CPV Towantic, LLC
Docket No. 192B

Interrogatories CSC-2
Dated: 1/26/15
Q-CSC-1

Witness: Andrew J. Bazinet

Question CSC-1:

Referencing Late Filed Exhibit 2c, from the photographs, it appears that the sign was placed on Woodruff Hill Road, just slightly north of the driveway to the Spectra Energy Compressor Station. Is that correct?

Response:

Yes, the sign was placed just north of the Spectra access road on the eastern side of Woodruff Hill Road.

Witness: **Jon Donovan**

Question CSC-2:

Referencing Late Filed Exhibit 2d, which ambient temperatures are the summer and winter efficiencies based on? What does "Average" indicate, e.g. based on the average temperature? Explain what LHV and HHV stand for.

Response:

The summer and winter efficiencies referenced in Late Filed Exhibit 2d filed on January 22, 2015 are based on 90°F and 20°F, respectively. The "average" column indicates the efficiency at average ambient temperature conditions; for this case, 59°F was used.

HHV stands for Higher Heating Value and LHV stands for Lower Heating Value. Whenever a hydrocarbon fuel is burned, one product of combustion is water. Due to high combustion temperatures, this water takes the form of steam which stores a small fraction of the energy released during combustion as the latent heat of vaporization. The total amount of heat liberated during the combustion of a unit of fuel is the HHV, which includes the latent heat stored in the vaporized water. The LHV is the amount of heat available from a fuel after the latent heat of vaporization is deducted from the HHV.

Witness: Lynn Gresock

Question CSC-3:

Referencing Late Filed Exhibit 2e, would the 2-mile radius visibility area be closer to 8,042 acres than 8,109 acres?

Response:

An area of 8,042 acres refers to that of a perfect circle having a 2-mile radius around a single point, while the identified 8,109 acres reflects the area encompassed in a 2-mile radius around each of the stacks. Although most of the area associated with each stack overlaps, this creates an irregular shape having the area noted.

Witness: Jon Donovan

Question CSC-4:

Would the air cooled condenser fans be staged according to demand so that the minimum required number of fans would be on at a given time (and more would turn on as needed) to minimize noise and power consumption?

Response:

Yes. As is standard power plant operating practice, the air cooled condenser (ACC) fans will be staged according to demand. At lower Facility output, fans will be turned off. Doing so results in the most efficient plant operation and also minimizes noise.

Witness: Dean Gustafson

Question CSC-5:

Where is the nearest Important Bird Area?

Response:

The National Audubon Society has identified 27 Important Bird Areas ("IBAs") in the State of Connecticut. IBAs are sites that provide essential habitat for breeding, wintering, and/or migrating birds. The IBA must support species of conservation concern, restricted-range species, species vulnerable due to concentration in one general habitat type or biome, or species vulnerable due to their occurrence at high densities as a result of their congregatory behavior.[1] The closest IBA to the subject property is the Naugatuck State Forest in Naugatuck, Oxford, and Beacon Falls located approximately 1.65 miles to the southeast. Please refer to the attached Important Bird Area Map. Naugatuck State Forest Preserve is a 3,542 acre forest with a mixture of habitat types ranging from conifer/deciduous forests to various streams, rivers, ponds, and lakes. The area is known as a particularly important area for bird species that require early successional habitats.

The open field that occupies the southwest corner of the subject property is approximately 8 acres. Open fields that could support critical habitat for grassland bird species are categorized in two groups: small grasslands are 10 to 75 acres in size and large grasslands are more than 75 contiguous acres.[2] Therefore, due to the distance of the Naugatuck State Forest Preserve from the subject property and the fact the subject property's open field is of insufficient size to support grassland bird species habitat, the Naugatuck State Forest Preserve IBA would not experience an adverse impact resulting from the proposed development of the Facility. The conclusion that the subject property's open field does not support significant grassland bird habitat is further supported by the CTDEEP Natural Diversity Data Base response letter of June 10, 2014 which did not identify any grassland bird species as being located in the vicinity of the subject property. Many of Connecticut's grassland bird species are identified as State-listed rare species (e.g., grasshopper sparrow [*Ammodramus savannarum*], State Endangered; bobolink [*Dolichonyx oryzivorus*], State

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[1] http://web4.audubon.org/bird/iba/iba_intro.html
[2] Rothbart, Paul and Steve Capel. 2006. **Maintaining and Restoring Grasslands (Chapter 3)** in *Managing Grasslands, Shrublands and Young Forests for Wildlife.* J.D. Oehler, D.R. Covell, S. Capel, B. Long (editors). Published by the Northeast Upland Habitat Technical Committee, Massachusetts Division of Fisheries & Wildlife. (p.14 – 27)

Special Concern; savannah sparrow [*Passerculus sandwichensis*], State Special Concern; eastern meadowlark [*Sturnella magna*], State Special Concern, etc.).

Witness: **Dean Gustafson**

Question CSC-6:

In reference to Tetra Tech, Inc. Environmental Overview in support of Petition for Changed Conditions (Exhibit 1), Tab F, the Department of Energy and Environmental Protection (DEEP) provided a response to a Natural Diversity Database request that identifies three bat species and one turtle species as "species of special concern." Will CPV Towantic, LLC (CPV Towantic) comply with DEEP's recommendations, particularly that work should not be done between May 1 and August 15 for bats and that sedimentation/erosion controls be installed in a staggered configuration for wildlife and reptiles traveling between habitats and that such products which embedded netting not be used? Will CPV Towantic be able to retain large diameter trees for bats to minimize long term impacts? If CPV Towantic is not able to comply with DEEP's recommendations, describe other alternative mitigation measures that would address DEEP's concerns.

Response:

An extension of time to respond to this interrogatory has been requested.

Witness: **Dean Gustafson**

Question CSC-7:

Is it correct that the Invasive Species Control Plan only covers the construction period, per Application A-22 through A-24? Would the Certificate Holder be amenable to a monitoring period up to three years following completion of construction?

Response:

The intent of the Invasive Species Control Plan referenced on pages A-22 through A-24 of the U.S. Army Corps of Engineers Category 2 Permit Application, dated October 2014, (Applicant Exhibit 1, Appendix C) is for it to be implemented only during the construction period. The Certificate Holder would be willing to implement this Invasive Species Control Plan for three years following completion of construction with the following success standards: (1) Management of invasive species will only focus on the target invasive plant species identified in the referenced Invasive Species Control Plan; and (2) Remedial action will occur to control target invasive plant species if they are found to encompass more than 10 percent total aerial coverage. Annual monitoring reports that would include an evaluation of these success standards and any remedial action would be submitted to the Connecticut Siting Council no later than December 31 of each year.

Witness: Lynn Gresock
Dean Gustafson

Question CSC-8:

Provide the specifications for the proposed Federal Aviation Administration (FAA) lighting for the stacks. How would the proposed FAA stack lighting scheme affect birds?

Response:

FAA review for the Facility's current configuration is ongoing, and no determination regarding stack lighting has yet been made. However, it is anticipated that lighting requirements will be similar to those imposed on the Facility in the most recent FAA Determination of No Hazard for the two 150-foot stacks (which expired in 2011). Stack lighting will be beneficial not only for the Facility, but for the existing penetrations to the VFR Horizontal Surface that exist in the vicinity (which are not lighted or marked).

As reflected in the D&M Plan submitted to the Council in 2000, stack lighting is anticipated to include dual lighting, with medium intensity flashing red lights (L-864) for nighttime operation and medium intensity flashing white lights (L-865) for daytime and twilight operation. Lights would be installed in accordance with U.S. Department of Transportation, FAA, Advisory Circular AC No. 70/7460-1 K, dated 2-1-07. Lights would be installed on three sides of each stack, with the side facing the other stack without a light. One level of dual lights will be installed within 20 feet of the stack tips in accordance with the above Circular requirements. A copy of Circular AC No. 70/7460-1K, Chapter 8 — Dual Lighting with Red/Medium Intensity Flashing White Systems, is attached.

The dual lighting system proposed for each stack achieves bird-friendly benefits in accordance with USFWS' recommendations and FAA's guidance.[3] The Facility is not proposing use of non-flashing/steady-burning red lights (e.g., L-810s), which have been documented to be associated with avian fatalities at towers. Therefore, the proposed stack dual lighting system would not have an adverse effect on birds.

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[3] Patterson, J.W., Jr. Evaluation of New Obstruction Lighting Techniques to Reduce Avian Fatalities. Federal Aviation Administration Technical Note DOT/FAA/TC-TN12/9. May 2012.

CHAPTER 8. DUAL LIGHTING WITH RED/MEDIUM INTENSITY FLASHING WHITE SYSTEMS

80. PURPOSE

This dual lighting system includes red lights (L-864) for nighttime and medium intensity flashing white lights (L-865) for daytime and twilight use. This lighting system may be used in lieu of operating a medium intensity flashing white lighting system at night. There may be some populated areas where the use of medium intensity at night may cause significant environmental concerns. The use of the dual lighting system should reduce/mitigate those concerns. Recommendations on lighting structures can vary depending on terrain features, weather patterns, geographic location, and in the case of wind turbines, number of structutes and overall layout of design.

81. INSTALLATION

The light units should be installed as specified in the appropriate portions of Chapters 4, 5, and 6. The number of light levels needed may be obtained from Appendix 1.

82. OPERATION

Lighting systems should be operated as specified in Chapter 3. Both systems should not be operated at the same time; however, there should be no more than a 2-second delay when changing from one system to the other. Outage of one of two lamps in the uppermost red beacon (L-864 incandescent unit) or outage of any uppermost red light shall cause the white obstruction light system to operate in its specified ”night” step intensity.

83. CONTROL DEVICE

The light system is controlled by a device that changes the system when the ambient light changes. The system should automatically change steps when

the northern sky illumination in the Northern Hemisphere on a vertical surface is as follows:

a. ***Twilight-to-Night***. This should not occur before the illumination drops below 5 foot-candles (53.8 lux) but should occur before it drops below 2 foot-candles (21.5 lux).

b. ***Night-to-Day***. The intensity changes listed in subparagraph 83 a above should be reversed when changing from the night to day mode.

84. ANTENNA OR SIMILAR APPURTENANCE LIGHT

When a structure utilizing this dual lighting system is topped with an antenna or similar appurtenance exceeding 40 feet (12m) in height, a medium intensity flashing white (L-865) and a red flashing beacon (L-864) should be placed within 40 feet (12m) from the tip of the appurtenance. The white light should operate during daytime and twilight and the red light during nighttime. These lights should flash simultaneously with the rest of the lighting system.

85. OMISSION OF MARKING

When medium intensity white lights are operated on structures 500 feet (153m) AGL or less during daytime and twilight, other methods of marking may be omitted.

Witness: **Fred Sellars**
Dean Gustafson

Question CSC-9:

Would the stacks themselves adversely affect birds such as allowing collisions or landing on a hot surface?

Response:

The stack top and sides of the stack, while hot during operation, do not represent attractive perching sites. The stack test platforms and associated ladders, however, are more suitable perching locations. These features safely support stack testers during plant operation and would not represent surfaces too hot for bird perching.

The majority of studies on bird mortality due to towers focuses on very tall towers (greater than 1000 feet), illuminated with non-flashing lights, and guyed. These types of towers, particularly if sited in major migratory pathways, can result in significant bird mortality (Manville, 2005).[4] More recent studies of short communication towers (<300 feet), which would be comparable to the two proposed 150-foot stacks, reveal that they rarely kill migratory birds.[5] Studies of mean flight altitude of migrating birds reveal flight altitudes of 410 meters (1350 feet), with flight altitudes on nights with bad weather between 200 and 300 meters above ground level (656 to 984 feet).[6] As discussed in the response to Q-CSC-8, the proposed stack lighting scheme follows USFWS recommendations for a bird-friendly design that would minimize possible bird collisions. With this bird-friendly lighting scheme and the relatively short stack heights (150 feet), which are unguyed, no adverse impact to migrating bird species is anticipated by the proposed Facility.

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[4] Manville, A.M. II. 2005. Bird strikes and electrocutions at power lines, communications towers, and wind turbines: state of the art and state of the science - next steps toward mitigation. Bird Conservation Implementation in the Americas: Proceedings 3rd International Partners in Flight Conference 2002. C.J. Ralph and T.D. Rich, editors. USDA Forest Service General Technical Report PSW-GTR-191. Pacific Southwest Research Station, Albany CA. pp. 1-51-1064.
[5] Kerlinger, P. 2000. Avian Mortality at Communication Towers: A Review of Recent Literature, Research, and Methodology. Prepared for U.S. Fish and Wildlife Service Office of Migratory Bird Management.
[6] Mabee, T.J., B.A. Cooper, J.H. Plissner, D.P. Young. 2006. Nocturnal bird migration over an Appalachian ridge at a proposed wind power project. Wildlife Society Bulletin 34:682-690.

Witness: **Lynn Gresock**
Fred Sellars

Question CSC-10:

Has CPV Towantic modeled the plume expected to emanate from the stacks? If so, provide copies of such model/analysis.

Response:

CPV Towantic has completed dispersion modeling of the exhaust that will emanate from each stack, and has provided the results of this modeling analysis in Attachment L of the Permit Application for Stationary Sources of Air Pollution/New Source Review (air permit application). The air permit application is contained in CPV Towantic's Response to Q-Middlebury-9.

CPV Towantic has not completed turbulence modeling of the plume expected to emanate from the stacks, although it has spent substantial time reviewing the various prior modeling reports and models currently available. The previous models, in particular the most recent MITRE report assessing the Towantic Facility (2012 – provided as an attachment to Raymond Pietrorazio's January 7, 2015 Pre-Hearing Submittal), focus on probabilities and concluded that aircraft upset conditions were not reached in association with the Facility. Specifically, on page 7-7, the MITRE Report stated "*By executing the Houbolt roll model over the three years of environmental data, it was determined that aircraft upset criteria were never reached at this proposed power plant*." An elevated risk to helicopters was identified, but only within 180 feet of the top of the stacks. This modeling was completed with input assumptions that would be expected to continue to reflect a conservative assessment for the Facility. A comparison of input parameters for the Facility as assessed in the 2012 MITRE report to the current configuration is provided in the following table.

Input	2012 MITRE Model	Current Project
Stack Height	150 feet	150 feet
Stack Separation	130 feet	138 feet
Stack Diameter	18.5 feet	22 feet
Exhaust Exit Velocity	58.4 feet/second	56.2 feet/second
Exhaust Exit Temperature	201°F	183.29°F

CPV Towantic is in the process of working with the most current MITRE model (2014) to calculate plume turbulence for the updated Facility configuration using the most recent FAA-recommended model. However, in preliminary use, we have brought to MITRE's attention a software defect that inaccurately handled temperature values. MITRE is currently correcting this defect; once the corrected software is provided, we will complete the model and provide the resulting information.

Witness: **Lynn Gresock**
Fred Sellars

Question CSC-11:

What is the exit velocity from the stack at full load at the top of the stack, 250 feet above the stack, and 500 feet above the stack assuming still air conditions? How much does increasing wind velocity affect this?

Response:

As discussed in the Response to Q-CSC-10, the exit velocity at full load at the top of the stack is 58.4 feet per second. Velocities would decrease substantially with height. As the velocity of the existing air (wind) into which the stack exhaust is being released increases, stack exhaust velocity would decrease more quickly.

Because the current MITRE modeling is not completed and no longer provides this type of output, Tetra Tech has utilized the spreadsheet plume rise model reflected in guidance from the Australian Government Civil Aviation Safety Authority (CASA) in 2004 (Advisory Circular 139-05(0)) to derive the dissipation of velocity associated with the stack exhaust. This indicates that the stack exit velocity of 56.2 feet per second (about 38 mph) reduces to 19.13 feet per second (about 13 mph) within 250 feet of the stack, and further reduces to 14.01 feet per second (about 9.5 mph) at a distance of 500 feet.

In addition, the 2012 MITRE report (which reflected stack parameters that would be expected to show greater plume lengths than the proposed Facility) presented probabilities for various plume lengths associated with the Facility. Under stable conditions (that is, calm ambient wind conditions which would produce the longest plumes) for the lightest weight aircraft, the MITRE model identified a median height of turbulent plumes at 29 feet above stack top, and a 90th percentile value for turbulent plumes at 133 feet above stack top, well below the height that aircraft should be flying. See Response to Q-CSC-14.

Witness: **Lynn Gresock**
Fred Sellars

Question CSC-12:

What is the exit stack temperature at full load at the top of the stack, 250 feet above the stack, and 500 feet above the stack assuming still air conditions? How much does increasing wind velocity affect this?

Response:

As discussed in the Response to Q-CSC-10, the exit stack temperature at full load at the top of the stack is 183.29°F. Increased wind velocity would more rapidly decrease temperature; ambient air temperature would also have an effect, with colder weather resulting in more rapid plume cooling. The model referenced in the Response to Q-CSC-11 identified that the exit temperature reduces to 79.25°F within 250 feet of the stack top, and to 65.57°F within a distance of 500 feet.

The results of the 2012 MITRE report evaluating the Facility are instructive in identifying heights at which turbulence would result, as discussed in the Response to Q-CSC-10.

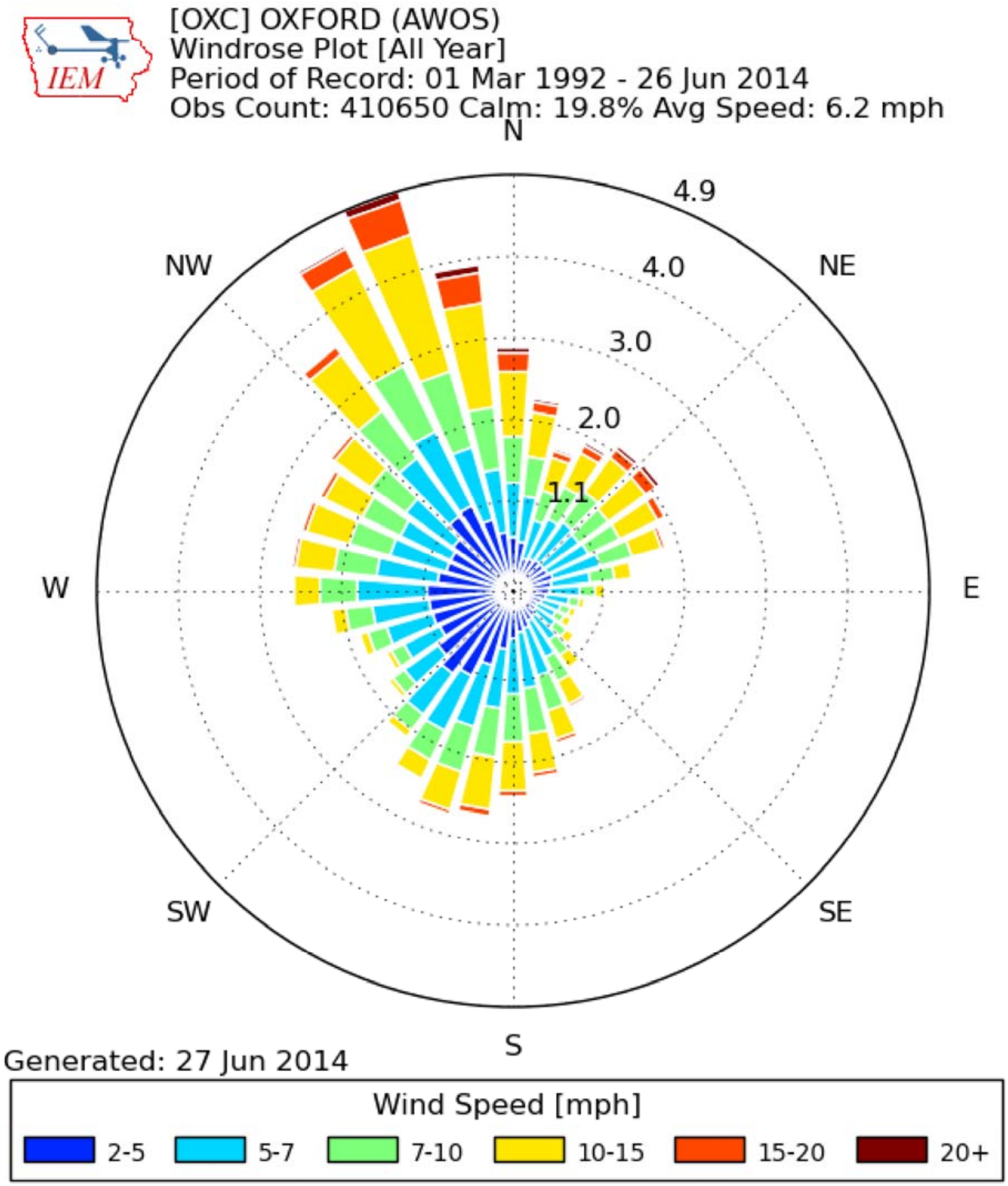
Witness: **Lynn Gresock**
Fred Sellars

Question CSC-13:

Provide a wind rose for Waterbury-Oxford Airport and include the wind directions and velocities.

Response:

A wind rose, providing wind directions and velocities, for the Waterbury-Oxford Airport is attached. The data reflect calm wind conditions 18.2% of the time (over the 21-year period represented). Please note that the meteorological data collection equipment at Waterbury-Oxford Airport does not collect wind data to the refined levels required for air dispersion modeling. For example, “calm” wind conditions are defined at the Waterbury-Oxford Airport (which has an AWOS unit, or Automated Weather Observing System) as wind speeds ranging from 2 to 5 miles per hour, whereas airports with an Automated Surface Observing System (ASOS) equipment – the precision required for air dispersion modeling – defines calms as less than 2 knots (2.3 miles per hour).


[OXC] OXFORD (AWOS)
Windrose Plot [All Year]
Period of Record: 01 Mar 1992 - 26 Jun 2014
Obs Count: 410650 Calm: 19.8% Avg Speed: 6.2 mph
N
NE
E
SE
S
SW
W
NW
4.9
4.0
3.0
2.0
1.1
Generated: 27 Jun 2014
Wind Speed [mph]
2-5
5-7
7-10
10-15
15-20
20+

Witness: Lynn Gresock

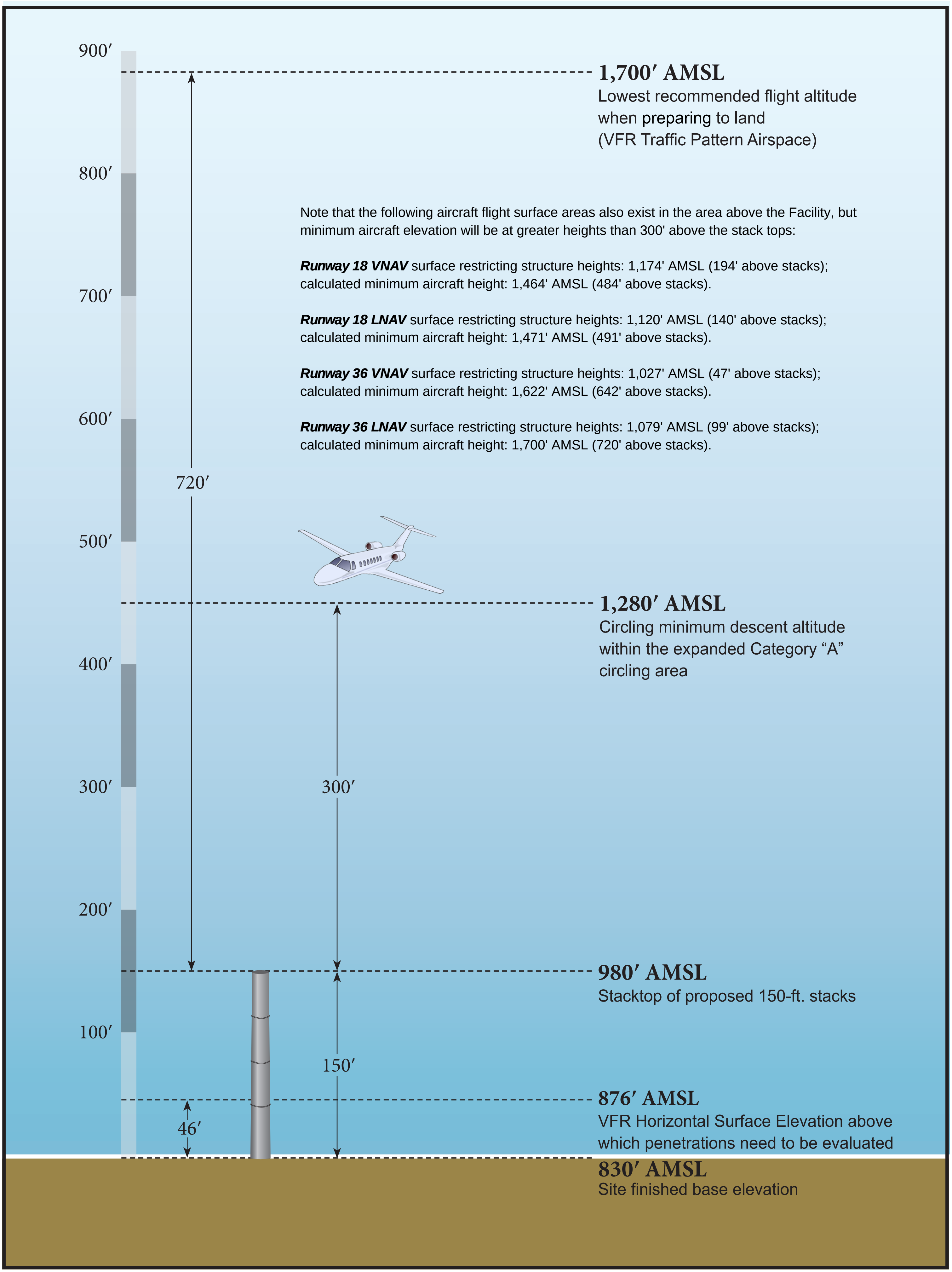
Question CSC-14:

Do the stacks penetrate the glide slope of the airport and, if so, by how many feet?

Response:

The stacks do not penetrate the glide slope of the airport. In fact, the lowest altitude at which aircraft should be flying in the vicinity of the stacks would be at 300 feet above stack top. In testimony on January 29, 2015, I incorrectly noted a calculated potential aircraft height of 277 feet above stack top associated with the Runway 36 (LNAV) Missed Approach Procedure. That value was calculated using standard FAA procedures, rather than the specific procedures required for the Waterbury-Oxford Airport. Using the correct airport-specific procedure, the calculated height of aircraft (it if accidently turns in the opposite direction from the required pattern or were significantly off-course) would be at 1,700' AMSL, or 720' above the stacks. Therefore, the circling minimum descent altitude within the expanded Category 'A' circling area would be the lowest height at which aircraft would be allowed. Aircraft would not necessarily be expected to fly as low as the minimum heights; note that, once the stacks are in place, in accordance with FAA Federal Aviation Regulations Part 91, aircraft are required to fly under Visual Flight Rule (VFR) conditions at heights that are 500' above the tallest obstacle in a given area.

Please see the attached graphic that illustrates heights at which aircraft could be expected based on airport travel patterns associated with the Waterbury-Oxford Airport.


900′
800′
700′
600′
500′
400′
300′
200′
100′
720′
300′
150′
46′
1,700′ AMSL
Lowest recommended flight altitude when preparing to land (VFR Traffic Pattern Airspace)
Note that the following aircraft flight surface areas also exist in the area above the Facility, but minimum aircraft elevation will be at greater heights than 300' above the stack tops:
Runway 18 VNAV surface restricting structure heights: 1,174' AMSL (194' above stacks); calculated minimum aircraft height: 1,464' AMSL (484' above stacks).
Runway 18 LNAV surface restricting structure heights: 1,120' AMSL (140' above stacks); calculated minimum aircraft height: 1,471' AMSL (491' above stacks).
Runway 36 VNAV surface restricting structure heights: 1,027' AMSL (47' above stacks); calculated minimum aircraft height: 1,622' AMSL (642' above stacks).
Runway 36 LNAV surface restricting structure heights: 1,079' AMSL (99' above stacks); calculated minimum aircraft height: 1,700' AMSL (720' above stacks).
1,280′ AMSL
Circling minimum descent altitude within the expanded Category “A” circling area
980′ AMSL
Stacktop of proposed 150-ft. stacks
876′ AMSL
VFR Horizontal Surface Elevation above which penetrations need to be evaluated
830′ AMSL
Site finished base elevation

Witness: **Lynn Gresock**
Andrew J. Bazinet

Question CSC-15:

Has CPV Towantic had any discussions with the FAA regarding the flight path to the airport and revisions of the flight path due to the plant. Provide any materials on this discussion. Is it possible to relocate or modify the flight path to avoid conflict with the power plant?

Response:

CPV Towantic has discussed only logistical matters associated with the review process with the FAA, but is preparing comments for submittal during the circularization process. Once completed, these materials can be provided to the Council. It is possible to convert Runway 18 from a left hand traffic pattern to a right hand traffic pattern. This change would move the VFR traffic pattern to the western side of the airport and away from both existing obstructions in the vicinity of the Facility and the Facility. However, we believe that even without that change, the Facility will not be determined to be a hazard to air navigation.

Witness: **Andrew J. Bazinet**
Curtis Jones

Question CSC-16:

Why was Wetland 1 partially filled when no other site work took place?

Response:

The attempt to fill Wetland 1 was conducted in 2009, prior to CPV acquiring its membership interest in CPV Towantic, LLC. Please see attached letter, dated March 27, 2009, from the attorney representing Towantic Energy, LLC to the Town of Oxford attorney regarding the filling activities and the Civil 1 inspection reports.

CUMMINGS & LOCKWOOD LLC

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March 27, 2009

Via E-Mail and Regular Mail
Francis A. Teodosio, Esq.
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P.O. Drawer 668
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Re: Towantic Energy, LLC; Permit IW-673

Dear Fran:

As you know, I represent Towantic Energy, LLC ("Towantic"), which holds permit IW-673 issued by the Oxford Conservation Commission/ Inland Wetlands Agency.

This is to advise you that on February 21, 2009, Towantic commenced work under this permit by cutting trees proximate to the intermittent watercourse located on its property. The trees within the limits of the clearing were removed and the stumps left in place. High spots and ruts created during construction were back bladed, and wood chips were spread to help stabilize areas with the most significant disturbance. An anti-tracking pad was installed at the entrance to the construction area. In addition, a silt fence was installed, along with hay bales. According to our engineers, Civil 1 Civil Engineers, who are completing the site inspection as required under the CT DEP General Permit, there is no evidence of erosion or sediment coming off the site. Our engineers will continue to inspect the site to insure that the erosion and sediment control measures continue to function properly.

Other work authorized by the permit will be performed later this year.

In accordance with prior discussions with you and Mr. Ferrillo (Conservation Commission/Inland Wetlands Agency Enforcement Officer), under Section 11.10 of Oxford's Inland Wetlands and Watercourses Regulations, Towantic's permit will remain valid, and in full force and effect until February 21, 2010, which is one year from the date the work authorized under the permit commenced.

If you have any questions, or would like to discuss this matter, please do not hesitate to call.

Sincerely,

John W. Cannavino

cc: Mr. Andy Ferrillo, Conservation Commission/Inland Wetlands Agency

JWC/bh

2524903_1.doc 3/27/2009

SITE VISIT REPORT – 2-10-10

An inspection of the Towantic Energy construction site was performed on February 10, 2010 to inspect the filling in of the intermittent watercourse and to inventory the installation and performance of the erosion control measures. In attendance at the site inspection was Zachary Lessard of Civil1.

Observations: The Earthworks Construction crew was completing site work at the time of the inspection. It was snowing at the time of the site inspection and the site was covered with approximately 1" – 2" of snow. The anti-tracking pad at the entrance to the construction area was still present from the previous construction activity performed at the site approximately one year ago and was in good shape. A row of silt fence was installed along the toe of the slope across the construction entrance. As seen in the photos below, the disturbed areas have been covered by hay/mulch.

The intermittent watercourse and surrounding areas have been filled in with approximately 1' - 2' of common fill, topsoil and hay/mulch. The area has been graded and leveled to promote sheet flow of any upgradient surface water runoff (Photo 2 & 3). There is no evidence of erosion or sediment coming off of the construction site at this time.

Recommendations: The site will need to be inspected during future rain events and following periods significant snow melt to ensure that the erosion and sediment control measures continue to work properly.

Respectfully submitted,

Brian J. Baker, P.E.
February 10, 2010

Photo 1

Photo 2

SITE VISIT REPORT – 2-22-10

An inspection of the Towantic Energy construction site was performed on February 22, 2010 to inspect the construction area and to inventory the performance of the erosion control measures. This inspection is part of the post-construction inspections required under the DEP General Stormwater Permit until the site is fully stabilized. This inspection was necessary because the site has not been inspected in 12 days. In attendance at the site inspection was Zachary Lessard of Civil1.

Observations: Since the previous site inspection, there was a single snow event on February 16, 2010 that covered the site with approximately 4" of snow. At the time of the site inspection, the area exposed to the South had experienced snow melt and no signs of erosion(Photo1). All disturbed and exposed areas have been covered with hay/mulch (Photo 1). The remaining areas of the site remained covered with approximately 2-3" of snow (Photos 2 & 3). The upgradient limits of construction of the site has been lined with silt fence to divert surface water runoff from upgradient areas away from the construction area until final stabilization is achieved (Photo 4). As seen in the photos below, the disturbed areas have been covered by hay/mulch.

There is no evidence of erosion or sediment coming off of the construction site at this time.

Recommendations: The site will need to be inspected during future rain events and following periods significant snow melt to ensure that the erosion and sediment control measures continue to work properly.

Respectfully submitted,

Brian J. Baker, P.E.
February 22, 2010

Photo 1

Photo 2

Photo 3

Photo 4

SITE VISIT REPORT – 8-10-10

An inspection of the Towantic Energy construction site was performed on August 10, 2010 to inspect the construction area and to determine is site is still stabilized. This inspection is part of the twice-monthly inspections required under the DEP General Stormwater Permit for three months after the site is fully stabilized. This inspection was performed since it has been approximately two weeks since the previous inspection. In attendance at the site inspection was Brian J. Baker, P.E. of Civil1.

Observations: As there has been no signficant rain since the last inspection there was no water flowing from the 6" PVC pipe under the anti-tracking pad at the end of the cul de sac (Photo 1). The riprap plunge pool at the inlet of the 6" PVC is dry, stable has no significant sediment build up and it does not require any maintenance at this time (Photo 2). There is no evidence of any additional erosion just above the plunge pool. The area further east is stable and well vegetated (Photo 3).

Recommendations: The site is stable and there is minimal potential for erosion. There is no maintenance no maintenance required and all erosion and sediment control measures have been removed. In accordance with the DEP General Stormwater Permit the post-stabilization inspections have been completed and there are no further inspections required under this General Permit.

Respectfully submitted,

____

Brian J. Baker, P.E.
August 10, 2010


Photo 1


Photo 2

Photo 3

Witness: **Dean Gustafson**
Curtis Jones

Question CSC-17:

Why was Wetland 1 difficult to fill? Are the flows emanating from that wetland so robust as to render the filling ineffective?

Response:

Wetland 1 was not difficult to fill. Field observations of soil profiles within and along the margins of Wetland 1 made by All-Points Technology Corporation, P.C. during the wetland investigation in 2014 revealed generally intact native poorly drained wetland soil profiles. Soil profile observations from numerous hand-dug test pits within Wetland 1 also revealed that the contractor who attempted the wetland filling work appeared to make no attempt to excavate the wetland topsoil or subsoil. In addition, no significant fill was placed over the original wetland topsoil; generally less than 6 inches of topsoil enriched with organics and wood chips (apparently from the clearing of trees within Wetland 1) was observed overlying native wetland topsoil and subsoil. No robust surface flows were observed within Wetland 1 and there is a lack of channelized flow patterns within this wetland. Wetland 1 appears to exhibit seasonally saturated soil conditions with any surface flows occurring during short-duration peak hydroperiods as shallow (e.g., 1 inch minus) sheet flow to the southwest across the breath of the wetland. Such wetland hydraulic conditions would not render any filling activities ineffective, if they had been performed properly in the first place.

Witness: **Dean Gustafson**
Curtis Jones

Question CSC-18:

Please detail the compensation/mitigation for lost Wetland 1 under the current plan and provide details that you have the technical capacity to effectively fill this wetland. How will that effect downstream water quality and recharge? How can you ensure that the wetland will not become a concentrator of degraded water and continue to enter the headwaters system and that sediments would flow down hill into Jacks Brook and the Naugatuck River?

Response:

An extension of time to respond to this interrogatory has been requested.

Witness: Dean Gustafson

Question CSC-19:

New U.S. Army Corps of Engineers (ACOE) regulations on vernal pools are triggered with any fill of a jurisdictional wetland. Therefore, can you confirm whether any vernal pool species surveys were conducted on the site (e.g. Wetlands 1-4)? Could such surveys be conducted this spring?

Response:

As indicated behind Attachment D of the U.S. Army Corps of Engineers Category 2 Permit Application (Applicant Exhibit 1, Appendix C), field inspections were performed on June 26, 2014, July 3, 2014, and July 12, 2014 in association with the wetland investigation. Although earlier spring inspections were not conducted in 2014 to determine if obligate vernal pool species egg masses were present or not in any of the four identified wetland areas, no vernal pool indicator species larvae were observed during the June 26th inspection, when the presence of larvae would be anticipated. In addition, no vernal pool indicator species metamorphs or adults were observed during any of the three inspection dates. Numerous adult green and pickerel frogs, which are not considered vernal pool indicator species, were observed within shallow pools (e.g., less than 6 inches deep) artificially created by tire ruts located along an existing electrical distribution line that crosses Wetland 2. Wetland 4 is a small (±178 square foot) and shallow (less than 6 inches deep; refer to Photo 12 located in Attachment B of the Category 2 Permit Application [Applicant Exhibit 1, Appendix C]) man-made depression. No inundation was observed in Wetland 4 and considering the small and shallow nature of this feature and the fact that it is located along the crest of the glacial hill and therefore receives little contributing surface flow, the hydroperiod of shallow inundation is anticipated to be too short to support successful breeding by vernal pool indicator species. No other areas of inundation were observed within Wetlands 1 or 3 which could possibly be utilized as breeding habitat by vernal pool indicator species. Therefore, a vernal pool survey that might be conducted during the early spring 2015 breeding period does not appear warranted.

Witness: **Dean Gustafson**

Question CSC-20:

What approvals are needed from ACOE to fill Wetland 1?

Response:

Authorization under the U.S. Army Corps of Engineers ("ACOE") Connecticut General Permit as a Category 2 eligible project is required to fill Wetland 1. This General Permit implements Sections 404 and 401 of the Federal Clean Water Act with the ACOE providing authorization under Section 404 and the Connecticut Department of Energy and Environmental Protection ("CTDEEP") providing authorization under Section 401. All ACOE comments have been addressed to date for the Category 2 application that was filed back in October 2014. The ACOE has verbally indicated that authorization will be granted for the filling of Wetland 1 conditioned on the Applicant's agreement for payment into the Connecticut In-Lieu Fee Program as compensatory wetland mitigation for the Facility's unavoidable wetland impacts.

CPV Towantic is currently working on addressing two minor comments issued by the CTDEEP: (1) redesign of the two stormwater detention basins as constructed stormwater wetland basins to provide additional mitigation for the loss of Wetland 1 (in combination with the ACOE's requirement for entering into the Connecticut In-Lieu Fee Program); and, (2) provide additional stormwater outlet protection at design point location DP-1. Once those two comments have been adequately addressed, CTDEEP has verbally indicated that authorization would be granted for the project.

Witness: Dean Gustafson

Question CSC-21:

Is Wetland 4 proposed to be filled? Is it a vernal pool albeit of anthropogenic origin?

Response:

Yes, filling of Wetland 4 is unavoidable due to its generally central location on the subject property and the building program needs of the proposed Facility. Please refer to the response to Response to Q-CSC-19 for a discussion of Wetland 4 and why it is not considered to support vernal pool breeding habitat.

Witness: Dean Gustafson

Question CSC-22:

Please expand the discussion as to values of Wetlands 1, 2, and 3 as habitat for eastern box turtle, spotted turtle, and eastern ribbon snake.

Response:

An extension of time to respond to this interrogatory has been requested.

Witness: Dean Gustafson

Question CSC-23:

Discuss the importance of these wetlands as headwaters wetlands, and how they contribute to downstream water quantity and quality. Provide detail as to how the proposed development will mitigate and preserve these pre-construction recharges and flows.

Response:

An extension of time to respond to this interrogatory has been requested.

Witness: Dean Gustafson

Question CSC-24:

Based on these questions and other data, please review your functions and values matrices to ensure they accurately factor in the potential for significant species and/or concentrations of wetland-dependent wildlife.

Response:

An extension of time to respond to this interrogatory has been requested.

Witness: **Dean Gustafson**

Question CSC-25:

With regard to Wetland 3, on the aerial map with the diagram of wetlands depiction provided in Tab B, is the "drainage ditch" shown by a thin yellow stripe with a black outline to the east of Woodruff Hill Road the same as the "dug drainage swale" described in the text of the Wetland 3 Classification Summary on p. 6?

Response:

Yes, those two references (drainage ditch and dug drainage swale) describe the same feature, which is located east of Woodruff Hill Road and south of Wetland 3.

Witness: **Andrew J. Bazinet**
Curtis Jones

Question CSC-26:

To whom or to what entity was the permit for wetland filling issued on February 22, 1999, and for what purpose? Has the permit expired and when?

Response:

The attached February 1999 permit was issued to Towantic Energy, LLC for the purpose of filling approximately 2,850 square feet of wetlands in conjunction with the proposed electric generating facility. Based on the letter attached to the response to Q-CSC-16, the authorization to complete activities under the permit expired in March 2010.

OXFORD
CONSERVATION COMMISSION
INLAND WETLAND AGENCY
TOWN HALL
OXFORD CONNECTICUT 06483

Application # 673

Name and Address of applicant Towantic Energy LLC
16 Riverside Commons, Westport, Ct 06880

Name and Address of property owner Town of Oxford

Site Woodruff Hill Rd

Disposition and date 2/22/99

Application approved, as per Feb 5, 1999 maps, for the construction of an electical generating plant, disturbance and/or filling of approximately 2850 sq ft of an intermittant watercourse/wetland area, (as defined by the Conn General Statutes), construction of a compensating wetland area of at least 4500 sq ft, + to permit (and require) the construction of a storm water discharge system for the purpose of taking care of the post construction runoff from the site, to the predevelopment peak rates

Subject to the following requirements/conditions.

1) Submittal of final maps reflecting all conditions of approval

2) Submittal, for IW approval, of revised plans reflecting the As-Built location of all site improvements

3) The holding of a pre-construction meeting, prior to any site activity, with the Applicant, Site Contractor, Town Engineer and Inland Wetlands Commission Enforcement Officer in attendance

4) Review and approval of erosion control measures prior to any site disturbance, by the Inland Wetlands Enforcement Officer

5) The posting of Performance and Maintenance bonds in amounts set by Town Engineer and form approved by Town Counsel, to assure completion of the required wetland compensation work and maintenance thereafter

6) The posting of Performance and Maintenance bonds in amounts set by Town Engineer and form approved by Town Counsel, to assure completion of the required stormwater detention pond work, and maintenance thereafter

7) Applicant shall create a viable wetland area of not less than 4500 sq ft in area, viability, of which, shall be determined by the IW Commission

8) Submittal of "Replacement Wetland Status Reports", prepared by a qualified wetlands professional, describing the status of the proposed wetland mitigation area for up to the next five years

9) Execution of a "Detention Basin Maintenance Agreement" including the establishment of a maintenance Escrow Account for the proposed detention pond, to be determined an an amount by the Town Engineer and in a form approved by Town Counsel

mb

OXFORD
CONSERVATION COMMISSION
INLAND WETLAND AGENCY
TOWN HALL
OXFORD. CONNECTICUT 06483

pplication # 673 cont'd pg 2

ame and Address of applicant Towantic Energy

ame and Address of property owner

isposition and date 2/17/99 cont'd

10) The submittal of final site plans as approved by the Planning & Zoning Commission, the Connecticut Siting Counsil and any other required approving agency, consistant with this approval

11) Procurement of all required State and Federal Permits including Ct DEP, US EPA etc, and submission, to Oxford IW Commission, of copies of such permits obtained

12) The incorporation of all outstanding Town Engineer comments into project plans

13) The submittal of annual reports, prepared by a Connecticut licensed professional engineer, describing the condition of the proposed storm water detention pond, including inspections made, maintenance performed, etc

14) IW Enforcement Officer must inspect and approve all siltation controls

15) During construction, activity to be monitored by Town Engineer and IW Enforcement Officer

16) Applicant shall provide, to the satisfaction of the IW Commission, evidence/details of presence of adequat leak detection systems and 110% containment, treatment, disposal, and/or discharge of oil and all hazardous materials on site, including, but not limited to, oil storage, ammonia storage, transformer, and all delivery and holding areas

17) Submission of water samples, as requested by the IW Commission

18) No discharge of hydrocarbons or any other chemicals in excess concentration of limits set by Ct DEP, and performance bond shall be posted in an amount determined by Town Engineer and in form approved by Town Counsel to ensure compliance

19) Hydrocarbons and other chemicals are subject to all present and future ordinances of the town of Oxford

Witness: **Curtis Jones**

Question CSC-27:

Why was Civil 1 on the scene to discover the wetland filling in February 2010? Were they doing regular environmental inspections of the property on behalf of Towantic?

Response:

Civil 1 was on site between February 23, 2009 and August 10, 2010 to perform erosion control inspections in accordance with the CT DEEP General Permit for the Discharge of Stormwater and Dewatering Wastewaters from Construction Activities. This was done on behalf of Towantic Energy, LLC.

Witness: **Dean Gustafson**

Question CSC-28:

The narrative on Wetland 1 says that it once contained an intermittent watercourse with well-defined banks. How was that ascertained? Was that described in the original permit application, or found in recent evaluations, or at some other time? The wetland apparently enlarged from its original size of ~2,850 square feet in the 1999 permit to ~10,322 square feet in the current evaluation. Is that just an error in the original mapping, or did the wetland actually enlarge? Were any studies done to determine the answer to this question? If no, could studies be done to determine the answer to this question?

Response:

An extension of time to respond to this interrogatory has been requested.

Witness: **Dean Gustafson**

Question CSC-29:

If the wetland referenced in question number 28 did enlarge, what were the hydrological dynamics behind the enlargement? Would the supposed intermittent watercourse have had anything to do with the possible enlargement? If the wetland did enlarge, and if certain hydrological dynamics can be found to explain the enlargement, would those dynamics affect the stability of the soil in the area of Wetland 1 to the extent of causing special construction challenges or a possible redesign?

Response:

An extension of time to respond to this interrogatory has been requested.

Witness: Andrew J. Bazinet

Question CSC-30:

What alternative water sources for the power plant are available, if any? How could water be obtained from these sources? Are any sources of well water available at or near the power plant site? Or could water flow come from neighboring towns such as Waterbury?

Response:

As background, CPV Towantic is proposing an air-cooled facility, elimination of the wet-surface air cooler, and recycling all process wastewaters to minimize overall water consumption and discharge. This design minimizes the amount of water consumed and discharged and results in usage that is a fraction of other comparable power plants.

Heritage Village Water Company (HVWC) is the franchised water company for the portion of Oxford in which the Facility will be located. Therefore, under Connecticut law, no other water company may deliver and sell water to customers within HVWC's water territory. Additionally, as the franchised water company, HVWC also has the obligation to provide adequate service at reasonable rates to all persons and entities within its service territories under Connecticut law as implemented and interpreted by the Connecticut Public Utility Regulatory Authority (PURA) and under Department of Public Health (DPH) regulations. Please see CPV Towantic LLC's administrative notice items 8-13 for relevant PURA and DPH materials on the Council's January 29, 2015 Hearing Program. Due to HVWC status and its related legal obligations and rights, HVWC is the only potable supplier available to the Facility absent a waiver of its rights by Heritage Village and approval by PURA. Based on these legal constraints, there are limited alternative water supply option, as discussed below.

Other potential water sources for the Facility include: (i) reclaimed water from the Waterbury wastewater treatment plant (WWTP), (ii) reclaimed water from the Naugatuck WWTP, and (iii) groundwater via onsite wells.

<u>Waterbury WWTP</u> - The Waterbury WWTP alternative would utilize reclaimed water from the Waterbury WWTP. It would involve 6-7 miles of new pipeline for supply and discharge lift stations for the rolling topography. Additionally, use of reclaimed water from the Waterbury WWTP facility (secondary treatment, combined sewer/stormwater) would necessitate the addition of costly front-end treatment to ensure the incoming and variable quality of water supply would meet the Facility specifications under all conditions.

Incurring such expense would only be feasible for a wet-cooled generating facility. In addition, the Connecticut regulatory approval process for use of grey water is uncertain and has been permitted in very limited circumstances. Due to the expense, the needed rights-of-way, the regulatory uncertainty, and the evaporative cooling tower plumes associated with a wet cooled facility, this option was eliminated.

Naugatuck WWTP - The Naugatuck WWTP alternative would involve many of the same issues as the Waterbury WWTP option. Further, use of reclaimed water from the Naugatuck WWTP would not be feasible because its design and average operating capacity are insufficient for the Facility's wet cooling needs.

Groundwater - CPV Towantic has not specifically examined the possibility of onsite wells as an option. However, USGS mapping (see attached Plate C-1) indicates that the areas beneath the CPV Towantic site are considered till overlying bedrock, and wells completed in these formations generally yield water at 2 gallons per minute. Bedrock well yields are variable and cannot be known without extensive on-site investigation and testing. Given the low range of anticipated mapped yield and the large number of wells that would be required to meet Facility needs, groundwater was not deemed to be a feasible option for further consideration.

EXPLANATION

BASIN DIVIDE
LOWER HOUSATONIC RIVER

SUB-BASIN DIVIDE

LINE OF EQUAL SATURATED THICKNESS OF UNCONSOLIDATED DEPOSITS

CONTACT DELINEATING STRATIFIED DRIFT FROM TILL AND BEDROCK

STRATIFIED-DRIFT AQUIFER

The only aquifer in the basin generally capable of supplying large amounts of water for public supply or industrial use. Yields of a few individual wells tapping this aquifer exceed 1,000 gallons per minute. Lines of equal saturated thickness of unconsolidated deposits show only in areas mapped as stratified drift and include any till underlying stratified drift. Interval 40 feet, with supplementary line at 10 feet

TRANSMISSIVITY OF STRATIFIED-DRIFT AQUIFER
(feet squared per day)

0-2700 | 2700-10,500
10,500-20,000 | GREATER THAN 20,000

D

PRINCIPAL GROUND-WATER RESERVOIRS

Bracket shows approximate extent. Letter designations are keyed to discussions in text and to figure 33 and table 19. Figure 33 shows detailed location and conditions assumed for hydrologic model. Table 19 summarizes analysis of potential yields.

TILL AND BEDROCK

Till, an ice-deposited mixture of clay, silt, sand, gravel and boulders is capable of yielding small supplies of water for for domestic or stock uses at favorable locations. Bedrock underlies the entire basin and is the source of on-site water supply for many homes. Approximately 90 percent of the wells tapping this aquifer reportedly yield at least 2 gallons per minute.

AREA OF TILL THICKNESS AT LEAST 40 FEET

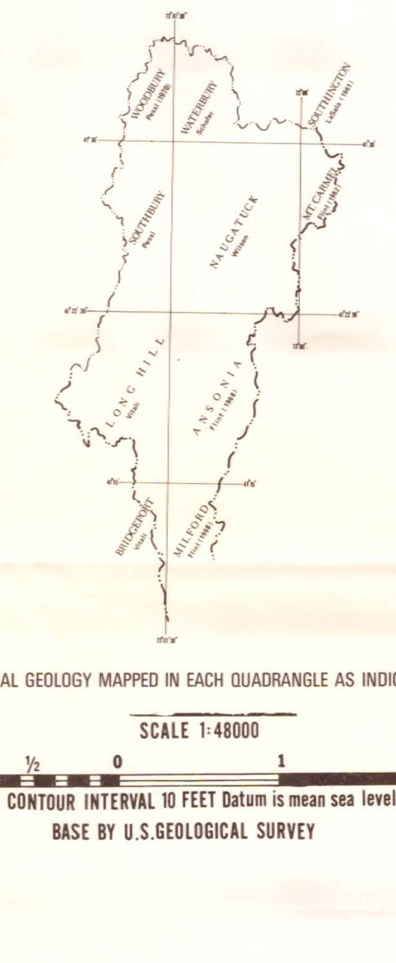
Extent based on landform and logs of wells. Symbols indicate locations of wells used for control.

x77 Well location approximate

o80 Well location precise; well not inventoried

•60 Well location precise; well inventoried

Numbers indicate thickness reported in drillers' logs. > Preceding number indicates thickness at least that shown; well was not drilled to bedrock.



SURFICIAL GEOLOGY MAPPED IN EACH QUADRANGLE AS INDICATED

SCALE 1:48000

1 ½ 0 1 2 MILES

CONTOUR INTERVAL 10 FEET Datum is mean sea level

BASE BY U.S. GEOLOGICAL SURVEY

HYDROGEOLOGY OF THE LOWER HOUSATONIC RIVER BASIN

Witness: **Andrew J. Bazinet**

Question CSC-31:

How was the water source for the power plant determined? How was the quantity of on-site water storage determined? Could the on-site water storage be increased or modified? Could all or part of the on-site water storage be underground?

Response:

The water source for the Facility was determined in accordance with the analysis described in the response to Q-CSC-30.

On-site water storage quantities were determined based on CPV Towantic's detailed "backcast" analysis of expected ULSD operation during the winter of 2013/2014, one of the two harshest winters on record in the past 25 years. The 52 hours of continuous ULSD fueled operation was deemed to be sufficient based on this analysis which yielded fifteen (15) separate ISO-NE dispatch requests, all of which would have been met by Towantic, and only two (2) requests would not have been fully satisfied by the 52 hours of operation. Furthermore, given the potential for additional supply from Heritage Village Water Company (HVWC) during its historically lower demand season (winter), CPV Towantic's projection of 52 continuous hours of operation on ULSD may be conservative because more water is likely to be available from HVWC.

Yes, it is feasible to increase or modify the on-site water storage. To determine how much of an increase is feasible would require additional analysis.

CPV has not explored the possibility of underground water storage. However, it would seem that the cost would likely be prohibitive given the analysis performed for Late-Filed Exhibit 2m submitted on February 5, 2015 and the likelihood of underground storage being more costly.

Witness: **Curtis Jones**
Jon Donovan

Question CSC-32:

What borings were done on the site and what did they show in terms of soil types and depths?

Response:

Please see the attached Geotechnical Investigation Report compiled by Burns and Roe Enterprises, Inc. in January, 2001. This report details the geotechnical investigations that were completed including 23 test soil borings, 12 test pits, piezometer readings and laboratory work. This report also describes soil types and depths.

GEOTECHNICAL INVESTIGATION REPORT

FOR

CALPINE

CALPINE CORPORATION

TOWANTIC ENERGY CENTER
OXFORD, CONNECTICUT

BURNS AND ROE ENTERPRISES, INC.
ORADELL, NEW JERSEY

GEOTECHNICAL INVESTIGATION REPORT

FOR

CALPINE

CALPINE CORPORATION

TOWANTIC ENERGY CENTER
OXFORD, CONNECTICUT

BURNS AND ROE ENTERPRISES, INC.
ORADELL, NEW JERSEY

GEOTECHNICAL INVESTIGATION REPORT

FOR

CALPINE CORPORATION

TOWANTIC ENERGY CENTER
OXFORD, CONNECTICUT

JANUARY 2001

BURNS AND ROE ENTERPRISES, INC.
800 KINDERKAMACK ROAD
ORADELL, NEW JERSEY

PREPARED BY: S. A. Nauss, P.E.

REVIEWED BY: V. Seditsky, P.E.

APPROVED BY: M. H. Rothstein, P.E.

GEOTECHNICAL INVESTIGATION REPORT

FOR

CALPINE CORPORATION

TOWANTIC ENERGY CENTER

EXECUTIVE SUMMARY

A geotechnical investigation was performed to determine the nature and competency of the subsurface materials for the Towantic Energy Center, located in Oxford, Connecticut. Evaluations were completed with respect to foundation support for the elements of the proposed combined cycle power project.

The investigation disclosed subsurface conditions consisting of glacial till soils. These soils consisted of medium dense to very dense silty sands (SM) and low plasticity silts (ML), with minor amounts of fine to coarse gravel. These glacial till soils occasionally contained cobbles and boulders.

In consideration of the anticipated foundation loads, shallow foundations may be utilized. Recommendations for shallow spread footings and mat foundations are provided. An allowable bearing pressure of 4,000 psf is recommended for the shallow spread footings, while an allowable bearing pressure of 3,000 psf is recommended for mat foundations. The recommended allowable bearing pressures may be increased by 33% for wind and other transient loads. For design of mat foundations, a coefficient of vertical subgrade reaction (K_v) equal to 250 kcf may be used. Both shallow spread footings and mat foundations should be founded at a minimum depth of 3'-6" for frost protection. The foundation subgrades should include a 6-inch (minimum) layer of crushed stone, or a 3-inch mud mat. A third shallow foundation scheme consisting of straight-sided or belled drilled footings is also recommended. This foundation system is particularly recommended for support of the Air Cooled Condenser columns that will be located within the detention pond. These footings should be founded at a minimum depth of 10 ft, and may be designed for an allowable net bearing pressure of 4,000 psf. As stated previously, the recommended allowable bearing pressures may be increased by 33% for wind and other transient loads. Bells, if used, should be constructed entirely in the natural, glacial till soils, and should be excavated with great caution to avoid bell excavation collapse.

Floor slabs may be designed as slabs-on-grade. The slabs-on-grade should be supported on a 9-inch (minimum) thick layer of crushed stone. The crushed stone layer should also include an underdrain system for relief of the groundwater pressure.

For tanks, an allowable net bearing pressure of 3,000 psf is recommended. The tank subgrade should include a 9-inch layer of well graded sand. The tanks can bear directly on the sand layer. A concrete ring beam should be constructed under the shell of the tanks. The ring beam should be placed a minimum of 3'-6" below final finished grade. Due to the sensitive nature of the natural, silty soils, and in order to protect the subgrade soils during ring beam construction, it is recommended that the ring beam subgrade include a minimum 6-inch layer of crushed stone, or a 3-inch mud mat layer. As an alternate to ring beam construction, the tanks may be supported on mat foundations.

The subsurface soils were found to be mildly corrosive. Groundwater encountered during the test boring drilling operations and in three installed piezometers was highly variable. As a result, a test pit investigation was conducted. This investigation indicated that typically water at the site accumulates in the upper medium dense silty sands, and is generally unable to penetrate to the lower more dense sitly soils, which appear to be acting as a confining unit. Test pits performed on-site generally indicated that water will typically flow out of the upper granular soils, down the sides of the excavations to the bottom. The water flow into the excavations was observed to be generally slow due to both the dense state of the subsurface soils and large amount of fines in the materials.

Excess excavated site soils are, in general, suitable for use as both Structural and Controlled Fill. However, due to the high fines content in these soils, precaution should be taken in order to assure that the material does not become excessively wet. Moisture content in the material should be maintained close to the optimum moisture in order to assure that placement would be successful. Stockpiles of excavated on-site soils should be covered in order to protect the material from becoming excessively wet. If the material becomes too wet, it should be scarified or disked and aerated until the proper moisture content is attained. If the on-site soils are used as Structural Fill, consideration should be given to protecting the finished subgrade by ground improvement. Cement stabilization of the prepared finished subgrade will protect these materials from deteriorating.

Structural Fill may also consist of imported, well graded, granular soils. It is highly recommended that Structural Fill used to grade the Power House Building area consist of imported Structural Fill.

Proof rolling of subgrade for foundations, floor slabs, and paved areas is required. Construction excavations should not be steeper than 1.5H:1V.

GEOTECHNICAL INVESTIGATION REPORT

FOR

CALPINE CORPORATION

TOWANTIC ENERGY CENTER

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GEOTECHNICAL INVESTIGATION REPORT

FOR

CALPINE CORPORATION

TOWANTIC ENERGY CENTER

1. PURPOSE AND SCOPE

A geotechnical investigation was performed to evaluate the subsurface conditions as they pertain to foundation support for the Towantic Energy Center. The investigation established the engineering and construction characteristics of the subsurface materials encountered, and allowed for the determination of the optimum foundation types.

The investigation consisted of soil test borings, in-situ testing, test pits, and laboratory testing. A review of available preliminary subsurface data for the site was also completed.

2. SITE DESCRIPTION

The Project site is located in a rural area in Oxford, Connecticut. A vicinity plan of the Project site area is presented in Figure 2.0-1. The site is a rectangular area with a length of approximately 1,300 feet and a width of 700 feet. Woodruff Hill, which peaks at El 910 feet above sea level approximately 1,400 feet northwest of the site, is the highest topographic feature within three miles. The site is located along a north-south trending ridge that makes up the southerly flank of Woodruff Hill.

The parcel of undeveloped land is mostly heavily wooded with the exception of the southern portion, which has been cleared previously. The southern portion of the site is presently covered with brush. The site is bounded by the Algonouin Gas Easement to the north, and the unpaved, Woodruff Hill Road to the west. In addition, a CL&P Easement crosses the site at the northwestern corner.

As shown in Figure 2.0-2, elevations vary substantially across the site. The site represents the top of a ridge with grades sloping steeply downwards at the western portion. The high point elevation, located at the central, northern most end of the site, is approximately El 862 ft. The site generally slopes downwards in a southerly direction, where elevations at the central, southern portion are approximately El 834 ft. There are steep slopes downward at the western end of the site; elevation at that end, at Woodruff Hill Road, is approximately El 802 ft. The site also slopes downwards gently towards the eastern edge.

Aerial photographs of the site are attached to this report.

3. PROJECT DESCRIPTION

3.1 General

The proposed Project will consist of construction of a Combined Cycle Power Plant. As shown in Figure 3.0-1, the power block complex will consist of the Power House Building, which will house the Combustion Turbine/Generators (CTGs) and the Steam Turbine Generator (STG). The Heat Recovery Steam Generators (HRSGs) and transformers will not be enclosed, and will be located adjacent to the Power House Building. The administration, maintenance, warehouse, and water treatment areas will be located within the Power House Building. Foundations for the Power House Building are anticipated to consist of shallow spread foundations and mats. The facility will also include an Air Cooled Condenser, Electrical Building, Boiler Feed Pumps, Switchyard, Condensate Storage Tank, Firewater Storage Tank, Oil Storage Tanks, Gas Metering Station, and a detention pond. Miscellaneous enclosures, utility racks, and access platforms will also be included within the facility.

As shown in Figure 3.0-2, finished site grade has been established at El 830 ft. Therefore, cut and fill operations will be required. Cuts up to 32 feet, and fills up to 22 feet can be expected.

The Project will include a perimeter fence around the site and a separate fence around the switchyard. Main access to the site will be by the paved main entrance road.

3.2 Combustion Turbine Support Structures

The combustion turbine support structures will be mat foundations.

3.3 Steam Turbine Support Structure

The steam turbine pedestal will be a reinforced concrete structure constructed on a mat foundation.

3.4 HRSG Structures

The steel-framed HRSG structures and related equipment will be constructed on mat foundations.

3.5 Transformer Foundations

Combustion turbine main, steam turbine main, and station service transformers' foundations will include spill containment, consisting of reinforced concrete retention pits. Transformers will include concrete or CMU firewalls.

3.6 Support Structures (Electrical, Boiler Feed, and Gas Metering Station Buildings)

Support structures will be located within the facility, and will typically be one-story, concrete or pre-engineered, steel-framed structures. Foundation systems for these buildings will be mats with peripheral grade beams, supported on prepared subgrades, or shallow spread footing foundation systems.

3.7 Equipment Foundations

The equipment foundations will consist of shallow or mat foundations. The foundations for static type equipment will be supported on pads or piers, elevated above the foundations' surfaces. Rotary and other vibrating equipment will be supported on mat foundations designed for the specific conditions imposed by the equipment.

3.8 Tank Foundations

Cylindrical vertical tanks will be supported on either ring wall or mat foundations.

3.9 Switchyard

The Switchyard overhead structures, including all turning towers and associated foundations, will be furnished and installed by the switchyard vendor. The top of the switchyard foundations will be six inches above finish grade. The surface of the switchyard will consist of crushed stone.

4. SITE INVESTIGATION

4.1 General

A detailed field investigation was conducted on-site. It included performing 23 test borings, installing three piezometers, performing ten resistivity tests, and excavating 12 test pits. The test borings, piezometers, and resistivity tests were conducted by Pare Engineering (Pare), along with their drilling subcontractor, Parratt-Wolff, and their geophysical subcontractor, Hager-Richter Geoscience. This investigation was conducted from October 3, through November 17, 2000. The test pit investigation was conducted by Stone Construction from December 1 through December 5, 2000. Burns and Roe Enterprises, Inc. (BREI) provided general technical oversight during the field activities.

Prior to this investigation, preliminary subsurface geotechnical information was collected at the site. The preliminary information included advancing borings and excavating test pits.

4.2 Test Borings

Twenty-three Borings, identified as B-101 through B-123, were drilled at the locations shown in Figures 4.0-1 and 4.0-2. Borings B-101 through B-112 were advanced in the Power House Building area to depths ranging between 23 and 35 ft beneath existing grade. Borings B-114 through B-119 were advanced in the Air Cooled Condenser and detention pond areas to depths ranging between 23 and 25 ft beneath existing grade. Borings B-113, B-120 and B-121 were advanced within the footprints of the tanks to depth of 24 ft each. Boring B-122 was advanced in the switchyard area to a depth of 29 ft. Boring B-123 was advanced in the pond area at the northwest corner of the site, to a depth 15 ft beneath grade.

The test borings were advanced by hollow stem auger techniques, using a truck mounted drilling rig. Soil samples were obtained via a 24-inch long split-spoon sampler (2-inch, O.D., 1-3/8-inch I.D.), driven by a 140-pound hammer free falling 30 inches. The number of blows required for penetration of the middle 12 inches of the sampler is the Standard Penetration Test (SPT) N-value (blows per foot). The SPT was completed in accordance with ASTM D1586. Standard Penetration Tests were performed continuously in the upper 10 feet of each test boring, and then at 5 foot interval thereafter, to the bottom of each test boring.

Boring B-117 caved-in after completion of the borehole; therefore, accurate groundwater measurements could not be obtained. As a result, another borehole identified as B-117A, was advanced adjacent to B-117. All boreholes were abandoned upon completion. The borings were backfilled and sealed with a cement-bentonite grout mix.

Three piezometers were installed on-site, at locations adjacent to Borings B-116, B-118, and B-119.

Test boring information is included in Appendix I; Appendix I(A) contains test boring survey information, Appendix I(B) contains the test boring logs resulting from this final investigation, Appendix I(C) contains piezometer construction details, and Appendix I(E) contains the preliminary investigation boring and test pit logs.

4.3 Test Pits

Twelve test pits, identified as TP-101 through TP-112, were excavated at the locations shown in Figure 4.0-3. Test pits were excavated throughout the site to depths ranging between 10'-0" to 18'-6" beneath the existing grade. Test pits were excavated in order to examine the groundwater conditions.

Test pit information is included in Appendix I; Appendix I(D) contains the test pit logs resulting form this final investigation.

4.4 Soil Resistivity Testing

Soil resistivity measurements were obtained at ten locations, R-1 through R-10; locations are shown in Figures 4.0-1 and 4.0-2. At each of the test locations, measurements were obtained in the North-South and East-West directions for electrode spacings of 8, 12, 20, 30, 50, 70, and 100 feet.

Testing was performed in accordance with the Wenner four-terminal method (ASTM G57). In summary, four probes are driven into the earth along a straight line, at equal distances A apart, driven to a depth B. The voltage between the two inner (potential) electrodes is then measured and divided by the current between the two outer (current) electrodes to give a value of resistance R. Where B is kept small compared to the distance between electrodes (A) the following formula applies:

$$\rho \text{ (soil resistivity)} = 2\,\pi\,A\,R$$

Resistivity test results are presented in Appendix I(F).

5. GEOLOGY AND SEISMICITY

5.1 Area Geology

According to the Surficial Geologic Map of Naugatuck Quadrangle, suficial geology of the entire Towantic Energy Center site consists of continuous, unconsolidated, non-sorted glacial till, deposited over bedrock. In general, these deposits consist predominantly of silty sands to clayey silts; minor constituents within these soils include gravel, cobbles, and boulders.

5.2 Seismic Data

Based on the 1996 BOCA National Building Code, as modified by the 1999 Connecticut Supplement and 2000 Amendments to the Connecticut Supplement, the Towantic Energy Center site is located in an area where a value of 0.15 may be used for the effective peak velocity-related acceleration (A_v), and a value of 0.11 for the effective peak acceleration (A_a). Based on the collected subsurface investigation data, the site has a soil profile type S_1, and therefore, a site coefficient value, S, equal to 1.0.

6. SUBSURFACE CONDITIONS

6.1 General

Detailed descriptions of the soils encountered are recorded on the individual boring and test pit logs included in Appendix I, parts (B), (D), and (E). The information presented on boring logs includes sample number, position, SPT N-values (blows/ft), groundwater level, and classification of the individual samples in accordance with the Unified Soil Classification System (ASTM D2487). Information presented on test pit logs includes classification of the encountered soils using both the Burmister and Unified Soil Classification Systems, and groundwater observation details. A general description of the soil materials encountered at the site is provided hereinafter.

The proposed Power Project site is presently an undeveloped tract of land, and is mostly heavily wooded with the exception of the southern portion, which has been cleared previously. Underlying the surficial organic materials, the site is underlain by glacial till soils.

6.2 Subsurface Profile

Underlying the surficial organic materials, the site is underlain by glacial till soils. In general, these soils consist of brown to gray silty sands (SM) to low plasticity silts (ML), with minor amounts of fine to coarse gravel. The soils also contained cobbles, and occasionally boulders. Based on SPT values, these soils were found to be in a medium dense to very dense state. In general, the fines content in these soils increased with depth. Thus, the silty sands were generally encountered in the upper portion of the subsurface profile while the low plasticity silts were typically encountered at the lower portions of the advanced borings. In addition, the density of these soils typically increased with depth.

6.3 Groundwater

Apparent, groundwater levels encountered during test boring drilling operations are recorded on the individual boring logs, included in Appendix I(B); the groundwater levels are also summarized in Table 6.0-1. Review of this information indicates that groundwater was encountered at highly variable elevations throughout the site. Encountered groundwater varied from 3 ft below existing grade to conditions where borings were found to be dry. In some instances dry borings were encountered adjacent to borings where the groundwater was indicated at very shallow depths. These results indicated the need for further investigation.

Three piezometers were installed in the detention pond area, since this area would be most influenced by the groundwater level. Piezometers were installed adjacent to Borings B-116, B-118, and B-119. The piezometer logs are presented in Appendix I(C); piezometer groundwater measurement data is also summarized in Table 6.0-2. While the information provided from the piezometers verified groundwater elevations obtained earlier, there was still uncertainty with regard to the groundwater behavior on-site.

To further understand groundwater conditions on-site, an extensive test pit investigation was conducted. Groundwater levels encountered in the test pits are recorded on the individual test pit logs, included in Appendix I(D); the groundwater levels are also summarized in Table 6.0-3. In general, the test pit investigation indicated that typically water at the site accumulates in the upper medium dense silty sands, and is generally unable to penetrate to the lower more dense silty soils, which appear to be acting as a confining unit. Test pits performed on-site generally indicated that water will typically flow out of the upper granular soils, down the sides of the excavations to the bottom. The water flow into the excavation was observed to be generally slow due to both the dense state of the subsurface soils and large amount of fines in the materials.

Groundwater levels are expected to fluctuate with daily and seasonal climatic conditions. Due to the silty nature of the soils on-site, localized groundwater may be encountered in shallow excavations especially if construction commences after a rainy season and/or heavy rainfall. Localized groundwater, if encountered during construction, may be controlled using conventional sump pump techniques.

7. LABORATORY TESTING

7.1 General

A laboratory testing program was developed to supplement the field investigation and to establish quantitative soil properties. All testing was performed by Pare, and was based on test requirements prepared by BREI.

Representative soil samples were subjected to the following testing:

- Moisture Content (ASTM D2216);
- Grain Size Analyses (ASTM D422 and D1140);
- Hydrometer Tests (ASTM D1140);
- Percent Passing No. 200 sieve (ASTM D1140);
- Atterberg limits (ASTM D4318);
- Modified Proctor Density (ASTM D1557); and
- Chemical Testing (pH, Chloride Content, and Sulfate Content).

The soil laboratory testing schedule is presented in Table 7.0-1. The tests were conducted in order to augment the visual classification, physical evaluation, and general soil characteristics. A summary of the Soil Laboratory Testing Results is presented in Table 7.0-2. Laboratory testing results are presented in Appendix II.

7.2 Natural Moisture Content

The natural moisture content was determined for representative samples of the site soils. The natural moisture content ranged from 5.44% to 27.34 %; however, for the majority of the tested samples, the moisture content typically ranged from 9% to 17%.

7.3 Gradation/Hydrometer Testing

Particle size analyses consisting of gradation, hydrometer, and -200 sieve testing were conducted on representative samples of site soils. These analyses indicated that the site soils typically consist of silty sands (SM). The fines content (-200 sieve) for these soils typically ranged between 20% and 45%. The fines generally consisted of 20% to 25% silts, and 10% to 15% clays.

7.4 Atterberg Limits

Atterberg Limit tests were performed on representative samples of the site soils. Results from these tests yielded liquid limits ranging from 22% to 33%, plastic limits ranging from 17% to 25%, and plasticity indices ranging from non-plastic to 13. These results indicated that these materials possess low to medium plasticity, and are generally over-consolidated.

7.5 Compaction Testing

The maximum dry density with respect to the optimum moisture content using modified effort, was determined from three representative samples obtained from borings B-119, B-120, and B-122. The maximum dry density was found to range between 129 pcf and 131 pcf, while the optimum water content ranged from 9.1 % to 9.3 %.

7.6 Soil Chemical Testing

Chemical testing consisting of pH, and chloride and sulfate ion concentration were conducted on representative samples. Samples subjected to this testing were obtained from depths consistent with those of the foundations.

8. FOUNDATION RECOMMENDATIONS

8.1 General

For satisfactory performance, the foundation of any structure must satisfy two independent design criteria:

(i) It must have an acceptable factor of safety against a bearing type failure under maximum design loads; and

(ii) Settlement during the life of the structure must not be of a magnitude that will cause structural damage, endanger piping connections, or impair the operational efficiency of the facility.

Selection of the foundation type to satisfy these criteria depends on the nature and magnitude of the structural loads, and the settlement tolerances. Where more than one foundation type satisfies these criteria, then cost, scheduling, and material availability will have an influence on, or determine, the final selection of the type of foundation.

The subsurface geotechnical investigation has indicated that beneath the surficial topsoil layer, the site is underlain by glacial till soils consisting of medium dense to very dense silty sands (SM) and low plasticity silts (ML). These subsurface soil conditions are adequate for support of the anticipated structural loads on shallow foundation systems. The Power Project structures may be supported on shallow spread footing systems, mat foundations, or drilled straight or belled, footings (shallow drilled shafts).

8.2 Shallow Foundations

8.2.1 General

The Power Project structures may be supported on shallow spread footing systems, mat foundations, or drilled straight or belled, footings (shallow drilled shafts).

8.2.2 Shallow Spread Footings

The site soils can provide adequate support of conventional shallow footing type foundations. It is recommended that foundations be designed for an allowable bearing pressure of 4,000 psf. The allowable bearing pressure may be increased by 33% for wind and other transient loads. Foundations may be founded within firm, competent, natural soils, or controlled, compacted Structural Fill. Due to the sensitive nature of the silty natural soils, and in order to protect the subgrade soils during foundation construction, it is recommended that the foundation subgrade include not less than a 6-inch layer of crushed stone, or a 3-inch mud mat layer. Column foundations should have a minimum width of three feet and wall foundation a minimum width of 1.5 feet. All foundations should be placed at least 3'-6" beneath finished grade for protection against frost.

To confirm the design bearing pressure, all foundation subgrades should be inspected by a Geotechnical Engineer prior to foundation construction.

