water is used mostly for farming. It is not known if any of these Middle Jubba dhesheegs will fill with floodwater from the river in post-dam floods if the dam is operated to maximize electricity generation. Soil nutrient enhancement from floodwater will also be reduced. Sediment will be deposited in the upper reservoir and dissolved nutrients will be diluted by mixing with reservoir water. Some dhesheegs may fill partially with rain water, but this water has fewer nutrients.

Lateral infiltration of river water will also be reduced. Projections for the Tana River suggest a deepening of the river channel and a lower floodplain water table which spreads less far from the river (Hughes 1985). Erosion of river channels results from clear water released from a dam picking up new sediments from the riverbed. The likely extent of this downcutting in the Jubba is unknown. Opinions of hydrologists vary from negligible effects (Alford 1987) to noticeable, but unquantified effects (AHT personal communication). If the Jubba behaves similarly to Tana projections, several consequences are likely:

- distinctive floodplain vegetation will narrow in extent to more closely follow the river channel;
- deeper rooting trees close to the river may continue to tap seepage of river water; and
- shallow rooting species such as wild grasses and field crops will probably decline in extent and productivity.

Reduced floodplain crop production downstream of dams is documented from other African river systems. Scudder (1988) quotes a 60-percent reduction in yam production within a few years of closure of Kainji Dam on the Niger River. This period coincided with a drought which must account for part of the reduced production. Also in Nigeria, Bakolori Dam caused reduced flooding leading to an approximate one-third reduction of area under dry season vegetable crops (Adams and Hughes 1986). These reductions in crop production are of a similar magnitude to the likely reduction in forage yield of wild grasses that can be inferred from Figure 14 when the "floodplain" and "prediction" lines are compared.

One of the aims of Baardheere Dam is to provide reliable irrigation to replace the unpredictable supplies of rain and often damaging flood water. However, the switch to controlled irrigation will not take place immediately or spontaneously when the dam is closed. Many floodplain farmers will suffer reduced crop production unless mitigatory measures are implemented.

One possibility is provided by the AHT (1986) dhesheeg-conversion project proposal. In this project, selected dhesheegs will be connected to the river by a canal with appropriate headworks to regulate flow to the dhesheeg, thereby allowing flood recession agriculture to continue. An alternative is to pump water from the river to dhesheegs. Another suggestion advocated by Scudder (1980; 1988) is to release a controlled flood from the dam. Such a flood would be of an appropriate magnitude to partially flood dhesheegs. Controlled releases also enable a predictable exposure and potential use of the drawdown zone around the reservoir (Scudder 1980). Both the dhesheeg conversion and controlled flood schemes would enhance floodplain agriculture to the extent of allowing predictable flooding of floodplain areas. However, soil nutrient inputs would still be lower than in the pre-dam situation, and addition of fertilizers or appropriate crop rotations may need to be employed.

Controlled floods reduce the amount of electricity that Baardheere Dam can produce. However, optimal power generation will supply more electricity initially than can be used in Somalia. Therefore, the possibility of controlled floods should be considered by MNPJVD. It will be necessary to determine riverbed and floodplain morphology in order to model the extent of flooding related to volume of water released from the dam. Such studies need not delay dam construction since several years remain before dam closure. Controlled flooding may be a temporary expedient to allow conversion from current floodplain agriculture to pumped irrigation. As this conversion is completed and demand for electricity increases, it may be desirable to phase out controlled floods.

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Recommendation: *The feasibility of controlled floods to maintain floodplain production systems should be assessed.*

Upstream of the dam, new "floodplains" will be created in the drawdown zone of the reservoir. Suggestions about the potential of this zone for agricultural or range production indicate that it should be included in planning of Jubba Valley development (see Sections V to VII). Scudder (1988) cites tens of thousands of cattle using the Kafue flats in the Zambian drawdown behind Kariba Dam and drawdown agriculture being practiced around Lakes Kariba, Volta, Aswan, and Kainji. However, such potential is not always realized. For example, Roggeri (1985) points to crop failures around Masinga reservoir on the Tana River.

The situation around Baardheere reservoir needs further study. Much of the drawdown zone is stony or rocky and will only be productive of wild grasses or crops if finer sediments are deposited in this zone. Some TEBS monitoring sites in the drawdown zone have gypseous soils and would not be suitable for agriculture (Appendix I). The current floodplain of the reservoir stretch immediately south of Luuq town will be the first area to be exposed by reservoir drawdown and is the most likely area to have deposition of new sediments. This narrow reservoir section will surely have potential for drawdown agriculture, or development of grasslands for livestock. Since drawdown will occur during dry seasons, the potential for increasing livestock and crop production should be significant. Seasonal grass production in floodplains in this area exceeds 1 t ha^{-1}. Exposure of 2,000 to 3,000 ha of riverine sediment south of Luuq could produce enough forage to feed more than 10,000 cattle for six weeks each drawdown season. This potential compares with the estimated loss of forage of more than 20 million kilograms as a result of inundation, assuming no drawdown forage (Section VII.E). Reservoir area livestock populations currently have a forage demand equivalent to more than 40,000 cattle. Such drawdown zone forage production should not be assumed, but the development of drawdown zone vegetation and its use should be monitored (Section X).

The largest drawdown area will be in the wide part of the reservoir in the vicinity of Buurdhuubo. This area should be delineated on the ground and surveyed so that its potential for agriculture or livestock forage production can be assessed. If potential exists, water releases from the dam should be programmed to optimize drawdown production at the lowest cost in lost power generation and downstream irrigation. Initially, drawdown of the reservoir could be coordinated with controlled floods to maintain floodplain agriculture during its transition to pumped irrigation (see above).

Recommendation: *Potential of the reservoir drawdown zone as a productive resource should be assessed and incorporated into land-use planning and dam operating schedules.*

X. MONITORING OF TERRESTRIAL ECOLOGY

An objective of JESS is to propose monitoring schemes to track important changes during development of the Jubba Valley. TEBS proposals for monitoring should be read in conjunction with those developed by SEBS (Craven, Merryman, and Merryman 1989) and Tillman (1989). Important considerations include building on TEBS baseline data; emphasizing important indicators of change; and determining monitoring frequency, methods to be utilized, and appropriate implementing agencies. Some TEBS monitoring proposals do not involve MNPJVD in data collection or analysis, but the Ministry (or an eventual "Jubba River Authority" is envisaged as the central authority involved in assessing changes and coordinating appropriate responses to adverse developments. It should be noted that monitoring is also useful in demonstrating successful planning and projects.

Effective use of TEBS monitoring data by MNPJVD will require a trained and motivated group of environmental scientists who can communicate with planners and policymakers. It is not enough to develop technical expertise to collect data, unless those data can be analyzed and interpreted in ways useful to planners and policymakers (see Tillman 1989).

Many of the monitoring activities specified below do not give direct information concerning land use, forestry, range management, and biological conservation sectors considered in this volume. Similar analyses to those of TEBS will be required to link, for example, livestock populations to range resources, or woody cover to forestry resources. Nevertheless, these monitoring methods are the best approach to overall environmental monitoring, provided a skilled monitoring unit can be assembled.

Simpler monitoring methods could be devised, but would not be reliable. For example, changes in availability of fuelwood or construction wood might be reflected in changes in market prices. But how would a sudden rise in the price of wood be interpreted in the ecological context? How could environmental interventions be devised on this basis? Such information may be useful in pointing to features requiring further analysis of the environmental monitoring data, but it cannot replace those data.

Most monitoring activities should begin before the dam is closed. Such a schedule enables a partial separation of trends begun before dam closure from those resulting from dam closure.

A. Rainfall

Rainfall records in the Jubba Valley have poor coverage and are unreliable. Yet rainfall is perhaps the most important variable determining ecosystem processes in semi-arid areas such as TEBS study area (Deshmukh 1986a). Range vegetation production and livestock stocking rates are usually closely correlated with amount of rainfall received. Optimizing water use for irrigation is also dependent on knowledge of local rainfall. However, problems exist in setting up a rain gauge network. Much of the river-dependent zone has no permanent settlements and, therefore, no one to take daily rainfall readings. Monthly storage gauges could be used in more remote areas, but these may be inaccessible during the rains. It is also probable that local people would find materials in a rain gauge useful, leading to destruction or removal of gauges. Even deeply buried sections of topographic benchmarks have been removed for the metal they contain. A rain gauge is much simpler to dismantle. Where settlements exist, rain gauges are often read sporadically or data are lost or left uncollected.

The Food Early Warning System of the Ministry of Agriculture has increased the number of rain gauges in the study area and improved data collection and analysis. This agency is appropriate to develop an enhanced rainfall data collection and analysis capability for the study area. Information would then be passed to MNPJVD.

Ideally, a grid of rain gauges would be established throughout the river-dependent zone with perhaps one gauge per 500 km^2, requiring 60 gauges. In the floodplain, one gauge per 25 km of river length (a total of 20 gauges) would be useful for agricultural planning given the gradient of rainfall north to south in the study area. However, reliable records are unlikely to be kept with such an evenly spaced network, since settlements are not located in such a regular manner. A better approach may be to set up daily-read gauges located at all new or existing project sites with permanent staff. Locations could include forest nurseries, health posts, agricultural projects, livestock stations, and conservation projects. Such a system will produce duplication in some areas and leave other areas unmonitored. Duplication is not disadvantageous since it enables cross-checking of nearby sites and an assessment of local variability. In areas with no projects, it may be possible to employ village leaders or enterprising farmers to keep records.

In all cases, effective record keeping requires motivation. People need to see that rainfall data are being used and are useful in their own lives. Every few months an agent from the Food Early Warning System or MNPJVD should visit rain gauge sites to show how accumulating records are used and to illustrate features of local interest which correlate with rainfall. For example, a farmer could be shown differences in crop growth in nearby areas with somewhat different rainfall.

This scheme will not produce adequate rainfall data for the river-dependent zone. An alternative to rain gauges for extensive areas is the African Real-Time Environmental Monitoring using Imaging Satellites (ARTEMIS) program established by FAO. Cloud cover, cloud-cover duration, and cloud-top temperatures are monitored to give estimates of precipitation and days with rainfall. The system is calibrated for West Africa, but East African calibration is under way. ARTEMIS information is available through the Regional Remote Sensing Center in Kenya, of which Somalia is a member. This program is probably the most appropriate means of obtaining rainfall data for the river-dependent zone.

Recommendation: *A system of rain gauges should be established in the Jubba floodplain with gauges located at all project sites and other appropriate locations.*

Recommendation: *Rainfall in the river-dependent zone should be monitored using the ARTEMIS system coordinated by FAO.*

Recommendation: *Collection and processing of rainfall data for the Jubba Valley should be performed by the Food Early Warning System (Ministry of Agriculture) who would routinely pass on appropriate information to MNPJVD.*

B. Vegetation

The monitoring site approach to TEBS vegetation studies was established with a view to continued monitoring after JESS. Of the three sets of monitoring sites (TEBS ground; TEBS aerial photographic; SRS ground) described in Section VI.B, it is suggested that the two sets of TEBS sites should continue to be monitored under the guidance of MNPJVD. The SRS sites are more appropriate for a national rangeland monitoring system for which they were designed. In the absence of such a national system, the SRS sites may be usefully reassessed if other developments indicate that information on rangeland resources distant from the river is important to MNPJVD (see Watson and Nimmo 1985 for details of SRS sites).

1. Aerial Photographic Monitoring Sites

Repetition of these photographs at appropriate time intervals is a relatively rapid method of objectively assessing changes in vegetation structure over the TEBS study area (see Section VI.B.2; Appendix B). Analysis of the photographs would be repeated as before for cover and size structure of woody vegetation. Effectiveness of this method depends on accurately photographing the same areas on each occasion. Should this precision not be possible, gross changes in vegetation structure should be detectable by taking a new random sample using the same stratification and making statistical comparisons between old and new photographs. However, re-photographing original sites is preferred since specific changes will be apparent. The original photographs are black and white. Color (or color infrared) photography should be used in the future to make analysis easier and to provide information about extent of herbaceous cover (see Appendix B).

This monitoring activity provides information on changes in distribution of structural vegetation types. Since forestry and range resources are closely related to relative proportions of vegetation types, human use of vegetation is also monitored (Section VII). Gross changes in land use, for example, loss of native vegetation to agriculture, would also be tracked by this method. Simple visual comparison of old and new photographs is an effective way of disseminating information about vegetation change requiring action from planners and policymakers.

A monitoring unit established in MNPJVD is the appropriate body to carry out this monitoring (see Tillman 1989). Photography should be repeated in June to August (when trees and bushes are in full leaf and herbaceous layer is green) at five-year intervals. The first repetition should be carried out before closure of Baardheere Dam. Besides flying time, which would be contracted out, analysis and interpretation should take two to three person-months (see Appendix B).

Recommendation: *Aerial photography vegetation monitoring sites should be re-photographed and analyzed at five-year intervals. Commissioning and analysis of aerial photography vegetation monitoring sites should be carried out by a monitoring unit in MNPJVD.*

2. Ground Monitoring Sites

The aerial photography monitoring sites provide a quantitative view of changing patterns of vegetation structure. However, they cannot be used to show changes in species composition and diversity unless these changes are very large. Since vegetation in and close to the Jubba floodplain is expected to change markedly due to hydrological changes and increasing human use, monitoring of species composition is important. Changes in relative abundance of species indicates availability of plants which have specific human uses (see Section VII.B). Reduction and possible loss of species, particularly those confined to the Jubba floodplain, are of importance to biological conservation. From a scientific viewpoint, changes in vegetation composition as a result of changes in floodplain hydrology are valuable in predicting impacts of future dams in similar environments.

For these reasons, monitoring of TEBS ground monitoring sites should be continued in the future. The first reassessment should be conducted before closure of Baardheere Dam with subsequent repetition at 10-year intervals. Monitoring procedures are given in Appendix A. The work should be undertaken in June to August, the season when most sites were established. Two to three months would be required for a team of four to five. Since the work is specialized and intermittent, it is not appropriate for MNPJVD to maintain such a team, although they should provide assistance in the field. This monitoring team could be led by appropriate personnel from the National University of Somalia, the NRA, or an expatriate specialist. Funding should come from an appropriate international agency or scientific research body, rather than being part of the MNPJVD recurrent budget. The data is primarily of scientific interest, or of interest to development planners in other countries, rather than being directly of use to MNPJVD.

Monitoring should be an important component of conservation projects such as the Shoonto and Barako Madow Forest Reserves and Shabeelle Swamps (see Section VIII). If properly protected from human destruction, the forests could provide information on effects of hydrological changes due to dam construction on riverine forest. Wildlife monitoring in conservation areas should also be conducted. The nature of such monitoring is properly defined in a management plan for each conservation area rather than in this overview of monitoring activities for the whole TEBS study area. Since NRA is responsible for conservation activities, it should oversee monitoring at these sites. SRP outlines a research program for the riverine forests which includes monitoring activities (Madgwick and Wood 1988). This program includes establishment of permanent vegetation plots to monitor growth rates and changes in species composition. Such changes will yield useful information for both forestry and conservation purposes. Effects of changed hydrology caused by Baardheere Dam would also be evident. Wildlife populations would also be monitored.

Recommendation: *TEBS ground monitoring sites should continue to be monitored to provide information on changes in vegetation species composition. These sites should be assessed again before closure of Baardheere Dam, then at 10-year intervals.Monitoring of ground sites should be coordinated by MNPJVD in collaboration with NRA and/or the National University of Somalia with expatriate technical assistance as required.*

Recommendation: *All designated conservation areas should have a monitoring system included in management plans.*

The Reservoir Drawdown Zone

Several TEBS ground and aerial photograph monitoring sites are in the drawdown zone of the future reservoir behind Baardheere Dam. These sites should continue to be monitored as outlined above; however, changes in landscape and position of tracks and other markers following inundation may prevent accurate relocation. Clearance of reservoir vegetation, as recommended in Section VII, should exclude these sites and a buffer zone around them, if possible. However, even if these sites are cleared before inundation, known prior vegetation and soil conditions may help to explain subsequent development of drawdown vegetation.

An additional monitoring system should be established to follow development of vegetation and surface soil in the drawdown zone. Techniques would be the same as those used at TEBS ground monitoring sites (see Appendix A). If soil changes are marked, more detailed soil analyses than those used in TEBS surface soil descriptions will be desirable. Parameters of interest include soil depth, texture, and chemical composition. Laboratory measurements should be possible at the Ministry of Agriculture soil laboratory, established as part of JuDAS project, with possible collaboration from the Faculty of Chemistry, National University of Somalia.

Paired vegetation monitoring sites would be established. One would be surrounded by a fence to exclude livestock and human removal of vegetation, while its partner would be open to these influences. In this way natural vegetation development and its modification by human use could be assessed. Twenty paired sites should be established at various levels in the drawdown zone and on various substrates such as current floodplain, togga, and different substrates of the current river-dependent zone (stony, rocky, gypseous, other fine soil types; see Appendix I).

Sites should be established before reservoir filling to determine conditions prior to inundation. For the first five to 10 years after dam closure, the sites should be assessed annually during the jiilaal drawdown. Frequency of subsequent monitoring would depend on results from the initial years. This work should be a collaborative effort between MNPJVD, NRA, and the National University of Somalia. Annual monitoring activities may be useful field training for students in the Botany and Range Science Department at the University, or the NRA Forestry, Range and Wildlife School.

Recommendation: *A vegetation monitoring system for the Baardheere Reservoir drawdown zone should be established as a collaborative project between MNPJVD and NRA and/or the National University of Somalia.*

C. Aerial Censuses and Aerial Photography

Aerial census provides a rapid view of the whole TEBS study area. Repetition of aerial censuses conducted for JESS will provide the most efficient view of changes in land use, rural human settlement patterns, and livestock and wildlife populations. Techniques, stratification, and baseline data are given in Watson and Nimmo (1988). Baseline data sets are also included in JESS data repositories.

1. Complete Enumeration of the River

A simple system that can flag undesirable developments is the most important aspect of monitoring from the point of view of development planning. Complete enumeration of riverine features provides the basis of such a system. Areas close to the river will change most rapidly due to development both before and after closure of the dam. Therefore, it is these areas that need most frequent monitoring. The enumeration method is rapid and, if repeated frequently enough, will give information that can be followed up by more detailed or quantitative aerial or ground monitoring. Features enumerated and mapped include counts of irrigation pumps, livestock watering points, boats and ferries, crocodiles and hippopotamuses, fishing activities, and assessments of riverside land use (Watson and Nimmo 1988). Important indicators likely to undergo rapid changes include the number of pumps and crocodiles and extent of riverbank agriculture. The technique would need to be modified slightly after closure of the dam to include the reservoir perimeter.

Because of rapid land-use changes described in Section V, these riverine enumerations should be repeated at two-year intervals, beginning in 1990. Jiilaal is the appropriate season since activities in the drawdown zone will be exposed and use of the river by livestock will be high. Analysis and interpretation of data should be rapid so that interventions to mitigate undesirable developments can be undertaken before these changes become too great. This work requires an experienced aerial resource assessment team who should be contracted by MNPJVD.

Recommendation: *Aerial enumerations of riverine features (including the reservoir perimeter) should be conducted at two-year intervals beginning in 1990.*

2. Sample Censuses of Floodplain and River-Dependent Zone

Riverine enumeration as described in the previous section cannot give a complete view of the Jubba floodplain and gives no information about the river-dependent zone. Monitoring of these larger areas is equally important, but need not be as frequent. The aerial strip sample censuses conducted for JESS should be repeated to assess changes in these areas (see Sections V and VII.B; Watson and Nimmo 1988). Quantitative information collected includes livestock and wildlife populations, livestock activities, land use, rural settlements, wood extraction features, and water sources.

Ten-percent censuses of the floodplain should be repeated at five-year intervals, with the first census before closure of Baardheere Dam. Three-percent censuses of the river-dependent zone should be repeated at 10-year intervals. Two censuses should be completed in each sampling year; one in late jiilaal and one in early to mid-xagaa. These timings are comparable with those of JESS censuses and should illustrate patterns of seasonal livestock occupancy. As with the riverine enumeration, an experienced aerial resource assessment team should be contracted by MNPJVD.

By using the same flight lines and sampling framework as JESS, these monitoring censuses will allow detailed comparisons of spatially fixed features such as land use and some rural structures. However, mobile features, notably livestock and other features associated with pastoralists, are subject to spatial fluctuations which make temporal trends difficult to detect. Nevertheless, as the length of time of monitoring increases, it will be possible to determine trends in these features since the river will remain the major dry season water source. Monitoring of livestock activities will enable developments in integration of crop and livestock production to be followed. Changes in the numbers of livestock feeding on crop residues will be an important indicator of this change.

Recommendation: *Sample aerial censuses should be conducted at five-year intervals in the Jubba floodplain and 10-year intervals in the river-dependent zone.*

3. Stereoscopic Aerial Photography

JESS commissioned stereoscopic aerial photography at 1:10,000 scale of a strip of land stretching approximately 2 km either side of the Jubba River. It is not recommended that this photography be repeated routinely. Such photography and its interpretation are expensive. However, many of the monitoring activities described above may highlight "hotspots" where land-use changes needing detailed analysis are located.

Recommendation: *In some instances it may be desirable to repeat stereoscopic aerial photography of selected areas for comparison with the earlier photography.*

4. Potential of Aerial Video

Aerial video, as a partial substitute for aerial photography, is potentially valuable as a monitoring tool. Advantages include lower price, a continuous record of the area overflown and an excellent medium for demonstration to planners, policymakers, or the general public. Techniques are rapidly improving in terms of resolution, stop-frame mechanisms, and use of infrared wavelengths.

Aerial video could be used in conjunction with many of the monitoring activities described above. For example, stop-frame techniques could replace the use of photographs in aerial vegetation monitoring. A continual visual record of river enumerations and sample census strips could be analyzed more completely than someone counting from an airplane. To reduce flying time, a new set of aerial vegetation monitoring sites could be placed on the census strips and extracted from the taped record. A permanent record allows new analyses to be made if they become desirable. However, such analyses should be used as an addition to rather than a replacement for the direct aerial counts. Direct counts are available more quickly than is likely from an analysis of a videotape. There is also a danger that a tape will remain unanalyzed, since there will always be a temptation to leave it until a later date.

Pertinent issues need to be resolved before a video system is adopted. These include finding a system which has the resolution necessary to enable livestock counts, while using an adequate strip width so that extra flying time is not required. For vegetation monitoring, resolution should be adequate to distinguish shrubs of at least 2-m crown diameter. Convenience of analysis for measurements of area, use of dot grids, and other techniques should also be considered.

Recommendation: *The possibility of using aerial video to carry out a variety of environmental monitoring tasks should be investigated.*

Annotations in square brackets following a reference indicate where more obscure items may be found.

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Ninety ground monitoring sites were established on or close to the Jubba floodplain. Detailed estimates were made of vegetation characteristics. Many sites were visited in different seasons when some measurements were repeated. These quantitative data are recorded in TEBS data bases, which are retained in JESS data repositories. Data bases relevant to ground monitoring sites are listed in Table 28. In addition, surface soil, and other readily observable features such as grazing, wood cutting, and burning were noted. Additional land-use and ethnobotanical information was gathered by interviewing local people whenever possible. The details of location and site descriptions are given in TEBS Ground Monitoring Sites, available at JESS data repositories (see Section II).

Table 28. Data Bases Using Information from TEBS Ground Monitoring Sites

NAME of DATABASE	CONTENT
SITEDESC	Site descriptions: location; structural vegetation type; soil type; woody biomass.
PLANTAX	Plant taxonomy and ethnobotany: taxonomic information; vernacular names; use of plants.
WOODYFP	Enumeration of all woody plants; floodplain sites.
WOODYNFP	Enumeration of all woody plants; river-dependent zone (non-floodplain).
HERBVEG	Herbaceous vegetation: point-frame and standing crop data.
HERBSPP	Herbaceous species: species on and around sites and indices of abundance.

Procedures at Each Site

Sites downstream of Baardheere Dam site were chosen to represent the major physiographic and vegetation types identified by AHT photo interpretation (AHT 1984; see Section V.B. and Hemming 1987). Upstream sites included floodplain, future drawdown zone, and above the maximum level of the future reservoir (see Appendix I). Location of sites was subjectively chosen to be representative of the range of vegetation types by the JESS ecologist after examination of vegetation and land-use photo interpretations of AHT (1984) and Trump (1987). Tables 11 and 12 and Figure 9 record the disposition of these sites relative to the randomly distributed aerial photograph monitoring sites.

Site Layout

Each site was a 20 m x 20 m or 10 m x 10 m square using a corner tree as marker. Four-hundred square meters was used as the minimum plot size suitable for riverine forest vegetation in East Africa (see discussion in Hughes 1985). For uniform grassed, shrubbed, or bushed sites 100 m^2 was used, but the larger plot was retained for more heterogeneous sites of these types. With sites ranging from high forest, through thicket bushlands, to grasslands, it is impossible to pick an ideal plot size which optimizes sampling rigor yet keeps labor within reasonable bounds. Time taken for complete enumeration of these sites with a field team of four to six varied from two to six hours. Usually it was not possible to complete more than two sites per day except where woody vegetation was sparse.

The square plot was temporarily delineated using tapes and a sighting compass. Permanent markers for future use were added later. These comprise half-meter lengths of galvanized iron pipe pounded vertically at each corner until below the soil surface. A metal detector will be used to locate these markers should sites be visited later. As an aid to finding the "first corner" of each site, pits and mounds were dug close to the nearest track (or other appropriate semi-permanent feature). Distances were recorded linking the track and plot corner by a compass bearing.

These standard procedures were modified at a few sites due to the nature of the vegetation. Sites 40 and 50 are 4 m x 100 m belt transects laid across a major livestock route close to a watering point. Site 76 was first designated as a standard 400 m^2 plot, but modified to 20 m x 10 m due to density and uniformity of woody vegetation. Procedures at sites with no woody plants taller than the low shrub layer are described below. Individual plot size and layout and directions to the site are given in TEBS Ground Monitoring Sites.

A set of four 35 mm photographic color slides was taken of each site using a 50 mm lens. Whenever possible, they were taken after a rainy season to show the vegetation in "good" condition. Two photographs were taken of the plot from a position 10 paces outside the square. The camera was pointed horizontally towards the square at head height (TEBS ecologist; 1.75 m tall) from a point 10 paces from the mid-point of two perpendicular sides. Two further slides were taken vertically downward of the ground from bent head height at points along the point-frame transect (see "Herbaceous Plants" below). One photograph was of the inner end of the transect and the other of the mid-point. Copies of these photographs are retained by USAID/Somalia and ARD. Minor positional variants of these standard photographs were necessary at some sites. These deviations are listed in TEBS Ground Monitoring Sites.

Enumeration of Woody Plants

The following data were recorded for each tree and shrub (excluding dwarf shrubs which were treated as herbaceous plants) in each plot. These measurements were made at the first visit to each site, since changes within the study period were not expected to be detectable. However, the following measurements should be repeated for long-term monitoring (see "Future Monitoring", below, and Section X):

- basal diameter of stem of trees or length of longer axis of basai stem cluster of asymmetric shrubs;
- crown diameter in two perpendicular horizontal directions (mean crown diameter was used in computations to correct for asymmetry);
- total height measured for smaller trees and shrubs or estimated visually for taller individuals;
- height above ground at which crown begins;
- whether the plant is single- (tree) or multi- (shrub) stemmed; and
- species field identifications or herbarium specimens for later identification (see Appendix D and PLANTAX data base described in TEBS Data Guide).

Percentage cover of woody canopy at each monitoring site was computed as the sum of crown area (assuming crown is circular) of all woody plants rooted in the plot relative to ground surface area of the plot. This method assumes that any crown overhang of measured plants outside the plot is equal to overhang of plants rooted outside into the plot.

Herbaceous Plants

Species composition was not measured quantitatively because of difficulty distinguishing vegetative parts in a sward. However, approximate relative abundance and height of recognizable species was recorded at the first visit to a site and subsequent major changes noted on seasonal visits (see Section VI.D for some examples). The abundance scale scored species as abundant (5), common (4), frequent (3) occasional (2), or rare (1). Height was scored as 4 (> 100 cm), 3 (51 to 100 cm), 2 (21 to 50 cm), or 1 (0 to 20 cm). A composite index for each species at each site, the sum of abundance and height scores, was also computed. Thus, a small rare plant will score 2 and a tall dominant species 9. These indices are recorded in HERBVEG data base. The "index of abundance" referred to in Table 15 is the sum of the composite index for each species across all ground monitoring sites. As with woody plants, specimens in suitable condition were collected for herbarium identification. The following quantitative estimates were made at each visit to a site.

Proportional cover was estimated using a point-frame. Ten pins were suspended 50 mm apart from a frame 0.5 m tall. Two sets of observations were made. First, number of pins hitting each type of plant and condition class (grass, forb, dwarf shrub; green or brown condition) was noted. Then, the nature of the ground at the point of each pin (soil, rock, plant litter, dung, unseen) was recorded. This procedure was repeated at 20 positions at marked 0.5 m intervals along a rope of known orientation within each plot. The position of this rope was recorded with respect to plot boundary tapes and compass bearing. In this way approximately the same 200 points were sampled during each seasonal visit to a plot.

Figure 13 presents a summary of this data showing seasonal changes. The ordinate scale is the mean number of hits across all monitoring sites visited in each month. Thus the maximum score for any category is 200 hits. Only data from sites downstream of the dam site are given since repeated visits were not made to upstream areas.

Standing crop of herbaceous vegetation was also estimated on each visit to sites with sufficient vegetation to warrant sampling. Analysis of data from sites assessed indicates that those with "insufficient" vegetation had less than 50 to 100 kg ha^{-1} standing crop. Ten 25 cm x 25 cm square quadrats were tossed randomly within the sample plot. All vegetation within each quadrat was clipped at ground level and stored in paper bags for air-drying in the field and subsequent oven-drying in Muqdisho.

At sites with no woody plants (14, 19, 21) a square plot was not laid out. Instead, a line transect was used. Point-frame samples were taken at fixed intervals along a marker tape. For tall grass sites (14, 21) a 1.5 m tall 5-pin frame (pins 10 cm apart) was used. See TEBS Ground Monitoring Sites for details of length of transects, intervals between point frames, and other data recorded at each of these sites.

Most sites were established in early xagaa when vegetation was in good condition for field or herbarium identification (Table 29). Herbaceous vegetation was also at its peak and ungrazed or barely grazed following dispersal of livestock during gu'. A minority of sites was set up during early jiilaal. Due to poor deyr rains in 1986 and 1987, vegetation condition was relatively poor in jiilaal.

Table 29. Dates of Establishment and Number of Vegetation Plots in Different Areas of the Jubba Valley

Downstream of Baardheere Dam Site:

MONTH	Floodplain	River-Dependent Zone	TOTAL
July-August 1986	25	11	36
January 1987	9	3	12
August 1987	0	2	2
January 1988	1	3	4
Total	35	19	54

Upstream of Baardheere Dam Site:

MONTH	Floodplain	Non-Floodplain to be inundated	Non-Floodplain above Reservoir	Total
July 1987	10	11	11	32
December 1987	2	2	0	4
Total	12	13	11	36

* *Exact position relative to reservoir water level is not certain; many "inundated" plots will probably be in the drawdown zone.*

Phenology

In addition to estimates of herbaceous cover, condition, and standing crop, visual estimates of phenological condition of dominant herbaceous and woody species were made on each visit to a site. Dates of visits are recorded in TEBS Ground Monitoring Sites and data base HERBVEG. Categories recorded were leaf or flower buds; young, mature, or senescent leaves; flowers; fruit. Each category was scored:

0 = no activity/absent,
1 = slight/few,
2 = moderate,
3 = high/common, or
4 = full/abundant.

A similar system was employed to record the degree of grazing or browsing on dominant species (0 = none, 1 = slight, 2 = moderate, 3 = heavy). To maintain consistency, these visual estimates were scored by the same individual on seasonal visits.

Figure 12 was prepared using these data. "Young leaf" and "leaf bud" categories were combined; there were no records for flower buds. Scores in each category were summed for dominant species at a site, then summed over all sites visited. This grand total was expressed as a percentage of the maximum possible score (number of sites x number of species x 4) for each phenological category. Looking, for example, at the first floodplain column in Figure 12: young leaves plus buds was 7 percent of total possible activity (100 percent); mature leaves 90 percent; senescent leaves 17 percent; flowering 10 percent; fruiting 6 percent. If all categories are showing maximum activity, the ordinate scale would be 500. Data presented are from sites downstream of the dam site since repeated visits were not made to upstream areas.

Other Information Recorded

Sites were described in terms of topography, drainage, and erosion and flooding features (see Appendix I). Whether floodplain sites were subjected to flooding was initially determined by presence or absence of two snail genera, *Pila* and *Achatina*. The former indicates that surface water is present at least part of the time, while the latter occurs in dryland conditions. Although not an absolute guide, experience showed that these snails are good indicators of flood regime. Confirmation of flooding was obtained at sites by interviews with local people wherever possible. Eventually, the large flood of May-June 1987 gave direct evidence as to which sites are likely to flood.

Surface soil was examined superficially at each site. Description of the surface was first made including the presence of litter, crusts, cracks, and termite activity. A shallow pit (c. 25 cm) was dug using hand-axe or shovel to indicate whether upper horizons could be distinguished. Presence or absence and shape of peds was noted if they occurred. Texture was approximated by a combination of visual examination using a x5 magnification hand-lens and stickiness and plasticity when wetted. A USDA soil texture triangle was used to classify soils (e.g., silt, clay, loam). Soil color was determined using a Munsell color chart.

Whenever present or brought to a site, local people were asked a series of questions about each site and the surrounding area. Questions included (but were not restricted to):

- flooding patterns—timing, frequency, depth;
- grazing/browsing patterns—timing, frequency and by whom, presence/absence of tsetse (including use of prophylaxis for trypanosomiasis), range burning;
- interactions with wildlife;
- ethnobotanical information—vernacular names of species and local uses of plants; and
- recent land use.

Future Monitoring

For future monitoring of TEBS ground monitoring sites (Section X.B.2) the same procedures should be used as given above. Some procedures may be omitted such as herbaceous standing crop estimates and visual assessment of phenology. These measurements make little sense unless seasonal visits are carried out. However, point frame measurements will be worthwhile as indicators of change in herbaceous vegetation. Repetition of site photographs should also be carried out for comparative purposes.

Monitoring of the drawdown zone (Section X.B.2) should also follow the same procedures. Paired plots would be established at the same level relative to receding water, but one would be fenced to exclude grazing and cutting. At least 10 pairs of plots should be established at different levels of the drawdown area and on different sediments (Section X.B.2). Since these plots will be monitored more frequently than others, standing crop and phenological assessments are useful, particularly for comparisons between plots in a pair.

To provide a statistically valid view of vegetation structure, which would supplement and complement ground monitoring sites, JESS commissioned sample vertical aerial photographs. These photographs, at approximately 1:1,000 scale, were taken in xagaa and early jiilaal 1987. These photographs are available at the JESS data repository at USAID/Somalia. Negatives are retained by RMR, Ltd. Due to camera malfunction, the photographs were not available until later in the project than intended. This problem limited the extent of analysis successfully completed.

A stratified random sample was taken divided between floodplain and river-dependent zone (see Section VI.B.2 and Watson and Nimmo 1988). Areas under cultivation were not photographed except where farming was so intensive that fields could not be avoided. Floodplain photography (291 prints) was stratified first by river section, then by physiographic units. For the river-dependent zone (269 prints), stratification was by river section and distance from the river east and west of the floodplain. River-dependent zone photography has also been assigned to strata used in the Southern Rangeland Survey (Watson and Nimmo 1985) in TEBS data bases. This additional stratification is provided for comparison with results of that survey. Number of prints per stratum is approximately related to total area of each stratum. Sampling intensity of the floodplain was almost 20 times that of the river-dependent zone since the former was a primary TEBS focus.

The strict random criterion was relaxed to the extent of making the photographs accurately mappable relative to landmarks. It is assumed that this process produces no discernible bias relative to vegetation types. Accurate mapping was required for two reasons. First, it was intended that TEBS would visit a proportion of photographic sites to check the accuracy of measurements made on the photographs relative to those made at ground sites. Unfortunately, late delivery of photographs and other priorities precluded this possibility. Second, if the photographs are to be used for monitoring, more or less exact replication of photographic sites is desirable.

Analysis of photographs took two forms. Percentage cover of woody plants was estimated using a dot grid with 100 dots in a stratified random pattern (Figure 18). The grid was placed over each photograph in turn, percent cover simply being the number of dots coinciding with trees and bushes. Only woody plants greater than ~ 2 mm diameter were included. This diameter corresponds approximately to plants 2 m tall (determined from ground monitoring site data) to make tree and bush assessment equivalent to that at ground sites. Other cover categories counted include grassy cover or bare ground (where discernible), fallen trees, water, vehicle tracks, human/livestock trails, and other human features (see TEBS Data Guide). These data are recorded on the VEGPHOTO data base.

Separation of "bushland" and "woodland/forest" categories (see Appendix C) was partly subjective based on the experience of the JESS ecologist. Average crown diameter of woody plants (see below) was used as a guide while viewing the photographs. A woody plant of approximately 5 m diameter is approximately 5 m tall according to data from ground monitoring sites. Use of crown diameters as the final arbiter of vegetation classification was not possible because of sampling problems described below.

An attempt was made to estimate size classes of trees and bushes with a view to biomass estimation. Size class of the random sample located by the dot grid (see above) was estimated using the device pictured in Figure 19. The clear plastic-film template was placed over each selected shrub and tree whose crown diameter was then assigned to one of the classes identified by numbers on the template. Class 1 is <2 m; Class 2, 2 to 4 m; Class 3, 4 to 6 m; Class 4, 6 to 8 m; Class 5, 8 to 10 m; Class 6, 10 to 15 m; Class 7, >15 m. Total number of woody plants within the dot-grid frame was also counted. Proportion of plants in each size class from the sample was then related to total number of plants to estimate the total number of plants in each size class in the dot-grid frame. The intention was to apply the crown diameter/biomass relationships developed in Appendix F to the vegetation photographs.

This sampling approach did not produce reliable results. Shortage of time resulting from unavoidably late delivery of photographs precluded alternatives from being tried. Problems included small sample size in some cases. Many plants were not measured

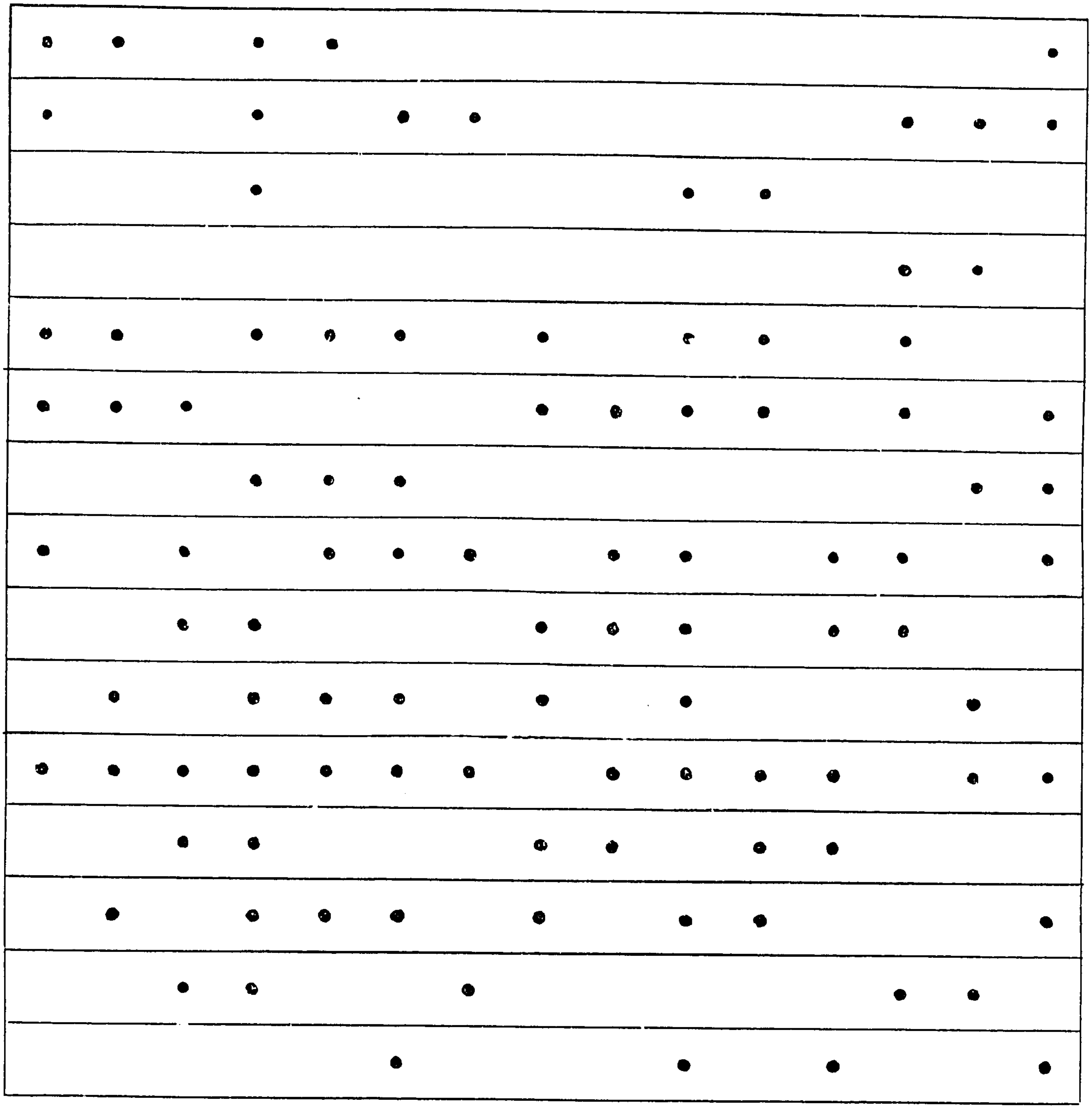

Figure 18. Dot-grid used in determining percent cover of woody vegetation and other features on aerial photographs of vegetation monitoring sites. Actual size is shown.

because of two or more crowns merging, a problem particularly evident in thickets and forests. Since these vegetation types contain a large wood biomass, accurate estimation is needed. Despite these problems, the crown size data are recorded in VEGPHOTO data base as they may be worthy of further analysis when monitoring procedures are operational (see Section X and "Monitoring", below). Because of these problems, biomass estimation was eventually done using a combination of ground monitoring sites and photographic monitoring sites as described in Appendix F.

Future Monitoring

Repetition of these photographs in the future will depend on accurate relocation and photography of sites by airplane. RMR is probably the only company that could repeat the photography as a result. Should RMR be unavailable, an alternative is to photograph another set of random locations using the same stratification and sampling technique (see Watson and Nimmo 1988). Statistical comparisons could then be made between successive sets of photographs, but specific changes at particular sites could not be observed. Given the small sample area represented by the photographs, (see Section VI.B.2), reassessing the same sites is preferred. It may be possible to locate sites on the ground using the mapped locations and set of photographs. Gross changes would be evident from ground visits.

Percentage woody cover on new photographs would be estimated as before using the dot grid in Figure 18. In the original study, the dot grid was placed centrally on the photograph with "TOP" being placed such that photographic frame references were at the bottom edge of each photograph. Color photography is recommended in Section X.B.1. This would give better definition of crowns of trees and bushes and allow a better estimate of herbaceous cover.

Improvements in assessing size structure of crowns would need a different sampling approach than using the dot grid. The crown size class template of Figure 19 could still be used, but a different sampling approach is needed. Crown diameter of a fixed number of (at least 30) randomly selected trees and bushes should be assessed rejecting plants where canopy shape suggests the crown is a mixture of several plants. Plants of size class 1 could be ignored since these contribute little usable biomass (see Appendix F). Density of plants per unit area should be assessed by counting in a sample of each photograph, rather than counting the whole frame. Color photography (see above and Section X.B.1) would help in assigning plants to size classes since the crown edge would be more clearly defined.

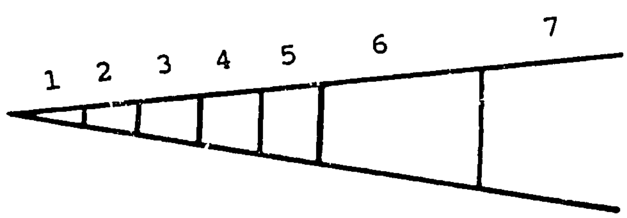

Figure 19. Template used to determine size of trees and shrubs on aerial photographs of monitoring sites. Actual size is shown.

The structural classification system builds upon that of Pratt and Gwynne (1977), but introduces greater resolution.

Woody cover (above the herbaceous layer which includes dwarf shrubs) is divided into two:

- "Canopy," height <2 m; and
- "Low shrub layer," >2 m.

It should be noted that "canopy" normally includes many shrubs (*i.e.*, multi-stemmed plants) also. The "low shrub layer" will also contain some single-stemmed woody plants, but in most situations the majority of plants are shrubs, some species of which never gain greater stature.

Sites are classified primarily by percentage canopy cover as in Pratt and Gwynne. However, extra categories are used in the 20 percent-plus range to give greater resolution. Also, allowance is made for sites with little or no herbaceous layer. "Woodland" is separated from "bushland" by mean height of trees/shrubs in the "canopy" stratum (*i.e.*, plants <2 m excluded from calculation). Thus, "woodland" has a mean height >5 m; "bushland" <5 m.

The following "canopy" cover classes are named:

• 0 to 2 percent	negligible;
• 2 to 19 percent	sparse;
• 20 to 39 percent	open;
• 40 to 59 percent	medium;
• 60 to 79 percent	dense; and
• 80+ percent	thicket (for bushland or low shrubland; forest for what would be thicket woodland).

These density classes are used for the low shrub, bush, and woodland/forest categories. The "negligible" or "sparse" categories may be replaced by "grassland," "wooded grassland," "bushed grassland," or "low-shrubbed grassland" combinations if the grass cover is sufficient. However, in situations where grass cover is negligible, then "open (woodland, etc.)" is used. Maximum seasonal herbaceous cover has been classified in the following way. The numbers refer to number of hits from a point frame giving a relative density (see Appendix A).

• 0 to 49 hits	negligible herb layer;
• 50 to 99 hits	sparse herb layer;
• 100 to 249 hits	medium herb layer; or
• 250+ hits	dense herb layer.

At least a sparse grass cover is required before such names as "grassland," "bushed grassland," "wooded grassland," are used. In other situations, different methods (including visual estimates) may be used to define herbaceous cover. Nevertheless, the same principles of classification can be used. If forbs predominate over grasses, the terms "forbland," "bushed forbland," etc., are applicable.

Normally, a site is named for its canopy/herbaceous strata as in Pratt and Gwynne, *e.g.*, "bushed grassland" if canopy cover is between 2 and 20 percent, or "open bushland" if herbaceous cover is negligible. The low shrub layer is only invoked if it is obviously important; for example, a "low shrubbed grassland" if >40 percent low shrub cover, or "sparse, open shrubland" if grass cover is negligible.

A complete structural description of a site includes all three strata. For example:

Name: *medium bushland*
  low shrub: open
  herb stratum: negligible
Name: *open shrubland*
  low shrub: open
  herb stratum: negligible
  (canopy stratum negligible by implication)
Name: *wooded grassland*
  low shrub: sparse
  herb stratum: dense
Name: *forest*
  low shrub: sparse
  herb stratum: negligible

The complete classification is given for ground monitoring sites in the SITEDESC data base.

This naming system can be used in a completely quantitative way by measuring cover and height of plants, or in a semi-quantitative way using visual estimates by an experienced worker. Complete mensuration of TEBS Ground Monitoring Sites produces names which match well with subjective visual estimates.

Plants that could not be identified in the field were collected, if in suitable condition. Repeated visits to many ground monitoring sites enabled most species to be identified. Four specimens were collected whenever sufficient material was available and distributed as follows:

- Somali National Herbarium, National Range Agency;
- National University of Somalia, Faculty of Agriculture herbarium (JESS working collection);
- Royal Botanic Garden, Kew, United Kingdom; and
- East African Herbarium, National Museums of Kenya.

Grasses and sedges were identified by Miss C. Kabuye (East African Herbarium) and other plants by Mr. J. Gillett at Kew. Field identifications were initially by Mr. C. Hemming who also handled liaison with the herbarium taxonomists. JESS is indebted to these workers for rapid identifications. Mr. Cali Warsame Yusuf took excellent care of the JESS working collection.

The following plant lists are subdivided to separate species found only in the floodplain from those of the river-dependent zone and those found in both habitats. Note that absence from one of these lists does not preclude the possibility of a species occurring elsewhere. For example, many floodplain species are known to occur in non-floodplain habitats in Somalia. Nomenclature follows Kuchar (1988). Further taxonomic and distributional data are given in PLANTAX data base. Species that could not be identified are not included. These plants are listed by vernacular names or as "unidentified" in WOODYFP, WOODYNFP, and HERBSPP data bases and in TEBS Ground Monitoring Sites. A question mark (?) indicates probable identification; two question marks (??) indicate doubtful/best guess.

SPECIES OF PLANTS
FOUND DURING TEBS GROUND SURVEYS

A. Species Found Only in the Floodplain

FAMILY	SPECIES	JESS Collection Numbers
Nymphaeaceae	*Nymhaea lotus*	407
Capparidaceae	*Capparis sepiaria*	237,246,253
	Gynandropsis gynandra	300
	Maerua sp.	43
	Maerua subcordata	354
Violaceae	*Rinorea elliptica*	31,94,238,244,261,432
Polygalaceae	*Polygala senensis*	415
Amaranthaceae	*Amaranthus graecizans*	310
	Amaranthus sparganiocephalus	276
	Digera muricata	311,325
Onagraceae	*Ludwigia* sp.	117
Nyctaginaceae	*Boerhavia elegans*	290
Tamaricaceae	*Tamarix aphylla*	
Curcubitaceae	*Cucumis dispsaceus*	10,101
Ochnaceae	*Ochna ovata*	55
Combretaceae	*Combretum aculeatum*	60,116
	Combretum constrictum	60,418,438
	Combretum illairii??	93
	Terminalia polycarpa?	170
Guttiferae	*Garcinia livingstonei*	168
Tiliaceae	*Corchorus trilocularis*	126
	Grewia trichocarpa	235
Sterculiaceae	*Cola* sp. *nov*	242
	Melhania ovata	134
Malvaceae	*Abutilon anglosomaliae*	291,352
	Abutilon hirtum	9
	Gossypium benadirense	280
	Hibiscus cannabinus	153
	Hibiscus hildebrandtii	155
	Pavonia propinqua	75
	Sida alba	222
	Symphochlamys erlangeri	260
Euphorbiaceae	*Bridelia cathartica*	192
	Caperonia fistulosa	84,165
	Drypetes natalensis	113
	Euphorbia acalyphoides	102
	Phyllanthus somalensis	16,138
	Spirostachys venenifera	1
Caesalpiniaceae	*Cassia fallacina*	112

Mimosaceae	*Acacia circummarginata*	29,76
	Acacia elatior	15,115,130
	Acacia macalusoi?	431
	Acacia rovumae	98
	Adenopodia rotundifolia	154
Papilionaceae	*Baphia??*	90
	Clitoria terneata	137
	Indigofera aspersa	204
	Indigofera brachynema	58
	Indigofera microcarpa	122
	Mundulea sericea	19
	Rhynchosia minima	129,149
Papilionaceae	*Rhynchosia minima*	344
	Sesbania bispinosa	6
	Sesbania sesban	248
	Tephrosia pentaphylla	205
	Tephrosia subtriflora	8
	Tephrosia uniflora	429
	Vigna unguiculata	107
Moraceae	*Ficus sycomorus*	193
Celastraceae	*Salacia stuhlmanniana*	225
Olacaceae	*Ximenia caffra*	430
Loranthaceae	*Erianthemum dregei*	218
	Tapinanthus zanzibarensis	219
Rhamnaceae	*Ziziphus mauritania*	282
	Ziziphus mucronata	171
Vitaceae	*Ampelocissus africana*	83
	Cissus aphylla	343
Simaroubaceae	*Harrisonia abyssinica*	69
Sapindaceae	*Allophylus rubifolius*	
	Allophylus senensis	70,46
	Camptolepis ramiflora	35
	Lepisanthes senegalensis	97
Anacardiaceae	*Sorindeia madagascariensis*	
Ebenaciae	*Diospyros cornii*	88
Sapotaceae	*Mimusops fruticosa*	20,119
Oleaceae	*Olea capensis*	96
Apocynaceae	*Landolphia* sp.	239,244
	Pleiocarpa pycnantha	33,40
	Saba comorensis	32
Rubiaceae	*Coffea rhamnifolia*	50
	Feretia sp.	51
	Meyna tetraphylla	120
	Pavetta transjubensis	121
	Polysphaeria multiflora	38,42,405
Compositae	*Erlangea somalensis*	150
	Launaea cornuta	82
	Vernonia cinerea	103,133
	Vernonia hildebrandtii	67
Gentianaceae	*Enicostema axillare*	80,111,206,249
Boraginaceae	*Cordia chisimajensis*	99
	Cordia goetzei	34,95,262
Solanaceae	*Solanum coagulans*	293
	Solanum incanum	127
Convolvulaceae	*Convolvulus capituliferus*	298
	Cressa cretica	190
	Ipomoea pes-trigridis	59
	Ipomoea plebeia	110,136
	Ipomoea sepiaria	105,157
Acanthaceae	*Asystasia gangetica*	81
	Barleria sp.?	283
	Ruellia patula	388
Verbenaceae	*Clerodendrum acerbianum*	22,209
Labiatae	*Leucas deflexa*	156,203
	Leucas nubica	305
	Leucas urticifolia	355,424
	Orthosiphon sp.?	166
Palmae	*Hyphaene* sp.	
	Phoenix sp.	
Cyperaceae	*Cyperus compressus*	123
	Cyperus grandibulbosus	306,307
	Cyperus sp. *nov*	279
Gramineae	*Acrachne racemosa*	294
	Brachiaria ramosa	357
	Chloris virgata	268
	Dactyloctenium aristatum	124
	Digitaria acuminatissima	125
	Dinebra retroflexa	308
	Echinochloa colona	266,316
	Echniochloa haploclada	72,77,229
	Eragrostis aethiopica	329
	Eriochloa fatmensis	269,327
	Panicum infestum	254,419
	Panicum maximum	79
	Rottboellia cochinchinensis	100
	Saccharum spontaneum	87
	Schoenefeldia transiens	71
	Setaria verticillata	296
	Sorghum arudinaceum	3,78,202
	Sporobolus nervosus	54
	Tetrachaete elionuroides	333
	Urochloa panicoides	132,390,409

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B. Species Found Only Outside the Floodplain

FAMILY	SPECIES	JESS Collection Numbers
Capparidaceae	*Boscia coriacea*	211
	Boscia minimifolia	
	Boscia tomentella	374
	Cadaba farionosa	
	Cadaba glandulosa	335,367
	Cleome brachycarpa	284,39[illegible]
	Maerua crassifolia	144
	Maerua sessiliflora	337
Resedaceae	*Reseda ellenbeckii*	318
Aizoaceae	*Zaleya pentandra*	285
Portulacaceae	*Portulaca foliosa*	403
Amaranthaceae	*Psilotrichum sericeum*	165,181
	Pupalia lappacea	201,397
	Sericocomopsis pallida	369
Nyctaginaceae	*Boerhavia* sp.	287
Passifloraceae	*Adenia aculeata*	
Combretaceae	*Terminalia parvula*	231,338,363
	Terminalia prunioides	220
Tiliaceae	*Grewia* sp.	322
	Grewia villosa	
Sterculiaceae	*Hermannia exappendiculata*	26
	Sterculia rhynchocarpa	162,258
Bombacaceae	*Adansonia digitata*	
Malvaceae	*Hibiscus somalensis*	320
	Pavonia arabica	271,376
Euphorbiaceae	*Euphorbia arabica*	362
	Euphorbia cuneata	
	Eurphobia erlangeri	347
	Eurphobia scheffleri	180
	Eurphobia sp. *nov*	379
	Jatropha rivae	286
	Jatropha trifida	212
Caesalpiniaceae	*Caesalpinia erianthera*	373
	Caesalpinia trothae	62,410
Mimosaceae	*Acacia bussei*	
	Acacia etbaica	
	Acacia horrida	
	Acacia mellifera	
	Acacia ogadensis	366
	Acacia senegal	
	Acacia sp.	221
	Acacia tortilis	
Papilionaceae	*Crotalaria pycnostachya*	216
	Dalbergia commiphoroides	
	Indigofera sp.	304
	Indigofera sp. *nov?*	317
	Indigofera spinosa	365,382
	Indigofera tinctoria	402
Celastraceae	*Elaeodendrum schweinfurthianum*	437
Salvadoraceae	*Azima tetracantha*	179
Opiliaceae	*Opilia campestris*	48
Loranthaceae	*Oncocalyx kelleri*	175
Rhamnaceae	*Ziziphus hamur*	
Rutaceae	*Vepris eugeniifolia*	435
	Vepris glomerata	44
Simaroubaceae	*Kirkia tenuifolia*	425
Burseraceae	*Boswellia* sp.	
	Commiphora africana	139
	Commiphora campestris	257
	Commiphora sp.	274
	Commiphora unilobata	368
Anacardiaceae	*Lannea* sp.	
Umbelliferae	*Trachyspermum aethusifolium*	172
Apocynaceae	*Adenium obsesum*	
Asclepidaceae	*Edithcolea grandis*	387
	Gomphocarpus sp.	
Asclepidaceae	*Calotropis procera*	
Rubiaceae	*Gardenia fiorii*	
	Spermacoce filituba	183
	Tarenna graveolens	210
Compositae	*Blepharispermum fruticosum*	423
Boraginaceae	*Boureria orbicularis*	259
	Cordia somaliensis	177
Solanaceae	*Solanum hastifolium*	250
	Solanum jubae	313,339,348
Convolvulaceae	*Hildebrantia* sp.	
	Ipomoea garckeana	188
	Ipomoea sinensis	398
	Seddera bagshawei	14,27
	Seddera microphylla?	384
Scrophulariaceae	*Cycnium tubulosum*	207
Pedaliaceae	*Pedalium murex*	395
	Sesamothamnus busseanus	
Acanthaceae	*Asystasia* sp.?	185
	Barleria argentea	321
	Barleria orbicularis	375
	Barleria proxima	272
	Barleria quadrispina	270,323
	Barleria ramulosa	23,63
	Berleria sp.	350
	Blepharis persica	
	Duosperma eremophilum	361

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Acanthaceae *(continued)*	*Ecbolium violaceum*	346,359
	Justicia flava	377
	Neuracanthus polyacanthus	360
	Satanocrater paradoxus	49,422
	Satanocrater sp.	341
Verbenaceae	*Vitex negundo*	176
Labiatae	*Endostemon gracilis*	182
	Ocimum canum	396
Liliaceae	*Aloe* sp.	
	Asparagus somalensis	358
	Asparagus sp.	
Cyperaceae	*Cyperus teneriffae*	404
Gramineae	*Aristida adscensionis*	215
	Aristida mutabilis	324
	Cymbopogon caesius	213
	Dactyloctenium geminatum	197
	Digitaria velutina	399
	Dignathia hirtella	412
	Enneapogon schimperanus	378,380
	Enteropogon macrostachyus	161
	Enteropogon sp.? *nov*	174,198
	Eragrostis ciliaris	173,303
	Sporobolus agrostoides	199,400
	Sporobolus ioclados	65
	Tetrapogon cenchriformis	334
	Tetrapogon villosus?	28,47
	Tragus heptaneuron	408
	Urochloa rudis	411
	Urochloa trichopus	196

C. Species Found Both In and Outside the Floodplain

FAMILY	SPECIES	JESS Collection Numbers
Annonaceae	*Monanthotaxis fornicata*	114
Cruciferae	*Farsetia robecchiana*	278,349
Amaranthaceae	*Achyranthes aspersa*	187
	Aerva lanata	64
	Aerva persica	
	Celosia polystachia	12,281,297,391
Zygophllaceae	*Tribulus terrestris*	299
	Zygophllum simplex	
Lythraceae	*Lawsonia inermis*	
Combretaceae	*Combretum contractum*	73
	Combretum hereroense	233,319
	Terminalia brevipes	5,18,217,428
Tiliaceae	*Corchorus olitorius*	104,326
	Grewia tenax	
Bombacaceae	*Ceiba pentandra*	85
Malvaceae	*Abutilion pennosum*	13
	Senra incana	345
	Thespesia danis	1
Euphorbiaceae	*Acalypha fruticosa*	92,223,236,256,353,389
	Cephalocroton cordofanus	147,251,426
	Flueggea virosa	68,158,169,194,227,228,234
	Tragia hildebrandtii	159
Caesalpiniaceae	*Cassia longiracemosa*	302
Mimosaceae	*Acacia drepanolobium*	146
	Acacia nilotica	
	Acacia nubica	
	Acacia reficiens	
	Acacia zanzibarica	189
	Albizia anthelmintica	148,436
	Dichrostachys cinerea	
	Newtonia erlangeri	36,57,152,195
Papilionaceae	*Indigofera coerulea*	370
	Indigofera schimperi	7,21,24,41,106,131,214
	Ormocarpum kirkii	61,108,160
Celastraceae	*Elaeodendron aquifolium*	434
Salvadoraceae	*Dobera glabra*	
	Dobera loranthifolia	255
	Salvardora persica	
Balanitaceae	*Balanites* sp.	381
Burseraceae	*Commiphora boiviniana*	45,247
Sapindaceae	*Lecaniodiscus fraxinifolius*	30,52,91,240
Boraginaceae	*Cordia sinensis*	164
	Heliotropium aegyptiacum	275
	Heliotropium zeylanicum	288,301
Convolvulaceae	*Merremia* sp.	184
Acanthaceae	*Anisotes trisulcus*	245
	Justicia sp.	312,334
Verbenaceae	*Premna resionsa*	11,44
Commelinaceae	*Commelina* spp.	17
Gramineae	*Cenchrus ciliaris*	53,140,200,401
	Dactyloctenium aegyptium	295
	Dactyloctenium scindicum	
	Digitaria milanjiana	141,421
	Eragrostia cilianensis	25,289
	Eriochloa meyerana	135
	Leptothrium senegalense	
	Paspalidium desertorum	267,328,414,420
	Setaria incrassata	151,427
	Sporobolus helvolus	4,13,47,109,128,191,252,31
	Sporobolus sp.	336
	Tetrapogon tenellus	226,331

The following list of names was collected during TEBS field surveys in the Jubba Valley. This list should not be used uncritically in determining scientific names when a vernacular name is given. Confirmation must be sought from someone familiar with the flora if specific names are important.

These names were collected throughout TEBS study area. However, regional variations exist such that a plant may have a different name in different areas. Even at one site, with one informant, a species may have more than one name. Some descriptive names are applied and used for many different species. For example, *geed cade* (meaning "white plant") is used for at least four species of tree in the Jubba Valley. *Balambaal* is used for many plants which are perceived as of no human use. Modern Somali orthography is used wherever possible such that "c" is a glottal stop and "x" an aspirated "h". However, local pronounciations are used as a basis for spelling rather than "official Somali." The Jubba Valley is strongly influenced by the *af Maay-maay* dialect and to a lesser extent, by Swahili.

Information in this table is also available in the PLANTAX data base housed in the JESS data repositories (see Section II).

A few names on the list are from sources other than TEBS. Those marked * are supplied by Michael Madaney, Jilib District (unpublished); # are from SOMAC/SAREC (1983) Jilib, Jamaame, and Kismaayo Districts; + are from Madgwick (1988), Bu'aale District.

VERNACULAR NAME	SCIENTIFIC NAMES
abaq*	*Acacia tortilis*
aboor makareen	*Rinorea elliptica*
adad geri	*Acacia ogadensis*
aqab*	*Acacia tortilis*
alaan/alan	*Terminalia brevipes*
aluundi	*Solanum jubae*
amaamiye	*Farsetia robecchiana*
anyah	*Boerhavia* sp(p).
awalle	*Clerodendrum acerbianum*
baar	*Hyphaene* sp./*Commelina* spp.
bakaraw+	*Kigelia africana*
bala baley	*Sorghum arudinaceum*
balambaal	see introductory notes
ballo	*Digitaria velutina*
baraari	*Cissus aphylla*
bar baraajis	*Ipomoea sepiaria*
big cade	*Melhania ovata*
bilcil	*Acacia mellifera*
bile	*Aristida adscensionis/A. mutabilis*
booc	*Calotropis procera*
bookoro	*Nymphaea lotus*
boqondhoo	*Balanites* sp(p).
buni	*Cephalocroton cordofanus*
cadaad	*Acacia senegal*
caday	*Salvadora persica*
calacheche+	*Ficus scassellatii*
caleen koris	*Ampelocissus africana*
canaaniye	*Tragia hildebrandtii*
caw	*Hyphaene* seedling
caws farqoole	*Dactyloctenium aristatum*
caws guri	*Cenchrus ciliaris*
caws jeerar	*Enteropgon* sp. nov.?
caws lagoley	*Panicum maximum*
caws shiir	*Indigofera microcarpa/I. schimperi*
caws weyn	*Eriochloa meyerana*
cismaan dooy	*Monanthotaxis fornicata/ Uvaria* sp.
ciddi shabeel	*Adenopodia rotundifolia/ Combretum aculeatum*
chengo+	*Afzelia quanzensis*
cilaan	*Lawsonia inermis*
daangoole	*Aerva lanata*
daba dabi	*Dactyloctenium scindicum*
dabiil/debeel	*Hyphaene* sp.
dabiriq#	*Commiphora boiviniana*
dabo	*Sporobolus nervosus*
dal	*Eriochloa meyerana*
damal/dambal	*Acacia elatior*
deegaan	*Mimusops fruticosa*
dhaanrab	*Sterculia rhynchocarpa/S. africana+*
dhalad	*Acrachne racemosa/Brachiaria ramosa/Eriochloa fatmensis*
dha(n)farrur	*Grewia tenax*
dharkayn+	*Euphorbia robecchii*
dharqe/dhirqe	*Indigofera schimperi*
dhaydhay/dheydhey#	*Newtonia erlangeri*
dhay ilmood	*Cassia fallacina*
dheg dhego	*Pupalia lappacea*
dheg dhegley	*Setaria verticillata*
dhidhiigle	*Jatropha rivae/J. trifida*
dhiigdaar/dhiigtar	*Dichrostachys cinerea*
dhiraandhir	*Euphorbia cuneata*
dhoomal	*Nymphaea lotus*

dhowey	*Bridela cathartica/Grewia trichocarpa/Grewia* sp(p).
dhugaal	*Maerua subcordata*
dhul muud	*Sporobolus helvolus*
dhumeek	*Grewia* sp(p).
dhuuji	*Dalbergia commiphoroides*
dhuundhug/dhoondhug	*Anisotes trisulcus*
dhuur	*Tamarix aphylla*
dibiriq	*Commiphora boiviniana*
digir jalow	*Vigna unguiculata*
digir jinni	*Clitoria terneata*
dooyo	*Dactloctenium aegyptium*
doraar	*Echinochloa haploclada*
dub hanraar	*Heliotropium aegyptiacum/H. zeylanicum*
dulan	*Diospyros cornii*
eesle gole	*Eriochloa meyerana*
ereeb	*Terminalia brevipes*
fargaan	*Garcinia livingstonei*
fiidey malabey	*Achyranthes aspersa/Ludwigia* sp.
food cade	*Aerva lanata/A. persica*
fulaay	*Acacia zanzibarica*
fulaay-bor	*Acacia drepanolobium*
gaduud madoone	*Ochna ovata*
galamash+	*Trichilia emetica*
galool/golog	*Acacia bussei*
gamoor	*Phyllanthus somalensis*
gamoor cade	*Flueggea virosa*
garawle	*Cenchrus ciliaris*
garas	*Dobera glabra*
garas weynle	*Dobera loranthifolia*
garroorey	*Meyna tetraphylla*
geed beered#	*Pupalia lappacea*
geed biyood	*Pleiocarpa pycnantha/Barleria orbicularis*
geed buureed	*Mundulea sericea*
geed cade	*Cola* sp. nov./(*Baphia* ?) /*Camptolepis ramiflora/ Cordia goetzei/Pavetta transjubensis*
geed goleed	*Saba comorensis*
geed gudundka#	*Indigofera schimperi*
geed hawaaleed xagar*	*Commiphora boiviniana*
geed kaar#	*Clerodendrum acerbianum*
geed maaluugees#	*Cadaba farinosa*
geed madow	*Cordia goetzei/Hunteria zeylanica+*
gerbi	*Hyphaene* sp.
gob/geb	*Ziziphus mucronata*
goriye haaris	*Digera muricata*
gorro/gorra	*Caesalpinia trothae*
gumur	*Acacia nubica*
habantir	*Phyllanthus somalensis*
half	*Aristida mutabilis/Tetrapogon cenchriformis*
hambooyow	*Aerva persica*
hidow	*Dactyloctenium scindicum*
hareeri	*Terminalia* sp(p).
himir	*Boureria orbicularis*
hiinfaal	*Cola* sp. nov.
hiiran	*Hildebtandtia* sp(p).
hinshili	*Grewia tenax*
hohob	*Grewia* sp(p).
hubur	*Ziziphus hamur*
humbawwe/hambeewi#	*Lecaniodiscus fraxinifolius*
humbow siib	*Enteropogon* sp. *nov.?*
humur	*Ziziphus hamur*
hurbuule	*Dactyloctenium aegyptium*
idaad geri	*Acacia senegal/A. rovumae*
il magor	*Leptothrium senegalense*
jabaan jow	*Jatropha trifida*
jaade jaade	*Satanocrater* sp.
jamba jamba	*Acalypha fruticosa*
jambo	*Phyllanthus somalensis*
jarbo/jarba/jarbe	*Sporobolus helvolus*
jiilaal makreen	*Enicostema axillare*
jiir xalooli	*Eriochloa meyerana*
jir	*Paspalidium desertorum*
jumeerik/jimeerik	*Barleria proxima/B. quadrispina*
kabesh/kobish/kemush	*Grewia villosa*
kabxaan	*Thespesia danis*
kishi	*Cadaba glandulosa*
kobon	*Thespesia danis*
kukih	*Commiphora* sp(p).
kulaan/kulun	*Balanites* sp(p).
kurdo	*Sporobolus agrostoides/Urochloa trichopus*
lafaay	*Flueggea virosa*
lavueeti	*Sesbania bispinosa*
liilow	*Celosia polystachia*
liwondho	*Sporobolus helvolus*
maalige	*Maerua* sp(p).
maaliqo	*Phoenix* sp.
macaratiil	*Indigofera* sp.
maci	*Euphorbia acalyphoides*
madah dhalis	*Seddera bagshawei*
madow madi edi	*Aerva persica*
mahan buuq	*Combretum illiari?*
majabe	*Phyllanthus somalensis*
makadey	*Sorghum arudinaceum*
makadey weyn	*Rotboellia cochinchinensis*
makaruumbi waaweyn	*Solanum incanum*
makongowey	*Acacia rovumae*
malaasow	*Digitaria acuminatissima*
mandharud	*Ximenia caffra*
mardaf	*Combretum aculeatum*

mared	*Cordia sinensis*
mareer	*Cordia sinensis*
mareer delib+	*Cordia goetzei*
mareer dool	*Cordia goetzei*
mareer orgaawe	*Cordia chisimajensis*
mareer orr gab	*Coffea rhamnifolia*
mar mardool	*Gardenia fiorii*
marjis	*Premna resinosa*
maroodi masiibe	*Ormocarpum kirkii*
maroodi matagen	*Ormocarpum kirkii*
masaar jabis	*Lepisanthes senegalensis*
mataan biyood	*Polysphaeria multiflora/ Sorindeia madagascarensis#*
meygaag	*Boscia minimifolia*
mudweyneeye	*Justicia* sp(p).
mukey	*Ficus sycomorus*
mukoy*	*Ficus sycomorus*
murishi	*Grewia tenax*
qabato	*Ziziphus mucronata*
qabi yari	*Euphorbia erlangeri*
qansaax/qansah	*Acacia reficiens*
qalanqaal	*Boscia coriacea/Cadaba spinosa+*
qal foon	*Cucumis dipsaceus*
qashin	*Senra incana*
qardo	*Rhynchosia minima*
qarunjo	*Cucumis dipsaceus*
qeendhi	*Tribulus terrestris*
qonji	*Cyperus compressus*
qoor(a)qabad	*Capparis sepiaria*
qoqon/qoqoon	*Combretum hereroense*
qurac	*Acacia tortilis*
qurdhubo	*Terminalia parvula*
quujo	*Cyperus compressus*
quul	*Setaria incrassata*
raasoow	*Northosaerva brachiata*
ramay	*Eragrostis cilianensis*
ramoole	*Sesbania sesban*
reexan	*Ocimum canum*
reydab	*Albizia anthelmintica*
riig	*Acacia reficiens*
roosac	*Commiphora campestris*
rufle	*Seddera bagshawei*
saaq saaq	*Ipomoea plebeia/Rhynchosia minima*
saar saar	*Rhynchosia minima*
saar saar hajiimow	*Ipomoea pes-tigridis*
sabciin	*Harrisonia abyssinica*
sakaay	*Veronia cinerea*
salaamac	*Sesamothamnus busseanus*
salbir	*Enicostema axillare*
sanriibi	*Ecbolium violaceum*
sariibiye#	*Pupalia lappacea*
sariin	*Duosperma eremophilum*
sarman	*Acacia horrida*
saydhi	*Chloris virgata*
seef dhaley	*Saccharum spontaneum*
seer	*Sporobolus fimbriatus*
shaati weebid	*Cyperus* sp. nov.
shabkaxle	*Drypetes natalensis*
shalbir	*Echinochloa colona*
shalooley	*Uvaria* sp.
shanfar(y)ood	*Garcinia livingstonei*
shiin shi	*Barleria quadrispina*
showri+	*Diospyros cornii*
sir mokaay	*Veronia cinerea*
subagoole	*Cressa cretica*
sunbul	*Veronia cinerea*
toosi	*Boscia tomentella*
tugaar	*Acacia nilotica*
umbulisaanga#	*Salacia stuhlmanniana*
ur uriqey	*Cassia longiracemosa*
wabaayo booneed	*Olea capensis*
wan are	*Lannea* sp(p).
waraan kool	*Spirostachys venenifera*
wisil dureed	*Indigofera schimperi*
xamakow	*Edithcolea grandis*
xanyo goleed	*Rinorea elliptica*
xararaay	*Allophylus rubifolius/ Flueggea virosa*
xaye goleed	*Rinorea elliptica*
xuskul	*Sansiviera* spp.
yaaq	*Adansonia digitata/Commiphora africana*
yacay	*Sericocomopsis hildebrandtii*
yagar	*Hibiscus cannabinus/H. hildebrandtii*
yululu	*Corchorus olitorius/C. trilocularis*

Destructive sampling is needed to conduct proper forest inventory in areas where mass/dimensional relationships are unknown. Such procedures are technically exacting and time consuming. An example of the painstaking methodology is provided by Bird (1988). The JESS project was not an appropriate activity for making such detailed assessments.

Throughout JESS, published regressions were sought relating crown dimensions of East African trees and shrubs to dry weight. Concurrently with JESS, the British Forestry Project, Somalia, was conducting the most thorough bushland biomass inventory yet performed in East Africa. In addition to published information, Denis Herlocker kindly provided unpublished data from his work in Marsabit District, northern Kenya.

The following relationships were examined. Mass is given in kilograms oven-dry weight; linear or area measurements are in meters or square meters.

- Western *et al.* (1981). A 22-species regression derived from trees and shrubs from the Amboseli region of Kenya. Both crown volume and crown area were used; for comparative purposes the following relationship is used here (and in Figure 20; line A = Western). Crown area was converted to diameter assuming a circular crown.

- Epp *et al.* (1982). Eight relationships were published, four for individual *Acacia* species, one for *Commiphora* spp., and three for various combinations of species. Data are for trees and shrubs from various semi-arid sites in Kenya. For all species combined, the relationship is (Figure 20; line MED = EPP;all)

  log[mass] = 0.04 + 1.53 log[crown area]

  mass = -7.76 + 7.49[crown diameter]

- A series of regressions determined by Herlocker (unpublished) in Marsabit District, Kenya. Two of these relationships are shown in Figure 20; for a mixture of *Acacia* species (line LOW = Herlocker; ACACIA) and for *Balanites* sp (line C = Herlocker; BALANITES). These are the highest and lowest lines in Herlocker's data.

ACACIA:

mass = -8.75 + 5.64[crown diameter]

BALANITES:

mass = -13.85 + 16.08[crown diameter]

- Bird (personal communication) has related crown diameter of *Acacia bussei* in Bay region, Somalia, to total weight (Figure 20; line HIGH = BIRD; TOTAL). He has also produced a relationship between crown diameter and weight of wood suitable for charcoal (Bird 1988; line D = BIRD; (CHARCOAL)).

TOTAL:

ln[mass] = -1.00547 + 3.02246(ln[crown diameter])

CHARCOAL:

ln[mass] = -4.1640 + 4.05271(ln[crown diameter])

- Watson and Nimmo (1985) used a somewhat different relationship involving crown diameter, tree height, and volume of saw wood. Typical heights and crown diameters from TEBS monitoring sites have been substituted in the equation, converted to "charcoal usable" wood (Watson and Nimmo 1985), and expressed as dry weight assuming a specific gravity of 0.6 (Synnott 1988). The result is line B = WATSON (CHARCOAL) in Figure 20.

In comparing lines in Figure 20 it should be remembered that the only statistically rigorous and verified relationships are those of Bird. The first point to note is that some relationships are arithmetic and others allometric. There is little doubt that over a wide range of sizes, allometric relationships are to be expected. However, for relatively small plants, arithmetic equations are appropriate. The studies of Herlocker and Epp *et al.* concern trees up to 5 m crown diameter. Examination of data plots of Bird (1988) show that an arithmetic relationship is suitable for smaller *A. bussei* plants, up to a crown diameter of perhaps 10 m. After this size, a logarithmic relationship is clearly required.

The second point to note is that the lines of Western *et al.* and Watson and Nimmo are substantially higher than other plots, particularly for larger plants. The appropriate comparisons are WESTERN with BIRD; TOTAL and WATSON with BIRD; CHARCOAL. Bird (1988) questions the methods (statisti-

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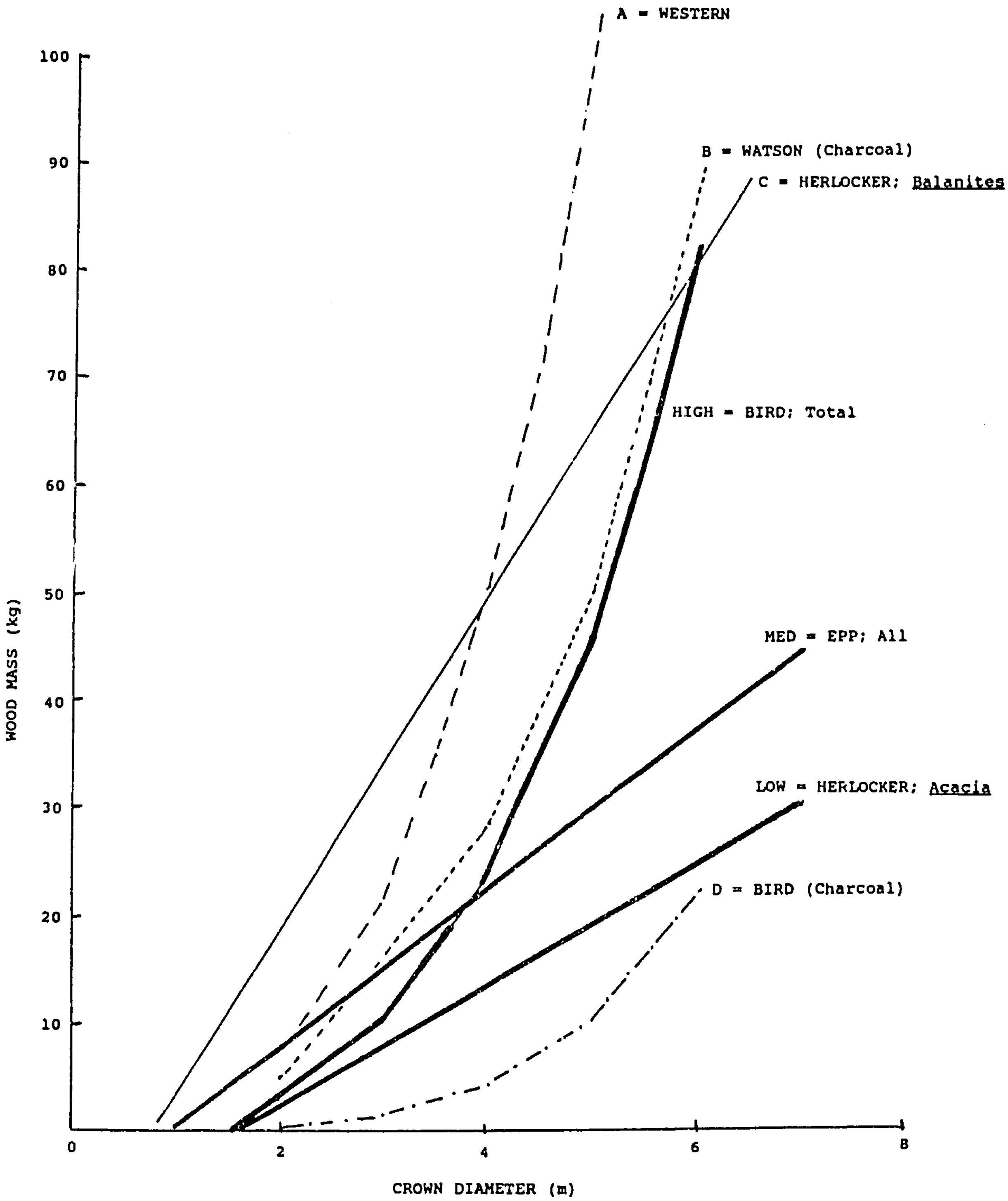

Figure 20. Comparison of several regression predictions relating dry mass of individual trees and shrubs in East Africa to their crown diameter. (See text for sources.)

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cal and sampling) used in these studies. The relationships of Epp *et al.* and Herlocker are more compatible with those of Bird, albeit relating to other species. *Acacia bussei* has a particularly high specific gravity. It may, therefore, be expected that wood mass for a given crown diameter will be higher than for other *Acacia* species, as is the case in Figure 20.

For JESS purposes it is concluded that the most appropriate relationships are those of Bird, Epp *et al.*, and Herlocker.

Applying Tree Mass Regressions to JESS Data

For each JESS ground monitoring site, three regressions were used to determine the mass of each woody plant of crown diameter greater than 2 m. It was assumed that smaller plants have negligible wood mass (as indicated by Figure 20). The three regressions used are labeled HIGH, MEDIUM, and LOW in Figure 20. Plant masses were summed for each site and expressed as tonnes per hectare.

Monitoring sites were then grouped according to vegetation structure using the classification developed in Section VI and Appendix C. Results are given in Table 30. Table 17, in the body of the text, was derived from Table 30 as follows.

For "bush" dominated sites (*i.e.*, shrubs and trees <5 m high) the LOW and MEDIUM regressions were deemed applicable. These relate to *Acacia* spp. and *Commiphora* spp., which dominate the Jubba bushlands. Since *A. bussei* is uncommon, a relationship predicting lower wood mass than HIGH (*A. bussei*) is appropriate.

For woodland and forest communities (dominant woody plants >5 m tall) the MEDIUM and HIGH regressions were used. Among these bigger plants an allometric relationship becomes increasingly appropriate as in the HIGH regression.

To obtain a "best estimate" of biomass for each vegetation type, the median of LOW and MEDIUM was used for bushland sites and the median of MEDIUM and HIGH for woodland and forest sites. These estimates are presented in Table 17. It must be emphasized that this approach is "rule of thumb" and neither accuracy nor precision can be determined. However, results in Tables 30 and 17 show sensible gradations between tall and low vegetation types and open and dense vegetation types. Standard errors within vegetation types are low indicating the homogeneity of the vegetation types selected.

Table 30. Biomass predictions applied to JESS ground monitoring sites grouped by structural vegetation type. High, medium, and low refer to application of similarly labeled regression lines in Figure 20.

		BIOMASS TONNES PER HECTARE					
		HIGH		MEDIUM		LOW	
VEGETATION TYPE	N[1]	MEAN	SEM[2]	MEAN	SEM	MEAN	SEM
Forest	10	225.9	67.7	34.5	4.2	22.4	2.6
Dense woodland	2	74.8	(20.6)	12.1	(1.6)	8.3	(1.1)
Open woodland	2	12.7	(2.8)	3.0	(0.6)	2.0	(0.4)
Wooded grassland	2	2.6	(1.1)	2.0	(0.6)	1.0	(0.6)
Bushland thicket	14	55.9	7.5	33.2	4.6	18.8	2.2
Dense bushlanld	6	16.1	1.7	11.5	0.5	6.9	0.3
Medium bushland	11	13.5	1.5	6.7	0.3	4.1	0.2
Open bushland	15	7.7	0.8	4.6	0.4	2.6	0.2
Sparse bushland	4	3.7	(0.5)	2.6	(0.2)	1.6	(0.1)
Bushed grassland	10	2.7	0.8	2.2	0.4	1.3	0.3

[1] *N = number of sites*
[2] *SEM = standard error of mean; those in parentheses are dubious, since N< 5*

Another way to judge these biomass figures is to compare them with estimates for other areas. As expected, data presented by Western *et al.* (1981) and Watson and Nimmo (1985) for vegetation communities are much higher than the JESS estimates. However, other authors give figures for wood biomass closer to those in Table 17. Bird's total biomass estimate of approximately 5 t ha^{-1} for open bushlands of *A. bussei* (personal communication) is similar to the JESS estimate. Lusigi (1984) gives wood biomass estimates of 0.5 to 11 t ha^{-1} for a variety of open bushlands and woodlands in Marsabit District, Kenya. In *Acacia seyal* coppice bushland in Senegal, Gibson and Muller (1985) recorded biomass of 2 to 8 t ha^{-1}. In conclusion, the JESS estimates seem reasonable. They probably err on the side of conservatism, particularly for woodlands and forests.

Estimation of study area under each vegetation type is described in Sections VI and VII. The "mixed" vegetation type (Tables 17 and 19) is from aerial photographic monitoring sites. Most "mixed" sites are in Lower Jubba and contain a composite of large trees, degraded bush, farmland, thicket, and grassland. Biomass is arbitrarily fixed at 5 t ha^{-1} based on examination of the photographs.

Estimating Wood Production

If little data on wood biomass for East Africa exists, even less is known about growth rates. The literature gives rates of net primary production per unit of standing crop, however. Most of this data comes from other areas of the world. Western *et al.* (1981) assess this data and present a graph relating net primary production to biomass. This compilation is independent of their biomass regression which is criticized above. Watson and Nimmo (1985) used similar sources in assessing wood growth. Figure 5 in Western et al (1981) has been used to produce usable wood production estimates for JESS vegetation types (Table 19). Annual wood production is assumed to equal 50 percent of total net production (Western *et al.* 1981). Wood production as a percentage of standing biomass ranges between 1.5 percent for forests to 5 percent for bushed and wooded grasslands and open bushlands. Usable wood is defined as that greater than 2 cm in diameter. Western *et al.* (1981) estimate usable wood as averaging about 70 percent of total wood. Gibson and Muller (1985) assessed wood suitable for charcoal (5 cm diameter) as 60 percent of total biomass, while Bird (personal communication) gives a figure of 40 percent for charcoal wood on a vegetation community basis. For JESS purposes, it is assumed that 60 percent of wood production is usable as firewood. Substantially less is suitable for charcoal, but charcoal manufacture is rare in the study area. These various factors are combined to give estimates of "usable wood production" for each vegetation type in Table 19.

As with biomass, JESS wood production figures are conservative. Usable wood production ranges from 0.05 t ha^{-1} $year^{-1}$ in bushed grasslands to 0.6 t ha^{-1} $year^{-1}$ in forest. Lusigi (1984) reports estimates equivalent to a maximum of 0.4 t ha^{-1} $year^{-1}$ for bushlands in Marsa' it District. Annual usable coppice wood production from *Acacia seyal* bushlands was 1.1 t ha^{-1} in Senegal. However, the management system in that area probably maximizes wood production (Gibson and Muller 1985). Western *et al.* (1981) estimate usable wood mass production as 0.02 to 5 t ha^{-1} $year^{-1}$ in Kenya's rangelands. However, they used their own estimates of wood biomass which have been judged too high (see above). Using the Marsabit and Senegal information, it may be reasonable to double the JESS estimates of usable wood production to obtain a less conservative assessment.

The only data available on increment of wood biomass in the study area comes from three JESS bushland sites in the floodplain. Each was cleared for agriculture and then abandoned a known number of years ago (Section VI.D). Using the methods outlined above it is assessed that these sites have had an average annual increment of usable biomass of between 0.6 and 2.5 t ha^{-1}. However, such data cannot be applied to other JESS sites for two reasons. First, these floodplain sites are likely to be more productive than non-floodplain sites. Most wood production and collection will inevitably occur away from the floodplain, although a proper assessment of floodplain production potential would be useful. Second, these sites began from zero biomass. The early stages of biomass increment are likely to be more rapid than when a mature community is present.

Forage Yield of Range Plants

Herbaceous Forage

Forage yield is defined as ungrazed harvestable above-ground biomass (dry matter) of herbage at the end of a growing season (Deshmukh in press). This quantity is not equivalent to net above-ground primary production, which is often double forage yield (see Deshmukh 1986b). Direct measurements of forage yield were made at TEBS ground monitoring sites after gu' rains of 1986 and 1987 and through other seasons (Appendix A; TEBS data bases).

It was expected that differences in forage yield would be apparent for different JESS vegetation types such that more heavily wooded sites would have less herbaceous vegetation. However, such differences were not clear. In the river-dependent zone, lack of such a relationship is attributed to a degraded herb layer (Section VII.D.1). In the floodplain, sites tended to be rather open with good grass cover or densely wooded with a negligible herbaceous stratum.

The approach finally adopted was to relate forage yield to estimated mean annual rainfall for each river section (rainfall is given in Section III.A.2 and Table 31). Mean annual rainfall was used rather than that received for a specific study period, because rainfall data are incomplete for 1986 when most vegetation data were collected. Peak herbaceous standing crop (post gu') for each river zone with ground monitoring sites is plotted against rainfall in Figure 16. Only sites with substantial grass growth were used in the relationships. Regression equations are:

floodplain:
$y = 15.62x - 1020.44 \quad (r^2 = 0.95)$

river-dependent zone:
$y = 10.79x - 1598.66 \quad (r^2 = 0.82)$

(y = forage yield, kg ha^{-1}, dry matter; x = gu' rainfall, mm)

Mean annual rainfall is substituted for gu' rainfall to give estimates for annual forage yield in each river section (Table 31). Figure 17 also shows a similar relationship for grasslands throughout eastern and southern Africa (Deshmukh 1984).

Table 31. Predicted herbaceous forage yield (kg ha^{-1} year^{-1}) in each river section comparing floodplain and river-dependent zone in years of average and low (drought) rainfall. Average rainfall is from Section III of this report. Low rainfall is a "typical" bad year (rather than absolutely lowest) of rainfall chosen by examination of long-term records for the study area presented by Watson and Nimmo (1985).

River Section	Mean Annual rain (mm)	Forage yield		Drought rain (mm)	Forage yield	
		FP	NFP		FP	NFP
I	300	3,666	1,692	200	2,104	559
II	350	4,447	2,178	200	2,104	559
III	400	5,228	2,717	300	3,666	1,692
IV	450	6,009	3,257	350	4,447	2,178
V	550	7,571	4,336	400	5,228	2,717
VI	650	9,113	5,415	450	6,009	3,257
VII/VIII	400	5,228	2,717	300	3,666	1,692

Herbaceous forage yield was extrapolated to the study area using the following assumptions:

- Land under range was estimated as the sum of "open" and "enclosed" land in Table 10.
- Rangeland under each TEBS vegetation type in each river section was calculated using the proportion of aerial photograph monitoring sites under each vegetation type for the floodplain and river-dependent zone.
- In the floodplain, forests, dense woodlands, and thicket bushlands were assumed to have negligible herbaceous forage, whereas dense bushlands had half of the forage yield predicted by the first equation above. All other vegetation types were regarded as having forage yield equal to that predicted for the relevant river section. These assumptions are derived from examination of TEBS data bases.
- In the river-dependent zone, the same assumptions about vegetation types were made, except that dense bushlands were assumed to have the full forage yield predicted by the second equation above (as the TEBS data base suggests). In addition, a multiplicative factor was introduced for

sites which were expected to have herbaceous vegetation because of low woody cover, but had a negligible amount. The factor is based on the proportion of TEBS ground monitoring sites which had negligible standing crop post gu'. In River Section II, the factor is 0.25; in River Section IV, 0.6 (i.e., 75 percent and 40 percent of sites had negligible standing crop, respectively). River Section II factor was applied to River Section I and a factor of 0.4 interpolated for River Section III. No adjustment was needed for other river sections.

Forage from Bushes and Trees

Very few estimates have been made of browsable forage in East African rangelands. Ecosystems (1985), using data gathered by the Integrated Project on Arid Lands (Marsabit District, Kenya), produced a predictive equation relating browse forage yield to rainfall and woody canopy cover:

$$y = 0.02x + 10.00A - 0.04 \quad (r^2 = 0.88)$$

(y = browse dry weight, kg ha^{-1} year^{-1}; x = mean annual rainfall, mm; A = percent woody canopy cover).

Species composition of the Kenyan study area is similar to that of TEBS river-dependent zone, although woody cover tends to be lower in the former. It is not possible to verify the accuracy of this relationship for TEBS study area. The only other published account known to JESS of browse production in East Africa is Wijngaarden (1985). Direct comparisons with the Ecosystems (1985) relationship are difficult. Wijngaarden's equations are more strongly influenced by rainfall than Ecosystems' and also take into account browsing pressure. At 10 percent canopy cover and 200 mm rainfall (and low browsing pressure), the two relationships produce similar predictions. Under most other feasible combinations of conditions, Wijngaarden predicts higher forage yield. Species composition of Wijngaarden's study area is less similar to TEBS than Marsabit District which has a much larger data base. It was concluded that Ecosystems's equation provides the best estimate available for TEBS study area. However, it must be emphasized that predicted browse yield cannot be verified unless complex field measurements are made in TEBS study area.

The relationship was applied to JESS aerial vegetation monitoring sites in each river section. The proportion of land under each vegetation type is the same as for herbaceous vegetation except that "enclosed" areas (Table 10) were assumed to have negligible browse. Woody vegetation is usually cleared or sparse within enclosures. Predictions of browse forage yield for each vegetation type are given in Table 21. The regression model is insensitive to rainfall so that differences for different rainfall regimes are negligible. However, forage yield does respond markedly to percentage of woody cover, which is higher in wetter areas. Thus, wetter areas have higher browse yield as indicated in Figure 15 for the river-dependent zone. In computing forage yield for each section of TEBS study area, it is assumed that browse produced in forests and dense woodlands is not consumed by browsers, since many trees are too tall, most species are unpalatable, and browsing was not evident at such ground monitoring sites. It is assumed that only 50 percent of browse yield in thicket bushlands is available since livestock cannot penetrate denser clumps of bushes. When forage is scarce, however, pastoralists make some of this "unavailable" browse accessible to livestock by cutting branches from taller trees and shrubs. This additional source of forage has not been included in TEBS computations since quantitative estimates do not exist.

Figure 15 presents graze and browse forage yield for each river section comparing floodplain and river-dependent zones.

Forage Consumption by Large Herbivores

Many studies exist of daily forage intake of wild and domestic African herbivores. However, most of these relate to stall-fed animals in good condition and eating a good diet. Under semi-arid range conditions less food is consumed than by stall-fed animals, although fewer data exist. Deshmukh (in press) collected information from 10 studies on free-ranging animals (including cattle, camels, sheep, and goats) and derived the following relationship.

$$y = 0.885x - 1.445 \quad (r^2 = 0.98)$$

y = log of daily food intake (kg, dry matter); x = log of live body weight of animal (kg).

Using population structure adjusted body weights (Watson and Nimmo 1988) of 304 kg for a camel, 180 kg for cattle, 150 kg for donkey, and 18 kg for sheep and goats, the equation predicts a daily forage intake of 5.65, 3.56, 3.03, and 0.46 kg, respectively. A 1,000 kg hippopotamus consumes 16.2 kg per day.

Annual forage consumption for each species and river section is then computed using density of each species in different sections from Watson and

Nimmo (1988). Number of days to which each set of aerial census densities were applied are discussed in Section VII.D.

Balance Between Forage Yield and Herbivore Consumption

Figure 15 presents total forage yield as though it is all available to large herbivores. Using such data herbivore consumption always seems to be a relatively low proportion of forage yield even in areas where herbivore density is high (Deshmukh in press). One reason that forage is not all consumable is that a proportion is unavailable or inaccessible to large herbivores. Where woody vegetation is tall or dense, parts of the crowns cannot be reached even by tall herbivores such as camels. Ecosystems (1985) suggest that 50 percent of total browse yield is available to camels and 25 percent to goats in Turkana District, northern Kenya. These proportions are assumed to be applicable to TEBS study area.

A similar situation applies to herbaceous forage. Accessibility is not a problem, except in thickets. Nevertheless, it is generally assumed that only about half of herbaceous forage is consumable by large herbivores over large areas, even though consumption locally may be higher. Herbaceous forage is lost to insects, decomposers, and by wasteful feeding methods and trampling by the large herbivores themselves (Deshmukh in press). Quantitative assumptions of proportion of herbage available include 50 percent (Watson and Nimmo 1985), 37.5 percent (Lusigi 1984), and 40 percent (Ecosystems 1985, who also quote 50 percent as the "standard practice in range science"). Measurements at ground monitoring sites in the floodplain indicate that as much as 70 to 80 percent of forage yield was consumed in some areas. An overall figure of 50 percent of herbaceous forage being available to large herbivores is considered reasonable for TEBS study area.

Balance between forage available and that consumed is given in Table 32 and summarized in Table 22. Assumptions are discussed above, or in Section VII.D. In Table 32:

- "goat browse" is 25 percent of total browse forage yield,
- "goat demand" is total annual goat food requirement,
- "camel browse" is any remaining goat browse from goat demand, plus a further 25 percent of total browse forage yield,
- "camel demand" is total annual camel food requirement,
- "browse balance" is [a) + c)] - [b) + d)],
- "total graze" is 50 percent of herbaceous forage yield,

Table 32. Computations of available forage and demand by grazers and browsers in different river sections (kg ha^{-1} $year^{-1}$).

River Section	Goat Browse	Goat Demand	Camel Browse	Camel Demand	Browse Balance	Total Graze	Grazer Demand	Graze Balance
A. FLOODPLAIN								
I	66.3	224	66.3	996	-1,087	2,582	34	+1,648
II	52.1	280	52.1	338	-513	2,920	652	+2,268
III	77.4	60	94.8	177	-82	1,962	507	+1,455
IV	75.4	9	141.8	344	-202	2,612	532	+2,080
V	100.0	10	190.0	54	+136	2,937	612	+2,325
VI	61.2	22	100.4	15	+85	2,490	630	+1,860
VII/VIII	50.8	16	85.6	23	+63	1,513	1,961	-448
B. RIVER-DEPENDENT ZONE								
I	81.3	69	93.6	326	-232	394	115	+279
II	97.1	49	145.2	137	+12	512	190	+322
III	99.4	27	171.8	223	-51	783	168	+615
IV	135.7	16	255.4	416	-161	1,820	193	+1,627
V	145.5	4	287.0	230	+57	3,172	258	+2,914
VI	137.6	17	258.0	137	+121	4,018	146	+3,872
VII/VIII	131.5	13	250.0	155	+95	1,840	151	+1,689

- "grazer demand" is total annual food requirement of cattle, sheep and donkeys, and
- "graze balance" is [d) - e)].

As elaborated in section VII.D.3, it is realized that the livestock species all consume browse and graze, but in different proportions. The analysis presented deliberately avoids having to assign such proportions since no information is available for the study area. However, camels and goats are given "first serving" of browse and cattle, sheep and donkeys "first serving" of graze.

The analysis is repeated for a "drought year" and summarized in Table 22. Browse yield was not altered because lower rainfall had negligible effect on estimates in Table 21. Herbaceous forage was reduced according to the predictive equations above (see Table 31).

Scientific Names of Animals Not Given in Text – Appendix H

COMMON NAME	SCIENTIFIC NAME
honey bee	*Apis mellifera*
tsetse fly	*Glossina* spp.
crocodile	*Crocodylus niloticus*
ostrich	*Struthio camelus*
duiker	*Cephalophus* spp.
gerenuk	*Litocranius walleri*
waterbuck	*Kobus ellipsiptymnus*
reedbuck	*Redunca redunca*
bushbuck	*Tragelaphus scriptus*
lesser kudu	*Tragelaphus imberbis*
oryx	*Oryx beisa*
oribi	*Ourebia ourebia*
dibatag	*Ammodorcas clarkei*
Soemmering's gazelle	*Gazella soemmeringi*
Grant's gazelle	*Gazella granti*
Hunter's antelope/ hartebeest	*Damaliscus hunteri*
topi	*Damaliscus korrigum*
giraffe	*Giraffa camelopardis*
black rhinoceros	*Diceros bicornis*
plains (Burchell's) zebra	*Equus burchelli*
Grevy's zebra	*Equus grevyi*
elephant	*Loxodonta africana*
warthog	*Phacochoerus aethiopicus*
bushpig	*Potamochoerus porcus*
hippopotamus	*Hippopotamus amphibius*
baboon	*Papio anubis*
vervet monkey	*Cercopithecus aethiops*

Appendix I, "Vegetation Survey of the JubbaValley and Baardheere Reservoir Zone", which follows, combines information from *JESS Report No. 9* – "Interim Report on Vegetation Survey of the Jubba Valley," Christopher F. Hemming, October 1986 and *JESS Report No. 23* – "JESS Interim Peport: Vegetation Survey of Baardheere Reservoir Zone," Christopher F. Hemming, August 1987. Associates in Rural Development, Burlington, Vermont.

Preface

This report presents the results of two separate consultancies by Mr. Christopher Hemming of Resource Management and Research, Ltd. (RMR), employed on a subcontract basis to assist JESS ecologist, Dr. Ian Deshmukh, in botanical investigations of the Jubba Valley and proposed Baardheere Reservoir zone.

The first consultancy, 13 July to 28 August 1986, involved field collections of specimens in the Jubba Valley from Baardheere to Goob Weyn. Thirty-six sites were selected for vegetation study and 222 plants were collected.

The second consultancy was carried out from 24 June to 29 July 1987 and concentrated on the proposed Baardheere Reservoir inundation area, which is between Luuq and Baardheere (See Figure 1 in the front of this volume.) Approximately 119 specimens were collected at 32 vegetation monitoring sites.

Mr. Hemming would like to acknowledge the assistance given him by the Ministry of National Planning and Jubba Valley Development (MNPJVD), the U.S. Agency for International Development (USAID), and Associates in Rural Development, Inc. (ARD). Help rendered in the field by the Jubba Sugar Company, Fanoole Rice Project, and Mogambo Rice Project was greatly appreciated. Finally, Mr. Hemming wishes to thank Dr. Deshmukh for his hospitality and many kindnesses; Mr. Bashir Sheikh Yusuf, whose knowledge of Somali botany was utilized extensively during the fieldwork; and JESS field team members, Abdulkadir Haji Ibrahim and Mohamed Hared.

I. Executive Summary

With assistance from the JESS field ecologist, a botanist conducted his first two-month consultancy which involved preliminary botanical surveys, development of recommendations for future botanical studies, and identification of botanical specimens. This was the first of two botany consultancies to be performed as part of JESS.

During this consultancy, a contact was established with the Herbarium of the National Museums of Kenya, and two field trips were made to the Jubba Valley between Baardheere and Goob Weyn. On the first trip, 13 sites were selected for vegetation study in the area north of Jilib; on the second, an additional 23 sites were selected in the lower and middle Jubba regions.

At each site, the general ecology was described (including soil information), vegetation measured, and plants identified and/or collected. When available, local informants were questioned on such subjects as the flooding regime, grazing practices in relation to tsetse flies, and local names and uses of plants.

Two hundred twenty-two plants were collected and divided into four sets for the following collections:

- Herbarium of the National Museums of Kenya;
- Herbarium of the Royal Botanic Gardens at Kew;
- National Herbarium of Somalia at the National Range Agency; and
- National University of Somalia.

The sets of plants for Nairobi and Kew were delivered by Mr. Hemming.

Extensive field notes were left with the JESS team in Muqdisho to support this report, which is essentially a summary of those pages.

During the second consultancy, field trips were made to 32 vegetation monitoring sites on the east and west banks of the Jubba River, from Luuq south to the Baardheere dam site (coinciding with the future reservoir zone). Specimens of 28 grasses and sedges, 23 dwarf shrubs, 30 forbs, 28 shrubs, and 10 bushes and trees were collected and delivered to herbariums in Somalia, Kenya, and the United Kingdom for subsequent identification.

While much vegetation in the lower parts of the reservoir zone will be irretrievably lost to flooding, dynamic vegetational changes will occur in the drawdown zone. Recommendations are made to maintain selected areas or plots in natural vegetation, even though most of the reservoir drawdown area will be used for temporal agriculture. The Ministry of National Planning and Jubba Valley Development (MNPJVD) should establish a monitoring unit to study the changes that will occur as the result of project development—especially in the drawdown zone and reservoir margin.

II. Vegetation Survey of the Jubba Valley

A. Introduction

This chapter of the report on botany field studies focuses principally on primary data collection in the Jubba Valley. The objectives of the first consultancy were:

- ground-truthing vegetation maps and available aerial photography;
- selecting and establishing vegetation transects for analysis;
- conducting preliminary ethnobotanical surveys and recommending procedures for continuing studies;
- identifying botanical specimens in the field and at the National Herbarium of Somalia; and
- establishing a liaison with appropriate herbaria in East Africa and the United Kingdom.

This report is largely descriptive in nature. Phase III of JESS will consist of analyses of field data collected during Phase II and other secondary data. Another botany consultancy during June and July 1987 was an extension of the inventory work begun during this consultancy (particularly in the inundation zone above the future dam) and provided more information for development of a long-term vegetation monitoring system (see Section III).

B. Technical Discussion

1. Ground-truthing Maps and Aerial Photographs

The physiographic and land-use interpretation prepared by Agrar-und HydroTechnik GMbH (AHT) for their dhesheeg study, and presented in an aerial photomosaic at a scale of 1:50,000, was used as the basic source for site selection. Quality of the interpretation was generally high. The land units recognized proved highly suitable for this consultancy and saved considerable time. Had these data not been available, much of the consultancy would have been spent in establishing criteria and boundaries for suitable land units, and little progress would have been made in the selection and description of sites.

Photograph interpretation was found to be at fault in only one geographic area. A small area near Jamaame was described as "flat floodplain with external drainage," but was, in fact, found to be slightly elevated and gently sloping so that it is never flooded. To the west of Jamaame, there was extensive flooding in mid-August 1986, in an area that the AHT interpretation indicates is rarely flooded, if ever. This may be due to the fact that the 1983 photographs were taken during a dry period, but it still requires clarification. It is recommended that all interpretation differences be brought to the attention of AHT and discussed with them.

2. Transects for Vegetation Analysis

Thirty-six sites were selected between Baardheere and Goob Weyn on both sides of the Jubba River. As indicated in Table 33, the sites are located in both floodplain and non-floodplain land classes, and are further described in Deshmukh 1989 (in this volume).

Table 33. Vegetation Study Sites

MAJOR CLASS	CATEGORY (AHT)	NO.	SITE DESIGNATION
Floodplain	L=Levee/Bank	7	4,5,8,10,17,32,33
	D=Dhesheeg	8	2,6,12,13,15,19,21,28
	d=External Drainage	7	14,16,20,24,25,29,31
	H=Heterogeneous Alluviums	2	27,34
	W=Wadi	2	1,36
Subtotal		26	
Non-Floodplain		10	3,7,9,11,18,22, 23, 26,30,35
Total		36	

Notes:

1. Two sites were on old levees where the river no longer runs.

2. Since construction of the Fanoole Barrage, three dhesheegs have either undergone no flooding or have had much reduced flooding.

3. Two sites were included to examine the effects of fires on non-floodplain areas.

In addition to recording the plant species found at and around each site, local informants were questioned on a range of issues (when possible), including the following:

- frequency and season of flooding;
- duration and depths of floods; and
- any changes noted since construction of the Fanoole Barrage.

These particular questions focus on the types of changes to be expected after completion of the Baardheere Dam. Furthermore, provided any perceived changes can be correlated satisfactorily with hydrologic and meteorologic records for this part of the valley, these questions may provide useful insights into likely consequences of construction of Baardheere Dam.

It is recommended that this possibility be borne in mind for future site selection and an attempt be made to secure more information on local perceptions of changes in the flooding regime following construction of the Fanoole Barrage. These changes should then be examined by careful reference to actual hydrometeorologic records.

3. Identification of Botanical Specimens and Herbaria Liaison

Many plants were identified in the field. However, identification was not possible at some riverine sites where tree species were either very tall (30 meters), making the collection of identifying material impossible, or the species were not in flower or fruit. Nonflowering specimens were also collected, but there is no guarantee that all of these items can be identified. Hence, it is recommended that on future visits to the sites, plants should always be collected when found flowering or bearing fruit.

At some study sites, a high proportion of plants could be identified in the field. For example, at site 35, 21 plants were identified to the generic level, 10 to the specific level, and eight collected for identification. Two hundred twenty-two plants were collected at and around the 36 sites studied in detail, and a few additional plants of special interest were collected wherever they were found in good condition. For instance, specimens were collected to investigate the identity of the two largest *Acacia* spp. in the Jubba Valley. Of the 222 plants collected, 35 were grasses and sedges. Since much of the study area consists of grasslands that are flooded seasonally, knowledge of the more common grasses is important.

The collection was divided into four sets for distribution to the following herbaria:

- the National Herbarium of Somalia at the National Range Agency;
- the herbarium at the National University of Somalia, which will be the working herbarium for this project;
- the Herbarium of the National Museums of Kenya, which contains the best collection of Somali plants in Africa, and where the grasses and sedges collected will be named; and
- the Herbarium of the Royal Botanic Gardens at Kew, United Kingdom, where the flowering plants will be identified.

To enhance the usefulness of the collection, summary habitat descriptions were prepared for each site, and these will be attached to the appropriate specimen labels. Plant herbarium labels for JESS were designed and printed in Muqdisho. They were filled out when plant identifications became available from taxonomists in early 1987 (see Appendix D in Deshmukh 1989).

Mr. J. B. Gillett and Ms. Kabuye agreed to help in naming plant specimens, provided they were in good condition and well-labeled. It is recommended that the two institutions they represent (the Royal Botanic Gardens at Kew and Herbarium of the National Museums of Kenya, respectively) be asked to help in future plant identifications, and that they be sent any specimens collected. The National Herbarium of Somalia is gradually acquiring a useful collection, but does not yet provide a comprehensive identification service.

4. Ethnobotanical Surveys and Further Studies

A large number of plants are used for special purposes beyond their more common uses, which include livestock forage, building and thatching material, and fuelwood. The fruit of many species are eaten, and large numbers of plants have medical uses (see the survey of traditional medical properties and uses of Somali plants carried out by the Somali Academy of Science [SOMAC]).

For this consultancy, the objective was to collect data about all possible uses of all plants. Such information was collected at 22 of the 36 sites. Informants ranged from passersby to guides who helped locate specific plants. In one case, the informant was a traditional healer. It is recommended that every effort be made to find an informant at sites where no data on plant uses have yet been collected. Questions to be posed to these informants include:

- What is the Somali name for this plant?
- What is this plant used for?

The responses should be recorded by a Somali team member who is fully conversant with the new orthography, and spelling should reflect local variations. In asking both questions, interviewers must be careful about the form of leading questions. All plant uses should be recorded even though there will be much repetition. During this consultancy, 151 plant uses were recorded and given to the JESS ecologist, Dr. Deshmukh.

5. General Recommendations on Site Descriptions

During the course of the fieldwork, a method was developed for describing the study sites. These descriptions consist of 116 pages of field notes that have been left with the JESS team in Muqdisho. The notes cover the site locations and descriptions, plant lists and collection numbers, and results of interviews about ethnobotany and site ecology. Recommendations were drawn from these notes and presented to Dr. Deshmukh for incorporation into his vegetation monitoring efforts.

Site Description

The following general points should be covered in the site description:

- geomorphology and topography (including geology, if known);
- drainage and erosion;
- grazing and browsing pressure, as indicated by the vegetation, track density, dung, and animals actually seen (*e.g.*, the presence of hippopotamus tracks should be recorded). Because it was clear in many places that grazing and browsing practices are severely controlled by tsetse flies, information on these issues should also be sought;
- human activity (*e.g.*, proximity to villages, infrastructure location, access), proximity of agriculture to the site, wood chopping for fuel or building materials, and charcoal production; and
- other biotic factors, *e.g.*, termites and ants; the presence or absence of *Pila*, the large East African water snail, which indicates flooding or extreme ponding; and of *Achatina*, the giant African land snail, which indicates that flooding is neither deep nor extensive.

A brief description of the topsoil should be made at each site. This portion of the site description should include:

- description of the surface cover by litter, sand, cracks, etc.;
- depth and horizons—only a rough indication of this can be given unless pits are dug, but some clues can be derived from the presence of stones or natural or man-made cuttings at or near the site (the riverine sites are generally deep, and horizons near the surface are unlikely to be seen);
- structure—ped shape (if any occur), hardness to ax, hardness of peds, and friability of peds if damp;
- consistency—stickiness and plasticity;
- texture—particle size descriptions using standard terms of sand, silt, clay, etc., and the U.S. Department of Agriculture's (USDA) soil-texture triangle;
- color—using Munsell soil color charts; and
- condition of soil at time of examination as dry, slightly damp, etc.—this is important as it will affect hardness, friability, and color.

All species of vegetation seen on or near the study site should be recorded in the following format:

Latin Name: Somali Name: Collection Number: Maximum Height: Frequency: Condition

The following terms are to be used to describe frequency and condition:

- frequency—dominant, common, frequent, occasional, rare; and
- condition—leafless, few young leaves, old leaves (for deciduous species), evergreen, pre-flowering, fruit-bearing, post-fruit-bearing, dry.

The vegetation summary should be based on the following terms:

- grassland;
- herbland;
- dwarf shrubland (less than 50 centimeters in height);
- shrubland (50 centimeters to two meters);
- bushland (two to four meters);

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- woodland (four to 10 meters, maximum height to be judged—10 meters is only a guideline); and
- forest (about 15 to 30 meters or more).

The main group should be chosen from one of these terms (*e.g.*, grassland). If there are numbers of shrubs in the grassland, it should be described as "shrubbed grassland." An indication of the density of plants should also be given (*e.g.*, sparsely shrubbed, tall, dense grassland with occasional trees). Genera should be included in the description where clear dominance and field identification is possible—for example, sparsely shrubbed *Phyllantus somalensis*, tall, dense grassland (*Sporobolus* spp.) with occasional *Dobera glabra* trees. If there is any clear vegetation pattern, such as arcs, clumps, or thickets, this should also be noted.

Local Information

Much valuable information can be gathered from local residents. It is recommended that every effort be made to obtain such information at every study site (for example, by bringing someone from the nearest village). The questions listed below have proven useful on field trips, but variations will be necessary to suit the ecology of specific sites.

Flooding Regime

- Does the site flood?
- How often? During which rainy season(s)?
- If both, which produces the most flooding?
- Does the floodwater remain or drain away?
- If it remains, how long does it stand?
- How deeply does the water stand?
- When did it last flood?
- What changes have been experienced in the flooding pattern since construction of the Fanoole Barrage?

Grazing Patterns

- Are tsetse flies ever present?
- Is the area used for graze/browse?
- If so, by whom (*e.g.*, local cultivators, local livestock owners, nomadic herders)?
- When is the area used most heavily?
- What diseases are animals inoculated against or which diseases is their regular prophylaxis for?
- Is the grass burned? Who burns it? When and how frequently is it burned?

III. Vegetation Survey of the Baardheere Reservoir Zone

A. Introduction

This chapter of the report presents the results of the second part of botany field studies in Phase II activities of JESS. The objectives of the second consultancy were to:

- assist in a vegetation survey concentrated in and around the inundation area of the proposed Baardheere Dam;
- locate and describe representative vegetation sites to be flooded, with emphasis on those sites of ecological, ethnobotanical, and conservation interest;
- examine sites at the edge of the future reservoir and in the drawdown zone in order to assess future vegetational change in this zone;
- suggest possible schemes for monitoring vegetational change around the reservoir and in the drawdown zone; and
- take primary responsibility for plant identification in the field and at herbaria receiving plant specimens.

This consultancy was to conduct a brief botanical inventory, and collect and later identify plant specimens from the area to be inundated by the proposed reservoir resulting from construction of the Baardheere Dam. Since the organization and identification of plant specimens is a long process involving multiple herbaria in three countries (United Kingdom, Kenya, and Somalia), this report cannot provide full descriptions of the botanical specimens collected, nor discuss (except in general terms) the significance of the collected material.

B. Technical Discussion

1. Vegetation Survey Comments

A field trip to establish and examine new vegetation survey sites in the area upstream of the Baardheere Dam site was undertaken between 4 and 22 July 1987. The timing of this trip was providential in a botanical context, as the Jubba River experienced unusually heavy flooding during late May and early June. By the time of the survey, soil moisture was still sufficiently high to prolong plant flowering and fruits were still visible. On a negative side, roads were nearly impassable due to mud. The flood was the largest in the last seven to 10 years. Various informants differed in their estimate of the time period, however, it was clearly an unusual flood.

A total of 32 sites were established and studied. These sites were situated on both the east and west banks of the Jubba River, being distributed from just north of Luuq to the dam site—approximately 30 kilometers north of Baardheere. The east and west distribution of the sites was from the present floodplain to above the margin of the proposed reservoir which is in a rugged part of northern Somalia. The reservoir is accessible by road at three points: Luuq, Buurdhuubo, and the dam site, but several tracks permit access at other points.

The 32 sites were studied using guidelines prepared during the first botanical consultancy (see Section II.B.5). The selected sites were located in the area to be perennially inundated, in the drawdown zone, and at the proposed reservoir margin. Table 34 shows the distribution of the locations in relation to the reservoir. Sites in this study are numbered from 60 to 91.

Table 34. Location of JESS Vegetation Sites 60 to 91

CATEGORY	SITE LOCATION	SITE NO.
1	Current Floodplain 10 sites (most to be permanently flooded)	60, 62, 64, 66, 68 70, 76, 77, 85, 89
2*	Drawdown Zone 9 sites (partially or completely submerged)	75, 78, 80, 82 **, 83, 86, 87, 88, 90
3*	Reservoir Edge 8 sites (145-155 meters above sea level [masl]	65, 67, 71, 72, 73, 81, 84, 91
4*	Above Reservoir 5 sites (above 155 masl)	61, 63**, 69**, 74, 79

**The soil/vegetation types sampled in categories 2, 3, and 4 are widespread and can be found in any adjacent zones.*

***Denuded areas around refugee camps.*

2. Vegetation Site Description

The sites to be flooded fall into two broad classes. The first class is the river floodplain, which is largely enclosed by thorn fencing. Part of each enclosure is usually used for maize production although sometimes, if the enclosure is within reasonable access of population centers, onions and tomatoes are grown. Sorghum is also being grown as a flood recession crop in some enclosures. Since the river floodplain is not flooded each year, many farmers have begun to use small pumps to draw irrigation water from the river. These pumps are temporary and can be moved from one enclosure to another. A large portion of most enclosures is not cultivated but used instead as a dry-season grazing reserve for the owner. Some areas that are normally irrigated were under pasture following the recent flood. As long as grazing is available elsewhere, grass in the enclosure remains largely unused. In one enclosure (site 70), no land was being cultivated.

Site 68 was prepared for irrigation some months ago, but the flood destroyed the crops which had been almost ready for harvest. Reported losses were 35 tons of maize, five trucks of onions, and a quantity of tomatoes.

At site 85, sorghum was planted on the receding floodplain after the maize crop had been destroyed. The sorghum was fully grown, but had not matured by 18 July.

The second class consists of natural dryland vegetation which is usually on gently sloping terrain, frequently very stony, and already under considerable pressure from grazing, heavy browsing, and chopping.

No sites of particular ecological, ethnobotanical, or conservation interest were seen, with the exception of the river floodplain. The rest of the area to be inundated is covered with vegetation typical to areas that will remain above the reservoir.

The 32 sites studied in this consultancy were (of necessity) determined by accessibility. It is recommended that a boat-based survey be undertaken in the northern and southern portions of the reservoir where steep terrain limits vehicular access. The boat survey, if undertaken, should concentrate on types of vegetation not encountered in this survey, such as woodlands other than *Acacia zanziburica*, and forest relicts, if present.

It clearly will not be possible to preserve any such areas (*e.g.*, riparian woodland or forest) as they will be inundated. However, before they are lost to rising reservoir waters, they should be collected exhaustively in order to know what has been irretrievably lost. Since the Jubba Valley is relatively unstudied botanically, recent collections have included occasional new species and many new records for Somalia. It is likely that, if extensively collected, a similar or higher proportion of new Somali records or species will be found in this interesting northern part of the Jubba River floodplain.

MNPJVD should encourage botanical collection in the inundation zone, primarily in collaboration with the National Herbarium of the National Range Agency (NRA) and the botany faculty of the National University of Somalia (NUS). It is also recommended that MNPJVD establish its own ecological monitoring unit as soon as possible to participate in the suggested botanical surveys. The MNPJVD staff would need some in-service training, which would be easily done if they were accompanied by National Herbarium staff on their first few field trips. If this should prove impossible, it might be necessary for a short-term consultant to train MNPJVD staff in collecting dry plant specimens and recording pertinent data.

The size of an ecological monitoring unit in MNPJVD will clearly depend upon the available financial resources for monitoring, but at a minimum, the unit should include one graduate agronomist or botanist, one field assistant, a driver, and a suitable four-wheel drive vehicle. It is likely that some of the area deserving study can only be reached by boat. JESS currently has two boats which can be placed at the disposal of MNPJVD for a variety of reservoir surveys, including botanical collections. However, due to the large number of crocodiles in the upper Jubba River, it is also highly recommended that MNPJVD use extreme caution in selecting a very capable boat pilot for any river expedition.

Floodplain dwellers recalled many cases of people and goats being taken by crocodiles. It is interesting that in this survey, no frames of branches and sticks were seen in the river which would protect people while collecting water or watering livestock. Such protective devices were frequently observed south of Baardheere during last year's botanical survey. This may be due to destruction by recent flooding.

At the moment, the Jubba River has steep banks along most of its length in the reservoir zone which are too steep for crocodiles. The risk of attack is greatest when people or stock climb down the bank to the river's edge. After the dam is completed, most (if not all) of the reservoir margin will have gently sloping banks which will allow free movement on the banks. River floodplain dwellers reported that after the flood this year, crocodiles came out of the main river channel onto the banks, but went back into the river when the flood receded. It can be anticipated that crocodiles will be a more serious pest after the reservoir is full. Control measures for crocodile skin exports could be a useful source of revenue, especially for foreign exchange.

3. Reservoir Margin

Examination of sites along the edge of the future reservoir and within the likely drawdown zone did not provide any distinct evidence of the vegetational change that will occur after the reservoir is in place. However, if one extrapolates from the evidence found in the present floodplain, there is a suggestion that deposition of rich alluvium (clay and silty sand) will cause soil enrichment. This, coupled with higher soil moisture, will lead to dramatic vegetation change on the reservoir perimeter.

Since the drawdown zone will be greatest in the central part of the reservoir, it is impossible to determine how much alluvium will be deposited in this zone, beyond saying that it will be the finer materials. It is likely that the drawdown zone soils will gradually improve as fine silts are deposited during maximum reservoir levels.

It is clear that the natural vegetation in the lowest levels of the drawdown zone (ca. 128 masl) will be killed by prolonged submergence, while those areas between 135 and 142 masl will be inundated for shorter periods of time and will benefit from alluvial deposition. Species composition will shift toward more flood-tolerant grasses, such as *Sporobolus helvolus* and *Echinochloa haploclada*, and away from the presently common annual dryland species. Any such change will be for the better as these perennial grasses will remain in an attractive grazing condition for a much longer period of time.

After the dam has been constructed, and if closure takes place during a wet season as anticipated, the water level should rise quickly. In addition, most of the present river floodplain will be submerged for much of the first year of filling and permanently so thereafter. As expected, the floodplain was the most useful and productive ecological zone encountered during this survey. Most of this land is enclosed by thorn fencing and used for crop production and dry-season grazing reserves.

The permanent submergence of the river floodplain will displace the present users, which are more numerous than anticipated. These displaced people will presumably try to establish claims at the reservoir margin and in the drawdown zone. Initially, based on their floodplain experience, they will only have a vague idea of the land's potential as well as the best way to manage this area for crop and forage production.

As has been mentioned, the potential of these areas will, to a large extent, be dependent upon the amount of alluvium deposited. The soils encountered in the drawdown zone and at the reservoir perimeter varied from sandy to silty clay loams. This is a small variation and it seems likely that the slope and presence or absence of large numbers of stones will be deciding factors in determining the ultimate potential of these zones without added alluvium. Table 35 summarizes the slope in addition to rockiness for 17 sites (Categories 2 and 3 in Table 34).

Table 35. Soils of Drawdown Zone Sites

SITE TYPES	SITE NO.
Stony Sites	
Sloping	67, 71, 75, 84, 91
Level	88
Non-Stony Sites	
Sloping	65, 73*
Level	2*, 78, 80, 81, 82, 83, 86, 87, 90

gypseous soil

Table 35 shows that a large majority (nine out of 11) of the non-stony sites are basically level. In such areas where the slope is extremely gentle, a small drop in reservoir water level will expose a wide expanse of land which, particularly if improved by alluvium, will present new opportunities for crop or forage production. Site 72 has a puffed-up gypseous soil and its potential may be less than other sites unless it is covered by a deep amount of alluvium.

The development potential of the sloping sites is more problematic as areas close together will be covered with water for considerably different periods of time.

Stony sites are clearly less suitable for crop or forage production. It is interesting to note that five out of six of the stony sites are sloping and consequently, are likely to have low potential for crops.

There is only one fairly level stony site (site 88) and it is impossible to estimate the future potential of this site. It will, to a large extent, depend on whether or not it is gradually covered with sediments.

4. Vegetation Monitoring

Construction of the Baardheere Dam will be the most expensive development project ever undertaken in the Jubba Valley, if not in all of Somalia, and it will clearly have extensive ecological effects.

As noted previously, it is recommended that MNPJVD establish a small monitoring unit to study the changes that will occur as a result of reservoir operation (drawdown zone and reservoir margin). It is certain that the reservoir edge will be settled as soon as the reservoir is full. It is recommended that a number of these dwellers be selected and required to leave a small strip (ca. 10 meters) extending from 20 meters above the reservoir edge to the bottom of the drawdown zone. This strip should not be cultivated, and natural vegetation should be allowed to develop. These sites should be selected as soon as possible after the reservoir reaches its maximum normal operating level. The monitoring unit should record plant species and also measure the rate of deposition of sediments. Steel bars fixed in concrete at these monitoring sites would aid in measuring sediment deposition as well as establishing permanent markers for each study site.

In order to ensure success of the monitoring unit, MNPJVD must assure proper liaison with the dam operations team so that monitoring times can be determined in advance. MNPJVD should also establish working relationships with the NRA and the botany faculty at NUS.

5. Collections

During this consultancy, 119 plant specimens were collected at the 32 study sites (see Appendix D of the Terrestrial Ecology Baseline Studies [Deshmukh 1989]: Jess Final Report, Volume II, Part A). Most of the sites (22) were in dry habitats surrounding the present floodplain. In most of the floodplain, *Acacia zanzibarica* (open woodland with a layer of grasses and herbs) were found. This year, owing to the flood, it was possible to collect both grasses and herbs in flower and fruit-bearing condition. In years when there is no flooding, it is probable that the ground vegetation will be almost absent. In one place on the floodplain (site 76), moderately dense monospecific communities were found on two sides of a levee: *Tamarix aphylla*, near the river, and *Salvadura persica*, a few meters further from the river. The finding of such sites emphasizes the need for further collections in areas not covered by this survey.

The collected plants consisted of:

- 28 grasses and sedges;
- 23 dwarf shrubs;
- 30 forbs;
- 28 shrubs; and
- 10 bushes and trees.

In this survey, species diversity was much greater on the dry slopes than the floodplain. Most of the species recorded at the study sites were identified to generic level and many to specific level. The specimens collected mostly represent those that could not be identified in the field to specific level. Due to the recent flood and rains, a high proportion of specimens was collected in flower and fruit while the dry, windy weather provided ideal drying conditions. The specimens were divided into four sets for the following institutions:

- Herbarium of the National Museums of Kenya;
- Herbarium of the Royal Botanical Garden at Kew;
- National Herbarium of the National Range Agency; and
- Herbarium of the National University of Somalia.

The sets for Kew and Kenya were delivered by the consultant after leaving Somalia. Four sets of herbarium labels were prepared as well as summary descriptions of the sites which were attached to the specimens in addition to the labels.

Mr. J. B. Gillett of the Royal Botanical Garden at Kew and Ms. Christine Kabuye of the National Museums of Kenya have kindly agreed to continue identifying specimens for JESS. It is a pleasure to note the speed with which names have been supplied in the past year. The consultant, on behalf of JESS, would like to express his grateful appreciation.

Appendix J, "Riverine Forests of the Jubba Valley", which follows, was first published as *JESS Report No. 17* – "JESS Interim Report: Riverine Forests of the Jubba Valley, Issues and Recommendations for Conservation," Ian Deshmukh, November 1987. Associates in Rural Development, Burlington, Vermont.

Preface

This report was prepared to provide timely background information on the status of the remaining riverine forests on the Jubba. Decisions about conservation of these forests need to be made soon.

I. EXECUTIVE SUMMARY

Riverine forests in the Jubba Valley of Somalia are in rapid decline due to human encroachment. The rate of loss is such that it is possible that all sizeable sections worthy of conservation may disappear within a few months or at most a few years. Following their expedition to Middle Jubba in July and August 1986, the Somali Research Project of University College, London, recommended that two forest reserves should be protected. The Somali Ecological Society (SES), with the support of the National Range Agency (NRA), is seeking funds to develop the reserves for conservation.

This document discusses the issues involved, the conservation status of the Jubba forests, and makes conservation recommendations for the short term. In particular, a meeting is proposed to discuss the forest conservation issue at national level. This meeting, convened by the NRA, but involving several other agencies and institutions, could help to establish a coherent strategy for conservation of the reserves, assuming that agreement on their importance is forthcoming. Ways of gaining local support for conservation measures and establishing effective boundaries for the reserves should be sought. Further action will depend upon the degree of success of these initial measures. Meanwhile, financial support is warranted both from the Government of the Somali Democratic Republic and from international agencies.

II. INTRODUCTION

In 1986, the Somali Research Project of University College, London (SRP) conducted three months of field research in two forest reserves in Jubba Valley (Figure 21). SRP recommended immediate conservation measures to further protect these important remnants of riverine forest (SRP 1986). A month after the SRP, an aerial survey revealed that a section of one of these reserves was being cleared for agriculture (RMR 1986). Because of human activity the Jubba forests are disappearing very rapidly. Therefore, decisions need to be made and appropriate actions taken now if some sections are to be conserved.

This document provides background information unavailable elsewhere, which gives a perspective on the issues involved and the status of the Jubba forests. It presents an incomplete view because information is limited. Actions to conserve Jubba forests probably need to be taken before all the information is analyzed. Ideally, this report should be read in conjunction with the interim report of SRP (1986). The latter contains more detailed information about the two forest reserves, including their legal status, and makes medium- and long-term recommendations for study and protection of the forests. The National Range Agency (NRA) and Somali Ecological Society (SES) are actively seeking funds to protect and manage the two reserves. Their more detailed proposals cover budgetary matters which are not discussed in this report.

III. ISSUES

A. Biological Conservation

The term biological conservation can be taken to mean the sustainable use or the strict preservation of biological resources. Ideally, conserved areas are designated for one, or a combination, of the following reasons (Deshmukh 1986):

- sites of high diversity;
- sites containing rare organisms;
- sites containing representative natural communities.

In reality, the non-biological criteria of land availability and the ability to regulate use of the chosen area can be added to this list of reasons. Because of these latter factors, designation of conservation areas is often opportunistic and political, rather than being based primarily upon a scientific rationale.

Two vital steps are necessary when establishing new conservation areas. The first step is to delimit the boundary for the area, and second, is to develop a management plan. SRP (1986) recommended boundaries for protected areas in the Barako

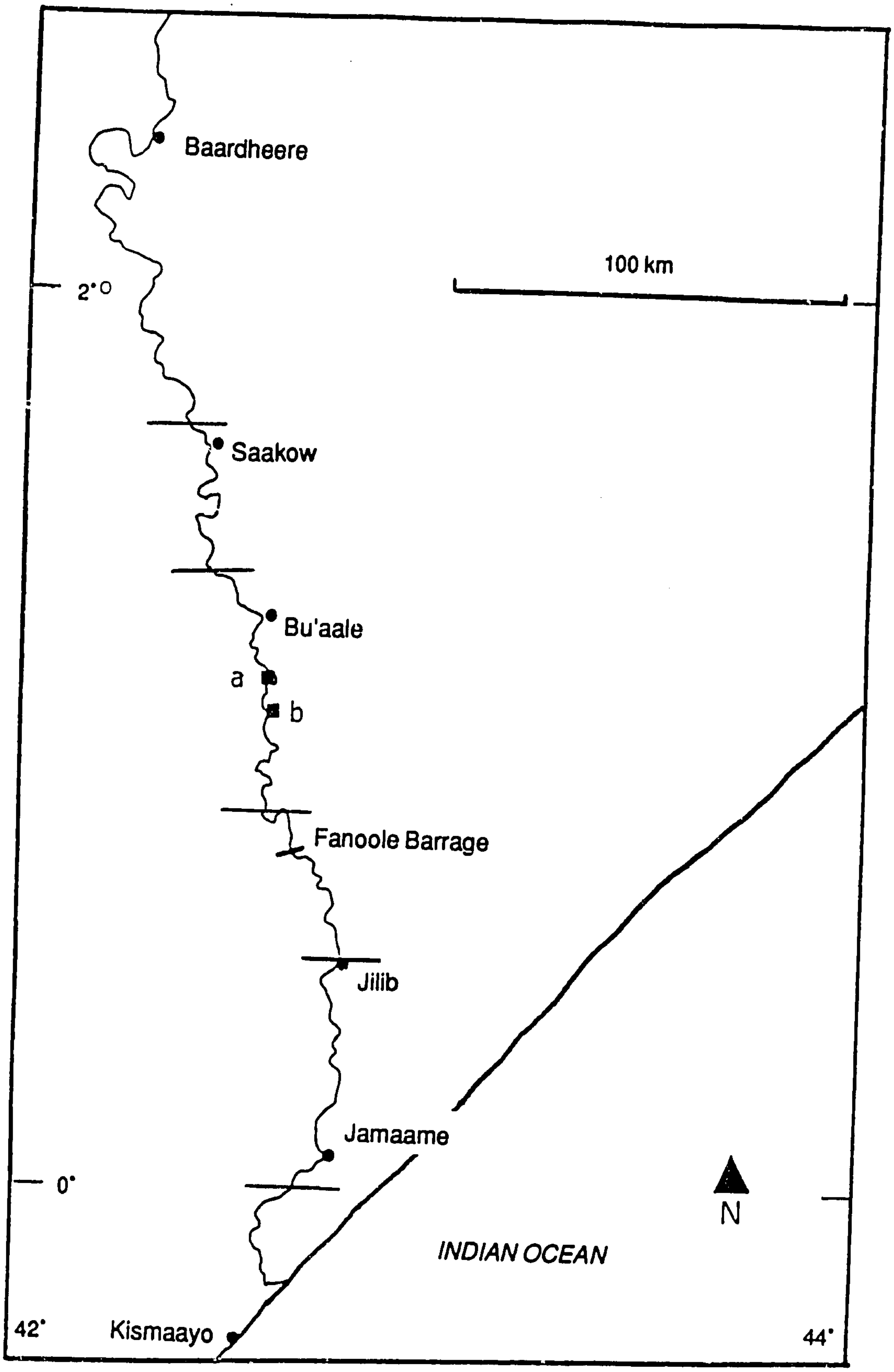

Figure 21. Jubba River. Horizontal lines are boundaries of map sheets.
a = Barako Mado Forest b = Shoonto Forest

Madow (140 ha) and Shoonto (265 ha) forest reserves on a map and added some preliminary management suggestions. Because of the rapid forest loss near these reserves, defining a workable reserve boundary is clearly the highest action priority. A comprehensive management plan is less urgent, assuming some simple management policies can be enforced by the NRA immediately. Such policies will probably entail prohibiting human activity in some areas and limiting the types of activity in surrounding buffer zones.

Theories of ecology and evolutionary biology have been extended to conservation biology (summarized in Deshmukh 1986). It is generally agreed that conservation areas should be large and unfragmented to maintain species diversity. Reserves should also be close to one another so that organisms can move between them. The size of populations of plants and animals is also important. Several thousand individuals of each species has been proposed as the minimum needed to maintain a "genetically healthy" population.

B. Decline of Jubba Valley Riverine Forests

There is no doubt that the riverine forests of Jubba Valley are in decline due to human encroachment. Table 36 shows the area under forest in Jubba Valley between 1° 40' north (just north of Saakow town) and the Jubba estuary in 1960, 1983-1984 and 1987 (dates of aerial photography). The area north of the Saakow map sheet is not included in the 1960 aerial photography. However, perusal of the aerial photographs for that area in 1983-1984 and 1987 plus field visits reveal negligible areas of closed riverine forest. The floodplain is very narrow or absent, and rainfall low in this section of the river. These conditions are not conducive to extensive forest formation.

Table 36 documents the tenfold decline in forest area between 1960 and 1987. The area lost through time and the compelling evidence that the rate of clearance overall has accelerated recently (see Table 37 including footnote). However, clearance has not been uniform when time is related to geographical zone. In 1960, there was little forest remaining in the southern sections of the river (Jamaame and Kismaayo Districts) because this area already had extensive irrigated agriculture. Between 1960 and 1983-1984, clearance proceeded from both north and south (Tables 36 and 37; Saakow and Jilib). By 1987, the only sizeable remnants of forest were concentrated in the Bu'aale and Fanoole areas of Middle Jubba Region. Figure 22 amplifies a section of Table 36 by giving size distribution of forest patches through time. Mean patch size in 1987 is less than half of that in 1960. All large patches (>200 ha) have disappeared leaving few areas worthy of a conservation effort.

Table 36. The extent and number of patches of forest in the Jubba Valley estimated from aerial photographs taken in 1960, 1983-1984, and 1987. Map sheets correspond to those indicated in Figure 21 moving from north to south.

	1960		1983-84		1987	
	Total	No.	Total	No.	Total	No.
MAP SHEET	ha	patches	ha	patches	ha	patches
Saakow	2,878	27	438	11	65	3
Dujuuma (Bu'aale)	3,009	23	1,361	18	505	9
Fanoole	1,658	14	549	9	163	6
Jilib	1,701	16	122	1	83	1
Jamaame	100	4	51	3	0	0
Goob Weyn	?	?	90	2	81	2
TOTAL	9,346	84	2,611	44	897	21

1. Sources: RMR interpretation for JESS of 1960 and Trump (1987); JESS modifications of AHT interpretation of 1983-4.
2. The 1960 photography is poor in some regions. Extensive areas are characterized as "dense vegetation" some of which is forest and some dense woodland or bushland. The total area of dense vegetation in the study area in 1960 was approximately 7,000 ha in 37 patches. It is for this reason that no estimates are given for Goob Weyn where 305 ha of dense vegetation was present.

Table 37. Estimates of loss of Jubba forests in area and rate of loss during the periods 1960-1983 and 1983-1987. Map sheets correspond to those indicated in Figure 21 moving from north to south.

	LOSS 1960-83		LOSS 1983-87	
	ha	mean	ha	mean
MAP SHEET		ha/year		ha/year
Saakow	2,440	106	373	93
Dujuuma (Bu'aale)	1,648	72	856	214
Fanoole	1,109	48	386	97
Jilib	1,579	69	39	10
Jamaame	49	2	51	13
Goob Weyn	?	?	9	2
TOTAL	6,825	297	1,714	429

1. 1983 is arbitrarily chosen as the base year for the 1983-1984 photography.
2. For lack of Goob Weyn data 1960-1983, see Table 36. If all "dense vegetation" in the 1960 photography is regarded as forest, the total loss between 1960 and 1983 becomes 13,860 ha and the annual rate of loss approximately 600 ha.

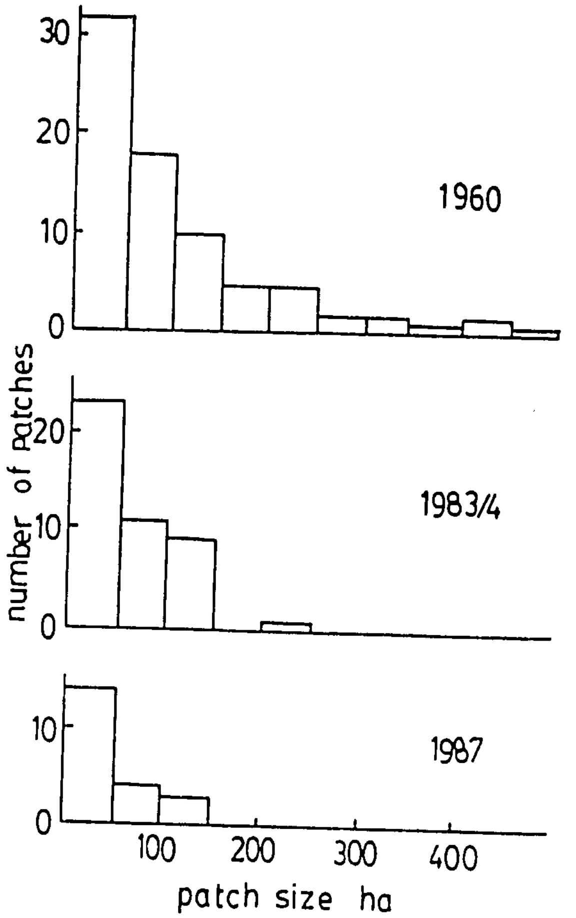

Figure 22. Frequency distribution of forest patch size in the Jubba Valley in 1960, 1983-1984, and 1987. Note decline in number of patches and loss of large patches.

The most important cause of forest decline is clearing for new agricultural land. Some of this clearance has been for large projects. For example, the development of Jubba Sugar Project accounted for much of the loss in the Jilib area between 1960 and 1983-1984. In the areas north of the Fanoole Barrage most clearance has been for smallholder farming and this remains the major threat to the forest remnants. Some other areas have been cleared, but not yet farmed, to uphold land registration claims. The Somali Land Law of 1975 requires that "improvements" be made to registered land, and forest removal is used as an expression of intent to farm even when no immediate intent exists according to an ARD land tenure consultant (Riddell 1988). Clearance for timber is not important. Smallholders usually burn the trees that are felled *in situ*.

It is important to realize that the forests and all floodplain vegetation types are dynamic. Throughout its length, Jubba River has a complex pattern of meanders. As the river changes course, areas of forest are naturally degraded to woodland and bush without human interference. With the addition of human encroachment, it is highly unlikely that new forests will form by natural processes. If new levees form they will probably be occupied by people before forest can develop. Forests on the Jubba River will not, therefore, continue in perpetuity under present conditions.

Construction of the proposed dam near Baardheere will add to the difficulty of predicting the future of riverine vegetation (see section E, below). However, the biological prospects for continuity of the present forests over many decades (possibly centuries) are good, if they are appropriately managed. Regeneration of canopy species within the forest is excellent, with many seedlings and saplings present in the understory (JESS vegetation surveys; Madgwick personal communication). However, it is unlikely that forest is capable of regeneration following clearance. Areas clear of forest that have been examined by JESS and SRP do not contain regenerating forest species. Fires and livestock grazing probably account for this lack of regeneration.

C. Conservation Status of Jubba Valley Forests

In an international context, the conservation status of Jubba riverine forests cannot be clearly stated at present. Recurrent reports of tree species endemic to these forests (*e.g.*, Dowhan 1984) were recently discounted by re-examination of herbarium collections (see discussion in Kuchar 1986). However, the recent collection of *Cola*, family Sterculiaceae, (Table 38) reopens the possibility of Jubba Valley endemics and significantly enhances international conservation status. It remains possible that further new taxa will emerge from the more comprehensive collections made by SRP.

At the national level, the Jubba Valley forests have high conservation value in terms of rare species of plants and animals and representative communities. Since there is no overall conservation strategy at the political level in Somalia, these important biological criteria should suffice. The Jubba and Shabeelle are the only large rivers in Somalia and almost no forest remains on the Shabeelle. Therefore, Jubba Valley remains the only opportunity to preserve representative riverine forests in Somalia. Preliminary identification of JESS plant collections indicates that common species include *Acacia elatior*, *Spiros-*

tachys venenifera, Garcinia livingstonei, Mimusops fruticosa, Ficus sycomorus, Rinorea elliptica, Acalypha fruticosa, and *Hyphanene* spp. Nine forest species found by JESS have not been collected before in Somalia and one tree species may be new to science (see Table 38).

Table 38. List of Jubba forest plants collected by JESS which have not been previously collected in Somalia. Identifications are provisional and those with ? need further confirmation because they are genera new to Somalia.

SCIENTIFIC NAME	VERNACULAR NAME
Acacia elatior	damal, dambal
Acacia rovumae	makogowey
Olea sp.	wabaayo booneed
Lepisanthes senegalensis	masaar jabis
Pleiocarpa pycnantha?	geed biyood
Monauthotaxis fornicata	cismaan dooy
Pavetta sphaerobotrys	geed cade
Cola (new species)?	hiinfaal
Baphia sp.	geed cade

JESS is indebted to J. Gillet of the Royal Botanic Garden, Kew, England for identifications and to Christopher Hemming for expediting the identifications.

Of the remaining Jubba forest remnants, there is no doubt that the two forest reserves of Barako Madow and Shoonto should be given top priority (Figures 21 and 23) for the following reasons:

- they have legal status as declared forest reserves (although they are not effectively gazetted);
- they are the largest patches remaining, with 100 ha and 250 ha under forest, respectively;
- they have changes less than other forest remnants in the last three to four years; and
- they are further from established human settlements than most forest remnants.

Barako Madow. Approximately 5 ha were cleared in 1986, presumably for agriculture. Prompt action is needed if further clearance is to be prevented. Behind the forest is a dhesheeg which floods rarely and is largely farmed (Figure 23). There are three nearby villages, but all are more than 1 km from the forest edge.

Shoonto. There are two patches of gallery forest (125 ha to the north and 25 ha to the south) connected by 100 ha of forest apparently above the floodplain level (Figure 23). There is also a large dhesheeg which is an important site for wading birds. An ARD ornithology consultant counted more than 1,000 wading birds and ducks in March 1987, when most other dhesheegs were dry. This dhesheeg covers 250 ha when full. In many years, it remains flooded and cannot be cultivated. However, in dry years flood recession agriculture is practiced. For example, in the 1987 jiilaal season, 125 ha was farmed. Much of the forest and dhesheeg is backed by woodland with no agriculture. With its limited agriculture and diversity of vegetation types, Shoonto is an excellent prospect for conservation.

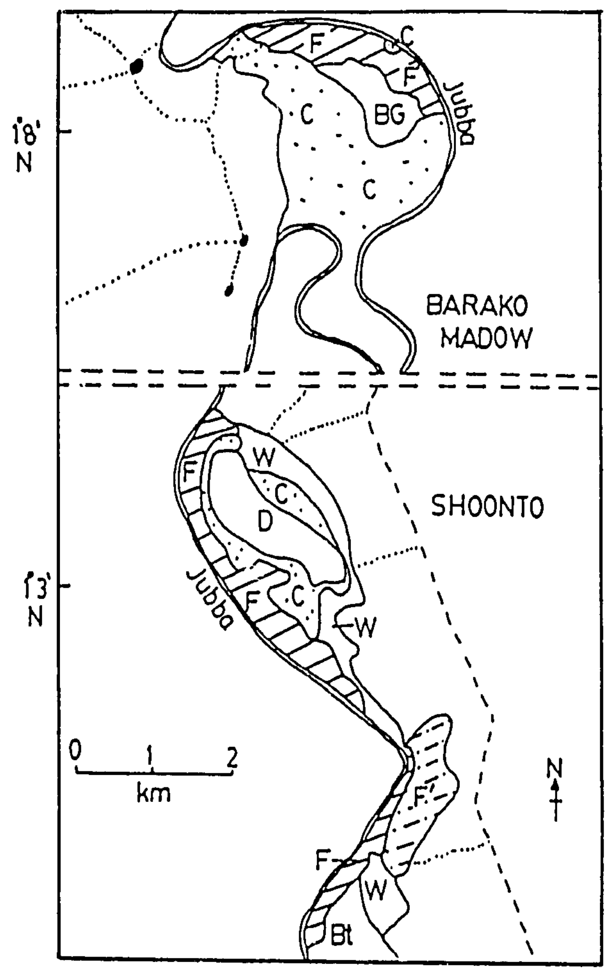

Figure 23. Vegetation and land use in and around Barako Madow and Shoonto forests from interpretation of 1987 aerial photography. F = floodplain forest; F' = forest above floodplain; W = woodland; BG = bushed grassland; Bt = bushland thicket; C = land in cropping cycle; D = open water in dhesheeg. Black areas are villages; dashed line, major tracks; dotted lines, minor tracks.

JESS has not examined Barako Madow and Shoonto forest reserves botanically, because SRP was conducting this work using compatible methods of vegetation survey. However, plant species are similar to those collected by JESS in other forest remnants (Madgwick, personal communication).

Vegetation types follow Pratt and Gwynne (1977); canopy refers to percentage of ground covered directly above by trees or bushes. Forest has almost 100 percent canopy and trees >7 m in height. Woodland has 20 percent canopy and trees <20 m in height. Bushed grassland has 2 to 20 percent canopy and bushes <10 m in height. Bushland thicket has an impenetrable canopy of bushes <10 m in height.

Among the SRP (1986) findings on vertebrates are the following: As many as 20 bird species are partially dependent on the riverine forest and may, therefore, be lost from Somalia if all the riverine forest disappears. Of eight bat species collected, two are new to Somalia and two others rare in eastern Africa. Many species and this type of community will, therefore, be lost from Somalia if some of these forests are not protected.

Tropical forests are renowned for their high species diversity of flora and fauna. In this respect, the Jubba forests are unremarkable when compared with large areas of rain forest. However, given their relative isolation from similar forests and their small and fragmented nature, the number of specialized species of birds and mammals remaining is noteworthy (SRP 1986). The invertebrate fauna is virtually unknown and likely to remain so for the foreseeable future. The third criterion for selecting conservation areas is that most applicable to the Jubba forests in an international context. It is probable that these forests represent communities (associations of species) not found elsewhere. Conclusive evidence is lacking because of incomplete analyses of Jubba surveys. However, the species composition of trees and shrubs collected by JESS is somewhat different to that observed in detail by Hughes (1985) on the Tana River in northwestern Kenya (the Tana is the closest large river south of Jubba River). Of 32 species of woody plants collected by JESS in and probably restricted to the Jubba forests, only 17 occur on the Tana floodplain. Internationally, the Jubba forests are also important, because they are the northern limit of the coastal forest types of eastern Africa.

Theoretical ideas about conservation biology (see section A, above) lead one to speculate that Jubba forests will become seriously impoverished in the future. Because of reduction in area and fragmentation, many species may disappear from the region and possibly from Somalia. The sizes of many populations and their probable isolation from immigration sources suggest that genetic viability will decrease. However, such speculations should not be used as an argument against conservation of the forests for two reasons. First, many of these theoretical ideas remain to be proven and some are hotly disputed. Riverine forests in dry and semi-arid areas of Africa are often fairly small in extent, relatively isolated and fragmented, and have been used by human populations for thousands of years. Yet they have persisted provided that human pressures are not too high. Second, the biological processes of impoverishment (particularly in the flora) are long-term.

Conservation priorities should be decided on the current biological status of proposed areas within a national or international policy context and not on the basis of unproven theories. Within the Somali national context, the biological value of these forests is very high. Conservation research in these reserves would be of much wider benefit and may help to answer some of the pressing questions posed by conservation theorists.

D. Use of Forests by Local People

Areas under forest represent a wealth of natural resources which are exploited by people. Removal of riverine forests often exposes good agricultural land. Alluvial soils, seasonal flooding, and a high water table due to proximity to the river all enhance this agricultural potential. Because of increases of human population in Bu'aale District, new farming land is required. New clearing for agriculture is the primary cause of forest reduction in Jubba Valley.

Another obvious use of forests is for wood for construction and fuel. Most of the JESS vegetation monitoring sites in forest show evidence of extensive chopping of parts of trees and shrubs. However, at several sites removal of wood is clearly at a sustainable level. Near one site (and presumably in other areas) occasional commercial extraction of timber occurs. Extraction rates of wood will be examined more closely by JESS forestry studies. There are also some areas of forest where no recent cutting has taken place, including a JESS monitoring site within walking distance of Bu'aale. Many other forest products are used by the local people. For instance, honey gathering is an important component of the Middle Jubba economy (Douthwaite 1985). Ethnobotanical surveys by JESS and SRP show myriad uses of forest plants as shade, foods, fibers, dyes, and medicines.

A factor currently limiting human activities in and around the forests is the tsetse fly, an important livestock parasite. The forests (particularly the edges) harbor substantial populations of these biting flies. The flies cause trypanosomiasis in livestock, but there is no record on human diseases spread by tsetse in Somalia. The ground flora in the forests is sparse and largely devoid of grasses. As a result, the forests are not attractive to livestock herders, irrespective of tsetse. However, nomads and permanent residents set many fires to control tsetse and bush and to prepare agricultural land. These fires are not controlled and often spread beyond the area being managed. Such fires are a potential threat to the forest remnants. Another significant factor in forest loss for new grazing lands is the effect of clearing nearby land. Removal of dense woody vegetation attracts more livestock and reduces favorable tsetse habitats. As forest fragments become smaller, the likelihood of regenerating forest tree species being grazed by livestock becomes significantly less likely.

Plans of the National Tsetse and Trypanosomiasis Control Project to eradicate tsetse and tsetse habitat could pose difficult management problems for the forests because livestock occupancy of the riverine area will increase. Greater livestock numbers would tend to prevent regeneration of trees and there would be pressure to reduce tree cover to make better grazing lands. Insecticides used to eliminate tsetse flies also kill other invertebrate species, reducing insect diversity and affecting animals and (Douthwaite 1985, SRP 1986). Bees are especially susceptible to insecticides used in tsetse control.

E. The Baardheere Dam

When the dam is constructed, it will cause many hydrological changes downstream. Most significant for floodplain vegetation will be changes in the flood regime. The dam is designed so that a controlled flood could be created to periodically inundate parts of the floodplain. Such floods would minimize changes in forest composition because they would mimic the natural situation. However, it is not likely that the dam will be managed with forest conservation as a priority objective. The latest proposals for maintaining floodplain agriculture after the dam is closed do not call for controlled flooding (AHT 1986).

If controlled floods are not included in the dam operation schedule, forest environments will be affected in several ways. Obviously, surface water on the floodplain will be reduced. The groundwater table will also be changed, becoming more constant and at a lower level at its maximum. Surface rooting plants will clearly have less access to water. Whether deeper rooting plants will continue to reach groundwater is open to speculation, depending on many unknowns, such as river levels, stability of the riverbed (whether it will be downcut), and rooting depths of the plants. A JESS hydrology study suggests that downcutting will not be severe. It seems likely that larger trees will continue to have access to adequate water, but seedlings may be adversely affected by the lowered and more constant water table. An absence of floods will also eliminate the deposition of nutrient-rich sediments on forest soils. Hughes (1985), from her studies on the Tana River in Kenya, suggests that lack of floods will reduce the width of the forest strip and that the diversity of plants will decline. Absence of floods will also mean that the forest land is accessible to people and livestock for longer periods of the year, leading to an increased potential for forest destruction. At Shoonto Forest Reserve, the dhesheeg may remain dry, except during extreme floods. If so, the conservation value as a site for wading birds will disappear. All of these factors will call for careful management practices in the future, if some sections of the forests are to be conserved.

A benefit of the dam from a conservation perspective is that changes in the course of the river are likely to be reduced. These changes are already very slow, with no noticeable changes between 1960 and 1987. After the dam is constructed the river course will undergo a slow adjustment due to the new hydraulic regime. Such changes will probably take centuries. In the absence of floods, the potential for sudden changes in meander pattern is much reduced.

IV. CONCLUSIONS AND RECOMMENDATIONS

Unless action is taken in the near future, it is possible that there will no longer be any areas of riverine forest worthy of conservation. A plan of action was suggested by SRP (1986) and support for it has been voiced by Somali Government agencies, USAID, the forestry project of Overseas Development Administration (British Government), and SES. SRP identified and worked in two forest reserves which represent the best prospects for conservations (see Figures 21 and 22). In 1987, SES has put forward a proposal for managing the reserves and is seeking financial support from the Somali Government, World Wide Fund for Nature (WWF), and USAID. The measures proposed by SRP and SES are sound. The SES proposal had detailed suggestions for management to which JESS contributed.

The following additional actions are recommended.

An ad hoc *meeting of interested parties in Mogadishu should be called under auspices of the NRA to discuss the fate of the Jubba valley forests.*

The establishment and maintenance of conservation areas in Somalia needs cooperation from many agencies. The NRA is the Somali agency charged with environmental conservation and forest management. Besides NRA, bodies represented should include the Ministry of Agriculture (land registration), the Ministry of National Planning and Jubba Valley Development, the National Tsetse and Trypanosomiasis Control Project, and the Somali Ecological Society. Because urgent action is needed, the meeting should be held as soon as possible.

A representative working group should be established from the institutions identified above to maintain liaison between the agencies involved so that contradictory actions do not take place in Muqdisho or in the field.

Agencies with field officers in Bu'aale District (Ministry of Agriculture, NRA) need to develop effective communications with those officers so that everyone involved can be kept abreast of developments in Muqdisho and in the reserves. It is also important that other regional and district government officials be kept informed and contribute to the development of effective protection measures for the reserves.

Any conservation program undertaken should involve discussions with local people living near the forest reserves with a view to determining realistic and equitable boundaries, land tenure, rights, and protection measures.

The forests can be protected effectively only if there is some degree of local support and understanding of conservation objectives. Although the boundaries of the forest reserves are mapped, they are not fully demarcated on the ground and they may be unrealistic in view of recent clearance. Since much of the agricultural land is unregistered, traditional "ownership" must also be taken into account. It may be possible to subdivide the reserves. In some areas, clearance may be unavoidable. In others, it may be appropriate to enforce the current regulations for forest reserves (such areas may provide an adequate buffer zone for more sensitive sites). There may be patches of pristine forests which should be completely protected as nature reserves.

Whatever the appropriate boundaries and buffer zones, they need to be decided upon with a degree of consensus among the proposed working group, local officials and other local residents. Wherever possible, local people should be employed by the NRA to guard the reserves and perform any conservation activities. Compensation for local people who were anticipating forest clearance or who are already farming within the reserve boundaries should be considered. As a means of gaining local support, it may be possible for the NRA to tie forest conservation measures to a crocodile control program since both activities are NRA responsibilities. JESS surveys, including Watson 1986, indicate that crocodiles are major predators on people and livestock in the area.

Funds should continue to be sought from international agencies to finance protection measures and develop the reserves for conservation.

GSDR has indicated willingness to provide salaries of local officials and make the land available through a grant from the NRA. MNPJVD has indicated a willingness to provide a vehicle for the reserve areas. SES expects to be able to provide locally based expertise on a voluntary basis. Grants from international donors would be used to pay for equipment and an expatriate project manager for the first year. An expatriate technical assistant is deemed necessary because of the lack of experience in Somalia in managing biological reserves.

These recommendations are all short-term. Until they (or similar measures) are carried out, it is unwise to suggest further action. In the medium-term, SRP will report more fully on their findings. The continued work of NRA, SES, and the proposed return visit of SRP merits financial support. The crucial need is for immediate action to preserve the forests, so that a long-term comprehensive management program can be devised.

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Aerial Resource and Land-Use Surveys in the Jubba Valley

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The data and analyses presented in this report are based on fieldwork performed by Murray Watson, Ph.D. of Resource Management and Research, Ltd. (RMR) for Associates in Rural Development, Inc. (ARD) in Somalia between September 1986 and December 1987.

The work is based on a series of aerial surveys made possible through the cooperation of military and civil authorities of the Government of the Somalia Democratic Republic (GSDR). Ms. Jennifer Nimmo participated in data assimilation, analysis and interpretation, and coauthored this report. As these surveys were performed in support of JESS' longer-term Terrestrial Ecology Baseline Studies (TEBS), continuous consultation and coordination was maintained with the JESS ecologist, Dr. Ian Deshmukh.

These surveys produced an enormous volume and wealth of baseline data on the terrestrial ecology and natural resource utilization systems in the Jubba Valley. Only the summaries of these data and their analyses are presented here. Full and complete sets of raw data, field maps, photography and computer records are being kept in repositories for JESS baseline data as described in the Foreword of this volume. This report was first issued in June 1988 and has been edited for publication in the JESS Final Report.

I. EXECUTIVE SUMMARY

This report describes the methods and results of a series of aerial surveys of the natural resources and resource-use systems of the Jubba Valley. The surveys included the following types:

- a total search and enumeration of the Jubba River Zone, made from 29 March to 7 April 1987. (An earlier total search of the river had been made in September 1986 and reported in Watson [1986]);
- aerial photography of the floodplain at 1:10,000 scale, taken in March 1987;
- aerial strip sampling of the Jubba Floodplain Zone and the Jubba Valley Zone, undertaken in three separate surveys:

  January/February 1987,
  first jiilaal survey of floodplain;

  March/April 1987,
  second jiilaal survey of floodplain and valley;

  July/August 1987,
  xagaa survey of floodplain and valley.

Results of these surveys are presented in analytical summaries and maps in this report. Some of the more scientific conclusions follow in their discussion.

The Jubba River is the dominant water source for livestock and people in the valley. The river is most important during the dry season. The riverbed and shallow waters also represent an important recreational area for people during low flows.

The rural population in the valley (outside of towns, villages, and refugee camps) is estimated at 58,000 to 94,000 settled people and 266,000 to 286,000 nomadic people. The area to be inundated is occupied or used by about 1,500 families who will have to be relocated.

Of a total survey area of approximately 35,000 km^2, four percent is or has been under rainfed cropping, found mostly on fine river alluviums of the floodplain. Only about one percent of the survey area is or has been under irrigation. Jubba waters are heavily exploited throughout its length by small irrigators using portable diesel pumps. Croplands, both irrigated and rainfed, are expanding at a rate of between four and eight percent annually, with most expansion taking place in the middle Jubba floodplain. After extensive flooding, as occurred during the survey period, even farmers working in traditional rainfed agriculture practice recessional agriculture to take advantage of this natural phenomenon. The area to be inundated is estimated to contain 3,000 to 4,800 hectares of rainfed cropland; 1,800 to 4,300 hectares of irrigated cropland; 4,000 to 5,600 hectares of enclosed land (not cropped); and 1,700 hectares of receding-flood cropland.

Livestock biomass for the whole survey area is 6,100 to 6,600 kg/km^2, which is higher than might be expected considering levels of rainfall. Riverine and cropland vegetation production are probably responsible for this "anomalous" biomass. Cattle and camels are the most important components of the valley's livestock biomass. Cattle favor the southernmost valley zones, while camels are more evenly distributed throughout the valley. Only a small proportion of Jubba Valley cattle use the inundation area.

There are 500,000 to 600,000 cattle (11 percent of the national population) using the Jubba Valley. They concentrate heavily on the floodplain in the dry season and migrate southward down the valley at this time. Some feeding on transported crop residues (two percent of the population) is taking place in the northernmost zone of the floodplain, but it has not yet developed to the 10 percent level seen in the Shabeelle Valley. However, 20 percent of cattle are feeding on current and old croplands in the dry season.

There are 350,000 camels (eight percent of the national population) using the Jubba Valley. They concentrate on the floodplain in the dry season and show a range of north/south movement up and down the valley at this time. No stall feeding of camels was seen and only seven percent were seen on current and old croplands.

There are 375,000 to 450,000 sheep (four percent of the national population) using the Jubba Valley. They concentrate in the floodplain in the dry season, but show no tendency to migrate southward down the valley. No stall feeding of sheep was seen, and only 10 percent were seen on current and old croplands. Sheep are a relatively unimportant component of the valley's biomass and favor the northernmost valley zones. A large number of sheep use the inundation area.

There are 650,000 to 700,000 goats (four percent of the national population) using the Jubba Valley. They concentrate on the floodplain in the dry season, but do not usually migrate southward down the valley. No stall feeding of sheep was seen, and only seven percent were seen on current and old croplands. Sheep are a minor component of the valley's biomass, and favor the northernmost valley zones. A large portion of the goat population uses the inundation area.

There are 5,000 to 10,000 donkeys (12 percent of the national population) using the Jubba Valley. They concentrate on the floodplain in the dry season, and show some southward migration down the valley. Very few donkeys were seen stall feeding, and 25 percent to 30 percent were seen on current and old croplands. Donkeys are an insignificant component of the valley's livestock biomass, and tend to avoid floodplain zones where the tsetse fly is present. A significant portion of the donkey population uses the inundation area.

Wildlife is a negligible component of the herbivore biomass, and terrestrial animals will not be important in the future development of the valley. However, the crocodile population is estimated at 40,000 to 150,000 and hippopotamus at 3,000 to 6,000.

Based on results of this survey, and the knowledge and experience of the authors in Somalia, a series of broad-based recommendations have been made:

- studies should be made to enable precise forecasting of the discharge pattern from the Baardheere Reservoir (both quantitative and qualitative);
- attention should be given by master planners and developers to solving the problem of how displaced persons (from the inundation area) can be absorbed into the expanding and intensifying agricultural system of the middle Jubba floodplain;
- a Jubba Water-use Authority should be established to operate a water-use master plan *before* the dam is completed;
- crocodile (and possibly hippopotamus) should be controlled and, if possible, the skins commercially exploited;
- two ferries should be established across the reservoir when it has been completed, and possible improvement of some ferries downstream of the dam should be considered;
- physical infrastructure should be developed downstream of the dam with all-weather roads and two bridges at Jilib and Saakow;
- a study should be commissioned to find methods of developing usable vegetation for the reservoir drawdown zones;
- it is urged that a program aimed at repatriating the Buurdhuubo refugee camp populations be initiated immediately;
- planners deciding on future developments in the middle and lower Jubba floodplain should examine the efficiency of the existing large-scale irrigation projects in the Jubba Valley;
- a cadastral survey should be carried out to enable a legally sound basis for determining compensation for those losing land and property in the inundation area; and
- it should be made clear to MNPJVD that land-use and resource data will become outdated, and monitoring and updating may be necessary if the construction schedule is extended.

II. INTRODUCTION

The Government of the Somali Democratic Republic (GSDR) intends to create an impoundment in the Jubba River in southern Somalia with construction of a high dam north of Baardheere. Among the many consequences of this modification of the river channel, will be widespread environmental changes stemming from the actual process of construction of the dam and its supporting infrastructure, from modifications in the surface and subsurface hydrology upstream and downstream of the dam, and land-use changes. Social, economic, and resource environments will be altered by the sequence of construction, reservoir filling, and prolonged hydrometeorological and ecological developments in the new and modified ecosystems.

RMR has performed several subcontracts concerned with remotely sensed aerial resource and land-use inventories and descriptions of the Jubba Valley. By making these very rapid surveys at appropriate moments in the annual climatic/hydrological cycle, it is intended that a baseline will be established in the context of resource and land-use statistics and dynamics on which more detailed studies and follow-up monitoring can be carried out by MNPJVD consultants and staff after the proposed dam is in place and development of the valley continues.

In structuring the RMR survey program, it was necessary to develop the concept of "impact zones"—areas within which there is certainty or reasonable probability of environmental change as a result of proposed developments (see Figure 1).

- *Jubba River Zone.* This has been defined as the water of the Jubba River, exposed riverbed, the banks of the channel and river islands, but excluding the large islet (Mombasa) created by the splitting of channels at Sabatuuni.
- *Jubba Floodplain Zone.* This has been defined as the flat deposit of young riverborne alluviums comprising a range of physiographic types reflecting different deposition conditions lying between low limestone hills, the limestone cliffs of the Jubba gorge, the slight escarpments of the eluvial and colluvial pediplains, and the low hills of raised fossil coral reefs.
- *Reservoir Zone.* This has been defined as the area expected to be covered by water at the highest water level of the proposed reservoir (142 m at the time of writing this report). This zone includes sections of the Jubba River and the Jubba Floodplain Zones.
- *Jubba Valley Zone.* This has been defined as that area north of 0° 28'N on each bank of the river lying between the outer boundary of Jubba Floodplain or the Reservoir Zone (whichever is further from the river) and a line drawn 30 km due east or west (away from the river) of that boundary; and south of 0° 28'N on the west bank of the river between the outer boundary of the Jubba Floodplain Zone and longitude 42° 00'E, and that land on the east bank of the river between the outer boundary of Jubba Floodplain and a line drawn 30 km due east of that boundary or the Somali coast, whichever is closest to the river.

The following surveys in these impact zones have been carried out:

Jubba River Zone

Two surveys of the Jubba River Zone were planned: one to be timed at a period of high-river flow and the other during low-river flow. The method chosen was a total search of the water surface, the exposed riverbed and small islands, and the river banks.

The first survey (high-river flow), was conducted between 28 and 30 September 1986 and has already been reported (Watson 1987). The second survey (low-river flow), was carried out between 28 March and 7 April 1987 and is dealt with in this report.

Jubba Floodplain Zone

Two types of data collection were performed for this zone. First, following recommendations made as a result of the first Jubba River Zone survey (Watson 1987), 1:10,000 scale photography of a strip of land on either side of the Jubba River was commissioned for the 1987 jiilaal season. These photographs were taken between 3 and 8 March 1987, and two sets of prints were delivered to ARD, Muqdisho, on 22 March, where they were interpreted by Trump (1987).

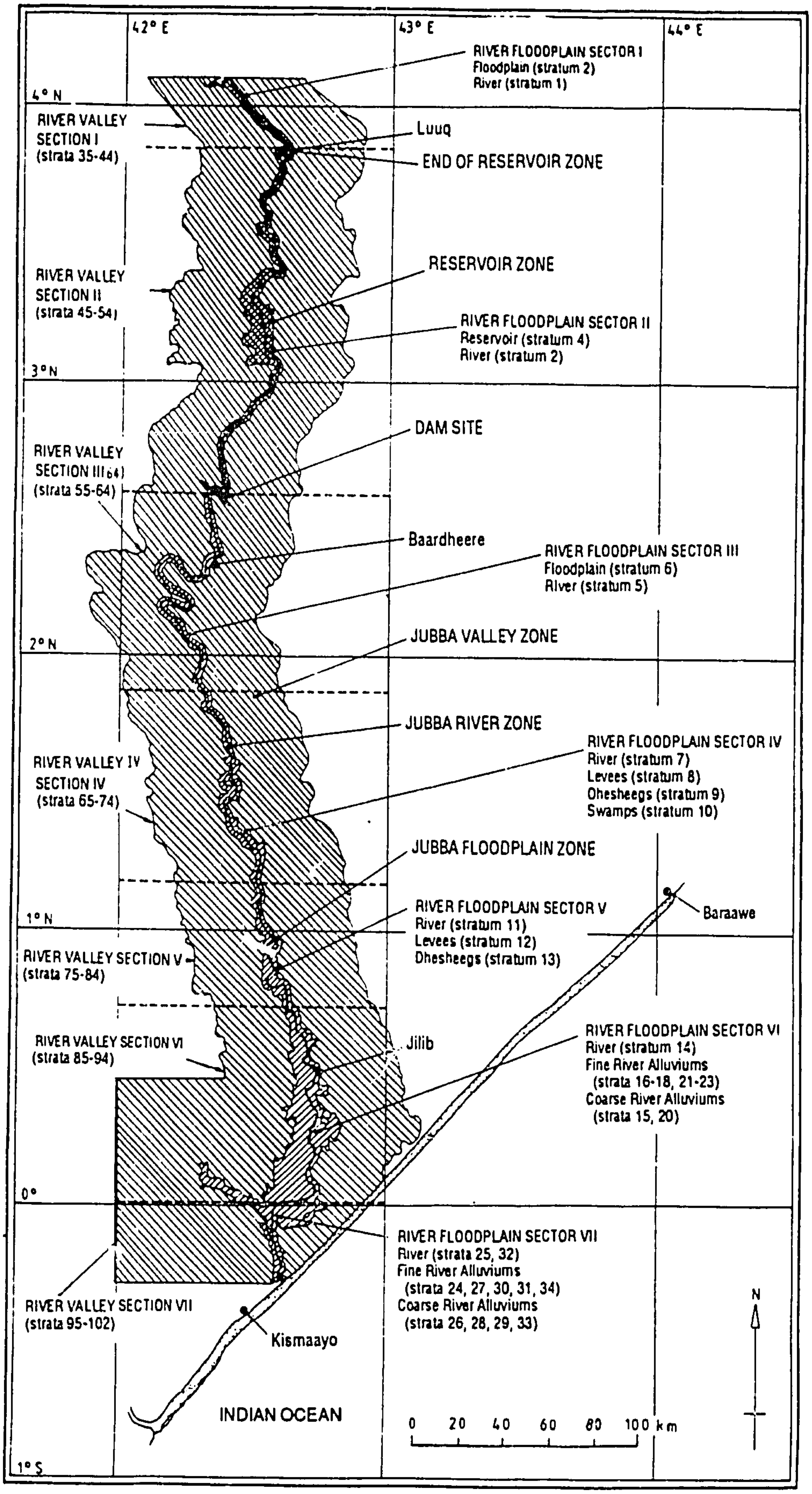


Figure 1. River Valley Sections, River Sectors, and Survey Strata of the Impact Zones

Second, a five-percent sampling by aerial strip samples of the Jubba Floodplain Zone (including the Jubba River Zone) had been planned for September/October 1986, but was postponed because it could not be completed before the onset of the deyr rains. It was decided to carry out two of these surveys in the jiilaal season (one in late January and another in late March 1987), and a third survey in the xagaa season between 29 July and 26 August 1987.

Reservoir Zone

A search of the Reservoir Zone for all houses and structures, which were counted (and photographed when in large clusters) and mapped, was carried out on 11 and 12 December 1987. The results of this work have been reported in Watson 1988.

Jubba Valley Zone

One three-percent aerial strip sampling of the Jubba Valley Zone was planned for the late jiilaal season. This survey was carried out simultaneously with the five-percent sampling of the Jubba Floodplain Zone between 28 March and 13 April 1987. A second three-percent aerial strip sampling of the Jubba Valley Zone was carried out in the xagaa season simultaneously with the five-percent sampling of the Jubba Floodplain Zone, in the period 29 July to 26 August 1987.

Jubba Floodplain Zone, Reservoir Zone, and Jubba Valley Zone

Vertical aerial photographs at a scale of approximately 1:1,000 scale were taken of 390 potential monitoring sites distributed throughout the terrestrial parts of the study area. Results of these surveys are presented in this report in the form of analytical summaries. The bulk of information generated is intended as raw or semi-aggregated baseline data for use by environmental scientists to gauge the extent and character of natural resources in Jubba Valley, and provide a basis on which to design an eventual monitoring program in order to assess the positive and negative effects of construction and operation of the Baardheere Dam and subsequent development of the valley, and to take appropriate mitigating measures.

The majority of field-oriented information exists in manuscripted field maps, photographs, and data bases which are being made available in very limited quantities (in some instances, the original only) in selected data repositories in Africa and the United States. A guide to the contents and utilization of data in these repositories is presented in Volume IV (Bibliography) of the JESS final report.

III. METHODS EMPLOYED FOR SURVEYS IN THE JUBBA VALLEY

A. Total Search and Enumeration of the Jubba River Zone

The survey method used was described in Watson (1987), but is repeated here for the sake of having all the survey methods in a single report. The aircraft used was a Piper Super Cub (PA18), modified for aerial surveillance work with long-range tanks, recorders, and radar altimeter. The aircraft panels were both open, giving the pilot (acting as observer) unobstructed views on both sides and below the aircraft. The open panels also allowed for photography with a maximum of flexibility.

The river was flown in relatively short sections in a south to north direction to gain the most loss-of-ground speed from the prevailing northeasterly winds and, hence, better observation conditions. River sections were selected in a north to south sequence, and the survey's progression down the river was organized to allow simultaneous survey of the Jubba floodplain and valley. Two surveys were carried out: 28 to 30 September 1986 and 28 March to 7 April 1987.

The survey employed observations and counts of items on and in the water, and on the immediate river bank. To accomplish total enumeration of this narrow strip, the aircraft was flown at 90 kph (55 mph) into the prevailing wind of about 15 kph (9 mph), which gives a ground speed down the river of 75 kph (46 mph). When items requiring more time for counting or scrutiny were seen, the aircraft was circled in a steeply banked position for continuous observation of the same point on the ground. In most cases, the features recorded on the 1:100,000 map sheets have been completely enumerated, given the limitations of the method which are explained later in this report. The features enumerated in this survey, with comments, are described in Appendix A of this report.

B. Aerial Photography of the Jubba Floodplain Zone

Aerial photography of the Jubba Floodplain Zone was carried out using a K17C camera mounted in a PA18 aircraft. The aircraft was flown along a path following the river, at a height of 5,000 feet, to give a negative scale of 1:10,000. Frames were given the standard 60-percent overlap for stereoscopic analysis. Two strips of photographs were taken, one on the east bank and the other on the west bank. Where possible, the river itself was included in every frame. The width on the ground of a 1:10,000 frame is 2.3 km, so that photo coverage extended between 1.5 and 2.0 km from the river, covering most of the floodplain except where it widens out between Jilib and Yontooy. The full extent of the Reservoir Zone is not covered by this photography.

The monochrome photography was carried out between 3 and 8 March 1987, and prints were delivered on 22 March. Interpretation was made using a Wild mirror magnifying stereoscope and a pocket stereoscope. Interpretations were transposed to 1:50,000 map sheets. The methods used have been described in detail in the internal report in Trump (1987).

C. Aerial Strip Sampling of the Jubba Floodplain Zone and Jubba Valley Zone

Aerial strip sampling is a well-established method of obtaining low-cost estimates of:

- livestock numbers, densities, and activities;
- wildlife numbers and densities;
- structure numbers and densities; and
- areas under different type of land use.

As with any sampling regime, the study area was geographically delineated into units of enumeration to facilitate analysis. The *stratum* represents the most basic unit of analysis. Strata, as depicted in Figure 1 and graphically illustrated in Figure 2.0, were based on the physiographic/land-use units established by the Jubba Valley Development master planning team (AHT 1988) on photomosaics. As detailed in Appendix D, strata are further aggregated by physiographic *regions* and eventually to *river floodplain sectors* and *river valley sections* which make up the Jubba Floodplain Zone and Jubba Valley Zone (Figure 1). Sectors comprise the area of the river and floodplain, while sections include the study area pertaining to the valley inclusive of the river and floodplain.

Three aerial strip sampling surveys were carried out in the Jubba Floodplain Zone and Jubba Valley

Zone. The methods employed are detailed in the following sections.

1. Stratification and Sampling

Jubba Floodplain Zone

Aircraft	PA18
Speed (ground speed)	6 mph (75 kph) to 64 mph (103 kph)
Height (aboveground)	260 feet (79 m)
Observation (mode)	through open panels by pilot (Dr. R. M. Watson)
Recording	Large groups photographed by 35 mm SLR camera on Ektachrome film. Other observations were recorded on tape. Times were measured by stopwatch.
Dates	26 January-3 February 1987 (first jiilaal) 28 March-13 April 1987 (second jiilaal) 29 July - 26 August (xagaa)

As mentioned, *strata* were based on the physiographic/land-use units established by AHT. However, north of the dam site, AHT made no physiographic/land-use interpretation. For River Section I (Ethiopia border to Luuq) and River Section II (Luuq to the Baardheere Dam site), RMR created four strata: the river (stratum 1), including islands, sandbanks, and bank, and the floodplain (stratum 2), called River Sector I; the river (stratum 3) including islands, sandbanks, and bank, and the floodplain (stratum 4), extending beyond the floodplain to the limits of the area to be inundated, called River Sector II. South of the dam site, some of the AHT units have been combined and some new strata have been created:

River Sector III

The river, sandbanks, islands, and banks	stratum 5
All floodplain units	stratum 6

River Sector IV

The river, sandbanks, islands, and banks	stratum 7
All levee units, alluvial fans, and coarse sediment physiographic units	stratum 8
All dhesheeg units, oxbows, and fine sediment physiographic units	stratum 9
All swamp (permanently flooded) units	stratum 10

[Note: These extend through other river sectors to the south]

River Sector V

The river, sandbanks, islands, and banks	stratum 11
All levee units, alluvial fans, and coarse sediment physiographic units	stratum 12
All dhesheeg units, oxbows, and fine sediment physiographic units	stratum 13

River Sector VI

The river, sandbanks, islands, and banks	stratum 14
All levee units, alluvial fans, and coarse sediment physiographic units	stratum 15
All dhesheeg units, oxbows, and fine sediment physiographic units	stratum 16
Irrigated sugar estates	stratum 17

[Note: These extend through other river sectors to the south]

Flat fine river alluviums	stratum 18
Villages	stratum 19

[Note: Not all villages have been have been separated out at stratum 19; villages are found in other river sectors to the south]

Mixed river alluviums	stratum 20
Irrigated rice of the Fanoole Project	stratum 21
Irrigated banana estates	stratum 22

[Note: These extend through other river sectors to the south]

Mixed irrigations of the Mogambo Project	stratum 23

[Note: Within the boundaries of the Mogambo Project, extensive areas are still being cleared for irrigation]

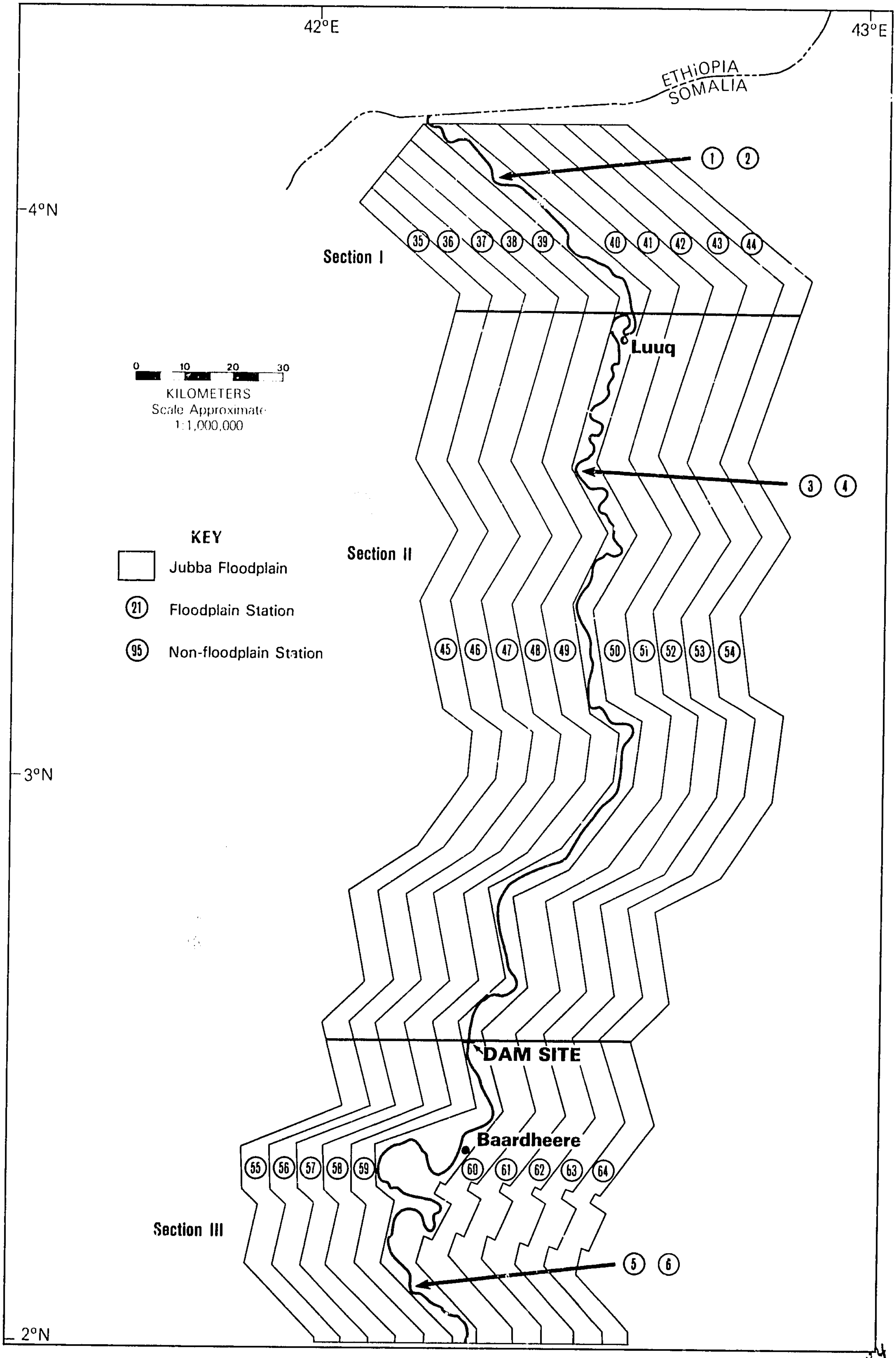
River Sector VIIA

Flat fine river alluviums	stratum 24
The river, sandbanks, islands, and banks	stratum 25
All levee units, alluvial fans, and coarse sediment physiographic units	stratum 26
All dhesheeg units, oxbows, and fine sediment physiographic units	stratum 27
Mixed river alluviums of the eastern part of the floodplain—for the most part, heavily cropped	stratum 28
Mostly uncultivated mixed alluviums	stratum 29
Flat fine alluviums of the Dhesheeg Waamo	stratum 30

River Sector VIIB

Flat and fine river alluviums	stratum 31
The river, sandbanks, islands, and banks	stratum 32
All levee units, alluvial fans, and coarse sediment physiographic units	stratum 33
All dhesheeg units, oxbows, and fine sediment physiographic units	stratum 34

The river sectors and survey strata are shown in Figure 1, and in Figure 2.0, a simplified diagram of the system of stratification can be seen.



42°E
43°E
ETHIOPIA
SOMALIA
4°N
3°N
2°N
Section I
Section II
Section III
Luuq
DAM SITE
Baardheere
0 10 20 30
KILOMETERS
Scale Approximate
1:1,000,000
KEY
Jubba Floodplain
21 Floodplain Station
95 Non-floodplain Station
1 2
3 4
5 6
35 36 37 38 39 40 41 42 43 44
45 46 47 48 49 50 51 52 53 54
55 56 57 58 59 60 61 62 63 64

184

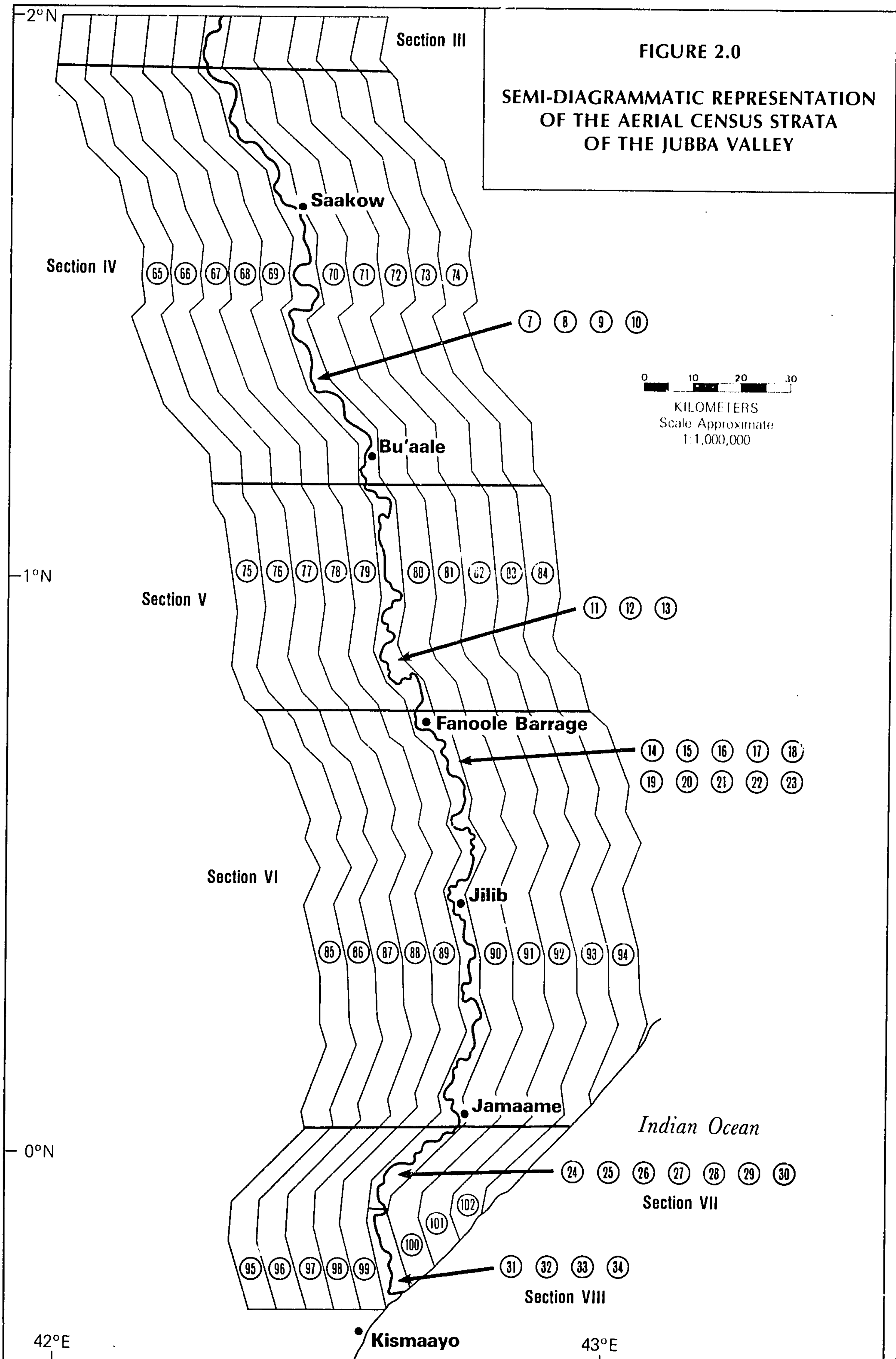


FIGURE 2.0

SEMI-DIAGRAMMATIC REPRESENTATION OF THE AERIAL CENSUS STRATA OF THE JUBBA VALLEY

Strip samples were selected at random, with probability proportional to size in each stratum. Because of the extremely small size of some strata in the Jubba Floodplain Zone, and because most of these are broken up into many discrete subunits, it was necessary to select more sampling units than the planned five-percent area cover to ensure adequate precision of the estimates.

Strip widths were estimated from observations of fixed grids at the base airstrips (Kismaayo, Jamaame, and Baydhabo) at the start and end of each sampling day. The strip width for all surveys was 228 m. Samples were oriented at right angles to the axis of the river where the floodplain is wide, but in the very narrow sections, an oblique orientation was selected to increase the length of the sampling units. This orientation was drawn on the map prior to the survey being flown to reduce the chances of introducing bias.

In addition, for each sampling unit, the total time taken to fly from the starting point to the ending point was recorded. If circling was necessary during the flying of any sample, to take photographs or clarify a particular observation, this time was deducted from the record. The distance from starting point to ending point was measured from the 1:100,000 map, or the 1:50,000 photomosaic.

Jubba Valley Zone

Aircraft	PA18
Speed (ground speed)	46 mph (75 kph) to 64 mph (103 kph)
Height (aboveground)	260 feet (79 m)
Observation (mode)	through open panels by pilot (Dr. R. M. Watson)
Recording	Large groups photographed by 35 mm SLR camera on Ektachrome film. Other observations were recorded on tape. Times were measured by stopwatch.
Dates	28 March - 13 April 1987 (second jiilaal) 29 July - 26 August (xagaa)

The Jubba Valley Zone has been stratified in two dimensions. River sectors (of the Floodplain Zone) have been extended eastward and westward to create seven *river sections*. These coincide in number with the river sectors of the Jubba Floodplain Zone, except that River Sectors VIIA and VIIB have been combined to form River Section VII for the Valley Zone.

Each river section has been divided into segments 6 km wide making five segments (strata), on each side of the Jubba Floodplain Zone. Strata are numbered from east to west, across each river section, starting at the northernmost section and continuing southward. There are 68 strata, being numbered 35 to 102. The river sections and survey strata are shown in Figure 1, and a simplified diagram of the system of stratification can be seen in Figure 2.0.

Strip samples were, at the scientific request of the client, selected at 6 km intervals, along east-west grid lines. Although this does not provide the most efficient sampling strategy, the evenness of cover and standardization of sampling strip orientation ensure a good spatial distribution of data. Strip widths were estimated from observations of fixed grids at the base airstrips (Kismaayo, Jamaame, and Baydhabo) at the start and end of each sampling day. The strip width for all surveys was 228 m. Observations were made using a tape recorder, times were measured by stopwatches, and large groups were counted from 35 mm transparencies using a 20 to 20 power zoom binocular microscope and mounted needles to mark the fuel emulsion when the animal or feature was counted. As with the Jubba Floodplain Zone, the phenomena observed during the strip samples were typified in Appendix B.

2. Computations and Analyses

Transcriptions of observations were entered into the RMR Aerial Resource Inventory System (ARIS) survey analysis program. When aerial photographs (as transparencies) were counted, the results were substituted for the frame reference numbers in the ARIS data base.

A number of correction factors and constants were also entered into the data base. Correction factors for animals spotted and counted (with the exception of hippopotamuses, crocodile, and turtles) on narrow sampling strips flown slowly for the cover conditions found in southern Somalia, have been based upon several hundred sets of observations made in 1983 and 1984 during the Southern Rangelands Survey (Watson and Nimmo 1985), and augmented by 105 additional observations. These correction factors are based upon repeated observations (visual counting and photographs) of discrete groups of livestock or wildlife which are followed through mixed vegetation types until they can be photographed at very low level in entirely open grassland. This last observation is taken to provide

Correction Factor(R) and Coefficients for Variation (C) for Livestock and Wildlife Concealed by Vegetation

Cover Category

SPECIES	OPEN R	OPEN C	MEDIUM R	MEDIUM C	DENSE R	DENSE C
Cattle	1.058	0.00872	1.190	0.00530	1.640	0.11625
Sheep	1.087	0.00822	1.275	0.00699	1.824	0.00758
Goat	1.087	0.00833	1.275	0.00699	1.824	0.00758
Camel	1.097	0.01135	1.245	0.01624	1.693	0.02151
Donkey	1.097	0.01135	1.245	0.01624	1.693	0.02151
Wildlife (Other)	1.336	0.03574	1.977	0.04625	3.759	0.04855
Hippopotamus	4.008		Not computed		(probably too large)	
Crocodile (Minimum)	30.000		Not computed		(probably large)	
Crocodile (Maximum)	100.000		Not computed		(probably large)	
Turtle			Not computed		(probably large)	

the true estimate of the number of animals in the group, when careful counting is made twice by an experienced counter, from a photograph in which animals are not tightly bunched. The true estimate has been tabulated alongside estimates made in dense, medium, and open cover under operational conditions, and correction factors for each species or group of species for the three cover categories have been calculated. These are shown on the following page.

For hippopotamus, a correction factor has been calculated using the statistics of one-third of a group being countable at any moment (Watson 1979a) and of 74.85 percent of all groups being spotted for counting. This provides an overall correction factor of 4.008. For crocodile previously calculated, correction factors for aerial counts have varied between 30 and 100, (Parker and Watson 1969; Watson and Parker 1970; Watson *et al.* 1971; Graham and Beard 1973). Therefore, 30 is used as the minimum and 100 as the maximum correction factors. Correction factors for turtles have not been worked out, but they will be very large. No correction factors have been worked out for counts of structures.

Computations of biomass have been based on the population mean weights shown in the table on the following page.

Computations were made on the entered data for estimates of number and densities of livestock, wildlife, water sources, structures, and cultural features. A full statistical explanation of the method is available in Jolly and Watson (1979), and in Jolly (1979).

In summary, the sampling of the Jubba Floodplain Zone is characterized as *stratified random strip sampling* with replacement, with probabilities of sample selection proportional to sample size. The sampling of the Jubba Valley Zone is termed *stratified systematic strip sampling* with equal probabilities of sample selection.

The formulae appropriate to the proportional-to-size method are:

$$\hat{Y} = \sum_i Z_i \bar{d}_i \qquad (1)$$

where

$\hat{Y}$ = estimated total of variant y

d_i = mean of y per unit area (km^2) as observed on a particular sample strip in stratum i

$\bar{d}_i$ = unweighted mean of the di observed in stratum i

Z_i = area of stratum i (km^2)

and where $\sum_i$ denotes summation over all strata.

The estimated variance of $\hat{Y}$ is given by:

$$\mathrm{Var}(\hat{Y}) = \sum_i (Z_i^2/N_i) Sd_i^2 \qquad (2)$$

where

$$Sd_i^2 = [\sum d_i^2 - (d_i)^2/N_i](N_i - 1)$$

N_i is the number of strips observed in stratum i

and $\sum$ denotes summation within a stratum.

