RESTORATION PLAN FOR ARMY CREEK LANDFILL SETTLEMENT

NEW CASTLE COUNTY, DELAWARE

Prepared by

Army Creek Natural Resources Trustees

October 1995

State of Delaware,
Department of Natural Resources and Environmental Control

U.S. Department of Interior,
Fish and Wildlife Service

U.S. Department of Commerce,
National Oceanic and Atmospheric Administration

The Army Creek Natural Resource Trustees have approved this Restoration Plan and Environmental Assessment for public distribution and review.

State of Delaware
Department of Natural Resources
and Environmental Control

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The Department of Interior,
U. S. Fish and Wildlife Service

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U.S. Department of Commerce,
National Oceanic and Atmospheric Administration

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EXECUTIVE SUMMARY

Under the authority of the Comprehensive Response, Compensation and Liability Act of 1980, as amended (CERCLA), the designated Natural Resource Trustees (Trustees) are restoring natural resources which were injured by releases of hazardous substances from the Army Creek Landfill Superfund site in New Castle County, Delaware. The Trustees are the Delaware Department of Natural Resources and Environmental Control (DNREC), the U.S. Department of Commerce's National Oceanographic and Atmospheric Administration (NOAA), and the U.S. Department of the Interior. As part of a Consent Decree requiring remedial actions at the Army Creek site, the Trustees agreed to a monetary settlement with certain responsible parties for natural resource damages. The settlement of $800,000 was designated for restoration, replacement, or acquisition of the equivalent natural resources injured, which included lost upland habitat, contaminated aquatic and wetland habitats, and lost use of groundwater. This document describes the plan which has been developed by the Trustees to restore the injured upland, aquatic and wetland habitats. In addition, to the above referenced amounts the State of Delaware settled a claim relating to loss or injury to groundwater resources. The groundwater issue is not included in this restoration plan.

The goal of the restoration plan (Plan) is to restore, replace, or acquire the equivalent quantity and quality of habitat and biodiversity of the upland and wetland (including aquatic) habitats within the Army Creek watershed. This goal will be achieved by the following two actions:

1) Restoration of tidal exchange to wetland habitats of Lower Army Creek in order to increase tidal flushing and tidal volume, which will improve exchange of inorganic and organic materials, access and use by biota, and the distribution and abundance of more desirable tidal marsh plant species; and

2) Acquisition and management of uplands within the Army Creek watershed to enhance ecological values, encourage wildlife use, and

provide a buffer between developed upland areas and Army Creek.

The proposed wetlands restoration project (i.e., #1 above) consists of two main elements: a water management plan and a vegetation management plan. The water management plan involves modification of an existing water control structure (at the confluence of Army Creek and the Delaware River) by adding automated tide gates which will allow rapid adjustments of direction, frequency and duration of tidal flows into and out of the Army Creek marsh. The enhanced tidal exchanges will allow ingress and egress of estuarine and anadromous fishes for spawning, feeding, and refuge, and will improve habitat quality and nutrient and detrital exchange. Automated control of water levels will help avoid flooding of adjacent property. The vegetation management plan includes suppression of phragmites colonization by a combination of herbiciding, burning and water level management to increase marsh plant diversity. Greater marsh plant diversity will result in improved habitats for waterfowl, wading birds, shorebirds, and aquatic mammals and will also provide aesthetic enhancement and improved recreational and educational opportunities. The wetlands restoration project also includes a plan for long-term operation and maintenance.

The proposed upland restoration project (i.e., #2 above) consists of acquisition and rehabilitation of approximately 60 acres of upland habitat, which the trustees consider to be appropriate compensation for the loss of similar upland acreage due to construction of an impermeable "cap" on the Army Creek landfill. Options available to the Trustees include a habitat restoration agreement, acquisition of property interests such as, easements and/or fee-simple acquisition. Candidate upland sites, both within and outside of the Army Creek watershed, have been identified according to screening criteria (including proximity to Army Creek, presence of wetlands, condition of the site, size/shape, degree of disturbance, potential management problems). A long-term maintenance plan will be developed upon acquisition of the properties. Final selection and acquisition of a parcel(s) will not take place until after public review/comment and subsequent finalization of this Plan.

INTRODUCTION

1.1 Authority

The Comprehensive Environmental Response, Compensation and Liability Act of 1980, as amended, (CERCLA) provides authority for the Environmental Protection Agency (EPA) to seek recovery for response costs from potentially responsible parties (PRPs) associated with the release of hazardous substances. Additionally, CERCLA provides the federal, state and tribal natural resource trustees with authority to seek damages for injury to, destruction of, or loss of natural resources resulting from releases of hazardous substances. The purpose of this provision is to authorize the Natural Resource Trustees (Trustees) to bring and resolve natural resource damage claims and to use recovered damages to compensate the public for losses by restoring, replacing, or acquiring the equivalent of the injured or destroyed resources.

Pursuant to Section 107 (f) (1) of CERCLA and Subpart G, 40 C.F.R. Part 300 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 are the designated natural resource trustees for among other resources the land, fish, wildlife, biota, air, water and groundwater associated with the Army Creek Superfund site. The Governor of the State of Delaware delegated his authority as natural resource trustee for the Army Creek Superfund site to the Secretary of the Delaware Department of Natural Resources and Environmental Control (DNREC) (March 4, 1993). For the purposes of development and implementation of this restoration plan (Plan), the Secretary of DNREC delegated his authority to the Director of the DNREC Division of Fish and Wildlife (March 29, 1993). The Secretary of Commerce's authority has been delegated to the Administrator of National Oceanic and Atmospheric Administration (NOAA) via Organizational Order No. 25-5A. Accordingly, the Trustees for the Army Creek Superfund site are the State of Delaware Division of Fish and Wildlife; U.S. Department of the Interior (DOI); and U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA). The natural resources of concern associated with the Army Creek Superfund site, which were identified by the Trustees according to their respective legal authorities, include migratory and other bird species; anadromous and other fish species; the upland, aquatic and wetland habitats utilized by those species (Army Creek, pond and marsh and the existing landfill habitat); and groundwater.

1.2 Purpose

The purpose of this Plan is to restore, rehabilitate, replace, or acquire the equivalent of those Trust natural resources and/or services injured as a result of impacts from the Army Creek Landfill. The terms restoration, rehabilitation, replacement, and acquisition of the equivalent all refer to acts of human intervention and will be collectively referred to in this plan as restoration. The injuries identified by the Trustees include the following: first, the landfill contaminated nearby groundwater resulting in the lost use of 2-3 million gallons per day which could have been used for the public water supply. Second, the contaminated groundwater was subsequently pumped to the surface and discharged to Army Creek where high concentrations of metals in the surface water and sediments of the creek and pond affected the food chain for migratory birds. The contamination of Army Creek was a factor in the State of Delaware's decision to not allow fish passage features in the tide gate when it was installed in 1987; thereby, excluding anadromous species from Lower Army Creek Marsh. Finally, injuries occurred when approximately 60 acres of upland habitat were destroyed during landfill capping. Cap design requirements significantly restricted habitat diversity.

The goal of this Plan is to restore the injuries identified above (with the exception of groundwater) by increasing the quality and quantity of wetland and upland habitat within the Army Creek watershed. This Plan includes the following objectives:

> Objective 1: Restore tidal exchange to Lower Army Creek to:
> A) increase tidal flushing to improve exchange of inorganic and organic materials and access and use by biota (including anadromous fish species such as striped bass, blueback herring, alewife, and shad); and
> B) increase tidal volume and marsh water levels to improve the distribution and abundance of more desirable tidal marsh plant

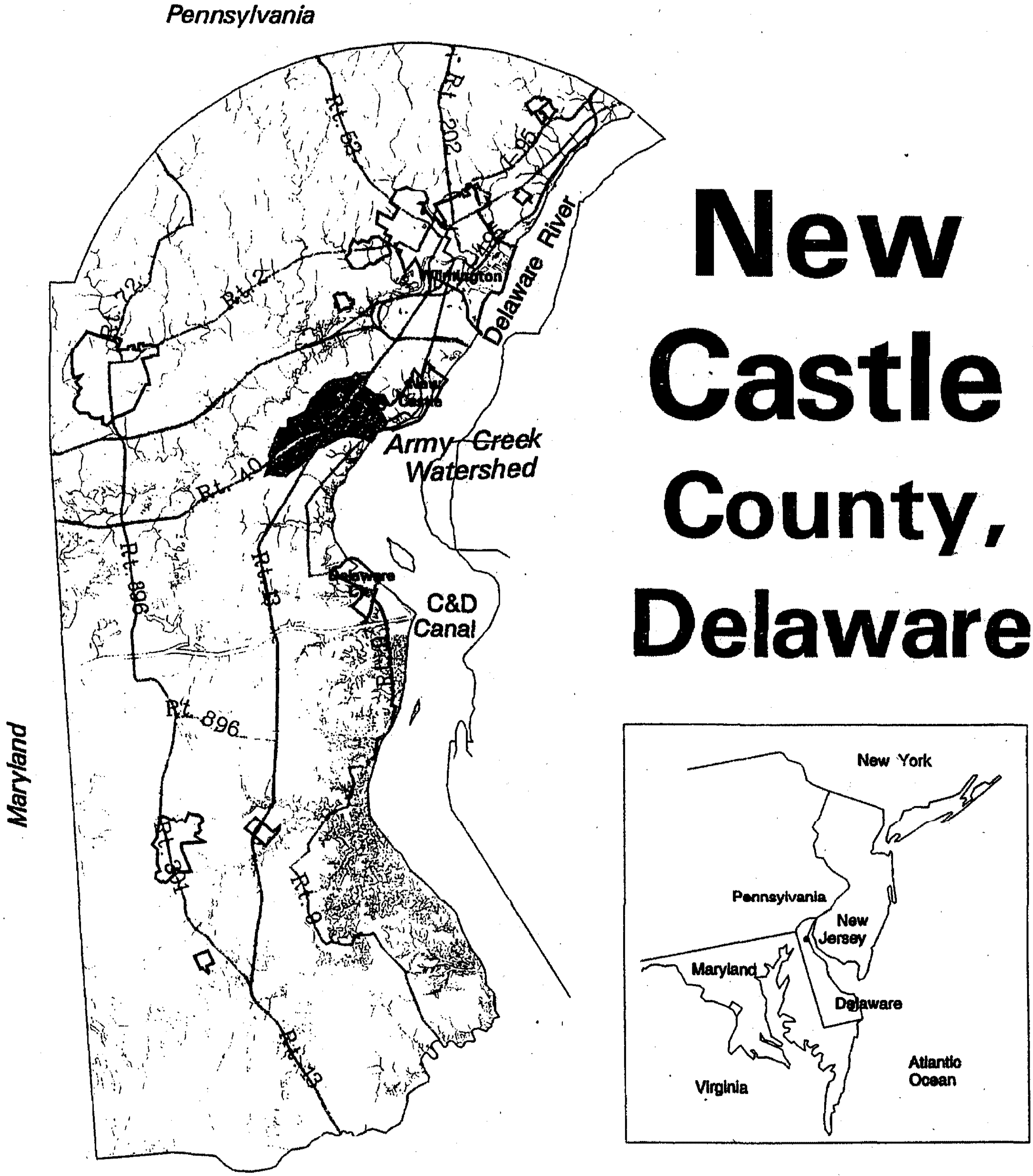


Figure 1. Army Creek site location

species without causing adverse secondary impacts such as, flooding of adjacent property.

Objective 2: Acquire and manage uplands within the Army Creek watershed to:
A) enhance ecological values,
B) encourage wildlife use, and
C) provide a buffer between developed upland areas and Army Creek.

Specifically, these objectives include the following activities: 1) the restoration of partial tidal flow to Lower Army Creek via modification of a tidal gate located at the mouth of the Creek to provide fish passage for anadromous species (striped bass, blueback herring, alewife, and shad); 2) improvement of habitat quality (i.e., Phragmites control and tidal circulation) and quantity (i.e., approximately 225 acres of restored wetlands); 3) acquisition and potential rehabilitation of uplands to benefit wildlife and improve water quality for aquatic species; and 4) long-term operations, maintenance, and protection of the area following restoration.

1.3 Background

The Army Creek Superfund site is located in New Castle County, Delaware (Figure 1). The 60 acre site was a former sand and gravel pit which was operated during the 1960s by New Castle County as a landfill for municipal and industrial wastes. Contaminants leaching from the landfill were discovered in nearby private drinking water wells in 1972. In 1973, the County installed a recovery well system which effectively prevented the contaminated groundwater from migrating to nearby public water supply wells. This removed the immediate threat to human health presented by the site. However, the recovered groundwater was discharged, without treatment, directly into Army Creek which forms the lower limits of the landfill area (Figure 2).

Army Creek, a tributary of the Delaware River, is about 3.9 miles long

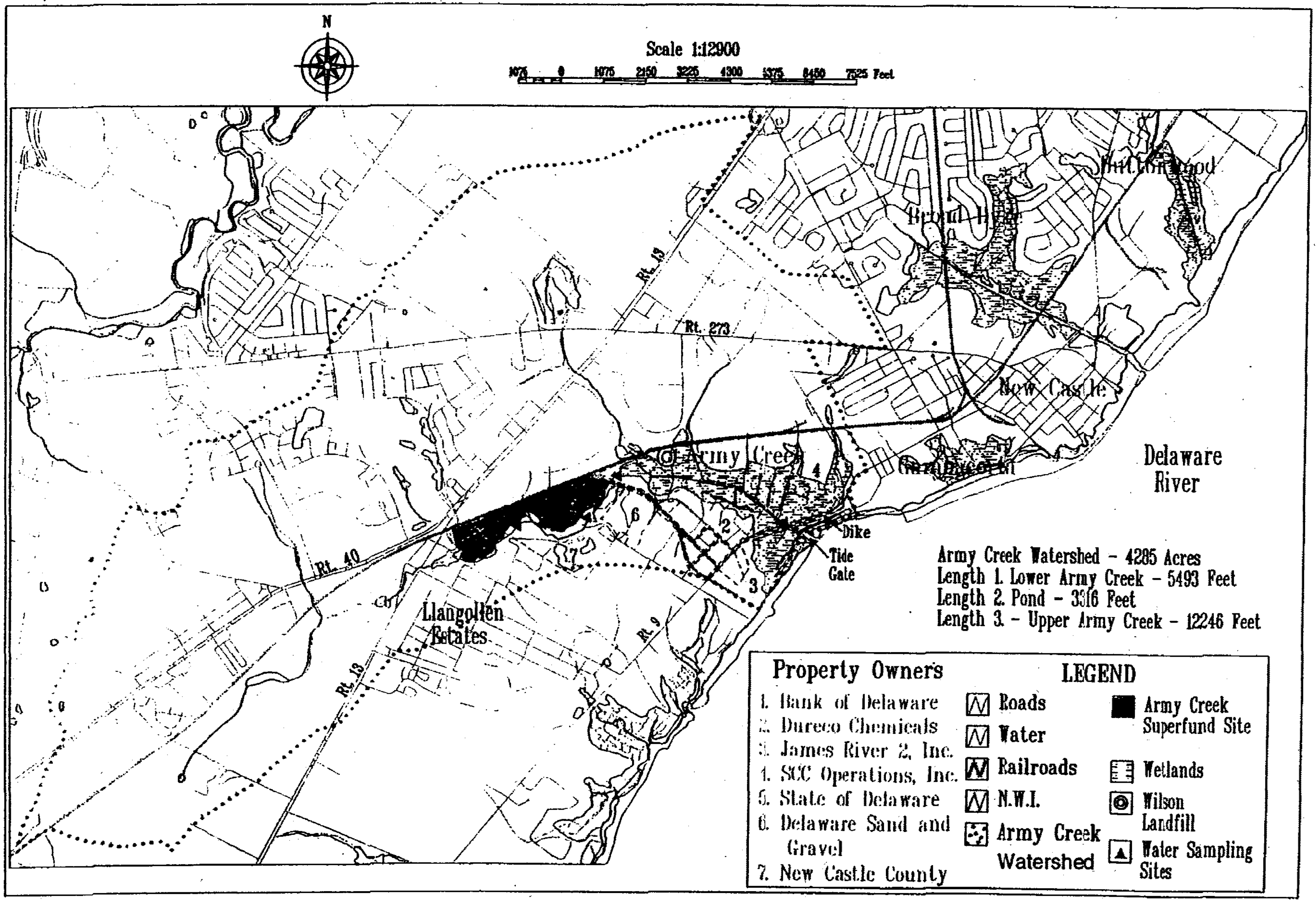


Figure 2. Army Creek Watershed

(Figure 2). Its drainage area is approximately 6.7 square miles. The upper 2.9 miles of the Creek, including a three acre pond, contains freshwater. The salinity of the lower one mile of the Creek, including a 225 acre emergent wetland, ranges from fresh to slightly oligohaline. A tidegate at the mouth of Army Creek limits exchange of water and biota from the Delaware River.

The landfill was placed on the National Priorities List in 1983. A remedial investigation/feasibility study (RI/FS) was completed in 1985 and a Record of Decision (ROD) was issued by EPA in 1986. The remedy selected in the ROD consisted of covering the landfill with an impermeable membrane/soil cap system to prevent precipitation from leaching through the waste and into the groundwater, plus continued operation of the recovery well system. A second RI/FS and ROD in 1989 determined that treatment was required for the recovery well discharges primarily because iron concentrations were greater than the criterion for the protection of aquatic life. The landfill cap was completed in December 1993, and the water treatment facility was completed in January 1994.

In February 1990, representatives of EPA, the State of Delaware and the settling PRPs reached an agreement with regard to the PRPs liability for response costs at the Army Creek Superfund Site. The PRPs requested that the Trustees grant a covenant not to sue for natural resource damages associated with the Army Creek site. At that time the Trustees entered into negotiations. Based upon a review of the litigation risks associated with the Trustees' claims, EPA's proposed remedial activities at the Army Creek site, a review of the resulting past and residual injuries associated with these resources and a review of the loss of these resources, the Trustees agreed to a monetary settlement. The proposal provided for on-site restoration actions, off-site habitat development and a monetary settlement for injuries associated with groundwater as reasonable compensation for losses to public trust resources.

On September 18, 1990, 18 PRPs entered into a Consent Decree to implement clean-up actions and reimburse the EPA for past response costs. The Consent Decree also required the PRPs to deposit $800,000 into a trust fund of which $200,000 was to be used solely by the State of Delaware for groundwater protection and restoration and $600,000 was to be used for habitat restoration by the Trustees. This restoration plan addresses habitat restoration only.

Upon approval of the Consent Decree by the court, it became the responsibility of the Trustees to plan and implement restoration actions, using the settlement funds. Army Creek was one of the first natural resource damage settlements requiring joint implementation of a restoration plan by three government entities. To implement the settlement the Trustees executed a Memorandum of Agreement (MOA) on October 22, 1991.

The MOA established among other things: 1) the division of settlement monies among the three government entities, 2) a repository for the settlement monies until spent, and 3) the Army Creek Site Natural Resources Trustee Committee (Trustee Committee) to serve as the decision making body for issues relating to the restoration of joint Trustee resources. Each government entity designated one voting member and an alternate to the Trustee Committee. The MOA requires consensus decision making by the Trustee Committee.

Public participation in the development of this restoration plan has been facilitated in three ways. First, pursuant to Delaware law, all restoration planning meetings conducted by the Trustee Committee were declared open to the public and advertised in the local newspapers. Second, the procedure established by the National Environmental Policy Act (NEPA) (See Appendices A and B), was followed in developing the Plan. NEPA requires a notice and comment period to allow the public to have input into the development of the restoration plan. Third, an administrative record, consisting of the restoration plan and documents relating to its development, has been compiled and is available for review at the DNREC New Castle Office.

1.4 Natural Resource Trustee Committee Actions

In 1992, the Trustee Committee established a Technical Advisory Committee (TAC) to investigate the level of contamination within Army Creek to determine if restoration could be undertaken on-site. A Report of the TAC on Army Creek Contaminant Issues (November 1994) recommended on-site resource restoration of Lower Army Creek, below the Pond, (Figure 2) because contaminant levels there were below those thought to cause adverse biological effects. The report also recommended delaying any decision regarding restoration of the Pond and Upper Creek until after completion of EPA's periodic review. To evaluate the anticipated environmental effects associated with on-site restoration and to comply with the NEPA, DOI, with the assistance of NOAA, drafted an Environmental Assessment (EA) which was released for public review and comment in January 1995. No comments were received. A Finding-of-No-Significant-Impact was made.

The EA reviews alternative restoration plans and explains reasons for the selection of the preferred alternative. The alternatives considered were: 1) No Action, 2) Restoration of natural resources at a site(s) outside of the Army Creek watershed which are equivalent to those which were injured or destroyed on-site, and 3) On-site restoration of injured or destroyed natural resources in the Army Creek watershed. The preferred alternative of on-site restoration within the Army Creek watershed was selected.

1.5 PLAN ORGANIZATION AND COMPLIANCE

In addition to the introduction, this report consists of five major sections and four appendices as follows:

Section 2.0 contains the wetlands and upland restoration plans. These plans address the restoration objectives presented in section 1.2.

Section 3.0 provides the monitoring plans for Lower Army Creek wetlands and upland sites. These plans describe how the sites will be monitored for mid-point correction and determination of a successful end-point.

Section 4.0 specifies how the restored sites will be operated and maintained and designates responsibilities for such.

Section 5.0 presents budgetary allocations of the settlement monies.

Appendix A contains the Environmental Assessment (EA) and two attachments--Upland Selection Criteria and Report of the Technical Advisory Committee on Army Creek Contaminant Issues. The EA considers whether or not restoration should occur on-site (i.e., within the Army Creek watershed) or off-site, and if on-site over what portion of the watershed.

Appendix B addresses compliance with the National Environment Policy Act (NEPA) concerning wetland and upland restoration projects and their long-term operations and maintenance.

Appendix C details the existing and proposed water control structure. The costs and schedule for this new structure are elaborated in this appendix.

Appendix D contains the proposed treatment process for phragmites control along with treatment costs.

Appendix E contains an abbreviated Wetland Monitoring Plan

2.0 Army Creek Restoration Project

2.1 Wetlands Restoration (Lower Army Creek)

2.1.1 Water Management Plan

The objective of this water management plan is restore tidal exchange to Lower Army Creek to increase tidal flushing and volume (See Figures C-1 and C-2 in Appendix C). Greater tidal flushing between Army Creek and the Delaware River will result in the following benefits:

* Improved water quality in Lower Army Creek and adjacent marsh;
* Flushing of nutrients, detritus, and sediments;
* Increased filtering and nutrient uptake by wetlands;
* Access to spawning, nursery, feeding and/or refuge habitats for diadromous and estuarine species
* Improved wetlands habitats for waterfowl, wading birds, shorebirds, and aquatic mammals;
* Increased structural complexity of shallow-water habitat;
* Suppressed growth and reinvasion of Phragmites;
* Reduced areal extent of mosquito breeding habitats;
* Increased predation on mosquitoes by larvivorous fishes (i.e. mosquito-larvae-consuming fishes); and
* Aesthetic enhancement and improved recreational and educational opportunities.

I. Scope of water management problem in Army Creek

The existing water control structure at Army Creek Marsh consists of five one-way flapgates that only allow outflow discharges of accumulated upland runoff water from the marsh. No tidal inflows into what should be a tidal marsh are permitted to occur (although some might occasionally happen if one or more of the flapgates becomes accidently obstructed in an open position during rising tides). The history of water management at Army Creek is similar to several other formerly tidal freshwater or brackish marshes along the lower Delaware River in Delaware (and at many other locations in the mid-Atlantic region). For purposes of flood prevention and development uses of low-lying areas for residences, businesses, industry or agriculture, marsh-adjacent upland areas (that were occasionally subject to tidal flooding during unusually high tides or storm surges) were "protected" by excluding all tidal inflows into the marshes, thereby eliminating a major cause of undesirable flooding. At many sites, this tidal inflow exclusion has gone on for decades if not centuries. Of course, this practice has led to the disruption of many important ecological and environmental processes involved in marsh-estuarine interactions, and has also caused degradations to ecological structure and biotic communities within the marsh.

In areas where upstream "leaky" landfills or other sites having contaminant release problems present potentially significant threats to water quality of the Delaware River, exclusion of tidal inflows and associated tidal exchanges becomes somewhat desirable, and is partially responsible for some of the current water management practices at some of these locations (e.g. Army Creek Marsh, Red Lion Creek Marsh). The recent refurbishing in 1987 of Army Creek's water control structure has an engineering design that both prevents flooding by riverine tidal waters of developed areas (the primary concern is for Rt. 9), and which also prevents penetration of tidal waters into Army Creek Pond or upstream Army Creek, where Superfund-site contaminants are most problematic. Until the causes of such contamination are remediated, for the health of estuarine systems it's often not desirable to have tidal exchanges in these contaminant-affected watersheds. Thus, restoring ecological structure and function to tidally-excluded marshes that are also in the same basins where significant upstream contaminant problems occur should involve not only the physical reintroduction of tides, but also abatement or remediation of the substantive upstream contaminants.

The primary problem of lack of tidal water in Army Creek Marsh is further exacerbated by a diminution of upstream runoff waters, through extractions or diversions of surface waters in Army Creek's developed upper watershed, and by a lowering of groundwater inputs by both upstream well extractions and groundwater pumping associated with contaminant containment and remediation at the Army Creek Superfund site. In aggregate, exclusion of tidal inflows, and to a lesser extent upstream water withdrawals or diversions, have essentially led to Lower Army Creek Marsh being a "water deficit" or "dry" wetlands, relative to what should be the marsh's natural hydroperiod as a riverine tidal freshwater/brackish marsh.

Army Creek Marsh's relative lack of water, in terms of frequencies, durations and areal extent of tidal inundations and heights of marsh water levels, has caused many ecological and environmental problems -- e.g. elimination of marsh-estuarine interactions for water quality effects and sediment budgets; elimination of spawning, nursery, foraging and refugia for estuarine and anadromous fishes; severe encroachment of robust, thick monotypic stands of phragmites over 90% of the lower marsh, lowering wetlands wildlife habitat values and decreasing the marsh's aesthetic appeal; diminution of permanent shallow water habitats in the marsh, lowering habitat values for waterfowl, aquatic furbearers, fishes and aquatic invertebrates; and enhanced mosquito production following rainfalls, necessitating more chemical insecticide use. Many of the restoration goals and objectives of the Restoration Plan are dependent upon implementing new hydrologic management practices within the marsh; if we can get the hydrology "right," many restoration goals and practices will fall into place.

Even though Army Creek Marsh can best be described as a "dry" wetland relative to what it should be, there are still occasional problems with flooding of developed property within the marsh, essentially limited to flooding of Rt. 9's surface which traverses the lower marsh, particularly on the north side of the Rt. 9 bridge. The relatively low elevation of Army Creek's marsh surface in relation to tidal datums in the adjacent Delaware River (i.e. most of Army Creek Marsh's surface is below mean sea level, 0.0 ft NGVD) limits the duration when water levels in the Delaware River are low enough to permit water discharges from the marsh (gravitational outflows can only occur about 4 hours out of each 12.5-hour tidal cycle). This limitation on discharge durations, combined with the numbers and sizes of the flapgates, sometimes causes accumulated upland runoff in the lower marsh to back-up, not being able to be discharged fast enough into the river to avoid flooding problems for Rt. 9. The heavier the rainfall, the faster the runoff enters the lower marsh basin, and the longer that storm conditions prolong elevated river heights preventing or limiting marsh outflows, the worse the flooding problems become for Rt. 9, in terms of both height and duration of flooding. Elaborations upon the scope of this flooding problem for Rt. 9, and how it might be resolved, are discussed elsewhere in the Restoration Plan.

II. Alternatives Considered and the Proposed Action

Achievement of the environmental objective, listed in Section 1.2, will depend upon successful management of marsh basin waters, both tidal (from Delaware River) and upland runoff. To assess the best water management strategy to achieve this objective, four alternative water management practices were examined. They are:

1. No action,

2. Uncontrolled (unmanaged) tidal flood-and-ebb,

3. Maximize marsh surface inundation, and the

4. PROPOSED ACTION -- Controlled (managed) tidal exchanges and marsh water level heights.

Each alternative is described in more detail below.

1) NO ACTION.

a) Description -- Make no modifications to the existing water control structure, which consists of 5 one-way flapgates which exclude almost all tidal flooding from the Delaware River, and discharge any upland runoff accumulated in the marsh from the marsh to the Delaware River twice per day. The prevention of tidal floodings and the rapid discharges of upland runoff keeps much of the marsh surface of lower Army Creek Marsh relatively dry, which minimizes concerns about floodings of developed property. The no action alternative is to continue with this water management strategy.

b) Consequences -- To meet the objectives, we cannot continue to maintain an abnormally dry marsh. An isolated marsh will have little benefit as spawning, nursery or feeding areas for estuarine or anadromous fishes. Shallow pool habitats beneficial to juvenile fishes, aquatic invertebrates, and foraging waterbirds are limited. The excessively dry conditions were a major factor in the extensive spread of dense phragmites cover over the marsh basin. The dry conditions are a major factor in perpetuating phragmites cover, lowering values of the marsh for wildlife habitat and estuarine detrital food webs, while decreasing aesthetic appeal of the wetlands. Perpetuating exclusion of almost all tidal exchanges between the Delaware River and marsh eliminates biogeochemical interactions and processes that normally occur between tidal wetlands and the open estuary. An excessively dry marsh creates mosquito-breeding problems following a rainfall event, when surface depressions isolated from access by larvivorous fishes become breeding pockets. Concerns with flooding of developed property would continue to be minimized.

2) UNCONTROLLED TIDAL EXCHANGES.

a) Description -- Remove the one-way flapgates from the existing water control structure and let Delaware River tidal waters flood-and-ebb into Army Creek basin in uncontrolled (unmanaged) fashion. The marsh's hydroperiod (flooding frequency, duration, height) would be determined solely by the varying tidal water level heights in the Delaware River in relation to surface elevations in the marsh and upland runoff conditions, with no hydroperiod management performed.

b) Consequences -- Although there will be benefits derived from this alternative, the overwhelming prohibition against this option will be flooding of Rt. 9 and surrounding private property. Flooding of developed property, particularly the roadbed and surfaces of Rt. 9, will create a serious transportation nuisance and safety problems at almost every high tide and major storm.

3) MAXIMUM POOL LEVELS.

a) Description -- Manage tidal exchanges and upland runoff to create and maintain extensive marsh surface inundations, maximizing the durations of surface floodings, with water depths ranging from relatively shallow (e.g. several inches) to relatively deep (e.g. several feet). This alternative produces a large, permanent, standing water pond controlled by a tidegate. A modified water control structure would restrict ebb tide discharges except during times of heavy upland runoff to prevent flooding.

b) Consequences -- Would provide good habitat for migratory waterfowl at certain times of the year, but at the expense of foraging habitat for wading birds and shorebirds. Limiting tidal exchanges will restrict access to the marsh by estuarine and anadromous fishes. Even this limited tidal exchange scenario would be an improvement over the current water management scheme. More permanent, deeper water areas will benefit aquatic invertebrates, but be detrimental to some wetland-estuarine biogeochemical interactions and processes. Limited tidal water exchanges will also cause some water quality problems, particularly regarding dissolved oxygen levels during summer nocturnal periods.

Prolonged inundation will cause a loss of emergent wetlands vegetation and reduce structural habitat diversity. Managing the lower marsh basin as a permanently flooded pool decreases mosquito egg-laying sites and provides the best non-chemical control strategy for mosquito abatement. Long-term phragmites suppression following initial eradications is best achieved with a maximum pool strategy, in that new phragmites would not reestablish from seed, nor would seedling survival be high.

Maintaining a relatively stable, albeit high, marsh water level will not present flooding problems for developed property, as long as good control can be maintained over upper threshold heights. Many people would find a large expanse of shallow open water, with fringes and sparse patches of emergent wetlands vegetation, to be aesthetically pleasing.

4) PROPOSED ACTION -- CONTROLLED (MANAGED) TIDAL EXCHANGES AND VARIABLE MARSH WATER LEVELS.

a) Description -- Manage marsh water levels while preventing excessive flooding by controlling tidal exchange between Lower Army Creek Marsh and the Delaware River. The existing water control structure will be modified by adding automated tidegates which respond to various water level cues on both the marsh and Delaware River sides of the structure. These modifications should permit rapid adjustments of the direction, frequency and duration of tidal flows into and out of the marsh, and rapid adjustments in marsh water level heights.

This modified structure will be operated according to a water management schedule that optimizes functions and values of natural resources within the marsh without flooding Rt. 9 and private property.

The manner in which tidal exchanges and marsh water levels are managed may vary greatly on a seasonal or more frequent basis. Detailed descriptions of the actions needed to modify the water control structure and details for water management schedule (over an annual cycle) are presented in Appendix C.

b) Consequences -- The proposed action will achieve the widest range of environmental benefits of any of the four alternatives considered. The proposed action's enhanced tidal exchanges will allow ingress and egress of estuarine and anadromous fishes to the marsh for spawning, nursery, feeding and refuge, and enhance habitat quality. Also, it reestablishes biogeochemical interactions and nutrient and detrital exchange processes between the marsh and open estuary.

This alternative will increase shallow water habitat diversity, improving habitat quality for aquatic invertebrates, fishes, and waterbirds. Because average marsh water levels will be higher (*ca.* 0.5 ft. higher) than existing conditions, diverse submerged aquatic communities will be established in the marsh's shallow ponds and surface depressions. Being able to elevate or maintain higher marsh water levels will promote non-insecticide control of mosquitoes and non-herbicide suppression of phragmites. Continuous inundation in areas of the restored marsh will most effectively control mosquito production and phragmites growth.

In order to ensure shallow-water habitat diversity within Lower Army Creek Marsh, and to promote biological control of mosquitoes by larvivorous fishes, it may be necessary to excavate shallow ponds and ditches, disposing the excavated spoil as a temporary, thin slurry over adjacent marsh surfaces (see Lower Army Creek Marsh -- Vegetation Management Plan). The excavated ponds will serve as reservoirs of permanent water during marsh drawdown periods, which will help to maintain submerged aquatic vegetation within the marsh while providing refuge for aquatic invertebrates and fishes; the excavated ditches will provide access for larvivorous fishes to isolated mosquito-breeding sites. The need to install any ponds or ditches will be determined after the tidal water management plan is initiated. If it is determined that such modifications are needed or desirable, the Trustees will contract with DNREC's Division of Fish and Wildlife (Mosquito Control Section) to selectively install the ponds and ditches.

