CITY OF PHILADELPHIA WATER DEPARTMENT NORTHEAST WATER POLLUTION CONTROL PLANT IMPOUNDMENT CLOSURE PLAN

TEXT & FIGURES ONLY

CITY OF PHILADELPHIA
WATER DEPARTMENT
NORTHEAST WATER
POLLUTION CONTROL PLANT
IMPOUNDMENT CLOSURE PLAN

Prepared for:

City of Philadelphia Water Department

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LIST OF ACRONYMS

ACT 2	Land Recycling and Environmental Remediation Standards Act
ACT 241	Solid Waste Management Act of 1968
Ag	Silver
As	Arsenic
Ba	Barium
BLS	The City of Philadelphia Bureau of Laboratory Services
Cd	Cadmium
C_{GW}	Area weighted average concentration of contamination plume
C_{SW}	Calculated surface water concentration
Cl	Chloride
cm/s	Centimeters per second
CPECs	Constituents of Potential Ecological Concern
Cr	Chromium
Cu	Copper
DC	Act 2 Direct Contact Numerical Values
DCNR	Department of Conservation and Natural Resources
DRBC	Delaware River Basin Commission
DI	Developed/Impervious Surfaces
EM	Electromagnetic Conductance Geophysical Method
EPA	U.S. Environmental Protection Agency
Fe	Iron
Fl	Fluoride
Foc	Fraction organic carbon
ft.	Feet
ft/sec	Feet per second
ft/day	Feet per day
ft^2/day	Square feet per day
ft^2/lb	Square feet per pound
ft^2/min	Square feet per minute

ftbg	Feet below grade
FTA	Fate and Transport Analysis
ft msl	Feet mean sea level
gpd	Gallons per Day
gpm	Gallons per minute
HASP	Health and Safety Plan
Hg	Mercury
ID	Inside Diameter
in.	Inch
K	Hydraulic conductivity
Koc	Octanol-water partition coefficient
MGD	Millions of gallons per day
mg/kg	Milligrams per kilogram
mg/l	Milligrams per liter
min.	Minute
Mn	Manganese
MODFLOW	Modular Three-Dimensional Finite-Difference Groundwater Flow Model
MSC	Act 2 Medium-Specific Concentrations
MW-1	Monitor Well #1
MW-FS	Monitor Well F Shallow
MW-FD	Monitor Well F Deep
n	Porosity
NO_3	Nitrate-nitrogen
NELAGB2D	Sludge Sample from Lagoon B, Boring #2, Deep Depth
NELAGB2M	Sludge Sample from Lagoon B, Boring #2, Mid Depth
NELAGB2S	Sludge Sample from Lagoon B, Boring #2, Shallow Depth
NIR	Notice of Intent to Remediate
NJGS	New Jersey Geological Survey
OW	Open Water Areas
PADEP	Pennsylvania Department of Environmental Protection

PAFBC	PA Fish and Boat Commission
Pb	Lead
PCB	Polychlorinated biphenols
PGC	Pennsylvania Game Commission
PH	Phragmites Community
PNDI	Pennsylvania Natural Diversity Inventory
PQLs	Practical Quantification Levels
ppb	Parts per billion
PRM	Potomac-Raritan-Magothy aquifer system
PWD	Philadelphia Water Department
PWS	Public Water Supply
QA/QC	Quality Assurance / Quality Control
Q_{GW}	Groundwater discharge from the cross-sectional area
Q_{SW}	Flow rate of the Delaware River
Rb	Bulk density
RM	Residual mean
RSOS	Residual sum of squares
SCWL	Scrub Wastelands
Se	Selenium
SGWL	Successional Grassy Wastelands
Slug Test	In-situ hydraulic conductivity Test
SMCL	Secondary Maximum Contaminant Levels
SO_4	Sulfate
SOP	Standard Operating Procedure
STG	Act 2 Soil to Groundwater Numerical Values
SUWL	Successional Woodlots
TDS	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen
TOC	Total Organic Carbon
TPH	Total Petroleum Hydrocarbons

ug/l	Micrograms per liter
ug/kg	Micrograms per kilogram
USACOE	US Army Corps of Engineers
USFWS	US Fish and Wildlife Service
USGS	United States Geological Survey
VOCs	Volatile organic compounds
Yd^3	Cubic yards

0.0 EXECUTIVE SUMMARY

RETTEW Associates, Inc. (RETTEW) has prepared this Closure Plan for the inactive sewage sludge impoundments located at the Philadelphia Water Department (PWD) Northeast Water Pollution Control Plant (NEWPCP). This Closure Plan was prepared in response to discussions conducted during a meeting between the PWD, the Environmental Protection Agency (EPA) and the Pennsylvania Department of Environmental Protection (PADEP) on May 4, 1999. The primary goal of the Closure Plan is to document site characterization activities that were conducted between November 1998 and November 2001 to determine if the impoundments present an environmental impact to the underlying Potomac-Raritan-Magothy (PRM) aquifer system. Activities conducted include monitor well installation, groundwater gauging and sampling, former and existing sludge impoundment sampling, surface water sampling, adjacent smelter waste sampling, aquifer testing, an ecological assessment and a groundwater contaminant Fate and Transport Analysis. All activities were completed as per the PADEP approved workplan dated February 9, 2000.

The PWD NEWPCP (hereby referred to as "site" or "facility") is located at 3899 Richmond Street in the City of Philadelphia, just south of the Betsy Ross interstate bridge. The site is bounded by Lewis Street to the northeast, North Delaware Avenue to the southeast, the former Franklin Smelter facility to the southwest, and Interstate 95 and Richmond Avenue to the northwest. Frankford Creek is located to the northeast roughly parallel with the northeast site property boundary.

Prior to 1961, sludge generated from the primary and secondary sedimentation tanks of the NEWPCP waste-water treatment process was disposed in Impoundments A, B, C, D and E, which were constructed in 1956. During that time period, screening and grit wastes were disposed by a waste contractor and landfilled. Between 1961 and 1980, the sludge was disposed of in the Atlantic Ocean, an accepted disposal practice at that time. Following 1980, the sludge was subject to more extensive treatment process which included thickening, anaerobic digestion, de-watering and solidification / compaction into a digested sludge cake. The sludge cake bi-product is either disposed by landfill or through composting into beneficial agricultural nutrient products.

The regulatory framework for closure of the PWD NEWPCP Impoundments is the Pennsylvania Land Recycling and Environmental Remediation Standards Act (Act 2). The Act 2 regulatory framework is applicable for the following reasons:

- The sewage sludge was generated and disposed in the NEWPCP Impoundments prior to 1961.
- Specific regulations dealing with the disposal of sewage sludge were not in existence during time of sludge disposal and no formal permits were required or in existence.
- No specific closure provisions were mandated by any State or Federal agency during the time of sludge disposal.
- The Solid Waste Management Act of 1968 (Act 241) was not in existence during the time of sludge disposal at the NEWPCP.

The key results of the Site Characterization and Fate and Transport Analysis performed in support of this closure plan are as follows:

- The subsurface conditions underlying the NEWPCP, in descending order, include 1) Surficial fill materials; 2) silty sand; 3) clay and silt; 4) sand and gravel; 5) saprolite, and; 6) bedrock. Clay and silt encountered at the site are thought to be part of the Lower Clay Unit of the PRM, the Middle Clay Unit of the PRM, or Quaternary marsh deposits. Sand and gravels are thought to be primarily part of the Lower Sand Unit of the PRM with some reworking by Quaternary deposits of the Trenton Gravel.

- The prominent hydraulic response observed in deep monitor wells at the NEWPCP is due to a direct hydraulic connection between the Delaware River and the Lower Sand Unit of the PRM. Although the potential groundwater flow directions change with the direction of the tide, the overall movement of groundwater near the NEWPCP is likely limited due to the repeating directional forces of the tidal pressure wave and the small storage changes within the semi-confined aquifer. The average potentiometric surface within the Lower Sand Unit underlying the NEWPCP is relatively flat with no ascertainable average direction of groundwater flow. The average flow direction within the shallow, unconfined aquifer is to the south/southwest towards the Delaware River.

- None of the volatile organic compounds (VOCs), semi-VOCs, pesticides, PCBs, and inorganics detected above the Practical Quantification Levels (PQLs) in the groundwater samples exceeded the Pennsylvania Department of Environmental Protection (PADEP) Non-Use Aquifer / Nonresidential Medium-Specific Concentrations. Concentrations of dissolved and total metals were detected in the groundwater samples. Antimony, arsenic, barium, cadmium, calcium, chromium, cobalt, copper, lead, magnesium, nickel, potassium, selenium, sodium, vanadium, and zinc were detected above the PQLs in many of the samples. None of these detected metals exceeded the PADEP Groundwater Non-Use / Nonresidential Aquifer Medium-Specific Concentrations.

- As documented in this report, no species or habitats of concern were identified during the Ecological Assessment Detailed Onsite Evaluation. Significant ecological impact does not exist based on the following documented facts: No species or habitats of concern, threatened or endangered species or exceptional value wetlands were identified on the NEWPCP site during the Detailed Onsite Evaluation. Therefore, based on the Act 2 Technical Guidance Manual, no further ecological evaluation is warranted for the site.

- Upon review of the results of the PWS data searches, no PWS wells are present in Pennsylvania within a mile radius of the NEWPCP impoundments. A total of 27 Public Water Supply (PWS) wells in New Jersey are present within a 2-mile radius of the facility. A Fate and Transport Analysis (FTA) was completed to determine if the constituents detected in groundwater underlying the NEWPCP at low concentrations would potentially impact PWS wells in New Jersey. Groundwater flow was simulated using the Modular Three-Dimensional Finite-Difference Groundwater Flow Model (McDonald and Harbaugh, 1988). The modeling effort was reviewed by McDonald Morrissey Associates, Inc. of Hopkinton, New Hampshire. Based on the hypothesis testing results of the model runs and particle tracking analysis, none of the perceivable scenarios indicate a risk to New Jersey PWS wells from groundwater underlying the NEWPCP.

- For all the low level contaminants present within the Lower Sand Unit underlying NEWPCP, none of the contaminants cause the Delaware River to exceed the applicable instream standards. For this reason, the low level groundwater contaminants under the NEWPCP are in compliance with the Clean Streams Law.

- Visual examination indicated that the sludge was homogenous in nature, with some minor building material such as brick or concrete occasionally encountered in a few borings. The sludge consisted of dark colored to black organic material primarily composed of human hair and organic human waste solids. The sludge was fully, comprehensively, and accurately characterized using the laboratory analysis of the 60 sludge samples collected during this investigation. Published PADEP numerical values were used in evaluation of the impoundment sludge. None of the VOCs, semi-VOCs, pesticides, PCBs, and inorganics detected above the laboratory PQLs in the sludge samples exceeded the PADEP Non-Use Aquifer / Nonresidential Direct Contact and Soil-to-Groundwater numerical values except for: Soil to Groundwater Pathway - 4-Chloroaniline, bis(2-Ethylhexyl)phthalate, DDE, DDT, and PCB-1260, and; Direct Contact Standard 0-2 foot interval - arsenic, cadmium, lead. No evidence of sludge material was found in borings advanced into former Impoundment E. Sludge from the former Impoundment E was removed previously and replaced with soil and fill material.

- The compounds that exceeded the Soil to Groundwater Pathway numerical values in the impoundment sludge (4-Chloroaniline; bis(2-Ethylhexyl)phthalate; DDE; DDT; and PCB-1260) were either not detected above the laboratory PQLs in groundwater or were well below the Groundwater Non-Use Statewide Health Standards. In addition, no other compound detected in groundwater above the PQLs exceeded the Groundwater Non-Use Statewide Health Standards. For these reasons, direct evidence of groundwater quality indicates that the sludge material, although exceeding the soil to groundwater pathway standards for some compounds, is not a source of groundwater contamination above the Statewide Health Standards.

- The nature and composition of the sludge may explain why concentrations of 4-Chloroaniline, bis(2-Ethylhexyl)phthalate, DDE, DDT, and PCB-1260 (and many other compounds) were not found at higher concentrations in groundwater. The sludge is composed of organic waste solids that have a very high carbon content and a very low permeability. For these reasons, the leaching rate of the compound is controlled by the rate of flux of water through the sludge, the compounds high octanol-water partition coefficient, and the organic content of the sludge. Calculated retardation factors for the compounds indicate that the compounds will move through and leach out of the sludge very slowly. For example, the 4-Chloroaniline will migrate in the sludge approximately 106 times more slowly than water flowing through the sludge. The retardation factors for the other compounds are much higher than 4-Chloroaniline, so would leach even slower from the sludge. The high organic carbon content of the sludge is the primary reason why only traces of constituents are detected in groundwater.

- The metals arsenic, cadmium and lead were detected in some of the sludge samples, which exceeded the PADEP Non-Use Aquifer / Nonresidential Direct Contact numerical values for the 0-2 foot interval. However, a direct contact exposure pathway does not exist for the following reasons:

  1. The impoundments are located within the PWD property which is secured by well maintained fences (since the PWD property will always be used for waste water treatment activities, fences will be maintained indefinitely) and are consequently inaccessible to the public.
  2. Limited access to the impoundments is granted by PWD only to qualified PWD employees.
  3. The composition of the sludge (black organic material primarily composed of human hair and organic human waste solids) reduces the possibility that long term exposure through ingestion or other direct contact exposures would occur in PWD employees.
  4. Access to the sludge material in the impoundments is difficult due to the presence of seasonal standing water and plant growth at the surface including thick reeds of *Phragmites*.

Based on all of the above facts, the Northeast lagoons are not an issue of concern to human health and thus, the lagoon site can be formally closed under Act 2 through the use of the Nonuse Aquifer Statewide Health Standards and Site Specific Standards.

To ensure that the closure complies with the Act 2, including the Clean Streams Law, sedimentation and erosion prevention requirements, best management practices, and the continued pathway elimination for the direct contact of the impoundment sludge, a formal deed notice and restriction will be placed on the lagoons property. The deed notice and restriction will include the following:

- Requirements for the maintenance of impoundment dikes to prevent sedimentation and erosion of the sludge material;
- Requirements for the maintenance of the current impoundment drainage network, which discharges surface water from the impoundments during heavy meteoric precipitation events to the influent of the NEWPCP treatment plant. The drainage network prevents impoundment flooding and potential breaches in the impoundment dikes;

- Restriction of public access to the impoundments including the maintenance of fencing;
- Requirements for continued protection of PWD worker safety through restricted access and implementation of a health and safety program and plan;
- Restriction of future uses of impoundments unless the direct contact pathway and sedimentation / erosion prevention issues have been otherwise addressed for the future use, and approval by the PADEP is granted prior to initiation of the future use.

In addition to the formal deed notice and restriction, the following additional activities will be completed to properly comply and document the Act 2 process for eligibility:

- Formal PADEP notification in the form of a Notice of Intent to Remediate (NIR);
- Formal municipal notice of the NIR;
- Formal public notice of the NIR;
- Public comment period if requested by municipality;
- Final Report document;
- Formal Final Report notice to municipality, and;
- Formal Final Report notice to public.

The information provided in this Closure Plan will be reissued as an Act 2 Final Report. The Act 2 final report will also include documentation of the proposed formal deed notice / restriction and results of any public comment.

PWD respectfully requests the PADEP's review and comment of this Closure Plan and the above listed activities to pursue closure of the impoundment sludge under Act 2. At this time, PWD also respectfully requests consideration of the petition to reduce the number of groundwater sampling events for the Soil to Groundwater Equivalency Demonstration listed in Section 14.2.2. If the PADEP agrees with this plan to close the impoundment sludge under Act 2, PWD will prepare the required deed notice and restriction information for PADEP review prior to submission of the Act 2 final report and subsequent notices.

1.0 INTRODUCTION

On behalf of the Philadelphia Water Department (PWD), RETTEW Associates, Inc. (RETTEW) has prepared this Closure Plan for the inactive sewage sludge impoundments located at the PWD Northeast Water Pollution Control Plant (NEWPCP)(*Figure 1*). This Closure Plan was prepared in response to discussions conducted during a meeting between the PWD, the Environmental Protection Agency (EPA) and the Pennsylvania Department of Environmental Protection (PADEP) on May 4, 1999. The primary goal of the Closure Plan is to document site characterization activities that were conducted between November 1998 and November 2001 to determine if the impoundments present an environmental impact to the underlying Potomac-Raritan-Magothy (PRM) aquifer system. Activities conducted include monitor well installation, groundwater gauging and sampling, former and existing sludge impoundment sampling, surface water sampling, adjacent smelter waste sampling, aquifer testing, an ecological assessment and a groundwater contaminant Fate and Transport Analysis. All activities were completed as per the PADEP approved workplan dated February 9, 2000.

A site-specific Health and Safety Plan (HASP) and a Quality Assurance / Quality Control (QA/QC) Plan describing the procedures that were followed throughout this investigation are included in Appendix A and Appendix B, respectively. A Standard Operating Procedure (SOP) for the various sampling activities is provided in Appendix C.

2.0 SITE DESCRIPTION

2.1 General Description

The PWD NEWPCP (hereby referred to as "site" or "facility") (Figure 2) is located at 3899 Richmond Street in the City of Philadelphia, just south of the Betsy Ross interstate bridge. The site is bounded by Lewis Street to the northeast, North Delaware Avenue to the southeast, the former Franklin Smelter facility to the southwest, and Interstate 95 and Richmond Avenue to the northwest. Frankford Creek is located to the northeast roughly parallel with the northeast site property boundary. Frankford Creek ranges in distance from the site between approximately 300 feet (from the northeast corner of site) to approximately 600 feet (from southeast corner of site). The Delaware river is located approximately 850 feet to 1000 feet southeast of the site (See Figures 1 and 2).

The aerial extent of the PWD NEWPCP property is approximately 120 acres. The northwest half of the site consists of several structures and treatment aeration tanks utilized for wastewater treatment activities. The southeast half of the property consists of four former sewage sludge impoundments (Impoundments A, B, C and D) and an abandoned sludge impoundment (Impoundment E).

2.2 Surrounding Industrial Activities

The site is surrounded by commercial and industrial land uses to the south, east and west. In particular, the former Franklin Smelter facility is located adjacent west of the site. This facility was historically used for copper recovery operations. A large stockpile of smelter waste currently exists adjacent to the PWD site. A former coal fired plant once operated by the Pennsylvania Electric Company (PECO) exists south of the site along the Delaware River. A waste transfer facility operated by Waste Management exists approximately ½ mile northeast of the site. Commercial and residential land uses exist to the north of the site.

2.3 Site History

Historically, wastewater treatment at the PWD NEWPCP followed a typical process. First, influent wastewater was pumped through screens to collect solid, non-digestible materials. Following the initial screens, grit was removed from the wastewater using grit chambers. Following grit removal, wastewater was pumped into primary sedimentation tanks where fine solids and silts were allowed to settle out. After the primary sedimentation, the wastewater was directed to aeration basins, where enhanced biological decay of dissolved and suspended materials occurred. Secondary sediment tanks were used following the aeration tanks to allow any remaining sediment to settle out or precipitate. Following secondary sedimentation, the treated effluent is chlorinated and discharged by permit to either the Delaware River. A schematic of a typical wastewater treatment process is provided in Figure 3.

Prior to 1961, sludge generated from the primary and secondary sedimentation tanks were disposed in Impoundments A, B, C, D and E, which were constructed in 1956. During that time period, screening and grit wastes were disposed by a waste contractor and landfilled. Between 1961 and 1980, the sludge was disposed of in the Atlantic Ocean, an accepted disposal practice at that time. Following 1980, the sludge was subject to more extensive treatment process which included thickening, anaerobic digestion, de-watering and solidification / compaction into a digested sludge cake. The sludge cake bi-product is either disposed by landfill or through composting into beneficial agricultural nutrient products.

In order to facilitate the plant expansion in the late 1970's, the physical boundaries of the impoundments were modified, and the sludge was relocated. Lagoon E was completely removed in 1978. In addition, 138,570 cubic yards (yd^3) of sludge was removed from Impoundment A and 58,650 yd^3 were removed from Impoundment C (Black & Veatch, 1990).

Estimates of the current sludge volume remaining in the impoundments where calculated and reported by Black and Veatch (1990). The estimates were calculated from original drawings and topographical maps of the impoundment facility. Black and Veatch estimated the following sludge volumes: Impoundment A – 129,766 yd^3; Impoundment B – 209,590 yd^3; Impoundment C – 106,165 yd^3, and; Impoundment D – 138,683 yd^3.

2.4 Regional Geology

Philadelphia is underlain by crystalline rocks of the Piedmont Plateau and by younger unconsolidated sediments of the Atlantic Coastal Plain physiographic provinces. The Piedmont Plateau lies in a broad area northwest of the Fall Line, whereas the Coastal Plain occupies a narrow band along the Delaware River. The Fall Line delineates the landward edge of the Coastal Plain, where crystalline bedrock and unconsolidated sediments meet at ground surface, and roughly transects the Philadelphia area from Morrisville to the northeast to Marcus Hook to the southwest.

The crystalline rocks primarily consist of the metamorphic Wissahickon Schist Formation, with lesser amounts of quartzite of the Chickies Formation. These rocks crop out in the Piedmont and their surface slopes southeastward, forming a basement beneath the Coastal Plain sediments (Black & Veatch, 1990; Greenman et al., 1961; Martin, 1990; Sloto, 1988; Pennsylvania Geologic Survey – Map 1: Geologic Map of Pennsylvania, 1980).

2.4.1 Coastal Plain Sediments

The Coastal Plain sediments are a seaward dipping wedge of alternating layers of sand, silt, and clay overlying the crystalline basement. Cretaceous and Tertiary age sediments generally trend northeast-southwest and slope 10 to 80 feet per mile to the southeast, whereas overlying Quaternary sediments, where present, are flat lying. The Coastal Plain sediments thicken to the southeast from a feather edge along the Fall Line to more than 6,500 feet thick in southern Cape May County.

In the Philadelphia and Camden area, the Coastal Plain sediments of Cretaceous age are regionally known as the PRM aquifer system and consist of permeable beds of sand and gravel separated by confining layers of clay and silt. The sediments were deposited in complex fluvial-deltaic environment and in the Delaware Valley are considered to be chiefly non-marine. In the Philadelphia area, the PRM aquifer system can be divided into six informal units: lower sand; lower clay; middle sand; middle clay; upper sand; and upper clay sediments (Black & Veatch, 1990; Martin, 1990; Sloto, 1988).

2.4.2 Lower Sand and Clay Units of the PRM

The lower sand unit is the lower-most unit of the PRM aquifer system in Philadelphia and consists chiefly of well-sorted coarse sand and fine gravel. The thickness of the lower sand unit ranges from less than one foot at the Fall Line to approximately 90 feet where it fills channels carved into the crystalline bedrock by the ancestral Delaware and Schuylkill Rivers. Throughout most of the area, the lower sand is overlain by a confining layer of the lower clay unit, the middle clay unit, or both. Near the Fall Line, these confining clays are absent and the lower sand is directly overlain by the upper sand unit or Tertiary and Quaternary deposits; the unit becomes part of the water table aquifer system.

The lower clay unit consists of a tough clay containing beds of softer clay and thin lenses of fine-grained sand. The lower clay unconformably overlies the lower sand unit and is generally 20 to 40 feet thick but can be up to 60 feet thick in places (Black & Veatch, 1990; Martin, 1990; Sloto, 1988).

2.4.3 Middle Sand and Clay Units of the PRM

The middle sand unit fills shallow channels in the lower clay unit and is not extensive in Philadelphia. This unit consists of a sequence of very fine to coarse grained sand beds and few thin beds of clay. The maximum thickness of the middle sand unit can exceed 40 feet but typically is less than 20 feet.

The middle clay unit is the most extensive clay of the PRM aquifer system in Philadelphia. It consists of a uniformly massive tough clay with very little sand. Its thickness commonly exceeds 20 feet and locally may be as thick as 60 feet. Because the middle clay unit lies directly upon the lower clay unit in much of the Philadelphia area, it is difficult to differentiate the two units (Black & Veatch, 1990; Martin, 1990; Sloto, 1988).

2.4.4 Upper Sand and Clay Units of the PRM

The upper sand unit unconformably overlies the middle clay unit and consists of medium to coarse sand, gravel, and lenses of clay. Gravel beds are common. The upper sand unit can be 50 feet thick but does not usually exceed 35 feet in thickness. In much of Philadelphia, the upper sand unit is part of the water table aquifer system.

Where locally present in Philadelphia, the upper clay unit overlies and confines the upper sand unit. This unit consists of a sequence of sandy, carbonaceous, and massive clays with a maximum thickness of 35 feet (Black & Veatch, 1990; Martin, 1990; Sloto, 1988).

2.5 Local Geology

Deposits of relatively flat lying Tertiary and Quaternary age sediments unconformably cover the Cretaceous sediments in the vicinity of the NEWPCP. These terrace and valley fill deposits consist of clay, silt, sand, and gravel. Their maximum thickness can be approximately 80 feet, but typically is about 40 feet. These deposits form an extensive water table aquifer and are locally known as the Bridgeton Formation, the Trenton Gravel, and Holocene sediments.

The Tertiary age Bridgeton Formation is primarily a quartz sand with beds of fine gravel that crops out in a three-mile wide band northwest of the Fall Line, roughly two miles northwest of the NEWPCP. The presence of gravel lenses, horizontal gravel beds, and crossbedded sand beds indicate the Bridgeton Formation was likely deposited in a fluvial paleoenvironment. This formation is generally 30 feet thick.

The Quaternary age Trenton Gravel crops out in a four-mile wide band southeast of the Fall Line, is generally about 50 feet thick, and consists of a medium to coarse grained, very gravelly sand. There are also interbedded clay and silt and crossbedded sand layers. The Trenton Gravel is generally continuous and occurs chiefly in the lowland along the Delaware River from Trenton to the Atlantic Ocean. The Trenton Gravel is believed to have been formed by meltwater and sediment derived from retreating glaciers and is the youngest deposit underlying the NEWPCP site.

Holocene sediments consisting of silt and fine sand underlie the channels and tidal flats of the Delaware River and its principal tributaries. These sediments can be nearly 80 feet thick near the confluence of the Delaware and Schuylkill Rivers, but the thickness is generally less than 20 feet in the vicinity of the NEWPCP sediments (Black & Veatch, 1990; Greenman et al., 1961; Martin, 1990; Sloto, 1988).

2.6 Water Use Determination

In September of 1998, RETTEW contacted the following agencies and companies in order to determine groundwater use within a 2-mile radius of the NEWPCP:

- United States Geological Survey (USGS)
- New Jersey Geological Survey (NJGS)
- Pennsylvania Department of Environmental Protection
- InfoMap Technologies

Upon review of the results of the PWS data searches, no PWS wells are present in Pennsylvania within a two mile radius of the NEWPCP impoundments. A total of 27 PWS wells in New Jersey are present within a two mile radius of the facility. The name, permit number and distance of each PWS well is provided in Table 1.

Table 1
Public Water Supply Wells Located Within a 2-Mile Radius of the NEWPCP

Well Name	Permit No.	Distance From NEWPCP
Morris Well 8	31-00944	6892 ft
Morris Well 3A	31-00945	10402 ft
Delaware Gardens Well 2	31-01417	3497 ft
Well 50	31-03456	8208 ft
Morris Well 10	31-04251	7762 ft
Morris Well 4A	31-04252	9487 ft
Well 51	31-04780	7884 ft
Well 52	31-04847	8836 ft
National Hwy Well 1	31-05110	10348 ft
Delaware Gardens Well 1	31-05228	3091 ft
Puchack Well 6	31-05450	5191 ft
Puchack Well 7	31-08526/A	5713 ft
Morris Well 11	31-15745	5137 ft
Morris Well 13	31-16813	4829 ft
Morris Well 12	31-16814	5473 ft
Well 54	31-18944	6665 ft
Well 53	31-18947	7146 ft
Well 55	31-20270	8496 ft
Morris Well 6	51-00051	5536 ft
Morris Well 7	51-00052	6312 ft
Delair Well 1	51-00053	2874 ft
Delair Well 2	51-00054	2833 ft
Delair Well 3	51-00055	3234 ft
Puchack Well 1	51-00056	4990 ft
Puchack Well 2	51-00057	5308 ft
Puchack Well 3	51-00058	5521 ft
Morris Well 9	51-00076	6092 ft

No PWS wells in Pennsylvania are present within a 2 mile radius of the facility. The locations of these wells (with New Jersey well permit number) are identified in Figure 4. Search data obtained from the agencies and InfoMap Technologies are provided in Appendix D.

The results of the water use determination research indicate the following:

- No groundwater is derived from wells or springs, nor used or planned to be used for drinking water or agricultural purposes within a radius of 1,000 feet downgradient of points of compliance (site boundary);
- No groundwater is used in the Pennsylvania / Philadelphia region within 2 miles of the site boundary;
- The area described above does not intersect a radius of ½ mile from a community water supply well source;
- PWS wells do exist in New Jersey opposite of the Delaware River.

3.0 SITE CHARACTERIZATION METHODOLOGY

Site characterization activities were conducted at the NEWPCP between November 1998 and December 2000 and included the installation of monitor wells, groundwater gauging and sampling, former and existing sludge impoundment sampling, surface water sampling, adjacent smelter waste sampling, aquifer testing, and an ecological assessment. The following section outlines the methodology and results of site characterization activities at the NEWPCP.

3.1 Existing Groundwater Monitoring Network

A network of five ground water monitoring wells (MW-1 through MW-5) were installed onsite between January and February 1989 by Black & Veatch, Inc. (Black & Veatch). Following installation, Monitor Well MW-3 was apparently destroyed during construction and another (Monitor Well MW-2) was properly abandoned by RETTEW due to the groundwater level being above the screened portion of the well. An additional eight monitoring wells (MW-AS, MW-AD, -BS, -BD, -CS, -CD, -DS, and –DD) were installed by RETTEW between October and November 1994 in order to characterize and provide soil and groundwater quality information for previous investigations. The well nomenclature used in this investigation is as follows: for MW-AD MW=Monitor Well; A=Well name; D = Deep well (D for deep well and S for shallow well).

The purpose of the shallow and deep monitoring wells was to screen the upper portion of the aquifer, including the surface of the water table, so that the hydraulic potential and contaminant concentrations in the shallow portion of the aquifer may be evaluated. Data from the eight newly installed monitoring wells were then integrated with that of the available existing wells installed by others to form a monitoring well network for the investigation. The eight RETTEW monitoring wells constructed in 1994 were installed in clusters (shallow well and deep well at each cluster location).

The physical location of monitoring wells MW-1, MW-4, and MW-5, and their construction were approved by Black & Veatch and the Pennsylvania Department of Environmental Resources prior to installation. Black and Veatch constructed the monitoring wells with 4-inch PVC schedule 40 pipe, which were protected on the outside with a square thin steel pipe protector casing.

3.2 Monitoring Well Installation

To facilitate the collection of groundwater samples in the vicinity of Impoundment A and Impoundment C, one well cluster consisting of MW-ES and MW-ED was installed on the NEWPCP property located near the intersection of Lewis Street and Delaware Avenue. The purpose of this new well cluster was to supplement the existing monitoring well network. In addition, existing monitoring wells MW-AS and MW-AD were damaged during roadway construction within the NEWPCP property. For this reason, these monitoring wells were properly abandoned and replaced with a new well cluster (MW-FS and MW-FD). The additional monitoring wells were constructed in November and December of 1999.

During the advancement of the soil borings for the monitoring wells, soil samples were collected continuously using a 2-inch ID split-spoon sampler until refusal was encountered. The soil samples were visually examined in the field and geologically logged according to the Burmister classification system. The samples were also screened with a calibrated photoionization detector (PID) for the presence of volatile organic compounds (VOCs) and recorded on the boring log for each well. A soil sample from both the deep and shallow aquifers were collected for laboratory analysis. The soil samples were analyzed by The City of Philadelphia Bureau of Laboratory Services (BLS). As part of a contract with the City, Lancaster Laboratory analyzed volatiles, semi-volatiles, and pesticides. The soil samples were analyzed for total organic carbon (TOC), clay mineral content and parameters listed below on Table 2.

Table 2
Soil Sample Laboratory Analysis Parameters

TCL volatiles
TCL semivolatiles
TPH
PH
TAL metals* + Cyanide
TCL Pesticides/PCBs
TOC
Clay Mineral Content

TAL – Target Analyte List TCL – Target Compound List

*TAL metals are listed below:
Aluminum, Antimony, Arsenic, Barium, Beryllium, Cadmium, Calcium, Chromium, Cobalt, Copper, Iron, Lead, Magnesium, Manganese, Mercury, Nickel, Potassium, Selenium, Silver, Sodium, Thallium, Vanadium, Zinc

The deep monitoring wells were completed by advancing a 8-inch diameter hollow-stem auger to a depth of approximately 35 feet below grade. Following drilling, 6-inch diameter steel casing was installed to approximately 5 feet below the top of the semi-confining layer and pressure grouted in place. This casing installation prevents cross-contamination of groundwater contaminants from the shallow water table zone to the deeper zone. After installation of the casing, the deep wells were continued by drilling through the confining layer using a 6-inch diameter hollow stem auger to a depth of approximately 40 feet. Following drilling, the well was completed using four-inch diameter, flush-threaded PVC casing and 0.010 inch slotted screen. Sand pack was placed in the annular space between the well screen and borehole to approximately two feet above the screen. A two-foot bentonite seal was placed on top of the sand, and the remaining annular space was filled with a grout. Monitoring well MW-FD was completed at the surface as a stick-up with the 6-inch ID steel casing extending above grade. MW-ED was completed as a flush mount. A 3-foot-diameter concrete pad was installed at the ground surface of the wells to a depth of approximately 3 feet below grade. The PVC wells were fitted with water-tight caps and the protective steel casings were fitted with a locking caps to preclude unauthorized entry; locks for all the wells were keyed alike.

The shallow wells were completed in similar manner to the deep monitoring well, without the need for 6-inch casing at depth. It was anticipated that the shallow wells would have a total depth of approximately 15 feet, however, actual field conditions required depths of approximately 18 feet. Monitor Well FD and the Stilling Well for Impoundment C were completed at the surface as a stick-up using a 5-foot-section of 6-inch ID steel protective casing which was installed to a depth of three feet. Monitoring Well MW-ES was completed as a flush mount. A 3-foot-diameter concrete pad was installed at the ground surface of the shallow wells to a depth of approximately 3 feet below grade. The PVC wells were fitted with water-tight caps and the protective steel casings were fitted with a locking caps to preclude unauthorized entry; locks for all the wells were keyed alike.

Each monitoring well installed by RETTEW was developed by purging with a clean submersible pump to remove any cuttings and drilling fluids present in the well. Following installation and well development, RETTEW professionally surveyed the horizontal and vertical locations of all onsite wells for incorporation into appropriate existing PWD site mapping. The location of all monitor wells at the NEWPCP is provided on Figure 5.

3.3 Ground Water Level Monitoring

Groundwater levels in both the shallow and deep wells were monitored on a continuous basis between November 5, 1999 to September 11, 2000. The data was collected to help aid in the determination of groundwater flow directions and aquifer response to anticipated tidal influences. Water level data was collected by digital dataloggers as described below.

On November 4, 1999, digital down-hole, water-level transducers / data recorders (Solinst Levelloggers™) were installed in nine of the thirteen monitoring wells. Both the shallow and deep wells were included in the monitoring well network. The recorders were programmed to collect water level data on a long term basis at 30 minute intervals. The nine loggers were installed in different well locations periodically through the monitoring period (every 4 months or so) to collect additional information. Water level data was collected for almost one full year (November 5, 1999 to September 11, 2000). During the monitoring period, one datalogger was dedicated to measure barometric pressure changes.

Water level data collected from the monitoring network was compensated for the influences of barometric pressure. This process was simplified because barometric pressure readings were collected at the same time intervals as the groundwater level data. The compensation routine was completed by subtracting the barometric pressure from the water pressure collected in the monitor wells. Following the barometric pressure compensation, the data was corrected to a fixed value, in this case, measurement by hand.

3.4 Groundwater and Surface Water Sampling

On January 18-19, 2000 (approximately 2 weeks after the new monitoring well cluster was installed and developed), one initial round of groundwater sampling was conducted from the thirteen (13) monitoring wells located at the site (MW-BD, -BS, -CD, -CS, -DD, -DS, -ED, -ES, -FD, -FS, -1, -4, and –5). After the initial round of monitoring, a follow up groundwater sampling event was conducted approximately 30 days after the initial event (March 1-2, 2000). This second monitoring event was considered the first quarterly sampling event. The remaining quarterly sampling events were conducted on June 12-13, 2000, September 11-12, 2000, and December 18-19, 2000.

Prior to collection of the groundwater samples, the monitoring wells were purged of a minimum of three well volumes or until each well was dry using a decontaminated submersible pump. This procedure ensured that a sample representative of the surrounding aquifer conditions was collected. After the wells had recovered to at least 75 percent of the original static water level, the groundwater samples were collected from each well using disposable polyethylene bailers. Samples collected for dissolved metals were field filtered using a 0.25 micron filter apparatus. All samples were preserved in the field by adding the appropriate preservative and keeping the samples cool. The City of Philadelphia BLS analyzed the groundwater samples for the parameters listed below in Table 3. As part of a contract with the City, Lancaster Laboratory analyzed volatiles, semi-volatiles, and pesticides. The purge water generated during the sampling activities was discharged into the wastewater influent of the NEWPCP for treatment. All down-hole equipment (except for disposable sampling bailers) was decontaminated using a steam-cleaner and brush scrub using alconox, clean water rinse, acid wash, and de-ionized water rinse prior to each use. The groundwater sample nomenclature used in this investigation is as follows: for NEMW-DD, NE=Northeast Water Pollution Control Plant; MW=Monitor Well; D=Well name; D=Deep well (D for deep well and S for shallow well).

Table 3
Groundwater / Surface Water Sampling Parameter List

TCL volatiles	Sulfate
TCL semivolatiles	Total sulfide
TCL pesticides/PCBs	Nitrate-N
TAL metals* (total & dissolved) + Cyanide	Nitrite-N
TKN	TDS
Turbidity	Chloride
TOC	Ammonia-N
TPH	Fluoride
COD	Alkalinity
Carbon Dioxide	Redox Potential
Ferrous Iron	BOD_5
Hardness	

TCL – Target Compound List   TAL - Target Analyte List

Surface water samples were collected from Frankford Creek at locations upstream and downstream relative of the site in March and September 2000. The location of the surface water sample stations is provided on Figure 6.

3.5 Sludge Sampling (Impoundments A, B, C, and D)

To facilitate the collection of representative sludge samples and to determine the depth of the NEWPCP sewage sludge impoundments, March 2000 borings were advanced into the impoundments using the hollow stem auger method of drilling facilitated by a wide-tracked off-road auger rig. Drilling activities were completed by Ameridrill Inc. of Morristown, Pennsylvania. The borings were completed at locations where access by the track drill was possible. Thick vegetation, standing water, saturated sludge and the limitations of the tracked drill rig dictated the areas where sludge samples were obtained. The horizontal location of each boring was surveyed by RETTEW. The location of the sludge borings within the NEWPCP sewage sludge impoundments is presented on Figure 7.

Five borings were advanced in each of the sewage sludge impoundments (Impoundments A through D). Water was encountered either at the surface as standing water or as water perched within the impoundment. During the advancement of the borings, sludge samples were collected continuously using a split-spoon sampler. Samples were collected until the base of the impoundments were encountered. The impoundment samples were visually examined in the field and logged. The samples were also screened with a calibrated PID for the presence of VOCs. PID readings were recorded on the corresponding boring logs. All down-hole equipment was decontaminated using a steam-cleaner and brush scrub using alconox, clean water rinse, acid wash, and de-ionized water rinse prior to each use.

Three sludge samples per boring were submitted for laboratory analysis. In general, the submitted samples were collected from the following intervals: 1) shallow (S) interval between 0 feet below grade (ftbg) and 2 ftbg; 2) a middle (M) interval approximately between 4 ftbg to 6 ftbg, and the; 3) deep (D) interval between the base of the impoundment to 2 feet above the base of the impoundment. The samples were analyzed by the BLS for the parameters listed on Table 4. The sludge sample nomenclature used in this investigation is as follows: for NELAGB2M, NE= Northeast Water Pollution Control Plant; LAG=Lagoon; B=Lagoon letter designation; 2=Sludge sample location; and; M=Mid depth (S for shallow depth sample, M for Mid depth sample, D for deep sample).

Table 4
Impoundment Sludge Sample Laboratory Analysis Parameters

TCL volatiles
TCL semivolatiles
TPH
PH
TAL metals
CYANIDE
TCL pesticides/PCBs
TCLP metals

TCLP – Toxicity Characteristics Leaching Procedure

3.6 Sludge Sampling (Impoundment E)

Two soil borings were advanced within the boundaries of the former Impoundment E footprint. Sludge from this impoundment had been removed previously and replaced with soil and fill material. The goal of this portion of the investigation was to confirm that the sludge had been removed. The borings were advanced using the hollow stem auger method of drilling. All down-hole equipment was decontaminated using a steam-cleaner and brush scrub using alconox, clean water rinse, acid wash, and deionized water rinse prior to each use. Auger cuttings and split spoon samples were visually examined and geologically logged. A calibrated PID meter was utilized to scan for the potential presence of VOCs. One sample of fill material/ sludge from each boring was analyzed for the parameters listed on Table 4. The location of the soil borings that were advanced into the former Impoundment E are provided in Figure 8.

