GEOTECHNICAL EVALUATION REPORT

EMBANKMENT AND FOUNDATION STABILITY

AND SETTLEMENT

HOUSATONIC RIVER and NAUGATUCK RIVER

FLOOD PROTECTION PROJECTS

SECTION I

ANSONIA and DERBY, CONNECTICUT

December, 2010

Prepared by:

PS&S
integrating design & engineering
67A Mountain Boulevard Extension
P.O. Box 4039
Warren, NJ 07059
Tel 732.560.9700

PS&S
integrating design & engineering

67A Mountain Boulevard Extension
P.O. Box 4039
Warren, NJ 07059
Tel 732.560.9700
www.psands.com

December 14, 2010
04019-0001

Mr. Michael J. Joyce, P.E.
Milone & MacBroom, Inc.
500 East Main Street- Suite 326
Branford, Connecticut 06405-0661

Reference: Geotechnical Engineering Support for Levee Certification
Section 1 of Derby and Ansonia-Derby Local Protection Projects
Municipalities of Ansonia and Derby, Connecticut

Dear Mr. Joyce:

Paulus, Sokolowski and Sartor Architecture and Engineering Connecticut, P.C. (PS&S) is pleased to submit this report to Milone & MacBroom, Inc. (MMI) which presents the results of our geotechnical engineering support for the levee certification being performed for the Section 1 of the Derby and Ansonia-Derby Local Protection project located in the municipalities of Ansonia and Derby, Connecticut.

PS&S performed a review of information provided to us by MMI; comprising of historic test borings, laboratory test data and geotechnical engineering analysis performed by the United States Army Corps of Engineers (USACE). PS&S also conducted a field investigation program, and performed laboratory testing and engineering analysis in general accordance with our proposal dated July 13, 2010.

Based upon our review of the existing USACE data and our confirmatory investigation, it is PS&S' opinion that, from a geotechnical standpoint, there is a reasonable certainty that the Section 1 levee system will contain the one percent annual chance exceedance flood (i.e., base 100 year flood) with regards to stability, seepage and settlement. PS&S offers comments and observation regarding items which, in our opinion, are important relative to proper levee performance (e.g., filling of animal burrows, control of vegetation and routine observation of toe drains).

It has been a pleasure conducting this investigation and preparing this report. PS&S looks forward to assisting MMI further on Section 1 and on other Sections of the river reaches.

Please contact us should you require additional information or further explanation of our findings, conclusions and recommendations.

Very truly yours,

PAULUS, SOKOLOWSKI AND SARTOR ARCHITECTURE AND ENGINEERING CONNECTICUT, P.C.

Walter W. Burke, P.E.
Vice President

Joseph J. Lifrieri, Ph.D., P.E., C.P.G., P.P.
Senior Vice President

TABLE OF CONTENTS

LIST OF PLATES

APPENDICES

1.0 INTRODUCTION

Paulus, Sokolowski and Sartor Architecture and Engineering Connecticut, P.C. (PS&S) is pleased to submit this geotechnical evaluation report for the Section 1 of the Derby and Ansonia-Derby Local Protection project located in the municipalities of Ansonia and Derby, Connecticut to Milone & MacBroom, Inc. (MMI).

PS&S performed a review of information provided to us by MMI; comprising plans, reports, historic test borings, laboratory test data and geotechnical engineering analysis performed by the United States Army Corps of Engineers (USACE). PS&S also conducted a confirmatory field investigation program, and performed laboratory testing and engineering analysis in general accordance with our proposal dated July 13, 2010.

The entire levee system servicing the municipalities of Derby and Ansonia, Connecticut comprises three distinct sections. All results, findings, analysis and recommendations discussed within this report pertain only to Section 1. Approximately 25 percent of the Section 1 levee system is located within the boundaries of Ansonia, Connecticut (i.e., portion north of Division Street). The remainder of Section 1 is located within the boundaries of Derby, Connecticut (i.e., portion south of the Division Street). The extent of Section 1 is illustrated on site vicinity map Figure-1, attached.

The results of our investigations and analyses indicate that the levees comply with the USACE and FEMA performance guidelines. Based upon our review of the existing USACE data and our confirmatory investigation, it is PS&S' opinion that, from a geotechnical standpoint, there is a reasonable certainty that the Section 1 levee system will contain the one percent annual chance exceedance flood (i.e., base 100 year flood) with regards to stability, seepage and settlement. There are some minor concerns regarding the observed physical condition of some of the embankments (specifically animal burrows) and calculated exit gradient at one of the toe drains investigated near PS&S's boring PSS 2. These concerns are discussed in greater detail in Section 6 of the report.

2.0 BACKGROUND

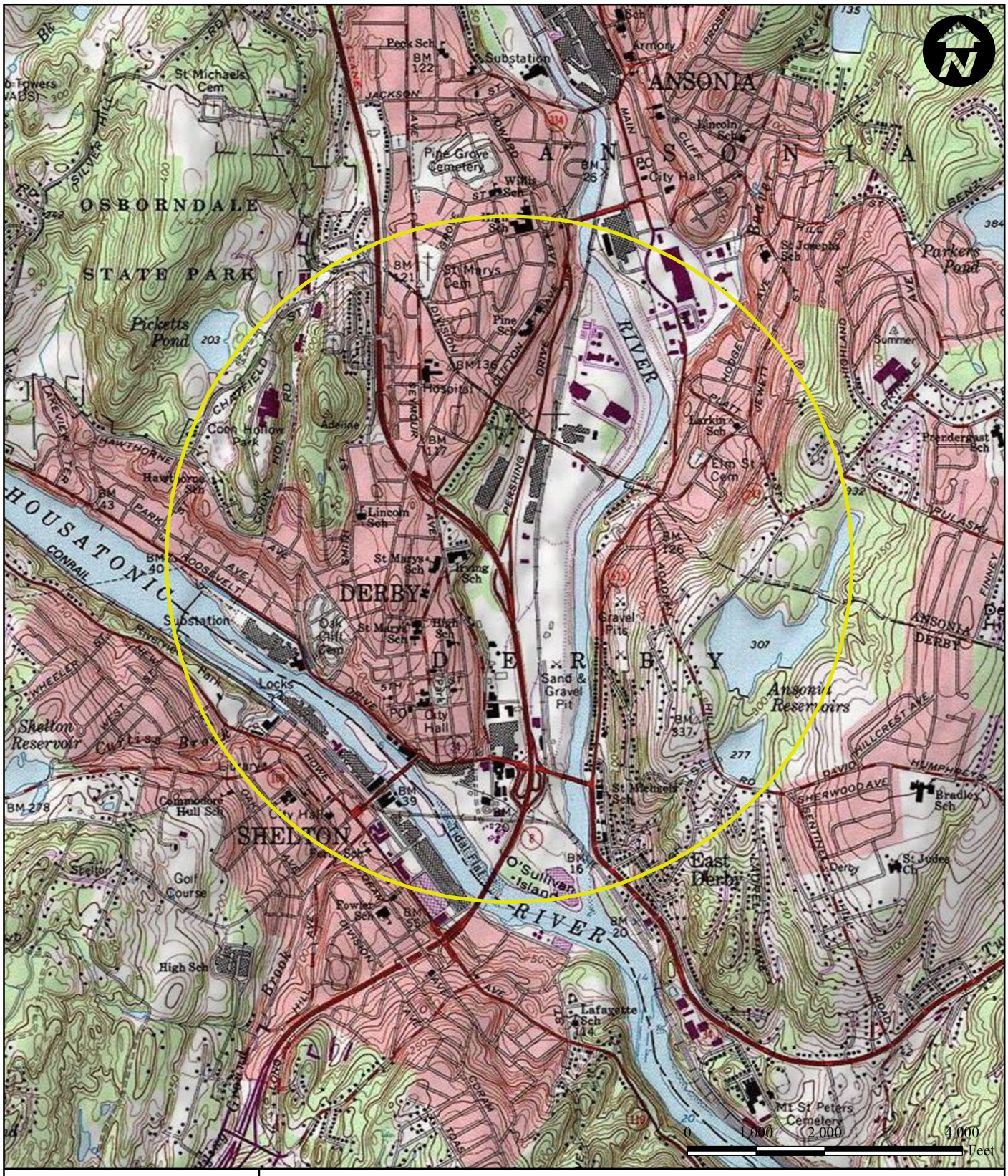
The municipalities of Ansonia and Derby, CT executed a Letter of Agreement with the Department of Homeland Security (DHS) to provide adequate compliance with the Code of Federal Regulations, Title 44, Section 65.10 (44 CFR 65.10) by August 7, 2010. Currently the levees has been designated as Provisionally Accredited Levees (PALs).

The FEMA requirements in Section 65.10 are separated into five categories:

A. General criteria;

B. Design criteria;

C. Operations plans and criteria;



Legend

Site Vicinity

Source:
USGS Topographic Map
7.5 Minute Series
Ansonia, 1985
STATE PLANE COORDINATES
E 907993.7
N 680199.1

USGS SITE LOCATION MAP

Ansonia and Derby Levee - Section 1
Local Protection Projects
Ansonia and Derby, New Haven County, Connecticut

PS&S
integrating design & engineering

Drawn By: ML	Scale: 1" = 2000'	Project No. 04019.001
Chk'd By: VL	Date: 11/11/2010	Figure No. 1

Path: P:\04019\001\Y\N\Maps\Fig1_USGS_111110_00.mxd

D. Maintenance plans and criteria; and

E. Certification requirements

.

This report is based on our understanding that the "levee certification" is a technical finding that there is a reasonable certainty that the levee system will contain the one percent annual chance exceedance flood (i.e., base flood). This report and the opinions presented herein rely on historic data and a limited confirmatory investigation program. It is not a warrantee or guarantee of the performance of the levee system.

On February 2, 2010, PS&S prepared a proposal to provide geotechnical engineering services to MMI in support of two adjoining flood control projects: the Derby Local Protection (DLP) project in the municipality of Derby, Connecticut and the Ansonia Local Protection (ALP) project in the municipality of Ansonia, Connecticut for levee certification.

The overall project comprises three sections, as follows:

> **Section 1:** The scope of this report is limited to Section 1 which consists of the west bank (right bank) of the Naugatuck River from 100 feet north of the railroad bridge in Ansonia, Connecticut to south to the confluence with Housatonic River and going upstream along the northeastern bank of the Housatonic River to Bridge Street in Derby, Connecticut.
>
> **Section 2:** Section 2, which is outside of the scope of this report, consists of the East bank of the Naugatuck River along the downtown of Ansonia, Connecticut, including the Beaver Brook branch.
>
> **Section 3:** Section 3, which is outside of the scope of this report, consists of Riverside Street levee system located on the west bank of the Naugatuck River at north of Maple Street.

PS&S' geotechnical engineering review of historic data along with limited engineering analyses performed and contained within this report, evaluated whether Section 1 of the levee system will contain the one percent annual chance exceedance flood (i.e., base flood), with a reasonable certainty, and focused on only the geotechnical-related FEMA requirements. Specifically, this report addresses the following criteria:

- Seepage Analysis (B3 of 44 CFR 65.10) to demonstrate that there will be no internal erosion of the embankment or the foundation material
- Embankment and Foundation Stability Analysis (B4 of 44 CFR 65.10) as defined in the U.S. Army Corps of Engineers (USACE) Engineer Manual 1110-2-1913, Chapter 6, Section II; and ,
- Settlement Analyses (B5 of 44 CFR 65.10) using procedures described in USACE Manual 1110-1-1904.

PS&S had prepared a certification in accordance with Item E, discussed in Appendix A, providing certifications only for the three analyses discussed above as B3, B4 and B5. The letter is provided under separate cover.

Discussion of the overall FEMA requirements as per 44 CFR 65.10 and as cited from the FEMA Fact Sheet entitled "Requirements for Mapping Levees Complying with Section 65.10 of the NFIP Regulations", dated November 2008, and are presented in Appendix A.

3.0 PURPOSE AND SCOPE

3.1 General

The purpose of this report is to present the results of supplemental geotechnical investigations and analyses performed to support a technical finding that there is a reasonable certainty that the levee system will contain the one percent annual chance exceedance flood (i.e., base flood). The intent of this report is to provide confirmatory support to previous investigation and analyses performed by the USACE and others.

PS&S's study is based on previous test borings, laboratory testing and engineering analysis performed by the USACE. In addition to the historic engineering study, PS&S's scope of services, in support of this report, comprised the following tasks:

- Review of the levee designs prepared by the USACE and existing geotechnical data, including a review of 93 historic borings, performed by the USACE, and a meeting with municipal emergency management personnel to obtain information regarding their observations of the levee system during past high flow conditions;

- Visual site reconnaissance survey and digital photo documentation regarding the existing condition of the flood protection system within Section 1 at the time of our field studies;

- A program of ten confirmatory test borings at widely spaced locations to investigate the subsurface soil and groundwater conditions at the selected locations; and to supplement and confirm existing USACE test boring data;

- Performed in-situ hydraulic conductivity testing (i.e., slug tests, and tidal survey) at select boring locations via temporary piezometers for determination of the in-situ soil permeability;

- Classified soil samples obtained from the test borings for geotechnical purposes;

- Performed confirmatory laboratory testing of selected soil samples from test borings to estimate the relevant engineering properties of the encountered soils;

- Estimated peak horizontal ground surface accelerations using United States Geologic Survey (USGS) data as needed to perform pseudo-static stability analysis;

- Performed engineering analyses to evaluate seepage, at five test boring locations, embankment and foundation stability analysis at seven typical cross-sections and settlement analysis at a typical cross section within Section 1. Our geotechnical analysis used the data obtained from this investigation and relied on the design data and design cross-sections provided within the USACE Reports entitled "Derby Local Protection Housatonic & Naugatuck Rivers, Connecticut, Design Memorandum No 4, Embankments, Foundations and Channel Improvements" dated July 1968 and "Ansonia-Derby Local Protection Naugatuck River, Connecticut, Design Memorandum No. 6, Embankments, Foundations and Channel Improvements" dated February 1966. The stability analyses also included evaluation of factors of safety for static, pseudo-static and rapid drawdown conditions.

- Developed recommendations for additional studies as necessary for the levee within Section 1;

- Developed generalized recommendations for future observation and maintenance of the Section 1; and,

- Prepared this geotechnical report for the levees within Section 1 of the project presenting the results of our investigations, reviews, analyses and conclusions.

3.2 Review of Historical Borings and Documents

PS&S performed a detail review of 93 historical borings performed between 1961 and 1966 by the US Army Engineering Division, New England Corps of Engineers, in Waltham, Massachusetts. Borings were drilled to depths of 20 to 40 feet below the ground surface. Testing was performed on selected representative soil samples in accordance with the USACE procedure to confirm the visual soil classification and to estimate the engineering and hydraulic conductivity properties of the encountered soils. Laboratory testing consisted of grain size distribution analyses, Atterberg Limits tests and testing for organic content on the organic soils.

In order to perform our evaluation, the historical boring logs were individually examined and the sample descriptions were rewritten by PS&S using currently accepted soil descriptions to present boring logs in a manner that could be easily reviewed and correlated to our confirmatory borings. The historic test boring logs that were examined, reviewed and re-typed by PS&S are included as Appendix B.

3.3 Visual Site Reconnaissance Survey

A visual site reconnaissance was performed by PS&S on August 13, 2010. The entire Section 1 portion of the project was reviewed in order to observe the existing physical condition of the levee earthen embankment as it existed at the time of our field investigation. Particular attention was paid to observe and document geotechnical related features or conditions that could affect the earthen portion of the embankments as well as the relief wells and toe drains. PS&S's observations were limited to readily observable issues with the embankment such as:

- Unwanted vegetation (i.e., trees, brushes etc.,)
- Sod cover condition and proper mowing
- Presence of equipment and objectionable vegetative matter within 15 feet of the toe of slope.
- Readily obvious visual evidence of slope stability concerns (i.e., slumping, sloughing or piping of the levee embankment material)
- Erosion issues
- Evidence of any adverse settlement concerns
- Depressions/rutting of the embankment
- Cracking issues
- Readily observable adverse animal or other apparent vector concerns
- Displacement of rip rap and vegetation.
- Toe drain surface condition
- Relief well visual condition
- Seepage

PS&S's scope of work did not include features which could not be readily observed at the time of our field investigation, below-grade structures or an evaluation of structural hydraulic control elements including pipes, valves, anti-seep collars, weirs, reinforced concrete walls or gates, which PS&S assumes will be performed by others.

The USACE Flood Damage Reduction Segment/System Inspection Reports (operation and maintenance manuals) were used as a guide during the site reconnaissance walk. Digital photographs were obtained throughout the visual inspection of Section 1 of the project. Appendix C includes, select photographs, applicable field notes and a reference map of the visual site reconnaissance survey.

A summary of items that were readily observed to be in need of additional maintenance and/or repair include the presence of unwanted (i.e., deep-rooted) vegetation, improper mowing of the sod, encroachment of undesirable trees, bushes within 15 feet of the toe of the landside slope, animal burrows in the embankment, sedimentation of toe drain and accessibility and/or readily apparent corrosion of the relief well risers. All other areas of observation within the scope of PS&S's services showed that the levee embankment and supporting features were, in our opinion, properly maintained and in satisfactory condition.