Using water management practices to control recolonization by phragmites in areas where marsh surfaces are subject to alternate flooding and exposure will probably be most effective during times of seed germination or young seedling growth. Continuous flooding of these areas for several weeks during critical growth periods (e.g. mid-spring) will suppress phragmities recolonization. Suppressing phragmites recolonization by a combination of herbiciding, burning (see Vegetation Management Plan), and management of water levels will increase the diversity of marsh plant species to include pickerelweed, arrow-arum, smartweeds, three-squares, rushes, sedges, cattails and mallows. Being able to control maximum marsh water levels will help avoid flooding of developed property except during unusual circumstances.

Flooding

The existing tidegated water control structure built in 1987 excludes tidal inflow into Army Creek Marsh, as did previous water control structures at Army Creek. Most of Lower Army Creek's marsh surface elevations are below mean sea level (i.e. below 0.0 ft NGVD), which limits discharging Army Creek's marsh waters into the Delaware River to less than one-half the duration of each tidal cycle. We estimate that whenever Lower Army Creek Marsh now comes to "flood stage" or 100% "full pool" level (i.e. almost all marsh surfaces are inundated with shallow water), as is occasionally caused by upland runoff events following storms, the Delaware River's water levels are low enough to allow marsh water outflows for only about 4 hours out of each 12.5-hour tidal cycle. This condition often leads to shallow flooding of Rt. 9's road surface, especially on the north side of the bridge where the roadbed was not elevated during the bridge's recent repair. During severe storm events, such as a 100-year storm, water levels within the lower marsh will rise and flood Rt. 9, with water backing up to also flood Army Creek Pond and portions of upper Army Creek. Fortunately, there are no homes, businesses or other developed structures of consequence located at elevations lower than the 10-foot NGVD contour line (FEMA's floodline demarcation for 100-year storm events), so the only concern with flooding for almost all storm events will be impacts to Rt. 9.

According to DELDOT engineers, the existing five-flapgated water control structure was designed to reduce flooding problems within the marsh in comparison to past conditions, by discharging upland runoff through larger diameter pipes than used in previous versions of the control structure, while still excluding tidal inflows. The proposed modified structure will have retrofitted automated vertical lift gates that will allow controlled or managed tidal inflows of Delaware River water into the marsh. These tidal inflows by themselves will never be permitted to raise marsh water levels above a desired shallow, 100% "full pool" level in Lower Army Creek Marsh. In terms of basin discharge capacity following storm events and upland runoff, the structure's proposed modifications will have little to no effect on marsh water discharge rates or discharge times in comparison to the existing structure, so concerns with potential flooding of developed property should not increase beyond current concerns (which are fairly minimal with exception of Rt. 9's road surface). DELDOT proposes to elevate the 2000-feet section of Rt. 9 north of the bridge that still readily floods, increasing roadbed height by approximately 2 feet. When done, this will permit full implementation of the Restoration Plan's proposed hydrographic regime without flooding the roadbed. Following completion of this roadbed work, it's anticipated that the major effect of the proposed restoration water management plan on "flooding" will be more frequent high water-level events in the lower marsh after storm runoffs, because "normal" lower marsh water levels in the restored marsh will be purposely kept somewhat higher and for longer durations than present conditions. However, this should not affect the frequency, duration or severity of flooding problems for developed property beyond what currently exits, and with Rt. 9's eventual elevation, flooding problems in the basin should actually lessen.

In modifying the structure and operation of the existing water control structure, there may be undesirable consequences to not being able to manipulate marsh water levels in event of failure of the structure to operate as designed or modified. The proposed automated vertical lift gates retrofitted to the existing structure will be designed to work in all types of weather, including ice conditions in the river or marsh. Design features will consider what do in the case of a mechanical failure or a physical obstruction to the gates' operating performance (e.g. a log stuck in one of the gates). If the structure's new gates are electrically operated, contingencies will be built in to the design or operation of the gates to deal with electric power loss. The structure will be designed, protected (hardened), secured, checked and operated in a manner that minimizes vandalism problems to the extent practicable. There will be manual override features that will allow the gates to be manually manipulated in event of a gate's loss of its primary mechanical mode of operation, or in event of a power loss if electrically operated. A primary safety design feature will be to be able to close the gates manually under any type of field condition in order to stop incoming tidal flood waters, yet still have the gates be able to discharge accumulated marsh waters as rapidly as possible whenever the river becomes low enough to permit gravitational outflows. These last design features are essentially the current conditions at the structure, so that we'll always be able to return to existing conditions (for better or worse) if so desired.

Benefits

The proposed action will achieve a mosaic of shallow open water interspersed with numerous stands or expanses of emergent vegetation and will create good foraging areas for wading bird and shorebirds. Being able to manage a marsh for these multiple resource objectives, while satisfactorily accommodating some socioeconomic concerns, should create a demonstration area for environmental education purposes.

Permits

c) Regulatory Permits -- It is probable that three types of wetlands permits will be needed to implement the water management plan, for both modification of the water control structure and management of tidal exchanges and marsh water levels.

1) Section 404 wetlands permit (federal) -- if an Environmental Assessment is required for this permit, it is probable that sections of the Restoration Plan fulfill this need.

2) State of Delaware wetlands permit -- Type I or II.

3) Section 401 water quality certification (State-issued) -- needed prior to issuance of the Section 404 permit.

The Trustees will work cooperatively with all wetlands regulatory authorities to ensure that all regulatory requirements are met. At the same time, the Trustees hope that the large amount of information contained in the Restoration Plan will serve to expedite all permitting needs.

d) Landowner permission/cooperation -- In undertaking new tidal water management practices affecting privately-owned marshlands in Lower Army Creek Marsh, it will be necessary to have the permission and cooperation of the landowners. This permission or cooperation can be obtained via a water management easement, property donation, or similar device. Since the marsh landowners in Lower Army Creek Marsh are all corporations, and since preliminary contacts have indicated a willingness to cooperate in some manner in the environmental restoration, the Trustees do not anticipate serious landowner problems in implementing the water management plan. The actions that the Trustees are planning to take should increase the values of these wetlands as wetlands. The general status of landowner permission or cooperation for marsh properties affected by the water management plan is reviewed in another section of the Restoration Plan.

III. Other Water Management Needs

1) Nonpoint-Source (NPS) Pollution -- In order to address other issues that may be affecting water quality in Army Creek's wetlands, in addition to Superfund-site contaminants and lack of tidal exchanges, it is necessary to at least examine the extent and magnitude of NPS pollution problems in Army Creek's watershed. The origins of diffuse, NPS pollution may be from road runoff, urban stormwater discharges, agricultural drainage, etc. The Trustees will work with DNREC's Division of Water Resources to examine and promote the clean-up of road runoff contaminants associated with the passages of Rts. 9 and 13 over Army Creek. The Division is currently in the process of developing a NPDES

permit (Section 402), giving requirements for New Castle County and DELDOT to follow to alleviate road runoff contaminants. The details for how this evolving NPDES program might apply to reducing road runoff problems on Rt. 9 or Rt. 13 crossings, in terms of problem identification and implementing voluntary or enforceable preventive or remedial actions, cannot yet be stated; however, the Trustees express a desire that these two road crossovers be a focus (if possible) for future implementation of the new NPDES pollution reduction program. For other NPS pollutants, the Trustees will contract (for about $10,000) with the New Castle Conservation District (NCCD) to perform an NPS pollution assessment of the Army Creek watershed, identifying the most serious NPS pollution issues within the basin, and recommending site-specific actions that should be undertaken to reduce or eliminate the major problems. Implementation of preventive or remedial actions to lessen NPS pollution could then be undertaken through various State or State-directed federal programs -- e.g. focused applications of Delaware's Erosion and Sediment Control Act (sediment and stormwater regulations); implementation of voluntary or enforceable actions associated with the Section 319 (federal Clean Water Act) or Section 6217 (federal Coastal Zone Management Act) NPS programs; or implementation of Best Management Practices through auspices of the New Castle Conservation District. The Trustees will not spend Natural Resources Damages monies to actually remediate these NPS pollution problems, but will use the NCCD's study results to encourage NPS clean-up via appropriate authorities or processes.

2) Rt. 9 Roadbed -- To fully implement the proposed water management plan for Lower Army Creek Marsh, particularly in regard to managing water levels at or near maximum proposed heights, it may be necessary to await future elevation by DELDOT of the Rt. 9 roadbed. The Rt. 9 bridge and its southside roadbed were elevated by the end of spring 1993, to heights where the proposed marsh water management will not cause transportation problems. However, the relatively low, northside roadbed may still be somewhat problematic at full pool levels (not in terms of road surface flooding, but perhaps in terms of roadbed stresses). According to DELDOT, the northside roadbed is also planned for elevation within the next 2-3 years, awaiting the appropriate funding cycle. The Trustees will work closely with DELDOT in seeing this highway project pursued to completion, and in managing marsh water levels on an interim

basis until the northside roadbed is eventually raised. It is important that DELDOT recognizes the need for this roadwork in order for the Trustees to eventually fully achieve the goals for many aspects of the marsh's restoration, and that DELDOT makes this project a high priority in their planning and implementation.

2.1.2 Vegetation Management Plan

The objective of this vegetation management plan is to restore the distribution and abundance of more desirable tidal marsh species which will result in the following benefits:

* Decreased abundance of phragmites;
* Increased species diversity of marsh plants;
* Improved wetlands habitats for waterfowl, wading birds, shorebirds, and aquatic mammals; and
* Aesthetic enhancement and improved recreational and educational opportunities;

I. Scope of phragmites problem in Army Creek.

About 210 acres of Lower Army Creek's 225 acres of wetlands are monotypic stands of phragmites. These stands have supplanted other wetland plant species more desirable as food and cover. Like many areas of coastal New Castle and Kent Counties in Delaware, Army Creek Marsh had relatively little phragmites cover as recently as 20-30 years ago. The Delaware General Assembly has declared phragmites to be a nuisance species and therefore may be controlled or eradicated. The Trustees propose to eradicate, to the extent practicable, the existing phragmites cover over approximately 200 acres. More desirable wetland plants will naturally volunteer (from dormant seedbeds, aerial seed dispersal, or vegetative outgrowth) after phragmites eradication, and might include species such as pickerelweed, arrow-arum, smartweeds, three-squares, rushes, sedges, cattails and mallows. The types of species to become established will depend in part upon the effects of the proposed water management plan. Not all phragmites cover will be attempted to be eradicated. In areas where phragmites is helping to stabilize and maintain levees or dikes, no eradication will be done. In marsh basin peripheral streams or upstream areas where phragmites is growing in the channels, helping to filter nutrients and sediments, no eradication will be done unless there is a drainage blockage problem. Leaving phragmites initially untreated along levees or in peripheral drainage ditches might serve as a source for some future recolonizations of phragmites into the open marsh (particularly via vegetative outgrowths); however, wherever this might be observed and determined to be undesirably excessive, localized control methods ("spot treatments") could be used.

II. Alternatives considered and the proposed action.

In order to try to eradicate phragmites from much of Lower Army Creek Marsh, there are only a few management techniques available for practical consideration:

1. No action -- Take no steps to directly control phragmites; let the phragmites respond to whatever water management practices are implemented for other purposes.
2. Flooding -- Use water management to raise marsh water levels high enough and for long enough duration to try to "drown" the established phragmites stands.
3. Mowing -- Cut down the phragmites, and leave the mowed culms on the ground to decay, or physically remove the mowed culms from the marsh, or burn the mowed culms on-site.
4. Burning -- Perform a prescribed burn of the standing phragmites culms.
5. Physical removal (mow/burn) and shallow flooding -- physically remove aboveground portions of phragmites stands by mowing or prescribed burning, followed by prolonged surface flooding, to try to kill both aboveground and belowground portions of the stands.
6. Herbicide treatment -- Apply an appropriate herbicide to kill the phragmites stands.
7. PROPOSED ACTION -- Herbicide-and-burn treatment -- Apply an appropriate herbicide to kill the phragmites, and then follow with prescribed burning of the standing dead culms.

The seven alternatives considered are described in more detail below. Descriptions of the environments (socioeconomic, geology, hydrology, ecology, land use) potentially affected by the alternative actions are given in the Restoration Plan's Environmental Assessment.

1) NO ACTION.

a) Description -- Take no actions to directly or purposely control the existing phragmites cover. Let the phragmites stands respond to whatever water management practices are implemented in the marsh for other purposes.

b) Consequences -- This action will not eradicate the extensive phragmites cover, since there are no effective water management practices involving freshwater or low salinity tidal waters (such as what is found in the adjacent Delaware River, from 1-5 ppt).

These extensive stands of phragmites result in a poorer quality, less accessible source of detritus for estuarine food webs. The dense, tall phragmites has replaced shallow-water open habitats to the detriment of many fish and wildlife species.

2) FLOODING.

a) Description -- Purposely elevate marsh water levels for a long-enough duration to try to "drown" the existing phragmites stands. In order to kill phragmites, it is first necessary to kill the underground portions of the plant (roots, rhizomes); if only the aboveground portions of phragmites are killed or removed, the stand rapidly regenerates itself from underground parts. In order to kill a stand by prolonged flooding, it is first necessary to block the "snorkel" effect of aboveground stems of the plant, which serve as uptake sites and conduits for oxygen to belowground plant parts; in theory, this might be achieved by total submergence of all aboveground stems for prolonged durations.

Primary sources of water to potentially elevate marsh water levels in Army Creek Marsh would come from Delaware River tidal inflows and/or retention of upland runoff. Allowing Delaware River tidal waters to flood into Army Creek Marsh will introduce slightly higher salinity waters (from 1-5 ppt) than what are usually found in the marsh (from 0-2 ppt). In order to achieve and maintain the desired volumes and depths for prolonged surface inundations, most of the water volume would have to come from Delaware River tidal waters captured during a flood tide(s) and retained at appropriate depths during all ebb tides. Reliance upon retention alone of upland runoff waters to provide adequate inundation depths across the marsh surface (in an attempt to "drown" the phragmites) might be adequate during seasons or periods of high rainfall and runoff, but would be unsatisfactory during seasons or periods of average rainfall or droughts.

b) Consequences -- To "drown" established, mature stands of phragmites, it would be necessary to raise water levels in Army Creek Marsh perhaps 10-15 feet above existing marsh surface and maintain this elevated level for several weeks or months. However, this is NOT possible because of flooding and closure of Rt. 9 and flooding of other developed property around the basin. Such flooding would also cause severe disruptions to other aspects of marsh structure and function. The Delaware Game and Fish Commission attempted but failed to eradicate existing, mature phragmites stands via flooding in the 1950's, in which stands were flooded with oligohaline waters to depths of 4 feet deep for 6 months continuous duration. Laboratory and field tests by the University of Delaware demonstrated that flooding, following another eradication technique, could successfully control phragmites only in the seed set or seedling growth stages.

In some locations the introduction or reintroduction of high salinity estuarine waters can negatively effect but not totally eradicate phragmites. This occurs at salinities 15-30 ppt, higher than those in the Delaware River adjacent to Army Creek. Thus, the reintroduction or flooding of tidal riverine waters into Army Creek Marsh would not be expected to have any salinity-associated inhibitory effects on the site's phragmites cover or growth.

3) MOWING.

a) Description -- Using appropriate heavy machinery capable of working in wetlands (e.g. a flail mower), cut aboveground phragmites culms as close as possible to ground level, and then let the mowed culms decay in place, or physically remove the mowed culms from the marsh, or burn the mowed culms on-site.

b) Consequences -- Mowing yields only temporary control of phragmites, since belowground portions of the stands would not be killed, leading to rapid regrowth and pre-mowed conditions within a single growing season. Mowing activities will cause temporary population level effects on some marsh surface wildlife. Mowing will leave dead culms to decay in place and create severe dissolved oxygen problems for aquatic organisms in the marsh. Removing the mowed material from the area will be costly, labor intensive, and damaging to marsh surfaces. Trying to burn mowed culms decumbent on wet marsh surfaces will be difficult.

Additionally, the practical problems of trying to mow large acreages of marsh require the use of heavy machinery. Such machinery would have to generate very low ground pressures to be able to work over soft, unstable bottoms; the machinery should be able to float and be driven or propelled in order to cross larger channels and ditches. This alternative is expensive and does not permanently eradicate the phragmites.

4) PRESCRIBED BURNING.

a) Description -- Conduct a prescribed burn of the standing phragmites cover in Lower Army Creek Marsh, preferably in late winter or early spring when marsh conditions are dry, wind conditions can be used to advantage, and fresh, green regrowth has not yet started. The burn would be conducted by Delaware Division of Fish and Wildlife personnel in cooperation with local fire companies.

b) Consequences -- Burning temporarily controls aboveground portions of phragmites stands, leading to rapid regrowth and pre-burn phragmites conditions within a single growing season. Phragmites marsh burns are not "deep" burns, so belowground plant parts are not killed. Thus, burning will not be a satisfactory control method. Burning will have temporary population level effects on marsh surface wildlife by forcing some organisms to leave, some to seek refugia, and some to perish. Other minor problems with burning include temporary air pollution problems, the potential for inadvertent burning of developed property in the unlikely event a burn gets out of control, and a temporary disruption caused by smoke or flames to traffic traversing the marsh on Rt. 9.

5) PHYSICAL REMOVAL (MOW/BURN) AND SHALLOW FLOODING.

a) Description -- A combination of actions, involving mowing or burning the aboveground portions of a phragmites stand (alternative actions #3 or #4), followed by prolonged marsh surface flooding with shallow waters to try to kill ("drown") the belowground portions of the stand (alternative action #2). Because the aboveground portions of the stand would be first removed by mowing or burning, thereby removing as much as possible the "snorkel" mechanism for transfer of oxygen to belowground parts, it will not be necessary to flood and maintain marsh water levels at relatively deep depths in order to submerge any remaining aerial parts and cover the belowground biomasses. Rather, much shallower flooding (e.g., 1-2 feet) will cover any remaining aboveground biomass.

b) Consequences -- The consequences of physical removals via mowing or prescribed burning were previously discussed under alternative actions #3 and #4, and would also apply here. The consequences of flooding and prolonged inundations were previously discussed under alternative action #2, and would also apply here, with exception that the practical problems associated with maintaining marsh water levels at relatively deep depths would be avoided (e.g., potential flooding problems to Rt. 9 will be avoided).

The efficacy of these combined techniques in eradicating phragmites is unlikely. Even without the aboveground parts of the plant (e.g. if they were to be removed or shortened by mowing or burning), it is unknown for how long marsh surface inundations with overlying waters must be maintained before oxygen deprivations or build-ups of toxic metabolites might eventually kill the plant's root-and-rhizome system, which may constitute over half of the total biomass in a phragmites stand. Based upon some preliminary laboratory evidence (University of Delaware), it might take several months or more to kill a stand.

In order for "drowning" to be effective in killing belowground portions of a stand, any oxygen deprivation effects or toxic metabolite effects resulting from standing water conditions would have to occur during the growing season. Another problem in eradicating phragmites is its large underground reserves of nutrients. Any adverse effects of purposeful flooding will occur during the growing season, when belowground portions of the plant rapidly produce aerial shoots. Thus, before a water depth of a few feet (e.g., 1-2 feet deep) might be able to cause any inhibitory effects on phragmites growth during the growing season, the belowground reserves will probably enable surface shoots to grow above the overlying waters.

Reliance upon prolonged inundations with shallow overlying waters to kill the belowground portions of a phragmites stand is tenuous. Thus, the use of shallow flooding with fresh or slightly brackish water for phragmites control will prevent establishment or recolonization of new stands that might occur from seed dispersal and seed set.

6) HERBICIDE APPLICATION.

a) Description -- Apply an appropriate systemic herbicide which will kill the roots and rhizomes of existing phragmites stands. Because of the large acreage and difficult access, any herbicide spraying of Lower Army Creek Marsh would be done by helicopter. Applications would be made at the appropriate time(s) of year to maximize treatment.

b) Consequences -- While there are herbicides that can kill much of an existing phragmites stand, one of the major problems with relying solely upon herbicide applications for control is that there are inhibitory shading effects of standing dead phragmites culms (following spray applications) on the growth of replacement plant species. For this reason it is undesirable to rely on herbicide applications alone.

7) PROPOSED ACTION -- HERBICIDE-AND-BURN TREATMENT.

a) Description -- This alternative involves the combination of a systemic herbicide application and subsequent prescribed burn, repeated annually over 2-3 consecutive years, in order to achieve successful eradication of robust phragmites stands. Detailed descriptions of this proposed treatment process are given in Appendix D. The Delaware Division of Fish and Wildlife has concluded that this approach is currently the best management strategy for phragmites control, in terms of treatment efficacy, environmental acceptability, and practicality. Treatment costs associated with this strategy are presented in Appendix D. Other vegetation management practices that may be desirable to do, in conjunction with the primary proposed course of action, are given in Section IV. Herbicide-and-burn treatment may be improved when followed by water management practices designed to suppress new phragmites growth or inhibit recolonizations originating from seed set.

b) Consequences -- The environmental consequences of the possible effects on non-target organisms of herbicide use and prescribed burning are described in Section III, with a conclusion that any detrimental impacts from either spraying or burning are minimal or tolerable, particularly in light of the net environmental benefits to be gained from successful phragmites eradication. Implementation of the herbicide-and-burn control strategy should result in successful phragmites eradication.

III. <u>Non-target impacts of proposed treatment process</u>.

The formulation of systemic herbicide glyphosate approved by the EPA for use in tidal (estuarine) environments has a non-ionic surfactant, with water used as a carrier; the product's brand name is Rodeo, manufactured by the Monsanto Corporation. The product when used according to label instructions has not been observed to produce adverse effects on marine invertebrates, fishes, birds or mammals. However, glyphosate can be a broad spectrum herbicide in terms of plant effects, so care must be taken to limit its application to targeted areas. Using a helicopter to perform broadcast applications, versus fixed-wing aircraft, helps to keep the product on-target by minimizing target area misses and drift problems. Not all areas of a treated marsh require two or more broadcast applications of glyphosate. Only those areas where regrowth of phragmites is unacceptably excessive by the end of the first complete growing season (which follows the first spray done at the end of summer the year before) will be targeted for a second spray application. Once again, using a helicopter for these relatively smaller areas during second or subsequent sprayings keeps the product more on-target.

An unavoidable side-effect with repetitive, broadcast sprayings of glyphosate during the initial years of intensive phragmites treatment is that the spray applications also kill some or much of many other wetland plant species which have volunteered during each growing season (prior to the late summer herbicide applications). Many of these non-phragmites species would have naturally senesced at the end of the growing season (particularly for annuals established via seed set), and as with the sprayed phragmites their aboveground parts are allowed to stand as dead matter throughout the winter, until the next spring's prescribed burn. The root and rhizome systems of non-phragmites perennial species which volunteered during the first complete growing season (following the initial glyphosate spraying toward the end of the previous summer) will also be affected by a second glyphosate spraying, with their aboveground dead structures also standing until the subsequent spring's prescribed burn.

Delaware-based research and operational observations indicate that colonizations of non-phragmites species are usually sparse during the first growing season following the initial glyphosate spray, but become much more extensive during the second growing season, which follows a second glyphosate application done toward the end of the first complete growing season. Ideally, no further broadcast glyphosate applications are needed after the second spraying. If third or even fourth-year broadcast sprays are needed, there will be some set-backs in establishing extensive covers of non-phragmites perennials, which cannot be avoided until after the need for all broadcast spraying ceases. If only two glyphosate broadcast applications are needed for the intensive treatment phase, non-phragmites cover should start to become extensive during the second complete growing season following start of the treatment program; if three broadcast sprays are needed, extensive non-phragmites cover would not be expected until the third complete growing season following start of the treatment program; in the unlikely event that a fourth consecutive broadcast spray is needed, extensive non-phragmites cover would not occur until the fourth complete growing season following start of the treatment program. Thus, during most of the initial intensive phragmites treatment period, the marsh surface is never colonized during any one year as thickly with non-phragmites cover as it could be, due to the usual necessity for at least one repeat glyphosate application in order to successfully eradicate a very tenacious target species.

In the long-run, these unavoidable spray-associated set-backs in establishing non-phragmites cover are only temporary, ceasing to be problematic after completion of the intensive 2-4 year treatment period (with its repetitive broadcast sprayings). Also, the negative consequences accompanying the need for repeat sprayings are not universally felt by all plant species, since not all wetland plants are equally affected by glyphosate exposure. For example, when some areas of saltmarsh cordgrass (Spartina alterniflora) have been sprayed with glyphosate, done inadvertently or in association with controlling recolonizing phragmites, the contact does not always have deleterious effects, perhaps due to the waxy surfaces of cordgrass leaves.

A potential problem of killing large biomasses of phragmites in a short period of time involves increases in biological oxygen demand within marsh waters, caused by enhanced microbial respiration in association with phragmites decomposition, potentially causing stress or death to aquatic organisms. Burning the dead phragmites culms helps to lessen biological oxygen demand problems by eliminating microbial substrates. The colder seasons prior to burning when the dead phragmites biomass is created and available for microbial decomposition (during fall, winter and early spring) also helps to lessen dissolved oxygen stresses.

The impacts of burning on the marsh are temporary in terms of vegetation recovery and effects on wildlife populations. The rapid and shallow nature of a marsh burn has little effect on muskrat lodges, and is done at a time of year when waterbird nesting is not affected. Prescribed burning of tidal marshes is a commonly-used tool by federal and state wildlife management agencies to promote vigorous new plant growth and retard undesirable successional stages (e.g. to limit shrub incursions), and is widely applied to cordgrass, three-square, and cattail marshes. However, there are undoubtedly at least temporarily adverse effects to some wildlife populations (e.g. voles), and great care must be taken in developed areas in order to avoid unintended fire damage to peripheral structures or property.

The occurrence of Torrey's rush (Juncus torreyi), an S1 State Plant Species of Special Concern (but not federally-listed as endangered or threatened), in a small stand along Rt. 9's roadside presents some concern for its protection when undertaking phragmites control actions. As described in the Restoration Plan's Environmental Assessment, this species has a widespread geographical distribution, extending over most of the eastern United States and Canada and throughout the American Southwest, but is relatively rare wherever it is found. In Delaware to date, Torrey's rush has been located at only two other sites (similar to Army Creek, these other two sites are also thought to be disturbed locations). The roadside stand of Torrey's rush in Lower Army Creek Marsh could be adversely affected by increased water levels (flooding), mowing, burning, herbicide applications, or combinations of two or more of the above. The proposed action for phragmites control of herbiciding-and-burning could locally eradicate Torrey's rush from Lower Army Creek Marsh. Even though this species' occurrence in Lower Army Creek is probably due to the artificial habitat created by the Rt. 9 elevated roadbed traversing the marsh, and even though its habitat was probably grossly disturbed during the process of raising Rt. 9's road surface (done recently on the southside of Rt. 9's bridge), care should still be taken where practicable to try to ensure perpetuation of Torrey's rush during and following phragmites treatment. The portion of the roadbed where the rush is growing could be excluded from both herbidide spraying and burning, particularly since the phragmites cover is not overwhelmingly dominant at the rush's location. However, in conducting the widespread herbicide-and-burn treatments necessary to control the phragmites problem in Lower Army Creek, it may not be possible or practicable to purposely exclude the Torrey's rush site from treatment, or to avoid inadvertently treating the area. If this be the case, then consideration will be given to transplanting as much of the stand as possible to a nearby site not subject to herbiciding or burning, or to establishing a stand at such a protected site from seed or transplants. In event of eradication of the species at its existing location during phragmites treatment, it may be possible to reestablish it at the site from seeds or specimens collected at the site prior to phragmites treatment, or from seeds or transplants taken from other locations. However, the preferred alternative is to avoid if practicable spraying or burning Torrey's rush when the phragmites control efforts are conducted, as long as the success of the control effort is not seriously compromised.

IV. <u>Other vegetation management practices</u>.

While the focus of the Lower Army Creek Marsh vegetation management plan is on phragmites control, other vegetation management measures will be taken. Much of the remaining vegetation management will be undertaken and achieved in conjunction with the water management plan. Water levels and tidal exchanges will be managed to encourage the establishment and maintenance of a diverse, brackish-water (oligohaline) tidal wetland community composed of naturally volunteering and occurring vegetation (e.g. submerged aquatic grasses, pondweeds, pickerelweed, arrow-arum, arrowheads, smartweeds, sedges, rushes, millets, cattails, hibiscus, shrubs, etc.). Achieving this goal will depend upon first eradicating the phragmites cover and then managing marsh water levels and tidal exchanges to establish and maintain the desired plant community. Managing for water levels that are higher than present conditions should help to suppress future phragmites recolonization. Additionally, enhanced tidal exchanges and a concomitant slight increase in salinity (from 0-2 ppt at present to 1-4 ppt after tidal restoration) should help to eliminate the potential for a purple loosestrife (Lythrum salicaria) invasion in Army Creek Marsh; purple loosestrife is an undesirable, pestiferous wetland plant that is rapidly colonizing many freshwater wetlands in New Castle County.

If it becomes desirable to increase wetland plant diversity beyond what occurs following the phragmites control effort and initiation of the water management plan, shallow ponds and ditches might be excavated to create the desired aquatic habitats, done to achieve a diverse mosaic of shallow water areas, mudflats, and emergent wetlands envisioned for the restored marsh. These shallow water habitats will also directly benefit aquatic invertebrates and fishes. The excavation of shallow ponds and ditches would most likely be done by the Delaware Mosquito Control Section, who have the excavation machinery to work in wetland areas; using this equipment, the excavated spoil is broadcast as a thin slurry over adjacent marsh surfaces, allowing for quick recovery of temporarily-covered vegetation. The excavation work might also be done in conjunction with reducing mosquito-breeding to acceptable levels, in order to decrease the need to apply chemical insecticides; the excavated shallow ponds and ditches serve as reservoirs for small, mosquito-consuming fishes (e.g. killifishes, mosquitofishes). If this work is to be done primarily for mosquito control purposes, increases in habitat diversity for wetland plants and aquatic organisms will still occur; however, the need for habitat diversity enhancement may or may not be the driving force for undertaking excavation work, depending upon how the marsh responds to phragmites control and initiation of the water management plan. If shallow water habitat and plant diversity are satisfactory, and mosquito-breeding acceptably low, then no excavation work may be necessary.

The estimated cost for creation of shallow ponds and ditches within Lower Army Creek Marsh, whether done to promote wetland plant diversity, fish habitat, mosquito control, or combinations of the three, is about $15,000. This estimation is based upon what it would cost to install an Open Marsh Water Management (OMWM) system of ponds and ditches in about 25 acres of marsh, and to selectively reclean some canals or ditches for improved water circulation or increased aquatic habitat diversity. Whether this is a cost that the Trustees have to meet cannot yet be determined, but should be determinable within a few years after initiating the restoration work, as an outcome of the proposed monitoring work.

Food plots of wetland plants desirable as waterfowl foods, such as native millets or wild rice, might also be established by seedings or by plantings. The Trustees will set aside $2000 to examine and perhaps initiate a waterfowl food plot project.

2.1.3 Landowner Cooperation

Cooperation and participation of affected landowners was considered essential to the implementation of this restoration plan. Contacts were made with the Army Creek marsh property owners early in the process because without their participation many of the marsh water and vegetation management efforts cannot be carried out. Potentially affected landowners were contacted by letter and invited to meet with representatives of the trustee group to discuss options for land access/acquisition and to get a preliminary commitment of willingness to participate. Options discussed included conservation easement water management agreement, donation to the State of Delaware, and outright purchase of both wetland areas and adjacent upland buffer zones. Preliminary commitments of cooperation have been received from each of the marsh property owners. After public comment on the restoration plan, agreements will be finalized based on an approach which is negotiated with each landowners.

2.2 UPLAND RESTORATION

2.2.1 BACKGROUND INFORMATION

The Army Creek Natural Resources Trustees (Trustees) selected the acquisition and rehabilitation of approximately 60 acres of upland habitat as appropriate compensation for the loss of similar acreage of upland habitat. To determine potential sites for acquisition and rehabilitation, a list of parcels with undeveloped acreage near Army Creek was prepared (TABLE 2-1). These parcels were subjected to a preliminary review under the "Acquisition Criteria for Site Selection" (See Attachment 1 of Appendix A). This review served to narrow the list of potential sites to 10 parcels. The parcels removed from consideration are reflected in Table 2-2.

Field inspection of the remaining sites were conducted. The parcels were ranked according to the "Acquisition Criteria for Site Selection" based in part upon these field inspections (TABLES 2-3 and 2-4). As parcels were only partly traversed, aerial photography (1992, 1988) was used to support field observations.

Landowner information was compiled from New Castle County tax maps (TRW-Redi Property Data Atlas, 1993). Zoning data was provided by the New Castle County Department of Planning. Soils data was compiled from New Castle County Soils Survey (USDA-Soil Conservation Service, 1970). Wetlands information was taken from the USFWS National Wetlands Inventory (1989).

In the event that conditions change so that it becomes infeasible to obtain any of the candidate upland sites described below, the Trustees shall identify alternative sites for acquisition. Selection of alternative upland sites, which do not affect proposed upland management options or other aspects of restoration, constitute a minor modification requiring no amendment to the overall plan. Additionally, alternative sites will be indentified, ranked and selected using the criteria provided in appendix A, table I and II, which are those that were used to select the current candidate sites, to maintain consistency in the selection process.