It is appreciated that the variable orientation of samples provides a new factor in the issue of selec-

BIOMASSES OF LARGE ANIMALS OBSERVED IN SURVEYS	
Cattle	180 Kg
Sheep	18 Kg
Goats	18 Kg
Camel	304 Kg
Donkey	150 Kg
Oxen	180 Kg
Duiker	15 Kg
Reedbuck	20 Kg
Oribi	12 Kg
Gerenuk	25 Kg
Waterbuck	105 Kg
Kesser Kudu	40 Kg
Oryx	90 Kg
Ostrich	80 Kg
Crocodile	200 Kg
Warthog	35 Kg
Baboon Troop	1000 Kg
Vervet Monkey Troop	200 Kg
Giraffe	800 Kg
Elephant	2500 Kg
Hippopotamus	1000 Kg
Honey Badger	30 Kg
Bush Pig	35 Kg

Water Source "Importance" Weightings	
Riverine Well	4
Well	4
Well in Dhesheeg	4
Sand Dune Well	4
Flowing Spring	8
Riverine Pool	4
Rainwater Pool	4
Riverine Seepage	2
Dry War	6
Abandoned War	4
War with Water	6
War under Construction	4
Balli with Water	6
Dry Balli	6
Abandoned Well	2

tion of sampling units, but no departure from the fundamental requirements of sampling theory has been introduced. Likewise, the systematic selection of sampling units for the survey in the Jubba Valley Zone would not allow a true computation of variance. However, since the observer saw no obvious relation between the 6 km inter-sample interval and any environmental features, it has been judged possible to use Jolly's (1969a) ratio method formulae for computing estimates and standard errors. It is not always appreciated that there are, in fact, several components making up the sampling error (variance) calculated by these procedures. Jolly and Watson (1979) described this situation as follows:

> Although the major component of sampling error is the variation among strips, other minor components arise from movement of the aircraft and observer, which may be regarded as errors of measurement, because they would occur even if the same strip were observed repeatedly while the same animals remained on it. The sampling model may therefore be formally regarded as a two-stage sampling process in which the primary units are the strips and each strip contains a theoretically infinite number of secondary units represented by the theoretically infinite number of possible observed values for that strip. The sampling procedure is in effect to select ni strips from the ith stratum as already described, and then to select one secondary unit - that is, to make one observation - for that strip. Formulae (1) and (2) for the probability-proportional-to-size estimate apply rigorously to this model, the estimate of variance, Var (Y), in particular, being unbiased.

Calibration of observed strip width is a time-consuming process, but as a potential source of bias, great accuracy is desired for this measurement. Sampling strips are defined by two parallel marker rods fixed to the left-hand wing strut. The projection of these from the pilot's eye onto the ground defines the sample strip. The mean ground width of the strip observed will depend solely on the height (altitude above datum) of the aircraft. Therefore, the aim of the calibration is to establish the relationship between height and strip width, and the procedure consists of making repeated flights over a line of white stones spaced at 5 m intervals on the ground. By lining up the inner wing marker with the zero mark on the ground, the position of the outer marker is recorded to the nearest 5 m, while an almost simultaneous reading is taken of the plane's radar altimeter. From a series of these observations the width-to-height ratio is estimated by:

$$Rc = \overline{Wr}/\overline{hr}$$

where $\overline{Wr}$ is the mean strip width recorded on the calibrating stones, and hr is the corresponding mean height above ground read from the radar altimeter.

During the surveys of the sample strips, height was recorded at 10-minute intervals. These readings

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represent quasi-random departures from the intended height, as it is virtually impossible for the pilot to maintain an exact given height when his attention is focused on observing the ground, and the terrain is uneven. An estimate of the mean strip width ($\overline{Ws}$) during the survey is then given by:

$$\overline{Ws} = Rc\overline{hs} \qquad (3)$$

where $\overline{hs}$ is the mean height observed during the survey. Since Rc and $\overline{hs}$ are independent, the approximate variance of $\overline{Ws}$ is:

$$Var(\overline{Ws}) = Rc^2 Var(\overline{hs}) + \overline{Ws}^2 CR_c^2$$

Likewise, $\overline{hs}$ will be the mean of a large enough number of readings to ensure that Var($\overline{hs}$) is also negotiable. Hence, Var($\overline{Ws}$) will ordinarily be negligible. If it were not, then a component would have to be added to the sampling error. The estimate ($\overline{Ws}$) of mean strip width will then be used, in conjunction with strip length measured on i for calculation of the density di. Thus, di is free of any bias from errors in the measurement of strip width. However, each di is still subject to random error from variation in the strip width actually viewed by the pilot at any given moment through (a) variation in height of the aircraft about its mean value, and (b) wing movement (*i.e.*, banking) and movement of the pilot's eye.

These will result in variation in the number of animals (or other features) counted, and will be included automatically as components of the sampling error estimated by formula (2). Jolly and Watson (1979) showed that these components are, in any case, very small and totally insignificant, using the following demonstration taken from real data collected in South Kordofan Province of Sudan in 1974.

> An approximate average of 80 animals was observed per sample strip, and the coefficient of variation for sampling error (per sample strip) within strata was the order of 110 percent. If the animals were sufficiently dispersed along the sample strip for each to be subject to independent effects of variation in the width of strip seen by the pilot, then it can be shown that the mean square Sd_i^2 in the computation of variance formula (2) would include a component:
>
> $$(C1^2 + C2^2)\bar{d}1^2/80$$
>
> where $C1$ and $C2$ are the coefficients of variation of 0.076 and 0.060 for the second aircraft. As a proportion of the total sampling variance, this gives a value of 0.000097. Since the average number of groups of cattle observed per strip was two, and because of the method of recording groups described in section 4, the actual effect will be even less than this. Thus, random variation in strip width observed is, in general, likely to represent an extremely small part of the total sampling error.

Jolly (1979) has developed a generalized theory to deal with the problem of the size of the sampled item (*i.e., observations of large objects and groups*). The problem stems from the fact that animals, whether wild or domesticated, occur in groups of one or more. For all species, information is usually wanted on herd or group size distribution as well as on total number of individuals. Therefore, if a group is encountered, part of which lies outside the strip defined by the wing markers, the pilot counts or photographs the entire group, circling as necessary and then returning to the exact position at which he left his original course. The herd must then be given a reduced weighting to avoid bias. This is done by tape marking both wing struts at intervals corresponding to adjacent strip widths so that on approaching the group, the pilot can note the number of adjacent strip widths wholly or partly occupied by the group. If this number is n, then a weighting of $1/n$ for the group gives an unbiased total of animals and groups.

The strip sample model used for counting animals, water sources, houses, and other cultural features does not apply efficiently for assessing *land-use types and conditions*. In this case, the inner transect marker becomes a sampling line (transect), and the time taken for a fixed point on that marker to pass over the particular land-use or land-condition type is recorded. Time is taken also for the marker to traverse the whole sampling line (after deducting time recorded by stopwatch for circling or other deviations from the sampling mode of flying). The proportion of each type of land-use or land-condition of the whole sampling unit is given by:

$$P_1 = \frac{\sum(t_{11} + t_{13} \text{———} t_{1n})}{T}$$

where P_1 is the proportion of land use type/condition 1 in a sampling unit; t_{11}, t_{12}, t_{13} ——— t_{1n} are the times taken for the fixed marker point to pass over the n areas of land-use type/condition; T is the total time taken for the fixed marker point to pass over the whole sampling unit in sampling made of flying.

The different P values computed above are treated as the di values of formulae (1) and (2) for calculating estimates, mean proportions (or percentages), variances, and standard errors.

The general theory underlying *bias corrections* is well-described in Jolly and Watson (1979).

When a bias is likely to be approximately proportional to the expected value of the variant, an appropriate correction factor is R estimated as:

$$R = \sum y/x \qquad (4)$$

where x and y are respectively the observed and true values of the variant in a sample of n and represents summation over the sample. Provided the data for estimating several correction factors are mutually independent and also independent of the survey observations, a fully adjusted population estimate $\hat{Y}_A$ is given by:

$$\hat{Y}_A = \sum_j \hat{Y}_{A_j} \qquad (5)$$

where $\hat{Y}_{A_j}$ is the fully adjusted estimate for a subset, j, of the survey observations, given by:

$$\hat{Y}_{A_j} = (\prod_k R_{jk})\hat{Y}_j$$

R_{jk} is the *kth* correction factor appropriate to the subject j; $\hat{Y}_j$ is the unadjusted estimate for subset j from (1); and $\prod_k$ denotes the product over k; and $\sum_j$ the summation over all subsets j.

In general, k will represent different sets of correction factors for different subsets j. The estimated variance of the adjusted estimate is then:

$$Var(\hat{Y}_A) = Var_o(\hat{Y}_A) + \sum_i \hat{Y}^2_{AR_i} C^2_i \qquad (6)$$

where $Var_o(\hat{Y}_A)$ is the sampling variance obtained by applying (2) to the fully adjusted data:

$\hat{Y}_{AR_i}$ is the fully adjusted (*i.e.*, adjusted by all relevant correction factors) estimate (from (1)) for data to which the correction R_i has been applied; C_i is the estimated coefficient of variation of R_i; and $\sum_i$ denotes summation over all correction factors R_i.

Thus (5) and (6) cover any conformation of adjustments whether or not the R_i are applied to mutually exclusive sets of data: they include, for example, a situation where two or more tests of data within the same sampling unit are subject to different correction factors.

Three significant sources of bias have been corrected in this survey: concealed animals, failure to observe or count entire groups, and techniques of counting from photographs.

Concealed Animals

Animals may be hidden from view by vegetation or by other animals in the group. Therefore, it is necessary to derive separate correction factors for individual animal species in different classes of vegetation cover, and for different times of year, if there are seasonal effects either in the behavior of the species or in vegetation patterns.

As described earlier, randomly selected groups of each species are first counted in the usual way, after which the pilot descends very low and counts or photographs again until all animals in the group have been accounted for. If necessary, before the recount, he waits for the group to move into more open cover where all animals are clearly visible. The resulting count is then taken to be the true count y. Together with the original count x, this enables a large number of random pairs of x/y values to be accumulated for the estimation of p from (4), and its coefficient of variation by standard ratio-estimation methods. (See table above on correction factors for livestock and wildlife.)

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Failure to Observe Complete Groups

The method of adjustment just described for animals concealed relies on groups of animals being first observed from the normal survey height. However, for small groups of one or more animals, there is a possibility that the group will be completely missed, resulting in the correction factor being underestimated. Therefore, an estimate is required of the number of groups of given size missed in this way. The method has been described in detail in Watson (1981). For these surveys, the correction factors for livestock groups missed are so small that no additional correction factor is required. For wildlife, where a large proportion of groups are of small size, the *R* values shown in the table on correction factors is significantly influenced by this component.

Counting from Photographs

Animals in photographs were counted under a low-power binocular microscope. Checks on the accuracy of the counting technique were made by recounting under higher magnification and taking more time. Recounting of 300 groups of livestock produced an estimated correction factor (*R*) of 1.0215 with a variation coefficient 0.0052.

D. Complete Search of the Reservoir Zone

This survey, carried out on 11 and 12 December 1987, produced a total census of non-refugee settlements and houses in the inundation area of the proposed Baardheere Dam. The survey was flown at 50-60 mph (80-100 kph) and at 200-300 feet (60-91 m) above the ground over the entire proposed inundation area, circling and searching for structures. Where the zone widens out from the river, the area was surveyed by blocks that were defined by easily distinguished natural and cultural features as described in Turner and Watson (1965).

Structures were classified as:

- occupied houses with conical grass roofs (*monduls*);
- occupied *agallo* (nomadic houses of skin or mats over a frame of curved wooden members);
- occupied nomadic shelters (temporary shelters of branches);
- occupied houses with pitched, usually central ridge roofs of thatch or iron; and
- other occupied dwelling houses.

Ancillary structures such as toilets, grain stores, and stables were not counted. Curiously, no unoccupied houses were observed.

Each structure or group of structures in the Reservior Zone was photographed at 35 mm format with Ektachrome 100 ASA film. The location of all structures or groups of structures was plotted on the 1:50,000 scale aerial photomosiac.

In addition to structures, occurrences and locations of other features were recorded as:

- land-use features:
  —rainfed cropping,
  —rainfed fallow,
  —abandoned rainfed cropland,
  —irrigated cropland,
  —irrigation pump,
  —enclosed land,
  —cleared land,
  —agricultural shelter, and
  —straw stacks/stores;
- abandoned livestock enclosures;
- occupied livestock enclosures;
- underground grain stores; and
- graveyards.

The limits of the inundation area were plotted on the 1:50,000 air photomosiacs based approximately from the 142 m contours on the 1:100,000 Soviet Mapping Agency maps, even though various water levels have been proposed for the Baardheere Dam.

During the work of the survey, it was decided to count not only structures below the 142 m contour, but also those above 142 m judged likely to be severely affected by the inundation. Two criteria were applicable in making this judgment. First, some structures are very close to the 142 m contour on gently sloping land. It is expected that environmental modifications resulting from the development of an extensive drawdown area, particularly with respect to human disease vectors (Jobin 1988) and livestock disease vectors such as *tabanids* and other biting flies, will force these people to move.

and livestock disease vectors such as *tabanids* and other biting flies, will force these people to move.

Second, where the valley wall is not precipitous, several villages that farm land on the river alluviums have been sited on higher (healthier) sites overlooking the farmland. These structures will lose all their productive cropland when inundation takes place. A similar classification has been applied to the refugee camps.

Finally, results of the three extensive aerial surveys using strip sampling and two total counts of the river have been used to give a rough indication of the numbers of pastoralists likely to be affected by the inundation and the consequent removal of their emergency dry-season fodder reserve. These surveys also indicate areas of cropland which will be lost.

E. Monitoring Site Photographs

Vertical, single-frame monochrome photographs were taken throughout the Jubba Floodplain, Jubba Valley, and Reservoir Zones. They were distributed as follows:

- 100 on the east bank in the Jubba Valley Zone;
- 100 on the west b... n the Jubba Valley Zone;
- 10 in each of strata 2, 6, 8, 12, 16, 24, 27, 28, 31, and 33;
- 15 in each of strata 9, 13, 15, 18, and 29;
- 20 in stratum 20; and
- 50 in stratum 4.

For purposes of sampling selection, it was decided to distribute about three samples in each of strata 35 to 102, thereby insuring a wide coverage of the east and west bank in the Jubba Valley Zone. The method of selection was as follows:

- before a day's flying, the sampling route was plotted and converted to (approximate) minutes, starting at minute 0 and ending at minute x;

  For example:

  Take off 0915

  start first sample (35/2) 0950 = minute 0

  end first sample (35/2-36/2) 0953 = minute 3

  end second sample (36/2-37/2) 0956 = minute 6

- using random numbers, the targeted number of sample sites for each stratum were selected; and
- photographs were taken on the stopwatch, provided the scene below the aircraft was not completely currently cropped (it turned out to be impossible in heavily cultivated strata to avoid all cropping and, in any case, the dynamics of the croplands will be an important feature to be monitored) and was easily relocated (being on a cut line, near a track, water source, or an obvious marking). Although it was a difficult task to ensure exact relocation without introducing bias, the pilot used a track, cut-line, water source, or other large feature only if there was no obvious influence from that feature on the vegetation, soil, and drainage.

A. Total Search and Enumeration of the Jubba River Zone

The lowest river level in the 1987 jiilaal occurred in mid-March, and by 28 March, waters had risen as a result of rainfall in the Ethiopian parts of its catchment. Nevertheless, there were still extensive areas of dry riverbed exposed in the upper river, surface flow had ceased below Jilib, and long stretches of the channel were dry south of Kamsuma Bridge as far as the tidal reaches between Yoontoy and Gaduud.

The results, in the form of photocopies of the 1:100,000 map sheets, annotated with all observations made in the Jubba River Zone including the sites and names of the refugee camps, the limits of the Jubba Floodplain Zone, and the sampling strips flown in the five-percent sampling of the Jubba Floodplain Zone, are contained in the JESS data repositories as described in Volume IV (Bibliography) of the JESS final report. Maps comprising 1:100,000 map sheets annotated with the results of the first survey of the Jubba River Zone (1986) were presented with the report of that survey. The positions of oblique aerial photographic views of the river are shown on these 1:100,000 maps, and the photographs themselves have also been included in the repositories grouped for each section of the Jubba River Zone.

Tabulation of the results of counting the listed features grouped for the Jubba River Zone (Region 76) by corresponding river sectors in Table 1. The equivalent numbers seen in the September 1986 high-river flow survey are also shown in this table. Note that river sectors correspond in number to river sections (see Figure 1), and are described as follows.

Sector I

The Jubba River from the Ethiopian border to a point due north of Luuq in the circular loop flowing around the town, about 3° 49'45"N. This is the point at which, at present, waters in the proposed Baardheere Reservoir will back up at highest water level (142m). This section of the river is characterized by numerous islets, the bed is slightly incised, and floodplain terraces are well-developed. (Analysis includes Region 1.)

Sector II

The Jubba River from the aforesaid point to the planned site of the Baardheere Dam. In this sector, the river starts to cut a significant gorge through suites of *Cretaceous* and *Jurassic* limestones and sandstones which constrict its course. In the southernmost part of this reach, the gorge is a narrow and spectacular gash, 50 m deep and 500 m wide. The present dam site is located where the river cuts latitude 2° 37'N. (Analysis includes Region 3.)

Sector III

From the dam site, the gorge continues southward for about 18 km, gradually widening to allow the river terraces to extend several 100 m from the river, which remains incised weakly in the limestone plains for another 170 km. Along this stretch, the river winds through eroding limestone plateau remnants, now reduced to low hills. At latitude intersect 1° 53'30"N, the river starts to meander in its own floodplain, and has entered Sector IV. (Analysis includes Region 5.)

Sector IV

This sector marks the part of the river where erosion and deposition processes are approximately in balance in the long- term. Dhesheegs and levees make their first appearance, and the valley lies in a shallow trough cut through the marine plain. The sector continues as far south as latitude intersect 1° 10'30"N. (Analysis includes Regions 7 and 10.)

Sector V

In this sector, deposition processes predominate over erosion, and no tract of the incised trough remain. The river meanders extensively in its own floodplain and there are well-developed levees and numerous dhesheegs. This sector ends at the Fanoole Barrage at 0° 44'45"N. (Analysis includes Region 11.)

Sector VI

The Jubba River south of Fanoole Barrage is meandering over its own floodplain, and obviously depositing more material than it is removing. Oxbows and ancient riverbeds are common in this reach, but levees and dhesheegs seem to be less abundant. Toward the end of this reach, the Shabeelle River channels join the Jubba from the east, and a little further south, the river runs up against the coastal limestone/duneland ridge, which diverts the river in a southwesterly direction. Sector VI ends at latitude 0° 03'N. (Analysis includes Region 14.)

Sector VII

Along this final stretch, the Jubba retains little energy and most of its silt has been deposited. It runs in a shallow incision cut by occasional floods, except where it crosses the limestone/dune ridge to enter the sea. At its mouth, the river flows over a shallow sand bar into the sea. There is no evidence of tidal flushing of the mouth, and salinity doesn't seem to be penetrating more than about 6 km (to Goob Weyn). There is no delta formation, partly because the river has lost its energy and silt load by the time it reaches the sea, and partly because of the strength of offshore currents sweeping alternately northeastward and southwestward across the river mouth. Although no measurements exist, it appears that there may be appreciable losses of water in this final sector through the riverbed—possibly in subsurface flow along ancient, former channels to the sea. Analysis includes Regions 25 and 32.)

Data presented in Table 1 give rise to a number of comments and points of discussion. These comments are segregated by each item enumerated and are intended to elucidate the data.

Hippopotamus

Counting hippopotamuses from the air is more easily accomplished in the time of low-river flow, when they concentrate in the deeper pools. At times of floods, hippopotamuses tend to disperse—especially from a river with so much human activity on its banks. Although every significant flooded area was searched carefully, they were extremely difficult to spot, partly because it was impossible to "predict" where the deep pools were, and because flooded areas presented a more patterened background against which it was difficult to spot hippopotamus heads. Some had left the river channel and were seen in the flooded riverine strip in this census.

Even under perfect spotting conditions, only a small number of hippopotamuses can be seen above water. In clear water, this problem is less serious, but the Jubba in September is totally opaque. Studies were made in the Rufiji River (Watson 1979b) of this phenomenon, and it was deduced that undisturbed hippopotamus groups had almost exactly one-third of their members visible at any sampling moment. In comments on the September survey (Watson 1987), it was deduced that the hippopotamus population of the Jubba River was between 400 to 800 range, although 980 to 1,260 is a more likely population. This is based on a clear water correction factor for hippopotamuses not seen because of water with a factor of 1.5 (half the factor for deep, turbid water) and a correction factor for groups not spotted of between 1.11 and 1.543 (typical of the range for a large animal in mixed cover).

There is no evidence between the two surveys of significant hippopotamus movement along the river, as the sector-by-sector analysis below indicates, showing the number seen at low flow divided by the number seen at high flow:

SECTOR	LOW-FLOW NUMBER/HIGH-FLOW NUMBER
I	0-(none seen either survey)
II	0-(none seen either survey)
III	0-(none seen high- flow survey)
IV	5.45
V	7.11
VI	5.82
VII	4.36
For all	6.24

Observations of hippopotamus tracks on the river bank, and the sighting of one dead hippopotamus in the river, suggest that the remaining hippopotamus population is responsible for appreciable crop damage in the dry season and at times of low-river flow.

Crocodile and Dead Crocodile

Crocodile present the same types of problems for spotting and counting as hippopotamuses, but if anything, they tend to disperse more rapidly and widely in floods. This is particularly true of the young, which, with sizes down to 15 cm, are virtually impossible to see from an aircraft. Several studies have been carried out to develop calibration factors useful for estimating the relationship between numbers seen from the aircraft and numbers present in the river. Essentially, the method hinges on two additional sets of data: counts carried out at night from a boat or by wading, using a spotlight to pick out and count crocodile eyes; and demographic modeling on the assumption of a stable population to "fill in" for the very small animals which are always missed in aerial observations, and which often take to the land at night when the boat or wading person approaches.

Correction factors for rivers similar to the Jubba vary between 30 and 100, with higher factors tend-

Table 1. Results of Total Enumeration of the Jubba River Zone

SECTOR (length)		I (90 km)		II (199 km)		III (159 km)		IV (133 km)	
NAME		NUMBER SEEN	DENSITY per km²	NUMBER SEEN	DENSITY per km²	NUMBER SEEN	DENSITY per km²	NUMBER SEEN	DENSITY per km²
Hippopotamus	'86	0	-	0	-	0	-	11	0.08
	'87	0	-	0	-	18	0.11	60	0.45
Dead Hippopotamus	'86	0	-	0	-	0	-	0	-
	'87	0	-	0	-	1	0.01	0	-
Crocodile	'86	7	0.08	37	0.19	26	0.16	42	0.32
	'87	4	0.04	36	0.18	37	0.23	272	2.05
Crocodile Nests	'86	0	-	0	-	1	0.02	2	0.02
	'87	0	-	0	-	0	-	0	-
Dead Crocodile	'86	0	-	0	-	0	-	0	-
	'87	0	-	1	0.01	0	-	2	0.02
Turtle	'86	0	-	3	0.02	0	-	5	0.04
	'87	0	-	0	-	2	0.01	12	0.09
Turtle Nests	'86	0	-	0	-	1	0.01	0	-
	'87	0	-	0	-	0	-	0	-
Water Birds	'86	0	-	4	0.02	0	-	13	0.10
	'87	0	-	2	0.01	5	0.03	11	0.08
Baboon Troops	'86		NOT COUNTED						
	'87	0	-	0	-	0	-	7	0.05
Warthog	'86	0	-	0	-	0	-	0	-
	'87	0	-	0	-	0	-	0	-
Islands	'86	35	0.39	15	0.08	7	0.04	6	0.05
	'87		NOT COUNTED						
Flowing Springs	'86	0	-	4	0.02	1	0.01	0	-
	'87	1	0.01	2	0.01	0	-	0	-
Dhesheeg	'86	0	-	0	-	0	-	12	0.09
	'87		NOT COUNTED						
Cropped Dhesheeg	'86	0	-	0	-	0	-	11	0.08
	'87		NOT COUNTED						
Cleared for Irrigation	'86	0	-	0	-	3	0.02	5	0.04
	'87	10	0.11	0	-	2	0.01	0	-
Cleared	'86	0	-	0	-	0	-	13	0.10
	'87	7	0.08	0	-	3	0.02	0	-
Furrow Irrigation	'86	0	-	0	-	0	-	0	-
	'87	0	-	0	-	0	-	0	-

SECTOR (length)		V (108 km)		VI (156 km)		VII (73 km)		I to VII (918 km)	
Hippopotamus	'86	36	0.33	33	0.21	14	0.19	94	0.10
	'87	256	2.37	192	1.23	61	0.84	587	0.64
Dead Hippopotamus	'86	0	-	0	-	0	-	0	-
	'87	0	-	0	-	0	-	1	0.00
Crocodile	'86	54	0.50	30	0.19	5	0.07	201	0.22
	'87	666	6.17	424	2.72	98	1.34	1537	1.67
Crocodile Nests	'86	0	-	0	-	0	-	3	0.003
	'87	0	-	0	-	0	-	0	-
Dead Crocodile	'86	0	-	0	-	0	-	0	-
	'87	8	0.07	0	-	0	-	11	0.01
Turtle	'86	1	0.01	0	-	1	0.01	10	0.01
	'87	5	0.05	5	0.03	3	0.04	27	0.03
Turtle Nests	'86	0	-	0	-	0	-	1	0.001
	'87	0	-	0	-	3	0.04	3	0.003
Water Birds	'86	8	0.07	6	0.04	7	0.10	38	0.04
	'87	7	0.06	19	0.12	4	0.05	48	0.05
Baboon Troops	'86		NOT COUNTED						
	'87	4	0.04	0	-	2	0.03	13	0.01
Warthog	'86	0	-	0	-	0	-	0	-
	'87	2	0.02	0	-	0	-	2	0.002
Islands	'86	1	0.01	0	-	0	-	64	0.07
	'87		NOT COUNTED						
Flowing Springs	'86	0	-	0	-	0	-	5	0.005
	'87	0	-	0	-	0	-	3	0.003
Dhesheeg	'86	11	0.10	4	0.03	0	-	27	0.03
	'87				NOT COUNTED				
Cropped Dhesheeg	'86	3	0.03	2	0.01	0	-	16	0.02
	'87		NOT COUNTED						
Cleared for Irrigation	'86	0	-	0	-	4	0.05	12	0.01
	'87	0	-	0	-	2	0.03	14	0.02
Cleared	'86	4	0.04	0	-	0	-	17	0.02
	'87	0	-	0	-	0	-	10	0.01
Furrow Irrigation	'86	0	-	0	-	2	0.03	2	0.002
	'87	0	-	0	-	1	0.01	1	0.001

SECTOR (length)		I (90 km)		II (199 km)		III (159 km)		IV (133 km)	
NAME		NUMBER SEEN	DENSITY per km²	NUMBER SEEN	DENSITY per km²	NUMBER SEEN	DENSITY per km²	NUMBER SEEN	DENSITY per km²
Riverbank	'86	0	-	20	0.10	1	0.01	2	0.02
Cropping	'87	16	0.18	124	0.62	20	0.13	13	0.10
Irrigation	'86	118	1.31	95	0.48	228	1.43	30	0.23
Pumps	'87	202	2.24	121	0.61	323	2.03	37	0.28
Abandoned	'86	2	0.02	17	0.09	16	0.10	0	-
Irrigation Area	'87	NOT COUNTED							
Abandoned	'86	1	0.01	0	-	2	0.01	1	0.01
Irrigation Works	'87	1	0.01	2	0.01	7	0.04	5	0.04
Wind-powered	'86	1	0.01	1	0.01	0	-	0	-
Pump	'87	1	0.01	1	0.01	0	-	0	-
Water Supply	'86	0	-	7	0.04	1	0.01	2	0.02
Installation	'87	1	0.01	6	0.03	1	0.01	2	0.02
Abandoned Water	'86	0	-	0	-	0	-	0	-
Supply Installation	'87	0	-	1	0.01	0	-	0	-
Drinking Place	'86	13	0.14	18	0.09	34	0.21	17	0.13
Livestock)	'87	11	0.12	50	0.25	45	0.28	34	0.26
Water Collection	'86	NOT COUNTED							
Point	'87	0	-	0	-	0	-	2	0.02
Bridge	'86	0	-	1	0.01	1	0.01	1	0.01
	'87	0	-	2*	0.02	1	0.01	1	0.01
Cable Ferry	'86	4	0.04	1	0.01	5	0.03	3	0.02
	'87	4	0.04	3	0.02	5	0.03	3	0.02
Boat Ferry	'86	1	0.01	2	0.01	0	-	0	-
	'87	1	0.01	1	0.01	0	-	0	-
Boat	'86	0	-	1	0.01	6	0.04	1	0.01
	'87	1	0.01	1	0.01	4	0.03	3	0.02
Canoe	'86	0	-	15	0.08	14	0.09	15	0.11
	'87	0	-	23	0.12	43	0.27	25	0.19
Raft	'86	5	0.06	8	0.04	1	0.01	0	-
	'87	8	0.09	9	0.05	0	-	0	-
Firewood	'86	11	0.12	0	-	0	-	0	-
Raft	'87	0	-	0	-	0	-	0	-
Fish Net	'86	0	-	0	-	0	-	0	-
	'87	0	-	0	-	0	-	0	-

* 1 under construction

SECTOR (length)		V (108 km)		VI (156 km)		VII (73 km)		I to VII (918 km)	
Riverbank	'86	2	0.02	0	-	1	0.01	26	0.03
Cropping	'87	36	0.33	16	0.10	5	0.07	230	0.25
Irrigation Pumps	'86	0	-	75	0.48	75	1.03	621	0.68
	'87	0	-	91	0.58	75	1.03	849	0.92
Abandoned	'86	3	0.03	1	0.01	0	-	39	0.04
Irrigation Area	'87	NOT COUNTED							
Abandoned	'86	3	0.03	4	0.03	9	0.12	20	0.02
Irrigation Works	'87	5	0.05	5	0.03	8	0.11	33	0.04
Wind-powered pump	'86	0	-	0	-	0	-	2	0.002
	'87	0	-	0	-	0	-	2	0.002
Water Supply	'86	0	-	5	0.03	2	0.03	17	0.02
Installation	'87	0	-	5	0.03	2	0.03	17	0.02
Abandoned Water	'86	0	-	0	-	0	-	0	-
Supply Installation	'87	0	-	0	-	0	-	1	0.001
Drinking Place	'86	1	0.01	0	-	4	0.05	87	0.09
(Livestock)	'87	7	0.06	8	0.05	4	0.05	159	0.17
Water Collection	'86	NOT COUNTED							
Point	'87	3	0.03	0	-	0	5	0.05	
Bridge	'86	1	0.01	1	0.01	1	0.01	6	0.01
	'87	1	0.01	1	0.01	1	0.01	7	0.01
Cable Ferry	'86	2	0.02	19	0.12	19	0.26	53	0.06
	'87	3	0.03	22	0.14	21	0.29	61	0.07
Boat Ferry	'86	0	-	0	-	0	-	3	0.003
	'87	0	-	0	-	0	-	2	0.002
Boat	'86	0	-	4	0.03	25	0.34	37	0.04
	'87	2	0.02	20	0.13	28	0.38	59	0.06
Canoe	'86	13	0.12	42	0.27	10	0.14	109	0.12
	'87	48	0.44	68	0.44	10	0.14	217	0.24
Raft	'86	0	-	0	-	0	-	14	0.02
	'87	0	-	5	0.03	0	-	22	0.02
Firewood	'86	0	-	0	-	0	-	11	0.12
Raft	'87	0	-	0	-	0	-	0	-
Fish Net	'86	0	-	0	-	2	0.03	2	0.002
	'87	3	0.03	4	0.03	6	0.08	13	0.01

SECTOR (length)		I (90 km)		II (199 km)		III (159 km)		IV (133 km)	
NAME		NUMBER SEEN	DENSITY per km^2	NUMBER SEEN	DENSITY per km^2	NUMBER SEEN	DENSITY per km^2	NUMBER SEEN	DENSITY per km^2
Basket Trap	'86	0	-	0	-	0	-	0	-
	'87	0	-	0	-	0	-	3	0.02
People Fishing	'86	0	-	0	-	0	-	0	-
(By Line)	'87	0	-	0	-	0	-	0	-
People in River	'86	0	-	0	-	0	-	0	-
	'87	162	1.80	521	2.62	445	2.80	174	1.31
Carts	'86	0	-	0	-	0	-	0	-
	'87	0	-	0	-	1	0.01	0	-
Cattle	'86	0	-	0	-	0	-	0	-
	'87	80	0.89	233	1.17	563	3.54	603	4.53
Goat	'86	0	-	0	-	0	-	0	-
	'87	42	0.47	56	0.28	12	0.08	0	-
Sheep	'86	0	-	0	-	0	-	0	-
	'87	4	0.04	25	0.13	7	0.04	0	-
Goat/Sheep	'86	0	-	0	-	0	-	0	-
	'87	28	0.31	189	0.95	774	4.87	135	1.02
Camel	'86	0	-	0	-	0	-	0	-
	'87	43	0.48	169	0.85	575	3.62	252	1.89
Donkey	'86	0	-	0	-	0	-	0	-
	'87	7	0.08	12	0.06	14	0.09	0	-
Dead Cattle	'86	0	-	0	-	0	-	0	-
	'87	0	-	0	-	0	-	1	0.01
Dead Camel	'86	0	-	0	-	0	-	0	-
	'87	0	-	0	-	1	0.01	0	-
Dead Donkey	'86	0	-	0	-	0	-	0	-
	'87	0	-	0	-	0	-	1	0.01
Refugee Camps	'86	1	0.01	10	0.05	0	-	0	-
	'87	1	0.01	10	0.05	0	-	0	-
Riverbed Wells	'86	0	-	0	-	0	-	0	-
	'87	0	-	0	-	0	-	0	-

SECTOR (length)		V (90 km)		VI (199 km)		VII (159 km)		VIII (133 km)	
Basket Trap	'86	2	0.02	0	-	0	-	2	0.002
	'87	1	0.01	7	0.04	2	0.03	13	0.01
People Fishing	'86	0	-	0	-	0	-	0	-
(By Line)	'87	0	-	0	-	2	0.03	2	0.002
People in River	'86	0	-	0	-	0	-	0	-
	'87	15	0.14	760	4.87	93	1.27	2170	2.36
Carts	'86	0	-	0	-	0	-	0	-
	'87	0	-	0	-	0	-	0	-
Cattle	'86	0	-	0	-	0	-	0	-
	'87	120	1.11	190	1.22	105	1.44	1894	2.06
Goat	'86	0	-	0	-	0	-	0	-
	'87	0	-	41	0.26	29	0.40	180	0.20
Sheep	'86	0	-	0	-	0	-	0	-
	'87	0	-	0	-	0	-	36	0.04
Goat/Sheep	'86	0	-	0	-	0	-	0	-
	'87	0	-	320	2.05	0	-	1446	1.58
Camel	'86	0	-	0	-	0	-	0	-
	'87	0	-	0	-	0	-	1039	1.13
Donkey	'86	0	-	0	-	0	-	0	-
	'87	0	-	0	-	0	-	33	0.04
Dead Cattle	'86	0	-	0	-	0	-	0	-
	'87	0	-	0	-	0	-	1	0.001
Dead Camel	'86	0	-	0	-	0	-	0	-
	'87	0	-	0	-	0	-	1	0.001
Dead Donkey	'86	0	-	0	-	0	-	0	-
	'87	0	-	0	-	0	-	1	0.001
Refugee Camps	'86	0	-	0	-	0	-	11	0.01
	'87	0	-	0	-	0	-	11	0.01
Riverbed Wells	'86	0	-	0	-	0	-	0	-
	'87	0	-	3	0.02	0	-	3	0.003

ing to apply to rivers in flood, with dense riverine vegetation. The two surveys have yielded 201 and 1,537 for high-flow and low-flow periods respectively, suggesting a crocodile population 20,000 to 45,000. Ample circumstantial evidence supports this somewhat surprising finding:

- in the high-flow survey, crocodile were observed at every site one would expect to see them (*i.e.*, slack water of back-flooded channels, downstream tailing from islands, flooded areas);
- at many places where people and livestock use the river bank to drink or collect water, a protective barrier was made using branches embedded in the riverbed to obstruct crocodile attacks; and
- dead crocodile, which have apparently been killed by people, were relatively common in River Sector V. There have been reports that these crocodile were killed by members of a fishing cooperative who compete with these animals for fish in the shallow lagoons and swamps, and who were attacked while fishing.

Crocodile are found throughout the whole length of the Jubba, with a marked concentration in Sector V and a general concentration in all the southern sectors (IV to VII). The change in numbers from the high-flow to the low-flow surveys shows a distinct succession:

SECTOR	LOW- FLOW NUMBER/HIGH- FLOW NUMBER
I	0.57
II	0.97
III	1.42
IV	6.48
V	12.33
VI	14.13
VII	19.60

It is probable that at least two factors are at work here. In low-flow periods, the visibility of crocodile is increased by the reduction in water turbidity and depth and their concentration in the few remaining favorable waters. This increase in visibility is not evenly distributed, but is progressively greater in the lower river reaches where river flow stops and becomes reduced to isolated pools. Crocodile are probably migrating up and down the river seasonally to take advantage of changing feeding conditions and the exposure of suitable nesting sites. Unfortunately, no excavated nest sites were sighted in the low-flow survey, and so there are few data to further an understanding of the seasonal breeding cycle. However, several crocodile sighted had the appearance of females guarding nests and were not readily disturbed by a low-flying aircraft. Therefore, it seems possible that hatching is taking place in mid- to late-April, and the net movement of crocodile to nesting sites may be downstream rather than upstream. More observations are required to clarify these observations.

Watson (1987) remarked that crocodile should be controlled in the Jubba and the value of their skins could annually gross U.S. $300,000 to $1.5 million. In view of the upward revision of the crocodile population, the gross value of skins that could be cropped annually would be between $1.5 to $3.4 million.

Crocodile Nest Sites

As mentioned above, no nest sites were seen in the low-flow survey, suggesting that egg-hatching had not occurred before the end of this survey (very early April). The distribution of crocodile judged to be "brooding" females indicated that most nests were being made in River Sectors IV and VII. Therefore, the reservoir may have little impact on crocodile population dynamics.

Turtle

As anticipated, more turtles were seen in the low-flow survey, but there is no strong evidence of seasonal migration.

Turtle Nests

Three recently excavated nests were seen in River Sector VII.

Water Birds

Large flocks of ducks and geese were seen in about the same numbers and with the same distribution as in the high-flow survey. Therefore, these were unlikely to be palearctic migrants, which would, in any case, be more observable from November to February.

Baboon Troops

Although baboon were sighted in the high-flow survey, it was decided that difficulties presented by the dense river bank cover made it impractical to record them, since those seen would represent such a small and unknown fraction of those present. In contrast, in the low-flow survey, many baboon troops were seen on the riverbed (mostly drinking, but also bathing) in conditions where it was felt a consistent record could be made. The results show baboon to be concentrated in the least-developed river sectors (IV and V).

Warthog

No warthog were seen on the riverbed or banks in the high-flow survey. Crocodile predation has probably caused warthog to avoid proximity to deep, turbid water. In the low-flow survey, although many warthog tracks were seen, only two animals were sighted on the riverbed. Possibly, warthog prefer to drink during very early morning or late evening, when human activity there is less.

Islands (Islets)

It is impractical to count islands during periods of low flow, when extensive sections of the riverbed are exposed.

Flowing Springs

Only three flowing springs were seen close to the river in the low-flow survey, indicating that some of the springs recorded in September are liable to stop flowing, at least on the surface, in the jiilaal. However, it was observed that several important springs are found on toggas up to 5 km from the Jubba River. Many of these springs flow intermittently on the surface, and it is possible that substantial subsurface spring flow is entering the Jubba upstream of the planned reservoir (with attendant implications for mineralization and stratification of the reservoir water body).

Dhesheegs and Cropped Dhesheegs

No attempt was made to record dhesheegs and cropped dhesheegs in the low-flow survey as the 1:10,000 photography will have provided a complete and consistent record of these features.

Riverbank Clearances

Curiously, both riverbank clearances for irrigation and other riverbank clearances show a markedly different distribution, with an apparent concentration in Sector I in the low-flow survey, in contrast with a concentration in Sectors III and IV in the high-flow survey. There is no obvious explanation of this phenomenon.

Furrow Irrigation

Only one furrow irrigation system was seen in the low-flow survey being seen in Sector VII.

Riverbank Cropping

Greater riverbank cropping (*jiimo*) was sighted in the low-flow survey, with a distinct concentration in River Sector II. This is to be expected as more riverbank becomes exposed, and as the distinction between natural vegetation and cultivation is more easily made.

Pumps

More pumps (37 percent more) were seen in the low-flow survey with the greatest increase being in Sectors I and III, as presented below:

SECTOR	LOW-FLOW NUMBER/HIGH-FLOW NUMBER
I	1.71
II	1.27
III	1.42
IV	1.23
V	1.00
VI	1.21
VII	1.00
ALL	1.37

Although some of the increase can be attributed to better visibility conditions prevailing during the low-flow survey, it seems that more pumps are operating on the Jubba in the March-April period.

Reduced flow of the river and exposure of extensive parts of the sandy bed have left many irrigation pumps with their inlet pipes out of water. Farmers have adapted a number of strategies to deal with the difficulty. Some have moved their pumps to new positions on the bank, and many farmers apparently have low-flow and high-flow sites from which they pump irrigation water. Some have dug channels in the sand to feed the entry pipe with water. This is done mostly by hand, but some mechanical diggers and bulldozers have been used. At Mombasa Island, immediately downstream of Sabatuuni, the eastern river channel was receiving no natural flow. Because several large banana farms are situated on this eastern branch, two large mobile pumps had been positioned on the riverbed on a small embankment to divert a flow of water into the dry channel.

It is clear that the low flows typical of the March/April period cause considerable difficulties for the irrigation of perennial crops such as bananas and sugarcane. Closing Fanoole Barrage to allow the irrigation of rice has held up the arrival of flows to the lower reaches of the river. A more intelligent apportionment of river water for all Jubba Valley irrigation needs should be encouraged.

Abandoned Irrigation Areas

No attempt was made to record abandoned irrigation areas in the low-flow survey, as the 1:10,000 photography will provide a complete and consistent picture of these features.

Abandoned Irrigation Works

More abandoned irrigation works were sighted in the low-flow survey, probably because the reduced dry-season vegetation cover allows some of the older schemes to be identified.

Wind-powered pumps

The same two wind-powered pumps were observed in the low-flow survey.

Water Supply Installation and Abandoned Water Supply Installations

One new water supply installation was seen (at the Halba Refugee Camp, north of Luuq) and one installation counted in the high-flow survey was judged to be abandoned in the low-flow survey (at Hilo Mareer).

Important Drinking Places for Livestock

Almost twice as many important drinking places were recorded in the low-flow survey, all of which were in use. Although 19 drinking places were sighted in Sectors V to VII (against five seen in September), the primary river areas of expanded use by drinking livestock were Sectors II to IV.

Water Collection Points

Five water collection points were seen in Sectors IV and V in the low-flow surveys, indicating that substantial populations can become dependent on the Jubba River for domestic water supplies in the jiilaal dry season.

Bridges

The same six bridges were sighted and one bridge was seen under construction at Buurdhuubo Refugee Camp. The location of this bridge is somewhat curious since it will be inundated when the dam is constructed. More important sites (Saakow and Jilib) for bridge construction have been noted.

Ferries

Slightly more cable ferries and one less boat ferry were sighted in the low-flow survey, although most were not in use, as the river had been reduced to a narrow, fordable channel or had dried up altogether over much of the channel.

Boats and Canoes

About twice as many boats and dugout canoes were sighted in the low-flow survey—primarily as a result of reduction of the riverbank vegetation which allows a better view of the river's edge.

Rafts

More rafts were seen in the low-flow survey with some recorded in River Sector VI (none were seen below Sector III in the high-flow survey). It is thought that these rafts are associated with exploitation of the gallery forest remnants, being made up of large tree trunks which are transported to sites to be made into canoes.

Firewood Rafts

No firewood rafts were sighted in the low-flow survey, probably because the reduced river flow would make it too laborious to pole these rafts downstream at this time of year.

Fish Nets

Thirteen fish nets were seen in the low-flow survey, being confined to Sectors V to VII. Nets seemed to be managed in two ways: some were set across the channel and visited by boat; in other cases, nets were cast in a ring to encircle the catch. Fishermen would wade into the water to drive fish into the nets. The encircling technique was used mainly in shallow dhesheegs and haro. Fish caught were preserved by sundrying.

Basket Traps

Thirteen basket traps were sighted in Sectors IV to VII.

People in the River

Over 2,000 people were counted on the riverbed or in the shallow river waters in the low-flow survey. People were distributed throughout the river, but Sector V, with 6.17 crocodile recorded per kilometer of river, showed low densities. No people were seen in the river in the high-flow survey. Most people on the riverbed were bathing, swimming, or washing, but some were fishing, digging wells, watering livestock, cutting channels to their pumps, or simply crossing the river. The importance of the river and riverbed for recreational and functional activities is clear, and consequently, there are major implications for the water quality and health aspects of water to be released from the reservoir.

Livestock in the River or the Riverbed

More than 4,500 livestock were observed drinking in the river or standing on the riverbed and banks. Clearly, the river is the most important single source of water for livestock in the Jubba Valley in the late jiilaal season. Not surprisingly, livestock densities are highest in sectors with many watering places:

SECTOR	DENSITY OF IMPORTANT DRINKING PLACES	DENSITY OF ALL LIVESTOCK
I	0.12	2.27
II	0.25	3.44
III	0.28	12.24
IV	0.26	7.44
V	0.06	1.11
VI	0.05	3.53
VII	0.05	1.84

Refugee Camps

This issue is dealt with in the following section.

Riverbed Wells

A few riverbed wells were seen in River Sector II. There may have been more of these, but a slight rise in river level occurred just before the survey, which would have flooded and obscured wells in the most low-lying parts of the riverbed.

Miscellaneous Observations

One cart, one dead cow, one dead camel, and one dead donkey were seen on the riverbed or in the river during the low-flow survey.

B. Aerial Photography of the Jubba Floodplain Zone

Two sets of prints of aerial photography at 1:10,000 were delivered in Somalia and are housed in JESS data repositories. An interpretation of land-use and vegetation was made at 1:50,000 scale. These maps and a descriptive text were presented in Trump (1987). The photographs and maps should be used in monitoring activities in the valley as development proceeds. A total list of maps and film products is presented in Appendix C.

C. Aerial strip sampling of the Jubba Floodplain Zone and the Jubba Valley Zone

Results of these surveys are set out in a standardized format consisting of references of time, space, and theme.

Time Reference

The three surveys are titled:

> **The First Jiilaal Survey**
> (26 January - 3 February 1987)
>
> **The Second Jiilaal Survey**
> (23 - 13 April 1987)
>
> **The Xagaa Survey**
> (29 July - 26 August 1987)

Space Reference

The fundamental areal units are the strata which have already been described. Combinations of strata have been made, all being classified as regions—some being hierarchical and others overlapping. The different combination systems are: Ecological Zones, Ecological Regions, Ecological Provinces, River Valley Subsections, River Valley Sections, River Valley Regions, and River and Floodplain Sectors. These are defined in Appendix D. Aerial census strata, the analytical basis for the creation of all other "regions", is shown in Figure 2 of this report. This cartographic representation of the strata will be used for presentation of data by stratum and theme later in this section of the report.

Theme Reference

For each survey, data has been combined based on counts of items or "themes" and distributed by strata and regions (space reference). These thematic data are presented in tabular (raw) form and are available in JESS data repositories. A list of the themes and corresponding table numbers is presented in Appendix E.

While a wealth of data was generated by the strip sampling surveys, only a brief review is presented in this section. As discussed earlier, much of the information is raw and semi-aggregated forms were utilized in preparing the JESS Terrestrial Ecology Baseline Studies (Deshmukh 1989; Part A of this volume). The major portion of specific information concerning the results of the surveys is found in JESS data repositories. The following sections are intended to give the reader an overview of survey results in tabular and cartographic form.

1. Livestock

The surveys produced the following results concerning cattle, sheep, goats, camels, and donkeys. (Refer also to Appendix D for geographical coverage of "Regions".)

Cattle (densities and estimates)

For the whole survey area, cattle density showed little change between the second jiilaal and the xagaa surveys. (About 18 percent fewer cattle were censused in the xagaa survey.) This suggests that cattle are not concentrating substantially in the Jubba Valley in a normal dry season from areas further than 30 km from the floodplain.

For the Floodplain Zone (Regions 75 and 76), cattle densities increased substantially in the driest time of the year. As Table 2 on the following page shows, cattle densities in the floodplain more than doubled in the second jiilaal survey, confirming the crucial importance of the floodplain vegetation and crop residues for cattle in the driest periods of the year.

Comparison of cattle densities for the Jubba Floodplain Zone (Regions 75 and 76) and Jubba Valley Zone (Regions 74 and 77) reveals that the floodplain supported more than seven times the density of cattle in the second jiilaal survey and almost four times the density of cattle in the xagaa survey. Density of cattle in the Jubba Valley Zone showed no significant change between the two surveys, indicating substantial increase in cattle density in the Floodplain Zone was more or less matched by a migration of cattle into the survey area.

A closer examination of cattle densities in the three major river regions has been made to investigate the differences in the movement patterns up the length of the river. It suggests there is movement of cattle down the valley from north to south in the dry season, and a return northward in the xagaa. Interestingly, the Inundation Region (72) supported the lowest densities of cattle in the xagaa of the three major river regions, reflecting generally sparser grass/herb vegetation and stonier, shallower soils in this region.

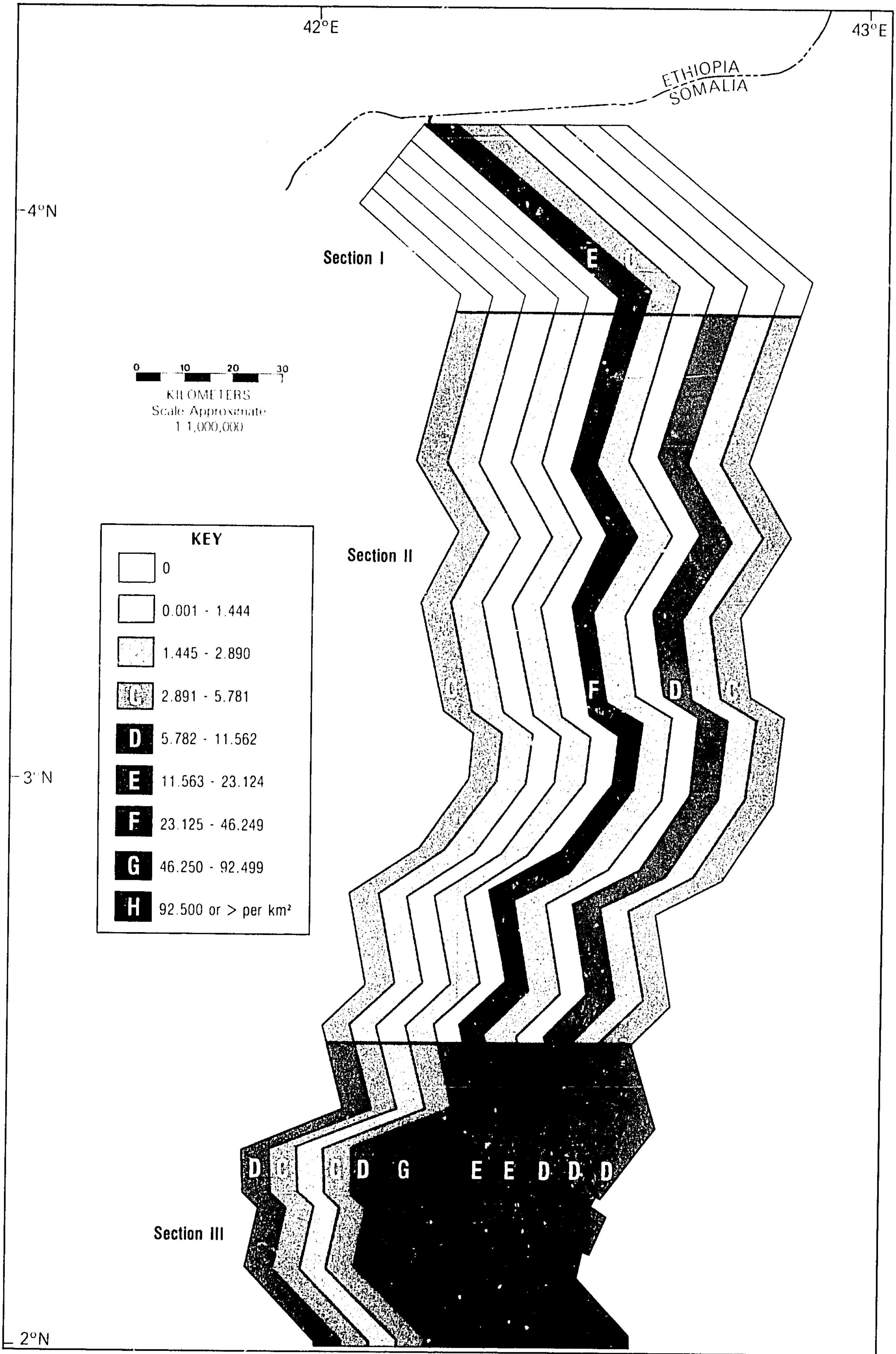
An examination of the seven river valley sections, the eight river floodplain sectors (Table 2), and Figures 2.1 and 3.1 gives a more detailed view of this movement pattern. It is evident that there is a progressive concentration of cattle in the southernmost valley sections in the dry season, with the density in Valley Section VII being approximately 30 times the density in Valley Section I in the second jiilaal survey. The return movement of cattle after the seasonal gu' rains produced a much less pronounced north-to-south density gradient, with the density in Valley Section VII approximately twice the density in that section in the xagaa survey.

Cattle densities of the eight floodplain sectors (Table 2) provide insight on the north-to-south pattern of concentration on the Jubba floodplain. The most extreme dry season concentration in the second jiilaal survey was found in Floodplain Sectors IV, V, and VI. From north to south, the degrees of second jiilaal survey concentration (given by dividing second jiilaal survey density by xagaa survey density) were:

SECTOR	DENSITY
I	0.24
II	0.99
III	2.14
IV	3.32
V	13.82
VI	2.56
VIIA	1.41
VIIB	1.30

This indicates a clear and spectacular concentration of cattle in Floodplain Sector V in the 1987 dry season. Densities of cattle in the eight floodplain sectors in the second jiilaal survey increased progressively from north to south to Floodplain Sector V, and maintained a more or less fixed level in Floodplain Sectors VI and VIIA. In the xagaa survey, densities decreased progressively from north to south from Floodplain Sector I to V, but from Floodplain Sector V to VIIB, densities progressively increased.

As shown in Table 3, the entire survey area was found to support 500,000 to 600,000 cattle—about 15 percent of the southern Somalia cattle population (Watson and Nimmo 1985) and 11 percent of the national population (Watson *et al.* 1979; Watson


42°E
43°E
ETHIOPIA
SOMALIA
4°N
Section I
E
C
0 10 20 30
KILOMETERS
Scale Approximate
1:1,000,000
Section II
KEY
0
0.001 - 1.444
1.445 - 2.890
C 2.891 - 5.781
D 5.782 - 11.562
E 11.563 - 23.124
F 23.125 - 46.249
G 46.250 - 92.499
H 92.500 or > per km²
F
D
C
3°N
D C C D G E E D D D
Section III
2°N

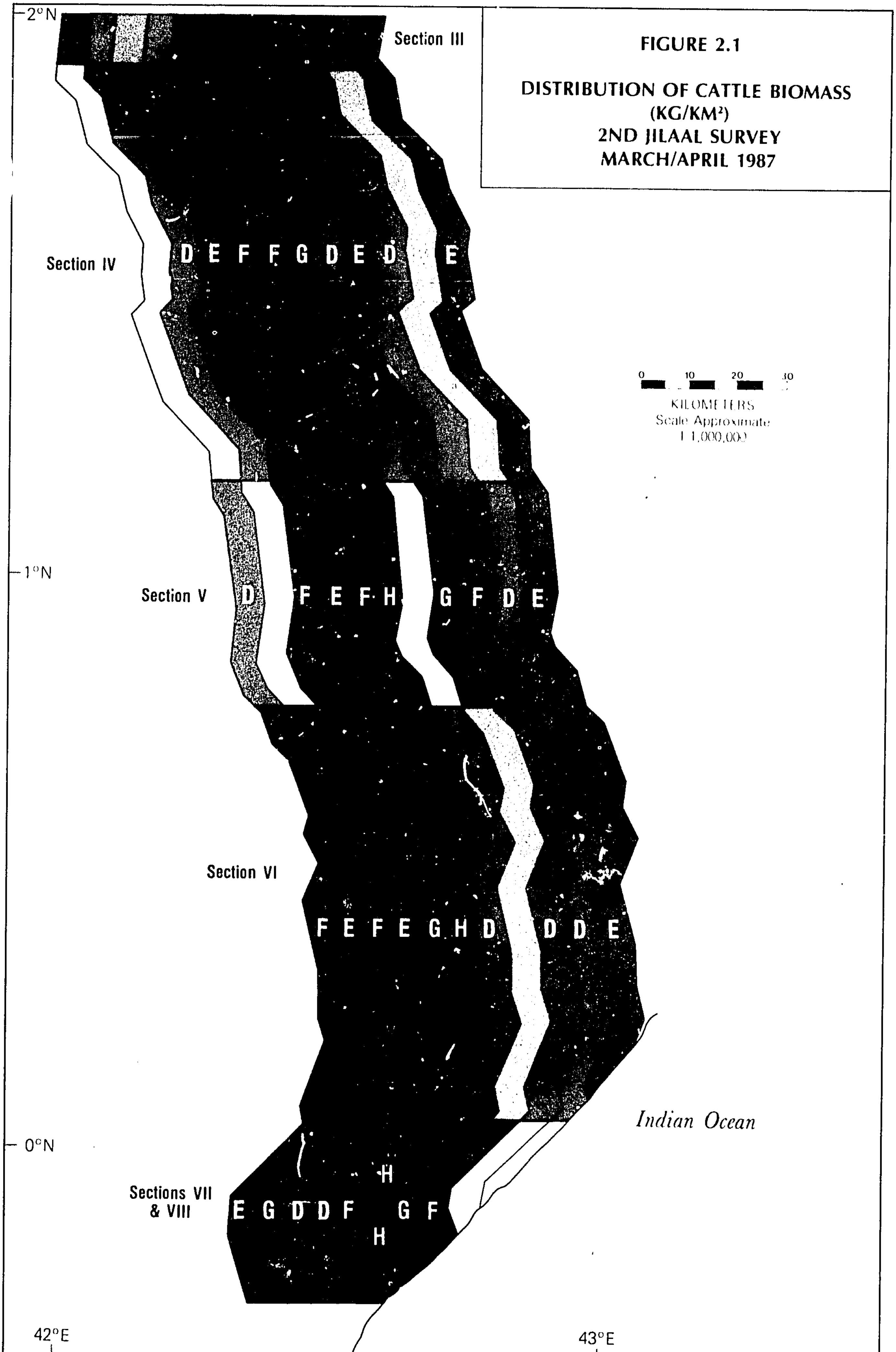
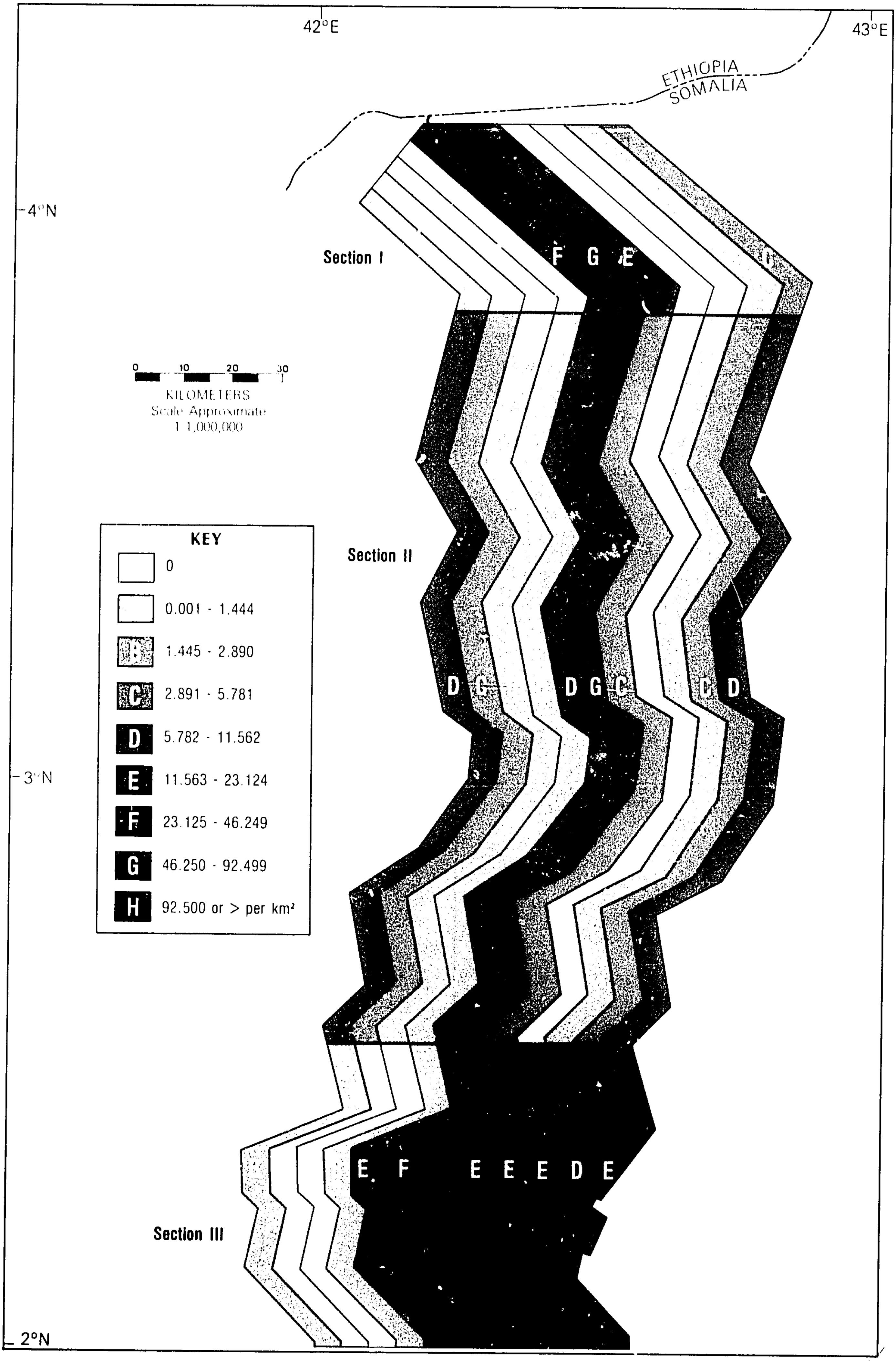


FIGURE 2.1

DISTRIBUTION OF CATTLE BIOMASS (KG/KM²)
2ND JILAAL SURVEY
MARCH/APRIL 1987



42°E
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ETHIOPIA
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Section I
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Section III
E F
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0 10 20 30
KILOMETERS
Scale Approximate
1:1,000,000
KEY
0
0.001 - 1.444
1.445 - 2.890
C 2.891 - 5.781
D 5.782 - 11.562
E 11.563 - 23.124
F 23.125 - 46.249
G 46.250 - 92.499
H 92.500 or > per km²

FIGURE 3.1

DISTRIBUTION OF CATTLE BIOMASS (KG/KM²) HAGGAI SURVEY JULY/AUGUST 1987

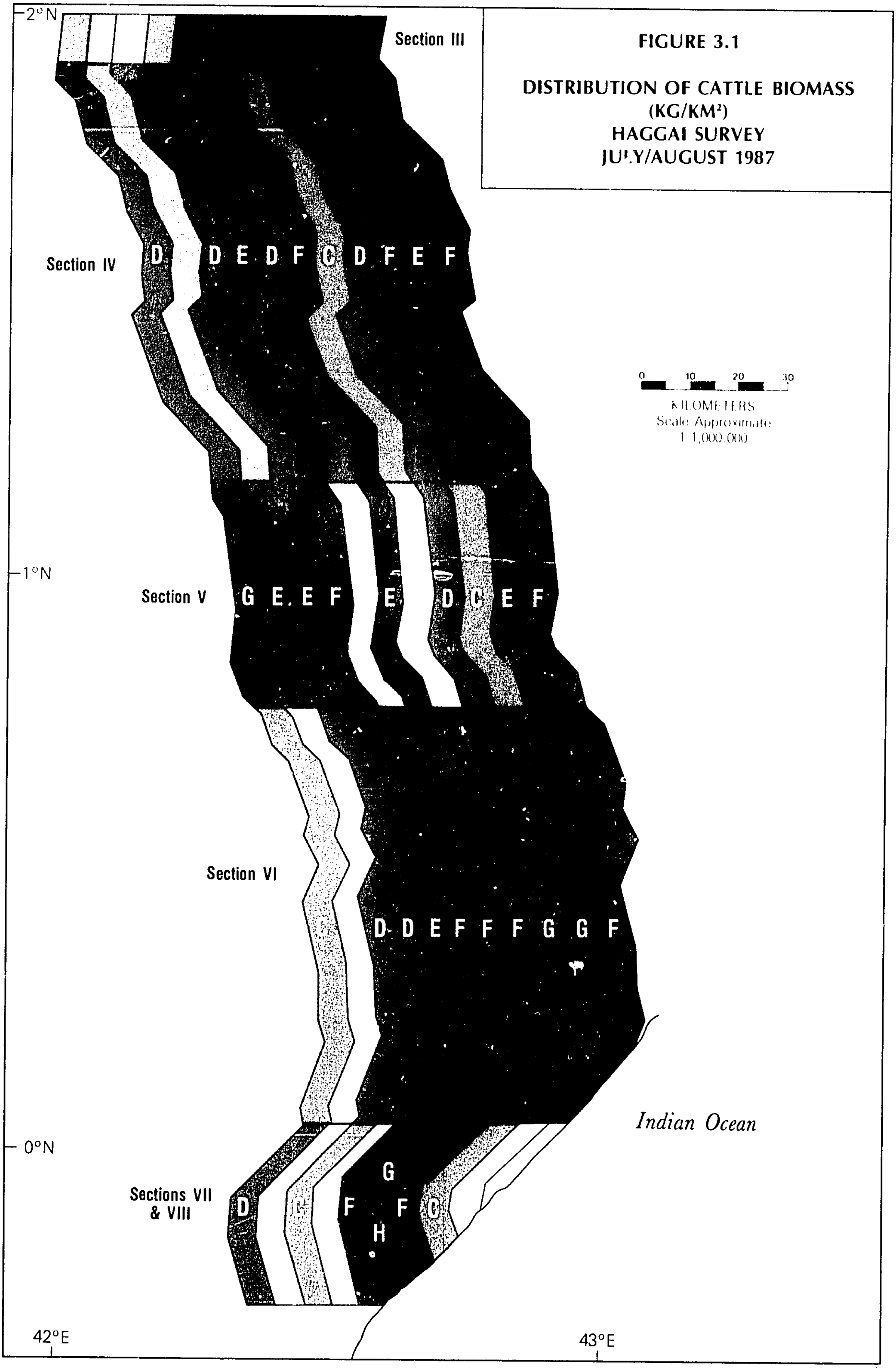


Table 2. Livestock Biomass Data (in kg/km²) for the Three Surveys

AREA	SURVEY	CATTLE	SHEEP	GOATS	CAMELS	DONKEYS	ALL LIVESTOCK
FLOODPLAIN AND VALLEY ZONES							
The whole survey area (Region 100)	2nd Jiilaal	3,040	237	373	2,944	42	6,636
	Xagaa	2,503	195	341	3,078	21	6,138
Jubba Flood-plain Sectors (Regions 75 & 76)	1st Jiilaal	7,790	395	1,103	2,677	111	12,076
	2nd Jilaal	16,561	764	1,039	5,640	255	24,259
	Xagaa	8,133	468	693	1,583	179	11,056
Jubba Valley Sections (Regions 74 & 77)	2nd Jiilaal	2,239	206	334	2,785	29	5,593
	Xagaa	2,170	179	320	3,166	11	5,846
MAJOR RIVER REGIONS							
River Region Above Reservoir (Region 64)	2nd Jiilaal	216	666	818	1,761	137	3,598
	Xagaa	1,565	548	791	4,019	90	7,013
Inundation Region (Region 65)	2nd Jiilaal	740	384	670	3,516	42	5,352
	Xagaa	1,028	393	690	2,209	28	4,348
Downstream Region (Region 73)	2nd Jiilaal	4,109	145	229	2,855	33	7,371
	Xagaa	3,099	92	176	3,297	11	6,675
VALLEY SECTIONS							
Valley Section I (Region 64)	2nd Jiilaal	216	666	818	1,761	137	3,598
	Xagaa	1,565	548	791	4,019	90	7,013
Valley Section II, (Region 65)	2nd Jiilaal	740	384	670	3,516	42	5,352
	Xagaa	1,028	393	690	2,209	28	4,348
Valley Section III (Region 66)	2nd Jiilaal	1,911	287	389	3,383	40	5,970
	Xagaa	2,189	125	252	3,241	27	5,834
Valley Section IV, (Region 67)	2nd Jiilaal	3,052	77	197	4,546	49	7,872
	Xagaa	2,616	68	181	7,089	8	9,954
Valley Section V (Region 68)	2nd Jiilaal	5,196	24	40	1,919	68	7,247
	Xagaa	3,518	24	44	3,910	0	7,496
Valley Section VI (Region 69)	2nd Jiilaal	5,103	126	204	2,336	10	7,779
	Xagaa	3,796	109	179	1,644	5	5,929
Valley Section VII A + B	2nd Jiilaal	6,494	107	184	1,822	25	8,632
(Region 70)	Xagaa	3,389	80	132	2,174	11	5,786
FLOODPLAIN SECTORS							
Floodplain Sector I (Region 78)	1st Jiilaal	2,362	1,101	2,458	5,443	600	11,964
	2nd Jiilaal	2,902	2,800	1,903	6,809	1,066	15,480
	Xagaa	12,140	2,055	2,444	18,899	1,622	35,538
Floodplain Sector II (Region 79)	1st Jiilaal	2,261	1,383	4,297	12,126	280	20,347
	2nd Jiilaal	7,403	1,945	3,392	9,188	705	2,633
	Xagaa	7491	1,529	2,613	2,228	332	14,193
Floodplain Sector III (Region 80)	1st Jiilaal	12,339	333	1,142	2,396	128	16,338
	2nd Jiilaal	9,179	1,086	1,739	9,148	207	21,359
	Xagaa	4,263	102	243	1,051	76	5,735
Floodplain Sector IV (Region 81)	1st Jiilaal	12,636	133	332	2,739	0	15,840
	2nd Jiilaal	14,250	462	1,230	28,029	155	44,126
	Xagaa	4,297	28	24	40	0	4,389
Floodplain Sector V (Region 82)	1st Jiilaal	5,545	78	177	81	0	6,058
	2nd Jiilaal	33,420	174	364	3,426	422	37,806
	Xagaa	2,418	41	13	286	0	2,758
Floodplain Sector VI (Region 83)	1st Jiilaal	3,873	83	232	5	5	4,198
	2nd Jiilaal	18,443	260	251	1,031	11	19,996
	Xagaa	7,207	160	231	74	30	7,702
Floodplain Sector VIIA (Region 84)	1st Jiilaal	21,747	250	436	153	128	22,714
	2nd Jiilaal	19,410	413	347	1,858	71	22,099
	Xagaa	13,748	110	67	0	62	13,987
Floodplain Sector VIIB (Region 85)	1st Jiilaal	10,208	0	168	132	53	10,563
	2nd Jiilaal	24,041	566	381	228	50	25,261
	Xagaa	18,457	243	197	0	28	18,925

1982). Clearly, any developments in the Jubba Valley have the potential to affect a large component of Somalia's cattle population.

In the second jiilaal survey, 30 percent of the cattle in the Jubba Valley were in the floodplain (which is 5.6 percent of the land area), at the time of the census. Undoubtedly, an even higher proportion of cattle were making temporary use of floodplain resources.

The Inundation River Region supported six percent of the cattle of the survey area in the second jiilaal survey and 10 percent of cattle in the xagaa survey, although it comprised 24 percent of the land area. This suggests that the impact of inundation *per se* on the cattle population in the Jubba Valley will be confined to a small portion of the total cattle population.

The actual area to be inundated (Region 79 estimated at 316 km^2) supports two percent of the cattle population in the second jiilaal survey, and three percent in the x ;aa survey. The Inundation Floodplain Sector (R.., on 79) comprises one percent of the entire survey area. This suggests that loss of this land will have minor impact on the overall cattle population of the valley in most years.

Sheep (densities and estimates)

For the whole survey area, sheep density showed only a small difference between the second jiilaal and xagaa surveys. (About 18 percent fewer sheep were censused in the xagaa survey, suggesting a close association between sheep and cattle in the Jubba Valley). Therefore, in a normal dry season, it would seem that sheep are not concentrating substantially in the Jubba Valley from areas further than 30 km from the floodplain.

For the Floodplain Zone (Region 75 and 76), sheep densities almost doubled in the second jiilaal survey confirming the crucial importance of the floodplain vegetation and crop residues for sheep in the driest periods of the year.

Comparison of sheep densities for the Floodplain Zone (Regions 75 and 76) and the Jubba Valley Zone (Regions 74 and 77), reveals that the floodplain supported almost four times the density of sheep in the second jiilaal survey, and about three times the density in the xagaa survey. Density in the Jubba Valley Zone showed a significant change between the two surveys, suggesting that migration of sheep into the survey area in the dry season was not completely matched by concentration into the Floodplain Zone.

A closer examination of sheep densities in the three major river regions was made to investigate differences in movement patterns up the length of the river. It suggested there was no north-to- south migration down the river valley during the jiilaal. The highest densities of sheep throughout the year were found in the northernmost river region, where shorter herbs and grasses are abundant.

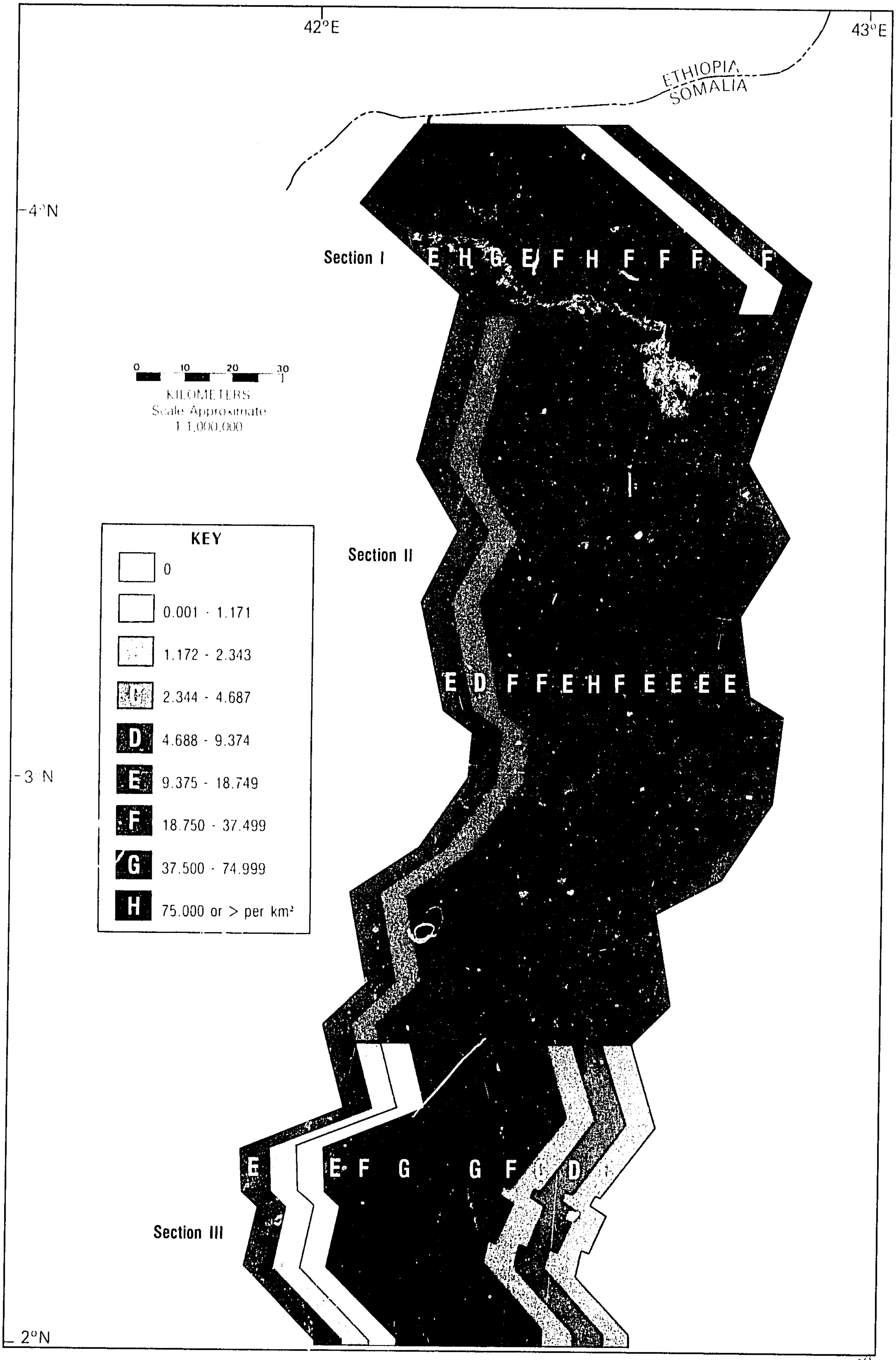
Examination of the seven valley sections, the eight floodplain sectors (Table 2), and Figures 2.2 and 3.2 gives a more detailed view of this movement pattern. Even at this level, it is evident that there is no north/south component in sheep movement patterns. Sheep densities were highest in Valley Section I and declined progressively southward to Valley Section V (the least-developed river section, where grasslands are frequently flooded). Valley Sections VI and VIIA/VIIB have slightly higher sheep densities presumably associated with the increased densities of croplands in these sections.

Sheep densities of the eight floodplain sectors (Table 2) show no simple pattern of use. Degrees of concentration from north to south during the second jiilaal survey were:

SECTOR	DENSITY
I	1.36
II	1.27
III	10.6
IV	16.5
V	4.24
VI	1.63
VIIA	3.75
VIIB	3.96

Sheep densities in the eight floodplain sectors in the second jiilaal survey decreased progressively from north to south from Floodplain Sector I to V, and then increased progressively from V to VIIB. In the xagaa survey, sheep densities showed a similar pattern.

The entire survey area was found to support 375,000 to 450,000 sheep (Table 3), which is about 28 percent of the southern Somalia population (Watson and Nimmo 1985) and about four percent of the national population (Watson *et al.* 1979; Watson 1982). Developments in the Jubba Valley have the potential to affect only a small portion of Somalia's sheep population.



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ETHIOPIA
SOMALIA
4°N
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Section I
E H G E F H F F F F
0 10 20 30
KILOMETERS
Scale Approximate
1:1,000,000
Section II
E D F F E H F E E E E
KEY
0
0.001 - 1.171
1.172 - 2.343
2.344 - 4.687
D 4.688 - 9.374
E 9.375 - 18.749
F 18.750 - 37.499
G 37.500 - 74.999
H 75.000 or > per km²
Section III
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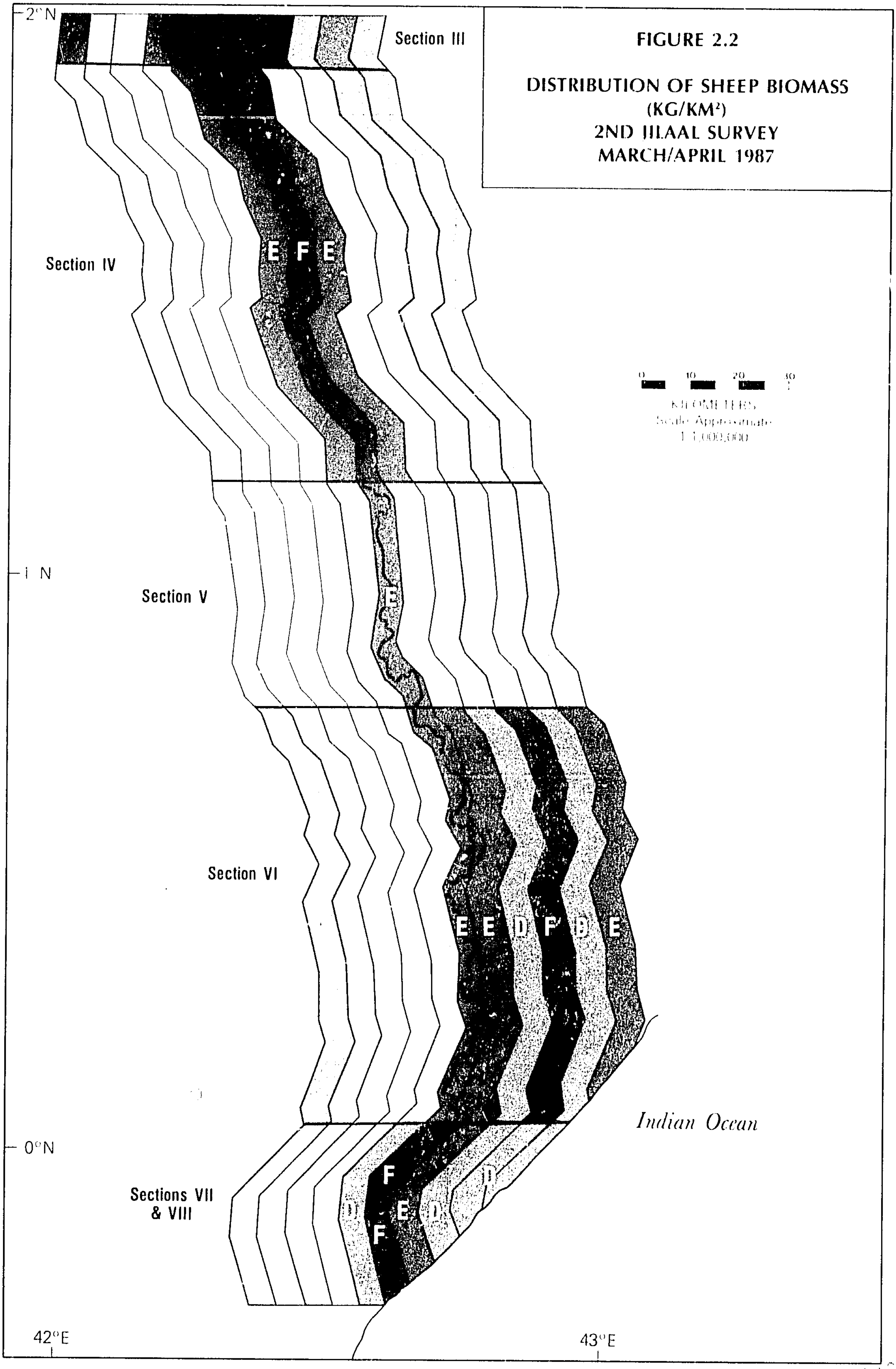
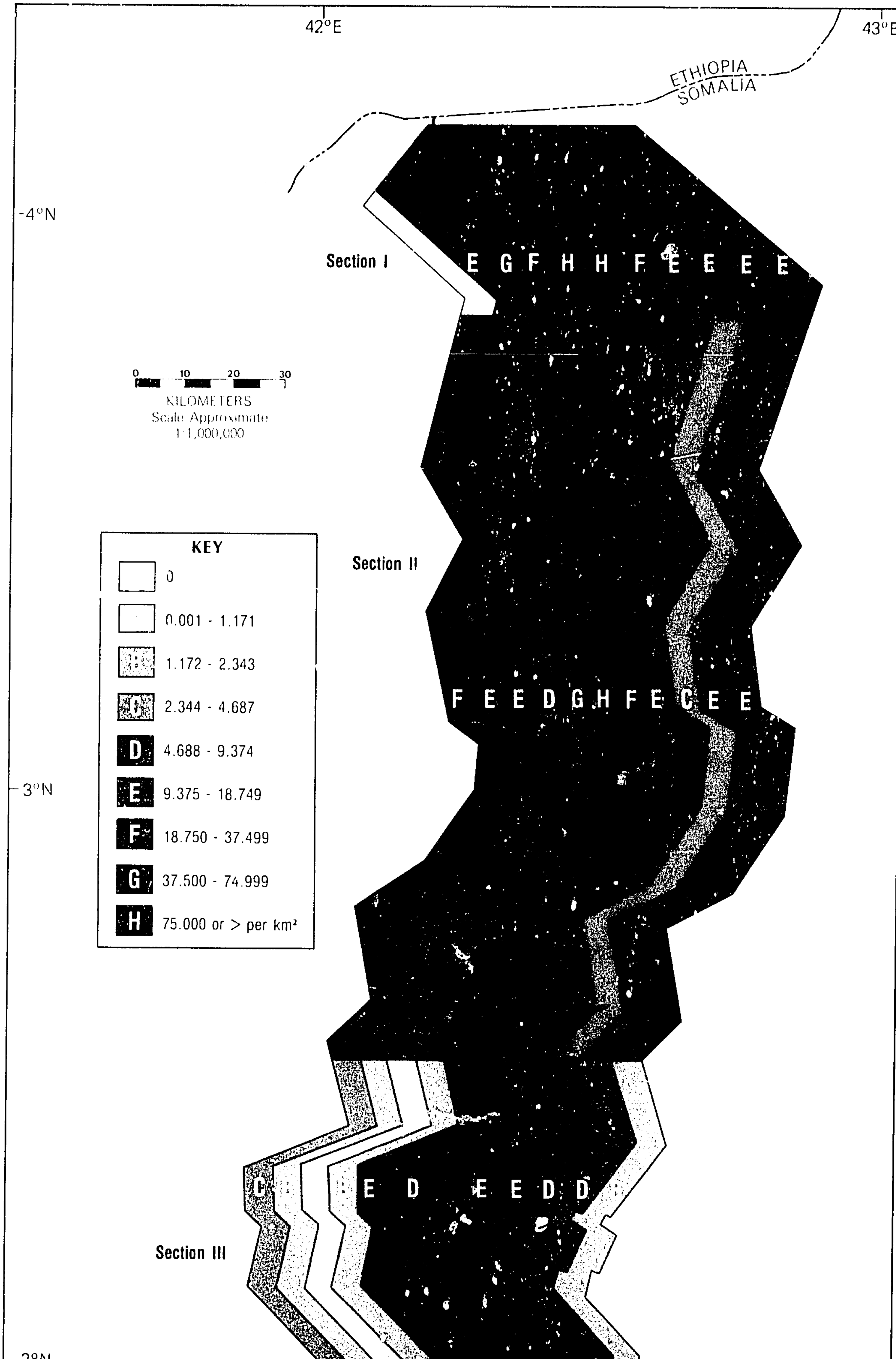


FIGURE 2.2

DISTRIBUTION OF SHEEP BIOMASS (KG/KM²) 2ND JILAAL SURVEY MARCH/APRIL 1987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Section I
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Section III
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0 10 20 30
KILOMETERS
Scale Approximate
1:1,000,000
KEY
0
0.001 - 1.171
B 1.172 - 2.343
C 2.344 - 4.687
D 4.688 - 9.374
E 9.375 - 18.749
F 18.750 - 37.499
G 37.500 - 74.999
H 75.000 or > per km²

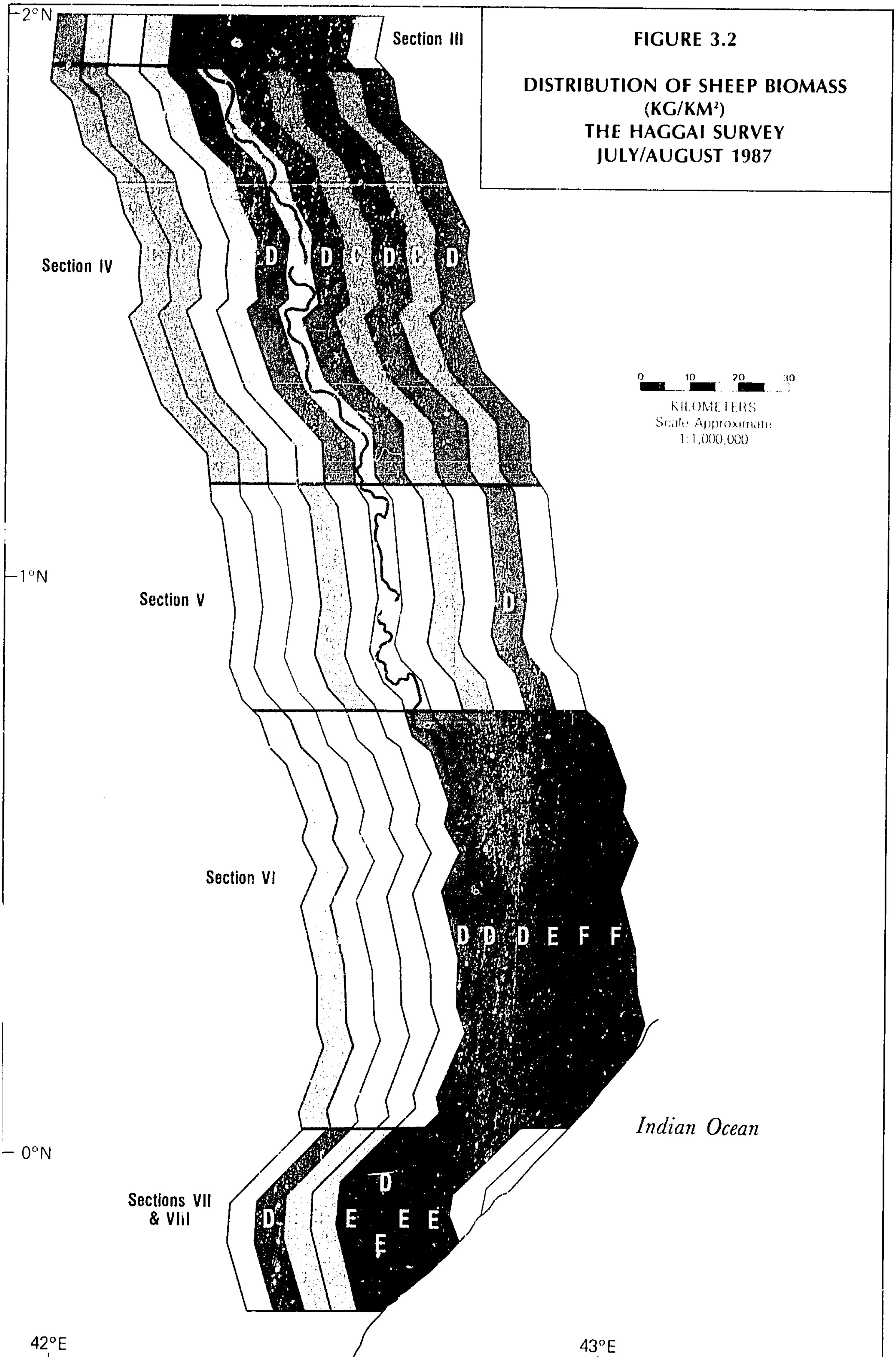

FIGURE 3.2

DISTRIBUTION OF SHEEP BIOMASS (KG/KM²) THE HAGGAI SURVEY JULY/AUGUST 1987

Table 3. Data on Livestock Numbers for the Three Surveys (To Nearest Hundred)

AREA	SURVEY	CATTLE	SHEEP	GOATS	CAMELS	DONKEYS	AREA IN km^2
FLOODPLAIN AND VALLEY ZONES							
The whole survey area (Region 100)	2nd Jiilaal	583,700	455,200	717,600	334,800	9,700	34,567
	Xagaa	480,800	373,800	655,000	350,000	4,800	34,567
Jubba Floodplain (Regions 75 & 76)	1st Jiilaal	83,600	42,200	118,600	17,000	1,400	1,932
	2nd Jiilaal	177,800	81,900	111,700	35,800	3,300	1,932
	Xagaa	87,300	50,200	74,500	10,100	2,300	1,932
Jubba Valley (Regions 74 & 77)	2nd Jiilaal	406,000	373,300	606,000	299,000	6,400	32,635
	Xagaa	393,500	323,700	580,500	339,900	2,500	32,635
MAJOR RIVER REGIONS							
River Region Above Reservoir (Region 64)	2nd Jiilaal	2,700	82,000	101,700	12,900	2,000	2,229
	Xagaa	19,400	67,100	98,700	29,500	1,300	2,229
Inundation Region (Region 65)	2nd Jiilaal	34,500	181,200	311,200	97,200	2,300	8,406
	Xagaa	48,000	182,800	322,600	61,100	1,600	8,406
Downstream Region (Region 73)	2nd Jiilaal	546,100	191,700	304,700	224,700	5,300	23,923
	Xagaa	411,900	123,400	232,900	259,400	1,800	23,923
VALLEY SECTIONS							
Valley Section I (Region 64)	2nd Jiilaal	2,700	82,000	101,700	12,900	2,000	2,229
	Xagaa	19,400	67,100	98,700	29,500	1,300	2,229
Valley Section II (Region 65)	2nd Jiilaal	34,500	181,200	311,200	97,200	2,300	8,406
	Xagaa	48,000	182,800	322,600	61,100	1,600	8,406
Valley Section III (Region 66)	2nd Jiilaal	66,700	99,100	136,700	69,900	1,700	6,279
	Xagaa	76,400	44,600	86,900	66,900	1,100	6,2790
Valley Section IV (Region 67)	2nd Jiilaal	65,800	17,100	42,100	58,000	1,300	3,880
	Xagaa	56,400	15,600	38,200	90,500	200	3,880
Valley Section V (Region 68)	2nd Jiilaal	87,700	4,100	6,800	19,200	1,400	3,036
	Xagaa	59,300	4,100	7,400	39,100	0	3,036
Valley Section VI (Region 69)	2nd Jiilaal	223,800	54,800	90,100	60,700	500	7,894
	Xagaa	166,500	46,500	79,700	42,700	300	7,894
Valley Section VII A + B (Region 70)	2nd Jiilaal	102,200	16,700	29,000	17,000	500	2,833
	Xagaa	53,300	12,700	20,700	20,300	200	2,833
FLOODPLAIN SECTORS							
Floodplain Sector I (Region 78)	1st Jiilaal	1,500	6,900	15,600	2,000	500	114
	2nd Jiilaal	1,800	17,100	12,600	2,500	800	114
	Xagaa	7,700	12,800	15,700	7,100	1,200	114
Floodplain Sector II (Region 79)	1st Jiilaal	4,000	24,300	75,300	12,600	600	316
	2nd Jiilaal	12,900	34,800	58,800	9,500	1,500	316
	Xagaa	13,100	27,000	45,700	2,300	700	316
Floodplain Sector III (Region 80)	1st Jiilaal	6,100	1,700	5,600	700	100	89
	2nd Jiilaal	4,800	5,400	8,500	2,700	100	89
	Xagaa	2,100	500	1,200	300	50	89
Floodplain Sector IV (Region 81)	1st Jiilaal	11,200	1,200	2,900	1,400	0	200
	2nd Jiilaal	12,600	4,200	10,800	14,700	200	160
	Xagaa	3,800	300	200	0	0	160
Floodplain Sector V (Region 82)	1st Jiilaal	5,400	800	1,700	50	0	176
	2nd Jiilaal	32,800	1,700	3,500	2,000	500	176
	Xagaa	2,400	400	100	200	0	176
Floodplain Sector VI (Region 83)	1st Jiilaal	15,300	3,200	9,300	0	0	713
	2nd Jiilaal	73,100	10,100	10,100	2,400	100	713
	Xagaa	28,600	6,400	9,100	200	100	713
Floodplain Sector VIIA (Region 84)	1st Jiilaal	37,700	4,800	7,700	200	300	312
	2nd Jiilaal	33,600	6,900	6,200	1,900	100	312
	Xagaa	23,800	2,000	1,100	0	100	312
Floodplain Sector VIIB (Region 85)	1st Jiilaal	2,400	0	400	0	0	42
	2nd Jiilaal	5,600	1,200	1,000	0	0	42
	Xagaa	4,300	500	600	0	0	42

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In the second jiilaal survey, 18 percent of the sheep population was in the floodplain (which is 5.6 percent of the land area) at the time of the census. Undoubtedly, an even higher proportion of the sheep population were making temporary use of the floodplain resources.

The Inundation River Region supported 40 percent of the sheep population of the survey area in the second jiilaal survey, and 49 percent of the sheep population in the xagaa survey, although it comprises only 24 percent of the land area. Therefore, it seems that the inundation process could have an impact on a large portion of the whole sheep population.

The actual area to be inundated (Region 79, estimated at 316 km^2) supported eight percent of the sheep population in the second jiilaal survey, and seven percent in the xagaa survey. The Inundation Floodplain Sector (Region 79) comprised one percent of the whole survey area. This suggests that loss of land will have a significant impact on the overall sheep population of the valley in most years.

Goats (densities and estimates)

For the entire survey area, the goat density showed only a small change between the second jiilaal and xagaa surveys. (Approximately nine percent fewer goats were censused in the xagaa survey). This suggests that goats are not concentrating significantly in the Jubba Valley in a normal dry season from areas more than 30 km from the floodplain.

For the Floodplain Zone (Regions 75 and 76), goat densities showed appreciable concentration throughout the jiilaal period, suggesting that goats are managed differently from sheep and cattle.

Comparison of goat densities for the Floodplain Zone (Regions 75 and 76) and the Jubba Valley Zone (Regions 74 and 77), reveals that the floodplain supported approximately three times the density of goats in the second jiilaal survey and about twice the density in the xagaa survey. Density in the Jubba Valley Zone showed only a small difference between the two surveys indicating that migration of goats into the survey area in the dry season was almost matched by concentration into the Floodplain Zone.

A closer examination of goat densities in the three major river regions was made to investigate the differences in movement patterns up the length of the river. These data did not show any north-to-south migration during the jiilaal. The highest densities of goats throughout the year were found in the northernmost river region, where shorter herbs and grasses are abundant.

Examination of the seven valley sections, the eight floodplain sectors (Table 2), and Figures 2.3 and 3.3 provides a more detailed view of this movement pattern. It is evident that, even at this level, there is no north/south component in the goat movement patterns. Goat densities closely parallel sheep densities, being highest in Valley Section I and progressively declining southward to Valley Section V. Valley Sections VI and VIIA/VIIB have slightly higher densities. Goat densities in Valley Section II are higher than sheep densities, reflecting the greater availability of browse in that zone.

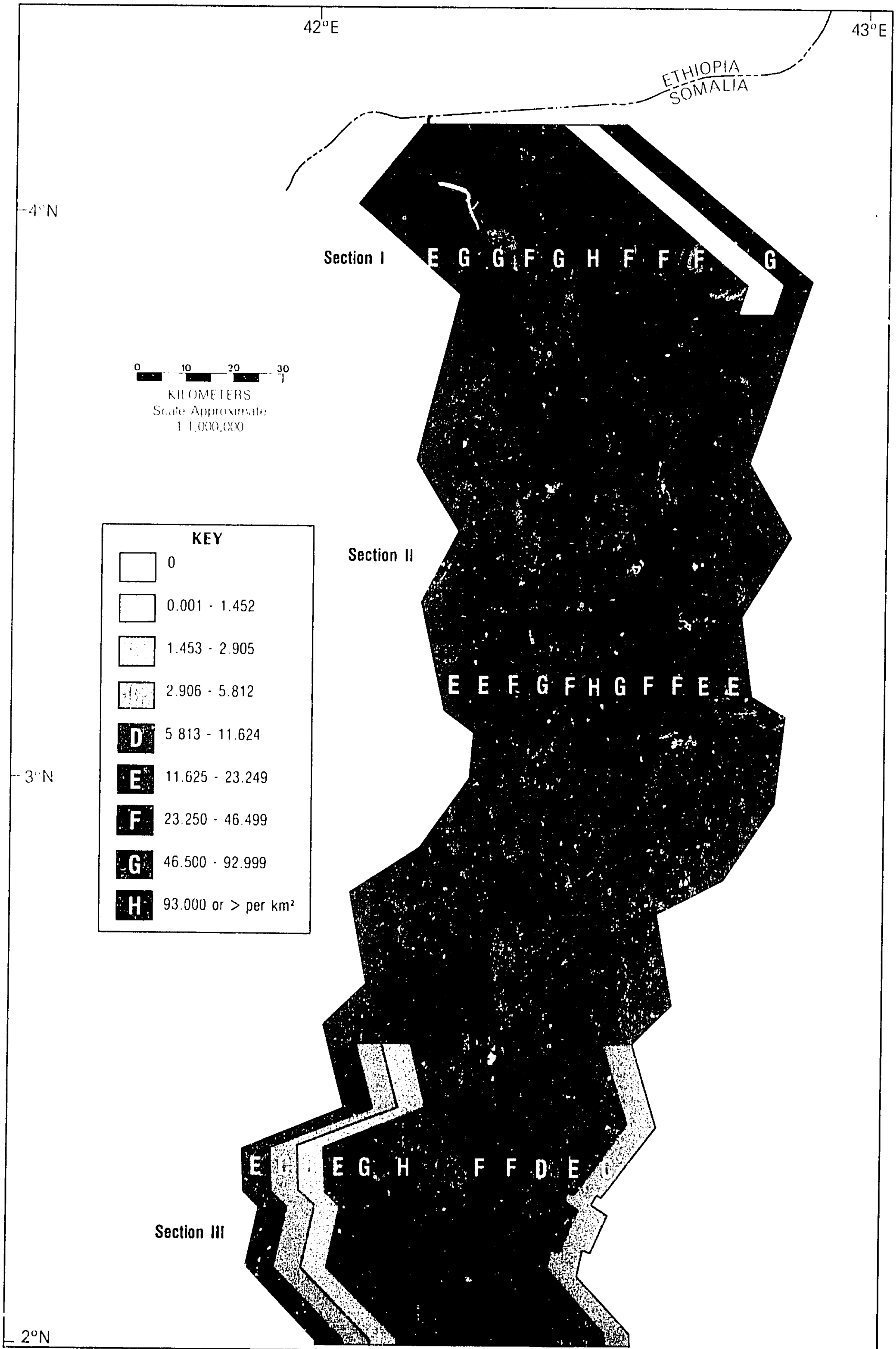
Goat densities of the eight floodplain sectors (Table 2) indicate the north-to-south pattern of concentration in the Jubba Floodplain. From north to south, the degrees of concentration of goat density observed in the second jiilaal survey were:

SECTOR	DENSITY
I	0.78
II	1.30
III	7.26
IV	51.25
V	28.00
VI	1.09
VIIA	5.18
VIIB	1.93

The densities of goat in the eight floodplain sectors in the second jiilaal survey increased from Floodplain Sector I to II, then decreased progressively from Floodplain II to Floodplain Sector VI, and finally increased again through Floodplains VIIA and VIIB. In the xagaa survey, goat densities showed no simple pattern, but were clearly concentrated in Floodplain Sector I and II.

The whole survey area was found to support 650,000 to 700,000 goats (Table 3), which is approximately 13 percent of the southern Somalia population (Watson and Nimmo 1985), and about four percent of the national population (Watson *et al.* 1979; Watson 1982). Developments in the Jubba Valley have the potential to affect only a small component of Somalia's goat population.

In the second jiilaal survey, 15 percent of the goat population was in the floodplain (which is 5.6 percent of the land area) at the time of the census. Undoubtedly, an even higher portion of the goat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Scale Approximate
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0.001 - 1.452
1.453 - 2.905
2.906 - 5.812
D 5.813 - 11.624
E 11.625 - 23.249
F 23.250 - 46.499
G 46.500 - 92.999
H 93.000 or > per km²

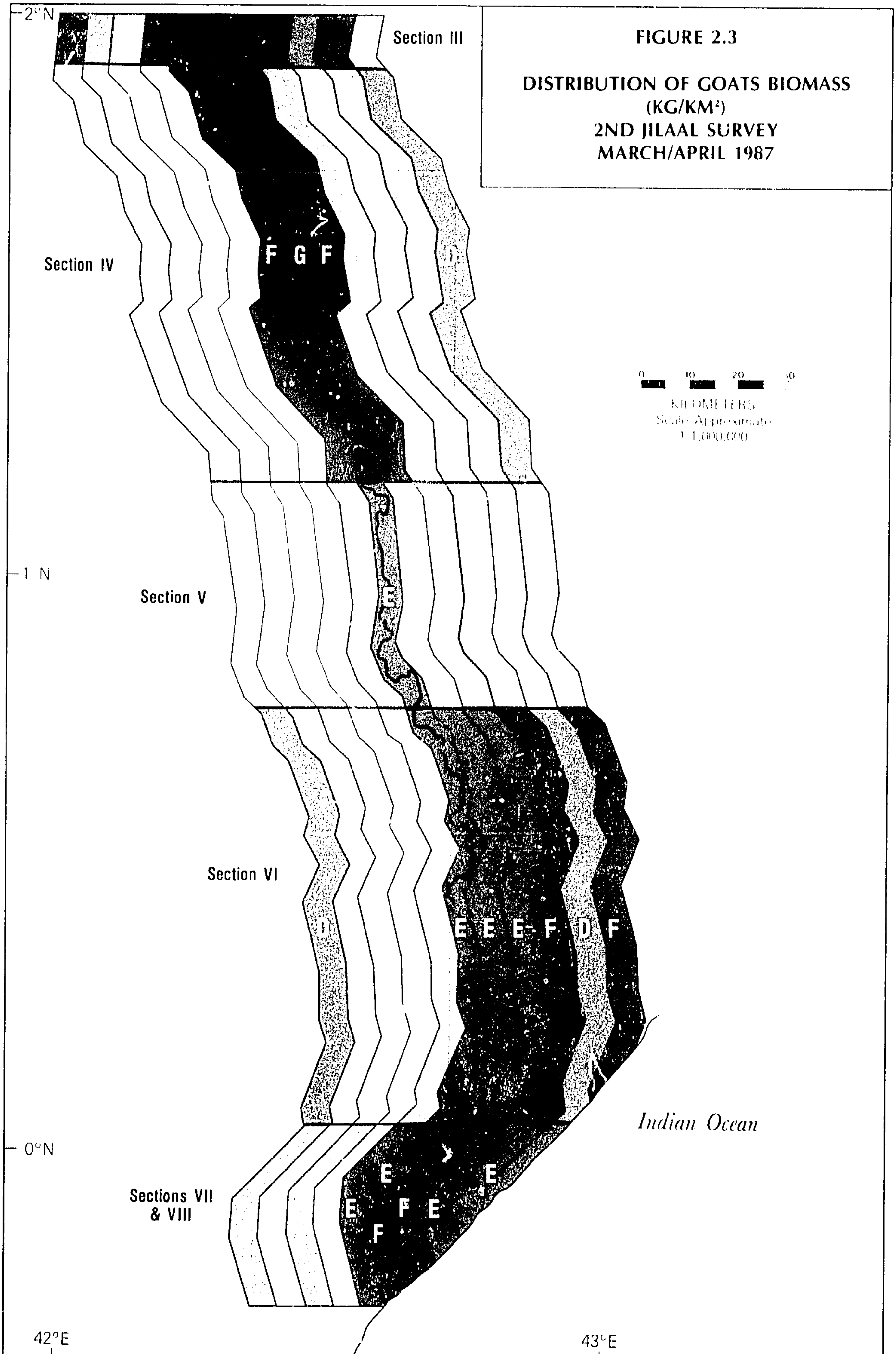
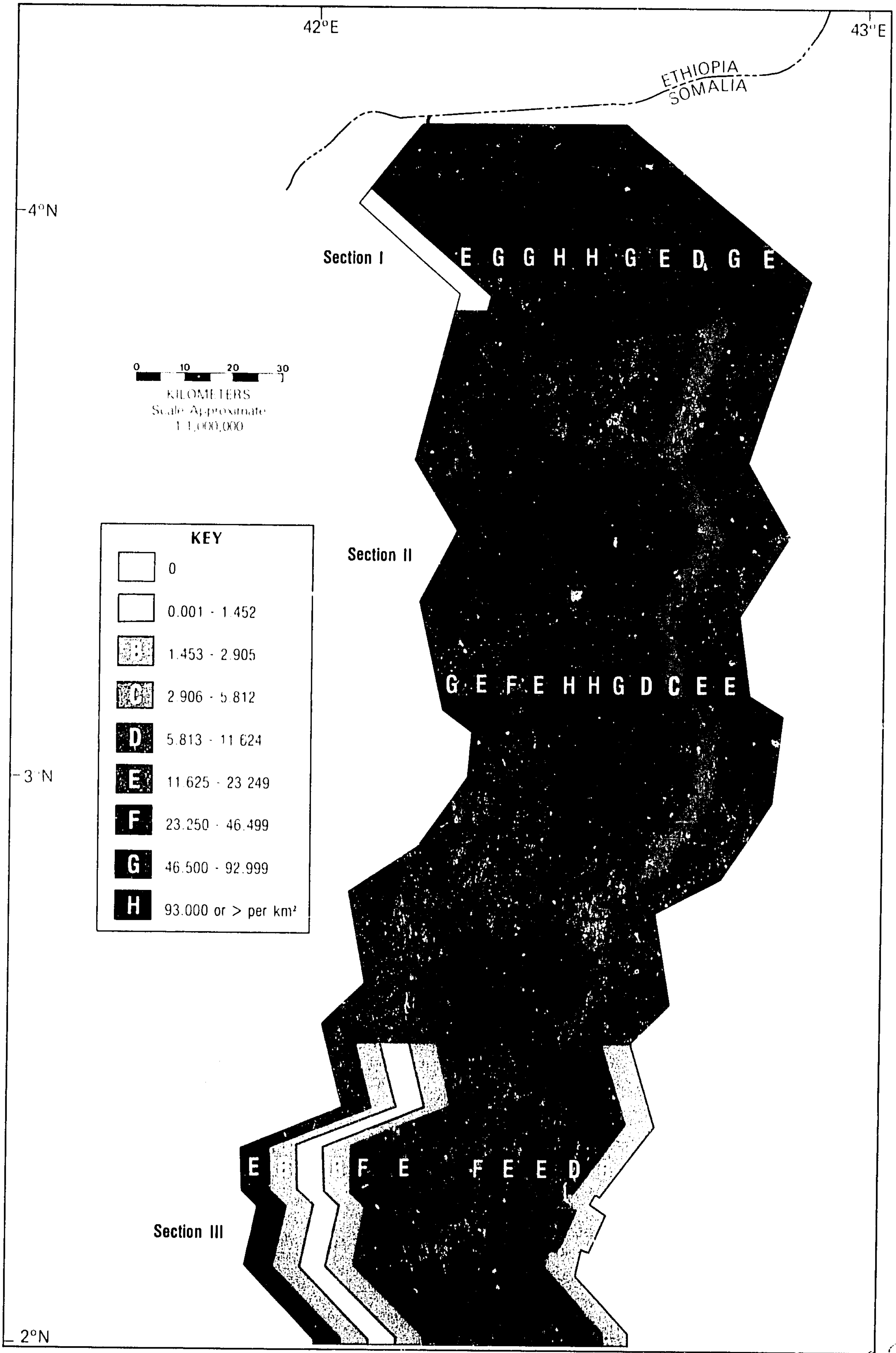


FIGURE 2.3

DISTRIBUTION OF GOATS BIOMASS (KG/KM²)

2ND JILAAL SURVEY

MARCH/APRIL 1987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Scale Approximate
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0.001 - 1.452
B 1.453 - 2.905
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E 11.625 - 23.249
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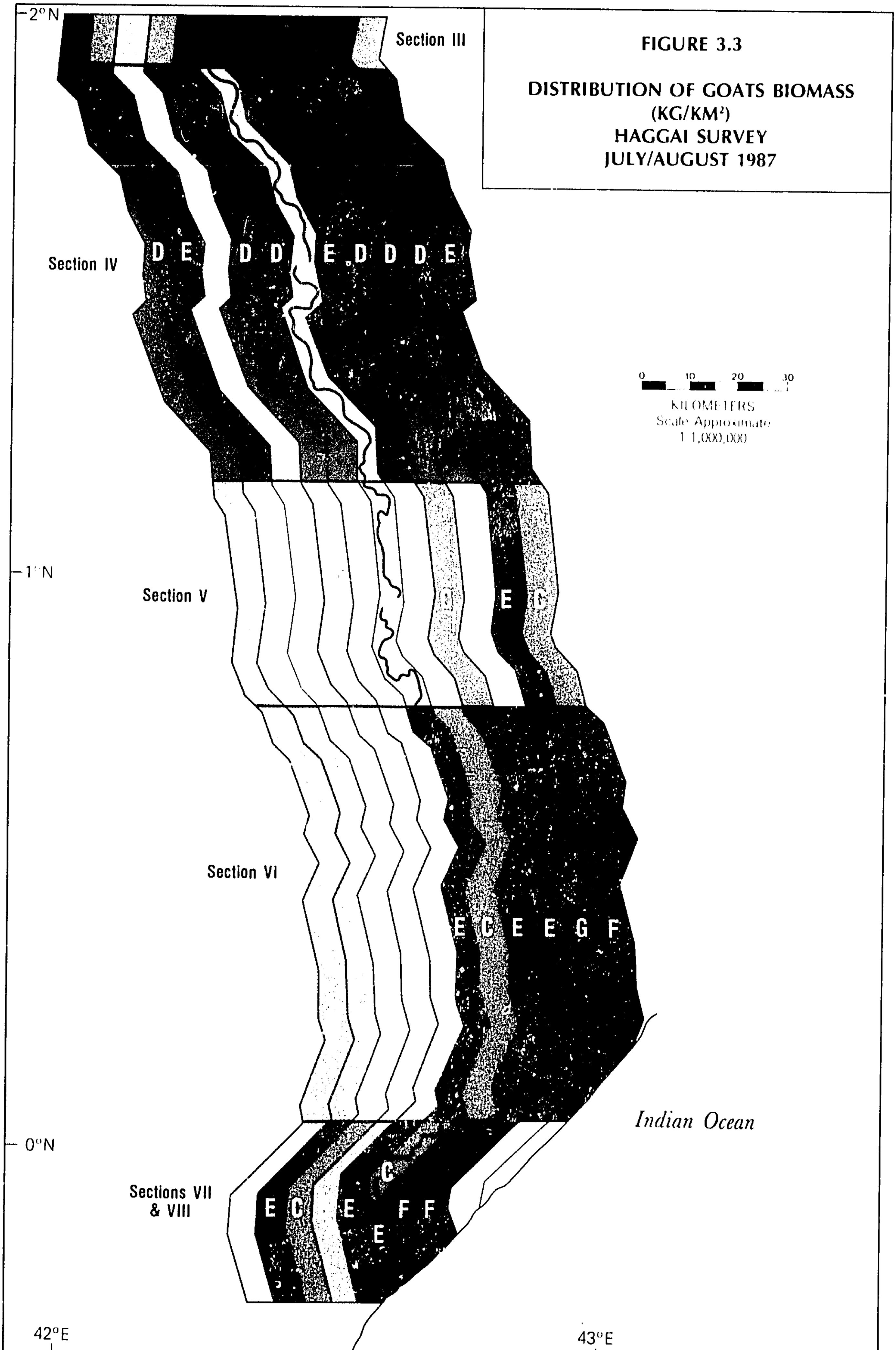


FIGURE 3.3

DISTRIBUTION OF GOATS BIOMASS (KG/KM²) HAGGAI SURVEY JULY/AUGUST 1987 population were making temporary use of floodplain resources.

The Inundation River Region supported 43 percent of the goat population of the survey area in the second jiilaal survey, and 49 percent of the goat population in the xagaa survey, although it comprises only 24 percent of the land area. Therefore, it seems that the inundation process could have impact on a large proportion of the whole goat population.

The actual area to be inundated (Region 79 estimated at 316 km^2) supported eight percent of the goat population in the second jiilaal survey, and seven percent in the xagaa survey. The Inundation Floodplain Sector (Region 79) comprises one percent of the whole survey area. This suggests that loss of land will have a significant impact on the overall goat population of the valley in most years.

Camels (densities and estimates)

For the entire survey area, the camel density showed very little change between the second jiilaal and xagaa surveys. (Approximately five percent more camels were censused in the xagaa survey.) This suggests that camel are not concentrating in the Jubba Valley in a normal dry season from areas further than 30 km from the floodplain.

For the Floodplain Zone (Regions 75 and 76), camel densities showed considerable concentration in the jiilaal period, with densities 70 percent higher in January/February and 250 percent higher in April. This reflects the crucial importance of the floodplain vegetation and crop residues for camels in the driest periods of the year, and the movements of camels into the floodplain to carry water supplies to pastoralists living outside the floodplain.

Comparison of camel densities for the Floodplain Zone (Regions 75 and 76) and the Jubba Valley Zone (Regions 74 and 77) shows that the floodplain supported twice the density of camels in the second jiilaal survey and half the density of camels in the xagaa survey. Density of camels in the Jubba Valley Zone showed a significant increase in the xagaa survey, suggesting that the concentration of camels in the floodplain was drawn primarily from the population of the Jubba Valley Zone.

A closer examination of camel densities in the three major river regions was made to investigate the differences in movement patterns up the length of the river. It seems that a limited north-to-south movement occured in the jiilaal, but only in the northern part of the valley. The highest densities in the jiilaal survey were found in the Inundation Zone (where there is the densest browse). In the xagaa survey, the highest densities of camels was found in the northernmost river region.

A more detailed view of this movement pattern is provided through an examination of the seven valley sections, the eight floodplain sectors (Table 2), and Figures 2.4 and 3.4. It is evident that there are no consistent north/south components of movement in the camel movement patterns, although local patterns are quite pronounced. Camel densities in the jiilaal showed no consistent pattern, but were highest in Floodplain Sectors IV, III, and II, and lowest in Floodplain Sector I. In the xagaa, camels were highest in Floodplain Sectors IV, I, and V, and lowest in Floodplain Sector VI.

Camel densities of the eight floodplain sectors (Table 2) showed the following degrees of concentration in the second jiilaal survey:

SECTOR	DENSITY
I	0.36
II	4.12
III	8.70
IV	700.73
V	11.98
VI	13.93
VIIA	0-
VIIB	0-

Densities of camel in the eight floodplain sectors in the second jiilaal survey generally increased progressively from north to south from Floodplain Sector I to IV, and decreased progressively from Floodplain IV to Floodplain Sector VIIB, (with a minor perturbation in Floodplain VI).

The survey area supported approximately 350,000 camels (Table 3), which is about 15 percent of the southern Somalia population (Watson and Nimmo 1985), and about eight percent of the national population (Watson *et al.* 1979; Watson 1982). Developments in the Jubba Valley have the potential to affect a significant poriton of Somalia's camel population.

In the second jiilaal survey, 11 percent of the camel population was in the floodplain (which is 5.6 percent of the land area) at the time of the census. Undoubtedly, an even higher portion of the camel population were making temporary use of the floodplain resources.

The Inundation River Region supported 29 percent of the camel population of the survey area in the second jiilaal survey, and 17 percent of the camel population in the xagaa survey. This region comprises 24 percent of the land area. Therefore, it seems that the inundation process could have impact on a small portion of the whole camel population.

The actual area to be inundated (Region 79 estimated at 316 km^2) supported three percent of the camel population in the second jiilaal survey, and fewer than one percent in the xagaa survey. The Inundation Floodplain Sector (Region 79) comprises one percent of the entire survey area. This suggests that loss of land will have almost no impact on the overall camel population of the valley in most years.

Donkeys (densities and estimates)

For the survey area (Region 100), the donkey density changed very little between the second jiilaal and xagaa surveys, although proportionally, 50 percent fewer donkeys were censused in the xagaa survey. It is possible that donkeys were concentrating in the Jubba Valley from areas more than 30 km from the floodplain, but the results were subject to large sampling errors and could not be classified as significant.

For the Floodplain Zone (Regions 75 and 76), donkey densities showed appreciable concentration in the second jiilaal survey, confirming the importance of the floodplain vegetation and crop residues and the Jubba River water supply to donkeys in the driest periods of the year.

Comparison of donkey densities for the Floodplain Zone (Regions 75 and 76) and the Jubba Valley Zone (Regions 74 and 77), shows that the floodplain supported almost nine times the density of donkeys in the second jiilaal survey and sixteen times the density of donkeys in the xagaa survey.

The density of donkeys in the Jubba Valley Zone showed a significant decrease in the xagaa survey, suggesting that the migration of donkeys into the survey area was not completely matched by concentration into the Floodplain Zone.

A closer examination of donkey densities in the three major river regions was made to investigate the differences in movement patterns up the length of the river. There was no evidence of consistent north/south movement patterns along the river valley. The highest densities of donkey throughout the year were found in the northernmost river region. Densities declined progressively southward as the wetter vegetation types and tsetse infestations were encountered.

A more detailed view of this movement pattern is provided through an examination of the seven valley sections and the eight floodplain sectors (Table 2). At this level of analysis, it seems that there was some southward component of movement in the jiilaal, but the position was confused by the entry of donkeys from outside the survey area in the jiilaal survey, and by the large sampling errors associated with donkey estimates.

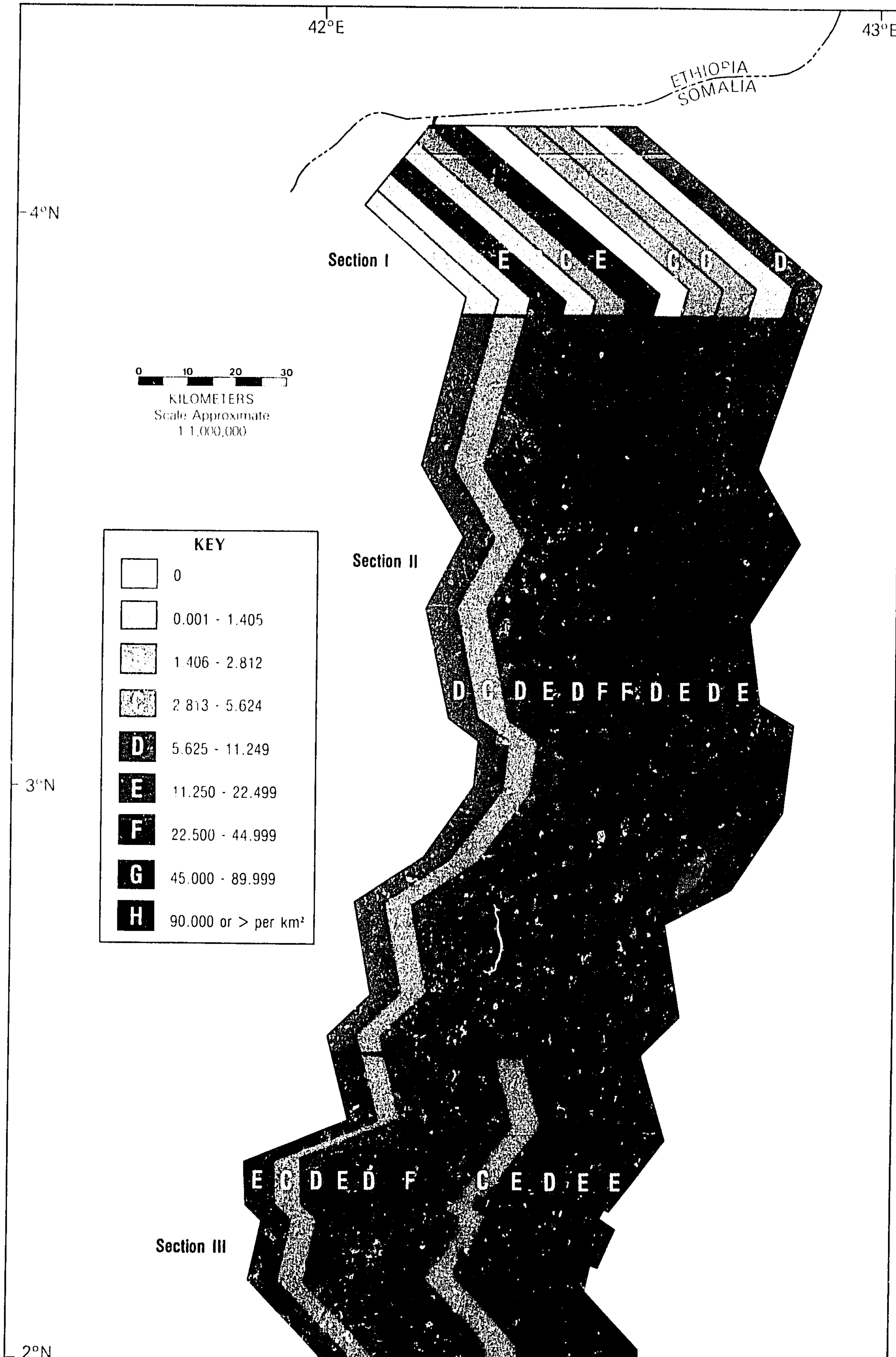
Data on donkey densities in the floodplain sectors (Table 2) were too complex, and associated with excessive variances, so that few reasonable deductions may be made. However, there was evidence that donkeys were very scarce in Floodplain Sectors IV, V, and VI—the area with the highest density of tsetse flies.

The whole survey area supported about 5,000 to 10,000 donkeys (Table 3), which is approximately 27 percent of the southern Somalia population (Watson and Nimmo 1985), and about 12 percent of the national population (Watson *et al.* 1979; Watson 1982). Developments in the Jubba Valley have the potential to affect an important component of Somalia's donkey population.

In the second jiilaal survey, 34 percent of the donkey population was in the floodplain (which is 5.6 percent of the land area) at the time of the census. Undoubtedly, a higher percentage was making temporary use of the floodplain resources.

The Inundation River Region supported 24 percent of the donkey population of the survey area in the second jiilaal survey, and 33 percent of the donkey population in the xagaa survey. This region comprises 24 percent of the land area. Therefore, it seems that the inundation process could have impact on a significant portion of the whole donkey population.

The actual area to be inundated (Region 79 estimated at 316 km^2) supported 15 percent of the donkey population in both the second jiilaal survey, and the xagaa survey. The Inundation Floodplain Sector (Region 79) comprised one percent of the whole survey area. This suggests that loss of land



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2.813 - 5.624
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E 11.250 - 22.499
F 22.500 - 44.999
G 45.000 - 89.999
H 90.000 or > per km²

22A

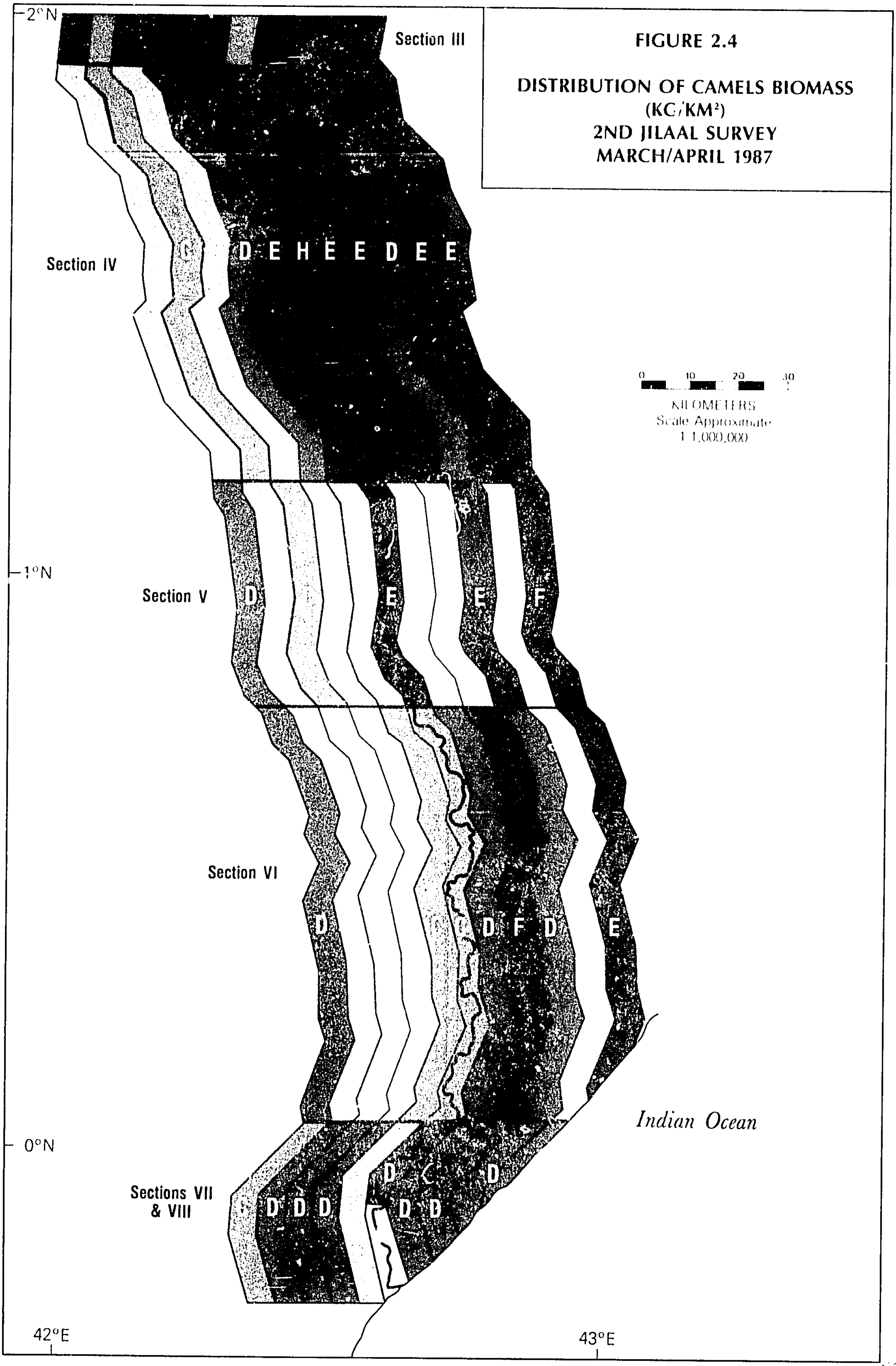
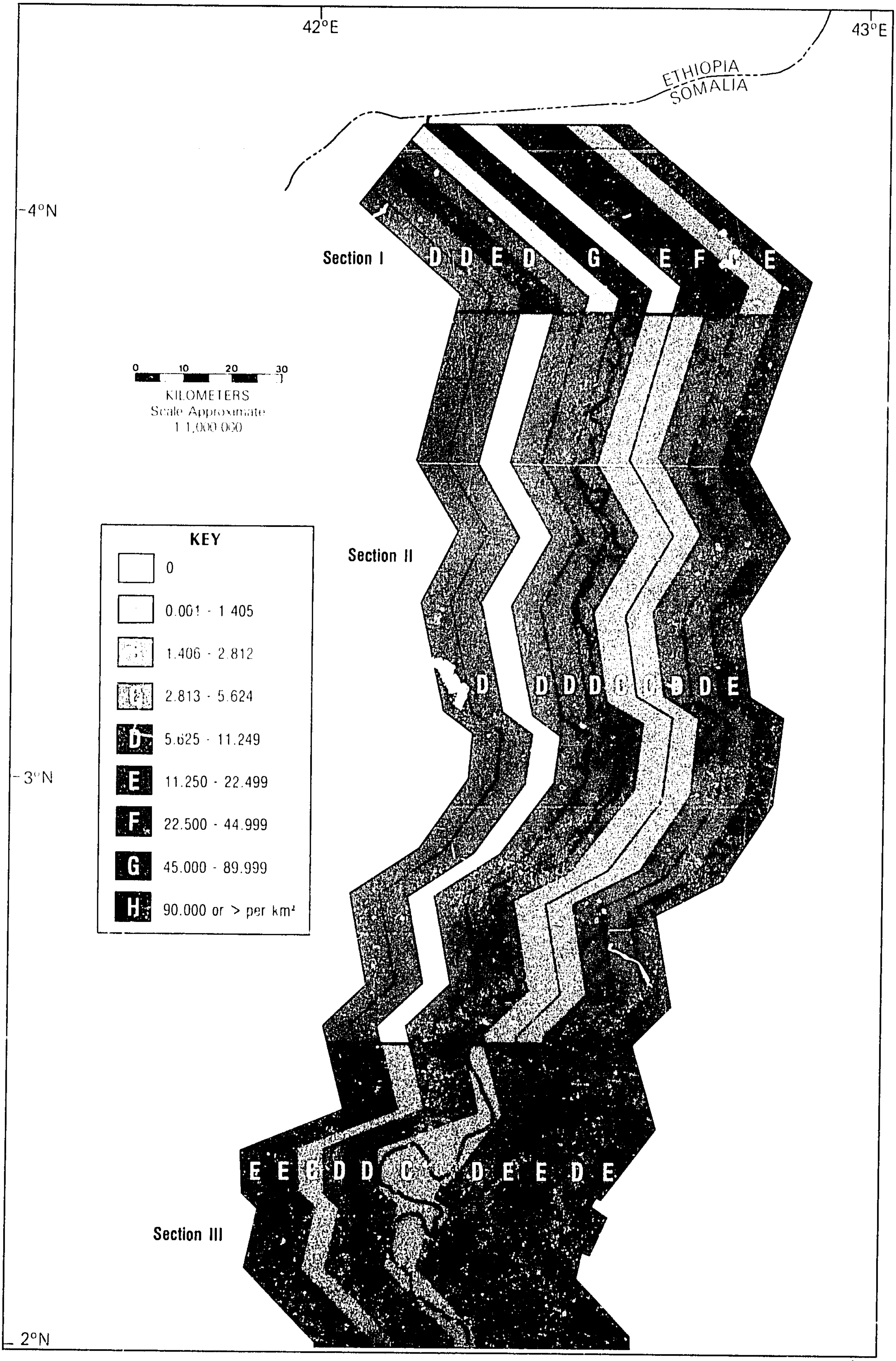


FIGURE 2.4

DISTRIBUTION OF CAMELS BIOMASS (KG/KM²) 2ND JILAAL SURVEY MARCH/APRIL 1987



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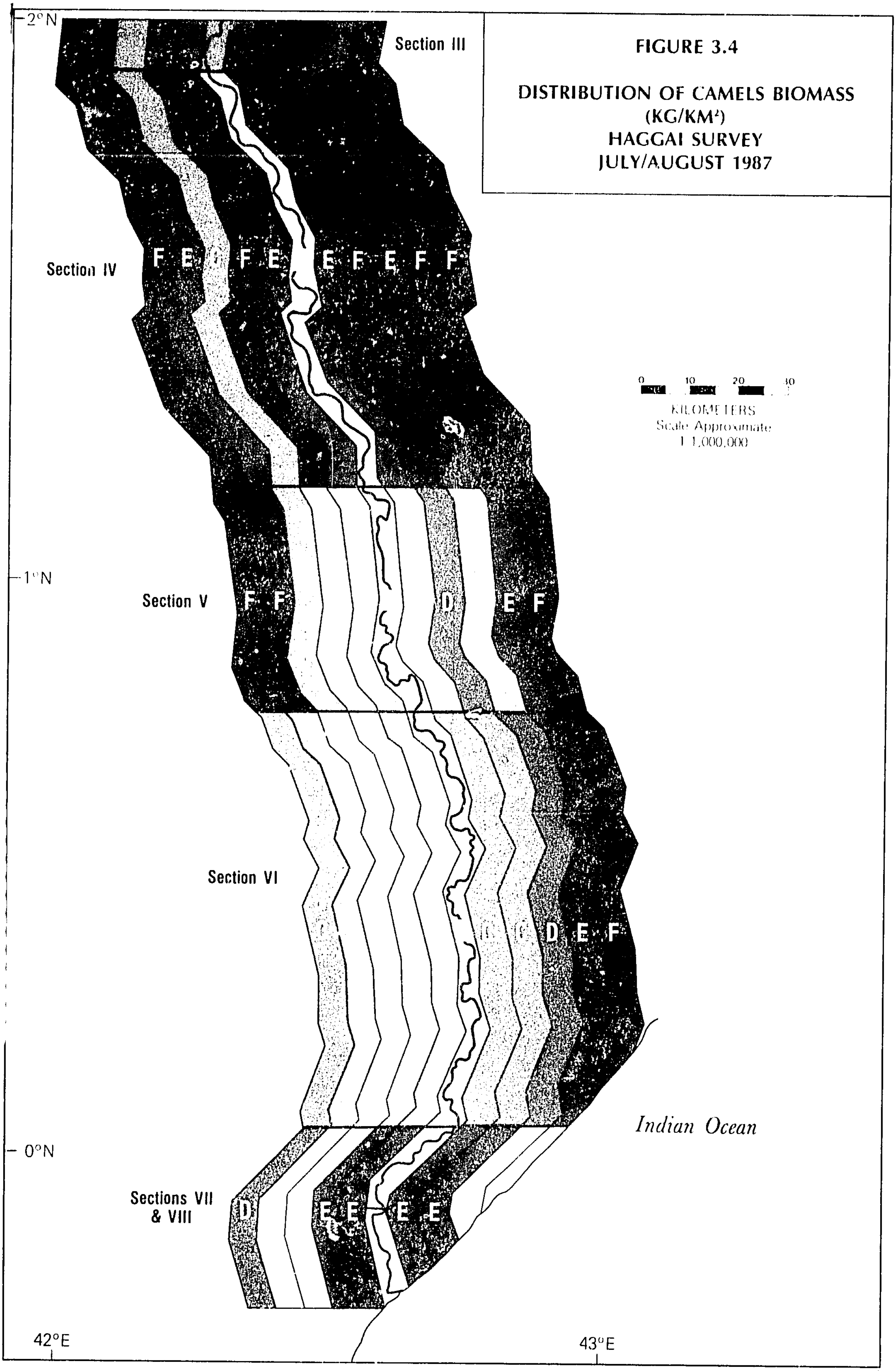


FIGURE 3.4

DISTRIBUTION OF CAMELS BIOMASS (KG/KM²) HAGGAI SURVEY JULY/AUGUST 1987 will have a significant impact on the overall donkey population of the valley in most years.

Livestock Biomass (densities and estimates)

For the whole survey area (Region 100), the livestock biomass densities showed little change between the second jiilaal and xagaa surveys. (Approximately eight percent less livestock biomass was censused in the xagaa survey). This suggests that livestock biomass is not concentrating significantly in the Jubba Valley in a normal dry season from areas more than 30 km from the floodplain. The absolute livestock biomass density is somewhat higher than might be expected because of rainfall/vegetation productivity. This undoubtedly reflects the influence of the riverine production of vegetation—both natural and cultivated. Cattle and camels are equally important and the dominant components of the livestock biomass. Sheep, goats, and donkeys are less important in the overall exploitation pattern, comprising less than 10 percent of the total biomass.

For the Floodplain Zone (Regions 75 and 76), livestock biomass densities more than doubled in the driest time of the year, confirming the crucial importance of floodplain vegetation and crop residues, and the Jubba River water supply for livestock using the Jubba Valley. The absolute livestock biomass density was substantially higher than expected because of rainfall/vegetation productivity, reflecting the importance of riverine vegetation and crop residues year-round. Cattle are the dominant component (71 percent) of livestock biomass in the floodplain with camel making up the other important element (19 percent).

Comparison of livestock biomass densities for the Floodplain Zone (Regions 75 and 76) and the Jubba Valley Zone (Regions 74 and 77) reveals that the floodplain supported four times the density of livestock biomass in the second jiilaal survey and about twice the density of livestock biomass in the xagaa survey. Densities of livestock biomass in the Jubba Valley Zone showed only a small difference between the two surveys, indicating that migration of livestock into the survey area was almost matched by concentration into the Floodplain Zone. The absolute livestock biomass density is substantially higher than could be expected because of rainfall/vegetation productivity, reflecting the influence of the floodplain in close proximity to the Jubba Valley Zone. Camels are the dominant component (52 percent) of the Jubba Valley Zone livestock biomass, with cattle making up the other important element (39 percent).

A closer examination of livestock biomass densities in the three major river regions was made to investigate the differences in movement patterns up the length of the river. These data showed that north-to-south movement of cattle in the jiilaal dominated other movement patterns. The highest densities of livestock biomass in the jiilaal survey occurred in the southernmost river region, and in the xagaa survey, occurred in the northernmost river region.

Examination of the seven valley sections, the eight floodplain sectors (Table 2), and Figures 2.5 and 3.5 provides a more detailed view of livestock biomass density. These data showed a uniform, overall livestock-use pattern in the xagaa survey, and an increasing density of livestock biomass from north to south in the second jiilaal survey.

Livestock biomass densities (indicative of overall grazing/browsing pressure) in the eight floodplain sectors (Table 2), showed the following degrees of concentration in the second jiilaal survey:

SECTOR	DENSITY
I	0.44
II	1.59
III	3.72
IV	10.05
V	13.71
VI	2.60
VIIA	1.58
VIIB	1.33

Livestock biomass densities in the second jiilaal survey did not show a simple pattern: for Floodplain Sectors I-III and VI-VIIB, densities ranged between 15,480 kg/km^2 and 25,261 kg/km^2, but Floodplain Sector IV had 44,126 kg/km^2 and Floodplain Sector V had 37,806 kg/km^2. However, in the xagaa survey, densities decreased progressively from north to south from Floodplain Sector I to Floodplain Sector V, and then increased progressively from north to south from Floodplain Sector V to Floodplain Sector VIIB.

The survey area supported approximately 15 percent of livestock biomass in southern Somalia (Watson and Nimmo 1985), and nine percent of the national livestock biomass (Watson *et al.* 1979; Watson 1982). Developments in the Jubba Valley have the potential to affect a significant portion of Somalia's livestock biomass.

Cattle (activities)

A summary and consolidation of cattle activities is provided in Table 4. In the whole survey area, 20 percent of the cattle were feeding on croplands or the various stages of regenerating vegetation on old croplands, and 10 percent were drinking or on their way to drinking. Only two percent in the second jiilaal survey were being fed on crop residues and cut browse which had been carried to their enclosures.

In the Floodplain Zone (Regions 75 and 76), higher numbers of cattle were feeding on current and old croplands (52 percent and 38 percent in the second jiilaal and xagaa surveys, respectively) than in the Jubba Valley Zone (Regions 74 and 77). The only significant feature evident from the data of the major river regions was the high number of cattle seen feeding on transported crop residues in the northernmost river region (Region 64).

The more detailed view of cattle activities provided by the analysis of the valley sections and floodplain sectors for the two surveys suggests tendency for more cattle to be seen in current and old croplands in the xagaa survey than in the second jiilaal survey in Floodplain Sectors I to VI. In Floodplain Sectors VIIA and VIIB, flooding and an out-of-phase cropping cycle probably distorted the picture. A progressive increase in the number of cattle seen on current or old croplands was evident in the xagaa survey from north to south in Floodplain Sectors I to V.

Sheep (activities)

A summary and consolidation of sheep activities is provided in Table 5. In the whole survey area, approximately 10 percent of the sheep were feeding on croplands or various stages of regenerating vegetation on old croplands, and about five percent were drinking or on their way to drinking. No sheep were being fed on transported crop residues in either survey.

In the Floodplain Zone (Regions 75 and 76), higher numbers of sheep were feeding on current and old croplands (32 percent and 27 percent in the second jiilaal and xagaa surveys, respectively), than in the Jubba Valley Zone (Regions 74 and 77).

There were no consistent seasonal trends in evidence from the data for the three major river regions (Regions 64, 65, and 73). However, there is a consistent north-to-south increase in the number of sheep seen on current and old croplands.

The more detailed view of sheep activities provided by the analysis of the valley sections and floodplain sectors for the two surveys suggests that there is no consistent seasonal trend in sheep activities. A progressive increase in the number of sheep was seen in the second jiilaal survey on current or old croplands from north to south from Floodplain Sectors I to IV and from V to VIIB. A progressive increase in the number of sheep was seen in the xagaa survey on current or old croplands from north to south from Floodplain Sectors II to IV and from VI to VIB.

Goats (activities)

A summary and consolidation of goat activities is provided in Table 6. In the survey area, approximately seven percent of the goats were feeding on croplands or various stages of regenerating vegetation on old croplands, and about six percent were drinking or on their way to drinking. No goats were being fed on transported crop residues in either survey.

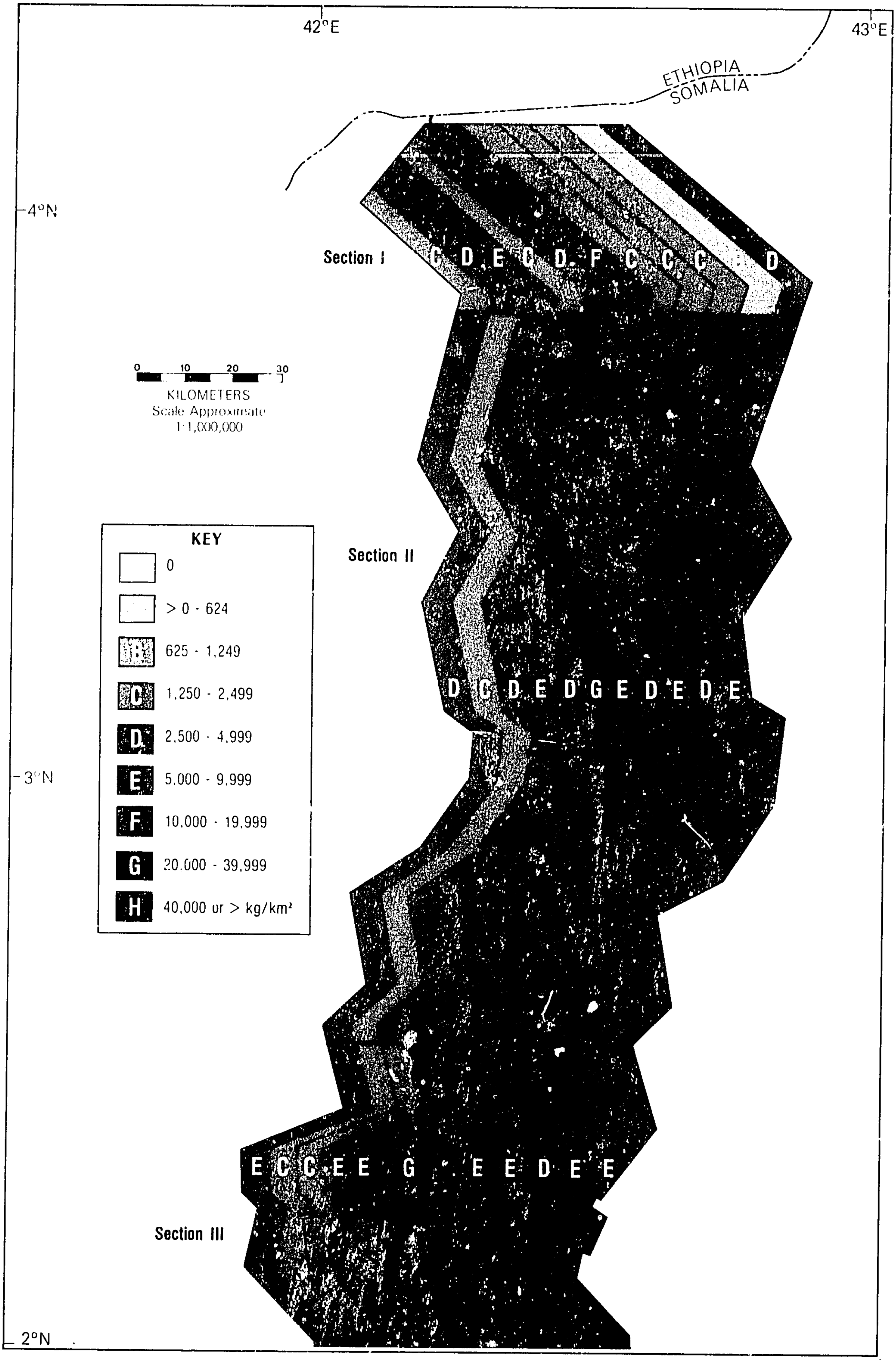
In the Floodplain Zone (Regions 75 and 76), higher numbers of goats were feeding on current and old croplands (26 percent and 25 percent in the second jiilaal and xagaa surveys, respectively), and were seen drinking (two percent and 33 percent in the second jiilaal and xagaa surveys, respectively) than in the Jubba Valley Zone(Regions 74 and 77).

Goat activities showed a small, progressive increase in numbers seen on current or old croplands in the second jiilaal survey for the three major river regions. No other seasonal or geographical trends were in evidence.

At a more detailed level, there was a tendency for more goats to be seen in croplands and old croplands in the xagaa survey than in the second jiilaal survey in Floodplain Sectors I to V. For cattle, flooding and a consequent out-of-phase cropping cycle may have obscured this pattern in Floodplain Sectors VI to VIIB. A progressive increase in the number of goats was seen on current or old croplands in the xagaa survey from north to south in Floodplain Sectors I to IV.

Camels (activities)

A summary and consolidation of camel activities is provided in Table 7. In the whole survey area, approximately seven percent of the camels were feeding on croplands or various stages of regenerating vegetation on old croplands, and about two percent were drinking or on their way to drinking.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G 20,000 - 39,999
H 40,000 or > kg/km²

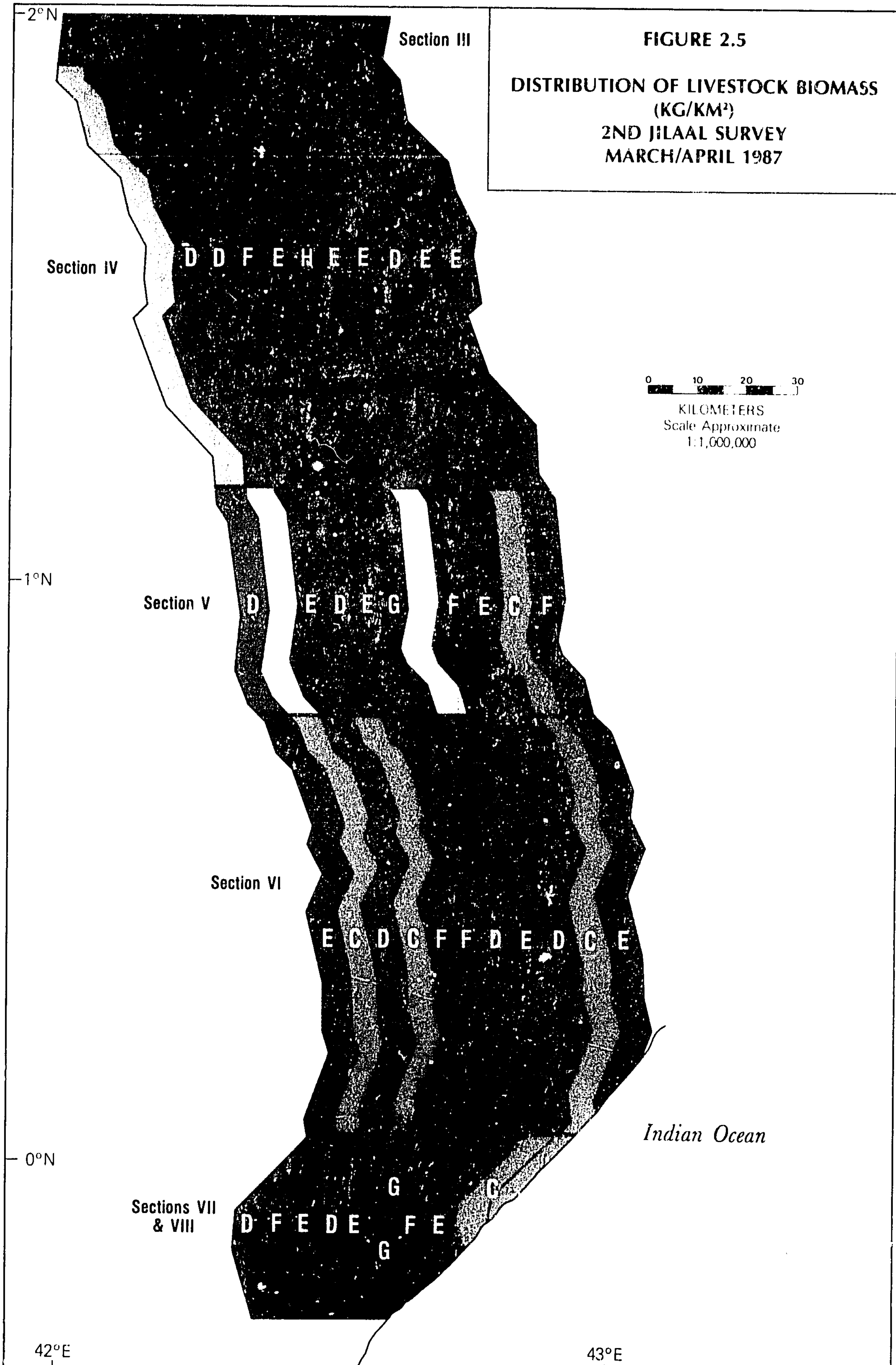
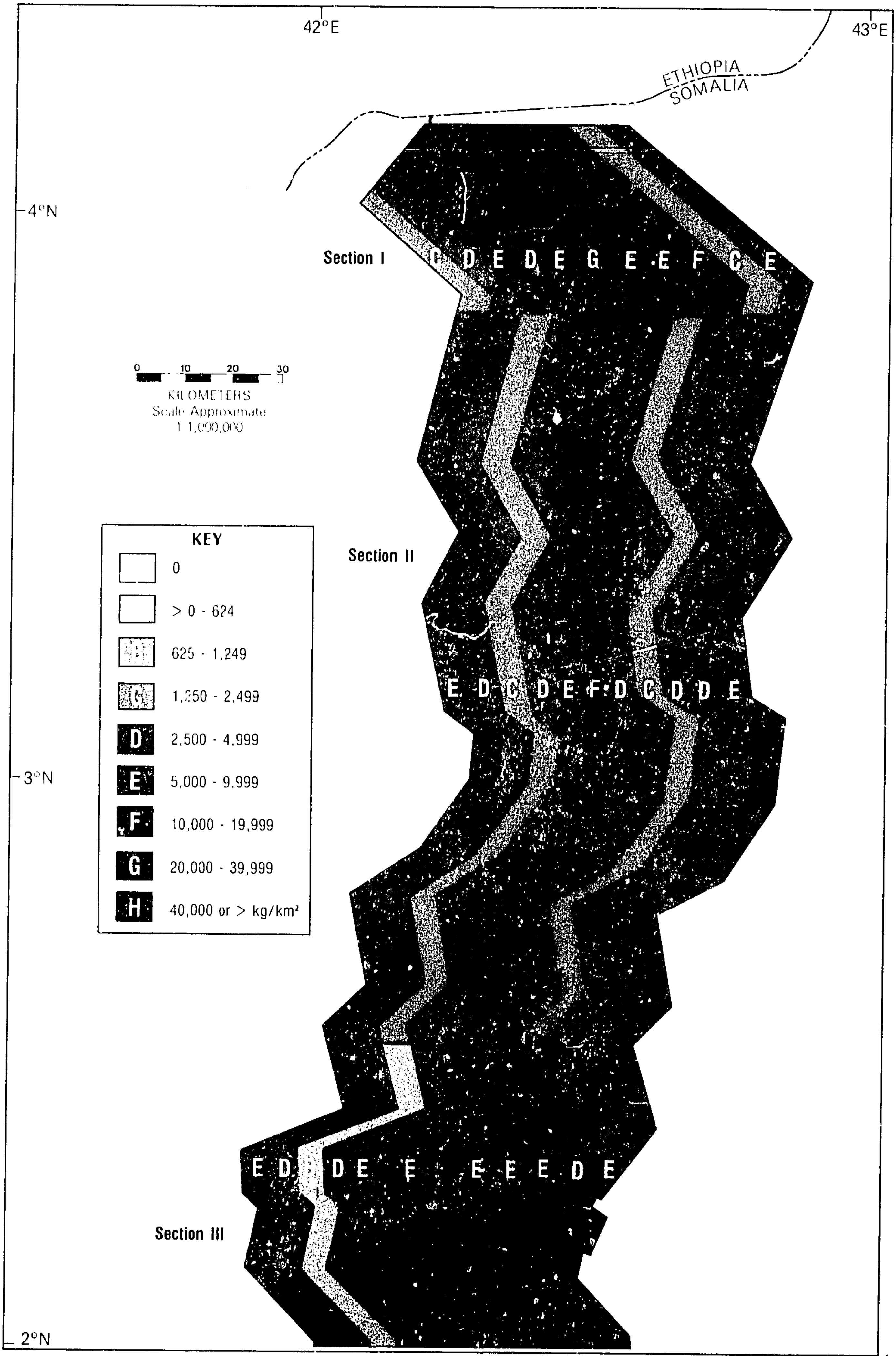


FIGURE 2.5

DISTRIBUTION OF LIVESTOCK BIOMASS (KG/KM²) 2ND JILAAL SURVEY MARCH/APRIL 1987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G 20,000 - 39,999
H 40,000 or > kg/km²

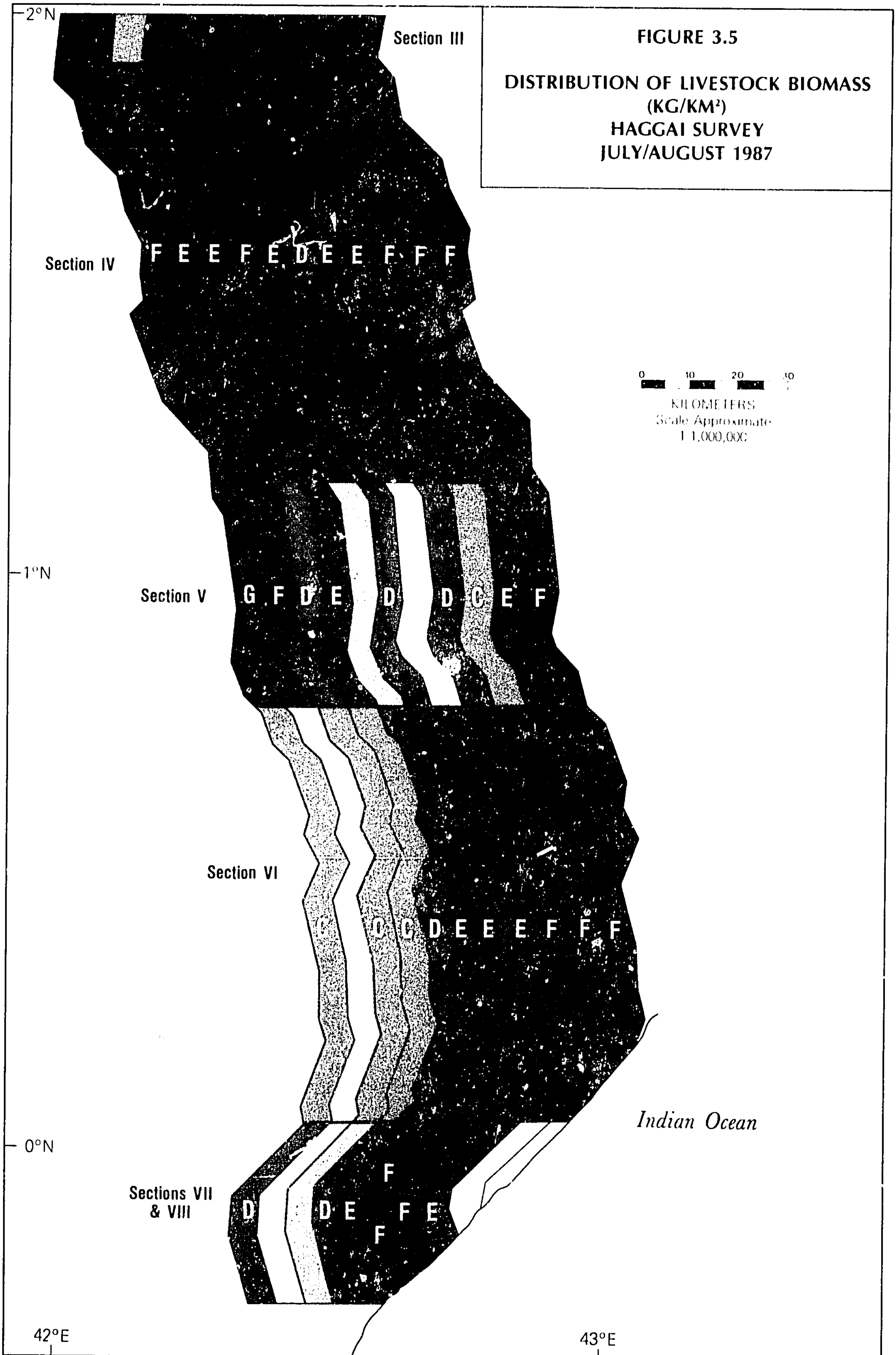


FIGURE 3.5

DISTRIBUTION OF LIVESTOCK BIOMASS (KG/KM²)
HAGGAI SURVEY
JULY/AUGUST 1987

Table 4. Cattle

DATA ON LIVESTOCK ACTIVITIES FOR THE THREE SURVEYS

AREA	SURVEY	% FEEDING ON RANGE	% FEEDING ON CROPLANDS OR VARIOUS STAGES OF CROPLAND REGENERATION	% DRINKING OR MOVING TO WATER	% FEEDING ON CROP RESIDUES	% OTHERS
FLOODPLAIN AND VALLEY ZONES						
The whole survey area (Region 100)	2nd Jiilaal	62	22	11	2	3
	Xagaa	66	17.6	9	0.4	7
Jubba Floodplain (Regions 75 & 76)	2nd Jiilaal	34	52	11	3	0
	Xagaa	41	38	8	1	11.5
Jubba Valley Section (Regions 74 & 77)	2nd Jiilaal	74	8	11	2	5
	Xagaa	72	12	9	0	7
MAJOR RIVER REGIONS						
River Region Above Reservoir (Region 64)	2nd Jilaal	56	14	0	30	0
	Xagaa	28	18	27	0	27
Inundation Region (Region 65)	2nd Jiilaal	65	23	9	2	1
	Xagaa	59	21	19	1	0
Downstream Region (Region 73)	2nd Jiilaal	62	25	11	2	0
	Xagaa	69	17	7	0.1	7
VALLEY AND FLOODPLAIN SECTORS						
Valley Section I (Region 64)	2nd Jiilaal	56	14	0	30	0
	Xagaa	28	18	27	0	27
Floodplain Sector I (Region 78)	2nd Jiilaal	36	20	0	44	0
	Xagaa	32	30	25	0	13
Valley Section II (Region 65)	2nd Jiilaal	65	20	9	2	4
	Xagaa	59	21	19	1	0
Floodplain Sector II (Region 79)	2nd Jiilaal	46	46	5	2	1
	Xagaa	41	40	13	1	5
Valley Section III (Region 66)	2nd Jiilaal	85	4	9	0	2
	Xagaa	33	40	5	0.1	22
Floodplain Sector III (Region 80)	2nd Jiilaal	30	27	35	7	1
	Xagaa	30	64	6	0	0
Valley Section IV (Region 67)	2nd Jiilaal	72	11	11	2	4
	Xagaa	70	24	5	0.2	1
Floodplain Sector IV (Region 81)	2nd Jiilaal	17	58	14	11	0
	Xagaa	12	88	0	0	0
Valley Section V (Region 68)	2nd Jiilaal	82	2	16	0	0
	Xagaa	96	4	0	0	0
Floodplain Sector V (Region 82)	2nd Jiilaal	75	5	20	0	0
	Xagaa	8	92	0	0	0
Valley Section VI (Region 69)	2nd Jiilaal	62	21	2	8	7
	Xagaa	76	12	10	0	2
Floodplain Sector VI (Region 83)	2nd Jiilaal	28	64	6	2	0
	Xagaa	32	67	0	0.5	0.4
Valley Section VII A + B (Region 70)	2nd Jiilaal	51	31	12	5	1
	Xagaa	68	5	11	0	16
Floodplain Sector VIIA (Region 84)	2nd Jiilaal	16	66	15	3	0.4
	Xagaa	72	2	0	0	26
FloodpPlain Sector VIIB (Region 85)	2nd Jiilaal	7	93	0	0	0
	Xagaa	14	52	0	0	34

Table 5. Sheep

DATA ON LIVESTOCK ACTIVITIES FOR THE THREE SURVEYS

AREA	SURVEY	% FEEDING ON RANGE	% FEEDING ON CROPLANDS OR VARIOUS STAGES OF CROPLAND REGENERATION	% DRINKING OR MOVING TO WATER	% FEEDING ON CROP RESIDUES	% OTHERS
FLOODPLAIN AND VALLEY						
The whole survey area	2nd Jiilaal	80	8	4	0	8
(Region 100)	Xagaa	75	9	7	0	9
Jubba Floodplain	2nd Jiilaal	63	32	2	0.4	3
(Regions 75 & 76)	Xagaa	37	27	33	0	3
Jubba Valley Section	2nd Jiilaal	84	4	3	0.2	9
(Regions 74 & 77)	Xagaa	81	6	3	0.1	10
MAJOR RIVER REGIONS						
River Region	2nd Jiilaal	90	1	3	0	6
AboveR eservoir (Region 64)	Xagaa	80	10	5	0	5
Inundation Region	2nd Jiilaal	89	4	3	0	4
(Region 65)	Xagaa	76	6	13	0	5
Downstream Region	2nd Jiilaal	68	15	5	0.4	12
(Region 73)	Xagaa	72	11	0.6	0.2	16
VALLEY SECTIONS AND FLOODPLAIN SECTORS						
Valley Section I	2nd Jiilaal	90	1	3	0	6
(Region 64)	Xagaa	80	10	5	0	5
Floodplain Sector I	2nd Jiilaal	79	5	11	0	5
(Region 78)	Xagaa	45	24	26	0	5
Valley Section II	2nd Jiilaal	89	4	3	0	4
(Region 65)	Xagaa	76	6	13	0	5
Floodplain Sector II	2nd Jiilaal	66	23	8	0	3
(Region 79)	Xagaa	29	23	47	0	1
Valley Section III	2nd Jiilaal	66	11	10	1	12
(Region 66)	Xagaa	54	20	0	0.5	26
Floodplain Sector III	2nd Jiilaal	43	33	23	0	1
(Region 80)	Xagaa	18	75	7	0	0
Valley Section IV	2nd Jiilaal	69	13	1	0	17
(Region 67)	Xagaa	80	4	1	0	15
Floodplain Sector IV	2nd Jiilaal	44	52	4	0	0
(Region 81)	Xagaa	0	100	0	0	0
Valley Section V	2nd Jiilaal	78	0	5	0	17
(Region 68)	Xagaa	90	10	0	0	0
Floodplain Sector V	2nd Jiilaal	89	0	11	0	0
(Region 82)	Xagaa	0	100	0	0	0
Valley Section VI	2nd Jiilaal	72	15	0	0	13
(Region 69)	Xagaa	87	6	0.6	0	6
Floodplain Sector VI	2nd Jiilaal	44	54	0	0	2
(Region 83)	Xagaa	48	46	4	0	2
Valley Section VII A + B	2nd Jiilaal	60	34	0	0	6
(Region 70)	Xagaa	68	4	2	0	26
Floodplain Sector VIIA	2nd Jiilaal	38	62	0	0	0
(Region 84)	Xagaa	79	10	11	0	0
Floodplain Sector VIIB	2nd Jiilaal	0	93	0	0	7
(Region 85)	Xagaa	23	77	0	0	0

Table 6.Goats

DATA ON LIVESTOCK ACTIVITIES FOR THE THREE SURVEYS

AREA	SURVEY	% FEEDING ON RANGE	% FEEDING ON CROPLANDS OR VARIOUS STAGES OF CROPLAND REGENERATION	% DRINKING OR MOVING TO WATER	% FEEDING ON CROP RESIDUES	% OTHERS
FLOODPLAIN AND VALLEY ZONES						
The whole survey area (Region 100)	2nd Jiilaal	80	7	5	0	8
	Xagaa	77	7	7	0	9
Jubba Floodplain (Regions 75 & 76)	2nd Jiilaal	69	26	2	0	3
	Xagaa	39	25	32	0	4
Jubba Valley (Regions 74 & 77)	2nd Jiilaal	84	3	4	0.2	9
	Xagaa	81	6	4	0.1	9
MAJOR RIVER REGIONS						
River Region Above Reservoir (Region 64)	2nd Jiilaal	89	0.2	3	0	8
	Xagaa	78	9	7	0	6
Inundation Region (Region 65)	2nd Jiilaal	89	3	5	0	3
	Xagaa	77	7	11	0	5
Downstream Region (Region 73)	2nd Jiilaal	68	13	5	0.4	14
	Xagaa	76	8	0.4	0.2	15
VALLEY SECTIONS AND FLOODPLAIN SECTORS						
Valley Section I (Region 64)	2nd Jiilaal	89	0.2	3	0	8
	Xagaa	78	9	7	0	6
Floodplain Sector I (Region 78)	2nd Jiilaal	75	2	9	0	14
	Xagaa	44	13	37	0	6
Valley Section II (Region 65)	2nd Jiilaal	89	3	5	0	3
	Xagaa	77	7	11	0	5
Floodplain Sector II (Region 79)	2nd Jiilaal	74	12	12	0	2
	Xagaa	36	25	38	0	1
Valley Section III (Region 66)	2nd Jiilaal	65	11	10	1	13
	Xagaa	61	18	0	0.4	21
Floodplain Sector III (Region 80)	2nd Jiilaal	39	36	24	0	1
	Xagaa	26	70	4	0	0
Valley Section IV (Region 67)	2nd Jiilaal	79	8	0	0	13
	Xagaa	86	2	0	0	12
Floodplain Sector IV (Region 81)	2nd Jiilaal	74	26	0.4	0	0
	Xagaa	0	100	0	0	0
Valley Section V (Region 68)	2nd Jiilaal	69	0	8	0	23
	Xagaa	98	2	0	0	0
Floodplain Sector V (Region 82)	2nd Jiilaal	85	0	15	0	0
	Xagaa	0	100	0	0	0
Valley Section VI (Region 69)	2nd Jiilaal	652	0	0	0	15
	Xagaa	87	5	1	0	07
Floodplain Sector VI (Region 83)	2nd Jiilaal	18	77	0	0	5
	Xagaa	42	45	10	0	3
Valley Section VII A + B (Region 70)	2nd Jiilaal	72	19	0	0	9
	Xagaa	71	2	0.4	0	26
Floodplain Zone VIIA (Region 84)	2nd Jiilaal	37	63	0	0	0
	Xagaa	81	12	7	0	0
Floodplain Sector VIIB (Region 85)	2nd Jiilaal	6	86	0	0	8
	Xagaa	56	44	0	0	0

Table 7. Camels

DATA ON LIVESTOCK ACTIVITIES FOR THE THREE SURVEYS

AREA	SURVEY	% FEEDING ON RANGE	% FEEDING ON CROPLANDS OR VARIOUS STAGES OF CROPLAND REGENERATION	% DRINKING OR MOVING TO WATER	% FEEDING ON CROP RESIDUES	% OTHERS
FLOODPLAIN AND VALLEY ZONES						
The whole survey area (Region 100)	2nd Jiilaal	89	10	0.4	0	0.5
	Xagaa	89	4	4	0.1	3
Jubba FloodPlain (Regions 75 & 76)	2nd Jiilaal	85	8	7	0	0.4
	Xagaa	43	14	43	0	0
Jubba Valley (Regions 74 & 77)	2nd Jiilaal	90	2	5	0.1	3
	Xagaa	90	2	4	0.1	4
MAJOR RIVER REGIONS						
River Region Above Reservoir (Region 64)	2nd Jiilaal	96	2	0.3	0	2
	Xagaa	72	2	24	0	2
Inundation Region (Region 65)	2nd Jiilaal	88	1	9	0	2
	Xagaa	80	3	15	1	1
Downstream Region (Region 73)	2nd Jiilaal	89	2	6	0	3
	Xagaa	93	2	1	0	4
VALLEY SECTIONS AND FLOODPLAIN SECTORS						
Valley Section I (Region 64)	2nd Jiilaal	96	2	0.3	0	2
	Xagaa	72	2	24	0	2
Floodplain Sector I (Region 78)	2nd Jiilaal	87	9	2	0	2
	Xagaa	30	9	61	0	0
Valley Section II (Region 65)	2nd Jiilaal	88	1	9	0	2
	Xagaa	80	3	15	1	1
Floodplain Sector II (Region 79)	2nd Jiilaal	73	7	20	0	0
	Xagaa	76	24	0	0	0
Valley Section III (Region 66)	2nd Jiilaal	85	3	9	0	3
	Xagaa	82	6	2	0	10
Floodplain Sector III (Region 80)	2nd Jiilaal	25	10	65	0	0
	Xagaa	95	5	0	0	0
Valley Section IV (Region 67)	2nd Jiilaal	92	2	4	0	2
	Xagaa	97	2	0.4	0	0.3
Floodplain Sector IV (Region 81)	2nd Jiilaal	99	0.3	1	0	0
	Xagaa	100	0	0	0	0
Valley Section V (Region 68)	2nd Jiilaal	32	4	64	0	0
	Xagaa	98	0	0	0	2
Floodplain Sector V (Region 82)	2nd Jiilaal	96	0	0	0	4
	Xagaa	0	100	0	0	0
Valley Section VI (Region 69)	2nd Jiilaal	90	0.2	6	0	4
	Xagaa	97	0.4	0.6	0	2
Floodplain Sector VI (Region 83)	2nd Jiilaal	49	0.5	50	0	0
	Xagaa	0	100	0	0	0
Valley Section VII A + B (Region 70)	2nd Jiilaal	88	7	3	0	2
	Xagaa	91	0	4	0	5
Floodplain Sector VIIA (Region 84)	2nd Jiilaal	26	66	8	0.5	0
	Xagaa	-	-	-	-	-
Floodplain Sector VIIB (Region 85)	2nd Jiilaal	100	0	0	0	0
	Xagaa	-	-	-	-	-

Few camels were feeding on transported crop residues in the xagaa survey.

In the Floodplain Zone (Regions 75 and 76), eight percent of the camels were seen on current and old croplands, and seven percent were seen drinking or on their way to drinking in the second jiilaal survey. In the xagaa survey, 14 percent of the camels were seen feeding on current and old croplands, and 43 percent were drinking or on their way to drinking. Except for variations in the number of camels drinking, there were no significant differences between the three major river regions (Regions 64, 65, and 73).

Similarly, the more detailed view of camel activities provided by the analysis of the valley sections and floodplain sectors for the two surveys did not reveal a consistent pattern of seasonal or ecological trends in camel activities in the Jubba Valley. This probably reflects the relative unsuitability of camels for a close integration into the riverine farming systems.

All Livestock (activities)

Although there are a few significant seasonal and geographical/ecological trends in livestock activities, the degree of integration of livestock into the present crop production system is the dominant determinant. This is most easily seen at the stratum level, where activity depends on: the land use of the stratum, particularly the relative amounts of irrigation and rainfed cropping; the degree of seasonal flooding; the vegetation productivity, structure,and vector environment of rangeland; and seasonal intensities of use of the stratum by each livestock species. These parameters determine the way the stratum is being used by livestock, but a correlation of these features with livestock activities is beyond the scope of this report.

2. Wildlife

A summary and consolidation of wildlife biomass densities is shown in Table 8. In the whole survey area, the wildlife biomass density was very small and demonstrated the relative unimportance of wildlife as an element of the whole ecosystem. In the second jiilaal survey, wildlife composed 4.1 percent of the total, larger herbivore biomass; in the xagaa survey, the figure was 2.9 percent.

The Jubba Floodplain Zone (Regions 75 and 76) supported the bulk of wildlife in Jubba Valley and biomass densities showed a marked increase (more than threefold) in the second jiilaal survey over the xagaa survey. The ecological regions (Regions 20

Table 8. Summary Data on Wildlife Biomass in Kg/Km^2 in the Jubba Valley

AREA	1ST JIILAAL	2ND JIILAAL	XAGAA
FLOODPLAIN AND VALLEY ZONES			
The whole survey area (Region 100)	-	286	184
Jubba Floodplain (Regions 75 & 76)	1,870	2,796	783
Jubba Valley (Regions 74 & 77)	-	145	150
MAJOR RIVER REGIONS			
River Region Above Reservoir (Reg. 64)	-	3	20
Inundation Region (Region 65)	-	22	72
Downstream Region (Region 73)	-	406	239
ECOLOGICAL REGIONS			
River and Swamps (Reg. 20)	20,286	29,382	7,001
Undiff. Floodplain (Reg. 21)	46	111	95
Fine River Alluviums (Reg. 22)	247	231	250
Villages (Region 23)	0	0	0
Riverside Limestones etc. (Reg. 24)	-	11	43
Distant Limestones etc. (Reg. 25)	-	21	60
Riverside Marine Plains etc. (Reg. 26)	-	74	116
Distant Marine Plains etc. (Reg. 27)	-	469	381
VALLEY SECTIONS AND FLOODPLAIN SECTORS			
Valley Section I (Region 64)	-	3	20
Floodplain Sector I (Region 78)	0	0	0
Valley Section II (Region 65)	-	22	72
Floodplain Sector II (Region 79)	0	67	177
Valley Section III (Region 66)	-	14	35
Floodplain Sector III (Region 80)	93	119	43
Valley Section IV (Region 67)	-	117	97
Floodplain Sector IV (Region 81)	160	2,667	0
Valley Section V (Region 68)	-	1,119	101
Floodplain Sector V (Region 82)	6,668	4,743	103
Valley Section VI (Region 69)	-	338	284
Floodplain Sector VI (Region 83)	2,674	1,305	468
Valley Section VII A + B (Region 70)	-	1,096	906
Floodplain Sector VIIA (Region 84)	736	989	752
Floodplain Sector VIIB (Region 85)	6,294	62,454	19,219

to 27) show that the river and swamps (Region 20) are, by far, the most important wildlife habitat, followed by the distant marine plains of mixed alluviums (Region 27).

The substantial relative increase in wildlife biomass observed in the second jiilaal survey has been the result of the movement of a small number of elephant into the survey area in the second jiilaal survey, a large increase in hippopotamus sightings, and a smaller increase in crocodile sightings in the Jubba River. It is not suggested that hippopotamus and crocodile have moved downstream from Ethiopia to cause this increase in sightings. The factor responsible was the use of a single correction factor for all the surveys. While this was judged to be valid for terrestrial animals in Jubba Valley, animals living in the river became much more easily spotted in the second jiilaal survey. This point is considered in some detail in Watson (1987).

The wildlife biomass densities (see Figures 2.6 and 3.6) of valley sections and floodplain sectors showed a progressive increase from north to south (in the second jiilaal survey) for Sections/Sectors I to V. The large hippopotamus biomass density of Floodplain Sector VIIB obscures the fact that Sector V was the most important for wildlife in the Jubba Valley in the second jiilaal survey.

In the xagaa survey, biomass densities tended to increase progressively from north to south throughout the length of the river from Sector I to Sector VII.

Creation of the Jubba Reservoir will have very minor impact on the large herbivore populations of the Jubba Valley.

The numbers of the more common species comprising the wildlife population of the Jubba Valley have been estimated for the various surveys as presented in the table in the next column.

These data reveal the typical limitations of aerial survey methods (both total search and sampling) for counting most terrestrial wildlife species and all aquatic wildlife species. Nevertheless, it is clear that:

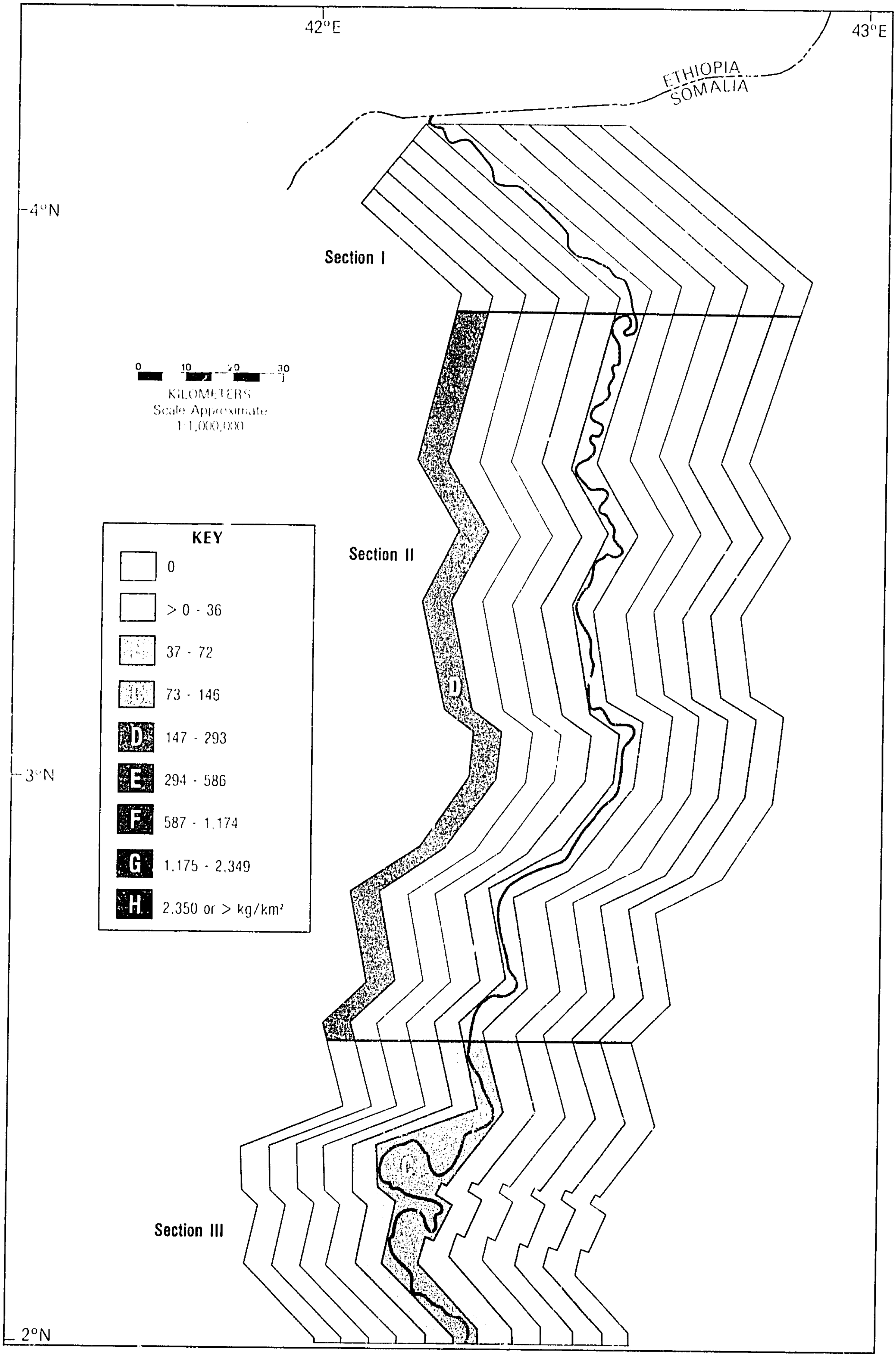
- lesser kudu are the most numerous terrestrial wildlife species, followed closely by gerenuk, and then by warthog and bush pig (which are not always easily distinguished from aerial views);

*Numbers of More Common Wildlife Species**

	1st RIVER SURVEY Sept 86	2nd RIVER SURVEY Mar/Apr 87	1st JIILAAL SURVEY Jan/Feb 87	2nd JIILAAL SURVEY Mar/Apr 87	XAGAA SURVEY Jul/Aug 87
Gerenuk				7,900 (6)	23,700 (6)
Lesser Kudu				14,500 (6)	28,500 (6)
Giraffe				2,000 (6)	3,000 (6)
Warthog and Bush pig				4,900 (6)	10,000 (6)
Oryx				300 (6)	1,500 (6)
Elephant				800 (6)	0
Hippo	400 - 800 (1)	980 - 1,260 (3)	3,300 (5)	4,800 (5)	1,200 (5)
Crocodile	6,000 - 20,000 (2)	45,000 (4)	103,500 - 344,900 (2)	46,100 - 153,700 (2)	37,800 - 125,900 (2)

*Correction Factors Used:
(1) 4.25 - 8.60
(2) 30 - 100
(3) 1.67 - 2.15
(4) 30
(5) 4.008
(6) 1.336 - 3.759 (depending on vegetation cover category)

- giraffe are still fairly numerous in the Jubba Valley;
- oryx and occasionally elephant also still occur in the Jubba Valley;
- other large wild animals seen were duiker (species unrecognized), reedbuck, oribi, waterbuck, ostrich, honey badger, baboon and vervet monkey;
- hippopotamuses are extremely difficult to spot, and the attempt at total searching of the Jubba River probably produced low estimates, even after using correction factors. It is likely that the sound of the aircraft circling along the river during river surveys caused more than the expected 67 percent of animals to submerge. It is also likely that searching the river required the pilot to search a strip wider than 250 m, with the attendant increase in visibility bias. In conclusion, a population of 3,000 to 6,000 is probably an accurate estimate;
- the first jiilaal crocodile estimate of 100,000 to 340,000 was the result of large numbers in strata 7, 11, and 14 (*i.e.*, Sectors IV, V, and VI. One explanation of this anomaly could be that more crocodile were seen in those river sectors at that time because the breeding cycle causes them to be out of the water more frequently.The other comparable estimates are in accord, and a populationf 40,000 to 150,000 is the most likely.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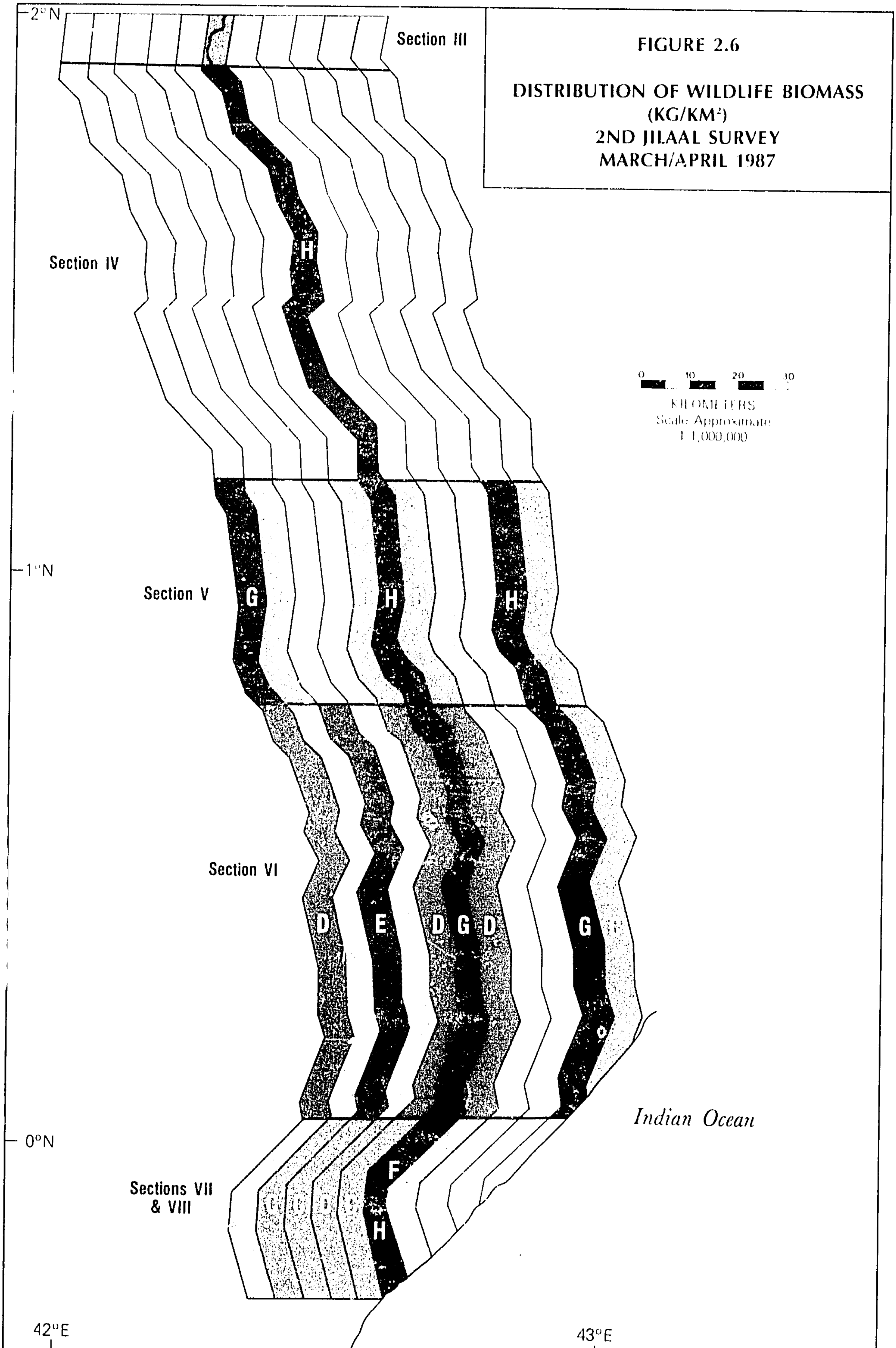
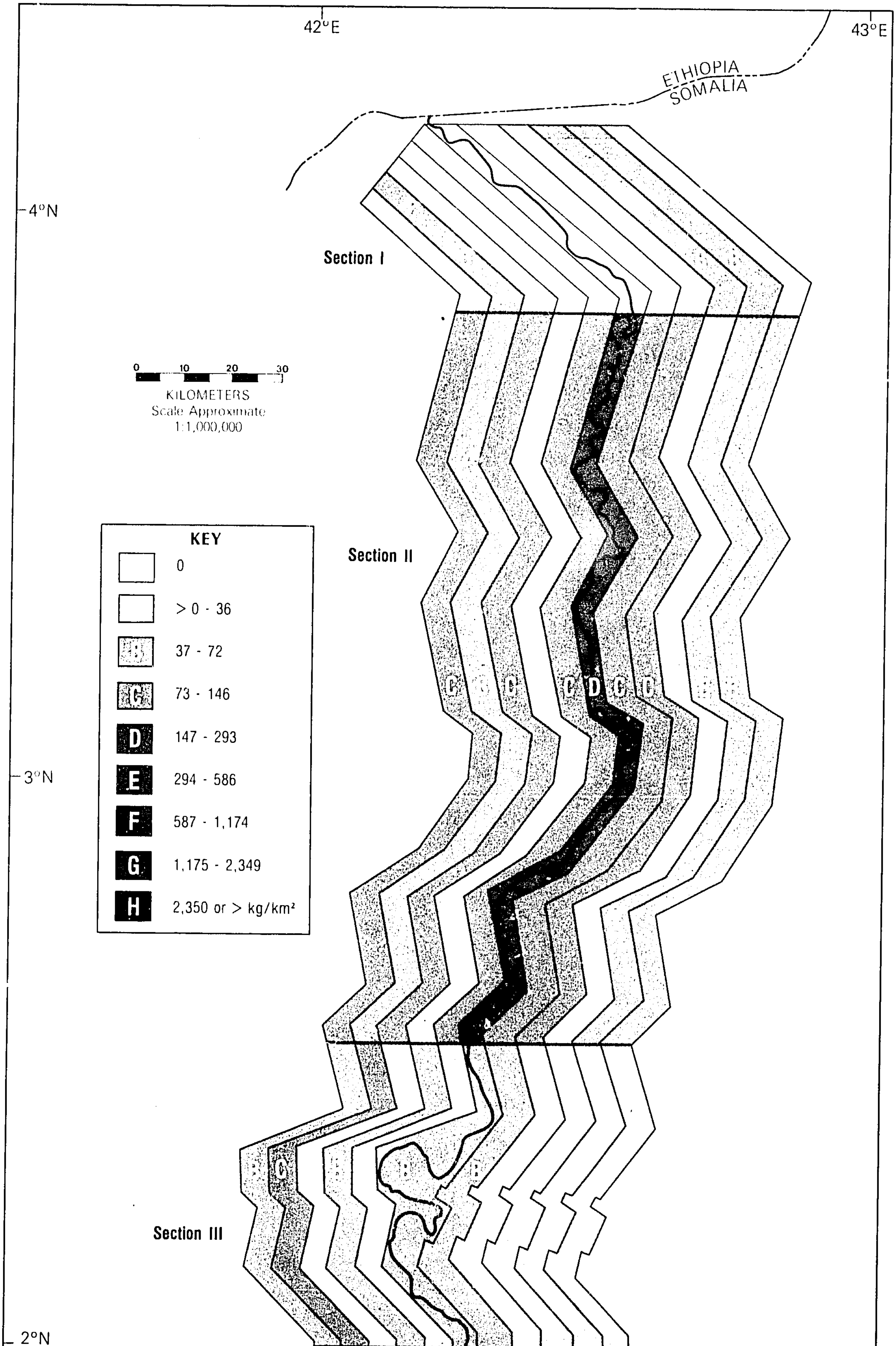


FIGURE 2.6

DISTRIBUTION OF WILDLIFE BIOMASS
(KG/KM^2)
2ND JILAAL SURVEY
MARCH/APRIL 1987



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H 2,350 or > kg/km²

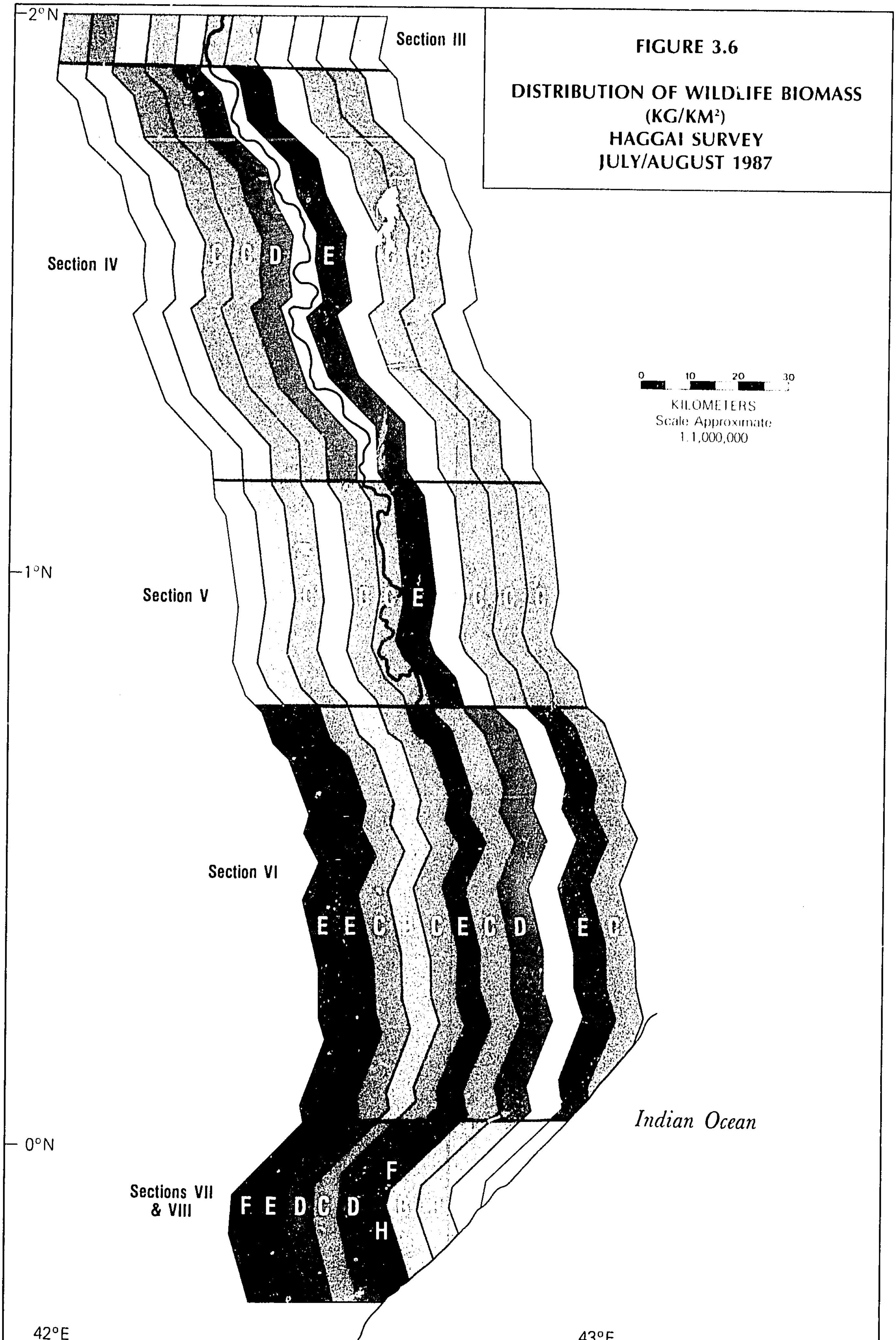


FIGURE 3.6

DISTRIBUTION OF WILDLIFE BIOMASS (KG/KM²) HAGGAI SURVEY JULY/AUGUST 1987

3. Water Sources

Consolidated and summarized data on water sources, excluding the Jubba River, are shown in Table 9. There are only a few significant seasonal or geographic trends in these data. Waro and balliyo are almost absent from the floodplain. Wells tend to be most numerous in the second jiilaal survey in the floodplain. Springs are naturally concentrated in Valley Sections II and III, the main limestone/gypseous areas.

4. Human Populations

Inferences concerning human populations have been drawn from censuses of rural structures which have been classified as nomadic (*i.e.*, temporary or movable) or fixed (*i.e.*, permanent and not movable. No attempt was made to census the structures of the towns and villages in these surveys.

Aerial photographs of Kismaayo, Garbahaarey, and Afmadow, together with photographs of all the towns and villages within about 1.8 km of the Jubba River, were delivered to JESS. From these photographs, the nonrural populations of the Jubba Valley can be easily estimated. A consolidation and summary of data on rural structures is shown in Table 10 and illustrated by season in Figures 2.7 and 3.7 for nomadic dwellings and Figure 2.8 for fixed dwellings.

Over the whole survey area, densities of nomadic structures were 1.10 and 1.18 for the second jiilaal and xagaa surveys, respectively. Densities of fixed houses were 0.39 and 0.24 for the second jiilaal and xagaa surveys, respectively.

On the assumption that a family of seven is associated with each occupied house, the rural population of the survey area is 58,000 to 94,000 settled people and 266,000 to 286,000 nomadic people. The total rural population of the survey area is 324,000 to 380,000. The number of people occupying the area to be inundated has been estimated separately and is discussed in a following section.

These results are compared with those of the three sampling surveys below:

	Survey of Inundation Zone (Dec 87)	1st Jiilaal Survey (Sept 86)	2nd Jiilaal Survey (Jan/Feb 87)	Xagaa Survey (Mar/Apr 87)
Nomadic Houses within zone	1,150 [757]*	1,760	1,959	8,741
Fixed Houses within zone	404 [279]*	174	329	824

* *1,150 nomadic houses and 404 fixed houses include structures very close to the limits of the zone, but nevertheless just outside it. The actual number of structures inside the zone is shown in brackets.*

For fixed houses, the estimates in the two jiilaal surveys are not significantly different from the more exact total count. There is some indication of an increase in the number of fixed houses between September 1986 and January/February 1987.