3.3.1 Unwanted Vegetation and Sod Mowing

Unwanted vegetation, defined as trees, shrubs, unmoved grass and deep rooted vegetative matter, was observed within the land side portions of the levee as well as within the toe drain gravels. It should be noted that such vegetative matter and presence of any equipments are undesirable within 15 feet of the toe of the slope. Active efforts to correct these conditions were underway at the time of the inspection. PS&S recommends that the operation and maintenance manuals as well as other applicable regulations should be followed to correct and maintain proper vegetation cover. Maintenance should comply with the USACE document EM 1110-2-301 or other USACE policies for regional vegetation maintenance.

Additional published recommendations are presented below:

"The establishment of good sod covers and regular proper vegetation management is a cornerstone of effective wildlife intrusion management. In most cases, wildlife will not inhabit an earthen dam that does not provide vegetation for food supply, protective cover, or shelter. If a variety of vegetation exists at the dam, then wildlife will choose to inhabit the earthen dam environment over other areas lacking in vegetation or without a water supply. Ideally, the earthen dam environment will contain appropriate grass species maintained such that dam inspections can be conducted easily without visual obstruction of the embankment and other appurtenant structures. Vegetation such as dense groundcover and thick, woody trees and shrubs not only hinder dam inspections, but can also obscure

indicators of potential performance problems such as animal burrows, settlement, depressions, cracks, and similar issues. If vegetation is too thick, animal burrows can go undiscovered and proper animal intrusion mitigation may not occur."-

FEMA-473: Technical Manual for Dam Owners, September, 2005.

"In general, it is advised to limit vegetation at the earthen dam to low-growing native grass that is mowed regularly, and to keep the embankment and spillway inlet and outlets free of vegetation. Vegetated emergency spillways should be maintained in a similar fashion as the dam embankment. Maintained grass will accommodate thorough inspections and limit the number of wildlife species that can easily inhabit the dam. If a dam contains vegetation other than appropriate grasses, then the dam owner should complete mitigation and management as outlined in the FEMA document, A Technical Manual on the Effects of Tree and Woody Vegetation Root Penetrations on the Safety of Earthen Dams (FEMA, 2002) and the FEMA brochure, Dam Owner's Guide to Plant Intrusion of Earthen Dams (FEMA, 2003)." -FEMA-473: Technical Manual for Dam Owners, September, 2005.

3.3.2 Clearance in Vicinity of Toe of Slope

Undesirable vegetative growth, trash, debris and equipment storage was observed within 15 feet outboard of the toe of slope. These areas should be cleared in order to allow proper maintenance of the levee and/or emergency operations.

3.3.3 Animal Control

Animal burrows were observed along the landside portion of the earthen embankments especially north of Division Street in Derby, CT. At the time of PS&S' field visits no animal burrows were observed on the riverside portion of the levee. This may be due to the size and amount of rip-rap protection. The rip-rap may prevent animals from forming burrow or conceal burrows that may exist. Each observed animal burrow on the landside portions of the levee was identified with wooden stakes and flagging. Each flag/stake was subsequently surveyed by MMI for documentation and ease of future repairs.

Repairs to animal burrows and prevention of new burrows should be implemented in accordance with the FEMA document entitled "Technical Manual for Dam Owners- Impacts of Animals on Earthen Dam FEMA-473, September, 2005". Re-inspection should be performed on a routine basis as an operations and maintenance item after all observed burrows have been properly repaired and after the vegetation on the embankment has been mowed to a proper height to allow for observation of any additional animal burrows.

3.3.4 Maintenance of Toe Drains

The toe drains were observed to include areas of unwanted vegetative growth as well as select areas of unwanted soil in-filling of the toe drain gravels. Proper maintenance and/or repair should be performed to correct and prevent these conditions. Portions of the toe drain gravel were being cleared of vegetation at the time our site visit and the sedimentation was reportedly removed recently along a portion of the toe drain. Sedimentation was noted to be restricted to the top several inches of the gravel toe drain.

3.3.5 Relief Wells

Five relief wells were opened and visually inspected by PS&S' representative. The metal risers near the ground surface exhibited signs of corrosion. An additional five relief wells could not be opened due to damaged lid bolts, however they were subsequently accessible for the video inspection of the relief wells by MMI. The results of the video inspection are addressed in MMI's December 2010 report entitled "Engineering Report-Interior Drainage Analysis". Relief wells should be pump tested to establish that drainage/exit gradients within the soils can be maintained as per the design intent.

3.4 Field Exploration Program

The field exploration program consisted of ten soil borings, which were performed between July 27, 2010 and August 24, 2010. PS&S retained CMI of Tappan, New York to perform the test borings and soil sampling. Prior to the start of the work, CMI contacted the statewide utility locator service responsible for identification of below grade existing utilities which were marked in the field.

All test borings were drilled with a truck-mounted Mobil B-61 drill rig. Borings were advanced into soil utilizing a $3^{7}/_{8}$ inch diameter tri-cone roller bit. Mud rotary drilling methods were used in conjunction with 4-inch diameter steel casing as necessary to maintain an open borehole. Casing was typically utilized to depths of approximately 40 ft below ground surface (bgs); below 40 feet soil conditions allowed open borehole drilling without the need for casing. Borings scheduled to receive temporary piezometers were drilled using only clear water recirculation as the drilling fluid so that boring sidewalls would not be coated with bentonite clay drilling fluid that could affect downhole permeability testing.

All test borings were drilled from the crest of the existing levee with the exception of boring PSS-7 which was located just behind a floodwall portion of the levee. The borings advanced to depths ranging from 51 feet to 87 feet bgs. All borings except PSS-7, were terminated in native soil units consisting of sands and silts. Boring PSS-7 terminated approximately three feet into bedrock.

Representative soil samples were generally recovered using the Standard Penetration Test (SPT) in accordance with the American Society of Testing and Materials (ASTM) Procedure D 1586. The Standard Penetration Test employs a split spoon sampler with a two-inch OD and a $1^3/_8$ inch ID driven 24 inches into soil by a 140-pound hammer freely falling 30 inches. The number of blows required to advance the sampler for every six inches of penetration is shown on the attached boring logs. The sum of the blows required to advance the sampler for the second and third six-inch increment is known as the SPT "N" value. Within paved areas and/or extremely packed road stone, the first soil sample was obtained below the crushed stone base course. A larger 3-inch ID split spoon driven with a 300-pound hammer, falling 24 inches, was utilized in the gravel deposits when poor sample recovery was noted with the standard SPT samples.

Soil samples were typically obtained continuously to a depth of about twelve feet bgs and then at five-foot intervals thereafter to the termination depth of the borings. As appropriate, additional three-inch diameter undisturbed Shelby tube samples of the fine grained soils (i.e., material passing No. 200 sieve) were obtained for subsequent laboratory testing. Groundwater levels were evaluated from four temporary standpipe piezometers installed during the field investigation for in-situ permeability testing (See Section 3.5 below). In order to obtain a sample of the bedrock at boring PSS-7, a double-tube NX core barrel equipped with a diamond studded drill bit was utilized.

All borings were backfilled with a cement/bentonite grout. Paved areas along the walking trail were restored using cold patch asphalt mix that was tamped firmly in-place. All excess drill cuttings and drill fluids were disposed off site. The as-drilled boring locations were surveyed by MMI and are shown on the attached Boring Location Plan, Plate-1.

Fieldwork was performed under the direct technical observation of a geotechnical representative from PS&S. Our field representative maintained a continuous log of the explorations as the work proceeded, and monitored sampling operations so as to obtain the required subsurface information.

Upon completion of the fieldwork, soil samples were brought to our Warren, New Jersey soil mechanics laboratory for further detailed examination and testing. The laboratory testing program included identification and index property testing (Atterberg Limits, grain size distribution, and natural moisture content) and a limited number of consolidation tests on selected undisturbed samples of fine-grained soils. All PS&S work was performed under the technical supervision and control of a Professional Engineer licensed in the State of Connecticut.

3.5 In-situ Permeability Testing

Temporary standpipe piezometers were installed in borings PSS-2, PSS-3, PSS-6 and PSS-8. The piezometers were used for conducting in-situ permeability testing

which included water level measurements, tidal influence measurements, slug tests, pump-in tests and a falling head tests. The use of a slug test to evaluate in-situ permeability was based on our review of the USACE boring logs and material descriptions. In the field some of the soil units were found to be more permeable than initially estimated based on our review of the USACE information. Detailed results of the in-situ permeability testing are presented in Section 4.3.

3.5.1 Piezometer Installation

Piezometers were installed and constructed utilizing two inch ID PVC piping and slotted well screens. The slotted screen portion of the piezometers was installed fully below the water table. The surrounding annulus around the screen was filled with # 2 filter sand to six inches above the screen. Approximately one foot of bentonite pellets was then placed above the filter sand in order to seal off any influences from the upper portion of the boring. Solid PVC riser pipe was then extended to just above the ground surface.

Four piezometers were installed during the field program for Section 1 at test boring locations PSS-2, PSS-3, PSS-6, and PSS-8. Locations of the piezometers are shown on the boring location plan. All temporary piezometers were removed immediately after completion of the field testing.

3.5.2 Water Levels and Tide Influence

Water level measurements were made in both the piezometers and in the adjacent river using a electronic water level indicator probe, a combination pressure transducer/data logger, and manual observations from a tile tide gauge located at Sluice Gate Structure No. 2 on the Housatonic River in Derby, CT. Please note that tidal elevations acquired from the tile tide gauge have been converted from mean sea level (MSL) to the NAVD 1988 vertical datum (MSL is 1.0 feet higher than NAVD 1988). Detailed information about specific data is presented in Section 4.3 to follow.

3.5.3 Slug Tests

Slug testing was performed by using an inert slug constructed of PVC. The inert slug was rapidly lowered into the piezometer, temporarily displacing the water column. An initial water level measurement was obtained prior to initiating the test. After the slug test was started a series of water level measurements were obtained at pre-determined time intervals until the water level returned to its original pre-test elevation. When the water level recovered to near initial levels, the slug was removed, causing the water level to drop. Water level measurements were obtained until the water level recovered to nearly pre-test levels. The water level measurement data acquired during the tests was then regressed and analyzed using the temporary well construction information to calculate the hydraulic conductivity values.

3.5.4 Pump-In Testing

In order to supplement the slug test data, several pump tests were implemented at piezometers in boring PSS-2, PSS-6 and PSS-8. Fresh water was pumped into the piezometer at PSS-2 at 16 gallons per minute gpm and then again at 55 gpm following the placement of a pressure transducer at the bottom of the piezometer. The pump rate was held constant for a given period of time and the resulting constant head was recorded.

3.5.5 Falling Head Test

A falling head test was performed at boring PSS-8. During the drilling of boring PSS-8, 4 inch I.D. drill casing was extended down to the gravel unit to a depth of 40 feet bgs. The casing was extended to two feet above the ground surface. The casing was flushed and filled with fresh water. The rate of the falling head was recorded using a combination pressure transducer and data logger.

3.6 Regression of Slug Test Data

The data collected during the in-situ permeability testing required regression and analysis. This data includes the results of the in-situ permeability testing and construction details of the temporary wells. The in-situ permeability test data collected in the field was regressed and analyzed using commercially available software and the results are discussed in section 4.3.2.

4.0 SUBSURFACE CONDITIONS

The purposes of PS&S's supplemental borings, testing and analysis were to confirm that the subsurface conditions presented by the USACE borings results were similar to those found by PS&S and to provide additional information required for our geotechnical engineering evaluation and laboratory testing.

4.1 Geologic Overview

The municipalities of Derby and Ansonia are situated between the confluence of the Naugatuck and Housatonic Rivers. The higher ground between the two rivers slopes upward into a ridge formation consisting of a glacial till deposit overlaying bedrock. The protection area immediately behind the levee system consists of glacial fluvial and lacustrine deposits overlain by man-made fills. The municipalities of Derby and Ansonia are within the upper reaches of tidal influence. A regular tidal oscillation at the confluence of the two rivers is documented to be about 8 feet of total movement. The river continues flowing to the south and eventually empties into the Long Island Sound. Coastal storms and tidal surges may funnel up the river valley resulting in occasionally abnormal tidal levels.

Prior to man-made filling and channel improvements, the stream patterns tended to meander back and forth in the low lying areas creating braided and interwoven stream patterns. Buried timbers, bulkheads and docks may be present along the historic waterfront.

Bedrock mapping for the area indicates that the Pumpkin Ground Member of the Harrison (Prospect) Gneiss is located throughout the Housatonic and Naugatuck River valley at varying depths depending on the amount of erosion the rock was subjected to over time. Rock outcrops can be observed a short distance upstream especially along the steeper bluffs of the Housatonic River embankments.

4.2 Site Subsurface Conditions

The subsurface soil and bedrock conditions at the site have been interpreted from the ten borings drilled through the crest of the existing levee as part of this study, the historic test borings performed by the USACE and the material description of the embankment levee presented within various USACE reports and design memoranda. A brief description of the material encountered are presented below in the order of increasing depth. The Standard Penetration test (SPT) values presented below are taken from PS&S' recent confirmatory test borings.

4.2.1 Surface Cover (Fill)

The surficial material on the river side of the levee slope consists of 12 to 18 inch thick riprap stone for erosion protection. Below the rip rap stone, at the crest and on the land side of the levee embankment, surficial material consists of tan brown, fine to coarse gravel and sand with varying amounts of silts on northern portion of Naugatuck Dike (Sta. 68+755 to Sta. 113+00) and fine to medium sand and clayey silts with little gravel on the remaining southern portion of Naugatuck dike (Sta.0+00 to Sta. 30+99) & Housatonic dike (Sta. 0+75 to Sta. 20+28.66). The surficial cover material was noted to be one to two feet thick and was noted to exhibit an in-place density of medium dense to dense within the test borings. The SPT blow counts generally ranged from 33 to refusal within the northern portion of Naugatuck Dike (levee). At test boring locations PSS-6 & PSS-7 (i.e., within the southern portion of the Naugatuck Dike and at the northern portion of the Housatonic Dike) the SPT values ranged from 9 to 17.

4.2.2 Levee Fill Material

Levee fill material below the surficial cover soil consisted of dense brown, fine to medium sand and stiff clayey silt with little gravel. These materials were described within the USACE documents as impervious fill and random fill soils. The thickness of this stratum varies from 23 feet to 28 feet with an average of about 26 feet. The SPT blow counts generally ranged from 25 to refusal (i.e., SPT blow counts greater than 100/6").

4.2.3 Gravel and Sand

The natural soils below the levee embankment consisted of gray, fine to coarse gravel with some fine to coarse sand. A review of the historic test borings indicates the presence of pockets of organic deposits at the Housatonic Dike (Levee). However test borings conducted as part of this investigation did not encounter organic deposits. This is consistent with a USACE document which indicates that the organic soils were to be removed prior to construction of the levee. The gravel particles consisted of angular to sub-angular fragments. This stratum was noted to have a very high permeability. The results of slug tests performed in this stratum are described in section 4.3 of this report. The thickness of this stratum varies from five to 15 feet. The SPT values generally range from 25 to refusal.

4.2.4 Silts and Sands

A layer of gray silt with trace fine sand was encountered in the northern portion of Naugatuck dike (Sta. 68+75 to Sta. 113+00) and medium fine sand and silts in the southern portion of Naugatuck dike (Sta.0+00 to Sta. 30+99) & Housatonic dike (Sta. 0+75 to Sta. 20+28). All test borings performed as part of this study were terminated in this stratum except test boring PSS-7. The compactness of this stratum ranged from medium dense to very dense with SPT N values ranging from 11 to 60.

4.2.5 Weathered Rock and Bedrock

Weathered rock exhibiting relic rock structure was encountered in test boring PSS-7 at 45 feet bgs (Elevation -20). Material observed in SPT spoon consisted of gray brown fine to coarse sand with little to some gravel and trace silt. Weathered rock is the result of in-place weathering of the underlying bedrock. Drilling using soil bit became progressively difficult as the weathered rock became more competent and refusal to soil drilling methods was encountered at 50 feet bgs. The test boring was terminated after obtaining one foot of confirmatory core at 50 feet bgs. Bedrock consisted of un weathered mica schist.

The logs of confirmatory test borings that were performed as part of this study are presented on Plates 3.1 thru 3.10.

4.3 Groundwater Conditions

4.3.1 Occurrence of Groundwater in Piezometers

While performing the borings, groundwater was first encountered in temporary piezometers PSS-2, PSS-6 and PSS-8 at depths ranging from 30 to 34 feet bgs (Elevation +1.0 to -3.0 feet). Groundwater was encountered in the gravel layer

beneath the levee under the unconfined condition (i.e. phreatic/water table). The groundwater within the gravel layer exhibited diurnal tidal influence that lagged the tidal periods observed in the river. The groundwater level was noted to fluctuate approximately 9.3 feet (Elevation +6.5 to -2.8 feet) in response to tidal action in the river.

4.3.2 Results of In-Situ Permeability Testing

The water level data collected during the field slug tests, pump-in test and falling head tests were evaluated at our office using commercial software. It was noted that there was insignificant displacement of the water level using the inert slug body. High transmissivity of the gravel layer and the rapid rate of water level recovery limited the use of the slug test data in determining hydraulic conductivity for the gravel layer.