TABLE 2-1: *Potential Upland Acquisition Sites*

Tax Map #	Parcel Address	Acreage	Tax Map #	Parcel Address	Acreage
10-023.00-010	Airport Rd.	91.36	10-036.00-008	Carroll Dr.	2.96
10-024.00-025	Christiana Rd.	58.45	10-040.00-022	S. DuPont Pkwy.	131.24
10-024.00-081	Churchmans Rd.	91.68	10-040.00-028	Federal La.	79.73
10-028.00-036	School Bell Rd.	74.00	10-041.00-001	River Rd.	75.70
10-030.00-076	River Rd.	2.27	10-041.00-002	River Rd.	25.45
10-031.00-003	River Rd.	165.16	10-041.00-004	River Rd.	69.81
10-034.00-067	Old State Rd.	11.65	10-045.00-007	Federal La.	316.61
10-034.00-069	Old State Rd.	13.00	10-045.00-011	River Rd.	42.99
10-034.00-070	S. DuPont Pkwy.	111.12	10-049.00-007	Bear Corbitt Rd.	1.30
10-034.00-077	S. DuPont Pkwy.	6.15	10-049.00-073	River Rd.	314.73
10-035.00-005	Grantham La.	29.56	10-050.00-006	River Rd.	86.36
10-035.00-006	Grantham La.	28.19	10-050.00-007	River Rd.	16.39
10-035.00-035	River Rd.	19.45	10-050.00-008	River Rd.	231.98
10-035.00-039	River Rd.	28.40	10-050.00-009	River Rd.	55.54
10-035.00-060	Grantham La.	11.82	10-050.00-011	River Rd.	42.20
10-035.00-061	Grantham La.	8.00	10-050.00-012	River Rd.	30.80
10-036.00-001	River Rd.	3.17	10-054.00-001	County Rd. 389	294.01
10-036.00-006	River Rd.	6.66	21-016.00--002	West 7th St.	5.29

TABLE 2-2: *Upland Sites Eliminated from Consideration*

Tax Map #	*Reason for Elimination*
10-023.00-010	*Barriers to movement of species sources (Routes 13 & 273)*
10-024.00-025	*Barriers to movement of species sources (Routes 13 & 273)*
10-024.00-081	*Barriers to movement of species sources (Routes 13 & 273)*
10-028.00-036	*Barriers to movement of species sources (Routes 13 & rail line)*
10-030.00-076	*Condition of site (hazardous waste--asbestos--on site)*
10-035.00-006	*Condition of site (landfill)*
10-035.00-039	*Barriers to movement of species sources (Route 9)*
10-035.00-060	*Condition of site (industrial park)*
10-035.00-061	*Condition of site (industrial park)*
10-036.00-001	*Condition of site (industrial park)*
10-036.00-006	*Condition of site (industrial park)*
10-036.00-008	*Condition of site (industrial park)*
10-040.00-022	*Condition of site (recorded subdivision--Buena Vista Park)*
10-041.00-001	*Condition of site (recorded subdivision--Beaver Brook)*
10-041.00-002	*Condition of site (quarry)*
10-041.00-004	*Condition of site (recorded subdivision--River Edge Estate)*
10-045.00-011	*Parcel acquired by other governmental agency*
10-049.00-007	*Size (parcel is 1.30 acres +/-)*
10-049.00-073	*Distance to Army Creek (@ 2.5 miles +/-)*
10-050.00-006	*Condition of site (recorded subdivision--Stockton Dev. Co.)*
10-050.00-007	*Distance to Army Creek (@ 2.5 miles +/-); Size (parcel is 1.30 acres +/-)*
10-050.00-008	*Barriers to movement of species sources (Route 9)* *Distance to Army Creek (@ 2.5 miles +/-)*
10-050.00-009	*Barriers to movement of species sources (Route 9)* *Distance to Army Creek (@ 2.5 miles +/-)*
10-050.00-011	*Barriers to movement of species sources (Route 9)* *Distance to Army Creek (@ 2.5 miles +/-)*
10-050.00-012	*Barriers to movement of species sources (Route 9)* *Distance to Army Creek (@ 2.5 miles +/-)*
10-054.00-001	*Barriers to movement of species sources (Route 9)* *Distance to Army Creek (@ 2.5 miles +/-)*

TABLE 2-3: *Upland Sites within the Army Creek Watershed*

Acquisition Criteria

TAX MAP #	*1. Distance - Species Sources*	*2. Disturbance*	*3. Size/ Shape*	*4. Proximity - Army Creek*	*5. Wetlands*	*6. Condition of Site*	*7. Side Effects*	*8. Endangered Species*	*9. Management*	*TOTAL*
10-031.00-003	*1*	*0*	*2*	*4*	*1*	*1*	*1*	*2*	*0*	*12*
10-034.00-067	*1*	*0*	*0*	*3*	*0*	*2*	*2*	*1*	*2*	*11*
10-034.00-069	*1*	*0*	*0*	*4*	*1*	*1*	*1*	*1*	*1*	*10*
10-034.00-070	*1*	*0*	*4*	*4*	*0*	*2*	*2*	*2*	*2*	*17*
10-034.00-077	*1*	*1*	*0*	*4*	*1*	*2*	*2*	*1*	*2*	*14*
10-035.00-005	*1*	*0*	*2*	*2*	*0*	*2*	*2*	*1*	*2*	*12*

TABLE 2-4: *Other Candidate Sites in the Vicinity of the Army Creek Watershed*

Acquisition Criteria

TAX MAP #	1. Distance - Species Sources	2. Disturbance	3. Size/ Shape	4. Proximity - Army Creek	5. Wetlands	6. Condition of Site	7. Side Effects	8. Endangered Species	9. Management	TOTAL
10-035.00-035	2	0	1	0	0	2	2	1	2	10
10-040.00-028	1	0	3	0	0	2	2	2	2	12
10-045.00-007	2	2	4	0	1	0	0	2	0	11
21-016.00-003	1	0	0	2	0	0	1	0	0	4

2.2.2 Candidate Upland Sites

Descriptions for these sites still under consideration are presented below. The parcels are listed in alphabetical order by Property Code. Property code refers to the alphabetical code, or letter, assigned to each parcel for map identification purposes on Map 2-1. This local area map, prepared by DNREC, Geographic Information System Section, was also used to supplement field observations. This map was prepared primarily for internal DNREC resource management purposes. The information is preliminary and subject to change or modification at any time. Use of this information by others is at their own risk and DNREC in no way guarantees the accuracy of the information. For ownership, soils and wetlands data, see TABLES 2-5 and 2-6.

Property Code A

Tax Map Number 10-030.00-046

Site Description This 35.98 acre parcel, is located in the Lower Army Creek marsh. Approximately 87 percent of this parcel is marsh, with a very small percentage in upland forest.

Site Problems This site exhibits signs of disturbance.

Acquisition Options/
Acquisition Methods The Bank of Delaware on behalf of their client has indicated that a fee simple acquisition at their latest appraisal would be acceptable.

Property Code B

Tax Map Number 10-031.00-003

Site Description This 165.16 acre parcel, zoned M-2 for light manufacturing, is located in the Lower Army Creek marsh. Approximately 67 acres of this parcel are upland. The upland areas are comprised primarily of meadow habitat. Woodlands are present on the property as isolated stands or bordering the meadow areas.

Site Problems — This parcel shows signs of significant human disturbance including arson, illegal hunting, and dumping of trash. The level of disturbance observed would seem to indicate that active management of the parcel would be required.

Acquisition Options/
Acquisition Methods — The landowner has indicated that fee simple acquisition at full fair market value is the only option that will be considered.

Property Code C
Tax Map Number 10-034.00-067
Site Description This 11.65 parcel, zoned R-1-C, R-1-B for single-family residential use-clustered, is former farm with old fence rows and some outbuildings still evident. The undeveloped areas are comprised of old fields and woodlands.

Problems — This site is located within a designated growth area in New Castle County's Five-Year Growth Plan. As this parcel is developed with a single family dwelling, less than 10 acres would be available for upland restoration.

Acquisition Options/
Acquisition Methods — The landowners have indicated that they would be willing to discuss granting a limited interest, such a conservation easement, on the undeveloped portions of the parcel.

Property Code D
Tax Map Number 10-034.00-069

Site Description This 13 acre parcel, zoned R-1-C, R-1-B for single-family residential use-clustered, is located along the upper reaches of Army Creek. The site is a mix of riparian wetlands and upland habitat. The upland appears equally divided between meadow and wooded areas.

Problems This site is located within a designated growth area in New Castle County's Five-Year Growth Plan. This parcel has been subject to dumping. Some material has been brought in as fill. The quality of the fill is difficult to discern. There has also been significant dumping of trash on site.

Acquisition Options/
Acquisition Methods No acquisition options or methods have been discussed.

Property Code E

Tax Map Number 10-034.00-070

Site Description This 111.12 acre parcel, zoned R-1-C for single-family residential use-clustered, is located along the upper reaches of Army Creek. The site is an active farm with approximately 50 acres currently being tilled. The remaining portion of the property is wooded.

Problems This site is located within a designated growth area in New Castle County's Five-Year Growth Plan. The site is adjacent to a subdivision including single family homes and town homes. The residents of the subdivision currently utilize the wooded portion of the site for passive recreation.

Acquisition Options/
Acquisition Methods This parcel is administered by a trustee who has indicated that his responsibility to the trust require that he consider only fee simple acquisition at full fair market value.

Property Code F
Tax Map Number 10-034.00-077
Site Description This 6.15 acre parcel, zoned C-2 for commercial use, is located along Army Creek in the vicinity of the Army Creek Landfill. The site contains wooded steep slopes, riparian wetlands and floodplain.

Problems No significant problems were observed during the field inspection.

Acquisition Options/
Acquisition Methods A bargain sale or donation of real property interest may be a possibility with this parcel because the natural features limit potential uses.

Property Code G
Tax Map Number 10-035.00-005
Site Description This 29.56 acre parcel, zoned M-1 for light manufacturing, is within or adjacent to the Army Creek watershed. The site is entirely wooded with a dense shrub layer.

Problems This site is located within a designated growth area in New Castle County's Five-Year Growth Plan.

Acquisition Options/
Acquisition Methods No acquisition options or methods have been discussed.

Property Code H
Tax Map Number 10-035.00-035
Site Description This 19.45 acre parcel, zoned R-1-B for single-family residential use-clustered, is not located within the Army Creek watershed. The site is entirely wooded with a dense canopy and open understory.

Problems — This site is adjacent to a subdivision of single family homes, however, there was no sign of encroachment on the site.

Acquisition Options/
Acquisition Methods — No acquisition options or methods have been discussed.

Property Code I
Tax Map Number 10-036.00-003
Site Description This 64 acre parcel, 46 acres tidal and 28 acres upland, is in the Lower Army Creek watershed. The site has some industrial development.

Problems — None known at this time.

Acquisition Options/
Acquisition Methods — No acquisition options or methods have been discussed.

Property Code K
Tax Map Number 10-036.00-007
Site Description This 72.88 acre parcel, 61 percent tidal and 39 percent upland is in the Lower Army Creek Marsh. Part of the parcel in residential development.

Problems — None known at this time.

Acquisition Options/
Acquisition Methods — No acquisitions options or methods have been discussed.

Property Code L
Tax Map Number 10-040.00-028
Site Description This 79.73 acre parcel, zoned R-2 for residential use, is not located within the Army Creek watershed. The site,

formerly farm fields, is now entirely wooded with a dense shrub layer.

Problems — No significant problems were observed during the field inspection.

Acquisition Options/
Acquisition Methods — The landowner has indicated that fee simple acquisition at full fair market value is the only option that will be considered.

Property Code **M**
Tax Map Number 10-045.00-007
Site Description This 319.31 acre parcel, zoned PEUD for Planned Extractive Use District, is an active gravel quarry. The site, though not located within the Army Creek watershed, does include riparian wetlands. Wooded areas are limited to riparian habitat.

Problems — This site is an active quarry. As a result, the cost of rehabilitation and restoration may be prohibitive. The site has been extensively altered and, prior to any restoration, a wetlands delineation would be required to determine upland areas suitable for restoration or rehabilitation.

Acquisition Options/
Acquisition Methods — No acquisition options or methods have been discussed.

Property Code **N**
Tax Map Number 21-016.00-002
Site Description This 5.29 acre parcel, zoned OS+R for open space and recreation, is located on the Delaware River. The site includes meadow and woodlands.

Problems — This site includes beach front along the Delaware River. This attraction has resulted in a high degree of human disturbance (dumping of trash) on site. In addition, adjacent lands have a developed trail system which encourages use of this parcel. The level of disturbance would seem to indicate that active management of the parcel would be required.

Acquisition Options/
Acquisition Methods — The landowner has indicated that fee simple acquisition at full fair market value is the only option that will be considered.

2.2.3 ACQUISITION OPTIONS

Options for acquisition of a real property interest in land available to the Trustees could include a habitat restoration agreement, acquisition of an easement, or fee-simple acquisition.

Habitat Restoration Agreement

An agreement would bind consenting parties with respect to their rights and duties involved in habitat restoration. Currently, the United States Fish and Wildlife Service (USFWS) uses such an agreement in its Partners for Wildlife program that seeks to restore fish and wildlife habitat (Appendix A). Though this agreement, the landowner grants the USFWS right of entry at reasonable times for the purposes of habitat restoration. Such an agreement may be modified at any time and is terminated at a specified time. The Partners for Wildlife agreement includes a five-year grace period during which the landowner may convert restored wetland habitat to its pre-restoration condition, as allowed by the U.S. Corps of Engineers under section 404 of the Clean Water Act. A habitat restoration agreement does not involve the transfer of any real property interest.

Acquisition of an Easement

An easement is a limited right of use associated with the land. An example of such a limited right would be an easement of access or right-of-way. When a landowner transfers a right-of-way to another, he has given away a right associated with his land. The holder of the easement of access holds the right to cross the lands of the grantor of the easement. An easement is a real property interest.

A conservation easement is another example of limited right of use associated with land. An easement of access provides a right-of-way to the holder of the easement, whereas a conservation easement transfers the right to protect important conservation values of the property to the holder of the easement. In Delaware, conservation easements are deemed valuable interests in real property and may be acquired by any governmental body or charitable corporation or trust which has the power to acquire interests in land. However, no conservation easement shall be acquired or held until accepted by the secretary or director of the agency or department receiving the easement or having jurisdiction over the subject matter of the easement (7 Del. C. Chapter 69).

An easement may be given for a limited period of time or in perpetuity. A temporary construction easement is an example of a limited right granted for a limited period of time. In Delaware, conservation easements must be granted in perpetuity.

Fee-Simple Acquisition

Holding title to land can be viewed as holding a bundle of rights. This bundle of rights includes, but is not limited to, mineral rights, water rights, and development rights. Ownership of the entire bundle of rights is termed ownership in fee. A fee-simple acquisition consists of acquisition of the entire bundle of rights associated with a parcel of land.

2.2.4 ACQUISITION METHODS

Real property shall be appraised before the initiation of negotiations toward acquisition of any interest. The Trustees will consider purchase of full fair market value, bargain sale, and donation.

Fair Market Value

Fee-simple interest in land can be purchased at full fair market value as determined by a qualified appraiser. Such a sale may involve transfer of all property interest at one time. A landowner may also choose to sell a portion of land with an option to sell the remainder in successive years. A limited right in property, such as a conservation easement, may also be purchased after its value has been determined by a qualified appraiser.

Not less than one appraisal report shall be furnished for the proposed acquisition. This appraisal must be in complete accordance with the Uniform Appraisal Standards for Federal Land Acquisitions. The appraised value of the parcel will serve as the basis for negotiations toward purchase.

Bargain Sale

A bargain sale involves the sale of land for less than full fair market value. The difference between the fair market appraised value of the parcel and the purchase price is considered a donation. A bargain sale to a qualified conservation organization can result in tax-benefits for the seller.

Donation

Interest in land can be donated. In an outright donation, the landowner transfers full title and ownership. A donor may choose not to transfer full title to land, but reserve rights, such as hunting or fishing rights, for himself. Conservation easements can be also donated. The donation of either fee-simple title or conservation easements can result in tax-benefits for the donor.

TABLE 2-5: *Upland Sites Within Army Creek Watershed*

Property Description

PROPERTY CODE	*TAX MAP #*	*OWNERSHIP*	*ACREAGE*	*LAND USE CODE*	*NWI*	*SOILS*	*CURRENT USE**
B	*10-031.00-003*	*SCC Operations 6064 Ridge Ave. Philadelphia, PA 19128*	*165.16*	*Vacant*	*X*	*Tm, MeB2, MeC2*	*marsh, some upland areas, scattered forest*
C	*10-034.00-067*	*Hamilton, Forest J. 200 Caravel Dr. Bear, DE 19701*	*11.65*	*Vacant*	*X*	*MeB2, Ot*	*some forested areas, some development*
D	*10-034.00-069*	*Wilson, Jerry R. 1818 Porter Rd. Bear, DE 19701*	*13*	*Vacant*	*X*	*MeB2, Ot*	*forested*
E	*10-034.00-070*	*Brennan, Al E.,Trustee c/o Brennan & Co. 1028 Weldin Cir. Wilmington, DE 19803*	*111.12*	*Farm*	*X*	*MeB2, Ot, WsA*	*50% forested area, 50% farmland*
F	*10-034.00-077*	*Szczepanski, Lucian K. 370 Pear St. Dover, DE 19901*	*6.15*	*Vacant*	*X*	*Jo, Gp, MeB2*	*forested, possibly development adjacent to Rt. 13*
G	*10-035.00-005*	*Petrillo Brothers, Inc. PO Box 628 New Castle, DE 19720*	*29.56*	*Vacant*		*MeB2, WsA, Ot*	*forested*

* *Based on examination of air photos, 01-08-92*

TABLE 2-6: *Other Candidate Sites in the Vicinity of the Army Creek Watershed*

Property Description

PROPERTY CODE	TAX MAP #	OWNERSHIP	ACREAGE	LAND USE CODE	NWI	SOILS	CURRENT USE*
H	10-035.00-35	Parkway Gravel, Inc 4048 New Castle Ave. New Castle, DE 19720	19.45	Vacant		Ot, MeB2, MsB, WsA	forested
L	10-040.00-028	Beyer, Malcolm Jr. 138 Beacon La. Jupiter, FL 33469	79.73	Forest/ Woodland		MeA, MeB2, KeA, KeB2, SaB2, SaC3	farmlands
M	10-045.00-007	Parkway Gravel, Inc 4048 New Castle Ave. New Castle, DE 19720	319.31	Vacant		EmB, Fs, KeA, KeB2, MeA, MeB2, MeC2, MeC3, MeD2, SaB2, SaC3, SaD3, SmE, Tm, WsA	some farmlands, gravel pits and quarries, and some reclaimed lands
N	21-016.00-002	SCC Operations P.O. Box 360 Essington, PA 19029	5.29	Vacant	X	Ot, Ou	marsh, some forested areas

* *Based on examination of air photos, 01-08-92*

Table 2-7: *Lower Army Creek Marsh*

Property Description

TAX MAP #	OWNERSHIP	ACREAGE	LAND USE CODE	SOILS*	CURRENT USE*
10-030.00-046	Bank of Delaware, Trustees 300 Delaware Ave. Wilmington, DE 19803	35.98	Vacant	Tm, MeB2, MeC2	marsh, small area of forested upland
10-031.00-003	SCC Operations 6064 Ridge Ave. Philadelphia, PA 19128	165.16	Vacant	Tm, MeB2, MeC2	marsh, some upland areas, scattered forest
10-036.00-003	James River 2, Inc. PO Box 110 New Castle, DE 19720	64.68	Vacant	Am, MsB	some marshlands, some industrial development
10-036.00-004	Dureco Chemicals, Inc. 950 River Rd. New Castle, DE 19720	1.69	Residential-Platted	Tm	marsh
10-036.00-007	Dureco Chemicals, Inc. 950 River Rd. New Castle, DE 19720	72.88	Residential-Platted	Am, Tm, MeB2, MeC2	some scattered forests, some industrial development

* From Soil Survey, New Castle County
* Based on examination of air photos, 01-08-92

TABLE 2-8 *RECOMMENDED SITES*

Property Code A
Tax Map Number 10-030.00-046
35.98 Acres

Bank of Delaware
300 Delaware Avenue
Wilmington, Delaware 19803

Land Use:	*Vacant*
Current Use:	*Marsh, Small upland forest*
Meets Project Needs:	*Wetlands and upland*

Property Code I
Tax Map Number 10-036.00-003
64.68 Acres

James River 2, Inc.
P.O. Box 110
New Castle, Delaware 19720

Land Use:	*Vacant*
Current Use:	*Marsh, Some Industrial development*
Meets Project Needs:	*Wetlands*

Property Code B
Tax Map Number 10-031.00-003
165.16 Acres

SCC Operations
6064 Ridge Avenue
Philadelphia, Pennsylvania 19128

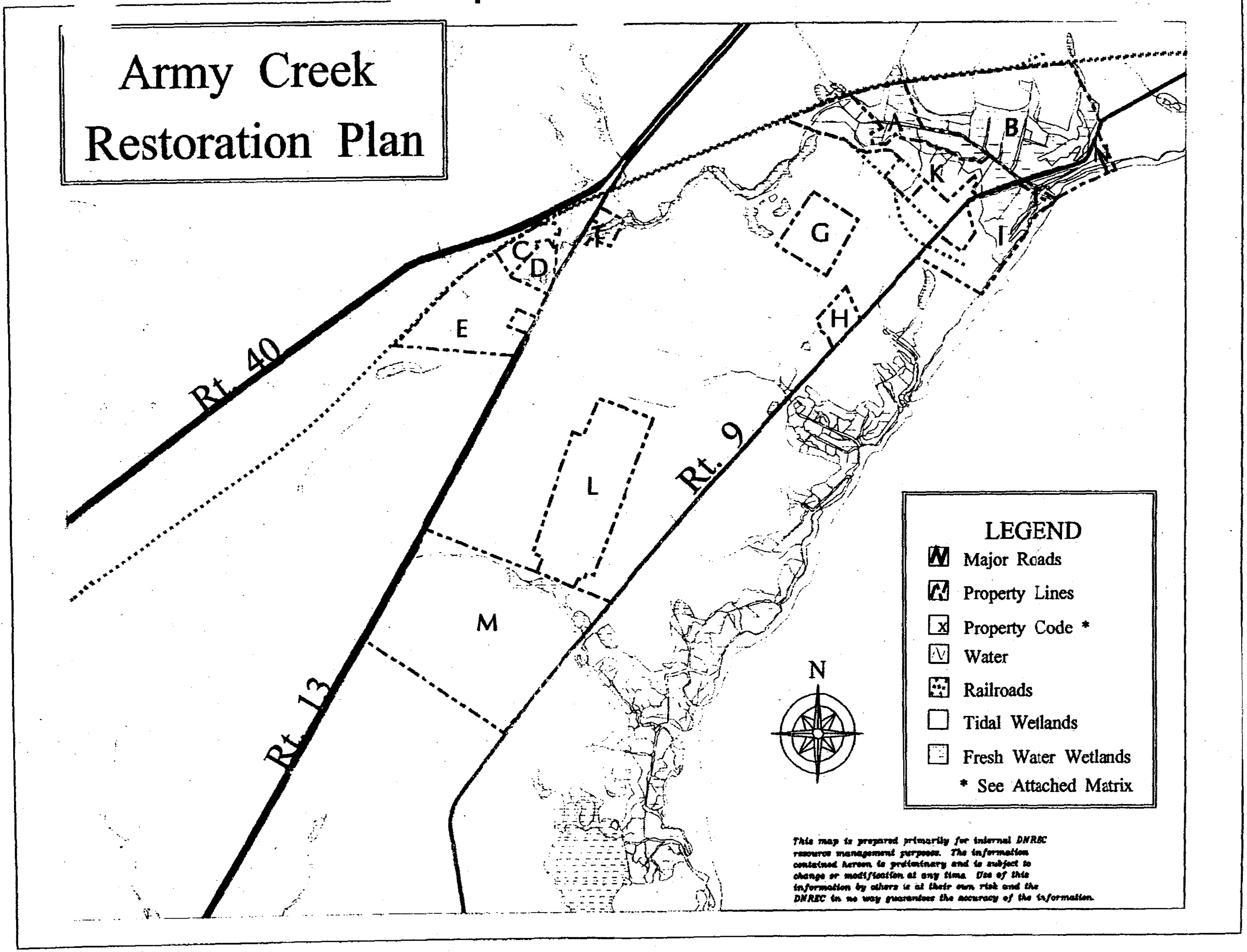
Land Use:	*Vacant*
Current Use:	*Marsh, Some upland scattered forest*
Project Needs:	*Rewatering, wetlands and uplands*

Property Code K
Tax Map Number 10-036.00-007
72.88 Acres

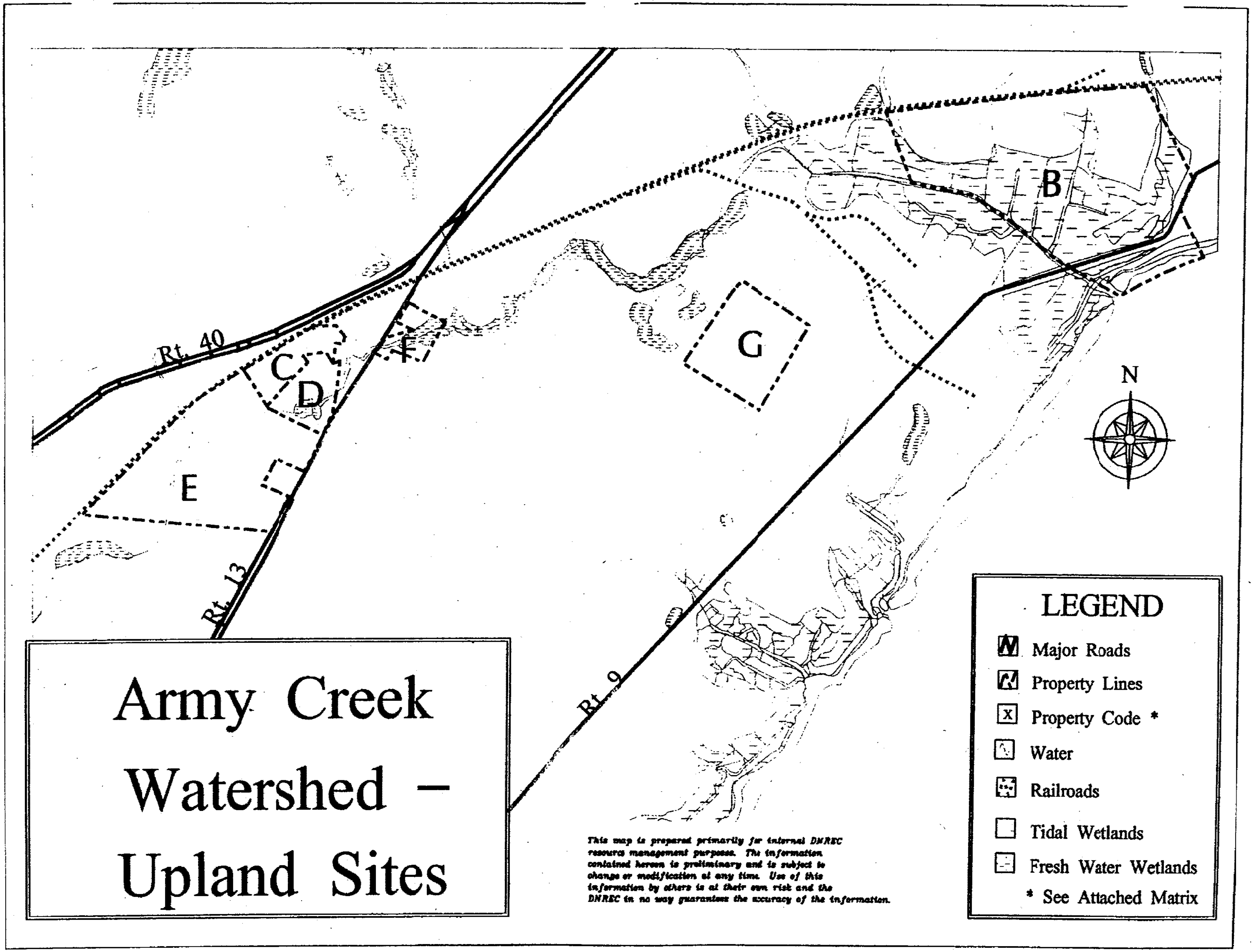
Dureco Chemicals, Inc.
950 River Road
New Castle, Delaware 19720

Land Use:	*Residential plotted*
Current Use:	*Marsh*
Meets Project Needs:	*Wetlands*

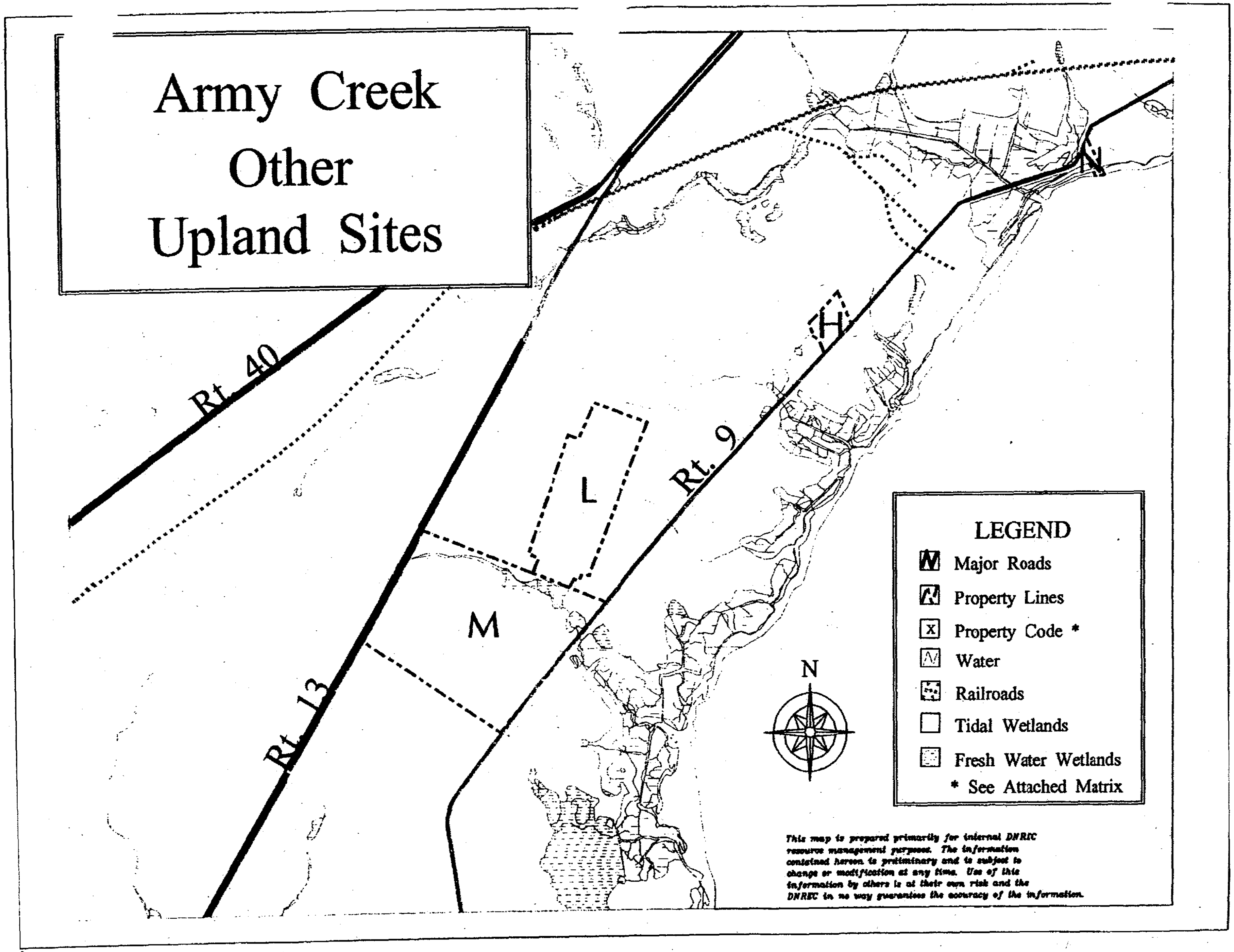
Map 2-1 C ndidate Sites



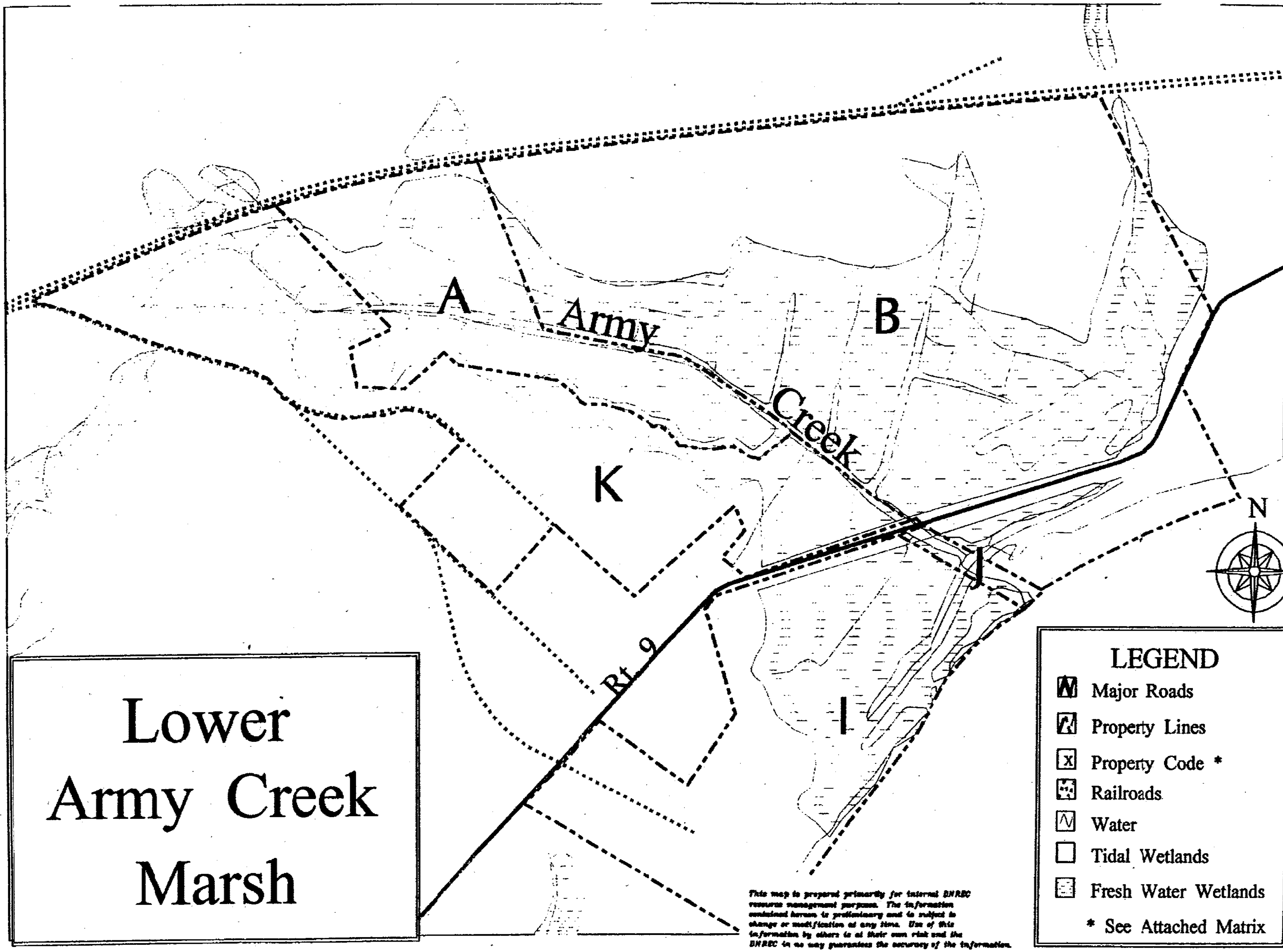
Enlargement of Map 2-1



Enlargement of Map 2-1



Enlargement of Map 2-1



3.0 ENVIRONMENTAL MONITORING PLANS

3.1 Army Creek Wetlands

A requisite to any restoration program is a well designed and cost-effective monitoring effort. Such an effort forms the foundation of and a prerequisite of restoration plans because it is the sole means of providing a measure of the viability, stability and persistence of the restoration and, therefore, an assessment of the effective use of public and private funds that have been allocated for the project.

