ATTACHMENT B

REPORT OF THE TECHNICAL ADVISORY COMMITTEE ON ARMY CREEK CONTAMINANT ISSUES

Submitted to Army Creek Natural Resources Trustees

November 1994

Technical Advisory Committee Members

State of Delaware,
Department of Natural Resources and Environmental Control
William H. Meredith

U.S. Department of Interior,
Fish and Wildlife Service
Robert E. Foley, Monica K. Maghini

U.S. Department of Commerce,
National Oceanic and Atmospheric Administration
James P. Thomas, Timothy E. Goodger, Peter T. Knight,
Miguel D. Jorge

The purpose of this report is to provide the Army Creek Natural Resources Trustees with the basis for making knowledgeable decisions regarding the appropriateness of restoring Army Creek. The Trustees are concerned with contaminant concentrations in sediments, water, and biota in Army Creek Pond and Army Creek above and below the Pond for the purpose of evaluating the potential for restoration of aquatic and wetland habitat within the Army Creek watershed.

To determine the suitability of restoring Army Creek, the Trustees examined the Remedial Investigations, Feasibility Studies, Records-of-Decisions, and accompanying documents for the Army Creek and Delaware Sand and Gravel Superfund sites. These documents were used as a basis to assemble source documents relative to sediment, water, biota, and human health issues. When germane, older materials referring to original documents were also obtained. The Trustees are convinced that a reasonable attempt has been made to collect and analyze all relevant, existing documentation pertaining to Army Creek and its environment.

The Army Creek information was then compared to data collected from other waterways to determine the appropriateness of restoring the public trust resources of Army Creek and, subsequently, providing access to the public to enjoy the benefits of those resources. As a result of this analysis, it is the unanimous opinion of the Army Creek Natural Resources Trustees that resource restoration of Lower Army Creek below the Pond could be implemented; whereas consideration of restoration of Army Creek Pond and Upper Army Creek adjacent to the landfill should be delayed until completion of the U.S. Environmental Protection Agency's periodic review.

____
State of Delaware, DNREC Date

____
U.S. Department of Commerce, NOAA Date

____
U.S. Department of Interior Date

REPORT OF THE TECHNICAL ADVISORY COMMITTEE ON ARMY CREEK CONTAMINANT ISSUES

Submitted to Army Creek Natural Resource Trustees

November 1994

Technical Advisory Committee Members

State of Delaware, Department of Natural Resources and Environmental Control
William H. Meredith

U.S. Department of Interior, Fish and Wildlife Service
Robert E. Foley, Monica K. Maghini

U.S. Department of Commerce, National Oceanic and Atmospheric Administration
James P. Thomas, Timothy E. Goodger, Peter T. Knight,
Miguel D. Jorge

TABLE OF CONTENTS

REPORT OF THE TECHNICAL ADVISORY COMMITTEE ON ARMY CREEK CONTAMINANT ISSUES

EXECUTIVE SUMMARY

This document represents the findings, conclusions and recommendations of the Technical Advisory Committee on Army Creek contaminant issues based on the review and synthesis of peer reviewed literature, agency reports and interviews with knowledgeable individuals. The report consists of an introductory discussion of the contaminant issues; descriptions of the physical, biological and chemical setting for the Army Creek area; detailed discussion of the Delaware Sand and Gravel Superfund site; road runoff issues; lateral leachate issues; and discussion of groundwater treatment, sediment/metals mobility, and monitoring. This is followed by a synthesis of the available contaminant data for sediment, water, biota and human health for Upper Army Creek, Army Creek Pond, and Lower Army Creek.

The Technical Advisory Committee concludes that wetland habitat restoration can be undertaken in Lower Army Creek basin, downstream of Army Creek Pond. We also conclude and recommend that this restoration should focus on several multiple resource objectives including but not limited to (1) enhancement of tidal exchange with the Delaware River, (2) enhancement of wetland habitats that serve as fish, waterfowl and wildlife habitats, and (3) increased potential use of the area for education and recreation. The Technical Advisory Committee presents 16 reasons for recommending this restoration, among which are included: (1) Lower Army Creek sediments and water appear less contaminated than elsewhere within the system; (2) species diversity in the Lower Creek is higher than elsewhere within the system; (3) increased water exchange with the Delaware River would enhance the dilution of contaminants without impacting the River; (4) residual contamination of sediment and water in the Pond and Upper Creek adjacent to landfill may require additional remediation following a periodic review by the U.S. Environmental Protection Agency before restoration of these habitats could be considered; and (5) the restoration of the Lower Creek can be undertaken.

REPORT OF THE TECHNICAL ADVISORY COMMITTEE
ON
ARMY CREEK CONTAMINANT ISSUES

1.0 PURPOSE

The purpose of this report is to provide the Army Creek Natural Resources Trustees with the basis for making knowledgeable decisions regarding the appropriateness of restoring Army Creek. We have assembled existing data from a number of sources and have presented them in this document in context with other related data or information. Issues of concern involve not only potential problems with the Army Creek Superfund site, but also other watershed problems not related to the site (i.e., general landscape runoff). Based on such synthesis the Technical Advisory Committee has formulated conclusions and presents these as a series of recommendations dealing with management and restoration of Army Creek.

2.0 INTRODUCTION

2.1 CERCLA and Army Creek Site Natural Resources Trustee Committee

Pursuant to Section 107(f)(1) of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and Sections 300.600 and 300.605 of the National Contingency Plan (NCP), the Governor of the State of Delaware, and the Secretaries of the United States Departments of Interior and Commerce have been designated as Trustees for the natural resources at this site. The Governor of the State of Delaware delegated his authority to the Secretary of the Delaware Department of Natural Resources and Environmental Control (DNREC) via letter dated March 4, 1993. The Secretary of DNREC delegated his authority to the Director of the Division of Fish and Wildlife via letter dated March 29, 1993. Within the U.S. Department of Interior, the designation has remained with the Secretary. The Secretary of Commerce delegated his authority to the Administrator of NOAA via Organizational Order No. 25-5A.

A Memorandum Of Agreement (effective October 22, 1991) between the State of Delaware (Delaware), U.S. Department of Interior (U.S.DOI), and the National Oceanic and Atmospheric Administration (NOAA) established an Army Creek Site Natural Resources Trustee Committee. Delaware, U.S.DOI, and NOAA each have one permanent, voting representative to the Trustee Committee and one alternate representative to serve in the absence of the designated representative. Pursuant to the Agreement the purposes of the Trustee Committee are to: 1) oversee a coordinated and cooperative application of natural resource damages recovered in the settlement of United States v. BP America, Inc., et al., Civ. A. No. 91-409 (D. Del.), and State of Delaware v. BP America, Inc., et al., Civ. A. No. 91-418 (D. Del.), or any other claim or lawsuit pertaining to the Superfund Site (except for groundwater resources), toward the restoration, replacement and/or acquisition of equivalent natural resources which have been injured, destroyed or lost resulting from the release or threatened release of hazardous substances from the Army Creek Landfill Superfund Site (the Superfund Site); and 2) to further coordinated and cooperative natural resource trustee responsibilities under CERCLA, and other applicable law for any future judgments, litigation, or settlements pertaining to the Site.

More specifically, the Trustee Committee is to oversee the development and implementation of a plan (Restoration Plan) for the restoration, replacement and/or acquisition of equivalent resources for those trust resources which have been injured, destroyed or lost by the release of hazardous substances at the Superfund Site or as a result of remedial actions at the Superfund Site. This report is one of a series of documents being developed for the restoration plan.

2.2 Technical Advisory Committee on Army Creek Contaminant Issues

The Trustee Committee is concerned about potential contaminant concentrations in Army Creek sediments, water, and biota relative to restoring wetland habitats in Army Creek to increase their attractiveness for use by fish and wildlife resources and the public. Because of recently published information (i.e., Long and Morgan, 1991) and often confusing arrays of previously published data, the Trustee Committee established a

Technical Advisory Committee composed of members from the State of Delaware (Department of Natural Resources and Environmental Control), the U.S. Department of Interior (Fish and Wildlife Service), and the U.S. Department of Commerce (National Oceanic and Atmospheric Administration) to examine contaminant issues and make recommendations relative to natural resources restoration.

The Technical Advisory Committee did not pursue an option to collect additional field data via sampling. Rather, the Trustees opted that all damages should be spent on restoration. Use of damages for Trustee administrative costs also were waived to again leverage additional dollars for restoration work. Therefore, the intent of the Technical Advisory Committee was limited to: 1) reviewing existing, relevant data indicative of the state of contamination (e.g., water or sediment contaminant concentrations; species composition, abundance, and diversity) from the Administrative Records for Army Creek and Delaware Sand and Gravel Superfund sites and elsewhere (e.g., published literature, state reports, U.S. government reports, etc.); 2) reviewing such data for quality control; 3) presenting these data in chronological order by category (i.e., sediment, water, biota, human health); 4) drawing conclusions from these data in terms of restoring Army Creek; and 5) making recommendations relative to restoration and associated actions necessary to improve extant conditions.

The Technical Advisory Committee reviewed numerous documents from the Administrative Records for Army Creek and Delaware Sand and Gravel Superfund sites, and from other sources to obtain contaminant and background concentrations. The Technical Advisory Committee decided that analytical quality control procedures instituted by the original investigators, as overseen by the EPA, should be considered reliable, unless inadequacies were recognized during data analyses. Any inadequacies are identified in this report. Further, Technical Advisory Committee members met with the U.S. Environmental Protection Agency (EPA), Region III Project Manager for Army Creek to obtain additional information and resolve certain technical issues. Information from these sources was used to determine the desirability of restoring Army Creek for fish and wildlife resources and, subsequently, for the public. This report focuses on sediment, water and biota, with implications for public trust resources and human health (i.e., Is it appropriate to encourage public access?). In essence this report addresses whether or not Army Creek or portions of Army Creek are clean enough for restoration.

2.3 Superfund Site History

The Superfund site, as defined by the U.S. Environmental Protection Agency (EPA) for remediation purposes, was a municipal landfill administered by New Castle County for deposit of household and industrial wastes between 1960 and 1968. The 60-acre Army Creek Landfill, contains 1.9 million cubic yards of refuse, and is located approximately 2 miles southwest of the city of New Castle, Delaware (Figures 1, 2 and 3). Map coordinates for the site are approximately 39 degrees, 39 minutes north latitude, and 75 degrees, 37 minutes west longitude. Approximately 30% of the refuse lies below the seasonal high-water table. Originally, sand and gravel were mined at the site. The Army Creek Landfill, a National Priorities Listed (NPL) site under Superfund, is west of Army Creek; Delaware Sand and Gravel Landfill (Figure 3), another NPL site consisting of a former industrial waste disposal site operated from 1960 to 1976, is to the east of Army Creek. The two landfills are hydrogeologically connected.

In late 1971, water in a residential well southwest of the Army Creek Landfill developed aesthetic and drinking water quality problems caused by organic and inorganic contaminants. Gradually, this condition became more pronounced and the water supply was abandoned. Analyses of water from this well by the Delaware Geological Survey and New Castle County Department of Public Works indicated the presence of substances consistent with landfill leachate in the groundwater supplying this well. In June 1972, the County retained Roy F. Weston, Inc., to determine the nature and extent of the problem, and to define and implement controls to mitigate groundwater contamination. Installation of monitoring wells began in July 1972, and well sampling and analyses commenced shortly thereafter to determine the source and extent of groundwater contamination.