For nomadic houses, it seems that their number almost doubles in the extreme dry season.

The results of the xagaa survey are anomalous and difficult to explain. However, it should be noted that the sampling error attached to estimates of single strata are large, and in fact, there is no significant difference between the second jiilaal and the xagaa results. Therefore, estimates found in the *Socioeconomic Baseline Studies* (Craven, Merryman, and Merryman 1989) of persons to be displaced by the creation of the Baardheere Reservoir appear to be supported by the results of the sampling surveys.

The highest densities of rural nomadic and fixed houses (and by inference of people) are found in the undifferentiated floodplain (Region 21). The fine river alluviums support fairly high densities of fixed rural structures, but very low densities of nomadic structures. The riverside and distant limestone/gypseous terraces, plateaus and hills, and marine plains of mixed alluviums support similar densities of fixed houses, and higher densities of nomadic houses.

No obvious seasonal or geographic trends are in evidence from the analysis of valley sections nd floodplain sectors in Table 10. The anticipated higher densities of people expected for the southernmost floodplain sectors probably live in the villages and towns of these zones.

5. Land Use

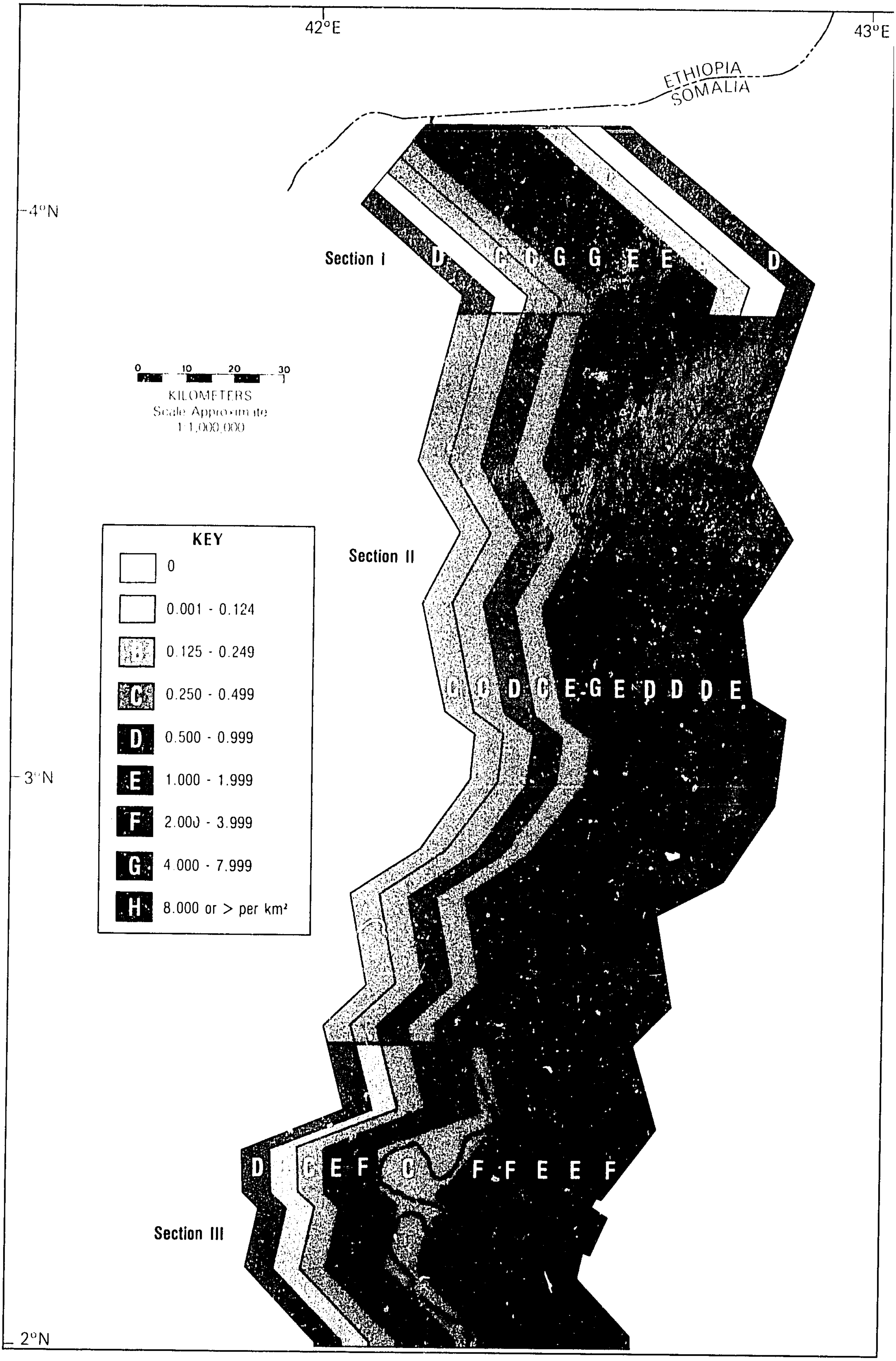
Consolidated and summarized land-use data are shown in Table 11. Further information on land use is shown in Figures 2.9 and 2.10. The chief features of these data are presented below:

Cleared Land

Recently cleared land, which indicates the rate of expansion of crop production, suggests that the area of cropping is expanding at between four and eight percent annually. Most of the expansion in croplands in the Jubba Valley is taking place in Ecological Regions 21 and 22 (undifferentiated floodplains and fine river alluviums).

Table 9. Data on Water Sources for the Jubba Valley

AREA	SURVEY	DENSITIES OF—				WEIGHTED WATER INDEX
		WELLS	SPRINGS	ALL WARO	ALL BALLIYO	
FLOODPLAIN AND VALLEY ZONES						
The whole survey area (Region 100)	2nd Jiilaal	0.02	0.02	0.05	0.01	1.12
	Xagaa	0.02	0.01	0.05	0.03	1.19
Jubba Floodplain (Regions 75 & 76)	2nd Jiilaal	0.18	0.03	0	0	1.44
	Xagaa	0.06	0.01	0	0	0.83
Jubba Valley (Regions 74 & 77)	2nd Jiilaal	0.01	0.02	0.05	0.01	1.10
	Xagaa	0.02	0.01	0.06	0.03	1.21
MAJOR RIVER REGIONS						
River Region Above Reservoir (Region 64)	2nd Jiilaal	0	0.05	0	0	2.92
	Xagaa	0	0.01	0	0	0.28
Inundation Region (Region 65)	2nd Jiilaal	0.03	0.05	0.02	0	2.10
	Xagaa	0.04	0.03	0.03	0	1.43
Downstream Region (Region 73)	2nd Jiilaal	0.02	0.01	0.06	0.01	0.61
	Xagaa	0.02	0	0.07	0.04	1.20
VALLEY SECTIONS AND FLOODPLAIN SECTORS						
Valley Section I (Region 64)	2nd Jiilaal	0	0.05	0	0	2.92
	Xagaa	0	0.01	0	0	0.28
Floodplain Sector I (Region 78)	2nd Jiilaal	0	0	0	0	0
	Xagaa	0	0	0	0	0
Valley Section II (Region 65)	2nd Jiilaal	0.03	0.05	0.02	0	2.10
	Xagaa	0.04	0.03	0.03	0	1.43
Floodplain Sector II (Region 79)	2nd Jiilaal	0.02	0.16	0	0	4.29
	Xagaa	0	0.11	0	0	3.37
Valley Section III (Region 66)	2nd Jiilaal	0.02	0.02	0.13	0	1.06
	Xagaa	0.01	0.02	0.13	0	1.29
Floodplain Sector III (Region 80)	2nd Jilaal	0.17	0.04	0	0	1.02
	Xagaa	0	0	0	0	0.18
Valley Section IV (Region 67)	2nd Jiilaal	0	0	0.01	0.01	0.17
	Xagaa	0.05	0	0.07	0.03	1.72
Floodplain Sector IV (Region 81)	2nd Jiilaal	0.29	0	0	0	1.17
	Xagaa	0	0	0	0	0
Valley Section V (Region 68)	2nd Jiilaal	0.01	0	0	0	0.03
	Xagaa	0	0	0.10	0.05	1.81
Floodplain Sector V (Region 82)	2nd Jiilaal	0.13	0	0	0	0.51
	Xagaa	0	0	0	0	0
Valley Section VI (Region 69)	2nd Jiilaal	0.03	0	0.05	0.01	0.64
	Xagaa	0.01	0	0	0.06	0.65
Floodplain Sector VI (Region 83)	2nd Jiilaal	0.24	0	0	0	0.96
	Xagaa	0	0	0	0	0
Valley Section VII A + B (Region 70)	2nd Jiilaal	0.03	0	0.09	0.01	0.70
	Xagaa	0.04	0	0.07	0.09	1.17
Floodplain Sector VIIA (Region 84)	2nd Jiilaal	0.30	0	0	0	1.22
	Xagaa	0.40	0	0	0	1.61
Floodplain Sector VIIB (Region 85)	2nd Jiilaal	0	0	0	0	0
	Xegaa	0	0	0.14	0	0.85



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F 2.000 - 3.999
G 4.000 - 7.999
H 8.000 or > per km²

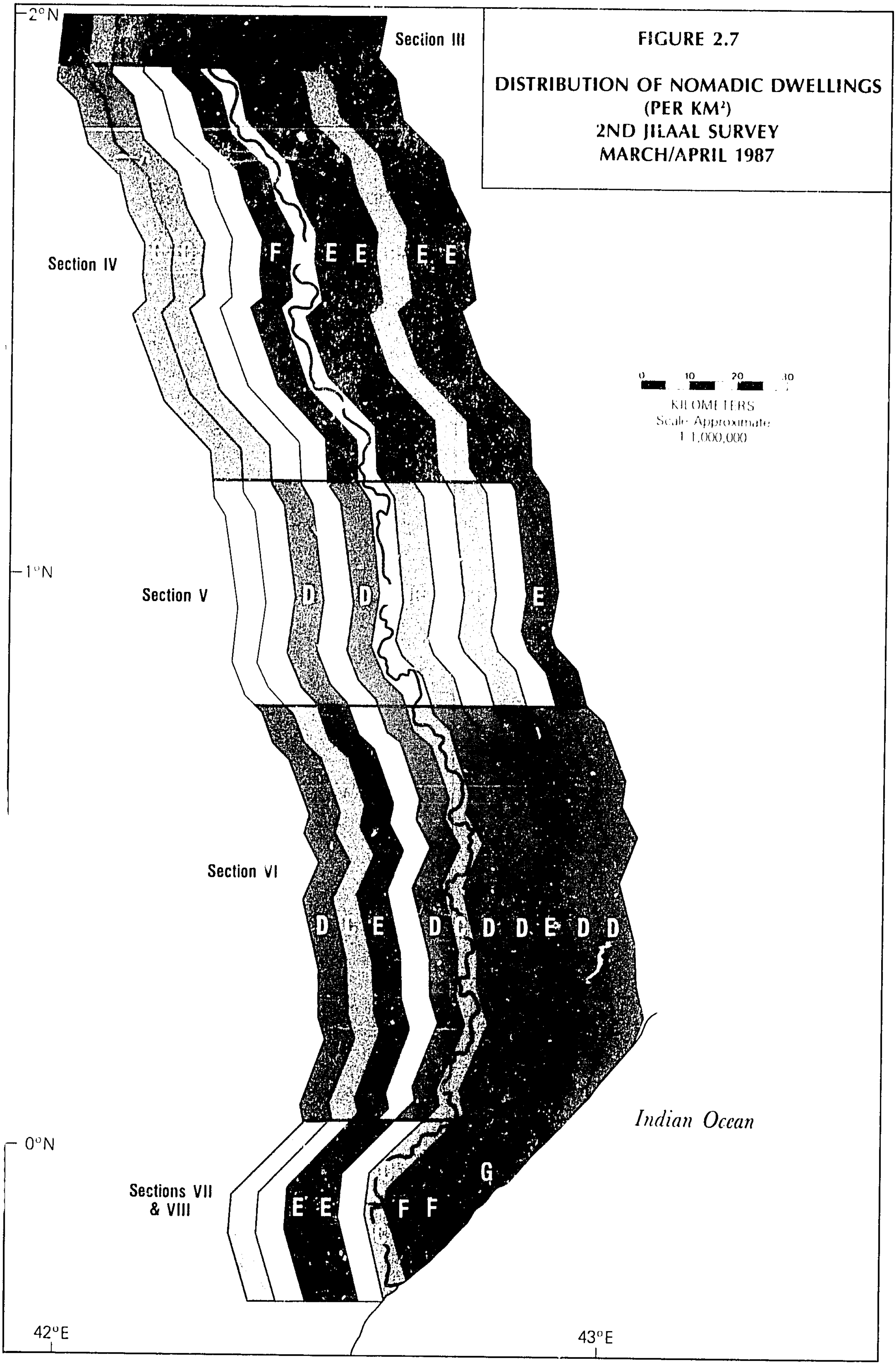
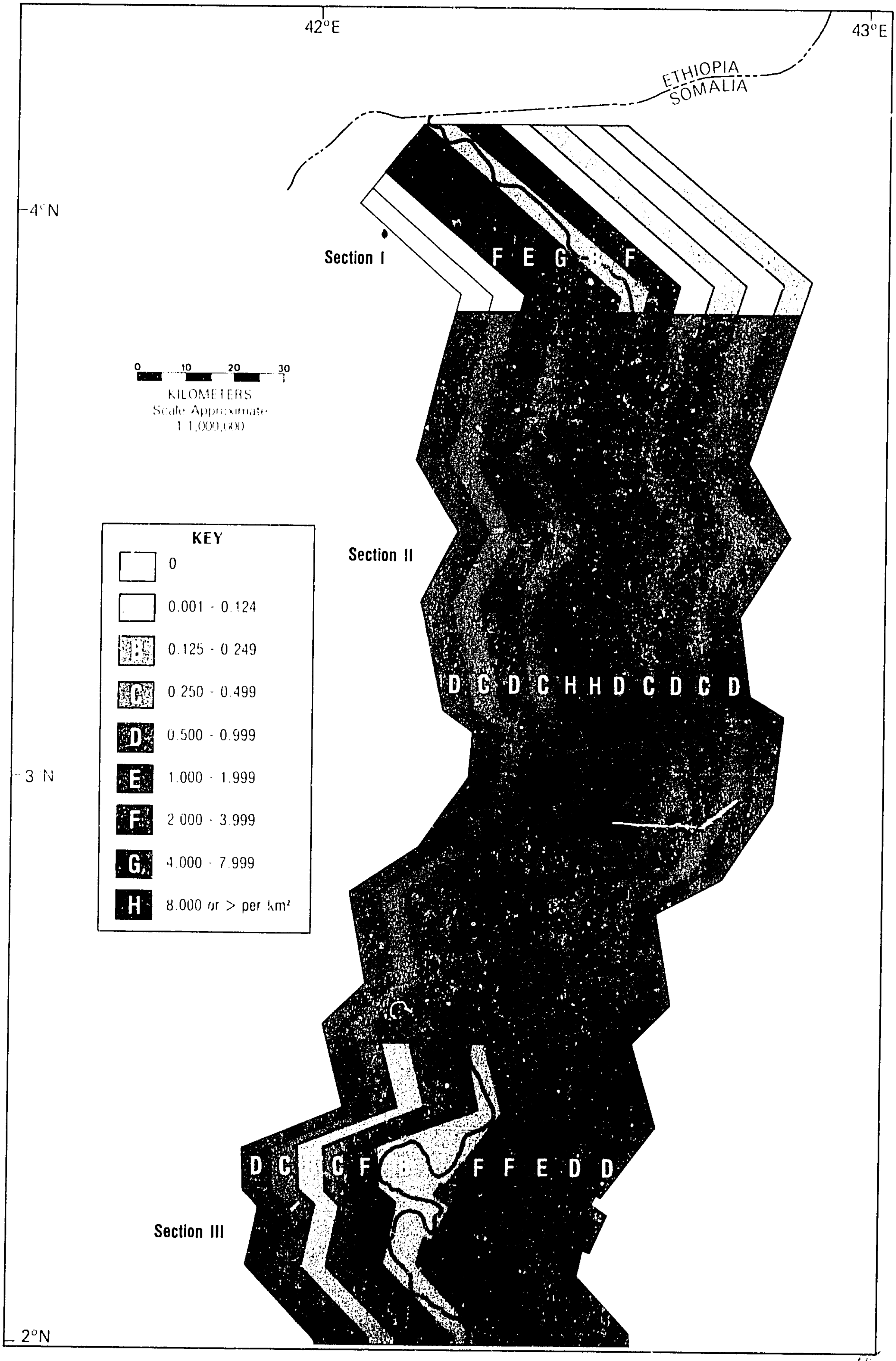


FIGURE 2.7

DISTRIBUTION OF NOMADIC DWELLINGS (PER KM²) 2ND JILAAL SURVEY MARCH/APRIL 1987



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Section III
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0 10 20 30
KILOMETERS
Scale Approximate
1:1,000,000
KEY
0
0.001 - 0.124
B 0.125 - 0.249
C 0.250 - 0.499
D 0.500 - 0.999
E 1.000 - 1.999
F 2.000 - 3.999
G 4.000 - 7.999
H 8.000 or > per km²

FIGURE 3.7

DISTRIBUTION OF NOMADIC DWELLINGS (PER KM²) HAGGAI SURVEY JULY/AUGUST 1987

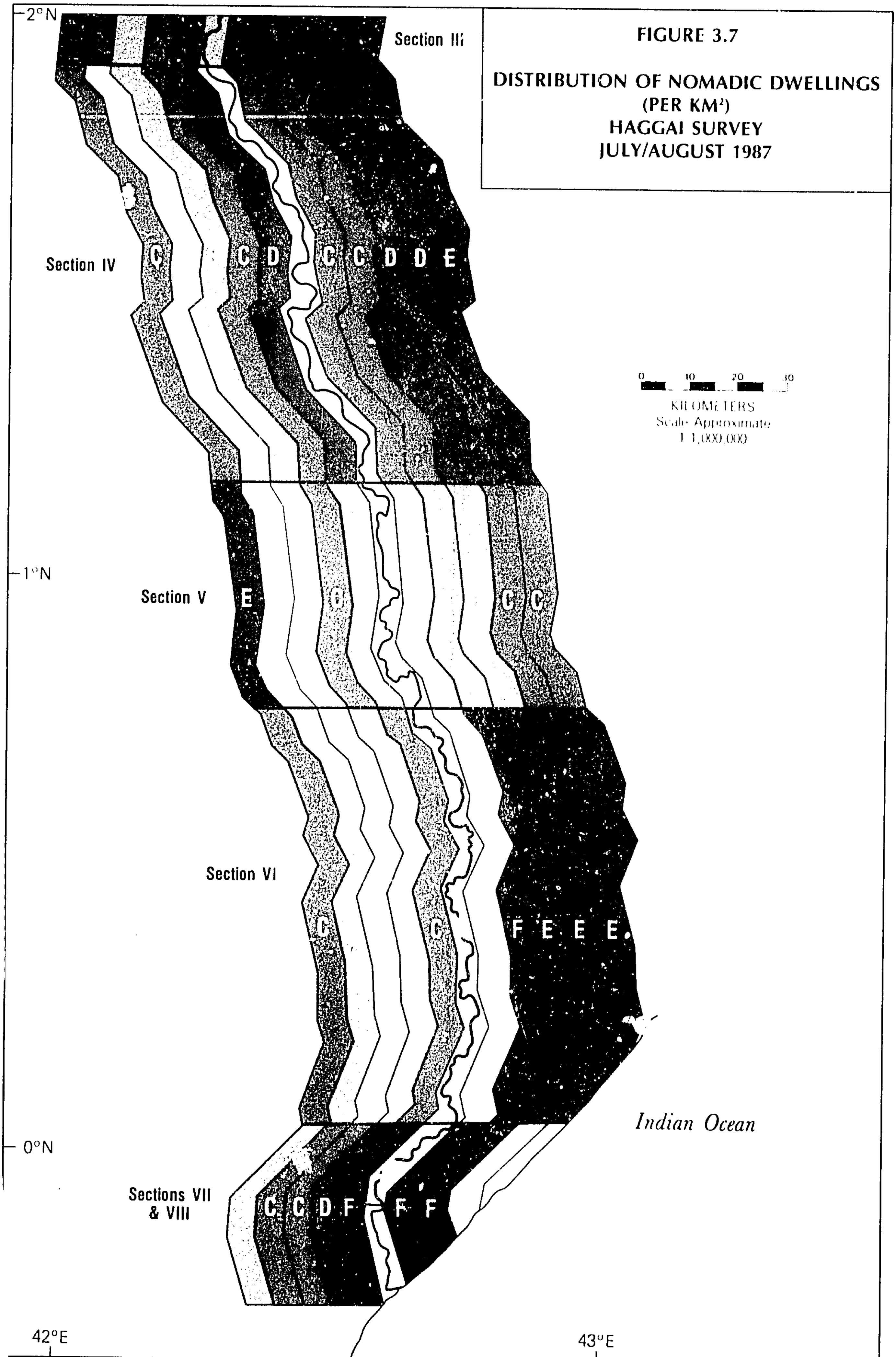
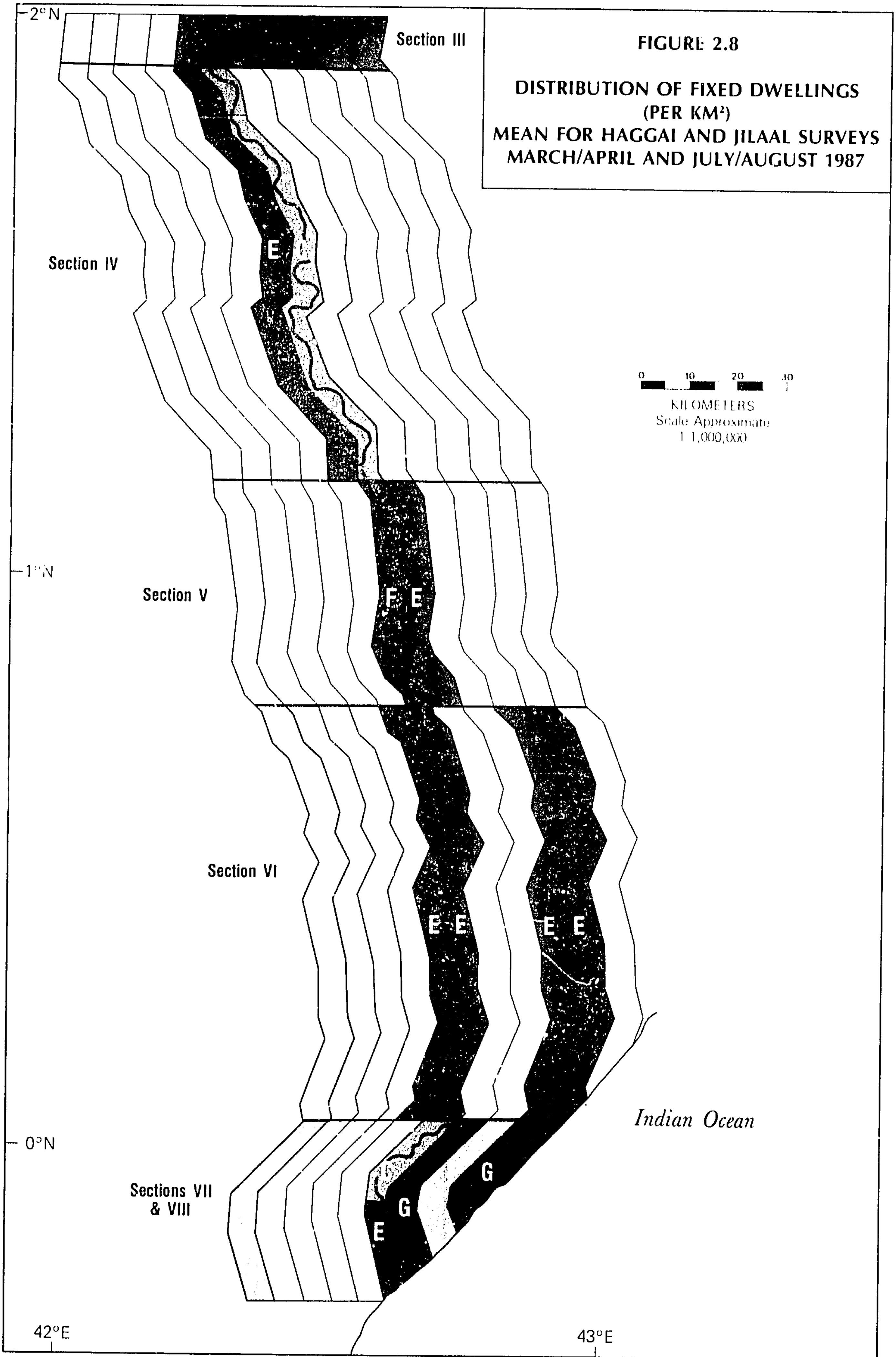
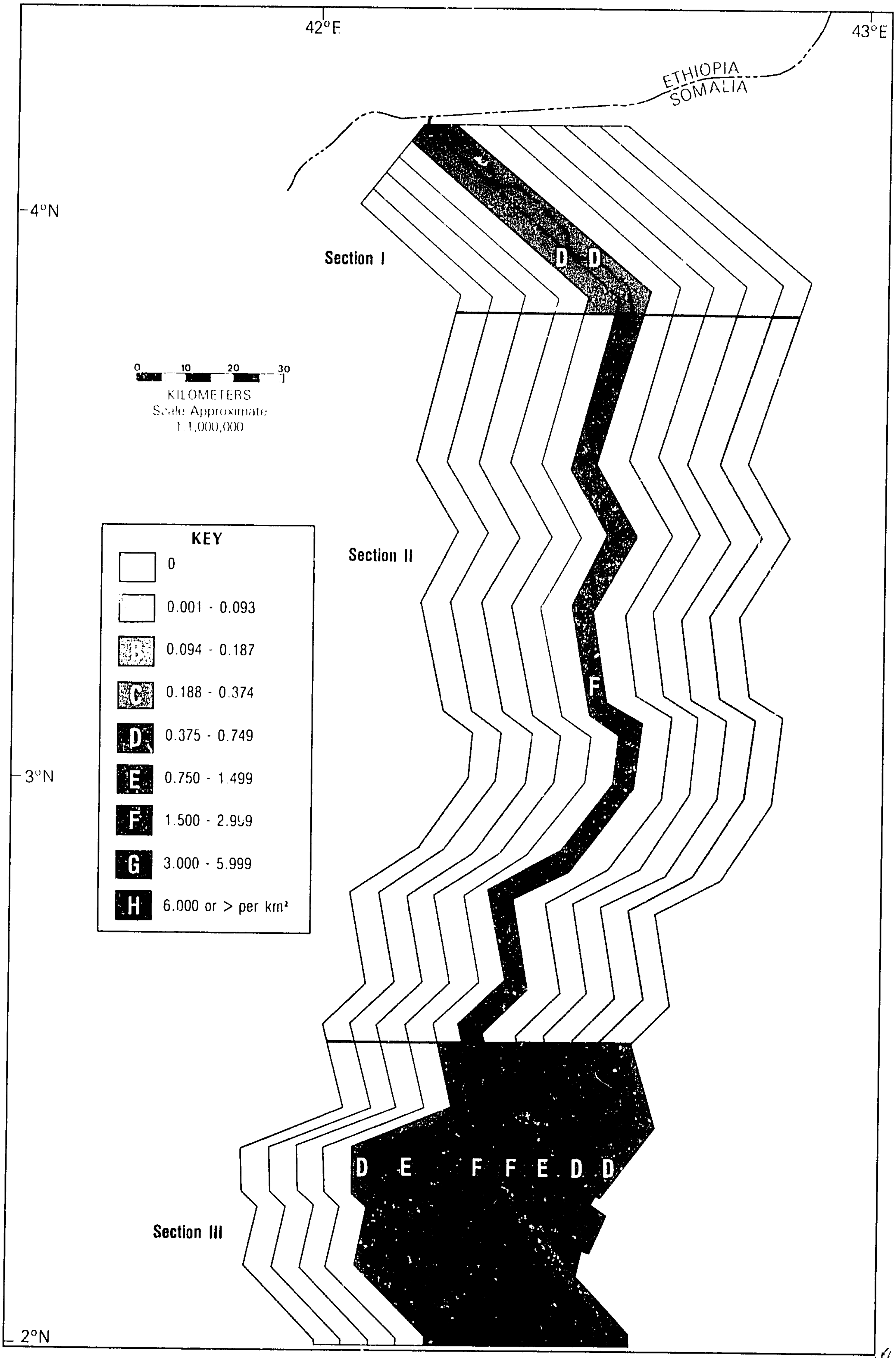


FIGURE 2.8

DISTRIBUTION OF FIXED DWELLINGS (PER KM²) MEAN FOR HAGGAI AND JILAAL SURVEYS MARCH/APRIL AND JULY/AUGUST 1987





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Section II
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KILOMETERS
Scale Approximate
1:1,000,000
KEY
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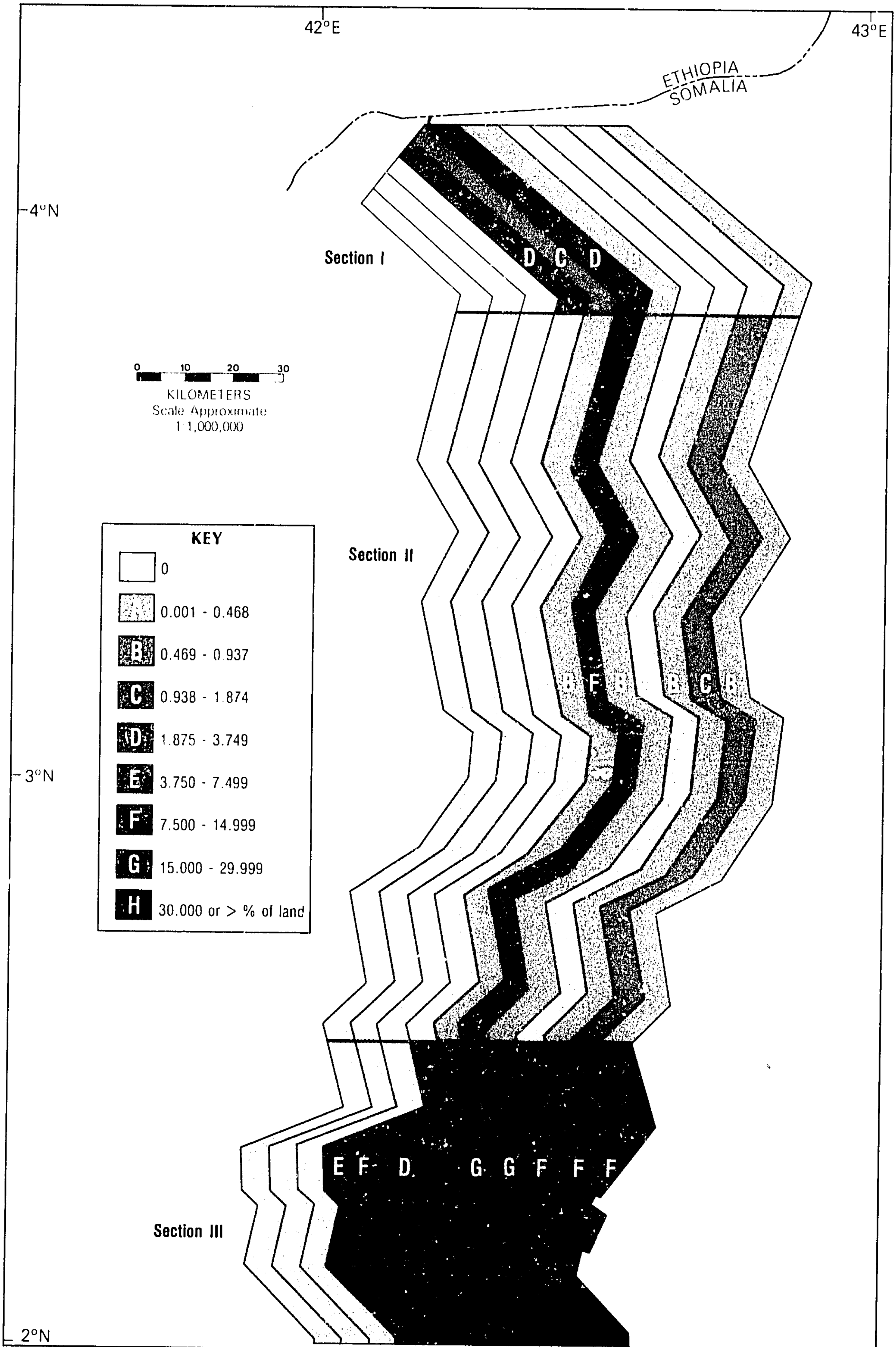
B 0.094 - 0.187
C 0.188 - 0.374
D 0.375 - 0.749
E 0.750 - 1.499
F 1.500 - 2.999
G 3.000 - 5.999
H 6.000 or > per km²



42°E
43°E
ETHIOPIA
SOMALIA
4°N
3°N
2°N
Section I
D C D B
Section II
B F B B C B
Section III
E F D G G F F F
0 10 20 30
KILOMETERS
Scale Approximate
1:1,000,000
KEY
0
0.001 - 0.468
B 0.469 - 0.937
C 0.938 - 1.874
D 1.875 - 3.749
E 3.750 - 7.499
F 7.500 - 14.999
G 15.000 - 29.999
H 30.000 or > % of land

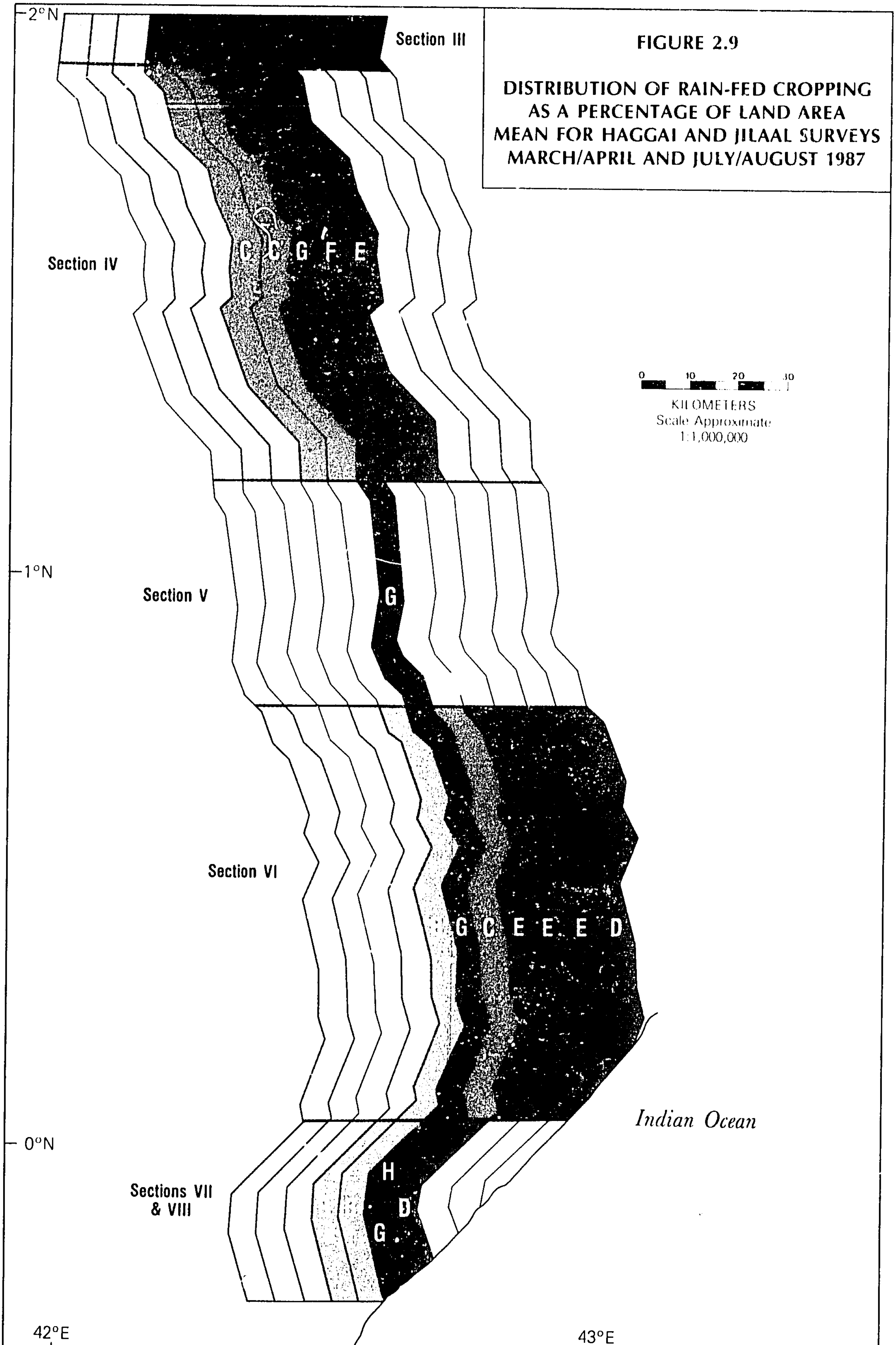
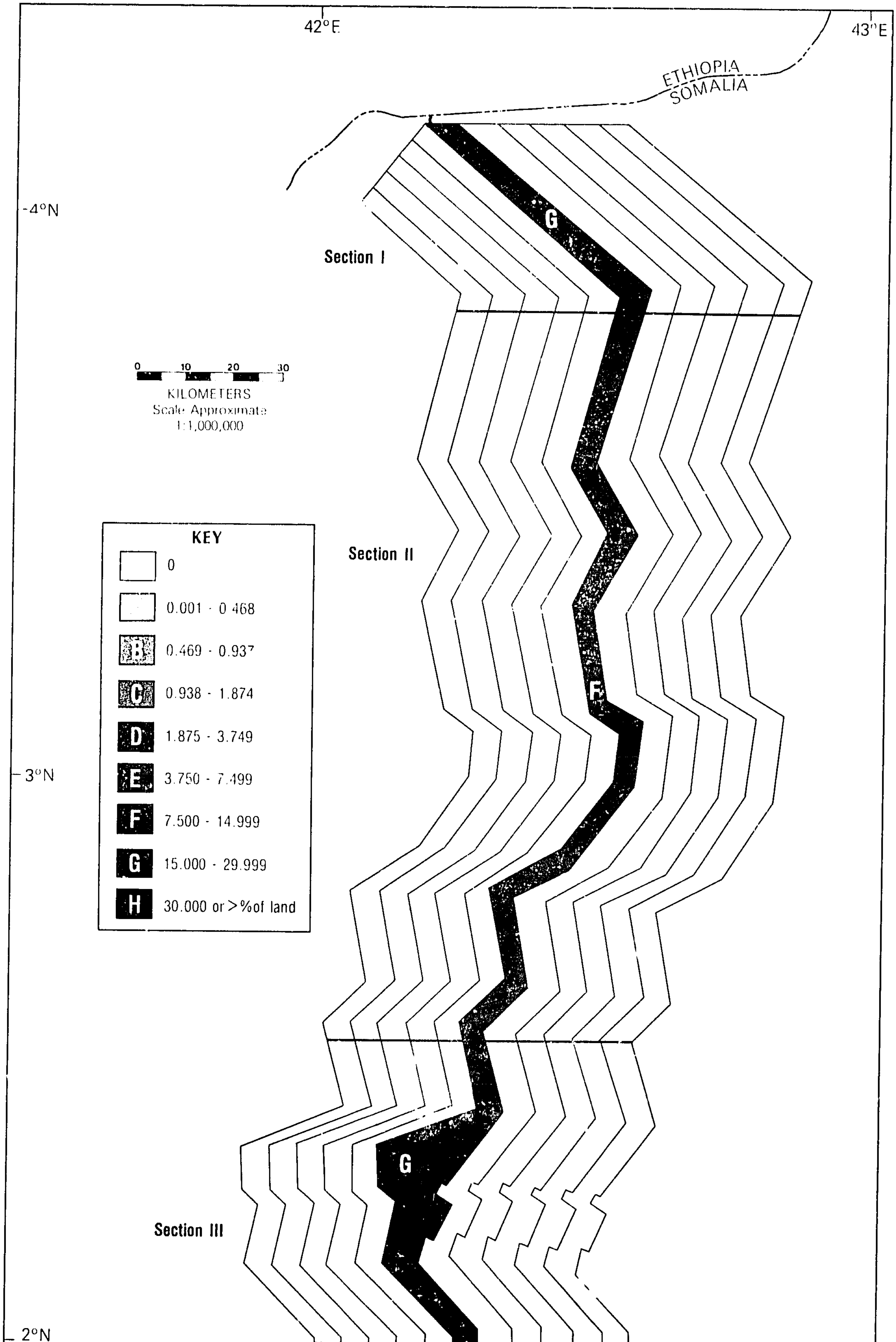


FIGURE 2.9

DISTRIBUTION OF RAIN-FED CROPPING AS A PERCENTAGE OF LAND AREA MEAN FOR HAGGAI AND JILAAL SURVEYS MARCH/APRIL AND JULY/AUGUST 1987


42°E
43°E
ETHIOPIA
SOMALIA
4°N
3°N
2°N
Section I
Section II
Section III
G
F
G
0 10 20 30
KILOMETERS
Scale Approximate
1:1,000,000
KEY
0
0.001 - 0.468
B 0.469 - 0.937
C 0.938 - 1.874
D 1.875 - 3.749
E 3.750 - 7.499
F 7.500 - 14.999
G 15.000 - 29.999
H 30.000 or > % of land

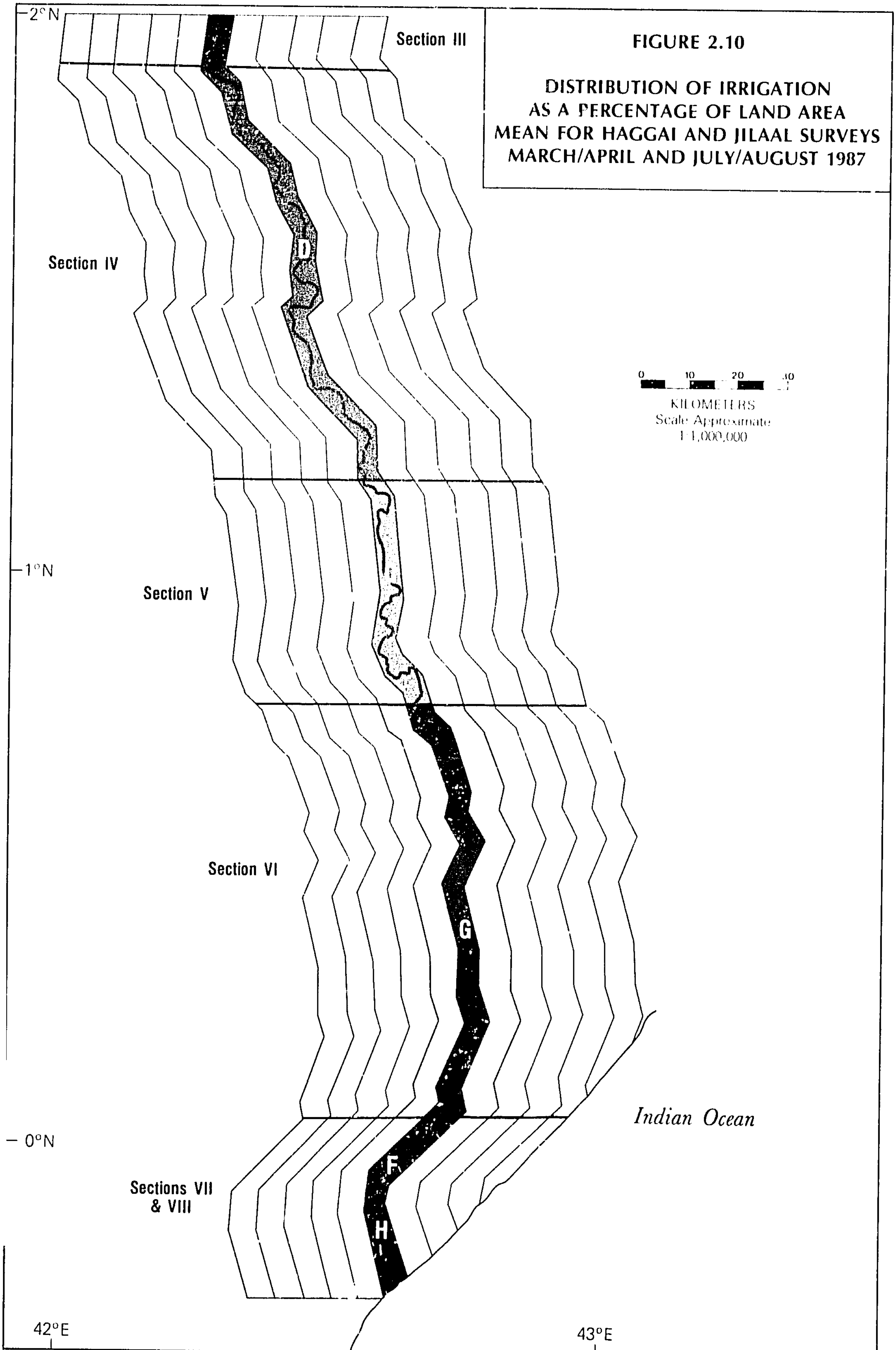


FIGURE 2.10
DISTRIBUTION OF IRRIGATION
AS A PERCENTAGE OF LAND AREA
MEAN FOR HAGGAI AND JILAAL SURVEYS
MARCH/APRIL AND JULY/AUGUST 1987
2°N
1°N
0°N
42°E
43°E
Section III
Section IV
Section V
Section VI
Sections VII
& VIII
D
G
F
H
0
10
20
30
KILOMETERS
Scale Approximate
1:1,000,000
Indian Ocean

Table 10. Summary Data on Densities of Occupied Rural Structures in the Jubba Valley

AREA	DENSITIES OF STRUCTURES					
	1ST JIILAAL		2ND JIILAAL		XAGAA	
	NOMADIC	FIXED	NOMADIC	FIXED	NOMADIC	FIXED
FLOODPLAIN AND VALLEY ZONES						
The whole survey area (Region 100)	-	-	1.10	0.39	1.18	0.24
Jubba Floodplain (Regions 75 & 76)	1.52	0.77	1.49	0.84	4.65	1.64
Jubba Valley (Regions 74 & 77)	-	-	1.07	0.46	0.97	0.16
MAJOR RIVER REGIONS						
River Region Above Reservoir (Region 64)	-	-	1.23	0.03	1.46	0.12
Inundation Region (Region 65)	-	-	1.07	0.07	2.36	0.10
Downstream Region (Region 73)	-	-	1.09	0.53	0.74	0.30
ECOLOGICAL REGIONS						
River and Swamps (Region 20)	0	0	0	0	0	0
Undiff. Floodplain (Region 21)	3.16	1.11	3.01	1.35	9.75	2.89
Fine River Alluviums (Region 22)	0.16	0.55	0.14	0.46	0	0.62
Villages (Region 23)	0	0	0	0	0	0
Riverside Limestones etc. (Region 24)	-	-	1.63	0.63	1.82	0.21
Distant Limestones etc. (Region 25)	-	-	0.92	0.22	0.54	0.06
Riverside Marine Plains etc. (Region 26)	-	-	0.96	0.50	0.68	0.15
Distant Marine Plains etc. (Region 27)	-	-	0.63	0.01	0.55	0.19
VALLEY SECTIONS AND FLOODPLAIN SECTORS						
Valley Section I (Region 64)	-	-	1.23	0.03	1.46	0.12
Floodplain Sector I (Region 78)	4.65	1.27	4.44	0.58	2.05	0.53
Valley Section II (Region 65)	-	-	1.07	0.07	2.36	0.10
Floodplain Sector II (Region 79)	5.57	0.55	6.20	1.04	27.67	2.61
Valley Section III (Region 66)	-	-	2.06	1.21	1.21	0.35
Floodplain Sector III (Region 80)	0.44	0.72	0.34	1.60	0.14	0.50
Valley Section IV (Region 67)	-	-	0.94	0.25	0.55	0.02
Floodplain Sector IV (Region 81)	0	0.05	0.03	0.02	0	0.52
Valley Section V (Region 68)	-	-	0.35	0.19	0.31	0.20
Floodplain Sector V (Region 82)	0	1.92	0.03	1.83	0	2.02
Valley Section VI (Region 69)	-	-	0.78	0.26	0.60	0.40
Floodplain Sector VI (Region 83)	0.17	0.64	0.42	0.65	0.05	1.76
Valley Section VII A + B (Region 70)	-	-	0.85	0.56	0.79	0.42
Floodplain Sector VIIA (Region 84)	1.58	0.44	0.27	0.48	0.04	0.11
Floodplain Sector VII B (Region 85)	0	3.71	0.42	3.53	0	12.61

Significantly more cleared land was recorded in the second jiilaal survey, probably because this is the season when most clearings are burned and become more conspicuous. Rates of clearance of land, relative to the areas currently cropped, showed the fastest expansion of cropping taking place in Valley Sections and Floodplain Sectors IV and V.

Rainfed Cropping

Almost four percent of the survey area was, or had recently been, under rainfed cropping. Rainfed cropping was concentrated in the Floodplain Zone (Regions 75 and 76). Although there was an apparent reduction in rainfed croplands from the second jiilaal to the xagaa surveys, this was probably the result of flooding (which covered almost 15 percent of the floodplain in the xagaa survey) obscuring croplands from view, or a consequence of the greater difficulty of recognizing abandoned croplands under conditions of lush vegetation. Much flooding over rainfed cropland was seen. It is possible that rainfed cropping has increased between the two surveys.

Within the floodplain, most rainfed cropping was found on the undifferentiated floodplain (Region 21) and on the fine river alluviums (Region 22). No obvious seasonal or geographical trends in the data on rainfed croplands appear when it is organized by valley sections and floodplain sectors. The area to be inundated has the following areas of rainfed crops, fallow, and abandoned rainfed land: 3,232 ha in the first jiilaal; 4,965 ha in the second jiilaal; and 2,988 ha in the xagaa.

Irrigation Cropping

Almost one percent of the survey area was, or had recently been under irrigated cropping. Irrigated cropping was virtually confined to the Jubba Floodplain Zone (Regions 75 and 76).

There was an apparent small reduction in irrigation from the second jiilaal to the xagaa surveys, although, as with rainfed cropping, flooding and the increased difficulty of recognizing abandoned irrigations in the xagaa season probably caused underestimation in the xagaa survey.

Within the floodplain, irrigation was virtually confined to the undifferentiated floodplain (Region 21) and the fine river alluviums (Region 22). Irrigation in the floodplain was uniformly distributed except that Floodplain Sectors IV and V(Regions 81and82) supported significantly less area under irrigation.

The area to be inundated had the following areas of irrigated cropland, as deduced from the three surveys:

	1st Jiilaal	2nd Jiilaal	Xagaa
Irrigated land and fallow irrigated land	1,771 ha	4,309 ha	1.449 ha
Abandoned irrigated land	0 ha	111 ha	12 ha
Land cleared for irrigation	24 ha	33 ha	0 ha

Some of the increased irrigation recorded in the second jiilaal survey could be a result of the greater ease with which irrigation can be recognized in the driest time of the year.

Enclosed Land

Approximately 1.3 percent of the whole survey area was enclosed, not showing any current or recent cropping use. The highest densities of enclosed land were found in the undifferentiated floodplain (Region 21). There was a progressive reduction in densities of enclosed land from north to south from Floodplain Sectors II to VI, and most enclosed land was found in Valley Sections I, II, and III, where dry-season graze and browse was a critical limiting factor. The area to be inundated (Region 79) had 4,000 to 5,600 hectares of enclosed land.

Riverbank Cropping

Riverbank cropping makes a negligible contribution to the crop production system in the Jubba Valley. It is confined to Floodplain Sectors I to VI and is concentrated in Sectors I to IV. Approximately 650 to 950 hectares of riverbank cropping occurred in the area to be inundated (Region 79).

Flood-Recession Agriculture

Cropping from receding floods could become significant in the Jubba Valley. If the floods are extensive, receding-flood cropping can fall out of phase with other crop production cycles. In general, it is an opportunistic response by farmers attempting to grow at least some crops in areas where flooding has destroyed or preempted production from rainfed crops.

The 1987 gu' rains created excellent flood-recession agriculture conditions in the 1987 xagaa. The highest densities of this type of cropping were seen in Floodplain Sectors I to V. In the area to be inundated (Region 79), approximately 1,700 ha of recession agriculture were seen in the xagaa survey.

Table 11. Summary Data on Percentages of Land Use in the Jubba Valley

1ST JIILAAL SURVEY

	ALL CLEARED	ALL RAINFED	ALL IRRIGATED	ENCLOSED	RIVER BANK CROPPING	RECEDING FLOOD CROPPING
FLOODPLAIN AND VALLEY ZONES						
The whole survey area (Region 100)	-	-	-	-	-	-
Jubba Floodplain (Regions 75 & 76)	1.443	22.211	15.643	2.658	0.500	3.303
Jubba Valley (Regions 74 & 77)	-	-	-	-	-	-
MAJOR RIVER REGIONS						
River Region Above Reservoir (Region 64)	-	-	-	-	-	-
Inundation Region (Region 65)	-	-	-	-	-	-
Downstream Region (Region 73)	-	-	-	-	-	-
ECOLOGICAL REGIONS						
River and Swamps (Region 20)	0.000	0.000	0.000	0.000	0.000	0.000
Undiff. Floodplain (Region 21)	1.147	25.535	8.971	5.130	1.042	0.988
Fine River Alluviums (Region 22)	2.078	23.215	26.408	0.459	0.000	6.588
Villages (Region 23)	0.000	0.000	0.000	0.000	0.000	0.000
Riverside Limestones etc. (Region 24)	-	-	-	-	-	-
Distant Limestones etc. (Region 25)	-	-	-	-	-	-
Riverside Marine Plains etc. (Region 26)	-	-	-	-	-	-
Distant Marine Plains etc. (Region 27)	-	-	-	-	-	-
VALLEY SECTIONS AND FLOODPLAIN SECTORS						
Valley Section I- (Region 64)	-	-	-	-	-	
Floodplain Sector I (Region 78)	0.325	4.864	15.726	3.108	0.608	0.000
Valley Section II (Region 65)	-	-	-	-	-	-
Floodplain Sector II (Region 79)	0.767	10.472	5.683	12.758	2.358	1.020
Valley Section III (Region 66)	-	-	-	-	-	-
Floodplain Sector III (Region 80)	1.489	3.480	24.760	2.123	0.055	0.604
Valley Section IV (Region 67)	-	-	-	-	-	-
Floodplain Sector IV (Region 81)	2.965	28.628	3.250	0.585	0.044	3.563
Valley Section V (Region 68)	-	-	-	-	-	-
Floodplain Sector V (Region 82)	3.672	17.803	1.406	0.202	0.664	4.971
Valley Section VI (Region 69)	-	-	-	-	-	-
Floodplain Sector VI (Region 83)	1.616	24.157	26.514	0.530	0.027	0.804
Valley Section VII A + B (Region 70)	-	-	-	-	-	-
Floodplain Sector VIIA (Region 84)	0.180	41.167	10.750	0.000	0.010	2.760
Floodplain Sector VIIB (Region 85)	1.080	22.802	33.099	1.323	0.000	0.177

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2ND JIILAAL SURVEY

	ALL CLEARED	ALL RAINFED	ALL IRRIGATED	ENCLOSED	RIVER BANK CROPPING	RECEDING FLOOD CROPPING
FLOODPLAIN AND VALLEY ZONES						
The whole survey area (Region 100)	0.390	3.620	0.986	1.291	0.023	0.038
Jubba Floodplain (Regions 75 & 76)	4.871	23.697	17.568	3.287	0.411	0.640
Jubba Valley (Regions 74 & 77)	0.124	2.432	0.000	0.740	0.000	0.002
MAJOR RIVER REGIONS						
River Region Above Reservoir (Region 64)	0.043	0.217	0.985	2.111	0.023	0.012
Inundation Region (Region 65)	0.054	0.834	0.526	2.059	0.077	0.000
Downstream Region (Region 73)	0.541	4.917	1.149	0.945	0.004	0.053
ECOLOGICAL REGIONS						
River and Swamps (Region 20)	0.000	0.069	0.000	0.000	0.000	0.157
Undiff. Floodplain (Region 21)	5.072	23.318	12.166	6.719	0.861	0.158
Fine River Alluviums (Region 22)	5.722	29.375	27.508	0.186	0.000	1.289
Villages (Region 23)	0.000	0.000	0.000	0.000	0.000	0.000
Riverside Limestones etc. (Region 24)	0.189	4.861	0.000	2.459	0.000	0.000
Distant Limestones etc. (Region 25)	0.010	1.814	0.000	1.726	0.000	0.000
Riverside Marine Plains etc. (Region 26)	0.225	2.148	0.000	0.216	0.000	0.000
Distant Marine Plains etc. (Region 27)	0.036	0.246	0.000	0.111	0.000	0.000
VALLEY SECTIONS AND FLOODPLAIN SECTORS						
Valley Section I (Region 64)	0.043	0.217	0.985	2.111	0.023	0.012
Floodplain Sector I (Region 78)	0.835	4.255	19.293	3.125	0.454	0.228
Valley Section II (Region 65)	0.054	0.834	0.526	2.059	0.077	0.000
Floodplain Sector II (Region 79)	1.215	15.088	13.998	17.684	2.042	0.000
Valley Section III (Region 66)	0.352	9.256	0.351	3.134	0.001	0.000
Floodplain Sector III (Region 80)	3.677	2.951	24.728	1.760	0.081	0.000
Valley Section IV (Region 67)	0.510	3.188	0.106	0.187	0.002	0.022
Floodplain Sector IV (Region 81)	8.660	25.375	2.586	0.383	0.043	0.541
Valley Section V (Region 68)	0.535	1.273	0.049	0.005	0.028	0.263
Floodplain Sector V (Region 82)	9.213	21.910	0.837	0.087	0.476	4.533
Valley Section VI (Region 69)	0.702	3.256	2.564	0.042	0.000	0.041
Floodplain Sector VI (Region 83)	6.146	22.985	28.377	0.241	0.000	0.373
Valley Section VII A + B (Region 70)	0.557	6.206	1.578	0.651	0.001	0.022
Floodplain Sector VIIA (Region 84)	3.324	48.666	9.611	0.004	0.009	0.202
Floodplain Sector VIIB (Region 85)	5.019	23.506	34.914	0.787	0.000	0.000

XAGAA SURVEY

	ALL CLEARED	ALL RAINFED	ALL IRRIGATED	ENCLOSED	RIVER BANK CROPPING	RECEDING FLOOD CROPPING
FLOODPLAIN AND VALLEY ZONES						
The whole survey area (Region 100)	0.183	3.610	0.785	1.298	0.050	0.221
Jubba Floodplain (Regions 75 & 76)	1.447	15.056	13.878	3.410	0.895	3.897
Jubba Valley Section (Regions 74 & 77)	0.973	2.937	0.006	1.175	0.000	0.002
MAJOR RIVER REGIONS						
River Region Above Reservoir (Region 64)	0.000	1.014	0.616	1.517	0.057	0.358
Inundation Region (Region 65)	0.061	0.990	0.174	1.992	0.112	0.207
Downstream Region (Region 73)	0.243	4.774	1.015	1.034	0.028	0.213
ECOLOGICAL REGIONS						
River and Swamps (Region 20)	0.009	0.000	0.000	0.000	0.000	0.217
Undiff. Floodplain (Region 21)	0.938	16.807	6.843	6.711	1.671	4.591
Fine River Alluviums (Region 22)	2.333	16.447	24.802	0.482	0.229	3.942
Villages (Region 23)	0.000	0.000	0.000	0.000	0.000	0.000
Riverside Limestones etc. (Region 24)	0.155	5.624	0.000	2.193	0.000	0.004
Distant Limestones etc. (Region 25)	0.082	2.684	0.000	1.781	0.000	0.000
Riverside Marine Plains etc. (Region 26)	0.159	2.113	0.024	0.479	0.000	0.004
Distant Marine Plains etc. (Region 27)	0.023	0.668	0.000	0.138	0.000	0.000
VALLEY SECTIONS AND FLOODPLAIN SECTORS						
Valley Section I (Region 64)	0.000	1.014	0.616	1.517	0.057	0.358
Floodplain Sector I (Region 78)	0.000	1.670	12.059	8.950	1.109	6.627
Valley Section II (Region 65)	0.061	0.990	0.174	1.992	0.112	0.207
Floodplain Sector II (Region 79)	0.337	9.463	4.628	15.058	2.989	5.514
Valley Section III (Region 66)	0.282	10.509	0.266	3.067	0.009	0.085
Floodplain Sector III (Region 80)	1.158	1.074	18.749	3.413	0.632	5.999
Valley Section IV (Region 67)	0.268	2.864	0.154	0.666	0.108	0.274
Floodplain Sector IV (Region 81)	2.671	18.574	3.753	2.266	2.627	6.439
Valley Section V (Region 68)	0.114	0.939	0.096	0.026	0.031	0.405
Floodplain Sector V (Region 82)	1.962	16.166	1.659	0.448	0.535	6.970
Valley Section VI (Region 69)	0.219	3.328	2.280	0.101	0.012	0.181
Floodplain Sector VI (Region 83)	1.248	18.184	24.956	0.093	0.137	2.006
Valley Section VII A + B (Region 70)	0.330	2.820	1.317	0.713	0.000	0.297
Floodplain Sector VIIA (Region 84)	2.395	18.163	7.795	0.008	0.000	2.689
Floodplain Sector VIIB (Region 85)	4.455	35.349	30.854	0.722	0.000	0.083

D. Complete Search of the Reservoir Zone

Results from this aerial survey were transferred to field maps, and counts were refined at a later date using 35 mm photographs. These materials and raw and tabular data are located in JESS data repositories. Reference should also be made to Table 10 and Figures 2.7, 3.7, and 2.8 for an interpretation of results. An overview of these results concerns three principal populations in the inundation zone: rural, refugee, and pastoral.

Rural Populations

The survey centered primarily on a count of dwellings (occupied and unoccupied). Dwellings were judged to be occupied from observations of:

- people at the structure;
- livestock and dogs at the structure;
- crop residues and crop processing taking place;
- burning fires at the structure; and
- paths in use going around and to the structure.

It has been assumed that occupied dwellings support a single household.

The total count for the Reservoir Zone indicated 1,015 resident rural families have dwellings which will be inundated, and an additional 539 families will be severely affected and have to seek new homesites and new cropland. This compares with *Socioeconomic Baseline Studies* data (Merryman field notes of 15 December 1987) showing 1,133 to 1,082 households "close to the river" in the area where flooding will take place. These figures (1,015 to be flooded according to this survey; 1,133 to 1,182 as judged by ground survey methods) are totally independent and strongly corroboratory.

Merryman also surveyed the gorge area (defined as the riverine strip between Buurdhuubo Bridge and the present dam site) in two ways and derived household estimates of 392 and 441. The latter estimate is the more accurate. In the present survey, 414 households of this gorge have been counted (which includes 26 houses to be severely affected). Once again, these data are independently corroborative.

In sum, currently, between 1,000 and 1,200 families (7,000 to 8,400 people) permanently occupy the area to be flooded. This population is also expanding. Another 500 to 600 families (3,500 to 4,200 people) will be so severely affected that, although their houses will not be flooded, they will have to seek their livelihood elsewhere.

Refugee Populations

Expected impacts on refugee populations of the inundation of the proposed reservoir zone are described (north to south) in the following table:

CAMP	BANK	OFFICIAL (1987) POPULATION	IMPACT
LUUQ CAMPS			
HALBA 1	W	20,000	Probably none
HALBA 2	W	8,000	Probably none
HORSEED	W	15,000	None of the camp flooded; loss of irrigated land and water supply installation; moderate environment deterioration
HALGAN	W	18,000	Almost no houses flooded; loss of irrigated land, water supply installation & some service buildings, moderate to severe environment deterioration.
BAN MANDULE	E	13,571	
DORIANLEY	W	17,000	Up to 10 percent of camp flood; loss of irrigated land and many services. Severe environment deterioration.
ALI MATAN	E	18,429	
MAGANEY	W	11,000	
BUURDHUUBO CAMPS			
MALKA HIDDAY	W	20,000	Completely flooded
SURIYE	W	16,000	Completely flooded
HILO MAREER	W	12,000	Completely flooded
BUURDHUUBO	W	20,000	Completely flooded

TOTALS		
	Probably not negatively affected by inundation	38,000
	Moderately negatively affected by inundation	15,000
	Moderately to severely negatively affected by inundation	31,571
	Severely negatively affected by inundation	46,429
	Inundated	68,000

According to these estimates, about 68,000 refugees in the Buurdhuubo group of camps will have to be resettled because their camps will be inundated. An additional 46,429 refugees in the camps Dorianley, Ali Matan, and Maganey will be severely affected and their camps will be partially flooded in parts of the year.

Some 31,571 refugees in the camps Halgan and Ban Mandule will be moderately to severely affected with minor flooding, and suffer significant loss of services and environmental deterioration. Some

15,000 refugees in the camp of Horseed will be moderately affected through the flooding of its water supply installations and environmental deterioration.

Pastoral Populations

The land bordering the planned reservoir comprises strata 45 to 49 on the west bank and strata 50 to 54 on the east bank. The reservoir is made up of stratum 3 (the river) and stratum 4 (floodplain).

Strata 45 to 49 (River Region 37) and strata 50 to 54 (River Region 38) extend 30 km from the edge of the planned reservoir. Populations within these strata probably depend annually for several weeks on crop residues and biomass reserves of the Jubba floodplain. The three aerial strip sampling surveys (detailed earlier) have estimated populations of people and livestock in these areas as summarized in the table below.

In most dry seasons, between 10,000 and 20,000 nomadic families (70,000 to 140,000 persons) will depend for short periods on the fodder reserves and crop residues found in the inundation area. These people will be accompanied by 30,000 to 50,000 cattle, 150,000 to 200,000 sheep, 300,000 to 350,000 goats, and 60,000 to 100,000 camels. In extreme dry periods (every few years), the numbers of people and livestock that might be dependent on the valley's biomass and crop residues could be two or three times greater.

Many crossing points for livestock will be impassable, and those nomads whose normal strategy involves crossing the river in the dry season, or in exceptional dry periods, will have to adopt new patterns of movement (at greater overall risk. There are about 50 places where the river is crossed regularly in the jiilaal.

E. Monitoring Site Photographs

Photographs at 1:1,000 scale were delivered to JESS for analysis and reporting and were used in preparation of the analyses in *Terrestrial Ecology-Baseline Studies* (Part A of this volume). These photographs have been placed in JESS data repositories (see Volume IV, Bibliography).

Valley Occupants and Uses

PERIOD	NH	OH	CATTLE	SHEEP	GOATS	CAMELS	RFM	AI	RFL
1st JIILAAL									
E.BANK 4045Km^2	.	.	.	.	.	.	.	.	
RIVER 46Km^2	0	0	260	8000	27000	9000	0	0	0
FLOODPLAINS 270Km^2	1759	173	4000	16000	48000	4000	7554 ha	1819 ha	1067 ha
W.BANK 4045Km^2	.	.	.	.	.	.	.	.	
2nd JIILAAL									
E.BANK 4045Km^2	4113	188	12000	71000	125000	54000	8423	0	0
RIVER 46Km^2	0	0	600	3000	7000	2000	0	0	0
FLOODPLAIN 270Km^2	1959	329	12000	32000	52000	8000	10701 ha	4453 ha	0
W.BANK 4045Km^2	2930	27	9000	76000	127000	33000	5613	0	0
XAGAA									
E.BANK 4045Km^2	2339	27	15000	62000	88000	30000	11261	0	0
RIVER 46Km^2	0	0	0	0	0	0	0	0	0
FLOODPLAIN 270Km^2	8738	823	13000	27000	46000	2000	7849 ha	1461 ha	2685 ha
W.BANK 4045Km^2	8736	27	20000	94000	188000	29000	6465	0	0

NH = NOMADIC HOUSES OH = OTHER HOUSES RFM = RAINFED MANAGED LAND
AI = ALL IRRIGATED LAND RFL = RECEDING FLOOD CROPLAND + RIVER BANK CROPPING

V. CONCLUSIONS AND RECOMMENDATIONS

It is expected that most of the recommendations stemming from the results of the surveys described here will be made in other JESS reports in which the results from many more studies will be combined to provide a more complete and detailed picture of the sequence of environmental and socioeconomic impacts. However, from the limited standpoint of aerial surveys and the authors' familiarity with the study area, some conclusions and recommendations are made.

The importance of the Jubba River, downstream of the proposed reservoir, as a source of water for people, livestock, and irrigation is clearly established, with possibly 15 percent of the human population living close to and depending on the river.

Therefore, realistic forecasts of the qualitative and quantitative nature of the water discharge to come from the reservoir are needed. To make such forecasts, it will be necessary to have a final engineering design, a range of discharge scenarios, the full hydrometeorological data (including data from the upper catchment—in particular, covering any likelihood that upstream impoundments could modify the hydrological regime), and other environmental data, such as the vegetation biomass in the inundation zone.

A large number of people (15,000 resident Somalis and 115,000 refugees) and about 15,000 hectares of managed land (rainfed farmland, irrigated land, and enclosed land) will be affected by the inundation. There are no obvious sites for development of large irrigation projects using the impounded water, since most of the soils that are able to be efficiently irrigated are distributed in small parcels down the Jubba Floodplain.

At present, the middle Jubba Floodplain (the southern part of Sectors III, IV, V and the northern part of Sector VI) is experiencing very rapid expansion of crop production. It is evident that the best opportunity for new crop/livestock farming in Somalia lies in these regions. In addition to the actual expansion of cropping, the whole floodplain is showing signs of agricultural intensification, with more efficient integration between livestock and crops, albeit not as intensive as the middle Shabeelle Valley. At present, only two percent of the cattle in the Jubba Valley feed on transported crop residues in the jiilaal; in the Shabeelle Valley, 10 percent of the cattle in the dry season of 1984 were feeding on transported crop residues (Watson and Nimmo 1985).

It is to be expected that flood control resulting from constructing Baardheere Reservoir will provide a further impetus to the process of expansion and intensification of agriculture of the Jubba floodplain. The social and administrative mechanisms of the present expansion processes and the details of the types of intensification of land use taking place, particularly ith respect to the relationship between livestock and cropping, are not fully understood. *Displaced persons should be absorbed in the agricultural expansion and intensification now taking place rapidly in the middle Jubba. A study will be required to design the most efficient way in which this absorption can be encouraged (or enforced). It is recommended that master planners be directed to consider this emphasis in the present studies of agriculture in the valley.*

It was evident in the extreme dry season that there is already serious competition for water in the valley among the large-scale users of irrigation water. (The Fanoole Project was taking water upstream during the 1987 jiilaal to grow high-cost rice for local consumption which decreased yields on export-earning banana farms downstream.) Although *ad hoc* water-sharing arrangements are evolving, there is no doubt that a more efficient organization of irrigation water use is needed as an interim measure until the new hydrologic regime is established following the dam's construction. Any new large-scale irrigation project should proceed only after a realistic appraisal is made of how it will fit into the overall water-use pattern. *An effective "Jubba Water Use Authority" is urgently needed and should continue to operate during and after construction. The Authority should immediately commission a study to produce a water use master plan, which would serve as its terms of reference.*

Control measures for the present crocodile and hippopotamus populations are needed, and consideration should be given to their commercial exploitation so that the control costs can be met from the sale of skins. A parallel research effort will be necessary to ensure maximum production and efficient management. Policy for the control of crocodile and hippopotamus populations which may be developed for the reservoir should be clarified, and measures prepared to carry out this policy.

The reservoir will create an uncrossable barrier between Luuq and Baardheere, flooding the newly built bridge at Buurdhuubo. *It is recommended that one or two ferry crossings be established across the dam at suitable locations to reduce the impact of this very long barrier.* The new hydrologic regime could also make it difficult to cross the river downstream, below the dam, in the dry season. This problem should be studied as soon as reliable forecasts of dam discharge patterns are available. An upgrading of present river crossing ferries is recommended to alleviate this type of problem.

In making decisions about the infrastructure required for the construction of the dam, it should be carefully noted that improved physical infrastructure from Baardheere down the Jubba River to Kismaayo would immeasurably assist in the expansion and intensification of agriculture in the Jubba Floodplain. *Good all-weather roads along both banks of the Jubba Floodplain, with two new bridges at Saakow and Jilib, are needed to develop cash cropping throughout the valley, and a generally more intense and technically based agricultural system.*

Loss of vegetation biomass and production (both natural and crop) in the reservoir zone will have a significant impact on the goat and sheep populations of the Jubba Valley, but only a small impact on cattle and camels in normal years. *It is recommended that a study be commissioned to design a set of measures which will maximize the development of usable vegetation biomass on the reservoir drawdown zone.*

Impending inundation of the Buurdhuubo refugee camps provides an opportunity to test radical new solutions to this apparently insoluble problem. The danger of allowing subsistence farmers and pastoralists to linger for many years in refugee camps is that their children are not taught the skills or values required to operate and successfully manage subsistence enterprises. These camps have been in operation since 1978, and the capability of their populations to resume rural self-sufficiency will soon start to fall off dramatically. *It is recommended that a workable rehabilitation program for the Buurdhuubo refugee population be put into effect as soon as possible, but no later than 1990.*

Observations of larger-scale irrigation projects (Fanoole, Mogambo, and Jubba Sugar) suggest they are not as efficient as small-scale, owner-operated irrigations. *It is recommended that water- and soil-use planning in the Jubba Valley take serious account of previous experiences in irrigation management in Somalia, and that appropriate studies be made to provide this input.*

MNPJVD officials should understand clearly that the present land-use system is very dynamic, and long delays before the Baardheere Dam is constructed will create *a need to monitor and update information on land use, resources, and the environment throughout the construction period and during the dam's operation*—particularly to detect early signs of land degradation processes.

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AIW *Abandoned Irrigation Works.* These are where fixed installations have been built in the past for irrigation water off-takes and subsequently abandoned; attempt was made to record all of these.

Bb *Baboon Troop.* In the more open river bank vegetation seen in March/April, it was possible to spot most of the troops of Baboons (*Papio cyanocephalus*) on the riverbed, islands, or river bank. These have been recorded.

BF *Boat Ferry.* The least common type of ferry is a boat with an engine crossing from bank to bank. Attempt was made to count them all.

Bk *Basket traps.* The barrel-shaped baskets of which two were seen on the September survey (Watson 1986, page 16) were apparently more numerous in the jiilaal season. No more deductions have been made of their function.

CF *Cable Ferry.* Most of the ferries use a low cable strung across the river to pull a boat across the river. The boat is attached to the cable by a pulley. The record "cable ferry" indicates a cable and one boat has been sighted. The boats used are mostly aluminium assault craft but some wooden clinker-built boats are also used as cable ferry boats.

CI *River Bank Clearances for Irrigation.* Some of the river bank clearances were obviously intended to become irrigation fields. These have been recorded separately, although no attempt has been made to produce a comprehensive inventory of these features.

Cl *River Bank Clearances.* Where bush and forest at the edge of the river has been cleared within the previous few weeks, the record of a river bank clearance has been made. As for abandoned irrigation areas, it is impossible to treat these as comprehensive, and they, too, should be regarded as indicative of the level of this sort of activity, rather than an inventory of cleared patches.

Cn *Canoe.* Traditional dug-out canoes on the river were totally counted. Several new canoes were seen. The twisted shape of several canoes suggested that suitable tree trunks are difficult to find.

CN *Crocodile Nests.* An attempt was made to count crocodile nests, which are recognizable from the shallow depressions left after hatching eggs are excavated by the female parent, but none were spotted in this survey.

Cr *Crocodile.* All crocodile in the water, on silty or sandy banks, in flooded areas, and haro (more or less permanent lakes representing tributaries of the Jubba cut off by the river levee) except the Waamo har. Only a small portion of the crocodile in the river will be seen in an aerial survey.

Ct *Cart.* One donkey-drawn cart was recorded on the riverbed.

DG *Water Birds.* Concentrations of water birds, mostly ducks and geese, were recorded; these data are only indicative of the general distribution of water birds.

DP *Important Drinking Places.* Important drinking places used by livestock are easily identified by the density of radiating tracks, the appearance of the bank, and, in many cases, the thorn barriers made in the water to protect such drinking locations from crocodile depredation. A complete inventory of important drinking places was made. Many of these sites are used as crossing places when the river level falls.

FI *Furrow Irrigation.* Open-channel irrigation was observed close to the river mouth. These channels carry water to irrigate coconut groves and may be taking advantage of changes in river level caused by tides.

FN *Fish Nets.* Several fish nets were seen in the river. These features are difficult to spot from an aircraft, but experience on other rivers and lakes suggests the net fishing on the Jubba is not widespread.

FR *Firewood Rafts.* No firewood rafts were spotted in spite of a careful search. The movement of firewood as described in Wat-

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son (1986, page 5) probably takes place only when the river is high.

FSp *Flowing Springs*. Springs feeding significant amounts of water into tributaries flowing into the Jubba were recorded.

H *Hippopotamus*. All hippopotamuses seen in the river and flooded areas were counted. The question of correcting for hippopotamus under the water at the time of the count is addressed in this report.

P *Pumps*. All pumps seen to be working or judged to be working from the condition of crops they serve were recorded.

PR *People*. Large numbers of people were seen in the riverbed either on the now exposed sand banks or bathing and swimming in the water. People generally stayed in very shallow water, but there will undoubtedly be regular loss of life through crocodile predation.

R *Raft*. Rafts made of three to five logs lashed together are found mostly in upper reaches of the river. All those in the water were counted.

RFC *River-bank cropping*. The actual bank of the river is planted with crops in a few places—an agricultural practice resembling falling flood cropping. River bank plantings are not easy to spot, since minimal land preparation is made and they resemble natural vegetation. Therefore, the records are an index rather than an inventory.

RW *Riverbed wells*. Extensive parts of the riverbed emerge as river levels fall which allows wells to be dug. These have been recorded.

T *Turtle*. A large river turtle was recorded in the river. Turtles appear to have a shell length of about 1 m. The ARD fisheries biologist caught several specimens of a species of turtle so far not identified, the largest of which is about 0.5 m long. He believes that larger specimens could have fought their way out of his nets, and it seems likely that the specimens he has photographed are the same species as that seen from the air. (It should be a simple matter to have a positive identification from the photograph he has provided from the National Museum of Kenya, and this information has been sought.)

TN *Turtle Nest*. Three small depressions on a sandy island were judged to be the old nest sites of the Jubba River turtle.

WCP *Water Collecting Points*. It was observed that in addition to Important Drinking Places (DP), some points on the river bank (which may also be drinking places) were being used for the collection of water by draught camels and donkeys carrying traditional woven water containers. These have been counted and recorded.

WH *Warthog*. The emergence of dry parts of the riverbed as river levels fall allowed warthog to enter the riverbed. These have been counted and recorded.

WM *Wind-powered Pump*. Only two wind pumps were seen.

WS *Water Supply Installations*. Water supply installations, composed of pumps, settling tanks, sterilizing units, etc. were recorded. One abandoned water supply installation (AWS) was recorded.

+H *Dead Hippopotamus*. Some dead hippopotamuses were recorded.

+Cr *Dead Crocodile*. More dead crocodile were seen, reflecting the intense competition between these dangerous predators and organized fisherman using the shallow flooded dhesheegs and haro. All dead crocodile seen had their bellies slit, and no attempt had been made to remove their valuable skins.

C,G, S, G/S, Cm,D *Herds of Livestock*. (C = Cattle, G = Goats, S = Sheep, G/S = indistinguished Goats/Sheep, Cm = Camels, D = Donkeys) Numerous livestock were seen bathing and drinking on the exposed riverbed and were counted and recorded, although counts of large herds by eye will be rather inaccurate.

Dead Livestock in the riverbed were denoted +C, +D, +Cm, and +G/S.

In addition to these features, the location of 35 mm oblique views of the river taken using wide angle (24 mm) and other lenses were marked on the

1:100,000 maps. These photographs are useful for general descriptions of the valley.

Finally, bridges were emphasized on the 1:100,000 maps where the original maps did not show these features. The two bridges constructed since the maps were drawn (at Bu'aale and the Fanoole head-works) have been marked on the maps.

One bridge was seen to be under construction immediately north of Buurdhuubo Refugee Camp and this has been marked on the maps.

Livestock

Cattle:
number in group or aerial photograph reference number; cover category for application of a counting correction factor; activity; number of transects in which the group occurs

Draft oxen:
number in group or aerial photograph reference number; cover category for application of a counting correction factor; activity; number of transects in which the group occurs

Sheep:
number in group or aerial photograph reference number; cover category for application of a counting correction factor; activity; number of transec in which the group occurs

Goats:
number in group or aerial photograph reference number; cover category for application of a counting correction factor; activity; number of transects in which the group occurs

Indistinguishable goats/sheep:
number in group or aerial photograph reference number; cover category for application of a counting correction factor; number of transects in which the group occurs

Camels:
number in group or aerial photograph reference number; cover category for application of a counting correction factor; activity; number of transects in which the group occurs

Donkeys:
number in group or aerial photograph reference number; cover category for application of a counting correction factor; activity; number of transects in which the group occurs

Dead cattle:
number seen within the transect markers

Dead sheep:
number seen within the transect markers

Dead goats:
number seen within the transect markers

Dead goats/sheep:
number seen within the transect markers

Dead camels:
number seen within the transect markers

Dead donkeys:
number seen within the transect markers

Wildlife

Gerenuk:
number in group; cover category for application of a counting correction factor, number of transects within which group occurs

Lesser kudu:
number in group; cover category for application of a counting correction factor, number of transects within which group occurs

Ostrich:
number in group; cover category for application of a counting correction factor, number of transects within which group occurs

Hippopotamus:
number in group; number of transects within which group occurs; correction factors for hippopotamus counts are complex and a single factor has been applied

Crocodile:
number within transect markers; two correction factors have been applied, regarded as the minimum and maximum

Warthog:
number in group; number of transects within which group occurs; cover category for application of a counting correction factor

Baboon troop:
no attempt has been made to count the number of individual baboon in a troop—they are too fast-moving and small—and so the records here show the number of troops within transect markers; number of transects within which group occurs; and the cover category for applications of a counting correction factor

Elephant:
number in group; number of transects within which group occurs; cover category for application of a counting correction factor

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Oryx:
number in group; number of transects within which group occurs; cover category for application of a counting correction factor

Vervet monkey troop:
no attempt has been made to count the number of individual monkeys in a troop—they are too fast-moving and small—and so the records here show the number of troops within transect markers and the cover category for applications of a counting correction factor

Giraffe:
number in group; cover category for application of a counting correction factor; number of transects within which group occurs

Bush pig:
number in group; cover category for application of a counting correction factor; number of transects within which group occurs

Turtle:
number seen

Elephant skeleton:
number seen (defined as bones without skin) within transect markers

Elephant carcass:
number seen (defined as bones with skin) within transect markers

Elephant tracks:
number of intersects with inner transect marker

Water Sources

Riverine (riverbed) well:
number seen within transect markers

Undifferentiated well:
number seen within transect markers

Well in dhesheeg floor:
number seen within transect markers

Flowing spring:
number seen within transect markers

Riverine pool:
number seen within transect markers

Rainwater pool:
number seen within transect markers

Riverine seepage:
number seen within transect markers

Dry war:
number seen with center point within transect markers

Abandoned war:
number seen with center point within transect markers

War with water:
number seen with center point within transect markers

Dry balli:
number seen with center point within transect markers

Balli with water:
number seen with center point within transect markers

Abandoned well:
number seen within transect markers

Structures/Cultural Features

Livestock enclosure:
number seen with center point within transect markers

Abandoned livestock enclosure:
number seen with center point within transect markers

Aqal:
number seen with center point within transect markers

Abandoned aqal:
number seen with center point within transect markers

Tin-roofed house:
number seen with center point within transect markers

Ridge-roofed house:
number seen with center point within transect markers

Conical-roofed house:
number seen with center point within transect markers

Abandoned conical-roofed house:
number seen with center point within transect markers

Cubical house of grass screens:
number seen with center point within transect markers

Graveyard:
number seen with center point within transect markers

Agricultural shelter:
number seen within transect markers

Store of crop residue (straw):
number seen within transect markers

Empty store of crop residue:
number seen within transect markers

Underground grain store:
number seen within transect markers

Other grain store (trees, above-ground structures):
number within transect markers

Poles cut for building (small piles and bundles):
number seen within transect markers
Firewood (small piles and bundles):
number seen within transect markers
Tree cut for fodder access:
number seen within transect markers
Beehive in trees:
number seen within transect markers
Charcoal kiln site:
number seen within transect markers
Wind-powered pump:
number seen within transect markers
Water supply installation:
number seen within transect markers
Water-collecting point on river:
number seen within transect markers
Drinking trough:
number seen within transect markers
Tractor:
number seen within transect markers
Bulldozer:
number seen within transect markers
Cart:
number seen within transect markers
Abandoned irrigation head works:
number seen within transect markers
Aqueduct:
number seen within transect markers
Flood protection bund:
number seen within transect markers
Irrigation pump on river bank:
number seen within transect markers
Boat:
number seen within transect markers
Dugout canoe:
number seen within transect markers
Raft:
number seen within transect markers
Cable ferry:
number seen within transect markers
People in river/on riverbed:
number seen within transect markers
Fish net or basket trap:
number seen within transect markers

Land-Use Features

Riverbank cropping:
numbers of strips cut by the inner transect marker (first two surveys); number of seconds taken for inner transect marker to pass over that land-use type (xagaa survey)
Abandoned forestry nursery:
number of seconds taken for inner transect marker to pass over the nursery
Receding flood-cropping on dhesheegs and other depressions:
number of seconds taken for inner transect marker to pass over that land-use type
Refugee camp:
number of seconds taken for inner transect marker to pass over that land-use type
Swamp (permanently or almost permanently flooded land):
number of seconds taken for inner transect marker to pass over that land condition type
Swamp (permanently or almost permanently flooded land):
number of seconds taken for inner transect marker to pass over that land condition type
Enclosed land:
number of seconds taken for inner transect marker to pass over that land-use type. The "enclosed land" category is confined to land which has been surrounded by thorn fences, but which has not been assigned to any other land-use category
Grass cutting:
number of seconds taken for inner transect marker to pass over that land-use type
Burned land:
number of seconds taken for inner transect marker to pass over that land condition type
Unspecified rainfed cropland:
number of seconds taken for inner transect marker to pass over that land-use type
Abandoned rainfed cropland:
number of seconds taken for inner transect marker to pass over that land-use type
Unspecified perennial rainfed cropland:
number of seconds taken for inner transect marker to pass over that land-use type
Coconut groves:
number of seconds taken for inner transect marker to pass over that land-use type
Land cleared for rainfed (and receding-flood) cropping:
number of seconds taken for inner transect marker to pass over that land-use type
Unspecified irrigated cropland:
number of seconds taken for inner transect marker to pass over that land-use type
Fallow irrigated cropland:
number of seconds taken for inner transect marker to pass over that land-use type

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Irrigated rice:
number of seconds taken for inner transect marker to pass over that land-use type

Fallow irrigated rice:
number of seconds taken for inner transect marker to pass over that land-use type

Irrigated coconut plantations:
number of seconds taken for inner transect marker to pass over that land-use type

Irrigated sugar estates:
number of seconds taken for inner transect marker to pass over that land-use type

Irrigated banana plantations:
number of seconds taken for inner transect marker to pass over that land-use type

Irrigated perennial cropland:
number of seconds taken for inner transect marker to pass over that land-use type

Mixed irrigated cropland:
number of seconds taken for inner transect marker to pass over that land-use type

The following is a list of maps and photographic products which have been delivered to JESS as original products only.

1. All 35 mm transparencies of livestock and other items taken during the strip sampling from which counts have been made
2. All 35 mm transparencies of dwellings taken in the complete count of the inundation area
3. A selection of 35 mm transparencies of oblique views of the Jubba River and floodplain, and the Jubba Littoral Zone
4. Maps of the first river survey at 1:100,000 scale
5. Maps of the second river survey at 1:100,000 scale
6. Maps of the Jubba Littoral Zone at 1:100,000 scale
7. Annotations of the aerial photomosaics of the Jubba floodplain south of Baardheere Dam
8. Maps showing the locations of aerial strip samples and monitoring site photographs at 1:100,000 scale
9. Annotations of 1:50,000 aerial photomosaics of the reservoir area showing locations of dwellings counted
10. 1:10,000 scale aerial photographs of the Jubba floodplain
11. 1:1,000 scale vegetation monitoring site photographs
12. 1:10,000 scale aerial photographs of Kismaayo, Garbahaarey, and Afmadow towns

**Most of these products are in the JESS data repositories (for details see JESS Final Report, Volume IV, Bibliography).*

Definition of Space References in Aerial Strip Sampling of the Jubba Floodplain Zone and Jubba Valley Zone – Appendix D

A. Ecological Zones

There are judged to be 19 nonoverlapping Ecological Zones in the overall survey area. The term "riverside" indicates land within 6 km of the floodplain, the term 6 km means within 6-12 km of the floodplain.

ECOLOGICAL ZONES	STRATUM NUMBERS	REGION NO.
Undifferentiated Upper Floodplain	2, 4, 6	1
River	1, 3, 5, 7, 11, 14, 25, 32	2
Fine (Depressed) River Alluviums (Dhesheegs)	9, 13, 16, 27, 30, 34	3
Coarse More Variable River Alluviums (Levees)	8, 12, 15, 26, 33	4
Riverine Swamps	10	5
Irrigated Estates	17, 21, 22, 23	6
Fine Flat River Alluviums	18, 24, 31	7
Villages	19	8
Mixed River Alluviums	20, 28, 29	9
Riverside Limestone/ Gypseous Terraces, Plateaus & Hills	39, 40, 49, 50, 59, 60	10
6 km Limestone/ Gypseous Terraces, Plateaus & Hills	38, 41, 48, 51, 58, 61	11
12 km Limestone/ Gypseous Terraces, Plateaus & Hills	37, 42, 47, 52, 57, 62	12
18 km Limestone/ Gypseous Terraces, Plateaus & Hills	36, 43, 46, 53, 56, 63	13
24 km Limestone/ Gypseous Terraces, Plateaus & Hills	35, 44, 45, 54, 55, 64	14
Riverside Marine Plains of Mixed Alluviums	69, 70, 79, 80, 89, 90, 99, 100	15
6 km Marine Plains of Mixed Alluviums	68, 71, 78, 81, 88, 91, 98, 101	16
12 kmMarine Plains ofMixed Alluviums	67, 72, 77, 82, 87, 92, 97, 102	17
18 km MarinePlains of MixedAlluviums	66, 73, 76, 83, 86, 93, 96	18
24 km Marine Plains of Mixed Alluviums	65, 74, 75, 84, 85, 94, 95	19

B. Ecological Regions

The Ecological Regions are not to be confused with the Survey Regions. The 19 Ecological Zones fall into eight Ecological Regions as the next layer of the hierarchy. The term "riverside" here means within 18 km of the floodplain, and the term "distant" means more than 18 km from the floodplain.

ECOLOGICAL REGIONS	REGION NUMBERS (from Ecological Zones)	REGION NO.
River and Swamps	R2, R5	20
Undifferentiated Floodplain	R1, R4, R9	21
Fine River Alluviums	R3, R6, R7	22
Villages	R8	23
Riverside Limestone/ GypseousTerraces, Plateaus& Hills	R10, R11, R12	24
Distant Limestone/Gypseous Terraces, Plateaus & Hills	R13, R14	25
Riverside Marine Plains of Mixed Alluviums	R15, R16, R17	26
Distant Marine Plains of Mixed Alluviums	R18, R19	27

C. Ecological Provinces

The eight Ecological Regions fall into three major Ecological Provinces, which form the top layer of the hierarchy.

ECOLOGICAL PROVINCES	REGION NUMBERS (from Ecological Regions)	REGION NO.
River and Floodplain	R20, R21, R22, R23	28
Valley Limestones	R24, R25	29
Valley Marine Plains	R26, R27	30

D. River Valley Subsections

The second hierarchy concerns the division of the Jubba Valley and Floodplain Zones into sections and subsections along the course of the river. The bottom layer of the hierarchy is shown on the next page.

RIVER VALLEY SUBSECTION	STRATUM NUMBERS	REGION NO.
River Subsection I	1	31
Floodplain Subsection I	2	32
East Bank Subsection I	35, 36, 37, 38, 39	33
West Bank Subsection I	40, 41, 42, 43, 44	34
River Subsection II	3	35
Floodplain SubsectionII	4	36
East Bank Subsection II	45, 46, 47, 48, 49	37
West Bank Subsection II	50, 51, 52, 53, 54	38
River Subsection III	5	39
Floodplain Subsection III	6	40
East Bank Subsection III	55, 56, 57, 58, 59	41
West Bank Subsection III	60, 61, 62, 63, 64	42
River Subsection IV	7	43
Fine River Alluviums Subsection IV	9	44
Coarse River Alluviums Subsection IV	8	45
East Bank Subsection IV	65, 66, 67, 68, 69	46
West Bank Subsection IV	70, 71, 72, 73, 74	47
River Subsection V	10, 11	48
Fine River Alluviums Subsection V	13	49
Coarse River Alluviums Subsection V	12	50
East Bank Subsection V	75, 76, 77, 78, 79	51
West Bank Subsection V	80, 81, 82, 83, 84	52
River Subsection VI	14	53
Fine River Alluviums Subsection VI	16, 17, 18, 21, 22, 23	54
Coarse River Alluviums Subsection VI	15, 20	55
East Bank Subsection VI	85, 86, 87, 88, 89	56
West Bank Subsection VI	90, 91, 92, 93, 94	57
River Subsection VII	25, 32	58
Fine River Alluviums Subsection VII	24, 27, 30, 31, 34	59
Coarse River Alluviums Subsection VII	26, 28, 29, 33	60
East Bank Subsection VII	95, 96, 97, 98, 99	61
West Bank Subsection VII	100, 101, 102	62
Villages [in many subsections]	19	63

E. The River Valley Sections (North to South)

The second layer of the hierarchy is the seven River Valley Sections into which the 32 River Valley Subsections fall. The seven River Valley Sections coincide with the seven River/Floodplain Sectors described under Section H of this appendix.

The River Valley Sections are:

RIVER VALLEY SECTION (North to South)	REGION NUMBERS (from River Valley Subsections)	REGION NO.
River Valley Section I	R31, R32, R33, R34	64
River Valley Section II	R35, R36, R37, R38	65
River Valley Section III	R39, R40, R41, R42	66
River Valley Section IV	R43, R44, R45, R46, R47	67
River Valley Section V	R48, R49, R50, R51, R52	68
River Valley Section VI	R53, R54, R55, R56, R57	69
River Valley Section VII	R58, R59, R60, R61, R62	70
Villages [in many sections]	63	63

F. The River Valley Regions (North to South)

The third and top layer of the hierarchy is the three River Valley Regions into which the seven River Valley Sections fall.

RIVER REGIONS (North to South)	REGION NUMBERS (from River Valley Sections)	REGION NO
Valley Above Reservoir Region	R64	71
Inundation Region	R65	72
Downstream of the Dam Region	R66, R67, R68, R69, R70	73

G. River Valley Regions (East to West)

An additional combination of strata has been made parallel to the river's axis.

RIVER REGION (East to West)	STRATUM NUMBERS	REGION NO.
East Bank	35, 36, 37, 38, 39, 45, 46, 47, 48, 49, 55, 56, 57, 58, 59, 65 66, 67, 68, 69, 75, 76, 77, 78 79, 85, 86, 87, 88, 89, 95, 96 97, 98, 99	74
Floodplain	2, 4, 6, 8, 9, 12, 13, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 26, 27, 28, 29, 30, 31, 33, 34	75
River	1, 3, 5, 7, 10, 11, 14, 25, 32	76
West Bank	40, 41, 42, 43, 44, 50, 51, 52, 53, 54, 60, 61, 62, 63, 64, 70, 71, 72, 73, 74, 80, 81, 82, 83,	77

H. River /Floodplain Sectors (North to South)

Finally, strata have been combined into River and Floodplain Sectors on a north to south basis.

RIVER AND FLOODPLAIN SECTOR	STRATUM NUMBERS	REGION NO.
River and Flood-plain Sector I	1, 2	78
River and Flood-plain Sector II	3, 4	79
River and Flood-plain Sector III	5, 6	80
River and Flood-plain Sector IV	7, 8, 9	81
River and Flood-plain Sector V	10, 11, 12, 13	82
River and Flood-plain Sector VI	14, 15, 16, 17, 18, 19, 20, 21, 22, 23	83
River and Flood-plain Sector VIIA	24, 25, 26, 27, 28, 29, 30	84
River and Flood-plain Sector VIIB	31, 32, 33, 34	85

K. The Whole Survey Area

The whole survey area is called Region 100.

The following list presents themes of tabular data available in JESS data repositories (see JESS Final Report, Volume IV, Bibliography). The list is made available here for information only.

1. **TABLE 3.0A**

   Stratum areas in km^2. Since these are the same for all surveys, they are shown only for the xagaa survey.

2. **TABLE 3.0B**

   Sampling Region areas in km^2.

3. **TABLES 1.1, 2.1, AND 3.1**

   Densities per km^2 and estimates of livestock by strata, with standard errors for the whole survey area.

4. **TABLES 1.2A, 1.2B, 2.2A, 2.2B, 2.2C, 3.2A, 3.2B, 3.2C, AND 3.2D**

   Densities per km^2 and estimates of wildlife and wildlife features by strata, with standard errors for the whole survey area.

5. **TABLES 1.3, 2.3, AND 3.3**

   Densities per km^2 and estimates of livestock carcasses by strata, with standard errors for the whole survey area.

6. **TABLES 1.4, 2.4, AND 3.4**

   Densities of livestock biomass by species in kg/km^2 by strata, with standard errors for the whole survey area.

7. **TABLES 1.5A, 1.5B, 2.5A, 2.5B, 2.5C, 3.5A, 3.5B, AND 3.5C**

   Densities of wildlife biomass by species in kg/km^2 by strata with standard errors for the whole survey area.

8. **TABLES 1.6, 2.6, AND 3.6**

   Densities of all livestock and wildlife biomass in kg/km^2 by strata with standard errors for the whole survey area.

9. **TABLES 1.7, 2.7A, 2.7B, 2.7C, 3.7A, AND 3.7B**

   Densities per km^2 and estimates of water sources by strata, including the weighted water sources index, and the standard errors for the whole survey area.

10. **TABLES 1.8A, 1.8B, 2.8A, 2.8B, 3.8A, AND 3.8B**

    Densities per km^2 and estimates of rural houses (excluding those in refugee camps, large villages, and stratum 19) by strata, including the sum of all structures, and standard errors for the whole survey area.

11. **TABLES 1.9A, 1.9B, 2.9A, 2.9B, AND 3.9**

    Densities per km^2 and estimates of agricultural features, by strata, and standard errors for the whole survey area.

12. **TABLES 2.10 AND 3.10**

    Densities per km^2 and estimates of wood exploitation features by strata, and standard errors for the whole survey area.

13. **TABLE 2.11**

    Densities per km^2 and estimates of water-use features by strata, and standard errors for the whole survey area.

14. **TABLES 1.12, 2.12, AND 3.12**

    Densities per km^2 and estimates of irrigation features by strata, and standard errors for the whole survey area.

15. **TABLES 1.13, 2.13, AND 3.13**

    Densities per km^2 and estimates of riverine features by strata, and standard errors for the whole survey area.

16. **TABLES 1.14, 2.14, AND 3.14**

    Densities of occurrences per km^2 of riverbank cropping (for Survey 1 and 2), percentage of area under riverbank cropping and area of riverbank cropping (for Survey 3) by strata, and standard errors for the whole survey area. Percentage of area under receding-flood cropping and area of receding-flood cropping by strata, and standard errors for the whole survey area.

17. **TABLES 1.15A, 1.15B, 2.15, AND 3.15**

    Percentage of area under rainfed cropland types and areas of rainfed cropland types by strata, with standard errors for the whole survey area.

18. **TABLES 1.16A, 1.16B, 2.16A, 2.16B, 3.16A, AND 3.16B**

Percentage of area and absolute areas under different types of irrigation cropping by strata, with standard errors for the whole survey area.

19. **TABLES 1.17, 2.17, AND 3.17**

Percentage of area and absolute areas under miscellaneous land use, or in miscellaneous condition states, by strata, with standard errors for the whole survey area.

20. **TABLES 1.18, 2.18, AND 3.18**

Percentage of area and absolute areas of consolidated land-use categories by strata, with standard errors for the whole survey area.

21. **TABLES 1.19, 2.19, AND 3.19**

Areas sampled in km^2, percentage area sampled, and number of sampling units for the strata of the survey area.

22. **TABLES 1.20, 2.20, AND 3.20**

Densities per km^2 and estimates of livestock by regions, with standard errors for the whole survey area.

23. **TABLES 1.21A, 1.21B, 2.21A, 2.21, B, 2.21C, 3.21A, 3.21B, 3.21C, AND 3.21D**

Densities per km^2 and estimates of wildlife and wildlife features by regions, with standard errors for the whole survey area.

24. **TABLES 1.22, 2.22, AND 3.22**

Densities per km^2 and estimates of livestock carcasses by regions, with standard errors for the whole survey area.

25. **TABLES 1.23, 2.23, AND 3.23**

Densities of livestock biomass by species in kg/km^2 by regions, with standard errors for the whole survey area.

26. **TABLES 1.24A, 1.24B, 2.24A, 2.24B, 2.24C, 3.24A, 3.24B, AND 3.24C**

Densities of wildlife biomass by species in kg/km^2 by regions with standard errors for the whole survey area.

27. **TABLES 1.25, 2.25, AND 3.25**

Densities of all livestock and wildlife biomass in kg/km^2 by regions with standard errors for the whole survey area.

28. **TABLES 1.26, 2.26A, 2.26B, 2.26C, 3.26A, AND 3.26B**

Densities per km^2 and estimates of water sources by regions, including the weighted water sources index, and the standard errors for the whole survey area.

29. **TABLES 1.27A, 1.27B, 2.27A, 2.27B, 3.27A, AND 3.27B**

Densities per km^2 and estimates of rural houses (excluding those in refugee camps, large villages, and stratum 19) by regions, including the sum of all structures, and standard errors for the whole survey area.

30. **TABLES 1.28A, 1.28B, 2.28A, 2.28B, AND 3.28**

Densities per km^2 and estimates of agricultural features, by regions, and standard errors for the whole survey area.

31. **TABLES 2.29 AND 3.29**

Densities per km^2 and estimates of wood exploitation features by regions, and standard errors for the whole survey area.

32. **TABLE 2.30**

Densities per km^2 and estimates of water-use features by regions, and standard errors for the whole survey area.

33. **TABLES 1.31, 2.31, AND 3.31**

Densities per km^2 and estimates of irrigation features by regions, and standard errors for the whole survey area.

34. **TABLES 1.32, 2.32, AND 3.32**

Densities per km^2 and estimates of riverine features by regions, and standard errors for the whole survey area.

35. **TABLES 1.33, 2.33, AND 3.33**

Densities of occurrences per km^2 of riverbank cropping (for Survey 1 and 2), percentage of area under riverbank cropping and area of riverbank cropping (for Survey 3) by regions, and standard errors for the whole survey area. Percentage of area under receding-flood cropping and area of receding-flood cropping by regions, and standard errors for the whole survey area.

36. **TABLES 1.34A, 1.34B, 2.34, AND 3.34**

Percentage of area under rainfed cropland types and areas of rainfed cropland types by regions, with standard errors for the whole survey area.

37. **TABLES 1.35A, 1.35B, 2.35A, 2.35B, 3.35A, AND 3.35B**

Percentage of area and absolute areas under different types of irrigation cropping by regions, with standard errors for the whole survey area.

38. **TABLES 1.36, 2.36, AND 3.36**

Percentage of area and absolute areas under miscellaneous land use, or in miscellaneous condition states, by regions, with standard errors for the whole survey area.

39. **TABLES 1.37, 2.37, AND 3.37**

Percentage of area and absolute areas of consolidated land-use categories by regions, with standard errors for the whole survey area.

40. **TABLES 1.38, 2.38, AND 3.38**

Areas sampled in km^2, percentage area sampled and number of sampling units for the regions of the survey area.

41. Profiles of strata 1-34 for the first jiilaal survey, of strata 1-102 for the second jiilaal and xagaa surveys. These profiles list the density or percentage, the estimate, and the standard errors for all observed phenomena for each strata.

42. Profiles of regions 1-9, 20-23, 28, 31, 32, 35, 36, 39, 40, 43- 45, 48-50, 53-55, 58-60, 75, 76, and 78-85 for the first jiilaal survey, of regions 1-85, and 100 for the second jiilaal and the xagaa surveys. These profiles list the density or percentage, the estimate, and the standard error for all observed phenomena for each region.

43. Estimates of the numbers of each livestock species (and the percentage for each species) observed in specific types of activity for strata 1-34 for the first jiilaal survey and for strata 1-102 for the second jiilaal and xagaa surveys. Where a stratum has no livestock, no table has been produced.

44. Estimates of the numbers of each livestock species (and the percentage for each species) observed in specific types of activity for regions 1-9, 20-23, 28, 31, 32, 35, 36, 39, 40, 43- 45, 48-50, 53-55, 58-60, 75, 76, and 78-85 for the first jiilaal survey, and of regions 1-85 and 100 for the second jiilaal and xagaa surveys. Where there are no livestock for any region, no table has been produced.

Forestry in the Jubba Valley

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This report was prepared as part of the author's 33-day consultancy for ARD. The author was in Somalia from 16 September to 18 October 1987 and visited the Jubba Valley from 24 September to 6 October, traveling from Luuq to Kismaayo (see Figure 1 at the front of this volume). In Muqdisho, he studied some of the available literature and had many talks and meetings with people involved in related subjects and projects.

The terms of reference, in summary, were to:

- evaluate existing forest resources and uses of tree and shrub products in the area, and predict effects of Jubba Valley development on these resources;
- review current forestry/agroforestry practices and future management needs; and
- propose measures for forest management, investment, monitoring, conservation, and meeting projected needs for forest resources.

The study did not cover grazing, fodder resources, or pastoral activities.

The Agrar- und HydroTechnik, GMbH (AHT) staff had not yet provided new information which could be used for quantifying resources, so the resources data presented here were obtained by consensus from available information. This consultancy emphasized the practical issues of the present condition and degradation of the natural vegetation, the difficulties experienced by villagers in obtaining firewood within easy walking distance, and the likelihood of negative effects from proposed future developments. Much attention was paid to the status of the natural forests, despite their small number, as some of the ecological aspects are controversial. The agroforestry aspects have been treated briefly, not because they are unimportant but because their success achieved locally is extremely clear and widely recognized.

This report is particularly directed at those planning development in the natural resource and land management sectors to promote sustainable and managed use of existing woodland and bushland, the conservation of endangered habitats, and the creation of new wood resources, especially by farm planting.

I. EXECUTIVE SUMMARY

Most of the Jubba Valley is covered with woodland and bushland of varying density. All areas are subject to some degree of cutting and other uses by local residents and nomadic pastoralists, but in most of the valley, the vegetation is in good condition. The stocking is not severely reduced, and the productivity of the vegetation is probably close to its potential maximum. Around the small villages and even most of the towns, fuelwood and poles are gathered by hand without serious difficulties for the people or deterioration of the vegetation. Commercial gathering of firewood, mainly dead wood, is spread over wide areas without causing significant depletion. Charcoal is produced on a small scale in many places for town markets, often using dead wood or trees felled for land clearance, without serious consequences. However, if the demand for charcoal grows, or if the Jubba Valley is used to supply significant quantities to Muqdisho, the impact and deterioration will be much greater.

In the Luuq District, the concentration of refugee camps has resulted in a very large local consumption of all types of wood and livestock browse. The degradation of vegetation and soils over a wide area is extreme and getting steadily worse. Many residents must now walk at least three hours to reach areas with suitable firewood, and the difficulties and local prices are increasing.

In the southern Jubba Valley, agricultural projects and local concentrations of workers have also greatly reduced the readily available supplies of firewood and other wood products, causing deterioration in the vegetation and difficulties for the residents.

Investment in management, provision of fuelwood, and tree planting will be essential to improve these situations and to avoid the same deterioration in future areas of settlement and development.

The remaining small areas of riverine forest and closed woodland are being cleared for agriculture at a rapid rate, eliminating important resources of large timber and a unique natural plant community. After evaluating their status and ecology, it is concluded that these areas are dependent on subsurface groundwater infiltrating from the river, and that regulating the floods will not necessarily endanger their future existence. The conservation of representative areas is justified by their uniqueness in Somalia, for the rare plants and animals which inhabit them and for future generations of Somalis who will learn and benefit from them.

Tree planting, especially of fruit and shade trees, is practiced throughout the Jubba Valley, although usually on a very small scale. The National Range Agency (NRA) runs a nursery in every district and distributes several thousand free trees annually for planting in villages, refugee camps, and compounds. Around Luuq, and on a smaller scale in Jilib, active extension programs with farmers have been successful. Many farmers are now planting fast-growing, multipurpose fuel/pole/fodder trees in rows and strips. These serve as a model for promoting tree planting in other districts to make an important contribution to local wood needs.

It is recommended that:

- improved nurseries and extension programs be developed in all districts, in combination with small pilot demonstration plantations and species trials, to promote tree planting on farms and in all settled areas, with the aim of contributing to local needs and reducing the demand for cutting in the natural vegetation;
- cutting and collection of fuelwood for sale continue to be regulated by NRA over sufficiently large areas to ensure sustainable supplies without degradation;
- the existing forest reserves with the riverine forest and any other areas found to be suitable for conservation be demarcated, protected, and managed; and
- forestry-related activities be implemented by NRA staff and funding for the necessary extra equipment, transport, training, and technical assistance be included in regional development plans.

A. Introduction

Trees and shrubs of the Jubba Valley are of major importance both for their use values and for their protective function. Important components of this consultancy were, therefore, to evaluate the existing wood resource, both qualitatively and quantitatively; its use value at present and in the future; its function in reducing wind and water erosion; and the changes in all these which are expected to occur as a result of building a dam and other infrastructure; and of changes in the land use, population, and river flow.

These objectives are hard to achieve in one month, especially since many of the components are known only very approximately from rather few sample data; and other variables, such as growth rates, have hardly ever been measured in these or neighboring regions.

While it is impossible to have much confidence in the present quantitative estimates (or to define their confidence limits), it is possible to present some figures based on the available data from the study area. These figures are compatible with estimates made in Kenya and with the observations, calculations, and experiences of scientists working on these subjects, supplemented by the author's own reconnaissance survey. While results of JESS have provided more comprehensive data, this particular consultancy focused on a logical appraisal of the resource information in relation to the observed present and expected future impacts, in order to identify the key elements, changes, and problems.

B. Existing Forest Resources

Wood resources stocking in the Jubba Valley is highly variable because of both natural and man-induced factors. Even in areas which have been little affected by cutting, such as those far from water sources, and used occasionally only by nomads, the vegetation varies from low bushed grassland to rather well-stocked woodland. In areas close to the river, the variation is even more extreme, from cleared agricultural land to closed forest.

Table 1.40 of the Southern Rangelands Survey (SRS) (Watson and Nimmo 1985) shows estimates of timber and wood fuel volumes in cubic meters per hectare and total annual production potential in tons per hectare, for nearly 200 land system units (LSUs) in southern Somalia (Vol. 1, Part 1.2, pp. 122-8,). A partial description of how these quantities were calculated and the assumptions made is given in the section, "Estimates of Annual Production Potential for Charcoal and Woodfuel," (Vol. 1, Part 1.1, pp. 174-5). The estimates do not take account of the species composition of the trees and shrubs studied or whether they are or can be readily used for timber, charcoal, or firewood. Nevertheless, if the totals for timber and wood fuel are added together, they give an estimate of total woody biomass, irrespective of potential uses.

Table 1, compiled from SRS Table 1.40, shows the estimated woody volumes (timber plus fuelwood) for the 46 ecological zones recognized. It is not easy to ascertain what minimum size was used to define "firewood," but it appears that it was probably a small size, perhaps two centimeters in diameter.

The lowest values, particularly those of zero to two cubic meters per hectare, refer almost exclusively to exceptionally open areas such as sand dunes, agricultural projects or wetlands. The highest values (reaching over 400 cubic meters per hectare in some individual LSU) refer to areas with closed forest or dense woodland. According to these data, the LSUs most typical of the region have total woody resources ranging between three and 30 cubic meters per hectare. If an average specific gravity (SG) of 0.6* is used for all trees, shrubs, stems, and branches, the equivalent typical woody biomasses are two to 18 tons per hectare. An SG of 0.6 is lower than that of the preferred fuelwood material, the stemwood and heartwood of *Acacia* spp. and other dense woods, but there are many abundant trees and shrubs with a much lower SG, including *Commiphora, Ficus,* and notably *Adansonia.*

* If the specific gravity is 0.6, one cubic meter of solid wood weighs, on average, 600 kg.

*Table 1. Estimated Woody Volumes**

GEOMORPHOLOGICAL GROUP	ECOLOGICAL GROUP	WOODY VOLUMES in m^3/ha
Limestones	I	26.0
	II	13.1
	III	8.8
	IV	27.5
	V	18.2
	VI	3.3
	VII	8.2
Limestone	VIII	5.2
Transitionals	IX	19.7
	X	7.1
	XI	41.9
Volcanics	XII	5.9
Anhdrites	XIII	8.0
	XIV	3.6
Sandstones	XV	56.2
	XVI	53.7
Basements	XVII	22.4
	XVIII	14.0
Coastal Limits	XIX	18.1
	XX	49.6
	XXI	48.6
Coastal Dunelands	XXII	0
	XXIII	9.3
	XXIV	25.5
	XXV	0
Inland Dunelands	XXVI	31.8
Undifferentiated	XXVII	24.1
Sediments	XXVIII	17.1
	XXIX	52.2
	XXX	24.2
	XXXI	9.4
	XXXII	81.2
	XXXIII	1.4
	XXXIV	7.3
River Alluviums	XXXV	9.3
	XXXVI	2.4
	XXXVII	15.1
	XXXVIII	10.4
	XXXIX	0
	XL	0
	XLI	0
	XLII	15.6
	XLIII	66.1
	XLIV	2.0
	XLV	164.9
Mangrove	XLVI	14.6

**Source: Watson and Nimmo 1985.*

In the time available, it has not been possible to attempt a correlation between these LSU (derived from satellite imagery and visual inspection) and the standard vegetation communities used for vegetation mapping. Thus, it is not possible to apply the Watson and Nimmo estimates directly to the appropriate mapping units used by AHT, JESS and the Land Resources Development Centre (LRDC) study of 1985. The difficulty increases when very different vegetation communities are included within one LSU, uniform in geology, soil, slope, or water relations, but not necessarily in existing vegetation (for example, LSU L.XLIII.147 includes forest, bushland, and grassland, all in alluvial valleys and levees).

Although the assumptions made and the methods for calculating the biomasses leave much room for doubt about the accuracy of the estimates in Table 1, they are the only data available. They can be used as indicators of the ranges and general levels of woody biomass in the area, pending a more detailed study (including biomass calculations in the JESS monitoring sites and a comparison of the SRS LSU with the latest photography).

The SRS estimates have been compared with the early and provisional calculations of woody biomass made by members of the joint Somalia-United Kingdom ODA Forestry Project in some overlapping areas of southern Somalia, which include data for total tree and shrub biomass as well as the biomass of woody material larger than five centimeters in diameter. Insofar as it is possible to compare similar vegetation communities, using brief descriptions for each LSU in the SRS report, the Watson and Nimmo estimates appear to be somewhat higher than the British team's results.

A comparison has also been made with the results published by Western and Ssemakula (1981), referring to rangelands of Kenya. In this report, vegetation is classified into only five units, with canopy covers of less than one percent, one to two percent, two to 20 percent, 20 to 40 percent, and 40 to 80 percent. The estimated biomasses, referring to woody material usable for firewood and larger than two centimeters in diameter, appear substantially higher than the results obtained in Somalia for apparently similar canopy covers.

Table 2 presents provisional estimates of the total biomass of woody material for each of the AHT vegetation mapping units. These estimates refer to

Table 2. Provisional Estimates of Total Biomass of Woody Material for AHT Vegetation Mapping Units

	WOODY BIOMASS m3/ha	t/ha
Grassland: land dominated by grasses and forbs, with a canopy cover of trees or shrubs of 2%.	0-2	0-1
Bushed grassland: grassland with shrubs and some trees, scattered or in groups, with a canopy cover of up to 20%.	2-8	1-5
Bushland: land carrying shrubs up to about 6 meters high, with a canopy cover of up to 20%, interspersed with open, grassy areas.	5-15	3-9
Bushland thicket: bushland in which the multistemmed shrubs form an almost full cover, difficult to penetrate, with few open, grassy areas.	10-20	6-12
Woodland: land with over 20% canopy cover formed by trees or tall shrubs 10-15 meters high, easy to walk under, with a variable amount of smaller shrubs and a ground cover of grasses and forbs.	10-25	15-40
Woodland thicket: a closed woodland in which the trees and shrubs together form a complete cover, difficult to penetrate, with a few grasses (*Acacia, Albizia, Commiphora, Dobera, Terminalia, Adenia, Adansonia*).	30-60	18-40
Forest: land with a closed or almost closed canopy of trees 10-40 meters high, with a more open understory of smaller trees and shrubs, with little grass (*Newtonia, Ficus, Garcinia, Mimusops*).	50-300	30-200

woody material of all species and sizes above two centimeters in diameter. They are intended to be compatible with the Watson and Nimmo data summarized in Table 1, assuming that their estimates of "firewood" include small sizes. The British team's data would indicate that the figures in Table 2 are too high, while the Western and Ssemakula results suggest that they are too low, but it was agreed in discussions in-country during this consultancy that these are suitable provisional estimates.

The details for each ecological zone and LSU shown in the SRS report, and summarized in Table 1, demonstrate the great variations in stocking in the region as a whole and within zones ranging from dense tropical forest to completely treeless areas. The units used by AHT and JESS for classifying and mapping the vegetation are more uniform with respect to plant biomass, although they also inevitably include substantial variation due to the use of a few units of classification to divide a broad continuum of vegetation densities. At this stage, for planning purposes, it is neither possible nor necessary to make more than an approximation of the range of biomass typically present in each of the main vegetation units recognized in the JESS surveys.

Table 2 gives details of the principal units of vegetation mapping and classification, and a range of woody resource biomass. It is suggested that most of the areas mapped in these units have a total biomass of more than two centimeters in diameter within the ranges shown in the table. Most sites probably carry a biomass in the lower part of the ranges shown; some sites within the mapping unit will also obviously have higher or lower values.

At this time, estimates of the total areas mapped in each of these vegetation types were not available. When available, the figures should be multiplied to give an estimate of total resources existing in the study area, if such an estimate is required by the future planning authorities.

However, in this consultant's opinion, the available resource data, including regressions for converting plant dimensions into solid volume or biomass, are insufficient for making a more reliable estimate of woody resources or calculating the precision of such estimates. Furthermore, the highly approximate estimates which can be made by multiplying area data by unit volumes or biomasses will probably be quite sufficient for planning purposes in the near future. Plans for forestry activities will be based on identified problems, shortages, yields and constraints, which occur at a local level.

JESS sample sites are suitable for monitoring changes in cover, stocking and composition, such that a remeasurement in about five years or more should produce interesting results. However, none of the available regressions will enable accurate estimates of biomass per plot because of the extreme variability between and within species. Equally, the plots will not necessarily enable accurate estimates to be calculated of biomass or biomass change over the JESS area as a whole.

The existing regressions of size on volume/biomass may be used for estimating resources only if a large number of sample trees or plots are measured in each vegetation type. The regressions calculated by N. Bird of the British forestry team, Muqdisho, have the strongest statistical base of any available for the region, but it is not known to what extent it can be applied to species other than the two *Acacia* species studied. In spite of doubts about the reliability of regressions used by Watson or by Western and Ssemakula, they are the best available means of estimating biomasses of some of the other species. In the author's opinion, they may be used for the same species and also applied to species with similar forms and structures to provide rough estimates (with no statistical precision) until better regressions are available. JESS does not have the resources for calculating more regressions nor for carrying out large-scale sampling in order to estimate biomass from the available regressions.

Aerial photographs have already been used for vegetation mapping, and new large-scale photos have been taken of selected sites. Because of the difficulties of distinguishing the outlines of individual plants from those of their neighbors and determining their exact sizes, they appear to be of little use for quantitative biomass estimates. They will be very valuable for monitoring future vegetation changes, but only if a second set of photographs is taken of exactly the same sites from the same altitudes (a difficult task even for the original pilot).

The estimates in Tables 1 and 2 (even if they happen to be accurate) are only a part of the information needed for planning purposes or for identifying issues and problems, for two reasons. First, data for total woody biomass (even when subdivided into size-classes appropriate for sawn timber, charcoal production and firewood) do not take into account the species composition or technical properties of the resource. Many of the trees and shrubs are not, in practice, valued as a fuelwood resource, although they may be valuable for some other purpose. Second, much of the woody resource occurs far from the places where it could be used; different products are collected over different distances, depending on their value and means of transport; and averages and ranges of stocking over the whole area reveal little about the supplies which are actually available within reach of the users.

C. Uses and Products of Forest Resources

At this point, it is necessary to examine the actual uses made of different components of forest resources. Vegetation in all parts of the Jubba Valley has been affected to some extent by cutting and browsing. In more remote areas, biomass and species composition have been slightly affected by selective cutting of preferred species by nomads for housing and various implements. Near villages and cultivated land, and in areas more accessible by road or river, cutting and grazing have long been intensive. In spite of a shortage of information, certain effects of human and livestock use can be described with some confidence.

The total quantity and the average stocking of forest resources in the Jubba Valley have been reduced to varying extents in different parts. Over very large areas, absolute and proportional reduction in biomass have been small, and most areas probably carry at least 50 percent of their potential (and past) maximum. Over significant areas within a few kilometers of towns, villages and agricultural areas near the river, the resource has been more severely reduced. In these areas, the resource has been reduced to 10 to 40 percent of the stocking the area could carry—and probably did carry a few decades ago when settlements were fewer and smaller and the total settled population was much lower than today. In some areas, notably within a few kilometers of concentrations of refugee camps and major watering points, woody vegetation has been reduced to an even smaller proportion of its previous stocking. In these areas, however, there are usually some trees or shrubs, except in the most severely affected core of the area. These areas are known to bear the brunt of the shortage of resources for local uses and environmental protection.

While not necessarily the worst in terms of the size of the remaining resources or the environmental risks, the most severe reductions in the local biomasses are in the closed forests and *Acacia tortilis* and *A. zanzibarica* woodlands in the immediate vicinity of the Jubba River and other important drainage lines. Reports, photographs, and continued observations make clear that these communities have been greatly reduced in area and density by partial and complete clearances, often associated with permanent and temporary cultivation. This clearing is important even though these areas often carry a large stocking of shrubs and trees as regrowth or as partly cut or lopped trees. Some areas of woodland now being cleared for cultivation are probably regrowth or natural regeneration which has developed after forest clearance for agriculture in past years.

Although there is clear evidence of reduced forest resources, at least locally, more detailed consideration is needed before problems can be accurately identified and possible solutions proposed. It is necessary to evaluate the availability of and demand for resources with different uses, values and local importance. The main categories to be considered are:

- large trees (50 centimeters in diameter) for canoes and carpentry;
- medium trees for posts, beams, and pillars;
- trees and shrubs for charcoal and firewood;
- poles and sticks for walls, fencing, and roofing; and
- branches for fences and animal enclosures.

There is some overlap and flexibility in these categories. For example, small poles can be used for buildings and fuel even when larger ones would be better and almost any woody material can be used for fuel, if necessary, even if it is not the preferred species. Nevertheless, with current practices, only large trees can be used for traditional canoes, twigs cannot be used for charcoal, and houses need long, fairly straight poles in large numbers.

As stated, wood resources in each of these categories are exploited at different intensities, in different total quantities, often in different places, and have different values. Consequently, understanding variations in resources, problems caused by local supply, and demand differences are important for planning purposes.

Firewood is the most important category because of the quantities used and its daily impact. The overwhelming majority of Jubba Valley residents use only, or almost only, firewood for cooking. However, users are highly selective. Reports, confirmed by observations, show that in most towns and villages, most of the firewood used (and seen in markets, households, and trucks) consists of dead wood—often long dead, as evidenced by patches of insect attack and partial decay. Some of the smaller pieces noted had bark partially or fully attached, but appeared to have been dead for at least a few months. Firewood cutters probably left some live trees and branches to dry for future collection and use—several felled but unused trees were seen. In many areas, however, there is plenty of dead wood available. The wood used is of high density, almost all from *Acacia, Terminalia*, and a few other genera. Overall, firewood collection is not having a seriously damaging effect on the wood resource in most areas.

Most people gather firewood without cutting trees. Firewood resources are only a small part of the total woody biomass. Surveys and interviews have indicated that most firewood users in villages and towns, from Baardheere to near Jilib, obtain firewood by collecting it from nearby bushlands and woodlands, work that typically takes from 1.5 to three hours on each occasion, two or three times a week. In these areas, firewood supplies are locally considered adequate. Some town residents buy firewood from dealers who arrange collections from greater distances by truck. On the whole, good firewood is still abundant in relation to overall demand.

The regional firewood consumption has been estimated at about 400 to 1,500 kilograms (or 0.6 to two cubic meters) per person per year. These estimates may be compared to the typical biomass figures in Table 1 in relation to the total area and population of the region under study (data not available at the time of writing). There have been no measurements of local fuel consumption in the Jubba Valley. It looks likely that the lowest estimates refer to charcoal use in Muqdisho, which are quite inapplicable to the Jubba Valley. Since cooking methods in this region do not efficiently use firewood, and firewood is abundant over most of the area, average annual consumption is probably more than one cubic meter of high-quality firewood per person per year. Therefore, for provisional planning purposes, a consumption of 1,000 kilograms may be assumed.

However, in places where the local population is large, the local demand is much greater and the impact on the resource correspondingly more severe. This is particularly true where refugee camps are so closely concentrated that areas used for collecting firewood overlap. In Luuq District for example, several refugee camps and the old town all lie within one to three kilometers of each other. The effect is that of a town of over 100,000 residents collecting firewood from surrounding woodland and bushland. The observed results are the same as those which occur in similar situations all over the drier parts of Africa: woody biomass has rapidly declined, people have to walk increasingly long distances to collect firewood (often three hours from Luuq in this case), and the preferred and more efficient fuels are increasingly unavailable. Smaller, less suitable, and more time-consuming materials are used for fuel and are, therefore, not available for fencing, building or fodder material. Around population centers, the preferred resources of firewood and all other woody resources have been severely depleted and, locally, eliminated within several kilometers, leaving only some stunted shrubs, a few trees or small woodland patches which have received special protection, or new communities of a shrub, *Calotropis procera*, which is virtually useless. In addition, the low plant cover greatly reduces the actual productivity of the local vegetation. Increased rates of erosion from the bare soil and decreased organic-matter content reduce the long-term productive capacity of local soils. These constraints have major importance for planning purposes.

In these areas, a high proportion of individual family labor must be spent collecting fuel. However, it must be stressed that the cause of these constraints is not the refugee status of so many of the inhabitants. A similar effect occurs in other regions and may occur elsewhere in the Jubba Valley when towns, such as Baardheere and Jilib, grow larger. On a smaller scale, it is similar to the impact Muqdisho has on the regional resources preferred for charcoal. A particular feature of the fuel situation around Luuq is that a very high proportion of the population is unable to buy their firewood and must collect it within walking distance. Therefore, a major part of the demand must be satisfied within a radius of perhaps 10 to 20 kilometers. This is in distinct contrast to the situation in Muqdisho and even small towns, such as Bu'aale, where a significant proportion of the wage-earning population buys wood collected by dealers over much larger areas.

The near intensive agricultural development areas in Jilib and Jamaame districts also suffer from serious resource depletion and a concentration of population. In these areas, woody resources have been greatly reduced, although there are substantial areas of well-stocked woodland and bushland. It appears that many of the lowest paid agricultural workers, as well as smallholders, depend on local firewood collection by family members. Where the population density is high, the local depletion of resources is also severe, and it is reportedly not uncommon for people to have to walk over two hours to find suitable firewood.

House construction requires large quantities of sticks, posts, and poles. Typical houses require from several hundred to a few thousand poles, mainly of two to four meters in length and two to four centimeters in diameter, amounting to two to four cubic meters total. Reportedly, houses that are well constructed and maintained, preferably mudded inside and out, typically last for 15 to 30 years without major additions or replacements of poles (although unroofed and unmudded fences of woven poles may last only two years). Typical round houses are reported to contain five to 10 cubic meters of wood, and rectangular houses even more, when built with traditional techniques. During this consultancy, detailed measurements were made in only one house, a round house at the Government Rest House in Saakow. This house was eight meters across, and contained about 4,000 pieces, mostly smaller than two centimeters in diameter. It was calculated to contain 3.75 cubic meters of wood. Careful investigations of the wood content of other houses and how long they typically last would provide more useful information. Clearly, the annual average consumption of building poles per person is much lower than for fuel, as is commonly the case elsewhere. No local estimates of this annual consumption are available, but studies elsewhere suggest that it may be about 0.1 cubic meters per person.

Building poles have a high-use value and generally command higher prices than fuelwood to cover the cost of transportation over longer distances. Many woodland trees and shrubs produce poles at various stages of their life, particularly when young or when coppicing after partial cutting. The pole resource is, therefore, widely available. Since ideal poles have clear specifications with regard to length and straightness, the actual cutting is also widely spread. Pole cutting affects forest resources over much wider areas than family collection of firewood, while annually removing quantities which are much smaller, both overall and per unit area affected.

Canoes are made from large riverine trees, particularly from *Ficus sycomorus* and *Mimusops fruticosus*. Historically, these species have grown mainly in closed forests, although *Ficus* is also found in more open communities. Riverine trees and forests now occur in much smaller quantities than in the recent past (see further discussion in Section III). The remaining area of closed forest has been estimated at only about 10 percent of the total of 40 years ago. Some large trees remain outside the forest as relicts in land partly cleared for cultivation, but trees suitable for canoes have presumably declined by as much or more, as they have probably been removed from otherwise intact riverine forest areas. The pattern of cutting and use is different from that of other categories, since large trees are restricted to limited areas along the river. Canoes are used all along the river, so distances are not a serious obstacle to cutting.

Large trees are also used for carpentry, such as for making doors, chairs, and stools for local use. In all the towns and villages visited, there were woodworkers and carpenters (some working only part-time, undertaking individual orders). They use a variety of timbers, often from trees already cut for agricultural clearing. The total resource available for carpentry is being steadily reduced by the extension of cultivation, but the amount of carpentry practiced appears to be so small that it probably does not have a significant impact on forest resources. The demand for furniture and other timber products, however, will certainly rise rapidly with economic improvements and eventually be constrained by a shortage of suitable resources. Large trees are also used locally for making beehives (*Dobera* and *Hyphaene*) and mortars (*Dobera*).

Charcoal making has a different pattern of distribution. In spite of contradictory information from official and unofficial sources, this consultant saw evidence of charcoal available for sale in all district headquarter towns that is produced locally, mainly within 10 to 20 kilometers of each town. Often it is associated with forest clearing or tall *Acacia* stands for cultivation (dryland and irrigated), but it is also made elsewhere in forestland and woodland. Near Luuq, charcoal-making sites were seen in fine *Acacia tortilis* woodland. Near Baardheere, there is reportedly a charcoal cooperative at Busley. Near Bu'aale, a charcoal maker has been in operation for 11 years, selling in Saakow, Bu'aale, and Jilib and claims a monthly production of 40 bags (usually about 60 kilograms each). At present, only a small proportion of town dwellers use charcoal. They still insist on a high-quality material. Only a few woods (*Acacia* and *Terminalia* spp.) are used for charcoal, and often only dead wood and trees cut for other reasons. The cutting is widespread and in general has a minor impact on the total forest reserve.

Thorn fences also consume large quantities of branches, shrub stems, and regrowth. Almost all thorny or spiny plants are used, especially *Acacia, Balanites, Commiphora,* and *Ziziphus*. Enclosures usually amount to little more than a linear pile of branches, 50 to 80 centimeters high, with more branches added from time to time to maintain the barrier. They are used to restrict movements of domestic animals rather than protect them from predators. Enclosures are also put around cultivated areas (rainfed and irrigated) and private land valued for grazing. Many of these are located at some distance from the main concentrations of population and fuel consumption, and these thorny branches are not appropriate for fuel. The total wood resource in use for fences and the amount cut annually cannot be calculated, but it is probably on a scale similar to the consumption of building poles and charcoal wood.

More important, thorny branches are extremely abundant, as cut branches and stumps usually resprout and provide the material needed for repairs. The impact of cutting is restricted to the immediate vicinity of the fencing, and branches are not transported long distances (rarely as much as 500 meters). Therefore, in most agricultural and livestock areas and areas where nomads occasionally build stronger fences, the effects on local and regional resources are insignificant. However, in areas with a high proportion of fenced agricultural land—especially around towns where construction of household fences is combined with constant browsing by livestock and a local shortage of firewood—fencing helps accelerate the depletion of vegetation. The region around Luuq is an extreme example of this situation.

This discussion shows that cutting activities and hence, the process of biomass reduction, are a complex of separate and partly overlapping activities, occurring at different sites and different distances from the end-use. The end-uses themselves occur in different places—firewood and poles in towns, villages and rural areas; canoes along the river; fencing around fields and livestock. Impact on the vegetation may appear simple (*e.g.*, either thinning or clearing), but it is a complex process, interacting with regrowth. Only in a few special situations do the impacts combine to produce a continuing decline and eventual elimination of all woody vegetation.

Many other forest products are of local importance—edible fruits, fibers, medicines, tool handles, honey flowers, and much else. Although important, they do not involve such large volumes or values as fuel and poles. Some forest products of socioeconomic importance are considered elsewhere in the JESS surveys. They are not considered further in this report. It is believed that, for planning purposes at this early stage of land management, the best way to maintain supplies of these products is to maintain the productivity of the habitats. The same principle applies to maintaining supplies of livestock fodder. The forestry activities proposed later in this report are designed to avoid or reduce habitat destruction by fuel and pole cutting and thus, ensure the continued supply of these and many other products.

D. Dynamics Among Cutting, Growth, and Resources

For planning purposes, it is not enough to know or estimate the standing biomass and the annual use or off-take unless these figures can be related to the growth rate or productivity of various components and the net annual change in the resources. These data are difficult to quantify, since annual productivity of the various woody components of different vegetation types has rarely been measured satisfactorily in woodland and bushland, even on a research scale.

In mature, stable, undisturbed vegetation, the average net annual increment of wood is zero, with mortality balancing growth. Dead wood may decay or be extracted as fuel without affecting this "zero" growth rate. If some trees are cut, the biomass is reduced. Growth of the remaining trees and shrubs tends to restore the original biomass, resulting in a net gain in volume or weight. This net annual gain may itself be cut from time to time, and the remaining plants will continue to grow to replace it. Thus, a reduction in biomass is associated with an increase in net production. Achieving a maximum net annual increment, in theory and in practice, depends on the method and intensity of cutting. In most woody communities studied elsewhere, however, a high proportion of the maximum potential annual yield can be obtained with a standing biomass that is quite a low proportion of the undisturbed maximum.

In the Jubba Valley, a reduced standing resource of trees and shrubs does not necessarily mean a correspondingly reduced productivity. A significantly reduced production of useful wood will result from an excessive reduction in the standing resource, combined with such a high frequency of recutting or browsing that the remaining plants do not have time to grow to the required sizes.

In natural vegetation, which is a mixture of species, sizes, and ages, the total annual production of large sizes (logs for timber) is much less than that of small sizes (poles and branches). Therefore, if a community is subject to uncontrolled cutting and browsing of all sizes, from thorn branches to large logs, annual production of large sizes will decline even when production of small sizes remains (at first) as high as ever. This has happened around many towns where the standing resource and annual supply of large trees has declined while yields of branches and small wood remains high.

Many woodland and bushland communities inspected near settlements have a high intensity of utilization, thus a high annual production (within the limits of the local climate), and yet show no sign of a process of continuing deterioration. Most trees and bushes have had some stems and branches cut, but have continued growing or have resprouted vigorously, and the stocking appears high (50 percent canopy cover or more). This is consistent with a conclusion that continuous cutting and utilization, at an appropriate intensity, can maintain the productivity of the vegetation (and also its protective function) at levels close to the potential maximum, despite a substantial reduction in standing biomass.

In spite of a lack of any reliable information about biomass production or growth rates in this region, some estimates may be needed for planning purposes. The writer suggests that a "guesstimate" of 0.5 cubic meters or 300 kilograms per hectare per year may be used as the approximate annual increment of wood larger than two centimeters in diameter, in woodland and bushland communities that are already affected by cutting but not so degraded that there is a large proportion of bare ground. On this basis, the land within about 10 kilometers of a village may be capable of yielding about 15,000 cubic meters of wood per year on a sustainable basis—enough fuel and poles for more than 10,000 people. This estimate could be refined by adjusting it for different rainfall zones, but more exact predictions would be impossible until more data are available. Actual useful yields are determined by the particular product required and the current state of the vegetation.

When the rate of removal by cutting or browsing is larger than the growth rate, the standing resource will steadily decline. At some point, its growth rate (net annual production) will also decline, and it will be impossible to maintain the same rate of removal. The cutting may then be distributed over a wider area, at greater cost or effort. If the rate of cutting also increases, the total area harvested must increase, together with the likelihood of serious depletion and total clearance in the nearest and most accessible areas. This process is now occurring around many towns, with their rapidly expanding populations, and it will accelerate. However, it is acute in only a few areas, such as around Luuq and the refugee camps, as described by Wieland and Werger (1985).

The problem around Luuq is not simply that too much wood is being cut; rather, wood is being cut over too small an area. If the same rate of cutting could be uniformly distributed over a larger area, cutting could be sustained indefinitely without deterioration. Unfortunately, the necessary area of bushland for such a concentrated population would be too large for easy harvesting on foot.

Other smaller towns have avoided deterioration because the cutting is distributed over a large area. Families insist on high-quality firewood and are willing to work for an hour or two to find it, thus spreading the impact over a wide area. The total removed is in balance with the growth rate of the vegetation.

In this context, it is appropriate to mention the role of the NRA Forestry Department. In their attempts to control and tax the production of firewood and charcoal, the forest guards probably do little to reduce the total consumption but a great deal to distribute the cutting over a wider area. NRA performs an important role in ensuring that cutting does not exceed sustainable levels, except in areas of extreme demand, even though probably no areas are completing protected from cutting. Future increases and concentrations of population will make this role more difficult and more necessary. Any decline in yields around towns will have severe local consequences. However, declines may be avoided if NRA and MNPJVD collaborate to plan and manage the cutting and supply of fuel according to local needs by introducing incentives for cutting only in specified areas and promoting concurrent tree planting.

E. Conclusion

The total of all forest resources in the Jubba Valley and the potential for sustainable annual production are high in relation to present internal demand and consumption. However, in large population centers, as around groups of refugee villages and agricultural projects, wood yields from the natural vegetation within easy walking distance are inadequate to supply local needs. Difficulties in obtaining firewood and the deterioration of the local environment are severe and getting worse.

Supplies of poles, charcoal, and firewood can be sustained without environmental deterioration if they are transported over longer distances. In the case of large trees for carpentry, supplies are now so reduced that future demand cannot be satisfied from local resources.

III. RIVERINE FORESTS

A. Introduction

During the past half century, riverine forests in the Jubba Valley have been reduced to a small fraction of their earlier size (Deshmukh 1987). By far, the main cause has been clearance for agriculture, a process which continues today.

The remaining areas of riverine forest exist in many small patches, principally in Bu'aale District, with some located downstream (and some significant areas of related forest along the "little Jubba"), and some small patches located as far north as the gorge above the Baardheere dam site. Many patches are very small, often less than one hectare in size. Some are little more than a small group of surviving trees. All these patches can be considered as riverine forests, easily recognized and distinguished from closed woodland on the basis of structure and composition, even when partially opened.

Six separate areas of forest were visited during this consultancy. Interpretation of the ecological status of the forests is based on personal observations and on the written and verbal comments of other people who have seen them, guided by personal research into tropical forest regeneration and ecology, and previous knowledge of isolated and riverine forests in arid and semi-arid regions of northern Kenya and Uganda. However, this was a short visit to an area subject to many complex processes, made without the benefit of the company of the JESS ecologist. Hence, many of the comments which follow are ideas and possibilities based on the author's experience elsewhere, rather than firm conclusions derived from extensive research in the Jubba River Valley.

The following impacts are affecting these forests and may be expected to lead to continued decline:

- forest and woodland clearance for agriculture—JESS studies have shown a continuing decline in the area of closed riverine forests equivalent to 25 percent per year (compound) during the past four-year period 1983-87 (JESS Report No. 17);
- cutting trees for local consumption of firewood, charcoal, poles, fencing, timber and canoes;
- cutting trees for charcoal production for transport to Muqdisho and other centers;
- changes in flooding, sedimentation, and groundwater regimes after dam construction;
- reduction of the area which exceeds the threshold for successful reproduction of some forest species, resulting in the disappearance of some species and communities; and
- browsing and grazing by livestock, likely to increase in intensity and duration if tsetse flies are reduced and if human and livestock numbers are increased, leading to reduced regeneration and densities and causing retreat of forest margins.

B. Protection

NRA has declared four forest reserves (FR) since about 1982. It was not possible to confirm the exact legal status and gazetted details of these reserves, but senior NRA officials have confirmed that their legal status is assured while their areas and boundaries and the mechanism for their continued protection are being reviewed. The areas shown below are the approximate areas of closed forest in each reserve as reported at the time of reservation, not the total FR area, which is and will be larger, to include some surrounding woodland.

RESERVE	DISTRICT	SIZE
Barako Madow FR	Bu'aale District	100 hectares
Shoor[illegible] FR	Bu'aale District	150 hectares
Kaytooy FR	Jilib District	50 hectares
Nus-Duniya FR	Saakow District	50 hectares

The forest areas which previously existed around Kaytooy and Nus-Duniya (and in many other areas) have been largely eliminated or reduced to small fragments in recent years. In the case of Barako Madow and Shoonto, boundaries have been surveyed, mapped and marked with paint on large trees, partly following local roads. These boundaries include a few hundred hectares of closed woodland surrounding the forest. In both forests, access roads were cut, probably in 1984, and guards posted in nearby villages to improve protection.

Inspection showed that some poles are still being cut and removed from these two FRs, and a couple of small charcoal kiln sites were seen. However, it appeared that the intensity of current cutting is very low, although many signs of much older cutting were seen. It seems that the forest guards inhibit tree cutting, although do not completely prevent it. Some large trees which had been felled and cut up several years ago were now decaying. The NRA representative said that they had been felled before the area had been declared a reserve and that their removal had been forbidden. In Shoonto, the access road reaches a large open area of bushed grassland with scattered trees and stumps, which was once farmland, although no farming is permitted now. The area known to have been recently cleared in Barako Madow was not farmed and is now protected from further disturbance, according to NRA staff. Doubtless, the current limited cutting and disturbance of these forests will have some effect on their final composition and may reduce the abundance of certain species, but will not pose a threat to their conservation and integrity as forests.

The legal status of the unreserved patches of forest is unclear. It appears that the forestry authorities have substantial legal power to regulate or prevent tree cutting, especially for any commercial purposes, although in practice it is difficult for them to exert this authority. However, the Ministry of Agriculture apparently has power to authorize cultivation without reference to the forestry authorities, irrespective of the local vegetation, and there is little effective control over clearance and cultivation occurring without official approval. There is every reason to expect that the great majority of remaining unreserved forest patches will gradually be cleared during the next few years. Unless more areas are protected as FRs immediately, there will soon be no areas worth special protection. Experience elsewhere suggests that, even then, there will always be a few very small patches remaining, containing trees of no value, or on uncultivable soils.

C. Water Regime

The forest patches derive their water from all or several of the following five sources. The first is rainfall, which is about 500 to 600 millimeters per year. There are usually two rainy seasons. This total is insufficient to maintain closed, multistoried forest, but enough for dense woodland with a nearly full cover of trees or shrubs, especially if some species are deciduous. The second source is early morning mist, common in this region, especially July through October. It does not contribute much water to the root system but certainly reduces evapotranspiration demand.

Third, surface flow and underground seepage come in from surrounding woodlands. Surface flow and sheet erosion occur in some of the woodlands and bushlands during heavy rains. Probably, some riverine forest areas receive some surface flow, at least in natural drainage lines and along seasonal water courses. It is more certain that soil humidity is maintained by subsurface water flow from surrounding woodlands through many natural drainage lines at certain times of year. The importance of sub-soil drainage is shown in many broad valleys in the study area where there are dense groves of large *Acacia* trees and green grass long after the rains and far from the lowest water flow-line of the valley.

A fourth source is floodwater overflowing from the Jubba River. This is equivalent in some respects to a very heavy rainfall. Some sites may receive their full annual water requirements in one flood, although the water would not in practice remain available for a whole year. However, these floods occur once a year at most, usually less often. Some of the old, closed forest of Barako Madow FR, including the camp site of the 1986 U. K. scientific survey team, was not flooded by the high 1987 floods. No evidence of flooding was seen during a walk of about 1.5 kilometers from the campsite, through forest as dense and varied as any seen elsewhere. This shows that annual inundation is far from necessary to maintain the forest.

Fifth is subsurface water flows from the Jubba River. Some lateral seepage undoubtedly occurs from the main river channel, and much of the soil moisture in riverside forest is probably dependent on direct replenishment from the river for much of the year. It is impossible to quantify the importance of subsurface water without soil auguring, but several factors suggest that it is a major source:

- The locally high regional saline water table, often with a layer of rainfed fresh water on top is shallow (0.5 to 3 meters in depth around Jilib and Jamaame); this probably causes a broad-perched water table of fresh water below and on both sides of the river (feeding many village wells and the surrounding trees).

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- The strata of thick limestone pavement, frequent just below the surface in many northern areas, would also tend to spread the river water laterally, even if it occurred at a depth of several meters.
- Some dhesheegs, such as Banta, flood annually by infiltration without surface flow from the river—this is reportedly not common, but is convincing evidence of subsurface flow and probably often occurs in a less conspicuous form.
- Finally, substantial areas of riverine forest are not frequently flooded, yet are obviously thriving—such forests do not occur along the water courses that regularly dry out.

D. Regeneration

In the forests inspected, whether they had been inundated or not in 1987, ground cover was typically sparse and included a typical mixture of herbs and young climbers, trees and shrubs. There was nothing unusual to be seen in the distribution of sizes, nor any suggestion that the forest has an inadequate distribution of age classes, nor not enough young plants to replace the mature trees. As is usual in tropical forests, there is relatively little regeneration under the shade of the understory trees and bushes, but abundant young plants in natural gaps (*e.g.*, in JESS site 39 under a recently dead *Newtonia*). Regeneration of some species is probably dependent on such gaps, which give light-demanding species a chance to grow. It is, therefore, quite normal that young plants do no fully correspond to the species composition of the canopy. This is especially typical of forests affected by violent fluctuations (droughts, floods, waterlogging, and windblow).

No evidence was observed of flood-induced seedling regeneration or a recent flush of seedlings in the forests. If such a flush occurred after the last rains or flood, it would probably be quickly reduced by browsing animals, as in other tropical forests, leaving only a few seedlings to survive and possibly mature. However, a few examples of abundant seedlings were seen in sediments left by the flood in open areas. Near Luuq, an area of abundant young regeneration of *Tamarix* was found on a broad, low bank of sandy silt, left by the last flood. Near Jamaame nursery, patches of locally abundant seedlings of *Spyrostachys venenifera* were found on small steps of silt left on the river bank by the retreating flood. Both these species form thickets or low forest along the river bank and levee. This kind of seedling regeneration may be the start of a potential succession leading to forest, if left undisturbed, or to the formation of conditions suitable for some larger river-edge species, such as *Ficus*. Some areas of apparently even-aged *Acacia zanzibarica* occur, as near JESS site 76 above Baardheere, but these may have been formed by regeneration after forest clearance for agriculture rather than after flooding.

E. Nutrients

Flooding is also an important source of mineral nutrients, dissolved in the floodwater and deposited as mud and detritus (including stranded riverine animals, such as dead catfish, which are sometimes found in temporary ponds). Mud is not always deposited widely or deeply on the forest floor—there was little sign of mud on the forest floors flooded five months before. Much is probably filtered out and deposited in the ground vegetation close to the river margin.

Tropical forests are remarkable for their ability to maintain themselves and cycle their nutrients, even in very poor soils. It is possible that the species mixtures of the riverine forests have evolved a nutrient cycle which is specially adapted to repeated flooding and silt deposition. However, there is no immediate reason to believe that a change in nutrient inputs, resulting from controlling the flood regime, will have significant short-term effects on the status of the forests.

F. Soil Saturation

Flooding saturates the forest soil for long periods, which usually damages trees and other plants, except for specially adapted species of swamp forests. When the soil is waterlogged, trees are also often more vulnerable to windblow. However, no evidence was seen of mortality directly attributable to flooding, although there were more dead standing trees than in typical lowland tropical forests. Two trees had fallen, uprooted, beside JESS site 8 near Shoonto FR since the 1987 flood. It is probable that flooding has a negative effect on some species and contributes to tree instability. It is also possible that the forest may develop a slightly different composition and become locally denser in the absence of flooding, all other things being equal.

G. Wildlife

Wild animals—from hippos to bushbuck and beetles to bats—exert an important influence on the forest by grazing and browsing, pollinating, and eating and distributing fruits. All of these influences have no doubt selectively affected different species and the general composition of the forest. There is no indication that the current impact of wild animals, the occasional entry of domestic animals or elimination of elephants are a threat to the conservation of the forests as such, although these and other more subtle changes will probably affect the species composition eventually.

H. Forest-Woodland Dynamics

Most areas described here as forest consist of species seldom found in woodland or bushland. On the other hand, the typical woodland and bushland species exemplified by *Acacia* spp. are seldom found in closed forest. (Exceptions here and elsewhere are often caused by a retreat of the forest, leaving isolated forest trees in fields or fallow land or, more rarely, by forest expansion.) Nevertheless, the density and biomass of some closed woodland are sometimes comparable to those of low or open forest.

In the Jubba Valley, notably between Bu'aale and Jilib, there are large areas of closed woodland where tree and bush cover is almost continuous and the vegetation has many elements of forest structure. Livestock densities are still low because of the presence of tsetse flies, and rainfall is adequate at 600 millimeters per acre. In some parts, the species composition and structure change repeatedly over short distances (50 to 100 meters) between closed and relatively open forest and closed and open woodland. This was seen most conspicuously in a large area of "forest" north of Shoonto, reached by the road from Bu'aale which continues through two villages to Shoonto, forming part of the FR boundary.

These alternating vegetation communities are interpreted as marginal. The balance falls between forest and woodland determined by some limiting factor, probably soil moisture based on the riverine freshwater table. A change in moisture conditions, induced by a change in river levels (or historically by climatic fluctuations), may be expected to tip the balance for some marginal areas. Some existing marginal forest areas may be dependent on extra abundant soil moisture associated with high river levels. If flooding is prevented, these may become more open or develop into partially deciduous woodland. Woodland species may gain entry and forest species fail to regenerate. On the other hand, some marginal woodland areas may be potentially able to support forest, but are at present limited by the January to March dry season, when river levels and soil moisture drop to a minimum. After dam construction, when the river levels are maintained permanently above the present minimum, the forest species in these areas may be able to occupy the woodland sites, allowing the forests to expand somewhat.

It is not known how the soil moisture varies with distance from the river and changes in flow levels. If the variations are slight, only a small proportion of the area will be affected by the future changes in flooding. The whole area is adapted to violent seasonal and annual changes, and there is no evidence that the expected change in river levels will have a drastic impact one way or the other.

Hughes' (1986) study of the Tana River forests suggested the possibility that forest and habitat diversity may result from and be dependent on a regeneration succession initiated on newly deposited sediments, with very long cycles, and that a change in the flood regime may greatly reduce the diversity of habitats. A very restricted version of this process may occur along the Jubba River, although the modest variation in forest communities appears to be related more to distance from the river, and thus the prevailing moisture regime, than to age or successional status. On a smaller scale, stabilizing the water regime will reduce variability by stabilizing the forest boundary, reducing the already limited periodic local expansion and contraction. It will also reduce mortality and gap formation caused by waterlogging, probably resulting in a slightly more homogeneous forest.

However, such subtle processes may be masked by the other impacts, including reduction in the breeding population of the trees. The author has no information about the breeding systems of the trees on which to predict possible results.

I. Conclusion

The remaining small areas of riverine forest in the Jubba Valley are rapidly being degraded by wood cutting or cleared for agriculture. If present trends continue, most of these forest patches will be cleared within the next few years.

Shoonto and Barako Madow FR are protected by NRA. As a result, current levels of human interference and browsing by domestic and wild animals are not a threat to the continued existence of the forest. The control of flooding will probably affect some marginal communities along the forest-woodland transition boundaries. A more serious effect is possible, but it is unlikely that control of flooding will seriously affect the forests. The survival of the forests, however, will depend on continued adequate protection from fire, cutting and livestock. If the demand for grazing, wood products, and farmland continues to grow, and if NRA cannot protect forests adequately, they will be quickly eliminated. These two remaining FRs are almost intact and are unique in Somalia. They provide sites of very great potential value for research, training, education, and gene conservation. Expenditures needed to protect them are fully justified.

IV. FORESTRY ACTIVITIES IN THE JUBBA VALLEY

During this consultancy, visits were made to most NRA forestry offices and to all NRA nurseries along the Jubba Valley, in Luuq, Baardheere, Saakow, Bu'aale, Jilib and Jamaame district headquarters, and also to examples of all tree-planting activities. This section describes briefly the current forestry work being carried out.

A. Organizations Involved in Forestry Activities

National Range Agency, Forestry Department—A district forestry officer is stationed in each of the districts visited (although it appears that one person sometimes fulfills several positions within NRA). Most of these staff have had some technical training in the existing or previous forestry training schools in Somalia and occasionally abroad.

Some but not all of the forestry officers have a forestry vehicle; the others have access to an NRA vehicle from time to time. They have basic office facilities and a variety of tools and equipment. All have nurseries of variable sizes in or a few kilometers outside the district headquarters (see below).

Forest guards and forestry workers are employed in all districts in very different numbers (not obtained), according to the local resources and work program. The main activities are:

- seedling production in nurseries and free distribution of seedlings;
- planting and maintaining NRA plantations (especially Luuq, Bu'aale, and Jamaame);
- control and supervision of dealers and producers of fuelwood and charcoal;
- timber production on a small scale (*e.g.*, Bu'aale);
- protection of Forest Reserves (especially Bu'aale); and
- promotion of tree planting in towns and villages, especially shade and fruit trees.

In most districts, distribution of trees to householders for planting takes place mainly for the annual tree-planting day in April. At present, extension programs to promote farm planting in shelter belts and agroforestry systems are not a major activity, except in Luuq.

Church World Services (CWS), Refugee Forestry Programme—This group established the nursery in Luuq around 1983, in close collaboration with NRA, and carried out an extension program, especially in refugee villages, to promote tree planting. This program is still in operation, but is due to end in late 1988.

Gedo Community Forestry Project—This NRA project was begun in Luuq in late 1984 with USAID funds. It has carried out expansion and improvement of the Luuq nursery and an intensive agroforestry extension program among local farmers, promoting a wide variety of trees and shrubs for many purposes. Some vehicles and much equipment have been bought and extra staff and workers hired.

This project has been very successful, and a high proportion (although reportedly still fewer than half) of farms with irrigated land now have shelter belts and sometimes small plots of fast-growing species, such as *Leucaena, Eucalyptus, Conocarpus, Casuarina, Albizia lebbeck, and Azadirachta.* (see Appendix A). The interest and enthusiasm of the local farmers, particularly for the good fodder and poles which they are already obtaining, are very high. In fact, local interest is now so high that intensive promotion is perhaps no longer necessary to ensure the continued success of this program, but the organized production and distribution of seedlings will still be required. The USAID contribution to this project has ceased, however, so its future is uncertain.

World Concern—This group runs a leprosy center and a small nursery in Jilib. A wide variety of trees and shrubs has been introduced for distribution, demonstration, and trials. Seedlings of the most successful species are sold and the demand is high. The work in progress here is quite exceptional in its attention to local species, local needs, and the introduction of new species of potential from a variety of international sources.

Japanese Volunteer Service—This group is working in Luuq on agricultural improvements among refugees. It maintains a small nursery (not seen by this consultant) and promotes tree planting along the same lines as the main NRA program in Luuq.

Swedish Primary Health Project—Members of this Bu'aale project also distribute seedlings, especially of palms and fruit trees, and encourage tree planting.

B. Nurseries

The following nurseries produce tree seedlings in the Jubba Valley:

NRA and CWS maintain a nursery in **Luuq.** It is well equipped with hand tools and water system, and a full complement of housing, residences, and stores with several thousand plants of many species in stock. The original spacious layout, equipment, and pump were supplied by CWS in 1983. USAID provided funding for extra equipment, expansion, and NRA involvement from October 1984 to December 1987. To promote planting, seedlings are distributed free to households in the towns, villages, and farms, using project vehicles. The Japanese Volunteer Service also has a small nursery in Luuq.

NRA established a nursery in **Baardheere** around 1982, beside the Jubba River several kilometers outside the town. It has a small water pump, feeding directly into irrigation channels, but very few hand tools and no buildings or permanent fence. The nursery is roughly enclosed by a thorn branch fence. Fewer than 500 plants are now in stock, mainly neem and mango, most of which will be distributed on the annual tree-planting day.

In 1979, NRA first established its nursery in **Saakow**. It was later moved to a site near the river which was flooded out in 1987. The site is now marked by a square plot of trees of neem, mahogany, and Jerusalem thorn near the government rest house. The nursery occupies a small plot near the town water pump, with a temporary thorn branch fence, a minimum of hand tools, and no buildings. About 1,000 mango, papaya, tamarind, and neem plants are in stock.

Bu'aale has had an NRA nursery for about 10 years. Its two hectares are well equipped with permanent buildings, stores, fencing, pump, hand tools, internal paths, and irrigation channels. Some assistance has been received from the World Food Programme. The nursery has well-established plantation plots of teak. mahogany, neem, as well as many oleander, citrus, guava, mango, papaya, pomegranate ,and other plants. Tomatoes, lettuce and watermelon are grown for local consumption. About 5,000 seedlings of several species are in stock for free distribution.

The NRA nursery in **Jilib** is situated on about two hectares in Alessandria. It was established in the 1960s. Many large, old flamboyant, tamarind, mango, dhalab, and a few other trees date from that time. There are young plantation plots and lines of eucalyptus, teak, Indian almond, neem, mahogany, and others. Annual production is reported at a few thousand plants for free distribution, but fewer than 500 plants were in stock, including neem, cassia, flamboyant, whistling pine, mango, and teak. Watering involves hand-carrying water from the river because the pump reportedly broke down some years ago.

The Agricultural Research Station Nursery in **Jilib** (not seen by this consultant) produces fruit trees, especially mango, for distribution to farmers and projects.

World Concern's small nursery in **Jilib** produces a large variety of local and introduced species, partly for distribution and sale to farmers and partly for research in collaboration with the Oxford Forestry Institute. This is an excellent demonstration of the potential of many species (notably several species of *Leucaena*, two *Moringa* species, *Gliricidia sepium*, and *Sesbania grandiflora*) and combined tree and food production techniques.

NRA's **Jamaame** nursery, several kilometers outside the town beside the river, is in a large area of land owned by NRA (legal status not known). There is a water pump, but no buildings. The nursery raises several hundred seedlings for farmers, households, and the NRA plantation of teak, guava, eucalyptus, whistling pine, and neem. NRA has a 16-hectare block plantation nearby, by far the largest and best in the Jubba Valley—mainly teak, with two species of eucalyptus and two of mahogany. The plantation is well tended, protected, and irrigated, with annual plantings from 1981 to the present. Different spacings and combinations of tobacco, lettuce ,and other crops are being tried.

C. Conclusion

Planting of shade and fruit trees is understood and practiced throughout the Jubba Valley, even in the smallest villages, although often on a very small scale. A very large number of tree species have proved themselves suitable and successful in many areas. Intensive extension activities have had conspicuous success around Luuq. All districts have staff experienced in raising trees, and a local tree-planting model is available as an example.

Local NRA nurseries range from apparently busy and resourceful (Luuq, Bu'aale, Jamaame) to relatively unproductive, with widely varying resources. Since almost all are fairly new, there is every reason to expect that steady improvements will continue in proportion to the funds available.

Techniques and proposals for monitoring vegetation change,and growth rates have been discussed with the project ecologist Dr. Ian Deshmukh. The recommendations are summarized here.

Repeated measurement of permanent plots allows greater precision in calculating changes and growth rates than other methods, including the repeated measurement of unmarked temporary plots. Although the initial costs are higher, the subsequent costs of required precision will be much lower if at least some permanent plots are used. To make sure that the exact site of the plot can be relocated, even after an interval of several years, a robust marking system is needed, in combination with accurate survey details and a careful description. A combination of earth cairns, trenches, and buried steel pipes is recommended.

The access path to each plot should start at a permanent feature, such as a road, which can be precisely located on a map. The starting point may be marked by a cairn of earth, about 50 centimeters high, a short distance from the roadway, using earth excavated from a direction trench, about 0.3 x 0.3 x 2.0 meters, pointing along a line towards the plot. For added certainty, a similar cairn may be built on the opposite side of the road. The path to the plot should be precisely surveyed and measured and, if necessary, intermediate cairns and direction trenches built. The last cairn should be centered at exactly, say, two meters north of the northeast corner of the square plot, the sides of which are oriented north, south, east and west. (Such details may be changed to suit the size and shape of the plot.) A center cairn need not be built unless the plot is much larger than 20 x 20 meters. At each corner, precisely measured, a steel rod or pipe of a convenient length, preferably one meter, may be hammered vertically into the ground, with the top concealed well below ground level. If the survey and location details are well recorded, it will be possible to locate the plot corners to within a few centimeters with a tape measure and, precisely, with a metal detector.

To characterize the plot, the species composition and the main elements of the biomass must be defined qualitatively and quantitatively. To measure biomass of the trees and shrubs, it will probably be necessary to measure more than one variable, *e.g.*, crown diameter and height or stem diameters, on each occasion. This is because a biomass curve or regression based on one variable may give quite acceptable precision for the standing biomass on one occasion, but not for the change in the biomass measured on successive occasions. Even a small amount of growth or decline may be large in relation to measurement errors and the "precision" of the regression relationship.

If all trees and shrubs in each plot are individually measured on each occasion, net trends and changes may be estimated for purposes of ecological monitoring (*e.g.*, to detect a general deterioration or increase in the vegetation). However, this will not make it possible to calculate net annual or periodic production or growth rates. (Obviously, standing biomass may remain stable or even decline because of mortality or off-take, even though the plants may be growing vigorously.) Such calculations require marking, measuring and recording each individually numbered stem in order to define losses and ingrowth. Setting up such intensively marked plots is not recommended until a system and organization are established to ensure that such plots and data will be used.

VI. RECOMMENDATIONS

At the time of this study, proposed development objectives and priorities for the Jubba Valley have not been fully defined. The need for clear objectives was suggested during discussions between the AHT and JESS teams. The following list is tentatively proposed as a general development framework for the forestry sector of the Jubba Valley.

Objectives

- Satisfaction of the wood-product requirements of the region's inhabitants;
- maintenance of an adequate cover of vegetation sufficient to maintain the productive capacity of the soils and avoid unacceptable environmental deterioration; and
- long-term conservation of representative areas of rare and endangered communities of plants and animals.

Outputs

- Establishment of a management system for a stable and sustainable rate of cutting, extraction, and browsing in the natural vegetation;
- increased production of wood, fodder, and food from planted trees and shrubs; and
- effective management and protection of designated Forest Reserves and other conservation areas.

Activities

- Strengthening of the capabilities of the Forest Department staff to achieve these outputs, by providing the necessary materials and training;
- establishment of an extension service to promote tree planting by farms, households, and villages;
- introduction of rational management and harvesting programs in the woodland and bush areas; and
- demarcation, patrolling, and protection of forest reserves.

Inputs

- Materials needed for effectively mobilizing, supervising, and communicating with the forest guards;
- materials and wages to expand and improve all district nurseries and set up extension services;
- training courses, workshops and local study tours for extension and other forestry staff;
- design of a cutting plan for fuelwood and poles;
- species trials of more promising trees and shrubs; and
- data collection on growth rates and productivity of natural and planted trees.

The following recommendations are made for inclusion in the overall development plan for the Jubba Valley. It is envisaged that the early years of integrated development may be organized as a project with a component of foreign funding, monitoring, and technical inputs. It is strongly recommended that the forestry component should remain the responsibility of NRA, with coordination by MNPJVD or a project director as appropriate, and that NRA should be strengthened to enable it to carry out this component. This will help to ensure that experiences gained in other parts of Somalia will be used in the Jubba Valley (and vice versa); and, more important, that NRA will be able to carry out these activities even when any overall development project or coordination comes to an end.

First, to partly redress the serious situation around Luuq, or at least to keep it from getting worse, *major efforts should continue to encourage all landowners and householders to plant trees to contribute to their own and local needs for wood and other products.*

Second, to *promote tree planting in all other districts,* justified by the success and benefits already evident in Luuq, *nurseries and extension activities should be improved throughout the valley.*

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Third, *cutting of fuelwood and poles for sale in all towns should be regulated sufficiently to spread cutting over a wide enough area to avoid deterioration.*

Fourth, when a population is expected to grow so large that sustained fuelwood supplies can no longer be obtained within easy walking distance without causing deterioration, *measures must be taken in advance to ensure that fuel is transported over longer distances.* This recommendation is directed to towns which will expand rapidly during or after dam construction or resettlement of refugees, such as Baardheere.

Fifth, *the trees and shrubs in the inundation zone should be used before flooding starts.* Charcoal burners and firewood dealers should be encouraged to exploit this resource before using other areas. As an incentive, the wood may be issued free of charge, as it will otherwise be wasted. However, harvesting this wood in competition with dealers who collect high-quality fuel in the natural woodland will probably not be a profitable commercial undertaking. This study did not reveal any clear environmental reason for cutting or clearing trees in the inundation zone unless they can be used.

Sixth, *special provisions should be made for fuel and pole supplies for construction camps and all workers involved in building the proposed dam.* Fuel should be transported from clearly designated areas, not from the usual fuel collection areas of the towns and villages. Cutting should be strictly regulated to ensure an adequate supply of fuel without environmental deterioration. The wood in the inundation zone may be harvested for this purpose, as a provision of construction contracts.

Seventh, around refugee camps, where there is already a critical shortage of wood and severe environmental deterioration, and where the situation cannot be improved simply by regulating cutting, more action will be required. It is recommended that the *responsible authorities take action to ensure provision of fuel just as they now provide for some other basic necessities, such as food and water.*

Eighth, *the status of Shoonto and Barako Madow Forest Reserves (and any other areas worth the expense of conservation) should be clarified and strengthened immediately, before more is lost.*

Finally, *a monitoring system should be set up, with the main purpose of environmental-ecological monitoring,* first, to detect and quantify habitat changes and trends, especially degradation; and second, to quantify the annual productivity of the vegetation (which is more difficult and less urgently needed for planning purposes).

The terms of reference for the forestry consultancy included checking the library resources of the Oxford Forestry Institute for forestry literature relating to Somalia. This was done in September. On arrival in Muqdisho, the references found in Oxford were checked against the comprehensive forestry bibliography prepared by Neil Bird and others of the British Forestry Project. Only a few extra references were found and these are now added to the main bibliography.

Because this full bibliography exists, with forestry references for the whole of Somalia, a separate list for the Jubba Valley is not included here. A large number of reports and publications were reviewed during this consultancy, and contributed to this interpretation of the forestry situation; the following have been referred to in this report:

Deshmukh, Ian. 1987. "JESS Interim Report: Riverine Forests of the Jubba Valley, Issues and Recommendations for Conservation." *JESS Report No. 17.* Associates in Rural Development, Inc., Burlington, Vermont.

Hughes, F. M. R. 1986. "The Tana River Floodplain Forest, Kenya." Unpublished Ph.D. thesis. University of Cambridge.

Watson, R. M. and Nimmo, J. M. 1985. "Southern Rangelands Survey." *Final Report to the National Range Agency.* Mogadishu

Western, D. and Ssemakula, J. 1981. "A Survey of Natural Wood Supplies in Kenya and an Assessment of the Ecological Impact of its Usage." *KREMU.* Nairobi, p. 48.

Wieland, R. G. and Werger, M. J. A. 1985. "Land Types and Vegetation in the Luuq District of South-Western Somalia." *Journal of Tropical Ecology*, 1, pp. 65-87.

There is a long history of tree planting in the Jubba Valley, beginning with coconut palms in coastal areas some centuries ago, and spreading with mangos and kapok trees in towns and private estates in the early years of this century. During the 1950s and 1960s, many more species were widely distributed and are now well-known.

Only a minority of farmers and householders have planted trees on their own property, but almost every village, even the smallest, has at least a few planted trees of a few species. Some old towns, such as Luuq, have a wide selection of planted trees, including many large and old specimens.

During the past few years, still more species have been introduced. Some occur only in experimental plots, while others have been rapidly accepted and distributed, such as *Leucaena*. The following list shows species that are well-known, widely planted, and/or conspicuously successful and can be confidently recommended for extension programs.

Albizia lebbeck, boordi. Some old trees in Luuq and younger trees elsewhere.

Annona spp., custard apple. Few, but successful, as in Saakow.

Azadirachta indica, neem, geeh-hindi. Abundant.

Carica papaya, papaya, paw-paw. Widespread.

Cassia spp., probably including *C. siamea* and *C. fistula* and some Australian fodder shrubs. Locally excellent.

Casuarina equisetifolia, whistling pine.

Citrus spp., oranges, lemons, limes, grapefruits, mandarins. Widespread.

Cocos nucifera, coconut, qumbo. Abundant in coastal areas, seldom inland.

Conocarpus lancifolius, damas, ghalab. Some old trees in Luuq; younger trees elsewhere.

Delonix reqia, flamboyant. Old trees in Jilib and elsewhere.

Entandrophraqma spp., mahoganies. At least two species seen, including reportedly *E. caudatum*, planted near old nurseries in Saakow, Bu'aale, Jilib, Jamaame.

Eucalyptus camaldulensis, the most common, successful eucalyptus.

Euphorbia tirucalli, often planted as hedging.

Leucaena leucocephala, especially near Luuq, very fast growth in irrigated plantations.

Manqifera indica, mango. Widely planted, especially near Jilib.

Moringa spp. One seen near Luuq, and two species at Jilib with exceptional growth rates.

Parkinsonia aculeata, Jerusalem thorn. Successful and locally naturalized.

Prosopis juliflora, mesquite. Luuq and elsewhere, good growth.

Psidium quayaba, zeitun, guava. Few, but productive.

Sesbania grandiflora, shawri. Excellent growth in irrigated windbreaks near Luuq and elsewhere.

Tamarindus indica, tamarind, ragay. Large old trees in Luuq, Jilib, and elsewhere.

Tamarix aphylla, tamarisk, dhuur. In shelter belts.

Tectona grandis, teak. Successful with irrigation.

Terminalia catappa, Indian almond. In several towns.

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Surveys of Palearctic Migrant Birds in Somalia's Middle and Lower Jubba Valley

prepared by
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This report combines information from "Survey of Palearctic Migrant Birds in Somalia's Middle and Lower Jubba Valley," *JESS Report No. 19*, David Pearson, October 1987, and "Second Survey of Palearctic Migrant Birds in Somalia's Middle and Lower Jubba Valley," *JESS Report No. 25*, David Pearson, December 1987. Associates in Rural Development, Burlington, Vermont. All photographs in this report are by the author.

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This report is one of many produced during Phase II of JESS, a two-year period of intensive field studies. It was prepared by Dr. David Pearson, an ornithologist based in Nairobi, Kenya, and describes his observations of birds in the Jubba Valley during surveys conducted in March and November of 1987.

I. EXECUTIVE SUMMARY

In March and November 1987, two surveys of Palearctic migratory birds were conducted along the Jubba River, the river floodplain, and peripheral wetlands on the coast upstream between Kismaayo and Bu'aale (see Figure 1 in the front of this volume.)

In the first survey, several thousand migrant wading birds were observed on inland wetlands (mainly dhesheegs), the floodplain, and other wetlands between Fanoole Barrage and Bu'aale. The primary species seen were the wood sandpiper (*Tringa glareola)* and little stint (*Calidris minuta*). Over 1,000 ruffs (*Philomachus pugnax*) were present on irrigated patches of Fanoole Rice Project. Several hundred migratory ducks of one species, the garganey (*Anas querquedula*), were also found. An important coastal mudflat feeding area near Kismaayo was supporting over 1,000 wading birds.

Seven Palearctic passerine species were wintering in the area in substantial numbers. Rufous bush chats (*Cercotrichas galactotes*) and Upcher's warblers (*Hippolais languida)* occupied drier bush and thicket; nightingales (*Luscinia megarhynchos*) were in green floodplain thickets; and pied wheatears (*Oenanthe pleschanka*), Isabelline wheatears (*O. isabelline*), yellow wagtails (*Motacillaflava*), and Eurasian swallows (*Hirundo rustica)* occurred in open or cultivated country.

In the November survey, approximately 20,000 migrant wading birds were estimated inland in the valley below Jilib. About half of these birds were on irrigated rice projects at Fanoole and Mogambo, with the rest at Dhesheeg Waamo or scattered among the remaining small dhesheegs and muddy pools in cultivated areas. The primary species were the wood sandpiper and the ruff. Few wading birds were seen on the deeper flooded areas along Fanoole Barrage. Wading birds were generally more numerous and encountered lower in the valley than during the March survey.

Eleven Palearctic land bird species were encountered frequently. Numerous nightingales and smaller numbers of sprosser (*Luscinia luscinia*) observed in floodplain thickets from Jamaame southward were mainly in passage. Spotted flycatchers (*Muscicapa striata*), Eurasian cuckoos (*Cuculus canorus*), red-backed shrikes (*Lanius collurio*) and northern wheatears (*Oenanthe oenanthe*) found mainly on the floodplain were also in passage. Pied wheatears, Isabelline wheatears, yellow wagtails, Eurasian swallows, and blue-cheeked bee-eaters (*Merops persicus*) were probably newly returned passage birds.

A variety of other passage land birds was recorded, but in very small numbers. Wintering rufous bush chats and Upscher's warblers had not yet returned to the peripheral bushlands.

During the March survey, 270 bird species were recorded in Jubba Valley including 56 new records for the valley. During November, 43 more species were added for a study total of 313 species. In November, 13 new valley and five new records for Somalia were included on the JESS species list presented in Appendix A.

Construction and operation of the Baardheere Dam is not expected to have any significant negative impacts on wading birds, beyond the reduction of small, flood-prone areas used by wading birds. The dam should not adversly affect elements of habitat on which southward passage depends, in that the more important sites of the irrigated rice projects and Dhesheeg Waamo will likely not be affected.

II. INTRODUCTION

Existing studies of Somali birds indicate that approximately 380 species of birds are known in southern Somalia's Jubba Valley (Ash and Miskell 1983). These include approximately 20 forest species confirmed in Somalia for this region alone and 30 species of large water birds. The list also includes over 60 species of Palearctic migrants that winter or pass through the valley and have breeding origins in northern or western Asia.

The proposed siting of Baardheere Dam on the upper Jubba River and associated agricultural development projects in the middle and lower Jubba Valley will lead to changes in bird habitats and population densities. In view of the international conservation aspect of migratory bird protection, JESS included two ornithological surveys of the lower Jubba Valley. The first survey occurred 18-28 March 1987 and a follow-up survey took place 5-12 November of the same year. This report summarizes results of both surveys which were previously reported separately.

The purpose of the March survey was to determine the importance of the area as a wintering ground for Palearctic migrants. The main group of migrants present were wading birds and passerines with breeding origins in northern and western Asia, respectively. A heavy passerine migration is known to occur through eastern Kenya during November when there is more habitat available to wading birds on the Jubba floodplain than in March. The second survey was planned to coincide with the southward Palearctic migration.

III. METHODOLOGY

A. First Survey

Surveys of migrant water birds were carried out from Kismaayo north to Bu'aale, including:

- counts made on the river's silty banks and edges along several stretches of one to two kilometers each;
- approximate numbers counted on each dhesheeg visited that was still wet and any areas of river floods encountered—these were all located in the middle section of the valley between the Fanoole Barrage and Bu'aale;
- assessment of the occurrence of migrants on the irrigated areas of the Jubba Sugar Project and Fanoole Rice Project in the lower Jubba Valley; and
- a brief survey of the numbers of migrant waders on the coast at Kismaayo.

Migrant songbirds were sought and listened for during the three hours after dawn and two hours before dark in a variety of habitats—green riverine and woodland, and thick, drier, dense *Acacia* sp. thickets on floodplain clay soils; green scrub around irrigated ditches and dams; and dry peripheral bushland on lighter soils, mainly *Acacia nilotica/Dobera* bush, but also *Acacia tortilis* woodland on red sandy soil near Kismaayo and Goob Weyn. The occurrence of migrant land birds was also assessed in open grasslands and cultivated areas, mainly when traveling by vehicle.

Although emphasis was on migrant birds throughout, notes were also kept on all Afro-tropical birds encountered. Counts of large African water birds were made at some sites, and an impression of their general abundance and distribution in the valley was recorded.

Mist-nets were available but not employed because there were indications that migrants were present in the bush and thickets in low density, and there were no identification problems to be resolved. Further, the use of nets greatly reduces mobility, and the time available for the whole survey was limited.

B. Second Survey

Surveys of migrant water birds were carried out from Kismaayo up to Fanoole as follows.

First, the largely flooded Fanoole and Mogambo Rice Projects were visited and surveyed extensively. Approximate estimates of wading bird numbers were obtained by recording abundances on paddies at different stages of flooding and rice growth, and multiplying densities.

Then, as many areas of natural inland flooding as possible were located, and complete counts or sample counts of wading birds and other water birds were made. Sites included:

- small, shallow pans or cultivated land which had been filled by rain and/or the river between May and August;
- larger, deeper dhesheeg areas (over 50 hectares) at Jamaame and Kamsuuma;
- deeply flooded pools and dhesheegs among woodlands, associated with the river at and up to a few kilometers north of Fanoole Barrage;
- the extensive Dhesheeg Waamo, which was dry at the eastern end, but still had over 50,000 hectares flooded, with dense vegetation at borders and open muddy shoreline areas where livestock had been watered regularly; and
- the coastal mudflats near Kismaayo.

Rain during the field visit made roads impassable above Fanoole Barrage and consequently, it was not possible to visit Shoonto or Bu'aale.

Palearctic passerines and other land birds were again observed in thicket and woodland habitat along the river, on the floodplain, and in the peripheral bushlands, mainly during the early morning and late afternoon. Where possible, sites visited during March were checked again on this trip. As a result of the rains between May and August, as well as heavy river flooding, an abundance of lush green habitat was present in the lower Jubba Valley, especially on the floodplain from the edge of the forested areas above Fanoole south to Jamaame. The

Woodland edge thicket—habitat of wintering nightingales. Warthogs in foreground.

Lilac-throated roller.

peripheral bushlands were also greener and thicker than in March, especially around small, wet or recently dried flood pools. The Deyr rains were a constant part of this survey, with rainfall at nearly every site visited. Substantial downpours were encountered at Jilib, Fanoole, and Jamaame, which resulted in a rapid greening of these areas during the period in the field and probably served to ground some overflying migrants. However, south of Jamaame, toward the coast and around Dhesheeg Waamo, the bushland was relatively dry.

A. First Survey

During the 10-day survey, 270 bird species were recorded in the Jubba Valley. Of these, 16 were new to the valley, according to the data given in Ash and Miskell (1983). There were 56 Palearctic species observed. The individual occurrence and status of these Palearctic species are detailed in the systematic list provided in Appendix A. A complete list of the Afro-tropical species recorded is given in Appendix B. Apart from five birds of prey—the booted eagle (*Hieraaetus pennatus*), Eurasian marsh harrier (*Circus aeruginosus*), pallid harrier (*C. macrourus*), Montagu's harrier (*C. pygargus*), and blue-cheeked bee-eater (*Merops persicus*), migrants were either water birds (waders, terns, one gull, and one duck) or passerines.

1. Palearctic Water Birds

The Palearctic water birds observed were waders (*Scolopacidae* or *Charadriidae*) with breeding origins in northern Siberia.

Edges of the Jubba River

Counts were done for one- to two-kilometer stretches along the river at Goob Weyn, near Jamaame, north and south of Jilib, at the Fanoole Barrage, near the Shoonto forest, and at Bu'aale. The numbers of waders seen along the river were low—with one exception, these counts yielded between two and 20 birds per kilometer with an average of four birds per kilometer. By extrapolation, this produces an estimate of only about 1,000 waders along the whole 170 kilometers of the river north to Bu'aale, which is relatively low in comparison to other sections of the river, different parts of the Jubba Valley, and similar rivers in East Africa (*e.g.*, the Tana in Kenya). The main species observed were the common sandpiper (*Actitis hypoleucos*), little stint (*Calidris minuta*), greenshank (*Tringa nebularia*), wood sandpiper (*T. glareola*), and ringed plover (*Charadrius hiaticula*). An unusual concentration of about 300 waders, as well as many African storks and herons, were present on the new cut around the Fanoole Barrage. Most of these waders were ringed plovers.

Dhesheegs with Residual Water and Flooded Areas Between the Fanoole Barrage and Bu'aale

Birds were counted at two large dhesheegs with over 100 hectares of standing water—one near the forest at Shoonto and the other near Bu'aale (Dhesheeg Rediile). Two smaller, muddy-edged areas of flooded bush near Fanoole were also examined. At least two more wet areas existed in thick bush a few kilometers north of Fanoole, but were not accessible. These areas were the only sites found outside irrigation projects with floodwater still present. All the dhesheeg sites on the lower Jubba were reportedly dry.

The Shoonto Dhesheeg supported an impressive and varied concentration of water birds, including about 1,000 waders and 50 garganey ducks (*Anas querquedula*). The little stint, wood sandpiper, and curlew sandpiper (*Calidris ferruginea*) were the main wader species seen here. Spotted redshanks (*Tringa erythropus*) and Temminck's stints (*Calidris temminckii*) were also of interest. The former has not been recorded before in the Jubba Valley.

About 900 waders were found at Dhesheeg Rediile. The little stint was again the main species, but marsh sandpipers (*Tringa stagnatilis*) numbered over 100 and a flock of 400 Caspian plovers (*Charadrius asiaticus*) was present. Garganey ducks (about 80) were also found.

Even without surveying a few additional large dhesheegs along the Fanoole-Bu'aale section that the author knows exist but was unable to visit, these counts would suggest that at least 3,000 to 5,000 waders were wintering in this part of the valley.

Irrigated Agriculture

Most of the irrigated agriculture areas visited from Jilib south were dry at the time of this survey. A few small, flooded pastures were observed along the Fanoole Canal and on the Jubba Sugar Estate at Mareerey, as well as canals, ditches, and ponds in the Jamaame area. Only a few hundred waders were found at these sites, predominantly wood sandpipers. The Mogambo Rice Project was dry, but an estimated five percent of the paddies on the Fanoole Project were flooded and supported over 1,000 ruffs (*Philomachus pugnax*) in addition to many hundreds of local ducks, geese, and a few garganey.

Estimates of the total numbers of various migrant water bird species on the Jubba's inland wetlands as far up as Bu'aale are shown in Table 1. In all, 15 species of migrant waders were recorded, but only eight of these were observed in substantial numbers. Except for the Caspian plover, which breeds in central Asia, the major species concerned were from northern Siberia. The overall number was approximately 10,000 birds, with the majority utilizing the middle Jubba dhesheegs and other flooded areas.

Table 1. Numbers of Palearctic Water Birds Estimated on Inland Wetlands of the Middle and Lower Jubba Valley, March 1987

common sandpiper (*Actitis hypoleucos*)	200-1,000
curlew sandpiper (*Calidris ferruginea*)	300-1,000
little stint (*C. minuta*)	2,000-10,000
Temminck's stint (*C.temminckii*)	30-100
Caspian plover (*Charadrius asiaticus*)	over 400
little ringed plover (*C. dubius*)	30-100
ringed plover (*C. hiaticula*)	500-2,000
common snipe (*Gallinago gallinago*)	few
black-tailed godwit (*Limosa limosa*)	over 2
ruff (*Philomachus pugnax*)	2,000-5,000
spotted redshank (*Tringa erythropus*)	over 20
wood sandpiper (*T. glareola*)	1,000-5,000
greenshank (*T. nebularia*)	200-500
green sandpiper (*T. ochropus*)	few
marsh sandpiper (*T. stagnatilis*)	300-1,000
TOTAL WADERS	7,000-25,000
garganey (*Anas querquedula*)	200-1,000
white-winged black tern (*Childonias leucopterus*)	over 200
gull-billed tern (*Gelochelidion nilotica*)	over 20

The Coast at Kismaayo

Like most of Somalia's coast that faces southeast, the shoreline near Kismaayo consists mainly of narrow sandy beaches with rocky coral headlands and associated small patches of seaweed. Such coastal habitat offers greater limited feeding possibilities for migrant waders than, for example, the extensive intertidal coral shelf present along much of Kenya's coast. Small numbers of waders (about 20 to 30 per kilometer) were counted on the beaches south of Kismaayo. The principal species here were the sanderling (*Calidris alba*), turnstone plover (*Arenaria interpres*), grey plover (*Pluvialis squatarola*), and curlew sandpiper. All of these species migrate from the arctic coasts of Siberia. Great and Mongolian sandplovers from southwest and central Asia were also observed.

A more important find was a tidal mudflat of 100 hectares or more at Kismaayo. This area supported about 4,000 feeding waders (see Table 2), with curlew sandpipers predominant. The numbers here were comparable with those found at Mida Creek, the best-known of Kenya's coastal wader sites. Thus, on a coast that supports only moderate numbers of migrant waders, the Kismaayo flats clearly constitute a feeding site of major importance.

Table 2. Numbers of Coastal Palearctic Waders Counted on Kismaayo Mudflats, 26 March 1987

common sandpiper (*Actitis hypoleucos*)	2
turnstone (*Arenaria interpres*)	200
sanderling (*Calidris alba*)	300
curlew sandpiper (*C. ferruginea*)	2,500
little stint (*C. minuta*)	300
Kentish plover (*Charadrius alexandrinus*)	3
little ringed plover (*C. dubius*)	1
ringed plover (*C. hiaticula*)	50
great sandplover (*C. leschenaultii*)	200
Mongolian sandplover (*C. mongolus*)	200
crab plover (*Dromas ardeola*)*	50
curlew (*Numenius arquata*)	3
whimbrel (*N.* phaeopus)	15
grey plover (*Pluvialis squatarola*)	60
greenshank (*Tringa nebularia*)	30
redshank (*T. totanus*)	8
Terek sandpiper (*Xenus cinereus*)	50
TOTAL	approximately 4,000

*Migrant from the Red Sea area.

2. Palearctic Passerines

In all, 19 migrant passerine species were recorded, but only eight were wintering in the Jubba Valley in substantial numbers. Three species were found in bush and thickets. The rufous bush chat (*Cerotrichas galactotes*) and Upcher's warbler (*Hippolais languida*) were almost always located in drier, scattered open bush peripheral to the floodplain. Densities of approximately 0.5 and 0.1 birds per hectare, respectively, appeared to be typical for these two species. They were more numerous (along with other Afro-tropical bush species) in the red sand woodlands (*Acacia tortilis*) near Kismaayo, but both presumably ranged north to Bu'aale and further up the Jubba. Nightingales (*Luscinia megarhynchos*) were found locally in riverine woodland thickets along the middle Jubba as well as in patches of rank bush around irrigation channels and ponds near Jamaame. They were confined to dense, green habitats on the floodplain and were only numerous at one site—on the green edges of a woodland thicket around the Shoonto Dhesheeg.

Four more species were widespread and commonly found in cultivated and open country. Hundreds of pied wheatears (*Oenanthe pleschanka*) were seen from the coast up to Bu'aale. Isabelline wheatears (*O. isabelline*) were as common on the flat, dusty plains nearer the coast, though uncommon further up the valley. Yellow wagtails (*Motacilla flava*) were found in small groups near water, at dhesheegs, on other flooded patches, and in cultivated areas. Finally, Eurasian swallows (*Hirundo rustica*) were seen in small numbers throughout the valley, though mostly on the floodplain.

All of the eight common wintering passerines discussed above would have originated mostly in southwest Asia. The rufous bush chat and Upcher's warbler have wintering ranges that are restricted to southern Somalia and eastern Kenya.

3. Afro-tropical Species

Large Water Birds

During this survey, the opportunity was taken to record the numbers of larger African water-bird species observed. Even very approximate estimates should provide a useful, dry-season baseline for future comparisons with wet periods, when the numbers will undoubtedly be far higher. The groups involved were the fish- and invertebrate-eating herons, storks, ibises, spoonbills, cormorants, ducks, and geese.

For the herons, 10 main species were seen including, commonly, the Goliath heron (*Ardea goliath*). A few thousand herons were found in all, with most on the lower Jubba. Over 300 were counted at the Shoonto Dhesheeg alone.

The storks seen were of four main species, including the very common and widespread open-billed stork (*Anastomus lamelligerus*) and large, spectacular saddle-billed stork (*Ephippiorhynchus senegalensis*), of which approximately 15 individuals were encountered. Well over 1,000 storks were seen in all, with open-bills often found in groups along the river's edge and in all cultivated and marginally wet areas on the lower Jubba as well as in larger flocks on the middle Jubba.

Three species of ibises were observed, totaling many hundreds of birds. Impressive gatherings of glossy ibis (*Plegadis falcinellus*) were present on some of the middle Jubba flood areas. Scores of African spoonbills (*Platalea alba*) and many long-tailed cormorants (*Phalacrocorax africanus*) and darters (*Anhinga rufa*) were also seen.

A few thousand ducks and geese were seen, which included large gatherings on dhesheegs and irrigated areas at the Fanoole Rice Project. The main species concerned were the Egyptian goose (*Alopochen aegyptiacus*), white-faced whistling duck (*Dendrocygna viduata*), and knob-billed duck (*Sarkidiornis melanotos*).

Forest Birds

The few remaining patches of riverine forest between Fanoole and Bu'aale were not visited, and no special attempt was made to observe forest birds However, many of the birds listed by Madgwick* as dependent on the remaining riverine forests were observed during this survey in thick bush, woodland, or mango trees near the river, mainly on the middle Jubba. This indicates that some, if not all, of these birds may not be as dependent on the riverine forests as suggested by Madgwick. The species concerned are these:

- Kenya crested guinea fowl (*Guttera pucherani*),
- African goshawk (*Accipiter tachiro*),
- Fischer's turaco (*Tauraco fischeri*),
- African wood owl (*Ciccaba woodfordii*),
- crowned hornbill (*Tockus alboterminatus*),
- black-headed apalis (*Apalis melanocephala*),
- eastern banded scrub robin (*Cerotrichas quadrivirgata*),
- dark-backed weaver (*Ploceus bicolor*),
- tambourine dove (*Turtur tympanistria*), and
- black-throated wattle eye (*Platysteira peltata*).

*Madgwick, *et al.* 1986. "An Ecological Study of the Remaining Areas of Riverine Forest in the Jubba Valley,, Southern Somalia." Preliminary report of the Somalia Research Project,. University College, Longon.

African spoonbills.

Great white heron, sacred ibis, black-headed heron, and woolly-necked stork.

Dhesheeg Rediile–Marabou storks.

Open-billed storks.

These species (also see Appendix B) would presumably survive on the Jubba even if the remaining areas of true riverine forest were lost to development.

B. Second Survey

During the eight-day survey, 43 more bird species were recorded in the lower Jubba Valley, in addition to the 270 species recorded in March (Pearson 1987), for a JESS study total of 313 species in the lower Jubba Valley. These new additions include 13 species previously unrecorded in the Jubba Valley and five new species records for Somalia (Ash and Miskell 1983). A total of 67 Palearctic species were observed during this survey, including 19 species not recorded in March. The individual occurrence and status of Palearctic species in March and November are detailed in the annotated list in Appendix A. Appendix B contains the complete checklist for all bird species recorded during the two surveys.

1. Palearctic Water Birds

A few migrant ducks had returned. Parties of up to 40 garganey (*Anas quequedula*) were noted at Jamaame and Dhesheeg Waamo, and two shovelers (*A. clypeata*) were seen. A black stork (*Ciconia nigra*) at Fanoole Rice Project was a new species record for Somalia. Otherwise, Palearctic water birds were all waders (*Scolopacidae* and *Charadriidae*). Their occurrence and abundance are outlined below.

Irrigated Rice Projects

At Fanoole, a high percentage of the paddies were flooded and had rice growing. Wading birds were thinly scattered in the main, but were concentrated particularly on newly churned up, muddy paddies and more open areas with short rice. Most paddies contained only one or two birds, but some had over 100. Multiplying densities gave a conservative estimate of about 3,000 wading birds on the whole project. Over two-thirds of these were wood sandpipers (*Tringa glareola*) and most of the remainder were ruffs (*Philomachus pugnax*).

The Mogambo Irrigation Project was about 50 percent flooded. Again, wading birds were scattered, but as many as 200 to 300 birds were found on some of the more open, muddy paddies. A crude estimate for the whole area gave some 8,000 birds, with wood sandpipers and ruffs in almost equal numbers and together, accounting for over 80 percent of all birds. Other major species were little stint (*Calidris minuta*), marsh sandpiper (*Tringa stagnatilis*), and ringed plover (*Charadris hiaticula*).

Natural Flood Areas

The dhesheegs and pools at and just north of Fanoole Barrage were deep and provided little muddy habitat. In contrast to March, this area supported few wading birds. Other flooded areas north to Bu'aale were inaccessible, but it is unlikely that sites such as the Shoonto Dhesheeg would provide much habitat for wading birds at this stage of the flood cycle.

A number of small, drying pools on cultivated areas near Jilib typically supported about 100 to 200 wading birds each. The main species were wood sandpipers and ruffs, with smaller numbers of little stints, curlew sandpipers (*Calidris ferruginea*) and greenshanks (*Tringa nebularia*). Similar sites near Jamaame and larger dhesheegs at Kamsuuma and Jamaame held a similar assortment of species, but numbers were never large. The number of small wading bird sites was limited and clearly decreasing fast as these remaining pools dried up. However, assuming that there were a considerable number of such pools which were not observed, an estimate of wading birds present on naturally flooded areas between Jilib and Jamaame would not be less than about 3,000 birds. Wood sandpipers predominated at such sites, followed by ruffs and little stints. Several sightings of Temminck's stints (*Calidris temminckii*) were noteworthy, as was the inland occurrence of terek sandpipers (*Xerus cinereus*) at Jilib and Jamaame.

The flooded part of Dhesheeg Waamo had a perimeter of at least 30 kilometers. Along one kilometer of relatively open shoreline with mud and short grass, 200 wading birds were counted. These included 80 wood sandpipers, 70 ruffs, and at least five great snipes (*Gallinago media*), a new species record for Somalia. Such high wader densities were not present along more highly vegetated stretches of the water's edge, but wood sandpipers were observed at most pools, even among reeds and *Acacia nilotica* thicket. There were local reports of other stretches of open shore on the other side of the dhesheeg. A reasonable estimate of wading birds at Dhesheeg Waamo would be over several thousand birds.

Kismaayo Coastal Mudflats

On 10 November, wading birds were observed moving up to the edge of these flats with the rising

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tide before flying off to roost. The total number of birds was 4,000 to 5,000, similar to the March count. The species composition was also similar with curlew sandpipers predominant, followed by great sandplovers (*Charadrius leschenaultii*), Mongolian sandplovers (*C. mongolus*), sanderlings (*Calidris alba*), and turnstones (*Arenaria interpres*). Three bar-tailed godwits (*Limosa lapponica*) and three oystercatchers (*Haematopus ostralegus*) were observed and added to the list of species recorded at this site in March.

Summary

Numbers of migrant wading birds at Fanoole (and probably elsewhere to the north) were much lower than in March because of the lack of shallow, muddy habitats. In contrast, numbers were greater from Jilib to Dhesheeg Waamo than along any section of the river in March, and probably exceeded 20,000 birds. As many as half of these were accommodated on two rice projects—Fanoole and Mogambo. The wading bird composition in irrigated areas appeared to be similar to that on naturally flooded areas, with wood sandpipers, followed by ruffs, as the main species (thousands of each), and little stints, marsh sandpipers, and ringed plovers in the hundreds.

2. Palearctic Land Birds

Migrant passerines and other land birds were present in greater numbers and variety than in March. In contrast with March, most were found in thicket and woodland on the floodplain rather than in the drier *Acacia* bushland. Most were passage birds in migration.

Nightingales (*Luscinia megarhynchos*) were widespread and locally abundant from Jamaame northward. Most were in thickets of *Acacia nilotica* fairly close to the river. Scores were present around Fanoole Barrage alone. Smaller numbers of sprossers (*L. luscinia*) accompanied nightingales at some sites. Spotted flycatchers (*Muscicapa striata*) were much more common than in March and red-backed shrikes (*Lanius collurio*) were widespread in small numbers. Few migrant warblers were found, but several marsh warblers (*Acrocephalus palustris*), a Basra reed warbler (*A. griseldis*), and a river warbler (*Locustella fluviatilis*) were particularly noteworthy. These species and the sprosser are among the migrants that are characteristic of the heavy movement through southeast Kenya.

Pied wheatears (*Oenanthe pleschanka*) and Isabelline wheatears (*O. isabelline*) were quite common and practically up to the wintering numbers found in March. In addition, northern wheatears (*O. oenanthe*), probably in passage, were frequent. On the other hand, no rufous bush chats (*Cercotrichas galactotes*) were seen and only a single Upcher's warbler (*Hippolais languida*) was found. These two wintering species had apparently not yet arrived in the Jubba Valley.

Grey wagtails (*Motacilla cinerea*) were seen surprisingly often in towns and villages. This is typically a highland wintering bird in East Africa and most of the Jubba records were assumed to have referred to passage migrants.

