NUS CORPORATION

Gannett Fleming ENVIRONMENTAL ENGINEERS, INC.

FINAL REPORT

FOCUSED REMEDIAL INVESTIGATION

ARMY CREEK LANDFILL SITE
NEW CASTLE COUNTY, DELAWARE

EPA WORK ASSIGNMENT
NUMBER 37-10-3L34
CONTRACT NUMBER 68-W8-0037

NUS PROJECT NUMBER 1017

JANUARY 1990

FINAL REPORT

FOCUSED REMEDIAL INVESTIGATION STUDY

ARMY CREEK LANDFILL SITE
NEW CASTLE COUNTY, DELAWARE

EPA WORK ASSIGNMENT NUMBER 37-10-3L34
UNDER
CONTRACT NUMBER 68-W8-0037

JANUARY 1990

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TABLE OF CONTENTS

TABLE OF CONTENTS (cont'd.)

TABLE OF CONTENTS (cont'd.)

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

AR301267

EXECUTIVE SUMMARY

SITE HISTORY

The Army Creek Landfill, formerly known as the Llangollen Landfill, is located approximately 7 miles southwest of the City of Wilmington, Delaware. The landfill is bordered to the north and west by Conrail tracks and on the south and east by Army Creek. The highways adjacent to the landfill are U.S. Routes 13 and 301 to the west and Delaware Route 9 to the east.

The Army Creek Landfill consists of a 60-acre site that was operated by New Castle County from 1960 through 1968 for the disposal of municipal and industrial wastes. The site is located adjacent to Delaware Sand and Gravel (DS&G), an industrial waste disposal site closed by the Delaware Department of Natural Resources and Environmental Control (DNREC) in 1976. Approximately 1.9 million cubic yards of refuse were landfilled at Army Creek.

After groundwater contamination was discovered in 1972, New Castle County installed a series of groundwater recovery wells downgradient of the landfill to prevent the contaminant plume from reaching wells belonging to the Artesian Water Company. According to the U.S. Environmental Protection Agency (EPA), it appears that pumping of the recovery wells has created a groundwater divide between the Army Creek Landfill and the Artesian Water Company's Llangollen Wellfield. The recovery wells appear to be effectively capturing the plume of organic and inorganic contaminants from both Army Creek and DS&G landfills that have been detected in the recovery wells and monitoring wells.

Remedial action of the landfill was previously addressed in a feasibility study report prepared for New Castle County (Weston, 1986) which was used by EPA to designate Operable Unit 1 (OU1) and to prepare a Record of Decision (ROD) in September 1986. The OU1 ROD will be implemented in two phases.

Phase 1 consists of:

- Installation of a RCRA-type cap to minimize the infiltration of rainwater. Capping of the landfill will include site clearing, regrading of the existing cover surface, adding soil backfill to achieve grades, installing the cap with gas vents, and constructing drainage ditches to direct runoff away from the landfill.

- Continued operation of the downgradient recovery well network.

- Evaluation of the capping system and the downgradient recovery well network for five years after the cap is installed. This will be done to assess effectiveness of the system during operation. This evaluation will include, but not be limited to, monitoring water levels, pumping rates, and water quality.

Phase 2 consists of:

- After the five-year evaluation period, a determination will be made as to whether to install upgradient controls on the northwestern boundary of the landfill to intercept lateral groundwater inflow.

- Continued monitoring of the water levels, pumping rates and water quality as in Phase 1.

- Operation and maintenance including at a minimum, regular inspections and, as necessary, repairs to the RCRA-type cap. The groundwater recovery system will also be monitored to ensure that it is capturing the contaminated plume.

The ROD further states that:

- Selection of a treatment alternative for the groundwater recovery well discharges has not been made at this time and will be the subject of a second operable unit decision document in the future.

- Also being deferred at this time is a decision on appropriate remedial measures for sediments in Army Pond. This decision will be made at the same time as groundwater treatment is considered and after further analysis is accomplished regarding the actual impacts on Army Pond.

Phase 1 of the OU1 is currently being implemented.

OBJECTIVES

The overall objectives of the focused Army Creek Remedial Investigation/ Feasibility Study (RI/FS) are to (1) identify risks from exposure to existing pond and creek sediments, creek surface water, and contaminated groundwater discharged to the creek, (2) to evaluate remedial action alternatives for treating contaminated groundwater and sediments, and (3) to assess the risks to human health and the environment for each alternative.

Specific objectives of the RI were developed to meet the project goals and to address the data limitations from previous investigations. These objectives, as provided in the Final Work Plan, include the following:

- To resample the discharges of nine groundwater recovery wells and analyze water for inorganic compounds, volatile and semivolatile organic compounds, including phthalate esters.

- To determine the risks to humans including both carcinogenic and noncarcinogenic health effects from exposure to the organic and inorganic contaminants present in stream sediments, surface water, and groundwater recovered at the site.

- To determine risk levels presented to the environment due to organic and inorganic contaminants in the sediments, surface water, and groundwater being discharged to the stream.

FIELD INVESTIGATION

Two field investigation tasks were conducted in the Focused RI: (1) the sampling of the discharges from the groundwater recovery wells and (2) hydrogeologic investigation which consisted of the measurement of the water flow into and out of Army Creek and Army Pond. The results from the field investigations are used to supplement the existing data for the assessment of the present and future risks to human health and the environment as well as to evaluate potential remedial alternatives.

As a result of the field hydrogeologic investigation and the subsequent water balance analysis, several conclusions can be made about surface water/ groundwater interactions in the vicinity of the Army Creek Landfill. Much of the surface water in Army Creek and Army Pond is being lost to the groundwater system. Contaminants in the surface water, therefore, may be transported into the subsurface and into the groundwater system. Contaminated groundwater discharged from the recovery wells into Army Creek may be returned to the groundwater system only to be pumped again. The contaminants in the surface water, however, may be attenuated to some degree in the sediments as the water infiltrates into the subsurface.

NATURE AND EXTENT OF CONTAMINATION

The groundwater discharges pumped from nine active recovery wells were sampled. Iron exceeded the EPA and State of Delaware ambient water quality criteria (AWQC) for freshwater life. The most contaminated wells were Wells 12, 28, and 29.

Evaluating the analytical results reported by Charters (EPA, 1988c), we found surface water in Army Creek and Army Pond to have elevated concentrations of the following contaminants that exceeded the water quality criteria for freshwater aquatic organisms set by EPA and/or State of Delaware: cadmium, chromium, iron, mercury, and zinc.

ENVIRONMENTAL FATE AND TRANSPORT

The most important contaminants at the Army Creek Site include metals, volatile organics, and semivolatile organics. These contaminants are found in the recovered groundwater, in surface .:ter, and in sediments. The diverse nature of the contaminants as well as the different media in which they reside dictate that the environmental fate and transport will be very complex. The important processes include: volatilization, photolysis, adsorption, desorption, dissolution, sedimentation, bioaccumulation, bioconcentration, chemical speciation, and biological degradation.

The hydrogeological study performed during this RI demonstrated that the surface water onsite is moving into the groundwater at a very high flow rate. This water movement facilitates the recycling of the water soluble contaminants through the three media of groundwater, surface water, and sediment. The ultimate sinks that can be postulated for the indicator contaminants are:

- For the volatile and less adsorbable organics: long-term recycling between surface water and groundwater, downstream transport, volatilization into the air, and degradation.

- For the semivolatile and more adsorbable organics: concentration in biota and sediments (with ultimate deposition into the sediments), downstream transport while adsorbed to sediments, and degradation.

- For iron: transport downstream by surface water, recycling between surface water and groundwater, and oxidation to the ferric form and precipitation in the sediments of Army Creek or Army Pond.

- For the other inorganics: bioaccumulation, sedimentation, recycling between surface water and groundwater, and transport downstream by surface water.

RISK ASSESSMENT

Identified potential human exposure routes included: inadvertent ingestion of groundwater recovery well discharges, surface water, sediment, and fish consumption; inhalation of volatile and semivolatile organic compounds from groundwater recovery well discharges and surface water; and dermal absorption of contaminants from inadvertent exposure to surface water, sediment, and recovery well discharges.

Potential public health risks were calculated for various scenarios of human exposure to the contaminants. The potential human carcinogenic risks were calculated to be minimal (10^{-9} level from inadvertent ingestion of groundwater recovery well discharges, surface water, or sediment; 10^{-7} level from inhalation of contaminants from groundwater recovery well discharges or surface water; and 10^{-10} to 10^{-7} level from dermal absorption of contaminants from groundwater recovery well discharges, surface water, or sediment). The potential noncarcinogenic risks were also calculated to be minimal for all of the exposure routes.

A more qualitative assessment was performed for the environmental impact of the contamination onsite. Detrimental effects on the biota could possibly result from contact with the contaminated groundwater recovery well discharges, or surface water. Contamination appeared to impact the aquatic environment more than the terrestrial environment. However, the upstream water from the site was also noted to be highly nutrient enriched which also adversely impacted the aquatic environment.

CONCLUSIONS

Under the anticipated exposure scenarios and current conditions, the focused study area and media do not present significant carcinogenic or noncarcinogenic risks to the general public. Iron in recovered groundwater and cadmium, chromium, mercury, and zinc in the surface water have been identified as contaminants of concern to the aquatic environment. Mitigation of iron contamination must be achieved by treatment of recovered groundwater prior to discharge to surface waters. Contamination by the other metals will be mitigated by completion of the landfill cap described by the OU1 ROD. Metals in the Army Pond sediments have been determined to not represent a threat to the aquatic environment.

1

AR301275

1.0 INTRODUCTION

1.1 PURPOSE OF REPORT

This report presents the results of the Focused RI conducted for the EPA at the Army Creek Landfill Site, located in New Castle County, Delaware. Preparation of this RI was accomplished in response to Work Assignment Number 37-10-3L34 under EPA Contract Number 68-W8-0037 pursuant to the Final Focused RI/FS Work Plan (WP) dated July 1989. This section summarizes the scope and objectives of the RI/FS. Included is a description of the site history and relevant background information.

1.2 SCOPE AND OBJECTIVES

The overall objectives of the Army Creek Focused RI/FS are (1) to identify risks from exposure to existing pond and creek sediments, creek surface water, and contaminated groundwater discharged to the creek, (2) to evaluate remedial action alternatives for treating contaminated groundwater recovery well discharges and sediments, and (3) to assess the risks to human health and the environment for each alternative.

Specific objectives of the RI were developed to meet the project goals and to address the data limitations from previous investigations. These objectives, as provided in the Final WP, include the following:

- To resample nine groundwater recovery wells and analyze water for inorganic compounds and volatile and semivolatile organic compounds, including phthalate esters.

- To determine the risks to humans including both carcinogenic and noncarcinogenic health effects from exposure to the organic and inorganic contaminants present in stream sediments, surface water, and groundwater recovered and discharged on site.

- To determine risk levels present in the environment due to organic and inorganic contaminants in the sediments, surface water, and groundwater being discharged to the stream.

AR301276

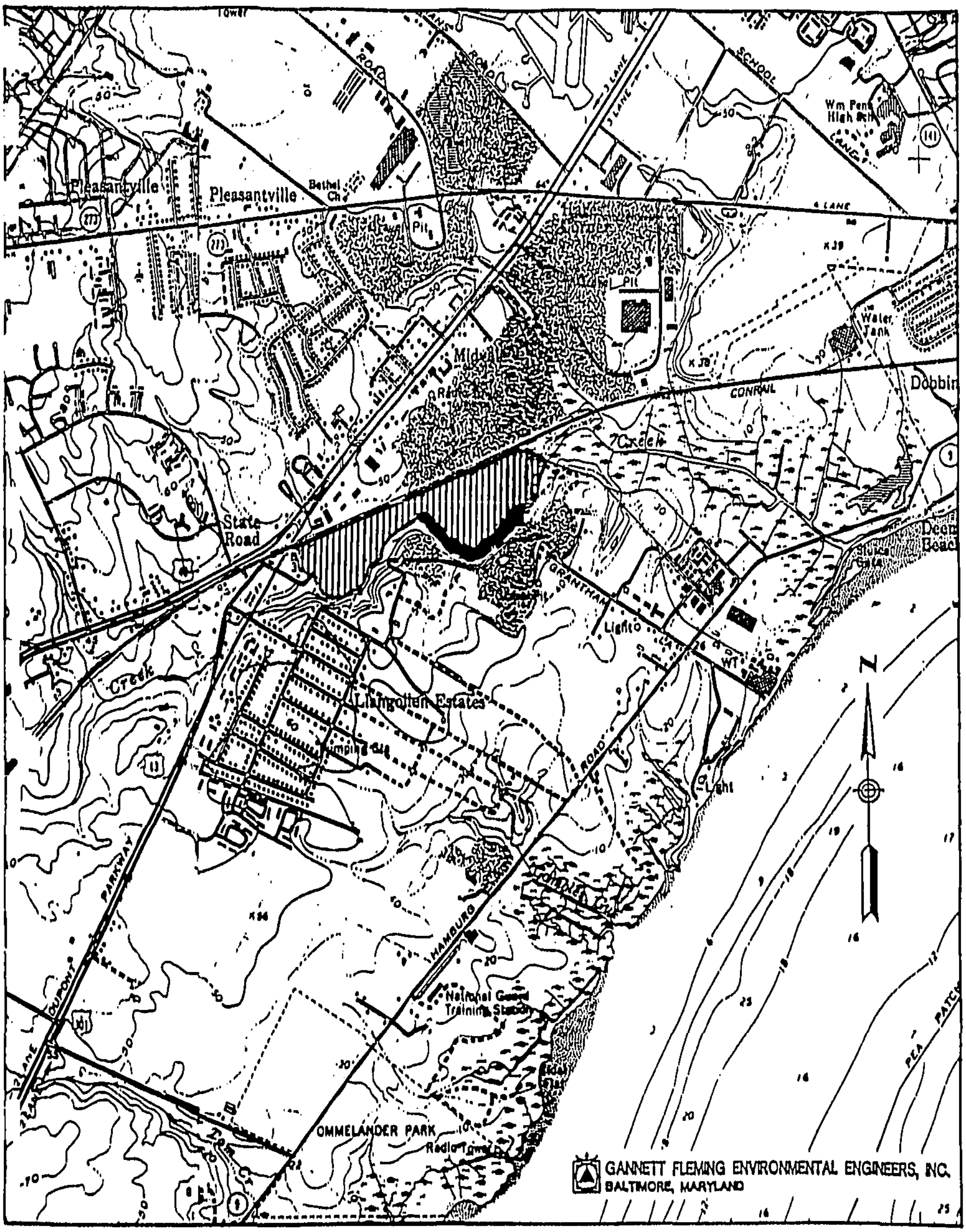
Various studies and data collection activities were conducted to meet these objectives. Due to the available data and the focused nature of this RI/FS, however, only a limited amount of field sampling and measurements were taken in the RI. Most of the studies, therefore, rely heavily on existing data and literature search. This RI report presents the findings and conclusions of these studies.

1.3 SITE BACKGROUND

This section provides the site location and description, site history, and summary of previous investigations associated with the Army Creek Site. The primary source of this information is the Technical Direction Memorandum (TDM) prepared by NUS Corporation/Gannett Fleming Environmental Engineers, Inc. (NUS/GF), for EPA in 1989.

1.3.1 Site Location and Description

The Army Creek Landfill, formerly known as the Llangollen Landfill, is located approximately seven miles southwest of the City of Wilmington, Delaware (Figure 1-1). The landfill is bordered to the north and west by Conrail tracks, and on the south and east by Army Creek. The highways adjacent to the landfill are U.S. Routes 13 and 301 to the west, and Delaware Route 9 to the east. Map coordinates for the site are approximately 39 degrees, 39 minutes north latitude, and 75 degrees, 37 minutes west longitude. The site was placed on the Superfund National Priorities List (NPL) due primarily to contamination of local groundwater which is withdrawn by the Artesian Water Company from water supply wells near Llangollen Estates, a residential development located southwest of the site (Figure 1-1). The former Amoco Chemical Plant, closed in 1980 due to fire, is located 1/4 mile east of the site. Delaware Sand and Gravel Site (DS&G), another landfill on the Superfund NPL, is located adjacent to Army Creek Landfill and separated from it only by Army Creek, a tributary of the Delaware River.



LEGEND

ARMY CREEK POND

ARMY CREEK LANDFILL SITE

FIGURE 1-1

ARMY CREEK LANDFILL SITE LOCATION

QUADRANGLE LOCATION

SCALE: 1" = 24,000

1 ½ 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

AR301278

1.3.2 Site History

The Army Creek Landfill consists of a 60-acre site that was operated by New Castle County from 1960 through 1968 for disposal of municipal and industrial waste. The site is located adjacent to DS&G, an industrial waste disposal site closed by the Delaware Department of Natural Resources and Environmental Control (DNREC) in 1976. Approximately 1.9 million cubic yards of refuse were landfilled at Army Creek.

After groundwater contamination was discovered in 1972, New Castle County installed a series of groundwater recovery wells downgradient of the landfill to prevent the contaminant plume from reaching wells belonging to the Artesian Water Company. Approximately 5,000 residential customers are serviced in that area by Artesian. According to EPA, it appears that pumping of the recovery wells has created a groundwater divide between the Army Creek Landfill and the Artesian Water Company's Llangollen Wellfield. The recovery wells appear to be effectively capturing, and thereby preventing further migration of the plume of organic and inorganic contaminants from both Army Creek and DS&G landfills that have been detected in the recovery wells and monitoring wells.

Army Creek was proposed for inclusion on the NPL in October of 1981, and was included on this list in September of 1983 (original NPL). In 1984, EPA entered into a Consent Agreement and Order with New Castle County to perform a FS which was completed in July 1986.

The Army Creek ROD was issued on September 30, 1986. The ROD required installation of a RCRA-type landfill cap and continued operation of the recovery well system at a currently estimated cost of $25 million total. The September 30, 1986 ROD deferred the decision on groundwater treatment until after the National Pollutant Discharge Elimination System (NPDES) permit was issued, and until the DS&G RI/FS was completed. The Army Creek FS addressed groundwater treatment focusing on iron and solids removal. The DS&G FS addressed isolated (near drum disposal area) groundwater contamination within the DS&G site and not the total site area. Neither study addressed all of the specific inorganic and organic contaminants found in groundwater recovery well discharges leaving the sites. A second ROD is needed to select a groundwater treatment remedy for the discharge of recovery well water to Army Creek, and to determine the appropriate remedial measure to clean up contaminated sediments in Army Pond, if necessary.

The background status of the community relations as well as a mailing list of interested parties, agencies, and media are included in Appendix A.

1.3.3 Previous Investigations

According to the field investigation data developed in August 1988 under EPA Work Assignment No. 0-123, Field Investigation, Army Creek Site, the groundwater recovery well discharges, surface water, and soils contain various concentrations of metals and organic compounds. Surface water and sediment in Army Creek contain elevated levels of iron, zinc, and chromium, and the water quality standards for these metals are exceeded. In order to comply with a Consent Order with the State of Delaware, signed in 1987, New Castle County is designing a groundwater recovery well water discharge treatment plant for iron removal (to meet the current NPDES permit level of 5 ppm iron in effluent) that is expected to be completed in July 1990.

The groundwater recovery well discharges have been sampled and analyzed in the past and have shown varying degrees of contamination with time. The validity and usefulness of these data were addressed in the NUS/GF TDM (1989). A representation of those data that are useful in the assessment of trend and environmental fate was presented in the WP. However, due to the concern of validity of the past data and the need of having timely data for the RI/FS, the groundwater recovery well discharges have been resampled in this study.

Wetlands were surveyed in 1988 by the U.S. Fish and Wildlife Service and the Delaware DNREC Wetlands Branch. Three on-site wetland types were identified. An additional environmental survey was conducted in conjunction with EPA sampling activities in 1987 and 1988. Section 3.6 discusses the available environmental and wetland survey data.

1.4 REPORT ORGANIZATION

The organization and content of the balance of this report are described below.

- Section 2.0, FIELD INVESTIGATION

  This section describes the RI field activities, including the hydrogeologic investigation and the groundwater recovery well discharge sampling activities.

- Section 3.0, NATURAL AND PHYSICAL CHARACTERISTICS OF THE SITE

  This section describes the surface features, climate, soils, geology, hydrogeology, demography and land use, and biota that are associated with the site. It is based upon both data obtained from the RI and information contained in previous reports.

- Section 4.0, NATURE AND EXTENT OF CONTAMINATION

  This section presents the results of the RI environmental sampling and analysis program. Included are data on the nature and extent of contaminants detected in the groundwater recovery well discharges during the RI. The nature and extent of contamination of the surface water and sediment were assessed through a literature search. The results of this assessment were also presented in this section.

- Section 5.0, ENVIRONMENTAL FATE AND TRANSPORT

  This section describes the potential migration routes for site-associated contaminants, including groundwater, surface water, sediment, and air. Potential contaminant migration routes, and the physical and chemical properties of the contaminants as they relate to environmental fate and transport are also included in this section.

AR301281

- Section 6.0, RISK ASSESSMENT

  This section presents an assessment of the public health and environmental risks associated with chemical contamination under the no-action scenario. Applicable or Relevant and Appropriate Requirements (ARARs) are identified; actual and potential carcinogenic and noncarcinogenic risks are estimated; and an assessment of the hazards posed to environmental receptors is presented.

- Section 7.0, SUMMARY AND CONCLUSIONS

  This section provides a summary of the findings under Sections 2.0 through 6.0, including the nature and extent of contamination, contaminant fate and transport, risk assessment, and risk-based recommended remedial action objectives.

- REFERENCES

- APPENDIX A--COMMUNITY RELATION CONCERNS AND MAILING LIST

- APPENDIX B--SAMPLE LOG SHEETS

- APPENDIX C--ANALYTICAL RESULTS FOR GROUNDWATER RECOVERY WELL DISCHARGES

- APPENDIX D--PREVIOUS SEDIMENT AND SURFACE WATER DATA

- APPENDIX E--TOXICOLOGIC PROFILES

- APPENDIX F--PUBLIC HEALTH RISK CALCULATIONS

- APPENDIX G--ENVIRONMENTAL SURVEY DATA

- APPENDIX H--PRIME FARMLAND AND HISTORIC AND ARCHAEOLOGICAL RESOURCES AROUND THE ARMY CREEK LANDFILL SITE

- APPENDIX I--LIST OF CONTRIBUTORS

AR301283

2

AR301284

2.0 FIELD INVESTIGATION

Two field investigation tasks were conducted in the Focused RI: (1) the sampling of the groundwater discharges from the recovery wells and (2) hydrogeologic investigation which consisted of the measurement of the water flow into and out of Army Creek and Army Pond. The results from the field investigations are used to supplement the existing data for the assessment of the present and future risks to human health and the environment as well as to evaluate potential remedial alternatives. The objectives presented in the Final WP (NUS/GF, 1989) were used to develop the Scope of Work for this project.

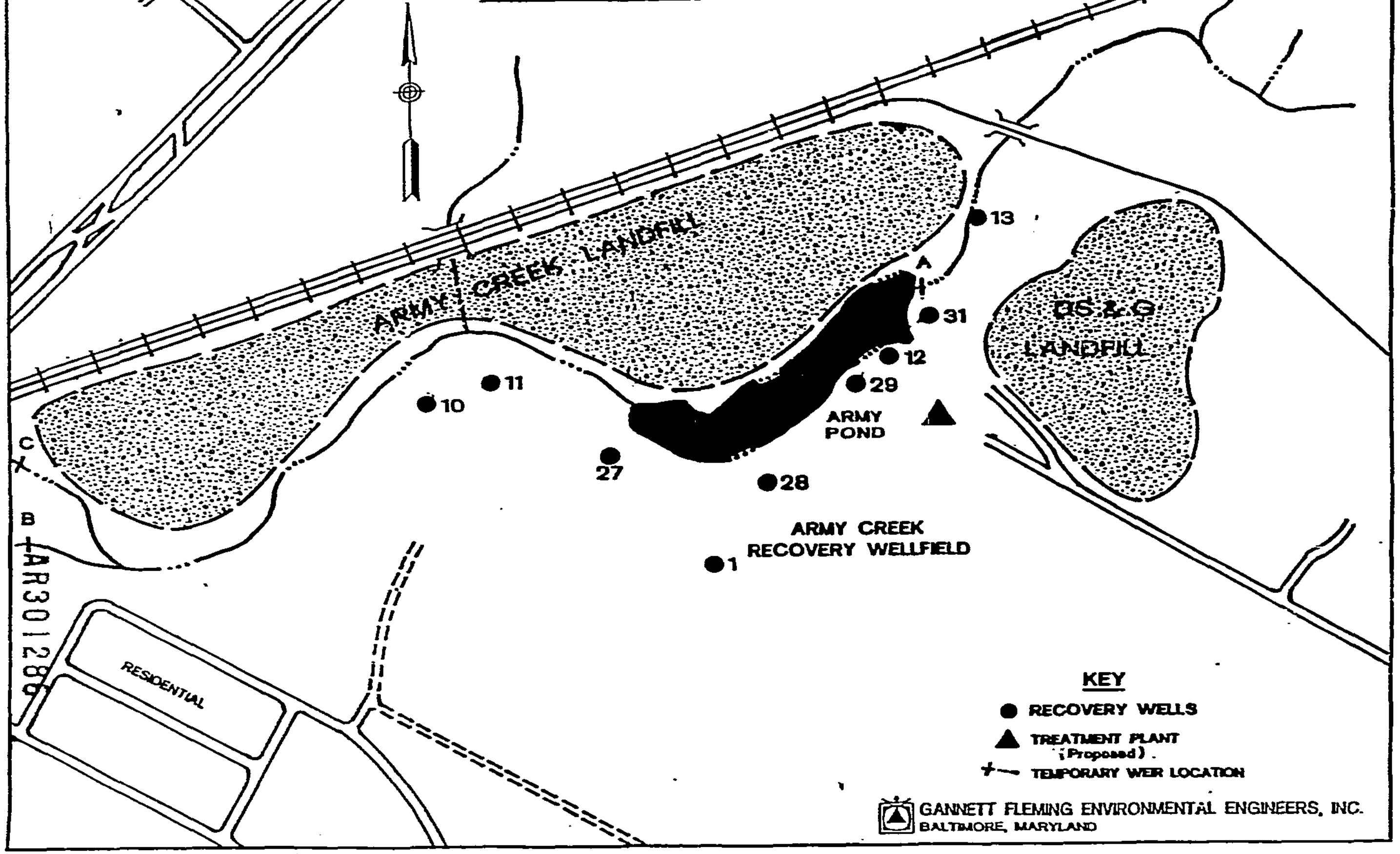
The field investigation activities, as developed in the Final WP and Project Operations Plan (POP) (NUS/GF, 1989), are briefly summarized in the following sections. Deviation from the WP and POP are noted. The sampling of groundwater recovery well discharges is presented in Section 2.1 and the hydrogeologic investigation is presented in Section 2.2.

2.1 SAMPLING OF GROUNDWATER RECOVERY WELL DISCHARGES

The sampling of groundwater recovery well discharges was carried out on July 6 and 7, 1989. The recovery wells sampled are referred to by the well numbers assigned to them by R.F. Weston. Altogether a total of nine recovery well discharges were sampled. The nine recovery wells were numbered 1, 10, 11, 12, 13, 27, 28, 29, and 31 (Figure 2-1). This was a deviation from the 10 recovery wells specified in the Final WP and POP, which was caused by the shutdown of Well 14, making the sampling of Well 14 impossible. R.F. Weston, the consulting firm retained by the Potentially Responsible Parties (PRPs), collected a set of split samples throughout the groundwater recovery well discharge sampling activities. This sampling event also included one set of duplicates, rinsate blanks, field blanks, and trip blanks. The details of the quality control samples were listed in Tables 3-1 and 4-1 in the Final POP.

FIGURE 2-1

ARMY CREEK ACTIVE RECOVERY WELLS



The groundwater recovery well discharge samples collected from the nine recovery wells were analyzed for the following:

- TCL organics
- TAL inorganics (filtered and unfiltered samples)
- Alkalinity and Acidity
- Total suspended solids (TSS) and total dissolved solids (TDS)
- Common anions: sulfate, chloride, nitrate, and nitrite
- Sulfide
- Ammonia and total Kjeldahl nitrogen
- Phosphate
- Total organic carbon

The following field measurements were taken on all groundwater recovery well discharge samples during the sampling event:

- pH
- Specific conductance
- Dissolved oxygen
- Temperature

The results of these analyses are presented in Appendix C. The results that are important for the risk assessment are presented and discussed in Sections 4.0 and 6.0. The results that are important for the evaluation of the potential water treatment alternatives will be presented and discussed in the FS report.

2.2 HYDROGEOLOGIC INVESTIGATION

The hydrogeologic investigation was conducted on August 7 and 8, 1989. The objective of this limited field activity was to establish a water balance inventory around the Army Creek/Army Pond area. The water balance inventory would then be used to assess the significance of the communication between the surface water and the groundwater recovery well discharges around the study area.

To gauge the surface water inflow into the Army Creek Landfill area, a temporary weir was installed in Army Creek upstream of the landfill. A second weir was installed in a small tributary upstream of the landfill. To gauge the surface water outflow from Army Pond, a temporary weir was constructed at the location of the former weir dam on Army Pond. The volume of groundwater recovery well discharges pumped into the Army Creek/Army Pond system was measured at the end of pipe at each of the recovery wells. A bucket and stopwatch were used to accomplish this activity. The results of the water balance inventory are presented and discussed in Section 3.4.3.

3

3.0 NATURAL AND PHYSICAL CHARACTERISTICS OF THE SITE

3.1 SURFACE FEATURES

The Army Creek Landfill, formerly known as the Llangollen Landfill, is located approximately 7 miles southwest of the City of Wilmington, Delaware (Figure 3-1). The site is bordered to the north and west by the Conrail (Penn Central) tracks, and on the south and east by Army Creek.

This site is located in the coastal plain province and overlies the Potomac and Columbia Formations. The topography is gently rolling and dissected by numerous streams. The site varies in elevation from less than 10 feet above mean sea level along Army Creek to a point elevation of 51 feet. The highest elevations within one mile of the site are a point elevation of 69 feet on State Route 273 east of Route 40, and mapping of the 60-foot contour in Llangollen Estates to the south, and to the west across Route 40.

3.2 CLIMATOLOGY

The nearest National Oceanic and Atmospheric Administration (NOAA) climatological station is located at the Greater Wilmington-New Castle County Airport, about one mile due north of the site. This station has been in continuous operation since 1947 at the various terminal buildings on the airport.

The climate is a mild continental/marine with warm humid summers, and generally mild winters. The proximity of the Delaware and Chesapeake Bays act to moderate the conditions. For ease of reference, the normals, means, and extremes of temperature, relative humidity, precipitation, wind speed, and wind direction have been summarized below.

- Temperature (°F):
  Daily Max.: 63.5
  Daily Min.: 44.5
  Max.: 102 (1966)
  Min.: -14 (1985)

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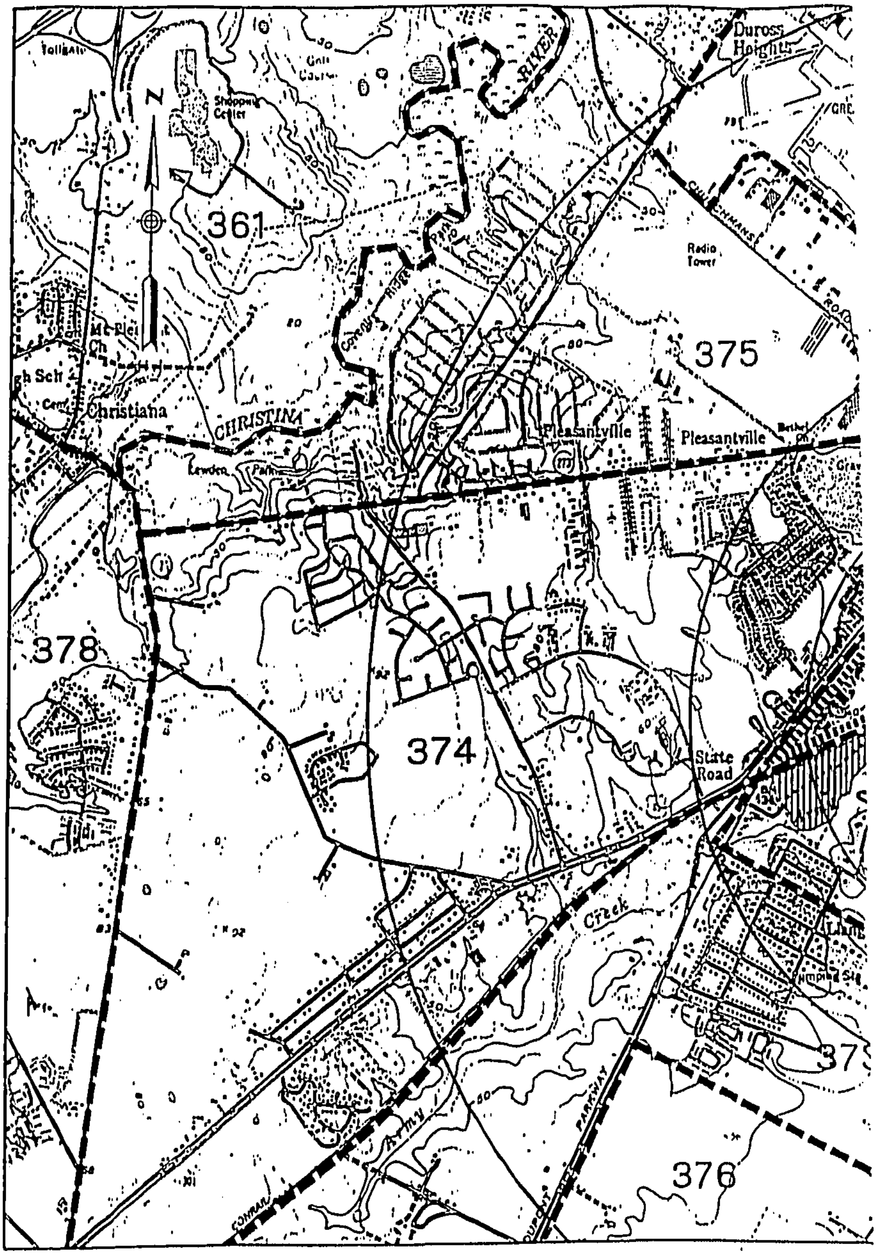


LEGEND

TREATMENT PLANT SITE (Proposed)

ARMY CREEK POND

POPULATED AREAS (WITHIN 1 MILE)

TRAFFIC ZONES

COMMERCIAL / INDUST. ZONE

ARMY CREEK LANDFILL SITE

QUADRANGLE LOCATION

ARMY (

1000 0 1000

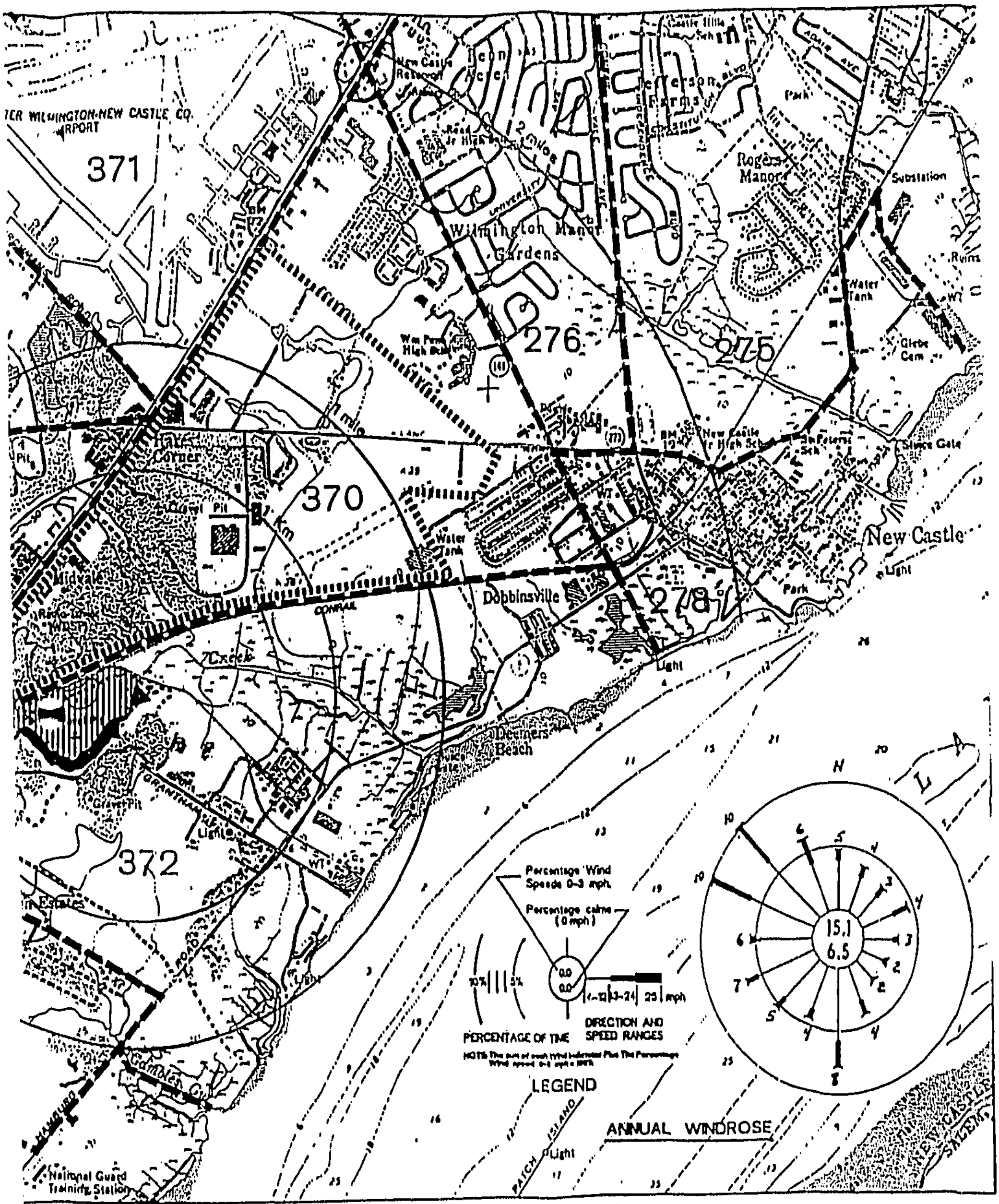


FIGURE 3-1

GANNETT FLEMING ENVIRONMENTAL ENGINEERS, INC.
BALTIMORE, MARYLAND

R[illegible]K LANDFILL SITE

SCALE 1 : 24,000

0 1 MILE

2000 3000 4000 5000 6000 7000 FEET

AR301291

- Relative Humidity (%), Local time:
  Hour 01: 78
  Hour 07: 78
  Hour 13: 55
  Hour 19: 66

- Precipitation (inches):
  Rain:
    - Annual Normal: 41.38
    - Monthly Maximum: 12.09
    - Monthly Minimum: 0.16
    - 24-hour Maximum: 6.83 (1989)

  Snow, Ice Pellets:
    - Monthly Maximum: 27.5 (1979)
    - 24-hour Maximum: 16.5 (1979)

- Wind:
  Mean Speed: 9.2 mph
  Prevailing Direction: South
  Peak Gust: 71 mph Northwest (1984)

3.3 GEOLOGY

3.3.1 Regional Geology

The Army Creek Landfill is located within the Atlantic Coastal Plain physiographic province, approximately 5 miles southeast of the Fall Line. The Fall Line marks the beginning of bedrock exposures, and is thus the geomorphic boundary between the Piedmont and Atlantic Coastal Plain provinces.

The Atlantic Coastal Plain consists of a wedge of seaward thickening and dipping, stratified, unconsolidated and semiconsolidated sediments that were deposited in both marine and nonmarine environments. This sediment wedge varies in thickness from nearly zero at the Fall Line up to several thousand feet near the coastline; its age ranges from early Cretaceous to Holocene (recent).

Southeast of the Fall Line outcrop the sediments of the Lower Cretaceous Potomac Formation consist of fluvial-deltaic continental and marginal marine deposits. The Potomac Formation forms the basal lithostratigraphic unit of the coastal plain sediments, and rests unconformably upon the basement rock surface. The basement complex is composed of Precambrian and Paleozoic igneous and metamorphic crystalline rocks. The upper surface of the basement complex is highly weathered, forming a cover of saprolite. The Potomac Formation is separated by major regional unconformities from the overlying later Cretaceous and various Tertiary deposits. Due to the proximity of the Army Creek Landfill to the Fall Line, however, a complete stratigraphic section is not present. Not only are units stratigraphically higher than the Potomac Formation absent in the Army Creek area, but also the Potomac Formation is of greatly reduced thickness, extending to depths of 400 to 650 feet.

The Potomac Formation is overlain by the sediments of the Columbia Formation. This sand-rich and gravel-rich unit was presumably deposited during the Pleistocene by braided glacial outwash streams flowing from the north and northeast. The base of the Columbia Formation, often indicated by a pebbly/cobbly layer or an iron-indurated zone, marks an erosional surface developed on the underlying Potomac deposits.

3.3.2 <u>General Site Geology</u>

<u>Quaternary Formations</u>

Based on data gathered during previous field investigations, the Army Creek Landfill is underlain by the Pleistocene Columbia Formation, which is characterized by moderately to poorly sorted, light-tan, brown-orange, and brown coarse to fine sand with variable amounts of fine to coarse gravel and traces of silt. Planar cross stratification is common, although not usually observable from borehole samples. The base of the Columbia Formation is usually marked by a thin layer of iron-cemented pebbles and cobbles. This basal conglomerate was probably removed by excavation in at least two places within the landfill.

The thickness of the Columbia Formation in the vicinity of the Army Creek Landfill ranges from 25 to 60 feet. The base of the Columbia Formation ranges from approximately -20 to +20 feet in elevation. The surface topography of the formation also varies.

Within the Army Creek valley are up to 30 feet of recent alluvial deposits, which consist of interbedded silts, clays, and peats. Because these deposits are restricted to the Army Creek valley, they probably owe their origin to the gradual filling of an older channel cut into the underlying Columbia Formation during a lower sea level stand. Typically, less than 10 feet of Columbia sediments underlie the Army Creek alluvial deposits.

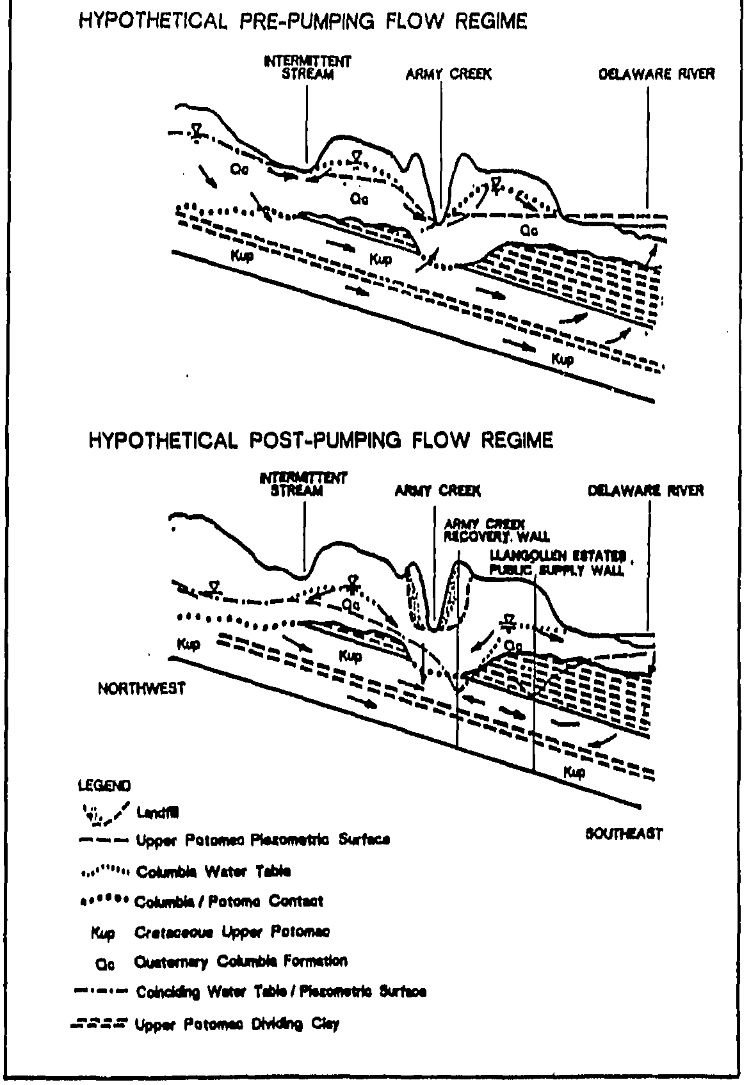
Potomac Formation

The Potomac Formation consists of unconsolidated clays, silts, and sands emplaced as channel deposits by southerly-flowing meandering streams. Three sand-rich zones, separated by thick, dense clays are generally recognized within the Potomac Formation: the Upper Potomac, the Middle Potomac, and the Lower Potomac. The sand units are elongated and tabular or lensatic in shape and are composed of moderately well sorted, medium to fine, white to light gray quartz sands with only trace amounts of clay and silt. The intervening clay units are generally dense gray clays or variegated red and white clays and contain frequent lignite fragments.

Underlying the Columbia Formation at the Army Creek Landfill is the uppermost clay unit of the Potomac Formation. Throughout much of the eastern portion of the landfill, the clay layer is either thin, sandy, or completely absent, while south of the landfill the layer ranges from 10 to over 80 feet thick (Figure 3-2).

The Upper Potomac sand-rich zone that underlies the uppermost Potomac clay unit, or the Columbia Formation where the clay unit is absent, is composed of white, light gray, tan, or light brown medium to very fine sand with traces of fine gravel and occasional light gray silty clay seams. A relatively thick silty clay or clayey silt unit subdivides the Upper Potomac into two sandy

FIGURE 3-2



HYPOTHETICAL PRE- AND POST-PUMPING GROUNDWATER FLOW REGIME IN THE VICINITY OF ARMY CREEK (not to scale)

AR301295

zones in some locations. This dividing clay ranges in thickness from about 6 to 32 feet.

The Upper Potomac is generally underlain by a thick, dense, medium gray silty clay, although variegated red and white clays are present in some areas. This clay layer is continuous and relatively impermeable. Underlying this clay unit are the Middle and Lower Potomac sand-rich zones and intervening clay units.

3.4 HYDROGEOLOGY

3.4.1 Aquifer Characteristics

The four aquifers recognized in the two Coastal Plain formations that occur in the vicinity of the Army Creek Landfill are the Columbia Aquifer and the Upper, Middle, and Lower Potomac aquifers. The saturated sand and gravel of the Columbia Formation form the regional unconfined water table aquifer. Water table elevations generally mimic local topography, and the base flow of surficial streams is derived from this aquifer. The hydraulic conductivity of the Columbia Aquifer is expected to range from 15 to 150 ft/day. Specific yield of the unconfined aquifer is expected to range from 0.10 to 0.25.

The three major sand-rich zones of the Potomac Formation form three artesian aquifers termed the Upper, Middle, and Lower Potomac Hydrologic Zones. The three hydrologic zones subcrop beneath the Columbia Formation to the west and north of the Army Creek Landfill. Water table conditions exist in the Potomac aquifers in the subcrop zones, which are areas of direct recharge to the confined groundwater system. The Upper Potomac Hydrologic Zone (UPHZ) contains a discontinuous, interbedded silty clay layer in some locations, forming an upper Upper Potomac Aquifer and a lower Upper Potomac Aquifer. The hydraulic conductivity of the UPHZ is estimated to range from 25 to 100 ft/day. Storativity in the UPHZ ranges from 0.00005 to 0.004, as expected for artesian conditions. R.F. Weston (1986) reported much higher storativity values of 0.01 to 0.03, indicating water table conditions in areas where the uppermost confining layer is sandy or missing.

AR301296

The vertical hydraulic conductivity of the uppermost Potomac confining layer, between the Columbia Aquifer and the UPHZ, averages from 0.05 to 0.005 ft/day. In the eastern portion of the Army Creek Landfill, this confining layer is relatively thin, sandy, or absent, producing a zone where the Columbia Aquifer and the UPHZ are in direct hydrologic contact. The zone where the uppermost Potomac confining clay layer is absent is referred to as the "zero area." A portion of the Army Creek channel is located within the zero area.

3.4.2 Groundwater Flow

Prior to groundwater withdrawal from the UPHZ, natural groundwater flow was from the subcrop zones toward the Delaware River, where upward leakage probably occurred. Groundwater withdrawals for public water supply have caused numerous interfering cones of depression in the potentiometric surfaces of the confined aquifers. Groundwater flow has been greatly accelerated toward the pumping wells from the subcrop zones and head declines have probably induced downward leakage from the Delaware River. The UPHZ has shown dramatic head declines over the past 30 years due to preferential use and probably receives recharge directly from its subcrop zone and indirectly as vertical leakage from both the overlying Columbia Aquifer and the underlying Middle and Lower Potomac Hydrology Zones.

The water table within the surficial Columbia Aquifer at the Army Creek Landfill Site reflected the land surface topography prior to the heavy pumpage of the UPHZ. Groundwater within the aquifer flowed to the south and southeast, and discharged into Army Creek (Weston, 1986; Dunn Geoscience Corporation (DGC, 1987). At that time, the artesian head levels in the UPHZ probably were higher than the water table surface in the zero area. Therefore, the zero area was an area of groundwater discharge for the Upper Potomac Aquifer. Army Creek was receiving water from both the Columbia and Upper Potomac Aquifers (DGC, 1987). Currently, groundwater flow in the Columbia Aquifer in the western portion of the Army Creek Landfill reflects the land surface topography, flowing to the southeast and discharging into Army Creek. In the eastern portion of the landfill, however, the Columbia Aquifer is nearly dewatered as a result of the hydrologic connection between the Columbia Aquifer and the underlying UPHZ at the zero area.

The large groundwater withdrawals from the UPHZ in recent years have produced a decline in artesian head levels and consequently reversed the original hydraulic gradient of the water table in the vicinity of the zero area. Water table elevations in the Columbia Aquifer near the zero area have dropped as water is pulled downward into the Upper Potomac Aquifer. Aiding this dewatering is the geometry of the Columbia Aquifer: the base of the aquifer slopes towards the zero area as a result of the paleochannel that exists beneath the current Army Creek channel (DGC, 1987). Because the bottom of the Army Creek channel is higher than the local water table, water will drain from the stream into the ground. Thus Army Creek is now discharging water through the channel bed in the vicinity of the zero area, with stream flow largely sustained by the recovery well pumpage that is discharged directly to Army Creek. Loss of stream waters to groundwater is hindered to some degree, however, by the fine-grained alluvial deposits that occur beneath the Army Creek channel.

3.4.3 Water Balance Inventory

To determine the net amount of water lost from Army Creek into the groundwater, a water balance inventory was performed. This water balance inventory was performed during a two-day monitoring effort. The amount of surface water lost to groundwater may be determined according to the following formula:

Net loss = (surface water inflow + imported water + surface runoff) - (surface water outflow + evaporation)

Each term of the equation is discussed below:

Surface Water Inflow - To gauge the surface water inflow into the Army Creek Landfill area, a temporary weir was installed on Army Creek upstream of the landfill. A second weir was installed on a small tributary upstream of the landfill. Discharge over the Army Creek weir was 11.51 gallons per minute (gpm) or 0.026 cubic feet per second (cfs). Discharge over the tributary weir was 3.83 gpm or 0.0085 cfs. Total surface water inflow, therefore, was 15.34 gpm or 0.0345 cfs.

Imported Water - The groundwater discharges pumped into Army Creek from the recovery wells is considered "imported" water. The discharge of each recovery well was measured at the outfall and totaled 800 gpm or 1.784 cfs.

Surface Runoff - DGC (1987) estimated runoff based on a technique described in EPA Manual SW-186, to be 10 to 15 percent of annual rainfall in the vicinity of Army Creek. Rainfall data from the Greater Wilmington Airport, located approximately one mile north of the Army Creek Landfill, indicate that normal annual rainfall is 41.38 inches. Runoff, therefore, is estimated at 4.1 to 6.2 inches annually. Over the 0.5 square mile drainage area between the upstream weirs and the former weir dam on Army Pond, approximately 8.22×10^9 to 1.24×10^{10} cubic inches run off annually. These values equate to 0.15 cfs and 0.23 cfs, respectively.

Surface Water Outflow - To gauge the surface water outflow from Army Pond, a temporary weir was constructed at the location of the former weir dam on Army Pond. Although some water was flowing around the weir, discharge over the Army Pond weir measured 49.1 gpm or 0.109 cfs.

Evaporation - Evaporation directly from the surface of Army Creek and Pond is estimated to be 30 inches annually, or 0.033 cfs (Strahler, 1970).

By inputting these values into the equation, the net amount of surface water lost to groundwater can be calculated:

Net loss = (0.0345 cfs + 1.784 cfs + 0.15 cfs) - (0.109 cfs + 0.033 cfs), or
Net loss = (0.0345 cfs + 1.784 cfs + 0.23 cfs) - (0.109 cfs + 0.033 cfs)

From this calculation, net loss of surface water from Army Creek and Army Pond to groundwater ranges from 1.83 cfs to 1.91 cfs. This amounts to approximately 93 percent of the total inflow. Even if the amount of surface water outflow is doubled to 0.218 cfs to account for the water lost around the weir, 88 percent of the surface water flow is lost to the groundwater.

3.4.4 Conclusions

As a result of the water balance inventory analysis, several conclusions can be made about surface water/groundwater interactions in the vicinity of the Army Creek Landfill. First, much of the surface water in Army Creek and Army Pond is being lost to the groundwater system. Contaminants in the surface water, therefore, may be transported into the subsurface and into the groundwater system. Contaminated groundwater discharged from the recovery wells into Army Creek may be returned to the groundwater system only to be pumped again. The contaminants in the surface water, however, may be attenuated to some degree in the sediments as the water infiltrates into the subsurface.

Another possibility is that contaminants in the sediments may be transported downward into the groundwater with the infiltrating surface water. If the contaminated sediments were dredged, this potential would be eliminated. Because the present Army Creek channel is underlain by up to 30 feet of older fine-grained sediments, dredging of the recent shallow sediments would not open a direct pathway into more permeable subsurface deposits.

3.5 DEMOGRAPHY AND LAND USE

Within a one-mile radius there are two concentrations of residential population--Llangollen Estates to the south and southwest, and a large subdivision between Routes 40 and 273 to the northwest. A portion of Llangollen Estates borders the site on the south side of Army Creek (Figure 3-1).

Llangollen Estates consists of a combination of single and multifamily dwellings that is projected to grow significantly in population. The subdivision across Route 40, known as Pleasantville, appears to be nearly built out closest to the site, while extensive development is occurring beyond one mile from the site towards Christiana.

The area between Llangollen Estates and the Conrail line contains the DS&G NPL site, a nonoperating chemical plant, and some scattered residential development (45 structures in 1987). To the north of the Conrail line, the properties are primarily commercial or slated as industrial park. The strip along Route 40 is mixed commercial/residential strip development. The next nearest residential concentrations are approximately 1.5 miles away. The City of New Castle's corporate limits are approximately 1-1/4 miles from the site, but most concentrated between 2 and 2-1/2 miles.

Population estimates have been based on the New Castle County Department of Planning Traffic Zone projections. Within the zones, population has been estimated by structure counts from available mapping and field reconnaissance.

No prime farmland occurs on or downstream from the Army Creek Site. However, according to Delaware's Land Evaluation and Site Assessment (LESA) system, many of the soils surrounding Army Creek upstream from the site are considered prime (see Appendix H). These include Matapeake silt loams and Woodstown loams. These soils occur both north and south of the site within one mile.

No known historic or archaeological resources currently listed on the National Register of Historic Places or in the Delaware Cultural Resources Survey are found on the Army Creek Landfill Site. However, the western end of the Army Creek Site is considered to be a potential prehistoric site area (see Appendix H). Within a one-mile radius of the Army Creek Site, there are at least 28 historic or archaeological sites that are listed in the Delaware Cultural Resources Survey. These sites consist primarily of houses, estates, churches, and one bridge. The town of New Castle, Delaware, located approximately 1.5 miles from the landfill, is a National Historic Landmark listed on the National Registry of Properties.

Future land use at the Army Creek Site may include a discontinuation of the pumping of groundwater recovery wells. If this were to occur it is doubtful if the onsite wetlands would remain in their current form. A possible result could be the shrinking of Army Creek into its natural banks with the surrounding pond returning to an associated flood plain.

3.6 BIOTA

Biological monitoring began at Army Creek in 1973 (R.F. Weston, 1986). From 1973 to 1982, Weston conducted 11 biological surveys of the Army Creek area. These surveys basically provide qualitative data on the presence/absence of plants, terrestrial and aquatic vertebrates, and aquatic macro- and micro-invertebrates. Between 1983 and 1985, the Delaware DNREC Division of Water Resources conducted two studies. A fish survey of Army Creek coupled with an analysis of fish tissue for some organic and inorganic compounds was conducted in May 1983. In June 1985, the Delaware DNREC performed a qualitative survey of aquatic macroinvertebrates above and below the Army Creek Pond as well as a water collection for a Ceriodaphnia bioassay. The EPA performed a biomonitoring survey coupled with both a Ceriodaphnia and a fathead minnow bioassay in March 1986. In May 1988, they also commissioned the U.S. Fish and Wildlife Service to do a wetlands survey, which dealt primarily with wetlands vegetation. A wetland study and mitigation plan was prepared by NUS/CF as part of the remedial design of the OU1 landfill cap.

Due to differences in survey techniques, levels of quantitation, sampling locations, and time of year when surveys were performed, it is very difficult to determine any changes in the biota of Army Creek over time. However, a good description of the general biota of Army Creek can be obtained from the combination of these data.

3.6.1 Vegetation

3.6.1.1 Direct Observations

The vegetation areas of the Army Creek Landfill Site consist primarily of disturbed upland vegetation of mixed wooded, shrub, and grass-dominated areas and a complex of primarily three wetland types. R.F. Weston (1986), in their biomonitoring surveys from 1973 to 1982, identified 37 species of woody plants and 37 species of herbaceous pl .its on the Army Creek Site (See Table 3-1). The majority of these species were upland species, though most were located along the bank of the pond. The landfill did appear to support a number of

TABLE 3-1

VEGETATION OF ARMY CREEK

ARMY CREEK LANDFILL SITE

VEGETATION	
White pine	Pinus strobus
Mockernut hickory	Carya tomentosa
Pignut hickory	Carya glabra
Black willow	Salix nigra
Beech	Fagus grandifolia
White oak	Quercus alba
Black oak	Quercus velutina
Red oak	Quercus rubra
Chestnut oak	Quercus prinus
Willow oak	Quercus phellos
Tulip poplar	Liriodendron tulipifera
Sycamore	Platanus occidentalis
Fire cherry	Prunus pennsylvanica
Black locust	Rubinia pseudoacacia
Staghorn sumac	Rhus typhina
Red maple	Acer rubrum
Silver maple	Acer saccharinum
Flowering dogwood	Cornus florida
Sweet gum	Liquidambar styraciflua
Spice bush	Lindera benzoin
Arrow-wood	Viburnum dentatum
Japanese honeysuckle	Lonicera japonica
Green briar	Similax sp.
Wild rose	Rosa multiflora
Sassafras	Sassafras albidum
Dwarf huckleberry	Gaylussacia dumosa
Virginia creeper	Parthenocissus quinquefolia
Acacia	Cassia sp.
Smooth alder	Alnus serrulata
Grape	Vitus sp.
Eastern red cedar	Juniperus virginica
Quaking aspen	Populus tremuloides
Crab apple	Pyrus sp.
Butternut hickory	Carya condiforms
Pitch pine	Pinus rigida
Redbud	Cercis canadensis
Large-toothed poplar	Populus grandidentata
Seaside alder	Alnus maritima
Black willow	Salix nigra
Elderberry	Sambucus canadensis
Red osier dogwood	Cornus stolinifera
Pin oak	Quercus palustris
Cattail	Typha latifolia
Reed	Phragmites australis
Rabbitfoot grass	Polypogon monspeliensis
Bunch grass	Unidentified
Mud plantain	Heteranthera reinformis

TABLE 3-1 (cont'd.)
VEGETATION OF ARMY CREEK
ARMY CREEK LANDFILL SITE
PAGE TWO

VEGETATION	
Braided plantain	Plantago asistata
Timothy	Phleum pratense
Bulrush	Scirpus atrovirens
Yardrush	Juncus tenuis
Sedge	Carex stipata
Orchard grass	Dactylis glomerata
Rye grass	Loluum parenne
Yarrow	Achillea millefolium
Pokeweed	Phytolaca americana
Smartweed	Polygonum sp.
Queen Anne's lace	Daucus carota
Redtop	Argrostis stolonifera
Shepherd's purse	Capsella Bursa-pastoris
Bluegrass	Poa sp.
Butter-and-eggs	Linaria vulgaris
Spatterdock	Nuphar luteum
Pickerel weed	Pontedaria cordata
Sensitive fern	Onoclea sensibilis
Jewelweed	Impatiens capensis
Boneset	Eupatorium perfoliatum
Skunk cabbage	Symplocarpus foetidus
Royal fern	Osmunda regalis
Burreed	Sparganium spp.
Water smartweed	Polygonum punctatum
Arrowhead	Sagittaria sp.
Broomsedge	Andropogon virginicus
Panic grass	Panicum sp.
Ragweed	Ambrosia artemisiifolia
Goldenrod	Solidago sp.
Aster	Aster sp.
Tickseed sunflower	Bidens polylepis
Partridge-pea	Cassia fasciculata
Clover	Lespedeza sp.
Crabgrass	Digitaria sanguinalis
Nodding foxtail	Setaria faberi
Purple lovegrass	Eragrostis spectabilis
Needlegrass	Aristida sp.
Arrow arum	Peltandra virginica
Yellow sweet clover	Melilotus officinalis
Rabbit-foot clover	Trifolium arvense
Daisy fleabane	Erigeron annus

early successional species (e.g., fire cherry, black locust, eastern red cedar) and also some species tolerant of low water conditions (e.g., pitch pine and eastern red cedar).

Wetland types and boundaries were determined by Rudis and Anderson in a 1988 wetland evaluation (U.S. Department of the Interior, Fish and Wildlife Service, 1988). The onsite wetlands consisted of three types. On the eastern end of the site, a palustrine emergent wetland fringed a disturbed area. This area was dominated by pickerel weed (Pontedaria cordata), sensitive fern (Onoclea sensibilis), jewelweed (Impatiens capensis), water smartweed (Polygonum punctatum) and various grasses. The approximate size of this area was 98 hectares. Scattered shrub species were also located along the margin.

The second wetland type was the open water area which was a shallow muck bottom pond of approximately 25 hectares. Some emergent vegetation consisting of pickerel weed (Pontedaria cordata), spatterdock (Nuphar luteum), cattails (Typha latifolia) and other species occurred around the margin of this pond.

The final onsite wetland type, a forested or shrub-dominated wetland, ran from the western end of the pond to the western margin of the site. This wetland type also encircled the pond. Dominant species in this wetland type included pin oak (Quercus palustris), red maple (Acer rubrum), and black willow (Salix nigra).

Immediately adjacent to the Army Creek Landfill Site to the east was an additional wetland complex. Army Creek flowed through this wetland to the Delaware River. This wetland was an estuarine emergent wetland approximately 870 hectares in size. The dominant plant species included phragmites (Phragmites australis) and jewelweed (Impatiens capensis).

Casual observations of the upland vegetation at the Army Creek Site were made by the samplers of this focused RI/FS during the July 5 and 6, 1989 sampling event. The upland areas appeared to be dominated by early successional species which had colonized since the discontinuation of landfill operations. Species included multiflower rose (Rosa multiflora), bittersweet (Celastrus sp.), Red ossiar dogwood (Cornus stolinifera), buckthorn (Rhamnus frangula), wild grapes (Vitis sp.), immature oaks (Quercus sp.), black cherry (Prunus pennsylvania), and goldenrods (Solidago sp).

3.6.1.2 Regional, Threatened, and Endangered Species

The overall regional vegetation of the Army Creek Landfill Site has been classified as Oak-Pine forest (Braun, 1950). Although little of this region and none of the Army Creek Landfill Site is undisturbed, it is likely that succession would result in upland forests dominated by various oaks and several pine species (Pinus taeda and Pinus palustris).

Over 630 plants are listed on the State of Delaware list of plants of special concern. Of these, six are considered apparently or demonstrably secure in Delaware. In addition, 30 plant species have been listed or are being considered for listing on the Federal U.S. Fish and Wildlife Service's list of endangered and threatened plants. It is of some importance given the extent of wetlands on and adjacent to the Army Creek Landfill Site that at least 4 of the 30 federally listed species can be considered wetland species, though none of these plants have been recorded in the Army Creek area (Trew, personal communication, 1989).

Two plant species of special concern in Delaware are located near the Army Creek Site. The bur-marigold, Bidens bidentoides, is located near the mouth of Army Creek along the Delaware River (Trew, personal communication, 1989). Its habitat requirements limit it to fresh to brackish tidal shores of the Hudson and Delaware Rivers (Fernald, 1950). This species was considered for inclusion on the federal list of threatened or endangered plants but proved to be more abundant or widespread than was previously believed. However, bur-marigold is very rare in Delaware. The shrub, Myrica cerifera, or wax-myrtle is also located near the mouth of Army Creek. This species is mainly southern in its distribution, found in thickets, woods, and swamps from Florida and Texas to southern New Jersey (Fernald, 1950). This species is not threatened or endangered federally but is only apparently secure in Delaware.

3.6.2 Wildlife

Wildlife as used here refers to amphibians, reptiles, fish, birds, and mammals.

3.6.2.1 Amphibians and Reptiles

Direct Observations

The summer and early fall censuses (1973, 1974, 1977, and 1978) performed by Weston (1986) yielded the greatest diversity of reptiles and amphibians (Table 3-2). As would be expected, censuses conducted in the late fall and winter (1975, 1980, and 1982) did not detect amphibians and reptiles at all. The species observed were reptiles: the eastern painted turtle, eastern mud turtle, snapping turtle, and northern water snake. The four amphibians observed were Fowlers toad, American toad, bullfrog, and northern leopard frog.

U.S. Department of Interior (1988), in the course of the wetlands survey, observed red-bellied, snapping and painted turtles, and frogs. EPA (1988c) also mentioned observing frogs and turtles at Army Creek in the pond area.

Regional, Threatened, and Endangered Species

Twenty-six species of amphibians and 38 species of reptiles are reportedly found in Delaware (Delaware National Heritage Program (DNHP), Appendix C). While no amphibians are listed as federally endangered, nine species are rare to endangered in the state. Six species of reptiles are currently on or are being considered for federal endangered or threatened status, while 16 species are rare to endangered in the state. None of the amphibians or reptiles which are known to occur on the Army Creek Landfill Site are considered state or federally endangered or threatened.

TABLE 3-2

REPTILES AND AMPHIBIANS OF ARMY CREEK

ARMY CREEK LANDFILL SITE

REPTILES	
Eastern painted turtle	Chrysemys picta
Eastern mud turtle	Kinosternon subrubrum
Spotted turtle	Clemmys guttata
Snapping turtle	Chelydra serpentina
Northern water snake	Nerodia sipedon
AMPHIBIANS	
American toad	Bufo americanus
Fowlers toad	Bufo woodhousei fowleri
Bullfrog	Rana catesbeiana
Northern leopard frog	Rana pipiens

Game Species

The bullfrog and the common snapping turtle are considered to be game species in Delaware (State of Delaware, DNREC, 1989a). According to Conant (1958), any permanent body of freshwater is suitable habitat for the snapping turtle. This species is omnivorous, feeding on various aquatic invertebrates, fishes, reptiles, birds, mammals, carrion, and vegetation. Bullfrogs live in permanent bodies of water and feed primarily on invertebrates or small vertebrates including fish, snake, mouse, duckling or baby turtles (Collins, 1959).

3.6.2.2 Fish

Direct Observations

A total of 19 species of fish have been identified in Army Creek from either the reaches upstream of the pond, the pond itself, or downstream of the pond (Table 3-3). All fish found were species tolerant of warm water conditions. Of the species found, nine species were detected in the 1973 to 1982 biomonitoring studies by Weston while the fish survey done in June 1983 by the Delaware DNREC detected nine species (State of Delaware DNREC, 1983). No surveys of the fish population have been performed since 1983 in Army Creek.

Regional, Threatened, and Endangered Species

Eighty-nine species of fish are reported in Delaware (Appendix G). Only the shortnose sturgeon is federally endangered but 28 species are rare to endangered in the State.

Four species of fish found in Army Creek are listed as being rare in the State of Delaware. These are smallmouth bass, striped bass, white crappies and yellow bullheads (Appendix G). In addition, the federally endangered species, the shortnose sturgeon, is found in coastal waters of the Atlantic and in the Lower Delaware River. It spawns in rivers over rubble in the spring (Cooper, 1983).

