US Army Corps
of Engineers
BALTIMORE DISTRICT

SITE INVESTIGATION
LIBERTY STATE PARK
JERSEY CITY, NJ
Volume 1
Text, Figures, and Tables

Prepared by:
U.S. Army Corps of Engineers
Baltimore District
10 South Howard Street
Baltimore, MD 21201

Project Partner:
U.S. Army Corps of Engineers
New York District
26 Federal Plaza
New York, NY 10278

April 2004

SITE INVESTIGATION
LIBERTY STATE PARK
JERSEY CITY, NJ

FINAL REPORT

Volume 1

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EXECUTIVE SUMMARY

This site investigation report documents the results of a geotechnical subsurface site investigation program performed at Liberty State Park, Jersey City, Hudson County, NJ. An initial phase (Phase I) of drilling and sampling program was performed during August and September of 2003. Thirty-eight drill holes were completed and a comprehensive geotechnical testing program was performed. An additional phase (Phase II) of drilling and sampling program was performed in February 2004. Eleven drill holes and six auger boring were completed along with geotechnical testing. This report contains the results of the geotechnical site investigation program and discussions of regional geology, soils, hydrogeology, and the geotechnical conditions observed at the site. Characterization of subsurface geotechnical conditions is consistent with a feasibility level site investigation program.

The geotechnical site investigation program revealed that project site is overlain with coarse-grained (sands, silty sands, silty gravels, etc.) soils. Average thickness of this coarse-grained layer is about 14-ft, although local variations exist with both thinner layers (3-ft) and thicker layers (30-ft plus) encountered. Underlying this coarse-grained layer is a layer of fine-grained soil (clay, clay with traces of shells, sand, and gravel, etc.). This fine-grained layer was observed in about 85% of the drill holes. On average, this fine-grained layer was encountered at a depth of about 13-ft, although local variations exist. Average thickness of this fine-grained layer is about 12-ft, although local variations exist with both thinner layers (1.5-ft) and thicker layers (27-ft plus) encountered. Subsequent lower layers of coarse-grained and then fine-grained soils were occasionally encountered. Man-made debris (refuse) materials were found in about 27 drill holes.

The coarse-grained surficial soils consist primarily of sand size particles, although minor amounts of gravel and silt or clay size particles were also included. The coarse-grained soils are typically very poorly sorted and the distributions are often skewed to the finer sized portion. The immediately underlying fine-grained soils consist primarily of silt or clay size particles, although some minor amounts of fine and medium sand are also typically included. The fine-grained soils are often highly plastic. Hydrologic soil properties for both the coarse-grained and fine-grained soils were also estimated.

Groundwater depths range from about 1.3-ft below existing grade to about 5.5-ft below existing grade, as measured from the twenty piezometers installed throughout the site. Maximum fluctuations in groundwater levels up to 3.1-ft were observed in the piezometers. Groundwater flow direction and average gradient calculations using LMNO Groundwater Flow Direction and Gradient Calculator software suggests that groundwater flow direction is about N35^{o} and discharges towards the adjacent Morris Canal.

Near surface excavation of this material should present no unusual excavation problems. However, deeper excavations, notably excavation of the Ecochannel in the vicinity of the North Cove, may present excavation problems. The presence of ‘Active’ clays may become result in stability and foundation problems in slopes and beneath structures. The presence of soft, fine-grained soils may cause excavation problems due to its very soft consistency, which may result in slumping of cuts and corresponding problems with maintaining channel grade control, its ability to stick to excavating equipment and tools, and its ability to deform and maintain excess pore pressure. Earthmoving type construction equipment may have difficulty operating directly on this material. Since the site is bounded by surface water on two separate sides, the impact of groundwater on any excavations may be significant and dewatering may be required. Additional subsurface investigations, engineering testing and further geotechnical analyses may alter or modify the current conceptual geotechnical characterizations.

SITE INVESTIGATION
LIBERTY STATE PARK
JERSEY CITY, NJ

1.0 INTRODUCTION

This document presents and summaries the geotechnical data obtained from the subsurface site investigation program performed at Liberty State Park (LSP), Jersey City, Hudson County, NJ. The Baltimore District, U.S. Army Corps of Engineers (BCOE) completed the subsurface site characterization program.

The Phase I site investigation obtained continuous sampling from thirty-eight (38) separate boreholes to a depth of approximately 30-ft below grade. Two additional drill holes located within the North Cove were drilled in the Phase II program. Twelve (12) piezometers were installed as permanent piezometers in existing drill holes for long-term groundwater level monitoring purposes and for future use in determining permeability (hydraulic conductivity) of the soil, if required. An additional eight (8) temporary piezometers were also installed in selected existing drill holes. These temporary piezometers shall be removed at the completion of the groundwater monitoring program. The Phase II site investigation obtained continuous sampling from eleven (11) separate boreholes, depths ranged from 30-ft below grade in the Contaminant Area to 20-ft below grade in the North Cove Area. Six auger borings were also drilled in the Berm Area. Geotechnical laboratory testing was completed on representative geotechnical samples to determine Unified Soil Classification System (USCS) soil classifications and engineering properties. Chemical analysis of select soil samples was performed by an off-site analytical testing laboratory at the Fort Monmouth Environmental Testing Lab, Fort Monmouth, NJ. The data collected was used to provide a descriptive summary of the horizontal and vertical extent of any chemical or constituent found at the site. Results of the chemical analyses are not included in this summary report, but are available in a separate technical summary report.

This work was completed under the North Atlantic Division's Regional Business Center (RBC) concept. The Baltimore District and the New York District partnered to plan, conduct, and complete this comprehensive site investigation. New York District personnel provided critical, and often invaluable, technical, administrative, and logistical support during prosecution of this work, as well as, providing all Project Management functions. Personnel from the Geotechnical Branch (Engineering Division) of the Baltimore District implemented the site investigation project and prepared this Site Investigation Report. This collaborative effort made optimal use of the technical capabilities and resources within the Division, with the partnering District organizations acting as a single business entity.

2.0 BACKGROUND

From the time of its opening on June 14, 1976, Liberty State Park has attracted sustained, significant public support from citizen groups interested in promoting and protecting New Jersey's first, and to date, only urban state park. Liberty State Park's 1,212 acres include magnificent views of New York Harbor, the Statue of Liberty, the historic Central New Jersey Rail Terminal, the Liberty Science Center and the Liberty Landing Marina. LSP also provides a historic gateway to Ellis Island and the Statue of Liberty. LSP serves nearly 4.5 million visitors annually, including visitors from Jersey City and Hudson County to travelers from across the region and the Nation.

Liberty State Park is managed and protected by the New Jersey Department of Environmental Protection (NJDEP) Division of Parks and Forestry, working closely with park constituencies ranging from Jersey City residents to local parks and environmental groups. Since 1986, the Liberty State Park Development Corporation (LSPDC), established by Governor Kean to promote public-private partnerships, also has had a significant role in park development. In recent years, numerous LSPDC proposals have generated significant controversy among citizens concerned about the park. With the recent completion of the General Management Plan, which determined the future of the remaining 251 acres of undeveloped space, there is little work remaining that falls under the LSPDC's original mandate. Accordingly, the McGreevey Administration has revisited the role of the LSPDC, in light of the vision for the future of Liberty State Park.

3.0 OBJECTIVES

In consultation with the public advisory committee established by NJDEP Policy Directive 2003-03, dated April 24, 2003, NJDEP's Division of Natural and Historic Resources was tasked to focus on the following priorities for Liberty State Park:

Acceleration of the Interior Restoration. In coordination with the United States Army Corps of Engineers, NJDEP shall accelerate the restoration of the Park's natural and vegetated areas, including the 251 acres identified for restoration in the center of the Park.

Active Recreation. Recognizing the needs of the surrounding Jersey City communities and the absence of significant facilities for active recreation, NJDEP shall expand and improve opportunities for active recreation at the Park to better serve Jersey City and other local residents.

Entrance and Transportation Improvements. NJDEP shall work to improve the Park entrance and develop road and transit improvements to increase access and convenience, reduce impacts of parking and transit, and improve the appearance of the Park.

Non-commercial entertainment. NJDEP shall develop a memorandum of understanding (MOU) with the New Jersey Symphony Orchestra (NJSO) to explore the possible siting of a limited-seating venue for NJSO performances and similar cultural events at the Park. Any proposal shall be fully reviewed by the Park advisory committee and subject to notice and comment prior to any final decision.

4.0 CONTAMINANTS AND PREVIOUS INVESTIGATIONS

The New York District of the US Army Corps of Engineers is partnering with the New Jersey Department of Environmental Protection (NJDEP) to characterize the sub-surface soils in the central part of Liberty State Park. This effort is part of the overall effort to construct a coastal wetland within that central area. This wetland would replicate what existed prior to settlement and industrialization. That area of LSP slated for this is entirely composed of fill material. The material is a mix of soil, construction debris, sunken wooden barges, and industrial waste. Land filling activities lasted approximately 75 years, finally completing in the late 1950's. The main activity on this filled in area was railroads. Railroad operations involved fueling, repair, maintenance, freight and passenger movements. By the mid 1960's railroad activities were winding done and by the early1970's ceased all together.

The NJDEP purchased the land in the late 1970's to create what is today Liberty State Park and embarked on a clean up and site restoration project that continues to this day. Restoration of previously existing wetlands is part of the NJDEP's overall plan. From the time of the NJDEP's purchase of the land to present there have been numerous sub-surface characterization projects. The focus of these projects was to determine the lateral and vertical extent of the pollutants. In this case the pollutants of concern are metals (the most concern is on hexa-valent, tri-valent chromium) and hydro-carbons (oil, either as free product or as absorbed into the soil). As a result of these characterizations an area of 50 acres has been fenced off and posted to prevent the public from entering this area. The soil in this restricted area is dredged sediment from the New York Harbor.

5.0 SITE LOCATION AND DESCRIPTION

The Liberty State Park Site is located in Jersey City, New Jersey, along the Hudson River, approximately two (2) miles south of the Holland Tunnel Crossing and on the mainland, just west of Ellis Island. Located in Hudson County, NJ, the potential restoration site is within the boundaries of Liberty State Park on a section of property generally bounded by Audrey Zapp Drive on the north side, Phillip Drive on the west side, Thomas McGovern Drive on the south side and Freedom Way, a flood control levee, along the east side.

Previous investigations of the fill material at Liberty State Park by NJDEP (NJDEP 1995) indicate that the material consists primarily of cinder and ash fill, mixed rubble and debris, and dredge spoil, likely underlain by organic clay, glacial meltwater deposit, alluvial deposits, and glacial till. Bedrock in nearby New Jersey Geological Survey (NJGS) borings is 40 feet deep or deeper. Hazardous, toxic, and radioactive waster (HTRW) contaminants reported by NJDEP in their 1995 investigation include chromium, lead, arsenic, and other heavy metals, petroleum hydrocarbons, pesticides, PCBs, and semi-volatile organics (NJDEP 1995). Heaving sands have also been reported by NJDEP at depths greater than 20 feet. A freshwater wetland that exists at the West Side of the site must be supported and maintained. Because of known HTRW contamination at the site area, it is a project requirement that no soils be removed from the site.

A regional location map showing Hudson County, NJ is shown in Figure #1. A Liberty State Park Vicinity Map is shown in Figure #2 and a Liberty State Park Site Map is shown in Figure #3.

6.0 GEOLOGY

6.1 Regional: New Jersey has a very diverse geology containing rocks ranging from the Precambrian Era through the Paleozoic Era, Mesozoic Era, Cenozoic era, and Holocene (recent) Era. Overall, the rock of these different Eras are distributed across the state from north to south according to age, although the order is reversed in the New Jersey Highlands due to thrusting of deeper and older Precambrian rocks over younger Paleozoic rocks. Four major geologic provinces occur in New Jersey, namely: (i) Appalachian Valley and Ridge, (ii) New England (Reading Prong), (iii) Piedmont, and (iv) Coastal Plain. A map showing the four geologic provinces is shown in Figure #4. The Liberty State Park project site is located within the Piedmont physiographic province. Rocks of the Piedmont providence included interbedded sandstone, shale, conglomerate, basalt, and diabase and underlie a broad lowland interpreted by long, generally northeast-southwest trending ridges and uplands. The rocks of the Piedmont Province are of Late Triassic and Early Jurassic age (230 to 190 million years old). They rest on a large, elongated, crustal block that dropped downward in initial stages of the opening of the Atlantic Ocean – one of a series of such blocks in the eastern part of North America. These dropped down block form valleys known as rift basins. Sediment eroded from adjacent uplands, was deposited along rivers and in lakes within the basins. These sediments became compacted and cemented to form conglomerate, sandstone, siltstone, and shale, which commonly have a distinctive reddish-brown color.

6.2 Glaciation: New Jersey has undergone three major glaciations. The last glacier (the late Wisconsin advance) began to melt back from its maximum extent approximately 20,000 years ago. North of the limit of the last Glaciation the surface is covered with glacial deposits. Upland areas in this region are thinly draped with till, and unsorted mixture of sand, clay, and boulders deposited directly from the glacier. Valleys and lowlands are filled with up to 350 feet of sand and gravel deposited from glacial meltwater and silt and clay that settled in glacial lakes. Much of the surficial deposits include artificial fill, alluvial, estuarine, and eolian sediments of postglacial age, and glacial meltwater deposits that are of late Wisconsin age.

6.3 Local: During each Glaciation, sea level dropped as water from the ocean was transferred to ice sheets. Rivers extended and deepened their valley to conform to the lower sea levels. When the ice sheets melted, sea level rose, flooding the deepened valleys and establishing new shorelines. The present configuration of the shoreline is the result of rapid post-glacial rise in sea level. Many of the estuaries along the shore are drowned lower reached of former river valleys. Mud and sand transported by rivers is gradually filled the former river valleys, creating extensive wetlands.

7.0 SITE INVESTIGATION PROGRAM

7.1 Drilling and Sampling:

Soil samples were obtained in accordance with ASTM D1586 (Standard Penetration Test (SPT) method). The SPT method is a procedure for driving a split-barrel (split-spoon) sampler to obtain a representative soil sample and to measure the resistance of the soil to penetration. The SPT method provides a disturbed sample for defining sediment stratification as well as blow count data, which gives an indication of soil consistency and relative density. The SPT method involves driving a 1-3/8 inch ID by two foot long split-spoon sampler using a 140 pound hammer free falling thirty inches onto an anvil attached to drill rods (viz., rods used to transmit downward force to the sampling spoon while drilling a borehole). The number of blows required to advance the sample spoon over each 6-inch drive increment was recorded. Often, the weight of the sampling spoon and drilling rods alone were sufficient to drive the sampling spoon into the soil (sediments). This condition was described as Weight of Rods (WR) or Weight of Hammer (WH), since no hammer blows were required to advance the sampling spoon. Split spoon sampling was performed using a CME-750 drill rig. Hollow Stem Augers (2-1/4-inch ID) were used to advance the boring and to stabilize the drill hole. The SPT test method is discussed in ASTM D 1586 Test Methods for Penetration Test and Split-Barrel Sampling of Soils.

A Phase I drilling and sampling program was completed during August and September of 2003. Thirty-eight drill holes were completed throughout the project site during this phase. Drill holes were designated as LSP-03-01 through LSP-03-40, respectively. Although drill hole Nos. LSP-03-21 and LSP-03-22 were not drilled in 2003. But they were drilled in 2004 and were renamed NC-04-01 and NC-04-02. The planned investigation sampling depth was typically -30.0 feet below existing grade. All borings were typically sampled continuously in one and one-half foot increments from the top of the drill hole to a typical depth of -30.0 feet. Recovered samples for each split-spoon were placed in clean, air tight, one-quart glass jars for preservation and then shipped to the geotechnical-testing laboratory. Approximately 1,123 linear feet of soil was drilled in the 38 subsurface borings with 753 separate sample spoons collected. Twelve drill holes were converted into permanent groundwater piezometers (LSP-03-01 through LSP-03-12) and eight drill holes were converted into temporary piezometers (LSP-03-17, LSP-03-19, LSP-03-24, LSP-028, LSP-03-31, LSP-03-32, LSP-03-35, and

LSP-03-38). A Phase I drill hole location plan is shown in Figure #5 and a Phase I drill hole location plan showing the location of drill holes where permanent piezometers were installed is shown in Figure #6.

An additional phase (Phase II) of drilling and sampling was conducted during February 2004. Six SPT drill holes were completed in the Containment Area, designated as CA-04-01 thorough CA-04-06. Five SPT drill holes were completed in the North Cove area, designated as NC-04-01 through NC-04-05. Two North Cove drill holes (NC-04-01 and NC-04-02) were completed from a barge located in the water within the North Cove. Six auger borings were completed in the Berm Area, designated as BA-04-01 through BA-04-06. A Phase II drill hole location plan is shown in Figure #7. Approximately 280 liner feet of SPT drilling was completed in this additional phase, with 187 separate sample spoons collected. Recovered samples for each split-spoon were placed in clean, air tight, one-quart glass jars for preservation and then shipped to the geotechnical-testing laboratory.

A general summary of the drilling program is shown in Table #1. Drill hole coordinates and top of drill hole elevations for all on-land drill holes are shown in Table #2. Drill hole locations and water depths for the offshore drill holes are sown in Table #3. Field (preliminary) drill logs are located in Appendix A. Final drill logs are located in Appendix B.

7.2 Positioning: Locations for each boring were established utilizing an Ashtek® ProMark2 Differential Global Positioning System (GPS). The ProMark2 has a reported static horizontal accuracy of 0.016-ft and a reported static vertical accuracy of 0.032-ft, subject to a number of operational conditions.

8.0 PIEZOMETERS

8.1 Permanent Piezometers: Twelve permanent piezometers were installed in drill hole Nos. LSP-03-01, LSP-03-02, LSP-03-03, LSP-03-04, LSP-03-05, LSP-03-06, LSP-03-07, LSP-03-08, LSP-03-09, LSP-03-10, LSP-03-11, and LSP-03-12. These piezometers are classified as standpipe type piezometers and are used to monitor piezometric groundwater levels across the site. Standpipe piezometers contain a porous element that is connected via rigid tubing to ground level. Piezometric pressure at the tip is indicated by the head of water that develops inside the standpipe tubing. A permanent leak-resistant cover was installed at the surface to protect the piezometer. As-built records for the twelve permanent piezometers are shown in Appendix E. Construction Schematics for the twelve permanent piezometers are shown in Appendix F.