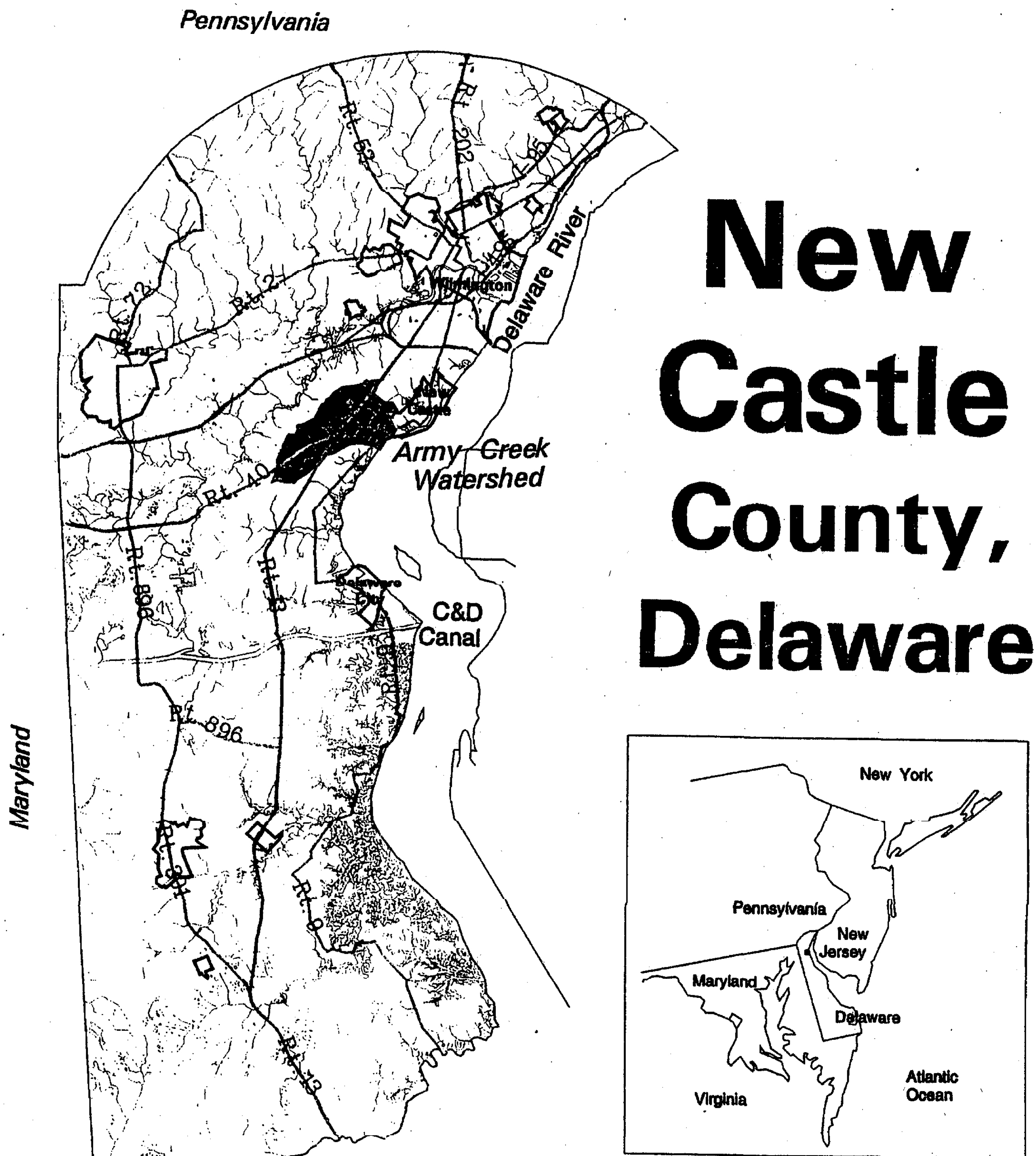

Figure 1. Army Creek site location

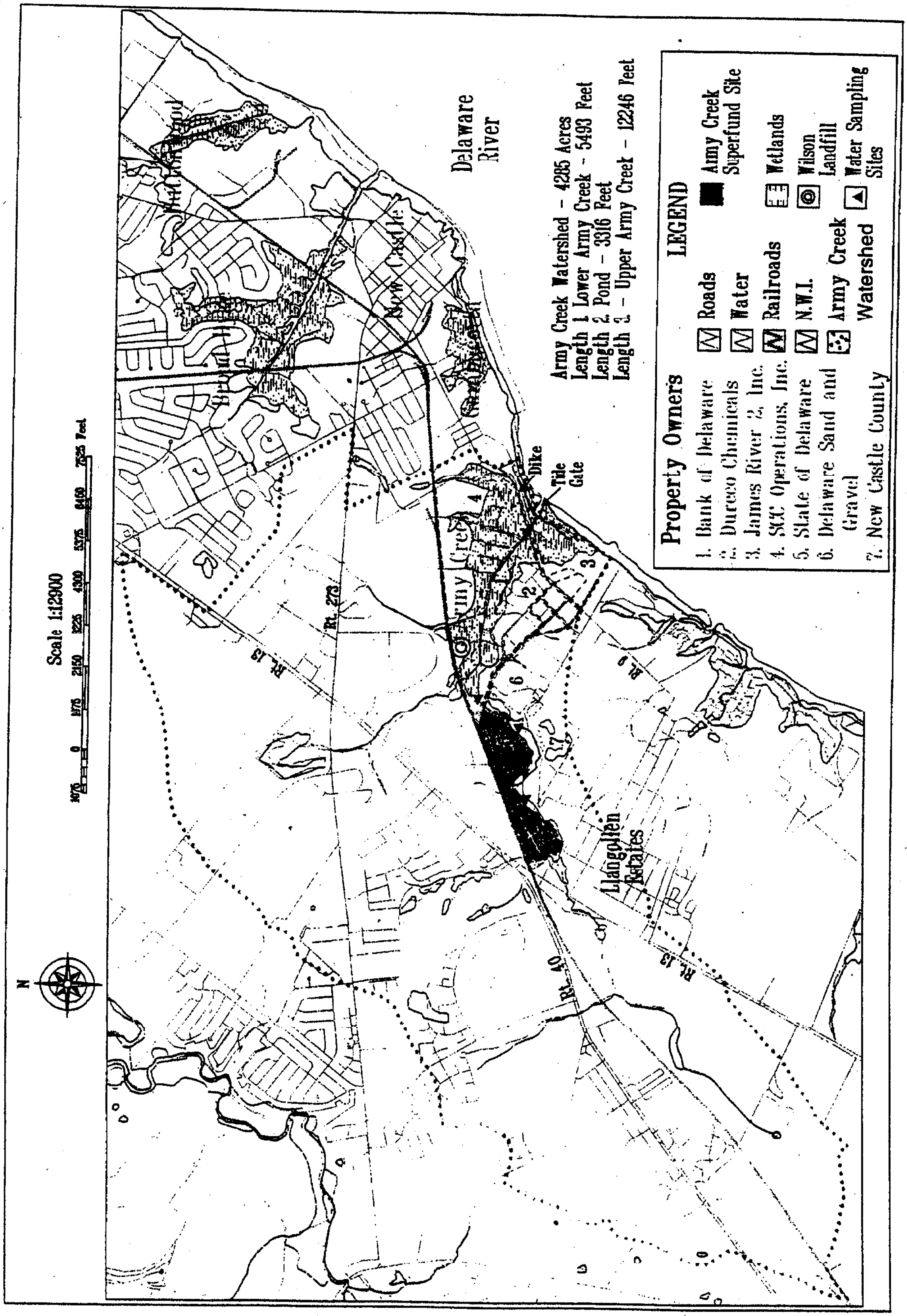

Figure 2. Army Creek Watershed

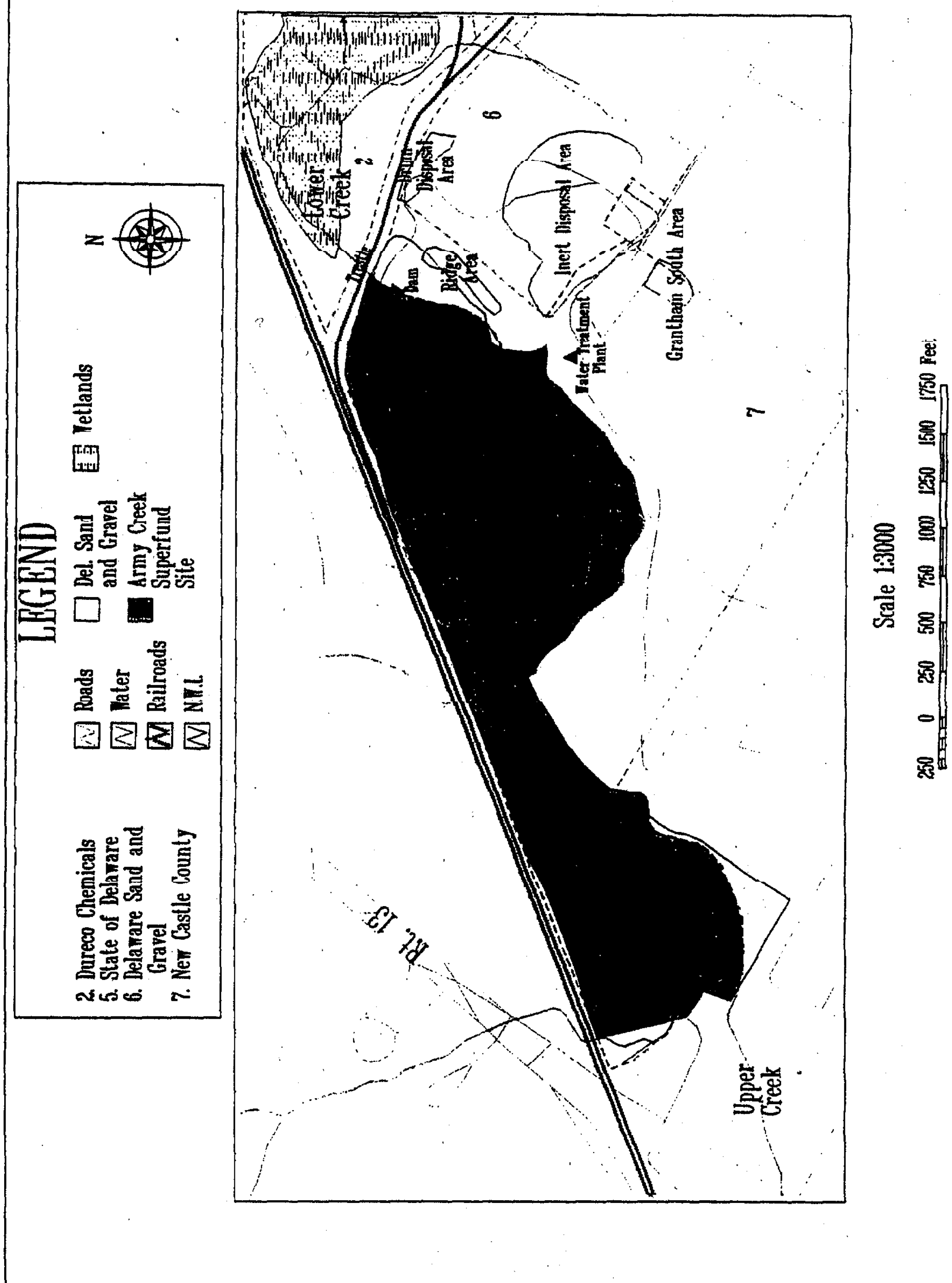

Figure 3. Army Creek and Delaware Sand and Gravel Superfund Sites

A subsequent hydrogeological analysis determined that leachates were formed by infiltration of rain water and lateral movement of groundwater through the refuse in the landfill. Leachate contaminants migrated as a plume southeasterly into the Upper Potomac aquifer under the influences of a natural gradient and pumping at Artesian Water Company's Llangollen wellfield, which supplies potable water. As a result of the field surveys, a recovery well system was installed and has operated continuously since 1973. The recovery well system created a hydrologic divide in the groundwater between the landfills and the Artesian Water Company's wellfield. This well system prevents migration of water-borne contaminants toward the public supply wells. Until January 1994, water from the recovery wells discharged directly to Upper Army Creek adjacent to the landfill, Army Creek Pond, and Lower Army Creek upstream of the trestle.

Army Creek became a NPL site in 1983. In 1984, EPA entered into a Consent Agreement and Order with New Castle County to perform a Feasibility Study (FS), which was completed in July 1986. The FS provided the basis for the first Record of Decision (ROD), issued September 30, 1986, in which a source control remedy involving capping wastes and preventing groundwater migration was selected. The ROD required both continued operation of the recovery well system and construction of a landfill cap similar in specifications to those required by the Resource Conservation and Recovery Act (RCRA).

In January 1990, a Focused Remedial Investigation (FRI) identified the potential risks from exposure to existing pond and creek sediments, creek surface water, and contaminated groundwater discharged to the creek; evaluated remedial action alternatives for treating contaminated groundwater and sediments; and assessed risks to human health and the environment for each alternative. This FRI found that surface water in Army Creek and Army Creek Pond had concentrations of cadmium (Cd), chromium (Cr), iron (Fe), mercury (Hg), and zinc (Zn) that exceeded the surface water quality criteria for freshwater aquatic organisms set by the EPA and/or DNREC. However, only Fe can be attributed to the recovery well discharges. Further, the investigation stated, "Detrimental effects on the biota could possibly result from contact with the contaminated groundwater recovery well discharges, or surface water." However, the

FRI also stated, "Metals in the Army Creek Pond sediments have been determined to not represent a threat to the aquatic environment."

A second ROD was issued June 29, 1990, which addressed the need to treat recovery-well groundwater prior to its discharge into Army Creek/Pond. The ROD directed that a water treatment facility be constructed and operated to reduce the concentration of iron in the extracted groundwater to a level that is protective of the designated uses of Army Creek (i.e., secondary contact recreation, fish and wildlife propagation, and water for agricultural use). Further, the ROD stated, "Because this remedy will result in hazardous substances remaining on site above health-based levels, a review will be conducted within five years after commencement of the remedial action to ensure that the remedy continues to provide adequate protection of human health and the environment."

On September 18, 1990, 18 potentially responsible parties signed a Consent Decree to implement the cleanup actions and reimburse the EPA for past response costs. The settlement also required the potentially responsible parties to deposit $800,000 into a Trust Fund, of which $200,000 went directly to the State of Delaware for groundwater protection and restoration. The Department of Interior, the National Oceanic and Atmospheric Administration (NOAA), and the State of Delaware formed an Army Creek Site Natural Resources Trustee Committee on October 22, 1991, to ensure that the remaining money ($600,000) is used for the restoration, replacement and/or acquisition of equivalent resources for those trust resources which have been injured, destroyed or lost by the release of hazardous substances at the Superfund Site or as a result of remedial actions at the Superfund Site..

The cap, completed December 1993, includes an impermeable layer covered by clean soil which is planted with low vegetation (i.e., no deep roots that could penetrate the impermeable layer). More specifically, the cap consists of: (from top) 6 inches of topsoil; 18 inches of select fill, non-woven geotextile, and geonet; 40 mil of geomembrane; and 12 inches of geomembrane base layer. Wildlife enhancement of the cap includes: seeding for wild flowers, construction of nesting perches around the perimeter, and planting of shrubs for animal cover. Also, the cap covers only 44 of the 52 acres of landfill. The edge of the landfill along Army

Creek was not covered with the impermeable cap to avoid filling wetland habitat along Army Creek.

The Water Treatment Facility was completed and began operation in January 1994. With completion of the Water Treatment Facility, all extracted groundwater is treated to remove iron and discharged through a single outfall to Army Creek Pond. The filter cake, containing iron and perhaps other contaminants, is analyzed and appropriately disposed.

Finally, the roadbed of Route 9 south of the bridge, which crosses Lower Army Creek, recently has been raised approximately one foot by the Delaware Department of Transportation (DELDOT) in conjunction with replacement and raising of the Route 9 bridge. These improvements should reduce the potential for road surface flooding in the future, should Lower Army Creek be opened for tidal flow. However, the roadbed on the north side of the Route 9 bridge has not yet been raised. DELDOT plans to do so in the next 2-3 years (this delay is caused by a funding cycle constraint), which could then permit restoration of tidal exchanges with greater amplitude in Lower Army Creek.

2.4 Extended Site Characterization

For purposes of natural resource injury assessment and restoration, the Natural Resources Trustees view the site as the entire Army Creek watershed. Because of the interconnectedness of the surface and groundwaters within a watershed, the localized mobility of many resident species, and the transient exposure of migratory species, significant potential exists for natural resource injuries to occur throughout a watershed, often extending beyond the boundaries of a Superfund site.

2.4.1 Physical and chemical setting

The site varies in elevation from mean sea level to +51 feet National Geodetic Vertical Datum (NGVD).

It is underlain by two water-bearing formations, the Columbia and the Potomac. The Columbia, the uppermost aquifer beneath the landfill, is of Pleistocene Age and is from 10 to 60 feet thick at the site. This formation, which dips to the southeast, consists of medium to coarse grained sands, gravels, silts and clays which were deposited in shallow lens-shaped channels. The silt and clay units of the Columbia are discontinuous and do not form confining units.

The Potomac Formation of Cretaceous Age underlies the Columbia Formation and is generally separated from it by a confining clay layer at the site. The Potomac Formation dips to the southeast, is up to 600 feet thick, and consists of silts and clays interbedded with sands and some gravel. The formation is divided into upper and lower units, which are separated by a thick confining clay unit. The upper Potomac Formation silts and clays are discontinuous and non-uniform; in some places, the sands of the Columbia and Potomac are in contact. The Potomac Formation is used as an aquifer for drinking water.

Army Creek, including the Upper Creek (approximately 2.3 miles in length), Army Creek Pond (approximately 0.6 mile in length), and the Lower Creek (approximately 1 mile in length), is about 3.9 miles long, 9 to 40 feet in width, and from less than 1 foot to 4 feet deep. Its drainage area is approximately 6.7 square miles. The Upper Creek and Pond are fresh. The salinity of the Lower Creek ranges from fresh to slightly oligohaline. A tidegate at the mouth of Army Creek limits exchanges of water and biota between the Delaware River and Army Creek. The mean tide range in the Delaware River adjacent to Army Creek is 5.6 feet. The tidegate consists of five one-way flapgates, each 48" in diameter, that prohibit tidal inflow and allow outflow of accumulated upland runoff when hydraulic head is sufficient to open the flapgates.

Cole and Fabean (1992) measured salinity, dissolved oxygen, and pH in the main channel of Lower Army Creek on five occasions -- December 1991, April, June, July, and August 1992. Salinity was 0 ppt on four occasions, and 0.5 ppt in August. Midmorning dissolved oxygen levels ranged from 3.7 to 13.0 ppm, with the lowest reading in June. pH ranged from 6.4 to 7.5. Wetland soil pH was measured at 6.5; soil phosphorus (100-150 lbs/acre) and potassium (105-300 lbs/acre) are adequate for plant growth, while soil nitrogen (5 lbs/acre) appears to be low relative to phosphorus, and therefore, may be limiting to plant growth.

Lower Army Creek was surveyed by the Delaware Division of Fish and Wildlife in May 1992, to determine its present habitat suitability for anadromous fish spawning. The open main channel of Lower Army Creek, from Route 9 upstream about two-thirds of a mile (1100 meters), had water depths ranging from 9 inches to 4 feet (22-120 cm), widths from 27 to 40 feet (9-13 meters), and a 1-foot (>25 cm) thick bottom layer of detritus, mud, and clay. The remainder of the main channel, upstream to the Pond, is narrow, shallow and completely choked with vegetation, having a bottom of soft sediments interspersed with some sand and hard clay. Water velocity is extremely slow throughout the entire length of Lower Army Creek. The absence of hard substrate and low freshwater inputs suggests that Lower Army Creek would not be conducive for successful anadromous fish spawning (C. Shirey, pers. comm. memo). However, with adequate volume and riverine tidal exchanges, Lower Army Creek may provide valuable nursery and feeding habitats for both resident and migratory fishes, such as striped bass, white perch, largemouth bass, yellow perch, black crappie, catfish, weakfish and spot.

Army Creek Pond, oriented parallel to the southern boundary of the landfill, is ellipsoid in shape and approximately 2000 feet long, 175 feet wide, and 1 foot deep. It was created during the 1950's as a water supply source for a quarrying operation. Stormwater runoff from the site, as well as flows from the recovery wells, are collected in this Pond, Upper and Lower Army Creek. Downstream of the Pond, the creek is enlarged by the flow from the recovery wells, which averages 1.4 million gallons per day. Compared to upstream flows, downstream flows are much more constant as a result of the recovery well input.