TABLE 3-3

FISH OF ARMY CREEK

ARMY CREEK LANDFILL SITE

FISH	
White perch	Morone americana
Carp	Cyprinus carpio
Killifish	Fundulus heteroclitus
Bluegill sunfish	Lepomis macrochirus
Pumpkinseed sunfish	Lepomis gibbosus
Bluespot sunfish	Enneacanthus gloriosus
Smallmouth bass	Micropterus dolomieui
Largemouth bass	Micropterus salmoides
Striped bass	Morone saxatilis
Gizzard shad	Dororsoma cepedianum
White sucker	Catostomus commersoni
White crappie	Pomoxis annularis
Black crappie	Pomoxis nigromaculatus
Brown bullhead	Ictalurus nebulosis
Yellow bullhead	Ictalurus natalis
American eel	Anguilla rostrata
Redfin Pickerel	Esox americanus
Golden Shiner	Notemigonus crysoleucas
Common Shiner	Notropis cornutus

Game Species

Game fish in Delaware include largemouth bass, smallmouth bass, black crappie, white crappie, rock bass, white bass, walleye, northern pike, chain pickerel, muskellunge and hybrids, salmon, trout, sunfish of the genus Lepomis, and striped bass hybrids. In addition, there is no ban on catching other species of fish. Seven species of fish found in Army Creek can be considered to be game fish though certainly other species such as carp and bullhead are known to be caught and consumed by humans on occasion.

All the game fish found in Army Creek are in the sunfish or Centrarchidae family. Most are tolerant of turbid conditions, with the exception of smallmouth bass, and feed on fish, insects, or crustaceans (Collins, 1959). Two other fish which are known to be taken from Army Creek, carp and brown bullheads, are bottom feeders and tend to be omnivorous (Collins, 1959).

3.6.2.3 Birds

Direct Observation

Sixty-five species of birds were observed on or near the Army Creek Site between 1973 and 1988 (Weston, 1986; U.S. Department of Interior, 1988; EPA, 1988c; and samplers in this RI/FS) (See Table 3-4). Using the classification system in Martin et al. (1951), the list of 65 species can be structured to include: four upland gamebirds (two doves, ring-neck pheasant, bobwhite); 11 species of marsh and shore birds (four herons, one sandpiper, three egrets, glossy ibis, killdeer, least bittern); five species of waterbirds (three ducks, one goose, one gull); five species of birds of prey (two hawks, kestrel, osprey, vulture); and 40 species of songbirds (blackbirds, warblers, sparrows, etc.).

Regional, Threatened, and Endangered Species

Two hundred and sixty-six species of birds are found in Delaware either as migrants or residents (Appendix G). Five species are either federally endangered or threatened. These are piping plover, brown pelican, golden

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TABLE 3-4

BIRDS OF ARMY CREEK

ARMY CREEK LANDFILL SITE

BIRDS	
Mallard	Anas platyrhynchos
Black duck	Anas rubripes
American kestrel	Falco sparverius
Osprey	Pandion haliaetus
Canada goose	Branta canadensis
Bobwhite	Colinus virginianus
Ring-necked pheasant	Phasianus colchicus
Snowy egret	Egretta thula
Cattle egret	Bubulcus ibis
Great blue heron	Ardea herodias
Green heron	Butorides virescens
Little blue heron	Florida caerulea
Great egret	Casmerodius albus
Black-crowned night heron	Nyctocorax nycticorax
Glossy ibis	Plegadis falcinellus
Killdeer	Charadrius vociferus
Spotted sandpiper	Actitis macularia
Mourning dove	Zenaidura macroura
Rock dove	Columba livia
Chimney swift	Chaetura pelagica
Belted kingfisher	Megaceryle alcyon
Yellow-shafted flicker	Colaptes auratus
Downey woodpecker	Dendrocopos pubescens
Eastern kingbird	Tyrannus tyrannus
Bank swallow	Riparia riparia
Rough-winged swallow	Stelgidopteryx ruficollis
Night hawk	Chordeiles minor
Chimney swift	Chaetura pelagia
Blue jay	Cyanocitta cristata
Common crow	Corvus brachyrhynchos
Mockingbird	Mimus polyglottos
Catbird	Dumetella carolinensis
Long-billed marsh wren	Cistothorus palustris
Brown thrasher	Toxostoma rufum
Robin	Turdus migratorius
Starling	Sturnus vulgaris
Yellow warbler	Dendroica petechia
Yellowthroat	Geothlypis trichas
Brown-headed cowbird	Molothrus ater
Red-winged blackbird	Agelaius phoeniceus
Common grackle	Quiscalus quiscula
Cardinal	Richmondena cardinalis
Indigo bunting	Passerina cyanea
American goldfinch	Spinus tristis
Chipping sparrow	Spizella passerina
Field sparrow	Spizella pusilla
Song sparrow	Melospiza melodea
House sparrow	Passer domesticus
Turkey vulture	Cathartes aura
Red-tailed hawk	Buteo jamaicensis
Carolina chickadee	Parus carolinensis
Carolina wren	Thryothorus ludovicianus
Bay-breasted warbler	Dendroica castanea
Eastern meadowlark	Sturnella magna
Junco	Junco hyemalis
White-throated sparrow	Zonotrichia albicollis
Wood duck	Aix sponsa
Marsh hawk	Circus cyaneus
Least bittern	Ixobrychus exilis
Tree swallow	Tridoprocne bicolor
Solitary vireo	Vireo solitarius
Pine warbler	Dendroica pinus
Ovenbird	Seiurus aurocapillus
Purple finch	Carpodacus purpureus
Herring gull	Larus argentatus

eagle, bald eagle, and peregrine falcon. State endangered lists are currently being compiled for birds and are not yet available; however, osprey is considered a State endangered species (Trew, personal communication, 1989). Habitat preferences and feeding requirements of these species are as follows (Peterson, 1980; Martin et al., 1951):

- Osprey and bald eagles are found near rivers, lakes, and along the coasts. Their preferred food is fish.

- Golden eagles are found in woods, mountains, or the badlands. Their food is mainly small mammals and birds.

- Peregrine falcons dwell in cliffs but also on high buildings. Their preferred food is medium-sized birds.

- Piping plovers prefer sandy beaches and mudflats, both on the coast and inland. Their diet includes crustaceans, marine worms, and insects.

- Brown pelicans live on the coasts in salt bays, beaches, and oceans. Their diet consists mainly of fish.

<u>Game Species</u>

Thirty-six species of birds are game species in Delaware. Nine species have been observed on the site. Their habitat requirements and food preferences are as follows (Martin et al., 1951):

- Black ducks and mallards live in almost any water and feed on aquatic vegetation, seeds, grains, and grasses.

- Wood ducks prefer freshwater marshes and swamps. They feed on aquatic plants, seeds, and nuts.

- Canada geese nest in marshes and feed on aquatic plants, seeds, grains, and grasses.

- Bobwhites live in brush and feed on seeds, insects, and vegetation.

- Ring-necked pheasants live along brushy edges and feed on insects, seeds, and berries.

- Mourning doves live in open woodlands, farmlands, suburbs, and roadsides, and feed on seeds and vegetation.

- Rock doves (pigeons) live in cliffs but also in cities or any places of human construction. They feed on seeds, nuts, and handouts.

- Common crows live in fields, woods, and along the coasts. They are omnivorous in their feeding habits.

3.6.2.4 Mammals

Direct Observation

Eight species of mammals were observed on the site including gray squirrel, cottontail rabbit, white-tail deer, woodchuck, raccoon, muskrat, meadow vole, and starnose mole (Weston, 1986; U.S. Department of Interior 1988). Raccoon tracks were also observed by EPA (1988c) and samplers for the current RI/FS (See Table 3-5).

Regional, Threatened, and Endangered Species

Forty species of mammals occur in Delaware. However, 13 species are marine mammals and are unlikely to be found on this site. The only nonmarine federally endangered species is the Delmarva fox squirrel. These squirrels prefer upland hardwood forests or any kind of dense forests including old growth loblolly pine stands (Chapman and Feldhamer, 1982). It is unlikely Delmarva fox squirrels would occur on or near the Army Creek Site due to their primarily early successional vegetation.

State endangered lists are currently being compiled for mammals and are not yet available.

TABLE 3-5

MAMMALS OF ARMY CREEK

ARMY CREEK LANDFILL SITE

MAMMALS	
Meadow vole	Microtus pennsylvanicus
Muskrat	Ondatra zibethica
Eastern cottontail rabbit	Sylvilagus floridanus
Woodchuck	Marmota monax
Racoon	Procyon lotor
Starnose mole	Condylura cristata
Eastern gray squirrel	Scirus carolinensis
White-tailed deer	Odocoileus virginianus

AR301315

Game Species

Eleven species of mammals are game species in the State of Delaware. Six of the eight mammals observed on the site are game species. Their habitat requirements and food preferences are as follows:

- Eastern cottontail rabbit can be found in heavy brush, strips of forest with open areas nearby, edges of swamps, and weed patches (Burt and Grossenheider, 1964). It feeds on tender herbaceous plants in summer but in winter it frequently resorts to twigs and bark of young trees (Martin et al., 1951).

- White-tailed deer typically dwell in forests but often frequent glades or woodland openings while feeding. They also forage along forest margins and in orchards and farmland (Burt and Grossenheider, 1964). The white-tailed deer is considered a browser and eats twigs, shrubs, fungi, acorns and grass and herbs in season (Martin et al., 1951).

- Large-toothed muskrat prefer marshes, ponds, lakes, and low-gradient streams. They feed on aquatic vegetation, fish, freshwater mussels, insects, crayfish, and snails (Martin et al., 1951).

- Raccoon live in open woodlands but are a common visitor to farms. They feed mostly along streams and lakes and are omnivorous eating fruits, nuts, grains, insects, frogs, crayfish, and bird eggs (Burt and Grossenheider, 1964).

- Northern gray squirrel is primarily arboreal in that it prefers dense forests of mature mast-producing hardwoods. They are partial to acorns, hickory nuts, and beechnuts, but will also consume insects, bird eggs, and nestlings (Martin et al., 1951). They also eat seeds, fungi, fruits, and often the cambium layer beneath the bark of trees (Burt and Grossenheider, 1964).

AR301316

- Woodchuck live in dens in fields, fence rows, and woodlands bordered by clearings. They feed on succulent plants (Martin et al., 1951).

3.6.3 Aquatic Microbiota

Aquatic microbiota includes phytoplankton, zooplankton, other noncrustacean invertebrates, and aquatic insects.

Direct Observations

Weston (1986) presented the results of their 1972 to 1983 aquatic surveys. In addition, the State of Delaware (1985) conducted a macroinvertebrate survey in Army Creek in 1985 and EPA (1986) conducted a macroinvertebrate survey in 1986.

Three phyla of phytoplankton were detected: Cyanophyta (bluegreen algae), Crysophyta (Diatoms), and Chlorophyta (green algae). The zooplankton included copepods (two orders), cladocera (three genera), rotifers (three genera), and ciliates. Benthic fauna had representatives from the Annelida (oligochaetes and leeches), mullusca (snails and clams), nematodes, ostracods, amphipods, isopods, and decapods (crayfish). Thirteen families of aquatic insects were identified from Army Creek either upstream from Army Pond, in the pond, or downstream from the pond (See Table 3-6).

TABLE 3-6

AQUATIC INVERTEBRATES OF ARMY CREEK

ARMY CREEK LANDFILL SITE

AQUATIC INVERTEBRATES		
PHYLA	COMMON NAME	CLASS/ORDER
Ciliates		
Rotifers		
Nematodes		
Molluscs		
	Clams	Sphaeridae
	Snails	Planorbidae
		Physidae
		Lymneidae
Annelida		
	Oligochaetes	Tubifidae
	Leeches	Hirudinae
Arthropoda		
	Crustacea	
		Amphipoda
		Isopoda
		Ostracoda
		Decapoda
	Crayfish	Palaemonidae
	Shrimp	Astacidae
		Cladocera
		Daphnia
		Macrothrix
		Ilyocryptus
		Chydoridae
		Copepoda
		Cyclopoida
		Harpacticoida
	Insecta	
	Mayflies	Ephemeroptera
	Damselfly	Odonata-zygop.
		Ischnura
		Argia
		Coenagrionidae
	Dragonfly	Odonata-anisop.
	Water Strider	Gerridae
	Water boatman	Corixidae
	Diving beetle	Gyrinidae
	Whirlygig beetle	Dytiscidae
	Caddisfly	Tricoptera
		Hydropsyche
	Midge	Chironomidae
	Midge	Ceratopogonidae
	Black fly	Simuliidae
	Mosquito	Culicidae
	Deer fly	Tabanidae

AR301318

4

4.0 NATURE AND EXTENT OF CONTAMINATION

4.1 GROUNDWATER RECOVERY WELL DISCHARGES

The sampling of groundwater recovery well discharges, as described in Section 2.1, included sample collection from nine recovery wells. The complete validated database for the groundwater recovery well discharge samples is presented in Appendix C. This section discusses the analytical results for the recovery well discharges. These results are presented in Tables 4-2 through 4-4. In calculating the flow weighted average concentrations of the compounds found in the recovery well discharges, nondetected values were assigned a value of one-half the Instrument Detection Limit (IDL) for inorganics, and one-half the IDL or Contract Required Quantitation Limit (CRQL), when an IDL could not be determined for organics.

A series of recovery wells are located hydraulically downgradient (south and east) of the Army Creek Site. According to the EPA, the recovery well pumping has created a groundwater divide between the landfill site and the Artesian Water Company's Llangollen Wellfield. Sampling of these wells was undertaken to determine their level of contamination. No upgradient sampling was performed. Table 4-1 presents a summary of general geochemical characteristics for the groundwater recovery well discharge samples. Wells 12, 28, and 29 have the highest geochemical concentrations.

<u>Total Inorganics</u>

A summary of total inorganics detected in the groundwater recovery well discharges is presented in Table 4-2. The inorganics present are largely heavy metals such as iron, manganese, cobalt, and barium, as well as saltwater constituents that include calcium, magnesium, potassium, and sodium. The highest concentrations were detected in Wells 12, 28, and 29 which are located to the southeast of the landfill. These wells are located quite close to and directly downgradient of Army Pond.

TABLE 4-1

SUMMARY OF ANALYTICAL RESULTS FOR RECOVERY WELL DISCHARGE
GENERAL CHEMICAL CHARACTERISTICS

ARMY CREEK LANDFILL
NEW CASTLE, DELAWARE

Characteristic	No. of Positive Detections/ No. of Samples	* Range of Concentrations (mg/L)	Average Concentration (mg/L)	Recovery Wells with 3 highest concentrations	Instrument Detection Limit (mg/l)
Acidity	0/9	ND	ND	ND	10
Alkalinity	9/9	26-250	ND	29/28/12	4
Ammonia	7/9	0.13-6.90	4.61	27/29/28	0.03
Chloride	9/9	16-64	29.6	29/28/12	5
Filterable Residue	9/9	72-320	128.3	29/28/12	10
Non-filterable Residue	7/9	6-31	14.8	29/28/12	4
Total Kjeldahl Nitrogen	9/9	0.31-15.78	5.25	29/28/12	0.03
Nitrate	9/9	0.08-2.69	1.05	10/11/27	0.05
Nitrite	0/9	ND	ND	ND	0.05
Total Phosphorus	0/9	ND	ND	ND	10
Total Acid Hydrol. Phosphorus	0/9	ND	ND	ND	10
Total Organic Phosphorus	0/9	ND	ND	ND	10
Total Reactive Phosphorus	2/9	10-30	20	29/12	10
Sulfate	9/9	8-17	10.2	29/11/27	5
Sulfide	0/9	ND	ND	ND	1
Total Organic Carbon	8/9	1-13	4.1	29/28/12	1

Notes:

ND Not Detected

* (1) Where duplicate samples were taken, the higher concentration was used.

(2) Concentrations in lab analyses labelled as estimated "J," were assumed to equal listed concentrations.

AR301321

TABLE 4-2

SUMMARY OF ANALYTICAL RESULTS FOR RECOVERY WELL DISCHARGE
TOTAL INORGANIC CONTAMINANTS

ARMY CREEK LANDFILL
NEW CASTLE, DELAWARE

Chemical	No. of Positive Detections/ No. of Samples	* Range of Concentrations (ug/L)	** Flow weighted Average Conc. (ug/L)	Recovery Wells with 3 highest concentrations	Instrument Detection Limit (ug/l)
Aluminum	1/9	132.0	29.6	29	12.0
Arsenic	1/9	2.7	1.0	28	1.8
Barium	9/9	74.5-377.0	184	29/28/27	1.2
Calcium	9/9	8,760-18,800	11,470	29/12/28	17.1
Cobalt	3/9	22.7-36.9	11.8	29/28/27	2.7
Iron	9/9	488-34,300	12,400	29/28/12	8.6
Magnesium	9/9	3,630-13,600	6,670	29/28/12	24.3
Manganese	9/9	249-2,710	945	29/28/31	1.5
Potassium	9/9	1,940-17,000	6,770	29/28/27	407.8
Selenium	2/9	1.4-1.5	0.8	1/10	1.4
Sodium	9/9	9,690-80,600	26,840	29/18/12	21.8

* (1) Where duplicate samples were taken, the highest value was used.

(2) Concentrations in lab analysis labelled as estimated "J," were assumed to equal listed concentrations.

** Values of 1/2 of the Instrument Detection Limits were used for the values of the nondetected results in calculation of averages.

TABLE 4-3

SUMMARY OF ANALYTICAL RESULTS FOR RECOVERY WELL DISCHARGE
DISSOLVED INORGANIC CONTAMINANTS

ARMY CREEK LANDFILL
NEW CASTLE, DELAWARE

Chemical	No. of Positive Detections/ No. of Samples	* Range of Concentrations (ug/L)	** Flow weighted Average Conc. (ug/L)	Recovery Wells with 3 highest concentrations	Instrument Detection Limit (ug/l)
Barium	9/9	75.6-367	182	29/28/27	1.2
Calcium	9/9	8,750-18,600	11,430	29/28/12	17.1
Cobalt	3/9	23.7-34.8	11.3	29/28/27	2.7
Iron	9/9	493-32,900	11,690	29/28/12	8.6
Magnesium	9/9	3,620-13,400	6,720	29/28/12	24.3
Manganese	9/9	247-2,660	935	29/28/31	1.5
Nickel	1/9	23.1	12.0	10	20.6
Potassium	9/9	1,930-16,500	6,650	29/28/12	407.8
Sodium	9/9	9,690-79,300	26,581	29/28/12	21.3
Zinc	3/9	5.1-82.4	11.2	13/12/28	4.0

* (1) *Where duplicate samples were taken, the highest value was used.*

(2) Concentrations in lab analyses labelled as estimated, "J," were assumed to equal listed concentrations.

** Values of 1/2 of the Instrument Detection Limits were used for the values of the nondetected results in calculation of averages.

TABLE 4-4

SUMMARY OF ANALYTICAL RESULTS FOR RECOVERY WELL DISCHARGE
ORGANIC CONTAMINANTS

ARMY CREEK LANDFILL
NEW CASTLE, DELAWARE

Chemical	No. of Positive Detections/ No. of Samples	* Range of Concentrations (ug/L)	**Flow-weighted Average Conc. (ug/L)	Recovery Well with highest Concentration	Instrument Detection Limit (ug/l)
Benzene	4/9	14-18	8.0	28	5
Bis(2-chloroethyl)ether	7/9	5-21	12.0	28	5
Bis(2-ethylhexyl)phthalate	1/9	3	1.8	29	3
Chlorobenzene	3/9	3-18	4.0	28	3
Chloroform	1/9	6	2.8	28	5
1,4-Dichlorobenzene	1/9	6	3.6	29	6
1,2-Dichloroethane	2/9	22-50	8.4	27	5
Ethylbenzene	2/9	4	2.6	13 & 29	4
Tetrachloroethene	1/9	2	1.1	11	2
Toluene	1/9	19	4.2	13	5
Trichloroethene	1/9	2	1.1	28	2
Total Xylenes	2/9	7-10	4.4	29	5

* (1) Where duplicate samples were taken, the higher concentration was used.

(2) Concentrations in lab analyses labelled as estimated, "J," were assumed to equal the listed concentration.

** Values of 1/2 of the Instrument Detection Limits were used for the values of the nondetected results in calculation of averages.

AR301324

Dissolved Inorganics

The chemicals detected in the dissolved inorganic analysis were nearly the same as those found in the total inorganic analysis. As with the total inorganic analysis, most of the detected chemicals were heavy metals as well as saltwater constituents, and the highest concentrations were found in Wells 12, 28, and 29. Table 4-3 presents a summary of the dissolved inorganics detected in the recovery wells.

A comparison of the groundwater recovery well discharge results for total and dissolved inorganics reveals that aluminum and selenium were found only in the total inorganic analysis and nickel and zinc in the dissolved inorganic analysis. Considering the remainder of the chemicals, which were detected in both analyses, it can be seen that the dissolved concentrations represent more than 70 percent of the total inorganic loading. This high dissolved percentage indicates that these contaminants are largely present in solution, with very small amounts of suspended particulates.

Organics

Table 4-4 presents a summary of the organics detected in the recovery wells. The organics were present in fewer locations, and in much lower concentrations than the inorganics. Nine of the 12 organic contaminants were found in two wells or less. Only bis(2-chloroethyl)ether, benzene, and chlorobenzene were present in three or more wells. Once again, Wells 29 and 28 had the highest concentrations.

4.2 SURFACE WATER AND SEDIMENTS

The database for surface water and sediment samples is included in Appendix D. The scope of this RI did not include additional sampling in these media. NUS/GF was instructed to use the sample data obtained on August 1-2, 1988. Although these data appeared to be of acceptable quality judging by quality control factors included with the data (matrix spike, surrogate spike, etc.), no mention of data validation protocols was made in the final report on Army Creek (EPA, 1988c).

4.2.1 Surface Water

Army Pond, oriented parallel to the southern site boundary, is ellipsoid in shape and approximately 2,000 feet long by 175 feet wide by 1 foot deep. Storm water runoff from the site as well as flows from the recovery wells are collected in this pond. In addition, Army Creek empties into the pond. Upstream of the pond, Army Creek is a low-volume seasonal stream largely dependent on storm runoff. Downstream of the pond, Army Creek, enlarged by the flow from the recovery wells, which averages 1.4 MGD, has more constant flows. Samples were taken in Army Pond, and in Army Creek both upstream and downstream of the pond. Summaries of the organic and inorganic analytical results for the surface water samples are presented in Tables 4-5 and 4-6. The chemicals found in the surface water include the pollutants 1,2-dichloroethane, bis(2-chloroethyl)ether, phenol, cadmium, chromium, thallium, and nickel, as well as elevated levels of minerals commonly found in surface waters (such as iron and zinc). Thallium and nickel were present in only one of eight samples. It is unclear based on the data available whether these may have been the result of method blank contamination, or if they were actually true positive results.

4.2.2 Sediments

The sediment sampling results are summarized in Tables 4-7 and 4-8. Five of the seven inorganic chemicals found in the surface water were also found in the sediment. Additional inorganics found in the sediment included arsenic, copper, and lead. Twenty organic chemicals were found in the sediment while only three were found in the surface water. The only organic chemical found in both surface water and sediment was phenol. Many of the chemicals found exclusively in the sediment samples have very high organic carbon partition coefficients, which indicates a propensity for soil and sediment adsorption.

Brown and Associates (1983) presents information on the average concentrations of naturally occurring metals in soils of the United States. Concentration ranges and averages are presented in Table 4-9 for arsenic, chromium, copper, lead, mercury, nickel, and zinc. No information was available in this report on iron concentrations in soil.

TABLE 4-5

SUMMARY OF ANALYTICAL RESULTS FOR PREVIOUS SURFACE WATER SAMPLING
ORGANIC CONTAMINANTS

ARMY CREEK LANDFILL
NEW CASTLE, DELAWARE

Chemical	No. of Positive Detections/ No. of Samples	* Range of Concentrations (ug/L)	** Average Concentration (ug/L)	Instrument Detection Limit (ug/l)
Bis(2-Chloroethyl)ether	3/8	3.6-7.5	3.4	3.6
1,2-Dichloroethene	2/8	2-5	1.6	2
Phenol	8/8	92-213	157	50

* Concentrations in lab analyses labelled as estimated, "J," were assumed to equal listed concentrations.

** Values of 1/2 of the Instrument Detection Limits were used for the values of the nondetected results in calculation of averages.

Source: EPA, 1988c.

AR301327

TABLE 4-6

SUMMARY OF ANALYTICAL RESULTS FOR PREVIOUS SURFACE WATER SAMPLING
INORGANIC CONTAMINANTS

ARMY CREEK LANDFILL
NEW CASTLE, DELAWARE

Chemical	No. of Positive Detections/ No. of Samples	* Range of Concentrations (ug/L)	** Average Concentration (ug/L)	Instrument Detection Limit (ug/l)
Cadmium	5/8	34-38	25	10.0
Chromium	7/8	57-150	84	50.0
Iron	7/8	980-2,860	1,549	500
Mercury	2/8	0.2	0.13	0.2
Nickel	1/8	150	62	100
Thallium	1/8	610	295	500
Zinc	8/8	25-640	167	10

* Concentrations in lab analyses labelled as estimated, "J," were assumed to equal listed concentrations.

** Values of 1/2 of the Instrument Detection Limits were used for the values of the nondetected results in calculation of averages.

Source: EPA, 1988c.

TABLE 4-7

SUMMARY OF ANALYTICAL RESULTS FOR PREVIOUS SEDIMENT SAMPLING
ORGANIC CONTAMINANTS

ARMY CREEK LANDFILL
NEW CASTLE, DELAWARE

Chemical	No. of Positive Detections/ No. of Samples	* Range of Concentrations (mg/kg)	** Average Concentration (mg/kg)	Instrument Detection Limit (mg/kg)
Acenaphthene	1/8	0.165	0.092	0.165
Acetone	8/8	0.025-0.719	0.254	0.010
Anthracene	2/8	0.180-0.339	0.132	0.180
Benzo(a)Anthracene	3/8	0.258-1.25	0.344	0.258
Benzo(a)Pyrene	4/8	0.239-1.07	0.316	0.239
Benzo(b)Fluoranthene	4/8	0.203-1.33	0.382	0.203
Benzo(g,h,i)Perylene	3/8	0.165-0.715	0.202	0.165
Benzo(k)Fluoranthene	2/8	0.446-0.786	0.278	0.330
2-Butanone	5/8	0.004-0.029	0.009	0.004
Chrysene	4/8	0.274-1.58	0.453	0.274
Di-n-Butylphthalate	7/8	0.236-1.08	0.489	0.330
Fluoranthene	4/8	0.331-1.62	0.556	0.330
Fluorene	1/8	0.161	0.090	0.161
Indeno(1,2,3-cd)Pyrene	3/8	0.182-0.808	0.229	0.182
4-Methylphenol	1/8	0.139	0.079	0.139
Phenanthrene	3/8	0.402-1.71	0.478	0.330
Phenol	2/8	1.20-1.80	0.693	0.848
Pyrene	4/8	0.302-3.20	0.714	0.302
Toluene	2/8	0.009-0.033	0.007	.005
Total Xylenes	1/8	21	0.005	.005

* Concentrations in lab analyses labelled as estimated, "J," were assumed to equal listed concentrations.

** Values of 1/2 of the Instrument Detection Limits were used for the values of the nondetected results in calculation of averages.

Source: EPA, 1988c

TABLE 4-8

SUMMARY OF ANALYTICAL RESULTS FOR PREVIOUS SEDIMENT SAMPLING
INORGANIC CONTAMINANTS

ARMY CREEK LANDFILL
NEW CASTLE, DELAWARE

Chemical	No. of Positive Detections/ No. of Samples	* Range of Concentrations (mg/kg)	** Average Concentration (mg/kg)	Instrument Detection Limit (mg/kg)
Arsenic	7/8	1.1-6	2.91	0.95
Chromium	6/8	8.3-45	19.4	5.0
Copper	6/8	11.3-43.9	21.3	5.0
Iron	8/8	1,830-68,800	22,205	50.0
Lead	7/8	6-97.8	49.6	0.49
Mercury	8/8	0.0459-0.119	0.071	0.01
Nickel	5/8	9.9-26.4	13.5	9.9
Zinc	8/8	16.4-273	106.7	10.0

* Concentrations in lab analyses labelled as estimated, "J," were assumed to equal listed concentrations.

** Values of 1/2 of the Instrument Detection Limits were used for the values of the nondetected results in calculation of averages.

Source: EPA, 1988c.

AR301330

TABLE 4-9

RANGES AND AVERAGES OF
METALS IN UNCONTAMINATED SOIL

ARMY CREEK LANDFILL
NEW CASTLE, DELAWARE

Chemical	Range of Concentrations (mg/kg)	Average Concentrations (mg/kg)	Comments
Arsenic	1-50	----	Usually 10 ppm or less
Chromium	1-1000	100	
Copper	2-100	30	
Iron	----	----	No information given
Lead	10-200	10	
Mercury	0.01-0.3	0.03	
Nickel	5-500	100	
Zinc	10-300	50	

Source: Brown and Associates, 1983.

---- No information given in Brown and Associates (1983).

Sediments are formed directly from upgradient soils. Through erosional processes soil particles are deposited in stream beds where they form sediments. Since sediments are largely derived from soil, metal levels in uncontaminated sediments should be comparable to those found in soils. As can be seen from a comparison of Tables 4-8 and 4-9, both the average and the range of concentrations of metals (with the exception of iron) found in Army Creek and Army Pond sediments were well within the ranges of normal metal concentrations in soil.

Table 4-10 presents a comparison of sediment and surface water chemical concentrations in Army Pond versus those in Army Creek, downstream of the pond. The sampling data used in Tables 4-5 through 4-8 were separated according to sample location. These data were used to calculate the average concentrations for each location. The concentrations were generally of the same order of magnitude, with slightly lower values in the downstream locations.

TABLE 4-10

COMPARISON OF SURFACE WATER AND SEDIMENT CONCENTRATIONS IN ARMY POND AND ARMY CREEK

ARMY CREEK LANDFILL
NEW CASTLE, DELAWARE

Chemical	** Average Surface Water Concentration in Army Pond (mg/L)	* Surface Water Concentration in Army Creek Downstream of Army Pond (mg/L)	** Average Sediment Concentration in Army Pond (mg/kg)	* Sediment Concentration in Army Creek Downstream of Army Pond (mg/kg)
ORGANICS				
1,2-Dichloroethane	0.003	ND	ND	ND
Benzo(a)pyrene	ND	ND	0.16	ND
Bis(2-chloroethyl)ether	0.0043	0.0068	ND	ND
Phenol	0.189	0.164	0.683	1.8
INORGANICS				
Arsenic	ND	ND	3.8	2.3
Cadmium	0.026	ND	ND	ND
Chromium	0.078	ND	27.6	15.5
Copper	ND	ND	29.9	13.1
Iron	2.22	2.26	36,800	20,900
Lead	ND	ND	57.4	21.2
Mercury	0.00013	ND	0.074	0.059
Nickel	0.083	ND	18.9	13.4
Thallium	0.370	ND	ND	ND
Zinc	0.145	0.640	155	57.1

ND Not Detected

* Based on one sample

** Values of 1/2 the Instrument Detection Limits were used for the values of the nondetected results in calculation of averages.

5

AR301334

5.0 ENVIRONMENTAL FATE AND TRANSPORT

Contaminant fate and transport at the Army Creek Site are discussed in this section. Contaminant transport within each medium is presented in Section 5.1. A brief discussion of potential contaminant transformation processes is found in Section 5.2. Cross-media or intermedia transfer and chemical and physical properties affecting contaminant migration are discussed in Section 5.3.

5.1 CONTAMINANT TRANSPORT WITHIN A MEDIUM

This section describes the pathways through which onsite contaminants are transported within a given medium and the population potentially exposed. Transport within groundwater, surface water, and sediment are discussed.

Groundwater

The recovery wells were installed to intercept groundwater flowing from the site to the wellfields downgradient. They are quite successful in fulfilling this objective. Failure of the recovery well network is unlikely since the County has and will continue to maintain them. No transport pathways within the groundwater are expected which would cause potential exposure of the downgradient populations.

Surface Water

Effluent from Army Pond is carried downstream in Army Creek. The flow rate from Army Pond is approximately 50 gpm (Section 3.4.3). The creek flows to the east for approximately one mile through undeveloped woods and marshland, offering ample opportunity for access by humans and wildlife before emptying into the Delaware River. The State of Delaware (1989) has designated Army Creek to have the following uses: (1) secondary contact recreation, (2) supporting fish, aquatic life, and wildlife, and (3) agriculture water supply. Because of the designated uses, exposure of swimmers and boaters is very unlikely. In addition, no crops intended for human consumption are currently being irrigated with Army Creek water. The potential transport pathways for contaminants in the surface water are therefore limited to the accidental human contact and the direct exposure of fish, aquatic life, and wildlife to surface water.

Sediment

The potential transport pathways for contaminants within the sediment include:

- Erosion: Normal flows will cause erosion of stream sediments and transport from the site.

- Scouring: During periods of heavy rains, existing sediments and adjacent soil will be washed downstream.

5.2 TRANSFORMATION OF CONTAMINANTS

Transformation is any change that occurs in the physical structure of a chemical contaminant. Transformation processes usually result in a reduction of contaminant concentration. However, transformation products may be more or less toxic to humans or environmental flora and fauna than the parent compound. Contaminants may be subject to more than one transformation process as they are transported or transferred across media. Contaminants may also interact with particulate matter and other contaminants during transformation. The relative importance of selected transformation processes of contaminants at the site is listed in Table 5-1, and contaminant specific transformation processes are discussed in Appendix E. The rationales of indicator chemical selection are discussed in Section 6.2.1.

Transformation processes of contaminants are complex and include oxidation, photolysis, hydrolysis, chemical speciation, and biodegradation. Oxidation is the reaction that occurs between a contaminant and an oxidizing agent. In an oxidizing reaction the oxidizing agent is reduced (gains electrons from the contaminant). Iron, for example, can be oxidized from Fe^{2+} to Fe^{3+} in the presence of cupric ions (Cu^{2+}). Oxidation can occur in air, surface water, groundwater, and soil. Ozone (O_3) and the hydroxyl radical ($OH\cdot$) act as oxidizing agents in the atmosphere while chlorine is an oxidizing agent in

TABLE 5-1

RELATIVE IMPORTANCE OF NATURALLY-OCCURRING PROCESSES FOR SELECTED CONTAMINANTS

ARMY CREEK LANDFILL
NEW CASTLE, DELAWARE

Compound	Adsorption	Volatilization	Photolysis	Hydrolysis	Bioconcentration	Potential Biodegradability
ORGANICS						
Benzene	+	+	+	-	-	D
Benzo(a)pyrene *	+	-	+	-	+	
Bis(2-chloroethyl)ether		+				
1,2-Dichloroethane	-	+	-	-	-	B
INORGANICS						
Arsenic	+	-	-		+	B
Cadmium	+	-	-		+	B
Chromium	+	-	-		+	B
Iron	+	-	-			B
Lead	+	-	-		+	B
Mercury	+	-	-		+	B
Nickel	+	-	-		+	B
Zinc	+	-	-		+	B

* Based on general information for polycyclic aromatic hydrocarbons.

+ Could be an important fate process
- Not likely to be an important fate process
D Significant degradation (less than seven days)
A Significant degradation (in seven to twenty-one days)
B Slow or no degradation

drinking water. Oxidation reactions are dependent upon the concentration of the contaminant, the concentration of the oxidizing agent, and the rate of reaction between them.

Photolysis is the breakdown of a chemical due to photochemical reaction which utilizes energy in the form of sunlight. The two types of photolysis which can occur are: (1) direct and (2) indirect. Direct photolysis occurs when a contaminant absorbs energy in the form of sunlight and undergoes a transformation reaction (e.g., oxidation, dissociation, or rearrangement of structure). Indirect photolysis utilizes intermediate substances to absorb light energy, which is then used to fuel a transformation process. Photolysis may be an important transformation process for contaminants in air, surface water, and in the soil surface. The rate of photolysis, however, is dependent on the intensity and spectral quality of the solar energy, the light energy absorption capabilities of the contaminant, and the tendency of a contaminant to undergo a photochemical reaction. Benzene and the other polycyclic aromatic hydrocarbons (PAHs) would most likely be influenced by photolysis at the Army Creek Site.

Hydrolysis is the decomposition of a molecule that occurs when a molecular bond is broken by the addition of water. Hydrolysis is a significant environmental transformation process for many organic compounds. Contaminants in air, surface water, and groundwater can undergo hydrolytic reactions. The rate of hydrolysis is dependent on pH. Some contaminants require a low pH while others require a high pH in order to undergo hydrolysis. As listed in Table 5-1, hydrolysis would probably not be a major transformation process for the contaminants found at the site.

Chemical speciation is an important transformation process for metallic compounds and involves the formation of complexes with inorganic or organic substances. Speciation processes can occur in all environmental media. The extent to which contaminants bind to media constituents will alter the solubility, volatility, and bioavailability of that contaminant. Speciation of metals found at the site will affect the intermedia mobility of those metals. For example, lead is soluble in groundwater in the form of lead ion

(Pb^{2+}), but after combination with carbonate (CO_3^{-2}) in soil, lead will form lead carbonate ($PbCO_3$), a less soluble compound.

Biodegradation is the transformation of a contaminant by a microorganism, plant, or animal. Most biodegradation occurs through the enzymatic action of microorganisms. The rate of degradation depends on the metabolic rates and characteristics, and the population densities of the biotic agents. Biodegradation can occur in the presence (aerobic) or absence (anaerobic) of oxygen, and some contaminants can be degraded in both types of environments. Table 5-1 lists the biodegradability potential of many chemicals found at the site. Many of the organic compounds could be transformed by biodegradation to more or less toxic compounds.

5.3 INTERMEDIA TRANSPORT OF CONTAMINANTS

Various processes occur in the environment which cause transfer of a chemical from one medium to another. These processes include volatilization, dissolution in water, adsorption/sedimentation, and bioaccumulation. A summary of the relative importance of these processes for the relevant indicator chemicals is contained in Table 5-1. Table 5-2 lists properties that affect a chemical's tendency to undergo these transformation processes. Intermedia transport depends on such things as pH, temperature, relative humidity, half-life in the particular medium, the nature of the compound containing the chemical of interest, and the properties listed in Table 5-2. A discussion of the various processes follow:

5.3.1 Transfer between Water and Atmosphere

Volatilization is a process by which a chemical compound is transformed from a liquid state into a gaseous state. Usually this results in the chemical being transferred from water or soil to the atmosphere. The rate at which this transfer process occurs is dependent upon the chemical properties of the compound of interest, and the physical characteristics (e.g., surface area and turbulence) of the water body. The chemical property of primary concern is the relationship between the concentration of the chemical in the aqueous phase to that in the gaseous phase when the two are in equilibrium with each

AR301339

TABLE 5-2

CHEMICAL AND PHYSICAL PROPERTIES AFFECTING CONTAMINANT MIGRATION

ARMY CREEK LANDFILL SITE
NEW CASTLE, DELAWARE

Chemical	Water Solubility (mg/l)	Vapor Pressure between 20-30 C (mmHg)	Henry's Law Constant (atm-cu.m/mol)	(1) Koc (mg/g)	(2) log Kow (1/kg)	(3) BCF (1/kg)	Maximum Half-Life (Days) **			
							Soil	Air	Surface Water	Ground Water
ORGANICS										
Benzene	1.75E+3	95.2	0.00559	83	2.12	5.2	(5)	6.00	6.00	(5)
Benzo(a)pyrene	1.2E-3	5.60E-9	1.55E-6	5.5E+6	6.06	(5)	480.0	6.00	(5)	(5)
Bis(2-chloroethyl)ether	1.02E+4	0.71	1.31E-5	13.9	1.50	6.9	(5)	(5)	(5)	(5)
1,2-Dichloroethane	8.52E+3	64.0	9.78E-4	14	1.48	1.2	(5)	127.00	0.17	(5)

AR301340

TABLE 5-2 (cont'd.)
CHEMICAL AND PHYSICAL PROPERTIES AFFECTING CONTAMINANT MIGRATION
ARMY CREEK LANDFILL SITE
PAGE TWO

Chemical	Water Solubility (mg/l)	Vapor Pressure between 20-30 C (mmHg)	Henry's Law Constant (atm-cu.m/mol)	(4) Kd (mg/g)	BCF (1/kg)	Maximum Half-Life (Days) **			
						Soil	Air	Surface Water	Ground Water
INORGANICS									
Arsenic (III)	(5)	0	NA	1.0 - 8.3	44	(5)	5.00	P	(5)
Cadmium	(5)	0	NA	1.26 - 26.8	81	(5)	4.80	P	(5)
Chromium (III)	(5)	0	NA	470 - 150,000	16	(5)	4.80	3.00	(5)
Chromium (VI)	(5)	0	NA	1.2 - 1,800	16	(5)	4.80	3.00	(5)
Iron	(5)	0	NA	1.4 - 1,000	(5)	(5)	(5)	(5)	(5)
Lead	(5)	0	NA	4.5 - 7,640	49	(5)	4.80	P	(5)
Mercury	(5)	2.00E-3	NA	(5)	5,500	(5)	4.80	P	(5)
Nickel	(5)	0	NA	(5)	47	(5)	(5)	(5)	(5)
Zinc	(5)	0	NA	0.1 - 8,000	47	(5)	4.80	P	(5)

Notes:

(1) Organic Carbon Partition Coefficient
(2) Octanol Water Partition Coefficient
(3) Bioconcentration factor
(4) Distribution Coefficient
(5) Not available
NA Not applicable
** If maximum half-life was not available, minimum half-life was used.
P Persistent for this medium

other (Henry's Law). Flow rate, water surface area, and turbulence in the water body each affect the volatilization rate causing this rate to increase as each parameter increases. For compounds with a relatively high Henry's Constant, the volatilization rate approaches an upper limit. For compounds with a low Henry's Constant, the volatilization rate approaches zero.

The volatilization half-life is the time required for half of the remaining aqueous contaminant concentration to be volatilized. Half-lives can vary by an order of magnitude depending upon water velocity, wind velocity, and the extent to which the compounds are exposed to the atmosphere.

Another property indicative of the tendency to volatilize is the vapor pressure. Vapor pressure is a relative measure of a chemical's tendency to volatilize from its pure state. The indicator chemicals with high vapor pressures and Henry's Constants, such as benzene and 1,2-dichloroethane will tend to have high volatilization rates.

Airborne droplets created by air currents and chemicals volatilized from the surface water can be carried by wind currents to locations beyond the site boundary. The effects of these airborne emissions can be evaluated using the windrose in Figure 3-1. The figure indicates that the prevailing winds blow from the north-northwest. Over 50 percent of the time, which includes 6.5 percent of the time that conditions are calm and the 15.1 percent of the time that wind speeds are between 0-3 mph, the winds would not be expected to carry significant amounts of pollutants toward residential areas within one mile of the site.

5.3.2 Transfer between Water and Sediment/Soil

Dissolution in Water

The solubility of a chemical in water and other liquids, as well as the ratios of liquid solubilities to other physical processes, are important determinants of the chemical concentrations in the surface water and groundwater at the Army Creek Site. The water solubilities contained in Table 5-2 are the maximum concentration of a chemical that will dissolve in water at a neutral pH and a temperature range of 20 to 30° C.

Partition between the Media

Partition of the contaminants between water and sediment/soil can involve the adsorption and desorption onto and from the surface of sediment/soil, the adsorption/desorption onto particulates in the water column, sedimentation which is the sinking and ultimate deposition of the particulates, and resuspension of adsorbed contaminants into the water column.

One useful parameter for estimating partitioning between water and sediment/soil is the octanol water partition coefficient. It is obtainable from the Log (K_{OW}), where K_{OW} is a measure of a chemical's equilibrium distribution of a chemical between octanol and water. The K_{OW} for a compound is defined as follows:

$$K_{OW} = \frac{C_{oct}}{C_W}$$

Where: C_{oct} = the concentration of a chemical in octanol, and
C_W = the concentration of a chemical in water.

K_{OW} data are widely available, and in combination with the organic carbon content of soil, can be used to estimate the organic carbon partition coefficient (K_{OC}) for an individual organic compound. A simple definition of K_{OC} is:

$$K_{OC} = \frac{C_{OC}}{C_W}$$

Where: C_{OC} = concentration of the chemical in the soil per unit weight of organic carbon, and
C_W = concentration of the chemical in water.

Calculated K_{OC}s are relatively independent of soil characteristics (e.g., pH and soil type). This coefficient is of particular importance in determining the chemical transfer that will occur during the groundwater recharge of

AR301343

approximately 1.90 cfs (Section 3.4.3) from Army Pond. Organic chemicals with high K_{oc} values and low water solubility such as benzo(a)pyrene and metals such as iron, lead, and cadmium will tend to concentrate in the soil and sediment. Those with low K_{oc} values and high water solubility such as benzene, bis(2-chloroethyl)ether, and 1,2-dichloroethane will tend to migrate with water.

Adsorption potential is also reflected by the K_{oc} value of a compound. The higher the K_{oc} value, the more strongly a chemical will bond to soil or sediment, so that less of the chemical will be available to migrate in the groundwater or surface water. Contaminants at the Army Creek Site which have low K_{oc} values, such as benzene, bis(2-chloroethyl)ether, and 1,2-dichloroethane could be expected to travel with the groundwater or surface water. The contaminants with low K_{oc} values may be available to follow the groundwater cycle previously described in Chapter 3.

For the inorganic chemicals, the distribution coefficient, K_d, is usually used to describe the partition of chemicals between soil or sediment and water. A simple definition of K_d is:

$$K_d = \frac{C_s}{C_w}$$

where C_s = concentration of the chemical in the soil or sediment and C_w is the concentration of the chemical in water.

Baes and Sharpe (1983) conducted a literature analysis of the reported K_d values. The range of these K_d values for the Army Creek Site contaminants, listed in Table 5-3, illustrate that the range of K_d values is very broad for most metals. The expected concentrations of metals in surface water can be calculated using these K_d values and the metal concentrations in sediments (Table 4-8). Results of these calculations are presented in Table 5-3. As can be seen, the observed surface water concentrations for all metals, except chromium and possibly zinc, are much lower than those calculated from K_d values and sediment concentrations. Apparently, the simple K_d calculation is

TABLE 5-3

COMPARISON OF OBSERVED AND CALCULATED SURFACE WATER CONCENTRATIONS
OF INORGANIC CONTAMINANTS

ARMY CREEK LANDFILL
NEW CASTLE, DELAWARE

Chemical	Observed Sediment Concentrations (mg/kg)	Sediment/Water Distribution Coefficient Used Kd (mg/g)	Calculated Equilibrium Surface Water Concentration (ug/l)	Observed Surface Water Concentration (ug/l)
Arsenic	1.1 - 6	5	220 - 1,200	ND
Chromium *	ND	14	NC	57 - 150
Copper	8.3 - 45	75,000	0.11 - 0.6	ND
Iron	1,830 - 68,800	500	3,660 - 137,600	980 - 2,860
Lead	6 - 97.8	3,800	1.6 - 25.7	ND
Mercury	0.0459 - 0.119	NA	NC	0.2
Nickel	9.9 - 26.4	NA	NC	150
Zinc	16.4 - 273	4,000	4.1 - 68	25 - 640

Notes:

NA = Not Available
NC = Not Calculable
ND = Not Detected

* Chromium (III) is assumed to be the predominant species in the sediment

not a good model for metal partitioning in the Army Creek sediments; metals in these sediments appear to be more tightly bound than average and less likely to partition into the surface water.

As discussed in Section 4.2.2, with the exception of iron, no sediment metal levels exceed the levels of metals found in uncontaminated soil (Brown and Associates, 1983). Based on this information, it appears that with the exception of iron, metal levels in the Army Creek sediments are probably not elevated above normal background metal levels.

5.3.3 Transfer between Water/Sediment and Biota

Many compounds are able to bioaccumulate in living organisms. Organisms can concentrate chemicals in their tissues at levels greater than a chemical's concentration in water or food. Many chemicals will partition into the adipose or fatty tissue of an organism. A measure of a chemical's ability to partition into fatty tissue can be made using K_{OW} where octanol is considered a surrogate for fat. Chemicals with large K_{OW} values tend to accumulate in soil, sediment, and biota. Conversely, chemicals with low K_{OW} values have higher water solubilities and will most likely partition into the water or air. Most of the organic contaminants at the Army Creek Site have relatively low K_{OW} values (see Table 5-2), except for the polycyclic aromatic hydrocarbons.

Another measure of a chemical's ability to accumulate in organisms is the bioconcentration factor (BCF). The BCF can be defined as follows:

$$BCF = \frac{\text{equilibrium concentration of an organic in an organism or tissue}}{\text{the concentration of an organic in water, soil, or food.}}$$

The BCF, however, is not usually applied to humans because the amount of a chemical in various food items of the human diet can vary greatly.

The rate of accumulation of contaminants in organisms will depend on the intake rate of the contaminant, the metabolic rate of the organism, and the ability of the contaminant to dissolve in fat. Contaminants which are most likely to have high BCFs are those that are soluble in fat and are capable of binding to tissue. Table 5-2 lists the BCF values as calculated for contaminant partitioning into fish. The values indicate that some of the contaminants found at the Army Creek Site may accumulate in fish. The BCF values, however, do not indicate in what type of tissue (muscle, bone, or fat) the contaminant will accumulate.

5.4 SUMMARY

The most important contaminants at the Army Creek Site include metals, volatile organics, and semivolatile organics. These contaminants are found in recovered groundwater discharges, in surface water, and in sediments. The diverse nature of the contaminants, as well as the different media in which they reside, dictate that the environmental fate and transport will be very complex. The important processes include: volatilization, adsorption, desorption, dissolution, sedimentation, resuspension, bioaccumulation, bioconcentration, chemical speciation, and biological degradation.

The hydrogeological study performed during this RI demonstrated that the surface water onsite is moving into the groundwater at a very high flow rate. This water movement facilitates the recycling of the contaminants through the three media of groundwater, surface water, and sediment. The ultimate sinks for each category of contaminants can be hypothesized to include the following:

- For the volatile and less adsorbable organics, i.e., benzene, 1,2-dichloroethane, and bis(2-chloroethyl)ether, ultimate sinks include: long-term recycling between surface water and groundwater, downstream transport, volatilization into the air, and degradation.

- For the semivolatile and more adsorbable organics, i.e., benzo(a)pyrene, ultimate sinks include: concentration in the biota and sediments, with ultimate deposition into the sediments, downstream transport while adsorbed to sediments, and degradation.

- For iron: the iron (mostly in ferrous form) pumped out of the groundwater, could be carried downstream by surface water, recycled between surface water and groundwater, and/or oxidized to the ferric form and precipitated in the sediments of Army Creek or Army Pond.

- For the other inorganics, the sinks include: bioaccumulation, sedimentation, recycling between surface water and groundwater, and transport downstream by surface water.

6

AR301349

6.0 RISK ASSESSMENT

This section presents the public health and environmental risk assessment for the Army Creek Landfill Site. The objectives of this assessment are to define the potential and actual risks to human health and the environment resulting from the presence of hazardous materials on the site, and to provide the basis for risk-based cleanup criteria to be used in the FS.

To assess public health and environmental risks, three major aspects of chemical contamination and environmental fate and transport must be considered: (1) contaminants with toxic characteristics must be found in environmental media and be released by either natural processes or human action, (2) pathways by which actual or potential exposure occurs must be present, and (3) human or environmental receptors must be present to complete the exposure route. Risk is a function of both toxicity and exposure; without one of the factors listed above, there is no risk.

This risk assessment estimates the potential for human health and environmental risks at the site by combining information on the toxicity of the compounds detected in the environmental media with a site-specific estimate of exposure probability. The risk assessment is presented in five sections: (1) Hazard Assessment (Section 6.1), (2) Dose-Response Evaluation (Section 6.2), (3) Exposure Assessment (Section 6.3), (4) Risk Characterization (Section 6.4), and (5) Environmental Assessment (Section 6.5).

6.1 HAZARD ASSESSMENT

The Hazard Assessment consists of two parts--the hazard identification and the toxicological evaluation. The hazard identification (Section 6.1.1) is primarily concerned with the selection of chemical contaminants that are representative of the type and magnitude of potential human health or environmental effects. Contaminant concentration, contaminant release and environmental transport mechanisms, exposure routes, and toxicity are considered to develop a list of contaminants that adequately define the site-associated risks. Section 6.1.2 presents a brief discussion of the basic toxicological terms used in this document. Appendix E provides detailed toxicity profiles and qualitative discussions of human and animal acute, chronic, or nonthreshold, carcinogenic effects of the indicator chemicals.

6.1.1 Hazard Identification

The nature and extent of contamination was presented in Sections 4.1 and 4.2. These sections and Appendix C (Recovered Groundwater Analytical Results) should be reviewed as necessary. Although many chemicals were detected during the sampling of the recovery well discharges, only a few of the chemicals pose a risk to human health or the environment.

This section is concerned with selecting a list of chemicals (indicator chemicals) that adequately characterize the carcinogenic and noncarcinogenic risks to potential human receptors. The rationale for inclusion or deletion of specific site contaminants follows.

Indicator Chemical Selection

Chemicals representative of the type and magnitude of potential carcinogenic and noncarcinogenic effects were selected as indicator chemicals. Criteria for selection included (1) an EPA carcinogenic weight-of-evidence classification of A, B1, or B2, (2) exceedance of criteria listed in Section 6.3., and (3) positive detection more than once onsite in any media. The last criterion was used to screen out single detections that might not represent the actual site conditions and chemicals that were only identified off site.

The chemicals chosen as indicator chemicals include the following organics: benzene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, bis(2-chloroethyl)ether, bis(2-ethylhexyl)phthalate, chrysene, 1,2-dichloroethane, tetrachloroethene, and trichloroethene. The inorganics chosen as indicator chemicals include the following: arsenic, cadmium, chromium (III), iron, lead, mercury, nickel, and zinc.

6.1.2 Toxicological Evaluation

The purpose of this section is to identify the potential health and environmental hazards associated with exposure to the indicator chemicals identified in Section 6.1.1. A toxicological evaluation characterizes the inherent toxicity of a compound. It consists of a review of scientific data to determine the nature and extent of the human health and environmental hazards associated with exposure to the various chemicals. The end product is a toxicity profile for each indicator chemical, each of which is presented in Appendix E. These toxicity profiles provide the qualitative weight-of-evidence that site contaminants pose actual or potential hazards to human health and the environment.

Toxic effects considered in these profiles include noncarcinogenic and carcinogenic health effects as well as environmental effects. Toxicological endpoints, routes of exposure, and doses in human and/or animal studies are discussed. Carcinogenic health effects are associated with exposure to a carcinogen. Route of exposure and doses in human and/or animal studies are provided. Also considered is the EPA's weight-of-evidence for a compound's carcinogenicity (i.e., Group A, known human carcinogens; Group B, probable human carcinogens; Group C, possible human carcinogens; Group D, not classifiable as to its carcinogenicity) (EPA, 1986b). Environmental effects include acute and chronic toxic effects observed in aquatic biota and terrestrial wildlife.

Available toxicological information indicates that some of the indicator chemicals have both noncarcinogenic and carcinogenic health effects in humans or in experimental animals. Although the indicator chemicals may cause adverse health and environmental impacts, dose-response relationships and the potential for exposure must be evaluated before the risks to receptors can be determined. Dose-response relationships correlate the magnitude of the dose with the probability of toxic effects, as discussed in the following section.

6.2 DOSE-RESPONSE EVALUATION

An important component of the risk assessment process is the relationship between the amount of compound to which an individual or population is exposed (dose) and the potential for adverse health effects resulting from exposure to that dose (response). Dose-response relationships provide a means by which potential public health impacts may be evaluated. The published information on doses and responses is used in conjunction with information on the nature and magnitude of human exposure to develop an estimate of health risks.

This section consists of the identification of ARARs that are used to evaluate public health and environmental impacts. Toxicity values such as reference doses (RfDs) and carcinogenic potency factors (CPFs) are discussed in Section 6.2.1. Federal and state water quality criteria are discussed in Section 6.2.2. Only federal and state ARARs applicable to surface water are discussed in this report. Drinking water ARARs such as Safe Drinking Water Act Maximum Contaminant Levels (MCLs), Maximum Contaminant Level Goals (MCLGs) and EPA Health Advisories are not discussed because (1) the recovery wells are pumped as a remediation action required under the first Army Creek Landfill ROD to protect downgradient drinking water resources, (2) the water pumped out of the recovery wells is discharged to surface water, and (3) the surface water that the recovered groundwater discharges into is not used as a drinking water source.

6.2.1 Toxicity Values

Two toxicity values that have been developed by the EPA for use in the risk assessment process are RfDs and CPFs. This section provides a brief description of these parameters.

Reference Dose--The RfD is developed by EPA for chronic or subchronic human exposure to hazardous chemicals and is based solely on the noncarcinogenic effects of chemical substances. The RfD is usually expressed as a dose (mg) per unit body weight (kg) per unit time (day). It is generally derived by dividing a no-observed-adverse-effect-level (NOAEL) or a lowest observed-adverse-effect-level (LOAEL) by an appropriate "uncertainty factor" and a "modifying factor". NOAELs and LOAELs are determined from laboratory or epidemiological toxicity studies.

The uncertainty factor is based on the availability of toxicity data, and is used to account for uncertainties of extrapolating from animals to humans. A factor of 10 is used when a RfD is extrapolated from valid experimental results of chronic human exposure to a chemical--a factor which accounts for individual variations in sensitivity. A factor of 100 is used when it is necessary to extrapolate from long-term studies on experimental animals or when results from human exposure are not available or are inadequate. A factor of 1,000 is used when extrapolating from subchronic exposures of experimental animals when no human data are available. Finally, a factor of 10,000 is used when it is necessary to derive a RfD from a LOAEL instead of a NOAEL. Professional judgment can also be used to incorporate an additional modifying factor of up to 10, depending on other uncertainties in the database not covered by an uncertainty factor, such as completeness or number of species tested. The default value for this modifying factor is one.

The RfD incorporates the uncertainty of the evidence for chronic human health effects. Even if applicable human data exist, the RfD, as diminished by the uncertainty factor, still maintains a margin of safety so that chronic human health effects are not underestimated. Thus, the RfD is an acceptable guideline for evaluation of noncarcinogenic risk, although the associated uncertainties preclude its use for precise risk quantitation.

Carcinogenic Potency Factor--CPFs are applicable for estimating the lifetime probability (assumed 70-year lifespan) of human receptors contracting cancer as a result of exposure to known or suspected carcinogens through ingestion or inhalation. This factor is generally reported by EPA in units of kg-day/mg and is derived through an assumed low-dosage linear relationship and an extrapolation from high to low dose-responses determined from animal studies. The value used in reporting the slope factor is the upper 95 percent confidence limit.

6.2.2 Water Quality Criteria

Federal AWQC and Delaware Proposed Water Quality Standards are discussed in this section for the indicator chemicals that pose a risk to human health or the environment.

Federal Ambient Water Quality Criteria--AWQC are nonenforceable regulatory guidelines and are of primary utility in assessing acute and chronic toxic effects in aquatic organisms. They may also be used for identifying human health risks. AWQC consider acute and chronic effects in both freshwater and saltwater aquatic life, and adverse carcinogenic and noncarcinogenic health effects in humans from ingestion of both water (2 liters/day) and aquatic organisms (6.5 grams/day), as well as from ingestion of water alone (3 liters/day). The AWQC for protection of human health for carcinogenic substances are based on the EPA's specified incremental cancer risk range of one additional case of cancer in an exposed population of 100,000 to 10,000,000 persons (i.e., the 10^5 to 10^7 range) and are generally based on older toxicologic data.

Delaware State Regulations--DNREC has established regulations for the preservation of surface water quality (State of Delaware, 1989). Numerical water quality criteria for the protection of aquatic life and for the protection of human health have been developed for many toxic chemicals. Thirty-four numerical criteria have been developed for aquatic life and 100 numerical criteria have been developed for human health. These regulations cover many of the same chemicals for which the EPA has developed AWQC, and they are at least as strict as the federal regulations. In addition, like the AWQC, the Delaware criteria are expressed in terms of acute and chronic exposure for freshwater and marine aquatic life. The criteria developed for protection of human health include ingestion of freshwater fish and water or fish only, and the ingestion of massive fish/shellfish.

Toxicity Values (RFDs and CPFs), AWQC, and Delaware water quality criteria for human health, and EPA weight-of-evidence for carcinogen classification are presented in Table 6-1. This table presents values for indicator chemicals that are known or suspected human carcinogens and for chemicals having only

TABLE 6-1

REGULATORY REQUIREMENTS AND DOSE-RESPONSE PARAMETERS FOR INDICATOR CHEMICALS

ARMY CREEK LANDFILL
NEW CASTLE, DELAWARE

Chemical	Delaware Freshwater Quality Criteria Human Health		EPA Ambient Water Quality Criteria Human Health		Health Advisory (mg/L)	Chronic Reference Dose (mg/kg/day)		Carcinogenic Potency Factor (kg-day/mg)		**EPA Weight of Evidence Carcinogenic Classification
	Water & Fish (mg/L)	Fish Only (mg/L)	Water & Fish (mg/L)	Fish Only (mg/L)		Oral	*Inhl	Oral	*Inhl	
ORGANICS										
Benzene	0.0012	0.089	66E-5	0.04	1 day/child 0.20 10 day/child 0.20 1E-4 Cancer Risk/Adult 0.10			0.029	0.029	A (1,0)
Benzo(a)pyrene	27E-7	37E-6								B2 (1,0)
Bis(2-chloroethyl)ether			3E-5	1.36E-3				1.1	1.1	B2 (1,0)
1,2-Dichloroethane	38E-5	0.123	94E-5	0.243	1 day/child 0.74 10 day/child 0.74 Longer-term/child 0.74 Longer-term/adult 2.60 1E-4 Cancer Risk/Adult 0.04			0.091	0.091	B2 (1,0)

TABLE 6-1 (cont'd.)
REGULATORY REQUIREMENTS AND DOSE-RESPONSE PARAMETERS FOR INDICATOR CHEMICALS
ARMY CREEK LANDFILL, NEW CASTLE, DELAWARE
PAGE TWO

Chemical	Delaware Ambient Freshwater Quality Criteria Human Health		EPA Ambient Water Quality Criteria Human Health		Health Advisory (mg/L)		Chronic Reference Dose (mg/kg/day)		Carcinogenic Potency Factor (kg-day/mg)		**EPA Weight of Evidence Carcinogenic Classification
	Water & Fish (mg/L)	Fish Only (mg/L)	Water & Fish (mg/L)	Fish Only (mg/L)			Oral	*Inhl	Oral	*Inhl	
INORGANICS											
Arsenic	0.05		2.2E-6	1.75E-5	1E-4 Cancer Risk/Adult	0.003	0.001			50	A (I,O)
Cadmium	0.01		0.010		1 day/child 10 day/child Longer-term/child Longer-term/adult Lifetime/adult	0.04 0.04 0.005 0.02 0.005	0.0005 (water) 0.001 (food)			6.1	B1 (I)
Chromium (Trivalent or total)	34.0	840	1.7E+2	3.4+3	1 day/child 10 day/child Longer-term/child Longer-term/adult Lifetime/adult	1.0 1.0 0.20 0.80 0.10	1.0 (III)				A (I)
Iron											
Lead	0.05		0.05				1.4E-3	4.3E-4			B2 (I,O)
Mercury					Longer-term/adult Lifetime/adult	0.002 0.002	3E-4				B2 (I,O)

TABLE 6-1 (cont'd.)
REGULATORY REQUIREMENTS AND DOSE-RESPONSE PARAMETERS FOR INDICATOR CHEMICALS
ARMY CREEK LANDFILL, NEW CASTLE, DELAWARE
PAGE THREE

Chemical	Delaware Ambient Freshwater Quality Criteria Human Health		EPA Ambient Water Quality Criteria Human Health		Health Advisory (mg/l)		Chronic Reference Dose (mg/kg/day)		Carcinogenic Potency Factor (kg-day/mg)		**EPA Weight of Evidence Carcinogenic Classification
	Water & Fish (mg/L)	Fish Only (mg/L)	Water & Fish (mg/L)	Fish Only (mg/L)			Oral	*Inhl	Oral	*Inhl	
INORGANICS (cont'd.)											
Nickel	0.62	5.7			1 day/child 10 day/child Long-term/child Long-term/adult	1.0 1.0 0.10 0.60	0.02			0.84 (Dust)	A (I)
Zinc							0.2				

Notes:

* Inhalation
** A - Known human carcinogen
B1 - Probable human carcinogen. Limited evidence of carcinogenicity in humans.
B2 - Probable human carcinogen. Sufficient evidence of carcinogenicity in animals with inadequate evidence in humans.
D - Not classifiable as to human carcinogenicity (inadequate or no evidence).
(I) - Inhalation
(O) - Oral

Sources:

(1) EPA, 1989a
(2) EPA, 1989b
(3) EPA, Integrated Risk Information System (IRIS)
(4) State of Delaware, July 20, 1989

noncarcinogenic effects. All available toxicity information is included in this table. Most of the data are from the Integrated Risk Information Service (IRIS), EPA's computerized toxicological database or the Health Effects Summary Tables (HEAST). However, if a parameter is not available in IRIS or HEAST, previously published values from other EPA sources are used if possible. For example, the RfDs for lead have been revoked. However, in order to be conservative, the original values are used. If the dose of a chemical exceeds these standards or guidelines, the potential exists for a receptor to experience adverse health effects. Expected doses of the indicator chemicals are in Section 6.4 and Appendix F.

Federal AWQC and Delaware water quality criteria for the protection of freshwater aquatic life are presented in Table 6-2. Dose-response relationships for environmental effects are limited to comparison with the AWQC for the protection of aquatic life. These criteria specify the concentration of a compound in surface water which, if not exceeded, should protect most aquatic life. These criteria are derived from both plant and animal data and were developed to protect the types of organisms necessary to support a healthy aquatic community. However, they may not protect all aquatic life under all conditions.

6.3 EXPOSURE ASSESSMENT

The purpose of this section is to evaluate the potential for human and environmental exposure to the hazardous compounds associated with the Army Creek Landfill Site. This section characterizes potentially exposed populations, identifies actual or potential routes of exposure, and estimates the degree or magnitude of exposure.

To determine whether there is an actual exposure or a potential for exposure at this site, the most likely pathways of contaminant release and transport, and the human and environmental activity patterns in the area must be considered. A complete exposure pathway has three components: (1) a source of chemicals that can be released to the environment, (2) a route of contaminant transport through an environmental medium, and (3) an exposure or

TABLE 6-2

WATER QUALITY CRITERIA FOR INDICATOR CHEMICALS
(FOR PROTECTION OF FRESHWATER AQUATIC LIFE)

ARMY CREEK LANDFILL
NEW CASTLE, DELAWARE

Chemical	EPA Ambient Water Quality Criteria Freshwater (1, 2) (ug/l)		State of Delaware Water Quality Criteria for Protection of Aquatic Life Freshwater (3) (ug/l)	
	Acute Toxicity (1-Hour Average)	Chronic Toxicity (4-Day Average)	Acute	Chronic
ORGANICS				
Benzene	5,300	NA		
1,2-Dichloroethane	118,000	20,000		
INORGANICS				
Arsenic (III)	360	190	360	190
Cadmium	3.9 (a)	1.1 (a)	3.9 (a)	1.1 (a)
Chromium (III)	1,737 (a)	207 (a)	1,737 (a)	207 (a)
Chromium (VI)	16	11	16	11
Iron	NA	1,000	NA	1,000
Lead	82 (a)	3.2 (a)	82 (a)	3.2 (a)
Mercury	2.4	0.012	2.4	0.012
Nickel	1,418 (a)	158 (a)	1,418 (a)	158 (a)
Zinc	117 (a)	106 (a)	117 (a)	106 (a)

Notes:

(a) Calculated based on the assumption of 100 mg/l of hardness

NA Not applicable

Sources:

(1) EPA, Integrated Risk Information System (IRIS)
(2) EPA, 1986a
(3) State of Delaware, July 20, 1989

AR301360

contact point for human or environmental receptors. These components are addressed in the following subsections. The magnitude of exposure is estimated in the final subsection.

The nature and extent of contamination were described in Section 4.0 of this report. Sources of contamination are summarized as follows:

- Recovery well water discharge
- Creek and pond surface water
- Creek and pond sediments
- Air in the area of the creek and pond

6.3.1 Receptor Identification

Potentially exposed human and environmental receptors are as follows:

- Persons trespassing on the site
- Persons residing or working downwind (to the north) of the site
- Aquatic biota in the creek and pond
- Terrestrial flora and fauna living on the site or seasonally using the site

Since the recovery wells were installed and operated, the Artesian Water Company production wells used for public water supply in the area have not been found to be adversely affected by site-related contamination.

6.3.2 Exposure Routes

There are five environmental routes through which identified receptors may be directly or indirectly exposed to site-related contaminants--groundwater collected by the recovery wells, surface water, sediments, air, and fish.

Exposure to recovered groundwater could occur through inadvertent ingestion of, or dermal contact with, discharges from the operating recovery wells. Exposure to surface water could occur through accidental ingestion or dermal contact while playing in the water. Exposure to site sediments could occur through accidental ingestion or dermal exposure of sediments that could accumulate on the hands or clothing of people visiting the site. Air exposure could occur through volatilization of organic compounds in the recovered groundwater discharges or the surface water. Finally, exposure through fish could occur as recreational anglers consume fish caught in Army Creek or Army Pond.

6.3.3 Exposure Estimates

The third step in the exposure assessment is to estimate the doses of contaminants incurred by a receptor. This section provides route-specific estimates of contaminants to which a receptor may be exposed. Estimated doses of contaminants are presented in the calculations provided in Appendix F.