Based on the recommendations for the design bearing pressure and for subgrade preparation, both total and differential settlement are expected to be within acceptable limits for the proposed development. The magnitudes of total settlement will be less than one inch, with less than one-half inch differential settlement in 25 feet.

8.2.3 Mat Foundations

The site soils can provide adequate support for mat foundations. In general, mat foundations, including the ones supporting the CTGs, STG, and possibly the tanks may be designed for an allowable bearing pressure of 3,000 psf. The allowable bearing pressure may be increased by 33% for wind and other transient loads. For design of the mat foundations, a coefficient of vertical subgrade reaction (K_v) equal to 250 kcf may be used. Note that the recommended value is for a 1 ft by 1ft square plate; value of actual size foundations must be scaled based on foundation size. Foundations may be founded within firm, competent, natural soils, or controlled, compacted Structural Fill. Due to the sensitive nature of the silty natural soils, and in order to protect the subgrade soils during mat foundation construction, it is recommended that the foundation subgrade include not less than a 6-inch layer of crushed stone, or a 3-inch mud mat layer. All mat foundations should be placed at least 3'-6" beneath finished grade for protection against frost.

To confirm the design bearing pressure, all mat foundation subgrades should be inspected by a Geotechnical Engineer prior to foundation construction.

Based on the recommendations for the design bearing pressure and for subgrade preparation, both total and differential settlement are expected to be within acceptable limits for the proposed development.

8.2.4 Straight-Sided or Belled Drilled Footings

In addition to shallow spread footings or mat foundations, straight-sided, or possibly belled, drilled footings may be utilized for support of structures. Straight-sided or belled, drilled footings are particularly recommended for support of the air-cooled condenser columns that will be located within the detention pond. It is recommended that drilled footings be designed for an allowable bearing pressure of 4,000 psf. The allowable bearing pressure may be increased by 33% for wind and other transient loads. These footings should be founded within the natural glacial till, silty soils on-site, at a depth of not less than 10 ft (minimum) beneath the site final finished grade. Note that since the bottom of the detention pond will be at El 816 ft, drilled footings located within the pond should be founded at El 806 ft (minimum). If bells are utilized, the entire belled portion of the foundation should be within the natural glacial till soils on-site. Drilled footings installed to the recommended depth will act in a similar manner as shallow spread footings, where the applied loads would be supported by end bearing resistance rather than shaft friction.

Bells should be used only if absolutely necessary, and should be constructed with great caution. Bells should not have a diameter greater than 6 ft, and the ratio of bell diameter to shaft diameter should not be greater than 2. Furthermore, bells should form an angle of 60 degrees or more with the subgrade soils.

The drilled footings may be installed by advancing an augered hole to the required depth; the use of a casing to keep the hole open is highly recommended. The bottom of drilled excavation should be dry and clean. Due to the sensitive nature of the natural, silty, subsurface soils, it is recommended that drilled footing excavations not be left open overnight. Typically, the silty subsurface soils will deteriorate if the excavations are left open for extensive periods. Therefore, drilled footings should be required to be constructed within the same day the excavations are performed.

To confirm the design bearing pressure, all drilled footings should be inspected by a Geotechnical Engineer prior to foundation construction.

Based on the recommendations for design bearing pressures, both total and differential settlement for drilled footings ranging from 2 ft to 6 ft in diameter, are expected to be small and within acceptable limits for the proposed development. The magnitudes of total settlement will be less than one inch, with less than one-half inch differential settlement in 25 ft.

Analyses for straight drilled footings indicate that a maximum lateral resultant capacity of 5 kips per foot of diameter of the foundation may be utilized in design (e.g. 1 ft diameter drilled foundation – lateral capacity is 5 kips, 2 ft diameter drilled foundation – lateral capacity is 10 kips, 3 ft diameter drilled foundation – lateral capacity is 15 kips, etc.). The recommended lateral resultant capacity is developed from the passive resistance of the soils surrounding the foundations. Therefore, when designing these foundations the soil lateral capacity resultant values provided above are to be applied at one-third the foundation height from the bottom of the foundation (two-thirds of the foundation height below finished grade). The design process for these foundations, which are to be considered as shallow foundations, should include applying all loads at the top of the foundation (e.g. compressive loads, lateral loads, and moments), along with the provided lateral resultant capacity at two-thirds the foundation height below finished grade, and assuring that the pressures applied on the subgrade soils (at foundation bottom) are within the allowable bearing pressure provided above.

8.2.5 Floor Slabs

Floor slabs in structures supported on shallow foundations should be designed and constructed as slabs-on-grade. The slabs-on-grade should be supported on a 9-inch (minimum) thick layer of crushed stone. The slabs should be formed and placed independently of wall, column, and equipment foundations. The crushed stone layer should also include an underdrain system for relief of the groundwater pressure. Vapor barriers should be placed between the slabs and the crushed stone subbase. If required for design of the slabs, a coefficient of vertical subgrade reaction (K_v) equal to 250 kips per cubic foot can be assumed.

8.3 Tank Foundations

Tanks including those for condensate storage, firewater, and oil storage are planned for the project. The tanks' subgrade should include a 9-inch layer of sand. A concrete ring beam should be constructed under the shell of the tanks. The ring beam may be founded within firm, competent, natural soils, or controlled, compacted Structural Fill. The bottom of the ring beam should be placed a minimum of 3'-6" below final finished grade. Due to the sensitive nature of the silty natural soils, and in order to protect the subgrade soils during foundation construction, it is recommended that the foundation subgrade include not less than a 6-inch layer of crushed stone, or a 3-inch mud mat layer.

In lieu of using ring beam construction, the tanks may be supported on mat foundations. If mats are used, recommendations provided in Section 8.2.1 should be used for their design and construction.

8.4 Grade Supported Foundations (Concrete Slabs)

Concrete slabs constructed to support light loads or equipment not sensitive to movement may be supported on grade. The grade supported concrete slabs should be supported on a 9-inch (minimum) thick layer of crushed stone, placed over firm, competent, natural soils, or controlled, compacted Structural Fill. In order to minimize the movement, the edges of the grade supported slabs should have returns extending a minimum of 18 inches beneath the final finished grade.

8.5 Dynamic Soil Properties

Shear wave velocity estimates were developed for the subsurface medium dense to very dense silty sands and low plasticity silts based on the results of the subsurface investigation. The recommended shear wave velocity profile consists of the following: i) a velocity of 800 ft/sec for soils from finished grade (El 830 ft) to El 815 ft; ii) a velocity of 1,100 ft/sec for soils from El 815 to El 795; and iii) a velocity of 1,300 ft/sec for soils beneath El 795 ft. Based on the recommend shear wave velocity profile, the dynamic shear modulus (G_{max}) is estimated as follows: i) a modulus of 2,300 ksf for soils from finished grade to El 815 ft; ii) a modulus of 4,400 ksf for soils from El 815 ft to El 795 ft; and iii) a modulus of 6200 ksf for soils beneath El 795 ft. Note that the recommended G_{max} is considered to be a low shear strain (10^{-4}%) value; and therefore, is to be used only for design of vibrating machinery.

8.6 Lateral Earth Pressure

Retaining walls unrestrained against lateral movement should be designed to resist lateral earth pressures on the basis of the active earth pressure coefficient K_a. Retaining walls that are restrained against lateral movement, should be designed on the basis of the "at-rest" earth pressure coefficient K_o.

The following parameters are recommended for the design of retaining structures.

	Structural Fill
Moist Unit Weight	118
Saturated Unit Weight	130
Earth pressure Coefficients	
Active (K_a)	0.38
At-Rest (K_o)	0.55
Passive (K_p)	2.66

Soil/Concrete Friction Coeff.	0.4

Conventional factors of safety should be used with the recommended design values. The earth pressure coefficients provided above are based on the assumption that Structural Fill will consist of the on-site silty sands and low plasticity silts. If applicable, design of retaining structures should take into account the groundwater table.

The design lateral earth pressures can be reduced if the walls are backfilled with free draining granular materials placed and compacted in a 45° wedge extending up from the wall foundation. For these conditions, the following parameters are recommended for the design of retaining structures.

	Structural Fill
Moist Unit Weight	118
Saturated Unit Weight	130
Earth pressure Coefficients	
Active (K_a)	0.29
At-Rest (K_o)	0.46
Passive (K_p)	3.39
Soil/Concrete Friction Coeff.	0.4

It is also recommended that retaining walls be designed with free draining backfill and incorporate measures such as wall drains for relief of hydrostatic pressures.

8.7 Detention Pond Slopes

In order to maintain the stability of the detention pond slopes, it is recommended that they be maintained at a slope not steeper than 3 (horizontal):1 (vertical).

For surficial stability of the detention pond slopes, it is recommended that the face of the slope consist of a layer of riprap, placed over nonwoven geotextile fabric. The section should include a crushed stone filter layer, to be placed between the riprap and geotextile fabric; No. 357 stone, as specified in ASTM D448, is recommended as the crushed stone filter layer.

8.8 Corrosion Potential and Ground Aggressiveness

8.8.1 Corrosion of Steel

Typically, four criteria are used to evaluate the corrosion potential of the subsurface soils to buried steel, these are: resistivity, pH, chloride, and sulfate content. Because they are related, the potential for corrosion cannot be evaluated by individual results, but rather by the combination of the criteria. The criteria established by the American Petroleum Institute (API) for determining corrosion potential are as follows:

- Resistivity

  Less than 500 ohm-cm, very corrosive
  500-1,000 ohm-cm, corrosive
  1,000-2,000 ohm-cm, moderately corrosive
  2,000-10,000 ohm-cm, mildly corrosive
  Greater than 10,000 ohm-cm, progressively less corrosive

- pH

  Between 5.0 and 6.5, corrosive
  Less than 5.0, very corrosive

- Chlorides

  300-1,000 ppm, corrosive
  Greater than 1,000 ppm, very corrosive

- Sulfates

  1,000-5,000 ppm, corrosive
  Greater than 5,000 ppm, very corrosive

Chemical testing results are summarized in Table 7.0-2; testing results are presented in Appendix I(F) and Appendix II. Comparison of the test results to the criteria provided above indicates that the site soils are mildly corrosive.

8.8.2 Degradation of Concrete

Typically, sulfate concentration in soil is used to evaluate the potential for concrete degradation. The criteria established by the American Concrete Institute (ACI) for degradation of concrete is as follows:

Sulfate Concentration (ppm)	Degradation Potential
> 20,000	Very Severe
20,000 – 2,000	High
2,000 – 1,000	Moderate
1,000 – 0	Low

Sulfate concentration testing results are summarized in Table 7.0-2; testing results are presented in Appendix II. Comparison of the test results to the criteria provided above indicates that the degradation potential of concrete at this site is low.

8.9 Site Development

Site development will include significant regrading activities. To achieve the subgrade elevation for the proposed Power Project, cut and fill operations will be required. Excavations of up to 32 feet will be required; and fills up to 22 feet. Fill can be placed directly on the existing subgrade after stripping of all vegetation, organics, roots, any other deleterious materials which are estimated to extend to depths ranging between 9 and 12 inches. After stripping and prior to placement of fill, proof rolling of the subgrade is required. All fill placement should be complete prior to the construction of foundations. Fill may consist of excavated on-site soils, free of organic or unsuitable materials, or may consist of imported, clean, granular soils. Fill should be placed in a controlled manner in accordance with the recommendations contained in this report.

8.10 Utilities

All underground utility excavations are recommended to extend to a depth of not less than 4 ft. Fill materials used as bedding materials for utilities, and also used to backfill around the utilities, up to not less than 6 inches above the top of the utilities, should consist of clean, granular soils with no more than 15% fines (passing the No. 200 sieve). The remaining portions of the utility trenches may be backfilled with Structural Fill consisting of the excavated on-site soils.

9. ROADWAY RECOMMENDATIONS

9.1 Subgrades

Subgrade preparation will be required for all roadways and paved areas. Generally, roadways and paved areas may be constructed on the natural subgrade materials or on controlled, compacted Structural Fill. Subgrades should be stripped of all unsuitable surface materials and proof rolled. Where required for adequate pavement design, the upper portion (approximately 10-inches) of the subgrade may be excavated and replaced in a controlled manner to achieve an in-place density equal to 95% of the maximum modified dry density (ASTM D1557).

Due to the high content of fines in the on-site soils, the quality of the subgrade soils will deteriorate rapidly if they become excessively wet. Consideration should be given to protecting the subgrade soils by ground modifications or improvements. The subgrade soils may be improved by cement stabilizing the upper 10-inches of subgrade soils.

If ground modifications, as suggested above is not a feasible solution for the project, consideration could be given to the use of geotextile fabric. Woven geotextile fabric could be placed over the prepared subgrade prior to construction of roadway and paved areas. The geotextile fabric would provide both reinforcement and a separation medium between the roadway base coarse and the underlying silty natural soils.

9.2 Embankments

It is recommended that embankments placed for roadway construction consist of Structural Fill. The embankments may be placed on existing grades after stripping of all the unsuitable surface materials. Before embankment construction, the subgrades should be proof rolled. It is recommended that side slopes for embankments be not steeper than 2H:1V. Where applicable, side slopes should be seeded for erosion control.

9.3 Pavement Sections

Recommended pavement sections for the project roadways and parking areas are provided below:

Rigid Pavement –

Concrete Slab –	8 inches thick (fc' = 4000 psi)
Crushed Stone Base Coarse –	4 inches thick

Flexible Pavement –

Bituminous Surface Coarse –	1.5 inches thick
Bituminous Base Coarse –	2.5 inches thick
Crushed Stone Base –	8 inches thick

9.4 Drainage

Roadways and parking areas should be adequately graded to allow for proper drainage. Ditches along the roadway sides should be constructed to facilitate drainage.

10. CONSTRUCTION RECOMMENDATIONS

10.1 Excavation

For construction of the proposed Power Project, the site must be stripped of all vegetation, topsoil, organics, tree roots, and any other unsuitable surficial materials. Required stripping of surficial materials is expected to extend to a depth of approximately one-foot. The topsoil may be stockpiled on-site for future use in landscaping. Any unsuitable materials encountered at the foundation level should be removed and replaced with Structural Fill.

For the construction of the foundations, excavation will be required. In general, excavated side slopes should be no steeper than 1.5H:1V and, to insure stability, the material at the bottom of the excavations should be maintained at its natural moisture content.

10.2 Fill, Backfill, and Compaction Requirements

10.2.1 Structural Fill (On-Site Silty Soils)

Structural Fill should be placed under foundations, floor slabs, and roadways. It is required that Structural Fill contain no organic or deleterious materials. Structural Fill may consist of on-site excavated soils, classified as "SM" or "ML", in accordance with the USCS (ASTM D2487). The maximum particle size should be three inches. Structural Fill should not contain more than 40% fines (materials passing the No. 200 sieve). In addition, the liquid limit and plasticity index should not exceed 30 and 10, respectively. Fill should be placed in lifts not exceeding 10 inches and compacted to 95% of the maximum modified dry density (ASTM D1557) of the soil.

Due to the high content of fines in the on-site soils, precaution should be taken in order to assure that the material does not become excessively wet. Moisture content in the material should be maintained close to the optimum moisture content (± 2%) in order to assure that placement would be successful. Stockpiles of excavated on-site soils should be covered in order to protect the material from becoming excessively wet. If the material becomes too wet, it should be scarified or disked and aerated until the proper moisture content is attained.

If the on-site soils are used as Structural Fill, consideration should be given to protecting the finished subgrade by ground modifications or improvements. Even if placed and compacted sucessfully, these soils will begin to deteriorate if they become excessively wet. For this reason, it is recommended that the finished subgrade be improved by cement stabilizing the upper 10-inches of soils. Since the soils being stabilized posses low to medium plasticity, between 4% to 8% cement by volume will be required to be added to the soil. If this scheme is to be utilized, laboratory tests should be conducted in order to determine the optimum cement content. Cement should be thoroughly mixed in with the finished subgrade soils.

10.2.2 Structural Fill (Imported Soils)

In lieu of using entirely the on-site soils as Structural Fill for the project, imported granular materials may be used as Structural Fill for the critical portions of the project. Imported granular Structural Fill is highly recommended for the required grading within the Power House Building area. Imported granular Structural Fill is recommended to consist of clean, well-graded, granular soil with no more than 15% fines (material passing the No. 200 sieve). The maximum particle size should be three inches. Fill should be placed in lifts not exceeding 10 inches and compacted to 95% of the maximum modified dry density (ASTM D1557) of the soil.

10.2.3 Controlled Fill

Controlled Fill will be required for elevating the site to the design grades. It is required that Controlled Fill contain no organic or deleterious materials. Controlled Fill may consist of on-site excavated soils, classified as "SM" or "ML", in accordance with the USCS (ASTM D2487). The maximum particle size should be six inches. Controlled Fill should not contain more than 40% fines (materials passing the No. 200 sieve). In addition, the liquid limit and plasticity index should not exceed 30 and 10, respectively. Fill should be placed in lifts not exceeding 10 inches and compacted to 90% of the maximum modified dry density (ASTM D1557) of the soil.

10.3 Proof Rolling

Subgrade for all foundations, floor slabs, and roadway is required to be proof rolled prior to construction. Proof rolling should consist of a minimum six passes of a 20 ton smooth-drum vibratory roller. Successive passes should be overlapped 20%. Soft or loose material detected during proof rolling should be compacted in place, or removed and replaced with Structural Fill. Unsuitable materials should be excavated. The use of proof rolling is also recommended for mat and footing subgrades to ensure that no loose material exists as a result of disturbance during excavation. Mat and footing subgrades should be proof tamped and compacted prior to foundation construction. A suitable mechanical hand held compactor should be used.

Backfilling within five feet of retaining walls should be performed using Structural Fill or free draining material; a suitable mechanical hand held compactor should be used.

10.4 Dewatering

Generally, it is not anticipated that extensive dewatering activities will be required. Since the on-site soils contain a large fines content and are generally in a dense state, the rate of water infiltration into excavations is considered to be slow. Dewatering or groundwater control may be conducted using conventional sump pump techniques.

10.5 Hydrotesting Tanks

It is recommended that tanks be tested using a controlled and monitored, stage-loaded hydrotest before piping connections are made. Hydrotesting generally consists of filling the tanks with water after construction, under controlled conditions, and will, therefore, reduce the amount of settlement that the tanks will experience after they are placed into service.

The tanks should be incrementally filled with water; increments could vary between 1/4 to 1/3 of the tank size. After each loading increment, the water level should be maintained until settlement observations indicate that the rate of settlement has decreased sufficiently. It is recommended that the tanks be held full during the hydrotest as long as possible to remove as much settlement as possible before the tanks are placed into service.

10.6 Inspection

As indicated earlier in this report all excavations, proof rolling, subgrade preparation and compaction, and shallow foundation installation should be inspected by a Geotechnical Engineer. Inspections should take place prior and during fill placement and during foundation construction.

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15. Pare Engineering Corporation (2000). "Addendum to Geotechnical Data Report, Towantic Energy Center, Oxford, Connecticut," November 16.

TABLES

Table 6.0-1 - Test Boring Groundwater Data

Boring No.	Ground Surface Elev. (ft)	Depth to Groundwater (ft)	Groundwater Elev. (ft)
B-101	826.0	8.5	817.5
B-102	819.6	Dry	-
B-103	816.6	5	811.6
B-104	815.2	5.4	809.8
B-105	831.3	5.5	825.8
B-106	829.1	10.2	818.9
B-107	831.2	Dry	-
B-108	831.1	5.4	825.7
B-109	836.3	9.2	827.1
B-110	836.0	Dry	-
B-111	838.9	22	816.9
B-112	833.3	6.3	827.0
B-113	827.6	7.3	820.3
B-114	822.7	5.4	817.3
B-115	818.3	16	802.3
B-116	834.9	15	819.9
B-117A	836.7	9	827.7
B-118	840.3	Dry	-
B-119	825.6	9.2	816.4
B-120	845.6	Dry	-
B-121	845.7	Dry	-
B-122	849.7	Dry	-
B-123	797.0	Dry	-

Table 6.0-2 - Piezometer Groundwater Data

Piezometer No.	Ground Surface Elev. (ft)	Groundwater Elevation			
		10/13/00	11/2/00	11/10/00	11/17/00
B-116	834.9	819.9	819.9	829.0	824.9
B-118	840.3	Dry	815.3	822.7	820.6
B-119	825.6	816.4	814.6	818.3	818.0

Table 6.0-3 - Test Pit Groundwater Data

Test Pit No.	Ground Surface Elev. (ft)	Depth to Groundwater (ft)	Groundwater Elev. (ft)
TP-101	824.0	9.0	815.0
TP-102	834.0	11.2	822.8
TP-103	830.0	4.3	825.7
TP-104	835.0	8.3	826.7
TP-105	838.0	10.0	828.0
TP-106	839.0	6.0	833.0
TP-107	835.0	10.0	825.0
TP-108	833.0	6.5	826.5
TP-109	841.0	7.0	834.0
TP-110	850.0	9.0	841.0
TP-111	846.0	5.0	841.0
TP-112	800.0	5.7	794.3

Table 7.0-1 - Laboratory Testing Schedule

BORING NO.	SAMPLE NO.	DEPTH (ft)	MOISTURE	GRADATION	HYDROMETER	% PASSING NO. 200	ATTERBERG LIMITS	CHEMICAL TESTS (pH, Chlorides, and Sulfates)	MODIFIED PROCTOR
B-103	S-2	2 - 4	X	X					
B-103	S-4	6 - 8	X				X		
B-103	S-7	15 - 17	X				X		
B-104	S-4	6 - 8	X			X			
B-104	S-6	10 - 12	X				X		
B-105	S-5	8 - 10	X			X			
B-105	S-7	15 - 17	X				X		
B-106	S-2	2 - 4						X	
B-107	S-2	2 - 4	X	X					
B-107	S-3	4 - 6						X	
B-107	S-6	10 - 12	X			X			
B-107	S-7	15 - 17	X				X		
B-108	S-1	0 - 2	X				X		
B-108	S-3	4 - 6						X	
B-108	S-5	8 - 10	X						
B-108	S-6	10 - 12	X	X	X				
B-108	S-7	15 - 17	X				X		
B-109	S-2	2 - 4	X			X			
B-109	S-5	8 - 10						X	
B-110	S-5	8 - 10						X	
B-111	S-3	4 - 6	X			X			
B-112	S-4	6 - 8						X	
B-117	S-3	4 - 6	X	X					
B-117	S-4	6 - 8	X	X	X				
B-117	S-6	13 - 15	X						
B-117	S-7	18 - 20	X			X			
B-117	S-8	23 - 25	X				X		
B-118	S-3	4 - 6	X				X		
B-118	S-5	8 - 10	X	X	X				
B-118	S-6	10 - 12	X						
B-118	S-7	15 - 17	X			X			
B-118	S-8	20 - 22	X			X			
B-119	S-3	4 - 6	X	X					
B-119	S-5	8 - 10	X	X					
B-119	CUTTINGS	-		X					X
B-120	S-4	6 - 8	X	X					

Table 7.0-1 - Laboratory Testing Schedule

BORING NO.	SAMPLE NO.	DEPTH (FT)	MOISTURE	GRADATION	HYDROMETER	% PASSING NO. 200	ATTERBERG LIMITS	CHEMICAL TESTS (pH, Chlorides, and Sulfates)	MODIFIED PROCTOR
B-120	S-8	20 - 22						X	
B-120	CUTTINGS	-		X			X		X
B-121	S-4	6 - 8	X						
B-121	S-5	8 - 10	X	X	X				
B-122	S-5	8 - 10	X	X					
B-122	CUTTINGS	-		X					X

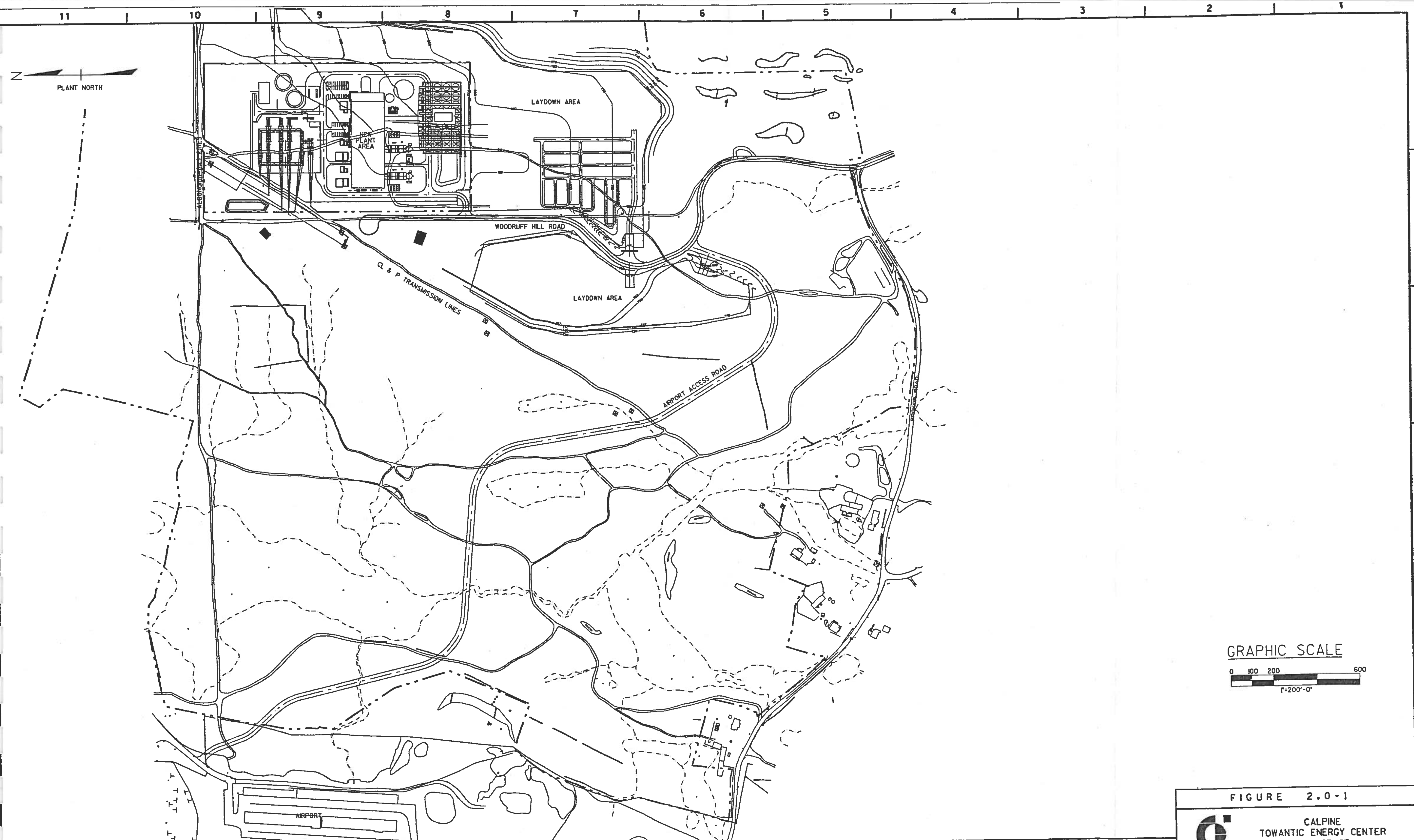
Table 7.0-2 - Summary of Soil Laboratory Testing Results

Boring No.	Sample No.	Depth (ft)	USCS	ω_n (%)	Gradation/Hydrometer Gravel (%)	Sand (%)	Fines (%)	Silt (%)	Clay (%)	Atterberg Limits LL (%)	PL (%)	PI (%)	Modified Proctor	Chemical Tests pH	Chlorides (ppm)	Sulfates (ppm)
B-103	S-2	2 - 4	SM	12.35	6.75	67.56	25.69									
B-103	S-4	6 - 8	SM	13.29						26.3	21.2	5.1				
B-103	S-7	15 - 17	SM	15.91						28.5	19.8	8.7				
B-104	S-4	6 - 8	SM	23.95			40.0									
B-104	S-6	10 - 12	ML	14.78						25.0	18.2	6.8				
B-105	S-5	8 - 10	SM	12.55			30.0									
B-105	S-7	15 - 17	ML	12.29						26.9	18.0	8.9				
B-106	S-2	2 - 4	SW-SM											5.6	ND	100
B-107	S-2	2 - 4	SM	11.34	10.99	66.17	22.84									
B-107	S-3	4 - 6	SM											7.1	ND	ND
B-107	S-6	10 - 12	SM	11.66			45.0									
B-107	S-7	15 - 17	SM	12.67						21.8	17.7	4.1				
B-108	S-1	0 - 2	SW-SM	27.34						28.8	25.1	3.7				
B-108	S-3	4 - 6	SM											7.2	ND	ND
B-108	S-5	8 - 10	SM	10.8												
B-108	S-6	10 - 12	SM	12.3	6.02	58.22	35.76	20.84	14.92							
B-108	S-7	15 - 17	SM	13.52						22.1	20.8	1.3				
B-109	S-2	2 - 4	SM	12.56			36.4									
B-109	S-5	8 - 10	SM											5.8	ND	ND
B-110	S-5	8 - 10	ML											7.8	ND	33
B-111	S-3	4 - 6	SM	12.13			32.1									
B-112	S-4	6 - 8	SM											7.0	ND	47
B-117	S-3	4 - 6	SM	8.5	8.49	67.5	24.01									
B-117	S-4	6 - 8	SM	7.76	13.24	55.09	31.67	21.08	10.59							
B-117	S-6	13 - 15	SW-SM	10.9												
B-117	S-7	18 - 20	SM	12.47			45.9									
B-117	S-8	23 - 25	ML	15.85						30.5	17.6	12.9				
B-118	S-3	4 - 6	ML	17.76						32.8	20.9	11.9				
B-118	S-5	8 - 10	SM	11.82	2.02	55.04	42.94	24.04	18.9							
B-118	S-6	10 - 12	SM	10.3												
B-118	S-7	15 - 17	SM	10.34			38.7									
B-118	S-8	20 - 22	SM	9.22			34.2									
B-119	S-3	4 - 6	SM	12.74	3.04	69.35	27.61									
B-119	S-5	8 - 10	SM	10.45	9.54	57.8	32.66									
B-119	CUTTINGS	-	SM	9.31	3.58	66.73	29.69						131 pcf @ 9.1%			
B-120	S-4	6 - 8	SM	10.12	7.74	53.1	39.16									
B-120	S-8	20 - 22	SM											7.6	ND	ND
B-120	CUTTINGS	-	SM	5.44	7.76	72.66	19.58			26.2	19.0	7.2	129 pcf @ 9.3%			
B-121	S-4	6 - 8	SM	10.9												

Table 7.0-2 - Summary of Soil Laboratory Testing Results

Boring No.	Sample No.	Depth (ft)	USCS	ω_n (%)	Gradation/Hydrometer					Atterberg Limits			Modified Proctor	Chemical Tests		
					Gravel (%)	Sand (%)	Fines (%)	Silt (%)	Clay (%)	LL (%)	PL (%)	PI (%)		pH	Chlorides (ppm)	Sulfates (ppm)
B-121	S-5	8 - 10	SM	9.54	16.36	48.24	35.4	19.91	15.49							
B-122	S-5	8 - 10	SM	13.45	7.29	47.12	45.59									
B-122	CUTTINGS	-	SM	11.56	2.2	77.85	19.95						131 pcf @ 9.2%			

FIGURES



Rev No	Revision	Date	Dwn	Chkd	Approved Chief Engr	Rev No	Revision	Date	Dwn	Chkd	Approved Chief Engr	Rev No	Revision	Date	Dwn	Chkd	Approved Chief Engr

Drawing Control

Purpose	Approved By	Date	Released By	Date
For Information				
For Comment				
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Arch		
Hvac		

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Manager-Design&Drafting

FIGURE 2.0-1

CALPINE
TOWANTIC ENERGY CENTER
OXFORD, CT

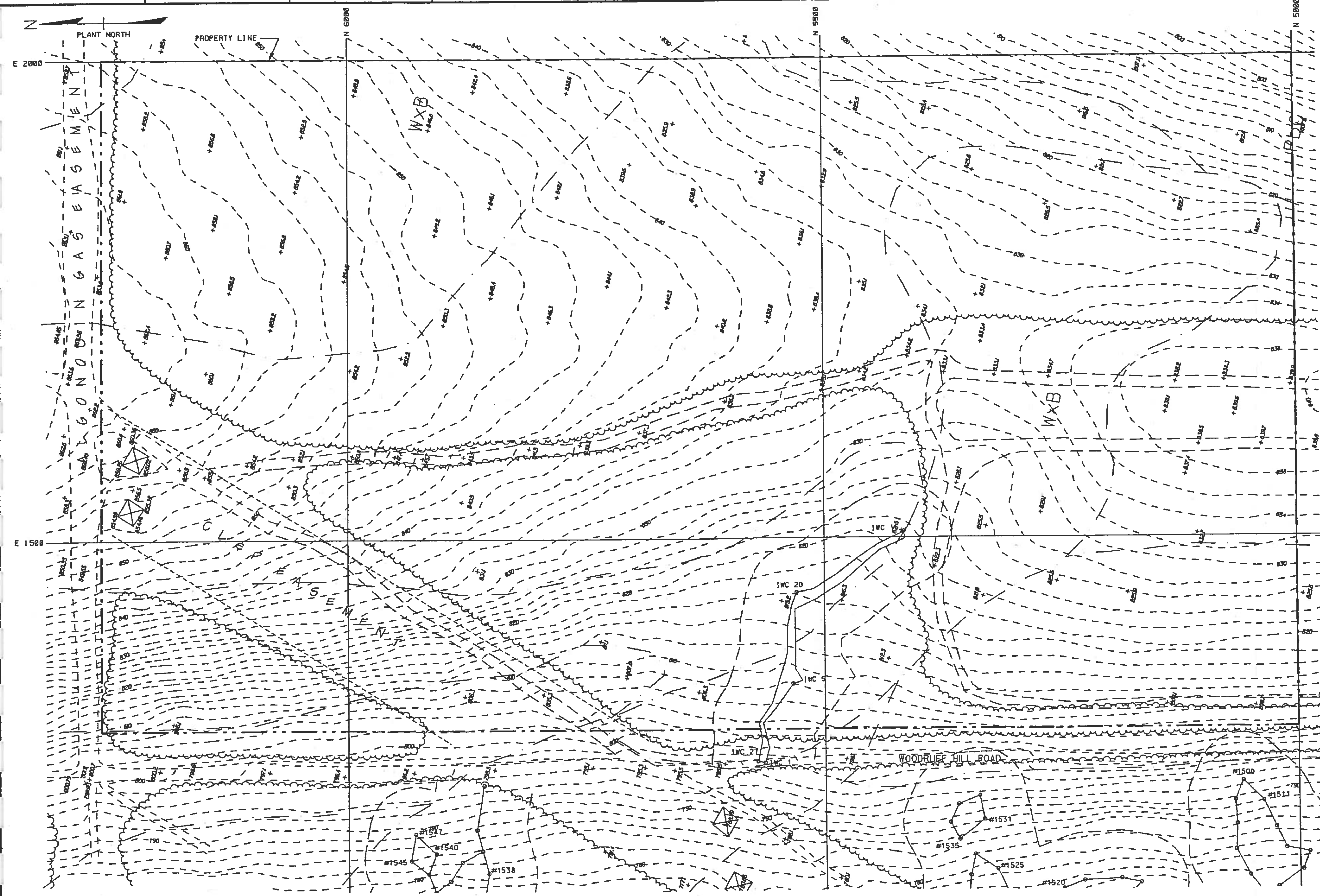
VICINITY PLAN

BURNS AND ROE ENTERPRISES, INC.
Engineers and Constructors - Oradell, NJ

Approved for Construction	Date	Work Order	Drawing No	Sh	Rev
Chief Civil Engineer	Scale 1"=200'-0"	2411			A

STATUS: 1/29/00

TOWANTIC/2328-01/FIG20I.dgn (200)



NOTES

1. FOR LEGEND SEE DRAWING C002.
2. THE EXISTING TOPOGRAPHIC INFORMATION SHOWN ON THIS PLAN IS BASED ON SURVEY PREPARED BY MICHAEL J. RIORDAN, LS REG # 14666, RIORDAN LAND SURVEYING, 701 MIDDLEROAD TURNPIKE, WOODBURY, CT 06798.

SOIL CLASSIFICATION

SYMBOL	NAME
PbB	PAXTON FINE SANDY LOAM, 3-15% SLOPE
WxB	WOODBRIDGE FINE SANDY LOAM, 3-8% SLOPE

GRAPHIC SCALE

0 25 50 100 150

1" = 50.0'

Rev No	Revision	Date	Dwn	Chkd	Approved Chief Engr	Rev No	Revision	Date	Dwn	Chkd	Approved Chief Engr	Rev No	Revision	Date	Dwn	Chkd	Approved Chief Engr

Drawing Control				
Purpose	Approved By	Date	Released By	Date
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For Comment				
For Bid				
For Construction	X			

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Nuc		
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FIGURE 2.0-2

CALPINE
TOWANTIC ENERGY CENTER
OXFORD, CT

EXISTING CONDITIONS

BURNS AND ROE ENTERPRISES, INC.
Engineers and Constructors - Oradell, NJ

Approved for Construction			Date	Work Order	Drawing No	Sh	Rev
Chief	Civil	Engineer	Scale 1"=50.0'	2411			A

STATUS: 1/29/01

TOWANTIC/2328-01/FIG202.DGN (50)

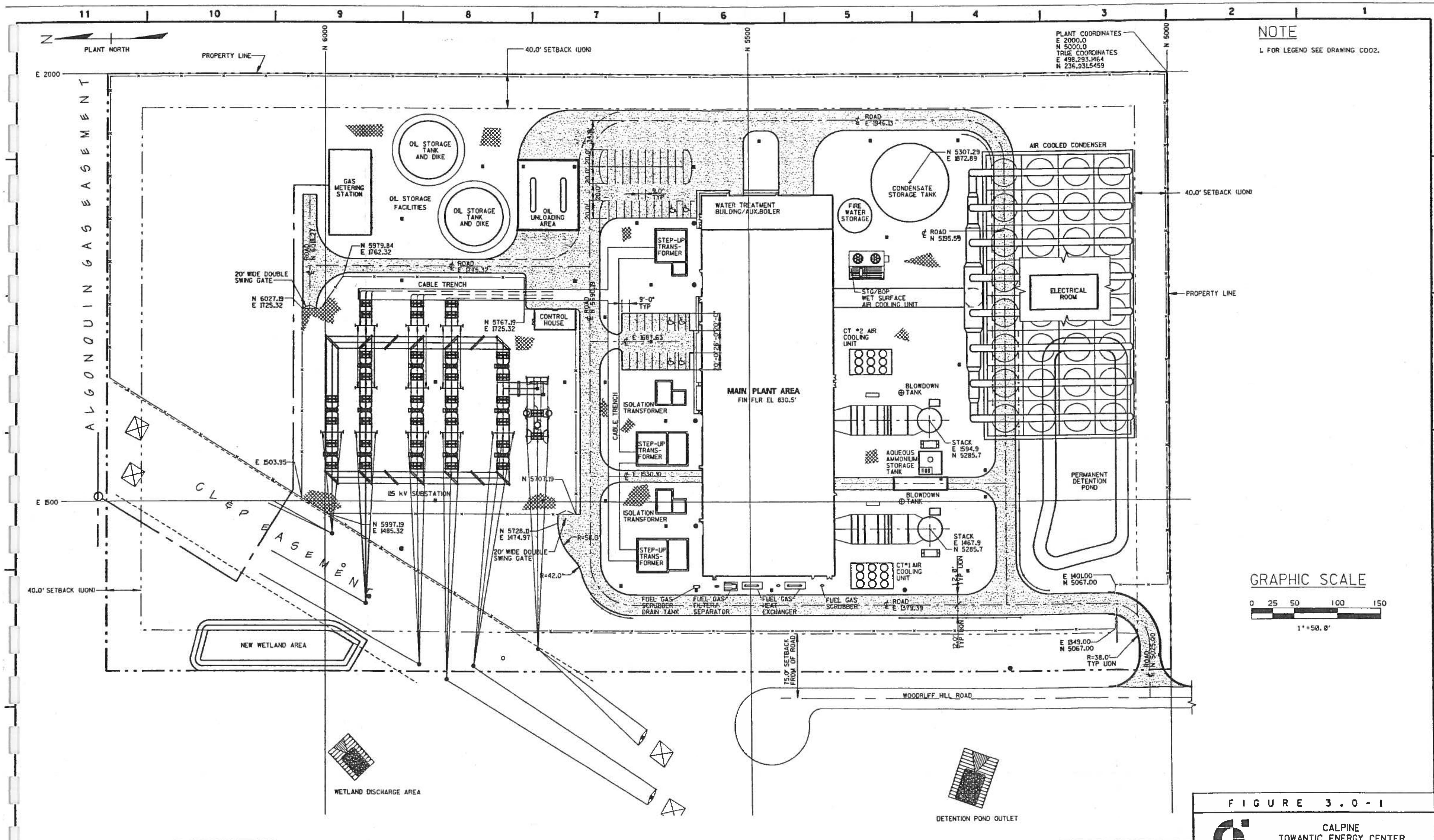


FIGURE 3.0-1

CALPINE
TOWANTIC ENERGY CENTER
OXFORD, CT

PLOT PLAN

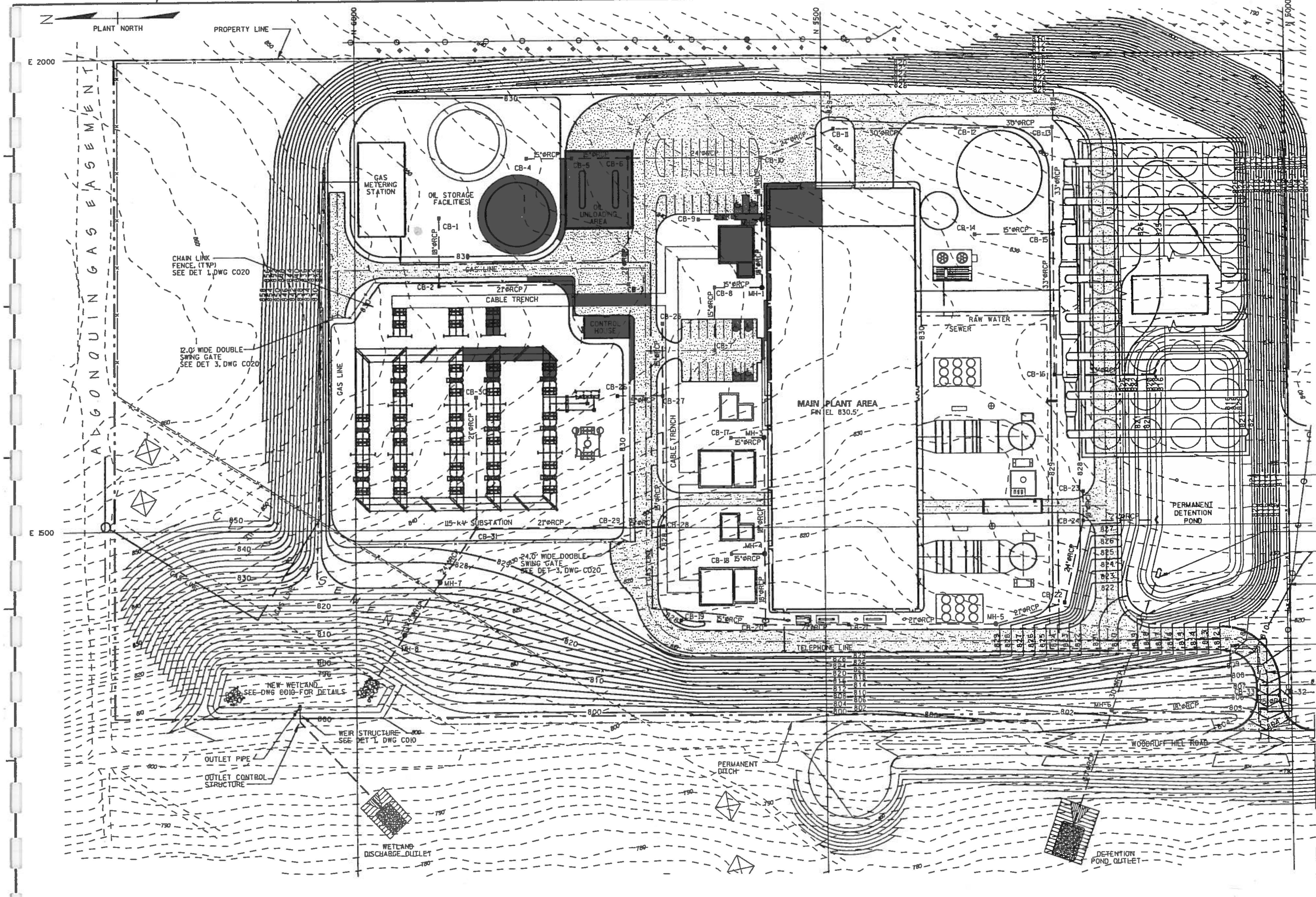
BURNS AND ROE ENTERPRISES, INC.
Engineers and Constructors - Oradell, NJ

VERA SEDITSKY
CONNECTICUT, PE NO. 22200

Work Order 2411 | Scale 1"=50.0' | Rev A

STATUS: 1/29/00

OWANTIC/2328-01/FIG301.DGN (50)



CONCRETE RETAINING WALL
SEE DETAIL 3 DWG C021
OUTLET CONTROL STRUCTURE
CHAIN LINK FENCE, (TYP) SEE DET 1, DWG C020
28.0' WIDE MOTORIZED SLIDE GATE SEE DET 5, DWG C020
RAW WATER
SEWER
TELEPHONE LINE

NOTE

1. FOR LEGEND SEE DRAWING C002.
2. FOR SOIL EROSION AND SEDIMENT CONTROL NOTES, SEE DRAWING C013.

GRAPHIC SCALE

0 25 50 100 150

1" = 50.0'

FIGURE 3.0-2

CALPINE
TOWANTIC ENERGY CENTER
OXFORD, CT

PHASE IV CONSTRUCTION
SEDIMENTATION & EROSION CONTROL PLAN

BURNS AND ROE ENTERPRISES, INC.
Engineers and Constructors - Oradell, NJ

Rev No	Revision	Date	Dwn	Chkd	Approved Chief Engr

Drawing Control	Approved By	Date	Released By	Date
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For Construction				

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Mech		
Elec		
Civil		
Arch		
Nuc		

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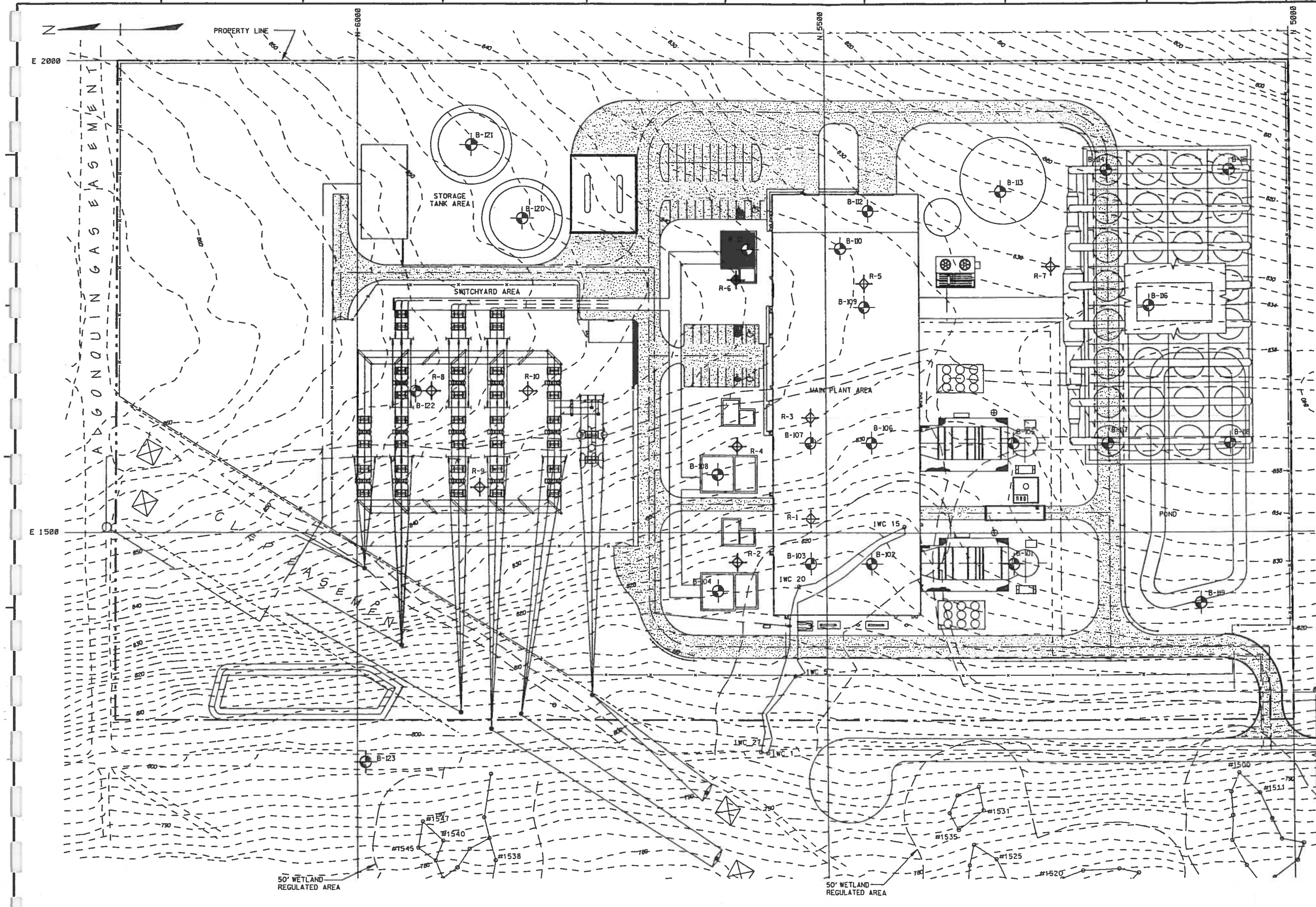
Reviewed By
Manager-Design&Drafting

Approved for Construction: Chief Civil Engineer | Date | Scale 1"=50.0' | Work Order 2411 | Drawing No | Sh | Rev A

STATUS: 1/29/01

TOWANTIC/2328-01/FIG302.DGN (50)



NOTE

1. FOR NOTES, BORING AND RESISTIVITY SCHEDULES SEE DRAWING C106.

LEGEND

B-101 PROPOSED TEST BORINGS

R-1 PROPOSED RESISTIVITY TEST

GRAPHIC SCALE

0 25 50 100 150

1" = 50.0'

FIGURE 4.0-1

CALPINE
TOWANTIC ENERGY CENTER
OXFORD, CT

BORING LOCATION PLAN

BURNS AND ROE ENTERPRISES, INC.
Engineers and Constructors - Oradell, NJ

Rev No	Revision	Date	Dwn	Chkd	Approved Chief Engr

Drawing Control				
Purpose	Approved By	Date	Released By	Date
For Information				
For Comment				
For Bid				
For Construction	X			

VERA SEDITSKY

CONNECTICUT, PE NO. 22200

Engineering Review		
Disc	Engr	Date
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Elec		
Civil		
Arch		
Nuc		
Dwn By	Chkd	SL
Reviewed By		
Manager-Design&Drafting		

Approved for Construction: Chief CIVIL Engineer | Date | Scale 1"=50.0' | Work Order 2411 | Drawing No | Sh | Rev A

TOWANTIC/2328-01/FIG401.DGN (50)

STATUS: 1/29/00

TEST BORING SCHEDULE

TEST BORINGS	COORDINATES EAST	COORDINATES NORTH	LOCATION	DEPTH SOIL (ft)	DEPTH ROCK (ft)	DEPTH TOTAL (ft)
B-101	1467.00	5298.00	HRSG	25	5	30
B-102	1467.00	5450.00	GAS TURBINE	25	10	35
B-103	1467.00	5517.00	GAS TURBINE	25	5	30
B-104	1438.00	5616.00	TRANSFORMER	25	–	25
B-105	1595.00	5298.00	HRSG	25	5	30
B-106	1595.00	5450.00	GAS TURBINE	25	10	35
B-107	1595.00	5517.00	GAS TURBINE	25	5	30
B-108	1562.00	5616.00	TRANSFORMER	25	–	25
B-109	1739.00	5458.00	STEAM TURBINE	25	10	35
B-110	1801.00	5484.00	GENERATOR	25	–	25
B-111	1800.00	5583.00	TRANSFORMER	25	–	25
B-112	1841.00	5453.00	WATER TREATMENT BLDG	25	–	25
B-113	1861.00	5310.00	FIRE WATER TANK	25	–	25
B-114	1884.00	5196.00	AIR COOLED CONDENSER	25	–	25
B-115	1884.00	5067.00	AIR COOLED CONDENSER	25	–	25
B-116	1740.00	5153.00	AIR COOLED CONDENSER	25	5	30
B-117	1595.00	5196.00	AIR COOLED CONDENSER	25	–	25
B-118	1595.00	5068.00	AIR COOLED CONDENSER	25	–	25
B-119	1425.00	5099.00	RETENSION POND	25	–	25
B-120	1833.00	5826.00	FUEL OIL TANK	25	–	25
B-121	1911.00	5879.00	FUEL OIL TANK	25	–	25

SOIL RESISTIVITY SCHEDULE

RESISTIVITY TEST	COORDINATES EAST	COORDINATES NORTH	LOCATION	PROBE SPACING
R-1	1515.00	5517.00	GAS TURBINE	8,12,20,30,50,70,AND 100
R-2	1469.00	5594.00	TRANSFORMER	8,12,20,30,50,70,AND 100
R-3	1622.00	5517.00	GAS TURBINE	8,12,20,30,50,70,AND 100
R-4	1592.00	5594.00	TRANSFORMER	8,12,20,30,50,70,AND 100
R-5	1764.00	5458.00	STEAM TURBINE	8,12,20,30,50,70,AND 100
R-6	1768.00	5595.00	TRANSFORMER	8,12,20,30,50,70,AND 100
R-7	1782.00	5257.00	-	8,12,20,30,50,70,AND 100
R-8	1650.00	5920.00	SWITCHYARD	8,12,20,30,50,70,AND 100
R-9	1548.00	5870.00	SWITCHYARD	8,12,20,30,50,70,AND 100
R-10	1650.00	5820.00	SWITCHYARD	8,12,20,30,50,70,AND 100

NOTES:

1. CONTRACTOR SHALL LOCATE AND DETERMINE GROUND SURFACE ELEVATION OF BORINGS AND RESISTIVITY TESTS.
2. CONTRACTOR SHALL VERIFY LOCATIONS OF UNDERGROUND UTILITIES ON-SITE PRIOR TO START OF DRILLING OPERATIONS.
3. DEPTHS OF SOIL DRILLING PROVIDED IN THE TEST BORING SCHEDULE ARE APPROXIMATE. ACTUAL BORING DEPTHS WILL BE DETERMINED IN THE FIELD, AS DIRECTED BY BURNS AND ROE REPRESENTATIVE. FOR BORINGS WHERE ROCK CORING IS SCHEDULED, CORING SHALL BEGIN AT REFUSAL DEPTH. LENGTH OF ROCK CORING SHALL BE SPECIFIED IN THE TEST BORING SCHEDULE.
4. STANDARD PENETRATION TEST (SPT) SHALL BE PERFORMED CONTINUOUSLY AT 2 FOOT INTERVALS IN THE UPPER TEN FEET (E.G., 0'-2', 2'-4', ETC.), AND AT 5 FOOT INTERVALS THEREAFTER (E.G., 13'-15', 18'-20', ETC.) TO THE DEPTHS SPECIFIED IN THE TEST BORING SCHEDULE. THE UNDRAINED COHESION OF ALL RECOVERED COHESIVE SOIL SAMPLES SHALL BE DETERMINED WITH A POCKET PENETROMETER.
5. UNDISTURBED SAMPLES SHALL BE COLLECTED BASED ON THE RESULTS OF THE SUBSURFACE INVESTIGATION; BURNS AND ROE REPRESENTATIVE WILL PROVIDE INFORMATION REGARDING LOCATION AND DEPTH OF SAMPLES TO BE COLLECTED. IT IS ESTIMATED THAT NOT MORE THAN 5 SHELBY TUBES WILL BE COLLECTED DURING THE SUBSURFACE INVESTIGATION.
6. CONTRACTOR SHALL UTILIZE DRILLING METHODOLGIES THAT ALLOW FOR OBTAINING GROUNDWATER MEASUREMENTS (HOLLOW STEM AUGER). AFTER OBTAINING GROUNDWATER MEASUREMENTS, CONTRACTOR MAY UTILIZE ANY DRILLING TECHNIQUE, IN CONFORMANCE WITH THE REQUIREMENTS OF THE PROJECT SPECIFICATIONS, FOR THE REMAINING DEPTH OF THE BORINGS.
7. CONTRACTOR SHALL PROVIDE A FIELD GEOTECHNICAL ENGINEER OR ENGINEERING GEOLOGIST FOR OVERSIGHT OF FIELD OPERATIONS.
8. RESISTIVITY TESTING SHALL BE PERFORMED IN ACCORDANCE WITH THE WENNER FOUR TERMINAL METHOD.
9. AT EACH TEST LOCATION, RESISTIVITY MEASUREMENTS SHALL BE PERFORMED IN BOTH NORTH-SOUTH AND EAST-WEST DIRECTIONS.
10. PROBE SPACING SHALL BE AS INDICATED IN THE SOIL RESISTIVITY SCHEDULE.

FIGURE 4.0-2

CALPINE
TOWANTIC ENERGY CENTER
OXFORD, CT

BORING & RESISTIVITY SCHEDULES

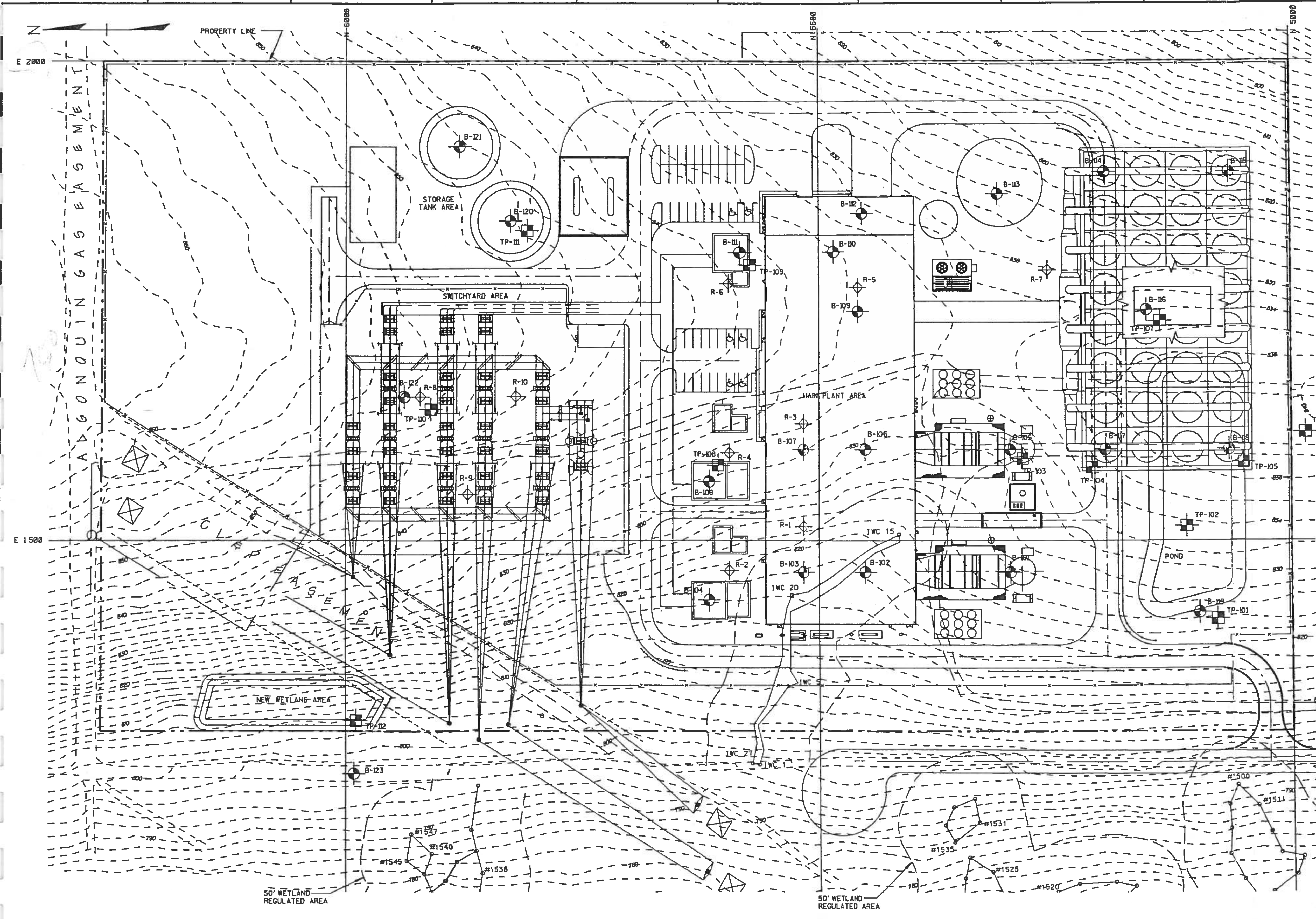
BURNS AND ROE ENTERPRISES, INC.
Engineers and Constructors - Oradell, NJ

VERA SEDITSKY
CONNECTICUT, PE NO. 22200

Work Order: 2411 | Rev: A | Dwn By / Chkd / SL

STATUS: 1/29/01

TOWANTIC/2328-01/FIG402.DGN (50)



NOTES

1. TEST BORINGS B-101 THROUGH B-123, AND RESISTIVITY TESTS R-1 THROUGH R-10 WERE PREVIOUSLY PERFORMED, AND ARE SHOWN FOR INFORMATION ONLY.
2. TEST PIT INVESTIGATION WILL CONSIST OF EXCAVATING TP-101 THROUGH TP-112.
3. TEST PIT LOCATIONS WILL BE DETERMINED BY BURNS AND ROE REPRESENTATIVE WITH THE ASSISTANCE OF THE TEST PIT CONTRACTOR.
4. TEST PITS SHALL BE EXCAVATED TO A MINIMUM DEPTH OF 15 FEET BELOW EXISTING GRADES. THE PURPOSE OF THE TEST PITS IS TO EXAMINE GROUNDWATER CONDITIONS AT THE SITE.
5. AFTER EXCAVATION, TEST PITS SHALL BE LEFT OPEN FOR A PERIOD OF TWO TO FOUR WEEKS, TO ALLOW FOR GROUNDWATER TO STABILIZE. CONTRACTOR SHALL INSTALL STAKES WITH PLASTIC CONSTRUCTION FENCE AROUND EACH TEST PIT FOR SAFETY. AFTER OBTAINING FINAL GROUNDWATER DATA, CONTRACTOR SHALL REMOBILIZE ON-SITE AND BACKFILL THE TEST PITS.

LEGEND

- TP-101 INDICATES TEST PIT LOCATION & NUMBER
- B-101 INDICATES PREVIOUSLY PERFORMED TEST BORINGS
- R-1 INDICATES PREVIOUSLY PERFORMED RESISTIVITY TEST

GRAPHIC SCALE

0 25 50 100 150

1"=50.0'

FIGURE 4.0-3

CALPINE
TOWANTIC ENERGY CENTER
OXFORD, CT

TEST PIT LOCATION PLAN

BURNS AND ROE ENTERPRISES, INC.
Engineers and Constructors - Oradell, NJ

VERA SEDITSKY

CONNECTICUT, PE NO. 22200

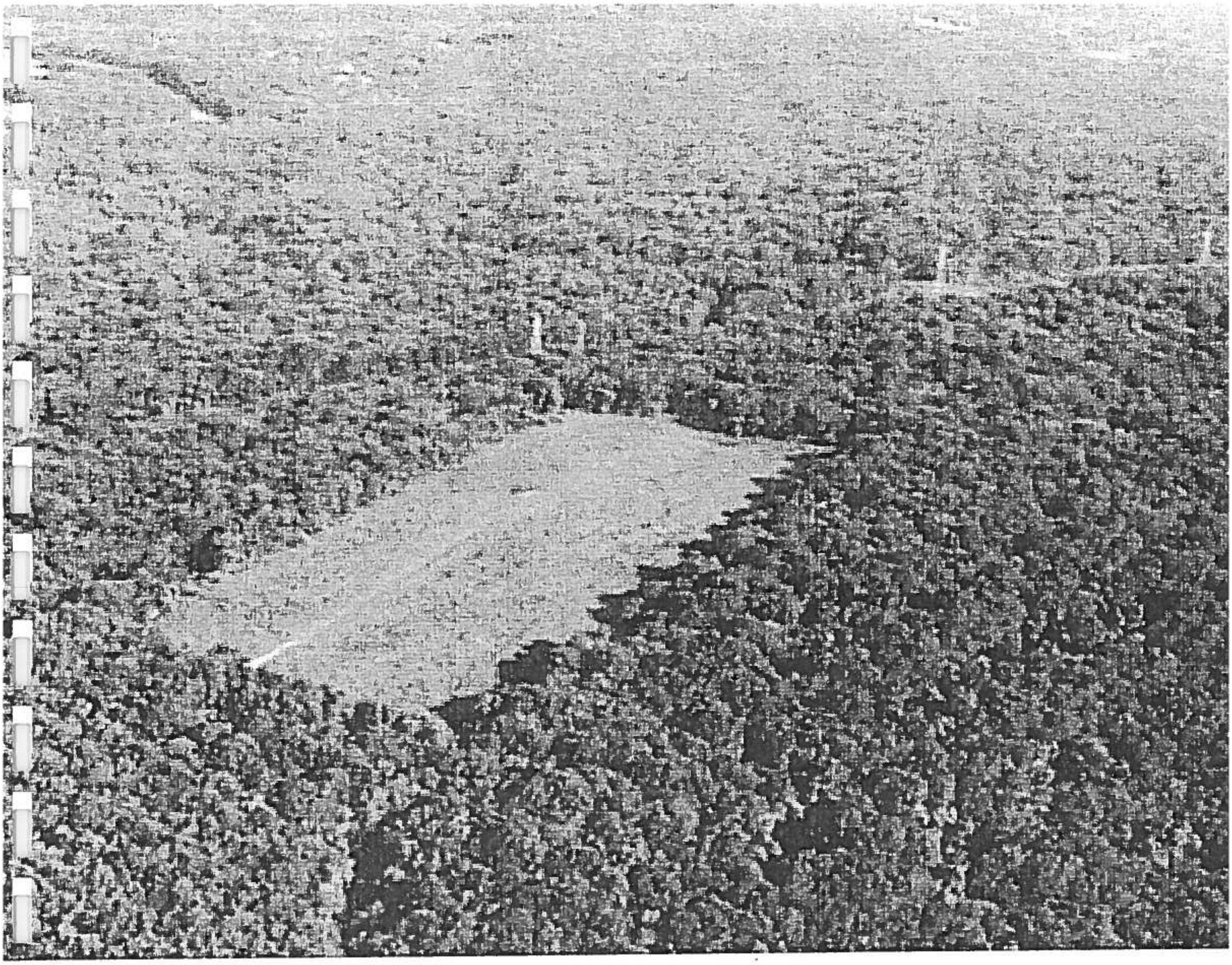
Purpose	Approved By	Date	Released By	Date
For Information				
For Comment				
For Bid				
For Construction				

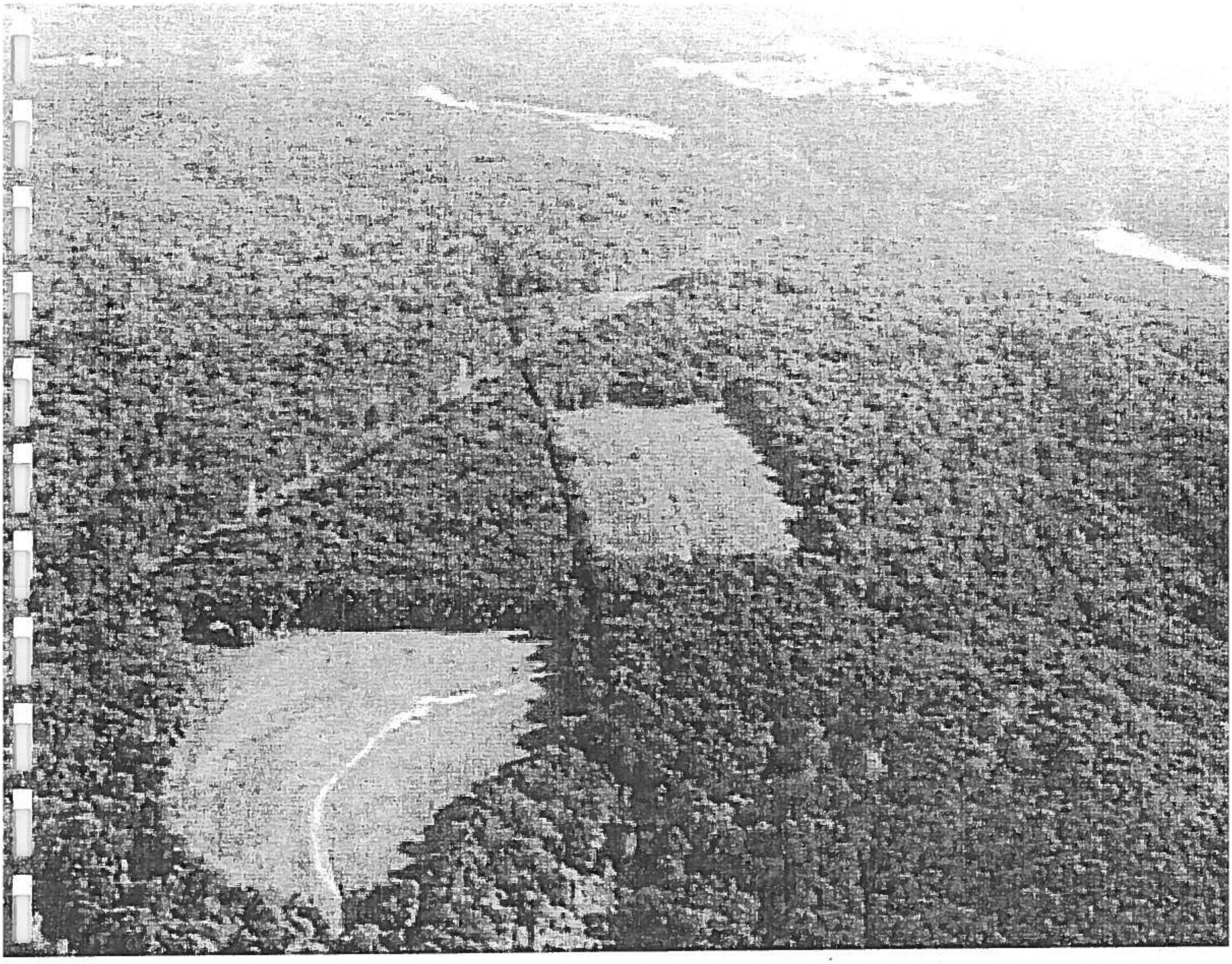
Work Order 2411 | Scale 1"=50.0' | Rev A

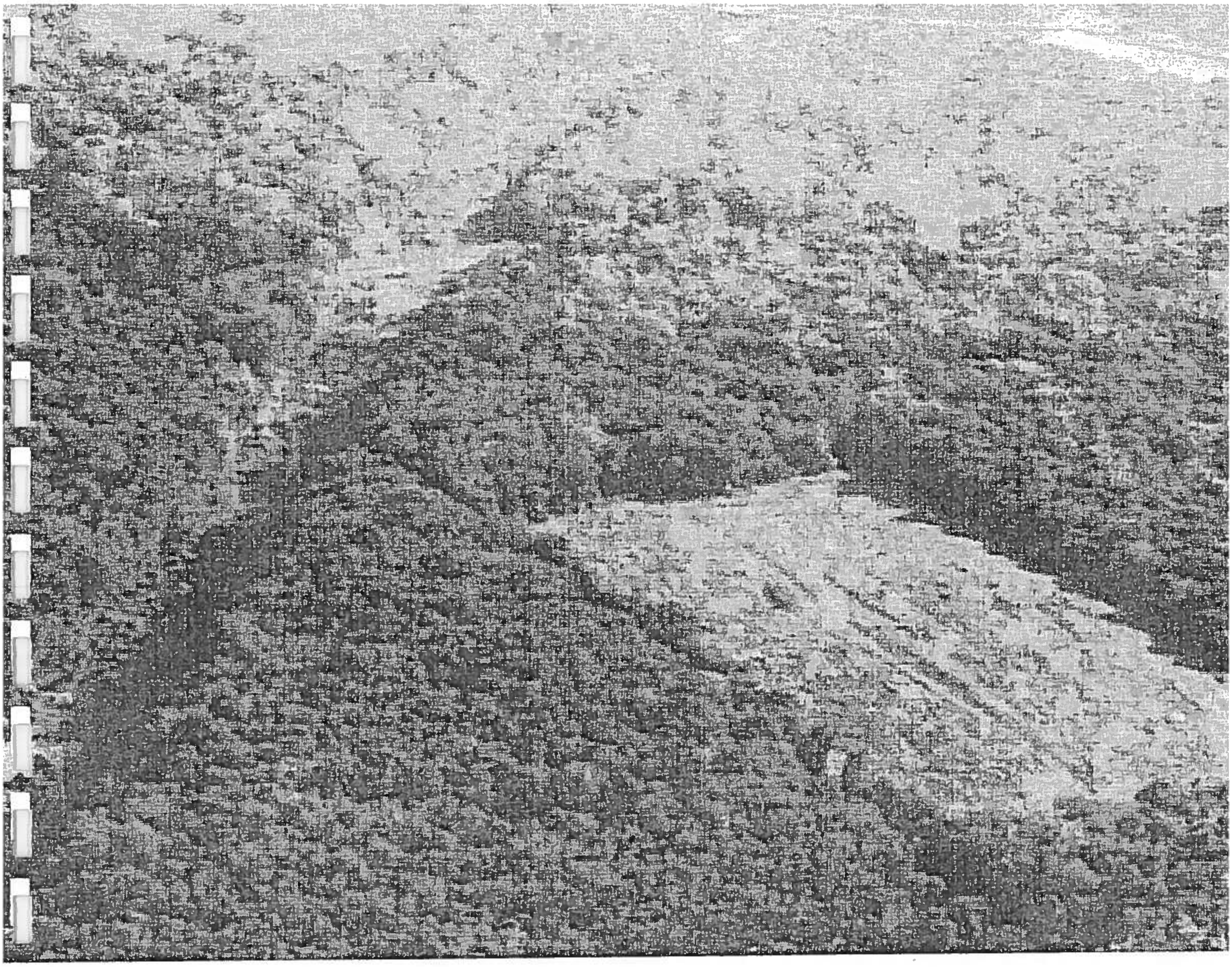
TOWANTIC/2328-01/FIG403.DGN (50)