3.7 Smelter Waste Sampling

Smelter waste from a large uncovered pile located on the Franklin Copper smelter property along the southwest property boundary of the NEWPCP (directly adjacent to Impoundment D) was observed to be drifting onto the PWD property. Two composite samples of the smelter waste (NELAGSW1 and NELAGSW2) was collected on March 23, 2000. The smelter waste samples were collected from along the site property boundary in the vicinity of the railroad line that extends southwest/ northeast across the site. The two samples were collected at the locations provided on Figure 9. The samples were analyzed by PWD BLS for the parameters listed on Table 5.

Bureau of Lab Services

Table 5
Smelter Waste Sample Laboratory Analysis Parameters

TCL volatiles
TCL semivolatiles
TPH
PH
TAL metals* + Cyanide
TCL Pesticides/PCBs
TCLP metals

TCL – Target Compound List   TAL – Target Analyte List

During sampling, wind was observed blowing smelter waste dust onto the PWD property. During heavy gusts, large "clouds" of material were present in the air. Based on this observation, it is likely that smelter waste has been historically wind-blown and deposited onto the NEWPCP property.

4.0 SITE CHARACTERIZATION RESULTS AND DISCUSSION

4.1 Monitoring Well Installation

RETTEW professionally surveyed the horizontal and vertical locations of all onsite wells for incorporation into appropriate existing PWD site mapping. The elevations of the top of PVC casing were determined in reference to U.S. Geological Survey Mean Sea Level. This information is provided on Table 6.

Table 6
Top of PVC Casing Elevations For Monitor Wells

Monitor Well	Elevation in Feet Mean Sea Level
MW-1	22.84
MW-4	11.80
MW-5	16.11
MW-BS	12.05
MW-BD	12.25
MW-CS	13.07
MW-CD	13.16
MW-DS	12.67
MW-DD	12.73
MW-ES	9.37
MW-ED	9.36
MW-FS	14.64
MW-FD	14.43

Boring logs for all of the monitor wells completed at the NEWPCP are provided in Appendix E. None of the parameters analyzed in the soil samples exceeded the published PADEP Non-Use Aquifer / Nonresidential Medium-Specific Concentrations (MSC) Direct Contact (DC) and Soil to Groundwater (STG) numerical values. Laboratory results for the soil samples collected during the installation of monitor wells is provided in Appendix F.

4.2 Site Stratigraphy

The generalized site stratigraphy presented in this section is based on the results of site drilling conducted by RETTEW in 1994 and 2000; and by Black & Veatch in 1989. While Black & Veatch conducted a site geotechnical investigation in 1989, their conclusions also reflect the results of previous site drilling conducted by Woodward-Gardner & Associates in 1971.

The various drilling projects targeted different areas of the site and although some overlap was necessary, i.e., to add wells to the groundwater monitoring system, the intent of the drilling conducted by RETTEW in 1999 and 2000 was to augment the efforts of previous investigations. The overlap also confirmed consistent findings between the various investigators. A geologic fence diagram of the stratigraphy underlying the NEWPCP is provided on Figure 10.

The subsurface conditions, in descending order, include:

- Surficial fill materials;
- Silty Sand;
- Clay and Silt;
- Sand and Gravel;
- Saprolite; and
- Bedrock

4.2.1 Surficial Fill Materials

Surficial fill materials were distributed throughout the site with thickness ranging from one foot in northern portions of the site to approximately 18 feet in the area of the impoundments. The fill material primarily consists of a mixture of fine sand and organic-rich clayey silts with some gravel, and abundant cinders and concrete/brick fragments. The fill was likely derived by reworking the Quaternary alluvial deposits of the extensive "Trenton Gravel", with lesser amounts of demolition debris and smelter waste.

4.2.2 Silty Sand

Silty sand commonly underlies the fill as a discrete deposit or has been reworked to form the fill matrix. The sand is generally fine-grained and is thought to be part of the Quaternary alluvial deposits of the extensive Trenton Gravel.

4.2.3 Clay and Silt

Clay and silt deposits thought to be Recent Alluvium were generally encountered in the southern portion of the site. These sediments, apparently the product of tidal marsh deposition, contained abundant roots. The thickness of these silts and clays ranges up to 20 feet in the area north of Impoundment B and apparently increases toward the Delaware River. Firm clay deposits, ranging between eight and ten feet thick and lacking root material, were revealed in borings located northwest of Impoundment A and north of Impoundment C. Clay and silt encountered at the site are thought to be part of the Lower Clay Unit of the PRM, the Middle Clay Unit of the PRM, or Quaternary marsh deposits. These units are often undifferentiated along the Delaware river in the vicinity of the NEWPCP.

4.2.4 Sand and Gravel

Sand and gravel deposits underlie the clays and silts. The sand generally is medium grained, contains some well-rounded gravel, and appears fairly continuous under the site. A discrete gravel lens was encountered adjacent to Impoundments A and C at a depth of approximately 30 feet below grade. The base of the sand and gravel deposits ranges between 45 and 50 feet below grade. These sand and gravels are thought to be primarily part of the Lower Sand Unit of the PRM.

4.2.5 Saprolite

Saprolite consisting of highly weathered and friable schist, underlies the sand and gravel deposits. The density if the saprolitic schist increases with depth as the degree of alteration decreases.

4.2.6 Bedrock

Bedrock, consisting of competent Wissahickon Schist, was encountered in the northeast portion of the site from cores drilled by Woodward-Gardner during their soil and foundation investigation. The competent bedrock was encountered between 71 and 77 feet below grade and is believed by RETTEW to have been the deepest site drilling.

4.3 Groundwater Level Monitoring Results

Time series plots of groundwater elevations collected between November 5, 1999 and September 11, 2000 from the shallow and deep aquifer systems are provided in Appendix G. The plots show that the deep semi-confined aquifer (Lower Sand Unit of the PRM) underlying the NEWPCP responds to tidal fluctuations of the Delaware River. Groundwater fluctuations with respect to the tidal influence of the Delaware river over a 36 hour period (between 18:00 on April 30, 2000 to 6:00 on May 2, 2000) are also provided. The mechanism for causing this prominent aquifer response may be: 1) loading and unloading of sediments of the deep semi-confined aquifer underlying the river from the rise and fall of the tides, or; 2) hydraulic connection between the Delaware River and the Lower Sand Unit of the PRM.

The interaction between the Delaware River and the underlying aquifer system is based on two major factors: 1) the orientation of the riverbed sediments and aquifer sediments at the base of the river, and; 2) the hydraulic conditions controlling flow from the river to the underlying aquifer. Along the Delaware River, many units of the PRM outcrop beneath the river. In the vicinity of the NEWPCP, the Lower Sand Unit aquifer system is present at the river's base. The river and the underlying formation is separated by riverbed material which is composed of river deposits and reworked formation material, all modified by dredging operations. The rate of flow between the river and the underlying aquifer is controlled by the hydraulic potential and the hydraulic conductivities of the underlying aquifer system and riverbed deposits (Navoy and Carleton, 1995).

A geophysical survey of the riverbed sediments at the base of the Delaware River was documented by Duran (1996 and 1997). The survey was conducted using a marine-seismic and electromagnetic conductance (EM) methods. Results of the survey estimated the relative permeability of the shallow riverbed sediments. A reprint of the results from this study is provided in Figure 11 (reprinted from Navoy and Carleton, 1995). Based on this study, riverbed sediments in the vicinity of the NEWPCP are primarily high permeable sediments described as sand and gravel.

Historic dredging activities have been conducted in the Delaware River by the US Army Corp. of Engineers. Dredging activities were completed to keep shipping lanes open to large commercial boat traffic at low tide (U.S. Army Corps of Engineers, 1975). In some places, the channel was dredged into and through the Lower Clay Unit of the PRM in the vicinity of the NEWPCP (Sloto, 1988). A map prepared by the US Army Corp. showing depths of the Delaware River near the NEWPCP is provided in Appendix H.

Based on the data presented and published literature references, the prominent hydraulic response observed in deep monitor wells at the NEWPCP is due to a direct hydraulic connection between the Delaware River and the Lower Sand Unit of the PRM. This hydraulic connection is possible due to the highly permeable riverbed sediments in the vicinity of the NEWPCP, the position of underlying aquifer stratigraphy, and historic dredging activities by the U.S. Army Corp of Engineers.

A transient groundwater flow regime exists within the Lower Sand Unit due to earth tides exhibited by the Delaware River. At high tide, the pore pressures within the semi-confined aquifer underlying the NEWPCP are highest near the river causing the potential for groundwater to flow away from the river (northwest near the NEWPCP). At low tide, the pore pressures are lowest near the river causing the potential for groundwater to flow back towards the river. Although the potential groundwater flow directions change with the direction of the tide, the overall movement of groundwater near the NEWPCP is likely limited due to the repeating directional forces of the tidal pressure wave and the small storage changes within the semi-confined aquifer (Serfes, 1987).

To determine if a general groundwater flow direction exists in the Lower Sand Unit, an average head elevation was calculated for each deep well at the NEWPCP as described by Serfes (1987). The head data was averaged over a 30 day interval. The monthly intervals were used to determine if seasonal changes have an influence on local groundwater flow. A mean hydraulic gradient can be calculated based on time weighted averages of the groundwater elevations. Average head data for the deep wells at the NEWPCP are presented in Table 7. Average hydraulic head for the shallow, unconfined aquifer is provided in Table 8.

Error was introduced into the monitoring data set from three sources: 1) instrument accuracy; 2) accuracy of manual hand measurements; 3) error introduced through barometric pressure compensation. The highest attributed error was introduced into the dataset through manual hand water level measurements. The maximum amount of error introduced into the dataset is 0.2 foot.

Table 7
Average Monthly Groundwater Elevations Collected from Deep Monitor Wells at the NEWPCP

Well	Month 1	Mont h 2	Month 3	Month 4	Month 5	Month 6	Month 7	Month 8	Month 9	Month 10
MW-BD	0.73	0.64	-0.01	0.33	0.96	1.06	1.33	1.28	1.16	1.26
MW-CD	0.82	0.70	0.19	0.38	NM	NM	NM	NM	NM	NM
MW-DD	0.59	0.46	0.00	0.26	0.90	1.04	1.11	1.01	0.94	1.06
MW-ED	NM	NM	NM	0.38	0.74	0.83	0.96	0.84	0.84	0.88
MW-FD	NM	NM	NM	0.32	0.80	0.94	1.05	0.92	0.86	0.91
MW-1	0.80	0.60	0.33	0.28	0.87	1.38	1.53	1.42	1.10	1.13
MW-4	0.85	0.75	0.09	0.40	NM	NM	NM	NM	NM	NM
MW-5	0.50	0.38	-0.16	0.21	0.90	1.00	1.09	0.85	0.77	0.81

Notes: *All elevations in feet above mean sea level*
NM = Not Measured

Table 8
Average Monthly Groundwater Elevations Collected from Shallow Monitor Wells at the NEWPCP

Well	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Month 7	Month 8	Month 9	Month 10
MW-BS	1.24	1.19	0.77	0.98	1.17	1.11	1.63	1.70	1.48	1.78
MW-CS	7.21	7.68	7.35	7.91	7.98	7.72	7.16	6.67	6.25	6.84
MW-ES	NM	NM	NM	3.22	3.68	3.90	3.57	3.24	2.80	3.43

Notes: All elevations in feet above mean sea level
NM = Not Measured

Based on data provided in Table 7, the average potentiometric surface within the Lower Sand Unit underlying the NEWPCP is relatively flat with no ascertainable average direction of groundwater flow. The error introduced into the dataset often exceeds the variation of head per each month of the monitoring period.

The average flow direction within the shallow, unconfined aquifer is to the south/southwest towards the Delaware River. As shown in Table 8, the highest heads exist in Monitor Well MW-CS. The lowest heads have been shown to exist in MW-BS. The stage of the water table within the shallow unconfined aquifer is controlled by meteoric precipitation and, to a minor extent, leakage into the underlying deep aquifer. Time series plots provided in Appendix G show the relationship between meteoric precipitation events and a rise in water table stage. The water table stage rises significantly to heavy recharge events.

4.4 Groundwater and Surface Water Sampling Results

Analytical results for the January (Initial Round), March (1st), June (2nd), September (3rd), and December (4th), 2000 groundwater sampling analyses are provided on an attached computer disk, found in Appendix I. A summary of the results is provided below, beginning in Section 4.4.1.

4.4.1 Volatile Organic Compounds

The results of the analysis indicated that the groundwater samples collected in January, March, June, September and December 2000 did not contain volatile organic compounds (VOCs) above the Practical Quantitative Levels (PQLs) except for some small detections of acetone, benzene, carbon disulfide, and chlorobenzene.

- Acetone was detected in the samples collected from monitoring well (MW)-CS during the January and March 2000 events at a concentration of 29 ug/l and 34 ug/l, respectively. Acetone was also detected in the trip blank sample during the September 2000 events at a concentration of 62.5 ug/l.

- Benzene was detected in the samples collected from MW-5 during the December 2000 events at a concentration of 6.7 ug/l.

- Carbon disulfide was detected in the samples collected from MW-BD, MW-CS (January 2000) and MW-DD (June 2000) at a concentration of 8 ug/l, 11 ug/l and 22 ug/l, respectively. A duplicate sample for MW-DD for June 2000 was below detection limit.

- Chlorobenzene was detected in the samples from MW-CS during the September 2000 events at a concentration of 1.9 ug/l.

The detected concentrations were well below the PADEP Non-Use Aquifer / Nonresidential Medium-Specific Concentrations for acetone, benzene, carbon disulfide, and chlorobenzene.

4.4.2 Semi-Volatile Organic Compounds

Groundwater samples collected in January, March, June, September and December 2000 did not contain semi-VOCs above the PQLs except for the following:

- Acenaphthene was detected in MW-CD and MW-CD (duplicate sample) during the September 2000 event at a concentration of 28 ug/l.

- Acenaphthylene was detected in MW-CD (March and September), MW-BS (June), and MW-5 (January, March, June, September, December) at concentrations ranging from 18 ug/l to 35 ug/l.

- The compound bis(2-ethylhexyl) phthalate was detected in MW-ED during the March 2000 at a concentration of 32 ug/l.

- Flourene and Naphthalene were detected in MW-5 during the December 2000 event at concentrations of 10 ug/l.

- Phenol was detected in MW-FD and MW-FD (duplicate sample) during the March 2000 at concentrations of 18 ug/l and 14 ug/l, respectively.

The detected concentrations were well below the PADEP Non-Use Aquifer / Nonresidential Medium-Specific Concentrations for acenaphthalene, acenaphthene, compound bis(2-ethylhexyl) phthalate, flourene, naphthalene, and phenol.

4.4.3 Pesticides and PCB's

The following groundwater samples collected in January, March, June, September and December 2000 were the only results above the PQLs for pesticides and PCBs.

- Aldrin was detected in the groundwater samples collected from MW-CD (March, June, September, and December), MW-BS (September), MW-BD (September), MW-4 (September), MW-ES (September), and MW-CS (September) at concentrations ranging from 0.0096 ug/l to 0.0347 ug/l.

- Beta BHC was detected at a concentration of 0.0321 ug/l (MW-FD) and 0.0266 ug/l (MW-CD) in March 2000 and 0.0112 ug/l (MW-CD) in June 2000.

- Delta BHC was detected in MW-CD, MW-CS and MW-ES in June 2000 at a concentration of 0.0112 ug/l, 0.099 ug/l and 0.0262 ug/l, respectively. Delta BHC was detected in MW-ES in March 2000 at a concentration of 0.037 ug/l. Delta BHC was detected at concentrations of 0.0172 ug/l (MW-CD), 0.036 ug/l (MW-CD-duplicate), 0.0105 ug/l (MW-BD), and 0.058 ug/l (MW-Equipment Rinse) in September 2000.

- The compound DDD was detected in MW-CS and MW-4 during the September events at concentrations of 0.071 ug/l and 0.019 ug/l, respectively.

- The compound DDE was detected in MW-FS during the January event and in MW-CS and MW-BS during the December event at concentrations of 0.048 ug/l, 0.035 ug/l, and 0.028 ug/l, respectively.

- The compound DDT was detected in MW-ES (March 2000) and MW-4 (September 2000) at 0.022 ug/l and 0.019 ug/l, respectively.

- Endosulfan I was detected in the groundwater samples collected from MW-BS (January), MW-CD (March and June), MW-ES (March, September, and December), MW-CS (September) and MW-4 (December) at concentrations ranging from 0.0096 ug/l to 0.0347 ug/l.

- Gamma chlordane was detected in the groundwater samples collected from MW-4 (January and December), MW-ED (December), MW-ES (January and December), MW-CS (December),, MW-BS (January and December), MW-5 (January and December), MW-FS (January and December) and MW-FD (December) at concentrations ranging from 0.011 ug/l to 0.922 ug/l.

- Heptachlor was detected in MW-CS (September 2000) at 0.0267 ug/l.

- Methoxyclor was detected in MW-FS (September 2000) at 0.096 ug/l.

The detected concentrations were well below the PADEP Non-Use Aquifer / Nonresidential Medium-Specific Concentrations for aldrin, Beta BHC, Delta BHC, DDD, DDE, DDT, endosulfan (1), gamma chlordane, heptachlor, and methoxyclor.

4.4.4 Metals and Inorganics

Concentrations of dissolved and total metals were detected in the groundwater samples. Antimony, arsenic, barium, cadmium, calcium, chromium, cobalt, copper, lead, magnesium, nickel, potassium, selenium, sodium, vanadium, and zinc were detected above the PQLs in many of the samples. None of these detected metals exceeded the PADEP Non-Use / Nonresidential Aquifer MSCs. Detected concentrations of aluminum, iron, and manganese did exceed the PADEP Secondary Maximum Contaminant Levels (SMCL) except for MW-CS (aluminum only) and MW-1 (manganese only) in September 2000. Mercury and beryllium were not detected above the method detection limit in any of the samples.

Concentrations of cyanide, sulfate, nitrate, and nitrite were detected were detected above the method detection limits in many of the groundwater samples during the monitoring period. However, the concentrations of cyanide, sulfate, nitrate, and nitrite were well below the PADEP Non-Use Aquifer / Nonresidential Medium-Specific Concentrations.

4.4.5 Surface Water Samples

Upstream and downstream surface water samples collected from Frankford Creek in March and September 2000 did not contain volatile organic compounds (VOCs), Semi-VOCs, pesticides or PCBs above the PQLs. Concentrations of aluminum, iron, and manganese were detected above the PADEP SMCL's in both the upstream and downstream samples.

4.5 Sludge Sampling Results (Impoundments A, B, C, D)

Visual examination indicated that the sludge was homogenous in nature, with some minor building material such as brick or concrete occasionally encountered in a few borings. The sludge consisted of dark colored to black organic material primarily composed of human hair and organic human waste solids. Screening debris consisting of small solid materials (stuff that would find its way down the drain or into a sewer line) was observed in Impoundment B. In most areas, the upper six inches of the sludge does support some plant life. Other areas of the lagoons are either too dry or are inundated much of the year to support plant growth. Boring logs for all of the impoundment borings are provided in Appendix J.

The depth of the impoundments was determined during the sludge sampling activities. Impoundment A consisted of sludge and fill material and ranged from 10 to 13 ftbg with refusal encountered in three of the borings. Impoundment B consisted of homogeneous sludge material and some screenings with an average depth of 10 ftbg. Impoundment C consisted of homogenous sludge and ranged in depth from 9 to 10 ftbg. Impoundment D was approximately 10 feet deep also consisted of homogenous sludge material. Impoundments B, C and D were all underlain by a gray silty clay.

Analytical results for the March 2000 impoundment sludge sampling analyses are provided on the attached computer disk in Appendix I. Published PADEP Non-Use Aquifer / Nonresidential Medium-Specific Concentrations Direct Contact and Soil to Groundwater numerical values were used in the evaluation of the impoundment sludge. In the Soil to Groundwater pathway evaluation, the least stringent standard was used when comparing the analytical result to the 100xMSC and Generic Values (a value of 1/10 th the Generic Value was used in the evaluation since the sludge is typically saturated with standing water). A summary of the results is provided below.

4.5.1 Volatile Organic Compounds

Compounds Acetone, 2-butanone, Benzene, Carbon Disulfide, Chlorobenzene, Ethylbenzene, Methylene Chloride, Styrene, Tetrachloreothene, Toluene and Total Xylenes were detected in many of the impoundment sludge samples above the PQLs achieved during the analytical analysis. However, the detected compounds did not exceed the PADEP Non-Use Aquifer / Nonresidential Medium-Specific Concentration (MSC) DC and STG numerical values.

4.5.2 Semi-Volatile organic Compounds (VOC's)

A total of twenty-three (23) semi-volatile compounds were detected in the impoundment sludge samples above the PQLs achieved during the analytical analysis.

- The compound 4-Chloroaniline exceeded the PADEP Non-Use Aquifer / Nonresidential MSC STG 100xMSC numerical value (41,000 ug/kg) in sample NELAGD5M (52,000 ug/kg).

- The compound bis(2-Ethylhexyl)phthalate exceeded 1/10th the PADEP Non-Use Aquifer / Nonresidential MSC STG generic value (630,000 ug/kg) in samples NELAGB2D (1,900,000 ug/kg), NELAGD2D (790,000 ug/kg), NELAGD3M (1,900,000 ug/kg), NELAGD4D (1,100,000), NELAGD5D (720,000 ug/kg), NELAGC3D (1,200,000 ug/kg), and NELAGC4S (730,000 ug/kg).

None of the other the detected compounds exceeded the PADEP Non-Use Aquifer / Nonresidential MSC DC and STG numerical values.

4.5.3 Pesticides and PCB's

The compounds Alpha Chlordane, DDD, DDE, DDT, Endrin Aldehyde, Gamma Chloridane, PCB-1254 and PCB-1260 were detected in some of the impoundment sludge samples above the PQLs achieved during the analytical analysis.

- The compound DDE exceeded 1/10th the PADEP Non-Use Aquifer / Nonresidential MSC STG generic value in samples NELAGB2D (120,000 ug/kg), NELAGB5S (101,000 ug/kg), NELAGD3M (152,000 ug/kg), NELAGD4S (141,000 ug/kg), NELAGD5M (147,000 ug/kg), NELAGC1S (179,000 ug/kg), NELAGC1M (118,000 ug/kg), NELAGC4D (91,000 ug/kg), NELAGC5S (100,000 ug/kg). The Non-Use Aquifer / Nonresidential MSC STG generic value for DDE is 870,000 ug/kg. A value of 1/10th of the generic value (87,000 ug/kg) was exceeded.

- The compound DDT exceeded 1/10th the PADEP Non-Use Aquifer / Nonresidential MSC STG generic value (33,000 ug/kg) in sample NELAGD4D (44,000 ug/kg).

- The compound PCB-1260 exceeded 1/10th the PADEP Non-Use Aquifer / Nonresidential MSC STG generic value (190,000 ug/kg) in sample NELAGD4D (510,000 ug/kg).

None of the other the detected compounds exceeded the PADEP Non-Use Aquifer / Nonresidential MSC DC and STG numerical values.

4.5.4 Metals and Inorganics

The metals arsenic, cadmium and lead were detected in some of the samples above the PADEP Non-Use Aquifer / Nonresidential MSC DC numerical values for the 0-2 foot interval. Arsenic was detected above the DC numerical value of 53 mg/kg in sample NELAGC1S. The detected concentration arsenic in NELAGC1S was 66.3 mg/kg. Cadmium was detected in samples NELAGC1S (228 mg/kg) and NELAGC4S (271 mg/kg) above the DC numerical value of 210 mg/kg. Lead was detected in samples NELAGB2S, NELAGB3S, NELAGB4S, NELAGB5S, NELAGD2S, NELAGD3S, NELAGD4S, NELAGD5S, NELAGC1S, NELAGC4S NELAGC5S, NELAGB1S, and NELAGA2S above the DC numerical value of 1,000 mg/kg. The highest lead concentration in the 0-2 foot interval was from sample NELAGC4S at 4,780 mg/kg. However, the PADEP Non-Use Aquifer / Nonresidential MSC DC for the 2-15 foot interval and STG numerical values were not exceeded.

None of the other metals detected above the PQL exceeded the PADEP Non-Use Aquifer / Nonresidential MSC DC and STG numerical values.

Total Petroleum Hydrocarbons (TPH) were detected at concentrations between 470 mg/kg (NELAGA5S) and 300,000 mg/kg (NELAGD4D). Due to the digestion process to perform the TPH analysis, all organic compounds within the sample are dissolved, extracted and analyzed. The sludge samples contain high concentrations of non-petroleum related waste organics (i.e. undigested human hair, fecal matter solids, etc). For this reason, the TPH analytical results reflects the total organic content of the samples. Volatile and semi-VOCs analytical analysis indicate that petroleum hydrocarbons only exist in trace amounts within the impoundment sludge.

4.6 Sludge Sampling Results (Impoundment E)

Several initial attempts to auger below a depth of three feet was met with auger refusal by the presence of concrete rubble. However, two locations were found Soil Borings E-1 and E-2, where the auger could be advanced to a depth of 17 and 19-feet respectively. No evidence of existing sludge was found in either boring, nor were any VOCs present. Analytical results are provided on the attached computer disk located in Appendix I. Neither of the Impoundment E samples exceeded the PADEP Non-Use Aquifer / Nonresidential MSC DC and STG numerical values.

4.7 Franklin Smelter Waste Sample Results

The Franklin Smelter waste pile samples contained primarily the following metals:

- Aluminum
- Calcium
- Copper
- Iron
- Lead
- Magnesium
- Manganese
- Potassium
- Sodium
- Zinc

The waste exceeded the PADEP Non-Use Aquifer / Nonresidential MSC DC numerical values for iron (both the 0-2 ft and 2-15 ft intervals) and lead (0-2 ft interval). Analytical results for the Franklin Smelter waste samples are provided on the attached computer disk in Appendix I.

5.0 SITE CHARACTERIZATION CONCLUSIONS

- The subsurface conditions underlying the NEWPCP, in descending order, include 1) Surficial fill materials; 2) silty sand; 3) clay and silt; 4) sand and gravel; 5) Saprolite, and; 6) bedrock. Clay and silt encountered at the site are thought to be part of the Lower Clay Unit of the PRM, the Middle Clay Unit of the PRM, or Quaternary marsh deposits. Sand and gravels are thought to be primarily part of the Lower Sand Unit of the PRM with some reworking by Quaternary deposits of the Trenton Gravel.

- The prominent hydraulic response observed in deep monitor wells at the NEWPCP is due to a direct hydraulic connection between the Delaware River and the Lower Sand Unit of the PRM. Although the potential groundwater flow directions change with the direction of the tide, the overall movement of groundwater near the NEWPCP is likely limited due to the repeating directional forces of the tidal pressure wave and the small storage changes within the semi-confined aquifer.

- The average potentiometric surface within the Lower Sand Unit underlying the NEWPCP is relatively flat with no ascertainable average direction of groundwater flow. The average flow direction within the shallow, unconfined aquifer is to the south/southwest towards the Delaware River.

- None of the VOCs, semi-VOCs, pesticides, PCBs, and inorganics detected above the PQLs in the groundwater samples exceeded the PADEP Non-Use Aquifer / Nonresidential Medium-Specific Concentrations (MSCs). Concentrations of dissolved and total metals were detected in the groundwater samples. Antimony, arsenic, barium, cadmium, calcium, chromium, cobalt, copper, lead, magnesium, nickel, potassium, selenium, sodium, vanadium, and zinc were detected above the PQLs in many of the samples. None of these detected metals exceeded the PADEP Non-Use / Nonresidential Aquifer MSCs. Detected concentrations of aluminum, iron, and manganese did exceed the PADEP SMCL except for MW-CS (aluminum only) and MW-1 (manganese only) in September 2000.

- Upstream and downstream surface water samples collected from Frankford Creek in March and September 2000 did not contain VOCs, Semi-VOCs, pesticides or PCBs above the PQLs. Concentrations of aluminum, iron, and manganese were detected above the PADEP SMCL's in both the upstream and downstream samples.

- Visual examination indicated that the sludge was homogenous in nature, with some minor building material such as brick or concrete occasionally encountered in a few borings. The sludge consisted of dark colored to black organic material primarily composed of human hair and organic human waste solids.

- The compounds 4-Chloroaniline, bis(2-Ethylhexyl)phthalate, DDE, DDT, and PCB-1260 exceeded the PADEP Non-Use Aquifer / Nonresidential MSC STG numerical values for some of the sludge samples. None of the other VOCs, semi-VOCs, pesticides, PCBs, and inorganics detected above the PQLs in the sludge samples exceeded the PADEP Non-Use Aquifer / Nonresidential MSC DC and STG numerical values.

- The metals arsenic, cadmium and lead were detected in some of the sludge samples above the PADEP Non-Use Aquifer / Nonresidential MSC DC numerical values for the 0-2 foot interval in some of the shallow sludge samples. The PADEP Non-Use Aquifer / Nonresidential MSC DC for the 2-15 foot interval and STG numerical values were not exceeded. None of the other metals analyzed detected above the PQL exceeded the PADEP Non-Use Aquifer / Nonresidential MSC DC and STG numerical values.

- Total Petroleum Hydrocarbons were detected in the sludge samples at concentrations between 470 mg/kg (NELAGA5S) and 300,000 mg/kg (NELAGD4D). Due to the digestion process to perform the TPH analysis, all organic compounds within the sample are dissolved, extracted and analyzed. The sludge samples contain high concentrations of non-petroleum related waste organics (i.e. undigested human hair, fecal matter solids, etc). For this reason, the TPH analytical results reflects the total organic content of the samples. Volatile and semi-VOCs analytical analysis indicate that petroleum hydrocarbons only exist in trace amounts within the impoundment sludge.

- No evidence of existing sludge was found in two borings drilled into the former location if Impoundment E. Neither of the Impoundment E samples exceeded the PADEP Non-Use Aquifer / Nonresidential MSC DC and STG numerical values.

- Franklin smelter waste that formerly encroached onto the PWD property exceeded the PADEP Non-Use Aquifer / Nonresidential MSC DC numerical values for iron (both the 0-2 ft and 2-15 ft intervals) and lead (0-2 ft interval).

6.0 AQUIFER TESTING METHODOLOGY

6.1 Step Drawdown Test

A step draw down test was conducted for Monitor Well MW-ED, and began at 0830 on October 11, 2000. A 3.0-hp Grundfos stainless steel submersible pump was hung at a depth of 30.00 ftbg (three feet above the bottom of the monitor well). The pump was three-phase electric and was hard wired to a diesel generator. Discharge water from the pumping test was diverted to impoundment C with approval from a representative of PWD. A water flow meter was installed in-line with the pump discharge hose to gauge the discharge rate. A check-ball type valve was used to regulate and adjust the flow of water. It should be noted that the water meter was installed before the valve unit, so that the meter read laminar flow rates only. The vegetation in the impoundment naturally attenuated the energy from the discharged water.

6.2 Constant Rate Aquifer Test

A 48-hour, constant-rate, pumping test was conducted at Monitor Well MW-ED, and began at 1336 on October 16, 2000, and concluded at 1100 on October 18, 2000. The same pump and piping system was left in place from the step drawdown test, and was utilized during the constant rate test. A pre-pumping static water level of 8.45-ft. below grade was recorded prior to the start of the pumping test. The pumping rate was set to 35-gpm. Over the course of the test, the discharge rate remained constant, between 35 and 36-gpm. Both a water level meter and a down hole transducer was used to record the change in hydraulic head over the course of the pumping test.

Prior to the start of the 48-hour pumping test, static water levels were collected from the entire monitoring well system located on the NEPWD property. During the course of the test, static water level measurements were collected every hour to measure the effects of any change in head from pumping MW-ED. To augment the hourly hand measurement, a series of 6 transducers were in placed in selected monitoring wells to record any change in head over time.

6.3 Tidal Response Analysis

RETTEW performed an analysis of the time-series water level data collected at Monitor Wells MW-1, MW-5, MW-BD, MW-DD, MW-ED, and MW-FD to estimate site specific values of transmissivity and storativity for the underlying deep aquifer. The analysis was completed by comparing observed field data collected between May 1, 2000 and May 11, 2000 to predicted water level data generated by the following equation (Todd, 1959; Yim and Mohsen, 1992; and, Serfes, 1987)

$$h(x,t) = \exp(-x\sqrt{\pi S/t_0 T})\,\sin(2\pi t/t_0 - x\sqrt{\pi S/t_0 T})$$

<u>where:</u>

h	is the predicted groundwater elevation (ft)
x	is the distance of the observation well from the tidally influenced river (ft)
t	is time (min)
h_o	is the tidal amplitude (ft)
t_o	is the tidal period (min)
S	is the Storativity of the aquifer influenced by tidal response
T	is the Transmissivity of the aquifer influenced by tidal response (ft^2/min)

The first part of the equation $\exp(-x\sqrt{\pi S/t_0})$ yields the amplitude of the groundwater response from the adjacent tidal rise of the river. The second part $\sin(2\pi t/t_0 - x\sqrt{\pi S/t_0 T}$ defines the behavior of the sinusoidal wave, including the wave frequency and the phase shift.

If loading of the deep aquifer is occurring and groundwater response is caused by the compression of the aquifer, the amplitude of the groundwater response must be corrected to account for the compressibility of the aquifer. In this case, the amplitude of the groundwater response is multiplied by the Tidal Efficiency (Gregg, 1966) which is defined as:

$$T.E. = B_p / (B_p + nB_w)$$

<u>where:</u>

B_p	is the vertical compressibility (ft^2/lb)
B_w	is the fluid compressibility (ft^2/lb)
n	is the aquifer porosity

Estimates of B_p and B_w are provided in Dominico and Schwartz (1990). The following ranges of vertical compressibility were given for geologic sediments between medium-hard clay to dense, sandy gravel: 3.3×10^{-6} ft^2/lb to 5.0×10^{-7} ft^2/lb. The compressibility of water at 25 degree Celsius is 2.3×10^{-8} ft^2/lb. The assumed porosity of the aquifer is 0.3. Since the last term nB_w is small relative to B_p, T.E. ranges from 0.997 to 0.986. The groundwater response was not multiplied by the T.E. as recommended by Gregg (1966) since T.E. is approximately 1.0 and ignorance of this term will not have significant impact on the calculation of T and S.

The values of T and S were estimated by using a graphical fitting procedure. Predicted groundwater elevation with respect to distance from the river and time was generated using a Microsoft Excel Spreadsheet. The predicted elevations were plotted with actual observed groundwater elevation data for the same period. Values of T and S were adjusted until a graphical fit was achieved between the observed and predicted elevations.

6.4 In-Situ Hydraulic Conductivity Testing

On November 4, 1999, RETTEW performed in-situ hydraulic conductivity (slug) testing at Monitoring Wells MW-1, MW-BS, and MW-BD to obtain a site-specific hydraulic conductivity values of the underlying aquifers. This procedure was performed twice at each selected well location to determine an average value. In general, slug tests involve removing a "slug" or bailer of water from a monitoring well and measuring the static water level response, or recovery, of the well with a Solinst Levelogger. Prior to the removal of the slug of water, the static water level is measured. Immediately after the slug is removed, the initial displacement is measured, and recovery monitored until the well has returned to approximately 90% of its initial static level water elevation.

Slug tests were performed and the data was extrapolated using the Bower-Rice slug/bail test method via Aquifer Test for Windows®version 2.5. This test can be applied to open boreholes or screened wells; the wells can be fully or partially penetrating. The test can also be used in confined and unconfined aquifers. The Bower Rice equation is:

$$K = (r^2_c \ln(R_e/R)/2L_e)\,(1/t)\,\ln(H_o/H_t)$$

where

K	is hydraulic conductivity (ft/sec or ft/day)
r_c	is the radius of the well casing (ft)
R	is the radius of the gravel envelope (ft)
R_e	is the effective radial distance over which head is dissipated (ft)
L_e	is the length oOf the screen or open section of the well through which water can enter.
H_o	is the drawdown at time $t = 0$ (ft)
H_t	is the drawdown at time $t = t$ (ft)
t	is the time since $H = H_o$ (day or sec)

The value of H_t as a function of t is plotted on a semilogarithmic scale, with H_t on the logarithmic axis. The data pairs will fall on a straight line from small values of time and large values of head. As the head dissipates and the time increases, the points may not follow the straight line

7.0 AQUIFER TESTING RESULTS

7.1 Step Drawdown Test

A pre-pumping static water level of 8.47-ft. below grade was recorded prior to the start of the step test. The discharge rate was incrementally increased until a final steady state discharge rate of 37.5-gpm was achieved. Results of the step drawdown test are provided in Appendix K.

7.2 Constant Rate Aquifer Test

A pre-pumping static water level of 8.45 ftbg was measured in the pumping well. The pumping test commenced at 1145. One minute later at 1146, the water level was measured at 26.30 ftbg. The hydraulic head remained fairly constant for approximately 55 minutes, before the well showed signs of recharge. At approximately 1900, the well again began a period of declining hydraulic head, followed by another period of increasing hydraulic head. Beginning at approximately 0514 on October 17, 2000, the hydraulic head became fairly constant for the remainder of the test. Over the entire pumping period, the discharge rate was closely monitored and did not fluctuate more than 3% over the entire 48-hour pumping test.

Observation well MW-ES is located approximately 10 feet from the well, and is completed to a total depth of approximately 18 ftbg. This well was monitored during the pumping test for influences from the pumping well and was the most likely well within the monitoring well system to exhibit influences from the pumping test. However, instead of a drop in head in MW-ES, the head actually rose over the course of the pumping test. There are two reasons for this. First, the confining clay layer separating the shallow and deep wells in homogenous and continuous in nature and therefore did not draw from water in which the nearby shallow well is completed. Second, during the pumping test the area received occasional rain showers. Stormwater flow into the lagoon from the surrounding area as well as the water that fell in the form of rain directly into the basin contributed to the recharge of the shallow water table system during the pumping test. The additional stormwater in the lagoon increased the potential of the shallow water table, which was reflected in the steadily increasing hydraulic head measurements recorded throughout the 48-hour pumping test.

Other monitoring wells within the network exhibited no change in hydraulic head from the pumping of MW-ED other than the expected and predictable fluctuations associated with the changing of tides in the Delaware River. After 48-hours of pumping, a total drawn-down of approximately 12 ft was observed in MW-BS. Well data recorded during the 48-hour constant rate pumping test is provided in Appendix L. Groundwater was collected from a valve near the flow meter at the beginning and the end of the constant rate test. Results of the groundwater samples collected during the constant rate test are provided on the attached computer disk in Appendix I.

7.3 Tidal Response Analysis

A study of the equation reveals that the storativity parameter controls the amplitude of the pressure pulse observed in the aquifer as distance from the river. The amplitude of the pressure pulse decreases with distance from the river. Values of storativity greater than 1.0×10^{-5} cause the amplitude of the pressure pulse to decrease or flatten. Storativity value less than 1.0×10^{-7} cause the amplitude of the groundwater pulse to increase to amplitudes to levels observed in the Delaware River. Because of the small range of storativity values that can produce the amplitudes observed in the field data, the S values calculated from the graphical match are robust.

The transmissivity parameter controls both the amplitude and "time lag" that is observed in the water level response. Time lag is the time it takes for a given tidal peak or trough of the river to reach a distance from the river. Transmissivity values were sensitive to less than a half an order of magnitude with regard to the "time lag". For this reason, T values determined from this method are believed to also be robust.

Results of the graphical fitting procedure are provided in Table 9. Figures showing the graphical fit between the field data and analytical model are provided in Appendix M.

Table 9
Results of the Tidal Response Analysis

Well	MW-BD	MW-DD	MW-ED	MW-FD	MW-1	MW-5	Log Average
S	4.00×10^{-6}	9.90×10^{-6}	7.00×10^{-7}	1.30×10^{-6}	9.90×10^{-6}	7.90×10^{-6}	3.76×10^{-6}
T (ft^2/min)	8.00×10^{-3}	1.50×10^{-2}	4.35×10^{-3}	4.27×10^{-3}	1.50×10^{-2}	7.00×10^{-3}	7.85×10^{-3}
T (ft^2/day)	11.52	21.6	6.26	6.15	21.6	10.08	11.30

7.4 In-Situ Hydraulic Conductivity Testing

Results of the slug tests are provided in Table 10. Test data is provided in Appendix N.

Table 10
Results of In-Situ Hydraulic Conductivity Testing

Well	MW-1	MW-BD	MW-BS
K (ft/sec)	7.23×10^{-5}	9.71×10^{-5}	7.51×10^{-5}
K (ft/day)	6.25	8.39	6.49

8.0 AQUIFER TESTING CONCLUSIONS

Aquifer tests conducted at the NEWPCP indicated that the Lower Sand Unit is very conductive to groundwater flow. As indicated in the tidal response analysis, transmissivities calculated by using the deep monitor wells averaged to approximately 11 ft^2/day. Also, the tidal analysis has calculated storativity values (average of approximately $4x10^{-6}$) to within values typically observed in semi-confined to confined aquifers. Slug tests calculated a hydraulic conductivity values were 6.25 ft/day to 8.39 ft/day for the Lower Sand Unit.