As an alternative method to using slug tests, a series of "pump-in tests" were implemented using a surface mounted pump system to discharge water rapidly into the temporary well casing to quickly raise the water level in the temporary well to an adequate height as needed to perform the test. The pump-in tests were performed in PSS-2, PSS-6 and PSS-8. The data from the pump in test were analyzed using the Bouwer & Rice Method (1976) and Hvorslev Method for unconfined aquifer conditions. The data evaluated from the field pump-in tests was measured from the end of the pump-in period until the water level dropped to the pre-pump-in levels.

The results of the in-situ permeability tests indicates that the in-situ hydraulic conductivity ranges from $2.1x10^{-4}$ cm/sec to $1.7x10^{-1}$ cm/sec. Copies of the in-situ permeability tests are included in Appendix D.

4.4 Laboratory Tests

Laboratory tests were performed on representative soil samples obtained from the recent test borings in accordance with current standard procedures described within the USACE manuals. All samples were visually classified in accordance with the Unified Soil Classification System (USCS) presented on Plate 2. The historic test boring logs are also reviewed and reclassified in accordance with the USCS. The reclassified logs are presented in Appendix B. To supplement the engineering properties of the site soils presented within USACE memoranda, laboratory testing on selected representative soil samples consisted of six grain size distribution analysis, two Atterberg Limit tests, four hydrometer analysis, one hydraulic conductivity test using fixed wall permeameters and two consolidation tests on the lower silt soils. The laboratory test results are summarized below and the test data are presented in Appendix E.

4.4.1 Gradation Analysis

The following Table 4.4.1 indicates the D_{10} and D_{60} particle sizes of samples tested.

Table 4.4.1: D_{10} and D_{60} Grain Size

Boring No	Sample No	Depth (ft)	Soil Classification	D10 (mm)	D60 (mm)
PSS-2	S6	10-10.4	Gray Br. F-C Sand, some F Gravel, trace Silt	0.14	3.6
PSS-6	S10	30-32	Br F-C Sand, and F-C Gravel, trace Silt / Clayey silt	0.12	5.6
PSS-8	S6	15-17	Olive Gr Br F-C Sand, and Clayey silt, Some F-C Gravel	0.004	0.4
	S7	20-22	Olive tan Gray F-M Sand , and Silt, trace F Gravel	0.0035	0.25
	S10	35-37	Olive Gr F-C Sand, and F-C Gravel, trace Silt	0.074	2.95
	S11	32-34	Gray Br. C-F Sand, F-C Gravel, trace Silt	0.21	9
PSS-10	S3	7--9	Gray F-C Sand, and Clayey silt, little F-C Gravel	0.0035	0.4
	S4	9--11	Br Gray F-C Sand, some Clayey Silt, little Gravel	0.002	0.45
	S7	25-27	Dk Gray F-M Sand, little Silt, little F Gravel occ, coal frags	*	0.39
	S8	30-32	Gray C-F Gravel, and F-C sand, trace Silt	0.16	14

Note * -- Hydrometer analysis was not performed

4.4.2 Laboratory Permeability Test Results

The following Table 4.4.2 lists the results of fixed wall permeability testing.

Table 4.4.2: Laboratory Permeability Test Results

Boring No	Sample No	Depth (ft)	USCS Symbol	Estimated Permeability K (cm/sec)
PSS-6	S10	30-32	SP-SM	1.38×10^{-4}
PSS-6	S11	32-34	SP-GP	6.66×10^{-3}

4.4.3 Consolidation Testing

The following Table 4.4.3a and Table 4.4.3b indicate the consolidation characteristics measured within the samples tested from Borings PSS-1 and PSS-2.

Table 4.4.3a: Consolidation Test Results

						Consolidation Tests				
Sample ID	**Depth (ft)**	**Strata**	**USCS Symbol**	**Dry Unit Weight PCF**	**Atterberg Limits**	**Po, TSF**	**Pc, TSF**	**OCR**	**$C_C/1+e_0$**	**$Cr/1+e_0$**
PSS-1 U-13	42-44	Silty Clay	ML/SM	84.8	Non-plastic	5.1	5.6	1.0	0.152	0.017
PSS-2 U-15	52-54	Silty Clay	ML/SM	85.2	Non-plastic	5.4	6.4	1.2	0.141	0.018

Table 4.4.3b: C_v Test Results from PSS 1 and PSS 2

Sample ID	**C_V(Ft2/day)/Cα**			
	Load, TSF			
	1	**2**	**4**	**8**
PSS-1 U-13	25.03	24.86	23.55	23.39
PSS-1 U-13	0.002	0.0025	0.004	0.005
PSS-2 U-15	--	17.306	19.66	23.55
PSS-2 U-15	0.004	0.0035	0.004	0.005

5.0 GEOTECHNICAL ENGINEEERING ANALYSIS

In accordance with our scope of work, PS&S performed embankment and foundation stability analyses; seepage analyses; and, settlement analyses in accordance with the USACE manuals and guidance and in accordance with the FEMA guidance cited below:

5.1 Embankment and Foundation Stability

Slope stability analyses were performed at seven selected representative levee sections. The analyses were performed using the computer program SLOPE/W, part of the GeoStudio 2007 suite of programs. The program considers various heterogeneous soil systems, anisotropic soil strength properties, and excess pore water pressures due to shear, static groundwater and surface water, pseudo-static earthquake loading. The pore pressures and seepage forces from the seepage analyses (i.e. the output from SEEP/W software) were imported into and utilized by the SLOPE/W program. This allowed pore water pressures and critical gradients to be incorporated into the slope stability analyses.

SLOPE/W is a limit-equilibrium program that utilizes methods of slices to determine a stability factor of safety against slope failure. Spencer's method of slices was selected as required by the USACE manual. The resulting stability factor of safety considers the capacity of the levee and foundation soils to resist shear stresses imparted on the foundation soils from gravity, seepage and earthquake forces acting on the levee. The factor of safety is expressed in terms of the ratio of resisting capacity or strength divided by driving forces and moments.

Slope stability analyses were performed at a total of seven cross-sections. At five sections, stability analyses were performed, using pore water pressures and seepage forces obtained from the SEEP/W software. Additional two sections were analyzed using a simple hydrostatic pressure, based on a phreatic surface, rather than importing the hydrologic conditions from the SEEP/W program.

5.1.1 Strength Parameters

The design strength parameters for the levee embankment and the foundation soils were based on the design data reported within USACE geotechnical reports, (Design Memorandum No, 6, dated February 1966 and Design Memorandum No, 4 dated July 1968 by USACE prepared during the initial phase of levee design). Based on the SPT blow counts within the levee embankment and the foundation material, it is PS&S' interpretation that the shear strength of the site soils is likely greater than the shear strength presented in the USACE memoranda. However, for this stability study, PS&S utilized the conservative shear strength parameters that are within USACE manuals as summarized in the following Table 5.1.1.

Table 5.1.1: Shear Strength Parameters for Levee Slope Stability Analysis

Material	Unit Weight		Shear Strength	
	Sat (pcf)	Moist (pcf)	ϕ (deg)	C (psf)
Stone Protection	140	140	35	0
Gravel Bedding and Gravel Fill	145	140	30	0
Compacted Impervious and Random Fill	140	130	30	400
Compacted Sand Fill	145	140	30	0
Compacted Pervious Fill	140	130	30	0
Foundation Gravel	145	130	30	0
Foundation Sand	140	130	30	0
Foundation Silts	120	100	25	0
Dumped Waste Fill	130	120	28	0

5.1.2 Summary of Slope Stability Results

Slope stability analyses were performed under steady state condition, high flood condition and sudden drawdown condition. The steady state condition, high flood condition and the sudden drawdown condition are referred to as normal operating condition, standard flood elevation for 100 years and low discharge river, respectively, in the following sections of this report and the groundwater elevation corresponding to these conditions are also described in the subsequent section of this report. To account for potential heterogeneity of the actual levee materials at locations between PS&S's borings, seepage was simulated for an assumed flood condition significantly more conservative than the USACE's design hydrograph. Specifically, the maximum flood elevation was assumed to remain in-place for a period of 24 hours rather than the much shorter time period which would be derived using the design hydrograph.

PS&S analyses were performed for both river and land side of the levee using Spencer's method of slices, a limit equilibrium method. In addition, a stability analysis also was performed for the "T" wall (concrete retaining wall) structure located between stations 3+08 and 3+95 along the Housatonic flood control project. A cross section at station 3+50 was utilized for the analysis of the "T" wall. The computed output of the stability analyses are presented in Appendix F and calculated factors of safety are summarized in the following Table 5.1.2

Table 5.1.2: Summary of Calculated Factor of Safety

Stability Location	Calculated Factor of Safety*				
	Steady State		Full Hydrostatic Pressure		Sudden Drawdown
	River Side	Land Side	River Side	Land Side	River Side
PSS-2	1.81	1.74	1.93	1.84	1.55
PSS-4	1.99	2.84	2.68	2.67	1.91
PSS-6	2.14	2.28	2.43	2.09	2.09
PSS-8	2.06	2.4	2.47	2.4	1.89
PSS-9	2.13	2.14	3.41	1.96	1.97
PSS-10	2.07	2.03	2.84	1.96	1.91
PSS-7 (T Wall)	N/A	N/A	N/A	N/A	2.02

* - Design parameters for the above stability analyses were conservatively selected from USACE documents

N/A – Analysis not performed

The estimated stability factors of safety are greater than the minimum recommended values presented within the USACE guidance documents (in particular EM-1110-2-1913, Table 6-1b, page 6-5). USACE recommends a stability factor of safety of 1.4 for the steady state seepage conditions and a stability factor of safety ranging from 1.0 to 1.2 under the rapid drawdown conditions for existing levees.

5.1.3 Pseudo Static Stability Analysis

Earthquake loadings are not normally considered in analyzing the stability of levees at full flood condition because of the low probability of an earthquake coinciding with periods of high flood. However, for completeness, the stability of the existing levee was evaluated using earthquake forces during normal steady state condition.

The peak horizontal ground surface accelerations for the pseudo-static analyses were estimated using United States Geologic Survey (USGS) data. For an estimated peak horizontal ground surface acceleration of 0.163g for type “C” soil profile, pseudo static seismic stability analysis considered an equivalent seismic

horizontal acceleration coefficient of 0.0815g. Seismic stability analyses were performed for two sections, one along the Housatonic River (section at PSS-9) and other along the Naugatuck River (section at PSS-2). The analyses indicate that the factors of safety are greater than the recommended factor of safety of 1.0 as per FEMA guidance (Federal Guidelines for Dam Safety Earthquake Analysis and Design of Dams, May 2005) which says "a pseudo-static factor of safety greater than 1.0 is very strong evidence that there would be little or no damage to the dam from an earthquake". The computed output of the pseudo static stability analyses are presented in Appendix F and the results of the analyses are presented on Table 5.1.3.

Table 5.1.3: Summary of Calculated Factor of Safety for Pseudo Static Condition

Stability Location	Pseudo Static Stability Factor of Safety under Steady State Condition	
	River Side	Land Side
PSS-2	1.39	1.45
PSS-9	1.61	1.69

5.1.4 Comparison of USACE and PS&S Stability Analysis

The USACE's calculations that support their designs were performed at a time when geotechnical analyses were typically performed manually without the aid of computer software. The slope stability analysis performed by USACE (design memorandum No 4 and No 6) assumed the presence of a thin soft layer at Elevation -10. Therefore, the analysis by the USACE considered a wedge type failure envelope sliding horizontally on the assumed soft material at Elevation -10. Their analysis for the riverside portion of the Housatonic Dike (levee) at station 18+00 indicated a factor of safety for sudden draw down and end of construction of 1.04 and 1.49, respectively. The stability factors of safety at the northern portion of Naugatuck dike (levee) were 1.14 and 1.60, respectively.

PS&S's recent test borings and the USACE as-built drawings support the interpretation that all organic that were observed within the historic test borings were over excavated and replaced by granular backfill at the time of initial levee construction. Therefore PS&S's analysis differs from the USACE's analysis in that our analysis utilized a circular/rotational failure envelopes to calculate the lowest factor of safety. A circular failure surface is applicable if a discrete weak horizontal failure plane is not present. PS&S's analyses were performed for both river and land side of the levee using Spencer's method of slices, a limit equilibrium method as discussed. PS&S's analyses did not consider presence of any weak or soft layer at Elevation -10.0 with the assumption that these materials were removed. PS&S's analysis and conclusion regarding stability are only valid

if all organic material were removed, as the results of our test borings suggest. PS&S did not duplicate USACE analyses and cannot comment on their analyses.

5.2 Seepage Analysis

Seepage analysis were performed using SEEP/W software (version 7.17) developed by GEOSLOPE Internationals of Alberta, Canada. SEEP/W is a two-dimensional finite element groundwater model with robust interactive pre and post processors. This software allows analysis of two dimensional geometries such as earth dams or levees and canals.

SEEP/W can be used for either confined or unconfined flow models in both steady state and transient conditions. The output from the SEEP/W model including pore water pressures, seepage forces and phreatic surfaces can be directly imported into the slope stability interface, SLOPE/W, which is integrated into the same software suite known as GeoStudio. This integral approach allows the slope stability analyses to utilize a more realistic ground water regime including soil pore water pressure profile as opposed to the conventional straight line phreatic surfaces that is used in conventional slope stability software. The use of these more realistic pore water pressure profiles can have a significant effect on the outcome of a slope stability analysis, especially when potential artesian or rapid drawdown conditions are present.

Five typical representative cross sections for section 1 of the Ansonia/Derby levee system were subjected to seepage analyses. The subsurface conditions interpreted from historic borings and PS&S' recent confirmatory test boring program were utilized for the seepage evaluation. The most critical cross sections as interpreted from the site subsurface conditions that are used for the evaluation consisted of: two sections from the left bank of the Ansonia/Derby Naugatuck River; one section from the left bank of the Derby Naugatuck River; and, two sections from the right bank of the Derby Housatonic River.

5.3 Design Parameters

Soil hydraulic conductivity parameters were based on the results of field investigation (test borings, visual classification of soil material and slug tests within gravel layer at selected test boring locations), laboratory gradation analyses on representative soil samples obtained from the test borings and design hydraulic conductivity data and gradation analyses within the USACE design memoranda.

The design hydraulic conductivity parameters used in the analyses of the levee are presented on Table 5.3.1a. The design parameters shown on the table consist of the hydraulic conductivity of the various soil layers and the estimated anisotropic ratio within each layer (i.e. ratio of horizontal hydraulic conductivity to vertical hydraulic conductivity). The actual flow quantities calculated are dependent upon and are sensitive to the permeability and relative position of each substratum within the embankment.

Table 5.3.1a: Hydraulic conductivity Parameters for Levee Seepage Analysis

	Material			Design Kv values from USACE (10^{-4} cm/sec)	Ratio of Kh/Kv used by USACE	Design Kv values used in PS&S Evaluation [1] (10^{-4} cm/sec)	Ratio of Kh/Kv used by PS&S
Naugatuck Dike (Levee) and Housatonic Dike (Levee)	Embankment Zone	Embankment Impervious Fill		<1.0	1	3	1
		Random Fill		<1.0	1	1	1
		Compacted Pervious Fill		20 to 300	4 to 9	100	1
		Trench Drain Gravel (processed gravel fill)		10000	1	10000	1
		Sand Fill		100 to 400	1	100	1
		Stone Protection (River side)		Not specified	1	10000	1
Naugatuck Dike (Levee)	Foundation Zone	Zone - I (Fill, Sand)	Sta 0+00 to 24+00	5 to 100	9 to 16	Varies[2]	
			Sta 24+00 to 30+00	1 to 10			
		Zone -II (Gravel)		100 to 500	9 to 16	18.73* 175**	10
		Zone -II (Sand or Silt)	Sta 0+00 to 10+00	1 to 150	9 to 16		
			Sta 10+00 to 30+00	1 to 20		0.03	1
Housatonic Dike (Levee)		Zone - I (Fill, Sand)	Sta1+00 to 4+50	1 to 200	9 to 16	100	1
			Sta 12+00 to 21+00	1 to 50		100	1
		Zone -II (Gravel)		50 to 400	9 to 16	175**	10
		Zone -II (Sand or Silt)	Sta 1+00 to 12+00	1 to 100	9 to 16	100	1
			Sta 12+00 to 21+00	1 to 50		100	1

Note : 1 - The PS&S design values are applicable to the specific cross section being evaluated. Actual value may vary between stationing considered by USACE

2 - PS&S analysis was performed at Sta 22+00. Since the material type differs greatly within Zone-I (i.e., natural site soils vs. dumped granular fill), the permeability varies significantly depending upon the type of material within zone-I

* Based on Slug test results from PSS-2

** Based on Slug test results from PSS-6

The design hydrographs, taken from the USACE Operations and Maintenance Manuals for the flood protection works along the Ansonia Connecticut Naugatuck and Housatonic Rivers, shown on Plates 4.1 and 4.2, are based on the project flood, dated 1955. These plates were utilized in developing the hydrological loading. The water levels were applied in accordance with profiles and water level

elevations provided in Table 5.3.1b. The flood stage durations up to the peak flood were consistent with the durations shown on the USACE hydrographs. The hydrographs indicates that the peak flood remains for a duration of four hours however, a peak flood level of 24 hours was conservatively assumed for PS&S's seepage and stability analysis to account for heterogeneity and saturation of the levee embankment. In PS&S's opinion, this assumption would represent a conservative scenario for slope stability. In addition, sudden drawdown was assumed to occur instantaneously to simulate a worst case condition.