The goals and benefits of the Army Creek restoration program are to increase acreage of suitable natural resources habitat, improve habitat quality, increase species diversity of fishes, waterfowl and invertebrates and, secondarily, reduce the use of chemical insecticides required to minimize mosquito populations in the vicinity of Army Creek. A monitoring plan that is designed with these in mind not only will provide an assessment of the success of the restoration but also will provide the necessary information to establish criteria for and evaluate need for mid-course corrections, should they be necessary. In fact, there is no other procedure that will provide Trustees and the public with the basis to make rational decisions to modify initial approaches to satisfying the established goals.

The most cost-effective restoration plan for Army Creek wetlands includes not only evaluating the success of the restoration effort but also establishing a baseline of scientific information upon which to make the necessary comparisons and determinations of mid-course correction needs and restoration success. By necessity, the monitoring plan does not include all aspects of the functional value of wetland and aquatic habitats because of financial constraints. The plan does, however, include those environmental and ecological factors deemed most measurable within the project framework and goals. Pre-construction and post-construction assessment of the development of the wetland plant communities which evolve using both aerial photography and ground truth assessments; evaluation of the fishery and waterfowl communities that use the restored habitats; and comparisons of these data at Army Creek and Gambacorta and Broad Dyke Marshes to determine the degree of convergence by Lower Army Creek, will provide the foundation of the requisite monitoring plan. We have sacrificed evaluation of sediment developmental aspects, e.g., changes in particle size and organic content, and the macrobenthic invertebrate community (both of which were in the original monitoring plan design), as part of the plan. While we recognize that the plan establishes a limited monitoring effort, it none-the-less incorporates those physical and biological components that integrate a number of non-measured environmental parameters, and those system components that are of utmost concern to the Trustees.

Details of the expected benefits, measures of success, specific monitoring procedures, schedules and estimated costs are provided in Appendix E.

3.2 Army Creek Uplands

Plans for monitoring restoration of uplands are, out of necessity, at an early stage of development because upland site selection procedures will not commence until the restoration plan is finalized. At that time, procedures will be implemented to identify an upland site and, after choosing a location, trustees will develop a monitoring plan to document habitat changes resulting from active restoration. After trustees establish an interest in the site, the ecological characteristics of the site will be determined. Restoration opportunities which are cost effective and within the scope of the monitoring effort will be identified. Components of the uplands which most closely replace service losses from capping the landfill area of the Army Creek Superfund site have highest priority for restoration.

The upland monitoring plan will describe restoration objectives applicable to important or desirable habitat categories that are present at the site, and ecological factors that objectively measure changing condition of the site. Trustees plan to develop services that increase nesting, feeding, and resting habitat for neotropical migratory birds. Also, functions of the upland site will be restored to improve quality of runoff and improve the ability of this upland habitat to buffer stream and wetland habitats adjacent to the site. Trustees will select and implement appropriate measures in the plan which monitor improvements in habitat and which document increases in services in the categories identified in the objectives.

4.0 OPERATIONS AND MAINTENANCE PLANS

4.1 LOWER ARMY CREEK WETLANDS

Implementation activities and long-term management needs associated with the restoration of the Lower Army Creek Wetlands will be funded, operated, maintained, and managed by a combination of agencies including: the Army Creek Natural Resources Trustees (Trustees), the Delaware Division of Fish and Wildlife (Division), the Delaware Department of Transportation (DelDOT), and the New Castle Conservation District (NCCD). An operation, maintenance, and management plan(s) identifying these responsibilities will be signed among the participating agencies prior to construction of the proposed water control structure and implementation of the water and vegetation management plans.

An agreement outlining the agency responsibilities associated with the proposed retrofitting of the water control structure at Army Creek Marsh have been identified in Appendix F. This agreement identifies funding, construction, maintenance, and operation responsibilities associated with the structure. As outlined, the Trustees will provide all funding for the construction of the proposed structure in an amount not expected to exceed $150,000. The Division shall operate the proposed structure by implementing the proposed water management schedule outlined in Appendix C. This management plan is subject to modifications dependent upon: a) ecological responses of the marsh system following implementation of the initial water management schedule; b) availability of additional biological, hydrological, and topographical information; c) engineering factors or constraints; d) climatic conditions; e) commitment limitations for operation and maintenance; f) economic costs; g) landowner cooperation, and h) better achieving all anticipated benefits and regional objectives of the proposed project.

The Division shall implement the proposed vegetation management plan for the Lower Army Creek Wetlands, outlined in Appendix D. The Trustees will provide financial assistance for phragmites control in the amount of $30,000. The Division may be able to recover a portion of this funding through the Division's 50:50 cost-sharing phragmites spraying program. Through this two-year program, landowners are eligible to have between 5 and 200 acres of phragmites treated with herbicide at a 50:50 cost-share with the Division. The Trustees will also provide an additional $2,000 in funding for the installation of wildlife enhancement structures and the establishment of beneficial plant species, such as native millet or wild rice, for waterfowl and other wildlife.

The Division shall implement and fund, as mandated by State statute, all mosquito control practices utilizing insecticide treatments within the lower Army Creek Wetlands. If biological control of mosquitoes utilizing water management and predacious fishes is desired, the Division will request funding assistance from the Trustees. This assistance, estimated to be approximately $15,000, will provide the funding required to selectively excavate the shallow ponds and ditches needed to provide refuges for predacious fish species and improve their access to isolated mosquito-breeding sites, respectively.

In order to address the impact of non-point source (NPS) pollution on the water quality of the Lower Army Creek Wetlands, the Trustees will contract with the NCCD (for approximately $10,000) to preform a NPS pollution assessment of the Army Creek watershed. This assessment should identify the most serious NPS pollution issues within the basin, and recommend site-specific actions needed to reduce or eliminate these problems. The Trustees will <u>not</u> spend Natural Resources Damages monies to remediate these NPS pollution problems, but will use the NCCD's study results to encourage clean-up via the appropriate state and county agencies responsible for NPS reduction.

Policies addressing public access, permissible public uses, vandalism, and trash removal will be developed for all publicly-acquired lands within the Lower Army Creek Wetlands. These policies will be developed by the Trustees and the agency(ies) responsible for land management. However, all property rights, privileges, and responsibilities of privately-owned lands will not be changed unless identified as a condition of an easement or sale agreement.

4.2 UPLAND SITES

Activities and long-term management needs associated with the management and restoration of publicly-acquired upland areas will be funded, operated, maintained, and managed by a combination of agencies. An operation, maintenance, and management plan(s) identifying these responsibilities will be signed among the participating agencies prior to acquisition and implementation of restoration plans. Policies addressing public access, permissible public uses, habitat management, vandalism, and trash removal will be developed for all publicly-acquired upland areas. These policies will be developed by the Trustees and the agency(ies) responsible for land management.

5.0 BUDGET SUMMARY (damages allocations)

The Natural Resources Damages Assessment for Army Creek Marsh was for $800,000, per settlement agreement with the Primary Responsible Parties (PRP's). $200,000 of this amount was used by the DNREC to undertake restoration activities as partial compensation for losses or injuries to groundwater resources. The remaining $600,000 is to be spent by the NRD Trustees for restoration activities to compensate for losses or injuries to surface natural resources, with an emphasis on injuries to fish and wildlife populations or their habitats.

The following breakdown of NRD fund expenditures is a preliminary proposed allocation, subject to revision as new information or conditions warrant, or as other supplemental monies might become available, with any changes to be made by consensus of the Trustees adhering as closely as possible to the goal of the restoration plan. For example, we do not know yet what wetlands, if any, we might have to acquire to enable the wetlands restoration to work to proceed. We will not know which potential upland acquisition site(s) we will purchase until we initiate land purchase negotiations. Land acquisition cost estimates may be affected by matching funding partnerships, thereby, lowering the Trustees' costs to acquire the compensatory lands. We will not be able to estimate precisely the costs of the new water control structure until the results of the hydrological engineering studies are available. These studies also will enable us to more effectively estimate the long-term operations and maintenance (O & M) costs for the water control structure. Finally, since the O & M costs for management of acquired wetlands or uplands properties will be site-specific, refinement of those costs will not be possible until after acquisition.

Note that the Trustees took NO administrative costs from the $600,000 in NRD's, even though the Trustee agencies incurred considerable expenses (especially in personnel time) in developing this Restoration Plan.

1) <u>Wetlands Restoration = $222,000-$227,000+</u>

<u>Water Management = $195,000+</u>

a) Hydrological modelling, engineering design = $30,000
b) Structure's cost and installation = $150,000+ (?)
c) Selected ponding/ditching (if needed) = $15,000
d) Rt. 9 roadbed raising = $0 (DELDOT)

<u>Vegetation Management = $27,000-$32,000</u>

a) Intensive 2-3 year phragmites treatment = $20,000-$25,000
b) Long-term phragmites spot treatment = $5000
c) Waterfowl food plots (plantings) = $2000

2) <u>Uplands Restoration = $70,500-$289,000+</u>

a) Property purchase costs = $60,000-$275,000
b) Appraisals, environmental audits = $5500-$7500
c) Surveys, title exams = $5000-$5500
d) Habitat restoration = ? (if needed, site dependent)

3) <u>Environmental Monitoring = $90,000</u>

a) Wetlands monitoring = $90,000 (maximum)
b) Uplands monitoring = $10,000 (if needed, to come out of the $90,000 for wetlands monitoring)

4) <u>Operations and Maintenance = $34,500-$52,000+</u>

<u>Wetlands Operations and Maintenance = $34,500-$52,000+</u>

a) Structure's long-term management = $7500-$25,000 (higher end of range to create a management trust)
b) Structure's routine maintenance and repair = $25,000 (to create a maintenance/repair trust)
c) Structure's major repair/replacement = ?
d) Structure's security measures (personnel) = ?
e) Interpretive signs for public I&E = $2000
f) Public access control to publicly-owned wetlands = ?
g) Trash prevention/removal on publicly-owned wetlands = ?

<u>Uplands Operations and Maintenance = ?</u>

a) Long-term habitat management = ? (site dependent)
b) *Public access control* to publicly-owned uplands = ?
c) Trash prevention/removal on publicly-owned uplands = ?

APPENDIX A

FINAL ENVIRONMENTAL ASSESSMENT

LOCATION OF NATURAL RESOURCE RESTORATION
ARMY CREEK SUPERFUND SITE
New Castle County, Delaware

Responsible Federal Agency: The Department of the Interior,
U.S. Fish and Wildlife Service
Department of Commerce,
National Oceanic And Atmospheric Administration

For Further Information Contact:

Robert E. Foley
U.S. Fish and Wildlife Service
177 Admiral Cochrane Drive
Annapolis, MD 21401
(410) 573-4519

Trustees

The Department of the Interior,
U.S. Fish and Wildlife Service

Department of Commerce,
National Oceanic And Atmospheric Administration

State of Delaware
Department of Natural Resources
and Environmental Control

FINDING OF NO SIGNIFICANT IMPACT
LOCATION OF NATURAL RESOURCE RESTORATION
ARMY CREEK SUPERFUND SITE
NEW CASTLE COUNTY, DE.

The State of Delaware, the U.S. Department of Interior, and the U.S. Department of Commerce (the Trustees) have conducted an environmental assessment (EA) regarding the location of the restoration activities to restore, replace, and/or acquire the equivalent of the natural resources injured, destroyed or lost during operation of a municipal and industrial waste landfill at the Army Creek Superfund Site in New Castle County, Delaware (the Site).

The Trustees identified and considered the following three alternatives in the EA: (1) taking No Action, (2) restoration of natural resources at one or more sites outside the Army Creek watershed which contain resources equivalent to those injured or destroyed at the site, and (3) rehabilitation and replacement of wetland and upland habitats in the watershed of Army Creek, including the headwaters of Army Creek, Army Creek Pond adjacent to the Army Creek Superfund Site, and Lower Army Creek and marsh. The proposed action is the latter, to rehabilitate Lower Army Creek and marsh. Specific actions for this proposal are identified in a Restoration Plan subject to public review and comment.

The public was notified of the availability of the EA for review and comment on January 8, 1995, by publication in the Wilmington News Journal. Owners of property abutting the Army Creek Superfund Site were notified of the availability of the EA by mail on January 9, 1995. After a public comment period of 45 days, no comments were received.

I find that the proposed action does not constitute a major Federal action significantly affecting the quality of the human environment. Therefore, in accordance with Section 102 (2) (c) of the National Environmental Policy Act of 1969 and the regulations of the Council of Environmental Quality (40 CFR 1508.9), an environmental impact statement will not be prepared for the project.

Gary Matlock
for Rolland A. Schmitten
Assistant Administrator for Fisheries
National Marine Fisheries Service
National Oceanic and Atmospheric Administration

SEP 8 1995
Date

FINDING OF NO SIGNIFICANT IMPACT
LOCATION OF NATURAL RESOURCE RESTORATION
ARMY CREEK SUPERFUND SITE
NEW CASTLE COUNTY, DELAWARE

The State of Delaware, the U.S. Department of the Interior and the U.S. Department of Commerce (the Trustees) have conducted an environmental assessment (EA) regarding the location of the restoration activities to restore, replace, and/or acquire the equivalent of the natural resources injured, destroyed or lost during operation of a municipal and industrial waste landfill at the Army Creek Superfund Site in New Castle County, Delaware (the Site).

The Trustees identified and considered the following three alternatives in the EA: (1) taking No Action, 2) restoration of natural resources at one or more sites outside the Army Creek watershed which contain resources equivalent to those injured or destroyed at the site, and 3) rehabilitation and replacement of wetland and upland habitats in the watershed of Army Creek, including the headwaters of Army Creek, Army Creek Pond adjacent to the Army Creek Superfund Site, and Lower Army Creek and Marsh. The third alternative will be referred to as the Proposed Action.

The public was notified of the availability of the EA for review and comment on January 8, 1995 by publication in the Wilmington News Journal. Owners of property abutting the Army Creek Superfund Site were notified of the availability of the EA by mail on January 9, 1995. After a public comment period of 45 days, no comments were received by the Trustees.

In implementing the Proposed Action, the trustees will restore natural resources in the Army Creek watershed through specific actions which will be identified in a Restoration Plan which shall be subject to public review and comment.

I find that the proposed action does not constitute a major federal action signigicantly affecting the quality of the human environment. Therefore, in accordance with the National Environmental Policy Act of 1969 and the regulations of the Council of Environmental Quality (40 CFR 1508.9), an environmental impact statement will not be prepared for the project.

John P. Wolflin 2/10/95

Field Supervisor Date

UNITED STATES FISH AND WILDLIFE SERVICE

ENVIRONMENTAL ACTION MEMORANDUM

Within the spirit and intent of the Council of Environmental Quality's regulations for implementing the National Environmental Policy Act (NEPA) and other statutes, orders, and policies that protect fish and wildlife resources, I have established the following administrative record and have determined that the action of:

Restoring marsh and upland habitat in the Army Creek watershed to rehabilitate for injuries caused by the Army Creek Superfund Site.

- is a categorical exclusion as provided by 516 DM 6 Appendix 1. No further documentation will be made (see instructions on back).

X is found not to have significant environmental effects as determined by the attached Environmental Assessment and Finding of No Significant Impact.

- is found to have special environmental conditions as described in the attached Environmental Assessment. The attached Finding of No Significant Impact will not be final nor any actions taken pending a 30-day period for public review (40 CFR 1501.4(e)(2)).

- is found to have significant effects, and therefore a "Notice of Intent" will be published in the Federal Register to prepare an Environmental Impact statement before the project is considered further.

- is denied because of environmental damage, Service policy, or mandate.

- is an emergency situation. Only those actions necessary to control the immediate impacts of the emergency will be taken. Other related actions remain subject to NEPA review.

Other support documents:

Environmental Assessment

John P. Wolflin
Field Supervisor

7/10/95
Date

FINAL ENVIRONMENTAL ASSESSMENT

LOCATION OF NATURAL RESOURCE RESTORATION
ARMY CREEK SUPERFUND SITE
New Castle County, Delaware

Responsible Federal Agency: The Department of the Interior,
U.S. Fish and Wildlife Service
Department of Commerce,
National Oceanic And Atmospheric Administration

For Further Information Contact:

U.S. Fish and Wildlife Service
177 Admiral Cochrane Drive
Annapolis, MD 21401
(410) 573-4519

Abstract:

The U.S. Environmental Protection Agency (EPA) has removed threats to human and environmental health under the Comprehensive Environmental Restoration, Compensation, and Liability Act at the Army Creek Superfund Site in New Castle County, Delaware. The federal and state natural resource trustees negotiated a settlement with several potentially responsible parties for injuries to natural resources associated with the Superfund site. This assessment describes three alternatives regarding a proposal to utilize these settlement monies to restore natural resources which were injured, destroyed, or lost due to operation of the Army Creek

Landfill and the remediation of the site. The assessment addresses the anticipated effects of implementing each alternative. The alternatives are: 1) No Action, 2) Restoration of natural resources at a site(s) outside of the Army Creek watershed which are equivalent to those which were injured or destroyed on-site, and 3) Restoration of the equivalent in injured or destroyed natural resources on site(s) in the Army Creek watershed. The proposed alternative is to perform restoration on-site in the Army Creek watershed.

FINAL ENVIRONMENTAL ASSESSMENT
NATURAL RESOURCE RESTORATION PLAN
ARMY CREEK SUPERFUND SITE
NEW CASTLE COUNTY, DELAWARE
TABLE OF CONTENTS

1.0 Project Description

The State of Delaware, the U.S. Department of the Interior, and the U.S. Department of Commerce are designated natural resource trustees (Trustees) for the Army Creek Superfund Site under the Comprehensive Environmental Restoration, Compensation, and Liability Act (CERCLA). The State of Delaware delegated authority to the Department of Natural Resources and Environmental Control (DNREC). The Fish and Wildlife Service (USFWS) is serving as lead trustee representative for the U. S. Department of the Interior. The U.S. Department of Commerce delegated authority to the National Oceanic and Atmospheric Administration (NOAA).

The Trustees entered into a settlement with a group of responsible parties for damages resulting from the injury to, destruction of, or loss of natural resources at the Army Creek Superfund Site (Site) located in New Castle County, Delaware. Releases or threats of release of hazardous substances at the Site resulted in injury to, destruction of, or loss of natural resources under Section 107(a)(C) and (f) of CERCLA, 42 U.S.C. 9607(a)(C) and (f). The settlement provided a total of $600,000 to be used by the Trustees to jointly restore natural resources injured, destroyed, or lost during operation of a municipal and industrial waste landfill at the Site. The settlement also provided that an additional $200,000 of the funds were to be utilized solely by Delaware for restoration activities associated with injuries to ground water resources.

The 60-acre Army Creek Landfill is located in New Castle County (Figure 1) approximately 2 miles southwest of the city of New Castle, Delaware. Operation of the landfill and subsequent remediation caused loss of use of, or injuries to fish populations, migratory birds, and wildlife habitats. Vegetation had recolonized the landfill surface to produce low quality upland and wetland habitat after cessation of disposal activities. Prior to remediation, approximately 3.3 acres of wetland existed on the surface of the landfill. On-site contaminants were migrating to existing pond and creek sediments, and surface water. The Focused Remedial Investigation for Operable Unit 2 identified possible detrimental effects on biota from contact with the contaminated ground water or surface water. The likely effects of contaminant releases from the Site included mortality, and decreases in reproduction and food availability for migratory and resident

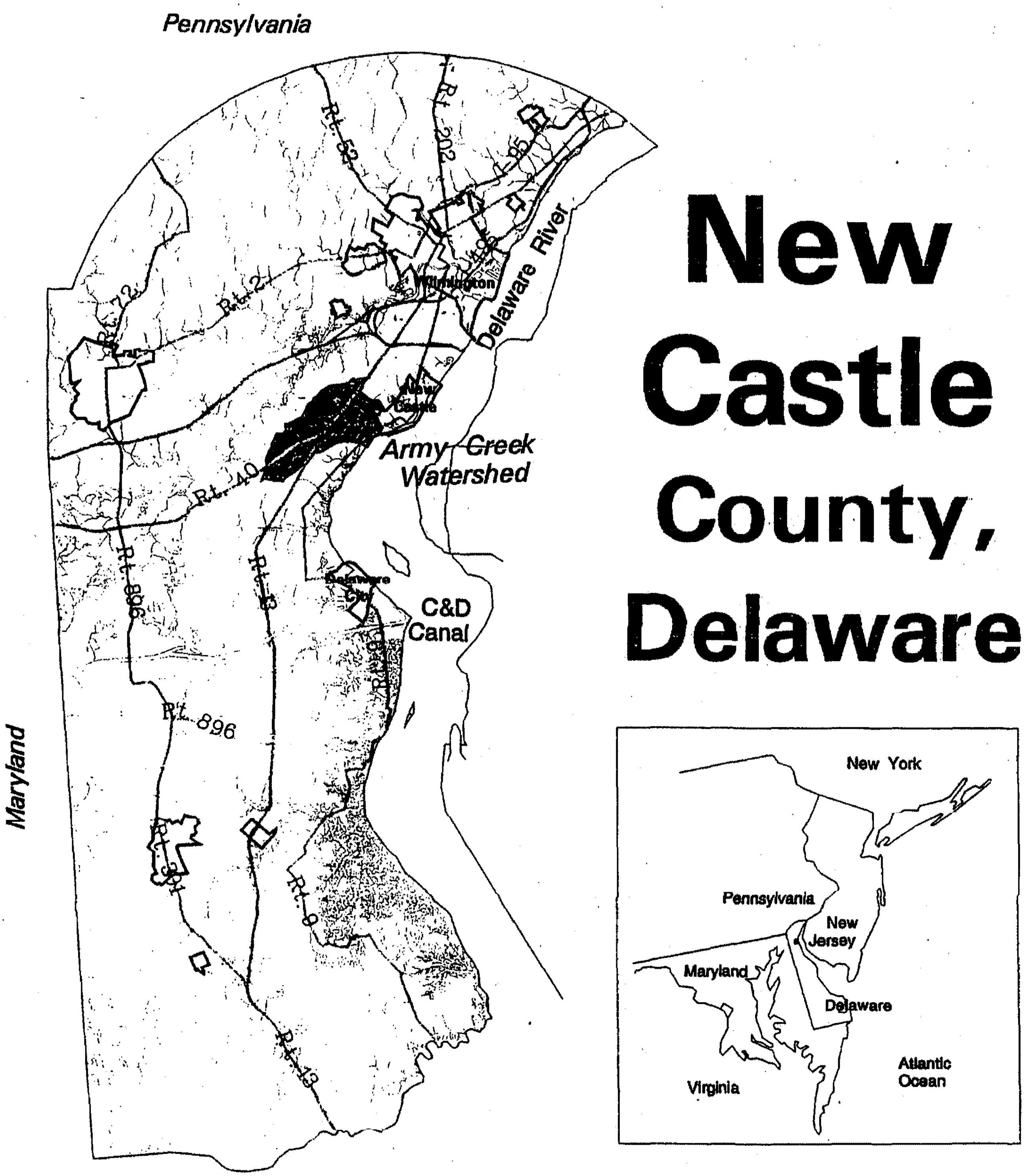


Figure 1. Army Creek site location

fish.

Remediation of the Site destroyed 60 acres of low quality mixed upland/wetland habitat which was distributed over the surface of the landfill. Capping the landfill resulted in the loss of wetland and upland migratory bird habitat that will not be recreated. The cap has been planted with a mixture of grasses, wildflowers, and low growing shrubs whose roots will not penetrate the impermeable layer of the constructed cap. Certain habitat restoration measures were incorporated into the remedial actions selected by the U.S. Environmental Protection Agency (EPA) and accepted by the settling parties. These measures included:

- o Planting species beneficial to wildlife (e.g., shrubs and upland plants) but not interfering with the integrity of the landfill cap to restore some upland plants and shrubs for cover. Maintenance of cap vegetation to minimize disturbance to wildlife uses encouraged by the selected vegetation, and;

- o Constructing small sedimentation basins to manage erosion during cap construction. With completion of the cap (December 1993) these basins are being allowed to revert to wetlands. A Phragmites control program will be implemented in these sedimentation basins by the responsible parties as part of the remedial action and is expected to enhance habitat values through a return to native wetland vegetation.

All remedial activities except monitoring the success of remedial design are complete.

For the purposes of this environmental assessment, "on-site" is defined as the watershed of Army Creek shown on Figure 2 and includes the headwater area of the creek, Army Creek Pond adjacent to the Army Creek Superfund Site, and Lower Army Creek and Marsh.

2.0 Purpose and Need

The intent of the natural resource damage provisions of CERCLA is to insure that natural resources which are injured, destroyed, or lost are

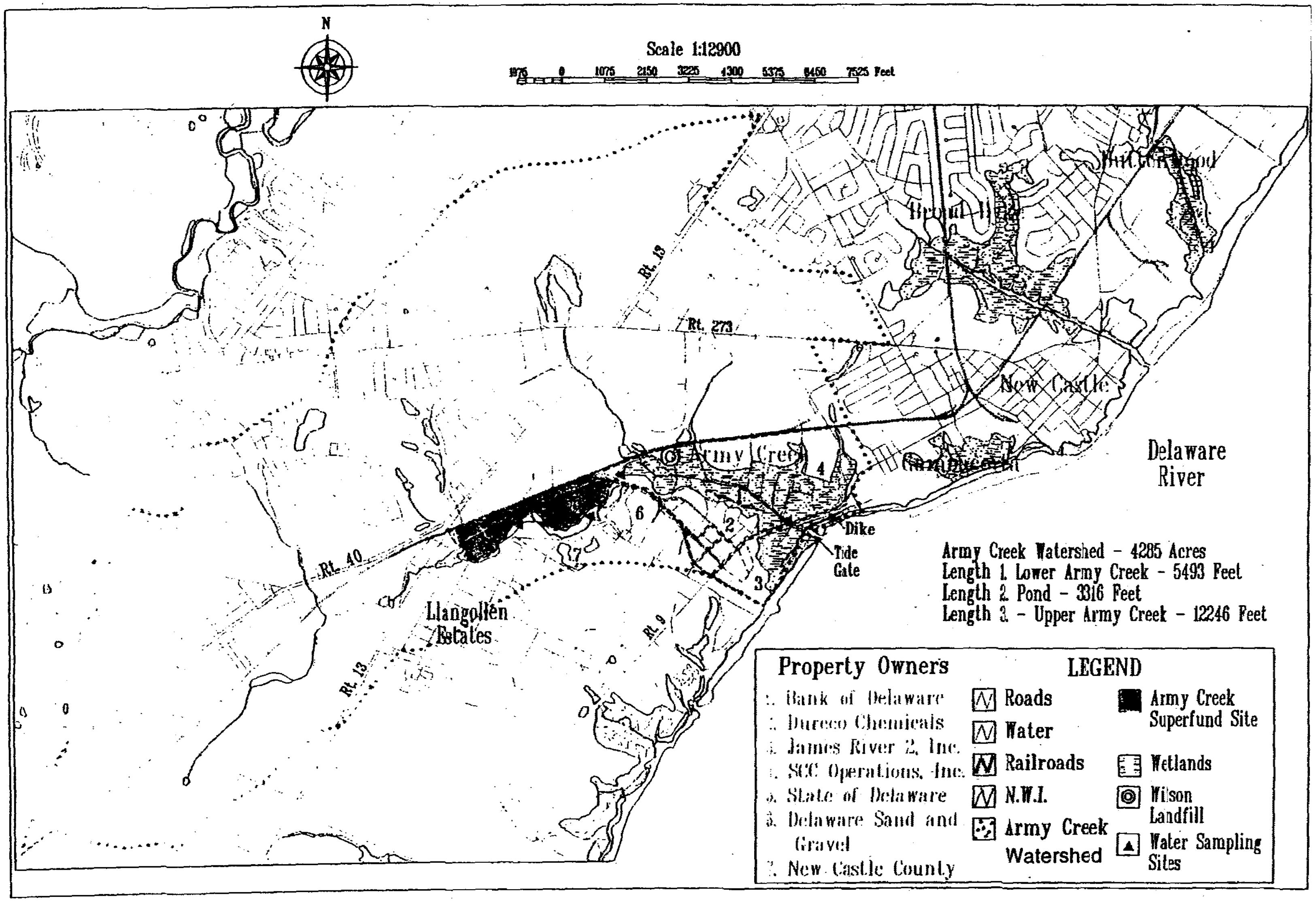


Figure 2. Army Creek Watershed

restored, rehabilitated, or replaced with equivalent resources. The preferred alternative is that restoration occur on-site. The purpose of this document is to determine whether or not on-site restoration is appropriate.

2.1 Significant Issues

Significant issues (i.e., potential environmental impacts of actions) (Table 1) include:

1. the potential for post-remedial contaminant levels to cause continued injury to trust resources on-site;
2. the possible rise in water table level at the Army Creek Superfund Site when ground water pumping ceases;
3. the continued input of heavy metals into the Army Creek watershed from road runoff;
4. the impact of restoration activities on DNREC mosquito control programs.

2.2 Issues Considered But Dismissed

1. Trustees considered whether reintroducing tidal fluctuation in Army Creek Marsh would have an effect on the remediated landfill. Water level elevations in Lower Army Creek Marsh that would be produced by introduction of tidal flow to this ecosystem would not be great enough to affect surface water hydrology at the Army Creek Superfund Site (Figure 3).

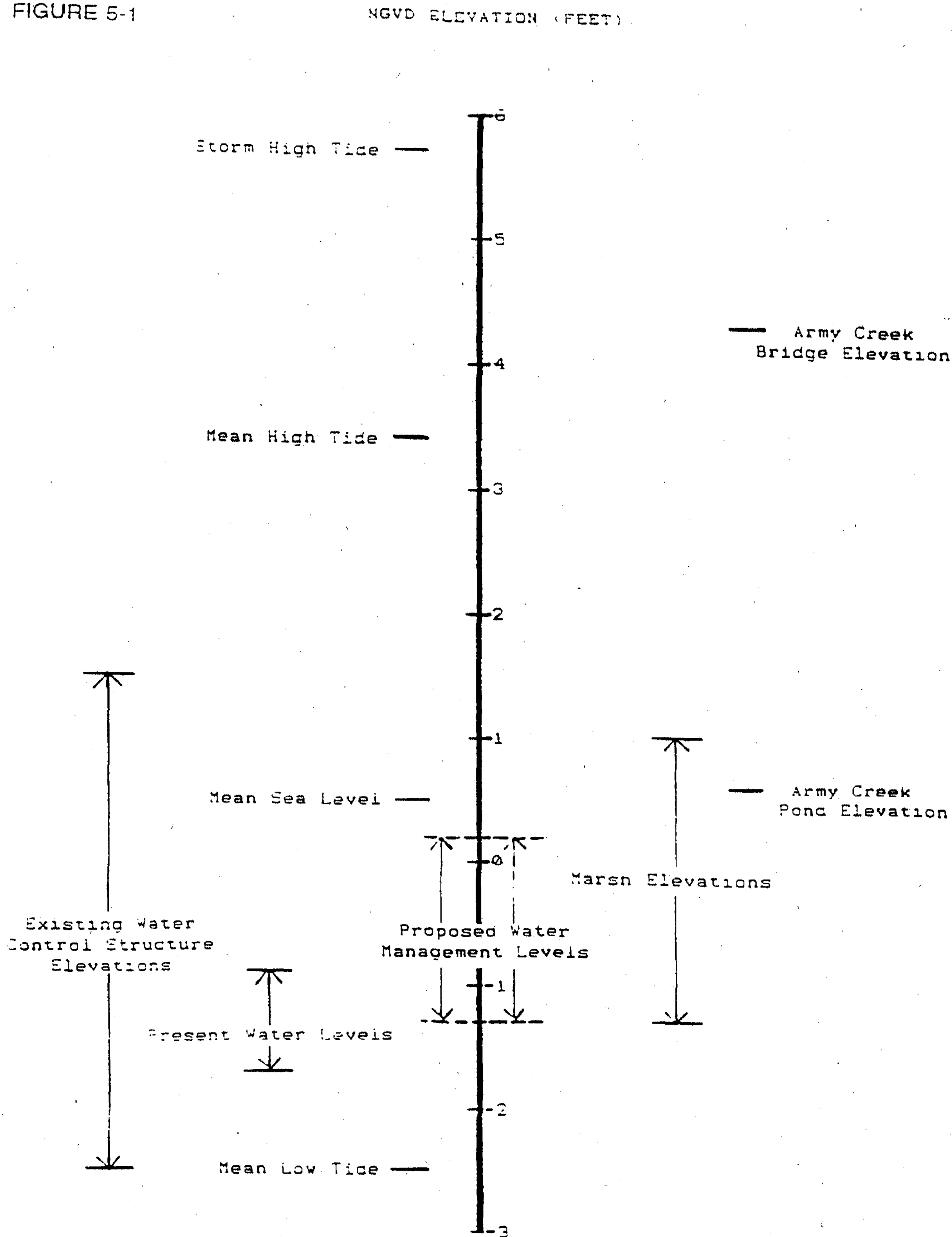
2. Trustees considered whether restoration should be delayed pending review of EPA's Five Year Remedial Evaluation (FYRE). From information summarized in AttachmentB, Trustees determined that Lower Army Creek Marsh received input of contaminants from the landfill over approximately twenty years. Contaminant exposure pathways from the landfill to Army Creek habitats existed and were influenced by surface water runoff within the watershed or lateral leachate from the landfill (Attachment B, Section 2.5). Contamination of

habitats within the Army Creek watershed probably reached an equilibrium during the period that the landfill acted as a source. These exposure pathways are being controlled or eliminated by Superfund site remedial activities and through the efforts of Delaware Department of Transportation such that source control will reduce transport of contaminants to Army Creek habitats. Trustees conclude from these actions that conditions in the creek and marsh will be no worse in the future and should improve over time because sources of leachate and ground water contamination will be controlled. Trustees believe that restoration of aquatic and terrestrial habitats should begin as soon as possible to limit further injuries or loss of services of natural resources in the watershed.