A dose is defined as the amount of a compound (in mg) absorbed (per day) by a receptor (per kg of body weight). Doses can be calculated for a lifetime exposure (for carcinogenic effects) or for either chronic or one-time acute exposure (for noncarcinogenic effects). A dose is generally estimated as follows:

$$\text{Dose} = \frac{\text{Contaminant Concentration} \times \text{Contact Rate} \times \text{Absorbed Fraction}}{\text{Body Weight}}$$

Exposure duration (or exposure fraction) is an important factor in calculating doses. A time-weighting factor for lifetime exposures is used for estimating doses of carcinogens, whereas for noncarcinogens, an annual time-weighting factor is more appropriate.

Exposure to Groundwater Recovery Well Discharges and Surface Water

The potential exposure scenario developed for the groundwater recovery well discharges in Section 6.3.2 includes exposure to site-related contamination through recovered groundwater ingestion. Ingestion exposures are estimated using the following equation (EPA, October 1986):

$$\text{Dose} = \frac{C \times IR \times AF \times ED}{BW \times lf}$$

Where: Dose = Daily intake per unit body weight (mg/kg - day)

C = Contaminant concentration in water (mg/l)

IR = Ingestion rate (l/day)

AF = Absorption fraction (unitless)

ED = Exposure duration (years) (omitted for noncarcinogens)

BW = Body weight (kg)

LF = Lifetime (years) (omitted for noncarcinogens)

The average contaminant concentration was used as a means of assessing the most possible accidental exposure. The ingestion rate was set at 0.1 liters/day for a 70-kg adult receptor and at 0.1 liter/day for a 30-kg child. The exposure frequencies were six exposures in 30 years for adults and one exposure per year for six years for a child. The absorption fraction was specified as 100 percent (1.0) for all groundwater contaminants.

Carcinogenic risk was based on an exposure duration of 30 years. This value is the maximum time an adult would be expected to live in the area (EPA, 1989c). Carcinogenic risk for a child was based on an exposure duration of 6 years. A lifetime was considered to be 70 years.

Inhalation exposures are estimated as follows:

$$\text{Dose} = \frac{C_{air} \times IR \times AF \times EF \times ED}{BW \times LF}$$

Where: Dose = Daily contaminant intake per unit body weight (mg/kg - day)

C_{air} = Air concentration of contaminant of concern (mg/m^3)

IR = Inhalation rate (m^3/day)

AF = Absorption fraction (unitless)

EF = Exposure frequency (days/year) (omitted for noncarcinogens)

ED = Exposure duration (years)

BW = Body weight (kg)

LF = Lifetime (years) (omitted for noncarcinogens)

AR301363

The inhalation rate was [illegible] m^3/day for both a 70-kg adult and a 30-kg child (EPA, 1989[illegible]). The absorption fraction was specified as 100 percent [illegible] for all the contaminants. The exposure frequency was estimated at six [illegible] for adults and one exposure per year for six years for [illegible] in 30 years for adults and [illegible] Carcinogenic risk was based on an exposure duration of 30 years for children. [illegible] A lifetime was considered to be 70 years [illegible] an adult and [illegible] years for a child. [illegible] were calculated by multiplying the weighted average [illegible] groundwater recovery well discharge concentration by Henry's Constants for [illegible] Air concentrations [illegible] example calculation in Appendix [illegible]. Air concentrations [illegible] for groundwater recovery well discharge [illegible] concentrations were used.

Exposure to Contaminated Sediment

Exposure [illegible] accidental ingestion of contaminated sediments can [illegible] as follows:

[illegible]

[illegible] intake of contaminant per unit body weight (mg/kg-day)

[illegible] concentration in sediment [illegible]

Ingestion rate [illegible]

Absorption fraction (unitless)

Exposure frequency (days/year)

Exposure duration (years) (omitted for noncarcinogens)

Body weight (kg)

Lifetime (years) (omitted for noncarcinogens)

[illegible] 70-kg adult and a 30-kg child were [illegible] potentially ingested by a receptor. The [illegible] years for adults and [illegible] Carcinogenic risk was based [illegible] 30 years for an adult and 6 years for a child. [illegible] 70 years. [illegible] present a worst case [illegible] concentrations [illegible] used in th[illegible] overestimated [illegible] most sedimen[illegible]

The inhalation rate was set at 1 m^3/day for both a 70-kg adult and a 30-kg child (EPA, 1989c). The absorption fraction was specified as 100 percent (1.0) for all air contaminants. The exposure frequency was estimated at six exposures in 30 years for adults and one exposure per year for six years for children. Carcinogenic risk was based on an exposure duration of 30 years for an adult and 6 years for a child. A lifetime was considered to be 70 years. Air concentrations were calculated by multiplying the weighted average groundwater recovery well discharge concentration by Henry's Constants for each contaminant (see example calculation in Appendix F). Air concentrations from surface water were calculated as for groundwater recovery well discharge except that maximum surface water concentrations were used.

Exposure to Contaminated Sediment

Exposure estimates for the accidental ingestion of contaminated sediments can be estimated as follows:

$$\text{Dose} = \frac{C \times IR \times AF \times EF \times ED}{BW \times LF}$$

Where: Dose = Daily intake of contaminant per unit body weight (mg/kg-day)
C = Contaminant concentration in sediment (mg/kg)
IR = Ingestion rate (mg/day)
AF = Absorption fraction (unitless)
EF = Exposure frequency (days/year)
ED = Exposure duration (years) (omitted for noncarcinogens)
BW = Body weight (kg)
LF = Lifetime (years) (omitted for noncarcinogens)

Ingestion rates of 10 and 50 mg/day for a 70-kg adult and a 30-kg child were used to represent the amount of soil potentially ingested by a receptor. The exposure frequency was estimated at six exposures in 30 years for adults and one exposure per year for six years for children. Carcinogenic risk was based on an exposure duration of 30 years for an adult and 6 years for a child. A lifetime was considered to be 70 years. The estimates present a worst-case scenario because maximum contaminant concentrations are used in the calculations. Soil ingestion rates are overestimates because most sediment would be washed off of hands and feet. The potential, however, does exist during periods of low water conditions for receptors to be exposed to uncovered sediments.

Dermal Contact with Contaminated Surface Water and Sediments

Exposure estimates for dermal contact with surface water are estimated with the following equation:

$$\text{Dose} = \frac{C \times K \times SA \times EF \times ED}{BW \times LF}$$

Where: Dose = Dermal exposure dose (mg/kg-day)

C = Contaminant concentration (mg/l)

K = Dermal absorption coefficient (0.001 $l/cm^2/hr$) (Dutkiewicz and Tyras, 1968, 1967)

SA = Surface area (cm^2)

EF = Exposure frequency (unitless)

ED = Exposure duration (years) (omitted for noncarcinogens)

BW = Body weight (kg)

LF = Lifetime (years) (omitted for noncarcinogens)

Surface areas of 8,750 cm^2 and 19,400 cm^2 were used for 100 percent body exposure for a child and an adult, respectively. The exposure frequency was estimated at six exposures in 30 years for adults and one exposure per year for six years for children. Carcinogenic risk was based on an exposure duration of 30 years for an adult and 6 years for a child. A lifetime was considered to be 70 years.

Dermal sediment exposure estimates are based on scenarios presented above and are calculated by the following equation:

$$\text{Dose} = \frac{C \times A \times BF \times EF \times ED}{BW \times LF}$$

Where: Dose = Dermal absorption dose (mg/kg/day)

C = Contaminant concentration (g/kg)

A = Total soil adhered (2 mg/cm^2)

BF = Bioavailability factor (100%)

EF = Exposure frequency (unitless)

ED = Exposure duration (years) (omitted for noncarcinogens)

BW = Body weight (kg)

LF = Lifetime (years) (omitted for noncarcinogens)

Calculations were made for a 30-kg child and a 70-kg adult suspected of trespassing onsite. Total exposed surface areas were estimated at 2,625 cm^2 and 5,820 cm^2 for a child and an adult, respectively. Therefore, based on an adhesion estimate of 2 mg per exposed surface area, the total estimated amount of soil adhered would be 5,250 mg for a child and 11,640 mg for an adult. This value can be considered as a maximum estimate (worst-case) because surface water would wash off most of the adhered sediment. The exposure frequency was estimated at six exposures in 30 years for adults and one exposure per year for six years for children. Carcinogenic risk was based on an exposure duration of 30 years for an adult and 6 years for a child. A lifetime was considered to be 70 years.

Dermal exposure calculations are concerned only with organic contaminants because metals are not expected to be absorbed through the skin.

Ingestion of Contaminated Fish

Exposure estimates for ingestion of contaminated fish depend on the following equation:

$$Dose = \frac{CLi \times CRi \times EF}{BW}$$

Where: Dose = Food ingestion dose (mg/kg/day)

CLi = Concentration of contaminant in foodstuff (mg/g)

CRi = Consumption rate of food group (g/day)

EF = Exposure factor (unitless)

BW = Body weight (kg)

AR301366

Exposure was based on a 70-kg adult consumption rate of 5.2 g/day (State of Delaware, 1989). This is the average consumption rate of freshwater fish for recreational anglers in Delaware. In a report by the State of Delaware (June 17, 1983), chromium (5.2 ug/g) and lead (5.0 ug/g) were found in bullhead catfish samples.

6.4 RISK CHARACTERIZATION

The objective of this section is to estimate the potential incidence of adverse health or environmental effects under the exposure scenarios defined in Section 6.3. EPA Guidelines (1986b) for the use of dose-additive models are used to combine the risks for individual chemicals to estimate cumulative risks for the mixtures found on the site, assuming that the toxicologic endpoints (effects) are the same. This section characterizes the potential carcinogenic, noncarcinogenic, and environmental risks associated with the Army Creek Landfill Site.

6.4.1 Uncertainty in Risk Assessment

Carcinogenic and noncarcinogenic health risks are estimated using a number of assumptions. Therefore, the values presented in this section contain an inherent amount of uncertainty. The certainty with which health risks can be characterized depends upon the body of information regarding the toxicity of chemicals and the accuracy of the exposure estimates.

Dose-response relationships are purposely developed to be conservative, and to tend toward overstating potential compound toxicity, in order to provide margins of safety that will be protective of human health and the environment. Exposure estimates are based on conservative scenarios. This conservatism results in predictions of adverse impacts that account for the many uncertainties in the risk assessment process, such as variations of susceptibility to chemical compounds among human receptors.

6.4.2 Carcinogenic Risks

Carcinogenic risks can be estimated by combining information in the dose-response assessment (CPFs) with an estimate of the individual intakes (doses) of a contaminant by a receptor.

Risk can be estimated as follows (EPA, 1986b):

Risk = (q*)(Dose)

Where: q* = Carcinogenic potency factor (slope of the dose-response curve in kg-day/mg)

Dose = Amount of a contaminant absorbed by a receptor in mg/kg-day

The resulting risk is a unitless expression of an individual's likelihood of developing cancer as a result of exposure to the carcinogenic indicator chemicals. When the above equation results in a risk greater than 0.1, the following equation is used:

Risk = 1 - exp(q*)(Dose)

This equation calculates incremental risk in addition to the risks incurred by everyday activities. The risk can also be applied to a given population to determine the number of excess cases of cancer that could be expected to result from exposure. For example, a risk value of 1×10^{-6} which indicate one additional case of cancer in 1,000,000 exposed persons.

The total risk for exposure to multiple compounds is presented as the summation of the risks for the individual contaminants. Risks can be calculated in this manner given the following assumptions:

- There are no a .agonistic/synergistic effects between contaminants
- Exposure to all chemicals produces the same result
- The exposed populations are the same (EPA, 1986b)

Detailed risk calculations are presented in Appendix F for each exposure scenario developed in Section 6.3. Input parameters and assumptions are defined for each scenario. Table 6-3 presents total incremental lifetime cancer risks for each exposure scenario. Since none of the carcinogenic risks exceeds the Superfund action level of 10^{-6} to 10^{-4}, there is no cause of concern for carcinogenic risk at the Army Creek Site.

6.4.3 Noncarcinogenic Effects

The potential for health effects resulting from exposure to noncarcinogenic compounds is estimated by comparing a time-weighted daily dose to an acceptable level such as a chronic RfD. If the ratio exceeds 1.0, there is a potential health risk associated with exposure to that particular chemical (EPA, 1986b). The ratios can be summed for exposures to multiple contaminants. The sum, known as a Hazard Index, is not a mathematical prediction of the severity of toxic effects, but rather a numerical indicator of the transition from acceptable to unacceptable levels. Table 6-4 presents a summary of the total potential Hazard Indices for the exposure scenarios described in Section 6.3. Since none of the total Hazard Indices exceeds 1.0, there is no cause of concern for noncarcinogenic risk at the Army Creek Site.

6.4.4 Summary of Risk Characterization

The carcinogenic and noncarcinogenic risks calculated for the possible human exposure to the groundwater recovery well discharges, the surface water, the sediment, and the fish consumption in this Focused RI are all under the normal acceptable risk levels. The calculated risks can be used in the FS to develop risk-based action levels for the various site media.

6.5 ENVIRONMENTAL ASSESSMENT

6.5.1 Water Quality

The State of Delaware classifies Army Creek for fish and wildlife propagation, and for agricultural use (State of Delaware, 1988). As of 1988, these uses were considered to be supported but threatened due to low flow and some organic enrichment.

TABLE 6-3

SUMMARY OF TOTAL POTENTIAL CARCINOGENIC RISKS

ARMY CREEK LANDFILL
NEW CASTLE, DELAWARE

Media	Scenario	AGE GROUP EXPOSED	
		Children 6-11 yrs	Adults 70-yr Life Span
Recovery Well Discharges*	Inadvertent Ingestion	1.2E-8	5.3E-9
	Inhalation of Volatiles Leaving Groundwater	7.2E-7	3.1E-7
	Dermal Absorption	9.7E-7	9.2E-7
Sediment**	Inadvertent Ingestion	8.2E-10 (0.01 g/day) 4.1E-9 (0.05 g/day)	3.5E-10 (0.01 g/day) 1.7E-9 (0.05 g/day)
	Dermal Absorption	NC	NC
Surface Water**	Ingestion	6.5E-9	2.9E-9
	Inhalation of Volatiles Leaving Surface Water	1.8E-7	7.6E-8
	Dermal Absorption	6.0E-7	5.7E-7

* Risks from groundwater recovery well discharges were calculated using the weighted average of pollutant concentrations detected during sampling, plus one-half the contract required quantitation or detection limit for nondetected values which had been detected in the past.

** Sediment and surface water risks were calculated using the highest pollutant concentrations detected during sampling.

NC These values could not be calculated due to a lack of sufficient information.

TABLE 6-4

SUMMARY OF TOTAL POTENTIAL HAZARD INDICES

ARMY CREEK LANDFILL
NEW CASTLE, DELAWARE

Media	Scenario	AGE GROUP EXPOSED	
		Children 6-11 yrs	Adults 70-yr Life Span
Groundwater Recovery Well Discharges*	Inadvertent Ingestion	1.5E-5	1.3E-6
	Inhalation of Volatiles Leaving Groundwater	NC	NC
	Dermal Absorption	NC	NC
Sediment**	Inadvertent Ingestion	7.2E-5 (0.01 g/day) 3.6E-4 (0.05 g/day)	6.2E-6 (0.01 g/day) 3.1E-5 (0.05 g/day)
	Dermal Absorption	NC	NC
Surface Water**	Inadvertent Ingestion	8.0E-4	6.9E-5
	Inhalation of Volatiles Leaving Surface Water	NC	NC
	Dermal Absorption	NC	NC
Fish	Ingestion ***	NC	0.26

* Risks from groundwater recovery well discharges were calculated using the weighted average of pollutant concentrations detected during sampling, plus one-half the contract required quantitation or detection limit for current nondetected values which had been detected in the past.

** Sediment and surface water risks were calculated using the highest pollutant concentrations detected during sampling.

*** For chromium and lead.

NC These values could not be calculated due to a lack of sufficient information.

AR301371

Two studies have compared the stream biota of Army Creek from locations above and below the landfill, beyond the pond outlet. The study conducted in 1985 by the State of Delaware (State of Delaware, 1985) found species richness at both the above and below landfill stations to be similar. Both stations exhibited high densities of macroinvertebrates but relatively low species diversity. Of the species present, facultative and pollution-tolerant organisms predominated. The authors suggested these communities were indicative of moderate inorganic enrichment. The second biomonitoring study was conducted in 1986 by EPA (EPA, 1986c). This study had three study sites, one upstream from the landfill, the second in the Army Creek Pond, and the third downstream of Army Creek Landfill. Results of this study were similar to those found in the 1985 State of Delaware Study. The EPA study did find that the downstream benthic community had more taxa and fewer organisms per taxa as well as more groups intolerant of water pollution, indicating an improvement in water quality over upstream stations. The pond station exhibited very low species richness and 95 percent of the groups found in the pond were pollution tolerant. This indicates poor water quality in the pond. In summary, Army Creek both above and below the landfill appears to be nutrient enriched. Although chronic toxic effects due to landfill effluent may be present, the effects cannot be distinguished from the stream biotic communities due to the confounding effects of the stream enrichment. The improvement in the benthic macroinvertebrate community below the pond outfall does suggest that the pond may be operating as a filter or aeration system, improving the water quality of the outflow water.

6.5.2 Bioassays and Chronic Toxicity Studies

A bioassay was performed on a composite whole-fish sample of four brown bullhead catfish collected by DNREC (1983). Results showed no tissue contamination by purgeable synthetic organic compounds but some inorganic contamination by zinc (18 ug/g), chromium (5.2 ug/g), copper (5.2 ug/g), and lead (5.0 ug/g). Polychlorinated biphenyls (PCBs) (1.2 ug/g) were also detected. The fish in this study were collected below the landfill at the edge of the Army Creek Site.

Brown bullheads are good indicator organisms for tracking potential contaminants. They can be thought of as integrator organisms as they are very tolerant of polluted conditions but are able to sequester contaminants over time. They are benthic dwelling as well as benthic feeders. Bioavailable contaminants from the sediments can partition into the fish through physical processes or through feeding effects. Although the fish may be receiving some metals from the sediments of Army Creek and Army Pond, it is likely that some of their contaminant loading may have come from offsite since the sediments do not have elevated metal concentrations compared to the average concentrations of metals in uncontaminated soil (Brown and Associates, 1983).

Two short-term chronic toxicity studies using Ceriodaphnia dupia were performed on recovery well water and Army Creek water from above and below the Army Creek Pond. The study performed by the State of Delaware in 1985 (State of Delaware, 1985) concluded that the effluent was not different from the influent in terms of adult survival and number of young produced. Both influent and effluent had relatively high adult survival in most cases, and numbers of young produced per adult were in the normal range for surface water. No recovery well water was tested in this study. The EPA study, conducted in 1986, showed similar results (EPA, 1986c). The survival and reproduction of the Ceriodaphnia were high for both the influent and effluent water. However, survival and reproduction of Ceriodaphnia in the effluent water were notably higher than that of the Ceriodaphnia in the influent. This could suggest better water quality of the effluent. Also, recovery wells RW9, RW28, RW29, and RW31 had very low adult survival and reproduction compared to a noncontaminated artesian well which was used as a control. A composite water sample of all recovery well water had intermediate results with adult survival similar to the artesian well water, but young production was significantly reduced. This suggests that water straight from the recovery wells which is currently discharged into Army Pond might be somewhat toxic to some pond biota.

The EPA also conducted a chronic toxicity study using the fathead minnow (EPA, 1986c), in conjunction with the aforementioned Ceriodaphnia study. Similar trends were observed with minnow survival and growth in the effluent exceeding that in the influent water. Only Well RW31 showed significant fish mortality.

Overall, these studies indicated that the effluent water is of higher quality than the influent water to the site. Also, although the recovery wells might be somewhat toxic, the effects are slightly reduced by the pond retention time.

6.5.3 Chemicals of Concern and Environmental Receptors

Table 6-5 presents the contaminant concentrations in the groundwater recovery well discharges, surface water, and sediments (see Tables 4-2 to 4-9) to the federal and state AWQC for freshwater aquatic life (Table 6-2).

Iron is the only chemical of concern from the groundwater recovery well discharges. The chemicals of concern from the surface water consist of cadmium, chromium, iron, mercury, and zinc since their environmental concentrations exceed the Federal and Delaware State AWQC. Chromium was included in the list in the +6 valence state because the more stringent criterion for Cr(VI) compared to Cr (III). For the sediment, when the conservatively calculated contaminant concentration levels in equilibrium with the AWQC (Section 6.3) were used for comparison, only iron exceeded the calculated levels.

Army Creek and its vicinity support a diverse flora and fauna. This has been discussed in detail in Chapter 3 with species found on the Army Creek Site or in Army Creek listed in Tables 3-1 to 3-6. Five species of special concern have been found in Army Creek or within the vicinity of the site. These are the bur-marigold, smallmouth bass, striped bass, white crappies and yellow bullheads. The bur-marigold is not found on the Army Creek Site, but rather at the mouth of Army Creek along the Delaware River. Because of the distance involved, it is not likely this species would be impacted by the Army Creek Site or its remediation. The four fish listed above could potentially be impacted by the Army Creek Site. Although these species have been found in Army Creek, they do not appear to be common species in the Creek. White crappies and smallmouth bass were found two times out of six sampling events between 1975 and 1983, while yellow bullhead and striped bass were found only once. Periodic surveys may be needed to monitor the health of these species and the aquatic environment in general.

TABLE 6-5

ENVIRONMENTAL CHEMICALS OF CONCERN

ARMY CREEK LANDFILL SITE
NEW CASTLE, DELAWARE

Chemical	Range of Environmental Concentration	Reason of Concern	Detection Limit
FROM RECOVERY WELL DISCHARGE			
Iron	488-34,300 ug/L	Exceeding federal and state AWQC (chronic) of 1,000 ug/L	8.6 ug/L
FROM SURFACE WATER			
Cadmium	34-38 ug/L	Exceeding federal and state AWQC of 1.1 ug/L (chronic) and 3.9 ug/L (acute)	10 ug/L
Chromium	57-150 ug/L	Possible exceedance of federal and state AWQC of 11 ug/L (chronic) and 16 ug/L (acute) as chromium (VI)	50 ug/L
Iron	980-2,860 ug/L	Exceeding federal and state AWQC (chronic) of 1,000 ug/L	500 ug/L
Mercury	ND-0.2 ug/L	Exceeding federal and state AWQC (chronic) of 0.012 ug/L	0.2 ug/L
Zinc	25-640 ug/L	Exceeding federal and state AWQC of 106 ug/L (chronic) and 117 ug/L (acute)	10 ug/L
FROM SEDIMENT			
Iron	1,830-68,800 mg/kg	Exceeding the calculated concentration of 500 mg/kg in equilibrium with AWQC	50 mg/kg

ND = Not Detectable

Five metals, cadmium, chromium, iron, mercury and zinc are found in Army Creek at concentrations above the AWQC (Table 6-5). These metals pose a potential hazard to aquatic organisms, especially those which are rare in occurrence in Army Creek. Of these metals, cadmium and zinc concentrations exceed both chronic and acute AWQC; iron and mercury concentrations exceed their chronic AWQC; chromium, if existed in the +6 oxidation state, would exceed both the chronic and acute AWQC.

Cadmium and zinc are chemically similar and cause similar types of chronic effects in fish. These include developmental abnormalities in fish larvae and mortality of fish fry (Rand and Petrocelli, 1985). Cadmium has been shown to reduce adult growth while zinc can reduce spawning and egg hatching (Spehar, 1976). Zinc has also been shown to cause edema and necrosis of liver tissue in rainbow trout fry (Leland, 1983).

Mercury in its methylated form can cause a variety of chronic effects in fish. These include teratogenic effects such as severe scoliosis and jaw abnormalities (McKim, et al., 1976). Other effects include poor embryo survival and necrosis of liver and kidney tissue.

Chronic effects of chromium are relatively poorly studied. However, effects include a reduction in fish growth (EPA, 1986a).

Although iron exceeds the AWQC in the surface water, it may not pose much of a hazard to fish. The AWQC for iron is based primarily on the physical hazards posed by Fe^{+2} oxidizing to Fe^{+3} forming iron oxides and precipitating. These iron precipitates or flocs can clog fish gills or smother benthic organisms and fish eggs (EPA, 1986a). Iron in very high concentrations can be toxic, but this occurs at concentrations much greater than those found in Army Creek.

The chemicals of concern could potentially reach aquatic organisms through several pathways. These include partitioning directly from the water into the organisms; resuspension from the sediments, then partitioning into the organisms; partitioning into the organisms directly from the sediments; ingestion by the organisms and uptake through respiration, particularly gills.

Routes of exposure to terrestrial organisms are more difficult to trace and exposures are less likely. Routes include ingestion of water, sediments, or contaminated foods; breathing contaminated air; and dermal exposure to contaminated water or sediments. Of these three routes, ingestion of water and aquatic foods (vegetation, fish, frogs, aquatic insects, etc.) is the most likely route of exposure, although dermal exposure could be very important for some organisms. Biomagnification could potentially be a problem for top level predators. For example, osprey, which feed primarily on fish, have been sighted at Army Creek. Were they to feed on fish from this site, they undoubtedly would receive some dose of certain compounds, particularly some metals. The long-term effects of this type of exposure are difficult to predict, but top level predators have repeatedly been shown to be more sensitive to certain contaminants than those lower on the food chain.

Because Army Creek flows offsite into the Delaware River, the potential exists for spreading contamination beyond the site boundaries. Since the effluent from Army Pond appears to be of slightly higher quality than the influent, deleterious effects on the Delaware River are unlikely.

7

AR301378

7.0 SUMMARY AND CONCLUSIONS

7.1 SUMMARY

7.1.1 Nature and Extent of Contamination

The groundwater discharges pumped from nine active recovery wells were sampled. Iron exceeded the EPA and State of Delaware AWQC for freshwater aquatic life. The most contaminated wells were Wells 12, 28, and 29.

The analytical results reported by Charters (EPA, 1988c) for the surface water and sediment in Army Creek and Army Pond were evaluated. The following contaminants were found to exceed the AWQC for freshwater aquatic life set by EPA and/or State of Delaware: cadmium, chromium, iron, mercury, and zinc.

7.1.2 Environmental Fate and Transport

The most important contaminants include metals, volatile organics, and semivolatile organics. These contaminants are found in the recovered groundwater, in surface water, and in sediments. The diverse nature of the contaminants as well as the different media in which they reside dictate that the environmental fate and transport will be very complex. The important processes include: volatilization, photolysis, adsorption, desorption, dissolution, sedimentation, bioaccumulation, bioconcentration, chemical speciation, and biological degradation.

The hydrogeological study performed during this RI demonstrated that the surface water onsite is moving into the groundwater at a very high flow rate. This water movement facilitates the recycling of the water soluble contaminants through the three media of groundwater, surface water, and sediment. The ultimate sink for the persistent and highly adsorbable contaminants will be the sediment.

7.1.3 Risk Assessment

Identified potential human exposure routes included: inadvertent ingestion of groundwater recovery well discharges, surface water, sediment, and fish consumption; inhalation of volatile and semivolatile organic compounds from groundwater recovery well discharges and surface water; and dermal absorption of contaminants from inadvertent exposure to recovered groundwater, surface water, and sediment.

Potential public health risks were calculated for various scenarios of human exposure to the contaminants. The potential human carcinogenic risks were calculated to be very low (10^{-9} level from inadvertent ingestion of groundwater recovery well discharges, surface water, or sediment; 10^{-7} level from inhalation of contaminants from groundwater recovery well discharges or surface water; and 10^{-10} to 10^{-7} level from dermal absorption of contaminants from groundwater recovery well discharges, surface water, or sediment). The potential noncarcinogenic risks were also calculated to be very low for all of the exposure routes.

A more qualitative assessment was performed for the environmental impact of the contamination onsite. Detrimental effects on the biota could possibly result from contact with the contaminated groundwater recovery well discharges or surface water. Contamination appeared to impact the aquatic environment more than the terrestrial environment. However, the upstream water from the site was also noted to be highly nutrient enriched which also adversely impacted the aquatic environment.

7.2 CONCLUSIONS

Under the anticipated exposure scenarios and current conditions, the focused study area and media do not present significant carcinogenic or noncarcinogenic risks to the general public. Surface waters in Army Creek and Army Pond are contaminated by several metals (iron, cadmium, chromium, mercury, and zinc) at concentrations that will cause detrimental impacts on the aquatic environment. Three sources of contamination can be envisioned:

- Recovered groundwater discharges contribute iron to the surface waters.

- Leachate seeps from the Army Creek landfill probably contribute cadmium, chromium, mercury, and zinc to the surface waters.

- Off-site surface runoff may contribute some of the metals observed in the surface waters.

Capping of the landfill under the 1986 ROD for OU1 will result in a gradual decrease in the quantities of metals reaching surface waters through leachate seeps. The proportion of metals emanating from leachate seeps and from off-site runoff should become evident through the monitoring program incorporated into the OU1 ROD. The need for future action to mitigate remaining problems will be identified through that monitoring activity. Iron contamination of recovered groundwater must be reduced by treatment of the recovery well discharges prior to release to the surface waters.

Sediments in Army Pond are deemed not to represent a threat to the aquatic environment. The metals cadmium, chromium, mercury, and zinc are present at concentrations that fall within ranges observed in natural soils. Iron concentration is higher than would be expected in natural soils, but the hydrologic regime at the sediment surface will prevent the sediments from contributing iron to the overlying surface water to the extent that would be deleterious to aquatic life.

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APPENDICES

A

AR301388

APPENDIX A

COMMUNITY RELATION CONCERNS AND MAILING LIST

GANNETT FLEMING
ENVIRONMENTAL ENGINEERS, INC.

VILLAGE OF CROSS KEYS
WEST QUADRANGLE, SUITE 417
BALTIMORE, MD 21210
(301) 433-8032

F
31

February 3, 1989

U. S. Environmental Protection Agency
841 Chestnut Street
Philadelphia, Pennsylvania 19107

Attention: Mr. Eric Newman

RE: ARCS III Program
EPA Contract No. 68-W8-0037
Army Creek Landfill Site, Delaware
EPA Work Assignment No. 37-04-3N34

Gentlemen:

We are enclosing a memorandum from one of our community relations specialists regarding her conversations with community leaders near the Army Creek Landfill site, along with an updated mailing list, in response to a request from Mr. William Draper at EPA Region III. Please let us know of any additional efforts you require for the site CR program.

Very truly yours,

GANNETT FLEMING ENVIRONMENTAL ENGINEERS, INC.

David L. Sheridan
Project Manager

DLS:ijk

cc: Ms. Stephany Del Re'
Mr. Robert E. Stecik, Jr.

GF: 25680

AR301390

February 3, 1989

MEMORANDUM

TO: David Sheridan

FROM: Betsy Tuttle BT

RE: Job 25680
Army Creek Landfill
Community Relations Plan

After speaking to persons on the contact list, I was able to update the list and get a general idea of community attidude. I was able to reach both the former President and present President of the Llangollen Civic Association. The conversations with the two gentlemen revealed two distinctly differing attitudes.

Mike Rush, the former President, expressed his concern over what he referred to as "EPA's lack of concern with the Army Creek Landfill Superfund site and, also, the Tybouts Corner Landfill Superfund Site." He was a resident of the Llangollen Estates before the site became a landfill and served as President of the Civic Association when the site was put on the NPL. Therefore, he is rather knowledgeable of the history of the landfill.

During the time he served as President, there was only one public meeting and hardly any contact between EPA and local officials. He feels that the citizen's low level of concern is based on the lack of a good informative public relations plan. He had to get most of his information from the Right to Know, Sunshine Legislation. He is available for further comment at the following telephone number: (302) 328-4826.

Thomas Neiger, the current President, can be contacted by telephone at (302) 328-4322, and his current address can be obtained from the List of Interested Parties. His Civic Association is consistently in contact with the necessary local, state and federal officials. He feels a need to be patient with the activities that are taking place at the Army Creek Landfill.

The Association keeps close contact with the residents of the Llangollen Estates, and they try to hear their concerns with the site. The greatest concern he revealed was over the direct pumping of the recovery well water into Army Creek. The effects of this procedure are of great concern for many community leaders and members. Mr. Neiger would like to back and cooperate with any remedial design activity selected for the Landfill. In order to accomplish this, he feels a necessity to conduct a meeting between EPA, the engineers and his staff before a Formal Public Meeting is held on the remedial design. He has faith that something will be done to correct the problems related to the Army Creek Landfill. And he feels if the community relations for Army Creek Landfill is planned correctly, the entire ordeal can be handled without an uprising.

8.0 LIST OF INTERESTED PARTIES

FEDERAL

Honorable William V. Roth, Jr.
United States Senator
Room 3021
J. Caleb Boggs Building
844 King Street
Wilmington, Delaware 19801
302-674-3308

Honorable Joseph R. Biden, Jr.
United States Senator
Room 6021
J. Caleb Boggs Building
844 King Street
Wilmington, Delaware 19801
302-573-6345

Honorable Thomas R. Carper
Member, U.S. House of Representatives
Room 5021
J. Caleb Boggs Building
844 King Street
Wilmington, Delaware 19801
302-573-6181

Eric Newman
Remedial Site Project Manager
U.S. Environmental Protection Agency
Region III
841 Chestnut Building
Philadelphia, Pennsylvania 19107
215-597-9238

William M. Draper
Community Relations Coordinator
U.S. Environmental Protection Agency
Region III
841 Chestnut Building
Philadelphia, Pennsylvania 19107
215-597-9238

STATE

Honorable Robert T. Conner
Delaware State Senate
12th District
Carvel Office Building
Wilmington, Delaware 19801
302-571-3724

Honorable Jeffrey G. Mack
Member, Delaware House of Representatives
17th District
Legislative Hall
Dover, Delaware 19901
302-736-4141

Roger Lucio
Community Relations Office
Delaware Dept. of Natural Resources and Environmental Control
89 Kings Highway
P.O. Box 1401
Dover, Delaware 19901
302-736-4506

LOCAL

David C. Clark, P.E.
New Castle County
Department of Public Works
100 New Churchmans Road
New Castle, Delaware 19720
302-323-2659

Dennis Greenhouse
County Executive
City-County Building
Office of the Executives
Eighth Floor
800 French Street
Wilmington, Delaware 19801
302-571-7500

Phil Clouthier
County Council President
City-County Building
800 French Street
Wilmington, Delaware 19801
302-571-7520

Michael P. Reynolds
City Solicitor
City Law Department
City-County Building
800 French Street
Wilmington, Delaware 19801
302-571-4200

Edward J. Murphy, Secretary
New Castle Board of Water and
Lights
216 Chestnut Street
New Castle, Delaware 19720
302-323-2330

Thomas Neiger, President
Llangollen Estates Civic Association
232 Shaeffer Boulevard
Llangollen Estates
New Castle, Delaware 19720
302-328-4322

OTHER

Dave Sheridan
ARCS Contractor
Gannett Fleming Engineers
Suite 417
West Quadrangle
Village of Cross Keys
Baltimore, Maryland 21210
301-433-8832

MEDIA

Wilmington News Journal, Newsdesk
831 Orange Street
P.O. Box 1111
Wilmington, Delaware 19899
302-573-2000

WCAU Channel 10, Newsdesk
Monument and City Avenues
Philadelphia, Pennsylvania 19131
215-581-5510

Delaware State News, Newsdesk
P.O. Box 737
Dover, Delaware 19901
302-674-3600

WILM Radio, Newsdesk
1215 French Street
Wilmington, Delaware 19801
302-656-9800

New Castle Eagle, Newsdesk
P.O. Box 95
New Castle, Delaware 19720
302-322-1100

WHYY Channel 12, Newsdesk
Independence Mall West
Philadelphia, Pennsylvania 19106
215-351-1200

KYW Channel 3, Newsdesk
Independence Mall East
Fifth and Market Streets
Philadelphia, Pennsylvania 19106
215-238-4700

WPVI Channel 6, Newsdesk
4100 Cityline Avenue
Philadelphia, Pennsylvania 19131
215-878-9700

PUBLIC MEETING LOCATION

Monroe Gerhart
William Penn High School
713 East Basin Road
New Castle, Delaware 19706
302-323-2724
Seating Capacity - 500
Advanced Notice - 1 week

INFORMATION REPOSITORY

Chris Paolini
Wilmington Public Library
P.O. Box 2303
Wilmington, Delaware 19899
302-571-7416

B

AR301395

APPENDIX B

SAMPLE LOG SHEETS

AR301396

Gannett Fleming
ENGINEERS AND PLANNERS

SAMPLE LOG SHEET

- ☐ Monitoring Well
- ☐ Domestic Well
- ☒ Other: RECOVERY WELL

Case #: 12178

By:

Project Site Name: ARMY CREEK LANDFILL

Project Site Number: 37-10-3634

Gannett Fleming Source No.: RW-01

Source Location: AC-01

Total Well Depth:	Purge Data				
Static Water Level:	Volume	pH	SC	Temp	
One Casing Volume:					
Start Purge(hrs):					
End Purge Time(hrs):					
Total Purge Time(min):					
Total Amt.Purged(gal):					
Monitor Reading:					
Purge Method:					
Sample Method:					

Depth Sampled:	GRAB SAMPLE DATA			
Sample Date: 7/5/89	pH	SC (μmho)	Temp (C)	DO (mg/l)
Sample Time: 1608				
Sampled By: L. FIORUCCI / C. YEN	6.68	125	18	4.85 ppm

Signature(s): [signature]

Observations/Notes:

Type of Sample

- Low Concentration ☒
- High Concentration ☐
- Grab ☒
- Composite ☐
- Grab-Composite ☐

Analysis	Preservative		Organic	Inorganic
S^{2-}	$Zn(OAC)_2$, NaOH	Traffic Report #	CCE45	MCBA 00, MCBA 01
NH_3, TKN	H_2SO_4	Tag #	3-1058501, 3-1058502, 3-1058503, 3-1058504, 3-1058505	3-1058506, 3-1058507, 3-1058508
P	$HgCl_2$	Air Bill #	639536295	639536306
NO_3^-, NO_2^-	H_2SO_4	Date Shipped	7/6/89	7/6/89
SO_4^{2-}, Cl^-		Time Shipped	1730	1730
ALK, ACID		Lab	GULF	SILVER
TSS, TDS		Volume	VOA: 40 ml BNA, PEST, PCB: 80 oz	1-L
TOC	H_2SO_4			

Gannett Fleming ENGINEERS AND PLANNERS

SAMPLE LOG SHEET

PAGE 1 OF 1

- ☐ Monitoring Well
- ☐ Domestic Well
- ☒ Other: RECOVERY WELL

Case #: 12178

By:

Project Site Name: ARMY CREEK LANDFILL

Project Site Number: 37-10-3L34

Gannett Fleming Source No.: RW-01A

Source Location: AC-01A

Total Well Depth:	Purge Data				
Static Water Level:	Volume	pH	SC	Temp	
One Casing Volume:					
Start Purge(hrs):					
End Purge Time(hrs):					
Total Purge Time(min):					
Total Amt.Purged(gal):					
Monitor Reading:					
Purge Method:					
Sample Method:					

Depth Sampled:	GRAB SAMPLE DATA			
Sample Date: 7/5/89	pH	SC (µmho)	Temp (C)	DO (mg/l)
Sample Time: 1608				
Sampled By: L. FIORUCCI/C. YEN	6.68	125	18	4.85 ppm
Signature(s): [signature]	Observations/Notes:			

Type of Sample

- Low Concentration ☒
- High Concentration ☐
- Grab ☒
- Composite ☐
- Grab-Composite ☐

Observations/Notes: Field Duplicate Sample

Analysis	Preservative
S^{2-}	$Zn(OAc)_2$, NaOH
NH_3, TKN	H_2SO_4
P	$HgCl_2$
NO_3^-, NO_2^-	H_2SO_4
SO_4^{2-}, Cl^-	
ALK, ACID	
TSS, TDS	
TOC	H_2SO_4

	Organic	Inorganic
Traffic Report #	CCE 46	MCBA 02, MCBA 03
Tag #	3-1058509, 3-1058510, 3-1058511, 3-1058512, 3-1058513	3-1058514, 3-1058615, 3-1058516
Air Bill #	639536295	639536306
Date Shipped	7/6/89	7/6/89
Time Shipped	1730	1730
Lab	GULF	SILVER
Volume	VOA: 40 ml BNA, PEST, PCB: 80 oz.	1-L

AR301398

Gannett Fleming
ENGINEERS AND PLANNERS

SAMPLE LOG SHEET

☐ Monitoring Well
☐ Domestic Well
☒ Other: RECOVERY WELL

Case #: 12178

By:

Project Site Name: ARMY CREEK LANDFILL

Project Site Number: 37-10-3L34

Gannett Fleming Source No.: RW-01B

Source Location: AC-01B

Total Well Depth:	Purge Data				
Static Water Level:	Volume	pH	SC	Temp	
One Casing Volume:					
Start Purge(hrs):					
End Purge Time(hrs):					
Total Purge Time(min):					
Total Amt.Purged(gal):					
Monitor Reading:					
Purge Method:					
Sample Method:					

Depth Sampled:	GRAB SAMPLE DATA			
Sample Date: 7/5/89	pH	SC (μmho)	Temp (C)	DO (mg/l)
Sample Time: 1608				
Sampled By: L. FIORUCCI/C. YEN				
Signature(s): [signature]	Observations/Notes:			

Field Blank

Type of Sample

- Low Concentration ☒
- High Concentration ☐
- Grab ☒
- Composite ☐
- Grab-Composite ☐

Analysis	Preservative		Organic	Inorganic
S^{2-}	$Zn(OAc)_2$, NaOH	Traffic Report #	CCE 47	MCBA 04
NH_3, TKN	H_2SO_4	Tag #	3-1058519, 3-1058518, 3-1058517, 3-1058520, 3-1058521	3-1058522, 3-1058523
P	HgCl	Air Bill #	639536295	639536306
NO_3^-, NO_2^-	H_2SO_4	Date Shipped	7/6/89	7/6/89
SO_4^{2-}, Cl^-		Time Shipped	1730	1730
ALK, ACID		Lab	GULF	SILVER
TSS, TDS		Volume	VOA 40ml BNA, PEST, PCB: 80 oz.	1-L
TOC	H_2SO_4			

AR301399

Gannett Fleming ENGINEERS AND PLANNERS

SAMPLE LOG SHEET

PAGE 1 OF 1

☐ Monitoring Well
☐ Domestic Well
☒ Other: RECOVERY WELL

Case #: 12178

By:

Project Site Name: ARMY CREEK LANDFILL
Project Site Number: 37-10-3L34

Gannett Fleming Source No.: RW-01C
Source Location: AC-01C

	Purge Data				
Total Well Depth:	Volume	pH	SC	Temp	
Static Water Level:					
One Casing Volume:					
Start Purge(hrs):					
End Purge Time(hrs):					
Total Purge Time(min):					
Total Amt.Purged(gal):					
Monitor Reading:					
Purge Method:					
Sample Method:					

	GRAB SAMPLE DATA			
Depth Sampled:				
Sample Date: 7/5/89	pH	SC (µmho)	Temp (C)	DO (mg/l)
Sample Time: 1608		-		
Sampled By: L. FIORUCCI/C. YEN				
Signature(s): [signature]	Observations/Notes:			

Rinsate Blank

Type of Sample

- Low Concentration ☒
- High Concentration ☐
- Grab ☒
- Composite ☐
- Grab-Composite ☐

Analysis	Preservative		Organic	Inorganic
		Traffic Report #		MCBA 05
		Tag #		3-1058528
		Air Bill #		639 536306
		Date Shipped		7/6/89
		Time Shipped		1730
		Lab		SILVER
		Volume		1-L

AR301400

Gannett Fleming
ENGINEERS AND PLANNERS

SAMPLE LOG SHEET

☐ Monitoring Well
☐ Domestic Well
☒ Other: RECOVERY WELL

Case #: 12178
By:

Project Site Name: ARMY CREEK LANDFILL
Project Site Number: 37-10-3L34
Gannett Fleming Source No.: RW-01D
Source Location: AC-01D

	Purge Data				
	Volume	pH	SC	Temp	
Total Well Depth:					
Static Water Level:					
One Casing Volume:					
Start Purge(hrs):					
End Purge Time(hrs):					
Total Purge Time(min):					
Total Amt.Purged(gal):					
Monitor Reading:					
Purge Method:					
Sample Method:					

	GRAB SAMPLE DATA			
Depth Sampled:	pH	SC (μmho)	Temp (C)	DO (mg/l)
Sample Date: 7/5/89				
Sample Time: 1608				
Sampled By: L. FIORUCCI /C. YEN				

Signature(s): [signature]

Observations/Notes:

Trip Blank

Type of Sample

- Low Concentration ☒
- High Concentration ☐
- Grab ☒
- Composite ☐
- Grab-Composite ☐

Analysis	Preservative		Organic	Inorganic
		Traffic Report #	CCE 48	
		Tag #	3-1058524, 3-1058525	
		Air Bill #	639536295	
		Date Shipped	7/6/89	
		Time Shipped	1730	
		Lab	GULF	
		Volume	40-ml	

AR301401

Gannett Fleming ENGINEERS AND PLANNERS

SAMPLE LOG SHEET

PAGE 1 OF 1

☐ Monitoring Well
☐ Domestic Well
☒ Other: RECOVERY WELL

Case #: 12178

By:

Project Site Name: ARMY CREEK LANDFILL   Project Site Number: 37-10-3L34

Gannett Fleming Source No.: RW-10   Source Location: AC-10

Total Well Depth:	Purge Data				
Static Water Level:	Volume	pH	SC	Temp	
One Casing Volume:					
Start Purge(hrs):					
End Purge Time(hrs):					
Total Purge Time(min):					
Total Amt.Purged(gal):					
Monitor Reading:					
Purge Method:					
Sample Method:					
Depth Sampled:	GRAB SAMPLE DATA				
Sample Date: 7/6/89	pH	SC (μmho)	Temp (C)	DO (mg/l)	
Sample Time: 1047		155	16.7	3.4 ppm	
Sampled By: C.Y. YEN					
Signature(s): [signature]	Observations/Notes: NOTE: pH NOT MEASURED				

Type of Sample

- Low Concentration ☒
- High Concentration ☐
- Grab ☒
- Composite ☐
- Grab-Composite ☐

Analysis	Preservative
S^{2-}	$Zn(OAc)_2$, NaOH
NH_3, TKN	H_2SO_4
P	$HgCl_2$
NO_3^-, NO_2^-	H_2SO_4
SO_4^{2-}, Cl^-	
ALK, ACID	
TSS, TDS	
TOC	H_2SO_4

	Organic	Inorganic
Traffic Report #	CCE 49	MCBA 06, MCBA 07
Tag #	3-1058529, 3-1058530, 3-1058531, 3-1058532, 3-1058533	3-1058534, 3-1058535, 3-1058565
Air Bill #	639536295	639536306
Date Shipped	7/6/89	7/6/89
Time Shipped	1730	1730
Lab	GULF	SILVER
Volume	VOA - 40 ml BNA, PEST, PCB - 80 oz.	1-L

AR301402

Gannett Fleming
ENGINEERS AND PLANNERS

SAMPLE LOG SHEET

☐ Monitoring Well
☐ Domestic Well
☒ Other: RECOVERY WELL

Case #: 12178

By:

Project Site Name: ARMY CREEK LANDFILL

Project Site Number: 37-10-3L34

Gannett Fleming Source No.: RW-11

Source Location: AC-11

Total Well Depth:	**Purge Data**				
Static Water Level:	Volume	pH	SC	Temp	
One Casing Volume:					
Start Purge(hrs):					
End Purge Time(hrs):					
Total Purge Time(min):					
Total Amt.Purged(gal):					
Monitor Reading:					
Purge Method:					
Sample Method:					
Depth Sampled:	**GRAB SAMPLE DATA**				
Sample Date: 7/6/89	pH	SC (μmho)	Temp (C)	DO (mg/l)	
Sample Time: 1047		168	18.5	4.2	
Sampled By: C.Y. YEN					
Signature(s): [signature]	**Observations/Notes:** NOTE: pH NOT MEASURED				

Type of Sample

- Low Concentration ☒
- High Concentration ☐
- Grab ☒
- Composite ☐
- Grab-Composite ☐

Analysis	Preservative
S^{2-}	$Zn(OAc)_2$, NaOH
NH_3, TKN	H_2SO_4
P	$HgCl_2$
NO_3^-, NO_2^-	H_2SO_4
$SO_4^=$, Cl^-	
ALK, ACID	
TSS, TDS	
TOC	H_2SO_4

	Organic	Inorganic
Traffic Report #	CCE 50	MCBA08, MCBA09
Tag #	3-1058557, 3-1058558, 3-1058559, 3-1058560, 3-1058561	3-1058563, 3-1058562, 3-1058564
Air Bill #	639536295	639536306
Date Shipped	7/6/89	7/6/89
Time Shipped	1730	1730
Lab	GULF	SILVER
Volume	VOA: 40-ml BNA, PEST, PCB: 80oz.	1-L

Gannett Fleming
ENGINEERS AND PLANNERS

SAMPLE LOG SHEET

PAGE 1 OF 3

- ☐ Monitoring Well
- ☐ Domestic Well
- ☒ Other: RECOVERY WELL

Case #: 12178

By: ______

Project Site Name: ARMY CREEK LANDFILL

Project Site Number: 37-10-3L34

Gannett Fleming Source No.: RW-12

Source Location: AC-12

	Purge Data				
Total Well Depth:					
Static Water Level:	Volume	pH	SC	Temp	
One Casing Volume:					
Start Purge(hrs):					
End Purge Time(hrs):					
Total Purge Time(min):					
Total Amt.Purged(gal):					
Monitor Reading:					
Purge Method:					
Sample Method:					

	GRAB SAMPLE DATA			
Depth Sampled:				
Sample Date: 7/5/89	pH	SC (μmho)	Temp (C)	DO (mg/l)
Sample Time: 1505	6.76	320	16	4.3 ppm
Sampled By: E. OLDS				

Signature(s): Emily Olds

Observations/Notes:

Type of Sample

- Low Concentration ☒
- High Concentration ☐
- Grab ☒
- Composite ☐
- Grab-Composite ☐

Analysis	Preservative
S^{2-}	$Zn(OAc)_2$, NaOH
NH_3, TKN	H_2SO_4
P	$HgCl_2$
NO_3^-, NO_2^-	H_2SO_4
SO_4^{2-}, Cl^-	
ALK, ACID	
TSS, TDS	
TOC	H_2SO_4

	Organic	Inorganic
Traffic Report #	CCE51	MCBA 10, MCBA 11
Tag #	3-1058547, 3-1058548, 3-1058549, 3-1058550	3-1058551, 3-1058552, 3-1058553, 3-1058554, 3-1058555, 3-1058556
Air Bill #	639536295	639536306
Date Shipped	7/6/89	7/6/89
Time Shipped	1730	1730
Lab	GULF	SILVER
Volume	80 oz	1-L

AR301404

Gannett Fleming
ENGINEERS AND PLANNERS

SAMPLE LOG SHEET

☐ Monitoring Well
☐ Domestic Well
☒ Other: RECOVERY WELL

Case #: 12178

By:

Project Site Name: ARMY CREEK LANDFILL

Project Site Number: 37-10-3634

Gannett Fleming Source No.: RW-12

Source Location: AC-12

Total Well Depth:
Static Water Level:
One Casing Volume:
Start Purge(hrs):
End Purge Time(hrs):
Total Purge Time(min):
Total Amt.Purged(gal):
Monitor Reading:
Purge Method:
Sample Method:
Depth Sampled:
Sample Date: 7/5/89
Sample Time: 1505
Sampled By: E. OLDS
Signature(s): Emily Olds

Purge Data

Volume	pH	SC	Temp	

GRAB SAMPLE DATA

pH	SC (μmho)	Temp (C)	DO (mg/L)
6.76	320	16	4.3 ppm

Observations/Notes:

Type of Sample

- Low Concentration ☒
- High Concentration ☐
- Grab ☒
- Composite ☐
- Grab-Composite ☐

Analysis	Preservative
S^{2-}	$Zn(OAc)_2$, NaOH
NH_3, TKN	H_2SO_4
P	$HgCl_2$
NO_3^-, NO_2^-	H_2SO_4
SO_4^{2-}, Cl^-	
ALK, ACID	
TSS, TDS	
TOC	H_2SO_4

	Organic	Inorganic
Traffic Report #	CCE51	MCBA 10, MCBA 11
Tag #	3-1058547, 3-1058548, 3-1058549, 3-1058550	3-1058551, 3-1058552, 3-1058553, 3-1058554, 3-1058555, 3-1058556
Air Bill #	639536295	639536306
Date Shipped	7/6/89	7/6/89
Time Shipped	1730	1730
Lab	GULF	SILVER
Volume	80 oz	1-L

AR301404

Gannett Fleming
ENGINEERS AND PLANNERS

SAMPLE LOG SHEET

☐ Monitoring Well
☐ Domestic Well
☒ Other: RECOVERY WELL

Case #: 12178
By:

Project Site Name: ARMY CREEK LANDFILL
Project Site Number: 37-10-3634
Gannett Fleming Source No.: RW-12
Source Location: AC-12

	Purge Data				
Total Well Depth:					
Static Water Level:	Volume	pH	SC	Temp	
One Casing Volume:					
Start Purge(hrs):					
End Purge Time(hrs):					
Total Purge Time(min):					
Total Amt. Purged(gal):					
Monitor Reading:					
Purge Method:					
Sample Method:					

	GRAB SAMPLE DATA			
Depth Sampled:				
Sample Date: 7/5/89	pH	SC (μmho)	Temp (C)	DO (mg/l)
Sample Time: 1505	6.76	820	16	4.3 ppm
Sampled By: E. OLDS				

Signature(s): Emily Olds

Observations/Notes:
~~field duplicate~~ EJO
Extra Volume for DO QC

Type of Sample
- Low Concentration ☒
- High Concentration ☐
- Grab ☒
- Composite ☐
- Grab-Composite ☐

Analysis	Preservative		Organic	Inorganic
		Traffic Report #	CCE 51	
		Tag #	3-1058536, 3-1058537, 3-1058538, 3-1058539, 3-1058540, 3-1058541	
		Air Bill #	689536295	
		Date Shipped	7/6/89	
		Time Shipped	1730	
		Lab	GULF	
		Volume	40 ml	

AR301405

Gannett Fleming
ENGINEERS AND PLANNERS

SAMPLE LOG SHEET

PAGE 3 OF 3

- ☐ Monitoring Well
- ☐ Domestic Well
- ☒ Other: RECOVERY WELL

Case #: 12178

By:

Project Site Name: ARMY CREEK LANDFILL
Project Site Number: 37-10-3634

Gannett Fleming Source No.: RW-12
Source Location: AC-12

	Purge Data				
Total Well Depth:	Volume	pH	SC	Temp	
Static Water Level:					
One Casing Volume:					
Start Purge(hrs):					
End Purge Time(hrs):					
Total Purge Time(min):					
Total Amt.Purged(gal):					
Monitor Reading:					
Purge Method:					
Sample Method:					

	GRAB SAMPLE DATA			
Depth Sampled:				
Sample Date: 7/5/89	pH	SC (μmho)	Temp (C)	DO (mg/l)
Sample Time: 1505	6.76	320	16	14.3 ppm
Sampled By: E OLDS				

Signature(s): Emily Olds

Observations/Notes:
~~Field duplicate~~ 650
Extra Volume for DO QC

Type of Sample
- Low Concentration ☐
- High Concentration ☐
- Grab ☐
- Composite ☐
- Grab-Composite ☐

Analysis	Preservative		Organic	Inorganic
		Traffic Report #	CCE 51	
		Tag #	3-1058542, 3-1058543, 3-1058544, 3-1058545, 3-1058546	
		Air Bill #	639536295	
		Date Shipped	7/6/89	
		Time Shipped	1730	
		Lab	GULF	
		Volume	VOA: 40 ml BNA, PEST, PCB: 80 oz.	

AR301406

Gannett Fleming
ENGINEERS AND PLANNERS

SAMPLE LOG SHEET

PAGE 1 OF 1

☐ Monitoring Well
☐ Domestic Well
☒ Other: RECOVERY WELL

Case #: 12178
By:

Project Site Name: ARMY CREEK LANDFILL
Project Site Number: 37-10-3L34
Gannett Fleming Source No.: RW-13
Source Location: AC-13

	Purge Data				
Total Well Depth:					
Static Water Level:	Volume	pH	SC	Temp	
One Casing Volume:					
Start Purge(hrs):					
End Purge Time(hrs):					
Total Purge Time(min):					
Total Amt.Purged(gal):					
Monitor Reading:					
Purge Method:					
Sample Method:					

	GRAB SAMPLE DATA			
Depth Sampled:				
Sample Date: 7/6/89	pH	SC (μmho)	Temp (C)	DO (mg/l)
Sample Time: 1000		130	15.2	3.5 ppm
Sampled By: C.Y. YEN				

Signature(s): [signature]

Observations/Notes:
NOTE: pH NOT MEASURED

Type of Sample
- Low Concentration ☒
- High Concentration ☐
- Grab ☒
- Composite ☐
- Grab-Composite ☐

Analysis	Preservative		Organic	Inorganic
S^{2-}	$Zn(OAc)_2$, NaOH	Traffic Report #	CCE 52	MCBA 12, MCBA 13
NH_3, TKN	H_2SO_4	Tag #	3-1058566, 3-1058567, 3-1058568, 3-1058569, 3-1058570	3-1058571, 3-1058572, 3-1058573
P	$HgCl_2$	Air Bill #	639536295	639536306
NO_3^-, NO_2^-	H_2SO_4	Date Shipped	7/6/89	7/6/89
SO_4^{2-}, Cl^-		Time Shipped	1730	1730
ALK, ACID		Lab	GULF	SILVER
TSS, TDS		Volume	VOA 40ml BNA, PEST, PCB: 80oz	1-L
TOC	H_2SO_4			

AR301407

Gannett Fleming
ENGINEERS AND PLANNERS

SAMPLE LOG SHEET

- ☐ Monitoring Well
- ☐ Domestic Well
- ☒ Other: RECOVERY WELL

Case #: 12178
By:

Project Site Name: ARMY CREEK LANDFILL
Project Site Number: 37-10-3L34
Gannett Fleming Source No.: RW-27
Source Location: AC-27

Total Well Depth:	
Static Water Level:	
One Casing Volume:	
Start Purge(hrs):	
End Purge Time(hrs):	
Total Purge Time(min):	
Total Amt. Purged(gal):	
Monitor Reading:	
Purge Method:	
Sample Method:	
Depth Sampled:	
Sample Date:	7/6/89
Sample Time:	1130
Sampled By:	E. OLDS
Signature(s):	Emily Olds

Purge Data

Volume	pH	SC	Temp	

GRAB SAMPLE DATA

pH	SC (µmho)	Temp (°C)	DO (mg/l)
	255	15	2.2 ppm

Observations/Notes:

NOTE: pH NOT MEASURED

Type of Sample

- Low Concentration ☒
- High Concentration ☐
- Grab ☒
- Composite ☐
- Grab-Composite ☐

Analysis	Preservative
S^{2-}	$Zn(OAc)_2$, NaOH
NH_3, TKN	H_2SO_4
P	$HgCl_2$
NO_3^-, NO_2^-	H_2SO_4
SO_4^{2-}, Cl^-	
ALK, ACID	
TSS, TDS	
TOC	H_2SO_4

	Organic	Inorganic
Traffic Report #	CCE 53	MCBA 14, MCBA 15
Tag #	3-1058574, 3-1058575, 3-1058576, 3-1058577, 3-1058578	3-1058579, 3-1058580, 3-1058581
Air Bill #	639534295	639536306
Date Shipped	7/6/89	7/6/89
Time Shipped	1730	1730
Lab	GULF	SILVER
Volume	VOA: 40-ml BNA, PEST, PCB: 80-02.	1-L

AR301408

Gannett Fleming
ENGINEERS AND PLANNERS

SAMPLE LOG SHEET

- ☐ Monitoring Well
- ☐ Domestic Well
- ☒ Other: RECOVERY WELL

Case #: 12178

By:

Project Site Name: ARMY CREEK LANDFILL Project Site Number: 37-10-3634

Gannett Fleming Source No.: RW-28 Source Location: AC-28

Total Well Depth:
Static Water Level:
One Casing Volume:
Start Purge(hrs):
End Purge Time(hrs):
Total Purge Time(min):
Total Amt. Purged(gal):
Monitor Reading:
Purge Method:
Sample Method:
Depth Sampled:
Sample Date: 7/5/89
Sample Time: 1715
Sampled By: E. OLDS
Signature(s): Emily Olds

Purge Data

Volume	pH	SC	Temp	

GRAB SAMPLE DATA

pH	SC (µmho)	Temp (C)	DO (mg/l)
6.98	360	16.5	2.4 ppm

Observations/Notes:

Type of Sample

- Low Concentration ☒
- High Concentration ☐
- Grab ☒
- Composite ☐
- Grab-Composite ☐

Analysis	Preservative
S^{2-}	$Zn(OAc)_2$, NaOH
NH_3, TKN	H_2SO_4
P	$HgCl_2$
NO_3^-, NO_2^-	H_2SO_4
SO_4^{2-}, Cl^-	
ALK, ACID	
TSS, TDS	
TOC	H_2SO_4

	Organic	Inorganic
Traffic Report #	CCE 54	MCBA 16, MCBA 17
Tag #	3-1058583, 3-1058582, [illegible], 3-1058584, 3-1058585	3-1058588, 3-1058587, 3-1058586
Air Bill #	639536295	639536306
Date Shipped	7/6/89	7/6/89
Time Shipped	1730	1730
Lab	GULF	SILVER
Volume	VOA: 40 ml BNA, PEST, PCB: 80 oz.	1 L

AR301409

Gannett Fleming
ENGINEERS AND PLANNERS

SAMPLE LOG SHEET

PAGE 1 OF 1

☐ Monitoring Well
☐ Domestic Well
☒ Other: RECOVERY WELL

Case #: 12178

By:

Project Site Name: ARMY CREEK LANDFILL

Project Site Number: 37-10-3L34

Gannett Fleming Source No.: RW 29

Source Location: AC-29

Total Well Depth:	Purge Data				
Static Water Level:	Volume	pH	SC	Temp	
One Casing Volume:					
Start Purge(hrs):					
End Purge Time(hrs):					
Total Purge Time(min):					
Total Amt. Purged(gal):					
Monitor Reading:					
Purge Method:					
Sample Method:					
Depth Sampled:	GRAB SAMPLE DATA				
Sample Date: 7/5/89	pH	SC (μmho)	Temp (C)	DO (mg/l)	
Sample Time: 1607	6.97	750	16.8	1.5 ppm	
Sampled By: C.Y. YEN					

Signature(s): [signature]

Observations/Notes:
The sulfide samples after preservation turned greenish blue, indicating probably low DO level and the presence of ferrous ion (Fe^{2+}).

