NEW ENGLAND POWER COMPANY

HARRIMAN DAM IMPROVEMENT PROJECT

FINAL REPORT

MARCH, 1982

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BOSTON, MA 02199

MAIN

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1 March 1982 1270-76-3

SUBJECT: Engineering Report for
Harriman Dam Improvement Project

Mr. Denton E. Nichols, Senior Engineer
New England Power Service Company
25 Research Drive
Westborough, MA 01581

Dear Denton:

MAIN is pleased to submit herewith, a final report discussing the purpose, design, analysis and construction of the downstream overlay placed on Harriman Dam. Soil testing summaries are enclosed to demonstrate the acceptability of all materials placed. "As-Built" drawings and plates illustrate many of the consruction related features. On the basis of MAIN's quality assurance program, performed throughout the construction period, Harriman Dam has factors of safety against shallow failure slides in excess of 1.8. The filter blanket installed will safely transfer embankment seepage through the embankment, without excessive pore water pressure buildup. All of the piezometers installed prior to construction were centralized to common readout locations, thereby, maintaining a check on embankment stability.

It is recommended that the Surveillance Program presented herein, be performed by NEPSCo through 1984. It is further recommended that the newly installed weir boxes be measured and recorded throughout this program.

Fifteen reports are enclosed for your distribution and review. If there are any questions or problems with respect to this report, do not hesitate to contact us.

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The cooperation of Messrs. Larry Underwood, Warner Goff, Forest Meader, Robert Harvey and Evert Flagg of New England Power Service Company was greatly appreciated.

Very truly yours,

CHAS. T. MAIN, INC.

Bill Walton

William H. Walton
Geotechnical Engineer

WHW:sac

Enclosures

cc: Mr. L.D. Pierce - NEPSCo
Mr. A.P. Davis, Jr. - MAIN

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HARRIMAN DAM IMPROVEMENT PROJECT

ENGINEERING REPORT

I. INTRODUCTION

Harriman Dam is owned and operated by New England Power Company. The dam is located just south of Wilmington, Vermont on the Deerfield River. The dam was constructed in 1922-23 by the semi-hydraulic fill method using high lift dumped fill shells and a puddle core formed by sluicing the dumped shells with hydraulic monitors. The original section is of compound slopes with a puddle core and beach (wash) zone occupying approximately the central half of the structure. The maximum section height is 215.5 feet above the toe, 1300 feet long, and has a crest width of 12 feet with a normal freeboard of 29.5 feet above spillway crest elevation 1386.0 Historic reservoir operation has included 6 feet of flashboards to elevation 1392.0. The right half of the dam is approximately 115 feet high.

Based on observations of seepage at several points on the downstream toe and abutments of the dam, a comprehensive analytic, field and laboratory investigation was performed on Harriman dam during the past year and a number of minor potential problems were identified geotechnically. These minor problems were addressed and solutions developed. New England Power Service Company retained Chas. T. Main, Inc. for geotechnical assistance to assess the problems and formulate solutions. Specifically, the purposes of the study were, 1) to eliminate the potential for seepage breakout onto the downstream slope of the embankment and 2) to raise the factor of safety for static stability above 1.5 for current (1981) standards.

II. DISCUSSION OF PROBLEMS

On the basis of visual observations and readings from piezometers installed on the downstream slope, high pore water pressures had been identified at several locations along the downstream face of the dam, generally below elevation 1370. Minor visible seepage was observed in late February, 1981 during a period of high pool elevation, a 55 year record monthly rainfall, and warm temperatures while the frost was still in the ground. At the same time, some of the shallow piezometers exhibited high pore water pressures close to the embankment surface. A numerical finite-element flownet analysis performed on Harriman dam indicated potential seepage breakout onto the downstream slope for a reservoir at elevation 1392.0.

Laboratory investigations performed by Geotechnical Engineers, Inc. (GEI), have been used to assign effective stress friction angles (Ø') and wet unit weights for each component of the dam (core, dumped shell, and the 1964 compacted overlay materials). A sufficient number of undisturbed samples were obtained to facilitate laboratory testing which indicated the following properties:

Material	Wet Unit Weight, pcf	Friction Angle, Ø
Puddle Core	130	35° ≠
Dumped Shell	135	35° ≠
1964 Overlay	145	37° ≠
Proposed 1981 Overlay	140	36° *

≠ - Undisturbed specimens
* - Compacted specimens

Considerable effort was focused toward assigning soil properties to the dumped shell material. At least seven boreholes were installed during the spring of 1981 to obtain undisturbed samples of till from the dumped shell. Triaxial testing illustrated that Ø' was at least 35°. The combination of high pore water pressure and moderate frictional resistance in the dumped shell (Ø' = 35°) yield factors of safety (FS) less than 1.5 for normal operating pool levels.

III. DESIGN AND ANALYSIS

It was determined a downstream overlay could raise the FS above 1.5 for steady state seepage at pool elevation 1392.0. This would eliminate the potential for seepage breakout (seepage breakout itself is not a failure mechanism; however, it provides an opportunity for "piping" to begin). The proposed 1981 improvement is shown on Plates 1 through 7. The improvement includes stripping the downstream face, installing a compacted filter drain, and placing a compacted fill on top of the filter providing a mass to increase the static factor of safety. To insure protection against seepage breakout, the proposed overlay will have a filter drain layer extending from the downstream toe up to a minimum elevation of 1374.0. It was specified that any addition to Harriman dam completed in 1981 should be able to accommodate a possible future raising. The proposed improvement will provide a bench at elevation 1380.0 for future work, if required.

Stability analyses on the proposed overlay were performed using MAIN's computer program SLØPE and piezometric pressures estimated for a steady state pool elevation of 1392.0. To define pore water pressures for the 1392.0 operating limit, actual piezometric records were analyzed to extrapolate pressure levels for higher pool elevations. Extrapolated pressures were determined by graphical construction techniques projecting data between June and September 1980.

Heavy inflows were recorded during November, 1980, and key piezometers responded with increasing pool elevations for this period. Extrapolations were again drawn for this period of record. Both extrapolations yielded similar results. The resulting pore water pressures were reasonable and provided for construction of a phreatic surface and equipotential lines of pressure within the embankment.

The simplified Bishop circular arc technique was used to assess slope stability. The computer program SLØPE was used to find the critical failure surface. Factors of safety from the SLØPE stability analysis were overly conservative since the program computes pore water pressure uplift as the vertical distance from the phreatic surface to the failure arc times the unit weight of water. This method is correct for vertical equipotential lines, but highly conservative for shallow sloping equipotential lines. Plate 8 illustrates the estimated equipotential lines and phreatic surface for a 1392 pool elevation, at station 12+00. Once the critical failure surface was defined, a hand calculated simplified Bishop analysis was performed, using flownet pore water pressure uplift values. The hand method provides a more accurate FS result for a given input. For the design overlay to elevation 1380.0, the minimum FS equals 1.8 using material properties noted earlier. In addition, Plate 8 illustrates the critical failure surface along with the elevation 1392.0 steady state pore water uplift pressure distribution.

IV. CONSTRUCTION DETAILS

a. General - The work consisted of constructing a compacted earth overlay and filter drain layer over the downstream face, installing collector drains to monitor seepage water, constructing a service road across the top of the overlay, installation of several new piezometers, and extending existing piezometer leads to monitoring stations adjacent to the dam. Plates 1 through 7 illustrate "As-Built" construction details, in addition, Photos 1 through 11 illustrate many of the construction details.

b. Contractor - The work was awarded to Pizzagalli Construction Company, Inc. of South Burlington, Vermont. Subcontractors to Pizzagalli were, 1) Timber Clearing - G. Browne, Wilmington, Vermont, 2) Filter Processing - T. Ondrick Construction Comapny, Chicopee, Massachusetts, 3) Filter Trucking - Eiler's Brothers, Readsboro, Vermont and 4) Instrumentation Relocation - Haley and Aldrich, Inc., Cambridge, Massachusetts. The contractor mobilized at the site on 10 August 1981.

c. Borrow Sources - A glacial till deposit, located immediately downstream from the right dam abutment, was the source for the impervious fill overlay material. The till borrow source was a 14 to 16 acre area extending from 1,000 to 4,000 feet downstream from the dam (along the right abutment valley slope) extending from elevation 1330.0 to 1440.0. See Plate 1 of the "As-Builts" for relative location. The contractor selected a hard blue-grey till as the overlay material, being careful to remove all overburden and control ground and surface water infiltration. Photo 1 shows the till borrow area during production. Overly wet and oversize material was rejected within the pit. Only the required amount of impervious till was removed from the borrow area to meet daily requirements. The till was not stockpiled due to occasional rain and excessive surface water runoff.

The filter drain blanket source was developed about 8.5 miles downstream from the dam and a half a mile downstream from Harriman powerhouse on the east side of Sherman Reservoir. See Plate 1 for relative location. A four to five acre area was prepared within a river terrace deposit for processing. These terraces exhibit silts, sands and gravels, well to poorly sorted. The location of this source is known as the Carbide pit, formerly used for the Bear Swamp Project - FERC LP No. 2669 during 1971 through 1973 for production and processing of concrete aggregate. Photo 2 shows the filter material borrow area.

d. Downstream Overlay and As-Built Quantities - The compacted earth overlay extends over the entire downstream face of the dam, except the top 30 feet (see Photo 11). Plate 2 presents a typical cross-section of Harriman Dam with the actual overlay shaded. The overall thickness of the overlay ranges from five to 20 feet measured normal to the slope. Stripping grades range from five to ten feet in the lower sections of the dam to no more than one or two feet near the top of the overlay. Heavier stripping was required on the lower slope to remove old stumps and root systems. Thickness of the filter drain blanket is three feet normal to the slope. Along the interface between the new overlay and the abutments, collector drains (filter fabric wrapped - four inch diameter perforated PVC pipe) were installed to collect and remove seepage water passing down through the filter blanket.

Piezometer leads from the former 25 piezometer cover pipes within the overlay area were collected and extended in shallow sand backfilled trenches, to two piezometer monitoring stations. Each monitoring station is located off the embankment at each abutment and convenient for vehicular access.

Placement of overlay material commenced on 25 August 1981 and finished on 25 November 1981, with an 18 inch thick gravel base material placed across the top of the overlay. The actual in-place quantities calculated by double-end area method, are tabulated below:

Material	Quantities
Subgrade excavation	47,200 CY
Filter Blanket	40,500 CY
Impervious Fill	111,200 CY
Collector Drain Pipe	3,050 LF

These quantities were used for payments.

e. Earthwork Control - New England Power Service Company provided the field testing laboratory and the quality control for the project. MAIN provided personnel to maintain quality assurance and to provide engineering/geotechnical decisions in the field. Visual and laboratory inspection was performed throughout construction. Examples of visual inspection include, evaluation of sufficient abutment treatment or subgrade preparation, acceptance of overlay material free of oversize and organics, monitoring lift thickness, insuring sufficient number of compactor passes, insuring the filter drain blanket was not contaminated or travelled on, and making sure that the contractor stayed within the contract specifications.

An on-site materials test laboratory was used to insure quality control on construction materials. The laboratory was fully equipped to perform: 1) the "Hilf Method of Rapid Compaction Control", USDI Bureau of Reclamation Engineering Monograph No. 26, 1966, Grain size analyses (ASTM D-422), including wash (#200) analyses, and Standard Proctor testing (ASTM D-698). The testing schedule met the following testing criteria:

Filter Drain Blanket Material

One (1) grain size analysis per lift or every 1000 cubic yards

Impervious Rolled Fill

One (1) Hilf Test per lift or every 1000 cubic yards

Standard Proctor test on borrow material - performed when directed by the Engineer.

To insure the filter drain would perform adequately, occasional moisture-density tests (sand-cone density test, ASTM D-1556) were performed on the in-place filter. Several times during the work, field permeabilities were performed to assess the adequacy of the filter. Many attempts were made during the pre-construction analysis program to assign in-place densities of the dumped shell material. Since the subgrade was stripped significantly below old ground, NEPSCo/MAIN performed moisture-density tests on the subgrade material. Plate 9 illustrates the relationship between dry density and the natural moisture content of the dumped shell material. Note the average saturated density, assuming the specific gravity of till equals 2.75, equals the assumed density used during the analysis program. In addition, grain size analyses were performed on filter material directly out of the processing plant (Carbide pit). These tests were performed several times a day and provided a preliminary check on the quality of the filter material before it was brought to the site. A brief summary of all the testing results are presented in Appendices A and B. Location of tests performed are shown on Plate 10.

(1) Subgrade Preparation and Abutment Treatment - The existing embankment and abutments were cleared, grubbed, and stripped to specified subgrade elevations. The subgrade, except for bedrock surfaces, was prepared by leveling with the backhoe and tracked with dozers so that the surface would be compact and bond well with the layer of filter material. Stripping

depths on the embankment ranged from one to ten feet. Plate 2 illustrates the typical subgrade used for the overlay.

Along the left abutment between elevations 1245.0 and 1330.0, bedrock was exposed. Special care was exercised to clean the bedrock of all muck and loose or weathered rock. Photo 5 shows the results of bedrock cleaning. Bedrock cleaning involved hand work and air jetting. Before earth fill was placed on the bedrock NEPSCo/MAIN personnel inspected the abutment for complete and proper cleaning.

To effectively tie the overlay into the earthen abutments, sufficient material was excavated to expose a minimum eight foot face. The excavation was extended into the abutment until acceptable material was exposed; under no circumstances were topsoil or organic materials included in the eight foot high cut.

During the initial phases of construction, subgrade excavation on the existing embankment was restricted to exposing only an area 15 feet above the overlay placement operations, as shown in Photo 3. As time went on, this restriction was relaxed due to the excavation operation holding up overlay placement. Therefore, subgrade excavation was extended up to 45 feet above overlay operations. Photo 9 illustrates the exposed subgrade from elevation 1330.0 to 1355.0. This change allowed for unrestricted overlay placement; when there was inclement weather, the filter blanket portion of the overlay was cleaned of all slope wash debris. Several times the subgrade was over-excavated to remove rain water saturated material back to a reasonable dry, solid material.

(2) Filter Drain Blanket Material - To intercept the minimal seepage passing through the original embankment, a 3.0 foot thick (normal to the slope) filter zone was placed in horizontal lifts on top of the subgrade. Photos 3, 6 and 7 show the filter blanket placement operations during the construction program. No moisture control was required for placement. There are two types of filter drain blanket materials placed the overlay. Filter material A extends from the toe, elevation 1208.0, to elevation 1296.0. Filter material B extends from elevation 1296.0 to the top of the filter zone, elevation 1374.0. Material A met the following gradational limits:

ASTM Sieve Size	Percent Passing by Weight
3"	100
3/8"	48 - 100
#4	35 - 100
#10	25 - 77
#40	7 - 40
#200	0 - 6 (dry sieve)

Acceptance or rejection of material A was based on results from dry sieve analyses recognizing, however, that the actual percentage of fines (silts and clays) passing the #200 sieve would be higher, if a wash analysis was performed. To insure that filter material A would pass seepage water readily, field laboratory measurements were performed to determine the material's permeability (k). Results from falling head permeability tests yielded permeabilities ranging from 1.6 to 7.0 x 10^{-3} cm/sec. The original dumped shell material, on which the filter material is placed, has permeabilities that range from 10^{-4} to 10^{-5}

cm/sec. Based on field tests published in the Phase II report by Geotechnical Engineers, Inc. (1981) filter material A demonstrates at least one magnitude greater permeability than the original dumped shell material. Furthermore, no visible water was seen ponded or set up on the filter blanket as a result of precipitation or storm runoff during construction.

To better control the amount of fines (< #200 sieve) present in the filter material, a second filter material, B, was required to accommodate the actual wet areas (seepage line extends from stations 11+00 to 12+50 along elevation 1327±), as well as potential seepage areas that range from elevation 1320.0 to 1360.0. Filter material B met the following gradational limits:

ASTM Sieve Size	Percent Passing by Weight
3"	100
3/4"	44 - 100
3/8"	27 - 100
#4	23 - 100
#10	17 - 77
#40	7 - 40
#200	0 - 6 (wash sieve)

The preceeding limits provide 1) an adequate filter to prevent "piping" of the dumped shell into the filter zone; and, 2) higher permeabilities than measured in filter material A.

At the interface between the two filter zones, a drain pipe system was installed to collect seepage water passing down through material B before it reaches material A. To insure that filter material B exhibited acceptable permeabilities, MEPSCo/MAIN performed in-situ field permeability tests (Well Permeater Method, USBR Designation E-19). Results of which follow:

Test	Station	Elevation	k (cm/sec)
P-1	10+50	1305.0	5×10^{-2}
P-2	9+40	1344.0	3.9×10^{-2}

In terms of filter design criteria, required permeabilities in the filter blanket should be greater than 10^{-3} cm/sec. All permeability tests performed satisfied this criteria; therefore, the in-place filter material should perform well, as it did throughout the construction period.

The filter material was end dumped into place and then loose graded into 12 inch lifts. Between elevation 1208.0 and 1296.0 (filter material A) the 12 inch lifts were compacted with two passes of a RayGo 600A smoothed wheeled roller. No vibration was used. Filter material B, between elevations 1296.0 and 1310.0 was placed in 12-inch loose lifts and compacted with two passes with the roller. At elevation 1310.0, the lift thickness was increased to 18 inches, however, two pass compaction remained the same. Upon reaching elevation 1350.0, the moisture content of the filter material delivered from "Carbide pit" was high and the subgrade surface overly saturated due to fall weather conditions. Whereupon, the 18 inch lifts were dozer compacted using a Case 850 up to elevation 1374.0. Summary of earthwork control data for the filter drain blanket material is presented in Appendix A. Moisture-density results for each filter type, lift thickness and compaction mode combinations are included.

A statistical summary of gradations performed on filter materials A and B are summarized in Appendix A. Plates A(1) and A(2) exhibit a range of gradations for both filter materials against a published range of gradations for the dumped shell material (Abstract of Stability-Related Data Harriman Dam, Geotechnical Engineers, Inc., 1981). The dashed line represents the cummulative average of all filter gradations measured. Filter materials A and B meet accepted filter design criteria. To avoid having the base material pass through the pores of the filter, the filter should meet the following criteria (Cedergren, 1977):

$$\frac{D_{15}\text{ (filter)}}{D_{85}\text{ (base)}} < 4 \text{ to } 5 < \frac{D_{15}\text{ (filter)}}{D_{15}\text{ (base)}}$$

Using filter material B as an example, the fine particle size limit for D_{85} base equals 0.65 mm and the coarse particle size limit for D_{15} filter equals 1.66 mm, the D_{15} (filter)/D_{85} (base) equals 2.5. Using the coarse limit for D_{15} of the base (0.16 mm), the D_{15} (filter)/D_{15} (base) equals 10.0. Both ratios meet the above criteria. Current filter design methods recommend a maximum particle size of three inches and there should be no more than five to six percent fines (< #200 sieve). Considerable effort was directed toward developing a relationship between dry sieve and wash sieve analyses, a composite plot showing this relationship is shown on Plate A(3) in Appendix B. Visual inspection of Plate A(3) reveals that a factor of 1.35 times the dry sieve percentage is equal to the wash sieve percentage.

The filter zone was tied directly into the abutment features. This insured pore water pressure equalization between the overlay and the abutment. Failure to allow pressure equalization could cause surface slides or excessive pore water pressure buildup. Occasionally the subgrade material was overly wet, requiring additional filter material to be placed. An additional foot of filter drain blanket material was used between station 11+00 and the left abutment extending from elevation 1311.0 to 1335.0. Additional filter drain blanket material was used between stations 9+00 and 11+00 from elevation 1317.5 to 1325.0. In these areas the four foot thick blanket insured a quality filter with no "pumped up" subgrade material, the additional filter material behaved much like a mud-mat, without adversely affecting the flow capacity of the three foot thick blanket.

(3) Impervious Rolled Fill - The major portion of the overlay was constructed with glacial till found along the right abutment. This material was well suited for the project with a natural moisture content averaging one percent above optimum (based on Standard Proctor tests) and the wet bulk density achieved during compaction was better than expected, averaging above 146.0 pounds per cubic foot (pcf). Minimal processing was required to prepare the till, and loaders were used to remove oversize in the pit (see Photo 1). Any oversize found on the overlay were pushed aside with dozers and hand labor.

Compaction effort for the till was accomplished using a DynaPac CC 50-PD (a double drum soil compactor with articulated steering and hydrostatically driven dual amplitude vibratory pad drums). Initially, this piece of equipment did not meet the particulars of the contract specification; therefore, requiring the machine to be proven on test sections. The machine performed favorably. Initial lift thickness was 12 inches loose with an eight inch maximum particle size. This was relaxed later to 18 inch lifts with 12 inch maximum particle size. To insure compactive effort, density measurements were made on the bottom six inches of the lift. There were only seven failures on the overlay section during the entire project. Either, overly wet material was brought onto the fill, or the actual section had not received the required number of passes. Each failed test resulted in corrective action by removing wet material or additional compaction and was retested.

The Hilf Method of Rapid Compaction Control compared well with the Standard Proctor tests performed on the borrow material. The Hilf method indicated that the optimum moisture content was 9.1 percent, Standard Proctor tests average 9.2 percent. On the basis of 161 Hilf tests performed, the average fill moisture was 10.1 percent. The average wet bulk density was 146.5 pcf. Based on wet bulk densities, the average fill density is 100.8 percent of Standard Proctor. In terms of dry density, Standard Proctor tests yielded an optimum density of 131.7 pcf.

Assuming averages with the Hilf method, the 146.5 pcf wet density is 133.1 pcf dry (10.1 percent water). Comparing dry densities (in-place Hilf tests with Standard Proctor tests) the percent compaction is 101.1 percent of Standard Proctor. This represents less than one percent error using the Hilf method. Earthwork control summaries on the Impervious Fill are presented in Appendix B. Results of Standard Proctor tests performed on the borrow material are presented on Plate B(1).

Throughout the construction program, the impervious fill was travelled uniformly to reduce rutting and pumping. In addition, after every period of rain or heavy frost a sufficient thickness of material was removed from the current working level to expose undisturbed material.

Progress of the construction effort was measured in terms of the amount of impervious fill placed to-date. The project fill curve is shown on Plate 11. Estimated daily truck count volumes (cubic yards) and elevations placed-to-date are shown on the curve.

f. Location of Wet Areas Exposed During Construction - Since Harriman Dam was overgrown with small shrubs and trees along the abutments, the stripping and excavation operations exposed a number of wet areas. These wet areas were located during the inspection and analysis programs (c. 1981). However, the extent and/or source of these wet spots were not well known nor understood. Plate 12 illustrates the seeps and wet areas exposed during the excavation operations. Overall, there was little seepage exiting through the embankment onto the downstream slope. Most seepage areas were limited to the embankment abutment contacts and were especially evident along the toe of the embankment between stations 3+50 and 7+00. There was one line of seepage on the embankment slope between stations 11+00 and 12+50 and elevations 1325.0 and 1328.0. Photo 7 shows the result of this line of seepage flowing down the exposed subgrade, it should be noted that the quantities are minimal. This line of seepage was recognized in 1979, when a NEPSCo/MAIN effort installed a french drain to collect a portion of this seepage for measurement.

