Periodic Inspection Report No. 6
Hopkinton Lake
Hopkinton, New Hampshire

Hopkinton Lake

June 2002

US Army Corps
of Engineers

New England District

CENAE-EP-D

5 December 2002
Mr. Descoteaux/dle/nak/600

MEMORANDUM THRU Chief Engineering/Planning Division

FOR Engineering/Planning Division Files

SUBJECT: Independent Technical Review (ITR) of Periodic Inspection Report No. 6, Hopkinton Lake, Hopkinton, New Hampshire

1. An ITR team comprised of the following reviewed the subject Periodic Inspection Report:

Team Leader	David Descoteaux, CENAE-EP-DG
Structural Engineer	Joseph Colucci, CENAE-EP-DG
Hydraulic Engineer	Steve Simmer, CENAE-EP-EW
Civil Engineer	Neil Beliveau, CENAE-CO-TS-T

2. The report authors have provided responses to the ITR comments concerning the subject report. These responses have been reviewed by the team members and adequately address the ITR concerns raised during the review.

3. It is recommended that the subject Periodic Inspection Report be approved.

Joseph Colucci
Structural Engineer
Concur ✓ JC Nonconcur ________

Steve Simmer
Hydraulic Engr.
Concur ✓ SS Nonconcur ________

Neil Beliveau
Civil Engineer
Concur ✓ NB Nonconcur ________

DAVID DESCOTEAUX
Team Leader

Approved ________ 12/10/02

Disapproved ________

DAVID L. DULONG, P.E.
Chief, Engineering /Planning Division

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THIS INSPECTION REPORT HAS BEEN CONDUCTED UNDER THE AUTHORITY IN ER 1110-2-100 WHICH PROVIDES FOR THE PERIODIC INSPECTIONS AND CONTINUING EVALUATION OF COMPLETED CIVIL WORKS STRUCTURES. THE PURPOSE OF THE INSPECTION IS TO EXAMINE THE PHYSICAL CONDITION OF THE HOPKINTON LAKE PROJECT AS PART OF A CONTINUING PROGRAM TO INSURE ITS STRUCTURAL STABILITY, SAFETY AND OPERATIONAL ADEQUACY. THE FIELD EXAMINATION INCLUDES SOILS AND GEOLOGIC ASPECTS OF EMBANKMENTS, CHANNELS AND OTHER COMPONENTS AS WELL AS STRUCTURAL, CONCRETE, MECHANICAL, ELECTRICAL AND HYDROLOGIC AND HYDRAULIC FEATURES OF THE PROJECT.

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PERIODIC INSPECTION NO. 6
HOPKINTON LAKE
HOPKINTON, NEW HAMPSHIRE

JUNE 2002

DEPARTMENT OF THE ARMY
NEW ENGLAND DISTRICT, CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS 01742-2751

HOPKINTON LAKE - HOPKINTON, NEW HAMPSHIRE

PERIODIC INSPECTION NO. 6
HOPKINTON LAKE
HOPKINTON, NEW HAMPSHIRE

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PERIODIC INSPECTION NO. 6
HOPKINTON LAKE
HOPKINTON, NEW HAMPSHIRE

1. EXECUTIVE SUMMARY

a. The sixth periodic inspection of Hopkinton Lake was performed on 4 June 2002. The inspection was conducted by a team of specialists representing various disciplines from Design, HTRW/Geotechnical Engineering and Water Resources Branches of the Engineering/Planning Division, and Construction/Operations Division, New England District, Corps of Engineers.

b. The purpose of the periodic inspection was to examine the physical condition of the Hopkinton Lake project as part of a continuing program to ensure the project's structural stability, safety and operating adequacy. The field examination included soils and geologic aspects of embankments, channels and other components, as well as the structural, concrete, mechanical, and hydrologic/hydraulic features of the project.

c. Based on visual inspection, project features of the Hopkinton Lake are generally in good condition. No deficiencies which could jeopardize the operation of the project during flood events were identified.

d. The next periodic inspection should be performed during FY 2007.

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(Team Captain)

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Geologist

2. GENERAL STATEMENT OF INSPECTION PROGRAM

a. Authority for periodic inspections is contained in ER 1110-2-100 which provides for the "Periodic Inspection and Continuing Evaluation of Completed Civil Works Structures." This program requires a detailed, systematic, technical inspection of each Corps-owned facility whose failure or partial failure would endanger the lives of the public or result in substantial property damage.

b. Failure at Hopkinton Lake has the potential to result in loss of life and cause serious damage to homes, agricultural, industrial and commercial facilities, important public utilities, main highways, or railroads. Based on hazard potential criteria adopted by the U.S. Army Corps of Engineers and presented in Appendix D of ER 1110-2-106 "Recommended Guidelines for Safety Inspection of Dams," Hopkinton Lake is a high hazard dam.

c. Approval authority for periodic inspection reports has been delegated by HQUSACE to the Division Commander, U.S. Army Corps of Engineers, North Atlantic Division, who has further delegated this responsibility to the Chief, Engineering/Planning Division of the New England District. The New England District conducts an in-depth review by Engineering and Operations disciplines prior to submittal to the Division.

3. PROJECT DESCRIPTION

a. Hopkinton Lake is a flood control reservoir situated on the Contoocook River just above the village of Hopkinton, New Hampshire and about 15 miles above the confluence with the Merrimack River. The Hopkinton reservoir is part of a 2 reservoir system with nearby Everett Lake and is divided into three storage areas – two located in the Contoocook River watershed and one in the Piscataquag River watershed. The sub-areas, connected by 2 canals, act as separate reservoirs during minor floods and as a single reservoir during moderate and/or major floods. With a net drainage area of 382 square miles, and total drainage area of 446 square miles, including Everett Lake, Hopkinton is operated to reduce flooding on the main stem of the Contoocook, the Piscatquoag and the Merrimack Rivers.

Once the stage at Hopkinton exceeds elevation 380 ft-NGVD, use of flood control storage in the Contoocook pool begins. At about elevation 382, water passes from the Contoocook pool into the Elm Brook Pool via Canal No. 1. When elevation 401 is reached, water passes from Elm Brook pool to Everett Lake via Canal No. 2. At spillway crest elevation, 416 ft-NGVD, 70,100 acre-feet of flood control storage would be utilized, and Hopkinton Lake would cover an area of 3,700 acres.

b. The dam at Hopkinton is rolled earth fill with rock slope protection. Discharges are passed by six 6-ft wide by 12-ft high slide gates. Gates 3, 4, 5, and 6 discharge directly into the Contoocook and are used exclusively for flood control. Gates 1 and 2 discharge into a forebay pool for the Hoague Sprague Dam immediately downstream. Maximum outlet capacity at spillway crest is 14,000 cfs.

4. BRIEF PROJECT SUMMARY

a. Project Characteristics

Purpose	Flood Control
Dates of Construction	November 1959- October 1962
Construction Cost	$21,360,000 (combined cost of Hopkinton-Everett Lakes)

Location of Structures

State	New Hampshire
County	Hillsborough and Merrimack
Town	Hopkinton

Reservoir

Drainage Area	382 square miles (net) 446 square miles (total)

Operating Levels

Pool	Elevation (Feet, NGVD)	Area (Acres)	Cum. Capacity (Acre-feet)
Invert	366.0	--	--
Recreation Pool	380.0	220	700
Spillway crest	416.0	3,700	70,100

Main Dam

Type	Rolled earth-fill, and rock fill w/ rock slope protection, impervious core
Maximum Height	76 feet
Length	790 feet
Top Elevation	437.0 feet NGVD

Spillway

Location	Right Bank about 7,500 ft. NE of dam
Type	Concrete ogee weir
Crest length	300 feet
Crest elevation	416 ft NGVD
Maximum Discharge Capacity	59,700 cfs

Outlet Works

Type	3-square conduits (2 flood control, 1 forebay)
Size	11 feet x 11 feet
Length	Flood control - 125 Ft. Forebay – 128 Ft.
Gates	(6) 6' x 12' high Slide Gates
Invert	366 Ft. NGVD
Discharge at Spillway Crest	14,000 cfs
Stilling Basin	2- 32 ft wide by 67 ft. long

Dike H-2

Type	Rolled earth-fill, w/rock-fill protection
Length	5,220 feet
Top Elevation	435 Ft. NGVD
Maximum Height	66 feet

Dike H-3

Type	Rolled earth-fill, w/rock-fill protection
Length	4,400 feet
Top Elevation	435 Ft. NGVD
Maximum Height	67 feet

b. Significant Storages Since Last Inspection

Table 1 list annual peak pool levels at Hopkinton Lake since the last periodic inspection. Annual Water years are from 1 October to 30 September.

TABLE 1
SIGNIFICANT STORAGES AT HOPKINTON LAKE
SINCE PERIODIC INSPECTION NO. 5

Date	Maximum Stage Feet	Maximum Elevation Ft NGVD	Watershed Equivalent Depth Inches	Storage Utilized (Spillway crest storage = 49,900 ac-ft Acre-Feet	Percent
Jun 1998	37.3	403.3	1.5	30,000	43
Sep 1999	25.0	391.0	0.4	7,800	11
Apr 2000	25.8	391.8	0.4	8,800	13
Apr 2001	33.8	399.8	1.1	22,400	32

Drainage Area = 382 sq. mi. (net) 446 (total); Stage = 452.0 ft NGVD

Record Pool Level

Apr 1987	85.2	415.8	3.4	69,300	99

c. **History of Major Remedial Measures**. There have been two major remedial projects constructed at Hopkinton Lake. These are discussed in Appendix I.

d. **Deficiencies Corrected Since Last Inspection**

This periodic inspection of Hopkinton Lake is the sixth conducted since initiation of the dam inspection program. Listed below are the dates of prior inspections.

Periodic Inspection No. 1	Nov 1972
Periodic Inspection No. 2.	Oct 1981
Periodic Inspection No. 3	June 1987
Periodic Inspection No. 4	July 1991
Periodic Inspection No. 5	June 1997

Deficiencies at the project which have been corrected as a result of findings presented in the last periodic inspection are listed below.

(1) Project personnel regularly monitor spalls at the downstream face of the spillway as recommended in the last periodic inspection report

(2) Limit switch settings on the gate operators are checked and adjusted by manufacturer.

(3) The thermostat on the east furnace is checked regularly during the annual maintenance on the furnace.

(4) Light bulbs and lamps are replaced as necessary

(5) Heavy vegetation in the approach channels of the north and south weir has been removed

(6) The bent shaft of the south weir sluice gate has been repaired, but is subject to recurring vandalism.

(7) Stone protection has been repaired/replaced at the south weir

(8) Trees and brush growing along the upstream toe of the dam have been removed.

(9) Project personnel regularly monitor the storm drain on crest of the dam taking measurements from the sidewalk curb to the guardrail every 3 months and monitoring storm drain outflows during heavy rainfall.

(10) Trees, large brush growth and grass are regularly removed from the downstream toe of the forebay pool and the west retaining wall.

(11) Project personnel monitor training walls and stone protection around the intake structure as recommended in the last periodic inspection report. Also, the missing stone under the west outlet channel has been replaced.

(12) Vegetation along the upstream toe of Dike H-2 has been removed as recommended in the last periodic inspection report.

(13) Trees and large brush on the upstream side of the impervious blanket at Dike H-3 has been removed.

(14) Vegetation on the upstream and downstream slopes of the North Weir has been removed.

e. **Past Deficiencies Not Yet Corrected.**

(1) Classification of the service gate wells as confined space has prevented project personnel from entering them to remove debris, as recommended in the last periodic inspection report.

(2) Investigation of the feasibility of installing trash racks on the upstream side of the concrete piers of the intake structures was performed. However implementation of recommendations has been delayed pending resolution of the removal of trash and debris collecting in the gate well.

(3) Replacement of the bent counterweight arm of the emergency gate lifting beam and the modification of the gate hook has been deferred pending an investigation and design by Engineering/Planning Division.

(4) Connections of the exhaust vent, generator exhaust pipe, light fixtures and the microwave antenna to the lightning protection system on the roof has not been done.

(5) Reconnection of the ground ring to the ground rods has not been done as recommended in the last periodic inspection report.

(6) Disconnect switches for the motor driven ventilators were not replaced.

(7) Modifications to the connections between the TVSS terminals and the circuit breakers were not done.

(8) Reprogramming and/or adjustment of the meter transducers to obtain correct meter readings will be completed at the upcoming inspection by Design Branch personnel.

(9) Funds for construction of access roads to the downstream toe of Dike H-3 have been requested, but have not been included in any of the budgets since the last periodic inspection.

5. INSPECTION RESULTS

a. Personnel. This inspection was performed by the following team members from Engineering/Planning

Nicholas Forbes (Team Captain)	Dam Safety Prog. Mgr.	CENAE-EP-M
Brian Waz	Hydrology/Hydraulics	CENAE-EP-MC
John Kedzierski	Concrete/Structural	CENAE-EP-DG
Deborah Gabrielson	Mechanical	CENAE-EP-DG
Thomas Ayau	Electrical	CENAE-EP-DG
Laura Fraser	Geotechnical	CENAE-EP-HE
Rose Schmidt	Geology	CENAE-EP-HC

Other personnel at the inspection were as follows:

Kerry Leblanc	Safety Office	CENAE-SO
Patricia Sumner	Safety Office	CENAE-SO
James Law	Construction/Ops Div	CENAE-CO
Theron Chase	Basin Manager Merrimack River Basin	CENAE-CO-MRB
Rob Shanks	Project Manager	CENAE-CO-MRB
Mike Currie	Park Ranger	CENAE-CO-MRB
Brad Clark	Park Ranger	CENAE-CO-MRB
Mike Hayward	Park Ranger	CENAE-CO-MRB

b. Embankments

(1) Main Dam. Visual inspection of the dam embankment and abutment areas showed no evidence of instability that would affect the performance of the dam.

(a) Upstream Slope. The upstream rock-fill slope protection appears stable and properly aligned (Photo E-1). The stone protection is in good condition. There is minor vegetation on the slope and large brush, trees, and grass along the toe at the water's edge. The access roads from the project office to the upstream berm and the downstream berm are both in good condition.

(b) Downstream Slope. The downstream rock-fill slope protection appears stable and properly aligned (Photo E-3). The stone protection appears to be poorly graded in spots with pockets of smaller and larger stone and gives an uneven appearance to the slope. There is minor vegetative growth on the slope. The crushed stone on downstream toe berm has an uneven appearance but is satisfactory. Near RW-5, there is an area where the crushed stone has settled into the rock-fill creating a small hole about 6 inches deep (Photo E-4); the surrounding area is stable. Vegetation growing in the crushed stone is minor. The rock slope from the toe berm to the forebay pool is covered by heavy brush.

(c) Crest. The crest of the dam (State Route 127) is in good condition (Photo E-5). The guardrail along the upstream edge appears properly aligned. The guardrail adjacent to the west storm drain along the downstream edge was previously reported as showing signs of movement. GES personnel, found that the outlet pipe had separated from the catch basin and water was draining directly into the gravel layer below the stone protection. The outlet pipe and the overlying gravel and rock-fill were repaired. The downstream guardrail still appears to lean in the downstream direction in front of the west storm drain, but the rip rap from the crest to the storm drain outlet appears to have stabilized. Both the east and west catch basins are clean of debris. There is grass growing in the sand and gravel deposits on the slope formed by the runoff.

(d) Forebay Dike. Previous inspections reported that the forebay dike, behind the east outlet retaining wall, had settlements of up to 18 inches by 1987. Due to this settlement, the dike was periodically covered with crushed stone that continued to settle into the underlying stone. In 1999, repairs were made to the outlet wall and forebay dike which included the excavation of the impervious fill behind the outlet wall, replacing it with a 4-foot wide pervious zone and drainage system adjacent to the concrete and finishing the fill with compacted impervious fill. The top of the dike was rebuilt and covered with crushed stone (Photo E-7). Currently, the forebay dike appears to be in excellent condition with no settlement of the crushed stone.

(e) Abutments. The abutments are satisfactory overall. The previous inspection reported the downstream right abutment to be sloughing near the top of the slope. At the time of this inspection the sloughing appeared to be very minor and poses no threat to Route 127. The left upstream abutment which was overgrown with trees and brush has been cleared and now has just minor vegetation growing on it (Photo E-8). Vegetation removal from the dam and dikes is on-going scheduled maintenance.

(f) Seepage. No abnormal seepage conditions such as piping, boils or depressions were observed during the inspection or reported by the Project Manager.

c. Spillway

(1) Approach Channel. The approach channel was in overall good condition. Some vegetation was observed in the approach channel, but will not obstruct flow (Photo D-1).

(2) Control. The overall condition of the concrete in the spillway is good. Minor joint deterioration was noted at various locations. There are isolated hairline cracks with efflorescence and there is vegetation at the joint between the spillway and the

west retaining wall (see Photo A-12). A spall (<1 s.f.) on the middle of the downstream face next to a weep-hole has not changed since the last inspection.

(3) Exit. The spillway discharge channel was in good condition with no major outgrowth of trees or vegetation (Photo D-3).

d. Outlet Works

(1) Approach

(a) Inlet Channel. . The inlet was in good condition with no apparent obstruction to flow (Photo D-4).

(b) Log Boom. The log boom was generally in good condition. All of the logs appeared to be floating properly. There was a buildup of debris behind the log boom at the time of the inspection, but is scheduled to be removed during June-July 2002.

(c) Inlet Structure The overall condition of the concrete at the inlet structure is good. A few tiles are missing from the gage at El. 384. The raking platform, walls, and pier are in good condition. The top of the west side wall appears to be leaning approximately ½" inward and the east side wall is about 1" inward all the way to the waterline in relation to the raking platform. It may be that these walls were cast this way, however, Periodic Inspection No. 5 noted "movement of the top of the west side wall...increased approximately ¼" since the last inspection".

The railings are rusted and there are loose/missing bolts at various base plate connections and at the top railing-parapet connection on the west side (see Photo A-4). There is also debris and vegetation on the raking platform.

(2) Conduit and Gates The project consists of three conduits numbered from west to east. Each conduit consists of nine monoliths numbered 0 to 8, with monolith 0 nearest the gates. Monoliths 0 through 2 are in the transition area, and 3 through 8 are in the main conduit. In the transition area, splitter walls divide each conduit into two barrels (lettered A through F from west to east) allowing for two gates in each conduit. Conduits 1 and 2 are used for flood control and conduit 3 leads to the forebay of the Hoague Sprague hydropower dam. Conduit 3 is submerged most of the time.

The concrete in the conduits, transitions, and splitter walls is in good condition with some areas of deterioration as described below and in the crack survey. Numerous joints between the monoliths have joint sealant that is missing, falling down, or loose (see Photos A-6 and A-7). Some of the joints on the conduit ceiling and the sides have active seepage, hairline cracks, and efflorescence. The conduits are abraded throughout the lower 3' about ¼" to ½" deep.

The downstream sides of gates 1, 2, 3, and 4 were inspected from inside the conduits and were found to be in excellent condition. Embedded steel at gates 1 through 4 was in good condition with minor rust. Air vents were clear except for at gate 3, where a board was lying across the vent. Gates 1 through 4 all showed minor leakage at the top and upper side seals. (See Photo B-1.) All six gate stems were in excellent condition. Large amounts of debris were found in all six service gate wells with gates 5 and 6 being the worst. Steel thrust nut cover plates from the original gates (which were replaced in 1996) were found in gate wells 2 and 6. Project personnel report that due to the area being classified as a confined space, debris has not been cleaned out for several years.

Operation of the emergency gate continues to be hampered by debris in the emergency gate slots which cause the gate and the lifting beam to get stuck part way down the slot, and by problems with the design of the lifting beam link pin mechanism. Debris has not been cleared out of the emergency gate wells for several years.

The lifting beam is provided with an automatic release mechanism which is designed to release the link pin from the gate hook when the weight of the gate is removed from the pin. The open design of the lifting beam permits debris to interfere with the operation of the link pin mechanism. (See Photo B-2.) This can cause the pin to release prematurely, or can prevent it from engaging with the gate hook, so that the gate cannot be retrieved. Debris also interferes with gate movement in the slot and can prevent tight gate closure

The forebay pool for conduit 3 was not drained and therefore could not be inspected. Concrete repairs were completed in 1998. Periodic Inspection No. 4 documented that this conduit is in overall good condition.

(3) Outlet Structure. The outlet structure consists of east and west concrete retaining walls, a concrete headwall, splitter wall between Conduits 1 and 2, and an apron with baffle blocks. The overall condition of the concrete at the outlet structure is good. Bonding and alignment of joints of the retaining walls and headwalls are good, except where noted at the east retaining wall. The east retaining wall has recently been modified to correct previous movement and is being monitored by the Geotechnical Engineering Section. The baffle blocks were underwater and were not inspected. There are isolated areas of light efflorescence, particularly at the east retaining wall (see Photo A-9). At the interface between the last monolith of Conduit 2 and the concrete apron, there is a 8" long x 4" wide x 2" deep spall about 2' from the east retaining wall. There is ½" deep abrasion on the apron and at the lower portions of the splitter wall close to the conduit monoliths.

The east retaining wall has numerous areas of scaling on the top horizontal portion of the wall. There is also a 12" x 7" x 2" deep spall (see Photo A-10), a 15" x 8" x 2" deep spall, and hairline to 1/16" cracks where the fence posts are attached to the top of the wall. There is a 4" offset between wall sections at the north end of the east retaining wall (see Photo A-11). This condition was noted previously, and it is being monitored by Geotechnical Engineering Section. The headwall over conduit 2 has heavy efflorescence at a horizontal construction joint. The outlet concrete at conduit 3 is in overall good condition with only one isolated hairline crack with efflorescence on the westerly wall.

(4) Exit Channel. The exit channel is in good condition (see Photo D-6).

e. Dike H-2

(1) Embankment. Dike H-2 is in good condition. The alignment and grade are good and the rock slope protection is in good condition.

(2) Upstream. There is minor vegetation growing on the upstream slope and, there is a small amount of high-pool debris on the slope (Photo E-9). There is minor brush and trees along the upstream toe. The upstream blanket is grass covered. The stone protection is in good condition with only minor weathering. Sporadically along the slope there are large stones (up to 3 feet in diameter) that have bridged and cause the appearance of "bumps" on the slope. These areas appear stable and there is no loss of the underlying gravel material. The area between stations 14+00 and 19+00 along the upstream toe is soft and moist due to groundwater draining off the abutment, as was noted in the last inspection. This drainage is evidenced in the cattails growing along the toe in this area. Also, as previously reported, there is ponded water on the upstream side of Dike H-2 adjacent to Elm Brook Road. The water is most likely from rainfall and runoff from Elm Brook Road.

(3) Downstream. The downstream slope of Dike H-2 is stable and clear of vegetation (Photo E-10). The ditch along the downstream toe between stations 6+00 and 9+00 was dry at the time of the inspection. The ditch ends near station 9+00, where a corrugated metal pipe daylights from under the access road (it is marked with steel posts). The outlet of the pipe was covered with vegetation and almost completely buried with sand and debris. The downstream toe access road is in good condition although at the lowest spot elevation there is large brush growing on the rock toe. About a ¼ mile from the left abutment the access road was blocked with 9 to 10 trees that have fallen across the road.

f. Dike H-3

(1) Embankment. Dike H-3 is in good condition. The alignment and grade are good. The rock slope protection is in good condition.

(2) Upstream. The upstream slope is clear of vegetation and the stone

protection is in good condition (Photo E-11). The upstream blanket is clear and has only grass growing on it. There are multiple tire tracks across the impervious blanket with ruts up to 4 inches deep. Project personnel stated that local groups who use the area drive across it when it is soft and wet.

(3) Downstream (Photo E-10). Vegetation along the downstream toe and access road has been kept cut back from the spillway wall to station 20+00 (Photo E-12). From station 20+00 to the right abutment there is excessive tree growth along the toe except near the swamp area (Photo E-13). The Access Road Study for the Merrimack River Basin, November 1989, recommends the downstream toe be cleared from station 20+00 to the right abutment and the areas inundated by the wetland between station 17+00 and 11+00 be made accessible by the construction of a gravel fill berm. .

g. Canal No. 1 The rock slopes of the canal appear to be in good condition. Brush and tree growth along the top of the rock slopes is somewhat heavy. There is some small to medium brush growing on the stone slopes, and also heavier brush along the center of the canal near the water (Photo E-14). Project personnel stated that this area is on the maintenance schedule of brush clearing. The floor of the canal was under a few feet of water but appeared to be in good condition.

h. North Weir

(1) Approach Channel. The approach channel is in good condition with no obstruction to flow.

(2) Control. The stone protection on the North Weir is in good condition, but has some brush on both sides of Sugar Hill Road. Also, there is tree growth in the rock protection on the lake side of the road. It appears the vegetation is being controlled by project personnel. The road over the weir has been paved and is in good condition (Photo E-17).

The conduit under the North Weir was replaced with a concrete box culvert and the inlet was reconstructed. At the time of the inspection the inlet was full of debris and there was minor spalling of the concrete at the outlet (Photo E-18). Both appear to be in good condition

i. South Weir

(1) Approach Channel. The approach channel is in good condition with no obstruction to flow (Photo D-8).

(2) Control. The floor of the canal downstream of the South Weir has been cleared of the heavy vegetation that was previously reported (Photo E-15). The right

slope downstream of the canal has some heavy brush and small trees on it, but is in good condition otherwise.

The rock slope protection on the slopes just upstream and downstream of the South Weir abutments is about 60% deteriorated due to weathering. Also, there is minor vegetation growth on the slopes. Rock protection has been added to the top of both abutments behind the spillway walls. The average stone size is 2.5 to 3 feet in diameter to reduce vandalism (Photo E-16). There is a hole in the left abutment safety fence adjacent to the control stem.

j. Stumpfield Marsh The overall condition of the concrete in this 10' x 12' conduit is excellent. There was minor amounts of debris at the inlet and the inside of the conduit was not inspected.

k. Project Instrumentation

(1) Rain Gage. The project is equipped with a Sutron tipping-bucket precipitation gage. The tipping-bucket gage was in good operating condition.

(2) Pool Stage Recorder. The project is equipped with a Sutron 8210 data collection unit that records and logs the pool stage, tailwater stage and rainfall data. A Handar RS485 encoder measures the pool stage and a Sutron Accubar pressure transducer measures the tailwater stage. At the time of the inspection, the equipment was in good condition and working properly

(3) Tile Staff Gage. Based on a visual inspection, the staff gages all appear in good condition. The lower tile gage had minor staining.

(4) Geotechnical Instrumentation. A complete description of geotechnical instrumentation is included in Appendix VI. A brief description follows.

(a) Piezometers. There are currently 20 piezometers installed at the dam: two on the upstream slope, two on the downstream slope, 13 along the downstream berm, two on the forebay pool dike, and one downstream and west of the stilling basin. PZ-9 and 11 were not working properly and were grouted; replacement piezometers were not necessary. A record of readings has been maintained with at least one monthly reading and daily readings during high pools. The Instrumentation Appendix indicates that the existing piezometers are adequate to characterize the piezometric levels at the dam.

The shallow (B) piezometers along the downstream toe berm appear to be influenced by the downstream forebay pool more than the upstream impoundment. The deep (A) piezometers east of the stilling basin have piezometric levels close to the pre-existing ground and are about 10 to 12 feet lower than the shallow piezometers. The levels in the B piezometer dropped when the forebay pool was emptied in September 1999, but the B levels were still higher than the A levels, indicating that there is not a significant artesian condition in the gravels underlying the dam. Data from PZ-13A, 14A, and 15 tend to confirm this. Piezometric levels in the upstream embankment respond to the pool level, while piezometric levels in the downstream embankment appear to be controlled by the drainage layer. Readings in PZ-13B are generally higher than the pool level and they sometimes peak before the pool peaks. It appears that surface water may be infiltrating the piezometer, possibly through a leaky seal, and may be perched within the piezometer.

PZ-3A/3B and 4A/4B near the outlet channel and stilling basin appear to be influenced by the discharge through the channel and drainage layers beneath the structures. Piezometers to the left of the outlet are not affected by the forebay pool but do respond to changes in the level of the upstream pool. Piezometric levels in PZ-3A and 3B also appear to be influenced by the nearby abutment, as the levels are slightly higher than in PZ-4A and 4B. The piezometric levels in PZ-15 appear to be influenced by recharge from the adjacent relief well RW-2.

(b) Crest Survey Monuments. Crest survey monuments were installed and initially surveyed in 1976. Additional surveys were performed in 1985, 1989, 1995, and 2001 by Corps of Engineers surveyors using electronic distance meter (EDM) instruments to locate the crest monuments both horizontally and vertically. The crest monuments are all in working condition. Monument 7 was missing half the survey disk.

The number and locations of the crest monuments are adequate to evaluate the embankment movements. Comparison of the data between 1996 and 2001 indicate horizontal displacements in the range of 0.0059 to 0.0608 foot (0.07 to 0.73 inch). Measured vertical movement since 1985 are less than 0.08 foot (less than 1 inch). These displacements and settlements are insignificant.

(c) Relief Wells. Eight relief wells were installed along the downstream toe berm during construction of the dam to relieve potential hydrostatic pressures in the gravelly deposits within the glacial till. The cover for RW-2 was missing. The sediment in the wells was pumped out in 1993. The water levels in RW-2 through RW-8 are controlled by the forebay pool (El. 381) which backs up in the T (El. 375) of the wells. Therefore, it is difficult to determine from the relief well readings whether any water is flowing in from the underlying gravel layer.

CENAE-EP-H personnel are preparing a report for the analyzing the effectiveness of the relief wells. The draft report concluded there was no excessive artesian pressure within the gravel layers in the dam's foundation. Hence, the relief wells are not needed. Recommendations include abandoning and back-filling the wells with crushed stone. This report has not been finalized to date.

(d) Tilt Plates. Seventeen tilt plates were installed in 1989 to monitor the movement of the east outlet channel and stilling basin retaining walls. All tilt plates are located on the top horizontal surface of the monoliths. Nos. 1-14 are located on the east outlet channel wall, No. 15 is on the east stilling basin wall, and Nos. 16 and 17 are on the stilling basin and west outlet wall respectively.

Repairs to the east outlet wall were completed in September 1999. A baseline survey for future alignment monitoring was established in April 2002. A new baseline for the tilt plate monitoring rotation has not been established since the repairs were completed.

6. RECOMMENDATIONS

The inspection team members and project personnel held an exit meeting at the dam where the findings and recommendations were jointly discussed. Needs and actions of the "normal maintenance" "budgetary" categories are presented within the inspection reports in Appendix V. Resulting dam safety recommendations are presented below.

a. Concrete/Structural. None

b. Mechanical. Project personnel should resume regular removal of debris from the service gate wells. If debris continues to build up, it could ultimately interfere with operation of and access to the service gates. Debris should be removed at least once and preferably twice a year. The Safety Office is available to assist in developing a standard procedure for entering and working in the service gate wells. Debris removal should take place when pool level is at the lowest normal level so that the bulk of the debris can be flushed downstream through the conduit. The two, steel thrust nut cover plates in gate wells 2 and 6 should be removed since they could be tossed about and cause damage to the gate stems during an extreme flood event.

c. Electrical. None

d. Hydrology and Hydraulics. None

e. Geotechnical/Geology. Vehicle access on the upstream impervious blanket at dike H-3 should be limited to when the blanket is dry and prohibited when the blanket is soft and wet.

APPENDIX I

HISTORY OF REMEDIAL MEASURES

PERIODIC INSPECTION REPORT
HOPKINTON LAKE
HOPKINTON, NEW HAMPSHIRE

HISTORY OF REMEDIAL REPAIRS

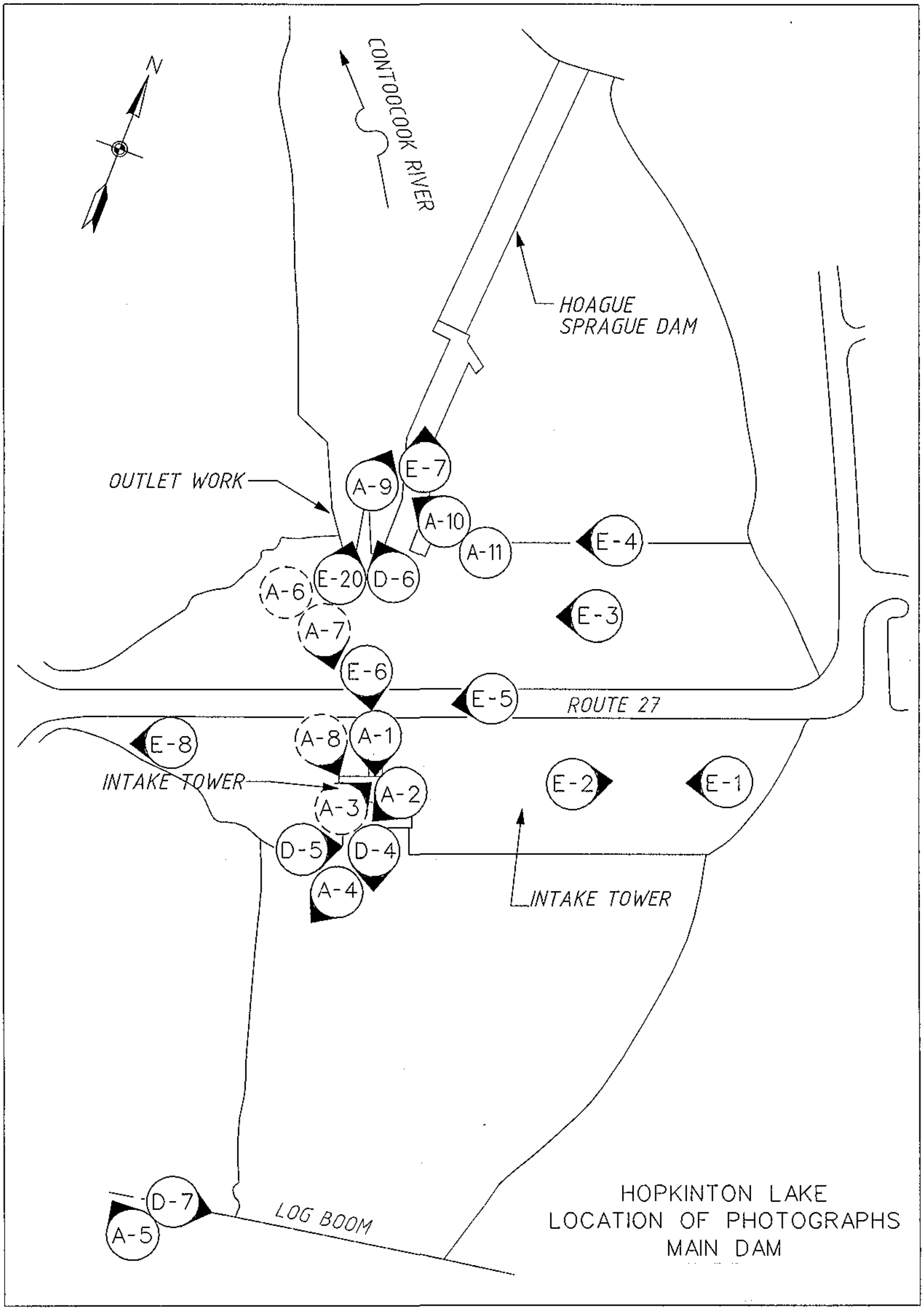
1. Rehabilitate Dike H-3. The 12 acre impervious blanket for Dike H-3 was rehabilitated in FY94. Work consisted of clearing vegetation, grubbing and seeding. Areas where stumps were removed were filled with impervious material. Work was initiated in September 1994 and completed in November 1995 at total cost of $37,400.

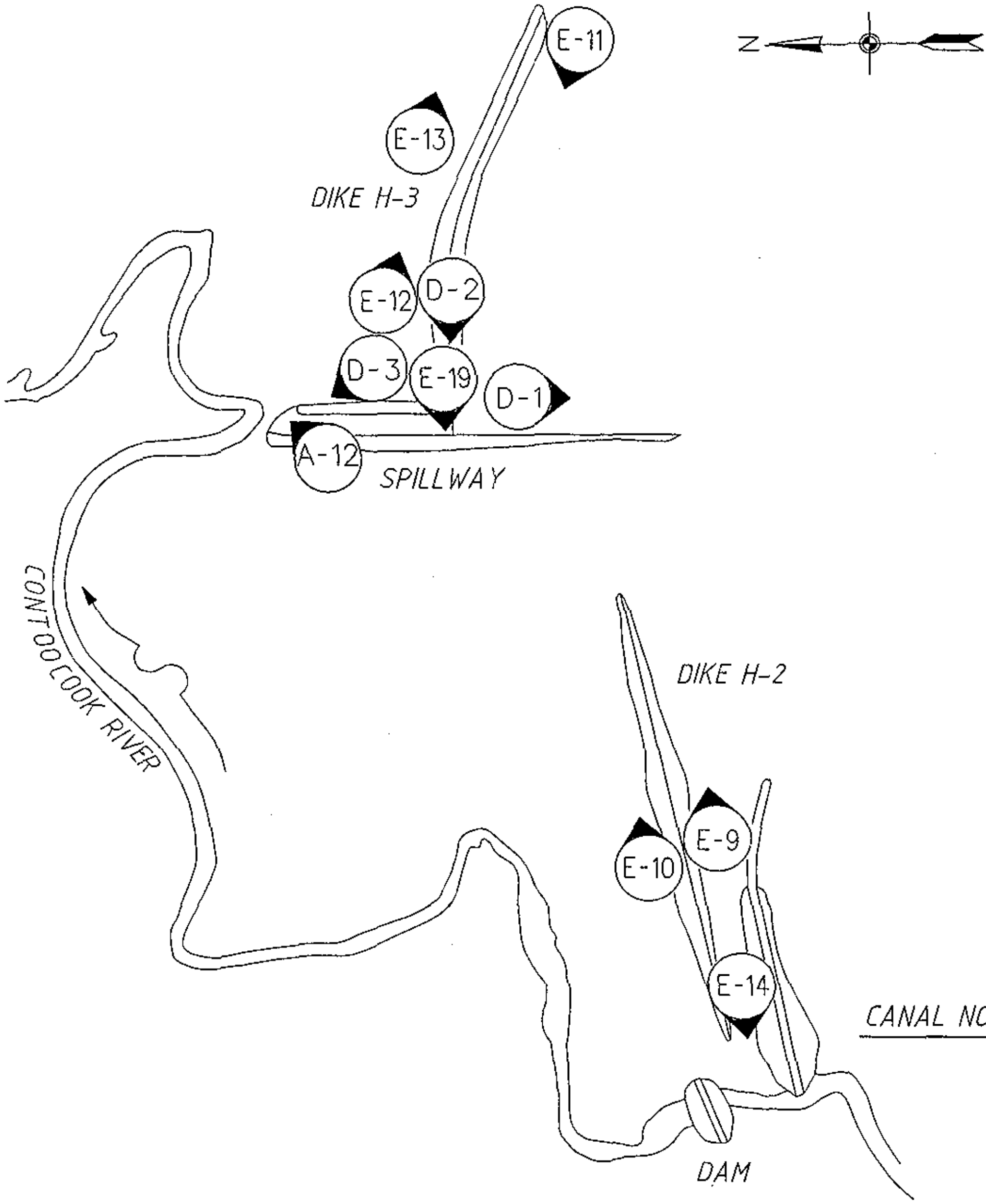
2. Replacement of Gates. In June 1995, several severe cracks and two large rectangular holes were discovered in the downstream face of gate 2. Gates 1 and 3 also showed cracking and surface deformation. All of the cracks and failures were located along the intersection of the gate skin plate with horizontal and vertical webs inside the gates. The gates were manufactured of cast iron by Goslin Birmingham in 1962. Although the reason for the failure has not been determined, it is though that a series of casting defects is the most likely cause.

A contract to install government furnished gates and actuators at the project was awarded in June 1996. Work began in August and was completed in January 1997. All six gates were replaced with fabricated stainless steel gates manufactured by Rodney Hunt. Gate stems and motorized gear operators were also replaced. Total construction cost was $740,000.

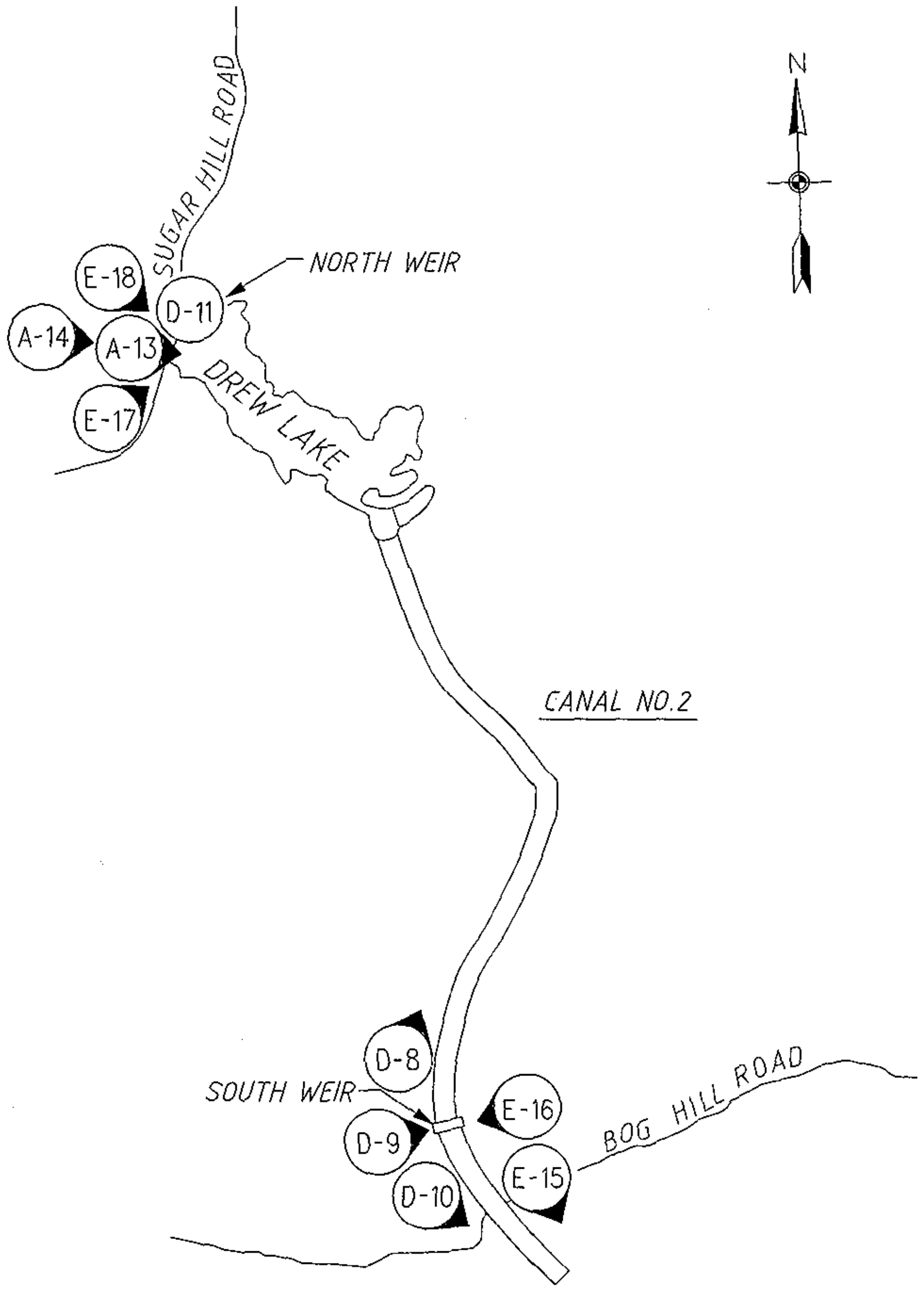
APPENDIX II

PHOTOGRAPHS


N
CONTOOCOOK RIVER
HOAGUE
SPRAGUE DAM
OUTLET WORK
A-9
E-7
A-10
A-11
E-4
E-20
D-6
A-6
E-3
A-7
E-6
E-5
ROUTE 27
E-8
A-8
A-1
INTAKE TOWER
A-2
E-2
E-1
A-3
D-5
D-4
A-4
INTAKE TOWER
D-7
A-5
LOG BOOM
HOPKINTON LAKE
LOCATION OF PHOTOGRAPHS
MAIN DAM



HOPKINTON LAKE
LOCATION OF PHOTOGRAPHS
DIKES AND CANAL



EVERETT LAKE
LOCATION OF PHOTOGRAPHS
CANAL NO.2

Photo A-1 – North face of control tower. Note hairline crack with light efflorescence at roof parapet.

Photo A-2 – Southwest chimney. Note sealed cracks in chimney and crack in flue liner, typical at northeast chimney.

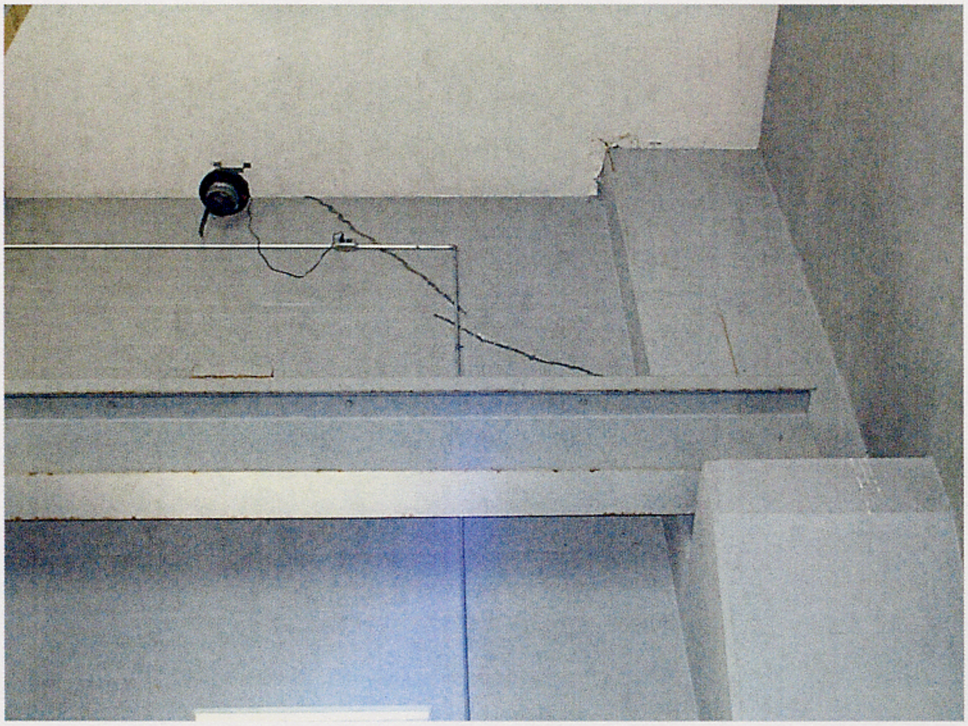


Photo A-3 – Interior of control tower, northeast corner. Note peeling paint on ceiling and sealed cracks.

Photo A-4 – Inlet Raking Platform. Note rust and missing bolts at railing base on raking platform.

Photo A-5 – Left log boom anchor, typical of right side.

Photo A-6 – Typical monolith joint. Note loose sealant material. Typical of conditions in conduit 2.

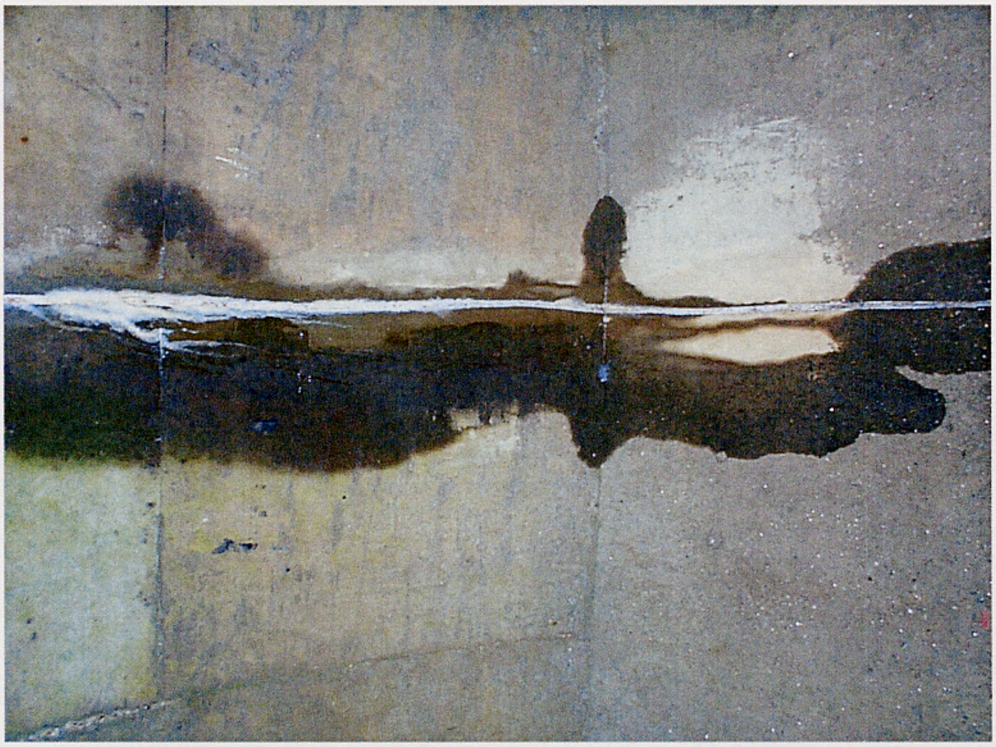


Photo A-7 – Hairline cracks with efflorescence and active seepage at ceiling joint of conduit 1 between monoliths 5 and 6. Typical of conditions in conduit 2.

Photo A-8 - Note rust on gate chamber steel and air vents. This condition is typical at all gates.

Photo A-9 - East retaining wall of outlet structure. Note isolated areas of efflorescence.

Photo A-10 - East retaining wall of outlet structure. Note spalled concrete and typical hairline cracks at fenceposts.

Photo A-11 - East retaining wall of outlet structure. Note 4" offset between wall sections.

Photo A-12 - Spillway weir/West retaining wall. Vegetation growth same as in 1997. Note hairline crack with efflorescence below horizontal construction joint.

Photo A-13 – ¼" crack at North Weir inlet wall.

Photo A-14 – Outlet of North Weir. Note spalling on top edge.

Photo B-1 - Gate 3, Downstream Side.

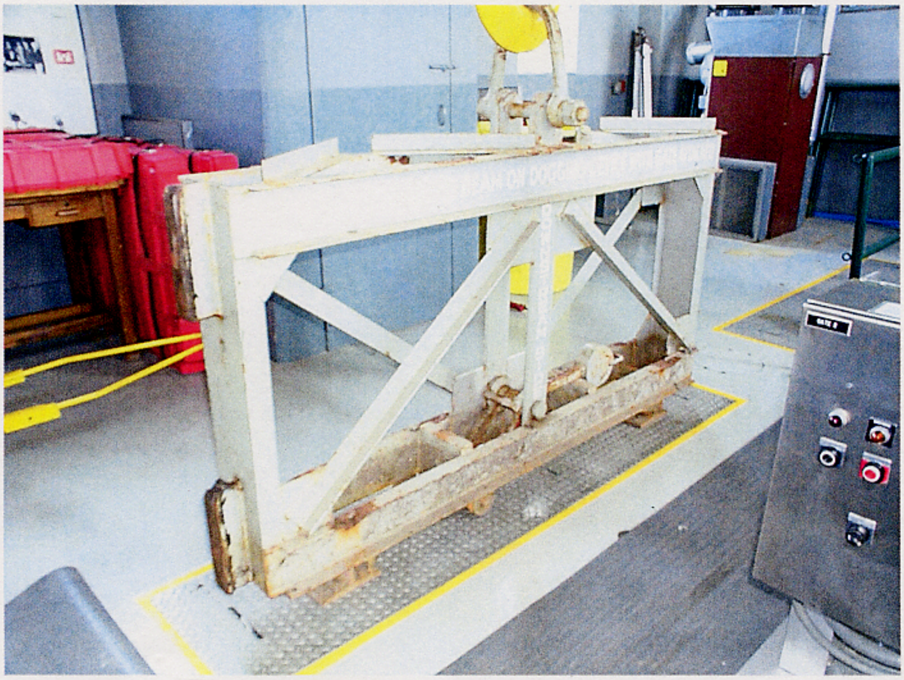


Photo B-2 - Emergency Gate Lifting Beam.

Photo D-1: Spillway approach channel, looking U/S.

Photo D-2: Spillway weir.

Photo D-3: Spillway discharge channel, looking D/S.

Photo D-4: View of the inlet channel, looking U/S.

Photo D-5: View of intake structure.

Photo D-6: View of outlet channel, looking D/S.

Photo D-7: View of log boom.

Photo D-8: Approach channel for the south weir, looking U/S.

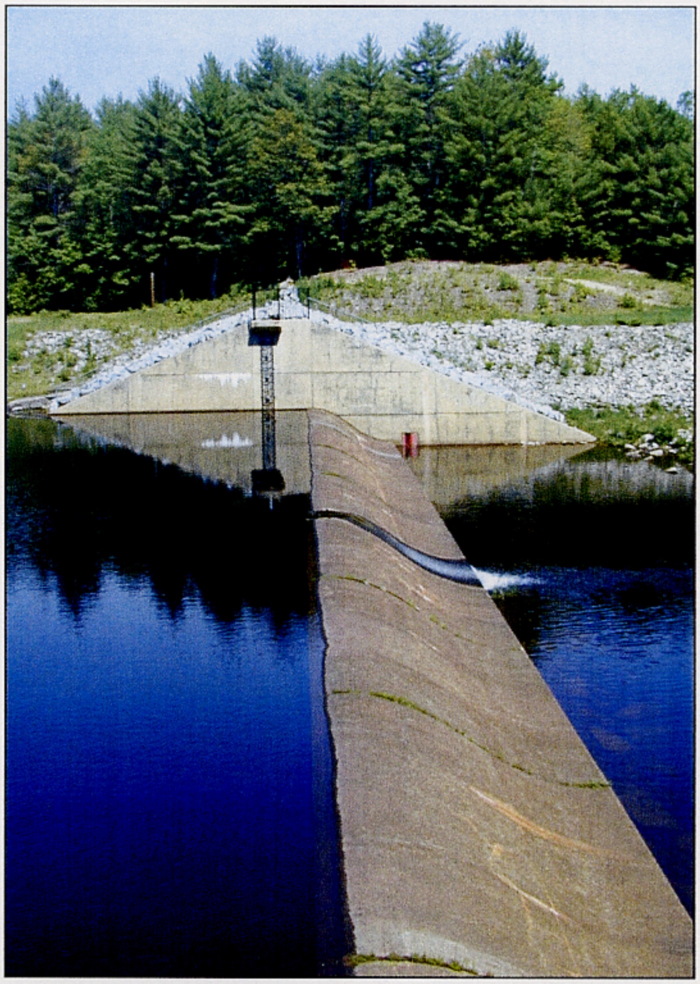


Photo D-9: South weir.

Photo D-10: South weir discharge channel, looking D/S.

Photo D-11: North weir stoplog structure.

Photo E-1: Upstream slope of the dam.

Photo E-2: Upstream Right Abutment slope.

Photo E-3: Downstream slope. Note the grass growing below the east drain outlet pipe.

Photo E-4: Downstream rock toe. Hole in crushed stone near RW-5.

Photo E-5: Crest and downstream guard rail. Dip in guard rail remains after the west outlet rain was repaired.

Photo E-6: Hole formed below the downstream sidewalk adjacent to the east catch basin.

Photo E-7: Downstream forebay dike; 2.5 years after rehabilitation repairs for the east outlet wall.

Photo E-8: Left upstream abutment. Trees have been cleared, but some brush has started to grow back.

Photo E-9: Dike H-2. Crest, upstream slope and upstream blanket.

Photo E-10: Dike H-2. Downstream slope and access road.

Photo E-11: Dike H-3. Upstream slope and impervious blanket.

Photo E-12: Dike H-3. Downstream slope and access road.

Photo E-13: Dike H-3. Area of the trees and wetland adjacent to the downstream toe.

Photo E-14: Canal No. 1. Note the vegetation along the channel, on the slopes, and at the top of the slopes.

Photo E-15: Canal No. 2 and the left downstream abutment of the south weir. The large trees and brush has been cleared.

Photo E-16: South Weir. Stone on the dike abutments has bee placed.

Photo E-17: North Weir. Note the vegetation on the upstream and lakeside of the dike. The road has recently been paved.

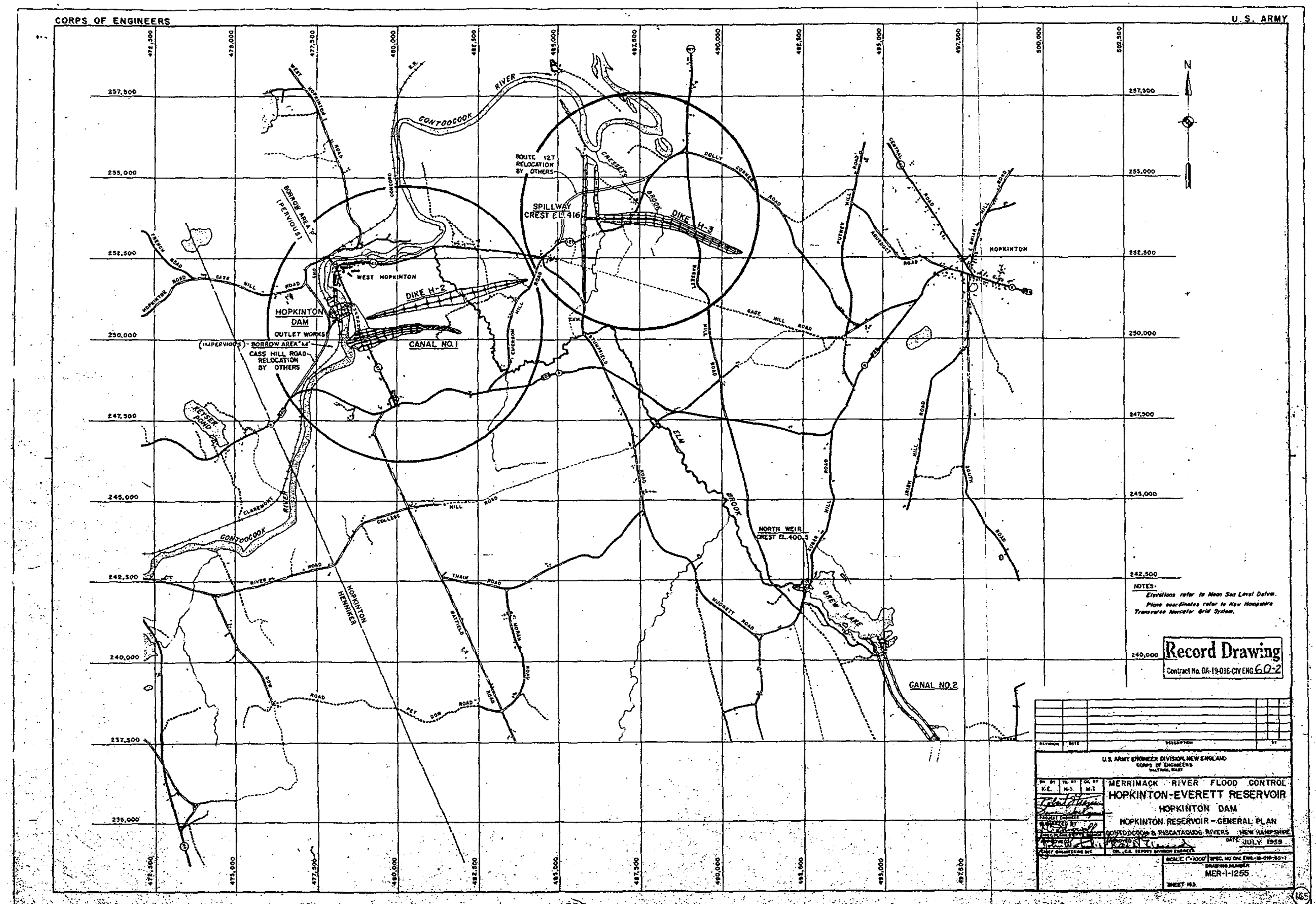
Photo E-18: North Weir. Outlet of the new box culvert under the road.

Photo E-19: Spillway. Note the vegetation growing at the top of the wingwall.

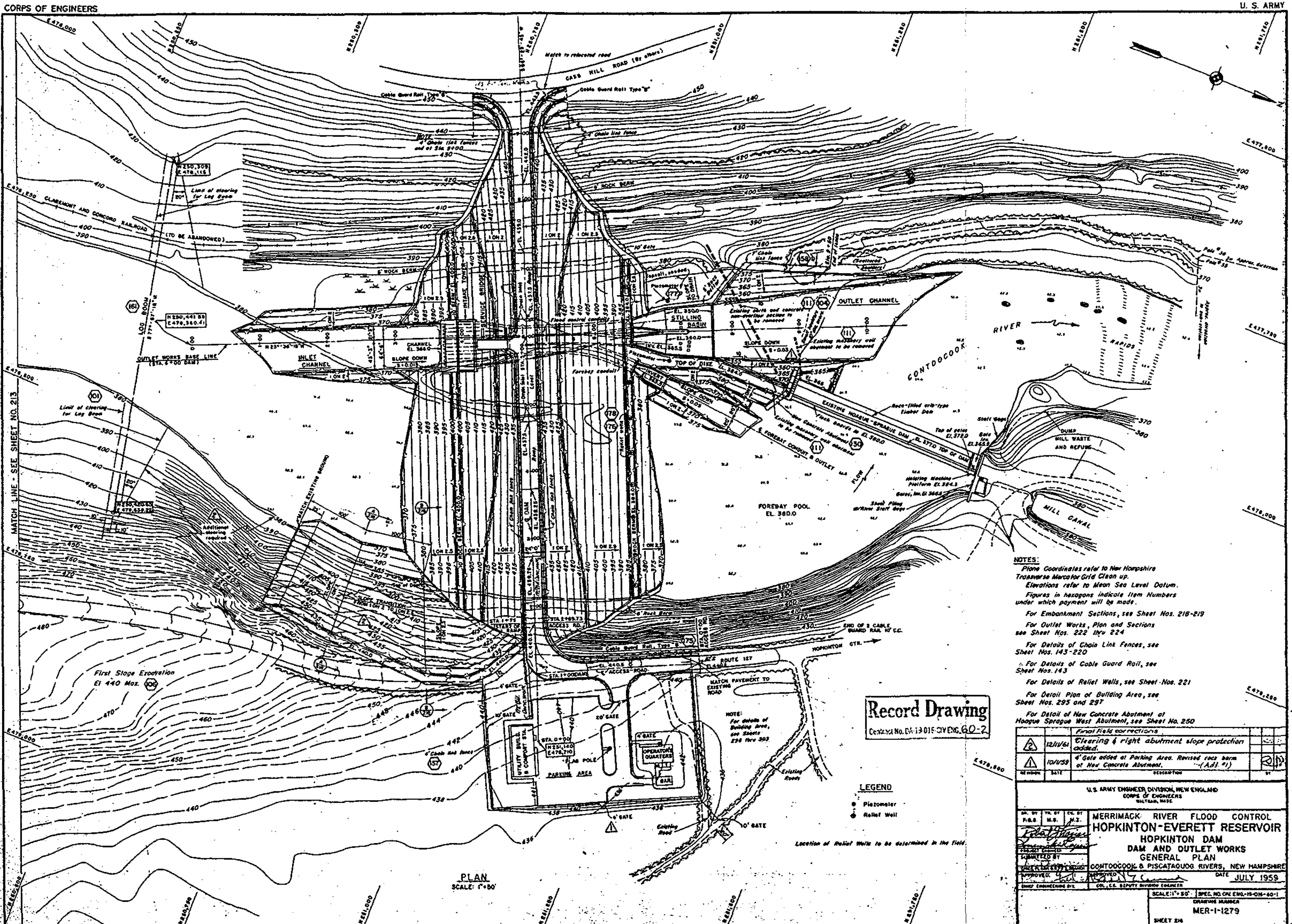
Photo E-20: Outlet and center pier. Note the trees growing in the stone.

APPENDIX III

FIGURES


CORPS OF ENGINEERS
U. S. ARMY
N
CONTOOCOOK RIVER
BORROW AREA "P" (PERVIOUS)
ROUTE 127 RELOCATION BY OTHERS
SPILLWAY CREST EL. 416
DIKE H-3
DIKE H-2
WEST HOPKINTON
HOPKINTON DAM
OUTLET WORKS
(IMPERVIOUS) BORROW AREA "M"
CASS HILL ROAD RELOCATION BY OTHERS
CANAL NO. 1
HOPKINTON
KEYSER POND
ELM BROOK
NORTH WEIR CREST EL. 400.5
DREW LAKE
CANAL NO. 2
HOPKINTON HENNIKER
NOTES:
Elevations refer to Mean Sea Level Datum.
Plane coordinates refer to New Hampshire Transverse Mercator Grid System.
Record Drawing
Contract No. DA-19-016-CIV ENG 60-2
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
MERRIMACK RIVER FLOOD CONTROL
HOPKINTON-EVERETT RESERVOIR
HOPKINTON DAM
HOPKINTON RESERVOIR – GENERAL PLAN
CONTOOCOOK & PISCATAQUOG RIVERS NEW HAMPSHIRE
DATE JULY 1959
SCALE 1"=1000'
DRAWING NUMBER
MER-1-1255
165

CORPS OF ENGINEERS | U. S. ARMY



NOTES:

Plane Coordinates refer to New Hampshire Transverse Mercator Grid Clean up.

Elevations refer to Mean Sea Level Datum.

Figures in hexagons indicate Item Numbers under which payment will be made.

For Embankment Sections, see Sheet Nos. 218-219

For Outlet Works, Plan and Sections see Sheet Nos. 222 thru 224

For Details of Chain Link Fences, see Sheet Nos. 143-220

For Details of Cable Guard Rail, see Sheet Nos. 143

For Details of Relief Wells, see Sheet Nos. 221

For Detail Plan of Building Area, see Sheet Nos. 295 and 297

For Detail of New Concrete Abutment at Hoague Sprague West Abutment, see Sheet No. 250

Revision	Date	Description	By
		Final field corrections	
2	12/11/61	Clearing & right abutment slope protection added.	
1	10/1/59	4' Gate added at Parking Area. Revised rock berm at New Concrete Abutment. (Add. #1)	

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

MERRIMACK RIVER FLOOD CONTROL
HOPKINTON-EVERETT RESERVOIR
HOPKINTON DAM
DAM AND OUTLET WORKS
GENERAL PLAN
CONTOOCOOK & PISCATAQUOG RIVERS, NEW HAMPSHIRE

DR. BY F.G.S. | TR. BY M.S. | CK. BY M.Z.

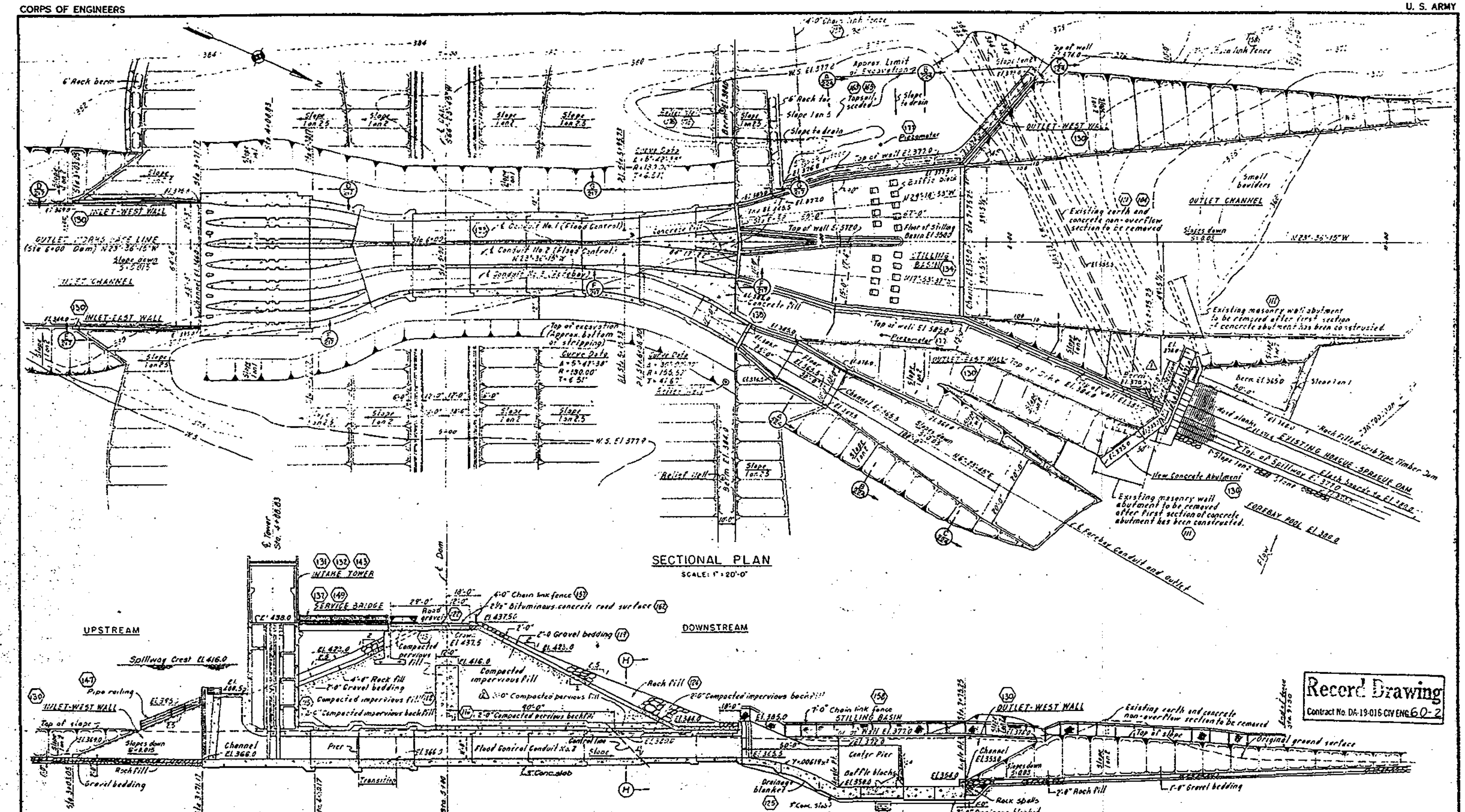
DATE JULY 1959

SCALE: 1" = 50' | SPEC. NO. CIV. ENG.-19-016-60-1

DRAWING NUMBER MER-1-1279

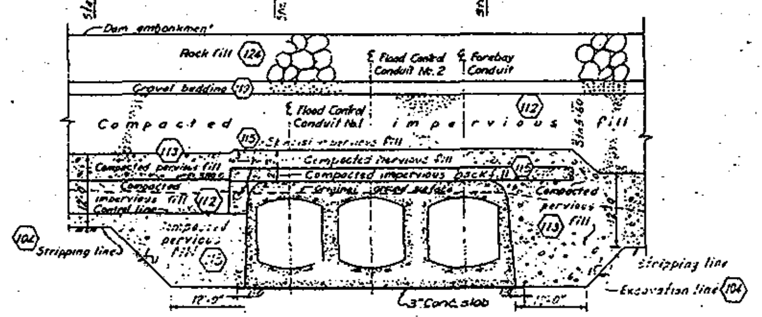
SHEET 216

CORPS OF ENGINEERS | U. S. ARMY



SECTION ALONG ℄ CONDUIT NO. 2

SCALE: 1" = 20'-0"



SECTION H-H

SCALE 1" = 10'-0"

NOTES:

Elevations refer to Mean Sea Level Datum.

Figures in hexagons indicate item number under which payment will be made.

For outlet works sections, see Sheet Nos. 223 & 224.

For intake tower concrete details, see Sheet Nos. 226 thru 231.

For conduit concrete details, see Sheet Nos. 236 thru 243.

For forebay conduit outlet channel concrete details, see Sheet No. 247.

For inlet and outlet channel concrete with details, see Sheet Nos. 225, 248, 249 & 250.

For embankment sections, see Sheet Nos. 217 thru 219.

For service bridge plan and details, see Sheet Nos. 292 thru 294.

For details of piezometers and relief wells, see Sheet No. 221.

For stilling basin concrete details, see Sheet Nos. 244 thru 246.

Revision	Date	Description
		Final field corrections
2	10/3/59	3'-0" Compacted pervious fill added. (Add. #2)
1	10/1/59	Rock berm at new concrete abutment raised to El. 372.0. Revision block added. (Add. #1)

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

MERRIMACK RIVER FLOOD CONTROL

HOPKINTON-EVERETT RESERVOIR

HOPKINTON DAM

OUTLET WORKS

PLAN & SECTION

CONTOOCOOK & PISCATAQUOG RIVERS NEW HAMPSHIRE

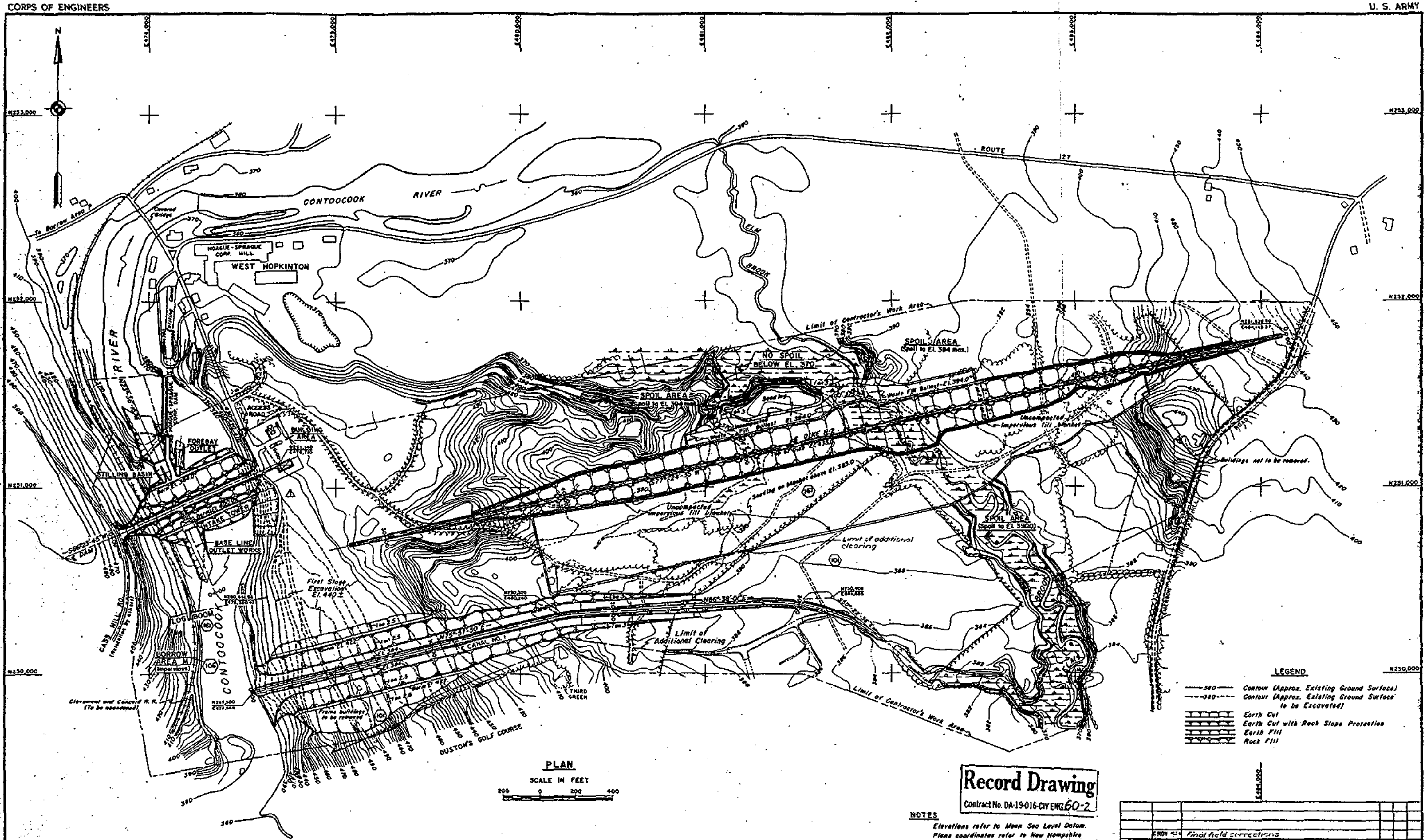
DATE JULY 1959

SCALE AS SHOWN | SPEC. NO. CIV. ENG-19-016-60-1

DRAWING NUMBER MER-1-1285

SHEET 222

CORPS OF ENGINEERS U. S. ARMY



PLAN

SCALE IN FEET

200 0 200 400

LEGEND

——340——	Contour (Approx. Existing Ground Surface)
- - -340- - -	Contour (Approx. Existing Ground Surface to be Excavated)
	Earth Cut
	Earth Cut with Rock Slope Protection
	Earth Fill
	Rock Fill

Record Drawing

Contract No. DA-19-016-CIV ENG 60-2

NOTES

Elevations refer to Mean Sea Level Datum.