Type of Sample
- Low Concentration ☒
- High Concentration ☐
- Grab ☒
- Composite ☐
- Grab-Composite ☐

Analysis	Preservative
S^{2-}	$Zn(OAc)_2$, NaOH
NH_3, TKN	H_2SO_4
P	$HgCl_2$
NO_3^-, NO_2^-	H_2SO_4
SO_4^{2-}, Cl^-	
ALK, ACID	
TSS, TDS	
TOC	H_2SO_4

	Organic	Inorganic
Traffic Report #	CCE 55	MCBA 18, MCBA 19
Tag #	3-1058590, 3-1058591, 3-1058592, 3-1058593, 3-1058594	3-1058595, 3-1058596, 3-1058597
Air Bill #	639536295	639536306
Date Shipped	7/6/89	7/6/89
Time Shipped	1730	1730
Lab	GULF	SILVER
Volume	VOA: 40 ml BNA, PEST, PCB: 80 oz	1-L

AR301410

Gannett Fleming
ENGINEERS AND PLANNERS

SAMPLE LOG SHEET

PAGE 1 OF 1

☐ Monitoring Well
☐ Domestic Well
☒ Other: RECOVERY WELL

Case #: 12178

By:

Project Site Name: ARMY CREEK LANDFILL

Project Site Number: 37-10-3L34

Gannett Fleming Source No.: RW-31

Source Location: AC-31

Total Well Depth:	Purge Data				
Static Water Level:	Volume	pH	SC	Temp	
One Casing Volume:					
Start Purge(hrs):					
End Purge Time(hrs):					
Total Purge Time(min):					
Total Amt.Purged(gal):					
Monitor Reading:					
Purge Method:					
Sample Method:					
Depth Sampled:	GRAB SAMPLE DATA				
Sample Date: 7/6/89	pH	SC (µmho)	Temp (C)	DO (mg/l)	
Sample Time: 1340	6.62	197	15.7	3.1 ppm	
Sampled By: E. OLDS					
Signature(s): Emily Olds	Observations/Notes:				

Type of Sample

- Low Concentration ☒
- High Concentration ☐
- Grab ☒
- Composite ☐
- Grab-Composite ☐

Analysis	Preservative		Organic	Inorganic
S^{2-}	$Zn(OAc)_2$, NaOH	Traffic Report #	CCE 56	MCBA 20, MCBA 21
NH_3, TKN	H_2SO_4	Tag #	3-1058601, 3-1058602	3-1058603, 3-1058604, 3-1058605
P	$HgCl_2$	Air Bill #	639536295	639536306
NO_3^-, NO_2^-	H_2SO_4	Date Shipped	7/6/89	7/6/89
SO_4^{2-}, Cl^-		Time Shipped	1730	1730
ALK, ACID		Lab	GULF	SILVER
TSS, TDS		Volume	80 oz	1 L
TOC	H_2SO_4			

AR301411

Gannett Fleming ENGINEERS AND PLANNERS

SAMPLE LOG SHEET

PAGE 1 OF 1

☐ Monitoring Well
☐ Domestic Well
☒ Other: RECOVERY WELL

Case #: 12178

By:

Project Site Name: ARMY CREEK LANDFILL   Project Site Number: 37-10-3634

Gannett Fleming Source No.: RW-31D   Source Location: AC-31D

Total Well Depth:	Purge Data				
Static Water Level:	Volume	pH	SC	Temp	
One Casing Volume:					
Start Purge(hrs):					
End Purge Time(hrs):					
Total Purge Time(min):					
Total Amt.Purged(gal):					
Monitor Reading:					
Purge Method:					
Sample Method:					
Depth Sampled:	GRAB SAMPLE DATA				
Sample Date: 7/6/89	pH	SC (μmho)	Temp (C)	DO (mg/l)	
Sample Time: 1340					
Sampled By: E. OLDS					
Signature(s): Emily Olds	Observations/Notes: Trip Blank				

Type of Sample

- Low Concentration ☒
- High Concentration ☐
- Grab ☒
- Composite ☐
- Grab-Composite ☐

Analysis	Preservative		Organic	Inorganic
		Traffic Report #	CCE 57	
		Tag #	3-1058526, 2 1058527	
		Air Bill #	639536295	
		Date Shipped	7/6/89	
		Time Shipped	1730	
		Lab	GULF	
		Volume	40 ml	

C

AR301413

APPENDIX C

ANALYTICAL RESULTS FOR GROUNDWATER RECOVERY WELL DISCHARGES

DATA SUMMARY FORM: V O L A T I L E S 1

WATER SAMPLES
(ug/L)

Site Name: ARMY CREEK LANDFILL

Case #: 12178 Sampling Date(s): 7/05/89 - 7/06/89

To calculate sample quantitation limit:
(CRQL * Dilution Factor)

CRQL	Sample No.	CCE45		CCE46		CCE47		CCE48		CCE49		CCE50		CCE51		CCE52		CCE53	
	Dilution Factor	1.0		1.0		1.0		1.0		1.0		1.0		1.0		1.0		1.0	
	Location	Field dup of CCE46 AC-01		Field dup of CCE45 AC-01A		Field Blank AC-01B		Trip Blank AC-01D		AC-10		AC-11		AC-12		AC-13		AC-27	
	COMPOUND																		
10	Chloromethane										UJ		UJ		UJ		UJ		UJ
10	Bromomethane										UJ		UJ		UJ		UJ		UJ
10	*Vinyl Chloride																		
10	Chloroethane																		
5	*Methylene Chloride	6	B	7	B	6		7		5	B	7	B	6	B	23	B	22	B
10	Acetone																		
5	Carbon Disulfide																		
5	*1,1-Dichloroethene																		
5	1,1-Dichloroethane										UJ		UJ		UJ		UJ		UJ
5	*Total-1,2-Dichloroethene																		
5	Chloroform																		
5	*1,2-Dichloroethane									22								50	
10	*2-Butanone		R		R		R		R		R		R		R		R		R
5	*1,1,1-Trichloroethane										UJ		UJ		UJ		UJ		UJ
5	*Carbon Tetrachloride																		
10	Vinyl Acetate										UJ		UJ		UJ		UJ		UJ
5	Bromodichloromethane																		

CRDL = Contract Required Detection Limit *Action Level Exists SEE NARRATIVE FOR CODE DEFINITIONS

revised 12/88

AR301415

Tabbed by: JJY 8/3/89 Verified by: CY 8/08/89

DATA SUMMARY FORM: V O L A T I L E S 2

WATER SAMPLES
(ug/L)

Site Name: ARMY CREEK LANDFILL

Case #: 12178 Sampling Date(s): 7/05/89-7/06/89

To calculate sample quantitation limit:
(CRQL * Dilution Factor)

CRQL	COMPOUND	CCE45	CCE46	CCE47	CCE48	CCE49	CCE50	CCE51	CCE52	CCE53
	Dilution Factor	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	Location	Field dup of CCE46 AC-01	Field dup of CCE45 AC-01A	Field Blank AC-01B	Trip Blank AC-01D	AC-10	AC-11	AC-12	AC-13	AC-27
5	*1,2-Dichloropropane									
5	Cis-1,3-Dichloropropene									
5	Trichloroethene									
5	Dibromochloromethane									
5	1,1,2-Trichloroethane									
5	*Benzene							14	16	
5	Trans-1,3-Dichloropropene									
5	Bromoform									
10	4-Methyl-2-pentanone					UJ	UJ	UJ	UJ	UJ
10	2-Hexanone					UJ	UJ	UJ	UJ	UJ
5	*Tetrachloroethene						2 J			
5	1,1,2,2-Tetrachloroethane									
5	*Toluene								19	
5	*Chlorobenzene							7		3 J
5	*Ethylbenzene								4 J	
5	*Styrene									
5	*Total Xylenes								7	

CRDL = Contract Required Detection Limit *Action Level Exists SEE NARRATIVE FOR CODE DEFINITIONS

revised 12/88

AR301416

DATA SUMMARY FORM: B N A S 1

WATER SAMPLES
(ug/L)

...e Name: ARMY CREEK LANDFILL

...se #: 12178 Sampling Date: 7/05/89-7/06/89

To calculate sample quantitation limit:
(CRQL * Dilution Factor)

Sample_No.	CCE45	CCE46	CCE47	CCE48	CCE49	CCE50	CCE51	CCE52	CCE 53
Dilution_Factor	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Location	Field dup of CCE46 AC-01	Field dup of CCE45 AC-01A	Field Blank AC-01B	Trip Blank AC-01D	AC-10	AC-11	AC-12	AC-13	AC-27
COMPOUND									
Phenol				Q ↓					
bis(2-Chloroethyl)ether	18	16					11 !	10	5 J
2-Chlorophenol									
*1,3-Dichlorobenzene									
*1,4-Dichlorobenzene									
Benzyl Alcohol	UJ	UJ	UJ		UJ	UJ	UJ	UJ	UJ
1,2-Dichlorobenzene									
2-Methylphenol									
bis(2-Chloroisopropyl)ether									
4-Methylphenol									
N-Nitroso-di-n-propylamine									
Hexachloroethane									
Nitrobenzene									
Isophorone									
2-Nitrophenol									
2,4-Dimethylphenol									
Benzoic Acid	UJ	UJ	UJ		UJ	UJ	UJ	UJ	UJ
bis(2-Chloroethoxy)methane									
2,4-Dichlorophenol									
1,2,4-Trichlorobenzene									
Naphthalene									
4-Chloroaniline									

...QL = Contract_Required_Quantitation_Limit   * Action_Level_Exists   SEE_NARRATIVE_FOR_CODE_DEFINITIONS

DATA SUMMARY FORM: B N A S 2

WATER SAMPLES
(ug/L)

Site Name: ARMY CREEK LANDFILL

Case #: 12178 Sampling Date(s): 7/05/89-7/06/89

To calculate sample quantitation limit:
(CRQL * Dilution Factor)

	Sample No.	CCE45	CCE46	CCE47	CCE48	CCE49	CCE50	CCE51	CCE52	CCE53
	Dilution Factor	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	Location	Field dup of CCE46 AC-01	Field dup of CCE45 AC-01A	Field Blank AC-01B	Trip Blank AC-01D	AC-10	AC-11	AC-12	AC-13	AC-27
RQL	COMPOUND									
10	Hexachlorobutadiene				Q ↓					
10	4-Chloro-3-methylphenol									
10	2-Methylnaphthalene	UJ	UJ	UJ		UJ	UJ	UJ	UJ	UJ
10	Hexachlorocyclopentadiene									
10	2,4,6-Trichlorophenol									
50	2,4,5-Trichlorophenol									
10	2-Chloronaphthalene									
50	2-Nitroaniline									
10	Dimethylphthalate									
10	Acenaphthylene									
10	2,6-Dinitrotoluene									
50	3-Nitroaniline	UJ	UJ	UJ		UJ	UJ	UJ	UJ	UJ
10	Acenaphthene									
50	2,4-Dinitrophenol							UJ		UJ
50	4-Nitrophenol	UJ	UJ	UJ		UJ	UJ		UJ	
10	Dibenzofuran									
10	2,4-Dinitrotoluene									
10	Diethylphthalate									
10	4-Chlorophenyl-phenylether									
10	Fluorene									
50	4-Nitroaniline	UJ	UJ	UJ		UJ	UJ	UJ	UJ	UJ
50	4,6-Dinitro-2-methylphenol				↓					

CRDL = Contract Required Detection Limit *Action Level Exists SEE NARRATIVE FOR CODE DEFINITIONS

revised 12/88

DATA SUMMARY FORM: B N A S 3

Site Name: ARMY CREEK LANDFILL

Case #: 12178 Sampling Date(s): 07/05/89 - 7/06/89

WATER SAMPLES
(ug/L)

To calculate sample quantitation limit:
(CRQL * Dilution Factor)

CRDL	Sample No.	CCE45	CCE46	CCE47	CCE48	CCE49	CCE50	CCE51	CCE52	CCE53
	Dilution Factor	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	Location	Field dup of CCE46 AL-01	Field dup of CCE45 AL-01A	Field Blank AL-01B	Trip Blank AL-01D	AL-10	AL-11	AL-12	AL-13	AL-27
	COMPOUND									
10	N-Nitrosodiphenylamine				Q					
10	4-Bromophenyl-phenylether									
10	*Hexachlorobenzene									
50	*Pentachlorophenol									
10	Phenanthrene									
10	Anthracene									
10	Di-n-butylphthalate									
10	Fluoranthene									
10	Pyrene									
10	Butylbenzylphthalate									
20	3,3-Dichlorobenzidine	UJ	UJ	UJ		UJ	UJ	UJ	UJ	UJ
10	Benzo(a)anthracene									
10	Chrysene									
10	bis(2-Ethylhexyl)phthalate									
10	Di-n-octylphthalate									
10	Benzo(b)fluoranthene									
10	Benzo(k)fluoranthene							UJ		UJ
10	Benzo(a)pyrene									
10	Indeno(1,2,3-cd)pyrene									
10	Dibenz(a,h)anthracene									
10	Benzo(g,h,i)perylene									

CRDL = Contract Required Detection Limit *Action Level Exists SEE NARRATIVE FOR CODE DEFINITIONS

revised 12/88

AR301419

DATA SUMMARY FORM: PESTICIDES AND PCBS

WATER SAMPLES
(ug/L)

Site Name: ARMY CREEK LANDFILL

Case #: 12178 Sampling Date(s): 7/05/89-7/06/89

To calculate sample quantitation limit:
(CRQL * Dilution Factor)

CRQL	Sample No.	CCE45	CCE46	CCE47	CCE48	CCE49	CCE50	CCE51	CCE52	CCE53
	Dilution Factor	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	Location	Field dup of CCE46 AC-01	Field dup of CCE45 AC-01A	Field Blank AC-01B	Trip Blank AC-01D	AC-10	AC-11	AC-12	AC-13	AC-27
	COMPOUND									
0.05	alpha-BHC	UJ	UJ	UJ	Q	UJ	UJ	UJ	UJ	UJ
0.05	beta-BHC	UJ	UJ	UJ		UJ	UJ	UJ	UJ	UJ
0.05	delta-BHC	UJ	UJ	UJ		UJ	UJ	UJ	UJ	UJ
0.05	*Gamma-BHC (Lindane)								UJ	UJ
0.05	*Heptachlor								UJ	UJ
0.05	Aldrin								UJ	UJ
0.05	Heptachlor Epoxide								UJ	UJ
0.05	Endosulfan I								UJ	UJ
0.10	Dieldrin								UJ	UJ
0.10	4,4'-DDE	UJ	UJ	UJ		UJ	UJ	UJ	UJ	UJ
0.10	*Endrin									
0.10	Endosulfan II								UJ	UJ
0.10	4,4'-DDD									
0.10	Endosulfan Sulfate									
0.10	4,4'-DDT								UJ	UJ
0.5	*Methoxychlor									
0.10	Endrin ketone									
0.5	*Alpha-Chlordane									
0.5	*Gamma-Chlordane									
1.0	*Toxaphene									
0.5	*Aroclor-1016									
0.5	*Aroclor-1221									
0.5	*Aroclor-1232									
0.5	*Aroclor-1242									
0.5	*Aroclor-1248									
1.0	*Aroclor-1254									
1.0	*Aroclor-1260									

CRDL = Contract Required Detection Limit *Action Level Exists SEE NARRATIVE FOR CODE DEFINITIONS

revised 12/88

DATA SUMMARY FORM: V O L A T I L E S 1

WATER SAMPLES
(ug/L)

Site Name: ARMY CREEK LANDFILL

Case #: 12178 Sampling Date(s): 7/05/89

To calculate sample quantitation limit:
(CRQL * Dilution Factor)

RQL	COMPOUND	Sample No. CCE54		CCE55		CCE56		CCE57	
	Dilution Factor	1.0		1.0		1.0		1.0	
	Location	AC-28		AC-29		AC-31		Trip Blank AC-31D	
10	Chloromethane		UJ		UJ		UJ		UJ
10	Bromomethane		UJ		UJ		UJ		
10	*Vinyl Chloride								
10	Chloroethane								
5	*Methylene Chloride	22	B	19	B	8	B	7	J
10	Acetone								UJ
5	Carbon Disulfide								
5	*1,1-Dichloroethene								
5	1,1-Dichloroethane		UJ		UJ		UJ		
5	*Total-1,2-Dichloroethene								
5	Chloroform	6							
5	*1,2-Dichloroethane								
10	*2-Butanone		R		R		R		R
5	*1,1,1-Trichloroethane		UJ		UJ		UJ		
5	*Carbon Tetrachloride								
10	Vinyl Acetate		UJ		UJ		UJ		UJ
5	Bromodichloromethane								

CRDL = Contract Required Detection Limit *Action Level Exists SEE NARRATIVE FOR CODE DEFINITIONS

revised 12/88

AR301421

DATA SUMMARY FORM: V O L A T I L E S 2

WATER SAMPLES
(ug/L)

Site Name: ARMY CREEK LANDFILL

Case #: 12178 Sampling Date(s): 7/05/89

To calculate sample quantitation limit:
(CRQL * Dilution Factor)

RQL	Sample No.	CCE54		CCE55		CCE56		CCE57	
	Dilution Factor	1.0		1.0		1.0		1.0	
	Location	AC-28		AC-29		AC-31		Trip Blank AC-31D	
	COMPOUND								
5	*1,2-Dichloropropane								
5	Cis-1,3-Dichloropropene								
5	Trichloroethene	2	J						
5	Dibromochloromethane								
5	1,1,2-Trichloroethane								
5	*Benzene	18		14					
5	Trans-1,3-Dichloropropene								
5	Bromoform								
10	4-Methyl-2-pentanone		UJ		UJ		UJ		
10	2-Hexanone		UJ		UJ		UJ		
5	*Tetrachloroethene								UJ
5	1,1,2,2-Tetrachloroethane								
5	*Toluene								
5	*Chlorobenzene	18							
5	*Ethylbenzene			4	J				
5	*Styrene								
5	*Total Xylenes			10					

CRDL = Contract Required Detection Limit *Action Level Exists SEE NARRATIVE FOR CODE DEFINITIONS

revised 12/88

AR301422

DATA SUMMARY FORM: B N A S 1

WATER SAMPLES
(ug/L)

Site Name: ARMY CREEK LANDFILL

Case #: 12178 Sampling Date(s): 7/05/89

To calculate sample quantitation limit:
(CRDL * Dilution Factor)

CRDL	Sample No.	CCE54		CCE55		CCE56		CCE57	
	Dilution Factor	1.0		1.0		1.0		1.0	
	Location	AL-28		AL-29		AL-31		Trip Blank AL-31D	
	COMPOUND								
10	Phenol						R		Q
10	bis(2-Chloroethyl)ether	21		17		14			
10	2-Chlorophenol						R		
10	*1,3-Dichlorobenzene								
10	*1,4-Dichlorobenzene			6	J				
10	Benzyl Alcohol		UJ		UJ		R		
10	1,2-Dichlorobenzene								
10	2-Methylphenol						R		
10	bis(2-Chloroisopropyl)ether								
10	4-Methylphenol						R		
10	N-Nitroso-di-n-propylamine								
10	Hexachloroethane								
10	Nitrobenzene								
10	Isophorone								
10	2-Nitrophenol						R		
10	2,4-Dimethylphenol						R		
50	Benzoic Acid		UJ		UJ		R		
10	bis(2-Chloroethoxy)methane								
10	2,4-Dichlorophenol						R		
10	1,2,4-Trichlorobenzene								
10	Naphthalene								
10	4-Chloroaniline								

CRDL = Contract Required Detection Limit *Action Level Exists SEE NARRATIVE FOR CODE DEFINITIONS

revised 12/88

AR301423

DATA SUMMARY FORM: B N A S 2

WATER SAMPLES
(ug/L)

Site Name: ARMY CREEK LANDFILL

Case #: 12178 Sampling Date(s): 7/05/89

To calculate sample quantitation limit:
(CRQL * Dilution Factor)

	Sample No.	CCE54	CCE55	CCE56	CCE57					
	Dilution Factor	1.0	1.0	1.0	1.0					
	Location	AC-28	AC-29	AC-31	Trip Blank AC-31D					
…OL	COMPOUND									
10	Hexachlorobutadiene				Q					
10	4-Chloro-3-methylphenol			R						
10	2-Methylnaphthalene	UJ	UJ	UJ						
10	Hexachlorocyclopentadiene									
10	2,4,6-Trichlorophenol			R						
50	2,4,5-Trichlorophenol			R						
.0	2-Chloronaphthalene									
50	2-Nitroaniline									
0	Dimethylphthalate									
0	Acenaphthylene									
0	2,6-Dinitrotoluene									
50	3-Nitroaniline	UJ	UJ	UJ						
0	Acenaphthene									
.0	2,4-Dinitrophenol			R						
0	4-Nitrophenol	UJ	UJ	R						
0	Dibenzofuran									
0	2,4-Dinitrotoluene									
0	Diethylphthalate									
0	4-Chlorophenyl-phenylether									
0	Fluorene									
.0	4-Nitroaniline	UJ	UJ	UJ						
.0	4,6-Dinitro-2-methylphenol			R						

CRDL = Contract Required Detection Limit *Action Level Exists SEE NARRATIVE FOR CODE DEFINITIONS

revised 12/88

DATA SUMMARY FORM: B N A S 3

WATER SAMPLES
(ug/L)

Site Name: ARMY CREEK LANDFILL

Case #: 12178 Sampling Date(s): 7/05/89

To calculate sample quantitation limit:
(CRDL * Dilution Factor)

CRDL	Sample No.	CCE 54		CCE 55		CCE 56		CCE 57											
	Dilution Factor	1.0		1.0		1.0		1.0											
	Location	AC-28		AC-29		AC-31		Trip Blank AC-31D											
	COMPOUND																		
10	N-Nitrosodiphenylamine								Q										
10	4-Bromophenyl-phenylether																		
10	*Hexachlorobenzene																		
50	*Pentachlorophenol						R												
10	Phenanthrene																		
10	Anthracene																		
10	Di-n-butylphthalate																		
10	Fluoranthene																		
10	Pyrene																		
10	Butylbenzylphthalate																		
20	3,3-Dichlorobenzidine		UJ		UJ		UJ												
10	Benzo(a)anthracene																		
10	Chrysene																		
10	bis(2-Ethylhexyl)phthalate			3	J														
10	Di-n-octylphthalate																		
10	Benzo(b)fluoranthene																		
10	Benzo(k)fluoranthene																		
10	Benzo(a)pyrene																		
10	Indeno(1,2,3-cd)pyrene																		
10	Dibenz(a,h)anthracene																		
10	Benzo(g,h,i)perylene																		

CRDL = Contract Required Detection Limit *Action Level Exists SEE NARRATIVE FOR CODE DEFINITIONS

revised 12/88

DATA SUMMARY FORM: PESTICIDES AND PCBS

WATER SAMPLES
(ug/L)

Site Name: ARMY CREEK LANDFILL

Case #: 12178 Sampling Date(s): 7/05/89

To calculate sample quantitation limit: (CRQL * Dilution Factor)

CRQL	COMPOUND	CCE 54	CCE 55	CCE-56	CCE 57					
	Dilution Factor	1.0	1.0	1.0	1.0					
	Location	AC-28	AC-29	AC-31	Trip Blank AC-31D					
0.05	alpha-BHC	UJ	UJ	UJ	R					
0.05	beta-BHC	UJ	UJ	UJ						
0.05	delta-BHC	UJ	UJ	UJ						
0.05	*Gamma-BHC (Lindane)	UJ	UJ	UJ						
0.05	*Heptachlor	UJ	UJ	UJ						
0.05	Aldrin	UJ	UJ	UJ						
0.05	Heptachlor Epoxide	UJ	UJ	UJ						
0.05	Endosulfan I	UJ	UJ	UJ						
0.10	Dieldrin	UJ	UJ	UJ						
0.10	4,4'-DDE	UJ	UJ	UJ						
0.10	*Endrin									
0.10	Endosulfan II	UJ	UJ	UJ						
0.10	4,4'-DDD									
0.10	Endosulfan Sulfate									
0.10	4,4'-DDT	UJ	UJ	UJ						
0.5	*Methoxychlor									
0.10	Endrin ketone									
0.5	*Alpha-Chlordane									
0.5	*Gamma-Chlordane									
1.0	*Toxaphene									
0.5	*Aroclor-1016									
0.5	*Aroclor-1221									
0.5	*Aroclor-1232									
0.5	*Aroclor-1242									
0.5	*Aroclor-1248									
1.0	*Aroclor-1254									
1.0	*Aroclor-1260									

CRDL = Contract Required Detection Limit *Action Level Exists SEE NARRATIVE FOR CODE DEFINITIONS

AR301426

Revised 12/88

Page 1 of 4

DATA SUMMARY FORM: TOTAL INORGANICS

Site Name: ARMY CREEK LANDFILL

Case #: 12178 Sampling Date(s): 7/5/89-7/6/89

WATER SAMPLES (ug/L)

+Due to dilution, sample quantitation limit is affected. See dilution table for specifics.

CRDL	Sample No.	MCBA00	MCBA02	MCBA04	MCBA06	MCBA08	MCBA10	MCBA12	MCBA14	MCBA16	MCBA18
	Dilution Factor	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	Location		DUP OF MCBA00	FIELD BLANK							
	ANALYTE	AC-01	AC-01A	AC-01B	AC-10	AC-11	AC-12	AC-13	AC-27	AC-28	AC-29
200	Aluminum							[22.2] B		[13.5] B	[32.]
60	Antimony										
10	*Arsenic									[2.7] K	
200	Barium	[80.8]	[80.9]		[122]	[147.]	[174.]	[74.5]	[189.]	278.	377.
5	Beryllium										
5	*Cadmium										
5000	Calcium	8740.	8760.		9260.	10000.	12200.	8870.	9330.	11900.	18800.
10	*Chromium										
50	Cobalt	[3.6] B	[5.1] B		[15.3] B	[7.1] B	[10.7] B	[13.4] B	[22.7]	[31.]	[36.9]
25	Copper										
100	Iron	1770.	1660.		488.	5190.	14400.	3600.	10300.	18200.	39300.
5	*Lead										
5000	Magnesium	[4350.]	[4410.]		5010.	5590.	6700.	[3630.]	6100.	7430.	13600.
15	Manganese	315.	323.		249.	326.	741.	365.	479.	1030.	2710.
0.2	Mercury										
40	*Nickel										
5000	Potassium	[1940.] L	[1920.] L		[3170.]	[3430.]	8570.	[1190.] L	8600.	10700.	17000.
5	Selenium	[1.5] K			[1.4]						
10	Silver										
5000	Sodium	9560.	9690.		11200.	10400.	23400	10900	18900.	28200.	80600.
10	Thallium										
50	Vanadium										
20	Zinc										
10	*Cyanide										

CRDL = Contract Required Detection Limit *Action Level Exists SEE NARRATIVE FOR CODE DEFINITIONS

TABBLD BY JJY 7/28/89

AR301427

revised 12/89

DATA SUMMARY FORM: TOTAL INORGANICS

WATER SAMPLES
(ug/L)

Site Name: ARMY CREEK LANDFILL

Case #: 12178 Sampling Date(s): 7/5/89-7/6/89

+Due to dilution, sample quantitation limit is affected.
See dilution table for specifics.

	Sample No.	MC8420																			
	Dilution Factor	1.0																			
	Location																				
CRDL	ANALYTE	AC-31																			
200	Aluminum																				
60	Antimony																				
10	*Arsenic																				
200	Barium	[142.]																			
5	Beryllium																				
5	*Cadmium																				
5000	Calcium	9720.																			
10	*Chromium																				
50	Cobalt	[6.3]	B																		
25	Copper																				
100	Iron	12[illegible].																			
5	*Lead																				
5000	Magnesium	[4660.]																			
15	Manganese	917.																			
0.2	Mercury																				
40	*Nickel																				
5000	Potassium	[2970.]																			
5	Selenium																				
10	Silver																				
5000	Sodium	13500.																			
10	Thallium																				
50	Vanadium																				
20	Zinc																				
10	*Cyanide																				

CRDL = Contract Required Detection Limit

*Action Level Exists

SEE NARRATIVE FOR CODE DEFINITIONS

AR301428

revised 12/88

[DISSOLVED]

DATA SUMMARY FORM: I N O R G A N I C S

Site Name: ARMY CREEK LANDFILL

WATER SAMPLES (ug/L)

Case #: 12178 Sampling Date(s): 7/5/89 - 7/6/89

•Due to dilution, sample quantitation limit is affected. See dilution table for specifics.

CRDL	Sample No.	MCBA 01		MCBA 03		MCBA 05		MCBA 07		MCBA 09		MCBA 11		MCBA 13		MCBA 15		MCBA 17		MCBA 19	
	Dilution Factor	1.0		1.0		1.0		1.0		1.0		1.0		1.0		1.0		1.0		1.0	
	Location			DUP OF MCBA01		RINSATE BLANK															
CRDL	ANALYTE	AC-01		AL-01A		AL-01C		AC-10		AC-11		AC-12		AC-13		AC-27		AC-28		AC-29	
200	Aluminum	[28.7]	B			[13.7]															
60	Antimony																				
10	*Arsenic																				
200	Barium	[80.8]		[82.7]		[2.3]		[123.]		[149.]		[174.]		[75.6]		[181.]		283.		367.	
5	Beryllium																				
5	*Cadmium																				
5000	Calcium	8640.		8750.		[64.9]		9160.		10100.		12000.		8870.		9150.		12200.		18600.	
10	*Chromium																				
50	Cobalt	[3.6]	B	[4.4]	B			[12.2]	B	[3.3]	B	[9.3]	B	[11.1]	B	[23.7]		[29.5]		[34.8]	
25	Copper																				
100	Iron	1370.		1330.		[15.1]		493.		4450.		13500.		3370.		7620.		17900.		32700.	
5	*Lead				UL	[1.0]		[1.5]	B	[1.3]	B	[1.9]	B			[1.0]	B	[1.3]	B	[2.6]	B
5000	Magnesium	[4330.]		[4410.]				[4920.]		5630.		6620.		[3620.]		5990.		7590.		13400.	
15	Manganese	321.		322.				247.		329.		734.		366.		450.		1050.		2660.	
0.2	Mercury																				
40	*Nickel							[23.1]													
5000	Potassium	[2000.]	L	[1780.]	L			[3130.]		[3110.]		8640.		[1930.]	L	8570.		10700.		16500.	
5	Selenium												UL		UL						
10	Silver																				
5000	Sodium	9646.		9690.		[43.0]		11100.		10600		23100.		10400.		18400.		28700.		79300.	
10	Thallium																				
50	Vanadium																				
20	Zinc											[11.7]	L	32.4	L			[5.1]	L		
10	*Cyanide		Q		Q		Q		Q		Q		Q		Q		Q		Q		Q

CRDL = Contract Required Detection Limit

*Action Level Exists

SEE NARRATIVE FOR CODE DEFINITIONS

TABBED BY JJY 7/28/89

Checked By KHW 7/31/89

revised 12/88

DISSOLVED

DATA SUMMARY FORM: I N O R G A N I C S

WATER SAMPLES
(ug/L)

Site Name: ARMY CREEK LANDFILL

Case #: 12178 Sampling Date(s): 7/5/89-7/6/89

+Due to dilution, sample quantitation limit is affected.
See dilution table for specifics.

	Sample No.	MCBA21										
	Dilution Factor	1.0										
	Location	AC-31										
CRDL	ANALYTE											
200	Aluminum											
60	Antimony											
10	*Arsenic											
200	Barium	[143.]										
5	Beryllium											
5	*Cadmium											
5000	Calcium	9830.										
10	*Chromium											
50	Cobalt											
25	Copper											
100	Iron	12100.										
5	*Lead											
5000	Magnesium	[4760]										
15	Manganese	922										
0.2	Mercury											
40	*Nickel											
5000	Potassium	[2960.]										
5	Selenium											
10	Silver											
5000	Sodium	13500.										
10	Thallium											
50	Vanadium											
20	Zinc											
10	*Cyanide		Q									

CRDL = Contract Required Detection Limit *Action Level Exists SEE NARRATIVE FOR CODE DEFINITIONS

AR301430

revised 12/88

DATA SUMMARY FORM:

SAS: PHOSPHATE

Site Name: ARMY CREEK LANDFILL

WATER SAMPLES
(ug/L)

Case #: 4728C Sampling Date: 07/05/89-07/06/89

To calculate sample quantitation limit:
(CRQL * Dilution Factor)

CRQL	Sample_No.	5-401		5-402		5-403		5-404		5-405		5-406		5-407		5-408		5-409	
	Dilution_Factor	1.0		1.0		1.0		1.0		1.0		1.0		1.0		1.0		1.0	
	Location	AC-01		Field dup of 5-401 AC-01A		Field Blank AC-01B		AC-10		AC-11		AC-12		AC-13		AC-27		AC-28	
	COMPOUND																		
	TOTAL PHOSPHOROUS	10	B			120				30	B	10	B			10	B		
	TOTAL REACT. PHOSPHOROUS											10							
	TOT. ACID HYSOL. PHOSPHOR.					50				10	B								
	TOT. ORGANIC PHOSPHOROUS	10	B			70				20	B					10	B		

CRQL = Contract_Required_Quantitation_Limit

Tabbed by J.Y.Y

Verified by EJO 10/16/89

AR301431

DATA SUMMARY FORM: SAS: PHOSPHATE

Site Name: ARMY CREEK LANDFILL

WATER SAMPLES (mg/L)

Case #: 4728C Sampling Date: 07/05/89-07/06/89

To calculate sample quantitation limit: (CRQL * Dilution Factor)

CRQL	Sample_No.	5-410		5-411								
	Dilution_Factor	1.0		1.0								
	Location	AC-29		AC-31								
	COMPOUND											
	TOTAL PHOSPHOROUS	160	B	20	B							
	TOTAL REACT. PHOSPHOROUS	30										
	TOT. ACID HYDROL PHOSPHOR			20	B							
	TOT. ORGANIC PHOSPHOROUS	90	B									

CRQL = Contract_Required_Quantitation_Limit

AR301432

DATA SUMMARY FORM: SAS: SULFATE & CHLORIDE

Site Name: ARMY CREEK LANDFILL

WATER SAMPLES (mg/L)

Case #: 4728C Sampling Date: 7/05/87-7/06/87

To calculate sample quantitation limit: (CRQL * Dilution Factor)

CRQL	Sample_No.	4-301	4-302	4-303	4-304	4-305	4-306	4-307	4-308	4-309
	Dilution_Factor	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	Location		Field dup of 4-301	Field Bank						
	COMPOUND	AC-01	AC-01A	AC-01B	AC-10	AC-11	AC-12	AC-13	AC-27	AC-28
	CHLORIDE	16	15		23	19	32	19	29	40
	SULFATE	10	10		9	14	8	8	10	9

CRQL = Contract_Required_Quantitation_Limit

Tabbed by JYY

AR301433

Verified by ESO 10/20/89

DATA SUMMARY FORM: SAS: SULFATE & CHLORIDE

WATER SAMPLES
(mg/L)

Site Name: ARMY CREEK LANDFILL

Case #: 4728C Sampling Date: 7/05/89-7/06/89

To calculate sample quantitation limit:
(CRQL * Dilution Factor)

CRQL	Sample No.	4-310	4-311							
	Dilution Factor	1.0	1.0							
	Location	AC-29	AC-31							
	COMPOUND									
	CHLORIDE	64	23							
	SULFATE	17	7							

CRQL = Contract Required Quantitation Limit

DATA SUMMARY FORM: SAS: SULFIDE

Site Name: ARMY CREEK LANDFILL

Case #: 4728C Sampling Date: 7/05/89 - 7/06/89

WATER SAMPLES
(mg/L)

To calculate sample quantitation limit:
(CRQL * Dilution Factor)

CRQL	Sample_No.	4-201	4-202	4-203	4-204	4-205	4-206	4-207	4-208	4-209
	Dilution_Factor	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	Location		Field dup of 4-201	Field Blank						
	COMPOUND	AC-01	AC-01A	AC-01B	AC-10	AC-11	AC-12	AC-13	AC-27	AC-28
	SULFIDE									

CRQL = Contract_Required_Quantitation_Limit

Tabbed by JYY

AR301435

Verified by EJO 10/20/89

DATA SUMMARY FORM: SAS: SULFIDE

Site Name: ARMY CREEK LANDFILL

Case #: 4728C Sampling Date: 7/05/89-7/06/89

WATER SAMPLES
(mg/L)

To calculate sample quantitation limit:
(CRQL * Dilution Factor)

CRQL	Sample_No.	4-210	4-211							
	Dilution_Factor	1.0	1.0							
	Location									
	COMPOUND	AC-29	AC-31							
	SULFIDE									

CRQL = Contract_Required_Quantitation_Limit

AR301436

DATA SUMMARY FORM:

SAS: NITRATE & NITRITE

Site Name: ARMY CREEK LANDFILL

WATER SAMPLES (mg/L)

Case #: 4728C Sampling Date: 7/05/89-7/06/89

To calculate sample quantitation limit: (CRQL * Dilution Factor)

CRQL	Sample_No.	3-501	3-502	3-503	3-504	3-505	3-506	3-507	3-508	3-509
	Dilution_Factor	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	Location	Field dup of 3-502 AC-01	Field dup of 3-501 AC-01A	Field Blank AC-01B	AC-10	AC-11	AC-12	AC-13	AC-27	AC-28
	COMPOUND									
	NITRATE	0.9	0.8		2.69	1.87	0.91	0.57	0.98	0.50
	NITRITE									

CRQL = Contract_Required_Quantitation_Limit

Tabbed by JJY 8/21/89 AR301437 Verified by EJO 10/6/89

DATA SUMMARY FORM: SAS: NITRATE & NITRITE

Site Name: ARMY CREEK LANDFILL

WATER SAMPLES (mg/L)

Case #: 4728C Sampling Date: 7/05/89 - 7/06/89

To calculate sample quantitation limit: (CRQL * Dilution Factor)

CRQL	Sample_No.	3-510	3-511							
	Dilution_Factor	1.0	1.0							
	Location / COMPOUND	AC-29	AC-31							
	NITRATE	0.08	0.97							
	NITRITE									

CRQL = Contract_Required_Quantitation_Limit

DATA SUMMARY FORM: SAS: AMMONIA & TKN

Site Name: ARMY CREEK LANDFILL

WATER SAMPLES (mg/L)

Case #: 9728L Sampling Date: 7/05/89-7/06/89

To calculate sample quantitation limit: (CRQL * Dilution Factor)

CRQL	Sample_No.	3-601		3-602		3-603		3-604		3-605		3-606		3-607		3-608		3-609	
	Dilution_Factor	1.0		1.0		1.0		1.0		1.0		1.0		1.0		1.0		1.0	
	Location	Field dup. of 3-602 AC-01		Field dup. of 3-601 AC-01A		Field Blank AC-01B		AC-10		AC-11		AC-12		AC-13		AC-27		AC-28	
	COMPOUND																		
	TOTAL KJELDAHL	0.56		0.56		0.10		1.77		1.28		9.30		0.31	B	7.86		9.89	
	AMMONIA	0.44	B	0.48		0.09		1.63		1.27		8.52		0.13	B	6.90		6.70	

CRQL = Contract_Required_Quantitation_Limit

Tabbed by JJY 8/21/89

AR301439

Verified by ESO 10/6/89

DATA SUMMARY FORM: SAS: AMMONIA & TKN

Site Name: ARMY CREEK LANDFILL

WATER SAMPLES (mg/L)

Case #: 4728C Sampling Date: 7/05/89-7/06/89

To calculate sample quantitation limit: (CRQL * Dilution Factor)

CRQL	COMPOUND				
	Sample_No.	3-610		3-611	
	Dilution_Factor	1.0		1.0	
	Location	AC-29		AC-31	
	TOTAL KJELDAHL	15.78		0.52	
	AMMONIA	6.80		0.44	B

CRQL = Contract_Required_Quantitation_Limit

D

APPENDIX D

PREVIOUS SEDIMENT AND SURFACE WATER DATA

TABLE 1. WATER CONCENTRATIONS OF VOLATILE ORGANIC COMPOUNDS
ARMY CREEK, NEW CASTLE COUNTY, DE
AUGUST, 1988
Concentrations reported in ug/L

Compound	Site Sample	1 1872	2 1874	3 1875	4 1876	5 1877	6 1878	7 1879	8 1880	Trip Blank 1881	Well 29 1883	Equip Blank 1884*	Minimum Detection Limit
Acetone		U	U	U	U	U	52	17	118	33	39	51	10
1,1 Dichloroethane		U	U	U	U	U	U	U	U	U	1J	U	5
1,2 Dichloroethane		U	U	2J	5	U	U	U	U	U	9	U	5
Trichloroethene		U	U	U	U	U	U	U	U	U	2J	U	5
Benzene		U	U	U	U	U	U	U	U	5	25	U	5
Chlorobenzene		U	U	U	U	U	U	U	U	2J	15	U	5
Ethylbenzene		U	U	U	U	U	U	U	U	U	4J	U	5

J - Data indicates the presence of a compound that meets the identification criteria. The result is less than the specified detection limit but greater than zero. The concentration is given as an approximate value.

U - The compound was analyzed for but not detected at the indicated detection limit.

* - Sediment sampling equipment rinsate.

TABLE 2. SEDIMENT CONCENTRATIONS OF VOLATILE ORGANIC COMPOUNDS
ARMY CREEK, NEW CASTLE COUNTY, DE
AUGUST, 1988

Concentrations reported in ug/kg

Compound	Site Sample	1 1872	2 1874	3 1875	4 1876	5 1877	6 1878	7 1879	8 1880	Minimum Detection Limit
Acetone		25	275	206	719	500	124	144	44	10
2-Butanone		4J	18	11	6J	29	U	U	U	10
Toluene		U	U	U	U	U	9	33	U	5
Xylene		U	U	U	U	U	U	U	21	5

J - Data indicates the presence of a compound that meets the identification criteria. The result is less than the specified detection limit but greater than zero. The concentration is given as an approximate value.

U - The compound was analyzed for but not detected at the indicated detection limit.

TABLE 3. WATER CONCENTRATIONS OF BASE/NEUTRAL/ACID EXTRACTABLE COMPOUNDS
ARMY CREEK, NEW CASTLE COUNTY, DE
AUGUST, 1988

Concentrations reported in ug/L

Compound	Site Sample	Water Blank	1 1872	2 1874	3 1875	4 1876	5 1877	6 1878	7 1879	8 1880	Well 29 1883	Minimum Detection Limit
Bis(2-chloroethyl)ether		U	6.80J	U	7.50J	3.60J	U	U	U	U	18.20	10.0
1,4 Dichlorobenzene		U	U	U	U	U	U	U	U	U	4.40J	10.0
Di-n-Butylphthalate		1.00J	U	U	2.70J	U	2.60J	U	2.50J	U	U	10.0
Bis(2-ethylhexyl)Phthalate		8.10J	3.80J	11.00	U	34.60	12.80	U	16.40	U	U	10.0
Di-n-Octyl Phthalate		8.60J	U	U	17.50	31.30	36.20	U	7.50J	3.80J	13.80	~10.0

J - Data indicates the presence of a compound that meets the identification criteria. The result is less than the specified detection limit but greater than zero. The concentration is given as an approximate value.

U - The compound was analyzed for but not detected at the indicated detection limit.

TABLE 4. SEDIMENT CONCENTRATIONS OF BASE/NEUTRAL/ACID EXTRACTABLE COMPOUNDS
ARMY CREEK, NEW CASTLE COUNTY, DE
AUGUST, 1988

Concentrations reported in ug/kg

Compound	Site Sample	Soil Blank	1 1872	2 1874	3 1875	4 1876	5 1877	6 1878	7 1879	8 1880
4-Methylphenol		330U	554U	776U	924U	882U	784U	139J	487U	411U
Acenaphthene		330U	554U	776U	924U	882U	784U	165J	487U	411U
Fluorene		330U	554U	776U	924U	882U	784U	161J	487U	411U
Phenanthrene		330U	554U	776U	924U	882U	784U	1710	890	402J
Anthracene		330U	554U	776U	924U	882U	784U	339J	180J	411U
Di-n-Butylphthalate		330U	554U	1080	638	390J	781J	236J	250J	369J
Fluoranthene		330U	554U	776U	924U	882U	331J	1620	1280	557
Pyrene		330U	554U	776U	924U	882U	302J	3200	1140	463
Benzo(a)Anthracene		330U	554U	776U	924U	882U	784U	1250	603	258
Chrysene		330U	554U	776U	924U	882U	274J	1580	868	354J
Bis(2-Ethylexyl)Phthalate		4480	416J	615J	533J	6910	503J	1190	1230	811
Di-n-Octyl Phthalate		904	2070	3520	1960J	957	2230	1090	389J	1810
Benzo(b)Fluoranthene		330U	554U	776U	924U	882U	422J	1330	690	203J
Benzo(k)Fluoranthene		330U	554U	776U	924U	882U	446J	786	487U	411U
Benzo(a)Pyrene		330U	554U	239J	924U	882U	784U	1070	500	242J
Indeno(1,2,3-cd)Pyrene		330U	554U	776U	924U	882U	784U	808	386J	182J
Benzo(ghi)Perylene		330U	554U	776U	924U	882U	784U	715	323J	165J

J - Data indicates the presence of a compound that meets the identification criteria. The result is less than the specified detection limit but greater than zero. The concentration is given as an approximate value.

U - The compound was analyzed for but not detected at the indicated detection limit.

TABLE 5. TOTAL AND SOLUBLE METALS ANALYSIS RESULTS FOR WATER, ARMY CREEK SITE, NEW CASTLE COUNTY, DE
AUGUST, 1988

Concentrations (ug/ml)

Parameter	Sample Site	1872 1 S	1872 1 T	1874 2 S	1874 2 T	1875 3 S	1875 3 T	1876 4 S	1876 4 T	1877 5 S	1877 5 T	1878 6 S	1878 6 T	1879 7 S	1879 7 T	1880 8 S	1880 8 T	1883 Well 29 S	1883 Well 29 T	1882 Rinse T	Detection Limit
Cadmium		u	u	u	u	u	u	0.036	u	u	u	0.034	u	0.036	u	0.038	u	u	u	u	0.01
Chromium		0.084	0.057	.058	.15	u	.083	.06	.093	u	.087	u	u	.08	u	.072	.064	u	u	u	0.05
Mercury		u	u	u	u	u	u	u	.0002	u	u	.0002	u	u	u	u	u	u	u	u	0.0002
Nickel		u	u	u	.15	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	0.1
Thallium		u	u	u	.61	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	0.5
Zinc		.64	.016	.38	u	u	.024	.031	u	.025	u	.16	0.1	.036	u	.039	.018	.02	u	u	0.01
Iron		.58	2.26	u	2.86	u	2.61	u	1.18	u	0.98	u	1.16	u	u	u	1.09	28.3	27.4	u	0.5

S = Soluble metals.
T = Total metals.
u = The compound was analyzed for but not detected at the indicated detection limit.

TABLE 6. METALS ANALYSIS RESULTS FOR SEDIMENTS, ARMY CREEK SITE, NEW CASTLE COUNTY, DE
AUGUST, 1988

Concentration (ug/g)

Parameter	Sample #	1872 Site 1	1874 Site 2	1875 Site 3	1876 Site 4	1877 Site 5	1878 Site 6	1879 Site 7	1880 Site 8	Detection Limit
Arsenic		2.3	u	6	4.9	5.8	1.1	1.6	1.1	0.95
Antimony		u	u	u	u	u	u	u	u	5.9
Beryllium		u	u	u	u	u	u	u	u	10
Cadmium		u	u	u	u	u	u	u	u	10
Chromium		15.3	u	45	35.2	30.9	8.3	14.9	u	5
Copper		13.1	u	43.9	43.3	32.5	11.3	20.9	u	5
Lead		21.2	6	76	90.3	97.8	45.8	59.2	u	0.49
Mercury		0.0592	0.0609	0.105	0.0492	0.1186	0.0797	0.0484	0.0459	0.01
Nickel		13.4	u	26.4	25.4	17.7	u	9.9J	u	10
Selenium		u	u	u	u	u	u	u	u	0.49
Silver		u	u	u	u	u	u	u	u	5
Thallium		u	u	u	u	u	u	u	u	10
Zinc		57.1	18.9	172	273	165	49.5	102	16.4	10
Iron		20500	1830	68800	39700	24700	7100	9960	4650	50

u = The compound was analyzed for but not detected at the indicated detection limit.

J = Approximate number, below method detection limit.

AR301448

TABLE 7. WATER CONCENTRATIONS OF ALKALINITY, HARDNESS, PHENOL, TOTAL CYANIDE, AND TOTAL SUSPENDED SOLIDS
ARMY CREEK, NEW CASTLE COUNTY, DE
AUGUST, 1988

Concentrations reported in mg/L

Parameter	Site / Sample	1 / 1872	2 / 1874	3 / 1875	4 / 1876	5 / 1877	6 / 1878	7 / 1879	8 / 1880	Well 29 / 1883	Minimum Detection Limit
Alkalinity		51.0	56.0	51.0	N/A	77.0	41.0	75.0	N/A	220.0	1.0
Hardness		53.0	58.0	61.0	N/A	105.0	120.0	105.0	N/A	109.0	1.0
Phenol		0.164	0.213	0.197	0.156	0.116	0.164	0.092	0.156	1.43	0.05
Total Cyanide		0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05
TSS		13.0	18.0	47.0	10.0U	10.0U	21.0	10.0J	10.0U	28.0	10.0

J - Data indicates the presence of a compound that meets the identification criteria. The result is less than the specified detection limit but greater than zero. The concentration is given as an approximate value.

U - The compound was analyzed for but not detected at the indicated detection limit.

N/A - Not analyzed.

TABLE 8. SEDIMENT CONCENTRATIONS OF PHENOL, TOTAL CYANIDE, AND TOTAL ORGANIC CARBON
ARMY CREEK, NEW CASTLE COUNTY, DE
AUGUST, 1988

Concentrations reported in mg/kg

Parameter	Site / Sample	1 / 1872	2 / 1874	3 / 1875	4 / 1876	5 / 1877	6 / 1878	7 / 1879	8 / 1880
Phenol		1.80	2.16U	2.40	2.40U	1.85U	1.19U	1.35U	0.848U
Total Cyanide		1.48U	2.02U	2.33U	2.30U	2.02U	1.34U	1.46U	1.19U
TOC		0.14	0.01U	0.98	2.36	1.03	0.23	0.44	0.05

J - Data indicates the presence of a compound that meets the identification criteria. The result is less than the specified detection limit but greater than zero. The concentration is given as an approximate value.

U - The compound was analyzed for but not detected at the indicated detection limit.

ARSENIC

Summary

Arsenic is a metal that is present in the environment as a constituent of organic and inorganic compounds; it also occurs in a number of valence states. Arsenic is generally rather mobile in the natural environment, with the degree of mobility dependent on its chemical form and the properties of the surrounding medium. Arsenic is a human carcinogen; it causes skin tumors when it is ingested and lung tumors when it is inhaled. Arsenic compounds are teratogenic and have adverse reproductive effects in animals. Chronic exposure to arsenic is associated with polyneuropathy and skin lesions. It is acutely toxic to some early life stages of aquatic organisms at levels as low as 40 μg/liter.

Background Information

Arsenic can be found in the environment in any of four valence states (-3, 0, +3, and +5) depending on the pH, Eh, and other factors. It can exist as either inorganic or organic compounds and often will change forms as it moves through the various media. The chemical and physical properties depend on the state of the metalloid. Only the properties of metallic arsenic have been listed; properties of other arsenic compounds are often quite different.

CAS Number: 7440-38-2

Chemical Formula: As

IUPAC Name: Arsenic

Chemical and Physical Properties

Atomic Weight: 74.91

Boiling Point: 613°C

Melting Point: 817°C

Specific Gravity: 5.72 at 20°C

Solubility in Water: Insoluble; some salts are soluble

Transport and Fate

In the natural environment, arsenic has four different oxidation states, and chemical speciation is important in determining arsenic's distribution and mobility. Interconversions of the +3 and +5 states as well as organic complexation, are the most important. Arsenic is generally quite mobile in the environment. In the aquatic environment, volatilization is important when biological activity or highly reducing conditions produce arsine or methylarsenics. Sorption by the sediment is an important fate for the chemical. Arsenic is metabolized to organic arsenicals by a number of organisms; this increases arsenic's mobility in the environment. Because of its general mobility, arsenic tends to cycle through the environment. Its ultimate fate is probably the deep ocean, but it may pass through numerous stages before finally reaching the sea.

Health Effects

Arsenic has been implicated in the production of skin cancer in humans. There is also extensive evidence that inhalation of arsenic compounds causes lung cancer in workers. Arsenic compounds cause chromosome damage in animals, and humans exposed to arsenic compounds have been reported to have an elevated incidence of chromosome aberrations. Arsenic compounds have been reported to be teratogenic, fetotoxic, and embryotoxic in several animal species, and an increased incidence of multiple malformations among children born to women occupationally exposed to arsenic has been reported. Arsenic compounds also cause noncancerous, possibly precancerous, skin changes in exposed individuals. Several cases of progressive polyneuropathy involving motor and sensory nerves and particularly affecting the extremities and myelinated long-axon neurons have been reported in individuals occupationally exposed to inorganic arsenic. Polyneuropathies have also been reported after the ingestion of arsenic-contaminated foods.

Toxicity to Wildlife and Domestic Animals

Various inorganic forms of arsenic appear to have similar levels of toxicity; they all seem to be much more toxic than organic forms. Acute toxicity to adult freshwater animals occurs at levels of arsenic trioxide as low as 812 μg/liter and at levels as low as 40 μg/liter in early life stages of aquatic organisms. Acute toxicity to saltwater fish occurs at levels around 15 mg/liter, while some invertebrates are affected at much lower levels (508 μg/liter). Arsenic toxicity does not appear to increase greatly with chronic exposure, and it does not seem that arsenic is bioconcentrated to a great degree.

Arsenic poisoning is a rare but not uncommon toxic syndrome among domestic animals. Arsenic causes hyperemia and edema of the gastrointestinal tract, hemorrhage of the cardiac serosal surfaces and peritoneum, and pulmonary congestion and edema; and it may cause liver necrosis. Information on arsenic toxicity to terrestrial wildlife was not reported in the literature reviewed.

Regulations and Standards

Ambient Water Quality Criteria (USEPA):

Aquatic Life

Freshwater

Acute toxicity: 440 μg/liter
Chronic toxicity: No available data

Saltwater

Acute toxicity: 508 μg/liter
Chronic toxicity: No available data

Human Health

Estimates of the carcinogenic risks associated with lifetime exposure to various concentrations of arsenic in water are:

Risk	Concentration
10^{-5}	22 ng/liter
10^{-6}	2.2 ng/liter
10^{-7}	0.22 ng/liter

CAG Unit Risk (USEPA): 15 $(mg/kg/day)^{-1}$

National Interim Primary Drinking Water Standard (USEPA): 50 μg/liter

NIOSH Recommended Standard (air): 2 $\mu g/m^3$ Ceiling Level

OSHA Standard (air): 500 $\mu g/m^3$ TWA

ACGIH Threshold Limit Value: 200 $\mu g/m^3$ (soluble compounds, as As)

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BENZENE

Summary

Benzene is an important industrial solvent and chemical intermediate. It is rather volatile, and atmospheric photooxidation is probably an important fate process. Benzene is a known human carcinogen, causing leukemia in exposed individuals. It also adversely affects the hematopoietic system. Benzene has been shown to be fetotoxic and to cause embryolethality in experimental animals. Exposure to high concentrations of benzene in the air causes central nervous system depression and cardiovascular effects, and dermal exposure may cause dermatitis.

CAS Number: 71-43-2

IUPAC Name: Benzene

Chemical Formula: C_6H_6

Chemical and Physical Properties

Molecular Weight: 78.12

Boiling Point: 80.1°C

Melting Point: 5.56°C

Specific Gravity: 0.879 at 20°C

Solubility in Water: 1,780 mg/liter at 25°C

Solubility in Organics: Miscible with ethanol, ether, acetic acid, acetone, chloroform, carbon disulfide, and carbon tetrachloride

Log Octanol/Water Partition Coefficient: 1.95-2.13

Vapor Pressure: 75 mm Hg at 20°C

Vapor Density: 2.77

Flash Point: -11.1°C

Transport and Fate

Volatilization appears to be the major transport process of benzene from surface waters to the ambient air, and atmospheric transport of benzene occurs readily (USEPA 1979). Although direct oxidation of benzene in environmental waters is unlikely, cloud chamber data indicate that it may be photo-oxidized rapidly in the atmosphere. Inasmuch as volatilization is likely to be the main transport process accounting for the removal of benzene from water, the atmospheric destruction of benzene is probably the most likely fate process. Values for benzene's log octanol/water partition coefficient indicate that adsorption onto organic material may be significant under conditions of constant exposure. Sorption processes are likely removal mechanisms in both surface water and groundwater. Although the bioaccumulation potential for benzene appears to be low, gradual biodegradation by a variety of microorganisms probably occurs. The rate of benzene biodegradation may be enhanced by the presence of other hydrocarbons.

Health Effects

Benzene is a recognized human carcinogen (IARC 1982). Several epidemiological studies provide sufficient evidence of a causal relationship between benzene exposure and leukemia in humans. Benzene is a known inducer of aplastic anemia in humans, with a latent period of up to 10 years. It produces leukopenia and thrombocytopenia, which may progress to pancytopenia. Similar adverse effects on the blood-cell-producing system occur in animals exposed to benzene. In both humans and animals, benzene exposure is associated with chromosomal damage, although it is not mutagenic in microorganisms. Benzene was fetotoxic and caused embryolethality in experimental animals.

Exposure to very high concentrations of benzene [about 20,000 ppm (66,000 mg/m^3) in air] can be fatal within minutes (IARC 1982). The prominent signs are central nervous system depression and convulsions, with death usually following as a consequence of cardiovascular collapse. Milder exposures can produce vertigo, drowsiness, headache, nausea, and eventually unconsciousness if exposure continues. Deaths from cardiac sensitization and cardiac arrhythmias have also been reported after exposure to unknown concentrations. Although most benzene hazards are associated with inhalation exposure, dermal absorption of liquid benzene may occur, and prolonged or repeated skin contact may produce blistering, erythema, and a dry, scaly dermatitis.

Toxicity to Wildlife and Domestic Animals

The EC_{50} values for benzene in a variety of invertebrate and vertebrate freshwater aquatic species range from 5,300 µg/liter to 386,000 µg/liter (USEPA 1980). However, only values for the rainbow trout (5,300 µg/liter) were obtained from a flow through test and were based on measured concentrations. Results based on unmeasured concentrations in static tests are likely to underestimate toxicity for relatively volatile compounds like benzene. A chronic test with *Daphnia magna* was incomplete, with no adverse effects observed at test concentrations as high as 98,000 µg/liter.

For saltwater species, acute values for one fish and five invertebrate species range from 10,900 µg/liter to 924,000 µg/liter. Freshwater and saltwater plant species that have been studied exhibit toxic effects at benzene concentrations ranging from 20,000 µg/liter to 525,000 µg/liter.

Regulations and Standards

Ambient Water Quality Criteria (USEPA):

Aquatic Life

The available data are not adequate for establishing criteria. However, EPA did report the lowest concentrations of benzene known to cause toxic effects in aquatic organisms.

Freshwater

Acute toxicity: 5,300 µg/liter
Chronic toxicity: No available data

Saltwater

Acute toxicity: 5,100 µg/liter
Chronic toxicity: No available data

Human Health

Estimates of the carcinogenic risks associated with lifetime exposure to various concentrations of benzene in water are:

Risk	Concentration
10^{-5}	6.6 µg/liter
10^{-6}	0.66 µg/liter
10^{-7}	0.066 µg/liter

CAG Unit Risk (USEPA): 2.9×10^{-2} $(mg/kg/day)^{-1}$

OSHA Standards: 30 mg/m^3 TWA
75 mg/m^3 Ceiling Level
150 mg/m^3 10-min Peak Level

ACGIH Threshold Limit Values: Suspected human carcinogen
30 mg/m^3 TWA
75 mg/m^3 STEL

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BENZO(a)ANTHRACENE

Summary

Benzo(a)anthracene is a four-ringed polycylic aromatic hydrocarbon (PAH). It is readily absorbed to organic matter and is probably moderately persistent in the environment. Benzo(a) anthracene is carcinogenic in mice and is reported to be mutagenic in several test systems. Carcinogenic PAHs such as benzo(a) anthracene cause immunosuppression, and dermal exposure causes chronic dermatitis and other skin disorders. The very limited information on its toxicity to aquatic life indicates that benzo(a)anthracene is chronically toxic to fish at concentrations of less than 1,000 μg/liter.

CAS Number: 56-55-3

Chemical Formula: $C_{18}H_{12}$

IUPAC Name: 1,2-benzanthracene

Important Synonyms and Trade Names: 1,2-Benzanthracene; 2,3-Benzophenanthrene; Benzo(b)phenanthrene

Chemical and Physical Properties

Molecular Weight: 228.28

Melting Point: 155-157°C

Solubility in Water: 0.009 to 0.014 mg/liter at 25°C

Solubility in Organics: Soluble in alcohol, ether, acetone, and benzene

Log Octanol/Water Partition Coefficient: 5.61

Vapor Pressure: 5×10^{-9} mm Hg at 20°C

Transport and Fate

Dissolved benzo(a)anthracene can undergo rapid, direct photolysis, and this process may be an important environmental fate in aquatic systems. Studies indicate that singlet oxygen is the oxidant and that quinones are the products in the photolytic reactions. The free-radical oxidation of benzo(a)anthracene in the environment is rapid and may be competitive with photolysis as a chemical fate process. When chlorine and ozone are present in aquatic systems in sufficient quantities, oxidation reactions resulting in the formation of quinones may be significant fate processes. Because benzo(a)anthracene does not contain groups amenable to hydrolysis, this process is not thought to be a significant environmental fate. Volatilization does not appear to be an important transport process either.

Available information indicates that benzo(a)anthracene will accumulate in the sediment and biotic portions of the aquatic environment and that adsorption to suspended matter is the dominant transport process. Sorption onto sediments, soil particles, and biota is strongly correlated with the organic carbon levels present. Although benzo(a)anthracene is readily and rapidly bioaccumulated, it is also rapidly metabolized and excreted. Therefore, bioaccumulation is short term and is not considered an important fate process. Benzo(a)anthracene is degraded by microbes and readily metabolized by multicellular organisms. Degradation by mammals is considered to be incomplete; the parent compound and metabolites are excreted by the urinary system. Biodegradation is probably the ultimate fate process for benzo(a)anthracene. It generally is more rapid in soil than in aquatic systems and is relatively fast in those systems chronically affected by polycyclic aromatic hydrocarbon contamination.

Atmospheric transport of benzo(a)anthracene can occur, and the chemical can be returned to aquatic and terrestrial systems by atmospheric fallout or with precipitation. Benzo(a)anthracene can also enter surface and groundwater by leaching from polluted soils.

Health Effects

Benzo(a)anthracene administered by different routes is carcinogenic in the mouse. It can produce hepatomas and lung adenomas following repeated oral administration and bladder tumors following implantation. Benzo(a)anthracene can also produce tumors in mice following subcutaneous injections. Although benzo(a)anthracene is a complete carcinogen for mouse skin, it produces less skin tumors with a longer latency than does benzo(a)pyrene. Benzo(a)anthracene has not been adequately tested in other species.

Benzo(a)anthracene is reported to be mutagenic in a variety of test systems. In some cases, a correlation is observed between mutagenicity and carcinogenic potency for benzo(a)anthracene and other polycyclic aromatic hydrocarbons. In other words, those compounds exhibiting greater mutagenic activity often have higher carcinogenic potency as well. No adequate information concerning the teratogenic effects of benzo(a)anthracene in humans or experimental animals is available.

Application of the carcinogenic polycyclic aromatic hydrocarbons, including benzo(a)anthracene, to mouse skin leads to the destruction of sebaceous glands, hyperplasia, hyperkeratosis, and ulceration. Workers exposed to materials containing polynuclear aromatic hydrocarbons may exhibit chronic dermatitis, hyperkeratoses, and other skin disorders. Repeated subcutaneous injections of benzo(a)anthracene to mice and rats produces gross changes in the lymphoid tissues. It has also been shown that many carcinogenic polycyclic aromatic hydrocarbons can produce an immunosuppressive effect, although specific results with benzo(a)anthracene have not been reported.

Toxicity to Wildlife and Domestic Animals

Adequate data for characterization of toxicity to wildlife and domestic animals are not available. One study involving freshwater fish reported an 87% mortality rate in bluegills exposed to 1,000 µg/liter benzo(a)anthracene for 6 months.

Regulations and Standards

Ambient Water Quality Criteria (USEPA):

Aquatic Life

The available data are not adequate for establishing criteria.

Human Health

Estimates of the carcinogenic risks associated with lifetime exposure to various concentrations of carcinogenic PAHs in water are:

Risk	Concentration
10^{-5}	28 ng/liter
10^{-6}	2.8 ng/liter
10^{-7}	0.28 ng/liter

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CADMIUM

Summary

Cadmium is a metal that can be present in a variety of chemical forms in wastes or in the environment. Some forms are insoluble in water, but cadmium is relatively mobile in the aquatic environment. Cadmium is carcinogenic in animals exposed by inhalation and may also be in humans. It is uncertain whether it is carcinogenic in animals or humans exposed via ingestion. Cadmium is a known animal teratogen and reproductive toxin. It has chronic effects on the kidney, and background levels of human exposure are thought to provide only a relatively small margin of safety for these effects.

Background Information

Cadmium is a soft, bluish white metal that is obtained as a by-product from the treatment of the ores of copper, lead, and iron. Cadmium has a valence of +2 and has properties similar to those of zinc. Cadmium forms both organic and inorganic compounds. Cadmium sulfate is the most common salt.

CAS Number: 7440-43-9

Chemical Formula: Cd

IUPAC Name: Cadmium

Chemical and Physical Properties

Atomic Weight: 112.41

Boiling Point: 765°C

Melting Point: 321°C

Specific Gravity: 8.642

Solubility in Water: Salts are water soluble; metal is insoluble

Solubility in Organics: Variable, based on compound

Vapor Pressure: 1 mm Hg at 394°C

Transport and Fate

Cadmium is relatively mobile in the aquatic environment compared to other heavy metals (USEPA 1979). It is removed from aqueous media by complexing with organic materials and subsequently being adsorbed to the sediment. It appears that cadmium moves slowly through soil, but only limited information on soil transport is available. Cadmium uptake by plants is not a significant mechanism for depletion of soil accumulations but may be significant for human exposure.

Health Effects

There is suggestive evidence linking cadmium with cancer of the prostate in humans (USEPA 1980). In animal studies, exposure to cadmium by inhalation caused lung tumors in rats, and exposure by injection produced injection-site sarcomas and/or Leydig-cell tumors (Takenaka 1983, USEPA 1981). An increased incidence of tumors has not been seen in animals exposed to cadmium orally, but four of the five available studies were inadequate by current standards (Clement 1983).

The evidence from a large number of studies on the mutagenicity of cadmium is equivocal, and it has been hypothesized that cadmium is not directly mutagenic but impedes repair (Clement 1983). Cadmium is a known animal teratogen and reproductive toxin. It has been shown to cause renal dysfunction in both humans and animals. Other toxic effects attributed to cadmium include immunosuppression (in animals), anemia (in humans), pulmonary disease (in humans), possible effects on the endocrine system, defects in sensory function, and bone damage. The oral LD_{50} in the rat was 225 mg/kg (NIOSH 1983).

Toxicity to Wildlife and Domestic Animals

Laboratory experiments suggest that cadmium may have adverse effects on reproduction in fish at levels present in lightly to moderately polluted waters.

The acute LC_{50} for freshwater fish and invertebrates generally ranged from 100 to 1,000 µg/liter; salmonids are much more sensitive than other organisms (USEPA 1980). Saltwater species were in general 10-fold more tolerant to the acute effects of cadmium. Chronic tests have been performed and show that cadmium has cumulative toxicity and acute-chronic ratios that range of from 66 to 431. Bioconcentration factors were generally less than 1,000 but were as high as 10,000 f : some freshwater fish species.

No adverse effects on domestic or wild animals were reported in the studies reviewed.

Regulations and Standards

Ambient Water Quality Criteria (USEPA):

Aquatic Life (Proposed 1984)

Freshwater

Acute toxicity: $e^{(1.30[\ln(\text{hardness})] - 3.92)}$ μg/liter

Chronic toxicity: $e^{(0.87[\ln(\text{hardness})] - 4.38)}$ μg/liter

Saltwater

Acute toxicity: 38 μg/liter
Chronic toxicity: 12 μg/liter

Human Health

Criterion: 10 μg/liter

CAG Unit Risk for inhalation exposure (USEPA): 6.1 $(mg/kg/day)^{-1}$

Interim Primary Drinking Water Standard (USEPA): 10 μg/liter

NIOSH Recommended Standards: 40 $\mu g/m^3$ TWA
200 $\mu g/m^3$/15 min Ceiling Level

OSHA Standards: 200 $\mu g/m^3$ TWA
600 $\mu g/m^3$ Ceiling Level

ACGIH Threshold Limit Values: 50 $\mu g/m^3$ TWA

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BIS(2-CHLOROETHYL)ETHER

Summary

bis(2-Chloroethyl)ether was used in the past as a soil fumigant and is now used as a solvent and chemical reagent. It is fairly soluble in water and is probably moderately persistent in the environment. bis(2-Chloroethyl)ether caused an increased incidence of liver tumors in male mice following oral administration, and it was found to be mutagenic using the Ames assay. In the air, it is irritating to the eyes and nasal passages and when inhaled can damage the lungs, liver, kidneys, and brain.

CAS Number: 111-44-4

Chemical Formula: $ClCH_2CH_2OCH_2CH_2Cl$

IUPAC Name: bis(beta-Chloroethyl)ether

Important Synonyms and Trade Names: sym-Dichloroethyl ether; 2,2'-Dichloroethyl ether; 1-Chloro-2-(beta-chloroethoxy)-ethane; DCEE; 1,1'-oxybis-(2-chloroethane)

Chemical and Physical Properties

Molecular Weight: 143.02

Boiling Point: 178°C

Melting Point: -24.5°C

Specific Gravity: 1.22 at 20°C

Solubility in Water: 10,200 mg/liter

Solubility in Organics: Miscible with most organic solvents

Log Octanol/Water Partition Coefficient: 1.58

Vapor Pressure: 0.71 mm Hg at 20°C

Vapor Density: 4.93

Flash Point: 55°C

Transport and Fate

There is little information available concerning the environmental transport and fate of bis(2-chloroethyl)ether and the relative importance of the various transport and fate processes. Some volatilization of this compound from aquatic and terrestrial systems, and subsequent atmospheric transport probably can occur. Because it is somewhat soluble in water, bis(2-chloroethyl)-ether can migrate through the soil. Direct photolysis is not expected to take place in the atmosphere or in surface waters. However, photo oxidation of the bis(2-chloroethyl)ether that reaches the troposphere is likely to occur. Slow hydrolytic cleavage of the carbon-chlorine bonds can occur and is probably the most important aquatic fate.

Adsorption on particulate matter does not appear to be a significant environmental transport process. A limited amount of indirect evidence suggests that bis(2-chloroethyl)ether has little potential for bioaccumulation. Available information is not adequate to characterize the importance of biodegradation as a fate process. It is reported that significant degradation can occur in aquatic systems after a period of acclimation.

Health Effects

bis(2-Chloroethyl)ether caused an increased incidence of hepatomas in male mice following oral administration. It is also reported to be mutagenic in Salmonella tester strains. No data concerning teratogenic or reproductive effects are available.

bis(2-Chloroethyl)ether concentrations of 100 ppm (600 mg/m^3) and possibly lower are irritating to the eyes and nasal passages, and may cause coughing and nausea. Exposure to concentrations above 550 ppm (3,300 mg/m^3) is considered to be intolerable. Concentrations of 500 ppm and 250 ppm are reported to be fatal in guinea pigs and rats, respectively. The most severe toxic effects are seen in the lungs, although the kidneys, liver, and brain may also be affected. No serious toxic effects were noted following chronic exposure of guinea pigs and rats to 69 ppm (420 mg/m^3) of bis(2-chloroethyl)ether.

bis(2-Chloroethyl)ether is a mild skin irritant. However, acutely toxic and lethal amounts may be absorbed through the skin. An oral LD_{50} of 75 mg/kg is reported for the rat.

Toxicity to Wildlife and Domestic Animals

Data adequate to characterize the toxicity of bis(2-chloroethyl)ether to wildlife and domestic animals are not available.

Acute toxicity of chloroalkyl ethers, in general, to freshwater aquatic life is reported to occur at concentrations as low as 238,000 μg/liter and would occur at lower concentrations among species more sensitive than those tested.

Regulations and Standards

Ambient Water Quality Criteria (USEPA):

Aquatic Life

The available data are not adequate for establishing criteria.

Human Health

Estimates of the carcinogenic risks associated with lifetime exposure to various concentrations of bis(2-chloroethyl)ether in water are:

Risk	Concentration
10^{-5}	0.3 μg/liter
10^{-6}	0.03 μg/liter
10^{-7}	0.003 μg/liter

CAG Unit Risk (USEPA): 1.14 $(mg/kg/day)^{-1}$

OSHA Standard: 90 mg/m^3 Ceiling Level

ACGIH Threshold Limit Values: 30 mg/m^3 TLV
60 mg/m^3 STEL

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CHROMIUM

Summary

Chromium is a heavy metal that generally exists in either a trivalent or hexavalent oxidation state. Hexavalent chromium (Cr VI) is rather soluble and is quite mobile in groundwater and surface water. However, in the presence of reducing agents it is rapidly converted to trivalent chromium (Cr III), which is strongly adsorbed to soil components and consequently is much less mobile. A number of salts of hexavalent chromium are carcinogenic in rats. In addition, an increased incidence of lung cancer was seen in workers occupationally exposed to chromium VI. Hexavalent chromium also causes kidney damage in animals and humans. Trivalent chromium is less toxic than hexavalent chromium; its main effect is contact dermatitis in sensitive individuals.

CAS Number: 7440-47-3

Chemical Formula: Cr

IUPAC Name: Chromium

Chemical and Physical Properties (Metal)

Atomic Weight: 51.996

Boiling Point: 2672°C

Melting Point: 1857 ± 20°C

Specific Gravity: 7.20 at 28°C

Solubility in Water: Insoluble; some compounds are soluble

Transport and Fate

Hexavalent Cr is quite soluble, existing in solution as a component of a complex anion. It is not sorbed to any significant degree by clays or hydrous metal oxides. The anionic form varies according to pH and may be a chromate, hydrochromate, or dichromate. Because all anionic forms are so soluble, they are quite mobile in the aquatic environment. Cr VI is efficiently removed by activated carbon and thus may have some affinity for organic materials in natural water. Cr VI is a moderately strong oxidizing agent and reacts with reducing materials to form trivalent chromium. Most Cr III in the aquatic environment is hydrolyzed and precipitates as chromium hydroxide. Sorption to sediments and bioaccumulation will remove much of the remaining Cr III from solution. Cr III is adsorbed only weakly to inorganic materials. Cr III and Cr VI are readily interconvertible in nature depending on microenvironmental conditions such as pH, hardness, and the types of other compounds present. Soluble forms of chromium accumulate if ambient conditions favor Cr VI. Conditions favorable for conversion to Cr III lead to precipitation and adsorption of chromium in sediments.

In air, chromium is associated almost entirely with particulate matter. Sources of chromium in air include windblown soil and particulate emissions from industrial processes. Little information is available concerning the relative amounts of Cr III and Cr VI in various aerosols. Relatively small particles can form stable aerosols and can be transported many miles before settling out.

Cr III tends to be adsorbed strongly onto clay particles and organic particulate matter, but can be mobilized if it is complexed with organic molecules. Cr III present in minerals is mobilized to different extents depending on the weatherability and solubility of the mineral in which it is contained. Hexavalent compounds are not strongly adsorbed by soil components and Cr VI is mobile in groundwater. Cr VI is quickly reduced to CR III in poorly drained soils having a high content of organic matter. Cr VI of natural origin is rarely found in soils.