3. Trustees considered the potential consequences that lateral leachate may have on restoration decisions. Trustees do not know of any pathway between ground water and the lower marsh which transported contaminants from the Site to the marsh. Available data indicate that the predominant flow in the stream and marsh is via surface water and that ground water recharge of the marsh does not occur. Additionally, the Record of Decision for Operable Unit Two requires that the responsible parties remedy contaminant problems resulting from lateral leachate.

4. The concept of holding funds for later use was considered. This concept involves combining funds from the Army Creek settlement with future settlements which would then be spent on appropriate restoration activities for the benefit of resources similar to those affected by the Army Creek Landfill. This option would consider use of combined settlement funds to complete restoration within or outside the Army Creek watershed. However, this concept would delay, for an unacceptable period of time, any ecological benefits derived from restoration.

FIGURE 5-1


NGVD ELEVATION (FEET)
6
Storm High Tide
5
Army Creek
Bridge Elevation
4
Mean High Tide
3
2
1
Mean Sea Level
Army Creek
Pond Elevation
0
Marsh Elevations
Existing Water
Control Structure
Elevations
Proposed Water
Management Levels
-1
Present Water Levels
-2
Mean Low Tide
-3

2.3 Permits Required

Permits under Section 10 of the River and Harbor Act and Section 404 of the Clean Water Act are required when certain works are performed in waters of the United States. This would be the case if the proposed alternative to perform on-site restoration is selected.

3.0 Description of the Proposed Action and Alternatives

This chapter identifies and describes the feasibility of on-site restoration actions and alternatives applicable to the Army Creek Superfund Site. After review and consideration of public comment on this environmental assessment, the Trustees will decide where restoration will be implemented. At that time Trustees will develop a restoration plan. This plan will present more specific details of selected restoration actions and the effects that these actions have on affected environments.

Potential alternatives that will be considered by this environmental assessment are:

- o No Action;
- o Restoration Action Off-Site;
- o Restoration Action On-Site (Preferred Alternative).

3.1 No Action

This alternative is not acceptable since CERCLA mandates that funds obtained pursuant to Section 107 must be used for restoration purposes. In addition, upland and wetland habitat would not be restored or replaced at a level equivalent to what was injured or lost if this alternative is chosen. In the absence of restoration in the Army Creek watershed, lost ecological functions will continue to impair fish and wildlife populations. The No Action alternative would not replace habitat values of resident and migratory fish populations which were reduced by alteration of the Army Creek tidegate, or the losses of food, cover, and resting areas for migratory birds that were lost through remediation of the Site. The No Action alternative would not replace upland habitat that was present on the landfill surface before remediation activities began.

3.2 Restoration Action Off-Site

This approach to restoration related to wetlands, uplands, and/or aquatic areas would be adopted if alternatives within the watershed are not feasible or fail to replace equivalent resources. Similar habitat selection, enhancement, and protection measures would be applied to appropriate lands to restore maximum natural resource value with the money available. An optimum mix of the following actions would be selected to replace equivalent wetland, upland, and aquatic habitats or their functions outside the Army Creek watershed:

- o enhancement of existing wildlife management or natural areas;
- o enhancement of new areas protected by easement;
- o enhancement of acquired or donated lands; and
- o enhancement of wetland or aquatic areas.

3.3 Restoration Action On-Site (Preferred Alternative)

On-site restoration would improve fish and wildlife habitat in the same watershed where habitat losses occurred as a result of site contamination and remediation. Trustees acknowledge the importance and necessity of water quality and diverse habitats to fish and wildlife populations in the vicinity of the remediated Site. Proposed restoration actions within the watershed will be developed which replace or improve the resource values around the Site but within the same watershed. In this alternative, restoration within the watershed would be carried out as rapidly as planning and construction allow once a restoration plan is developed and the environmental effects of the proposed action are evaluated.

Activities considered to be suitable for replacement or restoration of injuries within the Army Creek watershed include:

- o restoring tidal influence to Army Creek Marsh;

- managing tidal exchange to provide optimum marsh water levels that promote use of Army Creek Marsh by migratory and resident species of fish and waterbirds;

- acquiring easements or purchase land adjacent to the Site, within or along the edge of Army Creek Marsh, or within the Army Creek watershed along Delaware Bay; and

- providing a more diverse marsh plant community that offers food, shelter, and resting habitats for fish and wildlife.

This alternative proposes actions to restore lost function to the 225 acre marsh downstream of the Army Creek Superfund Site and to restore upland habitat injuries caused by installation of the landfill cap using upland areas within the watershed. Approximately 94 acres of upland area adjacent to the Army Creek Superfund Site or the lower marsh exist and may be available for restoration. However, if acreage within the watershed is insufficient, additional acreage will be sought off-site.

Army Creek Marsh will be enhanced by restoring tidal influence and migratory fish access to Army Creek habitats upstream of Route 9. This action will restore the role of the marsh as a nursery for migratory fish, improve waterbird habitat, and improve biological control of mosquitoes in the marsh. A water management plan will be developed which will include replacement of the existing tidegate just downstream of the Route 9 bridge over Army Creek. A vegetation management plan for elimination or control of <u>Phragmites</u> in Army Creek Marsh will be initiated by the trustees to further improve the quality of habitat for wildlife. This plan will result in replacement of <u>Phragmites</u> with vegetation having high wildlife value (e.g., rushes, sedges, smartweeds, emergents, etc.).

Land acquisitions within the watershed will be made if funds are available. Criteria for acquisition of land for restoration as upland habitat have been developed by Trustees (Attachment A). Improvements to upland habitat will be planned to provide food and cover to migratory birds and other wildlife, as well as to improve the quality of waters flowing from these lands.

4.0 Affected Environment

This chapter describes the baseline conditions of the natural resources and socioeconomics of the New Castle County.

4.1 Socioeconomics

New Castle County is the northernmost of Delaware's three counties, and contains approximately 36% of the State's population. Wilmington is the State's largest city and is located almost at the mid-point of the Boston-Richmond "Megalopolis." It is estimated that 30% of the United States population lives within a 350-mile radius of Wilmington. This strategic location provides Wilmington with an excellent transportation network including highways, passenger and freight rail, and the Wilmington and Philadelphia International Airports. In addition, the Port of Wilmington, which ranks within the top 10% of total tonnage handled in the United States, is the closest Delaware River port to the Atlantic Ocean.

New Castle County, including the City of Wilmington, has continued to grow for the last 2 decades. Projections show that the growth rate for New Castle County is expected to increase in the coming years. From current census data, the Delaware Population Consortium (January 30, 1989 Series) projected population growth through the year 2010 as follows.

Population Growth

	1980	1989	Annual Change
State of Delaware	594,338	662,350	1.27%
New Castle County	398,115	434,500	1.02%
	1990	2010	
State of Delaware	673,500	815,600	2.34%
New Castle County	440,300	513,750	1.85%

Statistics indicate a population in Wilmington of approximately 70,000 with an additional 40,000 persons comprising the weekday commuting work force. Projections by the planning departments of New Castle County and the City of Wilmington show a growth to 89,900± by the year 2000.

While not showing dramatic changes, growth in New Castle County and the City of Wilmington has been and is projected to continue at a steady pace. New Castle County contains a substantial portion of the area's commercial office and retail establishments, and this proportion can be expected to continue.
Manufacturing is strong in the Wilmington region. The largest employer is E.I. duPont de Nemours & Co., Inc., followed by Chrysler Corporation, Hercules, Inc., General Motors, and ICI United States, Inc.

4.2 Geology-Hydrology

Physical setting

The Army Creek Superfund Site varies in elevation from mean sea level to +51 feet 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. 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 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.

The Columbia and Potomac aquifers were contaminated by the Army Creek Superfund Site and the Delaware Sand and Gravel Superfund Site (DS & G). The DS & G is situated next to the south shoreline of Army Creek and contributed to contamination of ground water in this watershed (Attachment B, Section 2.5.1). Ground water remediation of these aquifers produces 1.4 million gallons of water per day that are released to Army Creek. Ground water releases will continue until monitoring shows that ground water is no longer contaminated by wastes from the superfund sites.

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. The mean tide range in the Delaware River adjacent to Army Creek is 5.6 feet. The mean tide level of the Delaware River at New Castle is 0.5 ft NGVD with a tidal period of 12.25 hours. A tidegate at the mouth of Army Creek limits exchanges of water and biota between the Delaware River and Army Creek. The tidegate was replaced in 1986 to prevent flooding of Route 9 and lands adjacent to the marsh. The tidegate consists of five one-way flap gates, each 48 inches in diameter, that prohibit tidal inflow and allow outflow of accumulated upland runoff when hydraulic head, in relation to the tide, is sufficient to open the flap gates.

Army Creek Pond, oriented parallel to the southern boundary of the landfill, is ellipsoid in shape and approximately 175 feet wide, and 1 foot deep. The Pond is formed by a gravel stream crossing. Storm water runoff from Upper Army Creek and the Site, as well as flows from the ground water recovery wells at the Site, are collected in this pond. 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 flows upstream of the pond, downstream flows are much more constant as a result of the recovery well input.

4.3 Ecology

4.3.1 Wetland Areas

In the upper portion of the Army Creek system, two wetland habitats were identified by Rudis and Andreasen (U.S. DOI, Fish and Wildlife Service 1988). The first is a shallow, muck bottom pond (Army Creek Pond) with scattered emergent vegetation comprised of pickerelweed (Pontedaria cordata), spatterdock (Nuphar luteum), cattail (Typha latifolia), and other species along the margin. The pond is encircled by a forested or shrub dominated wetland 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 (Impatiens pallida).

A recent characterization (Cole and Fabean 1992) of lower Army Creek Marsh, performed by the Delaware Division of Fish and Wildlife (DFW) with support from the Delaware Coastal Management Program, updated the information base on this degraded wetland. 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 DFW, identified 52 plant species in a floral survey of the Lower Army Creek marsh, with greater diversity occurring toward the upper end of the 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. This species is found in open, moist to wet sites, commonly colonizing ditches from Massachusetts to Saskatchewan, south to Alabama and Texas, west to California and northern Mexico (Godfrey and Wooten 1979). This rush has been found at only two other locations in Delaware, both of which are also believed to be disturbed sites. No federally listed threatened or endangered plants have been recorded in the Army Creek area (Trew, DNHI, pers. comm. 1989).

4.3.2 Fish and Wildlife

A review of information on the presence of species which are Federally listed or proposed for listing as endangered or threatened in the project area was performed in accordance with Section 7 of the Endangered Species Act (87 Stat. 884, as amended; 16 U.S.C. 1531 et seq.). Except for occasional transient individuals, no Federally listed or proposed endangered or threatened species are known to exist in the Army Creek watershed.

4.3.2.1 Wildlife

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 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 (Microtus pennsylvanicus), white-footed mice (Peromyscus leucopus), and house mice (Mus musculus), 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, NOAA, 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.

Sixty-five species of birds were observed in or near the Army Creek Site between 1973 and 1988 (Weston 1986; U.S. Department of the 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 (Phasinus colchicus), bobwhite quail (Colinus virginianus); 11 species of marsh and shorebirds (four herons, one sandpiper, three egrets, glossy ibis (Plegadis falcinellus), killdeer (Charadrius vociferus), least bittern (Ixobrychus exilis); five species of waterbirds (three ducks, one goose, one gull); five species of birds of prey (two hawks, kestrel, osprey (Pandion haliaetus), 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, DNHI, pers. comm., 1989 In 1990 FRI). 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 (Anas rubripes), mallard (Anas platyrhynchus), wood duck (Aix sponsa), Canada goose (Branta canadensis), bobwhite quail, ring-necked pheasant, mourning dove (Zenaida macroura), rock dove (Columbia livia), and common crow (Corvus brachyrhynchus). 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 (Anas crecca) (24), blue-winged teal (Anas crecca) (3), great blue heron (Ardea herodias) (4), double-crested cormorant (Phalacrocorax auritus) (1), and northern harrier (Circus cyaneus) (1).

Amphibians and reptiles known to occur at the Army Creek Landfill are:

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
Northern water snake, Nerodia sipedon
Northern black racer, Coluber constrictor

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.

4.3.2.2 Fish

Twenty-two species of fish have been identified in Army Creek from the reaches upstream of the pond, the pond itself, or downstream of the pond (Focused Remedial Investigation 1990; Cole and Fabean 1992, and Attachment B).

Four of the species of fish found in Army Creek are listed as "rare" in the State of Delaware (Attachment G of Focused Remedial Investigation 1990). They are:

Smallmouth bass, Micropterus dolomieu
Striped bass, Morone saxatilus
White crappie, Pomoxis annularis
Yellow bullhead, Ictalurus natalis.

In addition, a federally listed endangered species, the shortnose sturgeon (Acipenser brevirostrum), is found in coastal waters of the Atlantic, Delaware Bay, and the Lower Delaware River (i.e., adjacent to or near Army Creek) (Dadswell et al. 1984, O'Herron et al. 1993, and Attachment B). It appears that the lower Delaware estuary is used by adult sturgeon for feeding and/or overwintering. 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 gamefish. 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 (Cyprinus carpio) and brown bullheads (Ictalurus nebulosus) are bottom feeders and tend to be omnivorous (Collins 1959). The tidegate at the mouth of Army Creek prevents or limits entry of migratory and estuarine 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 (Lepomis gibbosus), bluegill (Lepomis macrochirus), mosquitofish (Gambusia gambusia), mummichog (Fundulus heteroclitus), black crappie (Pomoxis nigromaculatus), carp, brown bullhead, Atlantic menhaden (Brevoortia tyrannus), and white mullet (Mugil curema).

Lower Army Creek was surveyed by the Delaware Division of Fish and Wildlife in May 1992, to determine its present habitat suitability for migratory fish spawning. 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 migratory fish spawning (C. Shirey, pers. comm.).

Adjacent to Army Creek, based on a series of beach seine surveys along the Delaware River at Augustine Beach, Delaware and at Penn's Grove, New Jersey (south and north of Army Creek, respectively) in 1958, deSylva et al. (1960) identified 30 fish species. 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 (Attachment B, Section 2.4.2.6).

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 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 (61 cm). The bottom sediments are soft and unconsolidated, supporting low numbers and diversity of macroinvertebrates. Minimal water flow and decomposing leaf litter act to suppress dissolved oxygen levels, explaining the very low numbers and diversity of fish. Lack of freshwater flow, suitable substrates, and tide would prevent successful spawning of migratory fishes upstream of the pond.

4.4 Land Use

An initial review of area land use through New Castle County Department of Parks and Recreation information shows that generally the area is zoned industrial or commercial. The area to the north of the Army Creek Superfund Site is a mixed commercial/residential strip development, with some areas identified as future industrial parks. Several parcels, adjacent to the Army Creek Superfund Site or in the lower portion of the watershed, are composed of degraded upland habitat that could be acquired for restoration purposes. The DS & G is located adjacent to Army Creek in proximity to the Army Creek Superfund Site (Figure 2). The DS & G consists of 4 areas in which wastes were disposed. However, none are located in the floodplain of Army Creek (Attachment B). Remedial actions at the DS & G include removal and disposal of buried drums, contaminated soils, and pumping and treating ground water. Although the impact of DS & G on Army Creek and pumped recovery well water is not separable from Army Creek Landfill based on available information, remedial activites to remove the threat of the DS & G site site to Army Creek will not affect the restoration activities proposed in this Environmental Assessment. A second degraded parcel, the Wilson site, is adjacent to the marsh on the north side of the upper end of Lower Army Creek. This site is not in the floodplain of Army Creek. Between 1960 and 1976, the Wilson Contracting Company disposed of construction debris on the site. Trustees reviewed information available on disposal practices and contaminants present on the parcel. The effects of the Wilson site are highly localized and are of little consequence to Lower Army Creek Marsh (Section 2.5.2, Attachment B).

Residential developments are located south, southwest and northwest of the Army Creek Superfund Site. In addition there are scattered residences east of the Site. Residential development in the area directly south of the Site is expected to increase the population in the future.

Designated uses of Army Creek are secondary contact recreation, fish and wildlife propagation, and agricultural water supply. The soils surrounding Army Creek and upstream of the Site are considered prime agricultural soils, although they are not currently used for agriculture. There is no prime farmland downstream of the Site.

In summary, the Army Creek watershed is a degraded system with low flow except for augmentation from pumped ground water and occasional runoff from storm events. The ecosystem is isolated from the Delaware River by prohibiting tidal inflow through a tidegate at the mouth of Army Creek. Upland and wetland habitats in the watershed are degraded by two superfund sites and intense human development. Fish and wildlife utilize the area but at reduced levels because of habitat limitations. The habitat limitations are, at least, in part, a result of operation of the landfill and subsequent remediation. Degraded habitats exist in the watershed that are identified as candidates for restoration actions.

Comparison of Alternatives and Significant Issues

SIGNIFICANT ISSUES

Alternatives	Potential for Continued Injury Post Remediation	Change in Water Table After Pumping Ceases	Contaminant Input from Road Runoff and Landscape	Mosquito Control
On-Site Restoration	Enhances ecological diversity by meeting goals of Appendix B earlier. Lower Creek slightly contaminated, opening creek may further decrease contamination. Lessens injuries.	Not sure what water table will do after cessation of pumping. Lateral leachate from landfill may (but not likely) affect the Pond. EPA will remediate if lateral leachate affects Pond. A gravel crossing impounds the Pond minimizes potential adverse effects on Lower Army Creek.	New Castle is in the process of developing a plan to treat runoff. Acquiring land in watershed will allow stormwater treatment technologies to be used.	Earlier restoration reduces chemical control of mosquitoes.
No Action	No Change; Site injuries continue and may never be addressed.	Water table level in Army Creek independent of alternative.	No control of landscape inputs. Continued metals input into Army Creek watershed because the county or DELDOT may not address.	No change from current control.
Restoration Outside Watershed	Replaces natural resources with equivalent elsewhere (i.e. not at site). Site injuries continue and may never be addressed.	Not affected by site geo- hydrology	Continued metals input into Army Creek watershed because the county or DELDOT may not address.	No change from current control in Army Creek. Could enhance mosquito control elsewhere.

5.0 Environmental Impacts of the Proposed Action and Alternatives

5.1 Socioeconomics

5.1.1 No Action

Under this alternative, natural resources at the Site will remain in a degraded state with no replacement of habitat or improvement in resource value. In the absence of restoration the area is likely to have limited recreational or educational opportunities and is unlikely to attract the interest of groups that could serve as land stewards. Without restoration, services provided by the watershed (e.g., nursery habitat for fish, resting habitat and food for migratory birds, and improved water quality) will be available but very limited. Also, with no restoration, the state must continue mosquito control in Lower Army Creek using a chemical-intensive control strategy.

5.1.2 Restoration Action Outside of the Watershed

Restoration actions outside the watershed would involve enhancement of existing wildlife management or natural areas. These enhancements would be protected by easements. The effects will be similar to those for restoration actions within the watershed (Section 5.1.3), but would occur in a different location chosen using upland selection criteria in Attachment A. Restoration may enhance areas where this activity occurs, but would not benefit or correct deficiencies in habitat or services that they provide in the Army Creek watershed. Restoration outside of the watershed would not enhance water quality in the Army Creek watershed. This alternative produces little or no economic benefits at Army Creek.

5.1.3 Restoration Action Within the Watershed

Choosing this alternative provides for the most rapid rehabilitation of habitats, and fish and wildlife populations affected by Army Creek Superfund Site. On-site restoration activities, such as providing bird nesting boxes would attract wildlife, and opportunities for wildlife observation and photography in the watershed. Such actions would be

likely to increase the aesthetic value of the area and may result in nearby residential areas becoming more desirable places to live.
Restoration activities might result in local environmental, educational, or neighborhood groups taking an interest in the property and providing stewardship and management for the area.

The restored area could serve as a fish nursery and provide increased food and cover for migratory birds and mammals and perhaps some increases in the Delaware Bay fishery. The majority of marsh acreage along the Delaware River between the C & D Canal and the Pennsylvania border have tidegates. By retrofitting the Army Creek tidegate, Army Creek will be open to migratory fish use, thus eliminating another impassable barrier to fish use along this portion of the river. The economic value of the contribution to the fishery from Army Creek is unknown, but probably very small. However, an increase in nursery area in Delaware has potential to increase the current level of fish production in the bay.

Rehabilitating Army Creek will enhance biological control of mosquitoes in 225 acres of marsh, reduce release of pesticides to the environment, and reduce costs of chemical control. By retrofitting the tidegate to allow managed tidal flooding in addition to ebb flow, control of water levels in Army Creek Marsh is expected to increase the fish population in the marsh which will eliminate many parts of the marsh as mosquito breeding habitat. Managing marsh water levels (Figure 3) will increase the ability to control mosquito populations without relying heavily on chemical insecticides. Flooding the wetland should not be considered the final act of restoration. The introduction of biological controls and a more diverse marsh ecosystem will help to control potential mosquito problems. Use of biological controls will reduce the cost of state mosquito control programs and the adverse effects of pesticides on non-target natural resources.

Increases in the wetland areas regularly flooded by restoration activities should not limit the use of the surrounding land or affect changes in present land uses. Managed maximum pool level could be kept at a level below 100% marsh surface inundation (Figure 3), thus not affecting adjacent uplands. Planning to accommodate flood events will determine tidegate design.

5.2 Geology-Hydrology

5.2.1 No Action

Trustees anticipate no affects on the geo-hydrology in the absence of on-site restoration activities.

5.2.2 Restoration Action Outside of the Watershed

Effects would occur in other watersheds and would depend on types of restoration activities being considered. However, the injuries in the Army Creek watershed would remain.

5.2.3 Restoration Action Within the Watershed

On-site restoration will involve upland and wetland habitats and will not involve earth-moving, Trustees anticipate no effects on the geo-hydrology as a result of restoration activities. Prior to high-volume pumping of ground water, 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 ground water levels in the vicinity of the Site and, as a consequence, 88-93% of Army Creek flow recharges ground water through its channel bed (Focused Remedial Investigation 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 ground water 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).

The ground water-wetland connection between the Site and Lower Army Creek Marsh is not defined (Attachment B). Trustees do not know of any pathway between ground water and the lower marsh which transported contaminants from the Site to the marsh. Available data indicate that the predominant flow in the stream and marsh is via surface water and that ground water discharge to the marsh does not occur. The lower marsh has no tidal influence at this time. This alternative will return tidal influence and slightly increase the salinity of the marsh. Because managed elevations of marsh levels produced by the tide must be less than the elevation at the Site, Trustees do not anticipate a problem from salt water intrusion.

5.3 Ecology

5.3.1 No Action

In the absence of wetland restoration, there will not be a return of tidal flow to the Army Creek system. Therefore, the system will continue to be unavailable as nursery and feeding habitats for migratory and estuarine fishes. While the ground water remedy continues (pump and treat), freshwater flow in the creek and marsh will be fairly constant except after storm events. After the pump and treat remedy ends, the marsh will become more stagnant because flow in Army Creek is intermittent.

Without restoration, services such as nursery habitat for migratory and estuarine species of fish will not be available; and resting habitat and food for migratory birds, and improved water quality will be very limited. The natural resources of this watershed will be very limited and contribute very little to the Delaware Bay ecosystem.

In the absence of upland restoration, capping and maintenance of the cap will produce a simplified grassland on approximately 60 acres of land in the watershed. The services of forest buffers along Army Creek could moderate water temperatures of the stream and filter runoff from surrounding lands. These services would not develop in this alternative. The question of stewardship of these lands to control future activities in this watershed is uncertain because interest in promoting active stewardship would be much lower in an unrestored watershed. This alternative should have no effect on ground water. If lateral leachate problems develop after remediation, EPA is committed to address these problems with follow-up remediation. At present, natural resource values in the Army Creek ecosystem are limited and will not increase without active restoration. In this alternative, the Army Creek watershed would remain a simplified, partially isolated community that does not fulfill its potential role in the Delaware River drainage basin. At this time, no other restoration plans for the Army Creek watershed are planned.

Mosquito production will probably remain the same as present. State-of-the-art mosquito control technologies will continue with reliance on chemical insecticides, that may be detrimental to non-target wildlife species.

5.3.2 Restoration Action Outside of the Watershed

In this alternative, areas outside the Army Creek watershed would experience effects (benefits to fish and wildlife) similar to those produced by restoration within the Army Creek watershed. Upland restoration undertaken adjacent to existing protected lands/wildlife habitat might increase the diversity of the forest community. Wetland restoration actions outside of the Army Creek watershed will be designed to benefit fish and wildlife in ways that are similar to those in the proposed action. To acquire easements or fee title to lands off-site, monies from the Army Creek settlement will be needed. However, Trustees will need to establish that the contaminants status of the site is suitable for restoration which reduces the monies available for actual restoration of resources.

Acquisition in such areas might increase the productivity and stability of the habitat that is restored. Selection of areas outside the Army Creek watershed might reduce the potential exposure of wildlife to residual contaminants. However, in this alternative, the Army Creek watershed would remain a simplified, partially isolated community that provides natural resource habitat and services at less than its full potential to the Delaware River drainage basin. At this time, no other restoration plans for the Army Creek watershed are planned.

5.3.3 Restoration Action Within the Watershed

Existing data were reviewed by technical staff to ascertain the condition of fringe wetland between the cap and Army Creek, Army Creek Pond, Lower Army Creek itself, and Lower Army Creek Marsh and potential risks to biota from contaminants related to the Army Creek Superfund Site. Trustees concluded that levels of site-related contaminants in Lower Army Creek and Lower Army Creek Marsh were not injurious to fish and wildlife and that restoration of these habitats could occur (Attachment B). However, Trustees concluded that the levels of some site-related contaminants are potentially injurious to fish and wildlife in fringe wetland between the cap and Army Creek Pond, and in Army Creek Pond; therefore, Trustees decided that it is inadvisable to conduct restoration in these fringe wetlands and Army Creek Pond at this time (Attachment B). This decision is based on the fact that attracting wildlife to a restored area with unacceptable levels of contaminants is undesirable.

The decision to delay restoration in fringe wetland between the cap and Army Creek Pond, and Army Creek Pond is in agreement with a decision made by EPA and the responsible parties regarding the need to remediate Army Creek Pond now. Monitoring the success of remediation actions (the Five Year Remedial Evaluation) is planned, at which time EPA will decide on the need for further remedial cleanup. However, remedial measures may not address contamination problems for fish and wildlife in Army Creek Pond and might leave levels of contamination that the Trustees consider unacceptably high in Army Creek Pond.

Additional upland restoration must occur at other upland sites in the watershed. Trustees will plan to acquire property interests (fee or easements) in appropriate parcels. These sites will have the potential to provide restoration opportunities equivalent to those injured at the Site. Upland restoration activities, such as placing bird nesting boxes on-site, planting trees, and stream stabilization will result in increases in habitat value. It is possible that restoration activities would result in local stewardship of the land, and additional benefits to wildlife. It is unlikely that on-site contaminants will affect upland habitats because they should be contained beneath the cap and, therefore, be inaccessible to wildlife. Restoration of upland habitat in the Army Creek drainage basin could improve water quality in the Army Creek watershed by buffering the marsh and stream, and improve storm water retention.

A water management plan that returns tidal exchange to Lower Army Creek will be developed. The combined effect of ground water pumping during remediation and replacement of the tidegate will slightly increase salinity in the wetland. One plant species of concern to Delaware Natural Heritage Inventory, Torrey's rush (Juncus torreyi)is found in Army Creek marsh. 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 two other locations in the state, both of which are also believed to be disturbed sites. Although the proposed water level management for Army Creek Marsh may adversely affect Torrey's rush, the maximum proposed water level increase is modest (about 1 foot above present average marsh water level). The increase in water level has potential to create habitat elsewhere in the watershed similar to lost rush habitat allowing this plant to persist locally.

A vegetation management plan will be developed to control Phragmites and replace it with native salt marsh vegetation with high value for fish and wildlife in the portion of the marsh with tidal flow. Phragmites is an exotic species with low resource value which displaces native species. With adequate volume, marsh water levels, 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. Several of these species occur in the Delaware River but not in Army Creek at present (Attachment B). These species would have increased access to Army Creek. Increases in fish populations and vegetation management will increase available food for birds, mammals, and reptiles. These restoration activities should benefit ospreys, a species of special concern to the State of Delaware, by increasing both the quality and quantity of their foraging habitats. Also, this would increase/expand long-term productivity of the restored marsh. Tidal exchanges may result in slight decreases in the freshwater fish community and spawning areas for amphibians. The Proposed Alternative is not likely to affect the shortnose sturgeon which may visit the Lower Army Creek marsh occasionally (Attachment B).
Replacement of the current tidegate will allow for greater control of mosquitoes by nonchemical means. Fish populations are expected to increase and to have greater access to those areas of the marsh where mosquitoes breed. Rehabilitating Army Creek will enhance biological control of mosquitoes in 225 acres of marsh and reduce costs of chemical control and reduce release of pesticides to the environment. The introduction of biological controls and a more diverse marsh ecosystem will help to control potential mosquito problems.

Roadside runoff contamination of the marsh may continue if it is not abated, thus exposing animals attracted to the restored area to runoff contaminants (Attachment B). Management of roadside runoff will be necessary to prevent further degradation of wetland/stream areas.

5.4 Land Uses

5.4.1 No Action

In the No Action alternative, land use at the Site and in the Army Creek drainage may not change from the current state in which land in the marsh is in low quality uses. Several areas in proximity to the Site are zoned industrial or commercial and are left in an unmaintained state. It is likely that these areas will continue to degrade. In some cases, these sites are degraded by misuse of the land and impair the natural resources of the watershed.

Land use in surrounding areas is unlikely to change. However, development within the land use categories may continue. Aesthetics and quality of life in this area would not improve as long as current land use in the watershed allows for a slow transformation to more degraded conditions. No long term stewardship is likely for the Site and the surrounding area if restoration is not conducted.

5.4.2 Restoration Action Outside of the Watershed

The effects of restoration actions outside the watershed are likely to be similar to the effects of restoration within the watershed, but will occur in a different location.

5.4.3 Restoration Action Within the Watershed

In this alternative, land use changes will be necessary to allow for restoration to proceed. The scope of this alternative calls for re-introducing tidal flows in Lower Army Creek marsh and for developing upland habitats in the Army Creek watershed. An early step to restore the marsh requires refitting the tidegate downstream of Route 9. Control of water levels with this tidegate will cause changes in vegetation and increase the resource values of the marsh. This action will change surface hydrology of the marsh itself but should not change present land uses. Upland restoration actions require that Trustees gain landowner cooperation for the ability to change these habitats and control the use of these lands in perpetuity to restore natural resource losses at this Site.

6.0 List of Organizations Consulted

William Rector, New Castle County Department of Parks and Recreation, New Castle, Delaware

Robert Hossler, William Meredith, Chester Stachecki, Delaware Department of Natural Resources and Environmental Control, Dover, Delaware

Timothy Goodger, James Thomas, Kirsten Erickson, National Oceanic and Atmospheric Administration

John Organ, Ralph Abele, Daniel Murphy, Fish and Wildlife Service
Marcia Gittes, U.S. Department of the Interior, Newton Corner, MA
Dr. John Cairns, Jr., Virginia Polytechnic Institute and State University, Blacksburg, Virginia

7.0 Comments

8.0 List of Staff Preparing Environmental Assessment

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ATTACHMENT A

UPLAND ACQUISITION PROCESS

The following outline presents the land acquisition process to be used for acquiring upland or wetland property, to help meet natural resources compensation needs identified by the Army Creek Natural Resources Damages Trustees. The procedure is based upon the process used by the Delaware DNREC to acquire public property, and incorporates guidance criteria developed by the Army Creek NRD Trustees. The Trustees' guidance criteria are to help evaluate and select property for acquisition, rehabilitation, and protection, in order to help compensate for natural resource losses caused by contamination problems (and their remediation) at the Army Creek Superfund Site.

1. Determine ownership of potential parcels.

   A. Complete GIS mapping showing tax parcels for each potential acquisition site.

   B. Complete ownership list for each tax parcel.

   C. Prepare preliminary list of potential acquisition sites, considering guidance criteria developed by Army Creek NRD Trustees, i.e., size, location, natural resources, utilization, etc.

2. Select sites for acquisition negotiations..

   A. Visit each potential site on potential list.

   B. Rate individual properties in accordance with the attached guidance criteria developed by the Army Creek NRD Trustees.

   C. Select site(s) for acquisition after consideration of several factors, including but not limited to: 1)
   Trustees' guidance criteria to address environmental

compensation needs; 2) willingness of owner to negotiate or sell; 3) willingness of a public agency or private conservation group to assume the primary responsibility for a site's long-term management needs; 4) value for the dollar in meeting Trustees' compensation criteria and other public needs related to environmental resources (i.e. return on investment); etc.