Plane coordinates refer to New Hampshire Transverse Mercator Grid System.

Figures in hexagons indicate item numbers under which payment will be made.

For Dike H-2 Plan, Profile and Sections see Sheet Nos. 208 through 212.

For Canal No. 1 Plan, Profile and Sections see Sheet Nos. 213 through 215.

For Dam Plan, Profile and Sections see Sheet Nos. 216 through 219.

For Log Boom details see Sheet No. 220.

For Outlet Works Plan and Sections see Sheet Nos. 222 through 224.

For Building Area Plan, Sections and details see Sheet Nos. 295 through 297

REVISION	DATE	DESCRIPTION	BY
	NOV	Final field corrections	
△	12/11/61	Slope protection to right abutment added.	

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY K.E. DR. BY C.T.M. CK. BY M.Z.

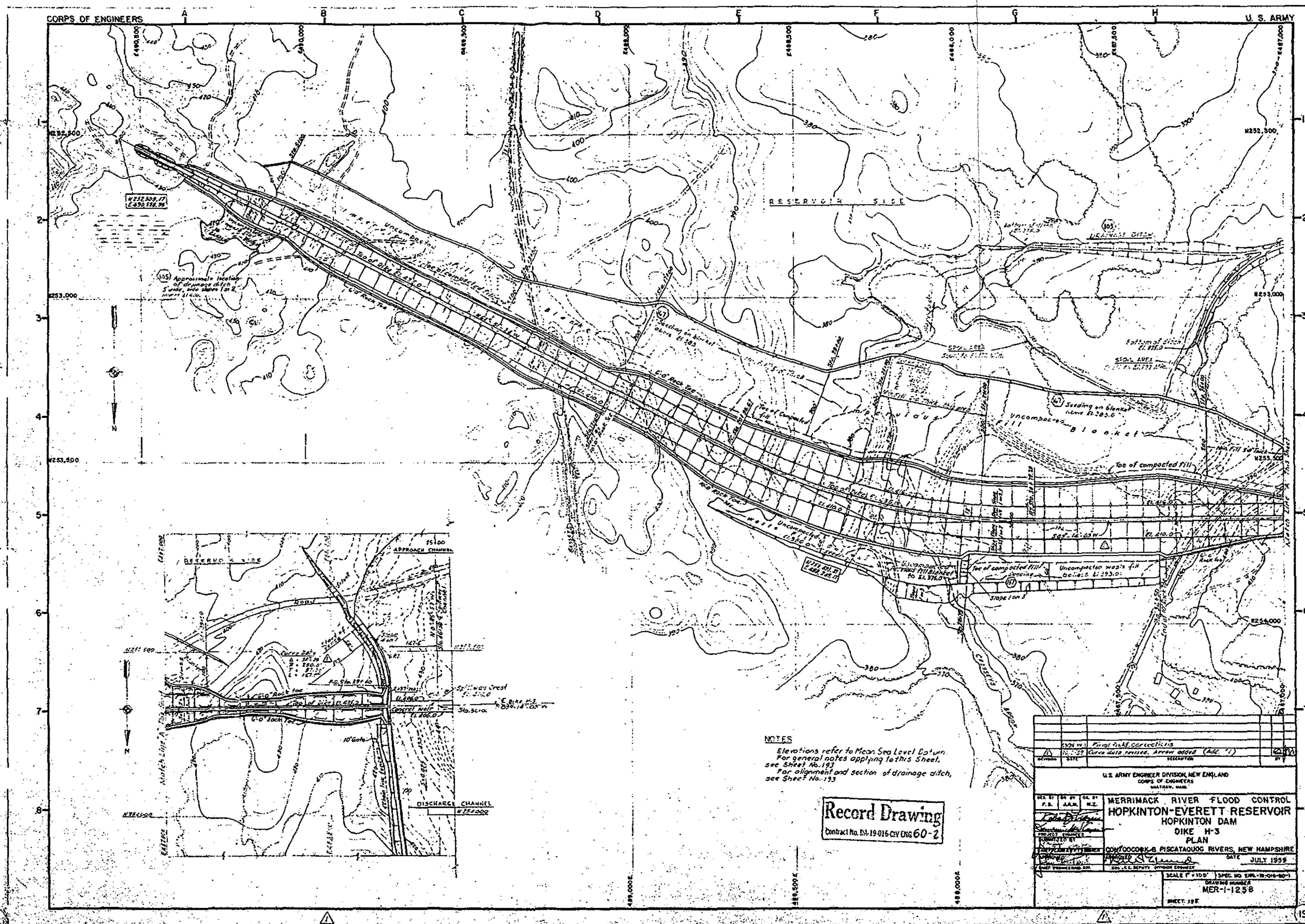
MERRIMACK RIVER FLOOD CONTROL
HOPKINTON-EVERETT RESERVOIR
HOPKINTON DAM
DAM - DIKE H-2 AND CANAL NO. 1
GENERAL PLAN
CONTOOCOOK & PISCATAQUOG RIVERS, NEW HAMPSHIRE

PROJECT ENGINEER
SUBMITTED BY
APPROVED
CHIEF, ENGINEERING DIV.
APPROVED
COL., C.E. DEPUTY DIVISION ENGINEER
DATE JULY, 1959

SCALE 1"=200' SPEC. NO. CIV. ENG-19-016-60-1

DRAWING NUMBER MER-1-1257

SHEET 194



CORPS OF ENGINEERS
U. S. ARMY
RESERVOIR SIDE
Toe of compacted fill
Uncompacted fill
Seeding on blanket above El. 383.0
6'-0" Rock Toe
APPROACH CHANNEL
DISCHARGE CHANNEL
Spillway Crest
10' Gate
Match Line "A" This Sheet
NOTES
Elevations refer to Mean Sea Level Datum.
For general notes applying to this Sheet, see Sheet No. 193
For alignment and section of drainage ditch, see Sheet No. 193
Record Drawing
Contract No. DA-19-016-CIV ENG 60-2
Final field corrections
Curve data revised. Arrow added (Add. 1)
REVISION
DATE
DESCRIPTION
BY
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.
MERRIMACK RIVER FLOOD CONTROL
HOPKINTON-EVERETT RESERVOIR
HOPKINTON DAM
DIKE H-3
PLAN
CONTOOCOOK & PISCATAQUOG RIVERS, NEW HAMPSHIRE
PROJECT ENGINEER
SUBMITTED BY
APPROVED
DATE
JULY 1959
SCALE 1" = 100'
DRAWING NUMBER
MER-1-1258
195

APPENDIX IV

INSPECTION CHECKLISTS

TEAM MEMBER CHECKLIST FOR PERIODIC INSPECTION NO. 6		
AREA EVALUATED	**BY**	**CONDITION**
CONCRETE/STRUCTURAL	JK	
CONTROL TOWER a. Exterior		
General Condition of Conc. Visible Reinforcement		Good. None
Roof		Good.
b. Interior		Good.
General Condition of Conc.		Good.
Visible Reinforcement		None
Cracks		Sealed cracks at northeast corner of tower.
Spalling		None.
Seepage/Efflor.		None
Rusting/Staining		None
INTAKE STRUCTURE General Condition of Conc.		Good.
Joints		Good.
Cracks		None.
Spalling		None.
Visible Reinf.		None.
Rusting/Staining		Railings of raking platform are rusted.
Seepage/Efflor.		None.
	JK	

TEAM MEMBER CHECKLIST FOR PERIODIC INSPECTION NO. 6 AREA EVALUATED	BY	CONDITION
CONDUIT AND TRANSITION	JK	
General Condition of Conc.		Good.
Joints		Missing/deteriorated joint filler.
Cracks		Isolated hairline cracks.
Spalling		Minor. Honeycombing typical on roof of Conduit 3.
Visible Reinf.		None.
Rusting/Staining		Minor.
Seepage/Efflor.		Typical at joints.
General Condition of Gates		Good.
General Condition of embedded steel.		Good, with surface rust.
OUTLET STRUCTURE		
General Condition of Conc.		Good.
Joints		Good, except as noted at east retaining wall.
Cracks		Isolated hairline cracks.
Spalling		Minor.
Visible Reinf.		None.
Rusting/Staining		None.
Seepage/Efflor.		Minor (at outlet headwall).
	JK	

TEAM MEMBER CHECKLIST FOR PERIODIC INSPECTION NO. 6 AREA EVALUATED	BY	CONDITION
SPILLWAY WEIR & RETAINING WALLS	JK	
General Condition of Conc.		Good.
Joints		Good.
Cracks		Isolated.
Spalling		Minor.
Visible Reinf.		None.
Rusting/Staining		None.
Seepage/Efflor.		Minor.
SOUTH WEIR & RETAINING WALLS @ CANAL NO. 2		
General Condition of Conc.		Good.
Joints		Good.
Cracks		Minor.
Spalling		None.
Visible Reinf.		None.
Rusting/Staining		None.
Seepage/Efflor.		Good.
	JK	

TEAM MEMBER CHECKLIST FOR PERIODIC INSPECTION NO. 6		
AREA EVALUATED	**BY**	**CONDITION**
NORTH WEIR STOP LOG STRUCTURE	JK	
General Condition of Conc.		Good.
Joints		Good.
Cracks		1/4" crack at inlet wall.
Spalling		None.
Visible Reinf.		None.
Rusting/Staining		None.
Seepage/Efflor.		None.
STUMPFIELD MARSH BOX CONDUIT		
General Condition of Conc.		Good.
Joints		Good.
Cracks		None visible.
Spalling		None.
Visible Reinf.		None.
Rusting/Staining		None.
Seepage/Efflor.		None.
	JK	

HOPKINTON DAM

TEAM MEMBER CHECK LIST FOR PERIODIC INSPECTION NO. 6		
AREA EVALUATED	**BY**	**CONDITION**
MECHANICAL		
SERVICE GATES (6)	DG	Excellent condition. All six gates replaced in 1996 with stainless steel gates. Gates 1, 2, 3 & 4 showed minor to moderate leakage at top and upper side seals. Significant debris in service gate wells, particularly at gates 5 and 6.
EMBEDDED STEEL	DG	Good condition.
ELECTRIC GATE OPERATORS	DG	Excellent condition. All six gate operators replaced in 1996.
EMERGENCY GATE	DG	Good condition. Debris in emergency gate slots interferes with operation of gate and lifting beam.
EMERGENCY GENERATOR 100 KW	DG	192.3 hours. Operation satisfactory.
OVERHEAD CRANE 25 Ton cap.	DG	Operation satisfactory.
WARM AIR FURNACES	DG	Operation satisfactory.

HOPKINTON LAKE

TEAM MEMBER CHECK LIST FOR PERIODIC INSPECTION NO. 6		
AREA EVALUATED	**BY**	**CONDITION**
ELECTRICAL	TA	
a. Gate Operator System		Good, relatively new.
Motors		Good.
Controllers		Good.
Wiring		Good.
Emergency Power System		
Generator		Good, relatively new
Battery		Satisfactory.
Charger		Satisfactory.
Wiring		Satisfactory.
Switchboard		Good, relatively new
Breakers		Good
Wiring		Satisfactory.
Meters		Needs adjustment.
Lighting		
Operating Floor		Satisfactory.
Wells		Needs improvement.
Exterior		Satisfactory.
Branch Circuit		
Devices		Satisfactory.
Wiring		Satisfactory.
Lightning Protection		
Roof Connections		Needs improvement.
Earth Connections		Needs repair.
Conductors		Satisfactory.
Service		
Equipment		Satisfactory.
Conductors		Satisfactory.

HOPKINTON LAKE

TEAM MEMBER CHECK LIST FOR PERIODIC INSPECTION NO. 6		
AREA EVALUATED	**BY**	**CONDITION**
ELECTRICAL	TA	
a. Gate Operator System		Good, relatively new.
Motors		Good.
Controllers		Good.
Wiring		Good.
Emergency Power System		
Generator		Good, relatively new
Battery		Satisfactory.
Charger		Satisfactory.
Wiring		Satisfactory.
Switchboard		Good, relatively new
Breakers		Good
Wiring		Satisfactory.
Meters		Needs adjustment.
Lighting		
Operating Floor		Satisfactory.
Wells		Needs improvement.
Exterior		Satisfactory.
Branch Circuit		
Devices		Satisfactory.
Wiring		Satisfactory.
Lightning Protection		
Roof Connections		Needs improvement.
Earth Connections		Needs repair.
Conductors		Satisfactory.
Service		
Equipment		Satisfactory.
Conductors		Satisfactory.

TEAM MEMBERS CHECKLIST FOR PERIODIC INSPECTION NO. 6		
AREA EVALUATED	**BY**	**CONDITION**
HYDROLOGY/HYDRAULICS	BW	
Spillway:		
Approach Channel		Clear. Some vegetation.
Control		Good.
Discharge Channel		Clear.
Outlet Works:		
Inlet:		
Channel		Clear.
Log Boom		Good.
Trash Racks		Good Condition. Minor Debris.
Gates		Good. Refer to Mechanical App..
Emerg. Closure		Operated Satisfactorily. Refer to Mech. App..
Air Vents		Clear.
Outlet:		
Conduit		Good.
Exit Channel		Clear.
North Weir:		
Approach Channel		Clear.
Stoplog Structure		Good.
Discharge Channel		Clear.
South Weir:		
Approach Channel		Clear.
Control		Good.
Discharge Channel		Clear.
Instrumentation:		
Rain Gage		Good.
Pool Stage Recorder	BW	Good.
Tailwater Gage		Good.
Tile Staff Gage		Good.

TEAM MEMBERS CHECKLIST FOR PERIODIC INSPECTION NO. 6		
AREA EVALUATED	**BY**	**CONDITION**
GEOTECHNICAL	LF	
DIKE H-3 EMBANKMENT		
Crest Elevation	RS	435.0 feet NGVD
Surface Cracks		None observed.
Crest Condition		Gravel surface in good condition.
Movement or Settlement of Crest		None observed.
Lateral Movement		None observed.
Vertical Alignment		Good.
Horizontal Alignment		Good.
Condition at Abutment		Good.
Indications of Movement of Structural Items on Slope		None.
Trespassing on Slopes		None observed.
Sloughing or Erosion of Slopes or Abutments		None observed.
Rock Slope Protection		Good.
Rip Rap Failures		None observed.
Unusual Movement or Cracking at or Near Toes		None observed.
Unusual Embankment or Downstream Seepage		None observed.
Piping or Boils		None observed.
Foundation Drainage Features:		
Toe Drains		Dry.
Upstream Impervious Blanket		Grass covered. Tire ruts up to 4" deep across blanket.
Instrumentation		None.
Vegetation		
Upstream Slope		None.
Crest		None.
Downstream Slope		None.
Toes	↓	D/S toe from swamp to right abutment heavily vegetated with trees.

TEAM MEMBERS CHECKLIST FOR PERIODIC INSPECTION NO. 6		
AREA EVALUATED	**BY**	**CONDITION**
GEOTECHNICAL	LF	
DAM EMBANKMENT		
Crest Elevation	RS	437.0 feet NGVD
Surface Cracks	↓	None observed.
Pavement Condition		Office parking lot pavement is Fair. Transverse cracks and new radial cracks in the pavement on the crest of the dam
Movement or Settlement of Crest		None observed.
Lateral Movement		None observed.
Vertical Alignment		Good.
Horizontal Alignment		D/S guardrail near the west drain still "dips". The drain's outlet pipe has been repaired and the slope is stable.
Condition at Abutment and at Concrete Structures		Good.
Indications of Movement of Structural Items on Slope		None observed.
Trespassing on Slopes		None Observed.
Sloughing or Erosion of Slopes or Abutments		There is a hole in the gravel shoulder under the sidewalk adjacent to the downstream east catch basin. D/S toe berm's crushed stone cover continues to settle into the rip-rap.
Rock Slope Protection Riprap Failures		Good overall. Some weathering of a few rocks. Some gravel deposits on the d/s slope below drain outlets. Small patch of gravel ½ way up slope in-line with PZ-3.
Unusual Movement or Cracking at or Near Toes		None observed.
Unusual Embankment or Downstream Seepage		None observed.
Piping or Boils		None observed.
Foundation Drainage Features		Eight relief wells at downstream toe. Forebay pool backed up in the wells.
Toe Drains		No toe drains at this dam.
Instrumentation System	↓	20 Casagrande-Type piezometers are in good condition. Tilt Plates & survey monuments good. Mon. 7 on crest broken.

TEAM MEMBERS CHECKLIST FOR PERIODIC INSPECTION NO. 6		
AREA EVALUATED	**BY**	**CONDITION**
GEOTECHNICAL DAM EMBANKMENT (cont'd.)	LF RS	
Vegetation or Debris	↓	
Upstream Slope		None.
Crest		None.
Downstream Slope		None.
Toe		U/S toe covered with grass and small brush at water's edge. D/S berm slope above forebay pool covered with brush.
SPILLWAY WEIR, APPROACH, AND DISCHARGE CHANNELS		
Approach Channel		
General Condition		Good. Gap between the bottom of the safety fence and stone.
Loose Rock or Trees Overhanging Channel		Tree growth on the top of the rock walls.
Floor of Approach Channel		Some brush in the u/s channel.
Discharge Channel		
General Condition		Good.
Loose Rock or Trees Overhanging Channel		Tree growth on the top of the rock walls.
Floor of Channel		Clear.
Other Obstructions		None.
OUTLET WORKS		
Intake Channel		
Slope Conditions		Good.
Rock Slides or Falls		None.
Drains or Weep Holes		Underwater.
Debris		Some debris on the trash racks.
Outlet Channel		
Loose Rock or Trees Overhanging Channel		None. Gap below safety fence along west wingwall.
Condition of Discharge Channel		Clear.

TEAM MEMBERS CHECKLIST FOR PERIODIC INSPECTION NO. 6		
AREA EVALUATED	**BY**	**CONDITION**
GEOTECHNICAL	LF	
DIKE H-2 EMBANKMENT		
Crest Elevation	RS	435.0 feet NGVD
Surface Cracks	↓	None observed.
Crest Condition		Gravel surface in good condition.
Movement or Settlement of Crest		None observed.
Lateral Movement		None observed.
Vertical Alignment		Good.
Horizontal Alignment		Good.
Condition at Abutment		Good.
Indications of Movement of Structural Items on Slope		No structural items on slope.
Trespassing on Slopes		None observed.
Sloughing or Erosion of Slopes or Abutments		None observed.
Rock Slope Protection		Good.
Rip Rap Failres		None observed.
Unusual Movement or Cracking at or Near Toes		None observed.
Unusual Embankment or Downstream Seepage		Drainage ditches dry. Ponded water u/s of toe near Elm Brook Rd.
Piping or Boils		None observed.
Foundation Drainage Features:		
Toe Drains		Culvert outlet @ sta 9+00 covered with debris and sand/gravel.
Upstream Impervious Blanket		Grass covered.
Instrumentation		None.
Vegetation		
Upstream Slope		None.
Crest		None.
Downstream Slope		None.
Toes	↓	Minor. Trees fallen across d/s access road.

APPENDIX V

SUMMARY OF INSPECTION NOTES

PERIODIC INSPECTION REPORT NO. 6
HOPKINTON LAKE
SUMMARY OF INSPECTION NOTES

TABLE OF CONTENTS

APPENDIX V-A

PERIODIC INSPECTION REPORT NO. 6
HOPKINTON LAKE
CONCRETE/STRUCTURAL NOTES

PERIODIC INSPECTION REPORT NO. 6
HOPKINTON LAKE
WEST HOPKINTON, NEW HAMPSHIRE
CONCRETE & STRUCTURAL FEATURES

1. FIELD INSPECTION

The concrete/structural portion of Periodic Inspection No. 6 of Hopkinton Lake Dam at West Hopkinton, New Hampshire was conducted on 4 June 2002 by John Kedzierski from the Design Branch, Engineering/Planning Division of New England District. Major features inspected were as follows:

- Control Tower
- Inlet Structure and Log Boom
- Conduits and Transitions
- Outlet Structure
- Spillway Weir
- Spillway Retaining Walls
- South Weir and Retaining Walls at Canal No. 2
- North Weir Stop Log Structure & Conduit
- Stumpfield Marsh Box Conduit

Conduit number 3 was not accessible during the 4 June 2002 inspection. It was inspected on 25 September 2002 after the forbay of the Hoague Sprague hydropower dam was drained allowing access to the conduit.

2. CONTROL TOWER

a. Exterior: The overall condition of the concrete at the exterior of the tower is good with some isolated areas of deterioration. The minor efflorescence at the left side of the entrance above the door has not changed since the last inspection. In addition there are isolated hairline cracks with light efflorescence along the north fascia of the parapet (see Photo A-1). The roof membrane and aggregate overlay appear to be in good condition with no known leakage to the interior of the structure. The roof aggregate does not cover the northern edge of the roof membrane adjacent to the parapet. The parapet has hairline cracks where lightning protection rods are attached. In addition, both chimneys have sections of cracked flue liners where they protrude from the masonry (see Photo A-2). The chimneys have cracks that have been sealed.

b. Interior – Operating Level: The overall condition of the concrete, ceiling, floor slabs, and steel crane supports are good. The condition of the concrete in the fallout shelter area is also good with no defects. There are two sealed cracks in the northeast corner of the control tower and peeling paint on the ceiling near the chimney/ceiling interface (see Photo A-3). The corbels supporting the overhead crane all appear to be in good condition with no visible cracks or deterioration.

c. Interior – Gate Wells: The overall condition of the concrete and ladders in the six service gates is good. The gate wells are numbered 1 to 6 from east to west. Gate well numbers 1 and 2 have significant amounts of debris at the lowest level (1 to 2 feet thick). The concrete is good and there were no spalls or cracks. The ladders are also in good condition. The concrete in the remaining gate wells was also in very good condition. There was also less debris in gate wells 3 through 6.

3. INLET STRUCTURE AND LOG BOOM

The overall condition of the concrete at the inlet structure is good. A few tiles are missing from the gage at El. 384. The raking platform, walls, and pier are in good condition. The top of the west side wall appears to be leaning approximately ½" inward and the east side wall is about 1" inward all the way to the waterline in relation to the raking platform. It may be that these walls were cast this way, however, Periodic Inspection No. 5 noted "movement of the top of the west side wall...increased approximately ¼" since the last inspection".

The railings are rusted and there are loose/missing bolts at various base plate connections and at the top railing-parapet connection on the west side (see Photo A-4). There is also debris and vegetation on the raking platform.

The log boom is in overall good condition. The log boom anchors also appear to be in good condition (see Photo A-5).

4. CONDUITS, TRANSITION & GATES

The project consists of three conduits numbered from west to east. Each conduit consists of nine monoliths numbered 0 to 8, with monolith 0 nearest the gates. Monoliths 0 through 2 are in the transition area, and 3 through 8 are in the main conduit. In the transition area, splitter walls divide each conduit into two barrels (lettered A through F from west to east) allowing for two gates in each conduit. Conduits 1 and 2 are used for flood control and conduit 3 leads to the forebay of the Hoague Sprague hydropower dam. Conduit 3 is submerged most of the time.

a. Conduits, Transitions, and Splitter Walls 1 & 2: The concrete in the conduits, transitions, and splitter walls is in good condition with some areas of deterioration as described below and in the crack survey. Numerous joints between the monoliths have joint sealant that is is missing, falling down, or loose (see Photos A-6 and A-7). Some of the joints on the conduit ceiling and the sides have active seepage, hairline cracks, and efflorescence. The conduits are abraded throughout the lower 3' about ¼" to ½" deep.

b. Conduit 3: This conduit can only be inspected when the forbay of the adjacent hydropower dam is drained. The conduit was inspected using a canoe to gain access up to the gates. There is about 4 feet of water and a thorough inspection of the conduit invert was impossible. The visible portions of the conduit, transition, and splitter walls are in overall good condition. There was a substantial amount of debris caught in the air vents. All the monoliths were well aligned. This conduit contains barrels E and F. There is evidence of cavitation in the concrete roof of Barrel E just downstream of the gate. Barrel F has a moderate spall on the roof near the manhole opening. There is honeycombing on the conduit roof typically throughout the entire length. There is moderate efflorescence and active seepage through the roof joint between monoliths 5 and 6. There is a 6' long spalled area at the joint between the roof and the west wall of monolith 3.

c. Gates: The overall condition of the gates and gate liners is good with no significant defects. The steel gate liners are rusted (see Photo A-8).

5. OUTLET STRUCTURE

The outlet structure consists of east and west concrete retaining walls, a concrete headwall, splitter wall between Conduits 1 and 2, and an apron with baffle blocks. The overall condition of the concrete at the outlet structure is good. Bonding and alignment of joints of the retaining walls and headwalls are good, except where noted at the east retaining wall. The east retaining wall has recently been modified to correct previous movement and is being monitored by the Geotechnical Engineering Section. The baffle blocks were underwater and were not inspected. There are isolated areas of light efflorescence, particularly at the east retaining wall (see Photo A-9). At the interface between the last monolith of Conduit 2 and the concrete apron, there is a 8" long x 4" wide x 2" deep spall about 2' from the east retaining wall. There is ½" deep abrasion on the apron and at the lower portions of the splitter wall close to the conduit monoliths.

The east retaining wall has numerous areas of scaling on the top horizontal portion of the wall. There is also a 12" x 7" x 2" deep spall (see Photo A-10), a 15" x 8" x 2" deep spall, and hairline to 1/16" cracks where the fence posts are attached to the top of the wall. There is a 4" offset between wall sections at the north end of the east retaining wall (see Photo A-11). This is apparently a pre-existing condition. The headwall over conduit 2 has heavy efflorescence at a horizontal construction joint. The outlet concrete at conduit 3 is in overall good condition with only one isolated hairline crack with efflorescence on the westerly wall.

6. SPILLWAY WEIR

The overall condition of the concrete in the spillway is good. Minor joint deterioration was noted at various locations. There are isolated hairline cracks with efflorescence and there is vegetation at the joint between the spillway and the west retaining wall (see

Photo A-12). A spall (<1 s.f.) on the middle of the downstream face next to a weephole has not changed since the last inspection.

7. SPILLWAY RETAINING WALLS

There are spillway retaining walls on both east and west sides of the channel. The overall condition of the concrete of the spillway retaining walls is good. Bonding and alignment of joints are good. The upstream side of the west retaining wall has vegetation growing out of a weephole and the downstream side has a hairline crack with efflorescence.

8. SOUTH WEIR & RETAINING WALLS AT CANAL NO. 2

The south weir sluice gate is still inoperative due to a broken gate stem, however, the sluice gate discharge conduit has been sealed with a steel plate. The remainder of the south weir is in overall good condition with no significant defects and only some minor vegetation along the joints. The overall condition of the concrete at the retaining walls is good. There is some minor efflorescence at horizontal joints of the west wall.

9. NORTH WEIR STOP LOG STRUCTURE & CONDUIT

The overall condition of the concrete is good. Deteriorated concrete has been repaired since the last Periodic Inspection in 1997. There is still a ¼" crack at the left inlet return wall (see Photo A-13). The outlet structure has minor spalling at the top edge (see Photo A-14).

10. STUMPFIELD MARSH BOX CONDUIT

The overall condition of the concrete in this 10' x 12' conduit is excellent. There was minor amounts of debris at the inlet and the inside of the conduit was not inspected.

11. STATUS OF PREVIOUS RECOMMENDATIONS

<u>Normal Maintenance:</u>

a. Project personnel should continue to cleanup all debris and tree branches for all service gate wells. Not completed.

b. Project personnel should monitor the concrete spalls at the downstream face of the spillway. Completed.

12. RECOMMENDATIONS

Normal Maintenance:

a. Clean debris on raking platform and within the gate wells. Estimated Cost = $8,000

b. Potential movement of inlet sidewalls should be monitored at subsequent Periodic Inspections. Estimated Cost = $0

c. Replace top sections of flue liner to prevent water damage to chimney. Estimated Cost = $2,000

d. Replace joint sealant in conduits. Estimated Cost = $30,000

e. Paint/corrosion at steel liners in gate chamber should be monitored at subsequent Periodic Inspections. Estimated Cost = $0

f. Paint railings at raking platform at install new mounting bolts, as necessary. Estimated Cost = $500

g. Continue to monitor pre-existing movement of outlet walls at subsquent Periodic Inspections. Estimated Cost = $0

APPENDIX V-B

PERIODIC INSPECTION REPORT NO. 6
HOPKINTON LAKE
MECHANICAL NOTES

PERIODIC INSPECTION REPORT NO. 6
HOPKINTON DAM
HOPKINTON, NEW HAMPSHIRE

1. FIELD INSPECTION

The mechanical portion of Periodic Inspection No. 6, Hopkinton Dam, was performed on 4 June 2002 by Ms. Deborah Gabrielson of Design Branch, Engineering Division.

Service gates 1 through 4 were closed and locked out. The conduits were accessed by an extension ladder lowered to the apron, and the downstream sides of these four gates and their associated embedded steel were inspected. Gates 5 and 6 are submerged in the pool impounded by the Hoague-Sprague Corporation Dam downstream. The gate stems were inspected from the service gate wells. Upstream embedded steel could not be inspected because normal upstream pool level (El. 382) is above the top of the service gates.

Mechanical items located in the gate tower were inspected as described below.

2. OUTLET WORKS

a. Control Tower

(1) Gate Operating System. Gate operators were tested using both commercial and emergency power. The operators performed smoothly and quietly. Backup torque switches were installed on the Limitorque operators in 1997.

(2) Emergency Generator. The 100 kw emergency generator started easily and ran smoothly. After the generator warmed up, power was manually transferred over to run the lights and service gates.

(3) Heating System. Project personnel report that warm air furnace operation is satisfactory. A temporary fuel tank has been installed on the operating floor pending repairs to the existing fuel storage tank fill and vent pipe system.

(4) Hoisting Equipment. Project personnel report that the 25 ton capacity bridge crane operates satisfactorily. The primary use of the crane is to install the emergency gate. Due to problems with debris in the gate wells (see below), installation of the emergency gate was not attempted.

b. Gates

(1) Service Gates. The downstream sides of gates 1, 2, 3, and 4 were inspected from inside the conduits and were found to be in excellent condition. Embedded steel at gates 1 through 4 was in good condition with minor rust. Air vents were clear except for at gate 3, where a board was lying across the vent. Gates 1 through 4 all showed minor leakage at the top and upper side seals. (See Photo B-1.) All six gate stems were in excellent condition. Large amounts of debris were found in all six service gate wells with gates 5 and 6 being the worst. Steel thrust nut cover plates from the original gates (which were replaced in 1996) were found in gate wells 2 and 6. Project personnel report that due to the area being classified as a confined space, debris has not been cleaned out for several years.

(2) Emergency Gate. Operation of the emergency gate continues to be hampered by debris in the emergency gate slots which cause the gate and the lifting beam to get stuck part way down the slot, and by problems with the design of the lifting beam link pin mechanism. Debris has not been cleared out of the emergency gate wells for several years.

The lifting beam is provided with an automatic release mechanism which is designed to release the link pin from the gate hook when the weight of the gate is removed from the pin. The open design of the lifting beam permits debris to interfere with the operation of the link pin mechanism. (See Photo B-2.) This can cause the pin to release prematurely, or can prevent it from engaging with the gate hook, so that the gate cannot be retrieved. Debris also interferes with gate movement in the slot and can prevent tight gate closure.

3. SLUICE GATE AT SOUTH WEIR (See Appendix D, Hydrologic and Hydraulic Features for report on condition of gate and recommendations.)

4. RECOMMENDATIONS

a. Dam Safety Items

(1) Project personnel should resume regular removal of debris from the service gate wells. If debris continues to build up, it could ultimately interfere with operation of and access to the service gates. Debris should be removed at least once a year. The Safety Office is available to assist in developing a standard procedure for entering and working in the service gate wells. The two steel thrust nut cover plates in gate wells 2 and 6 should be removed since they could be tossed about and cause damage

to the gate stems during an extreme flood event. It is likely that debris from wells 5 and 6 will have to be brought up to the operating floor for disposal. The level of the downstream pool at El. 380 is above the top of the gate passage, and this will prevent disposal of debris through the gate slot. Debris from wells 1-4 may be brought up to the operating floor for removal or, if the emergency gate has been inserted upstream of the gate being cleared, the debris may be dropped into the service gate slot for disposal. If the latter procedure is chosen, the work should be coordinated with removal of debris from the emergency gate wells (see below).

b. Budgetary Items

(1) Debris should be removed from emergency gate wells on an annual basis. Also, the board should be removed from the gate 3 air vent. Due to difficult access, and confined space issues, this work could be contracted out. Estimated cost for removal is $41,000. The Safety Office is available to assist in developing a standard procedure for entering and working in the emergency gate wells, if project personnel wish to perform this work themselves.

(2) The lifting beam should be modified to prevent debris from intruding through the sides of the beam. Estimated E&D for a structural design sketch is $2,000. Estimated construction cost is $500.

(3) When the fuel storage tank vent and fill lines are repaired and the tanks placed back into service, the existing fuel transfer pump system located below the operating floor should be removed, as it is unreliable and could result in a major oil spill if the fuel piping were to break. Each furnace should be provided with its own day tank and integral fuel transfer pump on the operating floor level. Estimated cost of two 10 gallon capacity tanks with pumps, secondary containment, and associated controls is $5,000.

c. Normal Maintenance See Dam Safety Items.

APPENDIX V-C

PERIODIC INSPECTION REPORT NO. 6
HOPKINTON LAKE
ELECTRICAL NOTES

PERIODIC INSPECTION REPORT NO. 6
HOPKINTON LAKE
ELECTRICAL

1. FIELD INSPECTION

The electrical features of Hopkinton Lake were inspected by Thomas Ayau of the General Engineering Section (GES), Engineering/Planning Division on 4 June 2002. The major feature inspected was the Outlet Works.

2. OUTLET WORKS

a. Gate Operator System. The gate actuators and motor controllers are relatively new and operated well. Insulation resistance measurements were taken of the individual feeders to the actuators and were satisfactory. The hinged plastic covers mentioned in the previous report as being detrimental to the operation have been removed and the condition is now considered satisfactory.

b. Emergency Power System. The generator was clean, started immediately, and ran steadily. The battery appeared to be new and the connections were clean and dry. The charger was operational with a satisfactory level of trickle charge present. The conductors were clean and dry. (The dust coating on the generator mentioned in the previous report has thus been cleaned.) The generator voltage and frequency were satisfactory and stable and exhibited good regulation from no load to the maximum load that could be imposed.

c. Switchboard, Equipment, Meters & Multi-function Meter.

(1) A Power Measurement Model 3710 ACM is the "MULTI-FUNCTION METER". The meter showed the correct voltage but the current and power was not checked. The "big" and the "small" current meters both show approximately "–001.3" ampere so the zero point needs to be recalibrated.

(2) As mentioned in the previous report, the conductors connected to the transient voltage surge suppressor (TVSS) are too long and reduce its effectiveness. The ground leads should be shortened and the power conductors to or from the exterior should be connected directly to the TVSS so that the power must flow immediately next to it.

d. Lighting. The interior lighting was satisfactory but two light fixtures in one gate well were out and there may have been other fixtures out. There should be at least two lights in each well, one at each of the upper landings.

e. Branch Circuits. The receptacle outlets were sufficient and appeared to be in satisfactory condition.

f. Lightning Protection. The roof was not inspected. The down conductors along the sides of the tower were satisfactory.

g. Service Entrance. The service entrance switches near the administration/utility building and the conductors to the control tower were satisfactory.

3. RECOMMENDATIONS

a. Dam Safety Items. None.

b. Budgetary Items.

(1) Switchboard. Although not critical, as mentioned in the previous report, the meters should be adjusted and the transient voltage surge suppressor (TVSS) cables should be reconnected and shortened. Estimated construction cost is about $2,000.

(2) Lightning Protection. As mentioned in the previous report, make repairs to the lightning protection system and paint the ventilator switches, $900.

c. Normal Maintenance Items.

(1) Lighting. Replace the lamps that are out in the gate wells or replace the fixtures if they are unserviceable.

PERIODIC INSPECTION NO. 6
ELECTRICAL DATA SHEET
HOPKINTON LAKE

A. Currents, Power, & Voltage

The following data is taken with the VIP System 3 Energy Analyzer (VIP). "STATUS" gives the time of recording (hour: minute: second), the gate number (#) motion (↑=up, ↓=down), and height in feet (') (when noted). "$\Sigma(3\phi)$" indicates the average of three phases. The second line (when an "OVERALL" type reading is taken) shows the $\Sigma(3\phi)$ power factor (%); the individual phase powers in watts; the $\Sigma(3\phi)$ of the line-to-line voltage, and the line-to-ground voltages. The VIP was set for 3-wire operation and the ground lead was not connected. The VIP was connected at the switchboard. Screw actuator motors have a nameplate rating of 37.4 horsepower, 47.2 amperes @ 460 volts. Calculated power requirement is 30 kW @ 80% power factor.

	CURRENT (amperes)				REAL POWER (watts)	VOLTAGE (volts)		
	Phase					Phase		
STATUS	L1	L2	L3	$\Sigma(3\phi)$ A		12	23	31
Rotation, p. f., neutral		power			$\Sigma(3\phi)$ V	L1	L2	L3
14:25:18 #5 ↑ 5'	13	13	11	13	7080	470	469	465
70%	2710	2270	2100			$\Sigma(3\phi) = 468$		
(The VIP internal batteries need replacement so the clock reset and to an erroneous hour.)								
31:45:31 #5 ↑ 7'	p.f. = 65%			12	6151	$\Sigma(3\phi) = 469$		
31:54:39 MAINS INTERRUPTION (commercial breaker opened)								
31:54:42 MAINS RETURN (generator breaker closed)								
31:55:12 #6 ↓	p.f. = 74%			13	7840	$\Sigma(3\phi) = 478$		
31:55:41 #6 ↓ 7.5'	13	12	13	13	7430	478	478	475
71%, 60.8 Hz	2490	2410	2530			$\Sigma(3\phi) = 477$		
31:42:06	p.f. = 99%			0.210	173	$\Sigma(3\phi) = 478$		

B. Insulation Resistance Tests (θ-G in megohms @ 1000 volts DC)

	PHASE:	A	B	C
Gate #1:	Feeder	∞	∞	∞
Gate #2:	Feeder	∞	∞	∞
Gate #3:	Feeder	∞	∞	∞

Gate #4:	Feeder	∞	∞	∞
Floodlight circuit #3:			7	7
Floodlight circuit #4:		63 (bottom)		57 (top)
Crane	Feeder	14	17	13

APPENDIX V-D

PERIODIC INSPECTION REPORT NO. 6
HOPKINTON LAKE
HYDROLOGY/HYDRAULIC NOTES

PERIODIC INSPECTION REPORT NO. 6
HOPKINTON LAKE
HYDROLOGY/HYDRAULIC FEATURES

1. FIELD INSPECTION

The hydrologic and hydraulic features of Hopkinton Lake were inspected by Brian Waz of the Water Management Section, Engineering/Planning Division. Major features inspected include the spillway, outlet and inlet works, north and south weirs, and hydrologic monitoring equipment. Past operating experiences were also reviewed.

2. SPILLWAY

a. Approach. The approach channel was in overall good condition. Some vegetation was observed in the approach channel, but will not obstruct flow (Photo D-1).

b. Control. The concrete spillway weir was in good condition with no major cracks or spalls that would affect hydraulic capacity (Photo D-2).

c. Discharge Channel. The spillway discharge channel was in good condition with no major outgrowth of trees or vegetation (Photo D-3).

3. OUTLET WORKS

a. Approach

(1) Inlet. The inlet was in good condition with no apparent obstruction to flow (Photo D-4).

(2) Log Boom. The log boom was generally in good condition. All of the logs appeared to be floating properly. There was a buildup of debris behind the log boom at the time of the inspection, but is scheduled to be removed during June-July 2002 (Photo D-7).

(3) Intake Structure. The intake structure appeared to be in good condition with some buildup of debris at the concrete piers (Photo D-5).

b. Conduit. Two of the three 11' X 11' conduits that are used for flood control were inspected and appear to be in good condition with no apparent spalls or cracks that would affect the hydraulic capacity. The third conduit is used to divert flow to the forebay pool for power plant operations and was not inspected. Refer to Appendix V-A, Conrete/Structural, for a more detailed discussion.

c. Outlet Channel. The outlet channel was in good condition (Photo D-6)

4. NORTH WEIR

a. Approach. The approach was in good condition with no obstructions to flow.

b. Control. The stoplog structure was in good condition. There is some minor debris just downstream of the stoplog structure at the entrance to the culvert under the road that should be removed (Photo D-11).

c. Discharge Channel. The discharge channel was in good condition with no obstruction to flow.

5. SOUTH WEIR

a. Approach. The approach channel is in good condition with no obstructions to flow (Photo D-8).

b. Control. The concrete spillway weir was in good condition with no major cracks or spalls that would affect hydraulic capacity (Photo D-9). The south weir sluice gate remains damaged from vandalism.

c. Discharge Channel. The spillway discharge channel was in good condition with no major outgrowth of trees or vegetation that would obstruct flow (Photo D-10).

6. PROJECT INSTRUMENTATION

a. Rain Gage. The project is equipped with a Sutron tipping-bucket precipitation gage. At the time of the inspection, the tipping-bucket gage was in good operating condition.

b. Pool Stage Recorder. The project is equipped with a Sutron 8210 data collection unit that records and logs the pool stage, tailwater stage, and rainfall data. A Handar RS485 encoder measures the pool stage and a Sutron Accubar pressure transducer measures the tailwater stage. At the time of inspection, the equipment was in good condition and operating properly.

c. Tile Staff Gage. Based on a visual inspection, the staff gages all appear in good condition. The lower tile gage had minor staining.

7. RECOMMENDATIONS

a. Budgetary Items. (No hydrology/hydraulic items)

b. Normal Maintenance. (No hydrology/hydraulic items)

APPENDIX V-E

PERIODIC INSPECTION REPORT NO. 6
HOPKINTON LAKE
GEOTECHNICAL NOTES

PERIODIC INSPECTION REPORT NO. 6
HOPKINTON LAKE
GEOTECHNICAL FEATURES

1. FIELD INSPECTION

Based on visual inspection performed on 4 and 5 June 2002, the geotechnical features of Hopkinton Lake Dam, Dikes H-2 and H-3, and the North and South Weirs appear to be in good condition. The major features inspected include the upstream toe and slope, the crest, the downstream toe and slope, access roads, outlet works, the spillway and its channels, all abutments, all rock walls, and instrumentation within the project limits. The geotechnical features were inspected by

Laura Fraser, CENAE-EP-HG, Geotechnical Engineer
Rose Schmidt, CENAE-EP-HC, Geologist

At the time of the inspection, water was flowing through the outlet works, and the pool elevation at Hopkinton Lake was 382.18 ft-NGVD (16.18 foot stage).

The highest pool impoundment since the last inspection was in June 1998 with a pool elevation at 403.3 ft-NGVD (stage 37.3 feet, and 43% full).

The record pool to date occurred in April 1987. The maximum pool elevation was 415.8 ft NGVD, stage 49.8 ft, and 95% full. The embankment performed satisfactorily.

2. EMBANKMENT

a. Main Dam. Visual inspection of the dam embankment and abutment areas showed no evidence of instability that would affect the performance of the dam.

1. Upstream Slope. The upstream rockfill slope protection appears stable and properly aligned (Photo E-1). The stone protection is in good condition. There is minor vegetation on the slope and large brush, trees, and grass along the toe at the water's edge. The access road from the project office to the upstream berm and the berm itself are both in good condition; both have very minor vegetation growing on them. The stone protection flanking the right abutment is also in good condition (Photo E-2). Drainage off the left abutment flows into the stone drain, through the culvert and into the pool protecting the access road from washouts or sediment deposition.

2. Downstream Slope. The downstream rockfill slope protection appears stable and properly aligned (Photo E-3). The stone protection appears to be poorly graded in spots with pockets

of smaller and larger stone and gives an uneven appearance to the slope. There is minor vegetative growth on the slope. About one-half way up the slope and in line with PZ-3, there is a patch of gravel with grass growing on it; no movement of the stone was noted in this area and this does not pose a concern at this time. Patches of grass continue to grow on sand and gravel deposited on the slope just below the east storm-drain outlet pipe; the sand and gravel deposit appears to have gotten larger since the last inspection. A smaller patch of grass is now growing at the outlet just below the west storm drain; an indication that water is now flowing out of the pipe and not into the embankment (see paragraph 3 below). The crushed stone on the downstream toe berm gives an uneven appearance and is unchanged since the last inspection. Also, near RW-5, there is an area where the crushed stone has settled into the rockfill creating a small hole about 6 inches deep (Photo E-4); the surrounding area is stable. Vegetation growing in the crushed stone is minor. The rock slope from the toe berm to the forebay pool is covered in heavy brush. Also, one of the no trespassing sign posts has fallen over, and another is missing its sign.

3. Crest. The crest of the dam (State Route 127) is in good condition (Photo E-5). The guardrail along the upstream edge appears properly aligned. The guardrail along the downstream edge was previously reported as showing signs of movement adjacent to the west storm drain. A subsequent inspection in the fall of 1997 by GES personnel, revealed that the outlet pipe had separated from the catch basin whereby the water from the catch basin was draining directly into the down stream embankment. This caused the gravel layer below the stone protection to move and a depression in the rock slope formed. Repairs were made to reattach the outlet pipe to the catch basin and reconstruct the overlying gravel and rockfill in 1998. At the time of this inspection the downstream guardrail still appears to lean in the downstream direction in front of the west storm drain, but the rip rap from the crest to the storm drain outlet appears to have stabilized. Both the east and west catch basins are clean of debris. The east storm drain still had a mound of soil with grass growing on it below the outlet of the east pipe. Similarly, grass has started to grow at the outlet of the west drain pipe, where the sand and gravel has been deposited on the slope by runoff draining from the catch basins. Also, on the downstream edge of the sidewalk, adjacent to the downstream east catch basin, a hole in the gravel fill below the sidewalk has formed. It is approximately 12 inches wide and 14 inches deep (Photo E-6). There are no other signs of material movement on the shoulder or slope.

4. Pavement. The bituminous concrete pavement along the crest of the dam is in fair condition and appears unchanged since the last inspection. There are transverse cracks about 1/4 inch wide and 30 feet apart. There is also a longitudinal crack down the centerline of the road. These conditions are similar to the last inspection, although some of the transverse cracks have slightly widened and minor radial cracks have formed. The office parking lot pavement is also in fair condition with shrinkage cracks that have been filled.

5. Forebay Dike. Previous inspections reported that the forebay dike, behind the east outlet

retaining wall, had settlements of up to 18 inches by 1987. Due to this settlement, the dike was periodically covered with crushed stone that continued to settle into the underlying stone. In 1999, repairs were made to the outlet wall and forebay dike which included the excavation of the impervious fill behind the outlet wall, replacing it with a 4-foot wide pervious zone and drainage system adjacent to the concrete and finishing the fill with compacted impervious fill. The top of the dike was rebuilt and covered with crushed stone (Photo E-7). Currently, the forebay dike appears to be in excellent condition with no settlement of the crushed stone.

6. Abutments. The abutments are satisfactory overall. Previous inspection reported the downstream right abutment to be sloughing near the top of the slope. At the time of this inspection the sloughing appeared to be very minor and poses no threat to Route 127. The left upstream abutment which was overgrown with trees and brush has been cleared and now has just minor vegetation growing on it (Photo E-8). Vegetation removal from the dam and dikes is on-going scheduled maintenance.

7. Seepage. No abnormal seepage conditions such as piping, boils or depressions were observed during the inspection or reported by the Project Manager.

b. Dike H-2.

1. Embankment. Dike H-2 is in good condition. The alignment and grade are good and the rock slope protection is in good condition.

2. Upstream. There is minor vegetation growing on the upstream slope and, there is a small amount of high-pool debris on the slope (Photo E-9). There is minor brush and trees along the upstream toe. The upstream blanket is grass covered. The stone protection is in good condition with only minor weathering. Sporadically along the slope, there are large stones (up to 3 feet in diameter) that have bridged and cause the appearance of "bumps" on the slope. These areas appear stable and there is no loss of the underlying gravel material. The area between stations 14+00 and 19+00 along the upstream toe is soft and moist due to groundwater draining off the abutment, as was noted in the last inspection. This drainage is evidenced in the cattails growing along the toe in this area. Also, as previously reported, there is ponded water on the upstream side of Dike H-2 adjacent to Elm Brook Road. The water is most likely from rainfall and runoff from Elm Brook Road.

3. Downstream. The downstream slope of Dike H-2 is stable and clear of vegetation (Photo E-10). The ditch along the downstream toe between stations 6+00 and 9+00 was dry at the time of the inspection. The ditch ends near station 9+00, where a corrugated metal pipe daylights from under the access road (it is marked with steel posts). The outlet of the pipe was covered with vegetation and almost completely buried with sand and debris. The downstream toe access road is in good condition although at the lowest spot elevation there

is large brush growing on the rock toe. About a ¼ mile from the left abutment, the access road was blocked with 9 to 10 trees that have fallen across the road.

c. Dike H-3

1. Embankment. Dike H-3 is in good condition. The alignment and grade are good. The rock slope protection is in good condition.

2. Upstream. The upstream slope is clear of vegetation and the stone protection is in good condition (Photo E-11). The upstream blanket is clear and has only grass growing on it. There are multiple tire tracks across the impervious blanket with ruts up to 4 inches deep. Project personnel stated that local groups who use the area drive across it when it is soft and wet. To protect the impervious blanket from further damage, access by vehicles should be limited during dry conditions and prohibited when the blanket is wet and soft.

3. Downstream (Photo E-10). Vegetation along the downstream toe and access road has been kept cut back from the spillway wall to station 20+00 (Photo E-12). From station 20+00 to the right abutment there is excessive tree growth along the toe except near the swamp area (Photo E-13). The Access Road Study for the Merrimack River Basin, November 1989, recommends the downstream toe be cleared from station 20+00 to the right abutment and the areas inundated by the wetland between station 17+00 and 11+00 be made accessible by the construction of a gravel fill berm. To preserve the wetland, it is recommended that only the trees along the toe from the right abutment to the limit of the wetland be removed; the new access road should be 15 feet wide. In the event of an emergency where access is needed in the limits of the wetland, a temporary access road could be constructed as necessary.

d. Canal No.1. The rock slopes of the canal appear to be in good condition. Brush and tree growth along the top of the rock slopes is somewhat heavy. There is some small to medium brush growing on the stone slopes, and also heavier brush along the center of the canal near the water (Photo E-14). Project personnel have this area on the brush clearing maintenance schedule. The floor of the canal was under a few feet of water but appeared to be in good condition.

e. South Weir & Canal No. 2.

1. Canal No. 2. The floor of the canal downstream of the South Weir has been cleared of the heavy vegetation that was previously reported (Photo E-15). The right slope downstream of the canal has some heavy brush and small trees on it, but is in good condition otherwise.

2. South Weir. The rock slope protection on the slopes just upstream and downstream of the South Weir abutments is about 60% deteriorated due to weathering but appears unchanged

from the last inspection. Also, there is minor vegetation growth on the slopes. Rock protection has been added to the top of both abutments behind the spillway walls. The average stone size is 2.5 to 3 feet in diameter in order to reduce vandalism (Photo E-16). There is a hole in the left abutment safety fence adjacent to the control stem.

f. North Weir

1. The stone protection on the North Weir is in good condition, but has some brush on both sides of Sugar Hill Road. Also, there is tree growth in the rock protection on the lake side of the road. The vegetation is being controlled by Project Personnel. The road over the weir has been paved and is in good condition (Photo E-17).

2. The conduit under the North Weir was replaced with a concrete box culvert and the inlet was reconstructed. At the time of the inspection the inlet was full of debris and there was minor spalling of the concrete at the outlet (Photo E-18). Both appear in good condition.

3. SPILLWAY

a. Approach Channels (Photo E-14). The spillway approach channel is generally in good condition. There is substantial brush and tree growth in the channel and on the rock faces. The rock slopes appear to be in overall good condition (Photo E-19). There is some loose rock along the channel walls and some minor rockfalls have occurred.

b. Discharge Channels. The spillway discharge channel is in good condition with minimal brush growth in the channel itself.

c. Wingwalls/Safety Fence. Some of the weepholes show evidence of water flow while some appear to be plugged with grass. The hole in the safety fence on the east wingwall has been repaired. There is still a gap between the bottom of the safety fence and stone protection.

4. OUTLET WORKS

a. Inlet Channel. The intake channel is in good condition. As previously reported, the training walls on either side of the intake conduit appear to have moved slightly due to the relative offset at the construction joints. Visual comparison to the last inspection photos indicate no observable change. (See Concrete/Structural Appendix).

b. Outlet Channel. The outlet channel was under water at the time of this inspection. The exposed features appeared to be in good condition. The retaining walls showed stains correlating to flow from the weep holes. The center pier has a tree growing on it (Photo E-20). There are also trees (up to 3 inches diameter) and brush adjacent to the west retaining wall.

c. East Outlet Retaining Wall. Construction to rebuild the fill behind the east outlet retaining was completed in September 1999 (see paragraph 2.a.5 above). The wall appears to be in good condition although the relative displacement between the monoliths is still evident. The measurement between the old scribe lines was 2-1/4 inches. The tilt plates and survey markers used to monitor movement are all in good condition.

d. Forebay Outlet Channel. The condition of the forebay outlet channel could not be determined due to the tailwater elevation.

e. Log Boom. See Appendix V-D.

f. Safety Fences. The safety fences along the outlet channels appear to be stable and in good condition. Adjacent to the west outlet channel wingwall, there is still a gap of missing stone that has been removed to create an access to the river.

5. PROJECT INSTRUMENTATION

Instrumentation to monitor embankment performance of Hopkinton Dam consists of 20 piezometers, 8 crest survey monuments, 8 relief wells, and 17 tilt plates. A complete discussion of the geotechnical instrumentation, interpretation, and evaluation of data is contained in the Instrumentation Appendix (IA) of this report and was prepared by GEI Consultants, Inc.

a. Piezometers. There are currently 20 piezometers installed at the dam: two on the upstream slope, two on the downstream slope, 13 along the downstream berm, two on the forebay pool dike, and one downstream and west of the stilling basin. PZ-9 and 11 were determined to not be working properly and have been grouted; replacement piezometers were deemed unnecessary. A record of readings has been maintained with at least one monthly reading and daily readings during high pools. The IA indicates that the existing piezometers appear adequate to characterize the piezometric levels at the dam.

The shallow (B) piezometers along the downstream toe berm appear to be influenced by the downstream forebay pool more than the upstream impoundment. The deep (A) piezometers east of the stilling basin have piezometric levels close to the pre-existing ground and are about 10 to 12 feet lower than the shallow piezometers. The levels in the B piezometers dropped when the forebay pool was emptied in September 1999, but the B levels were still higher than the A levels, indicating that there is not a significant artesian condition in the gravels underlying the dam. Data from PZ-13A, 14A, and 15 tend to confirm this. Piezometric levels in the upstream embankment respond to the pool level, while piezometric levels in the downstream embankment appear to be controlled by the drainage layer. Readings in PZ-13B are generally higher than the pool level. Occasionally, PZ-13B peaks before the pool. It appears that surface water may be infiltrating the piezometer, possibly through a leaky seal, and may be perched within the piezometer.

PZ-3A/3B and 4A/4B near the outlet channel and stilling basin appear to be influenced by the discharge through the channel and drainage layers beneath the structures. Piezometers to the left of the outlet are not affected by the forebay pool but do respond to changes in the level of the upstream pool. Piezometric levels in PZ-3A and 3B also appear to be influenced by the nearby abutment, as the levels are slightly higher than in PZ-4A and 4B. The piezometric levels in PZ-15 appear to be influenced by recharge from the adjacent relief well RW-2.

b. Crest Survey Monuments. Crest survey monuments were installed and initially surveyed in 1976. Additional surveys were performed in 1985, 1989, 1995, and 2001 by Corps of Engineers surveyors using electronic distance meter (EDM) instruments to locate the crest monuments both horizontally and vertically. The crest monuments are all in working condition. Monument 7 was missing half the survey disk at the time of this inspection.

The number and locations of the crest monuments are adequate to evaluate the embankment movements. Comparison of the data between 1996 and 2001 indicate horizontal displacements in the range of 0.0059 to 0.0608 foot (0.07 to 0.73 inch). Measured vertical movement since 1985 are less than 0.08 foot (less than 1 inch). These displacements and settlements are not considered significant.

c. Relief Wells. Eight relief wells were installed along the downstream toe berm during construction of the dam to relieve potential hydrostatic pressures in the gravelly deposits within the glacial till. At the time of this inspection the cover for RW-2 was missing. The sediment in the wells was pumped out in 1993. The water levels in RW-2 through RW-8 are controlled by the forebay pool (El. 381) which backs up in the T (El. 375) of the wells. Therefore, it is difficult to determine from the relief well readings whether any water is flowing in from the underlying gravel layer.

Additionally, CENAE-EP-H personnel are preparing an evaluation report for the analysis of the effectiveness of the relief wells. The draft report concluded there was no excessive artesian pressures within the gravel layers in the dam's foundation. Hence, the relief wells are not needed. Recommendations include discontinuing the monthly readings and potentially backfilling the wells with crushed stone. This report has not been finalized to date.

d. Tilt Plates. Seventeen tilt plates were installed in 1989 to monitor the movement of the east outlet channel and stilling basin retaining walls. All tilt plates are located on the top horizontal surface of the monoliths. Nos. 1-14 are located on the east outlet channel wall, No. 15 is on the east stilling basin wall, and Nos. 16 and 17 are on the stilling basin and west outlet wall respectively.

Repairs to the east outlet wall were completed in September 1999. A baseline survey for future alignment monitoring was established in April 2002. A new baseline for the tilt plate monitoring rotation has not been established since the repairs were completed.

6. RECOMMENDATIONS

a. Dam Safety.

Dike H-3. Vehicle access on the upstream impervious blanket should be limited to when the blanket is dry and prohibited when the blanket is soft and wet.

b. Budgetary Items.

The Access Road Study, November 1989, recommended the downstream toe of Dike H-3 from station 20+00 to the right abutment be made accessible. In order to protect the wetland, it is recommended that only the trees along the toe from the right abutment to the limit of the wetland be removed to create a 15-foot wide access road along the downstream toe. Funds that should be requested for FY04 are estimated at E&D cost $10,000, construction cost $50,000, and S&A cost $5,000.

c. Normal Maintenance.

1. Main Dam.

   a. The trees and brush along the upstream toe of the dam (at the water's edge) should be cut and removed.

   b. The vegetation on the dam embankment and abutments should continue to be controlled and removed as currently scheduled.

   c. The hole beneath the sidewalk on the downstream shoulder adjacent to the east catch basin should be filled in with gravel. Project personnel should then monitor this area; any subsequent loss of material should be reported to the Geotechnical Engineering Section.

   d. Project personnel should monitor the sand and gravel deposits on the downstream slope; larger brush and trees that take root should be removed immediately. If the deposits continue to get larger all the vegetation and sand/gravel deposits should be removed from the slope.

   e. The large brush, trees, and grass from the downstream toe along the forebay pool and the west retaining wall should be removed.

f. The small hole on the downstream rock berm should be filled with crushed stone and then monitored by Project personnel. Any changes to the area or additional loss of material should be reported to the Geotechnical Engineering Section.

g. The damaged and missing no trespassing signs on the downstream slope should be repaired/replaced.

2. Dike H-2.

   a. The vegetation along the upstream and downstream toes of Dike H-2 should be removed. The fallen trees along the downstream access road should be removed.

   b. The drainage pipe outlet (near station 9+00) on the downstream toe should be cleared of the sand and brush so that any flow can drain freely out of the pipe.

3. Dike H-3. Vegetation on the dike, the upstream blanket and downstream access road should continue to be controlled under the current schedule.

4. Canal No. 1. The brush and trees at the top of the rock slope protection, along the slopes and in the channel of Canal No. 1 should be removed.

5. South Weir. The hole in the safety fence should be repaired.

6. North Weir. Heavy vegetation on the upstream and downstream slopes of the North Weir should be removed.

7. Spillway. The gap below the safety fence should be blocked with stone.

8. Outlet Works. The training walls and the stone protection around the intake structure should be checked periodically, and changes should be reported to Geotechnical Engineering Section. The gap under the west outlet channel wingwall safety fence should be blocked with stone.

d. Instrumentation.

1. Piezometers. The piezometric levels should continue to be recorded and evaluated on the current schedule. PZ-13B should be tested to determine if surface water is infiltrating the piezometer.

2. Crest Monuments. The crest monuments should continue to be monitored on the current schedule. Monument 7 should be replaced before the next scheduled survey.

3.Relief Wells. Recommendations for the abandonment of the relief wells will be included in the final analysis report.

4.Tilt Plates. A new baseline for the tilt plate monitoring rotation should be established. The tilt plate surveys should be performed once per year to determine if they are no longer needed.

APPENDIX VI

INTERMEDIATE TRIP REPORTS

MEMORANDUM FOR THE RECORD

SUBJECT: Supplemental Inspection of Conduit No. 3

1. Summary. An inspection of Conduit No. 3 was performed at Hopkinton Lake Dam. The inspection was accomplished using a canoe to access the conduit and gates after the forebay to the Hoague Sprague hydropower dam was dewatered.

2. Purpose. The inspection was conducted to assess the condition of Conduit No. 3, which is normally under water. The inspection included the concrete conduit and the gates. A description of the conditions is provided below.

3. Date of Inspection. 25 September 2002

4. Participants. John Kedzierski, CENAE-EP-DG
Alex Garneau, CENAE-EP-DG
Rob Shanks, Hopkinton Project Manager

5. Photographs/Sketches. See Photo 1

6. Narration. This conduit can only be inspected when the forebay of the adjacent hydropower dam is drained. The conduit was inspected using a canoe to gain access up to the gates. There is about 4 feet of water and a thorough inspection of the conduit invert was impossible. The visible portions of the conduit, transition, and splitter walls are in overall good condition. There was a substantial amount of debris caught in the air vents. All the monoliths were well aligned. This conduit contains barrels E and F. There is evidence of cavitation in the concrete roof of Barrel E just downstream of the gate. Barrel F has a moderate spall on the roof near the manhole opening. There is honeycombing on the conduit roof typically throughout the entire length. There is moderate efflorescence and active seepage through the roof joint between monoliths 5 and 6. There is a 6' long spalled area at the joint between the roof and the west wall of monolith 3. The overall condition of the gates and gate liners is good with no significant defects. The steel gate liners and gates are rusted (see Photo 1).

7. Conclusions/Recommendations.

None.

John Kedzierski, P.E.
Structural Engineer

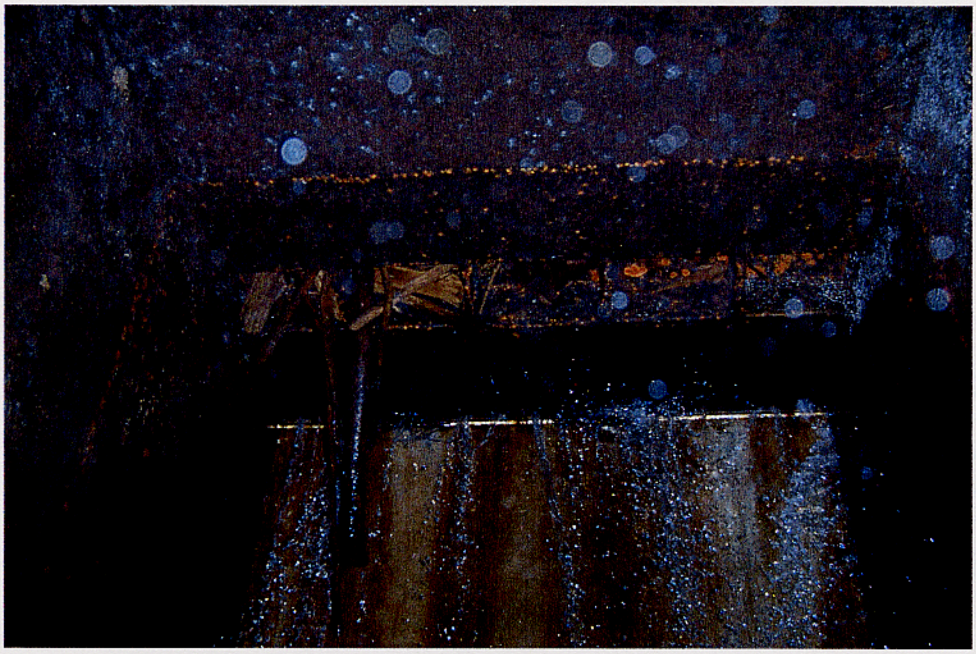


Photo 1 – Debris stuck in air vent. Typical paint condition of gate and gate liner in Conduit No. 3. Both gates were leaking.

Engrg/Plng Div Files

CENAE-EP-DG

8 February 2001
Ms. Gabrielsonjdd//78466

MEMORANDUM THRU Chief, Construction/Operations Division

FOR Park Manager, Merrimack River Basin Office

SUBJECT: Recommendations for Fuel System Modifications, Hopkinton Lake, Contoocook, NH

1. Ms. Deborah Gabrielson of Engineering/Planning Division, met with Mr. Martin Curran of Construction/Operations Division at Hopkinton Lake on 9 January 2001 to inspect the gate house fuel supply system. Two weeks prior to Ms. Gabrielson's visit, the local oil company attempted to deliver fuel oil and was unable to establish fuel flow into the storage tanks. The oil company has refused to provide any more oil deliveries.

2. The existing fuel system consists of three 275 gallon capacity vertical steel tanks located one level below the operating floor, and at the opposite side of the gatehouse from the main entrance and service bridge. The two tanks which serve the two warm air furnaces share a fill pipe and a vent pipe. The third tank which serves the emergency generator has its own fill and vent pipe. The fill and vent pipes run under the operating floor and exit the gate house wall near the service bridge. Fuel is provided to the generator by a fuel transfer pump located near the main storage tank which pumps to a day tank mounted on the wall above the generator. The two furnaces have no day tanks, and are supplied with fuel by two fuel transfer pumps which pump fuel continuously through separate piping loops between the storage tanks and the furnaces. Both furnaces and the emergency generator are located on the operating floor.

3. The system has had numerous problems in the past. The furnace fuel system frequently gets air in the lines which prevents the furnaces from operating. The piping of the vent and fill lines to the furnace storage tanks causes uneven filling of the tanks and has resulted in oil spills due to overfilling and fuel backing up out of the vent pipe. Ms. Gabrielson inspected the vent pipes after the vent caps at the service bridge were removed and found that one of the pipes appeared to be full of oil although the storage tank was only half full. It is likely that a slug of fuel in the horizontal section of the vent pipe is blocking the pipe and preventing oil from going into the fill pipe.

4. In addition to the potential for oil spills due to overfilling, significant fuel spills could occur if there were a break in the piping between the furnaces and the storage tanks. Since the transfer pumps run continuously, the potential exists for the entire contents of

the two furnace fuel tanks to be pumped out through a pipe break anywhere in the two furnace fuel piping loops. Also, if the storage tanks ruptured, the oil would flow into the entire floor area of the lower level where the tanks are installed.

5. The oil delivery company has submitted a proposal to replace the existing system with two 275 gallon double walled fuel tanks located on the operating room floor. The proposed tanks are of galvanized sheet steel with an interior polyethylene tank and are described as being for "basement" use. Due to space limitations on the operating floor, this tank (or any other standard size tank whether double or single wall) would be vulnerable to damage. A concrete block containment would provide protection for the tanks; however, available space is marginal due to the location of the gate well access openings. Therefore, we do not recommend that replacement tanks be located on the operating floor.

6. Based on these observations and the past history, we recommend the fuel system be modified as described below:

a. Replace existing fuel storage tanks with new single walled vertical steel tanks. Replace 1-1/2-inch vent pipes with 2-inch and reconfigure fill and vent lines to conform to code. Provide new overfill protection devices. Re-use existing level gauges. Build a dike across the storage tank room to confine oil spills from the storage tanks.

b. Provide new 10 gallon day tanks for the furnaces, and a new 25 gallon day tank for emergency generator. Each tank to include a rupture basin and dedicated fuel transfer pump and level controls. Rupture basins to be provided with separate float switches to alarm and shut off associated fuel transfer pump in the event of day tank rupture. Replace fuel oil return lines with larger day tank overflow lines draining back to new oil storage tanks. Pipe day tank vents outside the building.

c. To minimize the risk of spills during oil deliveries, project personnel should be present in the gatehouse to monitor the tank level gauges during each delivery Fill line caps should be locking type.

7. Estimated construction cost for these modifications is $18,000. Estimated E&D cost to prepare design documents is $3,500. E&D work cannot be completed until sometime during the 3rd or 4th quarter of this fiscal year.

CENAE-EP-DG
SUBJECT: Recommendations for Fuel System Modifications, Hopkinton Lake, Contoocook, NH

8. Project personnel should proceed with obtaining a temporary fuel supply system to provide fuel to the building furnaces for the remainder of this year's heating season. If the building is not heated, the roof drains may freeze up, causing water damage inside the building. Heat taping and insulating the interior portions of the drains might be a feasible alternative.

9. Please contact Ms. Gabrielson at extension 8466 if you have any questions.

DRO 2/8/01
C, GES

C, DES BR
HMc
DEP C, ENG
JAL HMc
C, ENG/PLNG

KENNETH E. HITCH, P.E.
Chief, Engineering/Planning Division

CF:
Ms. Gabrielson, Design Br
Mr. Forbes, Water Resources Br
Mr. Law, Con/Ops Div
Mr. Chase (Merrimack River Basin Office)
Mr. Shanks (Hopkinton Lake)
Engrg/Plng Div Files (Gabrielson/Hopkinton Fuel System TR)

CENAE-EP-DG

8 May 1998
Mr. Paton/jdd/78739

MEMORANDUM THRU Chief, General Engineering Section

FOR Chief, Design Branch

SUBJECT: Trip Report, Inspection of Gate 5, Hopkinton Lake

1. <u>Summary.</u>

a. While operating gate 5 on 4 May 1998, excessive vibration occurred while the gate was 4.5 feet above the invert and traveling downward.

b. The inspection team determined that the gate vibration was caused due to debris at the bottom of the gatewell.

2. <u>Recommendations.</u>

a. The debris at the bottom of gatewells 5 and 6 should be removed during contract work on the forebay pool this summer when the forebay pool is dewatered.

b. The bottom stem guide in gatewell 5 should be periodically monitored to check for interference between the stem guide bracket and the gate stem.

3. <u>Purpose.</u> To inspect gate 5 to include the gate stem system and electric gate actuator.

4. <u>Date of Inspection.</u> 5 May 1998

5. <u>Participants.</u>

David Shepardson, CENAE-CO-PM
Joanne Mercier, CENAE-CO-PM
Paul Hersom, CENAE-CO-PM
Thomas Rosato, CENAE-CO-TS
Kenneth Paton, CENAE-EP-DG

6. <u>Inspection.</u>

a. The inspection team met at the project office at 0900 hours on 5 May 1998, to discuss an incident where excessive vibration occurred at gate 5 the day before. The gate was being lowered from 8 feet above the invert. Gate operation was normal until the gate reached 4.5 feet above the invert, where it began to vibrate. The vibration and accompanying noise increased quickly to the point where the operator became concerned and stopped the gate's movement.

b. The inspection team entered gatewell 5 and inspected gate 5 and the stem system prior to initiating gate travel. The only item of concern noted was at the bottom stem guide. The clearance between the stem guide bracket and the gate stem was close to zero. Minor scratches were observed on the gate stem that appeared to be the result of the stem rubbing against the stem guide bracket. The close tolerance between the stem guide bracket and the gate stem is not believed to be the cause of the vibration, but it bears watching. All other aspects of gate 5 and the gate stem system appeared normal. It was noted that there was a substantial amount of debris at the bottom of gatewell 5.

c. Once the equipment condition was verified, gate travel in the upward direction was initiated. Gate 5 was raised to approximately 6 feet and lowered again. Gate travel was normal until the gate reached 4.5 feet above the invert while moving downward. The gate vibrated significantly while traveling from 4.5 to 4.4 feet. The vibration stopped from 4.0 feet until the gate reached the invert. Throughout the gate travel the motor current stayed fairly constant (approx. 4 amps). The motor current increased to 12 amps as the gate approached the invert. The torque switch indicator light blinked a few times, but did not appear to trip.

d. Gate 5 was raised and lowered two additional times, and vibration during the movement from 4.5 to 4.0 feet was repeated each time. Vibration was never observed while the gate was traveling in the up direction. It was observed that the vibration took place as gate 5 began crushing the debris at the bottom of the gate well. Debris is believed to be the cause of the vibration at gate 5, and also the reason for the high motor current when the gate approached the invert.

e. The debris should be removed from gatewells 5 and 6 this summer when the forebay pool is dewatered. The emergency gate will have to be installed in each gatewell before debris removal can be performed.

KENNETH PATON
Mechanical Engineer

APPENDIX VII

INSTRUMENTATION DATA AND/OR PLOTS

Instrumentation Appendix to Periodic Inspection Report No. 6 Hopkinton Lake Dam

Hopkinton, New Hampshire

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SUBMITTED TO

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Senior Project Manager

July 2002
Project 02065

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Executive Summary

This report provides a summary and evaluation of geotechnical instrumentation of the Hopkinton Lake Dam in Hopkinton, New Hampshire. The Hopkinton Lake Dam was constructed for flood control purposes and is a rolled earth fill with rock slope protection.

Geotechnical instrumentation at the dam consists of 8 crest monuments, 22 piezometers, and 17 tilt plates. In addition, there are also 8 relief wells located on the downstream berm. Plate 2 shows the locations of the geotechnical instrumentation.