Prior to high-volume pumping of groundwater, initiated in 1973, Army Creek was receiving water from both the Columbia and upper Potomac aquifers (Dunn Geoscience Corp., 1987, as referenced in Focused RI [Jan. 1990]). Pumping has lowered groundwater levels in the vicinity of the Superfund site and, as a consequence, Army Creek now discharges 88-93% of the systems total inflow water through its channel bed (FRI, 1990). This conclusion, which is thought to be too high by DNREC, is based on the net difference of surface water inflow (0.0345 cfs), imported groundwater discharge (1.784 cfs), surface runoff (0.15 to 0.23 cfs), surface water outflow from the Pond (0.109 cfs), and evaporation (0.033

cfs).

Upstream of the Pond, Army Creek is a low volume seasonal stream, largely dependent on storm runoff. In 1988, the Delaware Division of Fish and Wildlife surveyed the Upper Creek from the Pond to Route 13 for fishes and macroinvertebrates. This portion of the stream is extremely degraded by residential development and highway runoff, and serves primarily as a drainage ditch for surrounding areas. Stream width ranges from 9 to 15 feet (3-5 meters), and maximum depth is 2 feet (45 cm). The bottom sediments are soft and unconsolidated, supporting low numbers and diversity of macroinvertebrates. Minimal ambient water flow and decomposing leaf litter act to suppress dissolved oxygen levels, explaining the very low numbers and diversity of fishes. Lack of freshwater flow and unsuitable substrates would prevent successful spawning of anadromous fishes.

2.4.2 Biological setting

2.4.2.1 Upland areas

Since discontinuation of landfill operations, the upland area on top of the Army Creek Landfill was first dominated by early successional species. These were cleared for construction of the landfill cap. The cap, completed in December 1993, is planted with grasses and low growing shrubs whose roots will not penetrate the impermeable layer of the constructed cap. This report and analysis does not address issues related to upland natural resources, which are primarily associated with capping of the landfill.

2.4.2.2 Wetland areas

In the upper portion of the Army Creek system three on-site wetland types were identified by Rudis and Andreasen (U.S. DOI, Fish and Wildlife Service, 1988). A palustrine emergent wetland, dominated by pickerelweed (Pontedaria cordata), sensitive fern (Onoclea sensibilis), jewelweed (Impatiens capensis), water smartweed (Polygonum punctatum) and various grasses fringing a disturbed area, is present on the eastern end of the site. This wetland, approximately 242 acres (98 hectares) in size, has scattered shrub species along the margin.

The second wetland type is open water consisting of a shallow, muck bottom pond of approximately 62 acres (25 hectares), with scattered emergent vegetation comprised of pickerelweed (Pontedaria cordata), spatterdock (Nuphar luteum), cattail (Typha latifolia), and other species along the margin.

The third type, a forested or shrub-dominated wetland, encircles the Pond, extending from its western end to the western margin of the site. Dominant species include pin oak (Quercus palustris), red maple (Acer rubrum), and black willow (Salix nigra).

Adjacent to and east of Army Creek Landfill another large wetland complex exists. Lower Army Creek water flows through this wetland to the Delaware River. This wetland, a freshwater to low salinity emergent wetland of approximately 225 acres (91 hectares), is dominated by common reed (Phragmites australis) and jewelweed.

A recently completed study (Cole and Fabean, 1992) of Lower Army Creek Marsh, performed by the Delaware Division of Fish and Wildlife and supported by the Delaware Coastal Management Program, updated the information base on a wetland degraded in terms of fish and wildlife habitat. Of the 225 acre-wetland defined by DNREC below the Pond, 210 acres (93.3%) are covered by dense stands of Phragmites, 2 acres (0.9%) are mixed freshwater emergents (e.g., rice cut-grass, rose mallow, spatterdock, jewelweed, switchgrass, arrow arum, smartweed), and 13 acres (5.8%) are open water areas (e.g., main channel, side channels, shallow pannes). The Delaware Natural Heritage Inventory (DNHI), in cooperation with the Delaware Division of Fish and Wildlife, identified 52 plant species in a concomitant floral survey of the Lower Creek, with greater diversity occurring toward the upper end of the lower marsh. One plant species of special concern was found, Torrey's rush (Juncus torreyi). The DNHI designates Torrey's rush as an "S1" species (i.e., State Species of Special Concern [1= most concern]), found to date by DNHI in five or fewer places in Delaware; however, it is not a federally threatened or endangered species. No federally listed threatened or endangered plants have been recorded in the Army Creek area (Trew, pers. comm., 1989).

2.4.2.3 Mammals

Six of the eight mammals observed on the site are game species. They are:

Eastern cottontail rabbit, Sylvilagus floridanus;
White-tailed deer, Odocoileus virginianus;
Muskrat, Ondatra zibethica;
Raccoon, Procyon lotor;
Northern gray squirrel, Scirus carolinensis; and
Woodchuck, Marmota monax.

The entire site has been described by Weston (Biological Assessment of Army Creek Llangollen Landfill, Dec. 30, 1982) as, "...strewn with shot-gun shells, suggesting some hunting activity." Small mammal trapping in early May 1992, in the Lower Creek marsh collected meadow voles, white-footed mice, and house mice, with almost all captures occurring in dense Phragmites habitat (Cole and Fabean, 1992). Additionally, muskrat (Cole and Fabean, 1992), beaver (R. Wooten, pers. comm.) and beaver-cut trees (J. Thomas, pers. obs.) have been observed. Many of these species are considered residents of the area.

No threatened or endangered mammals have been recorded in the Army Creek area.

2.4.2.4 Birds

Sixty-five species of birds were observed in or near the Army Creek Site between 1973 and 1988 (Weston, 1986; U.S. Department of Interior, 1988; EPA, 1988; and investigators for the 1990 FRI [See Table 3-4 in 1990 FRI]). The list includes: four upland gamebirds (two doves, ring-necked pheasant, bobwhite quail); 11 species of marsh and shorebirds (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.). Although not federally listed, osprey are considered a species of special concern by the State of Delaware (Trew, pers. comm., 1989 In 1990 FRI). Osprey, found near rivers, lakes and along the coast, feed on fish. Within the list of 65 species of birds are nine species of game birds (including the 4 species of upland gamebirds) that have been observed on the site (black duck, mallard, wood duck, Canada goose; bobwhite quail, ring-necked pheasant, mourning dove, rock dove, and common crow). Nearby landowners report successful duck hunting in the area, and shotgun shells were found on and adjacent to the site.

Additionally, Cole and Fabean (1992) conducted three field trips (October 1991, and March and April 1992) to observe birds in Lower Creek marsh, but recorded only 6 species (with total numbers) in the lower marsh: wood duck (6), green-winged teal (24); blue-winged teal (3), great blue heron (4), double-crested cormorant (1), and northern harrier (1).

2.4.2.5 Amphibians and reptiles

Amphibians and reptiles known to occur at the Army Creek Landfill are (FRI, 1990):

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

The bullfrog and snapping turtle are considered game species, and turtle traps were found on the site. None of these amphibians or reptiles are State or federally listed as endangered or threatened.

2.4.2.6 Fish

A total of 22 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 (FRI, 1990; Cole and Fabean, 1992). They include:

Bluegill sunfish, Lepomis macrochirus;
Pumpkinseed sunfish, Lepomis gibbosus;
American eel, Anguilla rostrata;

Carp, Cyprinus carpio;
Black crappie, Pomoxis nigromaculatus;
White sucker, Catostomus commersoni;
Smallmouth bass, Micropterus dolomieu;
Largemouth bass, Micropterus salmoides;
Mummichog, Fundulus heteroclitus;
Gizzard shad, Dorosoma cepedianum;
Striped bass, Morone (Roccus) saxatilis;
White perch, Morone americana;
Bluespotted sunfish, Enneacanthus gloriosus;
White crappie, Pomoxis annularis;
Brown bullhead, Ictalurus nebulosis;
Yellow bullhead, Ictalurus natalis;
Redfin pickerel, Esox americanus;
Golden shiner, Notemigonus crysoleucas;
Common shiner, Notropis cornutus;
Mosquitofish, Gambusia affinis;
Atlantic menhaden, Brevoortia tyrannus; and
White mullet, Mugil curema.

Four of the species of fish found in Army Creek are listed as "rare" in the State of Delaware (Appendix G of FRI, 1990). They are:

Smallmouth bass,
Striped bass,
White crappies, and
Yellow bullhead.

In addition, a federally listed endangered species, the shortnose sturgeon (Acipenser brevirostrum), is found in the Delaware Estuary and River. A synopsis of existing biological information on the shortnose sturgeon illustrates that the species has been observed historically from Lambertville, New Jersey to the mouth of Delaware Bay (Dadswell et al., 1984). Movements of the shortnose sturgeon in the Delaware River between Philadelphia and Lambertville were recently studied (O'Herron, II et al., 1993), but little new information is available for the mid and lower estuary. Stranding information reported to the National Marine Fisheries Service from the Salem and Hope Creek Nuclear Generating Stations at Artificial Island describes eleven individuals that were impinged on the trash bars or caught in local gillnets between 1978 and 1994. It is believed that shortnose sturgeon spawn at Scudders Falls near Trenton; but it appears that the lower estuary is used only by portions of the adult population for feeding and/or over-wintering. Based on available data, it is not likely that shortnose sturgeon will enter Army Creek, except as an occasional transient.

Seven species of fish (including yellow perch and largemouth bass) found in Army Creek are considered to be game fish, though certainly other species such as carp and bullhead are known to be caught in Army Creek and consumed by humans on occasion. Most are tolerant of turbid conditions, with the exception of smallmouth bass, and feed on fish, insects, or crustaceans (Collins, 1959). Carp and brown bullheads are bottom feeders and tend to be omnivorous (Collins, 1959). The tidalgate at the mouth of Army Creek prevents or limits entrance of anadromous species from the Delaware River.

Fish sampling of Lower Army Creek by Cole and Fabean (1992) shows limited diversity. Seine and gill net sampling for fishes, conducted in December 1991, April 1992, and June 1992, collected only 16 individuals amongst 9 species: pumpkinseed, bluegill, mosquitofish, mummichog, black crappie, carp, brown bullhead, Atlantic menhaden, and white mullet.

Adjacent to Army Creek, based on a series of beach seine surveys along the Delaware River at Augustine Beach, Delaware and Penn's Grove, New Jersey (south and north of Army Creek, respectively) in 1958, deSylva et al. (1960) identified 30 species. Later Schuler (1973) collected 37 species during 1973, at Augustine Beach, Delaware and Sunken Ship Cove, New Jersey in the Delaware River near Artificial Island using 10, 25 and 225 foot seines and a 16 foot trawl. The combined species list is presented below. [[1] indicates those species caught by deSylva et al. (1960). [2] indicates those species caught by Schuler (1973). * indicates those species not found at present in Army Creek.]

Bullhead, Ictalurus nebulosus[1,2];
*Catfish, Ictalurus catus[1,2];
Carp, Cyprinus carpio[1,2];
*Goldfish, Carassius auratus[1,2];
Golden shiner, Notemigonus crysoleucas[1];

*Silvery minnow, Hybognathus nuchalis[1,2];
*Spottail shiner, Notropis hudsonius[1];
*Comely minnow, Notropis amoenus[1];
*Yellow perch, Perca flavescens[1,2];
Bluegill, Lepomis macrochirus[1,2];
Pumpkinseed, Lepomis gibbosus[1];
Crappie, Pomoxis annularis[1,2];
Black crappie, Pomoxis nigromaculatus[2];
*Bluefish, Pomatomus saltatrix[2];
*Spot, Leiostomus xanthurus[2];
*Striped mullet, Mugil cephalus[2];
*Naked goby, Gobiosoma bosci[2];
*Summer flounder, Paralichthys dentatus[2];
*Hogchoker, Trinectes maculatus[2];
Eel, Anguilla rostrata[1,2];
*Alewife, Alosa pseudoharengus[1,2];
*Blueback herring, Alosa aestivalis[1,2];
*Shad, Alosa sapidissima[1];
Menhaden, Brevoortia tyrannus[1,2];
Gizzard shad, Dorosoma cepedianum[2];
*Bay anchovy, Anchoa mitchilli[1,2];
*Striped anchovy, Anchoa hepsetus[2];
Mummichog, Fundulus heteroclitus[1,2];
*Banded killifish, Fundulus diaphanus[1];
*Striped killifish, Fundulus majalis[2];
*Sheepshead minnow, Cyprinodon variagatus[2];
*Fourspine stickleback, Apeltes cuadracus[1];
*Striped cusk-eel, Rissola marginata[2];
*Needlefish, Strongylura marina[1,2];
*Northern pipefish, Syngnathus fuscus[2];
*Silversides, Menidia spp.[1];
*Rough silverside, Membras martinica[2];
*Tidewater silverside, Menidia beryllina[2];
*Atlantic silverside, Menidia menidia[2];
*Crevalle jack, Caranx hippos[1,2];
Striped bass, Morone (Roccus) saxatilis[1,2];
White perch, Morone americana[1,2];
*Weakfish, Cynoscion regalis[1,2];

*Silver perch, Bairdiella chrysura[1,2];
*Croaker, Micropogon undulatus[1,2]; and
*Black drum, Pogonias cromis[1].

2.4.2.7 Phytoplankton and macroinvertebrates

Weston (1986) conducted aquatic surveys from 1972 to 1983. In addition, the State of Delaware (1985) conducted a macroinvertebrate survey in Army Creek in 1985 and the EPA (1986a) conducted a macroinvertebrate survey in 1986. Three phyla of phytoplankton were detected: Cyanophyta (bluegreen algae), Chrysophyta (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 (segmented worms and leeches), Mollusca (snails and clams), Nematoda (round worms), and Crustacea (water fleas and 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 in the 1990 FRI). Blue crabs are caught both commercially and recreationally in the Delaware River adjacent to and in the mouth of Army Creek (i.e., seaward of the tidegate).

Aquatic invertebrate sampling of Lower Army Creek showed limited diversity (Cole and Fabean, 1992). Sweep net samples for aquatic invertebrates in April and July 1992, collected amphipods and grass shrimp (Palaemonetes pugio), plus four insect taxa: odonates, corixids, gyrinids, and chironomids.

The sluggish, isolated waters found in the wetlands of the Lower Creek create prolific mosquito-breeding habitat in an urban area, producing pestiferous Aedes or Culex species which require nuisance and disease control. The marsh is routinely inspected by the Delaware Division of Fish and Wildlife's Mosquito Control Section from May through September for mosquito-breeding. When mosquito larvae production is found severe enough to warrant treatment, the Section aerially applies an environmentally, short-lived organophosphate larvicide, temephos (Abate), in liquid or granular form. This product is considered environmentally compatible by the EPA when applied at label-dictated field rates. In almost 30 years of field use, the Delaware Mosquito Control Section has observed no adverse effects on cohabitant macroinvertebrates, fishes, birds, or other invertebrates in mosquito-breeding marshes.

The recent mosquito-breeding history of Lower Army Creek Marsh is as follows: in 1989, mosquito production occurred on 7 occasions, twice severe enough to warrant aerial application of temephos; in 1990, 6 broods resulted in two aerial applications; in 1991, 7 breeding events needed four applications; and in 1992, 4 broods required only one such treatment. Mosquito production in Army Creek Marsh is not especially unique for the region, since several thousand acres of riverine marshes (impounded or unimpounded, tidal or non-tidal) along the Christina and Delaware Rivers require occasional larvicide treatments.