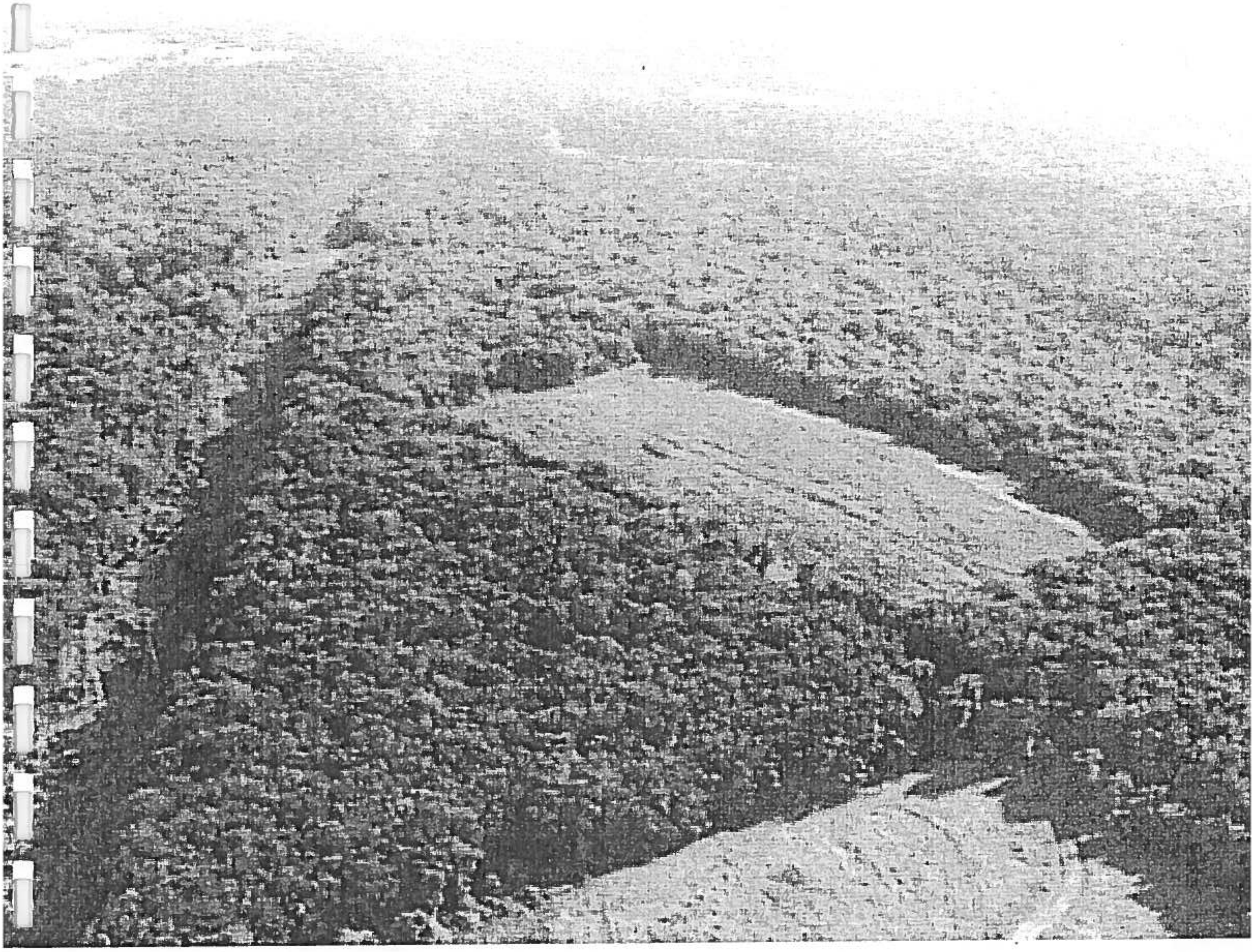
STATUS: 1/29/01

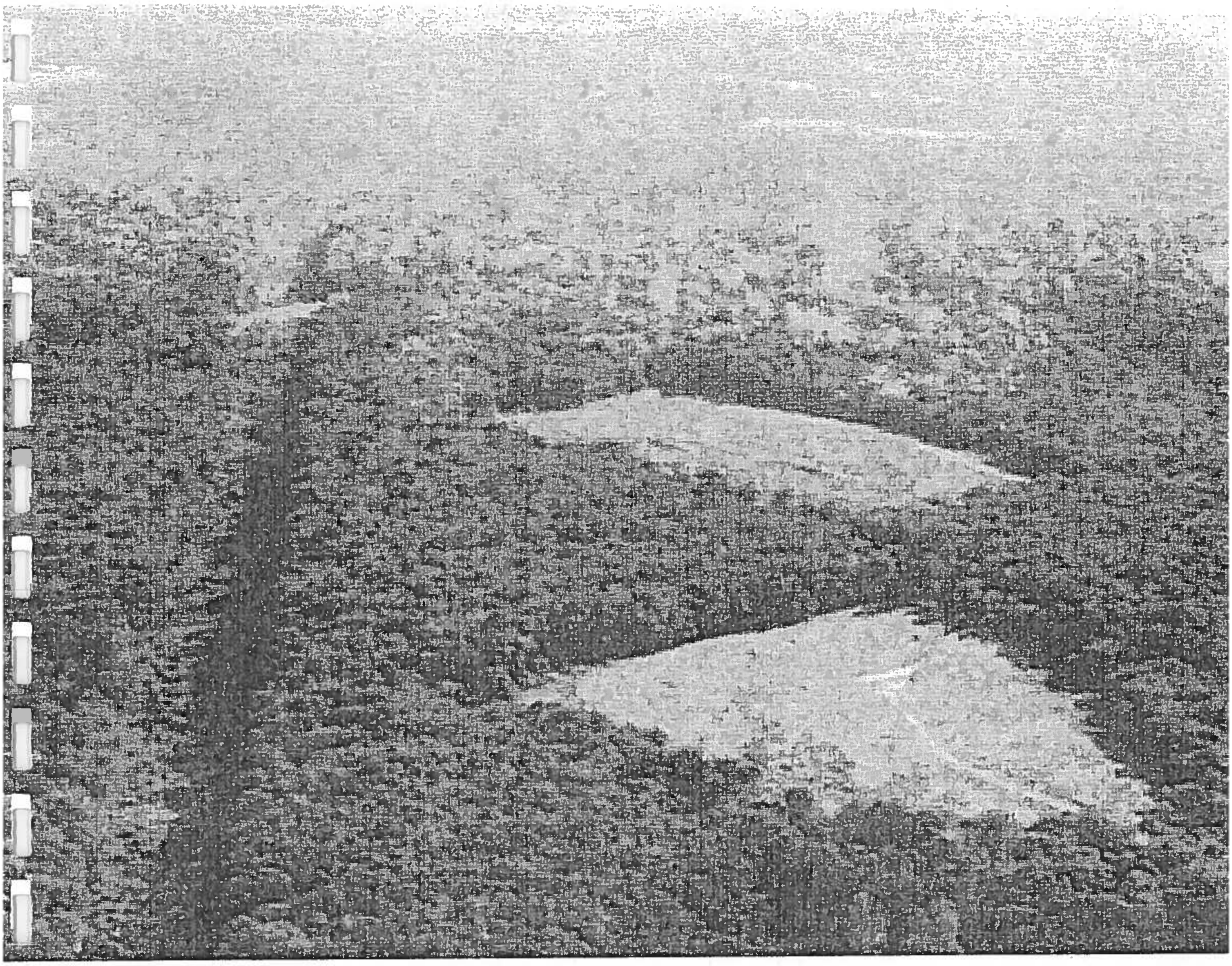
PHOTOGRAPHS

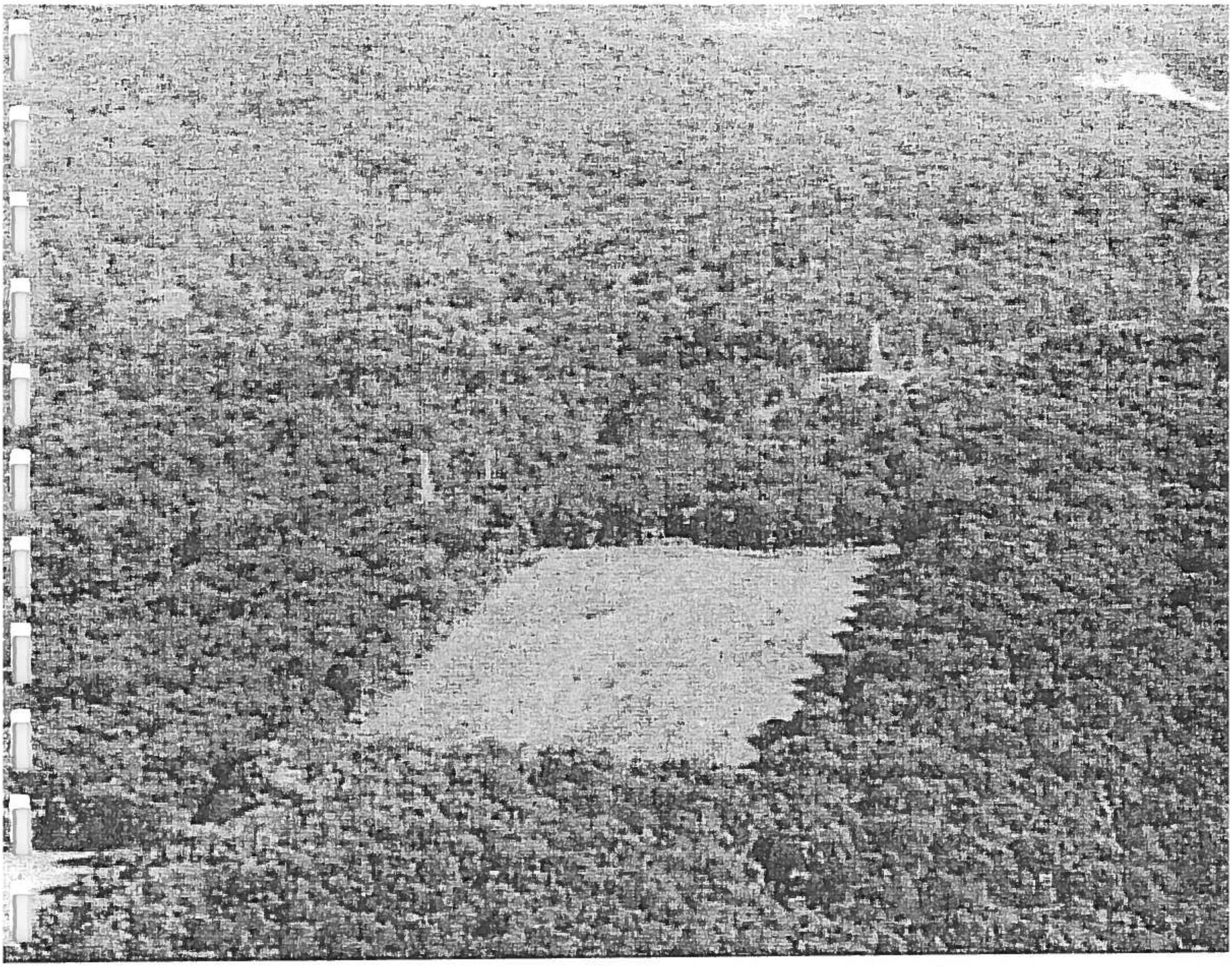


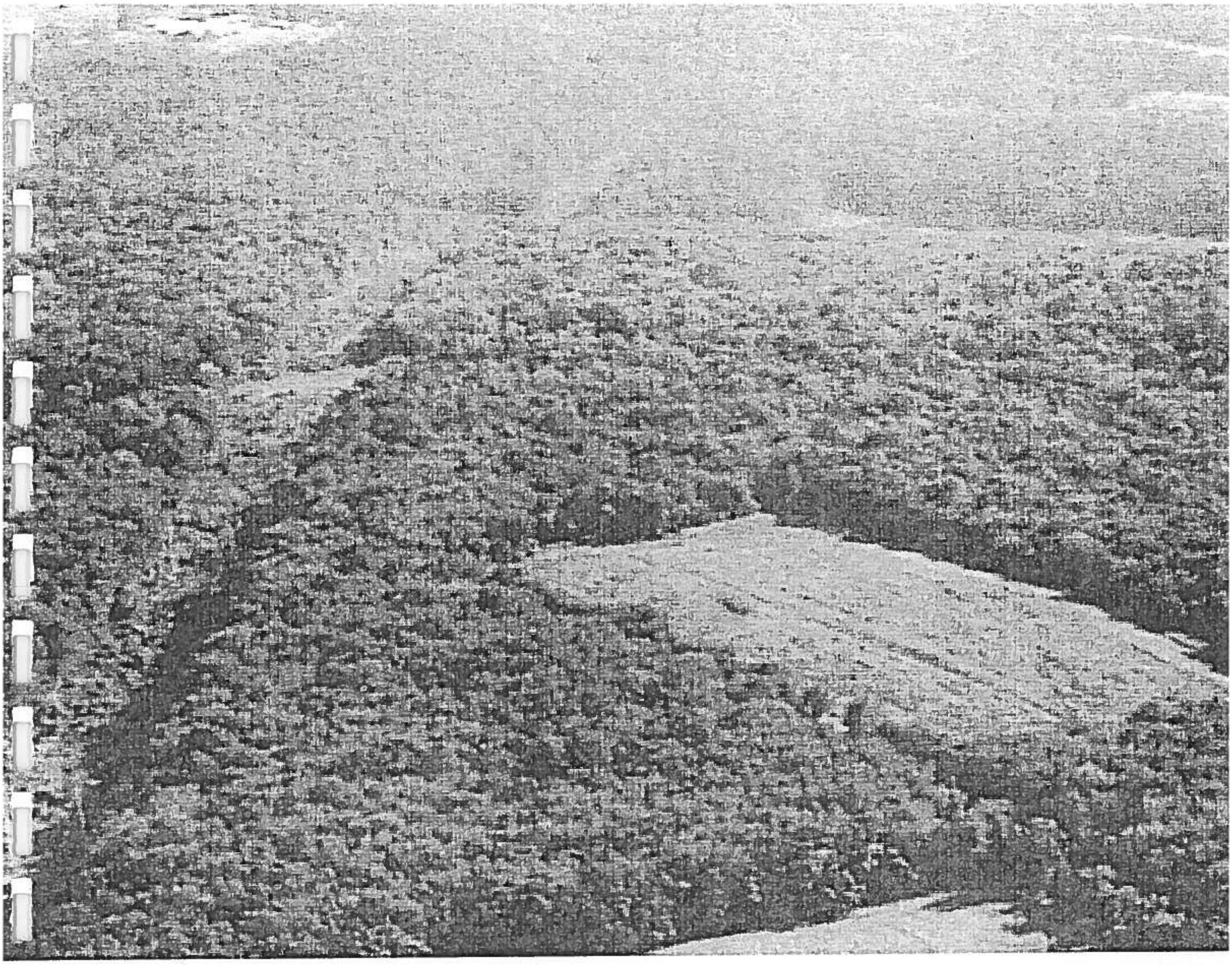












APPENDIX I(A)

TEST BORING / RESISTIVITY TEST SURVEY INFORMATION

RECEIVED
OCT 04 2000
20122.00

STEIN SURVEY

998 POND MEADOW RD
POST OFFICE BOX 1097
WESTBROOK, CT 06498

(860)399-5269 TELEPHONE
(860)399-8356 FAX
SURVEYOR@SNET.NET

October 4, 2000

Mr. J. Matthew Bellisle, PE
Pare Engineering Corporation
49 Walpole Street, Suite 2
Norwood, MA 02062

Re: Layout positions of test borings and resistivity tests
Towantic Energy Center, Oxford, CT

AS STAKED POSITIONS

HORIZONTAL DATUM: STATE PLANE COORDINATE SYSTEM, NORTH AMERICAN DATUM OF 1927
VERTICAL DATUM: NATIONAL GEODETIC VERTICAL DATUM OF 1929 (GROUND ELEVATIONS).

NORTH	EAST	ELEV.	TEST#
237131.4	498022.0	831.7	R-7
237323.0	497957.9	836.3	R-5
237457.2	497930.5	840.0	R-6
237347.7	497806.6	833.2	R-3
237323.0	497702.2	822.1	R-1
237387.4	497639.8	818.4	R-2
237415.8	497759.3	833.3	R-4
237649.2	497763.9	845.3	R-10
237746.5	497740.8	849.7	R-8
237674.1	497653.1	839.8	R-9
237402.0	497604.7	815.2	B-104
237430.3	497725.0	831.1	B-108
237312.1	497656.0	816.6	B-103
237341.4	497779.9	831.2	B-107
237452.8	497964.3	838.9	B-111
237335.8	498033.8	833.3	B-112
237356.8	497988.3	836.0	B-110
237317.1	497933.9	836.3	B-109
237201.5	498087.1	827.6	B-113
237095.9	498135.0	822.7	B-114
236970.1	498164.4	818.3	B-115
237020.1	498004.0	834.9	B-116
236904.7	497883.4	840.3	B-118
236895.2	497710.6	825.6	B-119
237098.7	497705.5	826.0	B-101
237128.1	497830.2	831.3	B-105
237028.7	497853.8	836.7	B-117
237276.6	497795.7	829.1	B-106
237246.5	497670.4	819.6	B-102
237697.3	497940.8	845.6	B-120
237767.1	498005.3	845.7	B-121

APPENDIX I(B)

TEST BORING LOGS

PARE ENGINEERING CORPORATION

49 WALPOLE STREET, SUITE 2, NORWOOD, MASSACHUSETTS

ENGINEERS *** PLANNERS *** CONSULTANTS

BORING NO. B101

SHEET 1 OF 1

PROJECT: Towantic Energy Center, Oxford, CT

PROJECT NO. 00172 00

CHKD. BY JMB

BORING CO. Parratt-Wolff

FOREMAN B. Waters

ENGINEER A. Orsi

BORING LOCATION SEE EXPLORATION LOCATION PLAN

GROUND SURFACE ELEVATION 826 0 DATUM NGVD 1929

DATE START 10/9/00 DATE END 10/9/00

SAMPLER: UNLESS OTHERWISE NOTED, SAMPLER CONSISTS OF A 2" SPLIT SPOON DRIVEN USING A 140 lb. HAMMER FALLING 30 in.

CASING: UNLESS OTHERWISE NOTED, CASING DRIVEN USING 300 lb. HAMMER FALLING 24 IN.

CASING SIZE:

OTHER: 3 3/4 H.S.A.

GROUNDWATER READINGS

DATE	TIME	WATER AT	CASING AT	STABILIZATION TIME
10/13	9:00	8 56	-	4 Days

DEPTH (ft)	CASING (bl/ft)	SAMPLE NO	PEN (in.)/ REC.	DEPTH (FT)	BLOWS/6"	TONS/FT² OR KG/CM²	SAMPLE DESCRIPTION Unified Soil Classification System CLASSIFICATION	REMARKS	STRATUM DESCRIPTION
		S-1	24/18	0-2	1 3		8" topsoil changing to moist, loose, orange silt with		TOPSOIL
					6 6		sand (ML) (Subsoil)		SUBSOIL
		S-2	24/20	2-4	5 7		Moist, m. dense, brown silty sand with gravel (SM)		
					12 14				
5		S-3	24/24	4-6	11 8		Moist, m. dense, brown silty sand with gravel (SM)		
					11 13				
		S-4	24/22	6-8	20 16		Moist, m. dense, brown silty sand with gravel (SM)		
					15 53			1	SILTY SAND
		S-5	24/24	8-10	15 12		Moist, m. dense, brown silty sand with gravel (SM)		WITH GRAVEL
10					17 16			∇	(SM)
		S-6	24/24	10-12	6 11		Moist, dense, brown silty sand with gravel (SM)		
					12 14				
15									
		S-7	24/24	15-17	10 14		Moist, dense, brown silty sand with gravel (SM)		
					17 22				
20									
		S-8	24/24	20-22	7 18		Moist, dense, gray-brown sandy silt with gravel (ML)		SANDY SILT
					24 25				WITH GRAVEL
									(ML)
25									
		S-9	24/24	25-27	8 19		Moist, dense, gray-brown sandy silt with gravel (ML)		
					30 28				
		S-10	24/24	27-29	17 23		Moist, dense, gray-brown sandy silt with gravel (ML)		
					26 31				
30							END EXPLORATION @ 29'		

GRANULAR SOILS BLOWS/FT	DENSITY	COHESIVE SOILS BLOWS/FT	DENSITY
0 - 4	V. LOOSE	<2	V SOFT
4 - 10	LOOSE	2 - 4	SOFT
10 - 30	M DENSE	4 - 8	M STIFF
30 - 50	DENSE	8 - 15	STIFF
>50	V DENSE	15 - 30	V STIFF
		>30	HARD

REMARKS:

1. Grinding at 7.5' - 8.0'.
2. Hole grouted to ground surface upon completion of boring.

UNIFIED CLASSIFICATION	
Gravel	G
Sand	S
Silt	M
Clay	C

Description shall reference USCS classification chart

NOTES:

a) THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES, TRANSITIONS MAY BE GRADUAL. SOLID LINES INDICATE AN OBSERVED SOIL CHANGE. DASHED LINES INDICATE AN APPROXIMATED SOIL BOUNDARY.

b) WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT TIMES AND UNDER CONDITIONS STATED ON THE BORING LOGS. FLUCTUATIONS IN THE LEVEL OF GROUNDWATER MAY OCCUR DUE TO OTHER FACTORS THAN THOSE PRESENT AT THE TIME MEASUREMENTS WERE MADE.

c) STANDARD PENETRATION RESISTANCE, N-VALUE, IS THE NUMBER OF BLOWS REQUIRED TO DRIVE THE SAMPLER FROM 6-18 INCHES OF PENETRATION.

d) UNCONFINED COMPRESSION STRENGTH, Qu, WAS DETERMINED FROM THE SPLIT SPOON SAMPLE UTILIZING A POCKET PENETROMETER.

e) TO CONVERT FEET TO METERS MULTIPLY BY $3.048X10^{-1}$

BORING NO. B101

PARE ENGINEERING CORPORATION

49 WALPOLE STREET, SUITE 2, NORWOOD, MASSACHUSETTS
ENGINEERS *** PLANNERS *** CONSULTANTS

BORING NO. B102
SHEET 1 OF 1

PROJECT: Towantic Energy Center, Oxford, CT
PROJECT NO.: 00172.00
CHKD. BY: JMR

BORING CO.: Parratt-Wolff
FOREMAN: B. Waters
ENGINEER: A. Orsi
BORING LOCATION: SEE EXPLORATION LOCATION PLAN
GROUND SURFACE ELEVATION: 819.6 DATUM: NGVD 1929
DATE START: 10/5/00 DATE END: 10/5/00

SAMPLER: UNLESS OTHERWISE NOTED, SAMPLER CONSISTS OF A 2" SPLIT SPOON DRIVEN USING A 140 lb. HAMMER FALLING 30 in.

CASING: UNLESS OTHERWISE NOTED, CASING DRIVEN USING 300 lb. HAMMER FALLING 24 IN.

CASING SIZE:
OTHER: 3 3/4 H.S.A.

GROUNDWATER READINGS

DATE	TIME	WATER AT	CASING AT	STABILIZATION TIME
10/6		Dry to 15'	-	1 Day

DEPTH (ft)	CASING (bl/ft)	SAMPLE NO	PEN. (in.)/ REC.	DEPTH (FT)	BLOWS/6"	TONS/FT² OR KG/CM²	SAMPLE DESCRIPTION Unified Soil Classification System CLASSIFICATION	REMARKS	STRATUM DESCRIPTION
		S-1	24/6	0-2	1 2		6" topsoil changing to loose, moist, orange silt with		TOPSOIL
					4 4		sand (ML) (Subsoil)		SUBSOIL
		S-2	24/20	2-4	8 10		Moist, m. dense, brown silty sand with gravel (SM)		
					11 12				
5		S-3	24/24	4-6	10 11		Moist, m. dense, brown silty sand with gravel (SM)		
					16 16				
		S-4	24/20	6-8	14 55		Moist, v. dense, brown-gray silty sand with gravel (SM)		
					19 20				
		S-5	24/24	8-10	8 14	3.6	Moist, dense, brown-gray silty sand (SM)		
10					16 17				
		S-6	24/24	10-12	7 35		Moist, v. dense, brown-gray silty sand with clay (SM)		SILTY SAND WITH GRAVEL AND CLAY (SM)
					19 16				
15									
		S-7	24/24	15-17	8 15		Moist, dense, brown-gray silty sand with clay (SM)		
					21 15				
20									
		S-8	24/24	20-22	14 18		Moist, dense, brown-gray silty sand with clay (SM)		
					24 24				
25		S-9	24/24	25-27	14 30		Moist, v. dense, brown-gray silty sand with clay (SM)		
					41 30				
		S-10	24/24	28-30	18 36		Moist, v. dense, brown-grey silty sand with gravel (SM)		
					39 81				
30							END EXPLORATION @ 29'		

GRANULAR SOILS BLOWS/FT	DENSITY	COHESIVE SOILS BLOWS/FT	DENSITY
0 - 4	V. LOOSE	<2	V.SOFT
4 - 10	LOOSE	2 - 4	SOFT
10 - 30	M.DENSE	4 - 8	M.STIFF
30 - 50	DENSE	8 - 15	STIFF
>50	V.DENSE	15 - 30	V.STIFF
		>30	HARD

REMARKS:
1. Hole grouted to ground surface upon completion of boring.

UNIFIED CLASSIFICATION

Gravel	G
Sand	S
Silt	M
Clay	C

Description shall reference USCS classification chart

NOTES:
a) THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES, TRANSITIONS MAY BE GRADUAL. SOLID LINES INDICATE AN OBSERVED SOIL CHANGE. DASHED LINES INDICATE AN APPROXIMATED SOIL BOUNDARY.
b) WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT TIMES AND UNDER CONDITIONS STATED ON THE BORING LOGS. FLUCTUATIONS IN THE LEVEL OF GROUNDWATER MAY OCCUR DUE TO OTHER FACTORS THAN THOSE PRESENT AT THE TIME MEASUREMENTS WERE MADE.
c) STANDARD PENETRATION RESISTANCE, N-VALUE, IS THE NUMBER OF BLOWS REQUIRED TO DRIVE THE SAMPLER FROM 6-18 INCHES OF PENETRATION.
d) UNCONFINED COMPRESSION STRENGTH, Qu, WAS DETERMINED FROM THE SPLIT SPOON SAMPLE UTILIZING A POCKET PENETROMETER.
e) TO CONVERT FEET TO METERS MULTIPLY BY 3.048×10^{-1}

PARE ENGINEERING CORPORATION

49 WALPOLE STREET, SUITE 2, NORWOOD, MASSACHUSETTS
ENGINEERS *** PLANNERS *** CONSULTANTS

BORING NO. B103
SHEET 1 OF 1

PROJECT: Towantic Energy Center, Oxford, CT
PROJECT NO. 00172.00
CHKD. BY JMR

BORING CO. Parratt-Wolff
FOREMAN B. Waters
ENGINEER A. Orsi

BORING LOCATION SEE EXPLORATION LOCATION PLAN
GROUND SURFACE ELEVATION 816.6 DATUM NGVD 1929
DATE START 10/4/00 DATE END 10/4/00

SAMPLER: UNLESS OTHERWISE NOTED, SAMPLER CONSISTS OF A 2" SPLIT SPOON DRIVEN USING A 140 lb. HAMMER FALLING 30 in.

CASING: UNLESS OTHERWISE NOTED, CASING DRIVEN USING 300 lb. HAMMER FALLING 24 IN.

CASING SIZE:

OTHER: 3 3/4 H.S.A.

GROUNDWATER READINGS

DATE	TIME	WATER AT	CASING AT	STABILIZATION TIME
10/4	2:55	2.9	30	
10/4	3:15	5.0	-	

DEPTH (ft)	CASING (bl/ft)	SAMPLE NO.	PEN. (in.)/ REC.	DEPTH (FT)	BLOWS/6"	TONS/FT² OR KG/CM²	SAMPLE DESCRIPTION Unified Soil Classification System CLASSIFICATION	REMARKS	STRATUM DESCRIPTION
		S-1	24/12	0-2	1 2		8" topsoil changing to moist, loose, brown-orange, silty		TOPSOIL
					8 13		sand (SM) with gravel (Subsoil)		SUBSOIL
		S-2	24/20	2-4	10 13		Moist, m. dense, brown-orange silty sand (SM)		SILTY SAND
					11 10			▽	AND GRAVEL
5		S-3	24/10	4-6	6 11		Wet, m. dense, orange silty sand (SM)		(SM)
					13 9				
		S-4	24/24	6-8	8 7		Wet, m. dense, brown-orange silty sand (SM)		
					8 7				
		S-5	24/24	8-10	4 6		Moist, m. dense, brown silty sand with clay (SM)		
10					11 11				
		S-6	24/24	10-12	11 12		Wet, m. dense, brown sitly sand with gravel and clay (SM)		SILTY SAND
					15 11				WITH GRAVEL AND CLAY
									(SM)
15									
		S-7	24/18	15-17	4 5		Wet, m. dense, brown silty sand with gravel (SM)		
					10 9				
20									
		S-8	24/18	20-22	5 8	4.0	Wet, m. dense, brown silty sand with gravel (SM)		
					21 13				
25									
		S-9	24/20	25-27	21 28		Wet, v. dense, brown silty sand (SM)		
					28 52				
		S-10	24/24	28-30	20 30		Wet, v. dense, brown silty sand (SM)		
30					42 44				
							END EXPLORATION @ 30'		

GRANULAR SOILS BLOWS/FT	DENSITY	COHESIVE SOILS BLOWS/FT	DENSITY
0 - 4	V. LOOSE	<2	V.SOFT
4 - 10	LOOSE	2 - 4	SOFT
10 - 30	M.DENSE	4 - 8	M.STIFF
30 - 50	DENSE	8 - 15	STIFF
>50	V.DENSE	15 - 30	V.STIFF
		>30	HARD

REMARKS:
1. Hole grouted to ground surface upon completion of boring.

UNIFIED CLASSIFICATION

Gravel	G
Sand	S
Silt	M
Clay	C

Description shall reference USCS classification chart

NOTES:
a) THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES, TRANSITIONS MAY BE GRADUAL. SOLID LINES INDICATE AN OBSERVED SOIL CHANGE. DASHED LINES INDICATE AN APPROXIMATED SOIL BOUNDARY.
b) WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT TIMES AND UNDER CONDITIONS STATED ON THE BORING LOGS. FLUCTUATIONS IN THE LEVEL OF GROUNDWATER MAY OCCUR DUE TO OTHER FACTORS THAN THOSE PRESENT AT THE TIME MEASUREMENTS WERE MADE.
c) STANDARD PENETRATION RESISTANCE, N-VALUE, IS THE NUMBER OF BLOWS REQUIRED TO DRIVE THE SAMPLER FROM 6-18 INCHES OF PENETRATION.
d) UNCONFINED COMPRESSION STRENGTH, Qu, WAS DETERMINED FROM THE SPLIT SPOON SAMPLE UTILIZING A POCKET PENETROMETER.
e) TO CONVERT FEET TO METERS MULTIPLY BY $3.048X10^{-1}$

BORING NO. B103

PARE ENGINEERING CORPORATION

49 WALPOLE STREET, SUITE 2, NORWOOD, MASSACHUSETTS
ENGINEERS *** PLANNERS *** CONSULTANTS

BORING NO. B104
SHEET 1 OF 1

PROJECT: Towantic Energy Center, Oxford, CT
PROJECT NO. 00172.00
CHKD. BY [illegible]

BORING CO. Parratt-Wolff
FOREMAN B. Waters
ENGINEER A. Orsi

BORING LOCATION SEE EXPLORATION LOCATION PLAN
GROUND SURFACE ELEVATION 815.2 DATUM NGVD 1929
DATE START 10/4/00 DATE END 10/4/00

SAMPLER: UNLESS OTHERWISE NOTED, SAMPLER CONSISTS OF A 2" SPLIT SPOON DRIVEN USING A 140 lb. HAMMER FALLING 30 in.

CASING: UNLESS OTHERWISE NOTED, CASING DRIVEN USING 300 lb. HAMMER FALLING 24 IN.

CASING SIZE:
OTHER: 3 3/4 H.S.A.

GROUNDWATER READINGS

DATE	TIME	WATER AT	CASING AT	STABILIZATION TIME
10/6		5.4	-	2 Days

DEPTH (ft)	CASING (bl/ft)	SAMPLE NO.	PEN. (in.)/ REC.	DEPTH (FT)	BLOWS/6"	TONS/FT² OR KG/CM²	SAMPLE DESCRIPTION Unified Soil Classification System CLASSIFICATION	REMARKS	STRATUM DESCRIPTION
		S-1	24/12	0-2	2 2		Moist, loose, orange silt with sand (ML) (SUBSOIL)		SUBSOIL
					4 9				
		S-2	24/12	2-4	6 11		Moist, m. dense, brown silty sand with gravel (SM)		SILTY SAND WITH GRAVEL (SM)
					15 14				
5		S-3	24/0	4-6	8 13		No recovery	∇	
					17 15				
		S-4	24/1	6-8	8 9		Moist, m. dense, brown silty sand with gravel (SM)	1.	
					10 10				
		S-5	24/20	8-10	5 8	2.4	Moist, m. dense, brown sandy silt with gravel (ML)		SANDY SILT WITH GRAVEL (ML)
10					10 11				
		S-6	24/24	10-12	3 6		Moist, m. dense, brown sandy silt with gravel (ML)		
					10 10				
15									
		S-7	24/18	15-17	6 13		Moist, m. dense, brown, sandy silt with gravel (ML)		
					13 19				
20									
		S-8	18/18	20-22	29 52		Moist, v. dense, brown, sandy silt with gravel (ML) several cobble fragments		
					70/5"				
		S-9	24/12	23-25	39 33				SILTY SAND WITH GRAVEL (SM)
25					35 62		Moist, v. dense, brown silty sand with gravel (SM)		
							END EXPLORATION @ 25'		
30									

GRANULAR SOILS BLOWS/FT	DENSITY	COHESIVE SOILS BLOWS/FT	DENSITY
0 - 4	V. LOOSE	<2	V.SOFT
4 - 10	LOOSE	2 - 4	SOFT
10 - 30	M.DENSE	4 - 8	M.STIFF
30 - 50	DENSE	8 - 15	STIFF
>50	V.DENSE	15 - 30	V.STIFF
		>30	HARD

REMARKS:
1. Pushed cobbles from 4-8'.
2. Hole grouted to ground surface upon completion of boring.

UNIFIED CLASSIFICATION

Gravel	G
Sand	S
Silt	M
Clay	C

Description shall reference USCS classification chart

NOTES:
a) THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES, TRANSITIONS MAY BE GRADUAL. SOLID LINES INDICATE AN OBSERVED SOIL CHANGE. DASHED LINES INDICATE AN APPROXIMATED SOIL BOUNDARY.
b) WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT TIMES AND UNDER CONDITIONS STATED ON THE BORING LOGS. FLUCTUATIONS IN THE LEVEL OF GROUNDWATER MAY OCCUR DUE TO OTHER FACTORS THAN THOSE PRESENT AT THE TIME MEASUREMENTS WERE MADE.
c) STANDARD PENETRATION RESISTANCE, N-VALUE, IS THE NUMBER OF BLOWS REQUIRED TO DRIVE THE SAMPLER FROM 6-18 INCHES OF PENETRATION.
d) UNCONFINED COMPRESSION STRENGTH, Qu, WAS DETERMINED FROM THE SPLIT SPOON SAMPLE UTILIZING A POCKET PENETROMETER.
e) TO CONVERT FEET TO METERS MULTIPLY BY 3.048×10^{-1}

PARE ENGINEERING CORPORATION 49 WALPOLE STREET, SUITE 2, NORWOOD, MASSACHUSETTS ENGINEERS *** PLANNERS *** CONSULTANTS	BORING NO. B105 SHEET 1 OF 1

PROJECT: Towantic Energy Center, Oxford, CT
PROJECT NO. 00172 00
CHKD. BY JMB

BORING CO. Parratt-Wolff
FOREMAN B. Waters
ENGINEER A. Orsi
BORING LOCATION SEE EXPLORATION LOCATION PLAN
GROUND SURFACE ELEVATION 831.3 DATUM NGVD. 1929
DATE START 10/9/00 DATE END 10/9/00

SAMPLER: UNLESS OTHERWISE NOTED, SAMPLER CONSISTS OF A 2" SPLIT SPOON DRIVEN USING A 140 lb. HAMMER FALLING 30 in.

CASING: UNLESS OTHERWISE NOTED, CASING DRIVEN USING 300 lb. HAMMER FALLING 24 IN.

CASING SIZE:
OTHER: 3 $^3/_4$ H.S.A.

GROUNDWATER READINGS

DATE	TIME	WATER AT	CASING AT	STABILIZATION TIME
10/9	2:00	25	25	-
	6:00	5 5	-	

DEPTH (ft)	CASING (bl/ft)	NO.	PEN (in.)/ REC	DEPTH (FT)	BLOWS/6"	TONS/FT² OR KG/CM²	SAMPLE DESCRIPTION (Unified Soil Classification System CLASSIFICATION)	REMARKS	STRATUM DESCRIPTION
		S-1	24/12	0-2	1 3		12" topsoil changes to moist, loose, orange silt with		TOPSOIL
					4 4		sand (ML) (Subsoil)		SUBSOIL
		S-2	24/12	2-4	5 16		Dry, dense, brown well graded sand with silt and gravel		
					32 18		(SW-SM)		
5		S-3	24/24	4-6	12 18		Dry, dense, brown silty sand (SM)		
					16 16				
		S-4	24/20	6-8	32 18		Moist, dense, brown silty sand with gravel (SM)		
					19 17				SILTY SAND
		S-5	24/24	8-10	6 7		Moist, dense, brown silty sand with gravel (SM)		WITH GRAVEL
10					9 10			▽	(SM)
		S-6	24/24	10-12	9 9		Wet, m. dense, brown, well graded sand with gravel (SW)		
					12 14				
15									
		S-7	24/24	15-17	4 6		Wet, m. dense, gray brown sandy silt with gravel (ML)		
					10 12				
								1.	SANDY SILT
									WITH GRAVEL
20									(ML)
		S-8	24/24	20-22	6 11		Wet, m. dense, gray brown sandy silt with gravel (ML)		
					18 24				
25									
		S-9	24/20	25-27	6 12		Wet, m. dense, gray brown sandy silt with gravel (ML)		
					45 35				
		S-10	24/2	27-29	35 46		Wet, m. dense, gray brown sandy silt with gravel (ML)		
					49 36				
30							END EXPLORATION @ 29'		

GRANULAR SOILS BLOWS/FT	DENSITY	COHESIVE SOILS BLOWS/FT	DENSITY
0 - 4	V LOOSE	<2	V SOFT
4 - 10	LOOSE	2 - 4	SOFT
10 - 30	M DENSE	4 - 8	M STIFF
30 - 50	DENSE	8 - 15	STIFF
>50	V DENSE	15 - 30	V STIFF
		>30	HARD

REMARKS:
1. Sandy silt liquid cuttings as in 102 and 119.
2. Hole grouted to ground surface upon completion of boring.

UNIFIED CLASSIFICATION

Gravel	G
Sand	S
Silt	M
Clay	C

Description shall reference USCS classification chart

NOTES:
a) THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES, TRANSITIONS MAY BE GRADUAL. SOLID LINES INDICATE AN OBSERVED SOIL CHANGE. DASHED LINES INDICATE AN APPROXIMATED SOIL BOUNDARY.
b) WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT TIMES AND UNDER CONDITIONS STATED ON THE BORING LOGS. FLUCTUATIONS IN THE LEVEL OF GROUNDWATER MAY OCCUR DUE TO OTHER FACTORS THAN THOSE PRESENT AT THE TIME MEASUREMENTS WERE MADE.
c) STANDARD PENETRATION RESISTANCE, N-VALUE, IS THE NUMBER OF BLOWS REQUIRED TO DRIVE THE SAMPLER FROM 6-18 INCHES OF PENETRATION.
d) UNCONFINED COMPRESSION STRENGTH, Qu, WAS DETERMINED FROM THE SPLIT SPOON SAMPLE UTILIZING A POCKET PENETROMETER.
e) TO CONVERT FEET TO METERS MULTIPLY BY 3.048×10^{-1}

BORING NO. B105

PARE ENGINEERING CORPORATION

49 WALPOLE STREET, SUITE 2, NORWOOD, MASSACHUSETTS

ENGINEERS *** PLANNERS *** CONSULTANTS

BORING NO. B106

SHEET 1 OF 1

PROJECT: Towantic Energy Center, Oxford, CT

PROJECT NO. 00172.00

CHKD. BY JMB

BORING CO. Parratt-Wolff

FOREMAN B. Waters

ENGINEER A. Orsi

BORING LOCATION SEE EXPLORATION LOCATION PLAN

GROUND SURFACE ELEVATION 829.1 DATUM NGVD. 1929

DATE START 10/10/00 DATE END 10/10/00

SAMPLER: UNLESS OTHERWISE NOTED, SAMPLER CONSISTS OF A 2" SPLIT SPOON DRIVEN USING A 140 lb. HAMMER FALLING 30 in.

CASING: UNLESS OTHERWISE NOTED, CASING DRIVEN USING 300 lb. HAMMER FALLING 24 IN.

CASING SIZE:

OTHER: 3 ¾ H.S.A.

GROUNDWATER READINGS

DATE	TIME	WATER AT	CASING AT	STABILIZATION TIME
10/13	9:00	10.17	-	3 Days

DEPTH (ft)	CASING (bl/ft)	SAMPLE NO.	PEN. (in.)/ REC.	DEPTH (FT)	BLOWS/6"	TONS/FT² OR KG/CM²	SAMPLE DESCRIPTION (Unified Soil Classification System CLASSIFICATION)	REMARKS	STRATUM DESCRIPTION
		S-1	24/12	0-2	1 2		6" topsoil changing to moist, loose, orange silt with		TOPSOIL
					4 4		sand (ML)		
		S-2	24/12	2-4	16 23		Dry, dense, brown well graded sand with silt and gravel		SAND WITH SILT AND GRAVEL (SW-SM)
					31 25		(SW-SM)		
5		S-3	24/18	4-6	12 11		Dry, dense, brown well graded sand with silt and gravel		
					15 22		(SW-SM)		
		S-4	24/20	6-8	20 48		Dry, dense, brown well graded sand with silt and gravel		
					33 21		(SW-SM)		
		S-5	24/4	8-10	8 14		Moist, dense, brown silty sand with gravel (SM)		SILTY SAND WITH GRAVEL (SM)
10					17 25				
		S-6	24/24	10-12	10 12		Moist, m. dense, brown silty sand with gravel (SM)		
					11 13				
15									
		S-7	24/6	15-17	11 18		Moist, m. dense, brown silty sand with gravel (SM)		
					19 17				
20									
		S-8	24/18	20-22	16 21		Moist, m. dense, brown silty sand with gravel (SM)		
					24 18				
25									
		S-9	24/18	25-27	17 20		Moist, m. dense, brown silty sand with gravel (SM)		
					18 16				
		S-10	24/24	27-29	17 23	2.75	Dense, moist, gray-brown sandy silt with gravel (ML)		SAND SILT WITH GRAVEL (ML)
					27 26				
30							END EXPLORATION @ 29'		

GRANULAR SOILS BLOWS/FT	DENSITY	COHESIVE SOILS BLOWS/FT	DENSITY
0 - 4	V. LOOSE	<2	V.SOFT
4 - 10	LOOSE	2 - 4	SOFT
10 - 30	M.DENSE	4 - 8	M.STIFF
30 - 50	DENSE	8 - 15	STIFF
>50	V.DENSE	15 - 30	V.STIFF
		>30	HARD

REMARKS:

1. Grinding ~7.0-7.5'.
2. Hole grouted to ground surface upon completion of the boring.

UNIFIED CLASSIFICATION

Gravel	G
Sand	S
Silt	M
Clay	C

Description shall reference USCS classification chart

NOTES:
a) THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES, TRANSITIONS MAY BE GRADUAL. SOLID LINES INDICATE AN OBSERVED SOIL CHANGE. DASHED LINES INDICATE AN APPROXIMATED SOIL BOUNDARY.
b) WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT TIMES AND UNDER CONDITIONS STATED ON THE BORING LOGS. FLUCTUATIONS IN THE LEVEL OF GROUNDWATER MAY OCCUR DUE TO OTHER FACTORS THAN THOSE PRESENT AT THE TIME MEASUREMENTS WERE MADE.
c) STANDARD PENETRATION RESISTANCE, N-VALUE, IS THE NUMBER OF BLOWS REQUIRED TO DRIVE THE SAMPLER FROM 6-18 INCHES OF PENETRATION.
d) UNCONFINED COMPRESSION STRENGTH, Qu, WAS DETERMINED FROM THE SPLIT SPOON SAMPLE UTILIZING A POCKET PENETROMETER.
e) TO CONVERT FEET TO METERS MULTIPLY BY $3.048X10^{-1}$

BORING NO. B106

PARE ENGINEERING CORPORATION 49 WALPOLE STREET, SUITE 2, NORWOOD, MASSACHUSETTS ENGINEERS *** PLANNERS *** CONSULTANTS	BORING NO. B107 SHEET 1 OF 2

PROJECT	Towantic Energy Center Oxford, CT	PROJECT NO.	00172.00
		CHKD. BY	JMB

BORING CO.	Parratt-Wolff	BORING LOCATION	SEE EXPLORATION LOCATION PLAN
FOREMAN	B. Waters	GROUND SURFACE ELEVATION	831.2 DATUM NGVD. 1929
ENGINEER	A. Orsi	DATE START	10/3/00 DATE END 10/4/00

SAMPLER: UNLESS OTHERWISE NOTED, SAMPLER CONSISTS OF A 2" SPLIT SPOON DRIVEN USING A 140 lb. HAMMER FALLING 30 in.

CASING: UNLESS OTHERWISE NOTED, CASING DRIVEN USING 300 lb. HAMMER FALLING 24 IN.

CASING SIZE: OTHER: 3 3/4 H.S.A.

GROUNDWATER READINGS

DATE	TIME	WATER AT	CASING AT	STABILIZATION TIME
10/6		Dry	-	2 Days

DEPTH (ft)	CASING (bl/ft)	SAMPLE NO.	PEN. (in.)/ REC.	DEPTH (FT)	BLOWS/6"	TONS/FT² OR KG/CM²	SAMPLE DESCRIPTION Unified Soil Classification System CLASSIFICATION	REMARKS	STRATUM DESCRIPTION
		S-1	24/18	0-2	1 2		8" topsoil changing to loose, moist, orange-brown, silty		TOPSOIL
					3 4		sand (SM) (Subsoil)		SUBSOIL
		S-2	24/16	2-4	3 6		Moist, m. dense, orange-brown silty sand (SM)		
					8 8				
5		S-3	24/24	4-6	8 16		Dry, dense, brown silty sand with gravel (SM)		
					22 19				
		S-4	24/22	6-8	16 32		Dry, dense, brown silty sand with gravel (SM)		
					17 14				
		S-5	24/21	8-10	5 11		Dry, dense, orange-brown silty sand (SM)		
10					21 15				
		S-6	24/22	10-12	8 11		Dry, m. dense, brown silty sand with gravel (SM)		SILTY SAND WITH GRAVEL (SM)
					16 15				
15									
		S-7	24/24	15-17	7 9		Moist, m. dense, brown silty sand with gravel (SM)	1.	
					12 24				
20									
		S-8	24/24	20-22	5 8		Moist, m. dense, brown sandy silt (ML)		
					12 19				SANDY SILT (ML)
25									
		S-9	24/24	25-27	7 14		Moist, dense, brown sandy silt (ML)		
					17 19				
		S-10	24/24	28-30	78 87		Moist, v. dense, brown silty sand with gravel (SM)		
30					23 25				

GRANULAR SOILS BLOWS/FT	DENSITY	COHESIVE SOILS BLOWS/FT	DENSITY
0 - 4	V. LOOSE	<2	V.SOFT
4 - 10	LOOSE	2 - 4	SOFT
10 - 30	M.DENSE	4 - 8	M.STIFF
30 - 50	DENSE	8 - 15	STIFF
>50	V.DENSE	15 - 30	V.STIFF
		>30	HARD

REMARKS:
1. Augers steaming indicating tight material.
2. Hole grouted to ground surface upon completion of boring.

UNIFIED CLASSIFICATION	
Gravel	G
Sand	S
Silt	M
Clay	C

Description shall reference USCS classification chart

NOTES:
a) THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES, TRANSITIONS MAY BE GRADUAL. SOLID LINES INDICATE AN OBSERVED SOIL CHANGE. DASHED LINES INDICATE AN APPROXIMATED SOIL BOUNDARY.
b) WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT TIMES AND UNDER CONDITIONS STATED ON THE BORING LOGS. FLUCTUATIONS IN THE LEVEL OF GROUNDWATER MAY OCCUR DUE TO OTHER FACTORS THAN THOSE PRESENT AT THE TIME MEASUREMENTS WERE MADE.
c) STANDARD PENETRATION RESISTANCE, N-VALUE, IS THE NUMBER OF BLOWS REQUIRED TO DRIVE THE SAMPLER FROM 6-18 INCHES OF PENETRATION.
d) UNCONFINED COMPRESSION STRENGTH, Qu, WAS DETERMINED FROM THE SPLIT SPOON SAMPLE UTILIZING A POCKET PENETROMETER.
e) TO CONVERT FEET TO METERS MULTIPLY BY 3.048×10^{-1}

BORING NO. B107

PARE ENGINEERING CORPORATION
49 WALPOLE STREET, SUITE 2, NORWOOD, MASSACHUSETTS
ENGINEERS *** PLANNERS *** CONSULTANTS

BORING NO. B107
SHEET 2 OF 2

PROJECT: Towantic Energy Center, Oxford, CT
PROJECT NO. 00172.00
CHKD. BY: JMG

DEPTH (ft)	CASING (bl/ft)	SAMPLE NO	PEN (in.)/REC	DEPTH (FT)	BLOWS/6"	TONS/FT² OR KG/CM²	SAMPLE DESCRIPTION (Unified Soil Classification System / CLASSIFICATION)	REMARKS	STRATUM DESCRIPTION
		S-11	24/24	33-35	32 24		Moist, v. dense, brown silty sand with gravel (SW-SM)		
35					32 35				
							END EXPLORATION @ 35'		
40									

GRANULAR SOILS		COHESIVE SOILS	
BLOWS/FT	DENSITY	BLOWS/FT	DENSITY
0 - 4	V. LOOSE	<2	V.SOFT
4 - 10	LOOSE	2 - 4	SOFT
10 - 30	M.DENSE	4 - 8	M.STIFF
30 - 50	DENSE	8 - 15	STIFF
>50	V.DENSE	15 - 30	V.STIFF
		>30	HARD

REMARKS:

UNIFIED CLASSIFICATION	
Gravel	G
Sand	S
Silt	M
Clay	C

Description shall reference USCS classification chart

NOTES:
a) THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES, TRANSITIONS MAY BE GRADUAL. SOLID LINES INDICATE AN OBSERVED SOIL CHANGE. DASHED LINES INDICATE AN APPROXIMATED SOIL BOUNDARY.
b) WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT TIMES AND UNDER CONDITIONS STATED ON THE BORING LOGS. FLUCTUATIONS IN THE LEVEL OF GROUNDWATER MAY OCCUR DUE TO OTHER FACTORS THAN THOSE PRESENT AT THE TIME MEASUREMENTS WERE MADE.
c) STANDARD PENETRATION RESISTANCE, N-VALUE, IS THE NUMBER OF BLOWS REQUIRED TO DRIVE THE SAMPLER FROM 6-18 INCHES OF PENETRATION.
d) UNCONFINED COMPRESSION STRENGTH, Qu, WAS DETERMINED FROM THE SPLIT SPOON SAMPLE UTILIZING A POCKET PENETROMETER.
e) TO CONVERT FEET TO METERS MULTIPLY BY $3.048X10^{-1}$

BORING NO. B107

PARE ENGINEERING CORPORATION

49 WALPOLE STREET, SUITE 2, NORWOOD, MASSACHUSETTS
ENGINEERS *** PLANNERS *** CONSULTANTS

BORING NO B108
SHEET 1 OF 1

PROJECT: Towantic Energy Center, Oxford, CT
PROJECT NO. 00172.00
CHKD. BY JMB

BORING CO. Parratt-Wolff
FOREMAN B. Waters
ENGINEER A. Orsi

BORING LOCATION SEE EXPLORATION LOCATION PLAN
GROUND SURFACE ELEVATION 831.1 DATUM NGVD. 1929
DATE START 10/3/00 DATE END 10/4/00

SAMPLER: UNLESS OTHERWISE NOTED, SAMPLER CONSISTS OF A 2" SPLIT SPOON DRIVEN USING A 140 lb. HAMMER FALLING 30 in.

CASING: UNLESS OTHERWISE NOTED, CASING DRIVEN USING 300 lb. HAMMER FALLING 24 IN.

CASING SIZE:

OTHER: 3 3/4 H.S.A.

GROUNDWATER READINGS

DATE	TIME	WATER AT	CASING AT	STABILIZATION TIME
10/4	10:15	10.95	-	16 Hours
10/6		5.35	-	2 Days

DEPTH (ft)	CASING (bl/ft)	SAMPLE NO	PEN (in)/ REC	DEPTH (FT)	BLOWS/6"	TONS/FT² OR KG/CM²	SAMPLE DESCRIPTION Unified Soil Classification System CLASSIFICATION	REMARKS	STRATUM DESCRIPTION
		S-1	24/14	0-2	1 2		4" topsoil changing to moist, loose, brown well graded sand with silt (SW-SM)		TOPSOIL
					2 5				
		S-2	24/12	2-4	3 9		Moist, m. dense, brown silty sand (SM)		SILTY SAND (SM)
					14 14				
5		S-3	24/18	4-6	9 14		Dry, m. dense, brown silty sand (SM)		
					14 14			1.	
		S-4	5/2	6-8	70/5"		Dry, m. dense, brown silty sand (SM)		
		S-5	24/14	8-10	29 15		Dry, m. dense, brown silty sand with gravel and clay (SM)		
10					11 15			2.	SILTY SAND WITH GRAVEL (SM)
		S-6	24/24	10-12	6 12		Dry, v. dense, brown silty sand with gravel and clay (SM)		
					55 25				
15									
		S-7	24/22	15-17	8 13		Dry, m. dense, brown silty sand with gravel and clay (SM)		
					15 17				
20									
		S-8	24/24	20-22	8 11		Dry, m. dense, grey-brown sandy silt (ML)		SANDY SILT (ML)
					14 14				
		S-9	24/12	23-25	26 14		Dry, dense, grey-brown sandy silt (ML)		
25					23 26				
							END EXPLORATION @ 25'		
30									

GRANULAR SOILS BLOWS/FT	DENSITY	COHESIVE SOILS BLOWS/FT	DENSITY
0 - 4	V. LOOSE	<2	V.SOFT
4 - 10	LOOSE	2 - 4	SOFT
10 - 30	M DENSE	4 - 8	M.STIFF
30 - 50	DENSE	8 - 15	STIFF
>50	V DENSE	15 - 30	V.STIFF
		>30	HARD

REMARKS:
1. Grinding at ~6.5'.
2. Grind thru cobble at 11'.
3. Hole grouted to ground surface upon completion of boring.

UNIFIED CLASSIFICATION	
Gravel	G
Sand	S
Silt	M
Clay	C

Description shall reference USCS classification chart

NOTES:
a) THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES, TRANSITIONS MAY BE GRADUAL. SOLID LINES INDICATE AN OBSERVED SOIL CHANGE. DASHED LINES INDICATE AN APPROXIMATED SOIL BOUNDARY.
b) WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT TIMES AND UNDER CONDITIONS STATED ON THE BORING LOGS. FLUCTUATIONS IN THE LEVEL OF GROUNDWATER MAY OCCUR DUE TO OTHER FACTORS THAN THOSE PRESENT AT THE TIME MEASUREMENTS WERE MADE.
c) STANDARD PENETRATION RESISTANCE, N-VALUE, IS THE NUMBER OF BLOWS REQUIRED TO DRIVE THE SAMPLER FROM 6-18 INCHES OF PENETRATION.
d) UNCONFINED COMPRESSION STRENGTH, Qu, WAS DETERMINED FROM THE SPLIT SPOON SAMPLE UTILIZING A POCKET PENETROMETER.
e) TO CONVERT FEET TO METERS MULTIPLY BY $3.048X10^{-1}$

BORING NO. B108

PARE ENGINEERING CORPORATION

49 WALPOLE STREET, SUITE 2, NORWOOD, MASSACHUSETTS
ENGINEERS *** PLANNERS *** CONSULTANTS

BORING NO. B109
SHEET 1 OF 1

PROJECT: Towantic Energy Center, Oxford, CT
PROJECT NO. 00172.00
CHKD. BY JMB

BORING CO. Parratt-Wolff
FOREMAN B. Waters
ENGINEER A. Orsi

BORING LOCATION SEE EXPLORATION LOCATION PLAN
GROUND SURFACE ELEVATION 836.3 DATUM NGVD, 1929
DATE START 10/10/00 DATE END 10/10/00

SAMPLER: UNLESS OTHERWISE NOTED, SAMPLER CONSISTS OF A 2" SPLIT SPOON DRIVEN USING A 140 lb. HAMMER FALLING 30 in.

CASING: UNLESS OTHERWISE NOTED, CASING DRIVEN USING 300 lb. HAMMER FALLING 24 IN.

CASING SIZE:
OTHER: 3 3/4 H.S.A.

GROUNDWATER READINGS

DATE	TIME	WATER AT	CASING AT	STABILIZATION TIME
10/10	1:30	Dry	-	
10/13	9:00	9.15	-	3 Days

DEPTH (ft)	CASING (bl/ft)	SAMPLE NO.	PEN. (in.)/ REC.	DEPTH (FT)	BLOWS/6"	TONS/FT² OR KG/CM²	SAMPLE DESCRIPTION (Unified Soil Classification System / CLASSIFICATION)	REMARKS	STRATUM DESCRIPTION
		S-1	24/18	0-2	5 4		Moist, loose, orange silt with Sand (ML) (Subsoil)	1.	SUBSOIL
					2 4				
		S-2	24/12	2-4	6 8		Moist, m. dense, brown silty sand (SM)		SANDY SILT WITH GRAVEL (ML)/SILTY SAND (SM)
					7 9				
5		S-3	24/24	4-6	7 12		Moist, m. dense, brown sandy silt with gravel (ML)/silty sand (SM)		
					14 14				
		S-4	24/24	6-8	12 17		Moist, m. dense, grey-brown sandy silt with gravel (ML)/ silty sand (SM)		
					18 18				
		S-5	24/1	8-10	12 18		Moist, m. dense, grey-brown sandy silt with gravel (ML)/ silty sand (SM)	2.	
10					21 18				
		S-6	24/22	10-12	7 15		Moist, m. dense, grey-brown sandy silt with gravel (ML)/silty sand (SM)		
					20 21			3.	
15									SILTY SAND WITH GRAVEL (SM)
		S-7	24/24	15-17	16 56		Dry, dense, brown silty sand with gravel (SM)		
					24 24				
20									
		S-8	24/24	20-22	9 17		Dry, dense, brown silty sand with gravel (SM)		
					18 32				
25									SANDY SILT WITH GRAVEL (ML)
		S-9	24/24	25-27	15 23		Moist, v. dense, gray sandy silt with gravel (ML)		
					36 31				
		S-10	24/24	27-29	12 32		Moist, v. dense, gray sandy silt with gravel (ML)		
					31 30				
30							END EXPLORATION @ 29'		

GRANULAR SOILS BLOWS/FT	DENSITY	COHESIVE SOILS BLOWS/FT	DENSITY
0 - 4	V. LOOSE	<2	V.SOFT
4 - 10	LOOSE	2 - 4	SOFT
10 - 30	M DENSE	4 - 8	M.STIFF
30 - 50	DENSE	8 - 15	STIFF
>50	V DENSE	15 - 30	V.STIFF
		>30	HARD

REMARKS:
1. 8" topsoil at the ground surface.
2. Majority of recovery appears to be collapsed topsoil.
3. Switch from HSA + Comp. Air drilling.
4. Hole grouted to ground surface upon completion of boring.

UNIFIED CLASSIFICATION	
Gravel	G
Sand	S
Silt	M
Clay	C

Description shall reference USCS classification chart

NOTES:
a) THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES, TRANSITIONS MAY BE GRADUAL. SOLID LINES INDICATE AN OBSERVED SOIL CHANGE. DASHED LINES INDICATE AN APPROXIMATED SOIL BOUNDARY.
b) WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT TIMES AND UNDER CONDITIONS STATED ON THE BORING LOGS. FLUCTUATIONS IN THE LEVEL OF GROUNDWATER MAY OCCUR DUE TO OTHER FACTORS THAN THOSE PRESENT AT THE TIME MEASUREMENTS WERE MADE.
c) STANDARD PENETRATION RESISTANCE, N-VALUE, IS THE NUMBER OF BLOWS REQUIRED TO DRIVE THE SAMPLER FROM 6-18 INCHES OF PENETRATION.
d) UNCONFINED COMPRESSION STRENGTH, Qu, WAS DETERMINED FROM THE SPLIT SPOON SAMPLE UTILIZING A POCKET PENETROMETER.
e) TO CONVERT FEET TO METERS MULTIPLY BY $3.048X10^{-1}$

BORING NO. B109

PARE ENGINEERING CORPORATION 49 WALPOLE STREET, SUITE 2, NORWOOD, MASSACHUSETTS ENGINEERS *** PLANNERS *** CONSULTANTS	BORING NO. B110 SHEET 1 OF 1

PROJECT: Towantic Energy Center, Oxford, CT
PROJECT NO. 00172.00
CHKD. BY JMB

BORING CO. Parratt-Wolff
FOREMAN B. Waters
ENGINEER A. Orsi

BORING LOCATION SEE EXPLORATION LOCATION PLAN
GROUND SURFACE ELEVATION 836.0 DATUM NGVD 1929
DATE START 10/5/00 DATE END 10/5/00

SAMPLER: UNLESS OTHERWISE NOTED, SAMPLER CONSISTS OF A 2" SPLIT SPOON DRIVEN USING A 140 lb. HAMMER FALLING 30 in.

CASING: UNLESS OTHERWISE NOTED, CASING DRIVEN USING 300 lb. HAMMER FALLING 24 IN.

CASING SIZE: OTHER: 3 $^3/_4$ H.S.A.

GROUNDWATER READINGS

DATE	TIME	WATER AT	CASING AT	STABILIZATION TIME
10/6		Dry	-	1 Day

DEPTH (ft)	CASING (bl/ft)	NO.	PEN. (in.)/ REC.	DEPTH (FT)	BLOWS/6"	TONS/FT² OR KG/CM²	SAMPLE DESCRIPTION Unified Soil Classification System CLASSIFICATION	REMARKS	STRATUM DESCRIPTION
		S-1	20/20	0-2	1 2		8" topsoil changing to moist, loose, orange sandy		TOPSOIL
					4 14		silt (ML) (Subsoil)	1.	SUBSOIL
		S-2	24/24	2-4	10 14		Moist, m. dense, brown silty sand with gravel (SM)		
					12 21				
5		S-3	24/24	4-6	6 11		Moist, m. dense, brown silty sand with gravel (SM)		SILTY SAND WITH GRAVEL (SM)
					22 31				
		S-4	24/24	6-8	19 22		Moist, m. dense, brown silty sand with gravel (SM)		
					14 20				
		S-5	24/24	8-10	6 17		Moist, m. dense, brown silty sand with gravel (SM)		
10					19 14				
		S-6	24/24	10-12	7 13		Moist, dense, grey-brown sandy silt (ML)		
					13 18				
15									
		S-7	24/24	15-17	7 15		Moist, dense, brown sandy silt (ML)		SANDY SILT WITH GRAVEL (ML)
					16 21				
20									
		S-8	24/24	20-22	7 13		Moist, dense, brown sandy silt with gravel (ML)		
					20 19				
		S-9	24/24	23-25	11 26		Moist, v. dense, brown sandy silt with gravel (ML)		
25					25 24				
							END EXPLORATION @ 25'		
30									

GRANULAR SOILS

BLOWS/FT	DENSITY
0 - 4	V. LOOSE
4 - 10	LOOSE
10 - 30	M.DENSE
30 - 50	DENSE
>50	V.DENSE

COHESIVE SOILS

BLOWS/FT	DENSITY
<2	V.SOFT
2 - 4	SOFT
4 - 8	M.STIFF
8 - 15	STIFF
15 - 30	V.STIFF
>30	HARD

REMARKS:
1. Hole grouted to ground surface upon completion of boring.

UNIFIED CLASSIFICATION

Gravel	G
Sand	S
Silt	M
Clay	C

Description shall reference USCS classification chart

NOTES:
a) THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES, TRANSITIONS MAY BE GRADUAL. SOLID LINES INDICATE AN OBSERVED SOIL CHANGE. DASHED LINES INDICATE AN APPROXIMATED SOIL BOUNDARY.
b) WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT TIMES AND UNDER CONDITIONS STATED ON THE BORING LOGS. FLUCTUATIONS IN THE LEVEL OF GROUNDWATER MAY OCCUR DUE TO OTHER FACTORS THAN THOSE PRESENT AT THE TIME MEASUREMENTS WERE MADE.
c) STANDARD PENETRATION RESISTANCE, N-VALUE, IS THE NUMBER OF BLOWS REQUIRED TO DRIVE THE SAMPLER FROM 6-18 INCHES OF PENETRATION.
d) UNCONFINED COMPRESSION STRENGTH, Qu, WAS DETERMINED FROM THE SPLIT SPOON SAMPLE UTILIZING A POCKET PENETROMETER.
e) TO CONVERT FEET TO METERS MULTIPLY BY $3.048X10^{-1}$

PARE ENGINEERING CORPORATION

49 WALPOLE STREET, SUITE 2, NORWOOD, MASSACHUSETTS
ENGINEERS *** PLANNERS *** CONSULTANTS

BORING NO. B111
SHEET 1 OF 1

PROJECT: Towantic Energy Center, Oxford, CT
PROJECT NO. 00172.00
CHKD. BY JMG

BORING CO. Parratt-Wolff
FOREMAN B. Waters
ENGINEER A. Orsi

BORING LOCATION: SEE EXPLORATION LOCATION PLAN
GROUND SURFACE ELEVATION 838.9 DATUM NGVD 1929
DATE START 10/10/00 DATE END 10/10/00

SAMPLER: UNLESS OTHERWISE NOTED, SAMPLER CONSISTS OF A 2" SPLIT SPOON DRIVEN USING A 140 lb. HAMMER FALLING 30 in.

CASING: UNLESS OTHERWISE NOTED, CASING DRIVEN USING 300 lb. HAMMER FALLING 24 IN.

CASING SIZE:
OTHER: 3 3/4 H.S.A.

GROUNDWATER READINGS

DATE	TIME	WATER AT	CASING AT	STABILIZATION TIME
10/13	9:00	Dry to 12'	-	3 Days

DEPTH (ft)	CASING (bl/ft)	SAMPLE NO.	PEN. (in.)/ REC.	DEPTH (FT)	BLOWS/6"	TONS/FT² OR KG/CM²	SAMPLE DESCRIPTION Unified Soil Classification System CLASSIFICATION	REMARKS	STRATUM DESCRIPTION
		S-1	20/10	0-2	1 3		8" topsoil changing to loose, moist, orange silt (ML)	1.	TOPSOIL
					6 10		(Subsoil)		SUBSOIL
		S-2	24/-	2-4	-		No sample (cobbles)		COBBLES
					-				
5		S-3	24/18	4-6	19 15		Dry, dense, orange-brown silty sand with gravel (SM)		
					17 19				
		S-4	24/18	6-8	14 19		Dry, dense, orange-brown silty sand with gravel (SM)		
					31 20				
		S-5	24/24	8-10	8 11		Moist, m. dense, brown silty sand (SM)		
10					14 17				
		S-6	24/24	10-12	4 12		Moist, dense, brown silty sand with gravel (SM)		SILTY SAND WITH GRAVEL (SM)
					33 30				
15									
		S-7	24/24	15-17	11 12		Moist, m. dense, brown silty sand with gravel (SM)		
					17 46				
20									
		S-8	24/24	20-22	15 23		Moist, v. dense, brown silty sand with gravel (SM)		
					78 28			▽	
		S-9	9/9	22-23	29 110/3"		Wet, v. dense, brown silty sand with gravel (SM)		
							END EXPLORATION @ 22.75'		
25									
30									

GRANULAR SOILS BLOWS/FT	DENSITY	COHESIVE SOILS BLOWS/FT	DENSITY
0 - 4	V. LOOSE	<2	V.SOFT
4 - 10	LOOSE	2 - 4	SOFT
10 - 30	M.DENSE	4 - 8	M.STIFF
30 - 50	DENSE	8 - 15	STIFF
>50	V.DENSE	15 - 30	V.STIFF
		>30	HARD

REMARKS:
1. Augers grinding from 20" to 4'.
2. Hole grouted to ground surface upon completion of boring.

UNIFIED CLASSIFICATION

Gravel	G
Sand	S
Silt	M
Clay	C

Description shall reference USCS classification chart

NOTES:
a) THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES, TRANSITIONS MAY BE GRADUAL. SOLID LINES INDICATE AN OBSERVED SOIL CHANGE. DASHED LINES INDICATE AN APPROXIMATED SOIL BOUNDARY.
b) WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT TIMES AND UNDER CONDITIONS STATED ON THE BORING LOGS. FLUCTUATIONS IN THE LEVEL OF GROUNDWATER MAY OCCUR DUE TO OTHER FACTORS THAN THOSE PRESENT AT THE TIME MEASUREMENTS WERE MADE
c) STANDARD PENETRATION RESISTANCE, N-VALUE, IS THE NUMBER OF BLOWS REQUIRED TO DRIVE THE SAMPLER FROM 6-18 INCHES OF PENETRATION
d) UNCONFINED COMPRESSION STRENGTH, Qu, WAS DETERMINED FROM THE SPLIT SPOON SAMPLE UTILIZING A POCKET PENETROMETER.
e) TO CONVERT FEET TO METERS MULTIPLY BY 3.048×10^{-1}

PARE ENGINEERING CORPORATION

49 WALPOLE STREET, SUITE 2, NORWOOD, MASSACHUSETTS

ENGINEERS *** PLANNERS *** CONSULTANTS

BORING NO. B112

SHEET 1 OF 1

PROJECT: Towantic Energy Center, Oxford, CT

PROJECT NO. 00172 00

CHKD. BY: JMB

BORING CO. Parratt-Wolff

FOREMAN: B. Waters

ENGINEER: A. Orsi

BORING LOCATION: SEE EXPLORATION LOCATION PLAN

GROUND SURFACE ELEVATION: 833.3 DATUM: NGVD 1929

DATE START: 10/10/00 DATE END: 10/10/00

SAMPLER: UNLESS OTHERWISE NOTED, SAMPLER CONSISTS OF A 2" SPLIT SPOON DRIVEN USING A 140 lb. HAMMER FALLING 30 in.

CASING: UNLESS OTHERWISE NOTED, CASING DRIVEN USING 300 lb. HAMMER FALLING 24 IN.

CASING SIZE:

OTHER: 3 3/4 H.S.A.

GROUNDWATER READINGS

DATE	TIME	WATER AT	CASING AT	STABILIZATION TIME
10/13	9:00	6.29	-	3 Days

DEPTH (ft)	CASING (bl/ft)	SAMPLE NO	PEN (in)/ REC	DEPTH (FT)	BLOWS/6"	TONS/FT² OR KG/CM²	SAMPLE DESCRIPTION (Unified Soil Classification System)	REMARKS	STRATUM DESCRIPTION
		S-1	24/15	0-2	1 2		8" topsoil changing to dry, loose, brown, silt with sand		TOPSOIL
					3 5		and gravel (ML) (Subsoil)		SUBSOIL
		S-2	24/20	2-4	5 13		Moist, m. dense, brown silty sand with gravel (SM)		
					16 26				
5		S-3	24/24	4-6	8 11		Moist, m. dense, brown silty sand with gravel (SM)		SILTY SAND WITH GRAVEL (SM)
					13 13				
		S-4	24/24	6-8	13 16		Moist, dense, brown silty sand with gravel (SM)		
					25 18				
		S-5	24/12	8-10	9 16		Moist, dense, brown silty sand with gravel (SM)		
10					28 22				
		S-6	24/24	10-12	7 10		Moist, m. dense, brown silty sand with gravel (SM)		
					19 17				
15									
		S-7	24/24	15-17	12 19		Moist, dense, brown silt with sand and gravel (ML)		SANDY SILT WITH GRAVEL (ML)
					25 28				
20									
		S-8	24/24	20-22	17 11		Moist, dense, brown sandy silt and gravel (ML)		
					24 17				
		S-9	24/24	22-24	17 28		Moist, v. dense, brown sandy silt and gravel (ML)		
					30 30				
25							END EXPLORATION @ 24'		
30									

GRANULAR SOILS BLOWS/FT	DENSITY	COHESIVE SOILS BLOWS/FT	DENSITY
0 - 4	V. LOOSE	<2	V.SOFT
4 - 10	LOOSE	2 - 4	SOFT
10 - 30	M.DENSE	4 - 8	M.STIFF
30 - 50	DENSE	8 - 15	STIFF
>50	V.DENSE	15 - 30	V.STIFF
		>30	HARD

REMARKS:

1. Hole grouted to ground surface upon completion of boring.

UNIFIED CLASSIFICATION

Gravel	G
Sand	S
Silt	M
Clay	C

Description shall reference USCS classification chart

NOTES:
a) THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES, TRANSITIONS MAY BE GRADUAL. SOLID LINES INDICATE AN OBSERVED SOIL CHANGE. DASHED LINES INDICATE AN APPROXIMATED SOIL BOUNDARY.
b) WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT TIMES AND UNDER CONDITIONS STATED ON THE BORING LOGS. FLUCTUATIONS IN THE LEVEL OF GROUNDWATER MAY OCCUR DUE TO OTHER FACTORS THAN THOSE PRESENT AT THE TIME MEASUREMENTS WERE MADE.
c) STANDARD PENETRATION RESISTANCE, N-VALUE, IS THE NUMBER OF BLOWS REQUIRED TO DRIVE THE SAMPLER FROM 6-18 INCHES OF PENETRATION
d) UNCONFINED COMPRESSION STRENGTH, Qu, WAS DETERMINED FROM THE SPLIT SPOON SAMPLE UTILIZING A POCKET PENETROMETER.
e) TO CONVERT FEET TO METERS MULTIPLY BY $3.048X10^{-1}$

BORING NO. B112

PARE ENGINEERING CORPORATION

49 WALPOLE STREET, SUITE 2, NORWOOD, MASSACHUSETTS

ENGINEERS *** PLANNERS *** CONSULTANTS

BORING NO. B113

SHEET 1 OF 1

PROJECT: Towantic Energy Center, Oxford, CT

PROJECT NO. 00172.00

CHKD. BY JMB

BORING CO. Parratt-Wolff

FOREMAN B. Waters

ENGINEER A. Orsi

BORING LOCATION SEE EXPLORATION LOCATION PLAN

GROUND SURFACE ELEVATION 827.6 DATUM NGVD, 1929

DATE START 10/11/00 DATE END 10/11/00

SAMPLER: UNLESS OTHERWISE NOTED, SAMPLER CONSISTS OF A 2" SPLIT SPOON DRIVEN USING A 140 lb. HAMMER FALLING 30 in.

CASING: UNLESS OTHERWISE NOTED, CASING DRIVEN USING 300 lb. HAMMER FALLING 24 IN.

CASING SIZE:

OTHER: 3 3/4 H.S.A.

GROUNDWATER READINGS

DATE	TIME	WATER AT	CASING AT	STABILIZATION TIME
10/11	9:00	Dry	10'	-
10/13	9:00	7.33	-	2 Days

DEPTH (ft)	CASING (bl/ft)	SAMPLE NO.	PEN. (in.)/ REC.	DEPTH (FT)	BLOWS/6"	TONS/FT² OR KG/CM²	SAMPLE DESCRIPTION (Unified Soil Classification System / CLASSIFICATION)	REMARKS	STRATUM DESCRIPTION
		S-1	24/15	0-2	2 2		8" topsoil changing to moist, loose, orange sandy silt (ML)		TOPSOIL
					3 6				SUBSOIL
		S-2	24/24	2-4	6 8		Moist, m. dense, brown silty sand with gravel (SM)		
					10 13				
5		S-3	24/24	4-6	7 21		Moist, dense, orange-brown silty sand with gravel (SM)		
					15 21				
		S-4	24/24	6-8	9 13		Moist, dense, brown silty sand with gravel (SM)	1.	
					17 16				SILTY SAND WITH GRAVEL (SM)
		S-5	24/24	8-10	5 12		Moist, dense, brown sandy silt with gravel (ML)		
10					17 16				
		S-6	24/24	10-12	10 23		Moist, dense, brown silty sand with gravel (SM)		
					19 20			2.	
15									
		S-7	24/15	15-17	24 40		Moist, v. dense, brown silty sand with gravel (SM)		
					35 51			3.	
20									
		S-8	24/24	20-22	15 27		Moist, v. dense, brown silty sand with gravel (SM)		
					28 28				
		S-9	24/24	22-24	19 30		Moist, v. dense, brown silty sand with gravel (SM)		
					29 26				
25							END EXPLORATION @ 24'		
30									

GRANULAR SOILS BLOWS/FT	DENSITY	COHESIVE SOILS BLOWS/FT	DENSITY
0 - 4	V. LOOSE	<2	V.SOFT
4 - 10	LOOSE	2 - 4	SOFT
10 - 30	M.DENSE	4 - 8	M.STIFF
30 - 50	DENSE	8 - 15	STIFF
>50	V.DENSE	15 - 30	V.STIFF
		>30	HARD

REMARKS:

1. Grinding on cobble at ~7".
2. Switched from HSA to compressed air drilling.
3. Griinding at 16'.
4. Hole grouted to ground surface upon completion of boring.