Crest Monuments

Eight crest monuments (Mons. 1 through 8) were installed in September 1985. There are also 4 control points labeled "SCOTT", B(H514), C, and D composed of brass discs set in ledge or concrete. Surveys for horizontal control were performed by the U.S. Army Corps of Engineers (USACE) in 1986, 1991, 1996, and 2001. Vertical movement surveys were performed in 1985, 1986, 1991, 1996, and 2001. Survey data are presented on Plates 12 and 13. Computed horizontal movements were small with a range of horizontal movement from 0.0059 to 0.0608 foot (0.07 to 0.73 inch) between 1996 and 2001. Given the fact that visual inspections by the USACE have shown no evidence of adverse movements at the dam, this amount of movement is not considered significant. The maximum net vertical movement recorded since 1985 is 0.08 foot (less than 1 inch) of settlement. This amount of settlement is close to the margin of error for the survey and thus is considered to be insignificant.

Piezometers

There are currently 22 piezometers installed at the dam. The piezometer locations are shown on Plate 2. Table 1 gives the station, offsets, boring numbers, and elevations of key piezometer features. Plates 15, 17, 18, and 19 show cross sections with the piezometer locations and piezometer data. PZ-9 and PZ-11 were not functioning properly and were abandoned in the fall of 1999.

The USACE project personnel measured piezometer pore water elevations according to the reading schedule shown in Appendix A. Table 3 lists the measured pore water elevations in the piezometers from March 1997 through December 2001. Table 3 data are plotted as time histories in Appendix B. Appendix C contains the piezometer time history data for the high pool event in June 1998. Appendix D contains plots of piezometer pore water elevation vs. pool elevation.

Based on the plots of piezometer pore water elevation vs. pool elevation, projections were made of the likely piezometer pore water elevations for a flood pool at spillway crest. These projections are listed in Table 5. Plates 15, 17, 18, and 19 show the average piezometer water levels, the maximum piezometer water levels recorded during the June 1998 high pool event, and the projected piezometer water levels for a flood reaching spillway crest for several cross sections and profiles.

Relief Wells

The USACE project personnel measured relief well water elevations according to the reading schedule provided in Appendix A. Table 4 lists measured water elevations in the relief wells from March 1997 through December 2001. Table 6 data are plotted as time histories in Appendix E. Appendix F contains the relief well time history data for the high pool event in June 1998. Appendix G includes plots of relief well water elevation vs. pool elevation.

Based on the plots of relief well water elevation vs. pool elevation, projections were made of the likely relief well water elevations for a flood pool at spillway crest. These projections are listed in Table 5. Plate 16 shows the average relief well water levels, the maximum relief well water levels recorded during the June 1998 high pool event, and the projected relief well water levels for a flood reaching spillway crest.

Tilt Plates

Tilt plates were installed along the top of the east outlet and stilling basin walls in 1989. The purpose was to monitor the movement of the east outlet channel and stilling basin retaining walls. Repairs to the east outlet wall were completed in September 1999. A baseline survey for alignment and elevation monitoring of each brass disk for future surveys was established during the April 2002 survey. A new baseline for the tilt plate monitoring rotation has not been established since the repairs were complete.

Recommendations

If unusual readings are obtained during the next survey, or if field evidence of embankment movement is discovered, the monitoring schedule will be adjusted as needed. Surveys should be performed at the same time of year to avoid seasonal movements. A Global Position Systems Survey, such as NAVSTAR, which can detect movements of less than 0.2 inch (ETL 1110-1-133), could be implemented if it becomes cost effective.

The piezometric levels should continue to be recorded and evaluated on the current schedule. We do not recommend that piezometers PZ-9 and PZ-11 be replaced at this time. We consider the number of piezometers installed to be adequate unless physical evidence of unusual seepage patterns observed in the future indicates the need for additional instrumentation. To reduce the number of inconsistent readings, unusual readings should be verified in the field by project personnel at the time the piezometers are read. Piezometer PZ-13B should be tested to determine if surface water is infiltrating the piezometer. We recommend that a falling head permeability test be performed in the piezometer, although the results of the test may not be conclusive.

We also recommend that tailwater elevation, rainfall data and outlet discharge information be provided for the next instrumentation report in order to determine the effects on piezometers located near the forebay pool.

Since the relief wells are controlled by the T connection to the forebay pool at El. 375, we recommend that the relief wells only be monitored if the forebay pool drops below El. 375. The relief wells should be checked twice a year to confirm that the T connection is not plugged.

A new baseline for the tilt plate monitoring rotation should be established. Tilt plate surveys should be performed in accordance with the schedule and recommendations for the crest monument survey.

Preface

Purpose and Scope

This report provides a summary and evaluation of geotechnical instrumentation of the Hopkinton Lake Dam in Hopkinton, New Hampshire.

GEI performed the following work:

a. Reviewed Periodic Inspection Report No. 5 and data provided by the U.S. Army Corps of Engineers (USACE) (Task 1).

b. Visited the dam on May 15, 2002.

c. Updated horizontal and vertical movement plates and created summary table (Task 2).

d. Prepared piezometer plots in Excel spreadsheets, including event plots for the high pool events; time-history plots for period March 1997 through December 2001, and plots of piezometer elevation vs. pool elevation. Also updated cross sections and profiles with new piezometer data and prepared a piezometer summary table (Task 3).

e. Prepared relief well plots in Excel spreadsheets, including event plots for the high pool events; time-history plots for period March 1997 through December 2001; and plots of relief well elevation vs. pool elevation. In addition, updated cross sections and profiles with new relief well data and prepared a relief well summary table (Task 4).

f. Summarized tilt plate survey data (Task 5).

g. Prepared this report summarizing Tasks 1-5.

Project Personnel

Gillian M. Gregory	Project Manager
Jeanne LeFebvre	Project Engineer
R. Lee Wooten	In-House Reviewer

Elevation Datum

All elevations in this report are referenced to National Geodetic Vertical Datum (NGVD).

Limitations

Our professional services for this project have been performed in accordance with generally accepted engineering practices. No other warranty, expressed or implied, is made.

1.0 Project Performance

The dam performance is rated as good based on the instrumentation data compiled to date. Crest monument data indicate that horizontal displacements between 1996 and 2001 were in the range of 0.0059 to 0.0608 foot (0.07 to 0.73 inch). Horizontal displacements since 1986 were in the range of 0.019 to 0.073 foot (0.23 to 0.88 inch). The vertical movement between 1996 and 2001 was less than 0.01 foot (0.12 inches). The maximum net vertical movement since 1985 was 0.08 foot (less than one inch). The piezometer readings, including the new piezometers, and dam performance indicate that the impervious central core is sufficient to lower the pore pressures and exit gradients so that seepage exits safely at the toe of the dam.

2.0 General Project Description

2.1 History

2.1.1 General

The Hopkinton Lake Dam project is part of one of the four reservoir projects that have been constructed in the Merrimack River Basin by the U.S. Army Corps of Engineers (USACE) for flood control and other purposes.

Hopkinton Lake Dam is located in the town of Hopkinton, New Hampshire, on the Contoocook River, approximately 18 miles southwest from the confluence of the Contoocook and Merrimack Rivers at Penacook, New Hampshire (Plate 1). Construction of the project was started in November 1959 and completed in July 1963. An upstream permanent pool is kept at approximately El. 380.0 feet NGVD. The downstream forebay pool created by the Hoague-Sprague Dam has an average elevation near 380.0 feet NGVD. The Hopkinton Lake Dam project was designed and built as part of the overall Hopkinton-Everett reservoir system.

2.1.2 High Pools

a. April 1987 Flood: During April 1987, the embankment was subjected to its highest impoundment to date with a maximum water surface elevation of 415.8 feet NGVD, stage 49.8 feet (0.2 foot below the spillway crest), 95% full. The embankment performed satisfactorily during this impoundment. The dam was inspected at the time of the flood by an Emergency Response Team from Geotechnical Engineering Section (GES). A small boil was reported at the base of the left downstream abutment. Also, several small clear seeps were observed emerging along the base of the downstream left abutment above El. 384 feet NGVD. These seepage flows were attributed to groundwater draining off the left abutment and not to seepage through the dam embankment. No other abnormal seepage conditions such as piping, boils from through seepage, or sinkholes were observed by the team or reported by the Project Manager.

b. June 1984 Flood: During June 1984, the embankment was subjected to its second highest impoundment to date with a maximum water surface of 407.5 feet NGVD, stage 41.5 feet (8.5 feet below spillway crest). The dam was inspected at the time of the flood by an Emergency Response Team from Geotechnical Engineering Section

(GES). No abnormal seepage conditions such as piping, boils, or sinkholes were observed then by the team or subsequently reported by the Project Manager.

c. March 1990 Pool: During March 1990, the embankment was subjected to its highest impoundment since piezometers 3 through 11 were installed in 1987 and 1988. The maximum water surface during this small event was at El. 397.2 feet NGVD, stage 31.2 (18.8 feet below the spillway crest).

d. August 1991 Pool: During the August 1991 event, the embankment was subjected to an impoundment of 394.6 feet NGVD, stage 28.6 feet (21.4 feet below spillway crest). The dam was inspected at the time by an Emergency Response Team from Geotechnical Engineering Section (GES). No abnormal seepage conditions such as piping, boils, or sinkholes were observed then by the team or subsequently reported by the Project Manager. During this time the forebay pool was empty (July 9 to October 24, for maintenance), which caused the water elevations in the piezometers and relief wells on the left side of the outlet channel to drop.

e. October 1996 Pool: During October 1996, the embankment was subjected to an impoundment of 403.2 feet NGVD, stage 37.2 feet (12.8 feet below spillway crest).

f. June 1998 Pool: During June 1998, the embankment was subjected to its highest pool for the period covered by this report. The pool elevation was 403.22, similar to the high pool for previous 5-year period (Ref. 6).

The instrumentation evaluation in this report is based on piezometer readings from 1997 to the present. In addition, a review was made of piezometer data reported in the prior report (Ref. 6).

2.2 Geology and Foundations

2.2.1 General

The Hopkinton Reservoir occupies low, flat, relatively wide areas in the pre-glacial Contoocook Valley, which has been generally deeply filled with outwash deposits and till. The entire reservoir was occupied during the recessional phase of the last glaciation by connected pools or sluggish-current lakes impounded behind ice and debris barriers that caused temporary damming and diversion of the natural drainage. In the areas occupied by the transient pools, deposits of sand, silt, and gravel occur. Till and till-covered bedrock hills that rise above the lowlands form the perimeter of the reservoir (Ref. 1).

2.2.2 Site Geology

The Contoocook River flows in a deep, narrow valley entrenched in till. The right abutment rises steeply from the edge of the river; the left abutment is less steep and rises from a narrow floodplain that occupies the left side of the valley bottom. Bedrock is deeply buried at the site occurring throughout at depths of up to 90 feet. The overburden is generally till that is overlain on the abutments by a thin blanket of silt or fine sand and in the valley bottom by variable, thin deposits of recent alluvial, mostly sands and gravels (see Plates 4A and 4B) (Ref. 1).

A plan of subsurface explorations performed for the original design of the dam is shown on Plate 3. The piezometer installation plan and relief well plan is shown on Plate 2. Plates 5A-11 show engineering logs for original foundation exploration borings, for piezometer borings, and for relief wells. Engineering log sections and a section with the highest piezometric and relief well levels from significant pool events are shown on Plates 14-19.

2.3 Dam and Appurtenant Structures Description

The dam embankment is a rolled earth fill with rockfill slope protection. It is 790 feet long with a maximum height of 73 feet above streambed. The top minimum elevation is 437.5 feet NGVD. Plates 21-28 contain a general plan and typical sections of the dam. The dam consists of a homogeneous section of impervious fill, with its slopes protected with a quarry-run type rock on gravel backing. Embankment seepage is controlled by a gravel chimney located near the center of the embankment and connected to a horizontal downstream pervious blanket. Foundation relief wells were provided at the downstream toe to control potential seepage and uplift development. The outlet works, located in the dam on the left bank of the river, consists of an approach channel, gate tower, three conduits, stilling basin, an outlet channel, and a forebay pool.

The Hoague-Sprague Dam located immediately downstream of the Hopkinton Lake Dam is used to supply water to the nearby paper mill.

The spillway is a concrete, trapezoidal weir (ogee section) founded on rock and is located at Dike H-3, located about 8,000 feet east of Hopkinton Dam (See Plate 1). Top elevation is El. 416 feet NGVD, and the crest length is 300 feet.

Instrumentation to monitor dam performance at Hopkinton Lake Dam consists of 8 crest monuments, 17 tilt plates, and 22 piezometers. There are also eight relief wells located along the downstream berm. A general plan of instrumentation is shown on Plate 2. There is no instrumentation at dikes H-2 and H-3.

3.0 Instrumentation

3.1 Crest Monuments

Eight survey crest monuments were installed at the dam and initially surveyed in September 1985 by contract. Other surveys were also done in March 1986, April 1991, March 1996, and August 2001. The crest monuments are USACEs brass discs set in 10 feet of NX steel casing filled with concrete and labeled Mon. 1 to Mon. 8. The crest monuments were installed flush with the ground surface in the middle of the sidewalk on the downstream side of the dam crest. The location of all crest survey monuments are shown on Plate 12. Four control points have been installed for monitoring movements of the dam, Mon. "Scott," B (H514), C, and D (Plate 12). Monument "Carl" was re-established during the August 2001 survey. All control points are assumed to be fixed reference points. Note that the benchmark on the west end of the crest of the dam previously referred to as BL1 should be changed to BL3. Benchmark BL3 had been disturbed and was reset during the August 2001 survey. According to the 1986 survey, BL3 was incorrectly stamped as BL1. Future surveys should refer to the benchmark as BL3. The current standards and procedures employed for crest monument surveys at Hopkinton Lake Dam are contained in Appendix A.

3.2 Piezometers

3.2.1 PZ-1 and PZ-2

PZ-1 and PZ-2 are open-type piezometers located at the bottom and ends of the foundation drain beneath the stilling basin; they were installed during construction of the stilling basin (see Plates 2 and 18). The piezometers were installed to measure the hydrostatic pressures at the bottom and at each end of the foundation drain located 15 feet below the base of the stilling basin.

3.2.2 PZ-3 to PZ-11

Twelve piezometers (PZ-3A to PZ-8B) were installed (two in each borehole) in September 1987 along the downstream berm (see Plate 2). The piezometers are labeled PZ-3A, 3B, 4A, 4B, 5A, 5B, 6A, 6B, 7A, 7B, 8A, and 8B. Three piezometers (PZ-9, 10, and 11) were installed in 1988 along the east outlet retaining wall and Hoague-Sprague forebay dike to aid in the analysis of the movement of the stilling basin and east outlet retaining wall. All piezometers are Casagrande-type with 3/4-inch, PVC riser pipe and are manually read using an M-Scope Water Level Indicator. PZ-9 and PZ-11 were not functioning properly and were abandoned in the fall of 1999.

3.2.3 PZ-13 to PZ-15

Five piezometers were installed in 1993 at approximately Station 5+25, two each in two boreholes (PZ-13A and B, PZ-14A and B) and one in a third borehole (PZ-15). The locations are shown on Plate 2. Graphic logs for the three borings and five piezometers are shown on Plates 9-11. The piezometers are Casagrande-type with 3/4 inch, PVC riser pipe and are manually read using an M-Scope Water Level Indicator.

Piezometer data, including piezometer location (station and offset), piezometer tip and tip elevation, and the zone/material where the tip is located, are included in Table 1.

3.3 Relief Wells

There are connected deposits of laminated fine sand and clay and stratified sands and gravels within and under the glacial till (Plates 4A and 4B). The relief wells were installed during construction of the dam to relieve potential development of hydrostatic pressures in the deposits within and under the till. The wells are 8 inches in diameter, approximately 74 feet deep, and discharge into the rockfill adjacent to the forebay pool. The wood stave screens are 24 feet in length and surrounded by 40 feet of gravel pack. A detail of the wells is shown on Plate 25. The relief well locations are shown on Plate 2. The water surface in each well is read with an M-Scope Water Level Indicator.

3.4 Tilt Plates

Tilt plates were installed along the top of the east outlet and stilling basin walls in 1989. The purpose was to monitor the movement of the east outlet channel and stilling basin retaining walls. With the data collected a study was performed and a Design Letter Report prepared in 1997 (Ref. 5) concluding that the movement of the wall was due to the combination of frost action and lateral loading due to earth pressures. Plans and specifications were prepared and repairs to the outlet were done in September 1999. The repairs included dewatering the forebay, excavating of the impervious fill behind the outlet wall, replacing the impervious fill with a 4-feet wide pervious zone and drainage system adjacent to the concrete, and finishing the fill with compacted impervious fill. The tilt plates and corresponding brass survey disks were not disturbed (i.e., broken, removed, vandalized, etc.) during remedial repairs.

4.0 Data Collection, Interpretation, and Evaluation

4.1 Crest Monuments

4.1.1 Data Collection

The results of the crest monument surveys are shown on Plates 12 and 13. Distances between control points and the crest monuments for the survey performed in August 2001 along with the coordinates and elevations of control points (which are assumed to be fixed reference points) and crest monuments are also shown on Plate 12. Monument "Carl" was re-established during the August 2001 survey. Benchmark BL3 had been disturbed and was also reset during the August 2001 survey. Computed horizontal and vertical movements of each monument are shown on Table 2 and are plotted on Plate 13.

4.1.2 Interpretation and Evaluation

The surveys were performed using an electronic distance meter (EDM) with Third Order, Class II accuracy (1:5000) for horizontal measurements and Third Order, Class I accuracy (1:10,000) for vertical measurements according to the standards and procedures outlined in Appendix A.

a. Vertical Movement: The surveys indicate that the total net vertical movement of any crest monument was limited to or less than 0.08 feet (less than one inch) of rise between 1985 and 2001 (Plate 13). Movements between 1996 and 2001 were 0.01 foot (0.12 inches) of rise or less. This range of movement is close to the margin of error for the survey methods; therefore, it is possible that no rise or settlement occurred at all. The magnitude of vertical movement is so minute that it is considered negligible, regardless of whether the readings were a result of embankment settlement or settlement of the monument itself, or the result of seasonal effects.

b. Horizontal Movement: The horizontal movement surveys, performed using a combination of trilateration angles, show the range of movement from 0.0059 to 0.0608 feet (0.07 to 0.73 inch) between 1996 and 2001 (Table 2, Plate 13). There was no physical evidence of movement, such as slumps, scarps, cracks, or depressions at any monument that would indicate significant movement of the embankment. The computed movement was attributed to the survey accuracy, natural soil adjustment, or seasonal effects. As shown in Table 2, all of the monuments moved in the downstream direction between the 1996 and 2001 surveys. Net horizontal movement since 1986 shows no overall pattern of movement. The small amount of movement recorded and the lack of any other manifestation of movement of the embankment lead to the conclusion that no significant movement of the dam is occurring at this time. From the data that have been acquired to date, it is concluded that there has been insignificant horizontal movement within the embankment, and any movements are probably due to instrument error or seasonal effects.

4.2 Piezometers

4.2.1 Data Collection

a. Location Maps: A general plan of the project showing the location of the active piezometers and the corresponding identification number for each piezometer is provided to project personnel to eliminate identification and data recording inaccuracies.

b. Data Collection Tables: A table listing the piezometer identification number, stationing and offset, as well as piezometer top and tip elevations is also provided for recording and submitting piezometer readings.

c. Reading Schedule (See Appendix A): Piezometer monitoring at Hopkinton Lake Dam has been maintained by project personnel since the installation of the piezometers in 1987. The minimum piezometer reading schedule presently in effect is as follows:

   (1) Routine: During periods when the reservoir is at or below the 22-foot stage (El. 387.5 feet NGVD), readings should be made by the project manager at least once a month. When access to instruments is made hazardous by snow or ice, the readings may be deferred until safe access is possible.

   (2) High Pool: During periods when the reservoir level (includes rising and falling pools) is above the 22-foot stage, readings should be made on a daily basis. Pool elevations should be recorded simultaneously with piezometer, relief well, and tail water pool readings. On a falling pool, piezometer readings should continue for approximately five days after the pool has returned to its normal elevation.

d. Special Conditions: If unusual changes in readings develop or if piezometers become inoperable, Geotechnical Engineering Section should be contacted.

Readings obtained from the piezometers are compiled in Table 3. Pertinent information includes the date of reading, pool elevation, and water elevations for each piezometer.

4.2.2 Interpretation and Evaluation

a. Presentation of Data: In this Instrumentation Appendix, piezometer and pool information is summarized in a series of time-history plots, event plots, and scatter plots. Plots were made using the Microsoft Excel© program.

Time-history plots were developed for each piezometer and the reservoir pool from March 1997 through December 2001, which are shown on separate sheets in Appendix B for each year. The highest pool elevation during this five-year period, 403.22, occurred in June 1998. Event plots were produced for the June 1998 event and are presented in Appendix C. Outlet discharge rates are included on the high pool event plots. Note that a pool elevation of 352.69 recorded on June 30, 1998, appears to be an error.

The plots in Appendix D show the response of the piezometers to the rise and fall of the reservoir pool. On each plot, the piezometer readings were projected to the anticipated reading with the pool elevation at the spillway crest at El. 416. The projections are based on April 1998 (pool elevation 398.2) and June 1998 (pool elevation 403.2) high pool events. These projections were extrapolated from piezometer readings at lower pool levels; which are lower than the recorded high pool to date. The projected readings are summarized in Table 5 and compared to the projections from Report No. 5 (Ref. 6). The projections in Report No. 5 were based on the October 1996 high pool of El. 403.2, an event similar to the June 1998 high pool.

b. Individual Piezometer Response: All pertinent information (station, offset, top and tip elevations, zone and material type where tip is located) for each piezometer is listed in Table 1 and shown graphically on cross sections on Plates 14 through 19. Falling head tests were performed immediately after completion of installation. These tests confirmed that all piezometers were in working order. Piezometer readings are included in Table 3. The following paragraphs summarize the performance of each piezometer during normal steady-state operation and during the June 1998 high pool event.

(1) PZ-1: Piezometer 1 is located on the downstream side of the dam adjacent to the east stilling basin wall with its tip at the bottom and end of the foundation drain beneath the stilling basin at El. 330.0. The piezometer tip is surrounded

by a sand filter extending from El. 329.0 to 337.0. The piezometer extends through the concrete base slab and compacted impervious fill zone of the forebay dike (Plates 18, 25, 27, and 28). The piezometer was installed at the same time the dam was constructed to measure the hydrostatic pressure in the foundation drain under the stilling basin. Material surrounding the tip is fine filter fill. The normal water level in PZ-1 ranged from El. 363.5 to about El. 368.4 for the period from 1997 to 2001 (Appendix B). This is a similar range of elevations as were reported for the period 1992 to 1997 (Ref. 6). The reading of El. 384.7 on October 1, 2001, (Table 3) appears to be an error. According to a prior report (Ref. 4), the foundation drain under the stilling basin, where PZ-1 and PZ-2 tips are located, is directly connected to the tailwater by an outlet into the stilling basin at El. 363.0. The outlet tends to control the water levels in PZ-1 and PZ-2 by relieving piezometric pressures during normal pools, and by increasing the piezometric level when the tailwater level rises above El. 363 and water backflows into the outlet. The piezometric level in PZ-1 does increase in response to rise in pool level, but the response is somewhat dampened. Appendix C shows the piezometric response to the pool level during the June 1998 high pool event, the response being similar to that of the October 1996 event. The water level in PZ-1 peaked 3 days before the upstream pool, dropped off slightly as the pool peaked, and then increased to a second but lower peak 3 days after the pool peak. This indicates that PZ-1 may be influenced by more than just the upstream pool. Data in Report No. 5 (Ref. 6) show that the piezometer water levels in PZ-1 correlate with outlet discharge. Appendix D shows the piezometric level plotted against pool elevation. The plot shows a projection of piezometric level for a pool at spillway crest. The projected piezometer elevation for the pool at spillway crest for PZ-1 is El. 370. This is approximately the same as the projected piezometer reading of El. 369.4 listed in Report No. 5 (see Table 5), which was based on the October 1996 high pool event.

(2) PZ-2: PZ-2 is also located on the downstream side of the dam adjacent to the stilling basin's west wall with its tip at El. 333.0. This piezometer is similar to PZ-1 in construction (Plates 18 and 25) and response to a rising pool. As mentioned above, PZ-2 is controlled by the outlet to the stilling basin at El. 363. Normal water level in PZ-2 from 1997 to 2001 ranged from El. 363.2 to about El. 368, a similar range to that for the period from 1992 to 1997. Response of PZ-2 to a rising pool is also similar to PZ-1, except that PZ-2 peaked 3 days after the pool peaked. Data in Report No. 5 (Ref. 6) show that the piezometer water levels correlate with outlet discharge. The projected piezometric level in

PZ-2 with pool level at spillway crest is El. 370. This is approximately the same as the projected piezometer reading of El. 369.3 listed in Report No. 5.

(3) PZ-3A: PZ-3A is located on the downstream berm, near the left abutment with its tip in foundation soils at El. 305.7. The tip is surrounded by filter sand extending from El. 303.5 to 321.2, which is capped with a 4.5-foot bentonite seal. The foundation material that influences the response of PZ-3A is a gray silty (25-35%) SAND with gravel (5-15%) with large cobble fragments (SM). The normal groundwater level in PZ-3A ranged from El. 374.2 to El. 377.5 over the period 1997 to 2001. This is similar to the range of from El. 375 to 377 from 1992 to 1997. The time-history plots show a rise in piezometric elevation with rise in pool level, with a lag of one or two days in response. The projected piezometric elevation with pool level at spillway crest is 381.5. This is slightly higher than the projected piezometer reading of El. 379.2 listed in Report No. 5

(4) PZ-4A: PZ-4A is located on the downstream berm, left of the outlet, with its tip in foundation soils at El. 305.7. The tip is surrounded by filter sand extending from El. 304.7 to 321.2, which is capped with a 4-foot bentonite seal. The foundation material that influences the response of PZ-4A is a gray-brown silty (22%) SAND with gravel (7%) and a trace of clay (SM). The normal groundwater level in PZ-4A ranges from El. 369.4 to El. 373.0 over the period 1997 to 2001. This is similar to the range of from El. 370 to 372 from 1992 to 1997. The time-history plots show a rise in piezometric elevation with rise in pool level, generally with a lag of a couple of days in response. The projected piezometric elevation with pool level at spillway crest is 376.5. This is slightly higher than the projected piezometer reading of El. 374.7 listed in Report No. 5.

(5) PZ-5A: PZ-5A is located on the downstream berm to the right of the outlet, with its tip in foundation soils at El. 305.6. The tip is surrounded by filter sand extending from El. 304.2 to 321.1, which is capped with a 4.1-foot bentonite seal. The foundation material that influences the response of PZ-5A is a gray sandy (48%) SILT with a trace of gravel (ML). The normal groundwater level in PZ-5A ranged from El. 367.6 to El. 370.4 over the period 1997 to 2001. This is similar to a range of El. 368 to 370 from 1992 to 1997. The time-history plots show a rise in piezometric elevation with rise in pool level. During the high pool in June 1998 the piezometer peaked 2 days before the pool and stayed at approximately the same elevation as the pool peaked. This response is slightly different than during the October 1996 event, during which PZ-5A peaked on the same day as the pool. The projected piezometric elevation with

pool level at spillway crest is El. 374. This is similar to the projected piezometer reading of El. 372.8 listed in Report No. 5.

(6) PZ-6A: PZ-6A is located on the downstream berm to the right of the outlet, with its tip in foundation soils at El. 305.9. The piezometer tip is surrounded by filter sand extending from El. 304.5 to 320.4, which is capped with a 5.1-foot bentonite seal. The foundation material that influences the response of PZ-6A is a gray-brown silty (25-35%) SAND with rock fragments (SM). The normal groundwater level in PZ-6A ranged from El. 367.9 to El. 370.0 over the period 1997 to 2001. This compares well to a range of from El. 368 to 371 from 1992 to 1997. The reading of El. 380.35 on December 23, 1999 appears to be an error. Inspection of the readings for that date shows that the readings for PZ-6A and PZ-6B were probably reversed on the data sheets. The time-history plots show a rise in piezometric elevation with rise in pool level. During the June 1998 high pool, the piezometer peaked the day before the pool. During the October 1996 high pool, PZ-6A also peaked one day before the pool peak. The projected piezometric elevation with pool level at spillway crest is 374.5. This is similar to the projected piezometer reading of El. 373.0 listed in Report No. 5.

(7) PZ-7A: PZ-7A is located on the downstream berm to the right of the outlet, with its tip in foundation soils at El. 305.2. The piezometer tip is surrounded by filter sand extending from El. 304.2 to 320.2, which is capped with a 5.0-foot bentonite seal. The foundation material that influences the response of PZ-7A is a gray-brown silty (10-20%) GRAVEL with sand (5-15%) and rock fragments (GM). The normal groundwater level in PZ-7A ranged from El. 368.0 to El. 369.8 over the period 1997 to 2001. This is similar to a range of from El. 368.2 to 371 from 1992 to 1997. The time-history plots show a rise in piezometric elevation with rise in pool level, generally with a peak on the same day or one day before the pool peak. PZ-7A peaked the day before the pool during both the June 1998 and October 1996 high pool events. The projected piezometric elevation with pool level at spillway crest is El. 374. This is similar to the projected piezometer reading of El. 372.9 listed in Report No. 5.

(8) PZ-8A: PZ-8A is located on the downstream berm to the right of the outlet, with its tip in foundation soils at El. 305.5. The piezometer tip is surrounded by filter sand extending from El. 304.5 to 320.8, which is capped with a 10.7-foot bentonite seal. The foundation material that influences the response of PZ-8A is a gray-brown silty (23-30%) SAND with gravel (SM). The normal groundwater level in PZ-8A ranged from El. 366.8 to El. 368.7 over the period

1997 to 2001. This compares well to a range of from El. 367 to 370 from 1992 to 1997. The reading of El. 379.49 on June 3, 2000 appears to be an error. Inspection of the readings for that date shows that the readings for PZ-8A and PZ-8B were probably reversed on the data sheets. The time-history plots show a rise in piezometric elevation with rise in pool level, generally with a peak on the same day or one day before the pool peak. PZ-8A peaked the day before the pool during both the June 1998 and October 1996 high pool events. The projected piezometric elevation with pool level at spillway crest is 373. This is similar to the projected piezometer reading of El. 372.1 listed in Report No. 5.

(9) PZ-15: PZ-15 is located on the downstream berm to the right of the outlet, with its tip in foundation soils at El. 301.0. The piezometer tip is surrounded by filter sand extending from El. 299 to 334, which is capped with a 6-foot bentonite seal. The foundation materials that influence the response of PZ-15 are stratified silty sands with rock fragments (SM) and some varved clay. From March 1997 to June 1998, the normal groundwater level in PZ-15 ranged from about El. 371 to El. 374. From June 1998 to December 2001, the normal piezometer levels dropped off to a range of about El. 367 to El. 370. It is not clear why the average piezometer levels were lower in the second half of the reporting period. The readings between March 1997 and June 1998 are more consistent with the normal range reported for the period from 1994 to 1997. The unusually low reading on July 31, 2000 appears to be an error. The time-history plots generally show a rise in piezometric elevation with rise in pool level, sometimes with a lag of one or two days in response. PZ-15 is also likely effected by the level of the forebay pool and outlet channel, but that information was not provided for this Instrumentation report. The projected piezometric elevation with pool level at spillway crest is El. 378.5. This is about the same as the projected piezometer reading of El. 378.1 listed in Report No. 5.

(10) PZ-3B: PZ-3B is located on the downstream berm, near the left abutment, with its tip in foundation soils at El. 349.7. The piezometer tip is surrounded by filter sand extending from El. 348.7 to 358.7, which is capped with a 3-foot bentonite seal. The foundation material that influences the response of PZ-3B is a gray, silty (31%) SAND with clay (SC-SM). The normal groundwater level in PZ-3B ranged from El. 374.8 to El. 377.6 over the period 1997 to 2001. This range is similar to the range of from El. 375.5 to 377.5 from 1992 to 1997. The time-history plots show a rise in piezometric elevation with rise in pool level, generally with a piezometer peak the day before the pool peak. During the June 1998 and the October 1996 high pool events, PZ-3B peaked one day before the

pool peak. The projected piezometric elevation with pool level at spillway crest is El. 382. This is higher than the projected piezometer reading of El. 379.7 listed in Report No. 5.

(11) PZ-4B: PZ-4B is located on the downstream berm, just left of the outlet, with its tip in foundation soils at El. 349.7. The piezometer tip is surrounded by filter sand extending from El. 348.7 to 358.7, which is capped with a 5-foot bentonite seal. The foundation material that influences the response of PZ-4B is a gray, silty (13%) SAND with gravel (SM). The normal groundwater level in PZ-4B ranged from El. 367.0 to El. 370.9 over the period 1997 to 2001. This is similar to the range of from El. 367.5 to 370.5 from 1992 to 1997. The time-history plots show a rise in piezometric elevation with rise in pool level, generally with a lag of a one or two days in response, although for the June 1998 high pool the piezometer peaked four days before the pool. During the October 1996 event, PZ-4B peaked the same day as the pool peaked. Water levels in PZ-4B appear to be influenced by the foundation drains for the adjacent stilling basin. The projected piezometric elevation with pool level at spillway crest is El. 375.5. This is higher than the projected piezometer reading of El. 373.3 listed in Report No. 5.

(12) PZ-5B: PZ-5B is located on the downstream berm to the right of the outlet, with its tip in foundation soils at El. 349.6. The piezometer tip is surrounded by filter sand extending from El. 348.6 to 359.1, which is capped with a 1.8-foot bentonite seal. The foundation material that influences the response of PZ-5B is a gray, silty (31%) SAND with clay (14%) and a trace of gravel (SC-SM). The normal groundwater level in PZ-5B ranged from El. 378.3 to El. 380.3 over the period 1997 to 2001. This is slightly lower than the range of from El. 379.5 to 382 from 1992 to 1997. The time-history plots show a rise in piezometric elevation with rise in pool level, with a lag of a couple of days in response. The readings on June 19, 1998, and June 3, 2000, appear to be errors. The water level in PZ-5B dropped as a result of the forebay pool dewatering for the east outlet wall work in September 1999. The projected piezometric elevation with pool level at spillway crest is 383. This is similar to the projected piezometer reading of El. 382.5 listed in Report No. 5.

(13) PZ-6B: PZ-6B is located on the downstream berm to the right of the outlet, with its tip in foundation soils at El. 349.9. The piezometer tip is surrounded by filter sand extending from El. 348.9 to 358.9, which is capped with a 3.6-foot bentonite seal. The foundation material that influences the response of PZ-6B is a gray, silty (28%) SAND with clay (10%) and gravel (5%) (SM). The normal

groundwater level in PZ-6B ranged from El. 378.3 to El. 381.7 over the period 1997 to 2001. This compares well to a range of from El. 378.5 to 380.5 from 1992 to 1997. The reading of El. 369.16 on December 23, 1999 appears to be an error and was likely reversed with the reading for PZ-6A, as explained previously. The time-history plots show a rise in piezometric elevation with rise in pool level, with a lag of up to a couple of days in response. The water level in PZ-6B decreased as a result of the forebay pool dewatering for the east outlet wall repair work in September 1999. The projected piezometric elevation with pool level at spillway crest is 383.5. This is similar to the projected piezometer reading of El. 382.9 listed in Report No. 5.

(14) PZ-7B: PZ-7B is located on the downstream berm to the right of the outlet, with its tip in foundation soils at El. 349.2. The piezometer tip is surrounded by filter sand extending from El. 348.2 to 359.2, which is capped with a 2-foot bentonite seal. The foundation material that influences the response of PZ-7B is a gray, silty (15%) clayey (14%) SAND with gravel (23%) (SC-SM). The normal groundwater level in PZ-7B ranged from El. 378.4 to El. 379.6 over the period 1997 to 2001. This compares similarly to a range of from El. 378.5 to 380.8 from 1992 to 1997. The time-history plots show a rise in piezometric elevation with rise in pool level, with a lag of up to a couple of days in response. The water level in PZ-7B dropped as a result of the forebay pool dewatering for the east outlet wall work in September 1999. The projected piezometric elevation with pool level at spillway crest is 383.5. This is similar to the projected piezometer reading of El. 382.9 listed in Report No. 5.

(15) PZ-8B: PZ-8B is located on the downstream berm to the right of the outlet, with its tip in foundation soils at El. 349.5. The piezometer tip is surrounded by filter sand extending from El. 348.5 to 358.5, which is capped with a 6-foot bentonite seal. The foundation material that influences the response of PZ-8B is a gray, sandy (43%) SILT with clay (18%) and a trace of gravel (ML). The normal groundwater level in PZ-8B ranged from El. 379.1 to El. 381.0 over the period 1997 to 2001, a similar range as for the period from 1992 to 1997. The reading of El. 368.27 on June 3, 2000 appears to be an error and was likely reversed with the reading for PZ-8A, as explained previously. The time-history plots show a rise in piezometric elevation with rise in pool level, with a lag of a couple of days in response. The water level in PZ-8B dropped as a result of the forebay pool dewatering for the east outlet wall work in September 1999. The projected piezometric elevation with pool level at spillway crest is 383.5. This is similar to the projected piezometer reading of El. 382.4 listed in Report No. 5.

(16) PZ-9: PZ-9 is located on the downstream dike adjacent to the stilling basin's east outlet channel wall with its tip in foundation soils at El. 340.5. The piezometer tip is located below the outlet wall base slab on the outlet channel side of the wall's seepage cutoff key and is surrounded by filter sand extending from El. 337 to 349, which is capped with a 2-foot bentonite seal. The foundation material that influences the response of PZ-9 is gray SAND with silt (5-15%) and gravel (10-20%) (SP-SM). The normal groundwater level in PZ-9 ranged from El. 364.0 to El. 364.7. PZ-9 was read as "dry" during the dewatering for the east outlet wall repairs in September 1999. The time-history plots show a rise in piezometric elevation with rise in pool level, with a lag of a couple of days in response. The projected piezometric level with the pool at the spillway crest is El. 372.5. Notes in the piezometer data starting September 20, 1999 indicated that PZ-9 was broken, although readings were provided through December 1999. PZ-9 was abandoned in 2000 and is no longer in service. The piezometer tip and riser pipe were grouted and the protective steel surface casing was removed.

(17) PZ-10: PZ-10 is located on the downstream dike adjacent to the stilling basin's east outlet channel wall with its tip in foundation soils at El. 323.8. The piezometer tip is surrounded by filter sand extending from El. 322.2 to 337.5, which is capped with a 1.7-foot bentonite seal. The foundation material that influences the response of PZ-10 is a gray silty (32%) SAND with gravel (14%) (SM). The normal groundwater level in PZ-10 ranged from El. 367.1 to El. 370.4 over the period 1997 to 2001. This is similar to the range of El. 367.1 to 370.4 from 1992 to 1997. The readings showed that PZ-10 appeared relatively unaffected by the dewatering of the forebay pool during the construction work on the east outlet wall. The time-history plots show a rise in piezometric elevation with rise in pool level, with a lag of a couple of days in response. The projected piezometric elevation with pool level at spillway crest is 375.5. This is higher than the projected piezometer reading of El. 372.6 listed in Report No. 5.

(18) PZ-11: PZ-11 is located on the downstream dike adjacent to the stilling basin's east wing wall with its tip in foundation soils at El. 353.1. The piezometer tip is located below the wall base slab similar to PZ-9 and is surrounded by filter sand extending from El. 349.8 to 358.2, which is capped with a 2-foot bentonite seal. The foundation material that influences the response of PZ-11 is a gray silty (36%) SAND with fine gravel (6%) (SM). The normal groundwater level in PZ-11 ranged from El. 365.2 to El. 366.4. PZ-11 was read as "dry" during the

dewatering for the east outlet wall repairs in September 1999. The time-history plots show a rise in piezometric elevation with rise in pool level, with a lag of a couple of days in response. The projected piezometric level with the pool at the spillway crest is El. 373. Notes in the piezometer data starting September 20, 1999 indicated that PZ-11 was broken, although readings were provided through December 1999. PZ-11 was abandoned in 2000 and is no longer in service. The piezometer tip and riser pipe were grouted and the protective steel surface casing was removed.

(19) PZ-13A: PZ-13A is located on the upstream slope of the embankment with its tip in foundation soils at El. 299.0. The piezometer tip is surrounded by filter sand extending from El. 297 to 315, which is capped with a 6-foot bentonite seal. The foundation materials that influence the response of PZ-13A are a dark gray, silty (25-35%) SAND with gravel (15-25%) (SM) and a brown sandy (30-40%) CLAY with little gravel (CL). The normal groundwater level in PZ-13A ranged from El. 366.8 to El. 371.9 over the period 1997 to 2001, which is similar to the range during the period from 1994 to 1997. The time-history plots show a rise in piezometric elevation with rise in pool level, with a lag of a couple of days in response. An unusually high reading on July 2, 1998, may be the result of transposing the depths recorded for PZ-13A and PZ-13B. The unusually high readings on June 29 and 30, 1998, also appear to be errors. The projected piezometric elevation with pool level at spillway crest is 378. This is higher than the projected piezometer reading of El. 375.3 listed in Report No. 5.

(20) PZ-14A: PZ-14A is located on the downstream slope of the embankment with its tip in foundation soils at El. 303.0. The piezometer tip is surrounded by filter sand extending from El. 300 to 320, which is capped with a 6-foot bentonite seal. The foundation material that influences the response of PZ-14A is a brown clayey (10-20%) SAND with gravel (15-25%) (SC). The normal groundwater level in PZ-14A ranged from El. 368.6 to El. 371.1 over the period 1997 to 2001, which is similar to the range during the period from 1994 to 1997. The time-history plot show a rise in piezometric elevation with rise in pool level, with a lag of a couple of days in response. Unusually high readings on June 26, 1998, and July 2, 1998, may be the result of transposing the depths recorded for PZ-14A and PZ-14B. The unusually low reading on June 25, 1998 appears to be an error. The projected piezometric elevation with pool level at spillway crest is 376.5. This is higher than the projected piezometer reading of El. 374.2 listed in Report No. 5.

(21) PZ-13B: PZ-13B is located on the upstream slope of the embankment with its tip near the boundary between embankment and foundation soils at El. 368.0. The piezometer tip is surrounded by filter sand extending from El. 366 to 374, which is capped with a 4-foot bentonite seal. The materials that influence the response of PZ-13B are a dark brown sandy (25-35%) SILT with trace gravel (ML) and a brown silty (30-40%) SAND with trace gravel (SM). The normal groundwater level in PZ-13B ranged from El. 385.6 and El. 388.8, which is higher than the normal pool level of El. 380. The time-history plots appear to indicate that the piezometric levels are generally 5 to 7 feet higher than pool level. This may indicate that the upper bentonite seal is not effective and surface water tends to infiltrate and perch in the piezometer. The readings for PZ-13B and PZ-14B appear to have been transposed on April 25, 1997, and April 29, 1997. The unusually high reading on August 22, 1997, appears to be an error. The unusually low reading on June 16, 1998 appears to be an error. The readings for PZ-13A and PZ-13B appear to have been transposed on July 2, 1998. Due to the large scatter in the data, the projected piezometric elevation with pool level at spillway crest was not estimated.

(22) PZ-14B: PZ-14B is located on the downstream slope of the embankment with its tip near the boundary between embankment and foundation soils at El. 369.0. The piezometer tip is surrounded by filter sand extending from El. 367 to 377, which is capped with a 6-foot bentonite seal. The soil material that influences the response of PZ-14B is a brown, medium to fine SAND with a trace of silt (SP), which is probably part of the embankment pervious fill drain. The groundwater level in PZ-14B ranged from El. 374.0 to El. 393.3 over the period 1997 to 2001, with the normal piezometer level approximately at the normal pool elevation of 380. The time-history plots show a rise in piezometric elevation with rise in pool level, with a lag of a couple of days in response. During the June 1998 high pool event, PZ-14B showed little response to the increased pool level, rising only about 0.5 foot. The readings for PZ-13B and PZ-14B appear to have been transposed on April 25, 1997, and April 29, 1997. Unusually low readings on June 26, 1998, and July 2, 1998, may be the result of transposing the depths recorded for PZ-14A and PZ-14B. Two other unusually low readings on June 25, 1998, and July 1, 1998, also appear to be errors. The readings on May 3, 1999, and July 1, 1999, also appear to be errors. The water elevation in PZ-14B dropped slightly due to the dewatering that occurred in September 1999. The projected piezometric elevation with pool level at spillway crest is 385. This is slightly higher than the projected piezometer reading of El. 382.6 listed in Report No. 5.

c. Profile Evaluation

(1) Downstream Berm, Profile B-B: Piezometers 3 through 8 are all located along the downstream berm, all in Profile B-B (Plate 15). Time-history data for the deep piezometers (PZ-3A, PZ-4A, PZ-5A, PZ-6A, PZ-7A, PZ-8A, and PZ-15) are shown together on yearly time-history plots in Appendix B and on the high pool event plot in Appendix C for Profile B-B, Deep Piezometers. Time-history data for the shallow piezometers (PZ-3B, PZ-4B, PZ-5B, PZ-6B, PZ-7B, and PZ-8B) are shown together on the yearly time history and the high pool event plot for Profile B-B, Shallow Piezometers. The data show responses similar to those shown in the prior periodic inspection report (Ref. 6). Both the deep and shallow piezometers respond to changes in pool elevation.

For the piezometers to the east of the outlet and stilling basin (PZ-5A through PZ-8B and PZ-15), piezometric levels in the deep piezometers were 10 to 12 feet lower than in the shallower piezometers, indicating that the downstream forebay pool affects the shallow (B) piezometers more than the deeper (A) piezometers. Average readings for shallow piezometers PZ-5B, PZ-6B, PZ-7B, and PZ-8B are in the range of 378.7 to 379.7 over the past five years. The water levels in these shallow piezometers dropped in September 1999 as a result of the forebay pool dewatering for the east outlet wall repair work. Water levels in the deep (A) piezometers to the east of the stilling basin were relatively unaffected by the dewatering of the forebay pool, and were still lower than the depressed levels of the shallow piezometers during the same time period. This indicates that there are not significant artesian conditions in the gravels underlying the dam.

The normal levels for the deep piezometers averaged about 367.7 to 369.7, an elevation that is probably close to the groundwater levels that would have existed prior to dam construction. The deep piezometers peaked one to two days before the pool peak during the June 1998 event. This indicates that the piezometers may also be affected by groundwater flowing through the gravels in the foundation from sources other than the seepage from the upstream pool. Possible sources for the additional seepage include flow from the abutments or flow into the foundation from the tailwater discharge. The June 1998 high pool event plots shows that there appears to be some correlation between the outlet discharge rate and the levels in the deep piezometers, which may account for the early peaking of the deep piezometers. Recent past and future high pool event plots should include rainfall data and outlet discharge rates in order to determine if there is a connection between the deep downstream toe piezometers and the tailwater discharge. Water levels in PZ-15 are sometimes higher than the other deep piezometers, likely due to the influence of relief well RW-2, which is closer to PZ-15 than any other relief well is to an adjacent piezometer.

Piezometers PZ-3A&B and PZ-4A&B are located to the west of the outlet and stilling basin. Piezometric levels in the deep piezometers to the west of the outlet (PZ-3A and PZ-4A) appear to be about 2 to 5 feet higher than the levels in the deep piezometers to the east of the outlet and stilling basin. The outlet discharge rate appears to have a significant influence on the levels of PZ-3A and PZ-4A. Piezometric levels in PZ-4B are about 1 to 2 feet lower than in PZ-4A, indicating that the levels in PZ-4B appear to be influenced by the foundation drains for the adjacent stilling basin. Piezometric levels for PZ-3A and PZ-3B are very similar over the five years. The level in PZ-3A is about 5 feet higher than for the deep piezometers in the valley bottom, indicating some influence from the west abutment. The level in PZ-3B is about 3 feet lower than for the shallow piezometers in the valley bottom, indicating less of a connection with the forebay reservoir. These results are similar to the trends reported in Instrumentation Appendix Report No. 5.

(2) Station 5+25, Section A-A: Piezometers PZ-13A&B, PZ-14A&B, and PZ-15 were installed during 1993 at approximately Sta. 5+25 (Plate 2, Section A-A; Plate 19). Time-history data are shown together in Appendices C and D for the past five years and for the high pool event, respectively. Normal piezometric levels in deep piezometers PZ-13A, PZ-14A, and PZ-15 are below the original ground surface levels, indicating that there is not a significant artesian condition in the gravels underlying the dam. The level in PZ-13B is generally 5 to 7 feet higher than the pool level. The high levels may be the result of surface water infiltration and/or groundwater perching. Piezometric levels in PZ-13B generally tend to increase with higher pool levels, although there were many unreliable readings and a large amount of scatter in the data. Piezometric levels are generally about 6 to 7 feet higher in PZ-13B than in PZ-14B. As would be expected, the compacted pervious fill drain layer affects the response of PZ-14B, limiting piezometric levels to an elevation corresponding to the top of the drain layer (Plate 19).

As shown on Plate 19, piezometric levels during the June 1998 high pool event rose by about 4 feet in the three deep piezometers. The piezometric level in PZ-14B had little response and rose by only 0.5 foot. The piezometric level in PZ-13B rose about 12 feet during the high pool event, and as shown on Table 3, the high piezometric level of El. 400.3 occurred four days prior to the high pool of El. 403.2. This indicates that rainfall may be infiltrating the piezometer, producing high piezometric readings in advance of the high pool. These results are similar to those described in the previous instrumentation report for the October 1996 high pool event. Rainfall infiltration could also be the cause of piezometer levels in PZ-13B that are higher than the pool level on other dates throughout the last five-year period and in the recent past.

Two estimated phreatic surfaces for the shallow and deep piezometers are shown on Plate 19 for the June 1998 high pool event. For the shallow piezometers, we have shown the location of the phreatic surface upstream of the dam centerline based on the average piezometric level in PZ-13B during the high pool event (about El. 393), rather than the peak reading. The phreatic surface for the shallow piezometers drops off at the pervious fill drain at PZ-14B. The phreatic surface for the deep piezometers is just below the original ground surface elevation, so that seepage is exiting at the downstream toe of the dam.

(3) East Outlet Channel Wall, Section C-C: PZ-9, PZ-10, and PZ-11 are located along the east stilling basin wall (Plate 2, Section C-C; Plate 17). Prior to April 2000, piezometric levels in all three piezometers were similar, with PZ-10 having slightly higher levels than PZ-9 and PZ-11. Repair work to the east outlet wall was performed in September 1999, and the forebay was dewatered. Notes in the piezometer data indicated that PZ-9 and PZ-11 were broken on September 20, 1999, likely due to the construction work on the outlet wall. PZ-9 and PZ-11 were abandoned in 2000 and are no longer in service. The piezometer tips and riser pipes were grouted and the protective steel surface casings were removed. The water levels in PZ-10 seem to represent the gradient between the forebay pool (El. 380) and the pool downstream of the Hoague-Sprague Dam (~El. 350).

(4) Stilling Basin Cross Section, Section D-D: PZ-1 and PZ-2 are located on either side of the stilling basin (Plate 2, Section D-D; Plate 18) with their tips in the fine filter material beneath the stilling basin. PZ-1 and PZ-2 are reported to be connected to the tailwater by an outlet into the stilling basin at El. 363. The responses of these two piezometers are affected more by the outlet discharge rates and height of water in the stilling basin than by high pool levels. The piezometers show a dampened response to changes in pool level. During normal pool levels, the outlet acts to relieve piezometric pressures in the drainage layer as well. The responses of PZ-1 and PZ-2 are very similar to one

another, as expected, and are consistent with data reported in the prior periodic inspection report (Ref.6).

Maximum piezometer levels recorded during the June 1998 high pool event are shown on Plate 20.

4.3 Relief Wells

4.3.1 Data Collection

Water surface elevations for relief wells are collected in the same manner as the piezometer data as described in subsection 4.2.1. However, only one set of readings was collected in fiscal year 1997. Relief well elevation readings are given in Table 4. Time-history plots of all eight relief wells are included in Appendix E. A time-history plot for the June 1998 high pool event is shown Appendix F. Relief well elevation vs. pool elevation plots are included in Appendix G.

4.3.2 Interpretation and Evaluation

Based on the soil profile, only RW-1, RW-4, and RW-8 intercept the gravel layer below the dam (Plate 16). The others are located in the glacial till. The strata surrounding RW-6 are questionable; the log for the relief well indicates a gravelly (water-bearing) riverbed sand, while the adjacent boring log indicates glacial till.

During January 1994, the relief wells were flushed (Ref. 7). Up to 7.7 feet of sediment was removed from the wells. Based on drawings showing design well depths (Plates 16 and 25), it appears that between 0.5 and 3.5 feet of sediment may have remained at the bottom of the wells after flushing (approximately 2 to 15% of the well screen length). It was also reported in Instrumentation Appendix No. 4 that inspection by a down-hole camera in 1992 had indicated a significant build-up of mineral deposits on the well screens that would restrict flow into the wells.

Relief wells 2 through 8 are located on the downstream toe berm to the east of the stilling basin outlet. These relief wells show a dampened response to rising pool elevation and generally remain at about El. 379 to 382. The forebay pool elevation is generally at 380 feet. The T-invert outlet of RW-2 through RW-8 is at El. 375 according to as-built plans (Plate 25). With the forebay pool above the relief well outlet elevation, water from the forebay pool can back up into the relief wells. Therefore, when the forebay pool is above El. 375, it is difficult to determine whether any water is flowing into the relief wells from the underlying gravel layer. In September 1999, the forebay pool was dewatered in order to work on the east outlet retaining wall, and the levels of RW-2 through RW-8 dropped below El. 370. This indicates that without the inflow from the forebay pool, the relief well levels would be below their outlet elevation under normal pool conditions (pool was at elevation 380.44).

RW-1 is located to the west of the stilling basin outlet. It appears not to be influenced by the forebay pool, and normal water levels in RW-1 generally range from El. 369 to 373. The water levels in RW-1 are similar to the level of natural groundwater prior to construction of the dam. RW-1 shows a stronger response to changes in pool elevation than the other relief wells. During the June 1998 high pool event, the water level in RW-1 rose a total of 4.3 feet while the pool level increased by 23.1 feet.

A plot of water elevation vs. pool elevation was prepared for each relief well. These show the projected reading if the upstream pool were to reach spillway crest elevation of 416.0 feet. Projected elevations are shown in Table 5.

4.4 Tilt Plates

4.4.1 Data Collection

There is a brass survey disk adjacent to each tilt plate that is located on the east outlet and stilling basin walls. A survey of the brass disks was performed in April 2002 to obtain alignment readings, northings, eastings, and elevations. The northing and eastings were obtained for reference only and should not be used in monitoring the wall movement. The alignment readings are read by setting a 00-00 reading from the north site to the south site. The distance between the center of each brass disk to the 00-00 site line is read. The distance values given on Table 6 are now the new baseline for future alignment monitoring. The elevations of each brass disk are now the new baseline for future vertical control surveys.

A new baseline for the tilt plate monitoring rotation has not been established since the repairs were complete.

5.0 Conclusions

5.1 General

Based on past performance of the dam and on the performance of the instrumentation to date, the Hopkinton Lake Dam appears to be suitably instrumented. Existing instrumentation indicates that the dam embankment is functioning suitably relative to seepage and crest movements.

5.2 Crest Monuments

5.2.1 Schedule

The planned schedule for crest monument surveys for the Hopkinton Lake Dam is once every five years, which coincides with the periodic inspection schedule. This schedule is adequate unless physical evidence of embankment movement is found or the next scheduled survey results in unusual readings. Therefore, the next scheduled survey should be performed in 2006, just prior to the next periodic inspection.

5.2.2 Evaluation of Adequacy

The number and locations of the crest monuments are adequate to evaluate embankment movements. Comparison of data between 1996 and 2001 indicates horizontal displacements in the range of 0.0059 to 0.0608 foot (0.07 to 0.073 inch). Measured vertical movement since 1985 are less than 0.08 foot (less than 1 inch). In the absence of any reported physical evidence to indicate embankment movement, these displacements and settlements are not considered significant.

5.3 Piezometers

5.3.1 Schedule

The current schedule of monitoring the piezometers is adequate.

5.3.2 Evaluation of Adequacy

The shallow (B) piezometers along the downstream toe berm appear to be influenced by the downstream forebay pool more than the upstream Hopkinton Lake. The deep (A) piezometers east of the stilling basin have piezometric levels close to pre-existing ground surface elevation and are about 10 to 12 feet lower than the shallow piezometers. The levels in the B piezometers dropped when the forebay pool was emptied in September 1999, but the B levels were still higher than the A levels, indicating that there is not a significant artesian condition in the gravels underlying the dam. In general, the deep piezometers (PZ-5A, PZ-6A, PZ-7A, and PZ-8A) tend to give similar results and reflect the same trends. The shallow piezometers (PZ-5B, PZ-6B, PZ-7B, and PZ-8B) also tend to duplicate the results of each other.

Data from PZ-13A, PZ-14A, and PZ-15 tends to confirm that there is not a significant artesian condition in the foundation soils. Piezometric levels in the upstream embankment (PZ-13B) respond to the pool level, while piezometric levels in the downstream embankment (PZ-14B) are controlled by the compacted pervious fill drainage layer that runs from the core of the dam to the downstream toe. Readings in PZ-13B are generally higher than the pool level and sometimes peak before the pool reaches a maximum level. It appears that surface water may be infiltrating the piezometer, possibly through a leaky seal, and water may be perched within the piezometer.

Piezometers near the outlet channel and stilling basin (PZ-1, PZ-2, PZ-3A&B, PZ-4A&B, PZ-9, PZ-10, PZ-11, and PZ-15) appear to be influenced by the discharge through the channel and drainage layers beneath the structures. Piezometers to the west of the outlet are not affected by the forebay pool, but do respond to changes in the level of Hopkinton Lake. Piezometric levels in the PZ-3A&B piezometers also appear influenced by the nearby abutment, as the levels are slightly higher than in the PZ-4A&B piezometers. The piezometric level in PZ-15 may be influenced by recharge from adjacent relief well RW-2.

There are a number of readings that appear to be in error, which are most likely due to errors in reading and/or recording the raw data.

With the exception of PZ-13B, the piezometers appear to be functioning properly. The number and location of the existing piezometers appear adequate to characterize piezometric levels at Hopkinton Lake Dam.

5.4 Relief Wells

5.4.1 Schedule

The current schedule of monitoring the relief wells is adequate.

5.4.2 Evaluation of Adequacy

The relief wells were originally installed to relieve possible uplift pressures under the dam. A gravel layer with a hydraulic connection to the reservoir was thought to exist under the dam footprint. Based on review of the piezometric data to date, it appears that without a permanent upstream high pool, significant artesian pressures do not exist under the dam, and thus the relief wells may not be needed. In addition, water levels in the forebay pool are higher than the T-invert outlets of the wells, and the levels in relief wells are generally controlled by the forebay pool level.

5.5 Tilt Plates

Repairs to the east outlet wall were completed in September 1999. A baseline for future alignment monitoring and elevations of each brass disk for future vertical control surveys were established during the April 2002 survey. A new baseline for the tilt plate monitoring rotation has not been established since the repairs were complete.

6.0 Recommendations

6.1 Crest Monuments

If unusual readings are obtained during the next survey, or if field evidence of embankment movement is discovered, the monitoring schedule should be adjusted as needed. Surveys should be performed at the same time of year to avoid seasonal movements. A Global Position Systems Survey, such as NAVSTAR, which can detect movements of less than 0.2 inch (ETL 1110-1-133), could be implemented if it becomes cost effective.

6.2 Piezometers

The piezometric levels should continue to be recorded and evaluated on the current schedule. The existing piezometers are considered adequate to evaluate the performance of the embankment and outlet walls. We do not recommend that piezometers PZ-9 and PZ-11 be replaced at this time.

To reduce the number of inconsistent readings, the sensitivity adjustment on the water level indicator housing should be set such that a loud, strong signal is heard when the water surface is contacted. If readings are inconsistent from previous readings or adjacent piezometers, then remove the probe from the piezometer, wipe the water off the probe tip, and reinsert the probe back into the piezometer. The water level indicator should be periodically checked and unusual readings should be verified in the field by project personnel at the time the piezometers are read.

Piezometer PZ-13B should be tested to determine if surface water is infiltrating the piezometer. Since the piezometer is located on the slope of the dam, it would be difficult to infiltrate surface water around the piezometer casing. We recommend that a falling head permeability test be performed in the piezometer, although the results of the test may not be conclusive.

We also recommend that tailwater elevation, outlet discharge rates, and rainfall information be plotted with the pool and piezometer responses for the recent past and all future high pool events in order to determine if there is a connection between the deep downstream toe piezometers and the tailwater discharge.

6.3 Relief Wells

Since the relief wells are controlled by the T connection to the forebay pool at El. 375, we recommend that the relief wells only be monitored if the forebay pool drops below El. 375. The relief wells should be checked twice a year to confirm that the T connection is not plugged.

6.4 Tilt Plates

A new baseline for the tilt plate monitoring rotation should be established. Tilt plate surveys should be performed in accordance with the schedule and recommendations for the crest monument survey, described above.

References

1. Department of the Army (1973). "Periodic Inspection Report No. 1 - Hopkinton Lake, Merrimack River Basin, Contoocook River, New Hampshire," New England Section, Corps of Engineers, March.

2. Department of the Army (1981). "Periodic Inspection Report No. 2 - Hopkinton Lake, Contoocook River, New Hampshire," New England Section, Corps of Engineers, October.

3. Department of the Army (1987). "Periodic Inspection Report No. 3 - Hopkinton Lake, Contoocook River, New Hampshire," New England Section, Corps of Engineers, May.

4. Department of the Army (1992). "Periodic Inspection Report No. 4 - Hopkinton Lake, Contoocook River, New Hampshire," New England Section, Corps of Engineers, April.

5. Department of the Army (1997). "Design Letter Report - Remedial Measures for Downstream Outlet Wall - Hopkinton Dam, Merrimack River Basin, New Hampshire," New England Section, Corps of Engineers, July.

6. Department of the Army (1997). "Periodic Inspection Report No. 5 - Hopkinton Lake, Contoocook River, New Hampshire," New England Section, Corps of Engineers, November.

7. GEI Consultants, Inc. (1994). "Removal of Sediment from Relief Wells, Hopkinton Dam, Hopkinton, New Hampshire," prepared for U.S. Army Corps of Engineers, New England Section, Contract No. DACW 33-91-D-0008, December.

Table 1 - Piezometer Data - Material Zones
Instrumentation Appendix to Periodic Inspection Report No. 6
Hopkinton Lake Dam
Hopkinton, New Hampshire

Piezometer Number	Station	Offset[1] (feet)	Riser Pipe Top Elevation (feet-NGVD)	Piezometer Tip Elevation (feet-NGVD) [2]	Zone	Material Influencing Tip
PZ-1	5+58	213	384.7	330.0	Drain	Filter Sand
PZ-2	6+49	213	376.3	333.0	Drain	Filter Sand
PZ-3A	7+07	155	385.1	305.7	Foundation	Gray Silty SAND (SM)
PZ-3B	7+07	155	385.1	349.7	Foundation	Gray Silty SAND w/Clay (SC-SM)
PZ-4A	6+43	155	385.1	305.7	Foundation	Gray Br. Silty SAND w/Gravel (SM)
PZ-4B	6+43	155	385.1	349.7	Foundation	Gray Silty SAND w/Gravel (SM)
PZ-5A	5+02	155	385.0	305.6	Foundation	Gray Sandy SILT (ML)
PZ-5B	5+02	155	385.0	349.6	Foundation	Gray Silty SAND w/Clay (SC-SM)
PZ-6A	4+50	155	385.3	305.9	Foundation	Gray Br. Silty SAND (SM)
PZ-6B	4+50	155	385.3	349.9	Foundation	Gray Silty SAND w/Clay (SM)
PZ-7A	4+02	155	384.6	305.2	Foundation	Gray Br. Silty GRAVEL (GM)
PZ-7B	4+02	155	384.6	349.2	Foundation	Gray Silty Clayey SAND (SC-SM)
PZ-8A	2+53	155	384.9	305.5	Foundation	Gray Br. Silty SAND w/Gravel (SM)
PZ-8B	2+53	155	384.9	349.5	Foundation	Gray Sandy SILT (ML)
PZ-9	5+47	275	384.8	340.5	Foundation	Gray SAND w/Silt (SP-SM)
PZ-10	5+28	318	384.7	323.8	Foundation	Gray Silty SAND w/Gravel (SM)
PZ-11	5+08	357	384.1	353.1	Foundation	Gray Silty SAND w/Gravel (SM)
PZ-13A	5+25	60	417.9	299.0	Foundation	Gray Silty SAND (SM) & Brown sandy CLAY (CL)
PZ-13B	5+25	60	418.0	368.0	Embankment	Dark Brown Sandy SILT, Trace Gravel (ML) & Brown silty SAND (SM)
PZ-14A	5+25	75	417.8	303.0	Foundation	Brown Clayey Sand w/Trace Gravel (SC)
PZ-14B	5+25	75	417.9	369.0	Embankment	Brown, M-F SAND w/Trace Silt (SP)
PZ-15	5+25	150	384.3	301.0	Foundation	Gray & Brown Stratified Silty & Clayey Sand w/Gravel (SM) over Gray Varved Clay w/M-F SAND (CL)

Note: 1) All piezometers are located downstream of the crest, except PZ-13A and PZ-13B.
2) Piezometer tip elevation based on June 9, 1997, soundings.

Table 2 - Horizontal and Vertical Movement Data
Instrumentation Appendix to Periodic Inspection Report No. 6
Hopkinton Dam
Hopkinton, New Hampshire

A. Horizontal Movements

Monument	September 1985		March 1986		April 1991		March 1996		August 2001		Change 1986-1991			
	Northing	Easting	Northing	Easting	Northing	Easting	Northing	Easting	Northing	Easting	Northing	Easting	Resultant	Direction
1	N / R	N / R	251153.912	478589.521	251153.931	478589.548	251153.8947	478589.5397	251153.9413	478589.5007	0.019	0.027	0.033	NE
2	N / R	N / R	251087.633	478533.563	251087.676	478533.579	251087.6544	478533.5795	251087.6878	478533.5444	0.043	0.016	0.046	NE
3	N / R	N / R	251047.923	478442.224	251047.945	478442.264	251047.9249	478442.2695	251047.9820	478442.2572	0.022	0.040	0.046	NE
4	N / R	N / R	251007.180	478349.652	251007.172	478349.686	251007.1779	478349.6942	251007.1967	478349.6604	-0.008	0.034	0.035	SE
5	N / R	N / R	250967.770	478258.772	250967.759	478258.824	250967.7658	478258.8316	250967.7704	478258.8092	-0.011	0.052	0.053	SE
6	N / R	N / R	250927.540	478166.833	250927.514	478166.886	250927.5253	478166.8962	250927.5383	478166.8757	-0.026	0.053	0.059	SE
7	N / R	N / R	250888.384	478075.658	250888.357	478075.681	250888.3538	478075.6906	250888.3815	478075.6838	-0.027	0.023	0.035	SE
8	N / R	N / R	250847.888	477983.211	250847.849	477983.261	250847.8451	477983.2733	250847.8510	477983.2736	-0.039	0.050	0.063	SE

Monument	Change 1991-1996				Change 1996-2001				Cumulative Change 1986 - 2001			
	Northing	Easting	Resultant	Direction	Northing	Easting	Resultant	Direction	Northing	Easting	Resultant	Direction
1	-0.036	-0.008	0.037	SW	0.0466	-0.0390	0.0608	NW	0.029	-0.020	0.036	NW
2	-0.022	0.000	0.022	S	0.0334	-0.0351	0.0485	NW	0.055	-0.019	0.058	NW
3	-0.020	0.005	0.021	SE	0.0571	-0.0123	0.0584	NW	0.059	0.033	0.068	NE
4	0.006	0.008	0.010	NE	0.0188	-0.0338	0.0387	NW	0.017	0.008	0.019	NE
5	0.007	0.008	0.010	NE	0.0046	-0.0224	0.0229	NW	0.000	0.037	0.037	E
6	0.011	0.010	0.015	NE	0.0130	-0.0205	0.0243	NW	-0.002	0.043	0.043	E
7	-0.003	0.010	0.010	SE	0.0277	-0.0068	0.0285	NW	-0.003	0.026	0.026	E
8	-0.004	0.012	0.013	SE	0.0059	0.0003	0.0059	N	-0.037	0.063	0.073	SE

B. Vertical Movements

Monument	Sept. 1985 El. (ft, NGVD)	March 1986 El. (ft, NGVD)	April 1991 El. (ft, NGVD)	March 1996 El. (ft, NGVD)	Aug. 2001 El. (ft, NGVD)	Change 1985-1986 1) (feet)	Change 1986-1991 1) (feet)	Change 1991-1996 1) (feet)	Change 1996-2001 1) (feet)	Net Change 1985-2001 1) (feet)
1	440.975	441.016	441.058	441.057	441.06	0.041	0.042	-0.001	0.00	0.08
2	440.590	440.636	440.670	440.664	440.66	0.046	0.034	-0.006	0.00	0.07
3	439.660	439.695	439.729	439.719	439.72	0.035	0.034	-0.010	0.00	0.06
4	438.135	438.157	438.198	438.188	438.19	0.022	0.041	-0.010	0.00	0.06
5	437.710	437.731	437.782	437.762	437.77	0.021	0.051	-0.020	0.01	0.06
6	437.840	437.869	437.910	437.887	437.89	0.029	0.041	-0.023	0.00	0.05
7	438.480	438.492	438.539	438.518	438.52	0.012	0.047	-0.021	0.00	0.04
8	441.300	441.312	441.352	441.332	441.33	0.012	0.040	-0.020	0.00	0.03

N / R = Information not recorded

1) Negative movements are downward (settlement).