The seeps along the right abutment between stations 9+00 and 7+50 are not directly related to embankment seepage. The seeps are generated from the swamp area. Seepage passing through the embankment is collected and carried by an ablation till (permeable silty sandy gravel) which overlays a lodgement till (impermeable silts and clays). The interface between these soil types carries considerable amounts of water. These two layers are easily recognized along the right abutment. The slope between the swamp area and the former river bottom (glacial terrace), as shown on Photo 4, exits a line of seepage across this slope. Plate 13 illustrates the hypothesis made above. Water draining down the slope from the two soil contacts collects along the embankment/abutment contact. The water flows downstream along the contact, however, it was evident when material was excavated the water did not saturate the embankment itself.

g. Drain Collector System - A series of perforated drain pipes were installed within the filter drain blanket. These drain pipes were located along the abutments and downstream toe of the embankment overlay as shown on Photo 6 and on Plates 4 and 7. Additional drain pipes were installed near visible wet spots, notably the drain pipe replacing the former french drain near station 12+00 (elevation 1327.0). Locating the drain pipe near the wet areas facilitates more rapid dewatering. At the interface between filter materials A and B a positively graded drain pipe system was installed in material B to collect embankment seepage before it entered material A (see Photo 7). The entire drain pipe collection system has six outfall locations. At each outfall, a 60° "V"-notch weir box, is provided to measure seepage flow. There are two weir boxes in a precast manhole to facilitate a dry measuring environment and minimize freeze of the drain pipe collection system. Plate 5 shows the "As-Built" details of the collector drain manholes. The collector drain manholes are located at three locations; 1) Manhole No. 1 - "swamp area", station 5+80/53+84 as shown in Photo 8; 2) Manhole No. 2 - toe of the embankment, station 10+00/56+43.5 and 3) Manhole No. 3 - left abutment, station 13+25/53+83. Weir box identification proceeds from right to left looking downstream, e.g. weir box #1 and #2 are located in Manhole No. 1.

Before construction began, a decision was made not to use the originally planned coarse filter material around the perforated drain pipe. In lieu of the coarse filter material, a four inch diameter PVC drain pipe with 5/8" perforated holes was wrapped with filter fabric (Mirafi or equivalent), thereby allowing the filter fabric wrapped drain pipe to be installed directly in the filter drain blanket material.

h. Instrumentation - Forty two (42) piezometers were installed on the downstream face of the embankment between the period of July 1979 and June 1981. To place an overlay on the downstream face, the instrument leads for each piezometer had to be relocated from their present location to centralized monitoring stations. Piezometer lead relocation was accomplished by removing the old cover pipes and splicing new leads onto the leads which connect to the piezometer unit in the embankment. Once the new leads were connected, piezometer readings were made to see if the readings might have changed. Plate 6 illustrates the details of the piezometer lead relocation program. None of the piezometer readings change significantly, but the time to obtain initial reading became longer, e.g. two to four minutes. Once the piezometer leads were filled with the nitrogen gas after the initial readings, the reading time was significantly reduced. The leads were then placed in trenches excavated at least two feet below the proposed stripping grades. Once the trenches were excavated to their required elevation, they were backfilled with two or three inches of filter material for bedding, then the piezometer leads were set on top. A two foot minimum of filter material was backfilled over the leads to insure proper protection. Random fill (till) was backfilled over the filter material to protect against truck traffic and slope wash. Locations of all the piezometer lead relocation trenches are shown on Plate 7.

There are two piezometer monitoring stations that contain all of the downstream leads. Monitoring Station No. 1 is located on the left abutment and Monitoring Station No. 2 is located on the right abutment. Details concerning the monitoring stations are shown on Plate 6. All piezometer leads are mounted with quick connect fittings to the instrument panel. In all cases, the black tube (output) is mounted on the left and the white tube (input) is mounted on the right. The layout arrangement for each panel is noted in the Haley & Aldrich, Inc. Memorandum to Pizzagalli Construction Co. dated 9 October 1981. This memorandum is included in Appendix C. In addition, this memo contains all piezometer readings recorded during the construction period.

Prior to overlay construction, there were nine ground water observation wells on the downstream slope. Many of these wells have been monitored continuously since c. 1934. It was decided that three of the wells, Nos.

21, 25 and 26, would be instrumented with piezometers. The remaining six wells Nos. 6, 19, 27, 29, 30 and 31, would be grouted and abandoned. Observation wells Nos. 21, 25 and 26 were instrumented with SINCO Model No. 51481 piezometers. Plate 5 illustrates such an instrumented observation well. Key information concerning the instrumented wells follows:

Well No.	Diaphragm Elevation	Bottom of Pipe
21	1312.0	1310.0
25	1313.2	1311.2
26	1366.5	1364.5

Piezometric pressures recorded from the wells are exactly the same as pressures measured in the instrumented soil borings and therefore should be treated equally in any future analyses.

Piezometers Nos. 11A, 12A, 13A and 14A located in borings B-11, 12, 13 and 14 located in the "swamp area" were buried. Observation well, GW-101, was also buried. If in the future, piezometric data is required from these boreholes, the cover pipes will have to be uncovered. To gain access to the impervious fill borrow area, the piezometers at B-10 were abandoned.

i. Crest Service Road - Filter material was used as base material for the roadway across the top of the overlay. The base is 18 inches thick and 20 feet wide. No bituminous surface treatment was applied due to inclement weather. The surface treatment should be applied early summer 1982.

j. Swamp Drain - Extending from the "swamp area" on the right abutment to the toe of the embankment is 342 feet of 12 inch diameter asphalt coated corrugated metal pipe (ACCMP). This drain exits water from the "swamp area" to the river valley bottom without erosion. Former drainage ran directly over the valley wall creating an unsightly gully. The only water entering this drain pipe is seepage water that enters the inverted filter drain which underlying the "swamp area" and also water passing through a newly installed french drain, which extends from Manhole No. 1 to drain pipe inlet headwall. Seepage water entering the swamp drain is almost entirely embankment toe seepage between stations 3+50 to 6+60. Location and details of the swamp drain are located on Plate 4.

k. Toe Spring - A rectangular weir was installed at the toe seep at Harriman dam, just right of the discharge tunnel rock spoil pile. Dimensions of the rectangular weir are; height of notch equal eight inches and the width of the notch is 12 inches. There is approximately four feet of still water behind the opening assuring laminar flows over the notch. See Plate 2 for weir location and Plate 5 for weir details.

V. SURVEILLANCE PROGAM

MAIN recommends that a select group of piezometers and weir boxes be read and recorded on a regular basis over the next two years. A list of 20 Critical Piezometers and seven weirs should be read on following schedule:

1 January to 28 Feburary -- once a week (Tuesday)

1 March to 31 May -- twice a week (Tuesday, Friday)

1 June to 31 December -- once a week (Tuesday)

This schedule should be revised during any abnormal storm period effecting the normal operation of the dam with the readings taken twice a week. A sample recording sheet is shown in Appendix D. In addition, all piezometers at Harriman dam should be read the first Tuesday of every month. The reservoir elevation should be recorded each time the peizometers are read. The surveillance program after two years (c. 1984) would be reduced to monitoring the Critical Piezometers and weirs biweekly and taking readings on all of the piezometers every two months to insure proper operation and to maintain nitrogen in the piezometer leads.

To calculate flow rates based on head levels running over the wiers, charts for the "V" notch and rectangular weirs are presented in Appendix D. Flow shall be recorded in cubic feet per second (cfs).

PHOTOGRAPHS

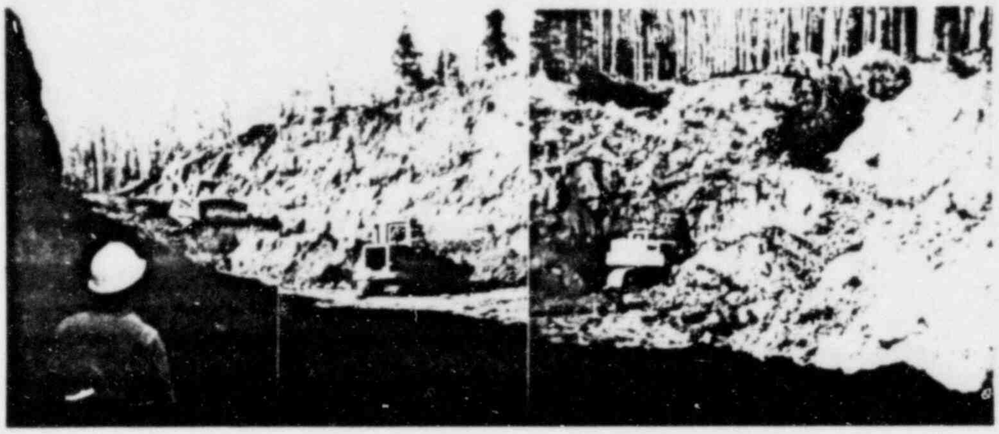


PHOTO 1
IMPERVIOUS TILL BORROW SOURCE (11-3-81)

PHOTO 2
"CARBIDE PIT" — FILTER BLANKET BORROW SOURCE.
MATERIAL PROCESSING INCLUDED SCREENING AND CRUSHING
(8-20-81)

PHOTO 3
OVERLAY CONSTRUCTION
AT EL. 1240 (9-4-81)

PHOTO 4
RIGHT ABUTMENT
CLEANING AND
SUBGRADE PREPARATION
AT EL. 1250 (9-4-81)

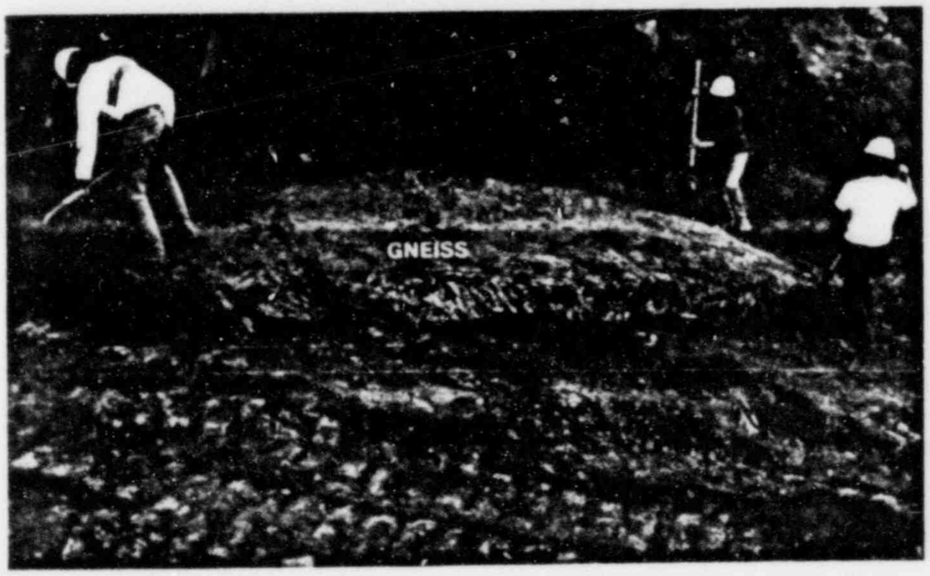


PHOTO 5
LEFT ABUTMENT
BEDROCK CLEANING
AT EL. 1250 (9-5-81)

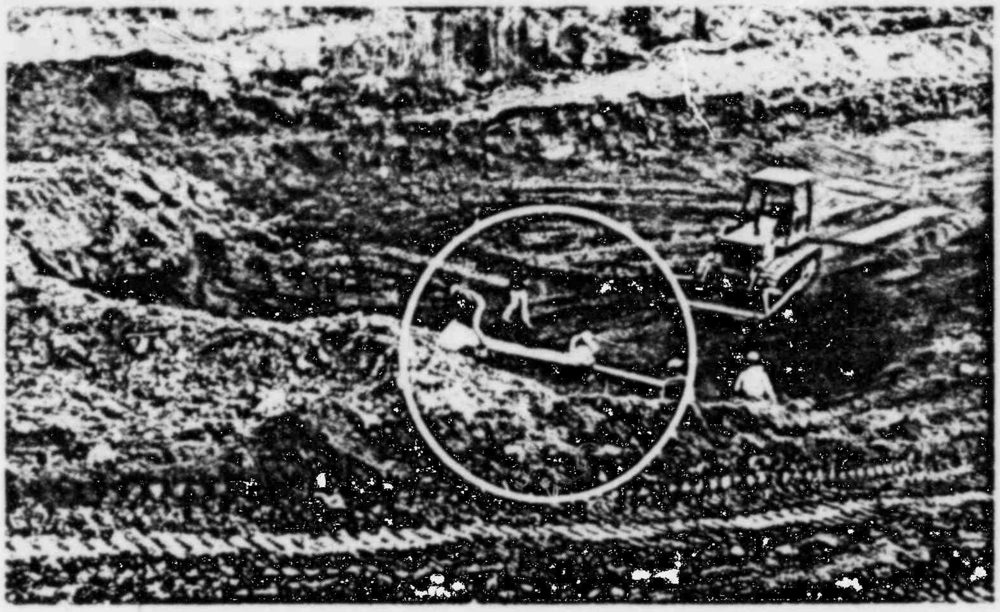


PHOTO 6
PLACEMENT OF
FILTER BLANKET
MATERIAL WITH TOE
DRAIN COLLECTOR
SYSTEM (9-21-81)

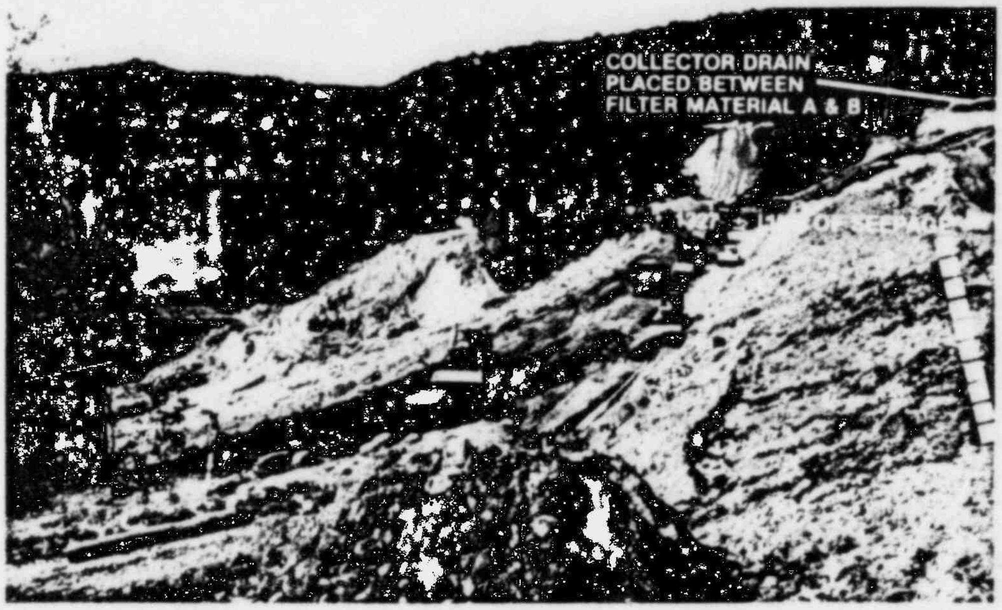


PHOTO 7
OVERLAY CONSTRUCTION
AT EL. 1302 (9-30-81)

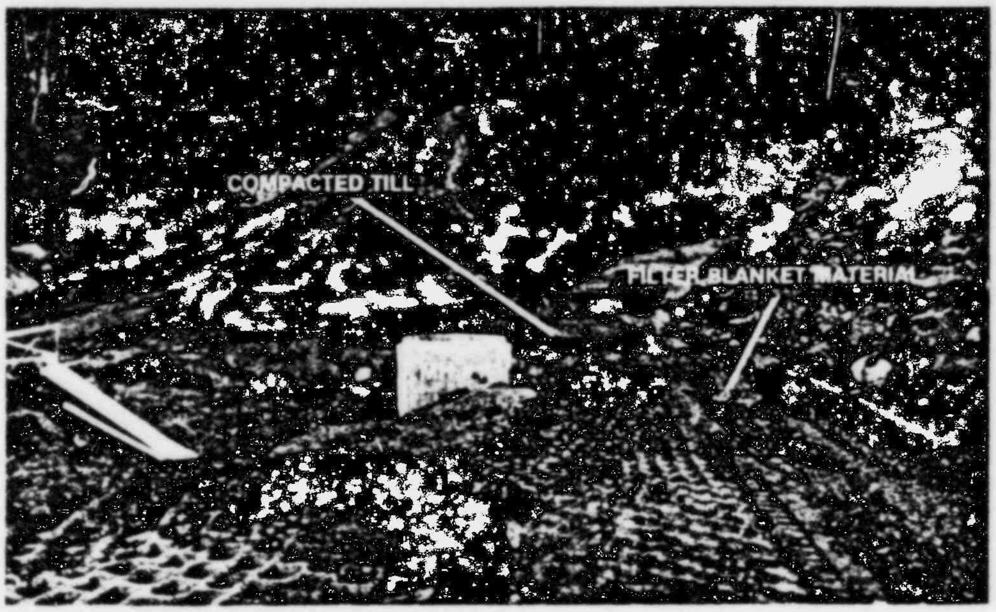


PHOTO 8
TOE DETAIL BETWEEN
STATIONS 6 + 00 AND
3 + 50, EL. 1302 (10-9-81)

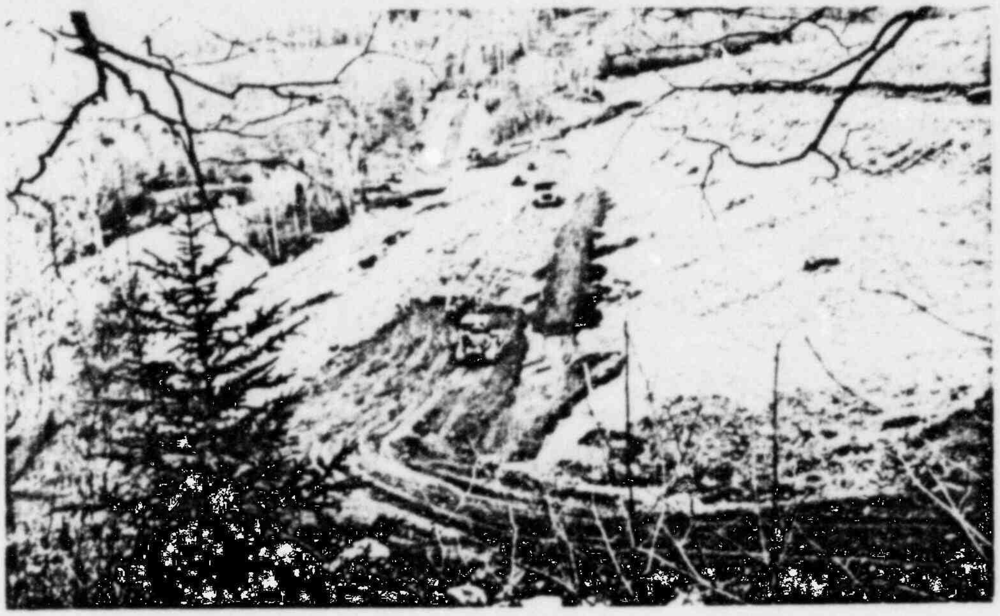


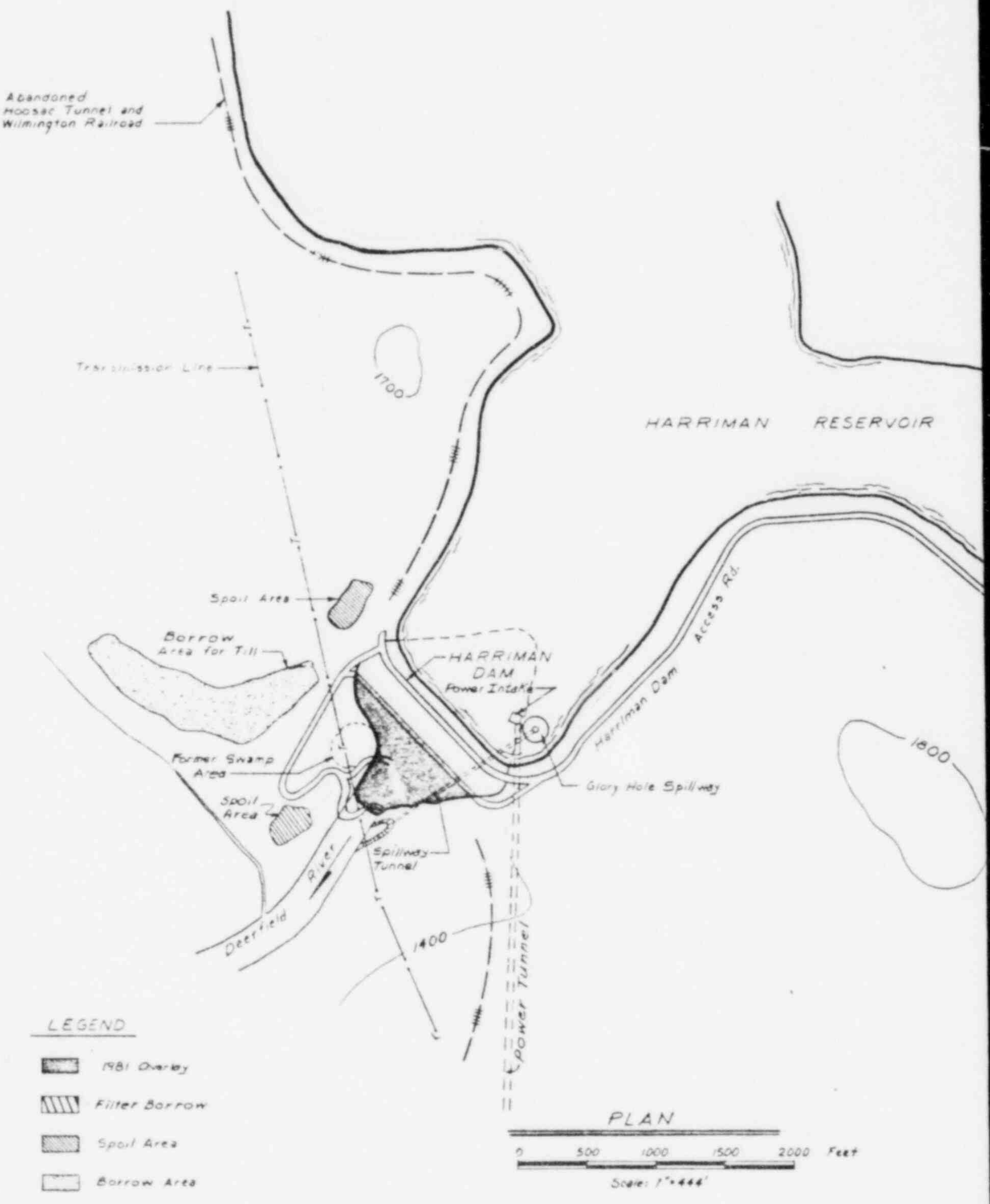
PHOTO 9
OVERLAY CONSTRUCTION
AT EL. 1330 (10-16-81)

PHOTO 10
OVERLAY CONSTRUCTION
AT EL. 1382 (11-12-81)