White wagtails (*Motacilla alba*) occurred increasingly throughout the week and, like parties of yellow wagtails (*M. flava*), were more common than in March. The latter species were quite numerous on the rice projects and especially at Dhesheeg Waamo.

Eurasian swallows (*Hirundo rustica*) were more numerous and widespread than in March, many of them perhaps in passage. Other passage birds noted several times were golden orioles (*Oriolus oriolus*), Eurasian cuckoos (*Cuculus canorus*), and Eurasian rollers (*Coracias garrulus*). Blue-cheeked bee-eaters (*Merops persicus*) had arrived and were moving south in parties in the Jilib-Fanoole area.

There was a general lack of migrant birds of prey, even though these birds pass through Kenya in large numbers and variety in early November. A single hobby (*Falco subbuteo*) and a single lesser kestrel (*F. naumanni*) were the only migrant falcons seen. A honey buzzard (*Pernis apivorus*) in tall trees along the river at Jilib was another new species record for Somalia.

3. Afro-tropical Water Birds

Numbers of the larger water birds—storks, ibises, herons, spoonbills, and pelicans—were compared broadly with those noted in March. These birds were present in much larger numbers on the lower part of the floodplain. Open-billed storks (*Anastomas lamelligerus*) were particularly abundant and numbered in the thousands. Hundreds of yellow-billed storks (*Mycteria ibis*) and marabou (*Leptoptilos crumeniferus*) and scores of woolly-necked storks (*Ciconia episcopus*) were also seen. Thirteen species of herons were recorded and comprised thousands of birds in all. Some 2,000 to 3,000 herons, including 300 squacco herons (*Ardeola ralloides*), were gathered in one small area of a few hectares of *Acacia nilotica* bush and reeds at the edge of Dhesheeg Waamo. Groups of glossy ibis (*Plegadis falcinellus*), sacred ibis (*Threskiornis aethiopica*), and African spoonbills (*Platelea alba*) were common.

A mixed colony of pink-backed pelicans (*Pelicanus rufescens*), marabous, and yellow-billed storks was found about 10 kilometers north of Kamsuuma, along the Mareerey Road. Over 500 pairs of each species appeared to be involved. Nests were five to 15 meters high in spreading trees in an area of tall thicket. According to a local report, the pelicans arrived first, about July to August, followed by the other two species. Nests contained chicks, and some young pelicans were already full grown. Nesting was said to be a regular phenomenon at this site.

Parties of white-faced whistling ducks (*Dendrocygna viduata*), together with a few fulvous whistling ducks (*D. bicolor*), were noted many times. Several thousand were present at Dhesheeg Waamo.

V. CONCLUSIONS

Many thousands of migrant wading birds use the Jubba Valley during November, and presumably more immediately after their arrival during September and October. These birds are concentrated at this time mainly in areas south of Jilib, where a high proportion (more than half) utilize irrigated rice land.

A variety of migrant land birds occurs in the lower Jubba Valley on southward passage, mainly in floodplain thickets and woodlands. The nightingale is particularly numerous in November, but the species characteristic of the heavy movement through southeast Kenya are represented only in small numbers or not at all. No significant passage of birds of prey seems to occur.

The planned construction of Baardheere Dam might lead to a reduction in the small, flooded areas used by wading birds south of Jilib, but the more important sites—the irrigated rice projects and Dhesheeg Waamo—would presumably not be affected. It is unlikely that the dam would adversely affect elements of habitat on which the southward passage depends.

A. First Survey

Sedge warbler, *Acrocephalus schoenobaenus*. Present and singing in *Typha* at Mareerey factory dams on 24 March. Also seen at Fanoole Rice Project on 27 March.

Common sandpiper, *Actitis hypoleucos*. Common in ones and twos along the river, and odd birds on other inland wetlands and the coast.

Garganey, *Anas querquedula*. Small parties on dhesheegs, dams, and irrigation from Mareerey up to Lake Rediile. Larger numbers seen were about 50 at Shoonto. 80 at Rediile, and 30 at Fanoole Rice Project.

Red-throated pipit, *Anthus cervinus*. One at Shoonto Dhesheeg on 22 March.

Turnstone, *Arenaria interpres*. Confined to the coast—common in groups on beaches and about 200 at Kismaayo flats.

Sanderling, *Calidris alba*. Confined to the coast—small parties common on beaches and about 300 at Kismaayo flats.

Curlew sandpiper, *Calidris ferruginea*. Widespread in small parties inland on muddy dnesheegs and floods, and also occasionally along the river. Common on coast, with about 2,500 at Kismaayo flats.

Little stint, *Calidris minuta*. Very common and widespread inland with ones, twos, and small parties along the river and scores on dhesheegs. Maximum of about 400 at Shoonto. On coast, about 200 at Kismaayo.

Temminck's stint, *Calidris temminckii*. Up to three together along the river's edge, Jilib and Bu'aale, over six at Shoonto, and three at Rediile.

Rufous bush chat. *Cercotrichas galactotes*. Widespread and common in dry bushland and thicket, predominantly *Acacia* bush or *A. tortilis* woodland outside the floodplain. The most common passerine migrant in this habitat, estimated at typically about five birds per 10 hectares, but more numerous on red soil near the coast. Occasionally, also on the floodplain, but not noted near the river.

Kentish plover, *Charadrius alexandrinus*. Three at Kismaayo mudflats on 26 March.

Caspian plover, *Charadrius asiaticus*. Over five seen at Mareerey sugar scheme on small flood patch on 19 March, one at Fanoole Barrage on 20 March and about 400 at Lake Rediile on 22 March.

Little ringed plover, *Charadrius dubius*. Ones and twos seen occasionally along river edges and elsewhere—Jilib, Shoonto Dhesheeg, and Kismaayo.

Ringed plover, *Charadrius hiaticula*. Ones and twos along the river and about 200 at the Fanoole Barrage. Common on other inland wetlands with over 100 at Shoonto Dhesheeg and also on the coast.

Great sandplover, *Charadrius leschenaultii*. Confined to coast, singly or in small groups. About 200 at Kismaayo flats.

Mongolian sandplover, *Charadrius mongolus*. A few birds on coastal beaches. About 200 at Kismaayo flats.

White-winged black tern, *Chlidonias leucoptera*. Small numbers on inland dams and flooded areas from Mareerey up to Bu'aale, with a maximum of over 70 at Shoonto.

Whiskered tern, *Chlidonias hybridus*. A few seen at Mareerey factory dams on 19 March and the Fanoole Barrage on 20 March. Possibly of Palearctic origin. Not previously recorded on the Jubba.

Eurasian marsh harrier, *Circus aeruginosis*. One seen at Fanoole Barrage on 20 March.

Montagu's pallid harrier, *Circus macrourus/pygargus*. Frequent, females seen at Jilib, Mareerey, Fanoole and Shoonto. Both species identified.

Eurasian roller, *Coracias garrulus*. One observed at Mogambo Rice Project on 24 March, which was perhaps a returning passage migrant.

Common snipe, *Gailinago gallinago*. Uncommon—a few at Mareerey on 24 March.

Gull-billed tern, *Gelochelidon nilotica*. A few seen inland at Fanoole and Shoonto, and also along the beach north of Kismaayo.

Booted eagle, *Hieraaetus pennatus*. Two seen at Fanoole on 20 March.

Upcher's warbler, *Hippolais languida*. The most common migrant warbler—widespread throughout dry *Acacia* bush-lands and *A. Tortilis* woodland outside the floodplain. Most common near the coast where many were in song on red-soil woodlands.

Olivaceous warbler, *Hippolais pallida.* Single birds singing and presumably wintering in floodplain *Acacia* thickets near Jilib and north of Jamaame.

Eurasian swallow, *Hirundo rustica.* Very common, but not numerous. Many on floodplain in cultivated and open-bush country.

Red-tailed shrike, *Lanius isabellinus.* A male of the race *speculigerus* at Jilib on 19 March was the only one recorded.

Lesser black-backed gull, *Larus fuscus.* One seen at Kismaayo.

Black-headed gull, *Larus ridibundus.* About 10 seen on beach at Kismaayo and one at the Fanoole Barrage.

Black-tailed godwit, *Limosa limosa.* Very uncommon—two seen at Fanoole Rice Project.

Nightingale, *Luscinia megarhynchos.* Frequently found in moist green thickets on the floodplain, a few in green scrub in irrigated agricultural country north of Jamaame, single birds along the river at Jilib, and near the Fanoole Barrage, and over 20 on the edge of woodland around Shoonto Dheesheeg.

Blue-cheeked bee-eater, *Merops persicus.* Quite common on the floodplain. Ones and twos perched on wires along canals, in cultivated country and small towns.

Rock thrush, *Monticola saxatilis.* One at Mareerey on 24 March, possibly on passage.

White wagtail, *Motacilla alba.* One at Jilib along the river on 19 March. This is the only species the survey was likely to have missed in late March due to an earlier spring departure date.

Yellow wagtail, *Motacilla flava.* Small parties were common, mainly on the floodplain, near water and around domestic stock. The birds racially assigned were mostly *beema* or *flava.*

Spotted flycatcher, *Muscicapa striata.* Only a few seen in riverine thickets and *Acacia* woodland at Jilib, Shoonto, and Bu'aale, and in *A. tortilis* woodland near Kismaayo. Some of these birds were completing their molt and thus were considered to be definitely wintering.

Curlew, *Numenius arquata.* Three seen at Kismaayo mudflats on 26 March.

Whimbrel, *Numenius phaeopus.* Ones and twos on coast. Maximum of five on Kismaayo mudflats.

Isabelline wheatear, *Oenanthe isabelline.* Very common on flat dusty plains around and below Jilib, and occasionally further north.

Northern wheatear, *Oenanthe oenanthe.* A single record only, seen at Jilib on 28 March, probably a passage bird.

Pied wheatear, *Oenanthe pleschanka.* Common and widespread in open bush and cultivated areas. Absent only from the thickly bushed areas near the river between Fanoole and Bu'aale.

Eurasian golden oriole, *Oriolus oriolus.* One seen at Fanoole on 20 March and two in the bush a few kilometers south of Bu'aale on 21 March, probably northward passage migrants. Not noted otherwise, although they might have been expected in woodlands and tall trees along the river.

Ruff, *Philomachus pugnax.* Small numbers seen on flood areas and dhesheegs from Fanoole to Bu'aale. Over 1,000 found on irrigated part of Fanoole Rice Project.

Willow warbler, *Phylloscopus trochilus.* Two seen in scrub along the new cut at Fanoole on 21 March, which were probably on passage. Not observed otherwise.

Grey plover, *Pluvialis squatarola.* Confined to the coast—ones, twos, and small parties. About 60 at Kismaayo flats.

Eurasian sand martin, *Riparia riparia.* One seen along the river at Jilib.

Caspian tern, *Sterna caspia.* Ones and twos seen along the coast and upriver to Goob Weyn.

Whitethroat, *Sylvia communis.* A presumed passage bird seen along new cut at Fanoole on 21 March.

Spotted redshank, *Tringa erythropus.* Over 10 seen at Shoonto and about 10 at Lake Rediile.

Wood sandpiper, *Tringa glareola.* Abundant and widespread on inland wetlands, with odd birds along the river and on irrigation ditches. Sometimes scores on small flooded patches and about 200 at Shoonto.

Greenshank, *Tringa nebularia.* Singly along the river and widespread in small numbers on lakes, dhesheegs, and the coast, with about 20 at Shoonto and 30 at Kismaayo.

Green sandpiper, *Tringa ochropus*. Singles at Mareerey factory dam.

Marsh sandpiper, *Tringa stagnatilis*. Locally inland on marshy or muddy flood lakes and dhesheegs. Maximum of about 100 at Lake Rediile.

Redshank, *Tringa totanus*. Eight seen at Kismaayo on 26 March.

Terek sandpiper, *Xenus cinereus*. Only on coast—about 50 at Kismaayo flats on 26 March.

B. Second Survey

Black stork, *Ciconia nigra*. One at Fanoole Rice Project on 5 November. New for Somalia.

Garganey, *Anas querquedula*. About 40 at Jamaame on 9 November. Small parties at Dhesheeg Waamo on 10 November.

Shoveler, *Anas clypeata*. Two at Jamaame on 9 November.

Eurasian marsh harrier, *Circus aeruginosus*. One at Mogambo Rice Project on 8 November.

Pallid harrier, *Circus macrourus*. One at Mogambo Rice Project on 8 November.

Booted eagle, *Hieraaetus pennatus*. One at Jamaame on 11 November.

Honey buzzard, *Pernis apivorus*. One in trees along river at Jilib, 6 November. New for Somalia.

Osprey, *Pandion haliaetus*. One at Jamaame on 9 November.

Hobby, *Falco subbuteo*. One near rainstorm at Kamsuuma on 7 November.

Lesser kestrel, *Falco naumanni*. One near storm at Fanoole on 6 November.

Oyster catcher, *Kaematopus ostralegus*. Three at Kismaayo flats on 10 and 11 November.

Caspian plover, *Charadrius asiaticus*. About 10 on rough ground outside Kismaayo on 11 November.

Kentish plover, *Charadrius alexandrinus*. Four at Kismaayo tidal flats on 10 November.

Little ringed plover, *Charadrius dubius*. Small parties of up to 20 common on mud pans and edges of dhesheegs.

Ringed plover, *Charadrius hiaticula*. Common inland on natural floods and rice projects. Hundreds at Mogambo Rice Project. Present at Kismaayo on tidal flats.

Greater sandplover, *Charadrius leschenaultii*. Confined to coast. Hundreds at Kismaayo flats.

Mongolian sandplover, *Charadrius mongolus*. Confined to coast. Hundreds at Kismaayo flats.

Grey plover, *Pluvialis squatarola*. Confined to coast. Scores at Kismaayo flats.

Curlew, *Numenius arquata*. Three at Kismaayo on 10 November.

Whimbrel, *Numenius phaeopus*. More than 15 at Kismaayo on 10 November.

Wood sandpiper, *Tringa glareola*. Very abundant and widespread on wetlands. The most numerous wader on rice schemes and natural floods. Thousands at Fanoole and Mogambo Rice Projects, and at Dhesheeg Waamo.

Greenshank, *Tringa nebularia*. Widespread in ones and twos in wet pans and in larger numbers on the two rice schemes. Tens on Kismaayo flats.

Green sandpiper, *Tringa ochropus*. One at Jilib on 5 November; a few at Mogambo Rice Project on 7 and 8 November.

Marsh sandpiper, *Tringa stagnatilis*. Common and widespread on inland wetlands. In ones and twos and small groups on pans and dhesheegs. Hundreds at Mogambo Rice Project.

Redshank, *Tringa totanus*. Five at Kismaayo tidal flats on 10 November.

Terek sandpiper, *Xenus cinereus*. Over 50 at Kismaayo tidal flats. Inland, two at Jamaame on 9 November and two at Jilib on 11 November.

Common sandpiper, *Actitis hypoleucos*. Very common and widespread in small numbers. More than 50 together at Fanoole Barrage.

Common snipe, *Gallinago gallinago*. Scores present at Dhesheeg Waamo on 10 November. Otherwise, in small numbers at Jamaame and on rice projects.

Great snipe, *Gallinago media*. More than five at Dhesheeg Waamo on 10 November. New for Somalia.

Sanderling, *Calidris alba*. Confined to coast. Hundreds at Kismaayo flats.

Curlew sandpiper, *Calidris ferruginea.* Widespread, but in small numbers, at inland sites. Over 2,000 at Kismaayo flats.

Little stint, *Calidris minuta.* Widespread and abundant at muddy inland sites, with hundreds on rice projects and at Dhesheeg Waamo.

Temminck's stint, *Calidris temminckii.* One at Dhesheeg Waamo on 10 November.

Black-tailed godwit, *Limosa limosa.* One at Dhesheeg Waamo on 10 November.

Bar-tailed godwit, *Limosa lapponica.* Three at Kismaayo flats on 10-11 November.

Ruff, *Philomachus pugnax.* Widespread and abundant on wetlands. Thousands at Mogambo, and over 1,000 at Dhesheeg Waamo.

Turnstone, *Arenaria interpres.* Hundreds at Kismaayo flats.

Lesser black-backed gull, *Larus fuscus.* A few at Kismaayo.

Herring gull, *Larus argentatus.* Two at Kismaayo.

Whiskered tern, *Chlidonias hybridus.* Two in non-breeding plumage on small dhesheeg at Jamaame—presumed Palearctic race.

White-winged black tern, *Chlidonias leucopterus.* A few hundred seen at Fanoole and Mogambo Rice Projects. Party of about 20 at Jamaame.

Gull-billed tern, *Celochidon nilotica.* A few tens in Jamaame area and Kismaayo.

Eurasian cuckoo, *Cuculus canorus.* Frequent. Singles at Jilib on 5 November, Kamsuuma on 8 November, and Goob Weyn on 11 November. Three at Mogambo on 8 November.

Eurasian bee-eater, *Merops apiaster.* Two on wires on Jilib-Fanoole road on 6 November.

Blue-cheeked bee-eater, *Merops persicus.* Scores along Jilib-Fanoole road on 5-6 and 11-12 November. Parties moving south.

Eurasian roller, *Coracias garrulus.* Uncommon. Three at Jilib-Fanoole on 6 November. One at Jilib on 7 November. Three south of Jilib on 9 November.

Eurasian swallow, *Hirundo rustica.* Common and widespread in scores and hundreds, especially on floodplain.

Golden oriole, *Oriolus oriolus.* One at Jilib on 5 November and three there, in trees along the river, on 6 November. Two at Goob Weyn in *Acacia tortilis* woodland on 11 November.

Nightingale, *Luscinia megarhynchos.* Very common on floodplain, mainly in *Acacia nilotica* thickets, with smaller numbers also in peripheral bushlands. Also from Jamaame area north. Scores around Fanoole Barrage on 7 November. Frequently in song. The most abundant migrant songbird.

Sprosser, *Luscinia luscinia.* A few in thicket near river at Jilib on 5, 6, and 12 November. More than 30 around Fanoole Barrage on 7 November. One near Jamaame on 9 November. Some in song. Always much outnumbered by nightingales.

Rock thrush, *Monticola saxatilis.* One at Jilib on 7 November.

Isabelline wheatear, *Oenanthe isabelline.* Confined to flatter, open areas of Jamaame and Dhesheeg Waamo. Common near Kismaayo and Goob Weyn.

Northern wheatear, *Oenanthe oenanthe.* Frequent and widespread, mainly on floodplain cultivation. A few at Jilib, Jamaame, and near coast at Goob Weyn and Kismaayo.

Pied wheatear, *Oenanthe pleschanko.* Frequent and widespread in open bush and on cultivation, on floodplain, and peripheral areas. From Dhesheeg Waamo and Jamaame north to Fanoole. None on coast.

Basra reed warbler, *Acrocephalus griseldis.* One along ditch at Mogambo Rice Project on 7 November.

Marsh warbler, *Acrocephalus palustris.* Uncommon. Two at Jilib on 5 November. Two at Fanoole Barrage and two or three after rain at Mogambo Rice Project on 7 November. One at Jamaame on 8 November. One at Kamsuuma on 9 November.

Upcher's warbler, *Hippolais languida.* Only one seen—at Goob Weyn—on 11 November.

Olivaceous warbler, *Hippolais pallida.* Uncommon. One at Fanoole Barrage on 7 November. One at Jamaame on 8 November and more than two at Kismaayo on 11 November.

River warbler, *Locustella fluviatilis.* One in *Acacia nilotica* thicket among rank grass by river at Jilib on 12 November. New for Somalia.

Barred warbler, *Sylvia nisoria.* A number in *Salvadora persica* thickets in *Acacia tortilis* woodland at Goob Weyn on 11 November. At least 10 birds in one small area.

Spotted flycatcher, *Muscicapa striata.* Quite common and widespread from coast up to Jilib, mainly on floodplain. Mostly singly, but more than 20 in patch of *Acacia tortilis* woodland at Jamaame.

Red-throated pipit, *Anthus cervinus.* Two at Dhesheeg Waamo on 10 November. Two at Jilib on 11 November.

Yellow wagtail, *Motacilla flava.* Common and sometimes numerous at wet sites on floodplain. Scattered birds on the two rice projects. Hundreds at Dhesheeg Waamo.

White wagtail, *Motacilla alba.* Frequent. Usually single in towns and near water. Seen at Jilib, Fanoole Barrage and Jamaame area. Mainly 8-11 November and probably just arriving.

Grey wagtail, *Motacilla cinerea.* Frequent, in towns, usually near water. Mainly singly, but four together at Jamaame on 8 November.

Red-backed shrike, *Lanius collurio.* Widespread and frequently seen in ones and twos, perched on bushes and thicket on floodplain. Recorded from Goob Weyn north to Fanoole Barrage.

This checklist was compiled by Robert (Gus) Tillman , Senior Environmental Scientist, based on observations by David Pearson in March and November 1987. Names are based on Ash and Miskell (1983).

Lower Jubba Valley - Somalia
March, November 1987

STRUTHIONIDAE - Ostriches
- Ostrich *Struthio camelus*

PODICIPEDIDAE - Grebes
- Little Grebe *Tachybaptus ruficollis*

PELECANIDAE - Pelicans
- Pink-backed Pelican *Pelecanus rufescens*
- White Pelican *P. onocrotalus*

PHALACROCORACIDAE - Cormorants
- Long-tailed Cormorant *Phalacrocorax africanus*
- Greater Cormorant *P. carbo*

ANHINGIDAE - Darters
- Darter *Anhinga rufa*

ARDEIDAE - Herons, Bitterns, Egrets
- Dwarf Bittern *Ixobrychus sturmii*
- Grey Heron *Ardea cinerea*
- Goliath Heron *A. goliath*
- Black-headed Heron *A. melanocephala*
- Purple Heron *A. purpurea*
- Squacco Heron *Ardeola ralloides*
- Cattle Egret *Bulbulcus ibis*
- Green-backed Heron *Butorides striatus*
- Great White Heron *Egretta alba*
- Black Heron *E. ardesiaca*
- Little Egret *E. garzetta*
- African Reef Heron *E. gularis*
- Yellow-billed Egret *E. intermedia*
- Night Heron *Nycticorax nycticorax*

SCOPIDAE - Hamerkop
- Hamerkop *Scopus umbretta*

CICONIIDAE - Storks
- Open-billed Stork *Anastomus lamelligerus*
- Abdim's Stork *Ciconia abdimii*
- Woolly-necked Stork *C. episcopus*
- Black Stork** *C. nigra*
- Saddle-billed Stork *Ephippiorhynchus senegalensis*
- Marabou *Leptoptilos crumeniferus*
- Yellow-billed Stork *Mycteria ibis*

THRESKIORNITHIDAE - Ibises, Spoonbills
- Hadada *Bostrychia hagedash*
- Glossy Ibis *Plegadis falcinellus*
- Sacred Ibis *Threskiornis aethiopica*
- African Spoonbill *Platalea alba*

PHOENICOPTERIDAE - Flamingos
- Greater Flamingo *Phoenicopterus ruber*

ANATIDAE - Ducks, Geese
- Fulvous Whistling Duck *Dendrocygna bicolor*
- White-faced Whistling Duck *D. viduata*
- Egyptian Goose *Alopochen aegyptiacus*
- Shoveler *Anas clypeata*
- Red-billed Teal *A. erythrorhynchos*
- Garganey *A. querquedula*
- African Pygmy Goose *Nettapus auritus*
- Knob-billed Duck *Sarkidiornis melanotos*

ACCIPITRIDAE - Birds of Prey
- White-backed Vulture *Gyps africanus*
- Hooded Vulture *Neophron monachus*
- Eurasian Marsh Harrier *Circus aeruginosus*
- Pallid Harrier *C. macrourus*
- Montagu's Harrier *C. pygargus*
- African Marsh Harrier *C. ranivorus*
- Harrier Hawk *Polyboroides radiatus*
- Brown Snake Eagle *Circaetus cinereus*
- Southern Banded Snake Eagle *C. fasciolatus*
- Bateleur *Terathopius ecaudatus*
- Shikra *Accipiter badius*
- Little Sparrowhawk *A. minullus*
- African Goshawk *A. tachiro*
- Tawny Eagle *Aquila rapox*
- Wahlberg's Eagle *A. wahlbergii*
- Grasshopper Buzzard *Butastur rufipennis*
- Honey Buzzard** *Pernis apivorus*
- Booted Eagle *Hieraaetus pennatus*
- Lizard Buzzard *Kaupifalco monogrammicus*
- Gabar Goshawk *Melierax gabar*
- Pale Chanting Goshawk *Merlierax poliopterus*
- Martial Eagle *Polemaetus bellicosus*
- African Fish Eagle *Haliaeetus vocifer*
- Black Kite *Milvus migrans*
- Swallow-tailed Kite *Chelictinia riocourii*
- Black-shouldered Kite *Elanus caeruleus*
- Bat Hawk *Macheiramphus alcinus*
- Osprey *Pandion haliaetus*
- Lesser Kestrel *Falco naumanni*
- Hobby *F. subbuteo*
- African Hobby** *F. cuvieri*
- Pygmy Falcon *Polihierax semitorsquatus*

PHASIANIDAE - Quail, Francolin
- Harlequin Quail *Coturnix delegorguei*
- Crested Francolin *Francolinus sephaena*

NUMIDIDAE - Guineafowl
- Vulturine Guineafowl *Acryllium vulturinum*
- Kenya Crested Guineafowl *Guttera pucherani*

RALLIDAE - Rails, Crakes
- Common Moorhen *Gallinula chloropus*
- Black Crake *Limnocorax flavirostra*

OTIDIDAE - Bustards
- Buff-crested Bustard *Eupodotis ruficrista*
- White-bellied Bustard *E. senegalensis*

JACANIDAE - Jacanas
Jacana *Actophilornis africanus*
ROSTRATULIDAE - Painted Snipe
Painted Snipe *Rostratula benghalensis*
HAEMATOPODIDAE - Oystercatchers
Oystercatcher *Haematopus ostralegus*
CHARADRIIDAE - Plovers
Kentish Plover *Charadrius alexandrinus*
Caspian Plover *C. asiaticus*
little Ringed Plover *C. dubius*
Ringed Plover *C. hiaticula*
Great Sandplover *C. leschenaultii*
White-fronted Sandplover *C. marginatus*
Mongolian Sandplover *C. mongolus*
Kittlitz's Sandplover *C. pecuarius*
Grey Plover *Pluvialis squatarola*
Spur-winged Plover *Vanellus spinosus*
Black-headed Plover *V. tectus*
SCOLOPACIDAE - Sandpipers, Snipes
Common Sandpiper *Actitus hypoleucos*
Curlew *Numenius arquata*
Whimbrel *N. phaeopus*
Spotted Redshank *Tringa erythropus*
Wood Sandpiper *T. glareola*
Greenshank *T. nebularia*
Green Sandpiper *T. ochropus*
Marsh Sandpiper *T. stagnatilis*
Redshank *T. totanus*
Terek Sandpiper *Xenus cinereus*
Common Snipe *Gallinago gallinago*
Great Snipe** *G. media*
Sanderling *Calidris alba*
Curlew Sandpiper *C. ferruginea*
Little Stint *C. minuta*
Temminck's Stint *C. temminckii*
Bar-tailed Godwit *Limosa lapponica*
Black-tailed Godwit *L. limosa*
Ruff *Philomachus pugnax*
Turnstone *Arenaria interpres*
RECURVIROSTRIDAE - Stilts, Avocets
Black-winged Stilt *Himantopus himantopus*
Avocet *Recurvirostra avosetta*
DROMADIDAE - Crab Plover
Crab Plover *Dromas ardeola*
BURHINIDAE - Thicknees
Spotted Thicknee *Burhinus capensis*
Water Thicknee *B. vermiculatus*
GLAREOLIDAE - Coursers, Pratincoles
Common Pratincole *Glareola pratincola*
LARIDAE - Gulls, Terns
Herring Gull *Larus argentatus*
Lesser Black-backed Gull *L. fuscus*
Sooty Gull *L. hemprichii*
Black-headed Gull *L. ridibundus*
Whiskered Tern *Chlidonias hybridus*
White-winged Black Tern *C. leucopterus*
Gull-billed Tern *Gelochelidon nilotica*
Little Tern *Sterna albifrons*
Lesser Crested Tern *S. bengalensis*
Crested Tern *S. bergii*
Caspian Tern *S. caspia*
PTEROCLIDIDAE - Sandgrouse
Black-faced Sandgrouse *Pterocles decoratus*
COLUMBIDAE - Pigeons, Doves
Namaqua Dove *Oena capensis*
Ring-necked Dove *Streptopelia capicola*
Mourning Dove *S. decipiens*
Red-eyed Dove *S. semitorquata*
Laughing Dove *S. senegalensis*
Emerald-spotted Wood Dove *Turtur chalcospilos*
Tambourine Dove *T. tympanistria*
PSITTACIDAE - Parrots
Orange-bellied Parrot *Poicephalus rufiventris*
MUSOPHAGIDAE - Turacos
White-bellied Go-away Bird
Corythaixoides leucogaster
Fisher's Turaco *Tauraco fischeri*
CUCULIDAE - Cuckoos, Coucals
Didric Cuckoo *Chrysococcyx caprius*
Klaas' Cuckoo *C. klaas*
Great Spotted Cuckoo *Clamator glandarius*
Black and White Cuckoo *C. jacobinus*
Eurasian Cuckoo *Cuculus canorus*
White-breasted Coucal *Centropus superciliosus*
STRIGIDAE - Owls
African Wood Owl *Ciccaba woodfordii*
Scops Owl *Otus scops*
Pel's Fishing Owl*Scotopelia peli*
CAPRIMULGIDAE - Nightjars
Slender-billed Nightjar *Caprimulgus clarus*
APODIDAE - Swifts, Spinetails
Little Swift *Apus affinis*
Palm Swift *Cypsiurus clarus*
COLIIDAE - Mousebirds
Speckled Mousebird *Colius striatus*
Blue-naped Mousebird *Urocolius macrourus*
ALCEDINIDAE - Kingfishers
Pied Kingfisher *Ceryle rudis*
Malachite Kingfisher *Alcedo cristata*
Pygmy Kingfisher *Ispidina picta*
Brown-hooded Kingfisher *Halcyon albiventris*
Striped Kingfisher *H. chelicuti*
Chestnut-bellied Kingfisher *H. leucocephala*
MEROPIDAE - Bee-eaters
White-throated Bee-eater *Merops albicollis*
Eurasian Bee-eater *M. apiaster*
Carmine Bee-eater *M. nubicus*
Blue-cheeked Bee-eater *M. persicus*
Little Bee-eater *M. pusillus*
Madagascar Bee-eater *M. superciliosus*
CORACIIDAE - Rollers
Lilac-breasted Roller *Coracias caudata*
Eurasian Roller *C. garrulus*

Broad-billed Roller *Eurystomus glaucurus*

UPUPIDAE - Hoopoes

Hoopoe *Upupa epops*

PHOENICULIDAE - Wood Hoopoes

Abyssinian Scimitarbill *Phoeniculus minor*

Scimitarbill *P. cyanomelas*

Green Wood Hoopoe *P. purpureus*

BUCEROTIDAE - Hornbills

Crowned Hornbill *Tockus alboterminatus*

Von der Denken's Hornbill *T. denkeni*

Red-billed Hornbill *T. erythrorhynchus*

Grey Hornbill *T. nasutus*

CAPITONIDAE - Barbets, Tinkerbirds

Black-throated Barbet *Lybius melanocephalus*

Brown-breasted Barbet *L. melanopterus*

Red-fronted Tinkerbird *Pogoniulus pusillus*

d'Arnaud's Barbet *Trachyphonus darnaidii*

INDICATORIDAE - Honeyguides

Black-throated Honeyguide *Indicator indicator*

Lesser Honeyguide *I. minor*

PICIDAE - Woodpeckers

Nubian Woodpecker *Campethera nubica*

Cardinal Woodpecker *Dendropicos fuscescens*

ALAUDIDAE - Larks

Chestnut-headed Sparrow Lark *Eremopterix signata*

Singing Bush Lark *Mirafra cantillans*

Red-winged Bush Lark *M. hypermetra*

Pink-breasted Lark *M. poecilosterna*

HIRUNDINIDAE - Swallows, Martins

Striped Swallow *Hirundo abyssinica*

Ethiopian Swallow *H. aethiopica*

Eurasian Swallow *H. rustica*

Wire-tailed Swallow *H. smithii*

Sand Martin *Riparia riparia*

DICURURIDAE - Drongos

Drongo *Dicurus adsimilis*

Square-tailed Drongo *D. ludwigii*

ORIOLIDAE - Orioles

Black-headed Oriole *Oriolus larvatus*

Golden Oriole *O. oriolus*

CORVIDAE - Crows, Ravens

Pied Crow *Corvus albus*

REMIZIDAE - Penduline Tits

Mouse-coloured Penduline Tit *Remiz musculus*

TIMALIIDAE - Babblers

Rufous Chatterer *Turdoides rubiginosus*

Scaly Babbler *T. squamulatus*

PYCONOTIDAE - Bulbuls

Zanzibar Sombre Greenbul *Andropadus importunus*

Yellow-bellied Greenbul *Chlorocichla flaviventris*

Nicator *Nicator chloris*

Northern Brownbul *Phyllastrephus strepitans*

Common Bulbul *Pycnonotus barbatus*

TURDIDAE - Thrushes, Robins

Rufous Bush Chat *Cerotrichas galactotes*

White-browed Scrub Robin *C. leucophrys*

Eastern Banded Scrub Robin *C. quadrivirgata*

Spotted morning Thrush *Cichladusa guttata*

White-browed Robin Chat *Cossypha heuglini*

Red-capped Robin Chat *C. natalensis*

Sprosser *Luscinia luscinia*

Nightingale *L. megarhynchos*

Rock Thrush *Monticola saxatilis*

Isabelline Wheatear *Oenanthe isabelline*

Northern Wheatear *O. oenanthe*

Pied Wheatear *O. pleschanka*

Bare-eyed Thrush *Turdus tephronotus*

SYLVIIDAE - Warblers

Lesser Swamp Warbler *Acrocephalus gracilirostris*

Basra Reed Warbler *A. griseldis*

Marsh Warbler *A. palustris*

Sedge Warbler *A. schoenobaenus*

River Warbler** *Locustella fluviatilis*

Black-headed Apalis *Apalis melanocephala*

Grey-backed Camaroptera *Camaroptera brachyura*

Grey Wren Warbler *C. simplex*

Siffling Cisticola *Cisticola brachyptera*

Winding Cisticola *C. galactotes*

Upcher's Warbler *Hippolais languida*

Olivaceous Warbler *H. pallida*

Willow Warbler *Phylloscopus trochilus*

Tawny-Flanked Prinia *Prinia subflava*

Whitethroat *Slyvia communis*

Barred Warbler *S. nisoria*

Northern Crombec *Sylvietta brachyura*

Somali Long-billed Crombec *S. isabellina*

MUSCICAPIDAE - Flycatchers

Grey Flycatcher *Bradornis microrhynchus*

Pale Flycathcer *B. pallidus*

Spotted Flycatcher *Muscicapa striata*

Black-throated Wattle Eye *Platysteira peltata*

Paradise Flycatcher *Terpsiphone viridis*

Grey-headed Batis *Batis orientalis*

MOTACILLIDAE - Wagtails, Pipits, Longclaws

Red-throated Pipit *Anthus cervinus*

Malindi Pipit *A. melindae*

Richard's Pipit *A. novaeseelandiae*

Pangani Longclaw *Macronyx aurantiigula*

African Pied Wagtail *Motalcilla aguimp*

White Wagtail *M. alba*

Grey Wagtail *M. cinerea*

Yellow Wagtail *M. flava*

Golden Pipit *Tmetothylacus tenellus*

MALACONOTIDAE - Bush Shrikes

Black-backed Puffback *Dryoscopus cubia*

Tropical Boubou *Laniarius ferrugineus*

Slate-coloured Boubou *L. funebris*

Grey-headed Bush Shrike *Malaconotus blanchoti*

Sulphur-breasted Bush Shrike *M. sulfureopectus*

Brubru *Nilaus afer*

Three-streaked Tchagra *Tchagra jamesi*

Black-headed Tchagra *Tchagra senegala*

LANIIDAE - Shrikes

Long-tailed Fiscal *Lanius cabanisi*
Red-backed Shrike *L. collurio*
Taita Fiscal *L. dorsalis*
Red-tailed Shrike *L. isabellinus*

PRIONOPIDAE - Helmet Shrikes
White Crowned Shrike *Eurocephalus ruepelli*
Helmet Shrike *Prionops plumata*
Retz's Helmet Shrike *P. retzii*

STURNIDAE - Starlings, Oxpeckers
Golden-breasted Starling *Cosmopsarus regius*
Wattled Starling *Creatophora cinerea*
Black-breasted Glossy Starling *Lamprotornis corruscus*
Ruppell's Long-tailed Glossy *L. purpuropterus*
Magpie Starling *Speculipastor bicolor*
Fischer's Starling *Spreo fischeri*
Superb Starling *S. superbus*
Red-billed Oxpecker *Buphagus erythrorhynchus*

NECTARINIIDAE - Sunbirds
Collared Sunbird *Anthreptes colluris*
E. Violet-backed Sunbird *A. orientalis*
Amethyst Sunbird *Nectarina amethystina*
Little Purple-breasted Sunbird *N. bifasciata*
Hunter's Sunbird *N. hunteri*
Violet-breasted Sunbird *N. pembae*
Variable Sunbird *N. venusta*
Mouse-coloured Sunbird *N. veroxii*

PLOCEIDAE - Weavers
Grosbeak Weaver *Amblyospiza albifrons*
Fan-tailed Widowbird *Euplectes axillaris*
Fire-fronted Bishop *E. diadematus*
Dark-backed Weaver *Ploceus bicolor*
Golden Palm Weaver *P. bojeri*
Black-headed Weaver *P. cucullatus*
Juba Weaver *P. dicrocephalus*
Masked Weaver *P. intermedius*
Chestnut Weaver *P. rubiginosus*
Red-billed Quelea *Quelea quelea*
Red-billed Buffalo Weaver *Bubalornis niger*
White-headed Buffalo Weaver *Dinemellia dinemelli*
White-browed Sparrow Weaver *Plocepasser mahali*
Grey-headed Sparrow *Passer griseus*
Yellow-spotted Petronia *Petronia pyrgita*
Steel-blue Whydah *Vidua hypocherina*
Paradise Whydah *V. paradisaea*
Pin-tailed Whydah *V. macroura*

ESTRILDIDAE - Waxbills
Waxbill *Estrilda astrild*
Crimson-rumped Waxbill *E. rhodopyga*
Red-billed Firefinch *Lagonosticta senegala*
Green-winged Pytilia *Pytilia melba*

FRINGILLIDAE - Buntings, Canaries, Seedeaters
Somali Golden-breasted Bunting *Emberiza poliopleura*
Yellow-rumped Seed-eater *Serinus atrogularis*

*** New Somali record.*

Biological Limnology of the Jubba River

prepared by

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I. EXECUTIVE SUMMARY

This report contains the findings of a four-week biological limnology consultancy conducted from 2 to 31 August 1987, during Phase II of JESS, by Dr. Stephen G. Njuguna and Dr. Francis M. Muthuri. The purpose of this consultancy was to carry out a first-time limnological study of the Jubba River.

The physical characteristics of the river water investigated showed that the river is slightly alkaline and well-buffered, with a pH range of 8.0 to 8.5. Electrical conductivity (EC) ranged from 220 to 350 umhos per centimeter and was found to be lower than that of a tributary, Isha Maalim (1,350 umhos per centimeter) and that of a dhesheeg, Harenka Shariffka (700 umhos per centimeter). The Jubba River was found to be remarkably turbid, with Secchi disk readings ranging between 10 and 37 centimeters.

A total of 36 genera of microflora were recorded. The dominant taxa of algae were *Chlorophyta* (green algae) and *Cyanophyta* (blue-green algae). Although the water had high turbidity, its microflora were found to be rich. The microflora will increase prolifically during the first few years of reservoir formation.

Two algal genera are likely to cause problems in the future reservoir. These are the bloom-forming *Anabaena circinalis* and *Mycrocystis aeruginosa.* In the section of the river downstream of the proposed reservoir, the microflora composition and abundance are likely to increase once the dam is completed.

The Jubba River macrophytes are notable in their lack of diversity and abundance, especially in river stretches upstream of the dam site. In downstream areas, *Typha domingensis* and *Phragmites karka* formed the most dominant communities of emergent macrophytes. A floating macrophyte, *Pistia stratiotes,* was recorded and this plant may cause serious problems as an aquatic weed in the proposed reservoir.

Nymphaea lotus, a rooted, floating-leaved macrophyte, was found to be common in canals, ditches and dhesheegs and is expected to colonize the proposed reservoir as a member of the littoral plant community. No submerged macrophytes were found in the Jubba River but the presence of *Chara* sp., a submerged macrophyte, in Isha Maalim stream may provide an inoculum for the proposed reservoir.

Although an inoculum of aquatic weeds is present in the Jubba Valley, their proliferation in the proposed reservoir will depend on the nutrient regime of the water. Downstream of the dam, the macrophyte populations are expected to decrease once the dam is in operation.

The microfauna community in the Jubba River is not rich in species diversity. It was found to be composed of rotifers, cladocerans, pigmented ciliates, a type of copepod, an unidentified nematode and larval forms of other invertebrates and fish.

Rotifers, *Brachionus* sp., dominated the microfauna in most of the areas sampled. The species composition and abundance are expected to increase within the reservoir and in downstream areas. In the first few years after dam completion, an explosive development of microfauna populations is to be expected.

The benthic community of the Jubba River was mainly composed of larval stages of *Ephemeroptera* (mayflies), *Coleoptera* (beetles), *Plecoptera* (stone flies), *Diptera* (flies), *Trichoptera* (caddis flies) and *Odonata* (dragonflies). Other groups of benthic organisms found in the river were *Oligochaeta* (aquatic earthworms) and *Gastropoda* (snails).

The gastropods were found in all sites investigated, but attained highest densities at Fanoole Barrage and Harenka Shariffka dhesheeg where there was slow-moving water. Creation of a reservoir will stimulate greater benthic populations, especially in the initial stages of reservoir formation. Of the benthic organisms, the presence of planorbid snails, vectors of bilharzia, may cause health problems.

II. INTRODUCTION

This report contains the findings of an August 1987 consultancy concerning the limnology of the Jubba River. The main objective of this consultancy was to conduct limnological studies in the Jubba River with emphasis on the vicinity of the proposed reservoir for the Baardheere Dam. These studies included:

- determining the abundance and diversity of microflora and microfauna in representative habitats of the Jubba River, with special emphasis on the proposed impoundment;
- investigating the potential for phytoplankton proliferation (*e.g.*, algal blooms) in the Baardheere Reservoir and recommending techniques for monitoring algal growth;
- determining the abundance and diversity of emergent, floating and submerged macrophytes and benthic organisms in representative aquatic habitats of the Jubba River, with special emphasis on the proposed impoundment;
- investigating the potential for aquatic weed proliferation in the Baardheere Reservoir and recommending techniques for monitoring the spread of aquatic weeds, with emphasis on exotic species;
- describing the likely changes in aquatic populations which may occur in the proposed impoundment;
- estimating downstream changes in aquatic populations as a result of regulated flow of the Baardheere Dam; and
- commenting, from a limnological perspective, on ramifications of reservoir operations recommended by other consultants.

The Jubba River was sampled from the lower reaches (estuary) to the upper reaches near Luuq during a two-week field trip to the Jubba Valley. In addition, a dhesheeg, Harenka Shariffka, near Saakow, and a tributary stream, Isha Maalim, were also investigated.

Analysis of the samples collected was carried out in the Faculty of Chemistry laboratories at the National University of Somalia (NUS).

According to reliable sources, this is the first time a limnological study has been conducted on the Jubba River. This present investigation was a brief study and time was not sufficient to visit all the sites and other areas of limnological interest. Appropriate equipment for intensive limnological investigation was not available. A boat, necessary for a more representative sampling of the river, was not available. It is anticipated that a more detailed limnological study will be carried out later.

A. Sampling

The locations of sampling stations are shown in Figure 1. Field sampling was carried out 10 to 20 August 1987. Five locations along the Jubba River (Goob Weyn, Fanoole Barrage, Baardheere Dam site, Buurdhuubo [mid-reservoir] and Luuq) were investigated. In addition, sampling was performed at two other locations, a dhesheeg near Saakow and a tributary near Daar Maalim Adam village, 30 kilometers northwest of Baardheere.

B. Field Measurements

At each location, the following physical parameters were measured:

- air and water temperature were measured with a Hach armored thermometer calibrated in tenths of a degree Celsius (Hach Chemical Company, Ames, Iowa, USA);
- Secchi depth was measured with a 20-centimeter black-and-white Secchi disk;
- pH was determined with a Hach Chemical Kit (Hach Company, Ames, Iowa, USA); and
- electrical conductivity (EC) was measured with a YSI model 33 S-C-T meter (Yellow Springs, Ohio, USA).

C. Microflora

Water samples for microflora analysis were collected using an improvised sampler consisting of a calibrated bucket tied to a rope. Surface samples were collected to an approximate depth of 15 centimeters. The samples were collected as far from the riverbank as possible, usually five to 10 meters from water's edge. The middle of the river could not be sampled since a boat was not available and sampling of the river from bridges and ferries was prohibited by national security. Known volumes of water were passed through a plankton tow net (No. 10W0630, Wards Natural Science Establishment, Rochester, New York, USA) for concentration of the microflora. In a few cases, the plankton net was thrown into the river and towed repeatedly for additional concentration. Epipelic and epiphytic (periphyton) microflora were collected in some littoral areas along the river by scraping mud surfaces and surfaces of partially submerged, dead and living littoral vegetation. All microflora samples were preserved in four percent formalin and transported to the lab at NUS for microscopic analysis. Identification was based on works available for the eastern Africa region.

D. Macrophytes

The macrophytes were surveyed from the shore. Notes on the dominant species and their approximate spatial extent were made throughout the field study.

At Goob Weyn, a transect line was laid and duplicate quadrats (0.25 square meters) were sampled for macrophyte biomass. Standing crop was estimated for *Typha* and sedge communities.

The collected samples were air dried and later oven dried at 85 degrees centigrade to constant weight at NUS. The data were computed as dry weight per unit area.

Specimens of all aquatic macrophytes found were collected and pressed for subsequent identification. The collected specimens were confirmed against specimens at the University of Nairobi and East African Herbarium, Nairobi.

E. Microfauna

Sampling for microfauna was carried out in the same manner as for microflora. Known volumes of water were passed through a 45 um sieve (Soiltest Inc., Model 365029, Mesh No. 325, Evanston, Illinois, USA) for concentration of microfauna.

Zooplankton samples were preserved in four percent formalin prior to transportation to the lab for analysis. Samples of epipelic and epiphytic microfauna were also collected and preserved in formalin.

Microfauna and microflora samples were examined under a Bausch & Lomb Academic HSM microscope (Model No. 19879) at 100x, 400x and 1000x (oil immersion) at the NUS lab. Identification was based on catalogs and other works available for the eastern Africa region.

F. Benthos

Benthos samples were collected at the stations mentioned in Section A. The sampling sites exhibited a certain degree of variability in their substrates. Luuq and Buurdhuubo had relatively compact substrates. The dam site was slightly disturbed and the substrate was mainly small stones, gravel and sand. At Fanoole there was soft mud which was heavily colonized by aquatic macrophytes. Goob Weyn had a relatively compact substrate, probably due to human activities (watering point). The dhesheeg was a flooded substrate where sedges and grasses were undergoing decomposition.

Benthic samples were taken with an Ekman Dredge (Bottom Sampling Dredge Code 1061, Chestertown, Maryland, USA). Again, only the edge of the river could be sampled. The area sampled by the Ekman Dredge was 20 centimeters by 11.4 centimeters.

Three replicate samples were collected and pooled into a pail, and all large particles were broken until there was a fine, homogeneous material. The homogenized material was poured through a series of sieves (Hubbard Scientific Co., Northbrook, Illinois, USA). The material remaining on the screens was retrieved into plastic vials and preserved with five percent formalin. In the laboratory, the collected samples (mixtures of mud, rocks, sand, debris and benthic organisms) were emptied into sorting pans and flooded with a sugar concentration (300 grams sugar per liter). The debris was stirred and soft-bodied lifeforms floating on the surface were scooped and preserved in a vial (Lind 1974).

Heavy-bodied organisms, such as snails, were picked from the bottom of the sorting pans with forceps. Organisms separated from the debris were washed free of sugar solution and preserved in five percent formalin. The organisms were identified, counted and reported as numbers of organisms per unit area. Further identification of snails was done at the Malacology Department of the National Museums of Kenya.

IV. RESULTS

A. Physical Characteristics

Physical characteristics investigated in the present study of the Jubba River are shown in Table 1.

Table 1. Physical Characteristics

STATION	AIR (°C)	WATER (°C)	pH	EC (umhos/cm)	SECCHI (cm)
Goob Weyn	30.5	27.0	8.0	310	10
Fanoole	31.0	27.0	8.3	263	14
Dam site	28.0	26.0	8.5	315	37
Dhesheeg	32.0	29.0	8.5	700	16
Tributary	30.0	28.0	8.5	1,350	clear
Buurdhuubo	33.0	27.0	8.5	350	31
Luuq	33.0	27.0	8.0	220	24

Air temperature determined during sampling at each site ranged from 28 to 33 degrees centigrade. The water temperature measured at the same time ranged from 26 to 29 degrees centigrade. The river was slightly alkaline with a pH range from 8 to 8.5. It is also well-buffered. EC ranged from 220 to 350 umhos per centimeter and is lower than that of the Isha Maalim tributary and the dhesheeg. Secchi disk readings varied from 10 to 37 centimeters, showing high turbidity from silt loads.

B. Microflora

The results of the microflora study are shown in Tables 2, 3, and 4. The Jubba River microflora is rich, including *Bacillariophyta* (diatoms), *Chlorophyta* (green algae), *Cyanophyta* (blue-green algae), *Pyrrophyta* (dinoflagellates) and *Euglenophyta* (flagellated algae). The microflora presented in this report includes planktonic (free-floating), epipelic (on mud), epilithic (on rocks) and epiphytic (on plants).

A total of 36 genera was recorded, the most common being *Chlorophyta* (47 percent). *Cyanophyta* ranked second with 27 percent of the specimens. Only one specimen each for dinoflagellates and euglenophytes was noted.

Fanoole Barrage recorded the highest number of organisms, followed by Goob Weyn in the estuary. In general, the diatoms were more abundant than the other groups of microflora in all stations.

Table 2. Number of Species per Sampling Station

STATION	TAXON					
	Bac	*Chl*	*Cya*	*Pry*	*Eug*	*Total*
Luuq	2	4	4	0	0	10
Buurdhuubo	3	4	4	0	0	11
Dam site	5	5	2	1	0	13
Fanoole	6	8	4	0	0	18
Goob Weyn	5	6	5	0	1	17
Tributary	4	7	4	0	0	15
Dhesheeg	5	3	1	0	0	9

Bac = Bacillariophyta Chl = Chlorophyta Cya = Cyanophyta
Pyr = Pyrrophyta Eug = Euglenopyta

Table 3. Spatial Distribution of Microflora

TAXON	GENUS	1	2	3	4	5	6	7
Bacillariophyta	*Achananthes*				+			+
	Melosira	+	+	+	+	+	+	+
	Navicula	+		+	+	+	+	+
	Nitzchia		+	+	+	+		
	Stephanodiscus			+		+	+	+
	Synedra		+	+	+	+	+	+
Chlorophyta	*Ankistrodesmus*		+	+		+		
	Chlamydomonas		+	+	+			
	Closterium			+				
	Coelastrum				+	+		
	Cosmarium				+		+	
	Desmidium					+		+
	Gleocystis					+	+	
	Micrasterias	+						
	Oocystis				+	+	+	
	Pediastrum	+	+	+	+			
	Scenedesmus					+		
	Spirogyra						+	+
	Staurastrum						+	
	Tetraedon			+				
Cyanophyta	*Anabaena*		+					
	Aphanizomenon	+	+					
	Gomphosphaeria	+				+		
	Lyngbya	+	+		+	+	+	
	Merismopedia					+	+	
	Microcystis		+	+	+	+	+	+
	Oscillatoria					+		
	Spirulina	+			+			
Pyrrophyta	*Peridinium*			+				
Euglenophyta	Unidentified					+		

1 = Luuq 2 = Buurdhuubo 3 = Dam site 4 = Fanoole
5 = Goob Weyn 6 = Tributary 7 = Dhesheeg

Table 4. Microflora Composition and Relative Abundance

STATION	TAXON	GENUS	RELATIVE ABUNDANCE
Luuq	*Bacillariophyta*	*Melosira*	D
		Navicula	A
	Chlorophyta	*Micrasterias*	A
		Pediastrum	P
		Trachelomonas	A
	Cyanophyta	*Gomphosphaeria*	P
		Lyngbya	C
Buurdhuubo	*Bacillariophyta*	*Melosira*	A
		Nitzchia	D
		Synedra	A
	Chlorophyta	*Pediastrum*	C
		Trachelommonas	P
	Cyanophyta	*Anabaena*	C
		Aphanizomenon	P
		Lyngbya	P
		Microcystis	C
Dam site	*Bacillariophyta*	*Melosira*	D
		Navicula	P
		Nitzchia	C
		Stephanodiscus	D
		Synedra	A
	Chlorophyta	*Ankistrodesmus*	P
		Chlamydomonas	P
		Closterium	P
		Pediastrum	P
		Tetraedon	A
	Cyanophyta	*Aphanizomenon*	P
		Microcystis	C
	Pyrrophyta	*Peridinium*	P
Faanoole	*Bacillariophyta*	*Achnanthes*	P
		Melosira	D
		Navicula	D
		Nitzchia	P
		Synedra	A
	Chlorophyta	*Ankistrodesmus*	P
		Chlamydomonas	A
		Coelastrum	P
		Cosmarium	D
		Oocystis	P
		Pediastrum	P
	Cyanophyta	*Anabaena*	C
		Lyngbya	P
		Microcystis	C
		Spirulina	P
Goob Weyn	*Bacillariophyta*	*Melosira*	P
		Navicula	A
		Nitzchia	P
		Stephanodiscus	A
		Synedra	A
	Chlorophyta	*Chlamydomonas*	D

STATION	TAXON	GENUS	RELATIVE ABUNDANCE
		Coelastrum	P
		Desmidium	P
		Gleocystis	C
		Oocystis	C
		Scenedesmus	A
	Cyanophyta	*Anabaena*	D
		Gomphosphaeria	P
		Lyngbya	P
		Merismopedia	P
		Oscillatoria	A
	Euglenophyta	Unidentified	D
Tributary	*Bacillariophyta*	*Melosira*	P
		Navicula	A
		Stephanodiscus	P
		Synedra	P
	Chlorophyta	*Ankistrodesmus*	P
		Cosmarium	C
		Gleocystis	P
		Oocystis	P
		Spirogyra	D
		Staurastrum	P
		Trachelomonas	P
	Cyanophyta	*Anabaena*	A
		Lyngbya	C
		Merismopedia	P
		Microcystis	C
Dhesheeg	*Bacillariophyta*	*Achnanthes*	P
		Melosira	A
		Navicula	P
		Stephanodiscus	D
		Synedra	P
	Chlorophyta	*Desmidium*	A
		Spirogyra	D
		Trachelomonas	P
	Cyanophyta	*Microcystis*	C

D = Dominant A = Abundant C = Common P = Present

Dominance of microflora varied from Luuq to Goob Weyn. At Luuq, the diatom *Melosira* sp. dominated the planktonic flora. At Buurdhuubo, *Nitzchia* sp., another diatom, was dominant, while *Melosira* sp. and *Stephanodiscus* sp. dominated at the dam site. At Fanoole, *Melosira* sp. and *Cosmarium* sp. (a green alga) were co-dominants. Finally, the estuarine microflora were dominated by a coccoid green alga, *Chlamydomonas* sp., and a blue-green alga, *Amabaena* sp.

It is important to note that although the water of the Jubba River is muddy, it supports a diverse and rich microflora.

C. Macrophytes

Perhaps the most notable characteristics of the Jubba River are the low diversity and the limited abundance of aquatic macrophytes. Only 24 species of aquatic macrophytes have been encountered. Some of them are not strictly aquatic but are hygrophilous ephemerals. Rooted macrophytes are the most prevalent vegetation of the Jubba River. Among the rooted emergent macrophytes, *Phragmites karka* and *Typha domingensis* dominate greater sections of the river. Development of aquatic macrophytes was more pronounced in the lower reaches (Fanoole and downstream) than the upper reaches (Fanoole to Luuq). For example, dense stands of emergent macrophytes were well-developed at Goob Weyn and Fanoole (see Table 5 below.) In these sites, the littoral vegetation was relatively more heterogenous and some general zonation could be distinguished.

Two broad zones of vegetation were recognized at Goob Weyn, the *Typha* and sedge zones. The *Typha* zone was a monoculture of *Typha domingensis* which extended to the water's edge. These plants reached a height of four meters. The aboveground standing crop of this community was estimated to be 1710 g m^{-2}. This included live plant material of 1350 g m^{-2} and dead plant material of 360 g m^{-2}. Behind the *Typha* zone was the sedge zone, dominated by *Fimbristylis dichotoma*. This zone was poorly interspersed with *Phragmites karka*, *Panicum maximum*, and *Ipomoea pes-caprae*. The aboveground standing crop of this zone was 1950 g m^{-2}, which included live plant material of 690 g m^{-2} and dead plant material of 1260 g m^{-2}.

At Fanoole Barrage, there was even greater aquatic

Table 5. Standing Crop of Emergent Vegetation at Goob Weyn

PLANT COMMUNITY	ABOVEGROUND STANDING CROP (gm^{-2}) LIVING	DEAD	TOTAL
Typha zone	1,350	360	1,710
Sedge zone	690	1,260	1,950

macrophyte development than at Goob Weyn. *Typha domingensis* formed the dominant zone, stretching for more than 10 meters into the barrage water. *Ipomoea cairica*, a creeper, occasionally grew and twined around *Typha domingensis* plants. Free-floating macrophytes, *Pistia stratiotes* and *Lemna* spp., were found on the surface of the calm, sheltered backwaters and grew as the understory of *Typha domingensis*. *Polygonum senegalense* was also found in the sheltered backwater. Behind the *Typha domingensis* zone on the landward side was a zone of *Phragmites karka*, *Panicum maximum* and *Echinochloa haploclada*, which blended with the terrestrial vegetation.

In other sites along the main river, emergent macrophytes were very poorly developed and did not form a distinct community. Scattered species of *Sphaeranthus polycephalus*, *Vahlia somalensis*, *Polygonum senegalense*, *Cyperus michelianus*, *Fimbristylis bisumbellata*, *Sporobolus helvolus*, and *Echinochloa colona* were found growing on the exposed mud at the riverbank. At Buurdhuubo, *Sphaeranthus polycephalus* and *Phragmites karka* were recorded. At Luuq, *Phragmites karka* was spotted growing on an island between the town and the World Concern camp (see Table 6.)

No submerged macrophytes were encountered in the Jubba River. However, a submerged macrophyte was recorded at a tributary stream, Isha Maalim, about 30 kilometers northeast of Baardheere. In this stream, which was transparent to the bottom, large clumps of *Chara* grew from the stream bottom to the surface. There was also a thick growth of filamentous green algae (*Spirogyra*) that was heavily trapped in *Chara* growth.

Table 6. Aquatic Macrophytes of the Jubba Valley

SITE	SPECIES	FAMILY
Goob Weyn	*Typha domingensis*	*Typhaeceae*
	Phragmites karka	*Gramineae*
	Ipomoea pes-caprae	*Convolvulaceae*
	Fimbristylis dichotoma	*Cyperaceae*
	Panicum maximum	*Gramineae*
Fanoole	*Typha domingensis*	*Typhaceae*
	Phragmites karka	*Gramineae*
	Panicum maximum	*Gramineae*
	Polygonum senegalense	*Polygonaceae*
	Cyperus immensus	*Cyperaceae*
	Cyperus exaltatus	*Cyperaceae*
	Echinochloa haploclada	*Gramineae*
	Ipomoea cairica	*Convolvulaceae*
	Pistia stratiotes	*Araceae*
	Lemna sp.	*Lemnaceae*
Dam site	*Sporobolus helvolus*	*Gramineae*
	Echinochloa colona	*Gramineae*
	Frimbristylis bisumbellata	*Cyperaceae*
	Cyperus michelianus	*Cyperaceae*
	Polygonum senegalense	*Polygonaceae*
	Sphaeranthus polycephalus	*Compositae*
	Vahlia somalensis	*Vahliaceae*
Buurdhuubo	*Sphaeranthus polycephalus*	*Composite*
	Phragmites karka	*Gramineae*
Luuq	*Phragmites karka*	*Gramineae*
Dhesheeg	*Nymphaea lotus*	*Nymphaeaceae*
	Cyperus longus	*Cyperaceae*
	Cyperus rotundus	*Cyperaceae*
Tributary	*Chara* sp.	*Characeae*
	Cyperus sp.	*Cyperaceae*
	Eleocharis geniculata	*Cyperaceae*

Apart from Fanoole, no floating macrophytes were encountered in any other section of the river. However, *Pistia stratiotes* and *Lemna* were common plants in ditches and pools in the Jamaame area. Floating-leaved macrophytes were not recorded at the sites investigated along the Jubba River. Nevertheless, *Nymphaea lotus*, a floating-leaved macrophyte, had infested ditches, canals, and pools of water in the Jamaame area. *Nymphaea lotus* was also recorded in the dhesheeg near Saakow.

D. Microfauna

The results of microfaunal analysis are shown in Table 7. The microfauna of the Jubba River consisted of 15 different organisms. These included five rotifers, two cladocerans, one copepod, three ciliated protozoans, three larval forms (mayfly, chironomid, and fish), and one nematode.

Table 7. Composition and Relative Abundance of Microfauna

STATION	ORGANISM	RELATIVE ABUNDANCE
Luuq	*Brachionus calicifloris*	D
	Mesocyclops	C
	mayfly larvae	P
	chironomid larvae	P
Buurdhuubo	*B. calicifloris*	D
	B. falcatus	A
	mayfly larvae	P
	chironomid larvae	P
Dam site	*B. calicifloris*	D
	B. plicatilis	C
Fanoole	*B. plicatilis*	D
	Brachionus sp.	C
	Philodina sp.	P
	Daphnia sp.	P
	Paramecium sp.	P
	Colpoda sp.	P
Goob Weyn	*Colpoda* sp.	D
	unidentified ciliate	A
	unidentified nematode	P
	fish larvae	P
Tributary	*B. plicatilis*	D
	Mesocyclops sp.	P
Dhesheeg	*B. falcatus*	A
	Philodina sp.	P
	Moina micrura	C
	Mesocyclops sp.	A

D = Dominant A = Abundant C= Common P = Present

A rotifer, *Brachionus calicifloris*, was the most abundant zooplankter at the Luuq, Buurdhuubo, and dam site stations. At Fanoole Barrage, another rotifer, *Brachionus plicatilis*, predominated. *B. plicatilis* was also the dominant species at the tributary station.

The estuarine community was dominated by pigmented ciliates. Three larval forms of mayfly, chironomids, and fish were found to form an important component of the microfauna at Luuq, Buurdhuubo, and Goob Weyn. Planktonic microfauna contributes significantly to the diet of fish and forms, an essential link between heterotrophic fish and autotrophic microflora.

E. Benthos

The groups of benthic organisms found along the Jubba River are shown in Table 8. They include mainly the larval forms of flies, beetles, mayflies, stone flies, caddis flies, and dragonflies. Other groups of benthic organisms recorded in the river were oligochaetes and snails.

Of the benthic organisms, only the flies and snails were represented in all the sites investigated. The benthic larval form of flies recorded in the sites were chironomids. Six species of snails were recorded along the river (Table 9). While living snails were encountered in all the sites except at Goob Weyn and Luuq, their highest density was recorded at Fanoole and the dhesheeg, both of which represent areas of slow-moving or stagnant water.

Table 8. Composition of Macrobenthos

ORGANISMS	DENSITY (organisms m^{-2}) *Luuq*	*Buurdhuubo*	*Dam*	*Fanoole*	*Goob Weyn*	*Dhesheeq*
Mayflies	146 20%	0	205 23%	29 3%	15 14%	0
Beetles	88 12%	73 16%	175 20%	29 3%	29 29%	0
Stone flies	0	29 6%	44 5%	29 3%	0	44 12%
Dipterans	292 41%	88 19%	102 11%	351 39%	44 43%	29 8%
Caddis flies	0	88 19%	336 38%	0	0	0
Dragonflies	0	0	0	0	0 8%	29
Oligochaetes	161 22%	161 34%	0	0	0	0
Snails	29 4%	29 6%	29 3%	453 51%	15 14%	263 72%
Totals	716 100%	468 100%	891 100%	891 100%	103 100%	365 100%

Table 9. Snail Distribution

SITE	SNAIL SPECIES
Goob Weyn	snail shells
Fanoole	*Bulinus forskalii/Cleopatra africana*/snail shells
Dam site	*Cleopatra africana*
Buurdhuubo	*Melanoides* sp.
Luuq	snail shells
Dhesheeg	*Cleopatra africana/Gabbiella parvipilla/Bulinus nasutus*

V. DISCUSSION AND CONCLUSIONS

In new reservoirs, biological development passes through three major stages during the initial years. First, there is deoxygenation in the hypolimnion due to the decay of drowned vegetation. Second, the organic matter is mineralized and nutrients are released into the water. Finally, the increased nutrient content results in the explosive growth of microflora, microfauna, benthos, macrophytes, and fish (Balon and Coche 1974; Moss 1980; Petr 1978; Symoens et al. 1981; Visser 1970). The initial high productivity of the tropical impoundments is followed by a decline in productivity corresponding to a change in nutrient status (Balon and Coche 1974; Petr 1978).

The microflora of the Jubba River is rich in terms of species diversity. The total number of microflora reported (36 genera) is high considering the river had been mightily flushed during floods in May and June 1987. An increase in the number of microflora taxa is expected during low-flow conditions, when the river will have characteristics more similar to those of the proposed reservoir. The recorded high diversity of microflora indicates that the reservoir will maintain a viable algal population since the genera of microflora identified can all proliferate in the lentic conditions created by the newly formed reservoir. In 1967, in Lake Kariba, 31 species of phytoplankters were present. This number increased to 39 species in 1970 (Begg 1973, cited in Balon and Coche 1974). As has been found in the Jubba River, where 16 species of chlorophytes were recorded in the present study, chlorophytes were dominant in Lake Kariba, with 15 species in this algal division.

It is important to note the presence of *Cyanophyta* (blue-green algae) at all the stations sampled. It is anticipated that when the Baardheere Reservoir is formed, blooms of blue-green algae will form during the initial stages. The three algal species that are likely to form blooms are *Anabaena circinalis*, *Microcystis aeruginosa*, and *Aphanizomenon* spp. The diatoms have also been known to form blooms as a result of eutrophication. Blooms of *Microcystis aeruginosa* have been reported to produce sufficient toxins to cause human health problems and cattle deaths (Noble and Hemens 1978). *Aphanizomenon* and *Anabaena* blooms are also reported to have caused fish kills, cattle deaths, and human health problems (Barica 1975). In addition, the blue-green algae impart noxious taste and odors to water.

Conditions that favor the growth of blue-green algae, such as high pH, high alkalinity and an abundance of nutrients (Fogg *et al.* 1973), are found in the Jubba River (Jobin 1986). The blue-green algae are also capable of growing under the low-light conditions found in the turbid waters of the Jubba River.

With ample micronutrients, suggested by the high electrical conductivity of the river water (Payne 1986), and sufficient soluble silica available, indicated by high pH and high temperatures, the nutrients that are likely to limit phytoplankton growth are nitrogen and/or phosphorus, the principal growth-limiting nutrients for phytoplankton in aquatic ecosystems. According to Jobin (1986), the Jubba River has high concentrations of nitrogen and phosphorus, with nitrate-nitrogen values ranging from one to 20 milligrams per liter and phosphate-phosphorus values of 0.001 to five milligrams per liter. These high concentrations do not suggest phosphorus or nitrogen limitation. These concentrations are indicative of eutrophic conditions and are highly suspect. At Baardheere, for example, the NO_3-N values reported range from 3.4 to four milligrams per liter. These levels are extremely high for a river system that apparently is not grossly polluted. NO_3-N concentrations reported for Lake Kariba ranged from 0.003 to 0.097 milligrams per liter (Balon and Coche 1974). As pointed out by Mitchell (1970), it is seldom that NO_3-N concentration in Lake Kariba reaches 0.020 milligrams per liter. Such low concentrations are in line with observations made in most East African lakes where NO_3-N remains below 0.030 milligrams per liter. The world average NO_3-N value is 0.3 milligrams per liter and this corresponds to Visser's average for East and West Africa lakes and rivers (Balon and Coche 1974). The mean NO_3-N concentration for African rivers is 0.8 milligrams per liter, according to Livingstone (1963). The limiting concentration of PO_4-P for phytoplankton development is 0.010 milligrams per liter (Talling and Talling 1965). This limiting value is far below the maximum value of five milligrams phosphorus per liter reported for the Jubba River by Jobin (1986). Jobin stated that the water chemistry values are very unreliable for the

Jubba River due to high turbidity and color of the river water when obtained with the colorimetric Hach kit. The methods used by Jobin in nutrient analysis are unknown to the authors since only tables of data extracted from the report were made available to them.

The increased algal growth due to the initial nutrient flux into the water will result in larger populations of zooplankton. The 15 species of microfauna recorded in this present study represent a viable zooplankton population. Begg (1973, cited in Balon and Coche 1974) found only 20 species of zooplankton in Lake Kariba in 1967, with rotifers and cladocerans co-dominants. The dominant zooplankters found in the Jubba River during the study period were rotifers. As in Lake Kariba, the microfauna community in the Jubba River lacks diversity. It is worth noting that the Jubba River was sampled after a major flood. In addition, ditches, canals, and dhesheegs, which were not visited due to the flooding, contained considerable unsampled species of microfauna representative of a lentic environment. These habitats would serve as sources of inoculum for the proposed reservoir.

In the newly formed reservoir, the zooplankton population explosion will be followed by an increase in both the populations and diversity of fish species. Thus, during the initial years of the creation of the dam, exceptional fish harvests can be expected. This peak in fish production is expected to decline after three to four years unless the eutrophic conditions are sustained by inputs from agricultural activity around the reservoir or from the upper catchment.

When a river valley is dammed, the river changes from a lotic to a lentic system. This reduces the rate of water flow. Coupled with an increase in nutrients, a characteristic of the initial stages of man-made lakes, it is expected there will be development of aquatic macrophytes in the proposed reservoir. Gaudet (1979) described the following pattern of succession of aquatic macrophytes in man-made lakes: the floating macrophytes develop first, followed by the sudd; there is a later decrease in floating macrophytes, an increase in submerged macrophytes and finally a development of drawdown flora. Such a sequence has been very pronounced in Lake Kariba.

Two of the floating macrophytes likely to cause great problems in the proposed reservoir are *Pistia stratiotes* and *Eichhornia crassipes*. In this survey, *Pistia stratiotes* was recorded at Fanoole Barrage and pools in the Jamaame area. Although there was no observation of *Eichhornia crassipes*, it has been reported that this weed infests irrigation canals (Tillman, personal communication).

As in other man-made lakes, one would expect *Pistia stratiotes* and *Eichhornia crassipes* to be pioneers in the proposed reservoir since they are independent of depth and substream requirements and are not affected by changes in water level. During the initial stages (the first three years of existence) of Lake Brokopondo (Surinam, South America), only floating macrophytes such as *Eichhornia crassipes*, *Ceratopteris pteridoides*, *Lemna valdiviana*, and *Spirodela biperforata* colonized the lake (Van Donselaar 1968). Results of this study show that *Pistia stratiotes* and *Eichhornia crassipes* were not found in the upper reaches of the river (above dam site). As a result, it is difficult to predict whether and when they might become a problem in the proposed reservoir. *Pistia stratiotes* and *Eichhornia crassipes* are most likely to become obnoxious pests if introduced during the initial stage of reservoir formation, since the lake will have high nutrient content at this time. The infestation of these weeds will depend mainly on their introduction to the reservoir by birds and other agents of dispersion.

Floating weeds have been known to cause major problems in African man-made lakes. Some of the problems that have been noted in these lakes are summarized in Table 10.

Table 10. Problems Caused by Aquatic Weeds (Symoens et al.)

LOCATION	SPECIES CONCERNED	TYPE OF PROBLEM
Lake Kariba	*Salvinia molesta*	interferes with navigation and fishing; reduces recreation; health hazard
Volta Lake	*Pistia stratiotes*, *Ceratophyllum demersum*	health hazards
Lake Mc-Llwaine	*Eichhornia crassipes*	health hazard; reduces recreation
Haatebees-port Dam	*Eichhornia crassipes*, *Salvinia molesta*, *Pistia stratiotes*	interfere with navigation

In addition to these problems, the presence of aquatic weeds in the proposed reservoir may pose a problem of water loss. There are a number of measurements to indicate that aquatic weeds lose considerable quantities of water by evapotranspiration. For example, evapotranspiration losses from *Eichhornia crassipes* communities have been reported to be 3.7 times higher (Timmer and Weldon 1967), four to five times higher (Little 1967) and 6.6 times higher (Penfound and Earle 1948) than evaporation losses from open water. However, this does not hold true for all aquatic weeds. Work on *Salvinia molesta* showed that evapotranspiration losses from weed mats were the same as evaporation losses from open water (Little 1969). Brezny *et al.* (1973) reported lower evapotranspiration loss from *Pistia stratiotes* than evaporation loss from open water.

The absence of submerged macrophytes in the Jubba River is mainly due to its high turbidity. *Chara* was the only submerged macrophyte found in this survey, although *Ceratophyllum demersum* was recorded previously in a dhesheeg north of Jilib (Jobin 1986). In the proposed reservoir the water will be much more transparent and this will allow greater light penetration, favoring the establishment of a submerged macrophyte community. These macrophytes will be established in the reservoir where the water depth does not exceed 10 meters and where the plants will not be adversely affected by large lake fluctuations.

The proposed reservoir will also be colonized by the rooted, floating-leaved macrophytes. Where the reservoir is shallow, there will be development of water lily zones, as *Nymphaea lotus* is a common feature of the ditches, canals, and dhesheegs of the Jubba Valley.

Although this survey has revealed poor development of emergent macrophytes in the upper reaches of the river, including the dam site, the inoculum is present in appreciable amounts. Hence, it is expected that the reservoir will be fringed by emergent macrophyte communities dominated by *Typha domingensis* and *Phragmites karka*. *Polygonum senegalense* will also be an important species in this community, especially where water does not exceed a depth of three meters.

Following the river impoundment, a large amount of terrestrial vegetation will be submerged. This flooded vegetation will play an important role in the development of the reservoir ecosystem, providing food as well as habitat in the form of drowned trees for the benthic organisms. Therefore, an increase in benthic population in the proposed reservoir can be expected. Especially important will be an increase in chironomid and ephemeropteran larvae, which have been reported to be an important source of food for the insectivorous fish in Lake Volta (Petr 1970).

The benthic organisms in the proposed reservoir most likely to cause health problems are the snails. Certain members of the genus *Bulinus* are the vectors of *Schistosoma haematobium*, which causes schistosomiasis (bilharzia). *Bulinus nasutus* has been reported to be the main intermediate host of *Schistosoma haematobium* in northwest and northeast Tanzania, coastal and western Kenya and some parts of Uganda, while *Bulinus abyssinicus* has been found to be the intermediate host of *Schistosoma haematobium* in Somalia (Brown 1980).

The above species of snails have been reported to occur in the waters of the Jubba Valley. *Bulinus nasutus* was found in Harenka Shariffka dhesheeg, while *Bulinus abyssinicus* was reported in the Fanoole Canal (Jobin 1986). The results of this study have shown that slow-moving and stagnant waters harbor the greatest snail population. Hence, the creation of the reservoir will provide conditions that favor an increase in snail population. Since some of the snails are vectors of bilharzia, the incidence of this disease can be expected to rise around the proposed reservoir. The situation will be made even worse by the presence of aquatic weeds such as *Ceratophyllum demersum*. The presence of this submerged weed in the proposed reservoir will provide ideal habitat for the *Bulinus* snail. In the dense *Ceratophyllum* beds, the snails feed, deposit eggs and find protection from predators.

The sedimentation rate of silt contained in the Jubba River was found to be fast. Water trapped behind emergent macrophytes at Fanoole Barrage is clear. Silt in the water samples collected at various points along the river settled quickly once the samples were placed on the laboratory bench. An experiment on the clarification rate carried out with water drawn from the river at Baardheere, where the Secchi depth measured 37 centimeters, showed that the Secchi depth increased to 75 centimeters in 13 days (Jobin 1986). It is expected that the proposed dam will have water of increased transparency and clarity. This in turn will extend the zone of effective light penetration into the water, resulting in increased algal production and stimulating development of submerged aquatic macrophytes such as *Ceratophyllum demersum*.

Initial flooding of the dam is expected to increase the surface area for periphyton, or attached algae, which will develop on the bottom of the newly formed shallows, submerged vegetation, and newly developed macrophytes. These shallow inshore areas favor a higher primary production compared with the open water due to frequent stirring to the bottom, increased nutrient release from the sediments and the proximity to inflows of nutrient-rich water and nutrient-rich effluents, as from agricultural sources.

In the section of the river downstream of the proposed dam, the composition and abundance of phytoplankton species will be increased. The reservoir will serve as a source of inoculum, since the discharge will contain abundant and diverse phytoplankton. The water will be of higher clarity, enhancing further development of the phytoplankton if the volume of outflow is maintained at average levels.

Experience with the construction and operation of existing reservoirs has shown that in most systems there is an initial deoxygenation of water in the hypolimnion due to the incorporation of organic matter from the flooded riverbed and floodplains. This deoxygenated condition may last from a few months to several years. In some cases, such as Lakes Nasser-Nubia and Kainji, the hypolimnial deoxygenated condition during thermal stratification seems to be a yearly occurrence (Symoens et al. 1981). Deoxygenation of the water below the thermocline reduces effective volume for primary production and for fish production. If the discharge from the reservoir is withdrawn from the hypolimnion through subsurface spillways rather than surface spillways, the aquatic flora and fauna are adversely affected. This hypolimnial water is devoid of oxygen and high in hydrogen sulfide, causing a reduction in aquatic populations downstream. The adverse effects of hydrogen sulfide from spillage water on the biota below the dam wall in Lake Kariba have been documented by Begg (1973, cited in Balon and Coche 1974).

Once a new reservoir has filled, the average river flow below the dam may be a little less than it was before. The seasonal pattern of flow is considerably changed, resulting in great changes in the lower river systems. The Jubba River floodplain will be reduced, with resultant reduction in diversity and abundance of macrophytes, especially on the lower reaches of the river. With the reduction of the floodplain, it is expected that there will not be enough water to feed the dhesheegs. This will result in a further reduction of diversity and abundance of aquatic populations downstream.

The silt load in a newly created dam is deposited in the reservoir itself. The silt deposit on the floodplains, which provides nutrient replenishment of the floodplains and serves as a detrital food source for inshore fishery, is greatly reduced. The fishery in the Mediterranean Sea off the River Nile delta is known to have declined since the closure of the Aswan High Dam, which impounds Lake Nasser-Nubia (Rzoka 1976). Further, without the silt loads to replenish the estuaries, coastal erosion may exceed the replenishment rate. This would lead to loss of the brackish water habitat and an increase in salt intrusion into the river and groundwater. During the filling of Lake Volta the river flow was reduced and the one percent salinity level moved upriver to about 50 kilometers from the sea (Moss 1980).

Finally, the dam will be a barrier to migrant fish, the most important being the eels, of which *Anguilla bengalensis* has been reported in the Jubba River by Meredith (1987).

This investigation required more time than was available. The actual time spent at each sampling site, an average of about two hours, was insufficient. A full day at each site would have allowed for more detailed work and replication of samples. Therefore, the absence of a species in the lists given does not necessarily mean it did not occur in the river.

Due to the shortage of the time available and extensive flooding in the lower reaches, making some sites inaccessible, it was not possible to investigate permanent dhesheegs, irrigation canals, and ditches. These are very important sources of inoculum of flora and fauna for the proposed reservoir. The determination of primary production and measurement of chlorophyll a were also not carried out due to lack of appropriate equipment and chemicals. Macrophyte cover, primary production and biomass studies were not conducted, again due to the shortage of time allocated to the whole survey.

VI. RECOMMENDATIONS

Once the reservoir is formed, *it is recommended that seasonal monitoring of phytoplankton growth be carried out. This monitoring should include measurements of primary production, phytoplankton biomass, and species composition. It is also recommended that zooplankton and benthic community production, biomass and species composition be determined regularly, as well as measurements of primary production, standing crop cover and species composition of aquatic macrophytes. Especially important in this respect will be the monitoring of aquatic weeds*, which can cause tremendous problems in the management of the proposed reservoir.

Post-impoundment surveys should be conducted regularly to locate new growths of aquatic weeds, particularly the exotic species, which could pose problems in the future. Monitoring for water weeds can be carried out by aerial surveys. Such surveys have been done in Lake Kariba (Mitchell 1974; Mitchell and Rose 1979) and Cabora Bassa (Bond and Roberts 1978). The surveys were done from a four- or six-seater aircraft flying about 300 meters above the lake surface at an air speed of 200 to 250 kilometers per hour. Three or four observers independently map areas of weed coverage to a scale map of the reservoir. The maps of several observers are compared after each flight and a composite map is compiled. The areas are subsequently measured with a planimeter.

In addition to the above method, a large number of aerial photographs can be taken and used as a basis for the estimation of extent of aquatic macrophytes. This procedure will provide a more accurate record of the area covered by water weeds and a useful check on the mapping estimate of aquatic weeds coverage. As a further check, the areas occupied by water weeds can be estimated from extensive boat surveys.

It is strongly recommended that another sampling be carried out during the low-flow months of January through March, when maximum development of microflora, macrophytes, microfauna, and benthic organisms can be expected to occur in the Jubba River. The present study was carried out after a major flood and during high water flow.

Finally, *the GSDR should establish a fully equipped laboratory for limnological and water quality studies. The training of local limnologists is absolutely essential for successful management of the reservoir.*

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Field Notes: Jubba River Limnological Study
2 to 31 August 1987

Sunday 2 August to Sunday 9 August 1987

- held briefing meetings with JESS team leader— discussed scope of work
- assembled field equipment
- were introduced to the National University of Somalia Chemistry Department
- obtained permits for field visits
- obtained USAID contractor identification cards
- obtained documents to permit us to take photographs of features of limnological interest

Monday 10 August 1987

- left Muqdisho for Jilib at 0830 hours
- crossed the Shabeelle River at Awdegle at 1000 hours; a brownish, chocolate-colored river, terrestrial vegetation merged with river, no aquatic macrophytes observed
- the lower Shabeelle area appeared to be very productive—bananas, mangoes, and grapefruits grown on the farms
- arrived at Jilib at 1630 hours; the vehicle got stuck near the entrance to the JESS guest house compound for two-and-a-half hours

Tuesday 11 August 1987

- early in the morning, at 0600 hours, started to fill a channel dug across the driveway to enable driving out from the JESS compound
- at 0800 hours , left Jilib and headed toward Kismaayo
- at 0900 hours, crossed the Jubba River at Kamsuuma
- at Kamsuuma , observed *Phragmites karka*, thick growths of *Nymphaea lotus* ,and *Pistia stratiotes*
- arrived at Kismaayo at 1030 hours; presented our papers to government authorities
- from Kismaayo, started looking for a suitable sampling site near the estuary
- located sampling site at Goob Weyn at 1230 hours; worked for three-and-one-half hours
- left for Jilib at 1600 hours
- in Jamaame, collected specimens of *Pistia stratiotes* and took photographs of *Nymphaea lotus community*
- there were extensive banana plantations in this region

Wednesday 12 August 1987

- presented papers to the government authorities
- left Jilib for Fanoole Barrage, arrived at 1325 hours
- en route to Fanoole, observed some growth of *Typha domingensis* in the ditches and ponds along the road
- began sampling at Fanoole at 1300 hours; the barrage seemed very rich in fish and the Chinese personnel spent hours catching fish
- were especially excited to find *Pistia stratiotes* at this site

Thursday 13 August 1987

- woke up at 0500 hours, broke camp and after breakfast, at 0800 hours, set off for Bu'aale and Saakow
- drive was OK as far as the Fanoole turnoff
- thereafter, road to Bu'aale became bad; five kilometers after Fanoole turnoff, started using the winch
- at one spot, spent at least three hours trying to get the Blazer out of the mud
- real trouble started when one of the belts of the power steering mechanism broke, fluid started to pour from the engine and one of the indicators started showing "water in fuel"
- after getting out of this spot, realized that the brakes were no longer working satisfactorily; with power-steering gone, the steering wheel became very rigid

- after several attempts to forge ahead, realized vehicle was beginning to lose power; decided to turn back to Jilib and proceed to Muqdisho to have vehicle repaired
- driving back to Jilib was a nightmare; worked nonstop—using the winch, digging up the soaked soil, paving the road, pushing the truck, etc.; the winch got cut
- we made it to a small village near Fanoole where truck stopped and all attempts to start it failed
- decided to call it a day at 2200 hours; Abul Kadir (Golden Boy) made us spaghetti with onion sauce and after dinner, we slept

Friday 14 August 1987

- in the morning, had orange squash for breakfast, cleaned the oil filter, and changed a flat tire
- at 1000 hours, Hassan and Kenyan went to Fanoole for help to get the Blazer started
- mechanic from Fanoole Barrage helped repair vehicle; left Fanoole for Muqdisho at 1200 hours
- arrived in Muqdisho at 2200 hours and reported to Gus Tillman about the problems of the Safari

Saturday 15 August 1987

- on Saturday morning, rested while the vehicle was being repaired
- in the afternoon, started preparations for the second trip, scheduled for Sunday 16 August 1987

Sunday 16 August 1987

- woke up at 0600 hours all set for the trip
- met Gus Tillman for a briefing on the trip and finances
- waited for a whole day; vehicle was not ready and the trip was postponed to the next day

Monday 17 August 1987

- left FSU for Baardheere at 0730 hours
- passed through semi-arid stretches where camel, cow, goat, and sheep rearing, and sorghum cultivation were the major human activities
- noticed in addition that there was a remarkable extent of overgrazing and environmental degradation
- arrived in Baardheere at 1430 hours and presented our papers to the government authorities

Tuesday 18 August 1987

- left for the dam site at 0715 hours, arriving at 0830 hours
- work at the dam site was finished at 1000 hours
- returned to Baardheere Guest House and had early lunch at 1100 hours; left for Harinka Shariffka dhesheeg, five kilometers upstream of Saakow
- arrived at the dhesheeg at 1530 hours and began our investigation immediately; this was a temporary dhesheeg and was very much influenced by human activities
- around the dhesheeg was a crop of sesame; saw evidence that farmers plant their crops as the water in the dhesheeg recedes

Wednesday 19 August 1987

- woke up at 0545 hours and started preparing for the trip
- at 0930 hours, left for Buurdhuubo
- reached Isha Maalim stream at 1030 hours; this was a clear water stream which had good growth of *Chara* and filamentous green algae (*Spirogyra*)
- after taking some measurements, proceeded to Buurdhuubo
- arrived in Buurdhuubo at 1430 hours and began sampling immediately
- found many small houses for refugees in the surrounding area

Thursday 20 August 1987

- left camp site at Buurdhuubo at 0800 hours
- passed through scrubland and arrived in Garbahaarey at 0915 hours
- arrived in Luuq at 1230 hours

- camped in World Concern compound
- after finishing sampling, crossed the Jubba River in a motorboat
- like Buurdhuubo, the area had many refugees

Friday 21 August 1987

- left Luuq for Muqdisho at 0840 hours
- encountered large herds of camels
- on arrival in Muqdisho at 2000 hours, reported to Gus Tillman and briefed him on our trip

Saturday 22 to Sunday 31 August 1987

- conducted analysis of the collected samples at the National University of Somalia
- met director of USAID mission in Somalia and discussed our limnological study of the Jubba River
- wrote draft report on our limnological findings
- submitted report to Gus Tillman
- left Somalia for Kenya on 31 August 1987

Fisheries in the Jubba River

prepared by
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JESS Consultant, Mr. Earl Meredith, studied the fishery resources along the Jubba River during two field trips, October to November 1986 and March to May 1987. Mr. Mohamad Hassan Aden, of the Ministry of National Planning and Jubba Valley Development (MNPJVD), assisted Mr. Meredith with the frame survey during the first consultancy. Further assistance was provided by Mr. Ahmed Abdulaahi Yassin, of the Ministry of Fisheries and Marine Resources (MFMR).

I. EXECUTIVE SUMMARY

This report details the results of a consultancy to assess the potential impacts of construction of the proposed Baardheere Dam on downstream fish populations and fisheries development in the Jubba Valley (see Figure 1 at the front of this volume). The goals of this fisheries assessment were to describe the status of the fisheries in the Jubba Valley, identify effects of the proposed dam on the fish populations in the Jubba River, and discuss fishery development and management issues relevant to the Valley as a whole.

The preliminary consultancy consisted of two field trips. The first, from the mouth of the Jubba River to Fanoole Barrage, took place from 6 to 20 October 1986. The second, from Saakow to Luuq, was conducted from 30 October to 17 November 1986. Field notes from the first trip are included in Appendix A of this report.

A second consultancy was completed between 22 March and 17 May 1987. Five field trips were conducted during this period. Three of these trips sampled fish populations in the Jubba Valley. The other two assessed fishery potential and observed fishing activities at the Jowhar Reservoir on the Shabeelle River. A Somali fisheries biologist was trained in rotenone chemofishing during these trips.

Ichthyomass (fish biomass) was estimated to be 350 to 1,250 kilograms per hectare, using an 80 percent confidence interval. Approximately 20 fish species were collected during the study. Based on predictive models, the annual sustained harvest from the Jubba River could be 1,800 metric tons, with a potential value of U.S. $900,000.

Dam operators should be aware that induced chanes in the Jubba's normal hydrological cycle and flooding could have serious implications for river fisheries. Minimum permissible flows should be determined and strictly maintained to protect the diversity and productivity of the fishery resource. Also, design alternatives should be incorporated in the dam to ensure reoxygenation of river water after it passes out of the reservoir and into the river.

Based on the experience and findings of this study, the following recommendations are made:

- more extensive training for selected field personnel is needed in fisheries and aquatic ecology in order to optimize planning, development and management of fisheries in the valley;
- MNPJVD and MFMR should develop a cooperative infrastructure for development of fisheries; and
- continuous monitoring and assessment surveys and short-term fisheries development and extension programs are encouraged, including those aimed at improving fish consumption, marketing, and the development of cooperative fishing centers.

II. INTRODUCTION

The Jubba River flows south from the highlands of south-central Ethiopia and the northeastern corner of Kenya. The headwaters of the Jubba River are formed by the confluence of the Gestro, the Genale, and the Dawa rivers, as they flow into Somalia at Dolow. Daget and Iltis (1965) and Welcomme (1985) would classify the Jubba River as a Sudanian floodplain river, flowing through a semi-arid savanna region, with associated Nilotic fish fauna.

The hydrological cycle of the Jubba River, shown in Figure 2, is bimodal. Three levels of discharge correspond to the maximum, average, and minimum flow regimes at Luuq from 1951 to 1982. The early flood occurs from April to June each year; the second flood, the major high-water period, is from September to November.

The primary development effort proposed for the Jubba River is the construction of a mainstream dam approximately 35 kilometers upstream from Baardheere Town, or 400 kilometers from the mouth of the river at the port town of Kismaayo. Specific objectives of the fishery assessment were to:

- describe the fish community in the Jubba River;
- determine present fishing activities and fish consumption by local communities along the river;
- estimate the present economic value of the Jubba River fishery;
- forecast downstream effects of the proposed Baardheere Dam on fish populations;
- estimate potential fish production in the reservoir of the proposed dam; and
- discuss development and management issues relevant to fish resources in the river.

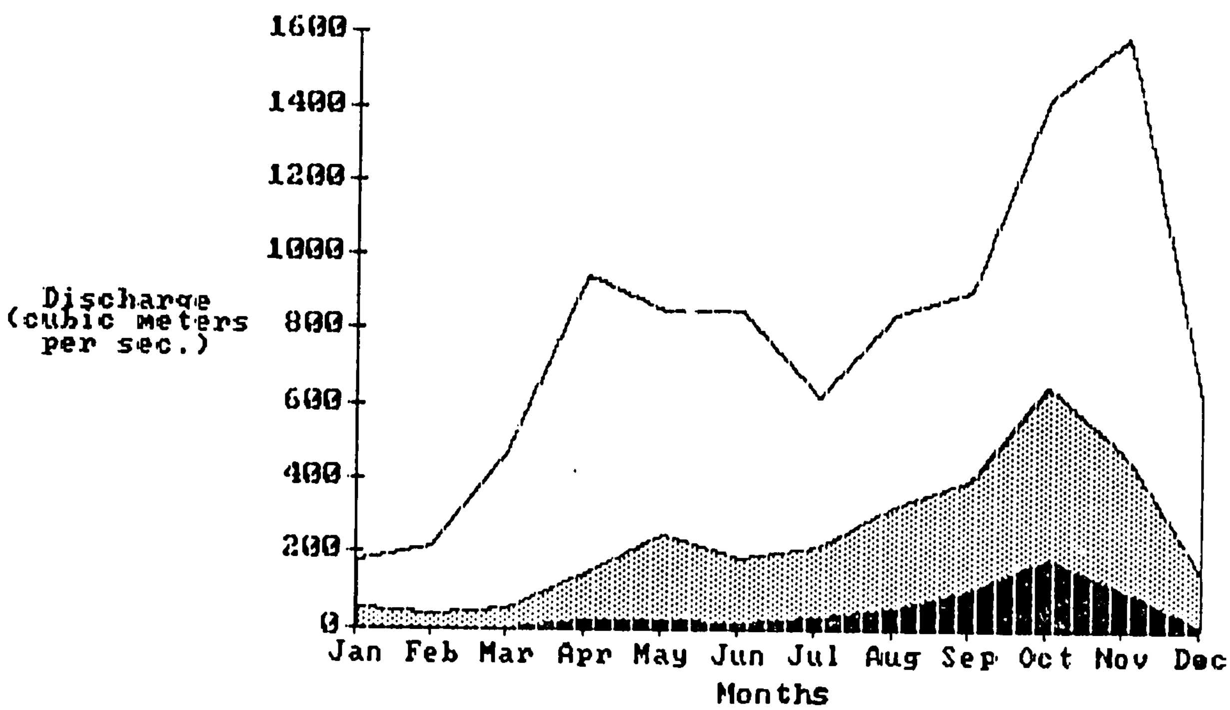

Figure 2. Jubba River Hydrological Cycle.

III. GENERAL RIVER CONCEPTS AND PREDICTIVE MODELS

Rivers and floodplains provide water for households, livestock, industrial use, transportation, irrigation, and hydroelectric power generation. A major use of African rivers is fishing, and most fisheries are local or regional. These small-scale, artisanal fisheries provide a source of income and valuable protein-rich food for families living along the river. Fishing usually is not a full-time activity, but is integrated into household, agricultural, and pastoral customs, which change with the hydrological cycle. On a continental basis, African rivers provide 40 to 50 percent of the total fish harvest (Welcomme 1985) and 25 percent of the total animal protein consumed by African peoples (Shell 1986).

Fisheries biologists in Africa have directed their efforts primarily toward assessing the status and potential of marine and lake fisheries. Until recently, rivers have received little attention, as is the case on a worldwide basis. One reason for this is that rivers are very complex ecosystems. They are open-ended, with potentially large variations in environments caused by seasonal changes in hydrological cycles and fluctuations in flow regimes. This diversity of habitats makes sampling, characterizing, assessing, and managing riverine fisheries very difficult. The sheer size of these systems, which sometimes cross international boundaries, compounds the management and development problems.

The necessity for comprehensive preimpoundment studies of African reservoir projects has been clearly recognized and discussed. Thorton (1980), Adenyi *et al.* (1981), and Marshall (1984) have offered predictive models of primary production and fish yields from African reservoirs using available preimpoundment information. Welcomme (1985) discussed the effects of river management and floodplain development practices on fish populations and river-basin ecosystems. His summary of the effects of hydraulic works on river fish communities is presented in Table 1.

Welcomme (1976) pointed out that, despite serious inadequacies in available catch data for African rivers, analysis of fish-yield patterns gives a fairly coherent picture of factors that can be used to determine the catch expected from a particular river system. Welcomme (1985) presented predictive models for annual fish catch for African rivers, using total basin area and main channel length. These models were applied to 20 rivers, and the results are presented in Table 2.

Excluding catches from exceptionally large flooded areas, the sample conformed to the following relationship:

$$C = 0.03A_C^{0.97}\ (r=0.91)$$

C and A_C are equal to annual catch (tons per year) and river basin area (square kilometers), respectively. Welcomme pointed out that, because river-basin area and total length of the longest channel (L) are correlated, fish catch can be depicted as a function of L (kilometers):

$$C = 0.0032L^{1.98}\ (r=0.90)$$

Thus, catch is approximately equal to $L^2/300$.

These models should only be used as tools to give fishery managers or resource administrators an estimate of potential harvest for riverine fisheries.

Marshall (1984) discussed using physical, hydrological, and chemical data to predict ecological parameters and fish yields in preimpoundment river-basin studies. Henderson and Welcomme (1974) pioneered the use of the morphoredaphic index (MEI) to predict fish yields in African reservoirs with the following relationship:

$$Y = 14.3136\ MEI^{0.4681}$$

Y equals the fish yield in kilograms per hectare and MEI the total dissolved solids (TDS) or conductivity divided by mean reservoir depth. This relationship was modified by Toews and Griffith (1979) to predict total catch (Y_T) from any particular system by adding lake surface area (A_o) in square kilometers to produce the following equation:

$$\text{Log } Y_T = 1.4071 + 0.3697 \log MEI - 0.00004565\ A_o$$

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Table 1. Summary of the Effects of Hydraulic Works on River Fish Communities

TEMPORAL CHANGES	EFFECTS
Changes in Flow	
Disruption of spawning patterns through inappropriate stimuli or unnatural short-term flows	Changes in community structure from seasonal spawners to species with more flexible spawning
Shift from pulse-regulated to stable-system dynamics	Diminished productivity at community level
Increase in flow rate (usually due to channelization)	Young fish in drift swept past appropriate sites for colonization; local shifts in species composition in tail race with accumulation of rheophilic (preferring flowing water) predators
Decrease in flow rate	Shifts from rheophilic to lentic communities in reservoir upstream and in controlled reaches downstream
	Changes in flushing rate resulting in accumulation or low dilution of toxic wastes or anoxic conditions leading to fish mortalities; loss of habitat
Prevention of flooding by dams and levees	Loss of floodplain area available for spawning growth; loss of habitat diversity; change in species composition with loss of obligate flood-plain spawners
	General diminution in productivity of whole system
Drowning of spawning substrates upstream of dams or in channelized reaches	Variable effects usually involving decline of lithophils or psammophils (specials that prefer rock or sand habitats, respectively), although new wave-washed shore or riprap may simulate rhithronic habitats
Blocking of Channel	
Interruption of migratory pathways by dam walls or by the creation of conditions unsuitable for passage	Elimination of diadromous or obligate migrants by preventing movement to upstream breeding sites by adults and slowing downstream movements of juveniles
Changes in Silt Load	
Changes in channel form (due to channelization or to changes in deposition/erosion process)	Reduction of habitat and community diversity; loss of species
	Increased rate of silt deposition (usually upstream of dams but also in newly cut-off portions of channel or channelized reaches downstream)
Changes in Silt Load (Cont.)	
	Choking of substrates for reproduction in lithophils /psammorphils
	Changes in density of vegetation, usually in favor of phytophils (vegetation-preferring species)
	Changes in quantity and type of food available and in the benthos (bottom substrate), leading to restructuring of the fish community toward iliophages
Decrease in suspended silt load	Changes in fish community, reduction in numbers of non-visual predators and omnivores
Lack of sediment (downstream from the dam)	Changes in nutrient cycle and in the nature of the benthos, leading to loss of illiophages and increase in benthic limnivores
Changes in Plankton Abundance	
Increase in phytoplankton in reservoir or downstream due to slower flow and higher water transparency	Increase in abundance of planktivorous fish
Changes in Temperature	
Changes in mean temperature caused by low-flow regimes	Increasing temperature variation can cause shifts in success of spawning due to adverse temperature for cold- or warm-water spawners
Stratification in reservoirs	Difficulties of passage for migrant species; elimination of fish in the deoxygenated hypolimnion; fish mortalities downstream of dams due to emission of anoxic waters and H_2S
Uptake of Water	
Induction of water into power stations or through pumps or irrigation canals	Entrainment of fish into currents diverting them; impingement of fish on turbines and pumps, resulting in loss of fish, particularly juveniles
Water transfers between river systems	Transfer of species and disease organisms from one system to another

Source: Welcomme 1985

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Marshall (1984) discussed the use of preimpoundment physio-chemical data to predict fish yields in African reservoirs. These data include:

- physical data — reservoir shoreline length (L_o) in kilometers; reservoir surface area (A_o) in square kilometers; mean depth (z) in meters; volume (V) in meters cubed x 10^6; catchment area (A_c) in square kilom ters; and
- chemical data — conductivity in S cm^{-1}; TDS in mg l^{-1}.

Table 2. Main Channel Length, Basin Area, and Catch from African Rivers

RIVER	CHANNEL LENGTH (km)	BASIN AREA (km^2)	ANNUAL CATCH (tons)
Nile	6,669	3,000,000	40,840
Zaire	4,700	4,014,500	82,000
Ubangi	1,060	772,800	4,670
Kasai	1,735	342,116	7,750
Niger	4,183	1,125,000	30,000
Benue	1,400	219,964	12,570
Zambezi	2,574	1,300,000	21,000
Senegal	1,641	335,000	16,000
Gambia	1,120	77,000	3,000
Volta B.	650	45,324	1,560
Volta R.	260	6,871	370
Volta W.	255	6,602	70
Pendjari	330	11,226	140
Oueme	700	40,150	646
Mono	360	22,000	533
Tana	600	38,000	500
Bandama	950	97,000	3,408
Sassandra	650	75,000	1,518
Comoe	1,160	78,000	2,142
Rufigi/Ruaha	750	17,700	3,600

Source: Welcomme 1985.

By using this information, it is possible to predict yields from simple, readily available morphometric data. Youngs and Heimbugh (1982) showed that lake area alone is a powerful predictor of fish yields in African reservoirs. They derived the following model to predict total yield (Y = total yield in tons) using lake area:

$$\log_e Y = 3.57 + 0.76 \log_e A_o \ (r=0.858)$$

A second approach uses a more detailed morphometry technique. Two concepts form the basis of this model—a dendritic reservoir (many coves and arms) would be more productive than a non-dendritic one and a shallow reservoir more productive than a deep one. Lake shoreline development (D_l), calculated using the following formula, indicates how dendritic a reservoir is:

$$D_l = L_o (2 \ A_o)^{-1}$$

Fish yields were plotted against D_l/z for seven African reservoirs, resulting in the following model, which had a good correlation:

$$Y \text{ (kg/ha)} = 19.996 + 32.038 \ (D_l/z)$$

Estimates of potential fish yield in the proposed Baardheere Reservoir can be made when the above physical and chemical data become available.

The assessment of the fisheries of the Jubba River was based on a fish-biology sampling (FBS) program and a catch-assessment survey (CAS). The CAS was conducted to determine the levels of fishing and the extent to which the resource is being exploited. In addition, fishery-related questions were added to the socioeconomic baseline studies (SEBS) to determine the amount of fish being sold in the marketplace and the role fishing and fish consumption play in the households of Jubba Valley villagers.

A. Fish-Biology Sampling

The objectives of the FBS program were to:

- identify species present in the river;
- determine relative abundance of each species;
- establish length-frequency distributions for each species caught;
- begin providing data which will be useful in establishing weight-length relationships and condition factors for each species;
- determine length at maturity and seasonality of spawning for valuable commercial species;
- attempt to identify fish migrations; and
- establish baseline catch per unit of fishing effort (CPUE) measures for experimental fishing gears for future comparisons of relative stock density.

The FBS was conducted using experimental gill nets, hoop nets, hook lines, and rotenone chemofishing techniques. Fish captured were weighed, measured, and identified by taxa. Sex and maturity were determined by visual observation of the gonads and ranked according to the following scale:

- sex not visually discernable;
- immature—sex discernable, but gonads translucent;
- mature and in spawning condition—running eggs or milt either by stripping or upon handling of the fish; and
- mature and spent—gonads well developed but empty and flaccid, much vascularization;

The adult stock of a particular species was considered to be all individuals equal to, or larger than, the smallest fish collected at Maturity Stage 4.

1. Experimental Gill Net Sampling

Experimental gill nets were monofilament and multifilament, each with seven panels, 50 feet long and eight feet deep. Mesh sizes for both types of gill nets, in both inch and millimeter bar measure, twine sizes, mounting ratios, and net depths measured in number of meshes are shown in Table 3.

Table 3. Gill Net Specifications Used During the Fishery Investigations in the Jubba River

Monofilament Experimental Gill Nets

MESH SIZE (inch)	MESH SIZE (mm)	TWINE Size	MOUNTING Ratio	NUMBER OF MESHES (in depth of net)
1.0	22	69	12/12	54
1.5	35	69	8/12	36
2.0	47	104	8/14	27
2.5	60	139	6/15	21
3.0	73	139	5/15	18
3.5	86	208	5/17.5	15
4.0	98	208	5/20	13

Multifilament Experimental Gill Nets

MESH SIZE (inch)	MESH SIZE (mm)	TWINE Size	MOUNTING Ratio	NUMBER OF MESHES (in depth of net)
1.0	22	104	12/12	54
1.5	35	104	8/12	36
2.0	47	139	8/14	27
2.5	60	139	6/15	21
3.0	73	139	5/15	18
3.5	86	208	5/17.5	15
4.0	98	208	5/20	13

The monofilament gill nets had a one-ounce lead on every other tie along the bottom line, and a #125 float every 60 inches along the top line. The top and bottom lines were #6 braided poly-nylon lines. Mul-

Experimental gill nets were set in the main channel and along the shoreline. During high-water season, nets were set at varying depths from the bottom to the surface; during low-water season, they usually filled the entire water column. The nets were generally set in the afternoon and fish were removed the following morning.

2. Hoop-Net Sampling

The hoop nets, a design proposed by Ahmed Yassin, were the type used extensively by the MFMR freshwater research group. They were constructed locally, using steel reinforcing bar and fishing net of two different multifilament nylon mesh sizes, 0.5-inch stretch mesh for the cod end, and two-inch stretch mesh for the remainder. Hoop nets were installed on the bottom of the river in several locations and in various depths of water. The openings were set facing downstream to trap fish swimming upstream. Traps were baited with fish and fish trimmings and most were set to a maximum depth of about six feet. The majority of hoop net sampling was done during the low- and rising-water seasons.

3. Rotenone Chemofishing

The rotenone sampling technique allows standing crops (numbers or kilograms per hectare) of fish to be estimated with relative nonselectivity for species and sizes of fish. Fish toxicants have been used worldwide for sampling fish populations. In the United States, rotenone, which inhibits respiration in gill-breathing organisms, has been most widely used for chemofishing sampling programs. Rotenone is an extract of the roots of plants of the family Leguminosae. *Derris*, a native of Australia, Oceania, and Southern Asia, is the most common genus. The crystalline forms of this substance ($C_{23}H_{22}O_6$) are insoluble in water, but soluble in organic solvents. Emulsified liquid formulations are most frequently used for fishery biology. The chemical is relatively safe, effective, and available.

Numerous fishery biologists in Africa have used this technique to classify fish populations in lakes and rivers. Toews and Griffith (1979) used chemofishing to estimate the ichthyomass (in kilograms per hectare) and potential yield for the Lake Bangweulu system in Zambia, Central Africa, and Kapetsky (1974) used this technique to determine ichthyomass and fish production in the Kafue River floodplain.

Chemofishing was conducted in the Jubba River during low-water season, from 31 March to 2 April 1987 in the Baardheere area, and from 23 to 24 April 1987 in the Jilib area. One rotenone sampling was conducted in the Jowhar Reservoir on the Shabeelle River between 4 and 6 May 1987.

The objectives of the rotenone sampling program were to:

- estimate ichthyomass in the Jubba River and Jowhar Reservoir to compare fish populations and estimate potential fish populations in the proposed Baardheere Reservoir;
- describe fish species compositions in the Jubba River and Jowhar Reservoir;
- develop length-frequency distributions for each species; and
- train a Somali fishery biologist in chemofishing techniques.

Materials used for rotenone sampling included:

- five percent liquid emulsified rotenone;
- one block net 12' X 100' X 1/8" (ace mesh);
- one block net 10' X 150' X 1/4" (knotted mesh);
- boat and outboard motor with necessary gear;
- dip nets, buckets, measuring boards, and weighing scales;
- survey equipment (tripod, survey level, Philadelphia rod, data book, etc.);
- crystalline potassium permanganate ($KMnO_4$) used for detoxification of rotenone; and
- miscellaneous materials, including rope, anchors, floats, water jugs, cameras, knives, calculator, and fish collection jars with formalin.

Holder and Crotchet (1984) described methods of setting up stream sampling sites and application of rotenone. These methods are more applicable to the United States, where proper equipment and logistical support are available. The methods were adapted to local conditions in the Jubba River.

Most river ichthyomass estimates are based on low-water sampling programs, since flows are too swift for rotenone sampling during the flood or high-water season. Small floodplain or riverbed pools created by exposed sandbars provide low-water habitat without strong currents. It was assumed that, during floods, the ichthyomass in the river would not differ significantly from that of the open-water areas of the floodplain. On the basis of repeated rotenone and seine sampling in open-water floodplain, the estimated ichthyomass was 337 kilograms per hectare. Samples taken during low water were less, 204 kilograms per hectare, but it was shown that the dry-season estimate was low due to fishing pressure and variability in sampling.

Sample sites were chosen based on the absence of current and the ease of closing off the area with block nets. These nets were relatively small, thus restricting the choice of sampling sites. No main-channel sampling was possible because the potassium permanganate, used to detoxify the rotenone downstream from the sample site, did not arrive until the water level increased and flows were too fast. Welcomme (1985) described several rotenone-sampling methods used by fishery workers on large rivers. He pointed out that rotenone sampling, and indeed any fish sampling in the main channel, is difficult due to strong currents, channel width, and labor force requirements.

For this reason, sampling in the Jubba River was done in small pools, ranging in size from .006 to .20 hectares, created by exposed or deposited sandbars and connected to the main channel. The two pool habitats can best be described as "dead-arm" and "slack-arm" pools (Figures 3 and 4). Welcomme (personal communication) described the interactions between these pools and the main channel of the river.

In a dead-arm pool, the sandbar is located on the outside of the river bend and has created a small island with a narrow arm separating it from the main bank. As the water level recedes and sand is deposited at the upper end, the upstream inlet closes and the small channel is blocked at the upper end. The downstream outlet remains open, but very little water exchange or interaction between the dead-arm pool and main river channel occurs (Figure 3).

A slack-arm pool is created on the inside of the river bend and by exposed sandbars, but the upstream portion of the bar is not isolated from the main bank. The slack-arm pool is usually smaller than the dead-arm pool. There is much more water exchange due to eddy turbulence created by the strong current close to the pool entrance (Figure 4). The small size of the pool contributes to interaction and water exchange with the main channel.

During rotenone sampling, the block net was placed in the water at the downstream end, completely blocking off the pool from the rest of the river, and the sink line was checked to make sure it was lying along the bottom so the net blocked the entire water column. The sample site was surveyed to determine surface area, mean depth was estimated, and enough five-percent rotenone was applied to the area to insure a one to two parts per million (ppm) concentration. All fish were collected, identified, measured, and weighed. Sometimes, because of a large number of fish and lack of trained manpower, a 10-percent subsample was taken, and individual weights were not taken.

Ichthyomass was calculated by dividing the number of kilograms of fish collected by the area sampled (in hectares). Fish biomasses were estimated for these small-pool habitats and do not necessarily reflect the entire river. However, the information collected will give first-order estimates of the fish population biomass, species composition, and length frequencies. These data, combined with the other stock assessment methods, will provide a valuable data base for fishery administrators.

B. Catch-Assessment Survey

For less exploited river systems, or for very dispersed fisheries, data collection is more difficult. Landings are not centralized or well defined, and few, if any, fish markets exist, making it difficult to sample fishermen to determine effort and catch. The sheer size of some river systems and the extremely low water conditions that can exist during dry periods also contribute to sampling problems. In these situations, other sampling methods, incorporating fish transportation and consumption surveys, have proven valuable.

Statistical sampling designs are varied and depend on the complexity of the system. Gulland (1972) described several sampling and statistical methods used by fishery biologists. In many designs, it is desirable to stratify the river system into relatively homogeneous spatial and temporal units to reduce variability and increase the effectiveness of sampling. It is also necessary to randomize sampling to reduce potential bias. Stratified random sampling is a common sampling method when physical and logistical conditions are favorable.

Basic estimates needed for fisheries assessment, monitoring, and subsequent management are:

- effort (E) — the number of fishing units operating on the system, *i.e.*, individual fishermen operating out of small dugout canoes or walking along the bank, or groups of fishermen operating out of larger boats;
- catch (C) — an estimate of total harvest; and
- CPUE — a measure of fishing success, dependent on catchability and relative abundance of fish. CPUE can also be a measure of the profitability for an individual fishing unit. Malvestuto and Meredith (in press) used the distribution of individual CPUEs on the Niger River in Niger, West Africa, to determine the percentage of no-profit days that fishermen experienced on that system.

After completing a preliminary fisheries survey in the Jubba Valley during the first consultancy, a stratified random sampling program was designed and implemented. This program proved to be difficult for the fishery technician to conduct, and manpower was very limited. During the second consultancy, the sampling design was modified so one person could collect as much data as possible.

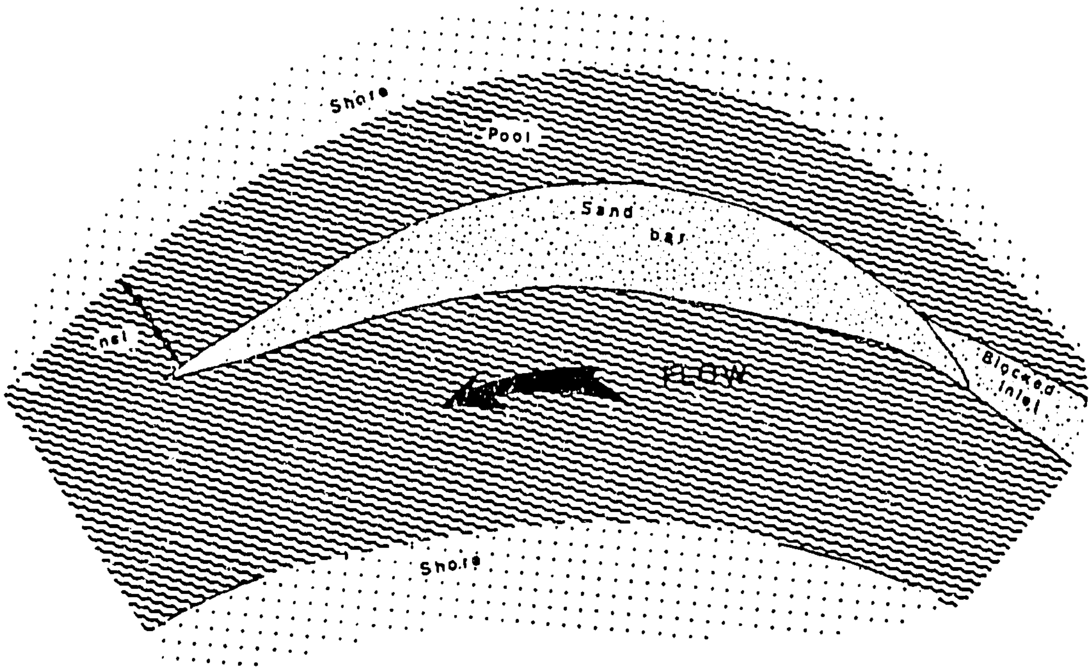


Figure 3. Dead-Arm Pool

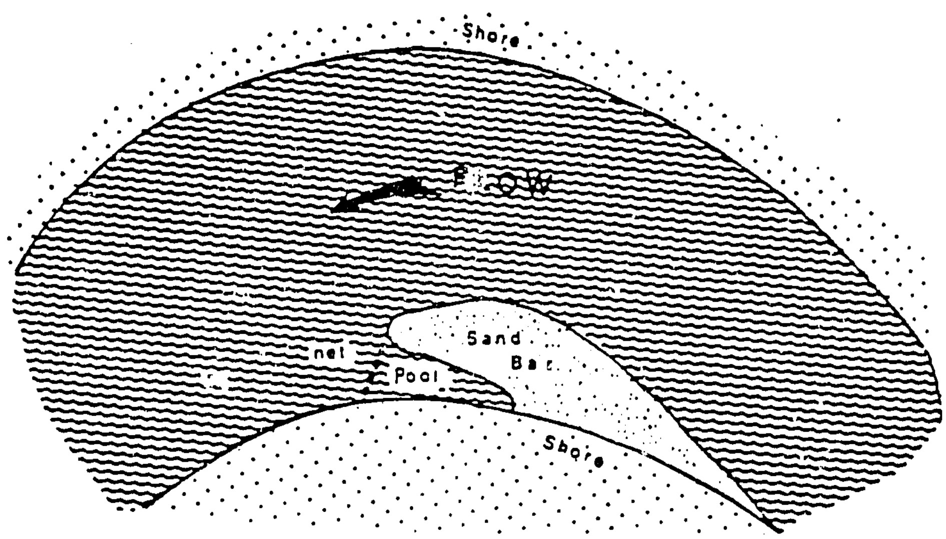
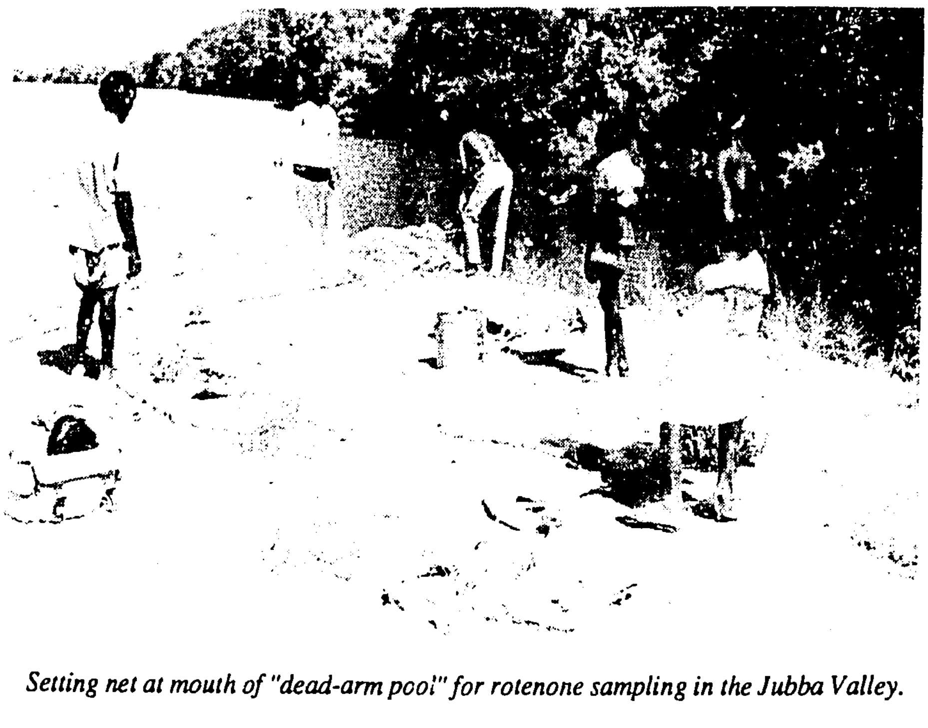


Figure 4. Slack-Arm Pool

Selection of "slack-arm pool" for rotenone sampling in the Jubba River, 10 kilometers downstream from Baardheere, 15 April 1987.



Setting net at mouth of "dead-arm pool" for rotenone sampling in the Jubba Valley.

Ahmed Abdulaahi Yassin surveying rotenone sampling site, 15 April 1987.

Ahmed Abdulaahi Yassin collecting fish during Jowhar rotenone sampling.

Ahmed Abdulaahi Yassin packing large Clarias gariepinus *and* Bagrus *spp. collected during rotenone sampling in the Jubba River, 15 April 1987.*

Ahmed Abdulaahi Yassin with large Clarias gariepinus *collected from the Jubba River rotenone sample.*

Earl Meredith collecting fish in "dead-arm" pool of the Jubba River.

Basins of Barbus *spp. collected during rotenone sampling in the Jubba River.*

Gonadal inspection of large Clarias gariepinus *captured in the Jubba River. The tip of the knife points to the ripe ovary.*

Preliminary results of the FBS and CAS are presented in this section. It is strongly recommended that sampling programs continue in a standardized fashion in order to monitor pre- to post-impoundment changes in the fish populations. Further data collection will improve the statistical validity of the assessment presented here.

The current sample sizes for each gear used are as follows:

gill net (gn)	20 sets
hoop net (hn)	9 sets
hook line (hl)	3 sets
rotenone	6 samples

A. Catch Per Unit of Effort

Calculation of CPUE, frequently used as an index of fish abundance, will allow comparisons of fish abundance before and after impoundment of the Jubba River. The CPUE for each experimental fishing gear type and size is presented in Table 4.

Table 4. Catch Per Unit for Experimental Fishing Gear

Stratum 1 (Northern Region)

GEAR TYPE	GEAR SIZE	SAMPLE FREQ.	MCPUE (gm)	MINCPUE (gm)	MAXCPUE (gm)
gn	1.0	8	725	50	1,600
gn	1.5	12	3,063	200	18,180
gn	2.0	9	6,027	670	14,730
gn	2.5	7	5,139	400	15,100
gn	3.0	7	5,051	1,460	12,200
gn	3.5	7	2,157	600	4,700
gn	4.0	4	7,468	870	10,500
hl	*	3	5,633	2,000	10,000
hn	*	9	1,513	40	9,650

Stratum 2 (Southern Region)

GEAR TYPE	GEAR SIZE	SAMPLE FREQ.	MCPUE (gm)	MINCPUE (gm)	MAXCPUE (gm)
gn	1.0	4	2,540	570	4,830
gn	1.5	8	2,481	220	8,725
gn	2.0	6	3,293	700	6,200
gn	2.5	5	2,770	700	6,500
gn	3.0	4	3,752	2,200	5,500
gn	3.5	4	9,000	2,400	18,500
gn	4.0	3	3,367	590	6,000

**Hoop nets and hook lines are of one size only.*

Number of samples taken (sample freq.), mean catch per set (mcpue), minimum catch per set (mincpue), and maximum catch per set (maxcpue) for each gear type and gear size by strata are shown. Gear types are abbreviated as gill net (gn), hook line (hl), and hoop net (hn). Gear sizes are in inch bar mesh.

By analyzing CPUE for gill net mesh sizes combined into a single fleet, rather than by individual mesh sizes, it is more practical to determine the number of sets needed to accurately estimate CPUE within a certain percentage confidence limit. The following formula was used to calculate the number of samples needed to obtain 80-percent confidence intervals of +25 percent and ± 30 percent:

$$n=(t^2)(CV^2)/d^2$$

where:

n = necessary sample size;
t = student's t value at n-1 degrees of freedom and at alpha=.20;
CV = coefficient of variation; and
d = desired confidence level.

CV and d are expressed as percentages. The resulting information is given in Table 5.

Table 5.

GEAR TYPE	MEAN CPUE (gm)	MINIMUM CPUE (gm)	MAXIMUM CPUE (gm)	CV (%)	SAMPLE SIZE at d = 25%	30%
gill net	3,900	50	18,500	105	29	20
hook line	5,633	2000	10,000	72	13	9
hoop net	1,513	40	9,650	202	107	74

B. Species Composition

1. Experimental Gill-Net Sampling

The species composition by percent weight and number from experimental gill-net sampling on each stratum of the Jubba River is shown in Table 6. Eleven positively identified species, and three species that could be identified to genus only, were captured in Stratum 1 (northern region). Six positively identified species and three species identified to genus only were caught in Stratum 2 (southern region).

In Stratum 1, the following four genera made up 88.6 percent of the catch by weight: *Eutropius depressirostris* (35.17%); *Clarotes* spp. (34.63%); *Labeo* spp. (12.67%); and *Synodontis* spp. (6.11 %). In Stratum 2, 95.5 percent of the experimental gill net catch in weight was composed of *Clarotes* spp.

(38.8%), *Labeo* spp. (28.6%), *Eutropius depressirostris* (16.5%), and *Synodontis* spp. (11.8%).

Table 6. Percent Species Composition by Number and Weight in Each Geographical Stratum

GENUS AND SPECIES GROUPS	NORTHERN REGION		SOUTHERN REGION	
	% wt	% N	% wt	% N
Mormyrops deliciosus	0.39	0.67	-	-
Petrocephalus gliroides	0.02	0.34	-	-
Mormyrus kannume	2.85	3.69	-	-
Alestes affinis	0.02	0.34	-	-
Labeo spp.	2.37	3.69	5.98	7.19
Labeo bottegi	10.30	14.43	22.51	12.50
Bagrus urostigma	3.32	2.35	2.64	0.63
B. bayad macropterus	-	0.28	0.31	
Clarotes spp.	25.62	14.43	3.11	1.56
C. laticeps	9.01	7.38	35.67	24.69
Malapterurus electricus	0.90	0.34	-	-
Eutropius depressirostris	35.17	32.55	16.50	28.13
Clarias gariepinus	3.90	1.68	-	-
Synodontis spp. (*schall*)	6.11	17.79	11.77	21.88
Oreochromis niloticus	0.02	0.34	1.55	3.13

Eutropius depressirostris was approximately twice as abundant in the northern stratum as in the southern stratum, *Labeo* spp. were approximately twice as abundant in the southern region as in the northern region, *Synodontis* spp. were about twice as abundant in the south, and *Clarotes* spp. were about equally abundant in both strata.

In Stratum 1, 90.3 percent of the species captured was composed of *Eutropius depressirostris* (32.6%), *Clarotes* spp. (21.8%), *Labeo* spp. (18.1%), and *Synodontis* spp. (17.7%). In Stratum 2, 95.6 percent of the catch was composed of *Eutropius depressirostris* (28.1%), *Clarotes* spp. (26.3%), *Synodontis* spp. (21.9%), and *Labeo* spp. (19.7%).

2. Hoop-Net Sampling

The hoop-net sampling program provided much fewer data than the other stock assessment survey methods. This was primarily because turtles caught in the opening of the funnel entrance prevented fish from entering and being trapped. Modifications did not improve the performance of these nets and further work is under way to improve the design. More sampling with this type of gear is necessary before data analysis would be warranted.

3. Rotenone Chemofishing

Five rotenone samples were taken in the Jubba River and one in the Jowhar Reservoir on the Shabeelle River. The samples were taken from relatively small areas, particularly Sample #4. It will be necessary to take more rotenone samples to validate the current results, although the kilograms per hectare expansions seem reasonable in magnitude and exhibit the normal range of variability for data of this nature (Tables 7 through 12). A fishery technician has been trained to conduct rotenone sampling for future monitoring purposes.

*Table 7. Rotenone Data for Sample #1**

SPECIES	NUMBER	WT (gms)	N (%)	WT (%)	kg/ha
Alestes affinis	10	140	27.8	2.3	7.0
Eutropius depressirostris	1	30	2.8	0.5	1.5
Oreochromis niloticus	2	100	5.6	1.7	5.0
Eleotris spp.	12	150	33.3	2.5	7.5
Synodontis spp.	4	490	11.0	8.0	24.5
Clarias gariepinus	1	2,500	2.8	41.2	125.0
Labeo spp. & *Barbus* spp.	6	2,660	16.7	43.8	133.0
Total	36	6,070	100.0	100.0	303.5

**Sample taken 31 March 1987. The area of this sample was .02 hectare, 10 kilometers south of Baardheere.*

*Table 8. Rotenone Data for Sample #2**

SPECIES	NUMBER	WT (gms)	N (%)	WT (%)	kg/ha
Alestes affinis	8	90	4.6	0.2	2.25
Eutropius depressirostris	4	770	2.3	1.5	19.25
Oreochromis niloticus	6	220	3.5	0.4	5.5
Eleotris spp.	5	70	2.9	0.2	1.75
Synodontis spp	7	560	4.1	1.1	14.0
Synodontis spp.	2	670	1.2	1.3	16.75
Clarias gariepinus	7	14,800	4.0	29.1	370.0
Labeo spp & *Barbus* spp.	127	30,940	73.4	60.9	773.5
Clarotes laticeps	7	2,700	4.0	5.3	67.5
Total	173	50,820	100.0	100.0	1,270.5

**Sample taken 1 April 1987. The area of this sample was .04 hectare, 10 kilometers north of Baardheere.*

*Table 9. Rotenone Data for Sample #3**

SPECIES	NUMBER	WT (gms)	N (%)	WT (%)	kg/ha
Alestes affinis	35	320	12.2	0.3	2.7
Eutropius depressirostris	33	870	11.5	0.9	7.3
Oreochromis niloticus	5	120	1.8	0.1	1.0
Eleotris spp.	2	100	0.7	0.1	0.8
Synodontis spp	18	1,364	6.3	1.4	11.4
Physailia somalensis	6	70	2.1	0.1	0.6
Clarias gariepinus	17	34,800	5.9	36.2	290.0
Labeo spp. & *Barbus* spp.	148	43,690	51.7	45.4	364.1
Clarotes laticeps	15	3,410	5.3	3.5	28.4
Bagrus urostigma	4	9,260	1.4	9.7	77.2
Malapterurus electricus	1	1,700	0.4	1.8	14.2
Mormyrops deliciosus	2	510	0.7	0.5	4.3
Total	286	96,214	100.0	100.0	801.8

**Sample taken 2 April 1987. The area of this sample was .12 hectare, 10 kilometers south of Baardheere.*

*Table 10. Rotenone Data for Sample #4**

SPECIES	NUMBER	WT (gms)	N (%)	WT (%)	kg/ha
Alestes affinis	35	460	52.2	18.3	76.7
Eutropius depressirostris	7	100	10.4	4.0	16.7
Oreochromis niloticus	3	600	4.5	23.9	100.0
Clarias gariepinus	1	600	1.5	23.9	100.0
Labeo spp. & *Barbus* spp.	8	620	12.0	24.7	103.3
Clarotes laticeps	8	110	11.9	4.4	18.3
Glossogobius giurus	5	20	7.5	0.8	3.33
Total	67	2,510	100.0	100.0	418.3

**23 April 1987. The area of this sample was .006 hectare, 5 kilometers upstream from Jilib.*

*Table 11. Rotenone Data for Sample #5**

SPECIES	NUMBER	WT (gms)	N (%)	WT (%)	kg/ha
Alestes affinis	188	1,400	13.9	1.8	21.5
Eutropius depressirostris	45	1,600	3.3	2.0	24.6
Oreochromis niloticus	30	1,200	2.2	1.5	18.5
Physailia somalensis	4	200	0.3	0.3	3.0
Clarias gariepinus	2	1,330	0.	0.2	1.7
Labeo spp. & *Barbus* spp.	968	70,900	71.4	90.0	1,090.8
Clarotes laticeps	116	2,000	8.7	2.5	20.8
Mormyrops deliciosus	1	70	**	**	1.1
Mugil spp.	1	60	**	**	0.92
Total	1,355	78,760	99.9	99.9	1,211.7

**Sample taken 24 April 1987. The area of this sample was .065 hectare, 5 kilometers downstream from Jilib.*

***Denotes values below .1 percent.*

*Table 12. Rotenone Data for Sample #6**

SPECIES	NUMBER	WT (gms)	N (%)	WT (%)	kg/ha
Oreochromis niloticus	398	149,600	64.0	43.0	748.0
Clarias gariepinus	41	145,200	6.6	41.8	726.0
Labeo spp. & *Barbus* spp.	183	52,800	29.4	15.2	262.5
Total	622	347,600	100.0	100.0	1,736.5

**Sample taken 5 May 1987. Main pool at drain of Jowhar Reservoir. The area of this sample was 20 hectare.*

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A. Preliminary Predictions of Yield from the Jubba River

The World Concern project has predicted potential annual catch for the Jubba River at 2,407 metric tons, using Welcomme's basin area (A) model, with A equal to 98,000 square kilometers. More up-to-date estimates of basin area for each of the three countries sharing the Jubba Valley drainage basin are shown in Table 13.

*Table 13. Drainage Basin Areas for the Jubba River System**

COUNTRY	AREA (A) IN Km^2
Ethiopia	134,000
Somalia	76,000
Kenya	10,000
Total	220,000

**Data provided by the MNPJVD-Baardheere Dam Project.*

The estimated annual sustainable yield for the Jubba River fishery in Somalia is 1,600 metric tons, using A equal to 76,000 square kilometers (Table 13) in Welcomme's basin area model. Expanding this to a U.S. dollar value, using 50 Somali shillings (SSh)* per kilogram of fish and 100 SSh per dollar, gives an estimated potential annual economic yield of US$800,000, or 80 million SSh.

Using Welcomme's main channel-length model, the estimated annual catch could be approximately 1,800 metric tons. This expands to an estimated value of approximately U.S. $900,000, or 90 million SSh.

It must be emphasized that these values are based on general river-fishery predictive models, which allow for general estimates of fishery potentials for resource managers. Local environmental or socioeconomic conditions can cause variations in these figures.

B. Biomass Estimation from Rotenone Sampling

The mean estimated fish biomass based on the rotenone samples taken in the Jubba River was 801 kilograms per hectare with a coefficient of variation (CV) of 55 percent. CVs associated with cove rotenone sampling programs conducted in Alabama reservoirs are usually between 50 and 100 percent. The 80 percent confidence limits around the mean are 350 to 1,250 kilograms per hectare.

The fish biomass of the Jowhar Reservoir on the Shabeelle River was estimated at 1,736 kilograms per hectare, based on one sample. This was about twice the estimate for the Jubba River and three to four times the fish biomass reported for Lake Kariba (Kapetsky and Petr 1984, quoting Balon 1974; Mitchell 1976; and Longerman, unpublished). Welcomme (personal communication) stated that the habitat sampled was not representative of the entire Jowhar Reservoir because fish are attracted to drainage dams and canals. Further sampling is highly recommended by the author and fisheries biologists from the Food and Agriculture Organization of the United Nations (FAO). More reasonable estimates of potential fish biomass for the Jowhar Reservoir would be from 500 to 1,000 kilograms per hectare.

C. Species Composition

Previous fishery investigations by colonial scientists have indicated that approximately 50 fish species would be expected to occur in the Jubba Valley. Welcomme (1985) discussed the differences in number of fish species between river systems and presented the following model that can be used to estimate the number of species (N) to be expected in any given African river, correlated against total basin area (A) in square kilometers:

$$N = 0.449A^{0.434} \quad (n=25; r=0.91)$$

Using 220,000 square kilometers for the entire Jubba River drainage basin, 93 species are estimated to occur. Excluding the Ethiopia and Kenya drainage areas, an estimated 58 species should occur. Approximately 20 freshwater species were collected during this study. Several marine and estuarine species from the families Sciaenidae, Carangidae, Arriidae, Clupeidae, and Mugilidae were collected at the mouth of the river.

The number of species in the two geostrata appear to be equal. Approximately 20 species were col-

**The International Monetary Fund calculated the average official exchange rate for 1987 at 105.6 SSh to the U.S. dollar. The purchasing power parity during the same period, however, was just over 166 SSh to the U.S. dollar.*

lected in both the northern and southern strata. The only three species that did not occur in the sample from the northern stratum were *Eleotris* spp., *Glossogobius giurus*, and *Mugil* spp. The absence of these species might be attributable to the Fanoole hydroelectric facility, which may have cut off upstream fish movement from the marine and estuarine environments. The Fanoole facility could possibly have contributed to the elimination of several obligate migratory species, resulting in a smaller number of fish species than expected.

The species diversity of the Jowhar Reservoir was smaller than that measured in the Jubba River. This is based on one sample and is not necessarily representative of the entire reservoir. In impounded rivers, the lotic (riverine) fish fauna is usually more diverse than the lentic (reservoir) fish fauna. Typically, the riverine genera which tend to thrive, or whose populations expand, in reservoirs are *Tilapia*, *Oreochromis*, *Labeo*, *Barbus*, *Clarias*, and *Clarotes*. The *Clarias* species contributed 43 percent and *Oreochromis* 42 percent by weight to the sample catch in Jowhar Reservoir. The percent contribution to weight of the *Clarias* catfish in the Jubba River was variable, with estimates ranging from 1.7 to 41.2 percent. *Labeo* and *Barbus* spp. contributed 15 percent by weight to the fish biomass in Jowhar Reservoir, but 25 to 90 percent in the Jubba River.

Length-frequency distributions for rotenone sampling are shown in Figures 5 through 13.

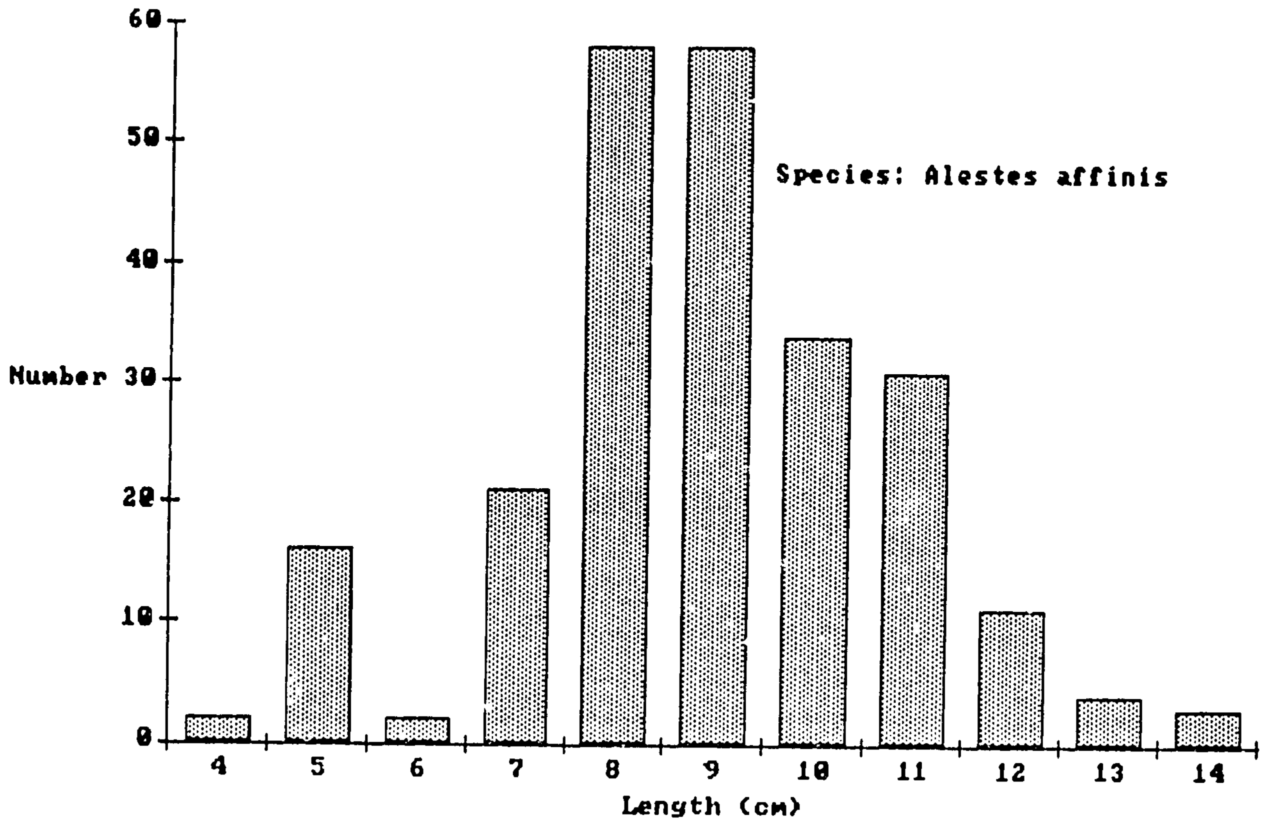

Figure 5. Species: Alestes Affinis.

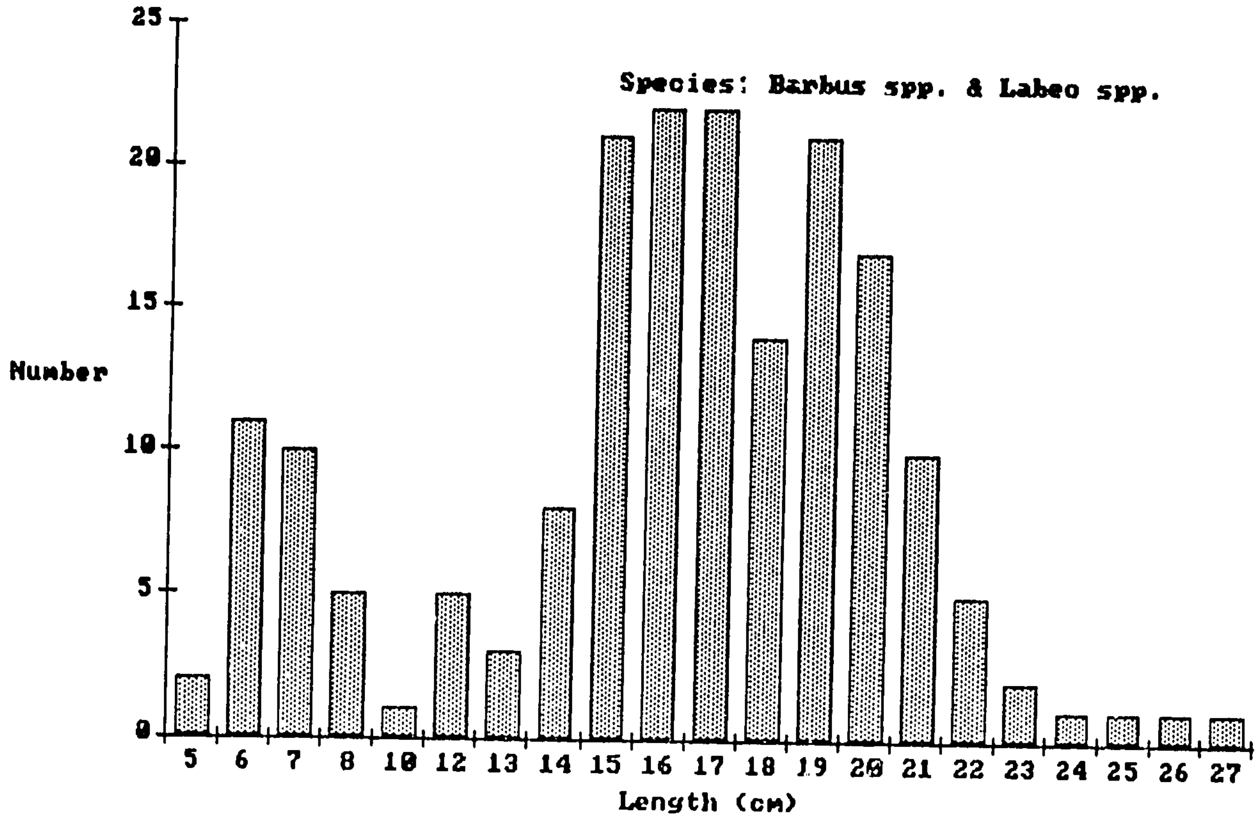

Figure 6. Species: Barbus *spp.* & Labeo *spp.*

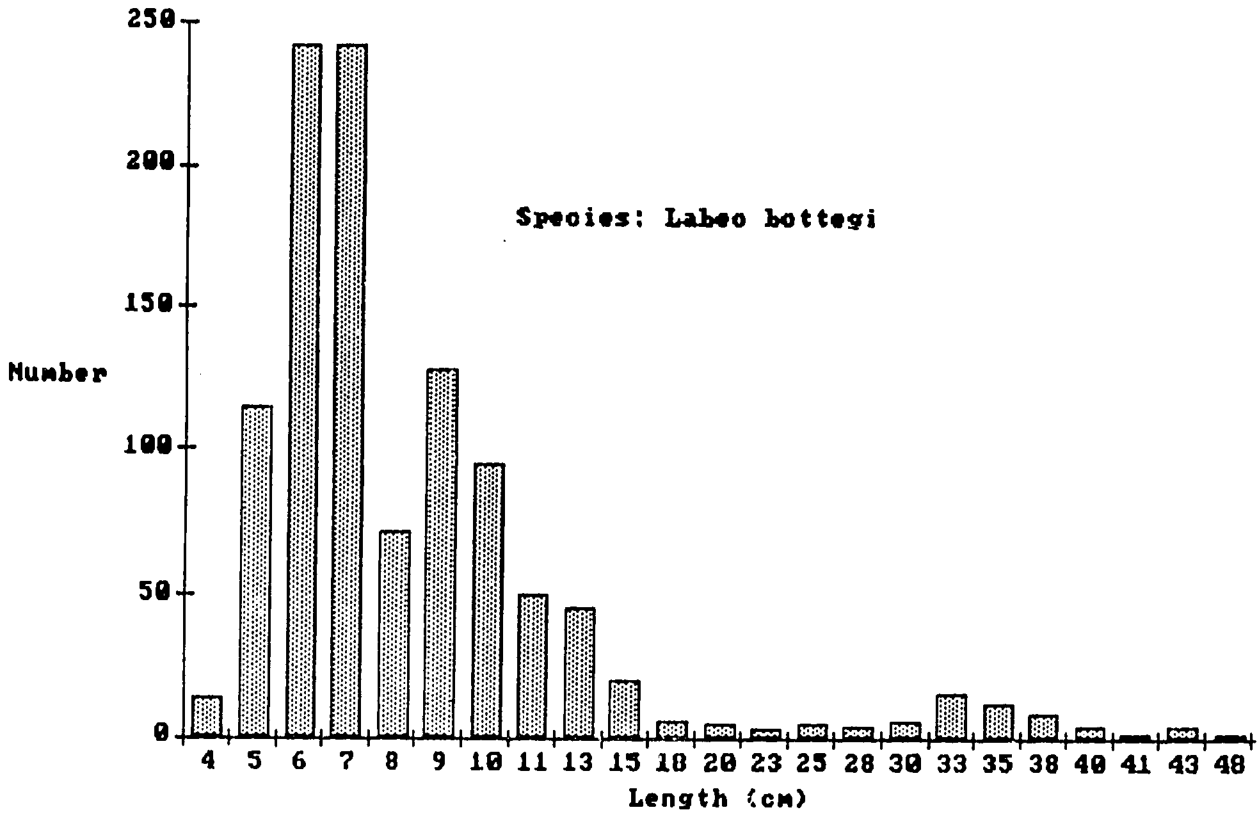

Figure 7. Species: Labeo bottegi.

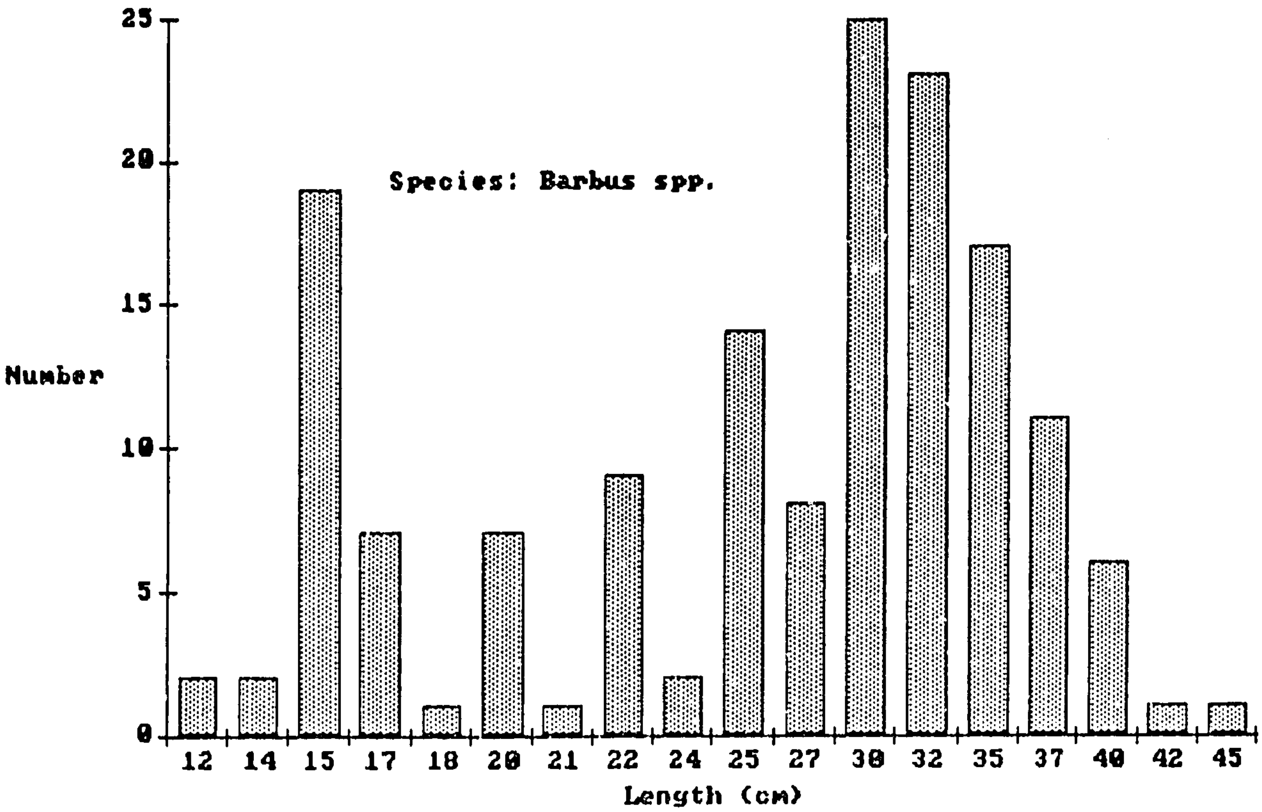

Figure 8. Species: Barbus *spp.*

Figure 9.

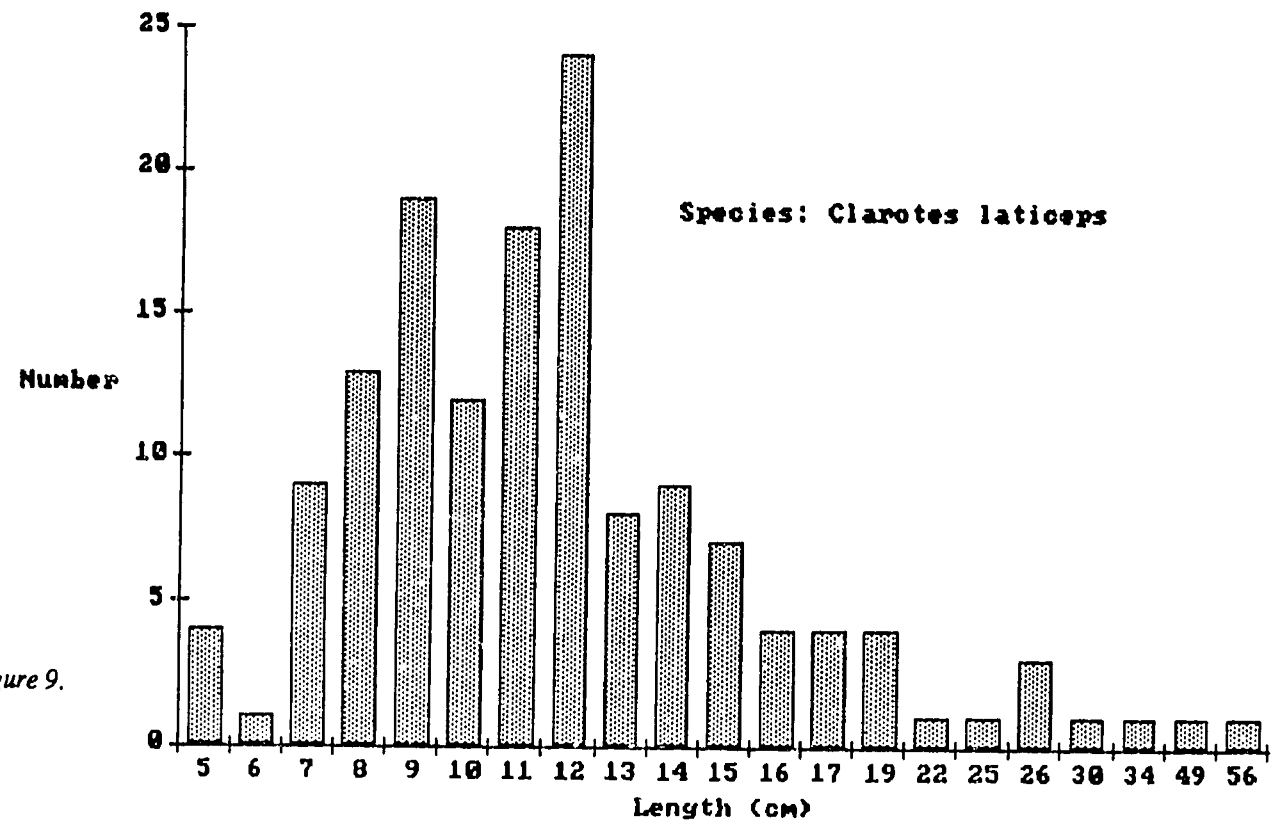

Figure 9. Species: Clarotes laticeps.

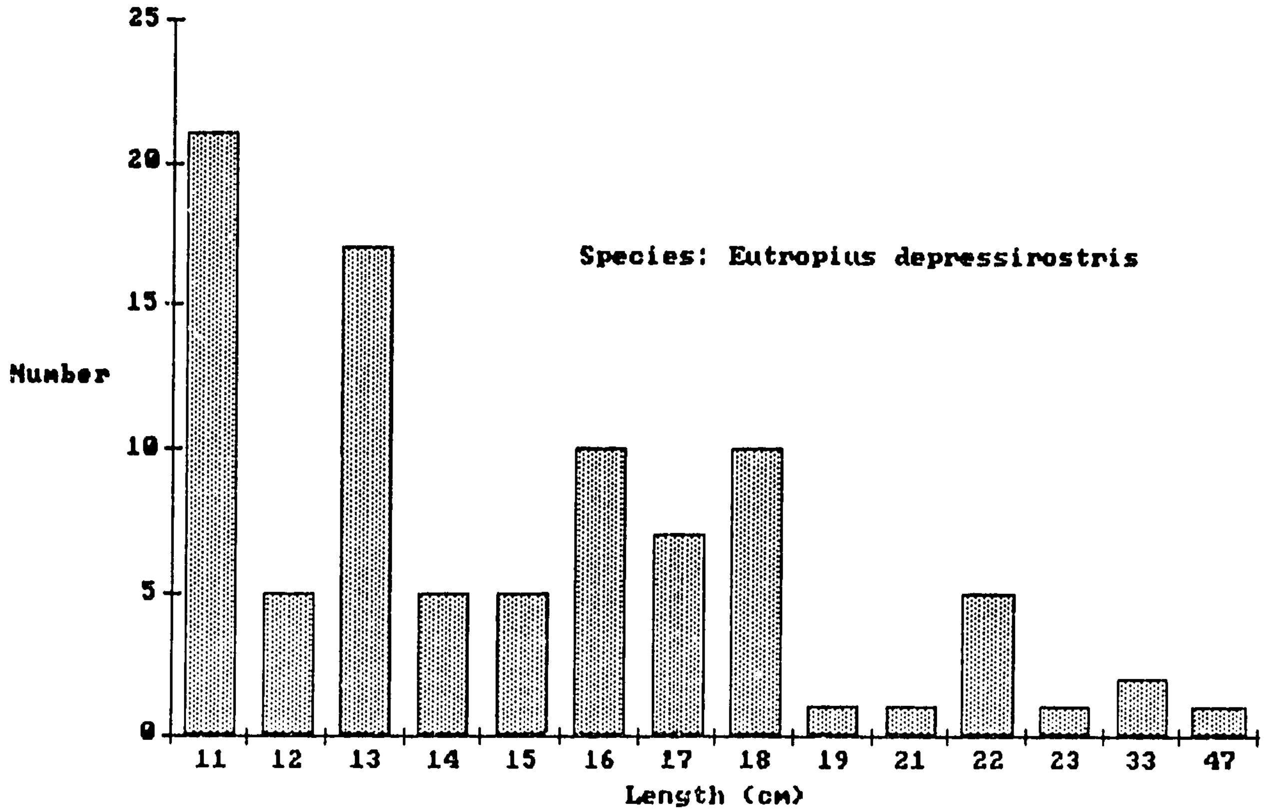

Figure 10. Species: Eutropius depressirostris.

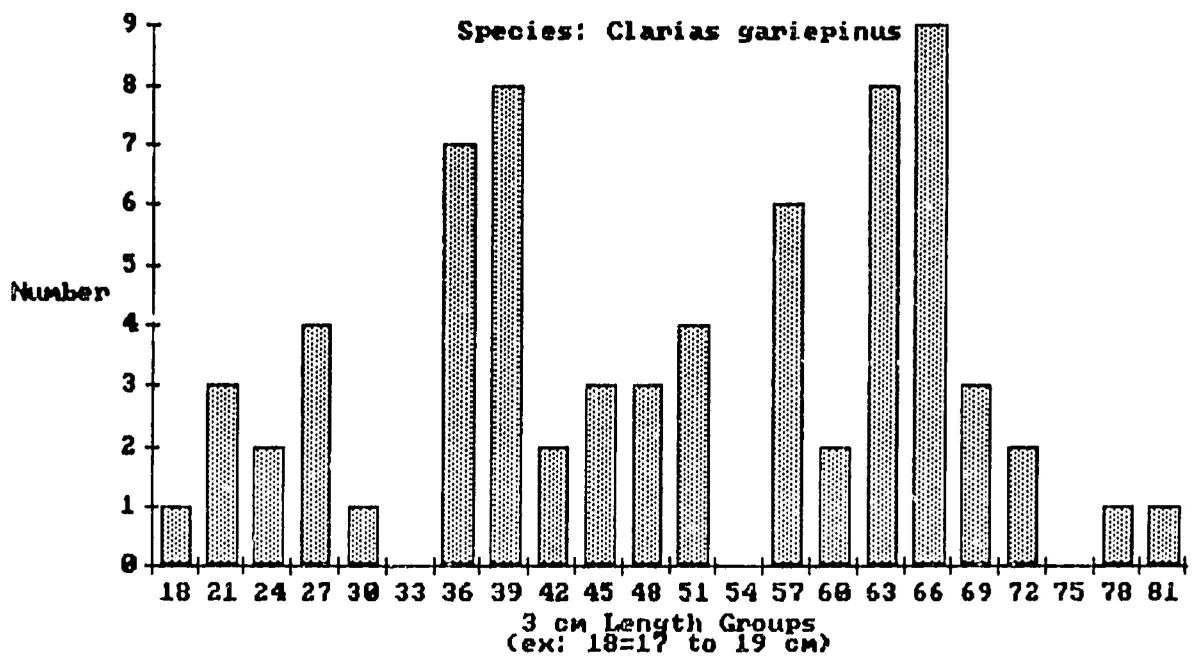

Figure 11. Species: Clarias gariepinus.

Figure 12.

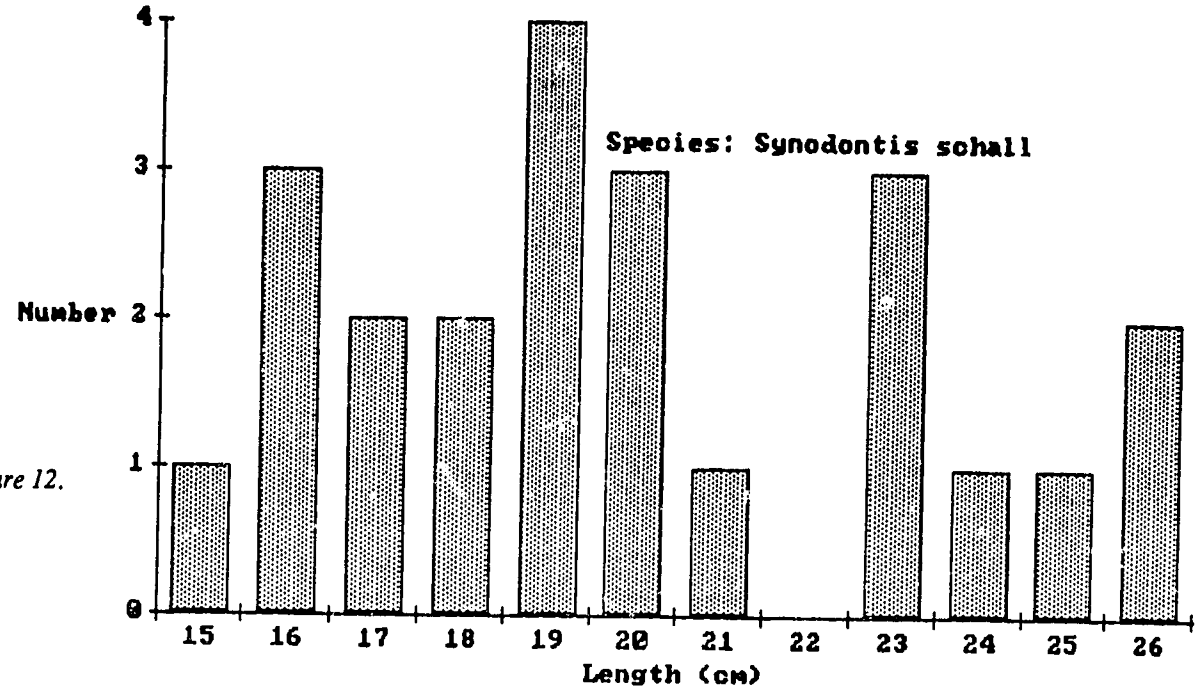

Figure 12. Species: Synodontis schall.

Figure 13.

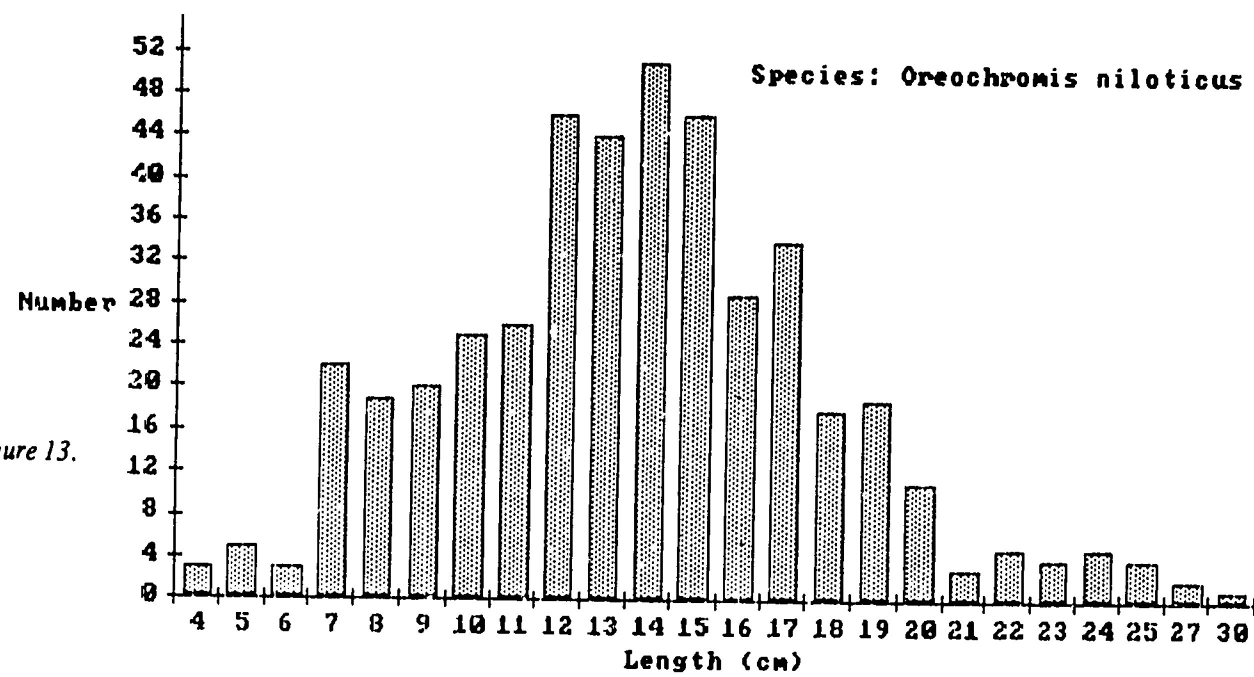

Figure 13. Species: Oreochromis niloticus.

VII. PROJECTIONS OF DOWNSTREAM IMPACTS

The impacts on fish populations after closure of mainstream dams in Africa are not well documented. Welcomme (1985) discussed the effects of various uses of river systems on fish populations, including changes in flow rates, silt load, water quality, habitat, plankton abundance, and temperature. (See Table 1 for a list of the major effects of dams on river ecosystems.)

This section focuses on potential impacts of the Baardheere Dam on the fish populations downstream. These could include the interruption of fish migrations, the disruption of normal annual hydrological cycles (reduced flows and restriction of the flood), and changes in temperature and water chemistry.

There are two types of fish migrations in river systems, as discussed by Daget (1960). Longitudinal migrations take place in the main channel of the river and are upstream or downstream movements. Lateral migrations take place between the main channel and the floodplain. Welcomme (1985) quoted Blache *et al.* (1964) and Williams (1971), who studied fish migrations on the Chari and Kafue rivers, respectively, and found four phases of fish movements. The following six main phases associated with various groups of fish emerge after combining these classifications:

- longitudinal upstream migrations within the main channel;
- longitudinal downstream migrations within the main channel;
- lateral migrations onto the floodplain;
- local movements on the floodplain and distribution among flood season habitats;
- lateral migration from the floodplain towards the main channel; and
- local movements within the dry-season habitat—this may be the river, adjacent lakes, or the sea.

Some species of African fish have movements that fall into one, or a combination, of the above categories, while others have distinct habitat preferences, or are confined to one specific area. These fish move only if they are put under stress due to changes in the environment, such as low dissolved oxygen, receding water levels, or chemical contaminants.Three groups of freshwater African species that display movements can be identified.

The first category, "blackfish," represents genera such as *Clarias* and *Clarotes*. These fish migrate laterally between the fringes of the main channel and the floodplain and are typically found in the *dhesheegs* (lagoons and residual pools on the floodplains of the Jubba Valley). These areas sustain the most important commercial fishery in the Jubba Valley, and the fish resources are dependent on the flood cycle to replenish the water supply and flush out nutrient-bearing silt.

A second group consists of species that undertake more modest movements between the main channel and the floodplain. These fish probably reproduce in the pools or lagoons and return to the main channel to avoid unfavorable conditions on the floodplain that the blackfish can survive. The mochocids, schilbeids, cyprinids, and mormyrids are likely to be included in this group.

The third group, "whitefish," migrate upstream during the early rainy or late dry season to avoid harsh low-water conditions downstream and to reproduce. This group includes mormyrids, characids, cyprinids, schilbeids, gobiids, and eleotrids.

The gobiids, ariids, muguliids, and anguilids are the only fish families that are potentially anadromous (migrating from the sea to the river for breeding purposes). Several *Arius* spp. were captured in gill nets installed in the Goob Weyn estuary area; gobies and mullet were captured here and in the Jilib area. No gobies, arius, or mullet were collected above the Fanoole hydroelectric facility. This indicates migration of these species has been curtailed by the dam.

The effects of Fanoole Barrage on the movements of other longitudinal species, such as characins and siluroids, are not known. Welcomme (1985) stated that the African characins and siluroids are conspicuous among the migratory species; cyprinids also exhibit this behavior. Due to lack of manpower and the short time allocated for fishery assessment in the Jubba Valley, it was decided that a fish migration sampling program was too ambitious and would result in very marginal data for the high cost involved.

It is probable that the construction of the Baardheere Dam will stop movements of the siluroids, cyprinids, mormyrids, and characins from the middle Jubba Valley (above Fanoole and in the Saakow region where several dhesheegs are located) up to the three main headwater drainages. As stated in the first report, many large *Eutropius depressirostris* were caught in gill nets in the Baardheere to Luuq region. These fish were all in nuptial (breeding) condition with ripe gonads and were probably migrating for spawning purposes.

Since the construction of a mainstream dam in the Jubba River will disrupt the normal hydrological cycle and flooding, discharge regulations and policies should be defined early in the planning process. It should be understood that the downstream river channel is as much an artificial, man-made, and man-controlled freshwater ecosystem as the reservoir upstream.

Bernacsek (1984) discussed dam design and operation to optimize fish production in impounded river basins. He stated that the most extreme effect on downstream aquatic environments can occur soon after the closure of the dam because initial filling can reduce flows to virtually zero, resulting in fish kills. During the initial filling of the Cabora Bassa Reservoir on the Zambezi River, flows were reduced from normal dry-season flows of 2,000 to 3,000 cubic meters per second to 60 cubic meters per second, against the advice of ecologists who recommended no less than 400 to 500 cubic meters per second. This caused large fish kills and stranding of breeding fish. Initial testing of hydroelectric equipment can create erratic flows, which have adverse effects on downstream environments.

Subsequent to initial filling of a river impoundment, downstream flow tends to become more constant, with smaller fluctuations and reduced flooding. This causes a change from a lentic to a more lotic fish species composition. Malvestuto and Meredith (in press) showed that during the Sahelian drought, low-flow regimes on the Niger River in Niger contributed substantially to the decline of the fishery; species composition of the harvest became less diverse with higher contributions by lentic species.

During drought years, reduced flows decrease the productivity of river fisheries by decreasing the amount of inundated floodplain. Welcomme (1986a) correlated a 20-year series of discharge data for the Niger River with fish landings at Mopti in Mali. The resulting multiple-regression equation had a high degree of predictability (R^2=0.87) when the catch from one year was regressed against hydrological indices for the two previous years. Catches were positively correlated with flows, implying that higher flows inundated more floodplain area, which enhanced reproductive success and survival of young fish. Thus, under the low-flow regime of the drought, or with reduced flows due to impoundment, it is certain that the carrying capacity of the river will be reduced.

Large dams also have a substantial impact on water quality downstream. Hydroelectric turbine intakes usually draw water from the hypolimnion or metalimnion water layer in the reservoir. The resulting discharge is much cooler, with lower or depleted dissolved oxygen, and sometimes contains hydrogen sulfide. Fish mortalities caused by oxygen depletion are common in large tail races below dams.

Bernascek (1984) presented various options for reoxygenation of discharge water. First, discharges through floodgates or overflow spillways can create tremendous turbulence as the water jet strikes the stilling pool below the dam and mixes with turbinated discharge water. This is often sufficient to effect reoxygenation. Unfortunately, not all dams have such discharge structures. For those that do, the reoxygenation benefit can be variable, since it will be realized only when the discharge structure is in actual use. Increasing the hydroelectric capacity of a dam's power station (a fairly common practice) results in more turbinated and less floodgate and spillway flow, thus further reducing the reoxygenation benefit.

Second, "natural" reoxygenation occurs mainly by diffusion from the atmosphere and by photosynthesis by phytoplankton and submerged macrophytes, whose growth is favored by the increased transparency of the water. These processes are, however, more gradual and the latter can be slowed considerably by the presence of toxic hydrogen sulfide.

Third, some rivers possess waterfalls or cataracts downstream from the dam, with resulting water turbulence responsible for reoxygenation. This, however, is not the case in the Jubba Valley.

None of the processes available for artificially improving the oxygen content of water discharged from dams, including aeration of the hypolimnion or the tailrace, is installed on African dams. In view of the magnitude of mechanical, hydraulic, and electrical power developed at multipurpose dams, artificial reoxygenation should not be expensive. Because of the drawbacks of the three reoxygenation processes discussed above, none can be relied on to rapidly restore oxygen to biologically nonstressful levels and to ensure complete protection against hydrogen sulfide throughout the year. There would appear to be no alternative to the use of artificial reoxygenation processes. It is strongly recommended that such processes be considered for incorporation into the design of the Baardheere Dam.

VIII. FISHERIES DEVELOPMENT AND MANAGEMENT ISSUESFOR THE PROPOSED BAARDHEERE RESERVOIR

The contribution of riverine fisheries in meeting the economic, social, and nutritional needs of African countries has been poorly understood or played down in the past. River and floodplain fisheries contribute substantially to household food and financial budgets in many riverside villages across Africa. Malvestuto and Meredith (in press) show that on the Niger River in West Africa, 20 percent of the catch is consumed by fishing households and 80 percent of the catch is sold for income.

In the Jubba Valley, the *maley madow* (Somali for "blackfish"), *Clarias gariepinus*, is believed to be valuable as a treatment for malaria. This is an example of a social value associated with the fishery which should be considered in evaluation of "yield" from the fish resource. Though most of the population of Somalia is traditionally nomadic and non-fish-consuming, a substantial number of villagers along the Jubba River are fish consumers.

Development and management of the river fish resources and the potential fishery created by the Baardheere Dam should be an integral part of the overall Jubba Valley development strategy. In the FAO (1986) strategies for the development and management of fisheries, it was stated that, "while acknowledging the specific circumstances of each country, the following guidelines should be taken into account when examining the contribution that fisheries can make to the achievement of national economic, social and nutritional objectives." Those guidelines are repeated here with modification and elaboration with regard to specific circumstances in Somalia.

A. General Development Guidelines

1. Fisheries comprise complex human and intersectoral activities in the overall national economy and within society in general. Therefore, fisheries development plans should be an integral part of national economic development and food security plans and in accord with social and nutritional goals and established priorities. The formulation of medium- and long-term plans, as central elements of fisheries development, should be considered in planning river basin development.

2. Objectives should be based on an assessment of the fishery resources available, existing technology, markets to be served, social and economic conditions, and the potential impact of other economic activities and relevant factors, including foreign operations, where applicable.

3. Fisheries development is often planned to meet several complementary objectives, but multiple objectives are not always compatible. Where compromises have to be made, objectives should be explicit, comparative advantages indicated, and priorities made clear.

4. Since the conditions within which fisheries are conducted are highly dynamic, objectives appropriate at one time may not be appropriate at another. Therefore, periodic evaluation of objectives is necessary.

5. There is a need for governments to establish mechanisms and develop skills for fisheries planning, involving all relevant disciplines.

6. Careful management and investment planning are necessary to achieve optimum utilization of resources. Countries should introduce appropriate conservation and management measures based on scientific evidence. Where there is little information on the resources and potential yields, expansion or investment should be undertaken carefully and continually monitored to allow detection of declining returns.

7. Reliable, timely data and statistics on all aspects of fisheries are needed for planning, implementation, and subsequent monitoring of fishery management and development. The national capability to collect data and information should be developed. Regional and subregional cooperation on collection and dissemination of data should be encouraged wherever necessary. (It should also be noted that intergovernmental agencies must, by necessity, cooperate and share responsibility in management and development of resources.)

8. It is essential to enhance the stock assessment capability of coastal states so that they can determine the allowable catch of living resources in the areas where they exercise sovereign rights. This

point applies to marine fisheries and inland freshwater fisheries where expatriate, migratory fishermen are exploiting fish resources and exporting the products. This is the case on the Niger River in West Africa where Malian and Nigerian fishermen migrate to Niger to fish and export the smoked fish to neighboring countries. In Somalia, fishery exploitation by foreign fishermen is quite likely. These fishermen could be encouraged to exploit the potential fishery created by the Baardheere Dam. Export of the fishery products would help generate foreign currency. Local consumption could be encouraged also.

9. Development plans should take into account all aspects of the fisheries sector, not only harvesting, processing, marketing, servicing, and material supply, but also the development of the infrastructure, technology, and human resources to enable better use of fishery resources. This will increase the value added to the economy and improve employment opportunities. It is essential to make all those involved understand the social value of fisheries as a source of food, employment, and profit, hence the need and the desirability of using fishing methods and processes which do not jeopardize economic viability by exhausting resources.

10. The formulation and execution of fisheries management and development plans require close consultation and collaboration among administrators, scientists, and those involved in fish production and marketing. Agencies and organizations such as MNPJVD, MFMR, SMP (Somali Marine Products), FAO, and AID need to form an alliance for fishery development and management in Somalia. Allocation of responsibilities can be distributed among these agencies and overseen by a single governing body, such as a Somali Fishery Development Authority.

11. Legal frameworks and institutional structures are essential if the objectives of fisheries management and development are to be achieved. This applies to marine fisheries as well as to inland fisheries and aquaculture and is of particular importance where there is competition among commercial fishermen and among commercial, artisanal, and recreational fisheries, and where there is intense competition from other land and water uses. For example, regulations or laws governing minimum flow rates or simulated flood in accordance with preimpoundment standards could be developed for the Jubba Valley.

12. Small-scale fisheries development requires special support from governments. An integrated approach with participation of fishing communities is often the best way of channeling technical, financial, and other assistance, since it is important to design and adopt technologies appropriate to local conditions.

13. Support from government could range from financing schemes for the implementation and expansion of fishing groups to extension activities for small-scale artisanal or medium-scale pelagic commercial fishing operations. Extension activities could encompass such topics as improvements and modifications to fishing gear, preservation of the catch via drying and smoking techniques, use of fishery products by the local non-fish-consuming segment of the population, and management inputs for self-managed community fishing organizations.

14. Development and management plans should consider the need to protect aquatic habitats from the effects of pollution and other forms of environmental degradation, *e.g.*, desiccation of the floodplain pools, chemical pollution from agriculture, deoxygenation or high sulfur dioxide content from dam discharges, and fisheries themselves, since aquaculture water released from installations is sometimes a source of pollution.

15. When planning the development of new fisheries, attention should be given to production and promotion of products that are low-cost and acceptable for local consumption. Early emphasis should be directed towards study and development of a fishery product that is acceptable to the local non-fish-eating population.

16. In formulating price policies, the interests of producers and consumers should be taken into consideration. Fishermen should be encouraged to increase their production after the fisheries are developed.

17. Finally, the potential for sport fisheries can be taken into account.

B. Management Strategies for the Baardheere Reservoir

Kapetsky (1986) discussed the management of fisheries on large African reservoirs. He stated that classical management methods have not been practiced, mainly because regulations (such as limits or number of fishermen or amount of fishing gear, gear characteristics and sizes, closed areas or closed seasons) are usually unacceptable for political and economic reasons. Reservoir fisheries provide rural employment, but most African fisheries agencies are severely underfunded and short of trained manpower, so it is extremely difficult to enforce fishing regulations or implement management schemes.

African reservoir fisheries appear to be underharvested and relatively unaffected by overfishing (Kapetsky 1986), with changes in species composition but little change in total fishery output. Therefore, management schemes that advocate limited entry or gear restrictions seem unnecessary, especially in the early stages of development. Most African reservoirs need fishery expansion or development rather than strict controls.

C. Considerations for Introductions of Non-Native Species

Fish communities in rivers usually have few species that are adapted to fill new niches created by impoundment. Management strategies that may be practical for the Baardheere Reservoir include introduction of non-indigenous species to take advantage of the new habitat and control of disease vectors. Non-native fish species introductions should be carried out only after exhaustive research, since the vast majority of fish introductions have had detrimental environmental or economic consequences.

Kapetsky and Petr (1984) and Kapestsky (1986) discussed the results of introduction of non-indigenous fish species into reservoirs where pre-impoundment studies showed no indigenous species in the rivers that would take advantage of the new open-water pelagic zones in the reservoir. The most successful introduction has been that of the sardine, *Limnothrissa miodon*, into Lake Kariba (Zambia/Zimbabwe) in 1967 and 1968.

The inadvertent introduction of common carp, *Cyprinus carpio*, into the Masinga Reservoir in central Kenya has had a detrimental economic effect on the fishery. During visits to fishing villages and fish regulatory agencies in the Tana River Reservoir area, it was found that the local fish-consuming population prefers *Tilapia* fishes, and carp are not as valuable. The carp/ population has increased to 50 to 60 percent of the harvest. In early years of development of this fishery, *Tilapia* comprised over 80 percent of the harvest. Thus, the economic value of the Masinga fishery has declined since the inadvertent introduction of the carp.

With the creation of the Baardheere Reservoir, habitats favorable to the snail vector of bilharzia may be created. Numerous experiments have been conducted on biological control of this vector. Welcomme (1981), quoting Jhingran and Gopalakrishnan (1974), stated that the introduction of *Astatoreochromis alluaudi* (pellegrin, an East African fish in the family Cichlidae) into Cameroon, Central African Republic, Congo, and Zaire fresh waters was successful in reducing snail populations by 64 to 98 percent.

D. Other Considerations and Recommendations

Due to the lack of adequately trained fishery personnel within MNPJVD and restrictions on time available for fisheries surveys during the consultancies, the assessment program reported here was the most ambitious possible. Results from this survey are limited, but provide a better understanding of existing fish resources and fisheries potential in the Jubba River Valley and should be useful for planning purposes. More trained personnel and more time for fisheries monitoring would result in larger sample sizes, improving the value of the FBS and CAS data. The optimum number of field personnel for fisheries work on the Jubba River system would be three in each of the two geostrata. These persons should take at least 20 samples per gear type per hydrological season.

More extensive training for selected field personnel in fisheries and aquatic ecology is highly recommended. The AID-supported aquaculture training program of the International Center for Aquaculture at Auburn University is a good hands-on training course in aquaculture and fisheries management. *MNPJVD desperately needs to develop technical expertise within its staff.* The Auburn program offers an excellent opportunity to begin this development. There are a number of international training facilities in Africa and numerous fisheries consulting firms that can provide in-country training programs as well. At the very minimum, *MNPJVD should provide fisheries administrative training to one of the present staff members, enabling logical interactions with associated government ministries (MFMR) for planning of fisheries development and management in the Jubba Valley.*

A serious problem identified in the Tana River Basin development in Kenya is the lack of coordination and cooperation among concerned agencies within the government structure. There is very little interaction between the Ministry of Tourism and Wildlife (the Fisheries Department is within this Ministry) and the Tana and Athi River Development Authority (TARDA), with resulting duplication of fisheries research and contradictory management policies. *MNPJVD and MFMR should develop a cooperative infrastructure for fisheries development and management in the Jubba River* to avoid the problems associated with the Tana River.

Another problem identified in the Tana River Basin is lack of availability of information from TARDA. *Scientific research and project information must be organized and available for review by scientists and project administrators at all times* to help avoid duplicating costly mistakes caused by a lack of knowledge of lessons learned.

The potential for freshwater fisheries development on the Jubba and Shabeelle rivers is evident. *Ongoing assessment surveys and short-term fisheries development programs with extension activities are recommended.* Predictions of maximum sustainable yield can be fine-tuned for management purposes by creating ongoing monitoring programs, which will establish relationships among effort, catch, and catch per unit. Welcomme (1986b) discussed these relationships for African rivers. Government agencies involved in fisheries management and development in the Jubba Valley will then be able to assess fisheries development and encourage appropriate expansions, or implement necessary restrictions, to insure the viability of the resource.

Development and extension programs should include encouragement of fish consumption by local villagers, development of local and international freshwater fish markets, and creation of community fishing centers that could provide low-cost fishing gear on a revolving-credit basis. These centers might implement extension efforts concerning fishing techniques, fish preservation, and formation of professional fishermen organizations.

Ben-Yami and Anderson (1985) discussed the guidelines for establishment and operation of community fishing centers. Several of these small fishery centers can be established around the reservoir and along the river to assist in development of the fishery resources in the Jubba Valley.

In Cameroon, West Africa, the ice plant built and operated for the construction of Lagdo Dam on the Benue River is now providing ice for preservation and shipping of fish from the reservoir to all parts of the country. Other infrastructure improvements made for the construction of the dam can benefit the fishery development process. Improved access roads and availability of electric power will encourage private-sector enterprises such as fish transporters, fish merchants, and fishing gear distributors.

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Field Notes for Fisheries Frame Survey—Trip 1

6-17 October 1986

Monday, 6 October and Tuesday, 7 October, mouth of river to Fanoole Barrage.

Made final preparations for field trip and travel to Qorioli, where we stayed the night in the Save the Children compound. This is a convenient stopoff if a team gets a late start from Muqdisho on the way to Jilib and needs a comfortable place to stay about three hours from Muqdisho. This stop allowed us to check the boat and trailer for any modifications or adjustments that needed to be made after assembling in Muqdisho. On Tuesday, we drove as far as Jilib and stayed the night in the JESS/U.S. Bureau of Reclamation (USBR) compound. We met with the mayor, Mr. Djamma, as the district commissioner (DC) was out of his office and busy with other matters. The mayor answered many of our questions and gave us his impressions of the value of fishery resources in this region. His impression is that fish is consumed quite a lot here. He said that there is no set price on fish, but it is based on supply and demand. He told me that there is no central fish market in Jilib. When people want to buy fish they go to a fisherman's house to see if he has caught any that day. I later found that there is a special location in the market where dried and fresh fish are sold. The majority of the fish consumed in Jilib is from the local dhesheegs. He said that people even go out to the dhesheegs to buy fish. I found that there is a vehicle which goes out to the dhesheegs on a daily basis and distributes fish to villages along the road from Yontooy to Jilib. He indicated that there are a few people who are more or less occasional fishermen and fish in the river with hook and line. Occasionally there are deliveries of frozen fish from Kismaayo marine fishery which are sold in the marketplace in Jilib and distributed to other villages in the district. We saw a broken-down refrigerator truck that Mohamad Hassan told me was once used by a private merchant to haul frozen fish from Kismaayo.

Wednesday, 8 October.

We drove to Kismaayo and met with the DC and local authorities to inform them of our intentions and work schedule. We also met with Captain J. R. Christensen of Somali Marine Products (SMP) to discuss trawl design and marine fishery systems in this area. Two trawl designs were discussed. Plans were made to build these nets and other necessary equipment to facilitate fish sampling along the coastal area outside the mouth of the Jubba River. We also discussed the possibility of hiring a trawl vessel from SMP to conduct these trawls, but J.R. said that he had no vessel available and didn't want to commit himself to this type of activity. We discussed using our boat for this type of sampling and I expressed doubt as to the applicability and safety of using this boat in the ocean. Two trawl nets were designed and begun. One is a tri-net to be used with two 15-kilogram trawl doors and towed behind the boat along the coast. The second net is a two-meter beam net that is to be used in the river for sampling deep mid-river habitat. The mesh size of this net (two-inch stretch) will allow sampling of adult fish. A special bag of 1/4-inch woven mesh can be inserted into the large mesh, allowing larval or juvenile fish studies. J.R. told us that there had been a man from upriver (Malenda, a village north of Jilib, just downriver from the Fanoole Dam) who wanted to establish freshwater fish sales to SMP. He claimed he would organize a group of fishermen in that area and could supply SMP with three tons of fresh fish per day from the river. This never materialized, however. J.R. asked him to bring in a 20-kilogram sample but never saw the man again. J.R. also told us of an organization (PRODMA, a subsidiary of Kellogg Seafoods) that did experimental trawls off the Kismaayo coast in the late 1960s. Perhaps this information can be found and comparisons drawn from pre- and post-impoundment sampling to determine changes in the coastal-estuarine fish communities. J.R. told us that some river fishermen buy fishing nets or hooks from the SMP stores and some build seines, called Yashi (small beach seines 50 to 60 feet long) and Yuma, (100 to 150 feet long and most commonly used in the marine fishery). These nets are also purchased in the store in Muqdisho. He didn't know the prices. Hooks can be purchased in most towns or villages.

Thursday, 9 October, Goob Weyn to mouth of river (on-water work).

This was the first on-water reconnaissance. We launched the boat at the old ferry site, where there is an old concrete ramp. It is easier to launch the boat during high tide as there are many large rocks in the water at the foot of the ramp which have a tendency to eat props. This is a difficult location to land the boat because the current is very swift just as you line the boat up for pulling onto the trailer. You must have a lot of experience in boat loading in order to drive right up onto the trailer. I showed Mohamad Hassan how to do this and he tried it a couple of times. I think he needs more practice and experience in boat handling but he learns very fast and will pick it up soon.

We found one hippo near the mouth and the fishermen we hired to help us said they smelled crocodiles. I entered the water near the mouth to see if the current was too fast for a 50-foot beach seine trial. The fishermen started yelling for me to get out of the water and not go in again as the current would carry me out to sea and the crocodile would eat me. We saw many ducks and various other water birds along this section of the river. A trial seine sample using the 150-foot seine was attempted and was partially successful. The water was very shallow, which made maneuvering the boat very difficult, and the current was very strong. We did, however, catch three fish in the family Cyprinidae. I gave Mohamid Hassan some training in boat handling and launching. The trial seine haul was also intended as a training experience and proved to be valuable, as it was marginally successful and very difficult, demonstrating the difficulty of fish sampling in flowing-water environments.

Friday, 10 October, Yontooy.

Location: on the main road from Jilib to Kismaayo, about 10 to 12 kilometers north of Goob Weyn.

Upon arriving at Yontooy we found a fisherman checking his gill net and we interviewed him before he took his fish into town for marketing. His name is Mohamad Awes Hadji and he works at the agricultural project there. He was fishing out of a small fiberglass boat, which belongs to the agricultural project and is used for repairs. He was fishing just downstream from the pump station for that project. He caught one *Clarotes laticeps*, weighing about 1.5 kilos. We didn't have the scales with us so we had to estimate the weight of this fish. He was using a four-finger (40-millimeter stretch mesh) gill net, 15 fathoms long and 35 meshes deep, which he bought in Kismaayo last year for 900 SSh. He set this net yesterday evening at about 5:00 and harvested at about 8:00 this morning. He also fishes with hook and line when the river is low. Hooks are purchased in Kismaayo for 10 shillings each and line costs about 100 shillings. He sells fish in Yontooy for about 50 shillings per kilo. I don't know how he weighs his fish. He said he cuts the fish up and sells it to people who come to his house. He fishes in the early morning and evening and works for the irrigation project during the day. Problems that he has with fishing include the crocodiles eating the fish out of his net and the hippos knocking his boat. During the high-water seasons, he has problems with debris caught in his net. When asked if he ever caught *Lates niloticus* he said yes, but mostly during the low-water season. We showed him several fish drawings and asked him to give us their local names. The following is a list of species or species groups and local Somali names:

Species group (spp.), Somali Name

Lates niloticus, Abungishar
Protopterus annectens, Mayumbe
Polypterus spp., Mayumbe
Heterotis niloticus, Gomia
Mormyridae family, Ballan
Hydrocunys spp., Abusef
Alestes spp., Gishar
Alestes brevis, Tewa
Citharinus spp., Mashirfato
Bagrus spp., Sharib
Clarotes laticeps, Lubi
Clarias or *Heterobranchus*, Malay Madow
Synodontis spp., Kurtay
Chiloglanis micropogon, Fumi

Crustacea

Atya gabonensis, Kambo Kambo

This list of names was compiled by showing the fisherman the pictures in Reed (1967), so it might not reflect the actual fish species or crustacea present in the Jubba River. More work needs to be done on this matter. It is interesting to note that in less developed fisheries there is not as well-developed a local or traditional naming system for individual fish species as is found in more developed fisheries. For example, in Niger there are names for almost every species of fish. We also recorded the local names of the fishing gear most commonly used in this area.

The following is a list of these gear types and Somali names:

GEAR TYPE	SOMALI NAME
fish trap	Sab or Irman
hook	Makalin
hook and line	Hadak makalin
gill net	Shabak
small sein	Yashi
large sein	Yuwa

The site where we found this fisherman is also a major watering site and an excellent launching ramp for the boat. We decided to return tomorrow to launch the boat here and go downriver on-water to Goob Weyn for some trial fishing and to interview more fishermen along the way.

Friday, 10 October, Mokomane.

Location: from Yontooy we drove down a dirt road about three to five kilometers along the river.

This village has up to 40 families, and people indicated almost every family has a hook and line that they use to fish. The fish are for their own consumption. Three other adjacent villages of significance for fishing are Yontooy, Wirkoy, and Buulo Gaduud. The people told us that they fish in the river near the village during low-water season, using hook and lines. They do the majority of their fishing during the early morning or late afternoon hours. They told us they only fish for personal consumption and, if they catch enough fish, they dry the leftover fish for future consumption. They never sell fish in their village or other villages.

Discussed with JESS team leader the possibilities of sampling along the river and the dhesheegs. He indicated that one 16-day sampling trip could be organized during a three-month period that would correspond to the phases of water level in the river. These phases are as follows: mid- to low-water dry season (August-October), high-water rain season (mid-October or early November-December to mid-January), low-water dry season (January - March), and high-water rainy season (April-July). These are approximate dates and seasons, and further research will be needed to temporally stratify for sampling purposes. These sampling trips could be made in conjunction with other sampling being carried out in the river basin. For example, trips could be coordinated with water-quality sampling teams or other socioeconomic sampling trips.

Saturday, 11 October, Yontooy to Goob Weyn.

On-water reconnaissance survey for fishing villages and fishing trails.

We hired one fisherman to work with us and guide us down the river. We saw about five cable ferries along the section of river that we traversed. We stopped at the largest of these and interviewed an old man who was running the ferry, Haji Mohamad Moussa. The cable ties two villages together, Mokomane and Haji Ali. There are approximately 100 families here. The old man told us that his people fish with hook and line for their own consumption. He really likes fish and said that he values them very much. He told us that when he was young he was in a local market one day and someone told him that he had fish to sell. He went to see the fish and the man didn't have fish, but fish oil, which he claimed to have made from fish caught from Dhesheeg Waarno. It was at that point that the old man said that he learned to eat fish and learned of their value.

He told us that during jiilaal (the low-water season), salt intrusion is very high and they have to dig shallow wells to get drinking water for themselves and their livestock. He also said that the women have to walk into the bush to find water. He told us they only eat fish during the low-water season.

We did some drift gill netting and a mini-rotenone sample. The catch from the gill net was very interesting, as there were several large *Synodontis* spp. and Siluridae that are the largest specimens I've ever seen. They were caught in the 1.5- and two-inch bar mesh nets. The drift gill net samples were rather difficult as we got hung up in the bottom about 10 minutes after we put the net in. The result was a very short sample and a couple of holes in the larger mesh panels. We are in need of mending line and net needles and I need to teach Mohamad and the other fishery personnel how to mend torn nets. I think it will also be valuable to purchase some locally available nylon net materials and teach Mohamad Hassan how to build his own experimental gill nets, thus eliminating the need to import expensive nets and increasing our units of experimental fishing. I will check this out when we return to Muqdisho.

I want to have a meeting with the MFMR personnel to discuss the possibility of integrating them into the freshwater fisheries evaluation and training since they are mostly concerned with the development of their extensive coastal marine fishery resource. They should also have some participation in the evaluation and development of their inland riverine and reservoir fisheries.

We did one trial mini-rotenone that was partially successful in that we caught several Silurides, *Labeo*, and an interesting Gobie that skips along the shore and can leave the water in pursuit of cover in the grass and reeds. The bottom was very muddy and made it very difficult to move around in the water. I don't think we should do any more of this kind of sampling until the low-water season, or we should at least stay in the boat and use dipnets to retrieve dead fish. It is also probably very dangerous to be in the water like that. The threat of crocodile attack is something we need to be very aware of. We need to have some form of security, like a policeman with a gun or someone in the team armed.

We saw six to 10 hippos and two crocodiles at an island located about the point in the river near Luglouw. The hippos were at the head of the island. The crocodiles were at the foot of the island on the perimeter of a small sandbar with grass and reeds. This seems to be a habitat type they prefer. So far I have heard many stories of villagers along the river being eaten or taken away by the crocodiles. They also seem to cause a lot of trouble in the few fishing nets that we have seen along the river.

The Blazer broke down due to two bad batteries, so we had to tow it back to Kismaayo with the Jeep and deposit it at the local garage for repair.

Sunday, 12 October, Dhesheeg Waamo.

Location: Dhesheeg Waamo is a large (approximately 72 square kilometers) lowland area located from about the town of Buulo Gaduud to Baar, west of the Jubba River (Figure 1). We traveled 10 kilometers on the Jilib road past Buulo Gaduub and turned west on a pretty rough dirt road. The dhesheeg is approximately 30 kilometers down this road, but the many branches are very confusing. I recommend that future teams either take along a guide who is very familiar with Waamo or take the transport vehicle which travels this road almost daily to buy fish from the fishermen and transport goods and people from the dhesheeg. You can find this vehicle in Kamsuuma by inquiring at the taxi stop or talking with Mohamad Ali Aden (the village chairman) or Abdulkadir Hassan Ali (the fishing organizer and transport coordinator).

Dhesheeg Waamo is inundated periodically by rains and river floodings that are controlled by opening flood control gates located along the dyke which parallels the river. This dyke was built by the Italians and a canal was dug from the river to the dhesheeg. I was told that the Ministry of Agriculture authorizes the opening of these gates whenever the river is high enough.

We found that there is a large component of fishermen operating here and a very large amount of fish harvested. There were two fishermen walking with bundles of dried *Clarias* spp. (probably *C. gariepinus*). These fishermen were from Jamaame and come here to fish for four to five days at a time. They said they are part of an organization of about 20 people who trade off fishing shifts of four days to one week. They are organized by a coordinator in the village who goes out to Waamo and sends out the transport vehicle to pick up the dried fish and change groups of fishermen. The fishermen were on their way to meet the vehicle, so they were in a hurry. I did get to ask them several questions concerning their fish. They told me that one bundle of fish would be sold for about 1,000 SSh. This bundle of dried fish weighed about 10 to 15 kilograms and contained about 30 to 35 dried *Clarias*.

We found two other fishermen and interviewed them much more extensively. These men were from Kamsuuma and were part of a kind of cooperative of about 50 people who come here for a few days to work and then return to their village. hey indicated that there is a coordinator (probably Mr. Abdulkadir Hassan Ali, mentioned earlier) who hires people or sends his sons to fish using his nets. They said it is common for several people to purchase a net or two, and for a cooperative fishing group to operate in this fashion. These fishermen indicated that a vehicle comes three times a week to pick up their fish and change fishermen.

These fishermen were using gill nets which were four and eight fingers (one finger equals 10 millimeters stretch mesh), 30 double-arm lengths (two outstretched arms are equal to one fathom or 1.9 meters), and about two meters deep. They learned to make and set these nets from the ocean fishermen in Kismaayo. They bought the line to make these nets in Kismaayo or Muqdisho for about 2,600 SSh.