Table 3 - Piezometer Readings
Instrumentation Appendix to Periodic Inspection Report No. 6
Hopkinton Lake Dam
Hopkinton, New Hampshire

Date	Water Surface Elevations (feet, NGVD)												
	Pool	PZ-1	PZ-2	PZ-3A	PZ-3B	PZ-4A	PZ-4B	PZ-5A	PZ-5B	PZ-6A	PZ-6B	PZ-7A	PZ-7B
3/31/97	391.09	PI	PI	PI	PI	PI	PI	PI	PI	PI	PI	PI	PI
4/21/97	398.04	368.26	368.03	378.60	379.88	373.78	372.01	372.27	382.11	372.67	381.66	372.36	381.81
4/22/97	398.20	368.95	368.66	379.69	379.85	374.76	372.96	372.79	382.21	372.87	381.76	372.79	378.60
4/23/97	397.03	368.89	368.72	379.78	379.59	374.40	372.47	372.60	382.15	372.70	381.59	372.53	381.71
4/24/97	394.28	369.28	369.02	379.75	379.19	374.76	372.63	372.47	382.28	372.37	381.46	372.20	381.58
4/25/97	392.17	368.95	368.72	379.52	378.73	374.57	372.30	372.14	382.21	372.08	381.23	371.80	381.32
4/26/97	385.98	368.23	367.90	379.13	378.28	373.94	371.42	371.48	381.85	371.26	380.71	371.12	380.83
4/27/97	383.05	366.75	366.59	378.24	377.82	374.17	370.34	370.83	382.05	370.96	380.51	370.33	380.47
4/28/97	383.35	PI	PI	PI	PI	PI	PI	PI	PI	PI	PI	PI	PI
4/29/97	385.02	367.47	367.18	378.21	378.93	373.16	370.93	371.22	382.15	371.36	380.77	371.31	380.73
4/30/97	383.52	367.11	366.95	378.24	378.73	372.76	370.79	371.06	381.75	371.13	380.44	371.08	380.63
6/3/97	380.55	363.73	366.75	375.85	376.24	370.53	368.14	368.89	379.59	369.29	378.48	369.51	378.50
7/9/97	379.95	363.87	363.64	375.29	375.52	370.20	367.81	368.53	379.72	368.83	378.51	369.28	378.60
7/30/97	380.14	364.10	363.87	375.32	375.49	370.24	367.87	368.46	379.91	368.67	378.71	369.05	378.73
8/22/97	379.91	363.80	364.52	374.99	375.91	369.91	368.01	368.20	379.62	368.30	378.51	368.79	378.37
10/2/97	380.31	363.57	363.34	374.76	375.39	369.71	367.48	368.20	380.28	368.47	378.90	368.95	378.83
11/4/97	383.36	366.46	366.19	376.31	377.23	371.65	369.61	369.64	381.69	369.62	380.28	369.80	380.24
12/1/97	383.30	364.13	363.90	375.59	376.60	370.40	368.10	368.99	381.62	369.29	380.31	369.90	380.27
1/6/98	383.20	363.70	363.47	375.55	375.75	370.24	367.84	368.63	381.52	369.03	380.12	369.51	380.04
2/11/98	382.60	PI	PI	PI	PI	PI	PI	PI	PI	PI	PI	PI	PI
3/3/98	385.50	366.62	PI	377.72	379.00	372.60	370.63	370.66	381.92	370.86	380.64	371.02	380.63
3/10/98	390.87	364.23	364.00	377.98	379.46	372.47	370.89	370.83	381.92	371.42	380.77	371.71	380.79
3/11/98	392.51	368.69	368.62	378.73	379.72	374.11	372.44	372.11	378.83	372.21	381.23	372.13	381.32
3/12/98	391.78	369.18	368.95	379.39	379.65	374.63	372.83	372.34	382.18	372.31	381.26	372.17	381.32
3/13/98	386.86	368.85	368.66	379.36	379.03	374.34	372.30	371.88	382.01	371.75	380.94	372.49	380.99
3/14/98	385.50	367.74	367.54	378.77	378.57	373.58	371.32	371.32	382.01	371.39	380.74	371.41	380.73
3/15/98	385.04	366.85	366.62	378.24	378.11	373.16	370.93	371.06	382.01	371.16	380.74	371.28	380.73
3/16/98	385.50	366.88	366.65	378.14	378.08	372.96	370.70	370.89	382.08	371.03	380.74	371.15	380.76
3/17/98	384.49	366.98	366.79	378.21	377.88	372.93	370.66	370.83	382.31	370.99	380.81	371.08	380.76
4/1/98	394.93	363.73	363.50	377.72	379.59	371.75	370.40	370.56	381.82	371.36	381.10	372.13	381.19
4/2/98	396.82	368.03	367.70	379.42	379.88	374.40	372.63	372.47	382.24	372.70	381.63	372.69	381.75
4/3/98	398.17	369.12	369.02	379.56	379.85	374.57	372.70	372.47	382.31	372.77	381.79	372.76	381.91

Table 3 - Piezometer Readings

Instrumentation Appendix to Periodic Inspection Report No. 6
Hopkinton Lake Dam
Hopkinton, New Hampshire

	Water Surface Elevations (feet, NGVD)									
Date	PZ-8A	PZ-8B	PZ-9	PZ-10	PZ-11	PZ-13A	PZ-13B	PZ-14A	PZ-14B	PZ-15
3/31/97	PI	PI	PI	PI	PI	PI	PI	PI	PI	PI
4/21/97	371.42	382.01	368.49	368.46	369.34	374.92	395.03	373.34	382.47	376.43
4/22/97	371.48	382.05	372.59	372.40	370.25	375.21	392.41	373.83	382.79	376.75
4/23/97	371.28	382.01	369.25	372.27	370.22	374.59	390.21	373.44	382.73	376.59
4/24/97	370.96	382.14	369.54	372.40	370.48	374.16	389.82	373.44	382.40	376.69
4/25/97	370.66	382.11	369.31	372.07	370.22	373.11	382.34	373.51	389.68	376.43
4/26/97	370.14	381.85	368.49	371.35	369.50	372.46	389.46	372.19	382.14	376.03
4/27/97	369.87	381.98	367.18	370.46	368.25	372.52	389.13	371.64	382.14	375.57
4/28/97	PI	PI	PI	PI	PI	PI	PI	PI	PI	PI
4/29/97	370.17	381.95	367.74	370.85	368.81	372.23	382.34	373.01	398.67	375.74
4/30/97	370.07	381.55	367.48	370.59	368.52	372.88	392.18	371.93	382.30	375.44
6/3/97	368.59	379.39	364.23	368.16	365.60	371.15	386.70	369.90	380.27	372.85
7/9/97	367.87	379.52	364.26	367.93	365.76	370.16	386.14	369.18	379.81	371.21
7/30/97	367.61	379.75	364.49	367.87	365.66	370.49	386.11	369.41	380.07	372.82
8/22/97	367.38	379.49	364.20	367.44	365.27	370.16	400.28	369.18	380.23	372.42
10/2/97	367.35	380.31	364.03	367.57	365.23	370.23	385.94	369.73	379.81	371.57
11/4/97	368.17	381.49	366.72	369.28	367.76	371.28	387.85	370.52	381.97	372.82
12/1/97	368.43	381.62	364.59	368.16	366.05	PI	PI	PI	PI	371.50
1/6/98	368.00	381.45	364.26	367.90	366.38	PI	PI	PI	PI	371.18
2/11/98	PI	PI	PI	PI	PI	PI	PI	PI	PI	PI
3/3/98	369.64	PI	367.02	370.20	368.48	PI	PI	PI	PI	372.49
3/10/98	370.30	381.59	365.02	369.34	367.47	374.00	402.09	372.95	382.76	372.16
3/11/98	370.76	382.08	369.05	371.84	370.75	372.62	394.31	373.97	382.30	373.83
3/12/98	370.76	382.01	369.54	372.20	371.27	374.26	390.51	373.34	382.40	374.00
3/13/98	370.33	381.95	369.18	371.81	370.84	373.18	388.47	372.75	382.10	373.64
3/14/98	370.10	381.98	368.07	371.05	369.93	PI	PI	PI	PI	373.08
3/15/98	370.00	381.98	367.28	370.56	369.17	PI	PI	PI	PI	372.88
3/16/98	369.84	382.01	367.28	370.46	369.17	PI	PI	PI	PI	372.72
3/17/98	369.74	382.11	367.38	370.53	369.34	PI	PI	PI	PI	372.75
4/1/98	370.79	381.62	364.46	369.21	366.55	374.20	389.13	371.87	382.20	371.67
4/2/98	371.22	382.14	368.46	371.84	369.93	374.92	389.42	373.51	382.76	373.77
4/3/98	371.28	382.21	369.38	372.30	370.71	374.89	390.28	373.64	382.86	373.96

Table 3 - Piezometer Readings

Instrumentation Appendix to Periodic Inspection Report No. 6
Hopkinton Lake Dam
Hopkinton, New Hampshire

	Water Surface Elevations (feet, NGVD)												
Date	Pool	PZ-1	PZ-2	PZ-3A	PZ-3B	PZ-4A	PZ-4B	PZ-5A	PZ-5B	PZ-6A	PZ-6B	PZ-7A	PZ-7B
4/4/98	397.65	369.05	368.92	379.85	379.59	374.83	372.89	372.53	382.28	372.67	381.69	372.59	381.84
4/5/98	396.48	368.95	368.85	379.82	379.36	374.76	372.70	372.43	382.24	372.47	381.56	372.43	381.65
4/6/98	393.79	369.41	369.05	379.78	379.03	374.76	372.67	372.27	382.18	372.24	381.36	372.10	381.48
4/7/98	390.49	368.72	368.39	379.49	378.57	374.37	372.07	371.84	382.05	371.72	381.00	371.54	381.12
4/8/98	384.12	367.57	367.28	378.70	377.95	373.12	370.83	370.89	381.98	370.83	380.54	370.79	380.60
4/9/98	383.67	366.16	365.87	378.11	377.72	372.63	370.14	370.50	381.72	370.60	380.31	370.82	380.40
4/10/98	384.19	366.33	366.03	377.88	377.72	372.50	370.14	370.50	381.98	370.77	380.54	370.92	380.60
4/11/98	384.01	365.28	368.39	377.59	377.52	372.17	370.11	370.24	381.82	370.54	380.38	370.72	380.40
4/12/98	383.33	366.10	365.80	378.05	377.62	372.57	370.11	370.43	381.65	370.50	380.25	370.75	380.37
4/29/98	383.57	363.77	363.50	376.41	376.73	370.86	368.53	369.22	381.75	369.68	380.38	370.16	380.43
5/27/98	380.09	363.60	363.34	375.75	375.98	370.34	367.97	368.63	379.49	369.06	378.48	369.51	378.53
6/15/98	393.79	364.03	363.70	376.90	378.96	371.35	**373.42**	370.01	380.05	370.57	379.62	371.21	379.81
6/16/98	397.90	**369.34**	367.77	377.52	379.46	372.70	371.06	371.15	380.21	371.62	380.44	371.90	380.33
6/17/98	400.23	368.49	368.29	378.80	379.82	374.21	372.76	**372.24**	380.54	372.50	380.41	372.43	380.63
6/18/98	402.93	367.57	367.41	379.06	**379.92**	373.98	372.60	372.17	380.34	**372.57**	380.41	**372.62**	380.70
6/19/98	**403.22**	368.16	367.90	379.23	379.65	374.14	372.57	372.17	384.56	372.47	**380.61**	372.53	**380.86**
6/20/98	402.77	368.62	368.49	379.29	379.52	374.27	372.70	372.11	380.60	372.31	380.51	372.30	380.79
6/21/98	402.13	368.85	368.56	379.39	379.36	374.40	372.83	372.11	380.60	372.21	380.44	372.13	380.66
6/22/98	401.34	368.89	**368.62**	**379.42**	379.26	**374.44**	372.76	371.97	380.57	372.04	380.35	372.00	380.50
6/23/98	400.09	367.21	367.01	379.29	378.93	374.08	372.24	371.84	**380.70**	371.98	380.44	371.94	380.66
6/24/98	399.09	368.69	368.49	379.26	378.67	374.24	372.27	371.78	380.51	371.75	380.15	368.39	380.33
6/25/98	396.22	368.69	368.43	379.10	378.24	374.14	372.04	371.58	380.41	371.52	379.89	371.34	380.07
6/26/98	394.03	368.36	368.26	378.96	378.37	373.94	371.68	371.35	380.34	371.26	379.72	371.15	379.84
6/28/98	390.90	367.87	367.74	378.57	378.34	373.52	371.32	371.09	380.34	371.09	379.49	370.98	379.58
6/29/98	388.55	367.90	367.64	378.47	378.08	373.45	371.12	370.92	380.28	370.86	379.36	370.85	378.83
6/30/98	352.69	366.65	366.42	377.98	377.65	372.73	369.52	370.24	380.21	370.17	379.49	370.29	379.25
7/1/98	382.11	366.59	366.16	377.55	377.72	372.40	369.94	370.27	380.18	370.40	379.20	370.46	379.28
7/2/98	383.05	367.18	367.01	377.88	378.11	372.83	370.57	370.43	380.28	370.60	379.20	370.56	379.22
7/3/98	382.15	367.28	367.08	378.01	377.95	372.96	370.66	370.60	380.18	370.67	379.10	370.56	379.15
8/3/98	379.81	363.64	363.44	375.32	375.59	370.01	367.68	368.27	379.68	368.63	378.51	369.02	378.53
8/26/98	380.28	364.39	367.41	375.29	375.59	370.20	367.81	368.33	379.95	368.57	378.77	368.75	378.83
10/1/98	380.12	364.00	363.77	374.99	375.26	369.91	367.58	368.10	379.85	368.30	378.64	368.52	378.63

Table 3 - Piezometer Readings

Instrumentation Appendix to Periodic Inspection Report No. 6
Hopkinton Lake Dam
Hopkinton, New Hampshire

Date	Water Surface Elevations (feet, NGVD)									
	PZ-8A	PZ-8B	PZ-9	PZ-10	PZ-11	PZ-13A	PZ-13B	PZ-14A	PZ-14B	PZ-15
4/4/98	371.25	382.11	369.38	372.30	370.88	374.66	390.24	373.64	382.76	374.03
4/5/98	371.12	382.11	369.31	372.17	370.81	374.36	390.60	373.44	382.66	373.96
4/6/98	370.76	382.14	369.71	372.33	371.14	373.97	391.00	373.28	382.53	373.96
4/7/98	370.43	381.65	369.05	371.77	370.81	373.25	391.00	372.69	382.40	373.47
4/8/98	369.64	381.88	367.90	370.53	369.43	372.23	390.77	371.70	382.40	372.75
4/9/98	369.61	381.72	366.59	369.94	368.29	372.26	390.70	371.37	382.40	372.23
4/10/98	369.74	381.85	366.72	370.13	368.42	372.46	390.87	371.47	382.56	372.42
4/11/98	369.48	381.65	365.90	369.57	367.76	372.33	390.44	371.24	382.14	372.09
4/12/98	369.54	381.62	366.46	369.87	368.25	372.13	390.47	371.34	382.14	372.16
4/29/98	368.95	381.55	364.36	368.43	366.22	371.51	388.50	370.23	382.30	371.21
5/27/98	368.40	379.45	364.06	367.97	365.66	368.95	387.85	369.67	380.23	370.19
6/15/98	370.04	379.91	364.62	368.92	365.89	373.31	**400.32**	370.91	380.63	371.24
6/16/98	370.59	380.37	368.13	371.02	368.81	373.97	370.36	372.36	380.69	372.55
6/17/98	370.99	380.47	368.82	371.84	369.76	374.82	396.87	**373.47**	380.79	373.41
6/18/98	**371.25**	380.31	368.03	371.58	369.07	**374.89**	391.49	373.31	380.69	373.18
6/19/98	371.19	380.57	368.53	371.81	369.63	374.62	391.26	373.31	380.73	373.41
6/20/98	371.05	380.50	368.89	371.84	369.93	374.33	391.69	373.21	**380.89**	371.83
6/21/98	370.86	380.50	369.08	**371.97**	370.06	374.16	392.31	373.18	380.69	**373.44**
6/22/98	370.76	380.50	**369.15**	371.90	**370.16**	374.07	392.90	373.11	380.79	373.44
6/23/98	370.56	**380.83**	367.74	371.28	368.91	373.74	393.52	369.47	380.86	373.21
6/24/98	370.40	380.41	368.95	371.64	370.06	373.64	393.49	369.18	380.82	373.21
6/25/98	370.14	380.31	368.89	371.58	369.99	373.21	394.28	351.03	372.59	373.14
6/26/98	369.94	380.24	368.66	371.28	369.96	372.92	399.04	380.72	372.39	372.88
6/28/98	369.87	380.27	368.17	370.99	369.43	372.66	393.88	374.00	380.63	372.65
6/29/98	369.74	380.18	368.13	370.85	369.17	393.75	393.52	371.90	380.73	372.52
6/30/98	369.22	380.18	367.02	370.07	369.57	394.60	393.52	371.11	380.89	371.80
7/1/98	369.32	380.24	366.82	369.97	367.86	371.90	399.59	371.08	374.20	371.67
7/2/98	369.48	380.14	367.44	370.30	368.52	393.03	369.10	380.56	371.61	371.90
7/3/98	369.45	380.01	367.54	370.39	368.61	372.36	392.08	371.57	380.63	372.00
8/3/98	367.77	379.45	364.10	367.47	365.23	370.39	388.04	369.27	380.10	369.27
8/26/98	367.38	379.88	364.69	367.90	365.86	370.36	388.01	369.24	380.17	369.50
10/1/98	367.18	379.75	364.36	367.54	365.73	370.10	387.72	370.00	380.50	369.47

Table 3 - Piezometer Readings

Instrumentation Appendix to Periodic Inspection Report No. 6
Hopkinton Lake Dam
Hopkinton, New Hampshire

	Water Surface Elevations (feet, NGVD)												
Date	Pool	PZ-1	PZ-2	PZ-3A	PZ-3B	PZ-4A	PZ-4B	PZ-5A	PZ-5B	PZ-6A	PZ-6B	PZ-7A	PZ-7B
10/30/98	382.05	363.77	363.50	375.09	375.72	369.97	367.55	368.37	381.55	368.70	380.12	369.05	380.14
12/2/98	382.62	363.70	363.47	375.36	376.14	370.17	367.81	368.60	380.24	368.83	380.05	369.18	380.01
1/5/99	382.10	363.83	363.50	375.26	375.42	370.04	367.58	368.37	381.49	368.63	379.92	368.95	379.94
3/30/99	385.78	367.61	367.31	378.34	378.93	373.26	371.29	371.12	382.08	371.19	380.77	371.21	380.89
5/3/99	379.95	363.60	363.34	375.68	375.95	370.20	367.78	368.53	379.68	368.90	381.69	369.24	378.56
5/26/99	380.62	363.64	363.41	376.31	375.59	370.17	367.87	368.43	380.08	368.83	378.44	369.11	378.56
7/1/99	380.02	364.13	363.83	375.19	375.22	369.42	367.65	368.17	379.91	368.34	378.64	368.42	378.69
7/26/99	379.94	363.64	363.41	374.83	375.36	369.68	367.45	367.81	379.65	368.14	378.44	368.16	378.56
8/31/99[1)]	380.44	PI	363.67	374.27	375.32	369.35	367.32	366.79	370.17	366.99	369.94	366.88	370.07
9/17/99[2)]	389.30	368.66	NA	376.47	377.91	372.63	371.19	370.66	380.34	370.57	379.33	370.29	379.51
9/18/99[2)]	389.49	369.02	NA	377.36	378.11	373.22	371.65	370.99	380.24	370.86	379.33	370.43	379.51
9/19/99	388.62	369.15	368.85	377.82	377.98	373.58	371.84	371.25	380.28	370.96	379.33	370.56	379.51
9/20/99[3)]	381.43	368.36	367.97	377.52	377.39	372.99	370.93	370.37	380.11	370.04	379.03	369.84	379.02
9/21/99	381.30	367.15	366.79	376.96	377.06	372.34	370.14	370.04	379.68	370.01	378.57	369.84	378.63
9/22/99[3)]	382.98	366.59	366.29	376.77	377.75	371.98	369.42	370.01	380.24	370.04	379.07	370.07	379.15
9/23/99[3)]	381.21	366.33	366.06	376.54	377.59	371.91	369.74	369.68	379.91	369.78	378.74	369.84	378.96
9/24/99[3)]	381.56	363.93	363.64	376.08	377.29	370.73	368.79	369.09	379.75	369.45	378.64	369.41	378.79
10/4/99	382.23	364.03	363.67	375.29	376.44	370.27	371.25	368.86	380.87	369.19	380.15	369.70	380.47
10/29/99	382.72	363.83	363.54	375.39	376.24	369.58	367.81	368.73	381.23	369.06	380.18	369.51	380.24
11/29/99	384.92	365.05	364.78	376.08	376.37	371.02	368.56	369.32	381.72	369.55	380.58	369.77	380.66
12/23/99	383.98	364.36	364.09	375.78	375.98	370.66	368.17	368.92	381.72	380.35	369.16	369.47	380.43
1/27/00	381.99	PI	PI	PI	PI	PI	PI	PI	PI	PI	PI	PI	PI
3/2/00	385.85	PI	PI	PI	PI	PI	PI	PI	PI	PI	PI	PI	PI
4/3/00	384.03	366.88	366.59	378.08	377.91	372.83	370.50	370.56	379.16	370.80	378.51	370.75	378.69
4/24/00	391.70	367.61	367.21	378.14	379.42	373.42	371.55	371.55	381.72	371.68	381.10	371.67	381.29
4/25/00	391.75	367.61	367.28	378.54	379.29	373.58	371.62	371.55	381.72	371.75	381.10	371.67	381.42
4/26/00	NA	368.62	368.26	378.90	378.87	374.08	371.71	371.45	381.62	371.26	380.81	371.08	380.99
4/27/00	382.80	368.00	367.67	378.51	378.67	376.83	371.16	371.09	381.36	370.99	381.53	370.85	380.50
4/29/00	381.39	366.95	366.69	378.34	378.96	373.16	370.86	370.99	381.36	371.19	380.35	371.08	380.11
4/30/00	381.62	367.47	367.18	378.01	378.51	373.22	370.93	370.89	381.29	371.03	380.12	370.89	380.24
5/1/00	380.61	365.70	365.44	378.01	378.41	372.63	370.37	370.17	379.88	370.34	378.97	370.29	379.09
6/3/00	380.28	363.64	363.34	375.45	376.04	370.34	367.94	368.60	372.57	368.99	378.41	369.31	378.56

Table 3 - Piezometer Readings
Instrumentation Appendix to Periodic Inspection Report No. 6
Hopkinton Lake Dam
Hopkinton, New Hampshire

Date	Water Surface Elevations (feet, NGVD)									
	PZ-8A	PZ-8B	PZ-9	PZ-10	PZ-11	PZ-13A	PZ-13B	PZ-14A	PZ-14B	PZ-15
10/30/98	367.67	381.49	364.20	367.67	365.96	371.51	388.50	370.23	382.30	369.80
12/2/98	369.41	NA	364.26	367.70	366.05	370.65	387.26	NA	381.61	369.77
1/5/99	367.54	381.39	364.33	367.70	365.96	PI	PI	PI	PI	PI
3/30/99	369.77	381.98	368.00	370.85	369.17	370.06	390.18	371.60	382.04	372.00
5/3/99	368.10	379.58	364.16	367.87	365.82	370.75	386.50	369.47	374.03	369.21
5/26/99	367.84	379.52	364.16	367.80	366.15	370.65	387.16	369.04	380.27	369.14
7/1/99	367.12	379.72	364.56	367.70	366.38	370.16	386.40	369.08	393.29	369.01
7/26/99	366.95	379.45	364.10	367.31	365.96	371.15	387.03	368.75	381.09	368.49
8/31/99[1)]	366.17	370.73	PI	PI	PI	370.95	386.83	368.16	374.85	PI
9/17/99[2)]	368.69	383.42	NA	370.69	NA	372.36	404.15	371.51	378.10	371.11
9/18/99[2)]	369.05	380.24	NA	371.02	NA	372.69	393.95	371.87	378.23	371.44
9/19/99	369.09	380.21	PD	371.15	PD	372.62	389.19	372.03	378.50	371.60
9/20/99[3)]	368.59	379.98	NA	370.43	NA	371.90	388.77	371.11	378.82	370.85
9/21/99	368.53	379.06	NA	369.84	NA	371.47	388.83	370.82	378.82	370.32
9/22/99[3)]	368.79	380.18	NA	369.67	NA	371.77	396.35	370.88	379.18	370.26
9/23/99[3)]	368.66	379.81	NA	369.41	NA	371.41	389.78	370.59	379.28	369.93
9/24/99[3)]	368.53	379.81	NA	368.26	NA	372.26	393.16	371.64	380.96	369.04
10/4/99	368.27	381.45	364.33	368.13	366.78	370.82	388.21	369.73	380.99	368.98
10/29/99	368.23	381.49	364.10	368.00	368.84	370.82	387.98	369.63	381.81	368.91
11/29/99	368.36	381.95	364.79	368.79	366.68	371.41	387.75	370.19	382.10	369.67
12/23/99	368.13	381.72	364.65	PF	366.51	370.98	387.88	369.90	382.01	369.21
1/27/00	PI	PI	PI	PI	PI	PI	PI	PI	PI	PI
3/2/00	PI	PI	PI	PI	PI	PI	PI	PI	PI	PI
4/3/00	369.71	379.32	NA	370.36	NA	372.69	386.57	371.64	380.07	370.68
4/24/00	370.40	381.88	NA	371.22	NA	373.84	391.00	372.49	382.27	371.57
4/25/00	370.40	381.91	NA	371.22	NA	373.70	388.93	372.56	382.07	371.67
4/26/00	369.91	381.85	NA	371.44	NA	372.79	388.14	372.49	381.94	371.83
4/27/00	369.74	381.59	NA	370.99	NA	372.72	392.41	372.19	382.30	371.41
4/29/00	369.91	381.68	NA	370.62	NA	373.02	388.70	371.93	382.17	371.08
4/30/00	369.71	381.32	NA	370.66	NA	372.82	388.47	371.90	382.04	371.14
5/1/00	369.32	379.62	NA	369.57	NA	372.33	388.21	371.44	381.84	370.19
6/3/00	379.49	368.27	NA	368.00	NA	370.85	387.22	369.31	380.17	368.45

Table 3 - Piezometer Readings

Instrumentation Appendix to Periodic Inspection Report No. 6
Hopkinton Lake Dam
Hopkinton, New Hampshire

	Water Surface Elevations (feet, NGVD)												
Date	Pool	PZ-1	PZ-2	PZ-3A	PZ-3B	PZ-4A	PZ-4B	PZ-5A	PZ-5B	PZ-6A	PZ-6B	PZ-7A	PZ-7B
7/11/00	379.93	363.70	363.44	375.09	375.88	370.07	367.78	368.27	379.26	368.60	378.44	368.82	378.60
7/31/00	381.30	364.49	364.19	375.29	376.41	370.30	368.01	368.53	379.72	368.90	378.74	369.02	378.89
8/28/00	382.30	367.97	367.74	378.47	379.03	373.52	371.25	371.15	381.36	371.13	380.25	370.95	380.37
10/2/00	382.08	363.80	363.50	374.93	375.68	369.88	367.58	368.07	381.26	368.50	379.92	368.69	380.01
11/1/00	382.24	363.73	363.44	374.96	375.72	369.84	367.45	368.23	381.23	368.53	379.98	368.79	380.07
12/1/00	383.07	363.70	363.41	375.29	376.08	370.04	367.65	368.40	381.36	368.73	379.98	369.08	380.11
7/6/01	379.95	363.50	363.18	375.32	376.04	370.01	367.71	368.27	379.00	368.57	378.51	368.95	378.63
7/31/01	379.60	363.50	363.18	374.96	375.62	369.74	367.45	367.97	379.00	368.30	378.41	368.52	378.53
9/5/01	379.84	363.60	363.34	374.54	375.16	369.52	367.22	367.64	378.93	367.88	378.41	367.97	378.53
10/1/01	379.73	364.70	363.21	374.50	375.49	369.45	367.25	367.64	378.34	368.01	378.34	368.23	378.43
10/30/01	381.24	363.64	363.34	374.21	374.80	369.48	367.09	367.77	379.72	367.98	379.56	368.16	379.65
12/4/01	381.56	363.70	363.41	374.50	375.32	369.52	367.15	367.77	381.19	367.98	379.72	368.03	379.81

Table 3 - Piezometer Readings
Instrumentation Appendix to Periodic Inspection Report No. 6
Hopkinton Lake Dam
Hopkinton, New Hampshire

	Water Surface Elevations (feet, NGVD)									
Date	**PZ-8A**	**PZ-8B**	**PZ-9**	**PZ-10**	**PZ-11**	**PZ-13A**	**PZ-13B**	**PZ-14A**	**PZ-14B**	**PZ-15**
7/11/00	367.71	379.19	NA	367.77	NA	370.49	387.42	369.27	380.23	368.22
7/31/00	367.84	379.95	NA	368.13	NA	370.65	399.66	369.60	380.27	365.24
8/28/00	369.77	381.52	NA	370.99	NA	372.79	390.24	372.00	382.24	371.44
10/2/00	367.41	381.39	NA	367.67	NA	370.23	386.40	369.18	381.02	368.22
11/1/00	367.51	381.45	NA	367.64	NA	370.29	386.99	369.18	381.81	368.35
12/1/00	367.81	381.42	NA	367.80	NA	370.49	387.03	369.37	381.74	368.42
7/6/01	367.77	379.55	NA	367.70	NA	370.46	387.09	369.24	380.23	368.09
7/31/01	367.41	379.45	NA	367.47	NA	366.85	386.34	368.95	380.10	367.86
9/5/01	366.76	379.52	NA	367.15	NA	369.67	385.68	368.62	380.04	367.67
10/1/01	367.08	379.52	NA	367.25	NA	369.77	385.94	368.72	380.40	367.67
10/30/01	366.85	380.96	NA	367.25	NA	369.70	385.62	368.68	381.42	367.80
12/4/01	366.69	381.26	NA	367.28	NA	369.73	385.32	368.68	381.61	367.90

Abbreviations
PD = Piezometer Dry
PI = Piezometer Inaccessible
NA = Information not Given
PF=Piezometer Frozen
PU=Personnel Unavailable to take readings

Shaded values indicate questionable data.
High pool readings are shown in **bold**.

1) Forebay dewatering - some piezometers NA.
2) Can't open PZ-9.
3) PZ-9&11 broken.

Table 4 - Relief Well Readings
Instrumentation Appendix to Periodic Inspection Report No. 6
Hopkinton Lake Dam
Hopkinton, New Hampshire

		Water Surface Elevations (feet, NGVD)							
Date	Pool	RW1	RW2	RW3	RW4	RW5	RW6	RW7	RW8
3/31/97	391.09	NA	NA	NA	NA	NA	NA	NA	NA
4/21/97	398.04	NA	NA	NA	NA	NA	NA	NA	NA
4/22/97	398.20	NA	NA	NA	NA	NA	NA	NA	NA
4/23/97	397.03	NA	NA	NA	NA	NA	NA	NA	NA
4/24/97	394.28	NA	NA	NA	NA	NA	NA	NA	NA
4/25/97	392.17	NA	NA	NA	NA	NA	NA	NA	NA
4/26/97	385.98	NA	NA	NA	NA	NA	NA	NA	NA
4/27/97	383.05	NA	NA	NA	NA	NA	NA	NA	NA
4/28/97	383.35	NA	NA	NA	NA	NA	NA	NA	NA
4/29/97	385.02	NA	NA	NA	NA	NA	NA	NA	NA
4/30/97	383.52	NA	NA	NA	NA	NA	NA	NA	NA
6/3/97	380.55	369.90	379.74	379.72	379.71	379.25	379.75	379.84	379.91
7/9/97	379.95	NA	NA	NA	NA	NA	NA	NA	NA
7/30/97	380.14	NA	NA	NA	NA	NA	NA	NA	NA
8/22/97	379.91	NA	NA	NA	NA	NA	NA	NA	NA
10/2/97	380.31	NA	NA	NA	NA	NA	NA	NA	NA
11/4/97	383.36	371.34	382.04	381.95	381.95	381.45	381.98	382.03	382.15
12/1/97	383.30	NA	NA	NA	NA	NA	NA	NA	NA
1/6/98	383.20	NA	NA	NA	NA	NA	NA	NA	NA
2/11/98	382.60	NA	NA	NA	NA	NA	NA	NA	NA
3/3/98	385.50	NA	NA	NA	NA	NA	NA	NA	NA
3/10/98	390.87	372.36	380.20	380.80	380.67	380.14	380.80	381.38	381.23
3/11/98	392.51	373.71	373.57	381.20	377.06	381.84	381.81	382.36	382.01
3/12/98	391.78	374.30	NA	NA	NA	NA	NA	NA	NA
3/13/98	386.86	NA	NA	NA	NA	NA	NA	NA	NA
3/14/98	385.50	NA	NA	NA	NA	NA	NA	NA	NA
3/15/98	385.04	NA	NA	NA	NA	NA	NA	NA	NA
3/16/98	385.50	NA	NA	NA	NA	NA	NA	NA	NA
3/17/98	384.49	NA	NA	NA	NA	NA	NA	NA	NA
4/1/98	394.93	371.11	381.97	381.95	381.91	381.51	381.98	382.03	382.11
4/2/98	396.82	374.07	382.40	382.34	382.34	381.88	382.41	382.53	382.57
4/3/98	398.17	374.03	382.46	382.44	382.47	381.94	382.47	382.53	382.67
4/4/98	397.65	374.43	382.40	382.44	382.37	381.94	382.44	382.53	382.64
4/5/98	396.48	374.39	382.33	382.38	382.37	381.88	382.41	382.46	382.61
4/6/98	393.79	374.43	382.43	382.38	382.41	381.94	382.47	382.63	382.64
4/7/98	390.49	374.07	382.23	382.25	382.24	381.71	382.27	382.30	382.44
4/8/98	384.12	373.15	382.13	382.21	382.14	381.68	382.18	382.30	382.34
4/9/98	383.67	372.39	382.07	382.05	382.04	381.61	382.14	382.20	382.28
4/10/98	384.19	372.13	382.23	382.18	382.18	381.68	382.24	382.30	382.44
4/11/98	384.01	371.80	382.07	382.05	382.04	381.61	382.11	382.20	382.24
4/12/98	383.33	372.46	382.04	382.05	382.01	381.58	382.08	382.17	382.18
4/29/98	383.57	370.39	381.94	381.95	381.91	381.12	381.95	382.07	382.15
5/27/98	380.09	369.87	379.84	379.82	379.75	379.32	379.85	379.84	379.88
6/15/98	393.79	370.85	380.17	380.15	380.14	379.68	380.21	380.30	380.37
6/16/98	397.90	371.84	380.53	380.51	**383.49**	380.04	380.53	380.66	380.70

Table 4 - Relief Well Readings

Instrumentation Appendix to Periodic Inspection Report No. 6
Hopkinton Lake Dam
Hopkinton, New Hampshire

Date	Pool	Water Surface Elevations (feet, NGVD)							
		RW1	RW2	RW3	RW4	RW5	RW6	RW7	RW8
6/17/98	400.23	373.84	**381.28**	380.57	380.60	380.14	380.63	380.69	380.80
6/18/98	402.93	373.54	380.49	380.44	380.40	379.97	380.47	380.56	380.64
6/19/98	**403.22**	373.77	380.76	380.67	380.70	380.23	380.73	380.79	380.90
6/20/98	402.77	373.87	380.66	380.64	380.50	380.17	380.67	380.72	380.87
6/21/98	402.13	374.10	380.66	380.70	380.40	380.20	380.67	380.79	380.83
6/22/98	401.34	**374.20**	380.66	380.64	380.60	380.10	380.67	380.72	380.80
6/23/98	400.09	373.94	381.02	**381.10**	381.09	**380.63**	**381.16**	**381.18**	**381.29**
6/24/98	399.09	373.97	380.56	380.54	380.53	380.04	380.60	380.62	380.73
6/25/98	396.22	373.80	380.49	380.34	380.37	380.04	380.50	380.56	380.60
6/26/98	394.03	373.71	380.40	380.38	380.34	379.87	380.44	380.46	380.54
6/28/98	390.90	373.28	380.53	380.47	380.47	380.01	380.53	380.59	380.67
6/29/98	388.55	373.18	380.40	380.38	380.37	382.86	380.44	380.49	380.57
6/30/98	352.69	372.52	380.46	380.44	380.40	380.01	380.50	380.53	380.64
7/1/98	382.11	372.00	380.82	380.80	380.83	380.40	380.90	381.02	381.03
7/2/98	383.05	372.52	380.46	380.41	380.37	379.94	380.44	380.49	380.57
7/3/98	382.15	NA	NA	NA	NA	NA	NA	NA	NA
8/3/98	379.81	369.64	379.84	379.78	379.78	379.28	379.85	379.87	379.98
8/26/98	380.28	369.83	380.36	380.28	380.24	379.78	380.31	380.36	380.44
10/1/98	380.12	369.54	380.13	380.15	380.14	379.71	380.17	380.23	380.31
10/30/98	382.05	369.51	381.91	381.82	381.85	381.38	382.24	381.94	382.05
12/2/98	382.62	369.87	381.81	381.79	381.91	381.35	381.91	381.94	382.01
1/5/99	382.10	PI	PI	PI	PI	PI	PI	PI	PI
3/30/99	385.78	373.08	381.71	381.95	382.31	381.68	382.18	382.49	382.11
5/3/99	379.95	369.70	380.00	379.92	379.85	379.45	379.91	380.00	379.98
5/26/99	380.62	369.54	379.84	379.92	379.88	379.38	379.94	379.97	380.05
7/1/99	380.02	373.02	380.17	380.15	380.14	379.71	380.21	380.26	380.34
7/26/99	379.94	369.41	379.84	379.78	379.81	379.32	379.85	379.90	379.98
8/31/99[1)]	380.44	369.15	367.14	367.68	368.10	366.55	367.97	366.94	368.63
9/17/99	389.30	372.33	380.43	380.41	380.40	379.94	380.50	380.53	380.64
9/18/99	389.49	373.02	380.49	380.08	380.44	379.97	380.50	380.53	380.64
9/19/99	388.62	373.34	380.46	380.41	380.40	379.97	380.50	380.56	380.64
9/20/99	381.43	372.89	380.23	380.31	380.17	379.81	380.24	380.39	380.41
9/21/99	381.30	372.20	379.97	379.95	379.94	379.81	380.01	380.07	380.18
9/22/99	382.98	371.77	380.46	380.41	380.40	379.97	380.47	380.56	380.64
9/23/99	381.21	371.57	380.00	379.98	379.98	379.55	379.94	380.13	380.18
9/24/99	381.56	370.62	380.10	380.08	380.08	379.61	380.14	380.23	380.28
10/4/99	382.23	369.80	381.87	381.88	381.85	381.35	381.85	381.94	382.05
10/29/99	382.72	369.77	381.94	381.82	381.81	381.35	381.85	381.90	382.05
11/29/99	384.92	370.65	382.36	382.31	382.31	381.84	382.31	382.43	382.51
12/23/99	383.98	370.33	382.13	PF	PF	PF	PF	PF	PF
1/27/00	381.99	PI	PI	PI	PI	PI	PI	PI	PI
3/2/00	385.85	PI	PI	PI	PI	PI	PI	PI	PI
4/3/00	384.03	372.59	379.58	379.56	379.55	379.12	379.62	379.64	379.82
4/24/00	391.70	373.12	382.17	382.18	382.14	381.68	382.18	382.23	382.34

Table 4 - Relief Well Readings
Instrumentation Appendix to Periodic Inspection Report No. 6
Hopkinton Lake Dam
Hopkinton, New Hampshire

		Water Surface Elevations (feet, NGVD)							
Date	**Pool**	**RW1**	**RW2**	**RW3**	**RW4**	**RW5**	**RW6**	**RW7**	**RW8**
4/25/00	391.75	373.38	382.13	382.18	382.14	381.68	382.21	382.26	382.34
4/26/00	NA	373.97	382.07	382.11	382.08	381.65	382.14	382.20	382.24
4/27/00	382.80	373.44	381.91	381.88	381.91	381.55	381.91	382.00	382.05
4/29/00	381.39	373.02	381.94	381.98	381.98	381.51	382.04	382.10	382.21
4/30/00	381.62	373.05	381.64	381.66	381.62	381.15	381.68	381.71	381.78
5/1/00	380.61	372.75	379.74	379.75	379.71	379.28	379.75	379.87	379.95
6/3/00	380.28	370.03	379.77	379.78	379.68	379.32	379.81	379.87	379.91
7/11/00	379.93	369.87	379.84	379.82	379.78	379.35	379.85	379.90	379.98
7/31/00	381.30	370.03	380.23	380.28	380.24	379.81	380.31	380.33	380.41
8/28/00	382.30	373.41	381.84	381.85	381.81	381.35	381.85	381.94	382.01
10/2/00	382.08	369.67	381.84	381.82	381.81	381.35	381.85	381.94	382.01
11/1/00	382.24	369.64	381.84	381.82	381.81	381.35	381.88	381.94	382.01
12/1/00	383.07	369.80	381.84	381.85	381.81	381.35	381.85	381.87	382.01
7/6/01	379.95	369.87	379.90	379.88	379.85	379.38	379.91	379.97	380.08
7/31/01	379.60	369.64	379.84	379.82	379.81	379.35	379.88	379.93	380.01
9/5/01	379.84	369.44	379.84	379.82	379.81	379.35	379.85	379.90	380.01
10/1/01	379.73	369.21	379.84	379.82	379.81	379.35	347.04	379.93	380.01
10/30/01	381.24	369.28	381.41	381.36	381.36	380.92	381.39	381.48	381.56
12/4/01	381.56	369.37	381.74	381.75	381.72	381.28	381.78	381.84	381.95

Abbreviations
PD = Piezometer Dry
PI = Piezometer Inaccessible
NA = Information not Given
PF=Piezometer Frozen
PU=Personnel Unavailable to take readings

Shaded values indicate questionable data.
High pool readings are shown in **bold.**

1) Forebay dewatering.

Table 5 – Predicted Piezometer and Relief Well Water Elevations for Pool Level at Spillway Crest (El. 416.0)
Instrumentation Appendix to Periodic Inspection Report No. 6
Hopkinton Lake Dam
Hopkinton, New Hampshire

Piezometer Number	Projected Piezometer Elevation For Reservoir at El. 416.0	
	Based on Data from March 1997 through December 2001	Based on Data from January 1992 through October 1997 [1)]
PZ-1	370	369.4
PZ-2	370	369.3
PZ-3A	381.5	379.2
PZ-3B	382	379.7
PZ-4A	376.5	374.7
PZ-4B	375.5	373.3
PZ-5A	374	372.8
PZ-5B	383	382.5
PZ-6A	374.5	373.0
PZ-6B	383.5	382.9
PZ-7A	374	372.9
PZ-7B	383.5	382.9
PZ-8A	373	372.1
PZ-8B	383.5	382.4
PZ-9	2)	369.4
PZ-10	375.5	372.6
PZ-11	2)	370.8
PZ-13A	378	375.3
PZ-13B	NP	NP
PZ-14A	376.5	374.2
PZ-14B	385	382.6
PZ-15	378.5	378.1
RW1	375.5	373.8
RW2	384	382.4
RW3	384	382.6
RW4	383.5	382.6
RW5	383	382.2
RW6	383.5	382.7
RW7	383.5	382.6
RW8	383.5	382.7

NP = Not predicted due to scatter in data.
1) Source: Instrumentation Appendix to Periodic Inspection Report No. 5.
2) PZ-9 & PZ-11 are no longer in service.

Table 6 - East Outlet Retaining Wall Baseline Survey, April 2002
Instrumentation Appendix to Periodic Inspection Report No. 6
Hopkinton Lake Dam
Hopkinton, New Hampshire

STATION (disk #)*	ROD READING	DIRECTION OF MOVEMENT**	ELEVATION (ft-NGVD)
1	0.10	RIGHT	385.384
2	0.14	RIGHT	385.392
3	0.13	RIGHT	385.295
4	0.13	RIGHT	385.292
5	0.11	RIGHT	385.245
6	0.13	RIGHT	385.248
7	0.13	RIGHT	385.136
8	0.12	RIGHT	385.121
9	0.15	RIGHT	385.120
10	0.16	RIGHT	385.149
11	0.17	RIGHT	385.150
12	0.00		385.109
13	0.00		385.104
14	0.01	RIGHT	385.085

See Survey book FC 183 for survey and control point information.

*The disk # corresponds to the tilt plate of the same number.
**EDM was on the north site and set to 00-00 reading on the south site therefore, a right direction is to the west and a left direction is to the east.

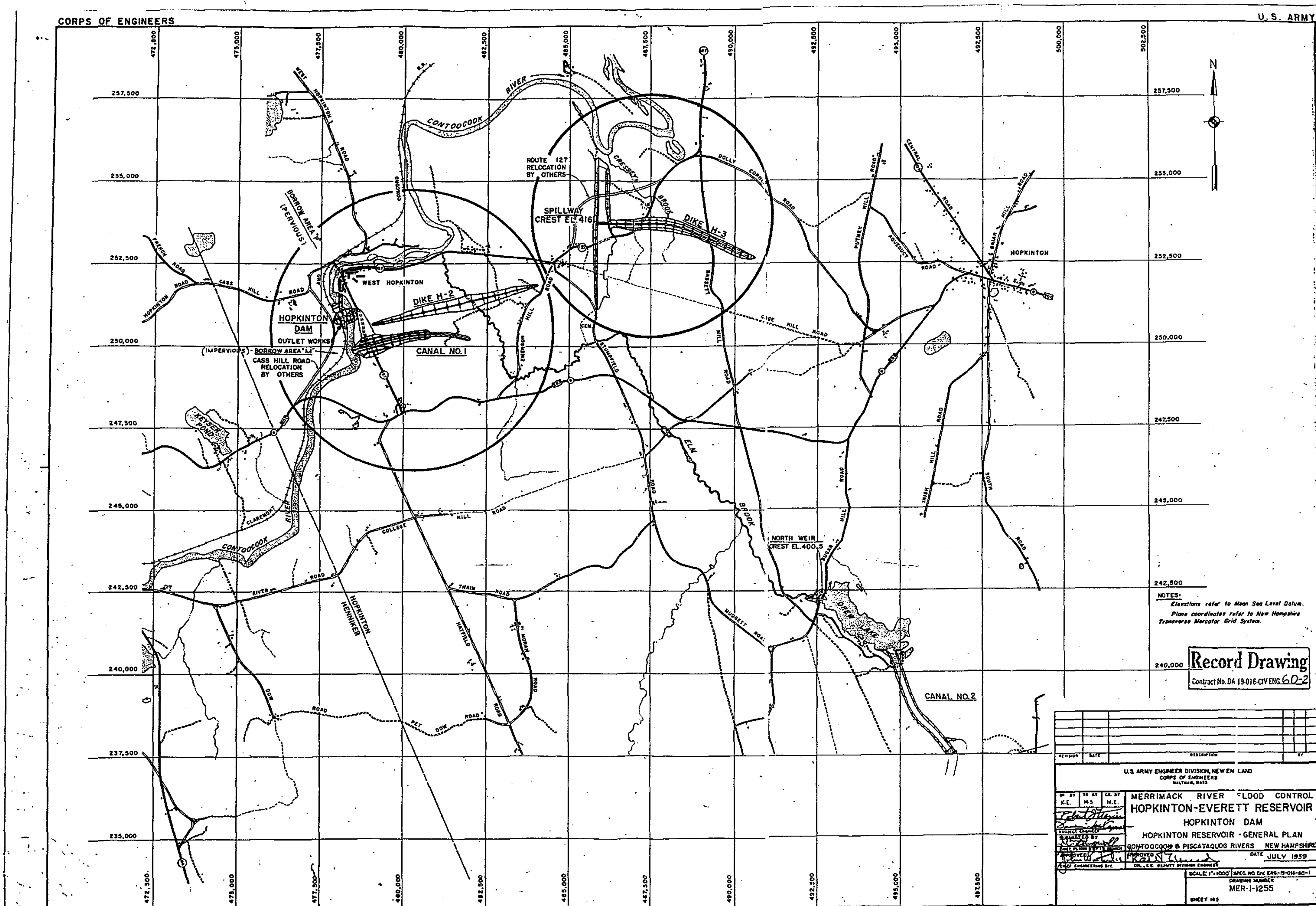
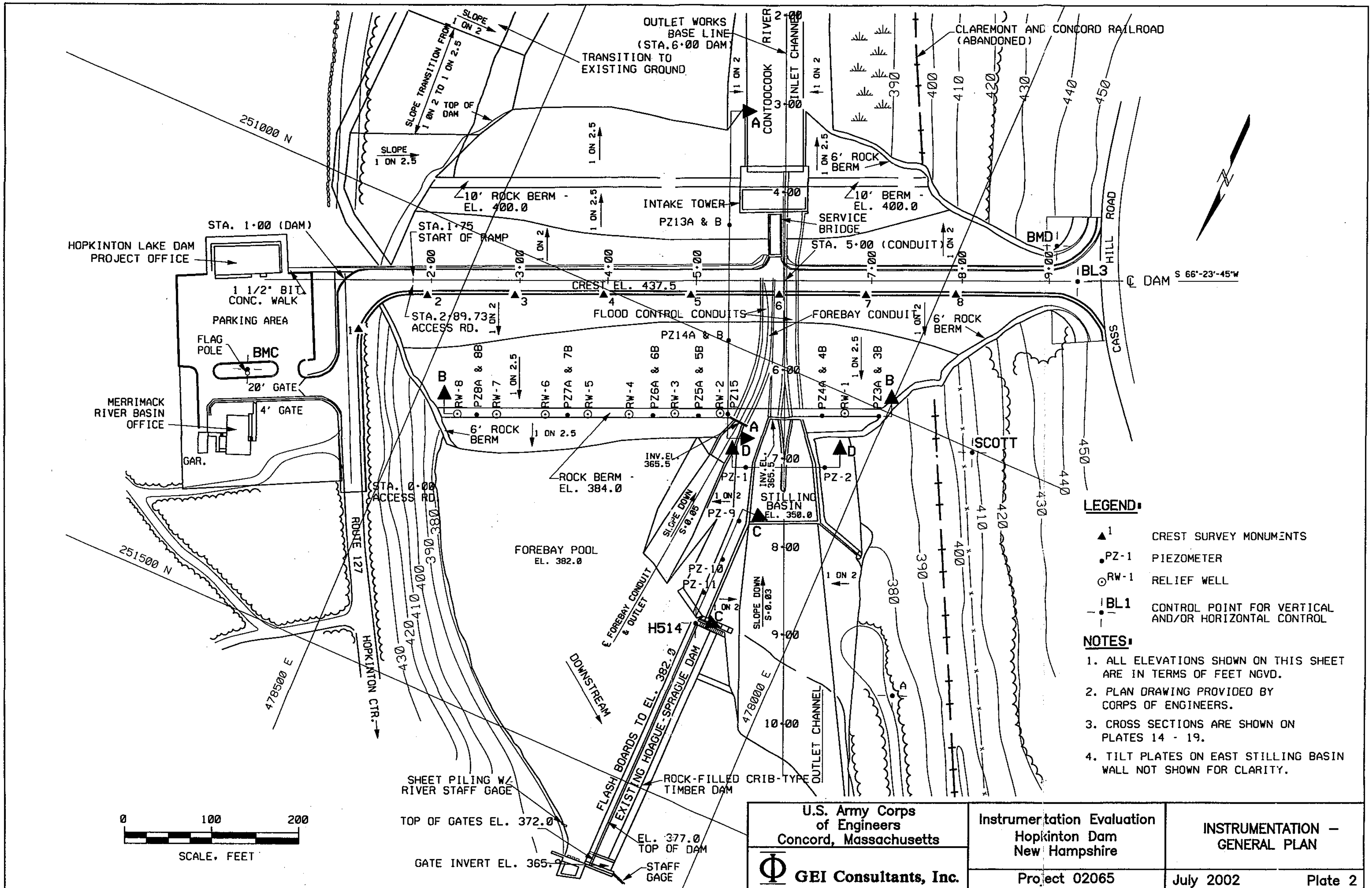

CORPS OF ENGINEERS
U.S. ARMY
N
CONTOOCOOK RIVER
ROUTE 127
RELOCATION
BY OTHERS
SPILLWAY
CREST EL. 416
DIKE H-3
BORROW AREA "P"
(PERVIOUS)
WEST HOPKINTON
DIKE H-2
HOPKINTON
DAM
OUTLET WORKS
(IMPERVIOUS) - BORROW AREA "M"
CANAL NO. 1
CASS HILL ROAD
RELOCATION
BY OTHERS
KEYSER POND
HOPKINTON
NORTH WEIR
CREST EL. 400.5
ELM BROOK
CANAL NO. 2
NOTES:
Elevations refer to Mean Sea Level Datum.
Plane coordinates refer to New Hampshire Transverse Mercator Grid System.
Record Drawing
Contract No. DA 19-016-CIV ENG 60-2
REVISION
DATE
DESCRIPTION
BY
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS
MERRIMACK RIVER FLOOD CONTROL
HOPKINTON-EVERETT RESERVOIR
HOPKINTON DAM
HOPKINTON RESERVOIR - GENERAL PLAN
CONTOOCOOK & PISCATAQUOG RIVERS NEW HAMPSHIRE
DATE JULY 1959
SCALE: 1"=1000'
SPEC. NO. CIV. ENG-19-016-60-1
DRAWING NUMBER
MER-1-1255
SHEET 165

PLATE 1



U.S. Army Corps of Engineers
Concord, Massachusetts

GEI Consultants, Inc.

Instrumentation Evaluation
Hopkinton Dam
New Hampshire

Project 02065

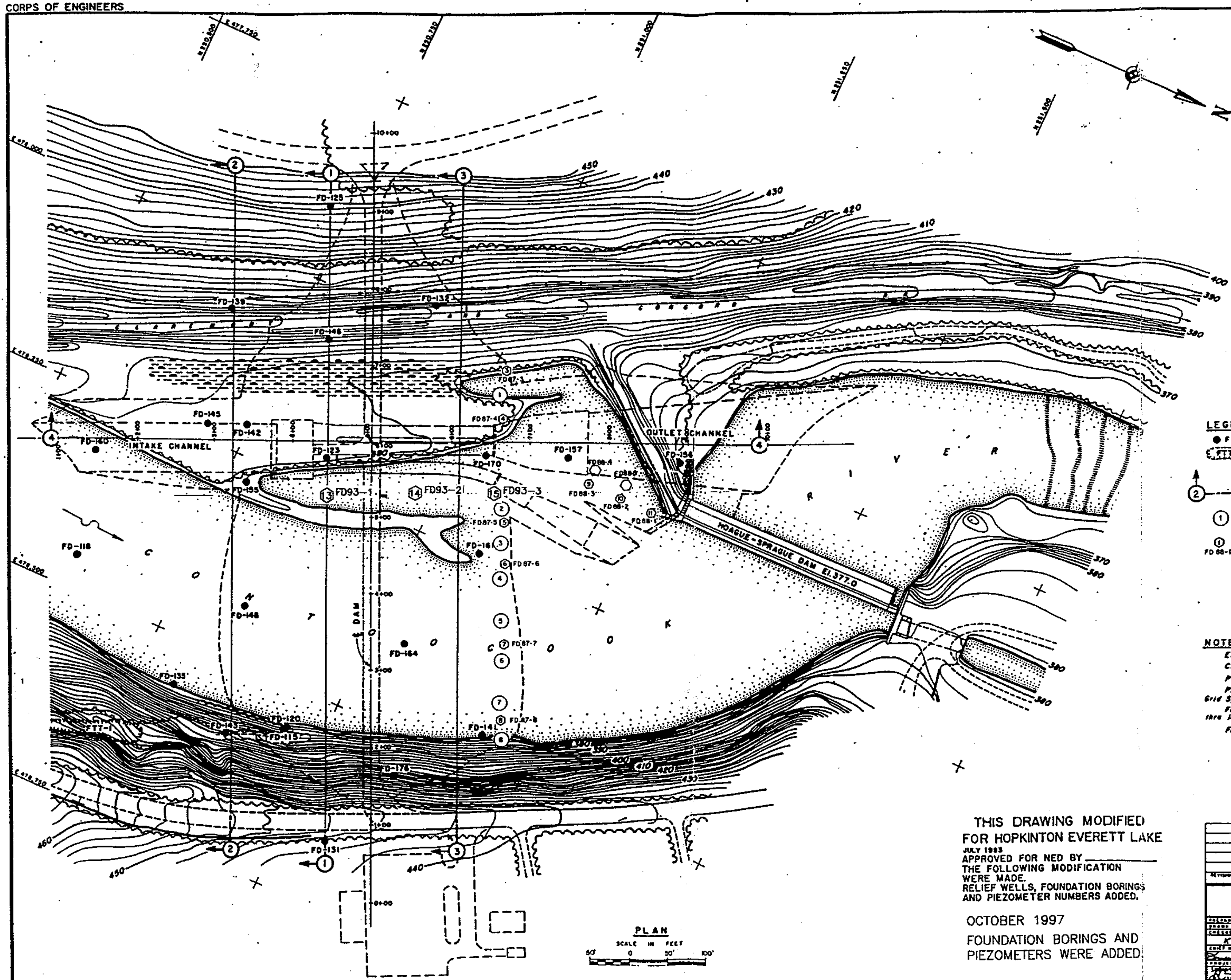
INSTRUMENTATION – GENERAL PLAN

July 2002

Plate 2

...\Plates\hoiapl002.dgn 07/18/02 02:11:17 PM

CORPS OF ENGINEERS — U. S. ARMY



THIS DRAWING MODIFIED FOR HOPKINTON EVERETT LAKE
JULY 1993
APPROVED FOR NED BY ____________
THE FOLLOWING MODIFICATION WERE MADE.
RELIEF WELLS, FOUNDATION BORINGS AND PIEZOMETER NUMBERS ADDED.

OCTOBER 1997
FOUNDATION BORINGS AND PIEZOMETERS WERE ADDED.

LEGEND

● FD	Foundation Test Boring (1957-58)
FTT	Foundation Test Trench (1957-58)
2 — 2	Geologic Section
1	Relief Well Location
1 FD 88-1	Foundation Boring (1988) - Piezometer number

NOTES

Elevations refer to Mean Sea Level Datum.

Contour interval is 2 feet.

Plan prepared from Plane Table Survey, Corps of Engineers, 1958.

Plane coordinates refer to New Hampshire Transverse Mercator Grid System.

For Record of Foundation Explorations, see Sheets No. 179 thru 182.

For Geologic Sections, see Sheets No. 173 and 174.

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS

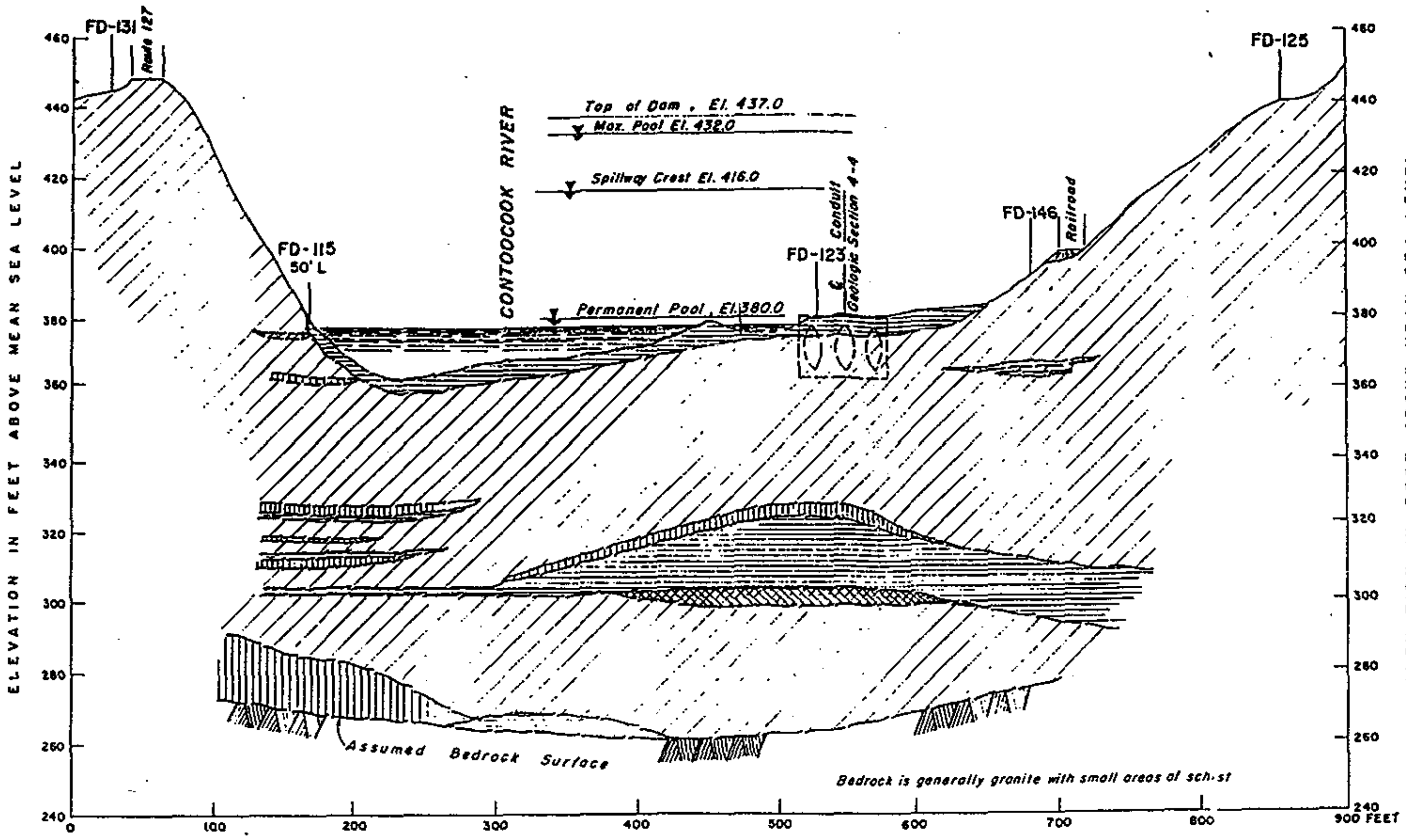
MERRIMACK RIVER FLOOD CONTROL
HOPKINTON-EVERETT RESERVOIR
HOPKINTON DAM
PLAN OF FOUNDATION EXPLORATIONS
CONTOOCOOK AND PISCATAQUOG RIVERS N H

DATE JULY 1959

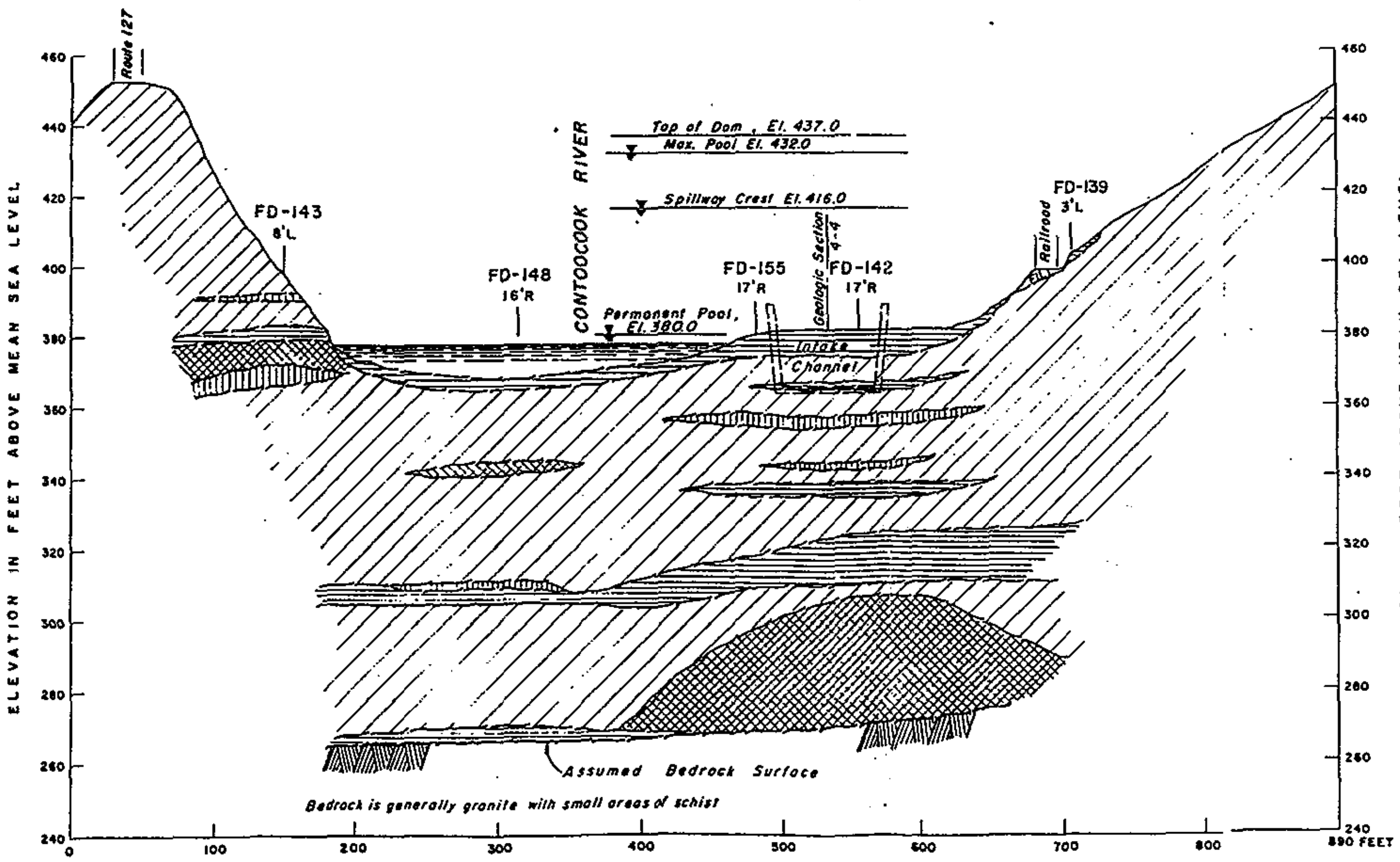
SCALE AS SHOWN

DRAWING NUMBER MER-2-1030

PLATE 3



GEOLOGIC SECTION 1-1, 55' UPSTREAM FROM ¢ DAM
(LOOKING UPSTREAM)



GEOLOGIC SECTION 2-2, 175' UPSTREAM FROM ¢ DAM
(LOOKING UPSTREAM)

LEGEND

- *TILL, a hetrogeneous mixture of variable gravelly, silty to clayey SAND with cobbles and boulders.*
- *Variable gravelly, silty and clayey SAND (TILL) with numerous thin laminae of sand, silt and clay.*
- *Laminated SILT and CLAY*
- *Variable SAND and GRAVEL, ranging from silty SAND to sandy GRAVEL*

Record Drawing
Contract No. DA-19-016-CIV ENG 60-1

NOTES

For Record of Foundation Explorations, see Sheets No. 179 thru 190.

For Location of Geologic Sections, see Sheet No. 168.

This drawing is presented for general information and is to be considered only as a supplement to the records of exploration in other contract drawings. Geologic sections shown hereon are the Government interpretation of subsurface conditions believed to exist at and between borings. Variations between elevations, composition and structure of the individual formations as represented hereon and as actually encountered in the progress of the work are to be anticipated.

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

PREPARED BY H A V
DRAWN BY W R
CHECKED BY R C G
CHIEF N.E.D. LABORATORIES
PROJECT ENGINEER
SUBMITTED BY
CHIEF, PLANNING DEPT'S BRANCH
APPROVED:
CHIEF ENGINEERING DIV.

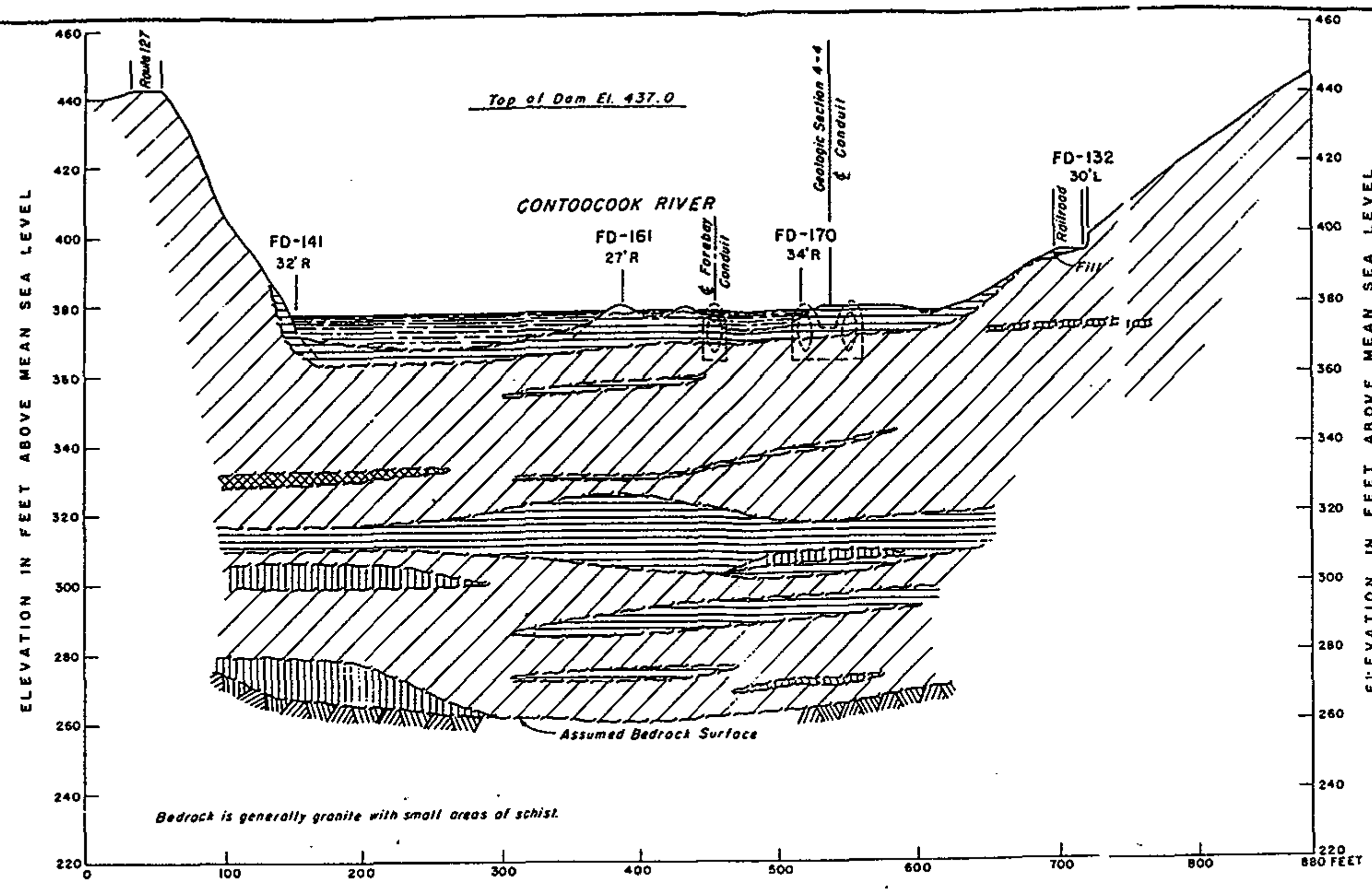
MERRIMACK RIVER FLOOD CONTROL
HOPKINTON-EVERETT RESERVOIR
HOPKINTON DAM
GEOLOGIC SECTIONS 1-1 AND 2-2
CONTOOCOOK AND PISCATAQUOG RIVERS N.H.

APPROVED:
COL., C.E. DEPUTY DIVISION ENGINEER
DATE JUNE 1959

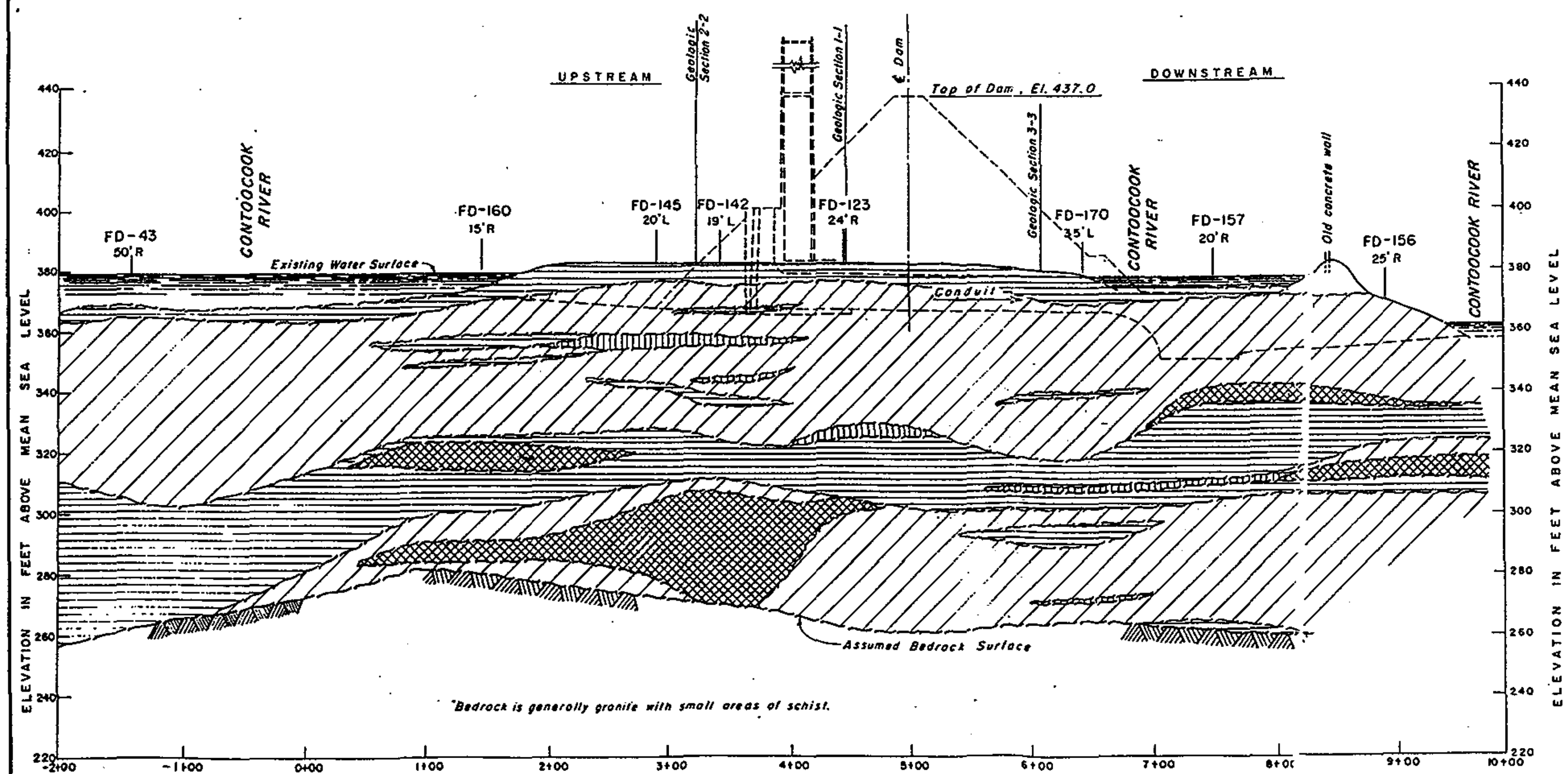
SCALE AS SHOWN
SPEC NO CIV ENG-19-016-60-1
DRAWING NUMBER
MER-2-1036
SHEET 173

PLATE 4A

CORPS OF ENGINEERS



GEOLOGIC SECTION 3-3, 110' DOWNSTREAM FROM ℄ DAM
(LOOKING UPSTREAM)



GEOLOGIC SECTION 4-4, ALONG ℄ OF CONDUIT
(LOOKING WEST)

LEGEND

- TILL, a hetrogeneous mixture of variable gravelly, silty to clayey SAND with cobbles and boulders.
- Variable gravelly, silty and clayey SAND (TILL) with numerous thin laminae of sand, silt and clay.
- Laminated SILT and CLAY
- Variable SAND and GRAVEL, ranging from silty SAND to sandy GRAVEL

Record Drawing
Contract No. DA-19-016-CIV-ENG-60-2

NOTES

For Record of Foundation Explorations, see Sheets No. 179 thru 190.

For Location of Geologic Sections, see Sheet No. 168.

This drawing is presented for general information and is to be considered only as a supplement to the records of exploration in other contract drawings. Geologic sections shown hereon are the Government interpretation of subsurface conditions believed to exist at and between borings. Variations between elevations, composition and structure of the individual formations as represented hereon and as actually encountered in the progress of the work are to be anticipated.

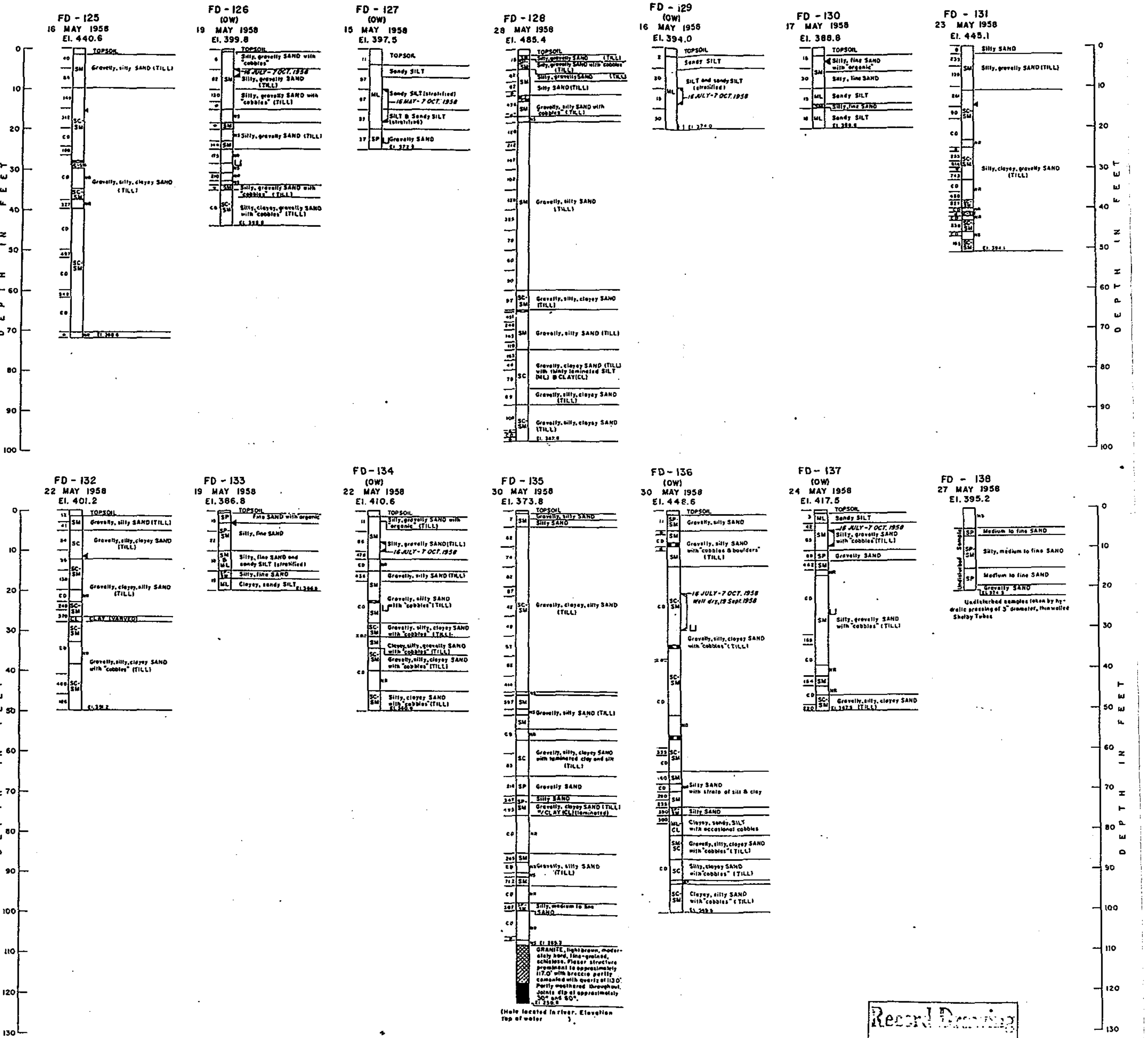
REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

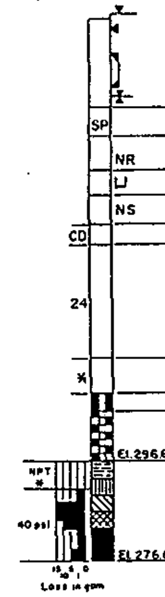
MERRIMACK RIVER FLOOD CONTROL
HOPKINTON-EVERETT RESERVOIR
HOPKINTON DAM
GEOLOGIC SECTIONS 3-3 AND 4-4
CONTOOCOOK AND PISCATAQUOG RIVERS N.H.