PHOTO 11
COMPLETED OVERLAY
(11-30-81)

PLATES

H-36647-1

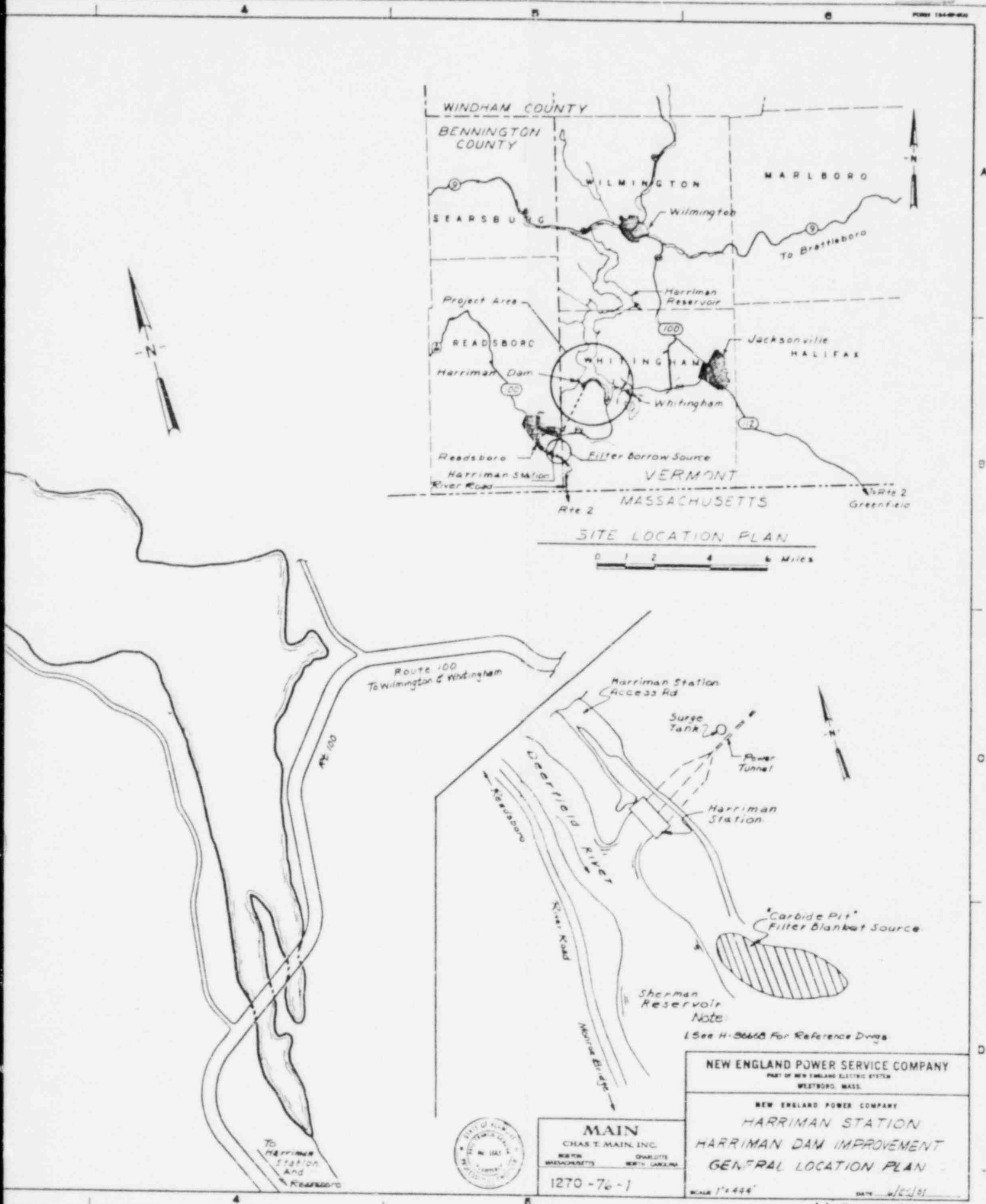


PLAN

REVISIONS

DESCRIPTION

Revised To Show As-Built Conditions



SITE LOCATION PLAN

Note:
1. See H-36668 For Reference Dwgs

NEW ENGLAND POWER SERVICE COMPANY
PART OF NEW ENGLAND ELECTRIC SYSTEM
WESTBORO, MASS.

NEW ENGLAND POWER COMPANY

HARRIMAN STATION
HARRIMAN DAM IMPROVEMENT
GENERAL LOCATION PLAN

SCALE 1" = 444'
DATE 6/25/81

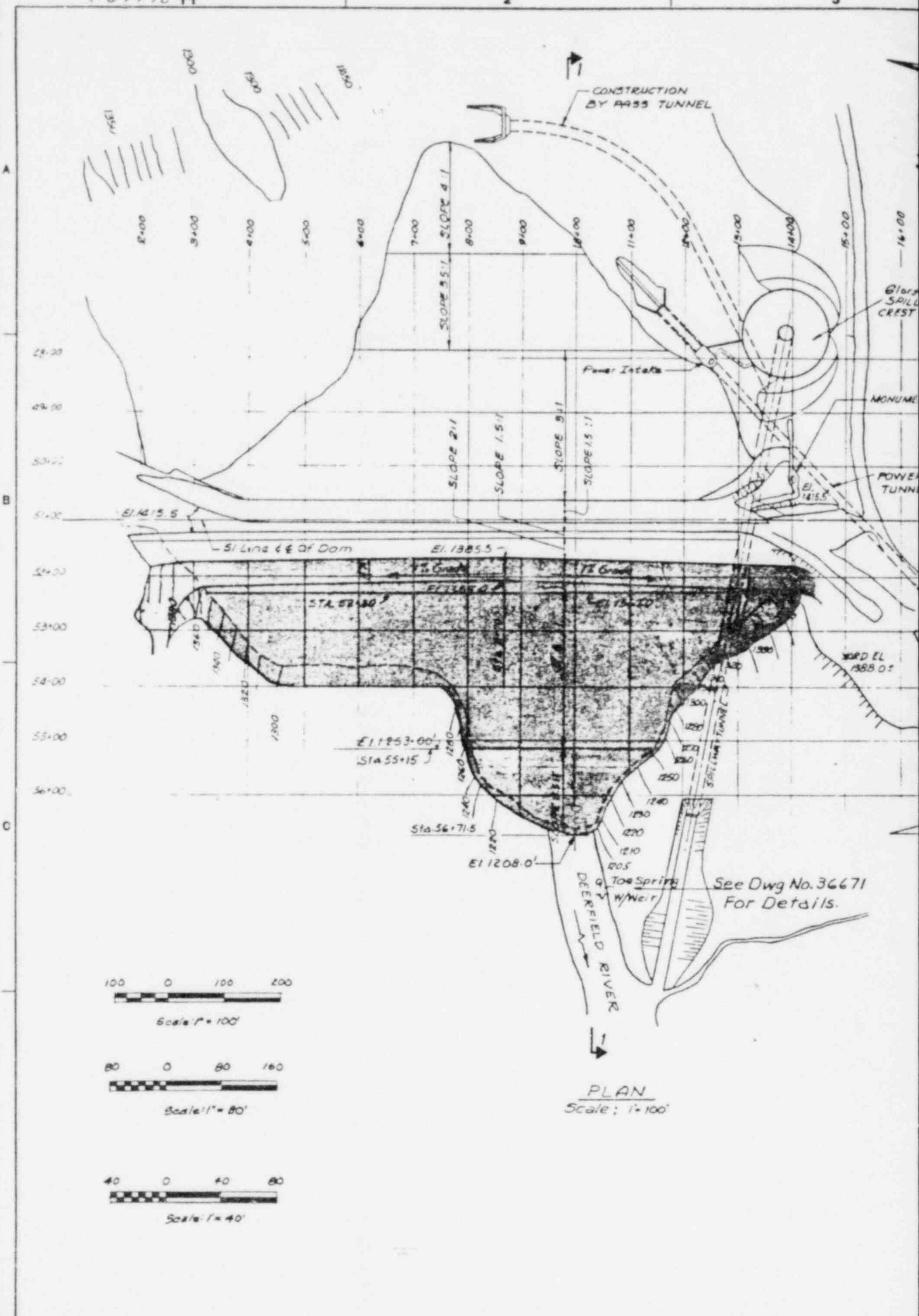
MAIN
CHAS. T. MAIN, INC.
BOSTON MASSACHUSETTS
CHARLOTTE NORTH CAROLINA

1270-76-1

H-36667-1

PLATE 1

H-36668-1

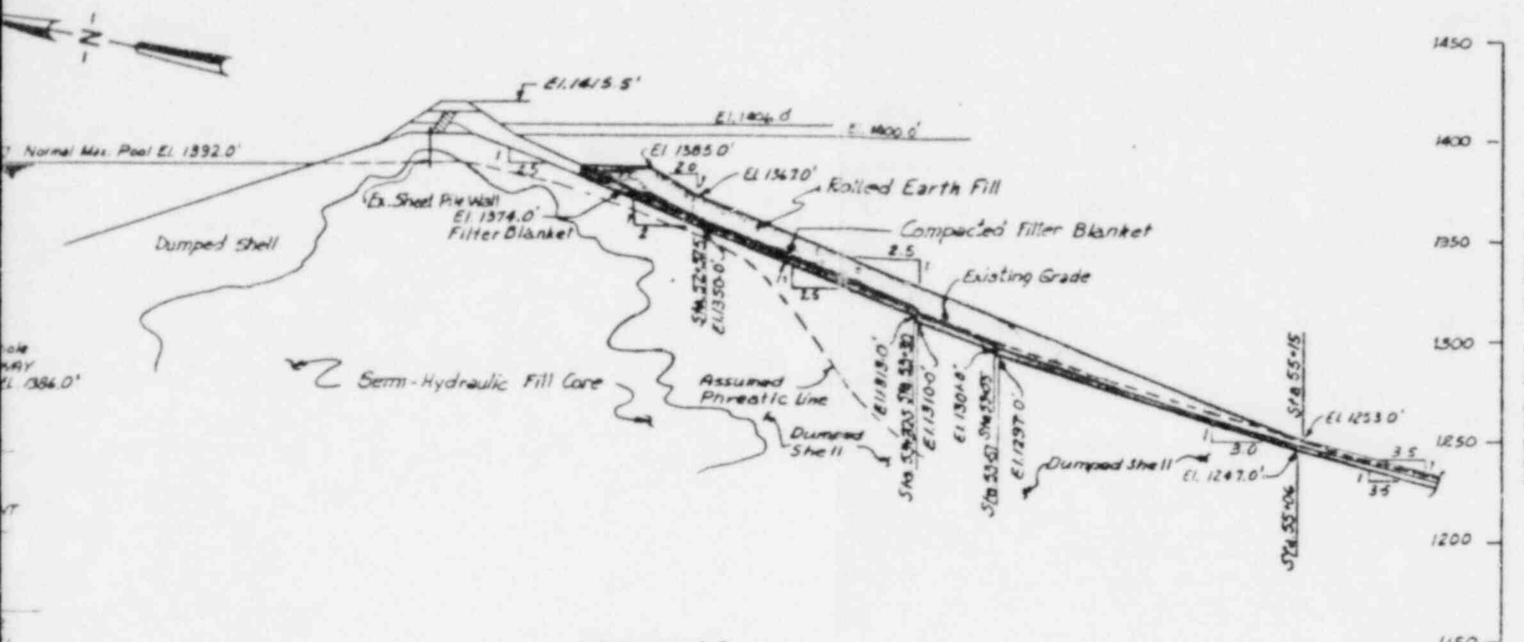


PLAN
Scale: 1" = 100'

REVISIONS

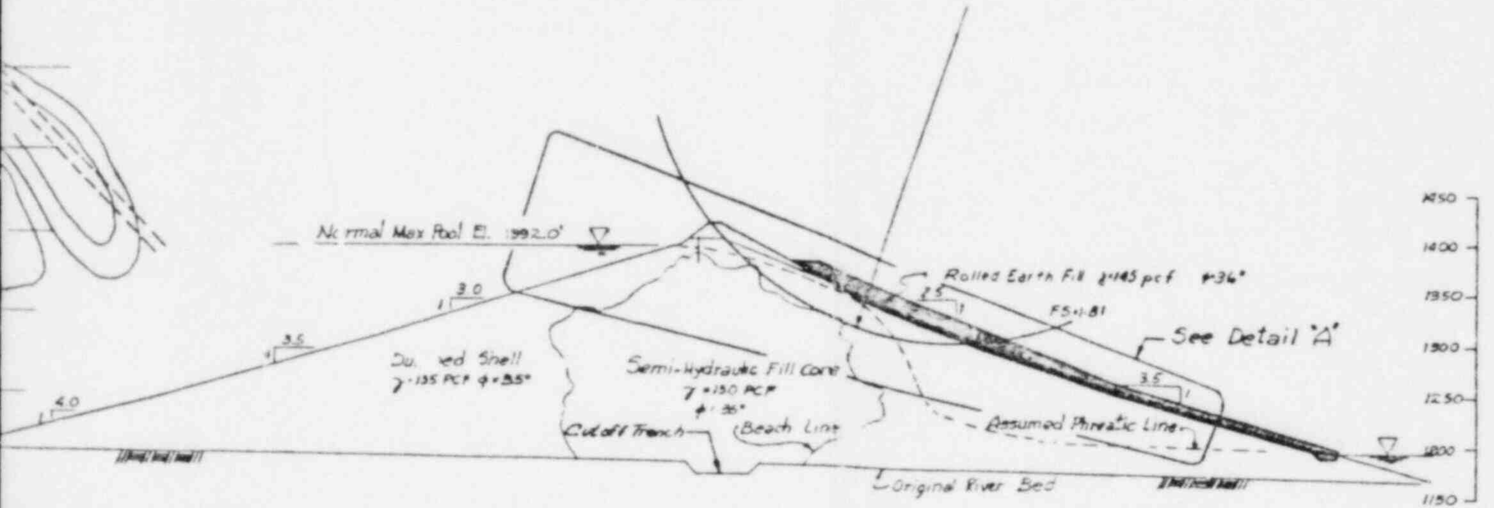
REV	DATE	DESCRIPTION	MADE	CHECKED	INSPECTED	CORRECT	APPROVED
	12/1/82	Revised To Show "As Built" Conditions			LAW		AD

ORIGINAL	
DATE	6/16/81
DESIGNED	WJW
CHECKED	
DRAWN	MAP
CHECKED	
INSPECTED	
CORRECT	
APPROVED	
APPROVED	



DETAIL-'A'

Station 10+00
Scale: 1" = 40'



SECTION 1-1

Station 10+00
Scale: 1" = 80'

LEGEND

▨ As Built 1981 Downstream Overlay

NOTES:

NEPSCo Datum is 105.66 Below NGVD

REFERENCE DRAWINGS

H-36667 General Location Plan
H-36669 Crest Details
H-36670 Details
H-36671 Instrumentation Details Sh 1
H-36672 Instrumentation Details Sh 2
H-36740 Overlay Instrumentation Location Details

MAIN
CHAS. T. MAIN, INC.
BOSTON MASSACHUSETTS
CHARLOTTE NORTH CAROLINA

1270 -76 - 2

NEW ENGLAND POWER SERVICE COMPANY
PART OF NEW ENGLAND ELECTRIC SYSTEM
WESTBORO, MASS.

NEW ENGLAND POWER COMPANY
HARRIMAN STATION
HARRIMAN DAM IMPROVEMENTS
PLAN & SECTIONS.

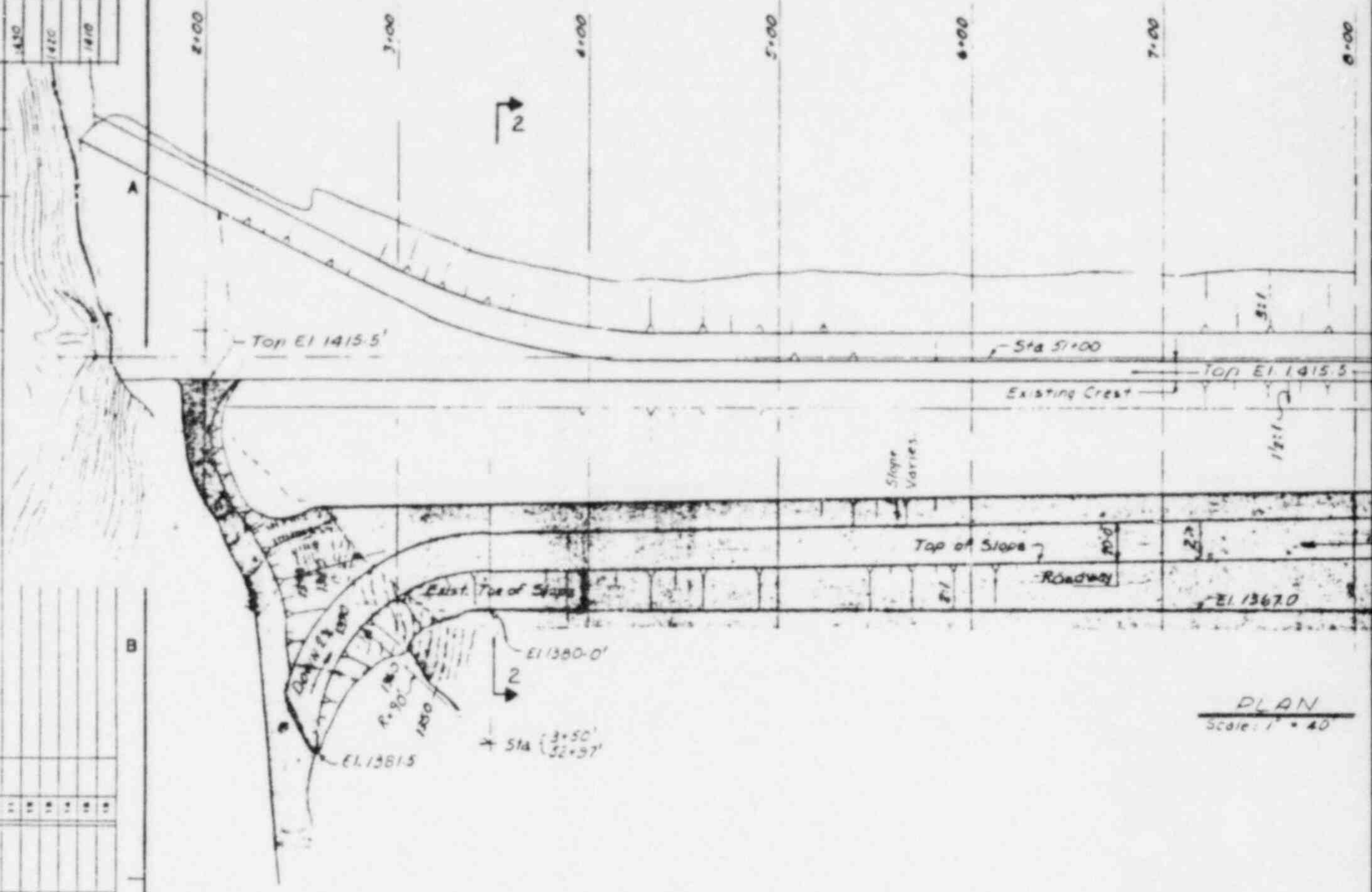
SCALE As Noted
DATE 6/25/81

H-36668

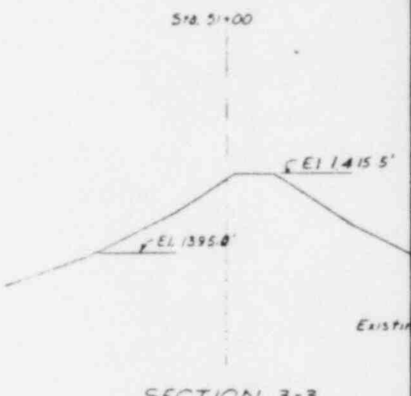
PLATE 2

H-32229-1

ORIGINAL	BY	REV	DATE	DESCRIPTION	MADE	CHECKED	INSPECTED	CORRECT	APPROVED	APPROVED	REV	DATE
DATE 8/16/81												
DESIGNED		1		Revised To Show 'As Built' Condition			WAW			PKH	9	
CHECKED		2									10	
DRAWN		3									11	
CHECKED		4									12	
INSPECTED		5									13	
CORRECT		6									14	
APPROVED		7									15	
APPROVED		8									16	

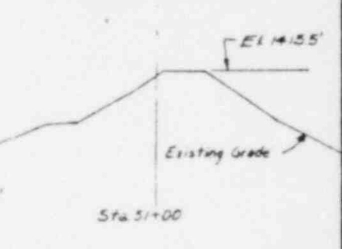


PLAN
Scale: 1" = 40'

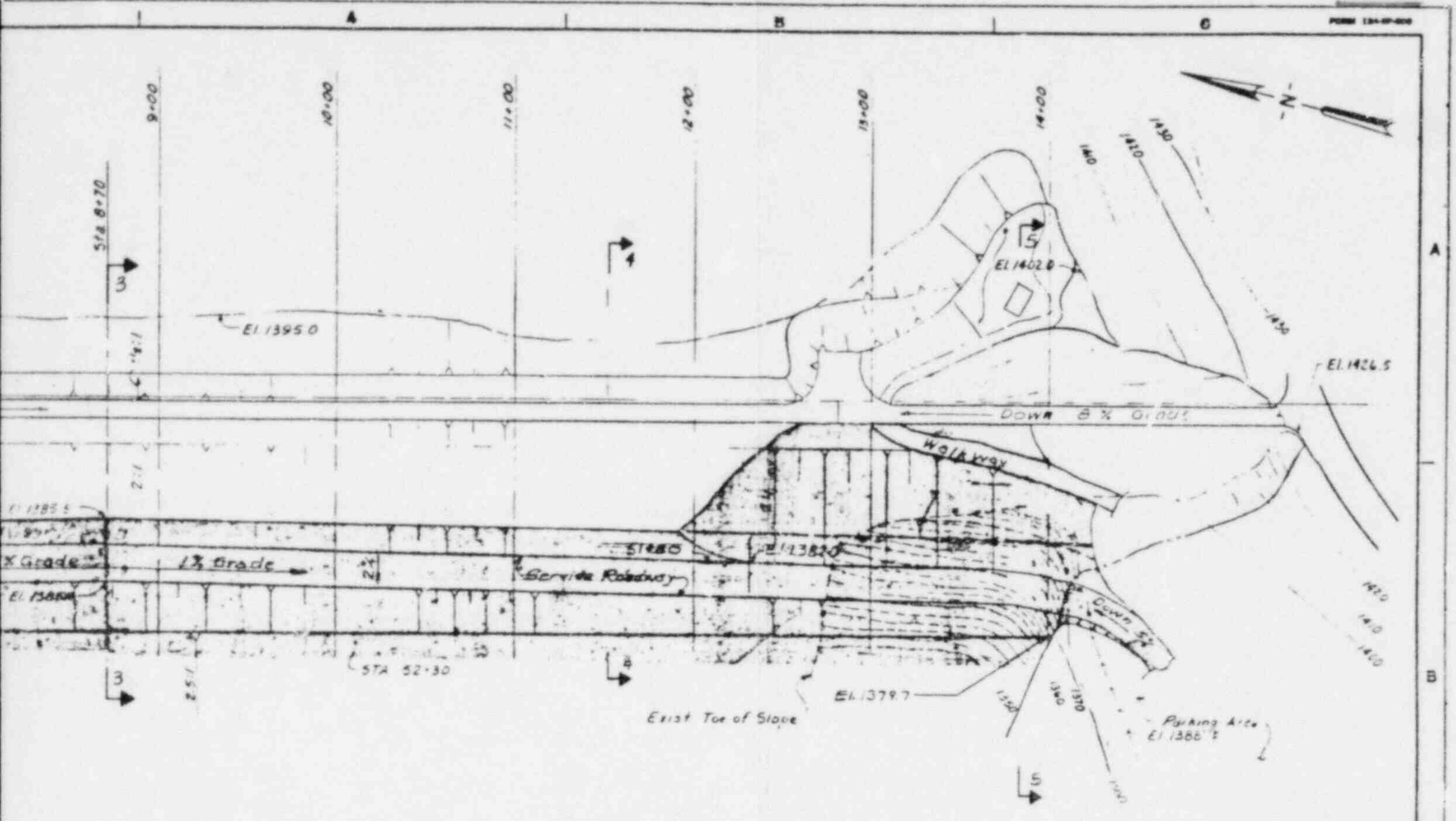


SECTION 3-3
Scale: 1" = 20'