It required 1.5 kilograms of cotton line to make these nets. One fisherman told us that they sometimes buy premade nets made of "plastic," meaning nylon, and they cost about the same. The lifetime of one of the cotton nets is about three to four years if they repair them periodically. The lifetime of the premade nylon nets is six months.

They indicated that they do not use hook and line or long lines in their fishing here in Waamo. During high-water seasons they use canoes, which they rent or borrow from someone on the other side of the dhesheeg. Usually there are three to four fishermen per canoe and they set one or two nets per fisherman.

They told us that the price of their fish is the same for dried or fresh. One fish would sell here for about 35 SSh and 100 to 135 SSh in their village. They had one very large *Clarias* sp., which measured about one meter long, maybe longer, and probably weighed 10 to 15 kilograms. They cut the fish up into strips and hang them in trees or racks to dry.

They indicated that there are problems with hippos getting into their nets and sometimes crocodiles (in the high-water season). They fish in the river only when the dhesheeg is too high or during low-water season in the river. They use hook and line when they fish in the river. When asked if their catches have changed in the past few years, they indicated that the number of fish has increased and the size distribution has not changed.

Monday, 13 October, Kismaayo and Goob Weyn.

This was a relatively down day as the Blazer and the trawl nets were not yet fixed. We decided to run several errands and try a dormant-set gill net overnight at Goob Weyn. This was also a very good opportunity to conduct some training for Mohamad Hassan Aden and give him some experience in boat handling. In the afternoon we went up to Goob Weyn and practiced launching and landing the boat. The gill net was set at 5:30 p.m., just upriver from Goob Weyn in a fairly shallow area on the edge of the left bank of the river.

The gill net is a Memphis Net and Twine product with seven panels of 50-foot length. The mesh sizes and twine sizes are given in the following table:

PANEL NO.	MESH SIZE (bar in inches)	MONOFIL SIZE
1	1	69
2	1.5	69
3	2	104
4	2.5	139
5	3	139
6	3.5	208
7	4	208

The experimental gill nets are built with two-inch hollow plastic floats and one-inch lead sinkers, enough to give it neutral buoyancy. This should be a standard unit of effort in the future so as to enable comparisons between CPUEs in subsequent fish sampling surveys.

Tuesday, 14 October, Goob Weyn.

We got a late start and ended up harvesting the gill net later than I had planned. It was 11:00 a.m. when we finally pulled in the net. The data from the catch are listed below:

MESH	SPECIES GROUP	LENGTH (cm)	WEIGHT (gm)
4	*Clarotes* spp	36	1,000
4	*Clarotes* spp.	55	1,600
4	*Eutropius*	47	910
1.5	*Synodontis* spp.	41	700
1.5	*Eutropius*	29	150

This was a very small catch for this kind of net, but it was improperly set and had two holes in it from the drifting gill net trials that we conducted the other day. The fish, however, are very large specimens; in fact, the largest of these species I've ever seen. This is an indication of little or no exploitation.

I suspect that larger catches will be obtained if the net is set properly and we harvest at proper times. We should try setting the net in the morning and checking it both in the evening and morning. This will give us a better idea of nighttime vs. daytime catchabilities. I'm very surprised at the lack of diversity of species in the catch.

Tuesday, 14 October, Bangeeni.

We moved on upriver and set up camp in Jamaame. From there we covered the section of river between Jamaame and Bangeeni to look for fishermen and fishing villages. We found that Bangeeni is composed of two villages, one on each side of the river. There is a cable ferry between the villages. This is the next village downriver from Jamaame. We talked to several people there and it was indicated that there are two or three people who fish, but because there is no market for fish, and plenty of meat, they don't fish for commercial reasons. They fish strictly for personal consumption.

At the ferry we found a gill net installed in the water and searched out the owner. He is the operator of the ferry and answered all our questions. He lives in Bangeeni on the left side. He set this net yesterday and told us that the crocodiles have eaten the lower halves of all the fish in the net. This net is 12 fathoms long and 1.5 deep. He said he made this net himself and that the mesh sizes vary from four to eight fingers. He purchased the cotton line to build this net in Kismaayo. His uncle taught him how to make and set nets. He told us that he fishes in the dhesheegs during the *gu'* season. His views are the opposite of the other fishermen we have interviewed so far. He said he catches more fish when the river is in flood stages, as opposed to low-water stages. During the low-water stages he prefers to fish in the dhesheegs. Later on in the interview he confessed he does fish in the pools left in the river during the low-water period. He said there is no market where he sells his catch, but that people come to his house when they know he has fish for sale.

Wednesday, 15 October.

Location: All of the villages visited on 15 October (except Mogambo) are located close to the river on the opposite side from Jamaame. There is a turnoff about three to four kilometers past the turnoff to cross the bridge for Jamaame. The road starts out paved and turns to dirt after about a kilometer. This road eventually goes back to the Jilib road.

Wednesday, 15 October, Sunguuni.

The people that we talked to said there are many fishermen here, but they were all out fishing at the dhesheeg. Ten fishermen were out at Dhesheeg Waamo. They indicated that 100 percent of the population in this village eats fish on a somewhat regular basis. They told us that during low water the men use nets in the river and that there is a problem with crocodiles here. During the high water several people use hook and line in the river to catch fish for personal consumption.

Wednesday, 15 October, Kobon.

There are no commercial fishermen here but many people use hook and line to catch fish for personal consumption. They indicated that a merchant does bring fish from Waamo to sell here and occasionally they jump on the vehicle that goes to Waamo to buy fish. They indicated that there are problems with the crocodiles in the river.

Wednesday, 15 October, Aboro.

There are about 40 families living in this village. At the present time, the four fishermen who live here are out at Waamo. During the low-water season they use gill nets in the river. They sell fish to people in other villages along the river as far up as Jamaame. They said everyone in this village eats fish on a regular basis. Many young people fish in the river during the high-water season with hook and line. Their catch is for personal consumption.

Wednesday, 15 October, Balad Raxan.

We found that there are two fishermen who fish here on a regular basis. These fishermen own nets, which are seven- and eight-finger mesh sizes, 41 to 32 fathoms in length and 2.5 fathoms deep. These nets were purchased ready-made in the Mogambo market. The fishermen mounted them on float and bottom lead lines. The 41-fathom net cost 1,500 SSh and the 32-fathom net cost 950 SSh. These nets have lasted for two years and three months. If the nets are properly mended they can last up to 3.5 years. They are presently being used at Dhesheeg Waamo.

The fisherman we talked to told us that his nets are being used by two young men from this village. He pays them 10 SSh per fish. He transports these fish back from Waamo and sells them from his house. The price is from 70 to 100 SSh per fish. He gets fresh fish on occasion and sells them at the same price. Fishing and sales of fish from Waamo are carried out all year. He does not fish in the river because he is afraid of the crocodiles. The villagers told us that there was a crocodile fatality just two nights ago.

Most families in this village have someone in the family, usually small children, who fishes in the river. The main type of fishing gear used is hook and lines, which are baited and placed in the river from the bank.

For monitoring the catch from the dhesheeg, there is a young man, Abdulkadir Ibrahim Abdou, who speaks English and could possibly measure and weigh the fish as they are brought to the village.

Wednesday, 15 October, Mana Moofa.

The estimated population of this village is 3,570.

Villagers told us of a group of Americans who came through here several years ago in an attempt to eradicate the crocodiles. A man related a story of one woman who was eaten last Saturday, and told of several other attacks in the last few months.

We found that there are about 20 fishermen living here. One fisherman uses a net and the others use hook lines. They fish for personal consumption only but sell fish if they have surplus. The villagers usually buy fish from Dhesheeg Waamo. They told us of a daily supply of fresh fish from Waamo that is sold along the road from a transporter going to Jilib. This vehicle usually comes by here around 3:00 to 5:00 p.m. The villagers prefer fresh fish and pay from 80 to 100 SSh per fish. They usually consume one fish per family per day.

Wednesday, 15 October, Fagan.

The people of this village do not eat fish and gave us displeasing looks and scrunched noses when we asked them about fish. They told us that the people who live next to the river eat fish.

Mogambo

We visited this village; however, no field notes were taken.

Thursday, 16 October, Jilib to Fanoole.

We drove up to the Fanoole Barrage and searched for a location to launch the boat. After looking around on the east side of the river with no luck, I walked across the barrage and found a suitable launch site. However, the guard at the electric facility would not move the tractor blocking the road.

We turned around and drove downriver to a small village where I was determined to launch. The name of this village is Nasib and it is located approximately three to five kilometers from the barrage. We launched the boat over a 12-foot-high cliff, which was a monumental task. Launching this boat will require great skill and care. After launching the boat we motored upstream to the barrage and counted about five crocodiles. We set the gill nets and attempted three trials with the beam trawl. All three trials were unsuccessful because the beam is made of wood and did not sink to an adequate depth for sampling fish on the bottom.

We harvested the nets and drove back to Jilib the next day.

Saturday, 18 October, Qalaaliyo.

This village is four kilometers south of Jilib. We found that there are 12 fishermen living in this village. We talked to two of these fishermen and they told us that they own gill nets. One fisherman has four nets and the other has one net. They are presently fishing at a local dhesheeg called Hamaca. This dhesheeg is probably from the Shabeelle River and is located on the road to Muqdisho. Most of the fish from that dhesheeg are sold in the Jilib market. They told us there are a lot of fish sold here and that they like to eat fish, one man even prefers it over meat. The fishermen bring dried fish, which has been stored for 10 to 14 days, from the dhesheeg. All 12 fishermen come and go as one group and they hire a vehicle to transport themselves and their fish.

The villagers told us of another dhesheeg called Shatole. This dhesheeg is farther up the road to Muqdisho (approximately 12 to 15 kilometers).

The fishermen told us that they have small plots (approximately one to two hectares) of land they cultivate, growing corn, sesame, and some millet.

One fisherman told us that he uses one hook and line in the river during the high-water season. During the low-water season he used several hooks and he indicated that there are a lot more fish and more fishing during this season. During the low-water season, they use nets in the dhesheegs and during the high-water season they use hooks. They sell these fish for 60 to 100 SSh per fish, no matter what size. They hire a truck from Jilib to transport their catch to that market. He told us that there are some people who use canoes that are rented from villagers in surrounding villages, but that there are no canoes in this village. A canoe rents for about 120 SSh per day. Most fishermen don't like to fish in the river because they are afraid of the crocodiles and hippos.

Ministry of Jubba Valley Development
Jubba Environmental and Socioeconomic Studies
Fisher Household Interview Questionnaire

Date:__________ Strata:______ Village:________________

Number of fisher households in village:______

Number of interviews:_____

Family name:__________ __________

List of fishing gear and cost:

Gear	Cost	Age of this gear

List of family members involved in fishing:

Member	Relationship	Activity (fishing or sales)
1.		
2.		
3.		
4.		
5.		

Seasons of fishing in river?______________________
Seasons of fishing in dhesheegs?__________________

Estimated amounts of fish captured daily in previous week:_______Kg Number of days fished:__________

Any comments on local indigenous fishery or water management structures or historical accounts of such organizations in this area:

Water Balance and Sediment Transport in the Jubba River Watershed

prepared by
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An earlier version of this report was published as "JESS Report on Water Balance and Sediment Transport in the Jubba River Watershed," *JESS Report No. 21*, Donald Alford, August, 1987. Associates in Rural Development, Burlington, Vermont. All photographs in this report are by the author.

This report summarizes the results of a six-week consultancy (18 January to 1 March 1987) dealing with the water balance and sediment transport characteristics of the Jubba River in Somalia, Kenya, and Ethiopia. (See Figure 1 at the front of this volume.) This consultancy was undertaken to

- assess the adequacy of the existing empirical data base related to the hydrometeorology and sediment transport of the Jubba River; and
- develop and evaluate water balance and sediment transport models.

This report is based largely on secondary sources of information, primarily syntheses of data prepared by consultants who have preceded this consultant in Somalia. Only the most salient conclusions are drawn, and the bulk of the information is presented in graphic and tabular form. The water balance and sediment transport models used here are elementary conceptualizations, describing in the simplest terms complex physical processes. These models are designed primarily to provide a formal structure in terms of which a qualitative description of these processes may be organized. While considerable elaboration is possible, the data base available to the consultant does not warrant such elaboration.

I. EXECUTIVE SUMMARY

This study of the hydrology of and sediment transport in the Jubba River has led to the following six major conclusions:

- The most probable hydrologic impact in the Jubba River Valley following construction of a dam above Baardheere, Somalia, will be a large decrease in the natural annual flood crest(s) along the lower river between the dam and the mouth of the river. This will eliminate the natural irrigation of those agricultural areas (dhesheegs) which are now flooded periodically by these crests.
- Base-level and gross morphology of the river channel below the proposed dam site are controlled primarily by material deposited in the channel by ephemeral tributaries to the river, which contain water only immediately following heavy local rainfall. These tributaries, having a much higher energy gradient than the main channel, deposit alluvial and colluvial material which the main channel cannot move. Minor morphological changes, involving a decrease in the depth-width ratio, may occur in those reaches of the main channel composed of fine sands, but these should have no appreciable impact on any downstream structures (*e.g.*, the bridge at Baardheere).
- An apparent error exists in the estimation of river discharge volumes on which much of the planning for the proposed reservoir has been based. For average monthly discharge volumes, the error is approximately +15 percent at high discharges and -30 percent at low discharges, and may cause an overestimate of mean annual volume of stream flow by as much as one km^3 (1,000,000,000 m^3), approximately 20 percent of the volume on which planning for dam design and reservoir management has been based. This error was introduced by an incorrect assumption concerning the relationship between precipitation and runoff in the upper basin.
- There is a difference of approximately +15 percent in the measured and calculated discharge volumes of the Jubba River in what is felt to be the best available data set and analysis, that of Agrar- und Hydrotechnik (AHT 1986). This difference is a result either of errors introduced by converting staff gauge measurements of river depth to discharge volumes, or of problems with the statistical model used. The existence of this error does not preclude the use of these data for planning purposes, but must be recognized in all planning efforts using this data base.
- Available measurements of sediment transport in the Jubba River system are not sufficient to define the volume or timing of sediment transported annually or seasonally through the system, nor the rate at which the proposed reservoir will fill with sediment. Measurements of sediment transport should be undertaken at both Luuq and Baardheere, Somalia, using accepted instruments and methods. It is probable that previous measurements have underestimated the fine sand component of the sediments transported through the system, inasmuch as they have been taken from near the river surface, and it is probable that the sand fraction moves as a quasi-bedload.
- Technically, the most difficult problem associated with a reservoir will be the efficient management of that reservoir. Management scenarios developed for mitigation of a potential environmental impact may conflict with those required to sustain the social and economic infrastructures which will develop to exploit the beneficial uses of the waters of the Jubba River made possible by the reservoir. Additionally, without advance knowledge of inflows to the reservoir, it may be virtually impossible to regulate outputs with any uniformity. For these reasons, every effort should be made to determine the feasibility of developing a runoff forecast model for the upper (Ethiopian) portion of the watershed, perhaps using an index derived from satellite imagery. Far more attention should be given to the complex interactions involved in reservoir management than has been the case to date.

II. GENERAL CHARACTERISTICS OF THE JUBBA RIVER

This report is based upon information available from previous studies of the hydrology of the Jubba River (AHT 1986; ELC 1984, 1986; Technital 1981), maps at scales of 1:100,000 (GSDR) and 1:1,000,000 (U.S. Defense Mapping Agency), and visits to the upper and lower river within Somalia, at which time-limited and preliminary samples of the fluvial sediments in the riverbed were collected for analysis.

A. Topography

The Jubba River originates at the confluence of three major tributaries near the town of Dolo (Doolow), Ethiopia. From west to east, the tributaries are: the Dawa Wenz, the Genale Wenz, and the Webi Gestro Wenz (Figure 2). The surface

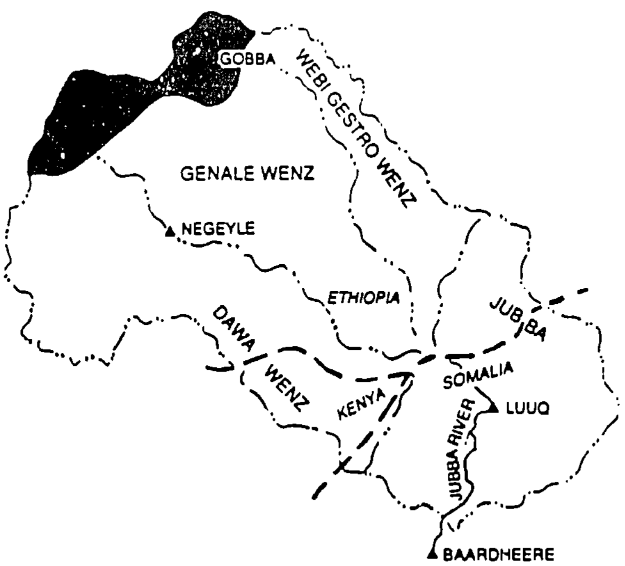


Figure 2. *A sketch map showing the location of the major tributaries which form the Jubba River, the political subdivisions of the watershed above the proposed reservoir and the approximate locations of portions of the watershed with a positive (shaded) and negative (unshaded) annual water balance. It is hypothesized that at least 90 percent of the annual streamflow of the Jubba River originates in the shaded portion.*

area of these tributaries is 61,700 km^2, 57,100 km^2, and 25,200 km^2, respectively. The total surface area of the watershed is approximately 220,000 km^2, of which 167,000 km^2 (approximately 75 percent) lies above Luuq, Somalia (see Table 1). The watershed is divided among three states: Somalia - 76,000 km^2 (35 percent of the basin); Ethiopia - 134,000 km^2 (60 percent); and Kenya - 10,000 km^2 (five percent). The total length of the river,

Table 1. Area-Altitude Relationships in the Jubba Watershed

ALTITUDE(m)	AREA (km^2)	% TOTAL
4001-4500	1,100	0.5
3501-4000	1,540	0.7
3001-3500	2,200	1.0
2501-3000	7,700	3.5
2001-2500	9,900	4.5
1501-2000	18,700	8.5
1001-1500	22,000	10.0
501-1000	25,300	11.5
0-500	132,000	60.0
TOTAL	220,440	100.0

measured from the furthest point upstream in the Bale mountains of Ethiopia, to the mouth near Kismaayo, Somalia, is approximately 1,300 km, of which 880 km are within Somalia.

Altitude above sea level (Figure 3) within the basin ranges from sea level, at the mouth of the river near Kismaayo, to 4,377 meters above sea level (masl) on the divide between the Genale Wenz and Webi

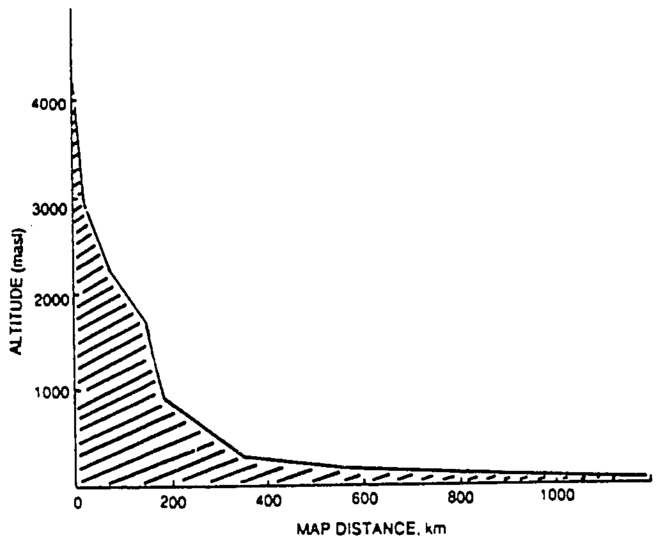


Figure 3. *A long profile of the Jubba River, from its headwaters in the Bale Mountains of Ethiopia to a point below the proposed reservoir.*

Gestro Wenz rivers . Within the Somali portion of the watershed, surface altitude seldom exceeds 300 masl.

B. Channel Gradient and River Morphology

Within the Ethiopian portion of the basin, the gradient of the river channel (*i.e.*, the ratio between horizontal travel distance and vertical drop) decreases from 0.065 (*i.e.*, 65-meter vertical drop for each kilometer of stream reach) near the headwaters, to 0.007 in the lower reaches. Below Dolo, Ethiopia, and including the entire reach within Somalia, the gradient averages between 0.0003 and 0.00015.

A cursory examination of the Jubba River suggests that, throughout much of its length between the Ethiopian border and the Indian Ocean, it is cutting in either bedrock or highly resistant, very fine-grained, unconsolidated sediments (silts and clays). The meander pattern appears to be a relict from a former era of much higher flow volumes and is probably, with possible local exceptions, relatively inactive under present conditions. As indicated by the presence of an established vegetation cover, many of the larger islands of the lower Jubba are stable under present conditions. The existing base level and gradient are apparently completely controlled by resistant outcrops of bedrock or alluvial materials which the river cannot move. The cross-sectional area of the channel is adjusted to a flood of 700 m^3/s (the "effective bankful discharge"). This cross-section varies widely, presumably controlled largely by local geologic factors (Figure 4).

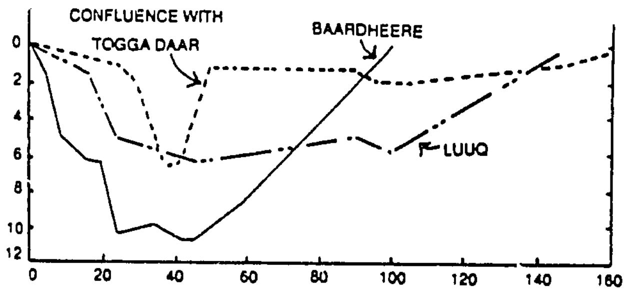


Figure 4. *Measured cross-sections of the channel of the Jubba River at Luuq, Baardheere (AHT 1986) and immediately downstream from the proposed dam site (this study).*

C. Water Balance Elements

1. Precipitation

Precipitation as rain is assumed to be the only input to the hydrologic cycle within the Jubba River watershed. Precipitation records for 36 stations are summarized in ELC (1984, V. 2, 1/3-1). Fifteen of these stations are in Somalia and 21 in Ethiopia. Of these 36 stations, data for 30 are presented as annual means and only six (Gobba, Ethiopia; Negeyle, Ethiopia; Luuq, Baardheere, Jilib, and Kismaayo, Somalia) have monthly means of precipitation (see Table 2, next page). In calculating the seasonal patterns of precipitation discussed below, only these six stations have been used. There is some suggestion that these stations may not be representative of precipitation patterns over the watershed (*e.g.*, Figure 5) and analyses of seasonal patterns based on the total data base may yield results which differ slightly from those discussed here.

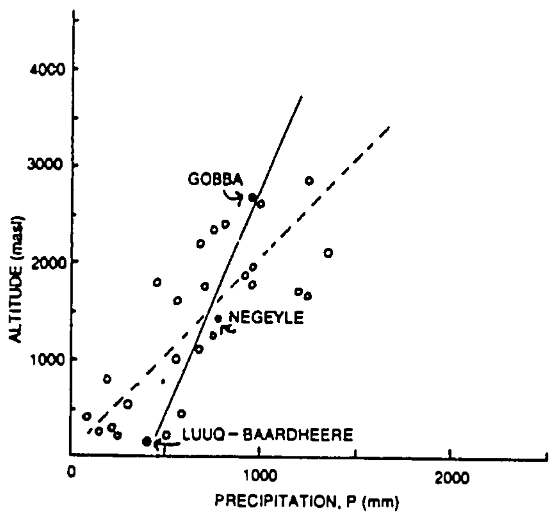


Figure 5. *The relationship between precipitation and altitude in the Jubba River watershed. (Open circles–annual values only; closed circles–annual values derived from monthly means.) (ELC 1986)*

Recorded precipitation amounts vary from near 200 mm per year in the vicinity of Luuq, Somalia - Dolo, Ethiopia, to more than 900 mm per year at Gobba, Ethiopia, near the headwaters of Webi Gestro Wenz. An isohyetal map of annual rainfall depth is contained in ELC (1984) and reproduced here as Figure 6 (next page). Within the range of the data (0-2,700 masl), these annual precipitation amounts show a reasonably uniform increase with station altitude, with a slope of three to five mm/m. An extrapolation of this trend to the highest altitudes present within the basin suggests that the probable

Table 2. Seasonal Distribution of Precipitation in the Jubba Watershed (in mm)

SITE	ALT (m)	JIILAAL	GU'	XAGAA	DEYR	ANNUAL
Gobba	2,700	140	280	325	160	905
Negeyle	1,440	100	385	55	225	765
Luuq	150	50	160	5	105	320
Baardheere	100	57	175	30	160	322
Jilib	25	60	300	95	140	595
Kismaayo	0	5	245	100	30	380

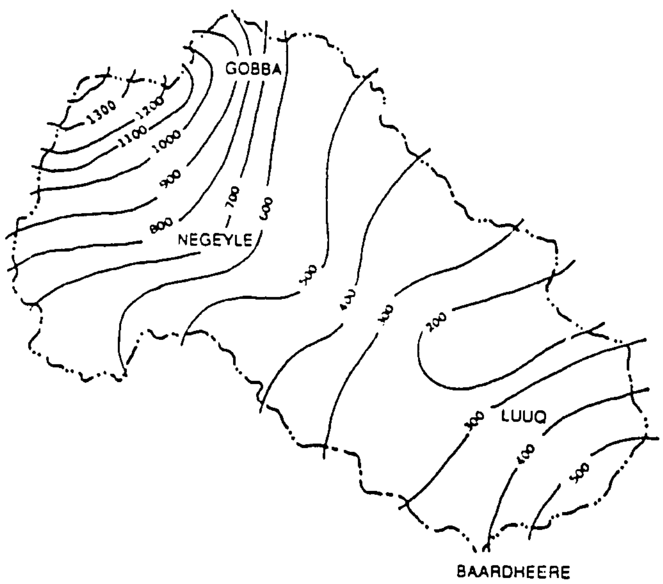


Figure 6. *An isohyetal (equal precipitation) map of mean annual values for precipitation (in mm) for the upper portion of the Jubba River watershed (ELC 1986).*

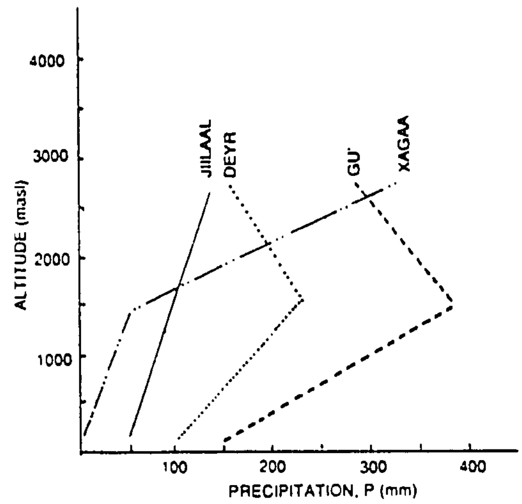


Figure 7. *Seasonal gradients of precipitation with altitude for the Jubba River watershed.*

maximum precipitation may exceed 1,500 mm/yr at the highest altitudes within the basin.

Seasonality of precipitation also seems to vary with altitude in the watershed (Figure 7). Within the Somali portion of the watershed, four distinct precipitation seasons are recognized:

- *Jiilaal* is a dry season which lasts approximately from December through March. During this season, the relationship between precipitation and altitude is essentially linear, with altitude within the range of the data, but with a shallow gradient of 0.03 mm/m. All portions of the watershed are quite dry during this season, with maximum precipitation amounts of approximately 200 mm at the highest altitudes. This is the season of minimum stream flow.
- *Gu'* is a rainy season that occurs during the months of April through June. During this season, the zone of maximum precipitation appears to be located in a 1,000 m vertical zone, centered approximately on 2,000 masl. Precipitation amounts within this zone are approximately 400 mm, decreasing to near 100 mm at the altitudinal extremes of the watershed.
- *Xagaa*, which is an intermediate season of lighter rainfall at lower altitudes, occurs during the months of July to September. Above approximately 1,500 masl, however, the data suggest that a steep precipitation gradient exists (approximately 1.5 mm/m), producing precipitation amounts of near 600 mm at the highest altitudes. Xagaa is the primary rainy season in the upper watershed.
- *Deyr*, a rainy season from October to November at lower altitudes, has an altitudinal distribution of precipitation similar to that of gu'. Maximum precipitation

Alluvial material in the channel of the Jubba River at mouth of Togga Daar, an ephemeral tributary immediately downstream from proposed dam site. The larger boulders in this alluvial material exceed one meter in diameter.

Remnant of German steamer on Togga Daar alluvium. The presence of this remnant, which presumably dates from before World War II, is an indication of the stability of this deposit.

amounts of between 200-3300 mm occur in a zone centered on 2,000 masl.

From these data describing the precipitation-altitude relationship, the following conclusions seem warranted:

- The seasonality of precipitation decreases with altitude within the Jubba River watershed. At sea level, the ratio between the wettest and driest seasons is approximately 50:1, while at 2,700 masl, it is about 2.5:1. Extrapolation of this trend to the highest altitudes within the watershed suggest that there is probably little variation in monthly amounts of precipitation above approximately 3,500 masl.
- The dominant phenomenon affecting the hydrologic regime of the watershed is a vertical shift in the zone of maximum precipitation. During the rainy seasons of gu' and deyr, this zone is located at an altitude of approximately 2,000 masl, while during the dry seasons of jiilaal and xagaa, it is at, or near, the highest altitudes present in the watershed. It is this seasonal shift in the altitude of maximum precipitation, in combination with the amounts involved, which determines the hydrologic regime of the Jubba River.

2. Evaporation and Transpiration

Combined evaporation and transpiration from plants, "evapotranspiration," represents the major water loss from the watershed. Based upon pan evaporation measurements at Mareerey, Somalia (AHT 1984), it has been estimated that potential evapotranspiration is approximately 3,000 mm/yr over much of the Somali portion of the watershed.

No information concerning spatial variations of evapotranspiration within the watershed was available for this study.

As a first approximation, it is assumed that evapotranspiration will decrease with increasing altitude above sea level within the watershed to negligible amounts between 3,500-5,000 masl (the estimated mean altitudinal range of the zero degree Centigrade isotherm). It has been further assumed that this decrease will be linear with altitude. It is probable that the actual trend is curvilinear but, without measurements from the higher altitudes, the exact form of the relationship cannot be specified with any confidence.

Tertiary bedrock outcrop in channel of ephemeral tributary immediately above confluence with Jubba River near proposed dam site. Such outcrops are extremely resistant to erosion, and control erosion in channel.

As with all science, hydrology is dependent upon empirical data for the testing of hypotheses. The accuracy of all conclusions concerning the water balance and sediment transport characteristics of the Jubba River, as well as water resources management planning, must ultimately be based upon empirical measurements.

There are at least two major potential sources of error in any hydrological historical data base: (1) errors inherent in the measurements of stream-flow volumes, and (2) errors introduced by analytical assumptions and procedures. If valid management decisions concerning the use of the Jubba River are to be made, it is necessary to develop some understanding of the potential magnitude of these errors.

The raw data on which all stream-flow estimates are based are measurements of river depth. By carefully measuring the cross-sectional area of the river channel, and the speed with which the water flows through that cross-section, measurements of depth may be converted to values of volume/time, expressed as cubic meters per second (m^3/s). The accuracy of this conversion, known as "stage-discharge" relationship, is dependent upon the accuracy with which the cross-section and speed of water flow at various river depths are measured, and the stability with time of the cross-sectional area. Where the cross-sectional area is stable with time, long series of records of river depth measurements may be converted to flow volumes using a single "rating curve" (the empirical relationship between depth and discharge), with confidence. Where the cross-section is unstable, it may be necessary to establish new rating curves on a frequent basis. Normally, river reaches with unstable cross-sections are not selected for river gauging stations.

The general history of stream-flow measurements on the Jubba River is summarized by Technital (1981), AHT (1984), and ELC (1986). Analyses of spatial and temporal trends are contained in each of these reports and will not be repeated here, except as they are relevant to specific points made in this discussion.

River gauging stations (RGSs), using primarily staff gauges, have been operated sporadically at six sites on the river between Luuq and Jamaame, Somalia, since the 1950s (Luuq, Baardheere, Kaytooy, Mareerey, Kamsuma, Jamaame). The period of measurement varies among stations from a maximum of approximately 30 years at Luuq to approximately seven years at Mareerey and three years at Kamsuma (AHT 1986).

The stability of the relationship between stage and discharge at the various RGS is discussed in previous reports only in the most qualitative terms:

- "... the rating curve ... [at Luuq] ... is stable, in spite of strong variations of bed level during floods" (AHT 1986).*
- "Discharge measurements ... [at Baardheere] ... cover only the lower and medium stages and the rating curve seems to be the least stable of all the stations" (AHT 1986).
- "At Mareerey, discharge measurements cover only the lowest levels and the rating curve has been obtained through correlations with data from Kaytooy" (AHT 1986).
- At Kaytooy, "... a well established stage-discharge relationship (1972-1980). Since 1981, the station has been influenced by the backwater of the Fanoole weir" (AHT 1986).
- "The general poor reliability of the river stage observations must be stressed ..." (ELC 1984).
- "Procedures ... [for converting depth to discharge] ... assume that the hydromorphological features of each measuring station [*e.g.*, cross-sectional area] remain stationary for long periods, though this is a somewhat doubtful assumption for water-courses which have large, prolonged floods" (Technital 1981).

In spite of these general concerns with respect to the reliability of the hydrological data base, it has not been possible to find any attempt to assess the possible error of estimate contained in that base. It is apparent that, while there may have been reservations on the part of each of those quoted above, ultimately the data were accepted and used for

**It is impossible for the rating curve to be stable if there are "strong variations of bed level."*

various analytical procedures. For many purposes, largely associated with reconnaissance hydrology, this may be acceptable, but for the planning of a major dam, it is essential that some understanding of potential errors exist. Without such an understanding, planning for the construction and management of the dam entails unacceptable risks.

Without a detailed program of current meter measurements, which is beyond the scope of this consultancy, it is not possible to determine the magnitude of absolute errors in the data base. It is only possible to compare the various data which have been presented in previous reports to determine the extent to which they vary. It is apparent that significant differences exist among the various reports on the hydrology of the Jubba River. For the purposes of this report, the data summary represented by AHT (1986) has been adopted as a "standard of reference" against which other data bases may be tested. This has been done largely because the analytical methods used by the Germans are understandable, straightforward, and explained clearly. The primary comparison involves the data base developed by the Italian firm of ELC (1984), in view of the detailed plans for the dam which have been developed from this base (ELC 1984, 1986).

Several differences and potential errors have been found. As mentioned above, the stream-gauging program on the Jubba River has been sporadic. An accepted practice for filling gaps in a discontinuous record uses a statistical approach, involving probabilities of event recurrence. This approach has been used by AHT (1986) to produce two data sets—one representing the original data base and the second a continuous set of data derived statistically.

A comparison of these two AHT data sets shows a random difference of approximately ± 15 percent (Figure 8). This must be taken as the minimum error of estimate for the Jubba River hydrological data base. All engineering designs and reservoir management plans will be subject to this error.

A comparison of the AHT and ELC data bases shows a number of significant differences. A systematic difference between the data bases used by these two groups exists. For average annual flows, the data set used by ELC for preliminary engineering design and reservoir management planning differs from that of AHT by approximately +15 to +20 percent at high-flow volumes and by as much as -30

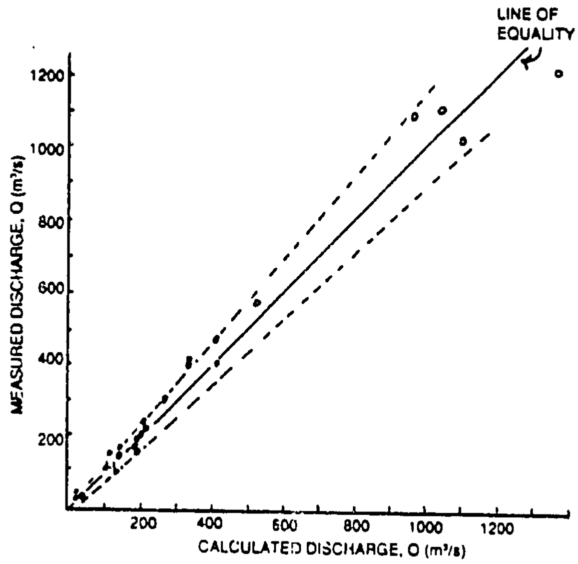


Figure 8. *The relationship between AHT measured and calculated stream discharge measurements at Luuq. The envelope represents a deviation of ±15 percent (AHT 1984).*

percent at low flows (Figure 9). It is probable that this difference is a result of differing analytical techniques used by the two firms. While AHT used a statistical model to fill in missing data, ELC created a synthetic data base by filling in missing data on the assumption that a constant relationship exists among annual, seasonal and monthly stream flow at Luuq, Somalia, and a weighted average precipitation derived from data for Luuq and Gobba, Ethiopia (Tables 3 and 4, next page). The

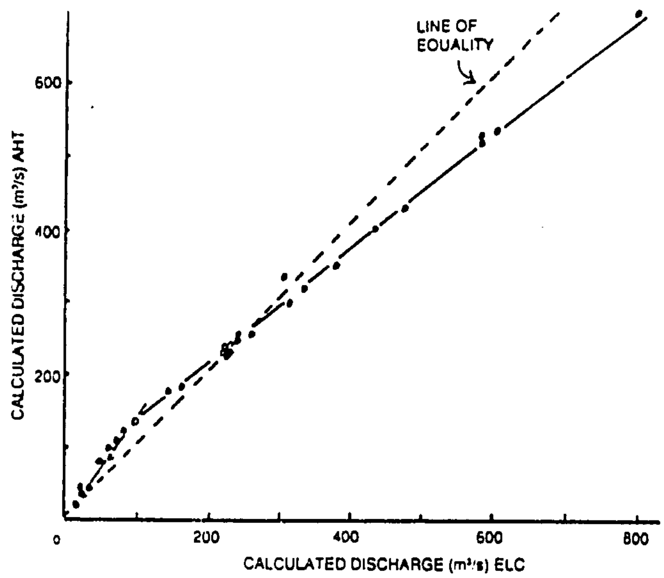


Figure 9. *The relationship between discharge at Luuq, Somalia (AHT 1984 and ELC 1984).*

regime in the upper basin of the Jubba River is probably erroneous. An alternative interpretation of available precipitation-runoff data, comparing mean monthly runoff at Luuq, Somalia, with precipitation at Gobba, Ethiopia, suggests significant seasonal shifts in this relationship (Figure 10). It seems most probable that ELC has introduced a systematic error in its calculations of surface runoff as a result of an incorrect assumption concerning the fundamental nature of the hydrologic regime of the upper Jubba River basin.

Table 3. Mean Monthly Discharge Estimates (m^3/s)

MONTH	AHT		ELC	FAO
January	49*	46**	45	40
February	27	31	29	19
March	12	42	38	39
April	87	164	126	95
May	223	254	238	229
June	154	159	155	133
July	185	188	186	175
August	248	275	276	304
September	292	292	299	303
October	442	431	457	425
November	255	346	363	338
December	93	126	137	162
YEAR	172	205	197	189

**calculated from empirical data*
***calculated from synthetic data*

Table 4. Estimates of Average Monthly Stream Flow (m^3/s)

MONTH	ELC	AHT	DIFF. (AHT/ELC)	%DIFF. (AHT/ELC)
January	45	49	+4	+9
February	29	27	-2	-7
March	38	12	-26	-68
April	126	87	-39	-31
May	238	223	-15	-6
June	155	154	-1	-
July	186	185	-1	-
August	276	248	-28	-10
September	299	292	-7	-2
October	457	442	-15	-3
November	363	255	-108	-30
December	137	93	-44	-32
YEAR	197	172	-25	-13

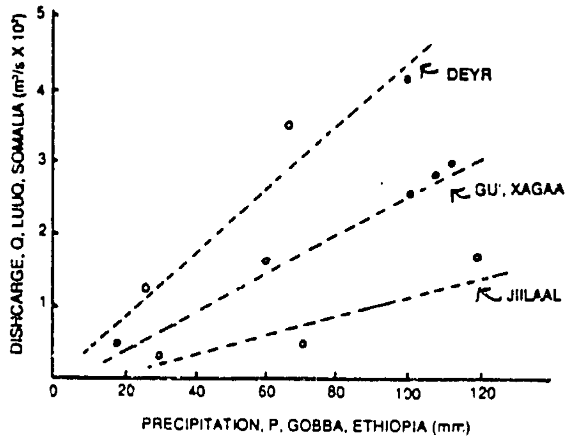


Figure 10. *Seasonal variations in the relationship between monthly streamflow at Luuq, Somalia, and monthly precipitation at Gobba, Ethiopia (AHT 1986 and ELC 1984)*

A. The Water Balance Model

The water balance model developed for the Jubba River watershed is based on the assumption that altitude is the primary control of the primary elements of the hydrologic cycle (precipitation and evapotranspiration) over the surface of the watershed. The model is designed to be internally consistent with this assumption. A different assumption concerning primary control(s) could produce significantly different results.

The surface runoff from any watershed is a conservative parameter, representing the algebraic summation of input (as precipitation), storage (as soil moisture, ice/snow or groundwater), and output (as evapotranspiration or runoff):

$$Q = P - Et + S\ \Delta \quad (1)$$

where:

Q = stream flow
P = precipitation
Et = evapotranspiration
S = storage
Δ = change

In order to evaluate the equation, it is necessary to express stream flow, Q, in specific terms, q, (*i.e.*, as depth [mm] per unit area [m^2]), so that the units of stream flow are comparable with those of precipitation and evapotranspiration:

$$Q/A = q \quad (2)$$

where A is the surface area (see Table 1).

While changes in storage, S, may vary over shorter time periods (*e.g.*, a single storm or a monthly series of storms), it is assumed here that seasonally and annually, the net change in S equals zero.

Following a determination of average specific runoff values for any area of interest, these may be converted to stream flow by a simple transformation of equation (2):

$$Q = qA \quad (3)$$

and to a time-volume value:

$$Q = qA/s \quad (4)$$

to give a stream flow in m^3/s.

B. Water Balance of the Jubba Watershed

Results of an analysis of the water balance of the watershed of the Jubba River, using equations (1) through (4) are presented in Tables 5 - 10. Precipitation and runoff represent average conditions for those periods over the entire watershed. No attempt has been made to calculate the water balance of the major subcatchments, due to a lack of necessary data from the Ethiopian portion of the watershed.

The spatial and temporal variations developed from the model are a result of "forcing" the precipitation-evapotranspiration curves to fit the empirical discharge data for Luuq, Somalia (AHT 1986). Qualitatively, the results provide a useful picture of the distribution of the surface water balance of the watershed, and illustrate the nature of the forecast model which will be required if the proposed reservoir is to be properly managed. Without some additional data from Ethiopia, there is no way to test the quantitative validity of the model. These relationships are illustrated graphically in Figures 11, 12A-B, and 13A-B.

The water-balance model on which the above tables are based (Thornthwaite method) is sensitive to small changes in surface area at the higher altitudes involved and small changes in annual or seasonal precipitation amounts at the lower altitudes. (In this case the author used an air temperature lapsed rate of .6°C per 100 m of altitude and assumed that at a mean annual temperature of 0°C, there would be no evapotranspiration.) Considerable sophistication is possible, given more precise data concerning precipitation and runoff trends in the Ethiopian portion of the watershed.

C. Groundwater Contribution

With few exceptions, the base flow of perennial rivers (those that flow throughout the year) is sustained by a groundwater component. Groundwater is recharged by precipitation which percolates into the ground surface below a level where it can be affected by evaporation or transpiration. It then slowly flows down-gradient (controlled either by geologic strata or gravity) to topographic lows where it reemerges at the surface. In all but exceptional circumstances (*e.g.*, a completely impermeable river channel), there is a constant interchange between the water flowing in the channel of the river and the surrounding groundwater. This may involve a net annual flow of water from the channel into groundwater storage (as appears to be the case with

Table 5. Calculated Water Balance--Annual Values

ALT (m)	AREA (km^2)	P (mm)	Et (mm)	q (mm)	Q (m^3 x 106)
4,250	1,100	1,450	0	1,450	940
3,750	1,540	1,350	350	1,000	985
3,250	2,200	1,200	700	500	1,820
2,750	7,700	1,050	950	100	700
2,250	9,900	950	1,450		
1,750	18,700	850	1,800		
1,250	22,000	700	2,150		
750	25,300	550	2,500		
250	132,000	450	2,850		
				TOTAL	5,325

Table 6. Calculated Water Balance--Jiilaal Season (December - March)

ALT (m)	AREA (km^2)	P (mm)	Et (mm)	q (mm)	Q (m^3 x 106)
4,250	1,100	190	0	190	210
3,750	1,540	170	0	170	260
3,250	2,200	155	160		
2,750	7,700	140	210		
Water balance negative below 3,500 m				TOTAL	470

Table 7. Calculated Water Balance--Gu' Season (April - June)

ALT (m)	AREA (km^2)	P (mm)	Et (mm)	q (mm)	Q (m^3 x 106)
4250	1,100	0	90	0	0
3750	1,540	120	100	20	30
3250	2,200	250	160	90	200
2750	7,700	380	260	120	920
Water balance negative below 2,500 m				TOTAL	1,150

KEY: Tables 5 - 9

P = precipitation

Et = evapotranspiration

q = depth of hypothetical stream per unit area

Q = stream flow

Table 8. Calculated Water Balance--Xagaa Season (July - September)

ALT (m)	AREA (km^2)	P (mm)	Et (mm)	q (mm)	Q (m^3 x 106)
4,250	1,100	620	0	630	620
3,750	1,540	480	150	330	510
3,250	2,200	430	220	210	460
2,750	7,700	330	290	40	310
Water balance negative below 2,500 m				TOTAL	1,900

Table 9. Calculated Water Balance--Deyr Season (October - November)

ALT (m)	AREA (km^2)	P (mm)	Et (mm)	q (mm)	Q (m^3 x 106)
4250	1,100	100	0	100	110
3750	1,540	120	0	120	185
3250	2,200	145	45	100	220
2750	7,700	175	100	75	590
2250	9,900	220	150	70	700
Water balance negative below 2,000 m				TOTAL	1,805

Table 10. Seasonal Water Balance Variations m^3 x 10^6

ALT (m)	Jiilaal	Gu'	Xagaa	Deyr	ANNUAL
4,250	210	0	620	110	940
3,750	260	30	510	185	985
3,250		200	460	220	880
2,750		920	310	590	1,820
2,250				700	700
1,750					
1,250					
750					
250					
TOTAL	470	1,130	1,900	1,805	5,325

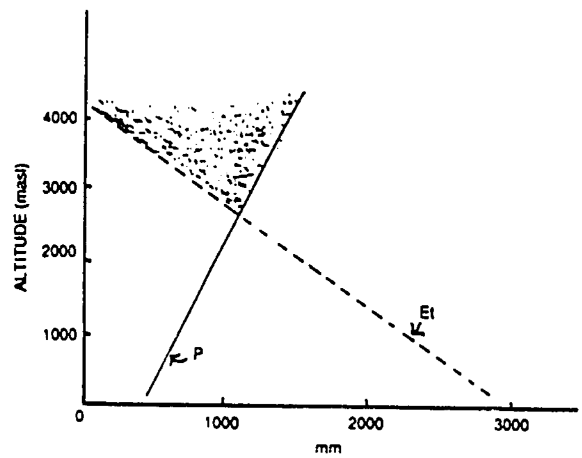
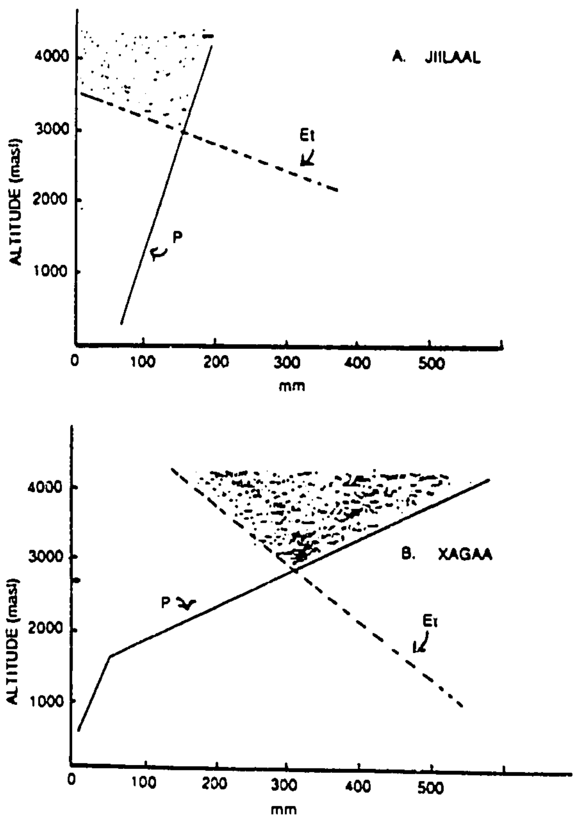
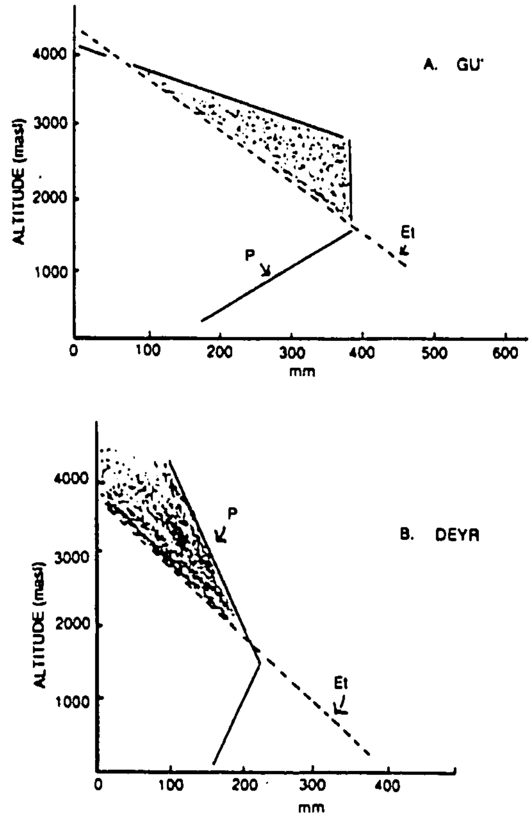


Figure 11. *The calculated trend of mean annual altitudinal distribution of precipitation and evapotranspiration over the Jubba River watershed. Shaded portion represents a first approximation of the portion of watershed with positive water balance (surface runoff), as indicated by model.*



Figures 12a and 12b. *The calculated mean seasonal altitudinal distribution of precipitation and evapotranspiration for the jiilaal and xagaa seasons.*



Figures 13a and 13b. *The calculated mean seasonal altitudinal distribution of precipitation and evapotranspiration for the gu' and deyr seasons.*

Jubba) or from groundwater storage into the channel of the river.

Only very indirect estimation of the groundwater component of the annual and seasonal flow of the Jubba River is possible from the existing data. Since no measurements of necessary groundwater parameters were found in the literature available for this study, an attempt has been made to evaluate this component by hydrograph analysis.

A hydrograph (the time-distribution of stream flow during the course of a hydrologic year) may be assumed to be composed of three components: storm flow, bank storage and base flow, or groundwater recharge. A hydrograph consists of a "rising limb," as the volume of water in the channel rises following a period of rainfall, and a "falling limb," as the peak flows recede. Watershed characteristics (primarily topography, geology, vegetation and drainage geometry) largely determine the slopes of both rising and falling limbs. While the rising limb of the hydrograph may be variable, rising limb of the hydrograph may be variable, depending upon factors such as precipitation intensity and antecedent soil moisture (the amount of water contained in the soil at the onset of precipitation), the slope of the falling limb, or "recession curve" is a constant. In theory, at least, this recession curve can be separated into the components of storm flow, bank flow, and base flow. The base flow component should equal the groundwater contribution to the flow of the river.

For the Jubba River at Luuq, an artificial hydrograph based upon data contained in AHT (1986) has been constructed (Figure 14). Analysis of this hydrograph suggests that the groundwater component will sustain the base flow of the Jubba River at Luuq for approximately 70 days, in the absence of any precipitation inputs (extrapolation of the groundwater recession curve to a discharge of Q = 0 m^3/s). This groundwater component does not appear to be sufficient to maintain the perennial flow of the Jubba River at this site without continuing precipitation inputs from the Ethiopian highlands.

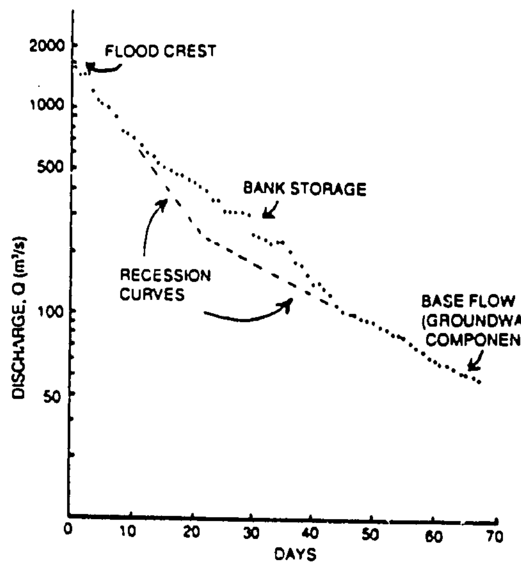


Figure 14. *A synthetic hydrograph of the Jubba River at Luuq, showing the assumed duration, in days, of the contribution of the flood crest, bank storage, and ground- water in streamflow maintenance.*

D. Conclusions

Based on this preliminary water balance model, only the most general conclusions are possible:

- perhaps as much as 90 percent of the mean annual runoff in the Jubba River at Luuq, Somalia, originates from less than 10 percent of the total surface area of the basin, lying above an altitude of 2,000 masl in the Bale mountains of Ethiopia, primarily as direct surface runoff from precipitation inputs;
- during the winter (jiilaal) and summer (xagaa) seasons, the flow of the river is largely maintained by runoff from these high-altitude portions of the watershed;
- during the spring (gu') and fall (deyr) seasons, the area contributing surface runoff expands downward to approximately 1,500 masl, to involve approximately 20 percent of the surface area of the watersheds; and
- with the exception of local, short-duration, high-intensity storm events which, while presumably of considerable local importance, add little to the total volume of annual runoff, calculations suggest that at least 80 percent of the surface area of the watershed is non-contributing throughout the year.

ELC (1984) lists approximately 260 measurements of total suspended sediment (TSS), made during the period 1965-81. Approximately 75 percent of these measurements were made at Mareerey, Somalia, during the period 1980-81. AHT (1986) gives stream flow-TSS values for Mareerey for 1980-81. Regarding these values, AHT states, ". . . isolated measurements of little consequence . . . It is possible that the water samples (from Mareerey) were not taken with the care necessary for suspended load measurements." This latter point is apparently in regard to the fact that the water samples were surface "grab" samples, rather than the more accurate integrated depth sample.

ELC (1984) discusses potential problems with the existing data set, but accepts the data for analytical purposes.

No measurements of bedload have been made.

A. A Sediment Transport Model

The ability of a river to transport sediment, or to modify the morphology of its channel, is largely determined by:

- available energy, associated with the conversion of potential to kinetic energy as the river flows down the gravity slope of the channel;
- the nature and location of the sediments available for transport; and
- the resistance of the bed of the river to erosion and modification.

The nature and location of sediments available for transport ,and resistance of the river bed to erosion are generally quite site-specific and can be determined only by an on-site inspection. There is commonly a strong interrelationship among all factors for any given river system. Hence, some insight for the potential for sediment transport can be gained from a consideration of the distribution of kinetic energy release from point to point along the reach of the river.

The "competence" of a river (its ability to transport sediment or to modify its channel) is determined by the amount of power, as kinetic energy, available along any reach. Kinetic, or fluvial, energy accomplishes work by entraining and transporting sediment. Stream "power" describes the rate of energy supply at the channel bed for overcoming friction (related to erosion) and for sediment transport. The available power supply, W, is the time rate of liberation, in kinetic form, of the potential energy as the flowing water descends the gravity slope, S (Bagnold 1966):

$$W^{*} = pgQS \quad (5)$$

where:

- p = density of water (kg/m^3)
- g = acceleration of gravity (m/s^2)
- Q = discharge (m^3/s)
- S = gravity slope, (stream gradient, m/km)

Numerous empirical equations, based upon results of studies for single river systems, may be found in the literature for determining the range of sediment sizes which can be entrained by various values of W. All are circumscribed with many qualifying assumptions, often related to the nature of local, site-specific controls, and they may produce large errors when applied to a second system. In general, it is best to establish competence by making careful measurement of the suspended sediment load and then attempting to understand the reasons for temporal and spatial variations in terms of basic theory.

In the case of the Jubba River, however, the empirical data base is insufficient to establish a clear relationship between stream flow and sediment transport. For this reason, it is useful to calculate the relative variation of stream power as it varies along the course of the river, on the assumption that these variations serve as an index to variations in the competence of the river. Such calculations can then be used as a point of departure for establishing a sampling program.

The results of these calculations, based upon equation (5), suggest that the competence of the Jubba River varies widely from the headwaters in the Bale Mountains to the plains of Somalia, with alternating

**As expressed in watts*

Sandbars in the channel of the Jubba River, looking upstream at proposed dam site. The volume of sediment moved annually through this river system as sand is unmeasured at present.

A wedge of sand, formed downstream from an obstruction in the river channel at the proposed dam site. The alluvial material at this site was very fine-grained silt and clay, suggesting a strong vertical zonation of suspended sediment sizes.

zones of erosion/sediment transport and aggradation (sediment deposition). This lateral alternation is shown graphically in Figure 15, which is based on the values contained in Table 11 (next page). It can be seen that the combination of steep channel gradients and large discharge volumes produce maximum values of W within the uppermost portions of the watershed. As the gradient of the river decreases, and moves toward the lower, non-contributing reaches within Somalia, the kinetic energy diminishes rapidly. There is a suggestion of alternating zones of erosion/sediment transport and aggradation along the river, but their actual existence will be determined by local conditions of geology and vegetation.

exist for discharges from efficient management of the reservoir.

For the Luuq-Baardheere reach of the Jubba River, a visual inspection of channel characteristics, analysis of fluvial sediments from the channel of the river, and the general theories of fluid dynamics indicate that the following conditions may exist there:

- in at least some reaches, the river is now eroding in bedrock;
- fluvial sediments within the channel consist predominantly of fine sand, silt, and clay (see Appendix B), interrupted at intervals by very coarse materials (up to one-meter diameter), deposited by high-energy ephemeral tributaries;
- the speed of the river ranges from approximately 0.5 m/s at low discharge to 1.0 m/s at high volumes (AHT 1986); and
- in the sand-silt-clay reaches, the bed of the river is relatively smooth and planar, with no systematic recurrent micro-relief such as ripples.

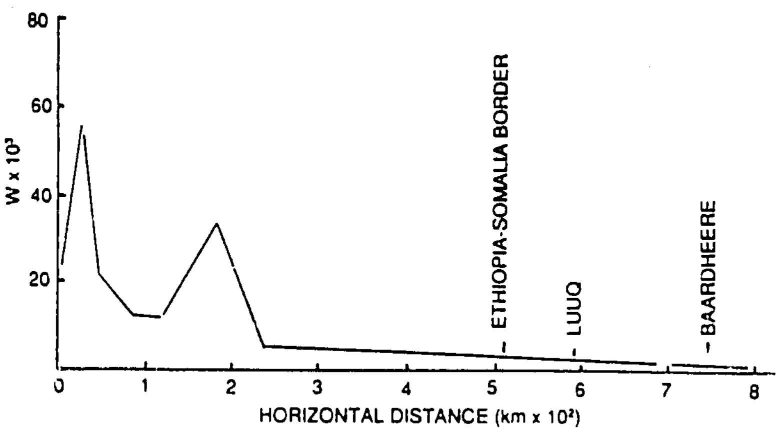


Figure 15. *The calculated lateral distribution of stream "power" (in watts) along the upper portion of the Jubba River. Variations result from a complex interaction between stream flow and channel gradient. Actual erosion, aggradation, and sediment transport are dependent upon local controls.*

For a typical river reach near Luuq or Baardheere, Somalia, the annual trend of available energy will be determined by variations in volume of stream flow (Table 12, next page).

The effective discharge (that volume required to fill the channel bank) is estimated to be approximately 700 m^3/s (AHT 1986). This discharge volume will have a W of about 2000 watts, which exceeds the mean annual value of approximately 500 watts (see Table 12). This latter value should closely approximate the maximum value of W which will

All of these factors suggest that, within the normal range of flow volumes, the Jubba River in the

Table 11. Calculated Kinetic Energy, W (watts)

ALT (m)	p (kg/m^2)	g (m/s^2)	Q (m^3/s)	Q (cum)	S	W
4,250	1,000	9.81	30	30	0.065	19,130
3,750	1,000	9.81	31	66	0.065	38,897
3,250	1,000	9.81	28	89	0.065	56,750
2,750	1,000	9.81	58	147	0.015	21,630
2,250	1,000	9.81	22	169	0.007	11,605
1,750	1,000	9.81		169	0.007	11,605
1,250	1,000	9.81		169	0.020	33,160
750	1,000	9.81		169	0.003	4,975
250	1,000	9.81		169	0.0003	498

KEY: Tables 11 - 12

p=density of water (kg/m^3)
g=acceleration of gravity (m/s^2)
Q=discharge (m^3/s)
S=gravity slope, (stream gradient, m/km)

Table 12. Calculated Seasonal Variations in W Luuq-Baardheere Region

MONTH	Q	p	g	S	W
January	49	1,000	9.81	0.0003	144
February	27				80
March	12				35
April	87				256
May	223				656
June	154				453
July	185				544
August	248				730
Sept.	292				860
Oct.	442				1300
Nov.	255				735
Dec.	93				274
ANNUAL	174				512

vicinity of the proposed dam site is characterized by "sub-critical" turbulent flow, in which only the finest sediments (silt, clay) are held in suspension. Bedrock ledges within the channel, as well as the coarser materials deposited by the ephemeral tributaries, constitute an effective base level which will be resistant to any changes in fluvial energy resulting from the construction of a dam. The sand fraction of the sediment load should be mobile only during flood events, although at that time, very high volumes may be moved during relatively short time periods.

Available empirical evidence from watersheds throughout the world suggests that the morphology and sediment-transport characteristics of rivers are adjusted to a flood with a recurrence interval of about 1.5 years, which will completely fill the channel of the river, without encroaching upon the adjacent floodplain (Dunne and Leopold 1978). In the Luuq-Baardheere reach of river, this "effective" flood volume has been estimated to be approximately 700 m^3/s (AHT 1986). A series of depth-integrated sediment concentration measurements to determine the sediment transport characteristics of the river at, and near, this flow volume will be required to determine the actual competence of the Jubba River.

B. River Morphology

Only the most qualitative estimates of the potential for morphological changes occurring following construction of a dam above Baardheere are possible. It is assumed that the reservoir will act to trap most of the sediment transported into it and, if properly managed, significantly reduce seasonal fluctuation in stream flow downstream from the dam. These two factors will tend to act in opposition: a decrease in sediment load will increase the energy available to do work, while a decrease in effective flow volume will decrease this energy. The net effect of this change on energy availability cannot be calculated with any confidence until reliable quantitative data on suspended sediment transport become available.

A river may respond to changes in water and sediment volumes in a variety of ways: changes in cross-sectional form (*e.g.*, depth, width, depth/width ratio), "armoring" of the bed (*i.e.*, selective transport of bed materials, leaving a coarser fraction in place), changes in the planform of the river (*e.g.*, meander wavelength, sinuosity of the channel), and changes in the gradient of the channel. All of these changes are completely interrelated, but will commonly proceed at differing rates.

The most probable changes to be expected in the near-term will be changes in the cross-sectional form of the channel and in the gradient of the river. In the case of the river reach immediately downstream from the proposed dam site, the gradient of the river appears to be completely controlled by bedrock ledges and by the coarse materials deposited in the channel by ephemeral tributaries. Since both are essentially resistant to modification by existing flow volumes in the main channel, it must be expected that this resistance will increase at the low range of volumes which should be produced by proper reservoir management. There should, therefore, be no detectable changes in channel gradient.

It is possible that the cross-sectional profile of the river may undergo some adjustment. Should this occur, the change will most probably decrease the width of the channel and increase the depth. These changes will result from a need to adjust the length of the "wetted perimeter" (the length of the channel cross-section at bankful levels) to the reduced flow regime of the river. The extent to which such a change will propagate downstream from the dam site, where they will occur most often, will depend upon a complex series of interactions, largely controlled by the stable sections associated with bedrock ledges and ephemeral tributaries. Only a series of continuing measurements of channel cross-section at selected points of interest between stable sections will determine the rate and distance of propagation, if it occurs.

VI. DISCUSSION AND RECOMMENDATIONS*

The purpose of a dam is to modify the natural discharge regime of a river system in such a way that both the water and potential energy of the system may be put to beneficial use. The extent to which this goal is achieved is determined largely by the efficiency with which the reservoir is managed. Efficient reservoir management is dependent upon an advance knowledge of the rate and volume of inflow to the reservoir, so that outflows, for whatever purpose, may be regulated accordingly. Without such advance knowledge, efficient management for any particular use is extremely difficult.

In addition, in assessing the environmental impact of the proposed reservoir, it is necessary to distinguish between two environments: pre-dam and post-dam. Each will have its own set of potential problems and benefits. From a hydrologic point of view, the primary environmental problems are felt to be associated with the latter situation, in which an inability to properly manage the reservoir will have a destabilizing impact on a largely socioeconomic environment which will not exist until after the reservoir is completed.

In this regard, it is suggested that the most pressing hydrological problems are those associated with efficient reservoir management. Foremost among these is the problem of developing a reliable forecast model for stream-flow inputs to the reservoir. The only discussion of this problem to date (ELC 1984, 1986) is based upon an analysis of the historical runoff patterns (containing the probable errors discussed in the section above). Excluding such errors, a scenario based upon the historical runoff trends must be considered as a hypothetical illustration of a management scenario and not an operational management model. Far more effort than has been expended to date should be focused on development of alternative management strategies and their socioeconomic implications. This effort should consider the proposed dam primarily from the standpoint of a more detailed analysis of the hydrometeorological characteristics of the uppermost portion of the watershed, to determine the extent to which a runoff forecast model, based upon some form of remote sensing, may be developed. It is recommended that, as a first step, a much more detailed study of the potential of various forecast models and remote sensing technologies (including satellite imagery) be undertaken. In conjunction with this study, the availability of historical hydrometeorological data from the Ethiopian portion of the watershed should be determined, as well as the possibility of obtaining, perhaps through an independent third party, real-time data on precipitation and runoff from that portion of the watershed.

From the available evidence, it seems reasonable to conclude that the empirical data base describing the volume and timing of the stream flow of the Jubba River contains an error of unknown magnitude, estimated to be at least +15 percent. The existence of this potential error does not preclude the use of these data for planning purposes, but must be taken into careful consideration in evaluating the implications of various planning scenarios.

The hydrologic criteria on which existing dam design and reservoir management scenarios have been based are almost certainly in error by at least -15 percent at high flow volumes and perhaps as much as +30 percent at low flows. This produces an overestimate of total volume of water entering the reservoir annually by approximately 1 km^3 (1,000,000,000 m^3). It is recommended that future design and planning be based on the hydrologic data set prepared by AHT.

The data are insufficient to permit a determination of the annual volume of sediment which will be transported into the reservoir. Until this is corrected, estimates of the useful life expectancy of the reservoir are largely speculative. It is recommended that an effort be made to collect the necessary information during at least one flood season, using accepted instruments, methods and procedures.

An individual with experience in the management of run-of-the-river (used here to describe a reservoir holding only some fraction of expected mean annual runoff) should be consulted to develop a realistic assessment of problems and opportunities which management of the proposed reservoir will present.

**NOTE: As a result of these recommendations, JESS attempted the development of a forecasting model. See "Upper Jubba Catchment Study "(Hart 1988), presented in* JESS Final Report, *Vol II, Part H.*

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Sally Patton, *JuDAS Project Manager, USAID*
J. D. Drury, *Sir Malcolm MacDonald & Partners, Ltd.*
Zakia Abasalam Alim, *Div. of Land & Water Resources, Ministry of Agriculture*
Ali Yusuf Wayrah, *Div. of Land & Water Resources, Ministry of Agriculture*
Earl Dudley, *Bureau of Reclacmation/JuDAS*
Duain McAndrews, *Bureau of Reclamation/JuDAS*
Heiko Brunken, *AHT*
E. Drannon Buskirk, *ARD/JESS*
R. E (Gus) Tillman, *ARD/JESS*
Kathryn Craven, *ARD/JESS*
Ian Deshmukh, *ARD/JESS*
Richard Donovan, ARD/*Burlington*
Jeffery Gritzner, *National Academy of Sciences/ Board of Science & Technology for International Development*

A seminar was presented on the study prior to departure from Somalia. It was attended by an estimated 40 representatives of GSDR agencies.

During on-site visits to the upper and lower reaches of the Jubba River, a series of samples of the fluvial sediments from the channel of the river were collected and subsequently analyzed to determine grain-size distribution. As of the time the consultant left Somalia, 13 of 17 samples had been analyzed. The results of this analysis are presented here.

SAMPLE	LOCATION
JR 1	Sandbar, 1-2 km below proposed dam site
JR 2	As above
JR 3	Highwater, seasonal flood, site as above
JR 4	Sandbar, ~20 km below proposed dam site
JR 5	As above
JR 6	Sandbar, Baardheere near bridge
JR 7	As above
JR 8	Un-named ephemeral tributary to Jubba River
JR 9	As above
JR 10	Sandbar, immediately north of Luuq
JR 11	As above
JR 12	Sandbar, immediately west of Luuq
JR 13	As above
JR 14	Near mouth of Jubba River (Goob Weyn)
JR 15	As above
JR 16	At Jilib
JR 17	As above

From the accompanying tabulation (Table 13, next page) of the results of the analysis of these samples, the following preliminary conclusions are drawn:

- Sediments from the floor of the channel ("sandbar" above) are composed primarily of fine sand (0.1 to 0.008 mm diameter) with varying admixtures of other sizes, which presumably vary in response to local controls.
- The single sediment sample from the high-water mark of the seasonal flood differs markedly from those from the sandbars (Figure 16). This suggests a strong vertical stratification of sediment transported by the river during these floods. It is essential that this vertical stratification be tested by a sampling program using a depth-integrating sediment sampler during at least one flood season (gu' or deyr).
- The samples from the unnamed tributary to the Jubba River (JR-8, 9) are considerably more coarse than those from the main river channel, with over 60 percent of each having grain sizes greater than two mm. For the most part, this fraction was actually composed of pebbles with a diameter greater than one cm. This grain-size distribution is indicative of a fluvial energy environment much greater than that found in the main channel. These sediments will be immobile in the main channel, except perhaps during exceptional floods.

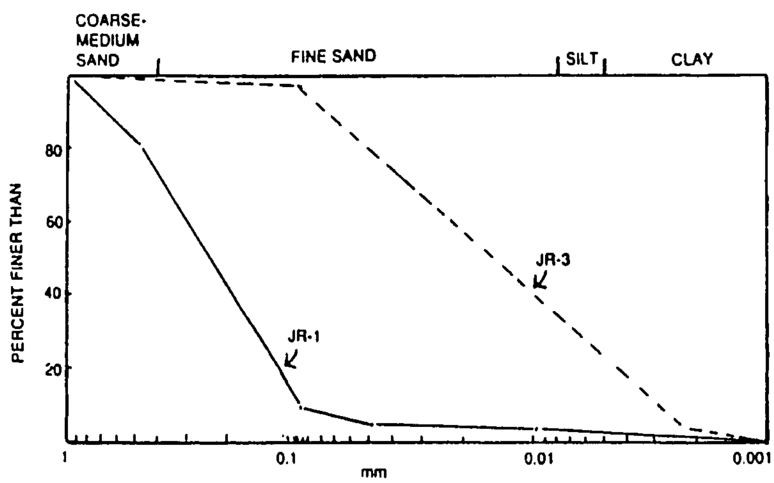

Figure 16. *A comparison of grain-size distributions of two samples from the site of the proposed dam above Baardheere. JR-1 is from a sandbar on the floor of the river channel, while JR-3 is from a deposit at the high-water mark for the seasonal flood. It is apparent that a surface "grab sample" at this location would be non-representative of the total range of sediment transport at this site.*

Table 13. Grain Size Distribution
Fluvial Sediments - Jubba River

SAMPLE	2mm%	TOTALS%	SAND: 2-1mm%	SAND: 1-0.5mm%	SAND: 0.5-0.25mm%	SAND: 0.25-0.106mm%	SAND: 0.106-0.05mm%	SILT %	CLAY %
1 JR		94.05	1.50	15.70	57.10	14.50	5.15	4.83	1.12
2 JR		94.55	1.85	21.40	61.00	6.80	3.30	4.49	0.96
3 JR		18.90	--	0.18	0.70	0.90	16.95	43.56	37.54
4 JR		98.20	4.35	27.35	53.50	12.00	0.80	1.80	0.00
5 JR		96.80	4.60	28.15	52.45	10.25	1.20	3.10	0.1
6 JR	17.48	97.60	12.00	40.75	36.45	6.00	2.10	2.30	0.10
7 JR	13.32	97.50	10.75	36.30	42.45	5.80	1.95	2.40	0.10
8 JR	62.94	87.90	37.50	13.00	5.25	19.50	12.50	7.32	4.78
9 JR	60.50	84.10	37.35	14.05	3.90	15.60	13.10	11.16	4.74
10JR	1.59	95.50	2.90	15.50	56.75	16.90	3.25	4.06	0.44
11JR		95.50	2.70	14.20	56.85	18.20	3.20	4.18	0.32
12JR		95.75	5.15	36.70	43.15	6.75	3.05	4.63	0.22
13JR		92.20	2.40	21.10	50.75	12.40	5.40	6.50	1.30

Upper Jubba Watershed Performance

prepared by
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Mr. Thomas C. Hart conducted this consultancy from 6 September 1987 to 30 September 1988. A brief field trip was made to Addis Ababa, Ethiopia, to review and compile available information on the upper Jubba catchment, information which was not readily available outside Ethiopia. Mr. Hart worked intermittently during the employment period as more information became available. This report marks the first known attempt to estimate across a time continuum the quantity of inflows to the proposed Baardheere Reservoir—information which JESS found lacking and of eventual importance to dam managers and developers of Jubba Valley.

The author extends warm thanks to the many people who helped to develop the project concepts, refine its new analytical techniques, collect the required data under difficult circumstances, and review the model results with an objective eye.

The basic premise for the project as a management asset for reservoir control was the idea of Gus Tillman, JESS team leader in Somalia. His drive and support throughout all phases was vital to the successful completion of the study. Don Alford of IIED (International Institute for Environment and Development) in Washington, DC gave valuable early advice, and his report on the hydrology of the upper catchment was a trailblazer for this study, particularly for his review of the Jubba flow records.

The analytical design benefited from the keen interest and comments given by Klaus Schmitt of the University of Bayreuth, by Jerry Barber of the Canadian econometrics team at the Treasury of Kenya, and by Mike Norton-Griffiths of the International Union for the Conservation of Nature.

Support during the data collection phase came from many colleagues who helped out of pure interest in the study's aims in terms of scientific method. Their assistance was both a selfless and key contribution.

Review of the complex results was an effort of concentrated thought on a variety of levels, and across several disciplines. The author was fortunate to have excellent suggestions from Andreas Speich of the Zurich Municipal Forest Reserve, and from Barry Henricksen of the Regional Centre for Surveying, Mapping, and Remote Sensing. The written drafts were reviewed with very helpful comments by Dave Mouat and Gus Tillman at ARD. For the sake of logistics reproduction, figures referred to in the text of this report are aggregated in Appendix B. These figures are photographic representations of imagery generated by the computer model used in the study.

I. EXECUTIVE SUMMARY

The upper reaches of the Jubba River system produce almost all of the reliable discharge which reaches the proposed 160 km-long Baardheere Reservoir at Luuq. While flow data for a number of gauging points along the river have been studied by several technical teams over the last decade, little emphasis has been placed on the physical variation and runoff performance patterns within the upper basin. The present study attempts to fill this information deficit and to identify which portions of the upper catchment actually produce the river flow measured in Somalia. With this information, a monitoring program can be developed to predict inflows, allow early release of reservoir holdings to extend irrigation schedules, and reduce build-up of disease vector populations.

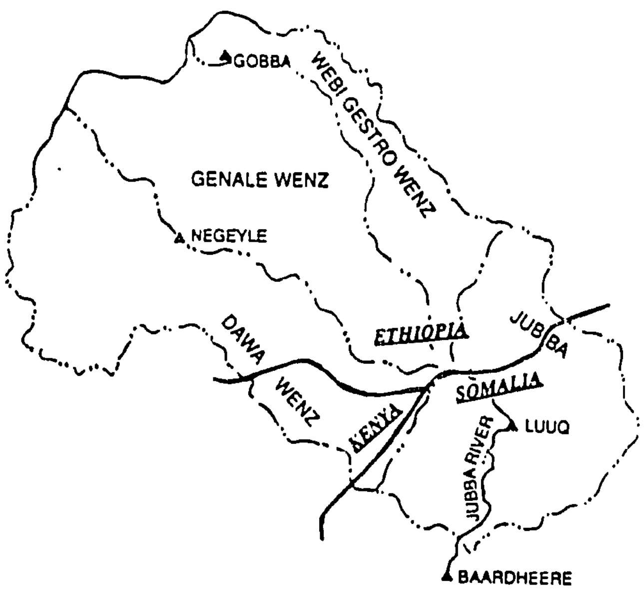
A series of descriptive maps and tables have been compiled from existing sources to show the wide variations of terrain, geology, soils, vegetation, and climate in the Ethiopian portion of the catchment. Point data from meteorological stations have been used to create rainfall and evaporation maps which take into account variations in topography between stations. Water balance has been calculated on a monthly basis for each 10 by 10 km cell in the study area using long-term average data. Runoff from each cell has also been estimated for the surface processes of storm flow and surplus from soil storage; no groundwater processes have been included in the calculation of runoff.

All the results are summarized for 15 subcatchments of the drainage area in Ethiopia. Each of these reporting units is evaluated on a percentage contribution basis for annual and monthly outputs. The runoff results are compared with flow records for Luuq near the border crossing point and entrance to the proposed reservoir, and several suggestions are made in explanation of the discrepancies. Due to the absence of contemporaneous daily rainfall and flow data, the length of time between rainfall and inflow to the proposed reservoir remains unknown, but hypotheses are put forward that some lags may be quite extended for certain seasons. In light of this possibility, a review of the current options for monitoring rainfall concludes that a combination of conventional gauges and remote sensing will provide the best mixture of information for reservoir management.

Simulation of the catchment's rainfall and flow regimes was done with new methodologies which offer promising results for dam managers at Baardheere, and wider application on the entire Jubba-Shabeelle system and catchment studies elsewhere. Improvements to the current output are quite feasible and would deliver rewards including: cooperation between Ethiopia and Somalia, fuller understanding of the flow systems, and ready forecasts of the effects of future river development initiatives.

A. Rationale

The impact research conducted for the Jubba Environmental and Socioeconomic Studies (JESS) has identified a need for information about the upper part of the Jubba catchment, extending north and west from the river's entry into Somalia from Ethiopia (see below). To characterize this very large feeder area for the JESS project, this study developed a mapped data structure for both spatial and temporal analysis. The results provide a description of the river basin's seasonal flow production regimes.



Schematic representation of Upper Jubba Watershed and its principal tributaries.

Variations in rainfall distribution on a seasonal basis are merged with terrain characteristics to determine how the set of subcatchments in the upper watershed produce river flow in a changing mixture of local contributions. The analysis takes the form of an empirical model, using a wide range of spatial data planes to produce an estimate of composite flow which is compared with the Luuq flow records. The goal is to simulate the delivery of recorded rainfall to the river's subcatchments, and to estimate the conversion of rainfall to runoff over a series of seasonal cases.

With the advent of spatially comprehensive precipitation estimates in 10-day intervals from FAO/ARTEMIS (Food and Agriculture Organization of the United Nations/African Real Time Environmental Monitoring Using Imaging Satellites), this type of analysis may be used for reservoir inflow predictions, providing extra flexibility to the reservoir-level managers at Baardheere. Benefits include the possibility of extending the irrigation seasons, an allowance for reservoir fluctuations to destabilize habitats for snail and mosquito disease vectors, and the more effective maintenance of optimal flows for power generation and downstream water management.

B. Objectives

The study objectives have significance in light of the catchment's considerable spatial heterogeneity. If the catchment had qualities of consistent drainage, slope, lithology and elevation/rainfall relationships, then a simple hydrologic model may give a reasonable approximation of the processes of river flow generation. However, there are extreme differences between subcatchments in terms of shape and slope, a full range of cover types and soil variation, as well as seasonal rainfall patterns in a complex bimodal monsoon system. The Jubba catchment is not at all simple, and its simulation must capture and explain its important variation. The specific study objectives follow:

- identify spatial variation of attributes which pertain to the contributions of runoff to river flow;
- describe on a subcatchment basis seasonal patterns of rainfall and runoff, and to express these as volumetric data which can be compared with Luuq flows;
- investigate the range of time lag between rainfall accumulation and inflow to the reservoir; and
- propose means of monitoring rainfall for predicting inflow, so that dam managers will have options for early release.

C. Technical Implementation

The study approach was to use a systematic compilation of land resource attributes for each subcatchment, standardized at first on a 1 by 1 km gridcell system, but then aggregated to a 10 by 10 km array for analysis. Each subcatchment case is represented by a population of between 56 and 133 cells. In this way, a subcatchment can be treated with its internal variation intact; it need not rain over the entire area, but the subcatchment as a unit still produces a particular quantity of runoff for a given time period.

Map data have been digitized and manipulated on a computerized map, image, and geographical information system named ERDAS (Earth Resources Data Analysis Systems Inc., Atlanta, Ga.). Data export to dBaseIII+ and Statgraphics v.2.6 software has facilitated data reduction, statistical analysis, and graphical presentation as necessary. The author's software was used for map aggregation, data repacking, water balance modeling, and tabular data summary. Extra programs were written in Fortran using the ERDAS Toolkit libraries. The analysis sequence for climate data interpolation involving steps of regression, normalization, creation of surfaces, and the reversal of normalization is a strategy of the author's own design.

The ERDAS system is a microcomputer-based software product which handles spatial data with a suite of approximately 150 routines. Capability includes the digitizing of line maps, the capture of grid maps (including satellite data) and the combining of such inputs into multilayered data sets. Display and editing are controlled, as are interpolated point data and reference to specific map coordinates. Its step-by-step, generic assets can be elaborated into custom sequences or new routines for unique use. Apart from digitization, it is a versatile gridcell manipulator.

III. DESCRIPTION OF THE UPPER JUBBA CATCHMENT

The study area consists of that portion of the Jubba River Basin which falls within the boundary of Ethiopia. While the original proposal included all areas up-catchment of the Baardheere Dam site, the Somalia and Kenya portions were deficient in data availability for vegetation and geomorphology/soils. These lower reaches of the proposed area were of such minor importance to the total hydrological performance that the decision was made by JESS to confine the study to Ethiopia.

Accordingly, the subject area lies within south-central Ethiopia, covering 141,635 sq km. It shares the administrative regions of Bale and Sidamo, and is a remote area with major towns and roads found only near its periphery. In terms of both basin area and flow, it must be considered Ethiopia's second-ranked river system, after the Blue Nile. Despite its potential, the Jubba area of Ethiopia has remained undeveloped to the degree that few natural resources studies have occurred within its watershed. Moreover, such results as may have been produced by oil companies, mining interests, or resettlement study teams are inaccessible in the public domain. The actual sources of data used on the study shall remain anonymous, due to the informal nature of cooperation in the data gathering stage.

The study exclusively relied on secondary information sources. Data were gathered to establish a physical baseline of the area in the form of digital grid maps at 1 sq km resolution for the attributes of elevation, subcatchment boundaries, climate, geomorphology/soils and vegetation/land use. Most of these data groups were used both for general purpose stratification and as quantitative parameters in the catchment water balance model.

A. Elevation and Subcatchment Characteristics

Topographic contours were digitized from 1:2,000,000 scale Africa base maps with contours at 200 m intervals (series 2201, sheet numbers 20ed7, 21ed5, 24ed9, and 25ed6, from the U.S. Defense Mapping Agency). A check of earlier editions of the same sheets showed poor correspondence of terrain pattern with Landsat MSS imagery. For instance, the southeastern ridges of the Bale Highlands were depicted as massive pyramidal peaks instead of the plateau stairsteps shown in the Landsat imagery; it is fortunate that updated editions were found to be suitably accurate.

After digitizing and editing, the contour line computer data were cast into a 1 by 1 km cellular data set representing the elevation gradients (Table 1; Figure 1, Appendix B). The map shows the three-stemmed valley networks headed in the west by the eastern margin of the East African Rift system, and headed in the north by the Bale volcanic massif; to the east, an intermittent line of small mountains separates the Jubba Basin from the Shabeelle Basin. The broad lowlands of the confluence area in the southeast are a continuation of the landscape near the proposed reservoir. To the northwest, as soon as higher ground is reached, the catchment splits into the Gestro to the northeast, the Genele in the middle, and the Dawa to the southwest.

Table 1. Jubba Catchment in Ethiopia

ELEVATION DISTRIBUTION

ELEVATION(m)	AREA(km^2)	PERCENTAGE
200-400	775	0.55
400-600	17,249	12.18
600-800	15,742	11.12
800-1000	12,439	8.78
1,000-1,200	15,601	11.02
1,200-1,400	20,642	14.57
1,400-1,600	17,198	12.14
1,600-1,800	13,934	9.84
1,800-2,000	8,373	5.91
2,000-2,200	4,525	3.19
2,200-2,400	3,116	2.20
2,400-2,600	3,544	2.50
2,600-2,800	2,964	2.09
2,800-3,000	2,238	1.58
3,000-3,200	1,008	0.71
3,200-3,400	595	0.42
3,400-3,600	357	0.25
3,600-3,800	350	0.25
3,800-4,000	418	0.30
4,000-4,200	308	0.22
4,200-4,400	259	0.18
Total	141,635	100.0

The three systems are very different in terms of shape and terrain. The Gestro has a narrow catchment in a ramp shape extending northeast, then southeast from the Bale Mountains. The Genele has a large, oval, dissected basin immediately south of the Bale Mountains, and is palmate in its tributary pattern. The Dawa drains the moderately high plateaus of the southwest, and has the shape of a long-boled, mature tree, *i.e.*, dendritic.

The further subdivision of the three systems into performance reporting areas is shown in Figures 2 and 3. Fifteen subcatchments were selected on criteria of hydrological integrity, terrain consistency, and approximately equal size. The elevation distributions of each subcatchment are shown in Table 2, and their locations in the 10 km data structure are shown in Figure 4.

B. Climate and Hydrology Baselines

Since the major purpose of the study was to calculate an enhanced description of the water regime in the upper catchment, this section will confine itself to the characteristics of the available station data used in the subsequent analyses.

The flow gauge records at Luuq were to provide the system output for guiding the parameterization of the catchment water balance model. At least five distinct long-term summaries of the river discharge patterns at Luuq have been compiled; their respective monthly means and annual means are given in Table 3. The IBRD (International Bank for Reconstruction and Development, World Bank) calculations were revised in April-May 1987, and were chosen by JESS a. .he data which provided the best long-term estimates. The period of 1952 to 1982 is shown in Figure 5.

Station data were required for both rainfall and potential evapotranspiration (pET), over as long a period of record and for as well-scattered a spatial sample as possible. Daily and monthly records were sought to sustain analyses of both single rain events

Table 2. Elevation of Subcatchments

Height Distributions
(area amounts are $km^2 \times 100$)

Masl	UGs	MGs	LGs	UGn	Wel	Dum	NEG	MGn	LGn	Awa	UDa	Fud	MDa	LDa	MJu
≥ 200:	.	.	2	.	.	.	.	.	.	.	.	.	.	.	3
≥ 400:	.	7	56.	.	.	.	.	.	36	.	.	.	.	16	61
≥ 600:	.	27	21	.	.	.	1	12	23	.	.	.	.	24	58
≥ 800:	.	31	13	.	.	.	11	16	29	.	.	.	11	17	9
≥ 1000:	.	22	1	.	4	12	22	15	20	1	1	2	26	31	.
≥ 1200:	.	22	1	2	17	27	21	26	14	8	7	16	46	21	.
≥ 1400:	.	15	.	9	16	11	12	27	4	5	23	31	27	4	.
≥ 1600:	.	4	.	16	14	4	5	9	.	10	38	23	19	.	.
≥ 1800:	2	3	.	15	8	4	5	1		14	31	5	.	.	.
≥ 2000:	3	2	.	16	5	2	1	.	.	14	11	.	.	.	.
≥ 2200:	6	.	.	9	1	2	.	.	.	7	9	.	.	.	.
≥ 2400:	16	.	.	15	1	.	3	.	.	4	4	.	.	.	.
≥ 2600:	10	.	.	9	2	.	.	.	.	5	2	.	.	.	.
≥ 2800:	4	.	.	15	2	2	.	.	.	6	.	.	.	.	.
≥ 3000:	1	.	.	6	.	1	.	.	.	2	.	.	.	.	.
≥ 3200:	2	.	.	2	2	.	.	.	.	.	.	.	.	.	.
≥ 3400:	3	.	.	2	1	1	.	.	.	.	.	.	.	.	.
≥ 3600:	3	.	.	2	1	1	.	.	.	.	.	.	.	.	.
≥ 3800:	3	.	.	.	1	.	.	.	.	.	.	.	.	.	.
≥ 4000:	2	.	.	.	1	.	.	.	.	.	.	.	.	.	.
≥ 4200:	1	.	.	.	.	1	.	.	.	.	.	.	.	.	.

Table 3. Jubba Monthly Flow Averages

Five Sources (Luuq Data –*from Alford 1987)

MONTH	VOLUME IN Mcm					PERCENTAGE OF ANNUAL				
	AHTe	AHTs	IBRD	ELC	FAO	AHTe	AHTs	IBRD	ELC	FAO
Jan	131	123	170	121	107	2.4	2.0	2.7	2.0	1.8
Feb	66	76	93	71	46	1.2	1.2	1.5	1.1	0.8
Mar	32	112	136	102	104	0.6	1.8	2.1	1.6	1.7
Apr	226	425	376	327	246	4.1	6.8	5.9	5.3	4.1
May	597	680	663	637	613	10.9	11.0	10.3	10.3	10.3
Jun	399	412	496	402	345	7.3	6.6	7.7	6.5	5.8
Jul	496	504	578	498	469	9.1	8.1	9.0	8.0	7.8
Aug	664	737	729	739	814	12.1	11.9	11.4	11.9	13.6
Sep	757	757	765	775	785	13.9	12.2	11.9	12.5	13.1
Oct	1,184	1,154	1,080	1,224	1,138	21.7	18.6	16.8	19.7	19.0
Nov	661	897	886	941	876	12.1	14.4	13.8	15.2	14.7
Dec	249	337	442	367	434	4.6	5.4	6.9	5.9	7.3
ANN	5,462	6,214	6,414	6,204	5,977	100.0	100.0	100.0	100	100.0

*AHTe: Agrar-und Hydrotechnik, GMBH (1986) empirical data**
*AHTs: Agrar-und Hydrotechnik, GMBH (1986) synthetic data**
IBRD: World Bank unpublished data (1987)
*ELC: Electroconsult (1984)**
*FAO: Technital (1981)**

and longer term behavior. The most important limiting factor was the lack of local flow records within the Ethiopian portion of the Jubba catchment. This meant that the comparison of rain inputs with flow outputs must occur strictly on the basis of the entire study area. In other words, a partial rainfall data set would be very difficult to use because its omissions would have contributed to the overall flow result to an unknown degree.

The spatial arrangement of the station data was critical to the success of the rainfall surfacing procedures. The network was designed to:

- effectively sample the rainfall spatial variation, and
- avoid clustered station distributions which would bias the surfaces by the combined weighting of nearby stations.

The design task was further complicated by the additional need for the network as a whole to represent a common time period. The available data were carefully examined against these requirements, and approximately half of the acquisitions were used.

In Ethiopia, daily rainfall data are state-classified information. While a daily record of about 40 percent of the study area was acquired, the corresponding data to represent the remainder of the catchment could not be obtained. Moreover, the corresponding daily flow data for Luuq were not complete. These two shortfalls led to the abandonment of objectives pertaining to individual rain events, and weakened the capability for examining flow lags.

Monthly data sets were more encouraging. Their spatial distribution was much more suitable than the daily data, but time correspondence was a persistent problem. Data from 1985 provided a relatively complete picture of rainfall; there were no concurrent pET data to use in balancing this 1985 rain, but mean long-term monthly values would suffice under the circumstances. A more serious deficiency was that Luuq discharge data for 1 June to 10 July 1985 were absent because the person who normally recorded the stage measurements was on leave. A decision was made, therefore, to defer the 1985 analysis until after the catchment was analyzed using multi-year mean monthly data. As will be presented, the results of this long-term analysis suggest that the knowledge gained by a model rerun on an incomplete individual year would be minimal.

The water balance model was constructed and tested on the strongest subset of the climate data: the long-term monthly means for rainfall and pET (Kenya Meteorological Dept. 1984; Obasi and Kiangi 1977). A total of 14 stations supplied rainfall records, while eight stations supplied the pET data (Table 4). The 14 rainfall stations were reduced to 12 after the entire set had been used to evaluate the relationship between elevation and monthly rainfall; the small set was more suited for the generation of surfaces due to its less clustered arrangement.

Figure 6 maps the set of 12 station sites against the pattern of elevation as summarized on the 10 km cells (which were used as the spatial data structure for all surfacing and model calculations). The monthly rainfall data are plotted in Figure 7, while Figure 8 shows the mean monthly pET of eight stations.

Implications of using mean monthly rainfall and pET data deserve discussion, in terms of both data averaging and the month-duration of time samples. Data time averaging gives a smoothing effect, not only to temporal variations, but also to the representation of a given station for its surrounding area. Yearly fluctuations in seasonal spatial pattern are reflected in the yearly samples of each month's data at a given station. On the other hand, there are dangers of defining an area's behavior as the mean of extremes because the mean is a situation which rarely occurs. Furthermore, differences in yearly

Table 4. Long-term Monthly Means of Met Station Data

(#yrs refers to rainfall data only; all pET data were acquired as averages)

STATION	LAT	LONG	XX	YY	MASL	#YRS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Luuq	347	4232	52	42	150	(9)												
				Rain:	yr=	215	1	2	20	93	21	1	1	0	0	21	40	15
Mand	356	4152	44	40	331	(45)												
				Rain:	yr=	255	2	7	19	93	31	1	1	2	2	44	44	9
				pET:	yr=	2036	177	178	195	160	162	169	170	178	181	156	147	163·
Mega	405	3820	5	39	2215	(4)												
				Rain:	yr=	592	46	21	86	136	109	26	25	8	13	13	75	6
				pET:	yr=	1276	134	127	130	105	82	89	97	98	111	95	100	108
Yabel	453	3806	3	30	1750	(8)												
				Rain:	yr=	665	11	9	119	203	95	13	25	23	42	72	44	9
				pET:	yr=	1178	116	118	125	102	78	83	82	85	96	92	98	103
H.Mar	538	3815	4	21	2000	(5)												
				Rain:	yr=	969	30	41	53	137	210	102	49	42	86	116	93	10
				pET:	yr=	1241	116	114	118	114	100	99	88	87	99	104	98	104
Negh	517	3945	21	25	1444	(29)												
				Rain:	yr=	780	14	30	45	209	171	11	7	6	40	184	54	9
				pET:	yr=	1163	117	115	123	92	92	81	79	89	94	90	88	103
Adola	555	3905	13	18	2170	(7)												
				Rain:	yr=	1051	15	21	96	237	190	54	48	54	63	161	96	16
				pET:	yr=	1235	104	105	130	113	106	94	90	99	104	102	96	92
H.Sel	628	3830	7	12	2840	(6)												
				Rain:	yr=	1202	14	32	72	175	188	111	129	138	131	125	69	18
				pET:	yr=	959	89	84	95	88	85	72	64	69	72	81	80	80
Mena	625	3951	22	13	1250	(5)												
				Rain:	yr=	711	2	8	60	220	259	26	7	7	55	42	25	0
Goba	701	4001	23	6	2750	(19)												
				Rain:	yr=	936	21	37	55	141	112	52	92	124	126	107	52	17
				pET:	yr=	901	77	83	100	77	80	78	72	73	68	59	63	71
Dins	705	3948	21	5	3170	(19)												
				Rain:	yr=	1200	13	24	99	171	119	86	163	183	164	129	33	16
Chor	700	3953	22	6	3500	(4)												
				Rain:	yr=	1091	12	24	110	180	159	64	71	119	177	130	36	9
Koro	659	3950	22	6	3850	(4)												
				Rain:	yr=	1101	14	26	113	182	163	72	91	134	158	108	31	9
Kont	655	3953	22	7	4050	(4)												
				Rain:	yr=	894	11	34	126	160	122	49	70	103	125	66	21	7

sets for each station may create a biased surface where a wetter set of years is interpolated with a drier set of years for a neighboring station. Under the circumstances, the averaging procedure yielded a robust analysis for examining catchment behavior.

Monthly rainfall data are composites of isolated events whose summed durations are usually only a small part of the month. Against this aggregate of sporadic events are set the pET totals, which represent a more or less continuous process. For many parts of the study area, a month is an interval which exceeds the cycle of rainfall, soil water storage, and soil desiccation (Thornthwaite 1952). Water balances calculated in these situations underestimate the moisture available for either runoff or plant growth, which would be more accurately depicted with a model whose temporal increment fits the moisture cycle (Tukhanen 1980; Hulme 1987). Thus, a monthly model is most effective in areas/months where balance is positive or slightly negative, and in other cases ,the model underestimates catchment yield. This problem makes it difficult to solve the process equations which turn moisture input into total catchment outflow. However, the study has the primary objective of identifying regions of substantial runoff generation, and its results are nearly as useful on a relative basis as they are in absolute quantitative terms.

C. Landform, Slope, and Soil Attributes

The input data for these attributes consisted of a single set of maps showing landform classes and a set of quantitative charts of the parent material, slope, and soil type complexes for each class. These data were produced by a national geomorphology and soils survey undertaken by a Food and Agriculture Organization of the United Nations/Government of Ethiopia (FAO/GOE) team in support of land- use planning at the national level. The maps have a scale of 1:1,000,000, and derive from previous soil survey results, field traverses, agroclimatic information, and Landsat interpretation. They show 84 distinct landscape complexes within the study area. Each of these complexes is further divided into facets, or landscape components (*e.g.*, floodplains, sideslopes, ridgecrests, or isolated hillocks). There are up to seven facets within a complex, and each is quantified in terms of proportional area, slope, and soil type (FAO 1984a).

Parent material descriptions are a key element of the overall catchment baseline, and are important contributions to a catchment performance summary. Parent material is also used as an additional attribute to modify soil ratings beyond what is possible with the soil type alone (the FAO soil classification is independent of parent material at the level used in the facet data). Six types of surficial parent material are shown in Figure 9, along with a listing of the 84 landscape classes. In most cases, it is not possible to separate the individual classes on the map. Table 5 gives the percentage area breakdown for the parent material types.

Volcanics are found at the highest reaches of the catchment in zones of high rainfall and a variety of landscapes, ranging through the classic Rift margin types from shield volcanoes to ash plateaus to parallel incisions on inclined, basalt-capped rift shoulders. There are also several small lava flows near Dolo at the outflow of the Ethiopian catchment.

Table 5. Parent Material of Catchment Landscapes

CATEGORY	% AREA	Km^2
Volcanic	15.8	22,378
Basement	26.2	37,108
Calcareous	34.4	48,723
Evaporites	19.0	26,911
Alluvial	2.9	4,107
Sandstone	1.7	2,408

Basement landforms occupy the southwest of the catchment. They consist of crystalline material of varying metamorphic histories, but their northern cases have been squeezed and upthrust into high relief north-south ridges by the same tectonic forces which have helped to form the Rift system. Elsewhere ,these materials form rolling, sandy plateaus with relatively poorly- developed drainage systems, especially in the extreme southwest corner of the catchment.

Calcareous landforms are positioned in a thick swath which runs transverse to all three of the major tributaries. The variation of lithologies within this large section of the basin is not documented in terms of the hydrologic implications, but as limestone is a major component, one would have to suspect that there are many inconsistencies in groundwater input and output regimes as flow crosses onto this section, and indeed, within the section itself. The caves on the Gestro at the upper transition point swallow the river for some distance, and it is unlikely that this is a unique local phenomenon. Any number of subsurface inflow and outflow points could change the nature of river discharge (Jennings 1985).

Evaporites cover the semi-arid plains near the border with Somalia. They have typically low relief discontinuous drainage and are primarily gypsiferous deposits often marked by saline soil chemistry.

The next category of parent material, *Alluvial* landscapes, is scattered through all but the highest areas of the catchment. Many of the cases are too narrow to survive the generalization to 1 km mapping cells, but certain zones along the major rivers have floodplain expansions which do show on the map. These areas are indicative of the presence of a reduced channel gradient, potential groundwater recharge, and/or the resurfacing of subsurface [illegible].

The last parent material type, *Sandstone*, is [illegible] in small ridgecrest units as remnant caps over the calcareous landforms. The sandstone units comprise such a small proportion of the catchment that their hydrologic significance is limited.

Quantitative use of geomorphology/soils data sets was motivated by a need to account for soil field capacity (or moisture storage capacity) in the water balance calculations. Also, the storm runoff fraction of total precipitation input is related to both local slope and infiltration characteristics, the latter being well-correlated with soil texture. Therefore, these data provide estimates which control the modeled amount of water stored in the soil, and the modeled amount of rain which runs off directly instead of entering the soil reservoir (Dunne and Leopold 1978).

The slope map might have been calculated from the topographic data, with a bias of underestimation due to the small scale of the original contour data. The geomorphology/soils data set gives field-oriented slope estimates for each distinct component of every landscape. The local nature of this approach and its avoidance of bias due to cartographic selection of terrain character, rendered it more suitable to area-by-area calculation of water balance. It did have the drawback that some of the classes were aggregates of a variety of cases found throughout Ethiopia and were not necessarily representative of the examples found in the Jubba area. For instance, the sideslopes of shield volcanoes are usually moderate, but on the southern slopes of the Bale Mountains, this norm is inappropriate, as the Harenna Escarpment falls 1,500 m over a distance of only 8 km (Hillman 1986).

Ratings for each class of parent material/soil type were established in terms of storage capacity as a percentage of volume (texture related) and soil depth. Dr. Anout Weeda of the Kenya Soil Survey undertook the rating responsibilities for 82 combinations of parent material, slope, and soil type. Slope data were used to guide the assignment of soil depth. Storage capacity estimates ranged from seven to 30 percent, with rocky surfaces given a null value. Depth was estimated at between 5 and 150 cm, resulting in a range of rain storage capacities from 0 to 330 mm (Table 6).

As an example of the way in which these data were used to set parameters for the model, class Rmg3 is a basement version of moderate to high relief hills and has five facets representing four grades of sideslope and the valley bottoms. Each facet has a different soil type: for example, facet #1 is the steepest of four sideslope facets (30 to 50 percent slope), the most common facet in the class (30 percent of the area), and has a soil type of Chromic Cambisols (lithic phase), rated 12 percent (vol) x 20 cm (depth) = storage of 24 mm of rain. Similar calculations for each facet fill out the list of storage amounts, which can then be averaged by the weights of the facets' area percentages to give a general storage figure (103 mm for Rmg3). This storage figure is then assigned to each square kilometer cell containing Rmg3. This process converts qualitative data into numerics, and the storages for 10 by 10 cells are obtained by averaging the 100 values in the smaller cells. In this way, a field capacity map is prepared to combine with moisture input levels in the map algebra of the water balance model.

D. Vegetation and Land-Use Patterns

A survey parallel to the geomorphology/soils work has produced a vegetation and land-cover inventory from 1976 and 1979 Landsat imagery (FAO 1984b). The FAO/GOE team split the Jubba area into 21 major classes of agricultural intensity, forest types, and structural types on the remaining natural vegetation along the standards of Pratt and Gwynne (1977). Figure 10 shows the map of these classes, and Table 7 gives their areal extent.

These results are useful for their delimitation of the cultivated and forested portions of the catchment. Significant areas of agriculture are limited to the

Table 6. Soils Ratings for Determination of Rainfall Storage Capacity

TYPE NAME(PHASE)	S	DEP	VP	H20	TYPE NAME(PHASE)	S	DEP	VP	H20
ALLUVIUM:					**BASEMENT:**				
eutric cambisols		110	14	154	chromic cambisol	s	150	12	180
calcic fluvisols(SA)		100	16	160	chromic cambisols(L)	m	30	12	36
eutric fluvisols		150	16	240	chromic cambisols(L)	v	20	12	24
eutric fluvisols(SA)		100	16	160	eutric cambisols		110	12	132
eutric nitosols		150	15	225	eutric cambisols(S)		100	10	100
orthic solonchaks(Y)		110	15	165	eutric cambisols(L)	m	30	12	36
chromic vertisols(SA)		110	15	165	eutric cambisols(L)	s	25	12	30
pellic vertisols		110	15	165	vertic cambisols		150	14	210
calcic xerosols(SA)		100	14	140	eutric fluvisols		150	12	180
VOLCANICS:					eutric fluvisols(S)		150	10	150
vitric andosols(L)		30	14	42	lithosols		5	12	6
chromic cambisols	s	30	14	42	chromic luvisols	m	110	13	143
chromic cambisols	v	25	14	35	chromic luvisols	s	70	13	91
eutric cambisols		110	14	154	chromic luvisols(S)		70	10	70
eutric cambisols(S)		70	11	77	vertic luvisols		110	14	154
eutric cambisols(L)		30	14	42	eutric nitosols		150	15	225
eutric fluvisols		150	16	240	eutric regosols(SA)		70	12	84
dystric gleysols		110	14	154	orthic solonchaks		150	15	225
dystric histosols		110	30	330	haplic xerosols		70	12	84
lithosols		5	14	7	haplic xerosols(S)		70	10	70
chromic luvisols		70	14	98	haplic xerosols(L)		30	12	36
chromic luvisols(S)	s	70	11	77	rock surface		0	0	0
chromic luvisols(S)	v	50	11	55	**CALCAREOUS:**				
orthic luvisols(S)		80	11	88	chromic cambisols		110	14	154
dystric nitosols		150	15	225	eutric cambisols		110	14	154
eutric nitosols		150	15	225	eutric cambisols(S)		100	11	110
chromic vertisols		110	15	165	eutric cambisols(L)		30	14	42
pellic vertisols		110	15	165	calcic cambisols		120	14	168
calcic xerosols		100	14	140	calcic cambisols(K)		70	11	77
stone surface		5	12	6	calcic cambisols(L)	m	30	14	42
rock surface		0	0	0	calcic cambisols(L)	s	25	14	35
EVAPORITES:					vertic cambisols (S)		100	12	132
lithosols	s	5	12	6	calcic fluvisols		150	14	210
lithosols	v	4	12	5	calcic fluvisols(S)		100	13	130
orthic solonchaks(Y)		110	15	165	lithosols	m	5	14	7
gypsic yermosols(SA)	g	110	14	154	lithosols	s	4	14	6
gypsic yermosols(SA)	m	100	14	140	rendzinas(L)	m	30	14	42
SANDSTONE:					rendzinas(L)	s	25	14	35
cambic arenosols		110	7	77	orthic solanchaks		150	15	225
cambic arenosols(L)		30	7	21	chromic vertisols		110	15	165
chromic cambisols		150	12	180	calcic xerosols		110	14	154
vertic cambisols 150		14		210	calcic xerosols(L)		30	14	42
lithosols	v	4	12	5	rock surface		0	0	0

S=slope % (g 2-8, m 8-16, s 17-30, v 31-50);
DEP=soil depth in cm
VP=water volume % (eg: sand 7, s. loam 11, loam 16, cl. loam 14, clay 15)
H20= rain storage capacity in mm (dep x vp / 10)
PHASES: S=stoney, SA=saline, L=lithic, K=petrocalcic, Y=petrogypsic

Table 7. Vegetation and Land Use of the Catchment

% AREA	CATEGORY	Km^2
.3	Afro-alpine Heath	441
.1	Dense Coniferous Forest	152
4.8	Dense Mixed Forest	6,869
2.9	Disturbed Forest	4,168
1.5	Disturbed Forest w/ Cultivation	2,166
.2	State Farms	242
1.9	Cultivation	2,738
2.0	Moderate Cultivation	2,877
2.4	Open Woodland	3,406
13.3	Dense Bushland	18,810
1.1	Open Bushland	1,503
11.8	Dense Shrubland	16,680
9.2	Open Shrubland	12,985
17.6	Open Grassland	24,923
22.4	Bushed/shrubbed Grassland	31,752
1.7	Wooded Grassland	2,422
1.9	Riparian Woodland/bushland	2,665
.1	Seasonal Marsh	69
2.4	Sand w/ scattered Shrub/grass	3,443
1.5	Bare Sand	2,080
.9	Bare Rock	1,245

extreme north (in the vicinity of Goba and Dinsho), in the extreme northwest (near Arbe Gona), and in the extreme west (around Hagere Mariam). Relatively small pockets of crops are also found in the areas of Neghele, Adola, and Oborso. This aspect of Jubba land use is likely to change rapidly, as has already happened since these data were compiled, due to the resettlement schemes planned for the region.

The forest areas are found on the southern slopes of the Bale Mountains, and to a lesser extent, on the slopes above Adola to the west. They make up 9.4 percent of the catchment area, and are a major factor in the flow regime of the entire catchment; along with the cultivated areas, forest locations are central to the zones of positive water balance and runoff production. Forests are especially important as inhibitors of storm runoff, and affect pET negatively by moderating microclimate, and positively by increasing transpiration. They also intercept a portion of rainfall in their canopy and litter layers, preventing moisture from reaching the soil, and enabling an increase in the direct evaporation of storm moisture.

The vegetation influences on water balance were handled by:

- removing a fraction of rainfall inputs as interception and direct evaporation, and
- rating each vegetation type for its reduction effect on storm runoff by inhibition of Horton overland flow (Dunne and Leopold 1978).

The vegetation classes were not used to differentiate transpiration, which instead was treated as a portion of the pET levels reducing the moisture stored in the soil.

The future study of land-use change in the catchment would involve reconnaissance-level interpretation of satellite imagery, with selected overflights of survey areas by light aircraft for boundary confirmation and close description of land-cover characteristics. Priority is highest for forest classes because of their strong influence on the flow results from areas rich in rainfall.

Errors in the vegetation/land-use map did not affect the water calculations appreciably. The moderate cultivation mapped on the moorlands of the Bale Mountains, the disturbed forest mapped in place of the Bale Mountains heather zone, and the overly broad riparian woodland/bushlands of the lower Genele and Gestro are all minor mapping errors which are inconsequential in terms of the performance of the subcatchments.

A. Overview

The study sought to describe the distribution of runoff production and estimate the flow travel-times between the source areas and the proposed reservoir in Somalia. After the data were collected, digitized, and edited, the analytical tasks split into two major activities:

- calculation of moisture surfaces from the original input data, and
- the design and implementation of a water balance model to determine the progressive change in soil water and runoff amounts through a calendar year.

B. Moisture Surfacing

In order to isolate the sources of flow volume which passes through a river-gauging station, one must examine the upstream catchment to quantify moisture inputs and evaporation over the entire area, not just at those points where the measured data are available. The contributions of each subarea to the total volumes are independent of whether that subarea has a meteorological station at a representative location. Therefore, an empirical method for point data interpolation was devised to create volume surfaces of precipitation and pET as initial, independent conditions for the water balance model. This method of point-to-surface transformation was developed by the author during an earlier study on the Aberdare Mountains of Kenya and is described below in summary, example, and review of both its benefits and its drawbacks.

The surfacing procedure used four steps:

- multiple linear regression of station data versus station position,
- correcting (or normalizing) station data to a common median elevation using the regression results,
- calculating a continuous data surface for the median elevation by standard trend surface (or interpolation) techniques, and
- modifying this surface by reintroducing elevation effects.

The use of regression results for mapping the area directly was attempted, but for rainfall data, this general solution left some areas poorly surfaced due to large residuals at stations where data did not fit the collective behavior.

Data for these odd stations were assumed to be robust, long-term means, and it was in the interest of the study to preserve their maverick character in the appropriate portion of the maps. Towards this objective, regression coefficients for elevation were used to calculate each station's monthly rainfall and pET as if the stations were all at a common elevation of 2100 meters. Other regression coefficients were irrelevant, beyond their cross-effect on the level of the elevation coefficient, because their terms dropped out in the use of simultaneous equations.

These normalized data were then used to fill in empty map positions between the station locations. The trend surfacing algorithm employed an inverse distance weighting to balance the influence of nearby stations. Finally, the surface was modified by using the elevation map (rather than just the station heights as before) in a reverse application of the elevation coefficient.

For example, a hypothetical pair of meteorological stations are located on ridge complexes of differing height and rainfall patterns. Between them is a major river valley where there is one station at a position downstream, so that together the three stations form an equal-sided triangle on a map. If a typical interpolation method were used on the raw data, there would be an assumption that the terrain was a smooth gradient between the three elevations, disregarding the presence of the river basin in the middle of the triangle. The climate of the area varies due to differences in elevation, and from a geographic gradient, due to its intermediate position between the dry horn of the continent and the "rainfall engine" of the Ethiopian highlands. Each of the stations shows a component of both types of influence, and a regression of their rainfall amounts against their position in X, Y, and Z dimensions gives a mathematical description of the variation.

An interpolation procedure will capture the geographic trends within the station data, but other methods must be used to preserve the elevation variation for each interpolated position. This is the rationale for using regression to make a rainfall surface for the area as if it were flat, producing a "data tent" which then must be reshaped to account for the terrain anomalies between the station sites. The final data for the station sites have been restored to their original levels, but the other parts of the reshaped tent are estimated for all three dimensions of the original data set's variation.

This reshaped tent is the resulting rainfall surface, and retains far less error than a directly regressed map because the height residuals effectively have been eliminated, and the surface procedure uses local solutions for interpolation rather than a general equation derived from the whole set—this reduces the error terms of both the X and Y components of the prediction. A rigorous statistical review would conclude that the randomness of the regression's error term is being violated by the removal (or addition) of non-random error (Neter *et al.* 1983). The author feels that the benefits of this approach outweigh its breach of statistical convention.

The regression results for the catchment's rainfall and pET monthly means are shown in Table 8. Coefficients are large where the data have a consistent trend along a certain dimension, but the coefficients should be compared between dimensions only with consideration of the varying range sizes among the input samples. It is clear that elevation has a strong positive relationship with rainfall, less so during the December-to-February dry season when the minor rain events are distributed more at random. On a similar seasonal pattern, the pET of a given month is negatively correlated with elevation. The effect of increasing east position is much less distinct, but increasing south position has a large positive contribution for the rainy season of March to May, then negative from July to September, and again positive in October to November. This corroborates the patterns of the maps presented below as well as the literature on Ethiopian climatology, which suggests that the northern and eastern slopes of the highlands receive moisture throughout the June-to-September period, when elsewhere there is a dry gap between two distinct rains (FAO 1983, FAO 1984a, Hillman 1986).

The standard errors shown in Table 8 make the point that pET data were far more stable geographically than were the rainfall data. The regressions for pET were strong enough, and their residuals sufficiently small and consistent, to allow the generation of pET maps by direct application of the regression equations to the xyz coordinate of the study area's grid-map, rather than going through the normalization and surfacing steps. This is fortuitous because the individual data elements for pET were probably less reliable than the overall pattern, so the removal of local misfits by regression was a net benefit.

Table 8. Linear Regression Results for Rainfall and pET

Met Station Data vs Locational X,Y, and Z
Rain (n=14); pET (n=8)

MONTHLY MEAN	ELEVATION COEFFICIENT		EASTING COEFFICIENT		SOUTHING COEFFICIENT		ST. ERROR (mm)*	
	Rain	pET	Rain	pET	Rain	pET	Rain	pET
January	.383	-.767	-.164	.121	.198	.552	8	8
February	.582	-.950	-.034	.155	.065	.449	10	7
March	1.986	-1.002	-.163	.256	.294	.362	20	10
April	3.093	-1.343	.065	.053	.827	.157	61	16
May	3.063	-1.368	-.156	.286	.559	-.027	77	15
June	1.441	-1.097	-.094	.303	.012	.199	30	17
July	1.790	-.557	.110	.415	-.266	.419	36	16
August	2.250	-.679	.325	.423	-.542	.405	34	14
September	2.625	-.915	.324	.283	-.490	.467	26	15
October	2.146	-1.661	-.072	.020	.416	.172	51	16
November	.736	-1.262	-.104	.012	.454	.242	27	12
December	.155	-1.167	.041	.133	.039	.322	6	9

Note. Input data were transformed to fit a 0-255 integer range. The modifications and sample ranges are as follows:

Rainfall mm/30-86
pETmm/320-65
Elevation (masl-100)/2001-21
Eastingkm/10 (NW origin)3-52
Southingkm/10 (NW origin)5-42

* *standard errors of rain/pET predictions are expressed as total mm, not as mm/3, so that they should be compared with ranges three times as large as those above.*

An actual example of the method of surfacing is provided by the data for October rainfall at Goba. The long-term mean is 107 mm, which is represented as 107/3 = 36 to keep the entire data set in a 0-to -255 integer range. The regression for October rain takes the form:

$$r = 2.146z(14)-.072x(23)+.416y(6).$$

The equation yields a prediction of 31, so the residual is 5. The calculation of what the October rain at Goba would be at a median elevation of 2,100 m (class 11) will only change the elevation input, and a pair of equations for normalized and actual elevation can be joined to give a difference (or correction level) between normalized and actual rainfall:

$$nr - r = 2.146(11-14) = -6.$$

This amount is added to the observed (not predicted) Goba rainfall for input into a surfacing procedure.

The normalized value for Goba is included in the interpolation calculation of all points within 240 km of Goba (this radius was selected to capture the most distant cell from any station). The value of Goba is used with a weighting of the ratio between the search radius (240 km) and the actual distance to the cell in question. As Goba becomes closer, its effect becomes stronger. All stations within the search radius of a given cell have calculated weightings and the value of the new cell becomes the sum of the products of station values and weights, all divided by the sum of the weights.

This produces a map of two-dimensional rainfall variation, without the elevation component of the original data's variation. Next, the algebra of normalization is run backwards by changing each cell in the two-dimensional rainfall map by the product of the elevation coefficient and the difference between the cell's elevation and the normalized elevation.

The distances from the 12 stations used for the surfacing are shown in Figure 11. While the average distance from a station site is 83 kilometers, there is a bias in the station distribution towards the west and north. The eastern portion is obviously underrepresented. An additional station at Ginnir has monthly data from 1968 to 1985 and is located 75 km east and slightly north of Goba. Unfortunately, these data were not available to the study team in time. Had they been included the search radius could have been reduced, and the character of seasonal rainfall to the northeast, outside of the immediate vicinity of the Bale Mountains, would have been described more completely. As some compensation, the area whose isolation is greatest has low rainfall relative to its elevation, so that the existing station network serves its character by associating it with the dry southeast stations.

Each long-term rainfall month was surfaced separately, but when added together they formed an annual rainfall surface as shown in Figure 12. This map is quite similar at the most coarse level to the general isohyet map published by ELC (1984), but on closer examination important new patterns are recognized. The Neghele ridge is more pronounced in its local rainfall high, the Mega area is a dry corner in the southwest, and the basin south and east of the Bale Mountains shows a surprisingly low annual total. The other important difference is that the individual cellular data preserve local topographic variety, which is significant to the volume calculations for areas as small as the subcatchment reporting units. The map has been summarized by volumes for each subcatchment in Table 9.

Table 9. Long-term Mean Annual Rainfall Volumes

		mcm*	%v	%a	Km²
MAJOR CATCHMENTS:					
A.	Gestro Wenz	12,309	15.0	18.7	28,300
B.	Genele Wenz	33,324	40.7	38.1	57,500
C.	Dawa Wenz	32,573	39.7	34.5	52,100
D.	Middle Jubba	3,738	4.6	8.7	13,100
SUBCATCHMENTS:					
1.	Upper Gestro	4,762	5.8	3.7	5,600
2.	Middle Gestro	4,837	5.9	8.8	13,300
3.	Lower Gestro	2,710	3.3	6.2	9,400
4.	Upper Genele	10,807	13.2	7.8	11,800
5.	Welmel	5,048	6.2	5.0	7,600
6.	Dumal	3,343	4.1	4.5	6,800
7.	N.E. Genele	3,536	4.3	5.4	8,100
8.	Middle Genele	5,760	7.0	7.0	10,600
9.	Lower Genele	4,830	5.9	8.3	12,600
10.	Awata	6,737	8.2	5.0	7,600
11.	Upper Dawa	9,292	11.3	8.3	12,600
12.	Fudali	3,542	4.3	5.1	7,700
13.	Middle Dawa	8,067	9.9	8.5	12,900
14.	Lower Dawa	4,935	6.0	7.5	11,300
15.	Middle Jubba	3,738	4.6	8.7	13,100
TOTALS		81,944	100.0	100.0	151,000

* *mcm = million cubic meters*

%V = percent of volume

%a = percent of area

The monthly variations in rainfall are graphed as volume totals in Figure 13, and the calculated surfaces are displayed in Figure 14. The latter figure is intended to give an impression of relative seasonality, and due to the limited space for legends, the data will be explained in detail here. Color codes are white for depths below 10 mm, gray for depths up to 20 mm, green up to 40 mm, blue up to 90 mm, purple up to 140 mm, pink up to 190 mm, and then orange/brown/red up to 260 mm. The patterns of the March-to -May rains are pervasive, then in turn the west-northwest and the north-northwest continue to receive rain during June to September. This clockwise rotation suggests a northerly moisture source, which changes abruptly in October as low elevation rain reaches only the south and west. The dry season of December to February is extreme from the standpoint of long-term monthly means.

The "haystack" results for isolated wet points in certain months—*e.g.*, Yabelo in March; Yabelo, Neghele, Adola and Mena in April; Mena in May—are minor misrepresentations which are artifacts of the usage of the broad (240 km) search radius in areas of densely clustered stations. The rainfall highs, which are true to these stations' data, should be mapped more broadly, but the generally drier data of neighboring stations is contributing too heavily to the interpolated values of cells even slightly offset from the highs. Correction of this minor bias would be delicate and would involve modification of proprietary (ERDAS) software. There is a good chance that ,in the end, the data would be left much the same.

Potential evapotranspiration was mapped directly from its regression equations. The results are displayed in Figure 15. The light gray values are low pET, while the dark gray are high pET. This map coding is consistent with a display of net moisture in Figure 20. The pET trends start with relatively strong levels at all elevations during the months of January to March, with the potential reaching its annual high in March. April is a wet month before the dry influence climbs markedly, at least for the eastern half, during the months of May to September. The rains of October cause a second drop in pET throughout the catchment; this drop persists for longer than the April case, extending nearly to the end of the year. For some months the elevation component of variation is most dominant, while in others east-west or north-south position is more important and evident in the maps (compare with Table 8).

C. Water Balance Modeling

The strategy for constructing a water balance model has been oriented to the prediction of runoff, which has resulted in significantly different input data and analysis sequences than would be needed to predict, for instance, the length of growing seasons, suitability for crop/tree varieties, or microcatchment efficacy. The initial strategy was a simple differencing of rainfall and pET, an accounting for the net values in the soil moisture bank, and the assignment of any soil overflow to runoff. This gave low runoff levels on the order of 50 to 60 percent of the observed outflow at Luuq on an annual basis.

Three modifications brought the annual runoff volumes into parity with outflow. First, an interception factor was calculated as a vegetation effect, representing the proportion of rainfall which was caught by the vegetation and directly evapotranspirated without reaching soil storage or runoff. Second, a storm runoff was calculated to account for the portion of rainfall which is so intense that it exceeds soil infiltration and runs off directly (this was added to the soil overflow runoff to make a total surface runoff result). The third modification lowered the rates of removal of stored soil moisture according to local pET values. Here, linear extraction at the full pET rate was replaced by a function which decayed with the emptiness of the soil storage on a logarithmic curve. Actual evapotransporation would then equal its potential only when the soil storage was fully charged, and at other times substantial moisture savings were realized, with the result that more runoff was produced from subsequent rain.

The water balance model is calculated for each map cell independently. There are no provisions for changes in riverbank, riverbed, or groundwater storage, and the soil storage reservoir is assumed to have no leaks. Accordingly, the current model has the following general configuration:

- rainfall at Soil Surface [RASS] =
  RAINFALL - INTERCEPTION (%)
- pET at Soil Surface [pETASS] =
  pET - INTERCEPTION (%)
- Storm Runoff [STRUN] =
  RASS * %FUNCTION(SLOPE,SOIL TEXT,VEG)
- Rainfall for Soil Storage [RAST] =
  RASS - STRUN
- Net Rainfall/Evap for Soil Storage [NET] =
  RAST - pETASS
- Soil Moisture Content [SM] =
  SM(t-1) + NET
- Runoff from SM above Field Capacity [SMRUN] =
  SM - FCAP
- Total Surface Runoff [TSRUN] =
  STRUN + SMRUN

The output levels of each step have been constrained by numeric limits and process abandonment under excess conditions. These controls will now be described in procedural sequence, but in summary, they have been applied to moderate levels and with relatively little optimization for this particular set of data.

The first two steps modify the rainfall and pET surfaces by lowering them by a percentage amount of the rainfall as interception. The percentages were assigned to each vegetation type according to literature reports, and were compiled by recoding the vegetation map. Table 10 gives the percentages for each class and Figure 16 shows the map. It is clear from the map that the data were constructed to account for the runoff suppression effects of dense woody vegetation. The literature is erratic in its varied reports on levels of interception attributable to the different structural communities (Reifsnyder 1982, Kittredge 1948, Petts and Foster 1985). The modest percentages used for the study are a conservative composite of reported data, with the exception of the value for riparian woodland/bushland, where the "mining" of subsurface riverbed storage is a direct reduction of runoff, and has not been accounted in any other part of the model.

Table 10. Interception Rates for Catchment Vegetation Classes

CLASS	COVERAGE (% Total Area)	INTERCEPTION (Mean % Monthly Rainfall)
Afro-alpine Heath	.3	1
Dense Coniferous Forest	.1	3
Dense Mixed Forest	4.8	5
Disturbed Forest	2.9	4
Disturbed Forest w/ Cultivation	1.5	3
State Farms	.2	1
Intensive Cultivation	1.9	2
Moderate Cultivation	2.0	1
Open Woodland	2.4	1
Dense Bushland	13.3	2
Open Bushland	1.1	1
Dense Shrubland	11.8	1
Open Shrubland	9.2	-
Open Grassland	17.6	1
Bushed/shrubbed Grassland	22.4	1
Wooded Grassland	1.7	1
Riparian Woodland/bushland	1.9	5
Seasonal Marsh	.1	2
Sand w/ scattered Shrub/grass	2.4	-
Bare Sand	1.5	-
Bare Rock	.9	-

Storm runoff was calculated as a percentage of the rainfall at the soil surface, with factors of two-level weightings (1 or 2) on each of three criteria: slope, soil texture, and vegetation. The threshold for weight 2 assignment was 16 percent on slopes, textures finer than sandy loams on soil texture, and non-forest as opposed to forest on vegetation cover (Petts and Foster 1985, Dunne and Leopold 1978, Kenya Water Dept. 1977). The maximum storm runoff was therefore 8 percent of monthly rain, found only on steep slopes with fine soils under non-forest cover. Figure 17 shows the slope map, and Figure 18 gives the calculated storm runoff percentage of local rainfall in map form. Figure 19 is the monthly map series for storm runoff, and reflects the conservative weightings given to the three criteria. The storm runoff depths are quite shallow and smooth in spatial pattern, and this is likely an unavoidable consequence of using long-term monthly mean rainfall (the extreme events and spatial variation are suppressed). Despite the conservative weightings and shallow depths, the volume of storm runoff is a significant proportion of total surface runoff in most cases (Table 11).

*Table 11. Percentage of Total Surface Runoff Volume as Storm Runoff **

SUBCATCHMENT	ANNUAL	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV
GESTRO	28	100	60	33	28	20	18	16	16	100
Upper Gs	22	100	38	24	28	20	18	15	16	100
Middle Gs	100		100	100			100	100		
Lower Gs	100		100	100						
GENELE	24	100	60	16	21	12	11	12	27	92
Upper Gn	17	100	44	11	22	12	10	12	18	92
Welmel	17	100	59	11	0	13	7	7	16	
Dumal	47	100	81	43			20	20	0	
N.East Gn	98		100	94		100	100	100		
Middle Gn	43		60	25					96	
Lower Gn	100		100	100					100	
DAWA	24	100	76	12	10	3	3	4	34	77
Awata	12	100	81	8	5	3	3	3	10	75
Upper Da	24	100	68	11	20	0	0	33	41	71
Fudali	100	100	100	100					100	
Middle Da	37		65	16					100	
Lower Da	100		100	100					100	100
MIDDLE JUBBA	100		100							
TOTAL CATCHMENT	25	100	66	16	18	13	12	12	27	85

**(Blank entries are cases with no total runoff)*

After subtracting storm runoff from the rainfall available at the soil surface, the next step is to difference the rainfall and pET amounts applicable to soil storage. Figure 20 shows the monthly maps of this positive/negative input, with the positive moisture falling off from blue into yellowish green, crossing into negative values as light gray and into strong negatives as dark gray. It is these data which are used for water balance along with available soil water storage, as determined from field capacity and previous moisture inputs or extractions.

Figure 21 is a map of the soil storage potential derived by the methods discussed in Section III.C. The average storage depth for the catchment is 110 mm. There are some areas, however, which retain a substantial amount of stored moisture throughout the year, and other areas which never fill their available storage volumes (at least on the basis of long-term mean seasonality). The map of field capacity therefore is only an intermediate step in assessing how much rainfall can be stored in the soil. A balance equation should use currently available net storage; in other words, the field capacity less the current amount of stored water (Thornthwaite and Mather 1955). This time element forces the establishment of an initial condition for soil moisture, which was set at field capacity for the start of the calender year. Monthly water balances were then calculated consecutively through multi-year cycles until convergence (when the result from the previous year matched the current year).

The balance equation takes the soil moisture level and adds the month's positive net input, placing any excess moisture into the surplus runoff map. If the month's net input is negative, the moisture level is reduced by the negative amount multiplied by the cube of the log-base-10 of the percent fullness of the soil. This odd function fit the published experimental results with the best compromise (Dunne and Leopold 1978, Petts and Foster 1985). Soil moisture was constrained further to the range of 10 to 100 percent of field capacity.

The resulting surplus runoff maps are shown in Figure 22. This uses the same color scheme as the storm runoff of Figure 19. The pattern of the surplus runoff generation is more concentrated and localized than that of the storm runoff. The net negative moisture of the November to February dry season draws down the stored water to the extent that none of the March rain runs off as surplus, and the same applies to all but a bit of the rainiest month of April. During May, most of the field-capacity volumes are saturated, and there is surplus rain in substantial depth over broad areas. However, during June the strong pET of the lower areas returns to dominate the following months, and surplus runoff is restricted to the higher elevations of the northwest. Soil moisture is diminished during this period to the extent that even the strong Neghele ridge rainfall of October fails to fill the soil and as a result no surplus runoff is produced.

The combination of storm and surplus runoff data yields the total surface runoff attribute. This is mapped in Figure 23, and is considered the endpoint of the study's data analysis. Monthly summaries for rainfall, storm runoff, surplus runoff, and total surface runoff are given in Tables 12 through 15 (Appendix A).

A by-product of the analysis is seen in Figure 24 as the soil moisture monthly map series. Here blue represents soil water in excess of 150 mm, dark brown covers the range of 50 to 130 mm, and yellow/tan shows the areas with 1 to 40 mm. The map shows areas whose soils are perennially moist under normal circumstances. For growing season applications, the use of 60 percent rainfall probability surfaces would be better than long-term rainfall mean surfaces.

A. Runoff Source Areas

Total surface runoff volumes are graphed for the four major catchment subunits in Figure 25. The runoff year has three parts:

- a dormant period from November through March,
- a peak flood in May carried by the Genele and Dawa, and
- a surge from July to October carried by the Genele and Gestro.

June is a hiatus month, while October shows a minor decline in the contribution of the Gestro, and a bulge in the Dawa's performance. These general points can be extended into more local descriptions through examination of Figures 26 to 31, which are paired graphs of monthly rainfall and total surface runoff volume for the Gestro, Genele, and Dawa subcatchments.

The annual summary is shown in Figure 32, a bar chart with rainfall and total surface runoff proportions for each subcatchment. Here it is obvious that the upper Genele is by far the most important runoff production area, responsible for about one-third of the catchment output. The Upper Gestro, Awata, Upper Dawa and Welmel form a second group, each tallying 10 to 15 percent of the total, and together yielding 45 to 50 percent of the runoff. The remaining subcatchments taken as the third group total 15 to 20 percent of the source.

B. Seasonal Pattern and Time Lag

The absence of groundwater process in the runoff model has given the results a strong seasonal bias. While the annual total surface runoff of 5,271 million cubic meters (mcm) closely matches the Luuq flow volumes of Table 3, the seasonal patterns show a poor fit. The inclusion of a catchment baseflow (or groundwater) output would soften the peaks and troughs to improve the fit, and would add at least 1,000 mcm to the modeled output total, but the calculation of a baseflow component on a monthly basis was beyond the scope of this study. Figure 33 shows the relationship between monthly rainfall (green in 1,000s) and both modeled runoff and Luuq flows (dotted blue and solid blue in 100s). The peaks are in all the correct places, but the shape of the blue curves are not at all the same.

Explanations of this discrepancy may be as numerous as the many steps of the complex analysis procedures, and as varied as the catchment's natural heterogeneity, for none of the procedures were calibrated perfectly, nor were the inputs flawless in their summary of the gradients. However, there are four likely sources of the discrepancy which deserve attention.

The first is a model design issue: if Luuq flows are assumed to be accurate for the time periods of the rainfall data which were used to calculate runoff, it appears that the soil storage "sponge" is filling too consistently and quickly, and is drying out too fast as well. With more varied and less permeable storage the April runoff might be increased, the May peak would be reduced as a lower proportion of the area would be saturated, and less loss would occur during the moderately dry time of June to August, keeping the sponge fairly full so that the October input peak would not be wasted so much on soil filling. The method of changing storage input/output might take the form of modifying the rates and limits of pET loss from stored water and/or introducing storage leaks as throughflow into a groundwater runoff subsystem.

The second explanation for the discrepancy is the jumble of years which have been analyzed as if the data were all contemporaneous. The rainfall surfaces are undoubtedly affected by this problem, and there cannot be good correspondence between that set of mixtures and the unknown original data from which the Luuq flow records were generated. The solution to this error source is to attempt an augmentation and weeding of the various input data sets.

The third point asks whether the spatial distribution of the meteorological stations has failed to document some significant performance patterns. The addition of more stations in the northeast would provide a better description of the September-October floods which are the weakest portion of the simulation. More stations also would allow better interpolation due to a smaller search radius, resulting in less negative influence by dry stations adjacent to important runoff production zones.

The fourth point is potentially the most explanatory and least tractable of bias sources. It is plausible and even probable that the catchment's flow delivery system is much perturbed by large subsurface aquifers with slow recharge/outflow rates in the calcareous zone underlying large portions of the middle reaches of each of the three main tributaries. Such major dampeners of flow delivery would fill up on a seasonal basis and release their storage as capacity is saturated towards the end of the March to October rainy period. The solutions for this source of misfit are not straightforward, but the nature of the perturbation should be examined with unaveraged data in a multi-year model application.

The time lags between accumulation of major rainfall input and the delivery of its runoff component to the Baardheere Reservoir depend on a variety of factors. The location of the rainfall mass will affect the time determinants of distance and the soil, slope, and vegetation conditions for its conversion to runoff. Given these conditions, the intensity of the rainfall would control the proportion of storm runoff, which delivers runoff faster than the other processes. The level of antecedent moisture under the rain mass would affect the rapidity of soil water outflow to runoff. Equally important is the absorption capacity of the river channels along the route(s) of runoff delivery; here antecedent moisture of floodplain storage is a determinant, and, especially for the Jubba Basin, this may include major seasonal effects of limestone cavity storage.

Because the available daily rain and flow data failed to represent common area or time period, the time lag analysis was not incorporated into the spatial modeling procedures. A rather cursory examination was achieved through a correlation between the 31 years of monthly flow volumes (per IBRD) and a repeated series of mean monthly rainfall volumes from the model results. A time lag of zero months produced a cross-correlation coefficient of .193, while the one-month lag coefficient was .265. Two-month and three-month results tailed off to .041 and .019. These numbers, while weak in their construction and resulting pattern, do suggest that the lags in the Jubba system may be measurable in weeks rather than days, particularly for the events which are near the beginning of the rainy seasons.

C. Prospects for Monitoring to Forecast Inflow

Assuming time lags are sufficient for the implementation of reservoir-level fluctuations, there are two main issues in the design of a rainfall monitoring program: what areas need to be watched and how is the watching to be done?

The model results show that there is fairly widespread runoff contribution in stormflow, but more restricted areas are important for their storage surplus flow. The widespread sources may best be monitored with remote sensing data from daily satellite coverage using both heat and vegetation detectors. In contrast, the major storage surplus sources, which deliver a majority of the volume and may be responsible for most of the yearly fluctuation, are slower performers whose behavior can be traced with the conventional machinery of a rain gauge and the fast-improving technology of data recorders and remote transmitters. An array of four to eight stations distributed across the northwest rim of the catchment should cover the spatial and seasonal variability. By the time the Baardheere Dam is constructed, these options will likely be far more feasible from both technical and political perspectives.

The efficacy of quick delivery of remote sensing data is evolving rapidly. In October 1988, FAO began delivering monitoring data for the Africa continent, under assistance from the governments of the Netherlands and Japan. The program, named ARTEMIS (African Real Time Environmental Monitoring Using Imaging Satellites), will estimate rainfall and vegetation activity for a 10-day period and deliver the data within the subsequent 10-day period. The data will be mapped on a continental gridcell array whose elements are approximately 7.5 km square. Rainfall will be estimated from Meteosat imagery reduction algorithms developed at the University of Reading in England, using cloud incidence and cloudtop temperatures to predict daily rainfall accumulated over the 10-day period. Vegetation response will be assessed by using National Oceanic and Atmospheric Administration, Advanced Very High Resolution Radiometry (NOAA AVHRR) imagery, again daily, transformed to a vegetation index which responds to the green biomass of the vegetation. This index is suppressed by cloud interference, so the selection of local maxima over 10 daily images will give the most cloud-free composite image for the period.

In the beginning, ARTEMIS data will be sent on diskette to regional dissemination points at Nairobi, Harare, and Niamey. The longer range plans are for Intelsat data transmission to users who have data subscriptions and who purchase an antenna and data processing station for $20,000 to $30,000. The program has standardized an historical archive dating back to 1980, so that users can immediately assess normative character and extreme event patterns for their study areas.

The data will have certain bias components. The rainfall estimator has been calibrated in the flat terrain of the West Africa Sahel and has recently done poorly in tests over mountainous terrain. For the vegetation index products, the 10-day composite is over too short a time period for cloud-free imagery of the cloudier areas of tropical Africa, and the highlands of the Jubba will be subject to this constraint. The selection of index maxima to avoid cloudy data also gives a monitoring bias towards the most lushly vegetated component of the landscape. Because original image elements are at least 1 by 4 km in size, this selection bias operates at a very coarse texture which should not impair data analysis of important storm tracks within the Jubba catchment.

A parallel initiative to ARTEMIS is being started by French scientists at the Meteorological Department in Nairobi. A receiving station for both Meteosat and NOAA AVHRR data will feed a dedicated data processing center, and higher resolution (7.5 km) data will be mapped for a region which is sure to include the Jubba area. The details of the data products have not been released to date, but the time-compositing interval is likely to be sufficient for cloud-free vegetation index data.

These developments are expected to dominate the regional remote sensing monitoring field for the next five to 10 years. By the time the dam is commissioned, there are likely to be additional technological breakthroughs for the delivery of better rainfall estimates from thermal imagery, and less cloudy vegetation data over shorter time periods. This will enable forecast of inflows over shorter lag times, so that a greater proportion of the Jubba River flow delivery will be predictable as time passes. Under the scenario that data of this nature are available to the dam management team, the rainfall estimates will need local calibration and the four to eight conventional rain gauges will help in this process. The vegetation index images will also help to calibrate the rainfall estimator, particularly for storm assessment in the drier areas.

D. Final Considerations

The resources data, moisture surfaces, and water balance results have given a broad description of the Ethiopian portion of the Jubba catchment. Rainfall and runoff yields and soil moisture distributions have been mapped to give an approximation of the long-term performance pattern of the study area. These data are of sufficient quality to be used in the selection of monitoring sites for future programs of reservoir inflow prediction.

Any modeling effort is usually open-ended as tempting new ideas and input data are forthcoming. Major refinement of this simulation of catchment behavior is possible and relatively straightforward now that the foundation has been built. There are undoubtedly many sets of data in the archives of the Ethiopian government which can be used to upgrade the existing baselines, leading to a marked improvement in the modeling results. These data are far closer to availability, from a Somali perspective, than they were in the past. If the current trend of rapprochement between Ethiopia and Somalia continues, their collaboration on an improved version of the Jubba flow model may be an attractive political initiative.

A follow-on project would take the form of a joint effort between the two governments to evaluate and manage the water resources of the Bale-Ogaden area. Additional meteorological data would be collected to improve on the climatic baselines, and the study area should be expanded to the adjacent Shabeelle Basin. A strong groundwater study component must be given priority. A suggested scope of work would include three years of fresh data collection in a five-year project, a pair of scientists from each of the donor and collaborating countries, all with three-year posts, and one year of short-term expertise. *

Ethiopia will depend increasingly on these less exploited areas as the productivity in the populous highlands continues its downward trend. *Somalia*

**Costs are estimated at $1.6 (based on 1988 dollars). It should be pointed out that such a study would have mutual value to calibrating applications of ARTEMIS and NOAA AVHRR in East Africa.*

has a vital need to protect and maintain its river systems as the only reserve against recurrent drought trauma. Common need and mutual benefit justify a systemwide study to determine normal and extreme behavior patterns of these two major rivers, and to refine methods for predicting flow production in a border region which is so critical to both nations.

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Table 12. Monthly Long-term Mean Rainfall

JANUARY

MAJOR CATCHMENT		*mcm*	*%v*	*%a*	*km²*
A.	Gestro Wenz	130	10.5	18.7	28,300
B.	Genele Wenz	334	27.0	38.1	57,500
C.	Dawa Wenz	734	59.3	34.5	52,100
D.	Middle Jubba	39	3.2	8.7	13,100
SUBCATCHMENT					
1.	Upper Gestro	61	4.9	3.7	5,600
2.	Middle Gestro	41	3.3	8.8	13,300
3.	Lower Gestro	28	2.3	6.2	9,400
4.	Upper Genele	132	10.7	7.8	11,800
5.	Welmel	37	3.0	5.0	7,600
6.	Dumal	25	2.0	4.5	6,800
7.	NE Genele	29	2.3	5.4	8,100
8.	Middle Genele	63	5.1	7.0	10,600
9.	Lower Genele	48	3.9	8.3	12,600
10.	Awata	104	8.4	5.0	7,600
11.	Upper Dawa	225	18.2	8.3	12,600
12.	Fudali	196	15.8	5.1	7,700
13.	Middle Dawa	140	11.3	8.5	12,900
14.	Lower Dawa	69	5.6	7.5	11,300
15.	Middle Jubba	39	3.2	8.7	13,100
TOTALS		1,237	100.0	100.0	151,000

FEBRUARY

MAJOR CATCHMENT		*mcm*	*%v*	*%a*	*km²*
A.	Gestro Wenz	301	13.9	18.7	28,300
B.	Genele Wenz	823	38.0	38.1	57,500
C.	Dawa Wenz	970	44.8	34.5	52,100
D.	Middle Jubba	73	3.4	8.7	13,100
SUBCATCHMENT					
1.	Upper Gestro	134	6.2	3.7	5,600
2.	Middle Gestro	112	5.2	8.8	13,300
3.	Lower Gestro	55	2.5	6.2	9,400
4.	Upper Genele	260	12.0	7.8	11,800
5.	Welmel	101	4.7	5.0	7,600
6.	Dumal	74	3.4	4.5	6,800
7.	NE Genele	89	4.1	5.4	8,100
8.	Middle Genele	173	8.0	7.0	10,600
9.	Lower Genele	126	5.8	8.3	12,600
10.	Awata	169	7.8	5.0	7,600
11.	Upper Dawa	282	13.0	8.3	12,600
12.	Fudali	92	4.2	5.1	7,700
13.	Middle Dawa	280	12.9	8.5	12,900
14.	Lower Dawa	147	6.8	7.5	11,300
15.	Middle Jubba	73	3.4	8.7	13,100
TOTALS		2,167	100.0	100.0	151,000

MARCH

MAJOR CATCHMENT		*mcm*	*%v*	*%a*	*km²*
A.	Gestro Wenz	953	14.5	18.7	28,300
B.	Genele Wenz	2,537	38.7	38.1	57,500
C.	Dawa Wenz	2,748	41.9	34.5	52,100
D.	Middle Jubba	324	4.9	8.7	13,100
SUBCATCHMENT					
1.	Upper Gestro	384	5.9	3.7	5,600
2.	Middle Gestro	357	5.4	8.8	13,300
3.	Lower Gestro	212	3.2	6.2	9,400
4.	Upper Genele	825	12.6	7.8	11,800
5.	Welmel	434	6.6	5.0	7,600
6.	Dumal	303	4.6	4.5	6,800
7.	NE Genele	274	4.2	5.4	8,100
8.	Middle Genele	367	5.6	7.0	10,600
9.	Lower Genele	334	5.1	8.3	12,600
10.	Awata	521	7.9	5.0	7,600
11	Upper Dawa	891	13.6	8.3	12,600
12	Fudali	502	7.7	5.1	7,700
13.	Middle Dawa	509	7.8	8.5	12,900
14.	Lower Dawa	325	5.0	7.5	11,300
15.	Middle Jubba	324	4.9	8.7	13,100
TOTALS		6,562	100.0	100.0	151,000

APRIL

MAJOR CATCHMENT		*mcm*	*%v*	*%a*	*km²*
A.	Gestro Wenz	3,069	14.5	18.7	28,300
B.	Genele Wenz	8,489	40.1	38.1	57,500
C.	Dawa Wenz	8,258	39.1	34.5	52,100
D.	Middle Jubba	1,328	6.3	8.7	13,100
SUBCATCHMENT					
1.	Upper Gestro	772	3.7	3.7	5,600
2.	Middle Gestro	1,337	6.3	8.8	13,300
3.	Lower Gestro	960	4.5	6.2	9,400
4.	Upper Genele	2,173	10.3	7.8	11,800
5.	Welmel	1,305	6.2	5.0	7,600
6.	Dumal	867	4.1	4.5	6,800
7.	NE Genele	907	4.3	5.4	8,100
8.	Middle Genele	1,681	8.0	7.0	10,600
9.	Lower Genele	1,556	7.4	8.3	12,600
10.	Awata	1,417	6.7	5.0	7,600
11.	Upper Dawa	2,018	9.5	8.3	12,600
12.	Fudali	1,000	4.7	5.1	7,700
13.	Middle Dawa	2,293	10.8	8.5	12,900
14.	Lower Dawa	1,530	7.2	7.5	11,300
15.	Middle Jubba	1,328	6.3	8.7	13,100
TOTALS		21,144	100.0	100.0	151,000

mcm = million cubic meters
%v = percent of total volume
%a = percent of total area

Table 12. Continued...

MAY

MAJOR CATCHMENT	*mcm*	*%v*	*%a*	*km²*
A. Gestro Wenz	1,929	11.9	18.7	28,300
B. Genele Wenz	7,211	44.4	38.1	57,500
C. Dawa Wenz	6,645	40.9	34.5	52,100
D. Middle Jubba	455	2.8	8.7	13,100
SUBCATCHMENT				
1. Upper Gestro	573	3.5	3.7	5,600
2. Middle Gestro	988	6.1	8.8	13,300
3. Lower Gestro	368	2.3	6.2	9,400
4. Upper Genele	2,001	12.3	7.8	11,800
5 Welmel	1,286	7.9	5.0	7,600
6. Dumal	808	5.0	4.5	6,800
7. NE Genele	772	4.8	5.4	8,100
8. Middle Genele	1,431	8.8	7.0	10,600
9 Lower Genele	913	5.6	8.3	12,600
10 Awata	1,283	7.9	5.0	7,600
11. Upper Dawa	1,852	11.4	8.3	12,600
12 Fudali	687	4.2	5.1	7,700
13. Middle Dawa	1,861	11.5	8.5	12,900
14. Lower Dawa	962	5.9	7.5	11,300
15. Middle Jubba	455	2.8	8.7	13,100
TOTALS	16,240	100.0	100.0	151,000

JUNE

MAJOR CATCHMENT	*mcm*	*%v*	*%a*	*km²*
A. Gestro Wenz	439	14.5	18.7	28,300
B. Genele Wenz	1,275	42.2	38.1	57,500
C. Dawa Wenz	1,265	41.8	34.5	52,100
D. Middle Jubba	44	1.5	8.7	13,100
SUBCATCHMENT				
1. Upper Gestro	285	9.4	3.7	5,600
2. Middle Gestro	119	3.9	8.8	13,300
3. Lower Gestro	35	1.2	6.2	9,400
4. Upper Genele	682	22.6	7.8	11,800
5. Welmel	214	7.1	5.0	7,600
6. Dumal	121	4.0	4.5	6,800
7. NE Genele	107	3.5	5.4	8,100
8. Middle Genele	90	3.0	7.0	10,600
9. Lower Genele	61	2.0	8.3	12,600
10. Awata	417	13.8	5.0	7,600
11. Upper Dawa	595	19.7	8.3	12,600
12. Fudali	94	3.1	5.1	7,700
13. Middle Dawa	110	3.6	8.5	12,900
14. Lower Dawa	49	1.6	7.5	11,300
15. Middle Jubba	44	1.5	8.7	13,100
TOTALS	3,023	100.0	100.0	151,000

JULY

MAJOR CATCHMENT	*mcm*	*%v*	*%a*	*km²*
A. Gestro Wenz	802	25.3	18.7	28,300
B. Genele Wenz	1,390	43.9	38.1	57,500
C. Dawa Wenz	892	28.2	34.5	52,100
D. Middle Jubba	80	2.5	8.7	13,100
SUBCATCHMENT				
1. Upper Gestro	524	16.6	3.7	5,600
2. Middle Gestro	240	7.6	8.8	13,300
3. Lower Gestro	38	1.2	6.2	9,400
4. Upper Genele	737	23.3	7.8	11,800
5. Welmel	199	6.3	5.0	7,600
6. Dumal	156	4.9	4.5	6,800
7. NE Genele	186	5.9	5.4	8,100
8. Middle Genele	62	2.0	7.0	[illegible]
9. Lower Genele	50	1.6	8.3	[illegible]
10. Awata	364	11.5	5.0	7,600
11. Upper Dawa	391	12.4	8.3	12,600
12. Fudali	50	1.6	5.1	7,700
13. Middle Dawa	49	1.5	8.5	12,900
14. Lower Dawa	38	1.2	7.5	11,300
15. Middle Jubba	80	2.5	8.7	13,100
TOTALS	3,164	100.0	100.0	151,000

AUGUST

MAJOR CATCHMENT	*mcm*	*%v*	*%a*	*km²*
A. Gestro Wenz	1,018	27.7	18.7	28,300
B. Genele Wenz	1,687	45.9	38.1	57,500
C. Dawa Wenz	853	23.2	34.5	52,100
D. Middle Jubba	115	3.1	8.7	13,100
SUBCATCHMENT				
1. Upper Gestro	648	17.6	3.7	5,600
2. Middle Gestro	320	8.7	8.8	13,300
3. Lower Gestro	50	1.4	6.2	9,400
4. Upper Genele	821	22.4	7.8	11,800
5. Welmel	246	6.7	5.0	7,600
6 Dumal	217	5.9	4.5	6,800
7. NE Genele	249	6.8	5.4	8,100
8. Middle Genele	80	2.2	7.0	10,600
9. Lower Genele	74	2.0	8.3	12,600
10. Awata	384	10.5	5.0	7,600
11. Upper Dawa	339	9.2	8.3	12,600
12. Fudali	29	0.8	5.1	7,700
13. Middle Dawa	49	1.3	8.5	12,900
14. Lower Dawa	52	1.4	7.5	11,300
15. Middle Jubba	115	3.1	8.7	13,100
TOTALS	3,673	100.0	100.0	151,000

Table 12. Continued...

SEPTEMBER

MAJOR CATCHMENT	mcm	%v	%a	km²
A. Gestro Wenz	1,145	21.4	18.7	28,300
B. Genele Wenz	2,566	48.1	38.1	57,500
C. Dawa Wenz	1,522	28.5	34.5	52,100
D. Middle Jubba	105	2.0	8.7	13,100
SUBCATCHMENT				
1. Upper Gestro	652	12.2	3.7	5,600
2. Middle Gestro	430	8.1	8.8	13,300
3. Lower Gestro	63	1.2	6.2	9,400
4. Upper Genele	946	17.7	7.8	11,800
5. Welmel	451	8.4	5.0	7,600
6. Dumal	346	6.5	4.5	6,800
7. NE Genele	348	6.5	5.4	8,100
8. Middle Genele	305	5.7	7.0	10,600
9 Lower Genele	170	3.2	8.3	12,600
10. Awata	466	8.7	5.0	7,600
11. Upper Dawa	563	10.5	8.3	12,600
12. Fudali	50	0.9	5.1	7,700
13. Middle Dawa	291	5.5	8.5	12,900
14. Lower Dawa	152	2.8	7.5	11,300
15. Middle Jubba	105	2.0	8.7	13,100
TOTALS	5,338	100.0	100.0	151,000

OCTOBER

MAJOR CATCHMENT	mcm	%v	%a	km²
A. Gestro Wenz	1,437	12.1	18.7	28,300
B. Genele Wenz	4,515	37.9	38.1	57,500
C. Dawa Wenz	5,485	46.1	34.5	52,100
D. Middle Jubba	473	4.0	8.7	13,100
SUBCATCHMENT				
1. Upper Gestro	494	4.1	3.7	5,600
2. Middle Gestro	538	4.5	8.8	13,300
3. Lower Gestro	405	3.4	6.2	9,400
4. Upper Genele	1,393	11.7	7.8	11,800
5. Welmel	510	4.3	5.0	7,600
6. Dumal	276	2.3	4.5	6,800
7. NE Genele	383	3.2	5.4	8,100
8. Middle Genele	1,087	9.1	7.0	10,600
9. Lower Genele	866	7.3	8.3	12,600
10. Awata	976	8.2	5.0	7,600
11. Upper Dawa	1,209	10.2	8.3	12,600
12. Fudali	506	4.2	5.1	7,700
13. Middle Dawa	1,786	15.0	8.5	12,900
14. Lower Dawa	1,008	8.5	7.5	11,300
15. Middle Jubba	473	4.0	8.7	13,100
TOTALS	11,910	100.0	100.0	151,000

NOVEMBER

MAJOR CATCHMENT	mcm	%v	%a	km²
A. Gestro Wenz	866	13.6	18.7	28,300
B. Genele Wenz	2,152	33.7	38.1	57,500
C. Dawa Wenz	2,833	44.3	34.5	52,100
D. Middle Jubba	539	8.4	8.7	13,100
SUBCATCHMENT				
1. Upper Gestro	176	2.8	3.7	5,600
2. Middle Gestro	290	4.5	8.8	13,300
3. Lower Gestro	400	6.3	6.2	9,400
4 Upper Genele	709	11.1	7.8	11,800
5. Welmel	232	3.6	5.0	7,600
6. Dumal	126	2.0	4.5	6,800
7. NE Genele	161	2.5	5.4	8,100
8. Middle Genele	384	6.0	7.0	10,600
9. Lower Genele	540	8.5	8.3	12,600
10. Awata	554	8.7	5.0	7,600
11. Upper Dawa	827	12.9	8.3	12,600
12 Fudali	305	4.8	5.1	7,700
13. Middle Dawa	626	9.8	8.5	12,900
14. Lower Dawa	521	8.2	7.5	11,300
15. Middle Jubba	539	8.4	8.7	13,100
TOTALS	6,390	100.0	100.0	151,000

DECEMBER

MAJOR CATCHMENT	mcm	%v	%a	km²
A. Gestro Wenz	220	20.1	18.7	28,300
B. Genele Wenz	345	31.5	38.1	57,500
C. Dawa Wenz	368	33.6	34.5	52,100
D. Middle Jubba	163	14.9	8.7	13,100
SUBCATCHMENT				
1. Upper Gestro	59	5.4	3.7	5,600
2. Middle Gestro	65	5.9	8.8	13,300
3. Lower Gestro	96	8.8	6.2	9,400
4. Upper Genele	128	11.7	7.8	11,800
5. Welmel	33	3.0	5.0	7,600
6. Dumal	24	2.2	4.5	6,800
7. NE Genele	31	2.8	5.4	8,100
8. Middle Genele	37	3.4	7.0	10,600
9. Lower Genele	92	8.4	8.3	12,600
10. Awata	82	7.5	5.0	7,600
11. Upper Dawa	100	9.1	8.3	12,600
12. Fudali	31	2.8	5.1	7,700
13. Middle Dawa	73	6.7	8.5	12,900
14. Lower Dawa	82	7.5	7.5	11,300
15. Middle Jubba	163	14.9	8.7	13,100
TOTALS	1,096	100.0	100.0	151,000

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Table 13. Monthly Storm Runoff Volumes in Million Cubic Meters

MARCH

MAJOR CATCHMENT	*mcm*	*%v*	*%a*	*km²*
A. Gestro Wenz	12	27.3	18.7	28,300
B. Genele Wenz	19	43.2	38.1	5,7500
C. Dawa Wenz	13	29.5	34.5	52,100
D. Middle Jubba	0	0.0	8.7	13,100
SUBCATCHMENT				
1. Upper Gestro	12	27.3	3.7	5,600
2 Middle Gestro	0	0.0	8.8	13,300
3. Lower Gestro	0	0.0	6.2	9,400
4. Upper Genele	15	34.1	7.8	11,800
5. Welmel	2	4.5	5.0	7,600
6. Dumal	2	4.5	4.5	6,800
7. NE Genele	0	0.0	5.4	8,100
8. Middle Genele	0	0.0	7.0	10,600
9. Lower Genele	0	0.0	8.3	12,600
10. Awata	2	4.5	5.0	7,600
11. Upper Dawa	9	20.5	8.3	12,600
12 Fudali	2	4.5	5.1	7,700
13. Middle Dawa	0	0.0	8.5	12,900
14. Lower Dawa	0	0.0	7.5	11,300
15. Middle Jubba	0	0.0	8.7	13,100
TOTALS	44	100.0	100.0	151,000

APRIL

MAJOR CATCHMENT	*mcm*	*%v*	*%a*	*km²*
A. Gestro Wenz	85	15.7	18.7	28,300
B. Genele Wenz	256	47.1	38.1	57,500
C. Dawa Wenz	176	32.4	34.5	52,100
D. Middle Jubba	26	4.8	8.7	13,100
SUBCATCHMENT				
1. Upper Gestro	34	6.3	3.7	5,600
2. Middle Gestro	25	4.6	8.8	13,300
3 Lower Gestro	26	4.8	6.2	9,400
4. Upper Genele	84	15.5	7.8	11,800
5. Welmel	33	6.1	5.0	7,600
6. Dumal	26	4.8	4.5	6,800
7. NE Genele	19	3.5	5.4	8,100
8. Middle Genele	50	9.2	7.0	10,600
9. Lower Genele	44	8.1	8.3	12,600
10. Awata	34	6.3	5.0	7,600
11. Upper Dawa	43	7.9	8.3	12,600
12. Fudali	11	2.0	5.1	7,700
13. Middle Dawa	51	9.4	8.5	12,900
14. Lower Dawa	37	6.8	7.5	11,300
15. Middle Jubba	26	4.8	8.7	13,100
TOTALS	543	100.0	100.0	151,000

mcm = million cubic meters
%v = percent of total volume
%a - percent of total area

MAY

MAJOR CATCHMENT	*mcm*	*%v*	*%a*	*km²*
A. Gestro Wenz	40	11.5	18.7	28,300
B. Genele Wenz	204	58.5	38.1	57,500
C. Dawa Wenz	105	30.1	34.5	52,100
D. Middle Jubba	0	0.0	8.7	13,100
SUBCATCHMENT				
1. Upper Gestro	26	7.4	3.7	5,600
2. Middle Gestro	13	3.7	8.8	13,300
3. Lower Gestro	1	0.3	6.2	9,400
4. Upper Genele	77	22.1	7.8	11,800
5. Welmel	31	8.9	5.0	7,600
6. Dumal	24	6.9	4.5	6,800
7. NE Genele	17	4.9	5.4	8,100
8. Middle Genele	38	10.9	7.0	10,600
9. Lower Genele	17	4.9	8.3	12,600
10. Awata	29	8.3	5.0	7,600
11. Upper Dawa	34	9.7	8.3	12,600
12. Fudali	6	1.7	5.1	7,700
13. Middle Dawa	27	7.7	8.5	12,900
14. Lower Dawa	9	2.6	7.5	11,300
15. Middle Jubba	0	0.0	8.7	13,100
TOTALS	349	100.0	100.0	151,000

JUNE

MAJOR CATCHMENT	*mcm*	*%v*	*%a*	*km²*
A. Gestro Wenz	7	24.1	18.7	28,300
B. Genele Wenz	16	55.2	38.1	57,500
C. Dawa Wenz	6	20.7	34.5	52,100
D. Middle Jubba	0	0.0	8.7	13,100
SUBCATCHMENT				
1. Upper Gestro	7	24.1	3.7	5,600
2. Middle Gestro	0	0.0	8.8	13,300
3. Lower Gestro	0	0.0	6.2	9,400
4. Upper Genele	16	55.2	7.8	11,800
5. Welmel	0	0.0	5.0	7,600
6. Dumal	0	0.0	4.5	6,800
7. NE Genele	0	0.0	5.4	8,100
8. Middle Genele	0	0.0	7.0	10,600
9. Lower Genele	0	0.0	8.3	12,600
10. Awata	2	6.9	5.0	7,600
11. Upper Dawa	4	13.8	8.3	12,600
12. Fudali	0	0.0	5.1	7,700
13. Middle Dawa	0	0.0	8.5	12,900
14. Lower Dawa	0	0.0	7.5	11,300
15. Middle Jubba	0	0.0	8.7	13,100
TOTALS	29	100.0	100.0	151,000

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Table 13. Continued...

JULY

MAJOR CATCHMENT	*mcm*	*%v*	*%a*	*km²*
A. Gestro Wenz	21	46.7	18.7	28,300
B. Genele Wenz	22	48.9	38.1	57,500
C. Dawa Wenz	2	4.4	34.5	52,100
D. Middle Jubba	0	0.0	8.7	13,100
SUBCATCHMENT				
1. Upper Gestro	21	46.7	3.7	5,600
2. Middle Gestro	0	0.0	8.8	13,300
3. Lower Gestro	0	0.0	6.2	9,400
4. Upper Genele	20	44.4	7.8	11,800
5. Welmel	2	4.4	5.0	7,600
6. Dumal	0	0.0	4.5	6,800
7. NE Genele	0	0.0	5.4	8,100
8. Middle Genele	0	0.0	7.0	10,600
9. Lower Genele	0	0.0	8.3	12,600
10. Awata	2	4.4	5.0	7,600
11. Upper Dawa	0	0.0	8.3	12,600
12. Fudali	0	0.0	5.1	7,700
13. Middle Dawa	0	0.0	8.5	12,900
14. Lower Dawa	0	0.0	7.5	11,300
15. Middle Jubba	0	0.0	8.7	13,100
TOTALS	45	100.0	100.0	151,000

AUGUST

MAJOR CATCHMENT	*mcm*	*%v*	*%a*	*km²*
A. Gestro Wenz	30	51.7	18.7	28,300
B. Genele Wenz	26	44.8	38.1	57,500
C. Dawa Wenz	2	3.4	34.5	52,100
D. Middle Jubba	0	0.0	8.7	13,100
SUBCATCHMENT				
1. Upper Gestro	29	50.0	3.7	5,600
2. Middle Gestro	1	1.7	8.8	13,300
3. Lower Gestro	0	0.0	6.2	9,400
4. Upper Genele	22	37.9	7.8	11,800
5. Welmel	2	3.4	5.0	7,600
6. Dumal	1	1.7	4.5	6,800
7. NE Genele	1	1.7	5.4	8,100
8. Middle Genele	0	0.0	7.0	10,600
9. Lower Genele	0	0.0	8.3	12,600
10. Awata	2	3.4	5.0	7,600
11. Upper Dawa	0	0.0	8.3	12,600
12. Fudali	0	0.0	5.1	7,700
13. Middle Dawa	0	0.0	8.5	12,900
14. Lower Dawa	0	0.0	7.5	11,300
15. Middle Jubba	0	0.0	8.7	13,100
TOTALS	58	100.0	100.0	151,000

SEPTEMBER

MAJOR CATCHMENT	*mcm*	*%v*	*%a*	*km²*
A. Gestro Wenz	29	44.6	18.7	28,300
B. Genele Wenz	33	50.8	38.1	57,500
C. Dawa Wenz	3	4.6	34.5	52,100
D. Middle Jubba	0	0.0	8.7	13,100
SUBCATCHMENT				
1. Upper Gestro	28	43.1	3.7	5,600
2. Middle Gestro	1	1.5	8.8	13,300
3. Lower Gestro	0	0.0	6.2	9,400
4. Upper Genele	26	40.0	7.8	11,800
5. Welmel	3	4.6	5.0	7,600
6. Dumal	3	4.6	4.5	6,800
7. NE Genele	1	1.5	5.4	8,100
8. Middle Genele	0	0.0	7.0	10,600
9. Lower Genele	0	0.0	8.3	12,600
10. Awata	2	3.1	5.0	7,600
11. Upper Dawa	1	1.5	8.3	12,600
12. Fudali	0	0.0	5.1	7,700
13. Middle Dawa	0	0.0	8.5	12,900
14. Lower Dawa	0	0.0	7.5	11,300
15. Middle Jubba	0	0.0	8.7	13,100
TOTALS	65	100.0	100.0	15,1000

OCTOBER

MAJOR CATCHMENT	*mcm*	*%v*	*%a*	*km²*
A. Gestro Wenz	20	11.9	18.7	28,300
B. Genele Wenz	89	53.0	38.1	57,500
C. Dawa Wenz	59	35.1	34.5	52,100
D. Middle Jubba	0	0.0	8.7	13,100
SUBCATCHMENT				
1. Upper Gestro	20	11.9	3.7	5,600
2. Middle Gestro	0	0.0	8.8	13,300
3. Lower Gestro	0	0.0	6.2	9,400
4. Upper Genele	44	26.2	7.8	11,800
5. Welmel	5	3.0	5.0	7,600
6. Dumal	0	0.0	4.5	6,800
7. NE Genele	3	1.8	5.4	8,100
8. Middle Genele	23	13.7	7.0	10,600
9. Lower Genele	14	8.3	8.3	12,600
10. Awata	11	6.5	5.0	7,600
11. Upper Dawa	14	8.3	8.3	12,600
12. Fudali	1	0.6	5.1	7,700
13. Middle Dawa	23	13.7	8.5	12,900
14. Lower Dawa	10	6.0	7.5	11,300
15. Middle Jubba	0	0.0	8.7	13,100
TOTALS	168	100.0	100.0	151,000

NOVEMBER

MAJOR CATCHMENT	*mcm*	*%v*	*%a*	*km²*
A. Gestro Wenz	1	4.5	18.7	28,300
B. Genele Wenz	11	50.0	38.1	57,500
C. Dawa Wenz	10	45.5	34.5	52,100
D. Middle Jubba	0	0.0	8.7	13,100
SUBCATCHMENT				
1. Upper Gestro	1	4.5	3.7	5,600
2. Middle Gestro	0	0.0	8.8	13,300
3. Lower Gestro	0	0.0	6.2	9,400
4. Upper Genele	11	50.0	7.8	11,800
5. Welmel	0	0.0	5.0	7,600
6. Dumal	0	0.0	4.5	6,800
7. NE Genele	0	0.0	5.4	8,100
8. Middle Genele	0	0.0	7.0	10,600
9. Lower Genele	0	0.0	8.3	12,600
10. Awata	3	13.6	5.0	7,600
11. Upper Dawa	5	22.7	8.3	12,600
12. Fudali	0	0.0	5.1	7,700
13. Middle Dawa	0	0.0	8.5	12,900
14. Lower Dawa	2	9.1	7.5	11,300
15. Middle Jubba	0	0.0	8.7	13,100
TOTALS	22	100.0	100.0	151,000

Table 14. Monthly Rain Surplus Above Soil Storage

APRIL

MAJOR CATCHMENT	*mcm*	*%v*	*%a*	*km²*
A. Gestro Wenz	54	19.4	18.7	28,300
B. Genele Wenz	169	60.6	38.1	57,500
C. Dawa Wenz	56	20.1	34.5	52,100
D. Middle Jubba	0	0.0	8.7	13,100
SUBCATCHMENT				
1. Upper Gestro	54	19.4	3.7	5,600
2. Middle Gestro	0	0.0	8.8	13,300
3. Lower Gestro	0	0.0	6.2	9,400
4. Upper Genele	109	39.1	7.8	11,800
5. Welmel	23	8.2	5.0	7,600
6. Dumal	6	2.2	4.5	6,800
7. NE Genele	0	0.0	5.4	8,100
8. Middle Genele	31	11.1	7.0	10,600
9. Lower Genele	0	0.0	8.3	12,600
10. Awata	8	2.9	5.0	7,600
11. Upper Dawa	20	7.2	8.3	12,600
12. Fudali	0	0.0	5.1	7,700
13. Middle Dawa	28	10.0	8.5	12,900
14. Lower Dawa	0	0.0	7.5	11,300
15. Middle Jubba	0	0.0	8.7	13,100
TOTALS	279	100.0	100.0	151,000

JUNE

MAJOR CATCHMENT	*mcm*	*%v*	*%a*	*km²*
A. Gestro Wenz	17	13.1	18.7	28,300
B. Genele Wenz	58	44.6	38.1	57,500
C Dawa Wenz	55	42.3	34.5	52,100
D. Middle Jubba	0	0.0	8.7	13,100
SUBCATCHMENT				
1. Upper Gestro	17	13.1	3.7	5,600
2. Middle Gestro	0	0.0	8.8	13,300
3. Lower Gestro	0	0.0	6.2	9,400
4. Upper Genele	56	43.1	7.8	11,800
5. Welmel	2	1.5	5.0	7,600
6. Dumal	0	0.0	4.5	6,800
7. NE Genele	0	0.0	5.4	8,100
8. Middle Genele	0	0.0	7.0	10,600
9. Lower Genele	0	0.0	8.3	12,600
10. Awata	40	30.8	5.0	7,600
11. Upper Dawa	15	11.5	8.3	12,600
12. Fudali	0	0.0	5.1	7,700
13. Middle Dawa	0	0.0	8.5	12,900
14. Lower Dawa	0	0.0	7.5	11,300
15. Middle Jubba	0	0.0	8.7	13,100
TOTALS	130	100.0	100.0	151,000

MAY

MAJOR CATCHMENT	*mcm*	*%v*	*%a*	*km²*
A. Gestro Wenz	82	4.4	18.7	28,300
B. Genele Wenz	1043	55.5	38.1	57,500
C. Dawa Wenz	755	40.2	34.5	52,100
D. Middle Jubba	0	0.0	8.7	13,100
SUBCATCHMENT				
1. Upper Gestro	82	4.4	3.7	5,600
2. Middle Gestro	0	0.0	8.8	13,300
3. Lower Gestro	0	0.0	6.2	9,400
4. Upper Genele	635	33.8	7.8	11,800
5. Welmel	262	13.9	5.0	7,600
6. Dumal	31	1.6	4.5	6,800
7. NE Genele	1	0.1	5.4	8,100
8. Middle Genele	114	6.1	7.0	10,600
9. Lower Genele	0	0.0	8.3	12,600
10. Awata	330	17.6	5.0	7,600
11. Upper Dawa	279	14.8	8.3	12,600
12. Fudali	0	0.0	5.1	7,700
13. Middle Dawa	146	7.8	8.5	12,900
14. Lower Dawa	0	0.0	7.5	11,300
15. Middle Jubba	0	0.0	8.7	13,100
TOTALS	1880	100.0	100.0	151,000

JULY

MAJOR CATCHMENT	*mcm*	*%v*	*%a*	*km²*
A. Gestro Wenz	87	28.1	18.7	28,300
B. Genele Wenz	162	52.3	38.1	57,500
C. Dawa Wenz	61	19.7	34.5	52,100
D. Middle Jubba	0	0.0	8.7	13,100
SUBCATCHMENT				
1. Upper Gestro	87	28.1	3.7	5,600
2. Middle Gestro	0	0.0	8.8	13,300
3. Lower Gestro	0	0.0	6.2	9,400
4. Upper Genele	149	48.1	7.8	11,800
5. Welmel	13	4.2	5.0	7,600
6. Dumal	0	0.0	4.5	6,800
7. NE Genele	0	0.0	5.4	8,100
8. Middle Genele	0	0.0	7.0	10,600
9. Lower Genele	0	0.0	8.3	12,600
10. Awata	60	19.4	5.0	7,600
11. Upper Dawa	1	0.3	8.3	12,600
12. Fudali	0	0.0	5.1	7,700
13. Middle Dawa	0	0.0	8.5	12,900
14. Lower Dawa	0	0.0	7.5	11,300
15. Middle Jubba	0	0.0	8.7	13,100
TOTALS	310	100.0	100.0	151,000

mcm = million cubic meters
%v = percent of total volume
%a = percent of total area

Table 14. Continued...

AUGUST

MAJOR CATCHMENT	mcm	%v	%a	km²
A. Gestro Wenz	133	32.1	18.7	28,300
B. Genele Wenz	217	52.4	38.1	57,500
C. Dawa Wenz	64	15.5	34.5	52,100
D. Middle Jubba	0	0.0	8.7	13,100
SUBCATCHMENT				
1. Upper Gestro	133	32.1	3.7	5,600
2. Middle Gestro	0	0.0	8.8	13,300
3. Lower Gestro	0	0.0	6.2	9,400
4. Upper Genele	186	44.9	7.8	11,800
5. Welmel	27	6.5	5.0	7,600
6. Dumal	4	1.0	4.5	6,800
7. NE Genele	0	0.0	5.4	8,100
8. Middle Genele	0	0.0	7.0	10,600
9. Lower Genele	0	0.0	8.3	12,600
10. Awata	63	15.2	5.0	7,600
11. Upper Dawa	1	0.2	8.3	12,600
12. Fudali	0	0.0	5.1	7,700
13. Middle Dawa	0	0.0	8.5	12,900
14. Lower Dawa	0	0.0	7.5	11,300
15. Middle Jubba	0	0.0	8.7	13,100
TOTALS	414	100.0	100.0	151,000

SEPTEMBER

MAJOR CATCHMENT	mcm	%v	%a	km²
A. Gestro Wenz	153	33.3	18.7	28,300
B. Genele Wenz	244	53.2	38.1	57,500
C. Dawa Wenz	62	13.5	34.5	52,100
D. Middle Jubba	0	0.0	8.7	13,100
SUBCATCHMENT				
1 Upper Gestro	153	33.3	3.7	5,600
2. Middle Gestro	0	0.0	8.8	13,300
3. Lower Gestro	0	0.0	6.2	9,400
4. Upper Genele	191	41.6	7.8	11,800
5. Welmel	41	8.9	5.0	7,600
6. Dumal	12	2.6	4.5	6,800
7. NE Genele	0	0.0	5.4	8,100
8. Middle Genele	0	0.0	7.0	10,600
9. Lower Genele	0	0.0	8.3	12,600
10. Awata	59	12.9	5.0	7,600
11. Upper Dawa	3	0.7	8.3	12,600
12. Fudali	0	0.0	5.1	7,700
13. Middle Dawa	0	0.0	8.5	12,900
14. Lower Dawa	0	0.0	7.5	11,300
15. Middle Jubba	0	0.0	8.7	13,100
TOTALS	459	100.0	100.0	151,000

OCTOBER

MAJOR CATCHMENT	mcm	%v	%a	km²
A. Gestro Wenz	108	23.2	18.7	28,300
B. Genele Wenz	242	51.9	38.1	57,500
C. Dawa Wenz	116	24.9	34.5	52,100
D. Middle Jubba	0	0.0	8.7	13,100
SUBCATCHMENT				
1. Upper Gestro	108	23.2	3.7	5,600
2. Middle Gestro	0	0.0	8.8	13,300
3. Lower Gestro	0	0.0	6.2	9,400
4. Upper Genele	206	44.2	7.8	11,800
5. Welmel	27	5.8	5.0	7,600
6. Dumal	7	1.5	4.5	6,800
7. NE Genele	0	0.0	5.4	8,100
8. Middle Genele	2	0.4	7.0	10,600
9. Lower Genele	0	0.0	8.3	12,600
10. Awata	96	20.6	5.0	7,600
11. Upper Dawa	20	4.3	8.3	12,600
12. Fudali	0	0.0	5.1	7,700
13. Middle Dawa	0	0.0	8.5	12,900
14. Lower Dawa	0	0.0	7.5	11,300
15. Middle Jubba	0	0.0	8.7	13,100
TOTALS	466	100.0	100.0	15,1000

NOVEMBER

MAJOR CATCHMENT	mcm	%v	%a	km²
A. Gestro Wenz	0	0.0	18.7	28,300
B. Genele Wenz	1	25.0	38.1	57,500
C. Dawa Wenz	3	75.0	34.5	52,100
D. Middle Jubba	0	0.0	8.7	13,100
SUBCATCHMENT				
1. Upper Gestro	0	0.0	3.7	5,600
2. Middle Gestro	0	0.0	8.8	13,300
3. Lower Gestro	0	0.0	6.2	9,400
4. Upper Genele	1	25.0	7.8	11,800
5. Welmel	0	0.0	5.0	7,600
6. Dumal	0	0.0	4.5	6,800
7. NE Genele	0	0.0	5.4	8,100
8. Middle Genele	0	0.0	7.0	10,600
9. Lower Genele	0	0.0	8.3	12,600
10. Awata	1	25.0	5.0	7,600
11. Upper Dawa	2	50.0	8.3	12,600
12. Fudali	0	0.0	5.1	7,700
13. Middle Dawa	0	0.0	8.5	12,900
14. Lower Dawa	0	0.0	7.5	11,300
15. Middle Jubba	0	0.0	8.7	13,100
TOTALS	4	100.0	100.0	151,000

Table 15. Monthly Total Surface Runoff Volumes

MARCH

MAJOR CATCHMENT		*mcm*	*%v*	*%a*	*km²*
A.	Gestro Wenz	12	27.3	18.7	28,300
B.	Genele Wenz	19	43.2	38.1	57,500
C.	Dawa Wenz	13	29.5	34.5	52,100
D.	Middle Jubba	0	0.0	8.7	13,100
SUBCATCHMENT					
1.	Upper Gestro	12	27.3	3.7	5,600
2.	Middle Gestro	0	0.0	8.8	13,300
3.	Lower Gestro	0	0.0	6.2	9,400
4.	Upper Genele	15	34.1	7.8	11,800
5.	Welmel	2	4.5	5.0	7,600
6.	Dumal	2	4.5	4.5	6,800
7.	NE Genele	0	0.0	5.4	8,100
8.	Middle Genele	0	0.0	7.0	10,600
9.	Lower Genele	0	0.0	8.3	12,600
10.	Awata	2	4.5	5.0	7,600
11.	Upper Dawa	9	20.5	8.3	12,600
12.	Fudali	2	4.5	5.1	7,700
13.	Middle Dawa	0	0.0	8.5	12,900
14.	Lower Dawa	0	0.0	7.5	11,300
15.	Middle Jubba	0	0.0	8.7	13,100
TOTALS		44	100.0	100.0	151,000

APRIL

MAJOR CATCHMENT		*mcm*	*%v*	*%a*	*km2*
A.	Gestro Wenz	141	17.1	18.7	28,300
B.	Genele Wenz	426	51.7	38.1	57,500
C.	Dawa Wenz	231	28.0	34.5	52,100
D.	Middle Jubba	26	3.2	8.7	13,100
SUBCATCHMENT					
1.	Upper Gestro	90	10.9	3.7	5,600
2.	Middle Gestro	25	3.0	8.8	13,300
3.	Lower Gestro	26	3.2	6.2	9,400
4.	Upper Genele	192	23.3	7.8	11,800
5.	Welmel	56	6.8	5.0	7,600
6.	Dumal	32	3.9	4.5	6,800
7.	NE Genele	19	2.3	5.4	8,100
8.	Middle Genele	83	10.1	7.0	10,600
9.	Lower Genele	44	5.3	8.3	12,600
10.	Awata	42	5.1	5.0	7,600
11.	Upper Dawa	63	7.6	8.3	12,600
12.	Fudali	11	1.3	5.1	7,700
13.	Middle Dawa	78	9.5	8.5	12,900
14.	Lower Dawa	37	4.5	7.5	11,300
15.	Middle Jubba	26	3.2	8.7	13,100
TOTALS		824	100.0	100.0	151,000

mcm = million cubic meters
%v = percent of total volume
%a = percent of total area

MAY

MAJOR CATCHMENT		*mcm*	*%v*	*%a*	*km²*
A.	Gestro Wenz	122	5.5	18.7	28,300
B.	Genele Wenz	1,241	55.8	38.1	57,500
C.	Dawa Wenz	863	38.8	34.5	52,100
D.	Middle Jubba	0	0.0	8.7	13,100
SUBCATCHMENT					
1.	Upper Gestro	108	4.9	3.7	5,600
2.	Middle Gestro	13	0.6	8.8	13,300
3.	Lower Gestro	1	0.0	6.2	9,400
4.	Upper Genele	709	31.9	7.8	11,800
5.	Welmel	291	13.1	5.0	7,600
6.	Dumal	56	2.5	4.5	6,800
7.	NE Genele	18	0.8	5.4	8,100
8.	Middle Genele	150	6.7	7.0	10,600
9.	Lower Genele	17	0.8	8.3	12,600
10.	Awata	360	16.2	5.0	7,600
11.	Upper Dawa	315	14.2	8.3	12,600
12.	Fudali	6	0.3	5.1	7,700
13.	Middle Dawa	173	7.8	8.5	12,900
14.	Lower Dawa	9	0.4	7.5	11,300
15.	Middle Jubba	0	0.0	8.7	13,100
TOTALS		2,226	100.0	100.0	151,000

JUNE

MAJOR CATCHMENT		*mcm*	*%v*	*%a*	*km2*
A.	Gestro Wenz	25	15.4	18.7	28,300
B.	Genele Wenz	75	46.3	38.1	57,500
C.	Dawa Wenz	62	38.3	34.5	52,100
D.	Middle Jubba	0	0.0	8.7	13,100
SUBCATCHMENT					
1.	Upper Gestro	25	15.4	3.7	5,600
2.	Middle Gestro	0	0.0	8.8	13,300
3.	Lower Gestro	0	0.0	6.2	9,400
4.	Upper Genele	73	45.1	7.8	11,800
5.	Welmel	2	1.2	5.0	7,600
6.	Dumal	0	0.0	4.5	6,800
7.	NE Genele	0	0.0	5.4	8,100
8.	Middle Genele	0	0.0	7.0	10,600
9.	Lower Genele	0	0.0	8.3	12,600
10.	Awata	42	25.9	5.0	7,600
11.	Upper Dawa	20	12.3	8.3	12,600
12.	Fudali	0	0.0	5.1	7,700
13.	Middle Dawa	0	0.0	8.5	12,900
14.	Lower Dawa	0	0.0	7.5	11,300
15.	Middle Jubba	0	0.0	8.7	13,100
TOTALS		162	100.0	100.0	15,1000

Table 15. Continued...