3. Commence negotiations.

A. Not less than one appraisal report shall be furnished for the site being negotiated.

(1) Each Appraisal must be completed in accordance with Uniform Appraisal Standards for Federal Land Acquisitions.

(2) Owner may also obtain an appraisal that meets

Rating Criteria for Upland Site Selection

Trustees have considered different mechanisms for replacing upland habitat lost at Army Creek. These options include purchase of the land or purchase of easements so that restoration or rehabilitation activities can take place. The goal of replacing upland habitat is to replace the equivalent function of the loses that resulted from remediation activities on-site. Purchase of the land or easements on the land will allow us to begin rehabilitation or restoration activities. A conservation easement is the most cost effective way to replace the upland habitat that was destroyed with a similar habitat with equivalent functions.

According to the U.S. Department of the Interior Natural Resource Damage Assessment; Notice of Proposed Rulemaking, 43 CFR Part 11 (1991), there are three options that are available to the trustees to mitigate damaged ecosystems. They are, in descending order of importance, restoration, rehabilitation, and replacement/acquisition of the equivalent of the damaged resource. In many cases, successful mitigation involves taking some combination of these actions rather than only one.

The Army Creek Natural Resources Trustee Committee has considered the option of upland habitat restoration as part of the overall restoration plan for the Army Creek Superfund Site (Site). Trustees used specific characteristics to define upland habitat. The soils of upland habitat are dry or moist but not wet during most of the year (Rodgors et. al., 1976). Upland habitat is an area of residence for an animal or plant species or community of species. Types of upland habitat include ridges, upper slopes, mid slopes, lower slopes, and well drained stream terraces.

Trustees considered several options for restoration of upland habitat destroyed during remediation of the Site:

> Restoration on-site, which would return the site to its original undisturbed condition;
>
> Rehabilitation on-site, which would restore some of the functions and species of the original upland habitat; and
>
> Replacement/acquisition, which would involve the acquisition of the equivalent of the damaged upland habitat elsewhere.

In order to devise a means to select upland habitat, the committee developed criteria to be used in judging the value and suitability of habitat to the restoration process. The criteria represent an untried method that was developed from appropriate literature and through consultation with restoration ecologists. This methodology represents a logical, decision based process that serves as the basis that the committee will use to select an upland habitat site. To develop this method as proven technology will require deliberate unbiased application of all criteria included in the method. Results of application of this method will need to be tested to develop a consensus on the value, strengths and weaknesses of this selection process.

All combinations of the options listed above were considered for the mitigation of Army Creek Superfund Site. The remediation alternative, a grassy RECRA cap, has altered the ecosystem so that any further restoration or rehabilitation of upland habitat is impossible. Consequently, a decision was made to consider acquiring and rehabilitating a habitat that is similar to the original upland habitat.

Following is a brief discussion of the proposed criteria for choosing sites for acquisition with rehabilitation. These discussions help to describe specific characteristics that distinguish between desirable and undesirable attributes. These discussions present the optimal characteristics for each criteria. It is expected that some criteria at each site will not be satisfied. Sites will be evaluated to determine whether they do not satisfy, partially satisfy, or totally satisfy a given criteria. Results will be tallied using the criteria table. The site with the highest resulting score will be chosen if possible - if not available, the site with the next highest score that is available will be chosen.

The area chosen for rehabilitation should be located within 5 miles of other preserved mature upland areas to which it is connected by a mature upland corridor or an area through which upland interior species can safely permeate (Schroeder et.al. 1992), such as an early successional forest or a bottomland forest which can serve as sources to replenish species lost at the site (Table I, 1) (Cairns and Pratt 1992). Corridors or high permeation areas can supply mechanisms for easy transportability of spores, eggs, larvae, seeds, flying adults, walking adults, etc. from unaffected areas to the newly rehabilitated area (Cairns and Pratt 1992). There should be a low probability of present and future disturbances to the habitat by human influences (Table I, 2) (Usher 1986). The area should not be totally surrounded by highways and housing developments or designated in the local (county) master plan for future intense commercial, industrial, or residential development.

The acquired lands should be large enough to be relatively self-supporting and sustain diverse populations of interior as well as edge species after rehabilitation (Table I, 3) (Usher 1986). The disturbed area at Army Creek Landfill encompasses approximately 60 acres. In a model for bottomland forests Schroeder et.al. (1992) suggested that hardwood tracts of up to 40 acres contain no interior dwelling bird species (Blake and Carr 1984), hardwood tracts of greater than 40 acres but less than 250 acres regularly contain interior dwelling bird species (Blake and Carr 1984), areas with between 250 acres and 7400 acres showed at least an 87% frequency of occurrence of some interior bird species (Temple 1986)

(Blake and Carr 1984), and at least 7400 acres are needed to contain all interior breeding birds in the mid-atlantic region (Robbins et.al. 1989). While the habitat of concern at Army Creek is upland forest, the bottomland hardwood forest model can be applied when discussing the relationship between self-supportiveness, tract size, and species richness. Any lands acquired should encompass at least 60 acres in the aggregate. Individual tracts of less than 60 acres may be acquired if the total area of all tracts equals 60 acres.

The area should be circular rather than oblong in order to have a large interior area that is removed from outside disturbances which can affect the health and well being of many species and meet the habitat requirements of interior dwelling species (Table I, 3) (Diamond 1975). However, shape may be irrelevant for interior species if the site is not a few hundred hectares in size (the Army Creek disturbed upland area is 60 acres or approximately 24 hectares) (Organ 1993).

The loss of upland habitat adjacent to Army Creek removes functions of riparian habitat that buffer the stream and improve its water quality. Replacing these functions in the stream system is an important consideration (Table I, 4). Army Creek eventually flows into the Delaware Bay. Improving and maintaining the water quality in Army Creek is important to overall water quality and to anadromous fish (fish which ascend rivers to spawn) that live and spawn in the Delaware Bay watershed.

The original Army Creek upland habitat contained small pockets of wetlands. The acquired and rehabilitated lands should contain wetland pockets similar to those that existed on the Army Creek Superfund Site prior to the disrupting force. The total resulting wetland area should be equivalent to what was lost (Table I, 5).

The general condition of the habitat that resulted from the action of a damaging force should be good enough to insure successful rehabilitation (Table I, 6) (Cairns and Pratt 1992). Residual toxicants and other human induced stresses should exist at minimal levels if at all (Cairns and Pratt 1992). The chemical and physical condition of the habitat should be healthy enough to insure recolonizing by plant and animal species to effect a quick and efficient recovery of the damaged ecosystem (Cairns and Pratt 1992). Terrestrial soils, surface and ground water, and aquatic sediments should meet criteria or descriptors contained in documents like Evaluating Soil Criteria (Beyer 1990), Quality Criteria for Water (EPA 1986), and The Potential For Biological Effects of Sediment-Sorbed Contaminants Tested in the National Status and Trends Program (Long and Morgan 1991).

There should be a low probability of undesirable side effects of rehabilitation (Table I, 7) (Cairns 1985). If not carefully designed, rehabilitation efforts can have further detrimental effects on the damaged lands as well as the surrounding lands. An effort should be made to use rehabilitation methods that have been proven to work with this type of habitat in the past. Prior to the initiation of the rehabilitation process, planners should be able to explicitly state the goals of the rehabilitation and scientifically predict the results (Cairns 1985).

A damaged ecosystem can be rehabilitated so that it aids in the restoration of a locally or regionally endangered species (Table I, 8) (Cairns 1986). The small-whorled pogonia is a woodland plant that is rare in Delaware that could benefit from the acquisition and rehabilitation of an area to upland woodland habitat.

Rehabilitation should be controlled by a management structure or organization with responsibility for monitoring the state of the system through time and introducing species or assisting in colonization (Table I, 9) (Cairns and Pratt 1992). The development of a rehabilitation plan and identification of the parties responsible for the rehabilitation should occur prior to initiation of the on-site rehabilitation procedures. The cost of rehabilitation and future monitoring and maintenance should be realistically affordable and acceptable (Cairns 1990).

Army Creek is an important tributary of Delaware Bay. Upland habitat provides an inherent benefit to a stream system by buffering it from outside interferences. Because of the loss of upland habitat adjacent to Army Creek and the buffering that it affords, there may be direct adverse effects on the water quality of the creek and Delaware Bay. This increases the possibility of deleterious effects on many species of wildlife including anadromous fish. The trustees place highest priority on acquisition and rehabilitation candidates within the Army Creek watershed and will use the criteria in the table to choose a replacement for upland habitat that was lost as a result of remedial activities.

The following table contains the criteria for Acquisition with Rehabilitation which are discussed above. This list can be used to rank the various candidates for possible acquisition and rehabilitation. Zero (0) indicates that a candidate does not satisfy the criteria, the second number signifies that the candidate partially satisfies the criteria, and the third number signifies that the candidate completely satisfies the criteria. The more important criteria have been assigned higher numbers than secondary criteria. The scores for each criteria are totalled at the bottom of the table to determine whether a site falls into the good, moderate, fair, or poor ranges. The site that successfully satisfies the most criteria will score the highest.

The Council chose a relatively simple ranking scale based loosely on those developed by Cairns in several papers. A site with the highest total score will be considered to satisfy 100% of the criteria. The remaining sites will proportionately ranked by dividing by the numerical rating of the site with the highest score. A score in the good range is equivalent to a grade of 80% of the highest score or better. Moderate scores fall between 60% and 80% of the highest score. Fair scores are between 40% and 60% and poor scores are less than 40%. No sites that score below the moderate range (60th percentile) will be considered for acquisition and rehabilitation by the Council.

Table I. Criteria to be used in selection of a site for acquisition with rehabilitation.

	CRITERIA	RANK		
1.	The area is no further than 5 miles from unaffected areas that can serve as species sources with opportunities for transport of propagules and dissemules (spores, eggs, larvae, seeds, flying adults, etc.) to the site through corridors or high permeability areas.	0	2	4
2.	There is a low probability of present or future disturbance.	0	2	4
3.	The size and shape of area is: -60 acres or more -circular rather than oblong	0	2	4
4.	The habitat is located on or adjacent to Army Creek and, therefore, aids in water quality and maintenance of anadromous fish populations.	0	2	4
5.	Wetlands pockets. The site contains small wetlands pockets similar and equivalent to those existing on the Army Creek Superfund Site prior to degradation.	0	1	2
6.	The chemical and physical condition of habitat following the damaging force is acceptable based on the appropriate criteria.	0	1	2
7.	There is a low probability of undesirable side effects of rehabilitation.	0	1	2

8.	The habitat can be rehabilitated in such a way as to help endangered species.	0	1	2
9.	Organizational capabilities exist for immediate and direct control of the restoration effort and the cost of rehabilitation and future monitoring is affordable and acceptable.	0	1	2

Total: >20 = Good, 16-20 - Moderate, 10-15 = Fair, <10 = Poor

Table II. Criteria to be used in selection of a site for acquisition.

CRITERIA	RANK		
1. The diversity of the site contributes to regional and/or national species and habitat diversity.	0	2	4
-species and genetic richness	0	2	4
-variation of species function	0	2	4
-number and inter-connectivity of trophic levels	0	2	4
2. The size and shape of the area is:			
-60 acres or more	0	2	4
-20 to 59 acres	0	2	
-Circular rather than oblong	0	2	4
3. The geographic location is:			
-On or adjacent to a wetland or riparian area	0	2	4
-On or adjacent to migratory corridors of waterfowl	0	2	4
-On or adjacent to endangered species habitat			
-On or adjacent to wildlife habitat	0	2	4
-Adjacent to other protected areas	0	2	4
-On or adjacent to Army Creek	0	2	4
4. Purpose. The area serves the desired purpose in spite of any future intense development in the area surround the site.	0	2	4
5. Naturalness. There is no human disturbance originating on or off site.	0	2	4
6. Representativeness. The site provides mature upland wildlife habitat.	0	2	4
7. Rarity. Rare, endangered, or unusual species			

and/or habitat on the area:

-Federally listed rare and endangered species	0	2	4
-Species of state concern	0	2	4
-Rare habitat	0	2	4

8. Management. The site is easily managed to limit degradation for the future:

-By existing management nearby	0	2	4
-By potential for management	0	2	4

9. Wetlands pockets. The site contains small wetlands pockets similar and equivalent to those existing on the Army Creek Superfund Site prior to degradation. 0 2 4

Total

>68 -= Good, 50-67 = Moderate, 34-49 = Fair, <34 = Poor

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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
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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.

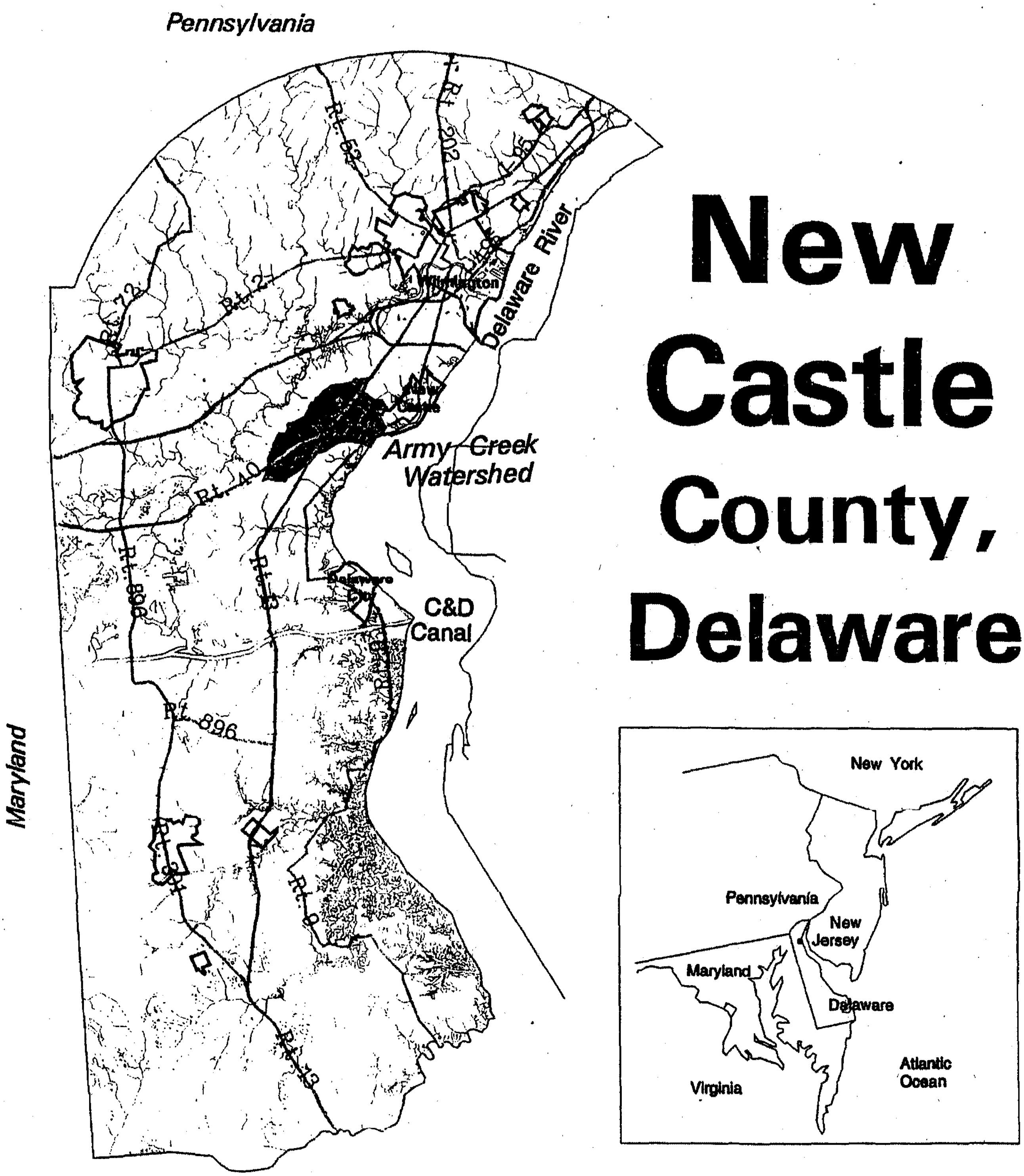

Figure 1. Army Creek site location

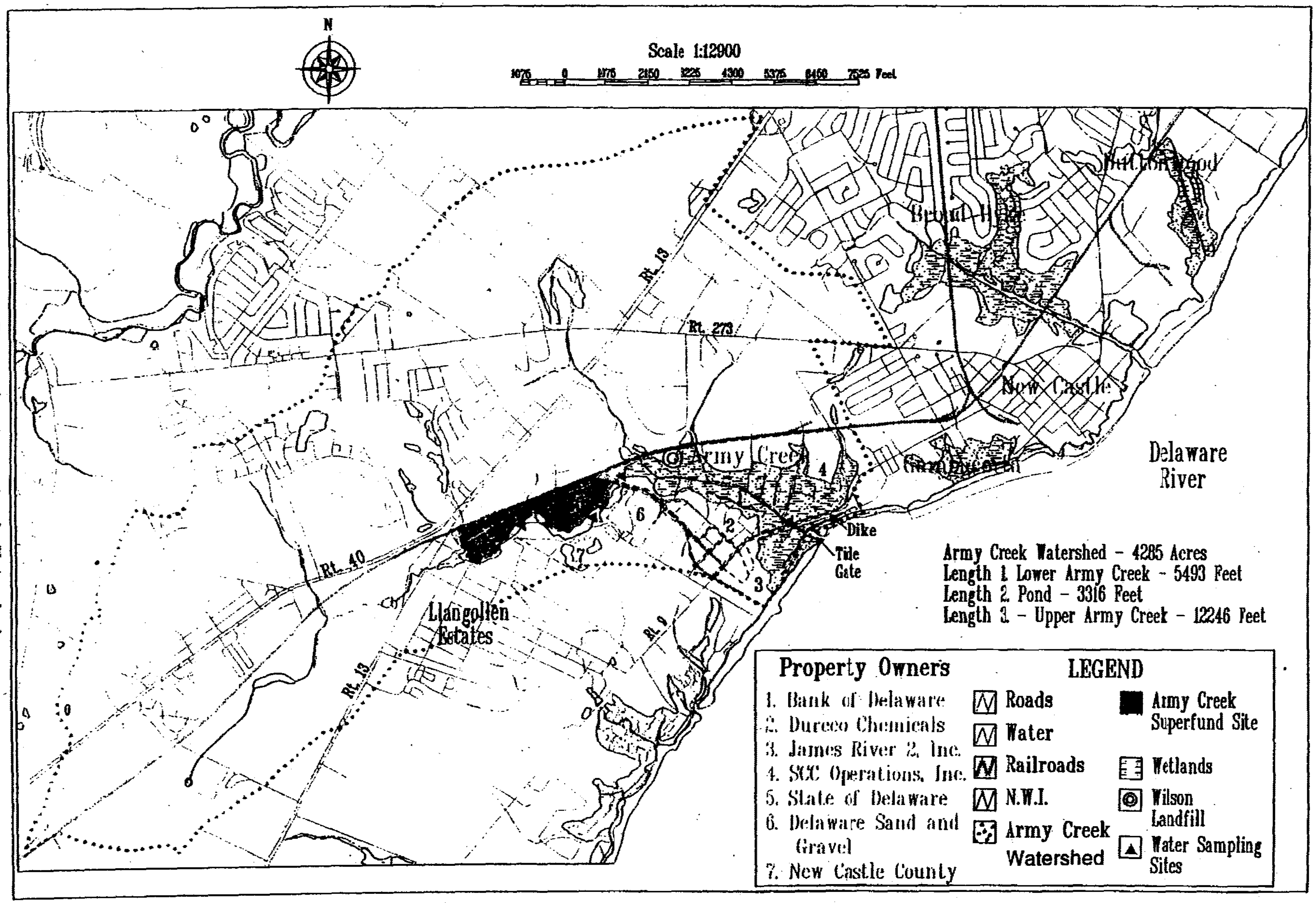

Figure 2. Army Creek Watershed

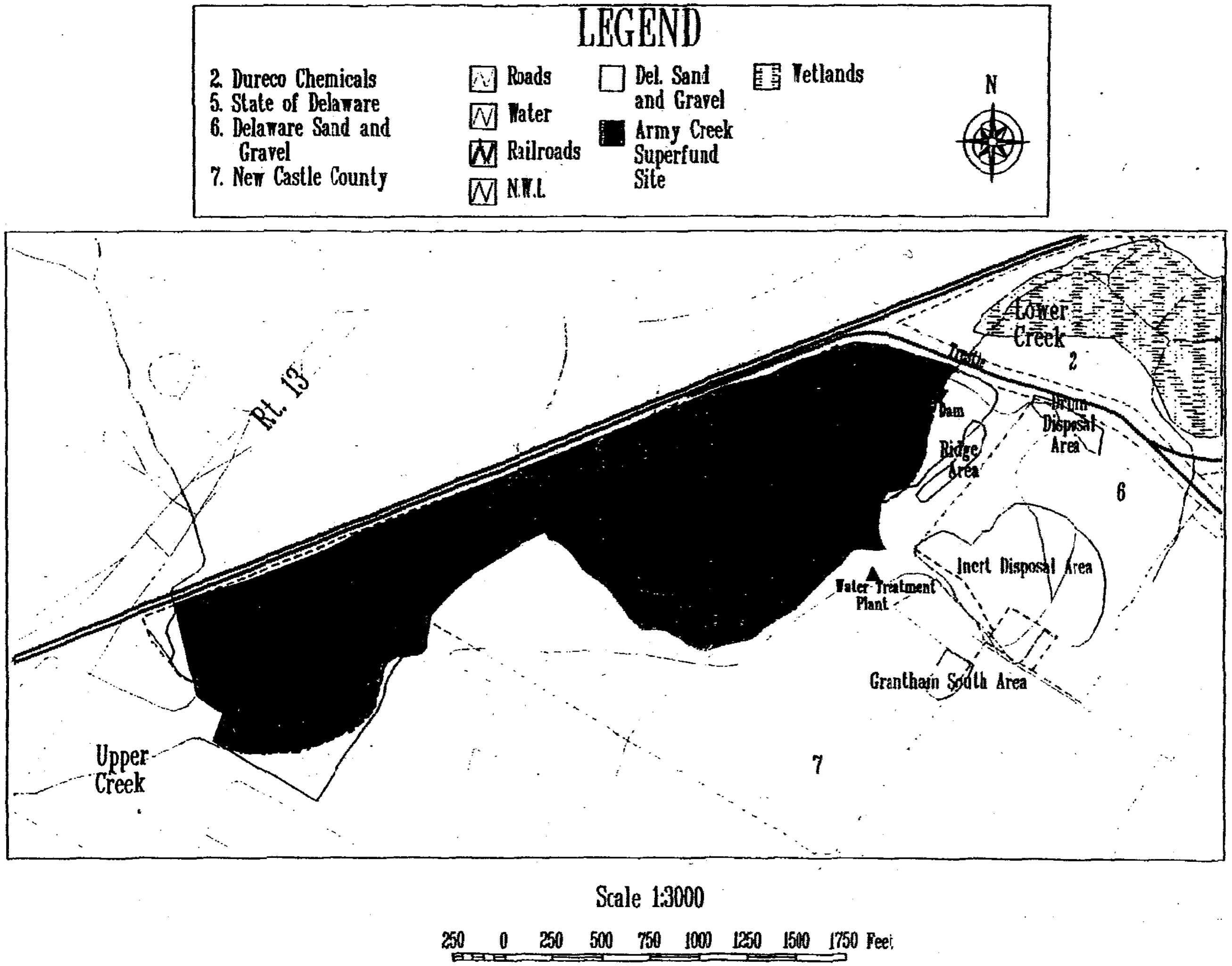

Figure 3. Army Creek and Delaware Sand and Gravel Superfund Sites

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, <u>Ictalurus nebulosus</u>[1,2];
*Catfish, <u>Ictalurus catus</u>[1,2];
Carp, <u>Cyprinus carpio</u>[1,2];
*Goldfish, <u>Carassius auratus</u>[1,2];
Golden shiner, <u>Notemigonus crysoleucas</u>[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		(*̲4̲)		
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), (*̲4̲)				
1983	20	3, (*2), (*̲4̲)				
1984	8	(*̲3̲)				
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 ations of contaminants in Army Creek sediments are compar 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, tàble 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).

TABLE 2B. ORGANIC CHEMICALS IN SE ENTS COMPARED WITH

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 Commençement 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. SEDIMENT METAL CONCENTRATIONS (ppm) IN THREE "CLEAN" 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

3.4 Human Health

The Trustees are concerned that following restoration there may be increased human access to the Army Creek watershed. Therefore, the Technical Advisory Committee, relying on the EPA's human health risk assessment, has reviewed and summarized data concerning human health issues.

The 1983, Brown Bullhead contamination data collected by DNREC is not applicable to human health risk assessment, because whole-fish samples were analyzed. Humans do not typically consume whole fish, but rather only eat fish muscle.

On May 23, 1990, DNREC collected 5 carp and 6 American eels from Army Creek. The carp were collected near Route 9 and analyzed as a composite fillet sample (Table 11), while the eels were collected from just below Army Creek Pond and analyzed as a skinned composite sample. Lead concentrations in both samples were below 1.0 ug/g; they may be higher than the FDA-Action Level (<0.3 ug/l), but this could not be determined because the actual level is less than the analytical sensitivity.

A Working Memorandum of Agreement (MOA) between the Delaware DNREC and Delaware Division of Public Health has established an organizational protocol for addressing fish contamination issues in Delaware. Issues that could be considered via this pending MOA include what waters to survey on an annual basis, how to respond to contamination findings, drafting of human health advisories, etc. Additionally, the Delaware DNREC has recently started a study of fish flesh consumption by humans for fish caught in Delaware's estuarine waters. The results of this study might eventually lead to modifications of the inputs and findings for human health risk assessment models used to determine when human health advisories are warranted.

In the Record-of-Decision-2 (June 29, 1990), the EPA presented a public health risk assessment. They considered potential sources of: 1) recovery well water discharge, 2) creek and pond surface water, 3) creek and pond sediments, 4) air in the area of the creek and pond, and 5) fish caught for human consumption. Persons who might be at risk were said to be those trespassing on the site and those residing or working downwind of the site. The potential human exposure routes included: a) inadvertent exposure to groundwater recovery well discharges (e.g., being splashed in the face) and surface water (e.g., falling into the pond), b) inhalation of volatile organic compounds from groundwater recovery well discharges and surface water (e.g., while playing in or near the pond), c) dermal absorption of contaminants from inadvertent exposure to recovered groundwater (e.g., falling into the pond), and d) fish consumption by recreational anglers. The EPA risk assessment for human health focused on carcinogenic and non-carcinogenic risks.

Table 12, Summary of Total Potential Carcinogenic Risks, shows that none of the exposure scenarios at this site, with respect to surface water and sediments, present an unacceptable risk to human health. In Table 12, an excess lifetime cancer risk of 1 x 10E-6 indicates that, as a plausible upper bound, an individual has a one-in-a-million chance of developing cancer as a result of site-related exposure to a carcinogen over a 70 year lifetime under the specific exposure conditions at a site.

The potential for human health effects resulting from exposure to non-carcinogenic compounds is estimated by comparing an estimated daily dose to an acceptable level. If the ratio exceeds 1.0, there is a potential health risk associated with exposure to that particular chemical. The ratios can be added for exposures to multiple contaminants. The sum, known as a Hazard Index, is not a mathematical prediction of the severity of toxic effects, but rather a numerical indicator of the transition from acceptable to unacceptable levels. Since none of the total Hazard Indices (Table 13) exceeds 1.0, there is no cause for concern for non-carcinogenic hazards to human health at the Army Creek site.

The Remedial Investigation found that neither the surface water, nor the recovery well discharges presented an unacceptable risk to human health or welfare; however, the most recent sampling results indicate that discharges may exceed Delaware Surface Water Quality Standard numeric criterion (1.77 ug/l for freshwater and 0.25 ug/l for marine and estuarine waters) for bis(2-chloroethyl)ether, established for protection of human health via the fish consumption exposure route. Note that in Table 7 the concentrations for bis(2-chloroethyl)ether are 4.3 ug/l (0.0043 mg/l) and

6.8 ug/l (0.0068 mg/l) in Pond water and Lower Army Creek, respectively. However, both of these values are below the method detection limit (10.0 ug/l or 0.010 mg/l).

Human Health Summary: Based upon evidence and analyses to date, types or levels of contaminants in Army Creek fish flesh have not warranted issuing a human health advisory against eating Army Creek fish. Examinations of various exposure scenarios to humans for carcinogenic or non-carcinogenic compounds found in Army Creek waters or sediments identified no unacceptable risks to human health. Therefore, restoration of natural resources from a human health perspective can be implemented based upon the EPA's human health risk assessment.

TABLE 11. COMPARISON OF CONTAMINANT CONCENTRATIONS IN BULLHEAD, CARP AND EEL WITH FDA ACTION LEVELS AND EPA PREDATOR-PROTECTION LEVELS.

Contaminant	FDA a Action Level ug/g	EPA b Predator-Protection Level ug/g	1983 Bullhead whole-body ug/g	1990 Carp Fillet ug/g	1990 Eel Skinned ug/g
As			0.6	<2.0	<2.0
Cd		<0.5	<2.0	<1.0	<1.0
Cu		<0.5	5.2	<5.0	<5.0
Hg	>1.0	<0.1	<0.1	<0.1	<0.1
Pb	>0.3	<0.1	5.0	<1.0	<1.0
Zn			18	11.2	14.9
Cr		0.2	5.2	<2.0	<2.0
Ni				<5.0	<5.0
PCB(Total?)	2.0	0.5	1.2		

a Concentration in fresh and saltwater food.
b Concentrations in predator forage items.

Note that the FDA action and tolerance levels should not be used to state that a human health problem exists, but rather to identify potential for a problem depending on the consumption habits of the individuals involved.

TABLE 12. SUMMARY OF TOTAL POTENTIAL CARCINOGENIC RISKS[1]

Media	Scenario	Age Group Exposed Children 6-11 yrs.	Age Group Exposed Adults 70 yr. life span
Groundwater Recovery Well Discharges	Inadvertent ingestion	1.2x10E-8	5.3x10E-9
	Inhalation of organics leaving groundwater	7.2x10E-7	3.1x10E-7
	Dermal absorption	9.7x10E-7	9.2x10E-7
Sediment *	Inadvertent ingestion	4.1x10E-9	1.7x10E-9
Surface Water *	Inadvertent ingestion	6.5x10E-9	2.9x10E-9
	Inhalation of organics	1.8x10E-7	7.6x10E-9
	Dermal absorption	6.0x10E-8	5.7x10E-7
Fish **	Ingestion	NC	7.7x10E-7

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

** Estimated using calculated average pollutant concentration during sampling, accepted bioconcentration factor and 5.2 g/day consumption rate. The exposure assessment assumes that 100 percent of the freshwater fish consumed by a receptor are taken from Army Creek/Pond.

NC These values could not be calculated due to a lack of sufficient information regarding fresh fish consumption for children 6-11 years old.

[1]Source: ROD-2 (EPA, 1990)

TABLE 13. SUMMARY OF TOTAL POTENTIAL NON-CARCINOGENIC HAZARD INDICES[2]

Media	Scenario	Age Group Exposed: Children 6-11 yrs.	Age Group Exposed: Adults 70-yr.life span
Groundwater Recovery Well Discharges	Inadvertent ingestion	0.000015	0.0000013
Sediment *	Inadvertent ingestion	0.00036	0.000031
Surface Water *	Inadvertent ingestion	0.0008	0.00069
Fish	Ingestion	NC	0.0048

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

NC These values could not be calculated due to a lack of sufficient informaation regarding average fresh fish consumption for children 6-11 years old.

If the Hazard Index exceeds 1.0, there is a potential health hazard associated with exposure to the medium.

[2]Source: ROD-2 (EPA, 1990)

TABLE 11. COMPARISON OF CONTAMINANT CONCENTRATIONS IN BULLHEAD, CARP AND EEL WITH FDA ACTION LEVELS AND EPA PREDATOR-PROTECTION LEVELS.

Contaminant	FDA a Action Level ug/g	EPA b Predator-Protection Level ug/g	1983 Bullhead whole-body ug/g	1990 Carp Fillet ug/g	1990 Eel Skinned ug/g
As			0.6	<2.0	<2.0
Cd		<0.5	<2.0	<1.0	<1.0
Cu		<0.5	5.2	<5.0	<5.0
Hg	>1.0	<0.1	<0.1	<0.1	<0.1
Pb	>0.3	<0.1	5.0	<1.0	<1.0
Zn			18	11.2	14.9
Cr		0.2	5.2	<2.0	<2.0
Ni				<5.0	<5.0
PCB(Total?)	2.0	0.5	1.2		

a Concentration in fresh and saltwater food.
b Concentrations in predator forage items.

Note that the FDA action and tolerance levels should not be used to state that a human health problem exists, but rather to identify potential for a problem depending on the consumption habits of the individuals involved.

. _E 1_. SUMMARY OF TOTAL POTENTIAL CARCINOGENIC RISKS*

Media	Scenario	Age Group Exposed: Children 6-11 yrs.	Age Group Exposed: Adults 70 yr. life span
Groundwater Recovery Well Discharges	Inadvertent ingestion	1.2x10E-8	5.3x10E-9
	Inhalation of organics leaving groundwater	7.2x10E-7	3.1x10E-7
	Dermal absorption	9.7x10E-7	9.2x10E-7
Sediment *	Inadvertent ingestion	4.1x10E-9	1.7x10E-9
Surface Water *	Inadvertent ingestion	6.5x10E-9	2.9x10E-9
	Inhalation of organics	1.8x10E-7	7.6x10E-9
	Dermal absorption	6.0x10E-8	5.7x10E-7
Fish **	Ingestion	NC	7.7x10E-7

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

** Estimated using calculated average pollutant concentration during sampling, accepted bioconcentration factor and 5.2 g/day consumption rate. The exposure assessment assumes that 100 percent of the freshwater fish consumed by a receptor are taken from Army Creek/Pond.

NC These values could not be calculated due to a lack of sufficient information regarding fresh fish consumption for children 6-11 years old.