SECTION 2-2
Scale: 1" = 20'



SECTION 4-4
Scale: 1" = 20'



LEGEND

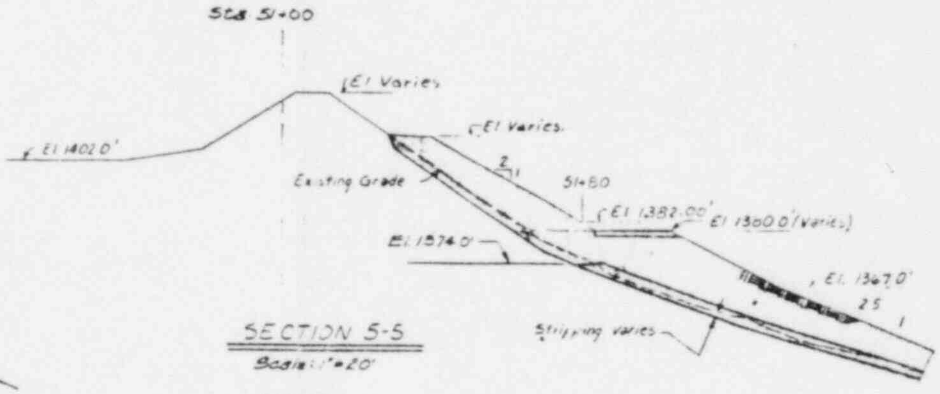
▭ Downstream Overlay

20 0 20 40

Scale: 1" = 20'

40 0 20 40

Scale: 1" = 40'

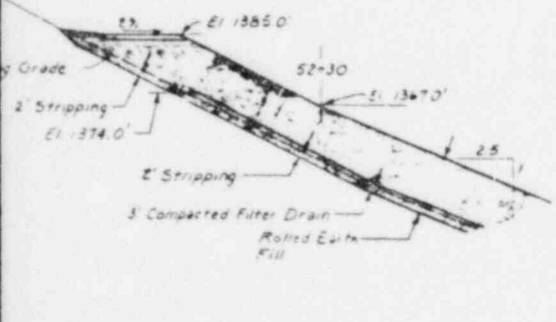


SECTION 5-5

Scale: 1" = 20'

NOTES

1. For Roadway Detail, See Section 7-7, H-36670
2. For Notes And Reference Dwgs. See H-36670



MAIN
CHAS. T. MAIN, INC.
BOSTON MASSACHUSETTS
CHARLOTTE NORTH CAROLINA

1270 - 76 - 3

NEW ENGLAND POWER SERVICE COMPANY
PART OF NEW ENGLAND ELECTRIC SYSTEM
WESTBORO, MASS.

NEW ENGLAND POWER COMPANY
HARRIMAN STATION

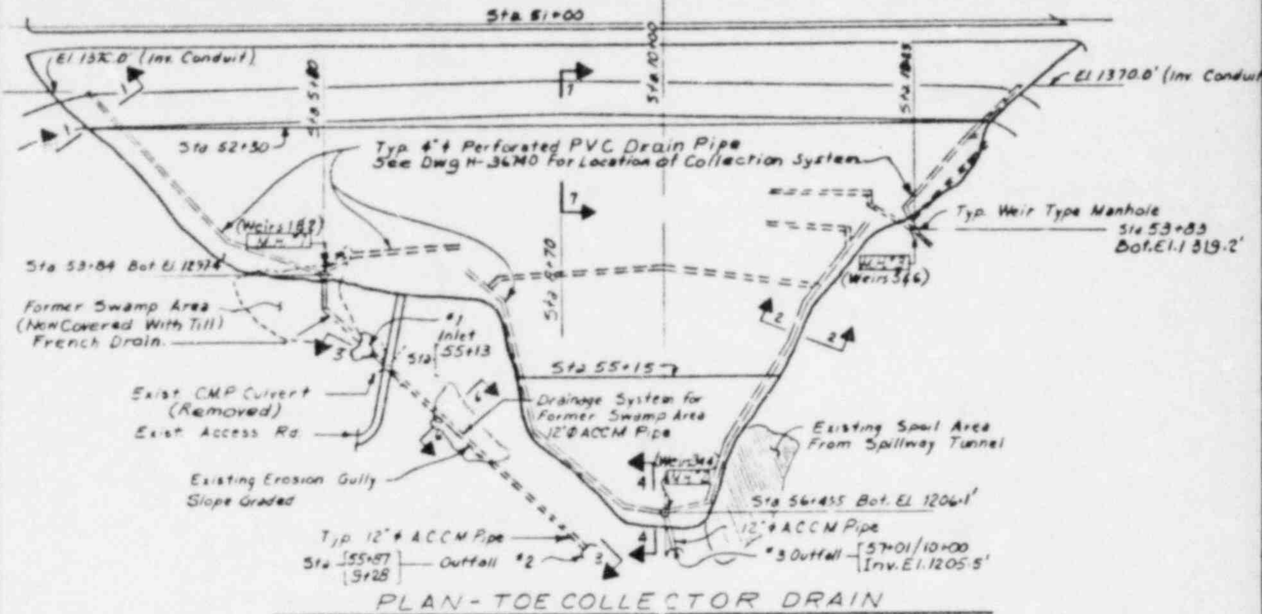
HARRIMAN DAM IMPROVEMENTS
CREST DETAILS

SCALE As Noted
DATE 6/25/81

H-36669-1

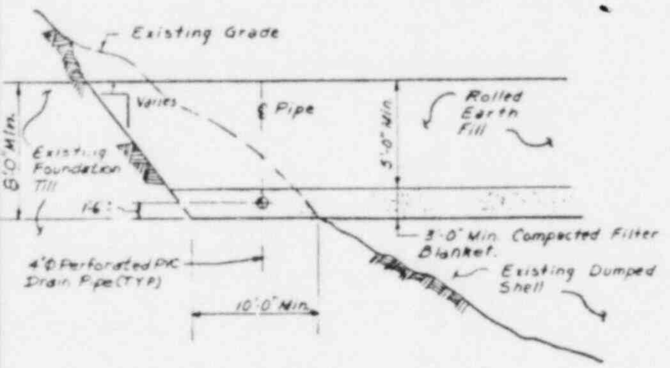
PLATE 3

H-36670-1



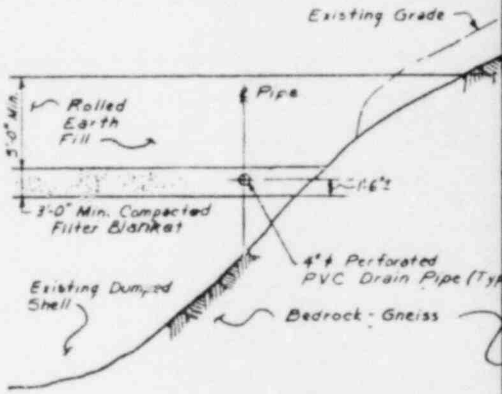
PLAN - TOE COLLECTOR DRAIN

Scale: 1" = 100'



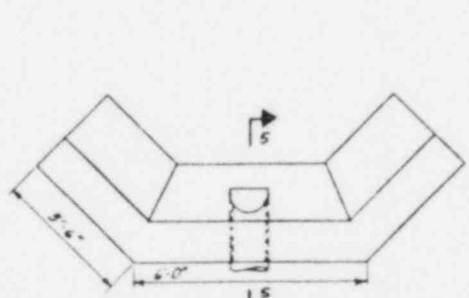
SECTION 1-1

No Scale



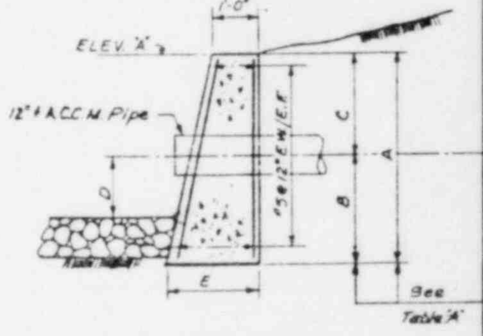
SECTION 2-2

No Scale



PLAN - INLET/OUTFALL

No Scale



SECTION 5-5

No Scale

TABLE "A" INLET							
No.	ELEV. "A"	A	B	C	D	E	REINF.
1	1300.0'±	4'-0"	2'-6"	1'-6"	6"	3'-0"	#5 @ 12" EW/EF
OUTFALL							
2	1215.0'±	6'-C	4'-0"	2'-0"	1'-0"	4'-0"	"
3	1200.0'±	4'-0"	2'-0"	2'-0"	1'-0"	3'-0"	"
4	Deleted						

REVISIONS

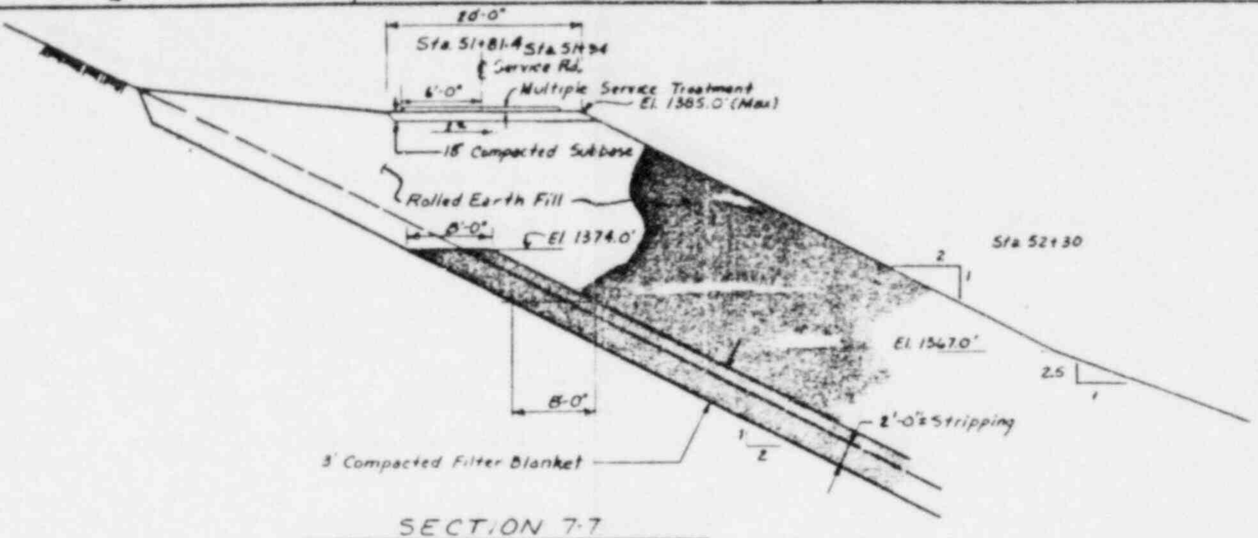
REV. 1 — Revised To Show As Built Conditions — WHW

REVISIONS

ORIGINAL

A B C

1 2 3



SECTION 7-7

STAGE 1 Overlay Sta. 8+70
Scale: 1" = 6'

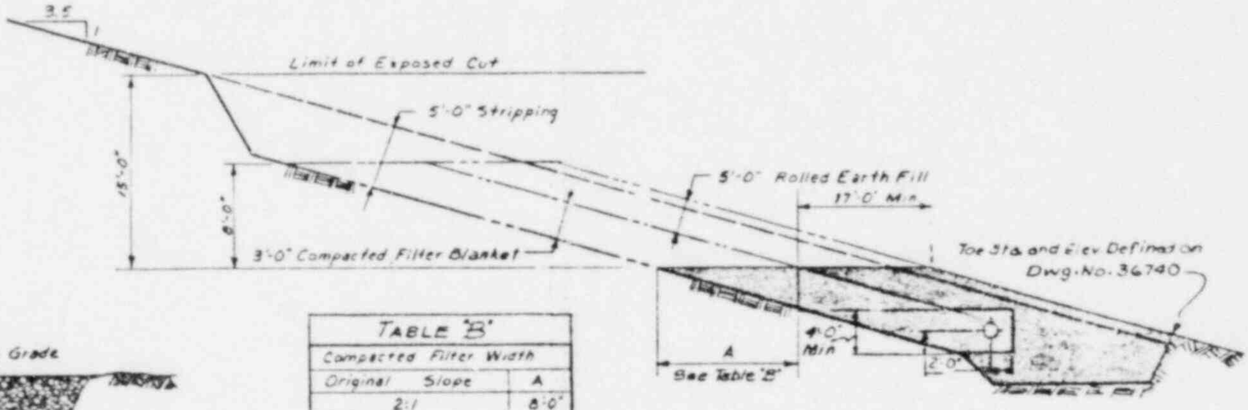
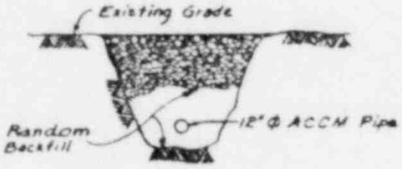


TABLE "B"	
Compacted Filter Width	
Original Slope	A
2:1	8'-0"
2.5:1	8'-0"
3:1	10'-0"
3.5:1	11'-0"



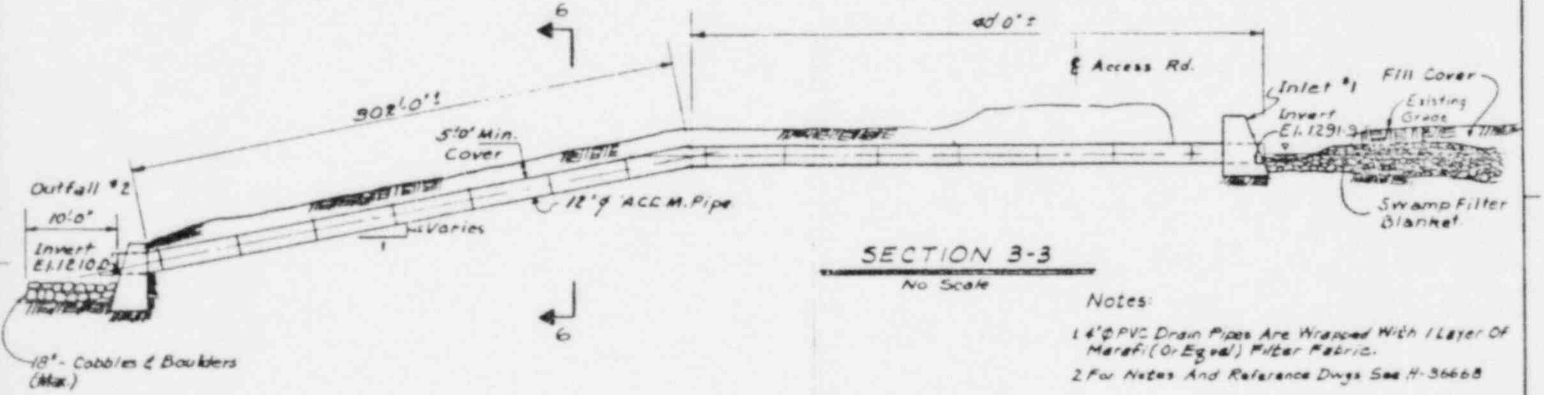
SECTION 6-6

No Scale

CONSTRUCTION PROCEDURE

SECTION 4-4

No Scale

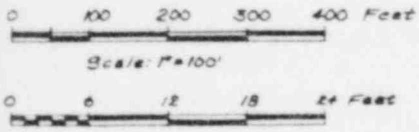


SECTION 3-3

No Scale

Notes:

1. 4" ɸ PVC Drain Pipes Are Wrapped With 1 Layer Of Marafi (Or Equal) Filter Fabric.
2. For Notes And Reference Dwgs See H-36668



MAIN
CHAS. T. MAIN, INC.
BOSTON MASSACHUSETTS
CHARLOTTE NORTH CAROLINA
1270 - 76 - 4

NEW ENGLAND POWER SERVICE COMPANY
PART OF NEW ENGLAND ELECTRIC SYSTEM
WESTBORO, MASS.

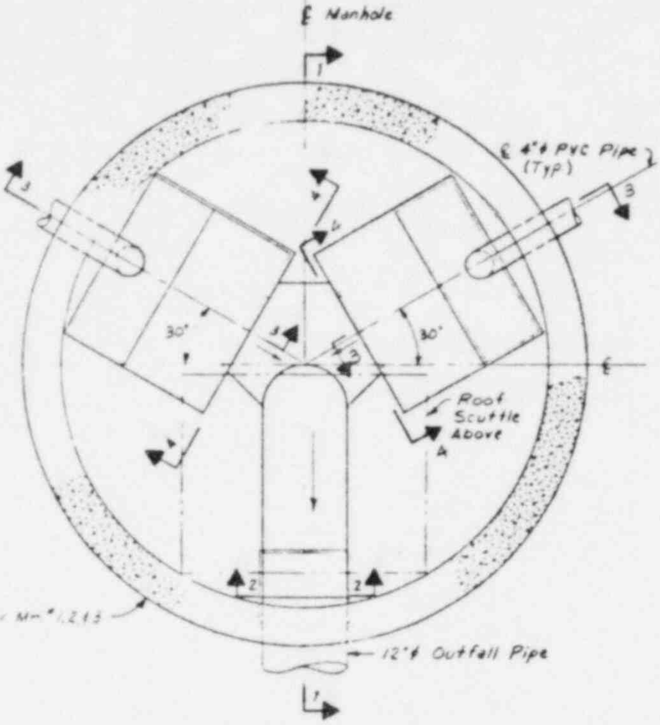
NEW ENGLAND POWER COMPANY
HARRIMAN STATION
HARRIMAN DAM IMPROVEMENTS
DETAILS

SCALE As Noted
DATE 6/25/81

H-36670-1

PLATE 4

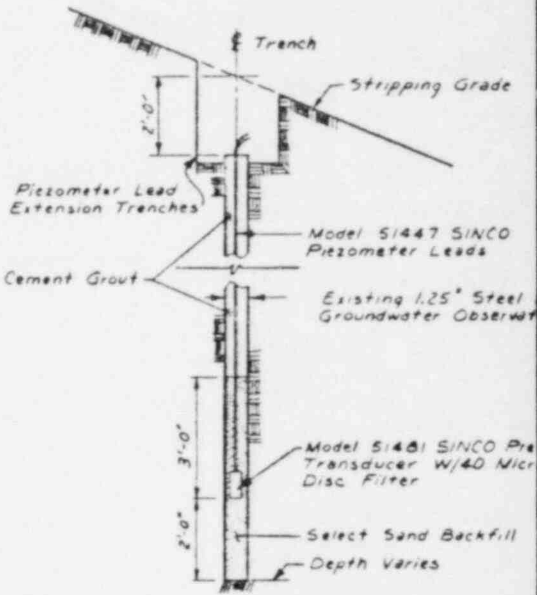
H-36771-1



NOTE: For Mn #1,2&3

PLAN- TYPICAL MANHOLE

Scale 1"=1'-0"

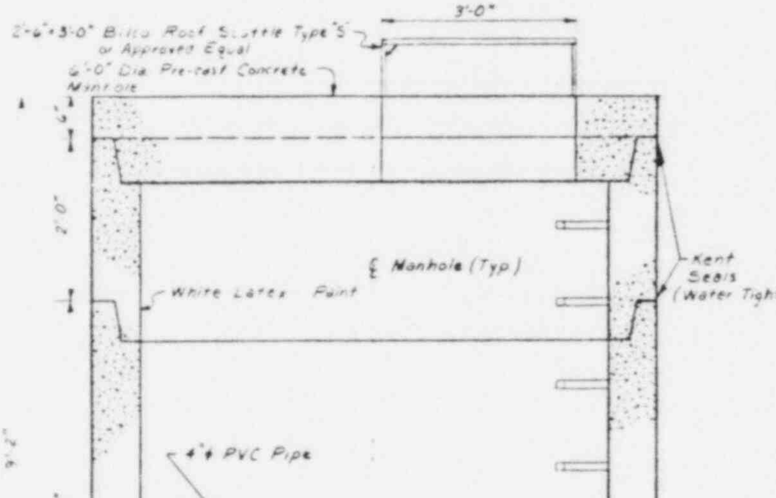


NOTE: The Existing Well Pipes Were Washed Throughly to the Bottom Removing All Debris From We

TYPICAL WELL DETAIL

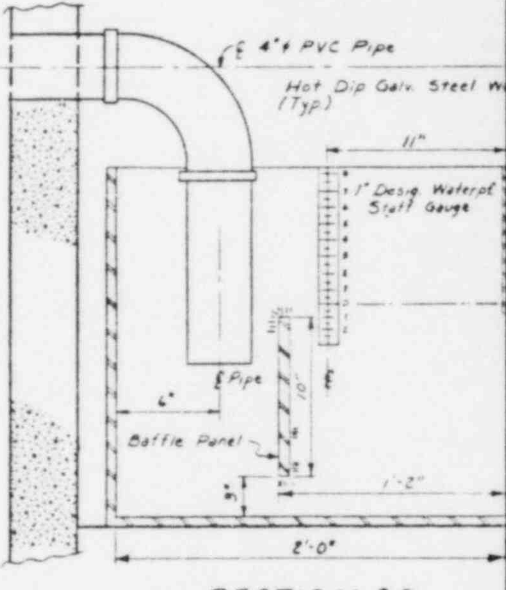
FOR WELLS W-21, 25 & 26

No Scale



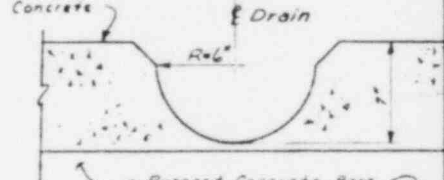
SECTION 1-1

Scale 1"=1'-0"