8.2 Temporary Piezometers: Eight temporary permanent piezometers were installed in drill hole Nos. LSP-03-17, LSP-03-19, LSP-03-24, LSP-03-28, LSP-03-31, LSP-03-32, LSP-03-35, and LSP-03-38. These piezometers are also classified as standpipe type piezometers and are used to monitor piezometric water levels across the site. No permanent leak-resistant cover was installed at the surface to protect the piezometer. These eight piezometers shall be removed at the completion on the site investigation program. As-built records for the eight temporary piezometers are shown in Appendix G. Construction Schematics for the eight temporary piezometers are shown in Appendix H.

9.0 GEOTECHNICAL TESTING

9.1 Geotechnical Testing Methodology: All geotechnical soil tests were performed by the Baltimore Districts Materials and Instrumentation (Soils Laboratory) Unit, located at 2603 Leahy Street, Ft McHenry Yard, Baltimore, MD 21230. Telephone (410) 962-4045, Fax (410) 962-7627. Upon receipt of the sample jars collected during the field investigation, a visual-manual USCS (Unified Soil Classification System) soil classification was completed on the soil in each (disturbed) jar sample collected. Visual-Manual Soil Classifications are shown in Appendix C. The Geotechnical Laboratory testing results are shown in Appendix D. A tabulated summary of the geotechnical laboratory-testing program performed on the soil is shown in Table #4. All soil testing was performed in accordance with EM 1110-2-1906 and appropriate ASTM Standard Testing Methods. Due to the potential contamination levels of the soils, the testing was completed using contaminated material testing protocols and performed under an approved "Management Plan for the Handling and Disposal of Laboratory Soil Samples." All soils were disposed at a designated facility that is permitted for hazardous waste treatment, storage, and disposal. All geotechnical testing was performed under an approved geotechnical laboratory "Quality Assurance Plan."

9.2 Soil Characterization:

9.2.1 General: Soils behave quite differently depending upon their geotechnical characteristics. In coarse-grained soils, where more than 50% of the soil is retained on the No. 200 (0.075 mm) sieve, the engineering behavior is influenced mainly by the relative proportions of the different sizes of grains present (gradation), the shapes of the soil grains, and the density of packing. In the USCS, coarse-grained soils have their major descriptors as either G (Gravel) or S (Sand). Minor descriptors include W (Well-Graded), P (Poorly Graded), M (Silty), and C (Clayey). In fine-grained soils, where more than 50% of the soil passes on the No. 200 (0.075 mm) sieve, the mineralogy of the soil grains, water content, inter-particle physico-chemical forces, etc., have a greater influence on the engineering behavior of the soil than the grain sizes. In the USCS, fine-grained soils have their major descriptors as M (Silt), C (Clay), or O (Organic). Minor descriptors include L (Low Plasticity), and H (High Plasticity).

9.2.2 Fine Grained Soil: Fine-grained soils are characterized by Plasticity parameters. Plasticity parameters, which are expressed in terms of moisture content of the soil (Atterberg limits) have been defined and standard methods for measurements have been established. Plastic Limit, PL, is defined as the water content on a dry weight basis corresponding to the arbitrary limit between plastic and brittle states of consistency of a soil. Liquid Limit, LL, is defined as the water content on a dry weight basis corresponding to the arbitrary limit between the liquid and plastic states of consistency of a soil. Plasticity Index, PI, is the difference between the liquid and plastic limits and represents the range of moisture within which the soil is plastic. Silts and sands have slight or no plasticity indices, whereas clays have higher indices. The Plasticity Index, in combination with the Liquid Limit, indicates how sensitive the soil is to changes in moisture. Liquidity Index, LI, is defined as the ratio of the difference between the natural soil water content and plastic limit to the soil plastic index (PI) of the same soil. If a soil Liquidity Index (LI) is less than 1.0, the soil water content is less than liquid limit. If a soil Liquidity Index (LI) is very low or close to 0.0, the soil water content is near to plastic limit and the soil will have a high cohesion. If the Liquidity Index (LI) is greater than 1.0, the soil behaves as a viscous liquid when sheared; if the LI is less than 0.0, the soils exhibits a brittle type fracture when sheared; and when the $0.0<LI<1.0$, the soil behaves as a plastic solid when sheared. Activity Index, A, defines the activity of a clay as the ratio of the PI to the percent clay fraction (clay fraction <0.002 mm) by weight. Activity is a good indictor of the potential swell-shrink associated with specific clays. The higher the Activity Index, the higher the swell-shrink potential. Clays with $A<0.75$ are classified as "inactive clays;" clays where $0.75<A<1.25$ are "normal clays;" and clays where $A>1.25$ are "active clays." High activity indexes suggests large volume changes when wetted; large shrinkage when dried; and very reactive (chemically) clays.

9.2.3 Coarse Grained Soils: Coarse-grained soils are divided into two major divisions: gravels and sands. If more than half of the coarse fraction by weight is retained on a No. 4 (4.75 mm) sieve, the soil is classified as a gravel. It is classified as a sand, if more than half of the coarse fraction is smaller than a No. 4 (4.75 mm) sieve. In general practice there is no clear-cut boundary between gravelly and sandy soils, and as far as behavior is concerned, the exact point of division is relatively unimportant. Where a mixture occurs, the primary name is the predominant fraction and the minor fraction is used as an adjective. For example, a sandy gravel is a mixture containing more gravel than sand by weight.

9.2.4 Borderline Soils: Coarse-grained soils that contain between 5 and 12 percent of material passing the No. 200 sieve (0.075 mm) are classified as border line and are given a dual symbol, such as GW-GM. Similarly, coarse-grained soils that contain more than 12 percent of material passing the No. 200 sieve, and for which the limits plot in the shaded portion of the plasticity chart, are classified as border line and require dual symbols, such as SM-SC. It is possible, in rare instances, for a soil to fall into more than one borderline zone. In this case, if appropriate symbols were used for each possible classification, the result would be a multiple designation consisting of three or more symbols.

9.2.5 Relative Density and Consistency: Coarse-grained cohesionless soils (sands, gravels, & non-plastic silts) are sufficiently pervious that excess pore pressures do not develop when stress conditions are changed. Their shear strengths are primarily characterized by the angle of internal friction. The value of the internal angle of friction depends upon the particle shapes, the gradation, and the relative density. The approximate relationship between the relative density of coarse-grained cohesionless soils and the standard penetration test (SPT) resistance is as follows:

RELATIVE DENSITY (SPT)

Coarse-Grained Soils	**Blows/Foot**
Very Loose	0 – 4
Loose	4 – 10
Medium Dense	10 – 30
Dense	32 – 50
Very Dense	Over 50

In fine-grained cohesive soils (clays & plastic silts), the shear strength is considerably more complex than coarse-grained soils because of their significantly lower permeability, higher void ratios, and the interaction between the pore pressure and the soils particles. The approximate relationship between the relative consistency of fine-grained cohesive soils and the standard penetration test (SPT) resistance is as shown below.

CONSISTENCY (SPT)

Fine-Grained Soils	**Blows/Foot**
Very Soft	0 – 2
Soft	2 – 4
Medium Stiff	4 – 8
Stiff	8 – 16
Very Stiff	16 – 32
Hard	Over 32

10. SUBSURFACE CONDITIONS

10.1 Fill: Numerous drill holes recovered man-made debris (refuse) materials consisting of cinders, wood, coal, brick, glass, leather, concrete, etc, including drill hole Nos.: LSP-03-05, LSP-03-06, LSP-03-11, LSP-03-12, LSP-03-13, LSP-03-14, LSP-03-16, LSP-03-17, LSP-03-20, LSP-03-23, LSP-03-24, LSP-03-25, LSP-03-26, LSP-03-28, LSP-03-29, LSP-03-34, LSP-03-35, LSP-03-38, LSP-03-39, CA-04-01, CA-04-02, CA-04-03, CA-04-04, CA-04-05, CA-04-06, NC-04-03, and NC-04-05. Traces of wood were found at the very top of two offshore borings (NC-04-01 and NC-04-02). Petroleum odor was evident in the drill hole Nos. NC-04-01, NC-04-02, NC-04-03, and NC-04-5.

10.2 Soils: The on-site soils vary considerably across the site. Both fine-grained and course grained soils are present. Soils in virtually all of non-organic USCS soil classifications are found on site. Table #1 shows the USCS soil classifications found in each drill hole. Visual-manual soil classifications are shown in Appendix C and geotechnical-testing results are shown in Appendix D. The DOD GMS software was used to develop the conceptual geologic model. An oblique view of the drill holes is shown in Figure #8 and a generalized conceptual geologic model of the subsurface is shown in Figure #9.

10.2.1 Distribution: Based upon the material recovered from the entire drilling and sampling program, approximately 61% of the top 30-ft of on-site soils are coarse-grained materials and approximately 39% of the soils are fine-grained materials, see Table #5. However, from depths of 0.0-ft to 10.5-ft below existing grade, approximately 87% of the on-site soils are coarse-grained materials and approximately 13% of the soils are fine-grained materials, as shown in Table #6. From depths of 0.0-ft to 4.5-ft below existing grade, approximately 91% of the on-site soils are coarse-grained materials and approximately 9% of the on-site soils are fine-grained materials, as shown in Table #7. Whereas in the two water borings (NC-04-01 and NC-04-02), approximately 8% of the soils are coarse-grained materials and 92% of the soils are fine-grained materials, as shown in Table #8. A general summary of the geotechnical laboratory testing results is shown in Table #9.

10.2.2 Coarse Grained Soil Properties: On average, fine grained Sand (<No. 70 sieve and >No. 200 sieve) comprise about 33% of the coarse-grained materials,; medium grained Sand (<No. 20 sieve and >No. 70 sieve) comprise about 20% of the coarse-grained materials; coarse grained Sand (No. 10 sieve) comprise about 8% of the coarse-grained materials; fine Gravel (<1/2-inch and > No. 4 sieve) comprise about 13% of the coarse-grained materials; and coarse Gravel (<3-inch and > 3/4-inch) comprise about 3% of the coarse grained materials. Silts and clays (< No. 200 sieve) comprise about 17% of the coarse grained materials. Although local variations exist, soils with considerably more coarse Gravels (41.7%) may be encountered in the on-site coarse-grained soils and soil with considerably more Silt and Clay (49.9%) size particles may also be encountered in the on-site coarse-grained soils. A summary of the grain size distributions for the coarse-grained soils is shown in Table #10.

10.2.2.1 Grain Size Analyses: One of the most important characteristics of soil is the size and distribution of the soil particles. Grain sizes analyses were conducted in selected coarse–grained soil samples in accordance with methods derived by Folk and Ward (1957). The Folk and Ward method estimates the Geometric mean, the skewness, and the kurtosis of the distribution. Results of the sediment size distribution for selected coarse-grained soils using the Folk and Ward analysis are presented in Table #11

Geometric Mean is considered the best measure for central tendency for a soil distribution. Standard deviation is the measure to which the sample spreads out around its mean and is a mathematical expression of sorting. A soil is described as well sorted if all soil particles have sizes that are close to the mean size (small standard deviation). If the soil particle sizes are distributed evenly over a wide range of sizes, the sample is considered well graded. A well-graded sample is poorly sorted; a well-sorted sample is poorly graded.

Skewness is a measure of symmetry of a distribution. A distribution, or data set, is symmetric if it looks the same to the left and right of the center point. Most natural systems do not produce normally distributed grain sizes, there are almost always more fine material than coarse material, or vice versa. A distribution has a longer tail less than the maximum, the function has negative skewness (viz., skewed to coarse-size materials). Otherwise, it has positive skewness (viz., skewed to fine-size materials).

Kurtosis is a measure of whether the data are peaked or flat relative to a normal distribution. That is, data sets with high kurtosis tend to have a distinct peak near the mean, decline rather rapidly, and have heavy tails. Data sets with low kurtosis tend to have a flat top near the mean rather than a sharp peak. A uniform distribution would be the extreme case. Kurtosis assesses the percent frequency distribution of particle sizes in terms of a different sort of departure from the normal distribution. If the distribution is excessively peaked it is called "Leptokurtic;" if it is squashed or flattened, it is called "Platykurtic." "Mesokurtic" distributions have zero Kurtosis. Relative relationships for a range of standard deviation, skewness, and kurtosis are shown below.

phi Size Range	**Verbal Description of Sorting**	**Kurtosis Value**	**Verbal Description of Kurtosis**	**Skewness**	**Verbal Description of Skewness**
under .35 phi	very well sorted	under 0.67	very platykurtic	from +1.00 to +0.30	strongly fine skewed
0.35 - 0.50 phi	well sorted	0.67 - 0.90	platykurtic	from +0.30 to +0.10	fine skewed
0.50 - 0.71 phi	moderately well sorted	0.90 - 1.11	mesokurtic	from +0.10 to -0.10	near symmetrical
0.71 - 1.0 phi	moderately sorted	1.11 - 1.50	leptokurtic	from -0.10 to -0.30	coarse skewed
1.0 - 2.0 phi	poorly sorted	1.50 - 3.00	very leptokurtic	from -0.30 to -1.00	strongly coarse skewed
2.0 - 4.0 phi	very poorly sorted	over 3.00	extremely leptokurtic		
over 4.0 phi	extremely poorly sorted				

10.2.2.2 Distribution Curves: An important characteristic of the distribution of soil particles is the shape of the distribution curve. Grain size distributions curves are also described by gradation characteristics, such as, shape (Coefficient of Uniformity: $Cu = D_{60}/D_{10}$) and curvature (Coefficient of Gradation: $Ck = (D_{30})^2/(D_{10})(D_{60})$). Where:

Cu < 5 very uniform
Cu = 5 medium uniform
Cu > 5 non uniform
1.0 < Ck < 3.0 indicates a well-graded soil
Ck < 0.1 indicates a possible gap-graded soil

Results of Uniformity and Curvature analyses on selected coarse-grained soil samples are shown in Table #12.

10.2.3 Fine-Grained Soil Properties: On average, Silts and Clays (< No. 200 sieve) comprise about 82% of the fine grained materials; fine grained Sand (<No. 70 sieve and >No. 200 sieve) comprise about 5% of the coarse-grained materials; medium grained Sand (<No. 20 sieve and >No. 70 sieve) comprise about 2% of the coarse-grained materials; coarse grained Sand (No. 10 sieve), fine Gravel (<1/2-inch and > No. 4 sieve), and coarse Gravel (<3-inch and > 3/4-inch) comprise <1% of the fine-grained materials. Although local variations exist, soils with considerably more fine and medium Sand may be encountered in the on-site fine-grained soils and rarely fine Gravel may rarely be encountered in the on-site fine-grained soils. A summary of the grain size distributions for the fine-grained soils is shown in Table #13. Most of the fine-grained materials contain highly plastic clays. Average Liquid Limits (LL) were about 67 and Plactic Limits (PL) were 32. An average Plasticity Index (PL)of 35 and Liquidity Index (LI) of 0.88 were observed. Thirty samples contained clay factions at or close to the 2μ size, which results in an average Activity Index (AI) of 1.66. Considerable ranges of LL, PL, and Water Contents were observed in the tested samples. A summary of the geotechnical laboratory testing results is shown in Table #9.

10.3 Buried Mud Flat: Remnants of a possible mud flat was encountered in several drill holes. Soils thought to be typically associated with a mud flat include very moist, soft, dark gray, highly plastic (fat) clay materials containing traces of sand, gravel and shells, occasionally containing traces of organic material. Soil materials thought to be typically associated with mud flat have been recovered in drill holes Nos. LSP-03-04, LSP-03-05 LSP-03-07, LSP-03-08, LSP-03-10, LSP-03-11, LSP-03-12, LSP-03-17, LSP-03-18, LSP-03-19, LSP-03-20, LSP-03-23, LSP-03-24, LSP-03-25, LSP-03-26, LSP-03-27, LSP-03-31, LSP-03-32, LSP-03-33, LSP-03-34, LSP-03-36, LSP-03-37, LSP-03-38, CA-04-01, CA-04-01, CA-04-02, CA-04-03, CA-04-04, CA-04-05, CA-04-06, NC-04-01, and NC-04-02.

10.4 Hydrologic Soils Groups: Soils are classified into Hydrologic Soil Groups (HSG) to indicate the minimum rate of infiltration obtained for bare soil after prolonged wetting. HSG's are based upon USDA soil textural classes. Hydrologic Soil Groups are at classified as A, B, C, and D. Two hydrologic soil properties are associated with the soil textural group: (i) the Effective Water Capacity (C_w) and (ii) the minimum Infiltration Rate (*f*). The effective water capacity of a soil is the fraction of the void space available for water storage, measures in inches per inch. The minimum infiltration rate is the final rate that water passes through the soil profile during saturated conditions, measured in inches per hour.

Saturated infiltration rate is a measure of how quickly water can move through the soil when it is saturated. Soil infiltration rate, in conjunction with water storage capacity, is fundamental to controlling the soil-water regime that determines land suitability for a range of purposes.

Soils with a slow infiltration rate at or near the soil surface (e.g. less than 1.18/hr) cannot transmit water from heavy showers of rain and this can lead to excessive run-off and potentially to erosion. Run-off also represents a loss of water that could have otherwise been available to plants. Subsoil layers are nearly always less permeable than surface layers because of the lower rates of biological activity. Soils with a strong texture contrast between topsoil and subsoil may have a sharp reduction in infiltration rate with depth. In this case, drainage of water is impeded and water logging can be a problem

Group A soils have low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sand or gravel and have a high rate of water transmission (greater than 0.30 in/hr).

Group B soils have moderate infiltration rates when thoroughly wetted and consist chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission (0.15-0.30 in/hr).

Group C soils have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine texture. These soils have a low rate of water transmission (0.05-0.15 in/hr).

Group D soils have high runoff potential. They have *very* low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a clay pan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very low rate of water transmission (0-0.05 in/hr).

Approximate numerical ranges for Infiltration Rate (f) and Effective Water Capacity (C_w) and the associated hydrologic soil groups for coarse-grained soils are shown in Table #14. Approximate numerical ranges for Infiltration Rate (f) and Effective Water Capacity (C_w) and the associated hydrologic soil groups for fine-grained soils are shown in Table #15.