Published results of hydraulic conductivity for the Lower Sand Unit in the Philadelphia County, Camden County and Gloucester County range from 1.1 x10-3 ft/s (95.04 ft/day) to 2.4x10-3 ft/sec (207.36 ft/day) with an average value of 1.6 x10-3 ft/sec (138.24 ft/day) (Sloto, 1988). Published values are much higher than estimates made at the NEWPCP. The values measured at the NEWPCP are likely an actual representation of the sediments underlying the NEWPCP and are site specific. The sediments underlying the NEWPCP represent a small fraction of the aquifer system in the vicinity of the Delaware River and New Jersey and likely represent some heterogeneity of the aquifer system. The values derived at the NEWPCP are site specific, but likely do not represent the aquifer system as a whole in the vicinity of the NEWPCP.

9.0 ECOLOGICAL ASSESSMENT

9.1 Introduction and Background

As outlined in Pennsylvania's Land Recycling Program Technical Guidance Manual (PADEP, 1997), a site specific ecological assessment was conducted under the Ecological Screening guidelines set forth by Act 2. The ecological screening procedure was developed by PADEP to determine if there are any impacts to ecological receptors and to minimize the need for a detailed ecological risk assessment. This Ecological Screening was completed for the impoundments located at the NEWPCP. The aerial extent of the NEWPCP property is approximately 120 acres. The northwest half of the site consists of several structures and treatment aeration tanks utilized for wastewater treatment activities. The southeast half of the property consists of four inactive sewage sludge impoundments (Impoundments A, B, C and D) and a former sludge impoundment (Impoundment E).

These impoundments are predominantly comprised of historic sewage sludge that has been partially vegetated with successional vegetation that is common in disturbed areas. Other sections of the impoundments support areas of open water with sporadic communities of common reed *(Phragmites australis)*. However, no jurisdictional wetlands are present on the site. It should be noted that the subject site has been extremely disturbed by historical activities and is located in a very industrialized section of Philadelphia just south of Exit 20 of Interstate Route 95, west of Frankford Creek and the Betsy Ross Bridge and north of the Delaware River.

Following the step by step process, RETTEW initially determined that Constituents of Potential Ecological Concern (CPECs) listed within Table II-2 of the Manual have been detected on the Site. It should be noted however, that the presence of such CPECs does not mean that such constituents have exceeded protective criteria or that complete exposure pathways exist. Thus, the ecological screening process proceeded to Step 6, the Detailed Onsite Evaluation, which will be discussed in greater detail below.

9.2 Technical Approach – Steps Taken In Ecological Assessment

According to *Pennsylvania's Land Recycling Program Technical Guidance Manual* (PADEP, 1997), the goal of the ecological screening procedure is to minimize, to the extent possible, the number of sites which require a detailed ecological risk assessment, while remaining protective of the environment. Therefore, RETTEW utilized the required step by step Ecological Screening Process outlined in the Manual. Because constituents of concern other than light petroleum products exist within the site's boundary and the sludge lagoons are greater than 2-acres with adjacent vegetated habitats, the ecological screening process immediately proceeded beyond Steps 1, 2 and 3 to Step 4. After identifying that CPECs were previously identified in the impoundment sludge on the site, the screening process skipped Step 5 (Preliminary Site Investigation) and proceeded onto Step 6. Step 6 includes the Detailed Onsite Evaluation to determine if species or habitats of concern exist on site in its current or intended use or if endangered or threatened species exist within a 2,500 feet radius of the site.

The following is a summary of the results of Step 6 (the Detailed Onsite Evaluation) and any subsequent steps necessary to determine the presence or absence of ecological impacts to the habitats and the potential ecological receptors on and adjacent to the NEWPCP.

9.3 Detailed Onsite Evaluation (Step 6)

According to the Manual, "the objective of the Detailed Onsite Evaluation is to identify species or habitats of concern and make observations that will permit a determination of whether any complete exposure pathways exist on the site." The Detailed Onsite Evaluation conducted by RETTEW involved the collection and analysis of background information and the detailed evaluation of the habitat cover-types, which included the inventory of the vegetative species and observed and potentially occurring wildlife species that utilize the habitats.

Accordingly, the tasks involved in completing the Detailed Onsite Evaluation under Step 6 included the following components:

1. Review of readily available site background information;

2. Identification of physical and habitat features of the area, evaluation to determine if species and habitats of concern are present, and a determination if stress induced signs appear in the project area;

3. Summary of findings that include identification of any suspect areas of disturbance or contamination;

4. Identification of the presence or absence of any species of concern including special, endangered, or threatened species within 2,500 feet of the site's borders; and

5. Identification of the presence or absence of habitats of concern <u>on the site</u>.

9.4 Review of Site Background Information

9.4.1 Operational History of Site and Sources of CPECs

Wastewater generated by residents and commercial/industrial facilities within the City limits was treated at the PWD NEWPCP using the more typical wastewater treatment process. First, the influent wastewater was pumped through screens to collect solid, indigestible materials. Following the initial screens, grit was removed from the wastewater either by centrifugal force or by screening. Following grit removal, wastewater was pumped into primary sedimentation tanks where fine solids and silts were allowed to settle out. After the primary sedimentation, the wastewater was directed to aeration basins where enhanced biological decay of dissolved and suspended organic materials occurred. Secondary sedimentation tanks were used, following the aeration tanks, to allow any remaining solids to settle out or precipitate. Following secondary sedimentation, the treated wastewater was chlorinated and discharged by permit to either the Delaware River or Frankford Creek.

Prior to 1961, sludge generated from the primary and secondary sedimentation tanks was disposed in Impoundments A, B, C, D and E, which were constructed in the 1950's. During that time period, screening and grit wastes were disposed in a landfill. Between 1961 and 1980, the sludge was disposed in the Atlantic Ocean, an accepted disposal practice at that time. Following 1980, the sludge was subject to more extensive treatment process which includes thickening, anaerobic digestion, dewatering and solidification / compaction into a digested cake. The cake byproduct is either disposed in a landfill or composted into agricultural nutrient products.

The most recent sampling of the sludge within the lagoons by RETTEW in 2000 indicates that the sludge contains high concentrations of metals and some pesticides, however, many of these compounds have not been detected in the underlying groundwater. Because of the time that has elapsed since the sludge has been deposited in the lagoons (1960's), many of these compound are likely stable and any minor concentrations in groundwater are a result of slow steady state leaching. Other than the use of chlorine for the chlorination of wastewater, no other chemicals were used at the NEWPCP that would be a probable source of CPECs.

9.4.2 Environmental Setting

As previously stated, the subject site has been extremely disturbed by historical activities and is located in a very industrialized section of Philadelphia just south of Exit 20 of Interstate Route 95, west of Frankford Creek and the Betsy Ross Bridge and north of the Delaware River. The site and its impoundments are located in a very flat area, of which they are completely self-contained with no effluent or surface water discharges to Frankford Creek or the Delaware River. The average elevation of the site is approximately 10 feet above mean sea level. Paved roadways form the borders around the perimeter of the site. The impoundments are predominantly comprised of historic sewage sludge that has been partially vegetated with successional vegetation that is common in disturbed areas. Some impoundments (Such as Impoundment A) support small areas of open water with sporadic communities of common reed *(Phragmites australis)*. However, no jurisdictional wetlands are present on the site. Any surface water existing on the site is due to the collection surface water from precipitation events. In fact, the depth to the shallow ground water table is between 3.5 to 15 feet below the impoundment areas.

The origination of any CPECs found in the groundwater or sludges on the site were the result of historical treatment of wastewater from residential, commercial and industrial sources that originated in Philadelphia and the storage of the resulting sludge in the lagoons. However, any metals in the sludge are unlikely to be bioavailable due to the alkaline composition of the sludge and high hardness values of the surface and ground water. As seen in Table 11, surface water collected from Impoundment A has a hardness value of 240.2 mg/L compared to Frankford Creek, which had an average hardness value of 81.2 mg/L. Of all of the analytical parameters that were tested in the surface water sample from Impoundment A, only manganese and DDE were detected at levels above the chronic protective criteria. As mentioned before, manganese naturally occurs in the environment. Although banned now, DDT was historically used as a pesticide for treatment of insects, of which DDE is a breakdown product. DDE is usually a breakdown product off DDT in soil, and in this case sludge. DDT was commonly sprayed to along waterways to kill insects such as mosquitoes. Since the sludge was deposited before the ban on DDT, DDE has since been formed as the by-product.

Other chemical influences on the NEWPCP site may have come from the large waste piles on the Franklin Smelter Waste Site situated just southwest of Impoundments B and D on the NEWPCP site. In fact, the U. S. Environmental Protection Agency had recently begun the covering or removing contaminated slag piles from Franklin Smelting and Refining along Castor Avenue in the last 3 years. The Franklin plant operated at the site from 1935 to 1997. The contaminants are in piles of slag from blast furnaces and in bags of dust captured by air pollution control equipment. The slag and soil on that site contains high concentrations of lead, cadmium and arsenic, and is investigating possible polychlorinated biphenyl (PCB) contamination at the site. Before 1998, and as recently as January 2000, large clouds of airborne dust could be observed blowing via prevailing winds onto the NEWPCP site. Such contaminants could have migrated onto the NEWPCP site and its sludge lagoons.

9.4.3 Relevant Information Regarding Habitats & Species of Concern

A search of the Department of Conservation and Natural Resources (DCNR), Pennsylvania Natural Diversity Inventory (PNDI) database revealed no plant species of special concern on or within the 2,500 feet of the project site. In addition, no rare, threatened or endangered species were noted during the field investigations in October and December 2000. See Appendix O for agency response letters.

9.5 Characteristics of Site Habitat and Wildlife Species

9.5.1 Physical & Habitat Features of Study Area

The site is surrounded by commercial and industrial facilities to the south, east and west. In particular, the former Franklin Smelter facility is located adjacent to the southwest property boundary. A large stockpile of smelter waste currently exists adjacent to the PWD site. The former coal fired PECO plant exists south of the site along the Delaware River. A waste transfer facility operated by Waste Management, Inc. exists approximately ½ mile southeast of the site. Land use to the north, is both commercial and residential.

Biological features of the site and the surrounding area were investigated to identify habitat covertypes and potential wildlife receptors. During this task, existing data, various maps, aerial photographs and pertinent literature were reviewed. Following this review, qualified ecologists conducted field surveys to characterize the site's ecosystems. However, due to the surrounding area being so urbanized and extremely developed with industrial, commercial and residential land uses, a nearby reference or background area with undisturbed habitats was not available for comparison. RETTEW's characterization describes the habitats present at the NEWPCP site, their associated vegetative composition and the wildlife likely to be found in these habitats. RETTEW also evaluated the habitats to determine if any habitats or species of concern existed.

9.5.2 Habitat Cover Types

The Lagoon Habitat Cover Type Map provided in Figure 12 shows the approximate location and extent of each habitat cover type within the sludge lagoons. A list of vegetation and comments regarding habitats is provided in Table 12. As seen in the Lagoon Habitat Covertype Map, there are six (6) primary habitats including Successional Woodlots, Scrub Wastelands, Phragmites Community, Open Water Area, Successional Grassy Wastelands, and Developed/Impervious Surfaces. Other variations of habitats on the NEWPCP Site include three additional covertypes that are combinations of the primary habitats. They include: Mix of Phragmites and Successional Grassy Wastelands, Mix of Successional Woodlots and Grassy Wastelands, and Mix of Phragmites and Successional Woodlots. These last three (3) habitats were not included in Table 12, however, they area comprised of the same combined vegetative species and provide habitat for wildlife species that would similarly be found in the primary habitats that are listed. The habitats that overlap each other are mapped as separate covertypes in the Lagoon Habitat Cover Type Map provided in Figure 12. Representative photographs of the primary habitats are also provided in Appendix P.

9.5.2.1 Successional Woodlots (SUWL)

The majority of this habitat cover type occurs in small bands along the edges of the impoundments, in patches within the interior or along the edge of the impoundments and around the open water areas. This cover type is present in smaller a amount than some of the other cover types but is present in some capacity within each of the 5 impoundment areas. The dominant species in the tree layer consist of *Salix nigra* (black willow), *Populus deltoides* (Eastern cottonwood), *Prunus serotina* (black cherry), *Ailanthus altissima* (tree-of-heaven), and *Morus rubra* (red mulberry). Also present in the tree layer, but not representing the dominant species, were *Robina pseudoacacia* (black locust) and *Populus tremula* (quaking aspen). The understory is comprised of *Rhus glabra* (smooth sumac) and some smaller black willow saplings. At the edges of the woodlots and in the openings in the canopy, *Rubus allegheniensis* (Allegheny blackberry), *Toxicodendron radicans* (poison ivy), *Ageratina altissima* (white snakeroot) and *Coronilla varia* (crown vetch) are the dominant species. This area does provide some areas for wildlife cover and nesting for ring-necked pheasants, songbirds and small mammals.

9.5.2.2 Scrub Wastelands (SCWL)

This cover type represents the smallest amount of land within the 5 impoundment areas. It is primarily land that has been previously disturbed and consists of fill material with scrubby shrubs and herbaceous pioneer species. The dominant species within the sapling layer in this cover type are *Paulownia tomentosa* (princess-tree), *Morus rubra*, and *Robina pseudoacacia*. Most of the species found within this habitat are common to disturbed or waste areas such as *Phytolacca dodecandra* (pokeweed), *Phragmites australis* (common reed), *Solidago canadensis* (Canada goldenrod), *Helianthus annuus* (common sunflower), *Erigeron annuus* (daisy fleabane), *Polygonum cuspidatum* (Japanese knotweed), and *Abutilon theophrasti* (velvetleaf). Other common species within this cover type include *Cuscuta americana* (American dodder), *Polygonum pensylvanicum* (Pennsylvania smartweed), *Datura stramonium* (jimsonweed), *Humulus lupulus* (common hops), *Ageratina altissima*, and *Rumex crispus* (curly dock). This habitat cover type also provides nesting or cover for songbirds and small mammals.

Table 11
Surface Water Laboratory Results
Philadelphia Water Department
Northeast Water Pollution Control Plant Ecological Screening
Philadelphia, Pennsylvania

PARAMETER	Impoundment A	PA Chapter 16 * (mg/L) Chronic	Frankford Creek (Upstream)	Frankford Creek (Downstream)	PA Chapter 16* (mg/L) Chronic
Total Metals					
Aluminum	0.2189	NA	0.1396	0.2745	NA
Arsenic	ND	0.15	ND	ND	0.15
Barium	0.056	NA	0.033	ND	NA
Beryllium	ND	NA	ND	ND	NA
Cadmium	ND	-	ND	ND	-
Chromium	ND	-	*0.0014*	*0.002*	0.0028
Cobalt	ND	NA	ND	ND	NA
Copper	*0.0055*	*0.019*	*0.0033*	ND	0.0078
Iron	1.276	1.5**	0.3843	0.5381	1.5**
Lead	*0.0043*	*0.0097*	*0.0018*	ND	0.0024
Manganese	$\boxed{2.597}$	1.0**	0.0504	0.0396	1.0**
Mercury	ND	0.00077	ND	ND	0.00077
Nickel	*0.0066*	*0.1095*	*0.001*	ND	0.0437
Selenium	ND	0.0046	ND	ND	0.0046
Thallium	ND	0.013	ND	ND	0.013
Vanadium	0.0015	NA	0.001	ND	NA
Zinc	*0.0272*	*0.2518*	*0.0201*	*0.0309*	0.1004
Dissolved Metals					
Aluminum	0.0358	NA	0.1272	0.2006	NA
Arsenic	ND	0.15	ND	ND	0.15
Barium	0.0367	NA	0.162	0.183	NA
Beryllium	ND	NA	ND	ND	NA
Cadmium	ND	-	ND	ND	-
Chromium	ND	-	*0.0016*	*0.0024*	0.0024
Cobalt	ND	NA	ND	ND	NA
Copper	*0.0019*	*0.01894*	*0.0023*	*0.0052*	0.0075
Iron	0.5475	1.5**	0.3101	0.4628	1.5**
Lead	*0.0011*	*0.0064*	*0.001*	$\boxed{0.0036}$	0.002
Manganese	$\boxed{1.642}$	1.0**	0.0424	0.0375	1.0**
Mercury	ND	0.00077	ND	ND	0.00077
Nickel	*0.004*	*0.1091*	*0.001*	*0.0018*	0.0436
Selenium	ND	0.0042	0.001	0.0015	0.0042
Thallium	ND	0.013	0.001	0.003	0.013
Vanadium	ND	NA	ND	ND	NA
Zinc	*0.0244*	*0.2482*	*0.0831*	$\boxed{0.1589}$	0.0989
Pesticides					
DDE (in ug/L)	$\boxed{0.065}$	0.001	$\boxed{0.019}$	$\boxed{0.019}$	0.001
Miscellaneous		PA Chapter 93**			PA Chapter 93**
Chloride	15.1	250	28.5	32.8	250
Flouride	0.18	2	0.133	0.188	2
Hardness	240.2	NA	82.32	79.99	NA
Nitrate	ND	10	1.201	1.148	10
Sulfate	5.5	250	24.3	28	250
Total Dissolved Solids	270	500	150	150	500

NOTE:
All values are listed in mg/L except where otherwise noted
*Chapter 16 PADEP's Rules & Regulations, January 2001 (unless otherwise noted as Chapter 93 via **)
**Chapter 93 PADEP's Rules & Regulations, January 2001
Screening Levels in *italics* are hardness dependent and are calculated for each metal.
ND: Non-detected or below laboratory detection limit
NA: Not Available
Values that are enclosed within a box exceed the PADEP continuous (chronic) criteria

Table 12
Characteristics of Ecological Habitat Cover Types
Philadelphia Water Department
Northeast Water Pollution Control Plant Ecological Screening
Philadelphia, Pennsylvania

Habitat Cover Type	Dominant Vegetation	Observed Wildlife	Comments/ Unique Characteristics
Successional Woodlots (SUWL)	*Populus deltoides* (Eastern cottonwood), *Salix nigra* (black willow), *Prunus serotina* (black cherry), *Ailanthus altissima* (tree-of-heaven), *Rhus glabra* (smooth sumac), *Toxicodendron radicans* (poison ivy), *Ageratina altissima* (white snakeroot), *Morus rubra* (red mulberry), *Rubus allegheniensis* (blackberry), *Populus tremula* (quaking aspen), *Robina pseudoacacia* (black locust) and *Coronilla varia* (crown vetch)	Cottontail rabbit, mourning dove, mice, American Kestrel, Songbirds,	Bird boxes along roadway next to some impoundments
Scrub Wastelands (SCWL)	*Paulownia tomentosa* (princess-tree), *Morus rubra, Cuscuta americana* (American dodder), *Phragmites australis, Solidago canadensis* (Canada goldenrod), *Helianthus annuus* (common sunflower), *Erigeron annuus (daisy fleabane), Polygonum pensylvanicum* (Pennsylvania smartweed), *Polygonum cuspidatum* (Japanese knotweed), *Phytolacca dodecandra* (pokeweed), *Datura stramonium* (jimsonweed), *Abutilon theophrasti* (velvetleaf), *Humulus lupulus* (common hops), *Ageratina altissima, Robina pseudoacacia* and *Rumex crispus* (curly dock)	Cottontail rabbit, ring-neck pheasants, American robin, mourning dove, mice, songbirds	Many successional, pioneer species that are commonly found in disturbed areas
Phragmites Community (PH)	*Phragmites australis* (common reed)	Songbirds, mourning doves, mice, American Crow	Dominated exclusively by *Phragmites* with only a few other scattered individuals
Open Water Area (OW)	No observed vegetation	Mallard, Canada geese	Average water depth = 2 feet
Successional Grassy Wastelands (SGWL)	*Erigeron annuus, Plantago lanceolata* (English plantain), *Meliotus officinalis* (yellow sweetclover), *Agrostis perennans* (upland bentgrass), *Setaria* sp. (foxtail grass), *Trifolium pratense* (red clover), *Cichorium intybus* (chicory), *Phragmites australis, Solidago canadensis, Helianthus annuus, Verbascum thapsus* (common mullein), *Taraxacum officinale* (common dandelion), *Solanum carolinense* (horse-nettle), *Verbascum blattaria* (moth mullein), *Cirsium arvense* (Canada thistle), *Ambrosia artemisiifolia* (ragweed), *Phytolacca dodecandra, Oenothera biennis* (common evening primrose), *Solidago stricta* (wandlike goldenrod), *Cirsium vulgare* (bull thistle), *Daucus carota* (Queen Anne's lace), *Lathyrus japonicus* (beach pea), *Apocynum androsaemifolium* (spreading dogbane) and *Asclepias* sp. (milkweed)	Cottontail rabbit, American kestrel, mice American Crow and songbirds	Large diversity of species; all herbaceous species
Developed/ Impervious Surfaces (DI)	No observed vegetation	Transient individuals	Parking lots, roads, railroad tracks, buildings

Table 13
Potential Ecological Receptors
Philadelphia Water Department
Northeast Water Pollution Control Plant Ecological Screening
Philadelphia, Pennsylvania

Common Name	Scientific Name	Relative Abundance	Habitat Cover Types					
			SUWL	SCWL	PH	OW	SGWL	DI
Deer Mouse	*Peromyscus maniculatus*	Common	X	X			X	
Eastern cottontail rabbit	*Sylvilagus floridanus*	Common	X	X			X	
House finch	*Carpodacus mexicanus*	Common	X	X			X	
Mourning dove	*Zenaida macroura*	Common	X	X	X		X	
Song sparrow	*Melospiza melodia*	Common	X	X	X			
Blue jay	*Cyanociita cristata*	Common	X	X	X			
American kestrel	*Falco sparverius*	Common	X				X	
Canada goose	*Branta canadensis*	Common				X	X	
Ring-necked pheasant	*Phasianus colchicus*	Common		X			X	
Mallard	*Anas platyrhynchos*	Common				X		
American robin	*Turdus migratoria*	Common	X				X	
American crow	*Corvus brachyrhynchos*	Common	X		X		X	

NOTES:
SUWL=Successional Woodlot
SCWL= Scrub Wastelands
PH= Phragmites
OW= Open Water
SGWL= Successional Grassy Wastelands
DI=Developed/Impervious Areas

9.5.2.3 Phragmites Community (PH)

This cover type represents a large portion of several of the impoundment areas. Within these areas, *Phragmites australis* is the dominant species with little to no other vegetative species present. This aggressive, invasive species has taken over the majority of Impoundments B and D and much of the surroundings of the open water areas in Impoundment A and former Impoundment E. This habitat cover type provides some cover for small mammals and songbirds, with no food value. This habitat covertype does not harbor any jurisdictional wetlands. *Phragmites* are known to rapidly colonize disturbed areas through rhizomes. Even though this plant has a wetland indicator status of Facultative wetland (FAW), it also often occurs in disturbed uplands or in waste materials that are not wetlands. This community type often occurs with the Grassy Wasteland and Successional Woodlot habitat covertypes to form a new habitat complex as seen on the covertype map. The Phragmites Community areas provides no wetland functions or does it support wetland hydrology. Therefore, the Phragmites Community areas on the site are not considered as a habitat of concern.

9.5.2.4 Open Water Areas (OW)

Within the Open Water Areas, there was little or no vegetation observed. The predominant habitat cover types surrounding the Open Water Areas are the Phragmites Community, Successional Woodlot and Successional Grassy Wasteland Communities. Open Water Areas are occasionally utilized by mallard ducks and Canada geese. As previously stated, these open water areas are not jurisdictional wetlands, as it consists of accumulated surface water on impounded sewage sludge materials. In fact, any past or future modifications to these areas would come under the purview of PADEP's waver of permit requirements found in Chapter 105.12 a(5). Furthermore, these areas provide no identifiable wetland functions, as they do not provide any food for wildlife and the geese and mallards that have been observed there never have been seen using the area for nesting or rearing purposes. Therefore, the open water areas on the site are not considered as a habitat of concern. Water from such Open Water Areas is pumped to the wastewater treatment plant for treatment before becoming part of the NEWPCP effluent.

9.5.2.5 Successional Grassy Wastelands (SGWL)

This cover type represents the largest amount of area within the impoundment areas. It occurs throughout most of the lagoons and on the outside edges of all the areas. This habitat cover type consists entirely of herbaceous species with no trees or shrubs noted within the cover type. It consists of species common to disturbed and waste areas as well as common herbaceous species found throughout the region. The dominant species include *Erigeron annuus, Plantago lanceolata* (English plantain), *Meliotus officinalis* (yellow sweetclover), *Agrostis perennans* (upland bentgrass), *Setaria* sp. (foxtail grass), *Trifolium pratense* (red clover), *Cichorium intybus* (chicory), *Phragmites australis, Solidago candensis, Helianthus annuus, Verbascum thapsus* (common mullein), *Taraxacum officinale* (common dandelion), *Solanum carolinense* (horse-nettle), *Verbascum blattaria* (moth mullein), *Cirsium arvense* (Canada thistle), *Ambrosia artemisiifolia* (common ragweed), *Phytolacca dodecandra, Oenothera biennis* (common evening primrose), *Solidago stricta* (wand-like goldenrod), *Cirsium vulgare* (bull thistle), *Daucus carota* (Queen Anne's lace), *Lathyrus japonicus* (beach pea), *Apocynum androsaemifolium* (spreading dogbane) and *Asclepias* sp. (milkweed). This area provides some cover and nesting areas for wildlife with limited food value for wildlife. This covertype is mixed with the Phragmites Community and the Successional Woodlot habitats on other sections of the NEWPCP to form new habitat complexes as seen on the Habitat Covertype Map provided in Figure 12.

9.5.2.6 Developed/Impervious Surfaces (DI)

Large paved or gravel areas that are used for parking lots, buildings, railroad tracks, and roads comprise this area. This cover type is not considered habitat because it is predominantly covered by impervious surfaces, buildings, or treatment facilities and does not support any vegetation or wildlife species. However, it is possible for transient mammal species to pass through these areas. In addition, some bird species may nest in the buildings or on rooftops. The entire northwestern half of the NEWPCP site can be considered as being comprised of this covertype. In the southeastern half of the site, this covertype comprises the interstitial spaces between the impoundments.

9.5.3 Qualitative Evaluation for the Presence of Species & Habitats of Concern

Such habitats of concern may include: typical wetlands with identifiable functions and values; breeding areas for species of concern; migratory stopover areas for species of concern (e.g., migrant shorebirds, raptors or passerines); wintering areas for species of concern; habitat for state endangered plant and animal species; federal, state and local parks and wilderness areas; areas designated as wild, scenic or recreational; and, areas otherwise designated as critical or of concern by the natural resource agencies. Regarding Habitats of Concern, there are habitats on the NEWPCP site that are jurisdictional wetlands that provide any functions and values. Likewise, the habitats do not provide any value for or harbor any species of concern and do not comprise any section of a park, wilderness, scenic or recreational area. A list of wildlife species that are known to occur on the site are provided in Table 13.

9.5.3.1 Terrestrial Wildlife Species

As seen in Table 3, some wildlife species were observed within different habitat cover types in the impoundment areas during the October 2000 field investigation. Because the lagoons are surrounded by fencing, the most dominant type of wildlife observed were bird species. Those observed included the house finch, mourning dove, song sparrow, blue jay, American kestrel, American robin, American crow, mallard, Canada goose and ring-necked pheasant. No large mammals or indirect observations of large mammals such as footprints or scat were noted. The small mammal species that were observed included the deer mouse and Eastern cottontail rabbit.

9.5.3.2 Aquatic Wildlife Species

There were no streams or watercourses on the site and only two of the lagoons had any notable open water areas. These areas, however, may periodically dry up and as such, no amphibians, reptiles or fish were observed during the investigations or are known to exist on the site. Because of being comprised of wastewater sludges, benthic macroinvertebrate species are not likely to be present within the lagoons.

9.5.4 Evaluation for Potential Signs of Ecosystem Impacts or Stressors

As required in the Ecological Screening process outlined in the Technical Guidance Manual for Pennsylvania's Land Recycling Program, RETTEW evaluated the habitat communities, its vegetation and observed wildlife during the site investigation for signs of stress that might be due to the presence of CPECs. Accordingly, RETTEW did not find anything that would outwardly suggest that there are any problems or threats posed to the vegetation or the wildlife that occurs on the NEWPCP site during the site reconnaissance. Specifically, RETTEW evaluated the entities of the site's ecosystems and came to the conclusions listed below.

1. There were no signs of stressed, dead or discolored vegetation in any of the habitats covertypes that supported vegetative growth and wildlife.

2. There are no watercourses on the NEWPCP site, and no discharges or runoff generated from the impoundments that would directly enter Frankford Creek. Likewise, no discolored soil, sediment or water was observed during the investigation.

3. No seeps or discharges were observed emanating from the ground or into Frankford Creek.

4. Due to the area surrounding the NEWPCP site being so urbanized and extremely developed with industrial, commercial and residential land uses, a nearby reference or background area with undisturbed habitats was not available for comparison to determine any community composition differences. The pioneer and successional vegetation that was observed on the site reflects the vegetation that would be expected to be found in disturbed urban areas and waste areas.

5. There was not an absence of any particular type of biota that would be expected to be found in an area that was disturbed such as the subject site and the surrounding landscape and land use. The wildlife and vegetative species that were observed on the site are common to highly developed areas. Because there are no streams that flow through the site, no benthic macroinvertebrates were sampled.

6. *Phragmites* was very prevalent in the habitat covertype communities that occurred on the site. However, it should be known that this species, also known as common reed, is prevalent throughout disturbed and undisturbed lands in and around the Philadelphia area (in uplands and wetlands). The vast majority of the site was colonized with pioneer or successional species that are commonly found in highly developed or industrial landscapes. Therefore, one could not use the presence of non-native or exotic species as an indicator of an ecosystem impact in this section of Pennsylvania. It should be noted that some native vegetative species that occur in suburban Pennsylvania habitats were also present among the pioneer species found in the different habitat covertypes.

7. RETTEW did not observe or expects the presence of any deformed organisms on the NEWPCP site.

8. There were no habitats of concern existing on or adjacent to the NEWPCP site and likewise, the compositions of the habitat covertypes are not conducive to supporting species of concern since the site's habitats do not meet their unique requirements. In general, the metals found in the sludge waste material and surface water of the open water areas are unlikely to be bioavailable due to the alkaline sludges and hard water conditions.

9.6 Summary of Suspected Areas of Sludge Concentration

Suspected areas of sludge concentration has been illustrated by the boundaries of the sludge impoundments as shown in the Habitat Covertype Map provided as Figure 12. Again, no species of concern were identified by the natural resource and protection agencies as being present in or within 2,500 feet of the site boundary and no habitats of concern are present on the site. Thus, since no reference or background site was available and no habitats of concern or species of concern are located on the NEWPCP site, no comparison in species diversities were made or were necessary. The lagoons are vegetated to a greater extent than the surrounding urban landscape however, the vegetation is predominantly representative of pioneer species that are normally associated with disturbed sites or found growing on fill materials.

In order to facilitate the plant expansion in the late 1970's, the physical boundaries of the impoundments were modified, and the sludge was relocated. Lagoon E was completely removed in 1978. In addition, 138,570 cubic yards (yd^3) of sludge was removed from Impoundment A and 58,650 yd^3 were removed from Impoundment C (Black & Veatch, 1990).

Estimates of the current sludge volume remaining in the impoundments were calculated and reported by Black and Veatch (1990). The estimates were calculated from original design(s) drawings and topographic maps of the impoundment facility. Black and Veatch estimated the following sludge volumes: Impoundment A – 129,766 yd^3; Impoundment B – 209,590 yd^3; Impoundment C – 106,165 yd^3, and; Impoundment D – 138,683 yd^3.

9.6.1 Impoundment A

Impoundment A is located along Lewis Street on the northeast side of the railroad tracks. This lagoon contains portions of Open Water, Phragmites Communities, Successional Woodlots and Successional Grassy Wastelands. The largest area of Open Water on the site was contained in this impoundment in the northeastern portion of the lagoon. In this area Canada geese and ring-necked pheasants were observed. Also noted within this area were songbirds and cottontail rabbits. Refer to the Lagoon Habitat Cover Type Map for the approximate locations of each habitat cover type within the impoundment areas in Figure 12.

9.6.2 Impoundment B

Impoundment B is located west of Impoundment A parallel to the railroad tracks and just east of Castor Avenue. The largest habitat covertype area within this impoundment is the Phragmites Community. This covertype dominates the entire western half of the impoundment and the majority of the middle section of the eastern half of the lagoon. Also present within the impoundment are small sections of Successional Woodlot and Scrub Wasteland and a fairly large area of Successional Grassy Wasteland, which encloses the entire eastern boundary of the lagoon. There were some trees, *Populus tremula*, in the upland areas at the edge of the Successional Grassy Wasteland area, which was dominated by *Asclepias* sp. and *Apocynum androsaemifolium*. Within this area, mourning doves and house finches were observed.

9.6.3 Impoundment C

Impoundment C is located at the intersection of Lewis Street and Delaware Avenue south of the railroad tracks in the southeastern corner of the NEWPCP site. At the west end of this impoundment are the chlorine contact tanks, chlorine building and effluent water pumping station. Impoundment C consists of a mixture of Successional Grassy Wastelands, Successional Woodlots, Phragmites Communities and a small area of Scrub Wasteland. This impoundment represented the greatest diversity of species, containing 29 herbaceous species, 2 vines and 7 woody species. There were bird boxes noted along Delaware Avenue within this impoundment and the wildlife species observed included mice, cottontail rabbits, and finches.

9.6.4 Impoundment D

Impoundment D is located west of Impoundment C along Delaware Avenue south of the railroad tracks in the southwestern corner of the site. This impoundment was dominated by a large, Phragmites Community. In the center of the community is a cross-shaped Successional Woodlot area and the edges of the lagoon consisted predominantly of a Successional Grassy Wasteland. There was also a small strip of Scrub Wasteland in the northeast corner of the impoundment. While dominated by *Phragmites australis*, there are also some eastern cottonwood and black willow saplings (*Populus deltoides* and *Salix nigra) present.* Wildlife species observed in this area included mourning doves, various songbirds, blue jays and American kestrels.

9.6.5 Former Impoundment E

Former Impoundment E is located north of Impoundment A along Lewis Street. It is located south of the primary sedimentation tanks. This impoundment was removed in 1978. Currently, the area consists of a mixture of Successional Woodlots, Successional Grassy Wastelands, Phragmites Communities and a small Open Water area. The rectangular-shaped area to the immediate southwest of Impoundment E (just south of the equipment storage and service buildings) consists entirely of a Successional Grassy Wasteland with various meadow species and *Populus tremula*. The Successional Woodlot covertype patches scattered within the former Impoundment E consists primarily of *Populus tremula, Robina pseudoacacia* and *Coronilla varia*. Wildlife species observed in this area included ring-necked pheasants, songbirds and mourning doves.

9.7 Evaluation of Threatened, Endangered and Species of Special Concern

A request for a threatened and endangered species review was sent to the PA Game Commission (PGC), PA Fish and Boat Commission (PAFBC), US Fish and Wildlife Service (USFWS) and DCNR for a search of the PNDI database. The requests specified a 2,500-foot radius outside the site's boundary as the search area for potential threatened or endangered species or designated critical habitats under the jurisdiction of these agencies. The PNDI, USFWS and PGC responses indicated the absence of threatened or endangered species and their critical habitat within the site and the requested 2,500-foot radius search area. The PAFBC indicated the presence of *Acipenser brevirostrum* (shortnose sturgeon), *Acipenser oxyrhynchus* (Atlantic sturgeon), *Pseudemys rubriventris* (red-bellied turtle) and *Rana utricularia* (Coastal Plain leopard frog) as Pennsylvania threatened and endangered species under their jurisdiction known to exist in the vicinity of the site. However, their letter also indicated that the known presence of all of these species is located outside the specified 2,500-foot radius of the site. They also mentioned that the red-bellied turtle and Coastal Plain leopard frog could have the potential to occur on a site if the proper habitat conditions existed (see attached response letters in Appendix O).

Pseudemys rubriventris (red-bellied turtle) is a large, aquatic turtle known to inhabit relatively large, deep streams, rivers, ponds, lakes and marshes with permanent water and ample basking sites. They also prefer dense, aquatic vegetation. The red-bellied turtle's range is limited today, but it was once known to inhabit the lower Delaware River, the lower Susquehanna River and a portion of the Potomac River Basin. Today it is found primarily in the lower Delaware River Drainage. It is listed as a Pennsylvania Threatened species. *Rana utricularia* (Coastal Plain leopard frog) is a small leopard frog species of wetlands, ponds, and moist meadows of southeast Pennsylvania. It resides in fresh or brackish water and is now only sporadically seen within its original range in the extreme southeastern area of Pennsylvania. It is known to venture into upland, moist meadow areas in search of food, sometimes at great distances from wetlands. It is listed as a Pennsylvania Endangered species.

It should be noted that the impoundment areas within the subject site are predominantly comprised of historic sewage sludge that has been partially vegetated with successional shrubby and herbaceous vegetation that is common in disturbed areas. As previously mentioned, the site has been extremely disturbed by historical activities and is located in a very industrialized section of Philadelphia. Other sections of the impoundments support areas of open water with sporadic communities of *Phragmites australis* (common reed). However, no watercourses, large, deep waterbodies or jurisdictional wetlands are present on the site. None of the characteristics of the required and preferred habitat of the red-bellied turtle or Coastal Plain leopard frog are present on the site.

Although both species are known to migrate into upland areas in search of food, the project site, as described above, does not offer suitable areas for either species. In addition, the area is within the City of Philadelphia and completely surrounded by fencing, parking lots, roads, railroads and buildings and would not be accessible or desirable for either species. The open water areas are not permanently flooded and consist predominantly of sewage sludge and pioneer vegetation, not the aquatic vegetation preferred by these species. Neither species were observed during the site investigations and as previously mentioned no other amphibian, reptile or fish species were observed on the site. Therefore, based on this information and the natural resource agencies' information, no species of concern are located on or within 2,500 feet of the NEWPCP site.

9.8 Evaluation of Habitats of Concern on the Site

RETTEW evaluated the land use, habitat communities, vegetative composition and observed wildlife during the site investigation found on the NEWPCP site to determine if the ecosystems meet any of the criteria to be a habitat of concern as required in the Ecological Screening process outlined in the Technical Guidance Manual. Accordingly, RETTEW determined that no habitats of concern occur on the NEWPCP site based on the criteria provide in the manual. Specifically, RETTEW evaluated the entities of the site's ecosystems and surrounding land use and came to the conclusions listed below for each criteria to demonstrate why <u>there are no</u> habitats of concern that exist on the NEWPCP Site.

- Does the site support typical wetlands with identifiable functions and values?: **NO**

As previously stated, the Open Water Areas are not jurisdictional wetlands, as they consist of accumulated surface water on impounded sewage sludge materials. Likewise, no other habitat covertypes on the site, including the Phragmites Community, are jurisdictional wetlands. According to US Army Corps of Engineers' (US ACOE) three parameter approach to wetland identification and delineation, dominant wetland vegetation, hydric (wet) soils and wetland hydrology must all be present under normal circumstances in order to designate an area as a wetland. None of the habitats on the NEWPCP site meet all three parameters. Any past or future modifications to the Open Water Areas (which are man made impoundments for the storage of sewage sludge) would come under the purview of PADEP's waiver of permit requirements found in Chapter 105.12 a(5). Furthermore, these areas provide no identifiable wetland functions, as they do not provide any food for wildlife and the geese and mallards that have been observed there never have been seen using the area for nesting or rearing or feeding purposes. There are no fish or amphibians in the Open Water Areas, and no food chain production or spawning areas in this habitat covertype. Therefore, the open water areas and all other habitat covertypes on the NEWPCP site <u>are not</u> considered to be habitats of concern because they are not wetlands.

- Does the site provide breeding areas for species of concern?: **NO**

As already stated, there are no species of concern on or within 2,500 feet of the site. Due to the highly developed nature of the site and surrounding urban landscape and the fact that most of the habitats occur within sludge impoundments, the habitats do not provide any breeding areas for species of concern.

- Does the site provide migratory stopovers for species of concern?: **NO**

As per the USFWS, PGC, and PNDI response letters provided in Appendix O, no migratory bird species of concern are found on or within 2,500 feet of the site. Due to the highly developed nature of the site and surrounding urban landscape, the limited habitat that occurs within sludge impoundments lacks the vegetative diversity, wetland characteristics, resting areas or tall tree snags that provide adequate habitat as stopover areas for migratory species of concern.

- Does the site provide wintering areas for species of concern?: **NO**

As per the USFWS, PGC, and PNDI response letters provided in Appendix O, no migratory bird species of concern are found on or within 2,500 feet of the site boundary. While the Delaware Bay does provide wintering areas for some waterfowl such as some species of geese and ducks, none are species of concern. Therefore, the habitat found on the NEWPCP site does not provided any wintering areas for species of concern.

- Does the site provide habitat for state endangered plant and animal species?: **NO**

As already stated, there are no species of concern on or within 2,500 feet of the site. The nature of the habitat on the NEWPCP site can not and does not provide the necessary habitat characteristics required to support state endangered plant and animal species.

- Is the site located on or near any Federal, State & local parks and wilderness areas?: **NO**

The NEWPCP site is not located near any Federal, state or local parks or wilderness areas. Situated in a very developed section of Philadelphia, the entire area surrounding the site is very industrialized and is not conducive to a park setting or wilderness area.

- Is the site located on or near areas designated as wild, scenic, recreational OR is it listed as an area otherwise designated by natural resource and protection agencies as being an area of critical habitat or of concern?: **NO**

The NEWPCP site is not located near any areas designated as wild, scenic, or recreational. Situated in a very developed section of Philadelphia, the entire area surrounding the site is very industrialized and is not wild, scenic or provide any recreational values or opportunities. Likewise, the site and its surrounding land use has not been identified by the PGC, PAFBC and DCNR as an area that is critical habitat or habitat of concern.