UNIFIED CLASSIFICATION

Gravel	G
Sand	S
Silt	M
Clay	C

Description shall reference USCS classification chart

NOTES:
a) THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES, TRANSITIONS MAY BE GRADUAL. SOLID LINES INDICATE AN OBSERVED SOIL CHANGE. DASHED LINES INDICATE AN APPROXIMATED SOIL BOUNDARY.
b) WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT TIMES AND UNDER CONDITIONS STATED ON THE BORING LOGS. FLUCTUATIONS IN THE LEVEL OF GROUNDWATER MAY OCCUR DUE TO OTHER FACTORS THAN THOSE PRESENT AT THE TIME MEASUREMENTS WERE MADE.
c) STANDARD PENETRATION RESISTANCE, N-VALUE, IS THE NUMBER OF BLOWS REQUIRED TO DRIVE THE SAMPLER FROM 6-18 INCHES OF PENETRATION.
d) UNCONFINED COMPRESSION STRENGTH, Qu, WAS DETERMINED FROM THE SPLIT SPOON SAMPLE UTILIZING A POCKET PENETROMETER.
e) TO CONVERT FEET TO METERS MULTIPLY BY 3.048×10^{-1}

BORING NO. B113

PARE ENGINEERING CORPORATION

49 WALPOLE STREET, SUITE 2, NORWOOD, MASSACHUSETTS
ENGINEERS *** PLANNERS *** CONSULTANTS

BORING NO. B114
SHEET 1 OF 1

PROJECT: Towantic Energy Center, Oxford, CT
PROJECT NO. 00172.00
CHKD. BY JMB

BORING CO. Parratt-Wolff
FOREMAN B. Waters
ENGINEER A. Orsi

BORING LOCATION SEE EXPLORATION LOCATION PLAN
GROUND SURFACE ELEVATION 822.7 DATUM NGVD 1929
DATE START 10/11/00 DATE END 10/11/00

SAMPLER: UNLESS OTHERWISE NOTED, SAMPLER CONSISTS OF A 2" SPLIT SPOON DRIVEN USING A 140 lb. HAMMER FALLING 30 in.

CASING: UNLESS OTHERWISE NOTED, CASING DRIVEN USING 300 lb. HAMMER FALLING 24 IN.

CASING SIZE: OTHER: $3\,^3/_4$ H.S.A.

GROUNDWATER READINGS

DATE	TIME	WATER AT	CASING AT	STABILIZATION TIME
10/11	12:00	Dry	10'	-
10/13	9:00	5.37	-	2 Days

DEPTH (ft)	CASING (bl/ft)	SAMPLE NO	PEN. (in.)/ REC.	DEPTH (FT)	BLOWS/6"	TONS/FT² OR KG/CM²	SAMPLE DESCRIPTION (Unified Soil Classification System CLASSIFICATION)	REMARKS	STRATUM DESCRIPTION
		S-1	24/12	0-2	1 3		6" topsoil changing to moist, loose, orange silt with		TOPSOIL
					3 10		sand (ML) (Subsoil)		SUBSOIL
		S-2	24/18	2-4	7 11		Moist, m. dense, brown silty sand with gravel (SM)		
					13 13				
5		S-3	24/24	4-6	6 9		Moist, m. dense, brown-grey silty sand with gravel (SM)		
					15 11				
		S-4	24/24	6-8	14 13		Moist, m. dense, brown-grey silty sand with gravel (SM)		
					16 19				SILTY SAND
		S-5	24/24	8-10	5 11				WITH GRAVEL
10					13 17				(SM)
		S-6	24/3	10-12	9 17		Moist, dense, brown-grey silty sand with gravel (SM)		
					18 20			1.	
15									
		S-7	24/24	15-17	13 23		Moist, dense, brown-grey silty sand with gravel (SM)		
					27 31				
20									
		S-8	24/24	20-22	15 22		Moist, dense, brown-grey silty sand with gravel (SM)		
					25 24				
		S-9	24/24	22-24	29 38		Moist, v. dense, brown-grey silty sand with gravel (SM)		
					55 36				
25							END EXPLORATION @24'		
30									

GRANULAR SOILS BLOWS/FT	DENSITY	COHESIVE SOILS BLOWS/FT	DENSITY
0 - 4	V. LOOSE	<2	V.SOFT
4 - 10	LOOSE	2 - 4	SOFT
10 - 30	M.DENSE	4 - 8	M.STIFF
30 - 50	DENSE	8 - 15	STIFF
>50	V.DENSE	15 - 30	V.STIFF
		>30	HARD

REMARKS:
1. Switched from HSA to compressed air drilling.
2. Hole grouted to ground surface upon completion of boring.

UNIFIED CLASSIFICATION

Gravel	G
Sand	S
Silt	M
Clay	C

Description shall reference USCS classification chart

NOTES:
a) THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES, TRANSITIONS MAY BE GRADUAL. SOLID LINES INDICATE AN OBSERVED SOIL CHANGE. DASHED LINES INDICATE AN APPROXIMATED SOIL BOUNDARY.
b) WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT TIMES AND UNDER CONDITIONS STATED ON THE BORING LOGS. FLUCTUATIONS IN THE LEVEL OF GROUNDWATER MAY OCCUR DUE TO OTHER FACTORS THAN THOSE PRESENT AT THE TIME MEASUREMENTS WERE MADE.
c) STANDARD PENETRATION RESISTANCE, N-VALUE, IS THE NUMBER OF BLOWS REQUIRED TO DRIVE THE SAMPLER FROM 6-18 INCHES OF PENETRATION.
d) UNCONFINED COMPRESSION STRENGTH, Qu, WAS DETERMINED FROM THE SPLIT SPOON SAMPLE UTILIZING A POCKET PENETROMETER.
e) TO CONVERT FEET TO METERS MULTIPLY BY 3.048×10^{-1}

PARE ENGINEERING CORPORATION

49 WALPOLE STREET, SUITE 2, NORWOOD, MASSACHUSETTS

ENGINEERS *** PLANNERS *** CONSULTANTS

BORING NO. B115

SHEET 1 OF 1

PROJECT: Towantic Energy Center, Oxford, CT

PROJECT NO. 00172.00

CHKD. BY VMB

BORING CO. Parratt-Wolff
FOREMAN B. Waters
ENGINEER A. Orsi

BORING LOCATION: SEE EXPLORATION LOCATION PLAN
GROUND SURFACE ELEVATION 818.3 DATUM NGVD. 1929
DATE START 10/11/00 DATE END 10/11/00

SAMPLER: UNLESS OTHERWISE NOTED, SAMPLER CONSISTS OF A 2" SPLIT SPOON DRIVEN USING A 140 lb. HAMMER FALLING 30 in.

CASING: UNLESS OTHERWISE NOTED, CASING DRIVEN USING 300 lb. HAMMER FALLING 24 IN.

CASING SIZE:

OTHER: 3 3/4 H.S.A.

GROUNDWATER READINGS

DATE	TIME	WATER AT	CASING AT	STABILIZATION TIME
10/13	9:00	Dry to 10'	-	2 Days

DEPTH (ft)	CASING (bl/ft)	SAMPLE NO.	PEN. (in.)/ REC.	DEPTH (FT)	BLOWS/6"	TONS/FT² OR KG/CM²	SAMPLE DESCRIPTION Unified Soil Classification System CLASSIFICATION	REMARKS	STRATUM DESCRIPTION
		S-1	18/8	0-2	2 3		5" topsoil changing to moist, loose, orange silt with	1.	TOPSOIL
					10 20/0"		sand (ML) (Subsoil)	2.	SUBSOIL
		S-2	24/20	2-4	6 9		Dry, m. dense, brown silty sand with gravel (SM)		
					11 21				
5		S-3	15/12	4-6	28 37		Dry, m. dense, brown silty sand with gravel (SM)		
					50/3"				
		S-4	-	6-8	-		No sample (cobble)	3.	
					-				
		S-5	18/12	8-10	28 22		Dense, moist, orange-brown silty sand with gravel (SM)		
10					23 30/0"				
		S-6	10/8	10-12	25 60/4"		Dense, moist, orange-brown silty sand with gravel (SM)	4.	SILTY SAND WITH GRAVEL (SM)
15									
		S-7	24/24	15-17	15 23		Wet, dense, orange-brown silty sand with gravel (SM)		
					27 24				
20									
		S-8	24/24	20-22	22 32		Wet, dense, orange-brown silty sand with gravel (SM)		
					46 40				
		S-9	11/11	22-23	47 80/5"		Wet, dense, orange-brown silty sand with gravel (SM)		
							END EXPLORATION @ 23'		
25									
30									

GRANULAR SOILS BLOWS/FT	DENSITY	COHESIVE SOILS BLOWS/FT	DENSITY
0 - 4	V. LOOSE	<2	V.SOFT
4 - 10	LOOSE	2 - 4	SOFT
10 - 30	M.DENSE	4 - 8	M.STIFF
30 - 50	DENSE	8 - 15	STIFF
>50	V.DENSE	15 - 30	V.STIFF
		>30	HARD

REMARKS:
1. Boring location moved 15' west to avoid boulder.
2. Grinding at 20".
3. Heavy grinding 5.5'-7'.
4. Switched from HSA to compressed air. Grinding at ~11' to 13'.
5. Hole grouted to ground surface upon completion of boring.

UNIFIED CLASSIFICATION

Gravel	G
Sand	S
Silt	M
Clay	C

Description shall reference USCS classification chart

NOTES:
a) THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES, TRANSITIONS MAY BE GRADUAL. SOLID LINES INDICATE AN OBSERVED SOIL CHANGE. DASHED LINES INDICATE AN APPROXIMATED SOIL BOUNDARY.
b) WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT TIMES AND UNDER CONDITIONS STATED ON THE BORING LOGS. FLUCTUATIONS IN THE LEVEL OF GROUNDWATER MAY OCCUR DUE TO OTHER FACTORS THAN THOSE PRESENT AT THE TIME MEASUREMENTS WERE MADE.
c) STANDARD PENETRATION RESISTANCE, N-VALUE, IS THE NUMBER OF BLOWS REQUIRED TO DRIVE THE SAMPLER FROM 6-18 INCHES OF PENETRATION.
d) UNCONFINED COMPRESSION STRENGTH, Qu, WAS DETERMINED FROM THE SPLIT SPOON SAMPLE UTILIZING A POCKET PENETROMETER.
e) TO CONVERT FEET TO METERS MULTIPLY BY 3.048×10^{-1}

PARE ENGINEERING CORPORATION 49 WALPOLE STREET, SUITE 2, NORWOOD, MASSACHUSETTS ENGINEERS *** PLANNERS *** CONSULTANTS	BORING NO. B116 SHEET 1 OF 1

PROJECT: Towantic Energy Center, Oxford, CT
PROJECT NO.: 00172.00
CHKD. BY: JMB

BORING CO.: Parratt-Wolff
FOREMAN: B. Waters
ENGINEER: A. Orsi
BORING LOCATION: SEE EXPLORATION LOCATION PLAN
GROUND SURFACE ELEVATION: 834.9 DATUM: NGVD. 1929
DATE START: 10/11/00 DATE END: 10/11/00

SAMPLER: UNLESS OTHERWISE NOTED, SAMPLER CONSISTS OF A 2" SPLIT SPOON DRIVEN USING A 140 lb. HAMMER FALLING 30 in.
CASING: UNLESS OTHERWISE NOTED, CASING DRIVEN USING 300 lb. HAMMER FALLING 24 IN.
CASING SIZE:
OTHER: 3 3/4 H.S.A.

GROUNDWATER READINGS

DATE	TIME	WATER AT	CASING AT	STABILIZATION TIME
10/11	2:30	23.68	10'	-
10/13	9:00	Dry to 15'	-	2 Days

DEPTH (ft)	CASING (bl/ft)	SAMPLE NO	PEN. (in.)/ REC.	DEPTH (FT)	BLOWS/6"	TONS/FT² OR KG/CM²	SAMPLE DESCRIPTION (Unified Soil Classification System / CLASSIFICATION)	REMARKS	STRATUM DESCRIPTION
		S-1	24/24	0-2	2 5		8" topsoil changing to moist, loose, orange sandy silt		TOPSOIL
					5 10		(ML) (Subsoil)		SUBSOIL
		S-2	24/12	2-4	27 31		Dry, dense, brown silty sand (SM) with gravel		
					22 16				
5		S-3	24/24	4-6	10 14		Moist, m. dense, brown silty sand with gravel (SM)		
					15 16				
		S-4	24/24	6-8	15 22		Moist, dense, brown silty sand (SM)		
					18 16				
		S-5	24/24	8-10	8 10		Moist, m. dense, brown silty sand (SM)		
10					11 12				
		S-6	24/6	10-12	7 16		Wet, dense, brown silty sand with gravel (SM)	1.	
					18 20				
15									
		S-7	24/24	15-17	8 17		Moist, dense, brown silty sand with gravel (SM)		
					18 18				SILTY SAND WITH GRAVEL (SM)
20									
		S-8	24/24	20-22	16 21		Moist, dense, brown silty sand with gravel (SM)		
					18 18				
25									
		S-9	24/24	25-27	9 16		Moist, dense, brown silty sand (SM) with a thin layer of fine sand		
					30 19				
		S-10	24/24	27-29	18 24		Wet, v. dense, silty sand (SM)		
					27 44				
30							END EXPLORATION @ 29'		

GRANULAR SOILS BLOWS/FT	DENSITY	COHESIVE SOILS BLOWS/FT	DENSITY
0 - 4	V. LOOSE	<2	V. SOFT
4 - 10	LOOSE	2 - 4	SOFT
10 - 30	M. DENSE	4 - 8	M. STIFF
30 - 50	DENSE	8 - 15	STIFF
>50	V. DENSE	15 - 30	V. STIFF
		>30	HARD

REMARKS:
1. Switch from HSA to compressed air drilling.
2. Hole grouted to ground surface upon completion of boring.
3. Boring collapsed to 15' prior to second water level reading.

UNIFIED CLASSIFICATION

Gravel	G
Sand	S
Silt	M
Clay	C

Description shall reference USCS classification chart

NOTES:
a) THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES. TRANSITIONS MAY BE GRADUAL. SOLID LINES INDICATE AN OBSERVED SOIL CHANGE. DASHED LINES INDICATE AN APPROXIMATED SOIL BOUNDARY.
b) WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT TIMES AND UNDER CONDITIONS STATED ON THE BORING LOGS. FLUCTUATIONS IN THE LEVEL OF GROUNDWATER MAY OCCUR DUE TO OTHER FACTORS THAN THOSE PRESENT AT THE TIME MEASUREMENTS WERE MADE.
c) STANDARD PENETRATION RESISTANCE, N-VALUE, IS THE NUMBER OF BLOWS REQUIRED TO DRIVE THE SAMPLER FROM 6-18 INCHES OF PENETRATION.
d) UNCONFINED COMPRESSION STRENGTH, Qu, WAS DETERMINED FROM THE SPLIT SPOON SAMPLE UTILIZING A POCKET PENETROMETER.
e) TO CONVERT FEET TO METERS MULTIPLY BY 3.048×10^{-1}

PARE ENGINEERING CORPORATION

49 WALPOLE STREET, SUITE 2, NORWOOD, MASSACHUSETTS
ENGINEERS *** PLANNERS *** CONSULTANTS

BORING NO. B117
SHEET 1 OF 1

PROJECT: Towantic Energy Center, Oxford, CT
PROJECT NO. 00172.00
CHKD. BY [illegible]

BORING CO. Parratt-Wolff
FOREMAN B. Waters
ENGINEER A. Orsi

BORING LOCATION SEE EXPLORATION LOCATION PLAN
GROUND SURFACE ELEVATION 836.7 DATUM NGVD. 1929
DATE START 10/3/00 DATE END 10/3/00

SAMPLER: UNLESS OTHERWISE NOTED, SAMPLER CONSISTS OF A 2" SPLIT SPOON DRIVEN USING A 140 lb. HAMMER FALLING 30 in.

CASING: UNLESS OTHERWISE NOTED, CASING DRIVEN USING 300 lb. HAMMER FALLING 24 IN.

CASING SIZE: OTHER: 3 3/4 H.S.A.

GROUNDWATER READINGS

DATE	TIME	WATER AT	CASING AT	STABILIZATION TIME
10/3	11:00	20.85		-
10/4	10:15		Cave-In	
10/13	9:00	8.95		2nd Hole

DEPTH (ft)	CASING (bl/ft)	SAMPLE NO.	PEN. (in.)/ REC.	DEPTH (FT)	BLOWS/6"	TONS/FT² OR KG/CM²	SAMPLE DESCRIPTION (Unified Soil Classification System)	REMARKS	STRATUM DESCRIPTION
		S-1	24/8	0-2	1 3		4" topsoil, changing to dry, m. dense, brown silty sand		TOPSOIL
					10 11		with gravel (SM) (Subsoil)		SUBSOIL
		S-2	24/12	2-4	8 14		Dry, dense, brown silty sand with gravel (SM)		SILTY SAND WITH GRAVEL (SM)
					20 23				
5		S-3	24/24	4-6	9 13		Dry, dense, brown silty sand with gravel (SM)		
					25 60				
		S-4	6/5	6-8	30 50/0"		Dry, v. dense, light brown well graded sand with silt and gravel (SW-SM)/silty sand (SM)		SAND WITH SILT AND GRAVEL (SW-SM)
		S-5	5/1	8-10	50/5"		Rock fragments	1.	
10									
		S-6	24/20	13-15	12 15		Dry, dense, brown well graded sand with silt and		
15					16 19		gravel (SW-SM)		
		S-7	24/24	18-20	11 17		Wet, dense, brown silty sand (SM)		SILTY SAND (SM)
20					21 22				
		S-8	24/20	23-25	39 17		Wet, dense, brown sandy silt (ML)		SANDY SILT (ML)
25					23 29				
							END EXPLORATION @ 25'		
30									

GRANULAR SOILS BLOWS/FT	DENSITY	COHESIVE SOILS BLOWS/FT	DENSITY
0 - 4	V. LOOSE	<2	V.SOFT
4 - 10	LOOSE	2 - 4	SOFT
10 - 30	M.DENSE	4 - 8	M.STIFF
30 - 50	DENSE	8 - 15	STIFF
>50	V.DENSE	15 - 30	V.STIFF
		>30	HARD

REMARKS:
1. Significant Auger grinding at 25'.
2. Hole grouted to ground surface upon completion of boring.
3. A second hole was drilled to 25' to determine water level.

UNIFIED CLASSIFICATION	
Gravel	G
Sand	S
Silt	M
Clay	C

Description shall reference USCS classification chart

NOTES:
a) THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES, TRANSITIONS MAY BE GRADUAL. SOLID LINES INDICATE AN OBSERVED SOIL CHANGE. DASHED LINES INDICATE AN APPROXIMATED SOIL BOUNDARY.
b) WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT TIMES AND UNDER CONDITIONS STATED ON THE BORING LOGS. FLUCTUATIONS IN THE LEVEL OF GROUNDWATER MAY OCCUR DUE TO OTHER FACTORS THAN THOSE PRESENT AT THE TIME MEASUREMENTS WERE MADE.
c) STANDARD PENETRATION RESISTANCE, N-VALUE, IS THE NUMBER OF BLOWS REQUIRED TO DRIVE THE SAMPLER FROM 6-18 INCHES OF PENETRATION.
d) UNCONFINED COMPRESSION STRENGTH, Qu, WAS DETERMINED FROM THE SPLIT SPOON SAMPLE UTILIZING A POCKET PENETROMETER.
e) TO CONVERT FEET TO METERS MULTIPLY BY 3.048×10^{-1}

BORING NO. B117

PARE ENGINEERING CORPORATION
49 WALPOLE STREET, SUITE 2, NORWOOD, MASSACHUSETTS
ENGINEERS *** PLANNERS *** CONSULTANTS

BORING NO. B117A
SHEET 1 OF 1

PROJECT: Towantic Energy Center, Oxford, CT
PROJECT NO. 00172.00
CHKD. BY

BORING CO. Parratt-Wolff
FOREMAN B. Waters
ENGINEER A. Orsi

BORING LOCATION SEE EXPLORATION LOCATION PLAN
GROUND SURFACE ELEVATION 836.7 DATUM NGVD 1929
DATE START 10/12/00 DATE END 10/12/00

SAMPLER: UNLESS OTHERWISE NOTED, SAMPLER CONSISTS OF A 2" SPLIT SPOON DRIVEN USING A 140 lb. HAMMER FALLING 30 in.

CASING: UNLESS OTHERWISE NOTED, CASING DRIVEN USING 300 lb. HAMMER FALLING 24 IN.

CASING SIZE:

OTHER: 3 3/4 H.S.A.

GROUNDWATER READINGS

DATE	TIME	WATER AT	CASING AT	STABILIZATION TIME
10/13	9:00	8.95		

DEPTH (ft)	CASING (bl/ft)	SAMPLE NO.	PEN. (in.)/ REC.	DEPTH (FT)	BLOWS/6"	TONS/FT² OR KG/CM²	SAMPLE DESCRIPTION Unified Soil Classification System CLASSIFICATION	REMARKS	STRATUM DESCRIPTION
5							Boring advanced for water level reading only. No samples were taken during the advancement of this boring		
10									
15									
20									
25							END EXPLORATION @ 25'		
30									

GRANULAR SOILS BLOWS/FT	DENSITY	COHESIVE SOILS BLOWS/FT	DENSITY
0 - 4	V. LOOSE	<2	V.SOFT
4 - 10	LOOSE	2 - 4	SOFT
10 - 30	M.DENSE	4 - 8	M.STIFF
30 - 50	DENSE	8 - 15	STIFF
>50	V.DENSE	15 - 30	V.STIFF
		>30	HARD

REMARKS:

UNIFIED CLASSIFICATION

Gravel	G
Sand	S
Silt	M
Clay	C

Description shall reference USCS classification chart

NOTES:
a) THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES, TRANSITIONS MAY BE GRADUAL. SOLID LINES INDICATE AN OBSERVED SOIL CHANGE. DASHED LINES INDICATE AN APPROXIMATED SOIL BOUNDARY.
b) WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT TIMES AND UNDER CONDITIONS STATED ON THE BORING LOGS. FLUCTUATIONS IN THE LEVEL OF GROUNDWATER MAY OCCUR DUE TO OTHER FACTORS THAN THOSE PRESENT AT THE TIME MEASUREMENTS WERE MADE.
c) STANDARD PENETRATION RESISTANCE, N-VALUE, IS THE NUMBER OF BLOWS REQUIRED TO DRIVE THE SAMPLER FROM 6-18 INCHES OF PENETRATION.
d) UNCONFINED COMPRESSION STRENGTH, Qu, WAS DETERMINED FROM THE SPLIT SPOON SAMPLE UTILIZING A POCKET PENETROMETER.
e) TO CONVERT FEET TO METERS MULTIPLY BY 3.048×10^{-1}

PARE ENGINEERING CORPORATION 49 WALPOLE STREET, SUITE 2, NORWOOD, MASSACHUSETTS ENGINEERS *** PLANNERS *** CONSULTANTS	BORING NO. B118 SHEET 1 OF 1

PROJECT: Towantic Energy Center, Oxford, CT
PROJECT NO.: 00172.00
CHKD. BY: JMB

BORING CO.: Parratt-Wolff
FOREMAN: B. Waters
ENGINEER: A. Orsi

BORING LOCATION: SEE EXPLORATION LOCATION PLAN
GROUND SURFACE ELEVATION: 840.3 DATUM: NGVD 1929
DATE START: 10/3/00 DATE END: 10/3/00

SAMPLER: UNLESS OTHERWISE NOTED, SAMPLER CONSISTS OF A 2" SPLIT SPOON DRIVEN USING A 140 lb. HAMMER FALLING 30 in.

CASING: UNLESS OTHERWISE NOTED, CASING DRIVEN USING 300 lb. HAMMER FALLING 24 IN.

CASING SIZE: OTHER: 3 $^{3}/_{4}$ H.S.A.

GROUNDWATER READINGS

DATE	TIME	WATER AT	CASING AT	STABILIZATION TIME
10/3	14:45	Dry	-	-
10/4	10:15	Dry to 13'	-	1 Day
10/5	9:00	Dry	-	2 Days

DEPTH (ft)	CASING (bl/ft)	SAMPLE NO.	PEN. (in.)/ REC.	DEPTH (FT)	BLOWS/6"	TONS/FT² OR KG/CM²	SAMPLE DESCRIPTION (Unified Soil Classification System CLASSIFICATION)	REMARKS	STRATUM DESCRIPTION
		S-1	24/14	0-2	1 2		4" topsoil changing to dry, loose, brown, well graded		TOPSOIL
					6 6		sand with silt and gravel (SW-SM)		
		S-2	24/16	2-4	4 12		Dry, m. dense, brown silty sand (SM) with gravel		
					14 11				
5		S-3	24/5	4-6	9 11		Wet, m. dense, brown silt with sand (ML)		
					16 21				
		S-4	24/1	6-8	17 18				
					21 20				
		S-5	24/22	8-10	11 17		Dry, dense, brown silty sand (SM)		SILTY SAND
10					20 19				WITH GRAVEL
		S-6	24/24	10-12	12 13		Dry, m. dense, brown, silty sand with gravel (SM)		(SM)
					15 18				
								1.	
15									
		S-7	24/24	15-17	11 18		Wet, dense, brown sitly sand with gravel (SM)		
					18 27				
20									
		S-8	24/24	20-22	21 21		Wet, dense, brown sitly sand with gravel (SM) (assumed wet,		
					25 26		cooked dry by heat - see Note 1)		
		S-9	24/18	23-25	20 25		Wet, v. dense, brown silty sand with gravel (SM)		
25					32 33				
							END EXPLORATION @ 25'		
30									

GRANULAR SOILS BLOWS/FT	DENSITY	COHESIVE SOILS BLOWS/FT	DENSITY
0 - 4	V. LOOSE	<2	V.SOFT
4 - 10	LOOSE	2 - 4	SOFT
10 - 30	M.DENSE	4 - 8	M.STIFF
30 - 50	DENSE	8 - 15	STIFF
>50	V.DENSE	15 - 30	V.STIFF
		>30	HARD

REMARKS:
1. Considerable Auger smoking at ~13-15' (cobbles/gravel?)
2. Hole grouted to ground surface upon completion of boring.
3. Hole collapsed to 13' prior to second water level reading.

UNIFIED CLASSIFICATION	
Gravel	G
Sand	S
Silt	M
Clay	C

Description shall reference USCS classification chart

NOTES:
a) THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES, TRANSITIONS MAY BE GRADUAL. SOLID LINES INDICATE AN OBSERVED SOIL CHANGE. DASHED LINES INDICATE AN APPROXIMATED SOIL BOUNDARY.
b) WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT TIMES AND UNDER CONDITIONS STATED ON THE BORING LOGS. FLUCTUATIONS IN THE LEVEL OF GROUNDWATER MAY OCCUR DUE TO OTHER FACTORS THAN THOSE PRESENT AT THE TIME MEASUREMENTS WERE MADE.
c) STANDARD PENETRATION RESISTANCE, N-VALUE, IS THE NUMBER OF BLOWS REQUIRED TO DRIVE THE SAMPLER FROM 6-18 INCHES OF PENETRATION.
d) UNCONFINED COMPRESSION STRENGTH, Qu, WAS DETERMINED FROM THE SPLIT SPOON SAMPLE UTILIZING A POCKET PENETROMETER.
e) TO CONVERT FEET TO METERS MULTIPLY BY 3.048×10^{-1}

PARE ENGINEERING CORPORATION
49 WALPOLE STREET, SUITE 2, NORWOOD, MASSACHUSETTS
ENGINEERS *** PLANNERS *** CONSULTANTS

BORING NO. B119
SHEET 1 OF 1

PROJECT: Towantic Energy Center, Oxford, CT
PROJECT NO. 00172.00
CHKD. BY JMF

BORING CO. Parratt-Wolff
FOREMAN B. Waters
ENGINEER A. Orsi

BORING LOCATION: SEE EXPLORATION LOCATION PLAN
GROUND SURFACE ELEVATION 825.6 DATUM NGVD. 1929
DATE START 10/3/00 DATE END 10/3/00

SAMPLER: UNLESS OTHERWISE NOTED, SAMPLER CONSISTS OF A 2" SPLIT SPOON DRIVEN USING A 140 lb. HAMMER FALLING 30 in.

CASING: UNLESS OTHERWISE NOTED, CASING DRIVEN USING 300 lb. HAMMER FALLING 24 IN.

CASING SIZE: OTHER: 3 3/4 H.S.A.

GROUNDWATER READINGS

DATE	TIME	WATER AT	CASING AT	STABILIZATION TIME
10/3	8:45	Dry	25	-
10/4	10:15	8.7'	-	1 Day
10/5	9:00	9.22'	-	2 Days

DEPTH (ft)	CASING (bl/ft)	SAMPLE NO	PEN. (in.)/REC.	DEPTH (FT)	BLOWS/6"	TONS/FT² OR KG/CM²	SAMPLE DESCRIPTION (Unified Soil Classification System / CLASSIFICATION)	REMARKS	STRATUM DESCRIPTION
		S-1	24/5	0-2	1 3		Topsoil		TOPSOIL
					5 5				
		S-2	24/0	2-4	4 10		No recovery		
					15 19				
5		S-3	24/24	4-6	35 18		Dry, dense, brown silty sand (SM)		
					30 34				
		S-4	24/24	6-8	20 27		Moist, dense, brown silty sand (SM)		
					21 45				
		S-5	24/24	8-10	12 31		Dry, v. dense, brown silty sand (SM)		
10					39 27				SILTY SAND (SM)
		S-6	24/4	13-15	33 34		Dry, v. dense, brown silty sand (SM)		
					31 30				
15									
		S-7	24/24	18-20	12 16		Dry, dense, brown silty sand (SM)		
20					22 27				
		S-8	24/	23-25	26 26		Dry, dense, brown silty sand (SM)	1.	
25					22 28				
							END EXPLORATION @ 25'		
30									

GRANULAR SOILS BLOWS/FT	DENSITY	COHESIVE SOILS BLOWS/FT	DENSITY
0 - 4	V. LOOSE	<2	V.SOFT
4 - 10	LOOSE	2 - 4	SOFT
10 - 30	M.DENSE	4 - 8	M.STIFF
30 - 50	DENSE	8 - 15	STIFF
>50	V.DENSE	15 - 30	V.STIFF
		>30	HARD

REMARKS:
1. Hole grouted to ground surface upon completion of boring.

UNIFIED CLASSIFICATION	
Gravel	G
Sand	S
Silt	M
Clay	C

Description shall reference USCS classification chart

NOTES:
a) THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES, TRANSITIONS MAY BE GRADUAL. SOLID LINES INDICATE AN OBSERVED SOIL CHANGE. DASHED LINES INDICATE AN APPROXIMATED SOIL BOUNDARY.
b) WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT TIMES AND UNDER CONDITIONS STATED ON THE BORING LOGS. FLUCTUATIONS IN THE LEVEL OF GROUNDWATER MAY OCCUR DUE TO OTHER FACTORS THAN THOSE PRESENT AT THE TIME MEASUREMENTS WERE MADE.
c) STANDARD PENETRATION RESISTANCE, N-VALUE, IS THE NUMBER OF BLOWS REQUIRED TO DRIVE THE SAMPLER FROM 6-18 INCHES OF PENETRATION.
d) UNCONFINED COMPRESSION STRENGTH, Qu, WAS DETERMINED FROM THE SPLIT SPOON SAMPLE UTILIZING A POCKET PENETROMETER.
e) TO CONVERT FEET TO METERS MULTIPLY BY $3.048X10^{-1}$

BORING NO. B119

PARE ENGINEERING CORPORATION

49 WALPOLE STREET, SUITE 2, NORWOOD, MASSACHUSETTS

ENGINEERS *** PLANNERS *** CONSULTANTS

BORING NO. B120

SHEET 1 OF 1

PROJECT: Towantic Energy Center, Oxford, CT

PROJECT NO. 00172.00

CHKD. BY JMF

BORING CO. Parratt-Wolff

FOREMAN B. Waters

ENGINEER A. Orsi

BORING LOCATION SEE EXPLORATION LOCATION PLAN

GROUND SURFACE ELEVATION 845.6 DATUM NGVD 1929

DATE START 10/12/00 DATE END 10/12/00

SAMPLER: UNLESS OTHERWISE NOTED, SAMPLER CONSISTS OF A 2" SPLIT SPOON DRIVEN USING A 140 lb. HAMMER FALLING 30 in.

CASING: UNLESS OTHERWISE NOTED, CASING DRIVEN USING 300 lb. HAMMER FALLING 24 IN.

CASING SIZE:

OTHER: 3 3/4 H.S.A.

GROUNDWATER READINGS

DATE	TIME	WATER AT	CASING AT	STABILIZATION TIME
10/13	9:00	Dry to 10'	-	1 Day

DEPTH (ft)	CASING (bl/ft)	NO.	PEN. (in.)/ REC.	DEPTH (FT)	BLOWS/6"	TONS/FT² OR KG/CM²	SAMPLE DESCRIPTION Unified Soil Classification System CLASSIFICATION	REMARKS	STRATUM DESCRIPTION
		S-1	24/18	0-2	1 2		4" topsoil changing to moist, loose, orange silt with		TOPSOIL
					2 8		sand (ML) (Subsoil)		SUBSOIL
		S-2	24/18	2-4	13 16		Moist, m. dense, brown silty sand (SM) with gravel		
					14 12				
5		S-3	24/12	4-6	20 27		Moist, v. dense, silty sand (SM)		
					31 32				
		S-4	24/24	6-8	14 17		Moist, m. dense, brown silty sand (SM)		
					20 23				
		S-5	24/24	8-10	4 9		Moist, m. dense, grey-brown, silty sand with gravel (SM)		
10					15 14				
		S-6	16/16	10-12	11 20		Moist, dense, grey-brown, silty sand with gravel (SM)		SILTY SAND WITH GRAVEL (SM)
					50/4"				
15									
		S-7	24/12	15-17	18 16		Moist, v. dense, grey-brown, silty sand with gravel (SM)		
					62 41				
20									
		S-8	24/12	20-22	16 39		Moist, v. dense, gray, silty sand with gravel (SM)		
					46 49				
		S-9	24/24	22-24	23 28		Moist, v. dense, gray, silty sand with gravel (SM)		
					22 27				
25							END EXPLORATION @ 24.0'		
30									

GRANULAR SOILS BLOWS/FT	DENSITY	COHESIVE SOILS BLOWS/FT	DENSITY
0 - 4	V. LOOSE	<2	V.SOFT
4 - 10	LOOSE	2 - 4	SOFT
10 - 30	M.DENSE	4 - 8	M.STIFF
30 - 50	DENSE	8 - 15	STIFF
>50	V.DENSE	15 - 30	V.STIFF
		>30	HARD

REMARKS:

1. Hole grouted to ground surface upon completion of boring.

UNIFIED CLASSIFICATION

Gravel	G
Sand	S
Silt	M
Clay	C

Description shall reference USCS classification chart

NOTES:

a) THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES, TRANSITIONS MAY BE GRADUAL. SOLID LINES INDICATE AN OBSERVED SOIL CHANGE. DASHED LINES INDICATE AN APPROXIMATED SOIL BOUNDARY.

b) WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT TIMES AND UNDER CONDITIONS STATED ON THE BORING LOGS. FLUCTUATIONS IN THE LEVEL OF GROUNDWATER MAY OCCUR DUE TO OTHER FACTORS THAN THOSE PRESENT AT THE TIME MEASUREMENTS WERE MADE.

c) STANDARD PENETRATION RESISTANCE, N-VALUE, IS THE NUMBER OF BLOWS REQUIRED TO DRIVE THE SAMPLER FROM 6-18 INCHES OF PENETRATION.

d) UNCONFINED COMPRESSION STRENGTH, Qu, WAS DETERMINED FROM THE SPLIT SPOON SAMPLE UTILIZING A POCKET PENETROMETER.

e) TO CONVERT FEET TO METERS MULTIPLY BY $3.048X10^{-1}$

BORING NO. B120

PARE ENGINEERING CORPORATION

49 WALPOLE STREET, SUITE 2, NORWOOD, MASSACHUSETTS
ENGINEERS *** PLANNERS *** CONSULTANTS

BORING NO. B121
SHEET 1 OF 1

PROJECT: Towantic Energy Center, Oxford, CT
PROJECT NO. 00172.00
CHKD. BY JMB

BORING CO. Parratt-Wolff
FOREMAN B Waters
ENGINEER A. Orsi

BORING LOCATION SEE EXPLORATION LOCATION PLAN
GROUND SURFACE ELEVATION 845.7 DATUM NGVD, 1929
DATE START 10/12/00 DATE END 10/12/00

SAMPLER: UNLESS OTHERWISE NOTED, SAMPLER CONSISTS OF A 2" SPLIT SPOON DRIVEN USING A 140 lb. HAMMER FALLING 30 in.

CASING: UNLESS OTHERWISE NOTED, CASING DRIVEN USING 300 lb. HAMMER FALLING 24 IN.

CASING SIZE: OTHER: 3 3/4 H.S.A.

GROUNDWATER READINGS

DATE	TIME	WATER AT	CASING AT	STABILIZATION TIME
10/12	1:30	Dry	10	-
10/13	9:00	Dry to 13'	-	1 Day

DEPTH (ft)	CASING (bl/ft)	SAMPLE NO.	PEN. (in.)/ REC.	DEPTH (FT)	BLOWS/6"	TONS/FT² OR KG/CM²	SAMPLE DESCRIPTION (Unified Soil Classification System CLASSIFICATION)	REMARKS	STRATUM DESCRIPTION
		S-1	24/12	0-2	1 2		4" topsoil changing to moist, loose, orange-brown silty		TOPSOIL
					2 2		sand (SM) (Subsoil)		SUBSOIL
		S-2	12/12	2-4	6 15		Moist, dense, orange-brown silty sand (SM)		
					25/0"				
5		S-3	24/24	4-6	5 8		Moist, m. dense, brown silty sand with gravel (SM)		
					10 12				
		S-4	24/24	6-8	7 10		Moist, m. dense, brown silty sand with gravel (SM)		
					12 15				
		S-5	24/24	8-10	10 16		Moist, v. dense, brown silty sand with gravel (SM)		
10					39 21				SILTY SAND
		S-6	24/12	10-12	27 28		Moist, v. dense, brown silty sand with gravel (SM)		WITH GRAVEL
					27 24				(SM)
15									
		S-7	24/24	15-17	9 14		Moist, m. dense, brown silty sand with gravel (SM)		
					13 17				
20									
		S-8	24/20	20-22	15 17		Moist, dense, brown silty sand with gravel (SM)		
					23 26				
		S-9	24/24	22-24	77 28		Moist, v. dense, brown silty sand with gravel (SM)		
					34 40				
25							END EXPLORATION @ 24.0'		
30									

GRANULAR SOILS BLOWS/FT	DENSITY	COHESIVE SOILS BLOWS/FT	DENSITY
0 - 4	V. LOOSE	<2	V.SOFT
4 - 10	LOOSE	2 - 4	SOFT
10 - 30	M DENSE	4 - 8	M STIFF
30 - 50	DENSE	8 - 15	STIFF
>50	V DENSE	15 - 30	V.STIFF
		>30	HARD

REMARKS:
1. Hole grouted to ground surface upon completion of boring.

UNIFIED CLASSIFICATION	
Gravel	G
Sand	S
Silt	M
Clay	C

Description shall reference USCS classification chart

NOTES:
a) THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES, TRANSITIONS MAY BE GRADUAL. SOLID LINES INDICATE AN OBSERVED SOIL CHANGE. DASHED LINES INDICATE AN APPROXIMATED SOIL BOUNDARY.
b) WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT TIMES AND UNDER CONDITIONS STATED ON THE BORING LOGS. FLUCTUATIONS IN THE LEVEL OF GROUNDWATER MAY OCCUR DUE TO OTHER FACTORS THAN THOSE PRESENT AT THE TIME MEASUREMENTS WERE MADE.
c) STANDARD PENETRATION RESISTANCE, N-VALUE, IS THE NUMBER OF BLOWS REQUIRED TO DRIVE THE SAMPLER FROM 6-18 INCHES OF PENETRATION
d) UNCONFINED COMPRESSION STRENGTH, Qu, WAS DETERMINED FROM THE SPLIT SPOON SAMPLE UTILIZING A POCKET PENETROMETER.
e) TO CONVERT FEET TO METERS MULTIPLY BY $3.048X10^{-1}$

BORING NO. B121

PARE ENGINEERING CORPORATION

49 WALPOLE STREET, SUITE 2, NORWOOD, MASSACHUSETTS
ENGINEERS *** PLANNERS *** CONSULTANTS

BORING NO. B122
SHEET 1 OF 1

PROJECT: Towantic Energy Center, Oxford, CT
PROJECT NO. 00172.00
CHKD. BY JMB

BORING CO. Parratt-Wolff
FOREMAN B. Waters
ENGINEER A. Orsi

BORING LOCATION SEE EXPLORATION LOCATION PLAN
GROUND SURFACE ELEVATION 849.7 DATUM NGVD, 1929
DATE START 10/12/00 DATE END 10/12/00

SAMPLER: UNLESS OTHERWISE NOTED, SAMPLER CONSISTS OF A 2" SPLIT SPOON DRIVEN USING A 140 lb. HAMMER FALLING 30 in.

CASING: UNLESS OTHERWISE NOTED, CASING DRIVEN USING 300 lb. HAMMER FALLING 24 IN.

CASING SIZE:

OTHER: 3 3/4 H.S.A.

GROUNDWATER READINGS

DATE	TIME	WATER AT	CASING AT	STABILIZATION TIME
10/12	10:00	Dry	5	-
10/13	9:00	Dry to 10'	-	1 Day

DEPTH (ft)	CASING (bl/ft)	SAMPLE NO.	PEN. (in.)/ REC.	DEPTH (FT)	BLOWS/6"	TONS/FT² OR KG/CM²	SAMPLE DESCRIPTION (Unified Soil Classification System CLASSIFICATION)	REMARKS	STRATUM DESCRIPTION
		S-1	24/3	0-2	1 5		3" topsoil		TOPSOIL
					4 6				
		S-2	24/0	2-4	12 26		No recovery	1.	
					24 25			2.	
5		S-3	24/24	4-6	90 19		Moist, dense, brown silty sand with gravel (SM)		
					14 16				
		S-4	24/24	6-8	15 21		Moist, dense, brown silty sand with gravel (SM)		
					20 15				
		S-5	24/18	8-10	6 10		Moist, m. dense, brown silty sand with gravel (SM)		
10					11 23				
		S-6	24/24	10-12	13 17		Moist, dense, brown silty sand with gravel (SM)		
					17 15				
									SILTY SAND WITH GRAVEL (SM)
15									
		S-7	24/24	15-17	8 16		Moist, m. dense, brown silty sand with gravel (SM)		
					28 19				
20									
		S-8	4/4	20-22	80/4"		Moist, v. dense, brown silty sand with gravel (SM)	3.	
25									
		S-9	24/24	25-27	10 12		Moist, m. dense, brown silty sand with gravel (SM)		
					15 16				
		S-10	24/24	27-29	15 18		Moist, dense, brown sandy silt (ML)		
					21 22				
30							END EXPLORATION @ 29'		

GRANULAR SOILS BLOWS/FT	DENSITY	COHESIVE SOILS BLOWS/FT	DENSITY
0 - 4	V. LOOSE	<2	V.SOFT
4 - 10	LOOSE	2 - 4	SOFT
10 - 30	M.DENSE	4 - 8	M.STIFF
30 - 50	DENSE	8 - 15	STIFF
>50	V.DENSE	15 - 30	V.STIFF
		>30	HARD

REMARKS:
1. Grinding at 4.5'.
2. Switched from HSA and compressed air at 5'.
3. 60 blows on cobble at 20'4".
4. Hole grouted to ground surface upon completion of boring.

UNIFIED CLASSIFICATION

Gravel	G
Sand	S
Silt	M
Clay	C

Description shall reference USCS classification chart

NOTES:
a) THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES. TRANSITIONS MAY BE GRADUAL. SOLID LINES INDICATE AN OBSERVED SOIL CHANGE. DASHED LINES INDICATE AN APPROXIMATED SOIL BOUNDARY.
b) WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT TIMES AND UNDER CONDITIONS STATED ON THE BORING LOGS. FLUCTUATIONS IN THE LEVEL OF GROUNDWATER MAY OCCUR DUE TO OTHER FACTORS THAN THOSE PRESENT AT THE TIME MEASUREMENTS WERE MADE.
c) STANDARD PENETRATION RESISTANCE, N-VALUE, IS THE NUMBER OF BLOWS REQUIRED TO DRIVE THE SAMPLER FROM 6-18 INCHES OF PENETRATION.
d) UNCONFINED COMPRESSION STRENGTH, Qu, WAS DETERMINED FROM THE SPLIT SPOON SAMPLE UTILIZING A POCKET PENETROMETER.
e) TO CONVERT FEET TO METERS MULTIPLY BY 3.048×10^{-1}

BORING NO. B122

PARE ENGINEERING CORPORATION

49 WALPOLE STREET, SUITE 2, NORWOOD, MASSACHUSETTS
ENGINEERS *** PLANNERS *** CONSULTANTS

BORING NO. B123
SHEET 1 OF 1

PROJECT: Towantic Energy Center, Oxford, CT
PROJECT NO. 00172.00
CHKD. BY JMB

BORING CO. Parratt-Wolff
FOREMAN B. Waters
ENGINEER A. Orsi

BORING LOCATION SEE EXPLORATION LOCATION PLAN
GROUND SURFACE ELEVATION ____ DATUM ____
DATE START 10/12/00 DATE END 10/12/00

SAMPLER: UNLESS OTHERWISE NOTED, SAMPLER CONSISTS OF A 2" SPLIT SPOON DRIVEN USING A 140 lb. HAMMER FALLING 30 in.

CASING: UNLESS OTHERWISE NOTED, CASING DRIVEN USING 300 lb. HAMMER FALLING 24 IN.

CASING SIZE: OTHER: 3 3/4 H.S.A.

GROUNDWATER READINGS

DATE	TIME	WATER AT	CASING AT	STABILIZATION TIME
10/12	6:00	Dry	-	-
10/13	9:00	Dry	-	1 Day

DEPTH (ft)	CASING (bl/ft)	SAMPLE NO	PEN (in)/ REC	DEPTH (FT)	BLOWS/6"	TONS/FT² OR KG/CM²	SAMPLE DESCRIPTION (Unified Soil Classification System CLASSIFICATION)	REMARKS	STRATUM DESCRIPTION
		S-1	24/12	0-2	3 2		Moist, loose, orange silt with sand (ML) (Subsoil)		SILT WITH SAND (ML)
					3 8				
		S-2	24/24	2-4	8 8		Moist, m. dense, brown sand with silt and gravel (SW-SM)/silty sand (SM)		SILTY SAND WITH GRAVEL (SM)
					9 10				
5		S-3	24/24	4-6	11 14		Moist, m. dense, brown, silty sand with gravel (SM)		
					10 13				
		S-4	24/24	6-8	6 16		Moist, m. dense, brown, silty sand with gravel (SM)		
					12 13				
		S-5	24/24	8-10	6 7		Moist, m. dense, brown, silty sand with gravel (SM)		
10					9 11				
		S-6	24/24	13-15	62 21		Moist, dense, grey-brown silty sand with gravel (SM)		
15					25 18				
							END EXPLORATION @ 15'		
20									
25									
30									

GRANULAR SOILS BLOWS/FT	DENSITY	COHESIVE SOILS BLOWS/FT	DENSITY
0 - 4	V. LOOSE	<2	V.SOFT
4 - 10	LOOSE	2 - 4	SOFT
10 - 30	M.DENSE	4 - 8	M.STIFF
30 - 50	DENSE	8 - 15	STIFF
>50	V DENSE	15 - 30	V.STIFF
		>30	HARD

REMARKS:
1. Located approx. 120 ft. south of gas easement, along dirt road (EL. 800±).
2. Hole grouted to ground surface upon completion of boring.

UNIFIED CLASSIFICATION

Gravel	G
Sand	S
Silt	M
Clay	C

Description shall reference USCS classification chart

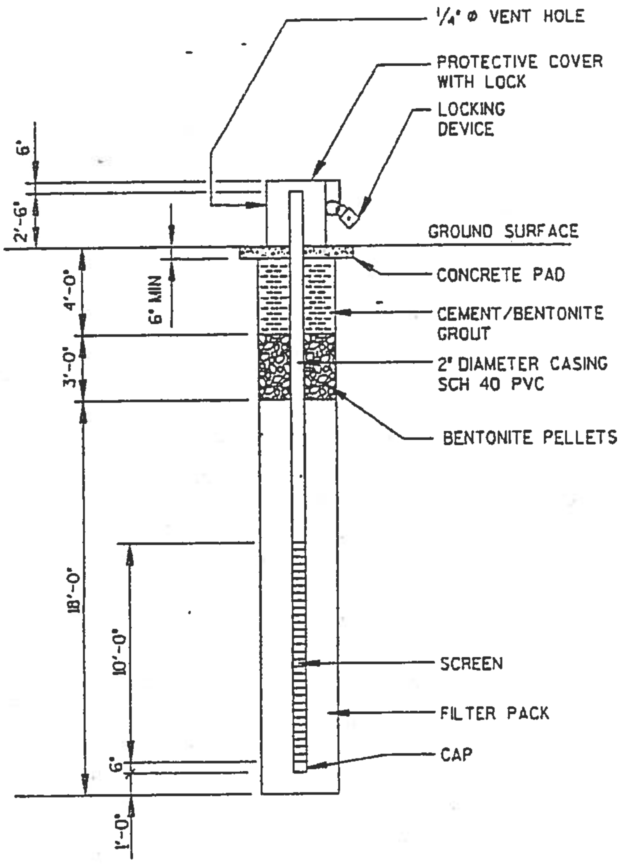
NOTES:
a) THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES, TRANSITIONS MAY BE GRADUAL. SOLID LINES INDICATE AN OBSERVED SOIL CHANGE. DASHED LINES INDICATE AN APPROXIMATED SOIL BOUNDARY.
b) WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT TIMES AND UNDER CONDITIONS STATED ON THE BORING LOGS. FLUCTUATIONS IN THE LEVEL OF GROUNDWATER MAY OCCUR DUE TO OTHER FACTORS THAN THOSE PRESENT AT THE TIME MEASUREMENTS WERE MADE.
c) STANDARD PENETRATION RESISTANCE, N-VALUE, IS THE NUMBER OF BLOWS REQUIRED TO DRIVE THE SAMPLER FROM 6-18 INCHES OF PENETRATION.
d) UNCONFINED COMPRESSION STRENGTH, Qu, WAS DETERMINED FROM THE SPLIT SPOON SAMPLE UTILIZING A POCKET PENETROMETER.
e) TO CONVERT FEET TO METERS MULTIPLY BY $3.048X10^{-1}$

BORING NO. B123

APPENDIX I(C)

PIEZOMETER CONSTRUCTION DETAILS

TOWANTIC ENERGY CENTER
OXFORD, CT



TYPICAL PIEZOMETER DETAIL

N.T.S.

PIEZOMETER NOTES:

1. PIEZOMETERS SHALL BE INSTALLED AT THE B-116, B-118 AND B-119 LOCATIONS.

2. APPROPRIATE SCREEN SIZE AND FILTER MATERIAL SHALL BE SELECTED FOR PIEZOMETER CONSTRUCTION.

3. CONSTRACTOR SHALL DEMONSTRATE THAT PIEZOMETER IS FUNCTIONING PROPERLY BY REMOVING WATER FROM THE PIEZOMETER RISER. DEVELOPMENT IS ESTIMATED TO CONSIST OF REMOVAL OF WATER EQUAL TO THREE TIMES THE RISER VOLUME.

PARE ENGINEERING CORPORATION

49 WALPOLE STREET, SUITE 2, NORWOOD, MASSACHUSETTS
ENGINEERS *** PLANNERS *** CONSULTANTS

BORING NO. B116A
SHEET 1 OF 1

PROJECT	Towantic Energy Center Oxford, CT	PROJECT NO. CHKD. BY	00172 00 JMB

BORING CO.	Parratt-Wolff	BORING LOCATION	SEE EXPLORATION LOCATION PLAN		
FOREMAN	B. Waters	GROUND SURFACE ELEVATION	834.9	DATUM	NGVD, 1929
ENGINEER	A. Orsi	DATE START	10/30/00	DATE END	10/31/00

SAMPLER: UNLESS OTHERWISE NOTED, SAMPLER CONSISTS OF A 2" SPLIT SPOON DRIVEN USING A 140 lb. HAMMER FALLING 30 in.

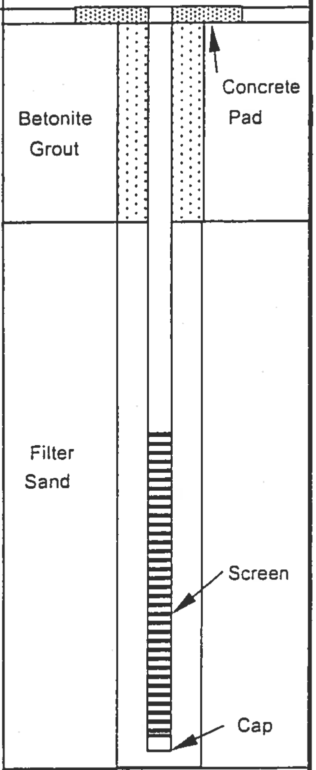
CASING: UNLESS OTHERWISE NOTED, CASING DRIVEN USING 300 lb. HAMMER FALLING 24 IN.

CASING SIZE: OTHER: 3 3/4 H.S.A.

GROUNDWATER READINGS

DATE	TIME	WATER AT	CASING AT	STABILIZATION TIME
31-Oct	14:45	21.14		6 hours
1-Nov	8:00	15.08		24 hours

DEPTH (ft)	CASING (bl/ft)	SAMPLE NO.	PEN. (in.)/ REC.	DEPTH (FT)	BLOWS/6"	TONS/FT² OR KG/CM²	SAMPLE DESCRIPTION: Unified Soil Classification System / CLASSIFICATION	REMARKS	STRATUM DESCRIPTION
								1	
5									
							No samples taken. Boring advanced for installation of piezometer.		
10									
15									
20									
25									
							END EXPLORATION @ 29'		
30									



GRANULAR SOILS BLOWS/FT	DENSITY	COHESIVE SOILS BLOWS/FT	DENSITY
0 - 4	V. LOOSE	<2	V.SOFT
4 - 10	LOOSE	2 - 4	SOFT
10 - 30	M DENSE	4 - 8	M STIFF
30 - 50	DENSE	8 - 15	STIFF
>50	V DENSE	15 - 30	V STIFF
		>30	HARD

REMARKS:
1. Piezometer protected with 2-ft standpipe with cap and lock.

UNIFIED CLASSIFICATION	
Gravel	G
Sand	S
Silt	M
Clay	C

Description shall reference USCS classification chart

NOTES:
a) THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES, TRANSITIONS MAY BE GRADUAL. SOLID LINES INDICATE AN OBSERVED SOIL CHANGE. DASHED LINES INDICATE AN APPROXIMATED SOIL BOUNDARY.
b) WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT TIMES AND UNDER CONDITIONS STATED ON THE BORING LOGS. FLUCTUATIONS IN THE LEVEL OF GROUNDWATER MAY OCCUR DUE TO OTHER FACTORS THAN THOSE PRESENT AT THE TIME MEASUREMENTS WERE MADE.
c) STANDARD PENETRATION RESISTANCE, N-VALUE, IS THE NUMBER OF BLOWS REQUIRED TO DRIVE THE SAMPLER FROM 6-18 INCHES OF PENETRATION
d) UNCONFINED COMPRESSION STRENGTH, Qu, WAS DETERMINED FROM THE SPLIT SPOON SAMPLE UTILIZING A POCKET PENETROMETER.
e) TO CONVERT FEET TO METERS MULTIPLY BY $3.048X10^{-1}$

BORING NO. B116A

PARE ENGINEERING CORPORATION

49 WALPOLE STREET, SUITE 2, NORWOOD, MASSACHUSETTS

ENGINEERS *** PLANNERS *** CONSULTANTS

BORING NO. B118A

SHEET 1 OF 1

PROJECT	Towantic Energy Center Oxford, CT	PROJECT NO.	00172.00
		CHKD. BY	JMB

BORING CO.	Parratt-Wolff	BORING LOCATION	SEE EXPLORATION LOCATION PLAN
FOREMAN	B. Waters	GROUND SURFACE ELEVATION	840.3 DATUM NGVD, 1929
ENGINEER	A. Orsi	DATE START	10/30/00 DATE END 10/30/00

SAMPLER: UNLESS OTHERWISE NOTED, SAMPLER CONSISTS OF A 2" SPLIT SPOON DRIVEN USING A 140 lb. HAMMER FALLING 30 in.

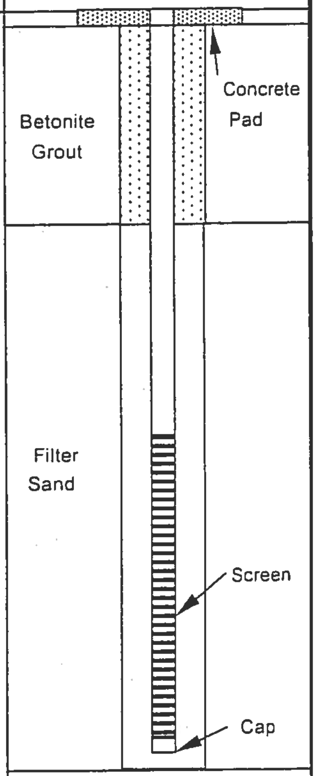
CASING: UNLESS OTHERWISE NOTED, CASING DRIVEN USING 300 lb. HAMMER FALLING 24 IN.

CASING SIZE: OTHER: 3 3/4 H.S.A.

GROUNDWATER READINGS

DATE	TIME	WATER AT	CASING AT	STABILIZATION TIME
31-Oct	12:00	Dry		
1-Nov	8:00	Dry		

DEPTH (ft)	CASING (bl/ft)	SAMPLE NO.	PEN. (in.)/ REC.	DEPTH (FT)	BLOWS/6"	TONS/FT² OR KG/CM²	SAMPLE DESCRIPTION Unified Soil Classification System CLASSIFICATION	REMARKS	STRATUM DESCRIPTION
							No samples taken. Boring advanced for installation of piezometer.	1	
5									
10									
15									
20									
25							END EXPLORATION @ 29'		
30									



GRANULAR SOILS BLOWS/FT	DENSITY	COHESIVE SOILS BLOWS/FT	DENSITY
0 - 4	V. LOOSE	<2	V.SOFT
4 - 10	LOOSE	2 - 4	SOFT
10 - 30	M.DENSE	4 - 8	M.STIFF
30 - 50	DENSE	8 - 15	STIFF
>50	V.DENSE	15 - 30	V.STIFF
		>30	HARD

REMARKS:

1. Piezometer protected with 2-ft standpipe with cap and lock.

UNIFIED CLASSIFICATION

Gravel	G
Sand	S
Silt	M
Clay	C

Description shall reference USCS classification chart

NOTES:

a) THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES, TRANSITIONS MAY BE GRADUAL. SOLID LINES INDICATE AN OBSERVED SOIL CHANGE. DASHED LINES INDICATE AN APPROXIMATED SOIL BOUNDARY.

b) WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT TIMES AND UNDER CONDITIONS STATED ON THE BORING LOGS. FLUCTUATIONS IN THE LEVEL OF GROUNDWATER MAY OCCUR DUE TO OTHER FACTORS THAN THOSE PRESENT AT THE TIME MEASUREMENTS WERE MADE.

c) STANDARD PENETRATION RESISTANCE, N-VALUE, IS THE NUMBER OF BLOWS REQUIRED TO DRIVE THE SAMPLER FROM 6-18 INCHES OF PENETRATION.

d) UNCONFINED COMPRESSION STRENGTH, Qu, WAS DETERMINED FROM THE SPLIT SPOON SAMPLE UTILIZING A POCKET PENETROMETER.

e) TO CONVERT FEET TO METERS MULTIPLY BY 3.048×10^{-1}

BORING NO. B118A

PARE ENGINEERING CORPORATION

49 WALPOLE STREET, SUITE 2, NORWOOD, MASSACHUSETTS

ENGINEERS *** PLANNERS *** CONSULTANTS

BORING NO. B119A

SHEET 1 OF 1

PROJECT: Towantic Energy Center, Oxford, CT

PROJECT NO.: 00172.00

CHKD. BY: IMB

BORING CO.: Parratt-Wolff

FOREMAN: B. Waters

ENGINEER: A. Orsi

BORING LOCATION: SEE EXPLORATION LOCATION PLAN

GROUND SURFACE ELEVATION: 825.6 DATUM: NGVD, 1929

DATE START: 10/30/00 DATE END: 10/30/00

SAMPLER: UNLESS OTHERWISE NOTED, SAMPLER CONSISTS OF A 2" SPLIT SPOON DRIVEN USING A 140 lb. HAMMER FALLING 30 in.

CASING: UNLESS OTHERWISE NOTED, CASING DRIVEN USING 300 lb. HAMMER FALLING 24 IN.

CASING SIZE:

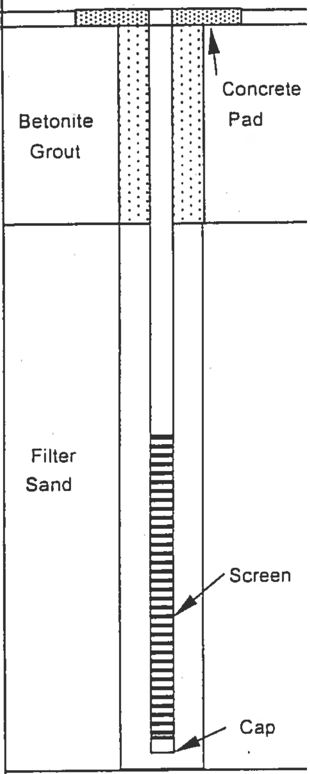
OTHER: 3 3/4 H.S.A.

GROUNDWATER READINGS

DATE	TIME	WATER AT	CASING AT	STABILIZATION TIME
31-Oct	7:00	12.94		19 hours
1-Nov	8:00	11.38		42 hours

DEPTH (ft)	CASING (bl/ft)	SAMPLE NO.	PEN. (in.)/ REC.	DEPTH (FT)	BLOWS/6"	TONS/FT² OR KG/CM²	SAMPLE DESCRIPTION — Unified Soil Classification System / CLASSIFICATION	REMARKS
								1
5								
							No samples taken. Boring advanced for installation of piezometer.	
10								
15								
20								
25								
							END EXPLORATION @ 29'	
30								

STRATUM DESCRIPTION



GRANULAR SOILS BLOWS/FT	DENSITY	COHESIVE SOILS BLOWS/FT	DENSITY
0 - 4	V. LOOSE	<2	V.SOFT
4 - 10	LOOSE	2 - 4	SOFT
10 - 30	M.DENSE	4 - 8	M.STIFF
30 - 50	DENSE	8 - 15	STIFF
>50	V.DENSE	15 - 30	V.STIFF
		>30	HARD

REMARKS:

1. Piezometer protected with 2-ft standpipe with cap and lock.

UNIFIED CLASSIFICATION	
Gravel	G
Sand	S
Silt	M
Clay	C

Description shall reference USCS classification chart

NOTES:

a) THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES, TRANSITIONS MAY BE GRADUAL. SOLID LINES INDICATE AN OBSERVED SOIL CHANGE. DASHED LINES INDICATE AN APPROXIMATED SOIL BOUNDARY.

b) WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT TIMES AND UNDER CONDITIONS STATED ON THE BORING LOGS. FLUCTUATIONS IN THE LEVEL OF GROUNDWATER MAY OCCUR DUE TO OTHER FACTORS THAN THOSE PRESENT AT THE TIME MEASUREMENTS WERE MADE.

c) STANDARD PENETRATION RESISTANCE, N-VALUE, IS THE NUMBER OF BLOWS REQUIRED TO DRIVE THE SAMPLER FROM 6-18 INCHES OF PENETRATION.

d) UNCONFINED COMPRESSION STRENGTH, Qu, WAS DETERMINED FROM THE SPLIT SPOON SAMPLE UTILIZING A POCKET PENETROMETER.

e) TO CONVERT FEET TO METERS MULTIPLY BY 3.048×10^{-1}

BORING NO. B119A

APPENDIX I(D)

TEST PIT LOGS

Burns and Roe Enterprises, Inc.

Date: December 1, 2001

Project: Towantic Energy Center
Oxford, Connecticut

Test Pit No.: TP-101

Ground Elev.: +824 ft

Test Pit Log

DEPTH (ft)	SAMPLE NO.	OBSERVATION & CLASSIFICATION OF MATERIAL
0 to 9"		Topsoil over
9" to		Brown fm Sand, some Clayey Silt, little fc Gravel and Cobbles (Silty Sands – SM)
15'-3"		
		Bottom of Test Pit – 15'-3" (El +808.75 ft)

GROUNDWATER DATA

12/1/00 9:30 AM – Groundwater at a depth of 15'-3" after excavation of test pit.
12/1/00 3:50 PM – Groundwater seeping from lower portion of test pit and accumulating at the bottom of the excavation.
12/5/00 – Groundwater at a depth of 9'-0".

Burns and Roe Enterprises, Inc.

Date: December 1, 2001

Test Pit No.: TP-102

Project: Towantic Energy Center
Oxford, Connecticut

Ground Elev.: +834 ft

Test Pit Log

DEPTH (ft)	SAMPLE NO.	OBSERVATION & CLASSIFICATION OF MATERIAL
0 to 6"		Topsoil over
6" to		Brown fm Sand, some Silt and Clay, little fc Gravel and Cobbles (Silty Sands – SM)
17'-9"		
		Bottom of Test Pit – 17'-9" (El +816.25 ft)

GROUNDWATER DATA

12/1/00 12:20 PM – No groundwater (dry) after excavation of the test pit.
12/1/00 3:40 PM – No groundwater (dry).
12/5/00 – Groundwater at a depth of 11'-2".

Burns and Roe Enterprises, Inc.

Date: December 1, 2001

Project: Towantic Energy Center
Oxford, Connecticut

Test Pit No.: TP-103

Ground Elev.: +830 ft

Test Pit Log

DEPTH (ft)	SAMPLE NO.	OBSERVATION & CLASSIFICATION OF MATERIAL
0 to 9"		Topsoil over
9" to		Tan Brown to Orange Brown fm Sand, some Clayey Silt, little fc Gravel. (Silty Sands – SM) over
6'-0"		
6'-0" to		Brown fm Sand, some Silt and Clay, little fc Gravel (Silty Sands – SM)
10'-0"		
		Bottom of Test Pit – 10'-0" (El +820 ft)

GROUNDWATER DATA

12/1/00 11:30 AM – Groundwater at a depth of 10'-0"; water seeping in excavation from a depth of 8'.
12/1/00 12:00 Noon – Groundwater at a depth of 9'-8".
12/5/00 – Groundwater at a depth of 4'-3".

Burns and Roe Enterprises, Inc.

Date: December 1, 2001

Test Pit No.: TP-104

Project: Towantic Energy Center
Oxford, Connecticut

Ground Elev.: +835 ft

Test Pit Log

DEPTH (ft)	SAMPLE NO.	OBSERVATION & CLASSIFICATION OF MATERIAL
0 to 9"		Topsoil over
9" to		Brown fm Sand, some Clayey Silt, little fc Gavel and Cobbles (Silty Sands – SM)
10'-9"		
		Bottom of Test Pit 10'-9" (El +824.25 ft)

GROUNDWATER DATA

12/1/00 11:15 AM – Groundwater at a depth of 10'-9".
12/5/00 – Groundwater at a depth of 8'-3".

Burns and Roe Enterprises, Inc.

Date: December 1, 2001

Project: Towantic Energy Center
Oxford, Connecticut

Test Pit No.: TP-105

Ground Elev.: +838 ft

Test Pit Log

DEPTH (ft)	SAMPLE NO.	OBSERVATION & CLASSIFICATION OF MATERIAL
0 to 9"		Topsoil over
9" to		Brown fm Sand, some Clayey Silt, little fc Gravel and Cobbles (Silty Sands – SM)
16'-3"		
		Bottom of Test Pit – 16'-3" (El +821.75 ft)

GROUNDWATER DATA

12/1/00 10:00 AM – No groundwater (dry) after excavation of test pit.
12/1/00 3:35 PM – Groundwater beginning to accumulate at the bottom of the test pit.
12/5/00 – Groundwater seeping into the excavation from a depth of 8'-0".

Burns and Roe Enterprises, Inc.

Date: December 1, 2001

Test Pit No.: TP-106

Project: Towantic Energy Center
Oxford, Connecticut

Ground Elev.: +839 ft

Test Pit Log

DEPTH (ft)	SAMPLE NO.	OBSERVATION & CLASSIFICATION OF MATERIAL
0 to 9"		Topsoil over
9" to		Brown fm Sand, some Clayey Silt, little fc Gavel and Cobbles (Silty Sands – SM)
18'-6"		
		Bottom of Test Pit 18'-6" (El +820.5 ft)

GROUNDWATER DATA

12/1/00 10:45 AM – No groundwater (dry) after excavation of test pit.
12/1/00 3:30 PM – No groundwater (dry).
12/5/00 – Excavation sides moist from a depth of 6'-0" to the bottom of the test pit.

Burns and Roe Enterprises, Inc.

Date: December 1, 2001

Project: Towantic Energy Center
Oxford, Connecticut

Test Pit No.: TP-107

Ground Elev.: +835 ft

Test Pit Log

DEPTH (ft)	SAMPLE NO.	OBSERVATION & CLASSIFICATION OF MATERIAL
0 to 1'-0"		Topsoil over
1'-0" to		Tan brown fm Sand, little Clayey Silt, little fc Gavel and Cobbles
		(Silty Sands – SM) over
4'-0"		
4"-0" to		Brown fm Sand, some Silt and Clay, little fc Gravel and Cobbles
		(Silty Sands – SM)
17'-8"		
		Bottom of Test Pit – 17'-8" (El +817.3 ft)

GROUNDWATER DATA

12/1/00 12:00 Noon – No groundwater (dry) after excavation of the test pit.
12/1/00 2:30 PM – Excavation side slopes moist from a depth of 10'-0" to the bottom of the excavation.
12/5/00 – Groundwater at a depth of 10'-0".

Burns and Roe Enterprises, Inc.

Date: December 1, 2001

Project: Towantic Energy Center
Oxford, Connecticut

Test Pit No.: TP-108

Ground Elev.: +833 ft

Test Pit Log

DEPTH (ft)	SAMPLE NO.	OBSERVATION & CLASSIFICATION OF MATERIAL
0 to 9"		Topsoil over
9" to		Tan brown fm Sand, little Clayey Silt, little fc Gravel and Cobbles (Silty Sands – SM) over
6'-0"		
6'-0" to		Brown fm Sand, some Silt and Clay, some fc Gravel and Cobbles (Silty Sands – SM)
16'-10"		
		Bottom of Test Pit – 16'-10" (El +816.2 ft)

GROUNDWATER DATA

12/1/00 12:50 PM – No groundwater (dry) after excavation of test pit.
12/1/00 3:15 PM – Water beginning to accumulate at the bottom of the excavation.
12/5/00 – Groundwater at a depth of 6'-6".

Burns and Roe Enterprises, Inc.

Date: December 1, 2001

Test Pit No.: TP-109

Project: Towantic Energy Center
Oxford, Connecticut

Ground Elev.: +841 ft

Test Pit Log

DEPTH (ft)	SAMPLE NO.	OBSERVATION & CLASSIFICATION OF MATERIAL
0 to 1'-0"		Topsoil over
1'-0" to		Tan brown fm Sand, some Clayey Silt, little fc Gavel
		(Silty Sands – SP) over
4'-0"		
4'-0" to		Brown fm Sand, some Silt and Clay, little fc Gravel
		(Silty Sands – SM)
16'-4"		
		Bottom of Test Pit – 16'-4" (El +824.7 ft)

GROUNDWATER DATA

12/1/00 1:15 PM – Test pit dry; however, groundwater beginning to seep from a depth of 3 ft to the bottom of the excavation.

12/5/00 – Groundwater at a depth of 7'-0".

Burns and Roe Enterprises, Inc.

Date: December 2, 2001

Project: Towantic Energy Center
Oxford, Connecticut

Test Pit No.: TP-110

Ground Elev.: +841 ft

Test Pit Log

DEPTH (ft)	SAMPLE NO.	OBSERVATION & CLASSIFICATION OF MATERIAL
0 to 9"		Topsoil over
9" to		Brown fm Sand, some Silt and Clay, some fc Gravel (Silty Sands – SM)
10'-0"		
		Bottom of Test Pit 10'-0" (El +831 ft)

GROUNDWATER DATA

12/5/00 – Groundwater at a depth of 9'-0".

Burns and Roe Enterprises, Inc.

Date: December 1, 2001

Project: Towantic Energy Center
Oxford, Connecticut

Test Pit No.: TP-111

Ground Elev.: +846 ft

Test Pit Log

DEPTH (ft)	SAMPLE NO.	OBSERVATION & CLASSIFICATION OF MATERIAL
0 to 6"		Topsoil over
6" to		Tan brown fm Sand, little Clay Silt, little fc Gravel
		(Silty Sands – SM) over
4'-0"		
4'-0" to		Brown fm Sand, some Silt and Clay, some fc Gravel and Cobbles
		(Silty Sands – SM)
16'-4"		
		Bottom of Test Pit 16'-4" (El +829.7 ft)

GROUNDWATER DATA

12/1/00 2:00 PM – Test pit dry; however, groundwater beginning to seep into excavation from a depth of 3 ft.

12/5/00 – Groundwater at a depth of 5'-0".

Burns and Roe Enterprises, Inc.

Date: December 2, 2001

Project: Towantic Energy Center
Oxford, Connecticut

Test Pit No.: TP-112

Ground Elev.: +804 ft

Test Pit Log

DEPTH (ft)	SAMPLE NO.	OBSERVATION & CLASSIFICATION OF MATERIAL
0 to 9"		Topsoil over
9" to		Brown fm Sand, some Clayey Silt, little fc Gravel
		(Silty Sands – SM)
4'-0"		
4'-0" to		Brown fm Sand, some Silt and Clay, little fc Gravel
		(Silty Sands – SM)
8'-0"		
		Bottom of Test Pit 8'-0" (El +796 ft)

GROUNDWATER DATA

12/5/00 – Groundwater at a depth of 5'-8".