Health Effects

The hexavalent form of chromium is of major toxicological importance in higher organisms. A variety of chromate (Cr VI) salts are carcinogenic in rats and an excess of lung cancer has been observed among workers in the chromate-producing industry. Cr VI compounds can cause DNA and chromsome damage in animals and humans, and Cr (VI) trioxide is teratogenic in the hamster. Inhalation of hexavalent chromium salts causes irritation and inflammation of the nasal mucosa, and ulceration and perforation of the nasal septum. Cr VI also produces kidney damage in animals and humans. The liver is also sensitive to the toxic effects of hexavalent Cr, but apparently less so than the kidneys or respiratory system. Cr III is less toxic than Cr VI; its main effect in humans is a form of contact dermatitis in sensitive individuals.

Toxicity to Wildlife and Domestic Animals

Chromium is an essential nutrient and is accumulated in a variety of aquatic and marine biota, especially benthic organisms, to levels much higher than in ambient water. Levels in biota, however, usually are lower than levels in the sediments. Passage of chromium through the food chain can be demonstrated. The food chain appears to be a more efficient pathway for chromium uptake than direct uptake from seawater.

Water hardness, temperature, dissolved oxygen, species, and age of the test organism all modify the toxic effects of chromium on aquatic life. Cr III appears to be more acutely toxic to fish than Cr VI; the reverse is true in long term chronic exposure studies.

None of the plants normally used as food or animal feed are chromium accumulators. Chromium absorbed by plants tends to remain primarily in the roots and is poorly translocated to the leaves. There is little tendency for chromium to accumulate along food chains in the trivalent inorganic form. Organic chromium compounds, about which little is known, can have significantly different bioaccumulation tendencies. Little information concerning the toxic effects of chromium on mammalian wildlife and domestic animal species is available.

Regulations and Standards

Ambient Water Quality Criteria (USEPA):

Cr VI:

Aquatic Life (Proposed Criteria)

Freshwater

Acute toxicity: 11 µg/liter
Chronic toxicity: 7.2 µg/liter

Saltwater

Acute toxicity: 1,200 µg/liter
Chronic toxicity: 54 µg/liter

Human Health

Criterion: 50 µg/liter

Cr III:

Aquatic Life (Proposed Criteria)

Freshwater

Acute toxicity: $e^{(0.819[\ln(\text{hardness})]+3.568)}$ µg/liter

Chronic toxicity: $e^{(0.819[\ln(\text{hardness})])+0.537)}$ µg/liter

Saltwater

The available data are not adequate for establishing criteria.

Human Health

Criterion: 170 mg/liter

CAG Unit Risk for inhalation exposure to CR VI (USEPA): 41 $(mg/kg/day)^{-1}$

National Interim Primary Drinking Water Standard: 50 µg/liter

NIOSH Recommended Standards for CR VI: 1 µg/m^3 carcinogenic
25 µg/m^3 noncarcinogenic TWA
50 µg/m^3 noncarcinogenic (15-min sample)

OSHA Standards: OSHA air standards have been set for several chromium compounds. Most recognized or suspected carcinogenic chromium compounds have ceiling limits of 100 µg/m^3.

ACGIH Threshold Limit Values: Several chromium compounds have TWAs ranging from 0.05 to 0.5 mg/m^3. Chromite ore processing (chromate), certain water insoluble Cr VI compounds, and chromates of lead and zinc are recognized or suspected human carcinogens and have 0.05 mg/m^3 TWAs.

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CHRYSENE

Summary

Chrysene is a five-ringed polycyclic aromatic hydrocarbon (PAH). It is rather persistent in the environment; biodegradation is probably the ultimate fate process. Dermal application of chrysene produces skin tumors in mice, and subcutaneous injection produces local sarcomas. Chrysene was found to be mutagenic using several test systems. Although there is little information on other toxic effects of chrysene, carcinogenic PAHs as a group cause skin disorders and have an immunosuppressive effect.

CAS Number: 218-01-9

Chemical Formula: $C_{18}H_{12}$

IUPAC Name: Chrysene

Important Synonyms and Trade Names: 1,2-Benzophenanthrene; benz(a)phenanthrene

Chemical and Physical Properties

Molecular Weight: 228.28

Boiling Point: 448°C

Melting Point: 256°C

Specific Gravity: 1.274 at 20°C

Solubility in Water: 0.002 mg/liter at 25°C

Solubility in Organics: Soluble in ether, alcohol, glacial and acetic acid

Log Octanol/Water Partition Coefficient: 5.61

Vapor Pressure: 10^{-11} to 10^{-6} mm Hg at 20°C

Transport and Fate

Very little specific information concerning the environmental transport and fate of chrysene is available. However, data can be derived with reasonable confidence from information concerning benzo(a)anthracene and other related polycyclic aromatic hydrocarbons (PAHs). Dissolved chrysene may undergo rapid, direct photolysis in aquatic systems. However, the relative importance of this process as an environmental fate is unknown. Singlet oxygen is the oxidant and quinones are the products in photolysis reactions involving polycyclic aromatic hydrocarbons. Free-radical oxidation of chrysene is likely to be slow and is not likely to be a significant fate process. Because chrysene does not contain groups amenable to hydrolysis, this process is not thought to be a significant environmental fate. Volatilization does not appear to be an important transport process.

Chrysene probably accumulates in the sediment and biota portions of the aquatic environment, and adsorption to suspended matter is likely to be the dominant transport process. It is probable that sorption onto sediments, soil particles, and biota is strongly correlated with the organic carbon levels present. Bioaccumulation of chrysene is expected to be short term and is not an important fate process. Although polycyclic aromatic hydrocarbons with four or less aromatic rings, like chrysene, are readily and quickly bioaccumulated, they also are rapidly metabolized and excreted. These kinds of PAHs are degraded by microbes and readily metabolized by multicellular organisms. Degradation by mammals is considered to be incomplete; the parent compound and metabolites are excreted by the urinary system. Biodegradation is probably the ultimate fate process for chrysene. However, the speed and extent of this process are unknown. Biodegradation of PAHs generally occurs more rapidly in soil than in aquatic systems and is also faster in those systems chronically contaminated with these compounds.

Atmospheric transport of chrysene can occur, and chrysene can be returned to aquatic and terrestrial systems by atmospheric fallout and with precipitation. It can enter surface and groundwaters by leaching from polluted soils.

Health Effects

The potential for polycyclic aromatic hydrocarbons to induce malignant transformation dominates the consideration given to health hazards resulting from exposure. This is because overt signs of toxicity are often not produced until the dose is sufficient to produce a high tumor incidence.

No case reports or epidemiological studies on the significance of chrysene exposure to humans are available. However, coal tar and other materials known to be carcinogenic to humans may contain chrysene. Chrysene produces skin tumors in mice following repeated dermal application. High subcutaneous doses are reported to result in a low incidence of tumors with a long induction time in mice. Chrysene is considered to have weak carcinogenic activity compared to benzo(a)pyrene. Chrysene is reported to be mutagenic in a variety of test systems. No information concerning the teratogenic effects of chrysene in humans or experimental animals is available.

Although there is little information concerning other toxic effects of chrysene, it is reported that applying the carcinogenic PAHs to mouse skin leads to the destruction of sebaceous glands, hyperplasia, hyperkeratosis, and ulceration. Workers exposed to materials containing these compounds may exhibit chronic dermatitis, hyperkeratoses, and other skin disorders. Although specific results with chrysene are not reported, it has been shown that many carcinogenic PAHs have an immunosuppressive effect.

Toxicity to Wildlife and Domestic Animals

Adequate data for characterization of the toxicity of chrysene to domestic animals and wildlife are not available.

Regulations and Standards

Ambient Water Quality Criteria (USEPA):

Aquatic Life

The available data are not adequate for establishing criteria.

Human Health

Estimates of the carcinogenic risks associated with lifetime exposure to various concentrations of carcinogenic PAHs in water are:

Risk	Concentration
10^{-5}	28 ng/liter
10^{-6}	2.8 ng/liter
10^{-7}	0.28 ng/liter

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1,2-DICHLOROETHANE

Summary

1,2-Dichloroethane (ethylene dichloride) is a volatile organic solvent, and volatilization and percolation into groundwater may be significant routes of transport. It has a low solubility in water and may be a component in nonaqueous-phase liquids. 1,2-Dichloroethane is carcinogenic in animals and mutagenic in bacterial test systems; it is a suspected human carcinogen.

CAS Number: 107-06-2

Chemical Formula: CH_2ClCH_2Cl

IUPAC Name: 1,2-Dichloroethane

Important Synonyms and Trade Names: Ethylene dichloride, glycol dichloride

Chemical and Physical Properties

Molecular Weight: 98.96

Boiling Point: 83-84°C

Melting Point: -35.4°C

Specific Gravity: 1.253 at 20°C

Solubility in Water: 8 g/liter

Solubility in Organics: Miscible with alcohol, chloroform, and ether

Log Octanol/Water Partition Coefficient: 1.48

Vapor Pressure: 61 mm Hg at 20°C

Flash Point: 15°C (closed cup)

Transport and Fate

The primary method of dispersion from surface water for 1,2-dichloroethane is volatilization. In the atmosphere, 1,2-dichloroethane is rapidly broken down by hydroxylation, although some may be absorbed by atmospheric water and return to the earth by precipitation. No studies on the adsorption of 1,2-dichloroethane onto soil were reported in the literature examined. However, 1,2-dichloroethane has a low octanol/water partition coefficient, is slightly soluble in water, and therefore leaching through the soil into the groundwater is an expected route of dispersal.

Health Effects

1,2-Dichloroethane is carcinogenic in rats and mice, producing a variety of tumors. When administered by gavage, it produced carcinomas of the forestomach and hemangiosarcomas of the circulatory system in male rats; adenocarcinomas of the mammary gland in female rats; lung adenomas in male mice; and lung adenomas, mammary adenocarcinomas, and endometrial tumors in female mice. It is mutagenic when tested using bacterial test systems. Human exposure by inhalation to 1,2-dichloroethane has been shown to cause headache, dizziness, nausea, vomiting, abdominal pain, irritation of the mucous membranes, and liver and kidney dysfunction. Dermatitis may be produced by skin contact. In severe cases, leukocytosis (an excess of white blood cells) may be diagnosed; and internal hemorrhaging and pulmonary edema leading to death may occur. Similar effects are produced in experimental animals.

Toxicity to Wildlife and Domestic Animals

1,2-Dichloroethane is one of the chlorinated ethanes least toxic to aquatic life. For both fresh- and saltwater species, it is acutely toxic at concentrations greater than 118 mg/liter, while chronic toxicity has been observed at 20 mg/liter. 1,2-Dichloroethane is not likely to bioconcentrate, as its steady state bioconcentration factor was 2 and its elimination half-life was less than 2 days in bluegill.

No information on the toxicity of 1,2-dichloroethane to domestic animals or terrestrial wildlife was available in the literature reviewed.

Regulations and Standards

Ambient Water Quality Criteria (USEPA):

Aquatic Life

The available data are not adequate for establishing criteria. However, EPA did report the lowest values known to be toxic in aquatic organisms.

Freshwater

Acute toxicity: 118 mg/liter
Chronic toxicity: 20 mg/liter

Saltwater

Acute toxicity: 113 mg/liter
Chronic toxicity: No available data

Human Health

Estimates of the carcinogenic risks associated with lifetime exposure to various concentrations of 1,2-dichloroethane in water are:

Risk	Concentration
10^{-5}	9.4 µg/liter
10^{-6}	0.94 µg/liter
10^{-7}	0.094 µg/liter

CAG Unit Risk (USEPA): 9.1×10^{-2} $(mg/kg/day)^{-1}$

OSHA Standards: 200 mg/m^3 TWA
400 mg/m^3 Ceiling Level
800 mg/m^3 for 5 min every 3 hr, Peak Concentration

ACGIH Threshold Limit Values: 40 mg/m^3 TWA
60 mg/m^3 STEL

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BIS(2-ETHYLHEXYL)PHTHALATE

Summary

bis(2-Ethylhexyl)phthalate (DEHP) is probably persistent in the environment. It is carcinogenic in rats and mice, causing hepatocellular carcinomas. Teratogenic and reproductive effects have been observed in experimental animals. Chronic exposure to DEHP retarded growth and increased liver and kidney weights in animals.

CAS Number: 117-81-7

Chemical Formula: $C_6H_4(COOCH_2CH(C_2H_5)C_4H_9)_2$

IUPAC Name: bis(2-Ethylhexyl)ester phthalic acid

Important Synonyms and Trade Names: DEHP, Di(2-ethylhexyl)phthalate, bis(2-ethylhexyl)ester phthalic acid

Chemical and Physical Properties

Molecular Weight: 391.0

Boiling Point: 386.9°C at 5 mm Hg

Melting Point: -50°C

Specific Gravity: 0.985

Solubility in Water: 0.4 mg/liter at 25°C

Solubility in Organics: Miscible with mineral oil and hexane

Log Octanol/Water Partition Coefficient: 5.3

Vapor Pressure: 2×10^{-7} mm Hg at 20°C

Flash Point: 218.33°C

Transport and Fate

bis(2-Ethylhexyl)phthalate (DEHP) is the most thoroughly studied of the phthalate esters. It probably hydrolyzes in surface waters, but at such a slow rate that this process is not environmentally significant under most conditions. Photolysis and oxidation do not appear to be important environmental fate processes. Although some researchers suggest that volatilization of DEHP from aqueous solution may be significant under some conditions, it probably is not an important environmental transport process in natural waters. In contrast, there is evidence that this compound can be slowly volatilized from DEHP-containing materials at relatively high temperatures. Consequently, some atmospheric dispersion of DEHP due to vaporization during manufacture, use, or waste disposal probably occurs.

Adsorption onto suspended solids and particulate matter and complexation with natural organic substances are probably the most important environmental transport processes for DEHP. The log octanol/water partition coefficient for DEHP suggests that this compound would be adsorbed onto particulates high in organic matter. This contention is supported by the fact that phthalate esters are commonly found in freshwater and saltwater sediment samples. DEHP can be dispersed from sources of manufacture and use to aquatic and terrestrial systems by complexation with natural organic substances. It readily interacts with the fulvic acid present in humic substances in water and soil, forming a complex that is very soluble in water.

A variety of unicellular and multicellular organisms take up and accumulate DEHP, and bioaccumulation is considered an important fate process. Biodegradation is also considered an important fate process in aquatic systems and soil. DEHP is degraded under most conditions and can be metabolized by multicellular organisms. Therefore, it is unlikely that long-term biomagnification occurs.

Analysis using EPA's Exposure Analysis Modeling System suggests that chemical and biochemical transformation processes for DEHP are slow and that transport processes will predominate both in ecosystems that have long retention times (ponds, lakes) and in those that have short retention times (rivers). If the input of DEHP remains constant, its concentration is expected to increase in aquatic ecosystems. If the input stops, the DEHP present is expected to persist for an undetermined length of time. The oceans are the ultimate sink for DEHP introduced into unimpeded rivers.

Health Effects

DEHP is reported to be carcinogenic in rats and mice, causing increased incidences of hepatocellular carcinomas or neoplastic nodules after oral administration (NTP 1982). Its status as a human carcinogen is considered indeterminate by the International Agency for Research on Cancer (IARC). The results of dominant lethal experiments with mice suggest that

DEHP is mutagenic when injected intraperitoneally. However, most experiments conducted with microorganisms and mammalian cells have failed to demonstrate genotoxic activity. Teratogenic and fetotoxic effects have been observed in experimental animals after oral and intraperitoneal administration. Other reproductive effects, including testicular changes in rats and mice, have also been reported.

DEHP appears to have a relatively low toxicity in experimental animals. The oral, intraperitoneal, and intravenous LD_{50} values reported for DEHP in rats are 31 g/kg, 30.7 g/kg, and 0.25 g/kg, respectively. DEHP is poorly absorbed through the skin, and no irritant response or sensitizing potential from dermal application has been noted in experimental animals or humans.

Chronic exposure to relatively high concentrations of DEHP in the diet has caused retardation of growth and increased liver and kidney weights in experimental animals.

Toxicity to Wildlife and Domestic Animals

Acute median effect values ranged from 1,000 to 11,100 µg/liter DEHP for the freshwater cladoceran *Daphnia magna*. The LC_{50} values for the midge, scud, and bluegill all exceeded the highest concentrations tested, which were 18,000, 32,000, and 770,000 µg/liter, respectively. As these values are greater than the water solubility of the chemical, it is unlikely that DEHP will be acutely toxic to organisms in natural waters. In a chronic toxicity test with *Daphnia magna*, significant reproductive impairment was found at the lowest concentration tested, 3 µg/liter. A chronic toxicity value of 8.4 µg/liter was reported for the rainbow trout. No acute or chronic values were reported for saltwater invertebrates or vertebrates. Reported bioconcentration factors for DEHP in fish and invertebrates range from 14 to 2,680.

Although insufficient data were presented to calculate the acute-chronic ratio for DEHP, it is apparently on the order of 100 to 1,000. Therefore, acute exposure to the chemical is unlikely to affect aquatic organisms adversely, but chronic exposure may have detrimental effects on the environment.

Regulations and Standards

Ambient Water Quality Criteria (USEPA):

Aquatic Life

The available data are not adequate for establishing criteria for bis(2-ethylhexyl)phthalate or for phthalate esters as a group.

Human Health

Criterion: 15 mg/liter

ACGIH Threshold Limit Values: 5 mg/m^3 TWA
10 mg/m^3 STEL

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IRON

Summary

There is some evidence that high concentrations of certain soluble iron salts may be teratogenic. The ingestion of excess amounts of iron can irritate the gastrointestinal tract. Inhaling some iron-containing dusts and fumes can cause siderosis, a type of benign pneumoconiosis.

Background Information

Iron is the fourth most abundant element in the earth's crust. The pure metal is very reactive chemically. It corrodes readily in the presence of oxygen and moisture, forming iron (III) hydroxide [$Fe(OH)_3$].

CAS Number: 7439-89-6

Chemical Formula: Fe

Chemical and Physical Properties

Atomic Weight: 55.847

Boiling Point: 2,750°C

Melting Point: 1,535°C

Specific Gravity: 7.86

Solubility in Water: Insoluble

Solubility in Organics: Soluble in alcohol and ether

Transport and Fate

Elemental iron and many iron compounds, including $Fe(OH)_3$ and the iron oxides, are insoluble in water. Iron also tends to chelate with organic and inorganic matter. Consequently, much of the iron present in aquatic systems tends to partition into the bottom sediments. Iron has relatively low mobility in soil. Atmospheric transport of iron can occur.

Health Effects

Some studies have indicated that inhalation exposure to high concentrations of iron oxide is associated with increased risk of lung and laryngeal cancers in hematite miners and foundry workers. However, the significance of these findings is not established since exposures were to a mixture of substances, including radon gas and decomposition products of synthetic resins. Iron dextran solutions are reported to cause injection site sarcomas in experimental animals. Some iron compounds, notably ferrous sulfate, are reported to have high mutagenic activity in test systems. Intravenous injection of high concentrations of soluble iron salts is reported to cause teratogenic effects, including hydrocephalus and anophthalmia, in various species of experimental animals.

Iron is an essential element in plants and animals. However, the ingestion of excess amounts of iron produces toxic effects, primarily associated with gastrointestinal irritation. Severe poisoning may cause gastrointestinal bleeding, pneumonitis, convulsions, and hepatic toxicity. A dose of about 30 g of a soluble ferric salt is likely to be fatal in humans. Persons ingesting more than 30 mg/kg should be observed for clinical symptoms and possibly hospitalized. Chronic ingestion of excess iron may lead to hemosiderosis or hemochromatosis. Long-term inhalation exposure to iron-containing dusts and fumes, especially iron oxide, can produce siderosis. This condition is considered to be a type of benign pneumoconiosis that does not progress to fibrosis. Exposure to aerosols and mists of soluble iron salts may produce respiratory and skin irritation. The toxic effects of iron in experimental animals are similar to those observed in humans.

Toxicity to Wildlife and Domestic Animals

The available data are not adequate to characterize the toxicity of iron to wildlife or domestic animals. Iron is unlikely to cause ecological toxicity.

Regulations and Standards

OSHA Standard: 10 mg/m^3 TWA (iron oxide fume)

ACGIH Threshold Limit Values:

5 mg/m^3 TWA (iron oxide fume, as Fe)
10 mg/m^3 STEL (iron oxide fume, as Fe)
1 mg/m^3 TWA (soluble iron salts, as Fe)
2 mg/m^3 STEL (soluble iron salts, as Fe)

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LEAD

Summary

Lead is a heavy metal that exists in one of three oxidation states, 0, +2, and +4. There is suggestive evidence that some lead salts are carcinogenic, inducing kidney tumors in mice and rats. Lead is also a reproductive hazard, and it can adversely affect the brain and central nervous system by causing encephalopathy and peripheral neuropathy. Chronic exposure to low levels of lead can cause subtle learning disabilities in children. Exposure to lead can also cause kidney damage and anemia, and it may have adverse effects on the immune system.

CAS Number: 7439-92-1

Chemical Formula: Pb

IUPAC Name: Lead

Chemical and Physical Properties

Atomic Weight: 207.19

Boiling Point: 1,740°C

Melting Point: 327.502°C

Specific Gravity: 11.35 at 20°C

Solubility in Water: Insoluble; some organic compounds are soluble.

Solubility in Organics: Soluble in HNO_3 and hot, concentrated H_2SO_4

Transport and Fate

Some industrially produced lead compounds are readily soluble in water (USEPA 1979). However, metallic lead and the common lead minerals are insoluble in water. Natural compounds of lead are not usually mobile in normal surface or groundwater because the lead leached from ores is adsorbed by ferric hydroxide or combines with carbonate or sulfate ions to form insoluble compounds.

Movement of lead and its inorganic and organolead compounds as particulates in the atmosphere is a major environmental transport process. Lead carried in the atmosphere can be removed by either wet or dry deposition. Although little evidence is available concerning the photolysis of lead compounds in natural waters, photolysis in the atmosphere occurs readily. These atmospheric processes are important in determining the form of lead entering aquatic and terrestrial systems.

The transport of lead in the aquatic environment is influenced by the speciation of the ion. Lead exists mainly as the divalent cation in most unpolluted waters and becomes adsorbed into particulate phases. However, in polluted waters organic complexation is most important. Volatilization of lead compounds probably is not important in most aquatic environments.

Sorption processes appear to exert a dominant effect on the distribution of lead in the environment. Adsorption to inorganic solids, organic materials, and hydrous iron and manganese oxides usually controls the mobility of lead and results in a strong partitioning of lead to the bed sediments in aquatic systems. The sorption mechanism most important in a particular system varies with geological setting, pH, Eh, availability of ligands, dissolved and particulate ion concentrations, salinity, and chemical composition. The equilibrium solubility of lead with carbonate, sulfate, and sulfide is low. Over most of the normal pH range, lead carbonate, and lead sulfate control solubility of lead in aerobic conditions, and lead sulfide and the metal control solubility in anaerobic conditions. Lead is strongly complexed to organic materials present in aquatic systems and soil. Lead in soil is not easily taken up by plants, and therefore its availability to terrestrial organisms is somewhat limited.

Bioaccumulation of lead has been demonstrated for a variety of organisms, and bioconcentration factors are within the range of 100-1,000. Microcosm studies indicate that lead is not biomagnified through the food chain. Biomethylation of lead by microorganisms can remobilize lead to the environment. The ultimate sink of lead is probably the deep oceans.

Health Effects

There is evidence that several lead salts are carcinogenic in mice or rats, causing tumors of the kidneys after either oral or parenteral administration. Data concerning the carcinogenicity of lead in humans are inconclusive. The available data are not sufficient to evaluate the carcinogenicity of organic lead compounds or metallic lead. There is equivocal evidence that exposure to lead causes genotoxicity in humans and animals. The available evidence indicates that lead presents a hazard to reproduction and exerts a toxic effect on conception, pregnancy, and the fetus in humans and experimental animals (USEPA 1977, 1980).

Many lead compounds are sufficiently soluble in body fluids to be toxic (USEPA 1977, 1980). Exposure of humans or experimental animals to lead can result in toxic effects in the brain and central nervous system, the peripheral nervous system, the kidneys, and the hematopoietic system. Chronic exposure to inorganic lead by ingestion or inhalation can cause lead encephalopathy, and severe cases can result in permanent brain damage. Lead poisoning may cause peripheral neuropathy in adults and children, and permanent learning disabilities that are clinically undetectable in children may be caused by exposure to relatively low levels. Short-term exposure to lead can cause reversible kidney damage, but prolonged exposure at high concentrations may result in progressive kidney damage and possibly kidney failure. Anemia, due to inhibition of hemoblobin synthesis and a reduction in the life span of circulating red blood cells, is an early manifestation of lead poisoning. Several studies with experimental animals suggest that lead may interfere with various aspects of the immune response.

Toxicity to Wildlife and Domestic Animals

Freshwater vertebrates and invertebrates are more sensitive to lead in soft water than in hard water (USEPA 1980, 1983). At a hardness of about 50 mg/liter $CaCO_3$, the median effect concentrations for nine families range from 140 µg/liter to 236,600 µg/liter. Chronic values for *Daphnia magna* and the rainbow trout are 12.26 and 83.08 µg/liter, respectively, at a hardness of about 50 mg/liter. Acute-chronic ratios calculated for three freshwater species ranged from 18 to 62. Bioconcentration factors, ranging from 42 for young brook trout to 1,700 for a snail, were reported. Freshwater algae show an inhibition of growth at concentrations above 500 µg/liter.

Acute values for twelve saltwater species range from 476 µg/liter for the common mussel to 27,000 µg/liter for the soft-shell clam. Chronic exposure to lead causes adverse effects in mysid shrimp at 37 µg/liter, but not at 17 µg/liter. The acute-chronic ratio for this species is 118. Reported bioconcentration factors range from 17.5 for the Quahog clam to 2,570 for the blue mussel. Saltwater algae are adversely affected at approximate lead concentrations as low as 15.8 µg/liter.

Although lead is known to occur in the tissue of many free-living wild animals, including birds, mammals, fishes, and invertebrates, reports of poisoning usually involve waterfowl. There is evidence that lead, at concentrations occasionally found near roadsides and smelters, can eliminate or reduce populations of bacteria and fungi on leaf surfaces and in soil. Many of these microorganisms play key roles in the decomposer food chain.

Cases of lead poisoning have been reported for a variety of domestic animals, including cattle, horses, dogs, and cats. Several types of anthropogenic sources are cited as the source of lead in these reports. Because of their curiosity and their indiscriminate eating habits, cattle experience the greatest incidence of lead toxicity among domestic animals.

Regulations and Standards

Ambient Water Quality Criteria (USEPA):

Aquatic Life (Proposed Criteria)

The concentrations below are for active lead, which is defined as the lead that passes through a 0.45-μm membrane filter after the sample is acidified to pH 4 with nitric acid.

Freshwater

Acute toxicity: $e^{(1.34\ [\ln(\text{hardness})]\ -\ 2.014)}$ μg/liter

Chronic toxicity: $e^{(1.34\ [\ln(\text{hardness})]\ -\ 5.245)}$ μg/li

Saltwater

Acute toxicity: 220 μg/liter
Chronic toxicity: 8.6 μg/liter

Human Health

Criterion: 50 μg/liter

Primary Drinking Water Standard: 50 μg/liter

NIOSH Recommended Standard: 0.10 mg/m^3 TWA (inorganic lead)

OSHA Standard: 50 μg/m^3 TWA

ACGIH Threshold Limit Values:

0.15 mg/m^3 TWA (inorganic dusts and fumes)
0.45 mg/m^3 STEL (inorganic dusts and fumes)

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MERCURY

Summary

Both organic and inorganic forms of mercury are reported to be teratogenic and embryotoxic in experimental animals. In humans, prenatal exposure to methylmercury has been associated with brain damage. Other major target organs for organic mercury compounds in humans are the central and peripheral nervous system and the kidney. In animals, toxic effects also occur in the liver, heart, gonads, pancreas, and gastrointestinal tract. Inorganic mercury is generally less acutely toxic than organic mercury compounds, but it does affect the central nervous system adversely.

Background Information

Several forms of mercury, including insoluble elemental mercury, inorganic species, and organic species, can exist in the environment. In general, the mercurous (+1) salts are much less soluble than the more commonly found mercuric (+2) salts. Mercury also forms many stable organic complexes that are generally much more soluble in organic liquids than in water. The nature and solubility of the chemical species that occur in an environmental system depend on the redox potential and the pH of the environment.

CAS Number: 7439-97-6

Chemical Formula: Hg

IUPAC Name: Mercury

Chemical and Physical Properties (Metal)

Atomic Weight: 200.59

Boiling Point: 356.58°C

Melting Point: -38.87°C

Specific Gravity: 13.5939 at 20°C

Solubility in Water: 81.3 µg/liter at 30°C; some salts and organic compounds are soluble

Solubility in Organics: Depends on chemical species

Vapor Pressure: 0.0012 mm Hg at 20°C

Transport and Fate

Mercury and certain of its compounds, including several inorganic species and dimethyl mercury, can volatilize to the atmosphere from aquatic and terrestrial sources. Volatilization is reduced by conversion of metallic mercury to complexed species and by deposition of HgS in reducing sediments, but even so atmospheric transport is the major environmental distribution pathway for mercury. Precipitation is the primary mechanism for removal of mercury from the atmosphere. Photolysis is important in the breakdown of airborne mercurials and may be important in some aquatic systems. Adsorption onto suspended and bed sediments is probably the most important process determining the fate of mercury in the aquatic environment. Sorption is strongest into organic materials. Mercury in soils is generally complexed to organic compounds.

Virtually any mercury compound can be remobilized in aquatic systems by microbial conversion to methyl and dimethyl forms. Conditions reported to enhance biomethylation include large amounts of available mercury, large numbers of bacteria, the absence of strong complexing agents, near neutral pH, high temperatures, and moderately aerobic environments. Mercury is strongly bioaccumulated by numerous mechanisms. Methylmercury is the most readily accumulated and retained form of mercury in aquatic biota, and once it enters a biological system it is very difficult to eliminate.

Health Effects

When administered by intraperitoneal injection, metallic mercury produces implantation site sarcomas in rats. No other studies were found connecting mercury exposure with carcinogenic effects in animals or humans. Several mercury compounds exhibit a variety of genotoxic effects in eukaryotes. In general, organic mercury compounds are more toxic than inorganic compounds. Although brain damage due to prenatal exposure to methylmercury has occurred in human populations, no conclusive evidence is available to suggest that mercury causes anatomical defects in humans. Embryotoxicity and teratogenicity of methylmercury has been reported for a variety of experimental animals. Mercuric chloride is reported to be teratogenic in experimental animals. No conclusive results concerning the teratogenic effects of mercury vapor are available.

In humans, alkyl mercury compounds pass through the blood brain barrier and the placenta very rapidly, in contrast to inorganic mercury compounds. Major target organs are the central and peripheral nervous systems, and the kidney. Methylmercury is particularly hazardous because of the difficulty of eliminating it from the body. In experimental animals, organic mercury compounds can produce toxic effects in the gastrointestinal tract, pancreas, liver, heart, and gonads, with involvement of the endocrine, immunocompetent, and central nervous systems.

Elemental mercury is not highly toxic as an acute poison. However, inhalation of high concentrations of mercury vapor can cause pneumonitis, bronchitis, chest pains, dyspnea, coughing, stomatitis, gingivitis, salivation, and diarrhea. Soluble mercuric salts are highly poisonous on ingestion, with oral LD_{50} values of 20 to 60 mg/kg reported. Mercurous compounds are less toxic when administered orally. Acute exposure to mercury compounds at high concentrations causes a variety of gastrointestinal symptoms and severe anuria with uremia. Signs and symptoms associated with chronic exposure involve the central nervous system and include behavioral and neurological disturbances.

Toxicity to Wildlife and Domestic Animals

The toxicity of mercury compounds has been tested in a wide variety of aquatic organisms. Although methylmercury appears to be more toxic than inorganic mercuric salts, few acute or chronic toxicity tests have been conducted with it. Among freshwater species, the 96-hour LC_{50} values for inorganic mercuric salts range from 0.02 µg/liter for crayfish to 2,000 µg/liter for caddisfly larvae. Acute values for methylmercuric compounds and other mercury compounds are only available for fishes. In rainbow trout, methylmercuric chloride is about ten times more toxic to rainbow trout than mercuric chloride, which is acutely toxic at about 300 µg/liter at 10°C. Methylmercury is the most chronically toxic of the tested compounds, with chronic values for Daphnia magna and brook trout of 1.00 and 0.52 µg/liter, respectively. The acute-chronic ratio for Daphnia magna is 3.2.

Mean acute values for saltwater species range from 3.5 to 1,680 µg/liter. In general, molluscs and crustaceans are more sensitive than fish to the acute toxic effects of mercury. A life-cycle experiment with the mysid shrimp showed that inorganic mercury at a concentration of 1.6 µg/liter significantly influences time of appearance of first brood, time of first spawn, and productivity. The acute-chronic ratio for the mysid shrimp is 2.9.

Chronic dietary exposure of chickens to mercuric chloride at growth inhibitory levels causes immune suppression, with a differential reduction effect on specific immunoglobulins

Regulations and Standards

Ambient Water Quality Criteria (USEPA):

Aquatic Life (Proposed Criteria)

Freshwater

Acute toxicity: 1.1 μg/liter
Chronic toxicity: 0.20 μg/liter

Saltwater

Acute toxicity: 1.9 μg/liter
Chronic toxicity: 0.10 μg/liter

Human Health

Criterion: 144 ng/liter

Primary Drinking Water Standard: 0.002 mg/liter

NIOSH Recommended Standard: 0.05 mg/m^3 TWA (inorganic mercury)

OSHA Standard: 0.1 mg/m^3 Ceiling Level

ACGIH Threshold Limit Values:

0.01 mg/m^3 TWA (alkyl compounds)
0.03 mg/m^3 STEL (alkyl compounds)
0.05 mg/m^3 TWA (vapor)
0.1 mg/m^3 TWA (aryl and inorganic compounds)

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NICKEL

Summary

In a number of epidemiological studies, occupational exposure to nickel compounds has been associated with excess cancer of the lung and nasal cavity. In addition, inhalation exposure to nickel subsulfide and nickel carbonyl has been shown to cause cancer in rats, while studies of other nickel compounds administered to animals by other routes have reported carcinogenic effects as well. Several nickel compounds are mutagenic and can cause cell transformation. In humans, nickel and nickel compounds can cause a sensitization dermatitis. The chronic toxicity of nickel to aquatic organisms is high.

Background Information

The commonly occurring valences of nickel are 0, +1, +2, and +3, with +4 rarely encountered. Although elemental nickel is seldom found in nature and is not soluble in water, many nickel compounds are highly soluble in water. Nickel is almost always found in the divalent oxidation state in aquatic systems.

CAS Number: 7440-02-0

Chemical Formula: Ni

IUPAC Name: Nickel

Chemical and Physical Properties

Atomic Weight: 58.71

Boiling Point: 2,732°C

Melting Point: 1,453°C

Specific Gravity: 8.902 at 25°C

Solubility in Water: Insoluble; some salts are soluble

Solubility in Organics: Depends on the properties of the specific nickel salt

Vapor Pressure: 1 mm Hg at 1,810°C

Transport and Fate

Nickel is a highly mobile metal in aquatic systems because many nickel compounds are highly soluble in water. However, the insoluble sulfide is formed under reducing conditions and in the presence of sulfur. Above pH 9, precipitation of the hydroxide or carbonate exhibits some control on nickel mobility. In aerobic environments below pH 9, soluble compounds are formed with hydroxide, carbonate, sulfate, and organic ligands.

In natural, unpolluted waters, sorption and coprecipitation processes involving hydrous iron and manganese oxides are probably at least moderately effective in limiting the mobility of nickel. In more organic-rich, polluted waters, it appears that little sorption of nickel is likely. The lack of other controls on nickel mobility probably makes incorporation into bed sediments an important fate of nickel in surface waters. However, much of the nickel entering the aquatic environment will be transported to the oceans.

In general, nickel is not accumulated in significant amounts by aquatic organisms. Bioconcentration factors are usually on the order of 100 to 1,000. Uptake of nickel from the soil by plants can also occur. Photolysis, volatilization, and biotransformation are not important environmental fate processes for nickel. However, atmospheric transport of nickel and nickel compounds on particulate matter can occur.

Health Effects

There is extensive epidemiological evidence indicating excess cancer of the lung and nasal cavity for workers at nickel refineries and smelters, and weaker evidence for excess risk in workers at nickel electroplating and polishing operations. Respiratory tract cancers have occurred in excess at industrial facilities that are metallurgically diverse in their operations. The nickel compounds that have been implicated as having carcinogenic potential are insoluble dusts of nickel subsulfide and nickel oxides, the vapor of nickel carbonyl, and soluble aerosols of nickel sulfate, nitrate, or chloride. Inhalation studies with experimental animals suggest that nickel subsulfide and nickel carbonyl are carcinogenic in rats. Evidence for the carcinogenicity of nickel metal and other compounds is relatively weak or inconclusive. Studies with experimental animals indicate that nickel compounds can also produce various types of malignant tumors in experimental animals after administration by other routes, including subcutaneous, intramuscular, implantation, intravenous, intrarenal, and intrapleural. Carcinogenic potential is not strongly dependent on route or site of administration but appears to be inversely related to the solubility of the compounds in aqueous media. Insoluble compounds, such as nickel dust, nickel sulfide, nickel carbonate, nickel oxide, nickel carbonyl, and nickelocene are carcinogenic, whereas soluble nickel salts such as nickel chloride, nickel sulfate, and nickel ammonium sulfate, are not.

Mammalian cell transformation data indicate that several nickel compounds are mutagenic and can cause chromosomal alterations. The available information is inadequate for assessing teratogenic and reproductive effects of nickel in humans and experimental animals.

Dermatitis and other dermatological effects are the most frequent effects of exposure to nickel and nickel-containing compounds. The dermatitis is a sensitization reaction. Most information regarding acute toxicity of nickel involves inhalation exposure to nickel carbonyl. Clinical manifestations of acute poisoning include both immediate and delayed symptoms. Acute chemical pneumonitis is produced, and death may occur at exposures of 30 ppm (107 mg/m^3) for 30 minutes. Rhinitis, nasal sinusitis, and nasal mucosal injury are among the effects reported among workers chronically exposed to various nickel compounds. Studies with experimental animals suggest that nickel and nickel compounds have relatively low acute and chronic oral toxicity.

Toxicity to Wildlife and Domestic Animals

In freshwater, toxicity depends on hardness; nickel tends to be more toxic in softer water. Acute values for exposure to a variety of nickel salts, expressed as nickel, range from 510 µg/liter for *Daphnia magna* to 46,200 µg/liter for banded killifish at comparable hardness levels. Chronic values range from 14.8 µg/liter for *Daphnia magna* in soft water to 530 µg/liter for the fathead minnow in hard water. Acute-chronic ratios for *Daphnia magna* range from 14 in hard water to 13 in soft water, and are approximately 50 in both hard and soft water for the fathead minnow. Residue data for the fathead minnow indicate a bioconcentration factor of 61. Freshwater algae experience reduced growth at nickel concentrations as low as 100 µg/liter.

Acute values for saltwater species range from 152 µg/liter for mysid shrimp to 350,000 µg/liter for the mummichog. A chronic value of 92.7 µg/liter is reported for the mysid shrimp, which gives an acute-chronic ratio of 5.5 for the species. Reduced growth is seen in saltwater algae at concentrations as low as 1,000 µg/liter. Bioconcentration factors ranging from 299 to 416 have been reported for the oyster and mussel.

Regulations and Standards

Ambient Water Quality Criteria (USEPA):

Aquatic Life

Freshwater

Acute toxicity: $e^{(0.76\ [\ln(\text{hardness})] + 4.02)}$ µg/liter

Chronic toxicity: $e^{(0.76\ [\ln(\text{hardness})] + 1.06)}$ µg/liter

Saltwater

Acute toxicity: 140 µg/liter
Chronic toxicity: 7.1 µg/liter

Human Health

Criterion: 13.4 µg/liter

CAG Unit Risk (USEPA): 1.15 $(mg/kg/day)^{-1}$

NIOSH Recommended Standard: 15 µg/m^3 TWA (inorganic nickel)

OSHA Standard: 1 mg/m^3 (metal and soluble compounds, as nickel)

ACGIH Threshold Limit Values:

0.1 mg/m^3 TWA (soluble compounds, as nickel)
0.3 mg/m^3 STEL (soluble compounds, as nickel)
0.35 mg/m^3 TWA (nickel carbonyl, as nickel)
1 mg/m^3 TWA (nickel sulfide roasting, fume and dust, as nickel; human carcinogen)

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TETRACHLOROETHYLENE

Summary

Tetrachloroethylene (PCE, perchloroethylene) induced liver tumors when administered orally to mice and was found to be mutagenic using a microbial assay system. Reproduction toxicity was observed in pregnant rats and mice exposed to high concentrations. Animals exposed by inhalation to tetrachloroethylene exhibited liver, kidney, and central nervous system damage.

CAS Number: 127-18-4

Chemical Formula: C_2Cl_4

IUPAC Name: Tetrachloroethene

Important Synonyms and Trade Names: Perchloroethylene, PCE

Chemical and Physical Properties

Molecular Weight: 165.83

Boiling Point: 121°C

Melting Point: -22.7°C

Specific Gravity: 1.63

Solubility in Water: 150 to 200 mg/liter at 20°C

Solubility in Organics: Soluble in alcohol, ether, and benzene

Log Octanol/Water Partition Coefficient: 2.88

Vapor Pressure: 14 mm Hg at 20°C

Transport and Fate

Tetrachloroethylene (PCE) rapidly volatiziles into the atmosphere where it reacts with hydroxyl radicals to produce HCl, CO, CO_2 and carboxylic acid. This is probably the most important transport and fate process for tetrachloroethylene in the environment. PCE will leach into the groundwater, especially in soils of low organic content. In soils with high levels of organics, PCE adsorbs to these materials and can be bioaccumulated to some degree. However, it is unclear if tetrachloroethylene bound to organic material can be degraded by microorganisms or must be desorbed to be destroyed. There is some evidence that higher organisms can metabolize PCE.

Health Effects

Tetrachloroethylene was found to produce liver cancer in male and female mice when administered orally by gavage (NCI 1977). Unpublished gavage studies in rats and mice performed by the National Toxicology Program (NTP) showed hepatocellular carcinomas in mice and a slight, statistically insignificant increase in a rare type of kidney tumor.[1] NTP is also conducting an inhalation carcinogenicity study. Elevated mutagenic activity was found in Salmonella strains treated with tetrachloroethylene. Delayed ossification of skull bones and sternebrae were reported in offspring of pregnant mice exposed to 2,000 mg/m^3 of tetrachloroethylene for 7 hours/day on days 6-15 of gestation. Increased fetal resorptions were observed after exposure of pregnant rats to tetrachloroethylene. Renal toxicity and hepatotoxicity have been noted following chronic inhalation exposure of rats to tetrachloroethylene levels of 1,356 mg/m^3. During the first 2 weeks of a subchronic inhalation study, exposure to concentrations of 1,622 ppm (10,867 mg/m^3) of tetrachloroethylene produced signs of central nervous system depression, and cholinergic stimulation was observed among rabbits, monkeys, rats, and guinea pigs.

Toxicity to Wildlife and Domestic Animals

Tetrachloroethylene is the most toxic of the chloroethylenes to aquatic organisms but is only moderately toxic relative to other types of compounds. The limited acute toxicity data indicate that the LC_{50} value for saltwater and freshwater species are similar, around 10,000 µg/liter; the trout was the most sensitive (LC_{50} = 4,800 µg/liter). Chronic values were 840 and 450 µg/liter for freshwater and saltwater species, respectively, and an acute-chronic ratio of 19 was calculated.

No information on the toxicity of tetrachloroethylene to terrestrial wildlife or domestic animals was available in the literature reviewed.

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[1] J. Mennear, NTP Chemical Manager; personal communication, 1984.

AR301510

Regulations and Standards

Ambient Water Quality Criteria (USEPA):

Aquatic Life

The available data are not adequate for establishing criteria. However, EPA did report the lowest values known to be toxic to aquatic organisms.

Freshwater

Acute toxicity: 5,280 μg/liter
Chronic toxicity: 840 μg/liter

Saltwater

Acute toxicity: 10,200 μg/liter
Chronic toxicity: 450 μg/liter

Human Health

Estimates of the carcinogenic risks associated with lifetime exposure to various concentrations of tetrachloroethylene in water are:

Risk	Concentration
10^{-5}	8.0 μg/liter
10^{-6}	0.8 μg/liter
10^{-7}	0.08 μg/liter

CAG Unit Risk (USEPA): 5.1×10^{-2} $(mg/kg/day)^{-1}$

NIOSH Recommended Standards (air): 335 mg/m^3 TWA
670 mg/m^3 15-min Ceiling Level

OSHA Standards (air): 670 mg/m^3 TWA
1,340 mg/m^3 Ceiling Level
2,010 mg/m^3 for 5 min every 3 hr, Peak Level

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TRICHLOROETHYLENE

Summary

Trichloroethylene (TCE) induced hepatocellular carcinomas in mice and was mutagenic when tested using several microbial assay systems. Chronic inhalation exposure to high concentrations caused liver, kidney, and neural damage and dermatological reactions in animals.

CAS Number: 79-01-6

Chemical Formula: C_2HCl_3

IUPAC Name: Trichloroethene

Important Synonyms and Trade Names: Trichloroethene, TCE, and ethylene trichloride

Chemical and Physical Properties

Molecular Weight: 131.5

Boiling Point: 87°C

Melting Point: -73°C

Specific Gravity: 1.4642 at 20°C

Solubility in Water: 1,000 mg/liter

Solubility in Organics: Soluble in alcohol, ether, acetone, and chloroform

Log Octanol/Water Partition Coefficient: 2.29

Vapor Pressure: 60 mm Hg at 20°C

Vapor Density: 4.53

Transport and Fate

Trichloroethylene (TCE) rapidly volatilizes into the atmosphere where it reacts with hydroxyl radicals to produce hydrochloric acid, carbon monoxide, carbon dioxide, and carboxylic acid. This is probably the most important transport and fate process for trichloroethylene in surface water and in the upper layer of soil. TCE adsorbs to organic materials and can be bioaccumulated to some degree. However, it is unclear whether trichloroethylene bound to organic material can be degraded by microorganisms or must be desorbed to be destroyed. There is some evidence that higher organisms can metabolize TCE. Trichloroethylene leaches into the groundwater fairly readily, and it is a common contaminant of groundwater around hazardous waste sites.

Health Effects

Trichloroethylene is carcinogenic to mice after oral administration, producing hepatocellular carcinomas (NCI 1976, NTP 1982). It was found to be mutagenic using several microbial assay systems. Trichloroethylene does not appear to cause reproductive toxicity or teratogenicity. TCE has been shown to cause renal toxicity, hepatotoxicity, neurotoxicity, and dermatological reactions in animals following chronic exposure to levels greater than 2,000 mg/m^3 for 6 months. Trichloroethylene has low acute toxicity; the acute oral LD_{50} value in several species ranged from 6,000 to 7,000 mg/kg.

Toxicity to Wildlife and Domestic Animals

There was only limited data on the toxicity of trichloroethylene to aquatic organisms. The acute toxicity to freshwater species was similar in the three species tested, with LC_{50} values of about 50 mg/liter. No LC_{50} values were available for saltwater species. However, a dose of 2 mg/liter caused erratic swimming and loss of equilibrium in the grass shrimp. No chronic toxicity tests were reported.

No information on the toxicity of trichloroethylene to domestic animals or terrestrial wildlife was available in the literature reviewed.

Regulations and Standards

Ambient Water Quality Criteria (USEPA):

Aquatic Toxicity

The available data are not adequate for establishing criteria. However, EPA did report the lowest values known to be toxic in aquatic organisms.

Freshwater

Acute toxicity: 45 mg/liter
Chronic toxicity: No available data

Saltwater

Acute toxicity: 2 mg/liter
Chronic toxicity: No available data

Human Health

Estimates of the carcinogenic risks associated with lifetime exposure to various concentrations of trichloroethylene in water are:

Risk	Concentration
10^{-5}	27 μg/liter
10^{-6}	2.7 μg/liter
10^{-7}	0.27 μg/liter

CAG Unit Risk (USEPA): 1.1×10^{-2} $(mg/kg/day)^{-1}$

NIOSH Recommended Standards (air): 540 mg/m^3 TWA
760 mg/m^3 10-min Ceiling Level

OSHA Standards (air): 540 mg/m^3 TWA
1,075 mg/m^3/15-min Ceiling Level
1,620 mg/m^3 for 5 min every 3 hr, Peak Concentration

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ZINC

Summary

Ingestion of excessive amounts of zinc can cause fever, vomiting, and stomach cramps. Zinc oxide fumes can cause metal fume fever. Inhalation of mists or fumes may irritate the respiratory tract, and contact with zinc chloride may irritate the eyes and skin. High levels of zinc in the diet have been shown to retard growth and produce defective mineralization of bone.

Background Information

Zinc generally exists in nature as a salt with a valence of +2, although it is also found in four other stable valences.

CAS Number: 7440-66-6

Chemical Formula: Zn

IUPAC Name: Zinc

Chemical and Physical Properties

Atomic Weight: 65.38

Boiling Point: 907°C

Melting Point: 419.58°C

Specific Gravity: 7.133 at 25°C

Solubility in Water: Insoluble; some salts are soluble

Solubility in Organics: Soluble in acid and alkali

Vapor Pressure: 1 mm Hg at 487°C

Transport and Fate

Zinc can occur in both suspended and dissolved forms. Dissolved zinc may occur as the free (hydrated) zinc ion or as dissolved complexes and compounds with varying degrees of stability and toxicity. Suspended (undissolved) zinc may be dissolved following minor changes in water chemistry or may be sorbed to suspended matter. The predominant fate of zinc in aerobic aquatic systems is sorption of the divalent cation by hydrous iron and manganese oxides, clay minerals, and organic material. The efficiency of these materials in removing zinc from solution varies according to their compositions and concentrations; the pH and salinity of the water; the concentrations of complexing ligands; and the concentration of zinc. Concentrations of zinc in suspended and bed sediments always exceed concentrations in ambient water. In reducing environments, precipitation of zinc sulfide limits the mobility of zinc. However, under aerobic conditions, precipitation of zinc compounds is probably important only where zinc is present in high concentrations. Zinc tends to be more readily sorbed at higher pH than lower pH and tends to be desorbed from sediments as salinity increases. Compounds of zinc with the common ligands of surface waters are soluble in most neutral and acidic solutions, so that zinc is readily transported in most unpolluted, relatively organic-free waters.

The relative mobility of zinc in soil is determined by the same factors affecting its transport in aquatic systems. Atmospheric transport of zinc is also possible. However, except near sources such as smelters, zinc concentrations in air are relatively low and fairly constant.

Since it is an essential nutrient, zinc is strongly bioaccumulated even in the absence of abnormally high ambient concentrations. Zinc does not appear to be biomagnified. Although zinc is actively bioaccumulated in aquatic systems, the biota appear to represent a relatively minor sink compared to the sediments. Zinc is one of the most important metals in biological systems. Since it is actively bioaccumulated, the environmental concentrations of zinc probably exhibit seasonal fluctuations.

Health Effects

Testicular tumors have been produced in rats and chickens when zinc salts are injected intratesticularly, but not when other routes of administration are used. Zinc may be indirectly important with regard to cancer since its presence seems to be necessary for the growth of tumors. Laboratory studies suggest that although zinc-deficient animals may be more susceptible to chemical induction of cancer, tumor growth is slower in these animals. There is no evidence that zinc deficiency has any etiological role in human cancer. There are no data available to suggest that zinc is mutagenic or teratogenic in animals or humans.

Zinc is an essential trace element that is involved in enzyme functions, protein synthesis, and carbohydrate metabolism. Ingestion of excessive amounts of zinc may cause fever, vomiting, stomach cramps, and diarrhea. Fumes of freshly formed zinc oxide can penetrate deep into the alveoli and cause metal fume fever. Zinc oxide dust does not produce this disorder. Contact with zinc chloride can cause skin and eye irritation. Inhalation of mists or fumes may irritate the respiratory and gastrointestinal tracts. Zinc in excess of 0.25% in the diet of rats causes growth retardation, hypochromic anemia, and defective mineralization of bone. No zinc toxicity is observed at dietary levels below 0.25%.

Studies with animals and humans indicate that metabolic changes may occur due to the interaction of zinc and other metals in the diet. Exposure to cadmium can cause changes in the distribution of zinc, with increases in the liver and kidneys, organs where cadmium also accumulates. Excessive intake of zinc may cause copper deficiencies and result in anemia. Interaction of zinc with iron or lead may also lead to changes that are not produced when the metals are ingested individually.

Toxicity to Wildlife and Domestic Animals

Zinc produces acute toxicity in freshwater organisms over a range of concentrations from 90 to 58,100 μg/liter and appears to be less toxic in harder water. Acute toxicity is similar for freshwater fish and invertebrates. Chronic toxicity values range from 47 to 852 μg/liter and appear to be relatively unaffected by hardness. A final acute-chronic ratio for freshwater species of 3.0 has been reported. Although most freshwater plants appear to be insensitive to zinc, one species, the alga Selenastrum capricornutum, exhibited toxic effects at concentrations from 30 to 700 μg/liter. Reported acute toxicity values range from 2,730 to 83,000 μg/liter for saltwater fish and from 166 to 55,000 μg/liter for invertebrate saltwater species. Zinc produces chronic toxicity in the mysid shrimp at 166 μg/liter. The final acute-chronic ratio for saltwater species is 3.0. Toxic effects are observed in saltwater plant species at zinc concentrations of 50 to 25,000 μg/liter. Bioconcentration factors of edible portions of aquatic organisms range from 43 for the soft-shell clam to 16,700 for the oyster.

Zinc poisoning has occurred in cattle. In one outbreak, poisoning was caused by food accidentally contaminated with zinc at a concentration of 20 g/kg. An estimated intake of 140 g of zinc per cow per day for about 2 days was reported. The exposed cows exhibited severe enteritis, and some died or had to be slaughtered. Postmortem findings showed severe pulmonary emphysema with changes in the myocardium, kidneys, and liver. Zinc concentrations in the liver were extremely high. Based on relatively limited data, some researchers have speculated that exposure to excessive amounts of zinc may constitute a hazard to horses. Laboratory studies and findings in foals living near lead-zinc smelters suggest that excessive exposure to zinc may produce bone changes, joint afflictions, and lameness. In pigs given dietary zinc at concentrations greater than 1,000 mg/kg, decreased food intake and weight gain were observed. At dietary levels greater than 2,000 mg/kg, deaths occurred as soon as 2 weeks after exposure. Severe gastrointestinal changes and brain damage, both of which were accompanied by hemorrhages, were observed, as well as changes in the joints. High concentrations of zinc were found in the liver.

Regulations and Standards

Ambient Water Quality Criteria (USEPA):

Aquatic Life

Freshwater

Acute toxicity: $e^{(0.83[\ln(\text{hardness})] + 1.95)}$ µg/liter
Chronic toxicity: 47 µg/liter

Saltwater

Acute toxicity: 170 µg/liter
Chronic toxicity: 58 µg/liter

Human Health

Organoleptic criterion: 5 mg/liter

Secondary Drinking Water Standard: 5 mg/liter

NIOSH Recommended Standard: 5 mg/m^3 (zinc oxide)

OSHA Standard: 5 mg/m^3 TWA (zinc oxide)

ACGIH Threshold Limit Values:

Zinc chloride fume:	1 mg/m^3 TWA
	2 mg/m^3 STEL
Zinc oxide fume:	5 mg/m^3 TWA
	10 mg/m^3 STEL
Zinc oxide dust:	10 mg/m^3 TWA (nuisance particulate)
Zinc stearate:	10 mg/m^3 TWA (nuisance particulate)
	20 mg/m^3 STEL

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Benzo(a)pyrene and Benzo(b)fluoronthene

Summary

Benzo(a)pyrene (BaP) and benzo(b)fluoranthene (BbF) are two of many compounds in a class of materials known as Polynuclear Aromatic Hydrocarbons (PAHs). PAHs can be formed in any hydrocarbon combustion process and may be released from oil spills. The major sources of PAHs in the environment are stationary sources such as heat and power generation plants. PAHs are also produced during the combustion of coal refuse piles, outcrops, and abandoned coal mines; residential external combustion of bituminous coal; coke manufacture; and residential external combustion of anthracite coal. Because of the large number of sources, most people have been exposed to PAHs at low levels.

CAS Number: 50-32-8 (BaP)
205-99-2 (BbF)

Chemical Formula: $C_{20} H_{12}$

Chemical and Physical Properties

Atomic weight -	252.3
Boiling Point:	495°C (at 1 atm) (BaP)
Melting Point:	179°c (BaP) 167-168°C (BbF)
Specific Gravity:	1.351 (BaP)
Solubility in Water:	3.8 ug/l (BaP) 14 ug/l (BbF)
Vapor Pressure:	5.6 X 10-9 mmHg (BaP) 5.0 X 10-7 mmHg (BbF)
Vapor Density:	----------------

Transport and Fate

Nearly all direct releases of BaP and BbF are to the atmosphere. Small amounts are released to water and land. Both compounds are removed from the atmosphere by photo-chemical oxidation and dry or wet precipitation. Half-lines in air are from 1 to 6 days for BaP and approximately 5.5 days for BbF. PAHs that reach the soil are very persistent with half-lines in the order of hundreds of days. In water, PAHs have half-lines on the order of hours. Aquatic organisms will accumulate PAHs, however, studies have shown that PAHs are metabolized and excreted quickly.

Health Effects

BaP is a probable human carcinogen (EPA classification - B2). Lung canger has been shown to be induced by exposure to various mixtures of PAHs. Cigarette smoke, roofing tar and coke oven emissions contain PAHs. The result of various animal studies with rodent and nonrodent species indicate that BaP is carcinogenic after administration by oral, intratracheal, inhalation and dermal routes. Results of the animal studies show that stomach tumors, mammary tumors, skin tumors and lung cancer may develop after exposure.

Toxicity to Wildlife and Domestic Animals

Data is not available.

Regulations and Standards

OSHA Standard (air):	0.2 mg/m^3 PEL for Benzone-soluble fraction of coal tar pitch volatiles.
ACGIH Threshold Limit Value:	0.2 mg/m^3 TWA for Benzene-soluble fraction of coal tar pitch volatiles.
NIOSH Threshold Limit Value:	0.1 mg/m^3 Cycloherane-soluble fraction of coal tar pitch volatiles.
U.S. EPA (water):	Zero, Ambient water quality criterion.
10^{-5} Cancer risk:	0.028 ug/l (water)

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F

APPENDIX F

PUBLIC HEALTH RISK CALCULATIONS

RISK ASSESSMENT SPREADSHEET - ACCIDENTAL GROUNDWATER INGESTION BY ADULTS

SITE NAME: ARMY CREEK LANDFILL
LOCATION: NEW CASTLE COUNTY, DELAWARE
DATE: 12/06/89

HAZARD INDICES AND INCREMENTAL CANCER RISKS ARE CALCULATED BY SPREADSHEET, EXPOSURES THROUGH WATER INGESTION BASED UPON WEIGHTED AVERAGE CONTAMINANT CONCENTRATIONS DETECTED IN THE GROUNDWATER. ASSUMPTIONS ARE OUTLINED BELOW.

REFERENCES: U.S. EPA, OCTOBER 1986
U. S. EPA, APRIL, 1988

RELEVANT EQUATION: DOSE=(C)*(CR)*(AF)/(BW)

ASSUMPTIONS: ADULTS ARE SUBJECT TO EXPOSURE THROUGH THIS ROUTE.

C = CONCENTRATION OF CONTAMINANT IN GROUNDWATER (MG/L)	
IR = ADULT WATER INGESTION RATE IN L/DAY	0.1
AF = ABSORPTION FRACTION (100%):	1
BW: = AVG. BODY WEIGHT OF ADULT (KG):	70

DETERMINE CONVERSION FACTORS:

DOSE = (C MG/L)*(IR L/DAY)/(BW KG)

DOSE = (CF)*(C) CFadult = 1.4286E-03

DETERMINE TIME-WEIGHTED AVERAGE DOSE

30	YEARS OF EXPOSURE PER 70 YEAR LIFETIME
0.2	DAYS OF EXPOSURE/YEAR 365 DAYS/YR FOR 1 YEAR

TIME WEIGHTING FACTOR (YEARS OF EXPOSURE / ONE YEAR) FOR NONCARCINOGENS:	5.4795E-04
TIME WEIGHTING FACTOR (YEARS OF EXPOSURE / 70 YEARS) FOR CARCINOGENS:	2.3483E-04

RISK ASSESSMENT SPREADSHEET - GROUNDWATER INGESTION BY ADULT (PAGE TWO)
ARMY CREEK LANDFILL, NEW CASTLE COUNTY, DELAWARE
SCENARIO: FLOW-WEIGHTED AVERAGE GROUNDWATER CONCENTRATIONS
CALCULATE DOSES:

CHEMICAL	C Ave (MG/L)	ABSORPTION FRACTION	ADULT DOSE (MG/KG/DAY)	NONCARCINOGENIC TIME-WEIGHTED AVERAGE DOSE (MG/KG/DAY)	CARCINOGENIC TIME-WEIGHTED AVERAGE DOSE (MG/KG/DA
ARSENIC	0.001	1	1.4286E-06	7.8278E-10	3.3548E-10
LEAD	0	1	0.0000E+00	0.0000E+00	0.0000E+00
CADMIUM		1	0.0000E+00	0.0000E+00	0.0000E+00
CHROMIUM	0	1	0.0000E+00	0.0000E+00	0.0000E+00
NICKEL	0.012	1	1.7143E-05	9.3933E-09	4.0257E-09
IRON	12.4	1	1.7714E-02	9.7065E-06	4.1599E-06
MERCURY	0	1	0.0000E+00	0.0000E+00	0.0000E+00
ZINC	0.0112	1	1.6000E-05	8.7671E-09	3.7573E-09
BENZENE	0.008	1	1.1429E-05	6.2622E-09	2.6838E-09
BENZO(a)PYRENE		1	0.0000E+00	0.0000E+00	0.0000E+00
BIS(2-CHLOROETHYL)ETHER	0.012	1	1.7143E-05	9.3933E-09	4.0257E-09
1,2-DICHLOROETHANE	0.0084	1	1.2000E-05	6.5753E-09	2.8180E-09

RISK ASSESSMENT SPREADSHEET - GROUNDWATER INGESTION BY AN ADULT (PAGE 3)
ARMY CREEK LANDFILL, NEW CASTLE COUNTY, DELAWARE
SCENARIO: AVERAGE GROUNDWATER CONCENTRATIONS
DETERMINE HAZARD INDICES AND CANCER RISK

CHEMICAL	RfD (MG/KG/DAY)	CPF (KG-DAY/MG)	HAZARD INDEX ADULT	CANCER RISK LIFETIME
ARSENIC	1.00E-03	1.75E+00	7.8278E-07	5.8708E-10
LEAD	1.40E-03		0.0000E+00	0.0000E+00
CADMIUM	5.00E-04		0.0000E+00	0.0000E+00
CHROMIUM	1.00E+00		0.0000E+00	0.0000E+00
NICKEL	2.00E-02		4.6967E-07	0.0000E+00
IRON			0.0000E+00	0.0000E+00
MERCURY	3.00E-04		0.0000E+00	0.0000E+00
ZINC	2.00E-01		4.3836E-08	0.0000E+00
BENZENE		2.90E-02	0.0000E+00	7.7831E-11
BENZO(a)PYRENE			0.0000E+00	0.0000E+00
BIS(2-CHLOROETHYL)ETHER		1.10E+00	0.0000E+00	4.4283E-09
1,2-DICHLOROETHANE		9.10E-02	0.0000E+00	2.5644E-10
TOTAL			1.2963E-06	5.3496E-09

AR301528

RISK ASSESSMENT SPREADSHEET - ACCIDENTAL GROUNDWATER INGESTION BY CHILDREN 6 TO 11 YEARS OLD

SITE NAME: ARMY CREEK LANDFILL
LOCATION: NEW CASTLE COUNTY, DELAWARE
DATE: 12/06/89

HAZARD INDICES AND INCREMENTAL CANCER RISKS ARE CALCULATED BY SPREADSHEET, EXPOSURES THROUGH WATER INGESTION BASED UPON WEIGHTED AVERAGE CONTAMINANT CONCENTRATIONS DETECTED IN THE GROUNDWATER. ASSUMPTIONS ARE OUTLINED BELOW.

REFERENCES: U.S. EPA, OCTOBER 1986
U. S. EPA, APRIL, 1988

RELEVANT EQUATION: DOSE=(C)*(CR)*(AF)/(BW)

ASSUMPTIONS: CHILDREN 6 THROUGH 11 YEARS OLD ARE SUBJECT TO EXPOSURE THROUGH THIS ROUTE.

C = CONCENTRATION OF CONTAMINANT IN GROUNDWATER (MG/L)	
IR = ADULT WATER INGESTION RATE IN L/DAY	0.1
AF = ABSORPTION FRACTION (100%):	1
BW: = AVG. BODY WEIGHT OF ADULT (KG):	30

DETERMINE CONVERSION FACTORS:

DOSE = (C MG/L)*(IR L/DAY)/(BW KG)

DOSE = (CF)*(C) CF = 3.3333E-03

DETERMINE TIME-WEIGHTED AVERAGE DOSE

6	YEARS OF EXPOSURE PER 70 YEAR LIFETIME
1	DAYS OF EXPOSURE/YEAR 365 DAYS/YR FOR 1 YEAR

TIME WEIGHTING FACTOR (YEARS OF EXPOSURE / ONE YEAR) FOR NONCARCINOGENS:	2.7397E-03
TIME WEIGHTING FACTOR (YEARS OF EXPOSURE / 70 YEARS) FOR CARCINOGENS:	2.3483E-04

AR301529

RISK ASSESSMENT SPREADSHEET - GROUNDWATER INGESTION BY CHILDREN (PAGE TWO)
ARMY CREEK LANDFILL, NEW CASTLE COUNTY, DELAWARE
SCENARIO: FLOW-WEIGHTED AVERAGE GROUNDWATER CONCENTRATIONS
CALCULATE DOSES:

CHEMICAL	C Ave (MG/L)	ABSORPTION FRACTION	CHILD DOSE (MG/KG/DAY)	NONCARCINOGENIC TIME-WEIGHTED AVERAGE DOSE (MG/KG/DAY)	CARCINOGENIC TIME-WEIGHTED AVERAGE DOSE (MG/KG/DA
ARSENIC	0.001	1	3.3333E-06	9.1324E-09	7.8278E-10
LEAD	0	1	0.0000E+00	0.0000E+00	0.0000E+00
CADMIUM		1	0.0000E+00	0.0000E+00	0.0000E+00
CHROMIUM	0	1	0.0000E+00	0.0000E+00	0.0000E+00
NICKEL	0.012	1	4.0000E-05	1.0959E-07	9.3933E-09
IRON	12.4	1	4.1333E-02	1.1324E-04	9.7065E-06
MERCURY		1	0.0000E+00	0.0000E+00	0.0000E+00
ZINC	0.0112	1	3.7333E-05	1.0228E-07	8.7671E-09
BENZENE	0.008	1	2.6667E-05	7.3059E-08	6.2622E-09
BENZO(a)PYRENE		1	0.0000E+00	0.0000E+00	0.0000E+00
BIS(2-CHLOROETHYL)ETHER	0.012	1	4.0000E-05	1.0959E-07	9.3933E-09
1,2-DICHLOROETHANE	0.0084	1	2.8000E-05	7.6712E-08	6.5753E-09

RISK ASSESSMENT SPREADSHEET - GROUNDWATER INGESTION BY AN CHILDREN (PAGE 3)
ARMY CREEK LANDFILL, NEW CASTLE COUNTY, DELAWARE
SCENARIO: WEIGHTE GROUNDWATER CONCENTRATIONS
DETERMINE HAZARD INDICES AND CANCER RISK

CHEMICAL	RfD (MG/KG/DAY)	CPF (KG-DAY/MG)	HAZARD INDEX CHILD	CANCER RISK LIFETIME
ARSENIC	1.00E-03	1.75E+00	9.1324E-06	1.3699E-09
LEAD	1.40E-03		0.0000E+00	0.0000E+00
CADMIUM	5.00E-04		0.0000E+00	0.0000E+00
CHROMIUM	1.00E+00		0.0000E+00	0.0000E+00
NICKEL	2.00E-02		5.4795E-06	0.0000E+00
IRON			0.0000E+00	0.0000E+00
MERCURY	3.00E-04		0.0000E+00	0.0000E+00
ZINC	2.00E-01		5.1142E-07	0.0000E+00
BENZENE		2.90E-02	0.0000E+00	1.8160E-10
BENZO(a)PYRENE			0.0000E+00	0.0000E+00
BIS(2-CHLOROETHYL)ETHER		1.10E+00	0.0000E+00	1.0333E-08
1,2-DICHLOROETHANE		9.10E-02	0.0000E+00	5.9836E-10
TOTAL			1.5123E-05	1.2483E-08

RISK ASSESSMENT SPREADSHEET - INHALATION OF VOLATILES FROM GROUNDWATER BY ADULTS

SITE NAME: ARMY CREEK LANDFILL
LOCATION: NEW CASTLE COUNTY, DELAWARE
DATE: 12/11/89

HAZARD INDICES AND INCREMENTAL CANCER RISKS ARE CALCULATED BY SPREADSHEET, EXPOSURES THROUGH AIR INHALATION OF VOLATILES BASED UPON WEIGHTED AVERAGE CONTAMINANT CONCENTRATIONS DETECTED IN THE GROUNDWATER. THESE CONCENTRATIONS WERE MULTIPLIED BY HENRY'S CONSTANT TO OBTAIN AIR CONCENTRATIONS. ASSUMPTIONS ARE OUTLINED BELOW.