10.5 Hydraulic Conductivity: Several empirical relationships exist between hydraulic conductivity (permeability) and the grin size distribution for a soil. Two notable methods include the Hazen Approximation Method and the Krumbein and Monk Method. The Hazen Approximation method is calculated as follows:

$$K = C(D_{10})^2$$

Where K is the hydraulic conductivity (cm/sec) and D10 is the Hazen's effective grain size (mm). The Hazen approximation of hydraulic conductivity is applicable when the effective size (D10) is between 0.1 mm and 3.0 mm. Several coarse-grained soils met the effective size criteria. Hazen derived hydraulic conductivity's for selected soil samples are shown in Table #16.

The Krumbein and Monk Method is also used to empirically estimate the permeability's of soil, and is calculated as follows:

$$k = 760\ (GM_e)^{2e\text{-}1.31\sigma\phi}$$

Where k is the intrinsic permeability (in darcies), GMe is the geometric mean grain diameter in mm, and σ_{ϕ} is the standard deviation in phi (ϕ) units. The Krumbein and Monk equation requires mean grain size ranging from –0.75ϕ (1.682 mm) to 1.25ϕ (0.420 mm) and standard deviations ranging between 0.04ϕ (0.973 mm) to 0.80ϕ (0.574 mm). No sample obtained in this site investigation meet that requirement, which precluded the application of the Krumbein and Monk method.

11.0 GROUNDWATER:

11.1 Levels: Piezometric groundwater levels varies across the site. Groundwater levels as encountered during drilling, at the completion of drilling, and after 24-hours are shone in Table #17. All drill holes remained open for at least 24-hours to obtain a groundwater level reading. Initial groundwater readings taken in all piezometers are shown in Table #18. Synoptic groundwater readings taken on 15 November 2003 are shown in Table #19. Synoptic groundwater readings taken on 8 February 2004 are shown in Table #20. Synoptic groundwater readings taken on 9 February 2004 are shown in Table #21. Synoptic groundwater readings taken on 10 February 2004 are shown in Table #22. Changes in groundwater readings are shown in Table #23. Changes in groundwater elevations observed in the permanent piezometers are plotted in Appendix I. Groundwater levels detected in temporary piezometer No. LSP-03-35 appears to be abnormally low and should be used only with caution until a determination as to the reliability of the readings is made. Groundwater levels in permanent piezometer No. LSP-03-05 appears to be abnormally high. Due to its proximity to the North Cove, this piezometer may be better hydraulically connected to water in the North Cove than any other piezometer. Groundwater-surface water interactions and tidal effects may effect groundwater levels, but were not considered in this report. Groundwater contour maps for groundwater readings taken in the permanent piezometers are shown in Figure Nos. 10, 11, 12, and 13 for groundwater levels obtained on15 Nov 03, 8 Feb 04, 9 Feb 04, and 10 Feb 04, respectively. Groundwater contours were created in GMS Version 4.0 using the simple triangulation TIN generation method.

11.2 Flow: Groundwater gradients were analyzed for each synoptic reading set. Groundwater gradients between all piezometers were analyzed to determine both the relatively steepest and flattest gradients and to determine the piezometers which have the relatively higher groundwater levels (flow toward) and the piezometers which have relatively lower groundwater levels (flowing away) from each permanent piezometer. The summary of groundwater gradients between piezometers based upon the 15 November 2003 synoptic reading set is shown in Table #24. The summary of groundwater gradients between piezometers based upon the 8 February 2004 synoptic reading set is shown in Table #25. The summary of groundwater gradients between piezometers based upon the 9 February 2004 synoptic reading set is shown in Table #26. The summary of groundwater gradients between piezometers based upon the 10 February 2004 synoptic reading set is shown in Table #27. Groundwater flow direction and average gradient calculations were also analyzed using LMNO Groundwater Flow Direction and Gradient Calculator software available from LMNO Engineering, Research, and Software, Ltd. Groundwater flow direction and average gradient calculations for the 15 November 2003 synoptic reading set is shown in Table #28. Groundwater flow direction and average gradient calculations for the 8 February 2004 synoptic reading set is shown in Table #29. Groundwater flow direction and average gradient calculations for the 9 February 2004 synoptic reading set is shown in Table #30. Groundwater flow direction and average gradient calculations for the 10 February 2004 synoptic reading set is shown in Table #31. A general groundwater flow direction map using averaged results from the LMNO Groundwater Flow Direction and Gradient Calculator software is shown in Figure #14.

12.0 GEOTECHNICAL CHARACTERIZATION

12.1 Strength: The strength of the surficial materials depends on their grain size, compaction, and water content. Estuarine, tidal, and alluvial deposits are typically of low strength because they have not been subject to water or sediment loads greater than those at present, and have been continuously saturated or moist, and so are not compact. They also may contain significant amounts of organic matter, which is weaker than mineral soil. Any significant structures which may be proposed for this site, other than those which are lightly loaded, may require addition foundation analyses to be performed once the structure has been sited.

12.1 Excavation: As discussed in Paragraph 10.2, silty Sand is predominate throughout the project site, especially within the top five feet. A review of SPT blow counts for the silty/clayey Sand (viz., sand without gravel or man-made fill materials) encountered with the top five feet, suggests an approximate average blow count of 8-9 blows per foot. This suggests that the soil be classified as ‘loose,’ although some ‘very loose’ and ‘dense’ soils were also encountered. Near surface excavation of this material should present no unusual excavation problems. However, deeper excavations, notably excavation of the Ecochannel in the vicinity of the North Cove, may present excavation problems. Much of the soft clays encountered in the vicinity of the North Cove (viz., drill hole Nos. LSP-03-03, LSP-03-04, LSP-03-05, LSP-03-20, NC-04-01, and NC-04-

02, etc.) is zero or very low blow count material. This suggests that the soil is 'very soft.' Based upon blow count data, the estimated unconfined compressive strength of the clay is less than 0.25 tons/sq. ft. This soil may exhibit excavation problems due to its very soft consistency, which may result in slumping of cuts and corresponding problems with maintaining channel grade control, its ability to stick to excavating equipment and tools, and its ability to deform and maintain excess pore pressure. Earthmoving type construction equipment may not be able to operate directly on this material. Special considerations may be needed during construction to minimize excavation problems if cuts into the soft Clay are needed to construct the proposed Eco-Channel near the North Cove.

12.3 Drainage and Dewatering: The site is bounded by surface water on two separate sides. Subsequently, the impact of groundwater on any excavations may be significant. As such, dewatering of excavations may be required to allow construction. Drainage of the coarse-grained, granular soils may be efficiently drained by gravity. Considerable quantities of water may be removed from the coarse-grained, granular soils. Water stored in soil pores is released slowly. In silty sands, drainage may take days or weeks. Sumps, drains, and open pumping may be effective in those areas with coarse-grained, granular soils. Drainage of clays is more problematic. The quantity of water to be removed in clays is typically small, often tens of gpm or less. Gravity drainage is usually not effective. A well-point type collection system may be required in those areas with extensive fine-grained, cohesive soils present. Since the water moves though the soil with difficulty, the spacing of collection (well) points must be very close and prolonged pumping time would be beneficial. Especially in those areas in the immediate proximity of surface water or where deep excavations are required.

12.4 Slopes: Stability of the excavated slopes for the Ecochannel depends upon the characteristics of foundation and slope materials and the geometry of the slope. Excavated slopes must be designed to ensure stability, as well as, practical considerations. The stability of slopes consisting of cohesionless materials depends upon the angle of internal frictions (Φ), the slope angle, the unit weight of soil, and internal pore pressures. Generally in granular materials, a slope of 1 vertical on 1-1/2 horizontal is adequate. However, slopes of 1 vertical to 3 horizontal are recommend to ensure safety of maintenance personal that may be required to work on the slope (viz., grass moving) or where the general public has unrestricted access to the slope. Even flatter slopes (viz., 1 V to 10H) should be considered if vehicle access is required into the channel. Stone protection and appropriate bedding should be provided on the slope face. Surface drainage features should also be provided to prevent erosion from surface runoff. Topsoil from stripping operations should be stockpiled ands spread over the excavated slope after excavation has been completed. This will provide a good base for vegetative growth.

13.0 CONCLUSIONS

13.1 Soils:

In general, the on-site soils consist primarily of coarse-grained materials overlying fine-grained soils, although about 15% of the drill holes did not encounter any fine-grained materials to the bottom of the drill hole. About 85% of the drill holes encountered at least one layer of fine-grained materials underlying the surficial coarse-grained layer. In theses drill holes, the overlying coarse-grained materials ranged from about 3-ft thick to about 27-ft thick, averaging about 14-ft thick. The average depth of the fine-grained layer immediately underlying the surficial coarse-grained layer was about 13-ft, although it was encountered at a depth of 3-ft to a depth of 28.5-ft in the drill hole. This fine-grained layer ranged from about 1.5-ft to about 27-ft thick, averaging about 12-ft thick. A second, lower coarse-grained layer was encountered in about 45% of the drill holes. The average depth of this lower, second coarse-grained layer was about 19-ft, although it was encountered at a depth of 6-ft to a depth of 28.5-ft in the drill hole. A second, lower fine-grained layer and a third, lower coarse-grained layer was detected in about 9% and 4% of the drill holes, respectively. Where detected, the thickness of the second, lower fine-grained layer was about 12-ft and the thickness of the third, lower coarse-grained layer was about 7-ft.

The coarse-grained soils consisted primarily of sand size particles, although minor amounts of gravel and silt or clay size particles were also typically found within the coarse-grained soils. The coarse-grained soils are typically very poorly sorted and the distributions are often skewed to the finer sized portion. The soil distributions were often leptokurtic (excessively peaked). Although some platykurtic (flatten) type distributions were also observed. Coefficient of Uniformity and Coefficient of Curvature analyses also suggest that the coarse-grained soils are non-uniform and well-graded, respectively. Based upon blows counts from the drilling and sampling program, the relative density of the coarse-grained soils suggests that the soil be classified as ‘loose,’ although some ‘very loose’ and ‘dense’ soils were also encountered.

The fine-grained soils consisted primarily of silt or clay size particles, although some minor amounts of fine and medium sand as also typically sound in the fine-grained soils. The fine-grained soils are often highly plastic (PI>15) and may have a tendency to swell. The typically high Activity Index of the fine-grained soils classifies it as an ‘active’ clay. Active clays are typically highly expansive and are the most troublesome in slopes and beneath structural foundations. Several samples of fine-grained soils has LI >1.0, which suggests that portions of these soils are already at its liquid limit water content and is extremely soft. High Liquid Limits (LL) and high clay (2μ size) content suggests that these soils are very cohesive and sticky. Based upon blows counts from the drilling and sampling program, much of the fine-grained soils are weight-of-rod or low blow count materials. This suggests that the in-situ consistency of the fine-grained soils soil is ‘very soft’ to ‘occasionally ‘soft.’

Based upon USDA soil textures classifications, the coarse–grained soils are typically in the Group A Hydrologic Soil Group. Group A soils have low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sand or gravel and have a high rate of water transmission (greater than 0.30 in/hr). Based upon USDA soil textures classifications, the fine–grained soils are typically in the Group B and C Hydrologic Soil Groups. Group B soils have moderate infiltration rates when thoroughly wetted and consist chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission (0.15-0.30 in/hr). Group C soils have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine texture. These soils have a low rate of water transmission (0.05-0.15 in/hr).

Base upon empirical relationships (viz., Hazen Approximation Method), the coarse-grained soils have an estimated Hydraulic Conductivity (K) of about 1.87 cm/sec.

13.2 Groundwater:

Groundwater depth range from about 1.3-ft below existing grade to about 12.1-ft below existing grade, as measured from the eighteen piezometers installed through out the site. Maximum fluctuations in groundwater levels up to 3.12-ft were observed in the piezometers.

The highest groundwater elevation was typically observed in piezometer No. LSP-03-09 and the lowest groundwater elevation was typically observed in piezometer No. LSP-03-04. This suggest that groundwater flows across the site away from LSP-03-09 and towards LSP-03-04.

Groundwater gradients are typically very flat. As such, relatively minor differences in groundwater readings between adjacent piezometers may impact the groundwater contour maps.

Groundwater flow direction and average gradient calculations using LMNO Groundwater Flow Direction and Gradient Calculator software suggests that groundwater flow direction is about N35^{o}. Based upon this analysis, groundwater flows across the site and discharges toward the adjacent Morris Canal.

13.3 Subsurface Conditions:

Near surface excavation of this material should present no unusual excavation problems. However, deeper excavations, notably excavation of the Ecochannel in the vicinity of the North Cove, may present excavation problems. The presence of ‘Active’ clays may become result in stability and foundation problems in slopes and beneath structures.

The presence of soft, fine-grained soils may cause excavation problems due to its very soft consistency, which may result in slumping of cuts and corresponding problems with maintaining channel grade control, its ability to stick to excavating equipment and tools, and its ability to deform and maintain excess pore pressure. Earthmoving type construction equipment may not be able to operate directly on this material.

Since the site is bounded by surface water on two separate sides, the impact of groundwater on any excavations may be significant. As such, dewatering of excavations may be required to allow construction.

Slopes of 1 vertical to 3 horizontal are recommend to ensure safety of maintenance personal that may be required to work on the slope (viz., grass moving) or where the general public has unrestricted access to the slope. Even flatter slopes (viz., 1 V to 10H) should be considered if vehicle access is required into the channel.

Stone protection and appropriate bedding should be provided on the slope face. Surface drainage features should also be provided to prevent erosion from surface runoff. Topsoil from stripping operations should be stockpiled ands spread over the excavated slope after excavation has been completed to provide a good base for vegetative growth.

14.0 RECOMMENDATIONS

14.1 Long Term Groundwater Monitoring fluctuations in groundwater levels should be studied in depth. Short-term, tidal, seasonal, and long-term fluctuations in groundwater may have a significant impact on wetlands. Fluctuations in groundwater can drastically impact the development and ecological integrity of wetlands. It is recommended that additional investigations be made into documenting and understanding the short-term, tidal, seasonal, and long-term fluctuations of groundwater at the Liberty State Park site.

14.2 Any future groundwater studies should also attempt to determine the 3D groundwater flow system including the local, intermediate, regional system, as well as the presence of stagnation points in the flow regime. 3D groundwater flow patterns can be quite complex at both small and large scales. The groundwater-surface water interaction may be the key to understanding the groundwater flow regime at Liberty State Park. Given the transit nature of groundwater flow patterns, as well as the complexities of groundwater flow patterns at both large and small scales, a good conceptualization of groundwater flow patterns is required for design.

14.3 Since the project site is bounded on two by water, dewatering during construction will probably be required. In order to better predict dewatering requirements, it is recommended that additional field investigations be undertaken to confirm the empirical hydraulic conductivity's presented in this report. Hydraulic conductivity testing may be conducted using 'slug' tests performed within the existing piezometers and analyzed using a suitable analytical method, such as Horslev or Bouwer and Rice.

15.0 REFERENCES

15.1 Required Publications

ASTM D 420
Standard Guide for Investigating and Sampling Soil and Rock

ASTM D 653
Standard Terminology Relating to Soil, Rock, and Contained Fluids

ASTM D 854
Standard Test Method for Specific Gravity of Soils

ASTM D 1542
Standard Practice for Soil Investigation and Sampling by Auger Borings

ASTM D 1586
Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils

ASTM D 1587
Standard Practice for Thin-Walled Tube Sampling of Soils

ASTM D 2487
Standard Test Method for Classification of Soils for Engineering Purposes (USCS)

ASTM D 2488
Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)

ASTM D 4220
Standard Practices for Preserving and Transporting Soil Samples

ASTM D 4220
Standard Practices for Handling, Storing, and Preparing Soft Undisturbed Marine Soil

ASTM D 5088
Standard Practices Decontamination of Field Equipment Used at Nonradioactive Waste Sites

EM 200-1-3
Requirements for the Preparation of Sampling and Analysis Plans

EM 1110-1-1802
Soil Sampling

EM 1110-1-1804
Geotechnical Investigations

EM 1100-2-1906
Laboratory Soils Testing

EM 1110-2-2504
Design of Sheet Pile Walls

ER 1105-2-100
Planing Guidance Notebook

TM 5-818-7
Foundations in Expansive Soils

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TABLES

TABLE 1

LIBERTY STATE PARK
SUMMARY OF DRILLING AND SAMPLING PROGRAM

DRILL HOLE NO.	TOTAL DEPTH OF DH (FT)	NO. OF DISTURBED SAMPLES	USCS SOIL CLASSIFICATIONS TYPES FOUND IN DRILL HOLE
LSP-03-01	26.4	18	SM, GP-GM, SP-SM, GM, SP
LSP-03-02	30.0	20	CL, SM, SP-SM
LSP-03-03	30.0	20	CL, SM, SP-SM, SM
LSP-03-04	30.0	20	SM, GM, CH
LSP-03-05	30.0	20	SM, SP-SM, GP-GM, SM, CH
LSP-03-06	30.0	20	SM, SC, SP-SM
LSP-03-07	30.0	20	SP-SM, GM, SM, CH, SC
LSP-03-08	30.0	20	SP-SM, CH, SM
LSP-03-09	30.0	20	SM, SP-SM, CH, SC, ML, GM
LSP-03-10	30.0	20	SM, SP-SM, CL, CH
LSP-03-11	30.0	20	SM, SP-SM, CH, SC
LSP-03-12	30.0	20	CL, SM, SC, CH, SC
LSP-03-13	21.3	15	SM, SC/SM, SC/GC
LSP-03-14	27.9	19	SM, SC, SM/SC, SP-SM
LSP-03-15	30.0	20	SM, GP-GM, SM, CL/ML
LSP-03-16	30.0	20	SP-SM, SM, CH, SC
LSP-03-17	30.0	20	SM, SM/SC, SC, CH
LSP-03-18	30.0	20	CL, SM, CH
LSP-03-19	30.0	20	SM, GM, CL/CH, CH
LSP-03-20	30.0	20	SM, CL/CH, CH
LSP-03-23	30.0	23	SM, GM, CH, SC, SP-SM
LSP-03-24	30.0	20	SM, CL, CH
LSP-03-25	30.0	20	SM, SC, CH, SP-SM
LSP-03-26	27.0	18	SM, SP-SM, CH
LSP-03-27	30.0	20	SM, SP-SM, ML, CH. CL
LSP-03-28	30.0	20	SM, SP-SM, CL/CH, CH
LSP-03-29	30.0	20	SP-SM, SC, CH, SM
LSP-03-30	30.0	20	SM, SP-SM, CL/ML, CH
LSP-03-31	30.0	20	SM, SP-SM, CH
LSP-03-32	30.0	20	SM, CL, CL/CH, CH, SC
LSP-03-33	30.0	20	SP-SM, SM, CH, SC
LSP-03-34	30.0	20	SM, CH, SC, SC/SM
LSP-03-35	30.0	20	SM, SP-SM, CL
LSP-03-36	30.0	20	SC/SM, SM, CH, SC, CL/SC, OL
LSP-03-37	30.0	20	SM, SP-SM, CH
LSP-03-38	30.0	20	SM, ML, CL, CH, SC
LSP-03-39	30.0	20	SM, GM, CH, SP-SM
LSP-03-40	30.0	20	SP-SM, SM, CL, SP