Table 5.3.1b: Summary of Water Level Surfaces for Levee Seepage Analysis

Seepage Location	Water Level Surfaces (EL. NFIP)	
	Water Surfaces	**River Side (EL)**
PSS-2	SFE	+26
	NOC	+8.5
	LDR	+3.0
PSS-4	SFE	+24.0
	NOC	+8.0
	LDR	+1.5
PSS-9	SFE	+26
	NOC	+6.0
	LDR	-1.0
PSS-10	SFE	+22
	NOC	+6.0
	LDR	-1.0

Notes : SFE = Standard Flood Elevation for 100 years
NOC = Normal Operation Condition
LDR = Low Discharge River

In addition to evaluating the seepage quantity SEEP/W also provides pore water pressures and equi-potential lines within the levees and, provides the exit seepage gradients under various conditions. The USACE guidance for exit gradients and various seepage condition trends is shown in Table 5.3.1c (USACE Engineering Technical Letter 1110-2-569).

Table 5.3.1c: USACE Guidance for Exit Gradients and Seepage Condition

Exit Gradient, (*i*)	**Seepage Condition**
0.0 to 0.5	None to Light seepage
0.2 to 0.6	Medium Seepage
0.4 to 0.7	Heavy Seepage
0.5 to 0.8	Sand Boils

In general the USACE guidance documents require that the exit seepage gradient into drainage ditches at the landside of the levee should not exceed 0.5, but may linearly increase to as much as 0.8 at a distance of 150 feet from the levee toe.

5.3.2 Summary of the Seepage Analysis Results

Seepage analyses were performed under each of the following conditions;

- Steady state condition: Since the river level fluctuates between Elevation -1.0 and +8.5 due to tidal influence, a water level of Elevation +6 to +8.5 was assumed for steady state condition;

- High flood condition: The high flood condition corresponding to hydrographs presented in plates 4.1 and 4.2 were utilized, with the exception that the high flood was conservatively assumed to remain for duration of 24 hours rather than the duration of about four hours shown on the hydrographs after the flood peak. In addition, a precipitation event of 0.3 inches/hr was assumed to occur simultaneously during flooding to simulate saturated ground condition (Note: additional seepage analysis with true hydrograph was also performed at PSS 2); and,

- Sudden drawdown condition: Instantaneous drawdown from high flood condition to elevation -1.0 to +3.0 (i.e., river bottom) was conservatively assumed to simulate a worst case scenario for stability analysis.

- Flood Duration : A theoretical seepage gradient was determined for an assumed conservative flood condition (i.e., 100 year flood elevation for a duration of 24 hours). The seepage gradient at location PSS-2 was also calculated using the flood elevation and duration derived from the design hydrographs.

The analyses were performed for both the river and land side of the levee. The graphical computer output of the seepage analyses are presented in Appendix G

and the calculated flow quantities and the calculated seepage exit gradient results are presented on Table 5.3.2.

Table 5.3.2: Summary of Calculated Seepage Flow Quantities, Ansonia/Derby Levee System

Seepage Location	Seepage Under Steady State			Seepage During High Flood Condition			
	Cumulative flow (gpm)	Flow through trench drain (gpm)	Exit gradient at bottom of trench drain	Cumulative flow (gpm)	Flow through trench drain (gpm)	Exit gradient at bottom of trench drain	Exit gradient on landside away from toe
PSS-2	0.015	0.015	0.02	0.99	0.81	0.46/0.6[see note]	0.4
PSS-4	0.22	0.21	0.03	3.71	3.62	0.5	0.05
PSS-9	0.12	0.11	0.02	2.61	2.42	0.4	0.1
PSS-10	0.22	0.22	0.03	3.04	3.04	0.4	0.06
PSS-7 ("T" Wall)	~ 0	~ 0	0.01	3.71	3.26	0.2	0.1

Note: The calculated exit gradient at PSS 2 is 0.46 for the flood condition represented by the design hydrograph and would exceed 0.5 for flood duration greater than the duration shown on the hydrograph.

The calculated exit gradient at four of the five sections was 0.5 or less for the conservative condition represented by a 100 year flood elevation lasting 24 hours. At location PSS-2, the calculated exit gradient (0.46) was less than the USACE guidance value (0.5), when the location was analyzed using the design hydrograph. Further calculations at location PSS-2 indicate that the theoretical gradients equals 0.5 for an assumed 100 year flood elevation duration about eight hours (i.e., twice the duration of that shown on the design hydrograph), and 0.6 for an assumed 100 year flood elevation duration of 24 hours (i.e., four times the duration of that shown on the design hydrograph). Based on these analyses, it is PS&S's opinion that the exit seepage gradient, at the five locations evaluated, satisfies the USACE guidance criteria. However, because excessive or uncontrolled seepage can result in a chronic adverse condition to water impoundment structures, PS&S recommends that the Operation and Maintenance manual include measures to monitor landward seepage during peak flow conditions.

5.4 Settlement Analysis

This section assesses the potential and magnitude of future losses of freeboard as a result of levee settlement in order to demonstrate that freeboard will be maintained within the minimum freeboard standards set forth in Section 2.0, B(1) of 44 CFR 65.10.

5.4.1 Compressibility of Foundation Soils and Age of Levees

PS&S' borings did not encounter the presence of any soft compressible soils within the foundation material below the embankment levees or within the embankment levees. This is consistent with the USACE design memorandum which recommended removal of pockets of organic deposits within foundation soils prior to construction of the levee embankment. PS&S borings indicates presence of stiff gray silt with fine sand below the gravel layer in the northern portion of Naugatuck Dike (levee) In the southern portion of Naugatuck Dike and the gravel layer was underlain by medium fine sand and silt. PS&S obtained two Shelby tube samples of the underlying silts and sand stratum in the northern portion of Naugatuck Dike (from test borings PSS-1 & PSS-2). Two consolidation tests were performed on the undisturbed tube samples to evaluate its compressibility characteristics. Results of the laboratory testing indicate the silt and sand layer is highly over consolidated and therefore not prone to significant settlement.

Assuming that all compressible organic materials were removed during the levee construction, continued long-term settlement of the levees is unlikely because soils encountered within and below the levee are of a granular nature and the silt and sand stratum is highly over-consolidated. Furthermore, because the levees were constructed over 40 years ago, generally any primary consolidation related settlement due to embankment loadings would have occurred during and immediately following construction of the levees. Because the foundation materials and fill soils are of the type which normally shows a small amount of compressibility, approximately 4.6 inches of secondary consolidation related settlement was estimated at northern portion of the Naugatuck Dike (borings PSS-1 & PSS-2) to have already occurred since construction of the embankments was completed. The calculations also indicate that one half inch or less of settlement of the underlying silt and sand stratum is anticipated to occur over the next 30 years. Settlement within southern portion of the Naugatuck Dike (levee) are expected to be much smaller due to the greater amount of sand in this stratum. A detailed settlement analysis using procedures described in USACE Engineering Manual EM 1110-1-1904 is shown in Appendix H.

5.4.2 Compressibility of Embankment Soils

The results of the borings indicate that the granular soils within the embankment are compact and not subject to significant internal settlement.

5.4.3 Construction Compaction Methods

The required fill materials for the embankment construction were either obtained from river excavations, from the designated borrow area or obtained by the contractor from designated borrow sources. The pervious fill material, random fill material and the gravel fill material were obtained from the excavations performed during the Naugatuck River Channel Improvement, from the Right Bank Dike Foundation toe drain, the Left Bank Dike Foundation Cut-off, the reach of the wall between Stations 7+80 and 21+00, and the area downstream of the Railroad Bridge. The impervious fill material was obtained from the Government furnished borrow area. Crushed stone fill; filter sand and gravel bedding materials as furnished by the Contractor were obtained from commercial sources within 20 miles of the site.

The details of the USACE Design Memorandum No. 6 indicate that for the pervious fill, random or gravel fill materials no laboratory compaction tests were performed. The USACE anticipated that the natural moisture content of these materials would be within ranges permitting adequate compaction without additional moisture content control. The design engineers estimated that in-place density readings for the compacted random fill and the compacted gravel materials would be on the order of 120 to 125 pcf, respectively.

During levee construction, laboratory compaction tests were performed on representative samples of the borrow area materials. Apparently it was the USACE opinion that based upon past experience with similar materials and available moisture content data, that the placement moisture content of the materials could be controlled within plus or minus two percent (2%) of the optimum moisture content. They reported that the in-place dry density of the compacted impervious fill would be on the order of 120 pcf.

The results of the test borings indicate that the materials comprising the embankments are mostly compact to very compact. In a few locations within PSS-6 and PSS-7 some loose to medium compact layers of fill material exists within the first 12 feet of embankment.

It is our opinion that loss of freeboard due to settlement of the levees is not anticipated.

6.0 RECOMMENDATIONS AND CONCLUSIONS

Based upon our review of the existing USACE data and our confirmatory investigation, it is PS&S' opinion that, from a geotechnical standpoint, there is a reasonable certainty that the Section 1 of the levee system will contain the one percent annual chance exceedance flood (i.e., base 100 year flood) with regards to stability, seepage and settlement. There are some minor concerns regarding the physical condition of some of the embankments which we observed at the time of our field studies (animal burrows). Further more the levees are founded upon a gravel formation exhibiting a high permeability. It is for this reason that the USACE designed the inboard relief toe drains to control seepage during the 100 year flood event. Our calculations, performed using measured and, inferred permeability values, suggest that the exit gradient value would not exceed the USACE guidance value of 0.5 for a flood event represented by the design hydrograph.

Because this report relies on design data obtained by others and limited confirmatory data, this report does not represent a warrantee or a guarantee of levee performance.

6.1 Recommendations for Additional Work

Based on our limited field observations and engineering evaluation of the site, PS&S recommends following additional study/maintenance items should be considered by the municipalities:

1) Perform an in-situ pump test(s) to better estimate the permeability of the gravel layer. Slug tests were found to be an inadequate test methodology due to the very high permeability of this stratum.

2) Maintain the toe drains from siltation and keep clear of vegetative growth.

3) Excessive and uncontrolled seepage represents a threat to earthen water impoundment structures. While our analysis suggests that the calculated seepage is not excessive, PS&S recommends that all toe drain structures be routinely monitored during all high water conditions. Routine monitoring measures should include observation and documentations of phenomena such as the formation of springs, upwelling of water, the formation of sand "boils" or the presence of turbid or muddy water. Implementation of more extensive monitoring measures could be developed if any of the above phenomenons are observed.

4) Repair animal burrow holes as per the FEMA guidelines (FEMA-473). It is our understanding that the municipality has incorporated FEMA guidelines within its O&M manual and the burrow hole repair activity has been scheduled to commence in December 2010. Inspection for and repair of all animal burrows should be implemented and maintained as a routine O&M task.

5) Maintain the levees free of unwanted vegetation such as trees, bushes and vegetative matter with deep roots.

6) The existing earth retaining structures near the rail crossings in the southern portion of the site should be reviewed in detail for its structural integrity.

6.2 Operation and Maintenance

The successful ongoing performance of the levee system is dependent upon ongoing maintenance and proper operation. Derby and Ansonia each have an Operation and Maintenance Manual to be followed. Additionally, updates as necessary, should be made to the manuals as required by local, state and/or federal regulations. Properly trained personnel are also important to the proper ongoing maintenance of the levees.

6.3 Geotechnical Consultation

PS&S is available to provide consultation, attend meetings and evaluate remedial measure concepts, if any, as the project progresses. Typical tasks would include performance of the pump tests, structural review of the earth retaining structures, attendance at working charrettes, meetings and guidance to members of the design team (particularly the Structural Engineer).

UNIFIED SOIL CLASSIFICATION SYSTEM

MAJOR DIVISION				GROUP SYMBOL (ASTM D2487)	TYPICAL DESCRIPTION
COARSE-GRAINED SOIL (MORE THAN 50% RETAINED ON NO. 200 SIEVE*)	GRAVEL (50% OR MORE OF COARSE FRACTION RETAINED ON NO. 4 SIEVE)	CLEAN GRAVEL (LESS THAN 5% FINES**)		GW	WELL GRADED GRAVEL, GRAVEL-SAND MIXTURES
				GP	POORLY GRADED GRAVEL, GRAVEL-SAND MIXTURES
		GRAVEL WITH FINES (MORE THAN 12% FINES**)		GM	SILTY GRAVEL, GRAVEL-SAND-SILT MIXTURES
				GC	CLAYEY GRAVEL, GRAVEL-SAND-CLAY MIXTURES
	SAND (MORE THAN 50% OF COURSE FRACTION PASSES NO. 4 SIEVE)	CLEAN SAND (LESS THAN 5% FINES**)		SW	WELL GRADED SAND, GRAVELLY SAND
				SP	POORLY GRADED SAND, GRAVELLY SAND
		SAND WITH FINES (MORE THAN 12% FINES**)		SM	SILTY SAND, SAND-SILT MIXTURES
				SC	CLAYEY SAND, SAND-CLAY MIXTURES
FINE-GRAINED SOIL (50% OR MORE PASSES NO. 200 SIEVE*)	SILT & CLAY (LIQUID LIMIT 50% OR LESS)			ML	INORGANIC SILT, VERY FINE SAND, ROCK FLOUR, SILTY OR CLAYEY FINE SAND
				CL	INORGANIC CLAY OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAY, SANDY CLAY, SILTY CLAY, LEAN CLAY
				OL	ORGANIC SILT, ORGANIC SILTY CLAY OF LOW PLASTICITY, LESS THAN 30% ORGANICS
	SILT & CLAY (LIQUID LIMIT GREATER THAN 50%)			MH	INORGANIC SILT, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILT, ELASTIC SILT
				CH	INORGANIC CLAY OF HIGH PLASTICITY, FAT CLAY
				OH	ORGANIC CLAY OF MEDIUM TO HIGH PLASTICITY, LESS THAN 30% ORGANICS
HIGHLY ORGANIC SOIL 30% OR MORE ORGANICS				PT	PEAT, MUCK, OTHER HIGHLY ORGANIC SOIL

* BASED ON MATERIAL PASSING THE 3" (75MM) SIEVE; COBBLES 3" TO 12"; BOULDERS > 12"
** MATERIALS WITH 5% TO 12% FINES ARE BORDERLINE CASES, DESIGNATED: GW-GM, SW-SC, ETC.

GRADATION

TERM	% BY DRY WEIGHT
TRACE	< 10
LITTLE	10 to 20
SOME	20 to 35
-Y	35 to 45
AND	45 to 50

RELATIVE DENSITY (COARSE-GRAINED SOIL)

TERM	SPT N-VALUE (BLOWS/FT.)
VERY LOOSE	0 to 4
LOOSE	5 to 10
MEDIUM DENSE	11 to 30
DENSE	31 to 50
VERY DENSE	> 50

CONSISTENCY (FINE-GRAINED SOIL)

TERM	SPT N-VALUE (BLOWS/FT.)
VERY SOFT	0 to 2
SOFT	3 to 4
MEDIUM STIFF	5 to 8
STIFF	9 to 15
VERY STIFF	16 to 30
HARD	31 to 50
VERY HARD	> 50

VALUES OF PERCENT CONTENT ARE FROM LABORATORY OR FIELD TEST DATA, WHERE APPLICABLE.
WHEN NO TESTING WAS PERFORMED, VALUES OF PERCENT CONTENT ARE ESTIMATED BASED ON VISUAL OBSERVATION.