SECTION 3-3

No Scale



SECTION 2-2

No Scale

REVISIONS

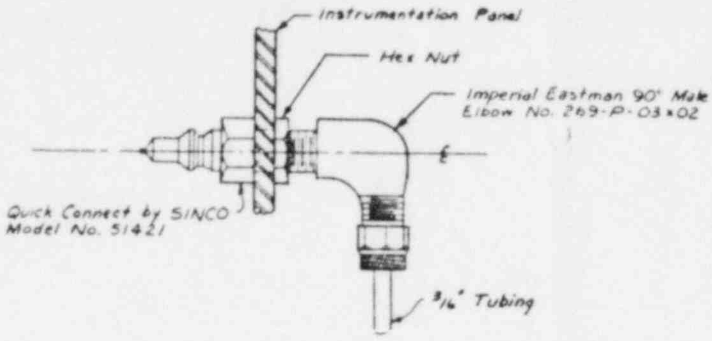
DESCRIPTION

Revised To Show As Built Conditions

INSTRUMENTED WELLS	
Well #	Diaphram El
W-21	1812.0
W-25	1813.2
W-26	1866.0

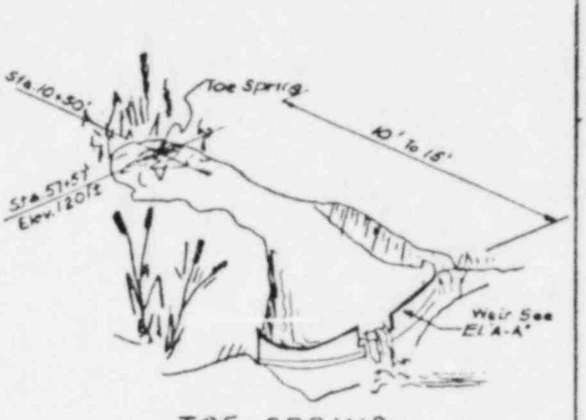
Pipe
on Wells

ssure
on



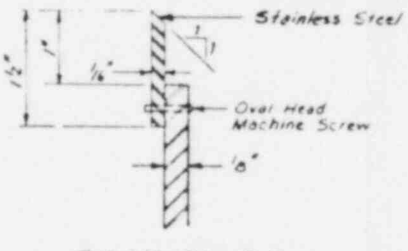
PIEZOMETER FITTING INSTALLATION

No Scale



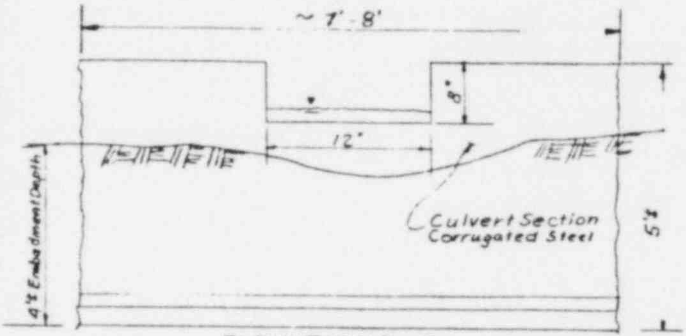
TOE SPRING

No Scale



SECTION 5-5

No Scale



ELEVATION 'A-A'
RECTANGULAR WEIR AT TOE SPRING

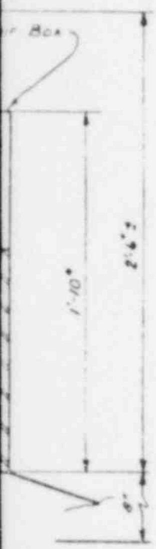
No Scale

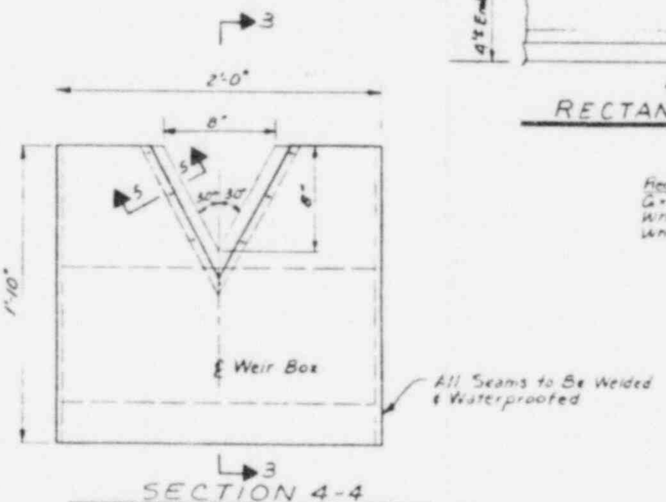
Rectangular Notch Formula

$G = 3.33(L - 0.2H)H^{3/2}$

Where G is in CFS

Where H is in Feet





SECTION 4-4

No Scale

V-Notch Formula

$G = 1.443 H^{5/2}$

Where G is in CFS

Where H is in Feet

Notes

1. For Notes And Reference Dwgs See H-36668

0 1 2 3 4

Scale: 1" = 1'-0"

MAIN
CHAS T MAIN INC
BOSTON MASSACHUSETTS
CHARLOTTE NORTH CAROLINA

1270-76-5

NEW ENGLAND POWER SERVICE COMPANY
PART OF NEW ENGLAND ELECTRIC SYSTEM
WESTBORO, MASS.

NEW ENGLAND POWER COMPANY
HARRIMAN STATION
HARRIMAN DAM IMPROVEMENTS
INSTRUMENTATION DETAILS (SH-1)

SCALE As Noted
DATE 6/25/81

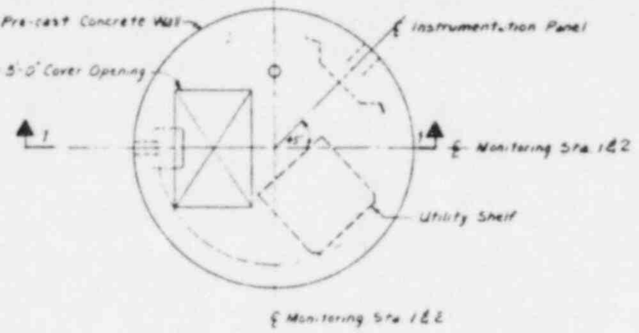
H-36671-1

PLATE 5

H-36672-1

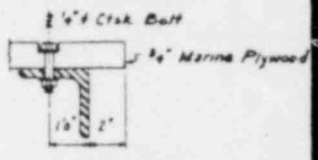
REVISIONS

Revised To Show "As Built Conditions"



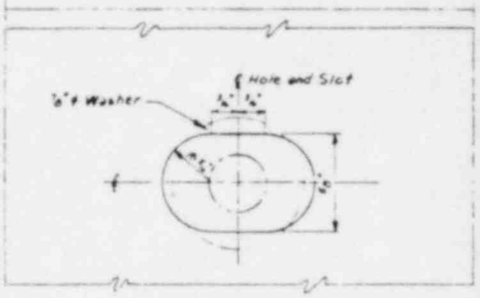
PLAN - PIEZOMETER MONITORING STATIONS 1 and 2

Scale ¼" = 1'-0"



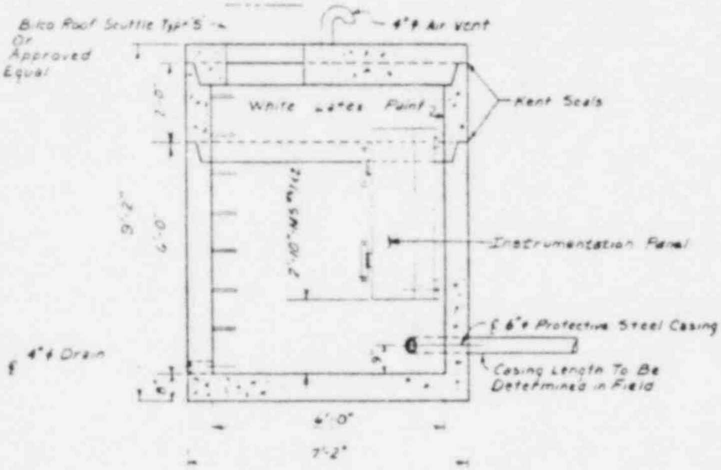
SECTION 3-3

No Scale



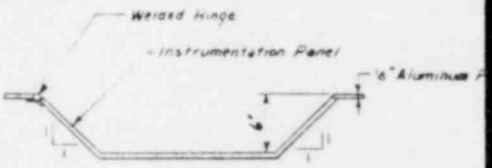
DETAIL "A"

Typical Panel Slot
No Scale



SECTION 1-1

Scale ¼" = 1'-0"



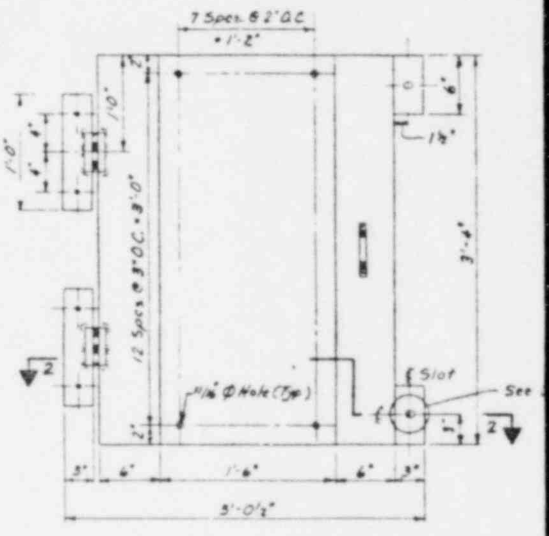
SECTION 2-2

Scale 1½" = 1'-0"

MONITORING STATION #1			
Layout on Instrumentation Panel			
4 A	4 B	5	109 A
109 B	109 C	109 D	110 A
110 B	110 C	110 D	111 A
111 B	112 A	112 B	112 C
114	115	116	117
202 A	202 B	202 C	212 A
212 B	212 C	W - 25	

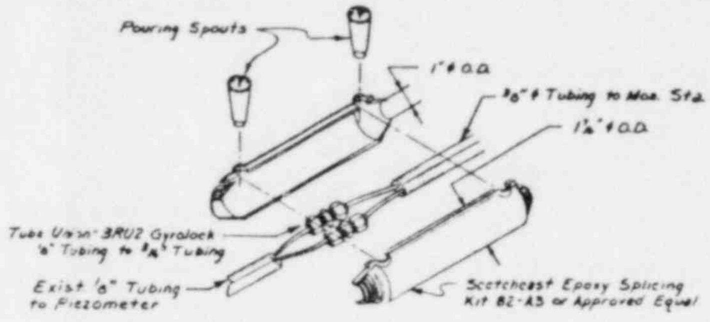
MONITORING STATION #2			
Layout on Instrumentation Panel			
101	102 A	102 B	104 A
104 B	104 C	105 A	105 B
107 A	107 B	108 A	108 B
118	119	201 A	201 B
201 C	208 A	208 B	208 C
W - 21	W - 26		

Note.
In All Cases The Black Tube is Mounted On left And The White Tube Is Mounted on The Right.

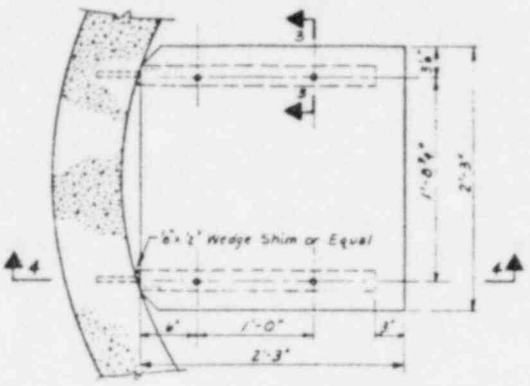


ELEVATION M.S. No 1 & No 2

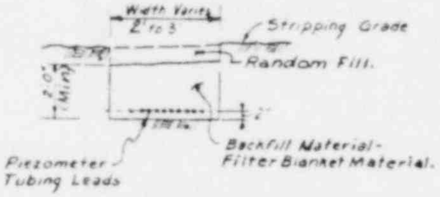
Instrumentation Panel For Monitoring Station No 1 and
Scale: 1½" = 1'-0"



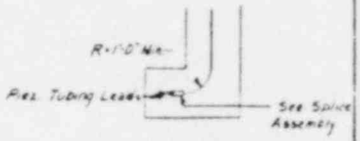
PIEZOMETER TUBE SPLICE ASSEMBLY
No Scale



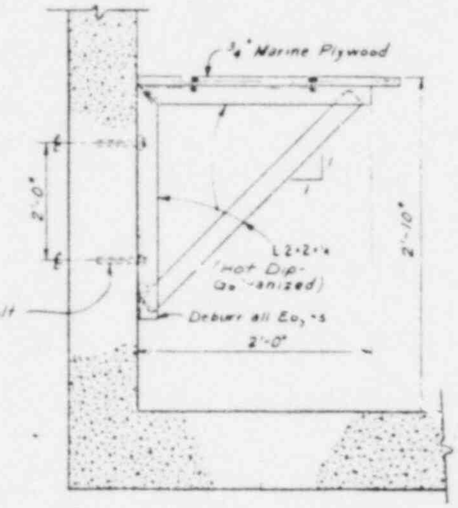
PLAN - UTILITY SHELF
Scale 1 1/2" = 1'-0"



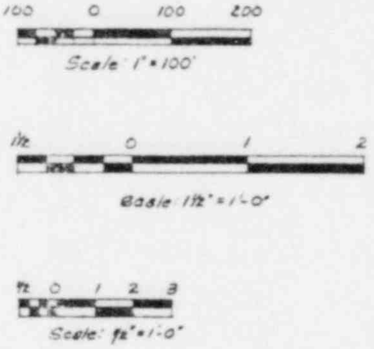
SECTION 5-5
No Scale



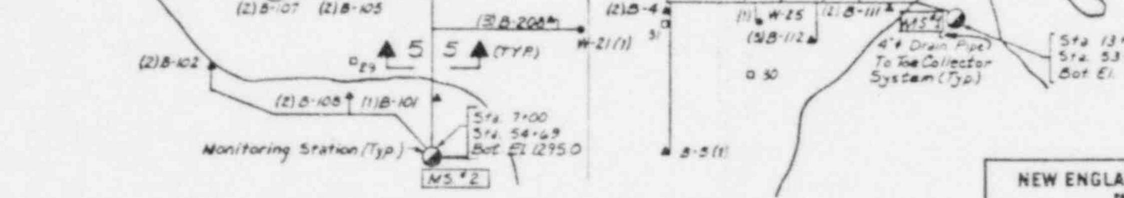
DETAIL "B"
No Scale



SECTION 4-4
Scale 1 1/2" = 1'-0"



Notes:
1. For Notes & Reference Dwgs See H-30668
2. See H-36740 For Location Of Leads



PLAN - RELOCATION of PIEZOMETER LEADS
Scale 1" = 100'-0"

LEGEND

▲● Piezometer And Well Locations

□27 Existing Well To Be Grouted and Abandoned

(1) Denotes Number of Piezometer Tips

MAIN
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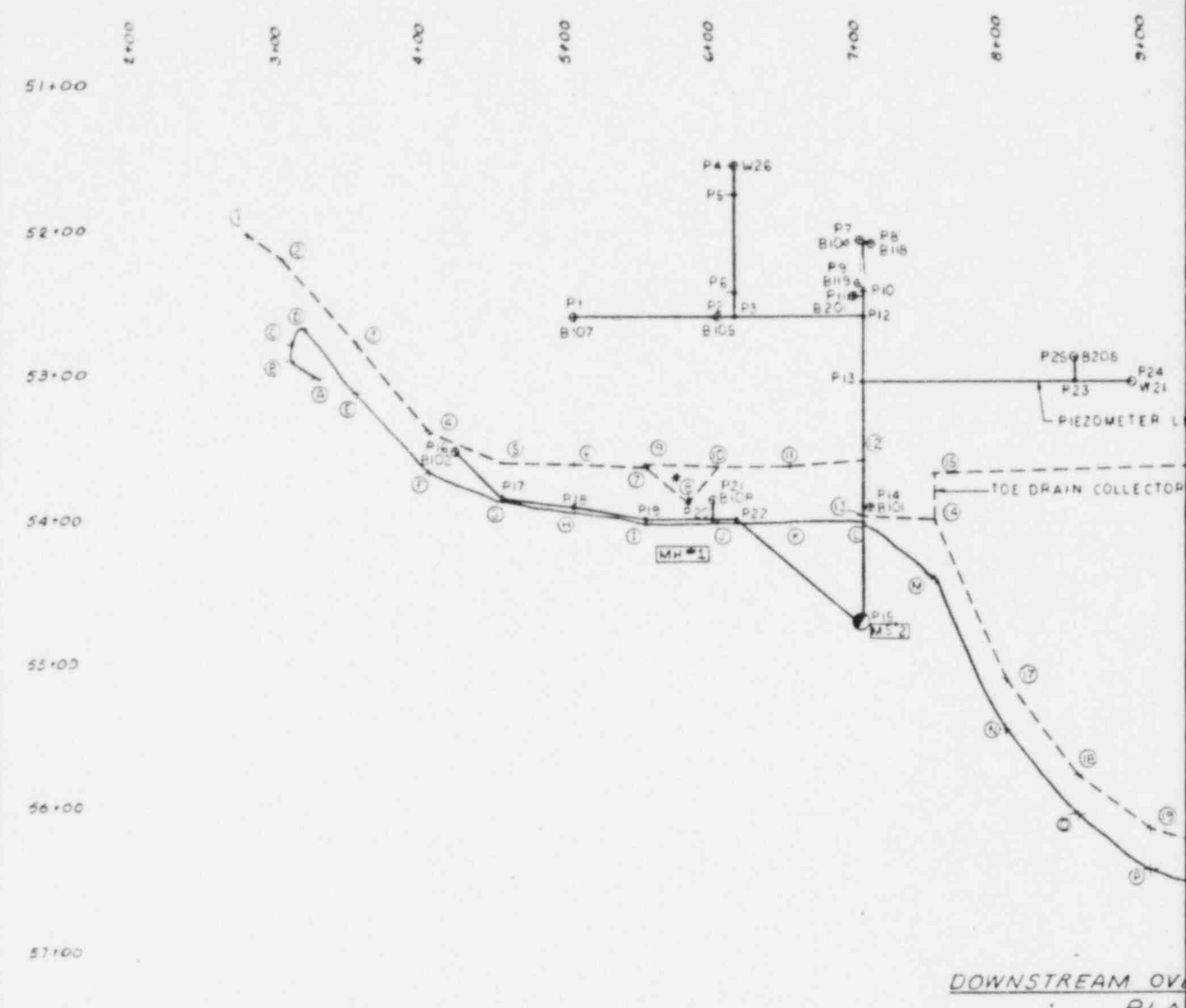
NEW ENGLAND POWER SERVICE COMPANY
PART OF NEW ENGLAND ELECTRIC SYSTEM
WESTBORO, MASS.

NEW ENGLAND POWER COMPANY
HARRIMAN STATION
HARRIMAN DAM IMPROVEMENTS
INSTRUMENTATION DETAILS (SH-2)

SCALE As Noted
DATE 6/25/81

H-36672-1

PLATE 6



DOWNSTREAM OV

PLA

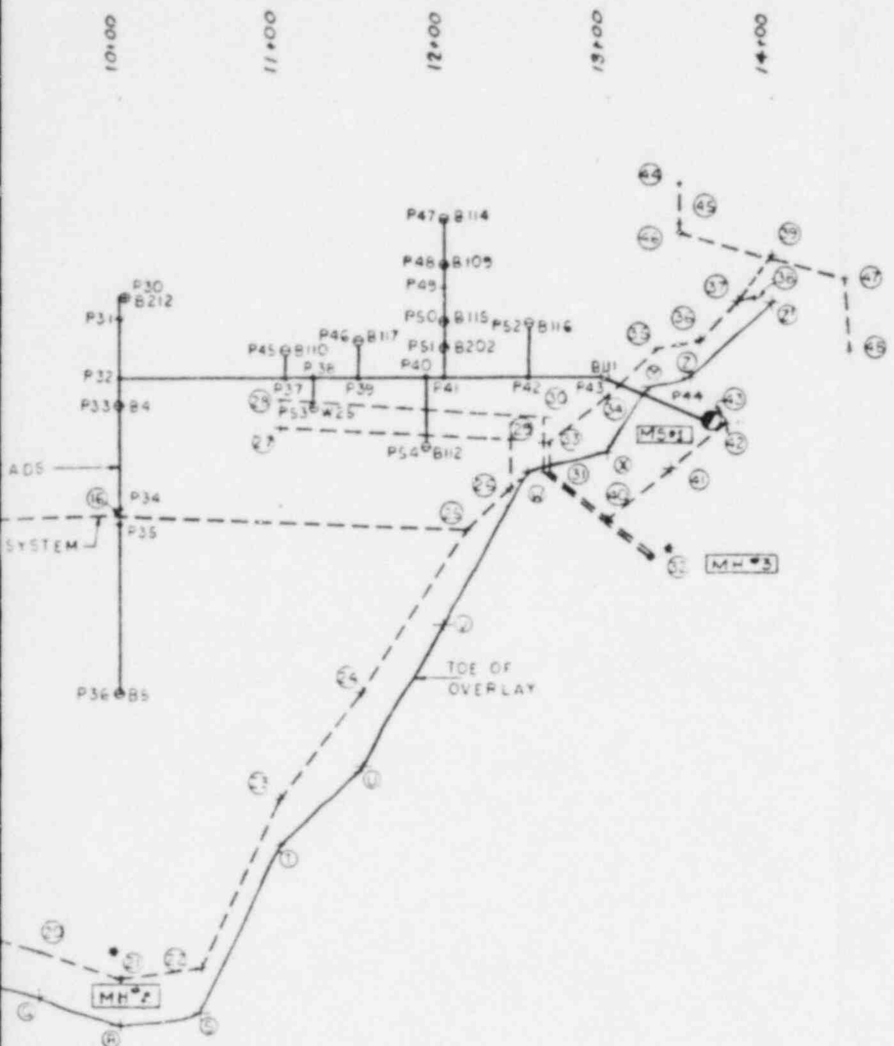
Scale I

Toe of Overlay		
Sta	Co-ordinates	Elevation
A	3+24/ 52+97.5	1350.0
B	3+05/ 52+84.5	1358.5
C	3+05/ 52+73.0	1353.0
D	3+15/ 52+62.0	1359.0
E	3+50/ 53+07.5	1336.0
F	4+00/ 53+62.5	1314.0
G	4+50/ 53+82.5	1306.0
H	5+00/ 53+90.0	1303.0
I	5+50/ 53+97.5	1300.0
J	6+00/ 53+97.5	1300.0
K	6+50/ 53+97.5	1300.0
L	7+00/ 53+97.5	1300.0
M	7+50 54+37.5	1284.0
N	8+00/ 55+42.3	1249.0
O	8+50/ 56+01.5	1228.0
P	9+00/ 56+40.0	1217.0
Q	9+50/ 56+54.0	1213.0
R	10+00/ 56+71.5	1208.0
S	10+50/ 56+64.5	1210.0
T	11+00/ 55+59.5	1240.0
U	11+50/ 55+12.0	1253.4
V	12+00/ 54+22.5	1290.0
W	12+50/ 53+30.0	1327.0
X	13+00/ 53+17.5	1331.0
Y	13+25/ 52+77.5	1348.0
Z	13+50/ 2+72.5	1350.0
Z'	14+00/ 2+26.0	1369.0