REFERENCES: U.S. EPA, OCTOBER, 1986; U.S. EPA, APRIL, 1988

RELEVANT EQUATION: DOSE=(C)*(CR)*(AF)/(BW)

ASSUMPTIONS: ADULTS ARE SUBJECT TO EXPOSURE THROUGH THIS ROUTE.

C =	CONCENTRATION OF CONTAMINANT IN AIR (MG/CU.M)	
IR =	ADULT AIR INHALATION RATE IN CU.M/DAY	1
AF =	ABSORPTION FRACTION (100%):	1
BW: =	AVG. BODY WEIGHT OF ADULT (KG):	70

DETERMINE CONVERSION FACTORS:

DOSE = (C MG/CU.M)*(IR CU.M/DAY)*(365 DAYS/YR)/(BW KG)

DOSE = (CF)*(C)   CFadult = 1.4286E-02

DETERMINE TIME-WEIGHTED AVERAGE DOSE

30	YEARS OF EXPOSURE PER 70 YEAR LIFETIME
0.2	DAYS OF EXPOSURE/YEAR 365 DAYS/YR FOR 1 YEAR

TIME WEIGHTING FACTOR (YEARS OF EXPOSURE / ONE YEAR) FOR NONCARCINOGENS:	5.4795E-04
TIME WEIGHTING FACTOR (YEARS OF EXPOSURE / 70 YEARS) FOR CARCINOGENS:	2.3483E-04

AR301532

RISK ASSESSMENT SPREADSHEET - INHALATION OF VOLATILES FROM GROUNDWATER BY ADULTS (PAGE 2)
ARMY CREEK LANDFILL, NEW CASTLE COUNTY, DELAWARE
SCENARIO: AVERAGE AIR CONCENTRATIONS VOLATILIZED FROM GROUNDWATER
CALCULATE DOSES:

CHEMICAL	C Ave (MG/CU.M)	ABSORPTION FRACTION	ADULT DOSE (MG/KG/DAY)	NONCARCINOGENIC TIME-WEIGHTED AVERAGE DOSE (MG/KG/DAY)	CARCINOGENIC TIME-WEIGHTED AVERAGE DOSE (MG/KG/DAY)
ARSENIC		1	0.0000E+00	0.0000E+00	0.0000E+00
LEAD		1	0.0000E+00	0.0000E+00	0.0000E+00
CADMIUM		1	0.0000E+00	0.0000E+00	0.0000E+00
CHROMIUM		1	0.0000E+00	0.0000E+00	0.0000E+00
NICKEL		1	0.0000E+00	0.0000E+00	0.0000E+00
IRON		1	0.0000E+00	0.0000E+00	0.0000E+00
MERCURY		1	0.0000E+00	0.0000E+00	0.0000E+00
ZINC		1	0.0000E+00	0.0000E+00	0.0000E+00
BENZENE	1.86	1	2.6571E-02	1.4560E-05	6.2399E-06
BENZO(a)PYRENE		1	0.0000E+00	0.0000E+00	0.0000E+00
BIS(2-CHLOROETHYL)ETHER	0.0065	1	9.2857E-05	5.0881E-08	2.1806E-08
1,2-DICHLOROETHANE	0.344	1	4.9143E-03	2.6928E-06	1.1540E-06

RISK ASSESSMENT SPREADSHEET - INHALATION OF VOLATILES FROM GROUNDWATER BY ADULTS (PAGE 3)
ARMY CREEK LANDFILL, NEW CASTLE COUNTY, DELAWARE
SCENARIO: AVERAGE AIR CONCENTRATIONS VOLATILIZED FROM GROUNDWATER
DETERMINE HAZARD INDICES AND CANCER RISK

CHEMICAL	RfD (MG/KG/DAY)	CPF (KG-DAY/MG)	HAZARD INDEX ADULT	CANCER RISK LIFETIME
ARSENIC		5.00E+01	0.0000E+00	0.0000E+00
LEAD	4.30E-04		0.0000E+00	0.0000E+00
CADMIUM		6.10E+00	0.0000E+00	0.0000E+00
CHROMIUM			0.0000E+00	0.0000E+00
NICKEL		8.40E-01	0.0000E+00	0.0000E+00
IRON			0.0000E+00	0.0000E+00
MERCURY			0.0000E+00	0.0000E+00
ZINC			0.0000E+00	0.0000E+00
BENZENE		2.90E-02	0.0000E+00	1.8096E-07
BENZO(a)PYRENE			0.0000E+00	0.0000E+00
BIS(2-CHLOROETHYL)ETHER		1.10E+00	0.0000E+00	2.3987E-08
1,2-DICHLOROETHANE		9.10E-02	0.0000E+00	1.0502E-07
TOTAL			0.0000E+00	3.0996E-07

AR301534

RISK ASSESSMENT SPREADSHEET - INHALATION OF VOLATILES FROM GROUNDWATER BY CHILDREN 6 TO 11 YEARS OLD.

SITE NAME: ARMY CREEK LANDFILL
LOCATION: NEW CASTLE COUNTY, DELAWARE
DATE: 12/11/89

HAZARD INDICES AND INCREMENTAL CANCER RISKS ARE CALCULATED BY SPREADSHEET, EXPOSURES THROUGH AIR INHALATION OF VOLATILES BASED UPON WEIGHTED AVERAGE CONTAMINANT CONCENTRATIONS DETECTED IN THE GROUNDWATER. THESE CONCENTRATIONS WERE MULTIPLIED BY HENRY'S CONSTANT TO OBTAIN AIR CONCENTRATIONS. ASSUMPTIONS ARE OUTLINED BELOW.

REFERENCES: U.S. EPA, OCTOBER, 1986; U.S. EPA, APRIL, 1988

RELEVANT EQUATION: DOSE=(C)*(CR)*(AF)/(BW)

ASSUMPTIONS: CHILDREN 6 THROUGH 11 YEARS OLD ARE SUBJECT TO EXPOSURE THROUGH THIS ROUTE.

C = CONCENTRATION OF CONTAMINANT IN AIR (MG/CU.M)	
IR = AIR INHALATION RATE IN CU.M/DAY	1
AF = ABSORPTION FRACTION (100%):	1
BW: = AVG. BODY WEIGHT OF ADULT (KG):	30

DETERMINE CONVERSION FACTORS:

DOSE = (C MG/CU.M)*(IR CU.M/DAY)*(365 DAYS/YR)/(BW KG)

DOSE = (CF)*(C) CF = 3.3333E-02

DETERMINE TIME-WEIGHTED AVERAGE DOSE

6	YEARS OF EXPOSURE PER 70 YEAR LIFETIME
1	DAYS OF EXPOSURE/YEAR 365 DAYS/YR FOR 1 YEAR

TIME WEIGHTING FACTOR (YEARS OF EXPOSURE / ONE YEAR) FOR NONCARCINOGENS:	2.7397E-03
TIME WEIGHTING FACTOR (YEARS OF EXPOSURE / 70 YEARS) FOR CARCINOGENS:	2.3483E-04

AR301535

RISK ASSESSMENT SPREADSHEET - INHALATION OF VOLATILES FROM GROUNDWATER BY CHILDREN (PAGE 2)
ARMY CREEK LANDFILL, NEW CASTLE COUNTY, DELAWARE
SCENARIO: AVERAGE AIR CONCENTRATIONS VOLATILIZED FROM GROUNDWATER
CALCULATE DOSES:

CHEMICAL	C Ave (MG/CU.M)	ABSORPTION FRACTION	CHILD DOSE (MG/KG/DAY)	NONCARCINOGENIC TIME-WEIGHTED AVERAGE DOSE (MG/KG/DAY)	CARCINOGENIC TIME-WEIGHTED AVERAGE DOSE (MG/KG/DAY)
ARSENIC		1	0.0000E+00	0.0000E+00	0.0000E+00
LEAD		1	0.0000E+00	0.0000E+00	0.0000E+00
CADMIUM		1	0.0000E+00	0.0000E+00	0.0000E+00
CHROMIUM		1	0.0000E+00	0.0000E+00	0.0000E+00
NICKEL		1	0.0000E+00	0.0000E+00	0.0000E+00
IRON		1	0.0000E+00	0.0000E+00	0.0000E+00
MERCURY		1	0.0000E+00	0.0000E+00	0.0000E+00
ZINC		1	0.0000E+00	0.0000E+00	0.0000E+00
BENZENE	1.86	1	6.2000E-02	1.6986E-04	1.4560E-05
BENZO(a)PYRENE		1	0.0000E+00	0.0000E+00	0.0000E+00
BIS(2-CHLOROETHYL)ETHER	0.0065	1	2.1667E-04	5.9361E-07	5.0881E-08
1,2-DICHLOROETHANE	0.344	1	1.1467E-02	3.1416E-05	2.6928E-06

RISK ASSESSMENT SPREADSHEET - INHALATION OF VOLATILES FROM GROUNDWATER BY CHILDREN (PAGE 3)
ARMY CREEK LANDFILL, NEW CASTLE COUNTY, DELAWARE
SCENARIO: AVERAGE AIR CONCENTRATIONS VOLATILIZED FROM GROUNDWATER
DETERMINE HAZARD INDICES AND CANCER RISK

CHEMICAL	RfD (MG/KG/DAY)	CPF (KG-DAY/MG)	HAZARD INDEX CHILD	CANCER RISK LIFETIME
ARSENIC		5.00E+01	0.0000E+00	0.0000E+00
LEAD	4.30E-04		0.0000E+00	0.0000E+00
CADMIUM		6.10E+00	0.0000E+00	0.0000E+00
CHROMIUM			0.0000E+00	0.0000E+00
NICKEL		8.40E-01	0.0000E+00	0.0000E+00
IRON			0.0000E+00	0.0000E+00
MERCURY			0.0000E+00	0.0000E+00
ZINC			0.0000E+00	0.0000E+00
BENZENE		2.90E-02	0.0000E+00	4.2223E-07
BENZO(a)PYRENE			0.0000E+00	0.0000E+00
BIS(2-CHLOROETHYL)ETHER		1.10E+00	0.0000E+00	5.5969E-08
1,2-DICHLOROETHANE		9.10E-02	0.0000E+00	2.4504E-07
TOTAL			0.0000E+00	7.2324E-07

RISK ASSESSMENT SPREADSHEET - DERMAL ABSORTION OF GROUNDWATER BY ADULT.

SITE NAME: ARMY CREEK LANDFILL
LOCATION: NEW CASTLE COUNTY, DELAWARE
DATE: 12/07/89

HAZARD INDICES AND INCREMENTAL CANCER RISKS ARE CALCULATED BY SPREADSHEET, EXPOSURES THROUGH DERMAL ABSORTION BASED UPON WEIGHTED AVERAGE CONTAMINANT CONCENTRATIONS DETECTED IN THE GROUNDWATER. ASSUMPTIONS ARE OUTLINED BELOW

REFERENCES: U.S. EPA, OCTOBER 1986
U.S. EPA 1988

RELEVANT EQUATION: DOSE=(C)*(K)*(SA)*(EF)/(BW)

ASSUMPTIONS: ADULTS ARE SUBJECT TO EXPOSURE THROUGH THIS ROUTE.

C = CONCENTRATION OF CONTAMINANT IN GROUNDWATER IN (MG/L)	
K = DERMAL ABSORPTION COEFFICIENT FOR ORGANICS (L/CM2/HR)	0.001
SA = EXPOSED SURFACE AREA (CM2)	19400
EF = EXPOSURE FREQUENCY (1 HR/DAY)	
BW: = AVE. BODY WEIGHT OF ADULT:	70

DETERMINE CONVERSION FACTORS:
DOSE = (C MG/L)*(SA CM2)/(BW KG)

DOSE = (CF)*(C)*(EF) CF = 2.7714E+02

DETERMINE TIME-WEIGHTED AVERAGE DOSE

30	YEARS OF EXPOSURE PER 70 YEAR LIFETIME
0.2	DAYS OF EXPOSURE/YEAR

TIME WEIGHTING FACTOR (YEARS OF EXPOSURE / ONE YEAR) FOR NONCARCINOGENS:	5.4795E-04
TIME WEIGHTING FACTOR (YEARS OF EXPOSURE / 70 YEARS) FOR CARCINOGENS:	2.3483E-04

RISK ASSESSMENT SPREADSHEET - DERMAL ABSORTION OF GROUNDWATER (PAGE 2)
ARMY CREEK LANDFILL, NEW CASTLE COUNTY, DELAWARE
SCENARIO: DERMAL ABSORPTION OF GROUNDWATER
CALCULATE DOSES:

CHEMICAL	C Ave (MG/L)	ABSORPTION COEFFICIENT	ADULT DOSE (MG/KG/DAY)	NONCARCINOGENIC TIME-WEIGHTED AVERAGE DOSE (MG/KG/DAY)	CARCINOGENIC TIME-WEIGHTED AVERAGE DOSE (MG/KG/DAY)
ARSENIC	0.001	0	0.0000E+00	0.0000E+00	0.0000E+00
LEAD	0	0	0.0000E+00	0.0000E+00	0.0000E+00
CADMIUM	0	0	0.0000E+00	0.0000E+00	0.0000E+00
CHROMIUM	0	0	0.0000E+00	0.0000E+00	0.0000E+00
NICKEL	0.012	0	0.0000E+00	0.0000E+00	0.0000E+00
IRON	12.4	0	0.0000E+00	0.0000E+00	0.0000E+00
MERCURY	0	0	0.0000E+00	0.0000E+00	0.0000E+00
ZINC	0.0112	0	0.0000E+00	0.0000E+00	0.0000E+00
BENZENE	0.008	0.001	2.2171E-03	1.2149E-06	5.2066E-07
BENZO(a)PYRENE	0	0.001	0.0000E+00	0.0000E+00	0.0000E+00
BIS(2-CHLOROETHYL)ETHER	0.012	0.001	3.3257E-03	1.8223E-06	7.8099E-07
1,2-DICHLOROETHANE	0.0084	0.001	2.3280E-03	1.2756E-06	5.4669E-07

RISK ASSESSMENT SPREADSHEET - DERMAL ABSORTION OF GROUNDWATER (PAGE 3)
ARMY CREEK LANDFILL, NEW CASTLE COUNTY, DELAWARE
SCENARIO: DERMAL ABSORPTION OF GROUNDWATER
DETERMINE HAZARD INDICIES AND CANCER RISK:

CHEMICAL	RfD (MG/KG/DAY)	CPF (KG-DAY/MG)	HAZARD INDEX ADULT	CANCER RISK LIFETIME
ARSENIC	1.00E-03	1.75E+00	0.0000E+00	0.0000E+00
LEAD	1.40E-03		0.0000E+00	0.0000E+00
CADMIUM	5.00E-04		0.0000E+00	0.0000E+00
CHROMIUM	1.00E+00		0.0000E+00	0.0000E+00
NICKEL	2.00E-02		0.0000E+00	0.0000E+00
IRON			0.0000E+00	0.0000E+00
MERCURY	3.00E-04		0.0000E+00	0.0000E+00
ZINC	2.00E-01		0.0000E+00	0.0000E+00
BENZENE		2.90E-02	0.0000E+00	1.5099E-08
BENZO(a)PYRENE			0.0000E+00	0.0000E+00
BIS(2-CHLOROETHYL)ETHER		1.10E+00	0.0000E+00	8.5909E-07
1,2-DICHLOROETHANE		9.10E-02	0.0000E+00	4.9749E-08
TOTAL			0.0000E+00	9.2394E-07

RISK ASSESSMENT SPREADSHEET - DERMAL ABSORTION OF GROUNDWATER BY A CHILD 6 TO 11 YRS OLD

SITE NAME: ARMY CREEK LANDFILL
LOCATION: NEW CASTLE COUNTY, DELAWARE
DATE: 12/07/89

HAZARD INDICES AND INCREMENTAL CANCER RISKS ARE CALCULATED BY SPREADSHEET, EXPOSURES THROUGH DERMAL ABSORTION BASED UPON FLOW WEIGHTED AVERAGE CONTAMINANT CONCENTRATIONS DETECTED IN THE GROUNDWATER. ASSUMPTIONS ARE OUTLINED BELOW

REFERENCES: U.S. EPA, OCTOBER 1986
U.S. EPA 1988

RELEVANT EQUATION: DOSE=(C)*(K)*(SA)*(EF)/(BW)

ASSUMPTIONS: CHILDREN BETWEEN AGES 6 AND 11 ARE SUBJECT TO EXPOSURE THROUGH THIS ROUTE.

C = CONCENTRATION OF CONTAMINANT IN GROUNDWATER IN (MG/L)	
K = DERMAL ABSORPTION COEFFICIENT FOR ORGANICS (L/CM2/HR)	0.001
SA = EXPOSED SURFACE AREA (CM2)	8750
EF = EXPOSURE FREQUENCY (1 HR/DAY)	
BW: = AVE. BODY WEIGHT OF CHILD (KG) 6 TO 11 YEARS OLD:	3?

DETERMINE CONVERSION FACTORS:
DOSE = (C MG/L)*(SA CM2)/(BW KG)

DOSE = (CF)*(C)*(EF) CF = 2.9167E+02

DETERMINE TIME-WEIGHTED AVERAGE DOSE

6	YEARS OF EXPOSURE PER 70 YEAR LIFETIME (AGES 6 TO 11 YEARS OLD)
1	DAYS OF EXPOSURE/YEAR (5D/WEEK)*(4WEEKS/MO)*(3MO/YR)*70% OF THE TIME FOR ONE YEAR

TIME WEIGHTING FACTOR (YEARS OF EXPOSURE / ONE YEAR) FOR NONCARCINOGENS:	2.7397E-03
TIME WEIGHTING FACTOR (YEARS OF EXPOSURE / 70 YEARS) FOR CARCINOGENS:	2.3483E-04

AR301541

RISK ASSESSMENT SPREADSHEET - DERMAL ABSORPTION OF GROUNDWATER (PAGE 2)
ARMY CREEK LANDFILL, NEW CASTLE COUNTY, DELAWARE
SCENARIO: DERMAL ABSORPTION OF GROUNDWATER
CALCULATE DOSES:

CHEMICAL	C Ave (MG/L)	ABSORPTION COEFFICIENT	CHILD DOSE (MG/KG/DAY)	NONCARCINOGENIC TIME-WEIGHTED AVERAGE DOSE (MG/KG/DAY)	CARCINOGENIC TIME-WEIGHTED AVERAGE DOSE (MG/KG/DAY)
ARSENIC	0.001	0	0.0000E+00	0.0000E+00	0.0000E+00
LEAD	0	0	0.0000E+00	0.0000E+00	0.0000E+00
CADMIUM	0	0	0.0000E+00	0.0000E+00	0.0000E+00
CHROMIUM	0	0	0.0000E+00	0.0000E+00	0.0000E+00
NICKEL	0.012	0	0.0000E+00	0.0000E+00	0.0000E+00
IRON	12.4	0	0.0000E+00	0.0000E+00	0.0000E+00
MERCURY	0	0	0.0000E+00	0.0000E+00	0.0000E+00
ZINC	0.0112	0	0.0000E+00	0.0000E+00	0.0000E+00
BENZENE	0.008	0.001	2.3333E-03	6.3927E-06	5.4795E-07
BENZO(a)PYRENE	0	0.001	0.0000E+00	0.0000E+00	0.0000E+00
BIS(2-CHLOROETHYL)ETHER	0.012	0.001	3.5000E-03	9.5890E-06	8.2192E-07
1,2-DICHLOROETHANE	0.0084	0.001	2.4500E-03	6.7123E-06	5.7534E-07

AR301542

RISK ASSESSMENT SPREADSHEET - DERMAL ABSORTION OF GROUNDWATER (PAGE 3)
ARMY CREEK LANDFILL, NEW CASTLE COUNTY, DELAWARE
SCENARIO: DERMAL ABSORPTION OF GROUNDWATER
DETERMINE HAZARD INDICIES AND CANCER RISK:

CHEMICAL	RfD (MG/KG/DAY)	CPF (KG-DAY/MG)	HAZARD INDEX CHILD	CANCER RISK LIFETIME
ARSENIC	1.00E-03	1.75E+00	0.0000E+00	0.0000E+00
LEAD	1.40E-03		0.0000E+00	0.0000E+00
CADMIUM	5.00E-04		0.0000E+00	0.0000E+00
CHROMIUM	1.00E+00		0.0000E+00	0.0000E+00
NICKEL	2.00E-02		0.0000E+00	0.0000E+00
IRON			0.0000E+00	0.0000E+00
MERCURY	3.00E-04		0.0000E+00	0.0000E+00
ZINC	2.00E-01		0.0000E+00	0.0000E+00
BENZENE		2.90E-02	0.0000E+00	1.5890E-08
BENZO(a)PYRENE			0.0000E+00	0.0000E+00
BIS(2-CHLOROETHYL)ETHER		1.10E+00	0.0000E+00	9.0411E-07
1,2-DICHLOROETHANE		9.10E-02	0.0000E+00	5.2356E-08
TOTAL			0.0000E+00	9.7236E-07

AR301543

RISK ASSESSMENT SPREADSHEET - ACCIDENTAL INGESTION OF SEDIMENT - AVERAGE SOIL INGESTION

SITE NAME: ARMY CREEK LANDFILL
LOCATION: NEW CASTLE COUNTY, DELAWARE
DATE: 12/06/89

HAZARD INDICES AND INCREMENTAL CANCER RISKS ARE CALCULATED BY SPREADSHEET, EXPOSURES THROUGH PICA INGESTION BASED UPON MAXIMUM CONTAMINANT CONCENTRATIONS DETECTED IN THE SEDIMENT. ASSUMPTIONS ARE OUTLINED BELOW

REFERENCES: U.S. EPA, OCTOBER 1986

RELEVANT EQUATION: DOSE=(C)*(CR)*(AF)/(BW)

ASSUPTIONS: ADULTS ARE SUBJECT TO EXPOSURE THROUGH THIS ROUTE.

C = CONCENTRATION OF CONTAMINANT IN SEDIMENT (MG/KG)

IR = AVERAGE SOIL INGESTION RATE IN G/DAY 0.01

AF = ABSORTION FRACTION: 1

BW: = AVE. BODY WEIGHT: 70

DETERMINE CONVERSION FACTORS:

DOSE = (C MG/KG)*(1 KG/1000 G)*(IR G/DAY)/(BW KG)

DOSE = (CF)*(C) CFave = 1.4286E-07

DETERMINE TIME-WEIGHTED AVERAGE DOSE

30 YEARS OF EXPOSURE PER 70 YEAR LIFETIME
0.2 DAYS OF EXPOSURE/YEAR

TIME WEIGHTING FACTOR (YEARS OF EXPOSURE / ONE YEAR) FOR NONCARCINOGENS: 5.4795E-04
TIME WEIGHTING FACTOR (YEARS OF EXPOSURE / 70 YEARS) FOR CARCINOGENS: 2.3483E-04

RISK ASSESSMENT SPREADSHEET - ACCIDENTAL INGESTION OF SEDIMENT (PAGE TWO)
ARMY CREEK LANDFILL, NEW CASTLE COUNTY, DELAWARE
SCENARIO: MAXIMUM SEDIMENT CONCENTRATIONS
CALCULATE DOSES:

CHEMICAL	C max (MG/KG)	ABSORPTION FRACTION	ADULT DOSE (MG/KG/DAY)	NONCARCINOGENIC TIME-WEIGHTED AVERAGE DOSE (MG/KG/DAY)	CARCINOGENIC TIME-WEIGHTED AVERAGE DOSE (MG/KG/DAY)
ARSENIC	6	1	8.5714E-07	4.6967E-10	2.0129E-10
LEAD	97.8	1	1.3971E-05	7.6556E-09	3.2810E-09
CADMIUM		1	0.0000E+00	0.0000E+00	0.0000E+00
CHROMIUM	45	1	6.4286E-06	3.5225E-09	1.5096E-09
NICKEL	26.4	1	3.7714E-06	2.0665E-09	8.8566E-10
IRON	68800	1	9.8286E-03	5.3855E-06	2.3081E-06
MERCURY	0.0119	1	1.7000E-09	9.3151E-13	3.9922E-13
ZINC	273	1	3.9000E-05	2.1370E-08	9.1585E-09
BENZENE		1	0.0000E+00	0.0000E+00	0.0000E+00
BENZO(a)PYRENE	1.07	1	1.5286E-07	8.3757E-11	3.5896E-11
BIS(2-CHLOROETHYL)ETHER		1	0.0000E+00	0.0000E+00	0.0000E+00
1,2-DICHLOROETHANE		1	0.0000E+00	0.0000E+00	0.0000E+00

AR301545

RISK ASSESSMENT SPREADSHEET - ACCIDENTAL INGESTION OF SEDIMENT (PAGE THREE)
ARMY CREEK LANDFILL, NEW CASTLE COUNTY, DELAWARE
SCENARIO: MAXIMUM SEDIMENT CONCENTRATIONS
DETERMINE HAZARD INDICIES AND CANCER RISK:

CHEMICAL	RfD (MG/KG/DAY)	CPF (KG-DAY/MG)	HAZARD INDEX ADULT	CANCER RISK LIFETIME
ARSENIC	1.00E-03	1.75E+00	4.6967E-07	3.5225E-10
LEAD	1.40E-03		5.4683E-06	0.0000E+00
CADMIUM	5.00E-04		0.0000E+00	0.0000E+00
CHROMIUM	1.00E+00		3.5225E-09	0.0000E+00
NICKEL	2.00E-02		1.0333E-07	0.0000E+00
IRON			0.0000E+00	0.0000E+00
MERCURY	3.00E-04		3.1050E-09	0.0000E+00
ZINC	2.00E-01		1.0685E-07	0.0000E+00
BENZENE		2.90E-02	0.0000E+00	0.0000E+00
BENZO(a)PYRENE			0.0000E+00	0.0000E+00
BIS(2-CHLOROETHYL)ETHER		1.10E+00	0.0000E+00	0.0000E+00
1,2-DICHLOROETHANE		9.10E-02	0.0000E+00	0.0000E+00
TOTAL			6.1547E-06	3.5225E-10

AR301546

RISK ASSESSMENT SPREADSHEET - ACCIDENTAL INGESTION OF SEDIMENT - HIGH SOIL INGESTION

SITE NAME: ARMY CREEK LANDFILL
LOCATION: NEW CASTLE COUNTY, DELAWARE
DATE: 12/06/89

HAZARD INDICES AND INCREMENTAL CANCER RISKS ARE CALCULATED BY SPREADSHEET, EXPOSURES THROUGH PICA INGESTION BASED UPON MAXIMUM CONTAMINANT CONCENTRATIONS DETECTED IN THE SEDIMENT. ASSUMPTIONS ARE OUTLINED BELOW

REFERENCES: U.S. EPA, OCTOBER 1986

RELEVANT EQUATION: DOSE=(C)*(CR)*(AF)/(BW)

ASSUPTIONS: ADULTS ARE SUBJECT TO EXPOSURE THROUGH THIS ROUTE.

C = CONCENTRATION OF CONTAMINANT IN SEDIMENT (MG/KG)	
IR = AVERAGE SOIL INGESTION RATE IN G/DAY	0.05
AF = ABSORTION FRACTION:	1
BW: = AVE. BODY WEIGHT:	70

DETERMINE CONVERSION FACTORS:

DOSE = (C MG/KG)*(1 KG/1000 G)*(IR G/DAY)/(BW KG)

DOSE = (CF)*(C)   CFave = 7.1429E-07

DETERMINE TIME-WEIGHTED AVERAGE DOSE

30	YEARS OF EXPOSURE PER 70 YEAR LIFETIME
0.2	DAYS OF EXPOSURE/YEAR

TIME WEIGHTING FACTOR (YEARS OF EXPOSURE / ONE YEAR) FOR NONCARCINOGENS:	5.4795E-04
TIME WEIGHTING FACTOR (YEARS OF EXPOSURE / 70 YEARS) FOR CARCINOGENS:	2.3483E-04

AR301547

CCPDAR2

RISK ASSESSMENT SPREADSHEET - ACCIDENTAL INGESTION OF SEDIMENT (PAGE TWO)
ARMY CREEK LANDFILL, NEW CASTLE COUNTY, DELAWARE
SCENARIO: MAXIMUM SEDIMENT CONCENTRATIONS
CALCULATE DOSES:

CHEMICAL	C max (MG/KG)	ABSORPTION FRACTION	ADULT DOSE (MG/KG/DAY)	NONCARCINOGENIC TIME-WEIGHTED AVERAGE DOSE (MG/KG/DAY)	CARCINOGENIC TIME-WEIGHTED AVERAGE DOSE (MG/KG/DAY)
ARSENIC	6	1	4.2857E-06	2.3483E-09	1.0064E-09
LEAD	97.8	1	6.9857E-05	3.8278E-08	1.6405E-08
CADMIUM		1	0.0000E+00	0.0000E+00	0.0000E+00
CHROMIUM	45	1	3.2143E-05	1.7613E-08	7.5482E-09
NICKEL	26.4	1	1.8857E-05	1.0333E-08	4.4283E-09
IRON	68800	1	4.9143E-02	2.6928E-05	1.1540E-05
MERCURY	0.119	1	8.5000E-08	4.6575E-11	1.9961E-11
ZINC	273	1	1.9500E-04	1.0685E-07	4.5793E-08
BENZENE		1	0.0000E+00	0.0000E+00	0.0000E+00
BENZO(a)PYRENE	1.07	1	7.6429E-07	4.1879E-10	1.7948E-10
BIS(2-CHLOROETHYL)ETHER		1	0.0000E+00	0.0000E+00	0.0000E+00
1,2-DICHLOROETHANE		1	0.0000E+00	0.0000E+00	0.0000E+00

RISK ASSESSMENT SPREADSHEET - ACCIDENTAL INGESTION OF SEDIMENT (PAGE THREE)
ARMY CREEK LANDFILL, NEW CASTLE COUNTY, DELAWARE
SCENARIO: MAXIMUM SEDIMENT CONCENTRATIONS
DETERMINE HAZARD INDICIES AND CANCER RISK:

CHEMICAL	RfD (MG/KG/DAY)	CPF (KG-DAY/MG)	HAZARD INDEX ADULT	CANCER RISK LIFETIME
ARSENIC	1.00E-03	1.75E+00	2.3483E-06	1.7613E-09
LEAD	1.40E-03		2.7341E-05	0.0000E+00
CADMIUM	5.00E-04		0.0000E+00	0.0000E+00
CHROMIUM	1.00E+00		1.7613E-08	0.0000E+00
NICKEL	2.00E-02		5.1663E-07	0.0000E+00
IRON			0.0000E+00	0.0000E+00
MERCURY	3.00E-04		1.5525E-07	0.0000E+00
ZINC	2.00E-01		5.3425E-07	0.0000E+00
BENZENE		2.90E-02	0.0000E+00	0.0000E+00
BENZO(a)PYRENE			0.0000E+00	0.0000E+00
BIS(2-CHLOROETHYL)ETHER		1.10E+00	0.0000E+00	0.0000E+00
1,2-DICHLOROETHANE		9.10E-02	0.0000E+00	0.0000E+00
TOTAL			3.0913E-05	1.7613E-09

AR301549

RISK ASSESSMENT SPREADSHEET - ACCIDENTAL INGESTION OF SEDIMENT - AVERAGE SOIL INGESTION

SITE NAME: ARMY CREEK LANDFILL
LOCATION: NEW CASTLE COUNTY, DELAWARE
DATE: 12/06/89

HAZARD INDICES AND INCREMENTAL CANCER RISKS ARE CALCULATED BY SPREADSHEET, EXPOSURES THROUGH PICA INGESTION BASED UPON MAXIMUM CONTAMINANT CONCENTRATIONS DETECTED IN THE SEDIMENT. ASSUMPTIONS ARE OUTLINED BELOW

REFERENCES: U.S. EPA, OCTOBER 1986

RELEVANT EQUATION: DOSE=(C)*(CR)*(AF)/(BW)

ASSUPTIONS: CHILDREN BETWEEN AGES 6 AND 11 ARE SUBJECT TO EXPOSURE THROUGH THIS ROUTE.

C = CONCENTRATION OF CONTAMINANT IN SEDIMENT (MG/KG)

IR = AVERAGE SOIL INGESTION RATE IN G/DAY 0.01

AF = ABSORTION FRACTION: 1

BW: = AVE. BODY WEIGHT OF CHILD (KG) 6 TO 11 YAERS OLD: 30

DETERMINE CONVERSION FACTORS:

DOSE = (C MG/KG)*(1 KG/1000 G)*(IR G/DAY)/(BW KG)

DOSE = (CF)*(C) CFave = 3.3333E-07

DETERMINE TIME-WEIGHTED AVERAGE DOSE

6 YEARS OF EXPOSURE PER 70 YEAR LIFETIME (AGES 6 TO 11 YEARS OLD)
1 DAYS OF EXPOSURE/YEAR

TIME WEIGHTING FACTOR (YEARS OF EXPOSURE / ONE YEAR) FOR NONCARCINOGENS: 2.7397E-03
TIME WEIGHTING FACTOR (YEARS OF EXPOSURE / 70 YEARS) FOR CARCINOGENS: 2.3483E-04

RISK ASSESSMENT SPREADSHEET - ACCIDENTAL INGESTION OF SEDIMENT (PAGE TWO)
ARMY CREEK LANDFILL, NEW CASTLE COUNTY, DELAWARE
SCENARIO: MAXIMUM SEDIMENT CONCENTRATIONS
CALCULATE DOSES:

CHEMICAL	C max (MG/KG)	ABSORPTION FRACTION	CHILD DOSE (MG/KG/DAY)	NONCARCINOGENIC TIME-WEIGHTED AVERAGE DOSE (MG/KG/DAY)	CARCINOGENIC TIME-WEIGHTED AVERAGE DOSE (MG/KG/DAY)
ARSENIC	6	1	2.0000E-06	5.4795E-09	4.6967E-10
LEAD	97.8	1	3.2600E-05	8.9315E-08	7.6556E-09
CADMIUM		1	0.0000E+00	0.0000E+00	0.0000E+00
CHROMIUM	45	1	1.5000E-05	4.1096E-08	3.5225E-09
NICKEL	26.4	1	8.8000E-06	2.4110E-08	2.0665E-09
IRON	68800	1	2.2933E-02	6.2831E-05	5.3855E-06
MERCURY	0.119	1	3.9667E-08	1.0868E-10	9.3151E-12
ZINC	273	1	9.1000E-05	2.4932E-07	2.1370E-08
BENZENE		1	0.0000E+00	0.0000E+00	0.0000E+00
BENZO(a)PYRENE	1.07	1	3.5667E-07	9.7717E-10	8.3757E-11
BIS(2-CHLOROETHYL)ETHER		1	0.0000E+00	0.0000E+00	0.0000E+00
1,2-DICHLOROETHANE		1	0.0000E+00	0.0000E+00	0.0000E+00

RISK ASSESSMENT SPREADSHEET - ACCIDENTAL INGESTION OF SEDIMENT (PAGE THREE)
ARMY CREEK LANDFILL, NEW CASTLE COUNTY, DELAWARE
SCENARIO: MAXIMUM SEDIMENT CONCENTRATIONS
DETERMINE HAZARD INDICIES AND CANCER RISK:

CHEMICAL	RfD (MG/KG/DAY)	CPF (KG-DAY/MG)	HAZARD INDEX CHILD	CANCER RISK LIFETIME
ARSENIC	1.00E-03	1.75E+00	5.4795E-06	8.2192E-10
LEAD	1.40E-03		6.3796E-05	0.0000E+00
CADMIUM	5.00E-04		0.0000E+00	0.0000E+00
CHROMIUM	1.00E+00		4.1096E-08	0.0000E+00
NICKEL	2.00E-02		1.2055E-06	0.0000E+00
IRON			0.0000E+00	0.0000E+00
MERCURY	3.00E-04		3.6225E-07	0.0000E+00
ZINC	2.00E-01		1.2466E-06	0.0000E+00
BENZENE		2.90E-02	0.0000E+00	0.0000E+00
BENZO(a)PYRENE			0.0000E+00	0.0000E+00
BIS(2-CHLOROETHYL)ETHER		1.10E+00	0.0000E+00	0.0000E+00
1,2-DICHLOROETHANE		9.10E-02	0.0000E+00	0.0000E+00
TOTAL			7.2131E-05	8.2192E-10

AR301552

RISK ASSESSMENT SPREADSHEET - ACCIDENTAL INGESTION OF SEDIMENT - HIGH SOIL INGESTION

SITE NAME: ARMY CREEK LANDFILL
LOCATION: NEW CASTLE COUNTY, DELAWARE
DATE: 12/06/89

HAZARD INDICES AND INCREMENTAL CANCER RISKS ARE CALCULATED BY SPREADSHEET, EXPOSURES THROUGH PICA INGESTION BASED UPON MAXIMUM CONTAMINANT CONCENTRATIONS DETECTED IN THE SEDIMENT. ASSUMPTIONS ARE OUTLINED BELOW

REFERENCES: U.S. EPA, OCTOBER 1986

RELEVANT EQUATION: DOSE=(C)*(CR)*(AF)/(BW)

ASSUPTIONS: CHILDREN BETWEEN AGES 6 AND 11 ARE SUBJECT TO EXPOSURE THROUGH THIS ROUTE.

C =	CONCENTRATION OF CONTAMINANT IN SEDIMENT (MG/KG)	
IR =	AVERAGE SOIL INGESTION RATE IN G/DAY	0.05
AF =	ABSORTION FRACTION:	1
BW: =	AVE. BODY WEIGHT OF CHILD (KG) 6 TO 11 YAERS OLD:	30

DETERMINE CONVERSION FACTORS:

DOSE = (C MG/KG)*(1 KG/1000 G)*(IR G/DAY)/(BW KG)

DOSE = (CF)*(C) CF = 1.6667E-06

DETERMINE TIME-WEIGHTED AVERAGE DOSE

6	YEARS OF EXPOSURE PER 70 YEAR LIFETIME (AGES 6 TO 11 YEARS OLD)
1	DAYS OF EXPOSURE/YEAR (5D/WEEK)*(4WEEKS/MO)*(8MO/YR)*70% OF THE TIME FOR ONE YEAR

TIME WEIGHTING FACTOR (YEARS OF EXPOSURE / ONE YEAR) FOR NONCARCINOGENS:	2.7397E-03
TIME WEIGHTING FACTOR (YEARS OF EXPOSURE / 70 YEARS) FOR CARCINOGENS:	2.3483E-04

AR301553

RISK ASSESSMENT SPREADSHEET - ACCIDENTAL INGESTION OF SEDIMENT (PAGE TWO)
ARMY CREEK LANDFILL, NEW CASTLE COUNTY, DELAWARE
SCENARIO: MAXIMUM SEDIMENT CONCENTRATIONS
CALCULATE DOSES:

CHEMICAL	C max (MG/KG)	ABSORPTION FRACTION	CHILD DOSE (MG/KG/DAY)	NONCARCINOGENIC TIME-WEIGHTED AVERAGE DOSE (MG/KG/DAY)	CARCINOGENIC TIME-WEIGHTED AVERAGE DOSE (MG/KG/DAY)
ARSENIC	6	1	1.0000E-05	2.7397E-08	2.3483E-09
LEAD	97.8	1	1.6300E-04	4.4658E-07	3.8278E-08
CADMIUM		1	0.0000E+00	0.0000E+00	0.0000E+00
CHROMIUM	45	1	7.5000E-05	2.0548E-07	1.7613E-08
NICKEL	26.4	1	4.4000E-05	1.2055E-07	1.0333E-08
IRON	68800	1	1.1467E-01	3.1416E-04	2.6928E-05
MERCURY	0.119	1	1.9833E-07	5.4338E-10	4.6575E-11
ZINC	273	1	4.5500E-04	1.2466E-06	1.0685E-07
BENZENE		1	0.0000E+00	0.0000E+00	0.0000E+00
BENZO(a)PYRENE	1.07	1	1.7833E-06	4.8858E-09	4.1879E-10
BIS(2-CHLOROETHYL)ETHER		1	0.0000E+00	0.0000E+00	0.0000E+00
1,2-DICHLOROETHANE		1	0.0000E+00	0.0000E+00	0.0000E+00

RISK ASSESSMENT SPREADSHEET - ACCIDENTAL INGESTION OF SEDIMENT (PAGE THREE)
ARMY CREEK LANDFILL, NEW CASTLE COUNTY, DELAWARE
SCENARIO: MAXIMUM SEDIMENT CONCENTRATIONS
DETERMINE HAZARD INDICIES AND CANCER RISK:

CHEMICAL	RfD (MG/KG/DAY)	CPF (KG-DAY/MG)	HAZARD INDEX CHILD	CANCER RISK LIFETIME
ARSENIC	1.00E-03	1.75E+00	2.7397E-05	4.1096E-09
LEAD	1.40E-03		3.1898E-04	0.0000E+00
CADMIUM	5.00E-04		0.0000E+00	0.0000E+00
CHROMIUM	1.00E+00		2.0548E-07	0.0000E+00
NICKEL	2.00E-02		6.0274E-06	0.0000E+00
IRON			0.0000E+00	0.0000E+00
MERCURY	3.00E-04		1.8113E-06	0.0000E+00
ZINC	2.00E-01		6.2329E-06	0.0000E+00
BENZENE		2.90E-02	0.0000E+00	0.0000E+00
BENZO(a)PYRENE			0.0000E+00	0.0000E+00
BIS(2-CHLOROETHYL)ETHER		1.10E+00	0.0000E+00	0.0000E+00
1,2-DICHLOROETHANE		9.10E-02	0.0000E+00	0.0000E+00
TOTAL			3.6066E-04	4.1096E-09

RISK ASSESSMENT SPREADSHEET - DERMAL ABSORPTION OF SEDIMENT BY ADULT.

SITE NAME: ARMY CREEK LANDFILL
LOCATION: NEW CASTLE COUNTY, DELAWARE
DATE: 12/06/89

HAZARD INDICES AND INCREMENTAL CANCER RISKS ARE CALCULATED BY SPREADSHEET, EXPOSURES THROUGH DERMAL ABSORPTION BASED UPON MAXIMUM CONTAMINANT CONCENTRATIONS DETECTED IN THE SEDIMENT. ASSUMPTIONS ARE OUTLINED BELOW

REFERENCES: U.S. EPA, OCTOBER 1986
U.S. EPA, APRIL 1988

RELEVANT EQUATION: DOSE=(C)*(A)*(BF)*(EF)/(BW)

ASSUPTIONS: ADULTS ARE SUBJECT TO EXPOSURE THROUGH THIS ROUTE.

C =	CONCENTRATION OF CONTAMINANT IN SEDIMENT (MG/KG)	
A =	TOTAL SOIL ADHERED ((5820 sq.cm.)*(2.0 g./sq.cm./day)).	11640
EF =	EXPOSURE FREQUENCY PER DAY	
BF =	BIOAVAILABILITY FACTOR (50% FOR ORGANICS):	0.5
BW: =	AVE. BODY WEIGHT OF ADULT:	70

DETERMINE CONVERSION FACTORS:

DOSE = (C MG/KG)*(1 KG/1000 G)*(1G/1000MG)*(A)*(BF)*(EF)/(BW KG)

DOSE = (CF)*(C)*(EF) CF = 1.6629E-04

DETERMINE TIME-WEIGHTED AVERAGE DOSE

30	YEARS OF EXPOSURE PER 70 YEAR LIFETIME
0.2	DAYS OF EXPOSURE/YEAR

TIME WEIGHTING FACTOR (YEARS OF EXPOSURE / ONE YEAR) FOR NONCARCINOGENS:	5.4795E-04
TIME WEIGHTING FACTOR (YEARS OF EXPOSURE / 70 YEARS) FOR CARCINOGENS:	2.3483E-04

RISK ASSESSMENT SPREADSHEET - DERMAL ABSORPTION OF SEDIMENT (PAGE 2)
ARMY CREEK LANDFILL, NEW CASTLE COUNTY, DELAWARE
SCENARIO: MAXIMUM SEDIMENT CONCENTRATIONS
CALCULATE DOSES:

CHEMICAL	C max (MG/KG)	BIOAVAILABILITY FRACTION	ADULT DOSE (MG/KG/DAY)	NONCARCINOGENIC TIME-WEIGHTED AVERAGE DOSE (MG/KG/DAY)	CARCINOGENIC TIME-WEIGHTED AVERAGE DOSE (MG/KG/DAY)
ARSENIC	6	0	0.0000E+00	0.0000E+00	0.0000E+00
LEAD	97.8	0	0.0000E+00	0.0000E+00	0.0000E+00
CADMIUM		0	0.0000E+00	0.0000E+00	0.0000E+00
CHROMIUM	45	0	0.0000E+00	0.0000E+00	0.0000E+00
NICKEL	26.4	0	0.0000E+00	0.0000E+00	0.0000E+00
IRON	68800	0	0.0000E+00	0.0000E+00	0.0000E+00
MERCURY	0.119	0	0.0000E+00	0.0000E+00	0.0000E+00
ZINC	273	0	0.0000E+00	0.0000E+00	0.0000E+00
BENZENE		0.5	0.0000E+00	0.0000E+00	0.0000E+00
BENZO(a)PYRENE	1.07	0.5	8.8963E-05	4.8747E-08	2.0891E-08
BIS(2-CHLOROETHYL)ETHER		0.5	0.0000E+00	0.0000E+00	0.0000E+00
1,2-DICHLOROETHANE		0.5	0.0000E+00	0.0000E+00	0.0000E+00

RISK ASSESSMENT SPREADSHEET - DERMAL ABSORPTION OF SEDIMENT (PAGE 3)
ARMY CREEK LANDFILL, NEW CASTLE COUNTY, DELAWARE
SCENARIO: MAXIMUM SEDIMENT CONCENTRATIONS
DETERMINE HAZARD INDICIES AND CANCER RISK:

CHEMICAL	RfD (MG/KG/DAY)	CPF (KG-DAY/MG)	HAZARD INDEX ADULT	CANCER RISK LIFETIME
ARSENIC	1.00E-03	1.75E+00	0.0000E+00	0.0000E+00
LEAD	1.40E-03		0.0000E+00	0.0000E+00
CADMIUM	5.00E-04		0.0000E+00	0.0000E+00
CHROMIUM	1.00E+00		0.0000E+00	0.0000E+00
NICKEL	2.00E-02		0.0000E+00	0.0000E+00
IRON			0.0000E+00	0.0000E+00
MERCURY	3.00E-04		0.0000E+00	0.0000E+00
ZINC	2.00E-01		0.0000E+00	0.0000E+00
BENZENE		2.90E-02	0.0000E+00	0.0000E+00
BENZO(a)PYRENE			0.0000E+00	0.0000E+00
BIS(2-CHLOROETHYL)ETHER		1.10E+00	0.0000E+00	0.0000E+00
1,2-DICHLOROETHANE		9.10E-02	0.0000E+00	0.0000E+00
TOTAL			0.0000E+00	0.0000E+00

RISK ASSESSMENT SPREADSHEET - DERMAL ABSORPTION OF SEDIMENT BY A CHILD 6 TO 11 YRS OLD

SITE NAME: ARMY CREEK LANDFILL
LOCATION: NEW CASTLE COUNTY, DELAWARE
DATE: 12/06/89

HAZARD INDICES AND INCREMENTAL CANCER RISKS ARE CALCULATED BY SPREADSHEET, EXPOSURES THROUGH DERMAL ABSORPTION BASED UPON MAXIMUM CONTAMINANT CONCENTRATIONS DETECTED IN THE SEDIMENT. ASSUMPTIONS ARE OUTLINED BELOW

REFERENCES: U.S. EPA, OCTOBER 1986
U.S. EPA, APRIL 1988

RELEVANT EQUATION: DOSE=(C)*(A)*(BF)*(EF)/(BW)

ASSUPTIONS: CHILDREN BETWEEN AGES 6 AND 11 ARE SUBJECT TO EXPOSURE THROUGH THIS ROUTE.

C	= CONCENTRATION OF CONTAMINANT IN SEDIMENT (MG/KG)	
A	= TOTAL SOIL ADHERED ((2625 sq.cm.)*(2.0 g./sq.cm./day)).	5250
EF	= EXPOSURE FREQUENCY PER DAY	
BF	= BIOAVAILABILITY FACTOR (50% FOR ORGANICS):	0.5
BW:	= AVE. BODY WEIGHT OF CHILD (KG) 6 TO 11 YAERS OLD:	30

DETERMINE CONVERSION FACTORS:

DOSE = (C MG/KG)*(1 KG/1000 G)*(1G/1000MG)*(A)*(BF)*(EF)/(BW KG)

DOSE = (CF)*(C)*(EF) CF = 1.7500E-04

DETERMINE TIME-WEIGHTED AVERAGE DOSE

6 YEARS OF EXPOSURE PER 70 YEAR LIFETIME (AGES 6 TO 11 YEARS OLD)
1 DAYS OF EXPOSURE/YEAR

TIME WEIGHTING FACTOR (YEARS OF EXPOSURE / ONE YEAR) FOR NONCARCINOGENS:	2.7397E-03
TIME WEIGHTING FACTOR (YEARS OF EXPOSURE / 70 YEARS) FOR CARCINOGENS:	2.3483E-04

RISK ASSESSMENT SPREADSHEET - DERMAL ABSORPTION OF SEDIMENT (PAGE 2)
ARMY CREEK LANDFILL, NEW CASTLE COUNTY, DELAWARE
SCENARIO: MAXIMUM SEDIMENT CONCENTRATIONS
CALCULATE DOSES:

CHEMICAL	C max (MG/KG)	BIOAVAILABILITY FRACTION	CHILD DOSE (MG/KG/DAY)	NONCARCINOGENIC TIME-WEIGHTED AVERAGE DOSE (MG/KG/DAY)	CARCINOGENIC TIME-WEIGHTED AVERAGE DOSE (MG/KG/DAY)
ARSENIC	6	0	0.0000E+00	0.0000E+00	0.0000E+00
LEAD	97.8	0	0.0000E+00	0.0000E+00	0.0000E+00
CADMIUM		0	0.0000E+00	0.0000E+00	0.0000E+00
CHROMIUM	45	0	0.0000E+00	0.0000E+00	0.0000E+00
NICKEL	26.4	0	0.0000E+00	0.0000E+00	0.0000E+00
IRON	68800	0	0.0000E+00	0.0000E+00	0.0000E+00
MERCURY	0.119				
ZINC	273				
BENZENE		0.5	0.0000E+00	0.0000E+00	0.0000E+00
BENZO(a)PYRENE	1.07	0.5	9.3625E-05	2.5651E-07	2.1986E-08
BIS(2-CHLOROETHYL)ETHER		0.5	0.0000E+00	0.0000E+00	0.0000E+00
1,2-DICHLOROETHANE		0.5	0.0000E+00	0.0000E+00	0.0000E+00

RISK ASSESSMENT SPREADSHEET - DERMAL ABSORPTION OF SEDIMENT (PAGE 3)
ARMY CREEK LANDFILL, NEW CASTLE COUNTY, DELAWARE
SCENARIO: MAXIMUM SEDIMENT CONCENTRATIONS
DETERMINE HAZARD INDICIES AND CANCER RISK:

CHEMICAL	RfD (MG/KG/DAY)	CPF (KG-DAY/MG)	HAZARD INDEX CHILD	CANCER RISK LIFETIME
ARSENIC	1.00E-03	1.75E+00	0.0000E+00	0.0000E+00
LEAD	1.40E-03		0.0000E+00	0.0000E+00
CADMIUM	5.00E-04		0.0000E+00	0.0000E+00
CHROMIUM	1.00E+00		0.0000E+00	0.0000E+00
NICKEL	2.00E-02		0.0000E+00	0.0000E+00
IRON			0.0000E+00	0.0000E+00
MERCURY	3.00E-04		0.0000E+00	0.0000E+00
ZINC	2.00E-01		0.0000E+00	0.0000E+00
BENZENE		2.90E-02	0.0000E+00	0.0000E+00
BENZO(a)PYRENE			0.0000E+00	0.0000E+00
BIS(2-CHLOROETHYL)ETHER		1.10E+00	0.0000E+00	0.0000E+00
1,2-DICHLOROETHANE		9.10E-02	0.0000E+00	0.0000E+00
TOTAL			0.0000E+00	0.0000E+00

RISK ASSESSMENT SPREADSHEET - SURFACE WATER INGESTION BY AN ADULT

SITE NAME: ARMY CREEK LANDFILL
LOCATION: NEW CASTLE COUNTY, DELAWARE
DATE: 12/06/89

HAZARD INDICES AND INCREMENTAL CANCER RISKS ARE CALCULATED BY SPREADSHEET, EXPOSURES THROUGH WATER INGESTION BASED UPON MAXIMUM CONTAMINANT CONCENTRATIONS DETECTED IN THE SURFACE WATER. ASSUMPTIONS ARE OUTLINED BELOW

REFERENCES: U.S. EPA, OCTOBER 1986
U.S. EPA, APRIL, 1988

RELEVANT EQUATION: DOSE=(C)*(CR)*(AF)/(BW)

ASSUMPTIONS: ADULTS ARE SUBJECT TO EXPOSURE THROUGH THIS ROUTE.

C = CONCENTRATION OF CONTAMINANT IN SURFACE WATER (MG/L)	
IR = ADULT WATER INGESTION RATE IN L/DAY	0.1
AF = ABSORPTION FRACTION (100%):	1
BW: = AVG. BODY WEIGHT OF ADULT (KG):	70

DETERMINE CONVERSION FACTORS:

DOSE = (C MG/L)*(IR L/DAY)/(BW KG)

DOSE = (CF)*(C) CFadult = 1.4286E-03

DETERMINE TIME-WEIGHTED AVERAGE DOSE

30	YEARS OF EXPOSURE PER 70 YEAR LIFETIME
0.2	DAYS OF EXPOSURE/YEAR 365 DAYS/YR FOR 1 YEAR

TIME WEIGHTING FACTOR (YEARS OF EXPOSURE / ONE YEAR) FOR NONCARCINOGENS:	5.4795E-04
TIME WEIGHTING FACTOR (YEARS OF EXPOSURE / 70 YEARS) FOR CARCINOGENS:	2.3483E-04

RISK ASSESSMENT SPREADSHEET - SURFACE WATER INGESTION BY ADULT (PAGE TWO)
ARMY CREEK LANDFILL, NEW CASTLE COUNTY, DELAWARE
SCENARIO: MAXIMUM SURFACE WATER CONCENTRATIONS
CALCULATE DOSES:

CHEMICAL	C max (MG/L)	ABSORPTION FRACTION	ADULT DOSE (MG/KG/DAY)	NONCARCINOGENIC TIME-WEIGHTED AVERAGE DOSE (MG/KG/DAY)	CARCINOGENIC TIME-WEIGHTED AVERAGE DOSE (MG/KG/DA
ARSENIC		1	0.0000E+00	0.0000E+00	0.0000E+00
LEAD		1	0.0000E+00	0.0000E+00	0.0000E+00
CADMIUM	0.038	1	5.4286E-05	2.9746E-08	1.2748E-08
CHROMIUM	0.15	1	2.1429E-04	1.1742E-07	5.0321E-08
NICKEL	0.15	1	2.1429E-04	1.1742E-07	5.0321E-08
IRON	2.86	1	4.0857E-03	2.2387E-06	9.5946E-07
MERCURY	0.0002	1	2.8571E-07	1.5656E-10	6.7095E-11
ZINC	0.64	1	9.1429E-04	5.0098E-07	2.1471E-07
BENZENE		1	0.0000E+00	0.0000E+00	0.0000E+00
BENZO(a)PYRENE		1	0.0000E+00	0.0000E+00	0.0000E+00
BIS(2-CHLOROETHYL)ETHER	0.0075	1	1.0714E-05	5.8708E-09	2.5161E-09
1,2-DICHLOROETHANE	0.005	1	7.1429E-06	3.9139E-09	1.6774E-09

AR301563

RISK ASSESSMENT SPREADSHEET - SURFACE WATER INGESTION BY AN ADULT (PAGE 3)
ARMY CREEK LANDFILL, NEW CASTLE COUNTY, DELAWARE
SCENARIO: MAXIMUM SURFACE WATER CONCENTRATIONS
DETERMINE HAZARD INDICES AND CANCER RISK

CHEMICAL	RfD (MG/KG/DAY)	CPF (KG-DAY/MG)	HAZARD INDEX ADULT	CANCER RISK LIFETIME
ARSENIC	1.00E-03	1.75E+00	0.0000E+00	0.0000E+00
LEAD	1.40E-03		0.0000E+00	0.0000E+00
CADMIUM	5.00E-04		5.9491E-05	0.0000E+00
CHROMIUM	1.00E+00		1.1742E-07	0.0000E+00
NICKEL	2.00E-02		5.8708E-06	0.0000E+00
IRON			0.0000E+00	0.0000E+00
MERCURY	3.00E-04		5.2185E-07	0.0000E+00
ZINC	2.00E-01		2.5049E-06	0.0000E+00
BENZENE		2.90E-02	0.0000E+00	0.0000E+00
BENZO(a)PYRENE			0.0000E+00	0.0000E+00
BIS(2-CHLOROETHYL)ETHER		1.10E+00	0.0000E+00	2.7677E-09
1,2-DICHLOROETHANE		9.10E-02	0.0000E+00	1.5264E-10
TOTAL			6.8506E-05	2.9203E-09

RISK ASSESSMENT SPREADSHEET - SURFACE WATER INGESTION BY A CHILD 6 TO 11 YEARS OLD.

SITE NAME: ARMY CREEK LANDFILL
LOCATION: NEW CASTLE COUNTY, DELAWARE
DATE: 12/06/89

HAZARD INDICES AND INCREMENTAL CANCER RISKS ARE CALCULATED BY SPREADSHEET, EXPOSURES THROUGH WATER INGESTION BASED UPON MAXIMUM CONTAMINANT CONCENTRATIONS DETECTED IN THE SURFACE WATER. ASSUMPTIONS ARE OUTLINED BELOW.

REFERENCES: U.S. EPA, OCTOBER 1986
U.S. EPA, APRIL, 1988

RELEVANT EQUATION: DOSE=(C)*(CR)*(AF)/(BW)

ASSUMPTIONS: CHILDREN ARE SUBJECT TO EXPOSURE THROUGH THIS ROUTE.

C = CONCENTRATION OF CONTAMINANT IN SURFACE WATER (MG/L)	
IR = CHILD WATER INGESTION RATE IN L/DAY	0.1
AF = ABSORPTION FRACTION (100%):	1
BW: = AVG. BODY WEIGHT OF CHILD (KG):	30

DETERMINE CONVERSION FACTORS:

DOSE = (C MG/L)*(IR L/DAY)/(BW KG)

DOSE = (CF)*(C) CFchild = 3.3333E-03

DETERMINE TIME-WEIGHTED AVERAGE DOSE

6 YEARS OF EXPOSURE PER 70 YEAR LIFETIME
1 DAYS OF EXPOSURE/YEAR 365 DAYS/YR FOR 1 YEAP

TIME WEIGHTING FACTOR (YEARS OF EXPOSURE / ONE YEAR) FOR NONCARCINOGENS:	2.7397E-03
TIME WEIGHTING FACTOR (YEARS OF EXPOSURE / 70 YEARS) FOR CARCINOGENS:	2.3483E-04

RISK ASSESSMENT SPREADSHEET - SURFACE WATER INGESTION BY CHILD.
ARMY CREEK LANDFILL, NEW CASTLE COUNTY, DELAWARE
SCENARIO: *MAXIMUM SURFACE WATER CONCENTRATIONS*
CALCULATE DOSES:

CHEMICAL	C max (MG/L)	ABSORPTION FRACTION	CHILD DOSE (MG/KG/DAY)	NONCARCINOGENIC TIME-WEIGHTED AVERAGE DOSE (MG/KG/DAY)	CARCINOGENIC TIME-WEIGHTED AVERAGE DOSE (MG/KG/DA
ARSENIC		1	0.0000E+00	0.0000E+00	0.0000E+00
LEAD		1	0.0000E+00	0.0000E+00	0.0000E+00
CADMIUM	0.038	1	1.2667E-04	3.4703E-07	2.9746E-08
CHROMIUM	0.15	1	5.0000E-04	1.3699E-06	1.1742E-07
NICKEL	0.15	1	5.0000E-04	1.3699E-06	1.1742E-07
IRON	2.86	1	9.5333E-03	2.6119E-05	2.2387E-06
MERCURY	0.0002	1	6.6667E-07	1.8265E-09	1.5656E-10
ZINC	0.64	1	2.1333E-03	5.8447E-06	5.0098E-07
BENZENE		1	0.0000E+00	0.0000E+00	0.0000E+00
BENZO(a)PYRENE		1	0.0000E+00	0.0000E+00	0.0000E+00
BIS(2-CHLOROETHYL)ETHER	0.0075	1	2.5000E-05	6.8493E-08	5.8703E-09
1,2-DICHLOROETHANE	0.005	1	1.6667E-05	4.5662E-08	3.9139E-09

RISK ASSESSMENT SPREADSHEET - SURFACE WATER INGESTION BY A CHILD (PAGE 3)
ARMY CREEK LANDFILL, NEW CASTLE COUNTY, DELAWARE
SCENARIO: MAXIMUM SURFACE WATER CONCENTRATIONS
DETERMINE HAZARD INDICES AND CANCER RISK

CHEMICAL	RfD (MG/KG/DAY)	CPF (KG-DAY/MG)	HAZARD INDEX CHILD	CANCER RISK LIFETIME
ARSENIC	1.00E-03	1.75E+00	0.0000E+00	0.0000E+00
LEAD	1.40E-03		0.0000E+00	0.0000E+00
CADMIUM	5.00E-04		6.9406E-04	0.0000E+00
CHROMIUM	1.00E+00		1.3699E-06	0.0000E+00
NICKEL	2.00E-02		6.8493E-05	0.0000E+00
IRON			0.0000E+00	0.0000E+00
MERCURY	3.00E-04		6.0883E-06	0.0000E+00
ZINC	2.00E-01		2.9224E-05	0.0000E+00
BENZENE		2.90E-02	0.0000E+00	0.0000E+00
BENZO(a)PYRENE			0.0000E+00	0.0000E+00
BIS(2-CHLOROETHYL)ETHER		1.10E+00	0.0000E+00	6.4579E-09
1,2-DICHLOROETHANE		9.10E-02	0.0000E+00	0.0000E+00
TOTAL			7.9924E-04	6.4579E-09

RISK ASSESSMENT SPREADSHEET - INHALATION OF VOLATILES FROM SURFACE WATER BY ADULTS

SITE NAME: ARMY CREEK LANDFILL
LOCATION: NEW CASTLE COUNTY, DELAWARE
DATE: 12/06/89

HAZARD INDICES AND INCREMENTAL CANCER RISKS ARE CALCULATED BY SPREADSHEET, EXPOSURES THROUGH AIR INHALATION OF VOLATILES BASED UPON MAXIMUM CONTAMINANT CONCENTRATIONS DETECTED IN THE SURFACE WATER. THESE CONCENTRATIONS WERE MULTIPLIED BY HENRY'S CONSTANT TO OBTAIN MAXIMUM AIR CONCENTRATIONS. ASSUMPTIONS ARE OUTLINED BELOW.

REFERENCES: U.S. EPA, OCTOBER 1986; U.S. EPA, APRIL 1988

RELEVANT EQUATION: DOSE=(C)*(CR)*(AF)/(BW)

ASSUMPTIONS: ADULTS SUBJECT TO EXPOSURE THROUGH THIS ROUTE.

C = CONCENTRATION OF CONTAMINANT IN AIR (MG/CU.M)	
IR = ADULT AIR INHALATION RATE IN CU.M/DAY	1
AF = ABSORPTION FRACTION (100%):	1
BW: = AVG. BODY WEIGHT OF ADULT	70

DETERMINE CONVERSION FACTORS:

DOSE = (C MG/CU.M)*(IR CU.M/DAY)/(BW KG)

DOSE = (CF)*(C) CF = 1.4286E-02

DETERMINE TIME-WEIGHTED AVERAGE DOSE

30 YEARS OF EXPOSURE PER 70 YEAR LIFETIME
0 DAYS OF EXPOSURE PER YEAR.

TIME WEIGHTING FACTOR (YEARS OF EXPOSURE / ONE YEAR) FOR NONCARCINOGENS:	5.4795E-04
TIME WEIGHTING FACTOR (YEARS OF EXPOSURE / 70 YEARS) FOR CARCINOGENS:	2.3483E-04

RISK ASSESSMENT SPREADSHEET - INHALATION OF VOLATILES FROM SURFACE WATER BY ADULTS (PAGE 2)
ARMY CREEK LANDFILL, NEW CASTLE COUNTY, DELAWARE
SCENARIO: MAXIMUM AIR CONCENTRATIONS
CALCULATE DOSES:

CHEMICAL	C max (MG/CU.M)	ABSORPTION FRACTION	ADULT DOSE (MG/KG/DAY)	NONCARCINOGENIC TIME-WEIGHTED AVERAGE DOSE (MG/KG/DAY)	CARCINOGENIC TIME-WEIGHTED AVERAGE DOSE (MG/KG/DAY)
ARSENIC		1	0.0000E+00	0.0000E+00	0.0000E+00
LEAD		1	0.0000E+00	0.0000E+00	0.0000E+00
CADMIUM		1	0.0000E+00	0.0000E+00	0.0000E+00
CHROMIUM		1	0.0000E+00	0.0000E+00	0.0000E+00
NICKEL		1	0.0000E+00	0.0000E+00	0.0000E+00
IRON		1	0.0000E+00	0.0000E+00	0.0000E+00
MERCURY		1	0.0000E+00	0.0000E+00	0.0000E+00
ZINC		1	0.0000E+00	0.0000E+00	0.0000E+00
BENZENE		1	0.0000E+00	0.0000E+00	0.0000E+00
BENZO(a)PYRENE		1	0.0000E+00	0.0000E+00	0.0000E+00
BIS(2-CHLOROETHYL)ETHER	0.00407	1	5.8143E-05	3.1859E-08	1.3654E-08
1,2-DICHLOROETHANE	0.20	1	2.8571E-03	1.5656E-06	6.7095E-07

AR301569

RISK ASSESSMENT SPREADSHEET - INHALATION OF VOLATILES FROM SURFACE WATER BY ADULTS (PAGE 3)
ARMY CREEK LANDFILL, NEW CASTLE COUNTY, DELAWARE
SCENARIO: MAXIMUM AIR CONCENTRATIONS VOLATILIZED FROM SURFACE WATER
DETERMINE HAZARD INDICES AND CANCER RISK

CHEMICAL	RfD (MG/KG/DAY)	CPF (KG-DAY/MG)	HAZARD INDEX ADULT	CANCER RISK LIFETIME
ARSENIC		5.00E+01	0.0000E+00	0.0000E+00
LEAD	4.30E-04		0.0000E+00	0.0000E+00
CADMIUM		6.10E+00	0.0000E+00	0.0000E+00
CHROMIUM			0.0000E+00	0.0000E+00
NICKEL		8.40E-01	0.0000E+00	0.0000E+00
IRON			0.0000E+00	0.0000E+00
MERCURY			0.0000E+00	0.0000E+00
ZINC			0.0000E+00	0.0000E+00
BENZENE		2.90E-02	0.0000E+00	0.0000E+00
BENZO(a)PYRENE			0.0000E+00	0.0000E+00
BIS(2-CHLOROETHYL)ETHER		1.10E+00	0.0000E+00	1.5019E-08
1,2-DICHLOROETHANE		9.10E-02	0.0000E+00	6.1057E-08
TOTAL			0.0000E+00	7.6076E-08

AR301570

RISK ASSESSMENT SPREADSHEET - INHALATION OF VOLATILES FROM SURFACE WATER BY CHILDREN 6 TO 11 YRS OLD

SITE NAME: ARMY CREEK LANDFILL
LOCATION: NEW CASTLE COUNTY, DELAWARE
DATE: 12/06/89

HAZARD INDICES AND INCREMENTAL CANCER RISKS ARE CALCULATED BY SPREADSHEET. EXPOSURES THROUGH AIR INHALATION OF VOLATILES BASED UPON MAXIMUM CONTAMINANT CONCENTRATIONS DETECTED IN THE SURFACE WATER. THESE CONCENTRATIONS WERE MULTIPLIED BY HENRY'S CONSTANT TO OBTAIN MAXIMUM AIR CONCENTRATIONS. ASSUMPTIONS ARE OUTLINED BELOW.

REFERENCES: U.S. EPA, OCTOBER 1986; U.S. EPA, APRIL 1988

RELEVANT EQUATION: DOSE=(C)*(CR)*(AF)/(BW)

ASSUMPTIONS: CHILDREN BETWEEN THE AGES OF 6 AND 11 ARE SUBJECT TO EXPOSURE THROUGH THIS ROUTE.