PS&S
integrating design & engineering

Log of Boring: PSS-1

Project: Ansonia/Derby Levee	Project Number: 04019-0001	Elevation (ft): 34.0	Datum: Site Datum
Location: Ansonia, Connecticut	Logged By: J. Knittel	Date Started: 8/2/2010	Date Completed: 8/3/2010
Drilling Contractor: CMI Subsurface Investigations, Inc.		Drilling Foreman: John Imparato	Completion Depth (ft): 62.0
Sampler: 2" O.D. Split Spoon		Casing Diameter (in): 4	Casing Depth (ft): 40
Drilling Equipment: 3 7/8" Tricone Roller Bit		Sampler Hammer: Donut	Weight (lbs): 140 / Drop (in): 30
Drilling Rig: Mobile B-61	Drilling Mud: Quick Gel	Water Level (ft) First: ▽	Completion: ▼ / 24 HR: ▼

Elev. (ft)	Strata	Material Symbol	Sample Description	Depth Scale	Sample Data: Number	Type	Recov. (in)	Penetr. Resist BL/6in	N-Value (Blows/foot)	Remarks
			S1: Tan gray f-c gravel, some f-c sand, little silt, occ. roots (GM)(FILL)	0	S1	SS		7 12 29 40	41	
			S2: Br. gray f-c sand, some f gravel, little silt (SM)(FILL)	2	S2	SS		70 100/5"	R	
			S3: Br. gray f-c sand, some clayey silt, little f gravel (SM)(FILL)	4	S3	SS		72 64 45 100/3"	109	
			S4: Dk. br. f-m sand, some clayey silt, tr. f gravel (SM)(FILL)	6	S4	SS		61 35 32 50	67	
			S5: Olive br. f-m sand, some f-c gravel, tr. silt (SP-SM)(FILL)	8	S5	SS		20 52 68 70	120	
			S6: "Do S5"	10	S6	SS		50 52 75 100/4"	127	
	F		S7: Dk. olive br. f-m sand, tr. f gravel, tr. silt (SP-SM)(FILL)	14	S7	SS		36 100/6"	R	
			S8: Dk. br. f-m sand, little f-c gravel, little silt (SM)(FILL)	20	S8	SS		41 43 100/6"	R	
			S9: "DO S8", tr. f gravel	24	S9	SS		23 36 100/5"	R	
5.5	G			28						Heavy chatter from 28 ' to 30'
				30						

Plate: 3.1

PS&S
integrating design & engineering

Log of Boring: PSS-1

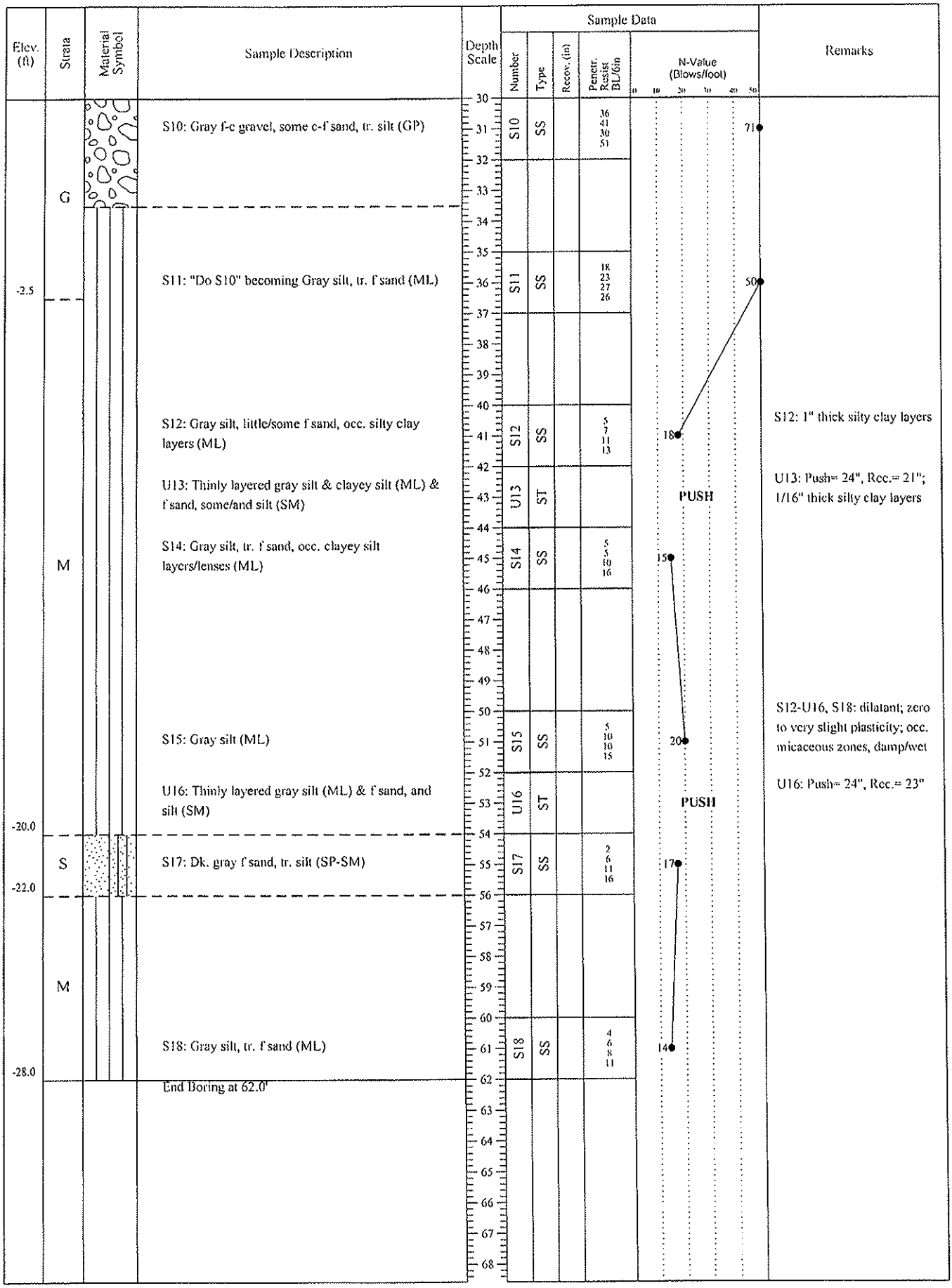


Plate: 3.1

PS&S
integrating design & engineering

Log of Boring: PSS-2

Project:	Project Number:	Elevation (ft):	Datum:
Ansonia/Derby Levee	04019-0001	34.0	Site Datum
Location:	**Logged By:**	**Date Started:**	**Date Completed:**
Ansonia, Connecticut	J. Knittel	7/29/2010	7/30/2010
Drilling Contractor:		**Drilling Foreman:**	**Completion Depth (ft):**
CMI Subsurface Investigations, Inc.		John Imparato	87.0
Sampler:		**Casing Diameter (in):**	**Casing Depth (ft):**
2" O.D. Split Spoon		4	45
Drilling Equipment:		**Sampler Hammer:**	**Weight (lbs):** / **Drop (in):**
3 7/8" Tricone Roller Bit		Donut	140 / 30
Drilling Rig:	**Drilling Mud:**	**Water Level (ft)**	**First:** / **Completion:** / **24 HR:**
Mobile B-61	Quick Gel		▽ 30.23 / ▼ / ▼ 30.26

Elev. (ft)	Strata	Material Symbol	Sample Description	Depth Scale	Sample Data: Number	Type	Recov. (in)	Penetr. Resist BL/6in	N-Value (Blows/foot)	Remarks
	F		S1: Tan br. f-m-c sand, little f gravel, little silt (SM)(FILL)	0	S1	SS		7 10 23 45	33	
			S2: "Do S1", some silt	2	S2	SS		100/6"		R
			S3: Olive tan br. f-m sand, some clayey silt, little f gravel (SM)(FILL)	5	S3	SS		31 59 95 100/3"		154
			S4: Dk. olive gray f-m sand, some silt, little f-c gravel (SM)(FILL)	7	S4	SS		71 74 100/3"		R
			S5: Olive gray f-c gravel, some c-f sand, tr. silt (GP)(FILL)	9	S5	SS		72 100/3"		R
			S6: Gray br. c-f sand, some f gravel, tr. silt (SP-SM)(FILL)	10	S6	SS		100/5"		R
			S7: Dk. gray f-m sand, some silt, little c-f gravel, occ. wood frags (SM)(FILL)	16	S7	SS		25 35 100/3"		R
			S8: Olive gray br. f sand, tr. silt (SP-SM)(FILL)	21	S8	SS		17 15 11 11	26	
			S9: Lt. tan f-c gravel, and f-c sand, tr. silt (GP-GM)(FILL)	26	S9	SS		28 45 64 72		109
7.0	G			27						

Plate: 3.2

PS&S
integrating design & engineering

Log of Boring: PSS-2

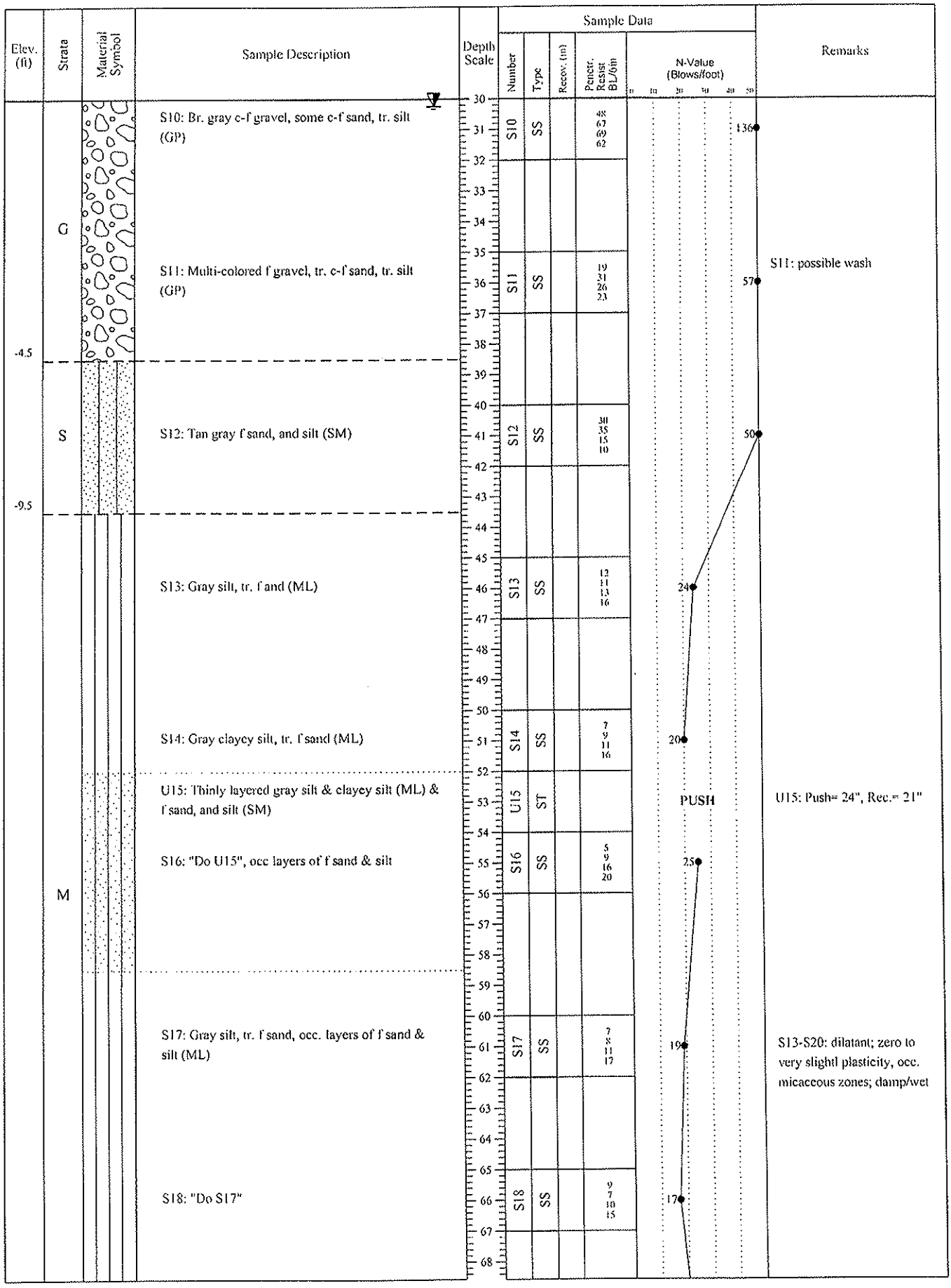


Plate: 3.2

PS&S
integrating design & engineering

Log of Boring: PSS-2

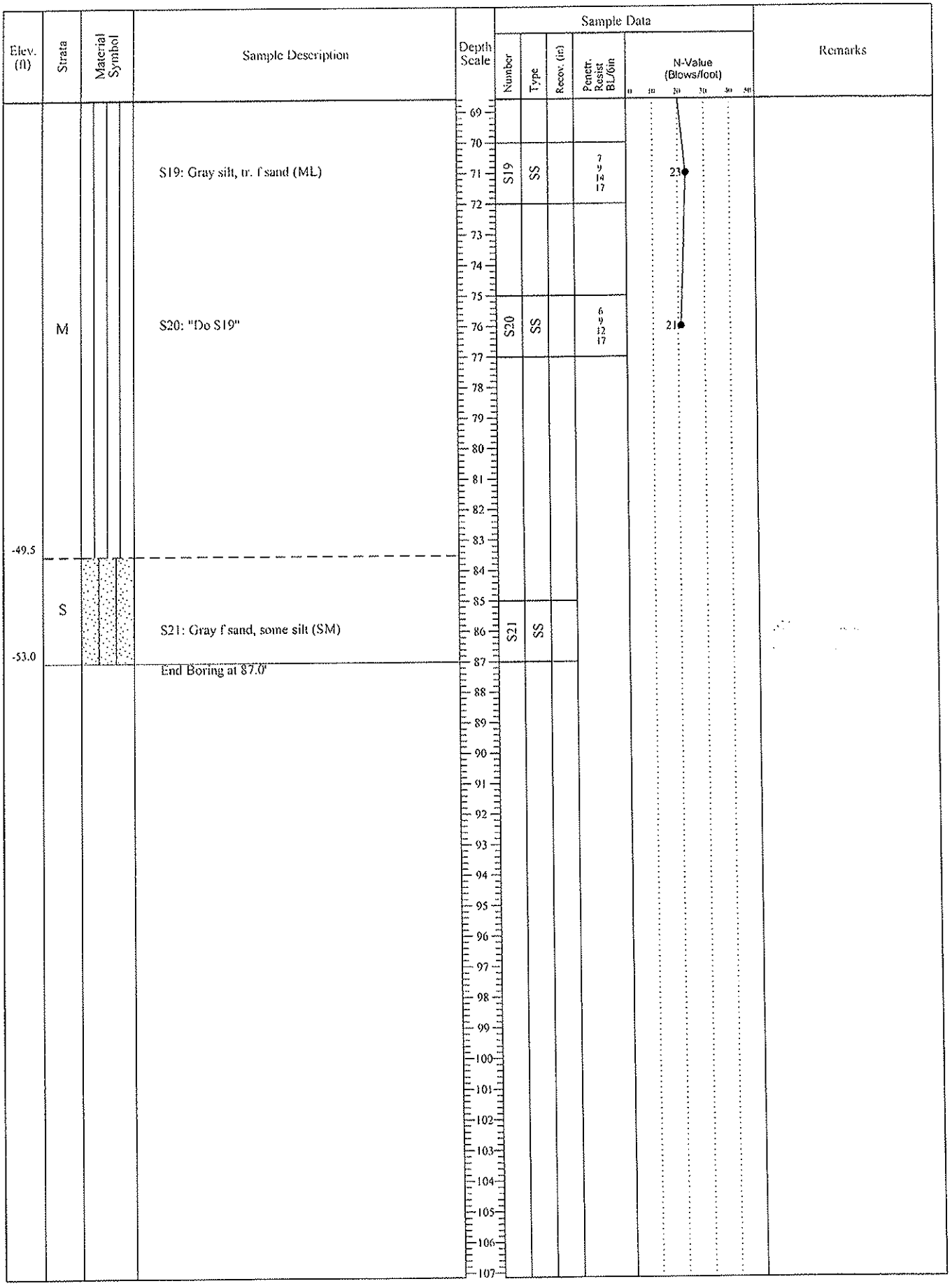


Plate: 3.2

PS&S
integrating design & engineering

Log of Boring: PSS-3

Project: Ansonia/Derby Levee	Project Number: 04019-0001	Elevation (ft): 34.0	Datum: Site Datum
Location: Ansonia, Connecticut	Logged By: J. Knittel	Date Started: 7/28/2010	Date Completed: 7/29/2010
Drilling Contractor: CMI Subsurface Investigations, Inc.		Drilling Foreman: John Imparato	Completion Depth (ft): 62.0
Sampler: 2" O.D. Split Spoon		Casing Diameter (in): 4	Casing Depth (ft): 35
Drilling Equipment: 3 7/8" Tricone Roller Bit		Sampler Hammer: Donut	Weight (lbs): 140 / Drop (in): 30
Drilling Rig: Mobile B-61	Drilling Mud: Quick Gel	Water Level (ft)	First: ▽ 29.71 / Completion: ▼ / 24 HR: ▼ 29.77

Elev. (ft)	Strata	Material Symbol	Sample Description	Depth Scale	Sample Data: Number	Type	Recov. (in)	Penetr. Resist BL/6in	N-Value (Blows/foot)	Remarks
			S1: Lt. tan f-m sand, and f-c gravel, little silt, occ. roots (SM)(FILL)	0	S1	SS		12 14 24 37	88	
			S2: Tan f-m sand, and silt, little f gravel (SM)(FILL)	3	S2	SS		33 27 51 100	78	
			S3: "Do S2"	5	S3	SS		27 70 100/4"	R	
			S4: Gray f-c gravel, some f-c sand, tr. silt (GP-GM)(FILL)	7	S4	SS		16 100/6"	R	
			S5: Dk. gray f-m-c sand, little/some f-c gravel, little silt, occ. roots (SM)(FILL)	8	S5	SS		100/3"	R	
			S6: "Do S5", occ. cinders	11	S6	SS		39 68 100/6"	R	
	F		S7: Dk. gray br. f-m sand, little silt, tr. f gravel, occ. cinders (SM)(FILL)	16	S7	SS		23 60 65 100/3"	125	
			S8: Dk. gray br. f sand, some silt, tr. f gravel, tr. m-c sand, occ. roots (SM)(FILL)	21	S8	SS		20 47 50 65	97	
			S9: Dk. br. gray f-m sand, some silt, tr./little f gravel, occ. wood, cinders & slag (SM)(FILL)	26	S9	SS		28 26 32 58	58	
5.5	G			30						