Prepared by H.A.V.
Drawn by W.K.
Checked by R.C.G.
Chief N.E.D. Laboratories
Project Engineer
Submitted by
Chief, Plans & Spec's Branch
Approved:
Chief Engineering Div.
Approved:
Col., C.E. Deputy Division Engineer
DATE JUNE 1959
SCALE AS SHOWN | SPEC.NO CIV.ENG. 19-016-60-1
DRAWING NUMBER MER-2-1037
SHEET 174

PLATE 4B



LEGEND FOR GRAPHIC LOGS



- FD - 135 — Foundation Test Boring (1957-58)
- (OW) — Observation well installed.
- 30 MAY 1958 — Date exploration completed.
- El. 373.8 — Elevation of ground surface during time of exploration.
- Maximum artesian head.
- Subsurface water level in boring at time of exploration.
- Range of subsurface water during period of observation.
- Artesian flow encountered.
- SP — Group letter symbol according to Unified Soil Classification System.
- NR — No Recovery or unsatisfactory soil samples recovered.
- Bottom of observation well.
- NS — Not Sampled. Hole advanced by Core-drilling, blasting and/or wash boring due to operational difficulty.
- CD — Sampling in overburden by the Core-drill Method.
- 24 — Blows per foot of penetration considered most representative, usually within a 5-foot drive, using a 300 or 350 pound hammer with a free fall of about 18 inches on a 2½" I.D. or 3" O.D. and/or 2" I.D. or 2½" O.D. size sample spoon equipped with a beveled and sharpened drive shoe.
- * — Blow count not recorded or not considered representative.
- Cobble or boulder (Core-drilled).
- Cobbles or boulders, continuous or nested. (Core-drilled and/or blasted and chopped).
- El. 296.6 Elevation of bedrock surface.
- Rock core recovery 0 - 25%
- Rock core recovery 25 - 50%
- Rock core recovery 50 - 75%
- Rock core recovery 75 - 90%
- Rock core recovery 90 - 100%
- El. 276.6 Elevation of bottom of exploration.

NPT — No Pressure Test Performed. Asterisk denotes that section could not be sealed for testing.

40 psi — Constantly maintained pressure for 1 to 5 minutes. Volume loss in gallons per minute under constant pressure, tested continuously in 5 foot sections. Scale expanded from 0 gpm to 1 gpm for clarification of low pressure losses.

Water levels recorded during subsurface explorations seldom correspond with the natural level of free ground water, except in extensive and thick deposits of sands and gravels which are sufficiently pervious to permit rapid stabilization of water levels in the exploratory hole. Absence of subsurface water level in the graphic log of any exploration is not necessarily to be construed that ground water will not be encountered in excavation at that location.

While the borings are representative of subsurface conditions at their respective locations and for their respective vertical reaches, local minor variations characteristic of the overburden and rocks of this region are anticipated, and if encountered, such variations will not be considered as differing "materially" from represented conditions within the purview of Article 4 of the Contract.

NOTE

Elevations refer to Mean Sea Level Datum.

INDEX FOR LOCATION OF FOUNDATION EXPLORATIONS

Hopkinton Dam - FD-125, FD-131, FD-132 and FD-135, see Sheet No. 168.

Canal No. 1 - FD-126, FD-127, FD-128, FD-129, FD-130, FD-133, FD-134, FD-136 and FD-137, see Sheet No. 169.

Spillway - FD-138, see Sheet No. 171.

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

MERRIMACK RIVER FLOOD CONTROL
HOPKINTON-EVERETT RESERVOIR
HOPKINTON DAM
RECORD OF FOUNDATION EXPLORATIONS
NO. 7
CONTOOCOOK AND PISCATAQUOG RIVERS N.H.

PREPARED BY — DRAWN BY — CHECKED BY — CHIEF S.&.D. LABORATORIES — PROJECT ENGINEER — SUBMITTED BY — CHIEF, PLAN. & DES'N BRANCH — APPROVED: CHIEF ENGINEERING DIV. — APPROVED: COL., C.E. DEPUTY DIVISION ENGINEER

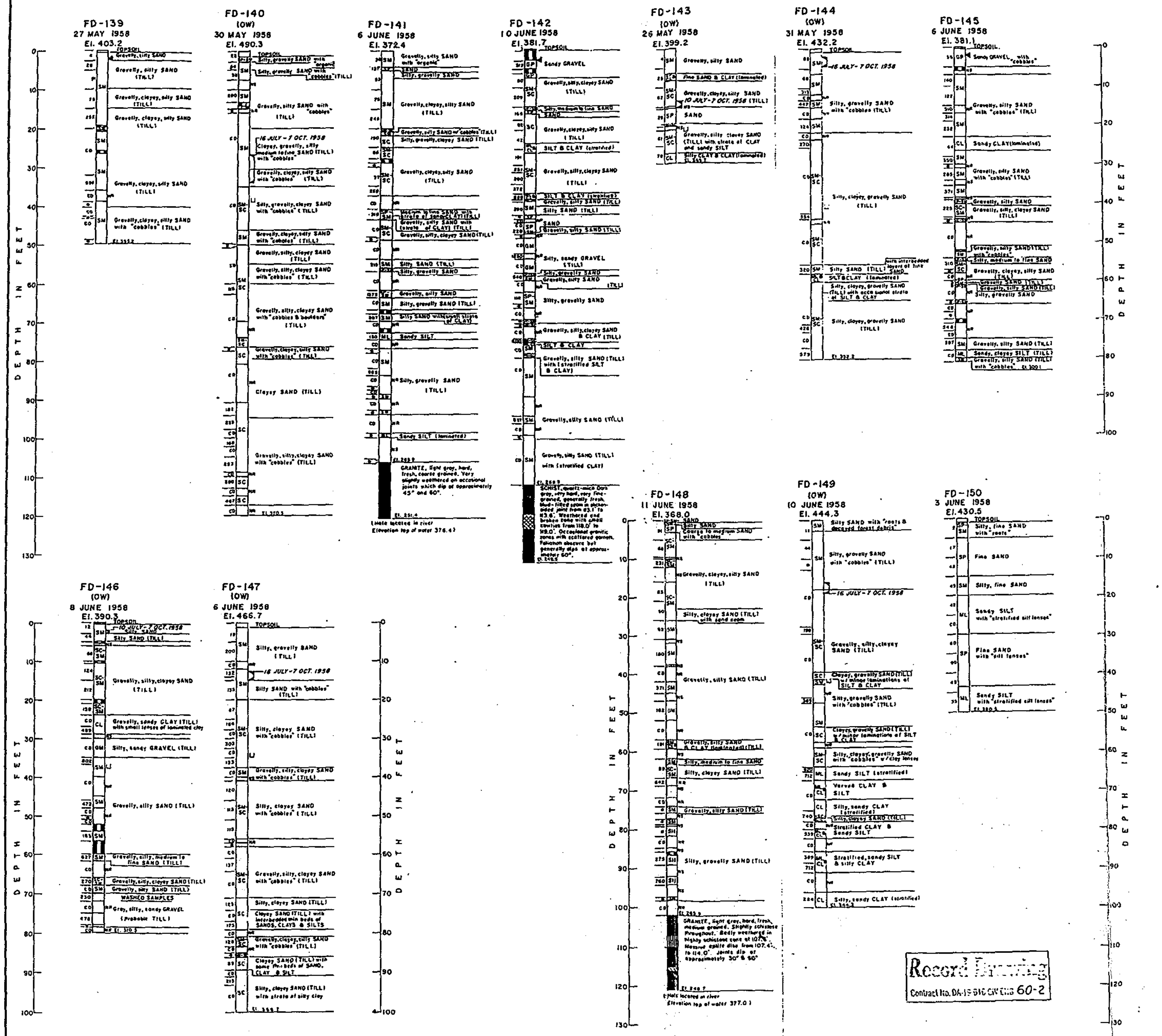
DATE JULY 1959

SCALE AS SHOWN | SPEC. NO. CIV. ENG - 19-016-60-1

DRAWING NUMBER MER-2-1048

SHEET 185

Record Drawing
Contract No DA-19-016-CIVENG-60-2



LEGEND FOR GRAPHIC LOGS

FD-140	Foundation Test Boring (1957-1958)
(OW)	Observation well installed.
30 MAY 1958	Date exploration completed.
El. 490.3	Elevation of ground surface during time of exploration.
	Maximum artesian head.
	Subsurface water level boring at time of exploration.
	Range of subsurface water during period of observation.
	Artesian flow encountered.
SP	Group letter symbol according to Unified Soil Classification System.
NR	No Recovery or unsatisfactory soil samples recovered.
	Bottom of observation well.
NS	Not Sampled. Hole advanced by Core-drilling, blasting and/or wash boring due to operational difficulty.
CD	Sampling in overburden by the Core-drill Method.
24	Blows per foot of penetration considered most representative usually within a 5-foot drive using a 300 or 350 pound hammer with a free fall of about 18 inches on a 2½" I.D. or 3" O.D. and/or 2" I.D. or 2½" O.D. sample spoon equipped with a beveled and sharpened drive shoe.
*	Blow count not recorded or not considered representative.
	Cobble or boulder, Core-drilled.)
	Cobbles or boulders, continuous or nested (Core-drilled and/or blasted and chopped.)
El. 370.2	Elevation of bedrock surface.
	Rock core recovery 0 - 25%
	Rock core recovery 25 - 50%
	Rock core recovery 50 - 75%
	Rock core recovery 75 - 90%
	Rock core recovery 90 - 100%
El. 276.6	Elevation of bottom of exploration.
NPT *	No Pressure Test Performed. Asterisk denotes that section could not be sealed for testing.
40 psi	Constantly maintained pressure for 1 to 5 minutes.
Loss in gpm	Volume loss in gallons per minute under constant pressure, tested continuously in 5 foot sections. Scale expanded from 0 gpm to 1 gpm for clarification of low pressure losses.

Water levels recorded during subsurface explorations seldom correspond with the natural level of free ground water, except in extensive and thick deposits of sands and gravels which are sufficiently pervious to permit rapid stabilization of water levels in the exploratory hole. Absence of subsurface water level in the graphic log of any exploration is not necessarily to be construed that ground water will not be encountered in excavation at that location.

While the borings are representative of subsurface conditions at their respective locations and for their respective vertical reaches, local minor variations characteristic of the overburden and rocks of this region are anticipated, and if encountered, such variations will not be considered as differing "materially" from represented conditions within the purview of Article 4 of the Contract.

NOTES

Elevations refer to Mean Sea Level Datum.

INDEX FOR LOCATION OF FOUNDATION EXPLORATIONS

Hopkinton Dam, FD-139, FD-141, FD-142, FD-143, FD-145, FD-146 and FD-148, see Sheet No. 168.

Canal No. 1, FD-140, FD-144, FD-147 and FD-149, see Sheet No. 169

Dike H-2, FD-150, see Sheet No. 170.

REVISION	DATE	DESCRIPTION	BY

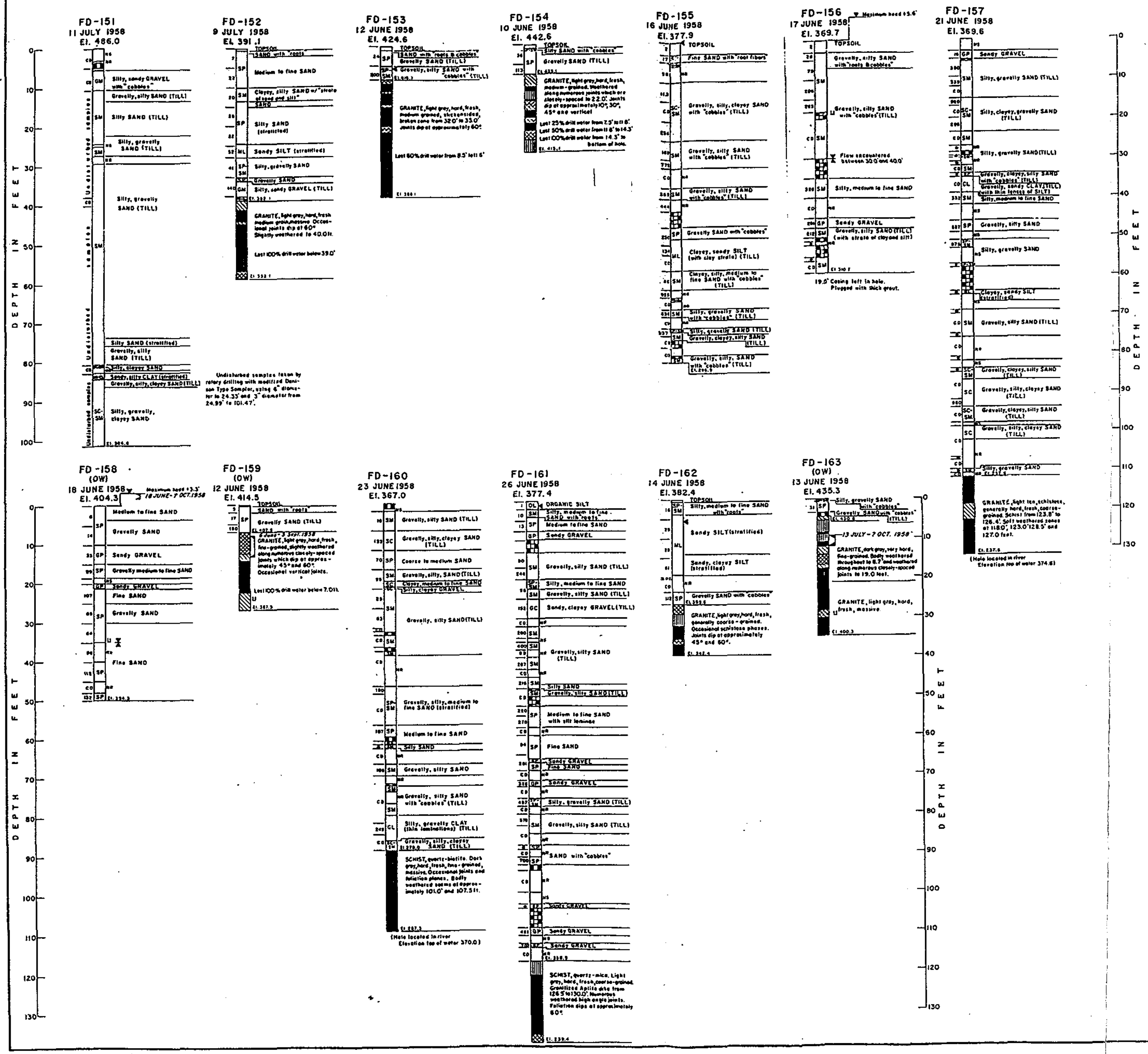
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

MERRIMACK RIVER FLOOD CONTROL
HOPKINTON-EVERETT RESERVOIR
HOPKINTON DAM
RECORD OF FOUNDATION EXPLORATIONS
NO. 8
CONTOOCOOK AND PISCATAQUOG RIVERS N.H.

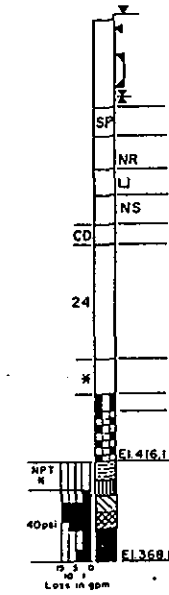
PREPARED BY H. A. V.
DRAWN BY H. C. S.
CHECKED BY R. C. G.
CHIEF N.E.D. LABORATORIES
PROJECT ENGINEER
SUBMITTED BY
CHIEF, PLAN. & EXPT'S BRANCH
APPROVED
CHIEF ENGINEERING DIV.
APPROVED
COL., C.E. DEPUTY DIVISION ENGINEER
DATE JULY 1959

SCALE AS SHOWN SPEC. NO. CIV ENG.-19-016-60-1
DRAWING NUMBER
MER-2-1049
SHEET 186

Record Drawing
Contract No. DA-19-016 CIV ENG 60-2



LEGEND FOR GRAPHIC LOGS



FD-153 — Foundation Test Boring (1957-58)
(OW) — Observation well installed.
12 JUNE 1958 — Date exploration completed.
EL 424.6 — Elevation of ground surface during time of exploration.

- Maximum artesian head.
- Subsurface water level in boring at time of exploration.
- Range of subsurface water during period of observation.
- Artesian flow encountered.
- Group letter symbol according to Unified Soil Classification System.
- No Recovery or unsatisfactory soil samples recovered.
- Bottom of observation well.
- Not Sampled. Hole advanced by Core-drilling, blasting and/or wash boring due to operational difficulty.
- Sampling in overburden by the Core-drill Method.
- Blows per foot of penetration considered most representative usually within a 5-foot drive using a 300 or 350 pound hammer with a free fall of about 18 inches on a 2½" I.D. or 3" O.D. and/or 2" I.D. or 2½" O.D. sample spoon equipped with a beveled and sharpened drive shoe.
- Blow count not recorded or not considered representative.
- Cobble or boulder (Core-drilled.)
- Cobbles or boulders, continuous or nested (Core-drilled and/or blasted and chopped.)
- Elevation of bedrock surface.
- Rock core recovery 0 - 25 %
- Rock core recovery 25 - 50 %
- Rock core recovery 50 - 75 %
- Rock core recovery 75 - 90 %
- Rock core recovery 90 - 100 %
- Elevation of bottom of exploration.

NPT * — No Pressure Test Performed. Asterisk denotes that section could not be sealed for testing.

40 psi — Constantly maintained pressure for 1 to 5 minutes.

Volume loss in gallons per minute under constant pressure, tested continuously in 5 foot sections. Scale expanded from 0 gpm to 1 gpm for clarification of low pressure losses.

Water levels recorded during subsurface explorations seldom correspond with the natural level of free ground water, except in extensive and thick deposits of sands and gravels which are sufficiently pervious to permit rapid stabilization of water levels in the exploratory hole. Absence of subsurface water level in the graphic log of any exploration is not necessarily to be construed that ground water will not be encountered in excavation at that location.

While the borings are representative of subsurface conditions of their respective locations and for their respective vertical reaches, local minor variations characteristic of the overburden and rocks of this region are anticipated, and if encountered, such variations will not be considered as differing "materially" from represented conditions within the purview of Article 4 of the Contract.

NOTES

Elevations refer to Mean Sea Level Datum.

INDEX FOR LOCATION OF FOUNDATION EXPLORATIONS

Hopkinton Dam - FD-155, FD-156, FD-157, FD-160 and FD-161, see Sheet No. 168
Canal No. 1 - FD-151, see Sheet No. 169
Dike H-3 - FD-158 and FD-162, see Sheet No. 172
Spillway - FD-152, FD-153, FD-154, FD-159 and FD-163, see Sheet No. 171

Contract No. DA 19-016-[illegible]-60-2

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

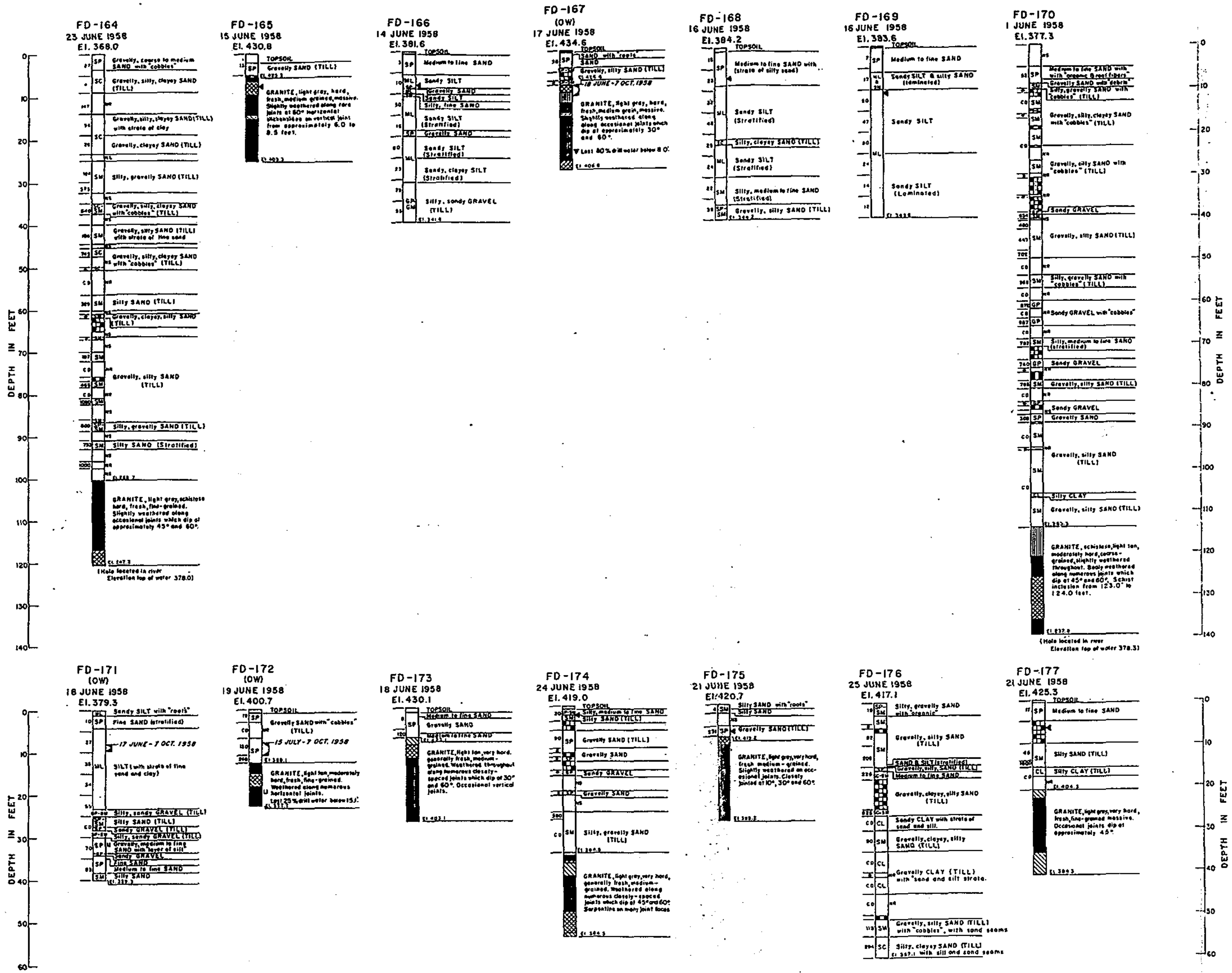
PREPARED BY H. A. Y.
DRAWN BY R. C. S.
CHECKED BY R. C. S.
CHIEF N E D LABORATORIES
PROJECT ENGINEER
SUBMITTED BY
CHIEF, PLANS & SPEC BRANCH
APPROVED
CHIEF ENGINEERING DIV.

MERRIMACK RIVER FLOOD CONTROL
HOPKINTON-EVERETT RESERVOIR
HOPKINTON DAM
RECORD OF FOUNDATION EXPLORATIONS
NO. 9
CONTOOCOOK AND PISCATAQUOG RIVERS N.H.

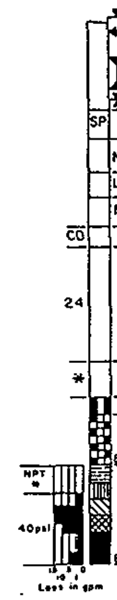
APPROVED
COL., C.E. DEPUTY DIVISION ENGINEER
DATE JULY 1959

SCALE AS SHOWN | SPEC. NO. CIVENG-19-016-60-1
DRAWING NUMBER
MER-2-1050
SHEET 187

PLATE 5C



LEGEND FOR GRAPHIC LOGS



FD-170 — Foundation Test Boring (1957-58)
(OW) — Observation well installed.
1 JUNE 1958 — Date exploration completed.
El. 377.3 — Elevation of ground surface during time of exploration.

Maximum artesian head.
Subsurface water level boring at time of exploration.
Range of subsurface water during period of observation.
Artesian flow encountered.
SP — Group letter symbol according to Unified Soil Classification System.
NR — No Recovery or unsatisfactory soil samples recovered.
U — Bottom of observation well.
NS — Not Sampled. Hole advanced by Core-drilling, blasting and/or wash boring due to operational difficulty.
CO — Sampling in overburden by the Core-drill Method.
24 — Blows per foot of penetration considered most representative usually within a 5-foot drive using a 300 or 350 pound hammer with a free fall of about 18 inches on a 2½" I.D. or 3" O.D. and/or 2" I.D. or 2½" O.D. sample spoon equipped with a beveled and sharpened drive shoe.
* — Blow count not recorded or not considered representative.
Cobble or boulder (Core-drilled.)
Cobbles or boulders, continuous or nested (Core-drilled and/or blasted and chopped.)
El. 370.2 — Elevation of bedrock surface.
Rock core recovery 0 - 25 %
Rock core recovery 25 - 50 %
Rock core recovery 50 - 75 %
Rock core recovery 75 - 90 %
Rock core recovery 90 - 100 %
El. 276.6 — Elevation of bottom of exploration.

NPT * — No Pressure Test Performed. Asterisk denotes that section could not be sealed for testing.
40 psi — Constantly maintained pressure for 1 to 5 minutes.
Volume loss in gallons per minute under constant pressure, tested continuously in 5 foot sections. Scale expanded from 0 gpm to 1 gpm for clarification of low pressure losses.

Water levels recorded during subsurface explorations seldom correspond with the natural level of free ground water, except in extensive and thick deposits of sands and gravels which are sufficiently pervious to permit rapid stabilization of water levels in the exploratory hole. Absence of subsurface water level in the graphic log of any exploration is not necessarily to be construed that ground water will not be encountered in excavation at that location.

While the borings are representative of subsurface conditions at their respective locations and for their respective vertical reaches, local minor variations characteristic of the overburden and rocks of this region are anticipated, and if encountered, such variations will not be considered as differing "materially" from represented conditions within the purview of Article 4 of the Contract.

NOTES

Elevations refer to Mean Sea Level Datum.

INDEX FOR LOCATION OF FOUNDATION EXPLORATIONS

Hopkinton Dam – FD-164, FD-170, and FD-176, see Sheet No. 168
Dike H-3 – FD-165, FD-166, FD-168, FD-169, FD-171 and FD-172, see Sheet No. 172
Spillway – FD-167, FD-173, FD-174, FD-175 and FD-177, see Sheet No. 171

REVISION	DATE	DESCRIPTION	BY

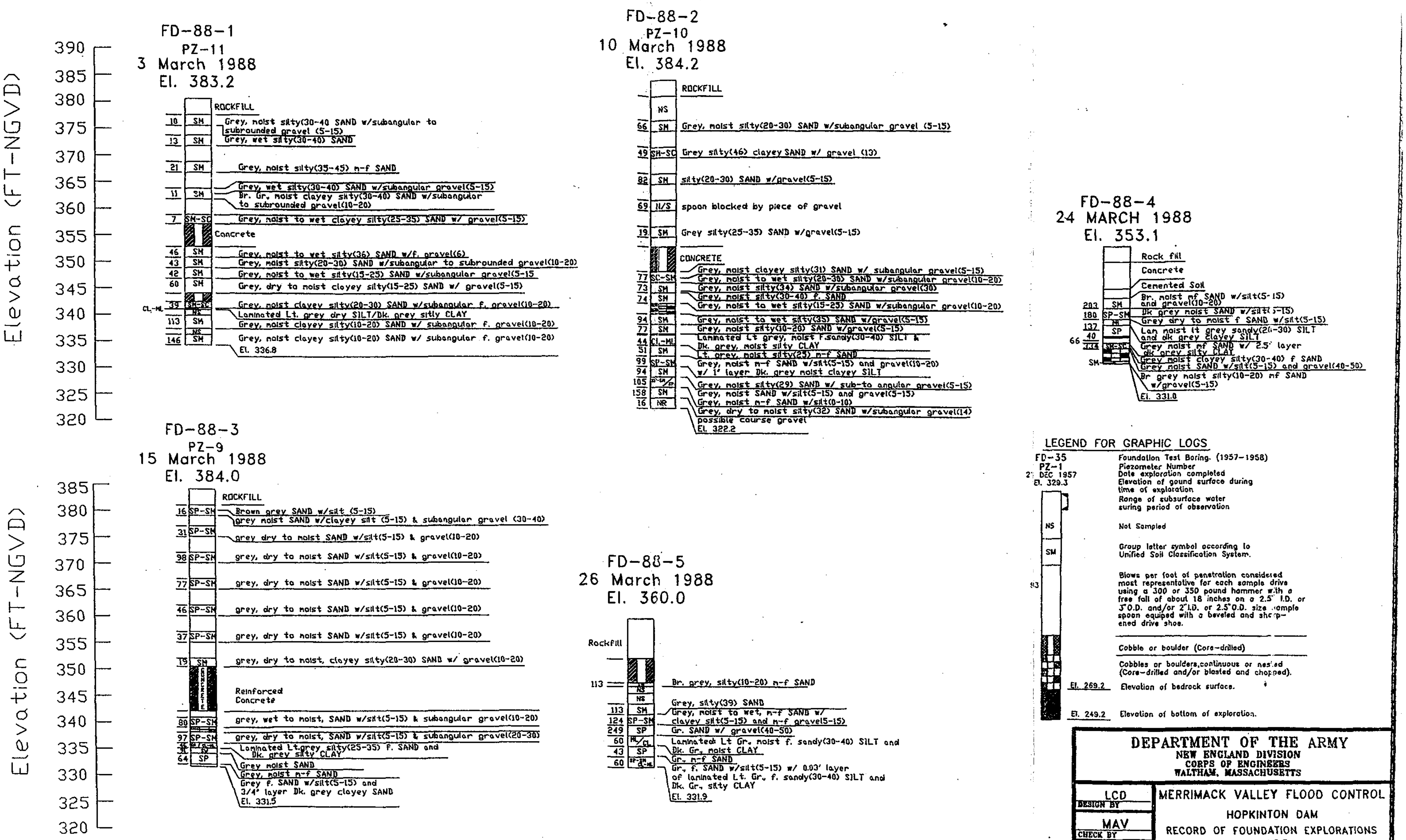
Record Drawing
Contract No. [illegible]60-2

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

MERRIMACK RIVER FLOOD CONTROL
HOPKINTON-EVERETT RESERVOIR
HOPKINTON DAM
RECORD OF FOUNDATION EXPLORATIONS
NO. 10
CONTOOCOOK AND PISCATAQUOG RIVERS N.H.

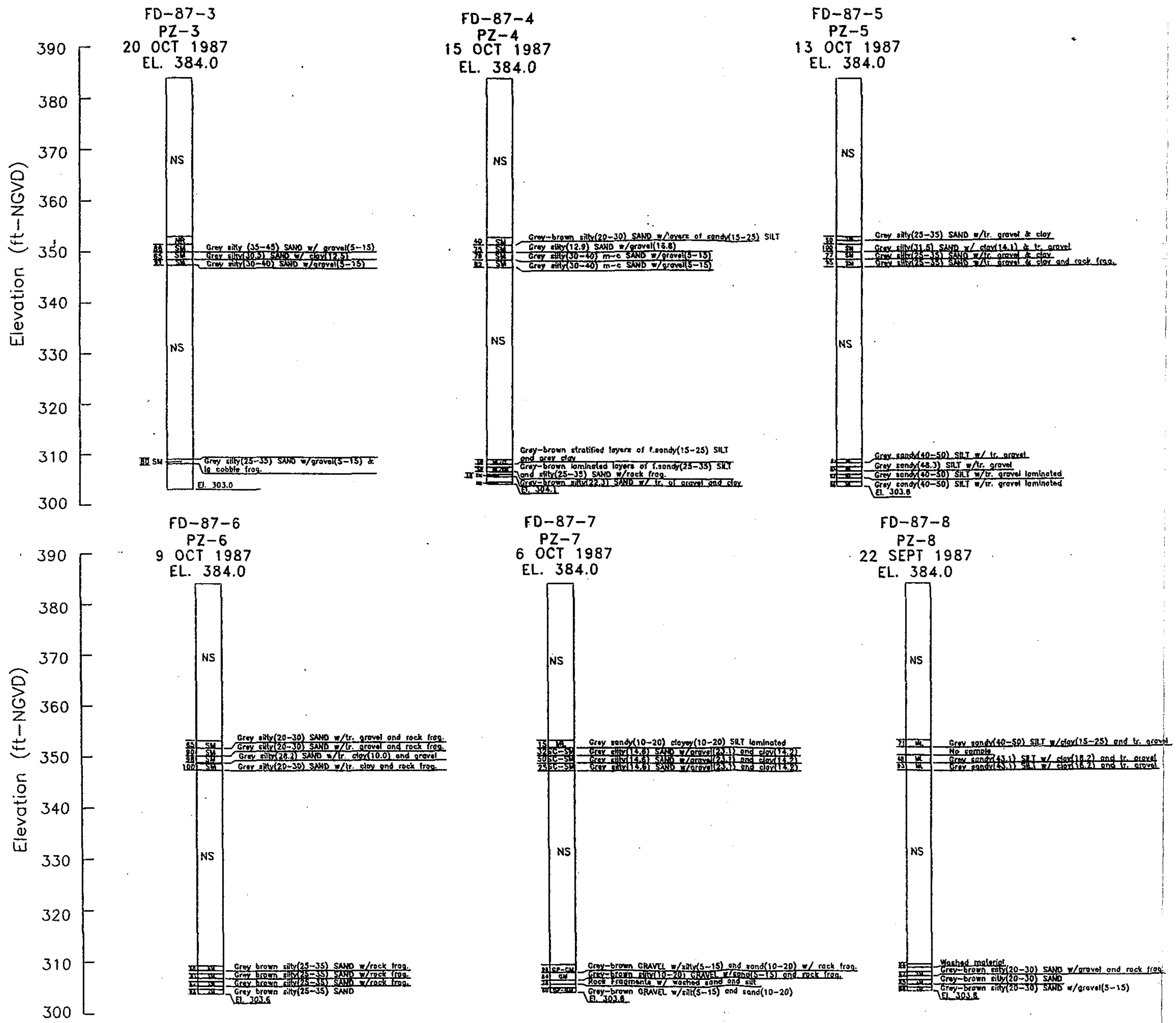
PREPARED BY H.A.V.
DRAWN BY R.A.W.
CHECKED BY R.C.S.
CHIEF N.E.D. LABORATORIES
PROJECT ENGINEER
SUBMITTED BY
CHIEF, PLANNING & EST. BRANCH
APPROVED
CHIEF ENGINEERING DIV.
APPROVED
COL., C.E. DEPUTY DIVISION ENGINEER
DATE JULY 1959

SCALE AS SHOWN SPEC.NO.CIV.ENG.-19-016-60-1
DRAWING NUMBER
M ER-2-1051
SHEET 188

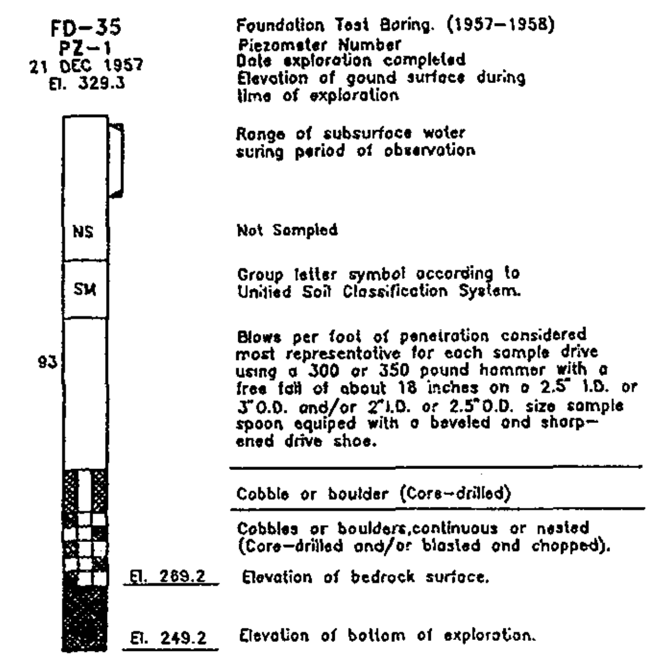


DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASSACHUSETTS

LCD DESIGN BY	MERRIMACK VALLEY FLOOD CONTROL
MAV CHECK BY	HOPKINTON DAM
LCD DRAWN BY	RECORD OF FOUNDATION EXPLORATIONS 1988
GEOTECH. ENG. DIV.	SCALE: AS SHOWN
PLATE NO. 6	DATE: JULY 1993

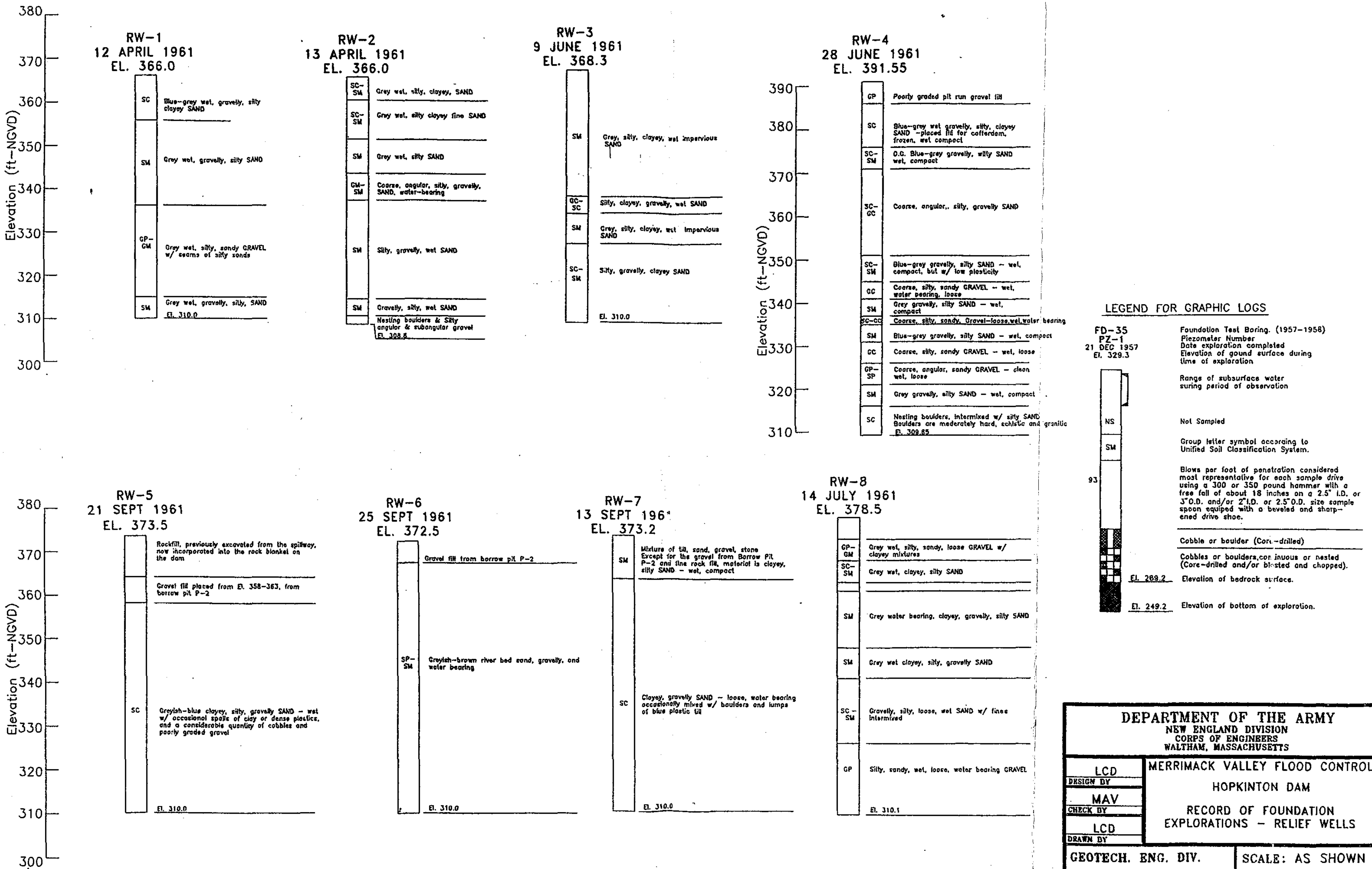


LEGEND FOR GRAPHIC LOGS



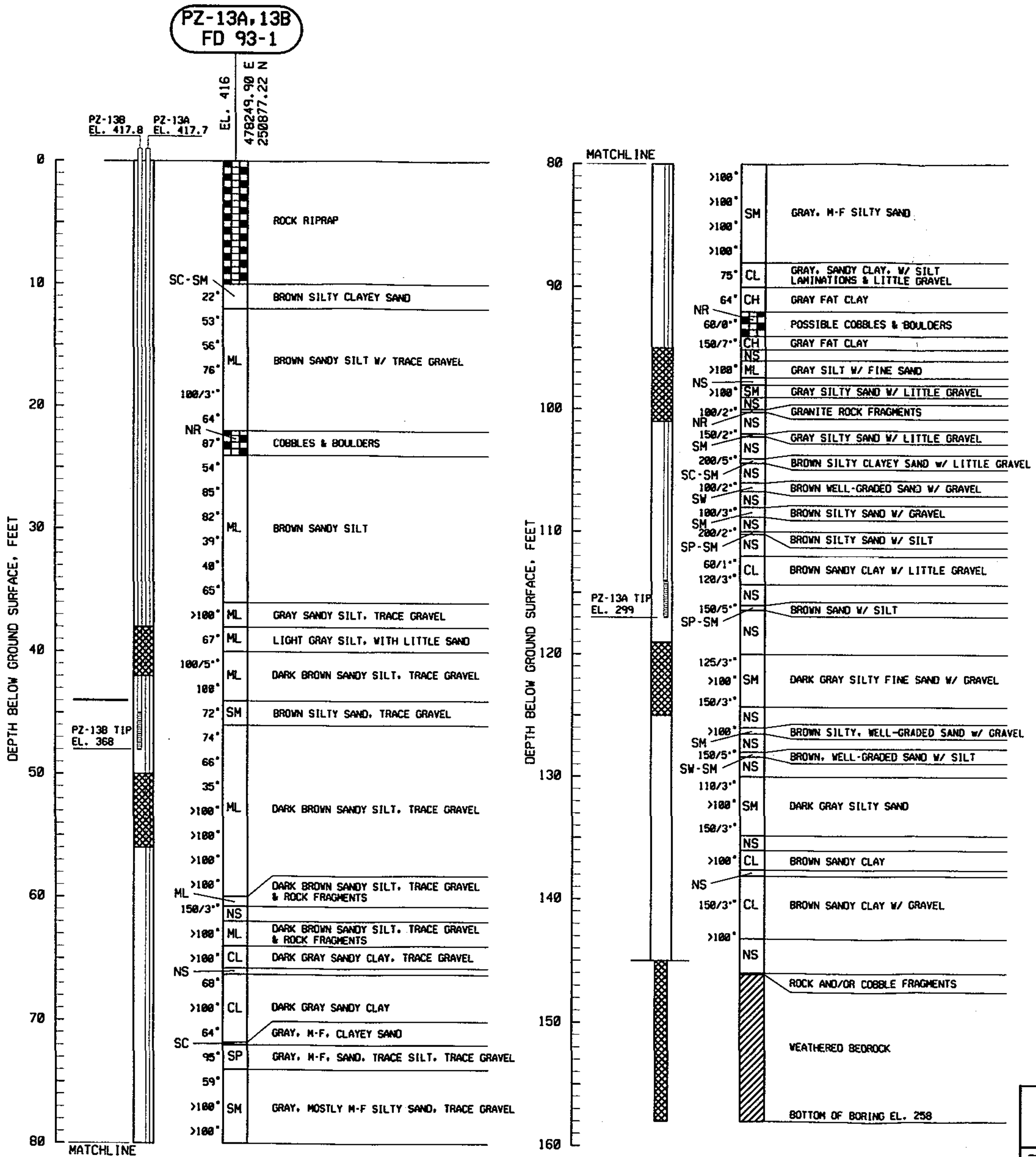
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASSACHUSETTS

LCD DESIGN BY	MERRIMACK VALLEY FLOOD CONTROL
MAV CHECK BY	HOPKINTON DAM RECORD OF FOUNDATION EXPLORATIONS - PIEZOMETERS 1987
LCD DRAWN BY	
GEOTECH. ENG. DIV. PLATE NO. 7	SCALE: AS SHOWN DATE: JULY 1993

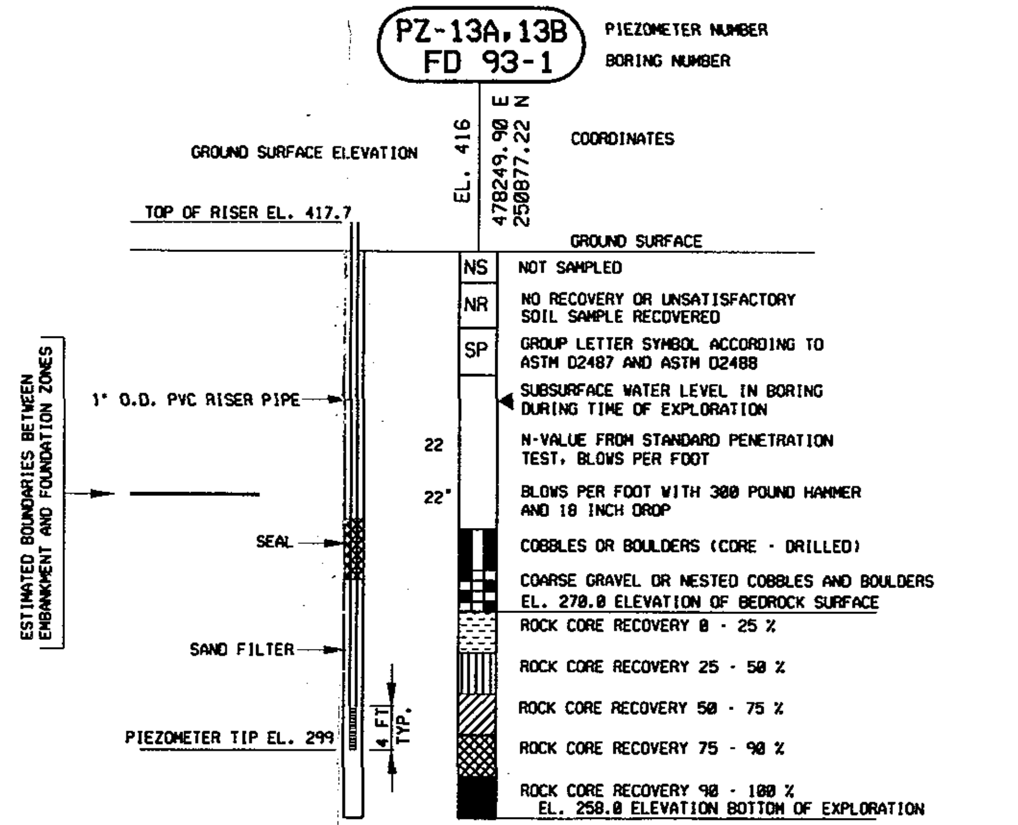


DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASSACHUSETTS

LCD DESIGN BY	MERRIMACK VALLEY FLOOD CONTROL HOPKINTON DAM
MAV CHECK BY	RECORD OF FOUNDATION EXPLORATIONS - RELIEF WELLS
LCD DRAWN BY	
GEOTECH. ENG. DIV. PLATE NO. 8	SCALE: AS SHOWN DATE: JULY 1993

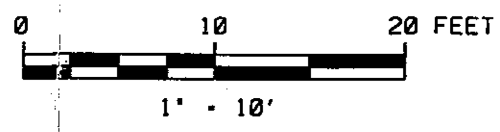


LEGEND FOR GRAPHIC LOG



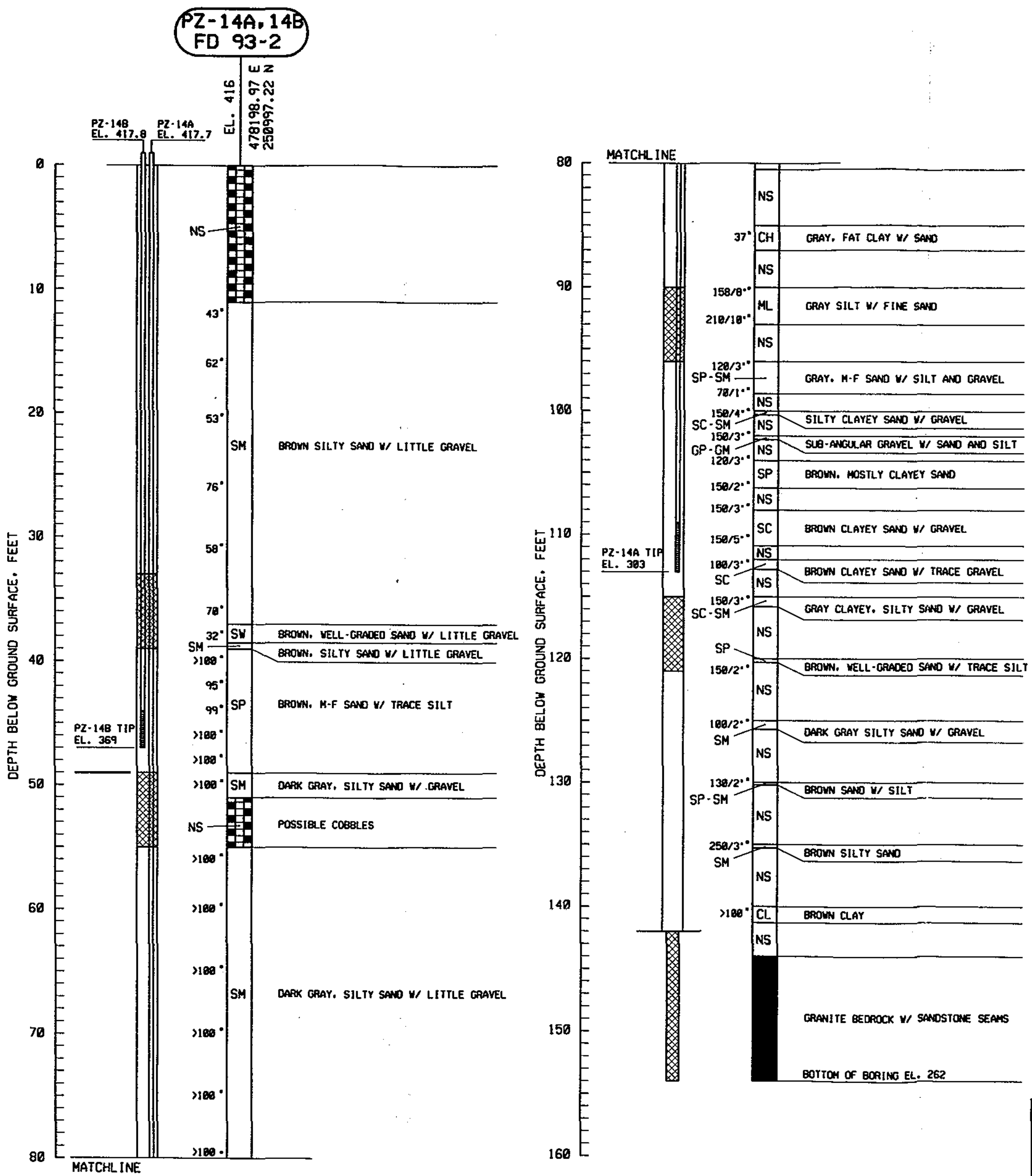
NOTES:

1. SEE PLATE 2 FOR BORING LOCATIONS.
2. ELEVATIONS REFER TO NATIONAL GEODETIC VERTICAL DATUM (NGVD) OF 1929.

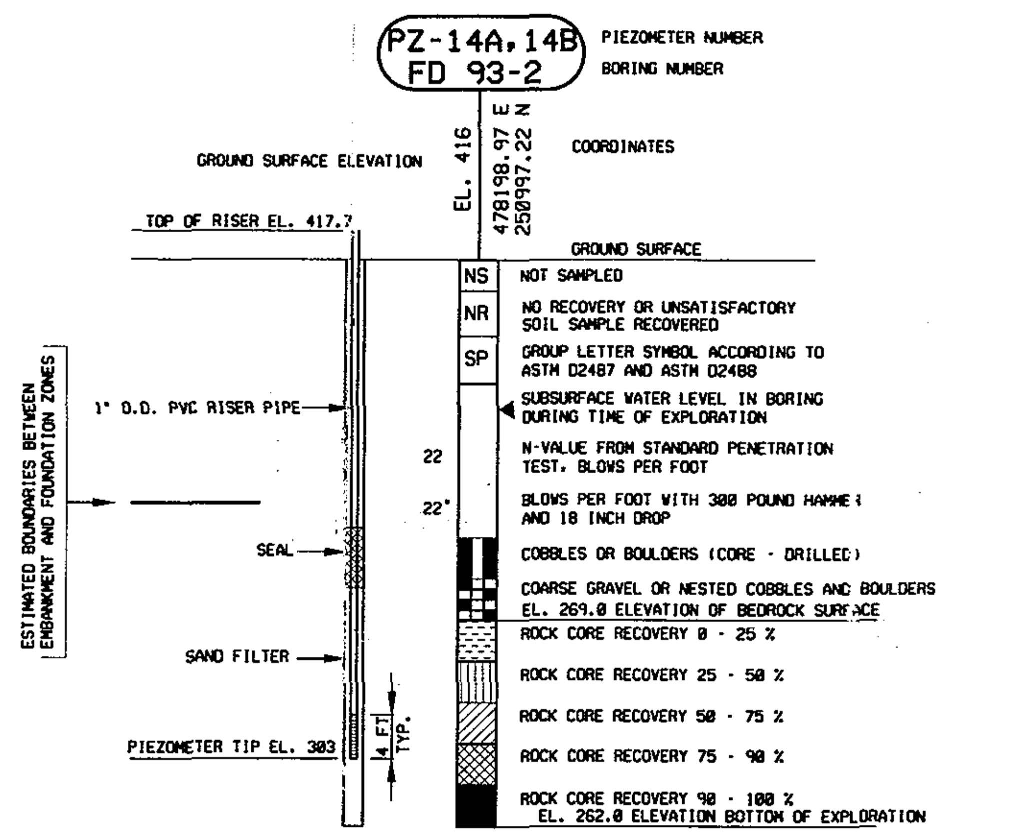


U.S. Army Corps of Engineers Concord, Massachusetts	Instrumentation Evaluation Hopkinton Dam New Hampshire	ENGINEERING LOGS FD 93-1
GEI Consultants, Inc.	Project 02065	July 2002 Plate 9

...\Plates\hoiapl009.dgn 07/18/02 02:10:39 PM



LEGEND FOR GRAPHIC LOG



NOTES:

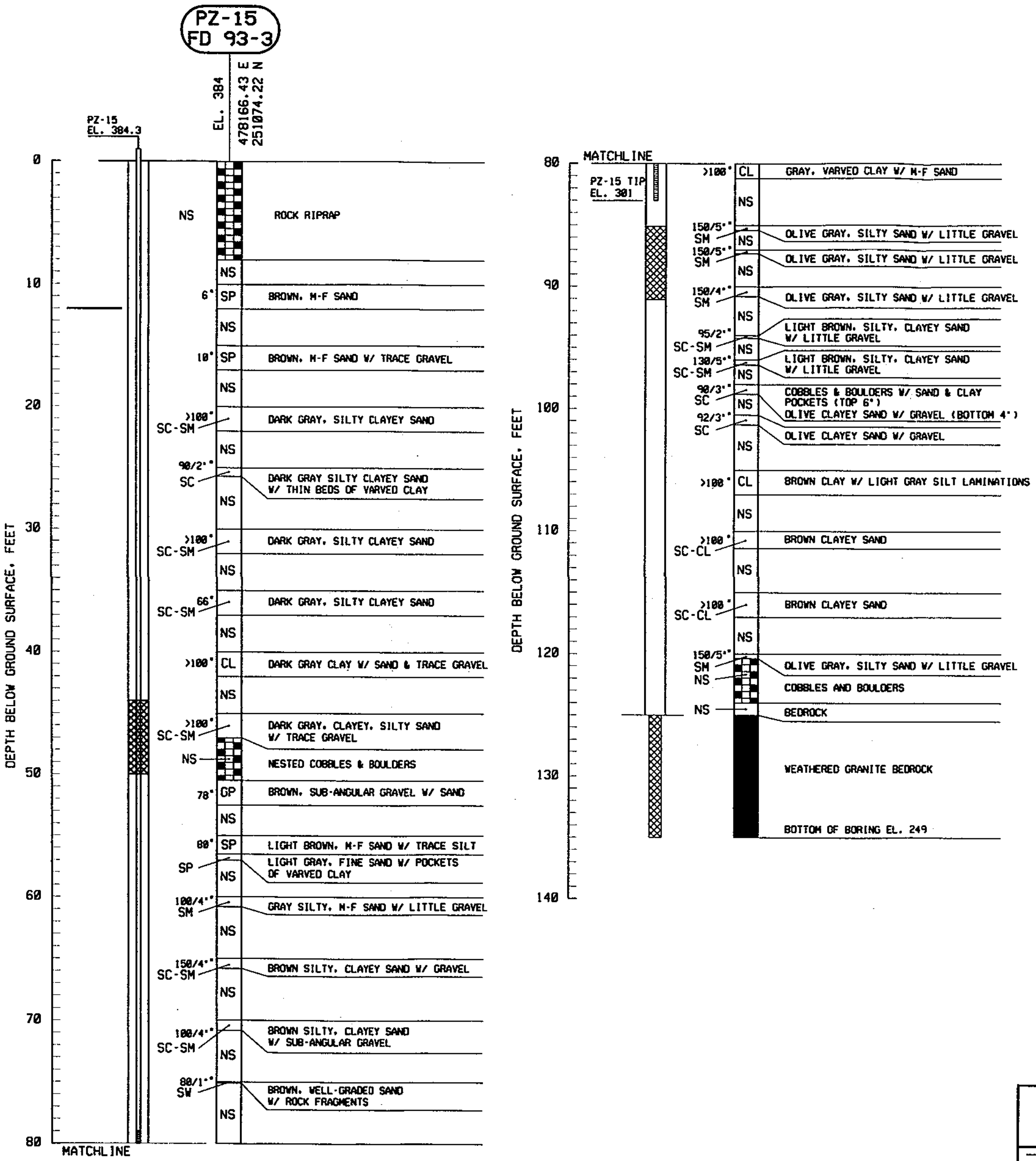
1. SEE PLATE 2 FOR BORING LOCATIONS.
2. ELEVATIONS REFER TO NATIONAL GEODETIC VERTICAL DATUM (NGVD) OF 1929.

0 10 20 FEET

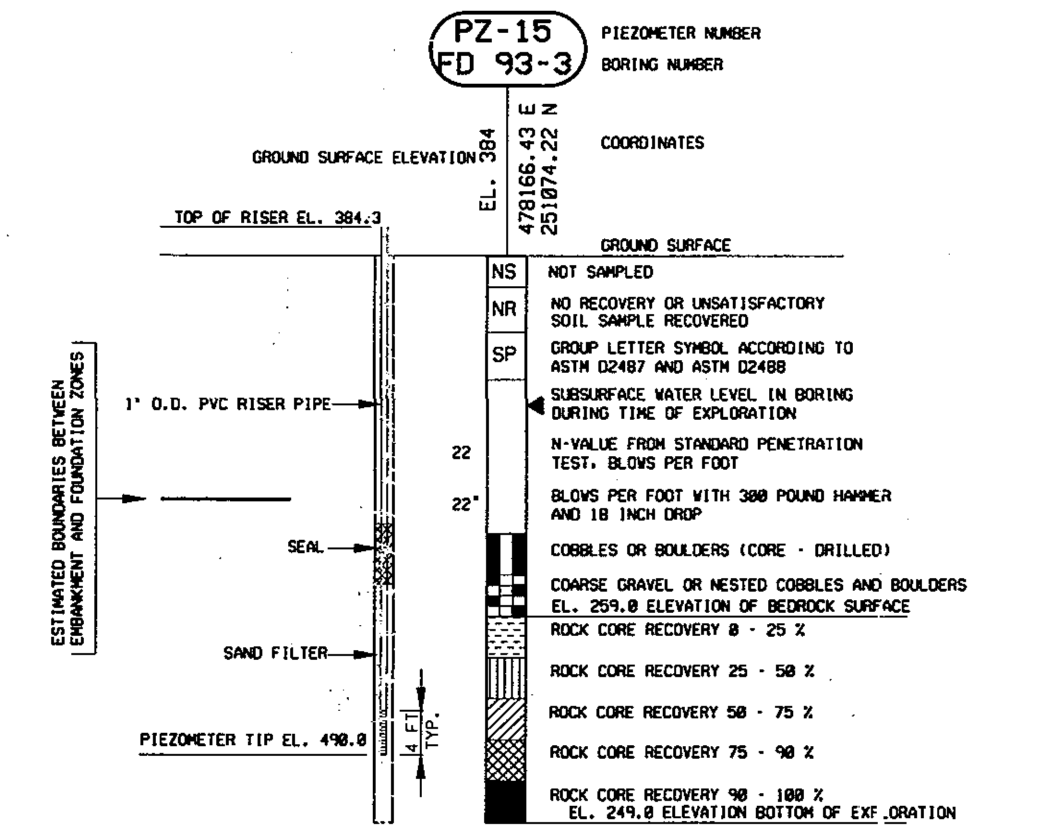
1" = 10'

U.S. Army Corps of Engineers Concord, Massachusetts	Instrumentation Evaluation Hopkinton Dam New Hampshire	ENGINEERING LOGS FD 93-2
GEI Consultants, Inc.	Project 02065	July 2002 Plate 10

...\Plates\hoiapl010.dgn 07/18/02 02:12:14 PM

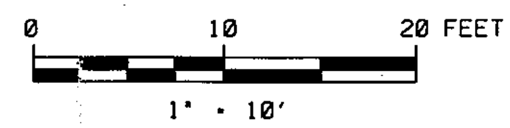


LEGEND FOR GRAPHIC LOG



NOTES:

1. SEE PLATE 2 FOR BORING LOCATIONS.
2. ELEVATIONS REFER TO NATIONAL GEODETIC VERTICAL DATUM (NGVD) OF 1929.



U.S. Army Corps of Engineers Concord, Massachusetts	Instrumentation Evaluation Hopkinton Dam New Hampshire	ENGINEERING LOGS FD 93-3	
GEI Consultants, Inc.	Project 02065	July 2002	Plate 11

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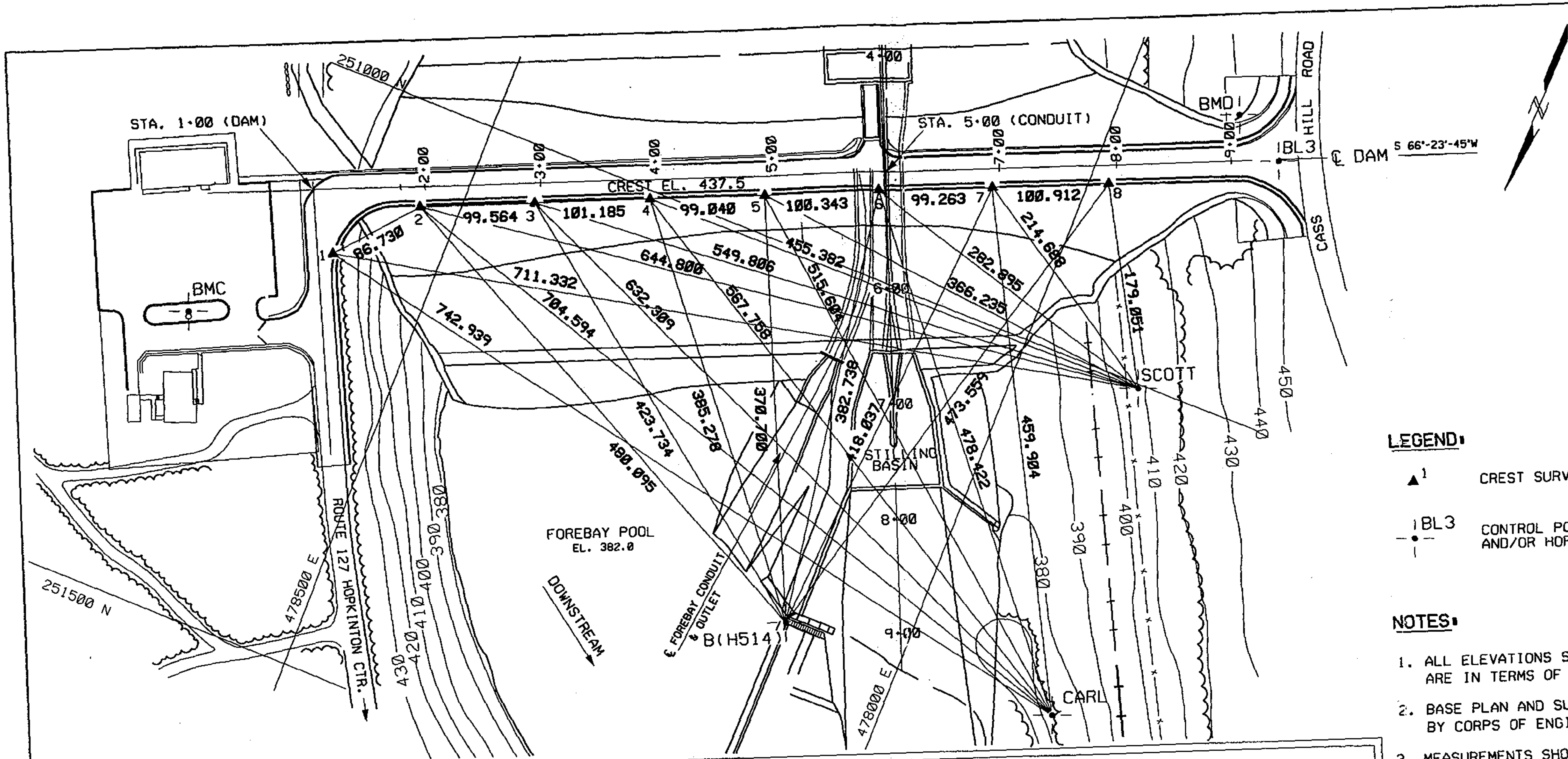

LEGEND:

▲1 CREST SURVEY MONUMENTS

BL3 CONTROL POINT FOR VERTICAL AND/OR HORIZONTAL CONTROL

NOTES:

1. ALL ELEVATIONS SHOWN ON THIS SHEET ARE IN TERMS OF FEET NGVD.
2. BASE PLAN AND SURVEY DATA PROVIDED BY CORPS OF ENGINEERS.
3. MEASUREMENTS SHOWN ARE FROM AUGUST 2001 SURVEY. REFER TO SURVEY BOOK FC 183 AND PLAN-SUR-801 FOR DESCRIPTION AND LOCATION OF CONTROL POINTS. BOOK AND PLAN ARE STORED IN THE CENAE DESIGN BRANCH, SURVEY UNIT.
4. N/R INDICATES INFORMATION NOT RECORDED.
5. ALL DISTANCES SHOWN ARE IN FEET
6. BL3 WAS PREVIOUSLY SHOWN AS BL1. THE CONTROL POINT WAS STAMPED INCORRECTLY IN THE FIELD, AND SHOULD BE REFERRED TO AS 'BL3'.

CREST MONUMENT COORDINATE DATA

	SEPTEMBER 1985			MARCH 1986			APRIL 1991			MARCH 1996			AUGUST 2001		
MON.•	NORTHING	EASTING	ELEVATION	NORTHING	EASTING	ELEVATION	NORTHING	EASTING	ELEVATION	NORTHING	EASTING	ELEVATION	NORTHING	EASTING	ELEVATION
1	N/R	N/R	440.975	251153.912	478589.521	441.016	251153.931	478589.548	441.058	251153.8947	478589.5397	441.057	251153.9413	478589.5007	441.06
2	N/R	N/R	440.590	251087.633	478533.563	440.636	251087.676	478533.579	440.670	251087.6544	478533.5795	440.664	251087.6878	478533.5444	440.66
3	N/R	N/R	439.660	251047.923	478442.224	439.695	251047.945	478442.264	439.729	251047.9249	478442.2695	439.719	251047.9820	478442.2572	439.72
4	N/R	N/R	438.135	251007.180	478349.652	438.157	251007.172	478349.686	438.198	251007.1779	478349.6942	438.188	251007.1967	478349.6604	438.19
5	N/R	N/R	437.710	250967.770	478258.772	437.731	250967.759	478258.824	437.782	250967.7658	478258.8316	437.762	250967.7704	478258.8092	437.77
6	N/R	N/R	437.840	250927.540	478166.833	437.869	250927.514	478166.886	437.910	250927.5253	478166.8962	437.887	250927.5383	478166.8757	437.89
7	N/R	N/R	438.480	250888.384	478075.658	438.492	250888.357	478075.681	438.539	250888.3538	478075.6906	438.518	250888.3815	478075.6838	438.52
8	N/R	N/R	441.300	250847.888	478983.211	441.312	250847.849	477983.261	441.352	250847.8451	477983.2733	441.332	250847.8510	477983.2736	441.33

CONTROL POINTS COORDINATE DATA

CONTROL POINT	NORTHING	EASTING	ELEVATION
SCOTT	251003.2253	477894.3016	N/R
B(H514)	251305.3410	478105.6280	N/R
BMC	251246.2656	478688.7467	441.07
BMD	N/R	N/R	440.50
BL3	250775.7265	477852.7360	443.92
CARL	251294.5954	477860.0079	N/R

0 100 200

SCALE, FEET

U.S. Army Corps of Engineers
Concord, Massachusetts

Φ GEI Consultants, Inc.

Instrumentation Evaluation
Hopkinton Dam
New Hampshire

Project 02065

CREST SURVEY MONUMENTS: GENERAL LAYOUT, LOCATION & SURVEY DATA

July 2002 Plate 12

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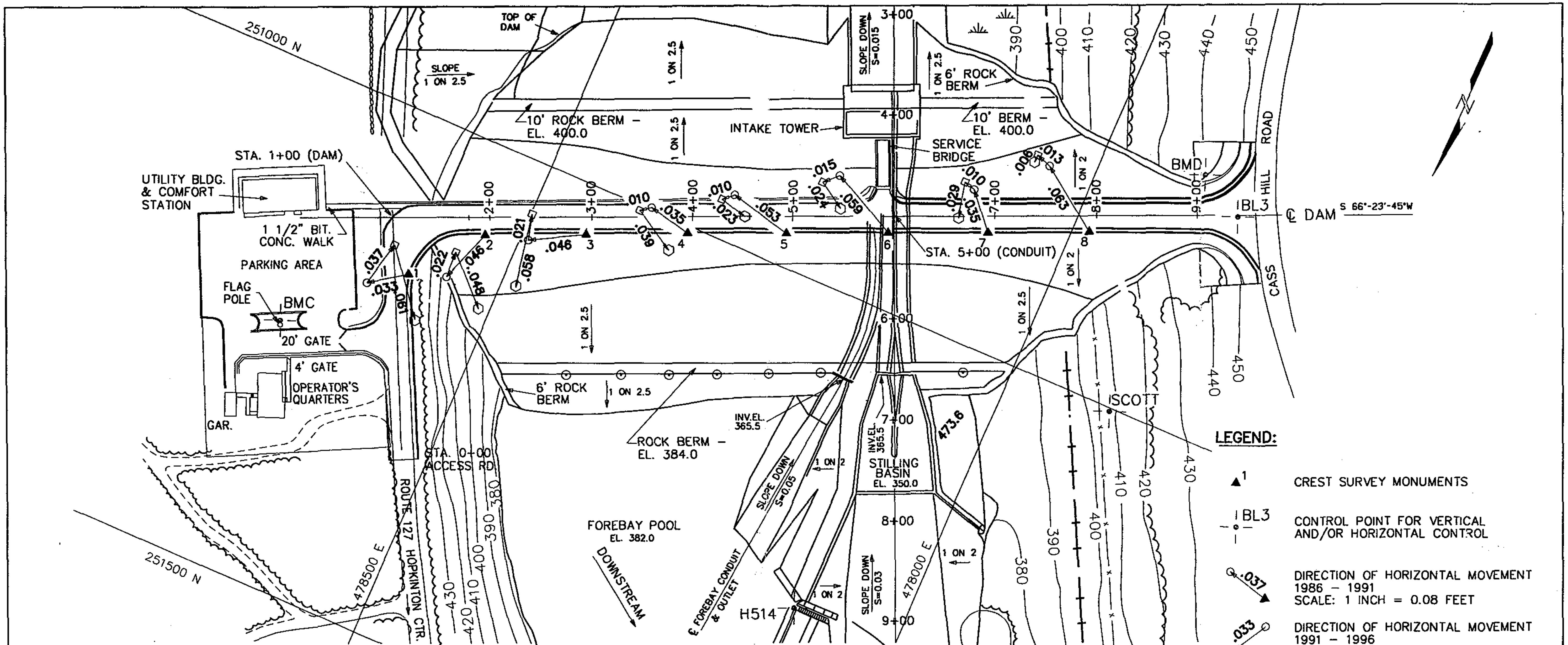
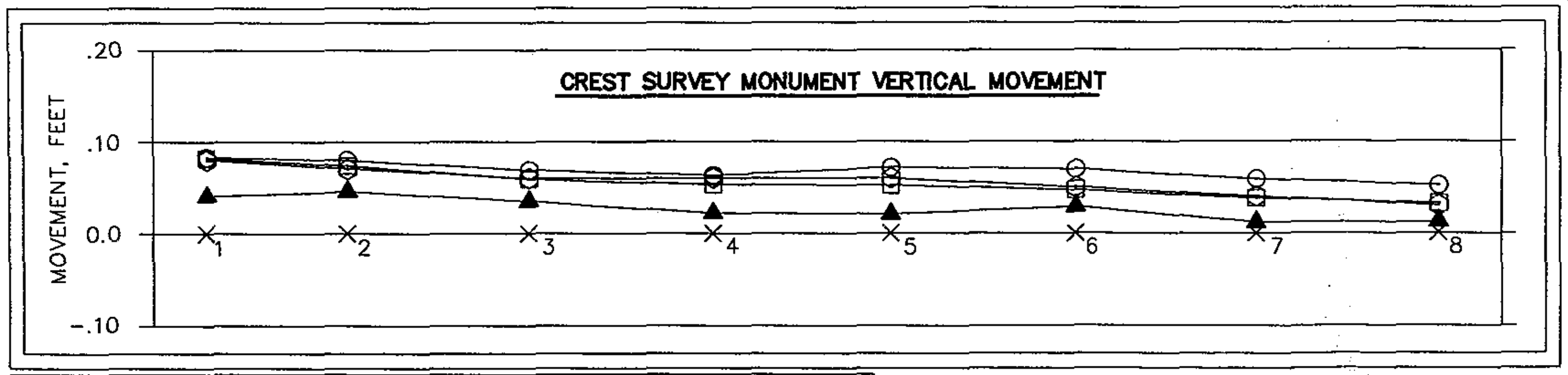


NOTES:

1. ALL ELEVATIONS SHOWN ON THIS SHEET ARE IN TERMS OF FEET NGVD.
2. PLAN DRAWING PROVIDED BY CORPS OF ENGINEERS.



LEGEND FOR VERTICAL MOVEMENT	
SYMBOL	DESCRIPTION
×	CREST MONUMENT SURVEY - INITIAL ELEVATION SEPT. 1985
▲	CREST MONUMENT SURVEY - MARCH 1986
⊙	CREST MONUMENT SURVEY - APRIL 1991
⊡	CREST MONUMENT SURVEY - MARCH 1996
⬡	CREST MONUMENT SURVEY - AUGUST 2001

0 100 200
PLAN SCALE, FEET
1" = 100'

0 0.08 0.16
HORIZONTAL MOVEMENT SCALE, FEET
1" = 0.08'

U.S. Army Corps of Engineers
Concord, Massachusetts

Φ GEI Consultants, Inc.