Source: ROD-2 (EPA, 1990)

TABLE 13. SUMMARY OF TOTAL POTENTIAL NON-CARCINOGENIC HAZARD INDICES*

Media	Scenario	Age Group Exposed: Children 6-11 yrs.	Age Group Exposed: Adults 70-yr. life span
Groundwater Recovery Well Discharges	Inadvertent ingestion	0.000015	0.0000013
Sediment *	Inadvertent ingestion	0.00036	0.000031
Surface Water *	Inadvertent ingestion	0.0008	0.00069
Fish	Ingestion	NC	0.0048

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

NC These values could not be calculated due to a lack of sufficient informaation regarding average fresh fish consumption for children 6-11 years old.

If the Hazard Index exceeds 1.0, there is a potential health hazard associated with exposure to the medium.

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* Source: ROD-2 (EPA, 1990)

4.0 GENERAL CONCLUSIONS AND RECOMMENDATIONS

4.1 Assessment Problems

Site-specific contamination data for sediment, water or biota, obtained from the Administrative Record and other sources, were used to determine the suitability of restoring Army Creek. These data represent information available before remediation has been completed. As remediation continues toward completion water quality conditions in Army Creek are anticipated to improve. Therefore, data used to make our determination may represent a period when conditions were most degraded.

4.2 Undertake Restoration Of Lower Army Creek Marsh

The Technical Advisory Committee, based upon its technical assessment, concludes that wetland habitat restoration could be undertaken in Lower Army Creek basin, downstream of Army Creek Pond. The landfill impacts on natural resources in Lower Army Creek are not severe enough to prohibit an undertaking of restoration activities in the near future. The restoration efforts in Lower Army Creek Marsh should focus on several multiple-resource objectives: 1) enhancement of tidal exchanges with the Delaware River to help restore functional processes for nutrient cycling and aquatic organism use; 2) enhancement of wetland habitats that serve as spawning, nursery or feeding areas for estuarine/anadromous fishes; 3) enhancement of wetland habitats for waterbirds and other wildlife; 4) reduction in the need for chemical insecticides for mosquito control; 5) potential increase in the use of the area for outdoor recreation or environmental education; etc. A monitoring effort following baseline studies will be needed to determine if the restoration goals are being met and if restoration activities should be adjusted to better meet the goals. Additionally, it would be desirable to determine the effects of the habitat restoration work on contaminant concentrations in sediments, surface water, and biota in the lower marsh.

4.3 Rationale For Restoration Of Lower Army Creek Marsh

The only feasible restoration work which could be immediately undertaken to help restore the Trustee resources of migratory waterfowl and anadromous/estuarine fish must occur in Lower Army Creek. The Technical Advisory Committee bases its recommendation to restore Lower Army Creek on the following information:

a) In comparison with the sediments of several other relatively uncontaminated creeks in Delaware, Lower Army Creek sediments have higher concentrations of some metals. Compared with sediments of the Delaware River, however, Lower Army Creek sediments have lower levels for many metals.

b) 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. Zinc, Pb, and Hg concentrations are between ER-L (Effects Range-Low) and ER-M (Effects Range-Median) and Cr is below the ER-L, suggesting that there is relatively minimal potential impact to biota in this area. Note that the taxa used in the Long and Morgan (1991) analyses have representatives found in Army Creek. 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. Therefore, minimal potential adverse effects would be expected for newly arriving anadromous species should Lower Army Creek be opened to the Delaware River.

c) With the exception of Fe and one Zn sample, none of the surface water concentrations of contaminants in Lower Army Creek exceed Federal AWQC for aquatic life or State of Delaware standards for non-tidal streams. Compared with the Delaware River, heavy metal concentrations in Army Creek surface waters are similar to or only slightly elevated. Thus, opening Lower Army Creek to the tidal influence of the Delaware River would not significantly increase surface water concentrations of heavy metals in Army Creek.

d) Fathead minnow survival and survival and reproduction of water fleas were not adversely affected by exposure to Lower Army Creek water.

e) Species diversity and the number of taxa are higher for Lower Army Creek than for either Upper Creek or the Pond.

f) Only a small percentage of the population of each diadromous species in the Delaware River system is likely to enter Army Creek or be significantly exposed to Army Creek contaminants should Lower Army Creek be opened to the Delaware River.

g) Individuals of diadromous species that do enter Army Creek are likely to be there for a relatively short (e.g., 6 months or less) but unspecified period of time, except for blue crab and American eel. The blue crab and American eel, which associate with bottom sediments, may reside in the creek for considerable periods of time, but most of their populations will be elsewhere.

h) American eels may be exposed to Pond sediments, because they are apparently capable of getting around small obstructions. However, no other diadromous species would be directly exposed to the more contaminated Pond habitat.

i) It is believed that no diadromous species spawn in Army Creek, suggesting that few sensitive life stages are present; however, juveniles may be present. The combination of limited exposure (i.e., relatively small percentage of total population in creek; unlikelihood of eggs or larvae being exposed even though juveniles may be present; and limited time in or near creek) plus relatively low levels of contamination in Lower Army Creek suggest, at worst, limited impacts on individuals and no significant impacts on populations, including those of endangered species, such as the shortnose sturgeon.

j) Species resident to Army Creek (e.g., resident fishes, amphibians, turtles, snakes, birds, mammals) are exposed to chronic, low levels of contaminants, but perhaps not much more so than those species living in or by many other Delaware creeks. Opening Lower Army Creek to tidal flow should result in no increased contaminant exposure or decreased populations (unless change in habitat or competition significantly decreases presence of species), and should improve habitat quality overall. Exchanges and dilutions of Army Creek water with tidal Delaware River water should have a beneficial effect on Army Creek habitat, and not significantly affect Delaware River quality. Opening the Lower Creek to tidal flow should help to restore emergent wetlands vegetation characteristic of tidal, oligohaline wetlands.

k) Any changes in contaminant exposure or population levels of both residents and non-residents probably will not be driven by changes in salinity (both adjacent river and creek are essentially fresh), but perhaps by changes in marsh water levels or tidal exchanges, by changes in habitat (e.g., Phragmites replaced by mixed emergents), or by changes in competition caused by arrival of new species (e.g., anadromous fishes).

l) It was estimated that the Delaware River would be minimally affected in terms of water quality by discharges of recovery wells to Army Creek. None of the discharges from the wells exceeds the water quality standards listed in the Delaware River Basin Commissions' July 1978 "Water Code of the Delaware Basin". The State of Delaware Surface Water Quality Standards for Streams, as amended August 27, 1982, states: "All waste discharges shall receive, at minimum, treatment necessary to comply with Federal, Delaware River Basin Commission (DRBC), or Department Regulations Governing the Control of Water Pollution, whichever regulation is applicable or more stringent."

m) After the eventual cessation of groundwater recovery pumping, which will cause decreased flow and lead to stagnation, water quality in Lower Army Creek is anticipated to substantially deteriorate without restoring tidal exchanges with the Delaware River.

n) Based on information to date, no human health advisory for consuming Army Creek fish flesh has been warranted or issued.

o) By working closely with the EPA, it is believed that the activities associated with capping and water treatment remediation efforts at both the Army Creek and Delaware Sand & Gravel (DS&G) Landfills, as well as any bio-remediation activities undertaken at DS&G, will not interfere or adversely affect resource restoration efforts in Lower Army Creek.

p) Highway runoff contaminants, such as Zn or Hg, should be adequately dealt with by the State of Delaware's (DNREC/DWR) pending National Pollutant Discharge Elimination System (NPDES) program requirements for stormwater discharges and by the State's proposed interactions with the Army Creek Trustees in regard to specific road runoff issues at the Army Creek site.

4.4 No Restoration At Present In Army Creek Pond or Upper Creek

Because of contamination levels in the sediments or surface water of Army Creek Pond and upstream reaches, the Technical Advisory Committee does not recommend that natural resource restoration efforts be undertaken in aquatic or wetland habitats in the Pond or upstream area, nor should any effort be made to attract fish and wildlife resources to these areas at the present time. In part, this conclusion is based upon:

a) 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 to those that exceed concentrations defined by the Effects Range-Median (ER-M). The highest concentration of Zn in the sediments of the Pond exceeds the Overall Apparent Effects Threshold as defined by Long and Morgan (1991).

b) Concentrations of Cd, Cr, Fe, Hg, and Zn in the surface waters of Army Creek Pond may exceed AWQC for protection of freshwater aquatic life.

c) Abundance and diversity of benthic macroinvertebrates and fishes is lower in Army Creek Pond and upstream areas than in Lower Army Creek.

d) Bioassay tests using ambient surface waters and presence/absence of indicator species also indicate that Army Creek Pond and Upper Army Creek environs are degraded in comparison to Lower Army Creek.

The Technical Advisory Committee has a concern that the sediments of Army Creek Pond may not be satisfactorily cleansed of residual contaminants accumulated prior to initiating groundwater treatment by the water treatment facility. For example, the Fe floc currently in the Pond sediments may not dissipate; the Zn in the sediments which may have come from the landfill or other landscape sources may not decrease. The Trustees will not resolve the issue of restoration for Army Creek Pond and Upper Army Creek until after periodic review by the EPA, no later than approximately 1999, for both the cap and the water treatment facility.

The results of the remediation efforts to reduce or eliminate contamination problems will have to be evaluated to judge if they have reduced contamination. For surface water that would mean that contaminant concentrations were below the Ambient Water Quality Criteria. In the case of sediment, concentrations of contaminants must not exceed EPA sediment criteria protective of natural resources (if they have been established), or the Long and Morgan (1991) sediment guidelines, or other more recent guidelines that may appear in the open literature. There may be other criteria that are examined (e.g., bioassays, criteria to protect wildlife health). As has been done in this report, a deliberative process will occur that will consider the preponderance-of-evidence for multiple factors and their criteria.

The Technical Advisory Committee recommends that future resource management considerations for Army Creek Pond include enhancement of fish habitat. To achieve this goal, the existing contamination levels must first be reduced. Other factors throughout the watershed such as water supply, sediment composition, sedimentation rates, water temperature, channel dimensions, etc. also should be addressed. Much of this effort would be dependent upon funding sources beyond the present damages.

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ACRONYMS AND ABBREVIATIONS

AET	Apparent Effects Threshold Approach
Ag	Silver
Al	Aluminum
As	Arsenic
AVS	Acid volatile sulfides
AWQC	Ambient Water Quality Criteria
Ba	Barium
BCCOA	Bioeffects/Contaminant Co-occurrence Analysis Approach
BMPs	Best Management Practices
Ca	Calcium
Cd	Cadmium
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
c.f.s.	Cubic Feet per Second
Co	Cobalt
Cr	Chromium
Cu	Copper
DELDOT	Delaware Department of Transportation
DNHI	Delaware Natural Heritage Inventory
DNREC	Delaware Department of Natural Resources and Environmental Control
DRBC	Delaware River Basin Commission
DS&G	Delaware Sand & Gravel Superfund Site
DWR	DNREC, Division of Water Resources
EPA	U.S. Environmental Protection Agency
ER-L	Effects Range Low
ER-M	Effects Range Median
FDA	Food and Drug Administration
Fe	Iron
FFS	Focused Feasibility Study
FRI	Focused Remedial Investigation

FS	Feasibility Study
FWS	U.S. DOI, Fish and Wildlife Service
FYER	Five Year Evaluation Review/Report
Hg	Mercury
K	Potassium
LC	Lethal concentration
MEK	Methyl ethyl ketone
Mg	Magnesium
mg/kg	ppm
mg/l	ppm
MIBK	Methyl isobutyl ketone
Mn	Manganese
MOA	Memorandum of Agreement
Na	Sodium
ND	Not Detectable
NGVD	National Geodetic Vertical Datum
Ni	Nickel
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NSD	Not Sufficient Data
OAET	Overall Apparent Effects Threshold
PAH	Polynuclear Aromatic Hydrocarbons
Pb	Lead
PCB	Polychlorinated Biphenyls
ppb	Parts per billion
ppm	Parts per million
ppt	Parts per thousand
PRP	Potentially Responsible Party
RCRA	Resource Conservation and Recovery Act

RI	Remedial Investigation
ROD	Record-of-Decision
RPM	Remedial Project Manager
S1	State Species of Special Concern [1= most concern]
Sb	Antimony
Se	Selenium
SLC	Screening Level Concentrations Approach
SSB	Spiked-Sediment Bioassay Approach
SWEPT	Sediment-Water Equilibrium Partitioning Approach
TAC	Technical Advisory Committee
TOC	Total organic carbon
ug/g	Microgram per gram (ppm)
ug/kg	Micrograms per kilogram (ppb)
ug/l	Micrograms per liter (ppb)
U.S. DOI	U.S. Department of Interior
Zn	Zinc

ADDENDUM

Since the completion of the Report of the Technical Advisory Committee on Army Creek Contaminant Issues (TAC Report) new information has come available regarding contaminant concentrations in marine and estuarine sediments and their potential biological effects. The purpose of this addendum is to review this new information and update the conclusions and recommendations of this report to reflect this new information. Many of the statements that follow are taken directly from Long et al. (In press) and Long and MacDonald (1992).

Using data available from all the major approaches to the development of effects-based criteria, Long and Morgan (1991) prepared informal guidelines for use by the National Oceanic and Atmospheric Administration (NOAA) to identify chemicals that occurred in concentrations that were sufficiently high to warrant concern and to identify sampling sites and areas in which there was a potential for toxicity. These guidelines also have been used to provide an estimate of the potential for adverse biological effects of sediment-associated contaminants on benthic organisms, based on a weight of evidence from analyses performed with multiple species and/or biological communities (Squibb et al., 1991; Mannheim and Hathaway, 1991; Soule et al., 1991). The use of these (Long and Morgan, 1991) guidelines was included in the report in Section 3.1 and is reflected in the conclusions and recommendations (Section 4.3). Subsequently, the database from which these guidelines were prepared has been updated and expanded and the approach refined (Long and MacDonald, 1992; MacDonald, 1992; Smith and MacDonald, 1992). The update and refinement were not included in the TAC Report and is the focus of this addendum.

The update and refinement of Long and Morgan (1991) has resulted in the development of a Biological Effects Database for Sediments (BEDS) which integrates chemical and biological data from numerous studies conducted throughout North America to support the derivation of the updated guidelines. The database used by Long and Morgan (1991) was refined by excluding data from freshwater studies and including data from additional sites, biological test endpoints, and contaminants. Nearly 350 publications were reviewed and screened for possible inclusion in the

BEDS. Data from equilibrium-partitioning modelling, laboratory spiked-sediment bioassays, and field studies of sediment toxicity and benthic community composition were critically evaluated. Only matching, synoptically-collected biological and chemical data from marine and estuarine studies were included in the database. Data were excluded if: 1) methods were not clearly described, 2) sediments were frozen before toxicity tests, 3) toxicity of controls were higher than commonly acceptable, 4) there was less than a 10-fold difference in the concentrations of all contaminants among sampling stations, 5) chemical analytical procedures were inappropriate, and 6) either no biological data or chemical data were reported.

Each concentration value entered in the BEDS was placed in ascending order and assigned an "effects/no effects" descriptor. An entry was assigned an "effects" descriptor if: 1) an adverse biological effect was reported and 2) concordance was apparent between the observed biological response and the measured chemical concentration. For broad applicability, the kinds of adverse effects included: 1) measures of altered benthic communities (depressed species richness or total abundance), significantly or relatively elevated sediment toxicity, or histopathological disorders in demersal fish observed in field studies; 2) EC_{50} or LC_{50} concentrations determined in laboratory bioassays of sediment spiked with single compounds or elements; and 3) toxicity predicted by equilibrium-partitioning models. These ascending data tables, as reported by Long and Morgan (1991) and updated by Long and MacDonald (1992), MacDonald (1992), and Smith and MacDonald (1992), summarized the available information for each chemical or chemical group that was considered.

With Long and Morgan (1991) the distributions of the effects data were determined using percentiles (Byrkit, 1975). Two values were derived for each chemical or chemical group. The lower 10th percentile of the effects data for each chemical was identified and referred to as the Effects Range-Low (ER-L). The median, or 50th percentile, of the effects data was identified and referred to as the Effects Range-Median (ER-M). The concentrations below the ER-L value represent a "Minimal-Effects" range; a range intended to estimate conditions in which effects would be rarely observed. Concentrations equal to and above the ER-L, but below the ER-M represent a "Possible-Effects" range within which effects would occasionally occur. Finally, the concentrations equivalent to and above the ER-M value represent a "Probable-effects" range within which effects would frequently occur.

The method used by MacDonald (1992) considered both the "effects" and "no effects" data, whereas that of Long and Morgan (1991) used only the "effects" data. For the MacDonald (1992) data, a threshold effects level (TEL) was calculated first as the square root of the product of the lower 15th-percentile concentration associated with observations of biological effects (the ER-L) and the 50th-percentile concentration of the no-observed-effects data (the NER-M). A safety factor of 0.5 was applied to the TEL to define a No-Observable-Effects-Level (NOEL). MacDonal has since dropped the calculation of NOELs as one-half of the TEL values (Long, pers. Comm.). Next, a Probable-Effects Level (PEL) was calculated as the square root of the product of the 50th-percentile concentration of the effects data (the ER-M) and the 85th-percentile concentration of the no effects data (the NER-M). Despite the differences in methods, the agreement between Long and Morgan (1991) and MacDonald (1992) is very good (Long and MacDonald, 1992). MacDonald (1992) also calculated guidelines only for those chemicals for which there was a minimum of 40 data points, after determining the minimum amount of data necessary to calculate reliable and consistent values. These minimum data requirements were established by iteratively calculating guidelines using data sets of increasing size and determining when the estimate of the guidelines stabilized.

Neither Long and Morgan (1991) nor MacDonald (1992) is preferred or advocated over the other (Long and MacDonald, 1992). According to Long and MacDonald (1992), the significant feature is the use of a weight of evidence developed in the ascending tables, not the specific method of using the data tables. The overall approach used by Long and Morgan (1991) and MacDonald (1992) to develop such guidelines is being used by Environment Canada and Florida Department of Regulation. It also has been adopted by a committee of the International Council for the Exploration of the Sea for use by member nations (Long and MacDonald, 1992).

Results

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. Additionally, zinc at the highest concentration observed exceeded the Overall Apparent Effects Threshold. 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.

However, Long and MacDonald (1992) only consider "No-Observable-Effects Levels" (approximately equivalent to Long and Morgan's ER-L) and "Probable-Effects Levels" (approximately equivalent to Long and Morgan's ER-M). Thus, the only comparisons to be made are between the ER-L and ER-M values of Long and Morgan (1991) and those equivalents of Long and MacDonald (1992).

For the sediments Army Creek Pond, zinc exceeds the ER-M of Long and Morgan (1991), but not the equivalent ER-M of Long and MacDonald (1992) [See Addendum Table 1a]. Lead concentrations in the bottom sediments of Army Creek Pond exceed the ER-L for Long and Morgan (1991) and the equivalent ER-L of Long and MacDonald (1992). Copper and nickel concentrations in the bottom sediments of Army Creek Pond did not exceed the ER-L of Long and Morgan (1991), but did the equivalent ER-L of Long and MacDonald (1992). Using the guidelines of Long and Morgan (1991), lead exceeds the ER-L value and zinc exceeds the ER-M value. Using the guidelines of Long and MacDonald (1992), copper, lead, nickel, and zinc concentrations in the bottom sediments of Army Creek Pond exceed the ER-L values. In addition to lead and zinc, copper and nickel are placed into the "Possible-Effects" range by Long and MacDonald (1992).

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).

For comparative purposes here, concentrations of lead, mercury, and zinc in the bottom sediments of Lower Army Creek range from less than those potentially causing adverse effects to those approximately twice the ER-L but less than the ER-M, based on the guidelines of Long and Morgan (1991). Based on the guidelines of Long and MacDonald (1992), arsenic, lead, mercury, and zinc concentrations in the bottom sediments of Lower Army Creek exceed the equivalent ER-L, but not the equivalent ER-M. Thus, the only difference in Lower Army Creek between the previous conclusions and modifications prompted by the newer Long and MacDonald (1992) data is the addition of arsenic as a "Possible Effects" problem. This addition is caused by a reduction in the ER-L value for arsenic from 33 ppm (Long and Morgan, 1991) to an equivalent ER-L of 8.2 ppm (Long and MacDonald, 1992), which is now lower than one of the three known arsenic sample concentrations from the bottom sediments of Lower Army Creek (arsenic sample concentrations from Lower Army Creek were 13.5, 5.4, and 2.3 ppm).

Summary and Conclusions

The application of the Long and MacDonald (1992) guidelines additionally identified copper and nickel in the sediments of Army Creek Pond as having "Possible-Effects" (i.e., greater than ER-L, but less than ER-M), and added arsenic as a metal having "Possible-Effects" in sediments of Lower Army Creek. The refinement of Long and Morgan's (1991) values by Long and MacDonald (1992) changed the category of these metals from "No-Observable-Effects" or "Minimal-Effects" (i.e., less than ER-L) to "Possible-Effects". In addition, the only other modification based upon Long and MacDonald (1992) is a change in the category of zinc in the sediments of Army Creek Pond from "Probable-Effects" (i.e., greater than ER-M) to "Possible-Effects".

For interpretive purposes Long et al. (In press) report that for most trace metals, biological effects were observed in 5-10% of the studies (depending on the particular metal involved) where concentrations were below the ER-L. For concentrations above the ER-M values, from 63-95% of the studies (depending on the particular metal involved) showed effects. According to Long (pers. comm.), "We interpret these data as saying that, based upon previous studies, there is about a 5.0% probability of toxicity at, say, arsenic concentrations of 8.2 ppm (the ER-L value) or less and about a 63% probability of effects at arsenic concentrations above the ER-M value." At concentrations in between, the probability of effects would range between 5% and 63%. "There are several exceptions to this pattern, the most notable of which is nickel. The incidence of toxicity above and below the ER-M and ER-L [respectively] are virtually the same. Therefore, we have no confidence in the guidelines for nickel" (Long, pers. comm.).

Based on this analysis, the changes noted above are viewed as minor since none involve a change to a "Probable-Effects" category. Concerning organics in sediments, no additional statements can be made, because the data are too sparse (See Addendum Table 1b). Therefore, the general conclusions and recommendations of the TAC Report remain unchanged.

Summary Table for Army Creek Pond and Lower Army Creek of exceedances 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) and MacDonald (1992). 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	*			*	#		
Arsenic					@		

* Army Creek Pond exceeds based on Long and Morgan (1991)
+ Lower Army Creek exceeds based on Long and Morgan (1991)
= Pond equals ER-L based on Long and Morgan (1991)
Army Creek Pond exceeds based on MacDonald (1992)
@ Lower Army Creek exceeds based on MacDonald (1992)

and Harbors, County of Los Angeles. University of Southern California, Los Angeles, CA. 206pp.

Squibb, K.S., J.M. O'Connor, and T.J. Kneip. 1991. New York/New Jersey Harbor Estuary Program. Module 3.1: Toxics characterization report. Prepared for U.S. Environmental Protection Agency, Region 2. NYU Medical Center, Tuxedo, NY. 65pp.

APPENDIX B

NEPA COMPLIANCE

NEPA COMPLIANCE CITATIONS: In an abbreviated fashion we refer to sections within the restoration plan where details of compliance can be found.

1.0 Purpose of and Need for Action

The purpose and need for action is specified in section 1.2 in the restoration plan. The Army Creek Natural Resources Trustees want to increase suitable habitat for natural resources under their Trusteeship as a Superfund (CERCLA) restoration activity. A general description on the background of the Army Creek site can be found in the introduction of the restoration plan, section 1.3.

1.1 Significant issues identified.

The Restoration Plan, section 2.0, identifies the lack of tidal inflows, and to a lesser extent, upstream water withdrawals and diversions, as a significant problem at the Army Creek Site.

The Environmental Assessment, Appendix A, section 2.1, details the potential environmental impacts at the Army Creek Site. Such impact considerations include the evaluation of contaminant levels that can cause continued injury to Trust resources, alterations of the water table level, road runoff problems and impacts on mosquito control.

2.0 Federal permits, licenses, and entitlements necessary to implement the project.

The Restoration Plan, section 2.0, explores possible State and Federal permit requirements, including the consideration of Federal wetland permit section 404.

No Federal or State threatened or endangered species have been found at Army Creek. Rare species, as classified by the Natural Heritage

Foundation, are discussed in the Restoration Plan section 2.1.2 and Appendix A, Attachment II.

Land acquisition activities are discussed in section 2.2 Upland Restoration.

3.0 Alternatives Including the Proposed Action

The Restoration Plan, section 2, details the water and vegetation plans with associated alternative proposals. The water management plan contains several proposals for tidal exchange: no action, unmanaged tidal exchange, maximize marsh surface inundation and the proposed action of controlled tidal exchanges. The vegetation plan addresses the alternatives for restoring desirable tidal marsh species. These alternatives encompass no action, flooding, mowing, burning, mow and burn, herbicide, and the proposed action herbicide and burn treatment.

4.0 List of Preparers

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

U.S. Department of the Interior,
Fish and Wildlife Service
Robert E. Foley

U.S. Department of Commerce,
National Oceanic And Atmospheric Administration
James P. Thomas, Timothy E. Goodger, Peter Leigh

5.0 List of Agencies, Organizations, and Persons to Whom Copies of the Statement are Sent.

State of Delaware,
Department of Natural Resources and Environmental Control

U.S. Department of Interior,

Fish and Wildlife Service

U.S. Department of Commerce,
National Oceanic and Atmospheric Administration

APPENDIX C

WATER CONTROL STRUCTURE AND SCHEDULE

Required Changes to Existing Structure for the Proposed Action

1) Existing Structure -- Meeting many of the environmental objectives will necessitate increasing tidal exchanges and marsh water levels. In order to achieve the desired tidal exchanges and marsh water levels in a controlled fashion, while also preventing excessive floodings, it will be necessary to modify and then manage the existing water control structure located at the mouth of Army Creek, adjacent to the Delaware River. The water control structure currently consists of five 48"-diameter pipes each fitted with one-way flapgates on the riverside, allowing only outflow of upland runoff and prohibiting tidal inflow.

The structure is equipped with slots for installing riserboards to control marsh water levels (using water derived from accumulated upland runoff), but to date managing Army Creek water levels using riserboards has not been done. Potential use of riserboards would primarily be to set and try to maintain minimum marsh water levels. Because the existing riserboard slots may not be high enough to achieve some of the desired management levels, it may also be necessary to modify the structure to allow higher riserboard settings. Problems with relying solely upon riserboards for marsh water management include the need for constant checking and manual manipulations of the riserboards in response to management objectives or storm events; very limited flexibility for managing tidal inflow in association with varying marsh water levels; inhibition of the frequency or duration of tidal inflows; diminished marsh water volume discharge capacity; and reliance upon upland runoff to meet most wetland water supply needs.

2) New Needs and Costs for the Water Control Structure -- In order to help achieve the water management goals necessary to restore and then maintain high quality wetlands habitat in Lower Army Creek Marsh, it will be necessary to retrofit one or more of the existing 48"-diameter pipes in the Army Creek water control structure with automated tidegates, thereby allowing controlled tidal exchanges. The automated gates could be either mechanical floatgates (which operate in response to water

levels on the river side) or electronic slidegates (which operate in response to sensing water levels on both sides of the structure). Any of the remaining one-way flapgates would continue to operate as in the past, and the desirability of using various configurations of riserboards in association with the new and old tidegates would be assessed.

The cost of an automated mechanical floatgate, such as the Steinke Self-Regulating Tidegate (SRT) is about $22,000 for one gate, or $20,000 per gate for two or more SRT's. The SRT is a mechanically-operated gate using floats on the structure's river side to automatically open the gate at a preset river height and to automatically close the gate at a preset river height, thereby controlling when flood waters can enter the marsh. These height settings are adjustable. This opening and closing occurs regardless of marsh water levels, presenting potential problems under certain conditions. The SRT discharges water from the marsh to the river on a gravity basis, whenever marsh water levels exceed river water heights; this also can present a potential problem in terms of excessively dewatering the marsh. Stoplogs or riserboards may be used in the structure's existing channels to partially offset this problem. If all five existing flapgates were replaced with SRT's, material costs will be about $100,000. To take off one existing flapgate and replace it with a SRT will involve about 1-1/2 days of labor for a 3-man crew with crane, costing about $2,000 per gate, or $10,000 for all 5 gates. Thus, the total cost for material and installation for replacing all five gates with SRT's would be about $110,000. It is not yet known if 1, 2, 3, 4 or all 5 gates will need SRT's (this awaits outcome of a hydrological engineering study).

If we want or need a structure enabling more responsive changes in marsh water levels under a wider range of conditions than achievable with SRT's, one or more of the existing flapgates could be replaced with an automatic Vertical Lift Gate (VLG) having water level electronic sensors on both marsh and river sides; this would enable control of the duration or amount of river flooding and the duration or extent of marsh discharge based on marsh water levels. The material cost of a single VLG is about $11,300. However, installing the first VLG would incur a total cost of about $39,300; beyond the VLG's material cost of $11,300, there would also be cost to remove the old flapgate ($2000), install the new VLG ($3500), add electronic water level sensors and computerized integration ($7500), install electric power lines and transformers running to the site ($5000), and provide for a secured control cabinet and electrical connections ($10,000). However, many of the above costs would not have to be repeated in order to add a second or more VLG's; it's estimated that each additional VLG could be installed for a total cost of $18,800 per gate. If all five existing flapgates were replaced with VLG's, the total cost could be $114,500.

The difference between the costs for five VLG's($114,500) vs. five SRT's ($110,000) is only $4500, so initial costs should not be a major factor in determining which type of gate to use. Rather, questions about the ability to achieve or maintain desired water level settings under variable conditions, about the ability to finely adjust marsh water level heights, about the ability to rapidly make adjustments, about the reliability of the gates to function as designed, about the gates' short-term and long-term maintenance and repair needs, and about other similar practical concerns will all enter into making the final choices. Depending upon the outcome of a hydrological engineering study and analyses of the above factors, the final water control structure design might be a mixture of VLG's, SRT's, and the flapgates.

The estimated total cost of about $150,000 is based on doing some type of replacement for all five existing flapgates, plus an additional $35,000-$40,000 as a buffer to accommodate what are usually inevitable unanticipated expenses. Of course, if one or more existing flapgates are left as is, the total estimated cost decreases. Efforts should also be made to incorporate practicable security or anti-vandalism features into the structure's design, which will also increase the structure's costs.

3) Hydrological Engineering Study -- In order to determine what types of structural modifications should be made to Army Creek's water control structure to achieve the water management objectives for wetlands restoration and maintenance, the Trustees will approve a contract with an engineering consulting firm to assess what the proposed water management schedule entails, and to plan and design a structure that will achieve the water management objectives. The engineering consultant will be contacted as soon as possible after the restoration plan is approved and funds are released to start the restoration work. It is estimated that the consultant's cost will be about $30,000 for a 6-12 month project. The consultant will be performing several tasks, which include in part:

1) Modeling of surface hydrological patterns in Army Creek's watershed, with an emphasis on how the current water control structure now discharges upland runoff, and on how future structural modifications would affect this discharge capacity.

2) Determination of how new, and unusually high, marsh water levels will affect potential for flooding problems on Rt. 9 or on developed properties around the wetlands periphery, and how the new marsh water levels will affect stormwater detention and discharge capacities.

3) Design of structural modifications to the existing water control structure in order to achieve the varying tidal exchange and marsh water level objectives that are desired, addressing issues such as:

a) Use of mechanical floatgates vs. electronic slidegates;

b) Number of existing flapgated pipes to be retrofitted with new tidegates (from 1 to 5);

c) Potential role of riserboards in future management schemes;

d) Management settings and schedules for operation of the new (modified) water control structure;

e) Reliability, security and maintenance considerations regarding the structure;

f) Economic costs of installing and maintaining the structure.

Additionally, the Trustees will have to address who are the responsible parties for the long-term operation and maintenance of the water control structure, which is examined in the Operations and Maintenance section of this plan.

Proposed Water Management Schedule

The proposed water management schedule is given in Table C-1, as part of the proposed action to accomplish the multiple environmental objectives. Based upon preliminary topographic surveys, accompanying Figures 5-1 and 5-2 show the relationships between tidal datum elevations, marsh surface elevations, structural elevations, and proposed water level management elevations (all important in understanding the proposed water management plan). A general picture of Lower Army Creek Marsh's wetlands vegetation cover, water cover, and surface water flows BEFORE implementing the proposed action (i.e. the existing conditions) is presented in accompanying Figure C-1. Essentially, this "before" condition consists of a wetland dominated almost exclusively by a thick, robust monoculture of phragmites; surface water cover confined primarily to deeper channels and guts; and surface water movements in only an outflow or discharge direction. A general picture of Lower Army Creek Marsh's wetlands vegetation cover, surface water cover (at a maximum managed pool level), and surface water flows AFTER implementing the proposed action is presented in accompanying Figure C-2. This "after" condition will have a diverse cover of emergent, brackish-water wetlands plants; surface water cover of varying heights, from full pool to channel waters only, as temporally prescribed in a water management schedule; and surface water tidal movements in both flood and ebb directions.

TABLE C-1. Proposed Water Management Schedule

Date	Manipulation	Rationale
March-April	Reduce pool level to 0% at LT, but do not exceed 100% pool at HT (approx. +0.2 ft. NGVD); allow semi-daily tidal floods until 100% pool is reached, and semi-daily maximum ebbs.	Promote maximum flushing of accumulated overwinter detritus and sediment; permit anadromous fish egress; allow regrowth of marsh emergents.
May	Manage for an average 50% pool level, with a 40-60% range per tide cycle; allow about 4 hrs. of flood near HT and 4 hrs. of ebb near LT.	Increase pool level and stability for waterfowl breeding without inundating nests; permit fish movements; continued regrowth of high marsh emergents
June-July	Manage for an average 75% pool level, with a 70-80% range per tide cycle; allow about 2 hrs. of flood near HT and 2 hrs. of ebb near LT.	Provide habitat for waterfowl brood rearing; increase aquatic invertebrate populations; encourage SAV growth, discourage phragmites; permit fish movements.
Aug.-Sept.	Manage for an average 50% pool level, with a 40-60% range per tidal cycle; allow about 4 hrs. of flood near HT and 4 hrs. of ebb near LT.	Provide exposed mudflats for migrating shorebirds; increase egress for estuarine fishes; promote growth of late season annuals.
Oct.-Feb.	Manage for an average 95% pool level, with a 90-100% range per tidal cycle; allow about 2 hrs. of flood near HT and 2 hrs. of ebb near LT.	Provide habitat for migratory and overwintering waterfowl; maintain water quality thru tidal.exchanges.