JULY

MAJOR CATCHMENT		*mcm*	*%v*	*%a*	*km²*
A.	Gestro Wenz	107	30.0	18.7	28,300
B.	Genele Wenz	188	52.7	38.1	57,500
C.	Dawa Wenz	62	17.4	34.5	52,100
D.	Middle Jubba	0	0.0	8.7	13,100
SUBCATCHMENT					
1.	Upper Gestro	107	30.0	3.7	5,600
2.	Middle Gestro	0	0.0	8.8	13,300
3.	Lower Gestro	0	0.0	6.2	9,400
4.	Upper Genele	172	48.2	7.8	11,800
5.	Welmel	16	4.5	5.0	7,600
6.	Dumal	0	0.0	4.5	6,800
7.	NE Genele	0	0.0	5.4	8,100
8.	Middle Genele	0	0.0	7.0	10,600
9	Lower Genele	0	0.0	8.3	12,600
10.	Awata	61	17.1	5.0	7,600
11.	Upper Dawa	1	0.3	8.3	12,600
12.	Fudali	0	0.0	5.1	7,700
13.	Middle Dawa	0	0.0	8.5	12,900
14.	Lower Dawa	0	0.0	7.5	11,300
15.	Middle Jubba	0	0.0	8.7	13,100
TOTALS		357	100.0	100.0	151,000

AUGUST

MAJOR CATCHMENT		*mcm*	*%v*	*%a*	*km²*
A.	Gestro Wenz	163	34.3	18.7	28,300
B.	Genele Wenz	246	51.8	38.1	57,500
C.	Dawa Wenz	66	13.9	34.5	52,100
D.	Middle Jubba	0	0.0	8.7	13,100
SUBCATCHMENT					
1.	Upper Gestro	162	34.1	3.7	5,600
2.	Middle Gestro	1	0.2	8.8	13,300
3.	Lower Gestro	0	0.0	6.2	9,400
4.	Upper Genele	211	44.4	7.8	11,800
5.	Welmel	29	6.1	5.0	7,600
6.	Dumal	5	1.1	4.5	6,800
7.	NE Genele	1	0.2	5.4	8,100
8.	Middle Genele	0	0.0	7.0	10,600
9.	Lower Genele	0	0.0	8.3	12,600
10.	Awata	65	13.7	5.0	7,600
11.	Upper Dawa	1	0.2	8.3	12,600
12.	Fudali	0	0.0	5.1	7,700
13.	Middle Dawa	0	0.0	8.5	12,900
14.	Lower Dawa	0	0.0	7.5	11,300
15.	Middle Jubba	0	0.0	8.7	13,100
TOTALS		475	100.0	100.0	151,000

SEPTEMBER

MAJOR CATCHMENT		*mcm*	*%v*	*%a*	*km²*
A.	Gestro Wenz	182	34.5	18.7	28,300
B.	Genele Wenz	278	52.8	38.1	57,500
C.	Dawa Wenz	67	12.7	34.5	52,100
D.	Middle Jubba	0	0.0	8.7	13,100
SUBCATCHMENT					
1.	Upper Gestro	181	34.3	3.7	5,600
2.	Middle Gestro	1	0.2	8.8	13,300
3.	Lower Gestro	0	0.0	6.2	9,400
4.	Upper Genele	218	41.4	7.8	11,800
5.	Welmel	44	8.3	5.0	7,600
6.	Dumal	15	2.8	4.5	6,800
7.	NE Genele	1	0.2	5.4	8,100
8.	Middle Genele	0	0.0	7.0	10,600
9.	Lower Genele	0	0.0	8.3	12,600
10.	Awata	64	12.1	5.0	7,600
11.	Upper Dawa	3	0.6	8.3	12,600
12.	Fudali	0	0.0	5.1	7,700
13.	Middle Dawa	0	0.0	8.5	12,900
14.	Lower Dawa	0	0.0	7.5	11,300
15.	Middle Jubba	0	0.0	8.7	13,100
TOTALS		527	100.0	100.0	151,000

OCTOBER

MAJOR CATCHMENT		*mcm*	*%v*	*%a*	*km²*
A.	Gestro Wenz	127	20.2	18.7	28,300
B.	Genele Wenz	330	52.4	38.1	57,500
C.	Dawa Wenz	173	27.5	34.5	52,100
D.	Middle Jubba	0	0.0	8.7	13,100
SUBCATCHMENT					
1.	Upper Gestro	127	20.2	3.7	5,600
2.	Middle Gestro	0	0.0	8.8	13,300
3.	Lower Gestro	0	0.0	6.2	9,400
4.	Upper Genele	249	39.5	7.8	11,800
5.	Welmel	32	5.1	5.0	7,600
6.	Dumal	8	1.3	4.5	6,800
7.	NE Genele	3	0.5	5.4	8,100
8.	Middle Genele	24	3.8	7.0	10,600
9.	Lower Genele	14	2.2	8.3	12,600
10.	Awata	105	16.7	5.0	7,600
11.	Upper Dawa	34	5.4	8.3	12,600
12.	Fudali	1	0.2	5.1	7,700
13.	Middle Dawa	23	3.7	8.5	12,900
14.	Lower Dawa	10	1.6	7.5	11,300
15.	Middle Jubba	0	0.0	8.7	13,100
TOTALS		630	100.0	100.0	151,000

NOVEMBER

MAJOR CATCHMENT		*mcm*	*%v*	*%a*	*km2*
A.	Gestro Wenz	1	3.8	18.7	28,300
B.	Genele Wenz	12	46.2	38.1	57,500
C.	Dawa Wenz	13	50.0	34.5	52,100
D.	Middle Jubba	0	0.0	8.7	13,100
SUBCATCHMENT					
1.	Upper Gestro	1	3.8	3.7	5,600
2.	Middle Gestro	0	0.0	8.8	13,300
3.	Lower Gestro	0	0.0	6.2	9,400
4.	Upper Genele	12	46.2	7.8	11,800
5.	Welmel	0	0.0	5.0	7,600
6.	Dumal	0	0.0	4.5	6,800
7.	NE Genele	0	0.0	5.4	8,100
8.	Middle Genele	0	0.0	7.0	10,600
9.	Lower Genele	0	0.0	8.3	12,600
10.	Awata	4	15.4	5.0	7,600
11.	Upper Dawa	7	26.9	8.3	12,600
12.	Fudali	0	0.0	5.1	7,700
13.	Middle Dawa	0	0.0	8.5	12,900
14.	Lower Dawa	2	7.7	7.5	11,300
15.	Middle Jubba	0	0.0	8.7	13,100
TOTALS		26	100.0	100.0	151,000

Imagery Generated by Computer Models Used in Upper Jubba Catchment Performance Study—Appendix B

No.	*Title*
1	Elevation
2	Elevation Detail - Western Portion
3	Elevation Detail - Eastern Portion
4	Jubba Subcatchments
5	Seasonal Flow Volumes at Luuq
6	Elevation as 10 x 10 km Means
7	Met Station Mean Monthly Rainfall
8	Met Station Mean Monthly Potential Evapotranspiration
9	Geomorphology/Soils Complexes
10	Vegetation and Land Use
11	Distance from Key Met Stations
12	Long-term Mean Annual Rainfall
13	Monthly Rainfall Volume
14	Long-term Monthly Rainfall Surfaces
15	Average Monthly Potential Evapotranspiration
16	Interception by Vegetation
17	Terrain Slope
18	Storm Runoff Potential
19	Runoff from Rainfall Intensity above Infiltration
20	Net Rainfall or Evaporation for Soil Storage
21	Soil Field Capacity
22	Runoff from Rain Surplus above Soil Storage
23	Runoff Totals without Groundwater Sources
24	Long-term Average Soil Moisture
25	Monthly Surface Runoff Volume
26	Gestro Monthly Rainfall Volumes
27	Gestro Monthly Surface Runoff Volumes
28	Genele Monthly Rainfall Volumes
29	Genele Monthly Surface Runoff Volumes
30	Dawa Monthly Rainfall Volumes
31	Dawa Monthly Surface Runoff Volumes
32	Upper Jubba Catchment Performance
33	Catchment Rainfall, Surface Runoff, and Outflow


km
1x1 km cells are shown with
numbered rows and columns omitted

Figure 1


1400 1600 m
1600 1800 m
1800 2000 m
200 - 400 m
400 - 600 m
600 - 800 m

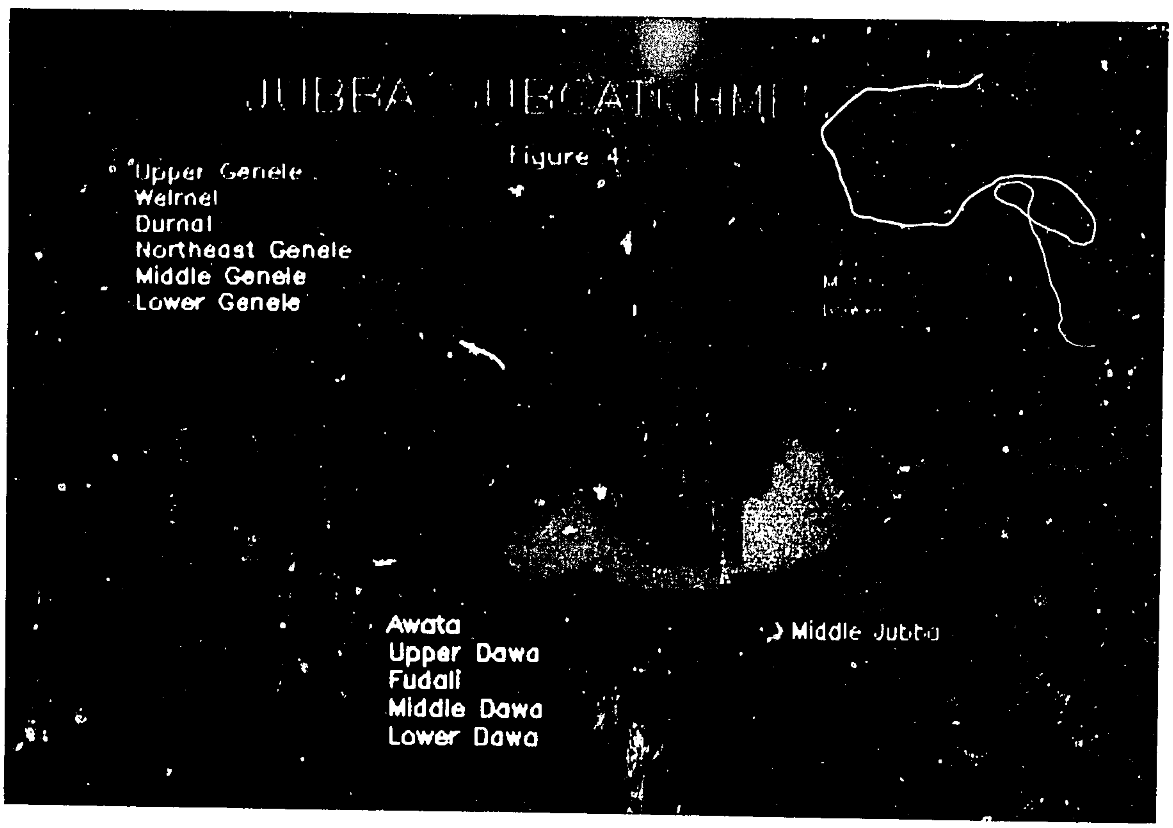


Figure 4
Upper Genele
Welmel
Dumal
Northeast Genele
Middle Genele
Lower Genele
Awata
Upper Dawa
Fudali
Middle Dawa
Lower Dawa
Middle Jubba

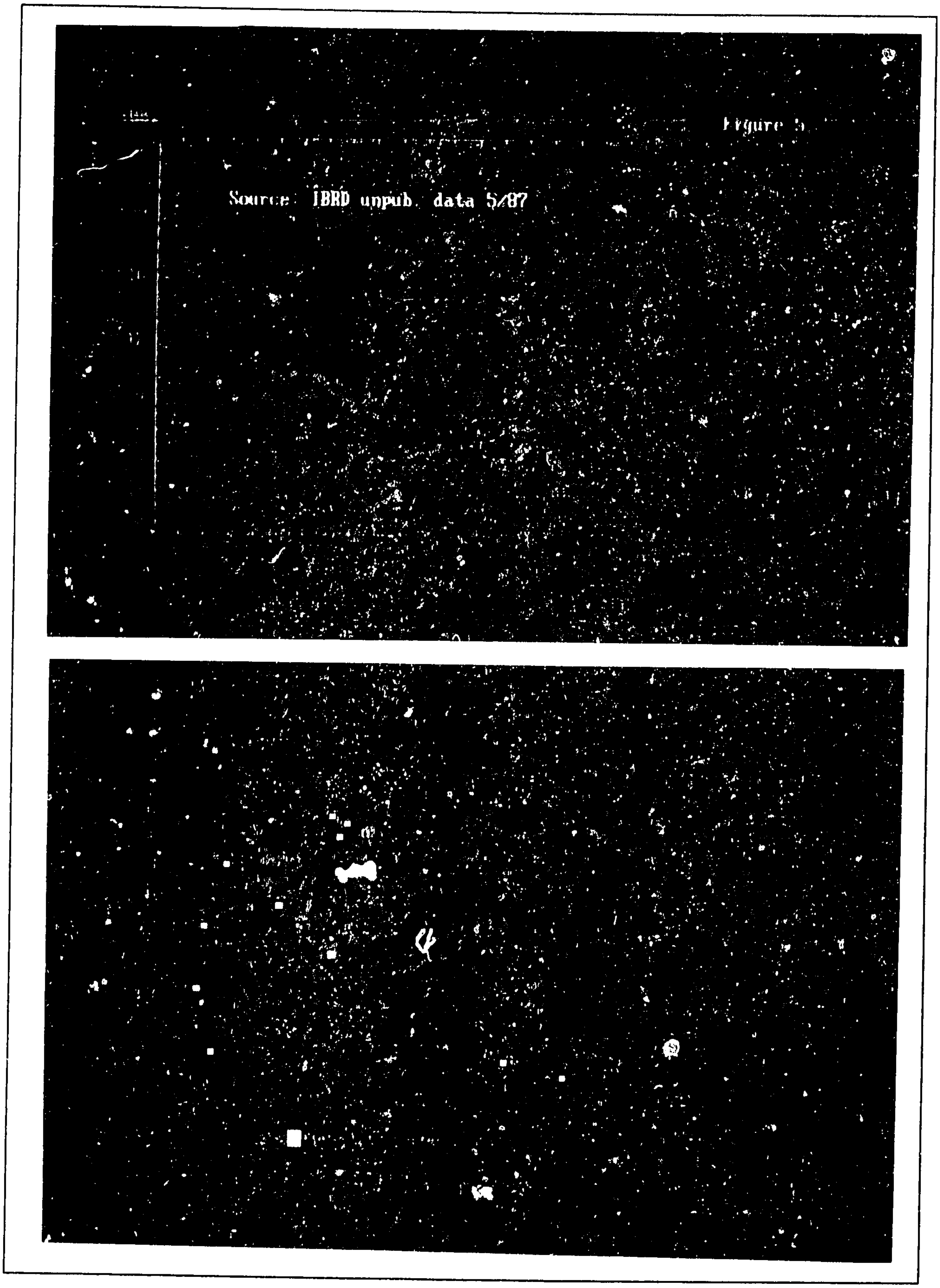
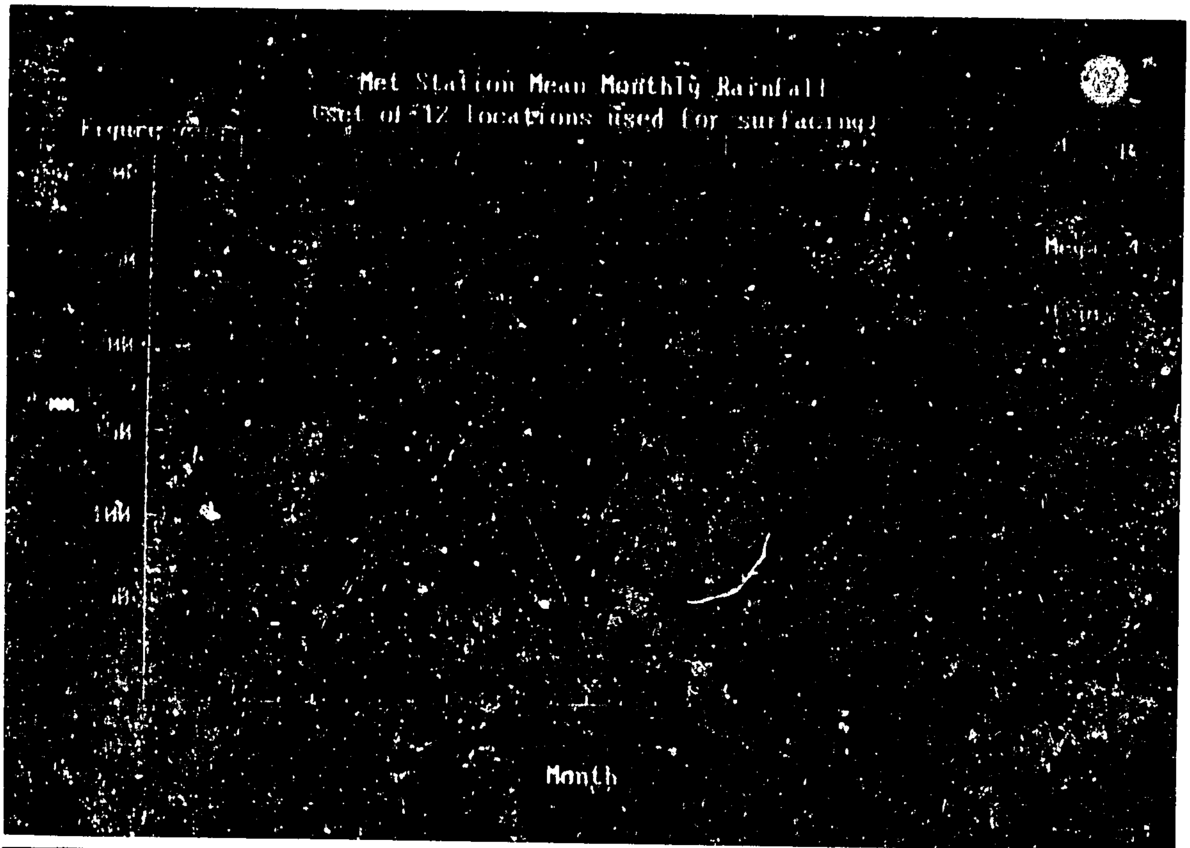
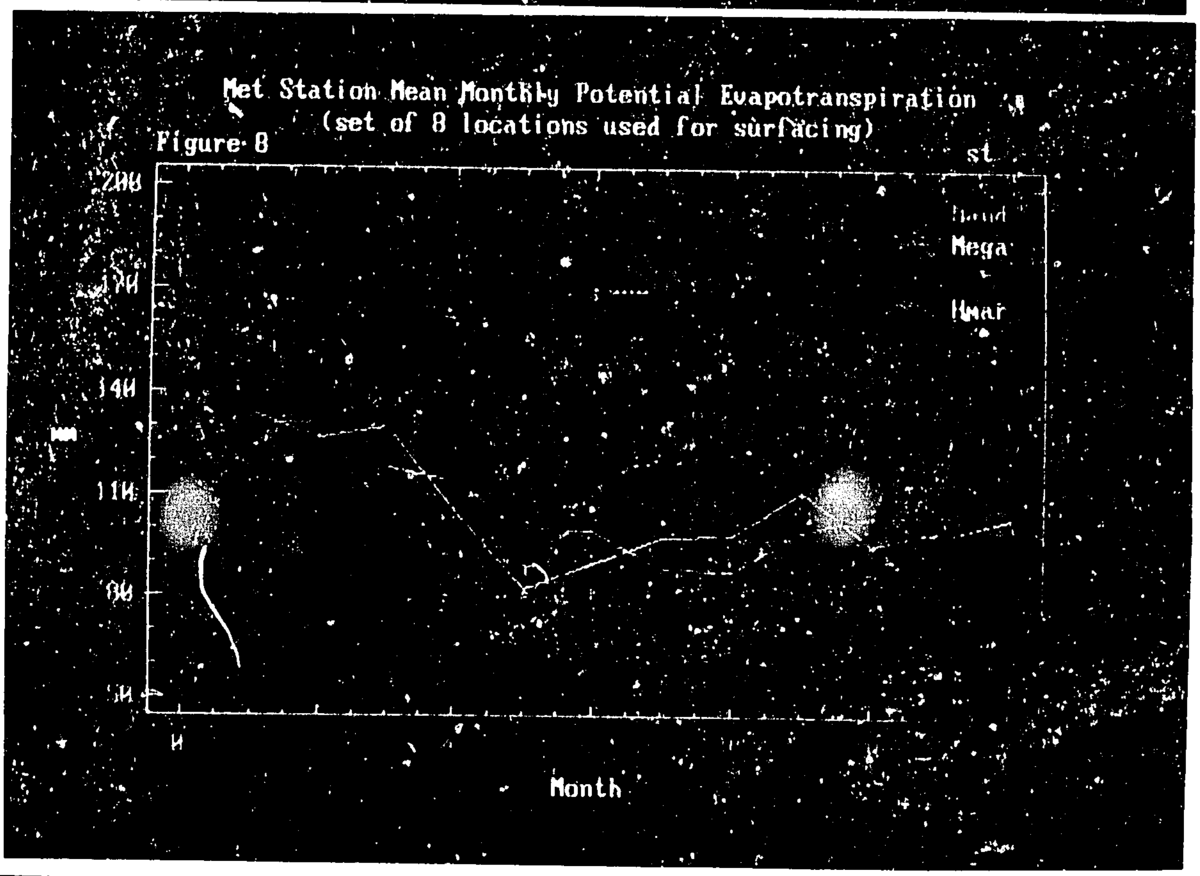
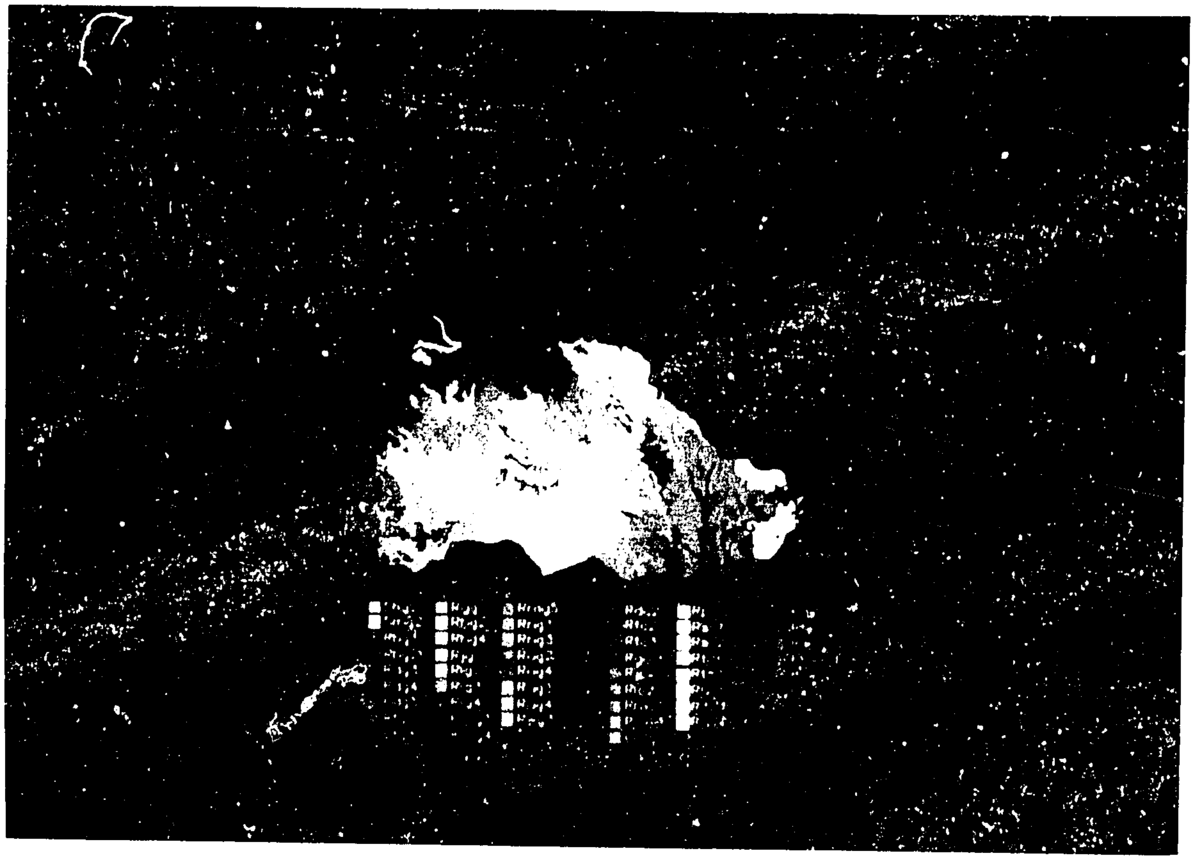
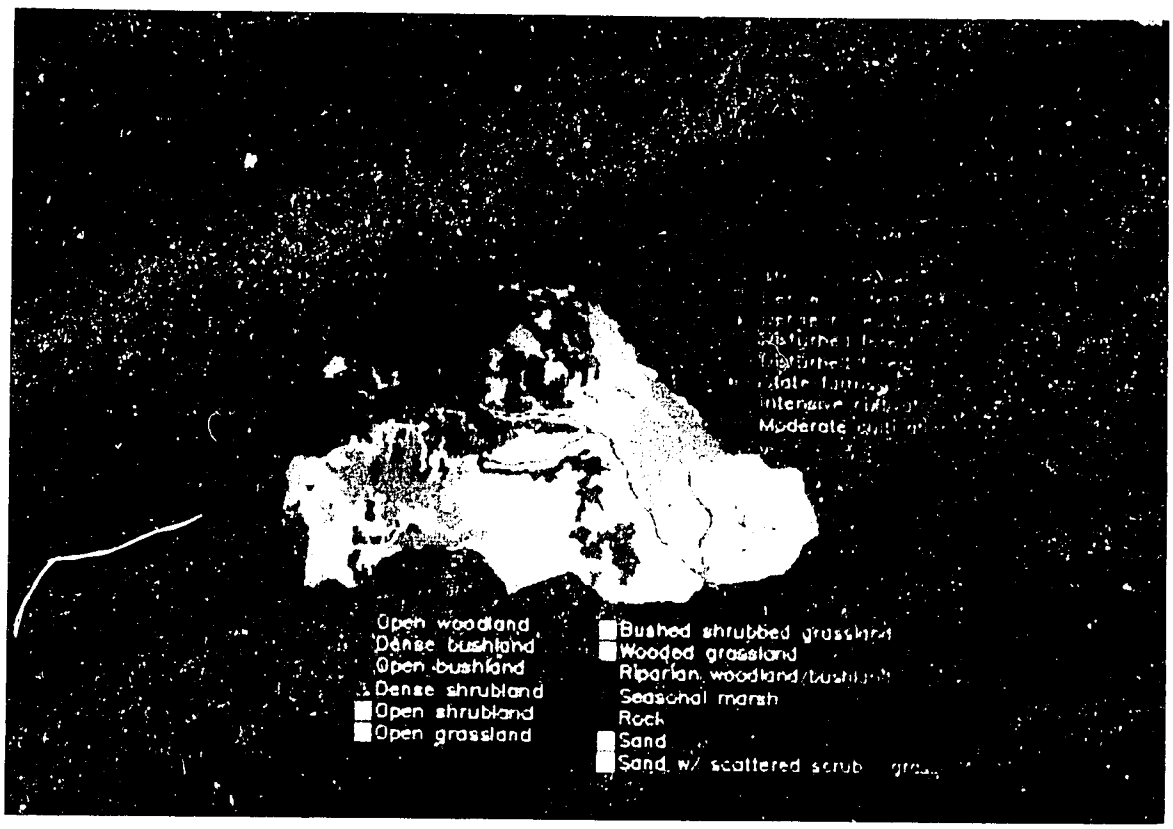


Figure 5
Source: IBRD unpub. data 5/87


Met Station Mean Monthly Rainfall
(set of 12 locations used for surfacing)
Month


Met Station Mean Monthly Potential Evapotranspiration
(set of 8 locations used for surfacing)
Figure 8
200
170
140
110
80
50
Mega
Month




Open woodland
Dense bushland
Open bushland
Dense shrubland
Open shrubland
Open grassland
Bushed shrubbed
Wooded grassland
Riparian woodland/
Seasonal marsh
Rock
Sand
Sand w/ scattered scrub

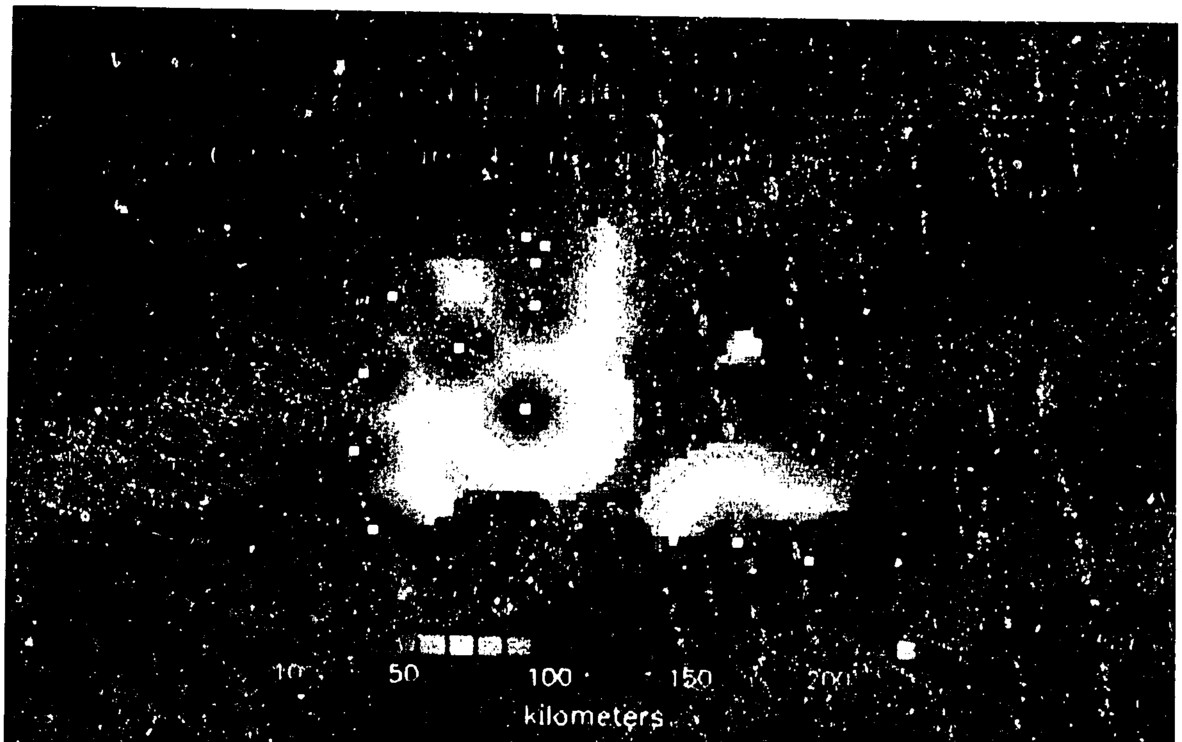


Figure 11

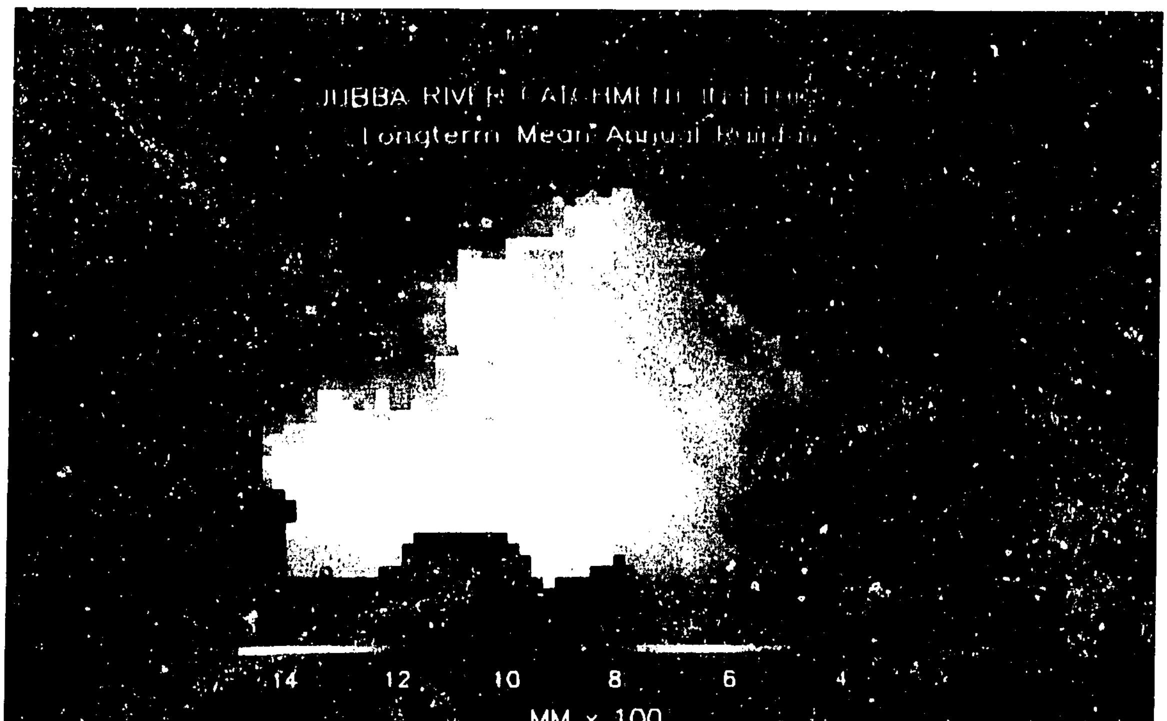
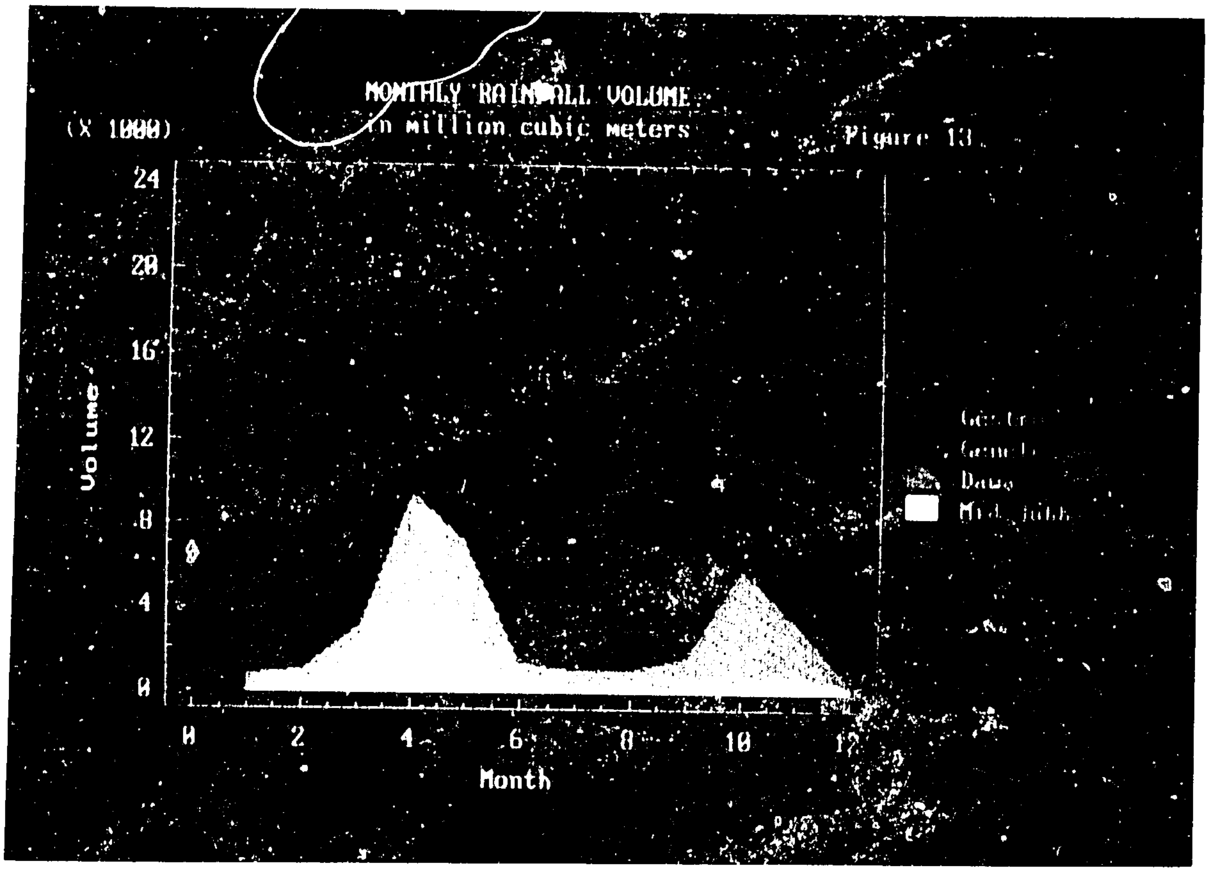
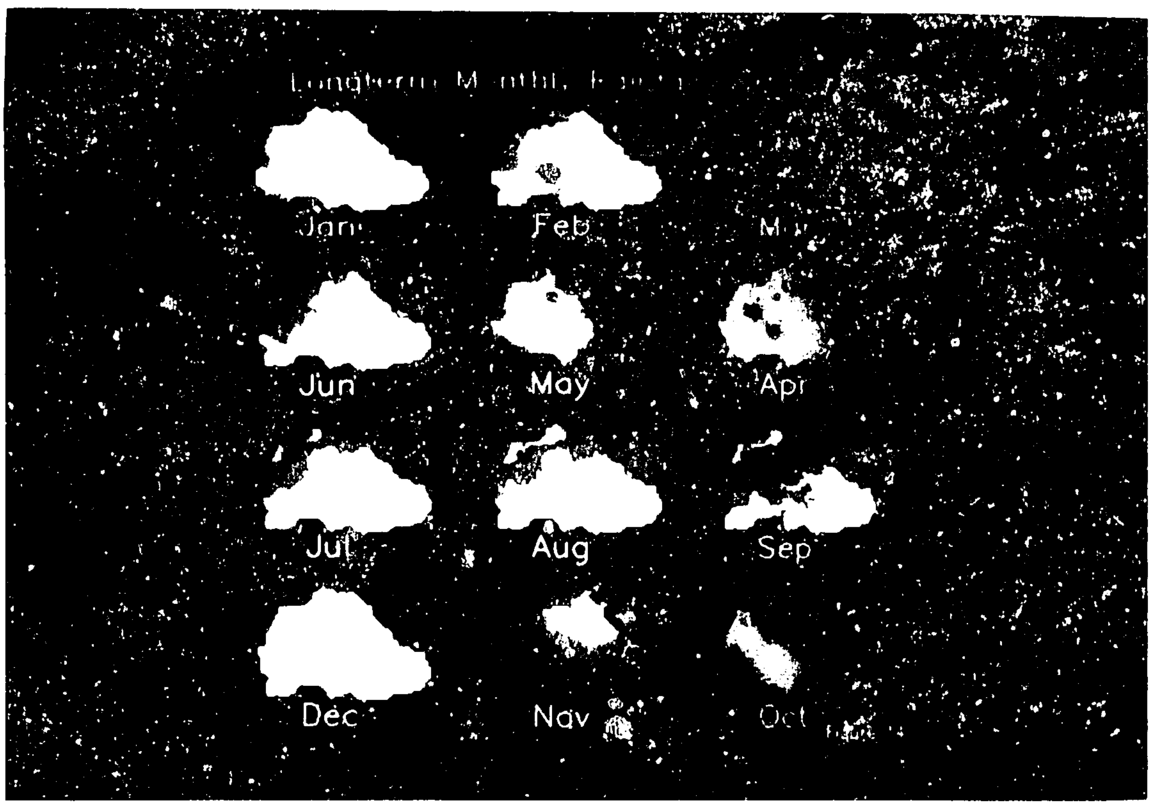
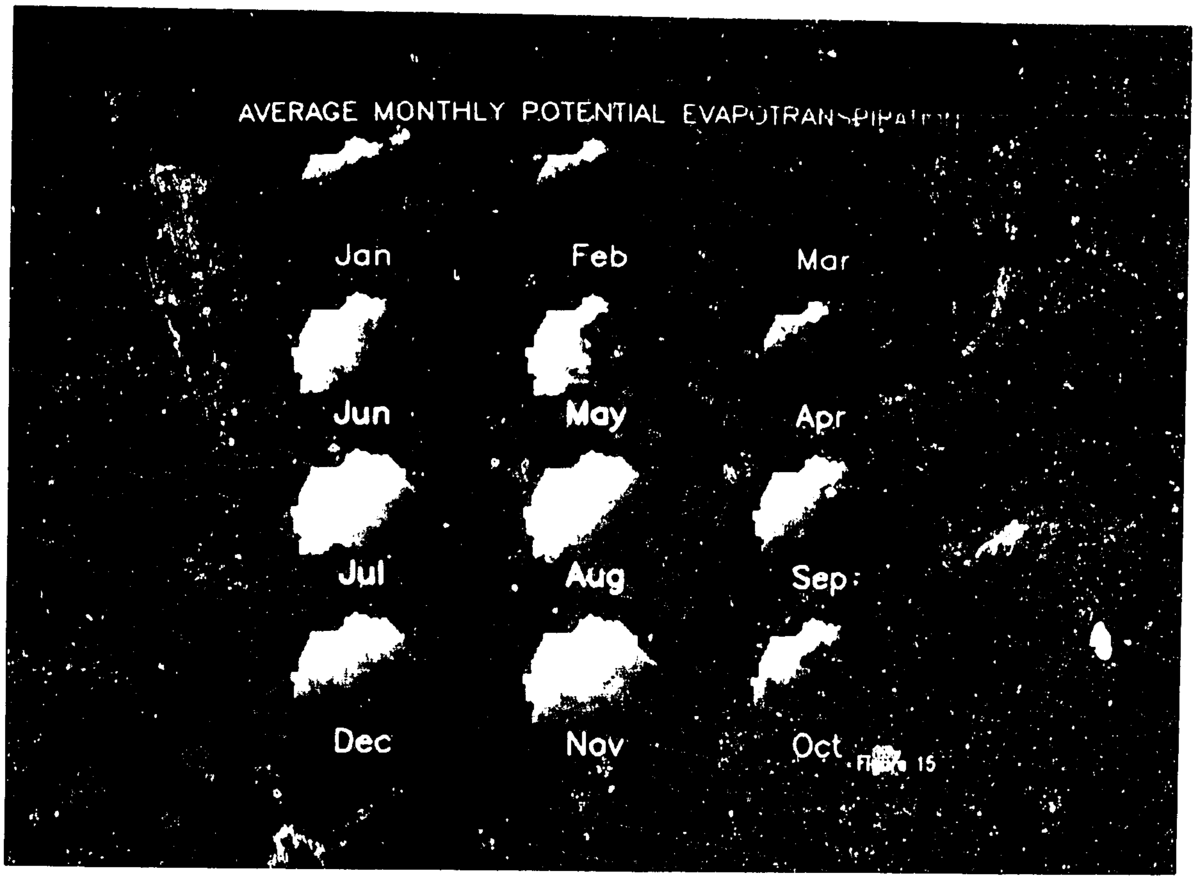
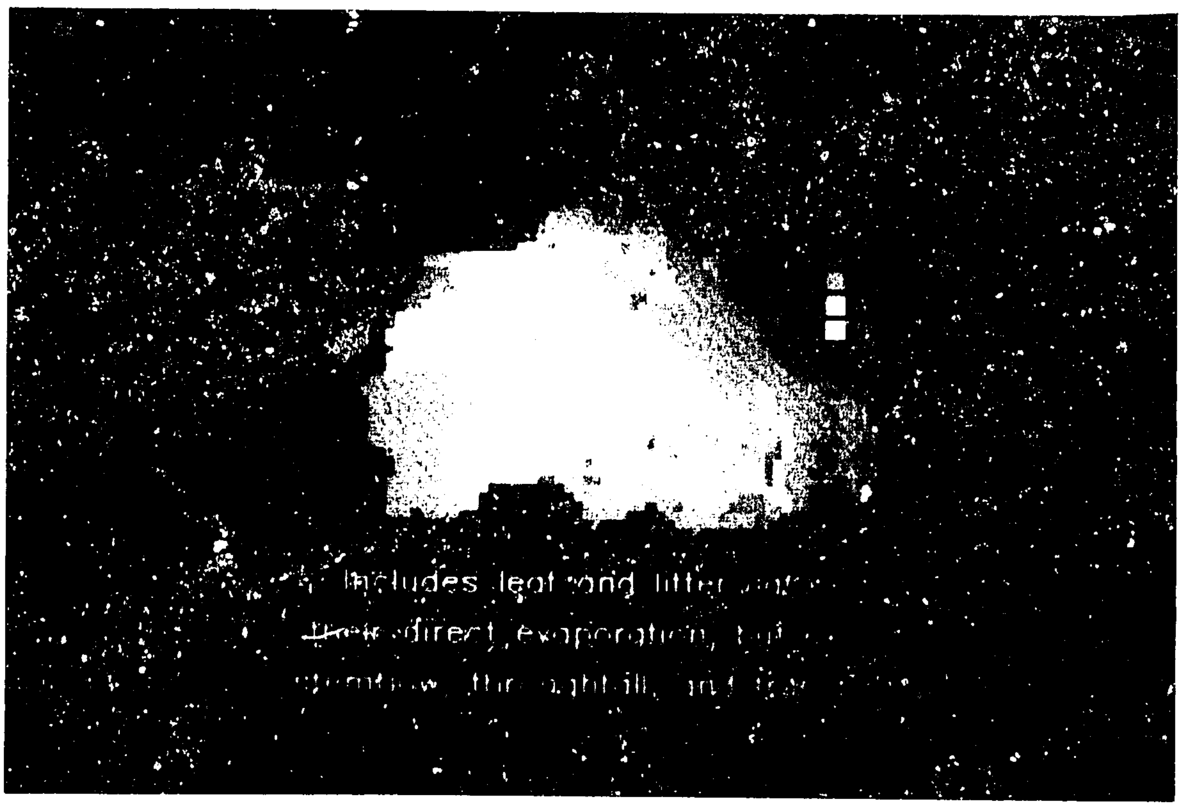


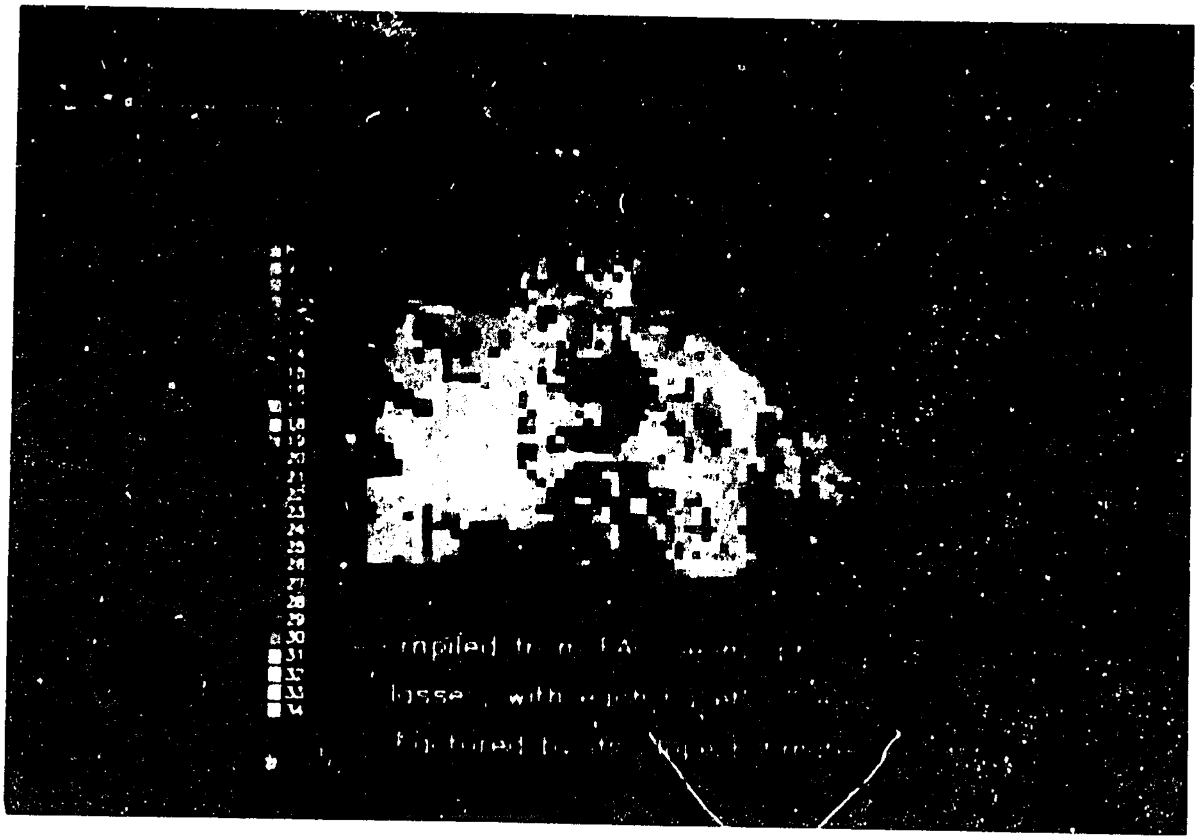
Figure 12

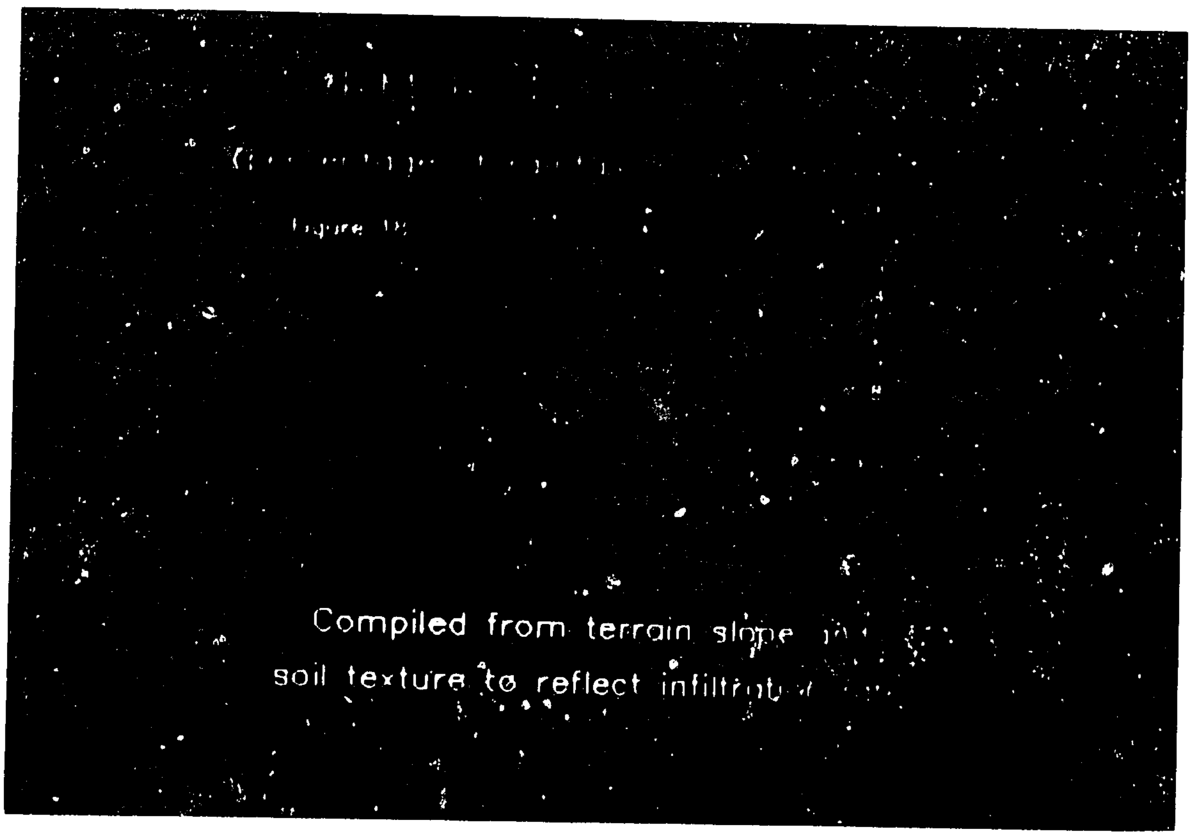

MONTHLY RAINFALL VOLUME
(X 1000)
in million cubic meters
Figure 13
24
20
16
12
8
4
0
Volume
0
2
4
6
8
10
12
Month
Dawa

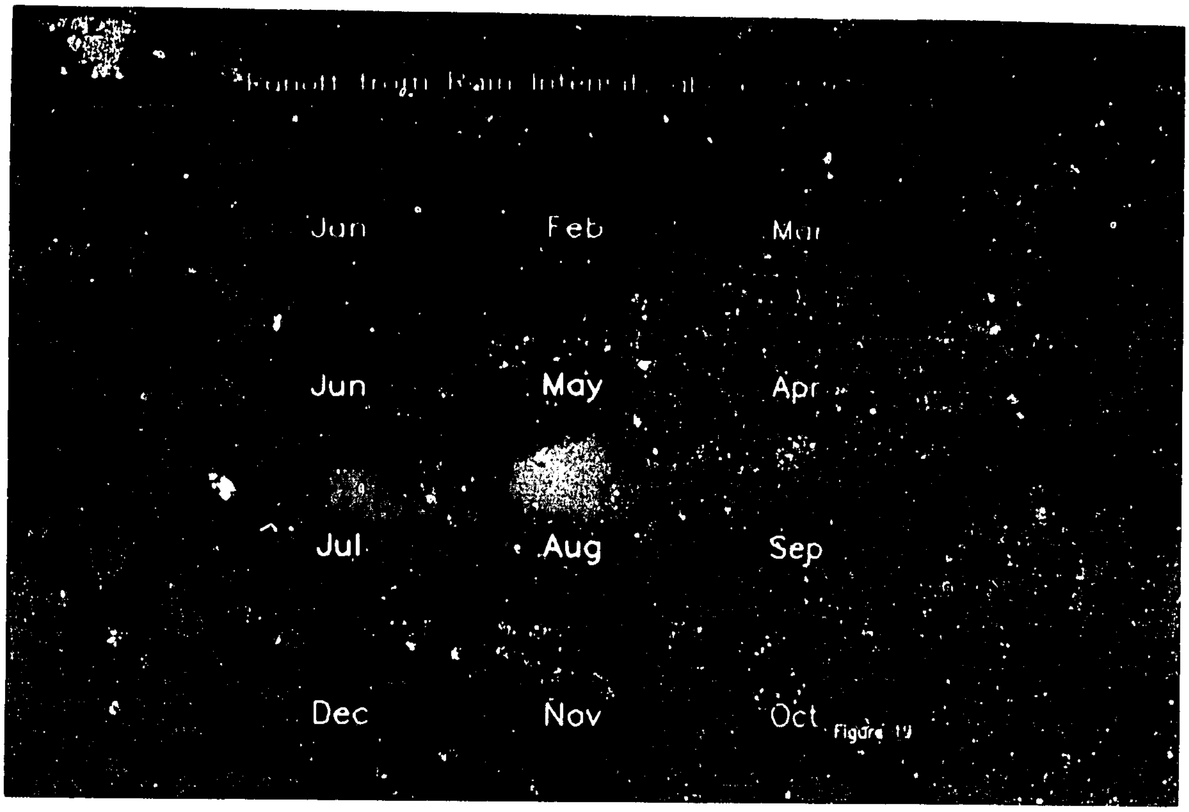

Jan
Feb
Jun
May
Apr
Jul
Aug
Sep
Dec
Nov
Oct

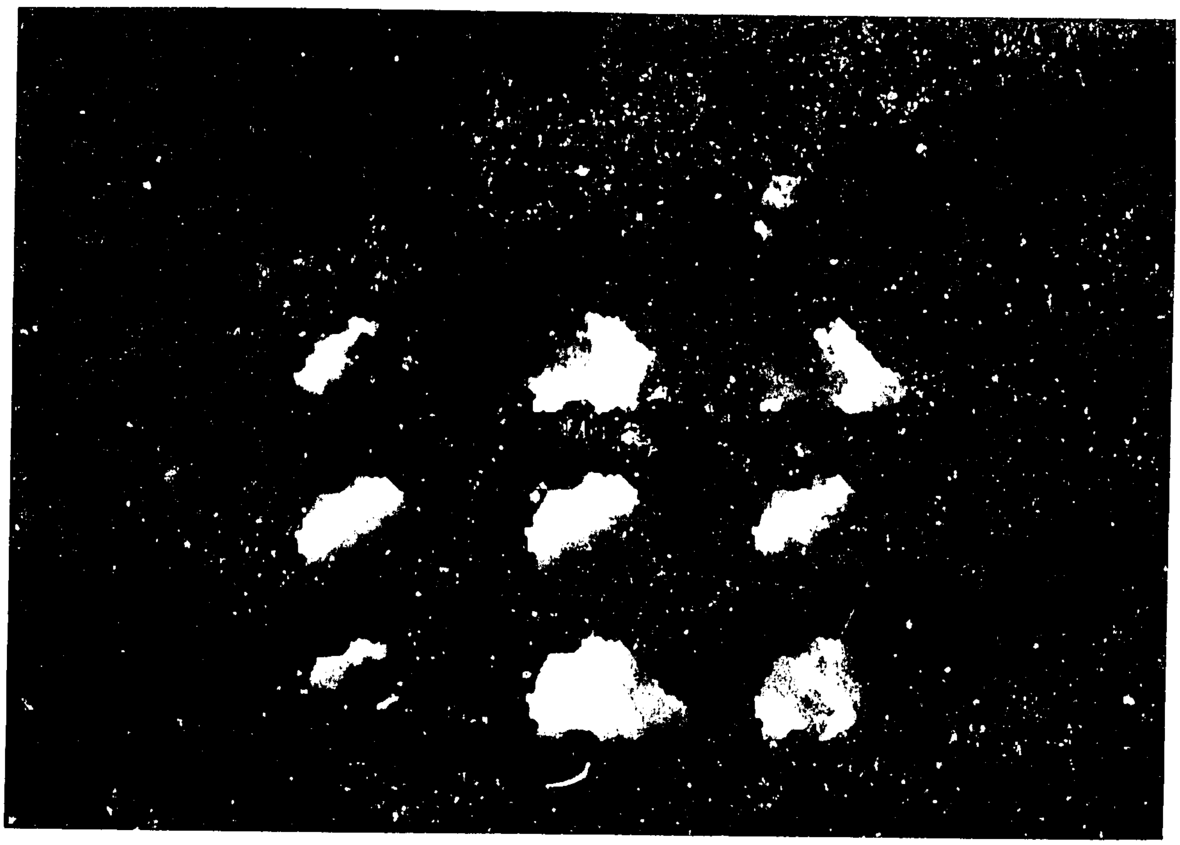

AVERAGE MONTHLY POTENTIAL
Jan
Feb
Mar
Jun
May
Apr
Jul
Aug
Sep
Dec
Nov
Oct

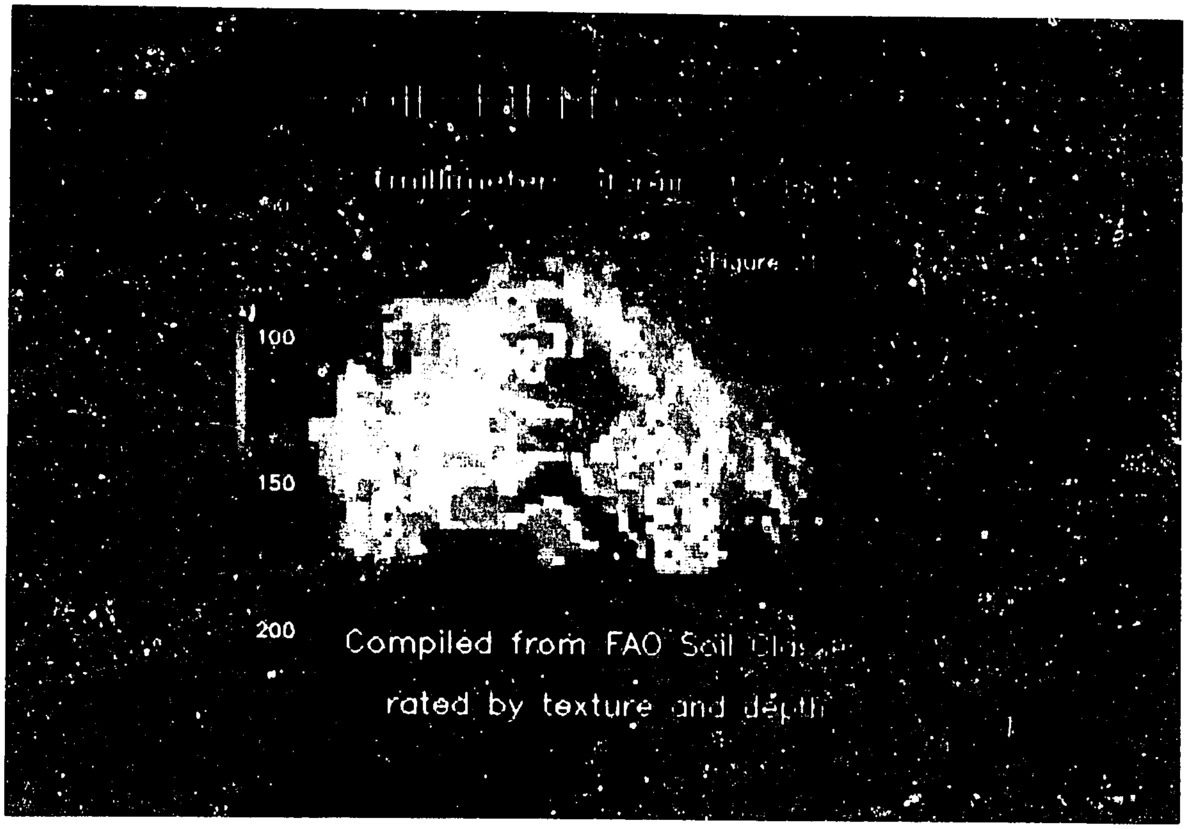


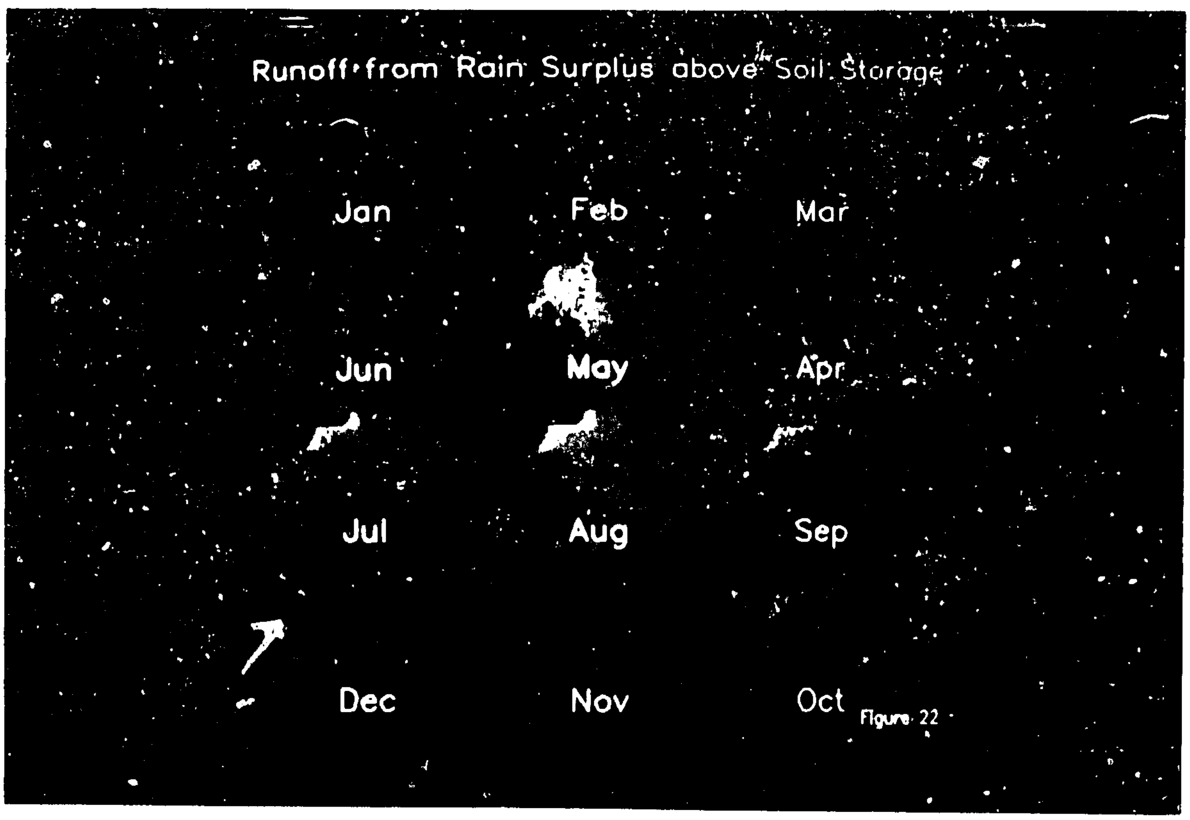


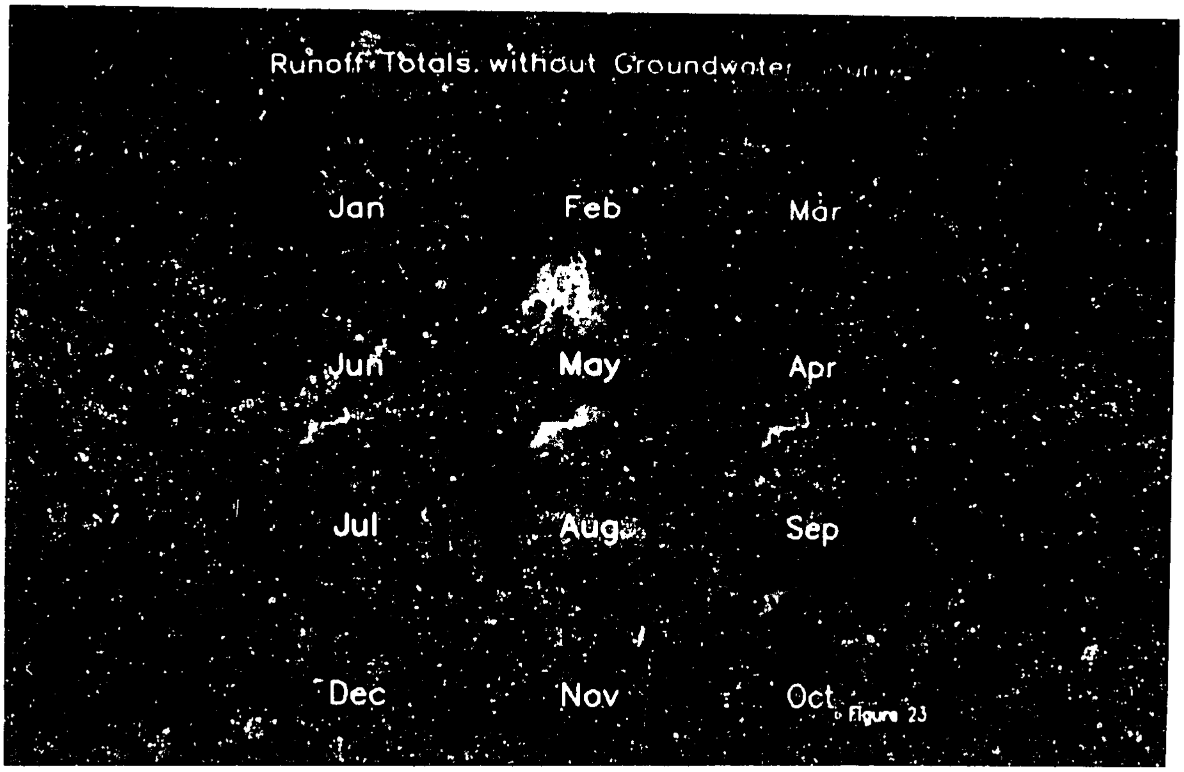

Compiled from terrain slope
soil texture to reflect

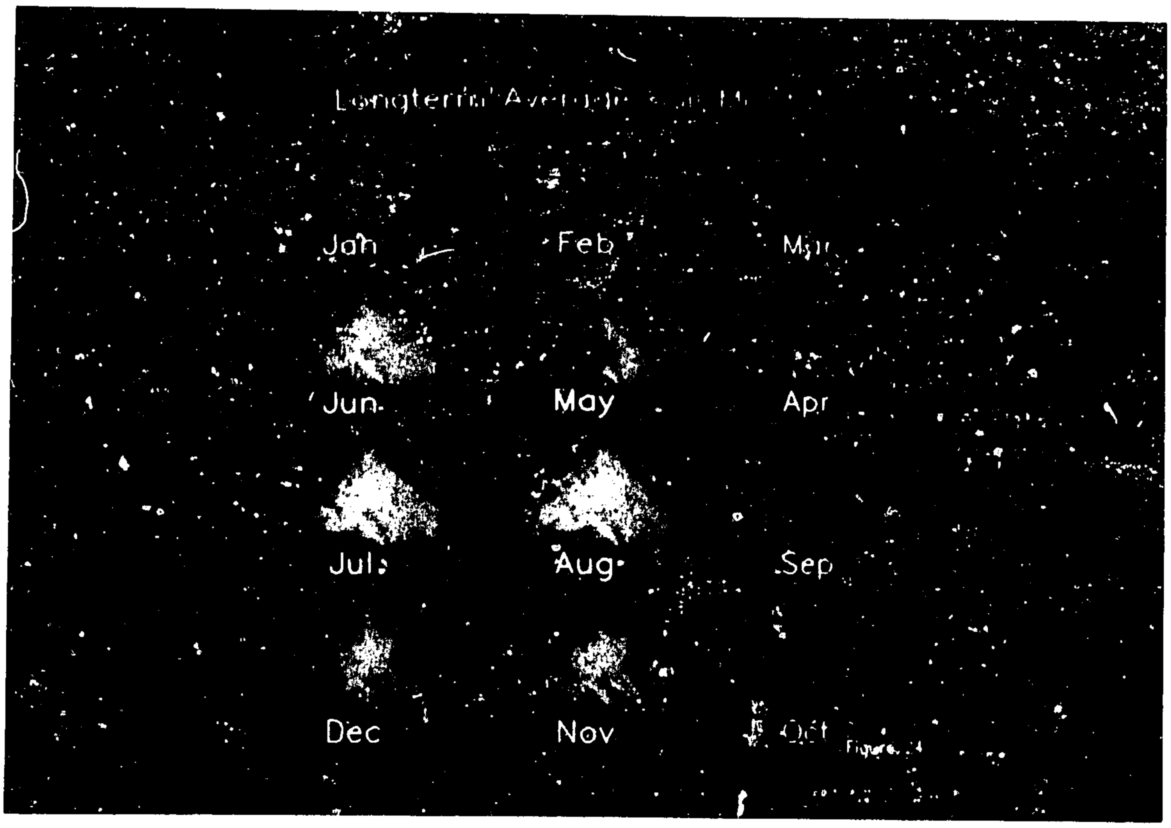

Jan
Feb
Mar
Jun
May
Apr
Jul
Aug
Sep
Dec
Nov
Oct
Figure 19

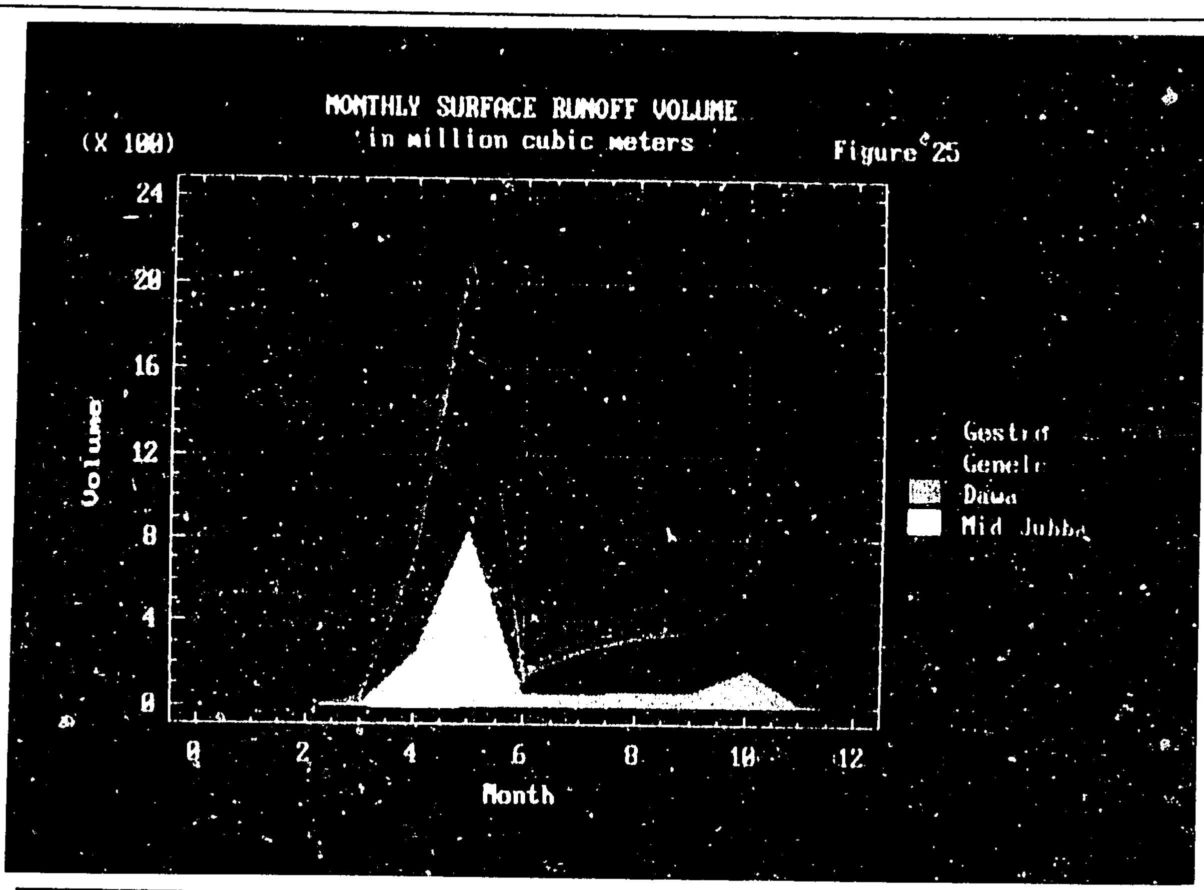



100
150
200
Compiled from FAO Soil
rated by texture and depth

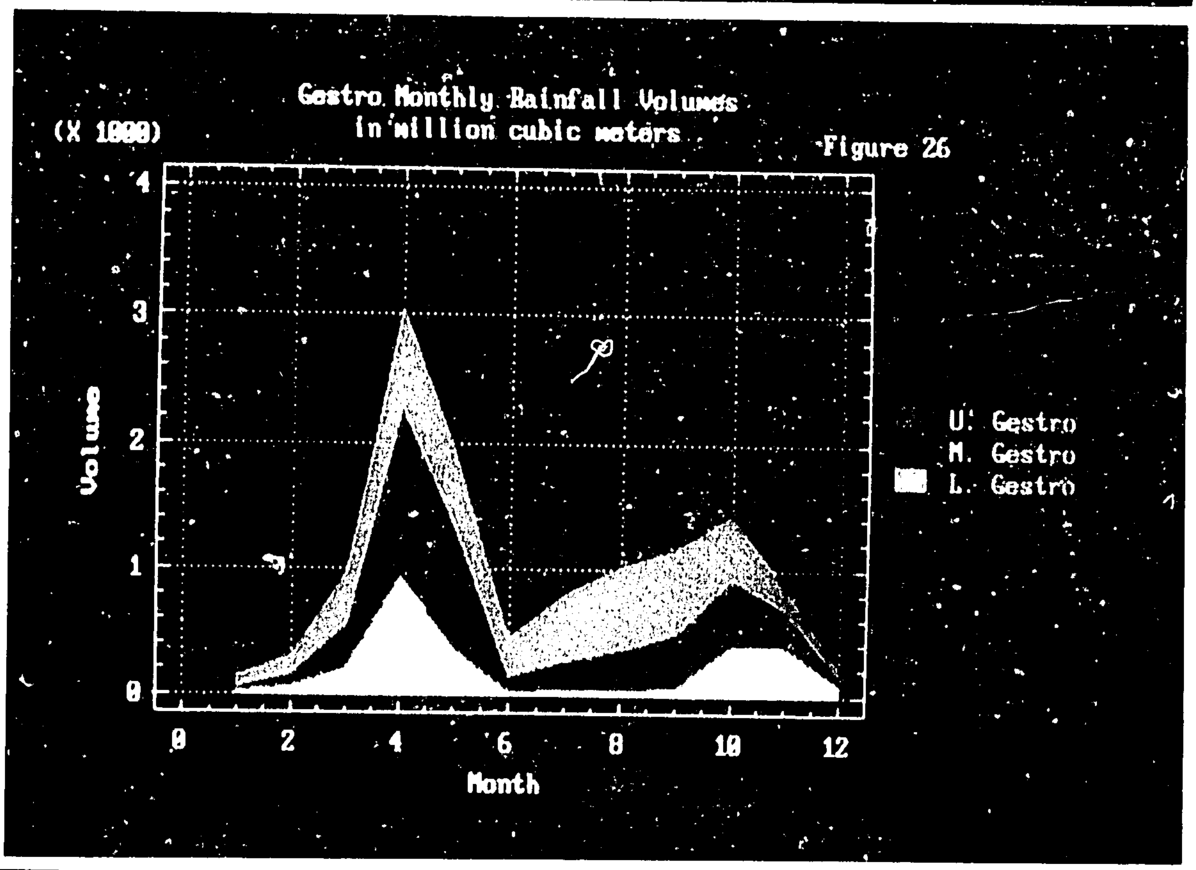

Runoff from Rain Surplus above Soil Storage
Jan
Feb
Mar
Jun
May
Apr
Jul
Aug
Sep
Dec
Nov
Oct
Figure 22


Runoff Totals without Groundwater
Jan
Feb
Mar
Jun
May
Apr
Jul
Aug
Sep
Dec
Nov
Oct
Figure 23

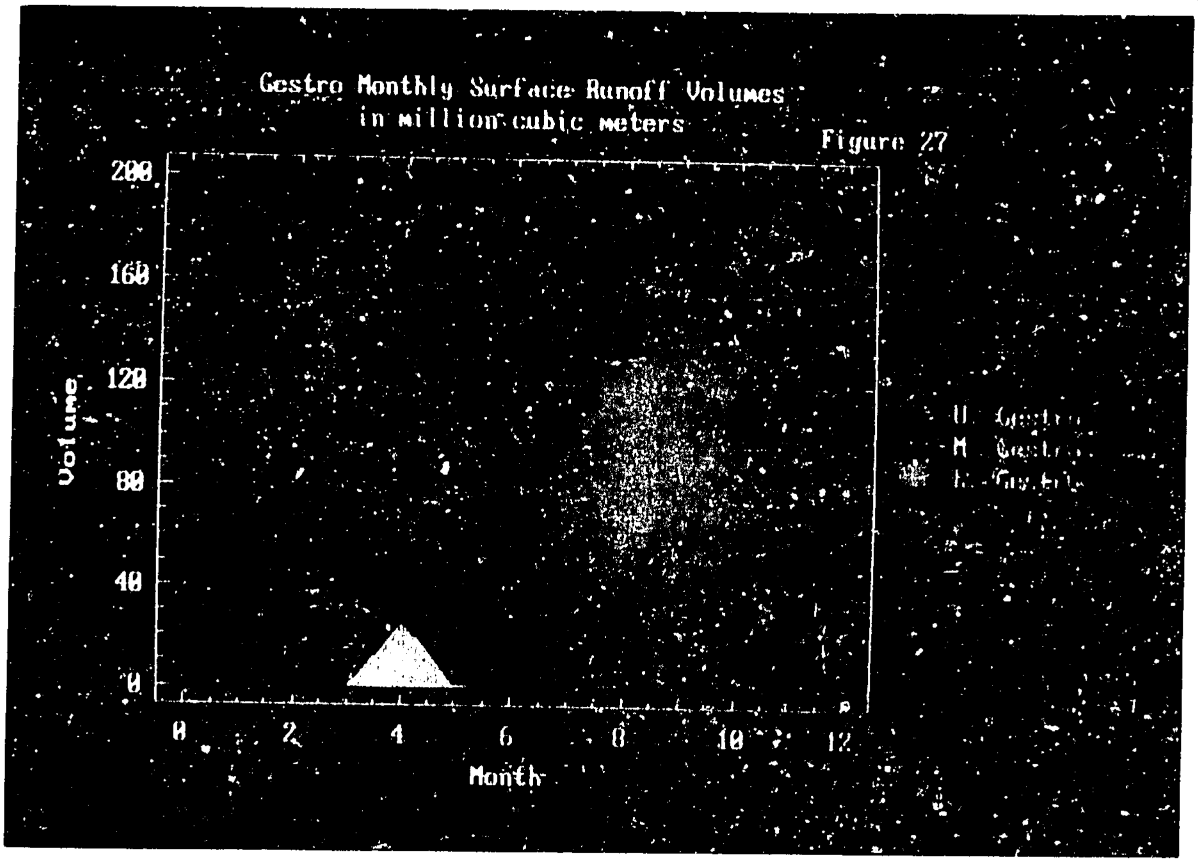

Longterm
Jan
Feb
Jun
May
Apr
Jul
Aug
Sep
Dec
Nov

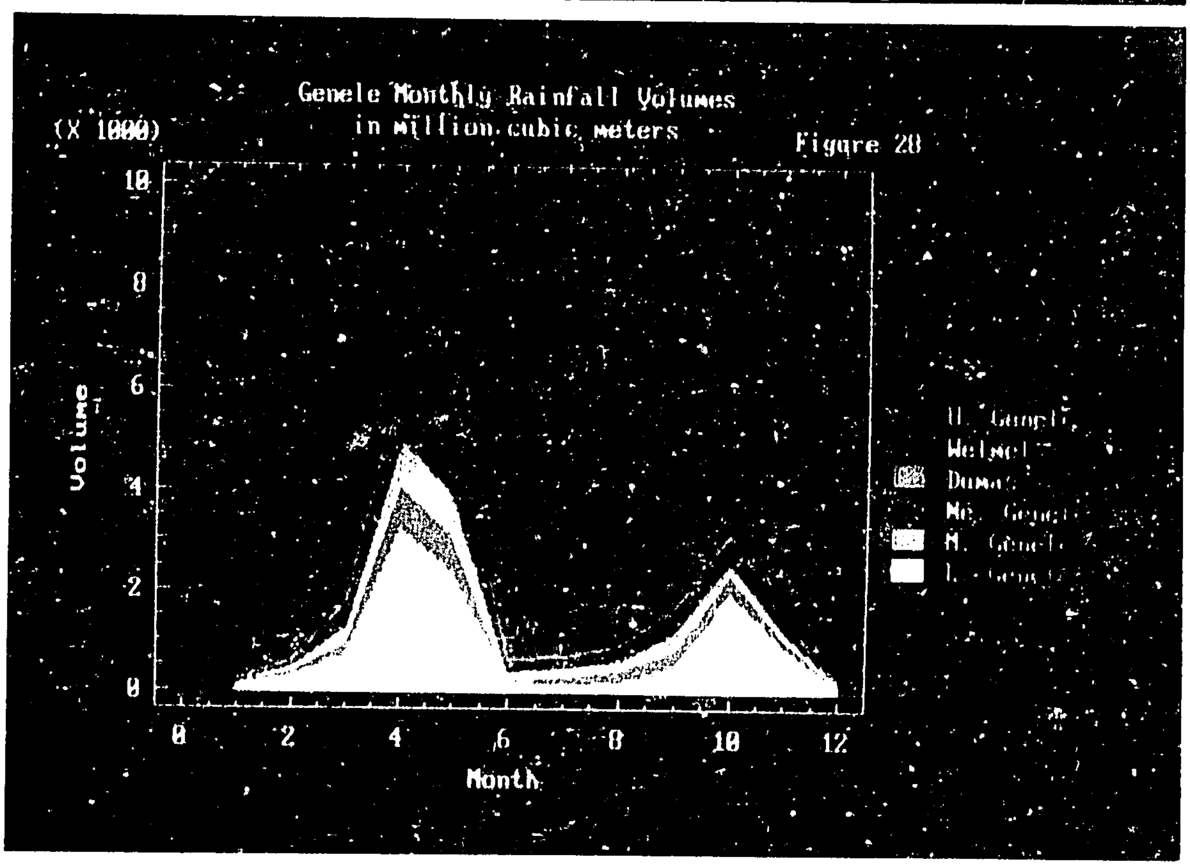


MONTHLY SURFACE RUNOFF VOLUME
in million cubic meters
(X 100)
Figure 25
Volume
Month
Gestro
Genale
Dawa
Mid Jubba



Gestro Monthly Rainfall Volumes
in million cubic meters
(X 1000)
Figure 26
Volume
Month
U. Gestro
M. Gestro
L. Gestro


Gestro Monthly Surface Runoff Volumes
in million cubic meters
Figure 27
200
160
120
80
40
0
Volume
0
2
4
6
8
10
12
Month


Genele Monthly Rainfall Volumes
in million cubic meters
(X 1000)
Figure 28
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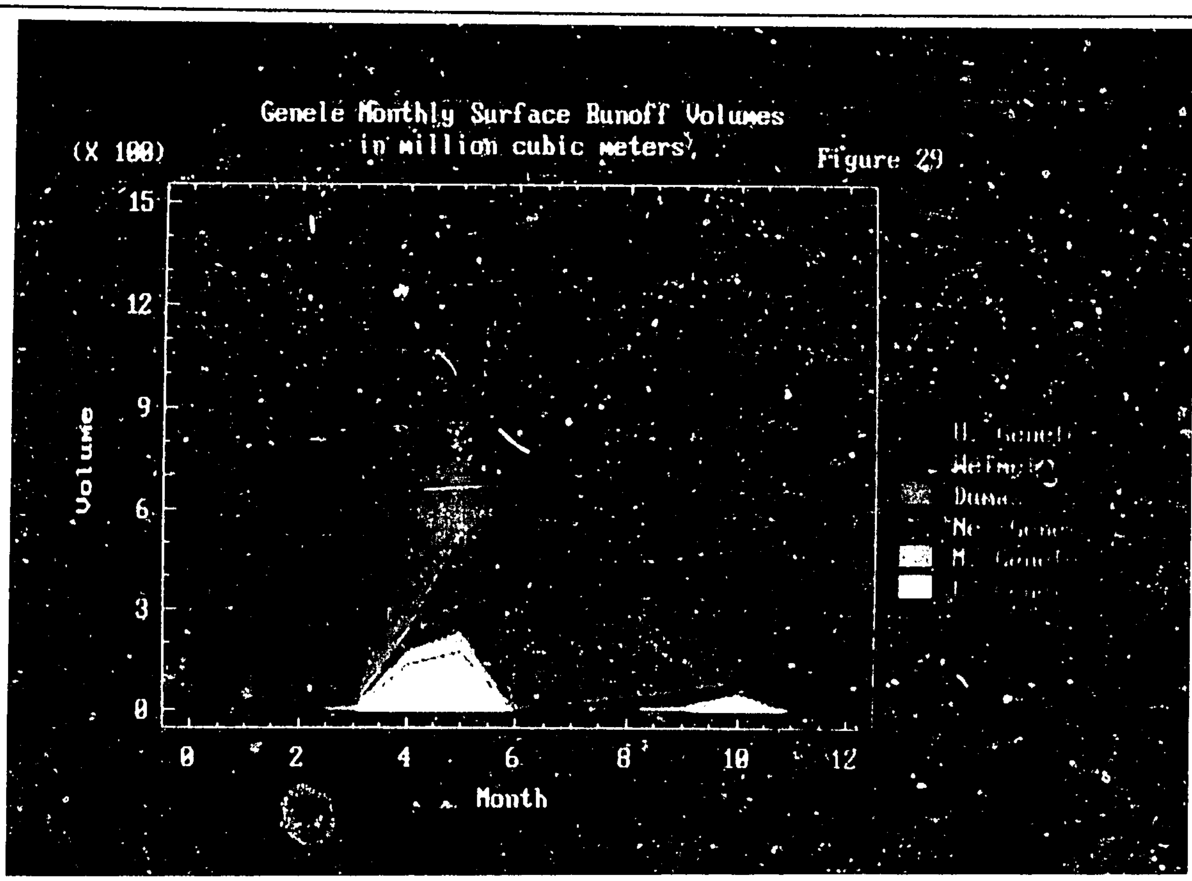
Genele Monthly Surface Runoff Volumes
in million cubic meters
(X 100)
Figure 29
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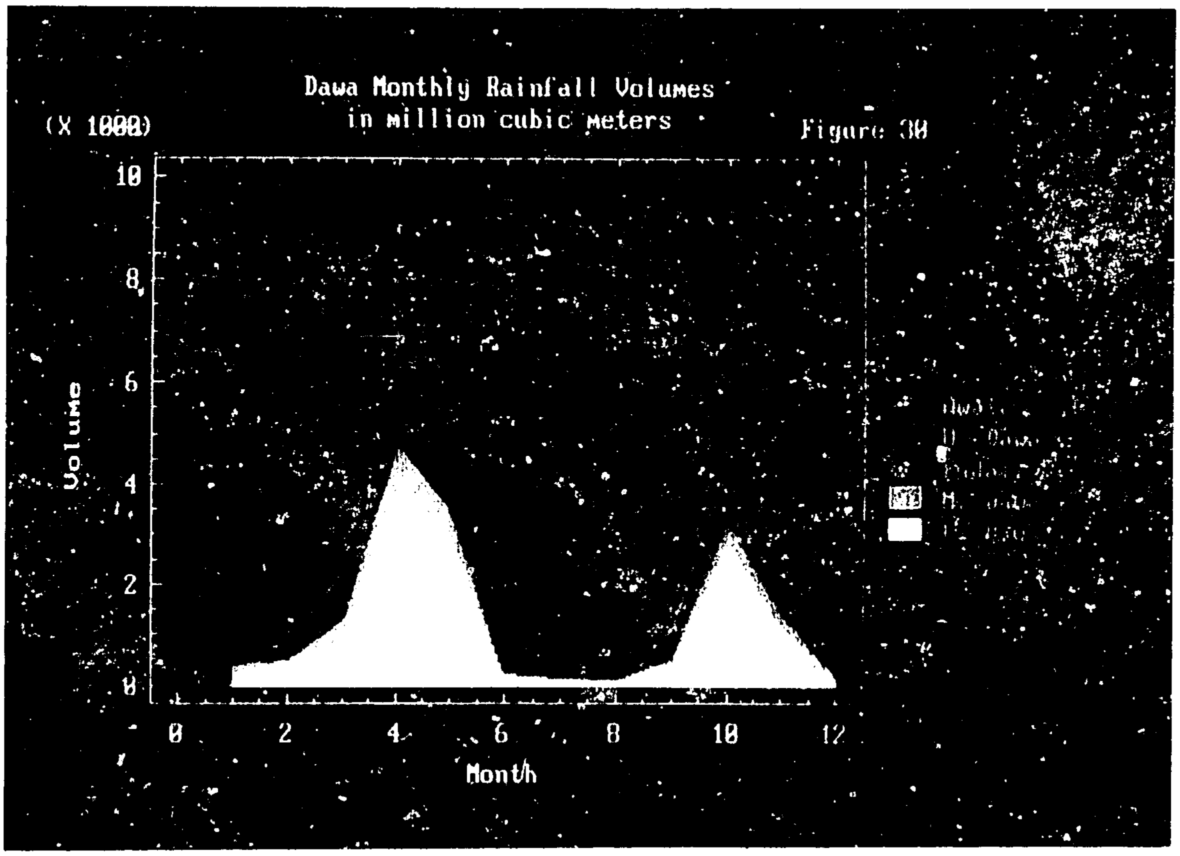
Dawa Monthly Rainfall Volumes
in million cubic meters
(X 1000)
Figure 30
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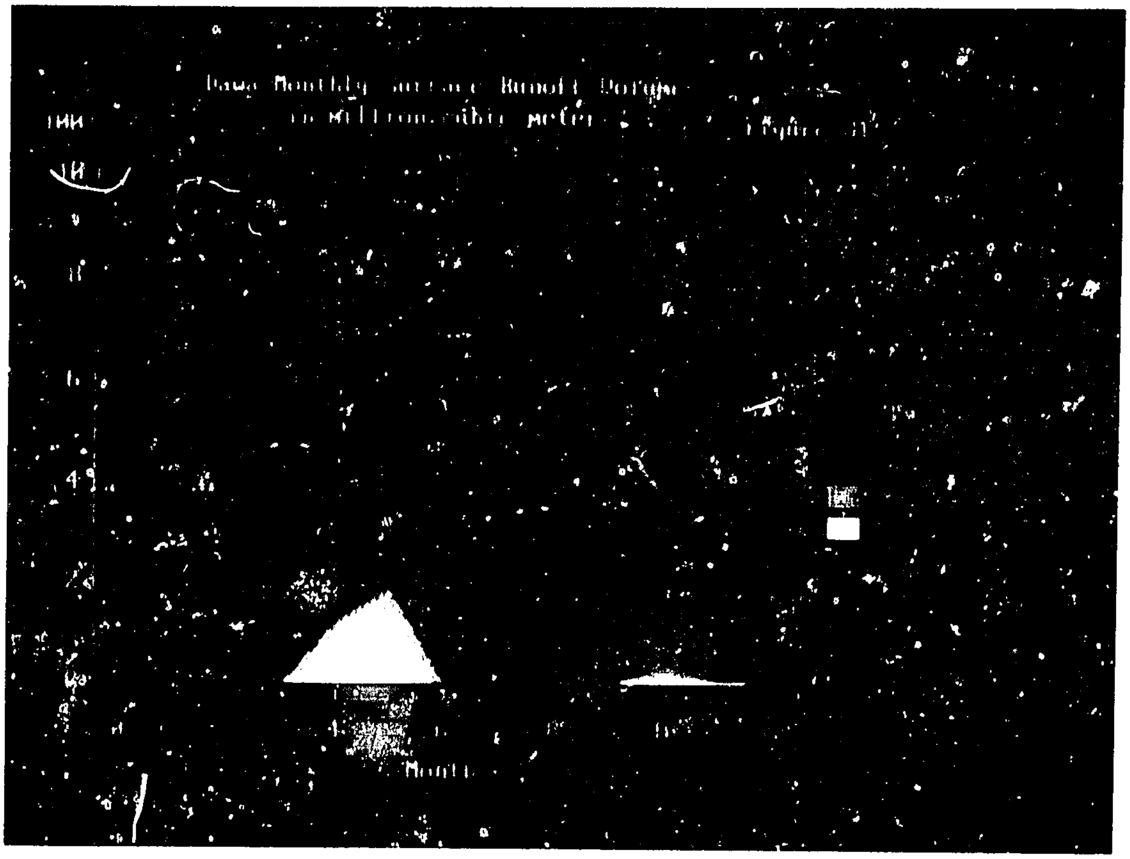

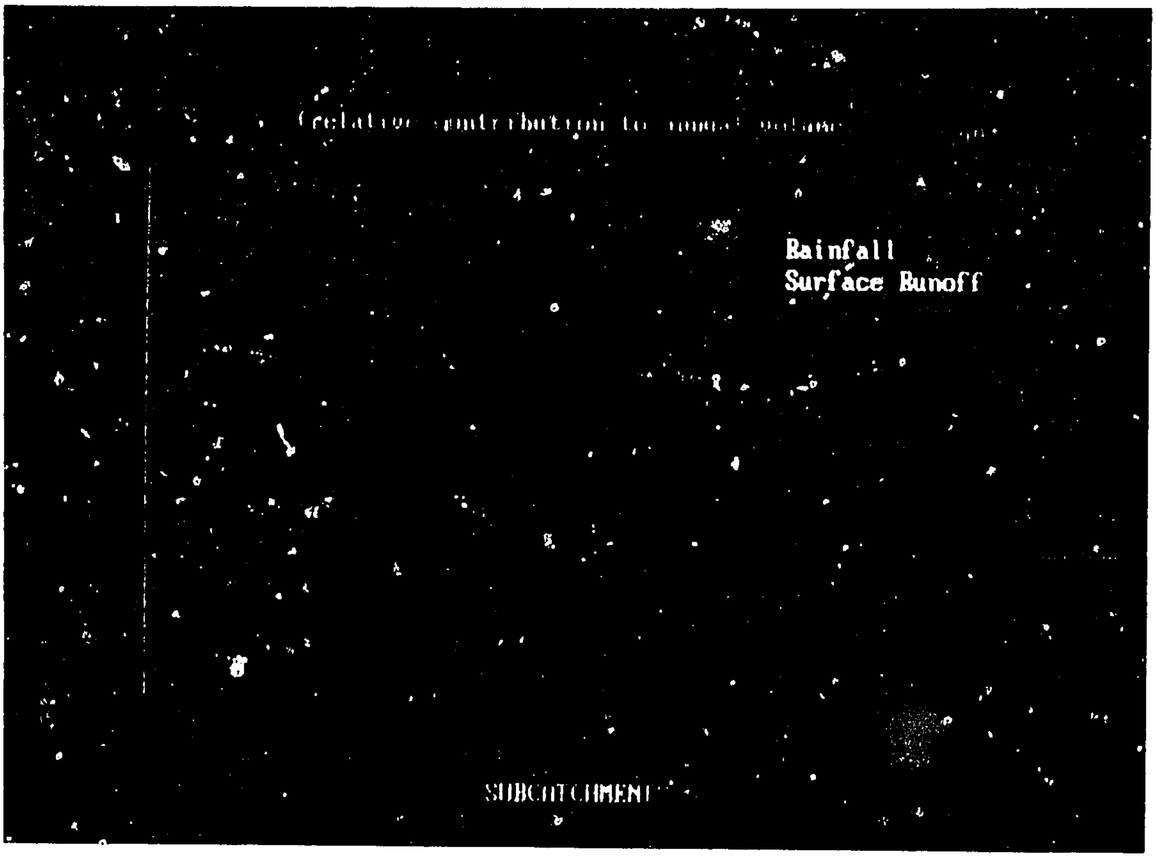

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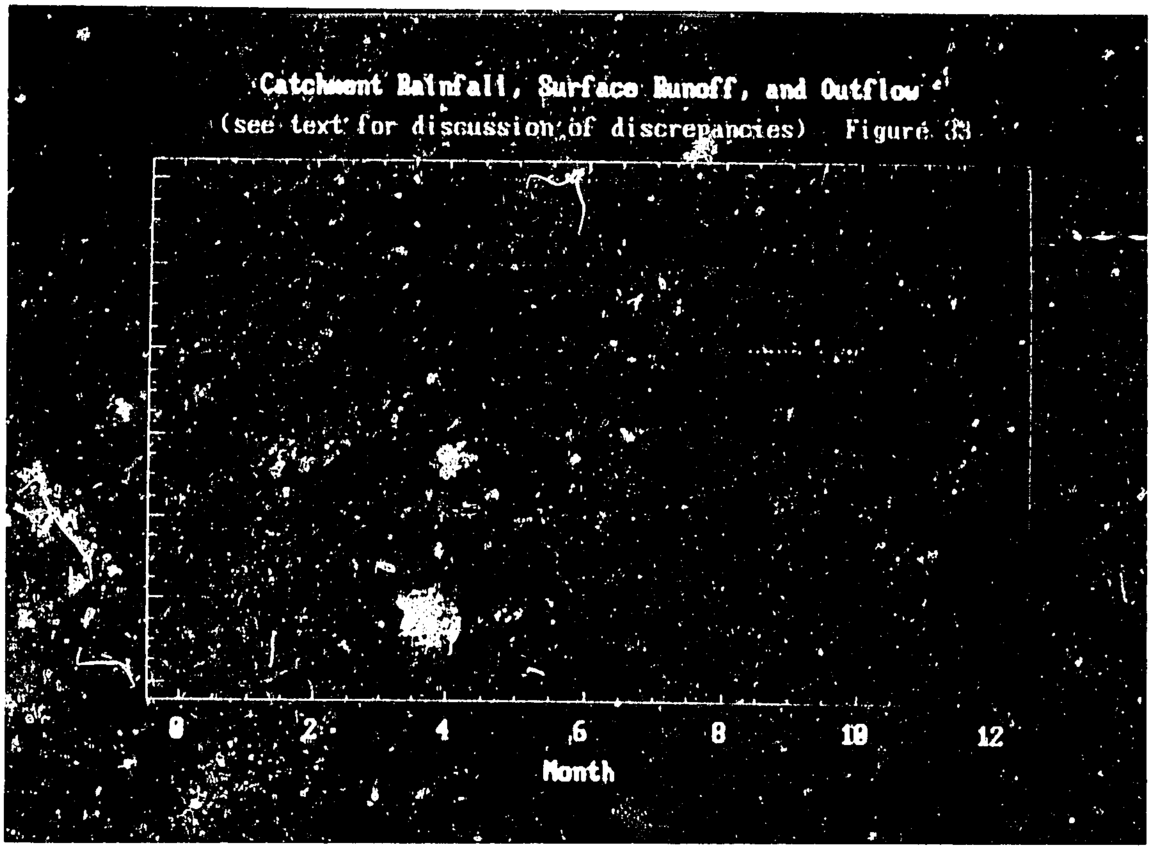
Catchment Rainfall, Surface Runoff, and Outflow
(see text for discussion of discrepancies) Figure 33
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4
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Month

Water Quality and Public Health Aspects of Proposed Dam and Development in the Jubba Valley

prepared by
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This final report on water quality and public health aspects was first presented in August 1988 for publication in JESS Final Report. The report combines information in reports first published as: "JESS Interim Report on Health Impacts of Design Alternatives for Proposed Baardheere Dam," *JESS Report No. 5*, William R. Jobin, November 1986; "JESS interim Report on Health Consequences of Design Criteria for Water Supply and Sanitation in New and Resettled Communities," *JESS Report No. 6*, William R. Jobin, November 1986; "JESS Consultancy Report on Water Quality and Public Health Engineering," *JESS Report No. 7*, William R. Jobin, November 1986; "JESS Second Consultancy Report on Water Quality and Public Health Engineering," *JESS Report No. 11*, William R. Jobin, January 1987; "JESS Third Consultancy Report on Water Quality and Public Health Engineering," *JESS Report No. 15*, William R. Jobin, July 1987; "JESS Report on Malaria Endemicity in the Lower Jubba Region," *JESS Report No. 29*, Marian Warsame Yusuf, April 1988; and "JESS Summary Report on Bilharzia and Distribution of *Bulinus Abyssinicus* in the Jubba Valley," Ralph Klumpp, August 1988, included in *JESS Report No. 39*. Associates in Rural Development, Burlington, Vermont. All photographs in this report are by the author.

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This report is based on surveys and analyses conducted in Phase II of JESS, during ARD consultancies by Dr. William R. Jobin and Dr. Ralph K. Klumpp of Blue Nile Associates (BNA). Field studies were conducted in the Jubba Valley in 1986-88. Special thanks are given to the following people who assisted in the fieldwork. From the Faculty of Chemistry, National University of Somalia, Professors Ali Warsame, Mohamed Abukar Ahmed, Abdel Ghaffar, Abdel Allahi Sheikh, and Bashir Musa assisted in collection and analysis of the water quality samples. Dr. Marian Warsame of the Faculty of Medicine assisted in the health surveys, Dr. Siad Mire and Mr. Hassan Igieh of the National Antimalarial Service (NAS) in the Ministry of Health provided supplies, equipment, and field technicians for the bilharzia and malaria surveys. Dr. Davis and Dr. Mott of the World Health Organization (WHO) Office in Geneva, Dr. Wahdan of the WHO Regional Office in Alexandria, Dr. Barzgar, Dr. Lundgren, Dr. Farid, and Dr. Garofalo of the WHO Office in Muqdisho assisted with encouragement and advice in planning of the surveys, as well as provision of supplies and drugs. The cooperation at all levels of WHO and NAS were especially appreciated and it is hoped that this can be continued as development of the valley occurs. Critical reviews and helpful comments on the final drafts by Dr. R. Tillman, Dr. J. Gerards, and Dr. F. DeWolfe Miller were greatly appreciated. Photos in this report were supplied by E.D. Buskirk, drawings were by L. Norwood, and graphics by P. Metcalf. This report was directed primarily to the Ministry of National Planning and Jubba Valley Development, referred to herein as the "Ministry."

I. EXECUTIVE SUMMARY

Baardheere Dam, proposed on the Jubba River in Somalia for power, flood control, and irrigation, should be operated in a manner which will also protect the health of affected people and livestock. Studies were carried out from 1986 to 1988 to determine the requirements for such protection, and evaluate water quality concerns.

Water quality surveys in the valley indicated that the river supplied the valley with water and nutrients essential for crops, but the high salt content of the river often exceeded desirable limits. Simple measures could correct excessive salt content, to make concrete for the dam. Once constructed, the dam would moderate downstream salinity fluctuations, reducing the maximum monthly conductivity to 500 micromhos/cm, which is acceptable for agriculture. However, development of intensive irrigation downstream would again raise conductivity in the lower valley to undesirable levels (above 750 micromhos/cm) in dry years. Calculations indicated that salinity will limit agricultural development, especially downstream of Jamaame.

Surveys of children in the valley indicated significant prevalences of malaria, urinary bilharzia, and diarrheal diseases. The [illegible]ion of the proposed reservoir would reduce malaria outbreaks by controlling floods, but subsequent expansion of irrigated agriculture could spread existing diseases and introduce new ones. Intensive irrigation could introduce the more severe intestinal form of bilharzia.

Four major steps are thus recommended:

- SETTLEMENT PROGRAM. A settlement program should be established to provide water supplies and drainage systems in agricultural communities, thus preventing severe increases in bilharzia, malaria, and diarrheal diseases.
- DAM OPERATIONS GROUP. A dam operations group should be created to include concern for livestock, drawdown agriculture and health in dam operation objectives. The reservoir shoreline should be modified to reduce disease transmission.
- INTENSIVE IRRIGATION. Intensive irrigation should be avoided in the valley, in favor of diversified crop rotations which use less water and would prevent salinization, waterlogging of the soil, and severe health risks. The spread of chloroquine-resistant malaria has already started in the lower valley, where irrigation is most intensive.
- AGRICULTURAL PESTS. Integrated pest management should be used in agriculture and health programs to minimize biocide usage as well as accidental poisonings and contamination of the environment.

Failure to follow these recommendations and provide necessary funds in the initial stages of development will lead to serious epidemics which would be uncontrollable with existing government resources.

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II. INTRODUCTION

A range of potential water quality and public health concerns were considered in this report to evaluate the impact of the proposed Baardheere Dam and parallel development of the Jubba Valley in southern Somalia (Figure II.1). The Jubba River begins as three tributaries on the southern slope of the Rift Valley in Ethiopia, gathers together into a single stream as it leaves Ethiopia near Dolow, then runs southward through Somalia to the Indian Ocean near Kismaayo. The lower portion of the river valley is well-suited to agriculture except for the vagaries of river flow. Long droughts are broken by massive floods, making farming unpredictable and hazardous. Three irrigation projects for sugarcane and rice have been started near Jilib and Jamaame, but they suffer from the erratic flow in the river.

The dam has been proposed to provide hydroelectric power for the valley and capital city of Muqdisho, and to moderate the flow. It would be a rockfill and concrete structure with a spillway elevation 144 meters above sea level (masl), creating a long, narrow reservoir reaching almost to Luuq. This structure would be capable of storing 5,000 million cubic meters of water when full, with a working capacity of 3,000 million cubic meters. The proposed reservoir would flood the existing town of Buurdhuubo as well as many small settlements. Storage in the reservoir would be large enough to contain the two annual floods during the deyr and gu' seasons, and eliminate most of the dry episodes now experienced during the two dry seasons called the jiilaal and the xagaa.

A. Water Quality

Based on available information. there were several concerns about the impact of the dam on water quality in the river. Because organic pollution of the river was not serious, thus analyses were concerned with chemical and physical parameters. A major concern was whether the slugs of salt and sediment presently passing straight through the valley to the ocean during the gu' and deyr floods would cause problems for agriculture or human health when trapped by the dam. There was also concern whether arsenic or boron were present in concentrations undesirable for agricultural use.

There have been serious water quality problems in the past with several tropical reservoirs—primarily, oxygen depletion during the first decade of operation due to decaying organic material and increases in salinity. The lack of oxygen was severe in the Brakopondo Reservoir of Suriname, creating a hazard to fish life and causing acidic conditions which increased corrosion of turbines and valves. Changes in salinity due to Aswan Reservoir in Egypt contributed to corrosion and caused problems for downstream agricultural users of the water.

Although Baardheere Reservoir did not exist at the time of the field surveys, studies were conducted to deal with concerns about low oxygen concentrations in the bottom of the proposed reservoir. The concentrations of sulfate in the river were evaluated to determine if the sulfate might cause spalling in concrete used in the dam. Generally high salinity during the end of the dry jiilaal period was monitored to determine whether it would cause health problems. An estimate was made of overall salinity of the dhesheeg behind the dam to determine its suitability for human or agricultural use.

B. Public Health

Most new impoundments in Africa have significant problems with malaria, bilharzia, and diarrheal diseases among nearby populations. These diseases were already present in the Jubba Valley, and expected to increase with further development of water resources. Two areas of particular concern were the perimeter of the proposed reservoir and the lower valley, where several irrigation projects have already been infested with malaria and bilharzia (Figure II.2). An international system for classifying tropical diseases related to water (presented below), identified most of the diseases found in the Jubba Valley, as well as several found not to be important. Those not present in southern Somalia were guinea worm, sleeping sickness, and yellow fever.

Previous surveys established that malaria and other diseases were present, but additional information on vector populations and disease intensity was needed. There was also a need to study vector habitat conditions in existing irrigation systems to assist in predicting the consequence of new developments.

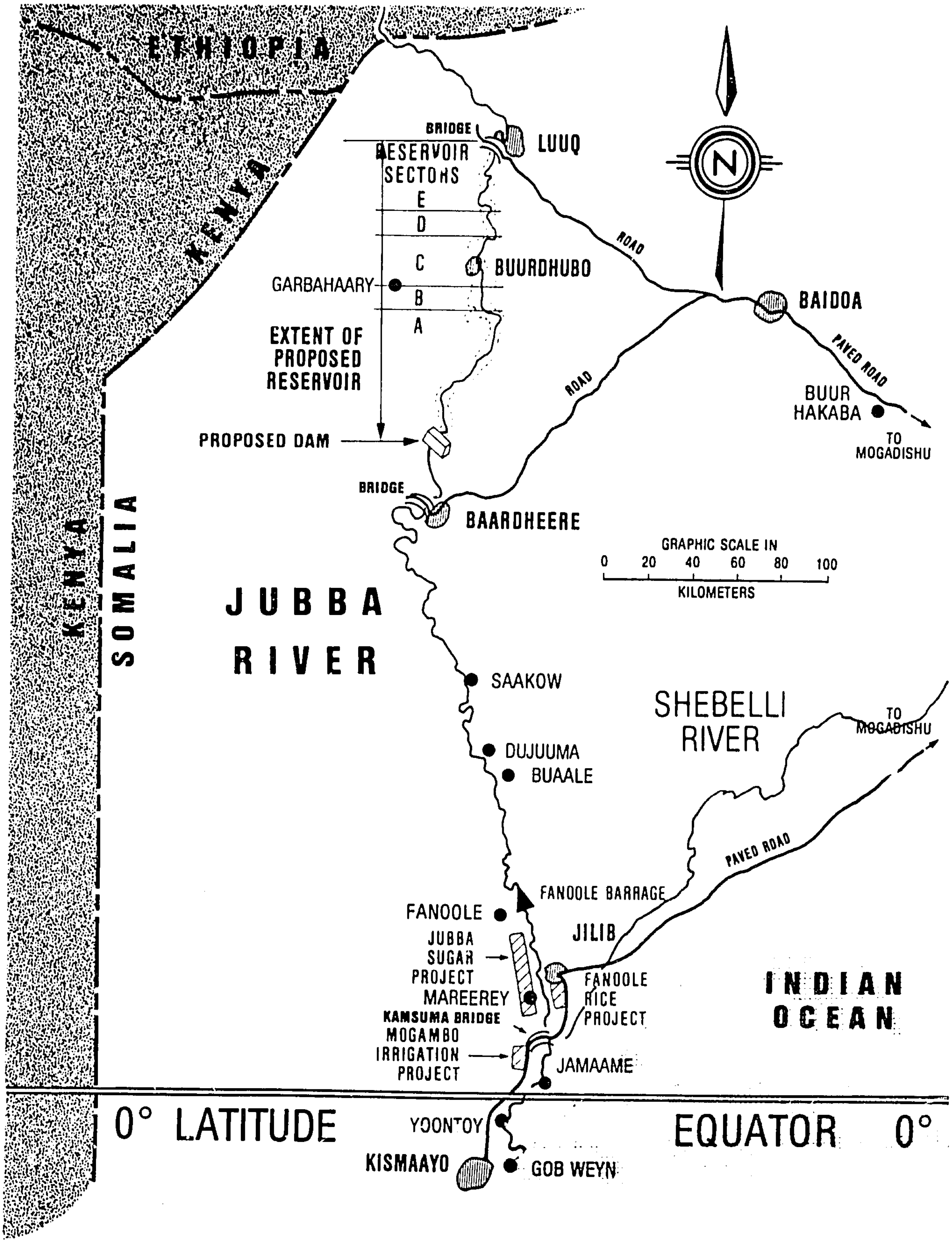

Figure II.1
Proposed Dam And Reservoir In Jubba Valley Of Somalia, With Existing Irrigation Schemes

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Figure II.2

Young boys near Little Jubba River on Jubba Sugar Project were most active age group regarding contact with potentially snail-infested waters.

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CLASSIFICATION OF INFECTIVE DISEASES IN RELATION TO WATER SUPPLIES.
Adapted from publications of International Decade of Drinking Water and Sanitation

CATEGORY	EXAMPLES
Water-born infections	
(A) Classical	Typhoid, Cholera
(B) Non-classical	Infective hepatitis
Water-washed infections	
(A) Skin and eyes	Scabies, Trachoma
(B) Diarrheal diseases	Bacillary dysentery
Water-based infections	
(A) Penetrating skin	Bilharzia
(B) Ingested	Guinea worm
Infections with water-related insect vectors	
(A) Biting near water	Malaria, Sleeping sickness
(B) Breeding in water	Yellow fever
Infections primarily of defective sanitation	Hookworm

Existing programs and facilities of health and water supply agencies were evaluated to assist in developing recommendations for future improvements. Although Somalia had adopted goals regarding community water supplies and public health under their decade plan for the International Decade of Drinking Water Supply and Sanitation, and the World Health Organization plan of health for All by the Year 2000, it was unlikely that the goals would be met in the Jubba Valley, given the limitations on government resources.

Under these plans, 80 percent of urban dwellings should have adequate water supplies and sewage disposal by the year 1990, half of all rural inhabitants should have adequate water supplies within 500 m of their dwellings by 1990, and 25 percent should have latrines. For the priority areas in Somalia, these goals would cost about $260,000,000 in 1983 U.S. Dollars. However, these funds have not been secured, and the Jubba Valley was not even listed among the priority areas in the country (WHO 1983).

From 1986 to 1988, field investigations were carried out to determine the water quality and public health conditions in the Jubba River Valley to provide a basis for evaluating the proposed Baardheere Dam and agricultural developments in the valley. To assist the reader in interpreting the data in this report, typical values of selected water-quality parameters in Jubba Valley, as compared to norms and standards, are presented in Appendix A.

A. Water Quality in River and Irrigation Systems

The Jubba River supplies Somalia's potentially most important agricultural area with the water, silt, and nutrients needed for growing crops, domestic use, and feeding livestock and wild animals. The quality and quantity of water in the river have been under study for decades to determine the best use of the river's flow. Almost all of the river's flow comes from rainfall in Ethiopia. The only other river in Somalia, the Shabeelle River, comes toward the Jubba River downstream of Kamsuuma, but disappears into the ground except in time of flood (Figure II.1).

1. The River

Investigations showed that the river had a highly variable flow, salt content, and sediment load. Assessment of the variations in salt content and their effect on use of the water for agriculture and drinking water required extensive field measurements and data analyses. In addition to summarizing available data on water quality in the river, a year of field sampling was conducted from June 1986 through May 1987 at several stations on the river from Luuq to the ocean. These data were analyzed in terms of seasonal patterns of flow and water quality.

Previously Available Data

Five previously available sources of water-quality data were summarized including three Baardheere Dam Project (BDP) Reports, a Ministry of Jubba Valley Development (MJVD) Report, and daily data records supplied by the Jubba Sugar Project (JSP) monitoring station at Mareerey (Astaldi Estero 1985a; Electroconsult-ELC 1985; Electrowatt 1985; AHT 1985; see Figure III.A.1). Data from reports on the Shabeelle River were used for comparison with results from the Jubba River (Lahmeyer 1986; Hussein and Ahmed 1984).

Reports prior to 1985, in the area of the proposed reservoir, indicated that salt and sediment concentrations in the river reached extremely high values during the gu' floods but also increased significantly with the deyr floods (Tables III.A.1 and 2). The maximum recorded suspended solids was over 4,000 mg/l, in April. During the extremely dry season of the jiilaal, high salinities also occurred due to the low flows in the river during March.

Table III.A.1. SUSPENDED SOLIDS IN JUBBA RIVER NEAR BAARDHEERE, 1963-1981.

Taken from ELC Report to BDP on Hydrology and Optimization of Dam Design, August 1985

MONTH	TOTAL Suspended Solids in mg/l Maximum	Minimum
January	393	11
February	715	34
March	789	29
April	4,111	600
May	2,745	190
June	545	494
July	437	386
August	489	287
September	773	225
October	1,085	271
November	899	192
December	1,231	49

Table III.A.2. CHEMICAL WATER QUALITY IN JUBBA RIVER AT RESERVOIR SITE. Range of values from March to May, 1985

Parameter	Bridge at Luuq (1)	Proposed Dam Site (2)	(3)
pH units	7.0 - 7.3	7.0 - 7.9	7.1 - 7.2
Ca++ mg/l	70 - 170	180 - 210	31 - 180
Mg++ mg/l	10 - 110	98 - 140	13 - 47
Na+ mg/l	97 - 1,000	850 - 1,120	8 - 100
K+ mg/l	0 - 7	4 - 8	0 - 0
Cl- mg/l	98 - 1,100	900 - 2,000	7 - 190
SO4= mg/l	104 - 283	200 - 275	14 - 540
HCO3- mg/l	175 - 210	180 - 250	118 - 200
Suspended Solids mg/l		2,700 - 4,800	

1. *Astaldi Estero Report BDP C-1, 1985a.*
2. *Astaldi Estero Final Report to BDP, 1985b.*
3. *Electrowatt Design Review Report to BDP, October 1985.*

Summaries of daily data from the JSP at their sampling station in Mareerey showed wide ranges in electrical conductivity at 25°C (EC25), and in

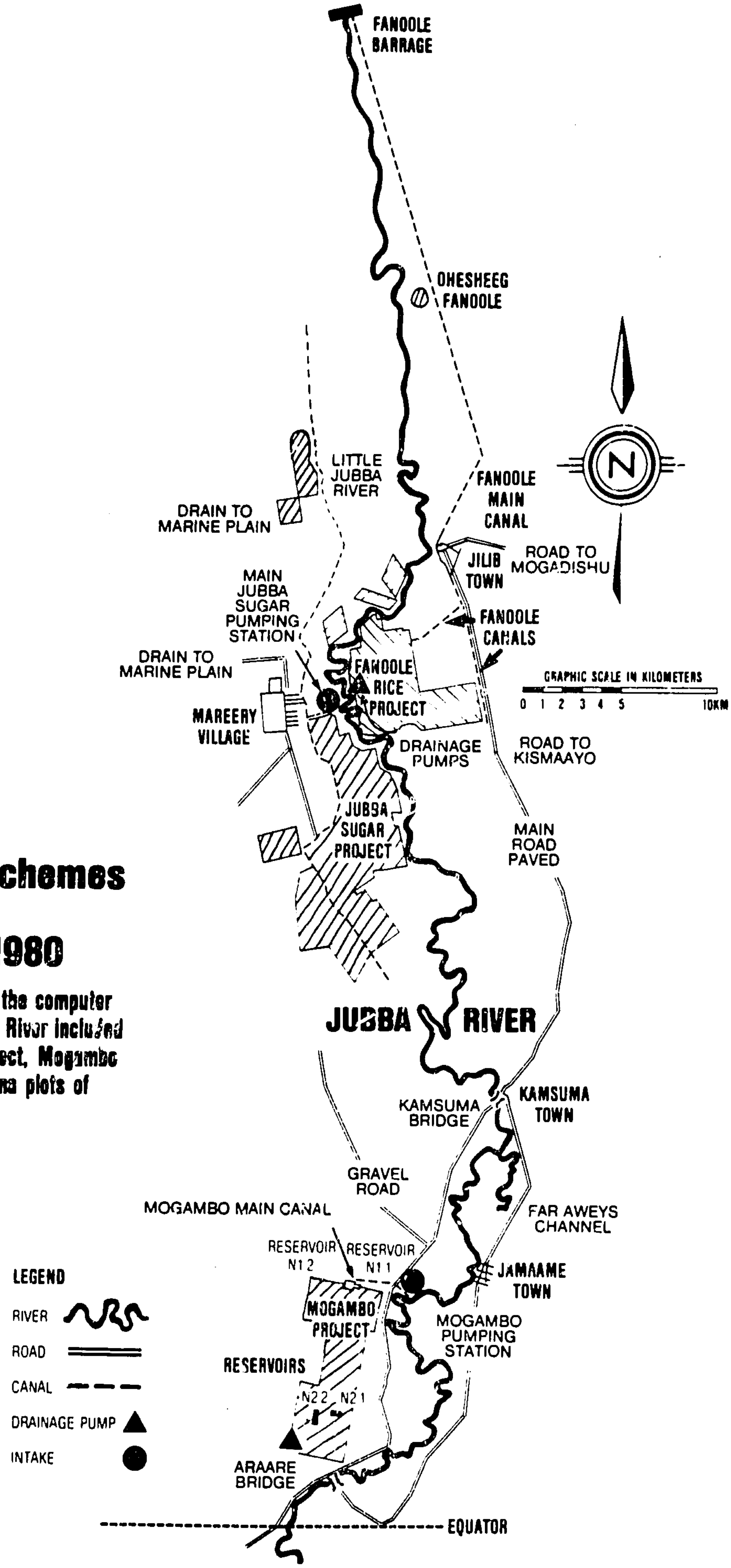

Figure III.A.1 Existing Irrigation Schemes In Lower Jubba River Valley 1980

Existing irrigation schemes included in the computer simulation of water quality in the Jubba River included Fanoole Rice Project, Jubba Sugar Project, Mogambo Irrigation Project and innumerable banana plots of Somalfruit Cooperative Banana Project.

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chlorides and suspended solids. The long-term records showed that monthly mean EC25 occasionally exceeded their upper limits for irrigating sugarcane, especially from February through May (Table III.A.3 and 4). They did not irrigate sugarcane when the EC25 exceeded 750 micromhos/cm.

Table III.A.3. EC25 OF JUBBA RIVER AT MAREEREY, 1978-1987. Monthly means of electrical conductivity in micromhos/cm at 25 °C.

From Agricultural Manager of JSP, June 1986

MON	1978	1979	1980	1981	1982	1983	1984	1985	MEAN
Jan	584	382	601	726	687	307	342	520	519
Feb	756*	772*	1,002*	1,067*	873*	484	525	884*	796
Mar	735	419	1,263*	1,135*	134	517	805*	1545*	819
Apr	549	749	1,635*	889*	1,447*	834*	1,174*	1,278*	1,069
May	404	366	1,26[illegible]	605	526	541	985	466	644
Jun	307	215	505	530	270	208	485	191	339
Jul	239	211	230	539	208	206	260	121	252
Aug	179	267	190	244	201	169	207	189	206
Sep	173	225	199	190	182	162	179	189	187
Oct	268	184	180	184	369	162	182	192	215
Nov	372	326	176	258	404	195	319	282	292
Dec	313	353	375	410	275	207	399	336	326
Means	407	372	635	565	465	333	484	516	472

** exceeded USDA limits of Class 2 irrigation waters of medium conductivity, EC25 750 micromhos/cm.*

Table III.A.4. WATER QUALITY OF JUBBA RIVER AT MAREEREY, 1986-1987.

From Agricultural Manager of JSP, September 1987

MON	EC25	Cations in mg/l			Anions in mg/l		
	micro-mhos/cm	Na+	K+	(Ca+Mg)++	Cl-	CO3=	HCO3-
1986							
Jan	549	57	3	93	81	0	171
Feb	919	8	5	155	152	0	183
Mar	1,247	12	6	222	209	0	140
Apr	1,268	9	6	242	163	0	128
May	427	34	4	106	53	0	110
Jun	304	20	3	77	25	0	183
Jul	258	21	2	61	21	0	128
Aug	208	23	2	149	18	0	152
Sep	197	18	2	77	21	0	165
Oct	272	7	2	100	28	0	165
Nov	266	27	3	84	32	0	140
Dec	403	45	2	113	46	0	171
1987							
Jan	505	58	3	135	67	0	177
Feb	880	90	4	213	127	0	177
Mar	1,300	108	5	264	396	0	183
Apr	880	-	-	190	223	0	146
May	643	-	-	164	124	0	134

- data not available

In an analysis of JSP data, it was pointed out by AHT in their January 1985 Report to the Ministry that the peak daily EC25 at Mareerey was 4,700 micromhos/cm, and that daily values above 2,250 micromhos/cm were observed every year, but for one to three days only. These salt slugs occurred just before the rise of a single, short flood wave, thus they did not constitute large loads of salt. The salt came to the river with the first flush of rain after long dry seasons, apparently from evaporated deposits in the watershed. Some salt slugs came at the beginning of the deyr rains also, but their concentrations did not reach 750 micromhos/cm—the limit for medium saline Class 2 irrigation waters, according to the U.S. Department of Agriculture (USDA) classification.

In the AHT report, it was also pointed out that calcium and magnesium were the major cations, except during low flows or in the salt slugs, when sodium predominated. The sodium absorption ratio (SAR), a measure of potential soil problems due to high ratios of sodium to calcium plus magnesium cations, was well within the desirable limits. Water with an SAR from 0-10 can be used for most soil types without danger. The SAR at Mareerey, calculated daily, ranged from 0.1 to 3.0 between 1985 and 1987.

Suspended solids had daily patterns approximating the salt slugs with peaks occurring in the first flushes of the gu' floods, and some lesser peaks in the deyr floods. The available data on suspended solids were probably not very reliable as samples were taken from the river surface, near the shore, and do not represent the true river concentration. Suspension of solids depends on local velocities and is not as uniform through the river cross-section as are dissolved concentrations of chemicals.

The lack of data on suspended solids seriously hindered the ability to predict the siltation rate of the proposed dam.

Field Surveys

Starting in June 1986 and continuing for 12 months, water samples were collected approximately monthly from the river at four stations and analyzed for several physical and chemical parameters. These four main stations were at Baardheere bridge, Jilib ferry, Araare bridge, and the Goob Weyn ferry (Figure II.1). Samples were also taken from the irrigation canals and drains, and a large dhesheeg on the East bank of the river just downstream of Fanoole Barrage (Figure III.A.1). In June 1987, when the surveys were initiated, samples were taken for three consecutive days at eight river stations from Luuq to the ocean to obtain a complete profile of water quality changes. Detailed sampling in the reservoir behind Fanoole Barrage was not conducted because of its small size and inaccessibility during most of the year. At the four bridges and at Goob Weyn, the samples were taken from the surface of the water at midstream. Gage readings of the river stage were recorded at Luuq, Baardheere, and Kamsuuma to determine river flows at the time of sampling, using stage-discharge curves from the Ministry of Agriculture.

Field measurements were made of water temperature, clarity, EC, pH, weather conditions, and time of sampling. Samples were taken to the chemistry laboratory of the National University in Muqdisho and analyzed for the other parameters according to Standard Methods of the American Public Health Association (APHA 1985). Subsamples were acidified in the field and then analyzed in the laboratory for total phosphates, nitrates, and sulfates. The accuracy of general laboratory procedures was verified by field measurements of pH, EC25, and chlorides during the first few months of sampling, using a battery-operated YSI conductivity probe and a colorimetric Hach test kit. Concentrations of trace metals and certain unusual values of other parameters were verified by testing duplicate samples at the government-certified Water Control Laboratories in Hopkinton, Massachusetts in the USA.

River conditions were monitored daily during April 1987 at Baardheere Bridge to obtain detailed measurements of the passage of salt flushes during the early gu' floods, and to time the passage of the salt slugs down to the daily sampling station at Mareerey. At 6 am, noon, and 6 pm, measurements were made of water temperature, suspended solids, EC25, and chlorides, from 9-29 April. This monitoring was also continued during the late passage of the peak gu' flood from 22-25 May 1987.

Results of Field Surveys

Results of the year of sampling were presented in terms of river flows, a June 1987 water quality profile from Luuq to the ocean, mean annual water quality at four major stations on the river and in Fanoole drain, and the seasonal variations in all parameters measured at Baardheere Bridge near the site of the proposed dam.

River Flow

River discharge during the year of sampling covered the range from extreme drought to severe flood (Table III.A.5). Flows were unusually low during the 1986 gu' flood (maximum flow occurred at Luuq on 26 May of only 600 cumecs) and low during the 1986 deyr flood. They dropped to zero during the end of the 1987 jiilaal dry season. This was followed by a late gu' flood in May 1987 . River discharge peaked on 21 May 1987 at Luuq Bridge and about 25 May at Baardheere Bridge,

Table III.A.5. RIVER STAGES AND DISCHARGES DURING 1986-87 SAMPLING PROGRAM.

km from ocean	600		400		68	
STATION	Luuq Bridge		Baardheere Bridge		Kamsuuma Bridge	
	Gage m	Discharge cumecs	Gage m	Discharge cumecs	Gage m	Discharge *
1986						
May 26	4.09	602 (flood peak)				
Jun 1	3.56	440	2.82	428		
Jun 11	3.40	396	2.74	408	4.30	
Jun 12	3.24	354	2.70	398	4.30	
Jun 13	3.20	344	2.64	384	4.80	
Jun 21	2.90	272	2.12	268		
Jun 22	2.90	272	2.08	260		
Jul 1	3.10	319	2.48	346		
Jul 10	2.95	283	2.22	289		
Jul 20	2.62	212	1.84	214		
Aug 1	2.43	175	1.72	193		
Aug 10	2.53	194				
Aug 20	2.58	204				
Sep 1	2.54	196				
Sep 10	2.66	220				
Sep 20	3.57	443				
Oct 15					4.00	
Oct 16			2.28	302		
Nov 5			2.00	244		
Nov 12			1.20	112		
Nov 27			1.10	99		
Dec 5			1.10	99		
Dec 10					2.15	
1987						
Jan 21					2.00	
Apr 3					0.45	
Apr 20			1.75	198		
Apr 23			1.90	225		
May 21		(flood peak at Luuq)				
May 23		1500 hrs	3.90	744		
		1800 hrs	4.35	899		
		2400 hrs	4.80	1068		
May 24		0600 hrs	5.10	1188		
		1200 hrs	5.20	1230		
		1800 hrs	5.30	1272		
		2400 hrs	5.32	1282		
May 25		0600 hrs	5.41	1319		
		0900 hrs	5.43	1328 (flood peak)		

* *cumecs not calibrated*

with a measurement at Baardheere of 1,328 cumecs. This was a flood of 10-year frequency.

River Profiles of Water Quality

Twice during the year of sampling, extra samples were taken to obtain a reliable measure of water quality from Luuq to the ocean to use in calibration of the river model. The special sampling runs were conducted in late June of the gu' season in 1986 and at the end of the extremely dry jiilaal in April 1987.

The most useful data were from the triple sampling of June 1986 which covered the river in greatest detail. This data set was used for the primary calibrations of the river model for chlorides and EC25. In June 1986, the chloride content ranged from 7 mg/l to 102 mg/l, and EC25 from 95 micromhos/cm to 538 micromhos/cm, with the highest concentrations near Jilib and Jamaame (Araare Bridge). Sodium levels ranged from 8 mg/l to 32 mg/l and followed the same pattern as chlorides and EC25 (Table III.A.6).

Table III.A.6. SALINITY IN JUBBA RIVER, JUNE 1986.

Mean concentrations from triple samples of chlorides, conductivity and sodium, in full length of Jubba River at end of moderate flood, June 1986

STATION	Chlorides in mg/l	Conductivity EC25 in micromhos/cm	Sodium in mg/l
Luuq Bridge	7	177	8
Buurdhuubo Ferry*	10	95	10
Baardheere Bridge	12	200	10
Fanoole Barrage*	17	180	4
Jilib Ferry	102	538	32
Mareerey*	25	304	20
Kamsuuma Bridge*	87	275	25
Araare Bridge (Jamaame)	101	425	32
Yontooy Ferry*	89	264	22
Goob Weyn	86	185	22

* *results of single sample only*

Extra data were also collected during the extremely dry months of March and April, just prior to the flood surges which came in about April 10, 1987. This was an extremely dry year. At the time of the sampling, the river flow was close to zero, containing mostly groundwater infiltrate with EC25 about 2,000 micromhos/cm (Table III.A.7). In the lower valley, no samples could be taken because the riverbed was dry, and at Goob Weyn, the ocean had intruded. These factors limited the usefulness of the data for further calibration of the river model.

Table III.A.7. CHLORIDES AND CONDUCTIVITY IN JUBBA RIVER, APRIL 1987.

Mean concentrations from samples of chlorides and conductivity in Jubba River during extremely low flow, early April 1987

Station	Chlorides in mg/l	Conductivity EC25 in micromhos/cm
Baardheere Bridge	535	1,563
Jilib Ferry	308	2,214
Mareerey	200*	1,827
Kamsuuma Bridge	372	2,072
Araare Bridge	river was dry at this station	
Goob Weyn	ocean	intrusion

* *very approximate estimate*

Four Main Stations

The mean values determined at the four main river sampling stations (with deletion of data from two incidents of ocean intrusion at Goob Weyn) and Fanoole Drain, confirmed previous data, but gave considerable additional information on nutrients, trace metals, and physical parameters.

Water temperatures were high, averaging 28.9° C in the river and 29.2° C in Fanoole Drain (Table III.A.8). The water had high turbidity with values reaching 420 standard units, and averaging 90 in the river. The secchi disk transparency was low, 23 cm in the river and 41 cm in the drain. Maximum transparency of 120 cm occurred when the ocean intruded at Goob Weyn. The river and the drain had high color of 8 and 14 standard units, respectively. The settleable solids averaged 3,700 mg/l and suspended solids were 867 mg/l.

Table III.A.8. PHYSICAL PARAMETERS AT FOUR MAIN RIVER STATIONS AND FANOOLE DRAIN, 1986-87.

STATION NAME	Water Temp °C.	Secchi Disk cm	Turbidity s.u.	Color s.u.	Settleable Solids mg/l	Suspend. Solids mg/l
Baardheere	28.1	26	73	8	2,800	558
Jilib	29.2	9	96	7	2,700	594
Araare	28.9	14	123	7	5,500	1,396
Goob Weyn*	28.9	13	120	11	3,300	1,106
River Mean	28.8	25	90	8	3,700	885
Adj. Mean*	28.9	23	90	8	3,700	867
Fanoole Drain	29.2	41	11	14	100	37

* *Adjusted Mean omits two incidents of ocean intrusion at Goob Weyn*

The river and Fanoole Drain were quite salty throughout the year with means for the river stations of EC25 of 799 micromhos/cm, and chlorides of 114 mg/l (Table III.A.9). This was a simply calculated mean value, but was not adjusted for seasonally varying flow rates; thus, it is not an estimation of

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the mean value to be expected after the dam is in operation. That value was estimated with the help of a mathematical model as reported in Section IV.C.

Table III.A.9 SALINITY AT FOUR MAIN RIVER STATIONS and FANOOLE DRAIN, 1986-87.

STATION NAME	EC25 micromhos/cm	Chlorides mg/l
Baardheere	785	128
Jilib	893	104
Araare	515	63
Goob Weyn	10,791*	3,569*
River Mean	3,793	1,116
Adjusted Mean*	799	114
Fanoole Drain	914	162

* *Adjusted mean omits two incidents of ocean intrusion at Goob Weyn.*

There was a general tendency for salinity to increase around Jilib and then gradually decrease toward the ocean. Fanoole Drain was significantly saltier than the river, probably due to leaching of agricultural fertilizers and accumulated soil deposits of salts in the rice fields.

The river carried remarkably high concentrations of phosphate nutrients in solution and suspended sediments with mean concentrations of 0.50 mg/l in solution and 0.42 mg/kg in the sediments (Table III.A.10). Nitrate nutrients were relatively low, 1.0 mg/l as N in the river and 0.48 mg/kg in sediments, reflecting the small amount of organic contamination. There was a noticeable downstream decrease of phosphates and nitrates in solution, and an apparent leaching of phosphates from the suspended sediments.

Table III.A.10. PHOSPHATES AND NITRATES IN JUBBA VALLEY.

Nutrient measurements at four main river stations and Fanoole Drain, 1986-87

STATION NAME	TOTAL DISSOLVED phosphates as P in mg/l	nitrates as N in mg/l	SUSPENDED SEDIMENT phosphates as P in mg/kg	nitrates as N in mg/kg
Baardheere	1.32	2.0	1.12	0.40
Jilib	0.33	0.7	0.68	0.13
Araare	0.23	0.5	0.15	0.71
Goob Weyn*	0.14	0.7	0.21	0.90
River Mean	0.49	1.0	0.42	0.49
Adj. Mean*	0.50	1.0	0.42	0.48
Fanoole Drain	0.47	0.5	0.74	0.07

* *Adjusted mean omits two incidents of ocean intrusion at Goob Weyn.*

For agricultural uses, arsenic, boron and selenium were well within acceptable limits for the yearly averages at all sampling stations (Table III.A.11). Boron is a desirable trace element for agricultural purposes at the concentrations observed, which were well below the desirable limit of 1 mg/l. Selenium, a potentially toxic element, was not detected in any of the samples. The maximum desirable value of arsenic for human consumption is 0.05 mg/l. However considerable seasonal fluctuations in arsenic concentrations, including a maximum daily value of 0.25 mg/l required a more careful analysis, made in a subsequent section. It was important to determine the potential of these arsenic slugs for human or animal toxicity.

Table III.A.11. ARSENIC, BORON, AND SELENIUM IN JUBBA VALLEY.

Trace element measurements at four main river stations and Fanoole Drain, 1986-87

STATION NAME	ARSENIC in mg/l	BORON in mg/l	SELENIUM in mg/l
Baardheere	0.03	0.24	<0.05
Jilib	0.05	0.17	<0.05
Araare	0.03	0.14	<0.05
Goob Weyn*	0.02	0.23	<0.05
River Mean	0.03	0.21	<0.05
Adj. Mean*	0.03	0.21	<0.05
Fanoole Drain	0.03	0.24	<0.05

* *Adjusted mean omits two incidents of ocean intrusion at Goob Weyn.*

Seasonal Variations in Water Quality at Baardheere

Because of the highly variable flow and quality of the river water, seasonal trends were important in understanding the river behavior. Therefore, this analysis followed the four seasons of Somalia.

The lowest temperature of 25.0 °C was observed in January at the beginning of the jiilaal season, with another low of 25.3 °C occurring in June at the beginning of the xagaa (Table III.A.12). The highest temperature occurred in November, 31.5 °C. The water was generally warmer during the deyr and gu' floods. Water clarity was almost nil except during the jiilaal season, from January to just before the gu' flood in April when the photic zone, measured by the secchi disk, reached 90 cm. The low penetration of sunlight from May through December indicated a period of low biological productivity, but the jiilaal season could have been quite productive with a photic layer of almost a meter. The highest turbidity occurred during the gu' flood, dropping to a low of three standard units during the dry period flow of the jiilaal. Color was moderate at six standard units through most of the year, except for a highly colored period in the gu' flood, reaching a maximum of 13 su in late April at the beginning of the flood. Settleable solids and suspended solids were an order of magnitude larger during the gu' flood, compared to the other three seasons. Maximum settleable solids were 12,800 mg/l in late May, and suspended solids reached 2,500 mg/l during that period.

Table III.A.12. WATER QUALITY AT BAARDHEERE.

Physical parameters of Jubba River at Baardheere Bridge, June 1986 to May 1987

DATE	Water Temp °C.	Secchi Disk cm	Turbd-ity s.u.	Color s.u.	Settleable Solids mg/l	Suspend. Solids mg/l
1986						
Jun	25.3	1	125	5	600	442
Jul-Oct	27.8	6	49	7	1,200	253
Nov	31.5	10	56	7	400	128
Dec	28.0	10	58	5	300	168
1987						
Jan	25.0	90	2	8	0	52
Mar-Apr	28.5	65	4	5	200	3
Apr	30.8	10	134	13	4,500	498
May	29.0	2	140	10	12,800	2,532
Xagaa mean	26.5	3	87	6	900	348
Deyr mean	29.8	10	57	6	400	148
Jiilaal mean	26.8	78	3	6	100	28
Gu' mean	29.9	6	137	12	8,700	1,515

Conductivity remained relatively low during the last half of 1986 with EC25 from 200 to 375 micromhos/cm (Table III.A.13). However, it rose above 1,500 during the low flow of the jiilaal season, dropped to 600 at the beginning of the gu' flood and then rose to its highest level after the peak of the gu' flood, reaching 1,714 micromhos/cm. Chlorides followed the same general pattern with a good correlation between the two parameters. The maximum concentration of chlorides, 535 mg/l, occurred in early April.

Table III.A.13. SALINITY AT BAARDHEERE.

Salinity in Jubba River at Baardheere Bridge, June 1986 to May 1987

Date	EC25 micromhos/cm	Chlorides mg/l	Sodium mg/l
1986			
Jun	200	11	25
Jul-Oct	245	12	6
Nov	275	23	12
Dec	365	38	19
1987			
Jan	1,083	168	70
Mar-Apr	1,563	535	254
Apr	611	22	10
May	1,714	122	72
Xagaa mean	245	12	8
Deyr mean	320	31	15
Jiilaal mean	1,323	351	162
Gu' mean	1,163	72	41
Annual mean*	785	128	62

* *not true means, not weighted for seasonal flow variations*

The conductivity and chloride concentrations at Baardheere were similar to those reported from Mareerey (Table III.A.4), if seasonal averages were used to eliminate the effect of the long flow time between the two stations.

Phosphate nutrients were present in the water and suspended sediments primarily during the gu' flood (Table III.A.14). During the jiilaal season, phosphate was virtually absent. It was too low to stimulate algae growth and probably the limiting nutrient. However, during the other three seasons, the dissolved phosphates were adequate to support considerable phytoplankton growth.

Table III.A.14. PHOSPHATES AND NITRATES AT BAARDHEERE.

Nutrient measurements in Jubba River at Baardheere Bridge, June 1986 to May 1987

DATE	Total phosphate as P in mg/l	Dissolved nitrate as N in mg/l	Suspended phosphate as P in mg/kg	Sediment nitrate as N in mg/kg
1986				
Jun	1.07	0.9	0.00	0.13
Jul-Oct	0.12	0.8	0.00	0.03
Nov	0.20	0.8	0.00	0.76
Dec	0.13	0.5	0.00	0.11
1987				
Jan	0.00	0.3	0.00	0.01
Mar-Apr	0.00	0.2	0.00	0.08
Apr	0.56	1.6	0.56	0.95
May	7.30	8.9	7.30	0.82
Xagaa mean	0.59	0.9	0.00	0.08
Deyr mean	0.17	0.7	0.00	0.43
Jiilaal mean	0.00	0.2	0.00	0.05
Gu' mean	3.93	5.3	3.93	0.89

The flood waters of the gu' season carried a large amount of fertilizing phosphates and nitrates in the suspended sediments which undoubtedly contributed to maintaining the fertility of the Jubba River floodplain.

The traces of elemental arsenic in solution gradually increased from zero in the river during June to concentrations of 0.09 mg/l, a level considered toxic for human use but suitable for agriculture (Table

III.A.15). In a shallow well at Buur Wakow in the Mogambo Irrigation Project, the well water contained 0.48 mg/l arsenic in June, which was probably the result of leaching soil and river chemicals from the surrounding fields. The maximum contaminant level recommended for arsenic is 0.05 mg/l in public drinking water (US EPA 1982). Arsenic is an unusual toxicant in that continuous doses of very small concentrations can increase the capacity of a person to withstand larger doses. This may explain why residents of the Jubba Valley do not report arsenic toxicity. However, visitors, such as temporary construction personnel for building Baardheere Dam, might be affected by the arsenic if they were to drink untreated river water during the gu' flood season.

Boron was at modest and safe levels throughout the year, ranging from 0.03 mg/l at the end of the jiilaal season to 0.48 mg/l during the gu' flood. At no time was selenium detected in any of the samples.

Table III.A.15. ARSENIC, BORON, AND SELENIUM AT BAARDHEERE.

Trace element measurements in Jubba River at Baardheere Bridge, June 1986 to May 1987

Date	Arsenic in mg/l	Boron in mg/l	Selenium in mg/l
1986			
Jun	0.01	0.16	-
Jul-Oct	0.00	0.10	-
Nov	0.00	0.05	-
Dec	0.02	0.10	-
1987			
Jan	0.03	0.50	-
Mar-Apr	0.02	0.03	-
Apr	0.05	0.37	-
May	0.09	0.48	-
Xagaa mean	0.00	0.13	-
Deyr mean	0.01	0.08	-
Jiilaal mean	0.02	0.27	-
Gu' mean	0.07	0.42	-

The concentration of sulfates was of interest because excessive sulfates in water used for mixing concrete in the dam could cause spalling of the concrete and considerably reduce its structural strength. Sulfates in water below 150 mg/l cause negligible problems. Concentrations over 1,000 mg/l cause considerable problems and above 2,000 mg/l, the damage is severe (USBR 1966). The concentration of sulfates was low in the river from June until December, but it began to rise in January as the river flow decreased, reaching a maximum of 1,584 mg/l in early April at the end of the jiilaal dry period (Table III.A.16). The concentration dropped temporarily to 55 mg/l at the beginning of the gu' flood, but then increased to 378 mg/l during the heavy flood. It was clear that precautions must be taken during the jiilaal and gu' seasons to use special cement or monitor and treat the river water during those periods. In addition to sulfates, the gu' floodwaters also contained significant amounts of suspended solids and other salts, thus requiring treatment regardless of the sulfate problem.

Table III.A.16 . SULFATES AT BAARDHEERE.

Sulfate measurements in Jubba River at Baardheere Bridge, June 1986 to May 1987

DATE	SULFATE in mg/l
1986	
Jun	25
Jul-Oct	16
Nov	28
Dec	53
1987	
Jan	142
Mar Apr	1,584
Apr	55
May	378
Xagaa mean	21
Deyr mean	41
Jiilaal mean	863
Gu' mean	217

Salt Surveys During Early Gu' Flood

In 1987, conductivity was monitored daily at Baardheere bridge from the end of the extremely dry jiilaal season to the peak of the large gu' flood which came during the end of May. This high frequency of sampling confirmed previous indications that the salt surges of the gu' flood were of short duration and usually occurred before the river discharge increased (Table III.A.17). Only a small load of salt was involved, and the simplified modeling of salt mixing in the proposed reservoir, using monthly means of salt concentrations, could be trusted to give adequate predictions.

In addition, passage of the salt surges downstream was simultaneously monitored by the JSP at their Mareerey intakes, making it possible to measure time of travel of the salt surges between Baardheere and Mareerey (Table III.A.18). During the passage of the surges, the stage (elevation) of the river at the gage at Baardheere bridge was noted, indicating the discharge rate of the river. Thus, three surges were tracked during these early floods, with travel times from 5-11 days (Table III.A.19). This information had general value for hydrologic analyses and can also be used in estimating patterns of decay of organic and biological contaminants in the river.

Table III.A.17. DAILY WATER QUALITY AT BAARDHEERE.

Daily monitoring of river conditions and salt concentrations at Baardheere Bridge, April-May 1987

DATE	Gage Elev m	EC micro-mhos/cm	Temp in lab °C	Chloride mg/l	Sett. Solids mg/l	Hardness $CaCO_3$ mg/l	Ca mg/l	Mg mg/l
April (noonday measurements)								
9	0.60	449	33.3	39	0.5	176	41	14
10	0.80	472	32.8	48	0.4	168	37	18
11	0.80	463	34.0	40	0.3	202	46	21
12	0.85	471	35.2	50	0.6	172	41	17
13	0.90	612	46.3	66	1.0	199	51	18
14	0.94	617	46.0	52	1.1	183	51	14
15	0.95	402	34.4	31	0.4	140	29	15
16	1.50	1,083	34.1	190	1.3	253	83	11
17	1.65	393	33.9	33	1.4	146	45	8
18	1.66	487	32.9	56	1.6	180	54	11
19	1.64	336	32.9	26	1.5	32		
20	1.80	268	33.4	21	1.4	36		
21	2.18	316	32.2		2.0			
22	1.92	242	32.6		2.5			
23	1.90	239	32.4	11	2.5			
24	1.70	537	32.2	68	3.0			
25	1.60	356	32.3	20	2.8			
26	1.50	316	32.4	12	2.6			
27	1.40	294	32.4	12	1.0			
28	1.50	302	32.0	14	1.0			
29	1.50	297	32.7	14	0.8			
(additional readings at peak of major flood)								
May 23								
3pm	3.90							
6pm	4.35	2,400						
11pm	4.80							
May 24								
6am	5.10	1,100						
noon	5.20	1,350						
6pm	5.30	1,600						
11pm	5.32	1,400						
May 25								
6am	5.41	1,370						

Table III.A.18. DAILY CONDUCTIVITY AT MAREEREY.

Daily measurements of EC25 at Jubba Sugar intakes at Mareerey, March-September 1987 (supplied by Agricultural Manager, Jubba Sugar Project).

DAY	MAR	APR	MAY	JUNE	JULY	AUG	SEPT
1	1,015	1,611	340	971	360	292	337
2	1,046	1,617	486	840	334	315	446
3	1,054	1,827	273	813	360	315	420
4	1,047	1,678	430	735	341	315	379
5	1,064	1,719	298	750	386	318	360
6	1,081	2,103	360	670	394	289	341
7	1,110	1,934	350	643	367	309	341
8	1,110	1,448	357	603	367	334	270
9	1,110	1,289	383	603	367	295	253
10	1,170	783	354	662	394	322	232
11	1,149	744	446	603	375	322	236
12	1,191	793	1,191	578	367	309	210
13	1,193	778	620	578	352	334	214
14	1,248	620	397	578	345	360	184
15	1,287	595	322	536	325	36[illegible]	202
16	1,252	511	365	525	348	35[illegible]	170
17	1,214	471	360	499	315	375	179
18	1,191	438	365	515	289	334	278
19	1,338	545	372	509	289	375	257
20	1,488	535	340	499	262	360	206
21	1,488	496	972	446	251	394	236
22	1,517	645	455	402	252	394	206
23	1,467	464	778	402	252	394	232
24	1,467	696	1,213	402	283	367	210
25	1,541	608	1,492	402	289	371	206
26	1,512	372	1,312	367	257	367	253
27	1,556	322	798	367	252	375	257
28	1,647	316	1,338	367	289	367	257
29	1,587	267	1,081	348	289	420	232
30	1,632	267	1,049	348	283	367	253
31	1,590		1,049		292	402	
Avg	1,302	883	643	552	320	349	262

Table III.A.19. TRAVEL TIMES ON JUBBA RIVER.

Travel times in Jubba River from Baardheere Bridge to Mareerey as determined by passage of salt surges, 1987

Date of Salt surge passing Baardheere	River Discharge at Baardheere in cumecs	Travel Time to Mareerey in days (342 river km)	Mean velocity cm/s
March 25	45	11	36
April 16	156	8	49
May	23	1,300	5

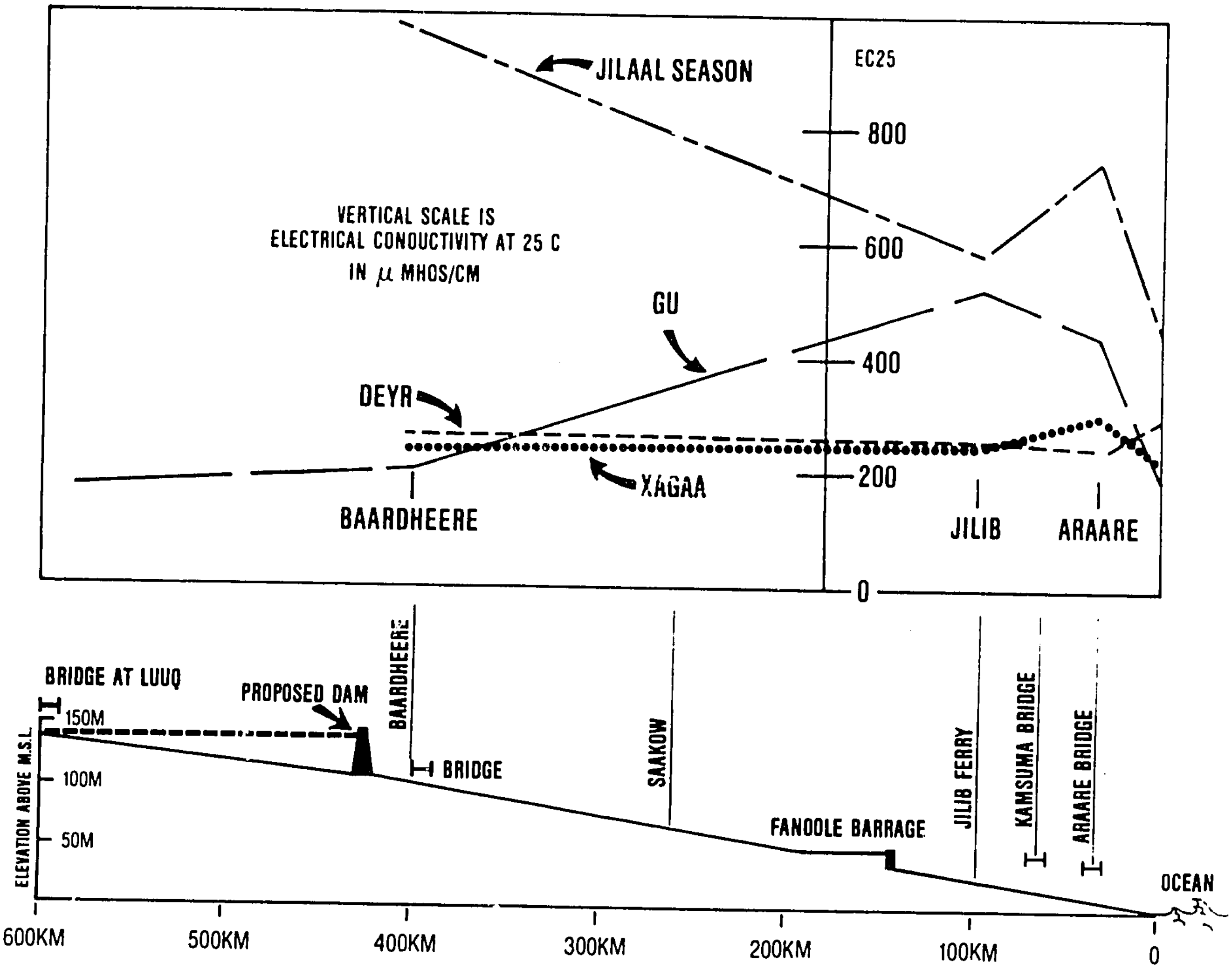


Figure III.A.2
Variations In EC25 In Jubba River For All Seasons 1986-87

Analysis of Four Seasonal Patterns

One way to understand the water quality conditions is to analyze the trends by season. These were summarized in the following paragraphs for the gu', xagaa, and deyr seasons of 1986 and the jiilaal and gu' seasons of 1987, using the collected data grouped by season.

The 1986 Gu' Season

This season lasted from April-June and usually involved rains in the entire valley. Three sampling runs for water quality were conducted in June 1986 from Luuq to the ocean, shortly after the gu' rainy season. When these runs were made, the roads and land in the upper valley were quite dry, but the lower valley was still partially flooded from local gu' rains. The river reflected this pattern, showing no increases in salts or suspended solids from Luuq to Baardheere, but large increases in Jilib and downstream areas. Electrical conductivity jumped from slightly over 200 micromhos/cm in the upstream reach to 400-500 micromhos/cm below Fanoole Barrage. Chlorides were below 20 mg/l above Baardheere, jumping to 100 mg/l in Jilib. These high values decreased slightly near the ocean due to overland flow coming from recent rains and drainage water pumped from banana fields which diluted the salts.

Suspended solids in the river also remained below 500 mg/l upstream of Baardheere, jumping to over 3,000 mg/l at Araare, also probably from drainage pumps. The suspended solids then decreased slightly to 2,000 mg/l at the ocean, probably due to the dilution from rainwater mentioned previously. In the next section, these data were used to calibrate a simple computer model of the salt concentration in the river, to be used later for predictive analyses.

The 1986 Xagaa Season

This season lasted from July to October, and was a moderately dry season with some coastal rains. Sampling runs were completed in July and August of the xagaa season, and early October which was similar to the dry months because the rains came late and were very slight in 1986. Thus there were three separate runs, all of which showed that the salts gradually dropped in concentration from Luuq to the ocean, and the suspended solids increased slightly (Figure III.A.2). Conductivity dropped from 314 micromhos/cm at Luuq to 217 micromhos/cm at the ocean, and chlorides dropped from 12 mg/l at Luuq to 11 mg/l at the ocean (Figure III.A.3). Suspended solids rose gradually from 250 mg/l at Luuq to 330 mg/l at the ocean (Figure III.A.4).

The 1986 Deyr Season

Lasting from October to December, this season usually experienced the heaviest rains of the year. Three sampling runs were made in November and one in December 1986. Apparently, because of the very slight rains in the deyr of 1986, the salt and suspended solids patterns were very similar to the xagaa dry season. Electrical conductivity, chlorides and suspended salts were almost constant throughout the river length. Conductivity varied between 253 and 286 micromhos/cm, chlorides ranged from 16 to 23 mg/l, and suspended solids varied from 153 to 228 mg/l. These variations were close to the normal sampling variations.

The 1987 Jiilaal Season

Normally the driest time of year, the 1987 season from January to May was extremely dry, causing severe problems for cattle and people until the late rains arrived at the end of May. Analysis of daily records on electrical conductivity at the Jubba Sugar pumps in Mareerey showed that monthly averages of conductivity during the dry jiilaal season almost always exceeded the desirable limit of 750 micromhos/cm, compared to the values of 200-500 in June, 200 in August, and 200-400 in November (Table III.A.18). During the jiilaal there was very little flow in the river, which sometimes dried completely. The agricultural significance of this high salt content can be evaluated by noting that the monthly mean conductivity exceeded the normal agricultural limit of 750 micromhos/cm six years out of eight in February, four years out of eight in March, and seven years out of eight in April for the period from 1979 to 1985 (Table III.A.3). The mean conductivity for the eight years during February, March, and April were 796, 819, and 1,069 micromhos/cm, respectively. The most likely sources of high concentrations of salt in the jiilaal season were agricultural drains and filtration from groundwater.

The water quality during the jiilaal had unique characteristics. During this season, the water was the clearest, with secchi disk readings as high as 1 m. However, algal growth was probably restricted due to lack of phosphate nutrients. Stream velocities approached zero and suspended solids were quite low. Only the high salinity prevented this season from being extremely favorable for aquatic invertebrates. This was probably the optimum time of

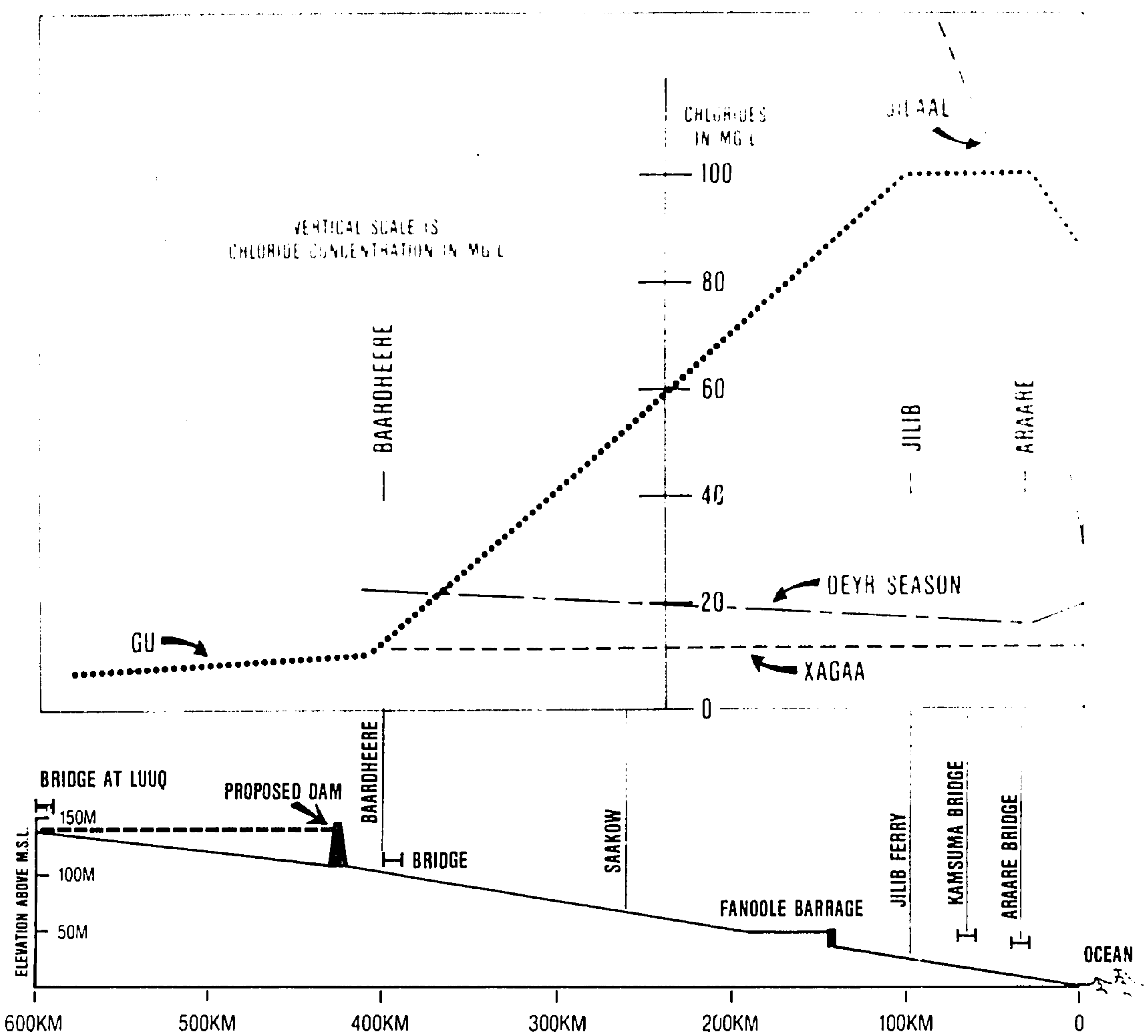


Figure III.A.3
Variations In Chlorides In Jubba River
For All Seasons 1986-87

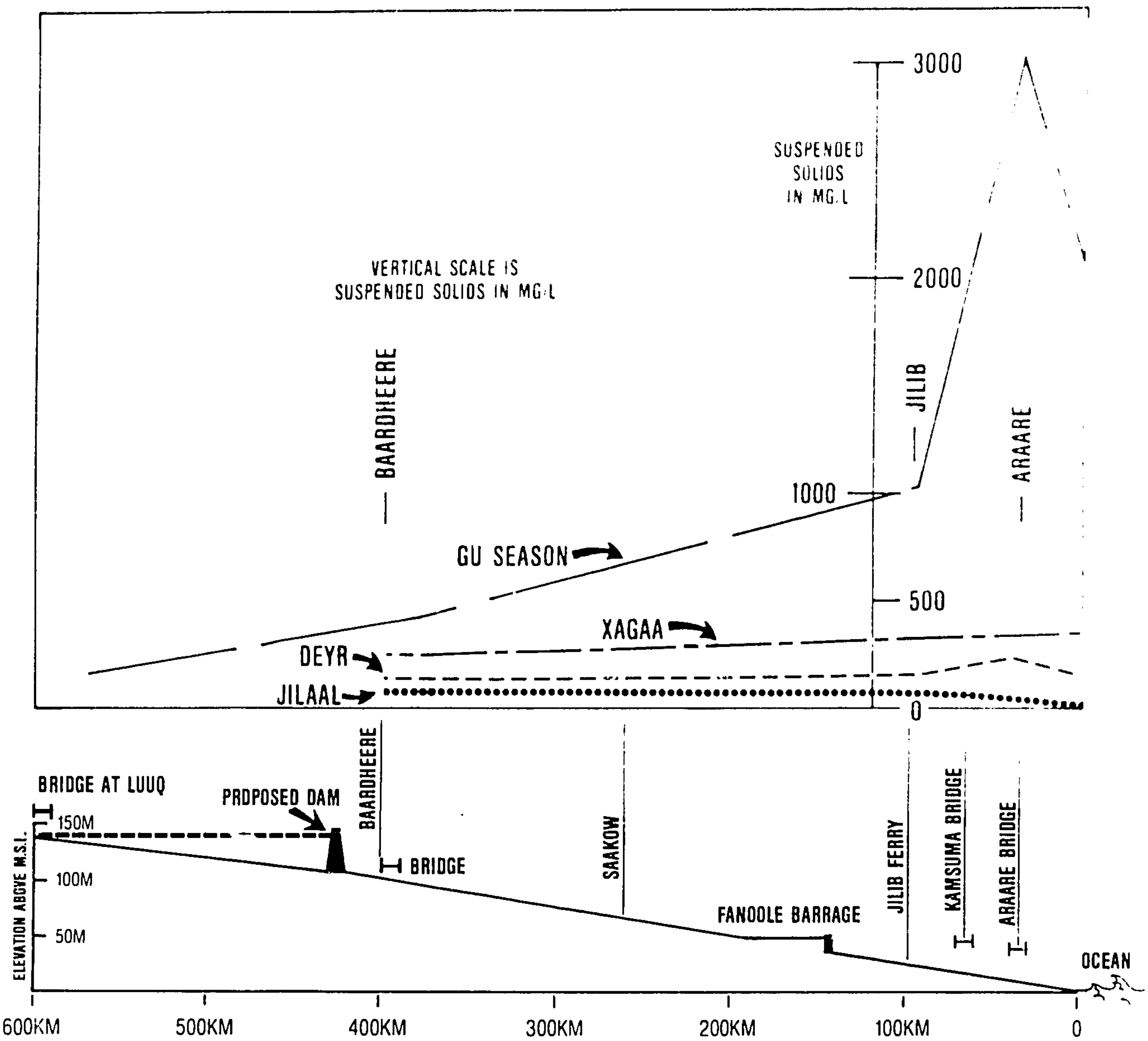


Figure III.A.4
Variations In Suspended Solids In Jubba River
For All Seasons 1986-87

year for bilharzia snail populations in the river or connected irrigation systems.

The river was unsuitable for agricultural uses during this time of year due to high salinity. During recent years, the interruption of flow below Fanoole Barrage amplified this problem for downstream irrigation intakes.

The EC25 for groundwater infiltrating to the river during extremely low river flow was about 1,500 micromhos/cm in the Baardheere area, but roughly 2,000 micromhos/cm in the irrigated zone from Fanoole Barrage to the ocean. Agricultural drains in this zone, such as those in the Fanoole system where active leaching was being practiced, had EC25 slightly higher: about 2,500 micromhos/cm.

River salinity will continue to rise during this season if irrigation is continued without construction of Baardheere Dam to increase dilution of the low flow.

Similarly, if the entire river flow is diverted to irrigation canals, as in the Fanoole system, the river water downstream will be unfit for many agricultural uses. This will be a major limitation on irrigation development in the valley and is considered in detail in simulation analyses presented in subsequent sections of this report.

The 1987 Gu' Season

In 1987, the rains produced a large gu' flood, arriving in late May and inundating most of the valley until August. A flood of this size occurs once in 10 years. Only the first portion was sampled since the annual sampling program terminated by the end of May 1987.

As soon as the first rains caused discharge increases, the river salinity dropped to acceptable levels due to dilution of the infiltrating, saline groundwater. This occurred around 10 April at Mareerey, causing the EC25 to drop from 1,289 micromhos/cm down to 500 micromhos/cm within one week, even though the river discharge was relatively low—around 50 cumecs. This condition existed until the large flood of 1,300 cumecs came through during the end of May. It caused a rise in EC25 above 750 micromhos/cm again for two weeks, which then gradually decreased throughout the following xagaa season.

Salt Data for Calibration of River Model

The value of the detailed data on existing water quality is their usefulness for predicting water quality after the dam is constructed, the reservoir fills, and flow and salinity of the lower river are moderated. A convenient method for making these predictions is to create a computer simulation of the chemical concentrations in the reservoir or river which was manipulated for a wide range of flow conditions, and then used to predict salt concentrations.

Reservoir or river models for salts are fairly simple because the salts are conservative substances which do not decay or settle. Thus, the only equations needed in the model are hydraulic mixing equations, expressing the mass balance of salt coming into and leaving a body of water, such as a length or reach of river. The river model was first tested for fit (calibrated) with field data, to evaluate its accuracy and estimate certain parameters which were not measured. After this calibration process, the model was then used to predict future river conditions.

The Jubba River has a simple configuration within Somalia, with no significant tributaries except for a drainage pump in Fanoole Rice Project. However, there are numerous small pumps used for irrigation and drainage all along the river. The most important of these is the SomalFruit group below Kamsuuma which irrigate bananas with over one hundred pumps. The river has four gaging stations where river flows are measured daily, although only three of them are calibrated (Luuq, Baardheere, and Mareerey; also Kamsuuma, which is not calibrated). Flow records at Luuq were extensive and have been analyzed in the ELC report of 1985.

The main questions to answer by modeling were related to salt concentrations in the river which often exceed the desirable limits for agriculture. The incoming salt will be changed in the future, with a more uniform seasonal distribution of the annual salt load coming out of the dam at Baardheere. This should reduce the problem of excess salt concentrations in the river. However, the return flows to the river from agricultural drainage will increase with increased agricultural development. These return flows can come from drains and drainage pumps, groundwater filtration to the river during extreme low flows, and overland runoff during floods. Estimation of this impact is probably the most important part of the modeling process.

Description of River Model

The model was based on a standard river segment, with calculation of concentrations of nondegradable or conservative chemical substances by simple mixing equations. The equations were applied at the upstream end of the river segment and again at the downstream end (Figure III.A.5). Along the segment, also known as the river reach, gradual changes in flow and concentrations occurred due to the evenly distributed flow from overland runoff due to rainfall, or from groundwater infiltration or exfiltration, depending on the relative elevation of the groundwater table and the river. The chemical concentration in this distributed flow had a significant impact on the concentration in the river. Segments were arranged so that tributaries or drainage pumps were situated at the upstream head of the river segment, and diversions or irrigation pumps were placed at the downstream tail of the segment.

The mass balance equation for a single reach in the model was

$$Q1C1 + Q3C3 + U5C5L + U6C6L - Q4C4 = Q2C2$$

in which Q was flow in cumecs, C was concentration in mg/l or micromhos/cm, U was unit flow rate per kilometer, and L was the length of the reach in kilometers. It was a simple and basic river model for conservative substances, following widely accepted practices (Tchobanoglous and Schroeder 1985).

In the Jubba River model, the entire 600 km length below Luuq was divided into 18 segments of variable length, based on the location of canal diversions, sampling stations, drainage pumps or important natural features such as the Waamo swale which joins the river near the Equator. The set of equations developed for a single reach were recalculated one reach at a time, beginning upstream at Luuq and ending at the ocean. During each calculation cycle, the final concentrations were computed for the tail of the river segment and any diversions such as Fanoole Main Canal or the Mogambo irrigation pumps. These values were printed out for each segment, before the model progressed to the next segment.

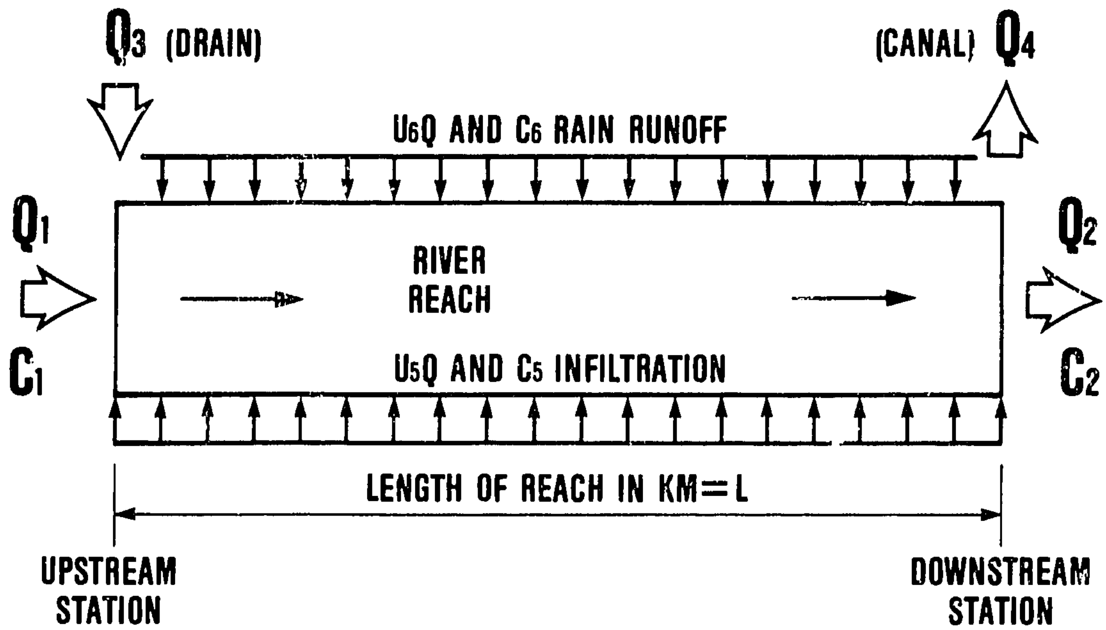
Calibration for Chlorides

...t model run for conservative substances in ...ba River was completed with the June 1986 ...a for chlorides (BNA Memo #2 to ARD of 6 March 1987). Analysis showed that the river was divided into two distinct portions with different characteristics of distributed flow runoff and chemical loadings. The upstream portion of the river above Fanoole Barrage had low runoff and loading compared to the portion from Fanoole Barrage to the Ocean.

Using flow records of the Ministry of Agriculture from the gages at Luuq and Baardheere, as well as the JESS chloride measurements, a runoff rate of 0.065 cumecs per kilometer was calculated for June 1986, as well as a chloride concentration in the runoff of 131 mg/l for the upper reaches of the river. During the June sampling in Baardheere and Luuq, roads were dry and there had been little or no rainfall. Infiltration through the soil was neglected for this run as the river was high, and flow would more likely be outward. These assumptions appeared logical for this dry region with salt deposits, and was confirmed by the low chloride concentration measured at Fanoole Barrage of 17 mg/l.

However, from Fanoole Barrage to Jilib Ferry, it was clear that a large loading of chlorides entered the river. The concentration jumped from 17 to 102 mg/l (Table III.A.21, page I-24). A higher runoff rate of 1 cumec per kilometer was arbitrarily assumed. This required about 900 mg/l chlorides in the runoff to raise the river concentration to the observed 102 mg/l at Jilib. Possible sources of this high loading of chlorides would be human wastes from Jilib on the east bank of the river, and agricultural runoff from the Jubba Sugar Project which began on the western bank of the river just below Fanoole Barrage.

From Jilib to Kamsuuma Bridge, there was a large drop in chlorides from 102 to 77 mg/l. Such a drop could only have been caused by a large inflow of water low in chlorides. Fanoole Drain entered in this reach but it carried 76 mg/l of chloride and could not have discharged more than a few cumecs. Based on the Fanoole Drain measurements, it was assumed for June 1986 that all agricultural drains had chloride concentrations of 76 mg/l during June. The mean flow of Fanoole Drain for the month of June was estimated at 1 cumec, and a possible flow from Jubba Sugar Drain was estimated at 0.1 cumecs. The required runoff to yield the observed 77 mg/l at Kamsuuma Bridge was then a flow of 5 cumecs per kilometer of river, with 10 mg/l chlorides. The source of this flow was probably the underground tributary of the Shabeelle River. Rainfall in early



LEGEND
Q = DISCHARGE IN CUMECS
C = CONCENTRATION OF SALT IN MG/L OR MICROMHOS/CM

Figure III.A.5
Schematic Of Single Reach In Water Quality Model For Jubba River

June was heavy in this area, especially around Jilib where many streets were flooded.

A significant rise in chlorides from Kamsuuma Bridge to the Mogambo pump intakes continued downstream to Araare Bridge. A runoff coefficient of 3 and chlorides of 400 brought the chlorides up to the observed 92 at Mogambo. The likely source for this high chloride load was the SomalFruit banana plantations on both banks, and possibly a small amount of human wastes from the town of Kamsuuma.

In the next two reaches, a runoff coefficient of 2 and chlorides of 300 and 200 were used to raise the chlorides to the observed 101 mg/l at Araare Bridge, just above the Equator. The only logical sources for this high loading of chlorides would be the SomalFruit banana plantations on both sides of the river, as well as human wastes from Jamaame town on the east bank about mid-way between Mogambo and Araare Bridge.

To represent the effect of 120 small pumps of the SomalFruit group, each one pumping about 1,000 cu m/day or 0.016 cumecs, fictitious pump intakes and drains were postulated in three pairs from Kamsuuma Bridge down to the ocean. Each pair represented 40 pumps which would be irrigating in the dry season and draining during the rains or floods. The first pair were at kms 55 and 40, the second pair at kms 38 and 20, and the third pair at kms 15 and 6. During the June 1986 simulation it was assumed that they were simultaneously irrigating and draining at 0.5 cumecs. The chloride concentration in the drainage water was estimated to be 76 mg/l, based on the Fanoole Drain measurements. Due to their small size, these pumps had no significant impact on flow or chloride calculations for this calibration.

From Araare Bridge to the last sampling station near the ocean, there was a drop in chlorides from 101 mg/l at the bridge to 86 mg/l at Goob Weyn. This indicated significant rainfall runoff—perhaps, much of it coming in at the Waamo drainage swale at km 26. A runoff coefficient of 8 and chlorides of 10 mg/l were used in the reach from Araare Bridge to the Waamo swale, and runoff coefficients of 2 and chloride concentrations of 10 were used in the final four reaches, ending at the ocean. These values for runoff were suggested by the swampy, flooded nature of the land from Yontooy to Goob Weyn. Both towns were flooded at the time of the June survey.

The overall impression from the first calibration exercise was that significant chloride loads were coming into the river in the lower reaches, alternating with dilution of the chloride concentrations in the river due to high rainfall runoff or underground flow from Jilib to Kamsuuma Bridge, and from Araare Bridge to the ocean. The sources of the chloride loads could have been either agricultural activities or waste loadings from the towns of Jilib, Kamsuuma, Mogambo, and Jamaame. The rain runoff and chloride loadings in the lower valley were much higher than those in the upper valley from Luuq to Fanoole Barrage.

Second Calibration for Chlorides

Two steps were necessary in the simulation of chlorides for June 1986 in the Jubba River. The first chloride simulation was revised after the subsequent conductivity calibration because it was clear that the rainfall runoff postulated for the lower reaches in the first chloride simulation was not high enough to also explain the conductivity data. Thus, these flows from the conductivity calibration were used in re-calibration, using the chloride data a second time.

The second and final chloride calibration showed the following characteristics of the river valley. There were two portions of the river receiving an increase in flow, from Jilib Ferry down to Kamsuuma Bridge, and from the Mogambo irrigation intakes down to the ocean. There were also two portions of the river which received major loadings of chlorides—both in the lower valley. The first was from Fanoole Barrage to the Jilib Ferry, and the second was from Kamsuuma Bridge down to Araare Bridge.

There was very little increase in river flow in the upper portion of the river from Luuq and Baardheere where it was slightly over 300 cumecs, down to the Fanoole Barrage where it was estimated at 335 cumecs (Tables III.A.20 and 21). However, the flow increased significantly from 370 cumecs at Jilib Ferry to 511 cumecs at Kamsuuma Bridge, and then made a major increase from 534 cumecs at Mogambo to 1,078 at the mouth of the river at Goob Weyn. The increase below Jilib was most likely runoff from the Jubba sugarcane fields on the west bank and flow from the Shabeelle aquifer on the east bank. The major increase below Mogambo was most likely from the Waamo swale which came in from the west, around Wiircoy. These two tributaries may have contributed overland or sub-

Table III.A.20. FLOWS ASSUMED IN SECOND CHLORIDE CALIBRATION OF RIVER MODEL.

Assumed flows in and out of river reaches for Jubba River

UPSTREAM END OF REACH KM	LOCATION	IN FLOW cumecs	IN CHLORIDES mg/l	OUT FLOW cumecs	OUT CHLORIDES mg/l
263	Saakow			5.0	17.9
136	Fanoole Barrage			0.7	61.9
116	JSP Labadaad			0.2	102.3
91	Fanoole Drain	1.0	76.0	0.6	89.4
78	JSP Drain	0.1	76.0		
68	Kamsuuma Bridge			1.0	91.3
60	Mogambo Pumps			0.5	93.4
40	SF Drain 1	0.5	76.0	0.5	99.5
20	SF Drain 2 Yontooy	0.5	76.0		
6	SF Drain 3	0.5	76.0		

Table III.A.21. PREDICTED AND OBSERVED CONDITIONS FOR SECOND CHLORIDE CALIBRATION OF RIVER MODEL.

Comparison of predictions with observations for flows and chlorides in model for Jubba River

UPSTREAM END OF REACH KM	LOCATION	FLOW PREDICT. cumecs	FLOW OBSERV. cumecs	CHLORIDES PREDICT. mg/l	CHLORIDES OBSERV. mg/l
600	Luuq	310	310	7	7
430	Baardheere Dam	321	324	11	12
263	Saakow	332		15	
136	Fanoole Barrage	335		18	17
116	JSP Labadaad	354		62	
100	RJ2 Pumps Jilib	370		102	102
91	Fanoole Drain	415		92	
88	JSP Mareerey	431		89	
78	JSP Drain	481		81	
68	Kamsuuma Bridge	511		77	77
60	Mogambo Pumps	534		91	92
55	SF Pumps 1	553		93	
40	SF Drains 1	613		99	
38	SF Pumps 2 Araare	621		100	101
26	Waamo Swale Wiircoy	765		100	
20	SF Drain 2 Yontooy	837		95	
15	SF Pumps 3	897		92	
6	SF Drain 3	1005		88	86
0	Ocean	1078		85	

surface flow, although inspections at their road crossings showed no evidence of surface flow on the three days of the field survey.

The upper portion of the valley from Luuq to Baardheere had a low runoff coefficient of 0.065 cumecs per kilometer, which was indicative of the dry conditions observed during the field visit. In contrast, the runoff coefficient in the lowest reaches of the river from Mogambo to the ocean was 12 cumecs per kilometer (Table III.A.25). This was reflected in the flooded condition of the towns of Yontooy and Goob Weyn observed at that time.

The chloride concentration in the river at Luuq and Baardheere was about 10 mg/l, and rose only slightly to 17 mg/l after 400 km of travel to Fanoole Barrage. This corresponded to a concentration in the runoff of 131 mg/l for this entire reach. However, in the short stretch from Fanoole Barrage to kilometer 100 at the Jilib Ferry, the chlorides in the river jumped to 102 mg/l, requiring an estimated concentration in the runoff of 800-1,000 mg/l. This reach has intense agriculture and high population density, which are probably the sources of the high chlorides.

Below Jilib, the chlorides dropped to 77 mg/l at Kamsuuma Bridge with estimated concentrations in the runoff of 10 mg/l, but then showed another significant increase from Kamsuuma to Araare Bridge, rising again from 77 mg/l to 101 mg/l. The estimated concentrations in the runoff in this reach were 400 mg/l from Kamsuuma Bridge to Mogambo, and 150 mg/l thereafter. Combined with the large runoff in this lower reach, the calibration indicated a major loading of chlorides coming to the river. This reach below Kamsuuma Bridge included the towns of Kamsuuma, Mogambo, and Jamaame, as well as intense banana cultivation along both banks—the likely sources of the chlorides (Table III.A.22).

Table III.A.22. ESTIMATED CHLORIDE CONCENTRATION IN RUNOFF.

Developed by calibrating salt model for Jubba River

FROM	TO	CHLORIDES IN MG/L
Luuq	Fanoole	131
Fanoole	Jilib	800 - 1,000
Jilib	Kamsuuma	10
Kamsuuma	Mogambo	400
Mogambo	Araare	100 - 150
Araare	Ocean	50

Conductivity Calibration

The final calibration of conductivity for June 1986 conditions in the Jubba River was made with flow data identical to the calibration for chlorides. Thus, the rainfall runoff coefficients used in the conductivity calibration were the same, reach by reach, as those used for chloride calibration.

Because the irrigation flows and drainage returns were so small in relation to the flow of the river during June, they had little impact on the flow or conductivity in the river (Table III.A.23). The major impact was from rainfall runoff and the salts it carried.

Table III.A.23. ASSUMED FLOW REGIME IN CALIBRATION OF RIVER MODEL FOR EC25.

Assumed flows in and out of river reaches for conductivity (EC25 in micromhos/cm) modeling of Jubba River

UPSTREAM END OF REACH KM	LOCATION	IN FLOW cumecs	IN EC25	OUT FLOW cumecs	OUT EC25
263	Saakow	5.0	278		
136	Fanoole Barrage	0.7	432		
116	JSP Labadaad	0.2	542		
91	Fanoole Drain	1.0	486	0.6	508
78	JSP Drain	0.1	486		
68	Kamsuuma Bridge	1.0	513		
60	Mogambo Pumps	0.5	497		
40	SF Drain 1	0.5	486	0.5	450
20	SF Drain 2 Yontooy	0.5	486	0.5	315
6	SF Drain 3	0.5	486		

However, there was a significant difference in the conductivity and chloride concentration patterns in the reaches from Mogambo to Araare. In these reaches, the conductivity declined, indicating heavy runoff of low conductivity water, while the chlorides rose (Tables III.A.21 and 24). This may have been caused by a decrease in concentrations of salts other than chlorides.

Following the river from Luuq down to the ocean, three distinct reaches were seen, based on the conductivity data. From Luuq to Baardheere, there was a slight increase in river flow and conductivity. This could be simulated by a rainfall runoff coefficient of 0.065 cumecs per kilometer and a conductivity of 350 micromhos/cm (Table III.A.25). Assuming the same runoff coefficient down to Fanoole Barrage would then require a conductivity of 1300 micromhos/cm in the runoff.

From Fanoole to Jilib, the conductivity rose sharply from 278 to 538. If the overland runoff coefficient was 1 cumec per km, then the conductivity of the runoff would have to be 3,000 micromhos/cm to produce the observed rise. This would indicate salts coming from agricultural activities and Jilib town.

Table III.A.24. PREDICTED AND OBSERVED CONDUCTIVITY IN JUBBA RIVER.

Comparison of predicted with observed flows and conductivity (EC25 in micromhos/cm) in salt model of Jubba River

UPSTREAM END OF REACH KM	LOCATION	FLOW PREDICT. cumecs	FLOW OBSERV. cumecs	EC25 PREDICT.	EC25 OBSERV.
600	Luuq	310	310	213	213
430	Baardheere Dam	321	324	218	218
263	Saakow	332		253	
136	Fanoole Barrage	335		278	278
116	JSP Labadaad	354		432	
100	RJ2 Pumps Jilib	370		542	538
91	Fanoole Drain	415		516	
88	JSP Mareerey	431		508	
78	JSP Drain	481		487	
68	Kamsuuma Bridge	511		476	476
60	Mogambo Pumps	534		513	513
55	SF Pumps 1	553		497	
40	SF Drains 1	613		455	
38	SF Pumps 2 Araare	621		451	452
26	Waamo Swale Wiircoy	765		368	
20	SF Drain 2 Yontooy	837		337	
15	SF Pumps 3	897		315	
6	SF Drain 3	1,005		282	278
0	Ocean	1,078		264	

Below Jilib, the conductivity dropped slowly from 538, and reaching 476 at Kamsuuma Bridge. This was simulated with a runoff coefficient of 5 and conductivity of 300 in the runoff (Table III.A.25).

Table III.A.25. CONDUCTIVITY IN RUNOFF.

Estimated conductivity in runoff derived from calibration of salt model for Jubba River

REACH FROM	REACH TO	RUNOFF COEFF. CUMECS PER KM	CONDUCTIVITY IN RUNOFF MICRO-MHOS/CM
Luuq	Baardheere	0.065	350
Baardheere	Fanoole	0.065	1,300
Fanoole	Jilib	1	3,000
Jilib	Kamsuuma	5	300
Kamsuuma	Mogambo	3	1,300
Mogambo	Araare	4	75
Araare	Ocean	12	10

The conductivity jumped to 513 at Mogambo and then continued a gradual decline to the ocean, decreasing to 278 at Goob Weyn. This was simulated by using a runoff coefficient of 4 and conductivity of 75 from Mogambo to Araare and then a runoff coefficient of 12 and conductivity of 10 from Araare to the ocean.

In summary, the overall simulation indicated very salty runoff in the Luuq-Baardheere reach, with slightly diluted runoff down to Fanoole Barrage. From Fanoole to Jilib, the runoff was extremely salty, with low conductivity water coming in from Jilib to Kamsuuma, then a burst of salty runoff again, from Kamsuuma to Mogambo, followed by runoff with low conductivity coming in from Mogambo to Araare, and extremely low conductivity coming in from Araare to the ocean (Table III.A.25).

2. Ocean Intrusion

Normally, there is an annual intrusion of ocean water up the mouth of the Jubba river at the end of the jiilaal dry season from March until April or May. Because of the simple nature of the river channel and mouth, the salinity intrusion occurs without significant stratification, in a wide and shallow channel of uniform cross-section. Maximum tidal range at Kismaayo is ±3.5 m and the mean river slope approaching the ocean is less than 0.0001.

Because dry season flow in the river often drops to nearly zero, ocean intrusion at high tide in this simple case represents the maximum possible upstream penetration of the ocean, and the salinity of the intrusion is essentially the same as ocean water, with only slight, local dilution from residual pools.

This situation occurred during the field survey in late March 1987, thus the maximum intrusion was monitored. Littoral currents had eliminated the sandbar usually blocking the river mouth. High tides of 3.5 meters occurred on 28 and 29 March, at levels exceeding any seen in 1986 or 1987. Because the deyr rains of 1986 had failed, the Jubba River flow had dwindled to a trickle by late March, and the riverbed was dry at the bridge crossings of Kamsuuma and Jamaame, and downstream. The river was reduced to a series of disconnected pools which contained salty groundwater infiltrate, with a conductivity of about 2,000 micromhos/cm.

In the early evening of 28 March, the high tide drove ocean water upstream to Yontooy where it entered the intakes of the Kismaayo drinking water system, 28 km upstream of the ocean (Figure III.A.6). Slightly further upstream, at a pump 1 km above Buulo Guduud (river km 41), a tidal fluctuation was observed but the water was groundwater infiltrate with a conductivity of only 1,350 units. Also, further upstream at Wiircoy (river km 45), a slight tidal fluctuation was seen, but was not ocean water. It was used for drinking water by the people on a riverbank farm, and was probably also groundwater infiltrate.

Thus, the maximum ocean intrusion to be expected is between Yontooy and Buulo Guduud, river km 30-40 (Figure III.A.6). The river was quite shallow in this reach—only a fraction of a meter in March. Given the wide river bed (200-500 m), wind mixing was strong and stratification not important. The same was true further downstream. The maximum depth at Goob Weyn was less than 2 m.

With even small river flows, the seawater intrusion was driven out nearly to the beach. There were no significant swamps or coastal spawning areas at the mouth of the river which might need the annual intrusion of sea water. A low barrier to prevent ocean intrusion upstream of Goob Weyn would avoid agricultural damage and also protect the intakes for the Kismaayo water supply.

The sandbar normally blocking the river mouth was eliminated by littoral currents during the jiilaal season when winds were from the southwest, allowing free passage of flow. Thus, at the beginning of the gu' flood the channel mouth was open and flooding due to blockage of the mouth did not occur.

3. Irrigation and Drainage

The existing water quality in the lower Jubba River Valley was already considerably modified by existing irrigation and drainage systems in 1986. Pumps extracting river water for irrigation were found from the very top of the valley near Luuq down to the coastal section near Kismaayo, including very large pumps of the Jubba Sugar Project and the Mogambo Irrigation Project. Probably the largest single impact on water quality came from the diversion at Fanoole Barrage and the return drainage below the rice fields. Less dramatic, but also important, were the many small pumps used for irrigation and drainage in the Somalfruit groves below Kamsuuma. These drainage returns carried fertilizers, salts, and perhaps biocides to the river. Biocides

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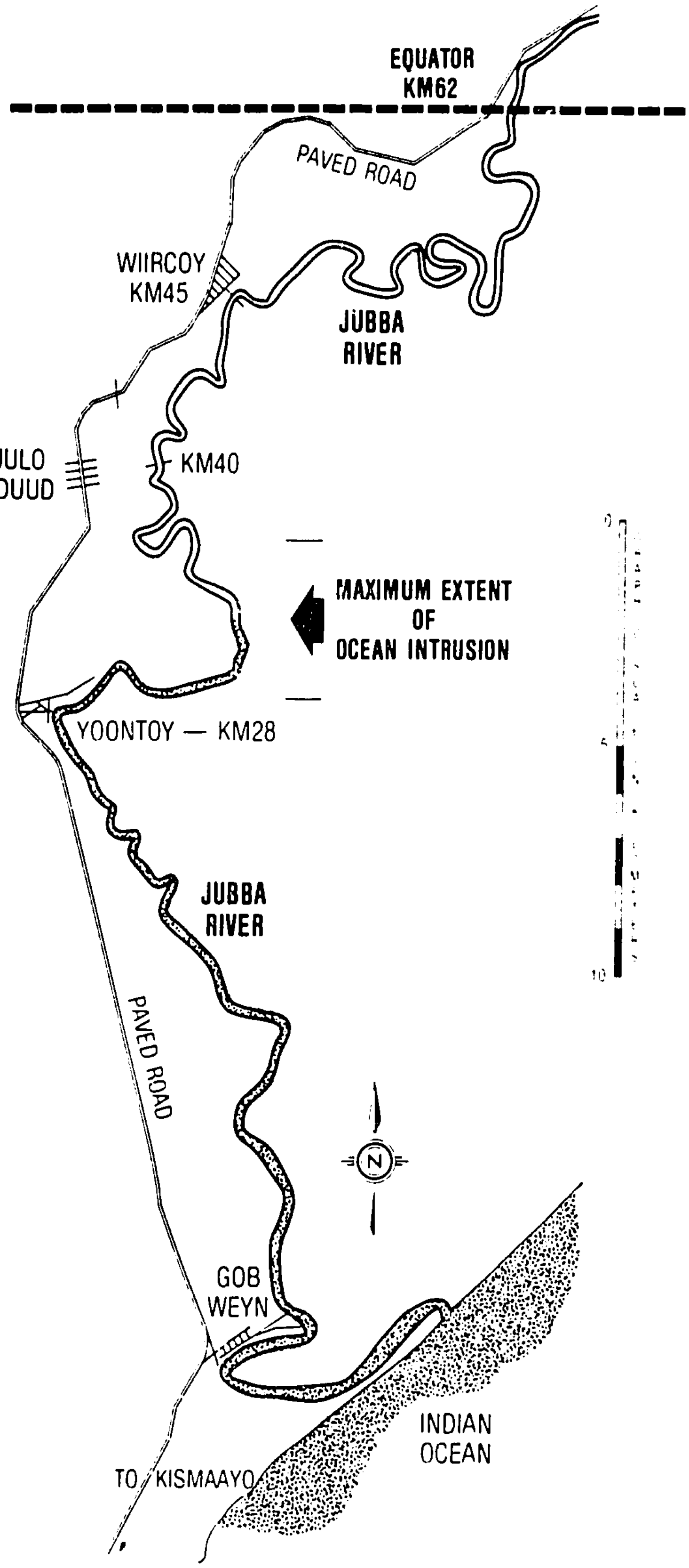


Figure III.A.6
Lower Reach Of Jubba River
Showing Extent Of Ocean Intrusion

Maximum ocean intrusion occurred at zero river flow in March 1987, reaching almost to Buulo Guduud.

were discussed later in this chapter because they also came from nonagricultural sources.

Fertilizers and Nutrients

Fertilizers applied to crops are often washed into drains by excess rain or irrigation water. When fertilizers reach the river or other surface waters they have the same effect on aquatic plants that they had on terrestrial crops (stimulating lush growths of algae, floating weeds such as water hyacinth, and submerged and emergent vegetation.) If fertilization of aquatic plants is excessive, it could lead to blockage of river flow and increased siltation. Although vegetation produces oxygen when stimulated by sunlight, at night or on cloudy days, excess vegetation respires and can deplete oxygen. This may lead to anaerobic conditions which are offensive and may be lethal to fish and other aquatic organisms.

Phosphate fertilizers are generally retained by the soil, but nitrates pass in solution to the groundwater. Each large irrigation scheme in the Jubba Valley used large quantities of fertilizer which would increase as irrigated area is increased in the future. About 4,000 metric tons of fertilizer were applied in 1986. Most of it was in various forms of nitrogen such as urea and disodium ammonium phosphate. (Table III.A.26).

Table III.A.26. FERTILIZER USAGE IN 1986.

Inventory of fertilizer use in Jubba River Valley, from June 1986 survey

USER	Fertilizer	Applied to crop area in ha	Application rate annually in kg/ha	Total in metric tons
FANOOLE RICE PROJECT	Urea	1,735	400	694
	Disodium Ammonium Phosphate (DAP)	150	260	
	Sodium, Phosphate Potassium Complex (NPK)		200	347
MOGAMBO IRRIGATION PROJECT	Urea	500	150	75
	DAF		150	75
	Zinc Sulfate	2	1	
	Copper Sulfate	Trace		
SOMALTEX	None	4,500		0
JUBBA SUGAR PROJECT	Urea	6,760	237	1,606
SOMALFRUIT	Urea	2,200	200	·440
	Ammonium Sulfate	100	220	
	Potassium Sulfate	100	220	
TOTAL Fertilizers applied annually in metric tons			3,938	

Groundwater Conductivity

Strategic sampling of the Jubba River wells, drains, and irrigation projects at the end of the 1987 jiilaal dry season indicated that even limited present water usage in the lower valley occasionally caused excessively high conductivity in local wells and the Jubba River as it passed through the irrigated zones. Subsequently, the irrigation systems refrained from pumping for short periods at the end of the jiiaal dry seasons.

The groundwater of Jubba Valley consisted of a deep deposit of fossil ocean water with extremely high conductivity, overlaid by lenses of sweet water percolating down from local rainfall, floods, the river, and irrigation systems.

In shallow wells, within irrigated areas such as that at Buulo Burwako in the Mogambo Irrigation Project, the conductivity of the water reached 4,200 units—unsuitable by normal standards, but tolerated by the residents. This high conductivity was apparently due to leaching of salts from surface soils in the irrigated fields.

However, shallow wells in towns or other unirrigated areas had low EC during the rainy season, due to percolation of rainwater and river flood water which then rested on top of the highly conductive fossil water.

At present, under towns such as Jilib and in other nonirrigated areas of the lower valley, the conductivity in this fresh water lens was about 500 micromhos/cm during most of the year, which is satisfactory for domestic and agricultural uses. Nonetheless, after a long, dry season such as the 1987 jiilaal, the water in wells tapping this lens also rose in conductivity to 1,500 micromhos/cm—well above the recommended drinking water limit.

Soil Salinity

Irrigation practices in the Fanoole Rice Project, where double cropping was practiced, were generally successful in removing salts from the upper soil layers. Rice yields remained over four tons per hectare in the scheme, and even highly alkaline soils have been reclaimed with this method. Heavy irrigation, combined with rapid and extensive drainage, kept the water table deep and lowered sodium in the soil to a concentration acceptable for agricultural purposes.

The irrigation water applied to the Fanoole Rice Project in June 1986 had 4 mg/l of sodium, while the drainage water leaving the scheme at the same time contained 48 mg/l (Table III.A.6). Chlorides in the irrigation water were at 17 mg/l and at 59 mg/l in the drains. Thus, the leaching process extracted 44 mg/l of sodium and 42 mg/l of chloride from the soil during this period.

There was considerable seasonal variation in water quality in the drain, with very high conductivity occurring in the dry jiilaal season of 1987 (Table III.A.27). During the driest month, EC25 reached 2,525 micromhos/cm in the drain, compared to values of 300-500 micromhos/cm in the drain during the rest of the year, and an annual mean of about 900 in the river, which approximated the quality of the water being supplied to the rice fields by the main irrigation canal (Table III.A.9). A portion of these leached salts found their way to the Jubba River near Mobarek via the drainage system, and the rest percolated directly downward to the groundwater. During low river flows, this

Table III.A.27. WATER QUALITY IN FANOOLE PROJECT.

Fanoole Rice Project irrigation and drainage system, 1986-87

DATE	Temp. °C	SECCHI disk cm	EC25 micro-mhos/cm	COLOR su	CHLORIDES mg/l	NITRATES mg/l as N	PHOSPHATES mg/l as P
1986	(samples from Fanoole Main Drain)						
June	27.6	38	486	28	76	2.0	0.0
Jul-Oct	30.2	38	421	11	39	-	-
Nov	30.7	15	377	10	29	2.6	0.2
Dec	26.0	40	499	9	51	2.9	0.1
1987							
Apr	33.0	20	2,525	10	334	4.5	0.0
May	28.0	63	1,178	17	442	2.2	2.5
MEAN	29.2	41	914	14	162	2.4	0.5
Mean in Fanoole main canal (samples from river above Jilib)							
	29.2	9	893	8	104	8.6	1.3

groundwater undoubtedly seeped into the river, given the 5-10 m height of the rice fields above the river bed.

Velocity in the drains was near zero, except in the immediate vicinity of the pump intakes, near the village of Mobarek. The drainage water contained less nitrate and phosphate in solution than the irrigation water, and more color. These conditions reflected the dense algae populations in the drains, as well as the general abundance of emergent vegetation. Nonetheless, snails were not very common in these drains, and bilharzia snails were never encountered. The water in the drains had a higher clarity, with a mean secchi disk depth of 41 cm, compared to 9 cm in the irrigation canal. This was due to the slower velocities and better settling.

In 1986, the Fanoole Main Canal delivered over 10 million cubic meters of water annually to the 500 hectares under cultivation. If half of the applied flow percolated downward through the soil, about 200 tons of sodium and 200 tons of chloride were leached from the surface soils annually within the Fanoole Project. The annual mean EC25 of the applied irrigation water in Fanoole Canal was about 800 micromhos/cm while EC in Fanoole drains was over 900 micromhos/cm (Table III.A.9). In the dry season, the applied water had an EC25 of about 2,000 micromhos/cm while the drain yielded more saline water with an EC25 of 2,500 micromhos/cm (Table III.A.7).

Filtration in the River

During the end of the 1987 jiilaal dry season, the flow in the Jubba River between Fanoole Barrage and Jamaame was zero, and water that collected in depressions in the river bed was infiltrating laterally from the irrigated fields of the Jubba Sugar Project and Fanoole Rice Project. This water had an EC of 2,000 micromhos/cm in March and April, 1987 (Table III.A.7). Even the water in the Jilib wells approached this level of conductivity in early May, indicating that the layer of fresh water over the aquifer in Jilib had been depleted by pumping and remaining water was coming from either the nearby irrigation projects or the lower stratum of fossil groundwater.

However, when the river was full or in flood, and the water level in the river bed was 5 or 10 meters higher than in the dry season, the direction of filtrating flow was reversed and went from the river out to the groundwater, adding relatively fresh water to the subsurface supply with EC25 below 700 micromhos/cm. This condition existed for several months during the gu' and deyr floods, charging the aquifer with sufficient fresh water to supply the towns along the river.

4. Dhesheegs as Vector Habitats

Because they were the only ones accessible throughout the year, two dhesheegs were monitored to determine their suitability for breeding of malaria mosquitos and bilharzia snails. One was between Fanoole main canal and the river, slightly downstream of Fanoole Barrage, and was monitored for water quality and general aquatic conditions. The other dhesheeg was across the paved road from Goob Weyn (Figure III.A.1).

February 1986

Dhesheeg Fanoole was given a preliminary inspection on 25 February. It was about 0.3 m deep, and full of water lilies and wading birds. A considerable variety of crops were planted along the receding shoreline. It had probably filled during the deyr flood of 1985, in September or October. Dhesheeg Goob Weyn was dry at the time of this first inspection.

June 1986

Both dhesheegs probably filled in May and June during the moderate gu' flood and rains of 1986. At the first water quality sampling on 6 June 1986, the water in Dhesheeg Fanoole was quite warm: 29.2° C. It was turbid and slightly saline with an EC25 of 566 micromhos/cm. The secchi disk reading was only 7 cm, and mean depth was 0.5 m. Aquatic vegetation, snails, fish, and birds were common, indicating a highly productive water body. Planted crops along the shoreline were also extensive.

The second dhesheeg, across the road from Goob Weyn, was a recently flooded area. It appeared to have filled about 1 June from rainwater, and had a surface area of about 5 sq km and mean depth of 1 m. It was also filled with turbid, warm water and contained many wading birds. It looked as if it would dry out in a month or two.

December 1986

Because of the low rainfall and low river level during the deyr season of 1986, the two dhesheegs did not fill during this season. Dhesheeg Fanoole was almost completely dry on 10 December, and would certainly be completely dry by the end of the year. The only water remaining was about 1 hectare of a weedy mudhole in the center. The rest of the land (estimated 30-40 hectares) was covered with nearly mature corn. The area had been dry since September.Dhesheeg Goob Weyn was completely dry, and probably had dried out by July or August.

April 1987

At the end of this extremely dry jiilaal season, both dhesheegs were completely dry and the areas were being grazed by goats and cattle. These conditions should not be expected every year as 1986 had been extremely dry.

March 1987

The river began to rise at Baardheere about 25 March. Within a month, a large flood covered the Jubba River Valley, completely covering both dhesheegs and extensive surrounding land. It was a flood with about a 10-year frequency. Thus, the dry period in the Fanoole dhesheeg extended from early January to late March 1987 (three months), and the dhesheeg near Goob Weyn was dry from July 1986 to March 1987—about nine months.

5. Community Water Supplies

The major towns and some villages of the Jubba River Valley were visited to determine existing community water supply systems and the institutional arrangements for their construction, operation, and maintenance. Nationwide, the larger water supplies were drilled, constructed, operated, and maintained by the Water Development Agency (WDA) of the Ministry of Mineral and Water Resources. The pump operators were employed by the WDA and collected funds were returned directly to the WDA for recurrent expenses. Their annual expenditures in 1984 were 66 million Somali shillings for development of new community water supplies and 50 million shillings for recurrent expenses. They collected 11 million shillings in tariffs from water consumers. Prices obtained at individual wells varied considerably from official figures. For 1986, the official price for WDA water was 18 shillings per cubic meter, with daily charges per head of livestock.

The independent Kismaayo Water Agency, which owned a surface water treatment system, was an exception to the national organization. This agency reported recurrent expenditures of 20 million shillings in 1984 and tariff collections from consumers of 7 million shillings. The deficit was covered by the Ministry of Finance.

The Ministry of Local Government and Rural Development also owned and operated some wells, as did the Ministries of Agriculture and of Livestock, Forestry, and Rangelands.

Surveys of existing water supply facilities were completed during December 1986, including the towns of Kismaayo, Jamaame, Jilib, Bu'aale, Saakow, Baardheere, Garbahaarey, and Luuq, as well as the villages of Goob Weyn, Buulo Burwako, Hargeisa-Loi Leida, and Canoole (Figure II.1).

Kismaayo Water Agency had a water intake and filtration system located in the village of Yoontoy with a 25 km pipeline to Kismaayo. The system was old and no longer provided efficient filtration due to lack of chemicals and spare parts. Water from the tap was soft but contained considerable turbidity, some of which settled out almost immediately. Staff at the agency office said several plans for rebuilding the filters have been discussed, but nothing has materialized. Capacity data was not available but was estimated at 700,000 cubic meters annually, based on tariff income. This would be 2,000 cubic meters per day—enough to supply 100 liters per day to a community of 20,000 people. There were a few private wells in the town but everyone was served by the pipe system.

The village of Goob Weyn obtained all of its water directly from the river. It was hauled by donkey carts carrying 200 liter drums.

The town of Jamaame had a well constructed in 1979 near the Somaltex compound at the southern entrance to the town. It was approximately 60 m deep with a diesel pump. An elevated storage tank of 20 cu m provided adequate pressure for supplying a piped distribution system. The tank was also used to supply donkey carts which came to the well site. The pump ran from 6 am to 6 pm, alternating an hour pumping with hourly rests.

Buulo Burwako Village in the Mogambo Irrigation Project had a dug well with a broken hand pump. The well was constructed by the local government about five years ago, but the pump had been broken for about a year. Water was drawn with a bucket. Although the users described the water as being sweet, clear, and reliable year-round, the conductivity was 4,200, chlorides were 1,000 mg/l, and sodium concentration was 400 mg/l. Arsenic concentration was 0.48 mg/l, which exceeded the desirable limit by a factor of 10.

The town of Jilib had two drilled wells, 72 m deep. The oldest well is located near the road crossing on the Fanoole Canal. This unit had a 20 horsepower Austrian diesel engine which drove a Capratti pump at 1500 rpm, running one hour off and one hour on, from 6 am to 6 pm. Elevated storage included a rectangular concrete tank of 18 cu m which supplied the piped distribution system, and a 10 cu m cylindrical metal tank for supplying donkey carts. The price charged to the donkey carts was 10 shillings for 200 liters, which they resold for 60 shillings. The estimated total consumption for Jilib from this well was 56 cu m, assuming the tanks were filled twice a day. However, in addition, there were 13 dug wells each 15 m deep, five of which were operated by the Ministry of Local Government with handpumps. The other wells include four in mosques and four private wells. Well water in Jilib was clear and did not have a salty taste, except during April 1987 at the end of the extreme jiilaal drought.

The town of Bu'aale was the Regional Center for the Water Development Agency and had a good dug well with pump and sweet water available year-round, through a piped distribution system and public standpipes.

The town of Saakow had a WDA well which was reliable and sweet, but the pump broke and had not been repaired. People were getting their water from the river with donkey carts. Water-associated diseases were a major concern in Saakow.

The village of Canoole, about 30 km south of Baardheere, relied completely on the river for water, which was distributed by donkey carts.

The town of Baardheere had a drilled well and a dug well, but the water had an EC over 10,000 micromhos/cm and was unsuitable for human or animal use. Thus, all drinking water was obtained by donkey carts which got water from the river near the bridge and at a point 1 km upstream. Some private pump systems were also used.

The town of Garbahaarey had a WDA well, 120 m deep with a six-inch casing, diesel-powered pump, and elevated storage. It had a yield of 38 cu m/hr, and the water had a conductivity of 3,000 with a salty taste. Homes were supplied by pipes and donkey carts. The well was reliable year-round, but seven shallow wells in dry streambeds were used when the pump failed or fuel was not available.

The town of Buurdhuubo, center for refugee activities, had two drilled wells which yielded 9 cu m/hr of salty water with a conductivity of 4,000. This system included elevated storage, but it should be realized that the town and surrounding refugee camps will be permanently flooded under 10 m of water when the reservoir behind Baardheere Dam fills. Nearby refugee camps had various filtration systems for river water, but they also will be flooded out.