Instrumentation Evaluation
Hopkinton Dam
New Hampshire

Project 02065

CREST SURVEY MONUMENTS: HORIZONTAL & VERTICAL MOVEMENTS

July 2002 Plate 13

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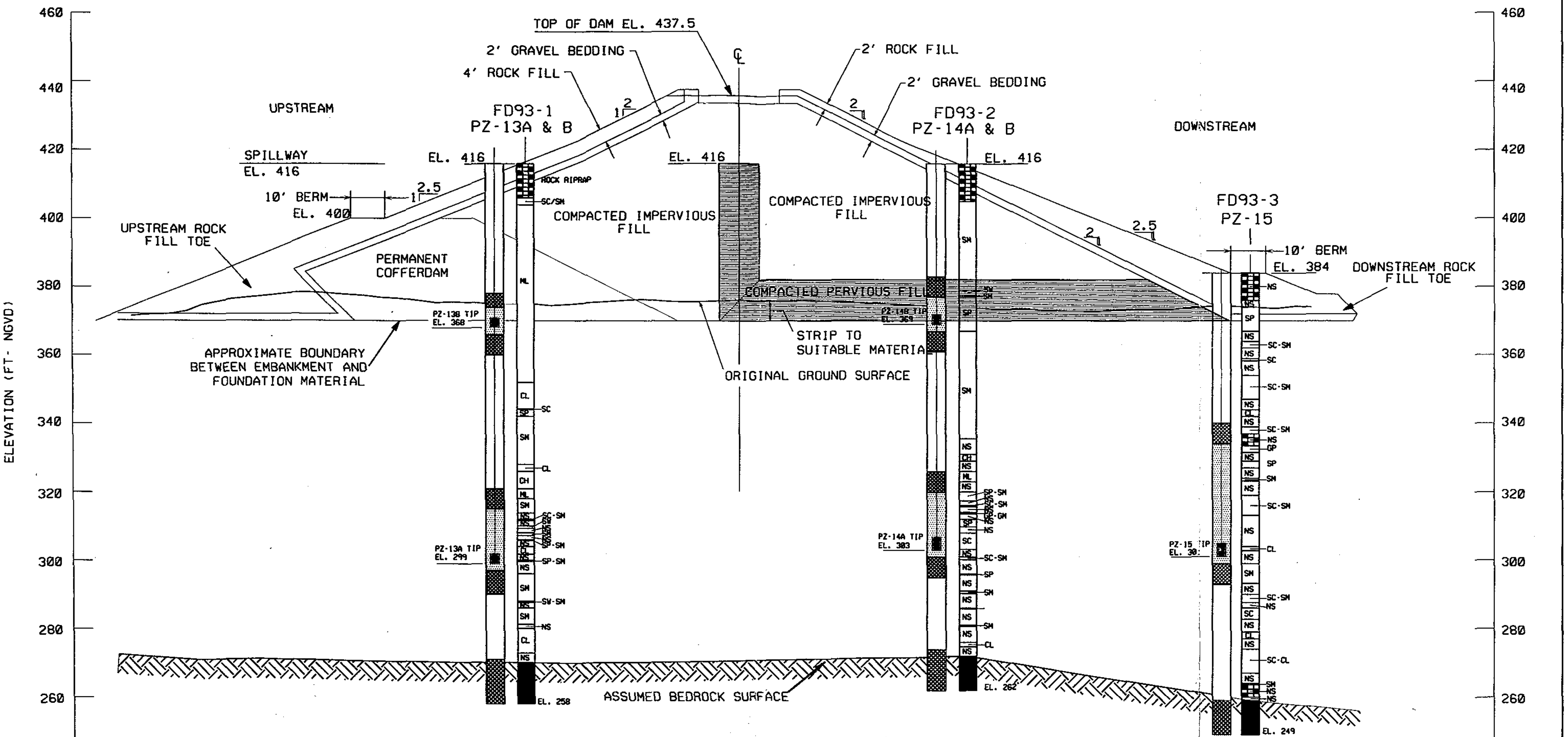

SECTION A-A - STATION 5+25 HOPKINTON DAM

NOTES:

1. ALL ELEVATIONS ARE IN FEET NGVD.
2. SEE PLATES 9 - 11 FOR COMPLETE LOG DETAILS.
3. SECTION BASED ON DRAWING PROVIDED BY CORPS OF ENGINEERS.

U.S. Army Corps of Engineers Concord, Massachusetts	Instrumentation Evaluation Hopkinton Dam New Hampshire	STATION 5+25
GEI Consultants, Inc.	Project 02065	July 2002 Plate 14

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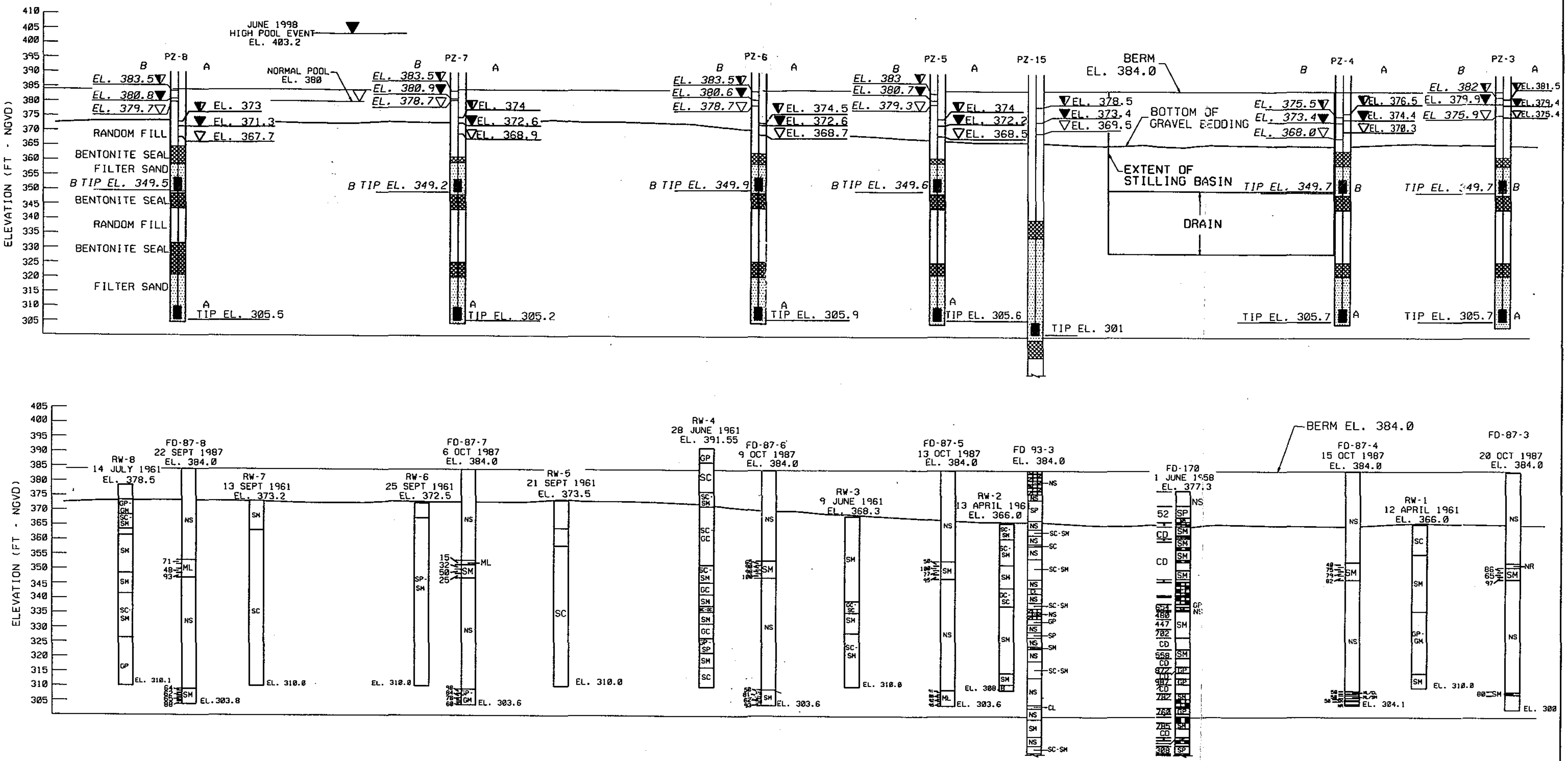

SECTION B-B ALONG DOWNSTREAM BERM

(LOOKING UPSTREAM)

0 35 70

SCALE, FEET

LEGEND:

- NS — NOT SAMPLED
- ▼ (projected) — PROJECTED PIEZOMETER READINGS WITH POOL AT SPILLWAY CREST (EL. 416)
- ▼ — MAXIMUM GROUNDWATER ELEVATION DURING JUNE 1998 HIGH POOL EVENT
- ▽ — AVERAGE NORMAL GROUNDWATER ELEVATION WITH NORMAL POOL (EL. 380)

NOTES:

1. SEE PLATES 5A - 11 FOR COMPLETE BORING LOGS
2. SECTION DRAWING PROVIDED BY CORPS OF ENGINEERS.
3. PIEZOMETER CONSTRUCTION DETAILS SHOWN FOR PZ-8, TYPICAL FOR ALL PIEZOMETERS.

U.S. Army Corps of Engineers Concord, Massachusetts	Instrumentation Evaluation Hopkinton Dam New Hampshire	DOWNSTREAM BERM PROFILE WITH PIEZOMETRIC PORE WATER LEVELS FROM PIEZOMETERS
GEI Consultants, Inc.	Project 02065	July 2002 Plate 15

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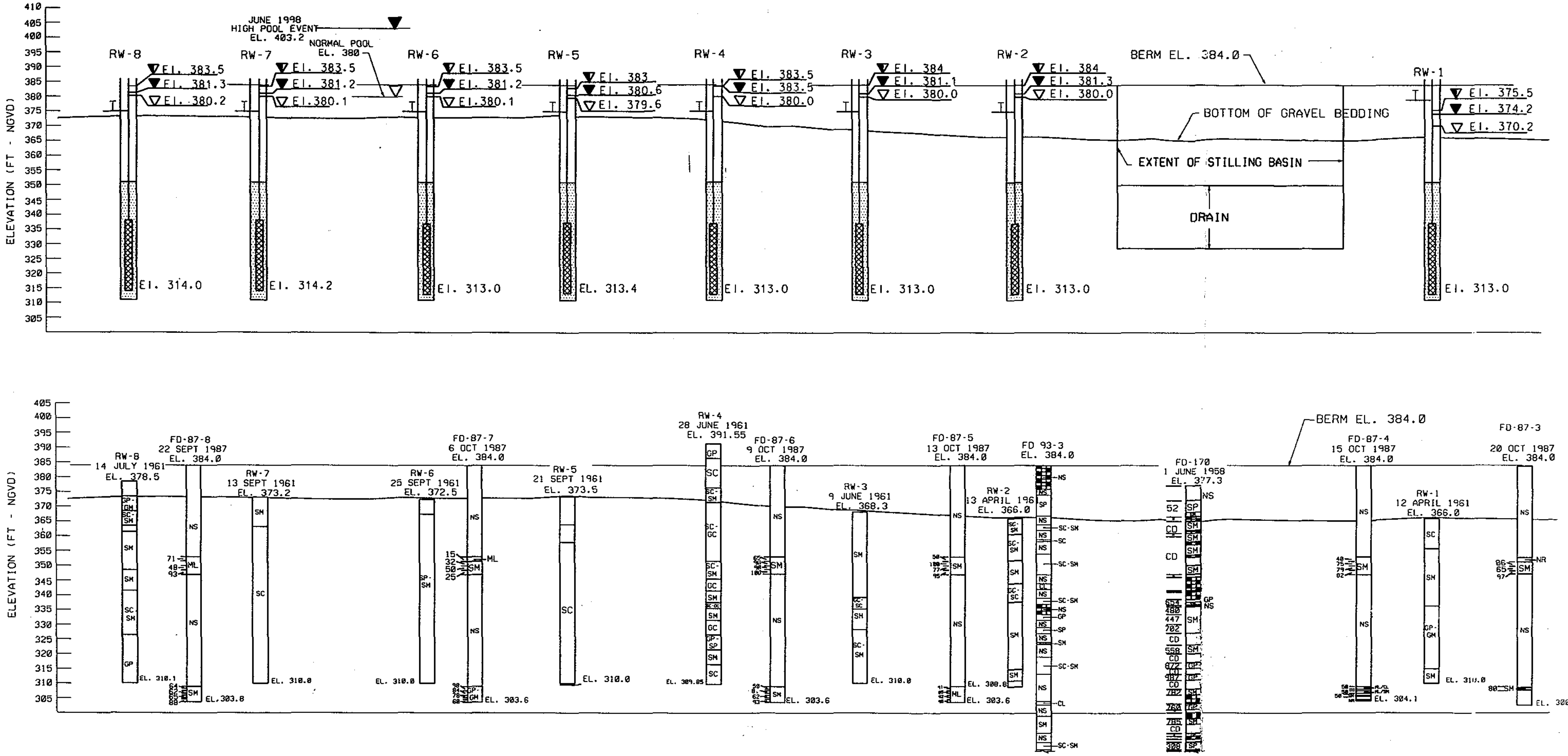

SECTION B-B ALONG DOWNSTREAM BERM

(LOOKING UPSTREAM)

0 35 70

SCALE, FEET

LEGEND:

NS	NOT SAMPLED
T	T-OUTLET ELEVATION RW-1 EL. 379 : RW-2-8 EL. 375
▼	PROJECTED RELIEF WELL READINGS WITH AT SPILLWAY CREST (EL. 416)
▼	MAXIMUM RELIEF WELL READING DURING JUNE 1998 HIGH POOL EVENT
▽	AVERAGE NORMAL RELIEF WELL READING WITH NORMAL POOL (EL. 380)

NOTES:

1. SEE PLATE 25 FOR RELIEF WELL DETAILS
2. SEE PLATES 5A - 11 FOR COMPLETE BORING LOGS
3. SECTION DRAWING PROVIDED BY CORPS OF ENGINEERS.

U.S. Army Corps of Engineers Concord, Massachusetts	Instrumentation Evaluation Hopkinton Dam New Hampshire	DOWNSTREAM BERM PROFILE WITH PIEZOMETRIC PORE WATER LEVELS FROM RELIEF WELLS
GEI Consultants, Inc.	Project 02065	July 2002 Plate 16

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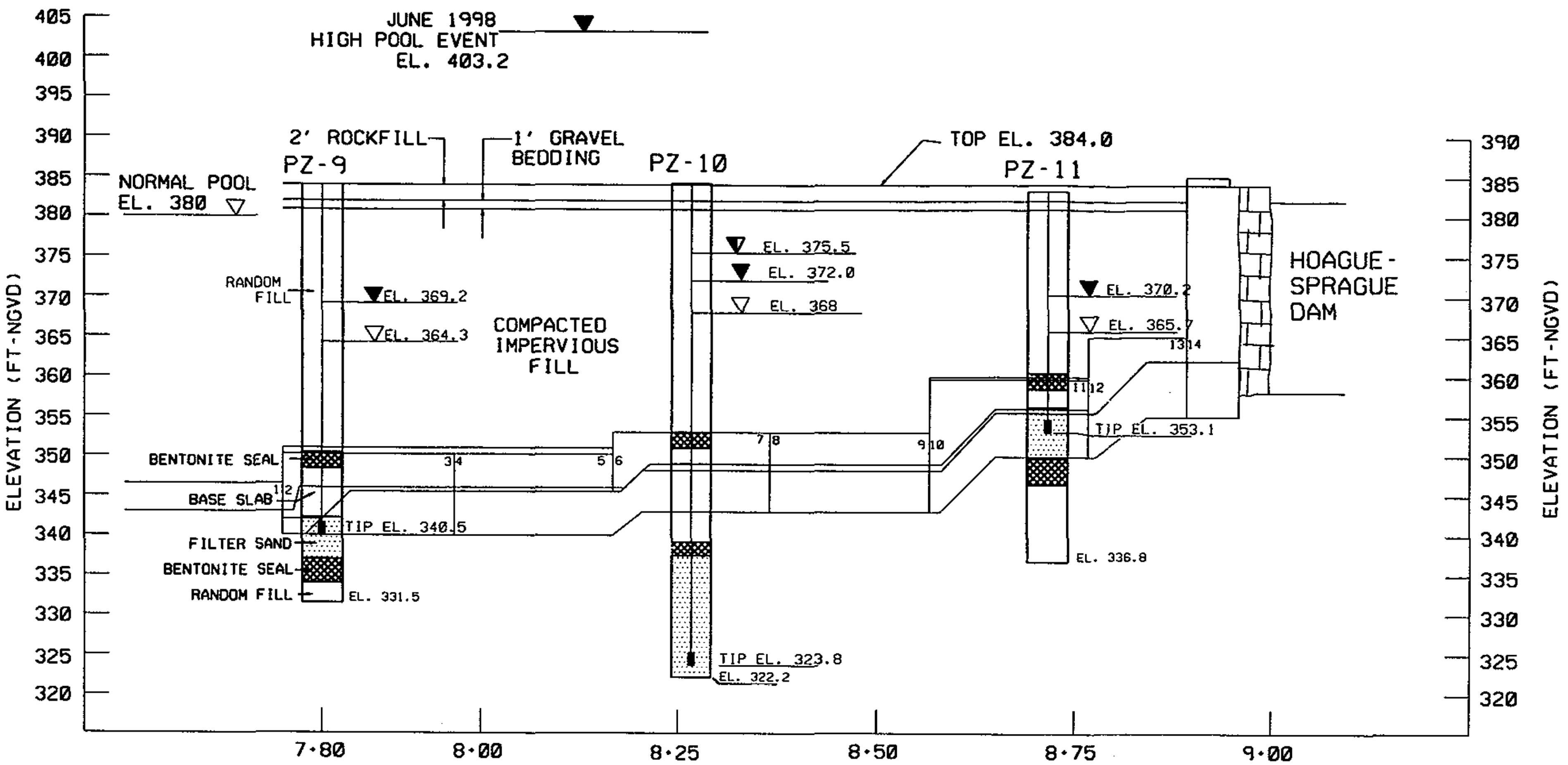

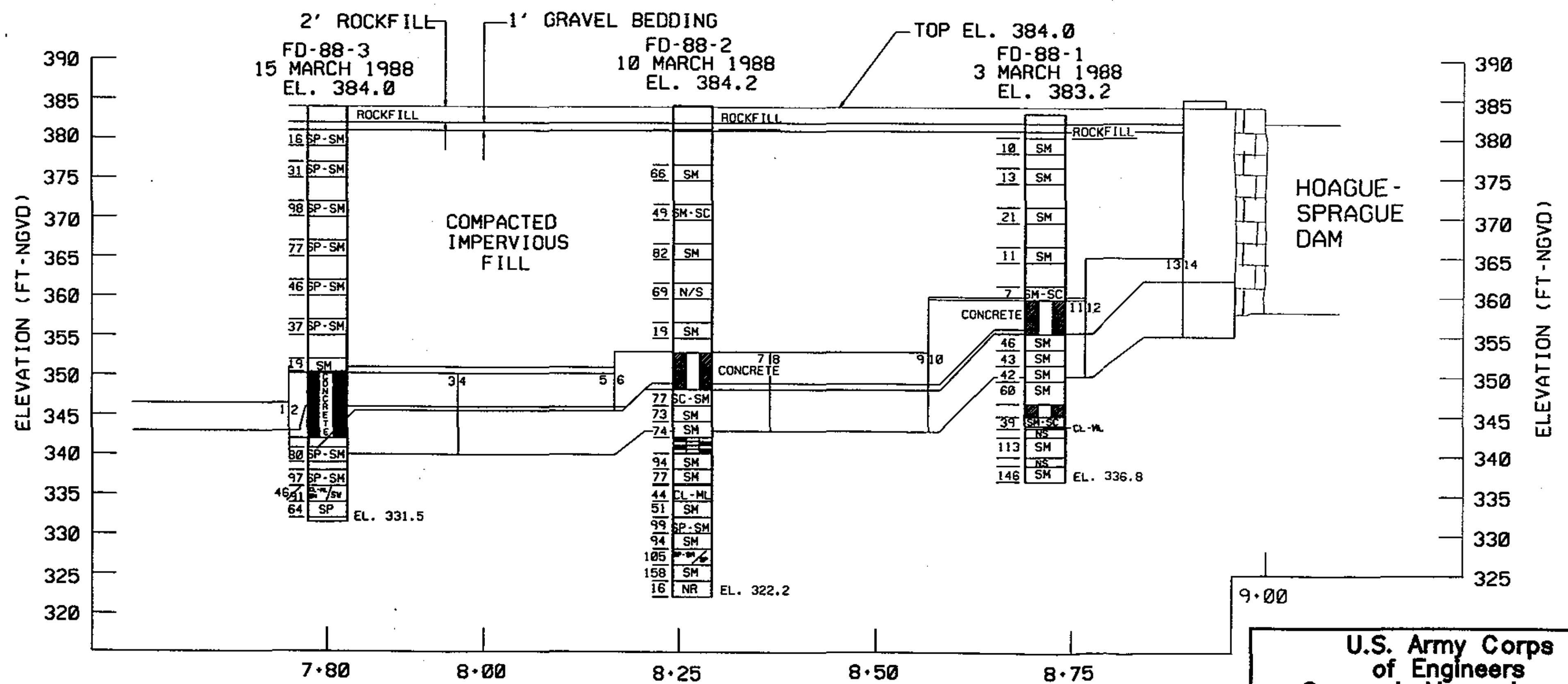

SECTION C-C ALONG EAST OUTLET CHANNEL WALL
(LOOKING TOWARDS LEFT ABUTMENT)

LEGEND:

▼ PROJECTED PIEZOMETER READINGS WITH POOL AT SPILLWAY CREST (EL. 416)

▼ MAXIMUM GROUNDWATER ELEVATION DURING JUNE 1998 HIGH POOL EVENT

▽ AVERAGE NORMAL GROUNDWATER ELEVATION WITH NORMAL POOL (EL. 380)

NOTES:

1. SEE PLATE 6 FOR COMPLETE LOG DETAILS.
2. SECTION DRAWING PROVIDED BY CORPS OF ENGINEERS.
3. PIEZOMETER CONSTRUCTION DETAILS SHOWN FOR PZ-9 TYPICAL FOR ALL PIEZOMETERS.

0 20 40
SCALE, FEET

U.S. Army Corps of Engineers Concord, Massachusetts	Instrumentation Evaluation Hopkinton Dam New Hampshire	EAST OUTLET CHANNEL WALL
GEI Consultants, Inc.	Project 02065	July 2002 Plate 17

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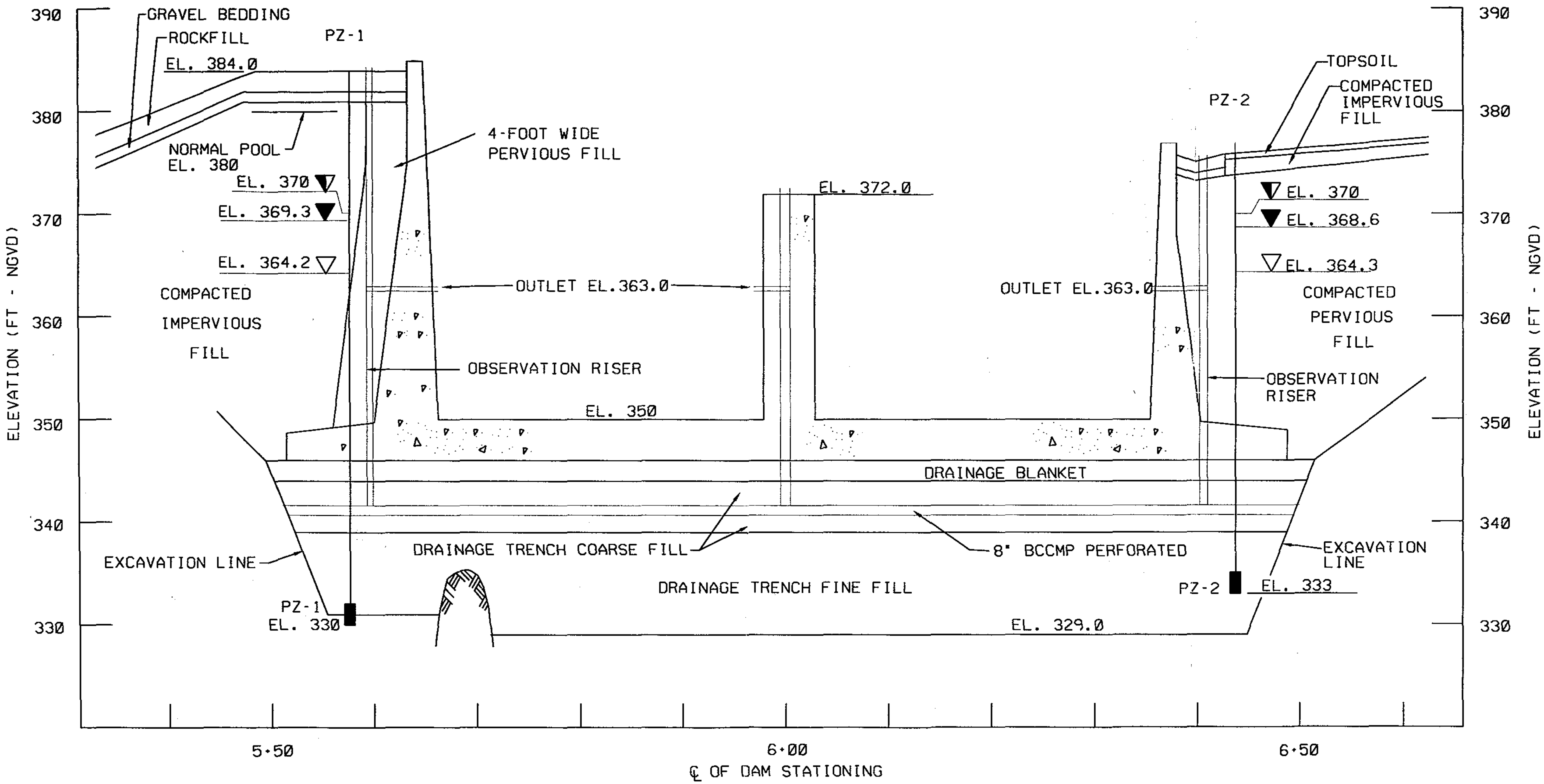


LEGEND:

▼ (half-filled) PROJECTED PIEZOMETER READINGS WITH POOL AT SPILLWAY CREST (EL. 416)

▼ MAXIMUM GROUND WATER ELEVATION DURING JUNE 1998 HIGH POOL EVENT

▽ AVERAGE NORMAL GROUND WATER ELEVATION WITH NORMAL POOL (EL. 380)

SECTION D-D THROUGH STILLING BASIN (LOOKING UPSTREAM)

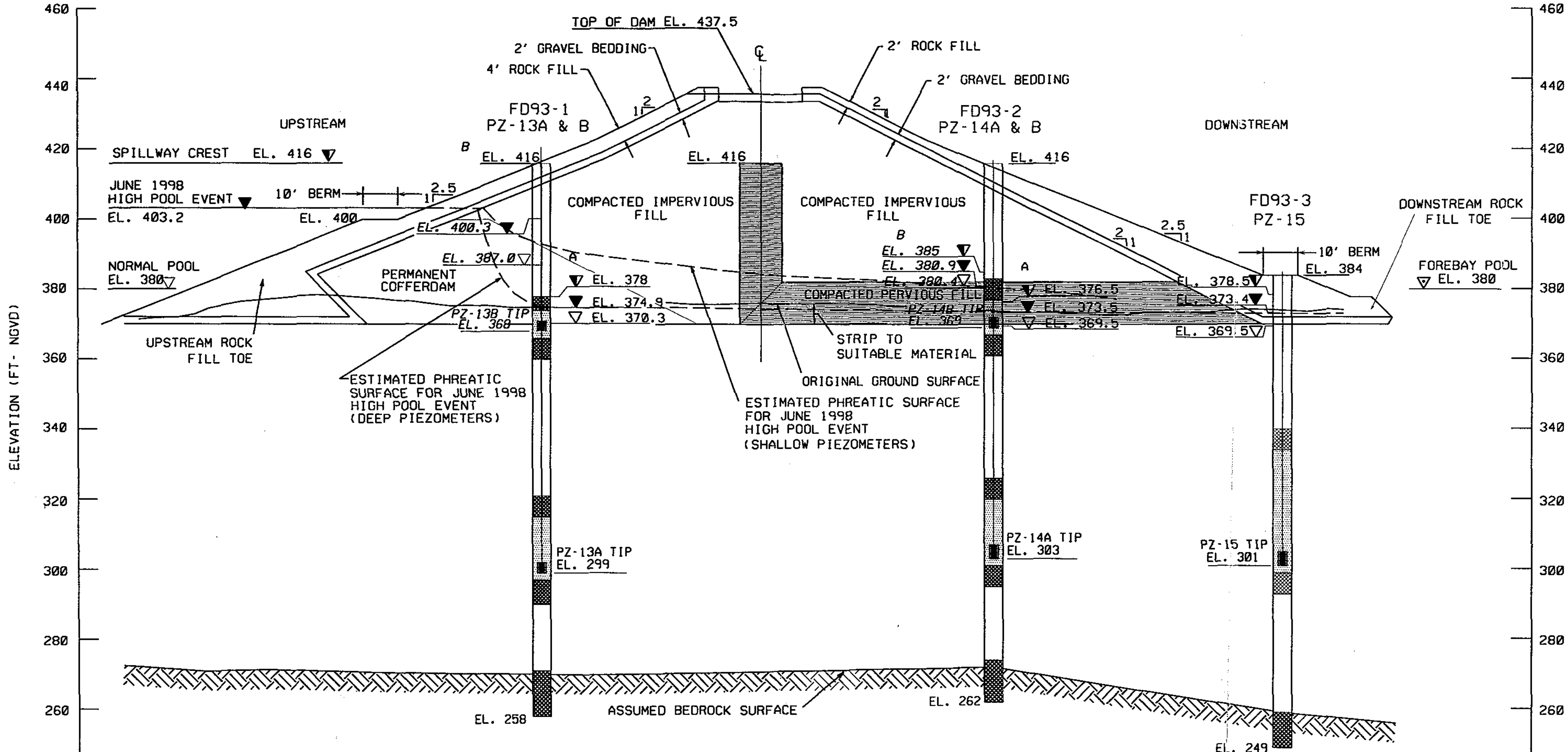
0 10 20
SCALE, FEET

NOTES:

1. SECTION DRAWING PROVIDED BY CORPS OF ENGINEERS.

U.S. Army Corps of Engineers Concord, Massachusetts	Instrumentation Evaluation Hopkinton Dam New Hampshire	STILLING BASIN CROSS SECTION
GEI Consultants, Inc.	Project 02065	July 2002 Plate 18

...\Plates\hoiapl018.dgn 07/18/02 03:16:51 PM



SECTION A-A - STATION 5+25 HOPKINTON DAM

0 30 60
SCALE, FEET

LEGEND:

- ▼ PROJECTED PIEZOMETER READINGS WITH POOL AT SPILLWAY CREST (EL. 416)
- ▼ MAXIMUM RECORDED GROUND WATER ELEVATION DURING JUNE 1998 HIGH POOL EVENT
- ▽ AVERAGE NORMAL GROUND WATER ELEVATION WITH NORMAL POOL (EL. 380)
- ---- ESTIMATED PHREATIC SURFACE, JUNE 1998 HIGH POOL EVENT

NOTES:

1. ALL ELEVATIONS ARE IN FEET NGVD.
2. SEE PLATES 9 - 11 FOR COMPLETE LOG DETAILS.
3. SECTION BASED ON DRAWING PROVIDED BY CORPS OF ENGINEERS.
4. NO PROJECTION OF PIEZOMETRIC ELEVATION WAS MADE FOR PZ-13B DUE TO SCATTER OF DATA
5. THE AVERAGE READING DURING THE JUNE 1998 HIGH POOL EVENT WAS USED FOR PHREATIC SURFACE AT PZ-13B.

U.S. Army Corps of Engineers Concord, Massachusetts	Instrumentation Evaluation Hopkinton Dam New Hampshire	STATION 5+25 WITH PIEZOMETRIC PORE WATER LEVELS
GEI Consultants, Inc.	Project 02065	July 2002 Plate 19

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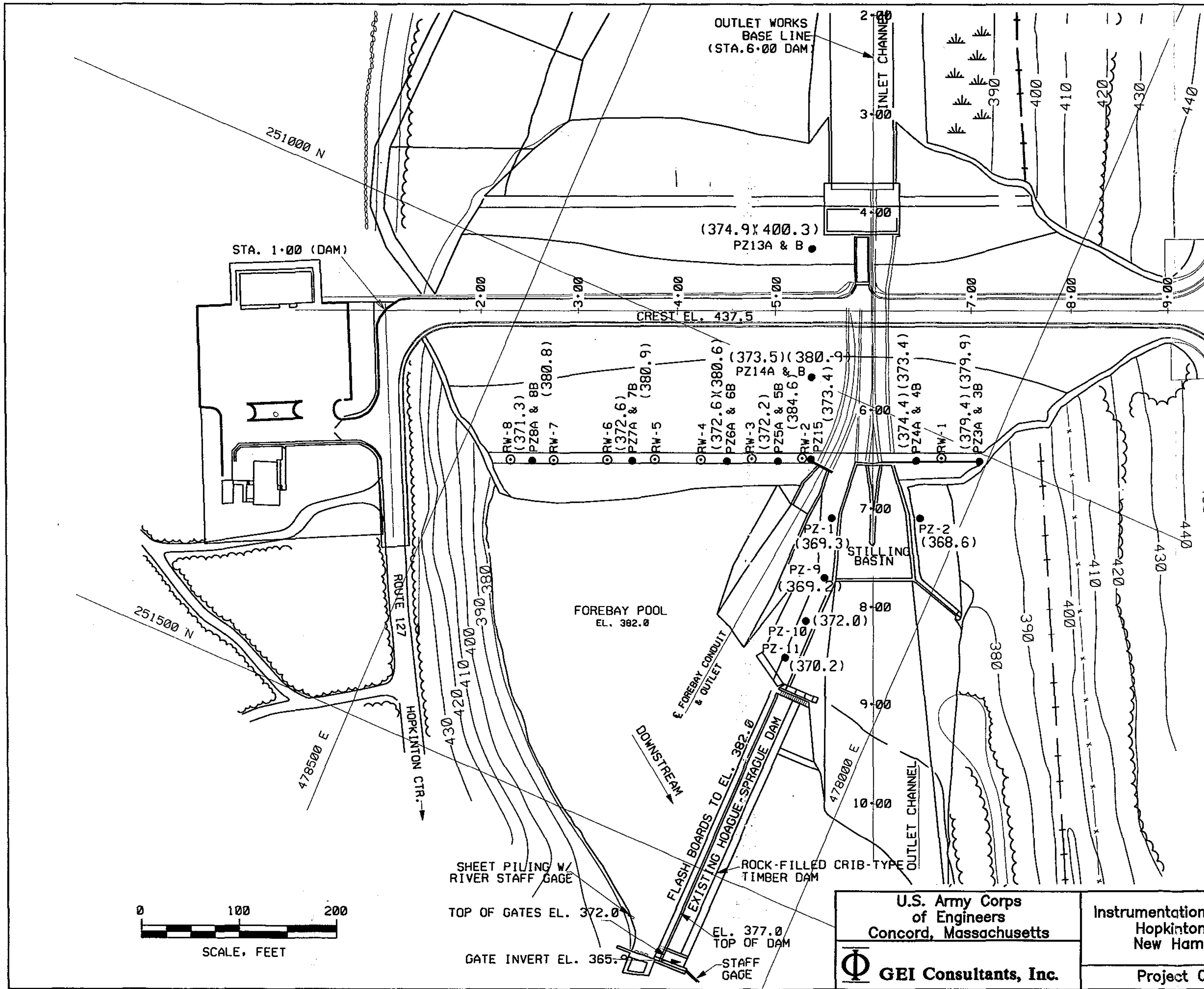


LEGEND:

- PZ-1 PIEZOMETER
- RW-1 RELIEF WELL

NOTES:

1. ALL ELEVATIONS SHOWN ON THIS SHEET ARE IN TERMS OF FEET NGVD.
2. PLAN DRAWING PROVIDED BY CORPS OF ENGINEERS.
3. MAXIMUM POOL WAS EL. 403.2 WHICH OCCURRED ON JUNE 19, 1998.
4. NUMBERS IN PARENTHESES REPRESENT MAXIMUM GROUND WATER LEVELS RECORDED DURING HIGH POOL EVENT OF JUNE 1998.

U.S. Army Corps of Engineers Concord, Massachusetts GEI Consultants, Inc.	Instrumentation Evaluation Hopkinton Dam New Hampshire	MAXIMUM GROUND WATER ELEVATION JUNE 1998 HIGH POOL
	Project 02065	July 2002 Plate 20

...\Plates\hoiapl020.dgn 07/19/02 01:43:17 PM

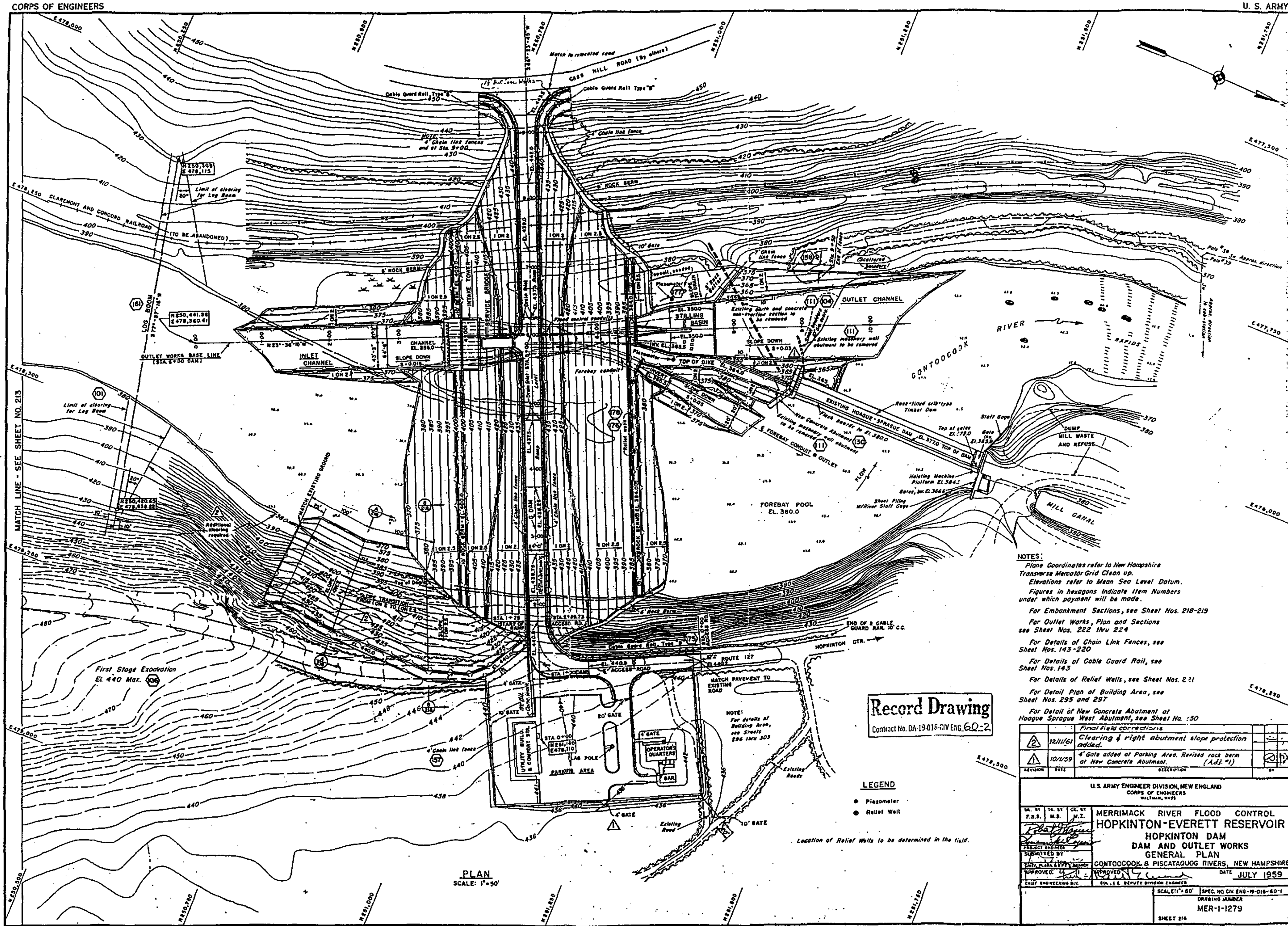
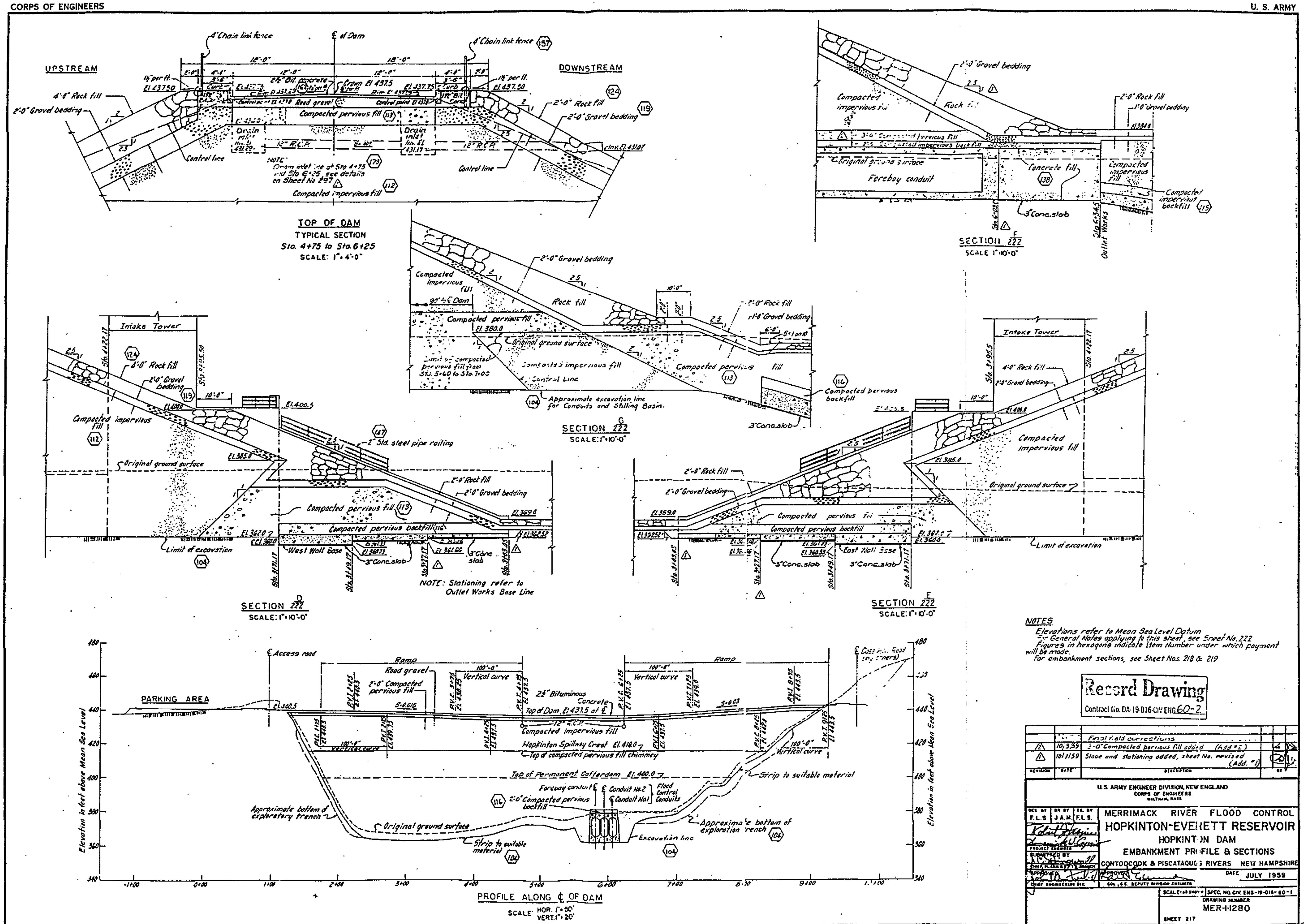

CORPS OF ENGINEERS
U. S. ARMY
PLAN
SCALE: 1"=50'
Record Drawing
Contract No. DA-19-016-CIV ENG 60-2
NOTES:
Plane Coordinates refer to New Hampshire Transverse Mercator Grid Clean up.
Elevations refer to Mean Sea Level Datum.
Figures in hexagons indicate Item Numbers under which payment will be made.
For Embankment Sections, see Sheet Nos. 218-219
For Outlet Works, Plan and Sections see Sheet Nos. 222 thru 224
For Details of Chain Link Fences, see Sheet Nos. 143-220
For Details of Cable Guard Rail, see Sheet Nos. 143
For Details of Relief Wells, see Sheet Nos. 2?1
For Detail Plan of Building Area, see Sheet Nos. 295 and 297
For Detail of New Concrete Abutment at Hoague Sprague West Abutment, see Sheet No. ?50
Final field corrections
2 12/11/61 Clearing & right abutment slope protection added.
1 10/1/59 4' Gate added at Parking Area. Revised rock berm at New Concrete Abutment. (Adj. #1)
REVISION DATE DESCRIPTION BY
LEGEND
Piezometer
Relief Well
Location of Relief Wells to be determined in the field.
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS
MERRIMACK RIVER FLOOD CONTROL
HOPKINTON-EVERETT RESERVOIR
HOPKINTON DAM
DAM AND OUTLET WORKS
GENERAL PLAN
CONTOOCOOK & PISCATAQUOG RIVERS, NEW HAMPSHIRE
DATE JULY 1959
SCALE: 1"=50'
SPEC. NO CIV. ENG-19-016-60-1
DRAWING NUMBER
MER-1-1279
SHEET 216
CONTOOCOOK RIVER
FOREBAY POOL EL. 380.0
OUTLET CHANNEL
INLET CHANNEL
STILLING BASIN
INTAKE TOWER
SERVICE BRIDGE
EXISTING HOAGUE-SPRAGUE DAM
MILL CANAL
CLAREMONT AND CONCORD RAILROAD (TO BE ABANDONED)
CASS HILL ROAD (By others)
ROUTE 127
PARKING AREA
OPERATOR'S QUARTERS
UTILITY BUILD. & COMPONENT STR.
MATCH LINE - SEE SHEET NO. 213
First Stage Excavation El. 440 Max.

PLATE 21


UPSTREAM
DOWNSTREAM
TOP OF DAM
TYPICAL SECTION
Sta. 4+75 to Sta. 6+25
SCALE: 1" = 4'-0"
SECTION 222
SCALE: 1" = 10'-0"
SECTION D 222
SCALE: 1" = 10'-0"
SECTION E 222
SCALE: 1" = 10'-0"
SECTION F 222
SCALE 1" = 10'-0"
NOTE: Stationing refer to Outlet Works Base Line
PROFILE ALONG ℄ OF DAM
SCALE: HOR. 1" = 50' VERT. 1" = 20'
PARKING AREA
Intake Tower
Foreboy conduit
NOTES
Elevations refer to Mean Sea Level Datum
For General Notes applying to this sheet, see Sheet No. 222
Figures in hexagons indicate Item Number under which payment will be made.
For embankment sections, see Sheet Nos. 218 & 219
Record Drawing
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.
MERRIMACK RIVER FLOOD CONTROL
HOPKINTON-EVERETT RESERVOIR
HOPKINTON DAM
EMBANKMENT PROFILE & SECTIONS
CONTOOCOOK & PISCATAQUOG RIVERS NEW HAMPSHIRE
JULY 1959
MER-1-1280
SHEET 217

CORPS OF ENGINEERS

U. S. ARMY

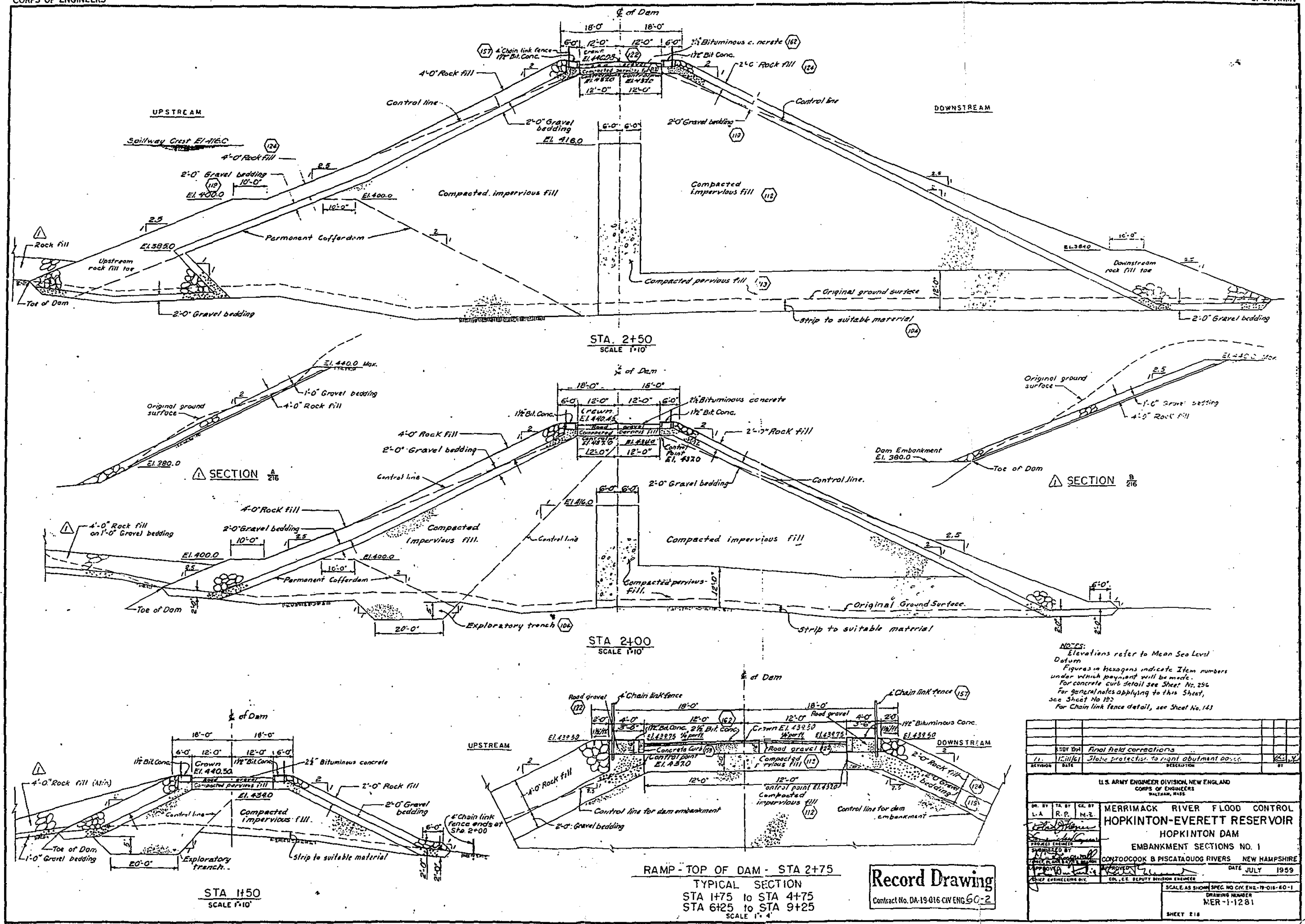
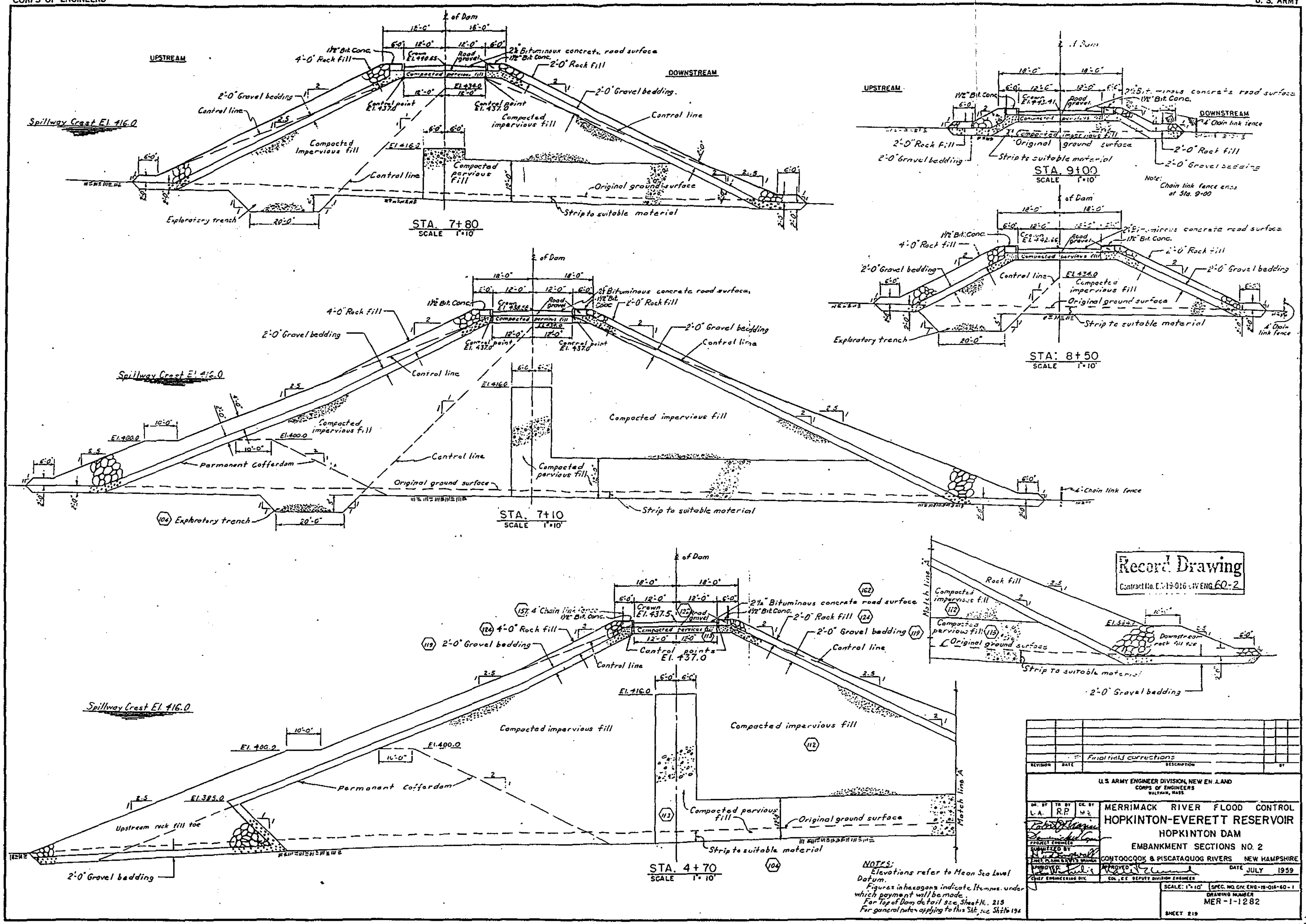


PLATE 23



UPSTREAM
DOWNSTREAM
Spillway Crest El. 416.0
STA. 7+80
SCALE 1"=10'
STA. 9+00
SCALE 1"=10'
Note: Chain link fence ends at Sta. 9+00
STA. 8+50
SCALE 1"=10'
STA. 7+10
SCALE 1"=10'
STA. 4+70
SCALE 1"=10'
2 1/2" Bituminous concrete road surface
1 1/2" Bit. Conc.
4'-0" Rock fill
2'-0" Rock fill
2'-0" Gravel bedding
Control line
Control point El. 437.0
Compacted impervious fill
Compacted pervious fill
Original ground surface
Strip to suitable material
Exploratory trench
Permanent Cofferdam
4' Chain link fence
Upstream rock fill toe
Downstream rock fill toe
Match line A
Record Drawing
Contract No. DA-19-016-CIV ENG 60-2
NOTES:
Elevations refer to Mean Sea Level Datum.
Figures in hexagons indicate items under which payment will be made.
For Top of Dam detail see Sheet No. 213
For general notes applying to this Sht. see Sht. No. 194
Final field corrections
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.
MERRIMACK RIVER FLOOD CONTROL
HOPKINTON-EVERETT RESERVOIR
HOPKINTON DAM
EMBANKMENT SECTIONS NO. 2
CONTOOCOOK & PISCATAQUOG RIVERS NEW HAMPSHIRE
DATE JULY 1959
SCALE: 1"=10'
SPEC. NO. CIV. ENG-19-016-60-1
DRAWING NUMBER MER-1-1282
SHEET 219

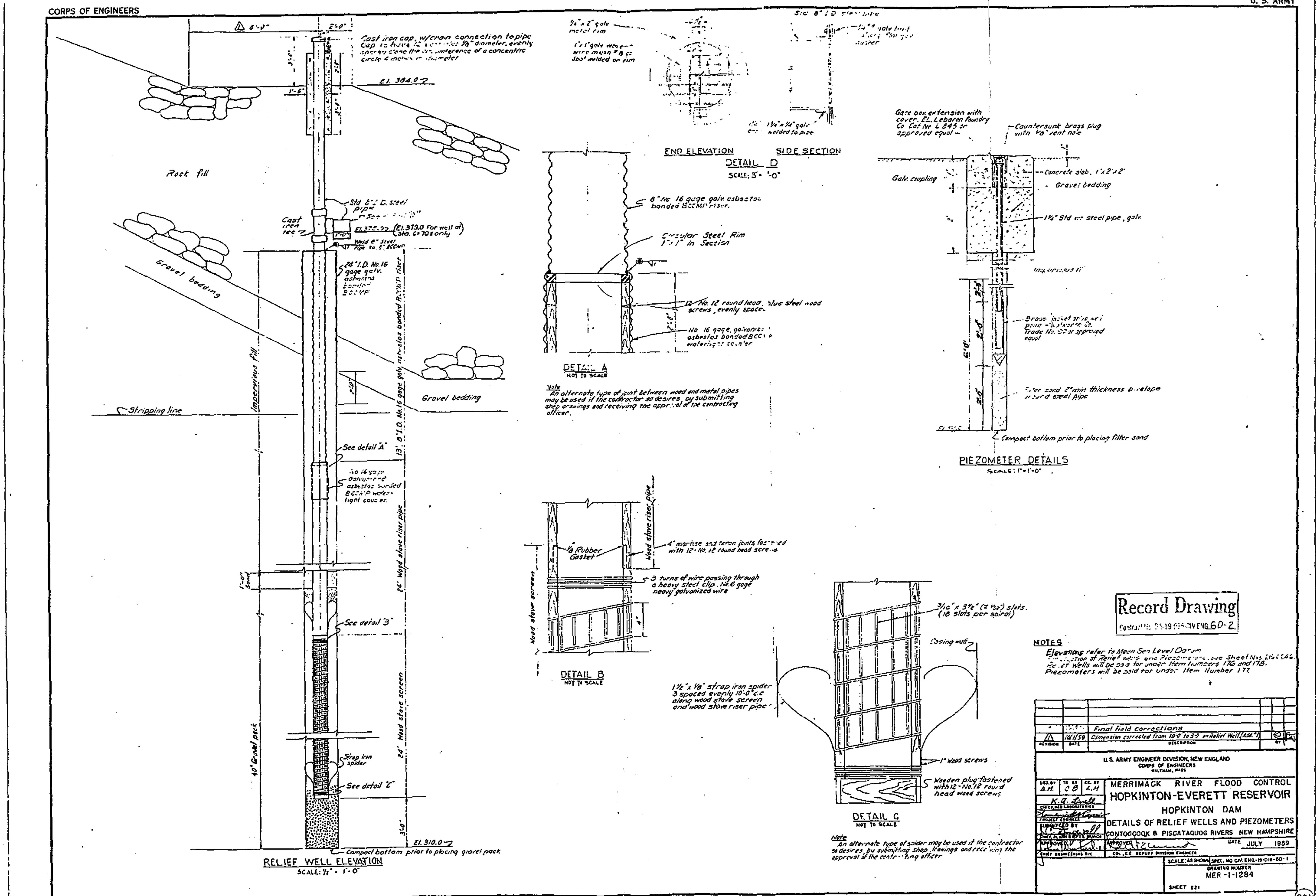

Cast iron cap, w/chain connection to pipe
El. 384.0
Rock fill
Gravel bedding
Cast iron tee
Impervious fill
Stripping line
See detail "A"
See detail "B"
See detail "C"
Strap iron spider
40' Gravel pack
24' Wood stave riser pipe
24' Wood stave screen
El. 310.0
Compact bottom prior to placing gravel pack
RELIEF WELL ELEVATION
SCALE: 1/2" = 1'-0"
END ELEVATION
SIDE SECTION
DETAIL D
SCALE: 3" = 1'-0"
8" No. 16 gage galv. asbestos bonded BCCMP riser.
Circular Steel Rim 1"x1" in Section
No. 16 gage galvanized asbestos bonded BCCMP watertight coupler
DETAIL A
NOT TO SCALE
Note
An alternate type of joint between wood and metal pipes may be used if the contractor so desires, by submitting shop drawings and receiving the approval of the contracting officer.
1/8" Rubber Gasket
4" mortise and tenon joints fastened with 12 - No. 12 round head screws
3 turns of wire passing through a heavy steel clip. No. 6 gage heavy galvanized wire
Wood stave screen
Wood stave riser pipe
DETAIL B
NOT TO SCALE
1 1/2" x 1/8" strap iron spider 3 spaced evenly 10'-0" c.c along wood stave screen and wood stave riser pipe
3/16" x 3 1/2" (± 1/32") slots. (18 slots per spiral)
Casing wall
1" Wood screws
Wooden plug fastened with 12 - No. 12 round head wood screws
DETAIL C
NOT TO SCALE
Note
An alternate type of spider may be used if the contractor so desires, by submitting shop drawings and receiving the approval of the contracting officer
Gate box extension with cover, EL. Lebaron Foundry Co. Cat. No. L 645 or approved equal
Countersunk brass plug with 1/8" vent hole
Galv. coupling
Concrete slab, 1'x2'x2'
Gravel bedding
1 1/4" Std wt steel pipe, galv.
Impervious fill
Compact bottom prior to placing filter sand
PIEZOMETER DETAILS
SCALE: 1" = 1'-0"
Record Drawing
NOTES
Elevations refer to Mean Sea Level Datum
Relief Wells will be paid for under Item Numbers 176 and 178.
Piezometers will be paid for under Item Number 177.
Final field corrections
Dimension corrected from 10'-0" to 5'-0" on Relief Well
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.
MERRIMACK RIVER FLOOD CONTROL
HOPKINTON-EVERETT RESERVOIR
HOPKINTON DAM
DETAILS OF RELIEF WELLS AND PIEZOMETERS
CONTOOCOOK & PISCATAQUOG RIVERS NEW HAMPSHIRE
DATE JULY 1959
DRAWING NUMBER
MER-1-1284
SHEET 221

PLATE 25

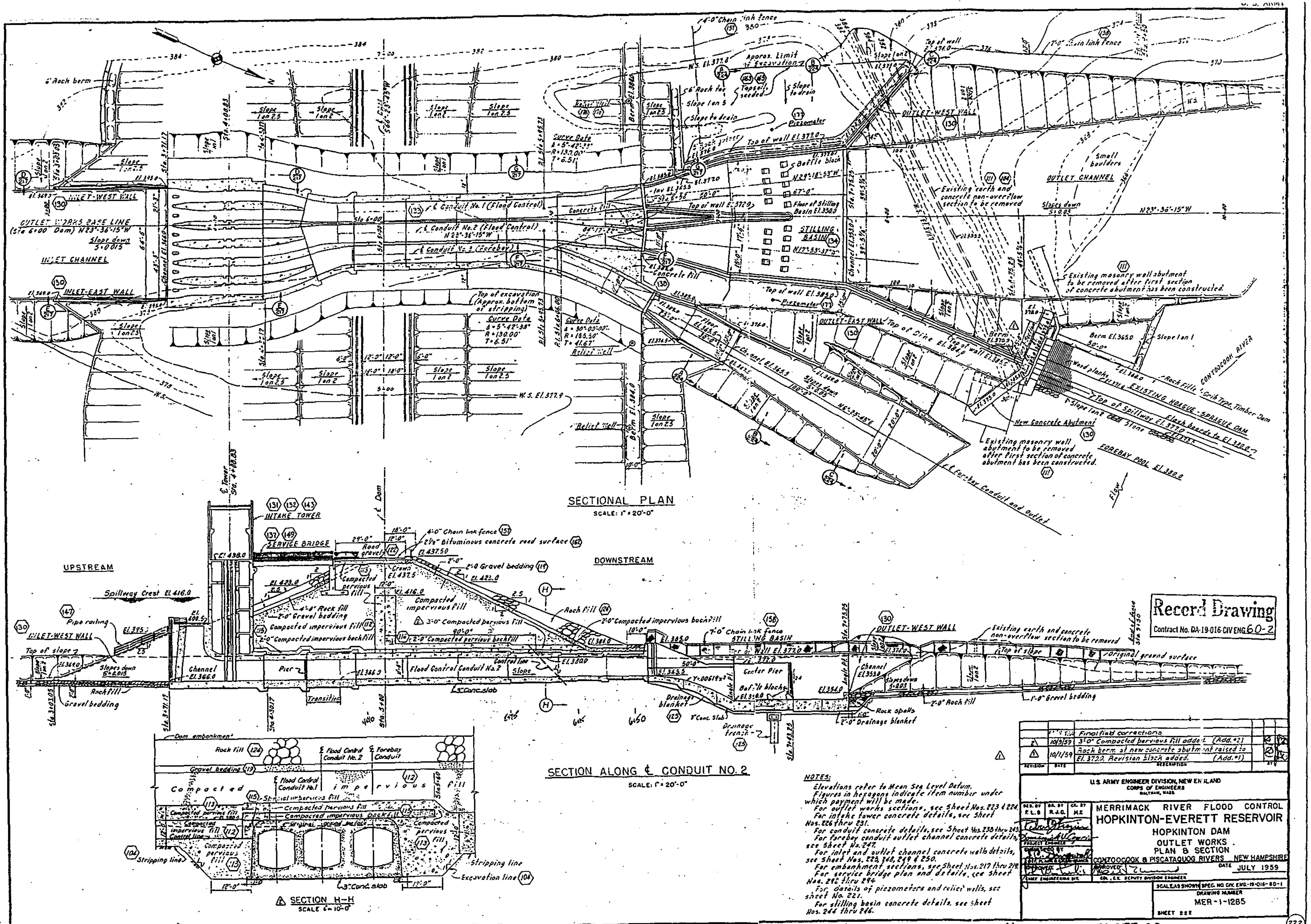
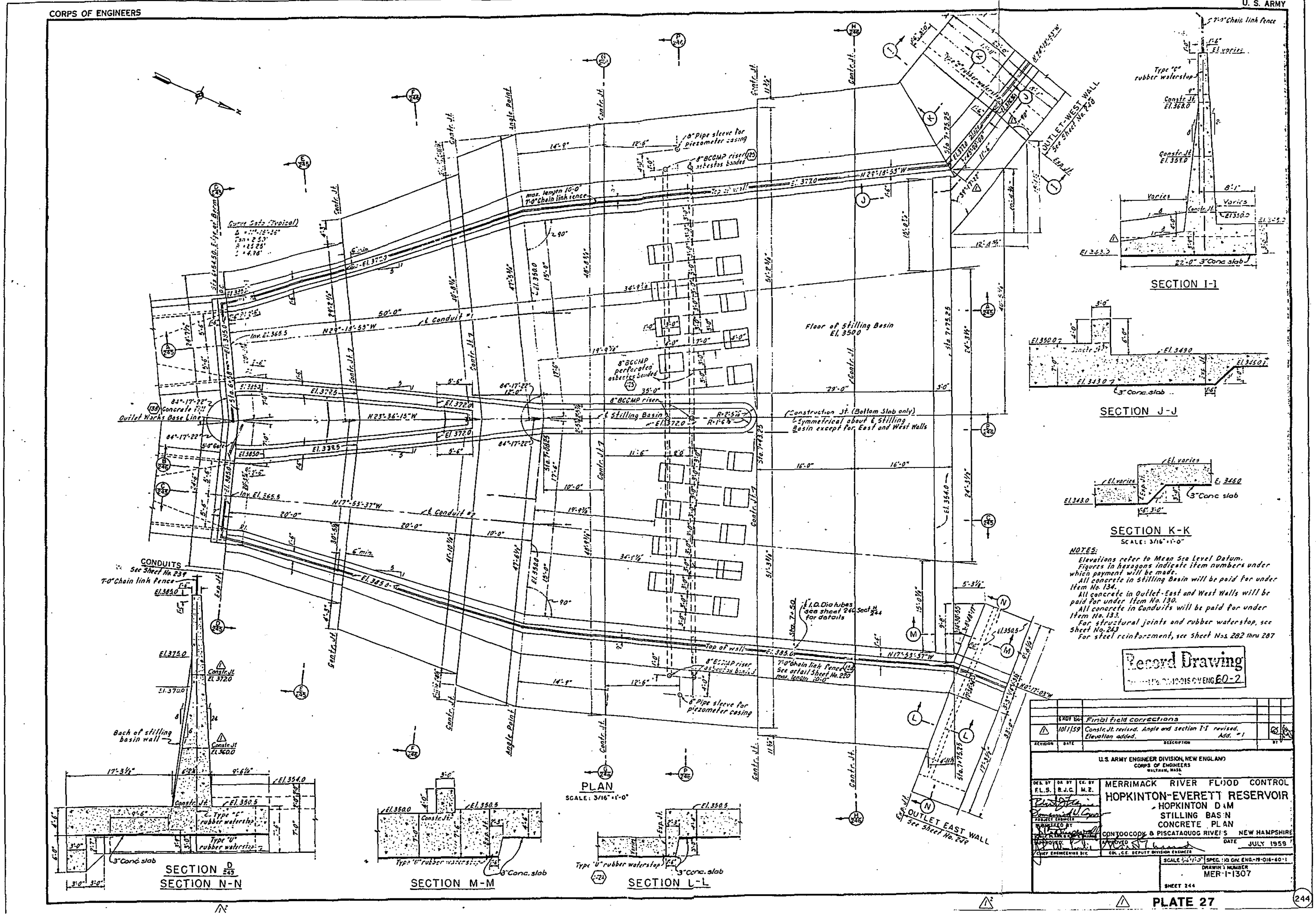
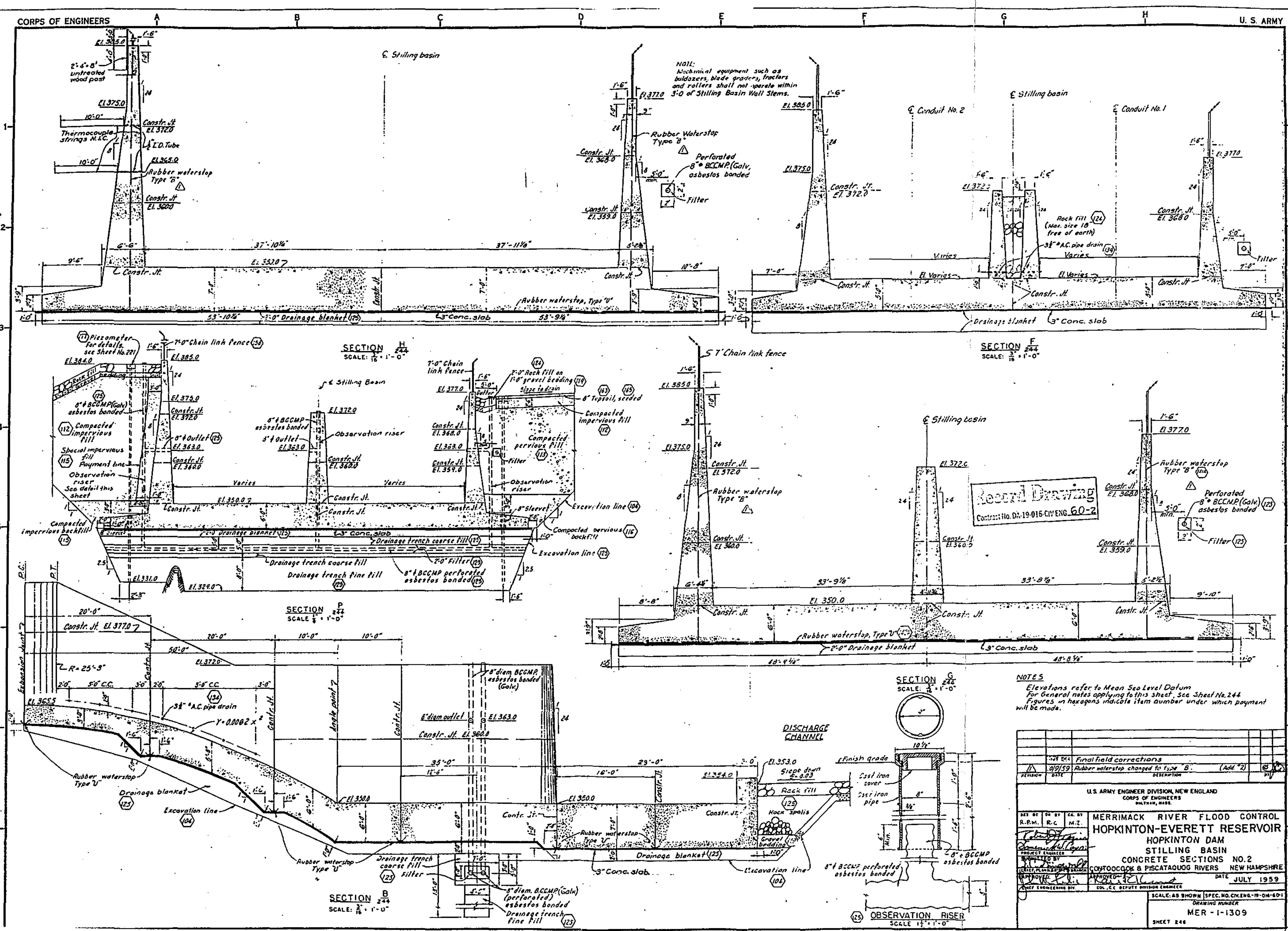

SECTIONAL PLAN
SCALE: 1" = 20'-0"
INLET-WEST WALL
INLET-EAST WALL
OUTLET WORKS BASE LINE (Sta 6+00 Dam) N23°-36'-15"W
Slope down 5:0.015
INLET CHANNEL
℄ Conduit No. 1 (Flood Control)
℄ Conduit No. 2 (Flood Control) N23°-36'-15"W
℄ Conduit No. 3 (Forebay)
OUTLET-WEST WALL
OUTLET-EAST WALL
OUTLET CHANNEL
STILLING BASIN
Baffle block
Floor of Stilling Basin El. 350.0
Existing earth and concrete non-overflow section to be removed
Existing masonry wall abutment to be removed after first section of concrete abutment has been constructed.
Small boulders
EXISTING HOAGUE-SPRAGUE DAM
CONTOOCOOK RIVER
Crib Type Timber Dam
New Concrete Abutment
FOREBAY POOL EL 380.0
℄ Forebay Conduit and Outlet
Flow
Relief well
Piezometer
Curve Data
SECTION ALONG ℄ CONDUIT NO. 2
SCALE: 1" = 20'-0"
UPSTREAM
DOWNSTREAM
INTAKE TOWER
SERVICE BRIDGE
Spillway Crest El 416.0
Pipe railing
Channel El. 366.0
Flood Control Conduit No. 2
Center Pier
Baffle blocks
Drainage blanket
Drainage trench
Rock fill
Compacted pervious fill
Compacted impervious backfill
Gravel bedding
Existing earth and concrete non-overflow section to be removed
Original ground surface
SECTION H-H
SCALE 1" = 10'-0"
Dam embankment
Stripping line
Excavation line
3" Conc. slab
Record Drawing
Contract No. DA-19-016-CIVENG 60-2
NOTES:
Elevations refer to Mean Sea Level Datum.
Figures in hexagons indicate item number under which payment will be made.
For outlet works sections, see Sheet Nos. 223 & 224.
For intake tower concrete details, see Sheet Nos. 226 thru 231.
For conduit concrete details, see Sheet Nos. 238 thru 243.
For forebay conduit outlet channel concrete details, see Sheet No. 247.
For inlet and outlet channel concrete walls details, see Sheet Nos. 225, 248, 249 & 250.
For embankment sections, see Sheet Nos. 217 thru 219.
For service bridge plan and details, see Sheet Nos. 292 thru 294.
For details of piezometers and relief wells, see sheet No. 221.
For stilling basin concrete details, see sheet Nos. 244 thru 246.
Final field corrections
2 10/9/59 3'-0" Compacted pervious fill added. (Add. #2)
1 10/1/59 Rock berm at new concrete abutment raised to El. 372.0. Revision block added. (Add. #1)
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.
MERRIMACK RIVER FLOOD CONTROL
HOPKINTON-EVERETT RESERVOIR
HOPKINTON DAM
OUTLET WORKS
PLAN & SECTION
CONTOOCOOK & PISCATAQUOG RIVERS NEW HAMPSHIRE
DATE JULY 1959
SCALE: AS SHOWN
SPEC. NO. CIV. ENG.-19-016-60-1
DRAWING NUMBER
MER-1-1285
SHEET 222

PLATE 26


CORPS OF ENGINEERS
U. S. ARMY
OUTLET-WEST WALL
See Sheet No. 248
OUTLET EAST WALL
See Sheet No. 249
Floor of Stilling Basin
El. 350.0
Outlet Works Base Line
℄ Conduit #1
℄ Conduit #2
℄ Stilling Basin
Construction Jt. (Bottom Slab only)
℄ Symmetrical about ℄ Stilling Basin except for East and West Walls
8" BCCMP riser asbestos bonded
8" BCCMP perforated asbestos bonded
6" Pipe sleeve for piezometer casing
7'-0" Chain link fence
Top of wall
Angle Point
Contr. Jt.
CONDUITS
See Sheet No. 239
SECTION I-I
SECTION J-J
SECTION K-K
SCALE: 3/16" = 1'-0"
PLAN
SCALE: 3/16" = 1'-0"
SECTION D/245
SECTION N-N
SECTION M-M
SECTION L-L
Type "C" rubber waterstop
Type "U" rubber waterstop
3" Conc. slab
NOTES:
Elevations refer to Mean Sea Level Datum.
Figures in hexagons indicate item numbers under which payment will be made.
All concrete in Stilling Basin will be paid for under Item No. 134.
All concrete in Outlet-East and West Walls will be paid for under Item No. 130.
All concrete in Conduits will be paid for under Item No. 133.
For structural joints and rubber waterstop, see Sheet No. 243
For steel reinforcement, see Sheet Nos. 282 thru 287
Record Drawing
Final field corrections
10/1/59 Constr. Jt. revised. Angle and section I-I revised. Elevation added. Add. #1
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.
MERRIMACK RIVER FLOOD CONTROL
HOPKINTON-EVERETT RESERVOIR
HOPKINTON DAM
STILLING BASIN
CONCRETE PLAN
CONTOOCOOK & PISCATAQUOG RIVERS NEW HAMPSHIRE
DATE JULY 1959
SPEC. NO. CIV. ENG.-19-016-60-1
DRAWING NUMBER MER-1-1307
SHEET 244
PLATE 27
244



CORPS OF ENGINEERS
U. S. ARMY
SECTION H 244
SCALE: 3/16" = 1'-0"
SECTION F 244
SCALE: 3/16" = 1'-0"
SECTION P 244
SCALE 1/8" = 1'-0"
SECTION G 244
SCALE: 1/8" = 1'-0"
SECTION B 244
SCALE: 3/16" = 1'-0"
OBSERVATION RISER
SCALE 1 1/2" = 1'-0"
DISCHARGE CHANNEL
℄ Stilling basin
℄ Conduit No. 2
℄ Conduit No. 1
NOTE: Mechanical equipment such as buldozers, blade graders, tractors and rollers shall not operate within 3'-0 of Stilling Basin Wall Stems.
Rubber waterstop Type "B"
Perforated 8" ⌀ BCCMP (Galv, asbestos bonded)
Filter
Constr. Jt.
Drainage blanket
3" Conc. slab
Rubber waterstop, Type "U"
7'-0" Chain link fence
Compacted impervious fill
Compacted pervious fill
Excavation line
Drainage trench coarse fill
Drainage trench fine fill
Observation riser
Rock fill
Rock spalls
Gravel bedding
Finish grade
Cast iron cover
Cast iron pipe
Record Drawing
Contract No. DA-19-016-CIV ENG. 60-2
NOTES
Elevations refer to Mean Sea Level Datum
For General notes applying to this sheet, See Sheet No. 244
Figures in hexagons indicate item number under which payment will be made.
Final field corrections
0/9/59 Rubber waterstop changed to type "B" (Add. "2")
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.
MERRIMACK RIVER FLOOD CONTROL
HOPKINTON-EVERETT RESERVOIR
HOPKINTON DAM
STILLING BASIN
CONCRETE SECTIONS NO. 2
CONTOOCOOK & PISCATAQUOG RIVERS NEW HAMPSHIRE
JULY 1959
SCALE: AS SHOWN
MER - 1 - 1309
SHEET 246

PLATE 28

Appendix A

Field Procedures:

Standards For Settlement Surveys, Reading Schedule for Piezometers

Standard No. 1

The following standards and procedures are employed for Crest Monument Surveys at Corps of Engineers Dams.