Note:
Toe Locations Run From The Left To The Right Abutments

Toe Collector Drain System					
Sta	Co-ordinates	Elevation	Sta	Co-ordinates	Elevation
1	2+75 / 51+97.5	1370.0	27	11+00 / 53+02	1325.8
2	3+00 / 52+15	1364.0	28	11+00 / 52+85	1331.8
3	3+50 / 52+73.5	1338.0	29	12+40 / 53+10	1321.9
4	4+00 / 53+34	1312.0	30	12+60 / 52+97	1329.0
5	4+50 / 53+56	1304.5	31	12+60 / 53+30	1324.3
6	5+00 53+57	1303.4	* 32	13+25 / 53+83	1322.8
7	5+50 / 53+58	1300.0	33	12+60 / 53+12	1324.5
* 8	5+80 / 53+84	1301.3	34	13+00 / 52+84	1337.0
9	5+50 / 53+57	1302.5	35	13+29 / 52+50.5	1348.0
10	6+00 / 53+58	1302.0	36	13+56 / 52+49.5	1349.0
11	6+50 / 53+58	1304.0	37	13+79 / 52+25	1356.5
12	7+00 / 53+55	1305.0	38	13+83 / 52+23	1357.0
13	7+00 / 53+94	1295.0	39	14+00 / 51+97.5	1370.0
14	7+50 / 53+96	1264.0	40	13+00 / 53+60	1323.2
15	7+50 / 53+64	1298.0	41	13+38 / 53+28	1338.8
16	10+00 / 53+57	1300.5	42	13+72 / 53+00	1345.0
17	8+00 / 55+07	1250.0	43	13+69 / 52+93	1346.0
18	8+50 / 55+73.5	1230.0	44	13+43 / 51+57.5	1383.5
19	9+00 / 56+12	1219.0	45	13+43 / 51+78	1382.7
20	9+50 / 56+26	1215.0	46	13+43 / 51+82.5	1378.6
* 21	10+00 / 56+43.5	1209.83	47	14+45 / 52+11.5	1376.2
22	10+50 / 56+36.5	1212.0	48	14+47 / 52+55.5	1372.1
23	11+00 / 55+31.5	1242.8			
24	11+50 / 54+66	1263.0			
25	12+13 / 53+65.5	1298.5			
26	12+40 / 53+40	1307.0			

* Note:
Sta. 8 = Manhole #1
Sta: 21 = Manhole #2
Sta: 32 = Manhole #3



ERLAY DETAILS
N
= 50'0"

Position of Piezometer Leads					
Sta	Coordinates	Elevation	Sta.	Coordinates	Elevation
P1	5+00 / 52+55	1338.0	P30	10+03 / 52+23	1352.0
P2	6+00 / 52+55	1338.0	P31	10+00 / 52+375	1345.0
P3	6+11 / 52+55	1338.0	P32	10+00 / 52+72	1331.0
P4	6+11 / 51+50	1391.0	P33	10+00 / 52+89	1324.0
P5	6+11 / 51+70	1378.0	P34	10+00 / 53+52.5	1298.0
P6	6+11 / 52+38	1345.0	P35	10+00 / 53+57	1294.0
P7	6+98 / 52+02	1363.0	P36	10+00 / 54+66	1257.0
P8	7+05 / 52+05	1363.0	P37	11+07 / 52+72	1331.0
P9	6+97 / 52+32	1348.0	P38	11+20 / 52+72	1331.0
P10	7+00 / 52+38	1345.0	P39	11+48 / 52+72	1331.0
P11	6+93 / 52+41	1344.0	P40	11+89 / 52+72	1331.0
P12	7+00 / 52+55	1338.0	P41	12+00 / 52+72	1331.0
P13	7+00 / 53+00	1320.0	P42	12+51 / 52+72	1331.0
P14	7+05 / 53+87	1299.0	P43	12+96 / 52+72	1335.0
P15	✝ 7+00 / 54+69	1295.0	✝P44	13+63 / 53+00	1339.0
P16	4+18 / 55+48	1310.0	P45	11+03 / 52+55	1338.0
P17	4+50 / 53+79.5	1302.0	P46	11+48 / 52+48	1341.0
P18	5+00 / 53+87	1296.0	P47	12+00 / 51+74	1377.0
P19	5+50 / 53+94.5	1296.0	P48	12+00 / 52+02	1363.0
P20	5+97 / 53+94.5	1296.0	P49	12+00 / 52+37.5	1345.0
P21	5+97 / 53+82	1296.0	P50	12+00 / 52+46	1341.0
P22	6+14 / 53+94.5	1296.0	P51	12+00 / 52+50	1340.0
P23	8+48 / 53+00	1320.0	P52	12+51 / 52+39	1346.0
P24	8+87 / 53+00	1320.0	P53	11+20 / 52+90	1324.0
P25	8+48 / 52+83	1327.0	P54	11+89 / 53+14	1314.0

✝ NOTE:
Sta P15 - Monitoring Station #2
Sta P44 - Monitoring Station #1

Note:
1 For Notes & Reference Dwgs, See H-36668

MAIN
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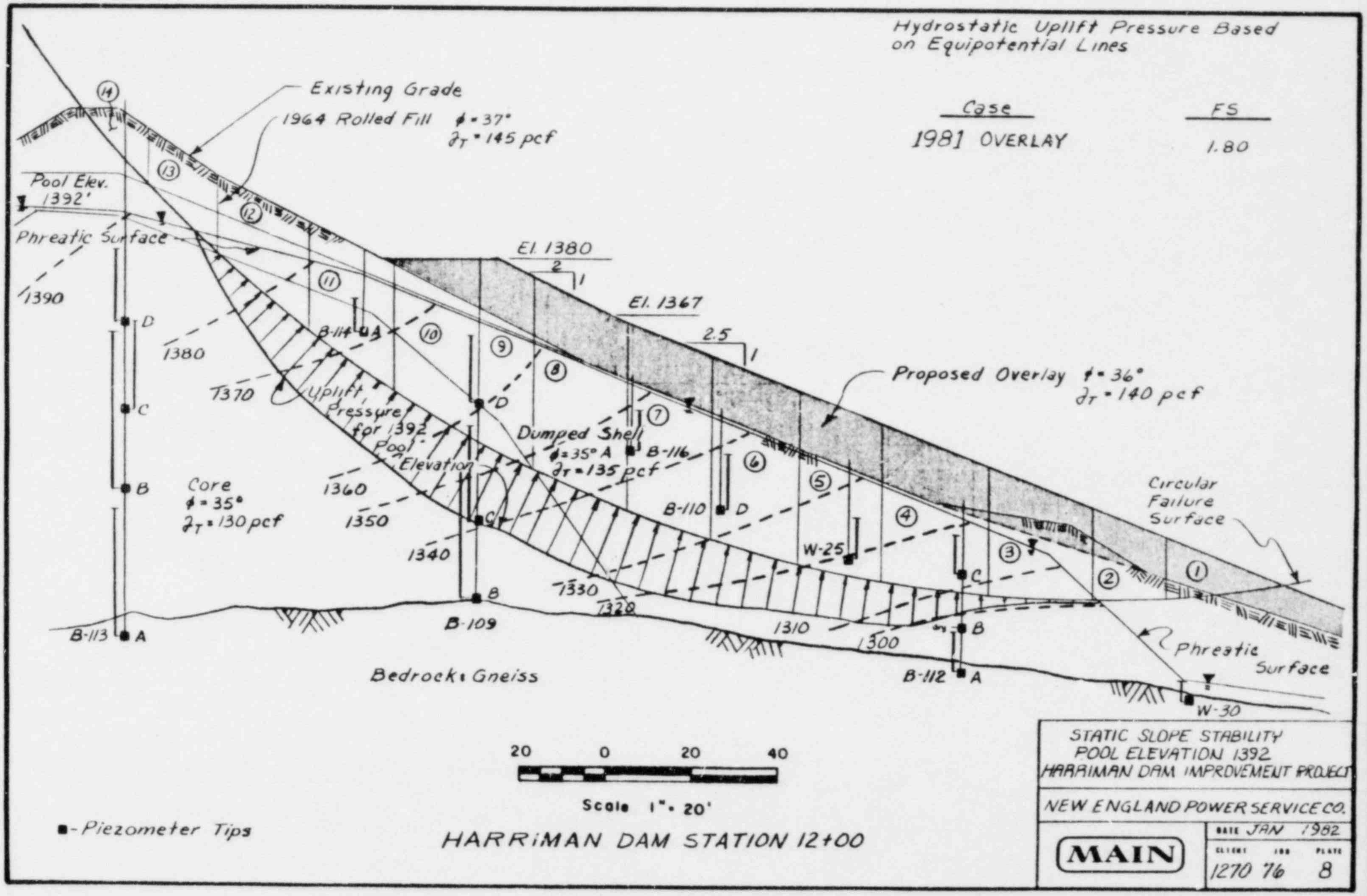
NEW ENGLAND POWER SERVICE COMPANY
PART OF NEW ENGLAND ELECTRIC SYSTEM
WESTBORO MASS.

NEW ENGLAND POWER COMPANY
HARRIMAN STATION
HARRIMAN DAM IMPROVEMENTS
OVERLAY INSTRUMENTATION
LOCATION DETAILS
SCALE 1" = 50'-0"
DATE DECEMBER 1981

H-36740-0

PLATE 7



HARRIMAN DAM STATION 12+00

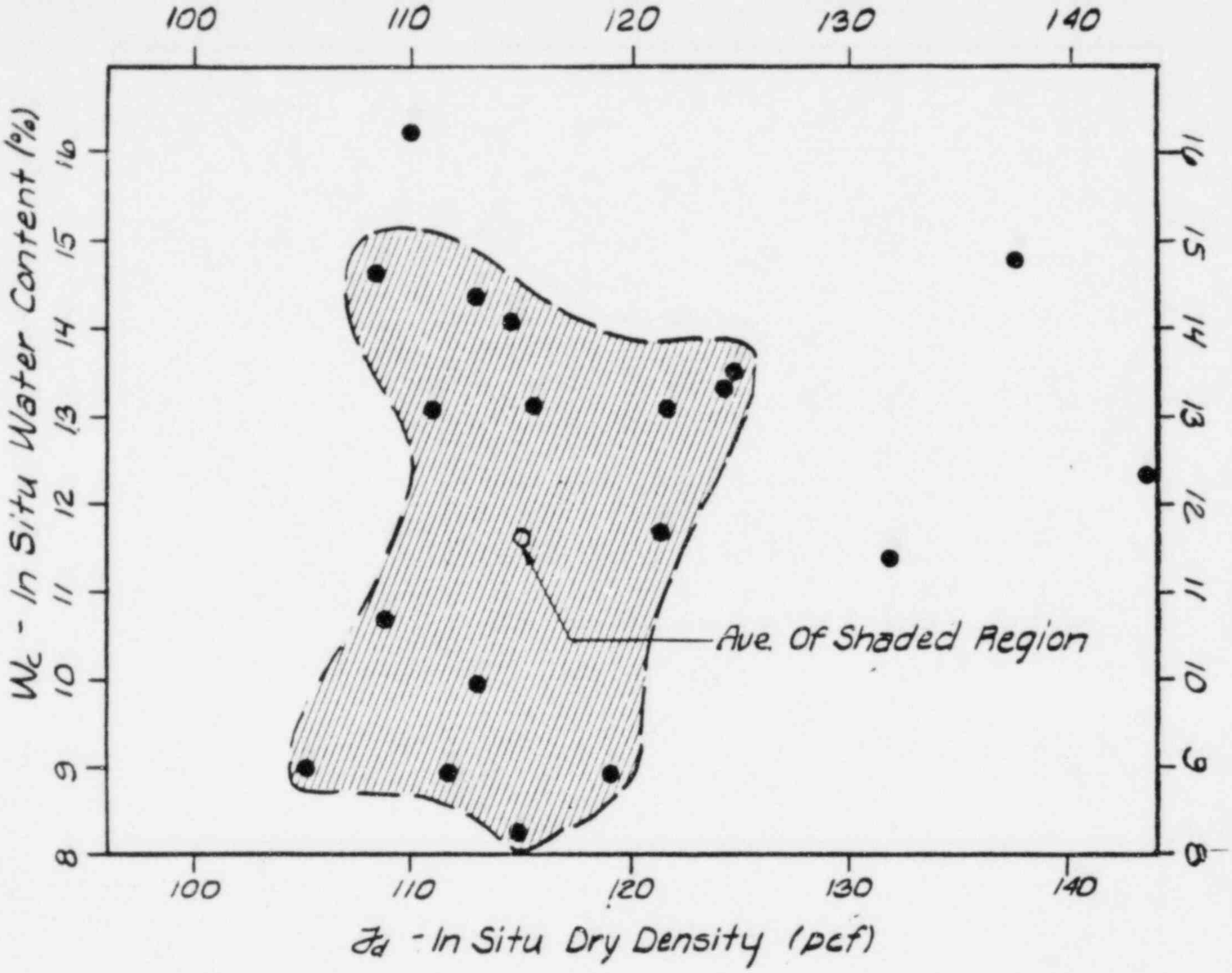
STATIC SLOPE STABILITY
POOL ELEVATION 1392
HARRIMAN DAM IMPROVEMENT PROJECT

NEW ENGLAND POWER SERVICE CO.

MAIN

DATE JAN 1982
CLIENT 1270
JOB 76
PLATE 8

PLATE 8



Based On In-Situ Data:
$\gamma_{d\,avg.} = 115$ pcf
$w_{c\,avg.} = 12.0\%$

Assuming 100% Saturation In The Dumped Shell Material The Fully Saturated Density (γ_s) Equals:

$$\gamma_s = \gamma_d + V_v \gamma_w$$

Where $V_v = 1 - \gamma_d / \gamma_w G_s$

Solving This Equation With, $\gamma_w = 62.4$ pcf, $G_s = 2.75$ and $\gamma_d = 115$ pcf, The Volume Of Voids (V_v) Equals 0.33. Solving For γ_s Results In An Average Saturated Field Density Of 135.5 pcf. This Value Compares Identically With The Density Assigned During The Analysis Program, ($\gamma_{dumped\ shell} = 135.0$ pcf), See Plate 8.

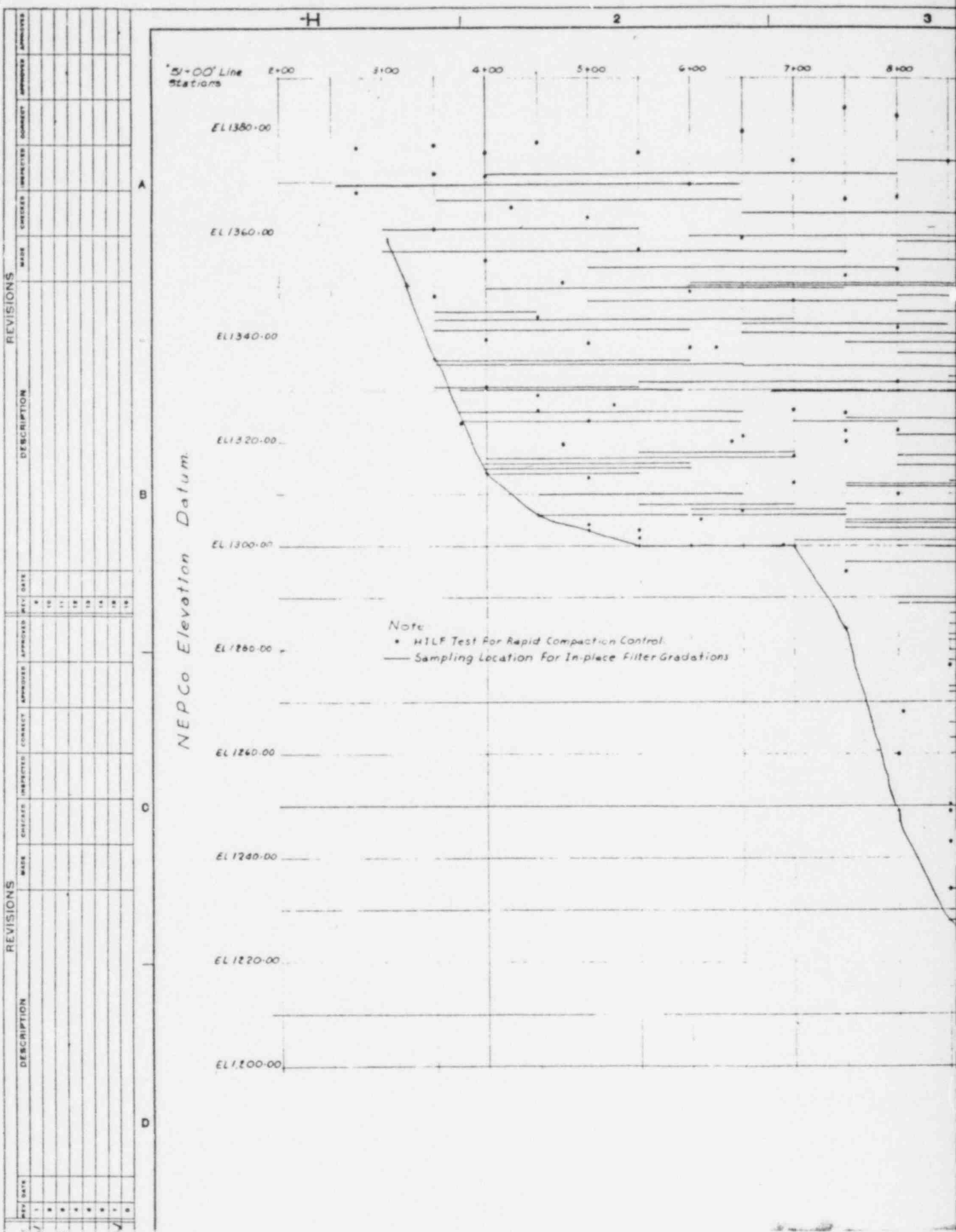
RESULTS OF FIELD DENSITY TESTS
PERFORMED ON SUBGRADE MATERIALS
HARRIMAN DAM IMPROVEMENT PROJECT

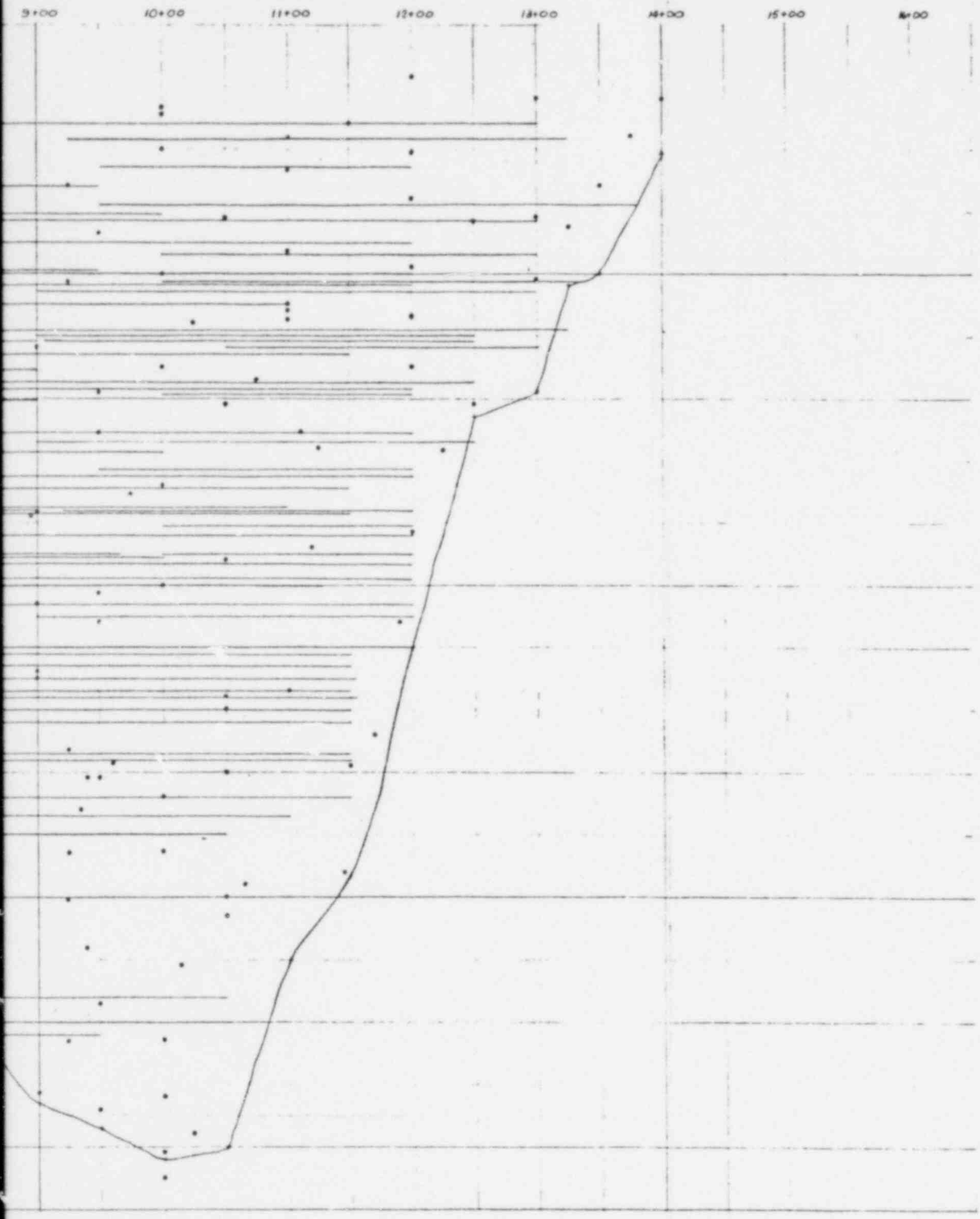
New England Power Service Company

MAIN

DATE January 1982

CLIENT	JOB	PLATE
1270	76	9


"51+00" Line Stations
2+00
3+00
4+00
5+00
6+00
7+00
8+00
EL 1380.00
EL 1360.00
EL 1340.00
EL 1320.00
EL 1300.00
EL 1280.00
EL 1260.00
EL 1240.00
EL 1220.00
EL 1,200.00
NEPCo Elevation Datum
Note:
• HILF Test For Rapid Compaction Control.
— Sampling Location For In-place Filter Gradations
1
2
3
A
B
C
D
REVISIONS
DESCRIPTION
MADE
CHECKED
INSPECTED
CORRECT
APPROVED
REV
DATE
ORIGINAL
DESIGNED
CHECKED
DRAWN
INSPECTED
APPROVED



NEW ENGLAND POWER SERVICE COMPANY
PART OF NEW ENGLAND ELECTRIC SYSTEM
WESTBORO, MASS.