Descriptive knowledge of the benthic communities in the lower Delaware River adjacent to Army Creek is sparse. As a result the EPA through the Delaware Estuary Program has been supporting since 1992, a benthic survey within the lower river region. The work is being conducted by Environmental Consulting Services, Inc. (ECSI) of Middletown, Delaware. The ESCI study partitioned the lower Delaware River into three depth strata (i.e., channel, shallow, and intertidal) plus several salinity zones. During summer in intertidal areas of the Delaware River in the vicinity of Army Creek (Zone 5), chironomids and amphipods comprise about 95% of the benthic invertebrate biomass, averaging 30.7 g/m^2 for chironomids and 64.6 g/m^2 for amphipods. The amphipods most commonly found were Gammarus spp. and Corophium spp., while the dominant chironomids were Polypedilum spp., Crypotochironomous spp., and Procladius spp. During the spring in the same intertidal river area, oligochaetes composed about 76% of the benthic invertebrate biomass, averaging 76.0 g/m^2, and were dominated by immature tubificids, various species of Naidae, Limnodrilus hoffoneisteri, and locally abundant Enchytraeidae. Isopods were not found in the intertidal stratum of Zone 5, but were encountered in the shallow stratum, where in the summer they averaged 62.6 g/m^2, dominated by Cyathura polita. Similarly, mollusks were not found in the intertidal stratum of Zone 5, but were found in shallow waters, averaging 50.0 g/m^2 in spring and 21.1 g/m^2 in summer, with Corbicula fluminca by far the dominant mollusk species. Polychaetes were found during spring in the intertidal stratum of Zone 5, averaging 8.6 g/m^2, but none were found in the summer; however, in shallow waters of Zone 5, polychaetes averaged

43.9 g/m^2 in spring and 5.7 g/m^2 in summer. Insects other than chironomids, nematodes, and crustaceans were also found in intertidal and shallow strata of Zone 5 during spring and summer, but biomasses were usually less than 1.0 g/m^2. The final ESCI study report was completed late 1993.

2.5 Issues of Concern

A number of issues have been identified which need to be considered in any decision regarding the suitability of Army Creek for potential restoration. The focal point of these issues is the recent past and projected quality of surface water and sediments, and the potential effects of the water and sediment quality on biota in the Upper Creek, Pond, and Lower Creek. These issues and other information (See section 3.0 DATA ANALYSIS AND FINDINGS) will be considered in making one of the following decisions: 1) undertake on-site restoration of all or part of Army Creek, or 2) pursue off-site rehabilitation and/or replacement/acquisition alternatives (i.e., not in Army Creek watershed).

2.5.1 Delaware Sand & Gravel Superfund site

Because of its proximity to the Pond and Lower Army Creek (Figures 1, 2, 3) and timing for remediation, the Delaware Sand & Gravel (DS&G) Superfund site could affect potential restoration of Army Creek. However, the site is not located in the floodplain of Army Creek, and no wetlands of significance exist on the site. The four areas of interest at DS&G are: Grantham South, Inert Area, Ridge Area, and the Drum Disposal Area (Figure 3). At the Grantham South Area (2 acres), copper (Cu), lead (Pb), nickel (Ni), and zinc (Zn) were contaminants of concern. At present Grantham South is capped and fenced for security, and contaminant migration is no longer an issue.

The Inert Area (11 acres) refuse consists of wire, hose, twine, cork dust, tires, cardboard and styrofoam, as well as cars, trucks, trailers, buses, storage tanks, industrial wastes, etc. "...wastes in this area are probably not completely inert" (EPA, 1993). Thus the refuse is to be removed and the area covered by a multi-layer composite barrier cap (EPA, 1993).

In the Ridge Area significant contamination is limited to discrete, relatively small areas. Metals detected above background in the Ridge Area were arsenic (As), antimony (Sb), barium (Ba), Cu, and Pb. PCB contamination in the Ridge Area ranged from 97 to 49,000 ppb. Some evidence exists that migration of surficial soil contamination may not be a large concern. The Ridge Area is not fenced and the large tanks which can be seen protruding from or on top of the ground have been steam cleaned, making them no longer a contaminant problem. Contaminated soils, drums, debris, and garbage containers will be removed and the area will be covered with clean topsoil and vegetated (EPA, 1993).

At the Drum Disposal Area, surficial soils are not a concern because of the removal action in 1984, which removed surface drums and then covered and revegetated the area. The area, however, is fenced and posted with signs reading, "Danger, Do Not Enter, Hazardous Area". The Drum Disposal Area contributes contamination to Army Creek via pumped groundwater (Dunn Geoscience Corp., 1987) contaminated by the contents of drums which have leaked or spilled into the Columbia and Upper Potomac water-bearing geological formations (See Site Characterization, Section 2.3.1). The Columbia is more contaminated than the Upper Potomac with respect to metals, and the Upper Potomac is more contaminated with respect to organics. Overall organic contamination decreases with distance from the Drum Disposal Area and metals decrease with distance from the DS&G area in general (Dunn Geoscience Corp., 1987). Among the contaminants from the Upper Potomac identified in the DS&G Remedial Investigation (Dunn Geoscience Corp., 1987) are: toluene (8.7 ppm), benzene, xylene, bis(2-chloroethyl)ether, ethyl benzene, MEK, acetone, bis(2-ethyl hexyl)phthalate, methylene chloride (18 ppm), MIBK, vinyl chloride (1-13 ppb), chloroform (13 ppb), and phenol (12-1700 ppb). Metals identified include: sodium, calcium, potassium, barium (14-1640 ppm), iron (<51 ppm), magnesium, manganese (<12.8 ppm), zinc (5-74 ppm), and copper (<25 ppb), but all concentrations were low (Dunn Geoscience Corp., 1987).

Metal concentrations in groundwater were low (Tables 5.22 and 5.23 In DS&G ROD, April 22, 1988). Distinct trends in the surface water quality, from upstream to downstream of the landfills, were not apparent. Based on the 1988 DS&G ROD (EPA, 1988b), Pond sediments were chronically toxic. Both benthic surveys and aquatic chronic toxicity tests showed that water quality was more degraded in Upper Creek than Lower Creek.

Remedial actions at the DS&G site, according to DS&G ROD signed April 22, 1988, and amended September 30, 1993 (EPA, 1993), include removal and off-site treatment/disposal of buried drums and soil vapor extraction/bioremediation of contaminated soils from the Drum Disposal (0.8 acres) and Ridge (0.5 acres) areas. Groundwater pumping is to continue and will be treated as part of ROD-2 for Army Creek Landfill.

The amended ROD (EPA, 1993) for the Drum Disposal and Ridge areas includes the construction of a slurry wall (Fall 1994) encasing a 3-acre area around the Drum Disposal Area. The area within the slurry wall is to be de-watered, and the Drum Disposal Area (0.8 acre) is to be excavated (i.e., soil and drums removed) to a depth of 15 feet (the depth of burial). The drums are to be sampled and appropriately disposed. Perforated piping is to be installed in the hole. The hole then will be refilled with the remaining contaminated soil from both the Drum Disposal Area and the Ridge Area (< 0.5 acre excavated to a depth of 5 feet). This soil then will be treated via soil vapor extraction and bio-remediation as has been tested successfully by the EPA. Finally, the area will be covered with a multi-layer composite barrier cap (EPA, 1993).

The present impact of DS&G on Army Creek is not separable from that of the Army Creek Landfill based on available information. Ambient conditions in Army Creek, including the combined effects of both DS&G and Army Creek Landfills after 30 years of impact, are discussed in Section 3.0 of this report.

2.5.2 Wilson Contracting Company Landfill

The Wilson Contracting Company Landfill (Figure 2) is located about 2 miles southwest of New Castle, Delaware in the Airport Industrial Park at Hares Corner (NUS Corp., 1988). The site coordinates are 39° 39' 20" N. latitude and 75° 36' 00" W. longitude. This location is adjacent to the marsh on the north side of the upper end of Lower Army Creek and just south of the railroad tracks. Army Creek marsh is approximately 10 feet from the site and borders the site on the south, east, and west. The Wilson Contracting Company dumped construction waste (i.e., concrete, tires, wood, paint cans, cardboard, shingles, broken glass, scrap metal, scrap plastic, and wire) in 1-1/2 acres of a 3 acre landfill from about 1960 to 1976. No permit was ever issued to operate the landfill. According to Mr. Blevins, a representative of Wilson Contracting Company, no hazardous waste was dumped in the landfill. However, he did note that illegal dumping of trash by the public did occur. In 1982, Howard Wilson donated the property to the Delaware Parks and Recreation Department. The property became part of the Brandywine Creek State Park Trust Fund, with the Bank of Delaware acting as trustee.

The site was discovered by Augustus M. Mergenthaler in response to a large fire which occurred March 24, 1986, in the Army Creek marsh area (Britt and Hack, no date). Mr. Mergenthaler observed approximately 18 exposed and deteriorating drums. A low priority site inspection was accomplished by DNREC on June 27, 1986. No samples were taken from Army Creek because it was approximately 1/4 mile from the site and was, therefore, considered to be "too far away to be a major target area" (NUS Corp., 1988). Low levels (up to 3.2 mg/kg) of polynuclear aromatic hydrocarbons (PAH) were found. "Total PAH levels in soils from relatively rural areas of the eastern United States range between 4,000 and 13,000 ug/kg [4-13 mg/kg]" (Blumer et al., 1977).

"The on-sight surface soil sample in the burned soil area revealed notable concentrations of several inorganics including antimony (81 mg/kg), cadmium (5.4 mg/kg), cobalt (165 mg/kg), lead (633 mg/kg), silver (15 mg/kg), and zinc (44,000 mg/kg)" (NUS Corp., 1988). "However, soil contamination does not appear to be pervasive and was confined to a single sample location" (NUS Corp., 1988). Based on Shacklette and Boerngen (1984) and the EPA (1982) upper soil range levels for these metals are: antimony, 8.8 mg/kg; cadmium, 0.7 mg/kg; cobalt, 70 mg/kg; lead, 300 mg/kg; silver, 5 mg/kg; and zinc, 2900 mg/kg.

"No other samples [in the area] revealed elevated concentrations of inorganics except for the marsh sediment, which had an antimony concentration of 15 mg/kg" (NUS Corp., 1988). For antimony in sediments the Effects Range-Low (ER-L) is 2 mg/kg, the Effects Range-Medium (ER-M) is 25 mg/kg, and the Overall Apparent Effects Threshold (OAET) is 25 mg/kg (Long and Morgan, 1991). A detailed explanation of ER-L, ER-M, and

OAET is presented in Section 3.1 of this report. Long and Morgan (1991) present the OAET as the concentration at and above which biological effects were usually or always observed in association with increasing concentrations of a chemical. The conclusion is that antimony at this concentration is not a major problem.

"No threats to human health or the environment are expected based on reported contaminant levels and conditions of exposure expected for this site" (NUS Corp., 1988). No radiation above background was found. Based on data presented in Section 3.1 of this report no exceptional concentrations of these contaminants were found in Lower Army Creek. The site is not in the flood plain of Army Creek and will not be, even if Army Creek is opened to tidal flow. We assume, therefore, that the effects of this site are highly localized and will be minimal on Lower Army Creek.

2.5.3 Road runoff issues

The source of trace metals in Army Creek sediments may be from Army Creek Landfill lateral leachate and/or general landscape and highway runoffs from Routes 13 and 9. Continuing additions of trace metals could affect potential restoration of Army Creek. However, capping should reduce any potential impacts from lateral leachate (Section 2.5.4).

Pursuant to amendments to Section 402 of the Federal Clean Water Act, non-point source pollutants originating from urban areas are now considered point-source discharges, and thus are regulated under the National Pollutant Discharge Elimination System (NPDES) program. To comply with these regulations, DNREC is requiring New Castle County and the Delaware Department of Transportation (DELDOT) to be co-applicants for a NPDES permit concerned, in part, with road runoff contaminant discharges. Regulations and policies being developed by DNREC will address: 1) determination of the scope and extent of road runoff contaminant problems (e.g., identifying outfalls); 2) set threshold criteria for initiating response actions; and 3) prescribe measures to prevent future road runoff contaminant discharges (e.g., BMP's).

In planning the development and implementation of the new Section 402 program, DNREC's Division of Water Resources (DWR) is willing to work with the Army Creek Trustees to focus, to the extent practicable, on road runoff issues germane to Army Creek. DWR has stated a preference for focusing part of the Section 402 initiative in areas where other environmental rehabilitation efforts are underway in an attempt to produce measurable results through combined restoration actions. As a result, the Army Creek Trustees have been invited to interact with DWR in considering how to assess present and prevent future road runoff contaminant problems in Army Creek adjacent to Route 9 or Route 13. Because road runoff contamination is being addressed through the Section 402 program, it will not be considered further in this document.

2.5.4 Lateral leachate issues

Leachate leaking laterally out of the landfill has been suggested as one of the potential sources of contamination to Army Creek. Approximately 30% of the refuse in the western lobe lies below the seasonal high-water table. Even though the cap will stop vertical infiltration of rainwater through the refuse, any lateral migration of water in the Columbia Formation could result in continued contamination of Army Creek. However, it is anticipated that the water table will rise in the Potomac aquifer and not in the Columbia. Due to a zero-clay area in the Upper Potomac confining layer located below the eastern lobe, the Columbia Formation has been dewatered. Therefore, lateral migration should not be a concern along the southeastern boundary of the landfill. If capping, the remedy mandated in Army Creek ROD-1 (EPA, 1986b), does not effectively reduce lateral leaching of contaminants from the landfill, additional measures may have to be implemented. The effectiveness of the capping remedy will be determined after periodic review, to be conducted by the EPA. To demonstrate that the goals of ROD-1 have been met, ground and surface water and sediment sampling will be conducted.

2.5.5 Groundwater treatment, sediment/metals mobility, and monitoring

According to the Focused Remedial Investigation/Feasibility Study (1990), no Cr, Cu, Pb, Hg, Ni, or Zn problems exist in the pumped groundwater. Therefore, the water treatment facility mandated by ROD-2 (EPA, 1990) and the DNREC NPDES Program was not designed to remove these metals.

The purpose of the Water Treatment Facility is to remove iron from groundwater by elevating the pH and precipitating out the iron before the pumped groundwater enters Army Creek Pond. Excessive iron concentrations discharged into Army Creek from groundwater recovery wells have resulted in the formation of floc, which can clog the gills of fish or suffocate benthos.

If and when groundwater pumping ceases, impacts to water levels in Army Creek are unknown. With no pumped groundwater being added to the system, water levels may decrease. However, the water table may rise because groundwater is not being removed. It is not known if either of these conditions will affect the mobility of metals in the sediments of what is now Army Creek Pond. Because the iron floc is concentrated in the Pond, maintaining the rip-rap structure that impounds the Pond should minimize these changes. Monitoring subsequent to cessation of pumping could then determine the effect, if any, on the mobility of metals in the sediments.

Heavy rainfall which produces several inches or more in a 24 hour period may wash contaminated sediments from Army Creek Pond into Lower Creek. We know that such rainfall events have occurred since 1970 (Table A), but we do not know if such events have resulted in the movement of contaminated sediment downstream. We know that between 1970 and 1992, rainfall events between 1" and 2" occurred on 213 days, between 2" and 3" on 54 days, between 3" and 4" on 9 days, between 4" and 5" on 3 days, between 5" and 6" on 6 days, and between 6" and 7" on 1 day. Additionally, discontinuous rainfall in excess of 2" occurred over an additional 15 days. In other words, about 300 events occurred over a 22 year period. While we can say nothing about the movement of sediment during any one of these events, we can say that rainfall events in the 2" to 3" range were distributed reasonably evenly during the time of most intense environmental sampling for contaminants (1984-91). On that basis alone we assume that the samples may include the effects of any downstream movement.

Table A. Precipitation over 24 hour period at Wilmington, Delaware. Data from the U.S. Department of Commerce, NOAA, National Climatic Data Center, Asheville, NC.

	# DAYS 1" - 2"	#DAYS 2" - 3"	#DAYS 3" - 4"	#DAYS 4" - 5"	#DAYS 5" - 6"	#DAYS 6" - 7"
1970	10	2		(*4)		
1971	13	2	2	(*2)	(*3)	
1972	6	2		1		
1973	12	3				
1974	11					
1975	11	4	(*2)			
1976	7	1				
1977	9	1				
1978	11	2	1			
1979	13	3				
1980	4	1				
1981	4	2				
1982	9	1, (*2), (*4)				
1983	20	3, (*2), (*4)				
1984	8	(*3)				
1985	5	2, (*2)	1, (*2)			
1986	14	1, (*2)				
1987	9	1				
1988	9	1, (*2)	1		(*3)	
1989	7	1				1
1990	8	2, (*2)				
1991	6	3				
1992	7	2, (*2)				

(*) = Continuous precipitation over # days in parenthesis.
(*) = Discontinuous precipitation over # days in parenthesis.