Standards For Settlement Surveys

1. Control points are stamped brass disks, preferably set in a ledge area. Where no ledge is available, they are set in concrete bounds placed flush with the ground.

2. Control points are set in areas such that the maximum possible number of crest monuments on the dam are visible.

3. Control points are tied into four reference points by distance. This provides a check each time they are occupied for settlement surveys or allows them to be replaced if found to be destroyed.

4. Distances are read and recorded between settlement bounds. Both distance and angle are read and recorded from the control points that are being occupied to locate each settlement bound on the dam.

5. In locating each settlement bound, a control point will be occupied setting 0-00'-00" (referenced line of site) on a second control point, reading and recording both interior and exterior angle closure, along with distances through each settlement bound located on the dam. Each settlement bound is located from a minimum of two control points. These locations are third order, class II survey with relative accuracies of not less than 1 part in 5,000.

6. Levels are run from control points through each settlement bound on the dam with a return run back into the control points to check the elevation closure on the run.

Closure tolerance should be no greater than 0.05 foot. These levels are third order, Class I survey with relative accuracies not less than 1 part in 10,000.

7. Crest monument surveys are performed using Topcon EDM Total Stations and recording both horizontal angles and horizontal distances.

Procedure Followed For Settlement Surveys

The horizontal and vertical monitoring plan for settlement bound movement points employed a combination of triangulation and trilateration angle and distance techniques to survey the control network. Control points, in the form of stamped brass disks, were placed off the dam structure in areas from which the entire length of the dam is visible. Settlement bounds themselves, with stamped brass disks, were placed on the dam structure in a location that is clearly visible from the control points. Horizontal coordinates of the control points are based on the State Plane Coordinate System. Elevations of the control points are based on the National Geodetic Vertical Datum (NGVD). Control points are occupied utilizing an EDM Total Station; observed distances and angles (interior and exterior angles), between control points and settlement bound establishing permanent bench marks. Standard leveling techniques are followed. Levels are double run and the means of the front and back runs were computed and recorded.

Data Adjustment

A combination of triangulation and trilateration surveying techniques are applied. Each crest monument is located from two control points and two sets of coordinates are calculated using adjusted field angles and compliments and EDM distances. The two sets of coordinates are averaged to give a net result. The averaged coordinates are then established on each settlement bound for use in determining shifts in the dam surface structure over a period of years by comparing repetitive surveys.

Reading Schedule for Piezometers

General. Piezometers are utilized to measure groundwater levels and pore pressures within the foundation and embankments of earth and rockfill dams. Experience has shown that installation of piezometers in earth fills and their foundation provides significant data indicating the magnitude and distribution of pore pressures and their variations with time and also patterns of seepage, zones of potential piping, and the effectiveness of under seepage control measures.

Piezometer Readings. At the present time, files are maintained for dams which have operating piezometers and most of the data is put on the computer. Data is transmitted to GEB in writing by the project manager. Piezometer data should be reduced in the field and each reading compared with previous data; thus, if a piezometer has an unusual reading, the reading can be checked immediately. Pool elevations, tailwater elevations, measuring weir discharge quantities, and rainfall data should be recorded simultaneously with piezometer readings.

a. Reading Schedules

(1) Routine. During periods when the reservoir is at or below the 22-foot stage (Elev 388) readings should be made by the project manager at least once a month. When access to instruments is made hazardous by snow or ice, the readings may be deferred until safe access is possible.

(2) High Pool. During periods when the reservoir level (includes rising and falling pools) is above the 22 foot stage, readings should be made on a daily basis. Pool elevations and all the other information requested in paragraph 2 above should be recorded simultaneously with piezometer readings. On a falling pool, piezometer readings should continue for approximately five days after the pool has returned to its normal elevation.

b. Data Collection

(1) Location Map. A general plan of the project showing the location of the active piezometers and the corresponding identification number for each piezometer is provided to eliminate identification and data recording inaccuracies.

(2) Data Collection Tables. A table listing the piezometer identification number, stationing and offset, as well as piezometer top and tip elevations is

also provided for recording and submitting piezometer readings. It should be noted that when two piezometers are located in the same protective casing, each shall be designated with a number as well as an "A" or "B." The letter "A" will indicate the deeper piezometer riser and the letter "B" shall designate the shallower riser for each such location. All piezometers shall be clearly labeled with the appropriate identification number and letter (if required). These labels shall be installed inside of the protective casings and attached to each respective piezometer riser by the project manger.

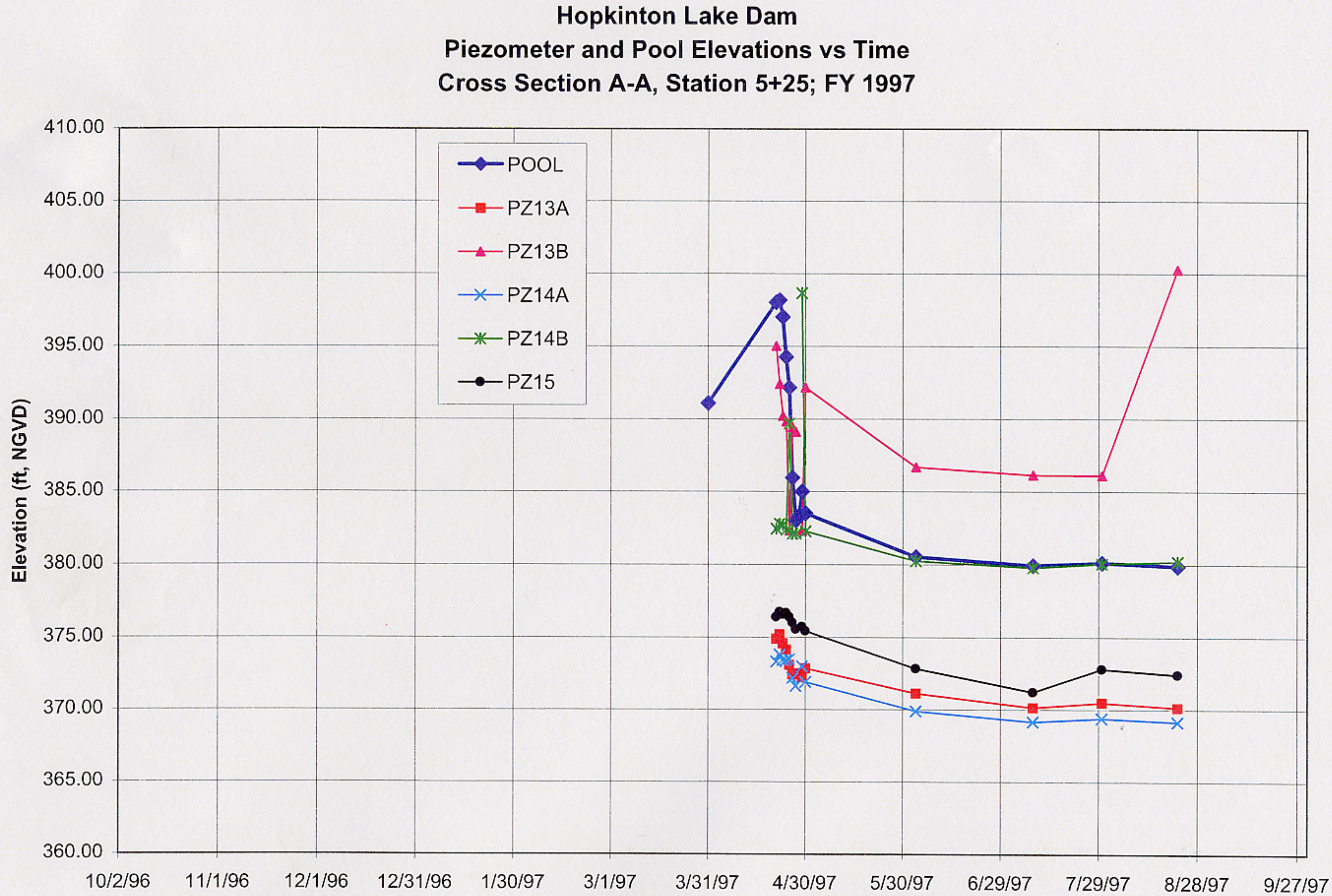
(3) Destination. All data should be sent to the following address on the first of each month.

U.S. Army Corps of Engineers
New England District
CENED-ED-GD
696 Virginia Road
Concord, MA 01742-2751
RE: PIEZOMETERS

(4) Special Conditions. If unusual changes in readings develop or if piezometers become inoperable, the Geotechnical Engineering Branch should be contacted.

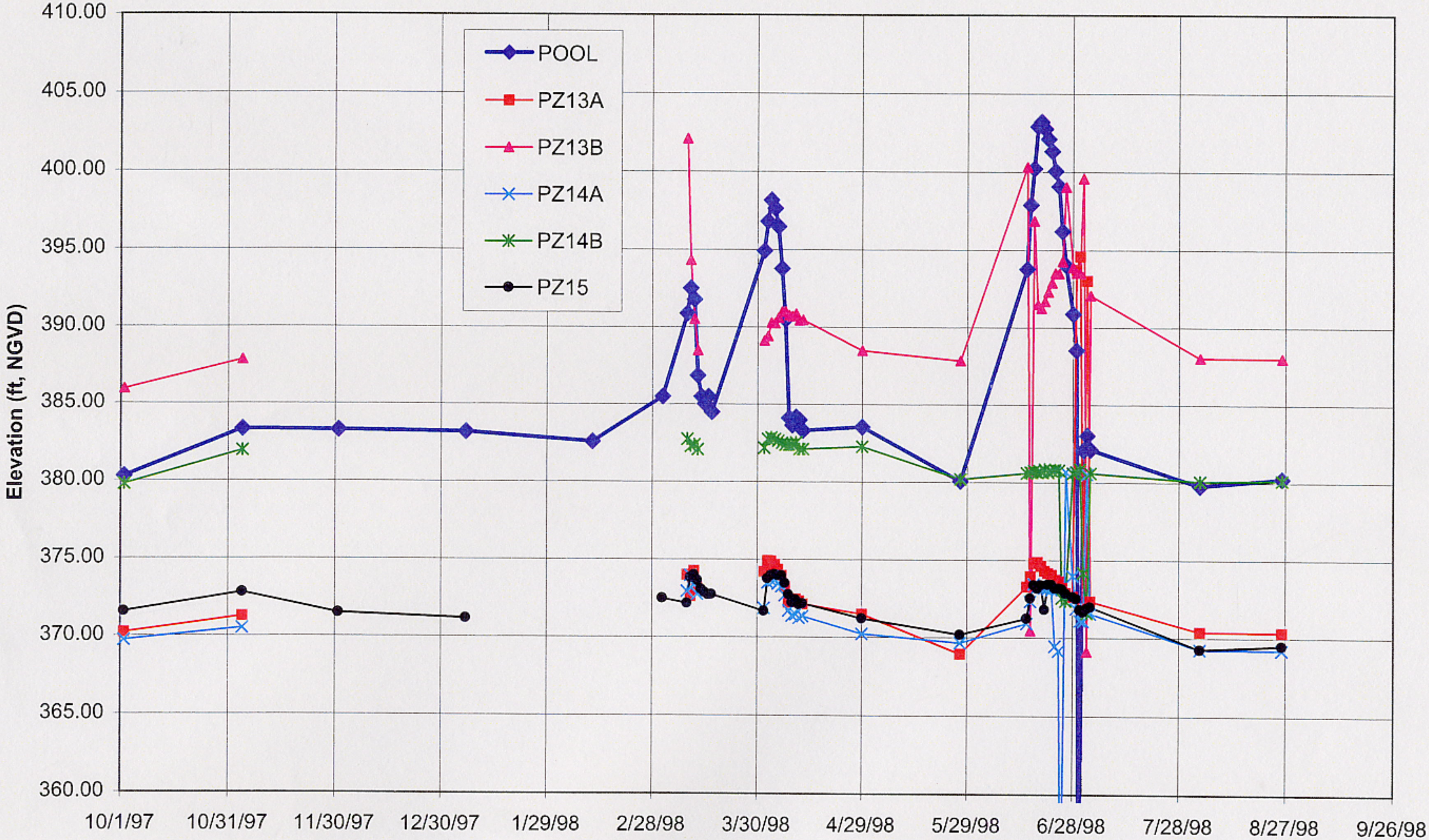
Appendix B

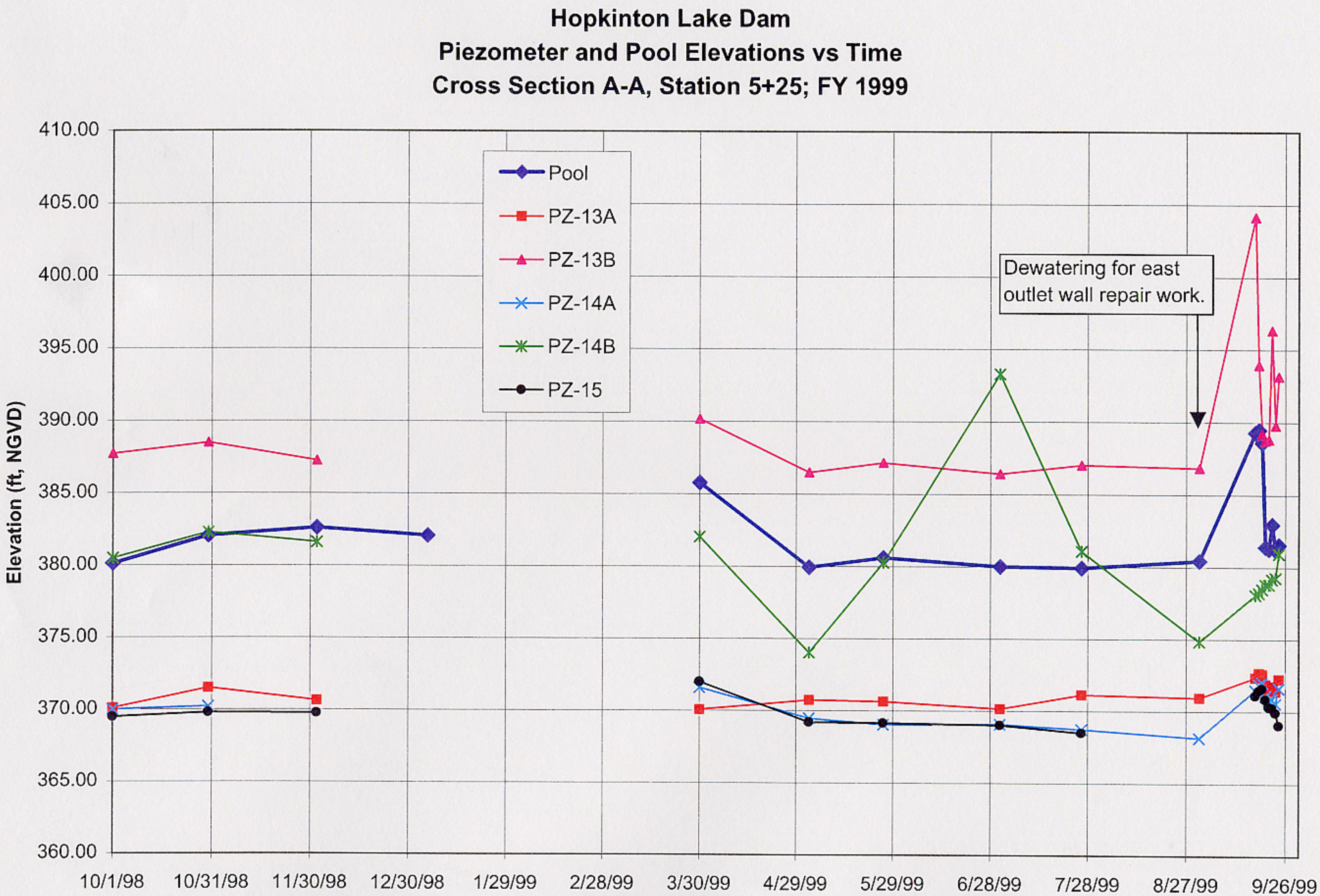
Piezometer Data, Time-History Plots



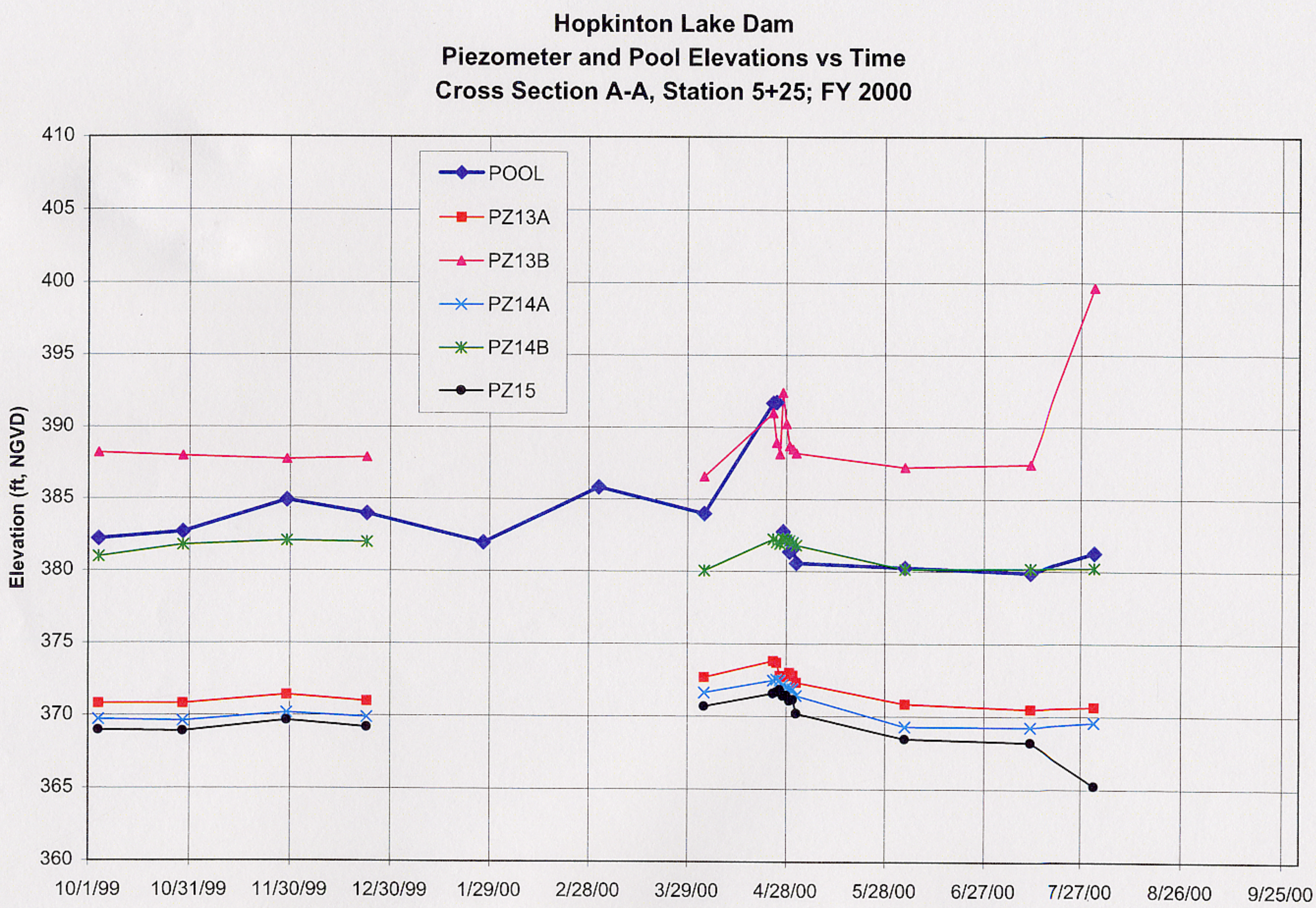
Hopkinton Lake Dam
Piezometer and Pool Elevations vs Time
Cross Section A-A, Station 5+25; FY 1997
POOL
PZ13A
PZ13B
PZ14A
PZ14B
PZ15
Elevation (ft, NGVD)
410.00
405.00
400.00
395.00
390.00
385.00
380.00
375.00
370.00
365.00
360.00
10/2/96
11/1/96
12/1/96
12/31/96
1/30/97
3/1/97
3/31/97
4/30/97
5/30/97
6/29/97
7/29/97
8/28/97
9/27/97

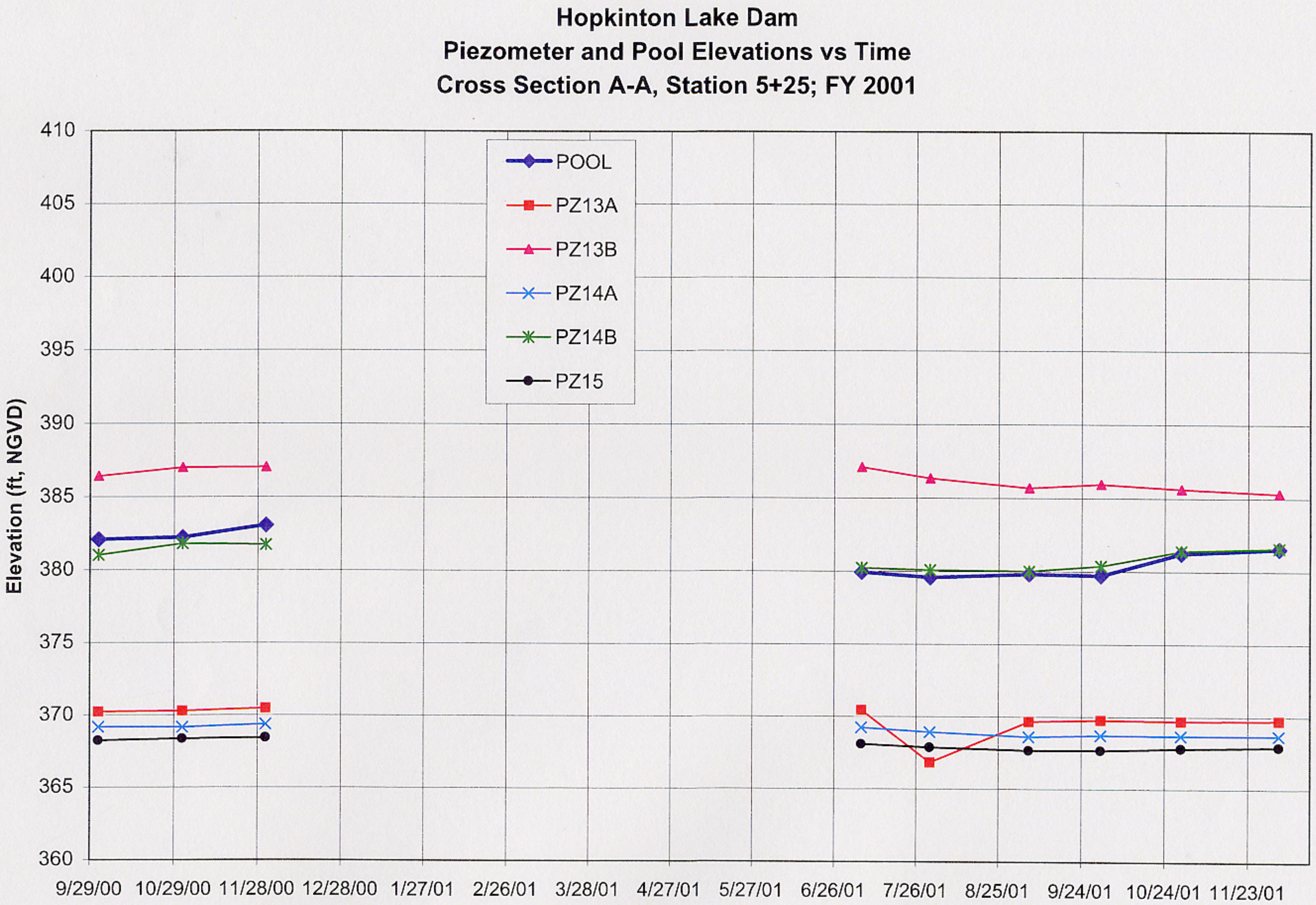
Hopkinton Lake Dam
Piezometer and Pool Elevations vs Time
Cross Section A-A, Station 5+25; FY 1998



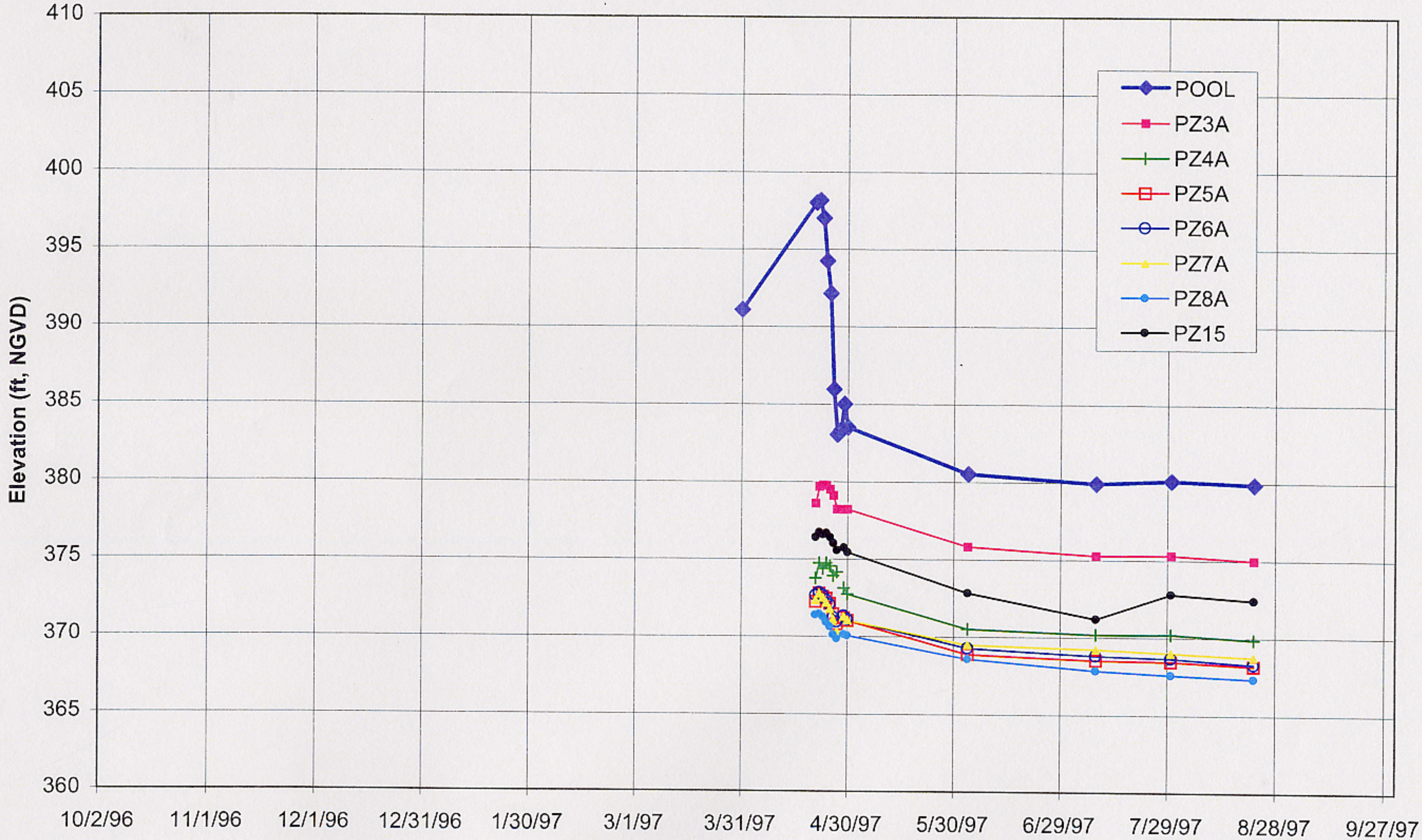


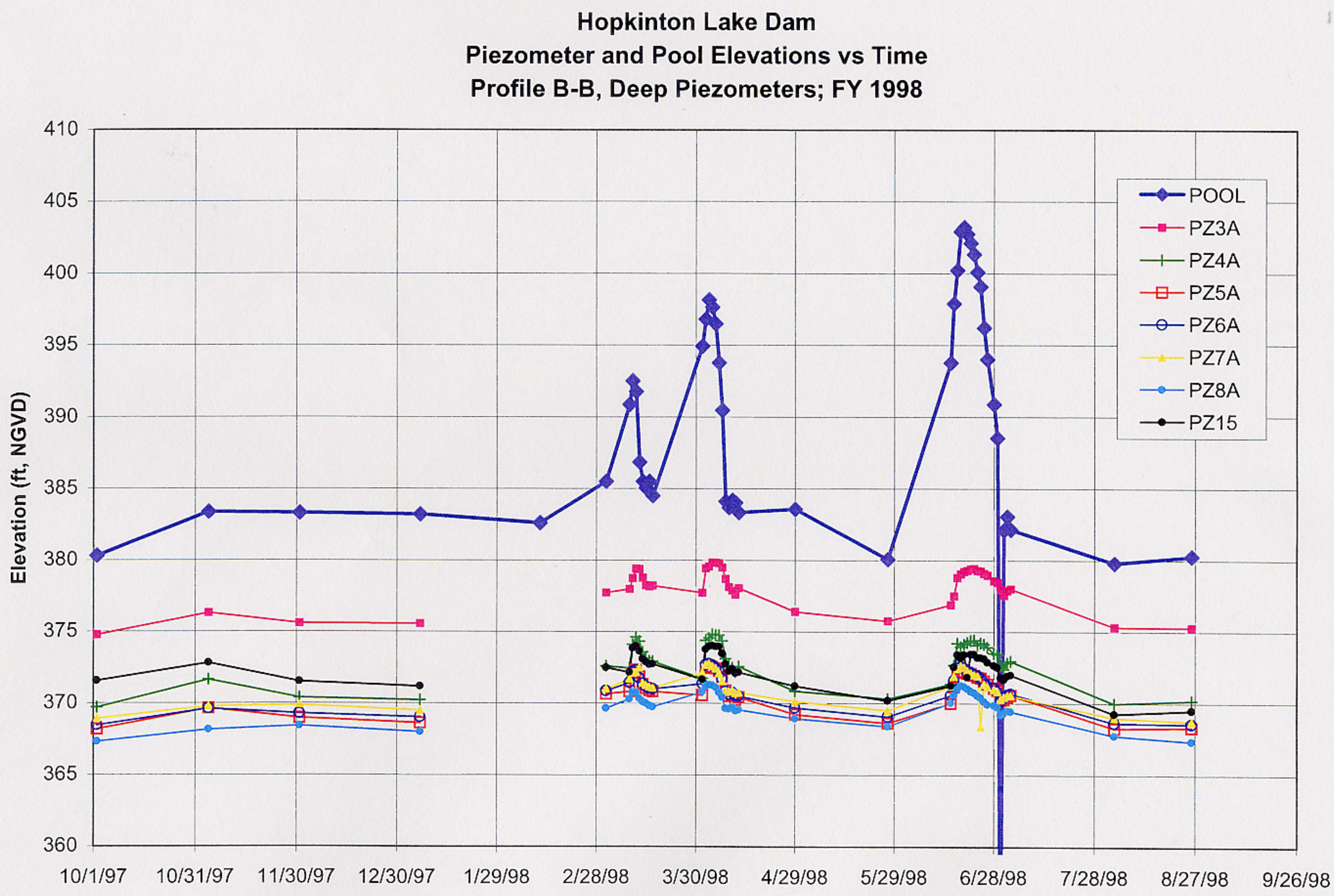
Hopkinton Lake Dam
Piezometer and Pool Elevations vs Time
Cross Section A-A, Station 5+25; FY 1999
Pool
PZ-13A
PZ-13B
PZ-14A
PZ-14B
PZ-15
Dewatering for east outlet wall repair work.
Elevation (ft, NGVD)
410.00
405.00
400.00
395.00
390.00
385.00
380.00
375.00
370.00
365.00
360.00
10/1/98
10/31/98
11/30/98
12/30/98
1/29/99
2/28/99
3/30/99
4/29/99
5/29/99
6/28/99
7/28/99
8/27/99
9/26/99


Hopkinton Lake Dam
Piezometer and Pool Elevations vs Time
Cross Section A-A, Station 5+25; FY 2000
Elevation (ft, NGVD)
410
405
400
395
390
385
380
375
370
365
360
10/1/99
10/31/99
11/30/99
12/30/99
1/29/00
2/28/00
3/29/00
4/28/00
5/28/00
6/27/00
7/27/00
8/26/00
9/25/00
POOL
PZ13A
PZ13B
PZ14A
PZ14B
PZ15

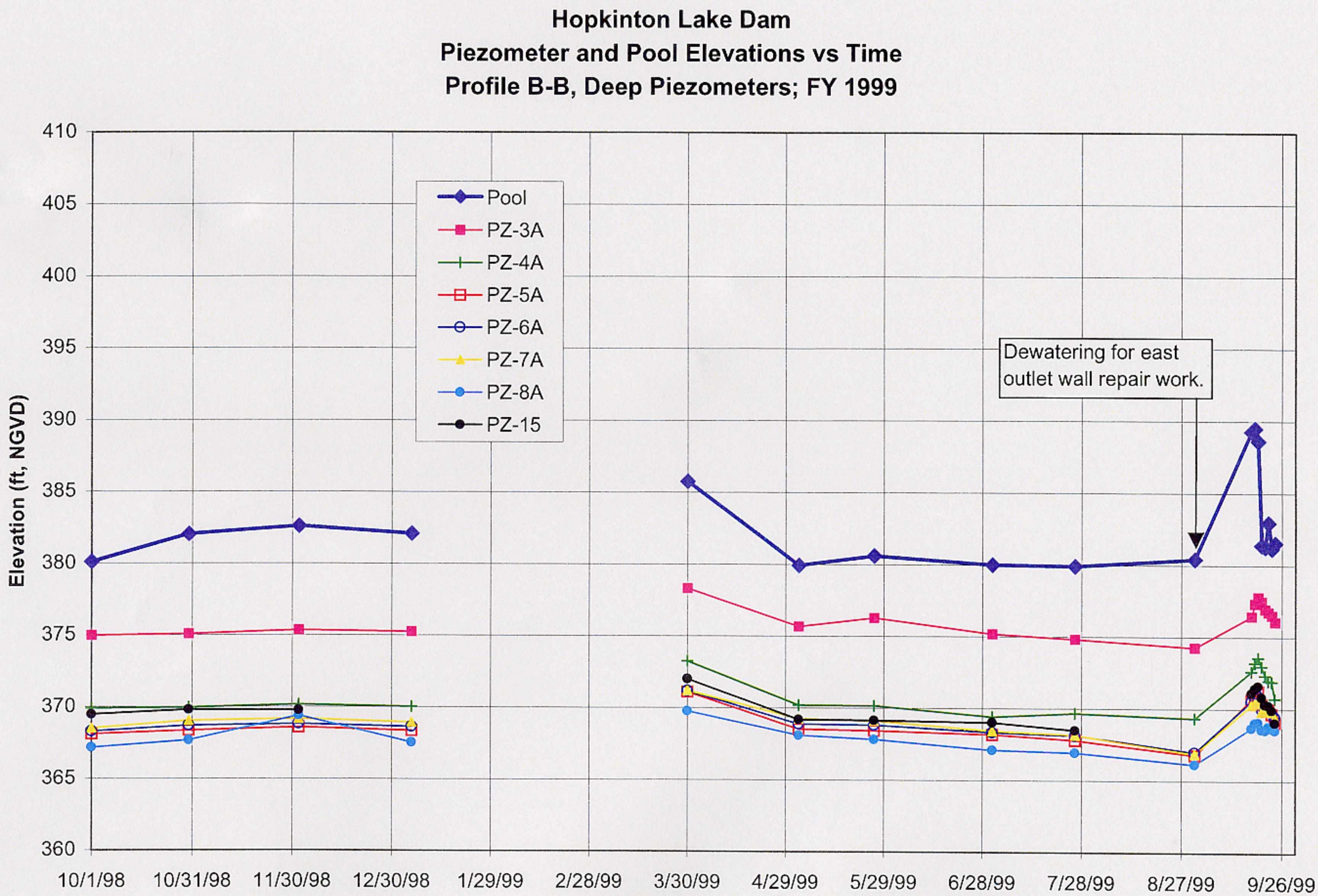

Hopkinton Lake Dam
Piezometer and Pool Elevations vs Time
Cross Section A-A, Station 5+25; FY 2001
Elevation (ft, NGVD)
410
405
400
395
390
385
380
375
370
365
360
9/29/00
10/29/00
11/28/00
12/28/00
1/27/01
2/26/01
3/28/01
4/27/01
5/27/01
6/26/01
7/26/01
8/25/01
9/24/01
10/24/01
11/23/01
POOL
PZ13A
PZ13B
PZ14A
PZ14B
PZ15

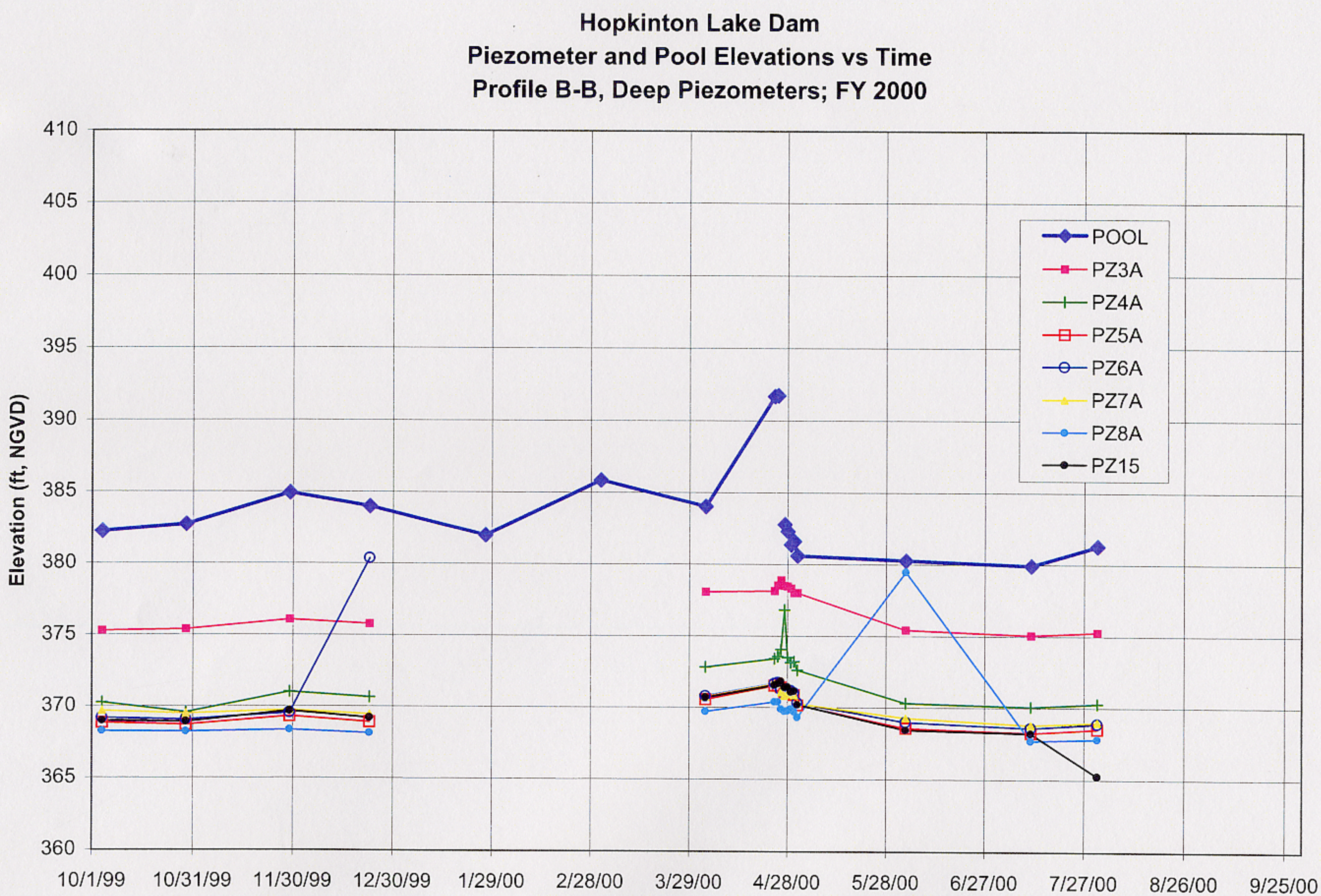
Hopkinton Lake Dam
Piezometer and Pool Elevations vs Time
Profile B-B, Deep Piezometers; FY 1997



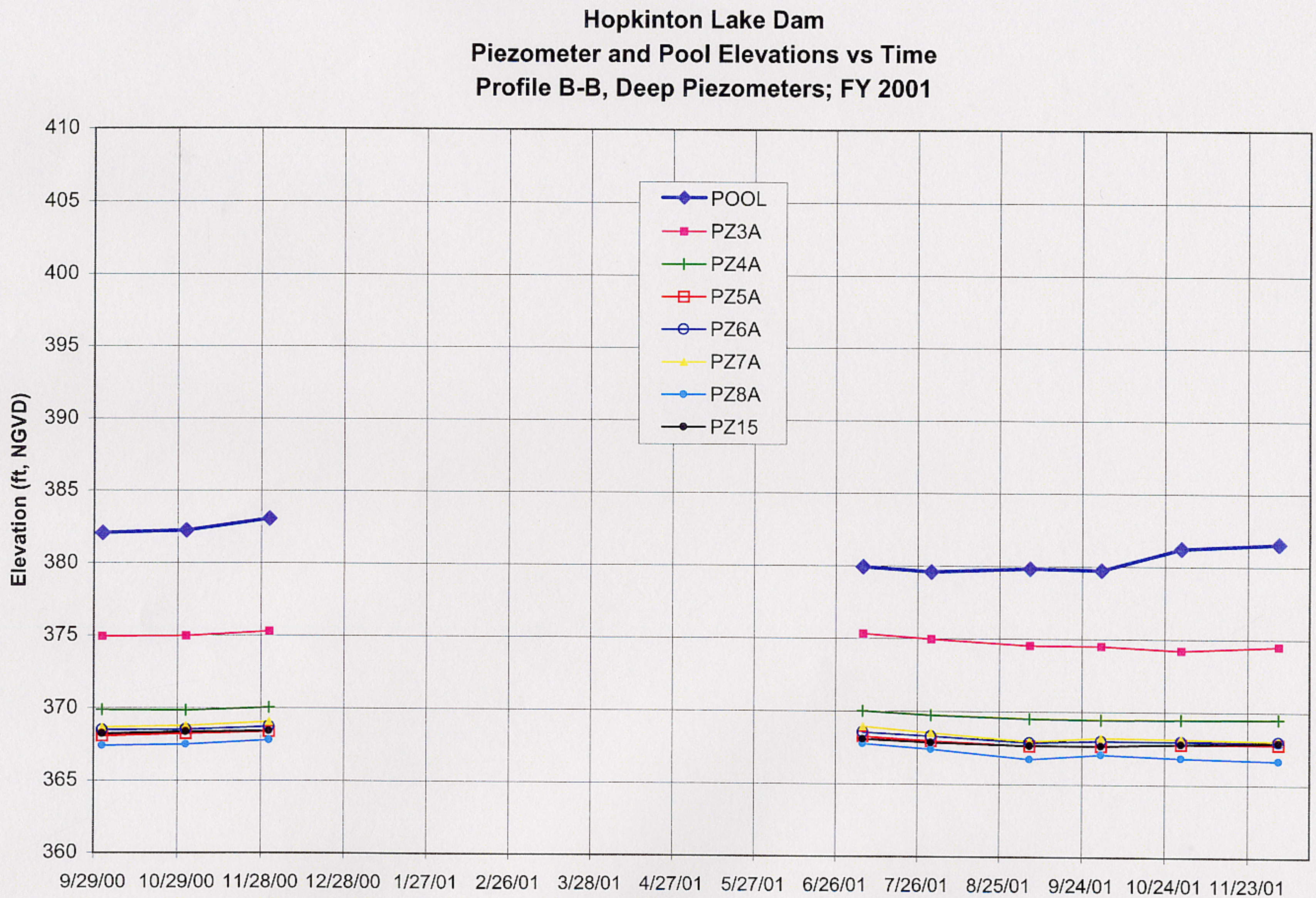


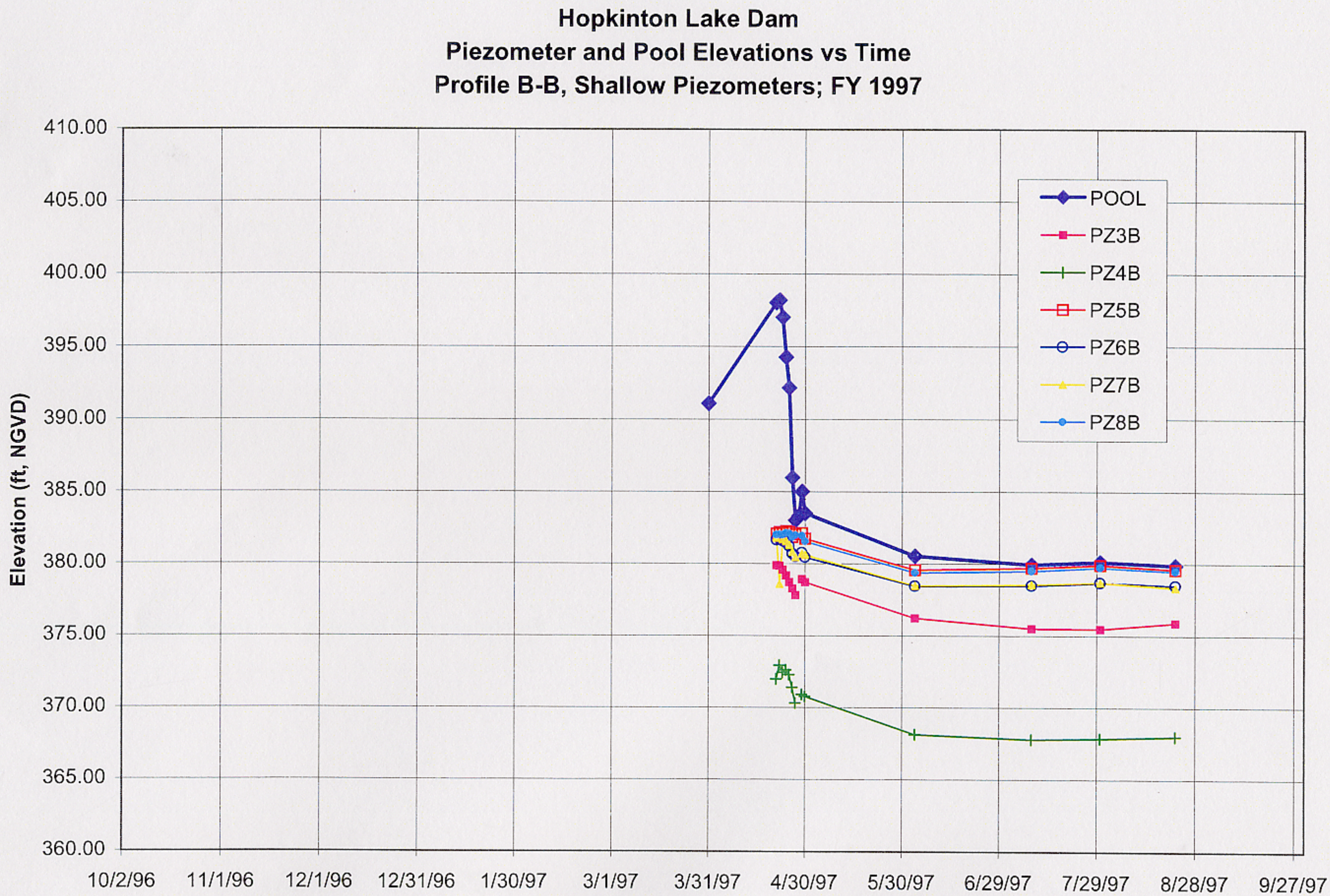
Hopkinton Lake Dam
Piezometer and Pool Elevations vs Time
Profile B-B, Deep Piezometers; FY 1998
Elevation (ft, NGVD)
410
405
400
395
390
385
380
375
370
365
360
10/1/97
10/31/97
11/30/97
12/30/97
1/29/98
2/28/98
3/30/98
4/29/98
5/29/98
6/28/98
7/28/98
8/27/98
9/26/98
POOL
PZ3A
PZ4A
PZ5A
PZ6A
PZ7A
PZ8A
PZ15


Hopkinton Lake Dam
Piezometer and Pool Elevations vs Time
Profile B-B, Deep Piezometers; FY 1999
Elevation (ft, NGVD)
410
405
400
395
390
385
380
375
370
365
360
10/1/98
10/31/98
11/30/98
12/30/98
1/29/99
2/28/99
3/30/99
4/29/99
5/29/99
6/28/99
7/28/99
8/27/99
9/26/99
Pool
PZ-3A
PZ-4A
PZ-5A
PZ-6A
PZ-7A
PZ-8A
PZ-15
Dewatering for east outlet wall repair work.



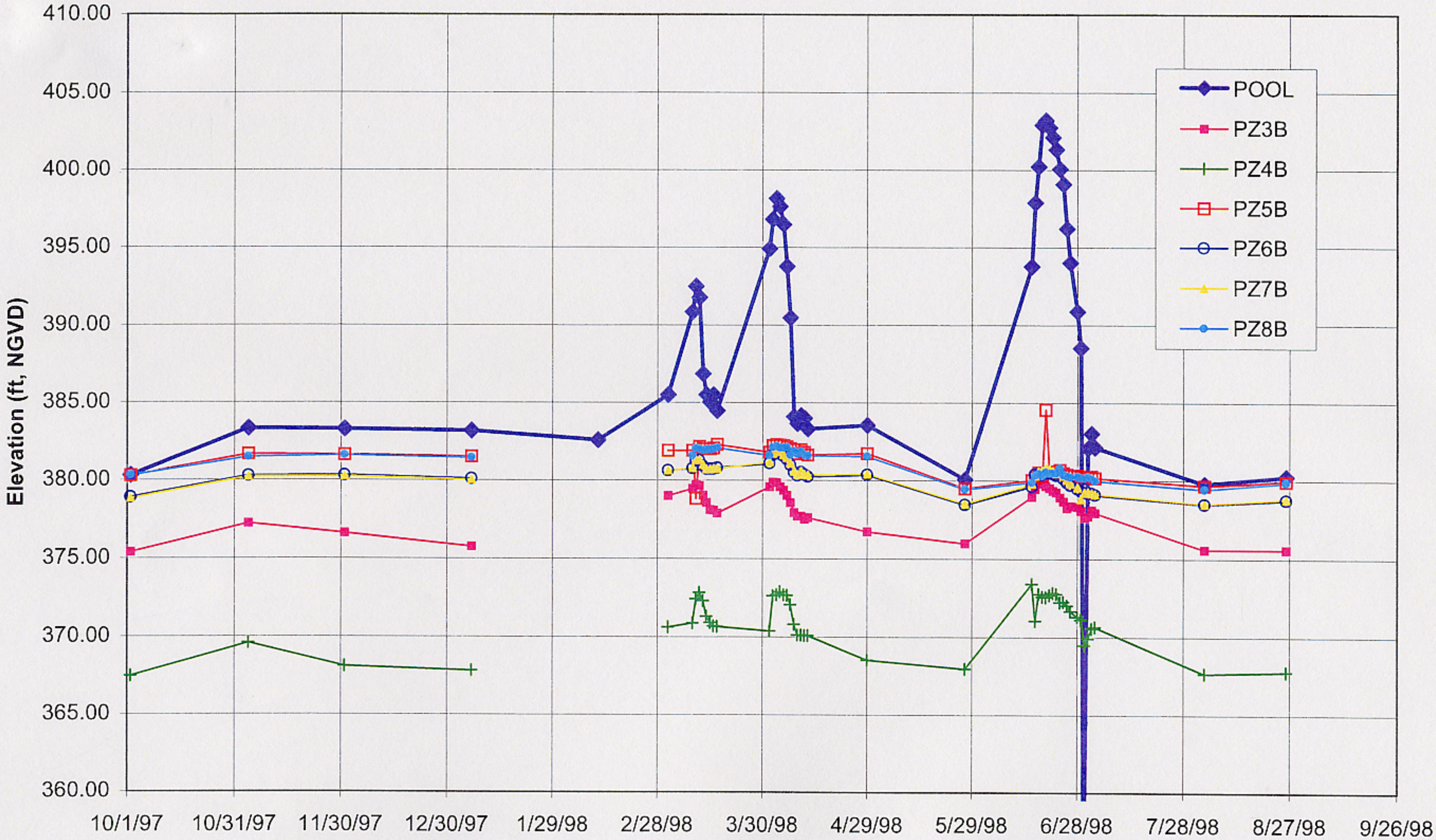
Hopkinton Lake Dam
Piezometer and Pool Elevations vs Time
Profile B-B, Deep Piezometers; FY 2000
Elevation (ft, NGVD)
410
405
400
395
390
385
380
375
370
365
360
10/1/99
10/31/99
11/30/99
12/30/99
1/29/00
2/28/00
3/29/00
4/28/00
5/28/00
6/27/00
7/27/00
8/26/00
9/25/00
POOL
PZ3A
PZ4A
PZ5A
PZ6A
PZ7A
PZ8A
PZ15

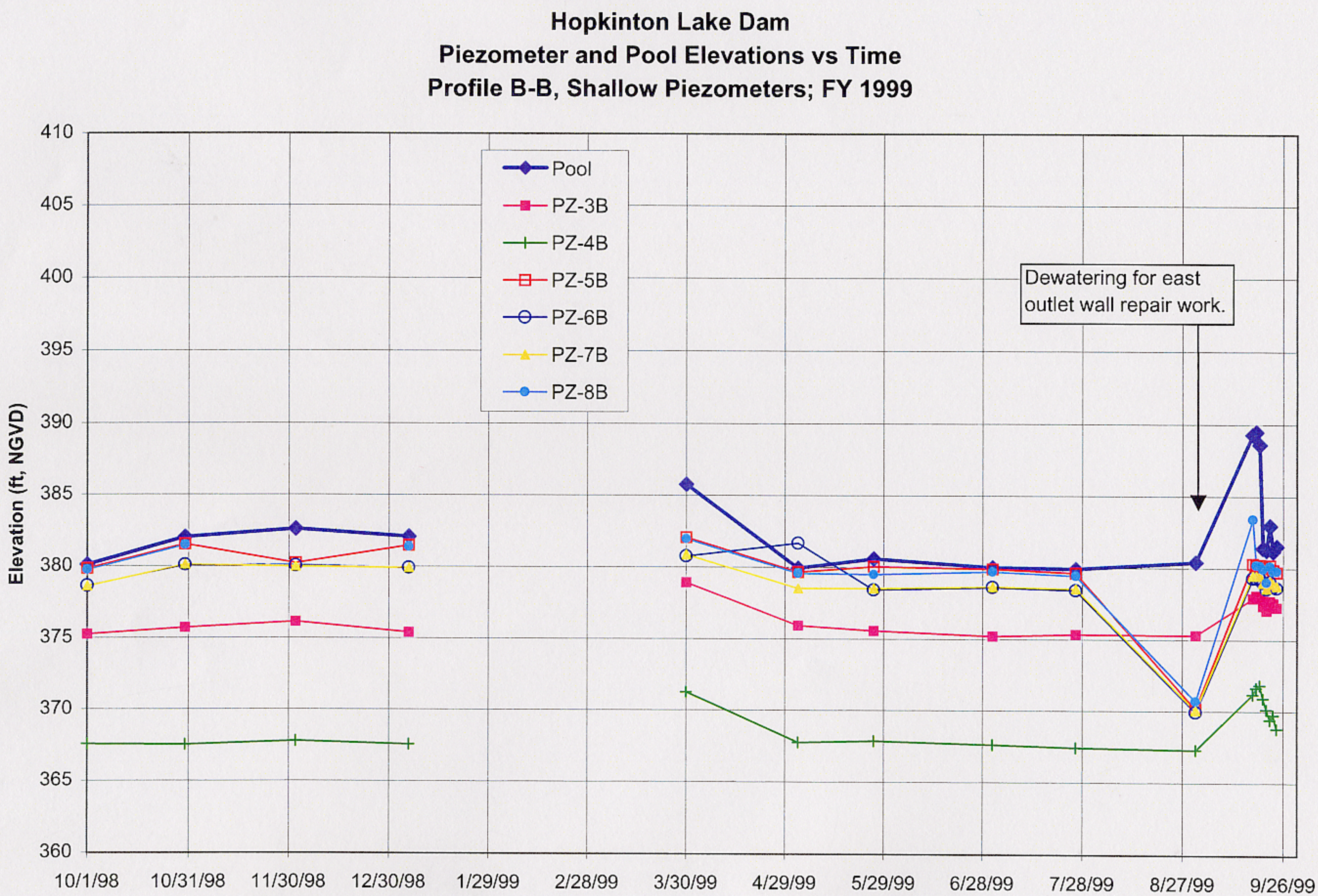

Hopkinton Lake Dam
Piezometer and Pool Elevations vs Time
Profile B-B, Deep Piezometers; FY 2001
Elevation (ft, NGVD)
410
405
400
395
390
385
380
375
370
365
360
9/29/00
10/29/00
11/28/00
12/28/00
1/27/01
2/26/01
3/28/01
4/27/01
5/27/01
6/26/01
7/26/01
8/25/01
9/24/01
10/24/01
11/23/01
POOL
PZ3A
PZ4A
PZ5A
PZ6A
PZ7A
PZ8A
PZ15



Hopkinton Lake Dam
Piezometer and Pool Elevations vs Time
Profile B-B, Shallow Piezometers; FY 1997
410.00
405.00
400.00
395.00
390.00
385.00
380.00
375.00
370.00
365.00
360.00
Elevation (ft, NGVD)
10/2/96
11/1/96
12/1/96
12/31/96
1/30/97
3/1/97
3/31/97
4/30/97
5/30/97
6/29/97
7/29/97
8/28/97
9/27/97
POOL
PZ3B
PZ4B
PZ5B
PZ6B
PZ7B
PZ8B

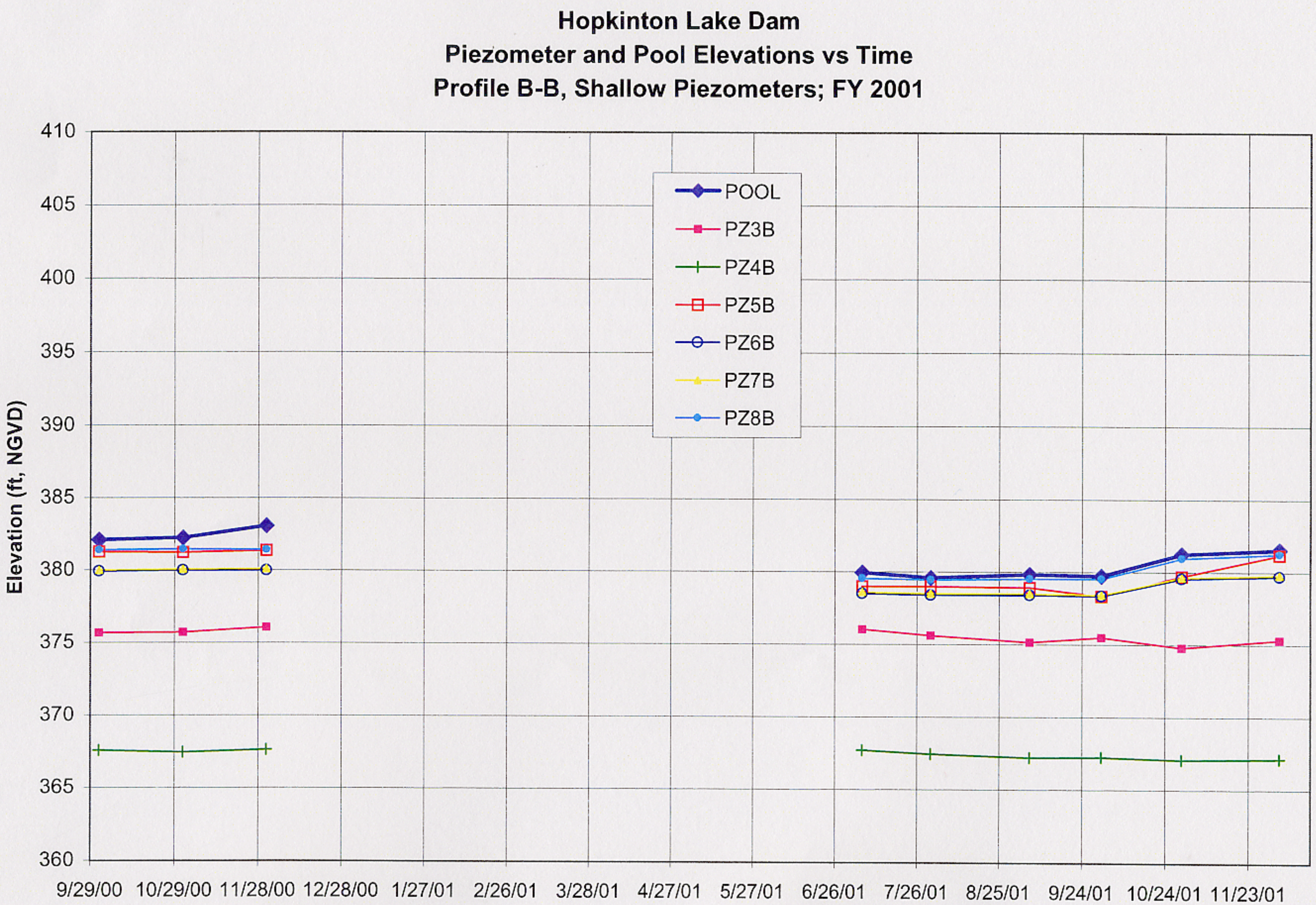
Hopkinton Lake Dam
Piezometer and Pool Elevations vs Time
Profile B-B, Shallow Piezometers; FY 1998



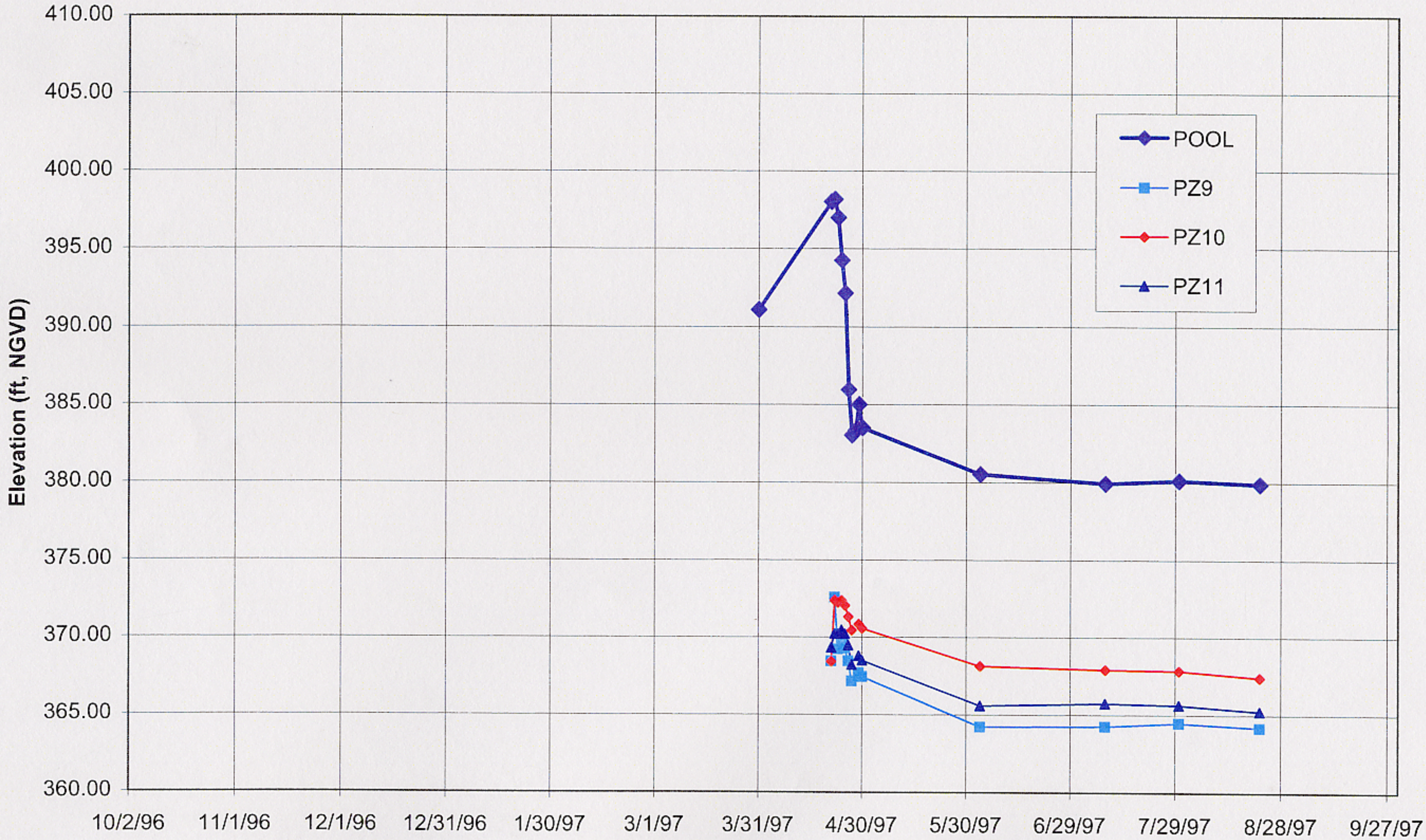


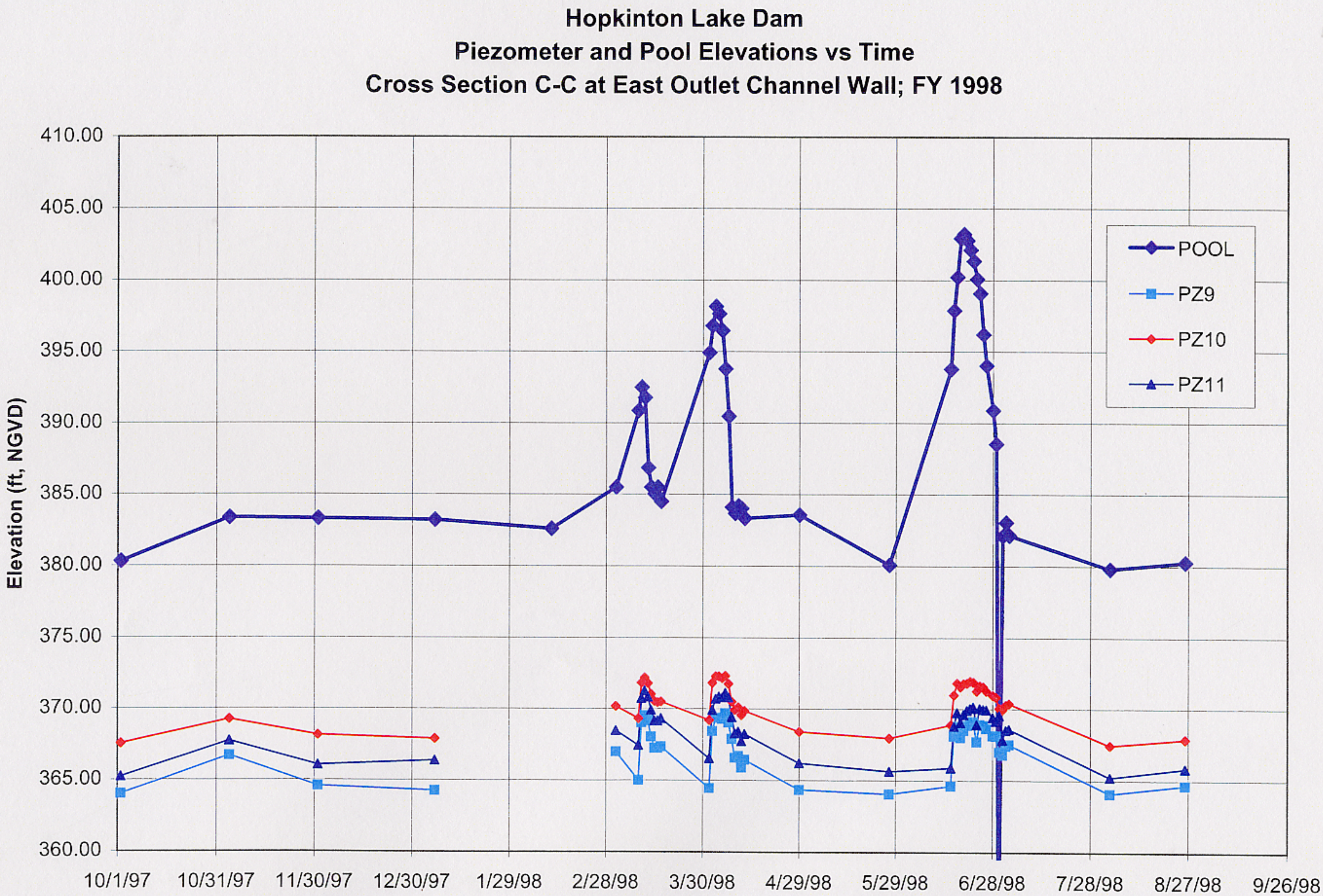
Hopkinton Lake Dam
Piezometer and Pool Elevations vs Time
Profile B-B, Shallow Piezometers; FY 1999
Elevation (ft, NGVD)
410
405
400
395
390
385
380
375
370
365
360
10/1/98
10/31/98
11/30/98
12/30/98
1/29/99
2/28/99
3/30/99
4/29/99
5/29/99
6/28/99
7/28/99
8/27/99
9/26/99
Pool
PZ-3B
PZ-4B
PZ-5B
PZ-6B
PZ-7B
PZ-8B
Dewatering for east outlet wall repair work.