Due to the fact that RETTEW's Detailed Onsite Evaluation has determined that no species or habitats of concern exist onsite in its current or intended use, no endangered or threatened species exist on or within a 2,500 feet radius of the border of the NEWPCP Site, and no exceptional value wetland occur on site, the screening process moves to Step 9 (Final Report: No Further Ecological Evaluation Required).

9.9 Final Report - No Further Ecological Evaluation Required (Step 9)

Since no species or habitats of concern were identified during the Detailed Onsite Evaluation (Step 6) RETTEW documented the findings of all the completed steps (Steps 1 through 6) of the ecological screening process as a written report provided above. RETTEW proceeded through Steps 1 through 5 to reach the conclusion in Step 6 that substantial ecological impact does not exist based on the following fact as documented:

No species or habitats of concern, threatened or endangered species or exceptional value wetlands were identified on the NEWPCP site during the Detailed Onsite Evaluation.

Therefore, in accordance with the Technical Guidance Manual, no further ecological evaluation is warranted for the site. RETTEW is submitting the above documented information from Ecological Screening Steps 1 through 6 as the Final Report to meet the requirements of Step 9.

10.0 SITE CONCEPTUAL MODEL

The USGS has modeled aquifer characteristics of the region that include the vicinity of the NEWPCP. These studies include Water Resources Investigations Report 86-4055, Simulation of Groundwater Flow in the Lower Sand Unit of the Potomac-Raritan-Magothy Aquifer System, Philadelphia, Pennsylvania (1988) and Open-File Report 87-528, Groundwater Flow in the New Jersey Coastal Plain (Martin, 1990). According to Sloto (1988), portions of the

Lower Sand Aquifer of the wedge-shaped, southeast dipping PRM aquifer system extend beneath the site and crop out along the Fall Line. The site is underlain by horizontal beds of the informally-named "Trenton Gravel" that rest unconformably over the Lower Sand Aquifer, whereas Martin (1990) describes the area of the site as underlain by the Middle Sand Aquifer of the PRM, with no mention of the Trenton Gravel in the region. Martin goes on to describe the confining clay units of the Lower Sand Aquifer and Middle Sand Aquifer possibly merging as one unit in the region, with the Lower Sand Aquifer absent in the area and the site underlain solely by the Middle Sand Aquifer of the PRM.

The Pennsylvania State Geologic Survey considers the area to be underlain by the Lower Sand Aquifer of the PRM, which in turn is blanketed by the Trenton Gravel (Sloto, 1988, after Greenman, 1961). The USGS and Pennsylvania Geologic Survey concur that basement rock, comprised of the Wissahickon Schist, is present in the area of the site at a depth of 60 to 75 feet below ground surface. According to a site investigation conducted in 1989 entitled Conceptual Alternatives for Sludge Lagoon Closure (Black & Veatch, 1990), site drilling conducted by Woodward-Gardner Associates, Inc. in 1971 revealed intact bedrock between 71 and 77 feet below ground surface.

Site drilling (Black & Veatch, 1989; RETTEW, 1994 and 2000) has confirmed the presence of a really extensive fill or fine sand, underlain in descending order, by clay and/or silt confining beds, highly permeable sands and gravels, saprolitic schist, and competent schist. Portions of the clay beds contain roots and appear to be remnants of former swamp deposits, typically found in the Trenton Gravel. Prior to 1917, the area of the impoundments was tidal marshes according to Black & Veatch (1990). Other beds of clay or silt, present at approximately the same stratigraphic position as the tidal marsh deposits, contain no root material and may represent a confining unit of the PRM. Drilling also revealed an extensive fine- to medium- grained sand or gravelly sand unit beneath the confining beds. This is prevalent throughout the site and grades into a distinctive gravel lens in the eastern corner of the site, in the area of Impoundments A and C.

A groundwater monitoring network was installed by RETTEW in 1994 and 2000 and included a series of well clusters comprised of shallow and deep wells. The shallow wells were screened in the uppermost water-bearing zone consisting of sandy fill or fine sand and generally did not extend more than 20 feet below ground surface. The deep wells were constructed to case off the fill/uppermost sand and the confining clay/silt unit and were screened in the lower sand and gravel lenses. Pressure transducers, capable of continuous data logging, also were placed in eleven wells to record groundwater levels. The data loggers, and manual water level measurements collected during quarterly sampling events, verified that deep groundwater was influenced by earth tides through the Delaware River.

Previous investigators who have done work in the region have had differing observations and points of view with regard to stratigraphy in the vicinity of the NEWPCP. For this reason, three possible conceptual models which describe the general hydrogeologic setting underlying the NEWPCP have been generated. RETTEW considers the third model, Conceptual Model Scenario #3, to best represent site conditions.

10.1 Conceptual Model Scenario #1

The first possible model closely follows the site concept set forth by Black & Veatch (1990). The general conditions of this model define the clay-silt unit as localized beds of the Trenton Gravel. The overlying fill/sand unit is recharged locally by precipitation and interconnection with the Delaware River. Discontinuities within the clay-silt and leakance allow the fill-sand unit to recharge the lower sand-gravel. The majority of the sediments appear to be Recent or Quaternary alluvium. Some portions of these units may consist of Cretaceous sediments of the Lower Sand Aquifer of the PRM.

RETTEW's investigations revealed many of the same drilling results as Black & Veatch (1990), but RETTEW differs from Black & Veatch regarding the tidal influence the Delaware River has on NEWPCP. Black & Veatch (1990) reports no significant tidal influence observed at the site, whereas RETTEW has measured considerable water level fluctuations that correlate with tidal changes in the river. The Black & Veatch investigation does not fully coincide with USGS studies which subscribe to the abundance of Cretaceous sediments underlying the site.

10.2 Conceptual Model Scenario #2

The second possible model incorporates site drilling data with the scenario described in USGS Report 87-528 (Martin, 1990). Martin considers the Lower Aquifer of the PRM to be absent in the subject area and depicts the NEWPCP as underlain by the Middle Aquifer of the PRM. This report also considers the confining clay unit between the Lower and Middle Aquifers to pinch out under, or in close proximity to the Delaware River and not reach as far northwest as the NEWPCP. This model does not consider the presence of Recent or Quaternary sediments, such as the Trenton Gravel.

The presence of extensive sand-gravel units, which overlie weathered basement rock beneath the site, lends additional credibility to this model. However, site drilling has revealed extensive clay-silt beds approximately eight to ten feet thick overlying the sand-gravel, and this conceptual model fails to explain the effects of this confining unit on the groundwater regime.

10.3 Conceptual Model Scenario #3 (Best Represents Site Conditions)

The third potential conceptual model is a hybrid of the previous two and is largely based on site drilling results and several concepts described by Sloto (1988) and Navoy and Carleton (1995). Sloto describes the Trenton Gravel cropping out in a four-mile wide band southeast of the Fall Line and blanketing the NEWPCP site. According to this report, typical Trenton Gravel sediments are terrace and valley fill deposits up to 50 feet thick and consist of beds of silt-clay, sand, and gravel. Holocene sediments consisting of silt and fine sand underlie the channel and tidal flats of the Delaware River and are probably no more than ten-feet thick in the section of the river closest to the site. These Tertiary and Quaternary age sediments unconformably overlie and completely cover the Cretaceous sediments of the PRM. Underlying the Tertiary and Quaternary age sediments at the NEWPCP are silty clays of the Lower Clay Unit of the PRM and sands and gravels of the Lower Sand Unit of the PRM.

As the silty clay deposits at the NEWPCP vary in thickness, so do organic content and root content throughout the site. It appears that the silty clay unit underlying the NEWPCP consists of discrete lenses of the Tertiary and Quaternary age tidal flat sediments unconformably cut into the underlying Lower Clay Unit of the PRM. Based on hydraulic response to tides in the Lower Sand Unit at the NEWPCP, the confining bed system comprised of the Tertiary and Quaternary age tidal flat sediments and the Lower Clay Unit are likely continuous throughout the NEWPCP and outcrop within the Delaware River.

The Lower Sand Unit and Lower Clay Unit of the PRM are located beneath the Delaware River and separated by Holocene riverbed deposits. In some places, a ship channel has been dredged into or through the Lower Clay Unit and into the sand and gravel of the Lower Sand Unit (Sloto, 1988 after U.S. Army Corps of Engineers, 1975). Where the Lower Clay Unit has been removed by dredging, the Lower Sand Aquifer of the PRM and the Delaware River are in direct contact. To simulate groundwater flow, Sloto (1988) assigned a constant head of zero (mean sea level) to simulate the direct hydraulic connection between the river and the Lower Sand Unit. A reach of Delaware River in the vicinity of the NEWPCP, has been dredged and the Lower Sand Unit is in direct contact with the river (Sloto, 1988; Navoy and Carleton, 1995).

A hydrogeologic cross-section of the sediments underlying the NEWPCP is provided in Figure 13. The stratigraphic cross section B-B' and F^1-F^2 provided by Navoy and Carleton (1995) exist as Figures 14 and 15, respectively. Cross sections B-B' and F^1-F^2 intersect very close to the geographic location of the site.

11.0 FATE AND TRANSPORT ANALYSIS METHODOLOGY

A Fate and Transport Analysis (FTA) was completed to determine if the constituents detected in groundwater underlying the NEWPCP at low concentrations would potentially impact Public Water Supply (PWS) wells in New Jersey. As indicated earlier in this report, the following conditions exist:

1. The Lower Sand Unit of the PRM in the vicinity of the NEWPCP ranges in thickness underlying the Delaware River from approximately 40 feet to 60 feet.

2. Low levels of dissolved metals and organic compounds were detected in groundwater of the Lower Sand Unit underlying the NEWPCP.
3. New Jersey PWS wells located within 2 miles from the NEWPCP produced a total of approximately 29.5 million gallons per day in 1988 from the Lower Sand Unit.
4. The Delaware River is approximately 2000 feet wide and 48 feet deep.
5. The Delaware River has been actively dredged by the U.S. Army Corp of Engineers to keep shipping lanes in the river open. The dredging activities have removed portions of the confining Lower Clay Unit of the PRM, causing the Lower Sand Unit to be in direct hydraulic connection with the river.
6. Direct hydraulic connection between the Delaware River and the Lower Sand Unit has been verified based on field data collected at the NEWPCP by RETTEW. Also, the hydraulic connection has been published by previous investigators.

Based on the above listed conditions, it may be possible that the pumping stress produced by New Jersey PWS wells within the Lower Sand Unit could cause groundwater in the vicinity of the NEWPCP to migrate southeast thought the Lower Sand Unit, under the Delaware River, towards the New Jersey PWS wells. However, this scenario is unlikely due to the size and depth of the Delaware River, as well as the fact that the river is in direct hydraulic connection with the Lower Sand Unit. The purpose of this FTA is to develop and perform a quantitative analysis to answer the following question: "Will groundwater within the Lower Sand Unit at the NEWPCP migrate under the Delaware River to pumping centers in New Jersey?"

11.1 Simulation of Groundwater Flow

Groundwater flow was simulated using the widely used and validated Modular Three-Dimensional Finite-Difference Groundwater Flow Model (MODFLOW). MODFLOW was developed by the United States Geological Survey (USGS) (McDonald and Harbaugh, 1988). MODFLOW can be used to represent the effects of wells, rivers, streams, drains, horizontal flow barriers, evapotranspiration, and recharge on flow systems with heterogeneous aquifer properties and complex boundary conditions to simulate groundwater flow. The preprocessor software, Groundwater Vistas, was utilized to create input files for MODFLOW and to view output results. Groundwater Vistas was written by Environmental Simulations International of Reston, Virginia. Steady state conditions were simulated using MODFLOW.

Steps for groundwater model development:
- Develop conceptual model;
- Build model grid and utilize appropriate horizontal and vertical discretization;
- Input model boundary conditions;
- Input reasonable hydrogeologic and recharge parameters;
- Run model using initial conditions and debug model to eliminate errors of MODFLOW input files;
- View output;
- Calibrate model using field data collected from study area to obtain reasonable match between actual and simulated heads;
- Perform sensitivity analysis;
- Perform hypothesis testing.

Construction of the flow model was completed by first developing a conceptual model for the site and surrounding area. This includes the determination of an appropriate land area that the model should encompass. The conceptual model is a description of the aquifer extent, boundary conditions, hydrogeologic properties and all sources and sinks for groundwater. A numerical representation of the conceptual model was developed and was calibrated to obtain a reasonable match to field data. Following calibration, a sensitivity analysis was conducted to determine the model's sensitivity to variation of important input parameters to judge the accuracy of the final model results. Finally, the model was used evaluate the fate of groundwater that flows beneath the NEWPCP site.

The modeling effort was reviewed by McDonald Morrissey Associates, Inc. of Hopkinton, New Hampshire. The review process was involved during the conceptualization, development, calibration, and simulation of the flow model. The simulation results and reporting were also included in the review process.

11.2 Conceptual Model

The conceptual model used was previously discussed in Section 10.3. This model was selected based on a review of published literature of the area and actual conditions observed at the NEWPCP.

11.3 Model Discretization

The model is a three dimensional representation of groundwater flow near the NEWPCP, the Delaware River, and major New Jersey pumping centers in the vicinity of the NEWPCP. The land area included as the "study area" is provided as a figure in Appendix Q. The model grid consists of 100 rows, 100 columns, and 5 layers (10,000 nodes per layer). The horizontal grid has a uniform spacing of 300 feet and variable spacing in the vertical. The model grid is shown as a figure in Appendix Q. The model grid was oriented approximately parallel to the bedrock Fall Line in Philadelphia and the reach of the Delaware River in the vicinity of the NEWPCP.

Vertical discretization was based on the conceptual model developed for the site (Section 10.3) which includes a stratigraphic interpretation as presented by Navoy and Carleton (1995). Their interpretation follows closely the stratigraphic scenario developed by RETTEW during this investigation. Stratigraphic data provided in the 1995 Navoy and Carleton publication was input and independently contoured for this modeling effort. Data used by Navoy and Carleton originated from many sources including Greenman et al. (1961) and Barton and Krebs (1990). In addition, data from drill logs at the NEWPCP was also included into the dataset. Resulting contoured data consisted of the vertical elevation of the top of each stratigraphic layer in the study area, including the top of bedrock.

Stratigraphic surfaces developed for this study are very similar to those presented by Navoy and Carleton (1995). These stratigraphic surfaces were imported into Groundwater Vistas to create the model layers. In areas were the MODFLOW layer thickness were less than 10 feet, the files were manually modified to represent a thickness of 10 feet. In particular, the thickness of the Lower Sand Unit was increased to a thickness of 10 feet in the vicinity of the Delaware River near both the northeastern and southwestern boundaries of the model area. Inclusion of sediment in model areas that would have normally been "pinched out" adds some conservatism to this analysis because the continuity of the model layers can allow flow beneath the Delaware River in areas where it may not actually occur. Cross sections of the model illustrating the vertical model discretization is provided in Appendix Q.

The five layers utilized in the model represent the general hydrogeologic framework of the PRM aquifer system in the study area. Each model layer represents the following:

- Layer 1: General section representing the Upper Clay Unit, the Upper Sand Unit, the Middle Clay Unit and the Middle Sand Unit of the PRM;
- Layer 2: Lower Clay Unit of the PRM;
- Layers 3 - 5: Lower Sand Unit of the PRM.

Layer 1 represents the general hydrogeologic section representing the upper portion of the PRM: Upper Sand Unit, Upper Clay Unit, Middle Sand Unit, and the Middle clay Unit. Since the focus of the modeling study is at the interaction between the Lower Sand unit and the Delaware River. Model layer 1 was designed to represent the overall average hydrogeologic properties and boundary conditions of these units. Layer 1 was modeled as an unconfined Type 3 aquifer.

Layer 2 represents the Lower Clay Unit of the PRM. This unit overlies the Lower Sand Unit and is thought to be a continuous unit of variable thickness throughout the southeast portion of the study site. In many parts underlying the Delaware River, the Lower Clay unit is missing through either erosion and/or dredging. At the NEWPCP, the Lower Clay Unit has been cut and unconformably overlain by silt and clay Tertiary and Quaternary age tidal flat sediments. However, the silt and clay of the tidal flat sediments and the Lower Clay Unit exist as an undifferentiated unit that exists throughout the NEWPCP. The silt and clay observed throughout most of the study site is discontinuous in northeast Philadelphia (northern portion of study site)(Navoy and Carleton, 1995). Layer 2 was modeled as an unconfined Type 3 aquifer.

Layers 3 through 5 represents the underlying Lower Sand Unit of the PRM. This aquifer system exists throughout the study site in both the Philadelphia and New Jersey sides of the Delaware River. To adequately represent flow gradients in the vicinity of the Delaware River, the Lower Sand Unit aquifer system was modeled using three layers. Layer 3, 4 and 5 were modeled as a confined Type 0 aquifer.

11.4 Boundary Conditions

The model boundaries were assigned to represent hydrogeologic boundaries of the flow system that are observed in the field. The bottom boundary of the model, the base of Layer 5, is assumed to be the bedrock surface underlying the Lower Sand Unit of the PRM and is modeled as a no-flow boundary. Groundwater flow between the Lower Sand Unit and the underlying bedrock is assumed to be insignificant.

Constant head boundaries were used to simulate the Delaware River and the regional potentiometric surface in New Jersey. Constant head cells were placed in the grid within the appropriate layers to represent actual bottom river elevations. In general, the constant head cells exist extensively in Layer 1 at cells representing the Delaware River. However, in areas where dredging activities have been conducted, constant head cells were placed in Layer 2, Layer 3 and sometimes Layer 4 depending upon the actual bottom elevation of the river (Appendix H). A value of zero feet mean sea level (ftmsl) was used for the Delaware River constant head cells. Also, a constant head boundary was also utilized in all five layers at the southeastern edge of the model (row 100). A value of –30 ftmsl was used at this boundary location as indicated by potentiometric surface maps provided by Navoy and Carleton (1995). Figures showing the location of constant head cells within the model grid are provided in Appendix Q.

New Jersey PWS wells were simulated in the model using the MODFLOW well package. Average pumping rates in millions of gallons per day (MGD) for the study area were provided by previous investigators (Navoy and Carleton, 1995; Barton and Krebs, 1990) and also obtained from the USGS and New Jersey Geologic Survey. The highest pumping rates were produced in the late 1980's in the recent past by many of the PWS wells. In addition, a more extensive hydraulic gauging dataset is available from PWS wells in the late 1980's. For these reasons, pumping rates for the year 1988 were used in the model. All of the wells are fully screened within the Lower Sand Unit aquifer system and were therefore modeled by evenly distributing the pumping stress between all three layers. Figures showing the location of cells used to simulate PWS wells are provided in Appendix Q. Pumping rates and location information for each of the modeled PWS is provided in Table 14.

Table 14
New Jersey PWS Well Locations and Pumping Rates Used in the Model

Well	Row	Column	Layer	Pumping Rate, 1988 (MGD)
Dela Garden 1A	61	41	3,4,5	0.177
Puchack 3	58	64	3,4,5	5.339
Woodbine 1	88	44	3,4,5	0.451
Woodbine 2	87	40	3,4,5	0.451
Camden Div 51	62	22	3,4,5	0.506
Camden Div 52	62	19	3,4,5	0.955
54	61	27	3,4,5	0.96
55	63	21	3,4,5	0.087
Park Ave 1	82	82	3,4,5	2.119
National Hwy 1	91	64	3,4,5	1.354
Marion 2	55	90	3,4,5	1.177
Delair1	50	56	3,4,5	0.14
Delair 2	49	55	3,4,5	0.14
Delair 3	50	55	3,4,5	0.14
Morris10	48	71	3,4,5	12.458
Morris4A	48	78	3,4,5	0.14
Morris6	50	64	3,4,5	0.14
Morris8	49	68	3,4,5	0.14
Morris Well	48	63	3,4,5	0.14
Morris Well	47	64	3,4,5	0.14
Morris Well	50	67	3,4,5	0.14
Morris Well	49	69	3,4,5	0.14
Morris Well	47	71	3,4,5	0.14
Morris Well	49	71	3,4,5	0.14
Morris Well	46	76	3,4,5	0.14
Morris Well	47	76	3,4,5	0.14
Morris Well	49	82	3,4,5	0.14
Morris Well	49	84	3,4,5	0.14
Morris Well	49	88	3,4,5	0.14
Browning 2A/1	86	27	1	1.059

11.5 Aquifer and Recharge Parameters

Hydraulic conductivity (K) values were input into the model in the form of several model zones. The K values and model zones were reproduced from the USGS groundwater model by Navoy and Carleton (1995). Initial K values used in each zone are provided on Table 15. The initial value for K used of the Lower Sand Unit aquifer system was 130 ft/day. Figures showing the location of K model zones is provided in Appendix Q.

Table 15
Initial Hydraulic Conductivity Values Used in Each Model Zone

Model Zone	K (ft/day)	Aquifer Represented
2	130	Lower Sand Unit
3	35	Middle Sand Unit
5	0.01	Lower Clay Unit
6	12	Tertiary and Quaternary Sediments

Two recharge zones were represented in the model based upon the USGS model by Navoy and Carleton (1995). The first model zone consists of cells located on the Philadelphia side of the Delaware River. A recharge value of 0.001 ft/day was used in this zone. The second recharge model zone consist of cells located at Petty Island and New Jersey. A recharge value of 0.002 ft/day was used in the second zone. The recharge model zones are provided in Appendix Q.

11.6 Model Calibration and Sensitivity Analysis

Field data used in the evaluation and calibration of model runs, called "target heads", was obtained from USGS monitor wells ("target wells") located within the study area. Historic head data from the target wells was obtained from USGS's web site at http://water.usgs.gov/nwis. For the use of model calibration, target heads for the year 1988 was used to compliment simulated pumping rates as described in Section 11.4. Field data collected from the NEWPCP was also used for model calibration. Target well location and head data is provided on Table 16. Also, target well locations are provided as figures in Appendix Q.

Table 16
Target Well Location and Head Data

Target Well	Row	Column	Layer	Target Head (ft msl)
Camden54	61	27	4	-32
Camden55	63	21	4	-29
TW-8-79	83	7	4	-36
CamdenDiv50	54	23	4	-27
Dela Garden 2	60	41	4	-20
Puchack MW-5M	64	61	1	-12
Delair 1	50	56	4	-17
City 16	55	12	4	-24
CamdenDiv 48	54	22	4	-34
Petty Island Obs	43	22	4	0
MW-1	30	49	4	1
MW-ED	36	49	4	1
MW-ES	35	49	1	4

The model was initially run with input values as describe above. Simulated hydraulic heads were compared with target heads. The difference, called a residual, was calculated at each target well location. As shown on Table 17, initial input values produced a good match of heads and a relatively low residual value. Residual sum of squares (RSOSs) and residual mean (RM) produced from the initial run were 2.86 feet and 2,565, respectively.

Table 17
Results of Initial Model Run

Target Well	Target Head (ft msl)	Calculated Head (ft msl)	Residual (feet)
Camden54	-32	-42.76	10.76
Camden55	-29	-37.07	8.07
TW-8-79	-36	-26.57	-9.43
CamdenDiv50	-27	-18.25	-8.75
Dela Garden 2	-20	-24.07	4.07
Puchack MW-5M	-12	-33.02	21.02
Delair 1	-17	-25.21	8.21
City 16	-24	-13.39	-10.61
CamdenDiv 48	-34	-18.04	-16.96
Petty Island Obs	0	-2.79	2.79
MW-1	1	5.45	-4.45
MW-ED	1	2.56	-1.56
MW-ES	4	4.08	-0.08
Residual Mean			2.86
Residual Sum of Squares			2565

To determine if values for RSOS and RM could be decreased, values of K and recharge were independently changed using a trail-and-error approach. Parameters were adjusted, a simulation was performed, and the results evaluated on the basis of RSOSs and RM calculations. Input data were then adjusted until the residuals between computed and observed heads were minimized.

Table 18 presents the residual sum of squares and residual mean for runs completed at K values ranging from 65 ft/day to 390 ft/day for the Lower Sand Unit (Layers 3, 4, and 5) Model Zone 2. Using the K value of 130 ft/day obtained from Navoy and Carleton (1995) produced a residual sum of squares (RSOSs) of 2,565 and a residual mean (RM) of 2.86. When the K value was increased by a factor of 2 (K = 260 ft/day), the RSOSs and RM fell to 2,087 and –0.46, respectively. Increasing the K value to 390 ft/day increased both the RSOSs and RM to a value of 2,173 and –1.74. Reducing the K value to 65 ft/day also increased the RSOS and RM to values above the optimum estimated Lower Sand Unit K value for the model which is 260 ft/day. Results of the runs indicate that the model heads are sensitive to minor changes in K the Lower Sand Unit.

The hydraulic conductivity of the Lower Clay Unit was similarly evaluated. Table 19 presents the RSOSs and RM for runs using variable values of K for Layer 2 of the model. Values of K were varied between $1x10^{-7}$ ft/day and $1x10^{-2}$ ft/day. RSOSs and RM both decreased as the K value for the Lower Clay Unit was increased. For example, the RSOSs and RM for a K value equal to $1x10^{-7}$ ft/day were 4,383 and 9.81, respectively, compared to values equal to 2,565 and 2.86 when a K value of $1x10^{-2}$ is used. Values of RSOS and RM when using a K value of 0.1 ft/day were slightly higher that than that calculated when a K of $1x10^{-2}$ was used. In this case, the K value of $1x10^{-2}$ was used for later model runs. Results of the runs indicate that model heads are not sensitive to order of magnitude changes of K for the Lower Clay Unit.

Table 20 present the results of model runs using adjusted recharge values for Layer 1. Values of recharge were changed by multiples of 0.1, 10.0, and 2. Changes in residual values indicate that the model is sensitive to recharge on Layer 1. However, the initial run values of 0.001 ft/day for Zone 2 and 0.002 for Zone 3 produced a RM of –0.46 and a RSOSs of 2087. An order of magnitude increase of recharge to values that our not realistic increased heads throughout the model. Based on the RSOSs and RM values for each run varying the recharge value for the model, the model is sensitive to recharge rates, however, the initial values used represent the best model fit.

11.7 Hypothesis Testing

Following calibration of the model, model runs were completed to test the following hypothesis: "Can groundwater within the Lower Sand Unit at the NEWPCP migrate under the Delaware River to pumping centers in New Jersey." The hypothesis was tested by performing a particle tracking analysis utilizing calibrated model runs and model runs simulating differing scenarios and pumping strategies. The particle tracking analysis was completed using MODPATH (Pollock, 1989). MODPATH uses output files produced from MODFLOW simulations and allows tracking of water "particles" placed at any location within the flow field. MODPATH calculates the paths taken by particles as they flow through the groundwater system. An assumed value of porosity was set at 0.3.

Prior to performing the particle tracking analysis, the model was run using many different scenarios. Many of the scenarios represent "worst-case" and are extremely conservative. In many cases, the input parameters were modified to values that are not representative of nature, such as reducing the hydraulic conductivity of the Lower Sand Unit in order to substantially increase gradients nearby New Jersey PWS wells. The model runs were completed using the following scenarios:

- Calibrated model run using 1988 pumping conditions
- Model run with a hypothetical new PWS well located directly across the Delaware River from the NEWPCP
- Model run using pumping conditions a factor of 10 greater than 1988 conditions
- Model run using a K value of 1×10^{-7} ft/day for the Lower Clay Unit
- Model run using a K value of 2.6 ft/day for the Lower Sand Unit
- Model run using a K value of 2,600 ft/day for the Lower Sand Unit

Following completion of the MODFLOW run for each scenario, a MODPATH particle tracking analysis was conducted. MODPATH particles were placed in Layer 3 and Layer 5 directly underneath the location of the NEWPCP. One hundred particles were simulated in each layer for a total of 200 particles. Both Layer 3 and Layer 5 represent the extremes with regard to aquifer elevation and were assigned particles to ensure that coverage was complete throughout the entire Lower Sand Unit. Figures showing the assigned location of the MODPATH particles is provided in Appendix Q. Copies of MODFLOW input and output files are provided in Appendix R.

12.0 FATE AND TRANSPORT ANALYSIS RESULTS

12.1 Model Run #1 - Calibrated model run using 1988 pumping conditions

Figures 16 through 18 present the results of the first model run. Heads within the Lower Sand Unit are similar to actual heads produced during pumping of New Jersey PWS wells in 1988. Simulated heads produced a RSOSs and RM values of 2.86 and 2565, respectively. Particle analysis indicates that particles within the Lower Sand Unit do <u>not</u> pass underneath the Delaware River to PWS wells in New Jersey. Instead, particles migrate southeast and discharge into the Delaware River.

12.2 Model Run #2 - Model run with addition of a hypothetical pumping well located directly across the Delaware River from NEWPCP

A simulated well was added to the model at a location directly across the Delaware River from the NEWPCP. The new well was placed within Layers 3, 4 and 5 at Row 51 and Column 47. The new well was simulated to pump the same amount as the MORRIS 10 well (12.46 MGD) which had the highest pumping rate within the study area in 1988. In addition to the new simulated well, all of the other New Jersey PWS wells were simulated to pump at 1988 rates during this run.

Figures 19 through 21 present the results of this model run. Approximately 120 feet of drawdown exists within the Lower Sand Unit at the location of the new pumping well. The presence of the new well has increased the hydraulic gradient sharply towards the Delaware River, however, the gradient ceases at locations near the middle of the river where the river is in direct hydraulic contact with the underlying sediments. Particle analysis indicates that particles from the NEWPCP do <u>not</u> pass underneath the Delaware river to any of the simulated PWS wells.

Table 18
Model Calibration Results Summary
Model Zone 2 - Hydraulic Conductivity of Lower Sand Unit

Zone 2 - Lower Sand Unit				K= 130 ft/day			K= 65 ft/day			K = 260 ft/day			K = 390 ft/day		
Name	X	Y	Layer	Observed	Computed	Residual	Observed	Computed	Residual	Observed	Computed	Residual	Observed	Computed	Residual
Camden54	7950	11850	4	-32	-42.75922	10.759216	-32	-65.09396	33.093956	-32	-30.27294	-1.727057	-32	-25.77336	-6.226643
Camden55	6150	11250	4	-29	-37.0756	8.0756	-29	-52.94686	23.946861	-29	-27.98322	-1.016781	-29	-24.66764	-4.332359
TW-8-79	1950	5250	4	-36	-26.57024	-9.429764	-36	-26.2686	-9.7314	-36	-26.54385	-9.45615	-36	-26.47465	-9.525347
CAMDENDIV50	6750	13950	4	-27	-18.25368	-8.746323	-27	-21.81343	-5.186573	-27	-15.63196	-11.36804	-27	-14.52255	-12.47745
DELAGARDEN2	12150	12150	4	-20	-24.06983	4.069834	-20	-29.62102	9.621016	-20	-19.98631	-0.013693	-20	-18.22948	-1.770521
PUCHACKMW-5M	18150	10950	1	-12	-33.01872	21.018723	-12	-48.7407	36.740704	-12	-21.34636	9.346359	-12	-16.99798	4.997976
DELAIR1	16650	15150	4	-17	-25.21591	8.215906	-17	-42.49634	25.496338	-17	-15.97012	-1.029883	-17	-12.51352	-4.486485
City16	3450	13650	4	-24	-13.39125	-10.60875	-24	-13.93251	-10.06749	-24	-12.9056	-11.0944	-24	-12.66243	-11.33757
CAMDENDIV48	6450	13950	4	-34	-18.03964	-15.96036	-34	-21.49372	-12.50628	-34	-15.51327	-18.48673	-34	-14.44744	-19.55256
PettyIslandobs	6450	17250	4	0	-2.78916	2.78916	0	-2.160724	2.160724	0	-3.092626	3.092626	0	-3.167296	3.167296
MW1	14550	21150	4	1	5.45705	-4.45705	1	9.992838	-8.992838	1	2.834698	-1.834698	1	1.911397	-0.911397
MWED	14550	19350	4	1	2.564508	-1.564508	1	4.802794	-3.802794	1	1.323856	-0.323856	1	0.892079	0.107921
MWES	14550	19650	1	4	4.080929	-0.080929	4	6.835328	-2.835328	4	2.563321	1.436679	4	2.03991	1.96009
Residual Mean						[illegible]			[illegible]			[illegible]			[illegible]
Res. Std. Dev.						13.231122			18.160618			12.200796			12.338328
Sum of Squares						[illegible]			[illegible]			[illegible]			[illegible]
Abs. Res. Mean						10.126866			15.727307			7.587639			8.346686
Min. Residual						-15.96036			-12.50628			-18.48673			-19.55256
Max. Residual						36			36.740704			36			36
Head Range						43			43			43			43
Std/Head Range						0.307701			0.42234			0.283739			0.286938

Table 19
Model Calibration Results Summary
Model Zone 5 - Hydraulic Conductivity of Lower Clay Unit

Zone 5 - Lower Clay Unit				K= 10-7 ft/day			K= 10-5 ft/day			K = 10-3 ft/day			K = 10-2 ft/day		
Name	X	Y	Layer	Observed	Computed	Residual	Observed	Computed	Residual	Observed	Computed	Residual	Observed	Computed	Residual
Camden54	7950	11850	4	-32	-60.71921	28.719208	-32	-60.66485	28.664852	-32	-55.50505	23.505054	-32	-42.75922	10.759216
Camden55	6150	11250	4	-29	-54.84541	25.845413	-29	-54.79218	25.792179	-29	-49.63874	20.638741	-29	-37.0756	8.0756
TW-8-79	1950	5250	4	-36	-34.02045	-1.979553	-36	-34.00278	-1.997223	-36	-31.80062	-4.199383	-36	-26.57024	-9.429764
CAMDENDIV50	6750	13950	4	-27	-35.83202	8.832024	-27	-35.77746	8.777458	-27	-30.83655	3.836554	-27	-18.25368	-8.746323
DELAGARDEN2	12150	12150	4	-20	-40.22168	20.221684	-20	-40.16977	20.169769	-20	-35.46673	15.466728	-20	-24.06983	4.069834
PUCHACKMW-5M	18150	10950	1	-12	9.983213	-21.98321	-12	9.832892	-21.83289	-12	-2.686023	-9.313977	-12	-33.01872	21.018723
DELAIR1	16650	15150	4	-17	-34.21753	17.217529	-17	-34.18643	17.186428	-17	-31.44965	14.449646	-17	-25.21591	8.215906
City16	3450	13650	4	-24	-30.79448	6.794477	-24	-30.73895	6.738949	-24	-25.74992	1.749924	-24	-13.39125	-10.60875
CAMDENDIV48	6450	13950	4	-34	-35.69733	1.69733	-34	-35.64236	1.642357	-34	-30.66893	-3.331074	-34	-18.03964	-15.96036
PettyIslandobs	6450	17250	4	0	-9.147711	9.147711	0	-9.127857	9.127857	0	-7.38397	7.38397	0	-2.78916	2.78916
MW1	14550	21150	4	1	5.559442	-4.559442	1	5.573454	-4.573454	1	5.559603	-4.559603	1	5.45705	-4.45705
MWED	14550	19350	4	1	2.53882	-1.53882	1	2.347461	-1.347461	1	2.406182	-1.406182	1	2.564508	-1.564508
MWES	14550	19650	1	4	-9	13	4	6.414259	-2.414259	4	5.873647	-1.873647	4	4.080929	-0.080929
Residual Mean						[illegible]			[illegible]			[illegible]			[illegible]
Res. Std. Dev.						14.724716			14.978074			12.665074			13.231122
Sum of Squares						[illegible]			[illegible]			[illegible]			[illegible]
Abs. Res. Mean						14.109743			13.304653			10.551034			10.126866
Min. Residual						-21.98321			-21.83289			-9.313977			-15.96036
Max. Residual						36			36			36			36
Head Range						43			43			43			43
Std/Head Range						0.342435			0.348327			0.294537			0.307701

Table 20

Model Calibration Results Summary

Recharge on Layer 1

				Recharge Zone 2 = 0.001 ft/day			Recharge Zone 2 = 0.0001 ft/day			Recharge Zone 2 = 0.01 ft/day			Recharge Zone 2 = 0.002 ft/day		
				Recharge Zone 3 = 0.002 ft/day			Recharge Zone 3 = 0.0002 ft/day			Recharge Zone 3 = 0.02 ft/day			Recharge Zone 3 = 0.004 ft/day		
Name	X	Y	Layer	Observed	Computed	Residual	Observed	Computed	Residual	Observed	Computed	Residual	Observed	Computed	Residual
Camden54	7950	11850	4	-32	-30.27294	-1.727057	-32	-33.00337	1.003368	-32	-8.692723	-23.30728	-32	-28.82807	-3.171934
Camden55	6150	11250	4	-29	-27.98322	-1.016781	-29	-30.96198	1.961977	-29	-4.825497	-24.1745	-29	-26.41995	-2.580046
TW-8-79	1950	5250	4	-36	-26.54385	-9.45615	-36	-28.55523	-7.444773	-36	-11.25294	-24.74706	-36	-25.51313	-10.48687
CAMDENDIV50	6750	13950	4	-27	-15.63196	-11.36804	-27	-17.76449	-9.235506	-27	1.532735	-28.53274	-27	-14.49574	-12.50426
DELAGARDEN2	12150	12150	4	-20	-19.98631	-0.013693	-20	-22.15147	2.151466	-20	-2.084039	-17.91596	-20	-18.82523	-1.174767
PUCHACKMW-5M	18150	10950	1	-12	-21.34636	9.346359	-12	-29.8775	17.877497	-12	47.937145	-59.93715	-12	-16.79591	4.795912
DELAIR1	16650	15150	4	-17	-15.97012	-1.029883	-17	-17.06512	0.065117	-17	-6.543015	-10.45699	-17	-15.37769	-1.622314
City16	3450	13650	4	-24	-12.9056	-11.0944	-24	-15.05283	-8.947174	-24	4.325129	-28.32513	-24	-11.76518	-12.23482
CAMDENDIV48	6450	13950	4	-34	-15.51327	-18.48673	-34	-17.66122	-16.33878	-34	1.760431	-35.76043	-34	-14.36926	-19.63074
PettyIslandobs	6450	17250	4	0	-3.092626	3.092626	0	-3.611766	3.611766	0	1.145671	-1.145671	0	-2.815184	2.815184
MW1	14550	21150	4	1	2.834698	-1.834698	1	0.284879	0.715121	1	27.630152	-26.63015	1	5.640954	-4.640954
MWED	14550	19350	4	1	1.323856	-0.323856	1	0.133391	0.866609	1	12.774413	-11.77441	1	2.629061	-1.629061
MWES	14550	19650	1	4	2.563321	1.436679	4	0.259481	3.740519	4	23.632292	-19.63229	4	5.061573	-1.061573
Residual Mean						-0.462544			1.859086			-27.23618			-1.937589
Res. Std. Dev.						12.200796			12.226239			17.45138			12.310864
Sum of Squares						2087.0272			2141.1197			14649.044			2174.3628
Abs. Res. Mean						7.587639			7.854262			27.236183			8.167746
Min. Residual						-18.48673			-16.33878			-68.96681			-19.63074
Max. Residual						36			36			-1.145671			36
Head Range						43			43			43			43
Std/Head Range						0.283739			0.284331			0.405846			0.286299

12.3 Model Run #3 - Model run using pumping conditions a factor of 10 greater than 1988 conditions

Camp Dresser and McKee (1984) determined that the demand for water supplies in New Jersey by water purveyors would increase by 27% over the 1995 demand by the year 2020. Camp Dresser and McKee also projected that the increase in demand by self-supplied users would be minimal. To simulate an extremely conservative increase in groundwater usage within the study area, New Jersey PWS wells were simulated to pump water from the Lower Sand Unit at a factor of 10 times the 1988 pumping rates. This is an increase of over 900% of current withdrawals.

Figures 22 through 24 present the results of increasing well withdrawals by a factor of 10. Gradients between the New Jersey PWS wells and the Delaware River have increased sharply in response to the increased pumping rates. Approximately 800 feet of drawdown exists within the Lower Sand Unit in the vicinity of Morris 10 PWS well and approximately 200 feet of drawdown in the vicinity of Camden PWS wells. These drawdowns are unrealistic since the maximum drawdown is at an elevation lower than the elevation of the Lower Sand Unit in the vicinity of the Delaware River. However, the particle analysis indicated that, even with the increased withdrawals and unrealistic gradients, particles from the NEWPCP do <u>not</u> pass underneath the Delaware river to any of the simulated PWS wells.

12.4 Model Run #4 - Model run using a K value of 1 x 10-7 ft/day for the Lower Clay Unit

Hydraulic conductivity of the Lower Clay Unit (layer 2) was decreased to a value of 1×10^{-7}. Although changes in K of the Lower Clay Unit is not sensitive to heads within the Lower Sand Unit, the decrease of K does causes a decrease in storage which is derived vertically from Layer 1 in the southern portion of the model. Because less storage is supplied vertically, the horizontal movement of groundwater in the Lower Sand Unit is increased causing a more storage to be derived from the areas where direct contact exists between the aquifer and the Delaware River.

Figures 25 through 27 present the results of decreasing K of the Lower Clay Unit. The particle analysis indicated that particles from the NEWPCP do <u>not</u> pass underneath the Delaware river to any of the simulated PWS wells.