The following monitoring for groundwater treatment is required under the terms of the ROD (EPA, 1990) as referenced in this report on page 12 (Section 2.3) and as described by Weston (1992) and Clean Tech (1994): 1) groundwater level, pH, total iron, and priority pollutants (i.e., volatile organic compounds, semivolatile organics, metals, nitrate, and pesticide/PCBs) for duration of pumping; 2) treated groundwater flow, total suspended solids, pH, total iron, priority pollutants, and bioassays (i.e., Ceriodaphnia survival and reproduction in treated groundwater) for duration of pumping and treatment; 3) surface water and sediment samples collected in the early fall and spring at five years after completion of capping (December 1993, plus five years or approximately 1999) and one year after pumping and treating has ceased for pH, temperature, specific conductivity, dissolved oxygen, priority pollutants, and bioassays at six locations (i.e., two above Pond, two in Pond, and two in Lower Army Creek just below trestle); and 4) Army Creek Pond habitat for water levels in Pond and characterization of vegetation 50 yards beyond Pond perimeter except for capped areas during continued discharge of treatment plant and for two years following cessation of plant discharge (includes control of Phragmites spp. if during two years following cessation of pumping, water levels in the Pond expose bare substrate which is then colonized by the plant). The results of the monitoring and periodic review will determine if the mandated remedies were effective, or whether additional actions will be required of the cooperating PRPs.

3.0 DATA ANALYSIS AND FINDINGS

3.1 Sediment

In January 1990, a NUS/Gannett Fleming report for the Focused Remedial Investigation (FRI, 1990) stated, "Sediments in Army Pond are deemed not to represent a threat to the aquatic environment." In lieu of established sediment criteria, the FRI's conclusions were based upon so called "background" concentrations of trace metals in upland soils as derived from Table 6.46, Trace Element Content of Soils, in Brown and Associates (1983). The FRI (1990) found that the concentrations of chromium (Cr), mercury (Hg), and zinc (Zn) sampled in Army Creek were within ranges previously found for "uncontaminated" or "natural soils". In fact the concentrations of Cr, Hg, and Zn observed in Army Creek are similar to those found in upland soils. Additionally, the FRI (1990) presented no comparative concentrations for cadmium (Cd) and listed nickel (Ni) as 100 ppm (See Table 1A). Brown and Associates (1983) list Cd at 0.06 ppm and Ni at 40 ppm (Table 1B). The concentrations of Cd in Army Creek are much higher than the average concentrations of Cd in upland soils reported by Brown and Associates (1983). The concentrations of Ni, however, are much lower in Army Creek than in upland soils.

The Technical Advisory Committee was concerned about the use of data from Brown and Associates (1983) to represent criteria for evaluating concentrations of contaminants in the sediments of Army Creek for the following reasons:

1) Brown and Associates (1983) presented data for upland soils. Use of these data in the FRI (1990) for evaluating concentrations in freshwater or estuarine sediments is questionable.

2) The use in the FRI (1990) of concentrations of trace elements from Brown and Associates (1983) does not involve any determination or estimation of the effects such concentrations may or may not have on aquatic life.

3) Brown and Associates (1983) referred to "normal" concentrations (Table 1b), which the FRI (1990) categorized as "uncontaminated"

soils (Table 1a). This may not be entirely valid, since the "normal" or naturally occurring concentrations referred to in Brown and Associates (1983) were an average of what was found. As further clarification Brown and Associates (1983) state, "[the] ranges [of metal concentrations] often include [those from] soils that contain naturally high concentrations of metals resulting in toxicity to all but adapted plants".

4) The concentrations listed in the FRI (1990) as "uncontaminated" are, in some cases (e.g., Cr and Ni), higher than those listed in Long and Morgan (1991) as possibly causing adverse biological effects (i.e., Effects Range-Low) for types of estuarine organisms potentially found in Army Creek.

Long and Morgan (1991) have recently produced a compendium evaluating sediment contaminant concentrations and observed biological effects. They assembled data from a wide variety of methods and approaches, and from many geographic areas to evaluate and as they say, "identify informal guidelines for use in evaluation of...sediment data. The data from three basic approaches to the establishment of effects-based criteria were evaluated: the equilibrium partitioning approach, the spiked-sediment bioassay approach, and various methods of evaluating synoptically collected biological and chemical data in field surveys [see definitions and discussion of approaches following Tables 2A and 2B]. The chemical concentrations observed or predicted by the different methods to be associated with biological effects were sorted, and the lower 10 percentile and median concentrations were identified along with an Overall Apparent Effects Threshold. The lower 10 percentile in the data was identified as an Effects Range-Low (ER-L) and the median was identified as an Effects Range-Median (ER-M). Note that these ER-L and ER-M values are not to be construed as NOAA standards or criteria...[and are] not intended for use in regulatory decisions or any other similar applications." For additional information on the various approaches, the reader should consult Chapman (1989), NAS (1989), and EPA (1992).

Further, according to Long (pers. comm.) it should be "acknowledged that the data used by Long and Morgan (1991) did not account for the factors, such as AVS [acid volatile sulfides] and TOC [total organic carbon], that can control or influence the bioavailability of toxicants in sediments. The majority of the data available to [them] did not include measures of these factors, so [they] were unable to include them. In order to account for them, the organics data should be expressed in units of TOC, not in units of dry weight, and metals data in units of AVS. [They] viewed this problem not as a weakness of [their] approach, but rather, a weakness of the data available at the time. The significance of this weakness is that X ppm of a toxicant may be toxic in sediments with 1% TOC, but it would require a concentration of 3X to cause toxicity in 3% TOC sediments. Without a measure of the TOC concentration, an ambient concentration that exceeds an ER-M may not be toxic at all, because it would be bound to the organic carbon and not bioavailable."

The Long and Morgan (1991) compendium was not available when ROD-2 was developed (prior to June 29, 1990). With no nationally-adopted, official, effects-based standards available, the use of a preponderance of evidence derived from many approaches was judged best by Long and Morgan (1991) for developing guidance for interpreting sediment data. In lieu of established criteria, the Technical Advisory Committee used the information derived from the various approaches presented by Long and Morgan (1991) as guidance to assess the potential for adverse biological effects based on concentrations of contaminants found in the sediments of Army Creek.

In determining the effects on biota of contaminated sediments, Long and Morgan (1991) reviewed studies involving a wide range of representative estuarine benthic organisms. The following organisms were commonly used in studies reviewed by them: nematodes, polychaetes, oysters, clams, cladocerans, amphipods, mysids, prawns, shrimp, midges, echinoderms and fishes. With the exception of oysters and echinoderms the remaining taxa have representatives in Army Creek. Mayer et al. (1987), in reviewing inter-taxa correlations for toxicity to aquatic organisms from both freshwater and saltwater habitats, found that the toxicity of a chemical to one species could be predicted from toxicity to another species. Additionally, this general trend was observed by LeBlanc (1984) and Suter and Vaughan (1985), who also concluded that the more distant the relationship between two species, the more different are their responses to chemical toxicity.

When compared with the multiple-approaches presented by Long and Morgan (1991), the data suggest Army Creek Pond sediments may be contaminated with heavy metals (Zn, Pb, Hg, Cu, Cr, and Ni) at levels which exceed concentrations thought to potentially cause adverse effects on biota based on one or more of the approaches (Table 2A). Zinc concentrations range from less than those potentially causing adverse biological effects to those that exceed concentrations defined by the Effects Range-Median (ER-M), the Apparent Effects Threshold (AET), the Bioeffects/Contaminant Co-occurrence Analysis (BCCOA), and the Spiked-Sediment Bioassay (SSB) as potentially causing adverse biological effects. Lead concentrations range from less than those of concern to those that exceed the Effects Range-Low (ER-L) and BCCOA. Mercury concentrations range from less than those of concern to those that are approximately equal to the ER-L, and exceed the Sediment-Water Equilibrium Partitioning Threshold (SWEPT), and the BCCOA. Copper concentrations range from less than those of concern to those that exceed the BCCOA and SSB. Chromium concentrations range from less than those of concern to those that exceed the SWEPT. Nickel concentrations range from less than those of concern to those that exceed BCCOA and SWEPT.

Long and Morgan (1991) also present the subjective degree of confidence they have in the ER-L and ER-M values for trace elements in their Table 70. For Cd, Cu and Zn they have a high degree of confidence; for Pb and Hg a moderate to high level of confidence; for Sb, Cr, Ni, and Ag a moderate level; and for As a low to moderate degree of confidence. They also list an Overall Apparent Effects Threshold as the concentration at and above which biological effects were usually or always observed in association with increasing concentrations of a chemical. These Overall Apparent Effects Thresholds are different from the AET and were determined by Long and Morgan (1991) independently of the ER-L and ER-M values by visually examining sorted data. Only Zn, with concentrations ranging from 18.9-273 ppm in the sediments of Army Creek Pond, comes close to exceeding the Overall Apparent Effects Threshold for Zn of 260 ppm (Table 2C).

For Lower Army Creek, the data suggest the sediments there may be contaminated with heavy metals (Zn, Pb, Hg, and Cr) at levels which exceed concentrations thought to potentially cause adverse effects on biota based on one or more of the approaches presented in Long and Morgan (1991) (Table 2A). Lead and Hg exceeded such concentrations at two stations (sites 1 and 4), Zn at one station (site 4) near Route 9 bridge, and Cr only at site 4 (Tables 2A and 3). Concentrations of Pb, Hg and Zn range from less than those potentially causing adverse biological effects to those approximately twice the ER-L but less than the ER-M. Lead concentrations also exceeded the BCCOA. Mercury concentrations also exceeded the AET, BCCOA, and SWEPT. Zinc concentrations also exceeded the BCCOA and SSB. Chromium concentrations do not exceed the ER-L at any of the sites, but do exceed the SWEPT once (site 4). When the concentrations of the above trace elements in the sediments of Lower Army Creek are compared with the Overall Apparent Effects Thresholds of Long and Morgan (1991), none exceed their Overall Apparent Effects Threshold (Table 2C).

When organic contaminants in the sediments of Army Creek as a whole (i.e., Upper Creek, Pond, and Lower Creek) are compared with Long and Morgan (1991), almost all have concentrations which range from near their detection limits to greater than the ER-L, but generally less than the ER-M (Table 2B). Only the highest concentrations of phenanthrene and pyrene exceed those of the ER-M. The highest concentrations of all other organic contaminants exceed those of the ER-L and at least one other approach. Except for acetone, benzo (k) fluoranthene, phenanthrene; phenol, toluene, and total xylenes, the lowest concentrations of all other organic contaminants in the sediments of Army Creek are at the instrument detection limit or below. When the concentrations of these organic contaminants are compared with the Overall Apparent Effects Thresholds of Long and Morgan (1991) as discussed above, of those listed, all but fluorene exceed their Overall Apparent Effects Threshold (Table 2D). No Overall Apparent Effects Thresholds are listed for acetone, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, 2-butanone, di-n-butylphthalate, indenol(1,2,3-CD)pyrene, 4-methylphenol, phenol, toluene, and total xylenes.

Confidence in these data may be related to subjective degrees of confidence as expressed by Long and Morgan (1991). Only fluoranthene has a high subjective degree of confidence in ER-L and ER-M values according to Long and Morgan (1991). Benzo(a)pyrene, chrysene, phenanthrene and pyrene have a moderate subjective degree of confidence. Anthracene and benzo(a)anthracene have low to moderate levels of confidence. Acenaphthene and fluorene have low levels of confidence.

A comparison of organic contaminants in the sediments of Army Creek Pond and Lower Army Creek considered only 1,2-dichloroethane, benzo(a)pyrene, bis(2-chloroethyl)ether, and phenol (See Table 7). Of these only benzo(a)pyrene (0.16 ppm average concentration) and phenol (0.683 ppm average concentration) are detectable in Army Creek Pond. Only phenol (1.8 ppm based on one sample) is detectable in the sediments of Lower Army Creek. Notice, however, that according to Charters et al. (No date) phenols were detected in sediments only from Site 3 (Pond) and Site 1 (Lower Creek) at concentrations of 2.4 and 1.8 ppm, respectively (See Table 2D). Di-n-Butylphthalate concentrations also were higher in the Pond than Lower Creek (Table 2D).

During April, 1985, and again in April, 1986, a total of 16 sediment samples were collected from Army Creek channel or adjacent areas in association with remediation planning for the Delaware Sand and Gravel (DS & G) Superfund site (See Table 5.18 in Dunn Geoscience Corp., 1987). No meaningful organic contaminants were found in any of the sediment samples. Iron and manganese were detected in the sediment samples, "at the same order of magnitude as the surficial soils" (Dunn Geoscience Corp., 1987). No ER-L, ER-M, or Overall Apparent Effects Threshold (OAET) values are given in Long and Morgan (1991) for Fe or Mn for comparative purposes. Barium was detected at lesser concentrations, but no analysis for barium is provided by Long and Morgan (1991). Selenium and beryllium were detected at very low concentrations, but again Long and Morgan (1991) provide no information about these two metals. Thallium, antimony, cadmium, and silver were not detected in the sediment samples.

Heavy metals which were detected in DS & G sediment samples (Dunn Geoscience Corp., 1987), and which are examined in Long and Morgan (1991), include zinc, lead, mercury, copper, arsenic, and chromium. None of the sediment concentrations for copper, arsenic, and chromium exceeded the ER-L of Long and Morgan (1991). Of the eight samples analyzed for mercury, all were below detection limits except for one sample from near the Rt. 9 bridge, which exceeded the ER-L but not the ER-M. Four of the eight sediment samples analyzed for lead exceeded the ER-L. Two of these were downstream of Army Creek Pond (i.e., near the railroad trestle and at Rt. 9). The remaining two, which slightly exceeded the ER-M, were in Army Creek Pond and upstream at Rt. 13. None of the sediment concentrations for lead exceeded the OAET. Finally, three of the eight sediment samples analyzed for zinc exceeded the ER-L (i.e., just downstream of the Pond near the railroad trestle, near Rt. 9 bridge, and in Army Creek Pond). However, only the sediment concentration of zinc in the Pond sample slightly exceeded both the ER-M and the OAET. Of all the heavy metals data from the DS & G sediment samples (Dunn Geoscience Corp., 1987) for which guidelines exist in Long and Morgan (1991), only zinc and, to a lesser extent, lead concentrations in the Pond may be of concern.

The Technical Advisory Committee also compared the contaminant concentrations found in Army Creek sediments to those found in the sediments of three relatively uncontaminated Delaware tidal creeks. Data for metal concentrations in estuarine sediments from the three sites are presented in Table 4. Compared with these sites, Army Creek Pond sediments have higher concentrations of Cr, Cu, Pb, Ni, and Zn (Tables 2A and 4). Mercury appears higher in Mashyhope Creek than in Army Creek Pond. For Lower Army Creek only Zn and Cr sediment concentrations are higher than those of the three sites. However, the lowest concentrations of Zn and Cr in Lower Army Creek sediments are approximately equal to the concentrations of Zn and Cr in the sediments of the three relatively uncontaminated sites (Tables 2A, 3 and 4). Lead and Hg appear to be less in Lower Army Creek than in the sediments of Blackbird Creek and Mashyhope Creek, respectively. However, in some cases the metal concentrations in Lower Army Creek and Army Creek Pond are at or below concentrations found in other tidal creeks and are always within an order of magnitude. Concentrations of iron in the sediments of Army Creek are higher than those of the relatively "clean" sites. Such concentrations, while not toxic, have resulted in the formation of an orange ferric oxide (iron) floc on the bottom of Army Creek Pond. The implications of this floc are discussed in Section 3.3 (Biota).