The town of Luuq used river water directly, supplied by donkey carts. However, in the surrounding refugee centers, there were at least four drilled wells which yielded up to 40 cu m/hr of satisfactory water with a conductivity of 700. These refugee centers were on high ground and will not be flooded by the proposed reservoir.

6. Biocides

During 1986, biocides were used considerably in the Jubba River Valley for agricultural purposes. The major applications were made by the Somalfruit cooperatives and the Fanoole Rice Project—primarily for control of fungus in bananas, and for weed and insect pest control (Table III.A.28). Although there undoubtedly have been some accidents and health effects from human and animal exposure to these chemicals currently in use, the impacts have not been documented.

Surveys of the major agricultural and public health agencies presently operating in the valley showed that chemicals from most classes of compounds toxic to people were used. They were stored in various locations throughout the lower valley in plastic containers, tins, sacks, and metal drums. The health hazards for such storage varied with each location but was the source of considerable safety hazard due to the large volume and variety of biocides.

A major concern was the amount of these biocides which may accidentally reach the Jubba River and its estuary. Monitoring of runoff from irrigated fields in Imperial Valley, California, USA showed that one to two percent of herbicides applied directly to dry soil was found in surface runoff (Haith 1987). An exception was two to 13 percent runoff of EPTC, an herbicide applied via irrigation water. Of insecticides applied from airplanes, up to one percent was found in surface runoff. No pesticides were found in effluents of subsurface tile drains. The amount of biocide in rainfall runoff decreased exponentially with the time elapsed from application of the biocide.

By 1986, biocide use in Jubba Valley amounted to 111 metric tons on 11,600 hectares cultivated per year— principally fungicides on bananas and herbicides in rice fields (Table III.A.28). From the experience in California, it was estimated that about two percent of this material was washed into drains leading to the Jubba River or the marine plain, due to rainfall runoff or excess irrigation water. Thus, about one ton of biocides per year reached the Jubba River, with a lesser amount going to the marine plain (Table III.A.29, next page).

Bioconcentration and accumulation of long-lasting biocides will occur in aquatic organisms such as lobsters and fish, and in their predators or consumers such as birds and mammals, including humans. The World Health Organization rates several of these biocides as highly toxic to people.

TABLE III.A.28. INVENTORY OF BIOCIDE USE IN JUBBA RIVER VALLEY, JUNE 1986

USER 1985/ 1986	CROP AREA PER YEAR in ha	BIOCIDE	PURPOSE	RATE OF APPLI-CATION	AMOUNT APPLIED ANNUALLY
Fanoole Rice	1,735	Propanyl	Herbicide	10 L/ha	17,350 L
		MCPA	Herbicide	1 L/ha	1,735 L
		2-4D	Herbicide	1 L/ha	1,735 L
		Quailtox	Birds		
Mogambo Irrig	500	Propanyl	Herbicide		11 T
		Fernasand	Herbicide		70 Kg
		Malathion	Insect		6 L
		Damfin	Seed Dressing		6 L
		Roundup	Herbicide		180 L
		MCPA	Herbicide		502 L
		Nuvacron	Insect		10 L
		Atrin	Insect		18 L
		Erbitox	Herbicide		
		RP	Ratpoison		
		Basudin	Insect		70 Kg
		Primextra	Insect		1 T
		Fostogas	Ratpoison		0
		Aldrin	Insect		25 Kg
		Dieldrin	Insect		
		Quailtox	Birds		
Somaltex	4,500	Bomex	Insect		375 Kg
		Nuvacron	Insect		
		Cytox-75PB	Insect		600 Kg
Jubba Sugar	2,700	Aldrin	Insect	3 Kg/ha	127 Kg
		Dieldrin	Insect	2 L/ha	48 L
		Suscon	Fungicide		
		Gesapax-C	Herbicide	6 L/ha	3,387 L
		Gesapax-H	Herbicide		
		Divron	Herbicide	6 Kg/ha	1,364 Kg
		Paraquat	Herbicide		
		2-4D	Herbicide	2 L/ha	6,202 L
		Roundup	Herbicide		
		Velpar	Herbicide	1 Kg/ha	170 L
		Gramuron	Herbicide	2.5 L/ha	5,845 L
		Tillex			
Somalfruit	2,200	Furadin	Nematodes		
		Calizin	Fungi		
		Bavistin	Fungi		
NTTCP (Tsetse flies)		Endosulfan	Insect	100 Kg/ha	

TABLE III.A.29. ESTIMATED ANNUAL RUNOFF OF BIOCIDES IN LOWER JUBBA RIVER VALLEY, 1985-1986.

LOCATION	Area in ha	Applied Amt. in Metric tons	Estimated Annual Load* Jubba River in Kg	Marine Plain in Kg
Fanoole Rice Project	1,735	21	420	0
Jubba Sugar Project	2,700	17	0	340
Mogambo Irrigation Proj.	500	13	0	260
Somaltex Coops	4,900	1	20	0
Somalfruit Coops	2,200	59	590	0
TOTALS	11,635	111	1,030	600

* *2 percent runoff*

B. Aquatic Habitats

Despite extensive flooding in the Jubba River Valley during the two rainy seasons, the most striking aspect of aquatic habitats for potential disease vectors such as malaria mosquitos and bilharzia snails, was the scarcity of surface waters during the dry seasons. Except for man-made irrigation schemes, there were virtually no waterbodies outside of the riverbed during the jiilaal season of 1987.In comparison to the luxuriant vegetation and humid environment along the Shabeelle River at all times of the year, the Jubba River Valley was relatively hostile to aquatic organisms. Even the main riverbed nearly went dry during the jiilaal season, and high salinity from groundwater infiltration, drainage returns, and ocean intrusion impeded survival of most freshwater organisms, especially during the extremely dry jiilaal season of 1987.

Field surveys were conducted in February, June, and November-December of 1986, March-April and December of 1987, and into January of 1988 covering roughly two years and a wide range of conditions. This period included light rains in 1986, a severe drought in early 1987, and a 10-year flood in late May 1987. Because the seasonal variations were large, the data was reported according to season.

In the surveys, data was collected on water quality, vegetation, current velocities, and bilharzia snails. A fine-screen dipper and forceps were used to collect the snails which were then identified from a key for African snails (Frandsen *et al.* 1980). Snails were crushed and examined under low-power microscope to determine infections with schistosome cercariae.

Although mosquito and other aquatic insect larvae were not collected except during January 1988, the habitats were described in terms of whether breeding of the principal malaria vector, *Anopheles arabiensis*, could have been expected.

1. The River

The river was fairly uniform throughout its middle reaches, but there were marked variations in the portion within the site of the proposed reservoir, and the tidal portion near Goob Weyn. Because of swift currents and the 600 km length of the river, only a small proportion of the total river was searched during each survey. However, the uniform turbidity and velocity of the river gave some assurance that the sites surveyed were fairly representative.

Site of Proposed Reservoir

A single survey was made in the proposed reservoir site at Luuq and Buurdhuubo, during June 1986. The river was a highly unlikely habitat for mosquitos or snails, with a measured discharge of 270 cumecs, estimated velocity of 50-60 cm/s, secchi depth of 2 cm and turbidity of 62 su. No vegetation in the river or snails of any kind were found.

Surveys near the bridge at Baardheere from June 1986 to May 1987, including frequent water quality measurements, also indicated that the river was an unlikely habitat for bilharzia snails or malaria mosquitos, except during the jiilaal (Table III.B.1).

Table III.B.1. AQUATIC HABITATS AT BAARDHEERE.

Seasonal variations in aquatic habitat conditions of Jubba River at Baardheere, 1986-1987

Date	Velocity in cm/s (est.)	Temp in °C	Secchi Depth in cm	Vegetation	Snails
1986					
June	50-60	25.3	1	None	None
August	50-60	26.8	6		
October	50-60	29.8	6		
November	60-70	31.5	10		
December	30-40	28.0	10	None	None
1987					
January	30-40	25.0	90		
April	20-30	30.0	10	None	None
May	70-80	29.0	2		

Velocities were estimated from time of travel studies and discharge measurements (Tables III.A.5 and III.A.19).

During January, and probably continuing until February or March, the river slowed and lost its turbidity. This provided conditions marginally favorable for bilharzia snails during this short period of one to three months, although none were found. Water temperature was 25° C in January—ideal for snail reproduction. However, the velocities were too high for mosquito larvae, even in January.

Following the rainy season, breeding sites and mosquitos were prevalent below the proposed damsite at Baardheere in June 1986, but not at mid-reservoir nor above the reservoir at Luuq.

Middle Portion

For the purpose of describing aquatic habitat conditions, the middle portion of the river (in this case) applied to the entire nontidal reach below Baardheere. This includes sampling stations at Jilib Ferry, Kamsuuma Bridge, and Araare Bridge.

Preliminary results from surveys on three consecutive days in June 1986 indicated that the Jubba River had moderate levels of conductivity and chlorides during June 1986. The discharge rate of the river at Kamsuuma Bridge was above 100 cubic meters per second during June, and gradually decreasing. This was near the average yearly discharge rate but varied considerably during the three days of the survey. Even at high tide there was no salt intrusion into the estuary at these flows. Light penetration into the water, as measured by secchi disk readings, was virtually zero in the entire river from Luuq to the ocean. This low clarity, as well as high concentrations of suspended solids and moderately high velocities, made the river unsuitable as a habitat for disease-bearing snails or mosquitos during June (Table III.B.2).

Table III.B.2. AQUATIC HABITATS IN MIDDLE VALLEY.

Seasonal variations in aquatic habitat conditions of Jubba River in middle portion, 1986-87

DATE	Velocity in cm/s (est.)	Temp in °C	Secchi Depth in cm	Vegetation	Snails
1986					
June	50-60	26.9	1	None	None
July-Oct	50-60	27.5	4		
November	60-70	31.9	8	None	None
December	30-40	30.0	15		
1987					
January	30-40	28.5	52		
March	river was generally dry below Fanoole Barrage				
May	70-80	29.0	2	None	None

Tidal Portion

Preliminary measurements were made of salinity in the river in June 1986 to locate the approximate extent of salt intrusion into the estuary. The results indicated that the intrusion did not reach even to Goob Weyn, about 2 km upstream from the ocean. The river gage at Kamsuuma bridge was at 530. Velocities at Goob Weyn at 0.6 depth in the center of the river were 80 cm/s. The river width at this point was 100 - 150 m.

One station was sampled in the tidal portion of the river in December 1986, about 6 km from the river mouth, at Goob Weyn (Figure III.B.1). The flow was much too fast and turbid for snails or mosquitos at any time of the year in this portion of the river (Table III.B.3). Salt water from the ocean intruded significantly for only a short time, during March and April 1987, reaching slightly upstream of Yontooy (Figure III.A.6).

Table III.B.3. AQUATIC HABITATS NEAR THE COAST.

Seasonal variations in aquatic habitat conditions of Jubba River in tidal portion, 1986-87

DATE	Velocity in cm/s (est.)	Temp in °C	Secchi Depth in cm	EC25 micro-mhos/cm	Vegetation	Snails
1986						
June	70-80	28.5	1	185	None	None
July-Oct	50-60	27.2	5	217	None	None
November	60-70	31.7	6	286		
December	30-40	29.0	20	452	None	None
1987						
January	30-40	28.0	120	26,372		
March	tidal	28.0		60,000	(ocean)	
April	70-80	30.0	2	1,611	None	None

2. Irrigation Systems

A general survey of all agricultural systems was made during November-December 1986 to estimate their potential as vector habitats. Based on this general survey, it was decided to focus on monitoring of snail populations in the Fanoole and Mogambo irrigation systems. Unexpectedly, there were very few bilharzia snails detected in any of these surveys. Bilharzia snails were found only in Fanoole Main Canal in February 1986, and a seepage area next to the canal in December 1986.

In June 1986, the main irrigation canals were uninhabited by snails or mosquitos due to the high turbidity of the water. No bilharzia snails were

Figure III.B.1

The Jubba River was 150m wide at this sampling station near Gob Weyn, 6km upstream from the river mouth. Salinity measurements were taken at mid-stream, indicating no ocean intrusion on December 1986 when river discharge was 100 cumecs at Baardheere. Technicians measured salinity from this boat at surface, mid-depth and bottom of river, finding mean EC25 of only 452 micromhos/cm. River widened to 300m as it approached the ocean downstream of this sampling station.

found in any of the irrigation canals, night storage ponds, or drains during the June surveys.

The Irrigation Zone suffered from heavy flooding and rainfall in May and June 1986, and mosquito habitats were found everywhere. This normally leads to a peak of malaria transmission in June and July, and another in December and January, almost every year.

Fanoole Rice Project

Although only 630 ha were planted in the Fanoole Rice Project (double-cropped rice) by June 1986, the potential for the complete Fanoole Barrage system was for gravity irrigation of 48,000 ha, including the Jubba Sugar Project and a proposed system at Hombooy. Rice in the Fanoole Project was of the 150-day variety, planted in February and late September, about two weeks before the dates of planting in the Mogambo Project. Salinity problems had been occurring in the first stage. The supply canals were used for night storage. A large drainage system, with a pump that discharged to the river, was located slightly south of the village of Mobarek (Figure III.A.1). The pump operated intermittently during the irrigation season to handle seepage water as well as excess rain. About 1,500 people were employed permanently with 500-800 casual workers, all of whom came from local villages.

In June 1986, Fanoole Main Canal was highly turbid although running much below capacity. It contained extensive growths of reeds and other emergent vegetation, but only *Cleopatra* snails (Figure III.B.2).

In December 1986, the Fanoole Main Canal near km 15 was choked with emergent vegetation including cattails and a vine with broad, waxy leaves. There was also considerable floating *Pistia* sp.(water lettuce), leaving only 25-50 percent of the canal section free-flowing. The water was brown and turbid, with a high velocity zone in the center of the channel but large, stagnant zones along each of the weedy margins. Depth was about 1.5 m and secchi disk readings were 30 cm (Table III.B.4). There were no snails of any kind, despite the clearer water. Electrical conductivity of the water was 489 micromhos/cm and the temperature at 1600 hours was 30° C. The canal attracted many frogs, birds, warthogs, monkeys, and cattle, and also a massive infestation of sow bugs on the east bank.

Across the road from the canal at about km 20, near a village of 100 huts called Hilosheed, a cattle watering hole had a maximum depth of 0.5 m and a total area less than 1 ha. About 10 percent of the fringes were covered with cattails, the water was green, the secchi disk reading was 1 cm, the conductivity was 1,200 micromhos/cm, and the temperature at 1700 hours was 31° C. The water was not used by the villagers, who went to the canal instead. There were no snails.

Table III.B.4. AQUATIC HABITATS IN IRRIGATION SYSTEMS.

Vector habitats in irrigated zone, June 1986. Parentheses indicate estimated values

SYSTEM	HABITAT	VELOCITY cm/s	DEPTH m	SECCHI cm	TEMP °c
Fanoole	Main Canal	31	1.0	6	26.2
	Standing water	0	0.3	0.3	30.5
	Drain	0	1-2	20-50	28.0
Mogambo	Main Canal	25	1.4	10	29.5
	Night Storage	0	1.5	10	26.6
Jubba	Main Canal	0	0.5	20	29.0
Somalfruit	standing water	0	0.2	20	-
Dhesheeg	near Fanoole	0	0.5	7	29.2
Jubba	at Jilib	(100)	2-3	1	27
River	at Goob Weyn	80	2	1	27
Rain Pond	near Goob Weyn	0	1	(20)	(30)

Almost all the ditches, ponds, and swampy areas along the canal were dry in December 1986, including those observed in June 1986. As the main canal passed through Jilib, the water became deeper and flow was slower due to control structures. At crossings and other places, human contact with the water was extensive. At 1700 hours, about 100 people were gathered on the canal at the road crossing in Jilib. Most were boys fishing, but many adults were bathing or drawing water.

Fanoole main canal south of Jilib was also deep and slow-flowing during December 1986, with highly turbid and brown water, until diversion into the rice fields. The dry section of the main canal, downstream of the diversions to the distribution system, occasionally contained pockets of rainwater or seepage water but no snails. These small pockets were clear, with emergent grasses, probably filling only for short durations after rains.

In June 1986, the Fanoole drains were fairly clear and generally free of vegetation, but did not harbor bilharzia snails. The main drainage station on Fanoole Drain near the village of Mobarek was being enlarged in December 1986 (Figure III.A.1).

Figure III.B.2

Velocity measurements with pygmy current meter in Fanoole Main Canal indicated low mean velocity of 31cm/s in June 1986. Although this is slow enough for bilharzia snails, and water temperature and vegetation were favorable, snails were found only in January and February due to high turbidity of water.

The pumping bay contained very little water, about 50 cm deep, colored light green from algae and had an estimated secchi disk reading of 80 cm.

During December 1986, drainage flow was diverted to a temporary ditch south of the pumping station which led directly to the river. Flow through the temporary ditch was very rapid at the point of diversion to the outfall drain, approaching 1 m/s. However, further upstream in the large drain along the access road coming from the main canal crossing, flow velocity was less than 1 cm/s, the secchi disk reading was about 1 m, and the color of the water was light green due to algae. Light emergent vegetation along the sides and other conditions indicated that this entire drainage system could be suitable for snails and mosquitos. Their absence at this time may have been due to the fluctuation in level caused by intermittent operation of the drainage diversion. Nearby fields were being leveled and prepared for rice planting.

It is very likely that the main canal and the drainage system will become ideal habitats for bilharzia snails during the dry months of January, February, and March, when the water clarifies. Transmission could occur near towns and villages, especially along the canal passing through Jilib.

Jubba Sugar System

The only potential snail or mosquito habitats found in the Jubba Sugar system were the main canal and an unfinished drainage system (Figure III.A.1). Two options were being considered for improving the drains. The original plan was to dig deep drains to leach out anticipated salt accumulations. These drains would have flowed to the southwest, then pumped to the Marine Plain. The second plan, under active consideration, was for a shallow set of drains flowing to the southeast, to be pumped over the flood dike into the Jubba River. The second option was favored because salt accumulations have been slight.

No bilharzia snails were found in Jubba Main Canal or in the Little Jubba River in June 1986, probably because of high turbidity (Table III.B.5). However, several other species of snails were present.

The Little Jubba River, used as the main canal upstream of Mareerey, was highly turbid, red in color, with a conductivity of 350 micromhos/cm, and a temperature of 28° C at 1200 hours in December 1986. The secchi disk reading was 20 cm, the velocity was about 1 cm/s, and the canal was about 1 m deep (Table III.B.5). This portion of canal was subject to large variations in depth and flow, having risen two days previously from nearly zero depth. Near Hargeisa-Loi Leida Village, about 50 people were in the canal at noon time, as it was their only source of water. A rain pool near the village had dried some months ago.

Table III.B.5. AQUATIC HABITATS DURING DEYR SEASON.

Deyr season results from second survey of potential habitats, December 1986

LOCATION	HABITAT	Velocity in cm/s	Depth in cm	Secchi disk in cm	Temp. °C
FANOOLE	main canal	50	150	30	30
	dhesheeg	---- dry ----			
	standing water	---- dry ----			
	drain	0	150	40-100	26
MOGAMBO	main canal	25	140	20	30
	reservoirs	waves	120	20	30
	drains	0	100	30-40	28-30
JUBBA	main canal	01	0-100	20	28
SUGAR	drains	under construction			
somalfruit	standing water	---- dry ----			
DHESHEEG	near Fanoole	---- dry ----			
JUBBA	near Jilib	(30)	(50-100)	20	30
RIVER	at Goob Weyn	tidal	(150)	20	29
RAIN POND	at Goob Weyn	---- dry ----			

The main spine canal and distributary canals had been recently filled, but no irrigation was being conducted. Conditions of the canal appeared very similar to those encountered in the June survey, but snail searches were not conducted because high turbidity usually indicates absence of bilharzia snails.

Mogambo Irrigation System

This new irrigation scheme was intended for rice cultivation but has diversified due to problems encountered with soil salinity when the rice was double-cropped. On their initial irrigated area of 500 ha they were experimenting with two alternative crop rotations:

- rice, sesame, and fallow, or
- rice, sesame, legumes, and fallow.

Their labor housing facilities were placed on clay soil near the river, without drains or sanitation facilities. The site was low and thus flooded half the year. In the meantime, most of the labor force had to find their own housing in local villages.

The rice being grown was a 150-day variety, IR-24. It was expected that they will change to a faster growing 100-day variety in the near future to allow more time between crops. Their canal system included five night storage ponds and one large drainage pump which discharged to the marine plain to the west (Figure III.A.1). A large flood relief channel ran from the Jubba River to the same marine plain, parallel and south of the Mogambo main supply canal. This new flood relief channel offered protection to banana growers downstream, and went into operation in May 1986.

In June 1986, water in the new Mogambo Main Canal and night storage reservoirs was highly turbid and contained no snails or vegetation. These sites appeared unsuitable for mosquitos as well, due to waves produced by strong winds. In December 1986, the flood diversion channel was dry and had not been used since June. Cattle were grazing along the canal bottom. In the rice fields, the precast inlet structures had stilling basins which may hold water long enough for mosquito breeding.

During the December 1986 survey, the two older night storage reservoirs (N11 and N12) were nearly full at noon on an extremely windy day (Figure III.A.1). East winds of 5-8 m/s were causing severe erosion on the western shores. Water coming in from the main canal had a conductivity of 470 micromhos/cm, the secchi disk reading was 20 cm, and the temperature was 30° C at 1200 hours (Table III.B.5). The water color was reddish-brown and the canals were free of vegetation.

The reservoirs contained no vegetation, but many shells of large ampullarid snails (*Pila* sp. and *Lanistes* sp.) were seen along the eroding shore which was largely gravel in composition. The presence of ampullarid snails indicated that general conditions were suitable for the bilharzia snails. Bilharzia snails are too short-lived to endure long periods of high turbidity when no algae are present for newly hatched snails to feed on. However, the ampullarids live about two years and may have an amphibious stage during which they can obtain food. The reservoir on the west side of the delivery canal contained crocodiles and many ducks, herons, egrets, and other aquatic birds.

Two new night storage reservoirs further downstream along the delivery canal were located immediately west of the village of Buulo Burwako and were put into operation in October 1986. These reservoirs were also filling at noon time when the survey was made. Guards claimed they were 10 m deep, and it is likely that some places may be deeper than the design depth of 2 m because the reservoir areas were excavated to obtain earth for filling surrounding dikes and roadways. The reservoirs contained no vegetation, were also eroding like the other two reservoirs, contained water of the same quality, and were similar in appearance to the other reservoirs. They contained large crocodiles and many birds.

The main drainage station was at the southwest corner of the project. A small amount of drainage water was flowing by gravity to the plain west of the project and the large pumps were not needed because of low water levels outside the system. Several drains leading to the pumping bay contained moderate floating and emergent vegetation, with 25 percent coverage by a vine with broad, waxy leaves. Water was green with a secchi disk reading of 30 to 40 cm and conductivity of 900-1,000 micromhos/cm. The temperature was 28-30° C at 1400 hours. The drains were about 10 m wide and 1 m deep with velocities near zero. There were crocodiles and large *Pila* sp. snails, but no bilharzia snails were found.

An important general observation for the Mogambo drains and maybe for the night storage reservoirs, was that they will probably become good habitats for bilharzia snails as they mature—especially in the dry months of January, February, and March when the water becomes more clear.

Somalfruit Cooperatives

This semi-private banana export agency dealt with 51 individual farms covering a total of 2,200 ha of bananas with a potential of up to 4,000 ha by 1988 and eventually 6,000 ha. There were 120 pumps in use to pump water from the river to earthen canals all year, except during the rainy season when the pumps were used for drainage. The management was changing over much of the system to a buried plastic pipe distribution network to avoid seepage losses and increase land availability. This system renovation was half completed in 1987 and would eventually eliminate many snail and mosquito habitats.

The canals and drains did not seem to be good habitats for bilharzia snails or mosquitos because of the intermittent flow and the turbulence and high turbidity from the pumping. In the future, if the ditches are replaced with underground pipes, there will be little possibility for aquatic habitats of disease vectors.

Somaltex Cooperatives

This was a government-operated cotton marketing scheme which included about 3,000 small farms of 1-2 ha each. The cotton was rainfed and there were no drainage systems and no aquatic habitats. Most farms were located near Jamaame between Kismaayo and Jilib, on the east side of the river.

3. Dhesheegs and Other Flooded Areas

A *dhesheeg* is a body of standing water not far from the river which dries out seasonally and usually fills when the river floods. Crops are planted along the shore as the water evaporates.

Fanoole Dhesheeg

Dhesheeg Fanoole appeared to be a suitable habitat for aquatic snails and mosquitos in June 1986, and supported extensive stands of aquatic vegetation including submerged *Ceratophylum* and floating lily pads (Table III.B.5). It also contained large numbers of fish, birds, insects, and snails, but not the bilharzia snails.

Because of the low rainfall and low river level, this dhesheeg did not fill during the 1986 deyr season, and was almost completely dry on 8 December (Table III.B.4). The only water remaining was about 1 ha in a weedy mudhole in the center. The rest of the land (about 30-40 ha) contained nearly mature corn. One of the farmers explained that the dhesheeg did not flood every year, and had almost completely dried out by September. However, the soil moisture remaining from the last gu' season and recent light showers was apparently sufficient to yield a modest crop.

The last surface water in the small mudhole was expected to disappear before the end of December. As most of the habitat was dry since September, snails and other aquatic organisms which inhabit the site will be dry until April when the rains will probably come again.

Goob Weyn Dhesheeg

A dhesheeg across the highway from Goob Weyn appeared to be a suitable habitat for anopheline mosquitos (Figure III.A.1). The pond was first filled about 1 June 1986 with a perimeter from 2-5 km, and by 14 June, it was shrinking noticeably in size with a large amount of grass and thin reeds beginning to emerge. It would probably be dry by early July, five or six weeks after filling.

Ponds

Bilharzia snails were found in standing waterbodies outside the irrigation systems in June 1986. Apparently, this is where bilharzia transmission normally occurs in the Jubba River Valley. Two roadside ponds near the southern end of the Mogambo Scheme contained lilies and cattails but no bilharzia snails in June 1986. These ponds were anaerobic at the bottom but contained large *Pila* and *Lanistes* snails, with dead shells of the bilharzia snail, *Bulinus abyssinicus*, and of another small, unidentified planorbid snail.

Seepage Areas

In June 1986, a roadside ditch about 5 km north of Jilib along Fanoole Main Canal—and probably containing seepage from the canal—contained clear water, small lily pads, abundant emergent grasses, and several large *Bulinus abyssinicus*, the intermediate snail host for urinary bilharzia.

In December 1986, a shallow pond near the village of Mana-Mufo on the east side of the road about 10 km north of Araare Bridge contained moderate sized *Pila* sp. snails and large *Cleopatra* sp. snails. The pond bottom was anaerobic, the water was clear, and the vegetation—including lilies and sawgrass—covered 90 percent of the surface. No bilharzia snails were found. This was probably seepage water from irrigation canals or the river, as there had been no recent rains.

Ecological Considerations

There is a paradoxical characteristic of the bulinid bilharzia snails which inhabit the Sahel of Africa and have developed high survival ability for long, dry seasons. When they find themselves in a habitat which does not dry out for a year or more, small populations of this particular group of bulinid snails often disappear because their survival rate in water is lower than their desiccation survival rate. They tend to lay few eggs, after an initial burst immediately upon reflooding of the habitat. Thus if the food density in the habitat is not high enough to stimulate intense egg production and offset the large number of deaths, the population disappears, even though it might have survived had the habitat dried out for several months.

This paradox undoubtedly was important in the Jubba Valley because of high river turbidity which lasted several months and blocked sunlight and thus, growth of algae and microepiphytes. These microorganisms serve not only as browsing food for adult snails but are critical in the survival of the tiny juvenile snails. This lack of food for the youngest snails may explain why bilharzia snail populations were not found in dhesheegs which had water throughout most of the year, but were found in temporary seepage pools which were quite small and probably had water for only a few months each year.

There is also the possibility that the large dhesheegs contained predators which eliminated the relatively vulnerable bilharzia snails, but could not deplete the smaller *Bulinus forskaali* or the larger ampullarids which had harder, denser shells.

Other non-Sahelian species of *Bulinus* and the more ubiquitous *Biomphalaria* species, which lay eggs in proportion to the density of vegetation, could theoretically survive in such dhesheegs during a wet year. However, over the long run, they would disappear if introduced because they could not survive the frequent and long dry periods.

C. Major Existing Diseases

Although the government did not regularly monitor diseases in the Jubba Valley, several surveys by independent organizations in the past few decades gave general indications of the existing prevalence of water-associated diseases, and a field survey was conducted specifically for the JESS program in late 1987 and early 1988.

General estimations of mortality for the settled populations in southern Somalia indicated short life expectancies at birth of 44 years for males and 49 years for females (Abernathy 1981). The crude death rate was estimated at 18 per 1,000, and infant mortality rate to two years was 160 per 1,000. Fertility among women was 49 per 1,000.

The most commonly reported diseases were malaria, tuberculosis, diarrheal diseases, bilharzia, hookworm, venereal diseases, skin ulcers, and respiratory infections (Cahill 1971). Those related to water or agriculture were malaria, bilharzia, diarrheal disease, and hookworm, treated in detail below.

1. Malaria

Somalis understood the malaria transmission cycle long before western medicine accepted the role of mosquitos in malaria. A traveller in Somalia, Sir Richard Burton, noted a Somali "myth" in 1854, stating that the local people "believed that the mosquito bite brings on deadly fevers: the superstition probably arises from the fact that mosquitos and fevers became formidable about the same time." However, Burton disregarded this "myth" as he had been taught by western physicians that miasmas spread malaria (Cahill 1971).

According to surveys by the National Antimalarial Service (NAS), the dominant species of malaria parasite in southern Somalia is *Plasmodium falciparum* (95 percent), and the principal mosquito vector is *Anopheles arabiensis*, formerly known as *A. gambiae*, species B. In national malaria laboratories and hospitals, reports on malaria parasites found in examined blood-slides indicated that transmission of the disease occurred throughout the year but reached highest levels in July and December, following the rains by about one month (Table III.C.1). The low humidity and lack of rainfall during the dry seasons quickly brought the mosquito populations and malaria transmission to an end in the dry zones of the country.

Table III.C.1. MALARIA IN SOMALIA BY MONTH, FOR 1985.

Monthly blood-slide positivity rates for malaria in Somalia, reported from government hospitals and laboratories, 1985 *

MONTH	Slides examined	Positive for malaria
January	4,157	9.67%
February	3,485	5.91
March	3,300	4.97
April	4,046	3.24
May	4,530	4.42
June	4,351	9.42
July	4,289	13.29
August	4,591	9.69
September	4,131	7.99
October	4,059	3.82
November	4,013	3.61
December	1,303	10.74
TOTALS	46,255	7.13%

* *from 1985 Annual Report, supplied by Director of National Antimalarial Service, Somali Ministry of Health.*

No background data was available from the Jubba Valley, but it was generally known that the extent of the seasonal malaria outbreaks was proportional to the size and duration of the gu' and deyr floods.

There were several species of anopheline mosquitos in the Jubba Valley, in addition to the main malaria vector, *A. arabiensis*. In the Gedo Region, the NAS reported finding *A. funestus*, *A. pharaoensis*, *A. d'thali*, and *A. salbon*. However, in the lower valley—in Jilib, Jamaame, and Kismaayo Districts—only *A. funestus* and *A. pharaoensis* were reported in addition to *A. arabiensis*. None of these additional species were important in malaria transmission in the Jubba Valley.

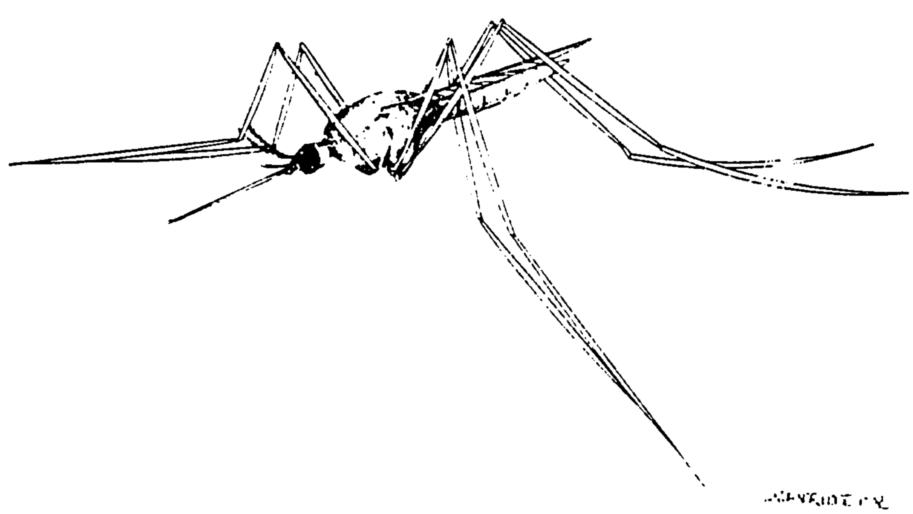
East of the Jubba Valley, the irrigated strip along the Shabeelle River was a major source of malaria. In the Jowhar District, just north of Muqdisho, surveys in 1968 showed that all of the workers in a sugar factory had been ill with malaria during the previous year (Cahill 1971), and 98 percent were *P. falciparum* infections.

In the northern part of Somalia, transmission was characterized by periodic outbreaks from November to May, following heavy rains. The main vector, *A. arabiensis*, was confined to wells or reservoirs during the dry season, but travelled around the countryside in nomads' water jugs, and then bred in shallow pools filled by the rains. In the northern region, *A. funestus* and *A. d'thali* were secondary vectors.

In late December 1987 and early January 1988, a malaria prevalence survey was conducted in the lower Jubba Valley under the JESS program, with assistance from the National Antimalarial Service (NAS) and WHO. The work was conducted by Dr. Marian Warsame in the Faculty of Medicine of the National University, and detailed in her February 1988 report for JESS (Appendix B).

A two-stage, stratified sample of villages in the area around Jamaame was selected by random methods, and all children two to nine years of age were examined in the selected villages. The total study area population was approximately 83,000 individuals, located around seven beels (principal villages and districts) which contained a total of 73 villages. Two beels out of the seven were selected in the first stage of sampling, then one village selected from each beel. Thus, there was a total of nine villages in the sample, plus Jamaame town (Table III.C.2).

In these villages, parents were asked to bring all children two to nine years of age for testing, except in Jamaame and Bangeni, where the children from the primary and Koranic schools were tested. This sampling procedure yielded 1,246 children, roughly 10 percent of the children of that age in the study



Anopheline Mosquito Which Spreads Malaria

The main malaria vector at present is ANOPHELES ARABIENSIS. But ANOPHELES FUNESTUS would probably become the vector around the proposed reservoir.

area, giving a reliable estimate of malaria prevalence for children in the study area.

From blood samples of the children, prevalence rates of the malaria parasites were determined and intensity of the infection was measured by counting parasite density per milliliter of blood. Enlargement of the child's spleen was also measured as a long-term indicator of previous malaria infections. Infected persons were treated with chloroquine after examination.

Table III.C.2. MALARIA PREVALENCE IN JAMAAME AREA, 1987-88.

Parasite prevalence, parasite densities, and spleen rates in sample from children of lower Jubba region, from two to nine years of age (Warsame 1988)

VILLAGE	Children sampled	Prevalence of malaria parasites	Parasite density* in blood	Prevalence of enlarged spleens
Buulo Maamow	67	50.7%	1,366	52.2%
Malaayleey	160	35.0%	432	26.5%
Beled Aamin	83	32.5%	839	20.0%
Mufo	137	32.1%	633	19.7%
Beled Raxma	168	21.4%	1,197	16.7%
Mana Moofo	99	19.2%	5,639	16.2%
Janaale Jaay	62	12.9%	4,215	3.4%
Bangeeni	121	8.3%	959	1.7%
Naftaa Quur	117	5.1%	1,137	1.7%
Jamaame	232	3.0%	2,306	1.6%
TOTALS	1,246	20.7%	1,872	

* *Geometric mean number of asexual forms of the malaria parasite per microliter of blood*

The prevalence rate for children in the study area was estimated to be 21 percent, with significant variation from 3 percent in the town of Jamaame to 50.7 percent in the village of Buulo Maamow (Table III.C.2). Almost all parasites were *Plasmodium falciparum* and the geometric mean of the parasite density was 1,900 parasites per microliter of blood. These data indicated serious malaria transmission during this season of the year—enough to cripple an agricultural community.

The proportion of enlarged spleens in these same children correlated very closely with the parasite prevalence rate, indicating that most spleens were enlarged due to the malaria infections, not due to other diseases (Table III.C.2). The maximum spleen rate was 52.2 percent in Buulow Maamow and the minimum was 1.6 percent in Jamaame. The mean enlarged spleens for each village ranged from Grade 1.5 to 2.9 according to the standard classification system of Hackett. Other data from the NAS had indicated that transmission was highly seasonal, with two transmission peaks following the two rainy seasons. This sample was intentionally taken during one of the peak transmission seasons. Transmission in the area would generally be classified as mesoendemic, with significant variations between villages and between seasons.

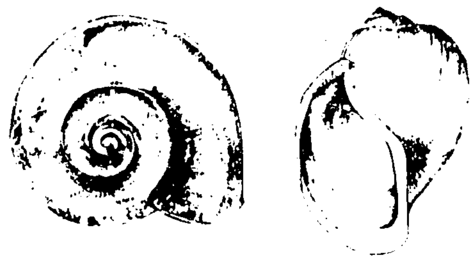
Entomological collections at the time of the survey confirmed previous indications that *Anopheles arabiensis* was the principal vector of malaria in the area. Indoor collections of adult mosquitos were made at night to identify the vectors. Also, waterbodies were investigated for evidence of mosquito breeding. Anopheline larvae were found in open wells, water collections near the wells, pits excavated for construction purposes, and seepage areas containing water from irrigation canals.

2. Urinary Bilharzia

Only the urinary form of bilharzia (*Schistosoma haematobium*) has been found in southern Somalia. The only snail intermediate host found in the south was *Bulinus abyssinicus*, a small planorbid snail highly resistant to drying (Arfaa 1975). In this 1968 survey, the highest prevalence of infection was in irrigation schemes near Jowhar and Jenaale in the Shabeelle Valley.

Occasional cases of intestinal bilharzia have been found in the North of Somalia. The snail that transmits intestinal bilharzia was found in three areas north of Hargeisa (Ayad 1956). Ministry of Health surveys in the Hargeisa region found no infections in 1,000 persons examined in 1979 (Koura 1981), but in 1987, WHO reported that intestinal bilharzia was found among refugees and Somali children in the north, indicating local transmission.

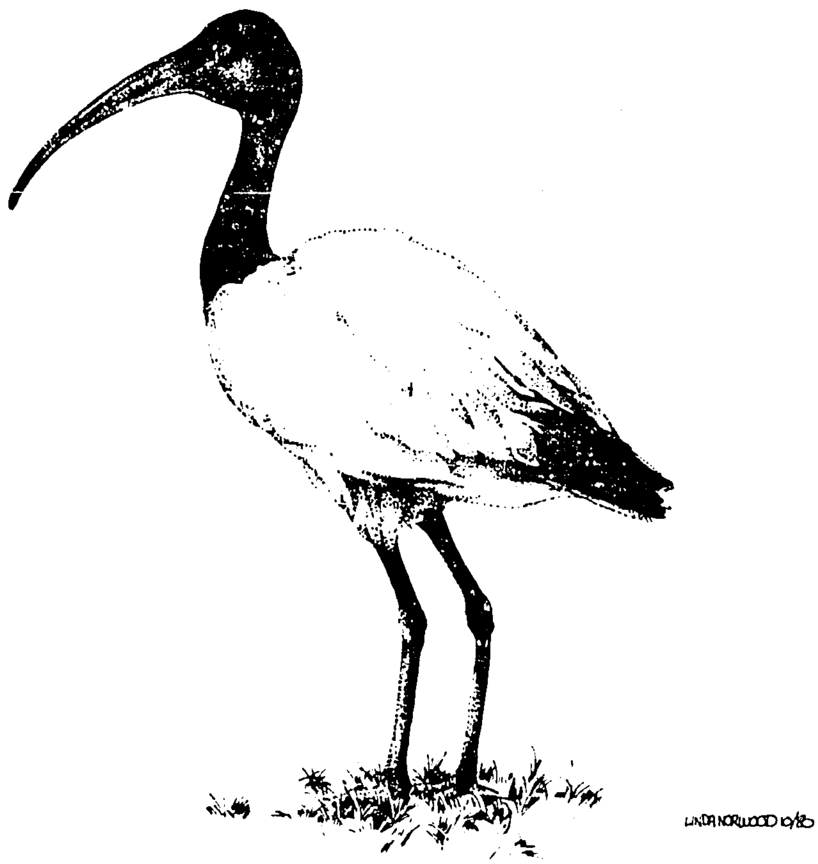
A number of published and informal reports on bilharzia in Somalia were available, primarily from WHO efforts since 1975. Only four gave recent data obtained from urine examinations in the Jubba Valley relevant to this study (Cahill 1971; Shunzhang and Hongming 1980; Koura et al. 1981; and Tonneke 1986). Surveys as early as 1956 indicated that the prevalence of bilharzia in the Jubba Valley was 20 percent in schoolchildren and 55 percent in the general population (Ayad 1956). In 1968, in Hombooy Village in Jilib District, the prevalence of urinary bilharzia in healthy males was 99 percent (Cahill 1971). In 1971, the prevalence throughout the Jubba Valley was 58 percent, and prevalence in



Shells of planorbid snails

Aquatic Snails Which Spread Bilharzia

Only the snail on the right is presently found in southern Somalia and spreads parasites to people and cattle. The other snail is found in northern Somalia, Ethiopia and Kenya, and could easily invade the Jubba Valley.



A Young Sacred Ibis

These birds migrate along the Nile and other major flyways. They may serve as passive carriers of small bilharzia snails which are sometimes found in mud on their feet.

the general population in the same village of Homboy was 89 percent (Shunzhang and Hongming). The difference in the two surveys in Hombooy was not significant, given the small sample sizes. Lower prevalences of bilharzia were reported for Baardheere District (Table III.C.3)

Table III.C.3. BILHARZIA IN JUBBA VALLEY IN 1971.

Prevalence of urinary bilharzia in Jubba Valley of Somalia in 1971, from Shunzhang and Hongming, 1980

DISTRICT	VILLAGE	Persons Examined	Prevalence
Kismaayo	Buulo Guduud	108	79%
Jilib	Hombooy	105	89%
Baardheere	Saakow	109	25%
Baardheere	Doblei	109	51%

The prevalence of infection was quite uniform in all age groups in three of the towns surveyed in 1971, but in Saakow, the 10-29-year-old group had prevalences much higher than the other age groups (Figure III.C.1). This implied that infections were obtained at some distance from Saakow, whereas people in the other towns were probably getting infections from contact with nearby pools from where they obtained drinking water. This implication is supported by reports that Saakow had a good well, whereas the other towns got their water only from surface pools.

Bilharzia prevalence was closely related to frequency of contact with surface water. In Buulo Guduud, 91 percent of the primary school children were infected and had clots of blood in their urine. Upon investigation, it was found that around the school, there were pools in which the children played and washed themselves. The pools contained the bilharzia snails (Shunzhang and Hongming 1980).

The prevalence of bilharzia increased with the duration of flooding. If the water in the lowlands lasted for two to three months, it gave adequate time for escape of larvae from infected snails. These larvae then infected people using the water. In Hombooy, which was 20 km from the river, the village was flooded when the Shabeelle River overflowed and the inhabitants contacted snail-infested waters frequently, resulting in the high prevalence.

Limited published data indicated that the intensity of infections in the lower Jubba Valley (236 eggs/ml) was much higher than in the Shabeelle Valley at Merka (32 eggs/10 ml) and Koryole (13 eggs/10 ml) (Koura 1981). However, the number of persons tested in the Jubba Valley was too low to make significant conclusions from this report.

Surveys were conducted in 1986 by personnel of the Swedish Church Relief group who operated PHC units in the middle valley. They reported prevalences of urinary bilharzia of 84 percent in schoolchildren from Gurmeysa of Saakow District, and 27 percent in Duqiyo Village of Bu'aale District. Adults in Duqiyo had a prevalence of 38 percent. The only difference found to explain the higher prevalence in Gurmeysa was the close proximity of a dhesheeg to that village (Torneke 1986).

Surveys were conducted for JESS by R. Klumpp and M. Warsame on bilharzia in December 1987 - January 1988, (Appendix C) and in June-July 1988 (Appendix D). Their results were in agreement with previous reports, and gave considerable detail about bilharzia prevalence and snail distribution in the Jamaame area.

In the 1987-88 surveys, prevalence of urinary bilharzia in 5- to 14-year-old children in villages of Jamaame District was 82 percent, and in Jamaame town, it was 46 percent (Table III.C.4). Geometric mean of the egg counts in urine was 43 eggs/10 ml in the villages and 28 eggs/10 ml in Jamaame—about the same as in Shabeelle Valley. The prevalence in boys was about the same as among girls. In the villages, 24 percent of the children had gross blood in their urine, which is a primary indicator of bilharzia infections. The lower prevalence of bilharzia in Jamaame Town was

Table III.C.4. BILHARZIA AROUND JAMAAME IN 1988

Prevalence of urinary bilharzia among 5- to 14-year—old children in the villages and town of Jamaame District, (Klumpp 1988)

VILLAGE	Children examined	Children infected	Prevalence of bilharzia
Sabatuuni	55	54	98%
Bandar Jadiid	125	118	94
Dheymo & Turdho	202	102	90
Nyiireey	110	99	90
Baardheere Yareey	101	87	86
Kobon	275	234	85
Beled Aamiin	148	123	83
Mana Moofa	120	88	73
Kamsuuma	175	126	72
Buulo Maamow	61	43	70
Beled Raxma	108	75	69
Janaale Jaay	44	30	68
Bangeeni	74	49	66
Above Villages	1,598	1,308	82%
Jamaame town	404	186	46%
GRAND TOTAL	2,002	1,494	75%

Figure III.C.1

About 2,000 schoolchildren in the major towns of the lower Jubba Valley were examined in late 1987 for malaria and bilharzia infections. This group serves as the best and most accessible indicators of disease transmission.

probably due to the community water supply which came from a deep well. Provision of safe water reduces the need for people to fetch water from surface pools, a major source of infected snails.

Bilharzia snails were found in 37 percent of the habitats surveyed—principally, in small ponds or depressions near villages (Table III.C.5). No snails were found in irrigation canals, but a few were found in drains in banana fields, and dhesheegs. The ponds near the villages were usually the only source of domestic water, and were used extensively by children for play and bathing. This situation was the same as that found in previous surveys in the Shabeelle River Valley (Upatham *et al.* 1981). The bilharzia snails were usually found coexisting with other harmless species of snails of the genera *Pila, Lanistes, Melanoides*, and *Gyraulus*, as well as *Bulinus forskali*.

Table III.C.5. SNAILS AROUND JAMAAME IN 1988.

Frequency of aquatic snails found in Jamaame District, according to habitat type (Klumpp 1988)

HABITAT	Number of times sampled	Snails Encountered* B*	P	L	M	G	F	O	Frequency of bilharzia snail occur.*
Roadside pools	16	9	11	7	6	6	1	0	56%
Banana drains	11	3	8	7	3	6	0	0	27%
Dhesheegs	5	2	4	2	1	2	0	1	40%
Irrigation canals	3	0	0	0	0	1	0	1	0%
Reservoirs or ponds	2	2	1	0	0	0	0	0	100%
Jubba River	6	0	0	0	0	0	0	1	0%
TOTAL	43	16	24	16	10	15	2	2	37%

* *Key to snail species:*
B = Bulinus abyssinicus, the snail species which transmits urinary bilharzia; P = Pila, L = Lanistes, M = Melanoides, G = Gyraulus, F = Bulinus forskali, and O = unidentified bivalves.

Infected snails were found in the Jamaame area in December 1987, after an early rainy season which started in November (Figure III.C.2). About 8 percent of the 510 bilharzia snails were infected with the fork-tailed schistosome cercaria—a relatively high prevalence (Table III.C.6). There were also 72 other snails infected with single-tailed and strigiid cercariae, not of medical importance.

The various surveys gave enough information to suggest the following transmission pattern. After the deyr rains and flood, waters collected in depressions near villages, dhesheegs, and rain pools. They slowly clarified and became ideal habitats for the snails for a short time, usually in December and January. Then the snails estivated in the mud until the rains and flood of the gu' season. However, in irrigation systems with low velocities, some snails continued to reproduce, given the high clarity of the water, ideal temperatures, and abundant algae.

Table III.C.6. INFECTED SNAILS AROUND JAMAAME IN 1988.

Number and cercarial infections of *Bulinus abyssinicus* snails found in various habitats in Jamaame District of the Jubba River Valley (Klumpp 1988)

HABITAT	No. of times sampled	No. of *B. abyssinicus* snails	No. infected by schistosome cercariae
Roadside pools	16	284	40
Banana drains	11	176	0
Dhesheegs	5	42	0
Irrigation canals	3	0	-
Reservoirs/ponds	2	3	0
Jubba River	6	0	0
TOTAL	43	510	40 (7.8%)

Thus, during the dry jiilaal season, the only surviving colonies were in the irrigation and drainage systems, which stayed favorable until the beginning of the gu' rains which brought in turbid water. Small bilharzia snails were found the previous February of 1986 in Fanoole Main Canal near Jilib, enjoying the clear water and microfauna for food.

The high turbidity brought in by the gu' rains probably cut off the microscopic food supply and forced the remaining snails to retract into their shells. Juvenile snails died of starvation and the population dropped quickly. As the flood waters clarified again, the few surviving adults laid another brood of eggs and continued shedding schistosome larvae from their previously acquired infections. Large snails were found in a small seepage ditch near Fanoole Canal 5 km north of Jilib during June 1986 (Figure III.A.1). Thus, transmission during June and July could occur in the natural depressions and seepage areas near irrigation canals.

Water in the river and all irrigation canals in June and July was highly turbid, thus bilharzia snails and schistosome transmission was not occurring in these water bodies as it did in February.

No other bilharzia snails were found during repeated searches in the river and all man-made waterbodies, such as irrigation reservoirs and canals, during surveys of June 1986, November 1986, and April 1987. Many aquatic snails were

Figure III.C.2

Bilharzia snail surveys were conducted in all man-made waterbodies in the Jubba Valley during the four annual seasons of 1987. Extra surveys were carried out near villages with high bilharzia prevalence during December 1987 and January 1988.

found in dhesheegs, canals, and drains, but none that transmit bilharzia (Table III.C.6). The river was generally too swift and turbid for any snails, except during the end of the jiilaal dry season.

The scarcity of snails in the lower Jubba Valley was quite different from the nearly continuous snail populations and transmission reported for the lower Shabeelle Valley, where peak transmission also occurred in January and June (Figure III.C.3). There was a notable ecological difference in the two valleys which probably explained some of the differences in bilharzia transmission. The biggest difference was that snail populations and bilharzia transmission in Jubba Valley were restricted to a few months each year, depending on the rains, whereas snails were found in the Shabeelle Valley at all times.

The Shabeelle Valley was verdant, humid, and full of standing waterbodies suitable for snail populations throughout the year. In contrast, Jubba Valley was parched dry, and water outside the riverbed was found only immediately after the floods or in man-made canals, drains, reservoirs, or dhesheegs. These differences were probably due to two things, inherent differences in soils and topography, and the highly developed irrigation culture of the lower Shabeelle Valley.

A study related to agricultural development was conducted regarding the bilharzia risks from two different crops in Jowhar: paddy rice and tobacco (Shunzhang and Hongming 1980). They reported that prevalence in workers in both crops was the same—about 100 percent—but the rice workers had severe infections and the tobacco workers had light infections. Nonagricultural staff working on the same project had prevalences below 50 percent, all light.

They also reported that in the rice fields, snails hibernated in cracks and crevices of dry land during December to March, but in April when the rainy season came and the rice fields were irrigated, a young brood of snails revived until July when the fields were dried prior to harvest. When the fields were irrigated in September for the second paddy crop, the large adult snails revived within one week of irrigation.

The snails resisted four months of drying in rice fields, and experiments indicated they could resist an additional six weeks. Local soils, which were alkaline with high salt content, did not adversely affect the snails.

3. Diarrheal Diseases

This broad category of disease has not been evaluated epidemiologically in Somalia, but cholera, typhoid, and hepatitis outbreaks at the beginning of the gu' season occurred with disastrous regularity throughout the country. At the end of the dry season, as surface waterbodies reduced, they became more contaminated. Rains washed in surrounding fecal contamination and highly turbid water which blocked the normal purification effect of sunlight, and provided an ideal medium for survival of human intestinal pathogens. Periodic cholera epidemics in Jubba Valley and elsewhere in Somalia are a major source of infant deaths. Military quarantines were imposed almost every year in towns in attempts to control the spread of the infections.

The annual intrusion of the ocean up to the intakes for the Kismaayo water supply often provoked an epidemic of diarrheal diseases in the town because people had to switch to local, shallow wells for their drinking water. Many of these wells were located in heavily populated areas and were contaminated.

Intestinal parasites also caused diarrheal disease, and in the Shabeelle Valley, included at least 10 species of worms and other parasites with prevalence rates for *Ascaris* and other worms above 20 percent in adult males (Cahill 1971). *Amebiasis* and *Shigella* bacterial infections caused significant cases of dysentery in the lower Shabeelle Valley. Gross fecal contamination of surface waters used for drinking water was incriminated in studies along the Shabeelle River (Cahill 1971).

4. Malnutrition

Despite considerable agricultural activity in the lower Jubba Valley, agricultural workers are malnourished. In systems which grow cash crops, or in large-scale monocultures, workers often are unable to find adequate and varied food. Serious malnutrition existed among farming families on the enormous Gezira Irrigation Scheme in central Sudan, because of emphasis on cotton as the main crop (Culwick, G.M. 1954). In the prosperous Nam Pong irrigation system in northeastern Thailand, children showed significant malnourishment during the planting season because both parents spent long hours in the fields and neglected the smaller children (Pongpaew 1987). Emphasis on rice, sugar, banana, and cotton production in the lower

Jubba Valley, and their value for export, did not produce enough varied and cheap foods in the local markets for a balanced diet.

Many refugees and settlers in Somalia came from Ethiopia to escape drought and famine. Malnutrition was a serious problem in refugee camps throughout the country, including those near the site of the proposed reservoir. Periodic assessments of the refugee populations in the upper Jubba Valley near the site of the proposed reservoir have shown that people are severely malnourished (Basra 1986). Surveys in the coastlands of Kenya have shown that infections of hookworm, malaria, and bilharzia combined with inadequate diet to cause severe anemia in children (Stephenson *et al.* 1985). These infections were implicated in protein-energy malnutrition in children and iron- deficiency anemia in persons of all ages (Kinoti *et al.* 1986).

5. Hookworm

In the Jubba Valley, hookworm infections from *Ancylostoma duodenale* were prevalent in 100 percent of the agricultural workers from the banana plantations, but in only 2 percent of nomads from semi-desert areas (Cahill 1971). The moist, clay soils required for banana cultivation are ideal for transmission of the hookworm infection. Similar conditions occur in coffee and tea plantations, due to the nature and moisture of the soil (Jobin 1980). School children in similar coastal lowlands of Kenya had 80-90 percent prevalences of hookworm with high geometric mean counts above 500 eggs per gram of feces (Stephenson 1986).

6. Other Diseases

Several other diseases were of interest because they were generally related to water or irrigated agriculture. However, none of them were serious problems in the Jubba Valley. *Ascariasis* and *trichuriasis*, intestinal parasites which spread under conditions of poor sanitation, were very common in Shabeelle Valley and are probably equally prevalent in Jubba Valley. *Onchocerciasis* has not been found in Somalia, but the blackfly which spreads this disease has been reported from the Shabeelle Valley (Zuretti 1955).

Yellow fever has never been reported from Somalia but the vector mosquito *Aedes aegypti* is extremely common and apparently spreads dengue fever in urban areas. Epidemics of yellow fever in Ethiopia during 1963 led to serological surveys which demonstrated the presence of yellow fever antibodies in Somalia in about 4 percent of adults in the Jowhar area, but did not prove transmission (Cahill 1971). *Leishmaniasis*, also known as oriental sore, has been reported occasionally from the Jowhar area; it was suspected that the sandfly *Phlebotomus orientalis* was the vector (Cahill 1971). Higher rates of antibody reaction to *Leishmania* were found in nomadic groups than in settled farmers (Kagan and Cahill 1968). *Dracunculiasis*, known also as guinea worm infection, was not found near the river systems but was common in the semi-desert areas of Somalia. Rift Valley Fever was never reported from Somalia but was found in Kenya (WHO 1982). In most towns of coastal East Africa, *Bancroftian filariasis* is spread by *Culex* mosquitos.

7. Livestock Diseases

Trypanosomiasis, also known as *ngana*, was the most important disease of livestock in Somalia, including Jubba Valley. It was estimated that about $88 million were lost annually in Somalia as a result of the impact of *trypanosomiasis* (Ahmed and Daiiri 1987). This blood parasite was spread by the tsetse fly, *Glossina pallidipes* in about 1,500 sq km of vegetation fringing the Shabeelle and Jubba River systems, with an additional 1,000-2,000 sq km along the southern border with Kenya. Small numbers of *G. longipennis* and *G. brevipalpis* co-existed with *G. pallidipes*.

Near Afgoi, tsetse flies were restricted to the riverine gallery forest in the dry season, but dispersed approximately 1 km into the acacia thickets in the wet season (Ahmed and Daiiri 1987). Trypanosome infection rates in the flies were 2.6 percent in the wet season and 1.5 percent in the dry season. Flies were infected with only the *vivax* and *congolense* group trypanosomes, and the major source of their infections seemed to be wild warthogs. No infections by the species affecting humans were found, and no human sleeping sickness has been reported from Somalia.

A tsetse fly control program was implemented in the early 1980's in the Shabeelle Valley because of the high prevalence of infection in cattle. The impetus came partly from the 1974 World Food Conference in which long-term attacks against *trypanosomiasis* were recommended (Matzke 1983). Aerial spraying was used to apply the insecticide endosulfan along the Shabeelle River at an application rate of 10-40 kg/ha, applying five sprays at 12-day intervals.

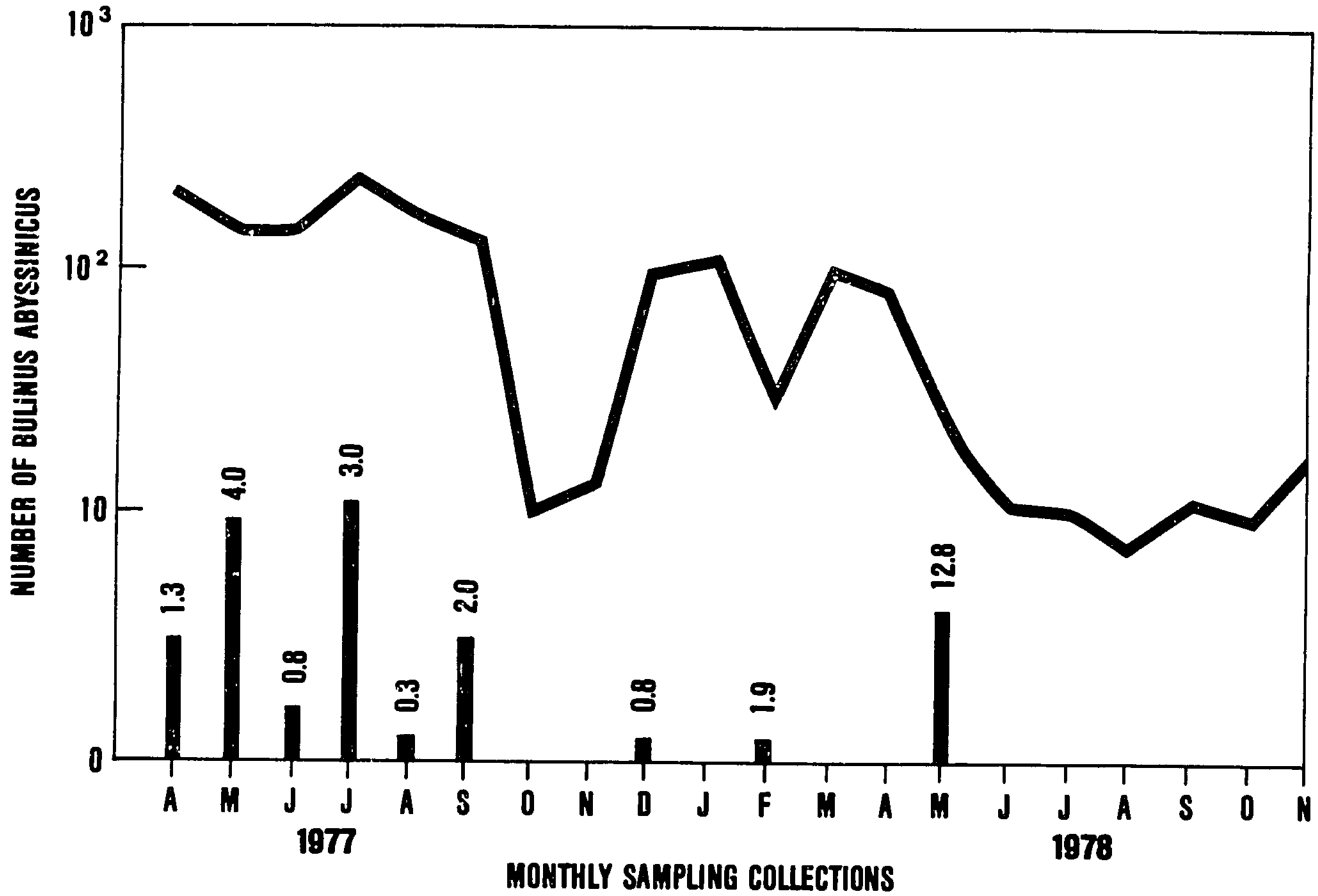


Figure III.C.3
Numbers Of B. ABYSSINICUS Found At Index Sampling Sites On East Side Of Shebelli River In Koryole District

Line represents numbers of B. ABYSSINICUS in standing-water habitats. The histograms show numbers of infected snails and the figures above the bars denote the respective percentages of the total monthly collection. Published studies on bilharzia transmission in the Shebelli Valley indicated transmission occurred principally from April-September, with a second, minor transmission season from December-February. Snail populations were present throughout the year (Upatham et al, 1981).

Plans were made to continue and expand this apparently successful attack on the flies.

Infections with *Echinococcus* parasites were reported in Somali cattle imported to Egypt (Cahill *et al.* 1971). These parasites produce hydatid cysts in cattle which precluded them from human consumption. Human infections with this parasite, known as hydatid disease, have not been reported from Somalia (Kagan and Cahill 1968).

A veterinary laboratory was established in Kismaayo in 1979, providing recent information on diseases of livestock in the lower Jubba Valley (Schoepf *et al.* 1984). *Trypanosomiasis* was the most common and feared disease in the region. This infection caused severe loss of vigor and high mortality (Zschekel 1980). *Theileriasis*, spread by ticks, and *anaplasmosis* were common infections, but of small importance. The most common species of tick on livestock was *Rhipicephalus pulchellus*, but *Amblyomma gemma* and *Amblyomma lepididum* were widely distributed in the lower valley (Figure III.C.4).

Epidemic lung disease in goats (contagious *Caprine pleuropneumonia*) was widespread. Every year about 20 percent of the goats died from it. *Brucellosis* in camels and cattle was widespread, and also found in people. Camels, cattle, sheep, and goats in the Kismaayo area suffered from ticks and a wide variety of intestinal parasites, especially *Trichostrongylus* and *Strongyloides*. There was a high prevalence of *Haemonchus contortus* and paramphistomes in camels, sheep, and goats. Very few infections of *Schistosoma bovis* and *Fasciola hepatica* were found, two parasites transmitted by aquatic snails somewhat similar to the bilharzia snails.

D. Existing Public Health Programs

1. Health Care System

The Ministry of Health operated no public health programs in the Jubba Valley except for hospitals at Luuq and Kismaayo and four malaria posts where passive case detection and treatment with chloroquine were offered. The NAS operated malaria laboratories at Baardheere, Dujumma, Jilib, and Jamaame with a microscopist and malaria officer. The Refugee Health Service also offered health care in refugee camps near the site of the proposed reservoir.

In general, people had recourse only to non-governmental agencies to provide minimal primary health care (PHC) and vaccination programs. Swedish Church Relief operated PHC units in Bu'aale and Saakow with several community health workers. The Jubba Sugar Project had a dispensary at Mareerey, and World Concern operated a leprosy hospital at Labade and a PHC unit in Jilib. UNICEF had a PHC center in Jamaame.

In all, the health facilities served only a few people who had transportation or lived close to the PHC units or hospitals. The Somali goal under the Health for All program is one community health worker for every 500 persons by the year 2000 (Ministry of Health 1987). In 1987, the ratio in the Jubba Valley was about 1:50,000, assuming two community health workers at each PHC unit. This was clearly inadequate for any kind of effective health care.

2. Disease Control Operations

Malaria Control

As in most of Africa and many parts of the tropical world, initial successes against malaria in the 1950's have been displaced by a discouraging trend toward crumbling control programs which have been hampered by enormous and growing problems. Despite various attempts to organize a national program against malaria in Somalia, success was only sporadic. In 1966, WHO reported that the National Malaria Control Program had not achieved its goals (Noguer 1966). A strategic retreat in policy to a pre-eradication program was initiated with the help of WHO in the early 1970's, utilizing house-spraying with DDT and active case detection in critical towns, and treating with chloroquine. This also was generally unsuccessful (Cahill 1971).

By 1987, a malaria crisis was brewing in Somalia. Due to lack of fuel and resources, the NAS had severely limited its operations outside Muqdisho since 1983. Monitoring of transmission and passive case detection was reduced from 118,000 blood slides per year in 1979 to 46,000 in 1985. House-spraying was eliminated in 1986. Usually, drought years, such as those from 1983 to 1985, meant decreases in the incidence of malaria in Somalia. Thus, it was extremely disquieting that the slide positivity rate for malaria in Somalia increased from 4 percent in 1983 to 7 percent in 1985, with further increases during the severe drought of 1986-87.

The Ministry of Health responded by shifting the operational responsibility for malaria control to the

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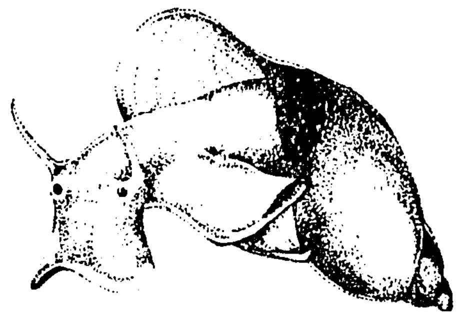
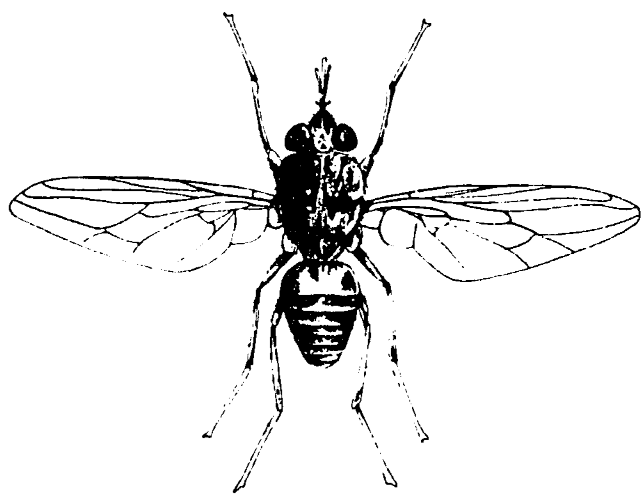


The Amphibious Lymnaeid Snail

The Amphibious Lymnaeid Snail spreads parasites to cattle, sheep and goats. This snail is often found in camp pasture near lakes and swamps, spending part of its life cycle on land. The adult snails are about 2 cm long and can spread a parasite of the genus FASCIOLA.



The Tsetse Fly

The Tsetse Fly is the vector of ngana or trypanosomiasis in cattle. It is found along the Shebelle and Jubba Rivers, depending on vegetation and humidity along the river to sustain it during the long dry season.

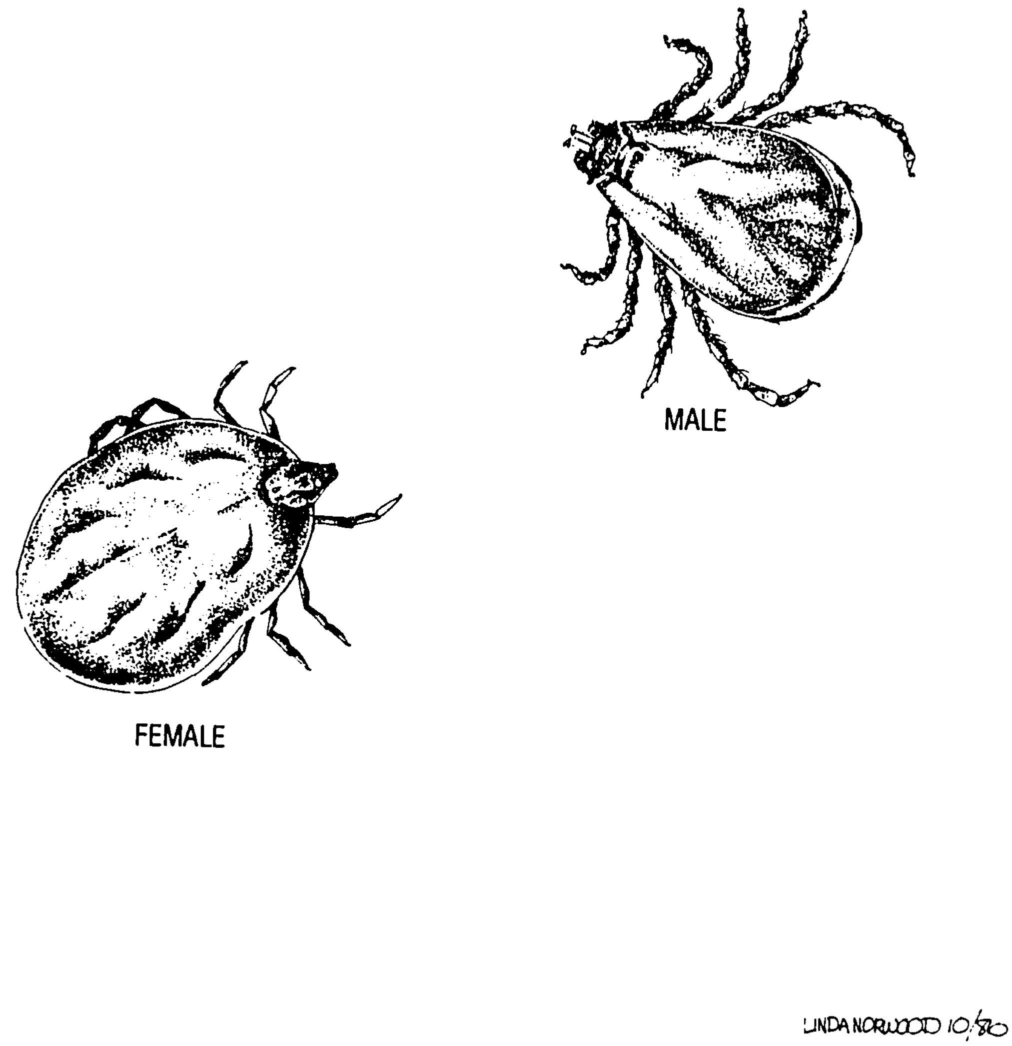


Figure III.C.4
Cattle Ticks
Typical Ticks Infesting Livestock And Other Animals

Various species of AMBLYOMMA and RHIPICEPHALUS ticks transmit anaplasmosis and theileriasis in Somalia, and also Nairobi Sheep Disease and heartwater. The ticks cause considerable traumatic irritations.

PHC system, in keeping with budget cuts and current global philosophy on public health in tropical countries. Of particular relevance to this report, the government had no PHC units in the Jubba Valley, relying on efforts of nongovernmental agencies. Even in Muqdisho and the rest of the country, the PHC system's only weapon against malaria was chloroquine—an inexpensive drug which gave limited benefits in the dispersed populations of rural Somalia.

This deficiency was compounded in 1986 when a chloroquine-resistant strain of malaria parasite appeared in several towns in southern Somalia (WHO and NAS 1986). Drug-resistant malaria had been present in Kenya and Ethiopia for several years and finally invaded Somalia. Reports from WHO in 1987 indicated that the resistant strain was spreading rapidly throughout southern Somalia.

The outlook for 1988 regarding prevention and treatment of malaria in Somalia was grim. No effective control programs were operating, and even chloroquine was no longer reliable as a preventive or curative measure for individuals. New drugs such as fansidar were not generally available and had to be used with caution. Local physicians were returning to the classical drug, quinine, for curative purposes.

The one element of hope was the demonstration that an inexpensive biological method of mosquito control was highly successful in the north (Alio, Isaq, and Delfini 1985a). An indigenous species of tilapia fish, *Oreochromis spiluris spiluris*, eliminated mosquitos from the reservoirs in the Burao district of the dry Togdheer region, and prevented malaria transmission in the surrounding populations despite heavy transmission in other similar areas (Alio, Isaq, and Delfini 1985b). This method had considerable potential as a low-cost technique which could be utilized by community organizations with only minimal assistance from the government.

The NAS reported there were other Somali fish which also had potential for control of malaria mosquitos. Another tilapia species, *Oreochromis niloticus*, was used in many parts of Africa to control mosquitos, and *Notobranchius* sp. was found effective for mosquito control in dry areas of Somalia. *Notobranchius* was known as the "instant fish" because its eggs survived long, dry periods in the mud, hatched as soon as the depression filled with water, and fed on the mosquito larvae which also appeared soon after the rains.

All of these fish could be useful in certain situations, but the following limitations have been noted by the NAS in Somalia. *O. niloticus* was sensitive to agricultural pesticides, and *O. spiluris* was very sensitive to high salinity. However, *Notobranchius* was not sensitive to either salinity or low oxygen concentrations.

Bilharzia Control

Bilharzia control efforts in Somalia have been sporadic over the past decade, starting under an agreement with WHO and the Ministry of Health signed in 1976, but then gradually disappearing by 1986. Preliminary field studies began during 1977 in Koryoley and Merka Districts (Figure 1 at the front of this volume), and the resettlement villages of Kurtunwary and Sablaale—all southwest of Muqdisho in the irrigated portion of the lower Shabeelle Valley (Koura *et al.* 1981; and Upatham *et al.* 1981).

In 1978, some infected people in these villages were treated with metrifonate, along with snail control efforts in their villages. Slow-releasing formulations of an organotin chemical, TBTF, and copper sulfate were tried in pilot studies for snail control. Preliminary results indicated some success in areas where both drugs and chemicals were used, but there was an increase in prevalence in areas where only drug treatment was given. Work in these areas was discontinued in 1979 due to lack of fuel and hard currency to purchase chemicals and drugs.

By 1982, the control effort was limited to passive case detection and treatment in the lower Shabeelle Valley, Jilib, and Jamaame. Progress toward interruption of transmission and reduction of bilharzia prevalence had been negligible (Arfaa 1982). In 1986, the national bilharzia control program was eliminated.

IV. PREDICTED SITUATION AROUND PROPOSED RESERVOIR

Despite the concentrated planning effort on dam design, cost analyses, agricultural planning, and estimations of power production, success of the Jubba River Valley development would ultimately be measured in terms of the human communities which develop in the valley. Without decent communities, inhabited by people with dependable supplies of food and water, in good health, and with educational and economic opportunities, the plans for development of the valley would mean little, even though national goals for power production may be met. Thus, serious attention must be given to assessment of the expected populations and community development in the entire valley, including the area around the proposed reservoir.

Some of the most directly affected populations would be those in the Gedo Region—especially those in close proximity to the proposed reservoir. In addition to camps of about 6,000 temporary residents during the construction of the dam, human settlements around the reservoir would be located above the normal high water line, and restricted to places where sufficient fresh water is available during the periods when the lake is at its minimum level. Other possible locations are places where the soil is good and near major roads, trails, or ferry boat crossings.

Basic economic support for such settlements would be activities such as fishing, drawdown farming, grazing animals, or commercial enterprises related to regional traffic by herds or vehicles. Growth of such communities may be fairly slow since, at present, overall soil conditions in the drawdown zone seem unfavorable for agriculture or grazing. Only after several years of reservoir fluctuation would the siltation in the drawdown zone be sufficient to support farming and grazing.

Fishing potential in the lake may be high within a few years after filling, but whether a fishing industry would develop is almost impossible to predict. Large herds of livestock could immediately congregate around the reservoir in search of drinking water, but they would be limited by available grasses for food. The number of people with these herds would be small and in temporary quarters, moving with the herds and the rise and fall of the lake.

Such herds probably did not congregate along the river before 1987 because accessible flat land was fully developed agriculturally and they were not permitted to graze in the fields except after harvest. Thus, access to the river was limited to rocky or steep areas, or along dry streambeds.

When the lake fills, the fertile strip of land on the west bank will be flooded and lost, except for remnants near Luuq. The drawdown zone to the west would be flat enough for farming in the central sections (C and D) but initially, the soil would be too thin (Figure IV.1).

At present, the significant communities along the river contain refugees from recent droughts (many of them from Ethiopia), residents of the five small towns along the river, plus agropastoralists who have lived along the river in scattered groups for several decades. Two possible developments in the future depend on whether those people leave—perhaps by settling in agricultural developments downstream or by returning to Ethiopia—or whether they are simply displaced to new locations slightly above the high water level.

If the refugee camps are not truly dispersed but are simply relocated along the edge of the new reservoir, they would continue to require outside support, with only their water and perhaps some fish derived locally. When the lake is low, the water would have to be brought from a great distance (1-5 km). The longer distance to their water source would result in decreased consumption and use of safe water and thus, increases in diarrheal and other water-associated diseases. This longer distance would not give them much protection against bilharzia transmission because the peak transmission season would occur when the reservoir is full or starting to recede—the time when the lake would be quite close to the camps.

Sites for refugee camps should be selected to make water more accessible for them when the lake is low. Therefore, they should be located above fairly steep slopes rather than on the flattest portion of the west bank where they are at present. There would then be no reason for being on the flat plain as the agricultural land on that level would be permanently flooded. The only limitations on the slope of suitable land for the relocated camps would be

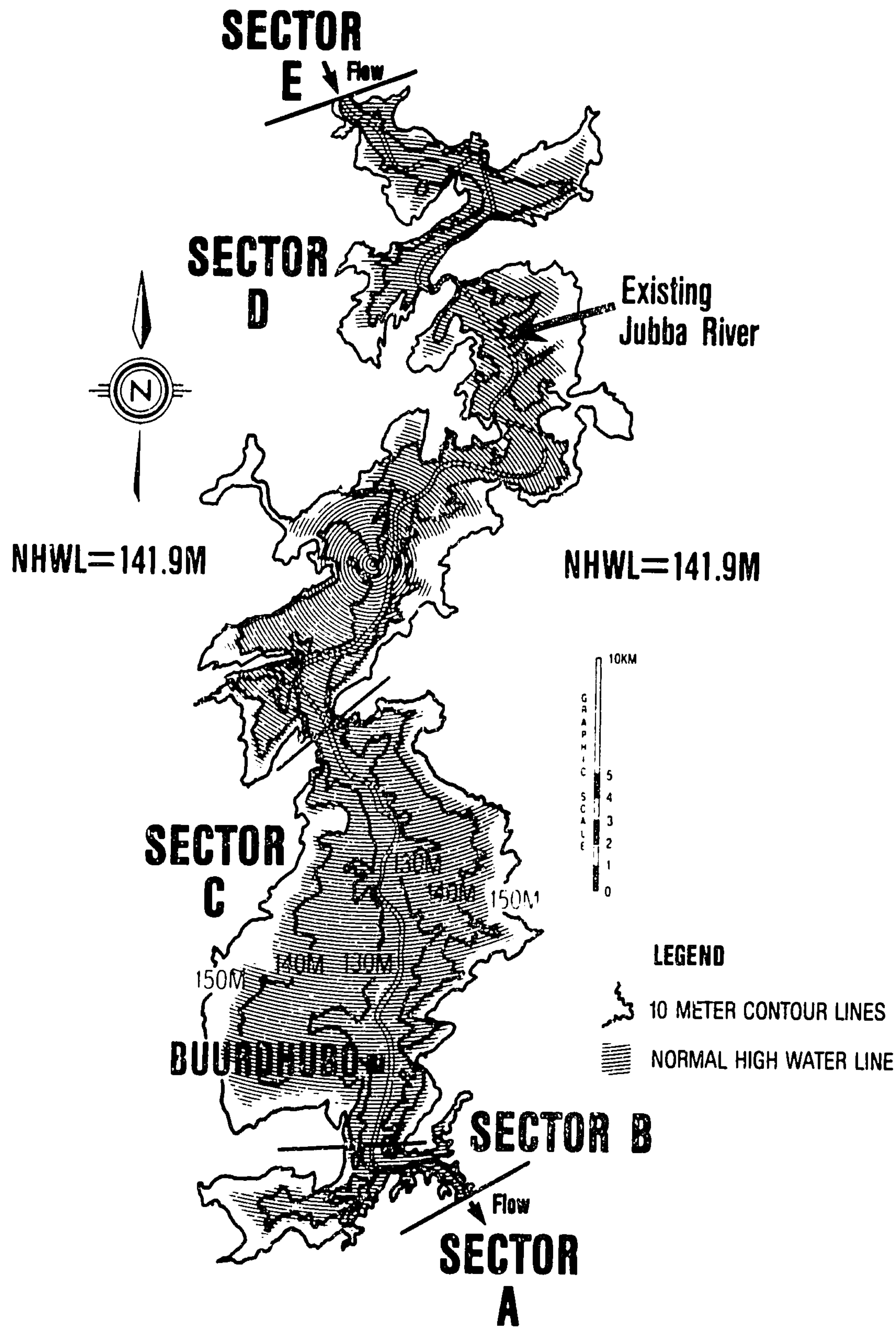


Figure IV.1
Central Portion Of Proposed Reservoir On Jubba River, Somalia

Of the five geographic sectors of the proposed reservoir, Sector C contains the most likely habitats for bilharzia snails and malaria mosquitos. Of particular concern would be a site on the southwestern shore of Sector C near the present location of Buurdhubo, due to the large expanse of flat shoreline protected from prevailing winds and waves. The narrow gorges in Sectors A and E have nearly vertical walls and would not support snail or mosquito colonies.

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accessibility and ease of travel, which would make it possible to locate them anywhere except the really steep gorges. Also, after the lake fills, there would be no reason for limiting the camps to the west bank.

If the Ministry does not intervene in developing new or expanded human communities in the valley, spontaneous, unplanned growth would occur due to normal biological increases and the attraction of the new developments to surrounding people–especially agropastoralists. Natural patterns would find clusters of homes developing near the reservoir and around existing settlements. Outstanding typical features of such natural population increases are extremely poor sanitation and severe problems with water- associated diseases.

As in many other natural population expansions, peripheral clusters of people expected to develop in the valley in the future would be forced to use polluted surface waters, or have very limited access to already strained water supplies in existing communities. This type of development was seen already along Fanoole Main Canal where every canal crossing point was marked by new, spontaneous settlements of two to 50 homes, simply because the sites had dependable water and a road.

The same attraction to the water exists for livestock herds and wild animals. Cursory inspection of Fanoole Main Canal upstream of Jilib showed innumerable contact points visited frequently by livestock, monkeys, warthogs, antelope, birds, and other local fauna. The same attraction should be expected for the shores of the reservoir behind Baardheere Dam.

A. Assumed Development Alternatives for Reservoir

Two possible futures for human use of the lake are: guided development and uncontrolled development. A third possibility, that of creating a protected natural reserve, was not evaluated in any detail because it would cause severe economic hardship on current residents of the area and be expensive to protect from future human settlements.

1. Guided Development

Guided development around the lake would require establishment of a strong central authority to:

- guide human settlements and community development patterns;
- manage lake levels by careful control of dam operation;
- prepare shoreline prior to filling the reservoir;
- guide herds, grazing practices and agricultural development in the drawdown zone;
- stock and manage fish populations; and
- monitor public and veterinary health, and control diseases with a comprehensive approach to management of disease vectors such as mosquitos, ticks, flies, and snails.

This controlled future would require the largest government investment, but also would have potential for significant local and national benefits through rational utilization of this large water and land resource. This future condition would require purposeful operation of the dam to benefit lakeside development as well as hydroelectric power and downstream irrigation. It would require a fundamental and clear decision by the government to include lakeside development as a major purpose of the Baardheere Dam Project. If this alternative were adopted and fully supported, it would make possible the optimum protection of human and animal health in a wide zone around the lake, and thus, the development of considerable food resources for local and regional consumption.

2. Uncontrolled Development

The second possibility of uncontrolled development of human and animal populations around the reservoir has been the usual fate for many large reservoirs—especially those in areas as remote from governmental control as Baardheere. Some local benefits may occur in this situation, but would probably be of minor economic significance.

The more common course of uncontrolled development would allow exploitation of some of the potential resources related to the lake, but would carry the potential for disastrous outbreaks of human and animal diseases. It is also unlikely to yield significant agricultural or economic benefits because lakeside activities would be adversely affected by erratic fluctuations in the water level. Sudden drawdowns or uncontrolled lake risings at critical times during the year could eliminate crops, deplete fish populations, and ruin grazing areas. Preliminary indications estimate that approximately 10,000 farmers presently inhabit the river banks, not including refugees. Deprived of their homes and sustenance, serious problems would arise for this large agricultural population. The initial years after dam construction would cause especially severe problems since the lake may fill precipitously if it is a wet year, flooding homes and crops even before salvage operations can start.

With a future of uncontrolled development, no stable human communities with good water supplies and sanitation could develop around the lake, given the unpredictable risks of agricultural enterprises. Thus, present outbreaks of cholera and other waterborne diseases would continue, nutrition would be unlikely to improve, and new problems of sporadic bilharzia and malaria outbreaks among people and diseases among livestock could be expected. It is unlikely that such a future for the lake would be of any net benefit to Somalia.

B. Assumed Populations and Community Development

Population growth and development of communities and basic community services would be quite different for either guided or uncontrolled development. The following assumptions about human and animal population growth for the two options were derived from preliminary and final reports available from JESS activities in 1988. The aggregate population figures came largely from the 1985 AHT report (based on the 1975 population census), with modifications. Some refinements were developed from the JESS socioeconomic surveys of 1986-87.

Population growth in the Gedo Region would not follow that of other regions because of the influence of the large reservoir, which would become the dominant geographical feature of the region. For predictive and analytical purposes, the population of the Gedo Region was subdivided into four categories of people: those settled in tertiary or larger villages, those in refugee camps, dispersed agriculturalists who are semi-nomadic, and true nomads (Table IV.A.1). In addition, livestock of the region were enumerated as cattle, camels, sheep, and goats. There would be a temporary influx of about 6,000-10,000 people involved in construction of the dam. Most of these would be single men without livestock.

In 1985, the existing population of the Gedo Region included about 400,000 people in the major towns of Baardheere, Luuq, and Garbahaarey, several small villages, a dozen refugee camps, scattered agricultural homesteads, and nomad camps (Table IV.A.1).

Table IV.A.1. ESTIMATED POPULATION IN GEDO REGION BY LOCATION, 1985.

LOCATION	POPULATION
Towns:	
Luuq	8,000
Baardheere	15,000*
Garbahaarey	5,000*
Villages:	
Buurdhuubo	500
Markabley	500
Lele Scodo	500
Durole	500
Sarsarre	500
Kelibas	500
Agropastoralists:	59,000**
Nomads:	166,000
*Refugees:****	
Buurdhuubo	20,000
Hilo Mareer	17,000
Malka Hiddo	20,000
Suriya	20,000
Camps near Luuq (nine)	70,000
TOTAL	403,000

** from JESS*
*** JESS surveys of 1987 indicated that 10,000-13,000 of these people were agropastoralists living within 0.5 km of the river, in the area of the proposed reservoir*
**** estimated 147,000 by EEC delegation of December 1982*

There were five villages including Buurdhuubo, on the west bank of the river and one on the east bank (Markabley). Except for Markabley, these villages and surrounding populations would have to be resettled before the dam fills.

Uncontrolled development of the reservoir would probably include moving refugee camps to locations slightly above the high water line, and result in severe hardship for the existing agropastoral population. However, this alternative would probably cause a fair increase among nomads due to improved water supply for their livestock, and removal of restrictions to their access to grazing land in the drawdown zone.

Guided development could cause a significant increase in the settled population, perhaps by creating magnet villages with basic facilities. Control of reservoir fluctuations would make it possible to slowly develop the drawdown zone for sedentary agriculture. Thus, the semi-nomadic population might subsist with their livestock for the first decade, if compensated for their losses due to the reservoir filling. Thereafter, it would be possible to slowly develop drawdown agriculture in combination with management of grazing lands. The second decade should then see significant growth in the semi-nomadic population and increases in the nomadic groups and their herds (Table IV.A.2). Refugee camps could be maintained at their present size if adequate water and food is provided by the national government.

Table IV.A.2. PREDICTED POPULATION OF PEOPLE AND LIVESTOCK FOR THE GEDO REGION OF SOMALIA, 1985-2005.

Numbers are in thousands of individuals

	1985	1995		2005	
	Existing	Uncon-trolled	Guided	Uncon-trolled	Guided
HUMAN POPULATION*					
Settled	31	30	35	30	40
Refugees	147**	147	147	147	147
Agropastoralists	59	45	60	45	70
Nomads	166	180	180	250	250
TOTAL*	403	402	422	472	507
LIVESTOCK POPULATION*					
Cattle	668				
Camels	867				
Sheep	635				
Goats	870				
TOTAL	3,040	3,[illegible]0	3,500	3,500	4,000

* *from AHT, 1985, pp. 46, 52, 94*
** *EEC delegation of December 1982*

C. Predicted Water Quality in Reservoir

The following description of seasonal changes in the reservoir to be formed by Baardheere Dam portray the expected water-quality and ecological conditions affecting disease transmission around the reservoir during a typical year. The lake will normally fluctuate from slightly below the spillway level of 144 masl down to the penstock elevation of 128 masl. However, water could also be discharged from the bottom outlets at 105 masl (Figure IV.C.1).

1. Predicted Seasonal Patterns for Typical Year

The reservoir will reach its lowest level at the end of the jiilaal dry season, usually about April. For the preceding three months of January, February, and March, river flow into the reservoir will be very small—less than 100 cumecs—and increasingly salty, normally reaching an EC25 of about 1,500 micromhos/cm by April. During the jiilaal season, the reservoir level will recede due to discharges through the turbines, at a monthly mean rate of 100-150 cumecs.

The reservoir level will drop to the minimum at the penstock intakes at 128 masl only during extremely dry periods where inflow remains below normal for two or three consecutive years. In these situations, the maximum amount of shoreline will be exposed, and desiccation from the hot, dry air of the jiilaal season will kill off the stranded aquatic vegetation and fauna.

As the gu' rains begin in Ethiopia and the Luuq area, the reservoir will start to rise slowly from the small flood, including a relatively stable, slow rise during the dry xagaa season. The reservoir will fill quickly when the large floods of the deyr season come in October and November. By December, the end of the deyr season, the reservoir level will reach its maximum elevation during a typical year at around 142 masl, before the gradual decline starts again in January during the jiilaal season.

Although this may represent the average seasonal cycle, the small size of the reservoir (5×10^9 cu m) in relation to the erratic drought and flood flows of the river (0-1,000 cumecs) and the occurrence of two annual floods, will combine to produce a seasonal reservoir cycle which will often deviate significantly from a simple, annual rise and fall.

Simulation of the proposed reservoir indicated that there will be many years when the reservoir level will remain relatively high (ELC 1985). When the reservoir remains full for two or three years in a row, heavy growths of marginal and floating vegetation can be expected to accumulate around the shoreline.

Shoreline vegetation will be strongly influenced by the annual reservoir cycle, and this in turn will determine the suitability of the reservoir edge for snail and mosquito habitats. After several years of stabilization, the protected shores of the lake will develop an enriched topsoil due to fertilization from minerals and silt in the lake waters, and growth and decay of rooted and floating vegetation. Therefore, even in areas now somewhat sandy or gravelly, a rich flora will eventually develop. However, in steep portions of shore exposed to prevailing winds which traverse several kilometers of open lake, shoreline erosion or formation of sandy beaches will take place, resulting in extensive clear sections of shoreline. It is in the protected coves and inlets

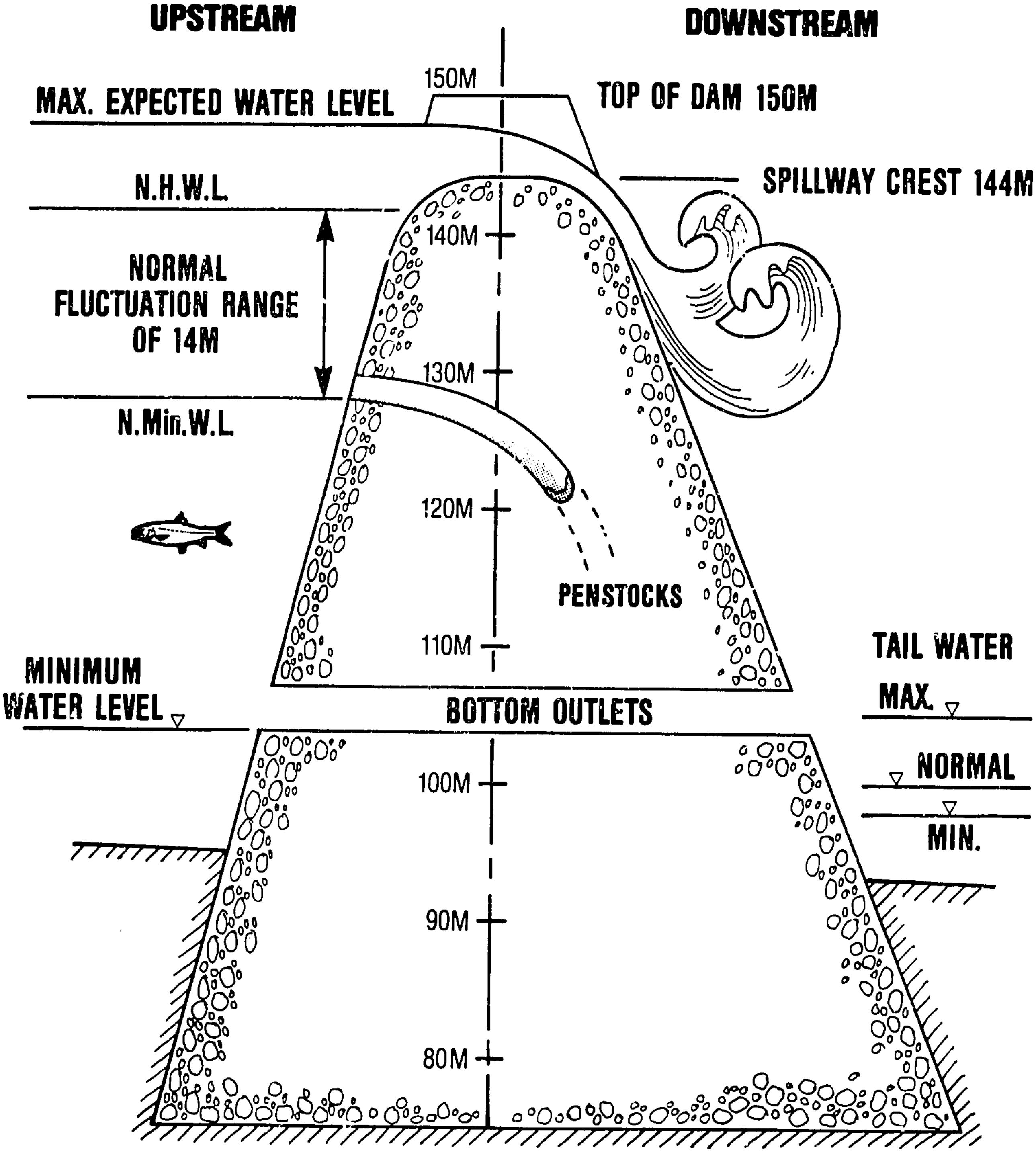

Figure IV.C.1
Schematic Section Through Proposed Baardheere Dam Showing Range Of Expected Water Levels

Proposed dam will be operated with normal fluctuation zone between 141.9m above sea level and 130-135m.
In initial years, because of low power demand, the reservoir will probably remain nearly full for most of the time.

that vegetation will take root, and suitable habitats for aquatic snails and mosquitos will develop.

In regard to disease transmission, the most important effect of seasonal changes in the reservoir will be related to the water level, water temperatures, water transparency, and growth of vegetation. These factors will control the basic population dynamics of insects and snails in the lakes, as well as human and mammalian activities which influence transmission of water-associated diseases.

Detailed investigations in Kainji Reservoir of Nigeria (Bidwell 1976) and Lake Volta of Ghana (Chu *et al.* 1981), which have single fluctuation cycles similar to the proposed Baardheere Reservoir, portrayed the seasonal dynamics of vegetation and invertebrates to be expected in Baardheere Reservoir.

During the period of highest lake level (from September through January), the numbers of bottom-dwelling organisms, such as insect larvae and snails, will be highest around the margins of the reservoir and lowest in the center. The plant biomass along the shore will be very high with emergent vegetation reaching its maximum density by January or February. Transparency will be minimal in October and November due to high turbidity entering during the peak flood of the river, but should improve from January through March as the inflow nearly ceases and the lake shoreline holds steady around 140 m, exceeding the spillway elevation of 144 m only during exceptionally large floods, with a maximum level of 148 m in extreme situations.

The first three to five months of the year, the lake will recede due to heavy discharges and little inflow. Emergent vegetation will slowly decline due to stranding and drying. Those organisms attached to floating vegetation or debris will survive while the other shoreline organisms will be quickly stranded and reduced to very low numbers. Lake water will be relatively clear at this time, thus the populations of bottom organisms in the depths of the lake will be growing, and algae and plankton populations will increase.

The lake level will be at its minimum for a short time in April or May as the river flow dwindles to zero. The lowest elevation the lake will reach is 128 m, but often it will descend only to 133 or 134 m by the time the gu' flood begins. Thus, the normal annual drawdown is 7 m over three to four months, or about 2 m per month. The maximum normal drawdown is 3 m per month or 12 m, while the extreme drawdown might reach 4 m per month over a four-month period. When this minimum stage occurs after four months of drawdown, the emergent vegetation will be stranded and disappear. Large numbers of snails, stranded by the receding water, will be found decaying on the shoreline.

The lake will begin to rise slowly in April or May when the first highly turbid flood waters enter, flood the previously exposed shoreline, and touch off population explosions among shoreline organisms—partly due to decomposition of submerged terrestrial vegetation. There will also be a regrowth of emergent aquatic vegetation and a rapid decline in populations of deep-water organisms due to high turbidity. The gu' flood is relatively small in total volume. Thus, the reservoir level will rise slowly until the deyr flood, and increase markedly in October and November. The reservoir will often be held at its peak level after October and, in exceptional years, will stay at this level for six months or more.

2. Density Currents

Density currents in the proposed reservoir could be caused by several factors, and have an important impact on objectionable qualities of the dam discharges which might cause corrosion of the turbines or adverse conditions for fish below the dam. The following evaluation of salinity, temperature, and suspended solids was made to indicate the significance and likelihood of the expected density currents. With careful monitoring, it should be possible to pass most of the corrosive and abrasive density currents through the bottom outlets, thus protecting the turbines. However, adverse conditions for fish and aquatic biota may still occur in the mixing zone immediately downstream of the dam.

Salinity

As the reservoir fills each year from April to November, southerly winds—especially strong in the xagaa season from May to October—will promote thorough mixing of the reservoir epilimnion as they parallel the long axis of the reservoir, with many open reaches of 10 km or more.

If the total annual salt load coming into the reservoir is thoroughly mixed with the lake water at maximum volume during this period, the expected concentration of salts will be low and the water will be fit for almost all human, animal, and agricultural uses. In a subsequent section of this report it was estimated that fully mixed conductivity levels in the lake during December will be approximately 350 micromhos/cm (Table IV.C.2).

The river flow entering the reservoir at Luuq during the time of maximum reservoir depth will be only slightly saline, with mean EC25 between 200 and 400 micromhos/cm— about the same as that in the fully mixed reservoir. Thus, there will be no density current due to salt as the river enters the reservoir at Luuq during the early jiilaal season.

Subsequent to the maximum reservoir elevation in December, river flow will drop markedly in January, remaining at low volume through March and perhaps April. During these dry months of the jiilaal, river flow drops to less than 50 cu m/s and the river EC25 rises to 1,500 micromhos/cm. It is likely that the small jiilaal flow would follow the old river channel due to the high differential in salt density. The flow rate in the river will be less than 100 cumecs, with a travel time to the dam in an average year around two or three months and assume a highly stratified flow. By the end of the jiilaal, this dense, salty flow would reach the dam in an average year.

At the beginning of the gu' floods in April or May, the river EC25 rises with short peaks up to 1,700 micromhos/cm, but for periods of less than a day. These conductivity rises occur in the first day of flow surges which may last for several days. However, the river EC25 quickly drops back to levels of 600-700 micromhos/cm even though the river flow may stay fairly high, having jumped by 100 or 200 cumecs each time a new flood surge arrives. Therefore, the salinity differential with the reservoir will no longer cause a density current during the gu' floods.

Mean EC25 in the fully mixed reservoir will rise after the gu' flood due to the several loads of salt brought in on the crest of successive surges, whether they are of local origin around Luuq or from further upstream in the Ethiopian mountains. However, the mean reservoir EC25 will not exceed 600 micromhos/cm in a typical year, but usually remain below 500 micromhos/cm. Thus, the reservoir water will meet the most sensitive use requirements throughout the year.

During the xagaa season, after the gu' flood and during the slow, steady rise of the river, the river flowing in at Luuq will have a lower conductivity than the mixed reservoir. The river conductivity ranges from 200-500 micromhos/cm while the reservoir mean value will be declining from 500-600 micromhos/cm at the end of the gu' to 300 or 400 micromhos/cm by the beginning of the deyr flood in October or November, due to the dilution provided by the fresh water flow of the xagaa season. If there were any density differential due to salt, it would be negative and cause the river flow to rise to the surface of the lake where surface mixing would be affected due to waves and wind currents. Therefore, a density current due to salt should not occur at this time. The deyr flood of October or November does not bring in high concentrations of salt such as those seen in the gu' flood, and the large volume of flow coming into the reservoir will insure adequate mixing.

In summary, conditions in Baardheere Reservoir will only favor stratification of the river flow due to salt during the end of the jiilaal season.

Water Temperature

The mean lake temperature can be estimated from its latitude and altitude, with a slight correction due to its shaded position in a narrow, deep gorge with north-south alignment. With a north latitude of approximately one degree and an altitude of roughly 100 masl, the estimated mean deep-water temperature (of the hypolimnion) will be about 28°C, if we use the equation:

$$\text{Temperature in}^\circ\text{C} = 28.07 - 0.0038 \times \text{altitude in meters}$$

without correction for latitude (Lewis 1973, p.216).

If a slight correction is made for one degree north latitude and the shading of the reservoir by its steep sides, an estimate of 26-27°C might be more accurate for the hypolimnion.

Surface temperatures will be higher due to solar heating, especially along the shore where most snail and mosquito habitats will be found. Population dynamics of snail and insect populations will be governed more by the monthly means which will also fluctuate slightly with changes in climate.

Climate and river conditions in the Luuq and Baardheere area have been graphically summarized (Entz 1982). Mean air temperatures reach a maximum of 31° C at Baardheere in March just before the gu' rains, while the minimum of 26° C occurs in November during the deyr rains. The relative humidity in Baardheere drops to 53 percent in February and March with a maximum of 62 percent

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occurring from May through August. Winds are strongest from May through October, blowing at almost 4 meters per second from the south-southwest.

The combined seasonal effects of air temperature, relative humidity, and wind cause a relatively constant evaporation rate of 180 mm per month throughout the year—about 2 m per year. Recent estimates by AHT place this closer to 3 or 4 m per year in the area of the proposed reservoir.

Water temperatures in the river coming through Luuq and Baardheere are highest during the floods of the gu' and deyr, about 30°C (Table III.A.12). They fall to 25°C by the end of December and in June. It is likely that the surface waters of the reservoir will follow a similar pattern due to the constant rate of evaporation and cooling throughout the year.

If hypolimnion temperatures remain stable at 26-27° C, then thermal differences of the river water entering at Luuq could cause a density current for a few months. In January, when the river temperature is 25° C, there would be up to a 1-2° C temperature difference, causing the entering flow to sink to the bottom. This would reinforce the saline density difference existing at that time. However, pronounced vertical circulation will probably occur in the reservoir during January, negating this tendency toward a density current.

This same condition would occur again in June when the river flow is much larger although a density current at this time is unlikely because the river will be much less saline than the reservoir. The salinity difference would thus negate the tendency toward a thermal density current.

For the rest of the year, the river water would be warmer than the mean lake temperature and river flow should remain near the surface and be well-mixed by waves and wind currents.

In the dead storage at the bottom of the lake near the dam, the coldest temperature would occur as cold surface water sinks to the bottom in December and January, reaching the same minima as that observed on the surface, 25°C (Figure IV.C.1).

Suspended Sediments

Density differences of the incoming flow due to salts or suspended solids might occur erratically at the beginning of the gu' floods when the highest concentration of suspended solids and salts are experienced in the river.

It is unlikely that the large concentration of salt in the gu' floods will cause density currents at the upstream end of the reservoir because salt surges last only a few hours and the temperature density-differential will be counteracting the salt density-differential. During the first floods of the gu' season, the river temperatures will be quite high (near 30° C) and thermal tendency toward a density current will not occur.

However, density differences caused by the sediment load may create a strong tendency towards density currents. Sediment concentrations during the gu' flood exceed 3,000 mg/l during May and June, a density increase of 0.3 percent over pure water. The surges of sediment last for a week or two.

Although much larger loads of sediment come down the river during the deyr flood, the concentrations do not exceed 1,000 mg/l, due to much larger flows than in the gu' season.

Density Current Effects on Discharge at Dam

The only likely time that density currents would cause short-circuiting of the river flow directly to the dam outlets and turbines would be during the end of the jiilaal season, according to the previous analyses of salt, temperature, and sediment conditions. Assuming the mean turbine discharge during this time is 100-150 cumecs and the river flow is 10-100 cumecs, turbines and bottom outlets could pass all of the density current plus some dilution water from the body of the lake. This period would yield the poorest water quality in the discharge—fairly saline water with an EC25 near 1,000 micromhos/cm. The temperature and suspended sediment conditions would be satisfactory, but it is likely that the water would have very little or no oxygen due to its passage along the dead storage zone. The low oxygen could have an adverse impact on fish immediately below the dam, but re-aeration would prevent this impact from extending very far downstream.

The most serious effect from the density current would be the high salinity which would be detrimental to irrigated agricultural uses. However, the salinity levels to be expected during this period will be lower than those presently experienced in the river valley, without the dam. Thus the situation will show a slight improvement, simply due to the dilution water mixed with the density current as it flows through the reservoir. Prediction of the salinity levels from the density currents is almost impossible, but they will probably not exceed an EC25 of 1,000 micromhos/cm for more than one month, and probably be less than 750 micromhos/cm except in a very dry year when the reservoir is extremely low.

3. Epilimnion and Stratification

The maximum depth of the reservoir will be 45 m in the gorge near the dam, and 22 m in the wide portion near Buurdhuubo (Figure IV.C.2). When full, the lake will stratify vertically into at least two layers. Wind shear on the surface will form a surface circulation cell called the epilimnion that will be a few meters in depth, and limited by the speed of the wind and resistance due to density of the deeper hypolimnion being brought up into the circulation cell. The deeper water will be slightly cooler and thus denser, requiring energy to raise it.

The circulating cell of the epilimnion would be warmer than the stagnant, lower water. There would also be more oxygen in the epilimnion because of algal photosynthesis in the top one or two meters, and less free nutrients due to algal incorporation during photosynthesis. The pH would also be higher due to photosynthesis and changes in the carbon dioxide concentrations.

In addition to the increase in oxygen from algae in the epilimnion, there would be a further decrease in oxygen in the hypolimnion due to decomposition of plankton which die and then settle into the darker cooler bottom waters. In the early years of the lake formation, it is very likely that this algal decomposition, in combination with the decomposing vegetation from the newly flooded reservoir shores, would deplete the oxygen in the hypolimnion and result in formation of hydrogen sulfide by anaerobic organisms using sulfur for energy. This anaerobic condition is most common in lakes which are highly productive with high concentrations of nutrients, poor circulation, and long detention times (Garzon 1984). Productivity in Baardheere Reservoir would probably be quite high in the first few decades, but may eventually be limited by carbon shortages since there are no large sources of organic contamination upstream.

Detention time for the reservoir in an average year would be fairly short—about nine months. However, in a drought year following a year of excess flow which filled the reservoir, detention time would increase to 20 months, and stagnant, anaerobic conditions would develop in the hypolimnion for several months prior to the January circulation. In flood years when flow reaches the volume of the 10-year flood, detention time for the reservoir would decrease to six months, and for a 100-year flood, it would decrease to three months. In these years, there would be no problems of stagnation.

4. Lake Circulation and Overturns

It is likely that large, vertical circulation and perhaps a complete overturn of the lake would occur in late December or January when the surface waters cool below the hypolimnion temperature, probably by 1-2 C. This would create an instability which would result in vertical circulation and uniform vertical conditions of temperature and chemical parameters such as salts, nutrients, and oxygen. However, this vertical uniformity would soon be eliminated as the dry jiilaal season progresses into February and surface waters are again heated to nearly 30 C.

The vertical circulation would bring higher concentrations of nutrients to the epilimnion, perhaps causing slight algal blooms in the following month. This is not likely to be a serious problem in terms of fish kills or human consumption, as the nutrient levels in the epilimnion would already be high and algal concentrations would be maintained at a moderate, steady-state level due to their self-limitation of sunlight penetration. Algal blooms are not as common in tropical lakes as in temperate lakes due to the uniform seasonal temperatures in the tropics, especially at low altitudes.

The net effect of the vertical circulation should be beneficial, reducing excessive anaerobic and saline conditions in the dead storage zone near the dam. Stratification would soon be re-established as the surface waters heat up again in February and March. However, this would usually be dissipated when the lake empties and the gu' flood enters in May or March, mixing with the residual waters.

5. Velocities in Reservoir

Velocities in the reservoir would have an important effect on the depth of the photic zone, algal density, and productivity, and subsequently, on the extent of anaerobic conditions and hydrogen sulfide formation in the hypolimnion and dead storage zone. Currents on the water surface would affect algae populations by shearing growing colonies, retarding development. In other respects, the reservoir behind Baardheere Dam would certainly be well-

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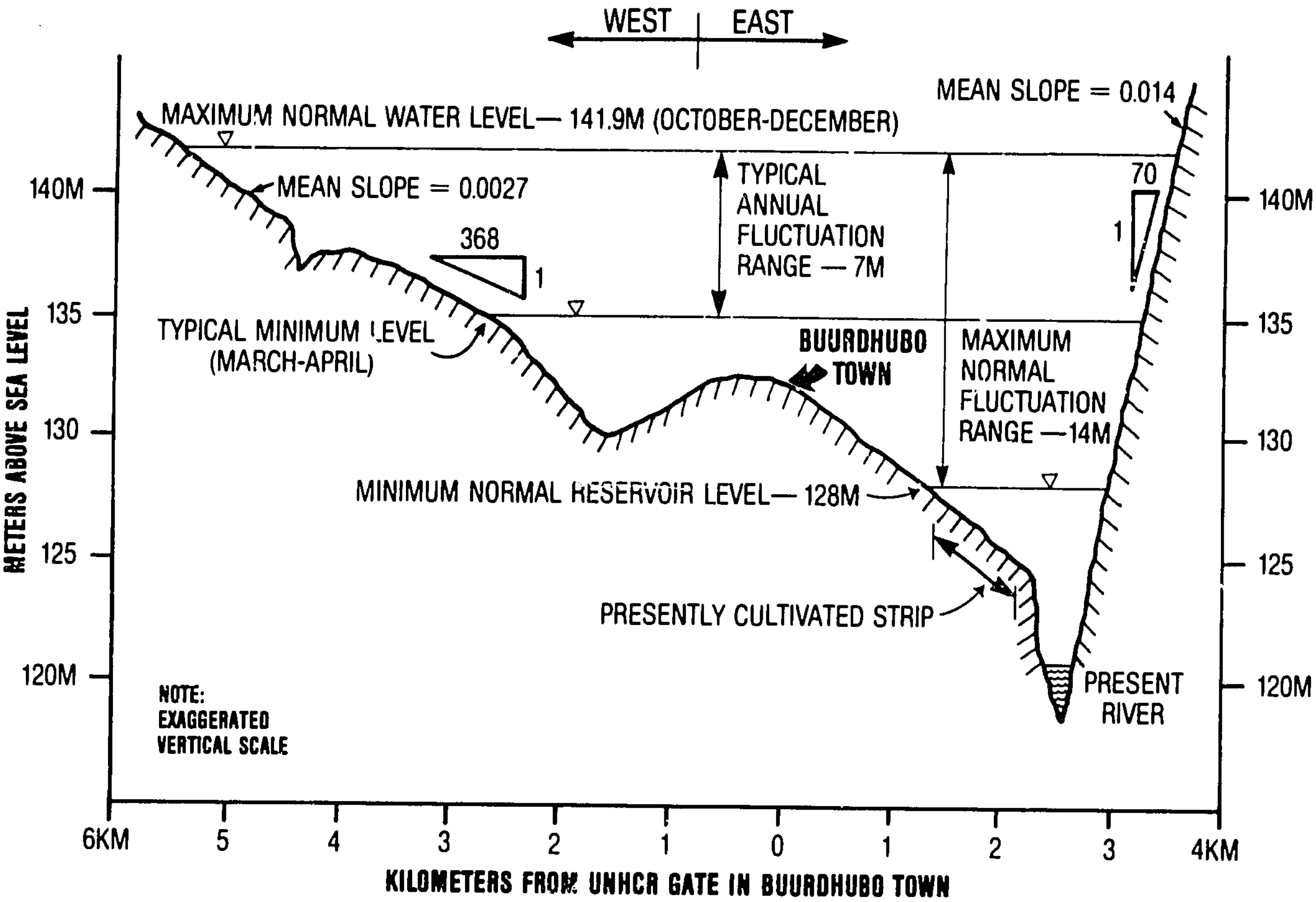

Figure IV.C.2
Cross Section Of Proposed Reservoir Along Road From Garbahaary To Ferry Crossing On Jubba River At Buurdhubo

An east-west section through Buurdhubo town on Jubba River indicated that most favorable aquatic habitats with flat slopes would be on the western shore of proposed reservoir.

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fertilized and the long reaches for mixing winds would insure that sufficient nutrients are always available to the epilimnion for algal growth. The possible range of velocities were estimated by evaluating extreme conditions of flow and stratification.

The flow of the Jubba River was 6×10^9 cu m for an average year. Thus, the mean detention time in the full reservoir of 5×10^9 cu m volume would be 0.8 years, dropping as low as 0.2 years with heavy floods, or rising as high as 1.6 years during droughts.

In the initial years after dam construction, if the river discharge in January or February is 50 cumecs and the lake volume is 3×10^9 cu m, then the travel time for a completely mixed flow would be 694 days. But if density currents keep this flow in 10 percent of the cross section, then travel time of the dense flow would shorten to 69 days, and surface flow would approach zero. Furthermore, if the mean discharge at the dam were 150 cumecs and the flow stratified, travel time for the dense flow would be reduced to 23 days. At 200 cumecs the travel time in this stratified situation would be 17 days, or 170 days in a fully mixed reservoir.

The distance from the dam site to Luuq is 170 km, so the average length of the reservoir would be about 150 km. Thus, mean velocity at low flows of 150 cumecs for 3×10^9 cu m volume would be 150 km/230 days or 0.0007 m/s, or roughly 0.1 cm/sec.

At flood flows of 2,000 cumecs and full reservoir of 5×10^9 cu m, transit time in the reservoir would be 29 days or a velocity of 0.6 cm/s. Such velocities are imperceptible even to sensitive field instruments. Thus, wind currents would dominate the movements of water in the epilimnion, and algae and plankton would flourish—especially in the widest portion of the lake and protected coves.

6. Nutrients

Nutrient levels in the reservoir would be the result of dissolved and suspended material entering at Luuq and recycled between the upper and lower strata of water. Wind mixing and an annual vertical circulation would insure that nutrient levels would be fairly uniform throughout the year, near the river mean concentrations of 0.50 mg/l of phosphates as P and 1.0 mg/l nitrates as N. These values are relatively high, insuring strong algae and macrophyte growth in the reservoir. On a long-term basis, nitrogen would probably be the limiting nutrient as the phosphorus values are far in excess of the necessary concentrations for good plant growth. River concentrations of phosphorus drop below 0.05 mg/l and possibly become limiting only during the jiilaal season. However, the recycling characteristics of the reservoir would probably supply sufficient nutrients in the reservoir during this period.

The flow passing through the dam would carry at least the mean nutrient values estimated for the reservoir—0.5 mg/l of phosphates and 1 mg/l of nitrates. It is possible that slightly higher concentrations would occur in the discharge due to nutrients added to the hypolimnion by sedimentation of algae from the productive epilimnion.

7. Predicted Secchi Disk Readings

The depth of the photic zone in the proposed reservoir would be a major determinant of biological productivity, and is measured in the field by lowering a black and white secchi disk until it is no longer visible to record the depth. This is then the depth of the photic zone and illuminated shore zone—an important parameter for estimating the amount of suitable habitat for vegetation, fish, mosquitos, and snails.

Clarity of the water can be reduced by high loads of suspended solids, as was the case most of the year in the swiftly flowing Jubba River. Impoundment of the river water would cause solids to settle and improve clarity. However, this would be offset by algal growth, a process which would proceed until a self-limiting condition is caused by the dense algae population. In the proposed reservoir, this self-limitation would occur because nutrient levels in the water are high and flow velocities would be much less than 1 cm/s—closer to 0.1 cm/s. This stagnant condition reduces hydraulic shear on the algae colonies, and with the high temperatures and nutrients, creates ideal conditions for rapid algal growth. The steady-state depth of the photic zone can be estimated from theoretical considerations and simulated from field studies.

A field experiment was arranged to simulate the conditions to be expected in the proposed reservoir regarding natural clarification of the surface waters. Conditions in Fanoole Main Canal on 12 April 1987 simulated the proposed reservoir fairly well because the canal was full but the low flow of only 2-3 cumecs caused low velocities of 1-5 cm/s in most of the canal. Secchi disk depths reached 1 m in the flowing reaches, but algal growth reduced light penetration to 0.5 m in the terminal section of the canal where the flow was stagnant.

A subsequent experiment on 17 April 1987 with water taken from the river at Baardheere, and placed in a 200 liter drum in a darkened room to avoid photosynthesis effects, showed that the secchi disk reading exceeded 0.75 m within 13 days.

Analysis of these two experiments together indicated that reservoir waters would clarify from the river conditions of 1-10 cm photic zone to a steady-state depth around 50 cm, within 10-15 days travel time into the reservoir. Total travel time or residence time in the reservoir would normally be over a month; therefore, the wide central portion of the lake would usually have a photic zone of 0.5 m.

Although the epilimnion would have only slightly better clarity than the river flow, the hypolimnion, which would be the source of most of the water passing through the dam, would not contain as much algae and should be more clear, with secchi disk readings estimated near 1 m.

8. Model Prediction of Salt Concentrations

Considerable data was available from previous years on EC25 at the Mareerey sampling station of Jubba Sugar Project, as well as long-term records of river discharge at Luuq. This combination of historical data made it possible to estimate, with some reliability, the range of salt concentrations to be expected in the proposed reservoir.

Preliminary analysis of the EC25 data indicated a relative stability in the mean annual EC25, even when the river flow and total salts went through extreme fluctuations (BNA Memo #2 of 6 March 1987). This analysis indicated that salt concentrations in the reservoir, computed for an average year, would also be fairly reliable for drought or flood years. The mean EC25 for the years 1978-1982 was about 470 micromhos/cm (Table IV.C.1). Although the total load of salts would be much higher in a flood year, concentrations would remain roughly the same as in an average year, due to the increased runoff and dilution of the eroded salts. Thus, a simple analysis for an average year was sufficient to predict salt concentrations in the reservoir, and discharges from the turbines and low dam outlets.

Analysis of salt concentrations to be expected in the reservoir was conducted with a simple computer model (BNA Memos #1, #2, and #5). Simulated flows out of the reservoir were derived from analyses by AHT in development of the Master Plan for the Jubba River. (Details are contained in BNA Memo #5 of June 1988.) The model of the mixing process in the proposed reservoir at Baardheere incorporated the assumption that all of the mixing took place in the central portion of the reservoir. This wide portion of sections B, C, and D includes most of the total reservoir volume (Figure IV.C.3). Mixing in the narrow section below Luuq and the gorge just above the dam was neglected due to the narrow channel shape.

Table IV.C.1. CONDUCTIVITY AT MAREEREY.

Computed mean values of electrical conductivity at 25°C (EC25) for Jubba River at Mareerey, 1978-82

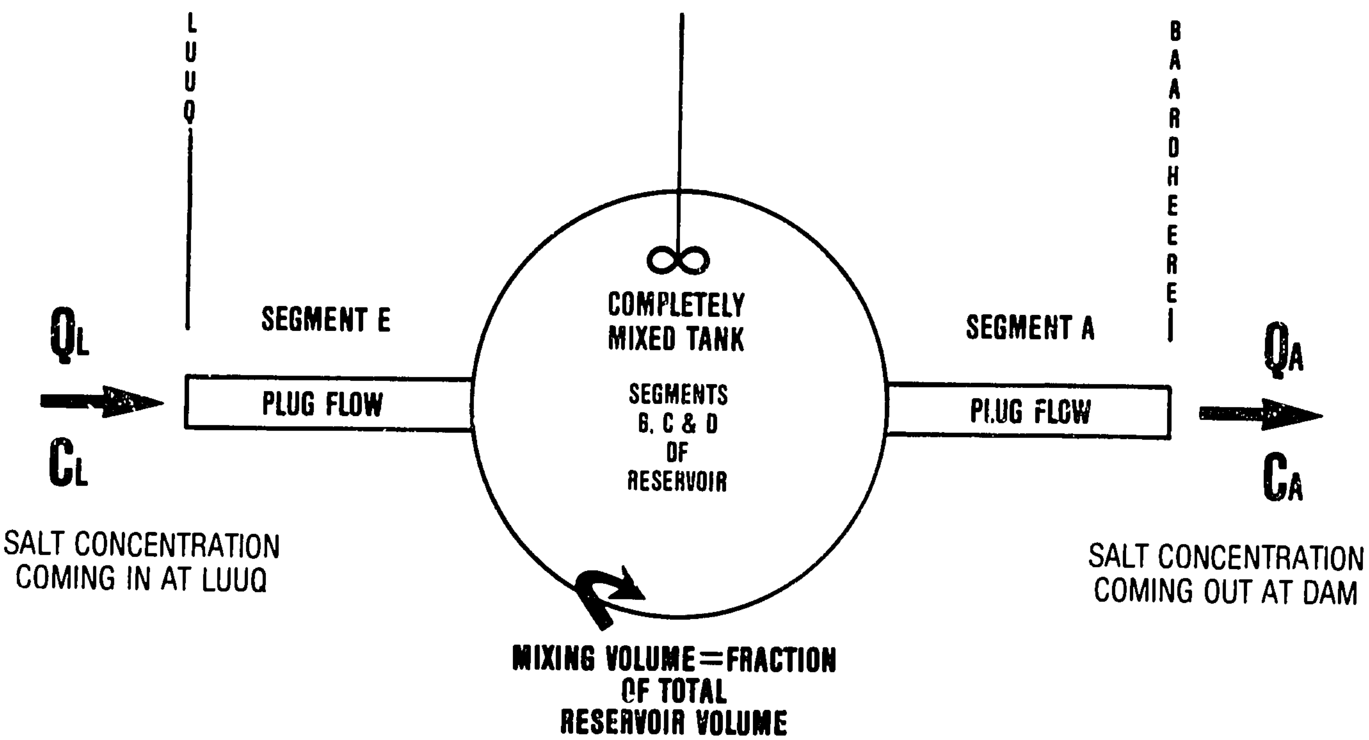
Year	Mean Flow at Luuq in cumecs	Mean EC25 in micro-mhos/cm	Equivalent lLoading*
1978	243	330	80,425
1979	170	327	55,980
1980	76	387	29,438
1981	259	528	137,092
1982	200	367	73,760

* *EC25 x Flow in cumecs x micromhos/cm (determined from monthly data).*

Under this simple model, in which it was assumed that the reservoir was well-mixed at all times of the year, the analysis indicated that neither chlorides nor EC25 coming from the dam outlets would be even close to the critical values for agriculture. The reservoir exerted an averaging effect on the sharp rise and fall in salt concentrations normally experienced at Luuq. This would be a clear benefit for agriculture.

Although the EC25 coming into the reservoir at Luuq exceeded 1,000 micromhos/cm in April, the EC25 in the dam outlets would not exceed 500-550 micromhos/cm. The predictions were that the EC25 would vary from a low of 350 micromhos/cm to a high of 524 micromhos/cm (Table IV.C.2). Restrictions on agricultural use would not be needed unless the EC25 exceeded 750 micromhos/cm. Residence time in the reservoir was approximately one year under the assumptions used in this analysis. Changes in residence time would not affect the final EC25 in the outlets, only the month in which it would be observed.

Due to high concentrations of suspended sediments during the gu' flood, it is likely that a density current would develop in late April or May, reaching the dam during May in an average year. This would cause slightly saline and deoxygenated water to be



LEGEND
Q = RIVER DISCHARGE IN CUMECS
C = CONCENTRATION OF SALT IN MICROMHOS/CM

Figure IV.C.3
Diagram Of Reservoir Mixing Model

discharged for about one month. The analyses also indicated that chlorides would not exceed the safe limit for agricultural uses of 140 mg/l.

Table IV.C.2. PREDICTED CONDUCTIVITY LEAVING RESERVOIR.

Predicted monthly electrical conductivity values (EC25 in micromhos/cm) for average year in proposed Baardheere Reservoir, assuming complete mixing and simulated flows for expected reservoir operation under typical year conditions including 35 cumecs evaporation (from AHT preliminary results)

MONTH	Flow past dam in cumecs	EC25 in micromhos/cm
January	133	350
February	149	363
March	141	380
April	149	403
May	145	481*
June	151	524**
July	145	515
August	147	491
September	154	447
October	264	406
November	257	362
December	136	354

* *Occasional salt surges due to density currents*
** *Normal maximum*

There were indications that local salt deposits might be flooded by the rising reservoir and contribute salinity, nutrients, or other soluble materials to the reservoir, if conditions were conducive to dissolution and mixing of the chemicals. Without extensive mapping and testing of the entire surface of the reservoir area, the importance of these deposits could not be assessed. Continuous monitoring of water quality at the entrance to the reservoir at Luuq and at the dam (especially during the first decade of operation), in combination with computer simulation of water quality in the reservoir, should be carried out by the dam operations group. This precaution could determine if unusual quantities of soluble materials were affecting the water quality and endangering agricultural or other uses of the river.

D. Predicted Habitats of Disease Vectors Around Proposed Reservoir

Expected amounts and locations of predicted habitats for disease vectors are presented in this section for the condition of uncontrolled development in which no special operational modifications are used to prevent disease around the reservoir, and for conditions under guided development. In Section E, predictions for expected disease transmission for uncontrolled development are given, followed by Section F, which estimates the impact of some of the possible remedial measures for reservoir operation and shoreline modification. In Section G, predictions are given for the expected disease transmission for guided development. Based on these predictions, alternative remedial actions are examined in detail in Chapter VI for both uncontrolled and guided development around the proposed reservoir, and their cost-effectiveness is compared. Conditions in the lower and middle valley are evaluated in Chapter V.

The creation of a large body of fresh water in a semi-arid region—the expected result of construction of Baardheere Dam—will attract all kinds of animals, including human populations drawn by the value of the water for domestic and agricultural uses. Unfortunately the water is also conducive to populations of aquatic insects, snails, flies, and other small organisms which spread diseases among man and his domestic animals. Experience with major reservoirs and irrigation schemes throughout Africa and other tropical regions has shown that this is an almost inevitable result of water resource development in the tropics. The major diseases include malaria and bilharzia, but many other diseases of man and his domestic herds are also to be expected.

Many of the important diseases expected to occur around the reservoir are environmental or ecological diseases. Their transmission patterns depend on complex interaction of insects, animals, vegetation, aquatic organisms, and people with the water of the reservoir. In this analysis, we examined all of these items, including the human factors. However, the analysis was limited to those ecological aspects which related directly to disease transmission.

1. Shoreline Aquatic Habitats

The initial step in evaluating health risks around the proposed reservoir was estimation of the extent of aquatic habitats to be expected within and around the lake. It was then possible to predict the insect and snail populations and potential for disease transmission for given conditions of the reservoir and human settlements. This process required a topographical map of the reservoir and information on seasonal wind patterns and weather, seasonal water temperature, clarity and quality, existing soil types, and expected water-level fluctuation patterns.

Assumed Vegetation

Expectations for the type of vegetation to appear around the proposed reservoir were based on experience and common patterns in other tropical reservoirs. In the drawdown zone, distribution of vegetation—submerged and floating—is strongly influenced by the annual fluctuation cycle. Drawdown vegetation has been thoroughly studied in Lake Kariba and Lake Kainji, as described by Bernacsek (1984). During low water, virtually all African reservoirs, including those in the desert, are surrounded by a green belt of vegetation delineating the drawdown zone. The more terrestrial species such as grasses and sedges die when the lake rises, resulting in a large release of nutrients. Dung from livestock and other animals releases even more nutrients. Subsequently, the biomass of invertebrates increases greatly around the shore, and shallow waters are invaded by fish, either to feed or breed. If the reservoir level remained stable all year, the large, periodic release of nutrients would not occur.

Submerged, rooted plants depend on a limited fluctuation of the water level for survival. Fluctuations greater than 3-4 m adversely affect them because they are submerged in relative darkness after the reservoir rises to maximum level. Because the normal fluctuation or drawdown range for Baardheere Lake would be only 2.5 to 4.0 m, there would be a heavy growth of submerged weeds, partly limited in the upstream reaches because of the high turbidity and poor sunlight penetration. This vegetation in the drawdown zone would increase snail and mosquito habitats along the shoreline by damping the waves which would otherwise erode the shorelines. One common weed in the Jubba Valley, *Ceratophyllum* sp., is extremely attractive to the bilharzia snails. It was found in dhesheegs, and would certainly invade the proposed reservoir.

Floating vegetation can also lead to health problems by providing shelter and food for snails and mosquitos. Large strands of the floating fern, *Salvinia* sp., water hyacinth, *Eichornia crassipes*, or water lettuce, *Pistia* sp., often develop in the early years of reservoir life when nutrient concentrations are high. Large drawdowns during the early years can be used to control these initial floating infestations, and can also be used occasionally later on when excess growth causes operating or navigational problems.

Because of high nutrient concentrations in the Jubba River, the moderate fluctuation range of the proposed reservoir, and the high probability of large numbers of grazing animals around the shoreline, it is highly likely that Baardheere Reservoir would yield large quantities of aquatic and drawdown vegetation.

In the flatter portion of the shoreline where wild and domestic animals would come to graze, there would be a higher-than-average level of nutrients due to the animal droppings, resulting in more vegetation. With time, soil in the flatter portions of the drawdown zone would develop in thickness and organic content, and become suitable for drawdown agriculture. However, in the first decade, conditions would probably be adequate only for light grazing of herds.

Assumed Fish Populations

The reservoir would probably be an excellent fish habitat, especially in the first 10 or 20 years, for three reasons. First, dissolved nutrient concentrations should be high in the reservoir because of the river's normally high concentration of nutrients and various salt deposits expected in the flooded zone. This would be the basis for a fairly productive epilimnion which would provide the basic food chain needed for fish populations. Second, the water level fluctuations should be small in the initial years due to low requirements for electrical generation and irrigation. Third, initially, the numbers of fishermen or other predators on the fish populations should be small.

Locations in the reservoir supporting the largest fish populations would undoubtedly be the shore zone of the widest portion of the lake, near Buurdhuubo, especially in areas where flooded trees and brush provide the fish with vegetation and cover. Gradually, these favorable conditions may decrease in importance and fish populations may eventually stabilize at a level much lower than that seen in the first decade.

In years when the reservoir experiences a very small drawdown and subsequent heavy vegetation growth, there would be increases in fish reproduction followed by noticeable fish population increases during the following two or three years. However, if drawdowns are large (greater than 4-5 meters) the vegetation and fish would show a noticeable decline.

Without predicting the species of fish to be expected in the reservoir, it is certain that surface feeding

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species would be present in large numbers along the shoreline. When there is little vegetation or other shelter they would feed heavily on mosquito larvae along the shore. However, these fish are not usually significant predators of bilharzia snails.

Predicted Mosquito Populations

Using the topographical map provided in the Electroconsult report of June 1985, the reservoir was divided into five geographically homogeneous sectors in order to simplify the analysis of potential mosquito and snail habitats (Figure II.1). The sectors were defined on the basis of similar shore slopes.

Mean shore slopes were determined for each sector, treating the west bank and east bank separately. The horizontal distance from the centerline of the river to the shoreline at the maximum normal operational level (142 masl) was measured perpendicular to the river at the junction of each small tributary, to estimate the horizontal component of shore slope. In Sector B, which has a relatively large tributary entering from the West, these measurements were made perpendicular to that tributary (Figure IV.D.1).

The horizontal width of each side of the reservoir was then divided by the vertical rise between the existing river bed and the high water level, to obtain the shore slope ratio for each sector. The slopes varied from 10:1 in Sector A to 225:1 in a small area on the west bank of Sector B where a large tributary came in (Table IV.D.1). However, the largest and most important flat area was the west bank of Sector C which had a mean slope of 148:1.

TABLE IV.D.1. CALCULATION OF SHORE SLOPES FOR FIVE SEGMENTS OF PROPOSED RESERVOIR BEHIND BAARDHEERE DAM.

All measurements were taken from ELC map BRD 2004 of June 1985 and are in meters

SECTOR	A		B		C		D		E	
BANK	W	E	W	E	W	E	W	E	W	E
Shore Width	427	330	500	1767	1650	2938	875	1314	186	357
river elevation	110		121		122		128		135	
vertical rise	31.9		20.9		19.9		12.9		6.9	

mean slope ratio = horizontal run : vertical rise of 1

slope ratio	13	10	24	225	83	148	68	102	27	*52

W = West E= East

* *unstable, rapidly fluctuating area at upstream margin of reservoir*

In combination with the slope of the shore, the prevailing wind patterns that cause waves and shore erosion would determine which portions of the shoreline are suitable for snail and mosquito habitats. There are two important seasonal wind directions for the Baardheere area: a south- southwest wind averaging 2.5-4.0 m/s from May to October, and an east wind at 2.0-2.9 m/s during December to March (Entz 1982). For shorter periods, transitional winds blow from the south at about 1.4 m/s during April and from the south-southeast at 2.3 m/s during November.

Delineation of the portions of shoreline which are in the wind shadow, and therefore protected from waves and erosion, showed that large areas of the flat shores in Sector C would be protected throughout the entire year (Figure IV.D.2). Because of its extremely flat slope (148:1) and large length (about 3.4 km), the area on the southwest perimeter of the Sector C shoreline may be the most important, although many other small areas may also harbor snails on both sides of the reservoir.

Smaller, protected and flat areas were also found by similar analysis of Sectors B and D (Figures IV.D.1 and 3). However, Sectors A and E had such steep shores (10:1) that the areas suitable for human settlement and animal grazing were almost nonexistent (Figure IV.1). Also, the width of the submerged shore illuminated by sunlight would only be a few meters in these two sectors—not sufficient for maintaining snail or mosquito populations.

Both malaria mosquitos and bilharzia snails depend on sunlight which produces aquatic vegetation for their food, protection, and breeding. This vegetation exists to the depth of sunlight penetration through the water, and is usually only found in quiet, shallow portions of reservoirs. Mosquito breeding is proportional to the length of the intersection line between this vegetation, the water, and the air. The meniscus formed at this intersection line is a place of attachment for the mosquito larvae where they are protected from predators and currents (Figure IV.D.4). For bilharzia snails, the vegetation is important primarily as food, and the rate of reproduction is usually proportional to the mass of vegetation per unit volume, within the strip of submerged shore illuminated by sunlight and known as the Illuminated Shore Zone (Figure IV.D.4).

Estimation of the precise length of intersection line would be necessary for prediction of the population

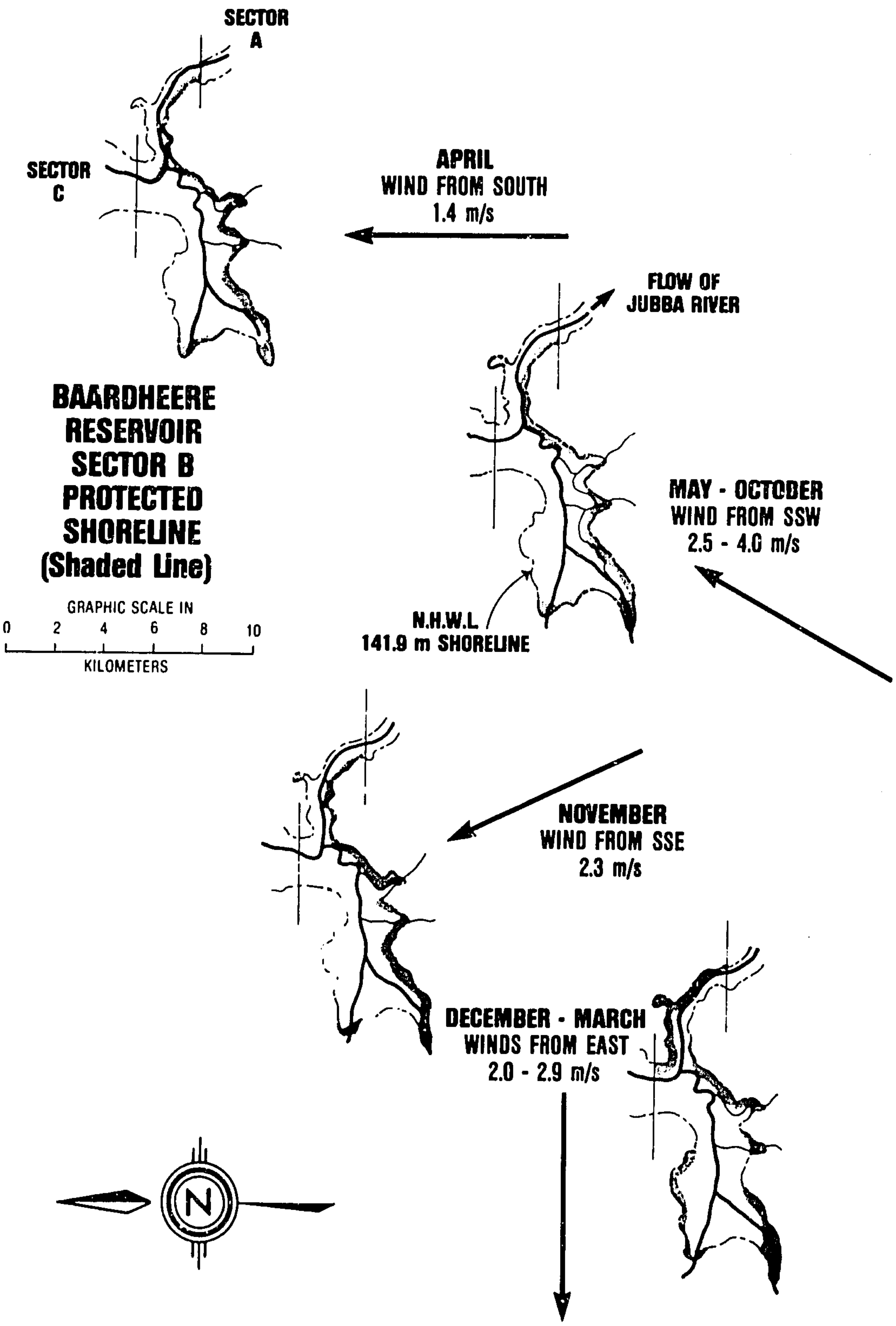

Figure IV.D.1
Four Views Of Sector B Of Proposed Baardheere Reservoir, Showing Seasonal Wind Patterns
(Shaded Lines Represent Shores Protected From Wind And Waves)

Although sites protected from the wind are found on both shores of Sector B, the present settlements and roads indicate potential human preference for the western shore. Guided development of new settlements should avoid these potential disease transmission sites, principally by providing community water supplies in safer areas.

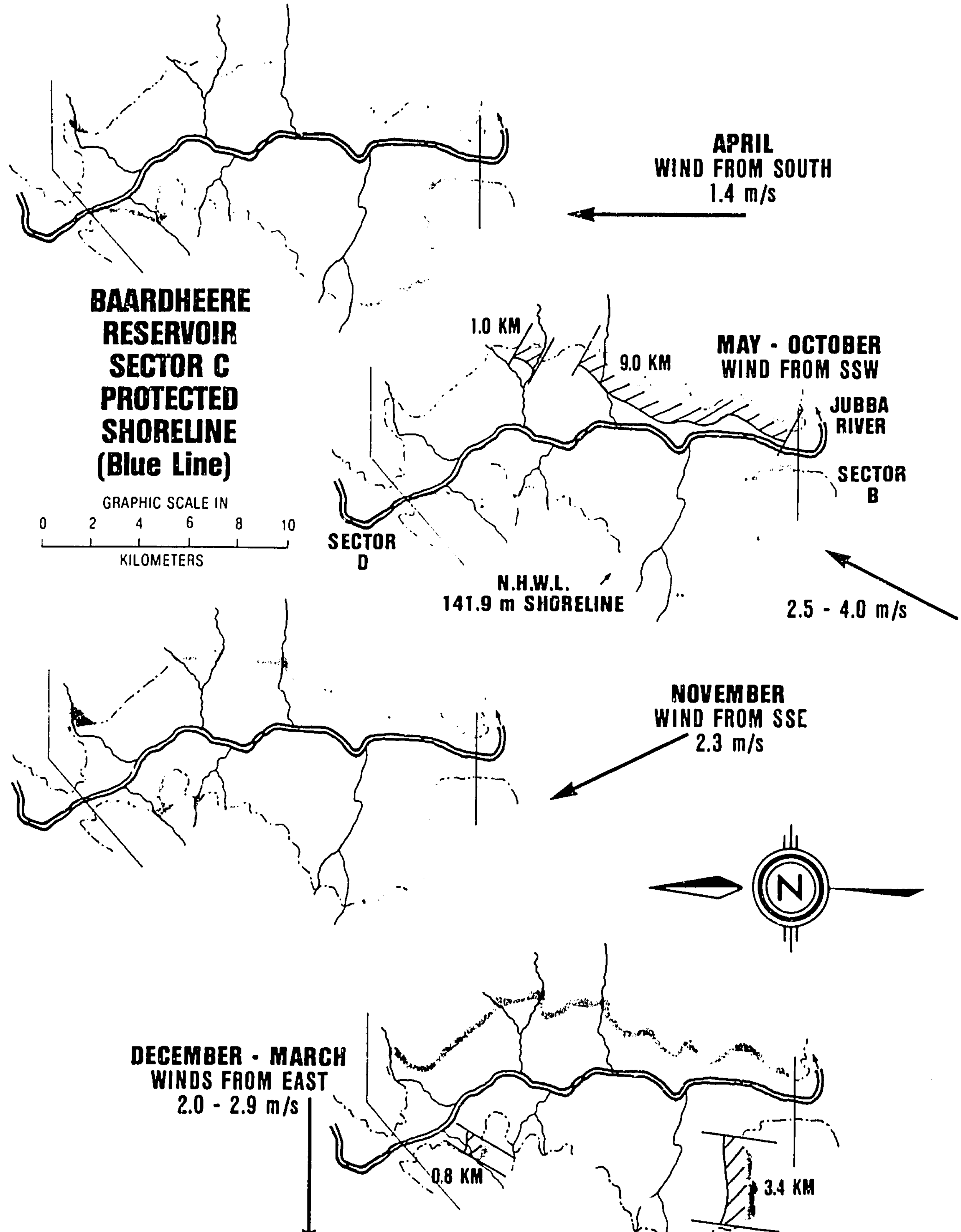

Figure IV.D.2
Four Views Of Sector C Of Proposed Baardheere Reservoir, Showing Seasonal Wind Patterns
(Wide Blue Lines Represent Shores Protected From Wind And Waves)

Although sites protected from the wind are found on both shores of Sector C, the present settlements and roads indicate potential human preference for the western shore. Guided development of new settlements should avoid these potential disease transmission sites, principally by providing community water supplies in safer areas.

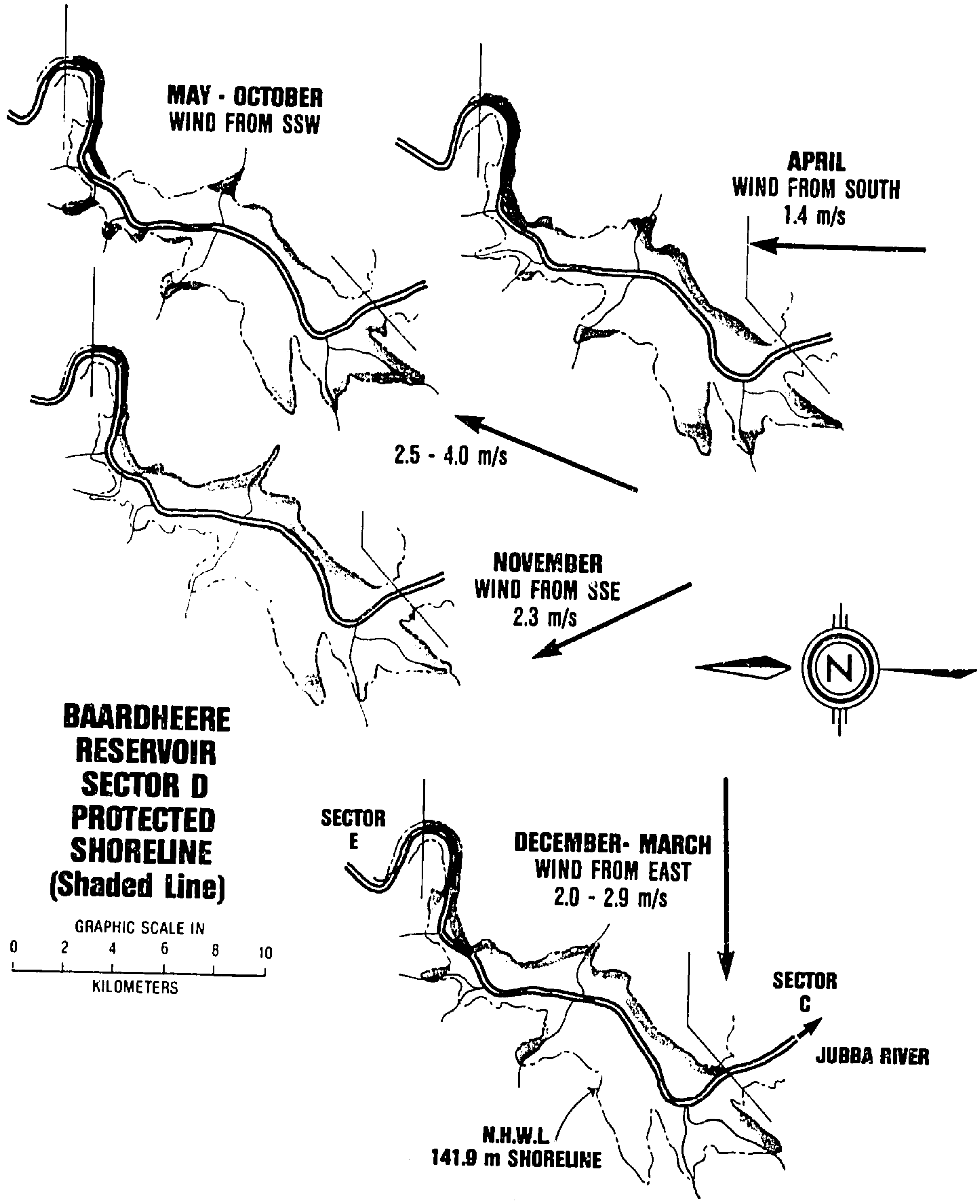

Figure IV.D.3
Four Views Of Sector D Of Proposed Baardheere Reservoir, Showing Seasonal Wind Patterns
(Dark Lines Represent Shores Protected From Wind And Waves)

Although sites protected from the wind are found on both shores of Sector D, the present settlements and roads indicate potential human preference for the western shore. Guided development of new settlements should avoid these potential disease transmission sites, principally by providing community water supplies in safer areas.

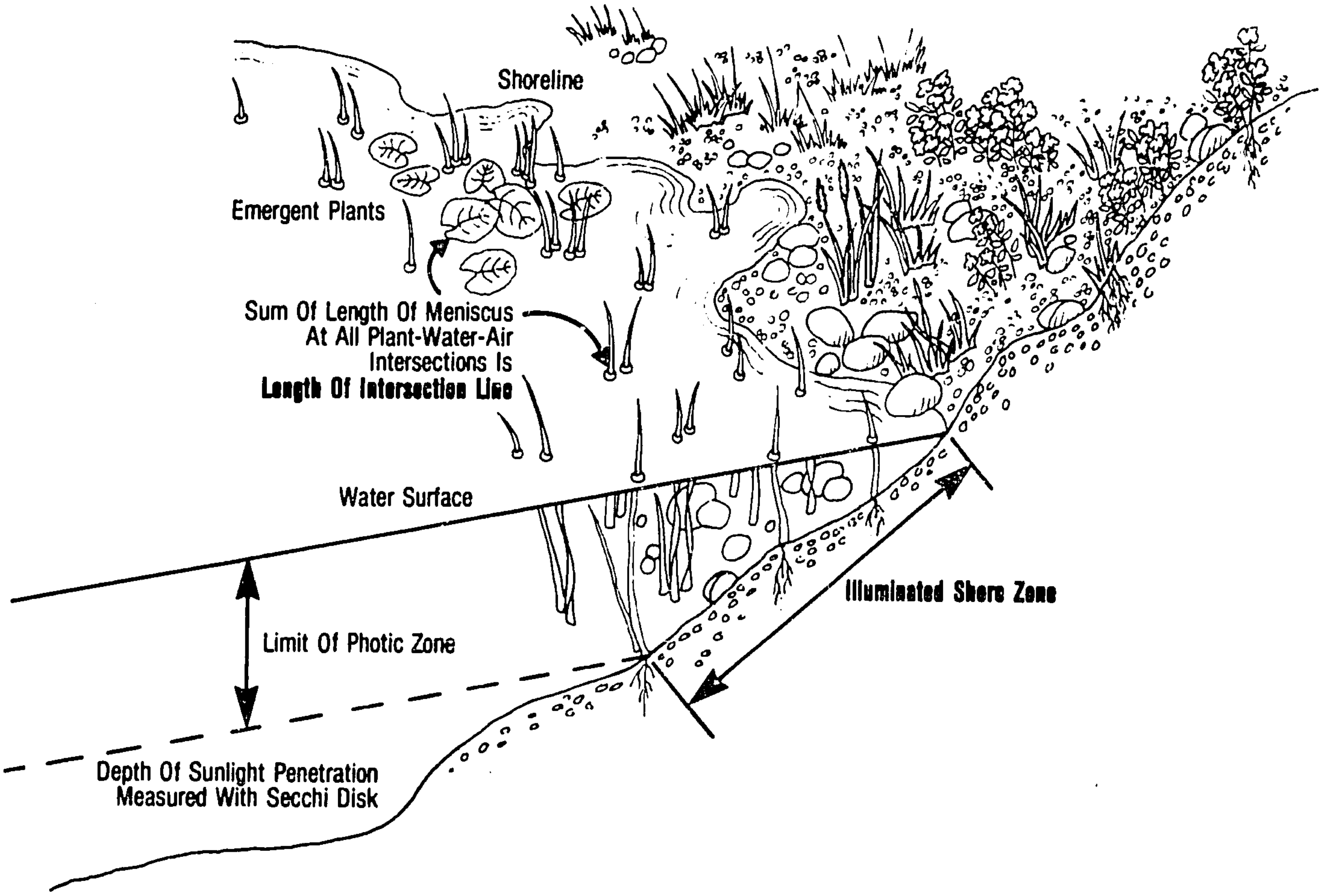

Figure IV.D.4
Definition Sketch For Illuminated Shore Zone
And Length Of Intersection Line Along Shore Of Typical Reservoir, An Ideal Habitat For Malaria Mosquitoes And Bilharzia Snails

dynamics of the expected mosquito populations in the proposed reservoir. There was insufficient information on aquatic vegetation and malaria mosquitos from Somalia to do this with any numerical precision, so a simpler approach was used. It was assumed that at least one of the anopheline mosquito species in Somalia was capable of breeding in the protected shore areas of the reservoir—probably *Anopheles funestus*, which normally inhabits lakes and other large waterbodies (WHO Offset Publication No. 66 1982). The second step was to evaluate the potential water-level changes in the reservoir to determine what times of year and how many months each year conditions would be generally favorable for vegetation and survival of mosquito larvae (Table IV.D.2).

By analyzing the simulation prepared for hydrologic optimization of reservoir design (ELC 1985), it was found that the reservoir would be very favorable for mosquito production in wet years, but only slightly so in average or dry years. In the wettest year simulated for 32 years of record, the reservoir level would remain stable at NHWL for seven months, causing heavy vegetation growth and allowing a long period of mosquito production (Figure IV.D.5).

It was estimated that the drawdown rate in the proposed reservoir would be slightly less than that required to get efficient stranding of the floating mosquito larvae. A successful program for controlling malaria mosquitos in the Tennessee Valley Authority (TVA) reservoirs in the USA utilized a

Table IV.D2. ASSUMED DRAWDOWN PATTERNS FOR PROPOSED BAARDHEERE RESERVOIR, using simulation for 32 years of record by ELC, 1985.

YEAR	Maximum Level	Start Drawdown	Lowest Level	Dry Time	Time in months	Fall in meters	meters per month	cm per day
1951	5	1	4	-	3	4.5	1.5	4.9
1952	9	11	5	8	6	9.0	1.5	4.9
1953	10	11	3	11	4	5.0	1.2	4.1
1954	8	11	7	9	8	10.0	1.2	4.1
1955	12	12	4	13	4	4.0	1.0	3.3
1956	11	12	4	11	4	5.0	1.2	4.1
1957	6	12	6	6	6	6.0	1.0	3.3
1958	9	12	5	9	5	4.0	0.8	2.6
1959	10	11	5	10	6	6.0	1.0	3.3
1960	12	12	4	13	4	4.0	1.0	3.3
1961	8	12	7	9	7	5.0	0.7	2.3
1962	11	11	3	11	4	5.0	1.2	4.1
1963	5	12	7	6	7	5.0	0.7	2.3
1964	10	12	7	10	7	11.0	1.6	5.2
1965	11	12	4	11	4	4.0	1.0	3.3
1966	9	11	4	9	5	5.0	1.0	3.3
1967	8	12	5	9	5	4.0	0.8	2.6
1968	6	11	5	6	6	4.0	0.7	2.2
1969	8	11	3	9	4	5.0	1.2	5.6
1970	7	10	12	8	2	2.0	1.0	3.3
1971	10	12	4	12	4	3.0	0.8	2.5
1972	6	12	4	6	4	4.0	1.0	3.3
1973	8	11	5	8	6	6.0	1.0	3.3
1974	9	11	4	10	5	8.0	1.6	5.2
1975	9	11	4	10	5	8.0	1.6	5.2
1976	8	11	3	9	4	4.0	1.0	3.3
1977	5	12	2	6	2	1.0	0.5	1.6
1978	5	12	3	5	3	2.0	0.7	2.2
1979	5	11	4	7	5	9.0	1.8	5.9
1980	6	6	2	*	8	2.0	0.2	0.8
1981	5	11	4	18	5	5.0	1.0	3.3
1982	9	10	3	10	5	4.0	0.8	2.6
MEANS	8.1	11.3	4.6	9.2	4.9	5.1	1.0	3.3

* *level did not rise in 1980, remained at 130 m*

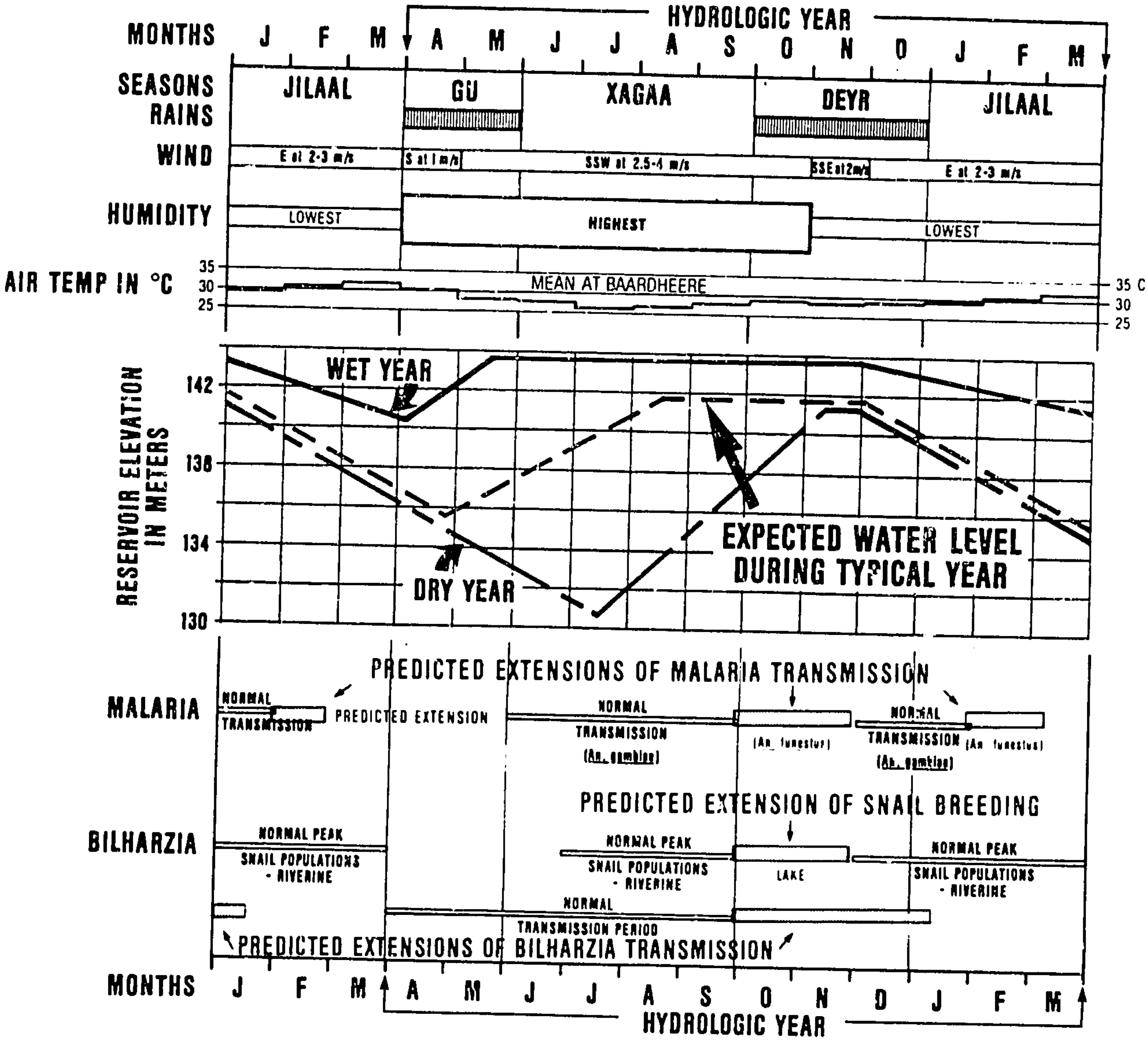

Figure IV.D.5
Seasonal Disease Transmission In Proposed Baardheere Reservoir

Predictions of bilharzia snail and mosquito populations in proposed reservoir for complete range of reservoir fluctuations indicated that the transmission season for malaria in the Gedo Region would extend to cover most of the year.

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7-10 day cyclical pattern of water level fluctuation with a drawdown rate of 6-10 cm/day in the recession phase of the cycle (TVA, 1947). This cyclical pattern caused the stranding of mosquito larvae before their week of development was completed. The average recession rate in the proposed Baardheere Reservoir would probably not strand all of the larvae as it would be much slower, an average of 3.3 cm/day with a range of 0.8 to 5.9 cm/day, based on an analysis of the ELC simulation (Table IV.D.2). It appears that for many years, malaria mosquitos could even breed along the shoreline during the recession phase of the reservoir, although at a rate much lower than when the reservoir was kept at NHWL.

The survival rate of mosquito larvae would be low during the relatively slow recession rate of the proposed Baardheere Reservoir because this rate would probably be adequate to reduce the length of intersection line caused by weeds and debris along the shore. The required rate in the TVA reservoirs for general recession of the water level during the weed-growing season was only about 0.4 cm/day, compared to the expected 0.8-5.9 cm/day recession in the proposed reservoir. The reduced shoreline vegetation during the recession phase of the reservoir would reduce mosquito reproduction somewhat, but not eliminate it.

Predation on mosquito larvae by surface-feeding fish would be severely impeded during these wet years when the reservoir remained full for several months. The weeds would give the larvae considerable cover. Thus, the overall expectation would be for large populations of the malaria vector, *A. funestus*, to occur around the reservoir.

If uneven local topography created isolated pools along the perimeter of the receding shoreline, these pools would be favorable habitats for the normal malaria vector, *A. arabiensis*. These pool-breeding sites could cause heavy local infestations of malaria mosquitos, even if there were few or no mosquitos breeding in the main body of the reservoir. The importance of these secondary breeding sites would depend on local topography as well as soil and vegetation conditions. In general, the soil is thought to be sandy, which would facilitate rapid drying of the pools by downward seepage.

Combining these various predictions, it was assumed that malaria mosquitos would breed in and around the proposed reservoir. While populations of *A. arabiensis*, the present malaria vector, would probably remain about the same, it was predicted that a second vector, *A. funestus*, would colonize the reservoir and develop large populations during the months when the reservoir is full, and also for the several months it recedes (Figure IV.D.5). This new species was not important in malaria transmission in the area, but would become the major vector after completion of the dam.

Predicted Bilharzia Snail Populations

Bilharzia snails would invade the new reservoir within a few years of completion and would find favorable conditions at certain times. Almost every lake or reservoir in tropical Africa contains these snails. The most likely bilharzia snail to inhabit the proposed reservoir would be a species of *Bulinus*, the genus which transmits urinary bilharzia, due to their ability to survive the long, dry periods when they would be stranded in the soil at the high water level of the reservoir. The local species, *Bulinus abyssinicus*, is highly tolerant to drying and very likely to be the important vector.

There would be many stretches of shoreline on the proposed reservoir which would be favorable for the snails. Although the reservoir site does not contain forests which could give extra protection to snail habitats, there would be many flat, shoreline habitats in the protected lee of the dominant winds, especially in the central portion of the reservoir on the western side (Figures IV.1 and IV.D.1-3). These would be the same sites which harbor malaria mosquitos. Exposed shores would develop eroding, sandy beaches unfavorable to the snails, but those sections of shore protected from the wind would develop dense vegetation stands and favorable conditions for the snails.

The number of bilharzia snails in various habitats in the reservoir would depend on local geography, and seasonal variations in water temperature, and clarity in the reservoir, as well as the amount of vegetation and seasonal impact of the rising and falling lake level. With available information on the proposed dam, it was possible to make some estimates of these conditions and the expected number of bilharzia snails for various localities and expected conditions in the reservoir.

The most important parameter related to stranding is the period of time between the stranding and the revival of the snails when the water returns. The length of this period depends entirely on flow in and out of the reservoir and elevation of the snail habitat on the reservoir shore, which would be determined by the initial high water level. The time for the water level to return to its previous elevation was determined from the reservoir operation simulations reported by ELC in 1985. The 32 years simulated indicated that there would be a mean stranding time of 9.2 months with a maximum of 18 months and minimum of five months (Table IV.D.2). The 18 months stranding occurred during two extremely dry years when the reservoir dropped to 130 masl and stayed there through the gu' and deyr floods (1980 simulation) not rising to the normal high water level (NHWL) around 140 masl until the following year. This only happened once for the 32 simulated years.

Preconstruction simulations of the expected water level in the reservoir indicated that after filling, the reservoir would often remain at a stable, high level for one to eight months (Figure IV.D.5). This would be an extremely favorable condition for bilharzia snails, allowing them to reproduce for several generations without being decimated through stranding by a receding shoreline. This condition would most likely occur during the first decade of dam operation before the power demand is fully developed.

The annual drawdown during dry years would reduce the snails to low numbers, but soon after the lake filled again the survivors would rapidly repopulate the shore zone. The net result of these two opposing effects would determine whether snail populations introduced into a habitat would eventually prosper or gradually disappear. By calculating these opposing forces of reproduction and death by desiccation, a computer model was used to predict whether *Bulinus abyssinicus* would populate the protected, flat shores of the reservoir. The model was described in *BNA Memo #3* (Jobin and Michelson 1969).

The volume of habitat in the illuminated shore zone was calculated from the shore slope and the depth of sunlight penetration, measured with a secchi disk. For a secchi disk reading of 0.5 m and a shore slope of 148:1, the southwest portion of Sector C would have a stable Illuminated Shore Zone 74 m wide. It was also 3.4 km long, thus covering about 250,000 sq m or 63,000 cu m of habitat suitable for aquatic vegetation, snails, and mosquitos. This habitat would pose a significant health threat to any human or animal populations attracted by the flat, weeded shoreline for water or food. This site would be near the preconstruction location of the village of Buurdhuubo and a large number of temporary refugee camps.

The most favorable time of year for reproduction of aquatic snail populations along the shore of the reservoir would usually be the first few months after filling when the lake would be stable, emergent vegetation would reach its peak, and the water would be clarifying due to natural sedimentation of turbidity. Snail populations would enjoy maximum food supply, cover from predators, and habitat stability during these months from September through December.

Reproduction in snail populations would be interrupted twice annually by the highly turbid waters of the gu' and the deyr floods. When turbidity blocks sunlight and algal growth, survival of juvenile snails that depend on algae for food is sharply curtailed. In addition, high death rates due to stranding and desiccation would occur from January through August because of the reservoir drawdown. A peak snail population would be expected around the beginning of the drawdown phase in December or January.

Because of the long, unfavorable period for snail survival and reproduction, there would be many areas in the reservoir unsuitable for stable bilharzia snail populations. The upstream portion of the reservoir near Luuq would be particularly unsuitable due to high turbidity during the floods and extreme fluctuations. In the deepest portion of the reservoir, near the dam, steep shore slopes would minimize potential snail habitats and human contact with the water.

Wider portions in the middle of the reservoir would probably be the most suitable areas for snail habitats due to the large extent of illuminated shore zone on the flat slopes of the western shore. Those slopes on this western portion, which are protected from wind during the high water periods from September to March, would be the most favorable sites, giving the snail populations time to increase to numbers sufficient to overcome the normal eight or nine months of stranding. Because of the highly adverse conditions created by the two flood seasons and the drawdown phase, the snail populations may flourish only in a series of wet years when the reservoir level remains fairly constant. In dry years with large fluctuations, the snail populations may subsist at only minimal numbers—even in the best habitats in the reservoir.

The illuminated shore zone inhabited by the snails at high water would extend into the reservoir to the depth of the secchi disk—the depth at which sunlight and thus microscopic vegetation is no longer found. If the water recedes fast enough (faster than 2-6 cm/day) and far enough during drawdown, the initial snail population within this illuminated shore zone would gradually be stranded until even the deepest snails are left on dry land. However, this process may take about a month, depending on the secchi disk depth and the drawdown rate. The population would continue reproducing for a while after the recession begins, until all snails are finally stranded.

With a secchi disk reading of 50 cm and shore slope of 148:1, the conditions to be found on the west slope of Sector C, the deepest snails would be 74 meters from the water's edge, at the normal high water level. Stranding would require a recession rate of at least 2 cm/day, and this rate occurred or was exceeded 30 years out of 32 in the ELC simulation (Table IV.D.2). The mean recession rate would be 3.3 cm/day, which is more than adequate. At the mean recession rate, it would take 15 days of recession before all snails in the illuminated shore zone were stranded, plus some additional time due to the snails' migration down the slope.

There is a diurnal migration behavior on sloping shores among these snails in which all of the snails move into deeper water, away from the bright noonday sun. On slopes of 148:1, they move downward about 1.5 m during each 12-hour period of daylight (Jobin and Michelson 1969). Therefore, in the time the water's edge recedes 74 m (during 15 days), the deepest snails would have migrated another 22 m into the reservoir. Adding the additional time needed to strand these migrating snails, final stranding of all snails would take about one month after recession begins. Thus the time calculated from the simulated water levels should be reduced by a month, indicating a mean stranded time of eight months for the 32 years of simulated record (Table IV.D.2). Such long, dry periods are not usually tolerated by snails of the genus *Biomphalaria*, but are well-tolerated by species of *Bulinus*, especially those from the Sahel region such as *Bulinus abyssinicus* (Jobin 1987).

For comparison, Lake Volta in Ghana, receded very slowly, from NHWL of 83.2 m elevation in mid-October to 81.0 m in mid-April, which demonstrated a decline of 0.37 m per month or 1.2 cm/day (Chu, Klumpp, and Kofi 1981). Because the secchi disk depth for Lake Volta was 3 to 6 m, the snails were able to follow the receding shoreline and therefore, seldom completely stranded (Entz 1969). Bilharzia transmission continued over several months, primarily during the full and drawdown phases (Table IV.D.3).

Table IV.D.3. RELATIVE SIZES OF ILLUMINATED SHORE ZONES OF AFRICAN LAKES.

Lake	Country	Secchi Disk *m*	Recession Rate *cm/day*	*m/month*	Time to strand deepest snail *months*
Volta	Ghana	3-6	1.2	0.37	8-16
Kainji	Nigeria	2-7	4.7	1.44	1-5
Baardheere	Somalia	0.5	3.3	1.00	0.5

In Kainji Lake, in Nigeria, the drawdown occurred from 139.2 m in March to 132.0 m in August—a decline of 1.44 m per month or 4.7 cm/day. This was a much faster recession than in Lake Volta and the proposed reservoir at Baardheere, but the secchi disk depth for Lake Kainji was 2-7 m, which allowed the snails to penetrate deeply into the lake and avoid stranding, as in Lake Volta. There was some bilharzia transmission around Lake Kainji, but not as severe as in Lake Volta. Thus, bilharzia transmission in the proposed reservoir would be much less intense than that in Lakes Volta and Kainji, due to the expected low secchi disk depth of 0.5 m and relatively fast drawdown rate of 3.3 cm/day.

Water temperatures in the proposed reservoir would be generally high, never going below the temperature of the entering river during January, about 25° C (Table III.A.12). The mean temperature for the deep waters was estimated as 28°C based on latitude and altitude. Heating effects on surface waters (especially in the shallow margins), along with the temperature stratification, would produce warmer surface temperatures, although the bottom temperature would drop to 25 °C during the beginning of the jiilaal, around January. The estimated seasonal water temperatures in the shore habitats would fluctuate slightly—an assumed annual mean of roughly 29.1°C—and vary from 26°C in January to 32.5°C in November. These estimates were made by adding 1° C to the temperatures recorded at Baardheere during the 1987 survey (Table III.A.12).

The amount of vegetation in the habitat is very important for population dynamics of *Biomphalaria* and many species of *Bulinus* snails for which egg production is directly proportional to grams of vegetation per liter of habitat. The vegetation would have two components: emergent vegetation in the drawdown zone, and microscopic floating algae.

The amount of rooted vegetation (submerged and emergent) in shoreline snail habitats in the drawdown zone, would be a function of the local soil condition and nutrients as well as the length of the growing season and the aquatic conditions during the submergence. These conditions were estimated for each habitat under analysis (Table IV.D.4). Microscopic algae would not be affected by drawdown, but by clarity of the water. Again the 1987 secchi disk readings for the river at Baardheere were used, with a maximum of 0.5 m, because of assumed steady-state conditions caused by a heavy algae population.

Egg-laying rates for *Bulinus abyssinicus* and other species of bilharzia snails from the Sahel, probably due to selective adaptation, were not so directly influenced by vegetation density. They have apparently adapted to surviving under long, Sahelian dry seasons by laying a large number of eggs immediately after being revived by the seasonal floods, even in the absence of vegetation. This could be a survival strategy which makes it possible for them to produce a large second generation which would have a month or two to mature before the short wet season ends. This second generation, if numerous enough, would thus guarantee some survivors of the dry period, even if it lasted six to 10 months. It was assumed that the erratic and undependable floods of Jubba River Valley have favored survival of bulinid snails with this type of reproductive strategy.

The best estimates for the resistance of the Somali strain of *Bulinus abyssinicus* to dessication were taken from data on Egyptian *Bulinus truncatus* which faced a similarly long, dry season (BNA Memo #3, 1987). The survival rate for a 10-day period of drying was 0.85. Using this rate meant that a stranded population of snails would have a 50 percent survival rate (dessication half-life) of six weeks for the slow drying which would occur along the receding margins of the proposed reservoir. For natural habitats, this dessication half-life implied that an initial population of 1,000 snails would result in one or more snails reviving at the end of 60 weeks of drying. A larger population of 100,000 snails could produce at least one survivor at the end of 23 months of natural drying. As these bilharzia snails

Table IV.D.4. ASSUMED HABITAT CONDITIONS IN RESERVOIR.

Assumed environmental conditions in favorable snail habitats on western shore of Section C in proposed reservoir, for complete range of dry to wet years, from simulation of 32 years of record (ELC 1985)

MONTH	TEMP* °C	SECCHI Disk** in m	VEGETATION Rooted	Algae	WATER LEVEL ANDSNAILS Dry year WL	Snails	Mean Year WL	Snails	Wet Year WL	Snails
Nov	32.5	0.1	max	min	SR	alive	HW	alive	HW	alive
Dec	29.0	0.1	max	min	RC	strand	SR	alive	SR	alive
Jan	26.0	0.5	mod	max	RC	strand	RC	strand	RC	strand
Feb	27.8	0.5	min	max	RC	strand	RC	strand	LW	strand
Mar	29.5	0.5	0	max	RC	strand	RC	strand	WR	strand
Apr	31.8	0.1	0	min	LW	strand	RC	strand	WR	strand
May	30.0	0.0	0	0	WR	strand	RC	strand	HW	revive
Jun	26.3	0.0	0	0	HW	strand	LW	strand	HW	alive
Jul	27.3	0.1	0	min	SR	strand	WR	strand	HW	alive
Aug	28.3	0.1	0	min	RC	strand	WR	strand	HW	alive
Sep	29.3	0.1	min	min	LW	strand	HW	revive	HW	alive
Oct	31.3	0.1	max	min	LW	strand	HW	alive	HW	alive
Nov	32.5	0.1	max	min	LW	strand	SR	alive	HW	alive
Dec	29.0	0.1	mod	min	LW	strand	RC	strand	SR	alive
Jan	26.0	0.5	min	max	LW	strand	RC	strand	RC	strand
Feb	27.8	0.5	0	max	LW	strand	RC	strand	RC	strand
Mar	29.5	0.5	0	max	WR	strand	RC	strand	RC	strand
Apr	31.5	1	0	min	WR	strand	RC	strand	RC	strand
May	30.0	0.0	0	0	HW	revive	RC	strand	RC	strand

* *water temperature from Baardheere (Table III.A.12) plus one degree increase for surface heating.*

** *secchi disk readings at Baardheere (Table III.A.12) with steady-state maximum of 0.5 m.*

LEGEND: WL = reservoir water level SR = start recession RC = receding reservoir level HW = high water LW = low water WR = water rising are hermaphroditic and can fertilize their own eggs, only one survivor is needed to repopulate a flooded habitat.

Computer simulations of *Bulinus* snails in the proposed reservoir were aimed at determining:

- whether the snail populations would survive in the reservoir in extremely dry or wet years, and
- what would be the seasonal fluctuations in numbers of snails during an average year.

The computer model of a snail population used in this planning estimation had been developed with field data from another species of African *Bulinus* snail and had been verified with data from three populations of *Biomphalaria* snails in Puerto Rico (Shiff 1964; and Jobin and Michelson 1969). Biological characteristics of *Bulinus abyssinicus* used in the model were estimated from the scientific literature (Tables IV.D.5-7). Details of the program used in the model, and results of the initial calibration runs using limited data from the ShabeelleRiver were documented in BNA Memo #3 (Jobin 1987).

Table IV.D.5. CONSTANTS USED IN SNAIL MODEL.

Constants for reproduction calculations in computer model of *Bulinus abyssinicus* snail populations in southern Somalia (BNA Memo #3 of 24 March 1987)

SYMBOL*	MEANING	Value assumed for *Bulinus abyssinicus*	Reference
A	Coefficient in fecundity equation, for range of temperatures below 25°C	0.07	Mousa *et al.*, 1972
B	Egg-laying rate in eggs per snail per day	300	calibration in BNA Memo #3
F	Constant in fecundity equation for range of temperatures below 25°C	0.79	Mousa *et al.*, 1972
Q	Constant in fecundity equation for range of temperatures above 25°C	3.78	Mousa *et al.*, 1972
R	Coefficient in fecundity equation for range of temperatures above 25°C	0.11	Mousa *et al.*, 1972
V	VOLZO or volume of crowding zone for snails in cu m	0.10	Jobin and Michelson, 1967

* *for fecundity equation in programming language which is EGGS(J) = B * BIRTH(J) * FTEMP * (FOOD/(ZONE*VOLUME). For temperatures TEMP(M) 25 C, FTEMP = A * TEMP(M) - F, and for temperatures TEMP(M) 25 C, FTEMP = Q = R * TEMP(M). ZONE is the number of snails per crowding zone volume (VOLZO).*

Table IV.D.6. SURVIVAL AND BIRTH RATES USED IN SNAIL MODEL.

Assumed age-specific survival rates and proportional birth rate factors for bilharzia snail *Bulinus abyssinicus*, developed from calibration of computer model with data from Shabeelle River of Somalia (Upatham *et al.* 1981 and BNA Memo #3, Jobin 1987.

TIME PERIOD IN 10 DAYS	SURVIVAL RATE	BIRTH RATE FACTOR
1	0.869	0
2	0.506	0
3	0.627	0
4	0.748	0
5	0.770	0
6	0.924	0.2
7	0.902	0.4
8	0.836	0.6
9	0.737	0.8
10	0.572	1.0
11	0.352	1
12	0.330	1
13	0.33	1
14	0.33	1
15	0.33	1
16	0.33	1
17	0.33	1
18	0.33	1
19	0.33	1
20	0.33	1
21	0.33	0.8
22	0.33	0.6
23	0.33	0.4
24	0.33	0.2
25	0.33	0
26	0.33	0
27	0.33	0
28	0.33	0
29	0.33	0
30	0	0

Table IV.D.7. DESSICATION SURVIVAL RATES USED IN SNAIL MODEL.

Survival rates assumed in computer simulation of population dynamics of *Bulinus abyssinicus* during desiccation and other conditions, over a 10-day period

SYMBOL	MEANING	VALUE	REFERENCE
D	Proportional interruption in oviposition time for strandings of less than 10-day duration	not applicable	
E	Desiccation survival of eggs	0	
G	Desiccation survival of adult snails	0.85	Jobin, 1970
CATAST	Survival of adult snails after catastrophe		for prediction purposes

The model was used to simulate the predicted snail populations in the most likely, favorable habitats along the western shore of Sector C in the proposed reservoir for three conditions: an average year, the driest year of the simulated 32 years of record (1980), and the wettest year (1978). Before and after the year being examined, average-year conditions were simulated. The maximum habitat volume simulated was that of the illuminated shore zone on the southwestern shore of Sector C: 62,900 cu m when the secchi disk was 0.5 m, 12,580 when it was 0.1 m, and 1,258 cu m when it was 0.01 or zero (Table IV.D.8). The initial snail population used in starting the simulation was three million snails, and habitat conditions were estimated from the conditions expected in the proposed reservoir, based on the water-level fluctuations previously outlined (Tables IV.D.8-10).

The population simulations unexpectedly indicated that bilharzia snails would be unable to persist in the protected habitats along the western lake shore, even in the wettest years when the reservoir remained full for several months (Figure IV.D.6). Relatively high water temperatures and low clarity of the water would occur due to high turbidity and heavy algae growth, based on field data from the 1986-87 surveys. Coupled with the rather large and rapid fluctuations in the water level, these adverse conditions would combine to severely limit reproduction by the snails.

Secondary simulations indicated that this was a "robust" prediction. Slightly more favorable conditions, such as lower water temperatures, were not sufficient to make the reservoir a suitable habitat for these snails. Even if water temperatures were 1-2°C lower than the expected temperatures, the bilharzia

Table IV.D.8. HABITAT DATA FOR SNAIL MODEL FOR AVERAGE YEAR.

Habitat conditions used for average year in computer simulation of snail populations in habitat of 62,900 cu m volume on southwestern shore of Sector C in proposed reservoir on Jubba River in Somalia

MONTH	I	CONDITION	G	VOLUME in cu m	TEMPERATURE in °C	FOOD in gm/cu m
1995						
Jan	1	stranded	1	62,900	26.0	150**
Feb	2	stranded	0.85	0*		
Mar	3	stranded	0.85	0		
Apr	4	stranded	0.85	0		
May	5	stranded	0.85	0		
Jun	6	stranded	0.85	0		
Jul	7	stranded	0.85	0		
Aug	8	stranded	0.85	0		
Sep	9	revived	1	12,580*	29.3	20**
Oct	10	alive	1	12,580	31.3	110
Nov	11	alive	1	12,580	32.5	110
Dec	12	alive	1	12,580	29.0	60
1996						
Jan	13	stranded	1	12,580	26.0	150
Feb	14	stranded	0.85	0		
Mar	15	stranded	0.85	0		
Apr	16	stranded	0.85	0		
May	17	stranded	0.85	0		
Jun	18	stranded	0.85	0		
Jul	19	stranded	0.85	0		
Aug	20	stranded	0.85	0		
Sep	21	revived	1	12,580*	29.3	20**
Oct	22	alive	1	12,580	31.3	110
Nov	23	alive	1	12,580	32.5	110
Dec	24	stranded	1	12,580	29.0	60
1997						
Jan	25	stranded	0.85	0		
Feb	26	stranded	0.85	0		
Mar	27	stranded	0.85	0		
Apr	28	stranded	0.85	0		
May	29	stranded	0.85	0		
Jun	30	stranded	0.85	0		

** snails are all stranded on dry shore so volume of habitat is zero and there is no water temperature or food.*

*** amount of vegetation or food is assumed from experience with calibration for Shabeelle River conditions. Minimum amount of rooted vegetation or of algae = 10 gm/cu m, moderate amount = 50 gm/cu m, and maximum amount = 100 gm/cu m. The two types of vegetation are additive, thus total amount of food could reach 200 gm/cu m.*

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snails would not survive during even the most favorable years (Figure IV.D.6).

Such simulations do not constitute rigid proof that the snails would not colonize the reservoir. A different snail species might invade the area, the present snail might adapt to reservoir conditions over a long period of time, or ecological conditions in the reservoir might develop in patterns other than predicted. However, the overall indications were that this proposed reservoir would be generally unfavorable for bilharzia snails.

Table IV.D.9. HABITAT DATA FOR SNAIL MODEL FOR DRY YEAR.

Habitat conditions used for driest year in computer simulation of snail populations in habitat of 62,900 cu m volume on southwestern shore of Sector C in proposed reservoir on Jubba River in Somalia

MONTH	I	CONDITION	G	VOLUME in cu m	TEMPERATURE in degrees C	FOOD in gm/cu m
1995						
Jan	1	stranded	1	62,900	26.0	150**
Feb	2	stranded	0.85	0*		
Mar	3	stranded	0.85	0		
Apr	4	stranded	0.85	0		
May	5	stranded	0.85	0		
Jun	6	stranded	0.85	0		
Jul	7	stranded	0.85	0		
Aug	8	stranded	0.85	0		
Sep	9	revived	1	12,580	29.3	20
Oct	10	alive	1	12,580	31.3	110
Nov	11	stranded	1	12,580	32.5	110
Dec	12	stranded	0.85			
1996						
Jan	13	stranded	0.85	0		
Feb	14	stranded	0.85	0		
Mar	15	stranded	0.85	0		
Apr	16	stranded	0.85	0		
May	17	stranded	0.85	0		
Jun	18	stranded	0.85	0		
Jul	19	stranded	0.85	0		
Aug	20	stranded	0.85	0		
Sep	21	stranded	0.85	0		
Oct	22	stranded	0.85	0		
Nov	23	stranded	0.85	0		
Dec	24	stranded	0.85	0		
1997						
Jan	25	stranded	0.85	0		
Feb	26	stranded	0.85	0		
Mar	27	stranded	0.85	0		
Apr	28	stranded	0.85	0		
May	29	revived	1	1,258***	30.0	0.1***
Jun	30	alive	1	1,258	27.3	0.1

** See corresponding note for Table IV.D.8.*
*** See corresponding note for Table IV.D.8.*
**** For full reservoir during normal gu' flood, a secchi disk depth of 0.01 m is assumed; thus, habitat volume is 1,258 cu m, not zero. Similarly, the food density is very low but not quite zero.*

Table IV.D.10. HABITAT DATA FOR SNAIL MODEL FOR WET YEAR.

Habitat conditions used for wettest year in computer simulation of snail populations in habitat of 62,900 cu m volume on southwestern shore of Sector C in proposed reservoir on Jubba River in Somalia

MONTH	I	CONDITION	G	VOLUME in cu m	TEMPERATURE in degrees C	FOOD in gm/cu m
1995						
Jan	1	stranded	1	62,900	26.0	150**
Feb	2	stranded	0.85	0*		
Mar	3	stranded	0.85	0		
Apr	4	stranded	0.85	0		
May	5	stranded	0.85	0		
Jun	6	stranded	0.85	0		
Jul	7	stranded	0.85	0		
Aug	8	stranded	0.85	0		
Sep	9	revived	1	12,580*	29.3	20**
Oct	10	alive	1	12,580	31.3	110
Nov	11	alive	1	12,580	32.5	110
Dec	12	alive	1	12,580	29.0	60
1996						
Jan	13	stranded	1	12,580	26.0	150
Feb	14	stranded	0.85	0		
Mar	15	stranded	0.85	0		
Apr	16	stranded	0.85	0		
May	17	alive	1	1,258***	30.0	0.1***
Jun	18	alive	1	1,258	26.3	0.1
Jul	19	alive	1	12,580	27.3	10
Aug	20	alive	1	12,580	28.3	10
Sep	21	alive	1	12,580	29.3	20**
Oct	22	alive	1	12,580	31.3	110
Nov	23	alive	1	12,580	32.5	110
Dec	24	alive	1	12,580	29.0	60
1997						
Jan	25	stranded	1	62,900	26.0	150
Feb	26	stranded	0.85	0		
Mar	27	stranded	0.85	0		
Apr	28	stranded	0.85	0		
May	29	stranded	0.85	0		
Jun	30	stranded	0.85	0		

** See corresponding note for Table IV.D.8.*
*** See corresponding note for Table IV.D.8.*
**** for full reservoir during normal gu' flood, a secchi disk depth of 0.01 m is assumed; thus, habitat volume is 1,258 cu m, not zero. Similarly, the food density is very low but not quite zero.*

2. Shoreline Terrestrial Habitats

The creation of a large, stable body of standing water in the midst of the barren badlands in southwestern Somalia would act as a magnet to people and their livestock, and to all sorts of other terrestrial beings, especially roving herds of mammals, flocks of birds, insects, reptiles, and amphibians. The long reservoir would disrupt large-scale patterns of migration of these animals, and be a fertile trap for wandering or windblown stray individuals of the incredibly large number of species of organisms found in East Africa. The shores of the reservoir would eventually become home for a wide variety of terrestrial organisms which could be important in transmission of parasites and other pathogens. From a health viewpoint, the most relevant of these organisms would be tsetse flies, ticks, blackflies, dogs, cows, and camels.

Human Communities

The human population along the river's edge in 1987 included an estimated 10,000-13,000 people in small agropastoral settlements scattered along both banks, but found primarily on the western side of the river. These communities have developed over several generations and depended on a relatively stable river flow, taking advantage of the yearly floods for drawdown agriculture. Filling of the reservoir would force them from their original locations and would require them to either continually move their dwellings, or to locate above the

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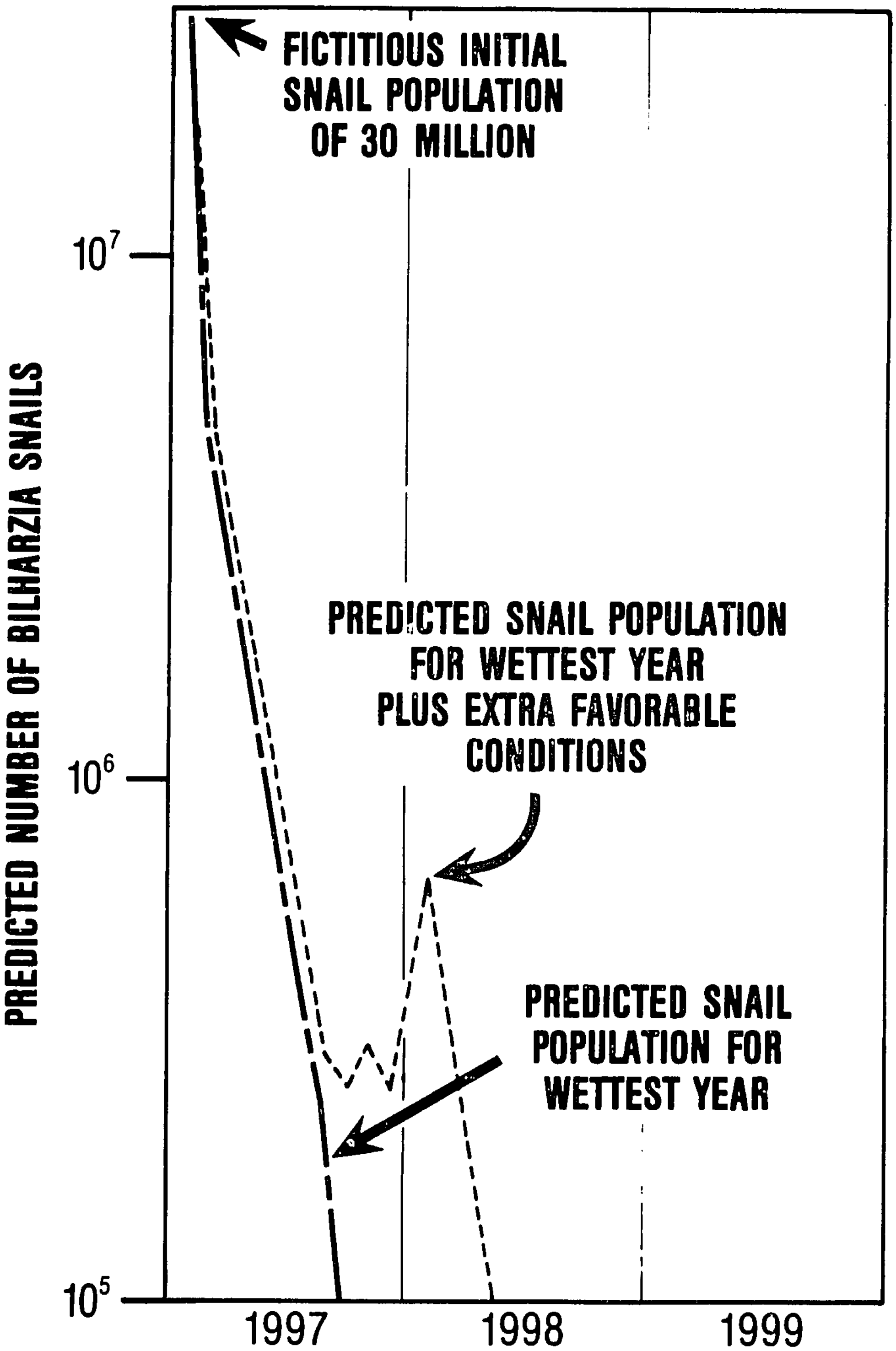

Figure IV.D.6
Predicted Populations Of Bilharzia Snail BULINUS ABYSSINICUS In Proposed Baardheere Reservoir In Somalia

The computer model was calibrated against published data from 3 pond studies in the Shebelli Valley by Upatham et al, 1981. The final calibration for conditions in a pond in Merka indicated reasonably close agreement between the computer predictions and the observed snail numbers.

NHWL where they would have to travel long distances for water during the periods of low water in the reservoir. These distances could be as long as 5-8 km in some years, causing hardship and severe risks of diarrheal diseases due to reductions in the quantity of water available per person for washing, bathing, and other sanitary uses.

Because of the large and erratic fluctuation pattern of the reservoir expected under normal operating conditions and the consequent difficulty expected in successfully cultivating crops, it was assumed that the reservoir population which could be sustained under uncontrolled development would be reduced by one-half from the pre-construction population of 10,000 to about 5,000. It was also assumed that these people would naturally locate along the flattest portions of the shore because of the more favorable conditions for agriculture. For predictive purposes it was assumed that they would be evenly scattered in 50 clusters of 100 persons each, along the flatter shorelines of Sectors B, C, and D (Figure IV.1).

The five listed towns which existed prior to 1987 were assumed to be completely eliminated by the filling reservoir as their wells, roads, and the fertile strip along the riverbank which sustained them, would be permanently submerged. There would be a new, small community near the proposed dam consisting of the people operating the dam and their families. This would probably replace Markabley.

The closest large town, Garbahaarey, would not be directly affected by the reservoir as it would be about 20 km away from the shore even at maximum expected water level. Luuq would also not be directly affected as significant rises of the water level would only occur in Sector E near Luuq during a few months of the year, and would be of small magnitude.

It was assumed that the existing refugee camps would be relocated with similar facilities just above the NHWL, and spread out along the western shore of Sector C (Figure IV.1).

Tsetse Flies

Experience in the Shabeelle Valley and elsewhere in East Africa indicated that tsetse flies lived in gallery forests along the river during the dry season, and dispersed only 1 km from the river into *Acacia* thickets during the more humid rainy season. With the rising of the reservoir, existing gallery forests would be destroyed, thus eliminating the protected sanctuary for these flies during the long dry season, and probably eliminating the population from the area.

Dogs

There is a potential for human hydatid disease which can be transmitted by dogs infected from cattle with *Echinococcus* sp.—infections which are common in Somali cattle. *Rabies* could be another concern with dogs, although the communities expected around the reservoir would be too small to maintain enough dogs to be a serious health hazard.

Ticks

Ticks, which can transmit diseases to livestock and wild beasts, usually inhabit grass which is in damp ground or a humid environment. During extra wet years, the reservoir would remain at the NHWL for periods up to seven months, which would allow time for considerable growth of grasses and other vegetation around the shoreline (Figure IV.D.5). These locations would then be attractive to animals for grazing and, at the same time, produce favorable conditions for tick populations to flourish, thereby producing the conditions necessary for ticks to attach to the animals and transmit diseases. The most common species of ticks in Lower Jubba Valley prior to dam construction were *Rhipicephalus pulchellus, R. humeralis, R. prevus, and Amblyomma gemma.*

It was assumed that tick populations would vary with reservoir fluctuations and generally be less of a problem after the reservoir filled. In wet years, it was expected that ticks would be a greater problem than they had been during the pre-construction period, but would be virtually eliminated during dry years. During an average year, they would also be less of a problem than in the past because there would be only one period of high water level compared to the two periods experienced during the pre-construction flooding pattern of the Jubba River.

Migratory Herds and Wild Beasts

Attraction of the sweet water in the proposed reservoir would be irresistible for migratory herds and wild animals during the long droughts characteristic of the Horn of Africa. It was difficult to make any predictions about kinds or numbers of animals, but the longer shoreline of the filled reservoir and decreased cultivation of the shores, due to thinner topsoil and erratic fluctuations, would increase the availability of the shoreline to herds and wild beasts compared to the pre-construction situation in which almost all flat and accessible land was cultivated.

E. Predicted Patterns of Disease Transmission Around Proposed Reservoir with Uncontrolled Development

The coexistence of human and mammalian populations with aquatic snails and insects along the shoreline of the proposed reservoir would produce the necessary conditions for transmission of many parasites and disease pathogens. Malaria and cholera would be the most important human diseases, and transmission of some parasites of sheep and cattle would be likely.

It is not likely that either bilharzia or the cattle disease, *ngana*, would become a serious problem around the reservoir as this area would be unsuitable for the transmitters—bilharzia snails and tsetse flies.

1. Predicted Malaria Transmission

The unfortunate geographical coincidence along the shores of Sectors B, C, and D of ideal aquatic habitats for malaria mosquitos with flat land which is attractive for agropastoralists and refugee camps, would produce severe malaria transmission in this area. In wet years, when the reservoir remains full for several months, the transmission period would lengthen and amplify far beyond anything presently experienced in the Upper Valley (Figure IV.D.5).

Because of the proximity of Luuq, Garbahaarey, and Baardheere to this intensive transmission zone, these towns would experience a secondary wave of malaria each year, due to infected persons bringing in heavy malaria parasite infections in their blood. In a wet year, this would cause severe transmission in the towns, which normally contain populations of the very efficient vector, *A. arabiensis*. Migratory groups that bring their livestock to the reservoir would be affected also during these outbreaks. Although malaria is a minor problem in the region at present, it would become the dominant communicable disease after construction of the proposed dam.

Under a policy of unguided development, the proposed reservoir would become a source of serious malaria transmission every year, with especially severe outbreaks from September to March during wet years, and would affect the entire population of the Gedo Region.

2. Predicted Bilharzia Transmission

It is unlikely that there would be any noticeable increase in the present, low level of bilharzia transmission along the river in the Gedo Region after construction of the proposed reservoir. The relatively turbid waters of the proposed reservoir would limit bilharzia snails to a narrow strip along the reservoir shore, even in the flat zones on the western edge of Sector C. The conditions in this strip would seldom be adequate to sustain a snail population through a complete year, even if occasional snails are brought into the reservoir from upstream or other places in the Jubba Valley.