*** See notes on next page for further explanation.

Notes:

1) "Pool level" refers to the percent of the general marsh surface area that is inundated with water, as a portion of the managed maximum 100% surface inundation that is desired.

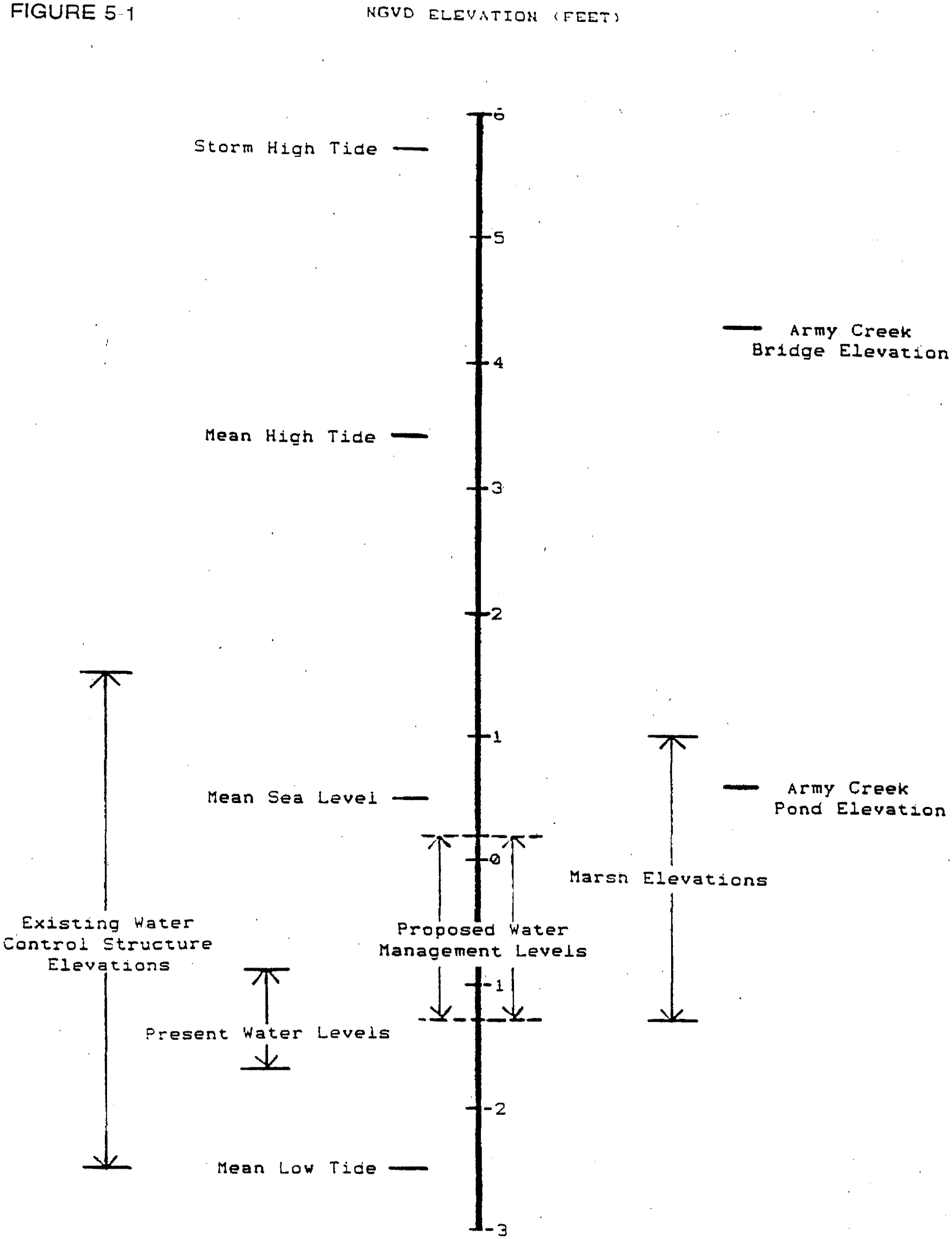
2) 0% pool level is no water over general marsh surface, although shallow ponds, channels and ditches may still have water. This is the typical existing condition for lower Army Creek Marsh.

3) 100% pool level is "full pool" at about +0.2 ft. NGVD, inundating about 80-90% of the general marsh surface of lower Army Creek Marsh, at depths ranging from only a few inches to 18" deep; waters deeper than 18" could occur in shallow ponds, channels and ditches.

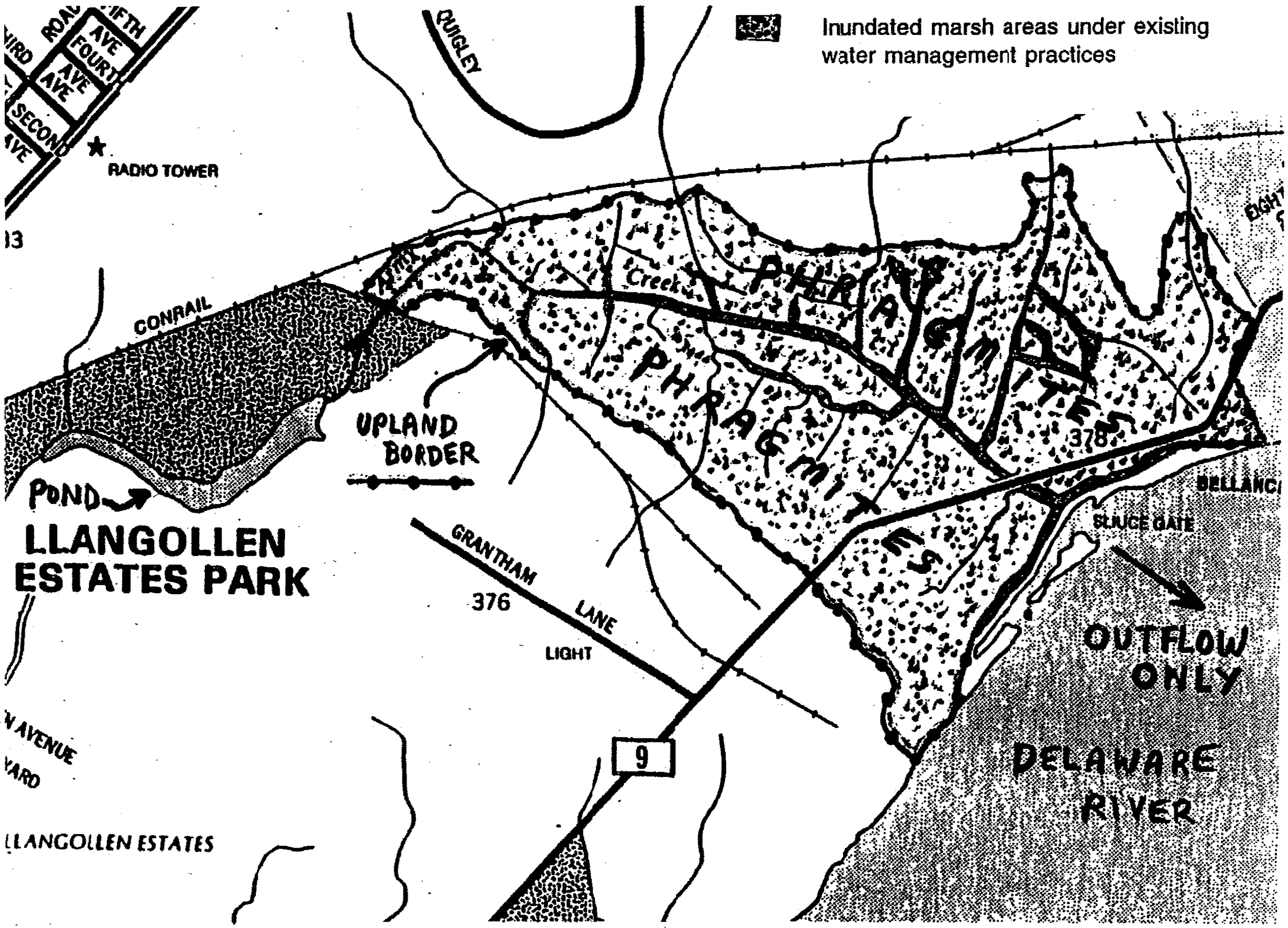
4) Water level elevation upstream in Army Creek Pond is above +0.6 ft. NGVD, so the maximum managed water level in the lower basin (+0.2 ft. NGVD) should not affect the Pond. If it's desirable to insure that lower basin water doesn't enter the pond on flooding tides, it may be necessary to construct a small spillway, with crest elevation = +0.6 ft. NGVD, on Pond's downstream end.

5) The proposed water management schedule is subject to future modifications dependent upon: a) ecological responses of the marsh system following implementation of the initial water management schedule; b) changed environmental objectives; c) future hydrological or topographic findings; d) engineering factors or constraints; e) commitment limitations for operation and maintenance; f) economic costs; g) landowner cooperation.

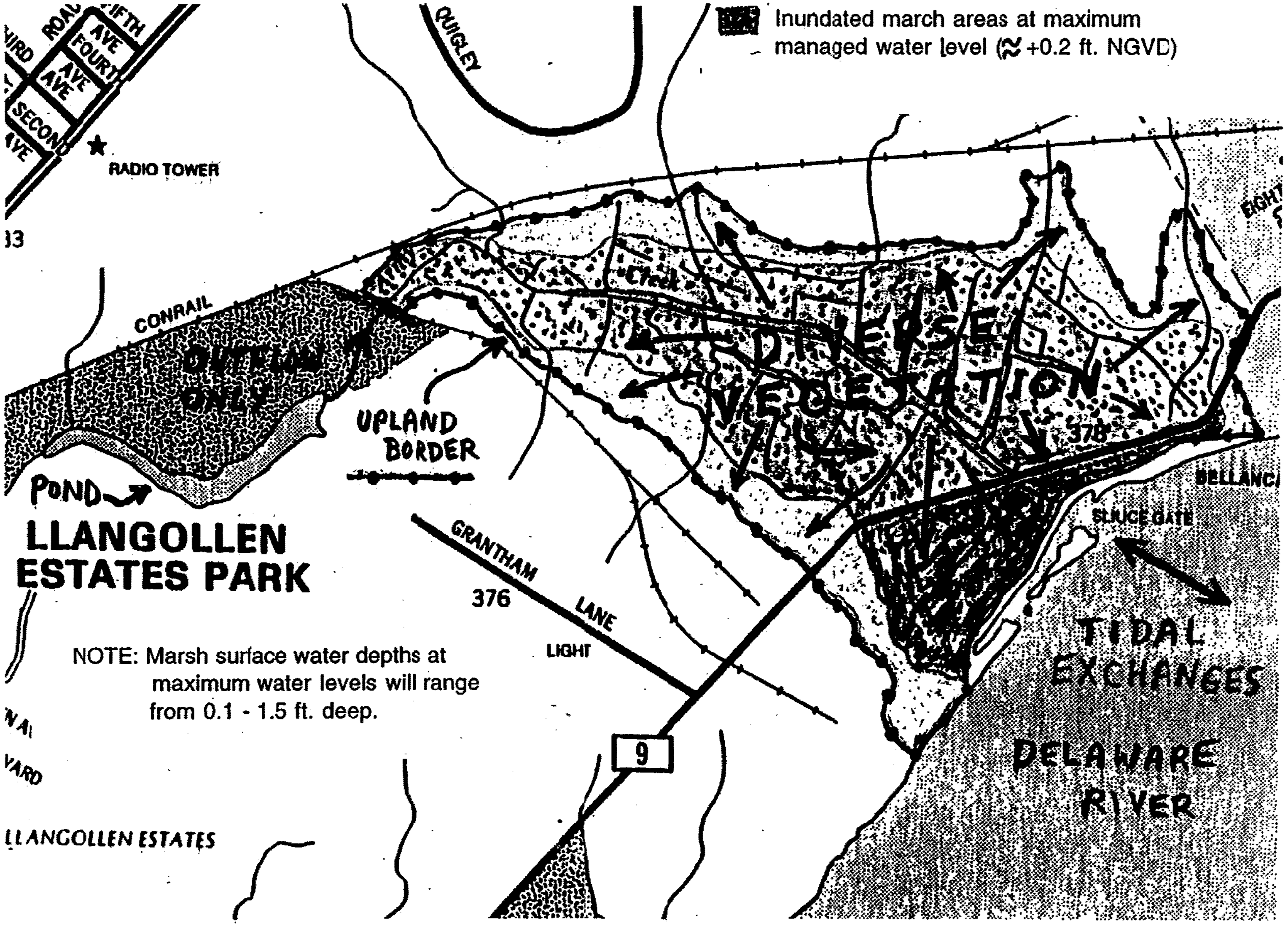
FIGURE 5-1


NGVD ELEVATION (FEET)
6
5
4
3
2
1
0
-1
-2
-3
Storm High Tide
Mean High Tide
Mean Sea Level
Mean Low Tide
Army Creek Bridge Elevation
Army Creek Pond Elevation
Marsh Elevations
Proposed Water Management Levels
Existing Water Control Structure Elevations
Present Water Levels

Map C-1 Lower Army Creek Marsh Before Restoration



Map C-2 Lower Army Creek Marsh After Restoration



APPENDIX D

Proposed treatment process for phragmites control.

The phragmites treatment process proposed for Army Creek Marsh has been developed by DNREC's Division of Fish and Wildlife, and has been in operational use since the mid-1980's on a statewide basis, sometimes involving a 50:50 cost-share program between the State and private landowners. The treatment involves the use of a systemic herbicide, glyphosate (Rodeo), aerially applied by helicopter during the late summers of two consecutive years, at a time when maximum aboveground photosynthate is being translocated to roots and rhizomes in preparation for winter dormancy; in controlling phragmites, it is necessary to kill the underground portions. Where possible, it is also highly desirable to follow each herbicide application in the subsequent early spring (i.e. March) with prescribed burning of the standing dead phragmites culms. This removes the negative shading effect of dead culms, thereby allowing sunlight to reach the marsh surface to release the seedbank of more desirable plants. Increased insolation of the marsh surface following burning also increases soil and water temperatures to promote plant growth, and may also increase nutrient releases to marsh waters. Burning allows for more effective follow-up herbicide coverage of resprouting phragmites, by eliminating intercepting debris during spray applications. The prescribed burns done in the early spring will be organized by the Division of Fish and Wildlife in cooperation with local fire authorities. During the two-year phragmites treatment phase of Army Creek Marsh's restoration, the marsh will be kept as dry as possible during February and March (i.e. 0% pool level, no tidal inflow) in order to create better burning conditions. Mowing and physical removal of the dead culms might also accomplish some of these desired effects, but soft marsh soils and the scale of removal do not usually make this a practical option for an area the size or nature of Army Creek Marsh.

After the two-year herbicide-and-burn treatment is completed, it is desirable to monitor over several years any future regrowth or reinvasion of phragmites, and to spot-treat with glyphosate any unacceptable incursions. In particularly robust stands of phragmites, such as what is found in Lower Army Creek Marsh, it is sometimes necessary to perform a third or even fourth year of the intensive herbicide-and-burn treatment (as part of the initial control effort).

Treatment costs.

The Trustees will contract with DNREC's Division of Fish and Wildlife to undertake the initial two-year phragmites treatment process; the Division may be able to recover a portion of the treatment costs through the 50:50 cost-share program, applicable to cooperative landowners within lower Army Creek Marsh. During the first year of herbicide treatment, glyphosate is applied at the rate of 4 pts/acre, yielding a total application cost (product + helicopter) of $60/acre; during the second year of treatment, glyphosate is used at a rate of 2 pts/acre, decreasing total application costs to $38/acre. Budgeting for a two-year program to treat about 200 acres will cost about $20,000. If a third year of initial intensive treatment is needed, another $5000 would be required. Spot-treatments of reinvading phragmites, following the 2-3 year intensive treatment phase, will probably necessitate $5000 more, spread over a 5-10 year period (or from 7-8 years, up to 12-13 years, after the start of restoration work). Thus, the maximum total costs for phragmites treatment, in today's dollars, will be about $30,000.

APPENDIX E

LOWER ARMY CREEK WETLANDS MONITORING PLAN

This monitoring plan will provide information to the Trustees as to whether the projects are functioning and providing services consistent with restoration goals. The design of this monitoring plan will permit detection of, and response to, significant changes in the community structure.

1.0 Restoration Benefits:

1.1 Increased acreage of available, suitable habitat for Trust Natural Resources.

1.2 Improved habitat quality via increased emergent plant diversity, shallow water pools, and substantially reduced Phragmites cover.

1.3 Increased species diversity, particularly for anadromous and estuarine fish species and blue crabs.

1.4 Increased numbers of birds using area, particularly waterfowl, wading birds, and shorebirds.

1.5 Reduced use of chemical insecticides for mosquito control.

2.0 Measures of Restoration Success:

2.1 Approaches

2.1.1 Comparison before and after restoration, e.g., some baseline to after restoration (requires pre-restoration survey of Lower Army Creek).

2.1.2 Comparison of after restoration to adjacent systems (i.e., convergence toward Gambacorta or Broad Dyke restored marshes). May also compare species presence with that of adjacent Delaware River.

2.2 Measures of success

2.1.1 Increase in area available to anadromous species.

2.2.2 Increase in volume and diversity of habitat available (i.e., tidal amplitude, shallow water pools, and marsh habitat).

2.2.3 Altered present dominant plant community.

2.2.4 Change in faunal composition and abundance to more anadromous and estuarine species (fish and blue crabs) and maintenance of or increase in bird and other faunal use.

2.2.5 Decrease in need for chemical control of mosquito.

3.0 **Monitoring**

3.1 Pre-restoration baseline (Do one year before implementing restoration).

3.1.1 Determine areal extent of suitable habitat available to aquatic plants and animals, particularly riverine, estuarine, and anadromous fish.

3.1.1.1 Undertake aerial photography of Army Creek Pond, Lower Army Creek and associated marsh during February-March and August-September of year before implementing restoration. Photographic missions will be flown to identify physical features (e.g., vegetated areas, shallow-water pools, drainage ditches, dikes, pannes, mudflats, rocky or concrete covered areas, etc.), upland-wetland boundaries, and degree of habitat diversity. Features are to be nested within the classification schemes of Cowardin et al. (1979) and Dobson et al. (1995).

3.1.2 Determine plant species composition via field survey and relate to vegetative coverage and aerial photography for Lower Army Creek.

3.1.2.1 August-September field survey will be performed at eight 1 m^2 quadrat stations on two transects; one positioned parallel to the main stem of the creek and the other perpendicular to the main stem but parallel to a secondary channel in the middle portion of the marsh system.

The intent of the two transects is to measure the potential changes in the plant communities with the introduction of Delaware River water through tidal flow. The transect parallel to the main stem will measure changes as a function of the flow penetration to the head waters, and the transect perpendicular to the main stem, but in the middle portion of the marsh, will measure changes relative to elevation along a secondary ditch. Stations/quadrats along the transects will be located using the following:

a) Number and location of existing plant communities during the pre-restoration survey,

b) Variations in elevation,

c) Accessibility.

3.1.2.2 Vegetative coverage.

February-March and August-September quantitative areal coverage will be determined for aerial photographs taken as described above. Plant species composition will be related to the areal coverage.

3.1.3 Determine faunal composition and abundance (i.e., number per unit area), particularly for anadromous, estuarine, and riverine fish species in Lower Army Creek.

3.1.3.1 Fishes and Blue Crabs

April sampling to consist of two 24-hr gillnet sets in upper and lower main channel to determine access and penetration of adult anadromous and estuarine fishes.

August-September to consist of two sampling experiences in upper and lower main channel, secondary guts and tertiary ditches using trap-nets, popnets, seines, back-pack electroshocker or other appropriate gear to determine utilization by resident, anadromous and estuarine species.

August-September sampling of blue crabs in upper and lower main channel, secondary guts and tertiary ditches using standard crab pots to determine the extent of use of the area by blue crabs. Numbers and size of collected crabs will be noted. Analysis should be done on site and all live blue crabs should be returned. The actual site selection will be random during the pre-restoration period. During the post-restoration phase, these previously sampled sites will be revisited and changes in relative abundance and sizes compared to pre-restoration samples will be noted.

Study design recognizes substrata or different habitat types within Army Creek, i.e., main channel, secondary guts, and tertiary ditches, as the basis for characterization during the pre- and post-restoration periods. The physical attributes of these different habitats dictate the use of collection gear of different types. Comparisons will be made only between like habitat types sampled with like collection gear. The site characterization will necessarily be only a semi-quantitative/qualitative composite of habitat types. A standardized unit of collection effort, such as number per unit volume of water sampled, would enhance comparisons between habitats. Ongoing work by DNREC includes the calculation of density from various pieces of equipment, but the volumetric methods are not described in the available reports. Use of such methods would be desirable. However, the density data from different gear would not be totally comparable because of varying degrees of collection efficiency related to an organisms avoidance of sampling equipment.

A push-trawl will be used in the main channel during both pre- and post-restoration periods. The blocking net/seine technique, as described by DNREC, does not depend on tidal flow; therefore, it will be used in the tertiary ditches during both pre- and post-restoration periods.

The choice of gear for the secondary guts is more difficult. The physical attributes, e.g., relatively vertical banks, narrow channels, and sometimes bottomless substrate, of these guts make an active technique like seining hard to employ. A less active technique, such as electro-shocking, would work well during the pre-restoration survey, but would be less effective and possibly inappropriate in the post-restoration surveys. As a compromise for the pre-restoration survey without tidal flow to push the fish into the gear, a channel net will be used along with techniques to scare, herd, and crowd fish into the net via the use of dip nets and small seines. In the post-restoration phase with tidal flow restored, the channel net as used by DNREC and others is the gear of choice and will be used.

3.1.3.2 Determine presence/absence of other aquatic-associated species (e.g., reptiles, amphibians, and mammals) in Lower Army Creek using appropriate techniques.

3.1.3.3 Determine species and numbers of birds using Lower Army Creek area, with emphasis on waterfowl, wading birds, and shorebirds. Conduct avian surveys in January, May, June, September and October during the morning hours of one day at observation points around or within Lower Army Creek marsh to be determined by avian expert.

3.2 Post-Restoration sampling (+3, 4, 6, and 10 years after initiating restoration). Beyond 10 years shift effort to Operations and Maintenance components of Restoration Plan. This sampling scheme is recommended, because years +3 and 4 are anticipated to show the most rapid recovery trends, while years +6-10 will provide a measure of stability and long-term success. All post-restoration sampling must match pre-restoration sampling relative to seasons, frequency, methods and locations.

3.2.1 Determine and compare areal extent of suitable, wetland habitat in Army Creek Pond, Lower Army Creek and associated marsh available to aquatic plants and organisms (particularly anadromous, estuarine, and riverine fish) with pre-restoration baseline.

Obtain aerial photography of Army Creek Pond, Lower Army Creek and associated marsh at high and low tide in February-March and August-September and compare with pre-restoration aerial photography. Identify physical features (e.g., vegetated areas, shallow-water pools, drainage ditches, dikes, pannes, mudflats, rocky or concrete covered areas, etc.), upland-wetland boundaries, and degree of habitat diversity. Nest identified features within the classification schemes of Cowardin et al. (1979) and Dobson et al. (1995). Do years +3, 4, 6, and 10.

3.2.2 Determine and compare plant species composition and areal coverage in Lower Army Creek with pre-restoration baseline. Match pre-restoration sampling methodology. Post-restoration sampling should occur at tidal stages that approximate pre-restoration water levels where feasible. Do years +3, 4, 6, and 10.

3.2.3 Determine and compare faunal composition in Lower Army Creek with pre-restoration baseline.

3.2.3.1 Determine and compare fish and blue crab species and abundance (particularly anadromous, estuarine, and riverine fish) in Lower Army Creek with pre-restoration baseline. Match pre-restoration sampling. Do years +3, 4, 6, and 10.

Additionally: At tide gate - Sample 6 tidal cycles per season by sampling a few minutes each 1/2 hour during entire flood and ebb cycles. Methods and equipment used will be similar to those of DNREC. Do years +3, 4, 6, and 10.

3.2.3.2 Determine and compare presence/absence of species of reptiles, amphibians and mammals in Lower Army Creek with pre-restoration baseline. Match pre-restoration sampling. Do years +3, 4, and 6.

3.2.3.3 Determine and compare with pre-restoration baseline the presence/absence of bird species, particularly waterfowl, wading birds, and shorebirds. Match pre-restoration sampling. Do years +3, 4, 6, and 10.

3.2.4 Compare pre and post restoration mosquito brood and control records.

3.2.5 Assess composition data for possible shifts in trophic structure.

3.2.6 Obtain and compare applicable results of sampling being accomplished in Gambacorta or Broad Dyke Marshes to determine degree of convergence by Lower Army Creek.

3.2.7 Compare lists of anadromous and estuarine fish present in Lower Army Creek based on post-restoration sampling with species present in adjacent Delaware River (e.g., see Contaminants Report appendix A attachment 2 section 2.4.2.6 and referenced citations) to determine degree of convergence.

4.0 Analyses

4.1 Analytical procedures - to be described by contractor and reviewed by Natural Resources Trustee Committee. All methods should be state-of-the-art, scientifically valid, and as quantitative as possible. Statistical validity should be invoked wherever possible.

4.2 Quality Assurance and quality control - Each technique must be used in a consistent manner from time to time and place to place from pre-restoration sampling to the termination of monitoring. As much consistency as possible in timing and approach is highly recommended. Methods used and quality assurance procedures instituted must be supplied in written form prior to contract and included with each progress and summary report.

4.3 Data presentation (graphs, overlays, etc.) - Data are to be presented in tabular and graphical form and as photographs and maps.

4.4 Mid-Course Corrections - Data on water related parameters and plant composition will be used at the end of 3 - 4 years following initial restoration to determine the need for mid-course corrections as described in section 2.1.2, page 2-24.

5.0 Review and approval for release. The Natural Resources Trustee Committee for Army Creek will determine appropriate review and release of data.

6.0 Storage and maintenance of data. The State of Delaware, Department of Natural Resources and Environmental Control will store and maintain the data resulting from this monitoring. Such data will be placed in the Natural Resources Trustee's Administrative Record for Army Creek.

7.0 Periodic reporting.

7.1 Progress Reports - Pre-restoration (Year 0), and years 3,4,6 and 10.

These are to be submitted to the Natural Resources Trustee Committee for Army Creek within 3 months of the end of sampling for a particular year. The reports will include sampling, analytical, and quality assurance methods used, and present all data for the particular year in tabular form with dates, times, tidal stage, and locations associated with each data point. Appropriate maps should be included to show not only where Army Creek is located, but also to show overall and detailed sampling locations. In short, enough information should be appended to the data so that someone other than the contractor could repeat the sampling or verify a location.

7.2 Summary Reports - Within 4 months of the end of sampling in years 6 and 10 a summary report including all previous sampling will be submitted to the Natural Resources Trustee Committee for Army Creek. The Summary Reports, in addition to what is included in the progress reports, will include trend information and discuss progress, or lack thereof, toward successful restoration.

8.0 Duration of Monitoring. Monitoring will continue for a period of at least ten years after the implementation of restoration.

9.0 Public access to data. All data shall be available to the public after it has been reviewed and approved by the Natural Resources Trustee Committee for Army Creek. The Coordinating Trustee, State of Delaware Department of Natural Resources and Environmental Control, will maintain these data as part of the Natural Resources Trustee's Administrative Record for Army Creek.

10.0 Schedule

Pre-survey year 0. - Sampling and analysis (vegetation, fish, blue crabs), Progress Report.

Post Restoration Year +3 - Sampling and analysis (vegetation, fish, blue crabs), Progress Report.

Year +4 - Sampling and analysis (vegetation, fish, blue crabs), Progress Report.

Year +6 - Sampling and analysis (vegetation, fish, blue crabs), Summary Report.

Year +10 - Sampling and analysis (vegetation, fish, blue crabs), Summary Report.

References

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Dobson, J.E., R.L. Ferguson, D.W. Field, L.L. Wood, K.D. Haddad, H. Iredale III, J.R. Jensen, V.V. Klemas, R.J. Orth, and J.P. Thomas. 1995. NOAA Coastal Change Analysis Project: guidance for regional implementation. NOAA Coastal Ocean Program, NOAA Technical Report. NMFS 123. 93pp.

APPENDIX F

AGREEMENT FOR ARMY CREEK MARSH BETWEEN ARMY CREEK NATURAL RESOURCES TRUSTEES, DELAWARE DIVISION OF FISH AND WILDLIFE, DELAWARE DEPARTMENT OF TRANSPORTATION, AND NEW CASTLE CONSERVATION DISTRICT.

This **AGREEMENT**, made this ____ day of ____________, 1994, by and between Army Creek Natural Resources Trustees (**TRUSTEES**), as party of the first part; and the Delaware Division of Fish and Wildlife (**DIVISION**), as party of the second part; and the Delaware Department of Transportation, (**DELDOT**), as party of the third part; and the New Castle Conservation District (**NCCD**), as party of the fourth part.

WITNESSETH:

WHEREAS, TRUSTEES desires to establish a new modified water control structure for the Army Creek Marsh, and

WHEREAS, TRUSTEES, DIVISION, DELDOT, and **NCCD** have an interest in the construction of the facility which is the subject of this agreement, and

WHEREAS, NCCD has a role of carrying out programs as a party in cooperation with State, County, municipal and other private and public interests,

NOW THEREFORE, TRUSTEES, DIVISION, DELDOT, AND **NCCD**, for and in consideration of the mutual covenants hereinafter stipulated to be kept and performed, agree as follows:

SECTION I - FUNDING: - **TRUSTEES** agree to provide all funding for construction of the proposed water control structure in the amount of $

SECTION II - CONSTRUCTION:

1. **NCCD** in cooperation with **TRUSTEES, DIVISION,** and **DELDOT** will manage the planning, construction, and administration of the project as follows:

   A. Be fully responsible for undertaking and supervising all phases of the necessary job planning, design, construction, supervision, and administration of this project with all aspects complying fully with State Laws.

   B. Secure the services of a qualified contractor to construct the planned works of improvement.

   C. Keep accurate records of the expenditure of these funds and will advise **TRUSTEES, DIVISION,** and **DELDOT** in writing when project is completed.

   D. Submit progress billings as work progresses on the project.

   E. **DELDOT** agrees to grant rights-of-way to the **NCCD** for construction and maintenance purposes as follows:

      a. **NCCD** shall construct the planned water control structure using **NCCD** or contractor resources to the limit of the projected cost of the project.

      b. **DELDOT** is responsible for removal or replacement of structures, fences, plantings, or other items they desire to salvage prior to construction.

      c. **DELDOT** is responsible to point out and clearly mark any property markers that are located in the rights-of-way. Property markers removed from excavated areas will not be replaced by the **NCCD**.

      d. **DELDOT** shall grant ingress and egress to the construction site for the personnel necessary to survey, plan, construct, and inspect installation of the water control structure.

SECTION III - MAINTENANCE:

1. **NCCD** shall have no maintenance responsibilities whatsoever for the completed structure.

2. **DIVISION** shall be responsible for the payment of any electrical service required for the operation of the proposed structure, and the maintenance and repair/replacement of any proposed electrical service to the structure.

3. **DIVISION** shall be responsible for the repair/replacement of any electrical facilities utilized in the operation of the proposed structure, including: water level sensors, vertical lift motor, and control panels.

4. **DIVISION** shall be responsible for the replacement of any floats required for the operation of the proposed structure.

5. **DELDOT** shall be responsible for the repair/replacement of all non-electrical facilities associated with the existing and proposed structure, excluding floats. These non-electrical facilities include but are not limited to the dike, pipes, concrete culverts, water control gates, and housings containing the water control gates.

6. **DELDOT** shall be responsible for annual inspections of the proposed water control structure.

7. **DIVISION** shall be responsible for weekly inspections of the proposed water control structure and the removal of any trash or debris from the structure. When requested, **DELDOT** shall assist the **DIVISION** in removing any large debris from the structure that requires special equipment or assistance.

8. **DIVISION** shall be responsible for: lubricating any electric motor, lift screw, or gate linkage; maintaining any water level sensors, and repairing any float required to operate the proposed structure.

9. **NCCD** will provide technical assistance to **DIVISION,** or **DELDOT** at their request.

SECTION IV - OPERATION:

1. **DIVISION** shall implement the "Water Management Plan" approved by the**TRUSTEES**, and shall be responsible for adjusting any floats, sensors, or computer programs to implement this plan. This "Water Management Plan is subject to adjustments and change based on the availability of additional information, climatic conditions, and in order to better achieve all biological and hydrological objectives.

2. **DELDOT** shall be responsible for maintaining a gate or barrier to restrict public access to the structure, but shall grant ingress and egress to the **TRUSTEES, DIVISION,** and **NCCD** for activities associated with the maintenance, operation, and inspection of the proposed structure; and to conduct biological and hydrological surveys of the surrounding area.

TRUSTEES, DIVISION, DELDOT and **NCCD** agree that this **AGREEMENT** is the entire and completed **AGREEMENT** between the parties and that no alternations, modifications, or amendments of this said **AGREEMENT** shall be made or deemed valid unless in writing and signed by all parties.

IN WITNESS THEREOF, the parties hereunto have caused this **AGREEMENT** to be executed in quadruplicate, the day and year first above written.

ARMY CREEK NATURAL RESOURCE TRUSTEES

By: ____________ ____________ ____________

Title: ______ ______ ______
Date: ______

NEW CASTLE CONSERVATION DISTRICT DIVISION OF FISH & WILDLIFE

By: ______ By: ______

Josef A. Burger
Title: Chairman

Andrew T. Manus
Title: Director

Date: ______ Date: ______

DEPARTMENT OF TRANSPORTATION

By: ______

Title: ______

Date: ______