Additionally, Bopp and Biggs (1972) was examined to determine if heavy metal concentrations in sediments of lower Delaware River/upper Delaware Bay were significantly different from those in Army Creek sediments below the Pond (see Table 5). With the exception of Ni, which is one to two orders of magnitude higher in river or bay sediments (Bopp and Biggs 1972), concentrations of Cr, Cu, Pb, Hg, and Zn in Lower Army Creek sediments approximate the low end of the range of concentrations found in the river (Table 5). Concentrations of Cd in Lower Army Creek and the lower Delaware River are similar. However, the closest sampling point in the Bopp and Biggs (1972) study was approximately 40 kilometers (25 miles) downstream from the mouth of Army Creek.

Sediment Summary: When compared with the multiple-approaches presented by Long and Morgan (1991), the data suggest Army Creek Pond sediments may be contaminated with heavy metals (Zn, Pb, Hg, Cu, Cr, and Ni) at levels which exceed concentrations thought to potentially cause adverse effects on biota based on one or more of the approaches. Zinc concentrations range from less than those potentially causing adverse biological effects (i.e., 18.9 ppm) to those that exceed (i.e., 273 ppm) concentrations defined by the Effects Range-Median (ER-M) (i.e., 270 ppm). Only the highest concentration of Zn in the sediments of the Pond exceeds the Overall Apparent Effects Threshold, which for Zn is 260 ppm. The suggestion is that the sediments of Army Creek Pond are not heavily contaminated with respect to metals. For example, similar concentrations are found in the sediments of the Lower Delaware River.

Lower Army Creek is considered to have better potential for restoration than the Pond. While Hg, Pb, Zn and Cr concentrations in sediments may be high enough to potentially cause adverse biological effects as defined by at least one of the sediment approaches in Long and Morgan (1991), none of the concentrations of the other metals (i.e., Cu and Ni) in Lower Army Creek sediments exceed any of the concentrations defined by the various approaches as potentially causing adverse biological effects. Concentrations of Pb, Hg and Zn range from less than those potentially causing adverse biological effects to those approximately twice the ER-L but less than the ER-M. When the concentrations of trace elements in the sediments of Lower Army Creek are compared with the Overall Apparent Effects Thresholds of Long and Morgan (1991), none exceed their Overall Apparent Effects Threshold. Comparison with the sediments of relatively uncontaminated creeks suggests that Lower Army Creek is more contaminated only with respect to Zn and Cr (Tables 2A and 4). Compared with Delaware River sediments, Lower Army Creek sediments appear to be less contaminated. As a result of the above analysis, we believe restoration could be considered for Lower Army Creek.

Even though concentrations of most of the organics present in Army Creek range from non-detectable to exceeding their Overall Apparent Effects Thresholds, the level of confidence that these concentrations would potentially cause adverse biological effects is much less than for the trace metals according to Long and Morgan (1991). In some instances, higher concentrations were measured in Upper Army Creek (Charters et al., No date). However, most organic compounds measured were non-detectable in both the Pond and Lower Creek (Table 2D). Therefore, the organics data show little difference between the Pond and Lower Army Creek.

Summary Table for Army Creek Pond and Lower Army Creek of exceeedances of heavy metal concentrations thought to potentially cause adverse effects on biota based on one or more of the approaches in Long and Morgan (1991). See body of report (Section 3.1) or Acronyms and Abbreviations and text following Tables 2a and b for explanation of approaches.

	Approaches in Long and Morgan (1991)						
Metals	SWEPT	SSB	AET	BCCOA	ER-L	ER-M	OAET
Zinc		* +	*	* +	* +	*	*
Lead				* +	* +		
Mercury	* +		+	* +	=+		
Copper		*		*			
Chromium	* +						
Nickel	*			*			

* Army Creek Pond exceeds
+ Lower Army Creek exceeds
= Pond equals ER-L

TABLE 1A. RANGES AND AVERAGES OF METALS CONCENTRATIONS IN "UNCONTAMINATED" SOIL (FRI, 1990)

Metal	Range (ppm)	Average Concentrations (ppm)
Cd	-	-
Cr	1 -1000	100
Cu	2 - 100	30
Fe	-	-
Hg	0.01- 0.3	0.03
Ni	5 - 500	100
Pb	10 - 200	10
Zn	10 - 300	50

TABLE 1B. RANGES AND AVERAGES OF "NORMAL" CONCENTRATIONS OF TRACE ELEMENTS IN SOILS (Table 6.46 in Brown & Associates, 1983).

Trace Elements	Range (ppm)	Average Concentrations (ppm)
Cd	0.01- 0.7	0.06
Cr	1.0 -1,000	100.0
Cu	2.0 - 100	30.0
Fe	-	-
Hg	0.01- 0.3	0.03
Ni	5.0 - 500	40.0
Pb	2.0 - 200	10.0
Zn	10.0- 300	50.0

TABLE 2A. METALS IN SEDIMENTS COMPA[...] WITH EFFECTS-BASED GUIDELINES

Con[...]tions of contaminants in Army Creek sediments are compa[...] [...]th multiple, effects-based guidlines (Long and Morgan, 1991).

Contaminant	ROD 1 Conc. ppm	ROD 2 ppm	Pond Conc. ppm	Below Pond Conc. # A ppm	Below Pond Conc. # B ppm S3; S4	Equil. Part. Thrshld ppm	Spiked Sediment Bioassay ppm	Apparent Effects Thresholds ppm	Co-occurance Analysis ppm	ER-L dry wt. ppm	ER-M dry wt. ppm	Background Sediment Quality ppm
Arsenic	<3.0-13.540	1.1-6	ND-4.9	2.3*-5.4^	13.5^	33.†-64.		57.0-700.0´	22.1-2257.1´	33.0´	85.0´	<3.0
Chromium	10.2-25.5	8.3-45	ND-45.0	14.9^-15.5*	4.7; 34	25†		260.0-270.0	60.9-1646.´	80.0´	145.0´	<10.0
Copper		11.3-43.9	ND-43.9	13.1*		136†-216	17.8-2296´	310.-1300.´	15.0-2820.0´	70.0´	390.0´	
Iron	9,505-45,175	1,830-68,800	1830-68800	45,175^	27,962^							2,867.00
Lead	21.4-175.0	6-97.8	6.0-90.3	21.2*	70.6^; 56.7^	132†-3360		300.0-660.0	27.0-1613.0´	35.0´	110.0´	10.11
Mercury	<0.5-0.6	0.0459-0.119	.049-.105	0.0592*	ND; 0.63^	.032-0.8†	2.15-13.1´	0.41-2.1´	0.08-11.2´	0.15´	1.3´	<0.5
Nickel		9.9-26.4*	ND-26.4	13.4*		20†		28.0-49.0´	21.0-350.0´	30.0´	50.0´	
Zinc	70.8-274	16.4-273	18.9-273	57.1*	143; 240^	760†-2240	51.-613.´	260-1600´	98.0-1804.0´	120.0´	270.0´	22.24
Manganese	167-1,320											24.26
Silver	<10.0		ND	ND*	<10^			5.2-6.1´	0.6-6.9´	1.0´	2.2´	<10.0
Cadmium	<10.0		ND	ND*	2.9; 2.4	31.0†	5.6-25.9´	5.1-9.6	4.3-41.6´	5.0´	9.0´	<10.0
Selenium	<0.500-0.7		ND	ND*	<0.5^							<0.5
Barium	38.3-234.0			145.0^	76.66^							<10.0

• Concentration of Contaminants Found in Army Creek ROD 1; pg 6, table 9, data from 1981-83 and ROD 2; pg 15, table 5, data from August, 88 (Gannett Fleming 1990. Focused Remedial Investigation). [* indicates low value of range is at instrument detection limit.]

• Pond Conc. refers to sediment concentrations in Army Creek Pond at sites 2, 3, and 4. Data derived from tables 4 and 6 in D. Charter's final report, August 1988.

• Below Pond Conc.#A refers to sediment concentrations at site 1 (below trestle) below Army Creek Pond (Data from D. Charters, 1988* and ROD-1, 1986^).

• Below Pond Conc.#B refers to sediment concentrations at site 3 (downstream from Pond outfall near trestle) or site 4 (upstream from Delaware River tide gate, near Rt. 9), from Enviresponse, Inc. (samples taken on 7/14/87). Data also from Charter, 1988* and ROD-1, 1986^.

• † Bolton, H.S., R.J. Breteler, B.W. Vigon, J.A. Scanlon, and S.L. Clark. 1985. National Perspective on Sediment Quality. Submitted by Battelle to EPA Criteria and Standards Division, Office of Water Regulation and Standards. EPA Contract #68-01-6986. Wash. D.C.
[See Table 2.1. Mercury corrected for organic carbon. Chromium and Nickel are EPA Region 5 guidelines for designating contaminated versus noncontaminated sediments.]

• ´Long, E.R. and L.G. Morgan. 1991. The Potential for Biological Effects of Sediment-Sorbed Contaminants Tested in the National Status and Trends Program. NOAA Technical Memorandum NOS OMA 52. Seattle Washington 175pp plus appendicies.

• Background Sediment Quality from Weston, R.F., 1986. Feasibility Study for the Army Creek Landfill, New Castle Co., DE (data from Table 1-32, station 7).

TABLE2B. ORGANIC CHEMICALS IN SF ENTS COMPARED WITH EFFECTS-BASED GUIDELINES.

Concentrations of contaminants in Army Creek sediments are compared with multiple, effects-based guidelines (Long and Morgan, 1991).

Contaminant	ROD 1 Conc. mg/L	ROD 2 Conc. ppm	Pond Ave. Conc. ppm	Below Pond Ave. Conc. ppm	Equil. Part. Thrshld ppm	Spiked Sediment Bioassay ppm	Screen Level Conc. ppm	Apparent Effects Thresholds (Puget S.) ppm	Co-occurence Analysis ppm	ER-L ppm	ER-M ppm	Background Sediment Quality ppm
Acenaphthene		0.165*			7.330-66.0			0.500-2.0′	0.119-39.557′	0.150′	0.650′	
Acetone		0.025-0.719										
Anthracene		0.080-0.339*			0.190-44.0†		0.163	0.960-13.0′	0.070-264.0′	0.085′	0.960′	
Benzo(a)Anthracene		0.258-1.25*			1.6-220.0†	10	0.261	1.3-5.1′	0.080-350.0′	0.230′	1.600′	
Benzo(a)Pyrene		0.239-1.07*	0.16	ND	10.63-1800.†	4.1	.396-397′	1.6-6.8′	0.404-220.0′	0.400′	2.500′	
Benzo(b)Fluoranthene		0.203-1.33*										
Benzo(g,h,i)Perylene		0.165-0.715*										
Benzo(k)Fluoranthene		0.446-0.786			5,000.0†							
2-Butanone		0.004-0.029*										
Chrysene		0.274-1.58*			1.2-460.0†		0.384′	1.400-9.2′	0.080-317.0′	0.400′	2.800′	
Di-n-Butylphthalate		0.236-1.08			2,000.0†							
Fluoranthene		0.331-1.62			1.6 - 360.0′	3.300-15.0′	.432-.644′	1.700-30.0′	0.382-2370.0′	0.600′	3.600′	
Fluorene		0.161*			0.059-28.0†	176.51	0.101′	0.540-3.6′	0.019-1250.0′	0.035′	0.640′	
Indeno(1,2,3-CD)Pyrene		0.182-0.808*			24,000.0†							
4-Methylphenol		0.139*										
Phenanthrene		0.402-1.71			0.110 - 56.0′	0.270-3.68′	.259-.368′	1.5-6.9′	0.222-2363.2′	0.225′	1.390′	
PCB					0.28†	1.0-10.8	.0029-.042	0.13-3.1	0.1-3550.05	0.05	0.368	
Phenol		1.20-1.80	0.683	1.8								
Pyrene		0.302-3.20*			0.85-198.0†	0.182-0.360	.434-.665′	2.6-16.0	0.350-1350.0′	0.350′	2.200′	
Toluene		0.009-0.033			10.0†							
Total Xylenes		21										

Sediment-Water Equilibrium Partitioning (EP) Approach. In this approach the criteria are established for single chemicals at concentrations in sediment that ensure that the concentrations in interstitial water do not exceed the applicable U.S. EPA water quality criteria (Bolton et al., 1985; JRB Associates, 1984). It is assumed that water quality criteria, when applied to the interstitial water of sediments, would protect infaunal organisms. Physical/chemical principles are used to predict the chemical concentrations that would occur in the interstitial water in equilibrium with those concentrations of the chemicals sorbed to particulates in the sediments, recognizing that the distribution of the chemicals between the two phases is highly influenced by the amount of organic carbon or acid volatile sulfides (AVS) present in the sediments. Tessier and Campbell (1987) reviewed many of the chemical and physical factors in sediments that can strongly influence the partitioning of trace metals between aqueous- and particle-bound phases of sediments and observed that, because of these factors, bulk chemical concentrations of trace metals were poor predictors of the bioavailability of these toxicants. Where criteria were listed in cited documents in units dry weight, they were used in this report without any modifications. Where criteria were listed in units of organic carbon, they were converted to units dry weight, assuming a stated organic carbon concentration (usually 1% total organic carbon [TOC]). Where the criteria were listed in the cited documents in units dry weight assuming a reported TOC concentration other than 1 percent (e.g., 4%), those reported values were used in this report without modification.

Spiked-Sediment Bioassay (SSB) Approach. This approach involves exposing organisms to pristine sediments spiked in the laboratory with known amounts of single chemicals (or mixtures), observing either mortality and/or sublethal effects and determining dose-response relationships (e.g., Swartz et al., 1988). Usually the criteria were reported as LC50 or EC50 values, the lethal concentrations or effective concentrations resulting in 50 percent mortality or 50 percent change in some sublethal end-point relative to controls. Where the bioassays were performed specifically for the purpose of determining sediment quality criteria, the values were listed in this report without modification and the species used and the exposure duration were noted. Where the bioassays were performed to determine the relative toxicity of various chemicals, the resulting values were also listed here without modification. Where bioassays of prospective dredge material or other sediments were performed to determine the potential for bioaccumulation and the authors noted their observations on mortality during the tests, those observations were included in this report.

Screening Level Concentrations (SLC) Approach. Field-collected data are used in this approach and patterns in co-occurrence in sediment concentrations of chemicals and matching analyses of benthic infaunal composition are determined. The SLC are the estimated highest concentration of selected nonpolar organic chemicals that co-occur with approximately 95 percent of the infauna. A cumulative frequency distribution of all stations at which a particular species of infaunal invertebrate is present is plotted against the organic carbon-normalized concentration in sediment of the selected contaminant. The concentration of the contaminant at the locus representing the 90th percentile of the total number of stations at which the species was present is estimated by interpolation and established as the species screening level concentration (SSLC). Next, the SSLCs for a large number of species are plotted as a frequency distribution, and the concentration above which 95 percent of the SSLCs are found is determined as the SLC (Neff et al., 1986; 1987). It is assumed that the contaminants occur in mixtures. The criteria reported in units organic carbon were converted to units dry weight in this document, assuming a TOC content of 1 percent.

Apparent Effects Threshold (AET) Approach. This approach also involves use of data from matched sediment chemistry and effects measures performed with field-collected sediment samples. **Similar to the SLC approach, it is assumed that the chemicals occur in mixtures.** An AET concentration is the sediment concentration of a *selected chemical above which statistically significant* ($P \leq 0.05$) biological effects (e.g., depressions in the abundance of benthic infauna or elevated incidence of mortality in sediment toxicity tests) always occur and, therefore, are always expected (PTI Environmental Services, 1988). The AET values reported for Puget Sound were based upon the evaluation of data from many surveys of various portions of that region and were used in this document without modifications. Values reported in 1986 were based primarily upon data from studies performed in the waterways of Commencement Bay and were updated with additional data from other areas in Puget Sound in 1988. In addition, AET values were calculated by the present authors for data from Mississippi Sound generated by Lytle and Lytle, 1985 and for data from San Francisco Bay generated by many investigators in independent surveys (Long and Buchman, 1989; Chapman et al., 1986; Word et al., 1988). These latter values were calculated using the SedQual version 1.1 software developed by PTI Environmental Services, Inc. (1988) for U.S. EPA Region 10 and a sorting procedure, using Microsoft Excel software on a Macintosh computer.