Plate: 3.3

PS&S
integrating design & engineering

Log of Boring: PSS-3

Elev. (ft)	Strata	Material Symbol	Sample Description	Sample Number	Sample Type	Recov. (in)	Penetr. Resist BL/6in	N-Value (Blows/foot)	Remarks
	G		S10: Br. c-f gravel, some c-f sand, tr. silt (GP)	S10	SS		13 20 16 40	36	
0.5			S11: Gray silt/clayey silt, tr. f sand (ML)	S11	SS		5 5 5 9	11	
			S12: "Do S11"	S12	SS		8 10 14 22	24	
			U13: Thinly layered gray silt & clayey silt (ML) & f Sand, and silt (SM)	U13	ST			PUSH	U13: Push= 24", Rec.= 20"
			S14: Gray-olive gray silt/clayey silt, tr. f sand (ML)	S14	SS		4 5 9 13	14	
	M		S15: Gray silt, tr. f sand (ML)	S15	SS		8 8 16 21	24	
			S16: "Do S15"	S16	SS		11 12 15 19	28	S16: low recovery
			S17: Gray silt (ML)	S17	SS		7 7 13 16	20	S11-S19: dilatant; zero to very slight plasticity; occ. micaceous zones; damp/wet
			S18: "Do s17"	S18	SS		4 7 11 14	18	
			S19: Gray silt/clayey silt, tr. f sand (ML)	S19	SS		6 9 15 17	24	
-28.0			End Boring at 62.0'						

Depth Scale: 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68

N-Value (Blows/foot): 0 10 20 30 40 50

Plate: 3.3

PS&S
integrating design & engineering

Log of Boring: PSS-4

Project: Ansonia/Derby Levee	Project Number: 04019-0001	Elevation (ft): 34.0	Datum: Site Datum
Location: Ansonia, Connecticut	Logged By: J. Knittel	Date Started: 7/27/2010	Date Completed: 7/28/2010
Drilling Contractor: CMI Subsurface Investigations, Inc.		Drilling Foreman: John Imparato	Completion Depth (ft): 62.0
Sampler: 2" O.D. Split Spoon		Casing Diameter (in): 4	Casing Depth (ft): 45
Drilling Equipment: 3 7/8" Tricone Roller Bit		Sampler Hammer: Donut / Weight (lbs): 140	Drop (in): 30
Drilling Rig: Mobile B-61	Drilling Mud: Quick Gel	Water Level (ft) First: ▽ 22.00 / Completion: ▼ / 24 HR: ▼	

Elev. (ft)	Strata	Material Symbol	Sample Description	Depth Scale	Sample Data: Number	Type	Recov. (in)	Penetr. Resist BL/6in	N-Value (Blows/foot)	Remarks
	F		S1: Br. c-f gravel, and f-m sand, little silt, occ. roots (GM)(FILL)	0–1	S1	SS		2, 7, 73, 29	80	
			S2: Br. f-m sand, some silt, tr. f gravel, occ. brick & roots (SM)(FILL)	2–4	S2	SS		35, 36, 48, 57	76	
			S3: "Do S2"	4–6	S3	SS		71, 100, 57, 70	157	
			S4: Gray br. f-m and, some f gravel, little silt (SM)(FILL)	6–7	S4	SS		100-5"	R	Drill chatter from 6.5' to 8'
			S5: Dk. gray br. f-m sand, little f gravel, little silt, occ. wood (SM)(FILL)	8–9	S5	SS		23, 74, 100-4"	R	
			S6: Dk. gray f-c sand, some f-c gravel, little silt, occ. cinder & metal (SM)(FILL)	10–11	S6	SS		70, 100-2"	R	
			S7: Dk. gray f-c sand, some f gravel, little silt (SM)(FILL)	15–16	S7	SS		100-5"	R	S7: low recovery Drill chatter from 15' to 16'
			S8: Dk. gray m-f sand, and f-c gravel, little silt, occ. roots & misc. debris (SM)(FILL) ▽	20–21	S8	SS		62, 100/5"	R	
10.5	G		S9: Tan gray br. c-f sand, and f-c gravel, tr. silt (SP-SM)	25–26	S9	SS		26, 37, 48, 64	85	

Plate: 3.4

PS&S
integrating design & engineering

Log of Boring: PSS-4

Elev. (ft)	Strata	Material Symbol	Sample Description	Depth Scale	Sample Data: Number	Type	Recov. (in)	Penetr. Resist BL/6in	N-Value (Blows/foot)	Remarks
	G		NR10: "No Recovery"	30	NR10	SS		14 23 16 10	39	
			S11: Multi-colored c-f gravel (GP)	32	S11	SS		20 18 23 25	41	S11: possible wash
			S12: Tan gray br. f gravel, some c-f sand, tr. silt (GP)	35	S12	SS		28 41 34 26	75	
-4.0				38						
			S13: Gray clayey silt, little/some f sand (ML)	40	S13	SS		12 13 10 13	32	
				42						S13, S14: no recovery with 2" O.D. split spoon, sample retrieved with 3" O.D. split spoon
			S14: Gray silt, little/some f sand (ML)	45	S14	SS		11 14 14 13	28	
	M			47						
			S15: "Do S14", tr./little f sand	50	S15	SS		8 9 11 14	20	S13-S17: dilatant; zero to very slight pasticity; occ. micaceous zones; damp/wet
			S16: Gray silt, tr. f sand, occ. clayey silt lenses (ML)	55	S16	SS		8 9 10 14	19	
			S17: Thinly laminated silt & clayey silt, tr. f sand (ML)	60	S17	SS		7 7 14 18	21	
-28.0			End Boring at 62.0'	62						
				68						

Plate: 3.4

PS&S
integrating design & engineering

Log of Boring: PSS-5

Project: Ansonia/Derby Levee	Project Number: 04019-0001	Elevation (ft): 34.0	Datum: Site Datum
Location: Ansonia, Connecticut	Logged By: J. Knittel	Date Started: 8/3/2010	Date Completed: 8/4/2010
Drilling Contractor: CMI Subsurface Investigations, Inc.		Drilling Foreman: John Imparato	Completion Depth (ft): 62.0
Sampler: 2" O.D. Split Spoon		Casing Diameter (in): 4	Casing Depth (ft): 40
Drilling Equipment: 3 7/8" Tricone Roller Bit		Sampler Hammer: Donut; Weight (lbs): 140	Drop (in): 30
Drilling Rig: Mobile B-61	Drilling Mud: Quick Gel	Water Level (ft); First: ▽; Completion: ▼; 24 HR: ▼	

Elev. (ft)	Strata	Material Symbol	Sample Description	Depth Scale	Sample Data: Number	Type	Recov. (in)	Penetr. Resist BL/6in	N-Value (Blows/foot)	Remarks
				0						3" asphalt over 7" gravel base
	F		S1: Olive br. f-m sand, some clayey silt, little f-c gravel (SM)(FILL)	1–2	S1	SS		12 24 21 37	45	
			S2: Olive gray br. f-m sand, and clayey silt, little/some f gravel (SM)(FILL)	3–4	S2	SS		30 49 43 18	92	
			S3: Olive gray clayey silt, little f sand, tr. f gravel (ML)(FILL)	5–6	S3	SS		11 18 24 32	42	
			S4: Olive gray br. f-c gravel, some f-c sand, tr. silt (GP-GM)(FILL)	7–8	S4	SS		3 19 76 65	95	
			S5: Olive gray f-m-c sand, some f-c gravel, little silt (SM)(FILL)	9–10	S5	SS		76 100/6"	R	
			S6: Dk. gray/blk. f-m sand, some silt, little f gravel, occ. metal, occ. roots (SM)(FILL)	15–16	S6	SS		38 100/3"	R	
			S7: Dk. gray/blk. f sand, and clayey silt, occ wood/twigs (SM)(FILL)	20–21	S7	SS		39 38 28 30	66	
10.5	G		S8: Gray br. f-c gravel, some f-c sand, tr. silt (GP-GM)	25–26	S8	SS		4 29 55 48	84	

PS&S
integrating design & engineering

Log of Boring: PSS-5

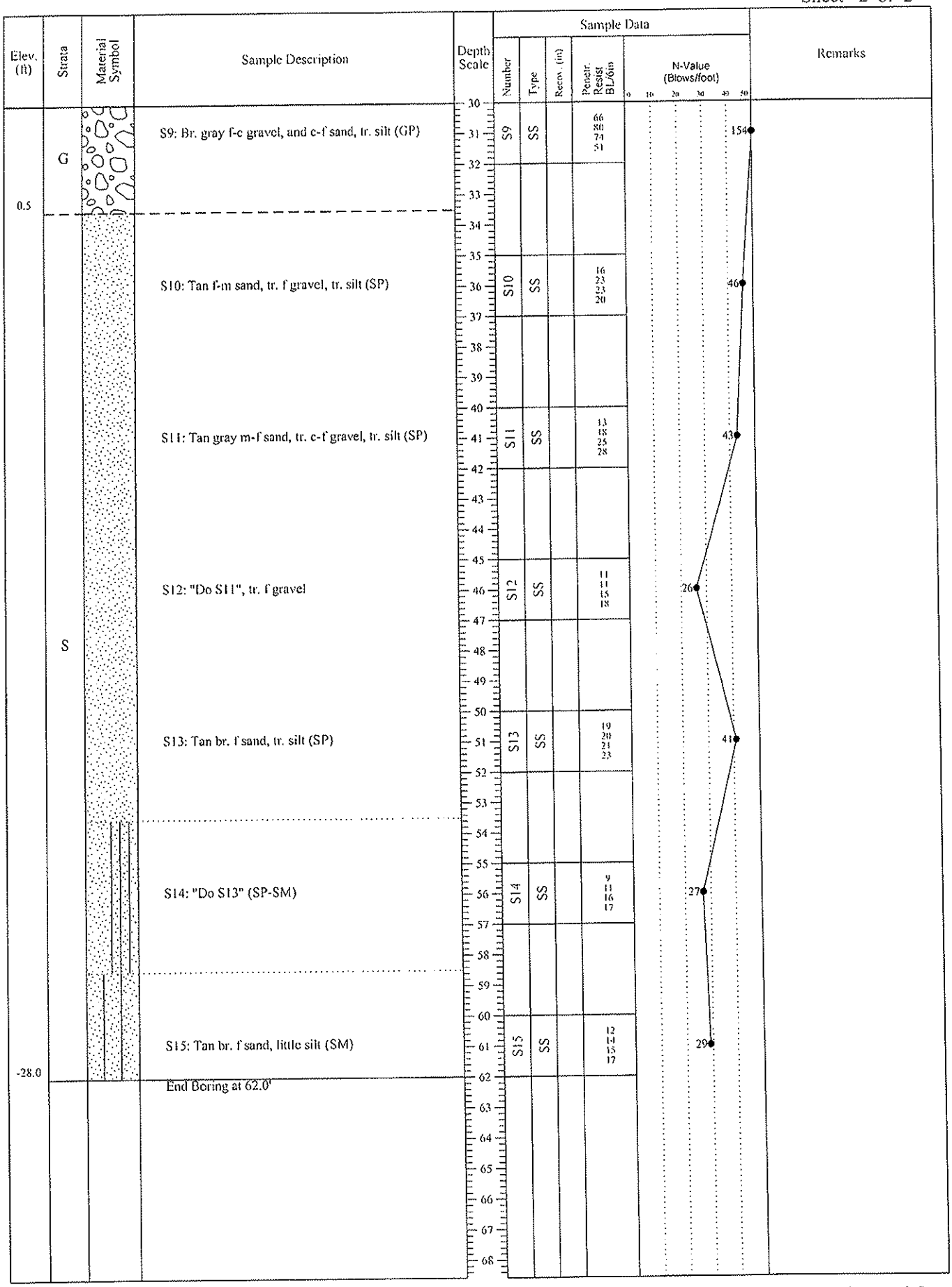


Plate: 3.5

PS&S
integrating design & engineering

Log of Boring: PSS-6

Project: Ansonia/Derby Levee	Project Number: 04019-0001	Elevation (ft): 34.0	Datum: Site Datum
Location: Ansonia, Connecticut	Logged By: J. Knittel	Date Started: 8/5/2010	Date Completed: 8/5/2010
Drilling Contractor: CMI Subsurface Investigations, Inc.		Drilling Foreman: John Imparato	Completion Depth (ft): 62.0
Sampler: 2" O.D. Split Spoon		Casing Diameter (in): 4	Casing Depth (ft): 40
Drilling Equipment: 3 7/8" Tricone Roller Bit		Sampler Hammer: Donut	Weight (lbs): 140 / Drop (in): 30
Drilling Rig: Mobile B-61	Drilling Mud: Water	Water Level (ft) First: 30.06	Completion: ▼ / 24 HR: 30.11

Elev. (ft)	Strata	Material Symbol	Sample Description	Depth Scale	Sample Data: Number	Type	Recov. (in)	Penetr. Resist BL/6in	N-Value (Blows/foot)	Remarks
				0						3" asphalt over 7" gravel base
	F		S1: Olive gray br. f-m sand, and clayey silt, little f-c gravel (SM)(FILL)	2	S1	SS		12 11 6 10	17	
			S2: Olive gray clayey silt & f-m sand, tr./little f gravel (ML)/(SM)(FILL)	4	S2	SS		12 6 3 7	9	
			S3: Gray clayey silt, some f sand, tr. f gravel (ML)(FILL)	6	S3	SS		7 9 4 10	13	
			S4: Tan br. f-m sand, some f-c gravel, tr. silt (SP-SM)(FILL)	8	S4	SS		16 19 39 60	58	
			S5: Tan br. m-f sand, some c-f gravel, tr. silt (SP)(FILL)	10	S5	SS		22 40 43 50	83	
			S6: Dk. gray c gravel (GP)(FILL)	15	S6	SS		45 100/5"	R	S6: Low recovery, gravel lodged in spoon tip
			S7: Dk. gray br. f-m sand, little f gravel, tr. silt, occ. roots & decaying organic matter (SM)(FILL)	19	S7	SS		75 100/3"	R	
			S8: Tan br. f sand, little silt (SM)(FILL)	24	S8	SS		19 14 28 56	42	
7.5				26						Heavy chatter at 27'
	G		S9: Br. gray c-f gravel & f-c sand, tr. silt (GP)/(SP)	29	S9	SS		44 50/2"	R	

Plate: 3.6

PS&S
integrating design & engineering

Log of Boring: PSS-6

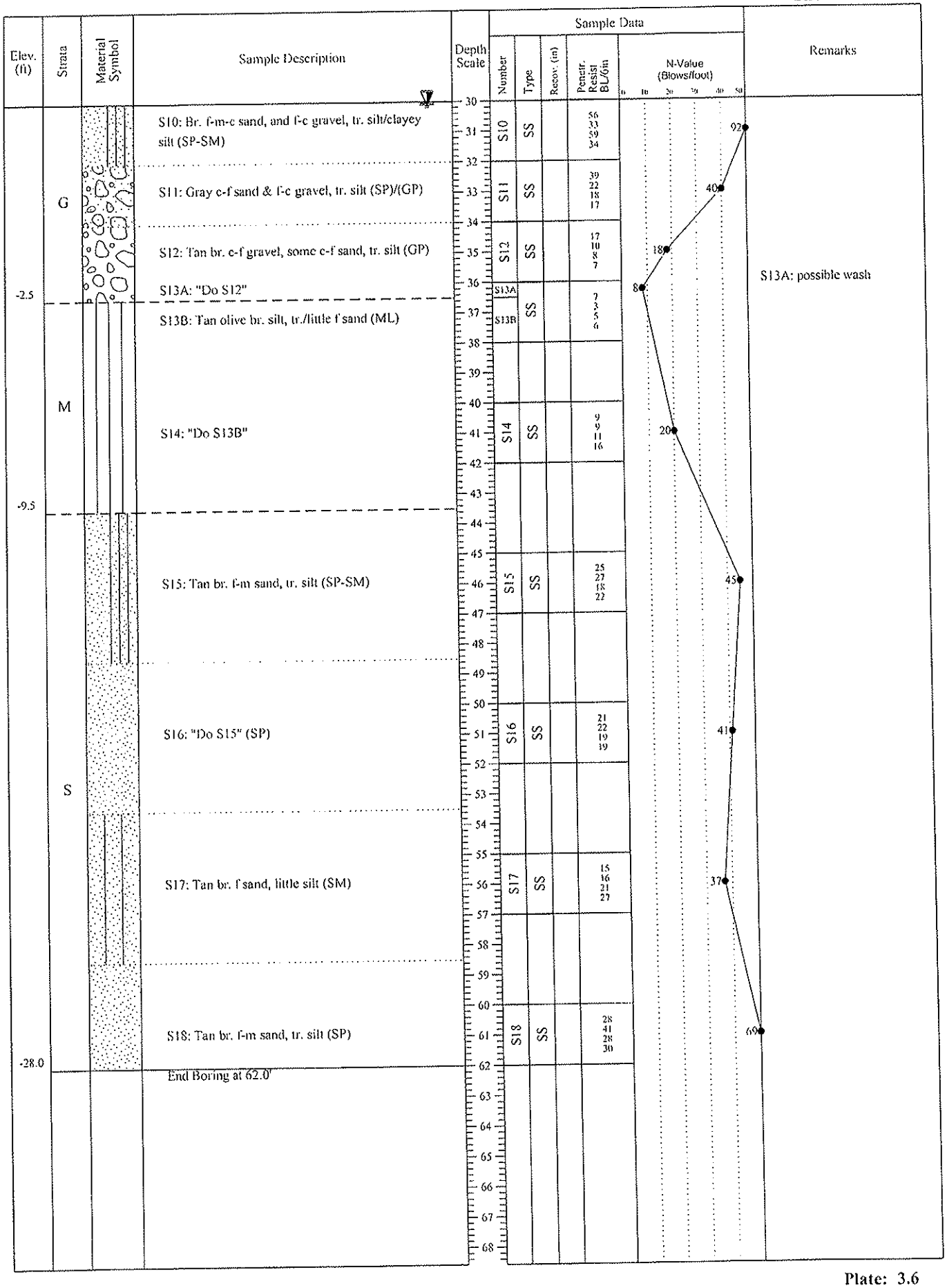


Plate: 3.6

PS&S
integrating design & engineering

Log of Boring: PSS-7

Project: Ansonia/Derby Levee	Project Number: 04019-0001	Elevation (ft): 25.0	Datum: Site Datum
Location: Ansonia, Connecticut	Logged By: J. Knittel	Date Started: 8/12/2010	Date Completed: 8/13/2010
Drilling Contractor: CMI Subsurface Investigations, Inc.		Drilling Foreman: John Imparato	Completion Depth (ft): 51.0
Sampler: 2" O.D. Split Spoon		Casing Diameter (in): 4	Casing Depth (ft): 44
Drilling Equipment: 3 7/8" Tricone Roller Bit		Sampler Hammer: Donut / Weight (lbs): 140	Drop (in): 30
Drilling Rig: Mobile B-61	Drilling Mud: Quick Gel	Water Level (ft) — First: ▽	Completion: ▼ / 24 HR: ▽