12.5 Model Runs #5 and #6 - Model run using differing K values for the Lower Sand Unit

Hydraulic conductivity of the Lower Sand Unit (Layers 3, 4 and 5) was modified because of the high sensitivity this parameter has on model results. The calibrated value of K for the Lower Sand Unit was decreased by a factor of 10 (26 ft/day, Model Run #5) and increased by a factor of 10 (2600 ft/day, Model Run #6). Changes to the new values of K are not realistic to the actual aquifer K value due to the high model sensitivity to this parameter. However, model runs were conducted with the unrealistic K values to evaluate the resulting gradients and the corresponding interaction between PWS wells and the Delaware river.

Model results to Model Run #5 and provided on Figures 28 through 30. The low value of K has increased gradients uniformly on both sides of the Delaware River. On the Philadelphia side, the lower conductivity value has increased the gradient between the northwest portion of the study area and the Delaware River because of recharge mounding as a result of lower K. Also, the gradients between the Delaware River and PWS wells in New Jersey have also increased significantly.

Figures 31 through 33 presents results of Model Run #6. The increased value of K for the Lower Sand Unit decreased gradients on both the Philadelphia and New Jersey sides of the River in the study area. Drawdown in the vicinity of the PWS wells is not pronounced in the Camden area or in the vicinity of Morris 10 PWS well. Particle analysis indicates for both Model Run #5 and #6 that groundwater underlying the NEWPCP does <u>not</u> pass underneath the Delaware river to any of the simulated PWS wells.

12.6 Flux of groundwater from the NEWPCP to the Delaware River

Groundwater underlying the NEWPCP slowly discharges into the Delaware River. The flux of groundwater leaving the NEWPCP towards the Delaware River was determined using the *cell-by-cell flow terms* calculated by MODFLOW during model runs. Based on the steady state calibrated model run using 1988 pumping conditions, the flux of groundwater leaving the NEWPCP towards the Delaware River from all model layers is a total of approximately 16,000 cubic feet per day.

The estimate of groundwater flux calculated by the model is extremely conservative for the following reasons:

- The simulated head gradients for the Lower Sand Unit in the vicinity of the NEWCPC are slightly steeper than actual conditions (groundwater monitoring at the NEWPCP has indicated that average potentiometric surface within the Lower Sand Unit is approximately flat);
- The hydraulic conductivity value used in the model for the Lower Sand Unit underlying the NEWPCP was approximately a factor of 10 higher than that calculated from on-site testing and the tidal response analysis;
- In similar flow regimes control by tides, the overall movement of groundwater is likely limited due to the repeating directional forces of the tidal pressure wave and the small storage changes within the semi-confined aquifer (Serfes, 1987).

13.0 FATE AND TRANSPORT ANALYSIS CONCLUSIONS

Based on the hypothesis testing results of the model runs and particle tracking analysis, none of the scenarios presented above indicate a risk to New Jersey PWS wells from groundwater underlying the NEWPCP. In all cases the hypothesis "Groundwater within the Lower Sand Unit at the NEWPCP will not migrate under the Delaware River to pumping centers in New Jersey" tested true for the varying simulated conditions. Instead of flowing through the Lower Sand Unit to New Jersey PWS wells, groundwater underlying the NEWPCP discharged directly into the Delaware River.

The rate of which the groundwater discharged to the Delaware River is a function of the hydraulic conductivity of the Lower Sand Unit and the hydraulic gradient within that unit. For the calibrated model based on 1988 conditions, the flux of groundwater to the Delaware River calculated by MODFLOW to be 16,000 cubic feet per day.

14.0 CLOSURE PLAN

The regulatory framework for closure of the PWD NEWPCP impoundments is the Pennsylvania Land Recycling and Environmental Remediation Standards Act (Act 2). The Act 2 regulatory framework is applicable for the following reasons (1997 Technical Guidance, Section III):

- The sewage sludges were generated and disposed in the NEWPCP impoundments prior to 1961.
- Specific regulations dealing with the disposal of sewage sludges were not in existence during time of sludge disposal and no formal permits were required or in existence.
- No specific closure provisions were mandated by any State or Federal agency during the time of sludge disposal.
- The Solid Waste Management Act of 1968 (Act 241) was not in existence during the time of sludge disposal at the NEWPCP.

According to Section III of the 1997 Act 2 Technical Guidance, the standard for closure of the NEWPCP impoundments under Act 2 is based on best management practices (to prevent pollution, odors, other nuisances) and characterization of the waste material and underlying groundwater. Many of the required activities for characterization were conducted and documented earlier in this report.

14.1 Groundwater

As discussed in Section 4.4, groundwater underlying the NEWPCP does not exceed the applicable Statewide Health Standard (PADEP Non-Use Aquifer / Nonresidential MSCs) for VOCs, semi-VOCs, pesticides, PCBs, metals and inorganics detected above the laboratory PQLs. Dissolved concentrations of aluminum, iron, and manganese did exceed the PADEP Secondary Maximum Contaminant Limits (SMCLs). However, the Secondary MCLs are limits established to assure that the aesthetic quality such as taste, odor, appearance and nuisance conditions of the water is acceptable to the public. Since the groundwater underlying the NEWPCP is not used, the Secondary MCLs are not applicable. Groundwater was fully characterized at the NEWPCP using groundwater collected from the 13 monitor wells. The Fate and Transport Analysis indicated that groundwater at the NEWPCP was not influenced by PWS wells located in New Jersey and would not migrate through the sediments underlying the Delaware River.

Based on the groundwater sampling and monitoring results, groundwater is not an issue of concern to human health and can be formally closed under Act 2 through the use of the Nonuse Aquifer Statewide Health Standards.

14.2 Impoundment Sludge

The sludge in Impoundments A, B, C, and D was fully, comprehensively, and accurately characterized using the laboratory analysis of the 60 sludge samples collected during this investigation. Published PADEP numerical values were used in evaluation of the impoundment sludge. No evidence of sludge material was found in borings advanced into former Impoundment E.

None of the VOCs, semi-VOCs, pesticides, PCBs, and inorganics detected above the laboratory PQLs in the sludge samples exceeded the PADEP Non-Use Aquifer / Nonresidential MSC DC and STG numerical values except for:

- 4-Chloroaniline, bis(2-Ethylhexyl)phthalate, DDE, DDT, and PCB-1260 (Soil to Groundwater Pathway)
- Arsenic, cadmium, lead (Direct Contact Standard 0-2 foot interval);

Based on the discussion below in Sections 14.2.1 and 14.2.2, the NEWPCP impoundment sludge is not an issue of concern to human health because the sludge is not an apparent source of groundwater contamination above the applicable Statewide Health Standards and a direct contact exposure pathway does not exist. According to the Act 2 regulations, the NEWPCP impoundment sludge can be formally closed under Act 2 through the use of both the Statewide Health Standard and the Site Specific Standard. The Statewide Health Standard can be used to address the soil to groundwater pathway risk by performing an equivalency demonstration for groundwater and the Site Specific Standard used address direct contact with the sludge since an exposure pathway does not exist. In addition, the sludge impoundments do not represent an exceptional value wetland, and no species or habitats of concern, threatened or endangered species were identified in or near the sludge impoundments. A formal deed restriction may be needed as an institutional control to satisfy Act 2 to prevent future uses of the sludge impoundments.

14.2.1 Soil to Groundwater Pathway - Impoundment Sludge

The compounds that exceeded the Soil to Groundwater Pathway numerical values in the impoundment sludge (4-Chloroaniline; bis(2-Ethylhexyl)phthalate; DDE; DDT; and PCB-1260) were either not detected above the laboratory PQLs in groundwater or were well below the Groundwater Non-Use Statewide Health Standards. In addition, no other compound detected in groundwater above the PQLs exceeded the Groundwater Non-Use Statewide Health Standards. For these reasons, direct evidence of groundwater quality indicates that the sludge material, although exceeding the soil to groundwater pathway standards for 4 compounds, is not a source of groundwater contamination above the Statewide Health Standards.

As discussed earlier, five rounds of groundwater samples were collected from groundwater monitor wells located at the NEWPCP. Laboratory analysis of the groundwater samples indicated that the sludge was not a significant contaminant source. Groundwater samples collected in January, March, June, September and December 2000 did not contain VOCs, Semi-VOCs, pesticides and PCBs above the laboratory PQLs during the analytical analysis except for some small quantities of the following parameters:

- acetone
- benzene
- carbon disulfide
- chlorobenzene
- acenaphthalene
- acenaphthene
- bis(2-ethylhexyl) phthalate
- flourene
- naphthalene

- phenol
- aldrin
- Beta BHC
- Delta BHC
- DDD
- DDE
- DDT
- endosulfan (1)
- gamma chlordane
- heptachlor
- methoxyclor

The detected concentrations in groundwater were well below the PADEP Non-Use Aquifer / Nonresidential MSCs.

The nature and composition of the sludge may explain why concentrations of 4-Chloroaniline, bis(2-Ethylhexyl)phthalate, DDE, DDT, and PCB-1260 (or many other compounds) were not found at higher concentrations in groundwater. The sludge is composed of organic waste solids that has a very high carbon content and a very low permeability. For these reasons, the leaching rate of the compound is controlled by the rate of flux of water through the sludge, the compound's octanol-water partition coefficient, and the organic content of the sludge.

The octanol-water partition coefficient (Koc) is a chemical-specific partition coefficient between organic carbon in soil or other material and the aqueous phase. Larger values of Koc indicate greater affinity of contaminants for the organic carbon fraction of soil. From the Koc of the compound of interest, a Retardation factor can be calculated. Retardation is the rate at which dissolved contaminants moving through a material can be reduced by sorption of contaminants to the solid matrix of the substrate. The degree of retardation depends on both the organic carbon content of the substrate and the Koc of the parameter of concern. The retardation factor is the ratio of the groundwater seepage velocity to the rate that organic chemicals migrate in the groundwater. A retardation value of 2 indicates that if the groundwater seepage velocity is 100 ft/yr, then the organic chemicals migrate at approximately 50 ft/yr.

Table 21 lists the Koc values for the 5 compounds of concern in the sludge. The values for many of the compounds are extremely high indicating that the compound absorbs onto organic matter very strongly.

Table 21
Koc values of some compounds detected in NEWPCP Impoundment Sludge

Parameter	Koc Value (from Table 5 of Act 2)
4-Chloroaniline	460 L/kg
bis(2-Ethylhexyl)phthalate	87000 L/kg
DDE	87000 L/kg
DDT	240000 L/kg
PCB-1260	1800000 L/kg

Based on the sludge sample analytical results, the average organic carbon content of the sludge averages at 38,640 mg/kg (3.8%) with a maxiumum of 300,000 mg/kg (30%). For purpose of calculation, the average organic carbon percentage 3.8% was used as the fraction organic carbon (Foc) value (0.038) for the sludge. From both the Koc and Foc values, a retardation factor can be calculated.

$R = 1 + [((Koc \times Foc) \times rb) / n]$

where:
rb = bulk density (kg/l)
n = porosity (unitless)
Koc = octanol-water partition coefficient (L/kg)
Foc = fraction of organic carbon (unitless)

Using the above equation, the retardation factor for each compound listed in Table 21 is provided in Table 22. The values for bulk density and porosity were assumed to be 1.8 kg/l and 0.3, respectively. The values of Koc and Foc are provided above.

Table 22
Calculated Retardation Factors For Compounds Detected in Impoundment Sludge

Parameter	Calculated Retardation Factor
4-Chloroaniline	106
bis(2-Ethylhexyl)phthalate	19,837
DDE	19,837
DDT	54,721
PCB-1260	410,401

As provided in Table 22, the calculated retardation factors for the compounds indicate that the compounds will move through and leach out of the sludge very slowly. For example, the 4-Chloroaniline will migrate in the sludge approximately 106 times slower than water flowing through the sludge. The retardation factors for the other listed compounds are much higher than 4-Chloroaniline, so would leach even slower from the sludge. The high organic carbon content of the sludge is the primary reason why only traces of constituents are detected in groundwater.

The Soil-to-Groundwater Pathway numerical values under Act 2 were developed for soil with an assumed Foc value of 0.0025. Because the NEWPCP impoundment sludge contains a much greater percentage of organic carbon, the STG numerical values overestimate the risk associated with groundwater impacts due to leaching. Based on the above calculation, the risk to groundwater underlying the sludge impoundments from leaching contaminants is low.

14.2.2 Direct Contact of Impoundment Sludge

The metals arsenic, cadmium and lead were detected in some of the sludge samples which exceeded the PADEP Non-Use Aquifer / Nonresidential DC numerical values for the 0-2 foot interval. However, a direct contact exposure pathway does not exist. The direct contact exposure pathway does not exist for the following reasons:

- The impoundments are located within the PWD property which is inaccessible to the public by well maintained fences (since the PWD property will always be used for water treatment activities, fences will be maintained indefinitely).
- Limited access to the impoundments is granted by PWD only to qualified PWD employees.
- The composition of the sludge (black organic material primarily composed of human hair and organic human waste solids) reduces the possibility that long term exposure through ingestion or other direct contact exposures would occur in PWD employees.

- Access to the sludge material in the impoundments is difficult due to the presence of seasonal standing water and plant growth at the surface including thick reeds of *Phragmites*.

14.3 Surface Water

As shown through the groundwater modeling, groundwater discharges from the sediments underlying the NEWPCP to the Delaware River as a diffuse, non-point source discharge. The discharge of groundwater into a surface water body falls under the Clean Streams Law which is currently interfaced into the Act 2 program. The Act 2 regulations provide that the diffuse discharge impact, if any, be modeled and compared to the applicable Water Quality Standards. In addition, other requirements include the evaluation of the potential for sedimentation and erosion in conformance with the requirements of Chapter 102.

Sections 250.309 and 250.406 of the Act 2 regulations provide for determining compliance with surface water quality standards from a diffuse groundwater discharge. The following formula was used to evaluate the impacts, if any, on the water quality of the Delaware River from groundwater underlying the NEWPCP. The formula assumes that the total contamination mass load into the river is constant and the diffuse flow into the cross-sectional area of the river is uniformly mixed:

$$C_{SW} = \frac{Q_{GW} \times C_{GW}}{Q_{SW}}$$

where:

Q_{GW} = groundwater discharge from cross-sectional area of plume into stream;
C_{GW} = area weighted average concentration of contamination plume;
Q_{SW} = surface water quantity upstream of the site at design flow conditions;
C_{SW} = surface water concentration (mass/vol)

The groundwater discharge from the cross-sectional area of the site (Q_{GW}) was calculated by the groundwater flow model as discussed in Section 12.6. The value of 16,000 ft^3/day was used and it is very conservative since actual flow to the river may be considerably less. The flow rate of the Delaware River (Q_{SW}) was determined from gauging data available from the Delaware River Basin Commission's (DRBC) collection station in Trenton New Jersey. Actual flow rates for the Delaware River were available for each month, as well as monthly normal averages. According to the DRBC, the average flow rate of the Delaware River at Trenton, NJ is 9,818 cubic feet per second (848,282,400 ft^3/day). Due to the proximity of Trenton, NJ significantly upstream from the NEWPCP, the average flow rate of the Delaware River is likely higher than 9,818 ft^3/sec near the NEWPCP. However, to keep the calculations conservative, a value of 9,818 ft^3/sec was used.

Based on the above mass balance relationship representing the groundwater / surface water mixing, the instream concentrations within the Delaware River will be a factor of 1.89×10^{-5} less than the initial groundwater concentration (Qgw / Qsw). This relationship can be applied to any compound in groundwater underlying the NEWPCP to determine an instream concentration for that compound. According to the Act 2 regulations, if the results of the mass balance calculation indicate that the surface water quality standards are being met, then no action is required.

The determination of the Delaware River instream concentration for any compound within groundwater underlying the NEWPCP can be calculated using the following relationship:

$$C_{SW} = 1.89 \times 10^{-5} \times C_{GW}$$

The highest concentrations detected in groundwater at the NEWPCP were those of metals, primarily iron, aluminum and manganese. Iron was detected at the highest concentrations of 80.2 mg/l (total). Based on the above relationship, the Delaware River instream concentration of iron is 0.0015 mg/l. According to Chapter 93.7 – Specific Water Quality Criteria of the Water Quality Standards, the instream applicable water quality standard for dissolved iron is 0.3 mg/l. The calculated instream concentration of 0.0012 mg/l is much lower than the applicable water quality standard of 0.3 mg/l. The results of the mixing calculation and comparison to applicable standards is provided below in Table 23 for many of the detected compounds in groundwater under the NEWPCP.

Table 23
Calculated Instream Concentrations

Parameter with Maximum Detected Groundwater Concentration	Calculated Instream Concentration for the Delaware River
Benzene, 0.0067 mg/l	1.26×10^{-7} mg/l
Bis(2-ethylhexyl) phthalate, 0.032 mg/l	6.03×10^{-7} mg/l
Gamma Chlordane, 0.000922 mg/l	1.74×10^{-8} mg/l
Aluminum (total), 18.6 mg/l	0.00035 mg/l
Antimony (total), 0.155 mg/l	2.92×10^{-6} mg/l
Arsenic (total), 0.223 mg/l	4.21×10^{-6} mg/l
Cadmium (total), 0.015 mg/l	2.83×10^{-7} mg/l
Iron (total), 80.2 mg/l	0.0015 mg/l
Lead (total), 0.036 mg/l	6.79×10^{-7} mg/l
Manganese (total), 7.2 mg/l	0.00014 mg/l

For all the low level contaminants present within the Lower Sand Unit underlying the NEWPCP, none of the contaminants cause the Delaware River to exceed the applicable instream standards. For this reason, the low level groundwater contaminants under the NEWPCP are in compliance with the Clean Streams Law and are eligible to be closed under the Act 2 program.

Direct instream sampling conducted of surface water within Frankford Creek indicates that diffuse non-point discharge from groundwater underlying the NEWPCP does not impact instream concentrations above the surface water quality standards. Therefore, diffuse discharges to Frankford creek are also in compliance with Clean Streams Law and are eligible to be closed under the Act 2 program.

Further requirement of the Clean Streams Law include the evaluation of the potential for sedimentation and erosion in conformance with the requirements of Chapter 102. As discussed in Section 2.3, the sludge has been disposed in diked impoundments which physically prevent the sedimentation and erosion of the sludge material. No swales or gullies exist in the impoundments which would cause the erosion and sedimentation of the sludge material to nearby surface water bodies such as Frankford Creek and the Delaware River. Seasonal standing surface water within the impoundments caused by rainfall events and snowmelt is controlled by a drainage network that allows the control of the standing water levels within the impoundments. The standing water is discharged to the influent of the NEWPCP for treatment. The drainage network and impoundment dikes are maintained by PWD. The vegetative cover and seasonal standing water prevent the potential of erosion by wind.

14.4 Petition to Reduce Number of Groundwater Sampling Events for Equivalency Demonstration

According to the Act 2 regulations, an equivalency demonstration may be substituted for the soil-to-groundwater numerical values. Five parameters which include 4-Chloroaniline, bis(2-Ethylhexyl)phthalate, DDE, DDT, and PCB-1260 were detected above the applicable Statewide Health Standard in the impoundment sludge. The equivalency demonstration requires a total of eight quarters of groundwater monitoring unless the petition is granted by the PADEP for less than 8 quarters.

Based on the information provided previously (Section 14.2.1), the risk to groundwater underlying the NEWPCP sludge impoundments from leaching is low. Groundwater collected from 5 sampling events indicated that only small quantities of the targeted parameters were detected and the concentrations were well below the PADEP Non-Use Aquifer / Nonresidential MSCs. The sludge has been in place for over 40 years and, due to the time frame involved, leaching is occurring at a steady state rate which is not impacting underlying groundwater significantly. For these reason, PWD respectfully requests that the data provided in this report satisfy the requirements of a Statewide Health Standard equivalency demonstration as described in Section 250.308 of the Act 2 regulations.

14.5 Activities to Complete Closure of the NEWPCP Impoundment Sludge

This study demonstrates that the lagoon site qualifies for closure under the Act 2 Program. Table 24 lists the applicable Act 2 standards that will fulfill the requirements for environmental closure of the impoundment sludge and underlying groundwater and eligibility for the liability release as offered by Act 2.

Table 24
Applicable Act 2 Standards for Closure of the NEWPCP Impoundments

Media	Fully Characterized?	Applicable Act 2 Standard	Required Activities
Impoundment Sludges – Groundwater Impact	Yes	Statewide Health Standard	Equivalency Demonstration
Impoundment Sludges – Direct Contact	Yes	Site Specific Standard for Direct Contact 0-2 feet	Pathway Elimination through continued Institutional Controls
Groundwater	Yes	Statewide Health Standard	None – Standard met
Surface water	N/A	Statewide Health Standard - Instream Mixing Calculation and Chapter 93 Water Quality Standards	None – Standard met

Notes: N/A = not applicable

To ensure that the closure complies with Act 2, the Clean Streams Law, sedimentation and erosion prevention requirements, best management practices, and the continued pathway elimination for the direct contact of the impoundment sludge, a formal deed notice and restriction will be placed on the lagoons property. The deed notice and restriction will include the following:

- Requirements for the maintenance of impoundment dikes to prevent sedimentation and erosion of the sludge material;
- Requirements for the maintenance of the current impoundment drainage network which discharges surface water from the impoundments during heavy meteoric precipitation events to the influent of the NEWPCP treatment plant. The drainage network prevents impoundment flooding and potential breaches in the impoundment dikes;
- Restriction of public access to the impoundments including the maintenance of fencing;
- Requirements for continued protection of PWD worker safety through restricted access and implementation of a health and safety program and plan;
- Restriction of future uses of impoundments unless the direct contact pathway and sedimentation / erosion prevention issues have been otherwise addressed for the future use, and approval by the PADEP is granted prior to initiation of the future use.

In addition to the formal deed notice and restriction, the following additional activities will be completed to properly comply and document the Act 2 process for eligibility:

- Formal PADEP notification in the form of a Notice of Intent to Remediate (NIR);
- Formal municipal notice of the NIR;
- Formal public notice of the NIR;
- Public comment period if requested by municipality;
- Final Report document;
- Formal Final Report notice to municipality;
- Formal Final Report notice to public.

The information provided in this Closure Plan will be reissued as an Act 2 Final Report. The Act 2 final report will also include documentation of the proposed formal deed notice / restriction and results of any public comment.

PWD respectfully requests the PADEP's review and comment of this Closure Plan and the above listed activities to pursue closure of the impoundment sludges under Act 2. At this time, PWD also respectfully requests consideration of the petition to reduce the number of groundwater sampling events for the Soil to Groundwater Equivalency Demonstration listed in Section 14.2.2. If the PADEP agrees with this plan to close the impoundment sludge under Act 2, PWD will prepare the required deed notice and restriction information for PADEP review prior to submission of the Act 2 final report and subsequent notices.

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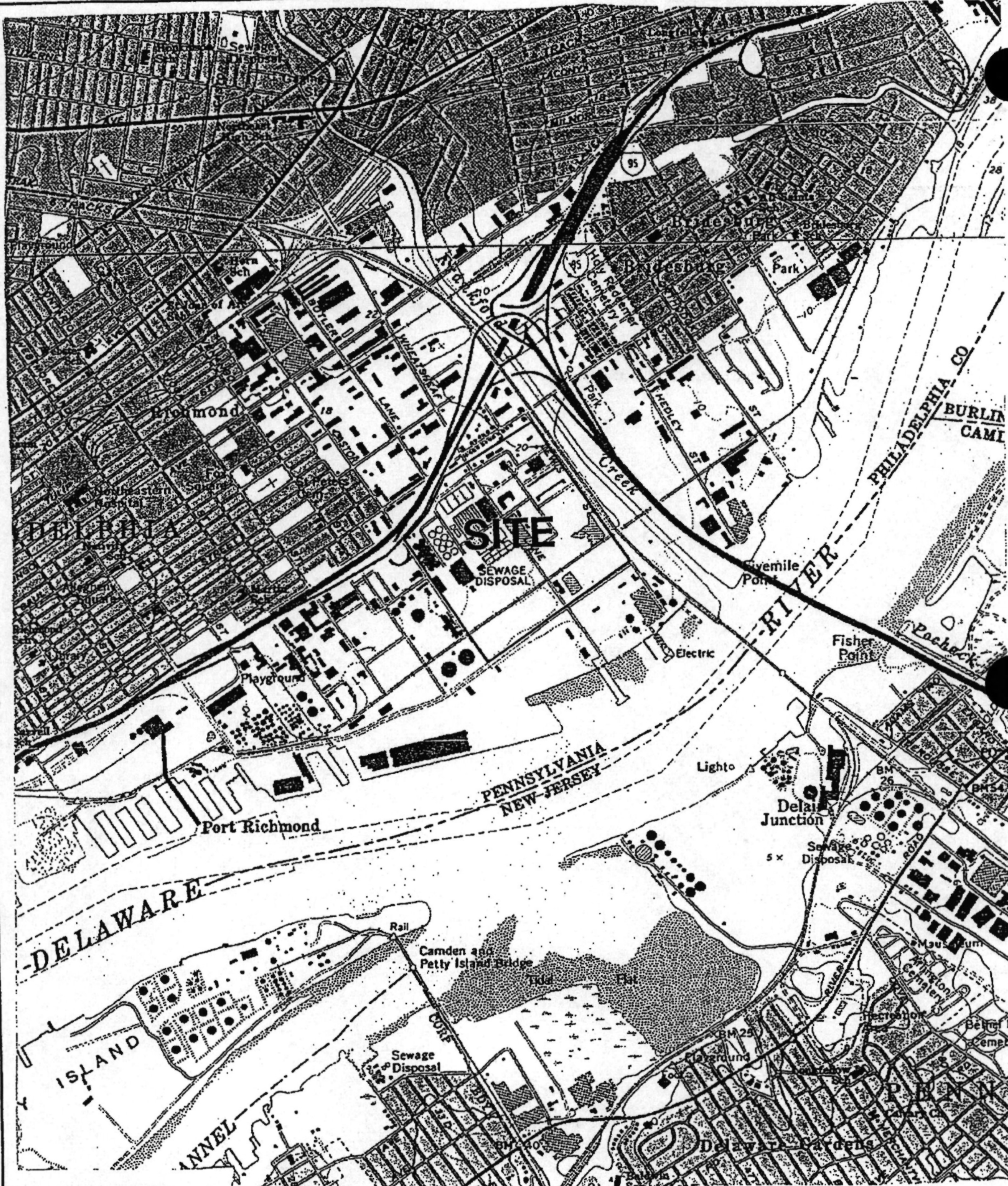


FIGURE 1

H:98\98159701\NEWPCP\Cadd Files for Closure Plan

SITE LOCATION MAP **PWD-NEWPCP CLOSURE PLAN** BASEMAP: CAMDEN, NJ 7.5' USGS TOPO QUAD	RETTEW ASSOCIATES, INC. 3020 Columbia Ave., Lancaster, PA 17603 TEL (717) 394-3721 · FAX (717) 394-1063	DRAWN BY: CTB DATE: 12/28/01 SCALE: 1" = 2000' DWG. NO. 98-1597-01

AR002378

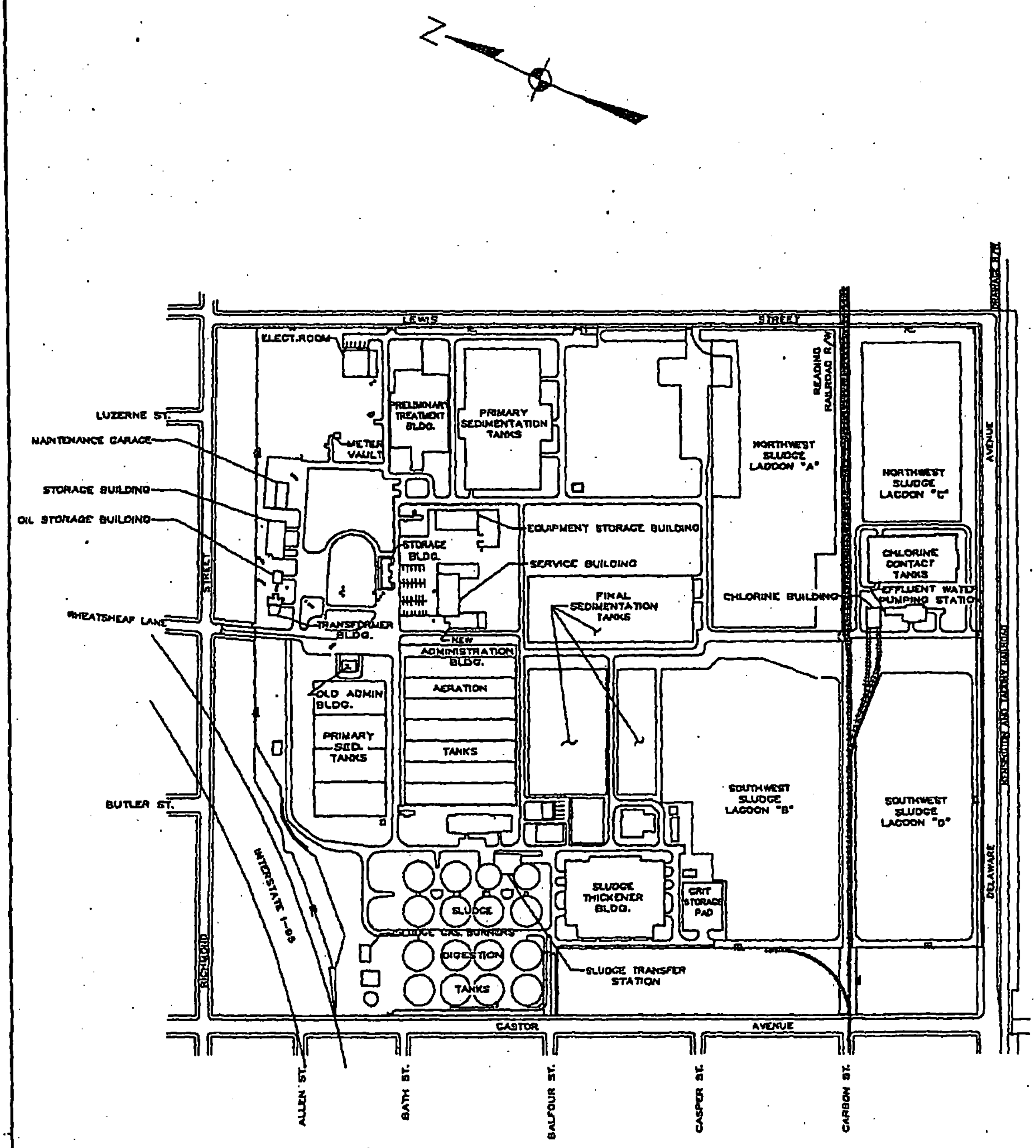


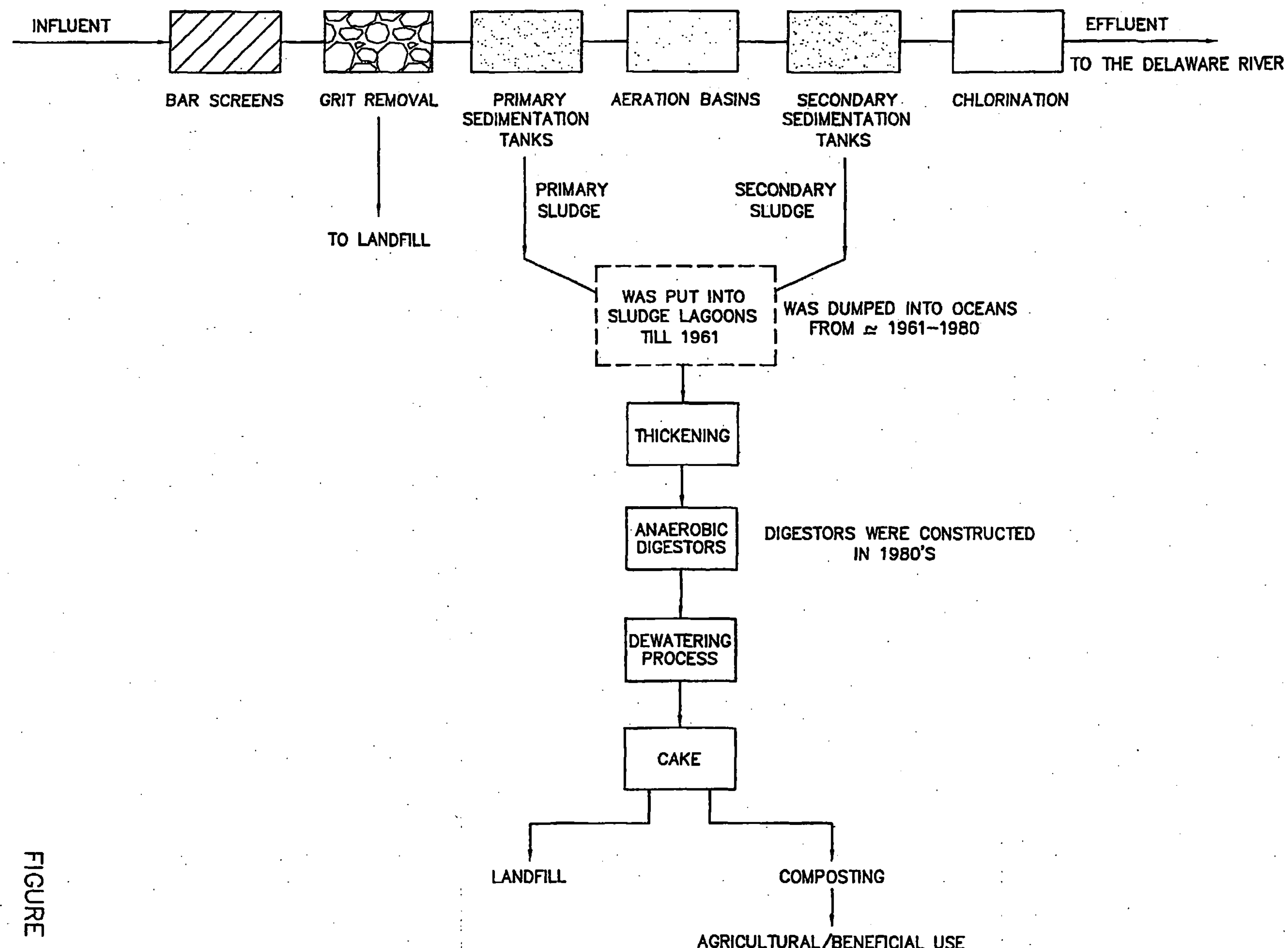
FIGURE 2

H:98159701\CADD\NEWPCP\CADD FILES FOR CLOSURE PLAN\SITEPLAN.DWG

SITE MAP FOR **PWD-NEWPCP CLOSURE PLAN**	**RETTEW** **ASSOCIATES, INC.** 3020 Columbia Ave., Lancaster, PA 17603 TEL (717) 394-3721 · FAX (717) 394-1063	DRAWN BY: TK DATE: 4/19/01 SCALE: 1"=500' DWG. NO. 981597-01-11

AR300238

A TYPICAL WASTEWATER TREATMENT PROCESS CONSISTS OF THE FOLLOWING:



AR300239

TYPICAL WASTEWATER TREATMENT PROCESS

PWD–NEWPCP CLOSURE PLAN

RETTEW ASSOCIATES, INC.
3020 Columbia Ave., Lancaster, PA 17603
TEL (717) 394-3721 · FAX (717) 394-1063

DRAWN BY: CTB
DATE: 12/31/01
SCALE: NOT TO SCALE
DWG. NO. 981597-01-11

H:\98159701\CADD\NEWPCP\TREATMENT PROCESS

FIGURE 3

FIGURE 4

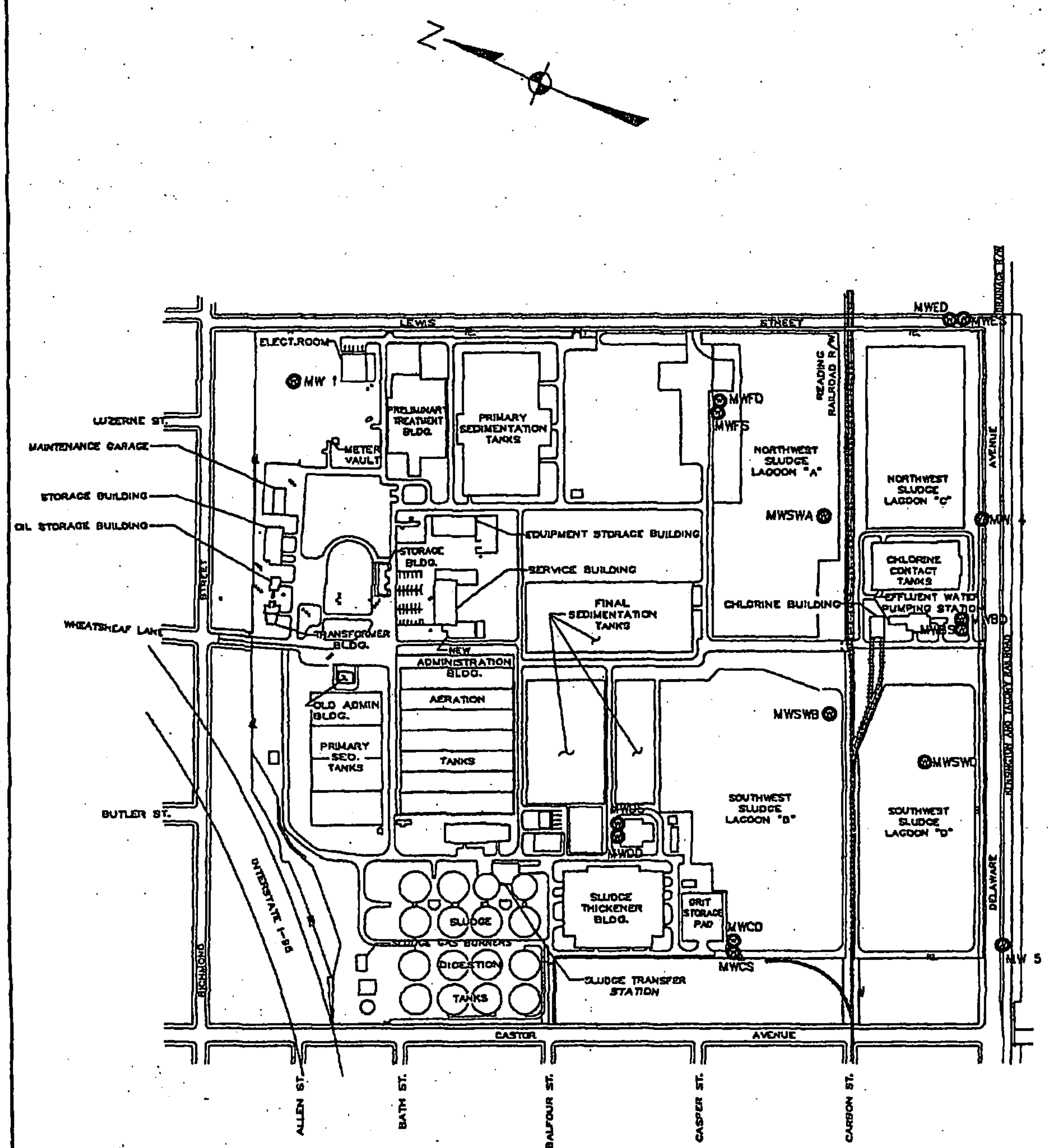
BASEMAP: CAMDEN, NJ 7.5' USGS TOPOGRAPHIC QUADRANGLE

SOURCE: NJDEP PUBLIC WATER SUPPLY WELL DATABASE

H:98\98159701\NEWPCP\Cadd Files for Closure Plan

LOCATION OF MAJOR WATER SUPPLY WELLS WITHIN 2-MILES OF NEWPCP IMPOUNDMENTS **PWD-NEWPCP CLOSURE PLAN**	RETTEW ASSOCIATES, INC. 3020 Columbia Ave., Lancaster, PA 17603 TEL (717) 394-3721 · FAX (717) 394-1063	DRAWN BY: CTB DATE: 12/28/01 SCALE: 1" = 1500' DWG. NO. 98-1597-01

AR300240



MW##
Represents the approximate location and corresponding number of monitoring well

MONITORING WELLS

ELEVATIONS ARE FROM TOP OF PVC PIPE

MW 1	ELEV. = 22.84
MW 4	ELEV. = 11.80
MW 5	ELEV. = 16.11
MWES	ELEV. = 8.37
MWED	ELEV. = 8.36
MWDS	ELEV. = 12.67
MWDD	ELEV. = 12.73
MWCS	ELEV. = 13.07
MWCD	ELEV. = 13.18
MWFD	ELEV. = 14.43
MWFS	ELEV. = 14.84
MWSWB	ELEV. = 11.47
MWSWD	ELEV. = 12.38
MWSWA	ELEV. = 11.58
MWBD	ELEV. = 12.25
MWBS	ELEV. = 12.05

1"=500'
0' 250' 500' 1000' 1500'