TABLE 1 - Continued

LIBERTY STATE PARK
SUMMARY OF DRILLING AND SAMPLING PROGRAM

DRILL HOLE NO.	TOTAL DEPTH OF DH (FT)	NO. OF DISTURBED SAMPLES	USCS SOIL CLASSIFICATIONS TYPES FOUND IN DRILL HOLE
NC-04-01	21.0	13	SM, CL, CH
NC-04-02	21.0	12	SM, CL, CH
NC-04-03	21.0	14	SM, SP-SM, ML
NC-04-04	21.0	14	SM, SP-SM
NC-04-05	21.0	14	SM SP-SM
CA-04-01	30.0	20	CL, SM, SP-SM, CL, CH
CA-04-02	30.0	20	ML/CL, CL, SM, SC, CH
CA-04-03	30.0	20	SM, ML, CL, SP, SP-SM, CH
CA-04-04	30.0	20	CL, SC, SM, SP-SM, CH
CA-04-05	30.0	20	CL, SM, ML, CL, CH
CA-04-06	30.0	20	SM, SP-SM, CL, CH
BA-04-01	20.0	0	--
BA-04-02	20.0	0	--
BA-04-03	20.0	0	--
BA-04-04	20.0	0	--
BA-04-05	20.0	0	--
BA-04-06	20.0	0	--

TABLE 2

LIBERTY STATE PARK
DRILL HOLE LOCATIONS AND ELEVATIONS
FOR ON-LAND DRILL HOLES

DH No.	NORTH	EAST	ELEVATION
LSP-03-01	683,832.04799	616,002.71436	6.90
LSP-03-02	683,517.39349	616,362.32508	7.37
LSP-03-03	683,192.86435	617,998.45475	7.05
LSP-03-04	682,884.30817	618,440.32038	5.04
LSP-03-05	682,589.50605	618,535.55579	9.78
LSP-03-06	682,834.70794	615,902.61584	7.56
LSP-03-07	682,579.04042	616,800.74738	6.53
LSP-03-08	682,280.46765	615,978.02068	6.73
LSP-03-09	682,011.33382	614,834.20085	11.59
LSP-03-10	681,879.57853	616,168.43446	9.05
LSP-03-11	681,149.50173	615,521.93873	7.91
LSP-03-12	681,514.54832	616,749.81368	8.70
LSP-03-13	683,740.03234	615,450.41968	9.86
LSP-03-14	683,756.67291	615,727.44005	7.96
LSP-03-15	683,548.61749	616,161.41928	7.13
LSP-03-16	683,160.30583	616,573.93342	6.64
LSP-03-17	682,979.20081	616,986.62282	6.80
LSP-03-18	682,828.57477	617,431.15663	9.09
LSP-03-19	682,477.62098	617,933.68717	7.38
LSP-03-20	682,601.90390	618,859.81917	9.85
LSP-03-23	682,551.80450	616,198.14123	6.35
LSP-03-24	682,189.16123	617,249.39812	10.31
LSP-03-25	682,458.36113	615,633.10481	6.42
LSP-03-26	682,185.59132	616,344.21849	6.67
LSP-03-27	682,017.45506	616,742.15925	7.61
LSP-03-28	681,500.67515	617,241.07892	7.45
LSP-03-29	681,837.12062	615,662.27604	7.65
LSP-03-30	681,511.76718	616,267.23026	7.58
LSP-03-31	681,126.57585	616,796.39857	7.16
LSP-03-32	680,562.33551	614,827.67803	8.15
LSP-03-33	680,802.27112	615,968.93213	6.69
LSP-03-34	680,785.98830	614,318.55425	13.16
LSP-03-35	681,672.48762	613,786.85158	12.46
LSP-03-36	681,220.83780	614,399.82904	11.85
LSP-03-37	680,938.00510	614,681.62305	10.89
LSP-03-38	680,654.67995	615,601.34192	9.44
LSP-03-39	683,052.44778	616,234.58076	7.55
LSP-03-40	682,836.04028	616,405.06099	6.24

TABLE 2 - Continued

LIBERTY STATE PARK
DRILL HOLE LOCATIONS AND ELEVATIONS
FOR ON-LAND DRILL HOLES

DH No.	NORTH	EAST	ELEVATION
NC-04-03	682,544.63	618,700.83	6.41
NC-04-04	682,668.42	618,819.14	6.43
NC-04-05	682,601.71	619,002.72	7.41
CA-04-01	682,986.23	617,851.94	9.16
CA-04-02	682,731.06	617,641.69	8.80
CA-04-03	682,461.27	617,438.02	10.02
CA-04-04	681,938.08	617,114.38	9.24
CA-04-05	681,689.74	616,900.75	9.30
CA-04-06	681,256.92	616,603.32	6.57
BA-04-01	682,153.40	615,159.08	7.11
BA-04-02	681,882.18	614,686.79	7.41
BA-04-03	681,669.09	614,566.37	9.35
BA-04-04	681,444.47	614,574.94	8.22
BA-04-05	681,162.64	614,663.81	11.34
BA-04-06	680,961.88	614,884.18	9.11

NOTES:
1. Final DH coordinates were obtained using an Ashtech ProMark2 GPS survey system.
2. Conversions obtained using Corpscon for Windows 5.11.08.
3. Horizontal Datum: State Plane, NAD83, Geographic NAD83.
4. Horizontal Zone: New Jersey – 2900   Horizontal Units: U.S. Survey Feet.

TABLE 3

LIBERTY STATE PARK
DRILL HOLE LOCATIONS AND WATER DEPTHS
FOR OFF-SHORE DRILL HOLES

DH No.	NORTH	EAST	WATER DEPTH
NC-04-01	682,441.45	618,911.02	7.90
NC-04-02	682,302.23	619,381.51	5.40

TABLE 4

LIBERTY STATE PARK
SUMMARY OF THE GEOTECHNICAL LABORATORY TESTING PROGRAM

NOMENCLATURE	NO. OF TESTS COMPLETED
Visual–Manual Classifications	958
Water Contents	68
Atterberg Limits	30
Mechanical Analysis (with hydrometer)	68

TABLE 5

LIBERTY STATE PARK
SUMMARY OF USCS SOIL TYPES ENCOUNTERED IN ALL DRILL HOLES
FROM 0.0-FT TO BOTTOM OF DRILL HOLE

USCS SOIL CLASSIFICATION	PERCENTAGE OF USCS SOIL TYPE ENCOUNTERED DURING DRILLING
GM (silty GRAVEL)	1%
GP-GM (GRAVEL w/silt)	1%
SP (poorly graded SAND)	1%
SP-SM (SAND w/silt)	14%
SM or SC (silty/clayey SAND)	44%
CL/ML (lean CLAY)	7%
CH/MH (fat CLAY)	32%

* Note: Excludes the Two Off-Shore Drill Holes (NC-04-01 & NC-04-02).

TABLE 6

LIBERTY STATE PARK
SUMMARY OF USCS SOIL TYPES ENCOUNTERED IN ALL DRILL HOLES
FROM 0.0-FT TO 10.5-FT DEPTH

USCS SOIL CLASSIFICATION	PERCENTAGE OF USCS SOIL TYPE ENCOUNTERED DURING DRILLING
GM (silty GRAVEL)	2%
GP-GM (GRAVEL w/silt)	1%
SP (poorly graded SAND)	0%
SP-SM (SAND w/silt)	18%
SM or SC (silty/clayey SAND)	66%
CL/ML (lean CLAY)	8%
CH/MH (fat CLAY)	5%

* Note: Excludes the Two Off-Shore Drill Holes (NC-04-01 & NC-04-02).

TABLE 7

LIBERTY STATE PARK
SUMMARY OF USCS SOIL TYPES ENCOUNTERED IN ALL DRILL HOLES
FROM 0.0-FT TO 4.5-FT DEPTH

USCS SOIL CLASSIFICATION	PERCENTAGE OF USCS SOIL TYPE ENCOUNTERED DURING DRILLING
GM (silty GRAVEL)	2%
GP-GM (GRAVEL w/silt)	1%
SP (poorly graded SAND)	0%
SP-SM (SAND w/silt)	21%
SM or SC (silty/clayey SAND)	67%
CL/ML (lean CLAY)	9%
CH/MH (fat CLAY)	0%

* Note: Excludes the Two Off-Shore Drill Holes (NC-04-01 & NC-04-02).

TABLE 8

LIBERTY STATE PARK
SUMMARY OF USCS SOIL TYPES ENCOUNTERED IN THE OFF-SHORE DRILL HOLES* FROM 0.0-FT TO BOTTOM OF DRILL HOLE

USCS SOIL CLASSIFICATION	PERCENTAGE OF USCS SOIL TYPE ENCOUNTERED DURING DRILLING
GM (silty GRAVEL)	0%
GP-GM (GRAVEL w/silt)	0%
SP (poorly graded SAND)	0%
SP-SM (SAND w/silt)	0%
SM or SC (silty/clayey SAND)	8%
CL (lean CLAY)	8%
CH (fat CLAY)	84%

* Note: Drill Hole Nos. NC-04-01 and NC-04-02.

TABLE 9

LIBERTY STATE PARK
GENERAL SUMMARY OF THE GEOTECHNICAL LABORATORY TESTING RESULTS

DH No.	Sample Depth (ft)	USCS	NatW%	%Gravel	%Sand	%Fines	%Clay	LL	PL	PI	LI	AI
LSP-03-01	3.0-4.5	SM	37.5	26.0	51.7	22.3	0	--	--	--	--	--
LSP-03-02	4.5-6.0	SM	32.7	11.5	50.1	38.4	0	--	--	--	--	--
LSP-03-03	4.5-6.0	GM	15.8	53.6	32.5	13.9	0	--	--	--	--	--
	24.0-25.5	CH	54.2	0.0	4.8	95.2	15	68	30	38	0.64	2.53
LSP-03-04	4.5-6.0	SM	29.6	24.8	56.9	18.3	0	--	--	--	--	--
	10.5-12.0	CH	57.1	7.0	9.4	83.6	25	68	31	37	0.71	1.48
LSP-03-05	4.5-6.0	GP-GM	9.6	50.5	42.8	6.7	0	--	--	--	--	--
	9.0-10.5	MH	60.5	2.6	35.2	62.2	14	74	39	35	0.61	2.50
LSP-03-06	3.0-4.5	GM	11.4	42.0	36.7	21.3	0	--	--	--	--	--
LSP-03-07	4.5-6.0	SM	30.9	32.8	53.1	14.1	0	--	--	--	--	--
	10.5-12.0	MH	55.6	1.2	6.3	92.5	23	64	32	32	0.74	1.39
LSP-03-08	7.5-9.0	CH	47.9	0.0	12.7	87.3	27	62	28	34	0.59	2.62
LSP-03-09	4.5-6.0	CH	66.1	0.0	8.5	91.5	27	72	32	40	0.85	1.48
LSP-03-10	15.0-16.5	CH	64.0	6.1	9.8	84.1	25	75	32	43	0.74	1.72
LSP-03-11	3.0-4.5	SP-SM	20.5	1.9	91.1	7.0	0	--	--	--	--	--
LSP-03-12	18.0-19.5	CH	58.2	0.2	21.3	78.5	22	64	30	34	0.83	1.55
LSP-03-13	6.0-7.5	ML	22.2	0.0	32.4	67.6	0	--	--	--	--	--
LSP-03-14	15.0-16.5	ML	21.1	0.0	44.0	56.0	0	--	--	--	--	--
LSP-03-15	1.5-3.0	GW-GM	6.0	65.2	26.0	8.8	0	--	--	--	--	--
	7.5-9.0	SM	39.8	26.0	49.9	24.1	0	--	--	--	--	--
LSP-03-16	1.5-3.0	SM	29.4	19.5	62.4	18.1	0	--	--	--	--	--
	18.0-19.5	CH	52.7	0.0	10.0	90.0	30	74	31	43	0.50	1.43
LSP-03-17	3.0-4.5	SW-SM	26.5	24.4	65.1	10.5	0	--	--	--	--	--
	22.5-24.0	MH	65.3	0.9	7.3	91.8	30	75	35	40	0.76	1.33

TABLE 9 - Continued

LIBERTY STATE PARK
GENERAL SUMMARY OF GEOTECHNICAL LABORATORY TESTING RESULTS

DH No.	Sample Depth (ft)	USCS	NatW%	%Gravel	%Sand	%Fines	%Clay	LL	PL	PI	LI	AI
LSP-03-18	4.5-6.0	SM	23.9	22.7	63.2	14.1	0	--	--	--	--	--
	12.0-13.5	CH	51.0	0.0	6.8	93.2	26	65	31	34	0.59	1.31
LSP-03-19	4.5-6.0	SM	38.0	16.3	66.3	17.4	0	--	--	--	--	--
	21.0-22.5	ML	55.3	0.0	3.4	96.6	29	69	32	37	0.63	1.28
LSP-03-20	1.5-3.0	SP-SM	3.6	1.6	88.6	9.8	0	--	--	--	--	--
	21.0-22.5	CH	75.7	0.0	11.8	88.2	24	92	38	54	0.70	2.25
LSP-03-23	10.5-12.0	MH	61.6	0.0	5.1	94.9	31	81	38	43	0.55	1.39
LSP-03-24	6.0-7.5	SM	32.7	27.6	57.5	14.9	0	--	--	--	--	--
	13.5-15.0	CL	52.8	0.0	13.2	86.8	24	49	27	22	1.17	0.92
LSP-03-25	13.5-15.0	CH	68.7	0.4	4.8	94.8	34	83	36	47	0.70	1.38
LSP-03-26	10.5-12.0	CH	69.8	0.0	1.3	98.7	26	80	35	45	0.77	1.73
LSP-03-27	4.5-6.0	SM	20.9	0.3	87.4	12.3	0	--	--	--	--	--
	12.0-13.5	CH	59.4	0.0	4.2	95.8	31	69	33	36	0.73	1.16
LSP-03-28	4.5-6.0	SM	17.6	3.3	76.2	20.5	0	--	--	--	--	--
LSP-03-29	3.0-4.5	SP-SM	22.9	2.4	91.0	6.6	0	--	--	--	--	--
LSP-03-30	1.5-3.0	SP-SM	12.6	0.0	90.8	9.2	0	--	--	--	--	--
LSP-03-31	3.0-4.5	SM	16.2	1.5	86.2	12.3	0	--	--	--	--	--
	13.5-15.0	SC-H	38.0	9.5	40.6	49.9	12	55	28	27	0.37	2.25
LSP-03-32	3.0-4.5	SM	21.0	20.6	55.8	23.6	0	--	--	--	--	--
LSP-03-33	10.5-12.0	ML	49.9	0.0	4.7	95.3	4	46	33	13	1.30	3.25
LSP-03-34	3.0-4.5	SM	9.2	14.8	62.1	23.1	0	--	--	--	--	--
LSP-03-35	4.5-6.0	SM	14.3	14.9	66.1	19.0	0	--	--	--	--	--
LSP-03-36	16.5-18.0	CH	45.2	0.0	17.4	82.6	20	56	28	28	0.61	1.40

TABLE 9 - Continued

LIBERTY STATE PARK
GENERAL SUMMARY OF GEOTECHNICAL LABORATORY TESTING RESULTS

DH No.	Sample Depth (ft)	USCS	NatW%	%Gravel	%Sand	%Fines	%Clay	LL	PL	PI	LI	AI
LSP-03-37	3.0-4.5	SM	22.6	0.3	77.3	22.4	0	--	--	--	--	--
LSP-03-38	19.5-21.0	CH	63.4	0.0	6.0	94.0	19	74	32	42	0.75	2.21
LSP-03-39	9.0-10.5	SM	52.1	2.5	71.3	26.2	0	--	--	--	--	--
LSP-03-40	4.5-6.0	SM	38.1	28.9	52.8	18.3	0	--	--	--	--	--
NC-04-01	4.5-6.0	CH	125.0	0.0	6.0	94.0	26	84	37	47	1.87	1.81
NC-04-02	3.0-4.5	MH	103.5	1.3	6.7	92.0	18	82	39	43	1.50	2.39
NC-04-03	1.5-3.0	SM	9.6	20.4	57.9	21.7	0	--	--	--	--	--
NC-04-04	1.5-3.0	SM	8.7	7.2	67.3	25.5	0	--	--	--	--	--
NC-04-05	4.5-6.0	SP-SM	8.9	43.5	46.9	9.6	0	--	--	--	--	--
CA-04-01	7.5-9.0	SW-SM	18.2	24.6	67.1	8.3	0	--	--	--	--	--
	18.0-19.5	CH	59.7	0.5	8.7	90.8	19	54	29	25	1.23	1.32
CA-04-02	4.5-6.0	SM	37.8	16.8	68.3	14.9	0	--	--	--	--	--
	15.0-16.5	MH	70.0	0.0	7.7	92.3	17	60	35	25	1.40	1.47
CA-04-03	4.5-6.0	SW-SM	31.1	24.9	64.8	10.3	0	--	--	--	--	--
	19.5-21.0	CH	53.8	0.5	16.6	82.9	16	56	29	27	0.92	1.69
CA-04-04	9.0-10.5	SW-SM	25.4	19.3	70.0	10.7	0	--	--	--	--	--
	15.0-16.5	MH	60.9	4.8	12.2	83.0	14	54	31	23	1.30	1.64
CA-04-05	7.5-9.0	SM	26.5	10.0	55.3	34.7	0	--	--	--	--	--
	15.0-16.5	MH	54.9	1.0	5.9	93.1	16	51	29	22	1.18	1.38
CA-04-06	3.0-4.5	SP-SM	23.6	0.5	91.0	8.5	0	--	--	--	--	--
	13.5-15.0	CH	59.4	0.0	6.0	94.0	24	52	27	25	1.30	1.04
							Average	*67*	*32*	*35*	*0.88*	*1.66*
							Maximum	*92*	*39*	*54*	*1.87*	*3.25*
							Minimum	*46*	*27*	*13*	*0.37*	*0.92*