Although human populations around the reservoir would undoubtedly contaminate it and bathe in it (behavior that ordinarily would be conducive to bilharzia transmission), the unsuitability of the reservoir as a snail habitat would prevent the bilharzia parasite from persisting in the human population. The overall likelihood of bilharzia becoming a serious health concern around the reservoir is very low.

3. Predicted Diarrheal Diseases

The expected human settlements around the proposed reservoir, under a policy of uncontrolled development, would be unable to construct, operate, or maintain adequate community water supplies. Although managers of the refugee camps may be able to develop new water supplies (at considerable expense), the scattered agropastoralists who would remain around the reservoir would be too few and far between to afford decent wells or water treatment systems. Therefore, it is predicted that diarrheal diseases would become greater health problems than they were prior to dam completion, and the transmission period would expand from the present months of April and May to two periods of three to four months each—probably April to July and October to January.

Heavy fecal contamination of drinking water would cause unusual risks of cholera, typhoid, and hepatitis, especially after the two rainy seasons. The worst period during the year would be from March to June when the reservoir is at an extremely low level (Figure IV.D.4). At this time, people would have to travel long distances to get water, and consequently, would not use enough for adequate cleanliness. Highly turbid water in the reservoir would offer protection to intestinal bacteria from the sterilizing effect of normal sunlight. To avoid the long trek to the reservoir, people would use closer, smaller sources of surface water which would be heavily contaminated. A second transmission period would occur immediately after the deyr rains, again due to the turbidity of the water which blocks the normal cleansing impact of sunlight on fecal bacteria and viruses. Cholera would be the most important diarrheal disease due to its rapid growth and spread under such conditions.

4. Predicted Livestock Diseases

The only serious livestock diseases expected around the proposed reservoir would be those transmitted by ticks. Other diseases such as ngana, liver fluke, and the species of bilharzia parasite that infects cattle, are not expected to be serious problems around the proposed reservoir, even under conditions of uncontrolled development. The ecology would not be suitable for tsetse flies or the species of snails that transmit these animal parasites, even though the livestock may congregate around the reservoir in large numbers.

The extent of livestock diseases transmitted by ticks in Somalia is not well-known. In the Kismaayo District, ticks are regarded as the second or third most important health problem by the livestock owners (Zschekel 1984). They are known to transmit anaplasmosis and Nairobi sheep disease, both presently of minor importance. Transmission of these diseases is not expected to increase around the proposed reservoir, except during very wet years when the reservoir remains at NHWL for several months, and livestock are brought in to graze the pasture along the receding shoreline. At these times, there may be severe outbreaks of these diseases, perhaps with a frequency of once in 10 years.

5. Alternative Disease Prevention Programs

If the policy of uncontrolled development is followed, prevention of malaria and diarrheal diseases—the two major health threats—would be very difficult and expensive.

Malaria control would be best accomplished with a program of reservoir fluctuation during the full reservoir phase and in the early part of the receding phase. Excess water should be available at these times, after the main flood coming into the reservoir has subsided, making it possible to quickly refill the reservoir to NHWL without any economic losses in power generation. There are no other practical measures that would be economically feasible for the Somali government.

Outbreaks of cholera, typhoid, and other diarrheal diseases would be difficult, if not impossible, to control. The most practical measure would be a campaign of health education and distribution of ORS to all families along the reservoir perimeter. If refugee camps continue in the Gedo Region, they would require very expensive and well-maintained water treatment systems to avoid disastrous epidemics. They are unlikely to find adequate wells in the new locations they would be forced to occupy by the rising waters.

F. Possible Reservoir Modifications and Operational Procedures for Disease Prevention Under Policy of Guided Development

The recommended option of guided development around the reservoir would allow coordination of reservoir operation with agricultural, domestic, power, and flood-control needs. It offers potential for supporting the pre-construction populations in the Gedo Region, and balanced development of the area with full use of its resources.

Predictions of disease transmission around the proposed reservoir under a policy of uncontrolled development made it clear that severe health problems would occur and prevention or control would be very difficult and expensive. It would be much better to guide development of human settlements around the proposed reservoir, and integrate operation of the reservoir with the needs of these settlements.

Guided development of the communities and land around the proposed reservoir—especially along the western shore near Buurdhuubo and the refugee camps—would make it economically feasible to avoid serious outbreaks of malaria and diarrheal disease. This guided development would require a multidisciplinary operations group for managing the dam to achieve maximization of reservoir potential. Provision of electric power for community water supplies to the resettlement communities and to Baardheere, Luuq, and Garbahaarey would avoid otherwise inevitable outbreaks of cholera and typhoid at the beginning of the rainy season every April or May.

A second possible course of guided development would be wholesale movement of all settlers in the area down to new settlements in the middle or lower valley. While this might be theoretically feasible, considerable expense and pre-construction development would be needed for community water supply, sanitation, and drainage facilities, in order to avoid severe disease outbreaks in these new communities. These community facilities would have to be completed one agricultural season before the dam fills, to avoid starvation of the moved population. Disease control in such communities in the middle or lower valley would be much more difficult than in Gedo Region because of higher rainfall, greater population density, and greater amounts of surface water where disease vectors would breed. In all surveys conducted, prevalences of malaria and bilharzia were much higher in the lower valley.

The alternative possibility of uncontrolled development around the proposed reservoir would decimate the existing agropastoral population due to malaria, malnutrition, and cholera, and cause serious secondary epidemics of malaria and cholera annually in the larger towns of Baardheere, Luuq, and Garbahaarey, and the relocated refugee settlements.

A policy of guided development would make possible the coordination of disease control operations and requirements for drawdown agriculture around the reservoir perimeter, with the downstream needs for power generation and irrigation. Before comparing the costs and benefits of reservoir modification and operation with other types of disease control in such an integrated policy of guided development, it was useful to review the possible measures available.

These measures have been developed principally in the malaria control experiences in the United States and the Soviet Union (TVA 1947; UNEP/USSR 1982; Jobin 1987). They included measures to be taken prior to filling the reservoir, operational procedures concerned primarily with control of the reservoir water level, and vector control measures integrated with the reservoir operations.

Implementation of these measures would require establishment of a highly capable operational health unit to be permanently located at the dam or at one or more strategic sites along the reservoir shores. Their main task would be to monitor the inevitable evolution of new conditions around the reservoir related to transmission of the major water-associated diseases, and organize an integrated program to control those diseases. The personnel in this unit would have to include a public health or environmental engineer, an aquatic biologist, a sanitarian, a laboratory technician, and field personnel for vector control activities. They would also need transport and equipment, including boats and light aircraft.

The health unit would work under the engineers who operate the dam, and provide health monitoring and current information on mosquito and snail populations to the dam operators for inclusion in determining the operation of the dam.

In addition, the pre-operational modifications to the reservoir would involve considerable earthwork and drainage, as well as clearing of brush and trees—items which would have to be added to the main construction contract for the dam.

1. Pre-operational Reservoir Modifications

The principal measures that could be taken prior to closing the dam and filling the reservoir, involve preparation of the reservoir shoreline to avoid unfavorable disease transmission after the reservoir fills. These measures should be taken at the same time that dam construction begins. The first step would be a detailed survey of topography, soils, and vegetation in critical areas. From this survey, the shoreline would be classified in terms of agropastoral potential and risk of disease transmission.

A land-use plan would then be prepared with delineation of areas reserved for wildlife refuges, grazing of livestock, drawdown agriculture, and agropastoral settlements. Based on this land-use plan for the reservoir shoreline, controls and modifications of the land would be designed and implemented. This would include locating preferred sites for "magnet communities" to guide post-construction settlements.

Purchase of Marginal Land

If the shoreline within 5 km of the proposed magnet communities can be straightened and made steep enough to prevent mosquito and snail infestations, communities could be placed closer to the reservoir's high water level. However, minimum recommended distance to the high water line is 1 km.

Prior to relocation of populations around the proposed reservoir, government agencies respon-

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sible for health would review the necessities for establishing operational bases on both shores of the reservoir at strategic locations. These bases would be used to monitor disease vector populations and disease transmission in humans and livestock, and to conduct control measures as necessary. In addition, land restricted for special uses, such as grazing or wildlife refuges, would be purchased or restricted at this time.

Clearing Vegetation

Clearing brush and timber from that portion of the reservoir fluctuation zone that could cause mosquito or snail production would be completed prior to the first filling of the reservoir. Elevations for clearing and portions of the shoreline to be cleared would be established from the land-use plan, predictions of disease transmission, and proposed operating rules for the reservoir.

Before starting these clearing operations, the maximum vector control elevation or "cleared line" would be established—usually the normal high water level. For Baardheere Reservoir, it was 141.9 masl (ELC 1985). The flood surcharge level is usually somewhat higher and is dependent on the spillway or gate elevation on the dam. This surcharge level was 148 masl for the proposed reservoir, based on the maximum expected flood of 1,050 cumecs passing over the spillway which was at 144 masl (Figure IV.C.1).

All trees, brush, logs, or other materials below the basic "cleared line" (maximum vector control elevation) would be removed. All similar material, including drift and debris as well as trees leaning so that branches touch the water surface at NHWL, would be removed from the area above the maximum vector control elevation for a landward distance of 3-5 m, except along cliffs or where the shoreline is likely to erode (TVA 1947).

The minimum vector control elevation would be the normal low water level, between 128 and 135 masl for the proposed reservoir. In critical areas, the clearing would proceed down to these elevations, or even further if navigation is contemplated in the reservoir.

Shoreline Straightening

In areas where mosquito and snail habitats are expected to pose disease hazards to nearby populations, the habitats would be eliminated or minimized by straightening of banks, deepening and filling of shallow areas, and simple, marginal drainage ditches.

Major Drainage Works

For large, potential vector habitats near permanent populations, permanent drainage works would be designed and constructed to eliminate vector habitats along the lake shore, within 5 km of the settlements.

2. Reservoir Operational Measures

Although basic operational determinants for the reservoir are power generation, irrigation, and flood control, they do not necessarily preclude other important objectives such as health and drawdown agriculture around the reservoir. Careful monitoring of flows and health conditions would make it possible to meet all the objectives during most years in the proposed reservoir at Baardheere. This possibility is very desirable for development around the reservoir because it would be the best and least expensive component of an integrated strategy for health protection.

In addition to improvements around the reservoir in the middle and lower valley, the chemical quality of water for human and animal use would be greatly improved by constructing the dam and subsequent regulation of river flow. The expected base flow during the jiilaal dry season should sustain freshwater recharge of the riverine aquifer and avoid the annual episodes of salt water intrusion to wells along the river and the Kismaayo water system intakes. These episodes occur presently during dry years and lead to severe problems in finding safe water for weeks in all communities in the lower valley. The possibility of providing a minimum discharge between 20-90 cumecs should be explored in balancing operational benefits from the dam.

The expected improvements in water supply should eliminate the majority of diarrheal disease epidemics which presently occur during the latter part of the jiilaal dry season. However, the diarrheal disease outbreaks in the early part of the gu' and deyr rains may still occur if people continue using the more convenient rain-filled ponds at this time of year.

Flood Surcharge

The proposed reservoir has a space for temporary storage of flood surcharges, between the NHWL of 141.9 masl and the maximum expected level of 148 masl. This surcharge zone could be used effectively for mosquito control through stranding of drift and flotage at the beginning of floods. Because the floating debris would be lifted up into the uncleared vegetation above the clearing line, it would be trapped behind this vegetation when the level drops. However, there must be a clear understanding with the dam operators that this surcharge storage shall not be maintained above the cleared line for more than one week, in order to prevent excessive mosquito production in the surcharge zone.

Constant Level

After the flood surcharge is allowed to flow out and the reservoir level drops to the cleared line, the reservoir would be maintained steady at this elevation until mosquito production begins. Maintaining a constant level pool before the beginning of mosquito breeding season would minimize encroachment of vegetation into the fluctuation zone, reducing the intersection line. This feature is most useful in areas where breeding is seasonal and limited by low air temperatures. Thus, it would not be very important in the proposed reservoir, and would last only a week or two until significant mosquito breeding begins.

High Water Fluctuations

For mosquito and snail control, a cyclical fluctuation of the water level during breeding season when the reservoir is full would be much better than a constant level. For control of mosquito larvae that are flushed out of the shoreline vegetation into open water where they are subject to predation, a fluctuation of 0.3 m on a weekly cycle would be sufficient. However, for bilharzia snail control, a slightly larger fluctuation of 0.5 m would be needed to cover the entire photic zone, and the period of fluctuation could be lengthened to 10 days. For control of both vectors, a weekly cycle of 0.5 m amplitude is recommended.

The ability to produce this fluctuation in a full reservoir would require considerable discharge capacity during floods. The primary consideration for the proposed reservoir would be the limit on downstream flow in the river due to flooding, which has been set at 750 cumecs. The reservoir surface at NHWL would be 310 sq km; thus, a drop of 0.5 m in 3.5 days would require a discharge which was 513 cumecs greater than the river flow coming into the reservoir.

Recession Phase Fluctuations

After the deyr flood diminishes, the reservoir level would begin to recede due to discharges at the dam for power generation and irrigation. This seasonal recession would cause some stranding of both mosquitos and snails, but because of the slow recession rates expected, it would be desirable also to maintain the weekly cyclical fluctuation superimposed on this seasonal recession.

A rise in the reservoir during the weekly cycle would require flow coming into the reservoir at Luuq to considerably exceed the discharge at the dam. At NHWL with a reservoir area of 310 sq km, the river would need a flow 513 cumecs greater than the discharge at the dam. By the time the reservoir level had dropped to its normal minimum of 135 m, the surface area of the reservoir would be 175 sq km, and the river flow would have to exceed the dam discharge by 289 cumecs.

3. Integrated Disease Control Measures

In addition to the engineering measures and operational rules that could minimize disease transmission, it would also be possible to provide an integrated program of vector and disease control measures along inhabited portions of the shoreline. There is a wide range of available methods, and all should be used in rational combination for best results.

Annual Shoreline Maintenance

Just prior to the annual rise in the reservoir level, mosquito and snail production in the reservoir should be reduced by removal of unwanted vegetation growth, stranded debris and drift, and maintenance of marginal drainage ditches. Minor shoreline topography alterations should also be made at this time to further reduce vector breeding sites which would occur during the recession phase.

Grazing and Aquatic Weed Control

Controlled and intensive grazing should be used to minimize weed growth at the upper levels of the drawdown zone, thus reducing the reproductive potential of these areas for mosquitos and snails when the lake fills. Grazing and manual removal of aquatic vegetation would accomplish the same effect, even at high water levels.

Biological Control

Numerous aquatic organisms such as fish and predator snails should be introduced into the reservoir and used to diminish the numbers of malaria mosquitos and bilharzia snails.

Application of Biocides

In certain cases, as a last resort, chemical application of larvicides and molluscicides could be used to control outbreaks of insects or snails. Their high cost in hard currency and the need for continuous application limit their usefulness in a comprehensive approach to disease control.

Treatment of Infected Individuals

Drugs are available for treatment of malaria, bilharzia, and livestock diseases. Because of their short-term effectiveness and the difficulty of achieving good coverage, they should only be used in combination with an integrated program of community participation and vector control. New drugs are available for bilharzia control, but malaria drugs are being rendered ineffective by the recent development of drug-resistant strains of the malaria parasite in Somalia. Inexpensive oral rehydration salts (ORS) should be distributed for home use in prevention of diarrheal death among infants.

Treatment with drugs as the sole method for bilharzia control has been found ineffective in WHO trials in the Shabeelle Valley. In fact, prevalence increased in the villages given drug treatment only (Upatham 1979a and b). Despite tendencies in the health profession toward this practice, it must be avoided in Somalia.

Community Education and Participation

The settlements around the reservoir would be isolated from contact with most government agencies, and would need to develop a great deal of self-reliance in health measures. The most useful intervention by health agencies of the government would be education of the communities and establishment of basic community organizations to initiate education, health care, and cooperative activities which would reduce disease transmission.

Primary Health Care

Training of community health workers in each settlement along the reservoir would make it possible to obtain early detection and treatment for most of the important diseases, as well as provide a person who could work on community education and organization.

Housing Protection

The use of mosquito and fly screens, as well as mosquito nets for sleeping, could be used to limit disease transmission when carefully applied.

Zoo-prophylaxis

In agropastoral communities, livestock should be used to minimize mosquito biting in the human community by pasturing the animals at night in a location between the human residences and mosquito breeding sites (UNEP/USSR 1982). The animals would attract the mosquitos and prevent them from reaching the human habitations, thus reducing malaria transmission and other diseases.

Water Supply and Sanitation

Safe, adequate, and convenient community water supplies and simple sanitation systems can have major impacts in reducing death and disease from bilharzia, cholera, typhoid, hepatitis, and other water-associated diseases, as well as the amount of labor required for fetching water. The dramatic impact of water supplies in preventing death is more than enough to justify their cost.

If careful planning and substantial investment in community development is not initiated early in Jubba Valley, unhealthy communities would proliferate around the reservoir and related agricultural projects. Such conditions already occurred at the Mogambo Irrigation Project where labor housing was constructed in low land with poor drainage. Flooding caused temporary abandonment of the houses in the first year of operation, and drainage and mosquitos were a continuous problem thereafter.

The Ministry could have a major influence on community development by providing safe water supplies at selected healthy locations. Safe water supplies should be used to influence the location of expected communities, and the size of the supplies must be adequate to insure healthy conditions among the expected populations. Adequate, safe, and convenient community water supplies would act as magnets to attract the local population to safe areas.

In upper Jubba Valley, the river and reservoir would be the only practical source of drinking water for people and animals, due to high salinity of groundwater. The reservoir would be of suitable chemical quality during all seasons to provide adequate water for the existing and expected human and animal populations.

Normally, the bacterial quality of the water would be fairly good. However, if communities are allowed to develop close to the reservoir's edge, water-associated diseases would cause severe

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health problems. Therefore, community water supplies, using filtered lake water, should be established on the flat land west of Buurdhuubo, 2 to 5 km west of the maximum normal operation level (142 masl) of the reservoir, and at similar locations on the east bank. By careful planning and collaboration with existing and potential residents, "magnet communities" should be created at these sites to draw the expected settlers.

The most economical location for such water supplies in the magnet communities would be along the beds of the ephemeral tributaries called *toggas*. Subterranean reservoirs should be created by placing clay dikes across the *togga* bed, thus trapping lake water during high reservoir levels and retaining adequate water for the time when the lake has receded. It is recommended that sites be developed with access roads, electricity, wide streets, and well-spaced community water taps.

In order to provide sufficient water to the 5,000-10,000 people who would be involved in construction of the proposed dam, a large treatment system should be built slightly downstream of the dam. During construction of the dam, it should be used to supply domestic water to the construction community, and a pipeline should be extended downstream to Baardheere Town. The size of the system should be adequate to supply both communities, including the expected growth in Baardheere during and after the dam construction. It could be located in a position to provide gravity operation of sedimentation and filtration units. Desalinization would also be needed for short times prior to dam construction, but afterwards, the mixed quality of the reservoir would be chemically satisfactory for human consumption without desalinization.

G. Predicted Patterns of Disease Transmission Around Proposed Reservoir with Guided Development Policy

By combining information developed on projected snail and mosquito populations with estimated location and size of the expected human communities, estimates were made of the importance and patterns of disease distribution around the proposed reservoir, under a policy of guided development.

1. Malaria Transmission

Mosquito production near the planned communities would be practically eliminated, and mosquito biting would be further reduced due to the zooprophylaxis measures, thus reducing the transmission of malaria to very low levels—probably below those presently experienced in the Gedo Region.

2. Bilharzia Transmission

As in the case of uncontrolled development, the predicted extent of bilharzia transmission around the proposed reservoir would be very small, due to the expected lack of bilharzia snails in the reservoir. However, a policy of guided development of human communities would give further assurance of preventing bilharzia transmission, in the event snails did colonize the reservoir. Careful grouping of communities would make it possible to provide safe community water supplies for the agropastoral settlements, thus reducing a major reason for human contact with snail-infested waters.

Although estimated conditions for the proposed reservoir were unfavorable for bilharzia transmission, the risk must be considered and provisions made for the possibility that it would occur. Frequent monitoring of the reservoir by the Ministry of Health in the early years is very important. Assistance from WHO should be sought if problems do occur.

3. Diarrheal Diseases

Community water supplies that would form the basis for the planned communities would be the most effective means of preventing diarrheal diseases. These water supplies, combined with the use of ORS for treating dehydration in infants, could reduce the death rate due to this class of diseases far below pre-construction levels. Cholera epidemics should no longer occur in this area.

4. Livestock Diseases

Trypanosome infections in livestock due to tsetse flies should be virtually eliminated around the reservoir. However, tick infestation during exceedingly wet years would cause some disease.

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V. PREDICTED SITUATION IN AGRICULTURAL DEVELOPMENTS

Various plans for individual agricultural developments were proposed for Jubba Valley in the last decade, including several which have been initiated. A comprehensive master plan was also commissioned by the Ministry in 1987, to outline the optimum directions and limits for development. In this chapter, the potential water quality and health conditions under some of these development plans were examined, including a computer simulation of conductivity in the river under intensive irrigation programs.

A. Assumed Populations and Community Conditions

The aggregate population figures used in this report came largely from the AHT (1985) report, based on the 1975 population census. Some refinements were developed from JESS socioeconomic surveys of 1986-87 for the reservoir area. The total population for 1984 was assumed to be 850,000, including 500,000 in the core area defined by AHT—the narrow strip along the river below the proposed dam. Of these 500,000 people, 345,000 were involved in agriculture. The number of people living in tertiary villages or larger in this core area was 300,000 (Table V.A.1). In the Gedo Region (location of the proposed reservoir), the population was about 400,000 in 1984. About 10,000 of these people were agropastoralists who lived in scattered communities within 0.5 km of the river, and it was estimated that another 3,000 lived in the five small towns along the river, excluding refugees in the camps.

Table V.A.1. SETTLED POPULATION IN CORE AREA OF JUBBA RIVER VALLEY, 1984.

DISTRICT	POPULATION
Kismaayo	54,800
Jamaame	80,200
Jilib	86,200
Bu'aale	26,100
Saakow	12,200
Baardheere	40,100
TOTAL	296,600

Projections to the year 2017 (AHT 1985) assumed a rough doubling of the 1984 population, thus a total of 1.7 million for the entire valley. These figures were generally based on a 2.7-percent population increase, except for the Jilib District which was assumed to grow at 6 percent due to the various development projects.

Detailed population figures were arbitrarily deduced from the larger aggregate figures, with important modifications in the reservoir area, based on preliminary reports from JESS field teams.

B. Predicted Water Quality in River

The method of predicting water quality available for irrigation and general agricultural development was to use the previously predicted water quality of the discharges from the dam, and then estimate conditions in the river and irrigation systems in the agricultural zone on both sides of the river—especially the withdrawals and returns of irrigated water in the valley below the dam.

1. General Program of Predictive Model Analyses

The predictive analysis for water quality in the river was based on estimations of the EC25 for dry season conditions in the year 2000, five years after construction of the dam. The expected flows were simulated for a drought condition expected once every five years. This situation would govern the types of crops which could be safely planted, expecting a normal harvest at least four years out of five.

Because the quality of the river water was extremely sensitive to the drainage return rate of the irrigation flow, this value was varied from 10 percent to 30 percent in the simulations, to assess the effects of intensive irrigation practices. In addition, the value of increased releases from the reservoir during the dry season was simulated, to evaluate this method of improving water quality and thus crop alternatives.

2. Assumed Conditions for Predictive Analyses

Conditions simulated in the modeling reflected the most current general plans for valley development obtained informally from Ministry officials and the AHT group developing the master plan.

Released Flow and EC25 from Dam

Based on information from AHT for the year 2000, under an improved mechanism for reservoir operation (AHT informal memo of November 1987), the expected mean release from the dam for a dry year

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would be 140 cumecs, with the discharge dropping to 131 cumecs in the driest month. EC25 of the reservoir release was estimated to range from 350-524 micromhos/cm in the previous section on reservoir analysis.

In the AHT memo, it was estimated that within five years after completion of the dam, consumption of water due to irrigation, evaporation, domestic, and livestock uses would reduce the river flow at the ocean to 20 cumecs in a dry month—a net diversion from the river below the dam of 111 cumecs.

Irrigation and Other Diversions

The location of future diversions from the river was needed for the model analysis. Estimating diversion for irrigation and other reasons in proportion to the expected area under cultivation by the time of dam completion (AHT, January 1985, p. 128), it was projected that 20 percent of the diversion from the river would occur in the upper portion from Baardheere to Fanoole Barrage, and 80 percent from Fanoole Barrage to the ocean. For the five individual reaches of the model, these diversions were then apportioned according to the length of the reach.

Drainage Return Flows

To simulate low-intensity irrigation, a return rate of 10 percent for drains and subsurface infiltration to the river was evaluated. However, to simulate the higher return rates, such as those in the Fanoole Rice Project where extra leaching water was applied to a double rice-crop and deep drains were pumped continually to the river to aid the leaching process and prevent salinization and waterlogging of the rice fields, a 30 percent return rate was simulated. The EC25 of the return water in the lower valley was estimated at 2,500 micromhos/cm, based on 1986-87 measurements in Fanoole drain. However, in the valley above Fanoole Barrage, an EC25 of 1,500 micromhos/cm was used based on the 1986 calibration results.

3. Structure of Model

The model of 18 reaches used in the 1986 calibration analyses was simplified for the predictive analysis of the year 2000. The river was divided into only five reaches and overland runoff was neglected for dry season conditions. Groundwater infiltration was also neglected as its effect was included in the simulated drainage returns.

Five Reaches

The reaches used in the predictive analysis went from Baardheere Dam to Fanoole Barrage, Fanoole drain, Mogambo pumps, the tidal limit, and then to the ocean (Figure V.B.1). These divided the river by the points of major changes in flow and water quality.

Irrigation and Drainage Flows

The diversion and return flows calculated for each reach were based on the distance in kilometers between stations on the reach. The majority of diversions occurred in the lower valley. The structure of the model placed the return flows at the top of the following reach and diverted flows at the bottom, although in fact, they may be distributed throughout the reach.

Diversions and return flows were calculated for Case 1 which simulated intensive irrigation, deep drains and a 30 percent return flow, and for Case 2 which simulated more traditional, small-scale irrigation and a 10 percent return flow. The calculations were made as follows:

Case 1. Intensive irrigation
with 30 percent return flows.

The simulated releases from the dam were 140 cumecs, and 200 cumecs, to evaluate extra releases. For dam releases of 140 cumecs, flow reaching the ocean was set at 20 cumecs, following AHT estimates, due to diversions for intensive irrigation development and other downstream needs. It was assumed that half of the diversions were used for intensive irrigation, and 30 percent of this diverted flow was returned to the river via pumping of deep drains. Thus, the total diversion for intensive irrigation was 70.5 cumecs and return flow was 21 cumecs. The other half of the diversions were for domestic uses and irrigation systems from which there were no drainage returns to the river. Evaporation along the river course was small and therefore neglected. Twenty percent of the diversion (28.2 cumecs) was made in the first reach, from Baardheere Dam to Fanoole Barrage. The return flow of 4.2 cumecs from Reach 1 was added after Fanoole Barrage. The remaining 80 percent of the diversions was apportioned in the lower four reaches by the length of the reach (Table V.A.2).

The EC25 in the dam release was evaluated for 350 and 524 micromhos/cm, covering the range predicted by the reservoir simulation for a dry year. A supplemented release rate of 200 cumecs was also

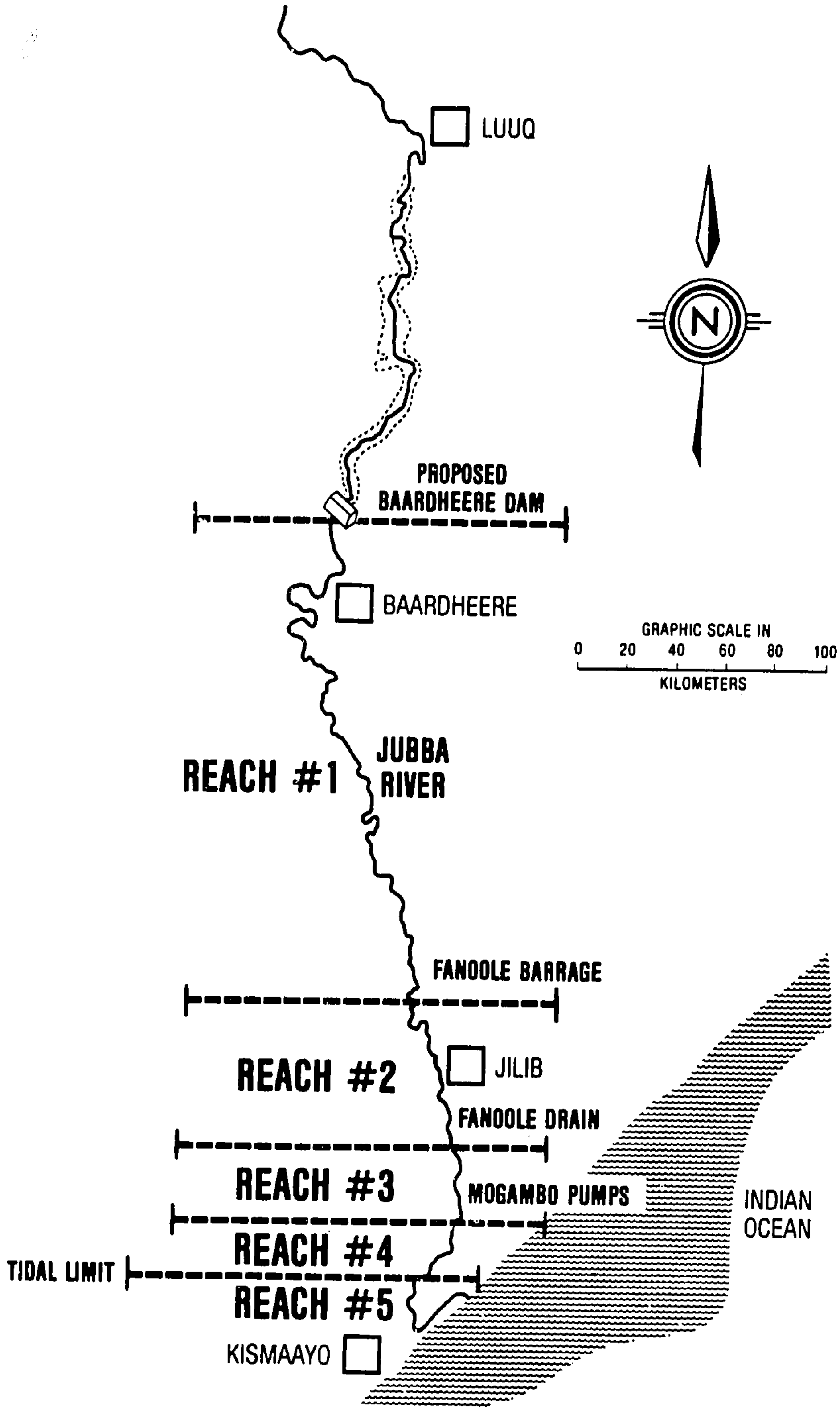

Figure V.B.1
Schematic Showing Location Of Stations For Water Quality Model Of Jubba River

Table V.A.2. CASE 1 - DIVERTED AND RETURN FLOWS BELOW BAARDHEERE DAM FOR INTENSIVE IRRIGATION DEVELOPMENT.

Diversion and 30 percent return flows utilized in water quality simulation for dry years, projected to year 2000

Reach No.	from/to	LENGTH km	[illegible]SION [illegible]cs	RETURN FLOW cumecs
	Baardheere Dam		[illegible]	
1		294		4.2
	Fanoole Barrage		37.3	
2		45		5.6
	Fanoole Drain		25.7	
3		31		3.9
	Mogambo Pumps		20.7	
4		25		3.1
	Tidal Limit		29.1	
5		35		4.2
	Ocean			
TOTALS		430	141.0	21.0

evaluated for the simulation with 524 micromhos/cm to determine how much of an extra release from the reservoir would be needed to protect the water quality downstream.

Case 2. Traditional irrigation with 10 percent return flows

As in Case 1, releases at the dam of 140 cumecs with EC25 of 524 were simulated—the mean flow and worst monthly mean conductivity for a dry year. It was similarly assumed that the flow reaching the ocean was only 20 cumecs. The same amount of unreturned flow was used as in Case 1, 70.5 cumecs. The remaining flow diversion to irrigation systems with 10 percent drainage returned to the river was again apportioned 20 percent in the first reach and 80 percent in the next four, according to length of the reach (Table V.A.3).

Table V.A.3. CASE 2 - DIVERTED AND RETURN FLOWS BELOW BAARDHEERE DAM FOR TRADITIONAL IRRIGATION DEVELOPMENT.

Diversion and 10 percent return flows utilized in water-quality simulation for dry years, projected to year 2000

Reach No.	from/to	LENGTH	DIVERSION km	RETURN FLOW cumecs
	Baardheere Dam		25.1	
1		294		1.2
	Fanoole Barrage		[illegible]	
2		45		1.7
	Fanoole Drain		22.9	
3		31		1.1
	Mogambo Pumps		18.5	
4		25		0.9
	Tidal Limit		25.8	
5		35		1.3
	Ocean			
TOTALS		430	125.5	6.2

4. Predictions for Year 2000

An important limitation on agriculture in the lower valley would be the salinity of the river during the dry years. If EC25 were to exceed 750 micromhos/cm during this time, the water would exceed Class II irrigation standards of the USDA and be unfit for sugarcane irrigation and other sensitive crops. There would be three sources of saline water which could cause this high conductivity: saline return flows to the river from drains, saline surge of a density current in the reservoir during the early gu' season, and ocean intrusion in the lower 35 km of the river. The situations examined in simulation of the year 2000 covered the range of expected conditions under current plans, as well as the impact of changes in the drainage return rate and minimum flow releases from the dam during dry seasons.

Dry Year

The model simulation of water quality predicted that within five years after completing the dam, with the use of intensive irrigation practices resulting in drainage return rates to the river of 30 percent or more, the river would reach EC25 values over 750 micromhos/cm from Jamaame downstream to the ocean, for several months (Figure V.B.2). The entire river would exceed that value during one month in the early gu' season due to density currents bringing highly conductive waters directly to the dam outlets. Furthermore, depletion of the river flow below 20 cumecs at the ocean because of irrigation diversions would allow the ocean to intrude 15-20 km upstream, causing severe damage to crops in this lower reach whenever high tides occurred during the jiilaal season.

If low-intensity irrigation regimes were used, thus developing only a 10 percent drainage return rate, the simulation for the year 2000 predicted that EC25 would remain below 750 micromhos/m throughout the entire reach of the river, except for two incidents (Figure V.B.3). These adverse situations would occur during one month in the early gu' when the density current in the reservoir would release a surge of highly saline water at the dam outlets, and when the high tides intruded during the jiilaal season.

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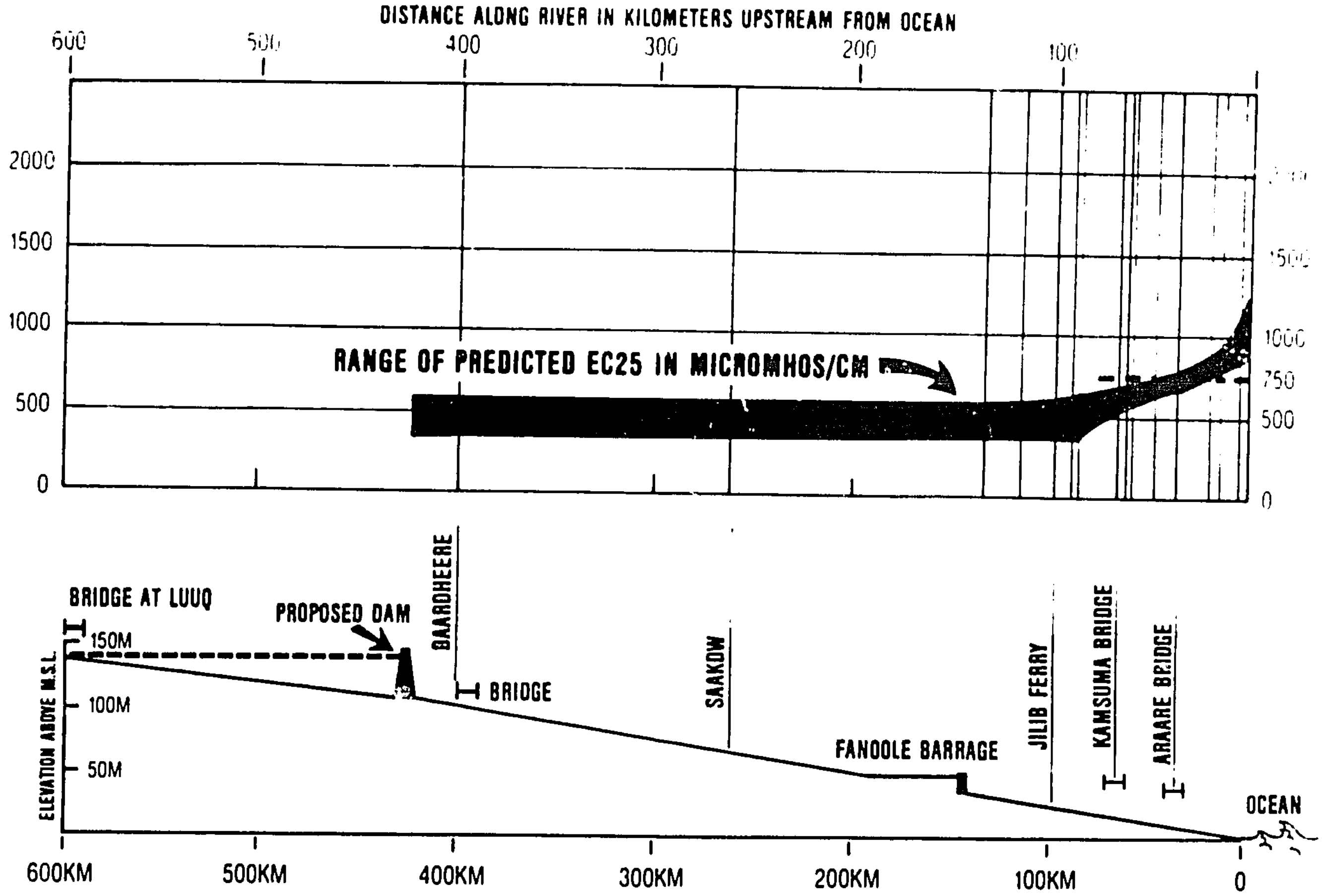

Figure V.B.2
Predicted Conductivity Profile For Jubba River

Case 1/Year 2000/Release At Dam=140 Cumecs/30% Return Flow

Simulations for conductivity under 5 year drought conditions in river with 30% irrigation return rates, for expected annual range in EC25 at dam.

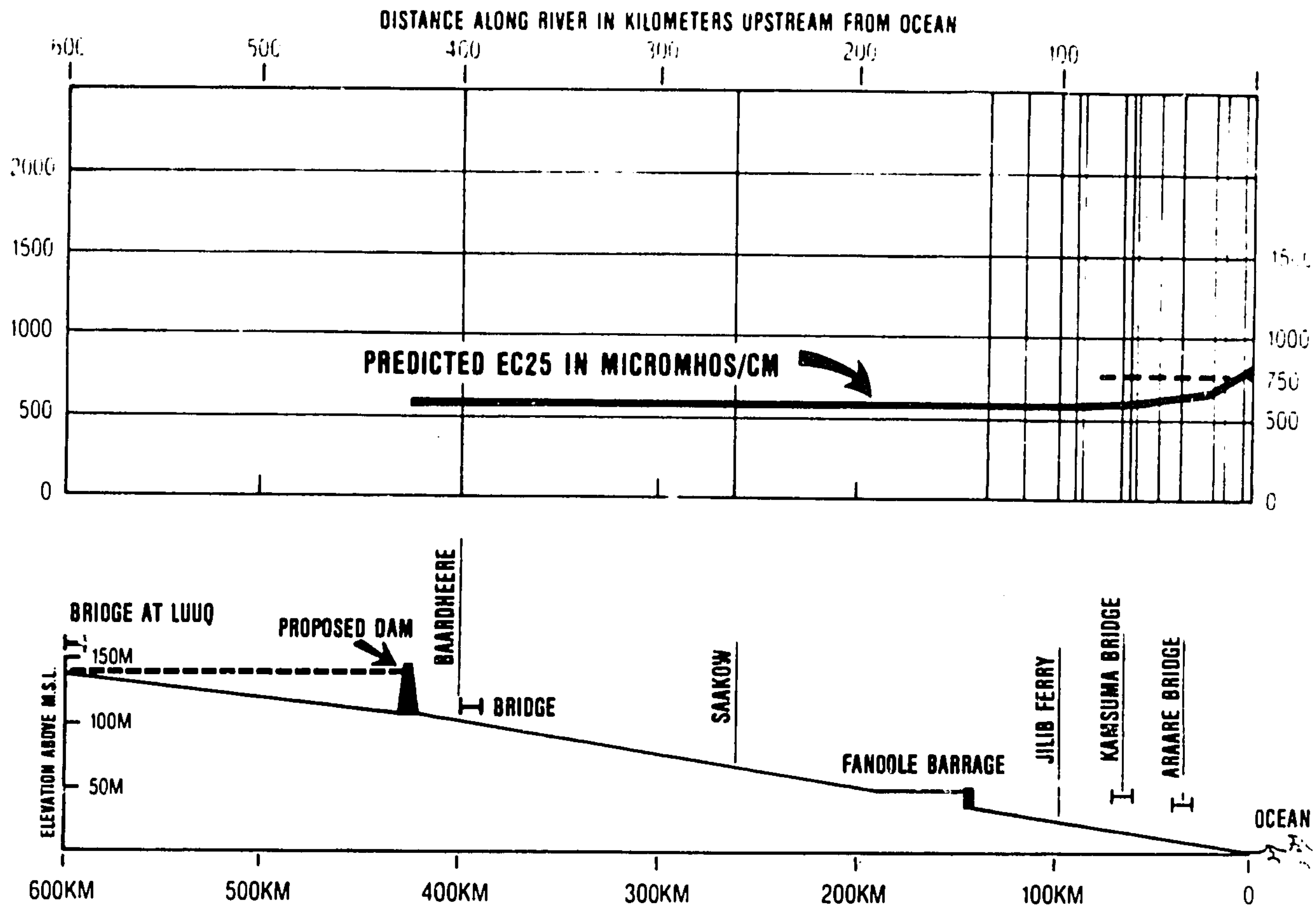

Figure V.B.3
Predicted Conductivity Profile For Jubba River

Case 2/Year 2000/Release At Dam=140 Cumecs/10% Return Flow

Simulation for conductivity under 5 year drought conditions in river with 10% irrigation return rates.

Minimum Release of 200 Cumecs

If a minimum flow release of 200 cumecs were maintained at the dam during the dry seasons, the model simulation predicted that the dilution would hardly be sufficient to lower the EC25 in the river below 750 micromhos/cm, with a high drainage return rate of 30 percent (Figure V.B.4). However, this flow would prevent the ocean from intruding at high tides, and probably sufficiently dilute the salinity surge from the density current to keep the conductivity within Class II limits. However, such a flow could seldom be maintained at the dam during dry years. Therefore, this method is not feasible for combatting the increased salinity to be expected from intensive irrigation in the lower valley.

Intensive irrigation with 30 percent return flow to the river was clearly the option to be avoided. Moreover, the generally high conductivity of the entire river from the proposed dam to the ocean, and the sensitivity of the conductivity predictions in the reservoir and river to the assumptions about the size of the mixing zone in the reservoir, indicated that there would be many instances when the entire river might be quite close to the unacceptable limit of 750 micromhos/cm. This precarious condition should also be avoided. The most logical way to do so would be to emphasize low-intensity irrigation—the type presently practiced in dhesheegs, smallholder farms, and cooperatives such as Somaltex.

5. Salt in Groundwater

Because the dam would moderate the annual floods and decrease the width of the floodplain that recharges the groundwater, there would be a change in quantity and quality of groundwater as well as in those shallow wells that use the upper lens of sweet water resulting from the annual floods.

Expected salinity of the groundwater has importance beyond its impact on agriculture as it directly affects the safest source of drinking water for the future population of the valley. In 1987, the riverbanks from Luuq to Baardheere and about halfway down to Saakow were high enough to prevent extensive flooding beyond 500 m from the river. There was little recharge of the groundwater from the gu' and deyr floods, except for the aquifer immediately below the flowing river. The deep, salty groundwater in this area was of ancient marine origin and undrinkable. Consequently, about 90 percent of wells drilled in this area were too salty for any human or animal use. In *toggas* or depressions in this area where the soil was extra sandy, there was a shallow layer of rainwater near the surface after the rains. This was occasionally extracted via shallow wells. However, the deeper the wells went, the saltier they became.

From Saakow to the equator, riverbanks were lower and periodic floods could extend over a band several kilometers wide on each bank of the river. In areas where the soil was sandy, this flood water percolated down into the aquifer and rested as a thin, fresh water layer on top of the salty groundwater. The two layers did not mix because of density differences.

Wells in Jilib, Jamaame, and other towns along the river extracted sweet water from this layer, but it was depleted in dry years, as in April 1987 when the gu' flood was delayed after a year of low rainfall and riverflow.

From the equator to the coast, sweet water was considerably more available in the aquifer because of higher rainfall, sandier soil which allowed more rapid percolation, and the confluence with aquifers from Dhesheeg Waamo and the Shabeelle Valley. The flatter riverbank allowed for wider floodplains; thus, the layer of freshwater over the salty layer was broader and contained more flow than in any other part of the valley.

Regulation of the river by the proposed Baardheere Dam would reverse the geographical pattern of flooding in the valley with significant changes in availability of sweet water in the aquifer. In the central, wide portion of the flooded reservoir around Buurdhuubo, fresh water would perch on top of the fossil, salty water and could be used for community supplies around the reservoir shores. The water could be extracted from shallow wells and trapped in sandy beds of tributary streams or *toggas*, using underground barriers.

In the middle valley, the reverse would occur and existing wells away from the river would deliver less sweet water as the normal recharge of their aquifers would be reduced by elimination of the annual floods, turning salty much earlier in the jiilaal dry season.

Along the coast near Goob Weyn and Kismaayo, there would probably be less impact from the dam as the aquifer in this area also receives sweet water recharge from Shabeelle River and Dhesheeg Waamo.

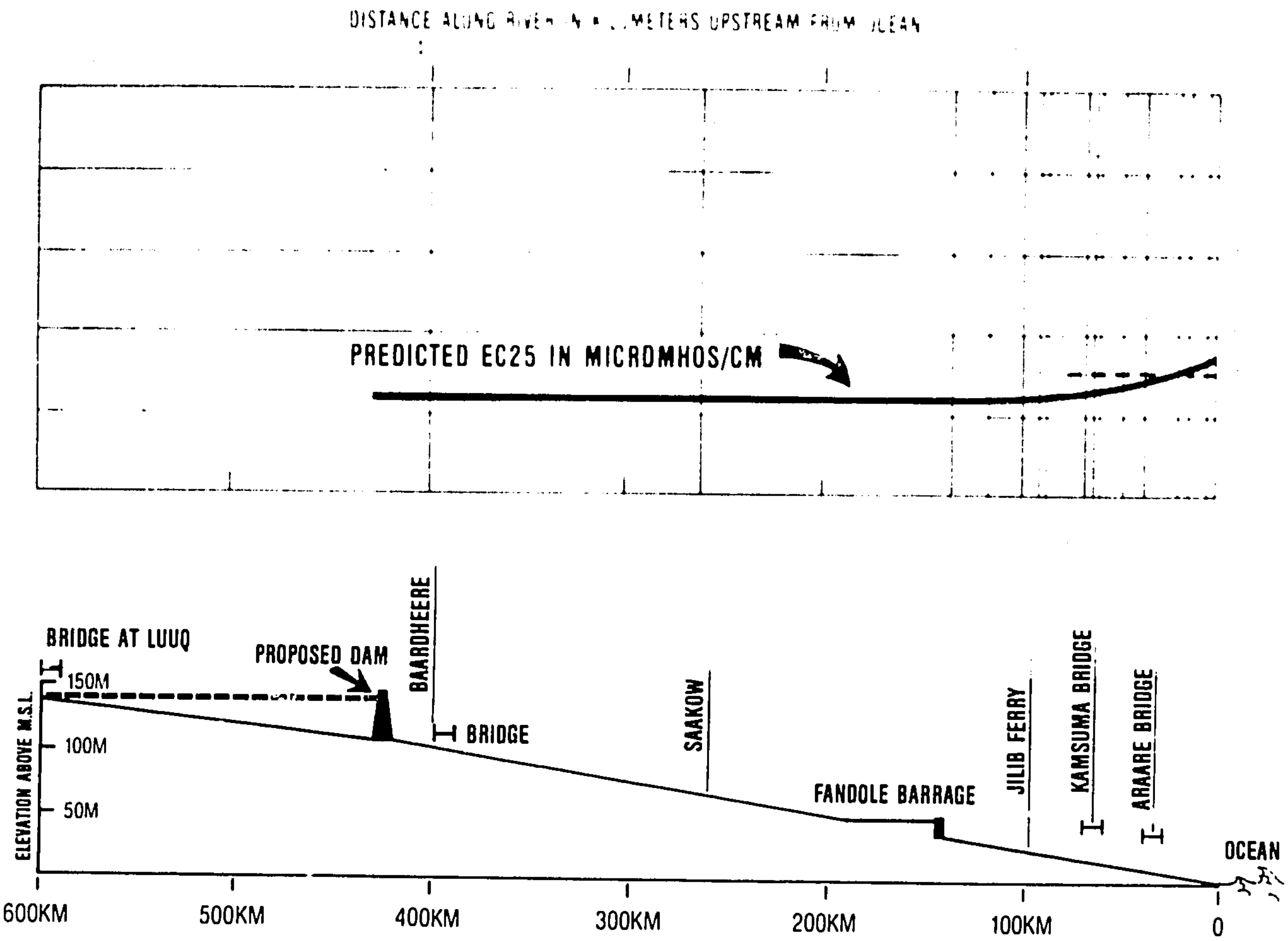

Figure V.B.4
Predicted Conductivity Profile For Jubba River

Case 200/Year 2000/Release At Dam=200 Cumecs/30% Return Flow

Simulation for conductivity under 5 year drought conditions in river with 30% irrigation return rates, and for 200 cumec base flow

Experience in the irrigated portions of the Shabeelle River indicated the likely and normal future changes in the groundwater of the lower Jubba Valley (Lahmeyer 1986; Hussein and Ahmed 1984). At the time of the field surveys, the depth to regional groundwater was 10 m in the strip close to the Jubba River near Jilib and Mogambo, where existing wells have been observed. These wells were in the mound of recharge coming from the river. Further away from the river, the water table was probably lower—perhaps down to 20 m, rising slightly after large-scale flooding.

Closure of Baardheere Dam would significantly reduce seasonal floods which cover the wide floodplains in the middle and lower valleys, resulting in a net recession of the regional groundwater surface. However, the localized mound under the riverbed would rise because river flow and infiltration would then be sustained during the seasons when the river previously went dry.

Another consequence of constructing the dam would be increases in extent and intensity of irrigation in the valley, and eventually in local rising of the groundwater under these irrigation schemes. Those schemes growing crops that use heavy applications of water such as bananas, rice, and sugar, would experience the largest rises–probably coming within 1 or 2 m of the surface after a decade or so of continuous irrigation. In projects with well-developed deep drainage systems, such as the Fanoole Rice Project, rising of the groundwater surface would be retarded.

An undesirable consequence of the local rise in the water table would be the upward flow of water to the surface by capillary action, resulting in waterlogging and salinization of the surface soil. In order to combat this effect, extensive deep drainage systems would be needed to carry away the additional flow needed to leach these salts downward. These practices were successfully used in the Fanoole Project but have not yet been adopted in the Jubba Sugar or Mogambo Projects.

Close to the river, within the mound of recharge contributed directly from the riverbed, the amount of groundwater would increase and the water table would rise. The quality of this water would be satisfactory for domestic use, following the moderate quality in the river, with EC25 varying between 500-600 micromhos/cm in the upper and middle valleys. The quality in the lower valley would be more saline due to increasing salinity of the river from return drainage water. However, it would not exceed desirable limits due to the large subsurface tributaries entering from the Shabeelle and Waamo drainage systems near the equator.

In the communities far removed from the riverbed, which depend on shallow wells for their domestic water supply, closure of the dam and subsequent drop in the regional groundwater would require pumping or drawing water from a greater depth and perhaps, deepening of the wells. The salinity of the water would also increase due to reductions in the recharge from annual floods. However, most of the towns and wells are presently located quite close to the river.

Agricultural laborers living in or near intensively irrigated systems such as the Fanoole or Mogambo Projects, would find increasingly saline water in their shallow wells due to the leaching of salts from alkaline soils by the irrigation waters–especially if the wells are outside of the river recharge mound. A well in the Mogambo Project, which did not have a deep drainage system, had water with EC25 exceeding 4,000 mg/l in 1986, and is expected to rise with increased cropping intensity. Although such wells provide adequate amounts of water at shallow depths, their salinity severely exceeds the recommended limits for human consumption, and even for livestock use. The extent of this problem would expand after completion of the dam. However, present dangerous concentrations of arsenic in such wells should decrease with construction of the dam, due to long-term mixing of the arsenic which comes in during the gu' season.

Because of the rise in local groundwater under and around the intensively irrigated agricultural schemes, it is clear that the yield and salinity of drainage water would rise significantly as the remedial measures of increased leaching and drainage are instituted to counteract the rising water table and soil salinization. This impact must be incorporated in projections on future soil and water salinity. The extent of these effects can be estimated from recent studies on the Shabeelle River, and rivers in similar geographic regions in other countries (Lahmeyer 1986).

Analysis of future changes in drainage and salinity should also recognize the separation of drainage patterns into those of the Mogambo Irrigation Project and Jubba Sugar Project which both drain into the marine plain west of the Jubba River, as contrasted with the Fanoole Rice Project and Somalfruit banana schemes which discharge directly to the Jubba River. Deep drainage systems for leaching salt and preventing waterlogging would require pumping, as opposed to the present gravity drainage to the marine plain in the Jubba Sugar Project.

Existing high salt content of the Jubba River in reaches passing through irrigated projects, indicated that expanded and unrestricted irrigation would eventually raise the conductivity of groundwater in the lower valley.

As the area of rice cultivation in the Fanoole scheme is increased from 500 ha to 8,000 ha, the required irrigation water would also increase by a factor of 16, resulting in 3,000 additional tons of sodium and 3,000 tons of chloride reaching the drains, river, and groundwater during the early years of operation.

Expansion of towns and new wells would impose an increasing drain on the aquifer, depleting the fresh water levels more rapidly. Thus, population increases in the lower valley would cause decreased per capita availability of the safer well water, resulting in increased water-associated diseases—especially diarrheal diseases such as cholera and hepatitis—due to the necessity to use increased amounts of surface water for domestic purposes.

6. Ocean Intrusion

In 1987, the maximum intrusion of the ocean up the riverbed occurred at the end of the jiilaal dry season around April. In exceptionally dry years, at maximum high tides, the ocean would reach almost to Buulo Guduud (about 40 km inland). If river flow at this time is zero, the salt would be at normal ocean concentration with chlorides near 18,000 mg/l. However, if there is substantial flow, the ocean would be driven back all the way to Goob Weyn, downstream of all agricultural activities. Flows of 90 cumecs were adequate to drive the salt out in June 1986. Full development of irrigation in the lower valley would increase irrigation withdrawal from the river, reducing the flow at the ocean to only 20 cumecs within five years after completion of the dam (AHT 1987). This may still be sufficient to hold back the ocean intrusion, but under lower flows, the ocean could intrude at least 30 km upstream.

Previous reports of salinity problems from ocean intrusion in irrigation water above Buulo Guduud were incorrect. High salinity in the river occurred during the end of the jiilaal dry period in March and April due to infiltration and drainage from the irrigation projects such as Fanoole Rice Project. Conductivity of this drainage water was between 1,400 and 2,500 micromhos/cm in April 1987, containing salts leached from alkaline soils. These salts were not due to ocean intrusion.

Provision of a minimum release from the dam would eliminate problems for the Kismaayo drinking water system and for agricultural users upstream of Goob Weyn. However, if irrigation development is allowed to divert water from the river and reduce the flow at the ocean below 20-90 cumecs, ocean intrusion to Yontooy would occur at high tides.

7. Fertilizers and Nutrients

An important effect of the impoundment on ecology of the river would be a rise in biological productivity throughout the year. During 1987, algal productivity was severely limited by the turbidity of the two floods which limited the depth of the photic zone for most of the year. The river water clarified significantly only in the dry jiilaal season, but productivity was again limited at that time by complete absence of phosphorus nutrients in solution, and perhaps, also by the high salinity of 1,500-2,000 micromhos/cm which would retard organisms accustomed to the lower mean annual salinity of 472 micromhos/cm.

By providing a large mixing basin for the river flow, the impoundment would eliminate both of these adverse effects on productivity. Sediments would settle in the reservoir, increasing the depth of the photic zone during most of the year. During the normally clear jiilaal season, sufficient phosphorus would be present in the mixed discharge flowing from the turbines. It was estimated that a stable secchi disk depth of 50-100 cm would occur in the river throughout the year, compared to the observed mean of 9-31 cm in the lower valley.

Expansion and intensification of irrigated agriculture in the Jubba River Valley from the 12,000 ha in 1986, would cause proportional increases of runoff, carrying nutrients to the drains and the river. If the irrigated area expands to 20,000 ha by 1990 after the dam is finished, the load of 4,000 tons of fertilizer in 1986 would increase to about 7,500 tons by 1990. By the year 2000, if irrigation expands to 50,000 ha, the amount of applied fertilizer would reach 17,000 tons. Existing phosphate and nitrate in the lower reaches of the Jubba River were 0.6 mg/l and 1.1 mg/l or higher, already sufficient to cause overgrowths of aquatic vegetation. Thus, heavy fertilizer applications would cause increases in aquatic vegetation in drains and perhaps, in the Jubba River.

8. Trace Elements

The sporadic occurrence of arsenic in samples from the river, drains, and even a shallow well in the Mogambo Irrigation Project made it somewhat difficult to predict what would happen after construction of the dam. The high values of arsenic were found only in late May and June, just before and during the gu' flood. At all other times of the year, concentrations were below 0.05 mg/l and acceptable for human consumption.

The source of the arsenic was probably the drainage basin around Luuq, as this seemed to be the source of most runoff in the early gu' floods. Arsenic in the Mogambo well was probably brought into the groundwater by the applied irrigation flow. Therefore, it was estimated that the mixing and diluting effect of the reservoir should lower the concentration in the river downstream to a fairly uniform level, equal to the observed annual mean—about 0.03 mg/l (Table III.A.8). This concentration is not dangerous for human consumption.

9. Soil Salinity

In the area of the Fanoole Project, soil was clay-sand with high concentrations of sodium. Presumably, this salinity was built up from annual floods and poor drainage. The project management got rid of it with heavy irrigation and by plowing under riceplants after harvest, as well as improving drainage. By applying excess irrigation water and pumping drains continually to raise flow rates in the drainage system, they leached out sodium from the worst soils in three years. They also bypassed the salty flush at the beginning of the gu' flood, thus water applied to fields was always sweet.

In the Jubba Sugar Project, they originally planned deep drains for fear of salt build-up. Since there was no initial problem (due to unplanned low irrigation rates), they installed only shallow drains. However, with steady river flow, this could create problems as they would begin to irrigate heavily and salts would increase in drainage water.

The dam would cause an increase in the mean salt concentrations in the flow during most months because salt surges would be trapped in the reservoir and mixed with the total flow. Also, as the irrigated area expands and competition for water increases, excess water for leaching would not be available. A salt balance would have to be carefully sought and monitored.

10. Salinity Problems in Dhesheegs

Dhesheegs had clay or silt soils which held annual floods for several months. Water loss was by evapotranspiration with very little chance for downward leaching, so salt must have been building up gradually in topsoils. Abandoned dhesheegs were probably too salty due to long agricultural use or especially tight soils. It is likely that high salinity was the main cause for abandoning dhesheegs. Therefore, crops in dhesheegs must be limited to those which are salt-tolerant.

After river regulation, the amount of water reaching improved dhesheegs should be more regular and would probably contain less salt, if the initial salty wave in the gu' flood were eliminated. The life of dhesheegs should be prolonged, compared to present usage. Deep drains and pumping systems could improve soils and extend their life even more.

11. Salinity Problems in Banana Fields

Although salt problems occurred in some of the Somalfruit banana fields, many of them had drainage pumps discharging into the river which made it possible to extract drainage water fast enough to leach salt downward. However, lack of fuel could negate the benefits from this drainage system.

If electricity is provided for drainage pumps, the salt problem should be easier to control. Also, dangerous peaking of salt concentrations in the river at the end of dry jiilaal season and in the first floods of gu' season would be avoided when the dam is completed, improving irrigation of the bananas.

12. Salinity, Snails, and Mosquitos

From field studies in the Dez Irrigation System in Iran, it was observed that *Bulinus truncatus* did not tolerate total dissolved solids concentrations above 2,000 mg/l, and did poorly in terms of reproduction and survival, at 1,300 mg/l (Chu, Massoud, and Arfaa 1968).

These limits corresponded roughly to EC25 of 2,500 and 3,000 micromhos/cm, respectively. These limits were seldom reached in the Jubba River for the period of records. Even in Fanoole Drain, the EC25 only reached 2,500 for a short time in March 1987. Therefore, distribution of bilharzia

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snails is unlikely to be seriously inhibited in the future.

It is also unlikely that populations of malaria mosquitos in the reservoir, river or irrigation systems would be significantly changed by the expected salinity changes.

C. Agricultural Development and Health Concerns

Significant potential exists for expansion of irrigated agriculture in the Jubba Valley after construction of Baardheere Dam. In addition to expanding the area of presently irrigated crops, it would be possible to intensify cropping in existing projects by adding new crops into the present rotations. It would also be possible to start completely new projects, with a variety of crops.

If these expansions and intensifications are agriculturally sound, they may produce significant economic benefits for people in the valley. However, the increased application of water for these crops would usually carry a health risk because of several water-associated diseases. The impact on health caused by crop intensification has been documented in the Nile Valley and other places in Africa (Gaddal 1985; Jobin 1987). Severe and widespread problems have been generated frequently enough to indicate that plans for agricultural intensification should not be made in the tropics without considering health implications (FAO/UNEP/WHO 1987).

Intensified cropping and the consequent increase in irrigation flows and lengthening of the irrigation season would provide larger and more favorable habitats for bilharzia snails, malaria mosquitos, and other insects which transmit serious human diseases. Heavier growths of aquatic vegetation in reservoirs and canals due to longer irrigation seasons would also create more favorable conditions for these snails and insects.

The agricultural population around a project would also increase significantly if cropping is intensified, because of additional labor required. This population growth would reduce the available safe water per person for domestic use, thus increasing the death rate from diarrhea and other diseases dependent on adequate safe water and sanitation.

Agricultural practices and increased maintenance requirements for the irrigation canals and drainage system would force laborers to spend more time immersed in water, directly increasing the rate of bilharzia transmission. Important examples of this would be the additional water contact during weeding of flooded rice fields and the large amount of water contact by crews removing excessive aquatic vegetation. The increased vegetation usually would occur in canals operated continuously, without the usual dry period associated with simple seasonal irrigation.

An analysis was conducted on potential cropping systems, incorporating the elements of labor and water requirements. In this analysis, the crops and agricultural practices being considered in the development of the Jubba Valley were ranked in terms of adverse health risks, as a guide for agricultural planners. Dhesheegs were considered separately from irrigated or rainfed crops.

1. Irrigated or Rainfed Projects

For the irrigated crops, a statistical comparison was developed in this analysis, based on water-use and labor requirements. It indicated that cultivation of certain crops would pose greater risks to health. This statistical comparison was developed by formulating a Malaria Index and a Bilharzia Index which were used to quantify the risks of disease from various factors in the agricultural operations.

The Malaria Index was developed for the Jubba Valley by multiplying the labor requirements for a given cropping practice by the total depth of water applied for that crop. By multiplying the annual water requirement for the crop (C) times the person-years of labor required (D), this roughly indicated the relative potential for malaria transmission by including the influence of the numbers of mosquitos affected by habitats created from irrigation water, and including the biting frequency which depends on number of people as well. The Index was divided by 1,000 to simplify it.

The highest Malaria Index of 130, and thus the highest risk of transmission, would occur for double-cropping of rice with semi-mechanization (Table V.C.1). Bananas would rank second with a Malaria Index of 100, followed by single-crop rice with an Index of 58. Cotton would have the lowest Index of 7.

A high Malaria Index, such as E=130 for cultivation of double-cropped rice with only slight mechanization, reflected the impact of waterlogged fields being irrigated all year long, full of myriad laborers who plant, transplant, weed, and continually maintain the field canals, ditches, and drains. If these

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Table V.C.1. RELATIVE MALARIA RISKS FOR VARIOUS CROPS.

Ranking of crops and agricultural practices regarding intensity of malaria transmission for proposed projects in Jubba River Valley. Agricultural data from AHT, 1985.

PARAMETERS	BANANAS	SUGAR CANE	CITRUS FRUITS	RICE			COTTON	SESAME WITH MAIZE
				DOUBLE CROP*	DOUBLE CROP**	SINGLE CROP**		
A. Cropping Intensity	100%	100%	100%	150%	150%	100%	100%	200%
B. Water Required in Meters per Season	3.35	3.35	2.95	1.95	1.95	1.95	2.05	1.38
C. Water Required in Meters per Year (C=A*B)	3.35	3.35	2.95	2.90	2.90	1.95	2.05	2.76
D. Labor Required in person-years by 2017	30,000	13,500	11,500	11,250	45,000	30,000	3,500	9,500
E. Index for Malaria (E = C*D/1000)	100	45	34	33	130	58	7	26
F. RANK for MALARIA INDEX	2	4	5	6	1	3	8	7

* *mechanized*
** *semi-mechanized*

Table V.C.2. RELATIVE BILHARZIA RISKS FOR VARIOUS CROPS.

Ranking of crops and agricultural practices regarding intensity of Bilharzia transmission for proposed projects in Jubba River Valley. Agricultural Data from AHT, 1985.

PARAMETERS	BANANAS	SUGAR CANE	CITRUS FRUITS	RICE			COTTON	SESAME WITH MAIZE
				DOUBLE CROP*	DOUBLE CROP**	SINGLE CROP**		
A. Cropping Intensity	100%	100%	100%	150%	150%	100%	100%	200%
B. Water Required in Meters per Season	3.35	3.35	2.95	1.95	1.95	1.95	2.05	1.38
C. Water Required in Meters per Year (C=A*B)	3.35	3.35	2.95	2.92	2.92	1.95	2.05	2.76
D. Labor Required in person-years by 2017	30,000	13,500	11,500	11,250	45,000	30,000	3,500	9,500
E. Water Contact Ration Compared to Rice	0.8	0.2	0.2	2	2	1	0.5	0.5
F. Index for Bilharzia (F = C*D*E/1000)	80	9	7	65	263	60	4	13
G. RANK for BILHARZIA INDEX	2	6	7	3	1	4	8	5

* *mechanized*
** *semi-mechanized*

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laborers live nearby, then they would be attacked in their sleep by the hordes of mosquitos which would breed in standing water around the rice fields.

By mechanizing the crop-rearing practices, the number of laborers required would be reduced to one quarter of the previous value, and thus, the Malaria Index would also fall to 33. The Malaria Index has little numerical significance, but using it to rank the two cropping practices showed clearly that the mechanized rice farming would be much safer (Table V.C.1).

The Bilharzia Index was computed in a fashion similar to that for malaria, but including multiplication by a water contact ratio. This was based on a subjective comparison of the amount of human contact with water required for that crop, using rice growing for the reference amount of contact.

The Bilharzia Index included the amount of water and the number of laborers, items also found in the Malaria Index. However, it included a third factor: the hours of contact by the laborers with irrigation water (Table V.C.2). Since this is the behavior which results in people becoming infected with bilharzia, it must be added to the other basic epidemiological factors. A constant of 1.0 was used for the total amount of water contact by one person in cultivation of a single rice crop. Other cropping systems were assigned a water contact ratio by estimating the amount of water contact for cultivation of that crop relative to rice cultivation; thus, the ratio for double-cropped rice would be 2. However, the ratio for citrus crops would be only 0.2, as very little water contact would be required in their cultivation.

The Bilharzia Index again indicated that double-cropped rice was the most dangerous to human health, but this risk could be substantially reduced by mechanization (Table V.C.2). The crops that would rank highest for bilharzia risk were double-cropped rice, bananas, and single-cropped rice, respectively. The remaining crops would have a slightly different ranking than that for malaria, with cotton and citrus fruits being ranked last.

The Bilharzia Index for cotton was the lowest, as it was for malaria. This low risk was solely because cotton in the Jubba Valley is rainfed, not irrigated. If it were irrigated, this would increase labor requirements and water contact, causing a large rise in the indices.

Sesame with maize, also would rank low in health risk because of low water and labor requirements. If planners consider rotation of several crops in the same field, the indices should be added together to estimate the total disease risk. These tables could be expanded in various combinations by agricultural planners exploring a larger variety of cropping alternatives.

From the above comparison, it appeared likely that intensive agricultural development of the Jubba Valley would eventually result in conditions quite similar to the Shabeelle Valley, suitable for stable populations of bilharzia snails and more widespread transmission of bilharzia. The present pattern of two transmission peaks would probably remain, but transmission during June and July would become more intense in the Jubba Valley due to the larger amount of seepage areas around irrigation systems.

It also appeared that Fanoole Main Canal was a major transmission source for bilharzia during the months of February to April because of the snail infestation and proximity of the canal to the town of Jilib. Also, seepage areas along the canal contained bilharzia snails and were probably important transmission sites near Jilib and other settlements during the main transmission periods in December and June. Increased irrigation would cause increased seepage and thus more areas for transmission of bilharzia, especially along elevated canals such as Fanoole Main Canal.

Expanded irrigation of bananas would inevitably spread hookworm infections, unless a conversion of open canals and drains to plastic pipe, such as the program of Somalfruit, is carried out in new systems as well. Additional measures are needed as explained below.

2. Dhesheegs

In agricultural planning documents, the expectation for dhesheegs was that cropping intensity would increase because of addition of limited irrigation and improvement of drainage works, which make it possible to maintain longer growing seasons. It had been estimated that intensity of cropping would increase from 200 percent at present to 250 percent by the year 2017 (AHT 1985). The number of farmers was also expected to rise to 25,000, growing onions, maize, and sesame, as well as tobacco, vegetables, and citrus tree crops.

During the field surveys in the Jubba Valley, bilharzia and malaria transmission were found in some villages located near dhesheegs. The adverse health effect from the expected increases in cropping intensity and farming populations would be slight, mainly increased malaria transmission, due to the shortened dry seasons and consequent increases in breeding of malaria mosquitos. High water temperatures would continue to limit the bilharzia snail populations somewhat, so increases in bilharzia transmission around the improved dhesheegs would not be severe. Thus, the health impact of dhesheeg development would be much less severe than that of large, intensified irrigation systems.

The proposed expansion and improvement of dhesheegs—with attention to rapid drainage and careful water management—would probably result in a decrease in snail and mosquito breeding, thereby producing a health benefit. If the AHT proposals for dhesheegs are carried out, design and operation of the initial projects should be carefully monitored to insure their favorable health impact. Experience with initial dhesheeg improvements can then be used to guide design of improvements throughout the core area.

Transmission of bilharzia in 1988 occurred to a limited extent in dhesheegs or irrigation systems in the Jubba Valley. However, the primary transmission sites were near villages in temporary, clear water bodies which filled with rainwater or flood waters. These pools clarified quickly and became suitable habitats for bilharzia snails and malaria mosquitos as well as attractive sites for domestic water supply, bathing, washing, swimming, and play by children.

Intensified irrigation and agriculture would have little effect on these waterbodies except that their use for domestic purposes would increase directly with the population increase. Human contamination would also increase, causing exponential rises in diarrheal diseases such as cholera and hepatitis. Irrigation intensification would therefore require increased community water supplies.

3. General Health Problems

There are many health problems in the Jubba Valley not related to water. However, they may be related to agricultural development in direct ways. General malnutrition, anemia, filariasis, and hookworm are examples.

Malnutrition

Although one would expect increased agricultural activity to reduce malnutrition and anemia in the valley, it will do so only if there are conscious decisions to include provisions for smallholder farms, rotation of food crops along with cash or export crops, and adequate compensation of agricultural laborers.

Hookworm

As long as bananas and other crops requiring moist, clay soil are cultivated in the valley, hookworm infections will be widespread—especially in children. The only practical method of avoiding infections is by encouragement of families to construct and use private latrines, and for people always to wear shoes or sandals. A campaign against hookworm requires major changes in behavior and should be approached as a long-term community project, including education in schools and villages.

Filariasis

In most coastal communities of tropical East Africa, *Bancroftian filariasis* is transmitted by *Culex* mosquitos. Increased populations and inadequate drainage and sewage disposal will lead to increased transmission. Community programs aimed at mosquito control in latrines and drainage will be necessary to prevent this.

D. Biocide Poisoning

Projections indicated that the agricultural area would double between 1986 and the time the dam is completed, about 1992 (AHT 1985). They also estimated that a much larger increase would occur within 20-25 years after the dam is completed, resulting in a five-fold increase of irrigated land between 1984 and 2017.

The amount of biocides will increase in proportion to the area of irrigated land, if present reliances on chemical control of pests in large monocultures are continued. It was estimated that about eight tons of biocides would escape annually to the river or marine plain by 2017. Much of this contamination would accumulate in biological systems over the years.

Direct toxic effects would be accompanied by many subtle but significant adverse impacts such as increased incidences of cancerous tumors in the human and animal populations of the valley. These would be irreversible and unmanageable health hazards, and must be avoided.

Fish are especially sensitive to accumulation of biocides, and those in the lower valley would be at very high risk due to the large amounts of biocides expected in agricultural drains and the river. In addition, the small tilapia fish that could be used in mosquito control would be drastically reduced in numbers by biocides. Interference with normal predation on mosquito larvae may actually increase malaria transmission in affected canals and drains (Karim *et al.* 1985).

One approach to biocide control is establishment of a review board which would issue permits for acceptable biocides, establish a system for tracking and safely disposing of biocide containers, and develop a monitoring program to measure biocide accumulation in food, animals, and people. These measures are worthwhile and recommended for the Ministries of Agriculture and Health. However, in practical terms, they are not likely to be successful under the difficult conditions in the Jubba Valley, given the modest resources of the ministries. A more practical alternative, such as integrated pest management (IPM), must be stressed. There are simply too many biocides in use to attempt controls on use of individual chemicals. It is more practical to develop alternative methods to control agricultural pests or disease vectors through IPM. This approach includes crop selection and rotation, genetic and cultural techniques, limited biocide use, and other nonchemical methods in a careful combination which drastically reduces the need for dangerous biocides.

E. Potential New Disease Introductions

Creation of the dam and expanded irrigation systems would provide many new ecotypes for invading snails and insects, giving them habitats to colonize and consequently, increasing risks for introduction of new organisms and new diseases. The most likely of these are intestinal bilharzia and river blindness, with some possibility of the introduction of Rift Valley fever which affects people and livestock.

1. Intestinal Bilharzia

It has been reported that the upper watershed of the Jubba Valley contained a focus of intestinal bilharzia transmission (WHO 1982). The site is near Negele, in the Sidamo Region of southern Ethiopia. *Biomphalaria pfeifferi* is the snail host of intestinal bilharzia in Ethiopia and is probably being washed downstream through the Jubba Valley during most floods (Figure V.E.1), although it has not colonized in the lower valley—probably because of the long, dry seasons and high water temperatures which it has difficulty in surviving.

Introduction of intensive cropping systems in large irrigation projects would convert the local ecology into a favorable habitat for this snail. Eventually, the snail would colonize the area, and disease transmission would start as soon as infected persons from Kenya, Ethiopia, or northern Somalia contaminated the snail habitat with their feces. There is a high likelihood of this happening if intensive cropping and irrigation practices are introduced into large areas in the lower valley. Fanoole Rice System was a potential habitat in 1988, and would pose an even higher risk if it were expanded in area.

There are also sources of infestation of this species of snail from northern Somalia and north-central Kenya, but the chances of invasion are smaller (Figure V.E.1).

2. River Blindness

Certain species of blackflies in Africa transmit a parasite which lodges in the eye of people bitten by the fly, eventually causing blindness. One of those blackfly species was reported from the Shabeelle Valley near Jowhar. Because the range of the flies may reach 400 km and because the winds are favorable, it is possible that the flies could invade the Jubba Valley (Figure V.E.2). Because the flies require high velocity flow to deposit their eggs, there have been few suitable sites in the valley previously. However, the spillway of the proposed dam would be an ideal site for the flies, as would the small spillways on Fanoole Main Canal near Jilib.

There are other sources of blackflies in coastal Kenya, Ethiopia, and in North Yemen, but they are further away from the Jubba Valley and the winds are not generally favorable (Figure V.E.2).

3. Rift Valley Fever

There is a small possibility of importation of a viral disease transmitted by mosquitos which affects people, camels, cattle, and sheep. Originally found only in Kenya and southern Africa, it spread in 1977 to Ethiopia, Sudan, and Egypt. It caused severe

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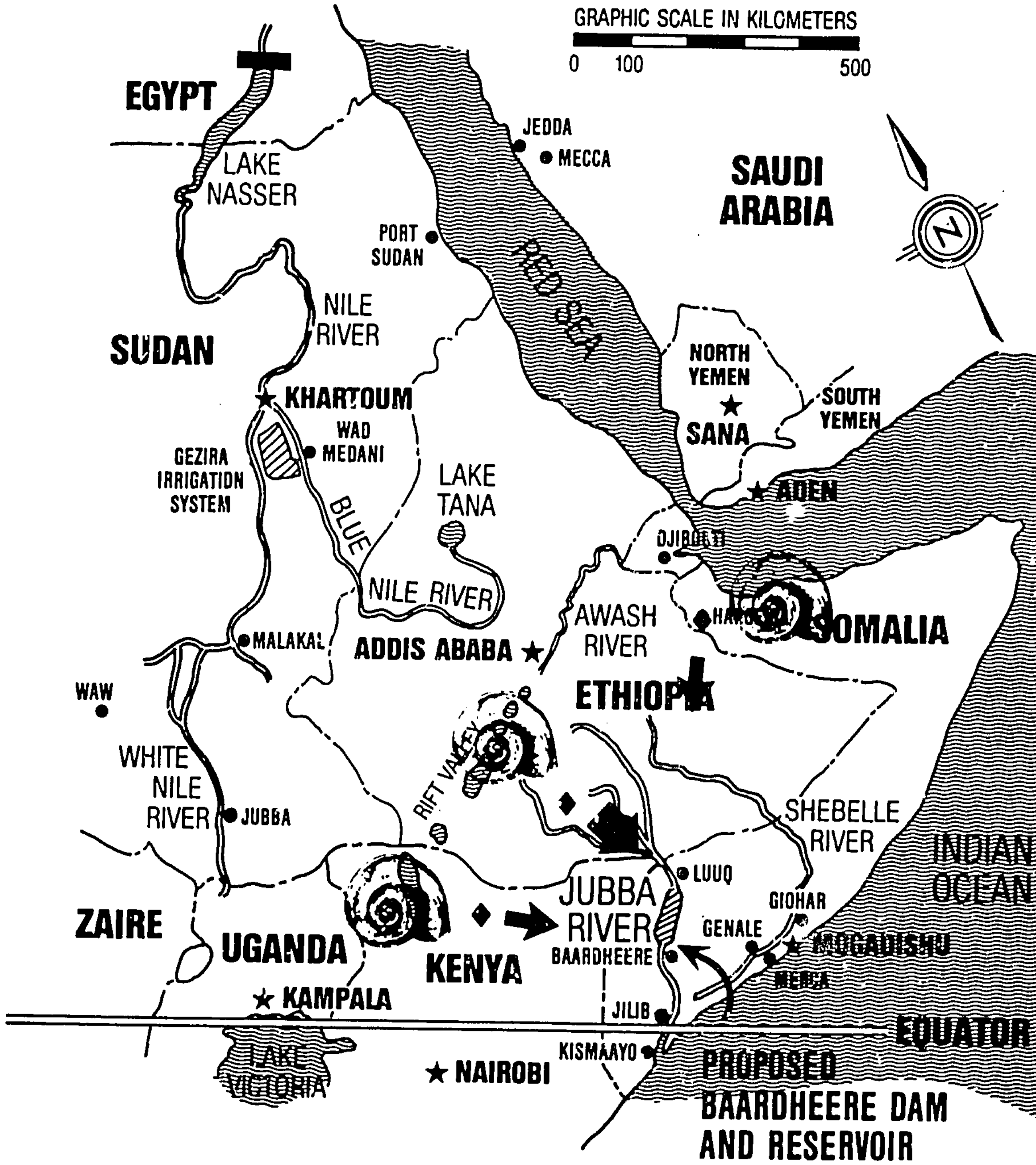

Figure V.E.1
Potential Invasion Routes For The Bilharzia Snail BIOMPHALARIA To Reach The Jubba Valley

Invasion of the Jubba Valley by the aquatic snails which transmit intestinal bilharzia is most likely to come from Ethiopia or Kenya due to the number of migratory herds and refugees moving between the two areas.

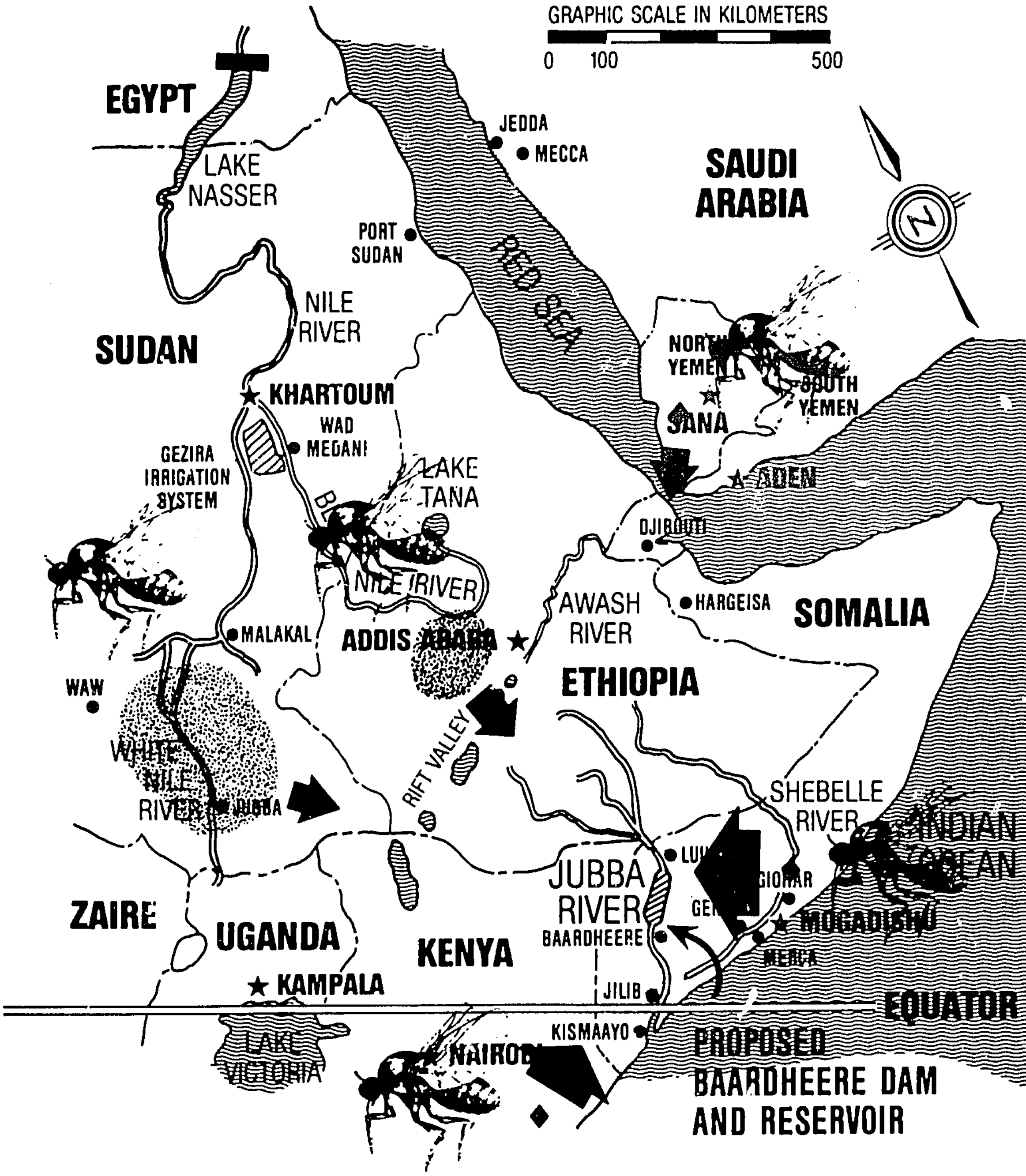

Figure V.E.2
Potential Invasion Routes For The Blackfly To Reach The Jubba Valley

Invasion of the Jubba Valley by the blackflies which transmit river-blindness would be most likely from the blackfly colony at Giohar, near Mogadishu. Other sources in Yemen, Ethiopia and Sudan are upwind of the valley.

disability and death in livestock as well as considerable human disease (WHO 1982).

More recently, in October 1987 an epidemic struck a group of camel and sheep herders gathered around the newly filled Foum Gleita Reservoir on the Gorgol River (Walsh, 1988, and Jouan, *et al.*, 1988). Within a month over 200 people were dead, with a case fatality rate about 50%. Although this recent epidemic occurred in West Africa, its close relation to the first filling of the reservoir was disquieting in its implications for Baardheere Reservoir. This is especially relevant because the virus was first noticed in the Rift Valley, not far from Somalia.

Very little is known about its transmission. It was suspected that the outbreak in Egypt was related to the congregation of livestock around Lake Nasser, created by the Aswan Dam. Heavy rains resulted in large mosquito populations. Their combination with the large animal populations— some that brought in the virus from Ethiopia or Kenya—are thought to be the elements which triggered the outbreak. There is some possibility that this could also happen after creation of the proposed reservoir in Somalia.

4. Other Water-associated Diseases

There is a minor possibility that mosquito-borne *filariasis* might be introduced into the valley after increases in population occur due to agricultural development. This would best be avoided by proper sanitation and drainage. Another parasitic disease known as *dracunculiasis* is often a problem in dry areas, but should not be a problem here if water supplies are adequate.

F. Community Water Supply and Sanitation

The inevitable large increase in human population which would accompany extensive agricultural expansion in the Jubba Valley would cause severe strains on existing community water supplies and sanitation systems. The major impacts would be a decrease in the mean quantity of safe water available per person, and a reduction in the supply of sweet water in wells within the irrigation schemes or far from the river.

From the expected decrease in per capita supply, a direct increase in diarrheal disease and bilharzia should be expected (Tameim *et al.* 1987). The diarrheal disease probably increases due to reduced washing of hands and eating or cooking utensils. The increase in bilharzia probably results from the increased need to use snail-infested surface waters for bathing.

Increased salinity of groundwater within the borders of irrigation schemes and in villages outside the smaller flood zone, would cause more people to use contaminated surface waters for drinking, thus raising the risks of diarrheal disease and cholera epidemics.

G. Alternative Disease Prevention Programs

The available disease prevention methods for communities in the irrigated zone of lower Jubba Valley include community education and participation, primary health care, environmental management for vector control, and water supplies. Many of the methods are similar to those available for health programs around the proposed reservoir.

1. Community Participation

Due to minimal resources available from the central government, it would be wise to concentrate them in encouraging community action programs in which residents of the Jubba Valley would organize to educate themselves, pool resources for improved health and sanitation facilities, and select community health workers who could provide primary health care.

2. Primary Health Care

By 1988, a few primary health care centers had been started in the valley by nongovernmental groups such as UNICEF, Swedish Church Relief, and World Concern. These groups should be assisted and encouraged to establish a primary health center (PHC) in every village with 500 or more residents.

3. Environmental Management for Vector Control

This would be perhaps the most cost-effective method for reducing mosquito and snail habitats in the new irrigation systems. Proper design of canals, irrigation structures, fields, and drains could minimize vector habitats. Outside of the irrigated fields but near agricultural settlements, vector control could be accomplished by filling depressions, developing improved drainage systems, and planting trees which absorb large amounts of water from lowlands, such as eucalyptus trees (WHO 1982a). Selection of crop rotation patterns that allow periodic drying of canals and fields would also be an efficient method of mosquito and snail control in new and existing irrigation projects.

Frequent maintenance of canals, drains, and irrigation structures—especially removal of sediment and aquatic vegetation—is an important method of reducing overbanking of canals and subsequent flooding of lowlands, a prime source of mosquito and snail habitats. The canals and drains themselves are also less likely to harbor disease vectors if they are properly maintained and cleaned. Proper supervision of agricultural and irrigation laborers can reduce bilharzia incidence by avoiding human contact with snail-infested waters from midday to sundown when the risk of infection is greatest.

The location of agricultural communities in relation to water bodies which are inhabited by disease vectors should be an important part of planning all new irrigation projects. Villages should be located 2-4 km away from fields, reservoirs, canals, or drains, and should have their own community water supplies. They should be located on well-drained ground and the area within 5 km of the village should be provided with adequate drainage facilities. Insect-proofed latrines should be constructed by homeowners to prevent fly and mosquito breeding. Elimination of contaminated sullage water around dwellings should be accomplished by community programs of land filling and drainage.

4. Community Water Supplies

Expansion of existing community water supply systems will be a minimal requirement for protecting health in the valley. A design goal of 100 liters per capita per day should be used to size the systems, allowing for expected population growth.

In new or proposed agricultural communities, adequate water supplies should be provided—preferably wells. Such water supplies should be provided in the initial development of each project, and would involve annual costs in the order of U.S. $5 per capita in 1988 prices (Tameim *et al.* 1987). These costs must be borne by the developers of the agricultural projects, or the Ministry in the case of resettlement. Thus, a program to relocate the 13,000 people who would be displaced by the rising reservoir would entail annual expenditures of about $65,000 over a 50-year life for the water supply systems.

These water supply costs must be provided for in the resettlement program, with the realization that about three-fourths of the annual cost is for amortization of the construction costs, which is the major component. Cost estimates should be developed from local designs, but the order of magnitude of the construction costs would be about $750,000 in 1988 U.S. dollars, required initially for the resettlement water supplies alone. The systems would have to be in operation the year before the dam was completed in order to prevent serious disease outbreaks in the resettled communities. Similar costs would be required for other proposed agricultural communities, and are major expenditures which, so far, have been omitted from development plans. Development of the dam and agriculture in the valley should not proceed until these costs are estimated and the necessary funds provided.

For many of the expected adverse impacts of the proposed reservoir, more than one remedy could be used to mitigate the effects. The more viable alternatives were compared in the following analyses. After a final plan is developed, cost comparisons should also be made to determine the optimum solutions, followed by detailed design of systems and programs.

A. Water Quality in Reservoir

The two potential problems with water quality in the reservoir concern the possible stagnation in the dead storage zone below 128 masl, and the possibility of density currents reaching the dam along the old river channel during the early months of the gu' season.

This stagnation would be likely to occur in the first decade when organic matter and mineral nutrients would be in sufficient supply to develop a large standing crop of algae and aquatic vegetation in the surface layer of the reservoir. This organic material would eventually settle into the dead storage zone and cause anaerobic conditions, including the formation of hydrogen sulfide and acid which would corrode metal. Of major importance in the early years, the decaying vegetation from the flooded shores of the river would also deplete oxygen in the lower levels of the reservoir.

Because of the low outlets in the dam, it should be possible to pass much of this anaerobic and corrosive flow under the turbines, thereby avoiding their corrosion. If the oxygen conditions in the dead storage zone near the dam are monitored, discharges through the outlet at appropriate times should be adequate to avoid this kind of damage. However, this should be done with caution, as the anaerobic conditions of the discharge could kill fish in the river downstream. Discharges should be mixed with flow through the turbines from higher elevations in the reservoir, adding water which contains oxygen. The combined discharge below the dam should have a dissolved oxygen content above 5 mg/l to avoid fish mortality.

Within a few decades, this danger should disappear because the reservoir would lose its organic content and productivity would be curtailed by a carbon shortage, even though phosphate and nitrate nutrients are in excess.

Expected density currents might also cause highly saline waters to pass through the turbines for short episodes. This would occur only during very dry gu' seasons which immediately followed very wet years, causing full reservoir conditions. The damage would be corrosion of metal in the turbines and valves, and biological shock to aquatic organisms immediately downstream of the dam. This shock should be avoided by mixing sweet water from the turbines, yielding a combined EC25 of 1000 micromhos/cm or less. These operations will require daily monitoring of the water quality at the dam, and a careful strategy of releases. The operations group at the dam should use simple water quality models to assist them in determining the optimum releases.

B. Water Quality in River

When the river flow decreased to near zero in 1987, the ocean intruded upstream for 30-40 km, reaching almost to Buulo Guduud at very high tides. This reach of the river was then unacceptable for any agricultural or domestic uses, and the water supply for Kismaayo became saline. This annual intrusion could be controlled by releases from the dam which resulted in a discharge reaching the ocean of 20-90 cumecs, or by construction of a low barrier below Yontooy. Monitoring of the salinity of the river at Goob Weyn and Yontooy should be conducted by the dam operations group to assist in preventing the ocean intrusion.

C. Planned Community Development and Health Protection

Development of healthy human communities in the valley after construction of the dam can best be achieved with a balanced investment in power generation, agriculture, health, and basic infrastructures such as roads, water supplies, and community education. Present plans should be expanded, and include financing and planning for a public health program against malaria, bilharzia, and diarrheal diseases. The program should be based on environmental management, public water supplies, community education, and primary health care.

1. Community Participation

It is essential that preliminary planning for development of resettlement and new communities be done in cooperation with the communities which are expected to settle. The possible health risks of uncontrolled development should be clearly explained, and community participation should be sought in a primary health care system, as well as in the operation and maintenance of community facilities such as water supply, drainage systems, health units, and education programs regarding health and sanitation.

The form of community participation would probably vary radically depending on the ethnic groups involved. Initially, ethnic leaders should be sought to develop community councils for each planned settlement. This would ensure that preferred water supply systems and health care measures would be adapted to ethnic preferences. As much as possible, decision making in the early planning of these facilities should be delegated to the community councils. This should include their preferences for site selection.

2. Planning Guidelines

Site selection for planned resettlement communities is very important. In addition to meeting community preferences in finding satisfactory locations for the settlements, minimum health guidelines should be satisfied. The principal means of stabilizing the size and location of planned communities would be by installation of adequate, safe, and convenient water supplies at the desired site. Around the reservoir, this would act as a magnet for resettled people and newcomers, thus avoiding uncontrolled settlements around the reservoir's edge. In the lower valley and the core irrigated strip along the river, this would meet a critical need for safe water, and take the pressure off existing towns and villages with inadequate supplies.

The villages should be located 2-5 km away from semi-permanent or permanent water bodies which could harbor malaria mosquitos or bilharzia snails. This includes irrigation canals, drains, and rice fields or other fields which contain standing water for periods longer than a few weeks at a time. Rice fields are especially dangerous, and a minimum distance of 5 km is recommended for planned communities.

The villages should be located on high ground above the maximum expected floods. A complete drainage system should also be installed at the time of construction of the water supply system, to avoid mosquito and snail habitats, protect the well, and avoid hookworm transmission in damp, contaminated soil around the village.

The community water supplies should be designed to supply 100 liters per capita served, per day. Estimated populations should be very generous; designs should include immigration and population growth, and use the design year of 2020 or later. Households should be provided with individual latrines—not community facilities.

Pens or locations for animals to be pastured at night should be located between the settlement and the nearest water body, to offer additional protection to the community from malaria mosquitos (UNEP and USSR 1982).

3. Magnet Villages

Sites around the reservoir should be selected for resettlement of existing populations, based on adequate supplies of water, good soil conditions, and convenient access to roads and markets. Completion of initial or magnet villages at these sites and transport of existing populations to the prepared sites should be made far in advance of the filling of the reservoir, about one agricultural season. The new settlements should be completed early enough to allow time for villagers to harvest their crops at their old settlement before the rising reservoir floods them, and to quickly move into the new settlements to plant their next crops.

The initial villages should be designed to attract existing and immigrating populations to the site by offering better facilities and conditions than scattered dhesheeg settlements. These facilities should include land, water supply, primary health care, and community education systems. This would be a far more effective method of guiding development in the region than by trying to prohibit and prevent settlements in unsafe areas.

4. Relocation Sites Around the Reservoir

Sites selected for relocated or new communities should be near streambeds or *toggas* which would be adapted as underground storage reservoirs for rain runoff with suitable soil and land conditions for agropastoral settlements, and equal population potential matched with water and land resources. If a large population could be supported by the available fertile land, then adequate water supplies for that population should be constructed at the very beginning.

For the underground reservoirs, a barrier of clay or other impermeable material should be placed across the streambed on bedrock, in a site where sand and gravel deposits upstream would give adequate storage for the community through a long, dry season of six to 10 months. The design capacity should be 100 liters per person, per day. Design of the barrier and a well should follow conventional standards for protection from contamination (Fal-laci 1985).

In flat areas near portions of the reservoir protected from winds and waves, it is important that the reservoirs be placed far above the NHWL of 142 masl, placing the community 2-4 km away from the mosquito-producing habitats. However, in areas with steep slopes or exposure to long reaches of prevailing winds, the reservoirs could be placed below the NHWL, thus ensuring that they would fill with sweet water every time the main reservoir fills. In this case, electric pumps should be provided to bring the drinking water to the village site at least 1 km above the NHWL, thereby establishing the site far enough away to avoid fecal contamination and risks of bilharzia transmission.

5. Integration of Reservoir Operation and Health Requirements

An operations group should manage the dam for the multiple purposes of maintaining health, and draw-down agriculture, as well as power, irrigation, and flood control. If this is not implemented, the population around the reservoir will be decimated by malnutrition and disease.

Since 1986, a chloroquine-resistant strain of malaria has spread to most of southern Somalia. Consequently, the existing malaria control strategy of primary health care and rapid treatment of fever cases was rendered useless.

River regulation through construction of the dam and improved drainage around towns and villages would be the most practical method of large-scale malaria prevention in the Jubba Valley. Careful avoidance of flooding in the lower valley for malaria control should be monitored when the dam is in operation, and discharge rules should be developed for the dam to avoid mosquito production in the lower valley.

Two major concepts should be used in operation of the reservoir for prevention of mosquito breeding near settlements around the reservoir. A flood surcharge should be caused every year during the first week of reservoir filling around November, raising the level 0.5 m above the NHWL and then dropping it quickly back to the NHWL. The purpose of the flood surcharge and rapid drawdown to NHWL is to strand debris and vegetation which comes in with the 'eyr flood, thereby minimizing the length of intersection line around the reservoir and extent of mosquito habitat.

After the flood surcharge, a weekly fluctuation below the NHWL of 0.5 m amplitude should be caused the entire time the reservoir is at NHWL, and for as long as possible after the drawdown begins. This would be a major deterrent to mosquito breeding and should not cause any losses in power production or irrigation as the river flowing into the reservoir would be carrying adequate flow to restore the water lost by the downward phase of the fluctuation. In most years, the extra discharge needed at the dam to cause the downward phase should not exceed the river capacity of 750 cumecs.

When flooding in the valley would occur (if the fluctuations were put into operation), spray teams should be dispatched to the mosquito habitats around the reservoir which threaten nearby communities. They should apply larvicides to the habitats and spray residual insecticides in the houses of the threatened communities. This should not be necessary more than once every 5-10 years, but should be decided by the dam operations team, based on current hydrological and epidemiological conditions. The cost of such spraying would be about $1 (in 1988 U.S. prices) per capita each year it was needed.

6. Need for Shoreline Modifications

In conjunction with the selection of sites for magnet villages around the reservoir, a plan for shoreline improvements should be developed and carried out within 5 km of all village sites. Shorelines should be straightened, flat beaches should be steepened by filling and cutting of soil from the NHWL to 1 m depth, and supplemental drainage ditches or pumped systems should be constructed where necessary to avoid isolated pools which support mosquitos and snails (WHO 1982a; and TVA 1947)

7. Relocation Sites in Middle and Lower Valley

Existing and new settlements of agricultural populations to be relocated in the lower valley should be designed and constructed by the management of each new agricultural scheme, according to the planning guidelines above. Approval for such new schemes by the Ministry should be contingent on the faithful and careful attention to the location, design, construction, and maintenance of these relocation sites. They must be large enough to accommodate significant population growth.

D. Agricultural Development and Disease Control

If intensive cropping systems such as double-cropped rice are expanded in the valley, control of salts in the soil would require heavy application of leaching water and also a deep drainage system with pumps for returning the saline drainage water to the river. This return drainage water would cause the salinity of the river to rise markedly, preventing its suitability for many crops in the lower valley below Jamaame.

Optimum and stable agricultural expansion should be assured by avoiding salinization of soil and drainage waters. The best strategy for this would be to combine carefully designed crop rotations with provision of a base river flow and deep drainage systems. The salinity problems could be avoided by using less intensive cropping systems which limited the drainage return rate to about 10 percent of the applied flow, or by providing a minimum release. This agricultural policy could prevent conductivity in the river from exceeding 750 micromhos/cm at any time, and would be the most cost-effective method in an integrated strategy to prevent bilharzia, malaria, and diarrheal diseases. A minimum release policy to provide 20-90 cumecs at the ocean would also prevent ocean intrusion during the jiilaal season.

E. Integrated Pest Management and Disease Control

Agricultural expansion and intensification should be developed gradually by emphasizing development of existing smallholder systems, such as dhesheegs and farming cooperatives, rather than large monoculture systems, and developing integrated pest management programs. This would be necessary to avoid ecological and health damage due to agricultural pests, disease vectors, malnutrition, and biocides.

Some of the large monoculture systems introduced new and unmanageable environmental and health risks from biocides. In 1986, over 100 tons of biocides were applied in the lower valley, involving 35 synthetic chemicals—many of them dangerous. It was estimated that about 1,000 kg of biocides were reaching the Jubba River annually, and 600 kg were discharged to the marine plain west of the river each year. These figures will increase in direct proportion to the area of new intensively cropped agricultural development.

Continued reliance on biocides would pose the risk of unmanageable increases in deaths and disease due to cancer in Kismaayo and other communities in the lower valley, accidental poisoning episodes in the agricultural populations around all irrigation projects, and drastic ecological damage to the lower valley—especially the coastal zone. It may be possible to develop a governmental system for regulating and controlling biocides, and this should certainly be attempted. However, the more effective and long-lasting preventive approach would be to decrease overall use of these chemicals by alternative approaches to agriculture, public health, and pest control.

Agricultural biocide use, including fungicides, herbicides, and insecticides is moderate at present, but would increase markedly if larger schemes are developed. The greatest amount of toxic chemicals was used by the large and modern Mogambo Irrigation Project, and the least amount was used in the cotton fields of the individual, small Somaltex farms. Of particular concern would be the fisheries at the mouth of the Jubba River which depend on the particulate matter and nutrients washed in from the river valley. These fisheries are presently being exploited for sale in Kismaayo and may have problems in the future with pesticide accumulation. The fish, prawns, and lobsters processed in Kismaayo should be monitored for biocides by the Ministry of Health, using facilities of the Faculty of Chemistry at the National University. If significant concentrations are found, the use of such chemicals in agricultural schemes should be reduced.

If public health programs using biocides are implemented in the future, use of organophosphate compounds should be avoided because of the possible accumulation of multiple exposures from agricultural and health programs. Pest control in sugarcane, rice, and other crops would require development of integrated pest management strategies which utilize cultural, genetic, and biological methods, and minimize application of dangerous biocides. In the long term, integrated pest management in agriculture, as in public health, is more logical than complete reliance on biocides.

F. Livestock Health

The proposed reservoir would generally create better health conditions for livestock than previously existed in that area due to the elimination of tsetse fly habitats, the expected poor conditions for aquatic snails which transmit cattle and sheep parasites, and generally longer dry seasons which should reduce tick populations in grazing areas at the NHWL. However, during excessively wet years or after a succession of wet years, mosquito and tick populations would increase along flat shorelines where terrestrial and emergent vegetation stands developed.

Local communities should be warned not to pasture animals near the reservoir at these times. This should not be difficult as pastoralists are aware of the role of ticks and mosquitos in disease. Adequate grazing should be available away from the reservoir during these wet years.

G. Prevention of New Diseases

There would be a small risk that river blindness might develop around the dam spillway near Baardheere and spillways on Fanoole Main Canal near Jilib, due to the potential for invasion by the blackfly from a focus along the Shabeelle River near Jowhar. The best way to eliminate this risk would be to investigate and eliminate the Jowhar population of blackflies. The Ministry of Health should request assistance from WHO for this purpose.

Establishment in the lower valley of the more serious intestinal form of bilharzia is a serious possibility due to existence of a focus of this infection near Nagele in the Sidamo Region of Ethiopia, along the Jubba River directly upstream of Luuq. Intensification of irrigation in the lower valley would provide suitable habitats for the species of bilharzia snail which transmits intestinal bilharzia, now found only in Nagele. New schemes should avoid the possibility of colonization of this new snail by careful programs of canal cleaning and maintenance, low-intensity crop rotations which would allow drying of canals and fields at three- to four-month intervals, and construction of extensive drainage systems.

VII. CONCLUSIONS AND RECOMMENDATIONS

In addition to power generation, irrigation, and flood control, the proposed development of Baardheere Dam and the agricultural potential of the Jubba Valley could cause significant improvements in health, nutrition, water quality, and community water supplies, if early modifications are made in design and operation. The expense of the additional investment for these modifications would be small compared with the extended operational costs of remedial measures needed, if the initial modifications were omitted.

Extensive malaria outbreaks could be curtailed in the lower valley after construction of the dam, by eliminating the frequent extensive flooding, and providing adequate drainage systems. Endemic malnutrition and the specter of famine could be overcome with increased and stable agricultural productivity made possible through river regulation and modified operation of the reservoir. The availability of electrical power in the valley could have important health and environmental benefits by supplying power for drainage systems and community water supplies, and providing a mechanism for guiding placement of new and relocated communities.

The three major processes available to the Ministry for directly influencing future health conditions in the Jubba Valley are:

- a settlement program,
- multipurpose operation of the dam, and
- selecting appropriate agricultural systems and practices.

The first process may be the most difficult of the three. The second process of dam operation needs careful evaluation and a degree of technical sophistication. The third process is complex, but clear guidelines are available which would insure integrated pest and disease prevention.

If these processes are neglected in the planning stage, the difficulty and cost of implementing remedial measures after dam construction would be far beyond the capacity and resources of Somalia. Disastrous epidemics of malaria and diarrheal diseases such as cholera, typhoid, and hepatitis would occur regularly.

The single, most important element requiring action by the Ministry to protect the inhabitants of the Jubba Valley from adverse environmental health and water quality effects would be the settlement program which involves planning and guided development of settlements for existing and expected agricultural communities. This would include populations in the Gedo Region in the area of the proposed reservoir, as well as the downstream agricultural communities.

The location of the settlements should be carefully selected to assure their suitability for the communities' agricultural activities and to minimize exposure to water-associated diseases. The plan and organization of the community and its public facilities should reflect the need to protect health at maximum efficiency and low cost.

Features to be stressed in planning these communities, in collaboration with the expected settlers, should include:

- adequate distances from mosquito and snail habitats;
- safe, adequate, and convenient community water supplies;
- local and regional drainage systems for rainwater;
- filling depressions and planting eucalyptus trees in waterlogged areas; and
- community participation in all aspects of disease prevention, including primary health care.

Community water supplies should be developed as the keystones to determine the location and size of these communities.

A. Community Water Supplies

Community water supplies would be a fundamental necessity for resettlements, new settlements, expanded communities, and the expected population of construction workers who will build the dam. *The Ministry should ensure that provisions for these water supplies be linked directly with construction of the dam and development of the valley.*

If careful planning and substantial investment in community development is not initiated early in development of the Jubba Valley, unhealthy communities would proliferate around the reservoir and related agricultural projects. A major influence the Ministry should have on community development would be the provision of safe water supplies at selected healthy locations. *Safe water supplies should be used to influence the location of expected communities, and the size of supplies should be adequate to insure healthy conditions among the expected populations.*

1. Magnet Communities Around the Reservoir

Guided development of the communities and land around the proposed reservoir (especially along the western shore near Buurdhuubo and the refugee camps), along with multipurpose operation of the dam, would make it economically feasible to avoid serious outbreaks of malaria and diarrheal disease. Provision of electric power for community water supplies and local drainage systems for the resettlement communities and Baardheere, Luuq, and Garbahaarey would avoid otherwise inevitable outbreaks of cholera and typhoid at the beginning of the rainy season every April or May, and malaria epidemics in very wet years.

The alternative possibility of uncontrolled development around the proposed reservoir would decimate the existing agropastoral population due to malaria, malnutrition, and cholera, and cause serious secondary epidemics of malaria and cholera annually in the larger towns of Baardheere, Luuq and Garbahaarey, and the relocated refugee settlements.

In the Gedo Region, water supplies will have to come from filtered surface waters because subsurface waters are too saline. The reservoir would be of suitable chemical quality during all seasons to provide adequate water for the existing and expected human and animal populations. Normally, the bacterial quality of the water would be fairly good. However, if communities are allowed to develop close to the reservoir's edge, water-associated diseases would cause severe health problems.

Community water supplies, using filtered water, should be established on the flat land west of Buurdhuubo, 2-5 km west of the maximum normal operation level (142 masl) of the reservoir, and at similar locations on the east bank. By careful planning and collaboration with existing and potential residents, "magnet communities" should be created at these sites to draw the expected settlers.

The most economical location for such water supplies in the magnet communities would be along the beds of the ephemeral tributaries called *toggas*. *Subterranean reservoirs should be created by placing clay dikes across the togga beds, thus trapping water underground and retaining adequate water for the time when the reservoir has receded.* Water might also be pumped from the reservoir, filtered, and distributed to these settlements through pipes.

It is recommended that the "magnet" sites be developed with access roads, electricity, wide streets with good drainage, and well-spaced community water taps. Domestic herds should be kept between the communities and the reservoir during the night to protect the people from malaria mosquitos.

If the shoreline within 5 km of the proposed magnet communities can be straightened and made steep enough to prevent mosquito and snail infestations, the communities could be placed closer to the reservoir high water level. However, minimum recommended distance to the high water line is 1 km. *The design capacity for community water supplies should be 100 liters per capita, per day, to ensure reserves enough to minimize deaths due to diarrheal disease as well as risk of bilharzia infections.*

2. Baardheere and Construction Camps

For the construction camps near the dam, a water treatment system should be built which will also supply water to Baardheere, after sedimentation and filtration. Desalinization during the construction period will probably be needed also. *The system should be constructed large enough for the ultimate expected population of Baardheere.*

The construction camps should be supplied with a health unit which has responsibility for health education, drainage and sanitation, medical screening, and treatment of personnel. They should also have facilities, personnel, and supplies for treating trauma from construction accidents as well as communicable diseases.

Baardheere town should be supplied with water from the reservoir by constructing a pipeline from the damsite to a treatment plant, with several distribution taps within the town and to the high ground east of the town to encourage development away from the river.

3. Middle and Lower Valley

If communities displaced by the proposed reservoir are moved out of the Gedo Region and resettled in areas such as new agricultural developments in the lower valley, major expenditures for community planning, water supplies, drainage, and primary health care will be needed for these new communities.

Severe disease problems would be inevitable in these resettlements if considerable investments are not made in planning and health facilities at the very beginning. Trouble has already occurred in such poorly planned villages in the Mogambo Irrigation Project due to improper location and lack of drainage.

Because the dam would moderate the annual floods and decrease the width of the flooding which recharges the groundwater, there would be a change in quantity and quality of groundwater in those shallow wells which use the upper lens of sweet water resulting from the annual floods. Close to the river, within the mound of recharge contributed directly from the riverbed, the amount of groundwater would increase and the water table would rise. The quality of this water would be satisfactory for domestic use, following the moderate quality in the river, with EC25 varying between 400-700 micromhos/cm.

For shallow wells outside of the new floodplain, the quantity of sweet water would decrease sharply. Also agricultural laborers living in or near intensively irrigated systems, such as the Fanoole or Mogambo Projects, would find increasingly saline water in their shallow wells due to the leaching of salts from the alkaline soils by the irrigation waters—especially if the wells are outside of the river recharge mound. A well in the Mogambo Project, which was not near a deep drainage system, had water which contained dangerous concentrations of arsenic and had a conductivity exceeding 4,000 micromhos/cm in 1986. These concentrations would rise with increased cropping intensity.

Because of these adverse conditions, *the Ministry should require that new irrigation developments in the lower valley include provisions for adequate community water supplies for both existing and expected populations within the systems*. This is the most sensible way to avoid epidemics of cholera and other water-associated diseases which would otherwise be inevitable as people sought sweeter but contaminated surface supplies.

In the middle and lower valley, chemical quality of water for human and animal use should be greatly improved by constructing the dam and the subsequent regulation of river flow. *A recommended base flow of 20-90 cumecs at the ocean during the jiilaal dry season would sustain freshwater recharge of the riverine aquifer and avoid the annual episodes of saltwater intrusion to wells along the river and the Kismaayo water system intakes.* These episodes occur presently during dry years and lead to severe problems in finding safe water for weeks in all communities in the lower valley.

The recommended improvements in water supply should eliminate the majority of diarrheal disease epidemics which presently occur during the latter part of the jiilaal dry season. However, the diarrheal disease outbreaks in the early part of the gu' and deyr rains may still occur if people continue using the more convenient rain-filled ponds at this time of year. Community education could gradually reduce this tendency.

B. Design of Reservoir and Operation of Dam

The proposed dam would create a biologically productive reservoir with chemical water quality suitable for agriculture, domestic, and livestock uses at all times. Nutrients should be quite high, reducing clarity of the surface waters to half a meter in depth due to a dense crop of algae.

The proposed reservoir would be generally unsuitable for colonization by the aquatic snails which transmit bilharzia. However, the reservoir would be a highly suitable habitat for mosquitos, and malaria transmission would be explosive in wet years.

The proposed reservoir would eliminate tsetse fly habitats from the area. During wet years, there would be some risk of tick infestations in areas along the shore, although in average and dry years, the risk would be minimal.

Although bilharzia and tsetse fly problems would be reduced by the proposed reservoir, under the original plans, serious hazards from malaria and cholera could threaten not only the reservoir inhabitants, but also the towns of Baardheere, Luuq, and Garbahaarey, as well as relocated refugee camps. The entire region would face malnutrition due to submergence of the present agricultural zone along the river. The original plans for operation of the reservoir would make it impossible for existing populations to maintain their agropastoral existence.

These problems could be avoided fairly easily if the dam were operated to include protection of drawdown agriculture and prevention of disease. This multipurpose operation would require creation of an operations group to manage the reservoir. The operations group should also oversee supplemental disease control operations around the dam, especially malaria control in very wet years. They should be provided with funds to operate a disease control unit stationed near the reservoir.

High concentrations of sulfates and suspended solids occurred in the river during the late jiilaal and early gu' seasons, posing a problem for concrete mixing during these months. *Simple precautions of sedimentation and use of special cement would easily avoid the danger of spalling in concrete for the dam.*

The presence of Rift Valley fever virus in herds around the proposed reservoir site should be monitored by an established virology laboratory, arranged through WHO. If the virus appears soon after the reservoir fills, *a military quarantine should be established around the dam and reservoir, in combination with a vaccination program.* This would probably be needed only for the first few years after the reservoir fills to spillway height.

1. Water Quality in the Reservoir

Although high concentrations of salt occurred in the first weeks of the gu' floods and the river became quite salty in the lower valley at the end of the jiilaal dry season, these episodes of salty water would be moderated when mixed in the reservoir and diluted by the fresh water of the large flows during the rest of the year, after the dam is completed. Thus, mean salt concentrations expected in the reservoir are within the limits for human, animal, and agricultural uses. For an average year under well-mixed conditions, the maximum expected concentration of chloride in the reservoir would be under 100 mg/l and the maximum expected electrical conductivity would be 500-550 micromhos/cm, compared to respective extreme values of 200 mg/l and 1,600 micromhos/cm presently experienced in the river. The tolerable limits for agriculture are 140 mg/l and 750 micromhos/cm, respectively, thus the reservoir conditions should be acceptable and a considerable improvement over present water quality.

If pronounced density currents were to occur in the reservoir, some of the peak salt concentrations at the beginning of the gu' floods might occasionally pass along the bottom of the reservoir to the dam. However, expected hydraulic mixing conditions in the reservoir indicated that such currents would seldom occur and the sporadic high concentrations in flow coming in at Luuq would be severely blunted by the time they reached the dam. Density currents during the end of the jiilaal dry season would be more likely, because the flow diminishes. However, the salt load is much lower than that of the gu' floods, therefore, normal turbine discharges of 150 cumecs during this period would draw additional stored water from the reservoir and dilution would be adequate to lower the mixed salt concentrations in the discharge to acceptable values.

2. Downstream Water Quality

During the 1986-87 field surveys, the river had a generally high salinity all year, contained very high saline surges during the gu' flood season, and when the river flow approached zero during the dry jiilaal season. For one or two months each year, the water became too saline for Class II irrigation uses, including irrigation of sugarcane and rice.

Besides the expected high concentrations of sodium, calcium, magnesium, chlorides, and carbonates, the river contained dangerous amounts of arsenic during the gu' season. Construction of the dam would result in considerable improvement in water quality of the river by providing long-term mixing of the flow coming into the reservoir at Luuq, and thus eliminating the unfavorable periods of high salinity and high arsenic concentrations. This would be a major improvement for agricultural systems and human communities in the valley. The extreme range of monthly mean conductivity, which was 200-1,000 micromhos/cm, would be reduced to a range of 350-525 micromhos/cm in the reservoir and discharge from the dam.

The river had a very shallow photic zone due to high turbidity for most of the year. The only season when the water clarified significantly was the jiilaal season when flow in the river almost ceased. However, algal productivity could not rise during this period due to complete absence of soluble phosphate nutrients. For the rest of the year, phosphate nutrients were high and nitrates were also adequate.

When the river flow decreased to near zero, the ocean intruded upstream for 30-40 km, reaching almost to Buulo Guduud at very high tides. This reach of the river was then unacceptable for any agricultural or domestic uses, and the water supply for Kismaayo became saline. The annual intrusion could be controlled by releases from the dam or by construction of a low barrier below Yontooy.

Some arsenic, boron, and selenium were found in the river waters. Due to mixing and dilution in the reservoir, arsenic would not pose agricultural or health risks after the dam is in operation. The boron and selenium would also be at satisfactory concentrations.

Expansion of intensively irrigated projects along the Jubba River would cause such high salinity in the return flows to the river that it would be impossible to provide sufficient dilution releases from the dam. Using computer simulations of the reservoir and river for the year 2000, it was estimated that an unacceptably high base flow of 200 cumecs would be needed to protect agricultural uses below Jamaame. Salinity would thus be a limiting factor in agricultural development.

At present, the ocean intrudes up the Jubba River almost to Buulo Guduud when the river flow stops in the late jiilaal season. If a base flow of 20-90 cumecs is maintained in the river, this intrusion would be eliminated and ocean water would not even intrude to Goob Weyn, which is about 6 km upstream from the beach.

3. Malaria and Cholera Prevention

Malaria occurs in the valley in annual epidemics triggered by the gu' and deyr floods. Severity and duration of the epidemics depended on the size of the flood, with severe outbreaks occurring after the 10-year flood of the 1987 gu' season. Completion of the dam and regulation of the floods would drastically reduce these malaria epidemics in the lower valley, constituting a major health benefit of the dam. However, there would be an increased risk of malaria transmission around the reservoir. Cholera epidemics would also occur fairly regularly if the development of communities around the dam is allowed to occur without guidance or controls.

Negative health impacts around the reservoir and in downstream irrigation projects with intensive irrigation could easily outweigh the other benefits, if major changes are not made in the trends of development in the Jubba Valley. *The most important change needed is an emphasis on diversified crop rotations which use less water. This would reduce salinization and severe health problems.*

Because of the irregular and large fluctuations expected in the reservoir water level, it was estimated that the reservoir would not be suitable for drawdown agriculture or fish populations in the long-term, under the proposed operating schedules. The health corollary to this adverse condition would be extensive habitats for malaria mosquitos. *Many of these disadvantages could be minimized by a revised schedule of operations which integrates requirements for drawdown agriculture, fish production, and control of aquatic vegetation, and disease vectors.* Encouragement of fish populations in the reservoir would reduce malaria risks as well as provide an important source of food.

4. Dam Operations Group

Multipurpose operation to avoid dangers of malaria and cholera transmission would require an operations group for managing the dam to achieve maximization of reservoir potential. *The operations group should also oversee supplemental disease control operations around the dam—especially malaria control in very wet years. They should be provided with funds to operate a disease control unit, stationed near the reservoir.*

Guided development of the communities and land around the proposed reservoir (especially along the western shore near Buurdhuubo and the refugee camps), combined with multipurpose operation of the dam, would make it economically feasible to avoid serious outbreaks of malaria and diarrheal disease.

River regulation through construction of the dam and improved drainage around towns and villages would be the most practical method of large-scale malaria prevention in the lower Jubba Valley. *Careful avoidance of flooding in the lower valley for malaria control should be monitored when the dam is in operation, and discharge rules should be developed for the dam, to avoid mosquito production in the lower valley.* Failure to provide these initial permanent improvements could result in the need for remedial emergency programs to control malaria, bilharzia, and cholera epidemics. These remedial programs would have annual costs near $10 in 1988 U.S. dollars per capita—far beyond the capacity of the Ministry of Health which spent about $2 per capita on all health services in 1987.

The operations group would also be able to use controlled releases during periods of high tides, to prevent ocean intrusion and agricultural damage. Maintaining minimum flows at the equator between 20-90 cumecs would also minimize salinity within the river and nearby wells.

If controlled and small annual floods are contemplated for agricultural or ecological purposes, their timing and extent must be carefully monitored to avoid creation of malaria outbreaks.

C. Preferred Crops and Agricultural Practices

Agriculture should be expanded gradually by emphasizing development of existing smallholder systems such as dhesheegs and farming cooperatives, rather than large monoculture systems, and by developing integrated pest management programs. This would be necessary to avoid ecological and health damage due to agricultural pests, disease vectors, malnutrition, and biocides.

1. Intensive Irrigation

Agricultural development, especially irrigated rice projects, would cause local foci of malaria and bilharzia transmission with severe consequences for the agricultural labor force and nearby communities. Intensified cropping and irrigation carry the additional risk of providing favorable habitats for introduction of intestinal bilharzia, a more severe form of the disease. Similar but lesser problems would occur around projects where other crops requiring large amounts of water are cultivated. As practiced in the Jubba Valley, double-cropped rice is the most dangerous agricultural activity, and rainfed cotton production of small farms in the Somaltex cooperatives is the least dangerous from the health perspective.

Biomphalaria pfeifferi, the snail host of intestinal bilharzia, has been found in upper Jubba Valley near Negele, Ethiopia. Thus, there is a risk of colonization of the lower Jubba Valley by this snail. It would probably colonize Fanoole Barrage first, and then Fanoole Rice Project, or any other system intensively using water. If this snail did appear, it would be inevitable that the more serious intestinal form of bilharzia would soon invade the lower valley, producing severe disease and death in people directly involved in agriculture and irrigation. *New projects should avoid the possibility of snail colonization by careful programs of canal cleaning and maintenance, crop rotations which would allow long-term drying of canals and fields at three- to four-month intervals, and construction of extensive drainage systems.*

2. Biocides

Agricultural biocide use, including fungicides, herbicides, and insecticides would increase markedly if larger projects are developed. Of particular concern would be the increased risk of human cancer and biocidal effects on fish, prawns, and lobster at the mouth of the Jubba River. These organisms depend on the particulate matter and nutrients washed in from the river valley. The fisheries are presently being exploited for sale in Kismaayo and may have problems in the future with biocide accumulation, population stresses, and carcinogenic effects on the people consuming them as food.

Some of the large monoculture systems introduced new and unmanageable environmental and health risks from biocides. The greatest amount of toxic chemicals was used by the large and modern Mogambo Irrigation Project, and the least amount was used in the small cotton fields of the Somaltex cooperative farmers. In 1986 over 100 tons of biocides were applied in the lower valley, involving 35 synthetic chemicals, many of them dangerous. About 1,000 kg of biocides were reaching the Jubba River annually, and 600 kg were discharged to the marine plain west of the river each year. Under the present master plan this could double by the time the dam is finalized, and eventually rise five-fold. Thus, eight tons of biocides would eventually be reaching the river annually.

Continued reliance on biocides would pose the risk of unmanageable increases in deaths and disease due to cancer in Kismaayo and other communities in the lower valley, accidental poisoning episodes in the agricultural populations around all irrigation projects, and drastic ecological damage to the lower valley—especially the coastal zone. Plastic containers for biocides and other chemicals are highly prized for storage of drinking water, thus tragic occurrences will be inevitable if these containers increase in numbers.

In addition to a decrease in biocide use, each irrigation project should be required to establish and maintain a toxicity treatment unit for the biocides which it uses, and educate its personnel about the early signs of intoxication. An inter-ministry government panel should review all import licenses to control particularly dangerous biocides.

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3. Salinization

Planned expansion of irrigated agriculture would soon cause salinity problems to return in the lower valley a few years after the dam is completed, imposing restraints on crop options. Existing alkaline soils would become increasingly saline and experience extensive waterlogging due to the locally rising water table. If intensive cropping systems such as double-cropped rice are expanded in the valley, control of salts in the soil would require heavy application of leaching water and also a deep drainage system with pumps for returning the saline drainage water to the river. This returning drainage water would cause the salinity of the river to rise markedly, preventing its suitability for many crops in the lower valley below Jamaame.

Stable agricultural expansion should be assured by avoiding salinization of soil and drainage waters. The best strategy for this would be to combine carefully designed crop rotations with provision of a base river flow and with deep drainage systems. The salinity problems could be avoided by using less intensive cropping systems which limit the drainage return rate to about 10 percent of the applied flow.

This agricultural policy could prevent conductivity in the river from exceeding 750 micromhos/cm at any time, and would be the most cost-effective method in an integrated strategy to prevent bilharzia, malaria, and diarrheal diseases. A minimum release policy to provide 20-90 cumecs at the ocean would also prevent ocean intrusion during the jiilaal season.

D. Prevention of New and Increased Diseases

Although the proposed dam should reduce malaria in the lower valley, and agricultural development should improve nutrition, there are two new diseases which might invade the valley after development.

There would be a small risk that the parasitic disease called river blindness may develop around the dam spillway near Baardheere and around spillways on Fanoole Main Canal near Jilib, due to the potential for invasion by the blackfly from a focus along the Shabeelle River near Jowhar. The best way to eliminate this risk would be to investigate and eliminate the Jowhar population of blackflies.

Although the proposed Baardheere Reservoir would probably not be suitable for bilharzia snails, the existing reservoir upstream of Fanoole Barrage is highly suitable as a snail habitat. In 1986, bilharzia snails (probably from the barrage) were found in Fanoole Main Canal. The only adverse condition for snails was the high turbidity of the water. This turbidity would largely be eliminated after construction of Baardheere Dam, and the small reservoir would become a prolific source of snail populations. Infections with urinary bilharzia were found to be widespread in the lower valley, with the large majority of children carrying the parasites. Over half of these infections could be eliminated by construction of simple wells for domestic water use.

There was no evidence of intestinal bilharzia anywhere in southern Somalia, nor of the species of snail which transmits intestinal bilharzia. However, *Biomphalaria pfeifferi*, the snail host of intestinal bilharzia, has been found in the upper Jubba Valley in Ethiopia and could conceivably colonize the lower Jubba Valley. The snail would most likely colonize Fanoole Barrage first, and then Fanoole Main Canal and rice fields, as well as any other system using water continuously. If this snail did appear, the more serious intestinal form of bilharzia would soon invade the lower valley, causing severe disease and death in people directly involved in agriculture and irrigation. This has happened in the Nile Valley in both the Egyptian delta and central Sudan, as well as rice-growing areas in West Africa. Again, new projects must avoid the possibility of snail colonization by careful programs of canal cleaning and maintenance, crop rotations which would allow drying of canals and fields at three- to four-month intervals, and construction of extensive drainage systems.

Since 1986, a chloroquine-resistant strain of malaria has spread to most of southern Somalia. Therefore, the existing malaria control strategy of primary health care and rapid treatment of fever cases will be rendered useless in the near future.

River regulation through constructing the dam and improving drainage, filling depressions, and planting eucalyptus trees around towns and villages would be the most practical method of large-scale malaria prevention in the Jubba Valley. The Ministry should require that all new developments include these features. Careful avoidance of flooding in the lower valley for malaria control should be monitored when the dam is in operation, and discharge rules should be developed for the dam to avoid mosquito production in the lower valley.

E. Intersectoral Needs

Development of healthy human communities in the valley after construction of the dam can best be achieved with a balanced emphasis on power generation, agriculture, health, and basic infrastructures such as roads, water supplies, and community education. *Present plans should be expanded to include financing and planning for a public health program against malaria, bilharzia, and diarrheal diseases. The program should be based on environmental management, public water supplies, community education, and primary health care.*

1. Public Health Program

The *initial cost of the public health program* would be high, and *should be financed as part of the construction costs of the dam and agricultural developments. Operation and maintenance of the program should be the joint responsibility of the local communities, the development projects, the National Anti-malarial Service, and the Ministry.* Remedial measures, in the absence of a well-planned preventive program, might cost as much as \$5-\$10 per capita annually, in 1988 U.S. dollars. Thus, initial expenditures for permanent preventive programs would be a wise investment.

2. Settlement Program

The Ministry should develop and manage a settlement program in cooperation with local councils of the existing or planned population groups, and the Ministries of Health, Mineral, and Water Resources, and Range and Livestock. The location of settlements should be carefully selected to assure their suitability for the communities' agricultural activities and minimize exposure to water-associated diseases. The plan and organization of the community and its public facilities should reflect the need to protect health at maximum efficiency and low cost. Community water supplies should be developed as the keystones to determine the location and size of these communities, and the communities should be assisted in organizing primary health care systems.

3. Integrated Pest Management

Pest control in sugarcane, rice, and other crops should be improved by requiring new agricultural projects to develop integrated pest management strategies which utilize cultural, genetic, and biological methods, and minimize application of dangerous biocides. In the long-term, integrated pest management in agriculture, as in public health, is more logical than complete reliance on biocides.

The use of fish for malaria control and control of aquatic vegetation would require *limitations on the chemicals which could be used in agricultural and health programs. Strict control on mixing and spraying operations would also be required to protect fish in drains and other waterbodies. These controls should be developed as part of an integrated pest management program.*

If public health programs using biocides are implemented in the future, *the use of organophosphate compounds should be avoided* because of the possible accumulation of multiple exposures by agricultural personnel from both agricultural and health programs.

F. Long-term Monitoring of Water Quality and Health

Salinity of drainage water should be monitored annually to determine if any of the major projects are returning excessively salty water to the river, to the detriment of downstream users. This could be done by any one of the chemistry laboratories in the larger schemes such as those at Jubba Sugar Project or Fanoole Rice Project. Further, agricultural development would then require changes to more salt-tolerant crops, limiting agricultural options.

Salinity of the water being discharged at the dam should be monitored daily by the dam operations group, to detect saline density currents or other conditions which might result in harmful concentrations of salt reaching the turbines or being released downstream. These data would provide a basis for selective withdrawals from the bottom outlets, and manipulation of the turbine discharges or the spillway, with the aim of optimizing water-quality conditions. Computer models developed in this report for water quality in the reservoir and downstream could be used by the operations group to guide their discharge strategies.

The fish, prawns, and lobsters processed in Kismaayo should be monitored for biocides by the Ministry of Health, using facilities of the Faculty of Chemistry at the National University. If significant concentrations are found, the use of such chemicals in agricultural projects should be reduced.

Fanoole Barrage and the Fanoole irrigation system should be monitored annually, around February, *for invasion by the snail which transmits intestinal bilharzia, Biomphalaria pfeifferi. Emergency assistance from WHO should be requested if this occurs. The new reservoir should also be surveyed for snails annually for at least the first 10 years of operation.*

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To assist the reader in interpreting the data in the report, the tables below provide typical values of selected water-quality parameters in the Jubba Valley as well as comparable norms for fresh water and salt water. Tables 2 and 3 indicate the maximum permissible concentrations of certain chemicals.

Table 1.

PARAMETER	Min.	Max.	Normal Range Fresh Water	Normal Ocean
pH	5.0	9.0	7.5-8.5	
Conductivity (EC)	100	5,000	200-3,000	5,000
Salinity (%0)	0	40	0-1	40
Secchi depth (cm)	0	500	1-200	
Color units	1	20	2-5	
Turbidity units	1	500	1-200	
Chlorides (mg/l)	1.0	19,000	1-500	19,000
Sulfates - SO_4 (mg/l)	1.0	200	1-50	
Nitrates - N (mg/l)	0.1	20	1-5	
Phosphates - P (mg/l)	.001	5	0.1-1	

*Table 2. Standards for Drinking Water Relevant to Jubba River Valley**

CONTAMINANT	UNITS	MAXIMUM PERMISSIBLE LEVEL
Arsenic	mg/L	0.05
Nitrate (as N)	"	10.0
Selenium	"	0.01
Turbidity	National Turbidity Units	1-5
Total Dissolved Solids	mg/l	500
Conductivity -EC25	micromhos/cm	500 (1,500 for camels)

** US EPA National Interim Primary Drinking Water Regulations, 1982*

Table 3. Standards for Agricultural Use

Parameters	UNITS	DEGREE OF RESTRICTION OF USE None	Slight to moderate	Severe
EC	millimhos/cm	<.7	0.7-3.0	3.0
TDS	mg/l	<450	450-2,000	2,000
Sodium	SAR	<3	3-9	>9
Chloride	meq/L	<4	4-10	>10
Boron	mg/L	<0.7	0.7-2.0	>2.0

Preface

This report presents the results of an epidemiological survey on malaria endemicity in the Lower Jubba Region carried out from 20 December 1987 to 10 January 1988. The study was sponsored by the U.S. Agency for International Development (USAID) and the Ministry of National Planning and Jubba Valley Development (MNPJVD) through JESS. It was coordinated by Dr. Marian Warsame Yusuf, who is on the Faculty of Medicine at Somali National University. The National Anti-Malaria Service (NAS), together with the World Health Organization (WHO) representative for malaria, participated actively in the planning phase and provided technical assistance.

The author wishes to express her grateful acknowledgment to Dr. Farid, WHO regional adviser on malaria, for his most sincere and open suggestions and advice during his visit to Somalia; and to Dr. A. A. Siad, Director of the National Anti-Malaria Service, Ministry of Health, for his great cooperation, understanding, and friendly responsiveness. For their understanding and cooperation, thanks are acknowledged to Dr. M. A. Barzger, WHO representative in Muqdisho, and Dr. Lindgren, WHO expert in maternal and child health (MCH). Last, but not least, is Dr. Ralph K. Klumpp, with whom were shared all the difficulties and obstacles during our fieldwork.

I. Introduction

Malaria is one of the most important tropical diseases in Somalia, where the entire population is exposed to the disease. Real epidemiological data on malaria endemicity in the different ecological strata are lacking. The extent of the problem can be estimated only through analysis of data obtained by passive case detection (fever cases referred to the laboratories) and, sometimes, by active case detection (search for the fever cases) by Malaria Station personnel.

The Malaria Station in the Lower Jubba Region is located in Jamaame, where basic facilities for malaria diagnosis and treatment are available. However, only villages close to the station can take advantage of this service.

The economy of the country is based on agriculture and livestock, and, therefore, development priority has been given to agricultural projects. Lower Jubba is an agriculturally fertile area and a primary focus for agricultural development in the country. Agricultural extension programs have just been established and the potential for further agricultural extension exists. There are many irrigation projects in operation, and new crops, such as rice, are being introduced. This is resulting in an influx of laborers into the area.

Previous experience has shown that, as the area of land involved in large-scale irrigation increases, the potential for adverse environmental health effects increases proportionally. Consequently, the pattern of water-borne diseases, such as *schistosomiasis* (bilharzia) and malaria, changes with the development of water-related projects. This is a threat to both the indigenous population and the immigrant workers, who are less immune. Therefore, it is essential to investigate the health situation before additional large water-related projects are implemented. The purpose of this study was to provide baseline data on malaria endemicity in the Lower Jubba Region for comparison with the post-project results.

The malaria survey was conducted in parallel with the JESS bilharzia study.

II. Methods

The malaria study was conducted by one parasitology and one entomology team of seven and five technicians respectively. Two microscopists from Jilib and two from Jamaame and their microscopes were made available to the survey. A field malaria laboratory was set up at the camp where daily laboratory work was done (staining and microscopy). Health officials at regional and district levels and district political leaders were informed upon the teams' arrival. The village leaders and teachers were informed in advance of each day's work.

The following definitions were used in conjunction with this study:

- parasite rate—percentage having detectable parasitaemia;

- parasite density (mean parasite density)—geometrical mean of individual parasite counts;
- spleen rate—percentage having enlarged spleens; and
- average enlarged spleen (AES)—mean of size of palpable spleens not including spleens classified as zero.

WHO classifies the degree of malaria endemicity on the basis of spleen rates as follows:

- hypoendemic—spleen rate of less than 10 percent in children (two to nine years of age);
- mesoendemic—spleen rate between 11 percent and 50 percent in children (two to nine years of age);
- hyperendemic—spleen rate in children (two to nine years of age) greater than 50 percent and in adults greater than 25 percent; and
- holoendemic—spleen rate in children (two to nine years of age) constantly greater than 75 percent, with high spleen rate in adults.

The same classification is used with parasite rate as the basis. The spleen rate is more constant in time because of the fluctuating nature of parasitaemia. Therefore, spleen rate indicates period prevalence (experience of the disease over a longer period) while parasite rate indicates point prevalence (at the point in time of sampling).

The study area consisted of seven beels (village centers) and 73 villages in the Lower Jubba Region. Two beels and eight villages (at least one village from each beel) were randomly selected. All but two of the villages fringe the river. The main occupation is agriculture, by subsistence farming and/or working on the big plantations. The main source of water is from the river and channels, although there is at least one well for every village.

The total population in the study area has been estimated at 83,000 (JESS). Ten percent of the children between two and nine years of age in the finite population were studied. The actual sample size was 1,246. In Jamaame and Bangeeni, schoolchildren (Koranic and primary) were studied. In the rest of the villages, parents were asked to bring the children to the selected test sites.

The name of each village and name, sex, age, and personal background of each examined child were recorded by the team. Splenic enlargement was identified, and spleen size was estimated with the child in a standing position. The spleen rate and degree of enlargement were also measured (Figure 1).

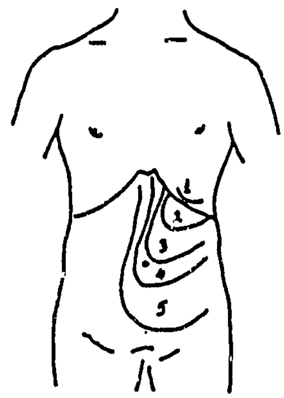

Figure 1. Classification of Spleen Sizes According to Hackett's Methods (WHO, 1963, Terminology of Malaria*).*

Blood films, thick and thin, were taken by finger pricks and transported to the field laboratory (under trees) where they were Giemsa-stained the next morning. Parasite species and density were determined. Positive cases were treated over a three-day period with a full therapeutic dose of chloroquine (25 milligrams per kilogram of body weight) starting the afternoon following diagnosis. Adults and younger children complaining of malaria symptoms were examined for malaria parasites and treated if they were positive.

III. Conclusions

Of the 1,246 children between two and nine years of age examined for enlarged spleen, 180 (14.4 percent) had palpable spleens. According to Hackett's classification, 21 children had spleen size corresponding to grade I; 82 to grade II; 63 to grade III; and 14 to grade IV. The average enlarged spleen was calculated to be 2.38. The spleen rates of children from various villages were significantly different, implying a different degree of malaria endemicity. Hence, it is important to present the findings of each village separately (Table 1).

The highest spleen rate (52.2 percent) was found in Buulo Maamow, while the lowest rates were encountered in Jamaame, Bangeeni, Beled Raxma, and Nafta Quur, indicating hyperendemic malaria in the first site and a hypoendemic situation in the second. The remaining villages, Mana-Moofa, Malaayleey, Beled Aamiin, and Janaale Jaay, showed mesoendemic transmission.

Table 1. Spleen Rates in Children Aged Two to Nine Years from the Lower Jubba Region

VILLAGE	Total Number	Spleen Rates(%)	Average Enlarged Spleen (AES)
Buulo Maamow	67	52.2	2.9
Beled Aamiin	160	26.5	2.5
Malaayleey	83	20.0	2.3
Moofa	137	19.7	2.4
Beled Raxma	168	16.7	2.2
Mana Moofa	99	16.2	2.3
Nafta Quur	62	3.4	1.5
Jamaame	121	1.7	2.3
Bangeeni	117	1.7	1.5
Janaale Jaay	232	1.6	2.0

Similarly, the highest parasite rate (50.7 percent) was found in Buulo Maamow, supporting the finding that the disease is hyperendemic in the village. Table 2 shows the parasite rates, parasite densities, and species in the different villages. The dominant species was *Plasmodium falciparum*. *P. malariae*, the only other species detected, was found in four villages, with the highest rate (14.3 percent) at Malaayleey. An average of 20.7 percent of the total sample was found positive for malarial parasites.

Table 2. Parasite Rates, Densities and Species in Children Aged Two to Nine Years from the Lower Jubba Region

VILLAGE	TOTAL NO.	Parasite Rates (%)	Parasite Densities (asexual/ul) GM	Parasite Species Pf%	Pm%
Buulo Maamow	67	50.7	1,366.3	97.1	2.9
Malaayleey	160	35.0	431.6	85.7	14.3
Beled Aamiin	83	32.5	838.6	100.0	0
Moofa	137	32.1	633.1	100.0	0
Beled Raxma	168	21.4	1,197.4	96.4	3.6
Mana Moofa	99	19.2	5,638.9	100.0	0
Janaale Jaay	62	12.9	4,215.1	90.0	10.0
Bangeeni	121	8.3	958.9	100.0	0
Nafta Quur	117	5.1	1,137.0	100.0	0
Jamaame	232	3.0	2,305.7	100.0	0
TOTAL	1,246				
	AVG.	20.7	1,872.17	95.7	4.3

GM=geometric mean Pf=Plasmodium falciparum Pm=Plasmodium malariae

In most of the villages, there was no significant discrepancy between spleen rate and parasite rate as far as degree of endemicity is concerned (Table 3). This strongly indicates that the splenomegaly in the children was due to malaria.

Table 3. Spleen and Parasite Rates in the Different Villages

VILLAGE	Spleen Rate %	Parasite Rate %
Buulo Maamow	52.2	50.7
Beled Aamiin	26.5	32.5
Malaayleey	20.0	35.0
Moofa	19.7	32.1
Beled Raxma	16.7	21.4
Mana Moofa	16.2	19.2
Nafta Quur	3.4	5.1
Jamaame	1.7	3.0
Bangeeni	1.7	8.3
Janaale Jaay	1.6	12.9

The difference of malariometric indices corresponds to the ecological and socioeconomic status of the villages. Villages along the river with lower socioeconomic levels had higher spleen and parasite prevalence than those far from the river and/or with a better socioeconomic status (as found in schoolchildren).

To study the entomology, live mosquitos were caught at night, with the aid of glass collecting suckers, when biting or resting indoors. They were later identified. *Anopheles arabienses* was found to be the important vector in the area. Nearby water collections from open wells were found to be Anophelene larval habitats. Larvae were also found in borrowpits and seepage from canals.

In summary, malaria is endemic in the Lower Jubba Region. The degree of endemicity varies from hypoendemic to mesoendemic with hyperendemic pockets. Environmental and socioeconomic status have an impact on the disease prevalence in the area.

To provide an accurate picture of malaria endemicity in this area, a complete entomological survey needs to be conducted over a longer period (one full year), particularly where seasonal fluctuation occurs.

IV. RECOMMENDATIONS

First, the hazards of malaria and other water-associated diseases and their relationship with the irrigation projects should be made known to the communities in the agricultural extension areas.

Second, a program of health education, using documentary films and group discussions, should emphasize methods by which the community can prevent the health hazards of water development projects and seek treatment if infected.

Third, all relevant health services should be provided to the communities in the project area, so that treatment of suspected malaria cases is available to all.

Fourth, full community participation should be emphasized when implementing all health service activities.

Fifth, laboratory technicians from the local health facilities should be trained in malaria microscopy.

Sixth, the concerned ministries and agencies should give the necessary support in solving the health problems in the area.

Finally, all these necessary health promotion and protective activities should be implemented within the primary health center context.

Preface

This report summarizes the epidemiological and malacological findings of a urinary bilharzia (schistosomiasis) survey in southeastern Somalia. Dr. Ralph K. Klumpp, of Blue Nile Associates, carried out fieldwork from 20 December 1987 to 16 January 1988 in the Jamaame District of the lower Jubba Valley. The Somalia Ministry of Health (malaria and schistosomiasis sections) provided most of the equipment used as well as the team of technicians. Other equipment and the drug, praziquantel, were kindly provided by the WHO office in Muqdisho.

The study was originally intended to incorporate three major health surveys in the upper, middle, and lower Jubba Valley: bilharzia, malaria, and nutrition/diarrhea. However, severe organizational and logistical problems prevented the combined work. In the end, the study was restricted to the lower Jubba Valley, and included only a malaria and bilharzia survey. Dr. Marian Warsame of the Faculty of Medicine, University of Somalia, headed the malaria team, and presents her findings in a separate report. (See Appendix A of this volume).

This study was a group effort, and I wish to thank the following people who made this work possible: Dr. W.R. Jobin (initial organization and recruitment); Dr. Robert Tillman (administrative and logistical support); Dr. Marian Warsame (organizational and field support); Dr. Siad Mire (technical support and equipment); Mr. Hassan Igeh (technical support and equipment); Dr. Lundgren (Acting WHO Representative, for releasing the praziquantel and Swinnex holders); the involved technicians from the Ministry of Health; and the involved staff of the Jubba Environmental and Socioeconomic Studies (JESS) project.

Executive Summary

A total of 2,002 children between five and 14 years of age were surveyed for *Schistosoma haematobium*. Due to a 17-day time constraint, stratified cluster sampling was carried out mainly at primary and Koranic schools. The area included the district capital, Jamaame (approximate population: 20,000) and 14 smaller villages (approximate population range: 400 to 3,200). All but five of the communities were within 1 km of the Jubba River. The remainder were about 2 to 12 km from the River. The overall prevalence of infection was 74.6 percent. This was the highest rate ever recorded in Somalia for such a large sample (Koura *et al.* 1981). The prevalence was even higher in the 14 villages: 81.8 percent (ranging from 66 percent to 98 percent). It was relatively low only in Jamaame (46 percent) where 404 children were examined.

Little difference in prevalence existed between males and females. The respective rates were 81 percent and 76 percent for 10-14 year-olds; 71 percent and 67 percent for 5-9 year-olds.

The degree of gross haematuria in the urine samples was 23.8 percent, even though the urine had to be collected before the optimal time of 1100h to 1300h. Rates ranged from 8 percent to 51 percent.

The overall geometric mean of parasite egg counts among those positive was 41 (per single 10-ml urine sample). The arithmetic mean was 205. The geometric means were at least 50 in six of the villages, indicating a heavy intensity of infection. Two villages recorded a GM of over 100 respectively. No significant difference appeared in this parameter between males and females.

Chemotherapy in the form of the one-dose drug, praziquantel, was offered to almost all of those found positive in the survey. The overall compliance rate was 78.2 percent (1,159 children), which was excellent given time, logistical, and social constraints. About 900 other children and adults were additionally treated in the villages or at the field camp (*ad hoc* day clinic). They were either diagnosed as positive with "Haemastixs" or presumed to have chronic haematuria.

Snail sampling was conducted in the above villages plus 10 others. The results indicated that the intermediate snail host of the parasite, *Bulinus abyssinicus*, was widespread in the area. It was mainly found in small, semi-permanent roadside or depression pools in the villages. All infected specimens came from this habitat. Irrigation drains around the numerous banana plantations yielded the second highest densities of the snail. It was collected in light density in the inland flood or rain dhesheegs. Not a single specimen was found in the Jubba River proper.

II. Materials and Methods

A. Prevalence-intensity Surveys

Because of the uncertainty of time available in the field and initial equipment shortages, it was impossible to design a proper survey based on normal statistical criteria. When the bilharzia detecting equipment arrived on 30 December, we simply started with Jamaame Town and continued in as many other villages as we could in the area. A total of 14 communities were surveyed, plus 11 children in the only uncooperative village, Turdho. The villages stretched from Kamsuuma and Baardheere Yareey in the north to Demo and Turdho in the south. Most villages fringed the river, but four were several kilometers away.

The sample population included 5-14 year-old children of both sexes. The original sample group of 10-14 year-old boys was unrealistic under the circumstances because of their small representation in the smaller villages, and the coinciding of the survey with the banana harvest.

Almost all of the children were surveyed at primary or Koranic schools. The latter schools contained most of the school-age children in every village. The school hours are normally from 0700h to 1000h, and sometimes again in the evening. This created problems in urine collecting since the best time to find high ova densities is between 1000h and 1400h, preferably from 1100h to 1300h. With the aid of the teachers, chiefs, and community health workers, it was possible to collect most urine samples between 0930h and 1100h.

The children were registered by school, name, age, sex, and ID number. They were individually given a urine container with their ID number. During most of the survey period, 198 urine containers were available each day. On most days, between 100 and 190 urine specimens were collected.

The urine cups had screw-top caps and were transported to the field lab (a large room with work tables) soon after urine collection and processed in the following manner: checked for gross haematuria (visible blood in urine), injected separately by plastic syringe in 10 ml amounts through Swinnex holders marked with the correct ID number. Inside the holders were Nytrel filters that trapped any *S. haematobium* ova. After this process, the filters were removed with forceps and placed top-side-up on the correct microscope slides (with the same ID numbers). The filters were then stained with 50 percent Lugol's iodine, and the slides stored in slide boxes. A few hours later, the slides were examined microscopically for schistosome ova. Depending on the amount of work, between four and five technicians were involved (and often, Dr. Klumpp). Using tally counters, quantitative egg counts were made on all positive filters (10X objective). The cutoff point was 2,000 eggs. Counts beyond that were unreliable. When filters appeared to have more than 200 eggs at first glance, the "criss-cross" counting method was used. This involved egg counts in the field of vision of the lens as it passed once vertically and horizontally across the widest part of the circular filter. The total count was then multiplied by two. The above modification has been evaluated in Sweden, and is statistically accurate. It is ideal for field use, where time is at a premium.

B. Treatment

Praziquantel was used exclusively. Four thousand tablets were donated by the WHO office in Muqdisho. Although cheaper, metrifonate could not be considered because it requires three dosages over a 28-day period and has more side effects.

Praziquantel was ideal for the survey because it is a one-dose drug with few side effects. Many children in the lower Jubba Region appeared to be malnourished, and a relatively high proportion had varying degrees of anemia. After initial trials revealed that they could tolerate the recommended dose of 40 mg/kg body weight, this dosage was maintained.

In most villages, treatment was confined to children who tested positive in the urine examination. Some mass treatment was done in other villages where the demand for the drug was exceptionally strong and the prevalence rate was very high. Some adults who claimed to have haematuria were also treated. Another 500 to 600 people (mainly children) came voluntarily to the field camp for treatment. A special day clinic was set up to accommodate them. Some came from as far as Jilib and Kismaayo.

C. Snail Sampling

This work began before the epidemiological survey and included 24 villages. It soon became apparent that the vector snail, *Bulinus abyssinicus*, could not survive in the Jubba River, and preferred standing water ecotypes. This, sampling was concentrated in standing water bodies and slow-flowing banana drains (the main drains in the area). All sampling took place in or very near human water contact points. Except for a few occasions, the snail sampling team consisted of four men. Each site was sampled for approximately 15 minutes (one person-hour of sampling). The equipment consisted of wading boots, long-handled snail scoops, collecting bottles, and forceps.

Other snail species were noted in each habitat, but only *B. abyssinicus* were picked and returned to the field camp.

At the camp, every snail was measured, washed, and placed in a shedding tube with some water (segregated by site). After one or more hours (usually between 1100h and 1300h), the tubes were examined for human and non-human cercariae with magnifying glasses.

III. Results

A. Prevalence of *Schistosoma haematobium*

The results were disturbingly high (Table 1). Only Jamaame children had a prevalence rate of less than 50 percent. Among the villages, the range was from 98.1 percent (Sabatuuni) to 66.1 percent (Bangeeni). The overall rate for the villages excluding Jamaame was 82 percent; and with Jamaame, 75 percent.

Table 2 shows the percentage of urine samples with gross haematuria. The overall rate was 24 percent, and was 51 percent at Sabatuuni. The rates would have been even higher if samples had been collected between 1100h and 1300h.

Contrary to expectations and findings in some African countries, little difference in prevalence existed between boys and girls (Table 3). Often, the rates in boys are significantly higher. As expected, the results revealed that 10-14 year-olds of both sexes had a higher prevalence than 5-9 year-olds (overall, 88 percent vs. 77 percent in the villages and 80 percent vs. 70 percent, including Jamaame).

B. Intensity of Infection

The children generally had a heavy infection. The most commonly used parameter to judge intensity of infection in field surveys is the geometric mean of parasite egg counts among those positive. This is simply the sum of the log values of the egg counts divided by the number of infected cases. The geometric mean is the antilog of the mean log. These are shown in Table 4 along with the arithmetic mean of the positive egg counts. The World Health Organization considers an egg count of 50 or more (per 10 ml urine sample) to be a heavy infection. By this arbitrary criterion, six of the sampled villages had a general population of "heavily-infected" children. The overall geometric mean for all the villages and Jamaame was almost in the "heavy" category (41 per 10 ml). The arithmetic mean egg counts per positive child ranged from 83 in Nyreey and Janaale Jaay to 414 at Sabatuuni. While this parameter is too easily biased by extreme values (highest egg counts), it reveals a heavy egg load in the communities surveyed, and thus a high transmission potential.

C. Chemotherapy Compliance

Table 5 gives the number of children treated who were found to be positive in the survey. The overall percentage treated with praziquantel was 78 percent, which is a very acceptable level considering shortage of time for treatment and absence of many children due to the banana harvest. Not listed are another 400-500 people treated without examination in the villages (those complaining of persistent haematuria), and 500-600 treated at the camp clinic.

D. Snail Sampling Results

Main findings are given in Tables 6 and 7, and in Appendix 3. A total of 510 *B. abyssinicus* were collected from 43 sampled locations in the 24 villages. The snail was found in 37 percent of the sites, indicating a wide distribution in the area. The only other snail species more widespread were the large prosobranchs, *Pila speciosa* and *Lanistes carinatus*. *B. abyssinicus* preferred standing water in small habitats—mainly roadside or village depression pools. It could not be found in the Jubba River (bank too steep, current too rapid, not enough vegetation) or in the small, temporarily filled irrigation canals (feeding banana farms). It was present in low density in the larger, shallow dhesheegs, and in the slow-flowing banana drains.

A total of 40 vector snails contained human cercariae (7.84 percent), which is a moderately high rate, but 36 of the infected snails came from one roadside pool at Kamsuuma (main water contact point in the village). The other four came from a similar pool at Beled Raxma. Thus, the level of schistosome transmission in the area during the survey was probably limited. Upatham's work in the lower Shabeelle Valley (1981) showed a similar seasonal pattern: the main transmission season was after the long rains in June and July, while the

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December-January period was a minor transmission period.

Present results suggest that schistosome transmission in the lower Jubba Valley is most widespread in the small, man-made habitats in and around the villages (roadside pools, other depression pools, and sluggish banana drains). The results also indicate that there can be peaks of heavy transmission in them—as was found at Kamsuuma. Although no live snails were found at Sabatuuni, a dry roadside pool in the village contained thousands of *B. abyssinicus* shells. The village elders confirmed that the site was the main playing and swimming point for the children, and contained water for much of the year.

IV. Conclusions and Follow-up Work

The survey fulfilled the objective of collecting baseline data on human prevalence rates and intensities of infection in the lower Jubba Valley. The rates are presently so high they will probably not be exacerbated by completion of the Baardheere Dam (barring widespread chemotherapy in the near future). From the limited snail sampling results during the low transmission season, it seems clear that transmission of the disease will be significantly reduced after impoundment. This is because the transmission sites are mainly the small semi-permanent depression pools and drainage canals caused by road construction and irrigation practices. The large dhesheegs, which might dry up after construction of the dam, seem to be only sporadic transmission foci. The perennial irrigation that will inevitably expand below the dam will certainly increase transmission potential. This has been a consequence in downstream areas all over Africa following dam construction.

A clearer picture of present and future transmission trends of the disease throughout the entire Jubba Valley must await a more thorough snail survey during a high-transmission season.

Meetings after the present survey were held with the WHO Representative and UNICEF Health Director in Muqdisho. There is a genuine desire by the Ministry of Health and international agencies to do more to control the disease in the Jubba Valley. The problem right now is the lack of a health infrastructure and lack of funds for praziquantel. The current WHO strategy for dealing with *S. haematobium* in such a river valley is almost entirely based on chemotherapy in conjunction with an expanding and competent primary health care system. At present, there is no role for molluscicіding. Unfortunately, the level of primary health care in the lower Jubba Valley is still in its infancy, and the current project price of the drug is about U.S. $1 per child.

Nevertheless, the commitment to controlling the disease in Somalia by the MOH, WHO, UNICEF, and other agencies should lead to tangible results in the future. With widespread chemotherapy alone,

Table 1.
Prevalence Rates Among 5-14 year-olds by Village.

VILLAGE	No. exam.	No. pos.	Prev.(%)
Sabatuuni	55	54	98.1
Bandar Jadiid	125	118	94.4
Demo &Turdho	202	182	90.1
Nyiireey	110	99	90.0
Baardheere Yareey	101	87	86.1
Kobon	275	234	85.1
Beled Aamiin	148	123	83.1
Mana Moofa	120	88	73.3
Kamsuuma	175	126	72.0
Buulo Maamow	61	43	70.5
Beled Raxma	108	75	69.4
Janaale Jaay	44	30	68.1
Bangeeni	74	49	66.2
SUBTOTAL	1,598	1,308	81.8
Jamaame	404	186	46.0
TOTAL	2,002	1,491	74.6

Table 2. Degree of Gross haematuria in Urine Samples Taken from 5-14 year-old Children.

Data for Jamaame Incomplete.

VILLAGE	No. of samples	No. with haemat.	% with haematuria
Sabatuuni	55	28	50.9
Bandar Jadiid	125	30	24.0
Demo & Turdho	202	52	25.7
Nyiireey	110	27	24.5
Baardheere Yareey	101	23	22.8
Kobon	275	62	22.5
Beled Aamiin	148	37	25.0
Mana Moofa	120	31	25.8
Kamsuuma	175	33	18.9
Buulo Maamow	61	16	26.2
Beled Raxma	108	27	25.0
Janaale Jaay	44	8	18.2
Bangeeni	74	6	8.1
TOTAL	1,598	380	23.8

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Table 3. Positivity and Prevalence Data by Age and Sex

VILLAGE	BOYS 10-14 n	BOYS 10-14 +	BOYS 5-9 n	BOYS 5-9 +	GIRLS 10-14 n	GIRLS 10-14 +	GIRLS 5-9 n	GIRLS 5-9 +	PREVALENCE RATES By Sex Boys	By Sex Girls	By Age 10-14	By Age 5-9
Sabatuuni	31	30	10	10	11	11	3	3	97.6	100.0	97.6	100.0
Bandar Jadiid	60	58	34	32	17	16	14	12	95.7	90.3	96.1	91.7
Demo & Turdho	70	62	92	82	15	15	25	23	88.9	95.0	90.6	89.7
Nyiireey	29	25	32	28	13	12	36	34	86.9	93.9	88.1	91.2
Baardheere Yareey	27	25	35	31	11	7	28	24	90.3	79.5	84.2	87.3
Kobon	84	79	119	94	31	29	41	32	85.2	84.7	93.9	78.8
Beled Aamiin	30	29	47	36	20	18	51	40	84.4	81.7	94.0	77.6
Mana Moofa	40	35	37	26	14	11	29	15	79.2	60.5	85.2	62.1
Kamsuuma	65	51	73	49	15	13	22	13	72.5	70.3	80.0	65.3
Buulo Maamow	17	15	15	11	12	10	17	7	81.3	58.6	86.2	56.3
Beled Raxma	48	34	42	31	8	2	10	7	72.2	55.6	66.1	73.1
Janaale Jaay	13	10	12	14	2	2	8	4	70.6	60.0	80.0	62.1
Bangeeni	22	17	29	16	11	11	11	6	64.7	77.3	84.8	55.0
SUBTOTAL	536	470	586	460	180	158	295	220	82.9	79.6	87.7	77.2
% pos.		87		78		87		74				
Jamaame	120	67	127	47	70	33	87	39	46.2	45.9	52.6	40.2
% pos.	55	37	47	44								
TOTAL	656	537	713	507	250	191	382	259	76.3	71.2	80.4	70.0
% pos.	81	71	76	67								

Table 4. Arithmetic and Geometric Mean Egg Counts (per 10 ml urine) per Positive Child.

VILLAGE	N	Arith. Mean	Geom. Mean
Sabatuuni	54	414	113
Buulo Maamow	43	264	100
Kamsuuma	126	261	62
Mana Moofa	88	261	60
Kobon	234	272	50
Beled Aamiin	123	237	50
Demo & Turdho	99	237	39
Bamgeemo	49	214	38
Beled Raxma	75	161	37
Baardheere Yareey	87	200	34
Nyiireey & Janaale Jaay	154	83	23
Bandar Jadiid	118	114	22
SUBTOTAL	1,308	208	43
Jamaame	186	186	28
TOTAL	1,494	205	41

Table 5. Number and Percentage of Positive Children Treated with Praziquantel.

VILLAGE	No. infected	No. treated	% treated
Sabatuuni	54	39	72.2
Bandar Jadiid	118	99	83.9
Demo	171	150	87.7
Nyiireey	99	79	79.8
Baardheere Yareey	87	41	47.1
Kobon	234	208	88.9
Beled Aamiin	123	81	65.9
Mana Moofa	88	72	81.8
Kamsuuma	126	119	94.4
Buulo Maamow	43	35	81.4
Beled Raxma	75	54	72.0
Janaale Jaay	30	21	70.0
Bangeeni	49	21	42.9
Jamaame	186	140	75.3
TOTAL	1,483	1,159	78.2

Table 6. Number of Bulinus abyssinicus and Infected Specimens by Type of Habitat.

HABITAT TYPE	No. times sampled	No. of *B. abyssinicus*	Infected with cercariae: human	single tailed	Strigiid
Roadside Pools	16	284	40	61	1
Banana Drains	11	176	0	0	0
Dhesheegs		5	42	0	10
Irrigation Drains	3	0	0	0	0
Reservoir/Ponds	2	8	0	0	0
River	6	0	0	0	0
TOTAL	43	510	40	71	1
Percent Infected			7.84	13.9	0.19

Table 7. Frequency of Finding Snails by Habitat.

HABITAT	No. times sampled	No. times with *B.a*	%	No. times other snails found: P	L	M	G	F	O	% of times w/at least 1 other snail
Roadside pools	16	9	56.2	11	7	6	6	1	0	87.5
Banana drains	11	3	27.2	8	7	3	6	0	0	90.9
Dhesheegs	5	2	100	4	2	1	2	0	1	80.0
Irrigation canals	0	40	0	0	0	1	1	0	0	
Reservoir/ Ponds	2	2	100	2	1	0	0	0	0	100
Jubba River	6	0	0	0	0	0	0	0	1	0
TOTAL	43	16	37.2	25	17	10	15	2	2	74.44

P = Pila; L = Lanistes; M = Melanoides; G = Gyraulus; F = B. forskalii; O = Other

morbidity from infection and transmission can be controlled on a long-term basis, beginning in communities and expanding to the regional level.

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Annex 1

List of Senior Individuals Contacted in Somalia Directly Connected with Work

Dr. Robert (Gus) Tillman, *JESS*

Mrs. Marie Tillman, *JESS*

Dr. Fleming Frandsen, *Director of Danish Bilharziasis Laboratory*

Mr. Wes Fisher, *USAID*

Head of USAID, *Somalia*

Dr. Marian Warsame, *Faculty of Medicine, University of Somalia*

Dr. Siad Mire, *Director of Malaria and Schistosomiasis, M.O.H.*

Mr. Hassen Igeh, *Director of Schistomiasis, M.O.H.*

Dr. M. A. Barzghar, *WHO Representative*

Dr. Lundgren, *Acting WHO Representative*

Dr. Chris Bently, *UNICEF Health Director*

Mr. Thomas McDermott, *UNICEF Representative* and

Regional Medical Officer of Health, Kismaayo

Deputy Regional Medical Officer of Health, Kismaayo

District Medical Officer, Jamaame

Regional Chief of Security, Kismaayo

District Police Chief, Jamaame

Preface

This study was carried out by Dr. Ralph K. Klumpp of Blue Nile Associates. The follow-up survey was informally planned by the author, and Dr. Tillman in January 1988 after the first JESS survey on malaria and bilharzia (schistosomiasis) in the lower Jubba Valley. It was then realized that further information on the distribution of *Bulinus abyssinicus* (the intermediate host of urinary bilharzia in Somalia) was needed for the lower, middle, and upper sections of the Jubba River. Information was also needed on the transmission ecology of the infection in these areas. In turn, this would serve as useful pre-dam baseline data, and allow more accurate predictions of the snail and the disease after impoundment. This proposal was agreed upon by Dr. Jobin and relevant staff at ARD in April. Timing of the survey was set for June and July 1988--a month when snail density and transmission potential was expected to be relatively high.

The author offers thanks to the following people whose assistance and support enabled this survey to be completed: Dr. Gus Tillman, JESS Project Manager; Dr. Bill Jobin, Blue Nile Associates; Drs. Paul Dulin and Kevin Fitzcharles, ARD; Dr. Marian Warsame, Faculty of Medicine, National University of Somalia; Mr. Hassan Igeh, Director, Schistosomiasis Control Program, Ministry of Health; and Dr. Mohammed Weys, Director, National Anti-malaria Service, Ministry of Health. The author is particularly grateful for the day-to-day assistance given by Mr. Adulaahi Hassan Osman, Mr. Abdi Karim Nuur, and Mr. Osman Ahmed Moilin. Many thanks to Ms. Christine Kabuye, Director of the East African Herbarium, Nairobi, for identifying plants collected from the Jubba.

I. Executive Summary

The consultant arrived in Somalia on 19 June and expected to start the fieldwork with three Somali assistants and one pickup truck, within a week. However, newly discovered mechanical faults in the vehicle (the one available for fieldwork at the time), compounded with a series of Somali holidays, delayed departure until 3 July.

The weather also created problems. The expected gu' flooding after April did not occur. Rainfall was patchy after April, and the xagaa rains were becoming heavy just before and during the fieldwork. Irrigation stopped as well; thus, semi-permanent, standing water was limited. The upper Jubba area was especially dry. Despite slippery, almost impassable roads, car problems, and bad weather, 50 villages (and Yontooy) in the south up to the Baardheere Dam site in the north were visited from 4-26 July. Twenty-five villages contained standing water suitable for sampling; in them, a total of 46 human water contact sites (WCSs) were searched. Ten dry villages were examined for snail shells. Twenty-six other sites away from WCSs were also sampled for snails.

It is believed that the survey was successful in mapping the distribution of the vector snail along much of the Jubba Valley, understanding some of the snail's ecological determinants in different areas, discovering sites of intense transmission of the parasite, and obtaining other information that will allow predictions on the distribution of the snail after the dam is completed.

A total of 779 *Bulinus abyssinicus* were collected from quantitative, person-time sampling in 45 human water contact sites in 25 villages from near Jamaame to the Saakow area. (See Figure 1, next page.) Of these, 157 were shedding *Schistosoma haematobium*. This infection rate of 20.15 percent is the highest ever recorded in Somalia from such an extensive survey.

The snail was found in 45.6 percent of all sampled water contact sites, and in 52 percent of standing water sites. Its distribution was almost continuous near the river and in irrigated areas from Sanguuni at the equator to the Fanoole Barrage. This was confirmed by sampling extra sites away from human activity. Further north, the snail was found in only one site (at Gurmeyso). However, few sites contained standing water north of Bu'aale. Snail shells were found as far north as Dhoobley, near the future Baardheere Dam site.

The infected snails were found in four sampled villages (16 percent) in eight different water contact sites (17 percent). In these sites, the percentage infected with the parasite was 32.5 percent (157/466), indicating a high transmission potential.

The most dangerous sites were shallow roadside depression pools between 0.15 and 1.0m deep, con-

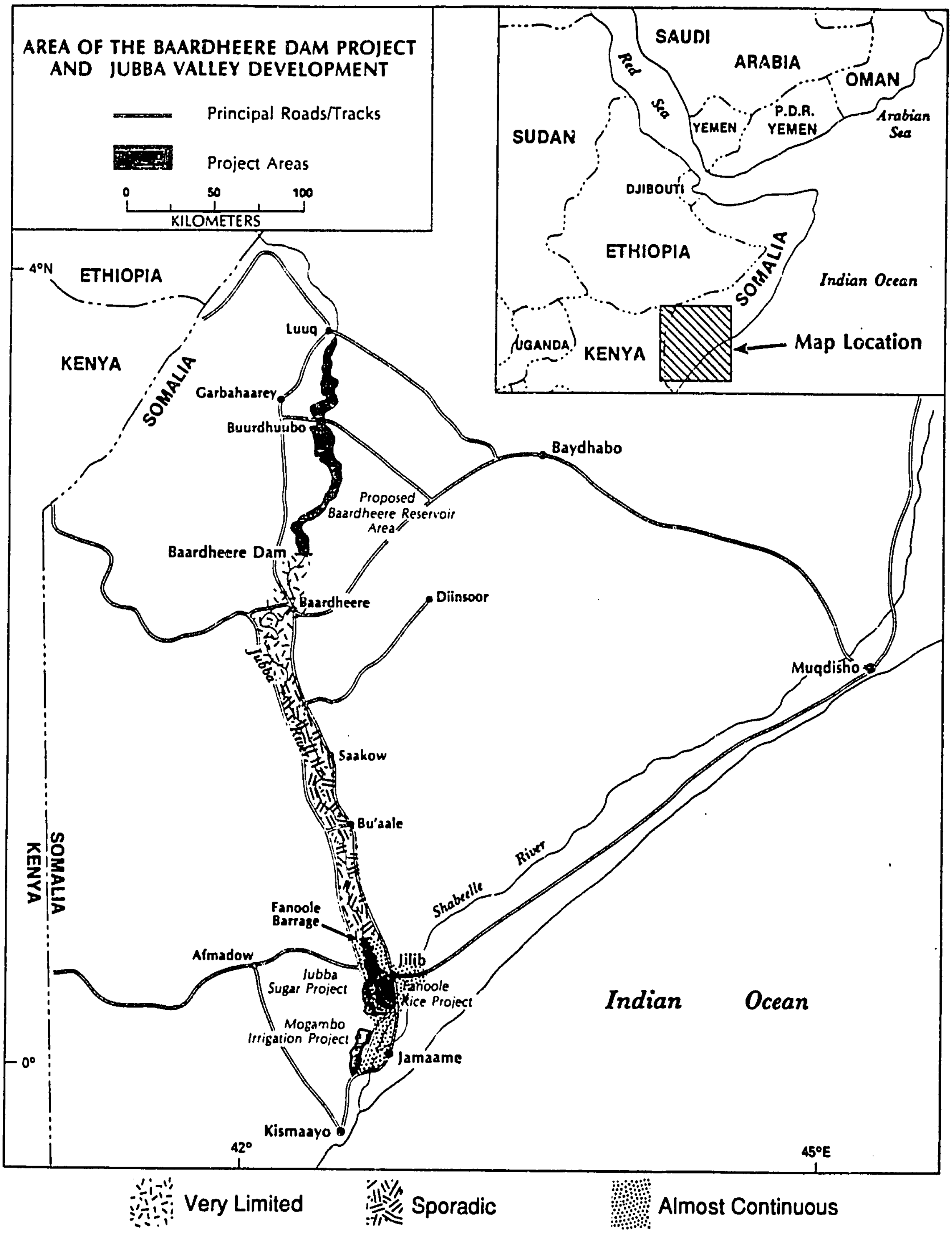

Figure 1. Distribution zones of Bulinus abyssinicus *in the Jubba Valley.*

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taining either *Nymphaea lotus*, *Cyperus exaltatus*, or *Ipomaea aquatica*. Seven of the eight infectious sites were of this type. The remaining transmission point was in an irrigation drain that had collected rain water over a two- to four-month period. These findings confirm the results from the earlier JESS survey (Klumpp 1988a).

Since the main transmission zones are in the lower and middle Jubba sections (to Fanoole Barrage) in areas of heavy irrigation, the completion of the future dam will have a minimal impact on transmission patterns in this downstream, riverine sector. However, the present survey does indicate that its construction would reduce the distribution of the snail and parasite in nonirrigated areas that presently receive the river flood, by preventing or greatly reducing flooding.

II. Snail Sampling Methods and Results

A. Materials and Methods

Snail sampling was conducted by the person-time method. Dr. Klumpp and Mr. Osman searched 30 minutes for *Bulinus abyssinicus* in human WCSs, and for shorter periods in sites with no human contact (qualitative, quick searching). Village residents usually assisted in pointing out the main sites. Sampling was planned for up to four sites per village, but usually took place in one or two because of the lack of standing water.

Wading boots, metal and wire-mesh sampling scoops, and forceps were used to collect *Bulinus abyssinicus* 3 mm and greater in shell height. They were placed in humid collecting bottles and labelled by site. Other species of aquatic snails seen or collected were also recorded. Some collected specimens were later preserved in 70 percent ethanol for shipment to the Danish Bilharziasis Laboratory, Copenhagen. Vegetation type, site size, and miscellaneous information were recorded when deemed necessary.

Because the infected snails were known to shed most cercariae between 1000h and 1400h, sampling normally took place between 0700h and 1200h. Shedding almost always took place at the field base of the day of collection between 1200h and 1500h.

The snails were removed, rinsed individually in clean water to remove excess clay and algae, and placed in separate thumb-sized shedding tubes half full with clean water. After one hour, they were examined with 10x magnifying glasses for presence of cercariae. These were lumped into three categories: human (*haematobium*), single-tailed, and other (mainly strigiid and bird cercariae). After grouping and segregation from uninfected snails, the snails were individually measured to the nearest mm in shell height.

B. Results

1. Distribution of *Bulinus abyssinicus*

Results from the December-January survey are already available from the JESS snail report. Tables below give further information on the distribution of *Bulinus abyssinicus* and other snails collected in July.

The results in Tables 1-6 highlight a number of facts, which must be interpreted in light of the lack of flooding in the gu' season combined with the late xagaa rains. Thus, a majority of visited villages did not have standing water of any permanence. In the 25 villages with standing water, *B. abyssinicus* was found in 14 (56 percent). Villages were most dry from Bu'aale to Baardheere, where there is no significant irrigation. Out of 23, 14, and nine sampled sites in the lower, middle, and upper Jubba areas, the snail was found in 13 (56 percent), seven (50 percent), and one (25 percent) respectively. It was always found within 5 km of the river in the July survey, but as far as 20 km from the river in the December-January survey.

Combining the results from both surveys, it can be concluded that *B. abyssinicus* has an almost continuous distribution near the Jubba River from near Kismaayo to Fanoole Barrage (main irrigation zone), and a patchy distribution further north. The snail can be found in upper Jubba only in low-lying parts of the river that readily flood (*e.g.*, small to medium dhesheegs) or inland dhesheegs that retain water most of the year.

B. abyssinicus is closely associated with *Pila speciosa* and *Lanistes carinatus*, although the latter snails tolerate flowing canals. The number of wet WCSs containing these species out of 46 samples in July was 21, 25, and 20, respectively. Other snails were much less widespread.

2. Snail Infection Rates

The overall percentage of *B. abyssinicus* infected with *Schistosoma haematobium* cercariae was extremely high— 157/779, or 20.15 percent. The percentage infected with non-human trematodes was much lower: 2.2 percent for single-tailed cercariae, and 2.6 percent for "other" (*brevifurcate*) cercariae.

Table 1. Villages, Water Contact Sites, and Non-water Contact Sites Sampled During July Survey.

(Division of Jubba Areas
Arbitrarily Based on Snail Ecology)

Lower Jubba Area = Sanguuni (S) to Kamsuma (N)
Middle Jubba Area = Madiina (S) to Fanoole Barrage (N)
Upper Jubba Area = Bu'aale (S) to Baardheere Dam site (N)

	JUBBA RIVER Lower	Middle	Upper	TOTAL
Number of villages visited	23	13	14	50
No. of visited villages with more than temporary standing water in July	11	9	5	25
No. of visited WCSs sampled (wet) including river	23	14	9	46
No. of non-WCSs sampled	10	16	0	26
No. of dry sites sampled for dead shells	3	2	5	10

**Villages visited in July that contained no standing water apart from temporary rain pools included:*

LOWER JUBBA
Jamaame, Buulo Maamow, Sabatuuni, Demo, Bandar Jadiid, Mareer, Boorini, Yontooy, Waamo, Makaalangow, Mafuula, Shongoole

MIDDLE JUBBA
Hiloshiid (main section), Balley, Maanyagaal, Misra

UPPER JUBBA
Baardheere, Dhoobley, Buloaraas,BuuloKaskaay, Gaaduure, Besire, Bu'aale.

Table 2. Snails Collected at Sampled Water Contact Sites in the Lower Jubba Villages.

VILLAGE	Habitat Code	Bulinus abyssinicus Collected	Infected SH	ST	OTH	Other Snails P	L	M	F	B	A
Buulo Gabio	1	1	0	0	0	1	1	0	1	0	0
Kamsuuma	1	0	0	0	0	1	0	1	0	0	1
	1	3	0	0	0	1	1	1	1	0	0
	1	26	0	2	0	1	1	1	0	0	1
	1	14	0	0	0	1	1	1	0	0	0
Mugaambow	5	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	1	0	0	0	0
Beled Raxma	2	148	0	0	0	1	0	0	0	0	0
	1	0	0	0	0	1	0	0	1	0	0
Mana Moofa	1	10	0	0	0	0	0	0	0	0	0
	1	10	0	0	0	0	0	0	0	0	0
	1	10	0	0	0	0	0	0	0	0	0
Kobon	2	0	0	0	0	0	1	0	0	0	0
	2	1	0	0	0	0	0	0	0	0	0
Beled Aamiin	a	0	0	0	0	0	0	0	0	0	0
Weltuweer	3	0	0	0	0	1	1	1	0	0	0
Sanguuni	1	55	55	0	0	1	1	0	1	1	0
	1	22	14	0	0	1	1	0	0	0	0
	1	38	6	5	0	1	0	1	1	1	0
Moofa	2	55	29	4	0	0	0	0	1	0	0
Masaagirow	2	2	0	0	0	1	1	0	0	0	0
TOTAL SNAILS		376	104	11	0						
No. of sites with snails		13				13	10	6	7	2	2
% of sites with snails		56				56	43	26	30		99
Snail infection rate (%)			27.7	2.9	0						

Habitat code as follows: 1 = roadside depression pool in village; 2 = irrigation drain; 3 = dhesheeg between 3,000 and 20,000 sq. m in area; 4 = irrigation canal; 5 = reservoir without vegetation, or livestock water hole; 6 = Jubba River; 7 = inlet or "side-arm" of Jubba River.

Types of cercariae in infected snails: S.H. = human (*S. haematobium*); S.T. = single-tailed; OTH = other types (mainly strigiid).

Other snails (1 = present; 0 = absent).
P = Pila speciosa; L = Lanistes carinatus; M = Melandoides tuberculata; F = Bulinus forskalii; B = yet to be identified bivales; A = ancylid.

However, the absence of long-term standing water limited the distribution of infectious sites to four villages: Sanguuni, Moofa (lower Jubba), Jilib, and Qalaaliyo (middle Jubba). This still represented 16 percent of all sampled villages with standing water, and 17 percent of all sampled WCSs. The transmission potential in the four villages was high.

At Sanguuni, all 55 snails (100 percent) were shedding the parasite. This was in a roadside depression pool next to the police barrier on the Kismaayo road (and village football field). The site was used extensively by residents and travellers. It measured about 50 x 20 m, and contained at least 500 *B. abyssinicus* at the time of sampling (all large specimens, between 10 and 17 mm in shell height). The other two sites at Sanguuni were in depression pools formed in an old, partially filled, wide drain.

At Moofa, 19 infected snails were found in an irrigation drain about 50 m from the nearest house. A water contact point was cleared in the drain but it

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Table 3. Snails Collected at Sampled Water Contact Sites in the Middle Jubba Villages.

VILLAGE	Habitat Code	Bulinus abyssinicus Collected	Infected SH	Infected ST	Infected OTH	Other Snails P	L	M	F	B	A
Qalaaliyo	1	42	30	3	2	1	1	1	1	0	0
	1	29	30	2	2	1	1	1	1	0	0
Jilib	1	181	1	1	7	1	0	0	0	0	0
	1	44	5	0	1	1	1	1	1	0	0
	4	0	0	0	0	1	1	1	1	0	0
	4	0	0	0	0	1	0	0	0	0	0
Hombooy	1	0	0	0	0	1	0	0	0	0	0
Hiloshiid*											
	1	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	1	1	1	0	0	0
Malenda	1	84	0	0	0	0	0	0	0	0	0
Madiina	3	17	0	0	0	1	1	1	0	0	0
Mareerey (1km from village)	3	3	0	0	0	0	0	0	1	0	0
Hargeisa	1	0	0	0	0	0	0	0	0	0	0
Muuna	1	0	0	0	0	0	0	0	1	0	0
Total snails		399	53	6	20						
No. of sites with snails		7				10	8	7	6		00
% of sites with snails		50				71	57	50	43		00
Snail infection rate (%)			13.2	1.5	5.0						

**nomadic section at main road*

Table 4. Snails Collected at Sampled Water Contact Sites in the Upper Jubba Villages.

VILLAGE	Habitat Code	Bulinus abyssinicus Collected	Infected SH	Infected ST	Infected OTH	Other Snails P	L	M	F	B	A
Tetay	3	0	0	0	0	1	1	1	0	0	0
Jabbi	5	0	0	0	0	0	0	0	0	0	0
Gurmeyso	1	4	0	0	0	0	0	0	0	0	0
Saakow	7	0	0	0	0	0	1	0	0	0	0
Bu'aale	7	0	0	0	0	1	0	0	0	0	0
Baardheere	6	0	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0
Buulo Garass	5	0	0	0	0	0	0	0	0	0	0
Total snails		4	0	0	0						
No. of sites with snails		1				2	2	1	0		00
% of sites with snails		25				22	22	11	0		00
Snail infection rate (%)		0									

Table 5. Areas Searched for Bulinus abyssinicus Shells in Dry Sites.

VILLAGE or AREA	HABITAT	QUALITATIVE DENSITY
LOWER JUBBA		
Sabatuuni (January)	Depression by river	Numerous
Road between Kamsuuma and Makalaangow	Depression by river	Numerous
Weltuweer	Dhesheeg 6 km from river	Absent
MIDDLE JUBBA		
Hombooy	Near depression pool	Absent
Misra	Depression near river	Absent
UPPER JUBBA		
Baardheere	Field near river	Absent
Dhoobley	Depression near river	Numerous
Gaaduure	Depression near river	Few
Gesire	Dhesheeg 1 km from river	Absent
Saakow	Depression near river	Absent

Table 6. Non-water Contact Sites Sampled Qualitatively for B. abyssinicus.

AREA	HABITAT	NO. WITH SNAIL/ NO. SAMPLED	RELATIVE
LOWER JUBBA			
Road between Mana Moofa & Kamsuuma	roadside pools	5/9	Light; snails expanding after rains
MIDDLE JUBBA			
Road between Jilib and Fanoole Barrage	roadside pools main canal	4/5 0/3	moderate
Road between Jilib and Shabeelle bridges	roadside pools	0/3	
Road 1-3 km S. of Jilib	roadside pools	0/3	
Road between Mugaambow and Mareerey	roadside pools	2/3	light

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was surrounded by vegetation. Infection was 53 percent.

Both sampled sites at Qalaaliyo were highly infectious (30 and 17 infected snails; an overall infection rate of 66 percent). This village is adjacent to the Fanoole Rice Farm where most residents work. During sampling, a depression pool about 100 m long and 20 m wide separated the main cluster of households from the main road leading to the rice field. The villagers walked through this depression pool along two to four well-marked footpaths to the farm. The snail was also found throughout the rice fields and adjacent pools in the estate (quick searches).

At Jilib, the main WCS was about 100 m from the old JESS compound, at the canal dike, and entrance to the Fanoole Barrage road. This site contained only one infected snail. But that is misleading because the site (approximately 100 x 30 m) contained at least 50,000 mature specimens and over 1,000,000 newly hatched snails. Thus, there were probably hundreds of infected snails shedding cercariae.

The second infectious site at Jilib was in another depression pool below the canal dike near the dirt road leading to the river at Misra. The WCS was used for washing, bathing, and playing. The infection rate here was 11.3 percent (5/44).

3. Snail Size

The mean shell height of all 779 *B. abyssinicus* collected in July was 10.33 mm. (S.D. 2.948). The largest specimen collected was 16.5 mm. Fewer snails were measured in the December-January survey (249). The mean shell height for these snails was 9.438 mm (S.D. 3.627).

The July survey also measured size of *S. haematobium* - infected snails (mean = 12.525 mm; S.D. 1.865). The mean shell height of all snails collected from infectious versus noninfectious sites was 11.73 mm (S.D. 1.871) and 8.248 (S.D. 2.993) respectively. However, one large brood of small snails at Beled Raxma (140 snails under 6.9 mm) added low bias to the non-infectious sites.

The largest shell height of any *B. abyssinicus* known to the Danish Bilharziasis Laboratory is 17.6 mm (DBL unpublished field guide to African freshwater snails; 3: North East African species, 1986). Therefore, the population structure in most sites in July indicated a large brood of mature and older snails, probably an "F1" generation that expanded after the gu' rains destroyed dry season populations. The large brood of small snails at Beled Raxma and newly-hatched snails at Jilib seem to indicate "F2" and "F3" populations. The incomplete size data from December-January are more difficult to interpret, but suggest a greater mixture of young and mature snails.

Figure 2 shows the size-frequency distribution of the July snails along with specimens infected with *S. Haematobium* cercariae. As expected, infection rates correlated positively with increasing snail size in an almost logarithmic progression after a slow buildup. This has also been observed in other countries for other snail species (Klumpp 1983).

4. Snail Distribution and Density by Habitat

The December-January survey determined that *B. abyssinicus* cannot be found in the main river channel or in rapidly flowing water (*e.g.*, main irrigation canals). Hence, the July sampling concentrated on standing water bodies. A few canal sites were searched in the middle Jubba area, and an attempt was made to find any aquatic snail in the river at Baardheere.

Table 7 summarizes snail distribution by habitat in July. Seven different ecotypes were noted: depression pools (mainly of the sides of roads); irrigation drains (mainly open ditches draining banana fields); dhesheegs (small lakes in old "oxbow" or other depressions that fill during natural or controlled river flooding, or heavy rains); irrigation canals (main, and secondary from river); reservoirs and water holes without vegetation (mainly for irrigation and livestock); river inlets or "side-arms" (low-lying, calm pockets of river); and the main Jubba River channel.

The results clearly show the relative abundance of depression pools along the Jubba and their suitability for all common species of snails. Irrigation drains and dhesheegs were less common but also favored by *B. abyssinicus*. The snail was not found in the other ecotypes.

Table 8 combines summary results from the two snail surveys. It confirms the importance of roadside depression pools for harbouring the largest number of infected and uninfected *B. abyssinicus*. The only other ecotypes of significance were irrigation drains, and to a lesser extent, dhesheegs.

Table 7. Snail Distribution by Habitat.

Type of site	No. times sampled	No. times containing snails B. abyss	Pila	Lanis	MelanB.	forsk.	Other
Depression pool	24	14	15	10	9	10	2
Irrigation drain	6	5	3	2	0	2	0
Medium/large dhesheeg	4	2	3	3	3	1	0
Irrigation canal	4	0	3	4	2	0	0
Reservoir/ water hole (no veg)	3	0	0	0	0	0	0
River inlet/ "side-arm"	2	0	1	1	0	0	0
River	3	0	0	0	0	0	0
TOTAL	46	21	25	20	14	13	2

5. Snails by Vegetation

Almost all of the *B. abyssinicus* collected in July were associated with three plants: *Nymphaea lotus*, *Cyperus exaltatus*, and *Ipomoea aquatica*. *Nyphaea* was the most widespread in long-standing depression pools, and the snail could be found clinging to the underside of the broad, floating leaves. The *Cyperus* was found in fewer sites, but contained larger numbers of *B.abyssinicus*. The snail preferred the sedge when the stems and leaves were almost in a horizontal position from partial decay and animal trampling. *Ipomoea* crept into irrigation drains and depression pools, and was a good substrate for the snail. *B. abyssinicus* was also found on banana stems and leaves, coconut fronds, and sticks. Floating masses of *Ludwigia* and *Alternanthera* species were common along the Fanoole main canal and often contained *Pila*, *Lanistes*, and *Melanoides*.

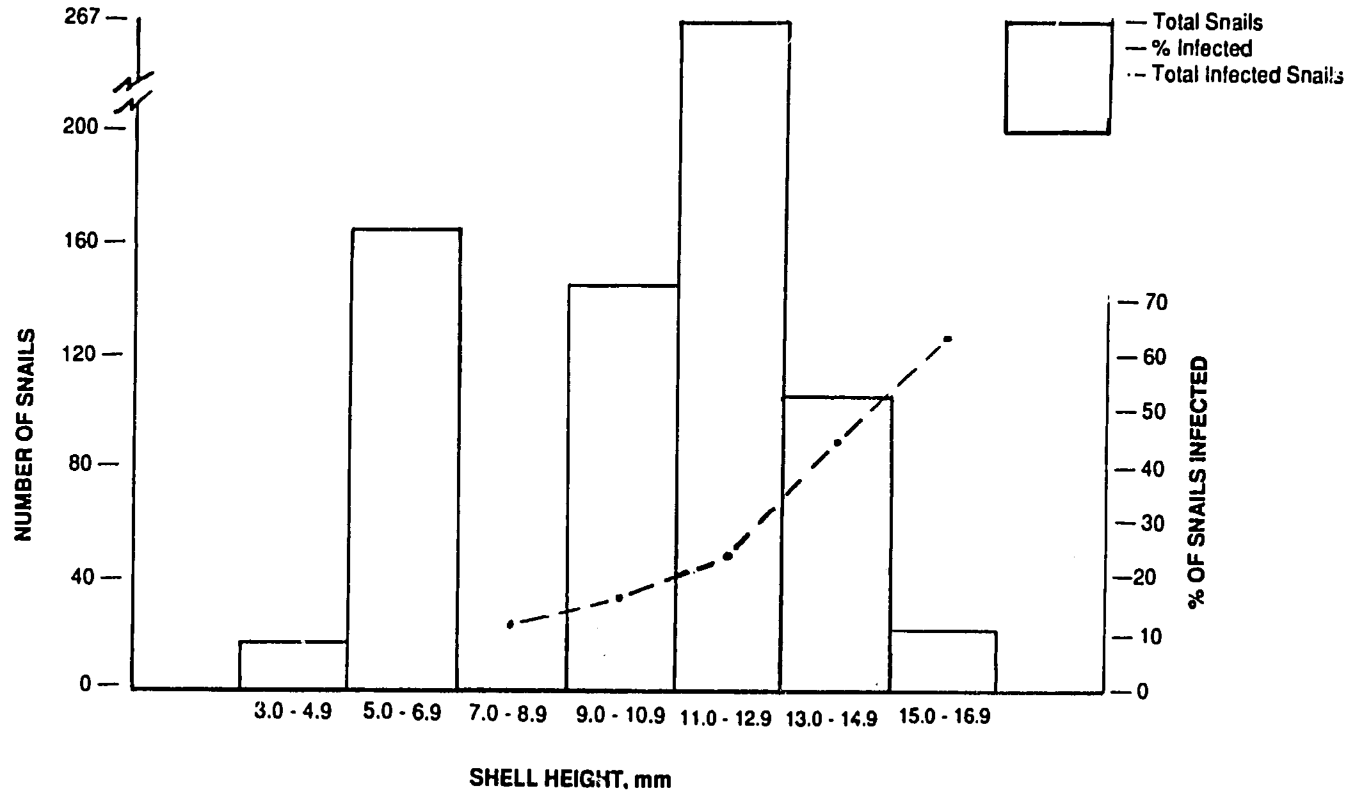

Figure 2. Size-Frequency breakdown of Bulinus Abyssinicus, *including those infected with* S. Laematobium cercariae.

Four *B. abyssinicus* were found in only one site without vegetation. This was in receding, turbid depression pool at Gurneyso (upper Jubba), which had been a flood dhesheeg during the last deyr season.

6. Snail Distribution and Human Prevalence of the Disease

The January JESS survey on schoolchildren in the lower Jubba established that the overall prevalence rate was 74.6 percent in Jamaame and 14 surrounding villages, and 81.8 percent excluding Jamaame. The geometric mean of parasite ova among all positives was 41 per 10 ml, despite early morning urine collection.

Table 8. Frequency and Density of B. abyssinicus by Habitat from Both JESS Snail Surveys.

Ecotype	No. times sampled	No. times with *B.a.*	% of times	Total *B.a.* collected	
				All	Infected
Depression pool	40	23	57.5	854	168
Irrigation drain	17	8	47.1	490	29
Dhesheeg	11	6	54.5	46	0
Irrigation canal	7	0	0	0	0
River channel	9	0	0	0	0
River inlet	2	0	0	0	0
Reservoir (no vegetation)	3	0	0	0	0

Discussions with World Concern staff at Jilib in July indicated that urinary bilharzia in the middle Jubba area, as far north as Fanoole Barrage, is a public health problem, with "high" prevalence [illegible] among children.

Ad hoc bilharzia screenings in the Bu'aale and Saakow areas have been undertaken by the Swedish Relief Church, although no published reports are available. From informal discussions with the Swedish staff, it is evident that bilharzia is less widespread in this sector. However, some villages that receive river flooding have known prevalence rates of over 70 percent among children.

Among the three sectors surveyed, bilharzia is least widespread around Baardheere. The District Medical Officer there reported only "a few" cases of the infection in the past two years. However, foci of infection do exist. In 1972, a Chinese team reported a 51.4 percent prevalence rate of *S. haematobium* at Dhoobley, near the future dam site (Mott *et al.*, undated, unpublished report). The July snail survey found 44 shells of *B. abyssinicus* in a dry dhesheeg that receives almost annual flooding. The children in the village complained of current "Kaadi Dhiig" (gross haematuria).

The July snail survey corresponds with the above prevalence information: the snail and the disease are widespread from at least Sanguuni in the south to Fanoole Barrage in the north, and limited to riverine dhesheeg foci farther north. These dhesheegs become less frequent upstream, along with the snail and the infection.

III. Conclusions and Recommendations

The main conclusions from both JESS snail surveys are as follows:

- *Bulinus abyssinicus* is widespread in standing water bodies in riverine and dhesheeg communities in the lower and middle Jubba sections. The main zone of snail density is from Turdho (south) to Fanoole Barrage (north), concentrated near the river and main roads. Further north, the snail is limited to low-lying riverine foci that receive flooding.
- The transmission season can continue for much of the year in the lower and middle Jubba sections where standing water abounds. It is shorter and very seasonal in villages that receive periodic river flooding. The main peaks of transmission are probably between June and August, and December and February in the main snail zones.
- Bilharzia in the lower and middle [illegible]a areas is largely a man-made disease, exacerbated by poor engineering and irrigation techniques that spread depression pools and drain pools in villages, along roads, fields, and dikes.
- The completion of the Baardheere Dam will have a major impact on the distribution of the snail intermediate host, both in the man-made reservoir and downstream. The snail is expected to proliferate in the sheltered coves and inlets of the reservoir before stabilizing and dying back some years after maximum reservoir impoundment. The snail and bilharzia will contract in its downstream distribution if dhesheeg flooding is cur-

tailed. If controlled flooding is allowed to continue, the snail and the infection will endure in the dhesheeg basins. The snail and parasite will continue to be a public health problem in the heavily-irrigated areas unless the numerous roadside and fieldside depression pools are filled in and primary health care improves.

- Providing well water in riverine and present dhesheeg villages will not have a major impact *per se* on reducing incidence of infection. Most transmission occurs among children playing in the water, and in areas of saline ground water. Jubba villagers prefer the sweet water in pools, drains, dhesheegs, canals and the river. However, providing well water has so many other public health advantages, it should be supported. Latrine projects are advantageous for sanitary improvement, but experience has shown that this would not lead to significant reduction in the transmission of urinary bilharzia.

Consequently, the following recommendations are cited as a means to reduce snail habitat or mitigate the effects of the proposed Baardheere Dam and subsequent development of the valley:

- All unnecessary depression pools in and around villages that contain water for more than a few months should be filled in.
- Irrigation drains should have a regular program of vegetation removal and maintenance. This would largely eliminate the snail problem. People should be discouraged from water contact in drains.
- Resettlement along the shores of the man-made reservoir behind the Baardheere Dam should be restricted.
- Controlled dhesheeg flooding after dam completion should be limited and engineered to prevent standing water from accumulating in riverside depressions and inland basins.

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ANNEX 1. List of Senior Officials Contacted

Muqdisho

Dr. Mohamed Weys, *Director of National Antimalaria Service*

Mr. Hassan Igeh, *Director of Schistosomiasis Control Program*

Dr. Robert A. Tillman, *JESS Project Manager*

Mr. Weston Fisher, USAID

Dr. Lundgren, *WHO Medical Officer, MCH*

Ms. D. Lupin, UNICEF

Mr. Mates Hoegelius, *Swedish Relief Church-Coordinator*

Jamaame

Mr. Ali, *District Commissioner*

Jilib

Dr. Cambell Miller, *World Concern*

Mr. Michael Madanly, *World Concern*

Mr. Bob West, *World Concern*

Bu'aale

Nurses, *Swedish Relief Church*

Baardheere

Dr. Ahmed Yusef, *District Medical Officer*