APPENDIX I(E)

PRELIMINARY TEST BORING AND TEST PIT INFORMATION

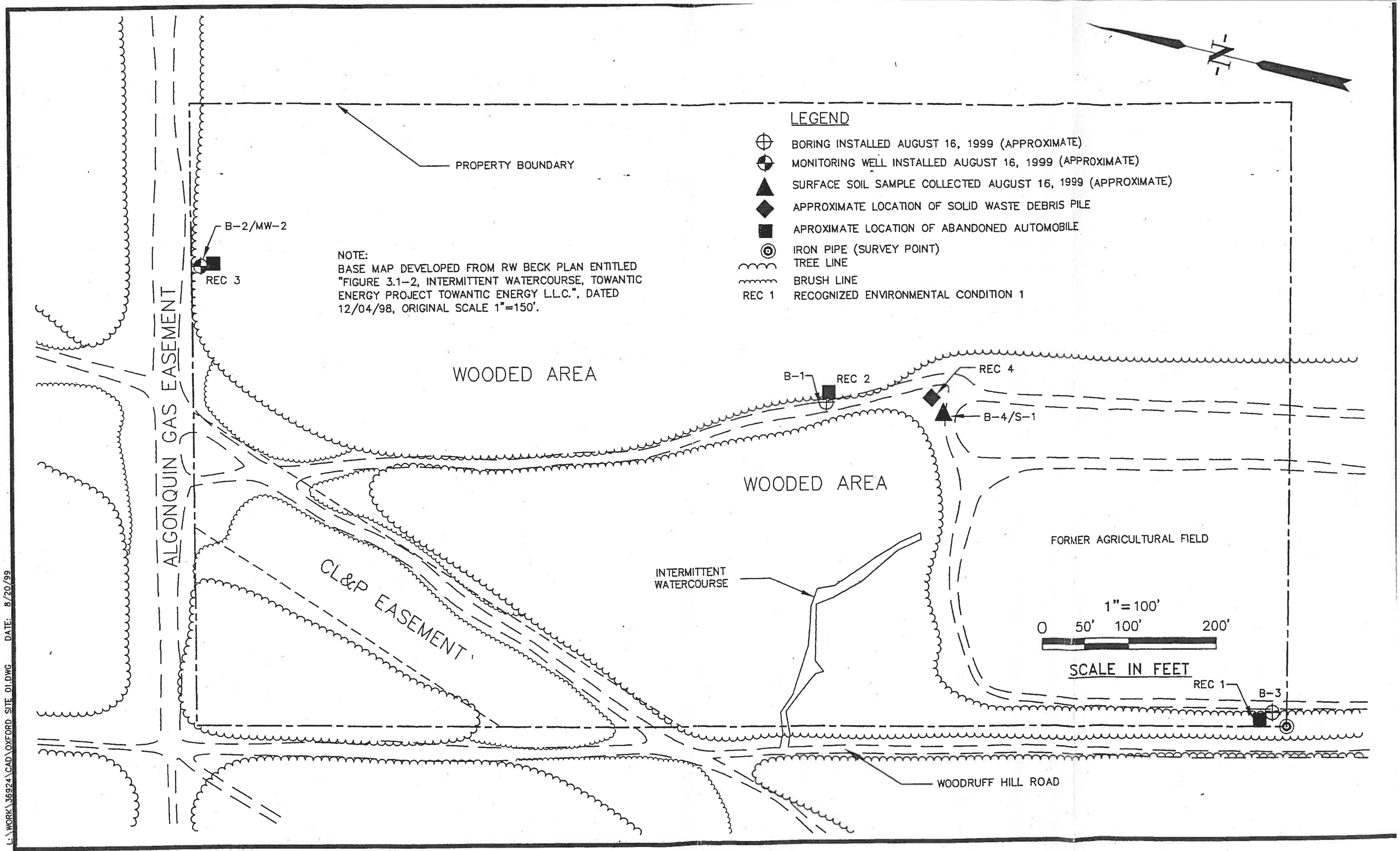


FIGURE 2
EXPLORATION LOCATION PLAN
TOWANTIC ENERGY PROJECT SITE OXFORD, CONNECTICUT

E A R T H T E C H

EARTH TECH 196 Baker Avenue Concord, Massachusetts 01742	PROJECT: Towantic Energy	BORING NUMBER B-1 GRADE~ [illegible] SHEET 1 OF 1 DATE 8/16/99 FILE 36924-01

BORING COMPANY	New England Boring Co.	BORING LOCATION	See attached site plan.
FOREMAN	Tim Carpenter	GROUND ELEVATION	NA
EARTH TECH ENGINEER	Jason Pierce/Tiffany Dalton	DATE STARTED	8/16/99 DATE ENDED 8/16/99

	HSA		SAMPLER	OTHER:
SIZE	3.25" I.D.	TYPE	2"	
HAMMER	N/A	HAMMER	140 lbs.	
FALL	N/A	FALL	30"	

GROUNDWATER READINGS

DATE	DEPTH	CASING	STABILIZATION TIME
8/16/99	NA		

Depth	SAMPLE NO.	REC.	DEPTH	BLOWS	SAMPLE DESCRIPTION	STRATA CHANGE AND GENERAL DESCRIPTION	FIELD TESTING OVM (ppm)	EQUIPMENT OR WELL INSTALLED
	S-1	12"	0-2'	8 - 13 20 - 28	0-2" - Dry, medium dense, brown SILTY ORGANICS. 2 -12" - Dry, medium dense, light brown, fine to medium SAND, trace(-) coarse Sand.	Sand	0 0	None
5'								
					Refusal to augers at 3.5' below ground surface.			
10'								
15'								
20'								
25'								

PROPORTIONS USED

TRACE	0 TO 10%
LITTLE	10 TO 20%
SOME	20 TO 35%
AND	35 TO 50%

PENETRATION RESISTANCE
140 LB WT FALLING 30" ON 2" O.D. SAMPLER

COHESIONLESS DENSITY		COHESIVE CONSISTENCY	
0-4	VERY LOOSE	0-2	VERY SOFT
5-9	LOOSE	3-4	SOFT
10-29	MED. DENSE	5-8	M/STIFF
30-49	DENSE	9-15	STIFF
50+	VERY DENSE	16-30	V-STIFF
		31+	HARD

WELL CONSTRUCTION LEGEND

CONCRETE	EEEEE	BENTONITE	^^^^^	GROUT	======
SILICA SAND		NATURAL BACKFILL		BEDROCK	++++++

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EARTH TECH 196 Baker Avenue Concord, Massachusetts 01742	PROJECT: Towantic Energy	BORING NUMBER B-1A GRADE SHEET 1 OF 1 DATE 8/16/99 FILE 36924-01

BORING COMPANY: New England Boring Co.
FOREMAN: Tim Carpenter
EARTH TECH ENGINEER: Jason Pierce/Tiffany Dalton

BORING LOCATION: See attached site plan.
GROUND ELEVATION: NA
DATE STARTED: 8/16/99 DATE ENDED: 8/16/99

	HSA		SAMPLER	OTHER:
SIZE	3.25" I.D.	TYPE	2"	
HAMMER	N/A	HAMMER	140 lbs.	
FALL	N/A	FALL	30"	

GROUNDWATER READINGS

DATE	DEPTH	CASING	STABILIZATION TIME
8/16/99	NA		

Depth	SAMPLE NO.	REC.	DEPTH	BLOWS	SAMPLE DESCRIPTION	STRATA CHANGE AND GENERAL DESCRIPTION	FIELD TESTING OVM (ppm)	EQUIPMENT OR WELL INSTALLED
					Augered to 5' to collect sample.			None
5'	S-2	24"	5-7'	25 - 13 22 - 23	0-6" - Dry, medium dense, dark brown, fine to medium SAND, little Silt. 6-18" - Dry, medium dense, brown, fine SAND, trace medium to coarse Sand, trace(+) Silt. 18-24" - Gray SILTY CLAY.		0.0	
10'	S-3	24"	10-12'	20 - 24 51 - 35	0-12" - Dry, medium dense, dark brown, CLAY and SILT. 12-24" - Dry, dense, gray, CLAYEY SILT.	Silty Sand & Clay	0.0	
15'	S-4	16"	15-17'	42 - 24 32 - 27	0-16" - Dry, dense, dark brown, fine SAND, trace medium to coarse Sand, little Silt.		0.0	
20'	S-5	8"	20-22'	75 - 24 31 - 36	0-8" - Dry, medium dense, olive gray, fine SAND, trace(-) coarse Sand, little Silt.		0.0	
					Bottom of exploration at 22' below ground surface.			
25'								

PROPORTIONS USED

TRACE	0 TO 10%
LITTLE	10 TO 20%
SOME	20 TO 35%
AND	35 TO 50%

PENETRATION RESISTANCE
140 LB WT FALLING 30" ON 2" O.D. SAMPLER

COHESIONLESS DENSITY		COHESIVE CONSISTENCY	
0-4	VERY LOOSE	0-2	VERY SOFT
5-9	LOOSE	3-4	SOFT
10-29	MED. DENSE	5-8	M/STIFF
30-49	DENSE	9-15	STIFF
50+	VERY DENSE	16-30	V-STIFF
		31+	HARD

WELL CONSTRUCTION LEGEND

CONCRETE	EEEEE	BENTONITE	nnnnn	GROUT	======
SILICA SAND		NATURAL BACKFILL		BEDROCK	++++++

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EARTH TECH 196 Baker Avenue Concord, Massachusetts 01742	PROJECT: Towantic Energy	BORING NUMBER B-2 SHEET 1 OF 1 DATE 8/16/99 FILE 36924-01

BORING COMPANY	New England Boring Co.	BORING LOCATION	See attached site plan.
FOREMAN	Tim Carpenter	GROUND ELEVATION	NA
EARTH TECH ENGINEER	Jason Pierce/Tiffany Dalton	DATE STARTED	8/16/99 DATE ENDED 8/16/99

	HSA		SAMPLER	
SIZE	3.25" I.D.	TYPE	2"	OTHER:
HAMMER	N/A	HAMMER	140 lbs.	
FALL	N/A	FALL	30"	

GROUNDWATER READINGS

DATE	DEPTH	CASING	STABILIZATION TIME
8/16/99	NA		

Depth	SAMPLE NO.	REC.	DEPTH	BLOWS	SAMPLE DESCRIPTION	STRATA CHANGE AND GENERAL DESCRIPTION	FIELD TESTING OVM (ppm)	EQUIPMENT OR WELL INSTALLED
	S-1	6"	0-2'	5 - 6 30 - 41	0-6" - Dry, medium dense, brown, fine to medium SAND, trace(-) Organics, little Silt.	Silty Sand	0.0	None
5'	S-2	20"	5-7'	28 - 30 36 - 37	0-20" - Dry, dense, light brown, fine SAND, little(+) medium to coarse Sand, little Silt.		0.0	
					Refusal to augers at 8.5' below ground surface.			
10'								
15'								
20'								
25'								

PROPORTIONS USED

TRACE	0 TO 10%
LITTLE	10 TO 20%
SOME	20 TO 35%
AND	35 TO 50%

PENETRATION RESISTANCE
140 LB WT FALLING 30" ON 2" O.D. SAMPLER

COHESIONLESS DENSITY		COHESIVE CONSISTENCY	
0-4	VERY LOOSE	0-2	VERY SOFT
5-9	LOOSE	3-4	SOFT
10-29	MED. DENSE	5-8	M/STIFF
30-49	DENSE	9-15	STIFF
50+	VERY DENSE	16-30	V-STIFF
		31+	HARD

WELL CONSTRUCTION LEGEND

CONCRETE	EEEEE	BENTONITE	^^^^^	GROUT	======
SILICA SAND		NATURAL BACKFILL		BEDROCK	++++++

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EARTH TECH 196 Baker Avenue Concord, Massachusetts 01742	PROJECT: Towantic Energy	BORING NUMBER B-2A SHEET 1 OF 1 DATE 8/16/99 FILE 36924-01

BORING COMPANY: New England Boring Co.
FOREMAN: Tim Carpenter
EARTH TECH ENGINEER: Jason Pierce/Tiffany Dalton
BORING LOCATION: See attached site plan
GROUND ELEVATION: NA
DATE STARTED: 8/16/99 DATE ENDED: 8/16/99

	HSA		SAMPLER	OTHER:
SIZE	3.25" I.D.	TYPE	2"	
HAMMER	N/A	HAMMER	140 lbs.	
FALL	N/A	FALL	30"	

GROUNDWATER READINGS

DATE	DEPTH	CASING	STABILIZATION TIME
8/16/99	10.6'	12.0'	0 hrs.
8/16/99	8.6'	17.0'	6 hrs.

	SAMPLE NO.	REC.	DEPTH	BLOWS	SAMPLE DESCRIPTION	STRATA CHANGE AND GENERAL DESCRIPTION	FIELD TESTING OVM (ppm)	EQUIPMENT OR WELL INSTALLED
								Refer to Groundwater Monitoring Report.
5'					Augered to 10' to collect sample.			
						Sand & Gravel		
10'	S-3	22"	10-12'	24 - 26 26 - 82	0-7" - Dry, medium dense, brown, fine SAND, trace(+) medium to coarse Sand. 7-22" - Wet, medium dense, brown, fine SAND, trace(+) medium to coarse Sand.		0.0	
15'	S-4	8"	15-17'	40 - 120/3"	0-8" - Wet, very dense, dark brown, fine SAND, trace(+) medium to coarse Sand.		0.0	
17'	S-5	12"	17-19'	32 - 25 31 - 38	0-12" - Dry, very dense, dark brown, fine to coarse SAND, little(-) fine gravel, trace(-) Silt.		0.0	
					Bottom of exploration at 19' below ground surface.	~ 841		

PROPORTIONS USED

TRACE	0 TO 10%
LITTLE	10 TO 20%
SOME	20 TO 35%
AND	35 TO 50%

PENETRATION RESISTANCE
140 LB WT FALLING 30" ON 2" O.D. SAMPLER

COHESIONLESS DENSITY		COHESIVE CONSISTENCY	
0-4	VERY LOOSE	0-2	VERY SOFT
5-9	LOOSE	3-4	SOFT
10-29	MED. DENSE	5-8	M/STIFF
30-49	DENSE	9-15	STIFF
50+	VERY DENSE	16-30	V-STIFF
		31+	HARD

WELL CONSTRUCTION LEGEND

CONCRETE	EEEEE	BENTONITE	nnnnn	GROUT	======
SILICA SAND		NATURAL BACKFILL		BEDROCK	++++++

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EARTH TECH 196 Baker Avenue Concord, Massachusetts 01742	PROJECT: Towantic Energy	BORING NUMBER B-3 ~~B7~~ -802 SHEET 1 OF 1 DATE 8/16/99 FILE 36924-01

BORING COMPANY	New England Boring Co.	BORING LOCATION	See attached site plan.
FOREMAN	Tim Carpenter	GROUND ELEVATION	NA
EARTH TECH ENGINEER	Jason Pierce/Tiffany Dalton	DATE STARTED	8/16/99 DATE ENDED 8/16/99

	HSA		SAMPLER	
SIZE	3.25" I.D.	TYPE	2"	OTHER:
HAMMER	N/A	HAMMER	140 lbs.	
FALL	N/A	FALL	30"	

GROUNDWATER READINGS

DATE	DEPTH	CASING	STABILIZATION TIME
8/16/99	NA		

	SAMPLE NO.	REC.	DEPTH	BLOWS	SAMPLE DESCRIPTION	STRATA CHANGE AND GENERAL DESCRIPTION	FIELD TESTING OVM (ppm)	EQUIPMENT OR WELL INSTALLED
	S-1	6"	0-2'	5 - 6 16 - 20	0-6" - Dry, medium dense, brown, fine to medium SAND, trace Organics.		0.0	None
5'	S-2	12"	5-7'	105 - 46 48 - 51	0-12" - Dry, very dense, light brown, fine SAND, trace(-) medium to coarse Sand, little fine to coarse Gravel.		0.0	
10'	S-3	20"	10-12'	20 - 26 30 - 32	0-20" - Dry, medium dense, brown, fine to medium SAND, little(+) coarse Sand, trace(+) fine to coarse Gravel.	Sand & Gravel	0.0	
15'	S-4	24"	15-17'	20 - 39 60 - 64	0-24" - Dry, very dense, brown, fine to medium SAND, trace(+) coarse Sand, trace(+) fine Gravel.		0.0	
20'	S-5	24"	20-22'	47 - 40 32 - 40	0-24" - Dry, dense, dark brown, fine to medium SAND, trace(+) coarse Sand, trace(+) fine Gravel.		0.0	
					Bottom of exploration at 22' below ground surface	B786		
25'								

PROPORTIONS USED

TRACE	0 TO 10%
LITTLE	10 TO 20%
SOME	20 TO 35%
AND	35 TO 50%

PENETRATION RESISTANCE
140 LB WT FALLING 30" ON 2" O.D. SAMPLER

COHESIONLESS DENSITY		COHESIVE CONSISTENCY	
0-4	VERY LOOSE	0-2	VERY SOFT
5-9	LOOSE	3-4	SOFT
10-29	MED. DENSE	5-8	M/STIFF
30-49	DENSE	9-15	STIFF
50+	VERY DENSE	16-30	V-STIFF
		31+	HARD

WELL CONSTRUCTION LEGEND

CONCRETE	EEEEE	BENTONITE	^^^^^	GROUT	======
SILICA SAND		NATURAL BACKFILL		BEDROCK	++++++

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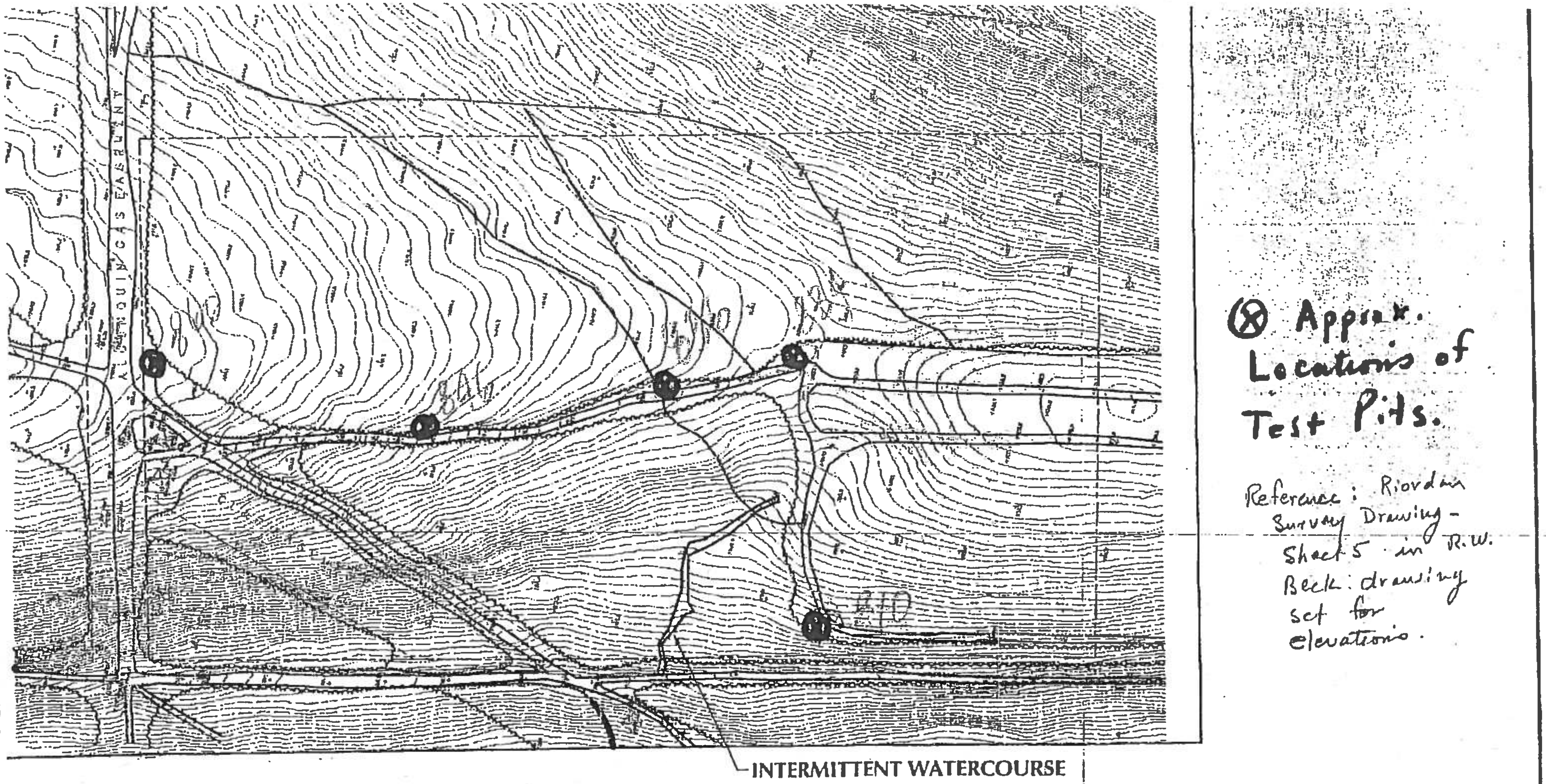
ALGONQUIN GAS EASEMENT
INTERMITTENT WATERCOURSE
⊗ Approx. Locations of Test Pits.
Reference: Riordan Survey Drawing - Sheet 5 in R.W. Beck drawing set for elevations.

FIGURE 3.1.2

PARSONS ENERGY & CHEMICALS GROUP INC.
SOIL/ROCK CLASSIFICATION SHEET

PROJECT	Towantic Energy Project	SHEET	1 OF 1
CLIENT	General Electric Company	TEST PIT NO.	TP98-1
LOGGED BY	Gregory Nadeau	COORDINATES	
EQUIPMENT	Link Belt LS-2800B	G.S. ELEV.	
		GWL DEPTH	N/A
		DATE	9/28/98
		W.O. NO.	924091-06200

DEPTH (FT)	SAMPLE TYPE & NO.	SAMPLE BLOWS/6" or RQD	SAMPLE REC.	SOIL or ROCK DESCRIPTION	REMARKS
				TOPSOIL 1.5'	No groundwater encountered
5				GLACIAL TILL (SM to GM) well graded silt to gravel size particles less gravel with depth trace to little cobbles slightly plastic fines light brown, damp very dense	
10				dark brown at 8' more silt and sand moist 13.5'	
15				Total Depth of Test Pit is 13.5'	

PARSONS ENERGY & CHEMICALS GROUP INC.
SOIL/ROCK CLASSIFICATION SHEET

PROJECT	Towantic Energy Project	SHEET	1 OF 1
CLIENT	General Electric Company	TEST PIT NO.	TP98-2
LOGGED BY	Gregory Nadeau	COORDINATES	
EQUIPMENT	Link Belt LS-2800B	G.S. ELEV.	
		GWL DEPTH	N/A
		DATE	9/28/98
		W.O. NO.	924091-08200

DEPTH (FT)	SAMPLE TYPE & NO.	SAMPLE BLOWS/6" or RQD	SAMPLE REC.	SOIL or ROCK DESCRIPTION	REMARKS
				TOPSOIL 0.5'	No groundwater encountered
				SAND, fine to medium, little gravel & cobbles moist, tan 1.5'	
5, 10				GLACIAL TILL (SM to GM) well graded silt to gravel size particles less gravel with depth trace to little cobbles slightly plastic fines light brown, damp very dense finer and wetter with depth turns to grayish brown 14.5'	
15				Total Depth of Test Pit is 14.5'	

PARSONS ENERGY & CHEMICALS GROUP INC.
SOIL/ROCK CLASSIFICATION SHEET

PROJECT: Towantic Energy Project
CLIENT: General Electric Company
LOGGED BY: Gregory Nadeau
EQUIPMENT: Link Belt LS-2800B

SHEET: 1 OF 1
TEST PIT NO.: TP98-3
COORDINATES:
G.S. ELEV.:
GWL DEPTH: N/A
DATE: 9/28/98
W.O. NO.: 924091-06200

DEPTH (FT)	SAMPLE TYPE & NO.	SAMPLE BLOWS/6" or RQD	SAMPLE REC.	SOIL or ROCK DESCRIPTION	REMARKS
				TOPSOIL 0.6'	No groundwater encountered
				SAND, fine to medium, little gravel & cobbles, moist, tan 1.5'	
5				GLACIAL TILL (SM) well graded silt to gravel size particles less gravel with depth trace to little cobbles low plasticity light brown, damp very dense finer and wetter with depth turns to grayish brown	
10				12.0'	
				VERY SILTY SAND (SM) trace gravel low plasticity gray moist to wet 14.5'	
15				Total Depth of Test Pit is 14.5'	

PARSONS ENERGY & CHEMICALS GROUP INC.
SOIL/ROCK CLASSIFICATION SHEET

PROJECT Towantic Energy Project
CLIENT General Electric Company
LOGGED BY Gregory Nadeau
EQUIPMENT Link Belt LS-2800B

SHEET 1 OF 1
TEST PIT NO. TP98-4
COORDINATES
G.S. ELEV.
GWL DEPTH N/A
DATE 9/28/98
W.O. NO. 924081-06200

DEPTH (FT)	SAMPLE TYPE & NO.	SAMPLE BLOWS/6" or RQD	SAMPLE REC.	SOIL or ROCK DESCRIPTION		REMARKS
				TOPSOIL	0.5'	No groundwater encountered
				SAND, fine to medium, little gravel & cobbles moist, tan	1.0'	
5				GLACIAL TILL (SM) well graded silt to gravel size particles less gravel with depth trace to little cobbles, with 4' boulder low plasticity light brown, damp very dense finer and wetter with depth turns to grayish brown	6.0'	
10				VERY SILTY SAND (SM) trace gravel low plasticity light grayish brown moist to wet at 8', little cobbles, more gravel	13.5'	
15				Total Depth of Test Pit is 13.5'		

PARSONS ENERGY & CHEMICALS GROUP INC.
SOIL/ROCK CLASSIFICATION SHEET

PROJECT	Towantic Energy Project	SHEET	1 OF 1
CLIENT	General Electric Company	TEST PIT NO.	TP98-5
LOGGED BY	Gregory Nadeau	COORDINATES	
EQUIPMENT	Link Belt LS-2800B	G.S. ELEV.	
		GWL DEPTH	N/A
		DATE	9/28/98
		W.O. NO.	924091-06200

DEPTH (FT)	SAMPLE TYPE & NO.	SAMPLE BLOWS/6" or RQD	SAMPLE REC.	SOIL or ROCK DESCRIPTION	REMARKS
				TOPSOIL 1.0'	No groundwater encountered
				GLACIAL TILL (SM) well graded silt to gravel size particles trace to little cobbles, low plasticity light brown, damp, dense 3.0'	
5				VERY SILTY SAND (SM) trace gravel low plasticity light grayish brown moist to wet	
10					
				14.0'	
15				Total Depth of Test Pit is 14.0'	

APPENDIX I(F)

RESISTIVITY TESTING RESULTS

SOIL RESISTIVITY TESTING
TOWANTIC ENERGY CENTER
OXFORD, CONNECTICUT

HAGER-RICHTER
GEOSCIENCE, INC.

Consultants in Geology & Geophysics

HAGER-RICHTER
GEOSCIENCE, INC.

SOIL RESISTIVITY TESTING
TOWANTIC ENERGY CENTER
OXFORD, CONNECTICUT

Prepared for:

Pare Engineering Corporation
49 Walpole Street
Suite 2
Norwood, Massachusetts 02062

Prepared by:

Hager-Richter Geoscience, Inc.
8 Industrial Way D-10
Salem, New Hampshire 03079

File 00J60
October 2000

HAGER-RICHTER
GEOSCIENCE, INC.

CONSULTANTS IN GEOLOGY & GEOPHYSICS
8 INDUSTRIAL WAY - D10
SALEM, NEW HAMPSHIRE 03079
TELEPHONE (603) 893-9944
FAX (603) 893-8313

VIA FAX & MAIL

October 13, 2000
File 00J60

Pare Engineering Corporation
49 Walpole Street
Suite 2
Norwood, Massachusetts 02062

ATTENTION: J. Matthew Bellisle, P.E.

PHN: 781-762-1442
FAX: 781-762-4780

CONCERNING: Towantic Energy Center
Oxford, Connecticut
Soil Resistivity Survey

Dear Mr. Bellisle:

This letter reports the results of measuring soil resistivity at the above referenced project location as authorized by Subcontract Agreement for PARE Project No. 00172.00, dated September 18, 2000.

INTRODUCTION

The soil resistivity was measured in ten locations at the Towantic Energy Center in Oxford, Connecticut by Hager-Richter Geoscience, Inc. for Pare Engineering Corporation (PARE) in accordance with the Specifications titled "Towantic Energy Center, Oxford, Connecticut," copy enclosed. The subsurface resistivity is required for the design of the grounding system for a new electric power plant. The approximate location of the site is shown in Figure 1.

The field work was performed on October 3-5, 2000 by Garrick Marcoux and William Desmaris of Hager-Richter. Mr. Allen Orsi of PARE, was present during a portion of the field work, and designated the locations of the resistivity lines. The weather was sunny, partly cloudy, ments, the system acquired data for 2 stacks only and the standard error of the resistance was 0.0% for all measurements.

The fundamental parameters that are measured for the determination of resistivity are the spacing of the electrodes, voltage, and current. The Wenner array uses four equally spaced electrodes placed in a straight line. For a spacing of "a," the resistivity ρ is given by

$$\rho = 2 \pi a (\Delta V/I)$$

The data for each of the ten locations are reported in the enclosed data sheets. In the data sheets, the Resistance is $(\Delta V/I)$, the Meter Multiplier is (1.9151 * a) — where the symbol * signifies multiplication, the constant 1.9151 is 2 * π*0.3048, and 0.3048 converts feet to meters — and Resistivity is *apparent* resistivity in ohm-m. The phrase apparent resistivity is used to indicate the value of resistivity for a uniform, isotropic half-space that would yield the measured resistance for a particular value of a.

The parameter a is measured with a tape, and the estimated accuracy is at least as good as 0.05 ft for distances of 20 ft or less. Therefore, for the smallest value of a, 8 ft, the accuracy is ± 0.6%. However, the estimated accuracy decreases with distance, and for a distance of 150 ft (maximum distance required to be measured for an a = 100 ft) it is estimated to be 0.5 ft, yielding an estimated accuracy of ± 0.3%. We estimate the accuracy of the ratio $\Delta V/I$ rather than the accuracies of ΔV and I separately because only the ratio is important for determining resistivity. After acquiring the field data, we use the Iris to measure $\Delta V/I$ with resistors placed between the electrode leads. In effect, we replace the earth with a resistor. We then measure the resistance of the resistors using several multimeters. The multimeter measurements typically agree to within 0.05%, and we conservatively estimate the accuracy of the multimeter measurement as ± 0.2%. We estimate the contribution to the overall accuracy from the measurement of a and $\Delta V/I$ to be about ¾%. (There are other factors over which we have no control — including lateral variation of geologic units, surface topography, non-horizontal and non-planar interfaces between geologic units, subsurface inhomogeneities, anisotropy, subsurface temperature, and time-varying natural earth currents.)

This Report is provided subject to the enclosed limitations.

If you have any questions or need more information, please call either Gene Simmons or me at your convenience.

Sincerely yours,
HAGER-RICHTER GEOSCIENCE, INC.

By Dorothy Richter
President

Encl. Specifications, Soil Resistivity Testing
Figure 1, General Site Location
Figure 2, Site plan
Data Sheets, Soil Resistivity Testing
IEEE Standard 81, "IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System," copy enclosed.
Limitations

LIMITATIONS

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This geophysical survey included a limited set of data obtained at the project Site and was conducted with limited knowledge of the Site and its subsurface conditions. Hager-Richter Geoscience, Inc. does not assume responsibility for the accuracy of information that was provided to us by others about the Site and its subsurface conditions. The findings provided by Hager-Richter Geoscience, Inc. are based solely on the information described in this document. The conclusions drawn from this investigation are considered reliable; however, there may exist localized variations in subsurface conditions that have not been completely defined at this time. It should be noted that our conclusions might be modified if subsurface conditions were better delineated with additional subsurface exploration including, but not limited to, coring and laboratory testing.

Contractor shall also record the average soil temperature at one-half the probe depth and include in its report.

Where a monument or any other known impediment to obtaining proper resistivity is present, the affected line shall be relocated as required to provide suitable clearance. Instrument error shall be no greater than 10% of the readings.

The instrument utilized for taking resistivity readings shall be one which is designed to minimize impact of extraneous currents in the ground from affecting readings.

Tests shall not be run if the test probes are inserted in frozen earth so that readings would be in error by more than 10% from those values that would be obtained without frozen earth.

The attached Soil Resistivity Testing Forms shall be used to record resistance readings and meter multipliers for each spacing and a copy of the Forms shall be submitted as field data to support the calculated resistivity values.

The contractor shall calculate the earth resistivity values in ohm-meters for various readings taken and submit completed Soil Resistivity Testing Forms with all requested data and information.

SOIL RESISTIVITY TESTING

Project Name: Location: Prepared for:	Date: Signature of Tester:
Instrument Mgf/Model #:	Remarks:
Instrument Calibration Date:	
Soil Temperature:	
Air Temperature:	
Ground Water Table:	
Last 48 Hours Precipitation (inches):	

Test Location	Reading #	Spacing (feet) A	Resistance (ohm) R	Meter Multiplier M	Resistivity (ohm-m)
Test Location R10 N-S	1	8			
	2	12			
	3	20			
	4	30			
	5	50			
	6	70			
	7	100			
Test Location R10 E-W	1	8			
	2	12			
	3	20			
	4	30			
	5	50			
	6	70			
	7	100			

SOIL RESISTIVITY SCHEDULE

RESISTIVITY TEST	COORDINATES		LOCATION	PROBE SPACING
	EAST	NORTH		
R-1	1515.00	5517.00	GAS TURBINE	8,12,20,30,50,70,AND 100
R-2	1469.00	5594.00	TRANSFORMER	8,12,20,30,50,70,AND 100
R-3	1622.00	5517.00	GAS TURBINE	8,12,20,30,50,70,AND 100
R-4	1592.00	5594.00	TRANSFORMER	8,12,20,30,50,70,AND 100
R-5	1764.00	5458.00	STEAM TURBINE	8,12,20,30,50,70,AND 100
R-6	1768.00	5595.00	TRANSFORMER	8,12,20,30,50,70,AND 100
R-7	1782.00	5257.00	-	8,12,20,30,50,70,AND 100
R-8	1791.00	5857.00	SWITCHYARD	8,12,20,30,50,70,AND 100
R-9	1754.00	5945.00	SWITCHYARD	8,12,20,30,50,70,AND 100
R-10	1716.00	5857.00	SWITCHYARD	8,12,20,30,50,70,AND 100

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SOIL RESISTIVITY TESTING

Project Name: Towantic Energy Center Location: Oxford, CT Prepared for: Pare Engineering Corporation	Date: 10/05/00 Signature of Tester: [signature]

Instrument Mgf/Model #: IRIS/ELREC-T	Remarks:
Instrument Calibration Date: 10/06/00	
Soil Temperature: 14.8° C	
Air Temperature: 16.0° C	
Ground Water Table: unknown	
Last 48 Hours Precipitation (inches): Trace	

Test Location	Reading #	Spacing (feet) A	Resistance (ohm) R	Meter Multiplier M	Resistivity (ohm-m)
Test Location R1 N105° E	1	8	69.17	15.32	1060
	2	12	25.00	22.98	575
	3	20	8.96	38.30	343
	4	30	3.99	57.45	229
	5	50	2.06	95.76	198
	6	70	1.61	134.06	216
	7	100	1.33	191.51	256
Test Location R1 N26° W	1	8	86.92	15.32	1332
	2	12	38.02	22.98	874
	3	20	9.16	38.30	351
	4	30	4.55	57.45	261
	5	50	3.40	95.76	326
	6	70	1.47	134.06	197
	7	100	1.22	191.51	233

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SOIL RESISTIVITY TESTING

Project Name: Towantic Energy Center Location: Oxford, CT Prepared for: Pare Engineering Corporation	Date: 10/05/00 Signature of Tester: [signature]
Instrument Mgf/Model #: IRIS/ELREC-T Instrument Calibration Date: 10/06/00 Soil Temperature: 14.8° C Air Temperature: 15.0° C Ground Water Table: unknown Last 48 Hours Precipitation (inches): Trace	Remarks:

Test Location	Reading #	Spacing (feet) A	Resistance (ohm) R	Meter Multiplier M	Resistivity (ohm-m)
Test Location R2 N69° E	1	8	39.59	15.32	607
	2	12	14.82	22.98	341
	3	20	6.38	38.30	245
	4	30	3.50	57.45	201
	5	50	1.91	95.76	183
	6	70	1.61	134.06	216
	7	100	1.37	191.51	262
Test Location R2 N40° W	1	8	30.81	15.32	472
	2	12	11.91	22.98	274
	3	20	5.30	38.30	203
	4	30	3.16	57.45	181
	5	50	1.89	95.76	181
	6	70	1.49	134.06	200
	7	100	1.27	191.51	244

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SOIL RESISTIVITY TESTING

Project Name: Towantic Energy Center Location: Oxford, CT Prepared for: Pare Engineering Corporation	Date: 10/04/00 Signature of Tester:
Instrument Mgf/Model #: IRIS/ELREC-T	Remarks:
Instrument Calibration Date: 10/06/00	
Soil Temperature: 14.8° C	
Air Temperature: 20.0° C	
Ground Water Table: unknown	
Last 48 Hours Precipitation (inches): unknown	

Test Location	Reading #	Spacing (feet) A	Resistance (ohm) R	Meter Multiplier M	Resistivity (ohm-m)
Test Location R3 N57° E	1	8	41.14	15.32	630
	2	12	16.56	22.98	380
	3	20	5.56	38.30	213
	4	30	2.96	57.45	170
	5	50	1.87	95.76	179
	6	70	1.33	134.06	178
	7	100	0.99	191.51	189
Test Location R3 N51° W	1	8	35.29	15.32	541
	2	12	15.25	22.98	351
	3	20	5.64	38.30	216
	4	30	3.03	57.45	174
	5	50	1.79	95.76	171
	6	70	1.41	134.06	188
	7	100	1.08	191.51	207

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SOIL RESISTIVITY TESTING

Project Name: Towantic Energy Center Location: Oxford, CT Prepared for: Pare Engineering Corporation	Date: 10/03/00 Signature of Tester:

Instrument Mgf/Model #: IRIS/ELREC-T	Remarks:
Instrument Calibration Date: 10/06/00	
Soil Temperature: 14.8° C	
Air Temperature: 16.0° C	
Ground Water Table: unknown	
Last 48 Hours Precipitation (inches): unknown	

Test Location	Reading #	Spacing (feet) A	Resistance (ohm) R	Meter Multiplier M	Resistivity (ohm-m)
Test Location R5 N24° E	1	8	33.76	15.32	517
	2	12	10.34	22.98	238
	3	20	4.61	38.30	177
	4	30	2.77	57.45	159
	5	50	1.79	95.76	172
	6	70	1.33	134.06	178
	7	100	1.03	191.51	198
Test Location R5 N62° W	1	8	37.67	15.32	577
	2	12	12.66	22.98	291
	3	20	4.66	38.30	179
	4	30	3.06	57.45	176
	5	50	1.59	95.76	153
	6	70	1.35	134.06	180
	7	100	1.02	191.51	196

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SOIL RESISTIVITY TESTING

Project Name: Towantic Energy Center Location: Oxford, CT Prepared for: Pare Engineering Corporation	Date: 10/03/00 Signature of Tester: [signature]

Instrument Mgf/Model #: IRIS/ELREC-T	Remarks:
Instrument Calibration Date: 10/06/00	
Soil Temperature: 14.8° C	
Air Temperature: 18.0° C	
Ground Water Table: unknown	
Last 48 Hours Precipitation (inches): unknown	

Test Location	Reading #	Spacing (feet) A	Resistance (ohm) R	Meter Multiplier M	Resistivity (ohm-m)
Test Location R6 N24° E	1	8	28.08	15.32	430
	2	12	11.25	22.98	259
	3	20	4.81	38.30	276
	4	30	3.09	57.45	178
	5	50	1.90	95.76	182
	6	70	1.40	134.06	188
	7	100	1.05	191.51	201
Test Location R6 N65° W	1	8	22.98	15.32	352
	2	12	9.96	22.98	229
	3	20	4.91	38.30	188
	4	30	2.97	57.45	171
	5	50	1.92	95.76	184
	6	70	1.35	134.06	181
	7	100	1.03	191.51	196

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SOIL RESISTIVITY TESTING

Project Name: Towantic Energy Center Location: Oxford, CT Prepared for: Pare Engineering Corporation	Date: 10/03/00 Signature of Tester:
Instrument Mgf/Model #: IRIS/ELREC-T Instrument Calibration Date: 10/06/00 Soil Temperature: 14.8° C Air Temperature: 19.0° C Ground Water Table: unknown Last 48 Hours Precipitation (inches): unknown	Remarks:

Test Location	Reading #	Spacing (feet) A	Resistance (ohm) R	Meter Multiplier M	Resistivity (ohm-m)
Test Location R7 N48° E	1	8	47.53	15.32	728
	2	12	12.83	22.98	295
	3	20	5.75	38.30	220
	4	30	3.27	57.45	188
	5	50	1.94	95.76	186
	6	70	1.44	134.06	193
	7	100	1.15	191.51	220
Test Location R7 N35° W	1	8	56.51	15.32	866
	2	12	18.65	22.98	429
	3	20	5.21	38.30	200
	4	30	3.17	57.45	182
	5	50	1.91	95.76	183
	6	70	1.47	134.06	197
	7	100	1.15	191.51	220

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SOIL RESISTIVITY TESTING

Project Name: Towantic Energy Center Location: Oxford, CT Prepared for: Pare Engineering Corporation	Date: 10/04/00 Signature of Tester:

Instrument Mgf/Model #: IRIS/ELREC-T	Remarks:
Instrument Calibration Date: 10/06/00	
Soil Temperature: 14.8° C	
Air Temperature: 19.0° C	
Ground Water Table: unknown	
Last 48 Hours Precipitation (inches): unknown	

Test Location	Reading #	Spacing (feet) A	Resistance (ohm) R	Meter Multiplier M	Resistivity (ohm-m)
Test Location R8 N21° E	1	8	37.42	15.32	573
	2	12	15.11	22.98	347
	3	20	5.74	38.30	220
	4	30	3.19	57.45	183
	5	50	1.85	95.76	177
	6	70	1.38	134.06	185
	7	100	1.10	191.51	212
Test Location R8 N53° W	1	8	36.60	15.32	561
	2	12	14.62	22.98	336
	3	20	5.21	38.30	199
	4	30	3.22	57.45	185
	5	50	1.84	95.76	176
	6	70	1.38	134.06	185
	7	100	1.10	191.51	210

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GEOSCIENCE, INC.

SOIL RESISTIVITY TESTING

Project Name: Towantic Energy Center Location: Oxford, CT Prepared for: Pare Engineering Corporation	Date: 10/05/00 Signature of Tester:

Instrument Mgf/Model #: IRIS/ELREC-T	Remarks:
Instrument Calibration Date: 10/06/00	
Soil Temperature: 14.8° C	
Air Temperature: 17.0° C	
Ground Water Table: unknown	
Last 48 Hours Precipitation (inches): Trace	

Test Location	Reading #	Spacing (feet) A	Resistance (ohm) R	Meter Multiplier M	Resistivity (ohm-m)
Test Location R9 N51° E	1	8	74.09	15.32	1135
	2	12	26.32	22.98	605
	3	20	7.33	38.30	281
	4	30	3.46	57.45	199
	5	50	2.04	95.76	196
	6	70	1.62	134.06	217
	7	100	1.24	191.51	238
Test Location R9 N26° W	1	8	49.90	15.32	764
	2	12	21.91	22.98	504
	3	20	6.26	38.30	240
	4	30	3.39	57.45	195
	5	50	2.06	95.76	197
	6	70	1.55	134.06	208
	7	100	1.22	191.51	235

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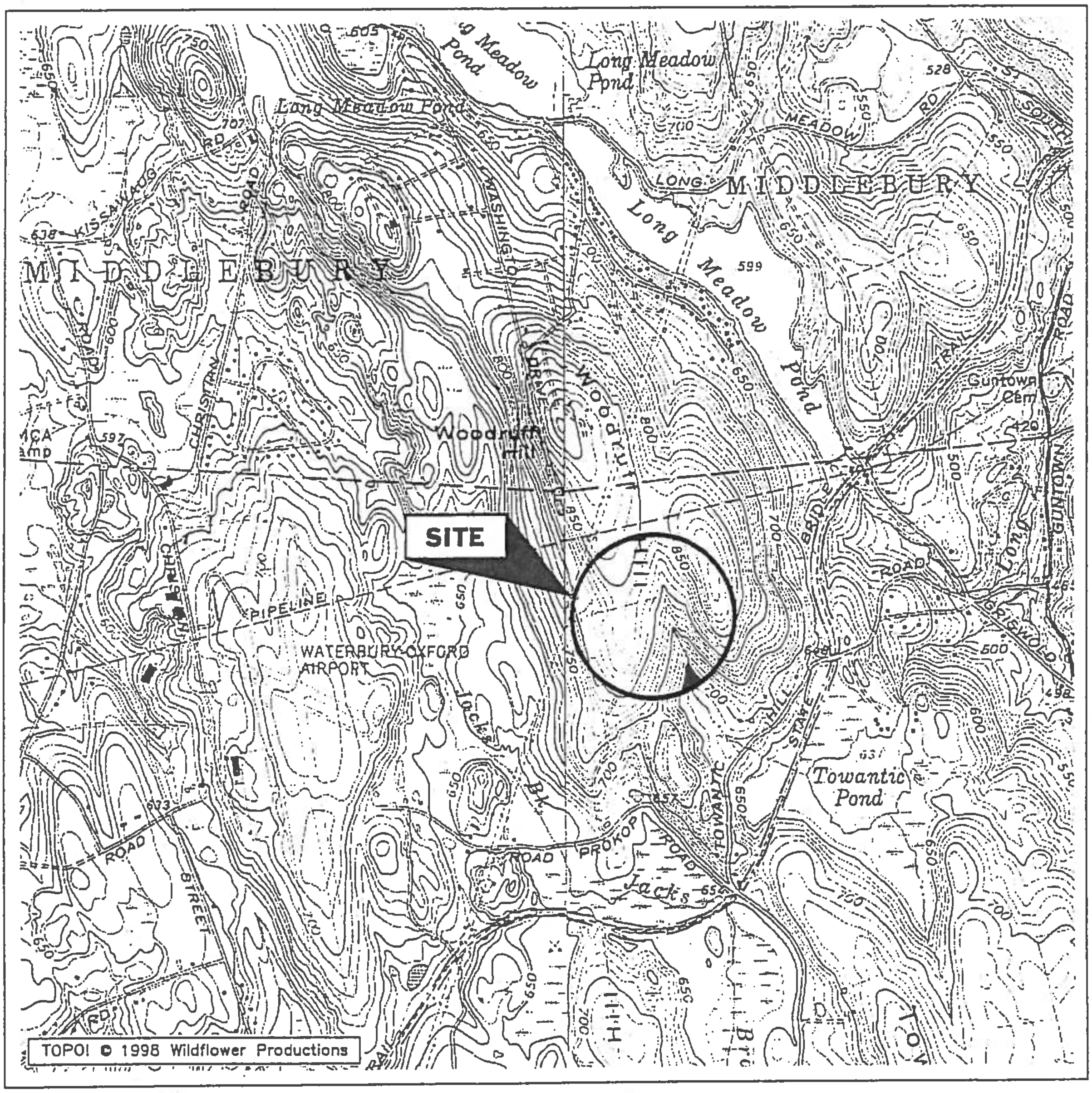
GEOSCIENCE, INC.

SOIL RESISTIVITY TESTING

Project Name: Towantic Energy Center Location: Oxford, CT Prepared for: Pare Engineering Corporation	Date: 10/04/00 Signature of Tester: [signature]
Instrument Mgf/Model #: IRIS/ELREC-T Instrument Calibration Date: 10/06/00 Soil Temperature: 14.8° C Air Temperature: 16.0° C Ground Water Table: unknown Last 48 Hours Precipitation (inches): unknown	Remarks:

Test Location	Reading #	Spacing (feet) A	Resistance (ohm) R	Meter Multiplier M	Resistivity (ohm-m)
Test Location R10 N56° E	1	8	39.04	15.32	598
	2	12	12.83	22.98	295
	3	20	5.42	38.30	208
	4	30	3.12	57.45	179
	5	50	1.80	95.76	172
	6	70	1.35	134.06	181
	7	100	1.07	191.51	204
Test Location R10 N20° E	1	8	42.14	15.32	646
	2	12	12.69	22.98	292
	3	20	5.00	38.30	191
	4	30	3.18	57.45	183
	5	50	1.82	95.76	174
	6	70	1.36	134.06	182
	7	100	1.06	191.51	202



LOCATION

SCALE (feet)

0 2000 4000

Figure 1
General Site Location
Soil Resistivity Testing
Towantic Energy Center
Oxford, Connecticut

File 00J60	October, 2000

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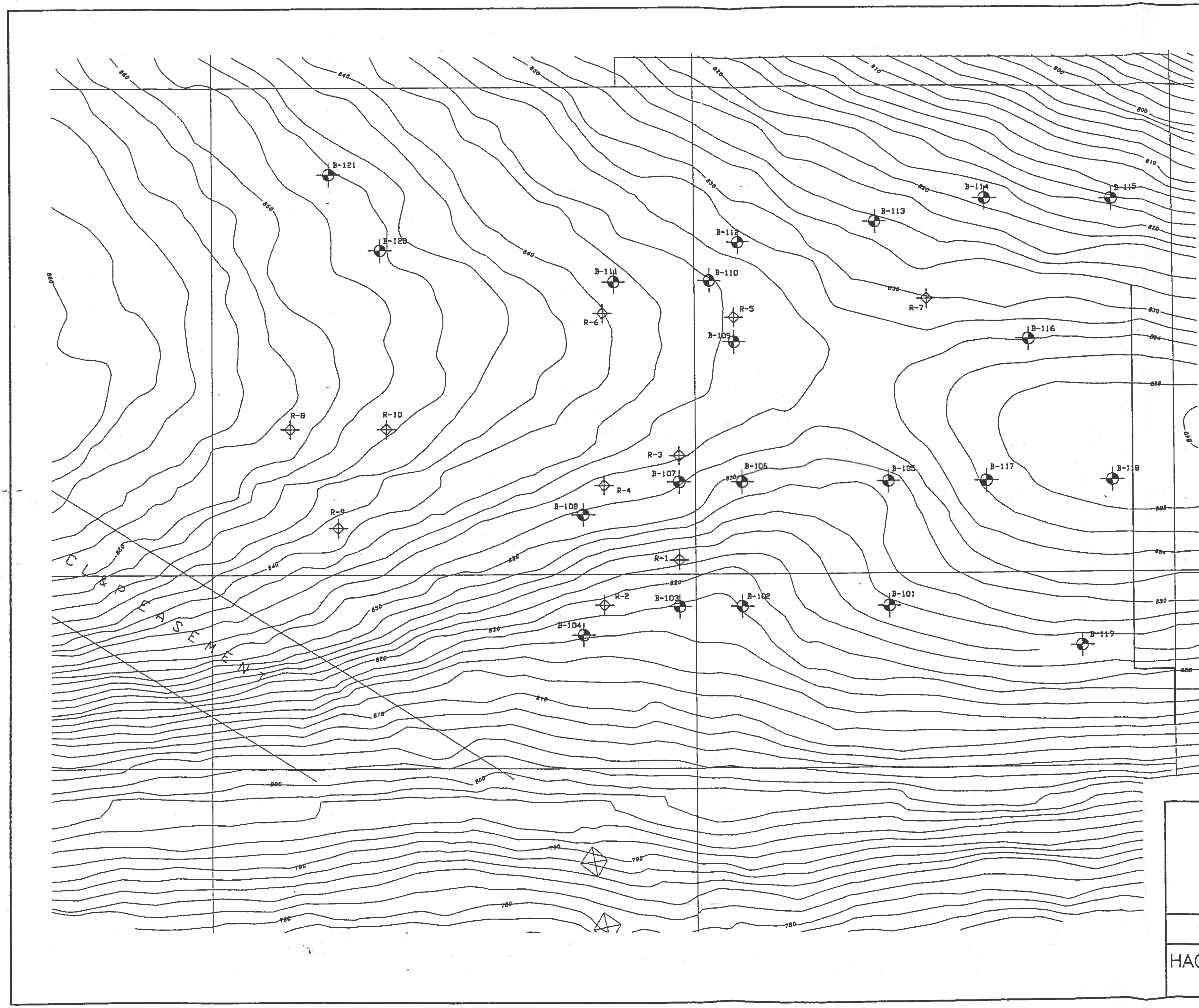

Z ◄ H-R

LEGEND

R-1 RESISTIVITY TEST

B-101 PROPOSED TEST BORING

SCALE (feet)

0 100 200

NOTE:

Site plan provided by Pare Engineering Corporation.

Figure 2
Site Plan
Soil Resistivity Testing
Towantic Energy Center
Oxford, Connecticut

File 00J60	October, 2000

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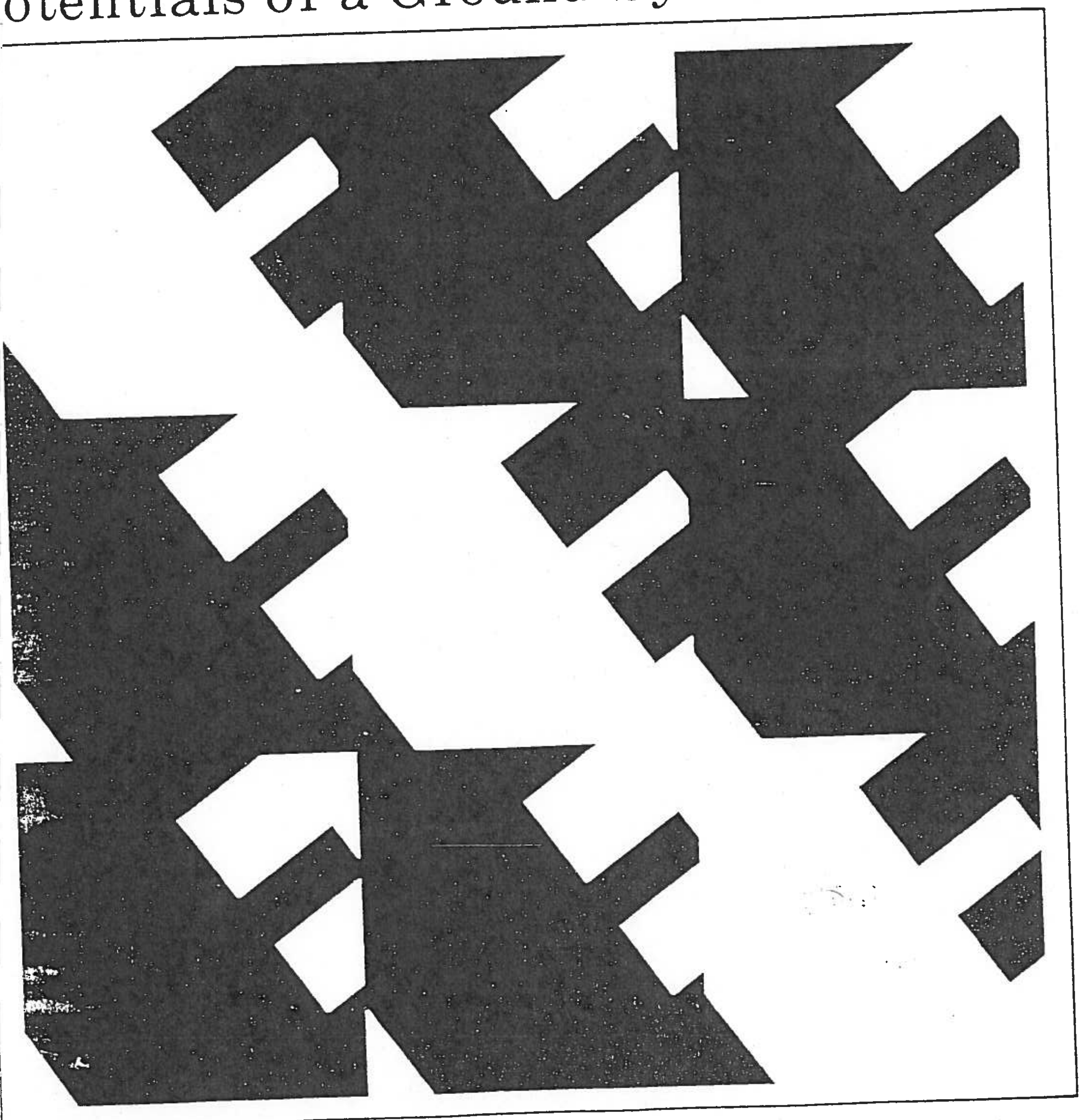
Salem, New Hampshire

IEEE Std 81-1983
(Revision of IEEE Std 81-1962)

EEE Guide for easuring Earth Resistivity, round Impedance, and Earth Surface otentials of a Ground System



New York, NY 10017 USA

IEEE
Std 81-1983
(Revision of IEEE
Std 81-1962)

IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System

Sponsor

Power System Instrumentation and Measurements Committee
of the
IEEE Power Engineering Society

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Comments on standards and requests for interpretations should be addressed to:

Secretary, IEEE Standards Board
345 East 47th Street
New York, NY 10017
USA

Foreword

(This Foreword is not a part of IEEE Std 81-1983, IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System.)

In order to increase its practical usefulness, this guide has been divided into two parts. Part I, *Normal Measurements*, covers the majority of field measurements which do not require special high-precision equipment and measuring techniques, and which do not encounter unusual difficulties such as may be found with extensive grounding systems, abnormally high stray ac or dc currents, etc. Part I has been extensively revised and updated. Part II, *Special Measurements*, is to be completed in the future. This part is intended to describe the methods of measurements applicable when unusual difficulties make normal measurements either impractical or inaccurate. Very large power station ground grids and counterpoises of transmission lines are examples of such grounding systems.

This guide was prepared by the Earth Resistivity, Ground Impedance, and Earth Surface Potential Measurement Working Group of the RLC Subcommittee, Power System Instrumentation and Measurements Committee. The working group's members at the time the guide was prepared were:

D. Mukhedkar, *Chairman*

F. Dawalibi, *Secretary*

G. Y. R. Allen
M. J. Anna
E. B. Curdts†
R. D. Crosier
W. K. Dick
W. G. Finney
J. L. Hayes†
R. Hall
R. J. Heh
J. F. Laidig
A. C. Legates
R. Malewski
H. C. Ramberg
B. Stanleigh
F. P. Zupa

†Deceased

W. J. Lyon — Liaison member with IEEE Std 80-1976.
W. K. Switzer — Liaison with Substations Committee.

When the IEEE Standards Board approved this standard on September 17, 1981, it had the following membership:

I. N. Howell, Jr, *Chairman*

Irving Kolodny, *Vice Chairman*

Sava I. Sherr, *Secretary*

G. Y. R. Allen
J. J. Archambault
J. H. Beall
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Loering M. Johnson
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J. S. Stewart
W. E. Vannah
Virginius N. Vaughan, Jr
Art Wall
Robert E. Weiler

*Member emeritus

Contents

SECTION PAGE

Part I Normal Measurements

SECTION PAGE

FIGURES

IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System

Part I Normal Measurements

1. Purpose

1.1 It is the purpose of this guide to describe and discuss the present state of the technique of measuring ground resistance and impedance, earth resistivity, potential gradients from currents in the earth, and the prediction of the magnitudes of ground resistance and potential gradients from scale model tests. Factors influencing the choice of instruments and the techniques for various types of measurements are covered. These include the purpose of the measurement, the accuracy required, the type of instruments available, possible sources of error, and the nature of the ground or grounding system under test.

1.2 The guide is intended to assist the engineer or technician in obtaining and interpreting accurate, reliable data. It describes test procedures which promote the safety of personnel and property, and prevent interference with the operation of neighboring facilities.

2. Scope

2.1 The testing methods covered in this guide include:

(1) The measurement of the resistance and impedance to earth of electrodes varying from small rods and plates to large grounding systems of stations.

(2) Ground potential surveys, including the measurement of step and touch voltages, and potential contour surveys.

(3) Scale-model tests for laboratory determination of the ground resistance and potential gradients for an idealized design.

(4) The measurement of earth resistivity.

2.2 The methods covered herein are limited to those using direct current, periodically reversed direct current, alternating sinusoidal current and impulse currents (for measuring transient impedances). This guide does not propose to cover all possible test signals and test methods.

2.3 Extreme precision is not always possible because of the many variables encountered; therefore, the measurements should be carefully made by the most suitable method available, with a thorough understanding of the possible sources of error.

3. Objectives of Tests

3.1 Measurements of ground resistance or impedance and potential gradients on the surface of the earth due to ground currents are necessary to:

(1) Verify the adequacy of a new grounding system

(2) Detect changes in an existing grounding system

(3) Determine hazardous step and touch voltages

(4) Determine ground potential rise (GPR) in order to design protection for power and communication circuits.

3.2 Scale-model tests are useful in studying or developing new designs for grounding systems which cannot be adequately studied by analytical methods (complex shape or complex soil structure).

3.3 Earth resistivity measurements are useful for:

(1) Estimating the ground resistance of a proposed substation or transmission tower

(2) Estimating potential gradients including step and touch voltages

(3) Computing the inductive coupling between neighboring power and communication circuits

(4) Designing cathodic protection systems

(5) Geological surveys

4. Definitions

Definitions of terms pertinent to the subject matter are listed here. Those approved or standardized by other bodies are used wherever possible.

Definitions as given herein apply specifically to the application of this guide. For additional definitions see ANSI/IEEE Std 100-1977, IEEE Standard Dictionary of Electrical and Electronics Terms.

ground. A conducting connection, whether intentional or accidental, by which an electric circuit or equipment is connected to the earth, or to some conducting body of relatively large extent that serves in place of the earth.

NOTE: It is used for establishing and maintaining the potential of the earth (or of the conducting body) or approximately that potential, on conductors connected to it, and for conducting ground current to and from the earth (or the conducting body).

grounded. A system, circuit, or apparatus referred to is provided with a ground.

ground-return circuit. A circuit in which the earth is utilized to complete the circuit.

ground current. Current flowing in the earth or in a grounding connection.

grounding conductor. The conductor that is used to establish a ground and that connects an equipment, device, wiring system, or another conductor (usually the neutral conductor) with the grounding electrode or electrodes.

grounding electrode. A conductor used to establish a ground.

grounding connection. A connection used in establishing a ground and consists of a grounding conductor, a grounding electrode and the earth (soil) that surrounds the electrode or some conductive body which serves instead of the earth.

ground grid. A system of grounding electrodes consisting of interconnected bare cables buried in the earth to provide a common ground for electrical devices and metallic structures.

NOTE: It may be connected to auxiliary grounding electrodes to lower its resistance.

ground mat. A system of bare conductors, on or below the surface of the earth, connected to a ground or a ground grid to provide protection from dangerous touch voltages.

NOTE: Plates and gratings of suitable area are common forms of ground mats.

grounding system. Consists of all interconnected grounding connections in a specific area.

ground resistance (grounding electrode). The ohmic resistance between the grounding electrode and a remote grounding electrode of zero resistance.

NOTE: By *remote* is meant at a distance such that the mutual resistance of the two electrodes is essentially zero.

mutual resistance of grounding electrodes. Equal to the voltage change in one of them produced by a change of one ampere of direct current in the other, and is expressed in ohms.

electric potential. The potential difference between the point and some equipotential surface, usually the surface of the earth, which is arbitrarily chosen as having zero potential (remote earth).

NOTE: A point which has a higher potential than a zero surface is said to have a positive potential; one having a lower potential has a negative potential.

equipotential line or contour. The locus of points having the same potential at a given time.

potential profile. A plot of potential as a function of distance along a specified path.

surface-potential gradient. The slope of a potential profile, the path of which intersects equipotential lines at right angles.

touch voltage. The potential difference between a grounded metallic structure and a point on the earth's surface separated by a distance equal to the normal maximum horizontal reach, approximately one meter.

step voltage. The potential difference between two points on the earth's surface, separated by a distance of one pace, that will be assumed to be one meter, in the direction of maximum potential gradient.

NOTE: This potential difference could be dangerous when current flows through the earth or material upon which a workman is standing, particularly under fault conditions.

resistivity (material). A factor such that the conduction-current density is equal to the electric field in the material divided by the resistivity.

coupling. The association of two or more circuits or systems in such a way that power or signal information may be transferred from one to another.

NOTE: Coupling is described as close or loose. A close-coupled process has elements with small phase shift between specified variables; close-coupled systems have large mutual effect shown mathematically by cross-products in the system matrix.

coupling capacitance. The association of two or more circuits with one another by means of capacitance mutual to the circuits.

resistive coupling. The association of two or more circuits with one another by means of resistance mutual to the circuits.

direct coupling. The association of two or more circuits by means of self-inductance, capacitance, resistance, or a combination of these that is common to the circuits.

inductive coupling (1)(communication circuits). The association of two or more circuits with one another by means of inductance mutual to the circuits or the mutual inductance that associates the circuits.

NOTE: This term, when used without modifying words, is commonly used for coupling by means of mutual inductance, whereas coupling by means of self-inductance common to the circuits is called direct inductive coupling.

(2) (inductive coordination practice). The interrelation of neighboring electric supply and communication circuits by electric or magnetic induction, or both.

effective resistivity. A factor such that the conduction current density is equal to the electric field in the material divided by the resistivity.

counterpoise (overhead lines) (lighting protection). A conductor or system of conductors, arranged beneath the transmission line, located on, above or most frequently below the surface of the earth, and connected to the footings of the towers or poles supporting the line.

5. Safety Precautions While Making Ground Tests

5.1 Station Ground Tests. It should be strongly impressed on all test personnel that a lethal potential can exist between the station ground and a remote ground if a power-system fault involving the station ground occurs while ground tests are being made.

Since one of the objectives of tests on a station-ground system is to establish the location of remote earth for both current and potential electrodes, the leads to these electrodes must be treated as though a possible potential could exist between test leads and any point on the station ground grid. Some idea of the magnitude of this possible potential may be gained from the consideration that even in the larger stations the ground grid shall have an impedance in the order of 0.05 Ω to 0.5 Ω. Assuming for this example that the ground-fault current through the grid is in the order of 20 kA the potential to remote earth (ground potential rise) will be in the order of 1.0 kV to 10 kV. For higher ground impedance or greater fault currents, the rise of station-ground voltage may exceed 10 kV.

The preceding discussion points to the necessity of caution when handling the test leads, and under no circumstances should the two hands or other parts of the body be allowed to complete the circuit between points of possible high-potential difference. It is true that the chances are remote that a station-ground fault will occur while test leads are being handled, but this possibility should not be discounted and therefore the use of insulating shoes, gloves, blankets, and other protection devices are recommended whenever measurements are carried out at an energized power station.

In all cases, safety procedures and practices adopted by the particular organization involved shall be followed.

5.2 Surge-Arrester Ground Tests. These grounds fall in a special category because of the extremely high short-duration lightning currents carried by surge-arrester grounds. These currents may be in excess of 50 000 A for surge currents, with a possibility of fault-system currents in the case of a defective surge arrester. An isolated surge arrester ground should never be disconnected to be measured, since the base of the arrester can be elevated to the line potential. A surge-arrester ground can be tested as long as precautions are taken to minimize arrester discharge.

5.3 Small Isolated Ground Tests. Another precaution concerns possible high-potential gradi-

The current electrode resistance should usually be less than 500 Ω. This resistance value is a function of the voltage generated by the power supply and the desired test current. The ratio of the generated voltage to the current electrode resistance determines the test current flowing in the current-indicating element of the instrument being used. As a rule of thumb the ratio between the current electrode resistance and the ground resistance being tested should never exceed 1000 to 1, preferably 100 to 1 or less.

In case (2), when dc tests are being made, the test current must be increased to overcome the interfering effects of stray dc earth currents. When tests with ac or periodically reversed dc signals are being made, the frequency of the test signal may be set to a frequency not present in the stray currents.

6.3 Stray Direct Currents. Conduction of electricity in the soil is electrolytic and direct current results in chemical action and polarization potential difference. Direct potentials are produced between various types of soil and between soil and metal by galvanic action. Galvanic potentials, polarization, and, if present, stray direct currents may seriously interfere with direct-current measurements. Therefore, periodically reversed direct current or sometimes a regularly pulsed current is used in making measurements. However, when using periodically reversed direct current for resistance measurements the resulting values will be fairly close, but they may not be accurate for alternating-current applications. Caution must be exercised in areas subject to solar-induced currents (quasi-dc).

6.4 Stray Alternating Currents. Stray alternating currents in the earth, in the grounding system under test, and in the test electrodes present an additional complication. The effects of stray alternating current may be mitigated in ground resistance measurements by utilizing a frequency that is not present in the stray current. Most measuring devices use frequencies within a range of 50 Hz to 100 Hz. The use of filters or narrow band measuring instruments, or both, is often required to overcome the effects of stray alternating currents.

6.5 Reactive Component of Impedance of a Large Grounding System. The impedance of a large grounding system may be extremely low (for example, 0.010 Ω) but it may have a significant quadrature component [23][1]. Certain precautions should be taken when measuring the 60 Hz impedance of a large grounding system. For such measurements the test device should be operated at an approximate system frequency of 60 Hz, but the test frequency should be slightly above or below 60 Hz, using a minimum of 50 A for the most accurate results and to avoid 60 Hz ground currents. Part II of this guide[2], *Special Measurements*, will cover impedance measurements of large grounding systems.

6.6 Coupling Between Test Leads. The effect of coupling between the test leads becomes important when measuring low values of ground impedance. Any voltage produced in the potential lead due to coupling from current flowing in the current lead is directly additive to the desired measured voltage and produces a measurement error. Since the 60 Hz inductive coupling between two parallel test leads may be as high as 0.1 Ω/100 m, the error can be appreciable. Low ground impedance usually is found with a large area ground, which requires long test leads to reach remote earth.

Conversely, a small area ground usually has fairly high ground impedance and requires shorter test leads to reach remote earth. Thus the effects of coupling can be expected to be worse on measurements of large area, low impedance grounds. As a rule of thumb test lead coupling is usually negligible on measurements of grounds of 10 Ω or greater, is almost always important on measurements of 1 Ω or less, and should be considered in the range between 1 and 10 Ω.

Test lead coupling may be minimized by appropriately routing the potential and current leads. When test lead couplings are anticipated, the potential and current leads should be placed at the maximum feasible angle.

6.7 Buried Metallic Objects. Partially or completely buried objects such as rails, water, or other industrial metallic pipes will considerably influence the measurement results [9], [36].

[1]The numbers in brackets correspond to those of the Bibliography listed in Appendix D of this guide.

[2]Part II of this guide has not been completed at this time.

Table 1
Geological Period and Formation

Earth Resistivity Ohmmeters	Quarternary	Cretaceous Tertiary Quarternary	Carboniferous Triassic	Cambrian Ordovician Devonian	Pre-Cambrian and Combinat. with Cambrian
1 Sea water 10 Unusually low 30 Very low 100 Low 300 Medium 1000 High 3000 Very high 10 000 Unusually high	Coarse Sand and Gravel in Surface Layers	Loam Clay Chalk	Chalk Trap Diabase Shale Limestone Sandstone	Shale Limestone Sandstone Dolomite	Sandstone Quartyite Slate Granite Gneisses

NOTE: Table 1 is from reference [38] of the Bibliography section.

The nature of the function ϕ is in general not simple and consequently the interpretation of the measurements will consist of establishing a simple equivalent function ϕ_e which will give the best approximation. In the case of power and communication circuits, a two horizontal layer configuration [10], [18], [20], [31], [38], [39], and an exponential earth [38], [42] have proved to be good approximations that can be useful in determining system designs.

Some publications [9], [10], [18], [20], [31], [36], [38], [39], [42], have shown that earth surface potential gradients inside or adjacent to an electrode are mainly a function of top soil resistivity. In contrast, the ground electrode resistance is primarily a function of deep soil resistivity, especially if the electrode is very large.

NOTE: This is not valid in those extreme cases where the electrode is buried in an extremely high resistivity top soil.

Transmission-line parameters at power frequencies are sensitive to the presence of layers of different resistivities. However, at power-line carrier frequencies, radio, or surge frequencies, earth return impedances are practically sensitive only to the top few meters of soil.

The above statements are good arguments in favor of methods which include both surface and deep soil-resistivity measurements. In such methods a number of readings are taken. At each reading the test current involves an increased volume of the surrounding earth.

7.2 Methods of Measuring Earth Resistivity

7.2.1 Geological Information and Soil Samples. Often, at the site where a grounding system is to be installed, extensive civil engineering work must be carried out. This work usually involves geological prospecting which results in a considerable amount of information on the nature and configuration of the site soil. Such data could be of considerable help to the electrical engineer who should try to obtain this information.

The determination of soil resistivity from the values of resistance measured between opposite faces of a soil sample of known dimensions is not recommended since the unknown interfacial resistances of the soil sample and the electrodes are included in the measured value.

A more accurate determination is possible if a four-terminal resistance measurement of the soil sample is made. The potential terminals should be small, relative to the sample cross-section, and located sufficiently distant from the current terminals to assure near-uniform current distribution across the sample. A distance equal to the larger cross-section dimension is usually adequate for the purpose of the determination.

It is difficult, and in some cases impossible, to obtain a useful approximation of soil resistivity from resistivity measurements on samples. This is due to the difficulty of obtaining representative, homogeneous soil samples, and in duplicating the original soil compaction and moisture content in the test cell.

7.2.2 Variation of Depth Method. This method, sometimes called a three-point method, is a ground-resistance test carried out several times, each time the depth of burial of the tested electrode is increased by a given increment. The purpose of this is to force more test current through the deep soil. The measured resistance value will then reflect the variation of resistivity at increased depth. Usually the tested electrode is a rod. Rods are preferred to other types of electrodes because they offer two important advantages:

(1) The theoretical value of ground-rod resistance is simple to calculate with adequate accuracy, therefore, the results are easy to interpret.

(2) The driving of a rod into the soil is normally an easy operation.

The above measurements can be carried out using one of the methods described in 8.2. One should bear in mind, however, that the measured value of the resistance should be as accurate as possible so that it can be successfully compared to the theoretical value. Therefore, the fall-of-potential method is preferably used for these measurements.

The variation of depth method gives useful information about the nature of soil in the vicinity of the rod (5 to 10 times the rod length). If a large volume of soil must be investigated, it is preferable to use the four-point method, since the driving of long rods is not practical.

7.2.3 Two-Point Method. Rough measurements of the resistivity of undisturbed earth can be made in the field with the shepard-soil resistivity meter and similar two-point methods. The apparatus consists of one small and one smaller iron electrode, both attached to an insulating rod. The positive terminal of a battery is connected through a milliammeter to the smaller electrode and the negative terminal to the other electrode. The instrument can be calibrated to read directly in ohm-centimeters at nominal battery voltage. This type of apparatus is easily portable and with it a number of measurements can be made in a short time on small volumes of soil by driving the electrodes in the ground or in the walls or bottom of excavations.

7.2.4 Four-Point Method. The most accurate method in practice of measuring the average resistivity of large volumes of undisturbed earth is the four-point method [43]. Small electrodes are buried in four small holes in the earth, all at depth b and spaced (in a straight line) at intervals a. A test current I is passed between the two outer electrodes and the potential V between the two inner electrodes is measured with a potentiometer or high-impedance voltmeter. Then V/I gives the resistance R in ohms.

Two different variations of the four-point method are often used:

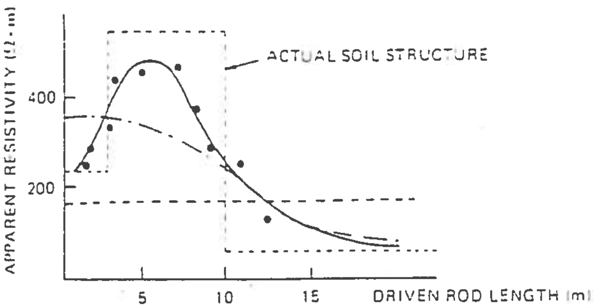
(1) *Equally Spaced or Wenner Arrangement.* With this arrangement the electrodes are equally spaced as shown in Fig 3(a). Let a be the distance between two adjacent electrodes. Then, the resistivity ρ in the terms of the length units in which a and b are measured is:

$$\rho = \frac{4\pi a R}{1 + \frac{2a}{\sqrt{a^2 + 4b^2}} - \frac{a}{\sqrt{a^2 + b^2}}} \qquad \text{(Eq 2)}$$

It should be noted that this does not apply to ground rods driven to depth b; it applies only to small electrodes buried at depth b, with insulated connecting wires. However, in practice, four rods are usually placed in a straight line at intervals a, driven to a depth not exceeding 0.1 a. Then we assume $b = 0$ and the formula becomes:

$$\rho = 2\pi a R \qquad \text{(Eq 3)}$$

and gives approximately the average resistivity of the soil to the depth a.