Elev. (ft)	Strata	Material Symbol	Sample Description	Depth Scale	Sample Data: Number	Type	Recov. (in)	Penetr. Resist BL/6in	N-Value (Blows/foot)	Remarks
	F		S1: Gray m-f sand, tr.silt (SP)	0–2	S1	SS		5 9 6 5	15	3" asphalt over 7" gravel base S1: low recovery - possible wash
			S2: Dk. br. gray f sand, some silt, num. wood frags (SM)(FILL)	2–4	S2	SS		5 3 8 21	11	S2: 2" asphalt at 4.5'
			S3: Tan m-f sand, tr. f gravel, tr. silt (SP)(FILL)	4–6	S3	SS		19 23 28 20	49	
			S4: Tan f-m sand, tr. silt (SP)(FILL)	6–8	S4	SS		8 11 15 21	26	
			S5: "Do S4", tr. f gravel	8–10	S5	SS		7 5 6 5	11	
			S6: Br. gray f-c sand, some f gravel, tr. silt (SP)(FILL)	10–16	S6	SS		10 8 100/5"	R	
8.0	BLD		Boulder	16–18						Boulder at 17'-18.5'
6.5	S		S7: Tan f-m sand, tr. f gravel, tr. silt	18–22	S7	SS		14 13 10 16	23	
1.5	G		S8: Gray br. f-c gravel & f-c sand, tr. silt (GP)/(SP)	22–26	S8	SS		16 18 20 23	38	
				26–30						

Plate: 3.7

PS&S
integrating design & engineering

Log of Boring: PSS-7

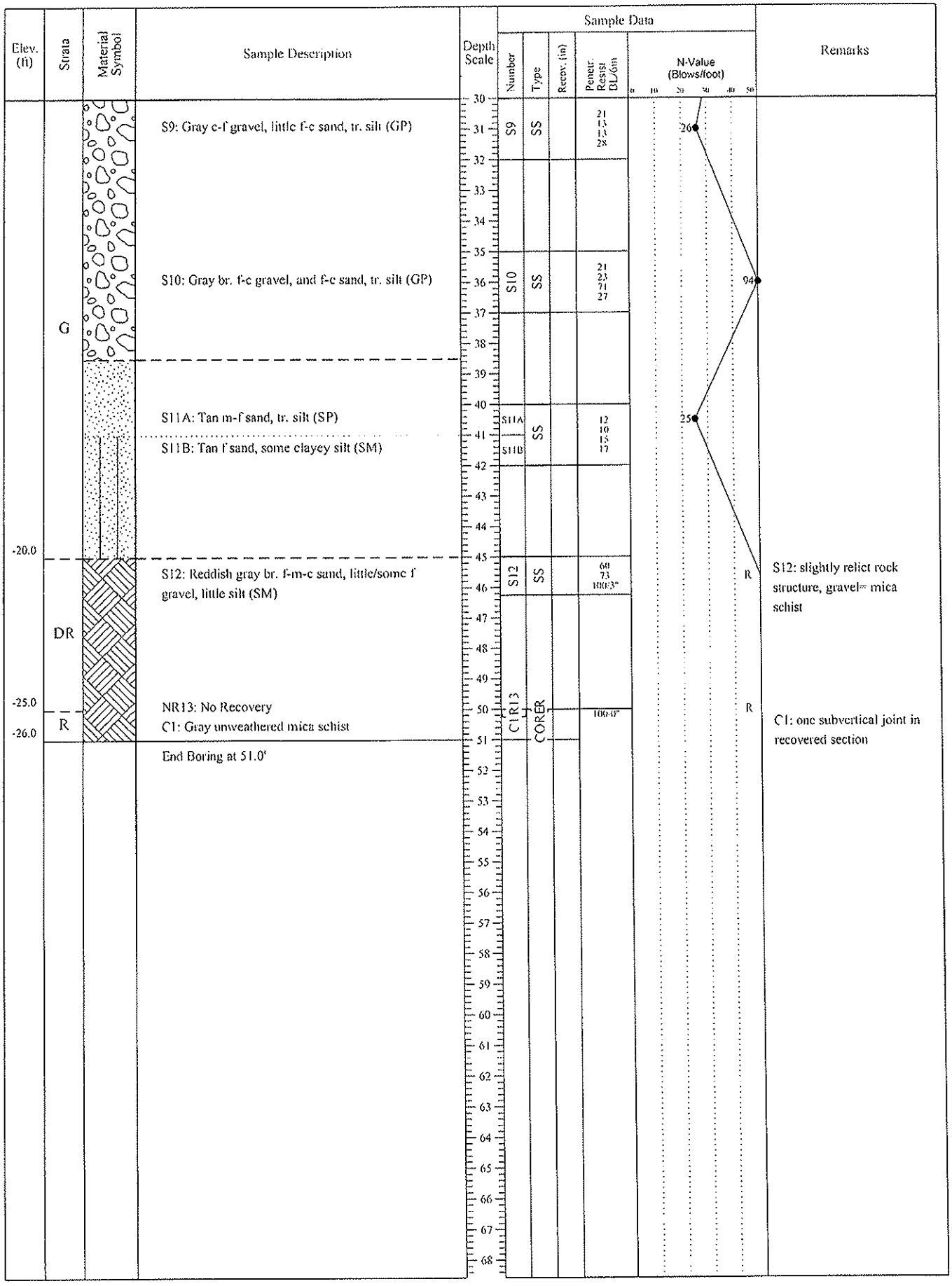


Plate: 3.7

PS&S
integrating design & engineering

Log of Boring: PSS-8

Project: Ansonia/Derby Levee	Project Number: 04019-0001	Elevation (ft): 34.0	Datum: Site Datum
Location: Ansonia, Connecticut	Logged By: J. Knittel	Date Started: 8/10/2010	Date Completed: 8/11/2010
Drilling Contractor: CMI Subsurface Investigations, Inc.		Drilling Foreman: John Imparato	Completion Depth (ft): 62.0
Sampler: 2" O.D. Split Spoon		Casing Diameter (in): 4	Casing Depth (ft): 42
Drilling Equipment: 3 7/8" Tricone Roller Bit		Sampler Hammer: Donut	Weight (lbs): 140 / Drop (in): 30
Drilling Rig: Mobile B-61	Drilling Mud: None	Water Level (ft) First: ▽ 30.11	Completion: ▼ / 24 HR: ▼ 32.94

Elev. (ft)	Strata	Material Symbol	Sample Description	Depth Scale	Sample Data: Number	Type	Recov. (in)	Penetr. Resist BL/6in	N-Value (Blows/foot)	Remarks
				0						3" asphalt over 7" gravel base
			S1: Olive gray f sand, and silt, tr. f gravel (SM)(FILL)	2	S1	SS		51 54 52 78	106	
			S2: Olive gray f-m sand, and silt, some f-c gravel (SM)(FILL)	3	S2	SS		32 100/5"	R	
			S3: Gray br. f-c gravel, and f-c sand, tr. clayey silt (GP-GM)(FILL)	5	S3	SS		100/1"	R	
			S4: Olive gray clayey silt, and f sand, tr. f gravel (ML)(FILL)	7	S4	SS		40 100/3"	R	
			S5: Olive gray br. f-m sand, and clayey silt, some c-f gravel (SM)(FILL)	9	S5	SS		75 100/6"	R	
	F			15						
			S6: Olive gray br. f-m sand, and clayey silt, some f-c gravel (SM)(FILL)	16	S6	SS		50 50 58 56	108	
			S7: Olive tan gray f sand, and silt, tr. f gravel (SM)(FILL)	21	S7	SS		24 34 58 77	92	
			S8: Tan br. f-m sand, some f gravel, little/some silt, occ. roots (SM)(FILL)	25	S8	SS		60 100/4"	R	
5.5	S/G			30						

Plate: 3.8

PS&S
integrating design & engineering

Log of Boring: PSS-8

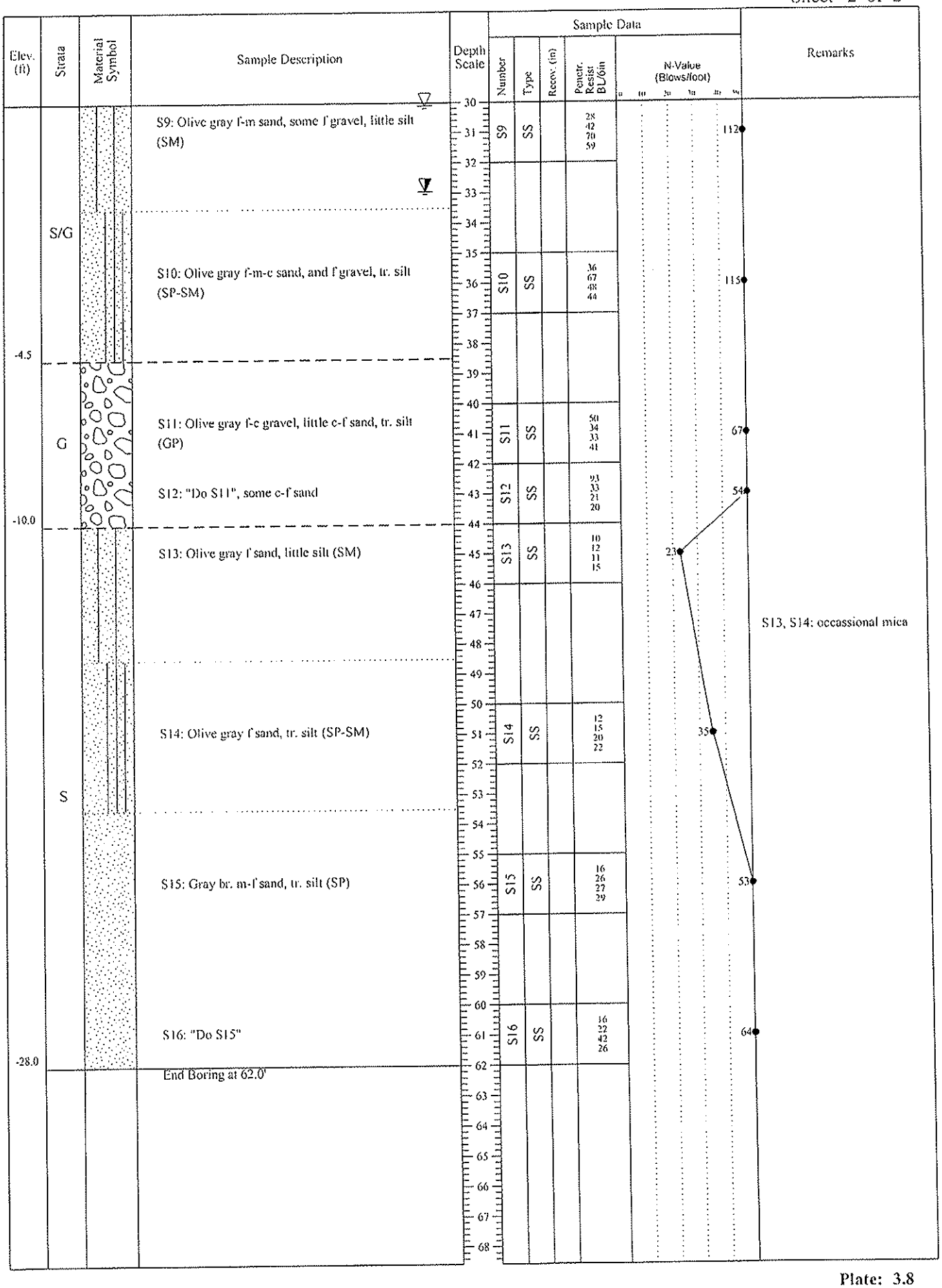


Plate: 3.8

PS&S
integrating design & engineering

Log of Boring: PSS-9

Project: Ansonia/Derby Levee	Project Number: 04019-0001	Elevation (ft): 31.5	Datum: Site Datum
Location: Ansonia, Connecticut	Logged By: J. Knittel	Date Started: 8/9/2010	Date Completed: 8/10/2010
Drilling Contractor: CMI Subsurface Investigations, Inc.		Drilling Foreman: John Imparato	Completion Depth (ft): 62.0
Sampler: 2" O.D. Split Spoon		Casing Diameter (in): 4	Casing Depth (ft): 50
Drilling Equipment: 3 7/8" Tricone Roller Bit		Sampler Hammer: Donut	Weight (lbs): 140 / Drop (in): 30
Drilling Rig: Mobile B-61	Drilling Mud: Quick Gel	Water Level (ft)	First: ▽ / Completion: ▼ / 24 HR: ▼

Elev. (ft)	Strata	Material Symbol	Sample Description	Depth Scale	Sample Data: Number	Type	Recov. (in)	Penetr. Resist BL/6in	N-Value (Blows/foot)	Remarks
				0						3" asphalt over 7" gravel base
			S1: Tan f-m sand, and c-f gravel, little silt (SM)(FILL)	2	S1	SS		27 29 31 23	60	
			S2: Olive tan gray f-m sand, and silt, tr./little f gravel (SM)(FILL)	4	S2	SS		42 34 41 40	75	
			S3: Olive gray f-m sand & clayey silt, tr. f gravel (SM)/(ML)(FILL)	6	S3	SS		22 22 21 19	43	
			S4: Gray clayey silt, and f-m sand, tr. f gravel (ML)(FILL)	8	S4	SS		30 100/6"	R	
			S5: Olive gray f-m sand & clayey silt, tr. f gravel (SM)/(ML)(FILL)	10	S5	SS		19 25 20 16	45	
	F			12						
			S6: Olive gray f-m sand, and clayey silt, tr. f gravel (SM)(FILL)	16	S6	SS		38 50 44 30	94	
			S7: Dk. br. f-m sand, little/some silt, little f gravel (SM)(FILL)	20	S7	SS		18 18 16 16	34	
			S8: Dk. br. f-m sand, some/and silt, tr. f gravel (SM)(FILL)	26	S8	SS		22 13 11 18	24	S8: low recovery
3.0	S			30						