TABLE 10

LIBERTY STATE PARK
GRAIN SIZE DISTRIBUTION SUMMARY FOR COARSE-GRAINED SOILS

DH No.	Sample Depth (ft)	USCS	%Coarse Gravel	%Fine Gravel	%Coarse Sand	%Medium Sand	%Fine Sand	%Silt or Clay
LSP-03-01	3.0-4.5	SM	0.0	26.0	8.9	22.4	20.4	22.3
LSP-03-02	4.5-6.0	SM	0.0	11.58	3.1	17.5	29.5	38.4
LSP-03-03	4.5-6.0	GM	30.6	23.0	6.5	10.4	15.6	13.9
LSP-03-04	4.5-6.0	SM	0.0	24.8	10.2	18.7	28	18.3
LSP-03-05	4.5-6.0	GP-GM	7.2	43.3	11.1	17.9	13.8	6.7
LSP-03-06	3.0-4.5	GM	26.5	15.5	4.7	13.8	18.2	21.3
LSP-03-07	4.5-6.0	SM	15.3	17.5	8.1	21.3	23.7	14.1
LSP-03-11	3.0-4.5	SP-SM	0.0	1.9	1.8	26.7	62.6	7.0
LSP-03-15	1.5-3.0	GW-GM	41.7	23.5	5.1	10.1	10.8	8.8
LSP-03-15	7.5-9.0	SM	3.8	22.2	4.8	18.5	26.6	24.1
LSP-03-16	1.5-3.0	SM	0.0	22.7	17.1	26.1	20.0	14.1
LSP-03-17	3.0-4.5	SW-SM	11.5	12.9	12.2	33.3	19.6	10.5
LSP-03-18	4.5-6.0	SM	0.0	22.7	17.1	26.1	20.0	14.1
LSP-03-19	4.5-6.0	SM	0.0	16.3	16.1	30.7	19.5	17.4
LSP-03-20	1.5-3.0	SP-SM	0.0	1.6	3.6	35.9	49.1	9.8
LSP-03-24	6.0-7.5	SM	4.5	23.1	11.3	25.7	20.5	14.9
LSP-03-27	4.5-6.0	SM	0.0	0.3	1.7	24.0	91.7	12.3
LSP-03-28	4.5-6.0	SM	0.0	3.3	9.0	45.5	21.7	20.5
LSP-03-29	3.0-4.5	SP-SM	0.0	2.4	0.2	22.8	68.0	6.6
LSP-03-30	1.5-3.0	SP-SM	0.0	0.0	0.0	24.9	65.9	9.2
LSP-03-31	3.0-4.5	SM	0.0	1.5	1.3	23.8	61.1	12.3
	13.5-15.0	SC-H	0.0	9.5	9.3	21.6	9.7	49.9

TABLE 10 - Continued

LIBERTY STATE PARK
GRAIN SIZE DISTRIBUTION SUMMARY FOR COARSE-GRAINED SOILS

DH No.	Sample Depth (ft)	USCS	%Coarse Gravel	%Fine Gravel	%Coarse Sand	%Medium Sand	%Fine Sand	%Silt or Clay
LSP-03-32	3.0-4.5	SM	5.1	15.5	5.4	21.5	28.9	23.6
LSP-03-34	3.0-4.5	SM	0.0	14.8	7.0	22.1	33.0	23.1
LSP-03-35	4.5-6.0	SM	0.0	14.9	11.5	24.7	29.9	19.0
LSP-03-37	3.0-4.5	SM	0.0	0.3	0.3	3.5	73.5	22.4
LSP-03-39	9.0-10.5	SM	0.0	2.5	6.0	30.1	35.2	26.2
LSP-03-40	4.5-6.0	SM	9.1	19.8	8.3	20.4	24.1	18.3
NC-04-03	1.5-3.0	SM	0.0	20.4	7.3	16.4	34.2	21.7
NC-04-04	1.5-3.0	SM	0.0	7.2	6.5	15.4	45.4	25.5
NC-04-05	4.5-6.0	SP-SM	22.2	21.3	8.6	19.1	19.2	9.6
CA-04-01	7.5-9.0	SW-SM	0.0	24.6	16.4	31.9	18.8	8.3
CA-04-02	4.5-6.0	SM	0.0	16.8	20.8	28.7	18.8	14.9
CA-04-03	4.5-6.0	SW-SM	0.0	24.9	22.0	25.0	17.8	10.3
CA-04-04	9.0-10.5	SW-SM	6.2	13.1	7.0	18.1	44.9	10.7
CA-04-05	7.5-9.0	SM	0.0	10.0	4.5	16.4	34.4	34.7
CA-04-06	3.0-4.5	SP-SM	0.0	0.5	0.9	16.2	73.9	8.5
		Average	*2.66*	*12.91*	*8.28*	*19.34*	*33.25*	*17.30*
		Maximum	*41.70*	*43.30*	*22.00*	*45.50*	*91.70*	*49.90*
		Minimum	*0.00*	*0.00*	*0.00*	*3.50*	*9.70*	*6.60*

TABLE 11

LIBERTY STATE PARK
SEDIMENT SIZE DISTRIBUTION FOR SELECTED COARSE-GRAINED SOILS
USING THE FOLK & WARD METHOD

DRILL HOLE No.	SAMPLE DEPTH (ft)	GM_e GEOMETRIC MEAN SIZE D_{50} (mm)	STANDARD DEVIATION	DESCRIPTION	COEFF. of SKEWNESS (*Sk*)	DESCRIPTION	COEFF. of KURTOSIS (*K*)	DESCRIPTION
NC-04-03	1.5-3.0	0.45	3.92	Very poorly sorted	-0.05	Near-symmetrical	1.03	Mesokurtic
NC-04-04	1.5-3.0	0.21	3.16	Very poorly sorted	0.01	Near-symmetrical	1.43	Leptokurtic
NC-04-05	4.5-6.0	2.11	3.30	Very poorly sorted	0.21	Fine-skewed	0.70	Platykurtic
CA-04-01	7.5-9.0	1.27	2.63	Very poorly sorted	0.15	Fine-skewed	0.89	Platykurtic
CA-04-02	4.5-6.0	1.12	3.26	Very poorly sorted	0.36	Fine-skewed	1.13	Leptokurtic
CA-04-03	4.5-6.0	1.21	2.44	Very poorly sorted	0.24	Fine-skewed	0.70	Platykurtic
CA-04-04	9.0-10.5	0.68	3.25	Very poorly sorted	-0.25	Coarse-skewed	1.27	Leptokurtic
CA-04-05	7.5-9.0	0.18	2.49	Very poorly sorted	-0.07	Near-symmetrical	1.24	Leptokurtic
CA-04-06	3.0-4.5	0.25	1.15	Poorly sorted	0.18	Fine-skewed	1.56	Very Leptokurtic

*Reference: EM 1110-2-1100 Part III, 30 Apr 02.

TABLE 12

LIBERTY STATE PARK
COEFFICIENT OF UNIFORMITY (C_u) AND COEFFICIENT OF CURVATURE (C_k) FOR SELECTED SOIL SAMPLES

DH No.	Sample Depth (ft)	USCS	D_{10} SIZE (mm)	D_{60} SIZE (mm)	C_u	D_{30} SIZE (mm)	C_k
CA-04-01	7.5-9.0	SW-SM	0.097	2.108	21.73	0.504	1.24
CA-04-02	4.5-6.0	SP-SM	0.016	1.788	111.75	0.323	3.64
CA-04-03	4.5-6.0	SW-SM	0.050	2.623	52.46	0.493	1.85
CA-04-04	9.0-10.5	SW-SM	0.060	0.575	9.58	0.232	1.56
CA-04-05	7.5-9.0	SM	0.008	0.271	33.88	0.058	1.55
CA-04-06	3.0-4.5	SP-SM	0.084	0.314	3.74	0.206	1.61
NC-04-03	1.5-3.0	SM	0.013	0.601	46.23	0.125	1.99
NC-04-04	1.5-3.0	SM	0.010	0.286	28.60	0.092	2.96
NC-04-05	1.5-3.0	SP-SM	0.080	7.025	87.81	0.466	0.39
				Average	*39.58*		*1.68*

*Reference: EM 1110-2-1100 Part III, 30 Apr 02.

TABLE 13

LIBERTY STATE PARK
GRAIN SIZE DISTRIBUTION SUMMARY FOR FINE-GRAINED SOILS

DH No.	Sample Depth (ft)	USCS	%Coarse Gravel	%Fine Gravel	%Coarse Sand	%Medium Sand	%Fine Sand	%Silt or Clay
LSP-03-03	24.0-25.5	CH	0.0	0.0	0.1	2.4	2.3	95.2
LSP-03-04	10.5-12.0	CH	0.0	7.0	1.7	4.1	3.6	83.6
LSP-03-05	9.0-10.5	MH	0.0	2.6	3.7	11.8	19.7	62.2
LSP-03-07	10.5-12.0	MH	0.0	1.2	0.3	2.3	3.7	92.5
LSP-03-08	7.5-9.0	CH	0.0	0.0	0.4	4.4	7.9	87.3
LSP-03-09	4.5-6.0	CH	0.0	0.0	0.1	2.7	5.7	91.5
LSP-03-10	15.0-16.5	CH	0.0	6.1	1.0	3.4	5.4	84.1
LSP-03-12	18.0-19.5	CH	0.0	0.2	0.3	4.1	16.9	78.5
LSP-03-13	6.0-7.5	ML	0.0	0.0	0.0	0.4	32.0	67.6
LSP-03-14	15.0-16.5	ML	0.0	0.0	0.4	9.6	34.0	56.0
LSP-03-16	18.0-19.5	CH	0.0	0.0	1.1	2.7	3.0	93.2
LSP-03-17	22.5-24.0	MH	0.0	0.9	0.8	3.1	3.4	91.8
LSP-03-18	12.0-13.5	CH	0.0	0.0	1.1	2.7	3.0	93.2
LSP-03-19	21.0-22.5	ML	0.0	0.0	0.4	1.2	1.8	96.6
LSP-03-20	21.0-22.5	CH	0.0	0.0	0.1	1.4	10.3	88.2
LSP-03-23	10.5-12.0	MH	0.0	0.0	0.9	1.6	2.6	94.9
LSP-03-24	13.5-15.0	CL	0.0	0.0	0.1	1.3	11.8	86.8
LSP-03-25	13.5-15.0	CH	0.0	0.4	0.5	1.6	2.7	94.8
LSP-03-26	10.5-12.0	CH	0.0	0.0	0.0	0.4	0.9	98.7
LSP-03-27	12.0-13.5	CH	0.0	0.0	0.8	1.6	1.8	95.8
LSP-03-33	10.5-12.0	ML	0.0	0.0	0.0	0.6	4.1	95.3
LSP-03-36	16.5-18.0	CH	0.0	0.0	0.4	3.8	13.2	82.6

TABLE 13 - Continued

LIBERTY STATE PARK
GRAIN SIZE DISTRIBUTION SUMMARY FOR FINE-GRAINED SOILS

DH No.	Sample Depth (ft)	USCS	%Coarse Gravel	%Fine Gravel	%Coarse Sand	%Medium Sand	%Fine Sand	%Silt or Clay
LSP-03-38	19.5-21.0	CH	0.0	0.0	0.2	1.8	4.0	94.0
NC-04-01	4.5-6.0	CH	0.0	0.0	1.2	1.4	3.4	94.0
NC-04-02	3.0-4.5	MH	0.0	1.3	0.4	1.4	4.9	92.0
CA-04-01	18.0-19.5	CH	0.0	0.5	0.3	2.4	6.0	90.8
CA-04-02	15.0-16.5	MH	0.0	0.0	0.6	2.3	4.8	92.3
CA-04-03	19.5-21.0	CH	0.0	0.5	1.1	5.3	10.2	82.9
CA-04-04	15.0-16.5	MH	0.0	4.8	1.2	3.3	7.7	83.0
CA-04-05	15.0-16.5	MH	0.0	1.0	1.0	1.3	3.6	93.1
CA-04-06	13.5-15.0	CH	0.0	0.0	0.2	1.2	4.6	94.0
		Average	*0.00*	*0.81*	*0.62*	*2.04*	*4.92*	*81.61*
		Maximum	*0.00*	*7.00*	*3.70*	*11.80*	*34.00*	*98.70*
		Minimum	*0.00*	*0.00*	*0.00*	*0.40*	*0.90*	*56.00*

TABLE 14

LIBERTY STATE PARK
HYDROLOGIC SOIL PROPERTIES CLASSIFIED BY USDA SOIL TEXTURES*
FOR COARSE-GRAINED SOILS

DH No.	Sample Depth (ft)	USCS	EQUIV. USDA %SAND	EQUIV. USDA %SILT	EQUIV. USDA %CLAY	USDA SOIL TEXTURAL CLASSIFICATION	EFFECTIVE WATER CAPACITY (inch/inch)	MINIMUM INFILTRATION RATE (inch/hour)	HYD SOIL GROUP
LSP-03-01	3.0-4.5	SM	66	28	6	SANDY LOAM	0.25	1.02	A
LSP-03-02	4.5-6.0	SM	63	30	7	SANDY LOAM	0.25	1.02	A
LSP-03-03	4.5-6.0	GM	70	30	0	LOAMY SAND	0.31	2.41	A
LSP-03-04	4.5-6.0	SM	78	20	2	LOAMY SAND	0.31	2.41	A
LSP-03-05	4.5-6.0	GP-GM	84	16	0	LOAMY SAND	0.31	2.41	A
LSP-03-06	3.0-4.5	GM	68	32	0	SANDY LOAM	0.25	1.02	A
LSP-03-07	4.5-6.0	SM	81	19	0	LOAMY SAND	0.31	2.41	A
LSP-03-11	3.0-4.5	SP-SM	97	3	0	SAND	0.35	8.27	A
LSP-03-15	1.5-3.0	GW-GM	80	20	0	LOAMY SAND	0.31	2.41	A
LSP-03-15	7.5-9.0	SM	70	30	0	LOAMY SAND	0.31	2.41	A
LSP-03-16	1.5-3.0	SM	79	21	0	LOAMY SAND	0.31	2.41	A
LSP-03-17	3.0-4.5	SW-SM	84	16	0	LOAMY SAND	0.31	2.41	A
LSP-03-18	4.5-6.0	SM	78	22	0	LOAMY SAND	0.31	2.41	A
LSP-03-19	4.5-6.0	SM	76	24	0	LOAMY SAND	0.31	2.41	A
LSP-03-20	1.5-3.0	SP-SM	93	7	0	SAND	0.35	8.27	A
LSP-03-24	6.0-7.5	SM	79	21	0	LOAMY SAND	0.31	2.41	A
LSP-03-27	4.5-6.0	SM	90	10	0	SAND	0.35	8.27	A
LSP-03-28	4.5-6.0	SM	80	20	0	LOAMY SAND	0.31	2.41	A
LSP-03-29	3.0-4.5	SP-SM	95	5	0	SAND	0.35	8.27	A
LSP-03-30	1.5-3.0	SP-SM	93	7	0	SAND	0.35	8.27	A
LSP-03-31	3.0-4.5	SM	90	8	2	SAND	0.35	8.27	A
LSP-03-31	13.5-15.0	SC-H	43	42	15	LOAM	0.19	0.52	B

TABLE 14 - Continued

LIBERTY STATE PARK
HYDROLOGIC SOIL PROPERTIES CLASSIFIED BY USDA SOIL TEXTURES*
FOR COARSE-GRAINED SOILS

DH No.	Sample Depth (ft)	USCS	EQUIV. USDA %SAND	EQUIV. USDA %SILT	EQUIV. USDA %CLAY	USDA SOIL TEXTURAL CLASSIFICATION	EFFECTIVE WATER CAPACITY (inch/inch)	MINIMUM INFILTRATION RATE (inch/hour)	HYD SOIL GROUP
LSP-03-32	3.0-4.5	SM	74	26	0	LOAMY SAND	0.31	2.41	A
LSP-03-35	4.5-6.0	SM	76	23	1	LOAMY SAND	0.31	2.41	A
LSP-03-37	3.0-4.5	SM	94	6	0	SAND	0.35	8.27	A
LSP-03-39	9.0-10.5	SM	76	21	3	LOAMY SAND	0.31	2.41	A
LSP-03-40	4.5-6.0	SM	75	25	0	LOAMY SAND	0.31	2.41	A
NC-04-03	1.5-3.0	SM	68	32	0	LOAMY SAND	0.31	2.41	A
NC-04-04	1.5-3.0	SM	77	23	0	LOAMY SAND	0.31	2.41	A
NC-04-05	4.5-6.0	SP-SM	100	0	0	SAND	0.35	8.27	A
CA-04-01	7.5-9.0	SW-SM	90	10	0	SAND	0.35	8.27	A
CA-04-02	4.5-6.0	SM	76	24	0	LOAMY SAND	0.31	2.41	A
CA-04-03	4.5-6.0	SW-SM	81	19	0	LOAMY SAND	0.31	2.41	A
CA-04-04	9.0-10.5	SW-SM	86	14	0	SAND	0.35	8.27	A
CA-04-05	7.5-9.0	SM	73	27	0	LOAMY SAND	0.31	2.41	A
CA-04-06	3.0-4.5	SP-SM	100	0	0	SAND	0.35	8.27	A
		Average	*76*	*17*	*0*	*LOAMY SAND*	*0.30*	*4.20*	

* Reference: Rawls, Brakensiek, and Saxton, 1982.