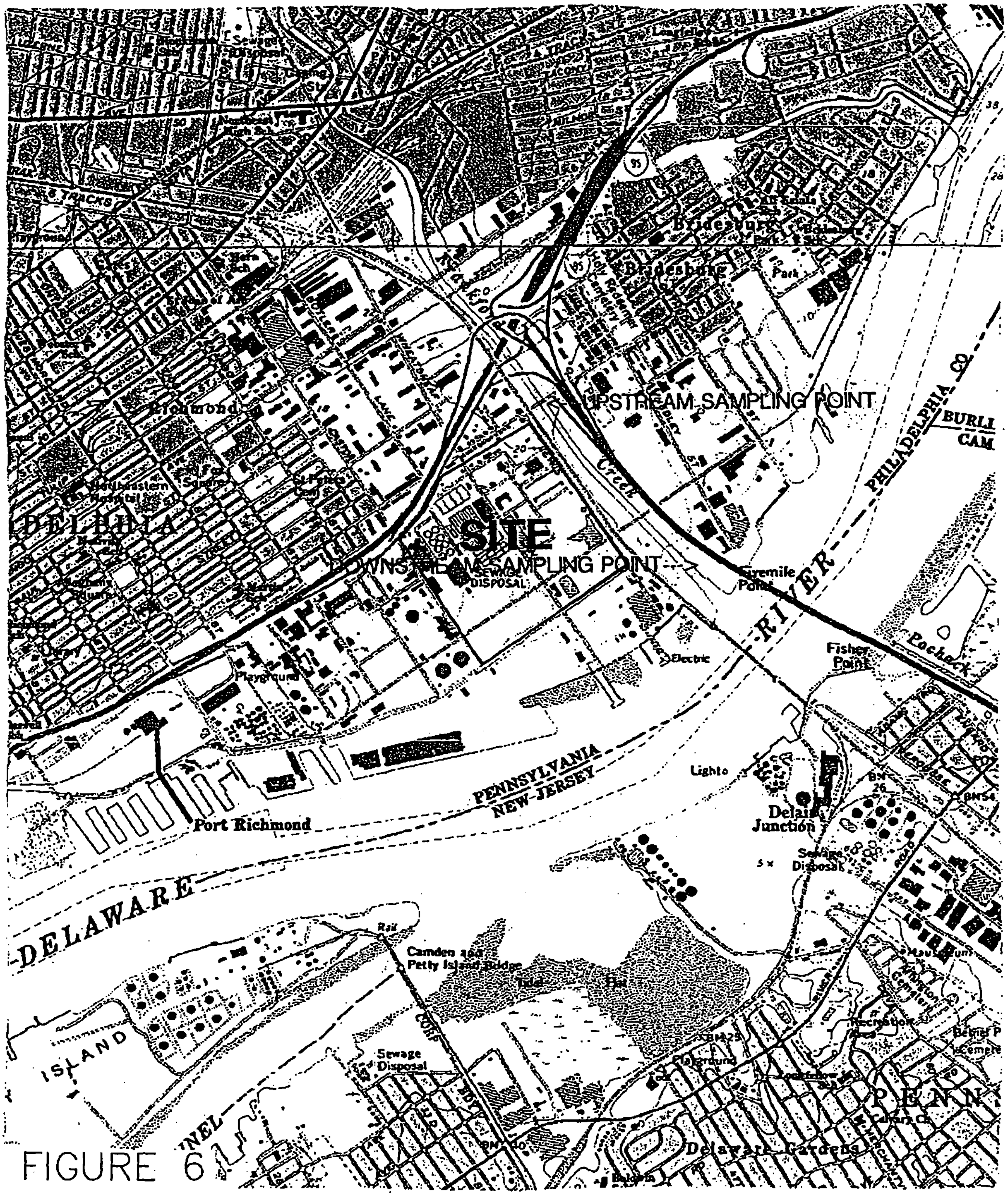
FIGURE 5

H:98159701\CADD\NEWPCP\CADD FILES FOR CLOSURE PLAN\SITEPLAN.DWG

LOCATION OF MONITORING WELLS
FOR
PWD-NEWPCP CLOSURE PLAN

RETTEW
ASSOCIATES, INC.
3020 Columbia Ave., Lancaster, PA 17603

DRAWN BY: TK
DATE: 4/19/01
SCALE: 1"=500'
DWG NO 981597-01-11

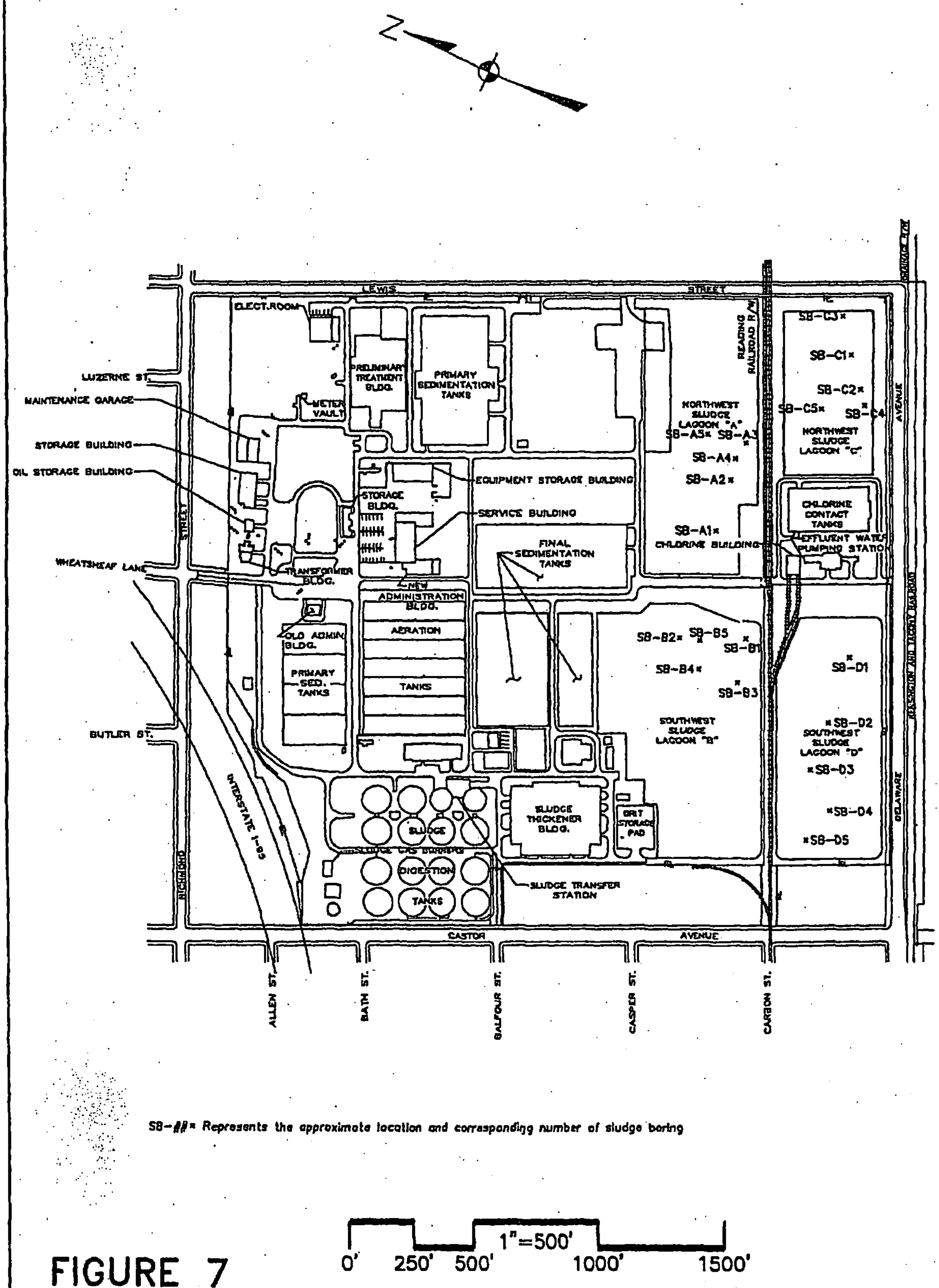


BASEMAP: CAMDEN, NJ 7.5' USGS TOPOGRAPHIC QUADRANGLE

H:98\98159701\NEWPCP\Cadd Files for Closure Plan

LOCATION OF FRANKFORD CREEK SURFACE WATER SAMPLES **PWD–NEWPCP CLOSURE PLAN**	**RETTEW** ASSOCIATES, INC. 3020 Columbia Ave., Lancaster, PA 17603 TEL (717) 394-3721 · FAX (717) 394-1063	DRAWN BY: CTB DATE: 12/31/01 SCALE: 1" = 1500' DWG. NO. 98-1597-01

AR300242



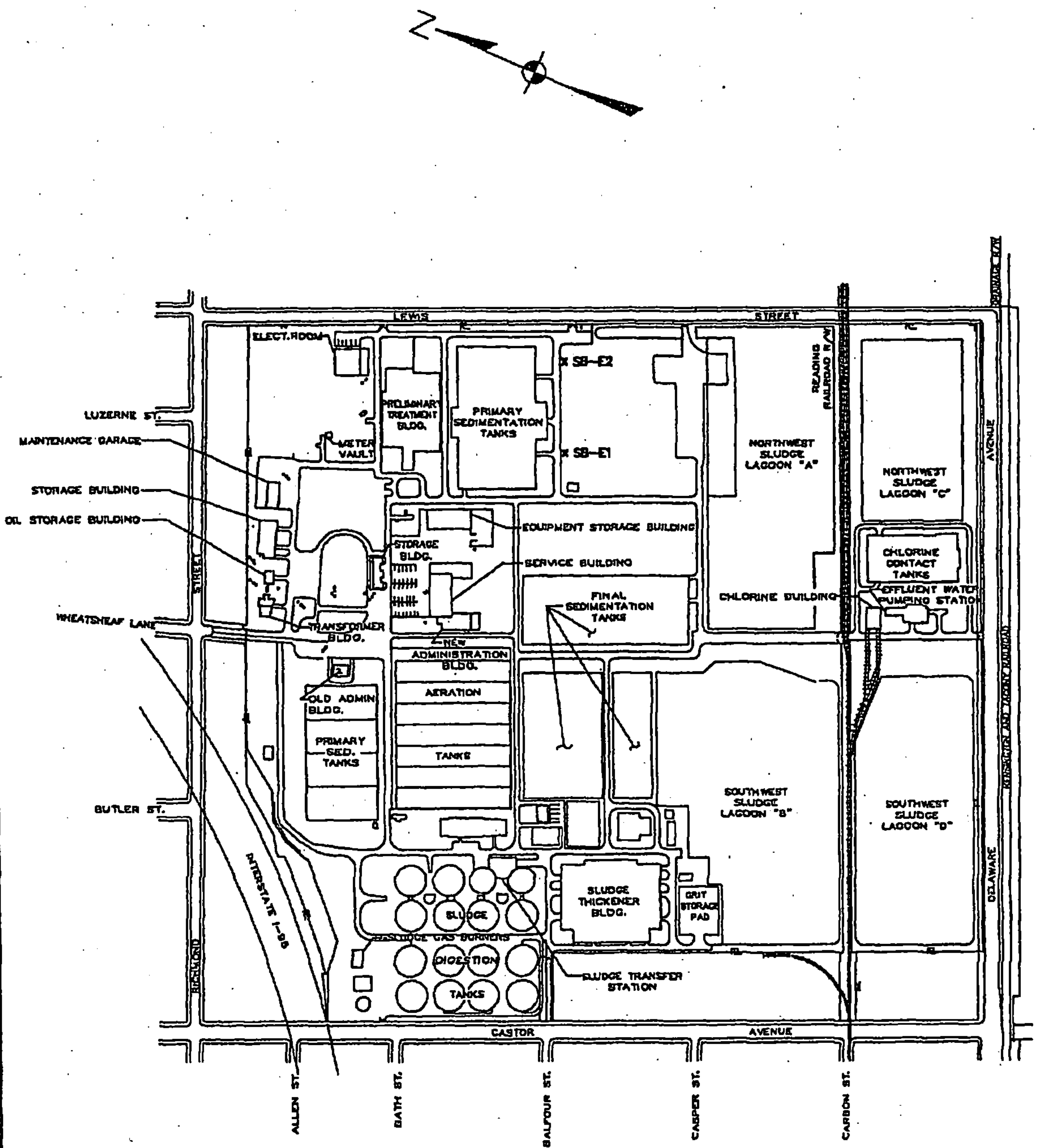
SB-##× Represents the approximate location and corresponding number of sludge boring

FIGURE 7

H:98159701\CADD\NEWPCP\CADD FILES FOR CLOSURE PLAN\SITEPLAN.DWG

LOCATION OF SLUDGE BORINGS FOR **PWD–NEWPCP CLOSURE PLAN**	**RETTEW** ASSOCIATES, INC. 3020 Columbia Ave., Lancaster, PA 17603 TEL (717) 394-3721 · FAX (717) 394-1063	DRAWN BY: TK DATE: 4/19/01 SCALE: 1"=500' DWG. NO. 981597-01-11

AR300243



SB-## x Represents the approximate location and corresponding number of former sludge borings

1"=500'

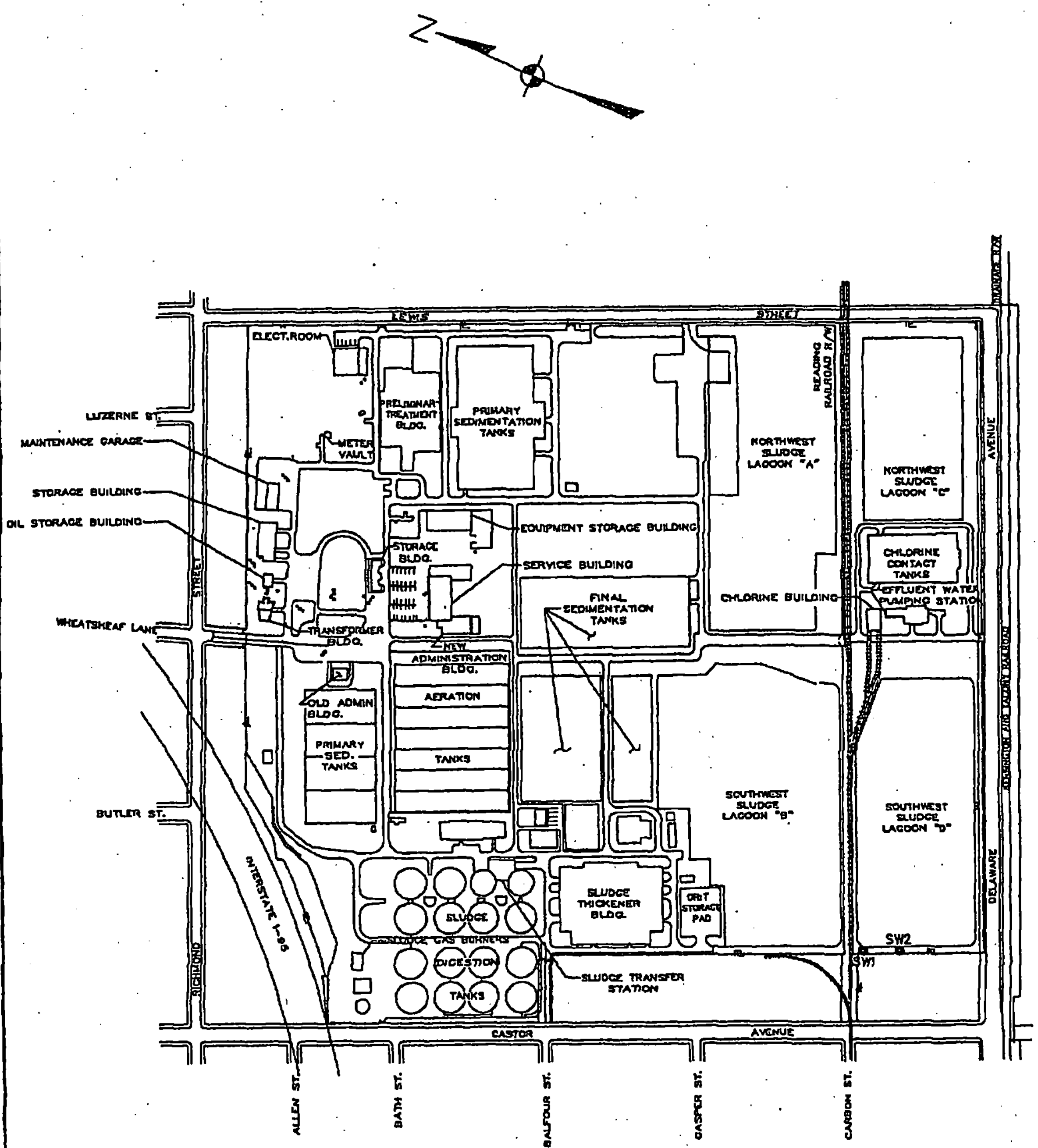
0' 250' 500' 1000' 1500'

FIGURE 8

H:98159701\CADD\NEWPCP\CADD FILES FOR CLOSURE PLAN\SITEPLAN.DWG

LOCATION OF FORMER IMPOUNDMENT E SLUDGE BORINGS FOR **PWD-NEWPCP CLOSURE PLAN**	RETTEW ASSOCIATES, INC. 3020 Columbia Ave., Lancaster, PA 17603 TEL (717) 394-3721 · FAX (717) 394-1063	DRAWN BY: TK DATE: 4/19/01 SCALE: 1"=500' DWG. NO. 981597-01-11

AR300244



SW2 ● Represents the approximate location and corresponding number of Franklin Smelter waste samples

1"=500'

0' 250' 500' 1000' 1500'

FIGURE 9

H:98159701\CADD\NEWPCP\CADD FILES FOR CLOSURE PLAN\SITEPLAN.DWG

LOCATION OF FRANKLIN SMELTER WASTE SAMPLES FOR **PWD-NEWPCP CLOSURE PLAN**	RETTEW ASSOCIATES, INC. 3020 Columbia Ave., Lancaster, PA 17603 TEL (717) 394-3721 · FAX (717) 394-1083	DRAWN BY: TK DATE: 4/19/01 SCALE: 1"=500' DWG. NO. 981597-01-11

AR300245

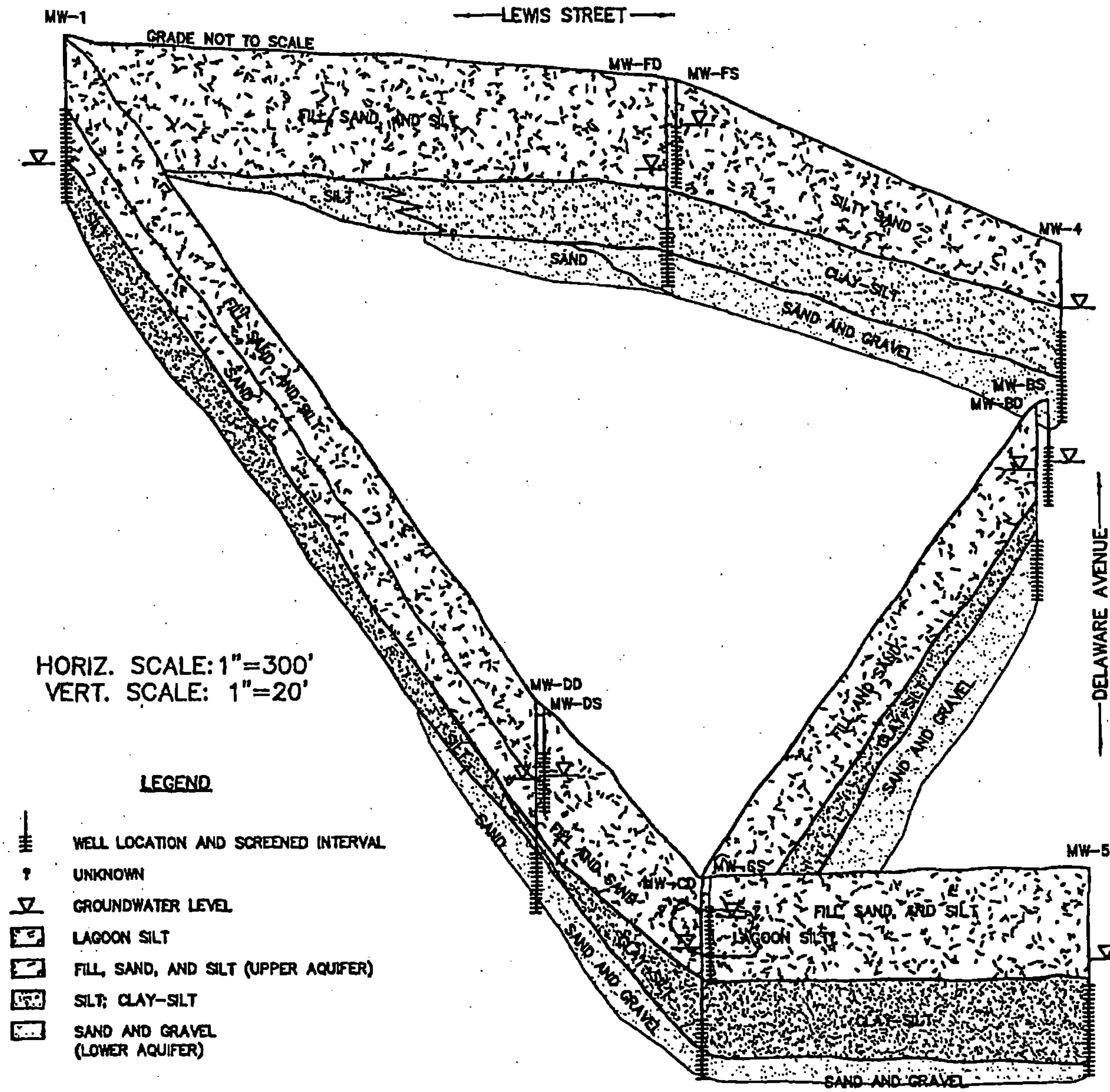
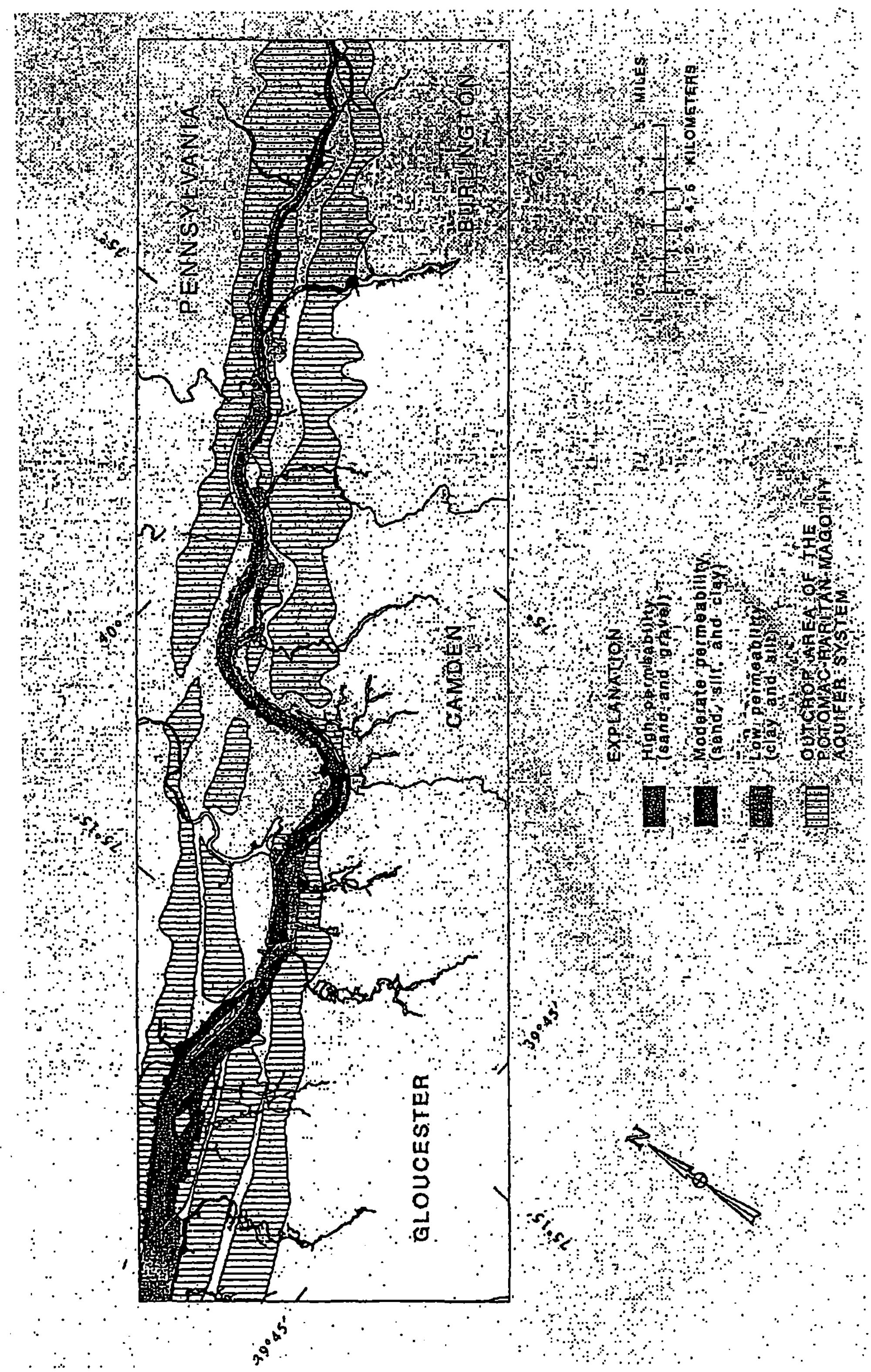


FIGURE 10

PWD-NEWPCP CLOSURE PLAN	GEOLOGIC CROSS SECTION MARCH 2001	
	PROJECT NO: 981597-01-11	RETTEW ASSOCIATES, INC.

98\98159701\NEWPCP\CADD Files for Closure Plan\Figures.dwg

AR300247



FROM NAVOY AND CARLETON, 1995

FIGURE 11

H:\98\98159701\CADD\GEOSCI\CROSS-SECTIONS.DWG

GEOPHYSICAL SURVEY RESULTS OF DELAWARE RIVER–RIVERBED SEDIMENTS REPRODUCED FOR **PWD–NEWPCP CLOSURE PLAN**	RETTEW ASSOCIATES, INC. 3020 Columbia Ave., Lancaster, PA 17603 TEL (717) 394-3721 · FAX (717) 394-1063	DRAWN BY: TK DATE: 12/21/01 SCALE: AS NOTED DWG. NO. 981597-01-04

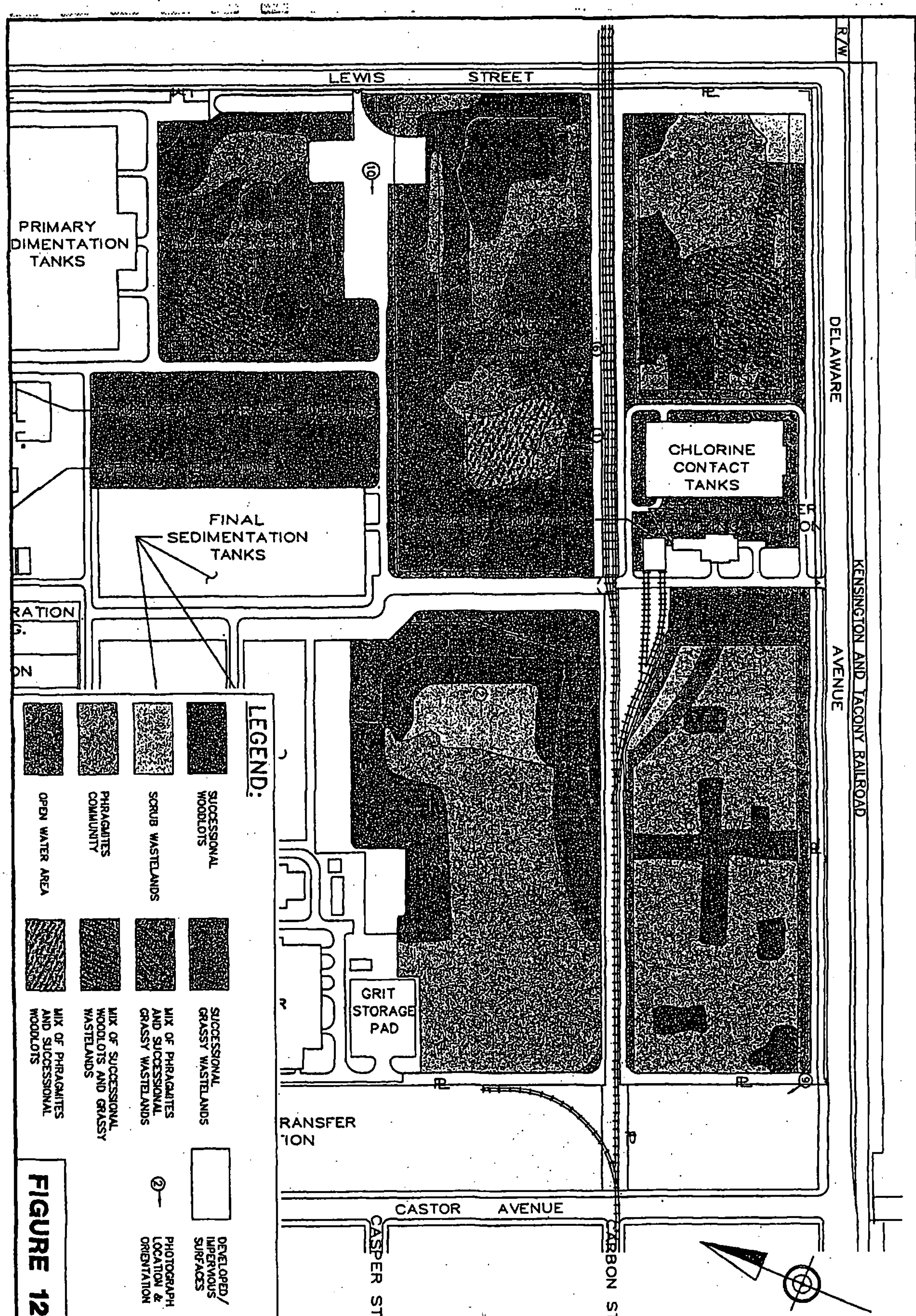


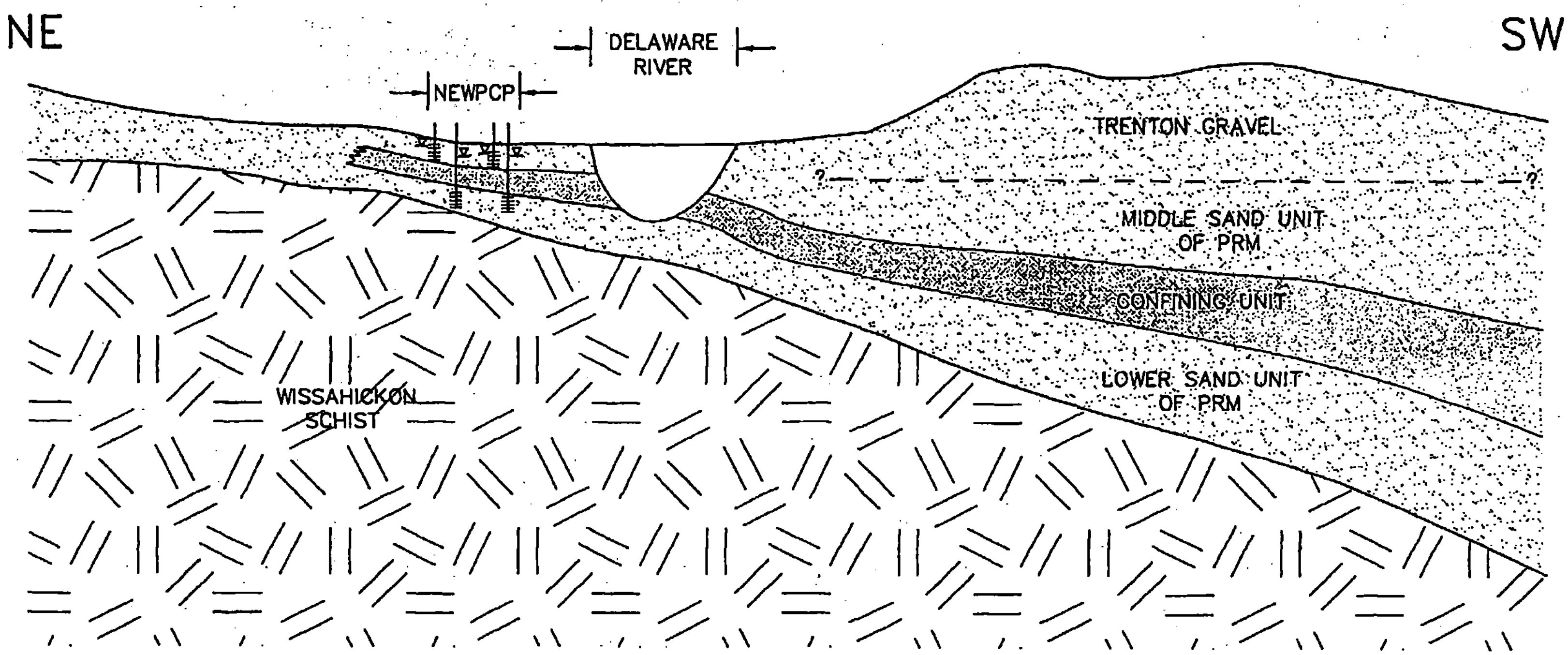
FIGURE 12

LAGOON HABITAT COVER TYPE MAP
FOR
PWP-NEWPCP CLOSURE PLAN

RETTEW
ASSOCIATES, INC.
3020 Columbia Ave., Lancaster, PA 17603
(717) 394-3721 · Fax (717) 394-1063
Engineers · Planners · Scientists · Landscape Architects · Surveyors

DRAWN BY: TK
DATE: 7/3/01
SCALE: 1"=200'
DWG. NO. 981597-01-11
H:\98159701\CADD\NEWPCP\HABITAT MAP.DWG

AR300248



500' HORIZONTAL SCALE

100' VERTICAL SCALE

CONFINING UNIT CONSISTS OF TIDAL FLAT SEDIMENTS (PROXIMAL TO THE DELAWARE RIVER) AND THE LOWER CLAY UNIT OF THE PRM

NEWPCP SHALLOW AND DEEP GROUNDWATER MONITORING WELLS AND STATIC WATER LEVELS

FIGURE 13

GENERALIZED HYDROGEOLOGIC CROSS-SECTION

PWD-NEWPCP CLOSURE PLAN

RETTEW ASSOCIATES, INC.
3020 Columbia Ave., Lancaster, PA 17603
TEL (717) 394-3721 · FAX (717) 394-1063

H:\98\981597.01\CADD\GEOSCI\CROSS-SECTIONS.DWG

DRAWN BY: TK
DATE: 12/21/01
SCALE: AS NOTED
DWG. NO. 981597-01-04

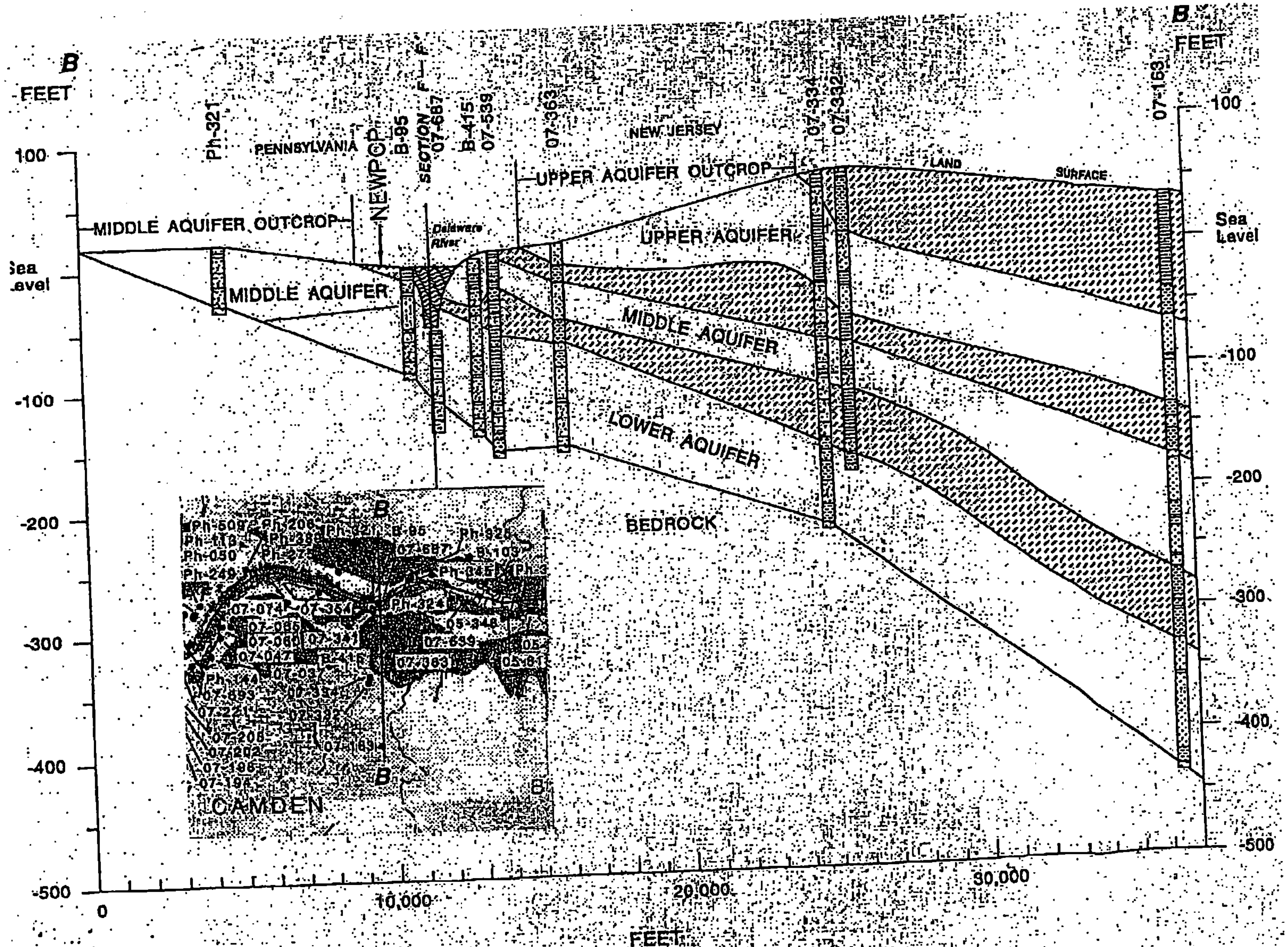


FIGURE 14

AR300250

CROSS-SECTION DEVELOPED BY NAVOY AND CARLETON, 1995
REPRODUCED FOR
PWD-NEWPCP CLOSURE PLAN

RETTEW
ASSOCIATES, INC.
3020 Columbia Ave., Lancaster, PA 17603
TEL (717) 394-3721 · FAX (717) 394-1063

H:\98\98159701\CADD\GEOSCI\CROSS-SECTIONS.DWG

DRAWN BY: TK
DATE: 12/21/01
SCALE: AS NOTED
DWG. NO. 981597-01-04

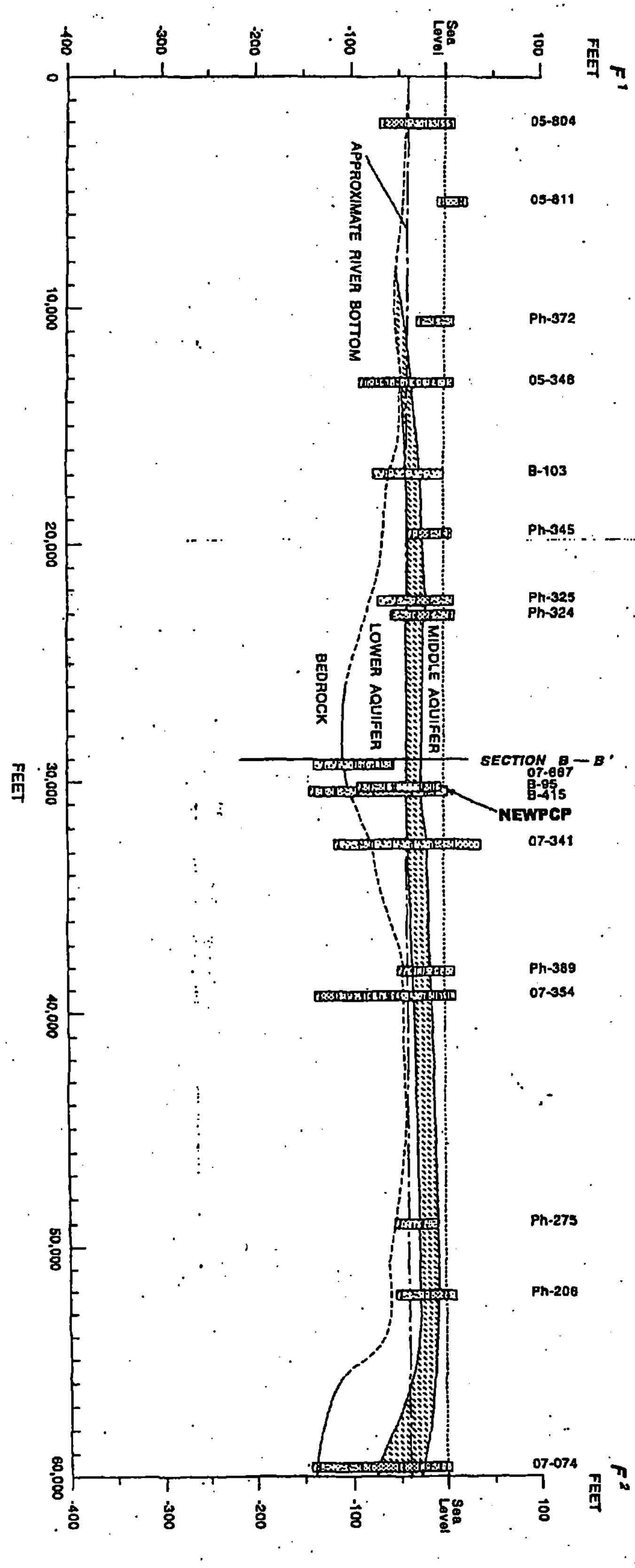


FIGURE 15

CROSS–SECTION DEVELOPED BY
NAVOY AND CARLETON, 1995

REPRODUCED FOR
PWD–NEWPCP CLOSURE PLAN

RETTEW
ASSOCIATES, INC.
3020 Columbia Ave., Lancaster, PA 17603
(717) 394-3721 · Fax (717) 394-1063
Engineers · Planners · Scientists · Landscape Architects · Surveyors