Bioeffects/Contaminant Co-Occurrence Analyses (COA) Approach. Similar to the SLC and AET approaches, this method also involves use of field-collected data in which chemical mixtures occur. It involves calculation of statistics of central tendency (i.e., means, standard deviations, maxima, minima) in chemical concentrations associated with matching samples determined to have high, intermediate, and low indications of effects. For example, DeWitt et al., 1988 listed means and standard deviations in concentrations of selected chemicals found to be nontoxic, intermediate in toxicity, and significantly toxic to the amphipod Rhepoxynius abronius in tests of Puget Sound sediments. Long (1989) listed the means, standard deviations, maxima, and minima in concentrations of nine physical and chemical parameters in sediments from the Commencement Bay waterways determined to be least, intermediate, and most toxic to R. abronius. Data from DeWitt et al., 1988 were used and expanded to accommodate many more chemicals *quantified in Commencement Bay sediments* and the co-occurrence values are reported herein. In addition, many reports in which matching sediment chemistry and sediment toxicity and/or benthic data were listed were evaluated, co-occurrence analyses were performed and the results reported herein.

ER-L (Effects Range Low) & ER-M (Effects Range Median): The data that remained following a screening step were from studies in which effects were either predicted or observed in association with increasing concentrations of the respective analyte. Then, they were sorted in ascending order and listed in Appendix tables for each chemical, Next, usually two values were determined *from these remaining* data for each chemical: an ER-L, a concentration at the low end of the range in which effects had been observed; and an ER-M, a concentration approximately midway in the range of reported values associated with biological effects. These two values were determined using a method similar to that used by Klapow and Lewis (1979) in establishing marine water quality standards for the State of California. For each chemical of interest, they assembled available data from spiked-water bioassays, examined the distribution of the reported (LC50 values, and determined the lower 10-and 50-percentile concentrations among the ranges of values. In the present document, the ER-L values were concentrations equivalent to the lower 10 percentile of the screened available data, and indicated the lower end of the range of concentrations in which effects were observed or predicted. They were used in the document as the concentrations above which adverse effects may begin or are predicted among sensitive life stages and/or species or as determined in sublethal tests. The ER-M values for the chemicals were the concentrations equivalent to the 50 percentile point in the screened available data. They were used in the document as the concentration above which effects were frequently or always observed or predicted among most species. The methods of Byrkit (1975) were used to determine the percentile values.

Above text from Long and Morgan, 1991.

TABLE 2C. TRACE METALS CONCENTRATIONS IN THE SEDIMENTS OF ARMY CREEK COMPARED TO THE OVERALL APPARENT EFFECTS THRESHOLDS (OAET) OF LONG AND MORGAN (1991).

Trace Metal	Pond (ppm)	Lower Creek (ppm)	OAET (ppm)
Arsenic	ND- 4.9	2.3-13.5	50
Cadmium	ND	ND-2.9	5
Chromium	ND-45.0	4.7-34.0	No
Copper	ND-43.9	13.1	300
Lead	6.0-90.3	21.2-70.6	300
Mercury	0.049-0.105	ND-0.63	1
Nickel	ND-26.4	13.4	NSD
Zinc	18.9-273	57.1-240.0	260

NSD = not sufficient data

TABLE 2D. ORGANIC CONTAMINANT CONCENTRATIONS IN SEDIMENTS OF ARMY CREEK COMPARED TO OVERALL APPARENT EFFECTS THRESHOLDS (OAET) OF LONG AND MORGAN (1991).

Organic Compound	ROD-2 (ppm)	Pond* (ppm)	Lower Creek* (ppm)	OAET (ppm)
Acenaphthene	0.165	ND	ND	0.15
Acetone	0.025-0.719	DNR	DNR	
Anthracene	0.180-0.339	ND	ND	0.30
Benzo(a)Anthracene	0.258-1.25	ND	ND	0.55
Benzo(a)Pyrene	0.239-1.07	J	ND	0.70
Benzo(b)Fluoranthene	0.203-1.33	ND	ND	
Benzo(g,h,i)Perylene	0.165-0.715	ND	ND	
Benzo(k)Fluoranthene	0.446-0.786	ND	ND	
2-Butanone	0.004-0.029	0.011-0.018	J	
Chrysene	0.274-1.58	ND	ND	0.90
Di-n-Butylphthalate	0.236-1.08	0.638-1.08	ND	
Fluoranthene	0.33-1.62	ND	ND	1.00
Fluorene	0.161	ND	ND	0.35
Indenol(1,2,3-CD)Pyrene	0.182-0.808	ND	ND	
4-Methylphenol	0.139	ND	ND	
Phenanthrene	0.402-1.71	ND	ND	0.26
PCB				0.37
Phenol	1.20-1.80	2.4	1.8	
Pyrene	0.302-3.20	ND	ND	1.00
Toluene	0.009-0.033	ND	ND	
Total Xylenes	21.0	ND	ND	

ND = not detectable.
DNR = Data not reliable.
J = present, but less than detection limit.
ROD-2 = Data from second Record-of-Decision not separated by location.
* = From Charters, D.W., G. Buchanan, and K. Munney (no date).

TABLE 3. SEDIMENT METAL SAMPLES (DOWNSTREAM OF ARMY CREEK POND)

A. Enviresponse, Inc. - July 14, 1987

1. Site #3, Sample # 6553 -- just downstream from pond outfall, near railroad crossing.

   Cd = 2.9 ug/g
   Cr = 4.7 ug/g
   Fe = Not sampled
   Hg = ND
   Zn = 37 ug/g

2. Site #4, Sample # 6554 -- upstream of Delaware River tidal gate, near Rt. 9 bridge.

   Cd = 2.4 ug/g
   Cr = 34 ug/g
   Fe = Not sampled
   Hg = 0.27 ug/g
   Zn = 190 ug/g

B. EPA - August 2, 1988

3. Site #1, Sample #1872 -- just downstream from pond outfall, near railroad crossing:

   Cd = not sampled
   Cr = 15.5
   Fe = 20,900 ug/g
   Hg = 0.059 ug/g
   Zn = 57.1 ug/g

INSERT TABLE 4. "CLEAN" SEDIMENT METAL CONCENTRATIONS (ppm) IN THREE STREAMS IN NEW CASTLE COUNTY, DELAWARE*

Metals	Beaverdam Branch (ppm)	Marshyhope Creek (ppm)	Blackbird Creek (ppm)	ER-L** (ppm)	Lower*** Army Creek (ppm)
Iron	2,290	1,756	15,012		
Copper	2.8	<2.4	11.5	70	13.1
Manganese	23.2	76.3	130		
Chromium	4.8	<2.4	8.7	80	4.7- 34
Silver	<2.9	<2.4	<2.5	1	-
Zinc	21	6.9	33.5	120	37 -190
Lead	9.7	4.7	51	35	21.2
Nickel	5.2	2.4	10.6	30	13.4
Cadmium	<2.9	<2.4	<2.5	5	2.4- 2.9
Mercury	<2.9	0.45	0.05	0.15	ND - 0.27
Arsenic	3.3	2.5	5.2	33	-

* From State of Delaware, Department of Natural Resources and Environmental Control,1992, Unpublished Report. (streams with no tidal influence).

**From Long and Morgan, 1991.

***Range of concentrations from Table 2A.

TABLE 5. Heavy Metal Concentrations in Sediments of Lower Delaware River/Upper Bay and Army Creek Below Pond.

Metal	Lower DE River/ Upper Bay (a) (ppm)	Lower Army Creek (b) (ppm)	Lower Army Creek (c) (ppm)
Chromium	33 - 340(1,2)	15.5	4.7 - 34
Copper	9 - 355(1,2)	13.1	
Iron	15,900-63,500(1)		
Lead	25 - 1,083(1)	21.2	
Mercury	.086 - 4.7(1)	.059	ND - 0.27
Nickel	175 - 3,633(1)	13.4	
Zinc	48 - 5,833(1)	`57.1	37 - 190
Cadmium	0.7 - 11.3(1)	10	2.4 - 2.9

(1) DE River is primary source.
(2) Ocean is primary source.

(a) Bopp, F. and R. B. Biggs, 1972. Trace metal environments near Shell Banks in Delaware Bay. College of Marine Studies, University of Delaware, Newark, Delaware. NOAA/Sea Grant DEL-SG-9-72.

(b) Source RI/FS

(c) Gannett Fleming Environmental Engineers, Inc. 1990. Focused Feasibility Study - Army Creek Landfill Site.

3.2 Water

In 1973, sampling for suspected sources of the groundwater contamination included "raw leachate" (Weston, 1986). The samples were analyzed for pesticide residues by Greenwood Laboratories, Inc. and by the EPA Residue and Special Projects Laboratory. Neither analysis could specifically identify the compounds present. However, both analyses agreed that organic contamination was present, probably as a type of organochlorine hydrocarbon contamination. No measurements for heavy metals seem to have been made on leachate.

In April 1974 sampling of water from a well (A5) on the landfill found "large amounts of chemicals, particularly phenol" (Weston, 1986). The 1990 FFS concludes, "Evidently, the source of phenol is either the sediments, contaminated leachate from the landfill, or contaminated runoff from off-site. Regardless of the source of phenol, its concentration in the surface water does not represent a hazard to aquatic life." However, the concentrations of phenols (0.35 to 6.9 mg/l, see Table 1-9 in Weston, 1986) in the groundwater from well A5 exceed both the EPA ambient water quality criteria (AWQC) and the DNREC non-tidal stream, surface water quality standard for phenol of 0.3 mg/l. If it is assumed that the phenol concentrations in A5 well water potentially may be representative of those in seepages coming laterally out of the landfill, then such concentrations may present a problem to organisms in direct contact with them prior to dilution by receiving waters. The remedy of capping the landfill, however, should eliminate this concern.

The April 1974, samples taken by the State of Delaware from Well A5 on the landfill contained "large amounts of chemicals, particularly phenol" (FS, 1986 by Weston). While Al, As, Ba, Ca, Co, Fe, K, Mg, Mn, Na, Ni, Se, and Zn, as well as a number of organic contaminants [including 1,2-dichloroethane and bis(2-chloroethyl)ether] were found in pumped groundwater, only Fe exceeded the EPA (EPA, 1986c) and State of Delaware AWQC for freshwater life (FRI, 1990). Most of the contaminants were present in solution along with very small amounts of suspended particulates. The pumped groundwater flowed into Upper Army Creek, Army Creek Pond and Lower Army Creek from 1973, to 1994. Since January, 1994, when the water treatment facility was completed per

Army Creek ROD-2, the pumped and treated groundwater flows only into Army Creek Pond.

The 1990 FRI also presented data for Army Creek Pond showing that Cd (0.026 mg/l), Cr (0.078 mg/l), Fe (2.22 mg/l), Hg (0.00013 mg/l), and Zn (0.145 mg/l) exceeded the AWQC for freshwater aquatic organisms set by the U.S. EPA and/or State of Delaware Surface Water Quality Standards (Tables 6 and 7). Only Fe (2.26 mg/l) and Zn (0.640 mg/l) were detected in Army Creek downstream of Army Creek Pond, based on a single sample (Table 7). Note that Zn concentrations were higher downstream than in the Pond. Probable sources of heavy metal contamination (i.e., Cd, Cr, Hg, Ni and Zn) to Army Creek surface water are lateral seepage out of the landfill into the Pond, and general landscape runoff including road runoff from Routes 13 and 9. From a water balance inventory (See Section 2.4.1) it was determined that most of the surface water in Army Creek and Army Creek Pond is lost to groundwater. The inorganic contaminants in surface water are believed to be attenuated by binding to sediment as the surface water infiltrates toward groundwater.

Concentrations of heavy metals in the water column of the lower Delaware River are generally of lower or similar concentrations as those found in Army Creek (Table 8, adapted from Church et al., 1986). Thus, opening Lower Army Creek to the tidal influence of the Delaware River should not increase surface water concentrations of heavy metals in Army Creek via direct contributions from the river; one might even predict a lowering of Army Creek surface water metals through riverine tidal dilutions.

The 1990 FRI further presented data showing that certain organic contaminants (1,2-dichloroethane; bis(2-chloroethyl)ether; phenol) also were present in Pond surface water (Table 7). While no statement was made about these concentrations relevant to AWQC, only bis(2-chloroethyl)ether (apparently from pumped well water) and phenol (apparently from leachate coming laterally out of the base of the landfill, as well as from recovery well water) were detected in the waters of Lower Army Creek. When phenol concentrations in surface waters of Army Creek Pond (0.189 mg/l) and Lower Army Creek (0.164 mg/l) are compared with DNREC non-tidal stream, surface water quality standards for phenol

(0.3 mg/l), it is evident that the phenol standard was not exceeded. No standard exists for bis(2-chloroethyl)ether for protection of aquatic life.

During April, 1985, and again in April, 1986, a total of 16 surface water samples were collected from Army Creek channel or adjacent areas in association with remediation planning for the Delaware Sand and Gravel (DS & G) Superfund site (See table 5.17 in Dunn Geoscience Corp., 1987). No significant organic contaminants were found in any of the surface water samples. Of the heavy metals analyzed, only iron, manganese, and magnesium, and to a lesser extent barium, were detectable at significant concentrations. All other metals analyzed (chromium, silver, zinc, lead, cadmium, mercury, arsenic, selenium, copper, nickel, beryllium, vanadium, antimony, thallium, cobalt, tin, and aluminum) were either below or very close to detection limits.

Of the heavy metals which were detectable at significant concentrations in the DS & G surface water samples (Dunn Geoscience Corp., 1987), no Ambient Water Quality Criteria (AWQC) for the protection of aquatic life exists for manganese, magnesium, or barium. Iron concentrations in five of the eight surface water samples collected in 1985 exceeded the State's AWQC for iron. Iron levels in Army Creek Pond were 1.8X the AWQC, and concentrations at all three stations downstream of the Pond exceeded the iron AWQC by a factor of 4.0-4.8X. An intermittent stream flowing off the DS & G site also yielded an iron concentration 4.4X the AWQC. When the surface water sampling effort was repeated in 1986, only one station (the intermittent stream on the DS & G site) exceeded AWQC for iron concentrations; this anomaly between iron concentrations observed in 1985 versus 1986 cannot be explained. Nevertheless, iron concentrations resulting in iron floc in surface waters of Army Creek are a concern. The iron floc may have harmful effects on aquatic life via clogging/irritation of gills of fishes and other organisms, and by smothering of benthos.

More recent metals sampling of Army Creek surface waters by DNREC/DWR (Table 9) during November 1991, and April 1992, at stations above and below Army Creek Pond, found that only Fe exceeded AWQC levels, while Cd, Cr, and Zn concentrations did not. While these data are the most recent surface water samples, they do not eliminate concern with exceedances of AWQC which have been found in previous samples.

Measurements for Hg were not made. Note that DNREC did not sample Pond water in either 1991 or 1992.

Water Summary: Both lateral leachate from the base of the landfill and recovery well water appear to have contributed organic contaminants, phenol and bis(2-chloroethyl)ether, to Army Creek. During at least one sampling period the Pond had levels of Cd, Cr, Fe, Hg, and Zn in surface waters which exceeded AWQC for freshwater aquatic life. Of these metals, cadmium and zinc concentrations exceeded both chronic and acute AWQC; iron and mercury concentrations exceeded their chronic AWQC; and chromium, if existing in the +6 oxidation state, would exceed both the chronic and acute AWQC. Army Creek Pond waters may be unacceptably contaminated for biota based upon these exceedances of AWQC (See Table 4-10 in FRI, 1990). During other sampling periods only Fe exceeded AWQC. Therefore, restoration of the Pond is questionable unless the surface water quality is improved via water treatment, capping the landfill, clean-up of bottom sediments, or control of road and rail runoff (if warranted) and other non-point sources from the landscape.

For Lower Army Creek, Fe exceeds the AWQC for freshwater life. However, at the concentrations observed, Fe is not toxic to aquatic life. Instead the Fe may precipitate to the bottom to form a floc that clogs gills or smothers benthic organisms. Additionally, the water treatment facility now on-line removing Fe from pumped groundwater being discharged to Army Creek Pond should help decrease Fe concentrations in both the Pond and Lower Creek. The single elevated Zn sample observed in Lower Army Creek, which exceeds the AWQC for freshwater life, may be attributed to road runoff from nearby Route 9. In comparison to surface water quality in Army Creek Pond, Lower Army Creek has a much better potential for immediate restoration.