TABLE 15

LIBERTY STATE PARK
HYDROLOGIC SOIL PROPERTIES CLASSIFIED BY USDA SOIL TEXTURES*
FOR FINE-GRAINED SOILS

DH No.	Sample Depth (ft)	USCS	EQUIV. USDA %SAND	EQUIV. USDA %SILT	EQUIV. USDA %CLAY	USDA SOIL TEXTURAL CLASSIFICATION	EFFECTIVE WATER CAPACITY (inch/inch)	MINIMUM INFILTRATION RATE (inch/hour)	HYD SOIL GROUP
LSP-03-03	24.0-25.5	CH	7	78	15	SILT LOAM	0.17	0.27	B
LSP-03-04	10.5-12.0	CH	13	59	27	SILTY CLAY LOAM	0.11	0.17	C
LSP-03-05	9.0-10.5	MH	37	48	15	LOAM	0.19	0.52	B
LSP-03-07	10.5-12.0	MH	12	65	23	SILT LOAM	0.17	0.27	B
LSP-03-08	7.5-9.0	CH	15	58	27	SILTY CLAY LOAM	0.14	0.17	C
LSP-03-09	4.5-6.0	CH	13	59	28	SILTY CLAY LOAM	0.14	0.17	C
LSP-03-10	15.0-16.5	CH	15	58	27	SILTY CLAY LOAM	0.14	0.17	C
LSP-03-12	18.0-19.5	CH	28	49	22	SILT LOAM	0.17	0.27	B
LSP-03-13	6.0-7.5	ML	63	35	2	SANDY LOAM	0.25	1.02	A
LSP-03-14	15.0-16.5	ML	62	34	4	SANDY LOAM	0.25	1.02	A
LSP-03-16	18.0-19.5	CH	14	56	30	SILTY CLAY LOAM	0.14	0.17	C
LSP-03-17	22.5-24.0	MH	6	63	31	SILTY CLAY LOAM	0.14	0.17	C
LSP-03-18	12.0-13.5	CH	15	59	26	SILT LOAM	0.17	0.27	B
LSP-03-19	21.0-22.5	ML	7	64	29	SILTY CLAY LOAM	0.11	0.17	C
LSP-03-20	21.0-22.5	CH	16	60	24	SILT LOAM	0.17	0.27	B
LSP-03-23	10.5-12.0	MH	6	62	32	SILTY CLAY LOAM	0.11	0.17	C
LSP-03-24	13.5-15.0	CL	18	58	24	SILT LOAM	0.17	0.27	B
LSP-03-25	13.5-15.0	CH	5	61	34	SILTY CLAY LOAM	0.11	0.17	C
LSP-03-26	10.5-12.0	CH	6	67	27	SILTY CLAY LOAM	0.11	0.17	C
LSP-03-27	12.0-13.5	CH	6	63	31	SILTY CLAY LOAM	0.11	0.17	C

TABLE 15 - Continued

LIBERTY STATE PARK
HYDROLOGIC SOIL PROPERTIES CLASSIFIED BY USDA SOIL TEXTURES*
FOR FINE-GRAINED SOILS

DH No.	Sample Depth (ft)	USCS	EQUIV. USDA %SAND	EQUIV. USDA %SILT	EQUIV. USDA %CLAY	USDA SOIL TEXTURAL CLASSIFICATION	EFFECTIVE WATER CAPACITY (inch/inch)	MINIMUM INFILTRATION RATE (inch/hour)	HYD SOIL GROUP
LSP-03-33	10.5-12.0	ML	16	80	4	SILT LOAM	0.17	0.27	B
LSP-03-36	16.5-18.0	CH	23	56	21	SILT LOAM	0.17	0.27	B
LSP-03-38	19.5-21.0	CH	10	71	19	SILT LOAM	0.17	0.27	B
NC-04-01	4.5-6.0	CH	7	67	26	SILT LOAM	0.17	0.27	B
NC-04-02	3.0-4.5	MH	8	74	17	SILT LOAM	0.17	0.27	B
CA-04-01	18.0-19.5	CH	6	75	19	SILT LOAM	0.17	0.27	B
CA-04-02	15.0-16.5	MH	11	73	16	SILT LOAM	0.17	0.27	B
CA-04-03	19.5-21.0	CH	20	63	16	SILT LOAM	0.17	0.27	B
CA-04-04	15.0-16.5	MH	15	70	15	SILT LOAM	0.17	0.27	B
CA-04-05	15.0-16.5	MH	6	77	17	SILT LOAM	0.17	0.27	B
CA-04-06	13.5-15.0	CH	9	77	24	SILT LOAM	0.17	0.27	B
		Average	*11*	*65*	*16*	*SILT LOAM*	*0.16*	*0.25*	*B*

*Reference: Rawls, Brakensiek, and Saxton, 1982.

TABLE 16

LIBERTY STATE PARK
HYDRAULIC CONDUCTIVITY (K) CALCULATION PER HAZEN APPROXIMATION*
FOR COARSE-GRAINED SOILS

DH No.	Sample Depth (ft)	USCS	D_{10} SIZE (mm)	C	K (cm/sec)
LSP-03-05	4.5-6.0	GP-GM	0.15	150	3.38
LSP-03-11	3.0-4.5	SP-SM	0.11	150	1.82
LSP-03-15	1.5-3.0	GW-GM	0.10	150	1.50
LSP-03-20	1.5-3.0	SP-SM	0.10	150	1.50
LSP-03-29	3.0-4.5	SP-SM	0.15	150	3.38
LSP-03-30	1.5-3.0	SP-SM	0.10	150	1.50
				Average	*1.87*

*Reference: Fetter, C.W. *Applied Hydrogeology*, 1994.

TABLE 17

LIBERTY STATE PARK
SUMMARY OF GROUNDWATER DEPTHS DURING DRILLING

DRILL HOLE NO.	GROUNDWATER DEPTH (ft) - AS ENCOUNTERED	GROUNDWATER DEPTH (ft) - AT COMPLETION	GROUNDWATER DEPTH (ft) - AT 24-HOURS
LSP-03-01	3.0	3.0	2.8
LSP-03-02	4.0	10.6	3.7
LSP-03-03	5.3	24.7	20.5
LSP-03-04	3.0	3.2	3.2
LSP-03-05	3.5	30.0	3.4
LSP-03-06	4.3	10.8	10.5
LSP-03-07	3.0	4.6	2.6
LSP-03-08	4.0	5.7	3.7
LSP-03-09	2.1	11.5	4.7
LSP-03-10	4.0	5.7	4.0
LSP-03-11	3.0	13.8	3.2
LSP-03-12	6.8	10.2	3.4
LSP-03-13	9.0	6.6	4.4
LSP-03-14	3.0	2.8	1.2
LSP-03-15	5.3	17.7	3.2
LSP-03-16	2.4	16.4	13.2
LSP-03-17	3.0	3.6	3.0
LSP-03-18	5.9	20.6	5.4
LSP-03-19	4.0	27.3	4.3
LSP-03-20	7.5	5.8	5.6
LSP-03-23	3.0	2.8	2.8
LSP-03-24	6.0	9.3	4.8
LSP-03-25	4.0	3.3	3.0
LSP-03-26	2.6	4.5	1.8
LSP-03-27	7.1	10.4	4.2
LSP-03-28	6.0	20.8	5.4
LSP-03-29	4.5	12.5	12.6
LSP-03-30	5.8	6.3	3.9
LSP-03-31	4.2	18.1	3.1
LSP-03-32	3.8	11.1	5.6
LSP-03-33	5.0	23.3	3.1
LSP-03-34	7.5	22.0	7.6
LSP-03-35	9.7	12.6	10.1
LSP-03-36	9.0	21.7	9.6
LSP-03-37	6.0	9.6	6.6
LSP-03-38	5.4	30.0	9.6
LSP-03-39	4.5	11.1	4.5
LSP-03-40	4.2	11.8	2.6

TABLE 17 - Continued

LIBERTY STATE PARK
SUMMARY OF GROUNDWATER DEPTHS DURING DRILLING

DRILL HOLE NO.	GROUNDWATER DEPTH (ft) - AS ENCOUNTERED	GROUNDWATER DEPTH (ft) - AT COMPLETION	GROUNDWATER DEPTH (ft) - AT 24-HOURS
NC-04-03	5.9	5.6	5.9
NC-04-04	6.0	6.7	6.3
NC-04-05	7.5	7.8	8.0
CA-04-01	5.5	11.4	4.8
CA-04-02	4.0	10.2	4.7
CA-04-03	6.2	27.2	5.2
CA-04-04	7.1	28.3	7.6
CA-04-05	8.0	28.1	6.2
CA-04-06	1.0	2.4	2.0

TABLE 18

LIBERTY STATE PARK
INITIAL GROUNDWATER READINGS IN PIEZOMETERS

PIEZOMETER NUMBER.	DATE WELL DEVELOPMENT COMPLETED	GROUNDWATER DEPTH at 24-HOURS (ft)	GROUNDWATER ELEVATIONS at 24-HOURS (ft MSL)
LSP-03-01	9 Sep 03	2.80	4.10
LSP-03-02	9 Sep 03	3.70	3.67
LSP-03-03	5 Sep 03	4.50	2.55
LSP-03-04	8 Sep 03	3.20	1.84
LSP-03-05	8 Sep 03	3.45	6.33
LSP-03-06	6 Sep 03	4.02	3.54
LSP-03-07	10 Sep 03	2.60	3.93
LSP-03-08	10 Sep 03	3.70	3.03
LSP-03-09	5 Sep 03	4.70	6.89
LSP-03-10	9 Sep 03	4.00	5.05
LSP-03-11	5 Sep 03	3.20	4.71
LSP-03-12	9 Sep 03	3.40	5.30
LSP-03-17	7 Sep 03	3.00	3.80
LSP-03-19	5 Sep 03	4.30	3.08
LSP-03-24	12 Sep 03	4.80	5.51
LSP-03-28	15 Sep 03	5.40	2.05
LSP-03-31	8 Sep 03	3.10	4.06
LSP-03-32	9 Sep 03	5.60	2.55
LSP-03-35	12 Sep 03	10.10	2.36
LSP-03-38	12 Sep 03	9.60	-0.16

TABLE 19

LIBERTY STATE PARK
PIEZOMETER GROUNDWATER READINGS FROM 15 NOVEMBER 2003

PIEZOMETER NUMBER	GROUNDWATER DEPTH (feet below grade)	GROUNDWATER ELEVATION (feet MSL)	TIME OF GROUNDWATER READING
LSP-03-01	1.61	5.29	09:55
LSP-03-02	3.67	3.70	08:48
LSP-03-03	4.88	2.17	10:06
LSP-03-04	3.16	1.88	10:12
LSP-03-05	4.32	5.46	10:20
LSP-03-06	4.82	2.74	08:52
LSP-03-07	1.74	4.79	08:30
LSP-03-08	3.72	3.01	08:17
LSP-03-09	3.43	8.16	08:57
LSP-03-10	4.74	4.31	07:58
LSP-03-11	2.99	4.92	08:08
LSP-03-12	4.02	4.68	07:42
LSP-03-17	3.15	3.65	08:40
LSP-03-19	4.14	3.24	07:28
LSP-03-24	5.48	4.83	07:23
LSP-03-28	4.64	2.81	07:33
[1]LSP-03-31	3.42	3.74	07:15
LSP-03-32	3.65	4.50	09:02
LSP-03-35	12.12	0.34	09:43
LSP-03-38	5.35	4.09	09:20
[2]LSP-03-31	3.42	3.74	10:18

Notes:
1. First Reading of day.
2. Last Reading of day.
3. Start Time:07:06 - Tide Reading: -0.2 Rising at the Battery.
4. Finish Time:10:18- Tide Reading: +2.8 Rising at the Battery.

TABLE 20

LIBERTY STATE PARK
PIEZOMETER GROUNDWATER READINGS FROM 8 FEBRUARY 2004

PIEZOMETER NUMBER	GROUNDWATER DEPTH (feet below grade)	GROUNDWATER ELEVATION (feet MSL)	TIME OF GROUNDWATER READING
LSP-03-01	NR	NR	NR
LSP-03-02	3.17	4.20	10:41
LSP-03-03	4.32	2.73	10:47
LSP-03-04	3.25	1.79	10:59
LSP-03-05	4.13	5.65	11:06
LSP-03-06	3.82	3.74	10:23
LSP-03-07	3.62	2.91	10:27
LSP-03-08	3.42	3.31	10:09
LSP-03-09	2.78	8.81	10:17
LSP-03-10	3.31	5.74	09:37
LSP-03-11	2.27	5.64	08:52
LSP-03-12	3.15	5.55	08;24
LSP-03-17	2.94	3.86	10:48
LSP-03-19	2.99	4.39	08:14
LSP-03-24	4.55	5.76	07:48
LSP-03-28	3.81	3.64	08:35
LSP-03-31	2.44	4.72	08:41
LSP-03-32	2.48	5.67	09:07
LSP-03-35	9.47	2.99	07:30
LSP-03-38	4.82	4.62	08:46

Notes:
1. Start Time: 07:30 - Tide Reading: +4.1 Rising at Bayonne.
2. Finish Time: 11:06 - Tide Reading: +3.1 Falling at Bayonne.
3. NR = Not Recorded due to ice covering piezometer.

TABLE 21

LIBERTY STATE PARK
PIEZOMETER GROUNDWATER READINGS FROM 9 FEBRUARY 2004

PIEZOMETER NUMBER	GROUNDWATER DEPTH (feet below grade)	GROUNDWATER ELEVATION (feet MSL)	TIME OF GROUNDWATER READING
LSP-03-01	NR	NR	NR
LSP-03-02	3.05	4.32	09:24
LSP-03-03	4.25	2.80	11:10
LSP-03-04	3.07	1.97	11:04
LSP-03-05	4.15	5.63	10:50
LSP-03-06	3.05	4.51	09:11
LSP-03-07	3.17	3.36	09:15
LSP-03-08	2.57	4.16	08:58
LSP-03-09	3.62	7.97	08:31
LSP-03-10	3.70	5.35	08:23
LSP-03-11	2.38	5.53	08:44
LSP-03-12	3.00	5.70	09:52
LSP-03-17	2.18	4.62	09:36
LSP-03-19	3.18	4.20	10:02
LSP-03-24	4.72	5.59	10:10
LSP-03-28	3.95	3.50	09:59
LSP-03-31	2.72	4.44	08:00
LSP-03-32	2.54	5.61	08:36
LSP-03-35	9.64	2.82	11:15
LSP-03-38	4.75	4.69	07:51

Notes:
1. Start Time: 07:51 - Tide Reading: -1.1 Rising at Kings Point.
2. Finish Time: 11:15 - Tide Reading: +4.3 Rising at Kings Point.
3. NR = Not Recorded due to ice covering piezometer.

TABLE 22

LIBERTY STATE PARK
PIEZOMETER GROUNDWATER READINGS FROM 10 FEBRUARY 2004

PIEZOMETER NUMBER	GROUNDWATER DEPTH (feet below grade)	GROUNDWATER ELEVATION (feet MSL)	TIME OF GROUNDWATER READING
LSP-03-01	NR	NR	NR
LSP-03-02	3.22	4.15	01:48
LSP-03-03	4.40	2.65	01:55
LSP-03-04	3.17	1.87	02:00
LSP-03-05	4.00	5.78	01:53
LSP-03-06	3.00	4.56	01:31
LSP-03-07	0.90	5.63	01:36
LSP-03-08	2.45	4.28	01:10
LSP-03-09	2.93	8.66	01:48
LSP-03-10	3.11	5.94	01:00
LSP-03-11	2.18	5.73	12:48
LSP-03-12	3.00	5.70	12:55
LSP-03-17	3.00	3.80	12:52
LSP-03-19	3.35	4.03	01:39
LSP-03-24	4.65	5.66	01:23
LSP-03-28	3.95	3.50	01:31
LSP-03-31	2.77	4.39	01:15
LSP-03-32	2.64	5.51	01:44
LSP-03-35	9.53	2.93	01:00
LSP-03-38	4.64	4.80	01:38

Notes:
1. Start Time: 12:48 - Tide Reading: +4.2 Falling at Bayonne.
2. Finish Time: 01:55 - Tide Reading: +2.1 Falling at Bayonne.
3. NR = Not Recorded due to ice covering piezometer.

TABLE 23

LIBERTY STATE PARK
CHANGES IN PIEZOMETER GROUNDWATER READINGS

PIEZOMETER	GROUNDWATER							
NUMBER	ELEV. at 24-HOURS (ft)	ELEV. on 15 Nov 03 (ft)	ELEV. on 8 Feb 04 (ft)	ELEV. on 9 Feb 04 (ft)	ELEV. on 10 Feb 04 (ft)	Min Elev. (ft)	Max Elev. (ft)	Range (ft)
LSP-03-01	4.10	5.29	--*	--*	--*	4.10	5.29	1.19
LSP-03-02	3.67	3.70	4.20	4.32	4.15	3.67	4.32	0.65
LSP-03-03	2.55	2.17	2.73	2.80	2.65	2.17	2.80	0.63
LSP-03-04	1.84	1.88	1.79	1.97	1.87	1.79	1.97	0.18
LSP-03-05	6.33	5.46	5.65	5.63	5.78	5.46	6.33	0.87
LSP-03-06	3.54	2.74	3.74	4.51	4.56	2.74	4.56	1.82
LSP-03-07	3.93	4.79	2.91	3.36	5.63	2.91	5.63	2.72
LSP-03-08	3.03	3.01	3.31	4.16	4.28	3.01	4.28	1.27
LSP-03-09	6.89	8.16	8.81	7.97	8.66	6.89	8.81	1.92
LSP-03-10	5.05	4.31	5.74	5.35	5.94	4.31	5.94	1.63
LSP-03-11	4.71	4.92	5.64	5.53	5.73	4.71	5.73	1.02
LSP-03-12	5.30	4.68	5.55	5.70	5.70	4.68	5.70	1.02
LSP-03-17	3.80	3.65	3.86	4.62	3.80	3.65	4.62	0.97
LSP-03-19	3.08	3.24	4.39	4.20	4.03	3.08	4.39	1.31
LSP-03-24	5.51	4.83	5.76	5.59	5.66	4.83	5.76	0.93
LSP-03-28	2.05	2.81	3.64	3.50	3.50	2.05	3.64	1.59
LSP-03-31	4.06	3.74	4.72	4.44	4.39	3.74	4.72	0.98
LSP-03-32	2.55	4.50	5.67	5.61	5.51	2.55	5.67	3.12
LSP-03-35	2.36	0.34	2.99	2.82	2.93	0.34	2.99	2.65
LSP-03-38	--**	4.09	4.62	4.69	4.80	4.09	4.80	0.71

Notes: *Readings were not available due to ice cover on piezometer.
**Reading was considered erroneous and was eliminated from consideration.