• • • • Test Results
——— Computed apparent earth resistivity curve based on an equivalent three-layer structure
—·—·— Computed apparent earth resistivity curve based on an equivalent two-layer structure
·········· Computed apparent earth resistivity curve based on an equivalent one-layer structure

Fig 4
Variation of Depth Results

resistivity value ρ which when plotted against l provides a visual aid for determining earth resistivity variation with depth. For more clarity, suppose that the field tests gave the curve shown in Fig 4. By inspection of the curve it can be concluded that soil structure is at least three distinct layers. For small values of l (2 to 5 m) soil has a resistivity value of 210 Ω·m. The middle layer resistivity is about 2 to 2.5 times that of the top layer. The thickness of this middle layer is not easy to determine by visual inspection of the curve. The third layer is very conductive. Its resistivity value is certainly less than 100 Ω·m. However, the exact value cannot be obtained through visual inspection. Two solutions are then possible:

(1) Continue measurements with rods driven deeper into the soil

(2) Use analytical techniques to compute, from the measured data, an equivalent earth structure

Additional measurements will certainly help in obtaining the third-layer resistivity. However the thicknesses of the two first layers are still not easy to determine. Moreover, driving rods to great depth may be difficult and expensive. Other alternatives consist of assuming earth as uniform, two-layer structured (or more), and being composed of a material whose resistivity varies with depth according to a simple mathematical law (linear, exponential . . .).

The resistance of a rod in such earth models is known or can be easily calculated (see Appendix B). Using a simple computer program or simply by a cut-and-try method, the best fit to the experimental results can be obtained (see Appendix B).

As already mentioned, the variation of depth method fails to predict earth resistivity at large distances from the area where the test rod is embedded (distances larger than 5 to 10 times the driven rod length).

7.3.3 Two-Point Method. Since this method is suited only for determining the resistivity of small volumes of soil, it is not recommended that extrapolation of the results be attempted.

7.3.4 Four-Point Method. The interpretation of the four-point method is similar to that of the method described in 7.3.2. For example, in the case of the Wenner arrangement, the measured apparent resistivity is plotted against the electrode spacing a. The resulting curve then indicates the soil structure. Again the depths of various layers are not easy to determine by visual inspection of the curve. Many authors [21], [39], give quick empirical rules to help in establishing the layer thickness. For example:

(1) The Gish and Rooney method [21]; from the resistivity curve, a change in formation, for example, another layer is reached at a depth equal to any electrode separation at which a break or change in curvature occurs.

(2) The Lancaster-Jones method [28]; the depth to the lower layer is taken as ⅔ the electrode separation at which the point of inflexion occurs.

However, a better solution assumes an earth model such as:

(a) Uniform resistivity

(b) Horizontal layers of uniform resistivities (see Appendix A)

(c) Exponential variation of the resistivity (see Appendix A)

For each model the mathematical relation between the apparent resistivity and the various earth parameters must, of course, be known or be easy to calculate. Some analytical methods frequently used are described in Appendix C.

The solutions are given for an exponential and two layer-soil model. Using an adequate analytical method, the best fit to the experimental data gives the required earth parameters

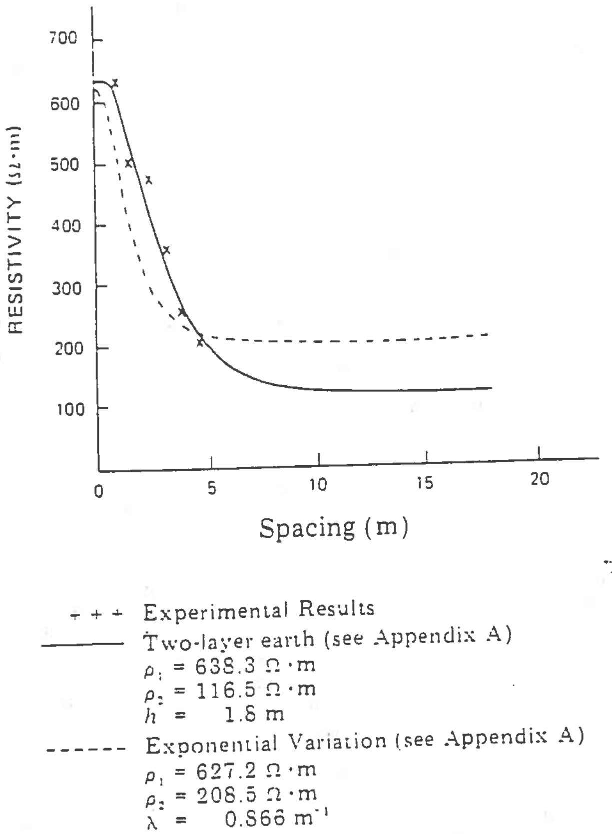


Fig 5
Example of an Earth Resistivity Interpretation

(Fig 5 shows the results obtained using models 2 and 3).

The best model to use depends on the purpose of the measurements. Often a two-layer earth model gives excellent results [39].

7.4 Instrumentation

7.4.1 Two-Point Method. Shepard-soil resistivity meter or similar (see 7.2 for complete description).

7.4.2 Four-Point or Variation-of-Depth Methods. One of the following instruments can be used (see Section 12).

(1) Power supply with ammeter and high-impedance voltmeter
(2) Ratio ohmmeter
(3) Double-balance bridge
(4) Single-balance transformer
(5) Induced-polarization receiver and transmitter.

Dependent on the mode of connection and terminals used these instruments can either measure ground resistance or earth resistivity.

In inductive coordination work, spacings up to 1000 m often have been used. For these long spacings, the resistance is of the order of a few hundredths of an ohm, and a sensitive direct-current potentiometer with a battery supply as high as 180 V may be required. For the shorter spacings, the four-terminal instruments shown in Figs 14, 15, and 16 are convenient and adequate. For some instruments correction may be required for the potential probe resistances; in such cases correction factors can usually be obtained from the supplier of the instrument.

The induced polarization transmitter is normally rated at a few hundred watts. However, for great spacings or extremely high top-soil resistivities, units rated at more than 1000 W may be necessary.

8. Ground Impedance

8.1 General. Connections to earth in general are complex impedances, having resistive, capacitive, and inductive components, all of which affect their current-carrying capabilities. The resistance of the connection is of particular interest to those concerned with power frequencies because it is affected by the resistivity of the earth in the area of the connection. The capacitance and inductance values are of interest to those concerned with higher frequencies, such as are associated with radio communications and lightning.

Ground-impedance measurements are made:

(1) To determine the actual impedance of the ground connections
(2) As a check on calculations
(3) To determine (a) the rise in ground potential and its variation throughout an area, that results from ground fault current in a power system, (b) the suitability of a grounding connection for lightning protection, and (c) the suitability of a grounding connection for radio-frequency transmission at a transmitter
(4) To obtain data necessary for the design of protection for buildings, the equipment therein, and any personnel that may be involved

Ground connections of all power and communication systems should be studied to determine the variation in ground potential that can be encountered during ground-fault conditions so as to ensure personnel safety, adequacy of insulation, and continuity of service.

8.1.1 Characteristics. The characteristics of a grounding connection vary with the composition and physical state of the soil as well as with the extent and configuration of the buried electrode. Earth in any given locality is composed of various combinations of dry earth, swampy ground, gravel, slate, sandstone, or other natural materials of widely varying resistivity. It may be relatively homogeneous over a large area, or it may be effectively saucered in granite, sand, or other matter having a high resistivity and thus be practically insulated from the surrounding area. Consequently, the characteristics of a grounding connection (ohmic resistance) vary with the seasons, which affect temperature, moisture content, and compactness of the soil.

Calculations and experience show that, in a given soil, the effectiveness of a ground grid is dependent largely upon the overall size of the ground grid. The addition of buried conductors and driven rods within an enclosure also aid somewhat in reducing the ground impedance. This reduction diminishes with the addition of each successive conductor or rod. A good method for reducing the ground resistance of a transmission-line tower or mast is to install radial counterpoises.

After the installation of a substation or other grounded structure, the settling of the earth with annual cyclical weather changes tends to reduce the ground impedance substantially during the first year or two.

The impedance of a grounding electrode is usually measured in terms of resistance because the reactance is generally negligible with respect to the resistive component. (This is not applicable for large grounding structures with impedance values below 0.5 Ω, and for grounds subject to surge or impulse currents.) This resistance will not usually vary greatly from year to year after the first year or two following the burial of the ground grid. Although the ground grid may be buried only half a meter below the surface, the variation of the resistance for larger stations seems to bear little relationship to the variation of the resistivity at the burial level. This is especially true for grids equipped with long driven rods in contact with the deep soil which normally is not influenced by weather conditions (temperature and moisture changes which result in top layer resistivity variations). However, this will not be true for grids buried over a high resistivity stratum, or simply for small electrodes (having an area of less than 50 m^2).

Although the above statements appear to be contradictory they are, nevertheless, true. Records which have been kept of large area ground grids over a period of eighteen years show little variation in the measured value of resistance, whereas, resistivity measurements in the same area show wide variations (as much as 17 to 1 at shallow depths). It should be recognized that the resistance of a grounding connection with a small number of driven rods may vary more closely with that indicated by resistivity measurements. This indicates that the resistance of large area ground grids is proportional to resistivity measurements made for greater depths where less variation is encountered.

Some of the ground-fault current from a transmission line fault to a substation ground grid tends to follow the transmission line. Depth of mean current path is directly proportional to the square root of the earth resistivity and inversely proportional to the square root of the frequency. Thus resistance tends to increase the cross-sectional area of the current path, whereas inductance tends to decrease it and to tie more closely to the transmission line. This tendency will also affect the pattern of the current path away from the electrode.

8.1.2 Theoretical Value of Ground Resistance. Calculated or theoretical values of the resistance of an electrode to remote earth can vary considerably from the measured value because of the following factors:

(1) Adequacy of the analytical equations used in the resistance calculations.

(2) Conditions of the soil at the time the measurement is made. Earth resistivities being different from those assumed in the calculations.

(3) Inaccurate or insufficient extent of the resistivity survey; for example, number and dispersal of tests, probe spacings, and inadequacy of the instrumentation used.

(4) Presence in the soil of adjacent metallic buried structures and ground wires which may divert a substantial amount of the test current.

In order to decrease the sources of error in establishing the relationship between earth resistivity and ground resistance it is advisable to take resistivity and resistance measurements under similar weather and moisture conditions.

If the measured values are used as data for the design of a grounding electrode, it is recommended that the measurements be carried out under various weather conditions. This will help the designer in establishing the most *restrictive* or *limiting* case, especially for small grounds which are influenced by seasonal changes in weather.

8.2 Methods of Measuring Ground Impedance

8.2.1 General. In this section only general methods are covered [6], [8], [12], [22], [30]. For the instrumentation available refer to Section 12. While in this section the ohmic value is called *resistance*, it should be remembered that there is a reactive component that should be taken into account when the ohmic value of the ground under test is less than 0.5 Ω, and the ground is of a relatively large extent. This reactive component has little effect in grounds with an impedance higher than 1 Ω. The resistance of a ground electrode usually is determined with alternating or periodically reversed current to avoid possible polarization effects when using direct current. The frequency of this alternating current should be near the power frequency.

8.2.1.1 Two-Point Method (Ammeter-Voltmeter Method). In this method the total resistance of the unknown and an auxiliary ground is measured. The resistance of the auxiliary ground is presumed to be negligible in comparison with the resistance of the unknown ground, and the measured value in ohms is called the resistance of the unknown ground.

The usual application of this method is to determine the resistance of a single rod-driven ground near a residence that also has a common municipal water supply system that uses metal pipe without insulating joints. The water pipe is the auxiliary ground and its ground resistance is assumed to be in the order of 1 Ω and must be low in relation to the permissible driven ground maximum resistance which is usually in the order of 25 Ω.

Obviously, this method is subject to large errors for low-valued driven grounds but is very useful and adequate where a *go, no-go*, type of test is all that is required.

8.2.1.2 Three-Point Method. This method involves the use of two test electrodes with the resistances of the test electrodes designated r_2 and r_3 and with the electrode to be measured designated r_1. The resistance between each pair of electrodes is measured and designated r_{12}, r_{13}, and r_{23},

where

$r_{12} = r_1 + r_2$ etc. Solving the simultaneous equations, it follows that:

$$r_1 = \frac{(r_{12}) - (r_{23}) + (r_{13})}{2} \qquad \text{(Eq 7)}$$

Therefore, by measuring the series resistance of each pair of ground electrodes and substituting the resistance values in the equation, the value of r_1 may be established. If the two test electrodes are of materially higher resistance than the electrode under test, the errors in the individual measurements will be greatly magnified in the final result. For the measurement, the electrodes must be at some distance from each other; otherwise absurdities may arise in the calculations, such as zero or even negative resistance. In measuring the resistance of a single-driven electrode the distance between the three separate ground electrodes should be at least 5 m with a preferable spacing of 10 m or more. For larger area grounding systems, which are presumably of lower resistances, spacings in the order of the dimensions of the grounding systems are required as a minimum. This method becomes awkward for large substations, and some form of the fall-of-potential method is preferred, if high accuracy is required.

8.2.1.3 Ratio Method. In this method the resistance of the electrode under test is compared with a known resistance, usually by using the same electrode configuration, as in the fall-of-potential method. Since this is a comparison method the ohm readings are independent of the test current magnitude if the test current is high enough to give adequate sensitivity.

8.2.1.4 Staged Fault Tests. Staged high-current tests may be required for those cases where specific information is desired on a particular grounding installation. Also, a ground impedance determination can be obtained as auxiliary information at the time of actual

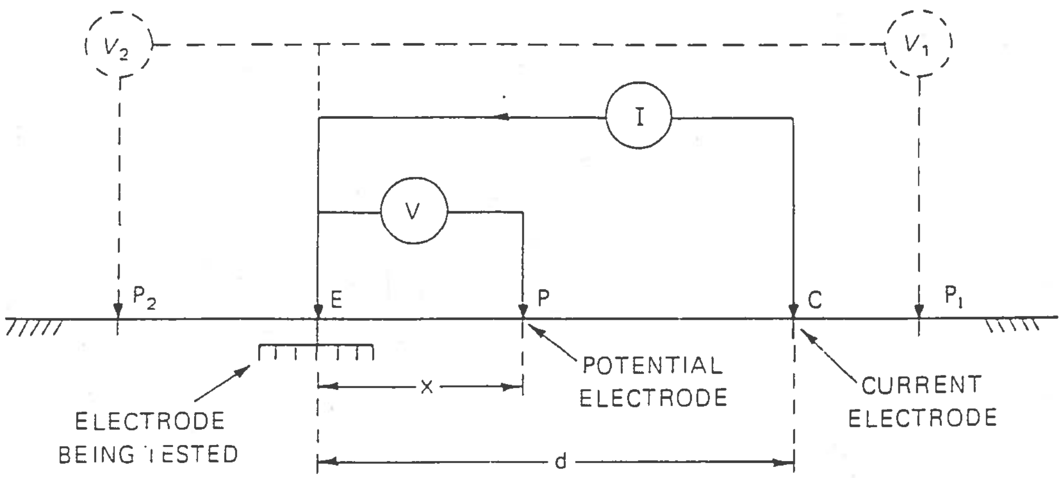


Fig 6
Fall-of-Potential Method

ground faults by utilizing an oscillograph or one element of the automatic station oscillograph.

In either case the instrumentation is the same. The object is to record the voltage between selected points on one or more oscillograph elements. The voltages to be recorded will probably be of such great magnitude that potential step-down transformers will be required. The maximum voltages that can be expected and thus the ratios of the potential transformers required may be determined in advance of the staged tests by using the fall-of-potential method at practical values of test current.

Another important consideration is the calibration of the oscillograph circuit, which is composed of a potential transformer with a possible high resistance in the primary. This resistance is composed of the remote potential ground in series with a long lead. A satisfactory calibration of the deflection of the oscillograph element may be made by inserting a measured voltage in the primary circuit in series with the lead and the remote potential ground as used during the test.

The location of the acutal points to be measured is dependent on the information desired; but in all cases due allowance must be made for coupling between test circuits, as given in 6.5.

8.2.1.5 Fall-of-Potential Method. This method has several variations and is applicable to all types of ground impedance measurements. As mentioned in 6.5, the impedance of a large grounding system may have an appreciable reactive component when the impedance is less than 0.5 Ω, therefore, the measured value is an *impedance* and should be so considered although the terminology often used is *resistance*.

The method involves passing a current into the electrode to be measured and noting the influence of this current in terms of voltage between the ground under test and a test *potential* electrode.

A test *current* electrode is used to permit passing a current into the electrode to be tested (see Fig 6).

The current I through the tested electrode E and the current electrode C, results in earth surface potential variations. The potential profile along the C, P, E, direction will look as in Fig 7. Potentials are measured with respect to the ground under test, E, which is assumed for convenience at zero potential.

The fall-of-potential method consists of plotting the ratio of $V/I = R$ as a function of probe spacing x. The potential electrode is moved away from the ground under test in steps. A value of impedance is obtained at each step. This impedance is plotted as a function of distance, and the value in ohms at which this plotted curve appears to level out is taken as the impedance value of the ground under test (see Fig 8).

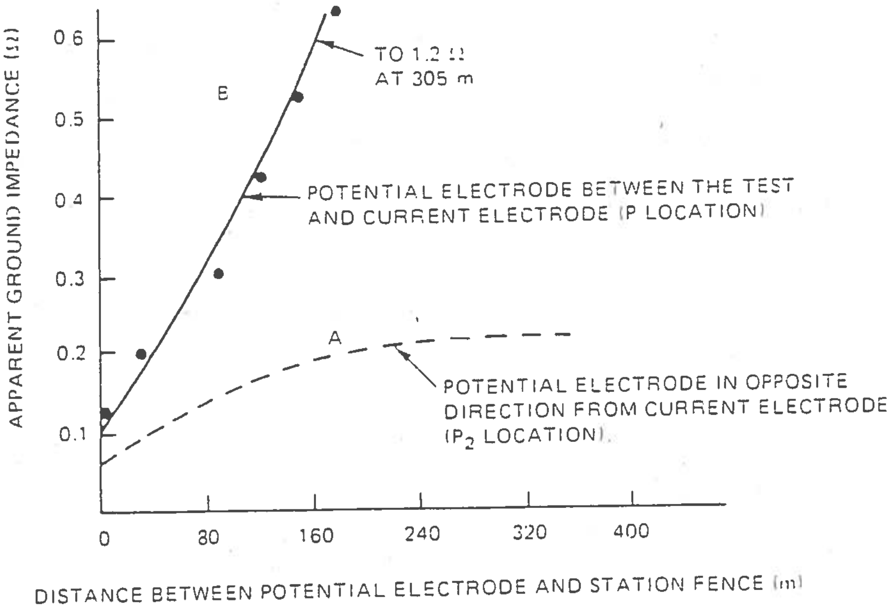


Fig 9
Case of a Low-Impedance Ground System

the ground to be tested. This influence is determined and allowed for during the test on ground grids or deep-driven ground rods of 1 Ω or less. In the case of small-area, such as single rod driven grounds, tower footings (not connected to overhead wires or counterpoises) the influence can be rendered negligible by keeping spacings in the order of 50 m which is practical and easy to achieve on site.

For large grounds the spacings required may not be practical or even possible. Consequently the flat portion of the curve will not be obtained and other methods of interpretation must be used.

It is important to note at this stage that theoretical analysis of the fall of potential problem [14], [19], [40], [41], shows that placement of the potential probe P at the opposite side with respect to electrode C (P_2) will result always in a measured apparent resistance smaller than the true resistance.

Moreover, when P is located on the same side as electrode C but away from it (P_1), there is a particular location which gives the true resistance.

It should be emphasized, however, that the P_2 arrangement presents the advantage of minimizing the coupling problem between test leads. If reasonably large distances between P_2 and C are achieved (with respect to the electrode E under tests), then it is possible to use this method to obtain a lower limit for the true resistance of electrode E.

A representative curve for a large grid ground is shown in Fig 9. The data for this figure were taken from a test made on a station that had a ground grid approximately 125 m by 150 m. Distances were measured from the station fence; hence the impedance is not zero at zero distance on the curve. Curve B is obtained with the potential probe located between E and C. Curve A is obtained with the potential probe located at the opposite side with respect to the current electrode C.

The test shows the existence of a mutual resistance between the current electrode and the station ground and that is why curve B does not level out. Curve A does seem to level out and can be used to obtain a lower limit for the impedance value of the electrode under test.

8.2.1.6 Interpretation of the Results. Appendix C shows that there is one potential probe spacing which gives the true ground impedance of the ground being tested.

The correct spacing may be very difficult, tensive ground systems imbedded in a uniform soil (based on the concept of electrical center) is described in a paper by Tagg [40]. It should be noted, however, that there is no proof that the *electrical center* is a physical constant (such as gravity center) which is not influenced by the current electrode location and characteristics.

As a general conclusion, the best guarantee of a satisfactory measurement is to achieve a spacing such that all mutual resistances are sufficiently small and the fall-of-potential curve levels out. The main advantage of the fall of potential method is that the potential and current electrodes may have a substantially higher resistance than the ground being tested without significantly affecting the accuracy of the measurement.

8.3 Testing the Integrity of the Ground Grid. In this test the object is to determine whether the various parts of the ground grid are interconnected with low-resistance copper. This copper is shunted by the surrounding earth, which usually has a very low impedance.

The best method for making integrity-of-ground-grid tests is to use a large but practical direct current and some means of detecting the voltage drop caused by this current. Direct reading ohmmeters can be used if the sensitivity is adequate.

The ammeter-voltmeter method, using alternating current, cannot be used satisfactorily for this test. The reactance of a large copper wire in this case is shunted by the surrounding earth, a path which may have slightly less reactance than the wire. Therefore, a continuity test for buried wire would give indeterminate results if alternating current were used.

By extension of this reasoning, one concludes that it is practically impossible to sensibly lower the impedance between two ground grids which are any distance apart, each of which has an impedance in the order of 0.1 Ω at 60 Hz. The addition of copper connectors, however large, will not lower the reactance between the two ground grids. The resistive component can be lowered by additional connectors, and this component is used to determine the integrity of the ground grid.

One practical *integrity* test consists of passing about five amperes into the ground grid between two points to be checked. The voltage drop across these points is measured with a millivoltmeter or portable potentiometer and the effective resistance is calculated from the current and voltage readings. From these readings and the calculated resistance of copper it can be determined whether there is an adequate connection. For those ground systems that have a direct voltage between points, the change of voltage caused by the test current is used to calculate the resistance.

For the majority of large ground systems in service there will be a realtively large alternating voltage between the points to be measured compared with the direct millivolts to be detected. The effects of the alternating component on the detector can be mitigated by shunting the moving coil in the millivoltmeter, or the galvanometer in the potentiometer, with a capacitor of 20 μF or more. This capacitor should preferably have a liquid impregnated paper dielectric, but some modern electrolytic condensers have so little leakage that they can be used in this application.

8.4 Instrumentation. The instruments used for ground resistance measurements are identical to those used for resistivity measurements. These instruments are described in Section 12.

9. Earth Potential

9.1 Equipotential Lines. As a result of current from an electrode to earth and through its earth path, equipotential surfaces plotted at right angles to these current lines will assume a shape controlled by the path of the current. The density of equipotential surfaces, having equal voltage differences between them, across a path in a given direction determines the step voltage which may be encountered. This gradient will be highest near the grounding electrode.

The distance between equipotential surfaces, measured along the surface of the earth radially from the grounding connection, will vary with a number of factors. These include variations in resistivity of the earth, the presence of buried pipes, conduit, railroad rails, steel fences, metallic cable sheaths, and the presence of overhead lines carrying ground current.

As indicated in 8.1, some of the ground-fault current tends to return to the source under the transmission line which carries the current. Consequently it will be found that the ground potential under the transmission line carrying fault current will have a steeper gradient than in the adjoining earth. This results in changing the pattern of the equipotential lines whenever a different transmission line terminating at the station is faulted. Therefore, equipotential lines cannot be established simply by measuring resistance from the grounding connection to various points around it.

When once established, the voltage between the equipotential lines for a given fault condition can be expected to vary directly with ground-fault current magnitude. This assumes no change in the resistivity of the earth around the grounding system during the flow of fault current.

9.2 Potential Contour Surveys. A potential contour survey is made to locate possible hazardous potential gradients in the vicinity of grounded electrical structures during fault conditions [7], [29]. The voltage drop to points surrounding the structure is measured from a known reference point and plotted on a map of the location. A potential contour map may then be drawn by connecting points of equal potential with continuous lines. If the contour lines have equal voltage differences between them, the closer the lines, the greater the hazard. Actual gradients due to ground-fault current are obtained by multiplying test current gradients by the ratio of the fault current to test current.

The most accurate measurements of potential gradients are made with the voltmeter-ammeter method. A known current, between 50 A and 100 A, held constant during test, is passed through the ground grid to a remote ground test electrode and returned through an insulated conductor. A remotely located ground test electrode is necessary to prevent gradient distortion, caused by the mutual impedance of inadequately spaced ground electrodes. This distance may vary from 300 m, for a small ground grid to a mile or more for larger installations. Measurements should be made with a very-high-impedance voltmeter on the surface of the earth along profile lines radial to the point of connection to the ground grid. Unless suitable means are employed to mask out residual ground current, the test current must be of sufficient magnitude to do so. At the same time care must be taken to prevent heating and drying of the soil in contact with the ground grid or test electrode to avoid variations in voltage gradients in a series of measurements. Economics and the necessary detail required will determine the number of measurements to be made.

When more than one overhead line or underground cable are connected to a substation, potential gradients in and around the substation may be quite different for faults on different lines or cables. Likewise, faults at different locations in large substations may result in differences in potential gradients in and around the substation. It may, therefore, be advantageous to determine potential gradients in and around a large substation for two or more fault conditions.

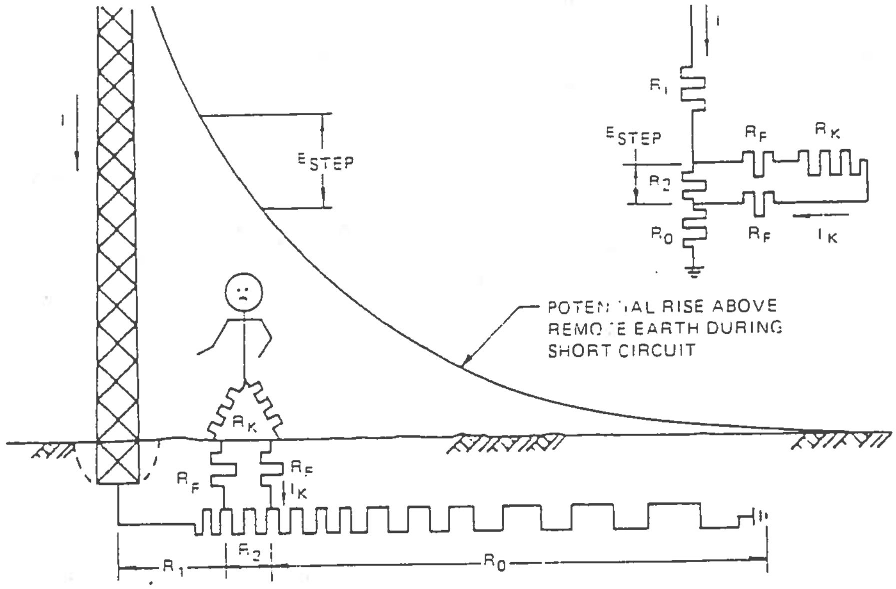
Underground metallic structures, for example, neutral conductors, metallic cable sheaths, metallic water and gas lines, etc, metallic structures on the surface of the ground such as railroad rails and fences, and overhead ground wires in the vicinity of a substation, whether connected to the ground grid or not, will usually have a significant effect on potential gradients and should be considered when making potential gradient measurements.

When a potential gradient survey cannot be justified economically, potential gradients may be calculated from ground resistance or soil resistivity measurements. The accuracy of such calculations will be dependent upon the accuracy of the measurements, and the unknown abnormalities of the earth around and below the ground grid.

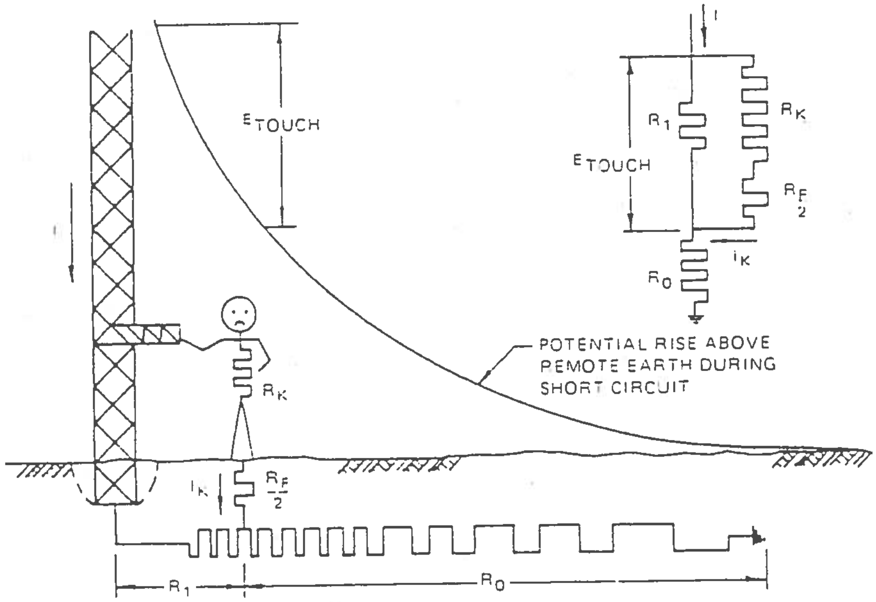
The adequacy of such calculations may be verified with relatively few potential gradient measurements.

9.3 Step and Touch Voltages. The magnitude of step and touch voltage (see Fig 11) may be scaled off of a potential contour map of the site or actually measured by the voltmeter-ammeter method. These values are proportional to the earth current and (provided that the deep soil resistivity is constant) to the top soil resistivity.

NOTE: A variation of resistivity of the top soil in some cases increases the ground resistance. This in turn may cause a variation in the earth current. The changes in step and touch voltages should therefore be determined by taking into account simultaneously, top-soil resistivity and earth current variations.



STEP VOLTAGE AT A GROUNDED STRUCTURE



TOUCH VOLTAGE AT A GROUNDED STRUCTURE

Fig 11
Step and Touch Voltages

10. Transient Impedance

10.1 Transient Impedance of Ground Systems

10.1.1 General. Many grounding systems are designed for operation under transient conditions, most commonly for carrying impulse current due to a lightning stroke. It has been shown [4], [15] that the impedance of a simple grounding electrode depends on the amplitude of the impulse current and also varies with time, depending on the impulse form.

The nonlinearity of the grounding impedance is caused by local discharges in soil in the area where the electric field gradient exceeds 2.5 kV–3 kV/cm. Since the field gradient attains the highest value at the ground electrode the discharges partly short circuit the layer of soil adjacent to the electrode. Consequently the transient impedance of the grounding system for high-current impulses is lower than the value measured with the conventional steady-state methods, or with an impulse of lower amplitude which does not produce the discharges in soil.

An opposite effect has been observed in the case of extended ground electrodes, wires or strips more than 300 m (1000 ft) long, when tested with steep front impulses. The voltage drop across the grounding impedance shows then a large inductive component. The instantaneous impedance is normally determined as a quotient of the applied transient voltage and current recorded at the same instant. The additional voltage component which appears across the grounding inductance at the steep impulse front (or at an abrupt collapse of the impulse current) is then interpreted as an increase of the grounding impedance.

10.1.2 Measurements of the Transient Impedance of Ground Systems. The grounding impedance measurements have to be performed using the real amplitude voltage and current impulses, because the nonlinear characteristics of this impedance exclude modeling techniques or reduced scale experiments. To perform such measurements a testing circuit is required which contains a high-voltage impulse current generator of adequate energy, as well as a precise voltage divider, current measuring shunt, and double beam impulse oscillograph. The lightning current ranges between 1 kA and 100 kA and a typical grounding impedance is of the order of 10 Ω.

Considering these typical requirements a mobile impulse generator which is normally used by power utilities for testing of insulation coordination in high-voltage substations can be suitable for measurements of the transient grounding impedance. Another possible solution consists of installing a prototype ground system in the soil near a high-voltage laboratory and connecting the laboratory generator, as well as the measuring apparatus, to the ground system under test.

The simultaneous oscilloscope recording of the voltage drop across the grounding impedance, and of the applied impulse current, requires a reference grounding point. The reference ground can be conveniently located at the impulse generator base, provided that there is sufficient distance to the examined ground. The transient impedance of ground is derived from the voltage and current oscillograms as a quotient of these two transients, calculated point by point for consecutive time intervals.

Since the variation of the grounding impedance depends on the impulse current amplitude and form, as well as on the electrode geometry and the type of soil, several measurements have to be taken to permit a more general interpretation of results and for a definite conclusion.

Attention should also be drawn to possible common mode interference which may appear in the measuring circuit if the grounding points of the voltage divider and shunt are shifted from the reference ground potential.

10.1.3 Instrumentation. The schematic diagram of the apparatus used is given in Fig 12.

Measurement of transient impedance of a driven grounding rod or of a distributed ground system requires specialized equipment, which is normally used in high-voltage laboratories. The high-voltage and high-current impulse is generated by discharge of a large capacitor into an impulse forming network. Although such a circuit can be improvized on the test site, in most practical cases a mobile impulse generator is used. There are no generally accepted standards for the current impulse form but the 8/20 μs or 4/10 μs impulse is frequently applied for measurements of the transient grounding impedance.

Apart from the ground to be measured the test circuit has to have another auxiliary ground which carries the return current from the impulse generator. This ground is preferably of the distributed type, such as a substation or a laboratory grounding mesh, and its impedance must be significantly lower than that of the measured ground.

The impulse generator is connected to this ground through a high-current shunt. The unit response of the shunt has to comply to the requirements of ANSI/IEEE Std 4-1978, IEEE Standard Techniques for High-Voltage Testing. Voltage drop across the resistance of the measured ground is measured by a voltage divider preferably of the resistive type and designed for the expected voltage range. It is essential to keep the shunt and the divider

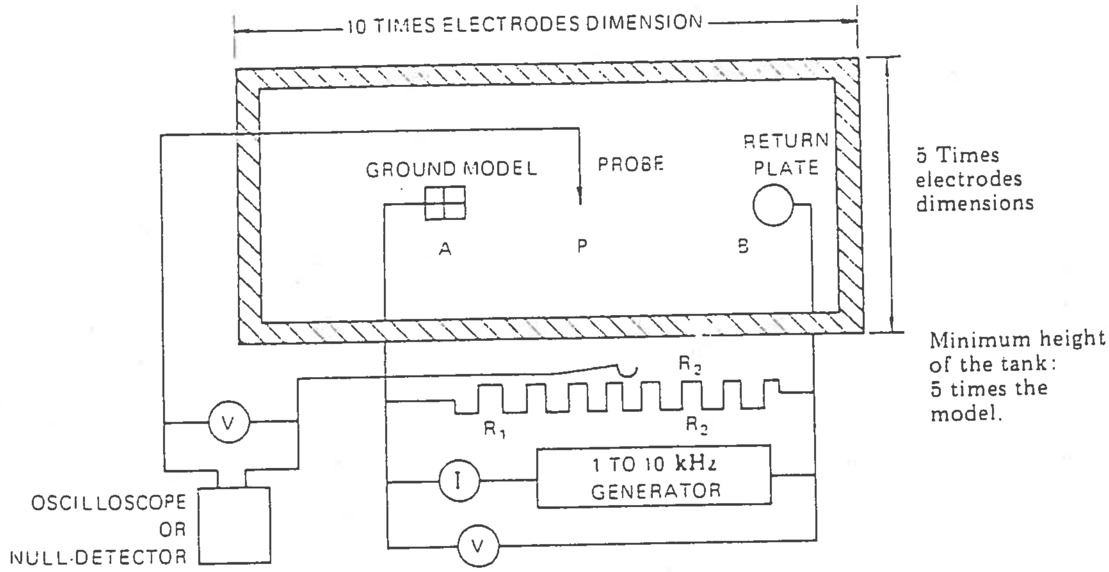


Fig 13
Electrolytic Tank

to be modeled; the reduced model will then have to obey certain laws [11]:

(1) All the geometrical dimensions of the earth model and of the test electrode should be scaled according to one unique factor μ_L.

(2) When the model consists of several layers of soil, the ratio of each layer resistivity to a reference layer should be equal to the ratio of their respective real life counterparts. The ratio of the real case to the model reference layer determines the resistivity scale factor $\mu\rho$.

When the above is completed the following precautions should be observed so as to minimize the errors caused by the finite size and limitations of the electrolytic tank.

(a) Alternating current should be used to prevent polarization of electrodes which would cause errors at low currents.

(b) Current densities should be kept less than 0.1 A/cm^2 of electrode.

(c) The probe should be about 3 mm diameter round rod cut off square and should not be immersed more than 3 mm.

(d) The model should be to scale and large enough to simplify its manufacture and assure a reasonable accuracy, but should be small enough to be convenient. A 20 to 1 scale is often satisfactory.

(e) The tank dimension should not be smaller than five times the model's maximum dimensions. This will give error of less than 10% of results obtained from an infinite tank.

11.3 Instrumentation. The materials required for model test are (see Fig 13):

(1) A tank of nonconducting material

(2) Various materials arranged adequately in the tank to constitute the layers of the earth to be modelled. The top layer should preferably be water with some quantity of common salt or copper sulfate to achieve the desired resistivity. The second layer could be simulated by a concrete block of appropriate dimensions.

(3) A scale model of the ground to be tested.

(4) An alternating current source of power with some means of varying the voltage. Use of a frequency in the range of 500 Hz to 1000 Hz aids in eliminating electrolytic polarization which causes potential distortions.

(5) A voltmeter with a minimum input impedance of 5 kΩ/V, or better, a potentiometer with an oscilloscope null detector.

(6) A *return path* plate and a small wire probe.

11.4 Resistance Measurements

(1) Suspend the scale ground model and the plate at A and B (AB should be at least 3 to 4 times the model ground dimension).

(2) Inject a small current I between A and B (0.1 to 0.5 A).

(3) Locate the probe P between A and B so that AP = 0.618 AB. Measure the voltage V between P and A.

(4) The scale model ground resistance is (see Appendix C):

$$R_A = V/I \qquad \text{(Eq 8)}$$

11.5 Potential Measurements. Using the model ground as the reference potential (zero potential), the electrolyte surface potential at any location can be measured simply by moving the probe P on the surface of the electrolyte. When a null detector and potentiometer are used, $R_1(R_1+R_2 = R = \text{constant})$ is adjusted so that the current through the null detector is minimum. The measured potential V_S is then in %: R_1/R, and in volts: $R_1 V_p/R$.

11.6 Interpretation of Measurements. The model results must be transformed to the real life case [11]:

Let:

$\mu_L = L_{real}/L_{model}$ (length)

$\mu_\rho = \rho_{real}/\rho_{model}$ (reference resistivity)

$\mu_I = I_{real}/I_{model}$ (current)

be the modelling scale factors, then the real life resistance is:

$$R_{real} = R_{model}\, \mu_\rho/\mu_L \qquad \text{(Eq 9)}$$

and the real life potential is:

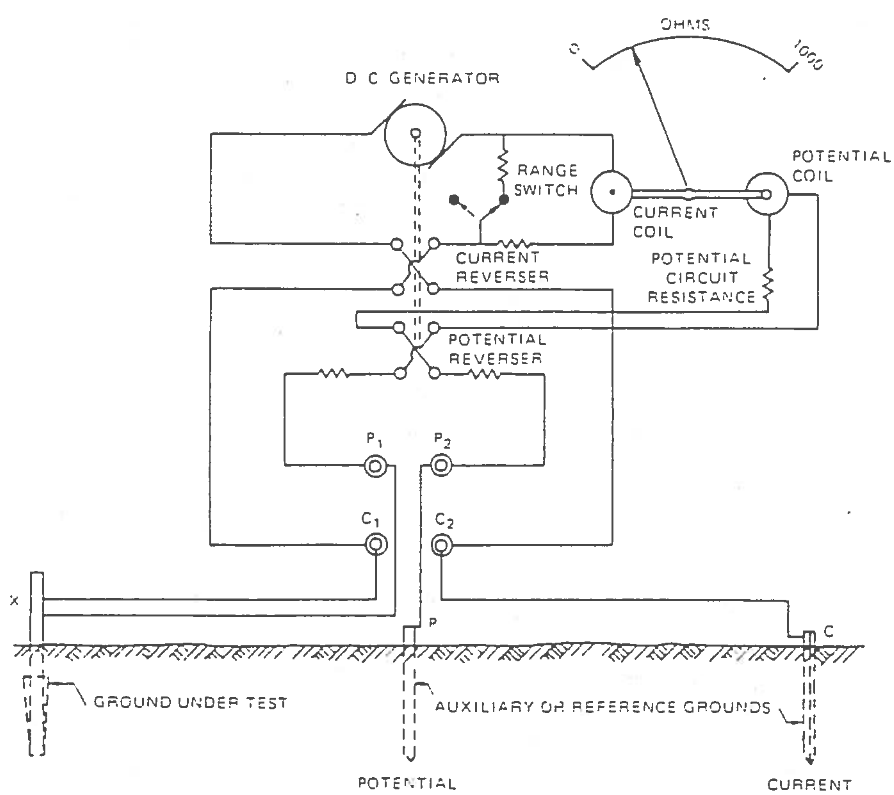
$$V_{real} = V_{model}\, \mu_I \mu_\rho/\mu_L \qquad \text{(Eq 10)}$$

12. Instrumentation

12.1 Ratio Ohmmeter. A commonly used instrument for measuring ground resistance is shown in Fig 14.

Current from the hand-cranked direct-current generator is reversed periodically by the current reverser and exists in the earth between ground X under test and current electrode C. The fall-of-potential between X and the potential electrode P is rectified by the potential reverser, which is on the same shaft, and therefore,

Fig 14
Ratio Ohmmeter



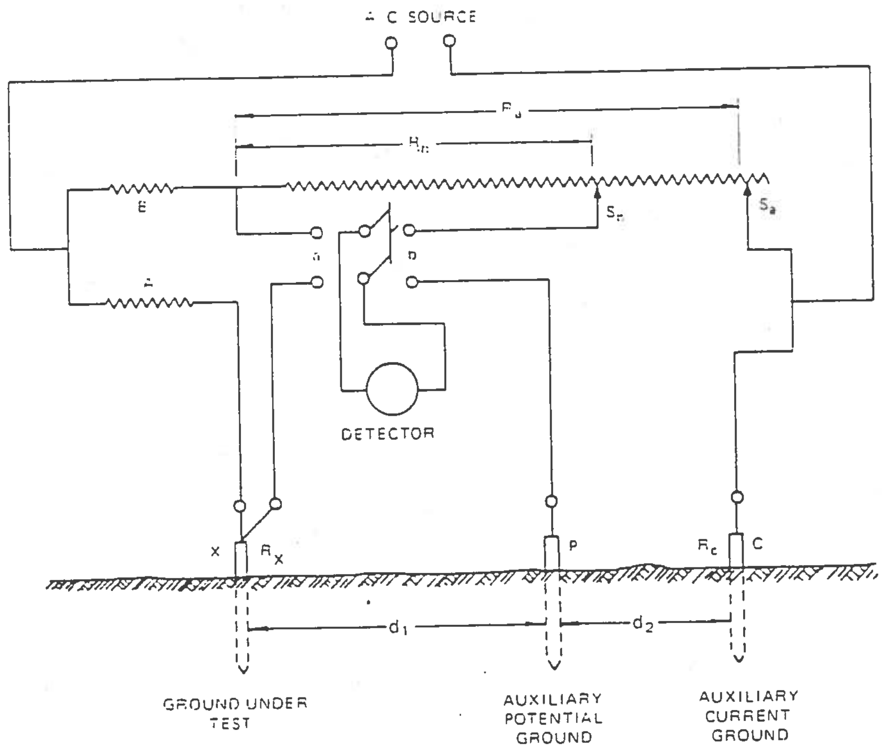


Fig 15
Double-Balance Bridge

operates in synchronism with the current reverser. The coils operate in a field provided by a permanent magnet. The current coil tends to turn the pointer toward zero, while the potential coil tends to turn the pointer toward a higher ohm reading. The operating current through these coils is furnished respectively by the current through and the voltage drop across the ground under test, therefore, the scale of the instrument can be calibrated in ohms. A suitable range switch provides a divider to the scale values.

By connecting terminals P_1 and C_1 (also P_2 and C_2) together, the instrument becomes a two-terminal ohmmeter and may be used in any of the methods, but the separate connections to the test electrodes, as shown in Fig 14, are preferred. For grounds over 1 Ω the P_1 and C_1 terminals may be connected together to use a common lead to the ground under test.

The synchronous reversing switch (combination current and potential reverser) used in this instrument makes it relatively insensitive to stray voltages in the potential circuit. In most cases a cranking speed, which eliminates the effect of relatively large stray voltages, can be used. Some difficulty may be experienced in obtaining a reading in an extreme case of a ground of less than 0.5 Ω with stray voltages of more than 10 V.

12.2 Double-Balance Bridge. This bridge method for measuring ground resistance is shown in Fig 15.

In this method current from the alternating-current source exists in two parallel circuits. The lower circuit includes fixed resistance A, electrode *X* under test, and auxiliary current electrode C. The upper circuit includes fixed resistance B and an adjustable slide rheostat on which two sliders, S_a and S_b, make contact. With the detector switch closed to the left, slider S_a is adjusted until the detector shows a balance. The currents in the two branch circuits are then inversely proportional to resistances A and B. The switch then is closed to the right, and slider S_b is adjusted until the detector again shows a balance. The potential drop between *X* and P is then equal to the drop in portion R_b of the slide rheostat, and the resistance of the ground under test then is

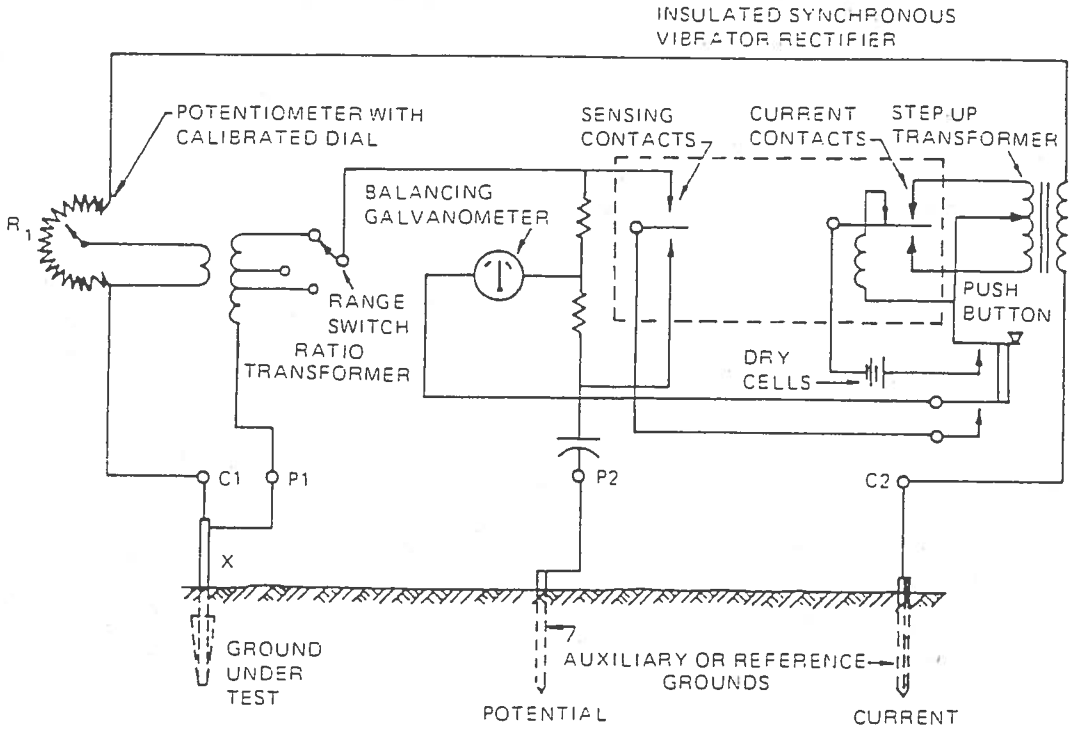


Fig 16
Single-Balance Transformer

given by

$$R_x = R_b \frac{A}{B}$$

The scale over which S_b moves can be calibrated to read R_x directly.

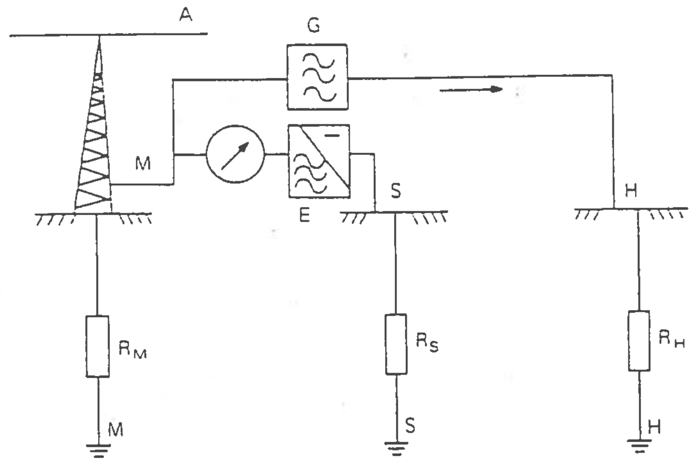
In testing high-resistance grounds the alternating-current source may be a vibrator operating from dry cells, and the detector may be a telephone receiver or a solid-state detector. The tone of the buzzer usually can be recognized and balanced out even in the presence of considerable background noise caused by stray alternating currents. Resistance at P merely reduces the sensitivity of the detector. Excessive resistance at C may limit the range of resistance that can be measured. The locations of electrodes P and C are determined by the same considerations as in the fall-of-potential method, given in 8.2.1.5.

12.3 Single-Balance Transformer. An instrument that uses a single balance to give a bridge type of measurement is shown schematically in Fig 16.

In this instrument a battery is used to drive a vibrator that has two sets of contacts. The first set of contacts reverses the direction of primary current to a transformer that provides test current between the current electrode and the ground under test. The second set of contacts gives *sense direction* to the balancing galvanometer, which then can indicate whether the dial setting is low or high.

When the slider of the potentiometer is adjusted until there is no potential between the slider and auxiliary electrode P, as shown by a galvanometer null, the portion of rheostat R_1 bears a definite relationship to the resistance of the ground under test. Therefore the potentiometer can be calibrated in ohms with appropriate multipliers provided by taps on the ratio transformer as selected by the range switch. Since a negligible current exists in the potential electrode circuit at balance, the resistance of the potential electrode does not affect the accuracy but does have an effect on the sensitivity of the galvanometer.

The instrument is relatively insensitive to stray voltages and only in an extreme case will difficulty be experienced, (see 12.1).



M = Tower
S = Probe
H = Return electrode
G = High frequency generator
E = High frequency receiver

A = Ground wire
R_M = Tower ground resistance
R_S = Probe ground resistance
R_H = Return electrode ground resistance

Fig 19
High-Frequency Meter

The two units (potential and current) are completely decoupled which is of great utility to eliminate coupling between the test leads.

12.5.1 Transmitter. The receiver measuring circuitry is triggered ON and OFF by the current pulses injected by the transmitter. Thus no direct cable connection is required between the receiver and transmitter. The transmitter passes a strong direct current into the ground through two electrodes and then abruptly interrupts this current. (Usually adjustable pulse duration is 2 s, 4 s, or 8 s current ON and current OFF periods.)

12.5.2 Receiver. Recent receivers are highly sensitive integrated circuitry measuring devices, thus reducing the weight and power requirements of time domain induced polarization equipment. Usually the main design features of the receiver console include:

(1) Automatic self potential compensation

(2) Remote (ground) triggering special filters for ac noise suppression

(3) Curve shape discrimination and automatic integral summations for random noise suppression.

12.5.3 Main Advantages. The units allow the field engineer to operate the receiver on the survey lines, and on occasion, allow the use of multiple receivers with one transmitter, thus greatly enhancing the survey efficiency. Due to the inherent noise suppression capability of this system, surveys can be conducted much closer to sources of spurious electrical noise such as power lines, and deeper effective penetration can be obtained without increasing power requirements. Also the coupling between leads can be completely eliminated. Finally, the light weight and low-power requirements allow for the maximum field mobility and versatility of operation.

12.6 High-Frequency Earth Resistance Meter. This relatively new instrument described in detail in [32] is intended for measuring the ground resistance of transmission line towers (not equipped with continuous counterpoises) with the static wires ON (insulated or not).

Danger will be avoided as work shall not be done near energized conductors. For operating principle see Fig 19.

The high-frequency meter is fully transistorized. A Ni-Cd battery is used as the power source. The generator is a self-excited power oscillator at 25 kHz. The loop current i flows through the current electrode H and the tower's ground M. The high-frequency receiver compares the measured voltage with a reference internal voltage.

It should be borne in mind that this meter uses the fall-of-potential method (the effect of the static wire is eliminated by use of high-frequency and neutralizing circuits). Therefore, adequate spacing between the test electrodes must be used in order to obtain reliable results.

13. Practical Aspects of Measurements

Performing resistivity and resistance tests can be physically exhausting especially if poor equipment is used during measurements. High-quality measuring instruments should be selected in order to obtain reliable data. Also, in many cases, special auxiliary equipment may be necessary to drive rods, to measure distances, and wind-up test leads.

13.1 Selection of Auxiliary Electrodes. The most practical electrodes are ground rods. Steel ground rods are preferred to lightweight aluminum rods since aluminum rods may be damaged if a hammer is used to drive them in hard soil. Screw type rods should not be used. The screw type rod fluffs up the soil and creates air in the area of the rod above the screw which results in high contact resistances. The driven rod compacts the soil giving minimum contact resistance.

The current electrode resistance is in series with the power source and is, therefore, one of the factors governing the testing current. If this current is low, it may be necessary to obtain a lower current electrode resistance by driving additional ground rods. In rocky soil it is a good practice to drive rods at an angle with respect to the vertical. Inclined rods will slide over the top of a rock.

The device used to measure the potential difference should have an internal resistance which is large compared with the potential electrode resistance. If this is not the case, additional ground rods may be required to lower the potential-electrode resistance.

13.2 Selection of Test Leads. Flexible leads must be used since during the measurements the leads will have to be wound up several times. The temperature at the site must also be considered to determine the adequate test lead. The lead insulation should not freeze or crack because of low temperatures. The test lead impedance should be low especially when testing low impedance ground systems.

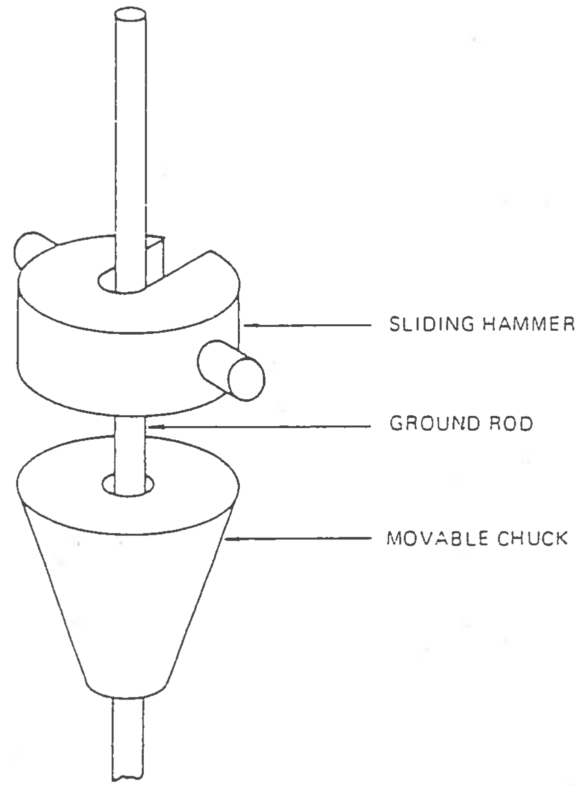


Fig 20
Chuck and Sliding Hammer

13.3 Selection of Auxiliary Equipment. The following additional equipment may be useful to ease and speed up the measurements.

13.3.1 Hammers. In normal soils, hand hammers (2 to 4 kg of mass) are satisfactory for driving the rods to depths of 2 m–3 m. The driving force should be axial to the rod in order to avoid undue whipping.

A practical type of hammer useful for the prevention of whipping consists of a chuck and sliding hammer (Fig 20). This device has the advantage that the work may be at a level convenient to the individual making the test without using an auxiliary platform. Also the blow is delivered to the rod at a point not far from the ground line.

When normal hand driving is not possible (hard or frozen soils, etc) it may be necessary to use mechanically operated hammers. These can be operated by either electric, pneumatic, or gasoline engines.

13.3.2 Distance Measurements. When the distances are not large a measuring tape or a

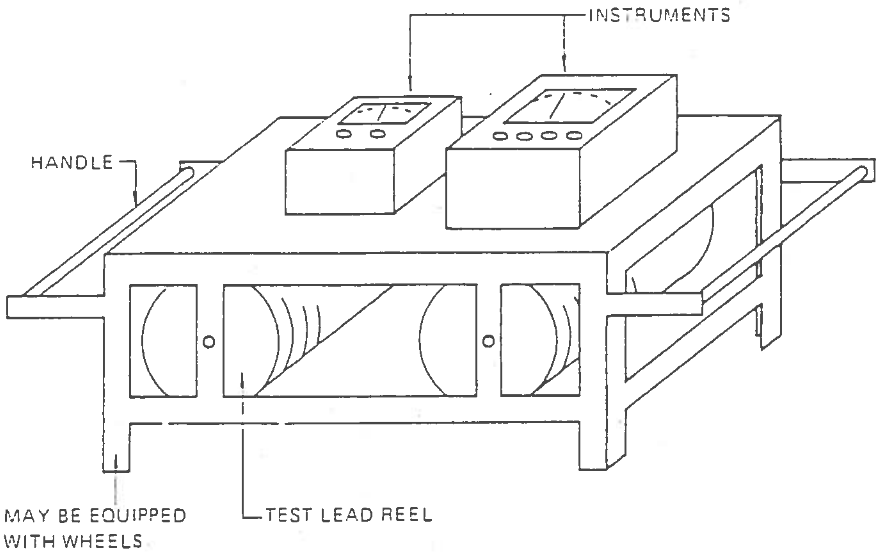


Fig 21
Test Table

marked chain may be used conveniently. When the distances are larger, the use of an odometer may be more practical and less time consuming. Extremely long distances may be read from appropriately scaled charts or maps of the area.

13.3.3. Lead Reels and Mobile Cart. Moving the test equipment from one location to another and winding up test leads may be simplified if a suitable mobile trolley is available.

The mobile trolley should be light and compact for ease of handling. Fig 21 shows a possible design for a convenient container equipped with four lead reels which could be spring cranked to wind up the test leads. The testing instruments are located on the upper shelf. The dc battery (if required), hammers, clips, and other handy tools may be stored in the lower shelf.

13.4 Testing Precautions. The most frequent problem experienced during testing is caused by stray currents flowing in the earth and by mutual coupling between leads.

The conduction through the soil is electrolytic in nature, and back voltages can develop at the auxiliary electrodes. An easy way to eliminate electrolytic effects is to use alternating test currents. If the current is of power frequency, electrolysis is not completely eliminated and stray alternating current at power frequencies may influence the results. At higher frequencies, electrolysis is negligible

but the self and mutual impedance of the leads are increased and errors may be introduced. Also if an impedance test is performed, the reactance component will be different from the 60 Hz value. Usually a compromise using frequencies in the order of 80 Hz is considered adequate.

If direct current is used, the effects of inductance and mutual impedance are eliminated, but electrolysis can be very troublesome. This problem can be solved by reversing the direct current periodically. The effects of inductance and mutual impedance are then evident only as transients which will be negligible, if the time constants of the various circuits are sufficiently low. Periodically reversed direct current, with a complete break in the circuit between reversals is the best power source for resistance or resistivity measurements. However, it is not adequate for impedance measurements.

13.5 Large Substations. The fall-of-potential method will give satisfactory results if the spacing between the grounding system under test and the test electrodes is large enough. It may happen that for large substations, adequate spacings are difficult to achieve using reels of wire. In these cases an outgoing line may be de-energized and used to inject test current into remote earth. Telephone cables may also be used in some cases [30], as potential lead

Appendixes

(The following Appendixes are not a part of IEEE Std 81-1983, IEEE Guide for Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System.)

Appendix A
Nonuniform Soils

A1. Two-Layer Soil Apparent Resistivity. With this model the earth is characterized (see Fig A1) by its:

First layer height, h
First layer resistivity, ρ_1
Deep layer resistivity, ρ_2
The reflection coefficient

$$K = \frac{(\rho_2 - \rho_1)}{(\rho_2 + \rho_1)} \qquad \text{(Eq A1)}$$

A resistivity determination using the Wenner method (see 7.2) results in an apparent resistivity which is a function of the electrode separation, a. In terms of the above parameters the apparent resistivity can be shown [39] to be:

$$\rho(a) = \rho_1 \left[1 + 4 \sum_{n=1}^{\infty} \frac{K^n}{\sqrt{1 + (2n\frac{h}{a})^2}} - \frac{K^n}{\sqrt{4 + (2n\frac{h}{a})^2}} \right] \qquad \text{(Eq A2)}$$

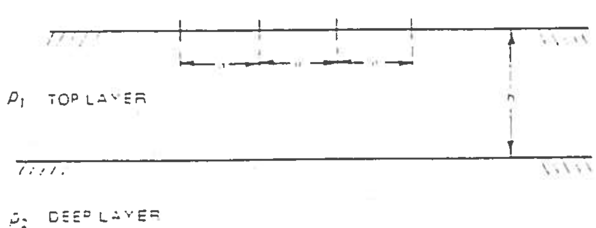


Fig A1
Two-Layer Earth

A2. Exponential Variation of Resistivity. With this model the earth is characterized by its:

Resistivity near the surface, ρ_1
Resistivity at great depth, ρ_2
A constant λ

A resistivity determination using the Wenner method (see 7.2) then results in an apparent resistivity which is a function of the electrode separation, a. It is given [42] by:

$$\rho(a) = \rho_2 - (\rho_2 - \rho_1)e^{-\lambda a}(2 - e^{-\lambda a}) \qquad \text{(Eq A3)}$$

A3. Ground Rod Resistance in a Two-Layer Soil. The ground resistance of a rod length l and radius r buried in the first layer of a two-layer soil is given by [39]:

$$R = \frac{\rho_1}{2\pi l} \quad ln \frac{2l}{r} + \sum_{n=1}^{\infty} \; K^n ln \frac{2nh + l}{2nh - l} \qquad \text{(Eq A4)}$$

Where K is the reflection coefficient defined above.

NOTES: (1) Since $0 \leq K \leq 1$ and $h \gg l$ only the first few terms of the infinite series are significant.
(2) $K = 0$ corresponds to the uniform soil model with

$$R = \frac{\rho_1}{2\pi l} \; ln \; \frac{2l}{r} \qquad \text{(Eq A5)}$$

If at a given site the ground resistance of a rod is measured for various lengths $l_1, l_2, l_3, \ldots l_n$ (at least three values), the measured values $R_1, R_2, R_3, \ldots R_n$ will provide a set of equations of type (A4) which can be solved to give the unknown values of ρ_1, K and h.

It may happen in some cases that absurd, or (when more than three measurements are made) contradictory results are obtained. This indicates either insufficient precision in the measurements or that the assumption of a uniform or two-layer soil was not an adequate approximation. It is preferable then, to use the four point or Wenner method with several values of probe separation and to interpret the results by visual inspection of the apparent resistivity curve (see 7.2).

Appendix B
Determination of an Earth Model

This Appendix is intended to assist the engineer in obtaining, from the measured resistivity data, the earth model which best fits the data. The earth model is limited to a two-layer soil configuration (see Fig A1).

Let ρ^0 be the apparent resistivity value as measured by the four-probe or Wenner method and ρ be the calculated resistivity value assuming that earth is a two-layer configuration. Both ρ^0 and ρ are functions of the probe spacing. A ρ is given by (Eq A2).

Let $\psi(\rho_1, K, h)$ be an error function given by:

$$\psi(\rho_1,K,h) = \sum_{m=1}^{N} \left[\frac{\rho_m^0 - \rho_m}{\rho_m^0}\right]^2 \qquad \text{(Eq B1)}$$

where

N = total number of measured resistivity values with probe spacing, a, as the parameter.

In order to obtain the best fit ψ must be minimum. To determine the values of ρ, K, and h which minimize ψ the method of steepest descent [19] is used.

$$\frac{\partial\psi}{\partial\rho_1} = -2\sum_1^N \left[\frac{\rho^0-\rho}{\rho^0}\right]\frac{\partial\rho}{\partial\rho_1}$$

$$\frac{\partial\psi}{\partial\rho_2} = -2\sum_1^N \left[\frac{\rho^0-\rho}{\rho^0}\right]\frac{\partial\rho}{\partial\rho_2}$$

$$\frac{\partial\psi}{\partial h} = -2\sum_1^N \left[\frac{\rho^0-\rho}{\rho^0}\right]\frac{\partial\rho}{\partial h} \qquad \text{(Eq B2)}$$

We have also:

$$\Delta\psi = \frac{\partial\psi}{\partial\rho_1}\Delta\rho_1 + \frac{\partial\psi}{\partial\rho_2}\Delta\rho_2 + \frac{\partial\psi}{\partial h}\Delta h \qquad \text{(Eq B3)}$$

In order to make sure that the calculations converge to the desired solution, the values of $\Delta\rho_1$, $\Delta\rho_2$, Δh should be such that

$$\Delta\rho_1 = -\tau\frac{\partial\psi}{\partial\rho_1}$$

$$\Delta\rho_2 = -\sigma\frac{\partial\psi}{\partial\rho_2}$$

$$\Delta h = -\gamma\frac{\partial\psi}{\partial h} \qquad \text{(Eq B4)}$$

τ, σ, γ being positive values and small enough to guarantee a solution with the desired accuracy. Normally values which lead to the following solutions are satisfactory:

$$\Delta_{\rho_1} = -0.005|\ \rho1|\left(\frac{\partial\psi}{\partial\rho_1}\right)\Big/\frac{\partial\psi}{\partial\rho_1}$$

$$\Delta_{\rho_2} = -0.005|\ \rho2|\left(\frac{\partial\psi}{\partial\rho_2}\right)\Big/\frac{\partial\psi}{\partial\rho_2}$$

$$\Delta h = -0.005\ |\ h|\left(\frac{\partial\psi}{\partial h}\right)\Big/\frac{\partial\psi}{\partial\rho_h} \qquad \text{(Eq B5)}$$

Using Eq B3 and Eq B4 the following equation is obtained

$$\Delta\psi = -\tau\left(\frac{\partial\psi}{\partial\rho_1}\right)^2 - \sigma\left(\frac{\partial\psi}{\partial\rho_2}\right)^2 - \gamma\left(\frac{\partial\psi}{\partial h}\right)^2 \qquad \text{(Eq B6)}$$

ρ is calculated using Eq 2 and, assuming initial values

$\rho_1^{(1)}$, $\rho_2^{(1)}$ and $h^{(1)}$, $\Delta\psi$ is calculated using Eq B6.

If $|\Delta\psi|>\epsilon$, the desired accuracy, the calculation is iterated.

At iteration k the new values are given by:

$$\rho_1^{(k)} = \rho_1^{(k-1)} + \Delta\rho_1$$

$$\rho_2^{(k)} = \rho_2^{(k-1)} + \Delta\rho_2$$

$$h^{(k)} = h^{(k-1)} + \Delta h \qquad \text{(Eq B7)}$$

The iterative calculations stop when $\Delta\psi$ as given (Eq B6) is such that:

$$|\Delta\psi| \leqslant \epsilon$$

ϵ being the accuracy desired.

$\Delta\rho_1$, $\Delta\rho_2$, and Δh are calculated using Eq B5

which in turn requires the values of

$\frac{\partial\psi}{\partial\rho_1}$, $\frac{\partial\psi}{\partial\rho_2}$ and $\frac{\partial\psi}{\partial h}$ given by Eq B2.

In Eq B2 the values of

$$\frac{\partial \rho}{\partial \rho_1}, \frac{\partial \rho}{\partial \rho_2}, \frac{\partial \rho}{\partial h}$$

are obtained from Eq A2 as follows:

$$\frac{\partial \rho}{\partial \rho_1} = 1 + 4 \sum_{n=1}^{\infty} \left[\left(1 - \frac{n(1-K^2)}{2K}\right)\left(\frac{K^n}{\sqrt{A}} - \frac{K^n}{\sqrt{B}}\right)\right]$$

$$\frac{\partial \rho}{\partial \rho_2} = \sum_{n=1}^{\infty} \left[\frac{2n}{K}\left(1-K^2\right)\left(\frac{K^n}{\sqrt{A}} - \frac{K^n}{\sqrt{B}}\right)\right]$$

$$\frac{\partial \rho}{\partial h} = \frac{16\rho_1 h}{a^2} \sum_{n=1}^{\infty} \left(\frac{K^n}{\sqrt{B^3}} - \frac{K^n}{\sqrt{A^3}}\right) \quad \text{(Eq B8)}$$

where:

$$A = 1 + (2nh/a)^2$$
$$B = 4 + (2nh/a)^2 \quad \text{(Eq B9)}$$

and ρ_1, ρ_2, and h are the calculated values at iteration K (Eq B7).

The method described in this Appendix is the basis of a computer program designed to determine the two-layer soil configuration which best fits the data obtained in the field. Figure 7.5 was obtained using this program.

Appendix C
Theory of the Fall of Potential Method

C1. Basic Definitions and Symbols

(1) When an electrode E does not conduct any current into the soil and is located at large distances from any other current carrying electrodes it's self potential P_E^E (or GPR) is zero (remote earth potential).

(2) If current I enters the soil through this electrode its potential rises to $P_E^E = R_E I$ where R_E is the electrode impedance. If $I = 1$ A then $P_E^E = V_E^E = R_E \cdot 1 = R_E$.

Therefore in the following V_E^E designates the potential rise of electrode E when 1 A enters the soil through the electrode. V_E^E is numerically equal to the electrode's impedance in ohms.

(3) Assume, now that at some finite distance from electrode E an electrode G injects a current I into soil (E does not conduct any current). Because of the local earth potential rise, electrode E, initially at zero potential, will be at potential P_E^G (this phenomena is often called *resistive coupling*). If $I = 1$ A, then $P_E^G = V_E^G$ (numerically equal to the so called *mutual resistance* between E and G).

(4) If electrode E carries 1 A while simultaneously electrode G conducts also 1 A, the potential rise of electrode E will be $V_E^E + V_E^G$.

The theoretical expressions which permit the calculation of V_E^E or V_E^G are complex and will not be given in this Appendix except for simple earth and electrode configurations.

C2. Derivation of the Fundamental Equations.

The problem is illustrated in Fig C1.

The current i in electrode P is assumed negligible to I. At a given time t, current I injected into the ground through E, is assumed positive and I, collected by G, is assumed negative.

Based on the definitions and symbols presented previously the following relations hold:

$$U_P = V_P^E \cdot (I') + V_P^G \cdot (-I') \quad \text{(Eq C1)}$$

$$U_E = V_E^E \cdot (I') + V_E^G \cdot (-I') \quad \text{(Eq C2)}$$

where

$$I' = I \text{ A}/1 \text{ A}$$

U_P and U_E are the potentials or GPR (with respect to remote ground) of electrodes P and E respectively.

The voltage V measured by the fall of potential method is:

$$V = U_E - U_P$$
$$V = I'(V_E^E - V_E^G - V_P^E + V_P^G) \quad \text{(Eq C3)}$$

V_E^E is the potential rise of electrode E resulting from its own current of 1 A. This is by definition the impedance R_E of electrode E. Therefore, Eq C3 can be written as:

$$R = \frac{V}{I} = R_E + (V_P^G - V_E^G - V_P^E)/1 \text{ A}. \quad \text{(Eq C4)}$$

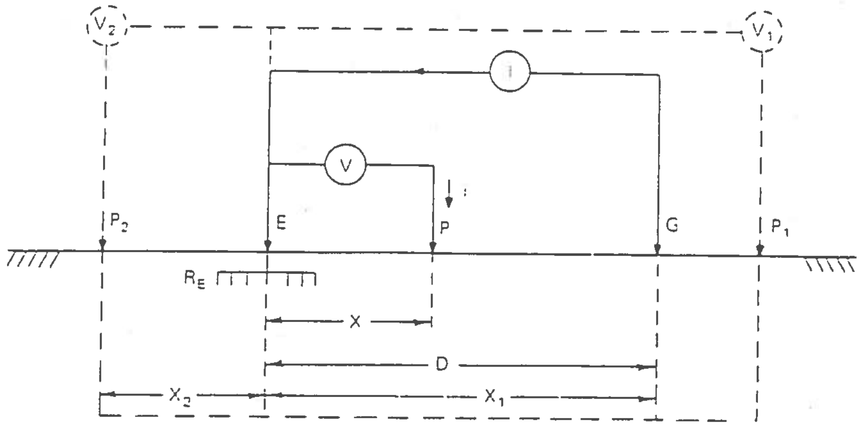


Fig C1
Fall-of-Potential Method

V_P^G and V_P^E are functions of the spacing between the electrodes (E, G and P), the electrode configurations, and the soil characteristics.

C3. Uniform Soil. Let us define the following functions η, ϕ, and ψ with respect to the coordinate system shown in Fig C1. (It is assumed that η, ϕ, and ψ are only functions of distances D and x):

$$V_E^G = \eta(D) \qquad \text{(Eq C5)}$$

$$V_P^G = \phi(D - x) \qquad \text{(Eq C6)}$$

$$V_P^E = \psi(x) \qquad \text{(Eq C7)}$$

According to Eq C4 the measured impedance $R = V/I$ will be equal to the true impedance R_E if:

$V_P^G - V_E^G - V_P^E = 0$, that is:

$$\phi(D - x) - \eta(D) - \psi(x) = 0 \qquad \text{(Eq C8)}$$

C4. Identical Electrodes and Large Spacings. If electrodes E and G are identical $\phi = \psi$ and if D is large enough such that $V_E^G = \eta(D) \sim 0$ then condition Eq C8 becomes:

$$\phi(D - x) - \psi(x) = 0$$

thus:

$x_o = D/2$

that is, the probe should be located midway between E and G.

C5. Hemispherical Electrodes. If electrodes E and G are hemispheres and their radii are small compared to x and D and if soil is uniform, then the potential functions ϕ, η, and ψ are inversely proportional to the distance relative to the hemisphere center. If the origin of the axes is at the center of hemisphere E then, Eq C8 becomes:

$$1/(D - x) - 1/D - 1/x = 0 \qquad \text{(Eq C9)}$$

The positive root of Eq C9 is the exact potential probe location x_o:

$x_o = 0.618\,D$

This is the usual 61.8% rule [8]. If the potential probe P is at location P_2 (E side, see Fig C1) then $D - x$ should be replaced by $D + x$ in Eq C9. In this case the equation has complex roots only. If P is at location P_1 (G side, see Fig C1) then $D - x$ should be replaced by $x - D$ in Eq C9. The positive root of Eq C9 is:

$x_o = 1.618\,D$

C6. General Case. If the soil is not uniform or electrodes E and G have complex configurations, or both, then, the functions ϕ, η, and ψ are not easy to calculate. In such cases, computer solutions are generally required [14].