C = CONCENTRATION OF CONTAMINANT IN AIR (MG/CU.M)

IR = CHILD AIR INHALATION RATE IN CU.M/DAY 1

AF = ABSORPTION FRACTION (100%): 1

BW: = AVG. BODY WEIGHT OF CHILD (KG) 6 TO 11 YEARS OLD: 30

DETERMINE CONVERSION FACTORS:

DOSE = (C MG/CU.M)*(IR CU.M/DAY)/(BW KG)

DOSE = (CF)*(C) CFchild = 3.3333E-02

DETERMINE TIME-WEIGHTED AVERAGE DOSE

6 YEARS OF EXPOSURE PER 70 YEAR LIFETIME
1 DAYS OF EXPOSURE PER YEAR

TIME WEIGHTING FACTOR (YEARS OF EXPOSURE / ONE YEAR) FOR NONCARCINOGENS: 2.7397E-03
TIME WEIGHTING FACTOR (YEARS OF EXPOSURE / 70 YEARS) FOR CARCINOGENS: 2.3483E-04

RISK ASSESSMENT SPREADSHEET - INHALATION OF VOLATILES FROM SURFACE WATER BY CHILDREN 6 TO 11 YRS (PAGE 2)
ARMY CREEK LANDFILL, NEW CASTLE COUNTY, DELAWARE
SCENARIO: MAXIMUM AIR CONCENTRATIONS
CALCULATE DOSES:

CHEMICAL	C max (MG/CU.M)	ABSORPTION FRACTION	CHILD DOSE (MG/KG/DAY)	NONCARCINOGENIC TIME-WEIGHTED AVERAGE DOSE (MG/KG/DAY)	CARCINOGENIC TIME-WEIGHTED AVERAGE DOSE (MG/KG/DAY)
ARSENIC		1	0.0000E+00	0.0000E+00	0.0000E+00
LEAD		1	0.0000E+00	0.0000E+00	0.0000E+00
CADMIUM		1	0.0000E+00	0.0000E+00	0.0000E+00
CHROMIUM		1	0.0000E+00	0.0000E+00	0.0000E+00
NICKEL		1	0.0000E+00	0.0000E+00	0.0000E+00
IRON		1	0.0000E+00	0.0000E+00	0.0000E+00
MERCURY		1	0.0000E+00	0.0000E+00	0.0000E+00
ZINC		1	0.0000E+00	0.0000E+00	0.0000E+00
BENZENE		1	0.0000E+00	0.0000E+00	0.0000E+00
BENZO(a)PYRENE		1	0.0000E+00	0.0000E+00	0.0000E+00
BIS(2-CHLORDETHYL)ETHER	0.00407	1	1.3567E-04	3.7169E-07	3.1859E-08
1,2-DICHLOROETHANE	0.2	1	6.6667E-03	1.8265E-05	1.5656E-06

RISK ASSESSMENT SPREADSHEET - INHALATION OF VOLATILES FROM SURFACE WATER BY CHILDREN 6 TO 11 (PAGE 3)
ARMY CREEK LANDFILL, NEW CASTLE COUNTY, DELAWARE
SCENARIO: MAXIMUM AIR CONCENTRATIONS VOLATILIZED FROM SURFACE WATER
DETERMINE HAZARD INDICES AND CANCER RISK

CHEMICAL	RfD (MG/KG/DAY)	CPF (KG-DAY/MG)	HAZARD INDEX CHILD	CANCER RISK LIFETIME
ARSENIC		5.00E+01	0.0000E+00	0.0000E+00
LEAD	4.30E-04		0.0000E+00	0.0000E+00
CADMIUM		6.10E+00	0.0000E+00	0.0000E+00
CHROMIUM			0.0000E+00	0.0000E+00
NICKEL		8.40E-01	0.0000E+00	0.0000E+00
IRON			0.0000E+00	0.0000E+00
MERCURY			0.0000E+00	0.0000E+00
ZINC			0.0000E+00	0.0000E+00
BENZENE		2.90E-02	0.0000E+00	0.0000E+00
BENZO(a)PYRENE			0.0000E+00	0.0000E+00
BIS(2-CHLOROETHYL)ETHER		1.10E+00	0.0000E+00	3.5045E-08
1,2-DICHLOROETHANE		9.10E-02	0.0000E+00	1.4247E-07
TOTAL			0.0000E+00	1.7751E-07

AR301573

RISK ASSESSMENT SPREADSHEET - DERMAL ABSORTION OF SURFACE WATER BY ADULT.

SITE NAME: ARMY CREEK LANDFILL
LOCATION: NEW CASTLE COUNTY, DELAWARE
DATE: 12/06/89

HAZARD INDICES AND INCREMENTAL CANCER RISKS ARE CALCULATED BY SPREADSHEET, EXPOSURES THROUGH DERMAL ABSORTION BASED UPON MAXIMUM CONTAMINANT CONCENTRATIONS DETECTED IN THE SURFACE WATER. ASSUMPTIONS ARE OUTLINED BELOW

REFERENCES: U.S. EPA, OCTOBER 1986
U.S. EPA 1988

RELEVANT EQUATION: DOSE=(C)*(K)*(SA)*(EF)/(BW)

ASSUMPTIONS: ADULTS ARE SUBJECT TO EXPOSURE THROUGH THIS ROUTE.

C =	CONCENTRATION OF CONTAMINANT IN SURFACE WATER IN (MG/L)	
K =	DERMAL ABSORPTION COEFFICIENT FOR ORGANICS (L/CM2/HR)	0.001
SA =	EXPOSED SURFACE AREA (CM2)	19400
EF =	EXPOSURE FREQUENCY (1 HR/DAY)	
BW: =	AVE. BODY WEIGHT OF ADULT:	70

DETERMINE CONVERSION FACTORS:
DOSE = (C MG/L)*(SA CM2)/(BW KG)

DOSE = (CF)*(C)*(EF) CF = 2.7714E+02

DETERMINE TIME-WEIGHTED AVERAGE DOSE

30	YEARS OF EXPOSURE PER 70 YEAR LIFETIME
0.2	DAYS OF EXPOSURE/YEAR

TIME WEIGHTING FACTOR (YEARS OF EXPOSURE / ONE YEAR) FOR NONCARCINOGENS:	5.4795E-04
TIME WEIGHTING FACTOR (YEARS OF EXPOSURE / 70 YEARS) FOR CARCINOGENS:	2.3483E-04

RISK ASSESSMENT SPREADSHEET - DERMAL ABSORTION OF SURFACE WATER (PAGE 2)
ARMY CREEK LANDFILL, NEW CASTLE COUNTY, DELAWARE
SCENARIO: SWIMMER DERMAL ABSORPTION OF SURFACE WATER
CALCULATE DOSES:

CHEMICAL	C max (MG/L)	ABSORPTION COEFFICIENT	ADULT DOSE (MG/KG/DAY)	NONCARCINOGENIC TIME-WEIGHTED AVERAGE DOSE (MG/KG/DAY)	CARCINOGENIC TIME-WEIGHTED AVERAGE DOSE (MG/KG/DAY)
ARSENIC		0	0.0000E+00	0.0000E+00	0.0000E+00
LEAD	0	0	0.0000E+00	0.0000E+00	0.0000E+00
CADMIUM	0.038	0	0.0000E+00	0.0000E+00	0.0000E+00
CHROMIUM	0.15	0	0.0000E+00	0.0000E+00	0.0000E+00
NICKEL	0.15	0	0.0000E+00	0.0000E+00	0.0000E+00
IRON	2.86	0	0.0000E+00	0.0000E+00	0.0000E+00
MERCURY	0.0002	0	0.0000E+00	0.0000E+00	0.0000E+00
ZINC	0.64	0	0.0000E+00	0.0000E+00	0.0000E+00
BENZENE	0	0.001	0.0000E+00	0.0000E+00	0.0000E+00
BENZO(a)PYRENE	0	0.001	0.0000E+00	0.0000E+00	0.0000E+00
BIS(2-CHLOROETHYL)ETHER	0.0075	0.001	2.0786E-03	1.1389E-06	4.8812E-07
1,2-DICHLOROETHANE	0.005	0.001	1.3857E-03	7.5930E-07	3.2541E-07

RISK ASSESSMENT SPREADSHEET - DERMAL ABSORTION OF SURFACE WATER (PAGE 3)
ARMY CREEK LANDFILL, NEW CASTLE COUNTY, DELAWARE
SCENARIO: SWIMMER DERMAL ABSORPTION OF SURFACE WATER
DETERMINE HAZARD INDICIES AND CANCER RISK:

CHEMICAL	RfD (MG/KG/DAY)	CPF (KG-DAY/MG)	HAZARD INDEX ADULT	CANCER RISK LIFETIME
ARSENIC	1.00E-03	1.75E+00	0.0000E+00	0.0000E+00
LEAD	1.40E-03		0.0000E+00	0.0000E+00
CADMIUM	5.00E-04		0.0000E+00	0.0000E+00
CHROMIUM	1.00E+00		0.0000E+00	0.0000E+00
NICKEL	2.00E-02		0.0000E+00	0.0000E+00
IRON			0.0000E+00	0.0000E+00
MERCURY	3.30E-04		0.0000E+00	0.0000E+00
ZINC	2.00E-01		0.0000E+00	0.0000E+00
BENZENE		2.90E-02	0.0000E+00	0.0000E+00
BENZO(a)PYRENE			0.0000E+00	0.0000E+00
BIS(2-CHLOROETHYL)ETHER		1.10E+00	0.0000E+00	5.3693E-07
1,2-DICHLOROETHANE		9.10E-02	0.0000E+00	2.9613E-08
TOTAL			0.0000E+00	5.6654E-07

AR301576

RISK ASSESSMENT SPREADSHEET - DERMAL ABSORTION OF SURFACE WATER BY A CHILD 6 TO 11 YRS OLD

SITE NAME: ARMY CREEK LANDFILL
LOCATION: NEW CASTLE COUNTY, DELAWARE
DATE: 12/06/89

HAZARD INDICES AND INCREMENTAL CANCER RISKS ARE CALCULATED BY SPREADSHEET, EXPOSURES THROUGH DERMAL ABSORTION BASED UPON MAXIMUM CONTAMINANT CONCENTRATIONS DETECTED IN THE SURFACE WATER. ASSUMPTIONS ARE OUTLINED BELOW

REFERENCES: U.S. EPA, OCTOBER 1986
U.S. EPA 1988

RELEVANT EQUATION: DOSE=(C)*(K)*(SA)*(EF)/(BW)

ASSUMPTIONS: CHILDREN BETWEEN AGES 6 AND 11 ARE SUBJECT TO EXPOSURE THROUGH THIS ROUTE.

C = CONCENTRATION OF CONTAMINANT IN SURFACE WATER IN (MG/L)	
K = DERMAL ABSORPTION COEFFICIENT FOR ORGANICS (L/CM2/HR)	0.001
SA = EXPOSED SURFACE AREA (CM2)	8750
EF = EXPOSURE FREQUENCY (1 HR/DAY)	
BW: = AVE. BODY WEIGHT OF CHILD (KG) 6 TO 11 YEARS OLD:	30

DETERMINE CONVERSION FACTORS:
DOSE = (C MG/L)*(SA CM2)/(BW KG)

DOSE = (CF)*(C)*(EF) CF = 2.9167E+02

DETERMINE TIME-WEIGHTED AVERAGE DOSE

6	YEARS OF EXPOSURE PER 70 YEAR LIFETIME (AGES 6 TO 11 YEARS OLD)
1	DAYS OF EXPOSURE/YEAR (5D/WEEK)*(4WEEKS/MO)*(3MO/YR)*70% OF THE TIME FOR ONE YEAR

TIME WEIGHTING FACTOR (YEARS OF EXPOSURE / ONE YEAR) FOR NONCARCINOGENS:	2.7397E-03
TIME WEIGHTING FACTOR (YEARS OF EXPOSURE / 70 YEARS) FOR CARCINOGENS:	2.3483E-04

RISK ASSESSMENT SPREADSHEET - DERMAL ABSORTION OF SURFACE WATER (PAGE 2)
ARMY CREEK LANDFILL, NEW CASTLE COUNTY, DELAWARE
SCENARIO: SWIMMER DERMAL ABSORPTION OF SURFACE WATER
CALCULATE DOSES:

CHEMICAL	C max (MG/L)	ABSORPTION COEFFICIENT	CHILD DOSE (MG/KG/DAY)	NONCARCINOGENIC TIME-WEIGHTED AVERAGE DOSE (MG/KG/DAY)	CARCINOGENIC TIME-WEIGHTED AVERAGE DOSE (MG/KG/DAY)
ARSENIC		0	0.0000E+00	0.0000E+00	0.0000E+00
LEAD	0	0	0.0000E+00	0.0000E+00	0.0000E+00
CADMIUM	0.038	0	0.0000E+00	0.0090E+00	0.0000E+00
CHROMIUM	0.15	0	0.0000E+00	0.0000E+00	0.0000E+00
NICKEL	0.15	0	0.0000E+00	0.0000E+00	0.0000E+00
IRON	2.86	0	0.0000E+00	0.0000E+00	0.0000E+00
MERCURY	0.0002	0	0.0000E+00	0.0000E+00	0.0000E+00
ZINC	0.64	0	0.0000E+00	0.0000E+00	0.0000E+00
BENZENE	0	0.001	0.0000E+00	0.0000E+00	0.0000E+00
BENZO(a)PYRENE	0	0.001	0.0000E+00	0.0000E+00	0.0000E+00
BIS(2-CHLOROETHYL)ETHER	0.0075	0.001	2.1875E-03	5.9932E-06	5.1370E-07
1,2-DICHLOROETHANE	0.005	0.001	1.4583E-03	3.9954E-06	3.4247E-07

AR301578

RISK ASSESSMENT SPREADSHEET - DERMAL ABSORTION OF SURFACE WATER (PAGE 3)
ARMY CREEK LANDFILL, NEW CASTLE COUNTY, DELAWARE
SCENARIO: SWIMMER DERMAL ABSORPTION OF SURFACE WATER
DETERMINE HAZARD INDICIES AND CANCER RISK:

CHEMICAL	RfD (MG/KG/DAY)	CPF (KG-DAY/MG)	HAZARD INDEX CHILD	CANCER RISK LIFETIME
ARSENIC	1.00E-03	1.75E+00	0.0000E+00	0.0000E+00
LEAD	1.40E-03		0.0000E+00	0.0000E+00
CADMIUM	5.00E-04		0.0000E+00	0.0000E+00
CHROMIUM	1.00E+00		0.0000E+00	0.0000E+00
NICKEL	2.00E-02		0.0000E+00	0.0000E+00
IRON			0.0000E+00	0.0000E+00
MERCURY	3.00E-04		0.0000E+00	0.0000E+00
ZINC	2.00E-01		0.0000E+00	0.0000E+00
BENZENE		2.90E-02	0.0000E+00	0.0000E+00
BENZO(a)PYRENE			0.0000E+00	0.0000E+00
BIS(2-CHLOROETHYL)ETHER		1.10E+00	0.0000E+00	5.6507E-07
1,2-DICHLOROETHANE		9.10E-02	0.0000E+00	3.1164E-08
TOTAL			0.0000E+00	5.9623E-07

Gannett Fleming
ENGINEERS AND PLANNERS

SUBJECT Risk Assessment – Ingestion of Fish | SHEET NO. 1 OF 1 | JOB NO. [illegible] | BY [illegible] DATE [illegible] CHKD. BY DATE | Army Creek Landfill

Risk Assessment - Ingestion of Contaminated fish
Site Name: Army Creek Landfill
Location: New Castle Co., DE

Relevant Equation: Dose = C * CR * EF ÷ BW
where C = Concentration of Contaminant in fish (mg/g)
CR Consumption Rate (g/day)
EF = Exposure frequency (day/yr)
BW = Body weight (Kg)

Let C = 5.2 ug/g (0.0052 mg/g) for Chromium III
5.0 ug/g (0.0050 mg/g) for lead

CR = 5.2 g/day (the average consumption rate of freshwater fish for recreational anglers in Delaware)

EF = 365 day/yr
BW = 70 Kg

Exposure Calculation for Chromium III:

$$\text{Dose (mg/Kg/day)} = \frac{(0.0052\ mg/g)*(5.2\ g/day)*(365\ days/yr)*(1\ yr/365\ days)}{(70\ Kg)}$$

$$= 3.9 \times 10^{-4}$$

Exposure Calculation for lead:

$$\text{Dose (mg/kg/day)} = \frac{(0.0050\ mg/g)*(5.2\ g/day)*(365\ days/yr)*(1\ yr/365\ days)}{(70\ Kg)}$$

$$= 3.7 \times 10^{-4}\ mg/kg/day$$

Calculation of noncarcinogenic risk

Contaminant	Dose (mg/kg/d)	RfD (mg/kg/d)	Hazard Index
Chromium III	3.9×10^{-4}	1.0 (oral)	3.9×10^{-4}
Lead	3.7×10^{-4}	1.4×10^{-3}	0.26
Total			~ 0.26

AR301580

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APPENDIX G

ENVIRONMENTAL SURVEY DATA

TABLE OF CONTENTS

Table 6-1 ~~Table 2~~. Delaware Fauna List

Categories

1. Nongame - any species which is not commonly trapped, killed, captured, or consumed, either for sport or profit.

   a. Unprotected (u) - species not protected under state or federal law.

   b. Protected (p) - species protected under state or federal law.

2. Game - any species specifically listed as game under Delaware law with a hunting season or a closed hunting season.

3. Exotic or feral - introduced or feral unprotected species.

4. Accidentals - non-residential recorded species.

Table 8-1 NONGAME SPECIES

MAMMALS-40

		Status
1. Small Mammals-21		
Shorttail shrew	Blarina brevicauda	uX
Masked shrew	Sorex cinereus	u
Least shrew	Cryptotis parva	u
Eastern mole	Scalopus aquaticus	u
Starnose mole	Condylura cristata	u
Meadow vole	Microtus pennsylvanicus	u
Pine vole	Pitymys pinetorum	u
Eastern chipmunk	Tamias striatus	u
Red Squirrel	Tamiasciurus hudsonicus	u
Southern flying squirrel	Glaucomys volans	u
Delmarva fox squirrel	Sciurus niger cinereus	Endangered
White-footed mouse	Peromyscus leucopus	u
House mouse	Mus musculus	u
Meadow jumping mouse	Zapus hudsonius	u
Deer mouse	Peromyscus maniculatus	u
Rice rat	Oryzomys palustris	u
Norway rat	Rattus norvegicus	u
Black rat	Rattus rattus	u
Longtail weasel	Mustela frenata	u
Striped skunk	Mephitis mephitis	u
Gray fox	Urocyon cinereoargenteus	u
2. Bats-6		
Little brown myotis	Myotis lucifugus	u
Silver-haired bat	Lasionycteris noctivagans	u
Eastern pipistrel	Pipistrellus subflavus	u
Big brown bat	Eptesicus fuscus	u
Red bat	Lasiurus borealis	u
Hoary bat	Lasiurus cinereus	u
3. Marine mammals-13		
Harbor Porpoise	Phocoena phocoena	p
Harbor Seal	Phoca vitulina	p
Atlantic Bottlenose Dolphin	Tursiops truncatus	p
Striped Dolphin	Stenella caeruleoalba	p
Atlantic Beaked Whale	Mesoplodon densirostris	p
Sperm Whale	Physeter catodon	Endangered
Rorqual Whale	Balaenoptera borealis	Endangered
Finback Whale	Balaenoptera physalus	Endangered
Blue Whale	Balaenoptera musculus	Endangered
Humpback Whale	Megaptera novaeangliae	Endangered
Right Whale	Balaena glacialis	Endangered
Pygmy Sperm Whale	Kogia breviceps	p
Pilot Whale	Globicephala macrorhyncha	p

Xu = unprotected p = protected

AMPHIBIANS-26

1. Salamanders and newts-11

Marbled salamander	Ambystoma opacum	u
Spotted salamander	Ambystoma maculatum	u
Eastern tiger salamander	Ambystoma tigrinum	Endangered
Northern dusky salamander	Desmognathus fuscus	u
Red-backed salamander	Plethodon cinereus	u
Four-toed salamander	Hemidactylium scutatum	u
Northern red salamander	Pseudotriton ruber	u
Northern two-lined salamander	Eurycea bislineata	u
Long-tailed salamander	Eurycea longicauda	u
Eastern mud salamander	Pseudotriton montanus	u
Red-spotted newt	Notophthalmus viridescens	u

2. Toads and frogs-15

Eastern spadefoot	Scaphiopus holbrooki	u
American toad	Bufo americanus	u
Fowler's toad	Bufo woodhousei	u
Northern cricket frog	Acris crepitans	u
Northern spring peeper	Hyla crucifer	u
Green treefrog	Hyla cinerea	u
Common treefrog	Hyla versicolor	u
Barking treefrog	Hyla gratiosa	u
Cope's treefrog	Hyla chrysoscelis	Endangered
New Jersey chorus frog	Pseudacris triseriata	u
Carpenter frog	Rana virgatipes	u
Green frog	Rana clamitans	u
Southern leopard frog	Rana utricularia	u
Wood frog	Rana sylvatica	u
Pickerel frog	Rana palustris	u

REPTILES-36

1. Land turtles-8

Stinkpot	Sternotherus odoratus	u
Eastern mud turtle	Kinosternon subrubrum	u
Spotted turtle	Clemmys guttata	u
Bog turtle	Clemmys muhlenbergi	Endangered
Wood turtle	Clemmys insculpta	u
Eastern box turtle	Terrapene carolina	u
Eastern painted turtle	Chrysemys picta	u
Red-bellied turtle	Chrysemys rubriventris	u

p - protected u - unprotected

2. Sea turtles-5

Atlantic green turtle	Chelonia mydas	p1
Atlantic hawksbill	Eretmochelys imbricata	Endangered
Atlantic loggerhead	Caretta caretta	p1
Atlantic ridley	Lepidochelys kempi	Endangered
Atlantic leatherback	Dermochelys coriacea	Endangered

3. Lizards and skinks-4

Northern fence lizard	Sceloporus undulatus	u
Ground skink	Scincella lateralis	u
Five-lined skink	Eumeces fasciatus	u
Broad-headed skink	Eumeces laticeps	u

4. Snakes-19

Red-bellied water snake	Natrix erythrogaster	u
Northern water snake	Natrix sipedon	u
Queen snake	Natrix septemvittata	u
Northern brown snake	Storeria dekayi	u
Northern red-bellied snake	Storeria occipitomaculata	u
Eastern garter snake	Thamnophis sirtalis	u
Eastern ribbon snake	Thamnophis sauritus	u
Eastern smooth earth snake	Virginia valeriae	u
Eastern hognose snake	Heterodon platyrhinos	u
Ringneck snake	Diadophis punctatus	u
Eastern worm snake	Carphophis amoenus	u
Northern black racer	Coluber constrictor	u
Rough green snake	Opheodrys aestivus	u
Corn snake	Elaphe guttata	u
Black rat snake	Elaphe obsoleta	u
Eastern kingsnake	Lampropeltis getulus	u
Milk snake	Lampropeltis triangulum	u
Northern copperhead	Agkistrodon contortrix	u
Northern scarlet snake	Cermophora coccinea	u

BIRDS-266

1. Waders and shorebirds - 88

XGreat Blue Heron	Ardea herodias	p
XLittle Blue Heron	Florida caerulea	p
XTricolored Heron	Hydranassa tricolor	p
XSnowy Egret	Egretta thula	p
XGreat Egret	Casmerodius albus	p
XCattle Egret	Bubulcus ibis	p
XBlack-crowned Night Heron	Nycticorax nycticorax	p
XYellow-crowned Night Heron	Nyctanassa violaceus	p
XGreen-backed Heron	Butorides striatus	p
XLeast Bittern	Ixobrychus exilis	p

1 - Federally threatened p - protected u - unprotected

XAmerican Bittern	Botaurus lentiginosus	p
XGlossy Ibis	Plegadis falcinellus	p
White Ibis	Eudocimus albus	p
XAmerican Oystercatcher	Haematopus palliatus	p
XBlack-necked Stilt	Himantopus mexicanus	p
American Avocet	Recurvirostra americana	p
Black-bellied Plover	Pluvialis squatarola	p
Lesser Golden Plover	Pluvialis dominica	p
Ruddy Turnstone	Arenaria interpres	p
Semipalmated Plover	Charadrius semipalmatus	p
XPiping Plover	Charadrius melodus	p1
XKilldeer	Charadrius vociferus	p
Short-billed Dowitcher	Limnodromus griseus	p
Long-billed Dowitcher	Limnodromus scolopaceus	p
Hudsonian Godwit	Limosa haemastica	p
Marbled Godwit	Limosa fedoa	p
Whimbrel	Numenius phaeopus	p
XWillet	Catoptrophorus semipalmatus	p
Greater Yellowlegs	Tringa melanoleuca	p
Lesser Yellowlegs	Tringa flavipes	p
Solitary Sandpiper	Tringa solitaria	p
Upland Sandpiper	Bartramia longicauda	p
Buff-breasted Sandpiper	Tryngites subruficollis	p
Ruff	Philomachus pugnax	p
Stilt Sandpiper	Micropalama himantopus	p
Pectoral Sandpiper	Calidris melanotos	p
Sanderling	Calidris alba	p
Purple Sandpiper	Calidris maritima	p
Red Knot	Calidris canutus	p
Dunlin	Calidris alpina	p
Least Sandpiper	Calidris minutilla	p
Semipalmated Sandpiper	Calidris pusilla	p
Western Sandpiper	Calidris mauri	p
Baird's Sandpiper	Calidris bairdii	p
White-rumped Sandpiper	Calidris fuscicollis	p
XSpotted Sandpiper	Actitis macularia	p
Northern Phalarope	Lobipes lobatus	p
Wilson's Phalarope	Steganopus tricolor	p
Red Phalarope	Phalaropus fulicariuas	p
XBlack Rail	Laterallus jamaicensis	p
Yellow Rail	Coturnicops noveboracensis	p
Brown Pelican	Pelecanus occidentalis	Endangered
Little Gull	Larus minutus	p
Glaucous Gull	Larus hyperboreus	p
Iceland Gull	Larus glaucoides	p
XHerring Gull	Larus argentatus	p
Ring-billed Gull	Larus delawarensis	p
Lesser Black-backed Gull	Larus fuscus	p

X - Breeding in Delaware p - protected u - unprotected
1 - Federally threatened

XGreater Black-backed Gull	Larus marinus	p
XLaughing Gull	Larus atricilla	p
Bonaparte's Gull	Larus philadelphia	p
Gull-billed Tern	Gelochelidon nilotica	p
Royal Tern	Sterna maxima	p
Caspian Tern	Sterna caspia	p
XLeast Tern	Sterna albifrons	p
Arctic Tern	Sterna paradisaea	p
XCommon Tern	Sterna hirundo	p
XForster's Tern	Sterna forsteri	p
Roseate Tern	Sterna dougallii	p
Black Tern	Chlidonias niger	p
XBlack Skimmer	Rynchops niger	p
Black-legged Kittiwake	Rissa tridactyla	p
Pomarine Jaeger	Stercorarius pomarinus	p
Parasitic Jaeger	Stercorarius parasiticus	p
Great Skua	Catharacta skua	p
Double-crested Cormorant	Phalacrocorax auritus	p
Great Cormorant	Phalacrocorax carbo	p
Northern Fulmar	Fulmarus glacialis	p
Cory's Shearwater	Puffinus diomedea	p
Greater Shearwater	Puffinus gravis	p
Sooty Shearwater	Puffinus griseus	p
Manx Shearwater	Puffinus puffinus	p
Audubon's Shearwater	Puffinus lherminieri	p
Wilson's Storm Petrel	Oceanites oceanicus	p
Leach's Storm Petrel	Oceanodroma leucorhoa	p
Northern Gannet	Morus bassanus	p
Dovekie	Alle alle	p
Razorbill	Alca torda	p

3. Raptors-23

XSharp-shinned Hawk	Accipiter striatus	p
XCooper's Hawk	Accipiter cooperii	p
Northern Goshawk	Accipiter gentilis	p
XNorthern Harrier	Circus cyaneus	p
XRed-tailed Hawk	Buteo jamaicensis	p
Rough-legged Hawk	Buteo lagopus	p
XRed-shouldered Hawk	Buteo lineatus	p
XBroad-winged Hawk	Buteo platypterus	p
Golden Eagle	Aquila chrysaetos	Endangered
XBald Eagle	Haliaeetus leucocephalus	Endangered
XOsprey	Pandion haliaetus	p
XTurkey Vulture	Cathartes aura	p
XBlack Vulture	Coragyps atratus	p
XAmerican Kestrel	Falco sparverius	p
Merlin	Falco columbarius	p
XPeregrine Falcon	Falco peregrinus anatum	Endangered
XShort-eared Owl	Asio flammeus	p
Long-eared Owl	Asio otus	p

X - Breeding in Delaware

XEastern Screech Owl	Otus asio	p
XGreat Horned Owl	Bubo virginianus	p
XBarred Owl	Strix varia	p
XCommon Barn Owl	Tyto alba	p
Northern Saw-whet Owl	Aegolius acadicus	p

4. Passerine birds-134

Northern Shrike	Lanius excubitor	p
XEastern Kingbird	Tyrannus tyrannus	p
XGreat Crested Flycatcher	Myiarchus crinitus	p
XEastern Phoebe	Sayornis phoebe	p
XEastern Wood Pewee	Contopus virens	p
Olive-sided Flycatcher	Nuttallornis borealis	p
XLeast Flycatcher	Empidonax minimus	p
XAcadian Flycatcher	Empidonax virescens	p
XWillow Flycatcher	Empidonax traillii	p
Alder Flycatcher	Empidonax alnorum	p
Yellow-bellied Flycatcher	Empidonax flaviventris	p
XHorned Lark	Eremophila alpestris	p
Water Pipit	Anthus spinoletta	p
XPurple Martin	Progne subis	p
XCliff Swallow	Petrochelidon pyrrhonota	p
XBarn Swallow	Hirundo rustica	p
XTree Swallow	Iridoprocne bicolor	p
XNorthern Rough-winged Swallow	Stelgidopteryx ruficollis	p
XBank Swallow	Riparia riparia	p
XChimney Swift	Chaetura pelagica	p
XBlue Jay	Cyanocitta cristata	p
Black-capped Chickadee	Parus atricapillus	p
XCarolina Chickadee	Parus carolinensis	p
XTufted Titmouse	Parus bicolor	p
XWhite-breasted Nuthatch	Sitta carolinensis	p
Red-breasted Nuthatch	Sitta canadensis	p
XBrown-headed Nuthatch	Sitta pusilla	p
XBrown Creeper	Certhia familiaris	p
XHouse Wren	Troglodytes aedon	p
Winter Wren	Troglodytes troglodytes	p
XCarolina Wren	Thryothorus ludovicianus	p
XMarsh Wren	Cistothorus palustris	p
XSedge Wren	Cistothorus platensis	p
Ruby-crowned Kinglet	Regulus calendula	p
Golden-crowned Kinglet	Regulus satrapa	p
XBlue-gray Gnatcatcher	Polioptila caerulea	p
XBrown Thrasher	Toxostoma rufum	p
XGray Catbird	Dumetella carolinensis	p
XNorthern Mockingbird	Mimus polyglottos	p
XEastern Bluebird	Sialia sialis	p
XAmerican Robin	Turdus migratorius	p
Gray-cheeked Thrush	Catharus minimus	p
Swainson's Thrush	Catharus ustulatus	p

X - Breeding in Delaware

Hermit Thrush	Catharus guttatus	p
XVeery	Catharus fucescens	p
XWood Thrush	Hylocichla mustelina	p
XLoggerhead Shrike	Lanius ludovicianus	p
XCedar Waxwing	Bombycilla cedrorum	p
XRed-eyed Vireo	Vireo olivaceus	p
XWarbling Vireo	Vireo gilvus	p
XYellow-throated Vireo	Vireo flavifrons	p
XWhite-eyed Vireo	Vireo griseus	p
Philadelphia Vireo	Vireo philadelphicus	p
Solitary Vireo	Vireo solitarius	p
XNorthern Parula Warbler	Parula americana	p
XYellow-throated Warbler	Dendroica dominica	p
Black-throated Green Warbler	Dendroica virens	p
Blackpoll Warbler	Dendroica striata	p
Black-throated Blue Warbler	Dendroica caerulescens	p
XCerulean Warbler	Dendroica cerulea	p
Magnolia Warbler	Dendroica magnolia	p
Yellow-rumped Warbler	Dendroica coronata	p
Cape May Warbler	Dendroica tigrina	p
XChestnut-sided Warbler	Dendroica pensylvanica	p
Bay Breasted Warbler	Dendroica castanea	p
Blackburnian Warbler	Dendroica fusca	p
XPine Warbler	Dendroica pinus	p
XPrairie Warbler	Dendroica discolor	p
Palm Warbler	Dendroica palmarum	p
XYellow Warbler	Dendroica petechia	p
XProthonotary Warbler	Protonotaria citrea	p
XBlack-and-white Warbler	Mniotilta varia	p
Canada Warbler	Wilsonia canadensis	p
XAmerican Redstart	Setophaga ruticilla	p
XBlue-winged Warbler	Vermivora pinus	p
Swainson's Warbler	Limnothlypis swainsonii	p
XWorm-eating Warbler	Helmitheros vermivorus	p
Tennessee Warbler	Vermivora peregrina	p
Orange-crowned Warbler	Vermivora celata	p
Golden-winged Warbler	Vermivora chrysoptera	p
Nashville Warbler	Vermivora ruficapilla	p
Wilson's Warbler	Wilsonia pusilla	p
XHooded Warbler	Wilsonia citrina	p
XKentucky Warbler	Oporornis formosus	p
Connecticut Warbler	Oporornis agilis	p
Mourning Warbler	Oporornis philadelphia	p
XCommon Yellowthroat	Geothlypis trichas	p
XYellow-breasted Chat	Icteria virens	p
Northern Waterthrush	Seiurus noveboracensis	p
XLouisiana Waterthrush	Seiurus motacilla	p
XOvenbird	Seiurus aurocapillus	p
XRed-winged Blackbird	Agelaius phoeniceus	p
XBrown-headed Cowbird	Molothrus ater	p
Rusty Blackbird	Euphagus carolinus	p

X - Breeding in Delaware

XCommon Grackle	Quiscalus quiscula	p
XBoat-tailed Grackle	Quiscalus major	p
Bobolink	Dolichonyx oryzivorus	p
XEastern Meadowlark	Sturnella magna	p
XOrchard Oriole	Icterus spurius	p
XNorthern Oriole	Icterus galbula	p
XScarlet Tanager	Piranga olivacea	p
XSummer Tanager	Piranga rubra	p
Lapland Longspur	Calcarius lapponicus	p
Dark-eyed Junco	Junco hyemalis	p
Snow Bunting	Plectrophenax nivalis	p
XDickcissel	Spiza americana	p
XNorthern Cardinal	Cardinalis cardinalis	p
Common Redpole	Carduelis flammea	p
XHouse Finch	Carpodacus mexicanus	p
Purple Finch	Carpodacus purpureus	P
Red Crossbill	Loxia curvirostra	p
White-winged Crossbill	Loxia leucoptera	p
Evening Grosbeak	Hesperiphona vespertina	p
XAmerican Goldfinch	Carduelis tristis	p
Pine Siskin	Carduelis pinus	p
XBlue Grosbeak	Guiraca caerulea	p
XIndigo Bunting	Passerina cyanea	p
XRose-breasted Grosbeak	Pheucticus ludovicianus	p
XRufous-sided Towhee	Pipilo erythropthalmus	p
XWhite-throated Sparrow	Zonotrichia albicollis	p
White-crowned Sparrow	Zonotrichia leucophrys	p
XChipping Sparrow	Spizella passerina	p
XField Sparrow	Spizella pusilla	p
American Tree Sparrow	Spizella arborea	p
XSong Sparrow	Melospiza melodia	p
XSwamp Sparrow	Melospiza georgiana	p
Lincoln's Sparrow	Melospiza lincolnii	p
Fox Sparrow	Passerella iliaca	p
XVesper Sparrow	Pooecetes gramineus	p
XSavannah Sparrow	Passerculus sandwichensis	p
Henslow's Sparrow	Ammodramus henslowii	p
XGrasshopper Sparrow	Ammodramus savannarum	P
XSharp-tailed Sparrow	Ammospiza caudacuta	p
XSeaside Sparrow	Ammospiza maritima	p

5. Nonpasserine and other birds-21

XYellow-billed Cuckoo	Coccyzus americanus	p
XBlack-billed Cuckoo	Coccyzus erythropthalmus	p
XCommon Nighthawk	Chordeiles minor	p
XWhip-poor-will	Caprimulgus vociferus	p
XChuck-will's-widow	Caprimulgus carolinensis	p
XRuby-throated Hummingbird	Archilochus colubris	p
XBelted Kingfisher	Megaceryle alcyon	p
XRed-headed Woodpecker	Melanerpes erythrocephalus	p

X - Breeding in Delaware

XPileated Woodpecker	Dryocopus pileatus	p
XNorthern Flicker	Colaptes auratus	p
XRed-bellied Woodpecker	Melanerpes carolinus	p
Yellow-bellied Sapsucker	Sphyrapicus varius	p
XDowny Woodpecker	Picoides pubescens	p
XHairy Woodpecker	Picoides villosus	p
Red-throated Loon	Gavia stellata	p
Common Loon	Gavia immer	p
XPied-billed Grebe	Podilymbus podiceps	p
Horned Grebe	Podiceps auritus	p
XRinged turtle-dove	Streptopelia risoria	p
Red-necked Grebe	Podiceps grisegena	p
Western Grebe	Aechmophorus occidentalis	p

FISHXX-1

Shortnose sturgeon	Acipenser brevirostrum	Endangered

XX Only endangered fish will be included at this time in the non-game program.

GAME SPECIES

meadow vole
starnose mole

MAMMALS-11

White-tailed deer	Odocoileus virginianus	p
Gray squirrel	ciurus carolinensis	p
Cottontail rabbit	Sylvilagus floridanus	p
Woodchuck	Marmota monax	u
Raccoon	Procyon lotor	p
Opossum	Didelphis marsupialis	p
Red fox	Vulpes fulva	p
Muskrat	Ondatra zibethica	p
Mink	Mustela vison	p
River otter	Lutra canadensis	p
Beaver	Castor canadensis	p

AMPHIBIANS-1

Bullfrog	Rana catesbeiana	p

REPTILES-2

Snapping turtle	Chelydra serpentina	p
Diamondback terrapin	Malaclemys terrapin	p

X - Breeding in Delaware

BIRDS-49

1. Waterfowl-36

Tundra Swan	Olor columbianus	p
Snow Goose	Chen caerulescens	p
White-fronted Goose	Anser albifrons	p
XCanada Goose	Branta canadensis	p
Brant	Branta bernicla	p
Fulvous Whistling Duck	Dendrocygna bicolor	p
XAmerican Black Duck	Anas rubripes	p
XGadwall	Anas strepera	p
XMallard	Anas platyrhynchos	p
Northern Pintail	Anas acuta	p
American Wigeon	Anas americana	p
Northern Shoveler	Anas clypeata	p
XBlue-winged Teal	Anas discors	p
XGreen-winged Teal	Anas crecca	p
XWood Duck	Aix sponsa	p
White-winged Scoter	Melanitta deglandi	p
Surf Scoter	Melanitta perspicillata	p
XBlack Scoter	Melanitta nigra	p
Oldsquaw	Clangula hyemalis	p
Harlequin Duck	Histrionicus histrionicus	p
King Eider	Somateria spectabilis	p
Common Eider	Somateria mollissima	p
Canvasback	Aythya valisineria	p
Redhead	Aythya americana	p
Ring-necked Duck	Aythya collaris	p
Lesser Scaup	Aythya affinis	p
Greater Scaup	Aythya marila	p
Common Goldeneye	Bucephala clangula	p
Bufflehead	Bucephala albeola	p
Ruddy Duck	Oxyura jamaicensis	p
Common Merganser	Mergus merganser	p
XRed-breasted Merganser	Mergus serrator	p
Hooded Merganser	Lophodytes cucullatus	p
XAmerican Coot	Fulica americana	p
XCommon Gallinule	Gallinula chloropus	p
Purple Gallinule	Porphyrula martinica	p

2. Waders-6

XKing Rail	Rallus elegans	p
XClapper Rail	Rallus longirostris	p
XVirginia Rail	Rallus limicola	p
Sora	Porzana carolina	p
Common Snipe	Capella gallinago	p
XAmerican Woodcock	Philohela minor	p

X - Breeding in Delaware

3. Galliforms-4

XWild Turkey	Meleagris gallopavo	p
XRing-necked Pheasant	Phasianus colchicus	p
XNorthern Bobwhite	Colinus virginianus	p
Ruffed Grouse	Bonasa umbellus	p

4. Passerine and other-3

XFish Crow	Corvus ossifragus	p
XAmerican Crow	Corvus brachyrhynchos	p
XMourning Dove	Zenaida macroura	p

EXOTIC OR FERAL SPECIES-4

XMute Swan	Cygnus olor	u
XEuropean Starling	Sturnus vulgaris	u
XHouse Sparrow	Passer domesticus	u
XRock Dove	Columba livia	u

X - Breeding in Delaware

RECEIVED

AUG 23 '89

GANNETT FLEMING
BALTIMORE

STATE OF DELAWARE
DEPARTMENT OF NATURAL RESOURCES
& ENVIRONMENTAL CONTROL
DIVISION OF PARKS & RECREATION
89 KINGS HIGHWAY
P.O. BOX 1401
DOVER, DELAWARE 19903

August 18, 1989

Mr. Chuck Campbell
Gannett, Fleming & Engineers
417 West Quad
Village of Crosskeys
Baltimore, MD 21210

Dear Mr. Campbell:

Enclosed please find copies of Delaware Natural Heritage Inventories (DENHI) Species of Special Concern lists for Plants, Amphibians, Reptiles, Invertebrates and Fishes.

We hope to have ranked lists of Birds, Mussels, and Natural Communities compiled in the near future.

To date, Delaware has no legislation regarding the protection of state rare species. Protection of habitats where these rare species occur is currently on a voluntary basis.

Those species that DENHI tracks that are Federally listed are protected by Federal legislation.

If I may be of any further assistance, please do not hesitate to contact me.

Sincerely,

Leslie D. Trew, Coordinator
Delaware Natural Heritage Inventory

LDT:dab
Enclosure

AR301596

Table 8-2 Species of Special Concern in Delaware

CRITERIA FOR DETERMINING STATE RANK

S1 = Typically 5 or fewer occurrences, very few remaining individuals, acres, or miles of stream or some factor of its biology making it especially vulnerable in Delaware.

S2 = Typically 6 to 20 occurrences, few remaining individuals, acres, or miles of stream, or factors demonstrably making it very vulnerable in Delaware.

S3 = Typically 21 to 100 occurrences, limited acreage, or miles of stream in Delaware.

S4 = Apparently secure in Delaware.

S5 = Demonstrably secure in Delaware.

SH = Histoically known from Delaware, but not seen in the past 15 years.

SX = Apparently extirpated from Delaware.

SE = Exotic, not native to Delaware.

SR = State Report only, no verified speciments known from Delaware.

SU = Status in Delaware is unknown.

SN = Regularly occurring, usually migratory. Does not typically breed in Delaware, but may pass through twice a year, or may remain in the winter.

Nomenclature follows Kartez and Kartez (1980) Synonymized Checklist of the Vascular Flora of the United States, Canada, and Greenland.

5/88 LT

FEDERAL STATUS

U.S. FISH AND WILDLIFE CATEGORIES OF ENDANGERED AND THREATENED PLANTS AND ANIMALS

LE--Taxa formally listed as endangered.

LT--Taxa formally listed as threatened.

PE--Taxa proposed to be formally listed as endangered.

PT--Taxa proposed to be formally listed as threatened.

S--Synonyms.

C1--Taxa for which the Service currently has on file substantial information on biological vulnerability and threat(s) to support the appropriateness of proposing to list them as endangered or threatened species.

C2--Taxa for which information now in possession of the Service indicates that proposing to list them as endangered or threatened species is possibly appropriate, but for which substantial data on biological vulnerability and threat(s) are not currently known or on file to support the immediate preparation of rules.

C3--Taxa that are no longer being considered for listing as threatened or endangered species. Such taxa are further coded to indicate three subcategories, depending on the reason(s) for removal from consideration.

- 3A--Taxa for which the SErvice has persuasive evidence of extinction.
- 3B--Names tha, on the basis of current taxonomic understanding, usually as represented in published revisions and monographs, do not represent taxa meeting the Act's definition of "species".
- 3C--Taxa that have proven to be more abundant or widespread than was previously believed and/or those that are not subject to any identifiable threat.

The above definitions are extracted from the January 6, 1989, U.S. Fish and Wildlife Service notice in the Federal Register.

REPTILES OF SPECIAL CONCERN
Delaware Natural Heritage Inventory

S..ENTIFIC NAME	STATE RANK	FED STAT	COMMON NAME
) KISTRODON CONTORTRIX	S1		NORTHERN COPPERHEAD
(RETTA CARETTA	SN	LT	LOGGERHEAD SEA TURTLE
CARPHOPHIS AMOENUS	S5		EASTERN WORM SNAKE
CEMOPHORA COCCINEA	S1		NORHTERN SCARLET SNAKE
(IELONIA MYDAS	SN	LELT	ATLANTIC GREEN TURTLE
(IELYDRA SERPENTINA	S5		SNAPPING TURTLE
CHRYSEMYS PICTA	S5		EASTERN PAINTED TURTLE
PSEUDEMYS RUBRIVENTRIS	S5		REDBELLY TURTLE
(EMMYS GUTTATA	S3		SPOTTED TURTLE
C.EMMYS MUHLENBERGII	S1	C2	BOG TURTLE
COLUBER CONSTRICTOR	S5		NORTHERN BLACK RACER
[illegible]RMOCHELYS CORIACEA	SN	LE	LEATHERBACK SEA TURTLE
I ADOPHIS PUNCTATUS	S5		RINGNECK SNAKE
E.APHE GUTTATA	S1		CORN SNAKE
ELAPHE OBSOLETA	S5		BLACK RAT SNAKE
I ETMOCHELYS IMBRICATA	SN	LE	ATLANTIC HAWKSBILL SEA TURTLE
I MECES FASCIATUS	S5		FIVE-LINED SKINK
EUMECES LATICEPS	S1		BROADHEAD SKINK
HETERODON PLATIRHINOS	S4		EASTERN HOGNOSE SNAKE
I NOSTERNON SUBRUBRUM	S5		EASTERN MUD TURTLE
I MPROPELTIS GETULA	S2		EASTERN KINGSNAKE
LAMPROPELTIS TRIANGULUM	S3		EASTERN MILK SNAKE
I EPIDOCHELYS KEMPII	SN	LE	ATLANTIC RIDLEY SEA TURTLE
I ACLEMYS TERRAPIN	S4		NORTHERN DIAMONDBACK TERRAPIN
N. DIA ERYTHROGASTER	S1		REDBELLY WATER SNAKE
NERODIA SIPEDON	S5		NORTHERN WATER SNAKE
(HEODRYS AESTIVUS	S2		ROUGH GREEN SNAKE
I GINA SEPTEMVITTATA	S1		QUEEN SNAKE
S.ELOPORUS UNDULATUS	S5		NORTHERN FENCE LIZARD
SCINCELLA LATERALIS	S1		GROUND SKINK
S ERNOTHERUS ODORATUS	S5		STINKPOT
S ORERIA DEKAYI	S3		NORTHERN BROWN SNAKE
STORERIA OCCIPITOMACULATA	S1		NORTHERN REDBELLY SNAKE
TERRAPENE CAROLINA	S5		EASTERN BOX TURTLE
T IAMNOPHIS SAURITUS	S3		EASTERN RIBBON SNAKE
T.IAMNOPHIS SIRTALIS	S5		EASTERN GARTER SNAKE
TRACHEMYS SCRIPTA	SE		SLIDER
VIRGINIA VALERIAE	S3		EASTERN EARTH SNAKE

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FISHES OF SPECIAL CONCERN
Delaware Natural Heritage Inventory

SCIENTIFIC NAME	STATE RANK	FED STAT	COMMON NAME
ACANTHARCHUS POMOTIS	S2		MUD SUNFISH
ACIPENSER BREVIROSTRUM	SU	LE	SHORTNOSE STURGEON
ACIPENSER OXYRHYNCHUS	SU		ATLANTIC STURGEON
ALOSA AESTIVALIS	S5		BLUEBACK HERRING
ALOSA MEDIOCRIS	S1		HICKORY SHAD
ALOSA PSEUDOHARENGUS	S5		ALEWIFE
ALOSA SAPIDISSIMA	S3		AMERICAN SHAD
AMBLOPLITES RUPESTRIS	S2		ROCK BASS
AMIA CALVA	SE		BOWFIN
ANCHOA MITCHILLI	S5		BAY ANCHOVY
ANGUILLA ROSTRATA	S5		AMERICAN EEL
APELTES QUADRACUS	S1		FOURSPINE STICKLEBACK
APHREDODERUS SAYANUS	S5		PIRATE PERCH
CARASSIUS AURATUS	SE		GOLDFISH
CATOSTOMUS COMMERSONI	S5		WHITE SUCKER
CLINOSTOMUS FUNDULOIDES	S4		ROSYSIDE DACE
COTTUS BAIRDI	S1		MOTTLED SCULPIN
COTTUS COGNATUS	SR		SLIMY SCULPIN
CTENOPHARYNGDON IDELLA	SE		GRASS CARP
CYPRINODON VARIEGATUS	S5		SHEEPSHEAD MINNOW
CYPRINUS CARPIO	SE		COMMON CARP
DOROSOMA CEPEDIANUM	S5		GIZZARD SHAD
ENNEACANTHUS CHAETODON	S1		BLACKBANDED SUNFISH
ENNEACANTHUS GLORIOSUS	S5		BLUESPOTTED SUNFISH
ENNEACANTHUS OBESUS	S2		BANDED SUNFISH
ERIMYZON OBLONGUS	S5		CREEK CHUBSUCKER
ESOX AMERICANUS	S5		REDFIN PICKEREL
ESOX MASQUINONGY	SR		MUSKELLUNGE
ESOX NIGER	S5		CHAIN PICKEREL
ETHEOSTOMA FUSIFORME	S4		SWAMP DARTER
ETHEOSTOMA OLMSTEDI	S5		TESSELLATED DARTER
EXOGLOSSUM MAXILLINGUA	S4		CUTLIPS MINNOW
FUNDULUS DIAPHANUS	S4		BANDED KILLIFISH
FUNDULUS HETEROCLITUS	S5		MUMMICHOG
FUNDULUS LUCIAE	S3S4		SPOTFIN KILLIFISH
FUNDULUS MAJALIS	S5		STRIPED KILLIFISH
GAMBUSIA AFFINIS	S4		MOSQUITOFISH
GASTEROSTEUS ACULEATUS	S3		THREESPINE STICKLEBACK
HYBOGNATHUS REGIUS	S4		EASTERN SILVERY MINNOW
HYPENTELIUM NIGRICANS	S1		NORTHERN HOG SUCKER
ICTALURUS CATUS	S5		WHITE CATFISH
ICTALURUS NATALIS	S3		YELLOW BULLHEAD
ICTALURUS NEBULOSUS	S5		BROWN BULLHEAD
ICTALURUS PUNCTATUS	S5		CHANNEL CATFISH
LAMPETRA AEPYPTERA	S2		LEAST BROOK LAMPREY
LAMPETRA APPENDIX	S2		AMERICAN BROOK LAMPREY
LEPISOSTEUS OSSEUS	S3		LONGNOSE GAR
LEPOMIS AURITUS	S4		REDBREAST SUNFISH
LEPOMIS CYANELLUS	SE		GREEN SUNFISH

08/18/89

FISHES OF SPECIAL CONCERN
Delaware Natural Heritage Inventory

S' ENTIFIC NAME	STATE RANK	FED STAT	COMMON NAME
I POMIS GIBBOSUS	S5		PUMPKINSEED
I POMIS GULOSUS	SE		WARMOUTH
LEPOMIS MACROCHIRUS	S5		BLUEGILL
LUCANIA PARVA	S4		RAINWATER KILLIFISH
M MBRAS MARTINICA	S4		ROUGH SILVERSIDE
M NIDIA BERYLLINA	S4		INLAND SILVERSIDE
MENIDIA MENIDIA	S5		ATLANTIC SILVERSIDE
M CROPTERUS DOLOMIEUI	S3		SMALLMOUTH BASS
M CROPTERUS SALMOIDES	S5		LARGEMOUTH BASS
M RONE AMERICANA	S5		WHITE PERCH
MORONE SAXATILIS	S3		STRIPED BASS
M RONE SAXATILIS X MORONE CHRYSOPS	S3		STRIPED BASS X WHITE BASS
M XOSTOMA MACROLEPIDOTUM	S1		SHORTHEAD REDHORSE
N COMIS MICROPOGON	SR		RIVER CHUB
NOTEMIGONUS CRYSOLEUCAS	S5		GOLDEN SHINER
N TROPIS AMOENUS	S2		COMELY SHINER
N TROPIS ANALOSTANUS	S3		SATINFIN SHINER
NOTROPIS BIFRENATUS	SU		BRIDLE SHINER
NOTROPIS CHALYBAEUS	S1S2		IRONCOLOR SHINER
N TROPIS HUDSONIUS	S5		SPOTTAIL SHINER
N TROPIS PROCNE	SU		SWALLOWTAIL SHINER
NOTROPIS SPILOPTERUS	S3		SPOTFIN SHINER
N TURUS GYRINUS	S4		TADPOLE MADTOM
N TURUS INSIGNIS	S2		MARGINED MADTOM
P CA FLAVESCENS	S5		YELLOW PERCH
PERCINA PELTATA	SU		SHIELD DARTER
P TROMYZON MARINUS	S3		SEA LAMPREY
P MOXIS ANNULARIS	S3		WHITE CRAPPIE
P MOXIS NIGROMACULATUS	S5		BLACK CRAPPIE
RHINICHTHYS ATRATULUS	S3S4		BLACKNOSE DACE
R INICHTHYS CATARACTAE	S3		LONGNOSE DACE
S LMO GAIRDNERI	SE		RAINBOW TROUT
SALMO TRUTTA	SE		BROWN TROUT
SALVELINUS FONTINALIS	SE		BROOK TROUT
S MOTILUS ATROMACULATUS	S3		CREEK CHUB
S MOTILUS CORPORALIS	S3		FALLFISH
SEMOTILUS MARGARITA	SU		PEARL DACE
S IZOSTEDION VITREUM	SE		WALLEYE
T NCA TINCA	SE		TENCH
U BRA PYGMAEA	S5		EASTERN MUDMINNOW

89

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PLANTS OF SPECIAL CONCERN
Delaware Natural Heritage Inventory

SCIENTIFIC NAME	STATE RANK	FED STAT	COMMON NAME
ACER SACCHARUM	S1		SUGAR MAPLE
ACTAEA PACHYPODA	S1		
ADIANTUM PEDATUM	S2		NORTHERN MAIDENHAIR-FERN
ADLUMIA FUNGOSA	SH		CLIMBING FUMATORY
AESCHYNOMENE VIRGINICA	SH	C2	SENSITIVE JOINT-VETCH
AGALINIS DECEMLOBA	SH		BLUE RIDGE FALSE-FOXGLOVE
AGALINIS LINIFOLIA	S1		
AGALINIS OBTUSIFOLIA	SH		
AGALINIS PURPUREA VAR PURPUREA	S3		
AGALINIS SETACEA	SH		
AGALINIS TENUIFOLIA	S1		
AGALINIS VIRGATA	SH		PINE-BARREN GERARDIA
AGRIMONIA GRYPOSEPALA	S1		TALL HAIRY GROOVEBUR
AGRIMONIA ROSTELLATA	SH		WOODLAND AGRIMONY
AGROSTIS STOLONIFERA VAR PALUSTRIS	SH		
ALLIUM TRICOCCUM	SU		SMALL WHITE LEEK
ALNUS MARITIMA	S2	3C	SEASIDE ALDER
ALOPECURUS CAROLINIANUS	S1		TUFTED FOXTAIL
AMARANTHUS PUMILUS	SH	C2	SEABEACH PIGWEED
AMIANTHIUM MUSCAETOXICUM	SH		FLY POISON
AMPHICARPUM PURSHII	S1		
ANAGALLIS MINIMA	SH		
ANAPHALIS MARGARITACEA	SH		PEARLY EVERLASTING
ANGELICA ATROPURPUREA	SH		GREAT ANGELICA
ANGELICA VENENOSA	S2		HAIRY ANGELICA
ANTENNARIA NEODIOICA SSP NEODIOICA	S1		
ANTENNARIA PARLINII SSP PARLINII	SH		
ANTENNARIA SOLITARIA	SU		SINGLE-HEAD PUSSYTOES
APLECTRUM HYEMALE	S1		PUTTYROOT
APOCYNUM ANDROSAEMIFOLIUM	SH		SPREADING DOGBANE
APOCYNUM CANNABINUM VAR CANNABINUM	S4		
APOCYNUM CANNABINUM VAR HYPERICIFOLIUM	SH		
ARABIS DRUMMONDII	SH		DRUMMOND ROCKCRESS
ARABIS LAEVIGATA	S1		SMOOTH ROCK-CRESS
ARABIS SHORTII	S1		SHORT'S ROCK-CRESS
ARALIA RACEMOSA	S1		AMERICAN SPIKENARD
ARETHUSA BULBOSA	SH		SWAMP-PINK
ARISAEMA DRACONTIUM	S1		GREEN DRAGON
ARISTIDA LANOSA	SH		WOOLLY THREE-AWN
ARISTIDA VIRGATA	S1		WAND-LIKE THREE-AWN GRASS
ARISTOLOCHIA SERPENTARIA	S1		VIRGINIA SNAKEROOT
ARNICA ACAULIS	SH		LEOPARD'S-BANE
ASCLEPIAS EXALTATA	S1		POKE MILKWEED
ASCLEPIAS LANCEOLATA	S2		FEW-FLOWERED MILKWEED
ASCLEPIAS LONGIFOLIA	S1		LONG-LEAF MILKWEED
ASCLEPIAS PURPURASCENS	S1		PURPLE MILKWEED
ASCLEPIAS QUADRIFOLIA	SH		WHORLED MILKWEED
ASCLEPIAS RUBRA	S1		RED MILKWEED

48/1

PLANTS OF SPECIAL CONCERN
Delaware Natural Heritage Inventory

SCIENTIFIC NAME	STATE RANK	FED STAT	COMMON NAME
ASCLEPIAS VERTICILLATA	SH		WHORLED MILKWEED
ASPLENIUM RHIZOPHYLLUM	SH		
ASPLENIUM TRICHOMANES	SH		MAIDENHAIR SPLEENWORT
ASTER CONCOLOR	SH		EASTERN SILVERY ASTER
ASTER DEPAUPERATUS	S1	C2	SERPENTINE ASTER
ASTER ERICOIDES	SH		WHITE HEATH ASTER
ASTER INFIRMUS	SH		CORNEL-LEAF ASTER
ASTER MACROPHYLLUS	SH		LARGE-LEAF ASTER
ASTER NEMORALIS	S1		BOG ASTER
ASTER PRAEALTUS	S1		WILLOW ASTER
ASTER PRENANTHOIDES	SH		CROOKED-STEM ASTER
ASTER RADULA	SH		ROUGH-LEAVED ASTER
ASTER SCHREBERI	S1		SCHREBER ASTER
ASTER SPECTABILIS	S1		SHOWY ASTER
ASTER X SAGITTIFOLIUS	SH		HYBRID
AUREOLARIA FLAVA	S1		YELLOW FALSE-FOXGLOVE
AUREOLARIA PEDICULARIA	SH		FERNLEAF YELLOW FALSE-FOXGLOVE
BARTONIA PANICULATA	S1		TWINING BARTONIA
BETULA ALLEGHANIENSIS	SX		
BETULA POPULIFOLIA	S1		GRAY BIRCH
BIDENS BIDENTOIDES VAR BIDENTOIDES	S1	3C	BUR-MARIGOLD
BIDENS CONNATA	S1		PURPLE-STEM SWAMP BEGGAR-TICKS
BIDENS CORONATA	S1		TICKSEED SUNFLOWER
BIDENS TRIPARTITA	S1		THREE-LOBE BEGGAR-TICKS
BIDENS VULGATA	SH		TALL BUR-MARIGOLD
BLEPHILIA CILIATA	SH		DOWNY WOODMINT
BLEPHILIA HIRSUTA	SH		HAIRY WOODMINT
BOLTONIA ASTEROIDES	S1		ASTER-LIKE BOLTONIA
BOTRYCHIUM MATRICARIIFOLIUM	S1		CHAMOMILE GRAPE-FERN
BRASENIA SCHREBERI	SH		WATERSHIELD
BUCHNERA AMERICANA	SH		BLUEHEARTS
BULBOSTYLIS CAPILLARIS	S1		DENSE-TUFT HAIR-SEDGE
CACALIA ATRIPLICIFOLIA	S1		PALE INDIAN-PLANTAIN
CALAMAGROSTIS CANADENSIS	SH		BLUE-JOINT REEDGRASS
CALTHA PALUSTRIS	SH		MARSH MARIGOLD
CALYSTEGIA SPITHAMAEA	SH		LOW BINDWEED
CARDAMINE LONGII	SU	C2	LONG'S BITTER CRESS
CARDAMINE PARVIFLORA VAR ARENICOLA	SH		SAND ROCK-CRESS
CARDAMINE ROTUNDIFOLIA	S1		ROUND-LEAF WATER CRESS
CAREX ALBURSINA	SU		A SEDGE
CAREX ANGUSTATA	SH		
CAREX ANGUSTIOR	SH		A SEDGE
CAREX BARRATTII	S1	C2	BARRATT'S SEDGE
CAREX BICKNELLII	SH		BICKNELL SEDGE
CAREX BREVIOR	SH		A SEDGE
CAREX BROMOIDES	S1		A SEDGE
CAREX BUSHII	S1		BUSH'S SEDGE
CAREX BUXBAUMII	S1		BROWN BOG SEDGE
CAREX CEPHALOPHORA	S1		OVAL-LEAVED SEDGE

AR301603

PLANTS OF SPECIAL CONCERN
Delaware Natural Heritage Inventory

SCIENTIFIC NAME	STATE RANK	FED STAT	COMMON NAME
CAREX COLLINSII	S1		COLLINS SEDGE
CAREX COMPLANATA	S1		HIRSUTE SEDGE
CAREX CONOIDEA	SH		FIELD SEDGE
CAREX CRISTATELLA	SH		CRESTED SEDGE
CAREX DAVISII	S1		DAVIS SEDGE
CAREX EMORYI	S1		EMORY'S SEDGE
CAREX EXILIS	S1		COAST SEDGE
CAREX FRANKII	S1		FRANK SEDGE
CAREX GIGANTEA	S2		
CAREX GRANULARIS	SH		MEADOW SEDGE
CAREX GYNANDRA	S1		
CAREX HAYDENII	S1		CLOUD SEDGE
CAREX HIRTIFOLIA	S1		PUBESCENT SEDGE
CAREX HYALINOLEPIS	SU		SHORE-LINE SEDGE
CAREX INTERIOR	S1		INLAND SEDGE
CAREX JOORII	S1		JOOR'S SEDGE
CAREX LANUGINOSA	SU		WOOLLY SEDGE
CAREX LONGII	S1		GREENISH-WHITE SEDGE
CAREX LUPULIFORMIS	S1		FALSE HOP SEDGE
CAREX MEADII	SH		MEAD SEDGE
CAREX MITCHELLIANA	S1		
CAREX ORMOSTACHYA	S1		NECKLACE SPIKE SEDGE
CAREX PEDUNCULATA	SH		LONGSTALK SEDGE
CAREX POLYMORPHA	SH	C2	VARIABLE SEDGE
CAREX PROJECTA	S1		NECKLACE SEDGE
CAREX RADIATA	SH		STELLATE SEDGE
CAREX ROSTRATA	SH		BEAKED SEDGE
CAREX SCABRATA	SH		ROUGH SEDGE
CAREX SEORSA	SU		WEAK STELLATE SEDGE
CAREX SILICEA	SH		SEA-BEACH SEDGE
CAREX SPRENGELII	SH		LONGBEAK SEDGE
CAREX STRIATULA	SH		
CAREX TETANICA	SU		RIGID SEDGE
CAREX TONSA	SH		SHAVED SEDGE
CAREX TRICHOCARPA	S1		HAIRY-FRUIT SEDGE
CAREX TRISPERMA	SH		THREE-SEED SEDGE
CAREX UMBELLATA	S1		A SEDGE
CAREX VENUSTA	SH		DARK GREEN SEDGE
CAREX VESICARIA	SH		INFLATED SEDGE
CAREX VESTITA	SH		A SEDGE
CAREX WILLDENOWII	SH		WILLDENOW SEDGE
CARYA PALLIDA	S1		SAND HICKORY
CASTILLEJA COCCINEA	SH		SCARLET INDIAN-PAINTBRUSH
CEANOTHUS AMERICANUS	S1		NEW JERSEY TEA
CELTIS OCCIDENTALIS VAR PUMILA	SU		
CENTELLA ERECTA	S1		ERECT COINLEAF
CENTROSEMA VIRGINIANUM	SH		COASTAL BUTTERFLY-PEA
CERASTIUM ARVENSE	SH		MOUSE-EAR CHICKWEED
CERASTIUM NUTANS	S1		NODDING CHICKWEED

PLANTS OF SPECIAL CONCERN
Delaware Natural Heritage Inventory

SCIENTIFIC NAME	STATE RANK	FED STAT	COMMON NAME
CHAEROPHYLLUM PROCUMBENS	S1		SPREADING CHERVIL
CHAMAEDAPHNE CALYCULATA	SH		LEATHERLEAF
CHAMAELIRIUM LUTEUM	SH		DEVIL'S-BIT
CHASMANTHIUM LATIFOLIUM	SH		
CHEILANTHES LANOSA	SX		HAIRY LIPFERN
CHENOPODIUM HYBRIDUM	SH		
CHIMAPHILA UMBELLATA SSP CISATLANTICA	SH		
CICUTA BULBIFERA	SX		BULB-BEARING WATER-HEMLOCK
CIRSIUM ALTISSIMUM	SH		TALL THISTLE
CIRSIUM MUTICUM	SH		SWAMP THISTLE
CIRSIUM VIRGINIANUM	SH		VIRGINIA THISTLE
CLEISTES DIVARICATA	SH		SPREADING POGONIA
CLEMATIS OCCIDENTALIS	SH		PURPLE CLEMATIS
CLEMATIS VIORNA	SH		VASE-VINE LEATHER-FLOWER
CLITORIA MARIANA	S1		MARYLAND BUTTERFLY-PEA
COELORACHIS RUGOSA	S1		
COMANDRA UMBELLATA	SH		UMBELLATE BASTARD TOAD-FLAX
COMMELINA ERECTA VAR ANGUSTIFOLIA	SH		
COMMELINA ERECTA VAR ERECTA	SH		
CORALLORHIZA MACULATA	SH		SPOTTED CORALROOT
CORALLORHIZA ODONTORHIZA	SH		AUTUMN CORAL-ROOT
CORALLORHIZA WISTERIANA	SH		SPRING CORALROOT
COREOPSIS ROSEA	S1		PINK TICKSEED
COREOPSIS TRIPTERIS	S1		TALL TICKSEED
CORYDALIS FLAVULA	S1		YELLOW CORYDALIS
CORYLUS CORNUTA	SH		BEAKED HAZELNUT
CRASSULA AQUATICA	SH		PYGMYWEED
CUPHEA VISCOSISSIMA	S1		CLAMMY CUPHEA
CUSCUTA POLYGONORUM	SH		SMARTWEED DODDER
CYNOGLOSSUM VIRGINIANUM	S1		BLUE HOUND'S-TONGUE
CYPERUS DIPSACIFORMIS	SH		
CYPERUS ENGELMANNII	S1		ENGELMANN UMBRELLA-SEDGE
CYPERUS GRAYI	S1		GRAY'S FLATSEDGE
CYPERUS LANCASTRIENSIS	SU		MANY-FLOWERED UMBRELLA-SEDGE
CYPERUS PLUKENETII	SH		A GALINGALE
CYPERUS RETROFRACTUS	SH		
CYPERUS ROTUNDUS	SH		
CYPERUS TENUIFOLIUS	SH		THINLEAF FLATSEDGE
CYPRIPEDIUM PUBESCENS	SH		YELLOW LADY SLIPPER
CYSTOPTERIS FRAGILIS VAR MACKAYI	S1		
DESCHAMPSIA FLEXUOSA	SU		
DESMODIUM CANADENSE	S1		SHOWY TICK-TREFOIL
DESMODIUM CUSPIDATUM	SH		TOOTHED TICK-TREEFOIL
DESMODIUM GLABELLUM	SH		
DESMODIUM GLUTINOSUM	S1		
DESMODIUM HUMIFUSUM	S1		SPREADING TICK-CLOVER
DESMODIUM LAEVIGATUM	SH		SMOOTH TICK-TREEFOIL
DESMODIUM MARILANDICUM	S1		MARYLAND TICK-TREEFOIL