N-Value (Blows/foot) scale: 0, 10, 20, 30, 40, 50

Plate: 3.9

PS&S
integrating design & engineering

Log of Boring: PSS-9

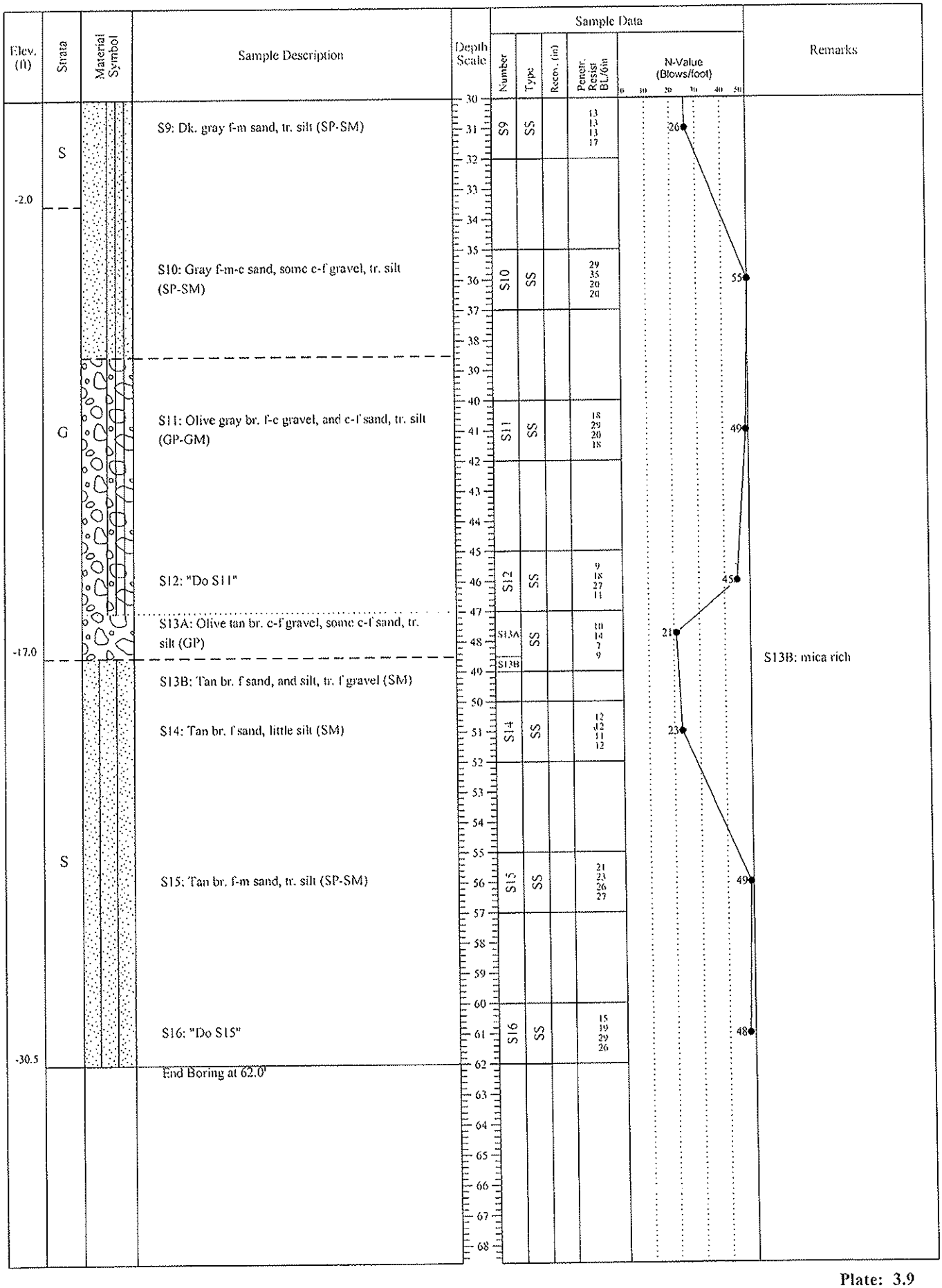


Plate: 3.9

PS&S
integrating design & engineering

Log of Boring: PSS-10

Project: Ansonia/Derby Levee	Project Number: 04019-0001	Elevation (ft): 34.0	Datum: Site Datum
Location: Ansonia, Connecticut	Logged By: J. Knittel	Date Started: 8/23/2010	Date Completed: 8/24/2010
Drilling Contractor: CMI Subsurface Investigations, Inc.		Drilling Foreman: John Imparato	Completion Depth (ft): 47.0
Sampler: 2" O.D. Split Spoon		Casing Diameter (in): 4	Casing Depth (ft): 45
Drilling Equipment: 3 7/8" Tricone Roller Bit		Sampler Hammer: Donut / Weight (lbs): 140	Drop (in): 30
Drilling Rig: Mobile B-61	Drilling Mud: Quick Gel	Water Level (ft) First: ▽	Completion: ▼ / 24 HR: ▼

Elev. (ft)	Strata	Material Symbol	Sample Description	Depth Scale	Sample Data: Number	Type	Recov. (in)	Penetr. Resist BL/6in	N-Value (Blows/foot)	Remarks
33.7	ASP			0						
			S1: Olive br. f-m sand, and clayey silt, tr. f gravel (SM)(FILL)	1–2	S1	SS		14 34 17 26		51
			S2: Tan f-m sand, some f-c gravel, little silt (SM)(FILL)	3–4	S2	SS		51 42 36 31		78
			S3: Gray f-m sand, and clayey silt, little f-c gravel (SM)(FILL)	7–8	S3	SS		31 38 65 22		103
			S4: Br. gray 'DO S3'	9–10	S4	SS		47 28 32 40		60
	F		S5: Olive gray clayey silt & f sand, tr. f gravel (ML)/(SM)(FILL)	15–16	S5	SS		28 35 36 26		71
			S6: Dk. gray/blk. f-m sand, some f-c gravel, some silt, occ. pieces of organic matter (SM)(FILL)	20–21	S6	SS		67 60 66 71		126
			S7: Dk. gray f-m sand, some silt, little/some f gravel, occ. coal frags (SM)(FILL)	25–26	S7	SS		18 20 35 63		55
5.5	G			30						

Plate: 3.10

PS&S
integrating design & engineering

Log of Boring: PSS-10

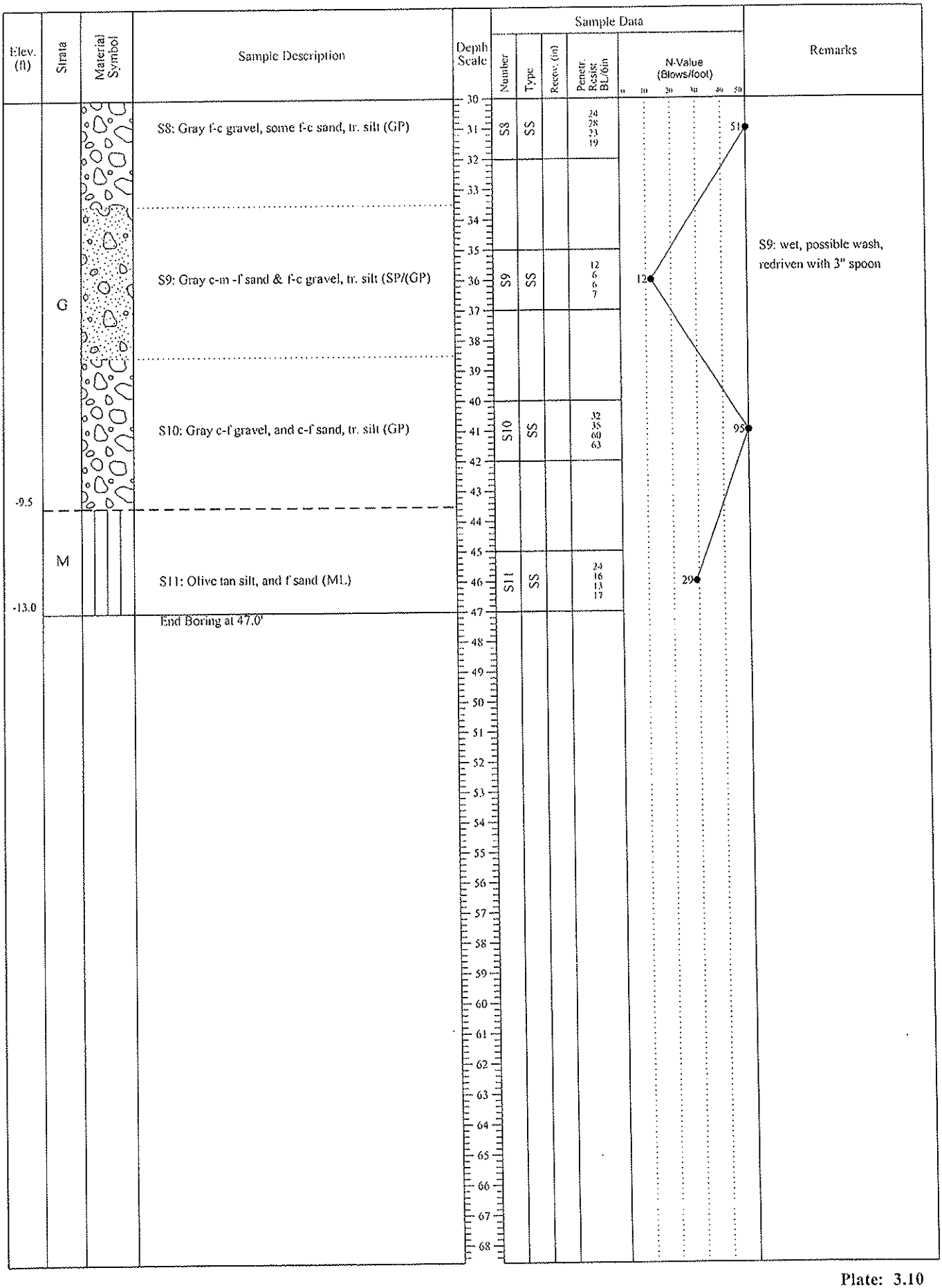


Plate: 3.10

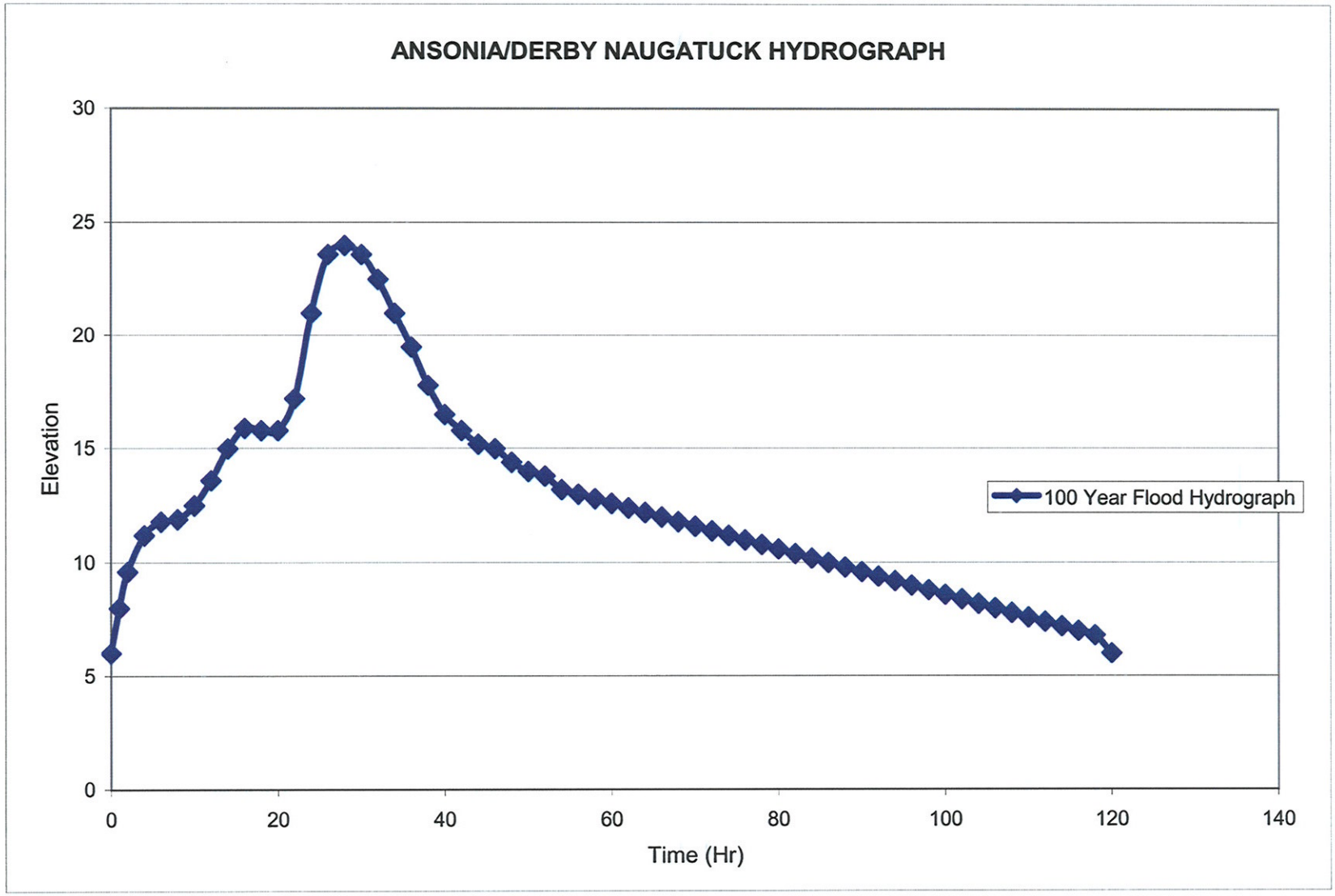

ANSONIA/DERBY NAUGATUCK HYDROGRAPH
30
25
20
15
10
5
0
Elevation
0
20
40
60
80
100
120
140
Time (Hr)
100 Year Flood Hydrograph

Plate 4.1

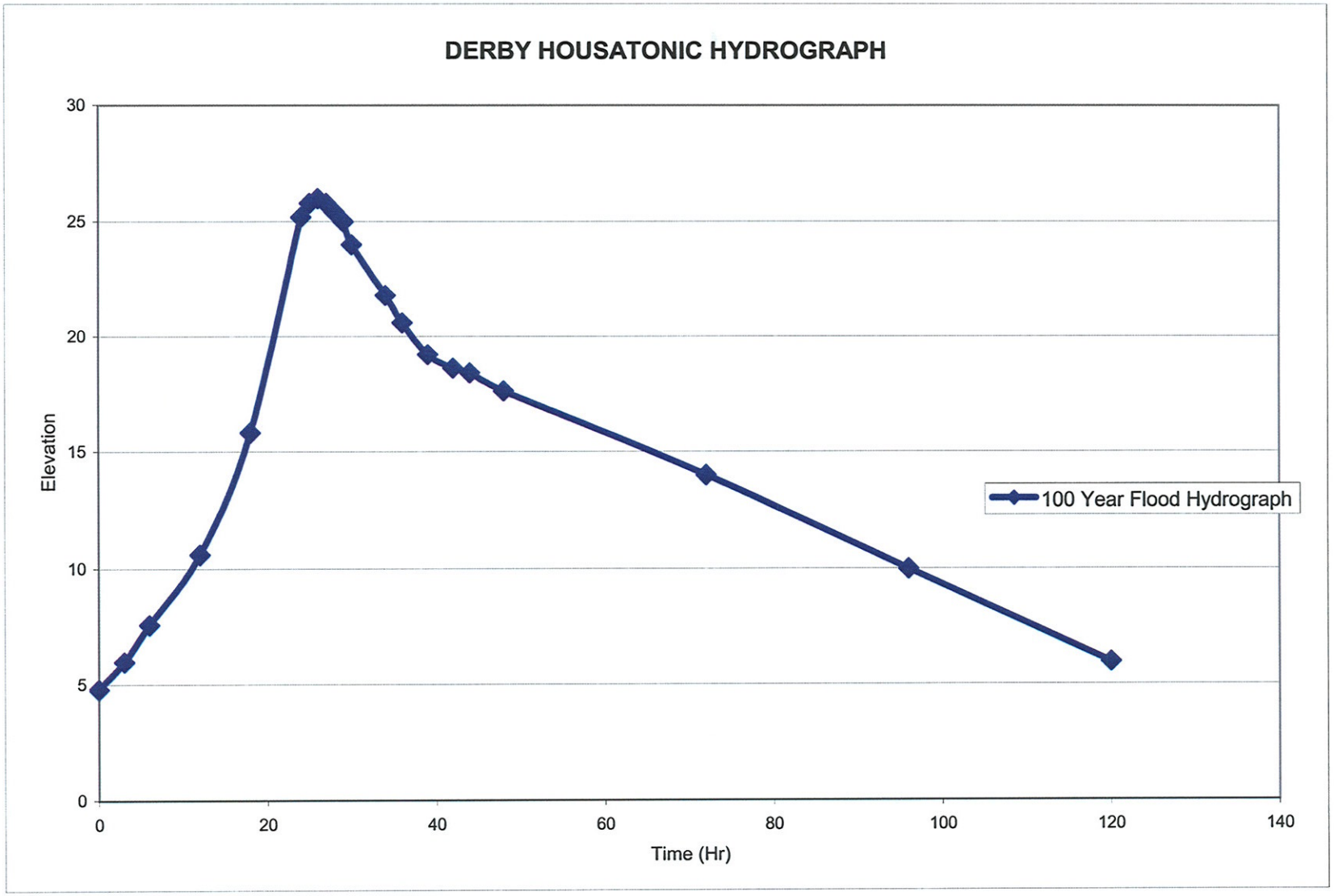

DERBY HOUSATONIC HYDROGRAPH
Elevation
30
25
20
15
10
5
0
0
20
40
60
80
100
120
140
Time (Hr)
100 Year Flood Hydrograph

Plate 4.2