Appendix D

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— END —

APPENDIX II

LABORATORY TESTING RESULT

LABORATORY SUMMARY SHEET

Project	Towantic Energy Center	Date	11/6/00
Project No.	00172.00	Technician	A. Orsi
Project Location	Oxford, CT	Checked By	J.M. Bellisle

Sample	Moisture Content	Gradation	Hydrometer	Percent Passing No. 200	Atterberg Limits		Chemical Tests			Modified Proctor	
					Liquid Limit	Plastic Limit	Chlorides	Sulfates	PH	Maximum Dry Density	Optimum Water Content
B-103, S-2	12.4	X									
B-103, S-4	13.3				26.3	21.2					
B-103, S-7	15.9				28.5	19.8					
B-104, S-4	24			40							
B-104, S-6	14.8				25	18.2					
B-105, S-5	12.6			30							
B-105, S-7	12.3				26.9	18					
B-106, S-2							ND	100	5.6		
B-107, S-2	11.3	X									
B-107, S-3							ND	ND	7.1		
B-107, S-6	11.7			45							
B-107, S-7	12.7				21.8	17.7					
B-108, S-1	27.3				28.8	25.1					
B-108, S-3							ND	ND	7.2		
B-108, S-5	10.8										
B-108, S-7	12.5				22.1	20.8					
B-109, S-2	12.6			36.4							
B-109, S-5							ND	ND	5.8		
B-110, S-5							ND	33	7.8		
B-111, S-3	12.1			32.1							
B-112, S-4							ND	47	7		
B-117, S-3	8.5	X									
B-117, S-6	10.9										
B-117, S-7	12.5			45.9							
B-117, S-8	15.9				30.5	17.6					
B-118, S-3	17.8				32.8	20.9					
B-118, S-6	10.3										
B-118, S-7	10.3			38.7							
B-118, S-8	9.2			34.2							
B-119, S-3	12.7	X									
B-119, S-5	10.5	X									
B-119, CUTTINGS	-	X								131	9.1
B-120, S-4	10.1	X									
B-120, S-8							ND	ND	7.6		
B-120, CUTTINGS	-	X			26.2	19				129	9.3
B-121, S-4	10.9										
B-122, S-5	13.5	X									
B-122, CUTTINGS	-	X								131	9.2

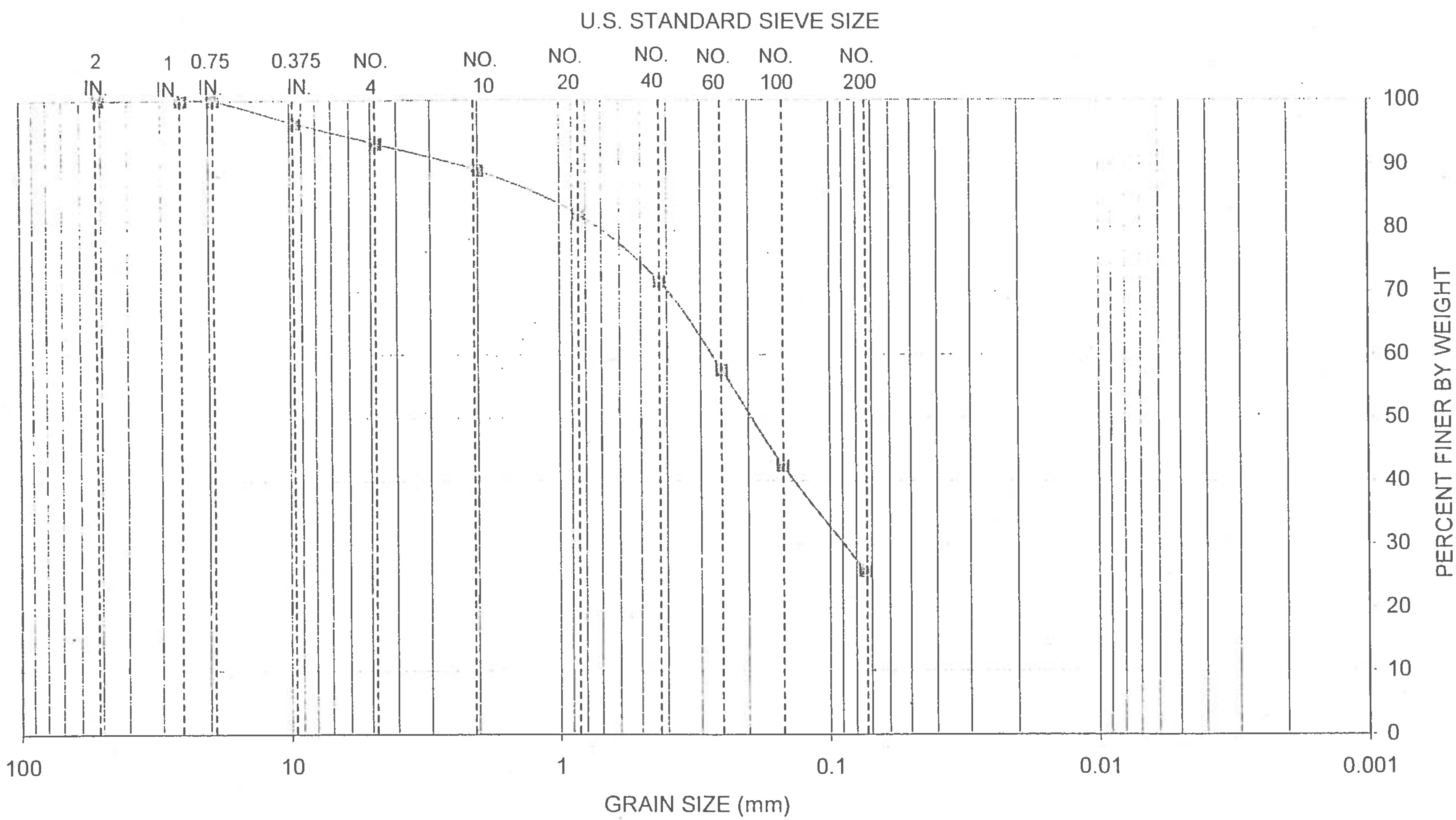
PARE ENGINEERING CORPORATION

SIEVE ANALYSIS

SOIL SAMPLE		WATER CONTENT			
Location:	Towantic Energy Center	Container No.	F	File No.	00172.00
Boring No.:	B-103	Wt. Container (g)	10.7	Test No.	2
Depth:	2-4'	Wt. Container, Wet Soil (g)	249.9	Date	10/19/00
Sample No.:	S-2	Wt. Container, Dry Soil (g)	223.6	Tested By:	ARO
		Wt. Water (g)	26.3	Checked By	JMB
Specific		Wt. Dry Soil (g)	212.9		
Gravity, Gs:		Water Content (%)	12.35%	Dry Sieve	
		Wt. Con, Washed Dry Soil (g)	185.2	Wash Sieve	
		Wt. Washed Dry Soil (g)	174.5	Combined	X

TOTAL SAMPLE

U.S. Standard Sieve No.	Sieve Opening (mm)	Sieve Wt. (g)	Sieve + Soil Wt. (g)	Accumulative Wt. of Soil Retained (g)	Accumulative Percent Retained	Total Sample Percent Finer By Wt.
2"	50.8	562.6	562.6	0.0	0.00	100.00
1"	25	545.8	545.8	0.0	0.00	100.00
0.75"	19.1	553.8	553.8	0.0	0.00	100.00
0.375"	9.5	537.2	544.7	7.5	3.52	96.48
4	4.76	498.4	505.3	14.4	6.75	93.25
10	2	483	492.1	23.5	11.02	88.98
20	0.85	436.2	450.9	38.2	17.91	82.09
40	0.425	378.3	400.8	60.7	28.46	71.54
60	0.250	348.9	378.7	90.5	42.43	57.57
100	0.149	330.5	362.9	122.9	57.62	42.38
200	0.074	340.4	376	158.5	74.31	25.69
Pan		374.8	391.2	174.9	82.00	18.00
Split Sample Wt (Washed)				38.4		
Total Sample Weight				213.3		



GRAVEL		SAND			SILT	CLAY
COARSE	FINE	COARSE	MEDIUM	FINE		

TEST	MATERIAL SOURCE	REMARKS
2	Towantic Energy Center Oxford, CT Boring B-103 S-2	Brown Silty Sand (SM)

PARE ENGINEERING CORPORATION

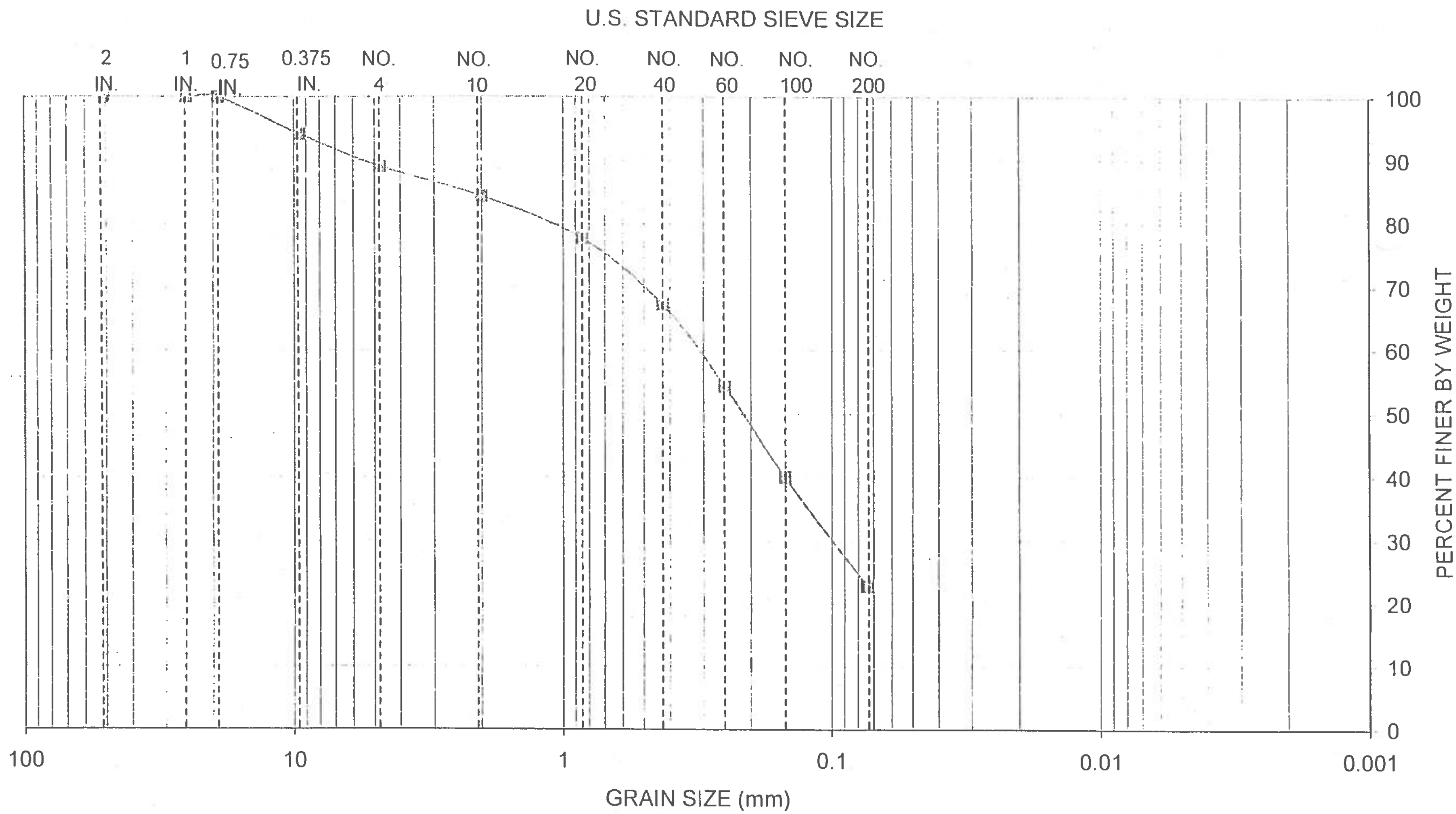
PARE ENGINEERING CORPORATION

SIEVE ANALYSIS

SOIL SAMPLE		WATER CONTENT			
Location:	Towantic Energy Center	Container No.	3	File No.	00172.00
Boring No.:	B-107	Wt. Container (g)	10.7	Test No.	3
Depth:	2-4'	Wt. Container, Wet Soil (g)	282.7	Date	10/19/00
Sample No.:	S-2	Wt. Container, Dry Soil (g)	255	Tested By:	ARO
		Wt. Water (g)	27.7	Checked By	JMG
Specific		Wt. Dry Soil (g)	244.3		
Gravity, Gs:		Water Content (%)	11.34%	Dry Sieve	
		Wt. Con, Washed Dry Soil (g)	210	Wash Sieve	
		Wt. Washed Dry Soil (g)	199.3	Combined	X

TOTAL SAMPLE

U.S. Standard Sieve No.	Sieve Opening (mm)	Sieve Wt. (g)	Sieve + Soil Wt. (g)	Accumulative Wt. of Soil Retained (g)	Accumulative Percent Retained	Total Sample Percent Finer By Wt.
2"	50.8	562.6	562.6	0.0	0.00	100.00
1"	25	545.8	545.8	0.0	0.00	100.00
0.75"	19.1	553.8	553.8	0.0	0.00	100.00
0.375"	9.5	537.2	551.4	14.2	5.82	94.18
4	4.76	498.4	511	26.8	10.99	89.01
10	2	483	494.3	38.1	15.62	84.38
20	0.85	436.2	452.6	54.5	22.35	77.65
40	0.425	378.3	403.8	80.0	32.80	67.20
60	0.250	348.9	380.2	111.3	45.63	54.37
100	0.149	330.5	365.4	146.2	59.94	40.06
200	0.074	340.4	382.4	188.2	77.16	22.84
Pan		374.8	385.5	198.9	81.55	18.45
Split Sample Wt (Washed)				45.0		
Total Sample Weight				243.9		



GRAVEL		SAND			SILT	CLAY
COARSE	FINE	COARSE	MEDIUM	FINE		

TEST	MATERIAL SOURCE	REMARKS
3	Towantic Energy Center Oxford, CT Boring B-107 S-2	Brown Silty Sand (SM)

PARE ENGINEERING CORPORATION

PARE ENGINEERING CORPORATION

SIEVE ANALYSIS

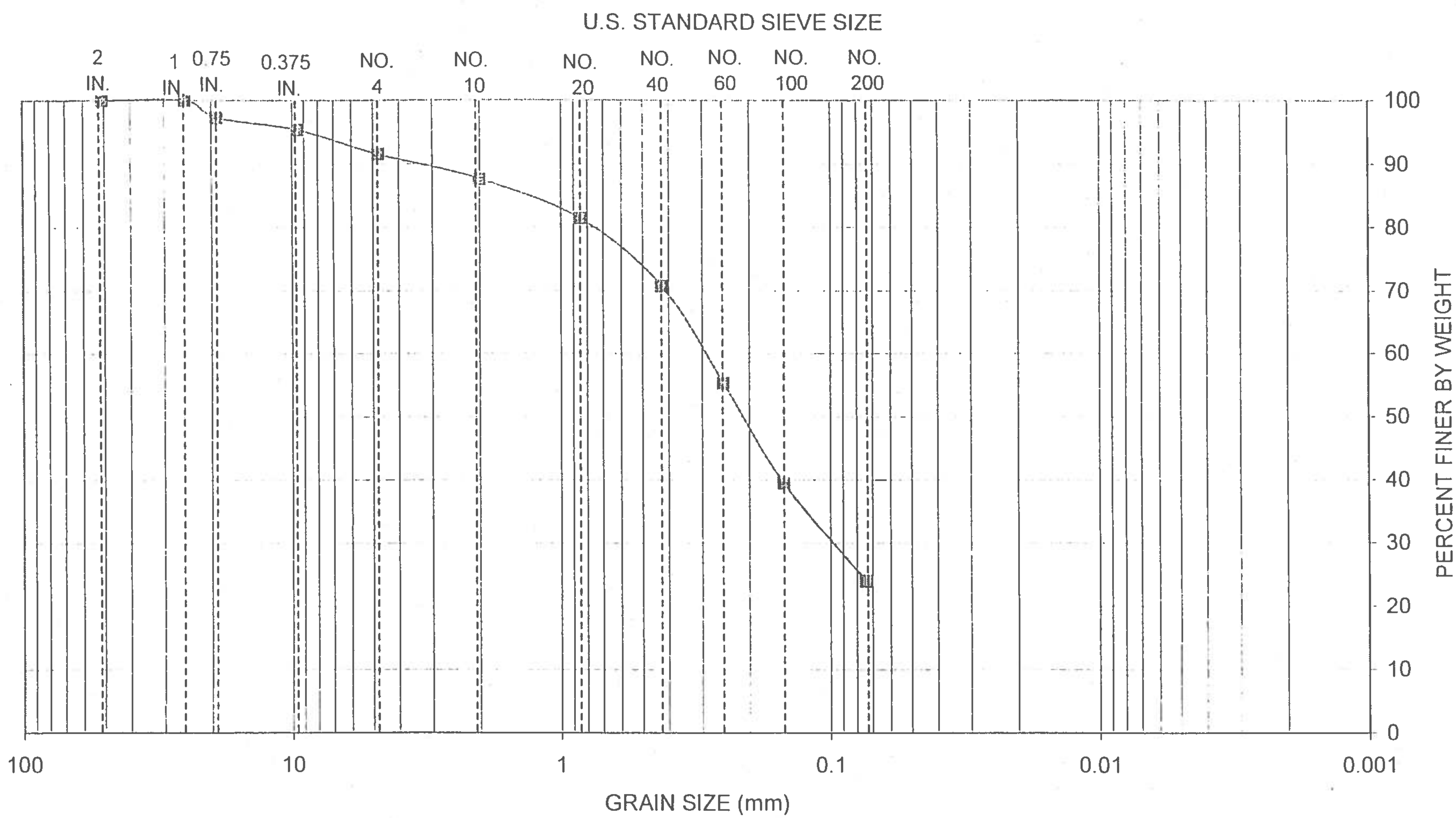
SOIL SAMPLE

WATER CONTENT

Location:	Towantic Energy Center	Container No.	D	File No.	00172.00
Boring No.:	B-117	Wt. Container (g)	10.8	Test No.	4
Depth:	4-6'	Wt. Container, Wet Soil (g)	259.6	Date	10/19/00
Sample No.:	S-3	Wt. Container, Dry Soil (g)	240.1	Tested By:	ARO
		Wt. Water (g)	19.5	Checked By	JMB
Specific		Wt. Dry Soil (g)	229.3		
Gravity, Gs:		Water Content (%)	8.50%	Dry Sieve	
		Wt. Con, Washed Dry Soil (g)	200.1	Wash Sieve	
		Wt. Washed Dry Soil (g)	189.3	Combined	X

TOTAL SAMPLE

U.S. Standard Sieve No.	Sieve Opening (mm)	Sieve Wt. (g)	Sieve + Soil Wt. (g)	Accumulative Wt. of Soil Retained (g)	Accumulative Percent Retained	Total Sample Percent Finer By Wt.
2"	50.8	562.6	562.6	0.0	0.00	100.00
1"	25	545.8	545.8	0.0	0.00	100.00
0.75"	19.1	553.8	559.8	6.0	2.65	97.35
0.375"	9.5	537.2	541.5	10.3	4.55	95.45
4	4.76	498.4	507.3	19.2	8.49	91.51
10	2	483	491.7	27.9	12.33	87.67
20	0.85	436.2	450.3	42.0	18.57	81.43
40	0.425	378.3	402.6	66.3	29.31	70.69
60	0.250	348.9	383.6	101.0	44.65	55.35
100	0.149	330.5	366.4	136.9	60.52	39.48
200	0.074	340.4	375.4	171.9	75.99	24.01
Pan		374.8	389.1	186.2	82.32	17.68
Split Sample Wt (Washed)				40.0		
Total Sample Weight				226.2		



GRAVEL		SAND			SILT	CLAY
COARSE	FINE	COARSE	MEDIUM	FINE		

TEST	MATERIAL SOURCE	REMARKS
4	Towantic Energy Center Oxford, CT Boring B-117 S-3	Brown Silty Sand (SM)

PARE ENGINEERING CORPORATION

PARE ENGINEERING CORPORATION

SIEVE ANALYSIS

SOIL SAMPLE

Location: Towantic Energy Center
Boring No.: B-119
Depth: 4-6'
Sample No.: S-3

Specific Gravity, Gs: ______

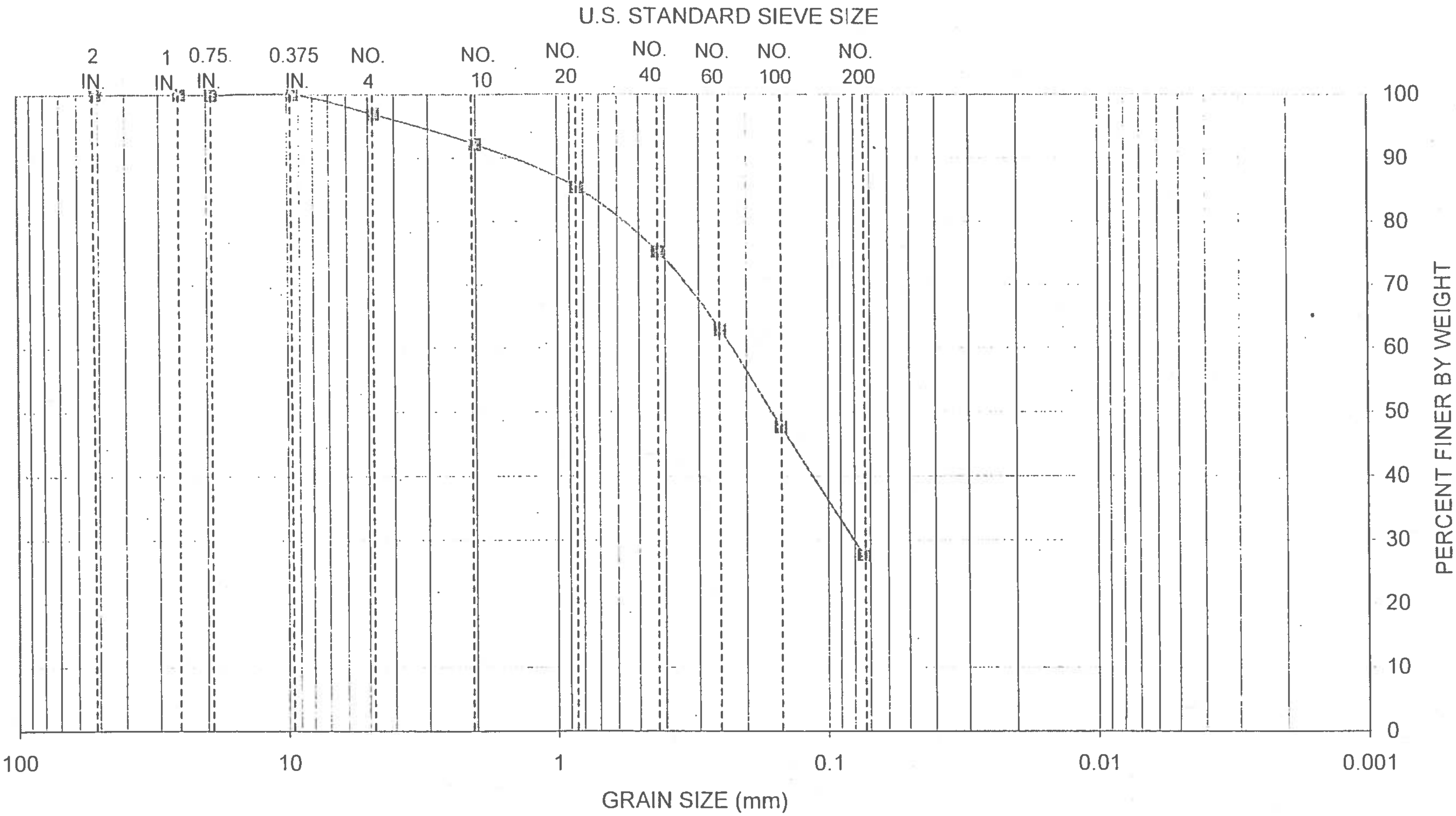
WATER CONTENT

Container No.: F
Wt. Container (g): 7.1
Wt. Container, Wet Soil (g): 252.2
Wt. Container, Dry Soil (g): 224.5
Wt. Water (g): 27.7
Wt. Dry Soil (g): 217.4
Water Content (%): 12.74%
Wt. Con, Washed Dry Soil (g): 178.9
Wt. Washed Dry Soil (g): 171.8

File No.: 00172.00
Test No.: 5
Date: 10/23/00
Tested By: ARO
Checked By: JMF
Dry Sieve: ______
Wash Sieve: ______
Combined: X

TOTAL SAMPLE

U.S. Standard Sieve No.	Sieve Opening (mm)	Sieve Wt. (g)	Sieve + Soil Wt. (g)	Accumulative Wt. of Soil Retained (g)	Accumulative Percent Retained	Total Sample Percent Finer By Wt.
2"	50.8	562.6	562.6	0.0	0.00	100.00
1"	25	545.8	545.8	0.0	0.00	100.00
0.75"	19.1	553.6	553.8	0.2	0.09	99.91
0.375"	9.5	537.4	537.2	0.0	0.00	100.00
4	4.76	498.9	505.5	6.6	3.04	96.96
10	2	483.1	493.6	17.1	7.87	92.13
20	0.85	435.6	450.1	31.6	14.54	85.46
40	0.425	378.1	400.4	53.9	24.80	75.20
60	0.250	349.1	376.1	80.9	37.23	62.77
100	0.149	330.4	363.2	113.7	52.32	47.68
200	0.074	340.4	384.0	157.3	72.39	27.61
Pan		374.7	389.1	171.7	79.02	20.98
Split Sample Wt (Washed)				45.6		
Total Sample Weight				217.3		



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<tr><td>COARSE</td><td>FINE</td><td>COARSE</td><td>MEDIUM</td><td>FINE</td></tr>
</table>

TEST	MATERIAL SOURCE	REMARKS
5	Towantic Energy Center Oxford, CT Boring B-119 S-3	Brown Silty Sand (SM)

PARE ENGINEERING CORPORATION

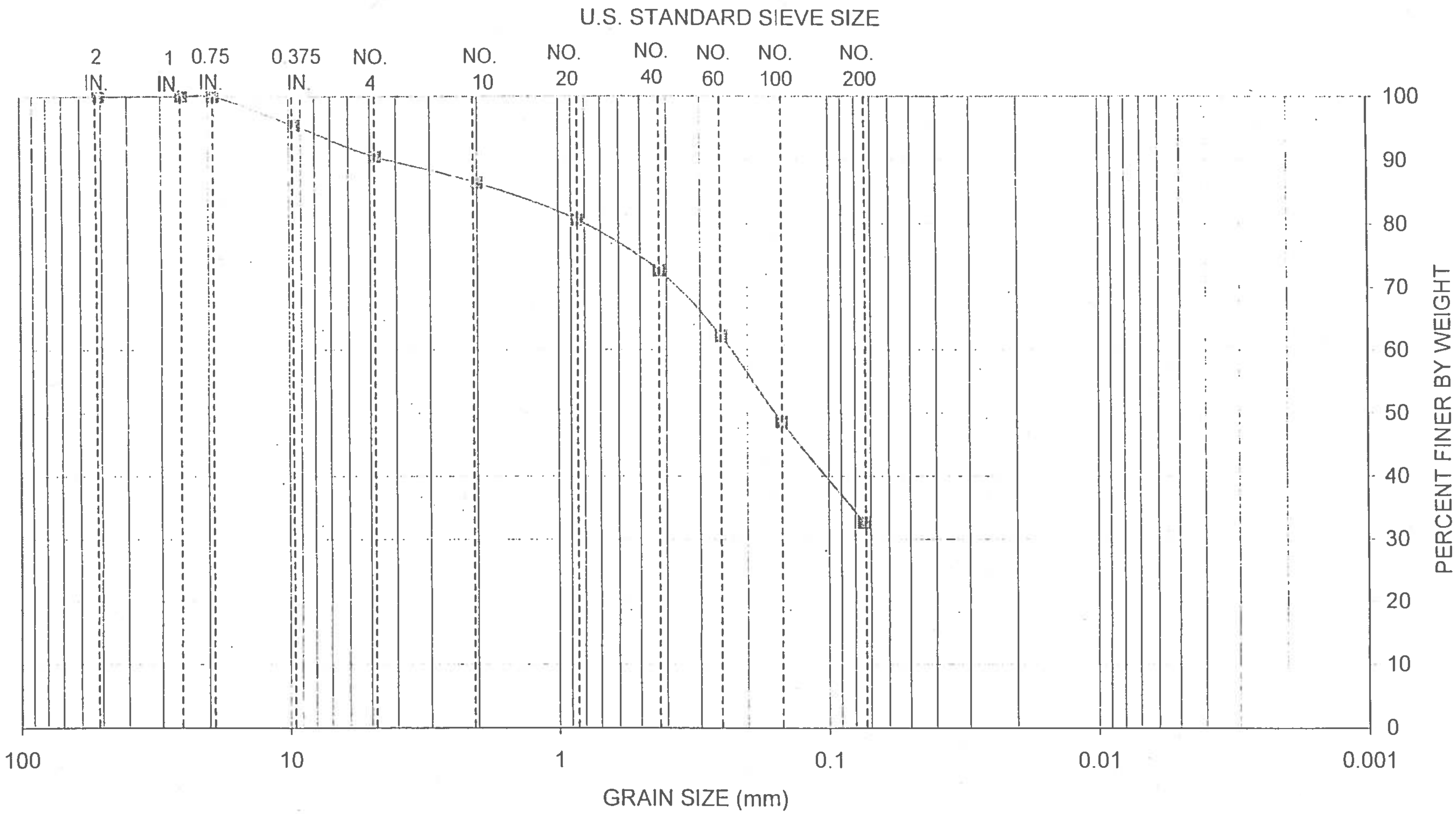
PARE ENGINEERING CORPORATION

SIEVE ANALYSIS

SOIL SAMPLE		WATER CONTENT			
Location:	Towantic Energy Center	Container No.	G	File No.	00172.00
Boring No.:	B-119	Wt. Container (g)	7.7	Test No.	7
Depth:	8-10'	Wt. Container, Wet Soil (g)	226.5	Date	10/24/00
Sample No.:	S-5	Wt. Container, Dry Soil (g)	205.8	Tested By:	ARO
		Wt. Water (g)	20.7	Checked By	JMB
Specific		Wt. Dry Soil (g)	198.1		
Gravity, Gs:		Water Content (%)	10.45%	Dry Sieve	
		Wt. Con, Washed Dry Soil (g)	147	Wash Sieve	
		Wt. Washed Dry Soil (g)	139.3	Combined	X

TOTAL SAMPLE

U.S. Standard Sieve No.	Sieve Opening (mm)	Sieve Wt. (g)	Sieve + Soil Wt. (g)	Accumulative Wt. of Soil Retained (g)	Accumulative Percent Retained	Total Sample Percent Finer By Wt.
2"	50.8	562.6	562.6	0.0	0.00	100.00
1"	25	545.8	545.8	0.0	0.00	100.00
0.75"	19.1	553.6	553.6	0.0	0.00	100.00
0.375"	9.5	537.4	546.4	9.0	4.54	95.46
4	4.76	498.9	508.8	18.9	9.54	90.46
10	2	483.1	491.1	26.9	13.58	86.42
20	0.85	435.6	447.1	38.4	19.38	80.62
40	0.425	378.1	394.1	54.4	27.46	72.54
60	0.250	349.1	369.8	75.1	37.91	62.09
100	0.149	330.4	357.1	101.8	51.39	48.61
200	0.074	340.4	372.0	133.4	67.34	32.66
Pan		374.7	380.6	139.3	70.32	29.68
Split Sample Wt (Washed)				58.8		
Total Sample Weight				198.1		



GRAVEL		SAND			SILT	CLAY
COARSE	FINE	COARSE	MEDIUM	FINE		

TEST	MATERIAL SOURCE	REMARKS
7	Towantic Energy Center Oxford, CT Boring B-119 S-5	Brown Silty Sand (SM)

PARE ENGINEERING CORPORATION

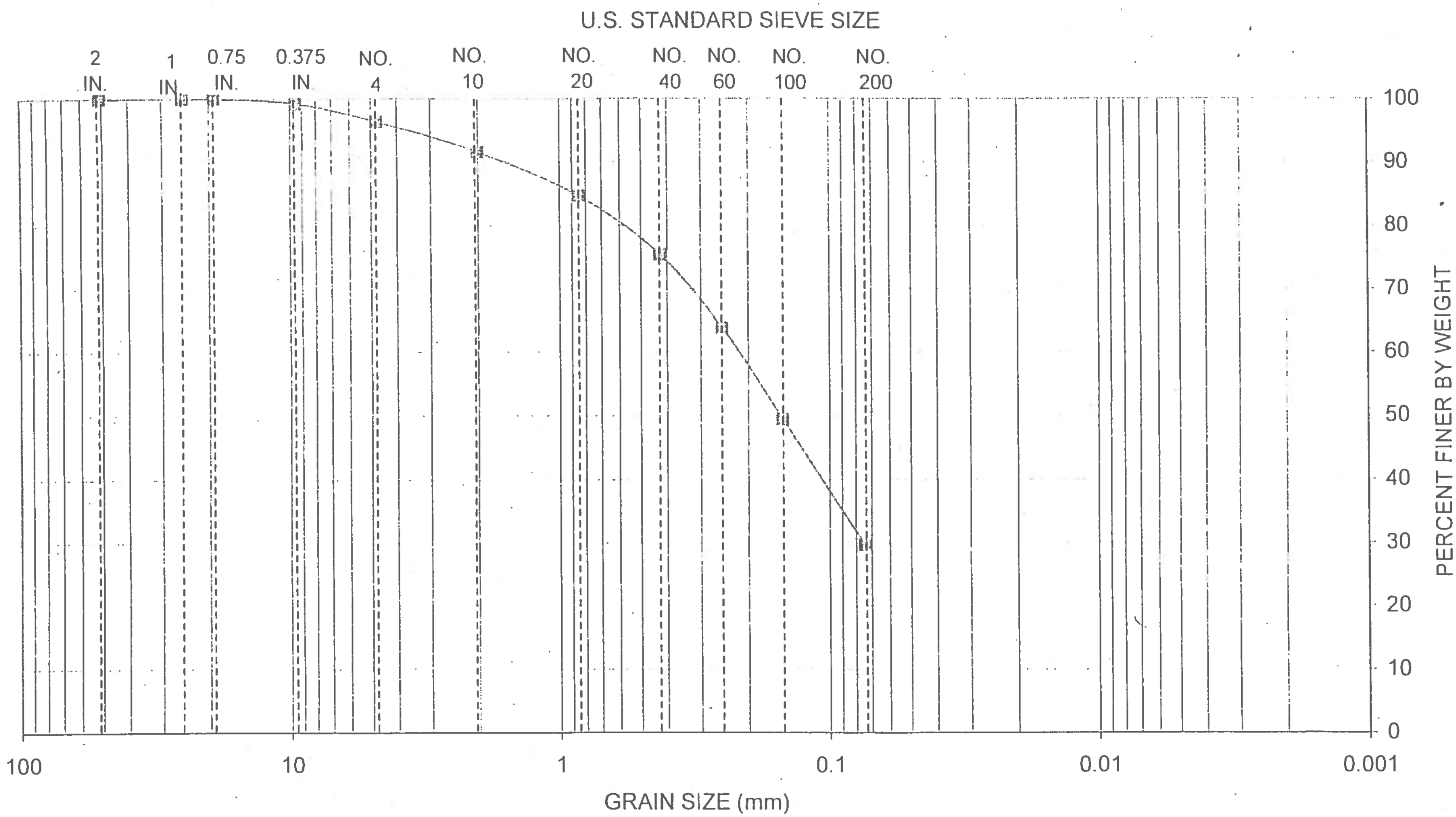
PARE ENGINEERING CORPORATION

SIEVE ANALYSIS

SOIL SAMPLE		WATER CONTENT			
Location:	Towantic Energy Center	Container No.	C1	File No.	00172.00
Boring No.:	B-119	Wt. Container (g)	10.6	Test No.	1
Depth:	1-25'	Wt. Container, Wet Soil (g)	740.6	Date	10/19/00
Sample No.:	Auger Cuttings	Wt. Container, Dry Soil (g)	678.4	Tested By:	ARO
		Wt. Water (g)	62.2	Checked By	JMB
Specific		Wt. Dry Soil (g)	667.8		
Gravity, Gs:		Water Content (%)	9.31%	Dry Sieve	
		Wt. Con, Washed Dry Soil (g)	530.3	Wash Sieve	
		Wt. Washed Dry Soil (g)	519.7	Combined	X

TOTAL SAMPLE

U.S. Standard Sieve No.	Sieve Opening (mm)	Sieve Wt. (g)	Sieve + Soil Wt. (g)	Accumulative Wt. of Soil Retained (g)	Accumulative Percent Retained	Total Sample Percent Finer By Wt.
2"	50.8	562.6	562.6	0.0	0.00	100.00
1"	25	545.8	545.8	0.0	0.00	100.00
0.75"	19.1	553.8	553.8	0.0	0.00	100.00
0.375"	9.5	537.2	542.4	5.2	0.78	99.22
4	4.76	498.4	517.1	23.9	3.58	96.42
10	2	483	515.2	56.1	8.39	91.61
20	0.85	436.2	482.4	102.3	15.30	84.70
40	0.425	378.3	440.3	164.3	24.58	75.42
60	0.250	348.9	426.5	241.9	36.19	63.81
100	0.149	330.5	427.1	338.5	50.64	49.36
200	0.074	340.4	471.9	470.0	70.31	29.69
Pan		374.8	425.2	520.4	77.85	22.15
Split Sample Wt (Washed)				148.1		
Total Sample Weight				668.5		



GRAVEL		SAND			SILT	CLAY
COARSE	FINE	COARSE	MEDIUM	FINE		

TEST	MATERIAL SOURCE	REMARKS
1	**Towantic Energy Center** **Oxford, CT** **Boring B-119 Auger Cuttings (1-25')**	**Brown Silty Sand (SM)**

PARE ENGINEERING CORPORATION

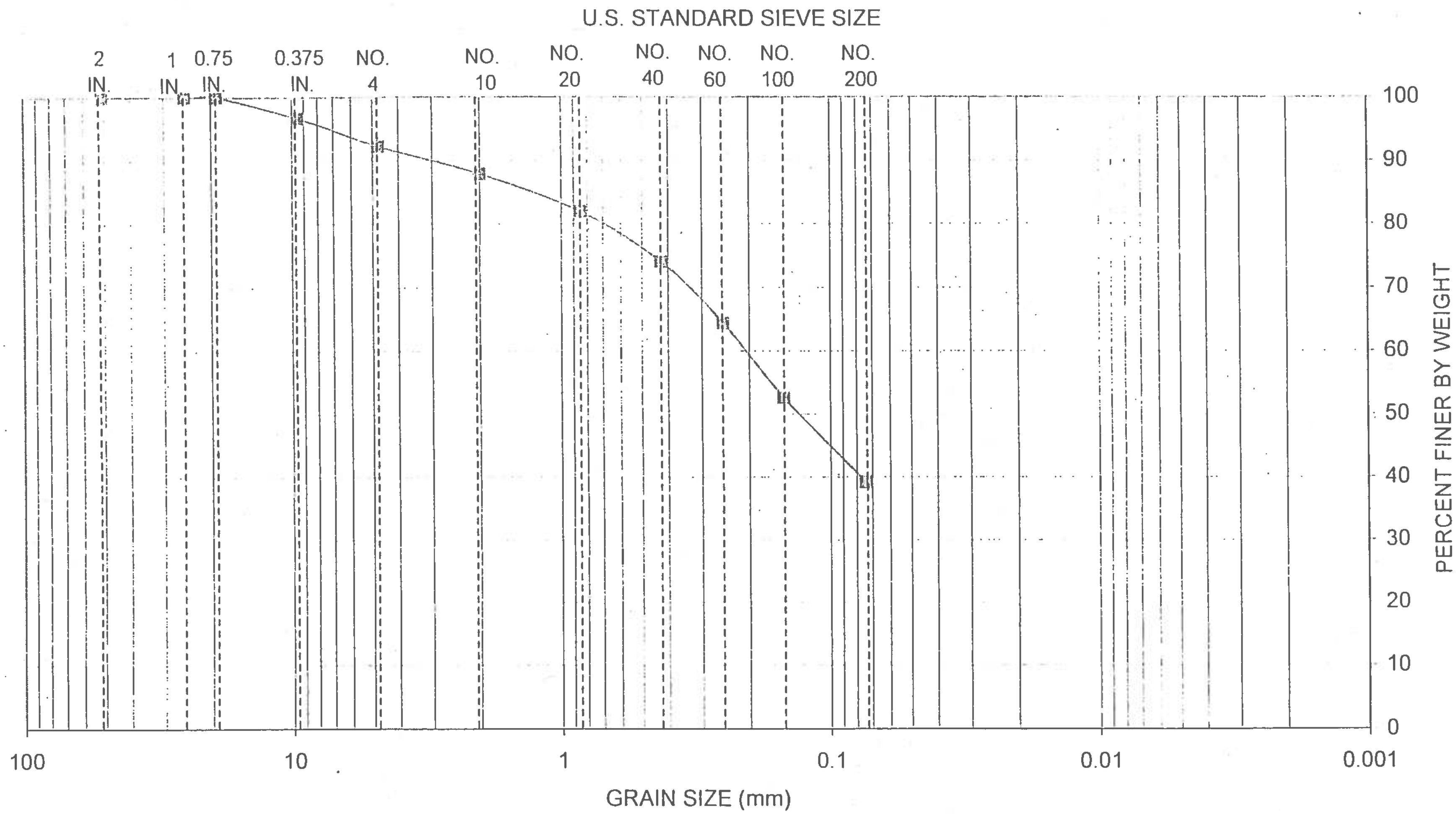
PARE ENGINEERING CORPORATION

SIEVE ANALYSIS

SOIL SAMPLE		WATER CONTENT			
Location:	Towantic Energy Center	Container No.	A	File No.	00172.00
Boring No.:	B-120	Wt. Container (g)	10.7	Test No.	8
Depth:	6-8'	Wt. Container, Wet Soil (g)	274.1	Date	10/24/00
Sample No.:	S-4	Wt. Container, Dry Soil (g)	249.9	Tested By:	ARO
		Wt. Water (g)	24.2	Checked By	JMB
Specific		Wt. Dry Soil (g)	239.2		
Gravity, Gs:		Water Content (%)	10.12%	Dry Sieve	
		Wt. Con, Washed Dry Soil (g)	160.7	Wash Sieve	
		Wt. Washed Dry Soil (g)	150	Combined	X

TOTAL SAMPLE

U.S. Standard Sieve No.	Sieve Opening (mm)	Sieve Wt. (g)	Sieve + Soil Wt. (g)	Accumulative Wt. of Soil Retained (g)	Accumulative Percent Retained	Total Sample Percent Finer By Wt.
2"	50.8	562.6	562.6	0.0	0.00	100.00
1"	25	545.8	545.8	0.0	0.00	100.00
0.75"	19.1	553.6	553.6	0.0	0.00	100.00
0.375"	9.5	537.4	545.3	7.9	3.31	96.69
4	4.76	498.9	509.5	18.5	7.74	92.26
10	2	483.1	493.5	28.9	12.09	87.91
20	0.85	435.6	449.9	43.2	18.08	81.92
40	0.425	378.1	396.9	62.0	25.94	74.06
60	0.250	349.1	372.2	85.1	35.61	64.39
100	0.149	330.4	358.6	113.3	47.41	52.59
200	0.074	340.4	372.5	145.4	60.84	39.16
Pan		374.7	379.1	149.8	62.68	37.32
Split Sample Wt (Washed)				89.2		
Total Sample Weight				239.0		



GRAVEL		SAND			SILT	CLAY
COARSE	FINE	COARSE	MEDIUM	FINE		

TEST	MATERIAL SOURCE	REMARKS
8	Towantic Energy Center Oxford, CT Boring B-120 S-4	Brown Silty Sand (SM)

PARE ENGINEERING CORPORATION

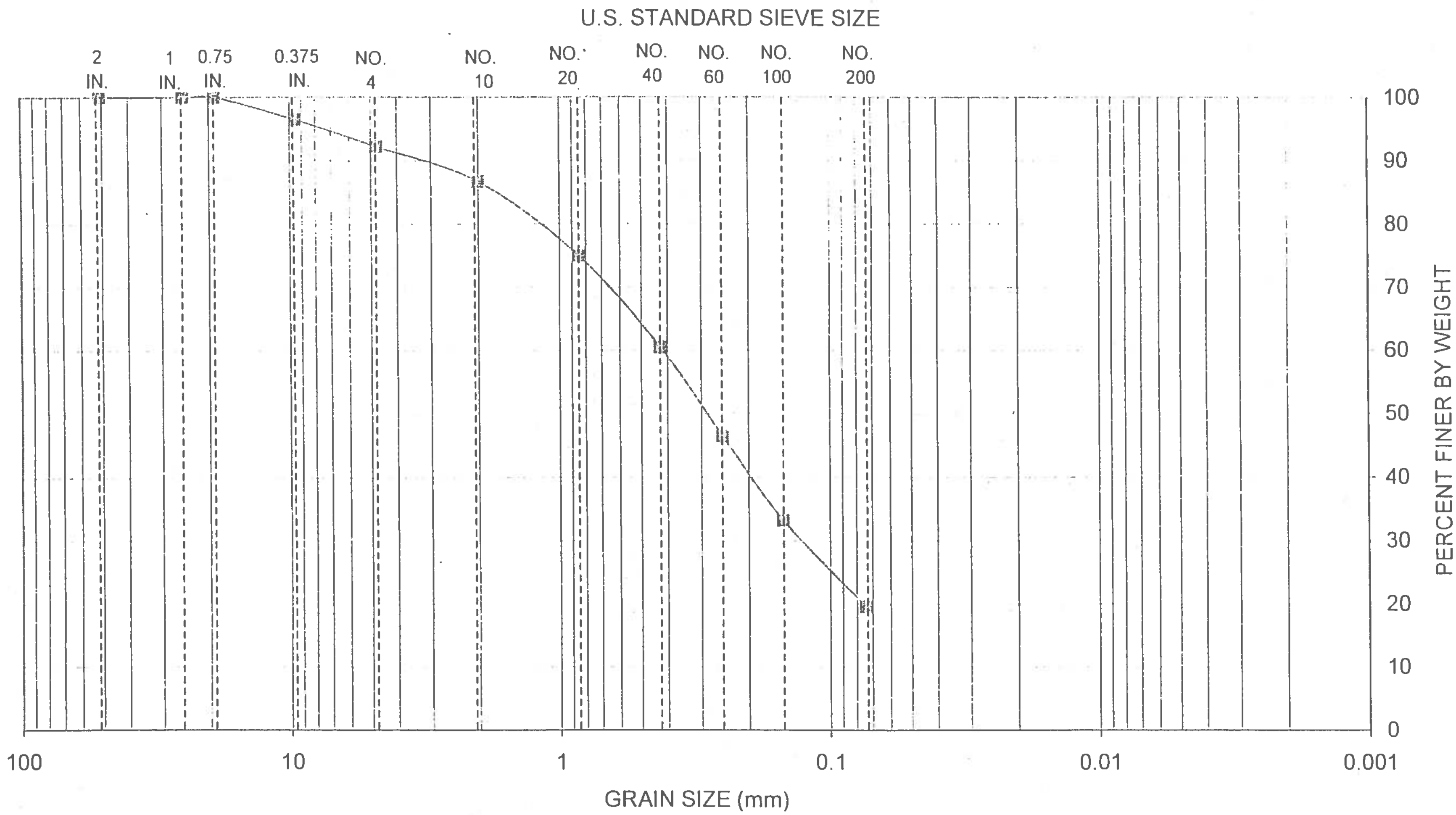
PARE ENGINEERING CORPORATION

SIEVE ANALYSIS

SOIL SAMPLE		WATER CONTENT			
Location:	Towantic Energy Center	Container No.	R	File No.	00172.00
Boring No.:	B-120	Wt. Container (g)	10.7	Test No.	10
Depth:	1-10'	Wt. Container, Wet Soil (g)	427.6	Date	11/1/00
Sample No.:	Auger Cuttings	Wt. Container, Dry Soil (g)	406.1	Tested By:	ARO
		Wt. Water (g)	21.5	Checked By	JMB
Specific		Wt. Dry Soil (g)	395.4		
Gravity, Gs:		Water Content (%)	5.44%	Dry Sieve	
		Wt. Con, Washed Dry Soil (g)	342.1	Wash Sieve	
		Wt. Washed Dry Soil (g)	331.4	Combined	X

TOTAL SAMPLE

U.S. Standard Sieve No.	Sieve Opening (mm)	Sieve Wt. (g)	Sieve + Soil Wt. (g)	Accumulative Wt. of Soil Retained (g)	Accumulative Percent Retained	Total Sample Percent Finer By Wt.
2"	50.8	562.6	562.6	0.0	0.00	100.00
1"	25	545.8	545.8	0.0	0.00	100.00
0.75"	19.1	553.6	553.6	0.0	0.00	100.00
0.375"	9.5	537.2	551.2	14.0	3.54	96.46
4	4.76	498.7	515.4	30.7	7.76	92.24
10	2	482.5	504.4	52.6	13.30	86.70
20	0.85	435.3	481.7	99.0	25.04	74.96
40	0.425	377.3	434.8	156.5	39.58	60.42
60	0.250	348.7	404.1	211.9	53.59	46.41
100	0.149	330.4	382.6	264.1	66.79	33.21
200	0.074	340.5	394.4	318.0	80.42	19.58
Pan		375	388.4	331.4	83.81	16.19
Split Sample Wt (Washed)				64.0		
Total Sample Weight				395.4		



GRAVEL		SAND			SILT	CLAY
COARSE	FINE	COARSE	MEDIUM	FINE		

TEST	MATERIAL SOURCE	REMARKS
10	Towantic Energy Center Oxford, CT Boring B-120 Auger Cuttings	Brown Silty Sand (SM)

PARE ENGINEERING CORPORATION

PARE ENGINEERING CORPORATION

SIEVE ANALYSIS

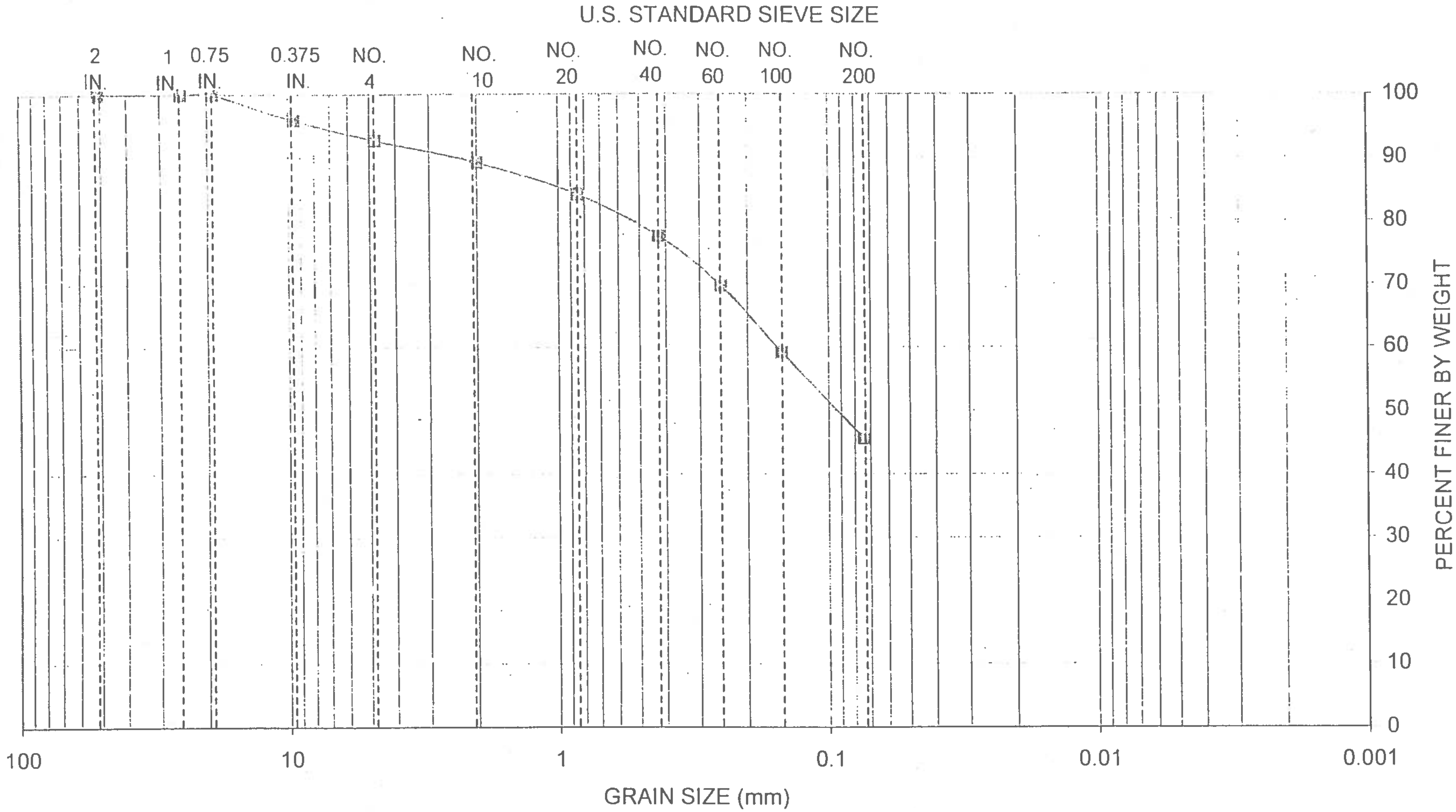
SOIL SAMPLE

WATER CONTENT

Location:	Towantic Energy Center	Container No.	R	File No.	00172.00
Boring No.:	B-122	Wt. Container (g)	10.7	Test No.	9
Depth:	8-10'	Wt. Container, Wet Soil (g)	283.2	Date	10/24/00
Sample No.:	S-5	Wt. Container, Dry Soil (g)	250.9	Tested By:	ARO
		Wt. Water (g)	32.3	Checked By	JMB
Specific Gravity, Gs:		Wt. Dry Soil (g)	240.2		
		Water Content (%)	13.45%	Dry Sieve	
		Wt. Con, Washed Dry Soil (g)	148.1	Wash Sieve	
		Wt. Washed Dry Soil (g)	137.4	Combined	X

TOTAL SAMPLE

U.S. Standard Sieve No.	Sieve Opening (mm)	Sieve Wt. (g)	Sieve + Soil Wt. (g)	Accumulative Wt. of Soil Retained (g)	Accumulative Percent Retained	Total Sample Percent Finer By Wt.
2"	50.8	562.6	562.6	0.0	0.00	100.00
1"	25	545.8	545.8	0.0	0.00	100.00
0.75"	19.1	553.6	553.6	0.0	0.00	100.00
0.375"	9.5	537.4	547.1	9.7	4.04	95.96
4	4.76	498.9	506.7	17.5	7.29	92.71
10	2	483.1	491.5	25.9	10.78	89.22
20	0.85	435.6	447.9	38.2	15.90	84.10
40	0.425	378.1	393.8	53.9	22.44	77.56
60	0.250	349.1	368.1	72.9	30.35	69.65
100	0.149	330.4	355.8	98.3	40.92	59.08
200	0.074	340.4	372.8	130.7	54.41	45.59
Pan		374.7	381.4	137.4	57.20	42.80
Split Sample Wt (Washed)				102.8		
Total Sample Weight				240.2		



GRAVEL		SAND			SILT	CLAY
COARSE	FINE	COARSE	MEDIUM	FINE		

TEST	MATERIAL SOURCE	REMARKS
9	Towantic Energy Center Oxford, CT Boring B-122 S-5	Brown Silty Sand [SM]

PARE ENGINEERING CORPORATION

PARE ENGINEERING CORPORATION

SIEVE ANALYSIS

SOIL SAMPLE

Location:	Towantic Energy Center
Boring No.:	B-122
Depth:	1-10'
Sample No.:	Auger Cuttings
Specific Gravity, Gs:	

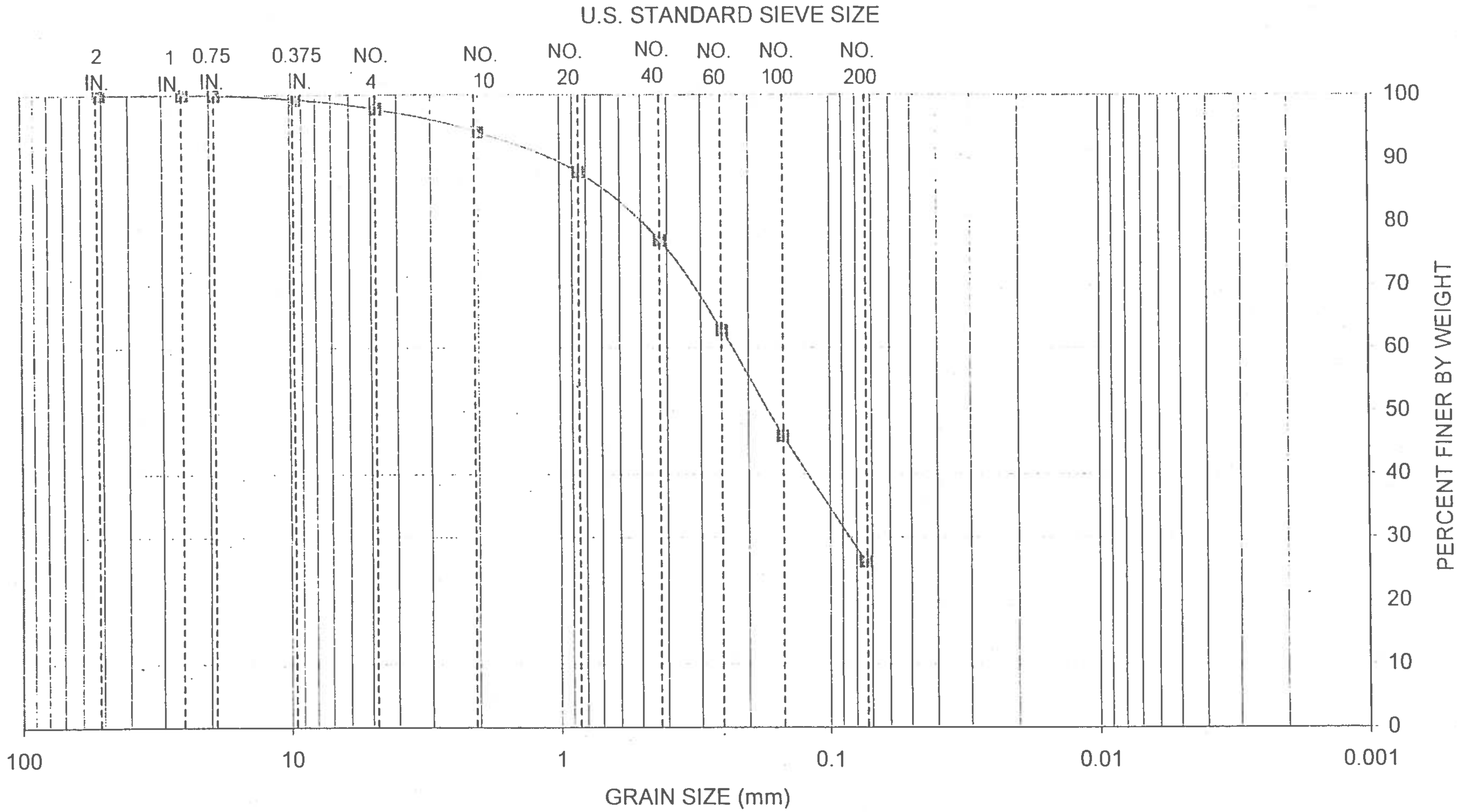
WATER CONTENT

Container No.	Q
Wt. Container (g)	10.7
Wt. Container, Wet Soil (g)	674.6
Wt. Container, Dry Soil (g)	605.8
Wt. Water (g)	68.8
Wt. Dry Soil (g)	595.1
Water Content (%)	11.56%
Wt. Con, Washed Dry Soil (g)	487.1
Wt. Washed Dry Soil (g)	476.4

File No.	00172.00
Test No.	6
Date	10/24/00
Tested By:	ARO
Checked By	JMR
Dry Sieve	
Wash Sieve	
Combined	X

TOTAL SAMPLE

U.S. Standard Sieve No.	Sieve Opening (mm)	Sieve Wt. (g)	Sieve + Soil Wt. (g)	Accumulative Wt. of Soil Retained (g)	Accumulative Percent Retained	Total Sample Percent Finer By Wt.
2"	50.8	562.6	562.6	0.0	0.00	100.00
1"	25	545.8	545.8	0.0	0.00	100.00
0.75"	19.1	553.6	553.8	0.2	0.03	99.97
0.375"	9.5	537.4	541.4	4.2	0.71	99.29
4	4.76	498.9	507.8	13.1	2.20	97.80
10	2	483.1	504.8	34.8	5.85	94.15
20	0.85	435.6	473.3	72.5	12.18	87.82
40	0.425	378.1	442.6	137.0	23.03	76.97
60	0.250	349.1	433.8	221.7	37.26	62.74
100	0.149	330.4	429.8	321.1	53.97	46.03
200	0.074	340.4	458.8	439.5	73.87	26.13
Pan		374.7	411.5	476.3	80.05	19.95
Split Sample Wt (Washed)				118.7		
Total Sample Weight				595.0		



GRAVEL		SAND			SILT	CLAY
COARSE	FINE	COARSE	MEDIUM	FINE		

TEST	MATERIAL SOURCE	REMARKS
6	Towantic Energy Center Oxford, CT Boring B-122 Auger Cuttings	Brown Silty Sand (SM)

PARE ENGINEERING CORPORATION

PARE ENGINEERING CORPORATION

SIEVE ANALYSIS

SOIL SAMPLE		WATER CONTENT			
Location:	Towantic Energy Center	Container No.	C4	File No.	00172.00
Boring No.:	B-108	Wt. Container (g)	12.8	Test No.	7
Depth:	10-12'	Wt. Container, Wet Soil (g)	262.9	Date	11/9/00
Sample No.:	S-6	Wt. Container, Dry Soil (g)	235.5	Tested By:	ARO
		Wt. Water (g)	27.4	Checked By	
Specific Gravity, Gs:		Wt. Dry Soil (g)	222.7		
		Water Content (%)	12.30%	Dry Sieve	
		Wt. Container, Washed Dry Soil (g)	162.9	Wash Sieve	
		Wt. Washed Dry Soil (g)	150.1	Combined	X
		Wt. Soil Passing #200 (g)	79.6		

TOTAL SAMPLE

U.S. Standard Sieve No.	Sieve Opening (mm)	Sieve Wt. (g)	Sieve + Soil Wt. (g)	Accumulative Wt. of Soil Retained (g)	Accumulative Percent Retained	Total Sample Percent Finer By Wt.
2"	50.8	562.6	562.6	0.0	0.00	100.00
1"	25	545.8	545.8	0.0	0.00	100.00
0.75"	19.1	553.0	553.0	0.0	0.00	100.00
0.375"	9.5	537.2	545.1	7.9	3.55	96.45
4	4.76	498.7	504.2	13.4	6.02	93.98
10	2	481.8	492.9	24.5	11.01	88.99
20	0.85	435.1	450.4	39.8	17.88	82.12
40	0.425	377.2	398.1	60.7	27.27	72.73
60	0.250	348.4	371.8	84.1	37.78	62.22
100	0.149	330.4	357.7	111.4	50.04	49.96
200	0.074	340.9	372.5	143.0	64.24	35.76
Hydrometer	0.0273					27.77
	0.0165					25.43
	0.0100					22.58
	0.0073					21.02
	0.0053					19.20
	0.0027					16.09
	0.0012					13.75
PAN		374.6	381.6	222.6	100.00	0.00

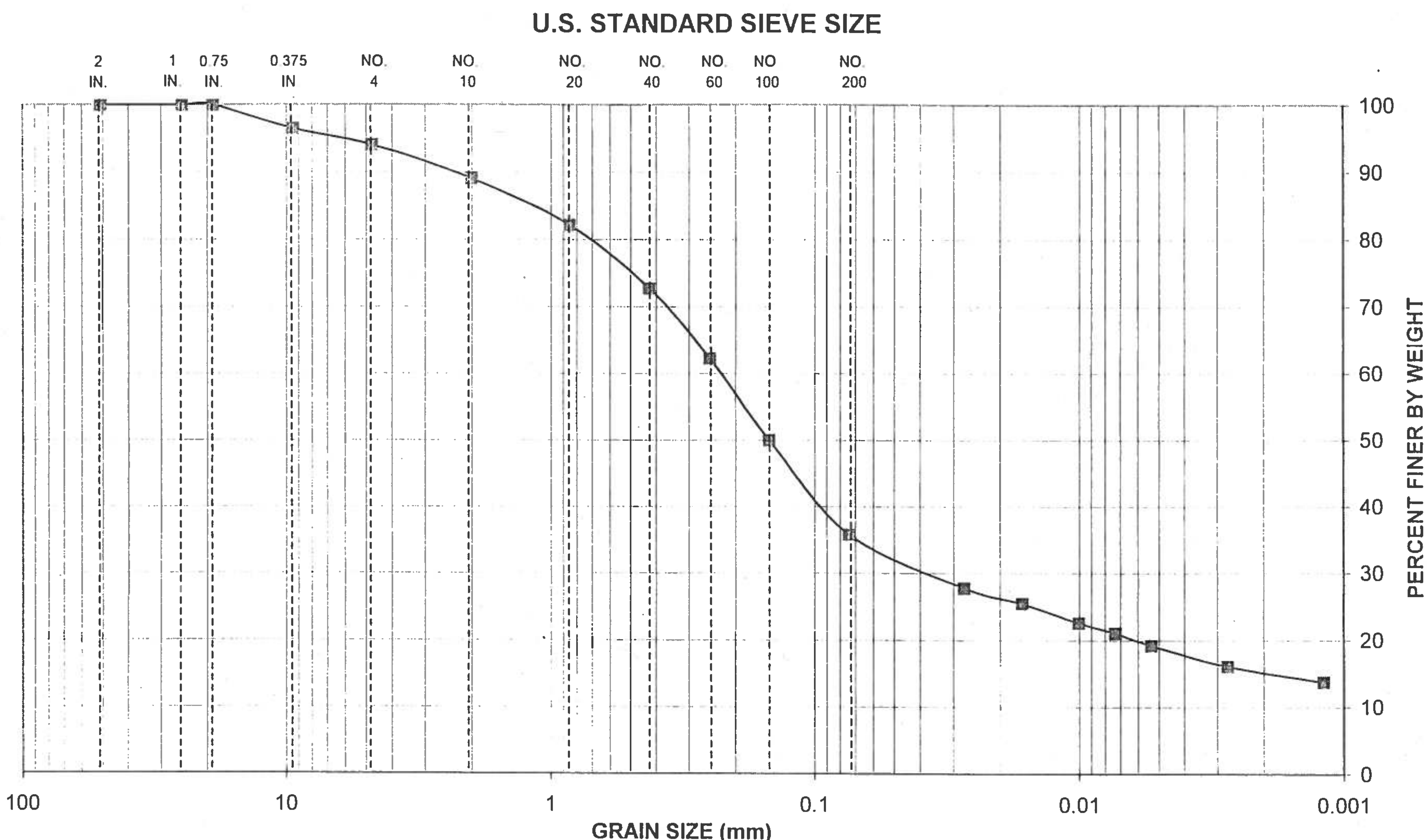
HYDROMETER ANALYSIS

PARE ENGINEERING CORPORATION

Location:	Towantic Energy Center	Container No.	R	Project No.	00172.00
Boring No.:	B-108	Wt. Container (g)	10.8	Test No.	7
Depth:	10-12'	Wt. Container, Dry Soil (g)	79.7	Start Date	11/14/00
Sample No.:	S-6	Wt. Dry Soil (g)	68.9	Tested By:	ARO
				Checked By	
Specific Gravity, Gs:	2.65	Hydrometer No.	152H		
		Dispersing Agent	Sodium Hexametaphosphate		
		Concentration	40 g/L		
		Composite Correction	-4.0		

Percent Finer

Time	Elapsed Time (min)	Temp (ºC)	Hydro-Reading (R')	Corrected Reading (R)	G_w, Specific Gravity at Test Temp (Table 3.1)	N, Viscosity at Test Temp	L (Table 6-5)	d (mm)	% Finer	
									Partial	Total
9:35:00 AM	0									
9:35:30 AM	0.5	22	>60	#VALUE!	0.997770	0.00961	#N/A	#N/A	-	-
9:36:00 AM	1	22	>60	#VALUE!	0.997770	0.00961	#N/A	#N/A	-	-
9:37:00 AM	2	22	57.5	53.5	0.997770	0.00961	8.40	0.02735	77.6	27.8
9:40:00 AM	5	22	53.0	49.0	0.997770	0.00961	7.60	0.01645	71.1	25.4
9:50:00 AM	15	22	47.5	43.5	0.997770	0.00961	8.50	0.01004	63.1	22.6
10:05:00 AM	30	22	44.5	40.5	0.997770	0.00961	9.00	0.00731	58.8	21.0
10:35:00 AM	60	22	41.0	37.0	0.997770	0.00961	9.60	0.00534	53.7	19.2
1:45:00 PM	250	22	35.0	31.0	0.997770	0.00961	10.60	0.00275	45.0	16.1
9:35:00 AM	1440	21.5	30.5	26.5	0.997882	0.00973	11.30	0.00119	38.5	13.8



GRAVEL		SAND			SILT	CLAY
COARSE	FINE	COARSE	MEDIUM	FINE		

TEST NO.	MATERIAL SOURCE	REMARKS
7	Towantic Energy Center Oxford, CT B-108 S-6	Brown silty sand with clay (SM)

PARE ENGINEERING CORPORATION

PARE ENGINEERING CORPORATION

SIEVE ANALYSIS

SOIL SAMPLE | **WATER CONTENT**

Location:	Towantic Energy Center	Container No.	1	File No.	00172.00
Boring No.:	B-117	Wt. Container (g)	11.1	Test No.	8
Depth:	6-8'	Wt. Container, Wet Soil (g)	241.7	Date	11/14/00
Sample No.:	S-4	Wt. Container, Dry Soil (g)	225.1	Tested By:	ARO
		Wt. Water (g)	16.6	Checked By	
Specific		Wt. Dry Soil (g)	214		
Gravity, Gs:		Water Content (%)	7.76%	Dry Sieve	
		Wt. Container, Washed Dry Soil (g)	155.5	Wash Sieve	
		Wt. Washed Dry Soil (g)	144.4	Combined	X
		Wt. Soil Passing #200 (g)	71.3		

TOTAL SAMPLE

U.S. Standard Sieve No.	Sieve Opening (mm)	Sieve Wt. (g)	Sieve + Soil Wt. (g)	Accumulative Wt. of Soil Retained (g)	Accumulative Percent Retained	Total Sample Percent Finer By Wt.
2"	50.8	562.6	562.6	0.0	0.00	100.00
1"	25	545.8	545.8	0.0	0.00	100.00
0.75"	19.1	553.0	553.0	0.0	0.00	100.00
0.375"	9.5	537.2	556.9	19.7	8.75	91.25
4	4.76	498.7	508.8	29.8	13.24	86.76
10	2	481.8	489	37.0	16.44	83.56
20	0.85	435.1	445.5	47.4	21.06	78.94
40	0.425	377.2	399.7	69.9	31.05	68.95
60	0.250	348.4	374.8	96.3	42.78	57.22
100	0.149	330.4	358.9	124.8	55.44	44.56
200	0.074	340.9	369.9	153.8	68.33	31.67
Hydrometer	0.0506					28.32
	0.0382					25.02
	0.0285					22.00
	0.0187					19.52
	0.0114					16.22
	0.0081					15.40
	0.0058					14.02
	0.0029					11.55
	0.0013					9.62
PAN		374.6	376.3	225.1	100.00	0.00

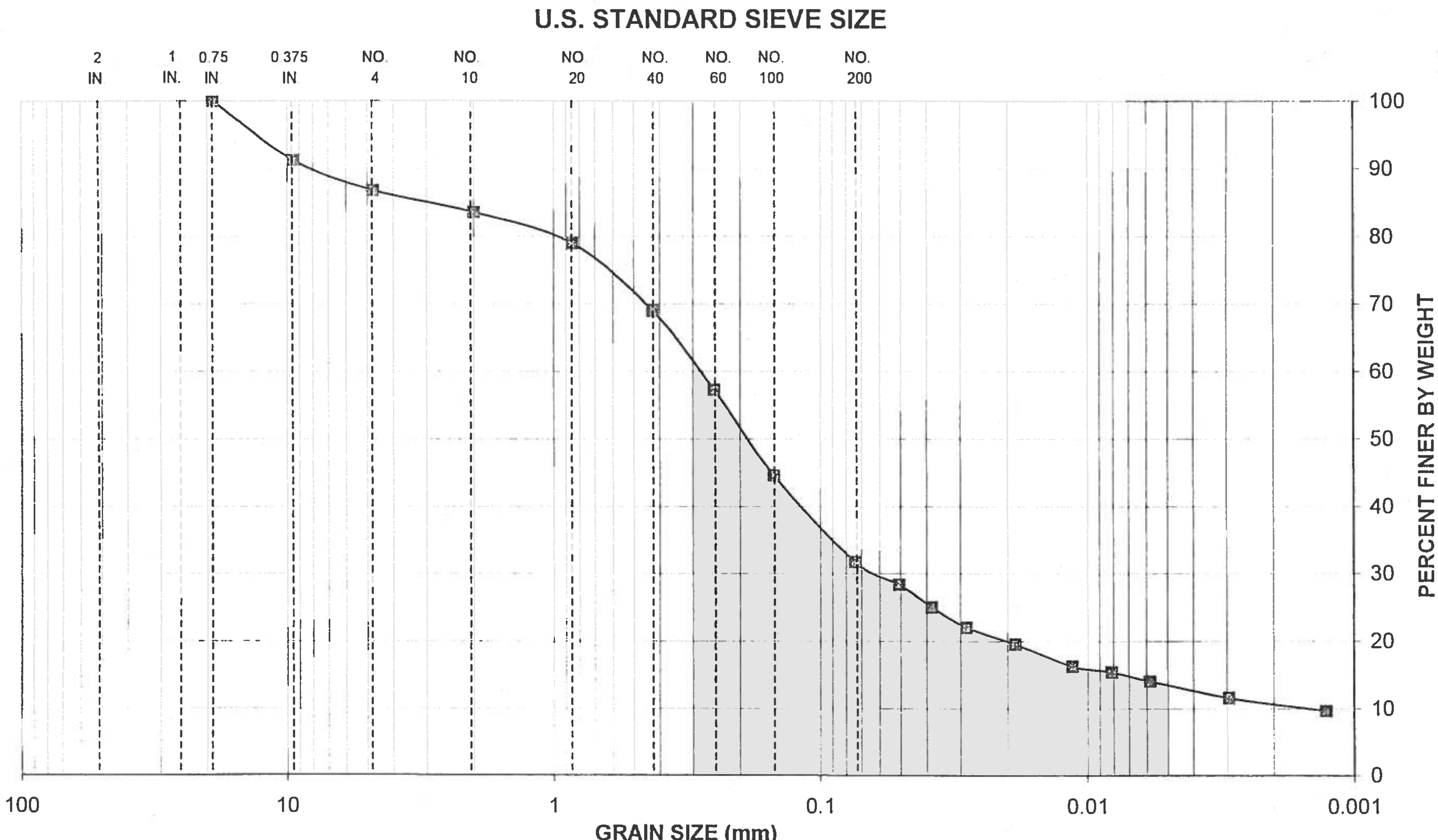
HYDROMETER ANALYSIS

PARE ENGINEERING CORPORATION

Location:	Towantic Energy Center	Container No.	C2	Project No.	00172.00
Boring No.:	B-117	Wt. Container (g)	10.6	Test No.	8
Depth:	6-8'	Wt. Container, Dry Soil (g)	68.2	Start Date	11/15/00
Sample No.:	S-4	Wt. Dry Soil (g)	57.6	Tested By:	ARO
				Checked By	
Specific Gravity, Gs:	2.65	Hydrometer No.	152H		
		Dispersing Agent	Sodium Hexametaphosphate		
		Concentration	40 g/L		
		Composite Correction	-4.0		