TABLE 24

SUMMARY OF GROUNDWATER GRADIENTS BETWEEN PIEZOMETERS ON 15 NOVEMBER 2003

PIEZOMETER (PZ) No.	GROUND WATER DEPTHS (ft)	GROUND WATER ELEV. (ft MSL)	STEEPEST gradient (ft/ft) FLOWING TOWARDS	FLATTEST gradient (ft/ft) FLOWING TOWARDS	No. of PZs FLOWING TOWARDS	STEEPEST gradient (ft/ft) FLOWING AWAY FROM	FLATTEST gradient (ft/ft) FLOWING AWAY FROM	No. of PZs FLOWING AWAY FROM
LSP-03-01	1.61	5.29	0.0013	0.0001	2	-0.0033	-0.0001	9
LSP-03-02	3.67	3.70	0.0033	0.0004	7	-0.0012	-0.0005	4
LSP-03-03	4.88	2.17	0.0041	0.0003	10	-0.0005	-0.0005	1
LSP-03-04	3.16	1.88	0.0116	0.0003	11	0.0000	0.0000	0
LSP-03-05	4.32	5.46	0.0007	0.0007	1	-0.0116	-0.0001	10
LSP-03-06	4.82	2.74	0.0040	0.0005	9	-0.0003	-0.0003	2
LSP-03-07	1.74	4.79	0.0016	0.0001	4	-0.0022	-0.0001	7
LSP-03-08	3.72	3.01	0.0044	0.0005	8	-0.0005	-0.0004	3
LSP-03-09	3.43	8.16	0.0000	0.0000	0	-0.0044	-0.0007	11
LSP-03-10	4.74	4.31	0.0029	0.0005	6	-0.0029	-0.0004	5
LSP-03-11	2.99	4.92	0.0029	0.0001	3	-0.0016	-0.0001	8
LSP-03-12	4.02	4.68	0.0018	0.0001	5	-0.0015	-0.0005	6

TABLE 25

SUMMARY OF GROUNDWATER GRADIENTS BETWEEN PIEZOMETERS ON 8 FEBRUARY 2004

PIEZOMETER (PZ) No.	GROUND WATER DEPTHS (ft)	GROUND WATER ELEV. (ft MSL)	STEEPEST gradient (ft/ft) FLOWING TOWARDS	FLATTEST gradient (ft/ft) FLOWING TOWARDS	No. of PZs FLOWING TOWARDS	STEEPEST gradient (ft/ft) FLOWING AWAY FROM	FLATTEST gradient (ft/ft) FLOWING AWAY FROM	No. of PZs FLOWING AWAY FROM
LSP-03-01	--*	--	--	--	--	--	--	--
LSP-03-02	3.17	4.20	0.0021	0.0006	5	-0.0012	-0.0006	5
LSP-03-03	4.32	2.73	0.0036	0.0001	9	-0.0017	-0.0017	1
LSP-03-04	3.25	1.79	0.0125	0.0006	10	0.0000	0.0000	0
LSP-03-05	4.13	5.65	0.0008	0.0000	2	-0.0125	0.0000	8
LSP-03-06	3.82	3.74	0.0038	0.0006	6	-0.0009	-0.0005	4
LSP-03-07	3.62	2.91	0.0030	0.0005	8	-0.0007	-0.0001	2
LSP-03-08	3.42	3.31	0.0055	0.0007	7	-0.0006	-0.0003	3
LSP-03-09	2.78	8.81	0.0000	0.0000	0	-0.0047	-0.0008	10
LSP-03-10	3.31	5.74	0.0023	0.0023	1	-0.0055	0.0000	9
LSP-03-11	2.27	5.64	0.0029	0.0000	3	-0.0019	-0.0001	7
LSP-03-12	3.15	5.55	0.0016	0.0000	4	-0.0025	-0.0007	6

* Note: LSP-03-01 was ice covered during reading cycle.

TABLE 26

SUMMARY OF GROUNDWATER GRADIENTS BETWEEN PIEZOMETERS ON 9 FEBRUARY 2004

PIEZOMETER (PZ) No.	GROUND WATER DEPTHS (ft)	GROUND WATER ELEV. (ft MSL)	STEEPEST gradient (ft/ft) FLOWING TOWARDS	FLATTEST gradient (ft/ft) FLOWING TOWARDS	No. of PZs FLOWING TOWARDS	STEEPEST gradient (ft/ft) FLOWING AWAY FROM	FLATTEST gradient (ft/ft) FLOWING AWAY FROM	No. of PZs FLOWING AWAY FROM
LSP-03-01	--*	--	--	--	--	--	--	--
LSP-03-02	3.05	4.32	0.0017	0.0002	6	-0.0011	-0.0001	4
LSP-03-03	4.25	2.80	0.0035	0.0004	9	-0.0015	-0.0015	1
LSP-03-04	3.07	1.97	0.0118	0.0008	10	0.0000	0.0000	0
LSP-03-05	4.15	5.63	0.0006	0.0000	2	-0.0118	0.0000	8
LSP-03-06	3.05	4.51	0.0026	0.0004	5	-0.0012	-0.0002	5
LSP-03-07	3.17	3.36	0.0023	0.0009	8	-0.0008	-0.0004	2
LSP-03-08	2.57	4.16	0.0032	0.0001	7	-0.0009	-0.0006	3
LSP-03-09	3.62	7.97	0.0000	0.0000	0	-0.0032	-0.0006	10
LSP-03-10	3.70	5.35	0.0020	0.0001	4	-0.0027	-0.0006	6
LSP-03-11	2.38	5.53	0.0022	0.0000	3	-0.0011	-0.0002	7
LSP-03-12	3.00	5.70	0.0011	0.0011	1	-0.0022	0.0000	9

* Note: LSP-03-01 was ice covered during reading cycle.

TABLE 27

SUMMARY OF GROUNDWATER GRADIENTS BETWEEN PIEZOMETERS ON 10 FEBRUARY 2004

PIEZOMETER (PZ) No.	GROUND WATER DEPTHS (ft)	GROUND WATER ELEV. (ft MSL)	STEEPEST gradient (ft/ft) FLOWING TOWARDS	FLATTEST gradient (ft/ft) FLOWING TOWARDS	No. of PZs FLOWING TOWARDS	STEEPEST gradient (ft/ft) FLOWING AWAY FROM	FLATTEST gradient (ft/ft) FLOWING AWAY FROM	No. of PZs FLOWING AWAY FROM
LSP-03-01	--*	--	--	--	--	--	--	--
LSP-03-02	3.22	4.15	0.0021	0.0001	8	-0.0010	-0.0009	2
LSP-03-03	4.40	2.65	0.0039	0.0007	9	-0.0014	-0.0014	1
LSP-03-04	3.17	1.87	0.0126	0.0010	10	0.0000	0.0000	0
LSP-03-05	4.00	5.78	0.0008	0.0001	2	-0.0126	0.0000	8
LSP-03-06	3.00	4.56	0.0030	0.0005	6	-0.0011	-0.0005	4
LSP-03-07	0.90	5.63	0.0015	0.0001	5	-0.0023	-0.0011	5
LSP-03-08	2.45	4.28	0.0037	0.0005	7	-0.0010	-0.0001	3
LSP-03-09	2.93	8.66	0.0000	0.0000	0	-0.0037	-0.0008	10
LSP-03-10	3.11	5.94	0.0020	0.0020	1	-0.0037	-0.0001	9
LSP-03-11	2.18	5.73	0.0027	0.0000	3	-0.0012	0.0000	7
LSP-03-12	3.00	5.70	0.0015	0.0000	4	-0.0018	-0.0001	6

*Note: LSP-03-01 was ice covered during reading cycle.

TABLE 28

LIBERTY STATE PARK
GROUNDWATER FLOW DIRECTION AND GRADIENT CALCULATIONS
FOR GROUNDWATER READINGS TAKEN ON 15 NOVEMBER 2003

Groundwater Flow Direction and Gradient Calculator	User enters heads at x, y locations. Groundwater flow direction, gradient, and rate computed. Confined or unconfined aquifer.

LMNO Engineering, Research, and Software, Ltd.
7860 Angel Ridge Rd. Athens, OH 45701 (USA) (740) 592-1890
LMNO@LMNOeng.com http://www.LMNOeng.com

Unconfined Aquifer	Stand-alone version	Click to Calculate
10 head measurements	Flow Direction, s (degrees):	35.55373310585864
Sandy Soil (sets K)	Composite Grad, h dh/ds (ft):	-0.003836060291998838
Heads in feet	Saturated Thickness, H (m):	Not used
Distances in feet	Flow per unit width, Q (gpd/ft):	0.08134220903455151
Flow per unit width in gpd/ft	Hydraulic Cond, K (cm/s):	0.0010
Hydraulic Conductivity in cm/s	http://www.LMNOeng.com	© 2000 LMNO Engineering, Research, and Software, Ltd.

Enter x (ft)	Enter y (ft)	Enter head, h (ft)
616362.32	683517.39	3.7
617998.45	683192.86	2.17
618535.56	682589.51	5.46
615902.62	682834.71	2.74
616800.75	682579.04	4.79
615978.02	682280.47	3.01
614834.2	682011.33	8.16
616168.43	681879.58	4.31
615521.94	681149.5	4.92
616749.81	681514.55	4.68

TABLE 29

LIBERTY STATE PARK
GROUNDWATER FLOW DIRECTION AND GRADIENT CALCULATIONS
FOR GROUNDWATER READINGS TAKEN ON 8 FEBRUARY 2004

Groundwater Flow Direction and Gradient Calculator	User enters heads at x, y locations. Groundwater flow direction, gradient, and rate computed. Confined or unconfined aquifer.

LMNO Engineering, Research, and Software, Ltd.
7860 Angel Ridge Rd. Athens, OH 45701 (USA) (740) 592-1890
LMNO@LMNOeng.com http://www.LMNOeng.com

Unconfined Aquifer	Stand-alone version	Click to Calculate
10 head measurements	Flow Direction, s (degrees):	34.16429816507535
Sandy Soil (sets K)	Composite Grad, h dh/ds (ft):	-0.005572663992161719
Heads in feet	Saturated Thickness, H (m):	Not used
Distances in feet	Flow per unit width, Q (gpd/ft):	0.11816623431993602
Flow per unit width in gpd/ft	Hydraulic Cond, K (cm/s):	0.0010
Hydraulic Conductivity in cm/s	http://www.LMNOeng.com	© 2000 LMNO Engineering, Research, and Software, Ltd.

Enter x (ft)	Enter y (ft)	Enter head, h (ft)
616362.32	683517.39	4.2
617998.45	683192.86	2.73
618535.56	682589.51	5.65
615902.62	682834.71	3.74
616800.75	682579.04	2.91
615978.02	682280.47	3.31
614834.2	682011.33	8.81
616168.43	681879.58	5.74
615521.94	681149.5	5.64
616749.81	681514.55	5.55

TABLE 30

LIBERTY STATE PARK
GROUNDWATER FLOW DIRECTION AND GRADIENT CALCULATIONS
FOR GROUNDWATER READINGS TAKEN ON 9 FEBRUARY 2004

Groundwater Flow Direction and Gradient Calculator	User enters heads at x, y locations. Groundwater flow direction, gradient, and rate computed. Confined or unconfined aquifer.

LMNO Engineering, Research, and Software, Ltd.
7860 Angel Ridge Rd. Athens, OH 45701 (USA) (740) 592-1890
LMNO@LMNOeng.com http://www.LMNOeng.com

Unconfined Aquifer	Stand-alone version	Click to Calculate
10 head measurements	Flow Direction, s (degrees):	31.993855052687778
Sandy Soil (sets K)	Composite Grad, h dh/ds (ft):	-0.004565750231604206
Heads in feet	Saturated Thickness, H (m):	Not used
Distances in feet	Flow per unit width, Q (gpd/ft):	0.09681500849017775
Flow per unit width in gpd/ft	Hydraulic Cond, K (cm/s):	0.0010
Hydraulic Conductivity in cm/s	http://www.LMNOeng.com	© 2000 LMNO Engineering, Research, and Software, Ltd.

Enter x (ft)	Enter y (ft)	Enter head, h (ft)
616362.32	683517.39	4.32
617998.45	683192.86	2.80
618535.56	682589.51	5.63
615902.62	682834.71	4.51
616800.75	682579.04	3.36
615978.02	682280.47	4.16
614834.2	682011.33	7.97
616168.43	681879.58	5.35
615521.94	681149.5	5.53
616749.81	681514.55	5.70

TABLE 31

LIBERTY STATE PARK
GROUNDWATER FLOW DIRECTION AND GRADIENT CALCULATIONS
FOR GROUNDWATER READINGS TAKEN ON 10 FEBRUARY 2004

Groundwater Flow Direction and Gradient Calculator	User enters heads at x, y locations. Groundwater flow direction, gradient, and rate computed. Confined or unconfined aquifer.

LMNO Engineering, Research, and Software, Ltd.
7860 Angel Ridge Rd. Athens, OH 45701 (USA) (740) 592-1890
LMNO@LMNOeng.com http://www.LMNOeng.com

This calculation has been purchased for use as a stand-alone program. User does not need to be connected to the internet. It is illegal to load this program on a publicly-accessible internet server.

Unconfined Aquifer	Stand-alone version	Click to Calculate
10 head measurements	Flow Direction, s (degrees):	35.44376108861692
Sandy Soil (sets K)	Composite Grad, h dh/ds (ft):	-0.005183477810710254
Heads in feet	Saturated Thickness, H (m):	Not used
Distances in feet	Flow per unit width, Q (gpd/ft):	0.10991368839644937
Flow per unit width in gpd/ft	Hydraulic Cond, K (cm/s):	0.0010
Hydraulic Conductivity in cm/s	http://www.LMNOeng.com	© 2000 LMNO Engineering, Research, and Software, Ltd.

Enter x (ft)	Enter y (ft)	Enter head, h (ft)
616362.32	683517.39	4.15
617998.45	683192.86	2.65
618535.56	682589.51	5.78
615902.62	682834.71	4.56
616800.75	682579.04	5.63
615978.02	682280.47	4.28
614834.2	682011.33	8.66
616168.43	681879.58	5.94
615521.94	681149.5	5.73
616749.81	681514.55	5.70

It is illegal for this calculation to run on any publicly-accessible website except www.LMNOeng.com

FIGURES

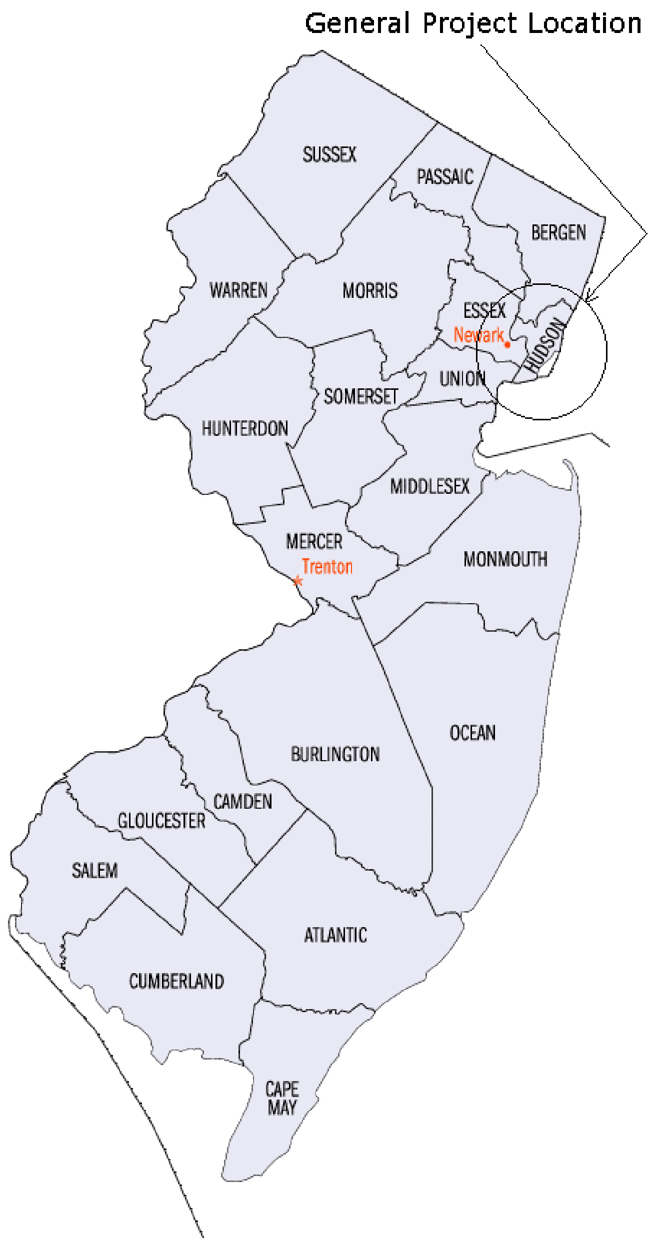

FIGURE #1 – Regional Location Map Showing Hudson County, NJ

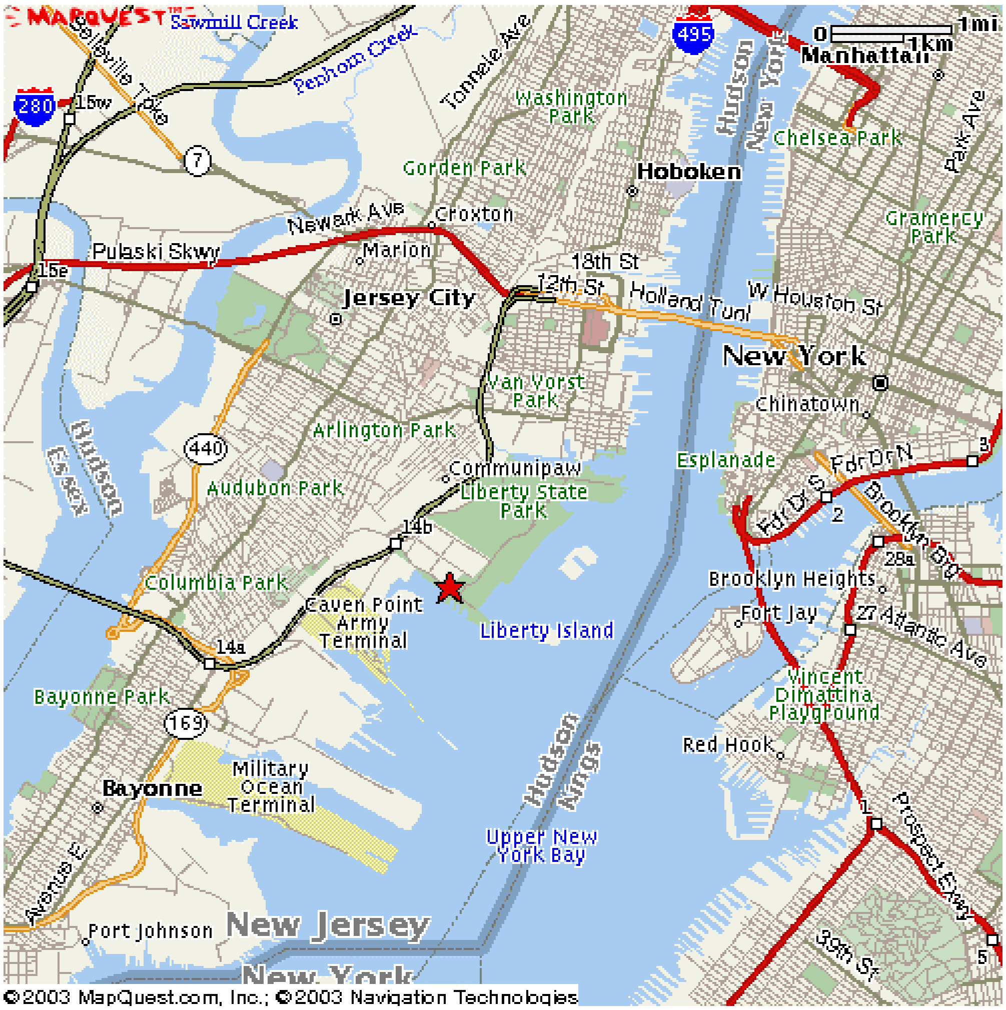

FIGURE #2 – Liberty State Park Vicinity Map.