TABLE 6. METALS OF CONCERN IN ARMY CREEK SURFACE WATERS. Data from Focused Remedial Investigation, 1990.

A. Eight stations sampled by EPA on August 2, 1988 (stations located in Upper Army Creek, Army Creek Pond and Lower Army Creek).

	Range for 8 stations	Reason for concern
Cadmium	34- 38 ug/l	Exceeds federal and state AWQC of 1.1 ug/l (chronic) and 3.9 ug/l (acute).
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).
Iron	980-2,860 ug/l	Exceeds federal and state AWQC (chronic) of 1,000 ug/l.
Mercury	ND-0.2 ug/l	Exceeds federal and state AWQC (chronic) of 0.012 ug/l
Zinc	25-640 ug/l	Exceeds federal and state AWQC of 106 ug/l (chronic) and 117 ug/l (acute).

B. Site #1 (sample # 1872) -- Sampled by EPA on August 2, 1988, just downstream from pond outfall, near railroad crossing. (These data part of above set of 8 stations.)

Cadmium = ND
Chromium = ND
Iron = 2260 ug/l
Mercury = ND
Zinc = 640 ug/l

TABLE 7. COMPARISON OF SURFACE WATER AND SEDIMENT CONCENTRATIONS IN ARMY POND AND ARMY CREEK

DATA FROM 1990 FRI

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	36,800.0	20,900.0
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	155.0	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.

TABLE 8. TRACE METALS IN LOWER DELAWARE RIVER WATER COLUMN (ADAPTED FROM CHURCH ET AL., 1986; FIGURE 2, 0-5 PPT SALINITY).

	Delaware River		Army Creek
METALS	Dissolved	Total	
	ug/l (ppb)	(ug/l ppb)	ug/l (ppb)
Fe	25	950	980-5724
Mn	190	250	
Co	36	136	
Zn	11	25	<20-640
Cu	2.4	5.4	
Ni	4	7	
Cd	0.19	0.37	< 1-38

TABLE 9. ARMY CREEK SURFACE WATERS SAMPLED BY DNREC/DWR TECHNICAL SERVICES

ARMY CREEK SURFACE WATER METALS:

I. November 14, 1991

		Station #114021 (Rt.13 above pond)	Station #114031 (railroad trestle below pond)
a)	Cd	<1.0 ug/L	<1.0 ug/L
b)	Cr(+6)	<10.0 ug/L	<10.0 ug/L
c)	Fe	1119.0 ug/L	2678.0 ug/L
d)	Hg	Not sampled	Not sampled
e)	Zn	31.2 ug/L	<20.0 ug/L

II. April 2, 1992

		Station #114021 (Rt.13 above pond	Station #114031 (railroad trestle below pond) * duplicate samples
a)	Cd	<1.0 ug/L	<1, <1 ug/L
b)	Cr(+6)	<10.0 ug/L	<10, <10 ug/L
c)	Fe	1579.0 ug/L	5672, 5724 ug/L
d)	Hg	Not sampled	Not sampled
e)	Zn	70.0 ug/L	27, 21 ug/L

Note: In the DNREC/DWR samples above, iron exceeds Fed/state chronic AWQC for all samples; no exceedance of chronic or acute AWQC was found for cadmium, chromium (+6), or zinc.

3.3 Biota

The sediments and water in certain areas of the Army Creek system have concentrations of several trace metals that may cause biological impacts. Biota living in or on the bottom of Army Creek or Pond, or in the vicinity of the Army Creek Landfill are potentially at risk of being adversely affected by these contaminants. However, the bioavailability of heavy metals in Army Creek sediments has not been determined. Metals may be chemically or physically bound so completely that they pose no biological threat.

Heavy metals are known to bioaccumulate in the tissues of benthic organisms, often in concentrations that are orders of magnitude higher than the surrounding environment. Higher trophic level organisms, such as fish and waterfowl, feeding on invertebrates may accumulate heavy metals and other contaminants (i.e., biomagnification). Predators consuming contaminated fish or shellfish may, in turn, face a health risk. In an effort to determine potential effects of on-site contaminants on biological systems, the Technical Advisory Committee reviewed available data on biota of Army Creek.

Biological monitoring began at Army Creek in 1973. A static bioassay toxicity test using pumped groundwater and leachate was conducted by Weston (1973). Bluegill sunfish (Lepomis macrochirus) were used as test organisms. The fish were acclimated to Delaware River water for 10 days prior to the bioassays and starved during the 96-hour test. A total of six dilutions of pumped leachate (35, 50, 60, 70, 85, and 100%) plus a control (river water) were set up, and a total of ten fish were used for each dilution. No fish were killed by any of the dilutions, and no deaths occurred in the control. However, during the last 48 hours of the test, one fish in 100% leachate lost equilibrium. Weston (1973) concluded that pumped leachate was not "toxic" over the test period to the organism chosen, and that "... the leachate may thus be presumed to have limited or no adverse effects upon the existing biological community of Army Creek or of the Delaware River."

In 1986, bioassays were conducted with well discharge water and Army Creek surface water using fathead minnows (Pimephales promelas) and a water flea (Ceriodaphnia dubia) as test organisms (Weston, 1986; EPA, 1986a). The bioassays yielded similar results. A test with composite well discharge water and fathead minnows showed "no significant effect and produced normal survival and growth" (EPA, 1986a). However, water from some individual wells significantly affected survival of minnows. Bioassays on fathead minnows conducted using Upper Creek surface water (i.e., above recovery well discharges) indicated that this water was "acutely toxic" (EPA, 1986a), but after standing a day these waters allowed normal survival and growth. Survival and growth of the fathead minnows in water from below the Pond was "very good" (EPA, 1986a). In contrast, in tests of survival or reproduction rates, Ceriodaphnia was adversely affected by composite discharge water from the recovery wells. In addition, the EPA data indicated that the upstream station on Army Creek produced significantly fewer young Ceriodaphnia than either the station below the Pond or a control reference; therefore, the water quality of the stream above the Pond appears more degraded than the water below the Pond (EPA, 1986a). Finally, bioassays using bacteria (i.e., Microtox Test) indicated only minor impacts regardless of the water source or location.

As part of the Consent Decree of September 12, 1991, New Castle County was required to conduct bioassay analyses once every three months (i.e., quarterly) until the start of groundwater treatment plant operations (which began January, 1994), and to continue such bioassay work after startup of the treatment plant. The quarterly bioassays performed prior to the plant's startup consisted of testing flow-proportioned grab samples collected from operating recovery wells. Bioassay testing involved chronic survival and reproduction studies of Ceriodaphnia dubia using the composite grab samples and controls. Some of the bioassays indicated toxicity problems in the pumped groundwater which may have been caused by iron or ammonia concentrations. However, samples of recovery well water which were "benchtop" treated with procedures to simulate future plant treatments (e.g., sample aeration, settling, lime addition, etc.) had bioassay results comparable to control samples.

In summary, the bioassay studies showed that composite well discharge water was not toxic to the fathead minnow, but was to the water flea. Some individual wells were toxic to the fathead minnow. For both the fathead minnow and the water flea, Upper Creek water was toxic; Lower Creek water was not toxic to either species.

On July 10, 1987, sediment grab samples were collected at six locations (i.e., Upper Army Creek above landfill, Upper Creek tributary at west end of landfill, upper end of Army Creek Pond, lower end of Army Creek Pond, Lower Army Creek just above trestle, and Lower Army Creek by tidegate) by Envirosponse, Inc. for pore water toxicity testing using Ceriodaphnia dubia (Donaghy et al., 1988). The number of surviving adults and the number of young produced per adult were recorded daily. The percent of Ceriodaphnia surviving exposure to the so called "reference background samples" ranged from 80% (Upper Creek tributary at west end of landfill) to 100% (Upper Creek above landfill), while those organisms exposed to the other four sampling locations exhibited 70% (upper end of Pond), 80% (Lower Creek above Trestle and Lower Creek by tidegate), and 100% (lower end of Pond) survival. No significant differences were found. The number of young, ignoring mortality, produced in the "background reference samples" was 30.10 (Upper Creek tributary at west end of landfill) and 26.30 (Upper Army Creek above landfill). At the other four locations the number of young produced was as follows: 22.71 (upper end of Pond), 22.70 (lower end of Pond), 21.25 (Lower Creek above trestle), and 25.88 (Lower Army Creek by tidegate). Significant differences were found between the "background reference samples" and all but the Lower Creek sample by the tidegate. "The differences may be the result of a slightly toxic condition or a reduction in dissolved organics" (Donaghy et al., 1988). While in general these results are inconclusive regarding the potential effects of contamination in Army Creek on biota, the number-of-young-produced bioassays may suggest improving conditions along the course of Lower Army Creek.

A series of twelve biological surveys were made between September 1973, and December 1983. The survey results are summarized in the Feasibility Study for the Army Creek Landfill prepared by Weston (1986). These surveys basically provide qualitative data on the presence/absence of plants, terrestrial and aquatic vertebrates, and aquatic macro- and micro- invertebrates. 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 biota and general status of Army Creek can be obtained from the combination of these data.

The September 1973, survey found aquatic life in the portion of Army Creek above the Pond "normal" with many invertebrates, frogs, and tadpoles. The Pond itself supported very few animal species (i.e., turtles, surface insects, some tolerant fishes). No benthic invertebrates were found. Emergent vegetation, however, flourished. Downstream of Army Creek Pond, species diversity increased. The survey concluded that the Pond was "suffering from severe pollution/organic enrichment stress". According to Weston (1986), "The causes were seepage of leachate from the landfill, and phosphate and total nitrogen concentrations entering via [Upper] Army Creek [(above Pond)] at levels 10 to 100 times above those in a 'clean' stream." In April and November 1975, severe localized damage to vegetation (i.e., Phragmites, cherry and red maple trees killed) was observed near landfill seepages. These landfill seepages had a pungent odor. Leachate pumped from wells appeared to be less toxic than seepage from the base of the landfill. In September 1977, a diverse, healthy biological community was found at the Pond outlet; this included mayflies and smallmouth bass, (Micropterus dolomieu), both of which require good water quality.

In 1986, macroinvertebrates were collected at three stations: above-Pond, Pond, and below-Pond (Weston 1986, EPA 1986a). The above-Pond station was dominated by oligochaete worms, gastropods (snails), and Heterodonta (fingernail clams). The below-Pond station was dominated by oligochaetes and chironomids (midges). The Pond station sample contained only oligochaetes and chironomids. The presence of overall low species diversity and composition indicates generally degraded water quality within the entire watershed (EPA, 1986a). The species assemblage of benthic organisms indicate that the creek is pollution enriched. Numbers of taxa collected in the Pond (only 3), versus numbers of taxa collected below or above the Pond (11 and 10, respectively), suggest a chronic toxicity problem in the Pond (EPA, 1986a). Differences in diversity and species composition indicate that the macroinvertebrate community downstream of the Pond (diversity = 2.0) is in slightly better condition than the upstream station (diversity = 1.4) (EPA, 1986a).

Diversity in the Pond is much lower (diversity = 0.3) than either upstream or downstream stations. The lower diversity evidenced in the Pond may result from iron floc accumulation and subsequent adverse physical impacts (e.g., suffocation, gill clogging, burial). The Technical Advisory Committee recognizes, however, that some of the differences between Lower and Upper Army Creek may be caused by natural habitat differences; Upper Army Creek is generally forested wetlands and Lower Army Creek mostly a Phragmites marsh. Additionally, the Pond is affected by highly variable flow from upstream and the input from groundwater recovery wells. In essence, however, the Pond may be functioning as a stormwater management basin by trapping sediments and other pollutants before discharging into Lower Army Creek.

Heavy metal and PCB concentrations in brown bullheads, collected by DNREC from Army Creek in 1983, were analyzed using extracts from a homogenized composite sample of four whole fish (Mitchell and Garrow, 1983). The brown bullhead is a bottom-feeding catfish that ingests sediments and benthic debris. Bullhead whole-body concentrations for Zn (18 ug/g), Cu (5.2 ug/g), and As (<0.6 ug/g) were not a cause for concern (Table 10). However, the whole fish concentration for Pb was 5.0 ug/g which may indicate a problem, since the Pb predator-protection level for fish tissue is <0.1 ug/g. The Cr concentration (5.2 ug/g) in bullhead tissue exceeded the recommended predator-protection level of 0.2 ppm. Although Cd and Hg concentrations were below detection levels, they still could be above predator protection limits (Table 10). Finally, the PCB concentration (assumed to be total PCB's) in bullhead tissue was 1.2 ug/g. This exceeds the limit of 0.5 ppm recommended for protection of aquatic life. The results of the DNREC study indicate that concentrations of Pb, Cr, and PCB in brown bullheads may adversely affect biota that consume these fish.

Use of Army Creek by migratory or colonial waterbirds is variable depending on the species and time of year. Shorebirds and waterfowl may use Army Creek only during migration, while colonial waterbirds (e.g. herons) may feed in the area for several months. Uptake of contaminants by birds from resident prey species, such as killifish, snails, and segmented worms, is a potential problem. The potential exists for adverse health effects in predators or their offspring that forage in Army

Creek as a result of increased exposure to metals.

Biota Summary: Bioassay testing on bluegills using pumped groundwater containing leachate showed no toxic effects, similar to what was observed for the effects of composite well discharge water on fathead minnows. However, some individual well discharges significantly affected fathead minnow survival, and bioassays on fathead minnows using Upper Army Creek water had initially acutely toxic results. Water flea (Ceriodaphnia) survival and reproduction was adversely affected by composite well discharge water and Upper Army Creek water, respectively. It appears that the quality of Army Creek groundwater or Upper Creek surface water can adversely impact some forms of aquatic life. Since water fleas may be an important food source for some fish species, population reductions could impact fishes. Fathead minnow survival, and survival and reproduction of water fleas, was not adversely affected by exposure to Lower Army Creek water. Toxicity tests using sediment and Ceriodaphnia were inconclusive, but may suggest improving habitat quality along the course of Lower Army Creek.

Benthic invertebrate survey data, based upon measures of species richness, species diversity, or presence/absence of indicator species, show Lower Army Creek to be less degraded than either Army Creek Pond or Upper Army Creek. The lower diversity evidenced in the Pond may result from iron floc accumulation and subsequent adverse physical impacts (e.g., suffocation, gill clogging, burial). This iron floc may dissipate in time as a result of the treatment plant eliminating new iron inputs.

Bioaccumulation or biomagnification of contaminants in prey species in Army Creek may be a potential source of harm to higher predators found within the system. Concentrations of Pb, Cr, and PCBs in adult brown bullheads from Lower Army Creek exceed recommended predator-protection levels; while not many species feed upon adult bullheads, those that do could be at risk. Other fishes which have not been tested also may be contaminated, and they too may be consumed by predators.

Army Creek Pond and Upper Army Creek should not be considered for restoration at this time based on the best available information involving bioassay tests, species diversity, number of taxa present, and presence or absence of indicator species, as well as on sediment and water quality. Following periodic review by the EPA, a re-assessment of the potential for restoration of Army Creek Pond and Upper Army Creek should be considered. However, restoration of natural resources in Lower Army Creek can be implemented based on this analysis.

TABLE 10. HEAVY METAL AND PCB CONCENTRATIONS IN BROWN BULLHEADS FROM LOWER ARMY CREEK (NEAR RAILROAD BRIDGE) IN 1983. DATA BASED ON EXTRACTS FROM A COMPOSITE SAMPLE OF FOUR WHOLE, GROUND FISH (MITCHELL AND GARROW, 1983).

Metal	Concentration ug/gm	Predator-Protection Levels ug/gm
As	< .6	
Cd	<2	< .5
Cr	5.2	< .2
Cu	5.2	
Hg	< .1	< .1
Pb	5.0	< .1
Zu	18	
PCB	1.2	< .5

* ppm = ug/gm