Percent Finer

Time	Elapsed Time (min)	Temp (ºC)	Hydro-Reading (R')	Corrected Reading (R)	G_w, Specific Gravity at Test Temp (Table 3.1)	N, Viscosity at Test Temp	L (Table 6-5)	d (mm)	% Finer Partial	% Finer Total
8:43:00 AM	0									
8:43:30 AM	0.5	22	55.5	51.5	0.997770	0.00961	7.2	0.05064	89.4	28.3
8:44:00 AM	1	22	49.5	45.5	0.997770	0.00961	8.20	0.03821	79.0	25.0
8:45:00 AM	2	22	44.0	40.0	0.997770	0.00961	9.10	0.02846	69.4	22.0
8:48:00 AM	5	22	39.5	35.5	0.997770	0.00961	9.80	0.01868	61.6	19.5
8:58:00 AM	15	21.5	33.5	29.5	0.997882	0.00973	10.80	0.01139	51.2	16.2
9:13:00 AM	30	22	32.0	28.0	0.997770	0.00961	11.10	0.00812	48.6	15.4
9:43:00 AM	60	22	29.5	25.5	0.997770	0.00961	11.45	0.00583	44.3	14.0
12:53:00 PM	250	22	25.0	21.0	0.997770	0.00961	12.20	0.00295	36.5	11.5
8:43:00 AM	1440	21	21.5	17.5	0.997992	0.00984	12.80	0.00127	30.4	9.6



GRAVEL		SAND			SILT	CLAY
COARSE	FINE	COARSE	MEDIUM	FINE		

TEST NO	MATERIAL SOURCE	REMARKS
8	Towantic Energy Center Oxford, CT B-117 S-4	Brown silty sand (SM) with clay and gravel

PARE ENGINEERING CORPORATION

PARE ENGINEERING CORPORATION

SIEVE ANALYSIS

SOIL SAMPLE

WATER CONTENT

Location:	Towantic Energy Center	Container No.	G	File No.	00172.00
Boring No.:	B-118	Wt. Container (g)	12.8	Test No.	6
Depth:	8-10'	Wt. Container, Wet Soil (g)	212.4	Date	11/9/00
Sample No.:	S-5	Wt. Container, Dry Soil (g)	191.3	Tested By:	ARO
		Wt. Water (g)	21.1	Checked By	
Specific Gravity, Gs:		Wt. Dry Soil (g)	178.5		
		Water Content (%)	11.82%	Dry Sieve	
		Wt. Container, Washed Dry Soil (g)	120.6	Wash Sieve	
		Wt. Washed Dry Soil (g)	107.8	Combined	X
		Wt. Soil Passing #200 (g)	76.6		

TOTAL SAMPLE

U.S. Standard Sieve No.	Sieve Opening (mm)	Sieve Wt. (g)	Sieve + Soil Wt. (g)	Accumulative Wt. of Soil Retained (g)	Accumulative Percent Retained	Total Sample Percent Finer By Wt.
2"	50.8	562.6	562.6	0.0	0.00	100.00
1"	25	545.8	545.8	0.0	0.00	100.00
0.75"	19.1	553.0	553.0	0.0	0.00	100.00
0.375"	9.5	537.2	537.2	0.0	0.00	100.00
4	4.76	498.7	502.3	3.6	2.02	97.98
10	2	481.8	489.1	10.9	6.11	93.89
20	0.85	435.1	445.1	20.9	11.72	88.28
40	0.425	377.2	392.2	35.9	20.12	79.88
60	0.250	348.4	366.3	53.8	30.16	69.84
100	0.149	330.4	352	75.4	42.26	57.74
200	0.074	340.9	367.3	101.8	57.06	42.94
Hydrometer	0.0252					33.35
	0.0167					30.81
	0.0102					27.31
	0.0073					26.04
	0.0053					23.82
	0.0027					20.33
	0.0012					17.47
PAN		374.6	380.5	178.4	100.00	0.00

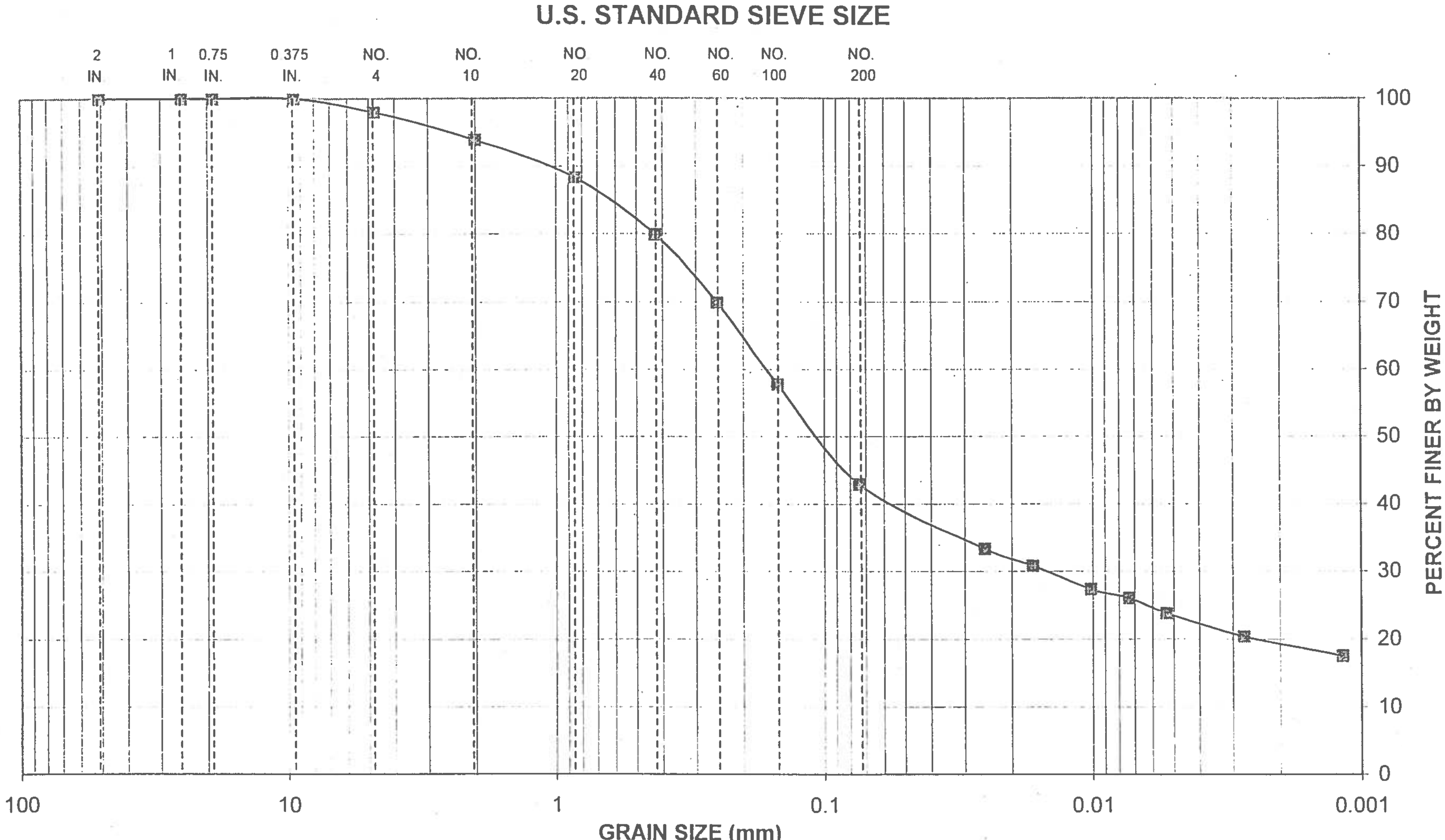
PARE ENGINEERING CORPORATION

HYDROMETER ANALYSIS

Location:	Towantic Energy Center	Container No.	U	Project No.	00172.00
Boring No.:	B-118	Wt. Container (g)	11	Test No.	6
Depth:	8-10'	Wt. Container, Dry Soil (g)	78.6	Start Date	11/14/00
Sample No.:	S-5	Wt. Dry Soil (g)	67.6	Tested By:	ARO
				Checked By	
Specific Gravity, Gs:	2.65	Hydrometer No.	152H		
		Dispersing Agent	Sodium Hexametaphosphate		
		Concentration	40 g/L		
		Composite Correction	-4.0		

Percent Finer

Time	Elapsed Time (min)	Temp (ºC)	Hydro-Reading (R')	Corrected Reading (R)	G_w, Specific Gravity at Test Temp (Table 3.1)	N, Viscosity at Test Temp	L (Table 6-5)	d (mm)	% Finer	
									Partial	Total
8:30:00 AM	0									
8:30:30 AM	0.5	21.5	>60	#VALUE!	0.997882	0.00973	#N/A	#N/A	-	-
8:31:00 AM	1	21.5	>60	#VALUE!	0.997882	0.00973	#N/A	#N/A	-	-
8:32:00 AM	2	21.5	56.5	52.5	0.997882	0.00973	7.05	0.02520	77.7	33.3
8:35:00 AM	5	21.5	52.5	48.5	0.997882	0.00973	7.70	0.01666	71.7	30.8
8:45:00 AM	15	21.5	47.0	43.0	0.997882	0.00973	8.60	0.01016	63.6	27.3
9:00:00 AM	30	21.5	45.0	41.0	0.997882	0.00973	8.90	0.00731	60.7	26.0
9:30:00 AM	60	22	41.5	37.5	0.997770	0.00961	9.50	0.00531	55.5	23.8
12:40:00 PM	250	22	36.0	32.0	0.997770	0.00961	10.40	0.00272	47.3	20.3
8:30:00 AM	1440	22	31.5	27.5	0.997770	0.00961	11.15	0.00117	40.7	17.5



GRAVEL		SAND			SILT	CLAY
COARSE	FINE	COARSE	MEDIUM	FINE		

TEST NO	MATERIAL SOURCE	REMARKS
6	Towantic Energy Center Oxford, CT B-118 S-5	Brown, silty sand with clay (SM)

PARE ENGINEERING CORPORATION

PARE ENGINEERING CORPORATION

SIEVE ANALYSIS

SOIL SAMPLE | WATER CONTENT

Location:	Towantic Energy Center	Container No.	P	File No.	00172.00
Boring No.:	B-121	Wt. Container (g)	10.9	Test No.	5
Depth:	8-10'	Wt. Container, Wet Soil (g)	240.5	Date	11/9/00
Sample No.:	S-5	Wt. Container, Dry Soil (g)	220.5	Tested By:	ARO
		Wt. Water (g)	20	Checked By	
Specific		Wt. Dry Soil (g)	209.6		
Gravity, Gs:		Water Content (%)	9.54%	Dry Sieve	
		Wt. Container, Washed Dry Soil (g)	151.4	Wash Sieve	
		Wt. Washed Dry Soil (g)	140.5	Combined	X
		Wt. Soil Passing #200 (g)	74.2		

TOTAL SAMPLE

U.S. Standard Sieve No.	Sieve Opening (mm)	Sieve Wt. (g)	Sieve + Soil Wt. (g)	Accumulative Wt. of Soil Retained (g)	Accumulative Percent Retained	Total Sample Percent Finer By Wt.
2"	50.8	562.6	562.6	0.0	0.00	100.00
1"	25	545.8	545.8	0.0	0.00	100.00
0.75"	19.1	553.0	568.7	15.7	7.49	92.51
0.375"	9.5	537.2	546.4	24.9	11.88	88.12
4	4.76	498.7	508.1	34.3	16.36	83.64
10	2	481.8	489.9	42.4	20.23	79.77
20	0.85	435.1	445.3	52.6	25.10	74.90
40	0.425	377.2	391.5	66.9	31.92	68.08
60	0.250	348.4	368	86.5	41.27	58.73
100	0.149	330.4	352.4	108.5	51.77	48.23
200	0.074	340.9	367.8	135.4	64.60	35.40
Hydrometer	0.0384					29.10
	0.0257					26.96
	0.0170					24.83
	0.0103					22.16
	0.0074					20.82
	0.0054					19.22
	0.0038					17.35
	0.0012					13.62
PAN		374.6	379.7	209.6	100.00	0.00

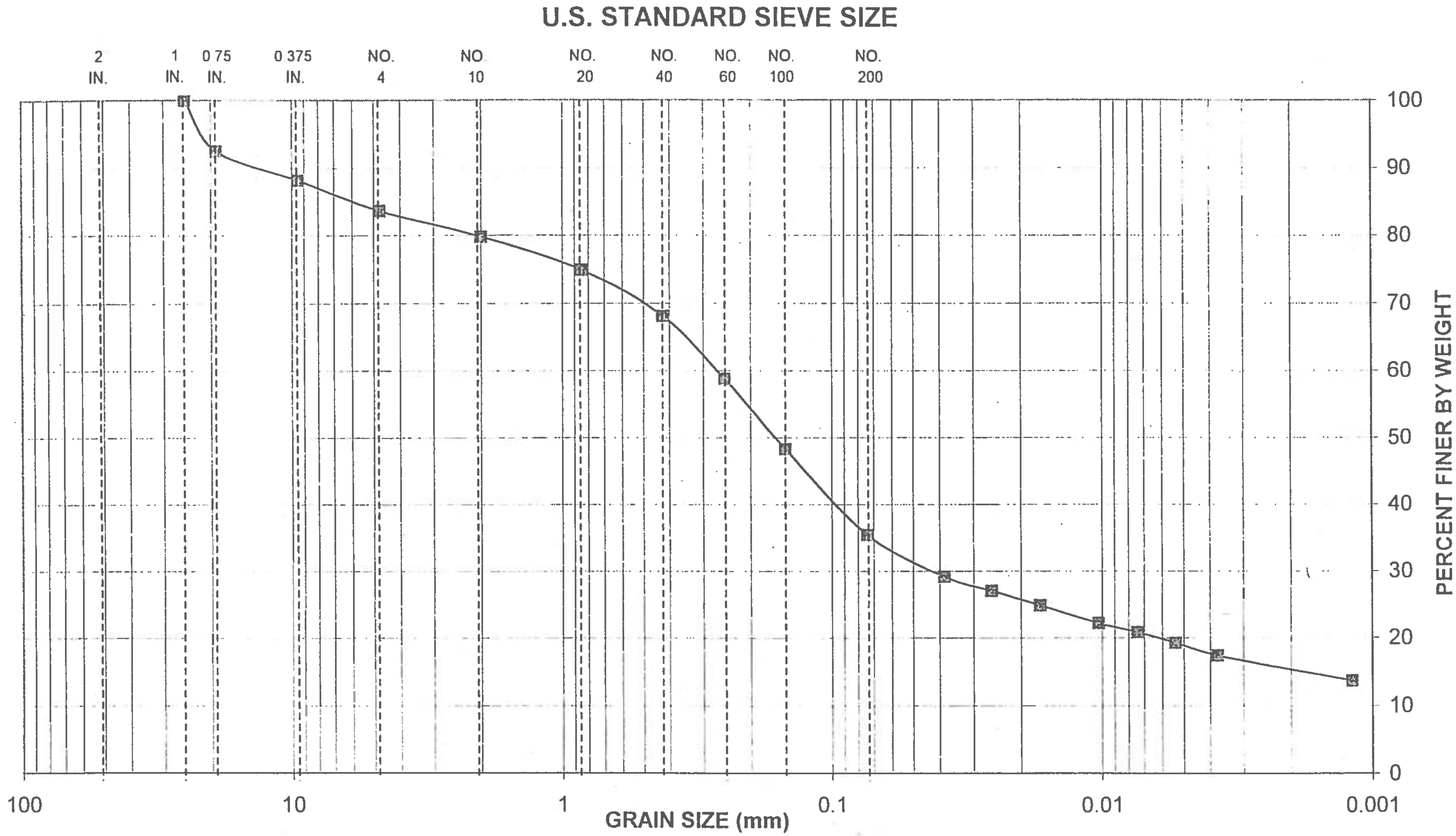
HYDROMETER ANALYSIS

PARE ENGINEERING CORPORATION

Location:	Towantic Energy Center	Container No.	S	Project No.	00172.00
Boring No.:	B-121	Wt. Container (g)	10.6	Test No.	5
Depth:	8-10'	Wt. Container, Dry Soil (g)	76.9	Start Date	11/13/00
Sample No.:	S-5	Wt. Dry Soil (g)	66.3	Tested By:	ARO
				Checked By	
Specific Gravity, Gs:	2.65	Hydrometer No.	152H		
		Dispersing Agent	Sodium Hexametaphosphate		
		Concentration	40 g/L		
		Composite Correction	-4.0		

Percent Finer

Time	Elapsed Time (min)	Temp (ºC)	Hydro-Reading (R')	Corrected Reading (R)	G_w, Specific Gravity at Test Temp (Table 3.1)	N, Viscosity at Test Temp	L (Table 6-5)	d (mm)	% Finer Partial	% Finer Total
2:37:00 PM	0									
2:37:30 PM	0.5	21.5	65	61.0	0.997882	0.00973	#N/A	#N/A	-	-
2:38:00 PM	1	21.5	58.5	54.5	0.997882	0.00973	8.20	0.03844	82.2	29.1
2:39:00 PM	2	21.5	54.5	50.5	0.997882	0.00973	7.35	0.02573	76.2	27.0
2:42:00 PM	5	21.5	50.5	46.5	0.997882	0.00973	8.00	0.01698	70.1	24.8
2:52:00 PM	15	21.5	45.5	41.5	0.997882	0.00973	8.85	0.01031	62.6	22.2
3:07:00 PM	30	22	43.0	39.0	0.997770	0.00961	9.20	0.00739	58.8	20.8
3:37:00 PM	60	22	40.0	36.0	0.997770	0.00961	9.70	0.00537	54.3	19.2
4:47:00 PM	130	22	36.5	32.5	0.997770	0.00961	10.30	0.00376	49.0	17.4
2:37:00 PM	1440	22	29.5	25.5	0.997770	0.00961	11.45	0.00119	38.5	13.6



GRAVEL		SAND			SILT	CLAY
COARSE	FINE	COARSE	MEDIUM	FINE		

TEST NO.	MATERIAL SOURCE	REMARKS
5	Towantic Energy Center Oxford, CT B-121 S-5	Brown, silty sand with clay and gravel (SM)

PARE ENGINEERING CORPORATION

PARE ENGINEERING CORPORATION

PERCENT LESS THAN 200 ANALYSIS

SOIL SAMPLE		WATER CONTENT			
Location:	Towantic Energy Center	Container No.	C2	File No.	00172.00
Boring No.:	B-104	Wt. Container (g)	10.8	Test No.	5
Depth:	6-8'	Wt. Container, Wet Soil (g)	64.1	Date	10/18/00
Sample No.:	S-4	Wt. Container, Dry Soil (g)	53.8	Tested By:	ARO
		Wt. Water (g)	10.3	Checked By	JMB
Specific Gravity, Gs:		Wt. Dry Soil (g)	43		
		Water Content (%)	23.95%		

ASTM Standard D 1140
- [x] Method A (Wash)
- [ ] Method B (Deflocculating Agent)

Wt. Dry Soil (g)	43.0
Wt.Container, Washed Dry Soil Retained on No. 200 (g)	36.6
Wt. Washed Dry Soil Retained on No. 200 (g)	25.8
Wt. Washed Dry Soil Passing No. 200 (g)	17.2
% Finer Than No. 200	40.0%

PARE ENGINEERING CORPORATION

PERCENT LESS THAN 200 ANALYSIS

SOIL SAMPLE		WATER CONTENT			
Location:	Towantic Energy Center	Container No.	C2	File No.	00172.00
Boring No.:	B-105	Wt. Container (g)	11.1	Test No.	3
Depth:	8-10'	Wt. Container, Wet Soil (g)	320.6	Date	10/20/00
Sample No.:	S-5	Wt. Container, Dry Soil (g)	286.1	Tested By:	ARO
		Wt. Water (g)	34.5	Checked By	JMB
		Wt. Dry Soil (g)	275		
Specific Gravity, Gs:		Water Content (%)	12.55%		

ASTM Standard D 1140
☑ Method A (Wash)
☐ Method B (Deflocculating Agent)

Wt. Dry Soil (g)	275
Wt.Container, Dry Soil Retained on No. 200 (g)	202.5
Wt. Dry Soil Retained on No. 200 (g)	191.4
Wt. Dry Soil Passing No. 200 (g)	83.6
% Finer Than No. 200	30%

PARE ENGINEERING CORPORATION

PERCENT LESS THAN 200 ANALYSIS

SOIL SAMPLE		WATER CONTENT			
Location:	Towantic Energy Center	Container No.	C3	File No.	00172.00
Boring No.:	B-107	Wt. Container (g)	10.6	Test No.	6
Depth:	10-12'	Wt. Container, Wet Soil (g)	251	Date	10/18/00
Sample No.:	S-6	Wt. Container, Dry Soil (g)	225.9	Tested By:	ARO
		Wt. Water (g)	25.1	Checked By	JMB
Specific		Wt. Dry Soil (g)	215.3		
Gravity, Gs:		Water Content (%)	11.66%		

ASTM Standard D 1140 ☑ Method A (Wash)
☐ Method B (Deflocculating Agent)

Wt. Dry Soil (g)	215.3
Wt.Container, Washed Dry Soil Retained on No. 200 (g)	129.1
Wt. Washed Dry Soil Retained on No. 200 (g)	118.5
Wt. Washed Dry Soil Passing No. 200 (g)	96.8
% Finer Than No. 200	45.0%

PARE ENGINEERING CORPORATION

PERCENT LESS THAN 200 ANALYSIS

SOIL SAMPLE		WATER CONTENT			
Location:	Towantic Energy Center	Container No.	C3	File No.	00172.00
Boring No.:	B-109	Wt. Container (g)	11	Test No.	7
Depth:	2-4'	Wt. Container, Wet Soil (g)	241.3	Date	10/23/00
Sample No.:	S-2	Wt. Container, Dry Soil (g)	215.6	Tested By:	ARO
		Wt. Water (g)	25.7	Checked By	JMB
Specific		Wt. Dry Soil (g)	204.6		
Gravity, Gs:		Water Content (%)	12.56%		

ASTM Standard D 1140
- [x] Method A (Wash)
- [ ] Method B (Deflocculating Agent)

Wt. Dry Soil (g)	204.6
Wt.Container, Washed Dry Soil Retained on No. 200 (g)	141.1
Wt. Washed Dry Soil Retained on No. 200 (g)	130.1
Wt. Washed Dry Soil Passing No. 200 (g)	74.5
% Finer Than No. 200	36.4%

PARE ENGINEERING CORPORATION

PERCENT LESS THAN 200 ANALYSIS

SOIL SAMPLE		WATER CONTENT			
Location:	Towantic Energy Center	Container No.	C5	File No.	00172.00
Boring No.:	B-111	Wt. Container (g)	10.8	Test No.	8
Depth:	4-6'	Wt. Container, Wet Soil (g)	285.4	Date	10/23/00
Sample No.:	S-3	Wt. Container, Dry Soil (g)	255.7	Tested By:	ARO
		Wt. Water (g)	29.7	Checked By	JMB
Specific Gravity, Gs:		Wt. Dry Soil (g)	244.9		
		Water Content (%)	12.13%		

ASTM Standard D 1140
- ☑ Method A (Wash)
- ☐ Method B (Deflocculating Agent)

Wt. Dry Soil (g)	244.9
Wt.Container, Washed Dry Soil Retained on No. 200 (g)	177.1
Wt. Washed Dry Soil Retained on No. 200 (g)	166.3
Wt. Washed Dry Soil Passing No. 200 (g)	78.6
% Finer Than No. 200	32.1%

PARE ENGINEERING CORPORATION

PERCENT LESS THAN 200 ANALYSIS

SOIL SAMPLE		WATER CONTENT			
Location:	Towantic Energy Center	Container No.	C5	File No.	00172.00
Boring No.:	B-117	Wt. Container (g)	10.6	Test No.	1
Depth:	18-20'	Wt. Container, Wet Soil (g)	236.1	Date	10/18/00
Sample No.:	S-7	Wt. Container, Dry Soil (g)	211.1	Tested By:	ARO
		Wt. Water (g)	25	Checked By	JMB
Specific Gravity, Gs:		Wt. Dry Soil (g)	200.5		
		Water Content (%)	12.47%		

ASTM Standard D 1140 ☑ Method A (Wash)
☐ Method B (Deflocculating Agent)

Wt. Dry Soil (g)	200.5
Wt.Container, Washed Dry Soil Retained on No. 200 (g)	119.0
Wt. Washed Dry Soil Retained on No. 200 (g)	108.4
Wt. Washed Dry Soil Passing No. 200 (g)	92.1
% Finer Than No. 200	45.9%

PARE ENGINEERING CORPORATION

PERCENT LESS THAN 200 ANALYSIS

SOIL SAMPLE

Location: Towantic Energy Center
Boring No.: B-118
Depth: 15-17'
Sample No.: S-7

Specific Gravity, Gs: ______

WATER CONTENT

Container No.	C6
Wt. Container (g)	10.7
Wt. Container, Wet Soil (g)	230.6
Wt. Container, Dry Soil (g)	210
Wt. Water (g)	20.6
Wt. Dry Soil (g)	199.3
Water Content (%)	10.34%

File No.	00172.00
Test No.	4
Date	10/18/00
Tested By:	ARO
Checked By	JMB

ASTM Standard D 1140
- ☑ Method A (Wash)
- ☐ Method B (Deflocculating Agent)

Wt. Dry Soil (g)	199.3
Wt.Container, Washed Dry Soil Retained on No. 200 (g)	132.9
Wt. Washed Dry Soil Retained on No. 200 (g)	122.2
Wt. Washed Dry Soil Passing No. 200 (g)	77.1
% Finer Than No. 200	38.7%

PARE ENGINEERING CORPORATION

PERCENT LESS THAN 200 ANALYSIS

SOIL SAMPLE		WATER CONTENT			
Location:	Towantic Energy Center	Container No.	C6	File No.	00172.00
Boring No.:	B-118	Wt. Container (g)	10.6	Test No.	2
Depth:	20-22'	Wt. Container, Wet Soil (g)	266.6	Date	10/23/00
Sample No.:	S-8	Wt. Container, Dry Soil (g)	245	Tested By:	ARO
		Wt. Water (g)	21.6	Checked By	JMB
Specific		Wt. Dry Soil (g)	234.4		
Gravity, Gs:		Water Content (%)	9.22%		

ASTM Standard D 1140 ☑ Method A (Wash)
☐ Method B (Deflocculating Agent)

Wt. Dry Soil (g)	234.4
Wt.Container, Washed Dry Soil Retained on No. 200 (g)	164.9
Wt. Washed Dry Soil Retained on No. 200 (g)	154.3
Wt. Washed Dry Soil Passing No. 200 (g)	80.1
% Finer Than No. 200	34.2%

PARE ENGINEERING CORPORATION

Atterberg Limits

SOIL SAMPLE

Location:	Towantic Energy Center	Container No.	P	File No.	00172.00
Boring No.:	B-103	Wt. Container (g)	10.8	Test No.	1
Depth:	6-8'	Wt. Container, Wet Soil (g)	43.2	Date	11/5/00
Sample No.:	S-4	Wt. Container, Dry Soil (g)	39.4	Tested By:	ARO
		Wt. Water (g)	3.8	Checked By	JMB
		Wt. Dry Soil (g)	28.6		
		Water Content (%)	13.29%		

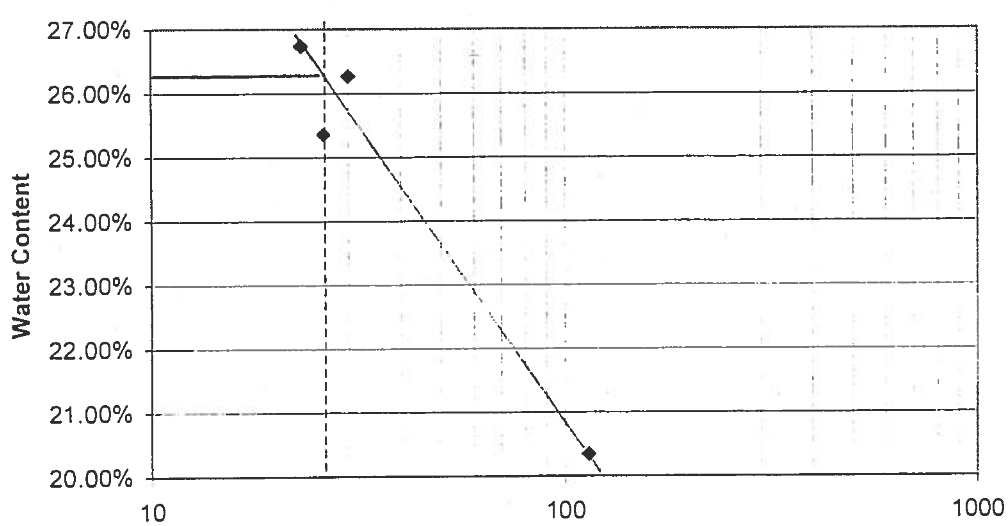
Plastic Limit Determination

Container No.	1	R	C4		
Wt. Container (g)	11	10.9	10.6		
Wt. Container, Wet Soil (g)	19.4	17.9	20.6		
Wt. Container, Dry Soil (g)	17.9	16.6	19		
Wt. Water (g)	1.5	1.3	1.6	0	0
Wt. Dry Soil (g)	6.9	5.7	8.4	0	0
Water Content (%)	21.74%	22.81%	19.05%	#DIV/0!	#DIV/0!

Plastic Limit = 21.20%

Liquid Limit Determination

Container No.	3	D	C1	C3	
Wt. Container (g)	10.7	10.3	10.8	10.8	
Wt. Container, Wet Soil (g)	17.8	19.2	23.6	23.3	
Wt. Container, Dry Soil (g)	16.6	17.4	20.9	20.7	
Wt. Water (g)	1.2	1.8	2.7	2.6	0
Wt. Dry Soil (g)	5.9	7.1	10.1	9.9	0
Water Content (%)	20.34%	25.35%	26.73%	26.26%	#DIV/0!
Number of Blows	114	26	23	30	



$\%M_{LL} = 26.3$

Atterberg Limits

SOIL SAMPLE

Location:	Towantic Energy Center	Container No.	3	File No.	00172.00
Boring No.:	B-103	Wt. Container (g)	10.7	Test No.	2
Depth:	15-17'	Wt. Container, Wet Soil (g)	66.8	Date	11/5/00
Sample No.:	S-7	Wt. Container, Dry Soil (g)	59.1	Tested By:	ARO
		Wt. Water (g)	7.7	Checked By	JMB
		Wt. Dry Soil (g)	48.4		
		Water Content (%)	15.91%		

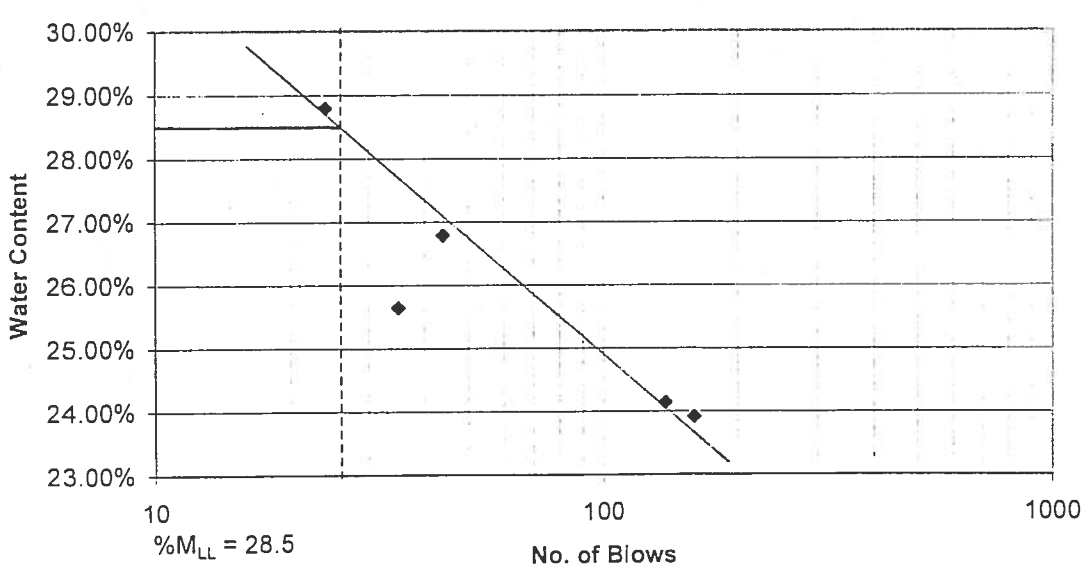
Plastic Limit Determination

Container No.	C4	1			
Wt. Container (g)	10.4	10.9			
Wt. Container, Wet Soil (g)	16.8	17.2			
Wt. Container, Dry Soil (g)	15.7	16.2			
Wt. Water (g)	1.1	1			
Wt. Dry Soil (g)	5.3	5.3			
Water Content (%)	20.75%	18.87%			

Plastic Limit = 19.8%

Liquid Limit Determination

Container No.	R	3	C6	C3	C5
Wt. Container (g)	10.7	10.5	10.5	10.8	12.1
Wt. Container, Wet Soil (g)	16.4	17.7	17.6	20.6	20.6
Wt. Container, Dry Soil (g)	15.3	16.3	16.1	18.6	18.7
Wt. Water (g)	1.1	1.4	1.5	2	1.9
Wt. Dry Soil (g)	4.6	5.8	5.6	7.8	6.6
Water Content (%)	23.91%	24.14%	26.79%	25.64%	28.79%
Number of Blows	160	138	44	35	24



$\%M_{LL} = 28.5$

Atterberg Limits

SOIL SAMPLE

Location:	Towantic Energy Center	Container No.	C1	File No.	00172.00
Boring No.:	B-104	Wt. Container (g)	10.7	Test No.	5
Depth:	10-12'	Wt. Container, Wet Soil (g)	50.3	Date	11/6/00
Sample No.:	S-6	Wt. Container, Dry Soil (g)	45.2	Tested By:	ARO
		Wt. Water (g)	5.1	Checked By	JMP
		Wt. Dry Soil (g)	34.5		
		Water Content (%)	14.78%		

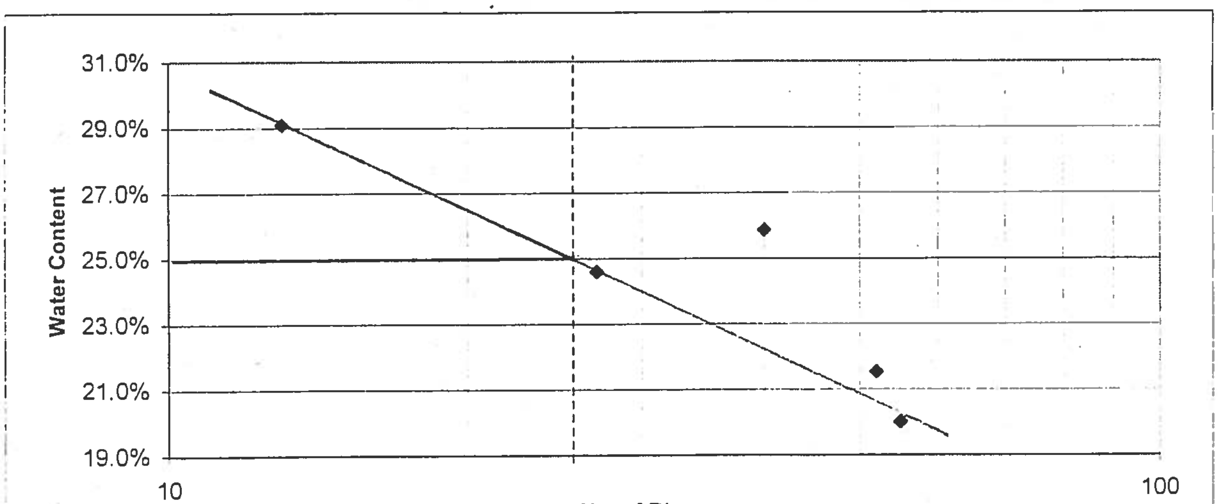
Plastic Limit Determination

Container No.	S	U			
Wt. Container (g)	11.2	11			
Wt. Container, Wet Soil (g)	18.5	18			
Wt. Container, Dry Soil (g)	17.4	16.9			
Wt. Water (g)	1.1	1.1			
Wt. Dry Soil (g)	6.2	5.9			
Water Content (%)	17.7%	18.6%			

Plastic Limit = 18.2%

Liquid Limit Determination

Container No.	C5	3	1	C4	C1
Wt. Container (g)	11.9	10.5	10.7	10.5	10.6
Wt. Container, Wet Soil (g)	19.8	16.5	18	18.1	17.7
Wt. Container, Dry Soil (g)	18.4	15.5	16.5	16.6	16.1
Wt. Water (g)	1.4	1	1.5	1.5	1.6
Wt. Dry Soil (g)	6.5	5	5.8	6.1	5.5
Water Content (%)	21.5%	20.0%	25.9%	24.6%	29.1%
Number of Blows	52	55	40	27	13



$\%M_{LL}$ = 25.0

Atterberg Limits

PARE ENGINEERING CORPORATION

SOIL SAMPLE

Location:	Towantic Energy Center	Container No.	C	File No.	00172.00
Boring No.:	B-105	Wt. Container (g)	7.6	Test No.	4
Depth:	15-17'	Wt. Container, Wet Soil (g)	54.2	Date	11/5/00
Sample No.:	S-7	Wt. Container, Dry Soil (g)	49.1	Tested By:	ARO
		Wt. Water (g)	5.1	Checked By	JMB
		Wt. Dry Soil (g)	41.5		
		Water Content (%)	12.29%		

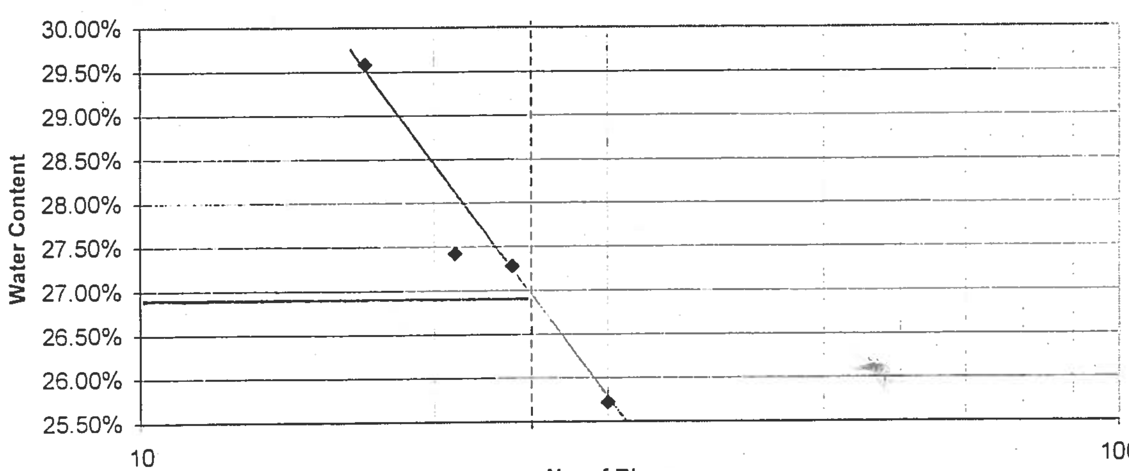
Plastic Limit Determination

Container No.	3	D			
Wt. Container (g)	10.6	10.5			
Wt. Container, Wet Soil (g)	20	21.4			
Wt. Container, Dry Soil (g)	18.6	19.7			
Wt. Water (g)	1.4	1.7			
Wt. Dry Soil (g)	8	9.2			
Water Content (%)	17.50%	18.48%			

Plastic Limit = 18.0%

Liquid Limit Determination

Container No.	C3	R	C5	B	
Wt. Container (g)	10.8	10.7	11.8	7	
Wt. Container, Wet Soil (g)	19.6	18.6	21	15.4	
Wt. Container, Dry Soil (g)	17.8	16.9	18.9	13.6	
Wt. Water (g)	1.8	1.7	2.1	1.8	
Wt. Dry Soil (g)	7	6.2	7.1	6.6	
Water Content (%)	25.71%	27.42%	29.58%	27.27%	
Number of Blows	30	21	17	24	



%M_{LL} = 26.9

PARE ENGINEERING CORPORATION

Atterberg Limits

SOIL SAMPLE

Location:	Towantic Energy Center	Container No.	B	File No.	00172.00
Boring No.:	B-107	Wt. Container (g)	7.1	Test No.	8
Depth:	15-17'	Wt. Container, Wet Soil (g)	57.8	Date	11/6/00
Sample No.:	S-7	Wt. Container, Dry Soil (g)	52.1	Tested By:	ARO
		Wt. Water (g)	5.7	Checked By	JMB
		Wt. Dry Soil (g)	45		
		Water Content (%)	12.67%		

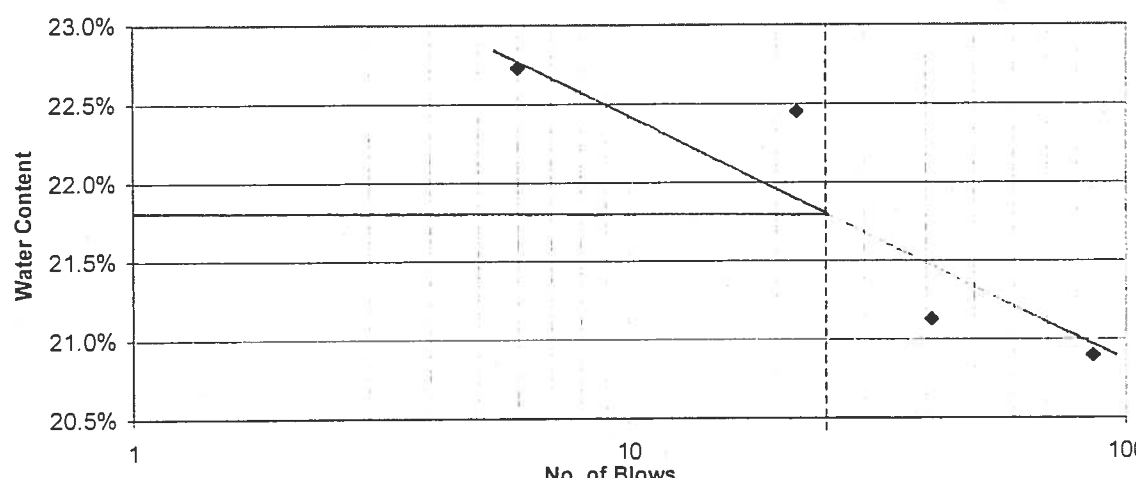
Plastic Limit Determination

Container No.	C	B			
Wt. Container (g)	7.7	7.1			
Wt. Container, Wet Soil (g)	18.8	20			
Wt. Container, Dry Soil (g)	17.1	18.1			
Wt. Water (g)	1.7	1.9			
Wt. Dry Soil (g)	9.4	11			
Water Content (%)	18.1%	17.3%			

Plastic Limit = 17.7%

Liquid Limit Determination

Container No.	C5	D	P	R	
Wt. Container (g)	10.8	10.6	11	10.9	
Wt. Container, Wet Soil (g)	18.9	19.2	17	21.7	
Wt. Container, Dry Soil (g)	17.5	17.7	15.9	19.7	
Wt. Water (g)	1.4	1.5	1.1	2	
Wt. Dry Soil (g)	6.7	7.1	4.9	8.8	
Water Content (%)	20.9%	21.1%	22.4%	22.7%	
Number of Blows	86	41	22	6	



%M_{LL} = 21.8

Atterberg Limits

SOIL SAMPLE

Location:	Towantic Energy Center	Container No.	U	File No.	00172.00
Boring No.:	B-108	Wt. Container (g)	10.7	Test No.	7
Depth:	0-2'	Wt. Container, Wet Soil (g)	62.4	Date	11/6/00
Sample No.:	S-1	Wt. Container, Dry Soil (g)	51.3	Tested By:	ARO
		Wt. Water (g)	11.1	Checked By	JMB
		Wt. Dry Soil (g)	40.6		
		Water Content (%)	27.34%		

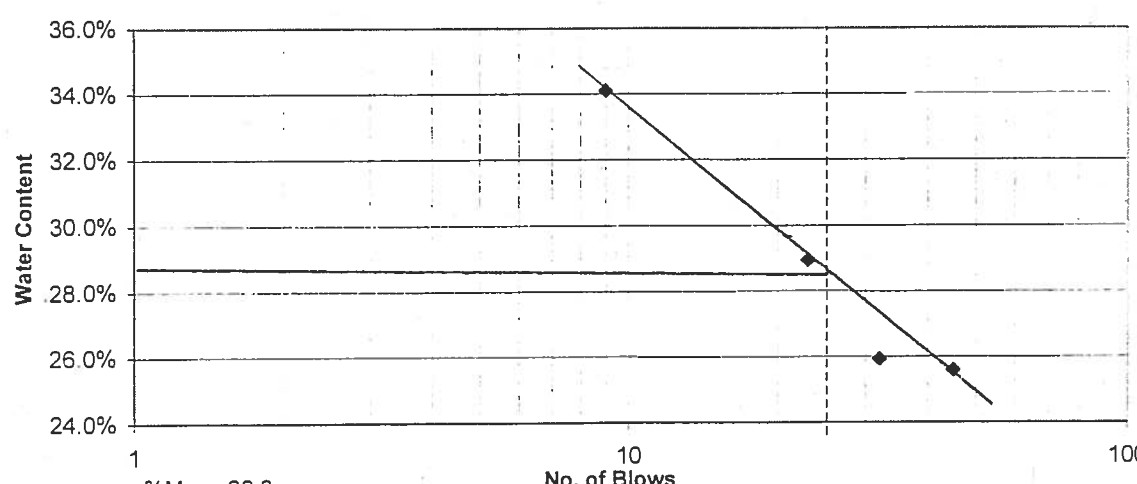
Plastic Limit Determination

Container No.	C2	C4			
Wt. Container (g)	11.3	10.7			
Wt. Container, Wet Soil (g)	28	21.3			
Wt. Container, Dry Soil (g)	24.6	19.2			
Wt. Water (g)	3.4	2.1			
Wt. Dry Soil (g)	13.3	8.5			
Water Content (%)	25.6%	24.7%			

Plastic Limit = 25.1%

Liquid Limit Determination

Container No.	C5	1	G	S	
Wt. Container (g)	11.7	10.9	10.7	11.1	
Wt. Container, Wet Soil (g)	17.1	17.7	15.6	17	
Wt. Container, Dry Soil (g)	16	16.3	14.5	15.5	
Wt. Water (g)	1.1	1.4	1.1	1.5	
Wt. Dry Soil (g)	4.3	5.4	3.8	4.4	
Water Content (%)	25.6%	25.9%	28.9%	34.1%	
Number of Blows	45	32	23	9	



$\%M_{LL}$ = 28.8

PARE ENGINEERING CORPORATION

Atterberg Limits

SOIL SAMPLE

Location:	Towantic Energy Center	Container No.	D	File No.	00172.00
Boring No.:	B-108	Wt. Container (g)	10.7	Test No.	9
Depth:	15-17'	Wt. Container, Wet Soil (g)	46.8	Date	11/7/00
Sample No.:	S-7	Wt. Container, Dry Soil (g)	42.5	Tested By:	ARO
		Wt. Water (g)	4.3	Checked By	JMB
		Wt. Dry Soil (g)	31.8		
		Water Content (%)	13.52%		

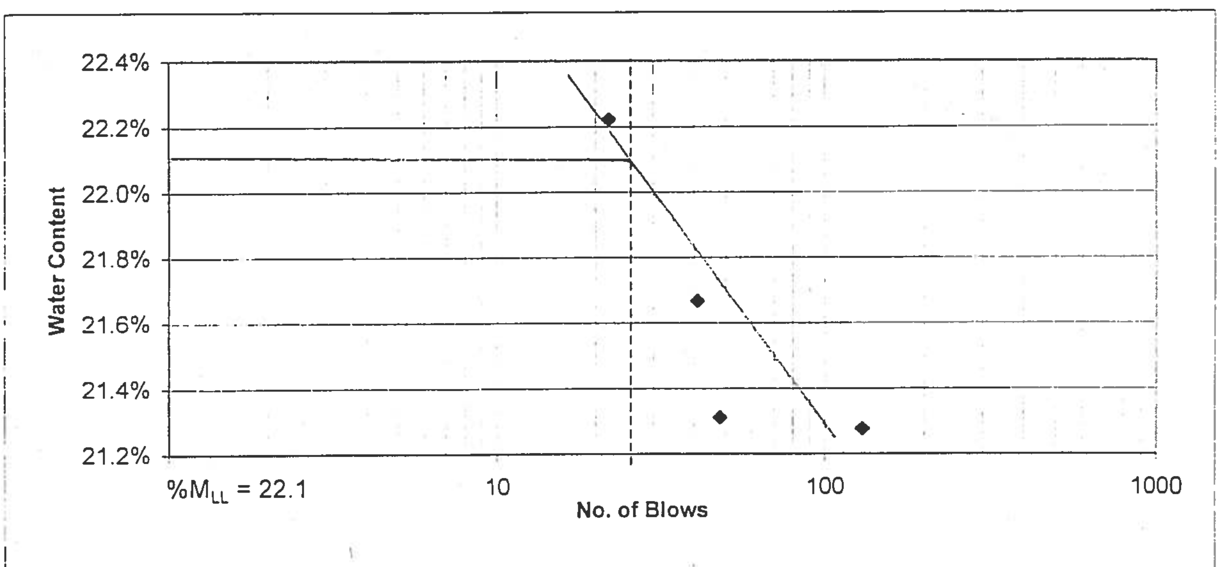
Plastic Limit Determination

Container No.	C	3			
Wt. Container (g)	10.4	10.8			
Wt. Container, Wet Soil (g)	18.2	21.1			
Wt. Container, Dry Soil (g)	16.8	19.4			
Wt. Water (g)	1.4	1.7			
Wt. Dry Soil (g)	6.4	8.6			
Water Content (%)	21.9%	19.8%			

Plastic Limit = 20.8%

Liquid Limit Determination

Container No.	2	C4	C5	1	
Wt. Container (g)	11.1	10.5	11.3	10.6	
Wt. Container, Wet Soil (g)	16.8	17.9	18.6	20.5	
Wt. Container, Dry Soil (g)	15.8	16.6	17.3	18.7	
Wt. Water (g)	1	1.3	1.3	1.8	
Wt. Dry Soil (g)	4.7	6.1	6	8.1	
Water Content (%)	21.3%	21.3%	21.7%	22.2%	
Number of Blows	130	48	41	22	



Atterberg Limits

PARE ENGINEERING CORPORATION

SOIL SAMPLE

Location:	Towantic Energy Center	Container No.	C3	File No.	00172.00
Boring No.:	B-117	Wt. Container (g)	10.8	Test No.	3
Depth:	23-25'	Wt. Container, Wet Soil (g)	48.8	Date	11/5/00
Sample No.:	S-8	Wt. Container, Dry Soil (g)	43.6	Tested By:	ARO
		Wt. Water (g)	5.2	Checked By	JMB
		Wt. Dry Soil (g)	32.8		
		Water Content (%)	15.85%		

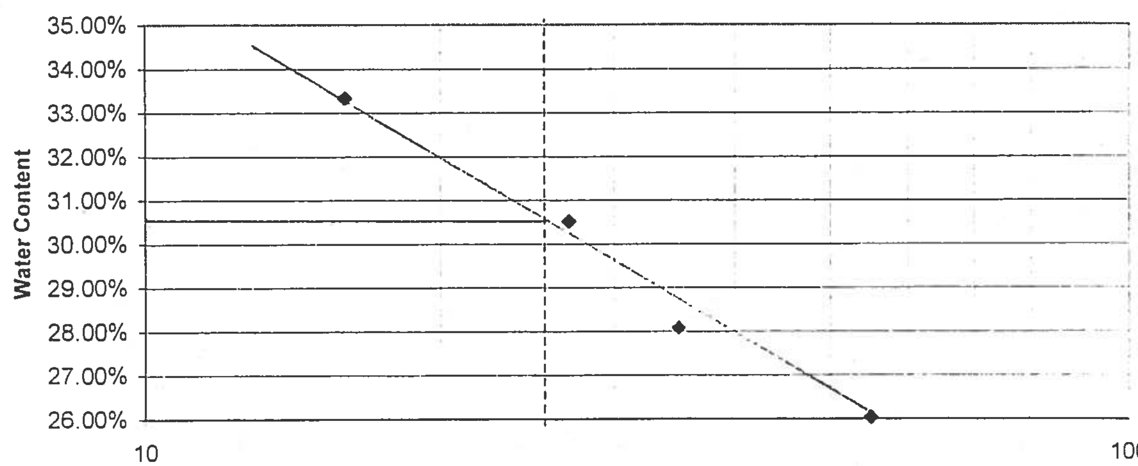
Plastic Limit Determination

Container No.	C	B			
Wt. Container (g)	7.6	7			
Wt. Container, Wet Soil (g)	14.9	16.4			
Wt. Container, Dry Soil (g)	13.8	15			
Wt. Water (g)	1.1	1.4			
Wt. Dry Soil (g)	6.2	8			
Water Content (%)	17.74%	17.50%			

Plastic Limit = 17.6%

Liquid Limit Determination

Container No.	U	S	1	C4	
Wt. Container (g)	11.3	11.3	10.7	10.3	
Wt. Container, Wet Soil (g)	20.5	18.6	18.4	17.1	
Wt. Container, Dry Soil (g)	18.6	17	16.6	15.4	
Wt. Water (g)	1.9	1.6	1.8	1.7	
Wt. Dry Soil (g)	7.3	5.7	5.9	5.1	
Water Content (%)	26.03%	28.07%	30.51%	33.33%	
Number of Blows	55	35	27	16	



$\%M_{LL} = 30.5$

Atterberg Limits

ENGINEERING CORPORATION

SOIL SAMPLE

Location:	Towantic Energy Center	Container No.	G	File No.	00172.00
Boring No.:	B-118	Wt. Container (g)	8.1	Test No.	10
Depth:	4-6'	Wt. Container, Wet Soil (g)	45.9	Date	11/7/00
Sample No.:	S-3	Wt. Container, Dry Soil (g)	40.2	Tested By:	ARO
		Wt. Water (g)	5.7	Checked By	JMB
		Wt. Dry Soil (g)	32.1		
		Water Content (%)	17.76%		

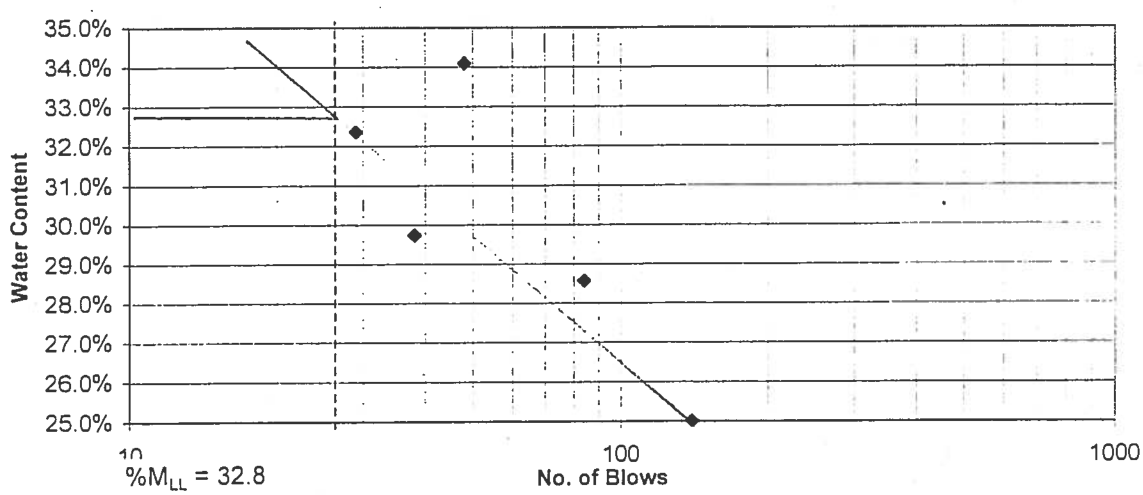
Plastic Limit Determination

Container No.	C	B			
Wt. Container (g)	7.6	7.1			
Wt. Container, Wet Soil (g)	15.5	17.8			
Wt. Container, Dry Soil (g)	14.1	16			
Wt. Water (g)	1.4	1.8			
Wt. Dry Soil (g)	6.5	8.9			
Water Content (%)	21.5%	20.2%			

Plastic Limit = 20.9%

Liquid Limit Determination

Container No.	R	U	C3	P	C6
Wt. Container (g)	10.7	11	10.7	11	10.6
Wt. Container, Wet Soil (g)	17.2	16.9	16.1	20.6	19.6
Wt. Container, Dry Soil (g)	15.9	15.4	14.9	18.4	17.4
Wt. Water (g)	1.3	1.5	1.2	2.2	2.2
Wt. Dry Soil (g)	5.2	4.4	4.2	7.4	6.8
Water Content (%)	25.0%	34.1%	28.6%	29.7%	32.4%
Number of Blows	140	48	84	38	29



%M_{LL} = 32.8

PARE ENGINEERING CORPORATION

Atterberg Limits

SOIL SAMPLE

Location:	Towantic Energy Center	Container No.	N/A	File No.	00172.00
Boring No.:	B-120	Wt. Container (g)	N/A	Test No.	6
Depth:	0-10'	Wt. Container, Wet Soil (g)	N/A	Date	11/6/00
Sample No..	Auger Cuttings	Wt. Container, Dry Soil (g)	NA	Tested By:	ARO
		Wt. Water (g)		Checked By	JMR
		Wt. Dry Soil (g)			
		Water Content (%)			

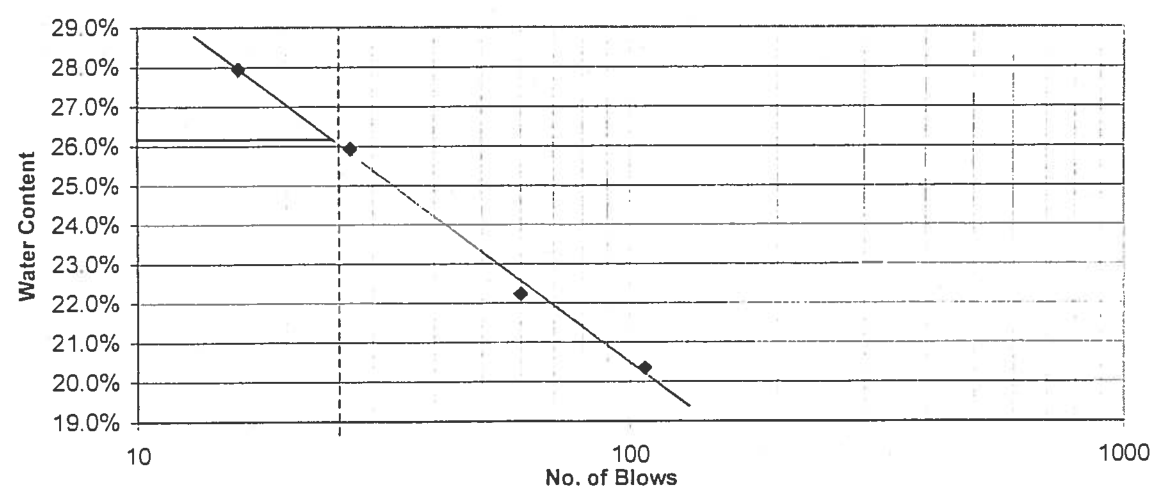
Plastic Limit Determination

Container No.	B	C			
Wt. Container (g)	6.8	7.6			
Wt. Container, Wet Soil (g)	16.5	16.1			
Wt. Container, Dry Soil (g)	15	14.7			
Wt. Water (g)	1.5	1.4			
Wt. Dry Soil (g)	8.2	7.1			
Water Content (%)	18.3%	19.7%			

Plastic Limit = 19.0%

Liquid Limit Determination

Container No.	C6	C3	R	P	
Wt. Container (g)	10.2	10.7	10.6	10.9	
Wt. Container, Wet Soil (g)	17.3	18.4	17.4	19.6	
Wt. Container, Dry Soil (g)	16.1	17	16	17.7	
Wt. Water (g)	1.2	1.4	1.4	1.9	
Wt. Dry Soil (g)	5.9	6.3	5.4	6.8	
Water Content (%)	20.3%	22.2%	25.9%	27.9%	
Number of Blows	107	60	27	16	



$\%M_{LL} = 26.2$

MODIFIED PROCTOR ANALYSIS
ASTM Designation D1557

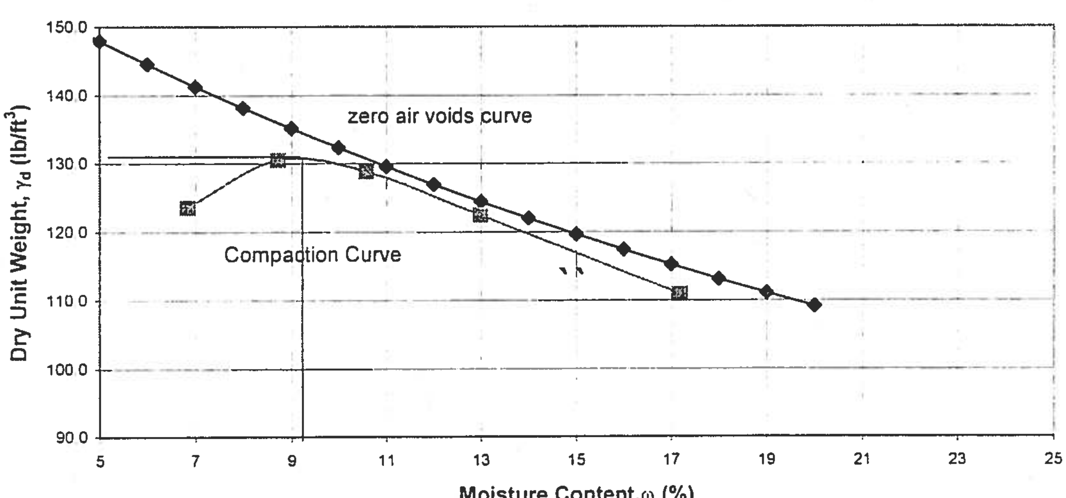
PARE ENGINEERING CORPORATION

Location:	Towantic Energy Center		
Soil Description	Brown, Silty sand (SM)	File No.	00172.00
Boring No.:	B-119	Test No.	1
Depth:	1-25'	Date	10/18/00
Sample No.:	Auger Cuttings	Tested By	ARO
Specific Gravity, Gs:	2.69	Checked By	JMR

Test #	1	2	3	4	5
Pan #	E	3	D	C	P
Pan Wt., g	7.8	7.6	7.0	7.8	10.8
Pan + Soil Wt. (wet), g	109.4	131.0	193.0	134.8	317.6
Pan + Soil Wt. (dry), g	102.9	121.1	175.2	120.2	272.6
Soil Wt. (dry), g	95.1	113.5	168.2	112.4	261.8
Water Wt., g	6.5	9.9	17.8	14.6	45.0
Water Content (%)	6.8	8.7	10.6	13.0	17.2

Assummed W.C.(%)	4	5	7	9	11
Water Content (%)	6.8	8.7	10.6	13.0	17.2
Soil + Mold Weight, g	10310	10645	10665	10525	10240
Mold Wt., g	5820	5820	5820	5820	5820
Soil Wt., g	4490	4825	4845	4705	4420
Soil Wt., lb	9.90	10.64	10.68	10.37	9.74
Mold Volume (ft^3)	0.075	0.075	0.075	0.075	0.075
Wet Density (lb/ft^3)	132.0	141.8	142.4	138.3	129.9
Dry Density (lb/ft^3)	123.5	130.5	128.8	122.4	110.9

Compaction Curve for the Modified Proctor Analysis



Max Dry Density: 131 PCF
Optimum Water Content: 9.1%

Comments:

MODIFIED PROCTOR ANALYSIS

ASTM Designation D1557

PARE ENGINEERING CORPORATION

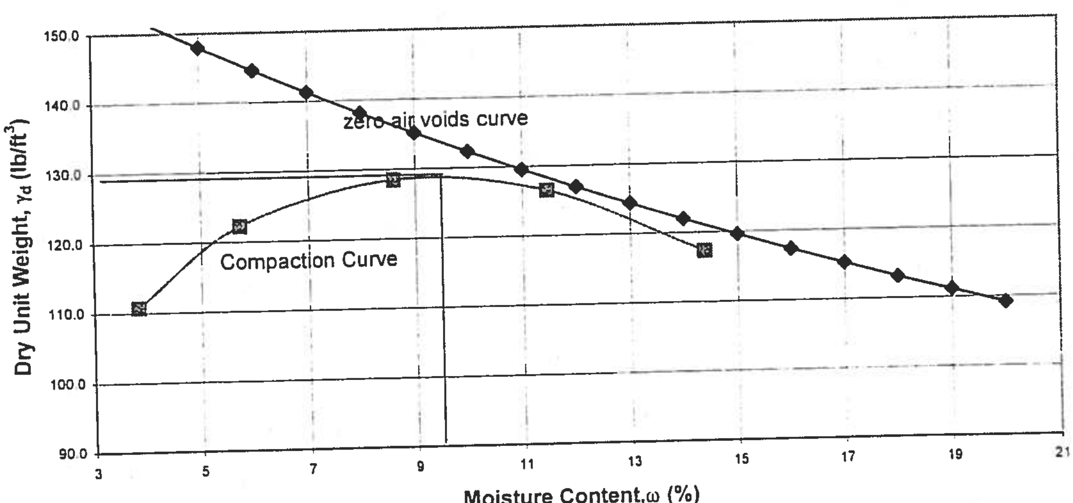
Location:	Towantic Energy Center
Soil Description	Brown, silty sand
Boring No.:	B-120
Depth:	1-10'
Sample No.:	Auger Cuttings
Specific Gravity, Gs:	2.69

File No.	00172.00
Test No.	3
Date	11/2/00
Tested By	ARO
Checked By	JMB

Test #	1	2	3	4	5
Pan #	R	C7	U	S	C4
Pan Wt., g	10.9	10.9	11	10.9	10.9
Pan + Soil Wt. (wet), g	217.6	276.9	264.8	248.3	279.7
Pan + Soil Wt. (dry), g	210	262.5	244.7	223.9	245.9
Soil Wt. (dry), g	199.1	251.6	233.7	213	235
Water Wt., g	7.6	14.4	20.1	24.4	33.8
Water Content (%)	3.8	5.7	8.6	11.5	14.4

Assummed W.C.(%)	2	4	6	8	10-
Water Content (%)	3.8	5.7	8.6	11.5	14.4
Soil + Mold Weight, g	9730	10215	10565	10615	10385
Mold Wt., g	5820	5820	5820	5820	5820
Soil Wt., g	3910	4395	4745	4795	4565
Soil Wt., lb	8.62	9.69	10.46	10.57	10.06
Mold Volume (ft^3)	0.075	0.075	0.075	0.075	0.075
Wet Density (lb/ft^3)	114.9	129.2	139.5	140.9	134.2
Dry Density (lb/ft^3)	110.7	122.2	128.4	126.5	117.3

Compaction Curve for the Modified Proctor Analysis



Max Dry Density$_t$ = 129 PCF

Optimum Water Content = 9.3

Comments:

MODIFIED PROCTOR ANALYSIS

ASTM Designation D1557

PARE ENGINEERING CORPORATION

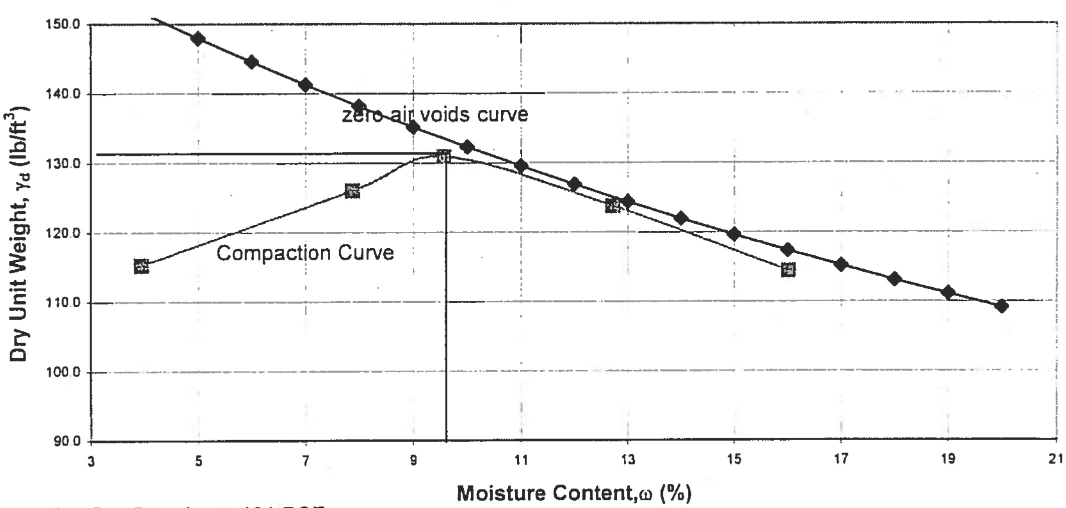
Location:	Towantic Energy Center
Soil Description	Brown, silty sand
Boring No.:	B-122
Depth:	1-10'
Sample No.:	Auger Cuttings
Specific Gravity, Gs:	2.69

File No.	00172.00
Test No.	2
Date	10/23/00
Tested By	ARO
Checked By	JMB

Test #	1	2	3	4	5
Pan #	C1	C5	C3	3	d
Pan Wt., g	10.7	11.1	10.7	10.7	10.8
Pan + Soil Wt. (wet), g	221.1	200.1	250	305.8	346.1
Pan + Soil Wt. (dry), g	213.1	186.3	229.1	272.5	299.8
Soil Wt. (dry), g	202.4	175.2	218.4	261.8	289
Water Wt., g	8	13.8	20.9	33.3	46.3
Water Content (%)	4.0	7.9	9.6	12.7	16.0

Assummed W.C.(%)	2	5	7	10	12
Water Content (%)	4.0	7.9	9.6	12.7	16.0
Soil + Mold Weight, g	9895	10445	10700	10565	10335
Mold Wt., g	5820	5820	5820	5820	5820
Soil Wt., g	4075	4625	4880	4745	4515
Soil Wt., lb	8.98	10.20	10.76	10.46	9.95
Mold Volume (ft^3)	0.075	0.075	0.075	0.075	0.075
Wet Density (lb/ft^3)	119.8	136.0	143.4	139.5	132.7
Dry Density (lb/ft^3)	115.2	126.0	130.9	123.7	114.4

Compaction Curve for the Modified Proctor Analysis



Max Dry Density = 131 PCF
Optimum Water Content = 9.2

Comments:

Premier
Laboratory, LLC

Route 205, The Regional Building
PO Box 700
Brooklyn, Connecticut 06234
FAX. 860-774-2689
860-774-6814 800-932-1150

ANALYTICAL DATA REPORT

Report Number: E010998
Project: Towantic Energy Center

prepared for:

Pare Engineering Corp.
8 Blackstone Valley Place
Norwood, MA 02062

Attn: Matthew Bellisle

Received Date: 10/24/2000
Report Date: 10/27/2000

FAXED COPY
Premier Laboratory, LLC
Authorized Signature

Connecticut Department of Health Services PH-0465
Massachusetts Department of Environmental Quality M-CT008
New Hampshire Department of Environmental Services 2020
New York Department of Health 11549
Rhode Island Department of Health 180

INORGANIC ANALYSIS DATA SHEET

Laboratory: Premier Laboratory, LLC
PL Report No: E010998
Date Received: 10/24/2000

Customer: Pare Engineering Corporation
Location: Oxford, MA
Project: Towantic Energy Center

Parameter	Result	DL	Units	Completed	By	Dilution
(1) B106, S-2						
Date Collected: 10/10/2000 Matrix: Solid						
Chloride by 9251 (soil modification)	ND	21	mg/kg	10/25/00	KW	
Sulfate by EPA 375.4 (soil modification)	100	33	mg/kg	10/25/00	JJ	
pH by SW-846 9040/9045	5.6		pH Units	10/24/00	IB	
(2) B107, S-3						
Date Collected: 10/4/2000 Matrix: Solid						
Chloride by 9251 (soil modification)	ND	17	mg/kg	10/25/00	KW	
Sulfate by EPA 375.4 (soil modification)	ND	31	mg/kg	10/25/00	JJ	
pH by SW-846 9040/9045	7.1		pH Units	10/24/00	IB	
(3) B108, S-3						
Date Collected: 10/3/2000 Matrix: Solid						
Chloride by 9251 (soil modification)	ND	21	mg/kg	10/25/00	KW	
Sulfate by EPA 375.4 (soil modification)	ND	28	mg/kg	10/25/00	JJ	
pH by SW-846 9040/9045	7.2		pH Units	10/24/00	IB	
(4) B109, S-5						
Date Collected: 10/10/2000 Matrix: Solid						
Chloride by 9251 (soil modification)	ND	29	mg/kg	10/25/00	KW	
Sulfate by EPA 375.4 (soil modification)	ND	36	mg/kg	10/25/00	JJ	
pH by SW-846 9040/9045	5.8		pH Units	10/24/00	IB	
(5) B110, S-5						
Date Collected: 10/5/2000 Matrix: Solid						
Chloride by 9251 (soil modification)	ND	20	mg/kg	10/25/00	KW	
Sulfate by EPA 375.4 (soil modification)	33	33	mg/kg	10/25/00	JJ	
pH by SW-846 9040/9045	7.8		pH Units	10/24/00	IB	
(6) B112, S-4						
Date Collected: 10/10/2000 Matrix: Solid						
Chloride by 9251 (soil modification)	ND	22	mg/kg	10/25/00	KW	
Sulfate by EPA 375.4 (soil modification)	47	23	mg/kg	10/25/00	JJ	
pH by SW-846 9040/9045	7.0		pH Units	10/24/00	IB	
(7) B120, S-8						
Date Collected: 10/12/2000 Matrix: Solid						
Chloride by 9251 (soil modification)	ND	22	mg/kg	10/25/00	KW	
Sulfate by EPA 375.4 (soil modification)	ND	35	mg/kg	10/25/00	JJ	
pH by SW-846 9040/9045	7.6		pH Units	10/24/00	IB	

Witness: Andrew J. Bazinet

Question CSC-33:

What is the minimum stream flow allowed by DEEP at various points where water will be extracted? How close to the allowed stream flow is the project expected to be? What are the current withdraw rates?

Response:

The Facility will not be extracting water from the Pomperaug River. Instead, Heritage Village Water Company (HVWC) will supply the Facility with water from a combination of (i) its five (5) groundwater wells (DEEP Diversion Registration No. 6800-006-PWS-GR); and (ii) its interconnection with the Connecticut Water Company (CWC) (DEEP Diversion Permit DIV-200902232GP).

The DEEP's stream flow standards and regulations do not contain quantitative stream flow levels for the Pomperaug River. Further, as a registered water diversion, HVWC is not subject to these regulations.

Average daily stream flow for the Pomperaug River is approximately 82 cubic feet per second, per a 2010 USGS study. If, conservatively, every gallon of groundwater withdrawn by HVWC represents one fewer gallon of stream flow, and every gallon used by the Facility was produced by HVWC's wells (instead of supplied via the CWC interconnect), the Facility's average water demand of approximately 67,000 gallons per day would represent a reduction in average stream flow of the Pomperaug River of approximately 0.1%. Similarly, the Facility's maximum daily demand of 218,000 gallons would represent 0.4% of average stream flow of the Pomperaug River. Even under "1 in 100" conditions of 7.3 cubic feet per second of streamflow, the Facility's average daily demand would represent less than a 1.3% reduction of stream flow. As of United States Geological Service's 2010 study, HVWC's average daily pumping rate was 0.93MGD on an annual basis; HVWC averaged 1.14MGD over the summer months of May through September, compared to 0.79MDG over the remaining months of the year. HVWC's pumping, even including the Project's maximum water use, is well within the 2.05MGD limitation set forth in HVWC's groundwater well diversion registration.