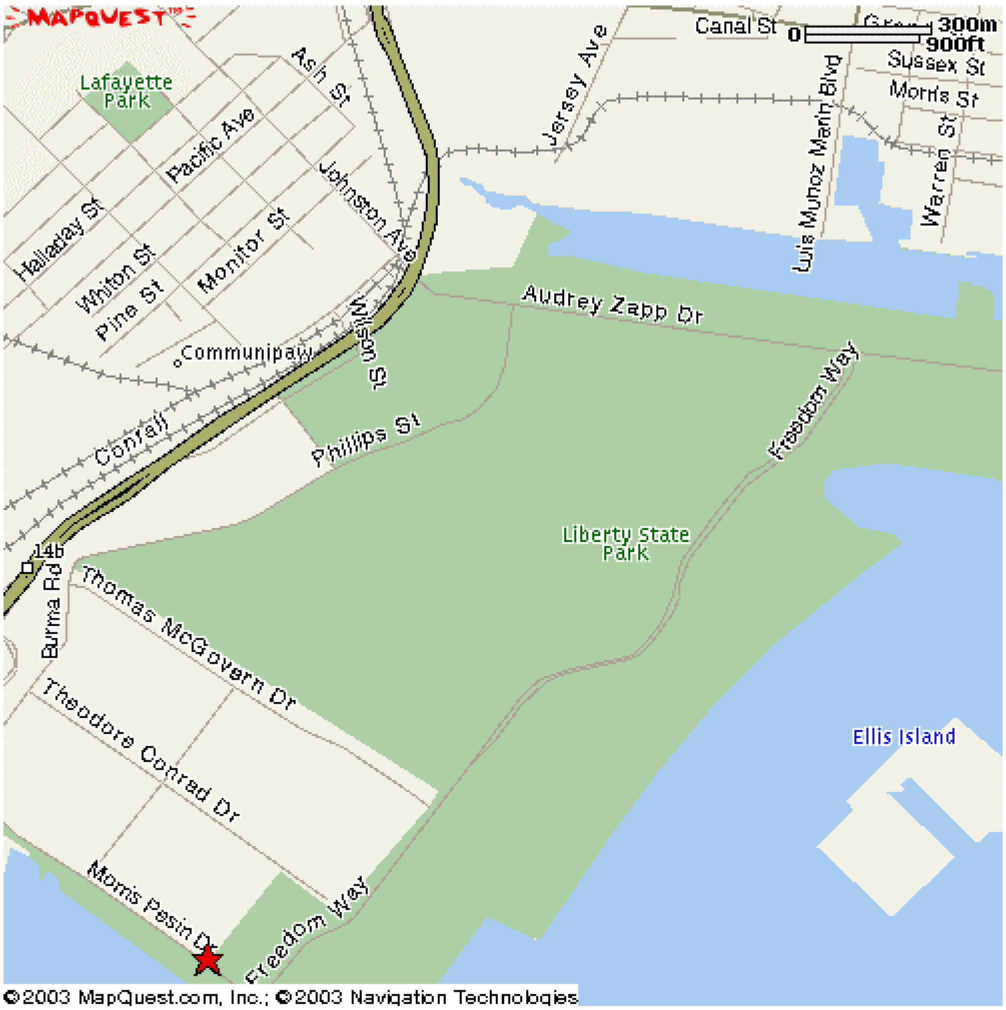

FIGURE #3 – Liberty State Park Site Map.

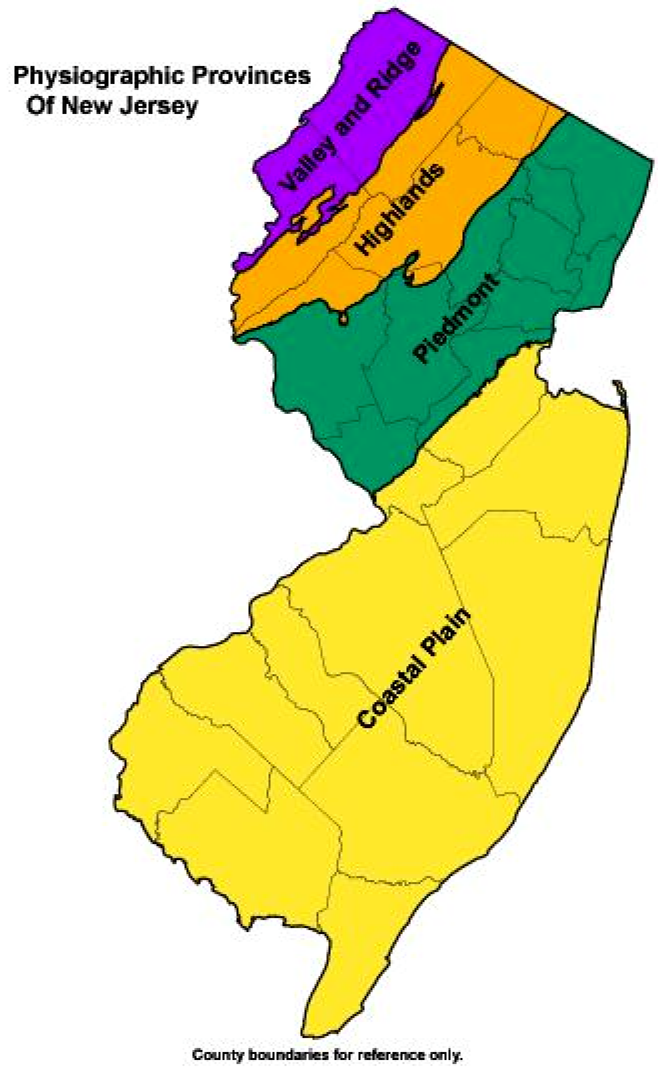

FIGURE #4 – Physiographic Provinces of New Jersey.

FIGURE #5 - Liberty State Park Phase I Drill Hole Locations.

FIGURE #6- Liberty State Park Permanent Piezometer Location Plan.

FIGURE #7 - Liberty State Park Phase II Drill Hole Locations.

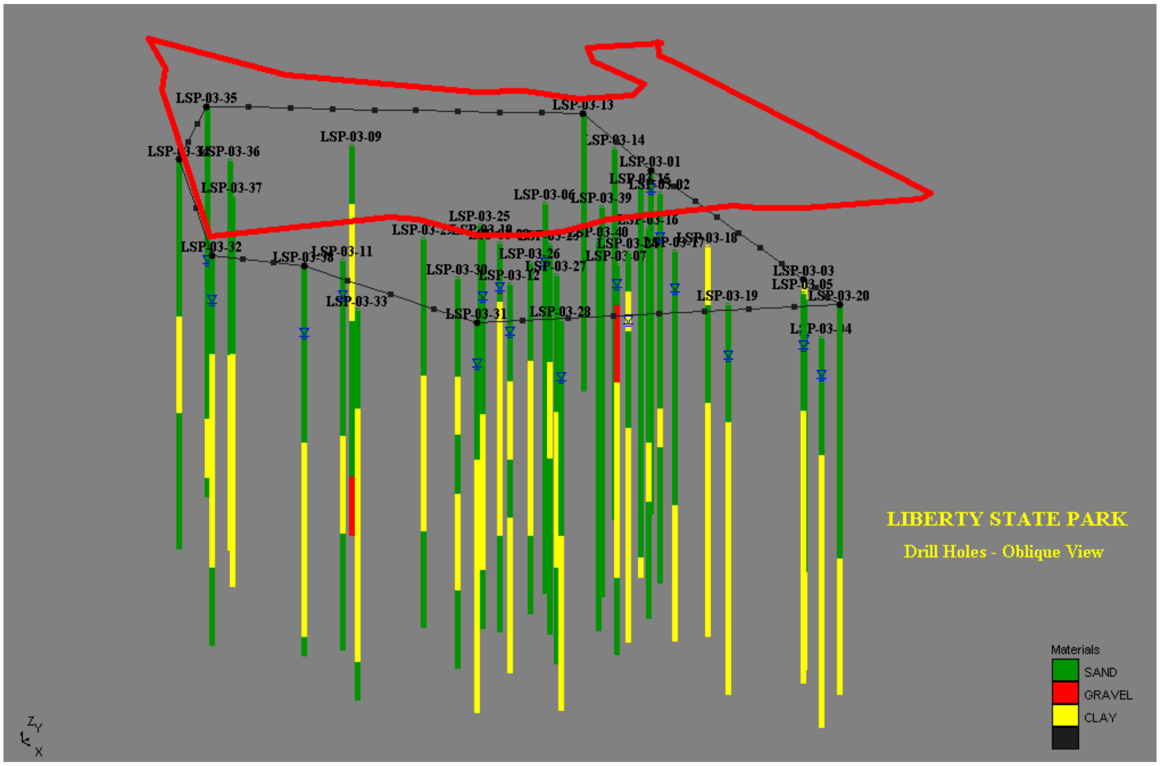

FIGURE #8- Liberty State Park Oblique View of Drill Holes.

Note: Drill Holes have been magnified 100x in the vertical scale.

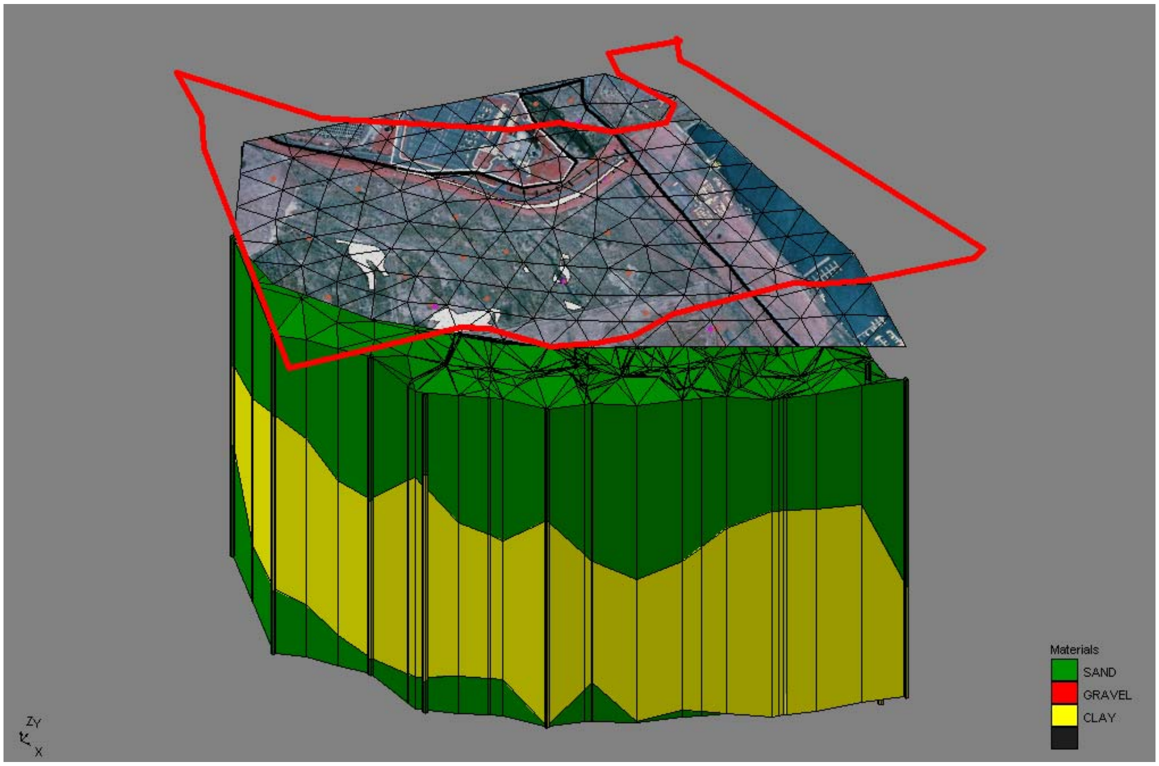

FIGURE #9 – Liberty State Park Generalized Conceptual Geologic Model.

FIGURE #10 – Liberty State Park Groundwater Contour Map - 15 Nov 2003.

FIGURE #11 – Liberty State Park Groundwater Contour Map - 8 Feb 2004.

FIGURE #12 – Liberty State Park Groundwater Contour Map - 9 Feb 2004.

FIGURE #13 – Liberty State Park Groundwater Contour Map - 10 Feb 04.

FIGURE #14– Liberty State Park General Groundwater Flow Direction using LMNO Software.

LIST OF ABBREVIATIONS AND ACRONYMS

LIST OF ABBREVIATIONS AND ACRONYMS

D_{10} Size = Particle diameter (mm) such that 10% of the particles are finer

D_{16} Size = Particle diameter (mm) such that 16% of the particles are finer

D_{25} Size = Particle diameter (mm) such that 25% of the particles are finer

D_{50} Size = Particle diameter (mm) such that 50% of the particles are finer

D_{60} Size = Particle diameter (mm) such that 60% of the particles are finer

D_{75} Size = Particle diameter (mm) such that 75% of the particles are finer

D_{84} Size = Particle diameter (mm) such that 84% of the particles are finer

D_{95} Size = Particle diameter (mm) such that 95% of the particles are finer

D_{10} = Effective Size (Hazen)

ϕ = Particle size in phi (ϕ) units:

$$\phi = -\log_2 d = -(\log_{10} d/\log_{10} 2)$$

where: d = diameter of particle (mm)

GM_e = Geometric (graphic) mean:

$$GM_e = [(\phi_{16} + \phi_{50} + \phi_{84})/3]$$

σ_ϕ = Inclusive (graphic) standard deviation:

$$\sigma_\phi = [(\phi_{84} - \phi_{16})/4] + [(\phi_{95} - \phi_5)6.6]$$

S_k = Coefficient of Skewness

K = Coefficient of Kurtosis

Cu = Coefficient of Uniformity:

$$Cu = D_{60}/D_{10}$$

Ck = Coefficient of Gradation:

$$Ck = (D_{30})^2/((D_{10})(D_{60}))$$

K = Permeability

C = Coefficient that factors in the sorting characteristics of the soil

Φ = Internal angle of friction

LIST OF ABBREVIATIONS AND ACRONYMS - Continued

ASTM = American Society for Testing and Materials

BCOE = Baltimore District, U.S. Army Corps of Engineers

DH = Drill Hole

GPM = Gallons Per Minute

HSG = Hydrologic Soil Group

HTRW = Hazardous, Toxic, and Radioactive Waste

LSP = Liberty State Park

LSPDC = Liberty State Park Development Committee

NJGS = New Jersey Geological Survey

NJDEP = New Jersey Department of Environmental Protection

SPT = Standard Penetration Test

USCS = Unified Soil Classification System

USDA = US Department of Agriculture Soil Classification System

WH = Weight of (drill) Hammer

WR = Weight of (drill) Rod

NatW% = Natural Water Content

%Gravel = % retained on No. 4 sieve by weight

%Coarse Gravel = % passing 3-inch sieve & retained on the ¾-inch sieve by weight

%Fine Gravel = % passing ¾-inch sieve & retained on the No. 4 sieve by weight

%Sand = % retained on No. 200 sieve by weight

%Coarse Sand = % passing No. 4 sieve & retained on the No. 10 sieve by weight

%Medium Sand = % passing No. 10 sieve & retained on the No. 40 sieve by weight

%Fine Sand = % passing No. 40 sieve & retained on the No. 200 sieve by weight

LIST OF ABBREVIATIONS AND ACRONYMS - Continued

%Silt or Clay = % passing No. 200 sieve by weight

%Fines = % passing No. 200 sieve by weight

%Clay = % Passing Clay Fraction <0.002 mm

LL = Liquid Limit

PL = Plastic Limit

PI = Plasticity Index

LI = Liquidity Index

AI = Activity Index

GW = Well-Graded Gravel, Fine To Coarse Gravel

GP = Poorly-Graded Gravel

GM = Silty Gravel

GC = Clayey Gravel

SW = Well-Graded Sand, Fine To Coarse Sand

SP = Poorly-Graded Sand

SM = Silty Sand

SC = Clayey Sand

ML = Silt

CL = Clay

OL = Organic Silt, Organic Clay

MH = Silt Of High Plasticity, Elastic Silt

CH = Clay Of High Plasticity, Fat Clay

OH = Organic Clay, Organic Silt

PT = Peat