NEW ENGLAND POWER COMPANY
HARRIMAN STATION
HARRIMAN DAM IMPROVEMENTS
IMPERVIOUS FILL AND FILTER BLANKET
FIELD TESTING LOCATIONS

SCALE As Noted
DATE January 1982

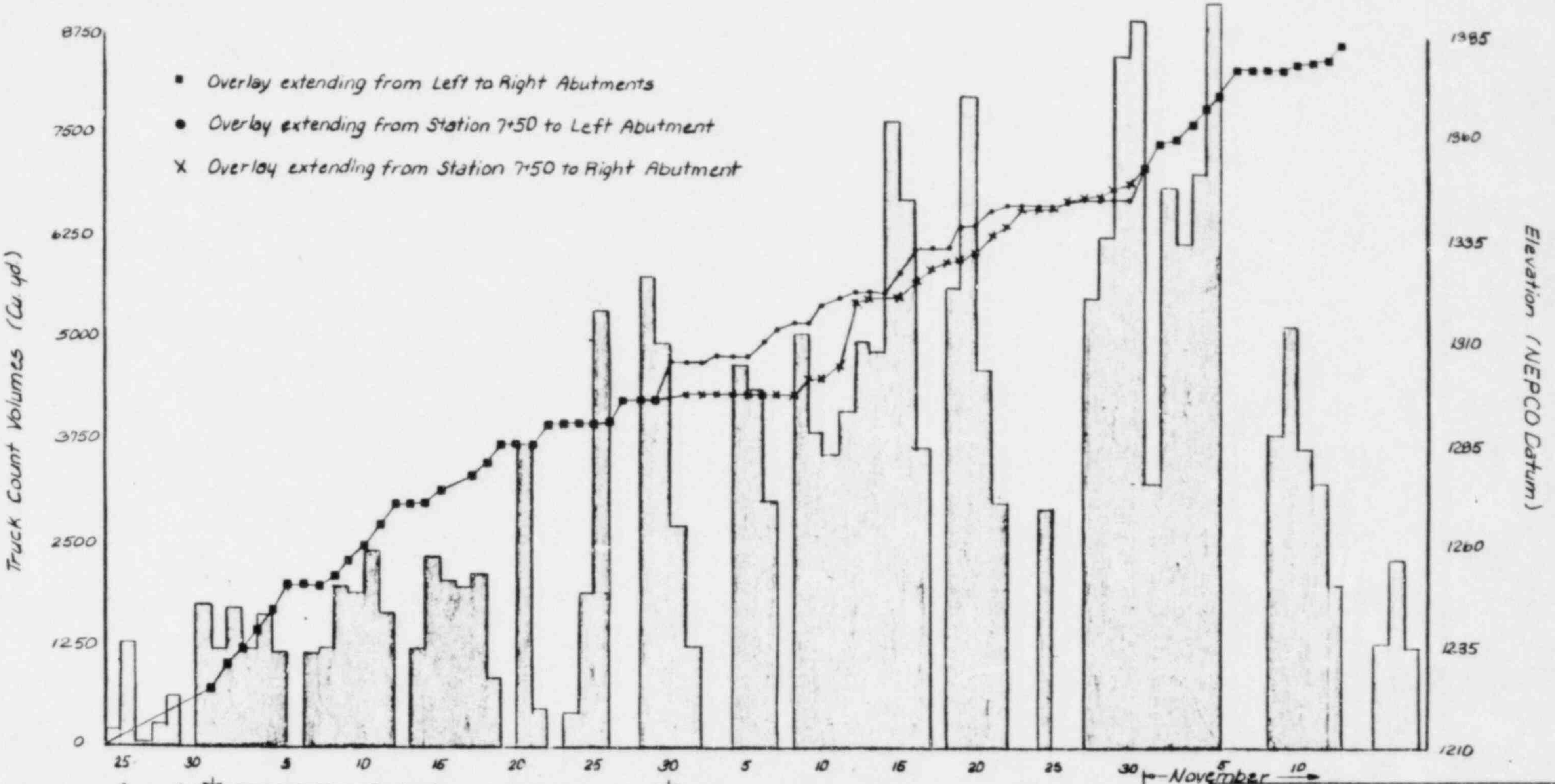
MAIN
CHAS. T. MAIN, INC.
BOSTON, MASSACHUSETTS
CHARLOTTE, NORTH CAROLINA

1270 - 76 - 10

H-

PLATE 10

PLATE 11



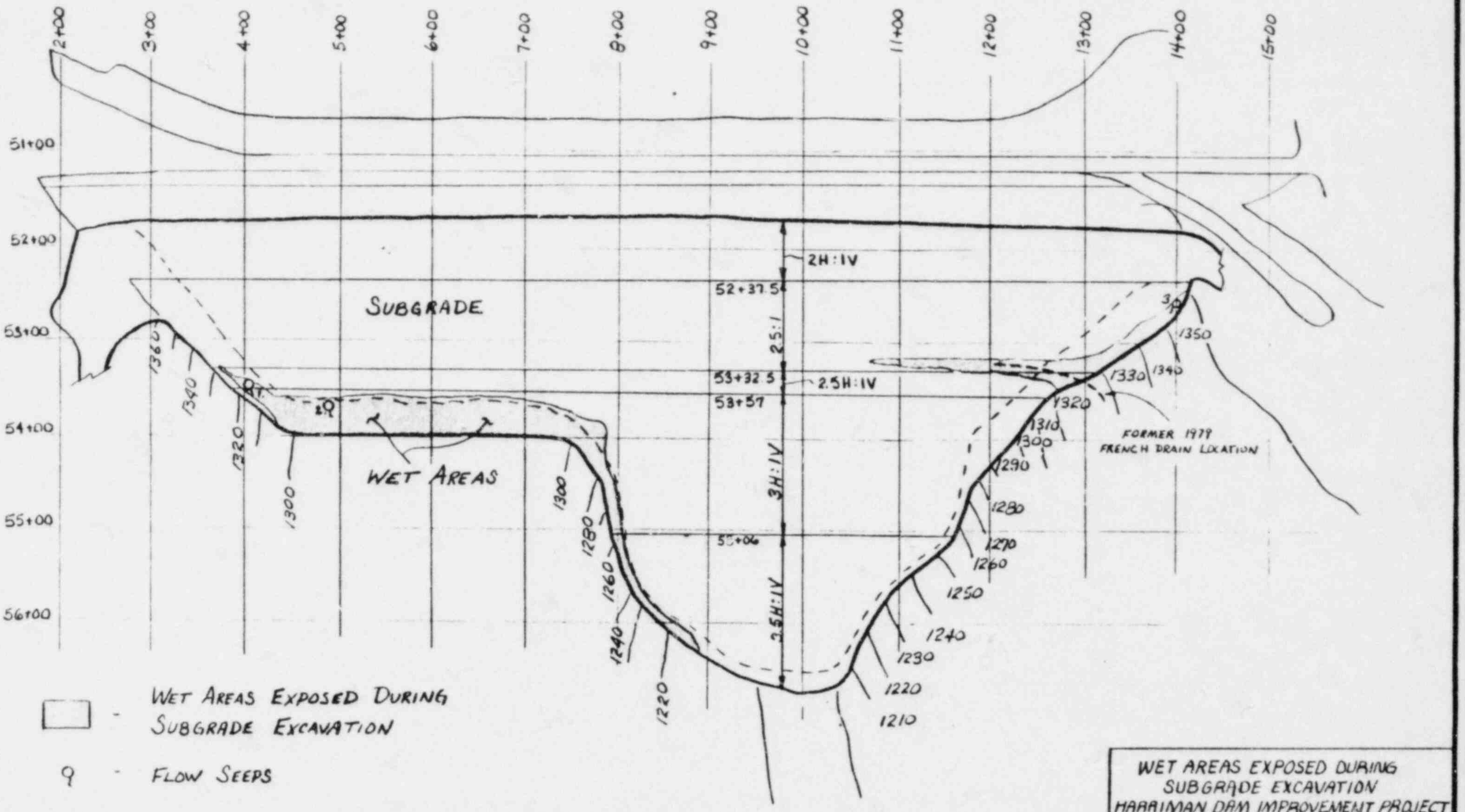
AS-BUILT
CONSTRUCTION FILL CURVE
HARRIMAN DAM IMPROVEMENT PROJECT

New England Power Service Company

MAIN

DATE January 1982

CLIENT	JOB	PLATE
1270	76	11



☐ - WET AREAS EXPOSED DURING SUBGRADE EXCAVATION

♀ - FLOW SEEPS

NOTES:

Estimated Flow Quantities *
1. 6 GPM
2. 50 GPM
3. 2 GPM

WET AREAS EXPOSED DURING
SUBGRADE EXCAVATION
HARRIMAN DAM IMPROVEMENT PROJECT

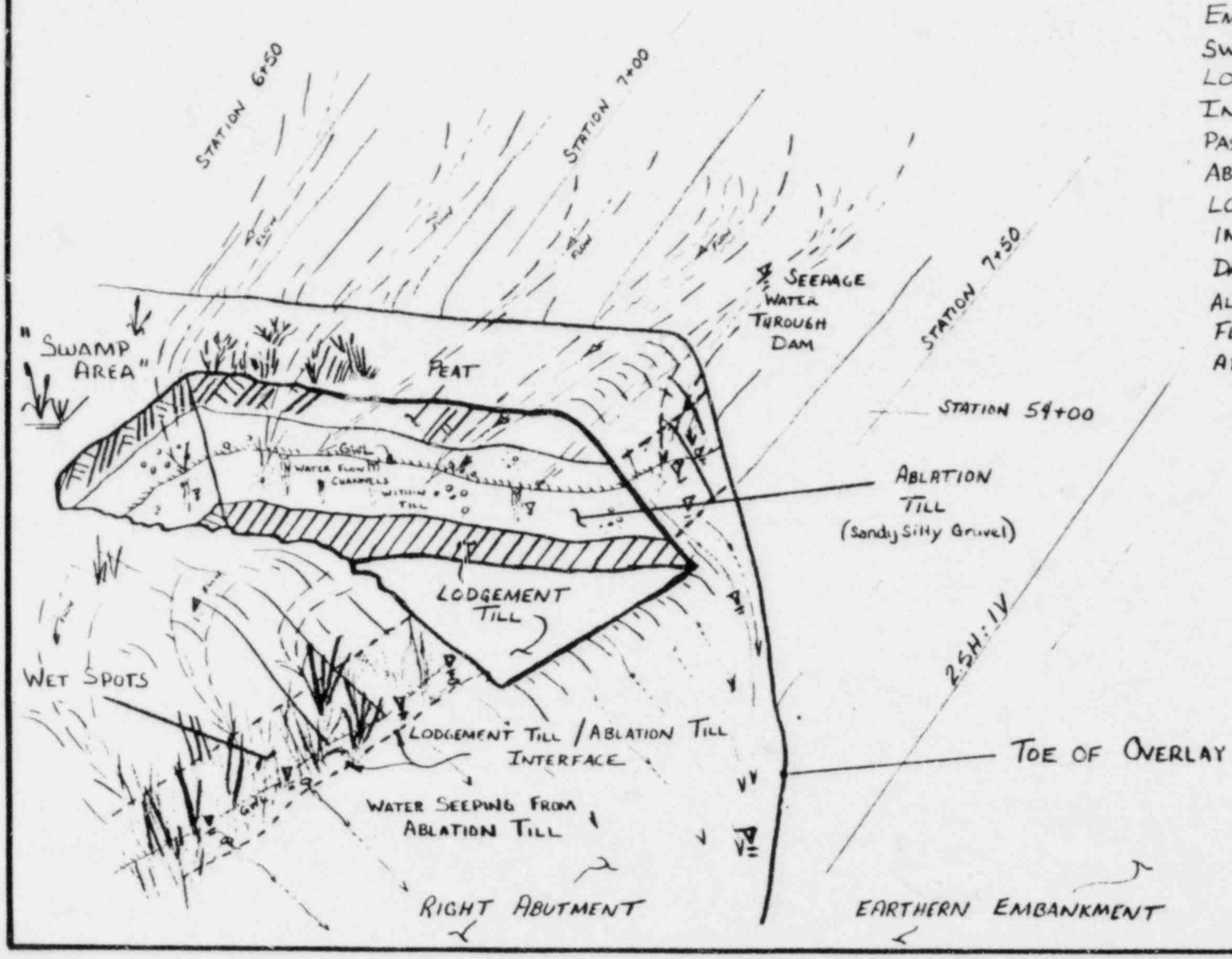
New England Power Service Company

MAIN

DATE January 1982

CLIENT 1270 JOB 76 PLATE 12

PLATE 12



EMBANKMENT SEEPAGE INTO THE SWAMP AREA EXITS ALONG THE LODGEMENT TILL / ABLATION TILL INTERFACE. SEEPAGE WATER PASSES READILY THROUGH THE ABLATION TILL. HOWEVER THE LODGEMENT TILL IS HIGHLY IMPERMEABLE. THE INTERFACE DAYLIGHTS ALONG THE VALLEY WALL ALLOWING SEEPAGE WATER TO FLOW FREELY OUT ONTO THE ABUTMENT SLOPE

SEEPAGE FLOW EXITING FROM
"SWAMP AREA"
HARRIMAN DAM IMPROVEMENT PROJECT

New England Power Service Company

MAIN

DATE January 1982		
CLIENT	JOB	PLATE
1270	76	13

PLATE 13

APPENDIX A

SOIL TESTING SUMMARY - FILTER BLANKET MATERIAL

SOIL TESTING SUMMARY

EARTHWORK CONTROL FOR FILTER BLANKET MATERIAL

	Cumulative Total
APPROXIMATE CUBIC YARDS PLACED	40,500
Number of gradations	109
Test rate (CY/test)	370

GRAIN SIZE CONTROL

Filter Material A (n = 24)

Gradation (% Passing)	Spec.	Max.	Min.	Cum. Ave.
3"	100	100	100	100
3/8"	48 - 100	86	37	62
#4	35 - 100	67	30	49
#10	25 - 77	57	23	38
#40	7 - 40	23	9	17
#200[1].	0 - 6	5.7	2.4	4.4

Filter Material B (n = 85)

Gradation (% Passing)	Spec.	Max.	Min.	Cum. Ave.
3"	100	100	100	100
3/4"	44 - 100	98	43	62
3/8"	27 - 100	61	28	46
#4	23 - 100	51	22	37
#10	17 - 77	41	17	29
#40	7 - 40	19	8	13
#200[1].	0 - 6	5.1	1.7	3.4
#200[2].	0 - 6	7.1	2.3	4.9

Note:

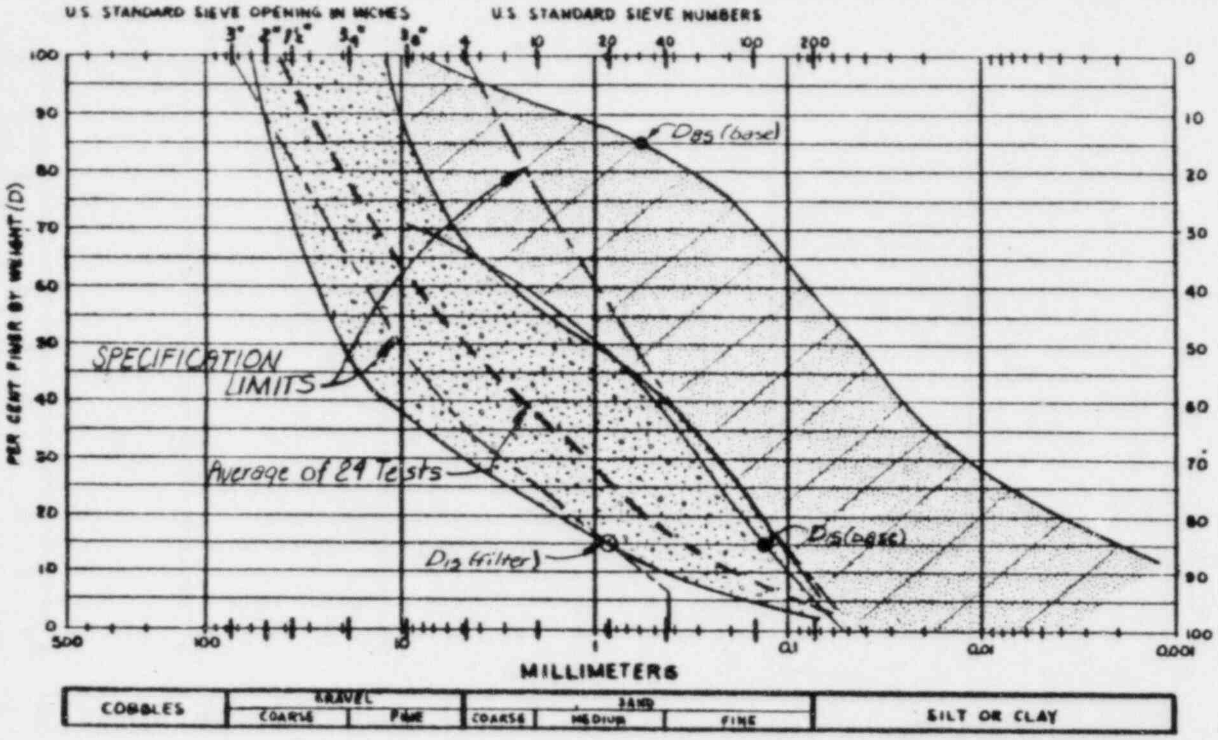
1. dry sieve analysis
2. wash sieve analysis

SOIL TESTING SUMMARY

EARTHWORK CONTROL FOR FILTER BLANKET MATERIAL

FIELD UNIT WEIGHT CONTROL

	Max.	Min.	Cum. Ave.
Filter Material A			
1. Elevation 1208.0 to 1296.0			
Method of Compaction - 12" lifts, 2 coverages w/RayGo 600A			
Moisture Content (%)	8.3	4.2	4.8
Dry Density (pcf)	136.0	125.9	131.3
Relative Density (%)	80.8	57.5	70.1
(n = 11)			
Filter Material B			
2. Elevation 1296.0 to 1310.0			
Method of Compaction - 12" lifts, 2 coverages w/RayGo 600A			
Moisture Content (%)	6.6	4.0	4.8
Dry Density (pcf)	139.0	130.1	132.8
Relative Density (%)	87.1	67.7	73.7
(n = 5)			
3. Elevation 1310.0 to 1350.0			
Method of Compaction - 18" lifts, 2 coverages w/RayGo 600A			
Moisture Content (%)	11.7	3.9	5.7
Dry Density (pcf)	141.7	119.4	131.4
Relative Density (%)	92.5	40.4	69.8
(n = 21)			
4. Elevation 1350.0 to 1374.0			
Method of Compaction - 18" lifts, dozer compaction (Case 850)			
Moisture Content (%)	8.4	3.6	5.0
Dry Density (pcf)	133.5	123.3	130.1
Relative Density (%)	75.4	50.9	67.6
(n = 8)			
RELATIVE DENSITY	145.6	106.4	



▨ Filter Material

▨ Dumped Shell

NOTES:

1. Grain Size Distributions for the Dumped Shell Material as Reported By GEI (1981).
2. Filter Material A - Percent Passing #200 Sieve Averages 4.4 (Dry Sieve Analysis)

Filter Criteria:

$$\frac{D_{15}\,(\text{filter})}{D_{85}\,(\text{base})} < 4 \text{ to } 5 < \frac{D_{15}\,(\text{filter})}{D_{15}\,(\text{base})}.$$

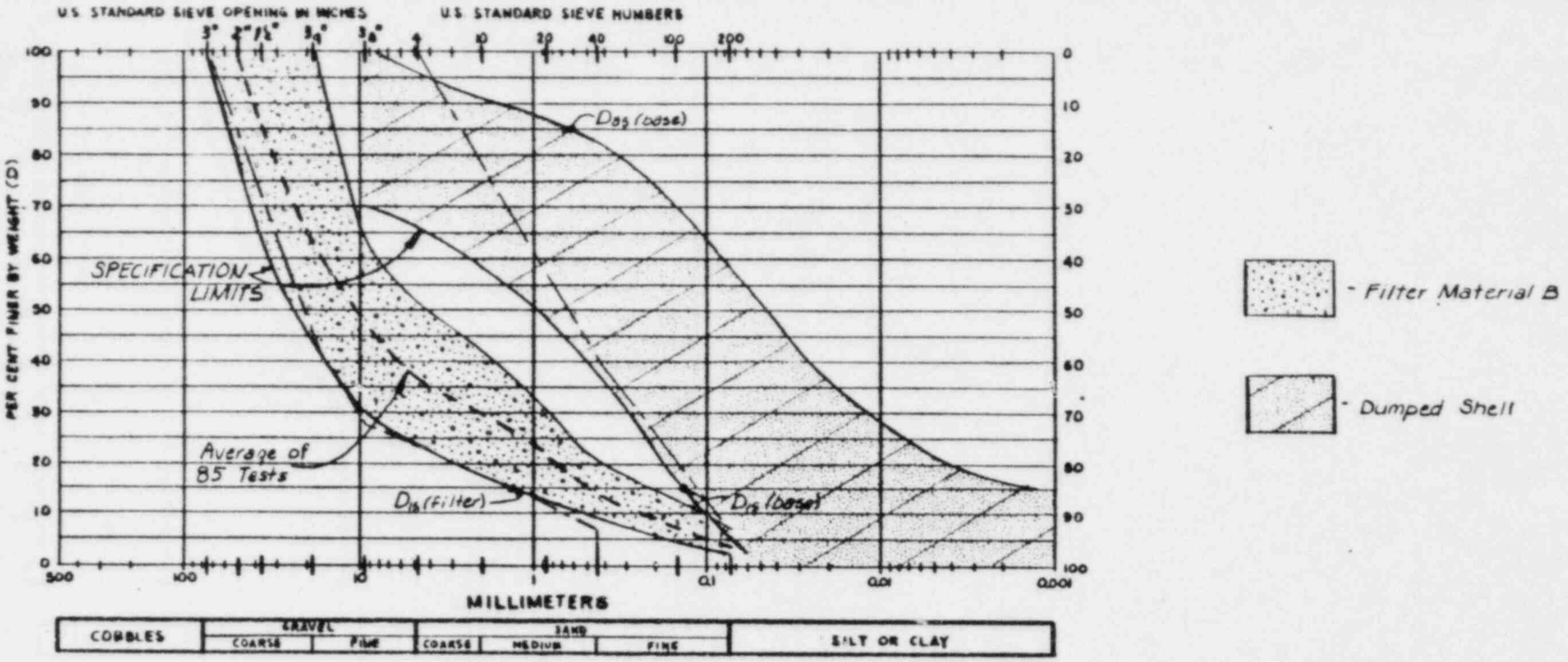
$$0.8 < 4 \text{ to } 5 < 5.0 \quad \text{O.K!}$$

ENVELOPES OF GRAIN SIZE
CURVES FOR FILTER MATERIAL A
AND DUMPED SHELL
HARRIMAN DAM IMPROVEMENT PROJECT

New England Power Service Company

MAIN

DATE January 1982		
CLIENT	JOB	PLATE
1270	76	A(1)



Filter Criteria:

$$\frac{D_{15}(filter)}{D_{85}(base)} < 4 \text{ to } 5 < \frac{D_{15}(filter)}{D_{15}(base)}$$

$$2.5 < 4 \text{ to } 5 < 10.0 \quad \text{OK!}$$

NOTE:

1. Grain Size Distributions for the Dumped Shell Material as Reported by GEI (1981).

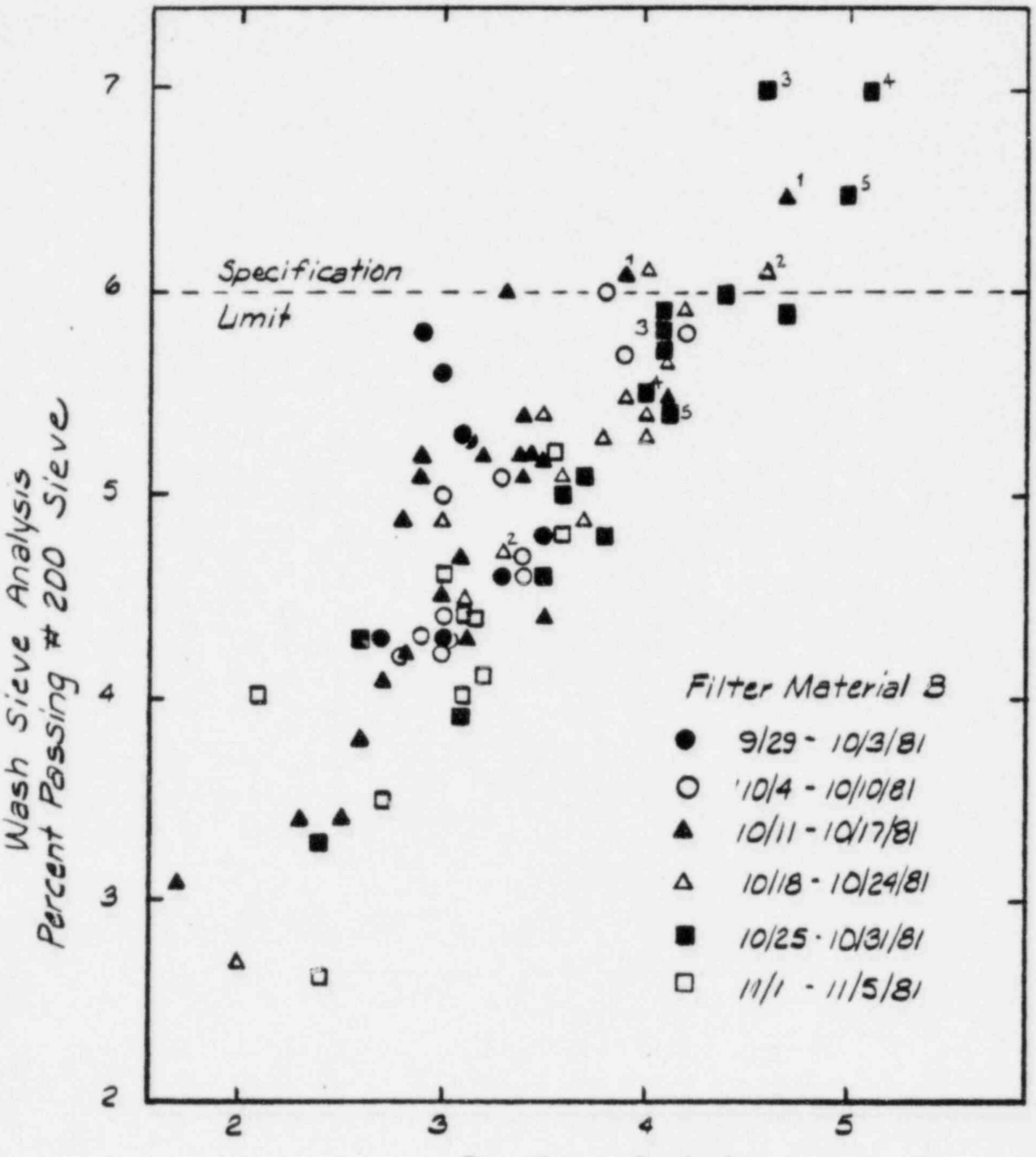
2. Filter Material B - Percent Passing #200 Sieve Averages 3.4 (Dry Sieve Analysis) Wet Sieve Analysis Yields An Average of 4.9%.

ENVELOPES OF GRAIN SIZE CURVES
FOR FILTER MATERIAL B
AND DUMPED SHELL
HARRIMAN DAM IMPROVEMENT PROJECT

New England Power Service Company

MAIN

DATE January 1982
CLIENT 1270
JOB 76
PLATE A(2)



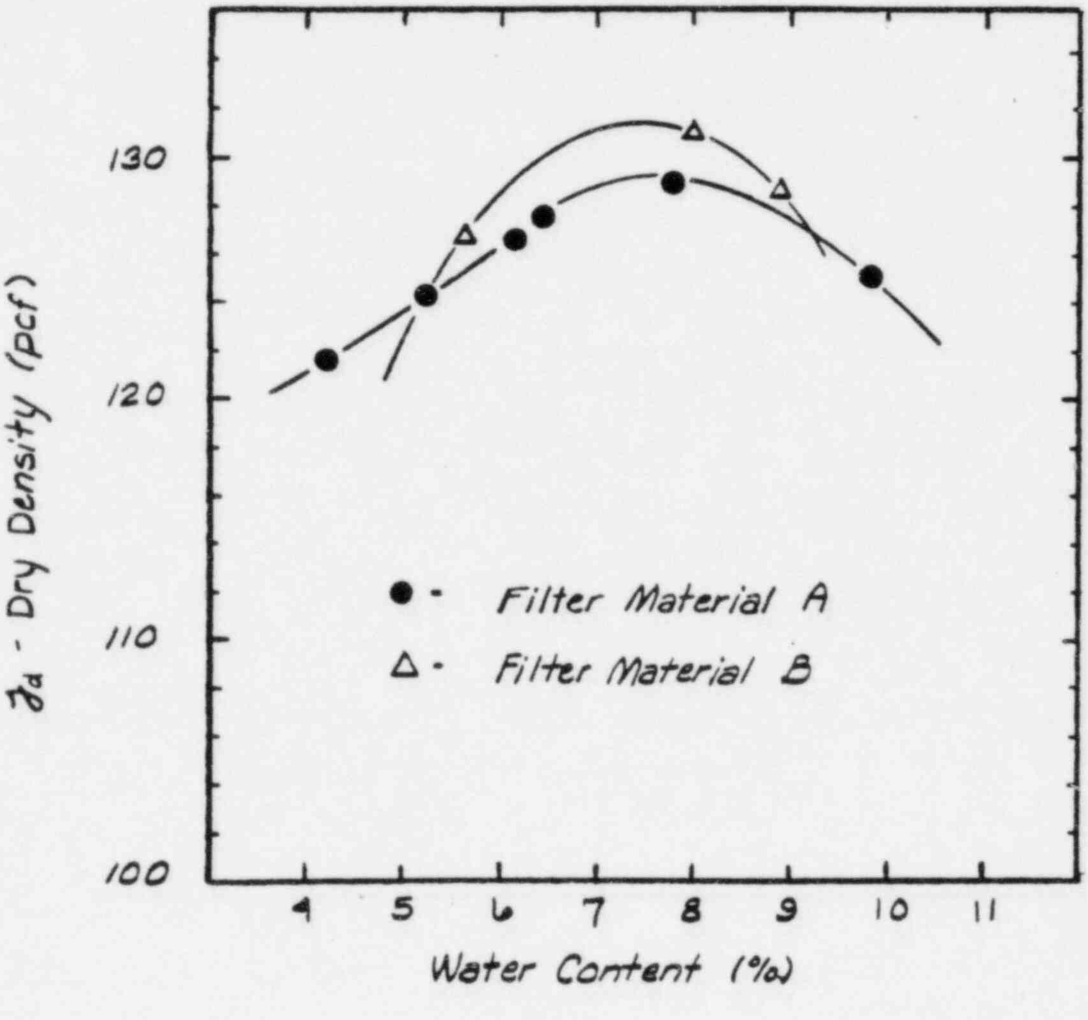
NOTE:
Test Results Exceeding 6% Fines Were Retested. The Numbered Tests Show Both Initial Failure And Retest Data.

DRY SIEVE VS. WASH SIEVE ANALYSIS
FILTER MATERIAL B
HARRIMAN DAM IMPROVEMENT PROJECT

New England Power Service Company

MAIN

DATE January 1982		
CLIENT	JOB	PLATE
1270	76	A(3)



LABORATORY STANDARD PROCTOR TESTS
PERFORMED ON FILTER BLANKET
MATERIAL
HARRIMAN DAM IMPROVEMENT PROJECT

New England Power Service Company

MAIN

DATE January 1982

CLIENT	JOB	PLATE
1270	76	A(4)

APPENDIX B

SOIL TESTING SUMMARY - IMPERVIOUS FILL MATERIAL

SOIL TESTING SUMMARY

EARTHWORK CONTROL FOR IMPERVIOUS FILL MATERIAL

	Cumulative Total
APPROXIMATE CUBIC YARDS PLACED	111,200
Number of Tests	161
Test rate (CY/test)	690

FIELD UNIT WEIGHT CONTROL (n = 161)

	Max.	Min.	Cum. Ave.
Wet bulk density (pcf)	157.9	121.3	146.5
Moisture content (%)	12.3	7.9	10.1
Dry density (pcf)	144.7	110.2	132.3

HIFT METHOD OF RAPID COMPACTION CONROL (n = 161)

Moisture control (based on standard proctor, 1/13.33 CF/mold)

			Frequency of Occurrence	F	Cum. F	Cum. %
$W_o - W_f$	% Below	> 2.8				
		2.3 - 2.7				
		1.8 - 2.2				
		1.3 - 2.2				
		1.3 - 1.7				
		0.8 - 1.2				
		0.3 - 0.7	|	1	1	0.6
		+0.2 to -0.2	𝍸 𝍸 𝍸 𝍸 𝍸 𝍸	30	31	19.3
	% Above	0.3 - 0.7	𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 ||||	39	70	43.5
		0.8 - 1.2	𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 |	31	101	62.7
		1.3 - 1.7	𝍸 𝍸 𝍸 𝍸 𝍸	25	126	78.3
		1.8 - 2.2	𝍸 𝍸 𝍸 𝍸 ||||	24	150	93.2
		2.3 - 2.7	𝍸 ||||	9	159	98.8
		2.8 - 3.2	||	2	161	100
		3.3 - 3.7				
		> 3.8				
		TOTALS		161		

$W_o - W_f$ = Variation of Fill Moisture of Minus -3/4" Material from Laboratory Optimum.

	Cum. Ave.
Mean Variation from Optimum Moisture (w_o-w_f)	+ 1.0% (wet)
In-Place Moisture Content	10.1%
Optimum Moisture Content (Hilf Method)	9.1%
Specification Limits for w_o-w_f	- 1.0% to + 3.0%

Relative Compaction Control (based on Standard Proctor, 1/13.33 cf/mold)

$$D = \frac{\text{Fill Wet Density} \times 100}{\text{Standard Proctor Maximum Dry Density (Minus - 3/4" Material)}}$$

	Frequency of Occurrence	F	Cum. F	Cum. %
< 89.0	|| *	2	2	1.3
90.0 - 90.9				
91.0 - 91.9				
92.0 - 92.9	| *	1	3	1.9
93.0 - 93.9	|| *	2	5	3.1
94.0 - 94.9	|| *	2	7	4.4
95.0 - 95.9	卌 |	6	13	8.1
96.0 - 96.9	||||	4	17	10.6
97.0 - 97.9	卌 |||	8	25	15.6
98.0 - 98.9	卌 卌 卌 卌	20	45	28.1
99.0 - 99.9	卌 卌 卌 |	16	61	38.1
100.0 - 100.9	卌 卌 卌 卌	20	81	50.6
101.0 - 101.9	卌 卌 卌 卌 ||	22	103	64.4
102.0 - 102.9	卌 卌 |||	13	116	72.5
103.0 - 103.9	卌 卌 卌 |||	18	134	83.8
104.0 - 104.9	卌 卌 |	11	145	90.6
105.0 - 105.9	卌 ||||	9	154	96.3
106.0 - 106.9	|||	3	152	98.1
> 107.0	||||	4	161	100
TOTALS		161		

	Max.	Min.	Cum. Ave.
Relative Compaction (%)	108.6	84.1*	100.8

Standard Proctor Tests Run on Impervious Fill Burrow Material (n = 4)

	Max.	Min.	Cum. Ave.
Optimum Moisture Density (%)	9.6	8.6	9.2
Optimum Dry Density (pcf)	134.3	129.1	131.7

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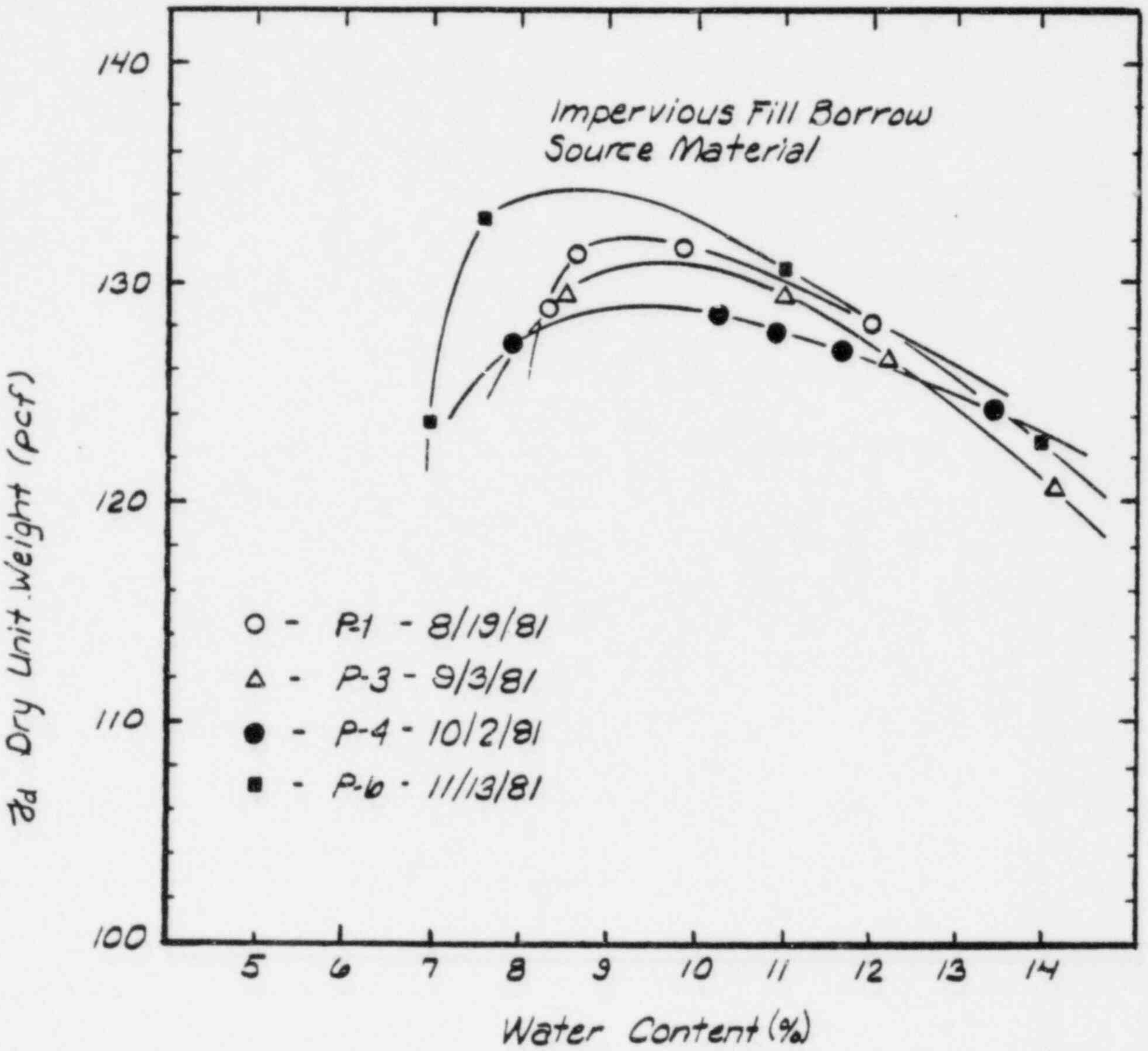
* Note: All tests were D < 95%. The actual fill was retested after remedial work.
All retests were acceptable.



LABORATORY STANDARD PROCTOR TESTS
PERFORMED ON IMPERVIOUS FILL
MATERIAL
HARRIMAN DAM IMPROVEMENT PROJECT

New England Power Service Company

MAIN

DATE January 1982

CLIENT	JOB	PLATE
1270	76	B(1)

APPENDIX C

HALEY & ALDRICH MEMO - PIEZOMETER RELOCATION

9 October 1981
File No. 4900

Pizzagalli Construction Co.
Harriman Road
Whitingham, VT 05361

Attention: Mr. Fred Kilar

Subject: Harriman Dam Instrumentation
Whitingham, VT

Gentlemen:

Enclosed are the requested piezometer readings that I took during the entrenching operation. They have been tabulated by date and the function they serve: i.e. before cut, after-splice and from the monitoring stations. Also included are the layout of the piezometers as I mounted them on the instrument panel for future reference, should there ever be a question as to which piezometer is which.

All the readings from the monitoring station indicate that the piezometers survived construction rigors and are in working order with the exception of 201C, which read anomolously high. See Bill Walton of C.T. Main for details of 201C. Please note that 108 A&B and 102 A&B have not yet been routed into MS#2 for a final check. I hope that these readings will be accepted by New England Power Service Co. as viable data.

If you have any questions please do not hesitate to call. It has been a pleasure working with you.

Sincerely yours,
HALEY & ALDRICH, INC.

JMLingham
Jeffrey M. Lingham

JML/bms
cc: C.T. Main, Inc.; Attn: Mr. William Walton
New England Power Service Co.; Attn: Mr. Larry Underwood

HALEY & ALDRICH, INC.
CAMBRIDGE, MASSACHUSETTS

CLIENT Pizzagalli Const. Co

PROJECT Harriman Dam, Whitingham Vt.

Subject: Dated Piezometer Readings
taken throughout extending Operation.

FILE NUMBER 4900
SHEET ___ OF ___
DATE ___
COMPUTED BY Jeffrey M. Lingham
CHECKED BY ___

	Aug. 2	Sept. 2	Sept. 4	Sept. 15	Sept. 16	Sept. 17	Sept. 18	Sept. 19	Sept. 30	Oct. 2
4A			?	2.13^{B}	2.16^{A}				1.87^{M}	
4B			0^{B}	0^{B}	0.10^{A}				0.28^{M}	
5	6.10^{B}	6.3 B 6.3 A							5.88^{M}	
109A			9.35^{B}			9.03^{B}	9.38^{A}		9.48^{M}	
109B			9.75^{B}			9.47^{B}	9.94^{A}		10.02^{M}	
109C			5.9^{B}			5.50^{B}	5.92^{A}		5.92^{M}	
109D			3.1^{B}			2.30 B 3.22^{A}	3.22^{A}		3.40^{M}	
110A			0^{B}	0.03^{B}		0.00^{A}			0.11^{M}	
110B			0^{B}	0.03^{B}		0.00^{A}			0.15^{M}	
110C			0^{B}	0.02^{B}		0.00^{A}			0.11^{M}	
110D			2.8^{B}	0.02^{B}		2.93^{A}			3.00^{M}	
111A			0.75^{B}					0.63 B 0.65 A	0.71^{M}	
111B			0^{B}					0^{B} 0^{A}	0.00^{M}	
112A			0^{B}				0^{B} 0^{A}		0.03^{M}	
112B			0^{B}				0^{B}	0.0^{A}	0.00^{M}	
112C			0.6^{B}				0.51^{B}	0.75^{A}	0.86^{M}	
114			3.7^{B}			3.20^{B} 3.57^{A}			3.97^{M}	
115			0^{B}			0.00^{B}	0.00^{A}			0.00^{M}
116			0^{B}			0.0^{B}				0.00^{M}
117			0^{B}	0.14^{B}		0.00^{A}				0.00^{M}
202A			4.55^{B}			4.51^{B}	4.62^{A}			4.72^{M}
202B			2.75^{B}			2.82^{B}	2.87^{A}			3.18^{M}
202C			0.3^{B}			0.1^{B}	0.43^{A}			0.46^{M}
212A			7.25^{B}	7.60^{A}						7.13^{M}
212B			10.6^{B}							10.52^{M}
212C			0^{B}							0.00^{M}
W25										$\sim 2.5^{M}$

M S #1

Layout on Inst. Panel

4A	4B	5	109A
109B	109C	109D	110A
110B	110C	110D	111A
111B	112A	112B	112C
114	115	116	117
202A	202B	202C	212A
212B	212C	W25	

In all cases The Black tube is mounted on Left, and the White tube is mounted on Right.

HALEY & ALDRICH, INC.
CAMBRIDGE, MASSACHUSETTS

CLIENT Pizzagalli Const. Co

PROJECT Harriman Dam. Whitingham Vt.

Subject: Dated Piezometer Readings taken throughout extending operation.

FILE NUMBER 4900
SHEET ______ OF ______
DATE ______
COMPUTED BY Jeffrey M. Lingham
CHECKED BY ______

	Aug. 21	Sept. 1	Sept. 9	Sept. 10	Sept. 11	Sept. 15	Oct. 1	Oct. 6	Oct. 8
101	4.61^{B}					3.80^{A}		5.12^{M}	
102A	5.25^{B}						4.98^{B}	5.20^{A}	
102B	5.50^{B}						2.72^{B}	2.96^{A}	
104A		12.15^{B}	12.4^{B}	11.9^{A}				12.40^{M}	
104B		8.15^{B}	8.3^{B}	7.8^{A}				8.13^{M}	
104C		2.0^{B}	1.9^{B}	1.5^{A}				1.70^{M}	
105A		4.5^{B}		4.5^{B}	4.0^{A}			4.65^{M}	
105B		0^{B}		0.3^{B}	0.3^{A}			0.00^{M}	
107A		2.0	2.6^{B}	2.6^{A}				2.19^{M}	
107B		0	0.2^{B}	0.2^{A}				0.10^{M}	
108A	669^{B}						5.82^{B}		5.42^{A}
108B	3.21^{B}						2.84^{B}		2.23^{A}
118		2.05^{B}	2.5^{B}	2.3^{A}				1.75^{M}	
119		0^{B}	0.3^{B}	0.3^{A}				0.03^{M}	
201A		5.5^{B}	5.5^{B}	4.3^{A}				5.20^{M}	
201B		4.95^{B}	4.8^{B}	3.9^{A}				4.40^{M}	
201C		1.95^{B}	1.9^{B}	2.4^{A}				* 14.2^{M}	
208A		0^{B}		0.2^{B}	0.2^{A}			1.00^{M}	
208B		195^{B}		1.5^{B}	1.7^{A}			1.75^{M}	
208C		2.6^{B}		2.3^{B}	2.4^{A}			3.02^{M}	
W21								1.35^{M}	
W26								1.75^{M}	

* See Bill Walton

MS #2

Lay out on Inst. Panel

101	102A	102B	104A
104B	104C	105A	105B
107A	107B	108A	108B
118	119	201A	201B
201C	208A	208B	208C
W21	W26		

In all cases, the Black tube is mounted on Left and the White tube is mounted on the Right.

APPENDIX D

CRITICAL PIEZOMETER - RECORDING SHEET