PLANTS OF SPECIAL CONCERN
Delaware Natural Heritage Inventory

SCIENTIFIC NAME	STATE RANK	FED STAT	COMMON NAME
DESMODIUM OBTUSUM	SH		STIFF TICK-TREFOIL
DESMODIUM OCHROLEUCUM	SH		CREAMFLOWER TICK-TREFOIL
DESMODIUM SESSILIFOLIUM	S1		SESSILE-LEAF TICK-TREFOIL
DESMODIUM STRICTUM	S1		PINELAND TICK-TREFOIL
DESMODIUM VIRIDIFLORUM	S1		VELVETY TICK-TREEFOIL
DICHANTHELIUM ACICULARE	S1	C2	
DICHANTHELIUM COLUMBIANUM	SH		
DICHANTHELIUM OLIGOSANTHES	S1		HELLER'S WITCHGRASS
DICHANTHELIUM OLIGOSANTHES VAR SCRIBNERIANUM	SU		
DICHANTHELIUM OVALE VAR ADDISONII	SH		
DICHANTHELIUM RAVENELII	S1		
DICHANTHELIUM SCABRIUSCULUM	S1		PANIC GRASS
DICHANTHELIUM WRIGHTIANUM	S1		
DICHANTHELIUM X SCOPARIOIDES	SH		
DIERVILLA LONICERA	S1		NORTHERN BUSH-HONEYSUCKLE
DIGITARIA ARENICOLA	SH		
DIRCA PALUSTRIS	SH		EASTERN LEATHERWOOD
DRACOCEPHALUM PARVIFLORUM	SX		AMERICAN DRAGONHEAD
DROSERA ROTUNDIFOLIA	S1		ROUNDLEAF SUNDEW
DRYOPTERIS CLINTONIANA	S1		CLINTON WOODFERN
DRYOPTERIS CRISTATA	S3		CRESTED SHIELD-FERN
DRYOPTERIS GOLDIANA	SH		GOLDIE'S WOODFERN
ECHINOCHLOA MURICATA	S3		
ECHINODORUS PARVULUS	SH		
ELATINE AMERICANA	S3		AMERICAN WATER-WORT
ELEOCHARIS BRITTONII	S1		
ELEOCHARIS EQUISETOIDES	S1		HORSE-TAIL SPIKERUSH
ELEOCHARIS ERYTHROPODA	S1		
ELEOCHARIS FALLAX	SH		CREEPING SPIKE-RUSH
ELEOCHARIS FLAVESCENS	SH		PALE SPIKERUSH
ELEOCHARIS HALOPHILA	SH		SALT-MARSH SPIKE-RUSH
ELEOCHARIS INTERMEDIA	SH		MATTED SPIKERUSH
ELEOCHARIS MELANOCARPA	S1		BLACK-FRUITED SPIKE-RUSH
ELEOCHARIS PALUSTRIS	S1		CREEPING SPIKE-RUSH
ELEOCHARIS QUADRANGULATA	S2		
ELEOCHARIS ROBBINSII	S2		
ELEOCHARIS ROSTELLATA	S1		BEAKED SPIKERUSH
ELEOCHARIS SMALLII	SH		CREEPING SPIKE-RUSH
ELEOCHARIS TORTILIS	S1		
ELEOCHARIS TRICOSTATA	S1		THREE-ANGLE SPIKERUSH
EPIGAEA REPENS	S3		TRAILING ARBUTUS
EPILOBIUM ANGUSTIFOLIUM	SH		FIREWEED
EPILOBIUM CILIATUM SSP CILIATUM	S1		
EPILOBIUM LEPTOPHYLLUM	SH		LINEAR-LEAVED WILLOW-HERB
EPILOBIUM STRICTUM	SH		DOWNY WILLOW-HERB
EQUISETUM FLUVIATILE	SH		WATER HORSETAIL
EQUISETUM SYLVATICUM	S1		
ERAGROSTIS HYPNOIDES	SH		TEAL LOVE GRASS

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PLANTS OF SPECIAL CONCERN
Delaware Natural Heritage Inventory

CIENTIFIC NAME	STATE RANK	FED STAT	COMMON NAME
RAGROSTIS REFRACTA	SH		MEADOW LOVEGRASS
ERIANTHUS BREVIBARBIS	SH		SHORT-BEARD PLUMEGRASS
RIANTHUS CONTORTUS	SH		BENT-AWN PLUMEGRASS
RIOCAULON COMPRESSUM	S1		FLATTENED PIPEWORT
RIOCAULON DECANGULARE	SH		TEN-ANGLE PIPEWORT
ERIOCAULON PARKERI	S1	C2	PARKER'S PIPEWORT
RIOCAULON SEPTANGULARE	S1		WHITE BUTTONS
RIOPHORUM GRACILE	SH		SLENDER COTTON-GRASS
ERIOPHORUM VIRGINICUM	SH		TAWNY COTTON-GRASS
EUONYMUS ATROPURPUREUS	SH		WAHOO
UPATORIUM ALBUM	SH		WHITE BONESET
UPATORIUM COELESTINUM	S1		BLUE BONESET
EUPATORIUM LEUCOLEPIS	S1		
UPATORIUM MACULATUM	SU		SPOTTED JOE-PYE WEED
UPATORIUM RESINOSUM	SX	C2	PINE BARRENS BONESET
UPATORIUM ROTUNDIFOLIUM VAR OVATUM	S4		
EUPATORIUM ROTUNDIFOLIUM VAR AUNDERSII	S4		
UPATORIUM SEMISERRATUM	S1		
UPHORBIA PURPUREA	SX	C2	DARLINGTON'S SPURGE
EUTHAMIA MICROCEPHALA	S1		
UTHAMIA TENUIFOLIA	S1		
BRISTYLIS ANNUA	SH		ANNUAL FIMBRY
BRISTYLIS PERPUSILLA	S1	C1	HARPER'S FIMBRISTYLIS
FRAXINUS NIGRA	S1		BLACK ASH
UIRENA SQUARROSA	S2		
ALACTIA VOLUBILIS	S1		DOWNY MILKPEA
GALEARIS SPECTABILIS	S2		SHOWY ORCHIS
ALIUM BOREALE	S1		NORTHERN BEDSTRAW
ALIUM HISPIDULUM	SH		COAST BEDSTRAW
ALIUM LANCEOLATUM	S1		
GALIUM PILOSUM	S1		HAIRY BEDSTRAW
AURA BIENNIS	SX		BIENNIAL GAURA
AYLUSSACIA BRACHYCERA	S1	3C	BOX HUCKLEBERRY
GAYLUSSACIA DUMOSA VAR BIGELOVIANA	SH		
GENTIANA ANDREWSII	S1		FRINGE-TIP CLOSED GENTIAN
ENTIANA AUTUMNALIS	SH	3C	PINE BARREN GENTIAN
ENTIANA CATESBAEI	S2		ELLIOTT'S GENTIAN
GENTIANA VILLOSA	SH		STRIPED GENTIAN
GENTIANOPSIS CRINITA	S1		
ERANIUM CAROLINIANUM	S1		CAROLINA CRANE'S-BILL
EUM LACINIATUM	SH		ROUGH AVENS
GEUM VIRGINIANUM	S1		PALE AVENS
LYCERIA ACUTIFLORA	SH		SHARP-SCALED MANNA-GRASS
LYCERIA CANADENSIS	SH		CANADA MANNA-GRASS
RATIOLA RAMOSA	S1		
GRATIOLA VIRGINIANA	S1		ROUNDFRUIT HEDGE-HYSSOP
RATIOLA VISCIDULA	SH		SHORT'S HEDGE-HYSSOP
YMNOPOGON BREVIFOLIUS	SH		BROAD-LEAVED BEARDGRASS

PLANTS OF SPECIAL CONCERN
Delaware Natural Heritage Inventory

SCIENTIFIC NAME	STATE RANK	FED STAT	COMMON NAME
HACKELIA VIRGINIANA	S4		VIRGINIA STICKSEED
HEDYOTIS UNIFLORA	S1		CLUSTERED BLUETS
HELIANTHEMUM BICKNELLII	S1		PLAINS FROSTWEED
HELIANTHEMUM PROPINQUUM	S1		LOW FROSTWEED
HELIANTHUS ANGUSTIFOLIUS	S1		
HELIOPSIS HELIANTHOIDES	SH		OX-EYE
HELIOTROPIUM CURASSAVICUM	SH		SEASIDE HELIOTROPE
HELONIAS BULLATA	S1	LT	A SWAMP-PINK
HEPATICA NOBILIS VAR ACUTA	S1		
HETERANTHERA DUBIA	S1		GRASSLEAF MUD-PLANTAIN
HONKENYA PEPLOIDES	SH		SEA-BEACH SANDWORT
HOTTONIA INFLATA	S1		FEATHERFOIL
HUDSONIA ERICOIDES	S1		GOLDEN-HEATHER
HUDSONIA TOMENTOSA	S3		SAND-HEATHER
HYBANTHUS CONCOLOR	S1		GREEN VIOLET
HYDRANGEA ARBORESCENS	SH		WILD HYDRANGEA
HYDRASTIS CANADENSIS	S2	3C	GOLDEN SEAL
HYDROCOTYLE VERTICILLATA VAR TRIRADIATA	SH		
HYDROCOTYLE VERTICILLATA VAR VERTICILLATA	S1		
HYPERICUM ADPRESSUM	S1		CREEPING ST. JOHN'S-WORT
HYPERICUM DENTICULATUM	S1S2		COPPERY ST. JOHN'S-WORT
HYPERICUM ELLIPTICUM	SH		PALE ST. JOHN'S-WORT
HYPERICUM GYMNANTHUM	SH		CLASPING-LEAVED ST. JOHN'S-WORT
HYPERICUM MAJUS	SX		LARGER CANADIAN ST. JOHN'S-WORT
HYPERICUM MUTILUM SSP BOREALE	SH		NORTHERN ST. JOHN'S-WORT
HYPERICUM PROLIFICUM	S1		SHRUBBY ST. JOHNSWORT
HYPOXIS HIRSUTA	SU		EASTERN YELLOW STARGRASS
IRIS PRISMATICA	S1		SLENDER BLUE FLAG
ISOETES ENGELMANNII	S1		APPALACHIAN QUILLWORT
ISOETES RIPARIA	S1		RIVER BANK QUILLWORT
ISOTRIA MEDEOLOIDES	S1	LE	SMALL WHORLED POGONIA
ISOTRIA VERTICILLATA	SU		LARGE WHORLED POGONIA
JUGLANS CINEREA	S1		WHITE WALNUT
JUNCUS ELLIOTTII	S1		
JUNCUS MILITARIS	S1		BAYONET RUSH
JUNCUS NODOSUS	SH		KNOTTED RUSH
JUNCUS PELOCARPUS	S1		BROWN-FRUITED RUSH
JUNCUS ROEMERANUS	S1		
JUNCUS SUBCAUDATUS	S1		WOODS-RUSH
JUNCUS TORREYI	S1		TORREY'S RUSH
JUSTICIA AMERICANA	SH		COMMON WATER-WILLOW
KALMIA ANGUSTIFOLIA	S1		SHEEP-LAUREL
KOELERIA CRISTATA	S1		JUNEGRASS
KRIGIA BIFLORA	S1		TWO-FLOWERED DWARF DANDELION
LACHNANTHES CAROLIANA	S1		

PLANTS OF SPECIAL CONCERN
Delaware Natural Heritage Inventory

SCIENTIFIC NAME	STATE RANK	FED STAT	COMMON NAME
LATHYRUS PALUSTRIS VAR MYRTIFOLIUS	SH		
LECHEA TENUIFOLIA	S1		NARROWLEAF PINWEED
LECHEA VILLOSA	SH		HAIRY PINWEED
LEMNA PERPUSILLA	SH		MINUTE DUCKWEED
LEPTOLOMA COGNATUM	SH		
LESPEDEZA ANGUSTIFOLIA	SU		NARROWLEAF BUSHCLOVER
LESPEDEZA STUEVEI	SH		TALL BUSH-CLOVER
LIATRIS SCARIOSA	SH		
LIATRIS SPICATA	SH		SPIKE GAY-FEATHER
LILAEOPSIS CHINENSIS	SU		EASTERN LILAEOPSIS
LILIUM CANADENSE	S1		CANADA LILY
LILIUM PHILADELPHICUM	SH		WOOD LILY
LIMNOBIUM SPONGIA	S1		AMERICAN FROG'S-BIT
LIMOSELLA AUSTRALIS	S1		
LINDERNIA DUBIA VAR INUNDATA	S1		
LINUM INTERCURSUM	SH		SANDPLAIN FLAX
LIPARIS LILIIFOLIA	S1		LARGE TWAYBLADE
LOBELIA BOYKINII	SH	C2	BOYKIN'S LOBELIA
LOBELIA CANBYI	S1		CANBY'S LOBELIA
LOBELIA ELONGATA	S1		ELONGATED LOBELIA
LOBELIA SPICATA	SH		PALE-SPIKED LOBELIA
LOPHIOLA AMERICANA	SH		
LUDWIGIA HIRTELLA	S1		HAIRY LUDWIGIA
L.DWIGIA LINEARIS	S2		
LUDWIGIA PEPLOIDES SSP GLABRESCENS	S1		
LUPINUS PERENNIS	S1		SUNDIAL LUPINE
LUZULA ACUMINATA	SH		HAIRY WOODRUSH
LUZULA MULTIFLORA VAR MULTIFLORA	SU		
LYCOPODIUM CLAVATUM	S1		RUNNING PINE
LYCOPODIUM TRISTACHYUM	S1		DEEP-ROOT CLUBMOSS
LYGODIUM PALMATUM	S1		CLIMBING FERN
MALAXIS UNIFOLIA	S1		GREEN ADDER'S-MOUTH
MATELEA CAROLINENSIS	SH		CAROLINA ANGELPOD
MECARDONIA ACUMINATA	S1		
MELAMPYRUM LINEARE VAR PECTINATUM	SH		
MELANTHIUM LATIFOLIUM	SH		HYBRID BUNCHFLOWER
MELANTHIUM VIRGINICUM	SH		VIRGINIA BUNCHFLOWER
MENTHA CANADENSIS	SH		CANADIAN MINT
MENYANTHES TRIFOLIATA	SH		BUCKBEAN
MERTENSIA VIRGINICA	S3		VIRGINIA BLUEBELLS
MICRANTHEMUM MICRANTHEMOIDES	SH	C1*	NUTTALL'S MICRANTHEMUM
MIMULUS ALATUS	S1		SHARP-WING MONKEYFLOWER
MINUARTIA CAROLINIANA	SX		PINE-BARREN SANDWORT
MINUARTIA STRICTA	SX		ROCK SANDWORT
MITELLA DIPHYLLA	S1		TWO-LEAF BISHOP'S-CAP
MONARDA CLINOPODIA	S1		BASAL BEE-BALM
MONARDA FISTULOSA	S1		WILD BERGAMOT BEE-BALM
MUHLENBERGIA CAPILLARIS	SH		LONG-AWN HAIRGRASS
MUHLENBERGIA SYLVATICA	S1		WOODLAND MUHLY

PLANTS OF SPECIAL CONCERN
Delaware Natural Heritage Inventory

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MUHLENBERGIA TENUIFOLIA	SU		SLIM-FLOWER MUHLY
MUHLENBERGIA TORREYANA	SH	C1	TORREY'S DROPSEED
MYOSOTIS VERNA	SH		SPRING FORGET-ME-NOT
MYRICA CERIFERA	S4		
MYRICA HETEROPHYLLA	SH		EVERGREEN BAYBERRY
MYRIOPHYLLUM HETEROPHYLLUM	S1		BROADLEAF WATER-MILFOIL
MYRIOPHYLLUM HIPPUROIDES	SH		
MYRIOPHYLLUM HUMILE	S1		
NARTHECIUM AMERICANUM	SX	C2	YELLOW ASPHODEL
NELUMBO LUTEA	S1		AMERICAN LOTUS
NOTHOSCORDUM BIVALVE	S1		CROW-POISON
NUPHAR LUTEUM	S3		YELLOW COWLILY
NYMPHAEA ODORATA	S4		AMERICAN WATER-LILY
NYMPHAEA ODORATA VAR ODORATA	SU		
NYMPHOIDES AQUATICA	S2		LARGE FLOWERING HEART
NYMPHOIDES CORDATA	S1		FLOATING-HEART
OBOLARIA VIRGINICA	S1		VIRGINIA PENNYWORT
OENOTHERA HUMIFUSA	S1		
ONOSMODIUM VIRGINIANUM	SH		VIRGINIA FALSE-GROMWELL
OPHIOGLOSSUM VULGATUM VAR PSEUDOPODUM	SH		
OROBANCHE UNIFLORA	S1		NAKED BROOMRAPE
THILIA SECUNDA SSP SECUNDA	SH		
YZOPSIS RACEMOSA	S1		BLACK-FRUIT MOUNTAIN-RICEGRASS
OSTRYA VIRGINIANA	SH		EASTERN HOP-HORNBEAM
OXYPOLIS CANBYI	SH	PE	CANBY'S DROPWORT
PANAX QUINQUEFOLIUS	S1	3C	AMERICAN GINSENG
PANICUM ANGUSTIFOLIUM	SH		
PANICUM AUBURNE	SH		
PANICUM HEMITOMON	S2		MAIDENCANE
PANICUM HIRSTII	S1	C2	HIRSTS' PANIC GRASS
PANICUM PHILADELPHICUM	S1		PHILADELPHIA PANIC GRASS
PANICUM TUCKERMANII	S1		
PARONYCHIA CANADENSIS	S1		FORKED NAIL-WORT
PARONYCHIA FASTIGIATA	S1		CLUSTER-STEMMED NAIL-WORT
PASPALUM DISSECTUM	S1		
PASSIFLORA INCARNATA	S1		PURPLE PASSION-FLOWER
PEDICULARIS CANADENSIS	S1		EARLY WOOD LOUSEWORT
PEDICULARIS LANCEOLATA	SH		SWAMP LOUSEWORT
PENSTEMON HIRSUTUS	SH		HAIRY BEARDTONGUE
PENSTEMON LAEVIGATUS	S1		SMOOTH BEARDTONGUE
PERSEA BORBONIA VAR PUBESCENS	S1		
PHACELIA DUBIA	SH		
PHASEOLUS POLYSTACHYUS	SH		WILD KIDNEY BEAN
PHLOX PILOSA	SH		DOWNY PHLOX
PHYLLANTHUS CAROLINIENSIS	SH		CAROLINA LEAF-FLOWER
PHYSALIS ANGULATA	SH		
PHYSALIS PUBESCENS VAR GRISEA	SH		
PHYSOCARPUS OPULIFOLIUS	SH		EASTERN NINEBARK

PLANTS OF SPECIAL CONCERN
Delaware Natural Heritage Inventory

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PLANTAGO HETEROPHYLLA	SH		SLENDER PLANTAIN
PLANTAGO PUSILLA	SH		DWARF PLANTAIN
PLATANTHERA BLEPHARIGLOTTIS	S1		WHITE-FRINGE ORCHIS
PLATANTHERA CILIARIS	SH		YELLOW-FRINGE ORCHIS
PLATANTHERA FLAVA	S1	3C	SOUTHERN REIN-ORCHID
PLATANTHERA GRANDIFLORA	SH		LARGE PURPLE-FRINGE ORCHIS
PLATANTHERA NIVEA	SH		SNOWY ORCHIS
PLATANTHERA PERAMOENA	S1	3C	PURPLE FRINGELESS ORCHIS
PLATANTHERA PSYCODES	SH		SMALL PURPLE-FRINGE ORCHIS
PLUCHEA CAMPHORATA	SH		MARSH FLEABANE
POA ALSODES	S1		GROVE MEADOW GRASS
POA CHAPMANIANA	SH		CHAPMAN BLUEGRASS
POA NEMORALIS	SH		WOODS BLUEGRASS
PODOSTEMUM CERATOPHYLLUM	SX		THREADFOOT
POGONIA OPHIOGLOSSOIDES	S1		ROSE POGONIA
POLYGALA CRUCIATA	S1		CROSS-LEAVED MILKWORT
POLYGALA CYMOSA	SH		TALL PINE-BARREN MILKWORT
POLYGALA PAUCIFOLIA	SH		GAY-WING MILKWORT
POLYGALA RAMOSA	SH		
POLYGALA SENEGA	SH		SENECA SNAKEROOT
POLYGONUM AMPHIBIUM VAR STIPULACEUM	S1		
POLYGONUM CAREYI	S1		CAREY SMARTWEED
POLYGONUM GLABRUM	S1		
POLYGONUM OPELOUSANUM	SH		NORTHEASTERN SMARTWEED
POLYGONUM ROBUSTIUS	S1		
POLYGONUM SCANDENS VAR CRISTATUM	S1		
POLYGONUM SETACEUM	SH		
POLYMNIA UVEDALIA	S1		YELLOW-FLOWERED LEAFCUP
POLYPODIUM POLYPODIOIDES	S1		RESURRECTION FERN
POPULUS BALSAMIFERA	SH		BALSAM POPLAR
PORTERANTHUS TRIFOLIATUS	SH		
POTAMOGETON ROBBINSII	SH		FLATLEAF PONDWEED
POTAMOGETON SPIRILLUS	SX		SPIRAL PONDWEED
PRENANTHES ALBA	S1		WHITE RATTLESNAKE-ROOT
PRENANTHES AUTUMNALIS	SH		SLENDER RATTLESNAKE-ROOT
PRUNUS MARITIMA	S3?		BEACH PLUM
PRUNUS VIRGINIANA	S1		CHOKE CHERRY
PSILOCARYA NITENS	S1		SHORT-BEAKED BALD-RUSH
PSILOCARYA SCIRPOIDES	S1		LONG-BEAKED BALDRUSH
PYCNANTHEMUM CLINOPODIOIDES	SH		BASIL MOUNTAIN-MINT
PYCNANTHEMUM SETOSUM	SH		AWNED MOUNTAIN-MINT
PYCNANTHEMUM TORREI	SH		TORREY MOUNTAIN-MINT
PYCNANTHEMUM VERTICILLATUM	SH		WHORLED MOUNTAIN-MINT
PYCNANTHEMUM VIRGINIANUM	S3		VIRGINIA MOUNTAIN-MINT
PYROLA CHLORANTHA VAR CONVOLUTA	SH		
PYROLA ELLIPTICA	S3		ELIPTICAL-LEAF WINTERGREEN
PYRRHOPAPPUS CAROLINIANUS	SH		CAROLINA FALSE-DANDELION
QUERCUS BICOLOR	S2S3		SWAMP WHITE OAK
QUERCUS ILICIFOLIA	S1		SCRUB OAK

PLANTS OF SPECIAL CONCERN
Delaware Natural Heritage Inventory

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QUERCUS IMBRICARIA	S1		SHINGLE OAK
QUERCUS MACROCARPA	SX		
QUERCUS MICHAUXII	SU		SWAMP CHESTNUT OAK
QUERCUS MUHLENBERGII	S1		
QUERCUS PRINOIDES	SH		DWARF CHINQUAPIN OAK
RANUNCULUS AMBIGENS	SH		WATER-PLANTAIN
RANUNCULUS FLABELLARIS	S1		YELLOW WATER-CROWFOOT
RANUNCULUS HISPIDUS	SH		HISPID BUTTERCUP
RANUNCULUS LAXICAULIS VAR LAXICAULIS	SH		
RANUNCULUS LONGIROSTRIS	S1		WHITE WATER-CROWFOOT
RANUNCULUS PENSYLVANICUS	S1		BRISTLY CROWFOOT
RANUNCULUS PUSILLUS	SH		PURSH BUTTERCUP
RHEXIA ARISTOSA	S1	C2	AWNED MEADOWBEAUTY
RHYNCHOSIA TOMENTOSA	S1		
RHYNCHOSPORA CEPHALANTHA	S1		CAPITATE BEAKRUSH
RHYNCHOSPORA CHALAROCEPHALA	S3S4		LOOSE-HEAD BEAKRUSH
RHYNCHOSPORA CORNICULATA	S1		SHORT-BRISTLE HORNEDRUSH
RHYNCHOSPORA FILIFOLIA	S1		THREAD-LEAVED BEAKRUSH
RHYNCHOSPORA FUSCA	S1		BROWN BEAKRUSH
RHYNCHOSPORA GLOBULARIS	S1		
RHYNCHOSPORA GLOMERATA	S1		CLUSTERED BEAKRUSH
RHYNCHOSPORA GRACILENTA	S2		SLENDER BEAK RUSH
RHYNCHOSPORA INUNDATA	S1		DROWNED HORNEDRUSH
RHYNCHOSPORA KNIESKERNII	SH	C1	KNIESKERN'S BEAKED-RUSH
RHYNCHOSPORA MICROCEPHALA	S1		TINY-HEADED BEAK RUSH
RHYNCHOSPORA OLIGANTHA	SX		FEW-FLOWERED BEAKED-RUSH
RHYNCHOSPORA PALLIDA	SH		PALE BEAKRUSH
RHYNCHOSPORA TORREYANA	S1		TORREY BEAKRUSH
RIBES AMERICANUM	SH		WILD BLACK CURRANT
ROTALA RAMOSIOR	S1		TOOTHCUP
RUBUS ODORATUS	S1		PURPLE FLOWERING RASPBERRY
RUDBECKIA FULGIDA VAR FULGIDA	S1		
RUDBECKIA FULGIDA VAR SULLIVANTII	SH		
RUDBECKIA TRILOBA	S1		BROWN-EYED SUSAN
RUELLIA CAROLINIENSIS	S1		CAROLINA PETUNIA
RUMEX TRIANGULIVALVIS VAR TRIANGULIVALVIS	SH		
SABATIA CAMPANULATA	S1		
SABATIA DIFFORMIS	S1		TWO-FORMED PINK
SACCIOLEPIS STRIATA	SH		GIBBOUS PANIC-GRASS
SAGITTARIA CALYCINA VAR SPONGIOSA	SH		
SAGITTARIA ENGELMANNIANA	S1		
SAGITTARIA GRAMINEA	S1		GRASSLEAF ARROWHEAD
SAGITTARIA LATIFOLIA	SU		BROADLEAF ARROWHEAD
SAGITTARIA RIGIDA	S1		SESSILE-FRUITED ARROWHEAD
SAGITTARIA SUBULATA	S1S2		SUBULATE ARROWHEAD
SAGITTARIA TERES	S1		SLENDER ARROWHEAD
SALICORNIA BIGELOVII	SU		DWARF GLASSWORT
SALIX BEBBIANA	SH		

PLANTS OF SPECIAL CONCERN
Delaware Natural Heritage Inventory

SCIENTIFIC NAME	STATE RANK	FED STAT	COMMON NAME
SALIX DISCOLOR	SH		PUSSY WILLOW
SALIX EXIGUA	S1		SANDBAR WILLOW
SALIX LUCIDA	S1		SHINING WILLOW
SALIX OCCIDENTALIS	SH		DWARF GRAY WILLOW
SANGUISORBA CANADENSIS	SH		CANADA BURNET
SANICULA MARILANDICA	SH		BLACK SNAKE-ROOT
SARRACENIA PURPUREA SSP PURPUREA	S1		
SAXIFRAGA PENSYLVANICA	SH		SWAMP SAXIFRAGE
SCHWALBEA AMERICANA	SH	C2	CHAFFSEED
SCIRPUS CYLINDRICUS	SH		SALT-MARSH BULRUSH
SCIRPUS ETUBERCULATUS	S1		
SCIRPUS EXPANSUS	S1		WOODLAND BEAKRUSH
SCIRPUS POLYPHYLLUS	S1		
SCIRPUS PURSHIANUS	SU		WEAKSTALK BULRUSH
SCIRPUS SMITHII	S1		SMITH BULLRUSH
SCIRPUS SUBTERMINALIS	S1		WATER CLUBRUSH
SCIRPUS VERECUNDUS	S1		BASHFUL BULRUSH
SCLERIA PAUCIFLORA	SH		FEWFLOWER NUTRUSH
SCLERIA RETICULARIS	S1		
SCLERIA TRIGLOMERATA	SH		WHIP NUTRUSH
SCLEROLEPIS UNIFLORA	S1		PINK BOG-BUTTON
SCROPHULARIA LANCEOLATA	SH		HARE FIGWORT
SCUTELLARIA ELLIPTICA	SU		HAIRY SKULLCAP
SCUTELLARIA GALERICULATA	S1		HOODED SKULLCAP
SCUTELLARIA NERVOSA	SH		NERVED SKULLCAP
SCUTELLARIA PARVULA	SH		SMALL SKULLCAP
SCUTELLARIA SAXATILIS	SH		ROCK SKULLCAP
SELAGINELLA RUPESTRIS	SX		LEDGE SPIKE-MOSS
SENECIO ANONYMUS	SH		SMALL'S RAGWORT
SENECIO PAUPERCULUS	SH		BALSAM RAGWEED
SILENE CAROLINIANA SSP PENSYLVANICA	SH		
SILENE VIRGINICA	SH		FIRE PINK
SISYRINCHIUM MUCRONATUM	S1		MICHAUX BLUE-EYED-GRASS
SMILAX BONA-NOX	SH		SAW GREENBRIER
SMILAX HISPIDA	S1		HISPID GREENBRIER
SMILAX LAURIFOLIA	SU		LAUREL-LEAF GREENBRIER
SMILAX PSEUDOCHINA	SH		LONG-STALK GREENBRIER
SMILAX WALTERI	SU		WALTER GREENBRIER
SOLIDAGO ARGUTA	S1		CUTLEAF GOLDENROD
SOLIDAGO ELLIOTTII	SH		ELLIOTT GOLDENROD
SOLIDAGO PATULA	S3		ROUNDLEAF GOLDENROD
SOLIDAGO RUGOSA SSP ASPERA	S1		
SOLIDAGO SQUARROSA	SH		STOUT-RAGGED GOLDENROD
SOLIDAGO STRICTA	SH		WAND LIKE GOLDENROD
SOLIDAGO ULIGINOSA	S1		BOG GOLDENROD
SOLIDAGO ULMIFOLIA	SH		ELM-LEAF GOLDENROD
SPHENOPHOLIS PENSYLVANICA	SU		SWAMP WEDGESCALE
SPIRAEA ALBA	S1		NARROW-LEAVED MEADOW-SWEET
SPIRANTHES CERNUA	S3		NODDING LADIES'-TRESSES

PLANTS OF SPECIAL CONCERN
Delaware Natural Heritage Inventory

SCIENTIFIC NAME	STATE RANK	FED STAT.	COMMON NAME
SPIRANTHES LUCIDA	SH		SHINING LADIES'-TRESSES
SPIRANTHES ODORATA	S1		SWEETSCENT LADIES'-TRESSES
SPIRANTHES PRAECOX	S1		GRASSLEAF LADIES'-TRESSES
SPIRANTHES TUBEROSA	SH		LITTLE LADIES'-TRESSES
SPOROBOLUS ASPER	SH		LONGLEAF DROPSEED
SPOROBOLUS CLANDESTINUS	S1		ROUGH DROPSEED
STACHYS ASPERA	SH		ROUGH HEDGE-NETTLE
STACHYS HYSSOPIFOLIA	SH		HYSSOP-LEAF HEDGE-NETTLE
STACHYS TENUIFOLIA VAR TENUIFOLIA	SU		
STELLARIA ALSINE	SU		TRAILING STITCHWORT
STELLARIA NEGLECTA	S1		
SYMPLOCOS TINCTORIA	S1		HORSE-SUGAR
TAENIDIA INTEGERRIMA	SH		YELLOW PIMPERNELL
TEPHROSIA SPICATA	S1		
TEUCRIUM CANADENSE VAR VIRGINICUM	S2		
THALICTRUM DIOICUM	SU		EARLY MEADOWRUE
THELYPTERIS PHEGOPTERIS	SX		NORTHERN BEECHFERN
THELYPTERIS SIMULATA	S1		BOG FERN
TIPULARIA DISCOLOR	S3		CRANEFLY ORCHID
TOFIELDIA RACEMOSA	SH		COASTAL FALSE-ASPHODEL
TRACHELOSPERMUM DIFFORME	SH		CLIMBING DOGBANE
TRIADENUM WALTERI	SH		WALTER ST. JOHN'S WORT
TRICHOSTEMA SETACEUM	SH		NARROW-LEAVED BLUE CURLS
TRIENTALIS BOREALIS	S1		NORTHERN STARFLOWER
TRIFOLIUM CAROLINIANUM	SH		CAROLINA CLOVER
TRIGLOCHIN MARITIMUM	SH		SEASIDE ARROW-GRASS
TRIGLOCHIN STRIATUM	SH		THREE-RIBBED ARROWGRASS
TRILLIUM CERNUUM	S1		NODDING TRILLIUM
TRILLIUM FLEXIPES	SH		
TRIOSTEUM ANGUSTIFOLIUM	SH		YELLOWLEAF TINKER'S-WEED
TRIOSTEUM AURANTIACUM	S1		COFFEE TINKER'S-WEED
TRIOSTEUM PERFOLIATUM	S1		PERFOLIATE TINKER'S-WEED
TRIPHORA TRIANTHOPHORA	SH		NODDING POGONIA
TROLLIUS LAXUS	SH		
UTRICULARIA BIFLORA	S1		TWO-FLOWER BLADDERWORT
UTRICULARIA CORNUTA	SH		HORNED BLADDERWORT
UTRICULARIA FIBROSA	SH		FIBROUS BLADDERWORT
UTRICULARIA GEMINISCAPA	S1		HIDDENFRUIT BLADDERWORT
UTRICULARIA INFLATA	S1		
UTRICULARIA INTERMEDIA	SH		FLATLEAF BLADDERWORT
UTRICULARIA JUNCEA	S1		SOUTHERN BLADDERWORT
UTRICULARIA PURPUREA	S1		PURPLE BLADDERWORT
UTRICULARIA RADIATA	S2		SMALL SWOLLEN BLADDERWORT
UTRICULARIA RESUPINATA	S1		NORTHEASTERN BLADDERWORT
VACCINIUM MACROCARPON	S1		LARGE CRANBERRY
VAHLODEA ATROPURPUREA	S1		
VERATRUM VIRIDE	S1		AMERICAN FALSE-HELLEBORE
VERBENA SIMPLEX	SH		NARROW-LEAVED VERVAIN
VERBESINA ALTERNIFOLIA	SH		WINGSTEM

PLANTS OF SPECIAL CONCERN
Delaware Natural Heritage Inventory

CIENTIFIC NAME	STATE RANK	FED STAT	COMMON NAME
'ERONICA AMERICANA	S1		
VIBURNUM LENTAGO	SU		NANNYBERRY
VIBURNUM RAFINESQUIANUM	SH		DOWNY ARROWWOOD
'ICIA CAROLINIANA	SH		CAROLINA WOOD VETCH
'IOLA ROTUNDIFOLIA	S1		ROUNDLEAF VIOLET
WOLFFIA COLUMBIANA	S1		COLUMBIA WATER-MEAL
WOLFFIELLA GLADIATA	S1		SWORD BOGMAT
'OODSIA OBTUSA	S1		BLUNT-LOBE WOODSIA
.EROPHYLLUM ASPHODELOIDES	SH		EASTERN TURKEYBEARD
XYRIS SMALLIANA	S1		
'ANTHOXYLUM AMERICANUM	SH		NORTHERN PRICKLEY ASH
IGADENUS LEIMANTHOIDES	SH		DEATH-CAMUS

INVERTEBRATES OF SPECIAL CONCERN
Delaware Natural Heritage Inventory

SCIENTIFIC NAME	STATE RANK	FED STAT	COMMON NAME
ACHALARUS LYCIADES	S4		HOARY EDGE
AGRAULIS VANILLAE	SA		GULF FRITILLARY
ALASMIDONTA HETERODON	SX	C2	
ANCYLOXYPHA NUMITOR	S5		LEAST SKIPPERLING
ANTHOCHARIS MIDEA	S4		FALCATE ORANGETIP
ASTEROCAMPA CLYTON	SU		TAWNY EMPEROR
ATALOPEDES CAMPESTRIS	SA		
ATLIDES HALESUS	SA		GREAT PURPLE HAIRSTREAK
ATRYTONE LOGAN	S4		
ATRYTONOPSIS HIANNA	SU		DUSTED SKIPPER
AUTOCHTON CELLUS	SH		GOLDEN-BANDED SKIPPER
BATTUS PHILENOR	SN		PIPEVINE SWALLOWTAIL
BOLORIA BELLONA	SU		MEADOW FRITILLARY
BOLORIA SELENE MYRINA	SU		SILVER BORDERED FRITILLARY
CALPODES ETHLIUS	SA		BRAZILIAN SKIPPER
CELASTRINA LADON	S5		SPRING AZURE
CERCYONIS PEGALA	S5		LARGE WOOD NYMPH
CICINDELA DORSALIS MEDIA	S?		A TIGER BEETLE
CICINDELA DUODECIMGUTTATA	S?		A TIGER BEETLE
CICINDELA FORMOSA GENEROSA	S?		A TIGER BEETLE
CICINDELA HIRTICOLLIS	S?		BEACH-DUNE TIGER BEETLE
CICINDELA MARGINATA	S?		A TIGER BEETLE
CICINDELA PATRUELA	S?		A TIGER BEETLE
CICINDELA PUNCTULATA	S?		A TIGER BEETLE
CICINDELA PURPUREA	S?		A TIGER BEETLE
CICINDELA REPANDA	S?		A TIGER BEETLE
CICINDELA RUFIVENTRIS	S?		A TIGER BEETLE
CICINDELA SEXGUTTATA	S?		A TIGER BEETLE
CICINDELA TRANQUEBARICA	S?		A TIGER BEETLE
COLIAS CESONIA	SA		DOGFACE BUTTERFLY
COLIAS EURYTHEME	S5		ORANGE SULPHUR
COLIAS PHILODICE	S5		COMMON SULPHUR
DANAUS PLEXIPPUS	S5		MONARCH
EPARGYREUS CLARUS	S5		SILVER SPOTTED SKIPPER
ERYNNIS BRIZO BRIZO	S4		SLEEPY DUSKYWING
ERYNNIS HORATIUS	S4		HORACE'S DUSKYWING
ERYNNIS JUVENALIS	S5		JUVENAL'S DUSKYWING
EUPHYDRYAS PHAETON	SU		BALTIMORE
EUPHYES CONSPICUA	SU		BLACK DASH
EUPHYES RURICOLA METACOMET	S5		DUN SKIPPER
EUPTOIETA CLAUDIA	SN		VARIEGATED FRITILLARY
EUREMA LISA	SN		LITTLE YELLOW
EUREMA NICIPPE	SA		SLEEPY ORANGE
EURYTIDES MARCELLUS	SA		ZEBRA SWALLOWTAIL
EVERES COMYNTAS	S5		EASTERN TAILED BLUE
HADENA ECTYPA	SU		
HEMILEUCA MAIA SSP 4	SH		WOODLAND BUCK MOTH
HESPERIA METEA	SU		COBWEB SKIPPER
HESPERIA SASSACUS	S4		INDIAN SKIPPER
HYLEPHILA PHYLEUS	SN		FIERY SKIPPER
INCISALIA IRUS	SU		FROSTED ELFIN
INCISALIA NIPHON	S4		EASTERN PINE ELFIN
JUNONIA COENIA	S5		BUCKEYE
LEREMA ACCIUS	SA		CLOUDED SKIPPER

AR301616

AMPHIBIANS OF SPECIAL CONCERN
Delaware Natural Heritage Inventory

SCIENTIFIC NAME	STATE RANK	FED STAT	COMMON NAME
ACRIS CREPITANS	S5		NORTHERN CRICKET FROG
AMBYSTOMA MACULATUM	S1		SPOTTED SALAMANDER
AMBYSTOMA OPACUM	S3		MARBLED SALAMANDER
AMBYSTOMA TIGRINUM	S2		EASTERN TIGER SALAMANDER
BUFO AMERICANUS	S5		EASTERN AMERICAN TOAD
BUFO WOODHOUSII FOWLERI	S5		FOWLER'S TOAD
DESMOGNATHUS FUSCUS	S5		NORTHERN DUSKY SALAMANDER
EURYCEA BISLINEATA	S5		NORTHERN TWO-LINED SALAMANDER
EURYCEA LONGICAUDA	S1		LONGTAIL SALAMANDER
HEMIDACTYLIUM SCUTATUM	S1		FOUR-TOED SALAMANDER
HYLA CHRYSOSCELIS	S1		COPE'S GRAY TREEFROG
HYLA CINEREA	S3		GREEN TREEFROG
PSEUDACRIS CRUCIFER	S5		NORTHERN SPRING PEEPER
HYLA GRATIOSA	S1		BARKING TREEFROG
HYLA VERSICOLOR	S4		GRAY TREEFROG
NOTOPHTHALMUS VIRIDESCENS	S4		RED-SPOTTED NEWT
PLETHODON CINEREUS	S5		REDBACK SALAMANDER
PSEUDACRIS TRISERIATA	S4		NEW JERSEY CHORUS FROG
PSEUDOTRITON RUBER	S4		NORTHERN RED SALAMANDER
RANA CATESBEIANA	S5		BULLFROG
RANA CLAMITANS	S5		GREEN FROG
RANA PALUSTRIS	S5		PICKEREL FROG
RANA SPHENOCEPHALA	S5		SOUTHERN LEOPARD FROG
NA SYLVATICA	S4		WOOD FROG
RANA VIRGATIPES	S1		CARPENTER FROG
SCAPHIOPUS HOLBROOKII	S4		EASTERN SPADEFOOT

INVERTEBRATES OF SPECIAL CONCERN
Delaware Natural Heritage Inventory

SCIENTIFIC NAME	STATE RANK	FED STAT	COMMON NAME
LIMENITIS ARCHIPPUS	S5		VICEROY
LIMENITIS ARTHEMIS ASTYANAX	S5		RED SPOTTED PURPLE
LYCAENA HYLLUS	S2S3		BRONZE COPPER
LYCAENA PHLAEAS	S5		AMERICAN COPPER
MEGACEPHALA VIRGINICA	S?		A TIGER BEETLE
MEGISTO CYMELA	S5		LITTLE WOOD SATYR
MITOURA HESSELI	S1	3C	HESSEL'S HAIRSTREAK
NASTRA LHERMINIER	S4		SWARTHY SKIPPER
NYMPHALIS ANTIOPA	S5		MOURNING CLOAK
ORCONECTES LIMOSUS	S?		SPINYCHEEK CRAYFISH
PANOQUINA OCOLA	SA		LONG-WINGED SKIPPER
PANOQUINA PANOQUIN	S4		SALT-MARSH SKIPPER
PAPILIO GLAUCUS	S5		TIGER SWALLOWTAIL
PAPILIO PALAMEDES	SA		PALAMEDES SWALLOWTAIL
PAPILIO TROILUS	S5		SPICEBUSH SWALLOWTAIL
PARRHASIUS M-ALBUM	S4?		WHITE M HAIRSTREAK
PHOEBIS SENNAE	SA		CLOUDLESS GIANT SULPHUR
PHOLISORA CATULLUS	S5		COMMON SOTTYWING
PHYCIODES THAROS	S5		PEARLY CRESCENTSPOT
PIERIS RAPAE	SE		EUROPEAN CABBAGE WHITE
POANES AARONI AARONI	SU		SAFFRON SKIPPER
POANES HOBOMOK	S4		HOBOMOK SKIPPER
POANES MASSASOIT	SU		MULBERRY WING
POANES VIATOR ZIZANIAE	S4		
POANES ZABULON	S5		ZABULON SKIPPER
POLITES CORAS	S5		
POLITES ORIGENES	S5		CROSSLINE SKIPPER
POLITES THEMISTOCLES	S4		TAWNY-EDGED SKIPPER
POLYGONIA COMMA	S5		COMMA
POLYGONIA INTERROGANTIONIS	S5		QUESTION MARK
PONTIA PROTODICE	SU		CHECKERED WHITE
PYRGUS COMMUNIS	S5		COMMON CHECKERED SKIPPER
SATYRIUM CALANUS FALACER	S5		BANDED HAIRSTREAK
SATYRIUM KINGI	S1		
SPEYERIA CYBELE	S4		GREAT SPANGLED FRITILLARY
STRYMON MELINUS	S5		GRAY HAIRSTREAK
THORYBES BATHYLLUS	S4		SOUTHERN CLOUDYWING
THORYBES CONFUSIS	SH		CONFUSED CLOUDY WING
THORYBES PYLADES	S5		NORTHERN CLOUDYWING
THYMELICUS LINEOLA	SE		EUROPEAN SKIPPER
URBANUS PROTEUS	SA		LONG-TAILED SKIPPER
VANESSA ATALANTA	S5		RED ADMIRAL
VANESSA CARDUI	S5		PAINTED LADY
VANESSA VIRGINIENSIS	S5		AMERICAN PAINTED LADY
WALLENGRENIA EGEREMET	S5		NORTHERN BROKEN DASH

H

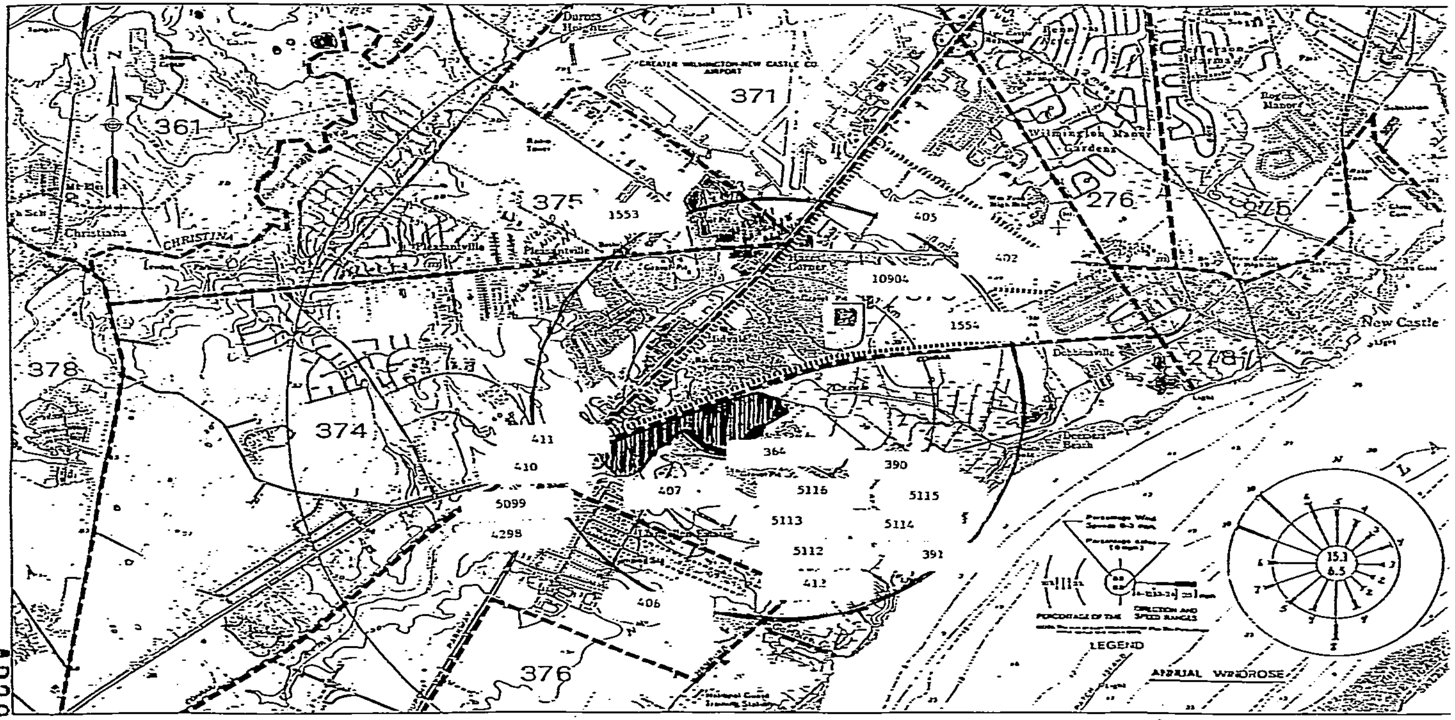
APPENDIX H

PRIME FARMLAND AND HISTORIC AND ARCHAEOLOGICAL RESOURCES

AROUND THE ARMY CREEK LANDFILL SITE

HISTORIC AND ARCHAEOLOGICAL RESOURCES

Mr. Bob Williamson of Gannett Fleming, Inc. met with Ms. Faye Stocum of the Delaware Office of the Bureau of Archaeology and Historic Preservation on February 14, 1990. Ms. Stocum provided information from the Delaware Cultural Resources Survey and the National Register of Historic Places.



LEGEND

- TREATMENT PLANT SITE (Proposed)
- ARMY CREEK POND
- POPULATED AREAS (within 1 mile)
- TRAFFIC ZONES
- COMMERCIAL / INDUST. ZONE
- ARMY CREEK LANDFILL SITE

QUADRANGLE LOCATION

FIGURE 3-1

ARMY CREEK LANDFILL SITE

SCALE: 1 : 24,000

GANNETT FLEMING ENVIRONMENTAL ENGINEERS, INC.
BALTIMORE, MARYLAND

AR301622

DELAWARE CULTURAL RESOUCES IN THE VICINITY OF THE ARMY CREEK LANDFILL SITE

Delaware Cultural Resources Number	Beer's Atlas	Description
364	yes	Grantham House
390	no	Inshore lightkeeper's house
391	no	Shore lightkeeper's house
402	no	Airhanger
405	yes	New Castle Trustee's farm
406	no	Old Schaefer Place
407	yes	Sunny Acres
410	no	House
411	yes	House
412	yes	House
1553	no	Site of Bethel Church
1554	no	Spring Garden
4298	no	Bridge
5099	no	Church
5112	no	House- 1909
5113	no	House
5114	no	House
5115	no	House
5116	no	House
10904	yes	Walnut Cottage

CULTURAL RESOURCE SURVEY
ARCHAEOLOGICAL SITE FORM

Form CRS-4

FOR OFFICE USE ONLY

BUREAU OF ARCHAEOLOGY AND
HISTORIC PRESERVATION
HALL OF RECORDS
DOVER, DELAWARE 19901
(302) 678-5314
DOCUMENT 20-06/78/01/5

CRS no. N-11180
Arch. Site 7NC-E-88
SPO Map 08-09-33
Soil Map ______
Quad Wilm South
Drainage ______

1. Site Designation Bethel Church Area sites 7NC-E-88 Date ______

2. Location 100 Christiana Road (north side of DE Rt273 near DELDOT Sta. 110)

New Castle County

3. Owner or Contact John Palumbo (owner)

4. Site Description: Soil Type BaB2 Cultivated no Other X

Grassy yard with trees, shrub and driveway to recent structure. Partially capped structure on SE side of lawn; cemetery to north (overgrwon and wooded)

5. Description of Field Work ______

6. Collections at Island Field Museum
Accession No. ______ By Whom ______

Date ______ Surface ______ Excavation ______ Location ______

Accession No. ______ By Whom ______

Date ______ Surface ______ Excavation ______ Location ______

Accession No. ______ By Whom ______

Date ______ Surface ______ Excavation ______ Location ______

Accession No. ______ By Whom ______

Date ______ Surface ______ Excavation ______ Location ______

7. Other Collections ______

8. Cultural Characterization late 18th century to prsent. Site of Bethel Church, Circa 1786, two other structures added by B. Booth circa 1868. Materials collected date from mid-19th century to present. Earliest gravestone noted upon casual inspection: 1813; most recent 1946.

AR301624

CULTURAL RESOURCE SURVEY
ARCHAEOLOGICAL SITE FORM

BUREAU OF ARCHAEOLOGY AND
HISTORIC PRESERVATION
HALL OF RECORDS
DOVER, DELAWARE 19901
(302) 678-5314
DOCUMENT 20-06/78/01/5

Form CRS-4

FOR OFFICE USE ONLY

CRS no. N-11181
Arch. Site 7NC-E-89
SPO Map 08-09-33
Soil Map ______
Quad Wilm South
Drainage ______

1. Site Designation Step Site 7NC-E-87 Date ______

2. Location Parway Gravel Inc lot, north side of DE Rt273, near DelDot Station 136, New Castle County

3. Owner or Contact Parkway Gravel, Inc. (owner)

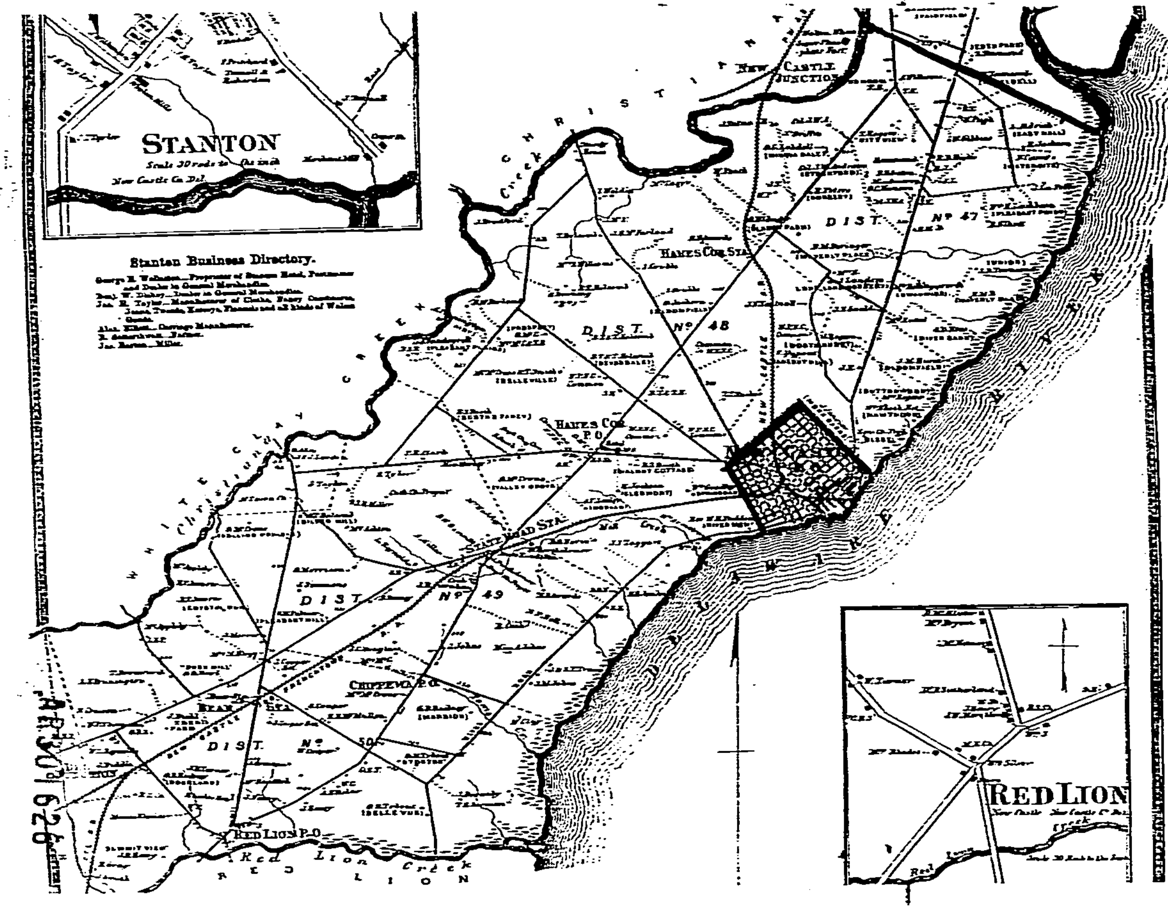
4. Site Description: Soil Type ______ Cultivated ______ Other x
recent woods and brambles near Rt 273, gradually turning to gravel pit spoils

5. Description of Field Work ______

6. Collections at Island Field Museum
Accession No. ______ By Whom ______
Date ______ Surface ______ Excavation ______ Location ______
Accession No. ______ By Whom ______
Date ______ Surface ______ Excavation ______ Location ______
Accession No. ______ By Whom ______
Date ______ Surface ______ Excavation ______ Location ______
Accession No. ______ By Whom ______
Date ______ Surface ______ Excavation ______ Location ______

7. Other Collections ______

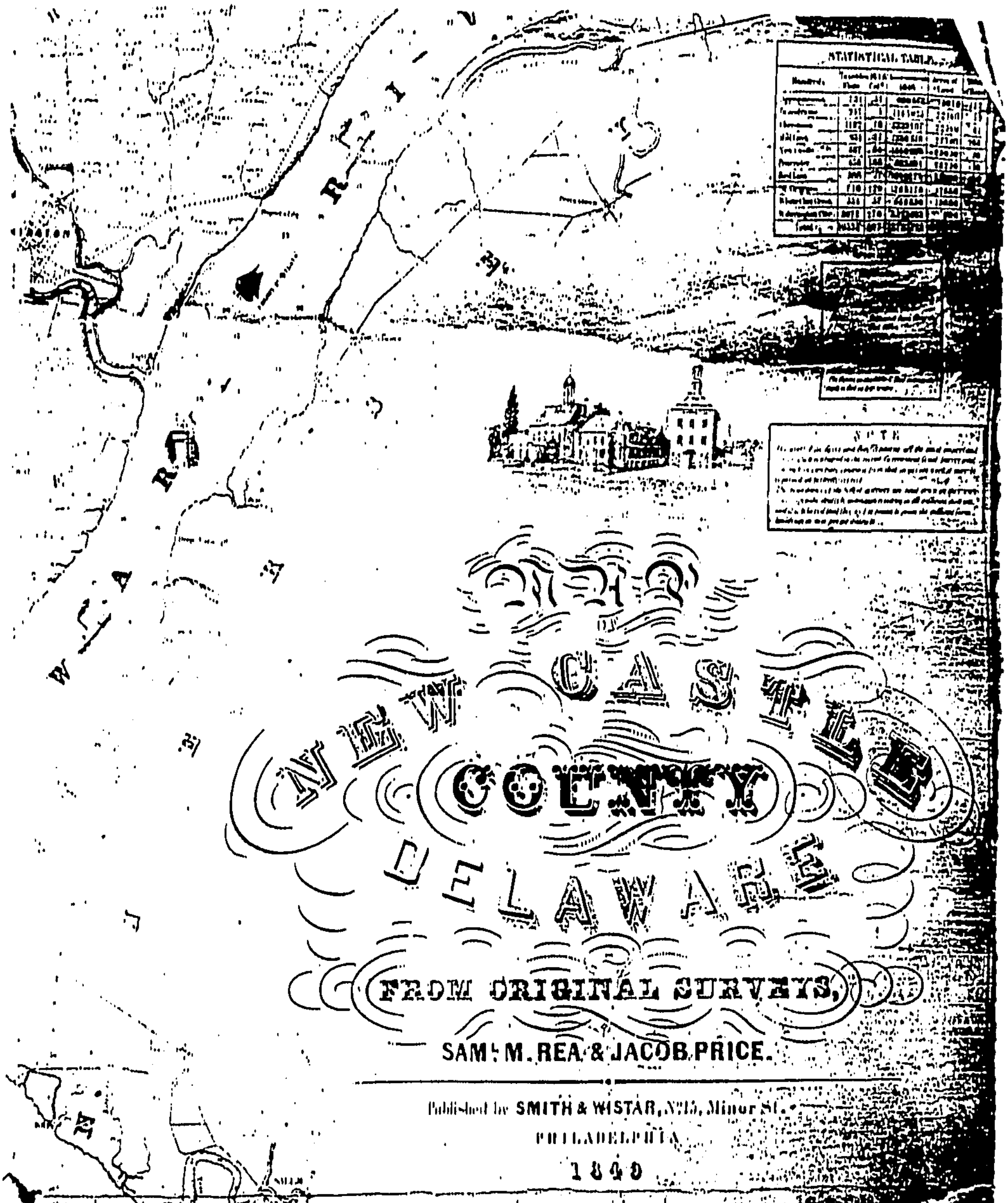
8. Cultural Characterization Artifactual material recovered dates from mid-19th century to present, and consists of a combination of domestic, architectural and agricultural items . Historical information indicates a structure at this location circa 1849, 1868, and 1928 (intervening mapping indicate no structures)



AR301626

New Castle Hundred

from Beers' Atlas of the State of Delaware (1868)

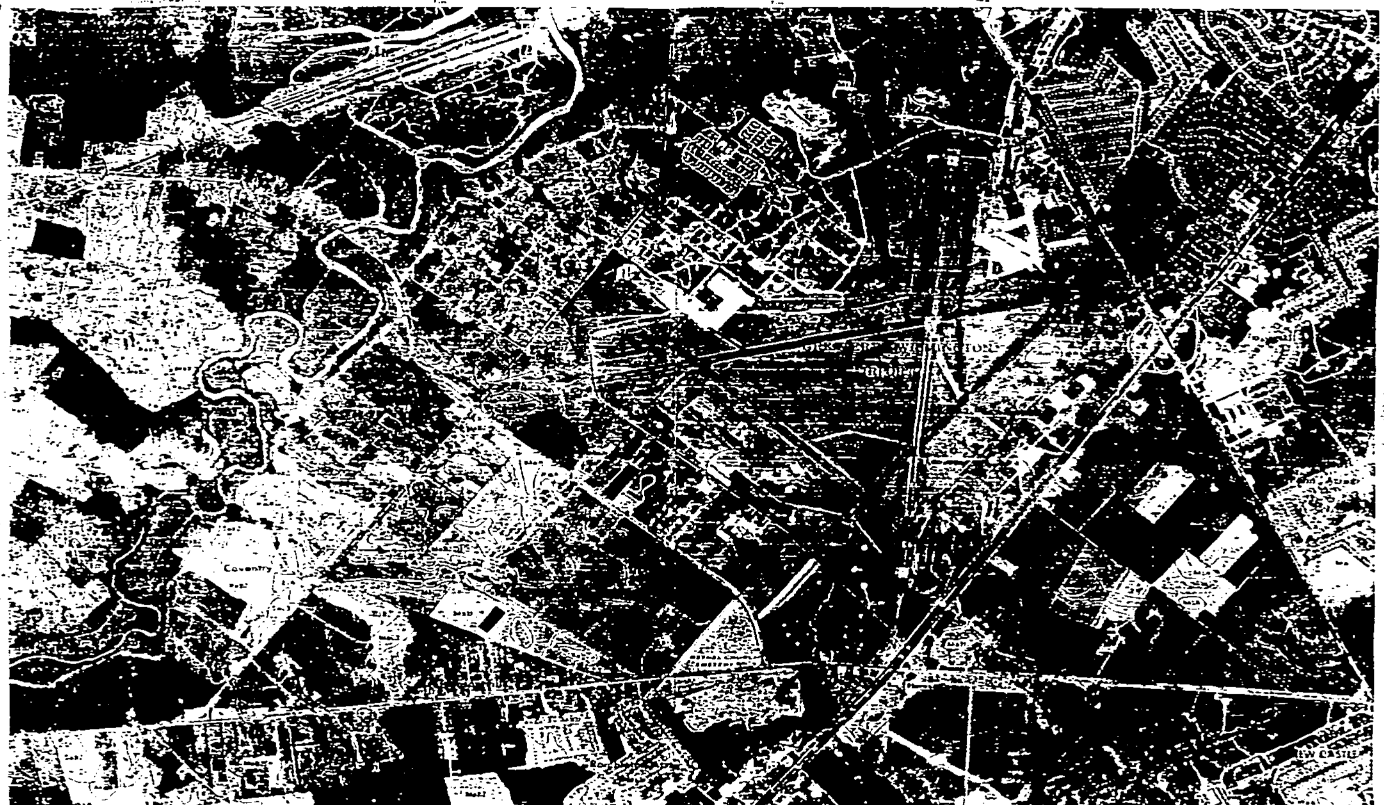

NEW CASTLE
COUNTY
DELAWARE
FROM ORIGINAL SURVEYS,
SAMl. M. REA & JACOB PRICE.
Published by SMITH & WISTAR, No. 15, Minor St.
PHILADELPHIA

NEW CASTLE COUNTY, DELAWARE — SHEET NUMBER 24

Scale 1:15 840

Prehistoric Archaeology Site [illegible] Area

NEW CASTLE COUNTY, DELAWARE — SHEET NUMBER 20



[////] potential prehistoric archaeological sites

AR301630

STATE OF DELAWARE

DEPARTMENT OF AGRICULTURE
KEVIN C DONNELLY
SENIOR RESOURCES PLANNER
AGRICULTURAL LANDS PRESERVATION

2320 SOUTH DuPONT HIGHWAY
DOVER, DELAWARE 19901

(302) 736 4811
(800) 282-8685 (DE ONLY)
FAX (302) 697 6287

AR301631

Technical Appendix
for Delaware's Land Evaluation and Site Assessment System

Purpose

The intent of this Technical Appendix is to explain the use of Delaware's Land Evaluation and Site Assessment (LESA) system. It is designed to take an evaluator through the steps necessary for a sound LESA evaluation. We have incorporated standards to make the evaluator's job less tedious and have tried to include the resource data needed throughout the evaluation process.

Introduction

The LESA system is designed to determine the quality of land for agricultural purposes and to assess its long-term agricultural viability. The Department of Agriculture will use LESA to evaluate state and federally funded projects that affect farmland. The LESA system is designed to be a tool to assist decision makers by providing them with documentable information, using locally developed criteria that will help them make rational, consistent, and sound land-use decisions.

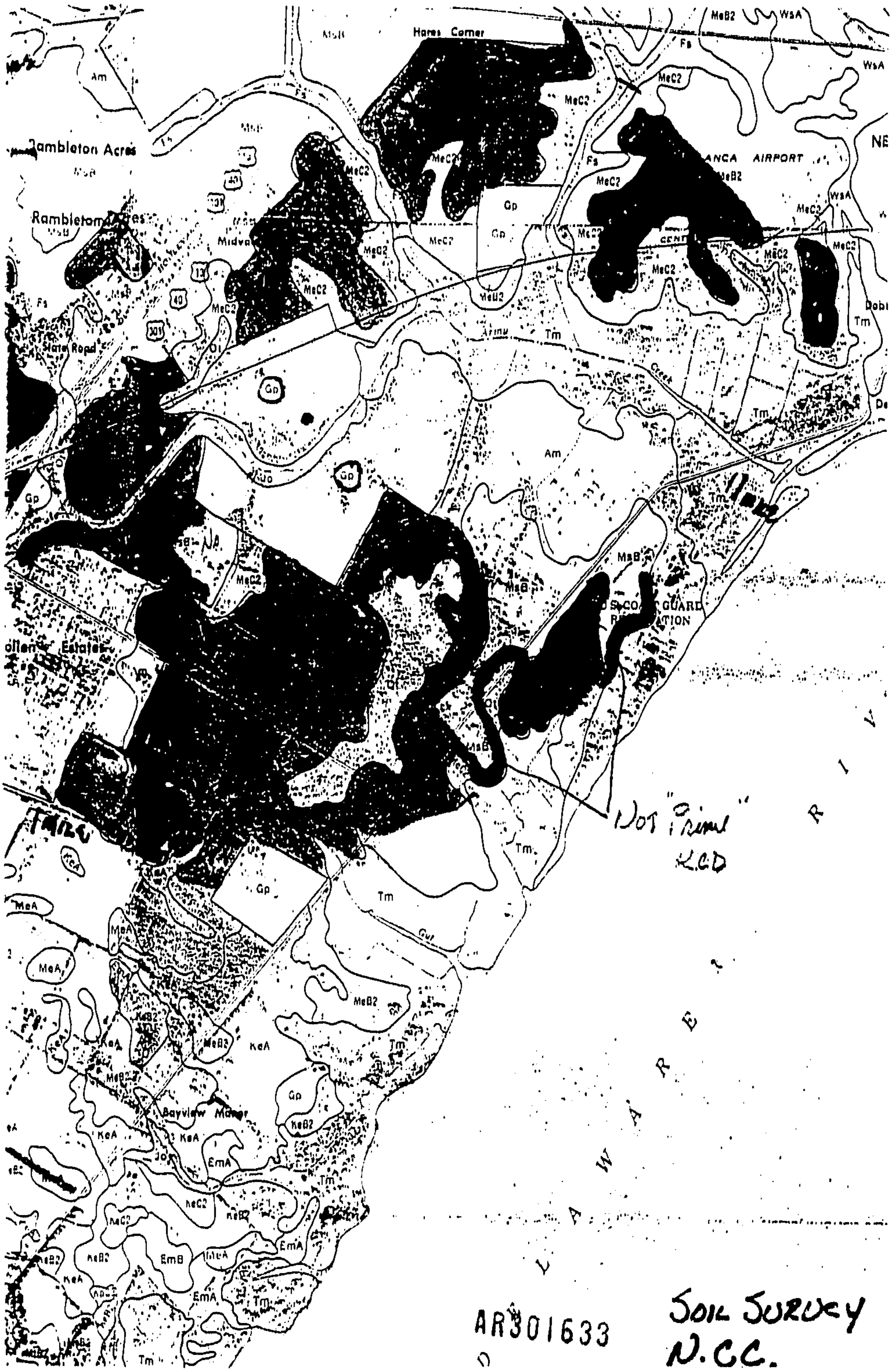
LESA's Analytical Unit

Evaluators should use contiguous tax parcels under the same owner's name as their analytical unit. Inclusion of rental lands in the analytical unit was discounted by the county committees because of the difficulty in obtaining rental agreement records.

Evaluators should refer to Appendix C: Section 8333 of the State of Delaware - Report of State Farmland Evaluation Advisory Committee - January 1986, for a definition of applicable land use for consideration as agricultural, horticultural, or forestry uses.

Land Evaluation

LESA consists of two parts. In the first part, land evaluation, soils are rated and placed into ten groups ranging from the best to the worst suited for an agricultural use based on information from the USDA Soil Conservation Service. The best group contains soils with the highest yields and the fewest limitations. This group is assigned a value of 100 and all other groups are assigned lower values. In the Delaware LESA system the three lowest groups have no relative value.



Soil Survey N.C.C.

APPENDIX I

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