DRAWN BY: ______
DATE: 12/21/01
SCALE: AS NOTED
DWG. NO. 981597-01-04
H:\...\GEOSCI\CROSS-SECTIONS.DWG

SIMULATED HEADS IN THE LOWER SAND UNIT

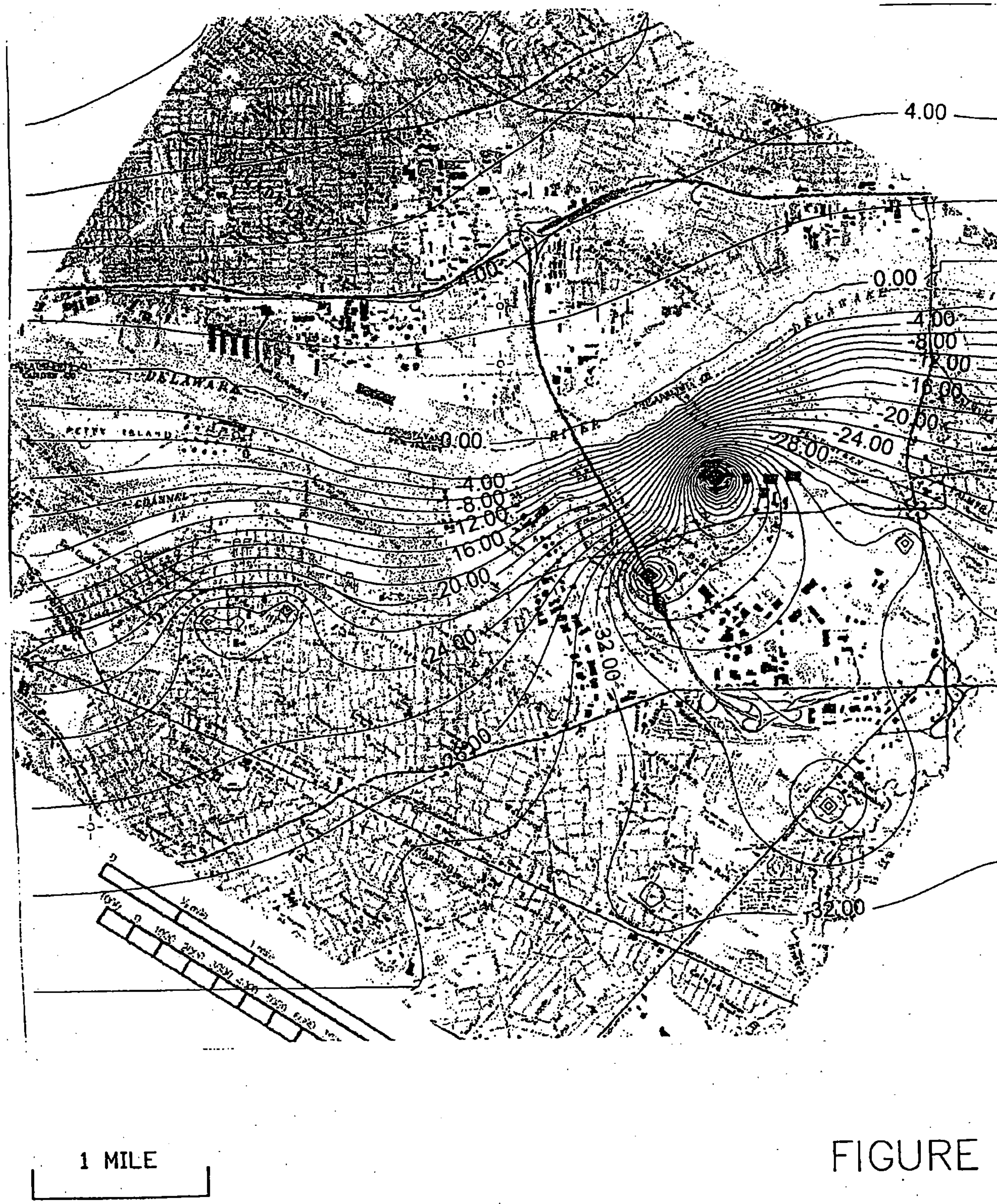
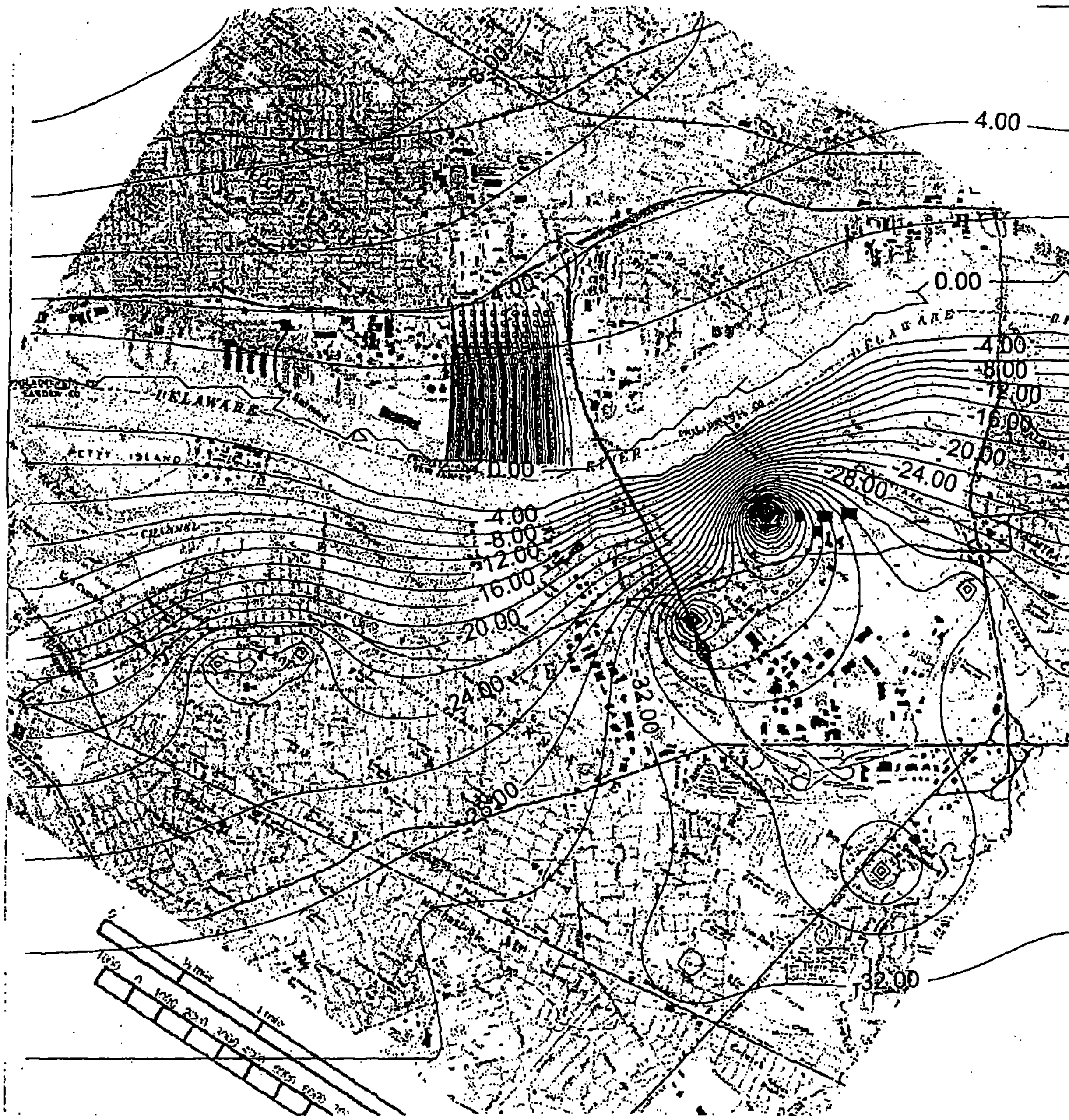


FIGURE 16

H:98\98159701\NEWPCP\Cadd Files for Closure Plan

MODEL RUN #1 STEADY STATE CALIBRATED MODEL SIMULATING 1988 PUMPING CONDITIONS **PWD–NEWPCP CLOSURE PLAN**	**RETTEW** ASSOCIATES, INC. 3020 Columbia Ave., Lancaster, PA 17603 TEL (717) 394-3721 · FAX (717) 394-1063	DRAWN BY: CTB DATE: 12/31/01 SCALE: 1" = 4250' DWG. NO. 98-1597-01

AR300252



1 MILE

FIGURE 17

H:98\98159701\NEWPCP\Cadd Files for Closure Plan

MODEL RUN #1 RESULTS OF PARTICLE TRACKING ANALYSIS **PWD–NEWPCP CLOSURE PLAN**	**RETTEW** ASSOCIATES, INC. 3020 Columbia Ave., Lancaster, PA 17603 TEL (717) 394-3721 · FAX (717) 394-1063	DRAWN BY: CTB DATE: 12/31/01 SCALE: 1" = 4250' DWG. NO. 98-1597-01

AR300253

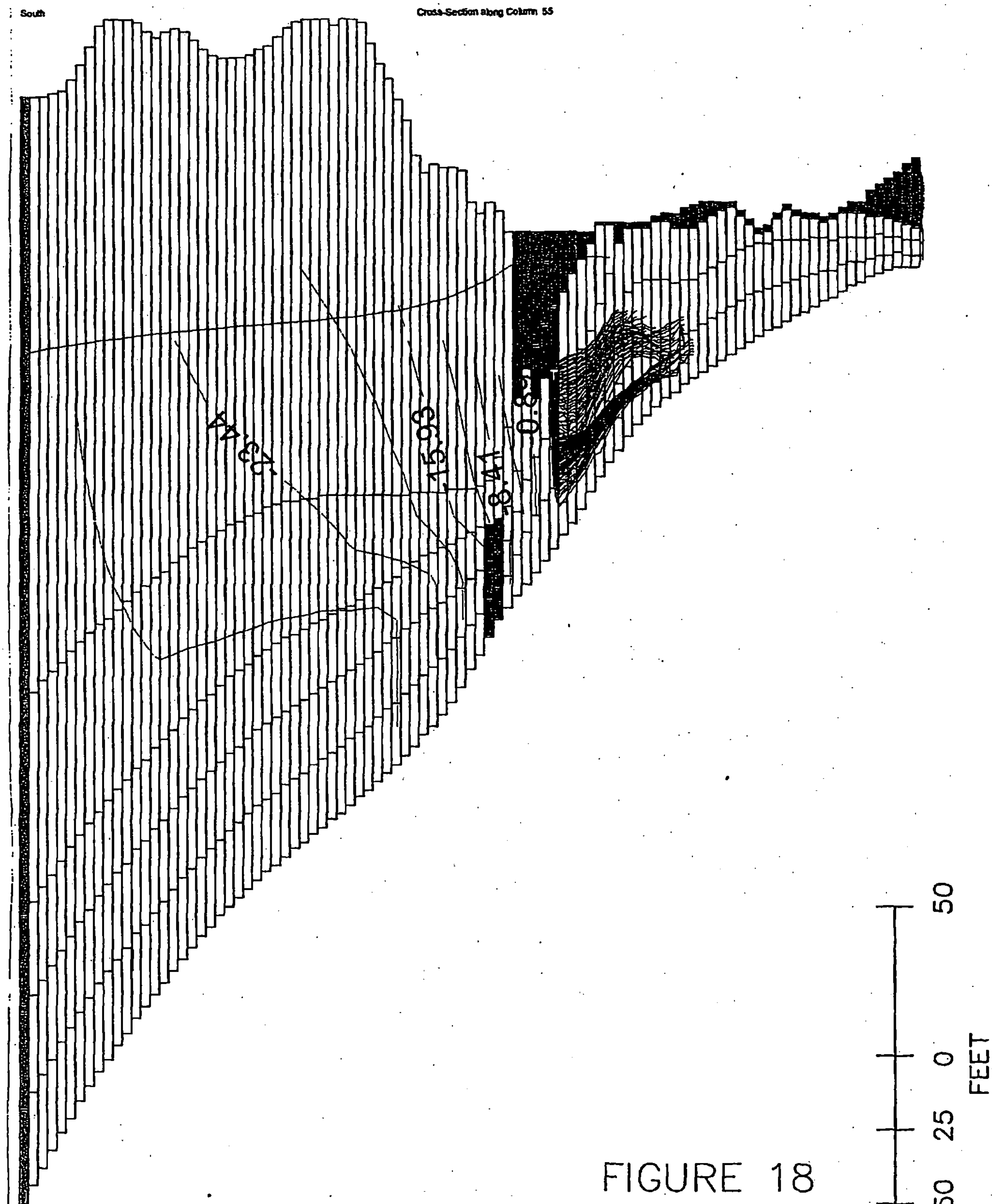


FIGURE 18

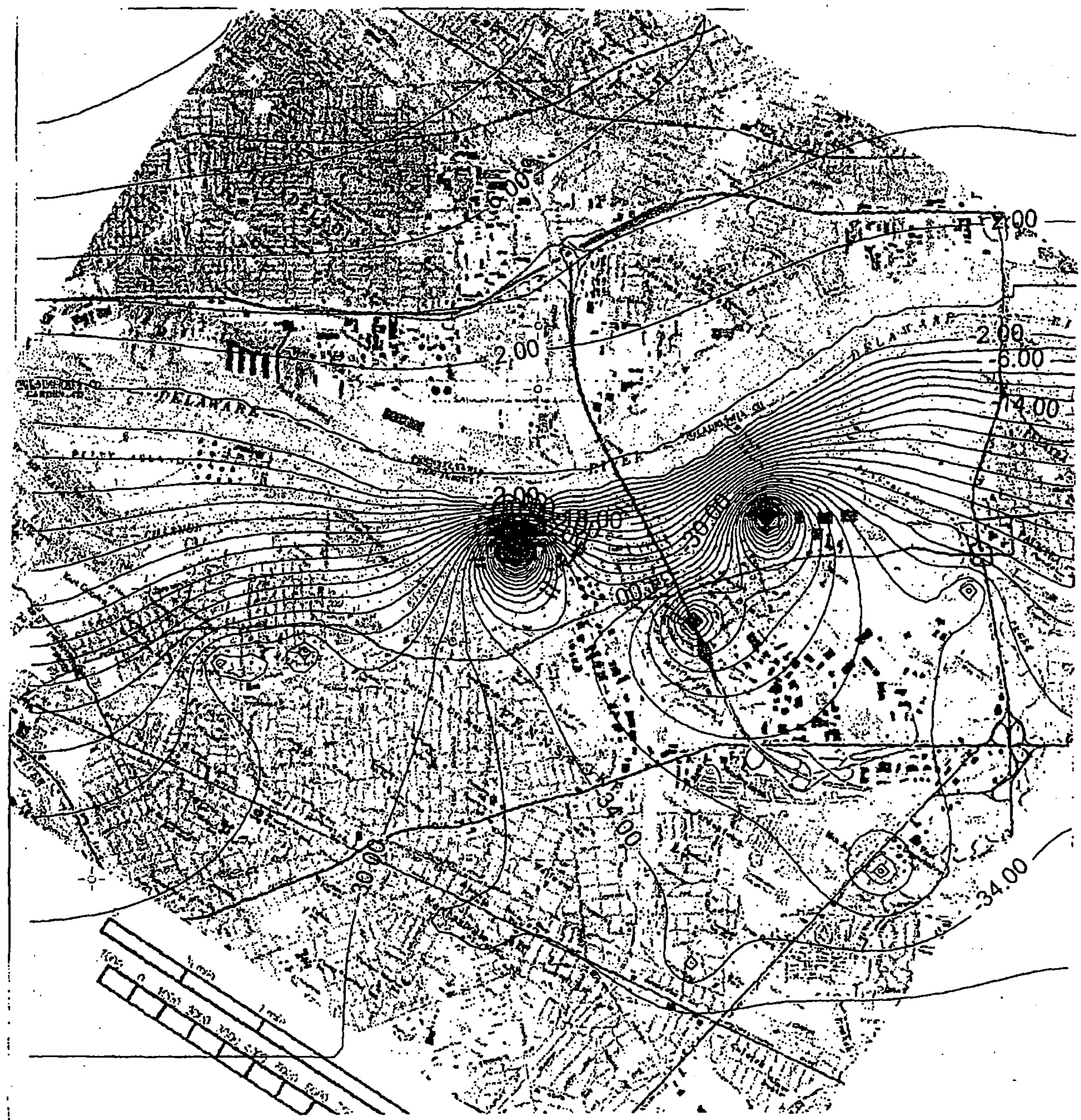
H:98\98159701\NEWPCP\Cadd Files for Closure Plan\Closure Plan Figure Templates.dwg

MODEL RUN #1
RESULTS OF PARTICLE TRACKING ANALYSIS
PWD-NEWPCP CLOSURE PLAN

RETTEW
ASSOCIATES, INC.
3020 Columbia Ave., Lancaster, PA 17603
TEL (717) 394-3721 · FAX (717) 394-1063

DRAWN BY: CTB
DATE: 12/31/01
SCALE: NTS
DWG. NO. 98-1597-01

SIMULATED HEADS IN THE LOWER SAND UNIT



1 MILE

FIGURE 19

H:98\98159701\NEWPCP\Cadd Files for Closure Plan

MODEL RUN #2 ADDITION OF HYPOTHETICAL PUMPING WELL ACROSS THE DELAWARE RIVER **PWD–NEWPCP CLOSURE PLAN**	RETTEW ASSOCIATES, INC. 3020 Columbia Ave., Lancaster, PA 17603 TEL (717) 394-3721 · FAX (717) 394-1063	DRAWN BY: CTB DATE: 12/31/01 SCALE: 1" = 4250' DWG. NO. 98-1597-01

AR300268

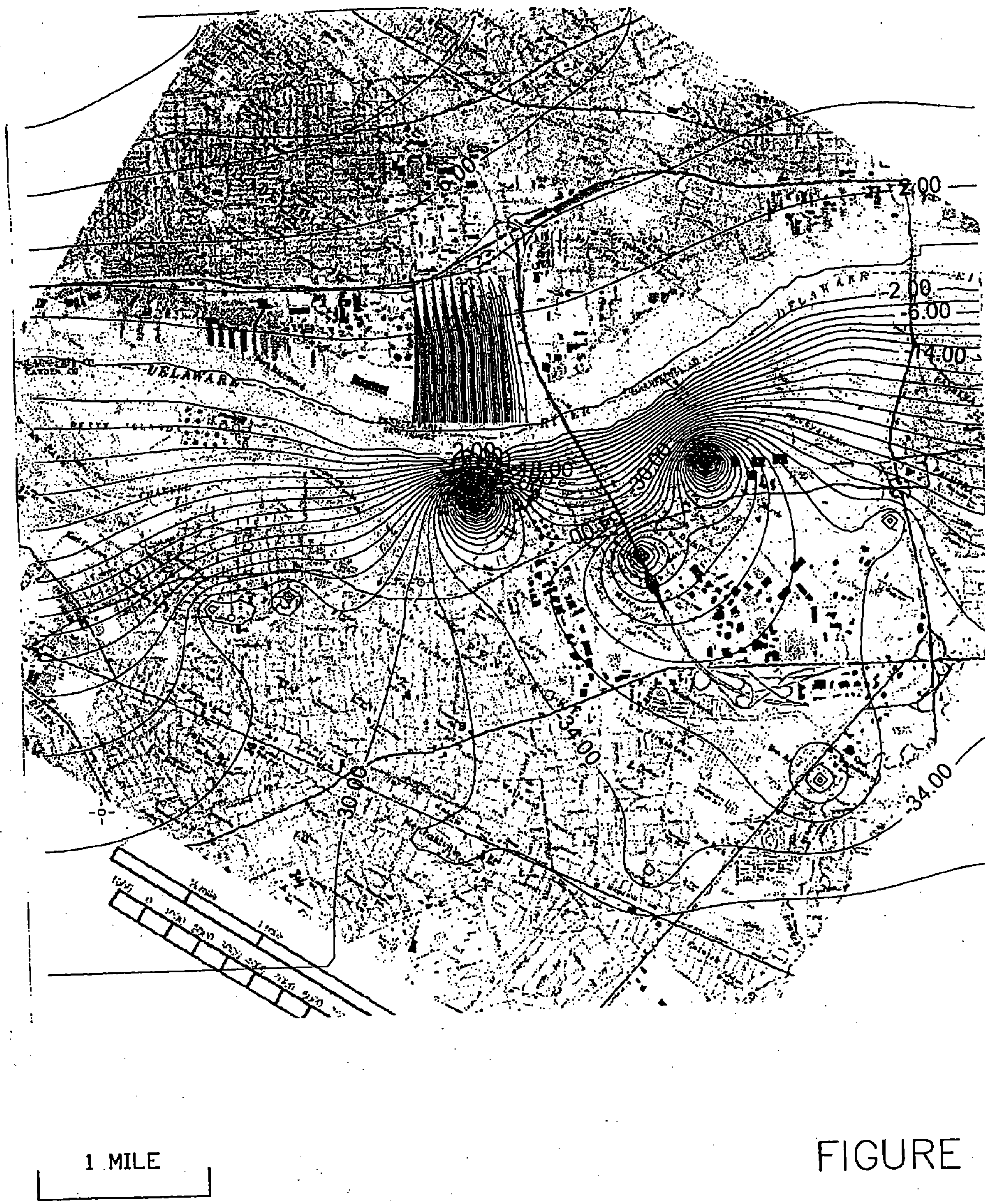


FIGURE 20

H:98\98159701\NEWPCP\Cadd Files for Closure Pla

MODEL RUN #2
RESULTS OF PARTICLE TRACKING ANALYSIS
PWD–NEWPCP CLOSURE PLAN

RETTEW ASSOCIATES, INC.
3020 Columbia Ave., Lancaster, PA 17603
TEL (717) 394-3721 · FAX (717) 394-1063

DRAWN BY:	CTB
DATE:	12/31/01
SCALE:	1" = 4250'
DWG. NO.	98-1597-01

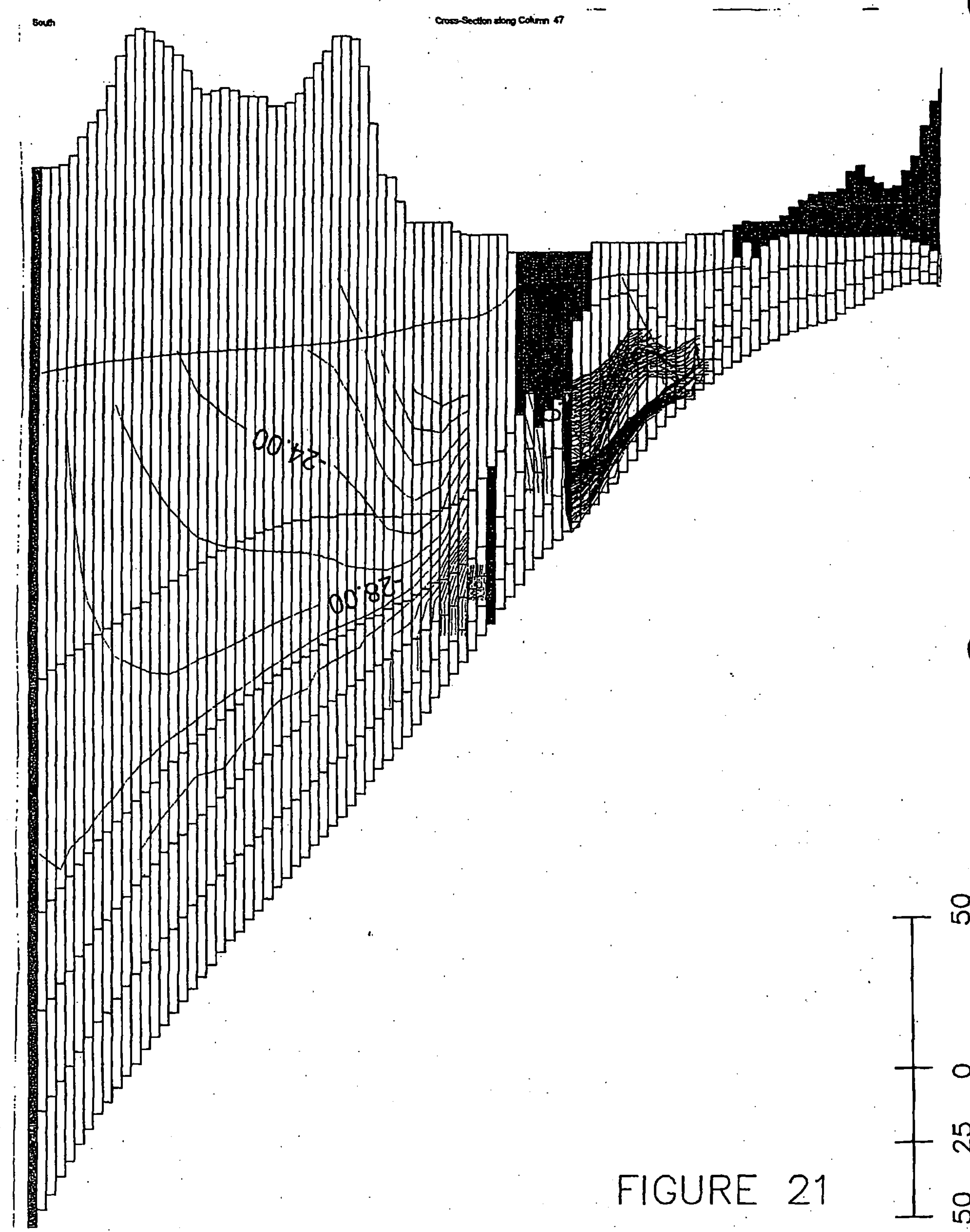


FIGURE 21

H:98\98159701\NEWPCP\Cadd Files for Closure Plan\Closure Plan Figure Temp

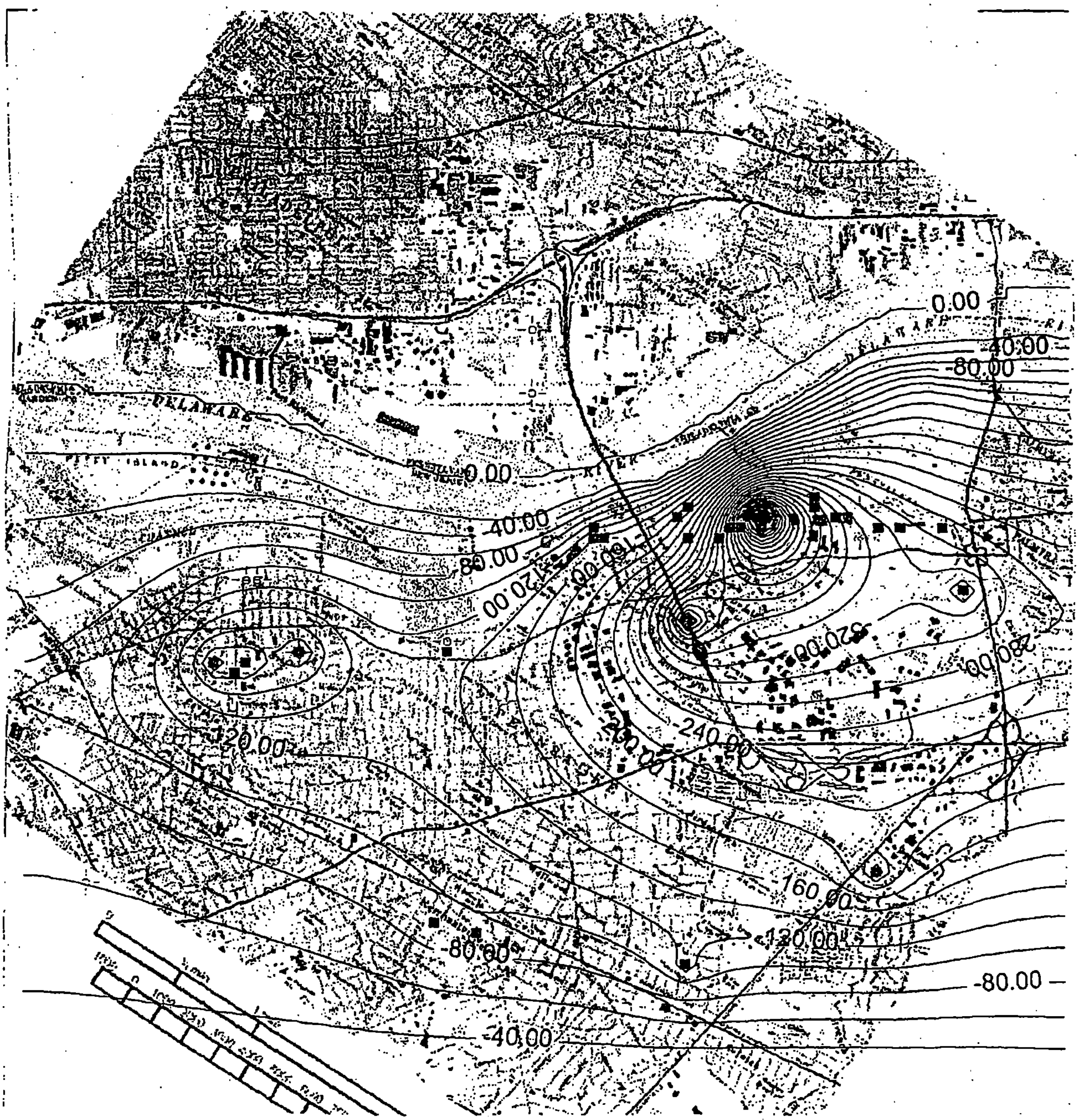
MODEL RUN #2
RESULTS OF PARTICLE TRACKING ANALYSIS
PWD–NEWPCP CLOSURE PLAN

RETTEW
ASSOCIATES, INC.
3020 Columbia Ave., Lancaster, PA 17603

DRAWN BY: CTB
DATE: 12/31/01
SCALE: NTS
DWG. NO. 98–1597–01

AR300257

SIMULATED HEADS IN THE LOWER SAND UNIT



1 MILE

FIGURE 22

H:98\98159701\NEWPCP\Cadd Files for Closure Plan

MODEL RUN #3 SIMULATED PUMPING RATES
TEN TIMES GREATER THAN 1988 RATES

PWD-NEWPCP CLOSURE PLAN

RETTEW ASSOCIATES, INC.
3020 Columbia Ave., Lancaster, PA 17603
TEL (717) 394-3721 · FAX (717) 394-1063

DRAWN BY: CTB
DATE: 12/31/01
SCALE: 1" = 4250'
DWG. NO. 98-1597-01

AR300258

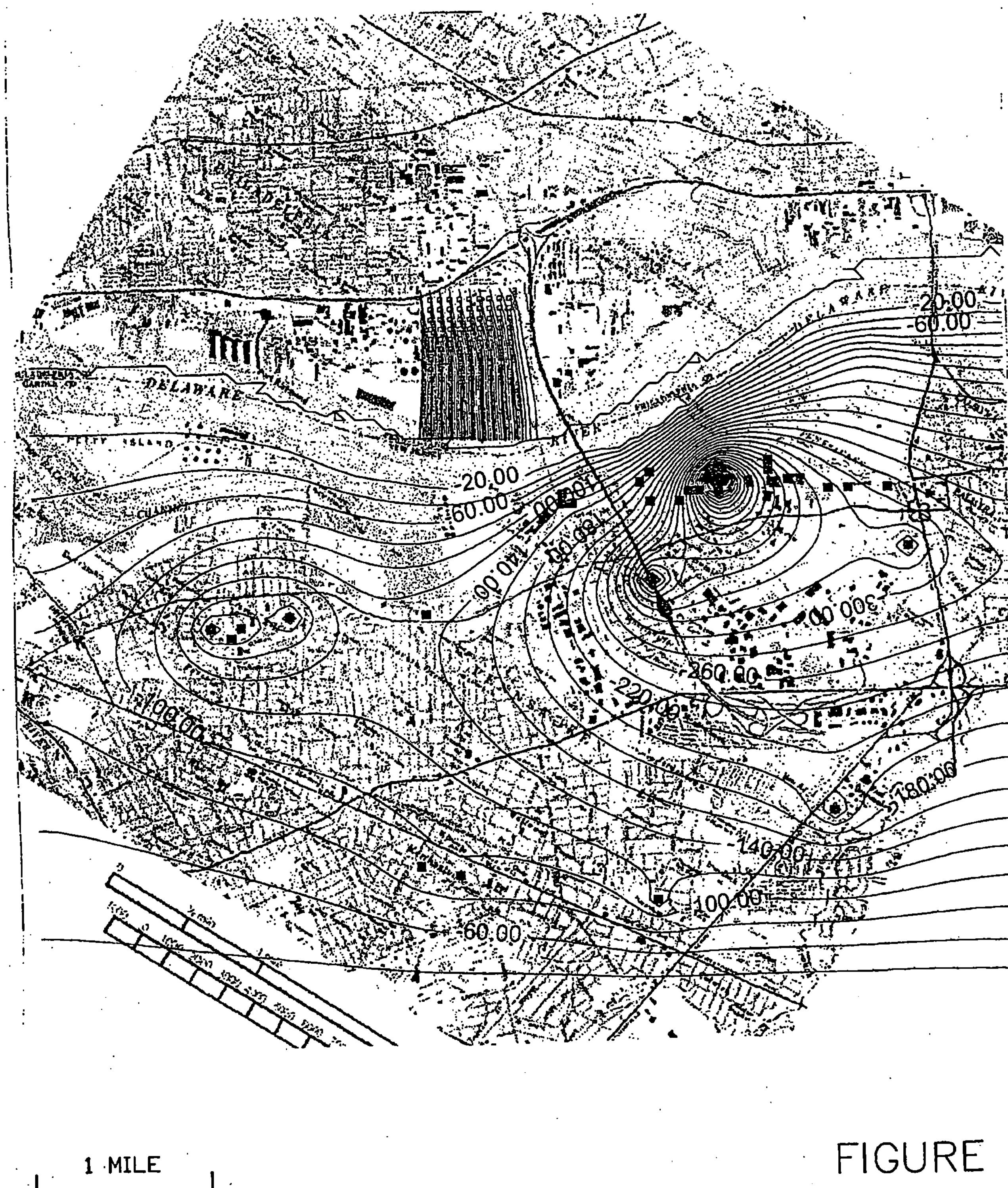


FIGURE 23

H:98\98159701\NEWPCP\Cadd Files for Closure Plan

MODEL RUN #3 RESULTS OF PARTICLE TRACKING ANALYSIS **PWD-NEWPCP CLOSURE PLAN**	**RETTEW** ASSOCIATES, INC. 3020 Columbia Ave., Lancaster, PA 17603 TEL (717) 394-3721 · FAX (717) 394-1063	DRAWN BY: CTB DATE: 12/31/ SCALE: 1" = 4250' DWG. NO. 98-1597-01

AR300259

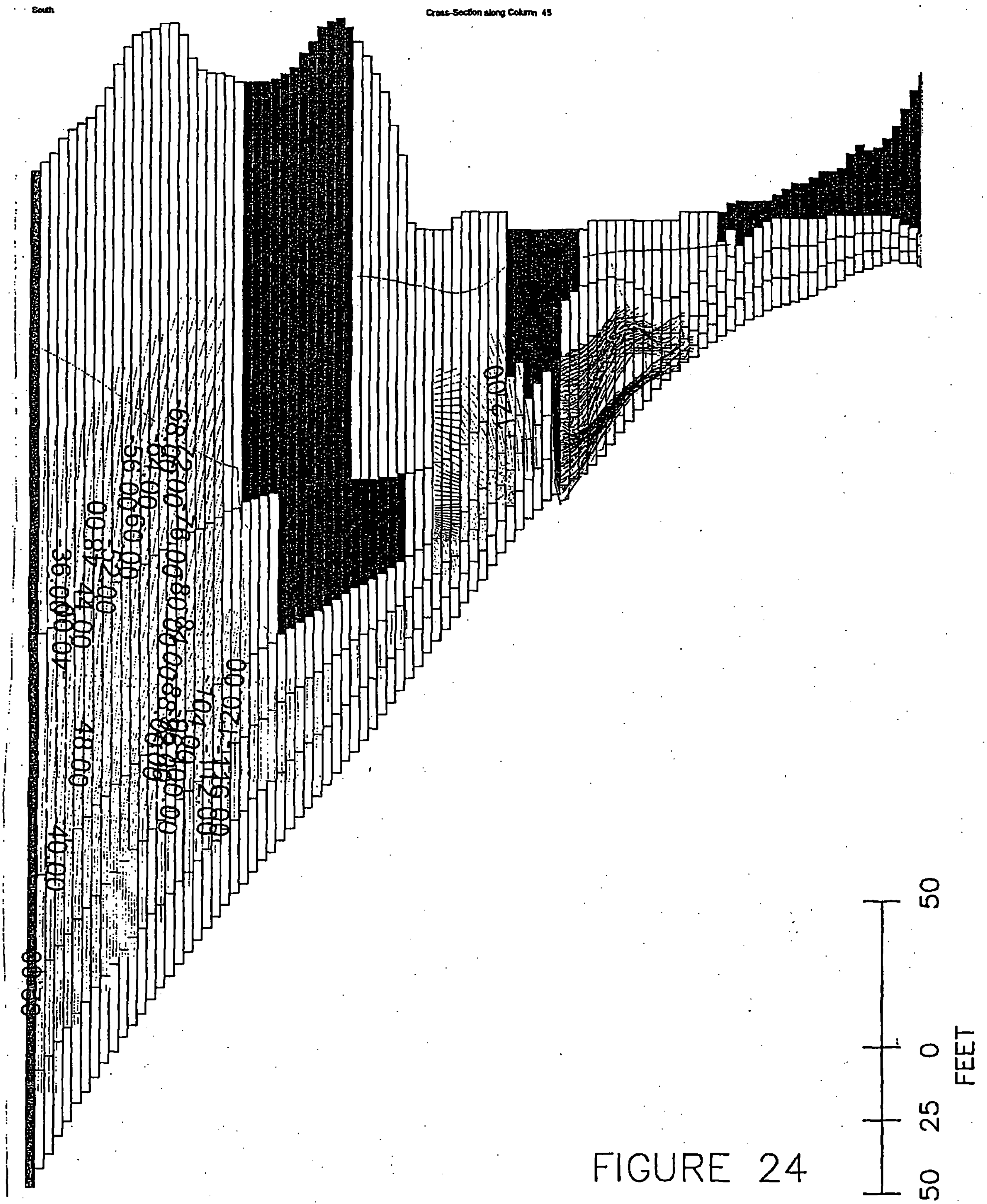


FIGURE 24

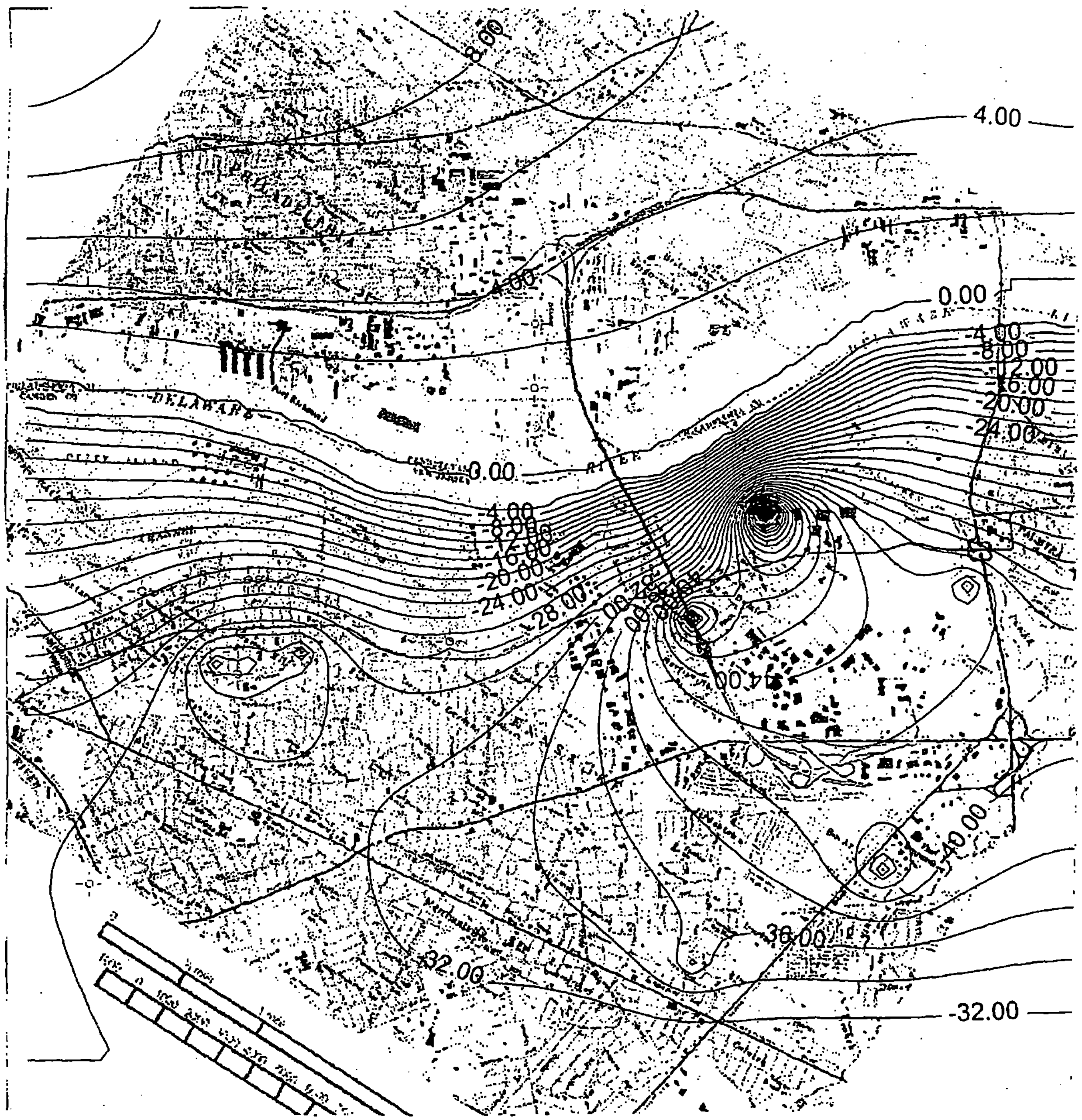
H:98\98159701\NEWPCP\Cadd Files for Closure Plan\Closure Plan Figure Templates.dwg

MODEL RUN #3
RESULTS OF PARTICLE TRACKING ANALYSIS
PWD–NEWPCP CLOSURE PLAN

RETTEW
ASSOCIATES, INC.
3020 Columbia Ave., Lancaster, PA 17603
TEL (717) 394-3721 · FAX (717) 394-1063

DRAWN BY: CTB
DATE: 12/31/01
SCALE: NTS
DWG. NO. 98-1597-01

SIMULATED HEADS IN THE LOWER SAND UNIT



1 MILE

FIGURE 25

H:98\98159701\NEWPCP\Cadd Files for Closure Plan

MODEL RUN #4 HYDRAULIC CONDUCTIVITY OF THE LOWER CLAY UNIT = 1x10^-7 FT/DAY

PWD-NEWPCP CLOSURE PLAN

RETTEW ASSOCIATES, INC.
3020 Columbia Ave., Lancaster, PA 17603
TEL (717) 394-3721 · FAX (717) 394-1063

DRAWN BY: CTB
DATE: 12/31/01
SCALE: 1" = 4250'
DWG. NO. 98-1597-01

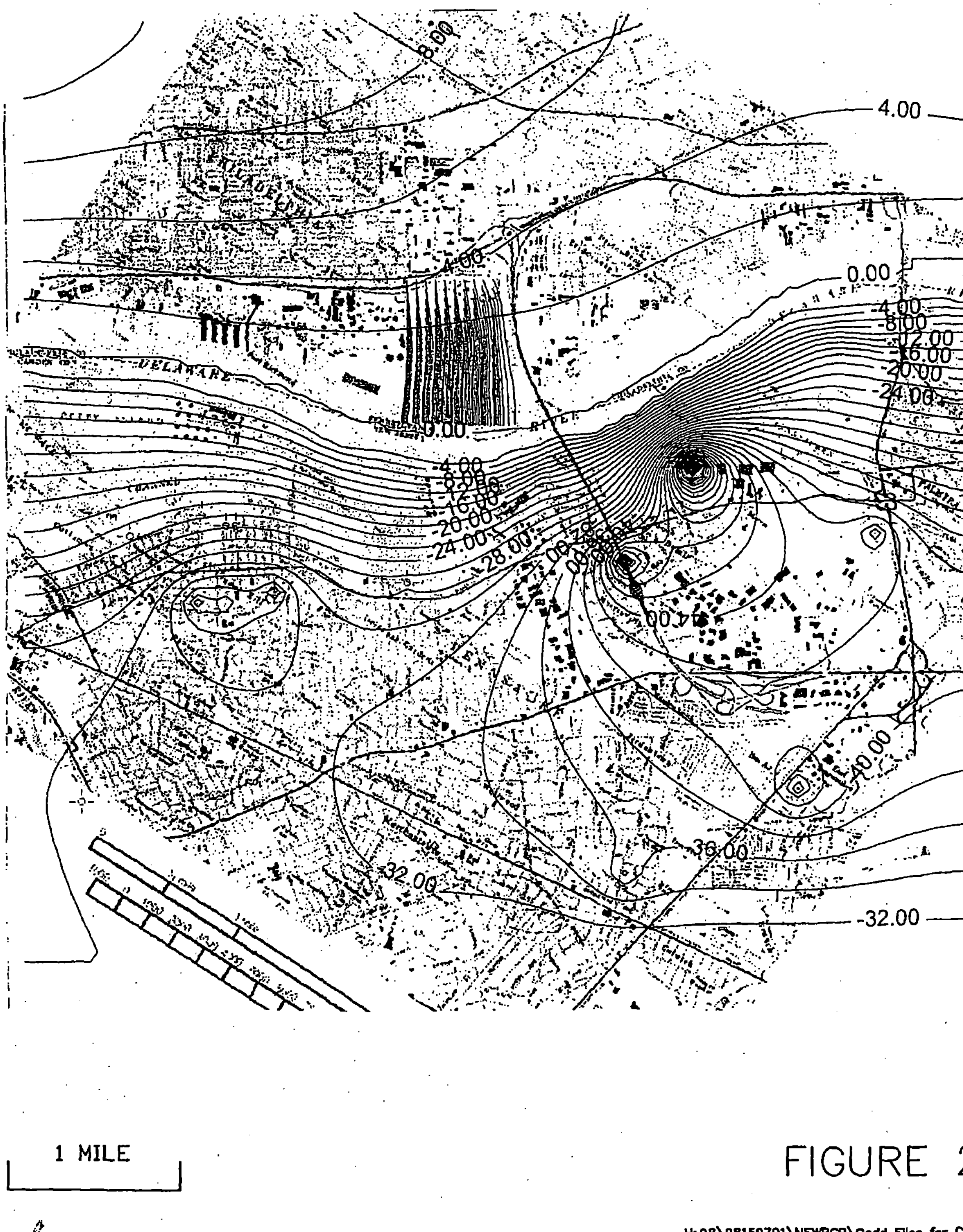


FIGURE 26

H:98\98159701\NEWPCP\Cadd Files for Closure Plan

MODEL RUN #4 RESULTS OF PARTICLE TRACKING ANALYSIS **PWD-NEWPCP CLOSURE PLAN**	RETTEW ASSOCIATES, INC. 3020 Columbia Ave., Lancaster, PA 17603 TEL (717) 394-3721 · FAX (717) 394-1063	DRAWN BY: CTB DATE: 12/31/01 SCALE: 1" = 4250' DWG. NO. 98-1597-01

AR300262

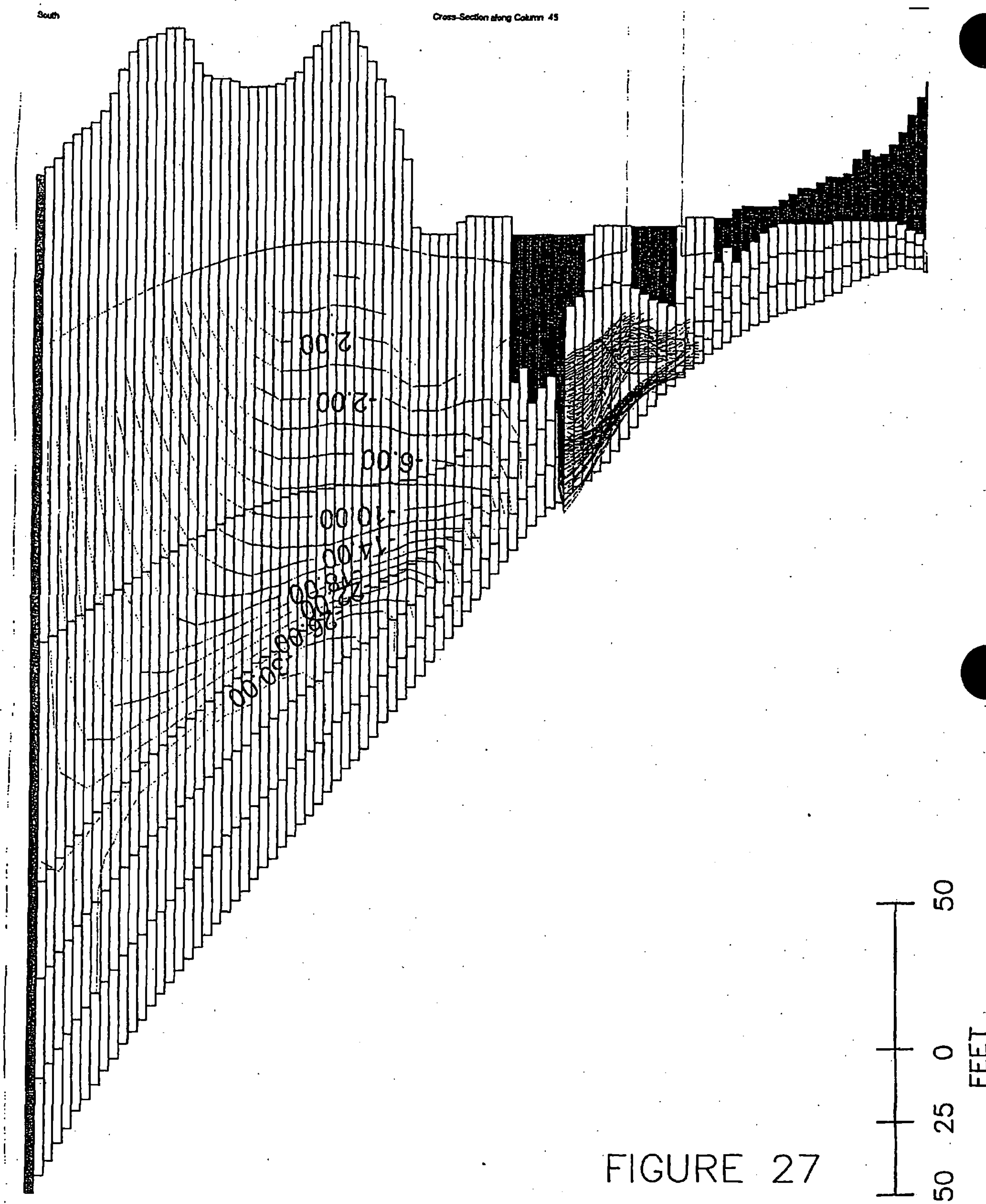


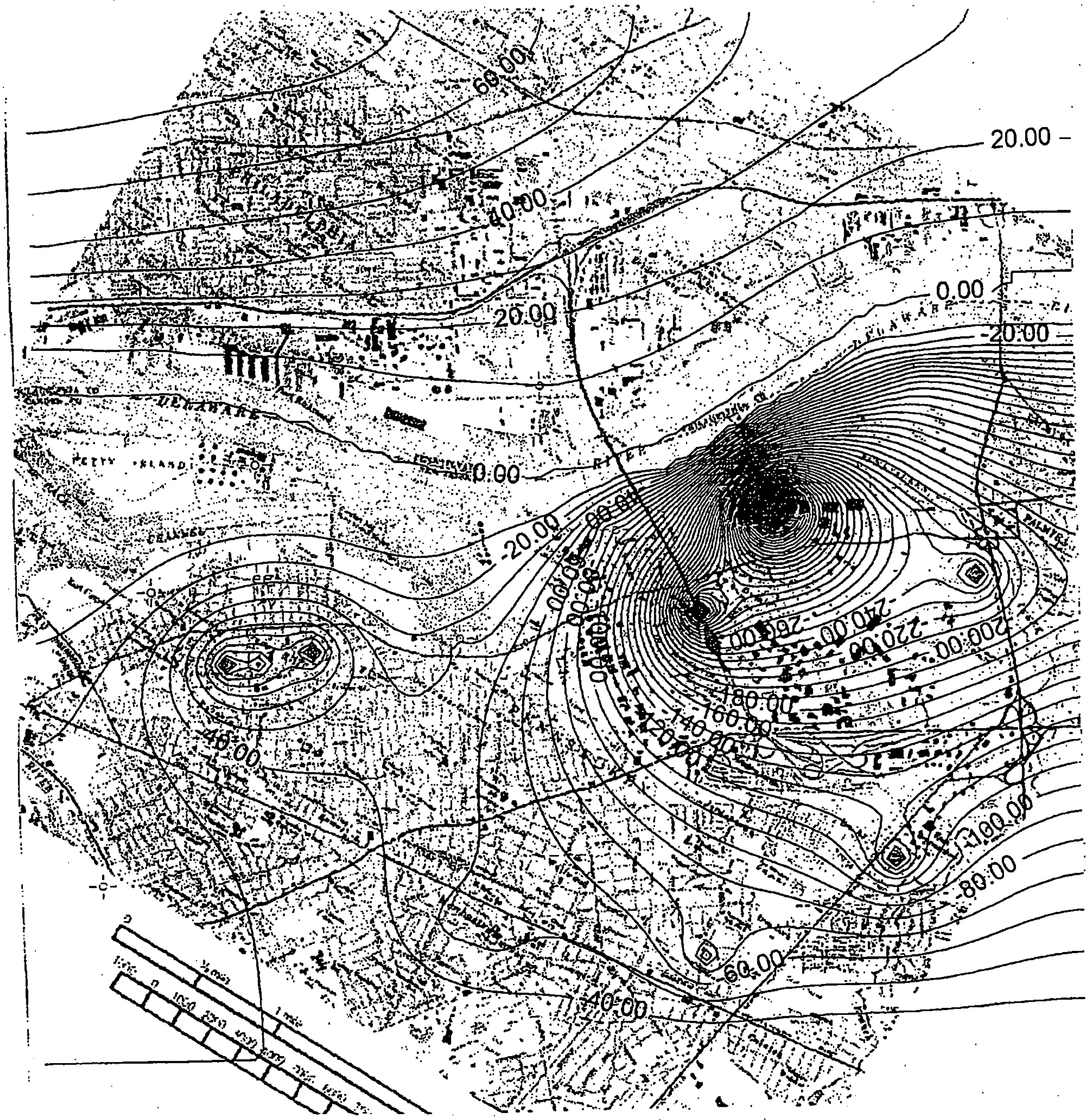
FIGURE 27

H:98\98159701\NEWPCP\Cadd Files for Closure Plan\Closure Plan Figure Templates.dwg

MODEL RUN #4 RESULTS OF PARTICLE TRACKING ANALYSIS **PWD–NEWPCP CLOSURE PLAN**	RETTEW ASSOCIATES, INC. 3020 Columbia Ave., Lancaster, PA 17603 TEL (717) 394-3721 · FAX (717) 394-1063	DRAWN BY: CTB DATE: 12/31/01 SCALE: NTS DWG. NO. 98-1597-01

AR002698

SIMULATED HEADS IN THE LOWER SAND UNIT



1 MILE

FIGURE 28

H:98\98159701\NEWPCP\Cadd Files for Closure Plan

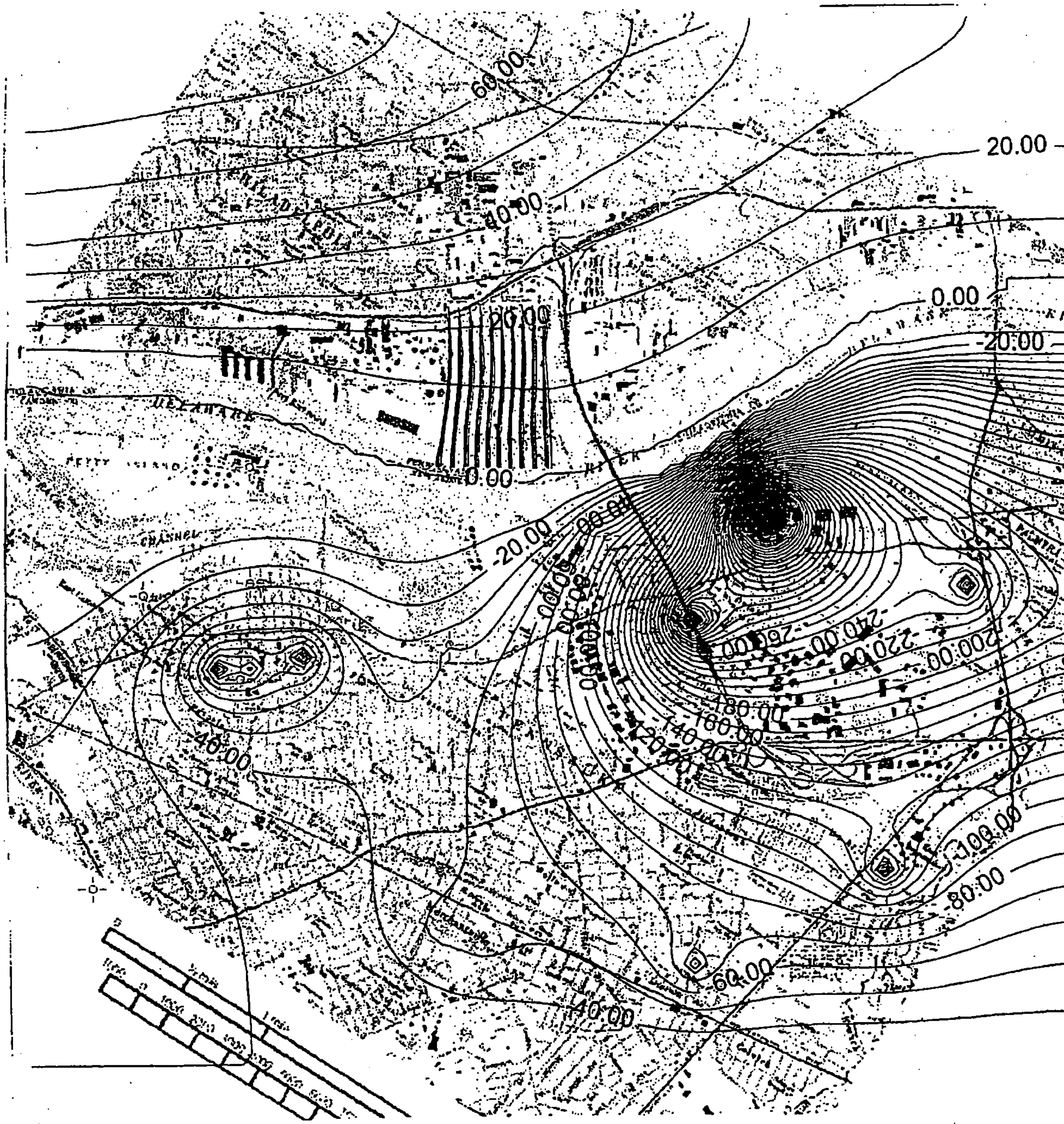
MODEL RUN #5 HYDRAULIC CONDUCTIVITY OF LOWER SAND UNIT EQUAL TO 26 FT/DAY

PWD-NEWPCP CLOSURE PLAN

RETTEW ASSOCIATES, INC.
3020 Columbia Ave., Lancaster, PA 17603
TEL (717) 394-3721 · FAX (717) 394-1063

DRAWN BY: CTB
DATE: 12/31/01
SCALE: 1" = 4250'
DWG. NO. 98-1597-01

AR300264



1 MILE

FIGURE 29

H:98\98159701\NEWPCP\Cadd Files for Closure Plan

MODEL RUN #5
RESULTS OF PARTICLE TRACKING ANALYSIS
PWD-NEWPCP CLOSURE PLAN

RETTEW ASSOCIATES, INC.
3020 Columbia Ave., Lancaster, PA 17603
TEL (717) 394-3721 · FAX (717) 394-1063

DRAWN BY: CTB
DATE: 12/31/
SCALE: 1" = 4250'
DWG. NO. 98-1597-01

AR300265

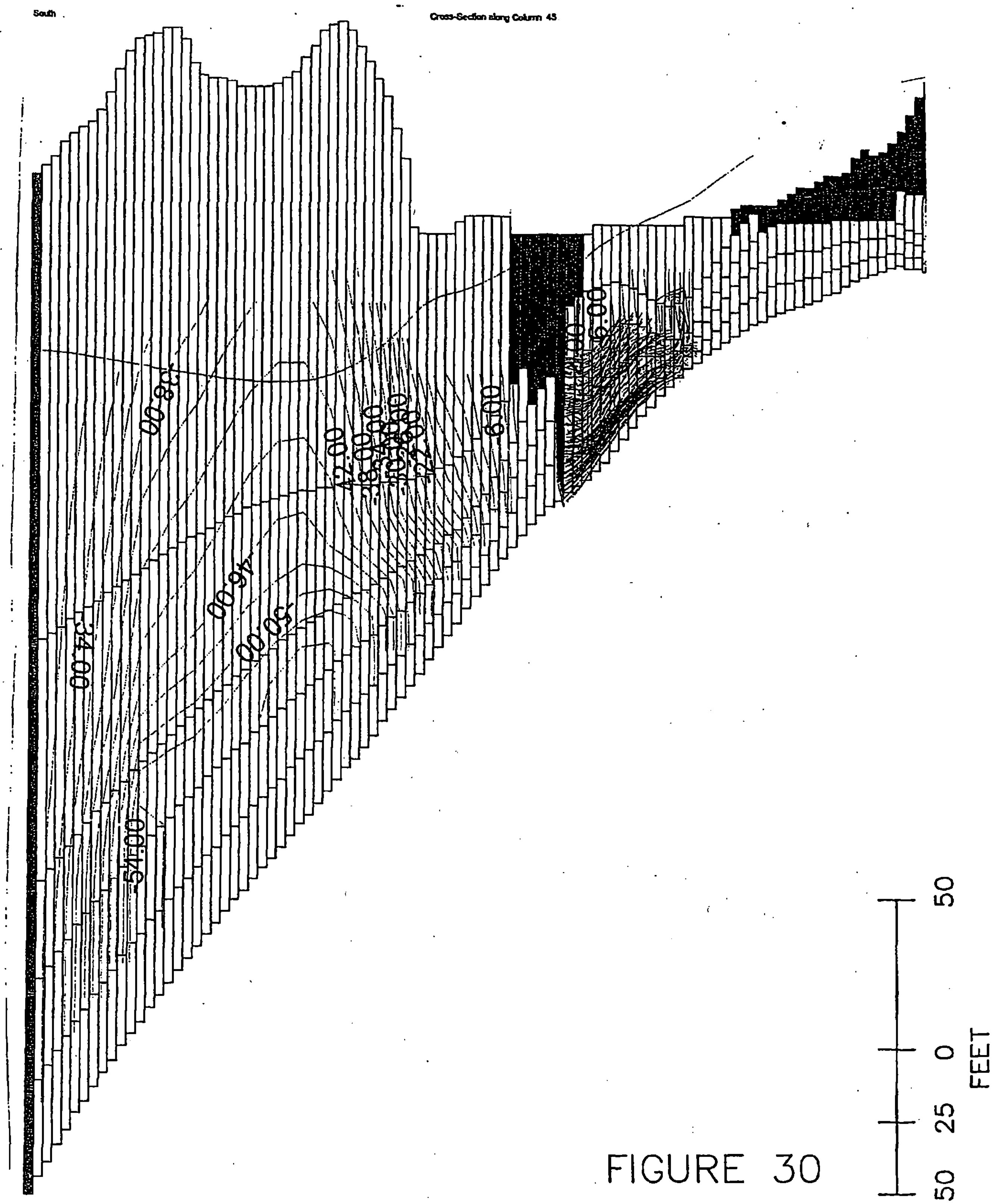


FIGURE 30

H:98\98159701\NEWPCP\Cadd Files for Closure Plan\Closure Plan Figure Templates.dwg

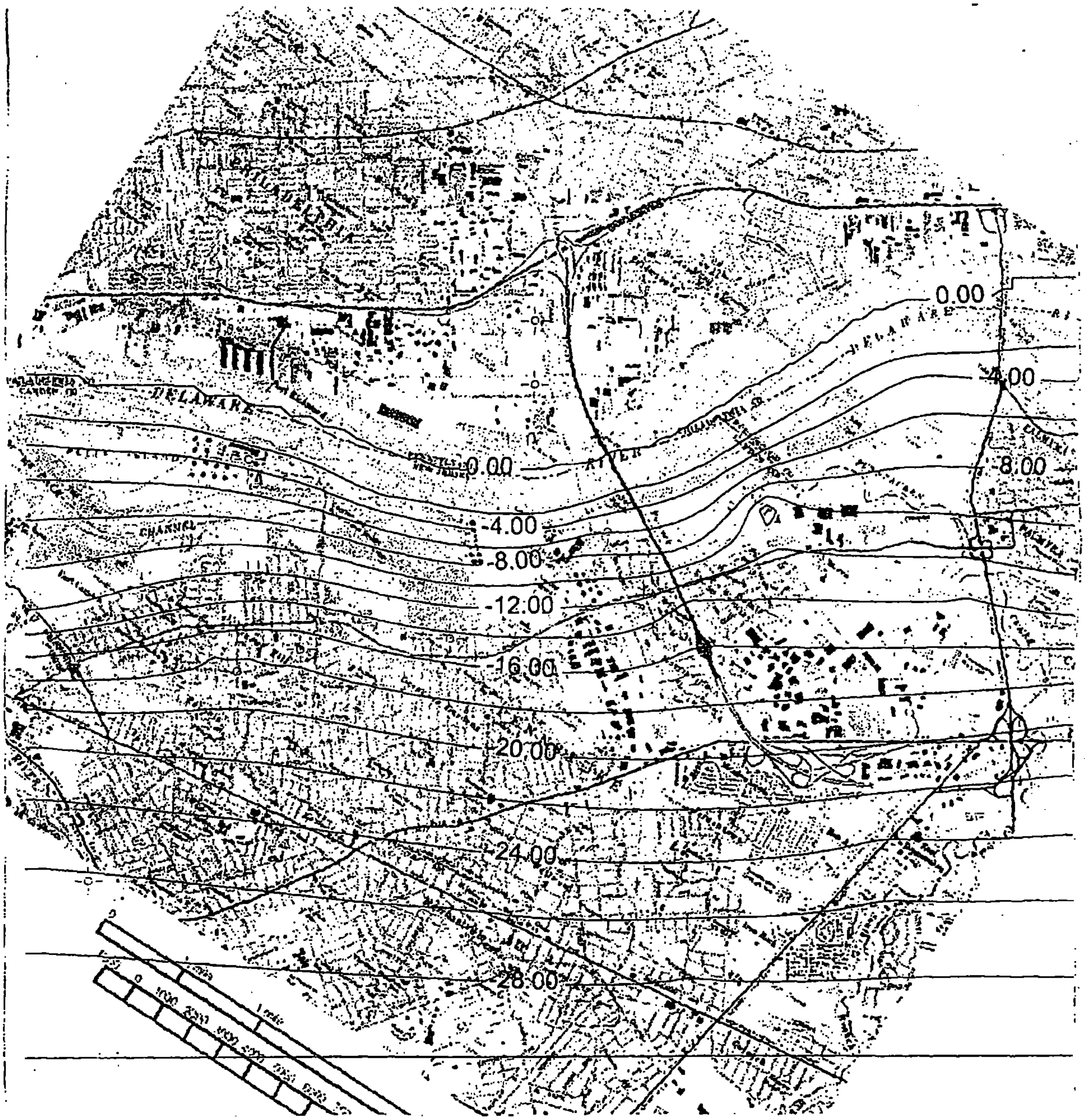
MODEL RUN #5
RESULTS OF PARTICLE TRACKING ANALYSIS
PWD–NEWPCP CLOSURE PLAN

RETTEW
ASSOCIATES, INC.
3020 Columbia Ave., Lancaster, PA 17603
TEL (717) 394-3721 · FAX (717) 394-1063

DRAWN BY: CTB
DATE: 12/31/01
SCALE: NTS
DWG. NO. 98-1597-01

AR300266

SIMULATED HEADS IN THE LOWER SAND UNIT



1 MILE

FIGURE 31

H:98\98159701\NEWPCP\Cadd Files for Closure Plan

MODEL RUN #6 HYDRAULIC CONDUCTIVITY OF THE LOWER SAND UNIT EQUAL TO 2600 FT/DAY

PWD-NEWPCP CLOSURE PLAN

RETTEW ASSOCIATES, INC.

3020 Columbia Ave., Lancaster, PA 17603, TEL (717) 394-3721 · FAX (717) 394-1063

DRAWN BY: CTB

DATE: 12/31/01

SCALE: 1" = 4250'

DWG. NO. 98-1597-01

AR300267

1 MILE

FIGURE 32

H:98\98159701\NEWPCP\Cadd Files for Closure Pla

MODEL RUN #6
RESULTS OF PARTICLE TRACKING ANALYSIS
PWD-NEWPCP CLOSURE PLAN

RETTEW ASSOCIATES, INC.
3020 Columbia Ave., Lancaster, PA 17603
TEL (717) 394-3721 · FAX (717) 394-1063

DRAWN BY: CTB
DATE: 12/31/01
SCALE: 1" = 4250'
DWG. NO. 98-1597-01

AR300268

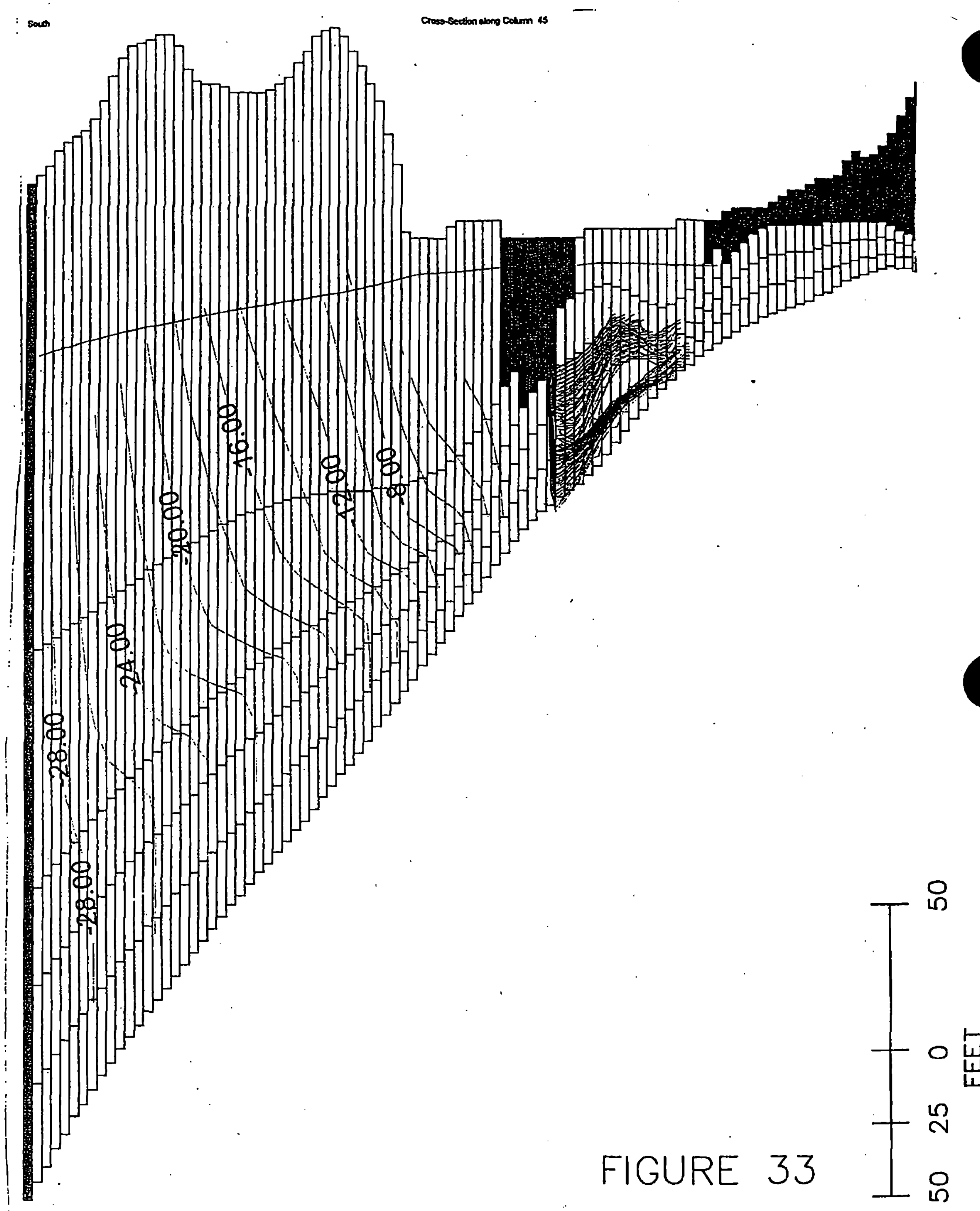


FIGURE 33

H:98\98159701\NEWPCP\Cadd Files for Closure Plan\Closure Plan Figure Templates.dwg

MODEL RUN #6 RESULTS OF PARTICLE TRACKING ANALYSIS **PWD–NEWPCP CLOSURE PLAN**	**RETTEW** ASSOCIATES, INC. 3020 Columbia Ave., Lancaster, PA 17603 TEL (717) 394-3721 • FAX (717) 394-1063	DRAWN BY: CTB DATE: 12/31/01 SCALE: NTS DWG. NO. 98-1597-01

AR300269

SPH33

[redacted]

FedEx Express **USA Airbill**

FedEx Tracking Number 8455 4713 6698

Form I.D. No. 0215

1 From Please print and press hard.

Date 6/28/2004 Sender's FedEx Account Number 1509-0196-0

Sender's Name Krizhrie Matzko Phone 215 814-5719

Company EPA (3HS21)

Address 1650 ARCH ST

Dept./Floor/Suite/Room

City PHILADELPHIA State PA ZIP 19103-2029

2 Your Internal Billing Reference OPTIONAL
First 24 characters will appear on invoice.

3 To

Recipient's Name Andy Freebnitz Phone (610) 491-9688

Company Tetratech NUS

Address 600 Clark Ave

To "HOLD" at FedEx location, print FedEx address. We cannot deliver to P.O. boxes or P.O. ZIP codes.

Address Suite 3

Dept./Floor/Suite/Room

City King of Prussia State PA ZIP 19406-1433

0268150808

4a Express Package Service *Packages up to 150 lbs.*
Delivery commitment may be later in some areas.

- [ ] FedEx Priority Overnight — Next business morning
- [x] FedEx Standard Overnight — Next business afternoon
- [ ] FedEx First Overnight — Earliest next business morning delivery to select locations
- [ ] FedEx 2Day — Second business day
- [ ] FedEx Express Saver — Third business day

FedEx Envelope rate not available. Minimum charge: One-pound rate

4b Express Freight Service *Packages over 150 lbs.*
Delivery commitment may be later in some areas.

- [ ] FedEx 1Day Freight* — Next business day
- [ ] FedEx 2Day Freight — Second business day
- [ ] FedEx 3Day Freight — Third business day

* Call for Confirmation

5 Packaging * Declared value limit $500

- [ ] FedEx Envelope*
- [ ] FedEx Pak* — Includes FedEx Small Pak, FedEx Large Pak, and FedEx Sturdy Pak
- [ ] Other

6 Special Handling Include FedEx address in Section 3.

- [ ] SATURDAY Delivery — Available ONLY for FedEx Priority Overnight, FedEx 2Day, FedEx 1Day Freight, and FedEx 2Day Freight to select ZIP codes
- [ ] HOLD Weekday at FedEx Location — NOT Available for FedEx First Overnight
- [ ] HOLD Saturday at FedEx Location — Available ONLY for FedEx Priority Overnight and FedEx 2Day to select locations

Does this shipment contain dangerous goods?
One box must be checked.

- [ ] No
- [ ] Yes — As per attached Shipper's Declaration
- [ ] Yes — Shipper's Declaration not required
- [ ] Dry Ice — Dry Ice, 9, UN 1845 ___ x ___ kg

Dangerous Goods (including Dry Ice) cannot be shipped in FedEx packaging.

- [ ] Cargo Aircraft Only

7 Payment *Bill to:* Enter FedEx Acct. No. or Credit Card No. below.

- [ ] Sender — Acct. No. in Section 1 will be billed.
- [ ] Recipient
- [ ] Third Party
- [ ] Credit Card
- [ ] Cash/Check

FedEx Acct. No. / Credit Card No. Exp. Date

Total Packages	Total Weight	Total Declared Value†	
		$ .00	FedEx Use Only

† Our liability is limited to $100 unless you declare a higher value. See back for details.

8 Release Signature *Sign to authorize delivery without obtaining signature.*

By signing you authorize us to deliver this shipment without obtaining a signature and agree to indemnify and hold us harmless from any resulting claims.

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Terms And Conditions

Definitions On this Airbill, "we," "our," and "us" refer to Federal Express Corporation, its employees, and agents. "You" and "your" refer to the sender, its employees, and agents.

Agreement To Terms By giving us your package to deliver, you agree to all the terms on this Airbill and in our current Service Guide, which is available on request. You also agree to those terms on behalf of any third party with an interest in the package. If there is a conflict between the Service Guide and this Airbill, the Service Guide will control. No one is authorized to change the terms of our Agreement.

Responsibility For Packaging And Completing Airbill You are responsible for adequately packaging your goods and properly filling out this Airbill. If you omit the number of packages and/or weight per package, our billing will be based on our best estimate of the number of packages we received and/or an estimated "default" weight per package as determined by us.

Responsibility For Payment Even if you give us different payment instructions, you will always be primarily responsible for all delivery costs, as well as any cost we incur in either returning your package to you or warehousing it pending disposition.

Limitations On Our Liability And Liabilities Not Assumed

- Our liability in connection with this shipment is limited to the lesser of your actual damages or $100, unless you declare a higher value, pay an additional charge, and document your actual loss in a timely manner. You may pay an additional charge for each additional $100 of declared value. The declared value does not constitute, nor do we provide, cargo liability insurance.
- In any event, we will not be liable for any damage, whether direct, incidental, special, or consequential in excess of the declared value of a shipment, whether or not Federal Express had knowledge that such damages might be incurred including but not limited to loss of income or profits.
- We won't be liable:
  - for your acts or omissions, including but not limited to improper or insufficient packing, securing, marking, or addressing, or those of the recipient or anyone else with an interest in the package.
  - if you or the recipient violates any of the terms of our Agreement.
  - for loss or damage to shipments of prohibited items.
  - for loss, damage, or delay caused by events we cannot control, including but not limited to acts of God, perils of the air, weather conditions, acts of public enemies, war, strikes, civil commotions, or acts of public authorities with actual or apparent authority.

Declared Value Limits

- The highest declared value allowed for a FedEx Envelope and FedEx Pak shipment is $500.
- For other shipments, the highest declared value allowed is $50,000 unless your package contains items of extraordinary value, in which case the highest declared value allowed is $500.
- Items of extraordinary value include shipments containing such items as artwork, jewelry, furs, precious metals, negotiable instruments, and other items listed in our Service Guide.
- You may send more than one package on this Airbill and fill in the total declared value for all packages, not to exceed the $100, $500, or $50,000 per package limit described above. (Example: 5 packages can have a total declared value of up to $250,000.) In that case, our liability is limited to the actual value of the package(s) lost or damaged, but may not exceed the maximum allowable declared value(s) or the total declared value, whichever is less. You are responsible for proving the actual loss or damage.

Filing A Claim YOU MUST MAKE ALL CLAIMS IN WRITING and notify us of your claim within strict time limits set out in the current Service Guide.

You may call our Customer Service department at 1.800.Go.FedEx® 800.463.3339 to report a claim; however, you must still file a timely written claim.

Within 90 days after you notify us of your claim, you must send us all the information you have about it. We aren't obligated to act on any claim until you have paid all transportation charges, and you may not deduct the amount of your claim from those charges.

If the recipient accepts your package without noting any damage on the delivery record, we will assume the package was delivered in good condition. For us to process your claim, you must make the original shipping cartons and packing available for inspection.

Right To Inspect We may, at our option, open and inspect your packages before or after you give them to us to deliver.

Right Of Rejection We reserve the right to reject a shipment when such shipment would be likely to cause delay or damage to other shipments, equipment, or personnel; or if the shipment is prohibited by law; or if the shipment would violate any terms of our Airbill or our current Service Guide.

C.O.D. Services C.O.D. SERVICE IS NOT AVAILABLE WITH THIS AIRBILL. If C.O.D. Service is required, please use a Federal Express C.O.D. Airbill.

Air Transportation Tax Included A federal excise tax when required by the Internal Revenue Code on the air transportation portion of this service, if any, is paid by us.

Money-Back Guarantee In the event of untimely delivery, Federal Express will, at your request and with some limitations, refund or credit all transportation charges. See current Service Guide for more information.

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