Hopkinton Lake Dam
Piezometer and Pool Elevations vs Time
Profile B-B, Shallow Piezometers; FY 2000

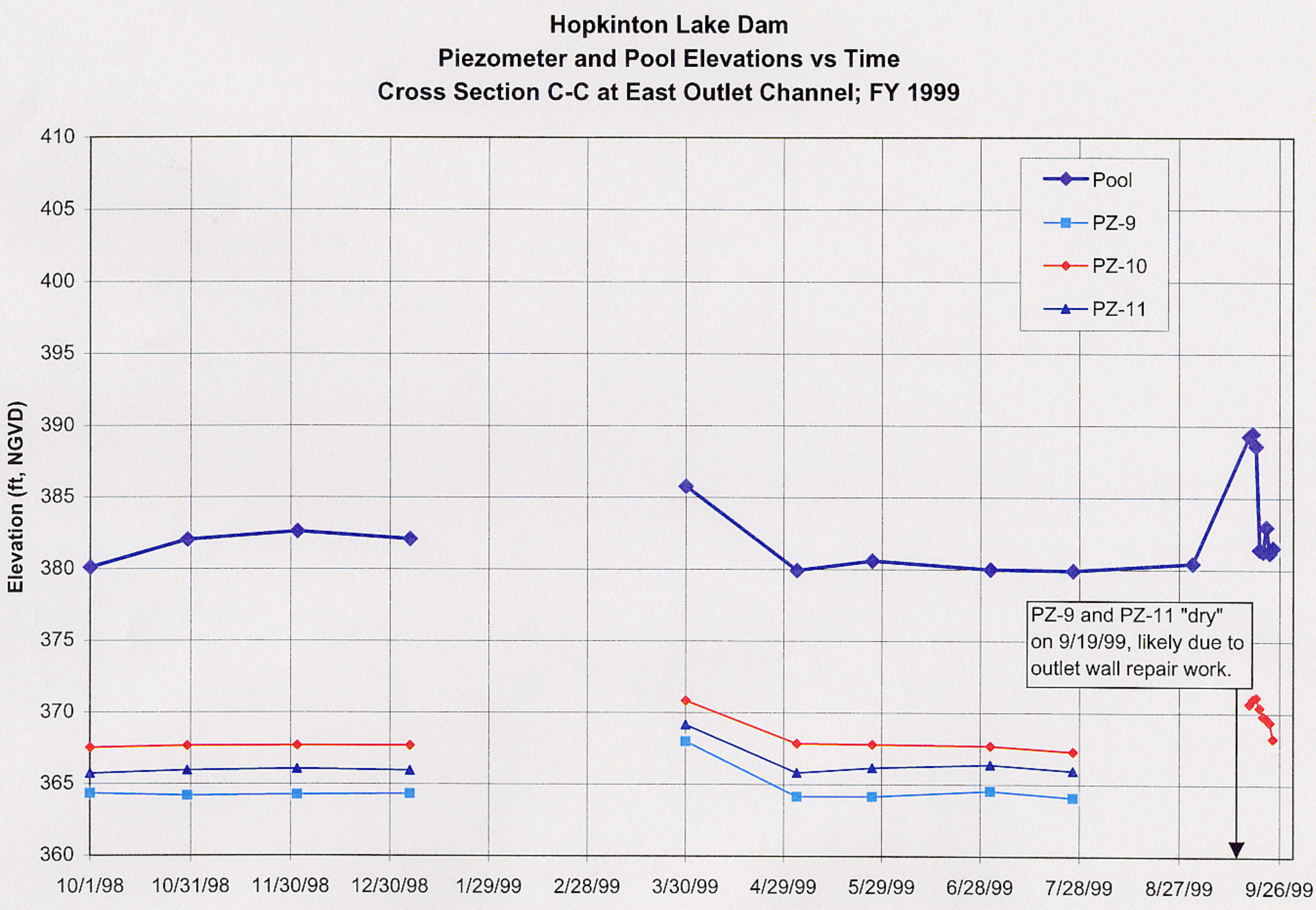

Hopkinton Lake Dam
Piezometer and Pool Elevations vs Time
Profile B-B, Shallow Piezometers; FY 2001
410
405
400
395
390
385
380
375
370
365
360
Elevation (ft, NGVD)
9/29/00
10/29/00
11/28/00
12/28/00
1/27/01
2/26/01
3/28/01
4/27/01
5/27/01
6/26/01
7/26/01
8/25/01
9/24/01
10/24/01
11/23/01
POOL
PZ3B
PZ4B
PZ5B
PZ6B
PZ7B
PZ8B

Hopkinton Lake Dam
Piezometer and Pool Elevations vs Time
Cross Section C-C at East Outlet Channel Wall; FY 1997



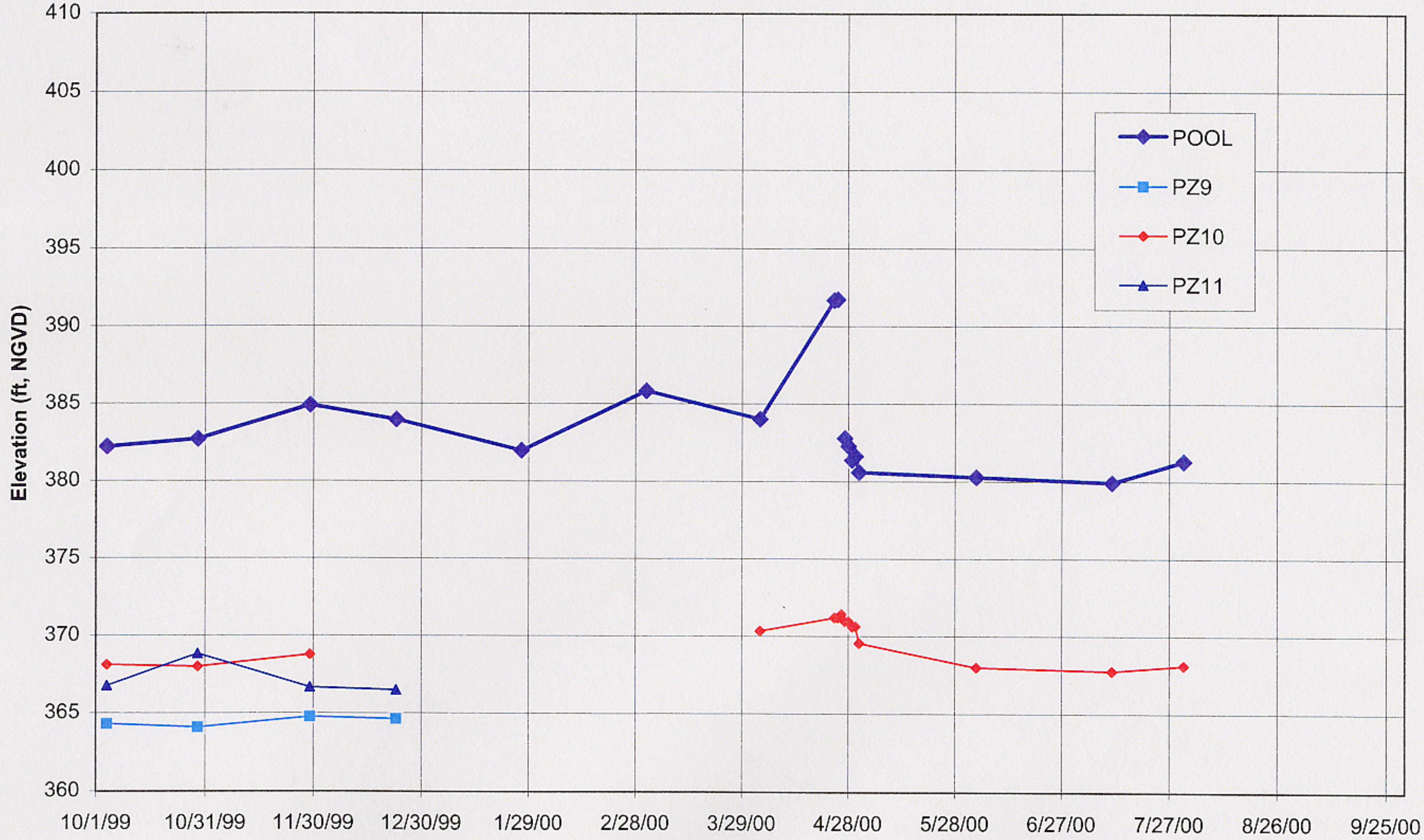


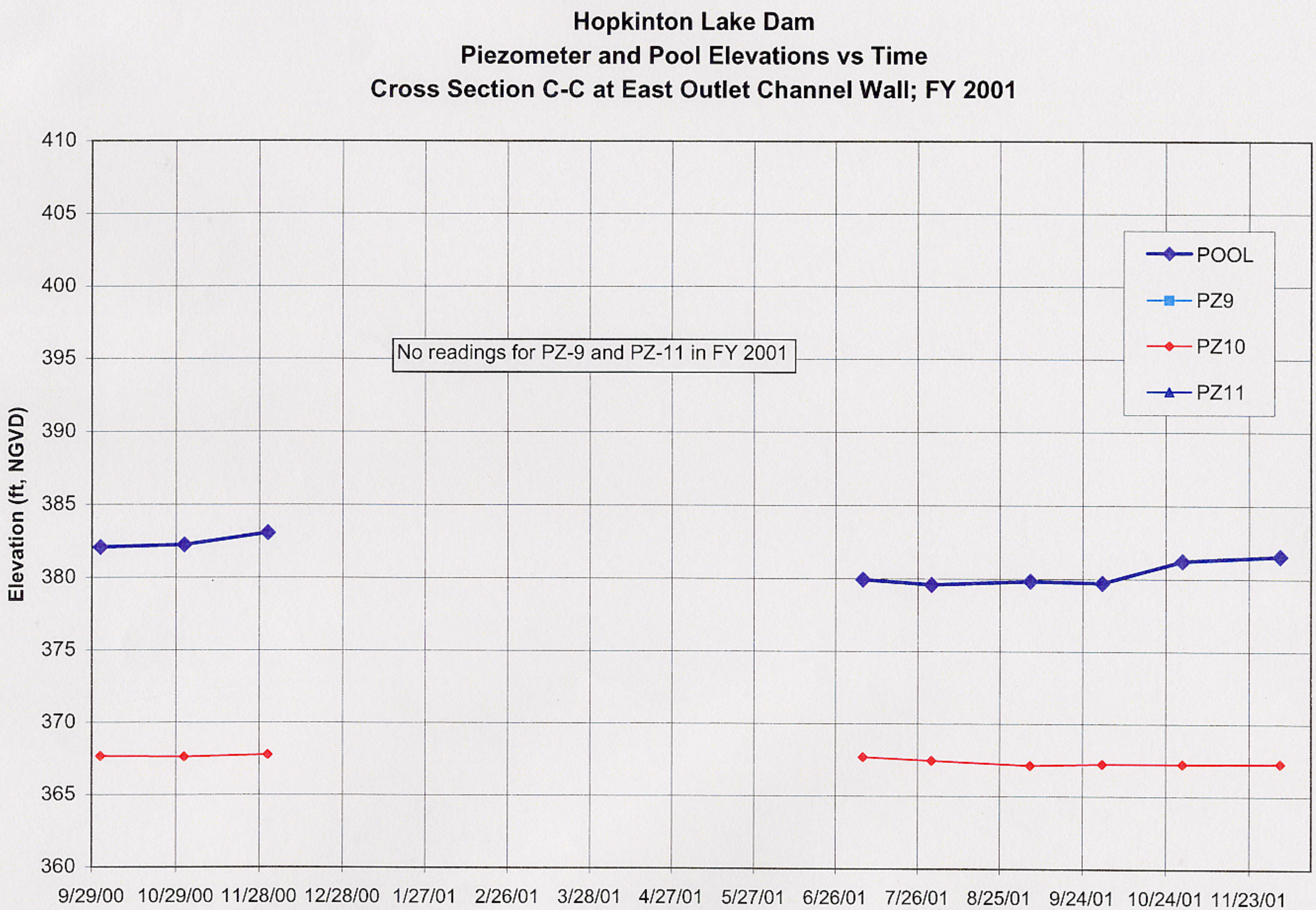
Hopkinton Lake Dam
Piezometer and Pool Elevations vs Time
Cross Section C-C at East Outlet Channel Wall; FY 1998
Elevation (ft, NGVD)
410.00
405.00
400.00
395.00
390.00
385.00
380.00
375.00
370.00
365.00
360.00
10/1/97
10/31/97
11/30/97
12/30/97
1/29/98
2/28/98
3/30/98
4/29/98
5/29/98
6/28/98
7/28/98
8/27/98
9/26/98
POOL
PZ9
PZ10
PZ11



Hopkinton Lake Dam
Piezometer and Pool Elevations vs Time
Cross Section C-C at East Outlet Channel; FY 1999
Elevation (ft, NGVD)
410
405
400
395
390
385
380
375
370
365
360
10/1/98
10/31/98
11/30/98
12/30/98
1/29/99
2/28/99
3/30/99
4/29/99
5/29/99
6/28/99
7/28/99
8/27/99
9/26/99
Pool
PZ-9
PZ-10
PZ-11
PZ-9 and PZ-11 "dry" on 9/19/99, likely due to outlet wall repair work.

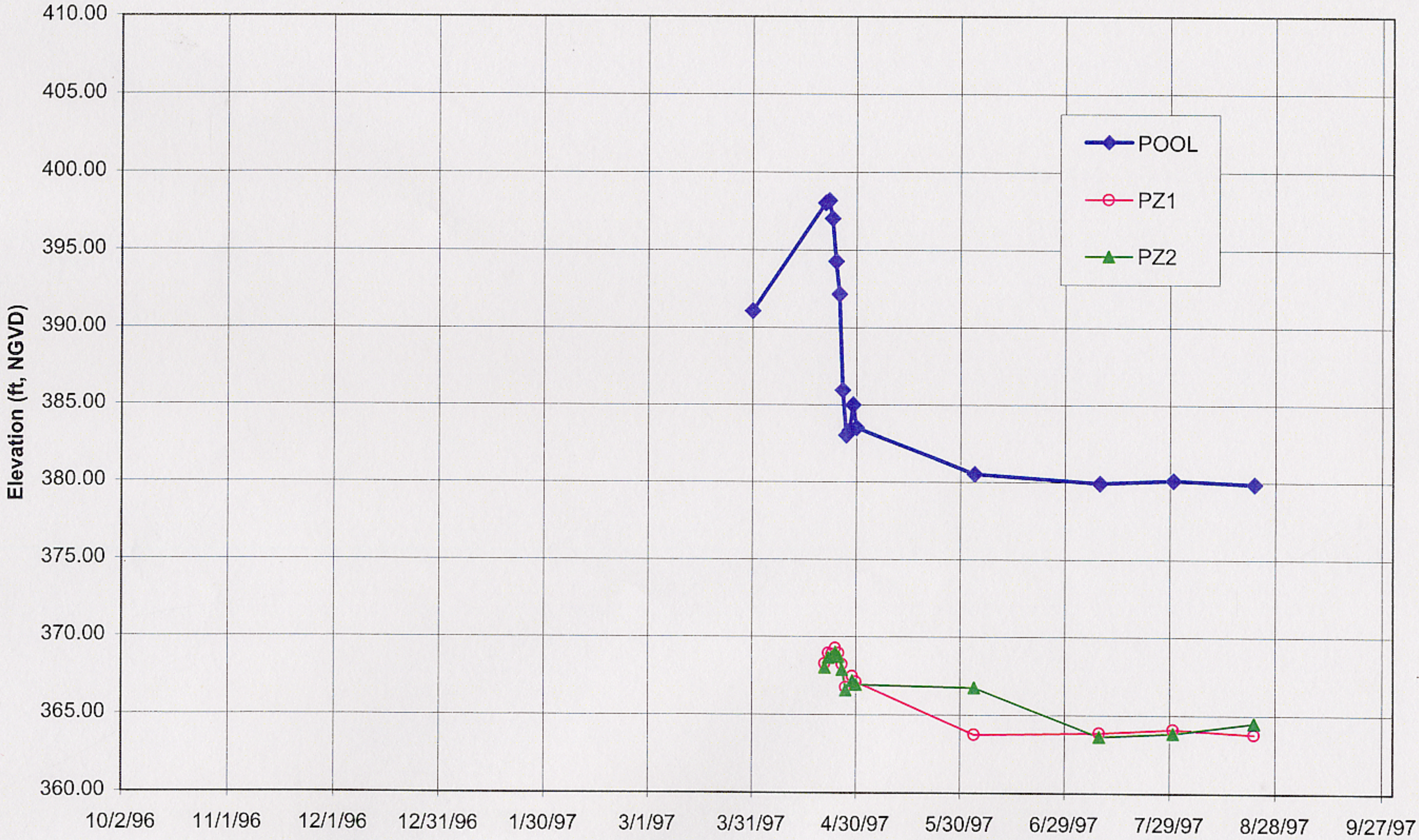
Hopkinton Lake Dam
Piezometer and Pool Elevations vs Time
Cross Section C-C at East Outlet Channel Wall; FY 2000



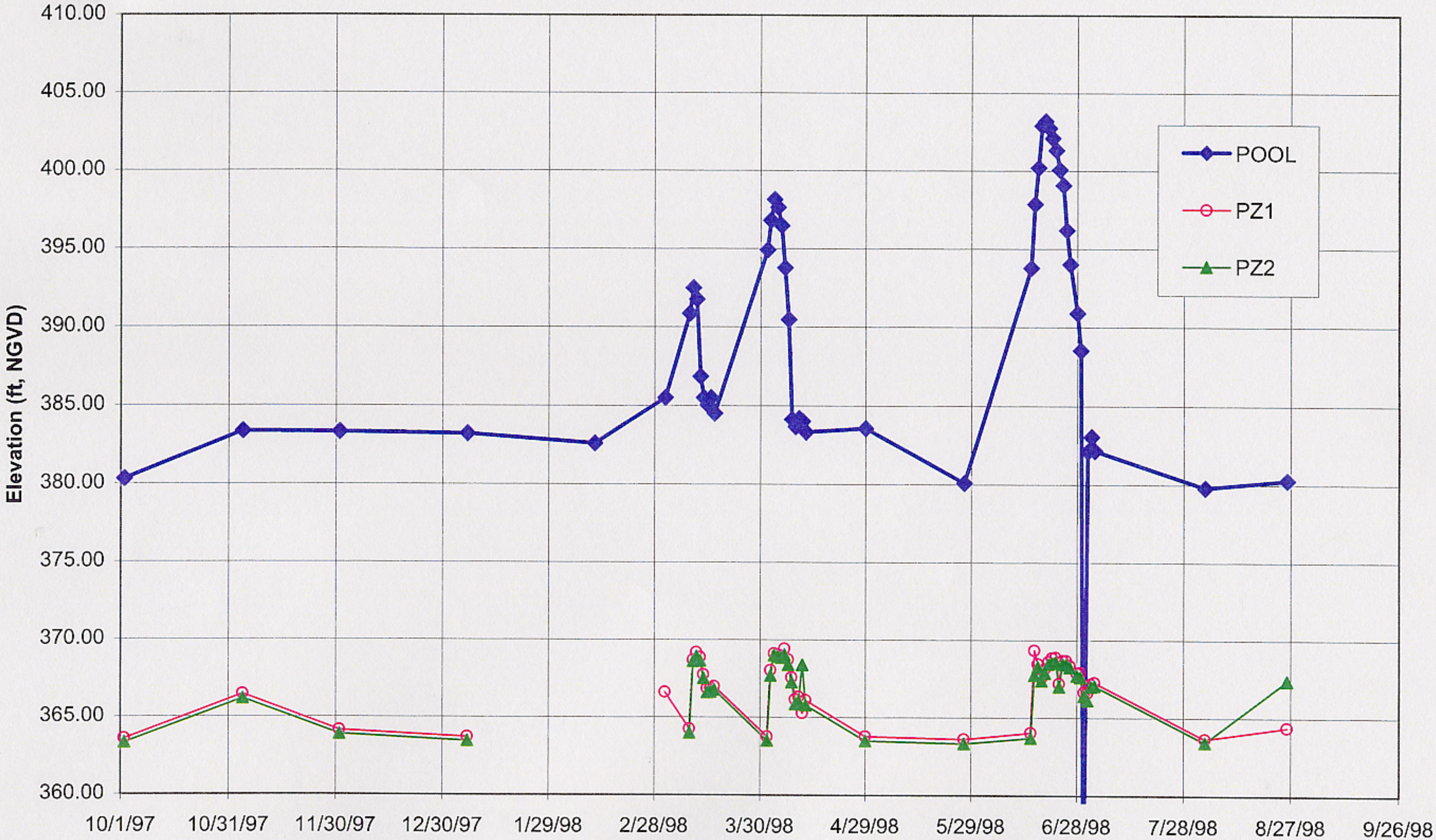


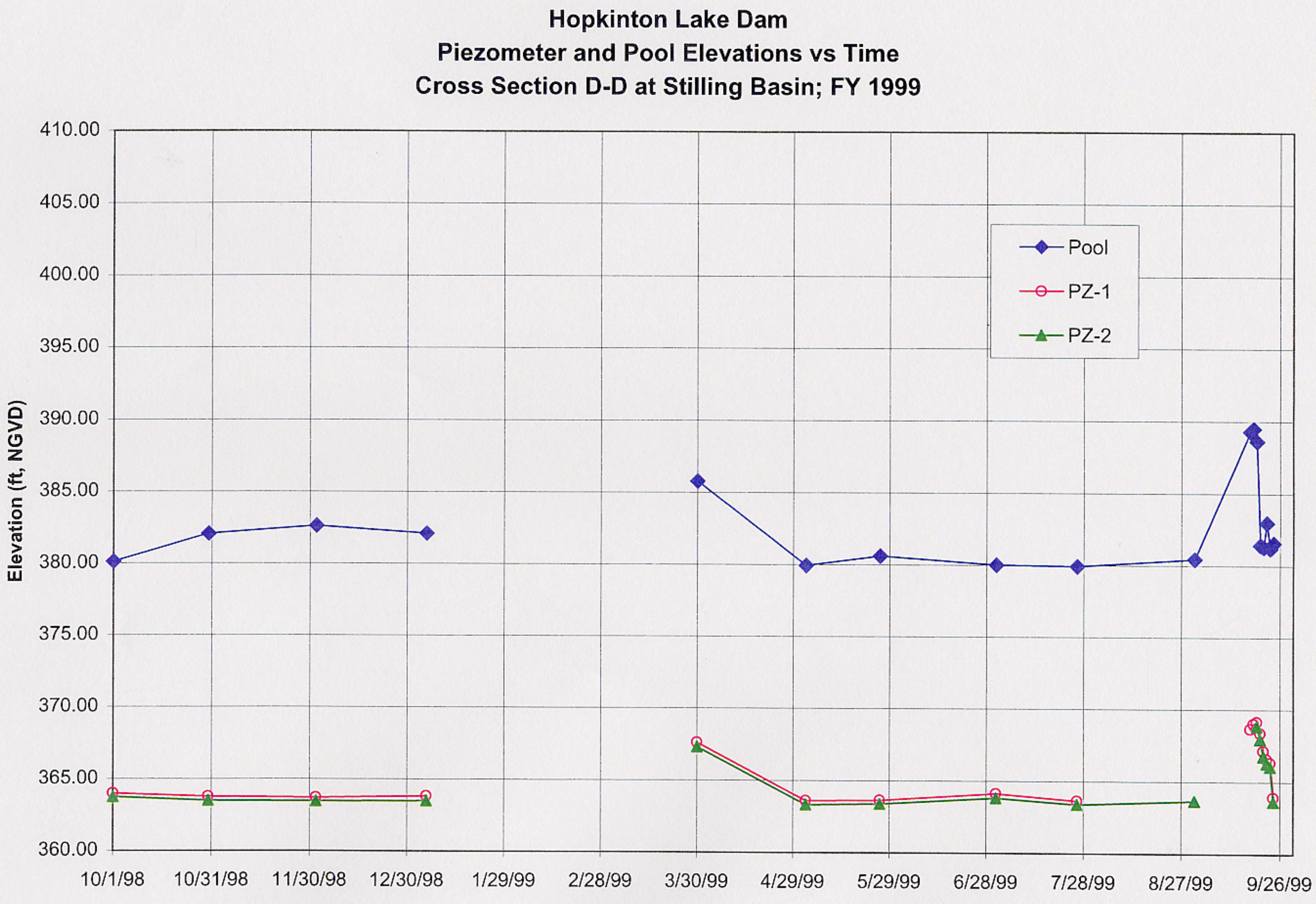
Hopkinton Lake Dam
Piezometer and Pool Elevations vs Time
Cross Section C-C at East Outlet Channel Wall; FY 2001
410
405
400
395
390
385
380
375
370
365
360
Elevation (ft, NGVD)
9/29/00
10/29/00
11/28/00
12/28/00
1/27/01
2/26/01
3/28/01
4/27/01
5/27/01
6/26/01
7/26/01
8/25/01
9/24/01
10/24/01
11/23/01
No readings for PZ-9 and PZ-11 in FY 2001
POOL
PZ9
PZ10
PZ11

Hopkinton Lake Dam
Piezometer and Pool Elevations vs Time
Cross Section D-D at Stilling Basin; FY 1997



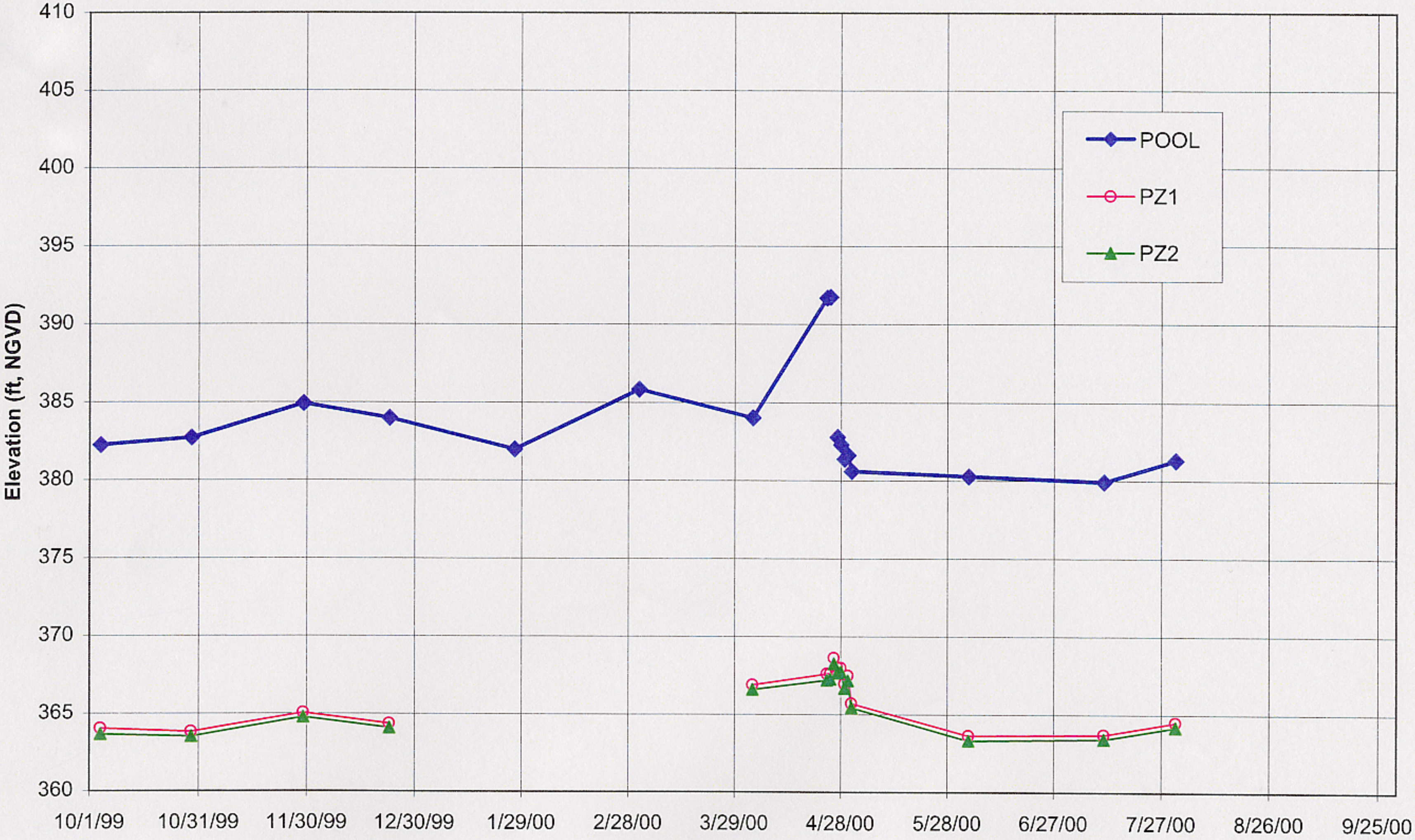
Hopkinton Lake Dam
Piezometer and Pool Elevations vs Time
Cross Section D-D at Stilling Basin; FY 1998



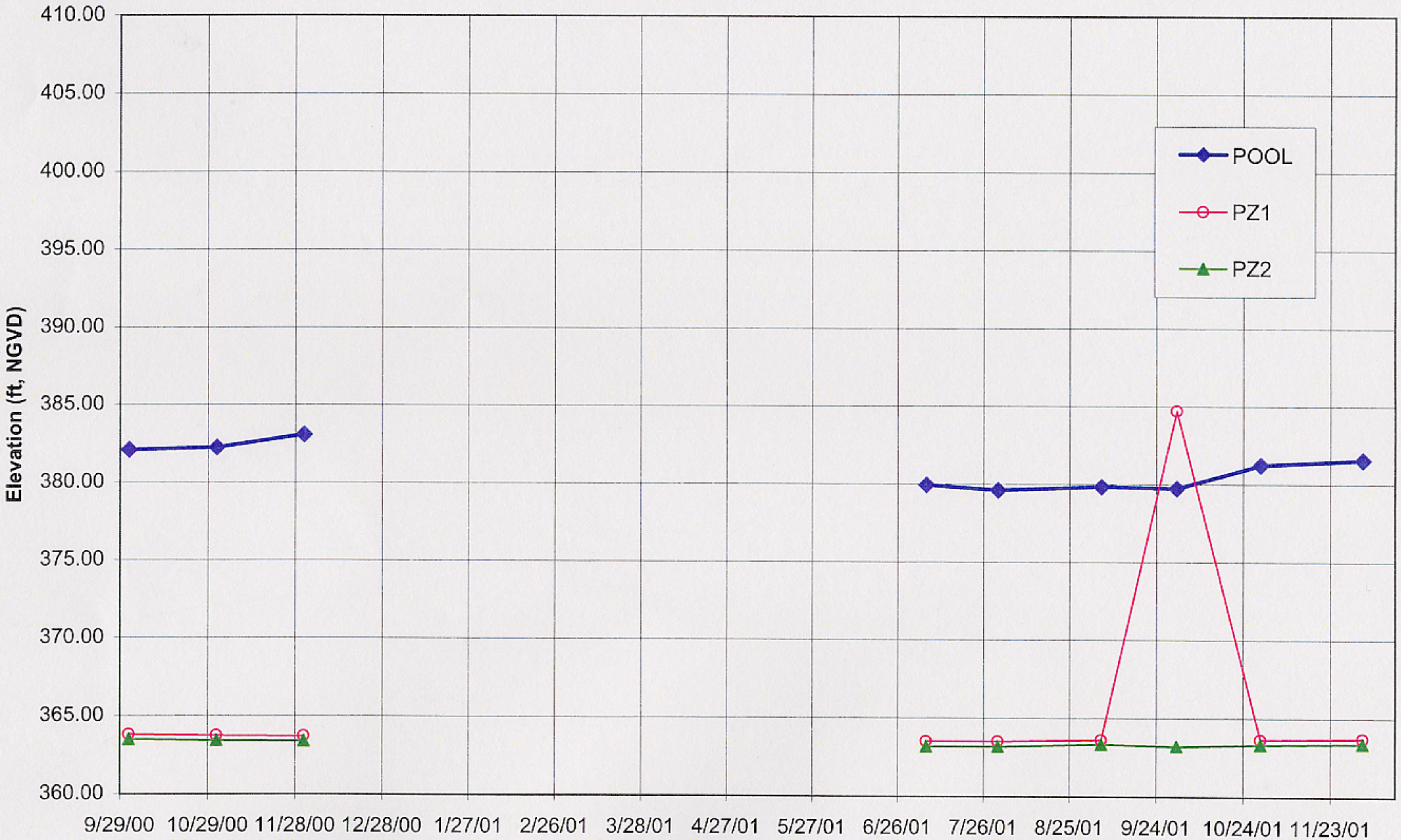


Hopkinton Lake Dam
Piezometer and Pool Elevations vs Time
Cross Section D-D at Stilling Basin; FY 1999
Elevation (ft, NGVD)
410.00
405.00
400.00
395.00
390.00
385.00
380.00
375.00
370.00
365.00
360.00
10/1/98
10/31/98
11/30/98
12/30/98
1/29/99
2/28/99
3/30/99
4/29/99
5/29/99
6/28/99
7/28/99
8/27/99
9/26/99
Pool
PZ-1
PZ-2

Hopkinton Lake Dam
Piezometer and Pool Elevations vs Time
Cross Section D-D at Stilling Basin; FY 2000



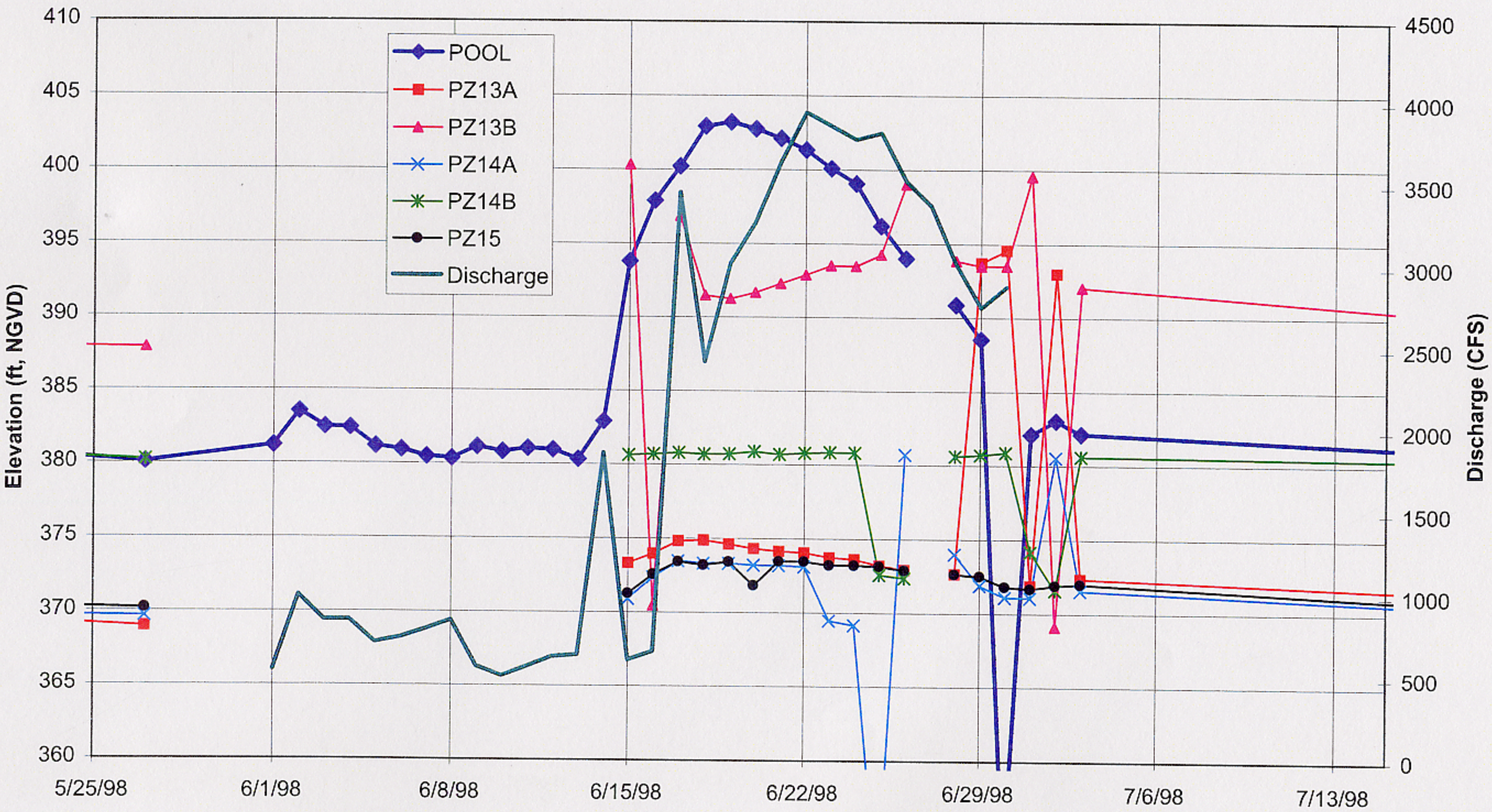
Hopkinton Lake Dam
Piezometer and Pool Elevations vs Time
Cross Section D-D at Stilling Basin; FY 2001

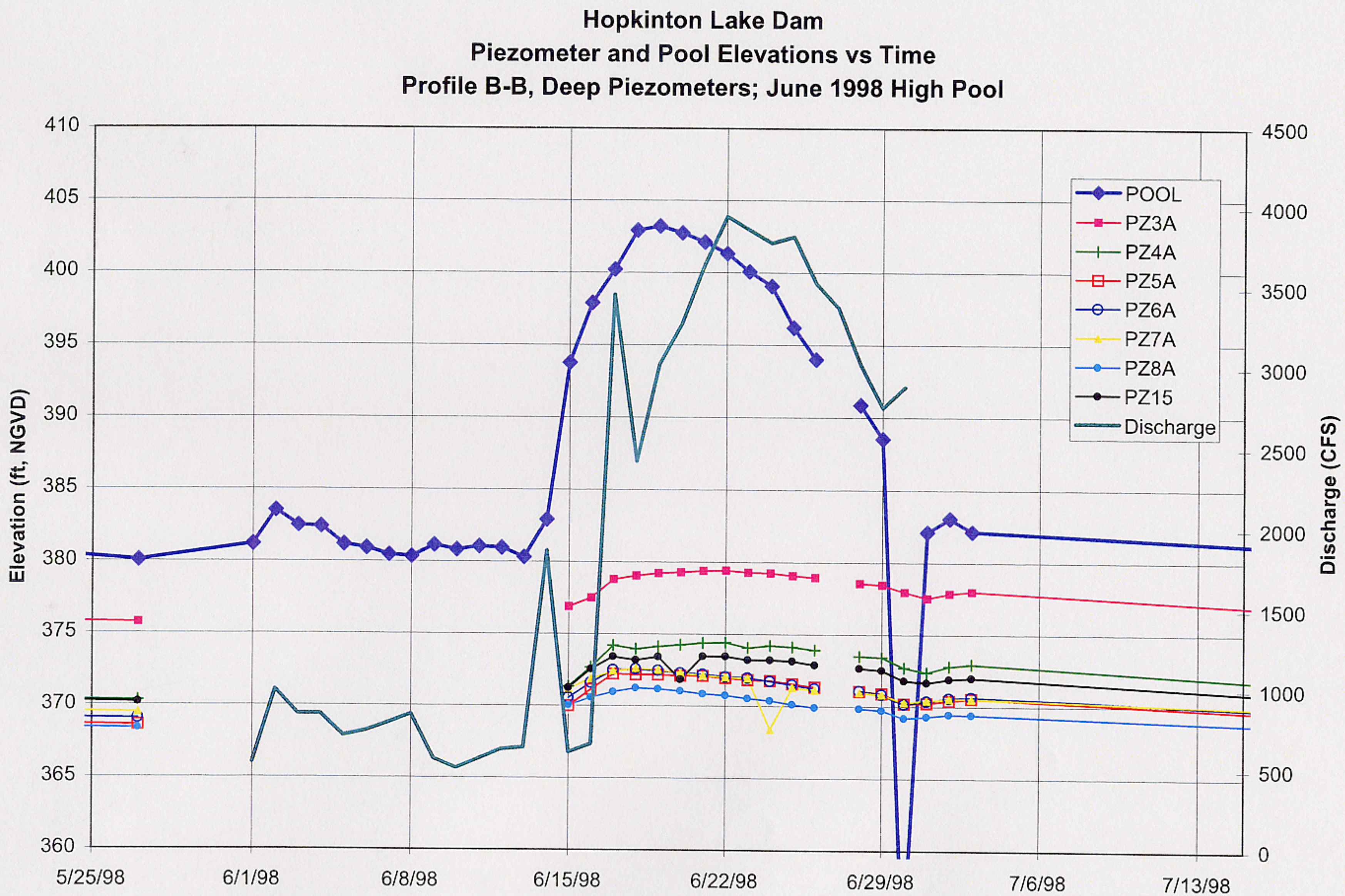


Appendix C

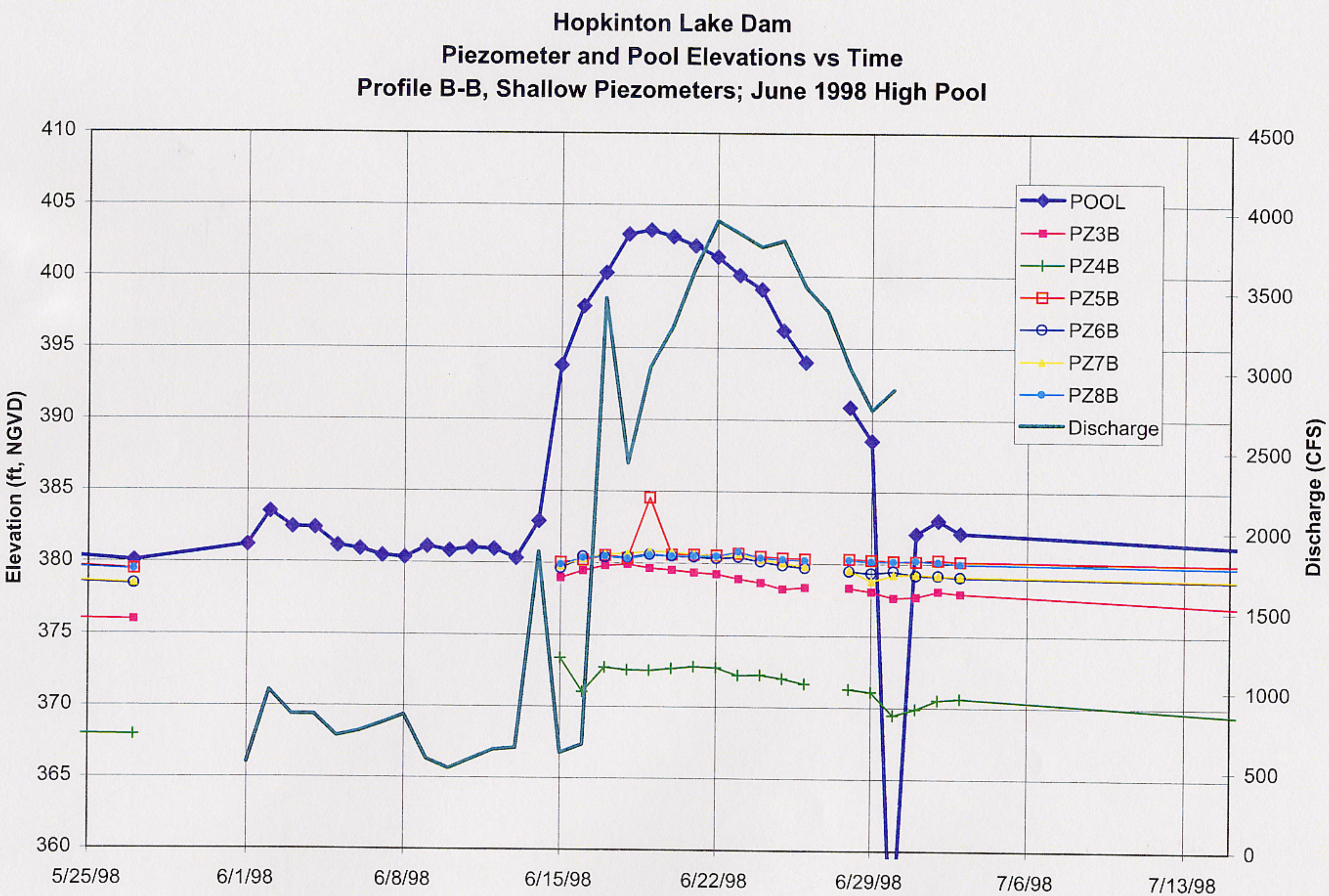
Piezometer Data, June 1998 Event Plots

Hopkinton Lake Dam
Piezometer and Pool Elevations vs Time
Cross Section A-A, Station 5+25; June 1998 High Pool

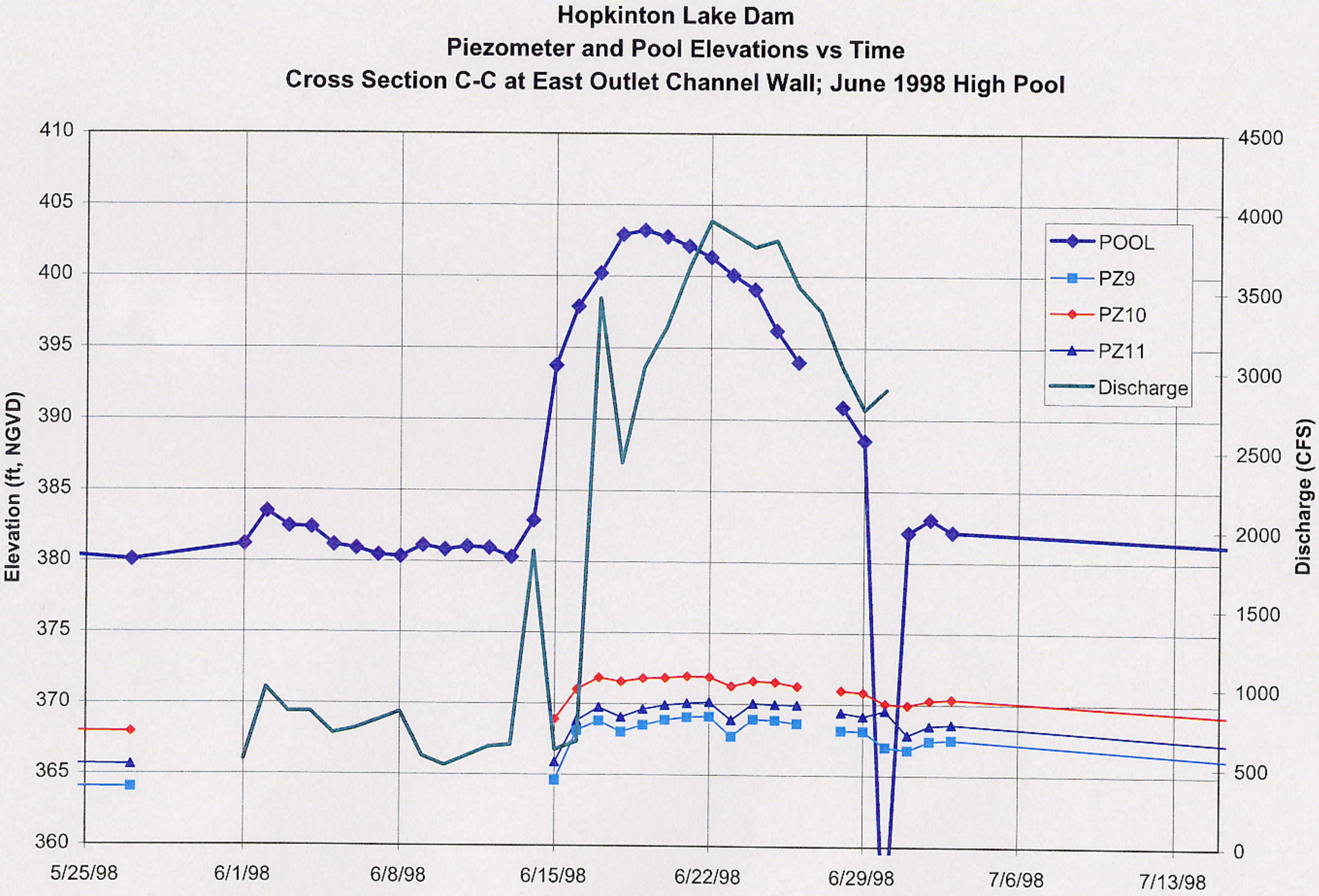




Hopkinton Lake Dam
Piezometer and Pool Elevations vs Time
Profile B-B, Deep Piezometers; June 1998 High Pool
Elevation (ft, NGVD)
Discharge (CFS)
410
405
400
395
390
385
380
375
370
365
360
4500
4000
3500
3000
2500
2000
1500
1000
500
0
5/25/98
6/1/98
6/8/98
6/15/98
6/22/98
6/29/98
7/6/98
7/13/98
POOL
PZ3A
PZ4A
PZ5A
PZ6A
PZ7A
PZ8A
PZ15
Discharge

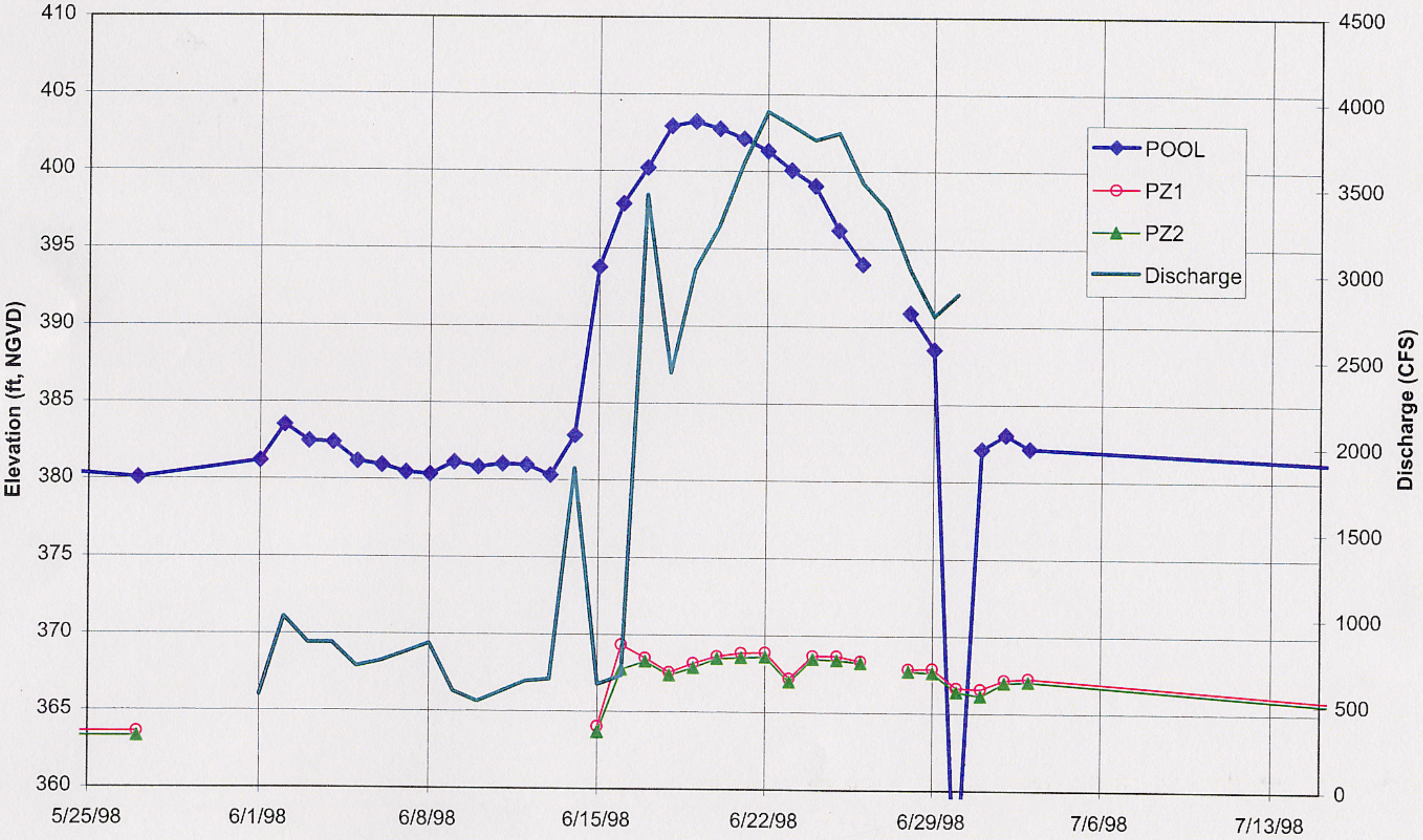


Hopkinton Lake Dam
Piezometer and Pool Elevations vs Time
Profile B-B, Shallow Piezometers; June 1998 High Pool
Elevation (ft, NGVD)
Discharge (CFS)
410
405
400
395
390
385
380
375
370
365
360
4500
4000
3500
3000
2500
2000
1500
1000
500
0
5/25/98
6/1/98
6/8/98
6/15/98
6/22/98
6/29/98
7/6/98
7/13/98
POOL
PZ3B
PZ4B
PZ5B
PZ6B
PZ7B
PZ8B
Discharge



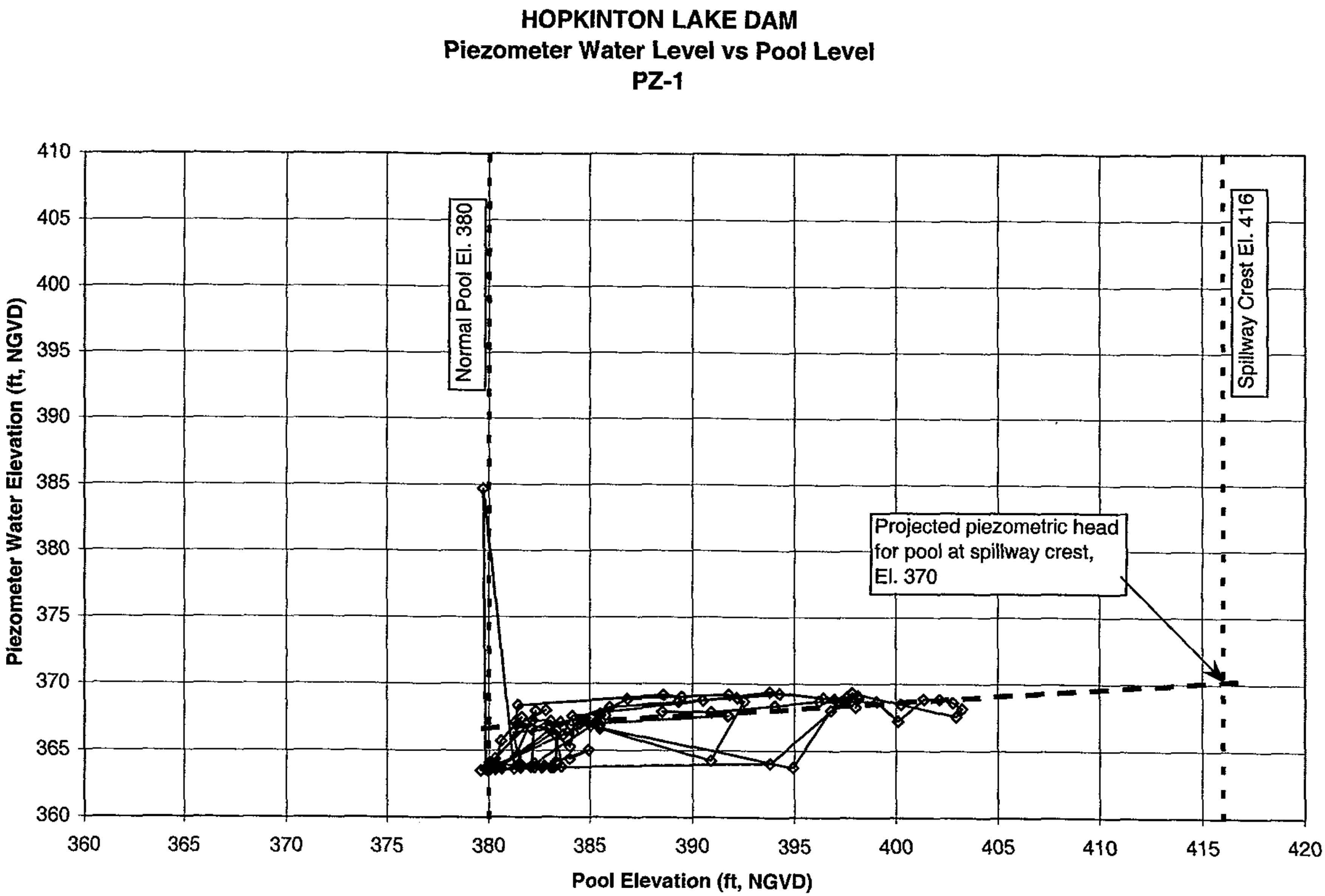
Hopkinton Lake Dam
Piezometer and Pool Elevations vs Time
Cross Section C-C at East Outlet Channel Wall; June 1998 High Pool
410
405
400
395
390
385
380
375
370
365
360
Elevation (ft, NGVD)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Discharge (CFS)
5/25/98
6/1/98
6/8/98
6/15/98
6/22/98
6/29/98
7/6/98
7/13/98
POOL
PZ9
PZ10
PZ11
Discharge

Hopkinton Lake Dam
Piezometer and Pool Elevations vs Time
Cross Section D-D at Stilling Basin; June 1998 High Pool



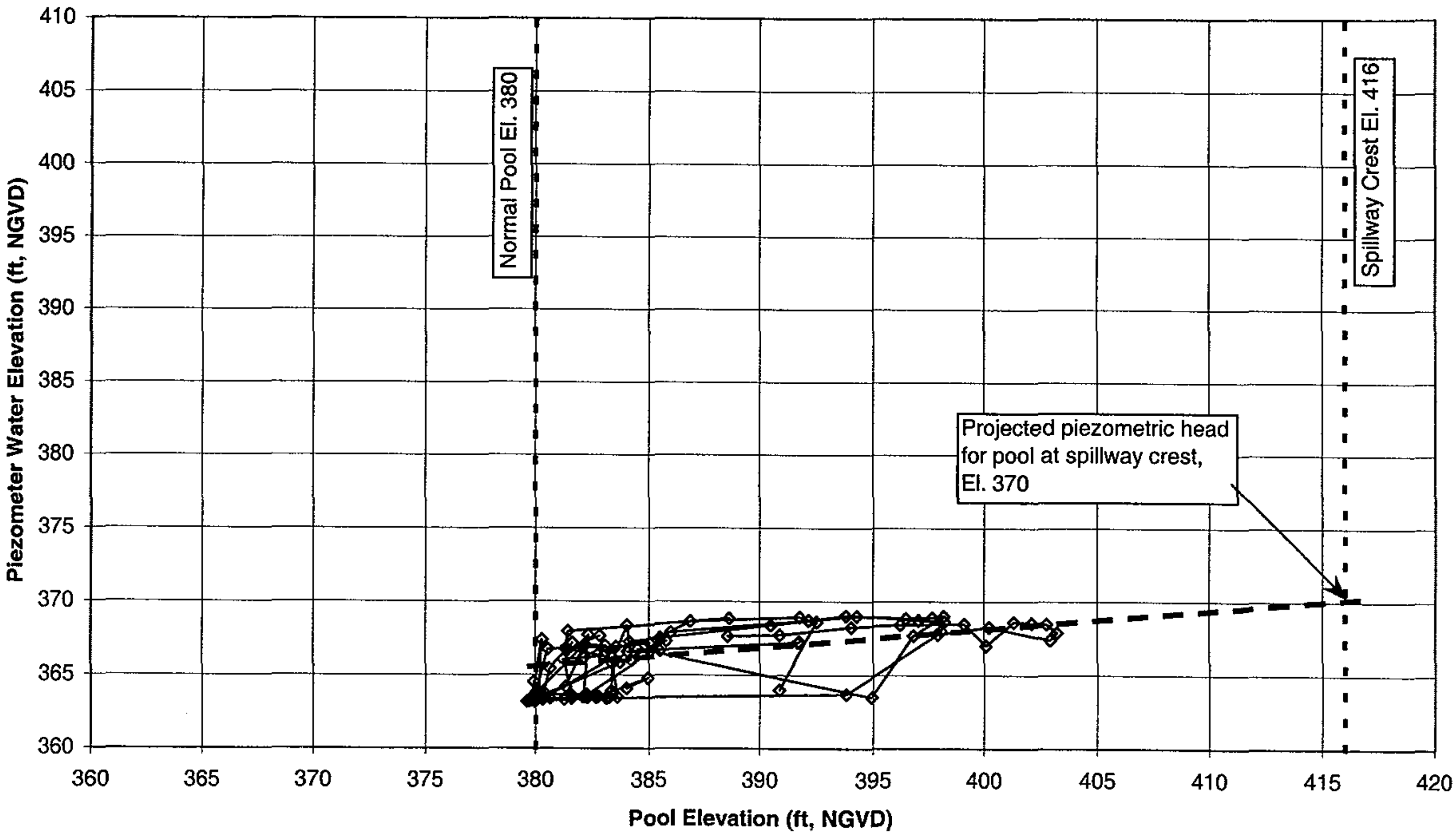
Appendix D

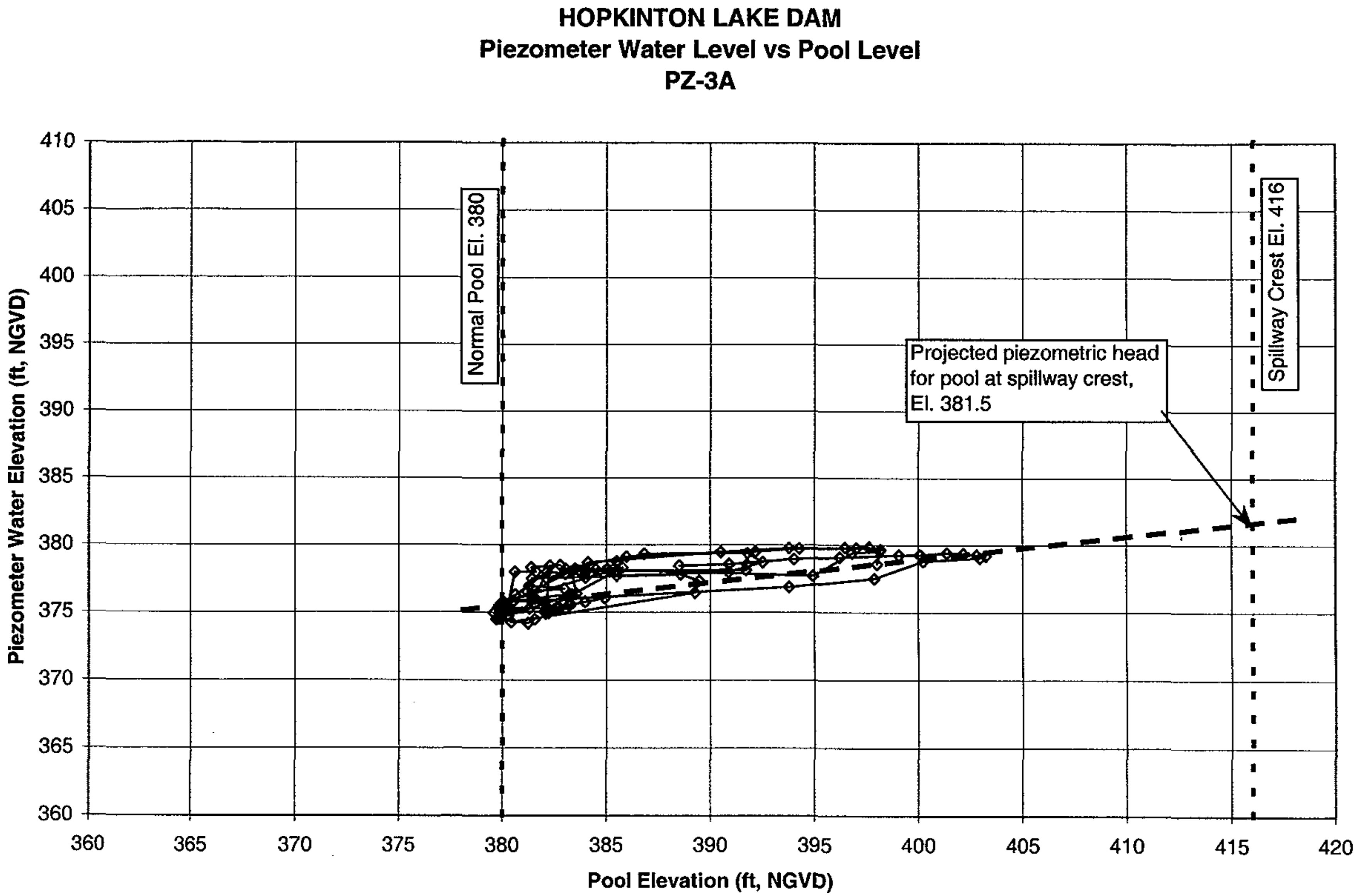
Piezometer Elevations vs. Pool Elevations



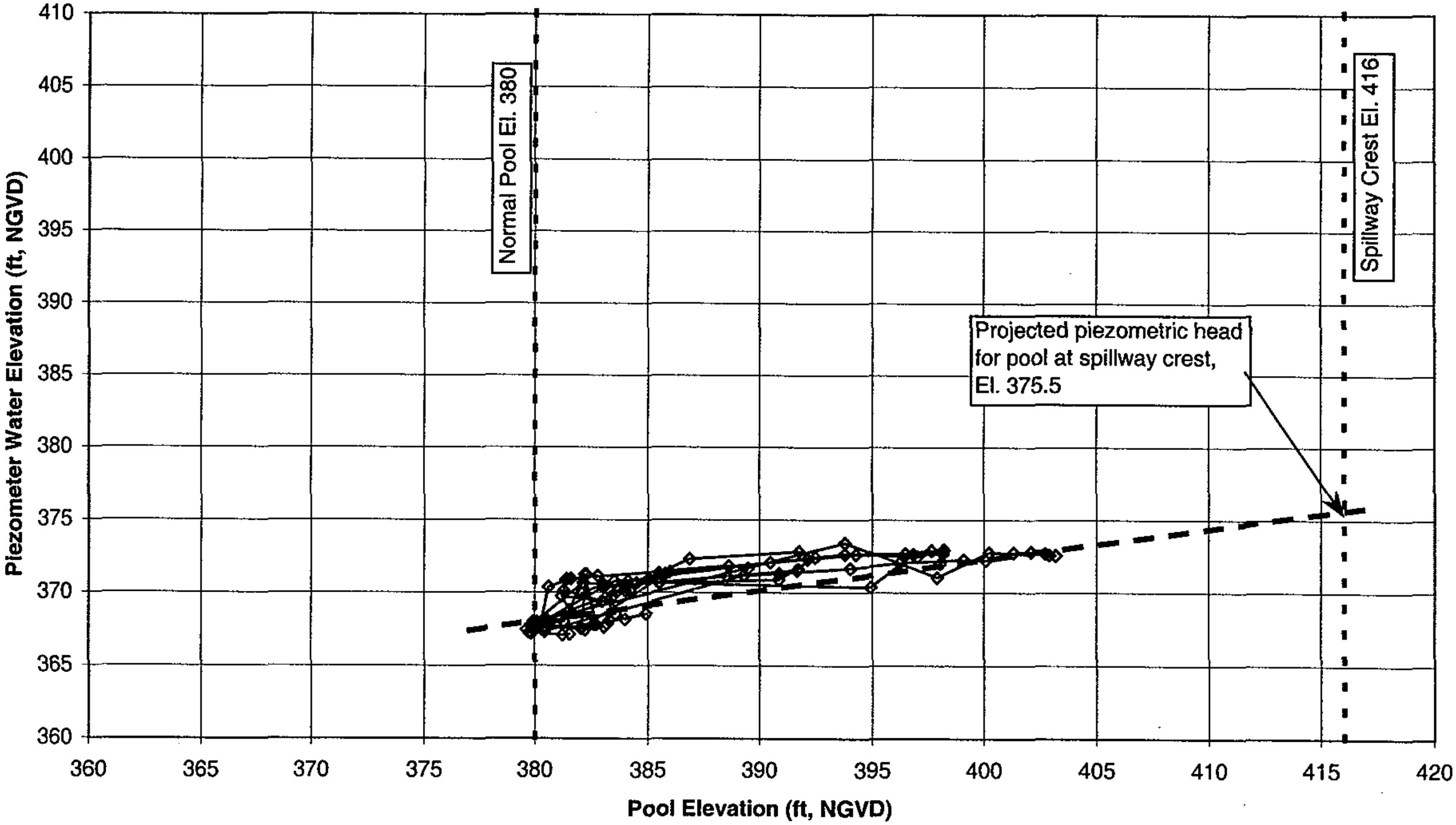
HOPKINTON LAKE DAM
Piezometer Water Level vs Pool Level
PZ-1
Piezometer Water Elevation (ft, NGVD)
410
405
400
395
390
385
380
375
370
365
360
Normal Pool El. 380
Spillway Crest El. 416
Projected piezometric head for pool at spillway crest, El. 370
360
365
370
375
380
385
390
395
400
405
410
415
420
Pool Elevation (ft, NGVD)

HOPKINTON LAKE DAM
Piezometer Water Level vs Pool Level
PZ-2

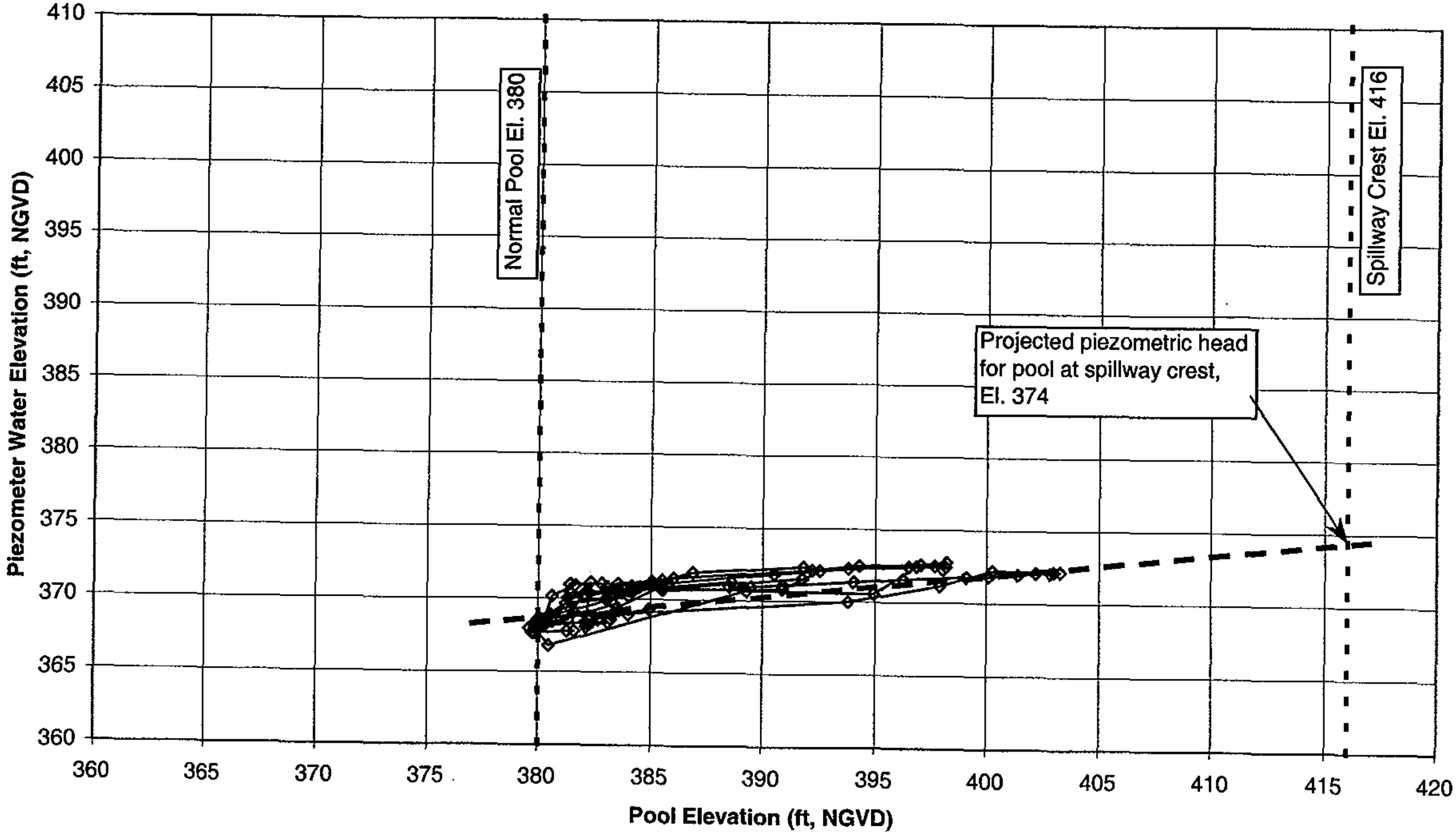



HOPKINTON LAKE DAM
Piezometer Water Level vs Pool Level
PZ-3A
Piezometer Water Elevation (ft, NGVD)
Pool Elevation (ft, NGVD)
Normal Pool El. 380
Spillway Crest El. 416
Projected piezometric head for pool at spillway crest, El. 381.5
410
405
400
395
390
385
380
375
370
365
360
360
365
370
375
380
385
390
395
400
405
410
415
420

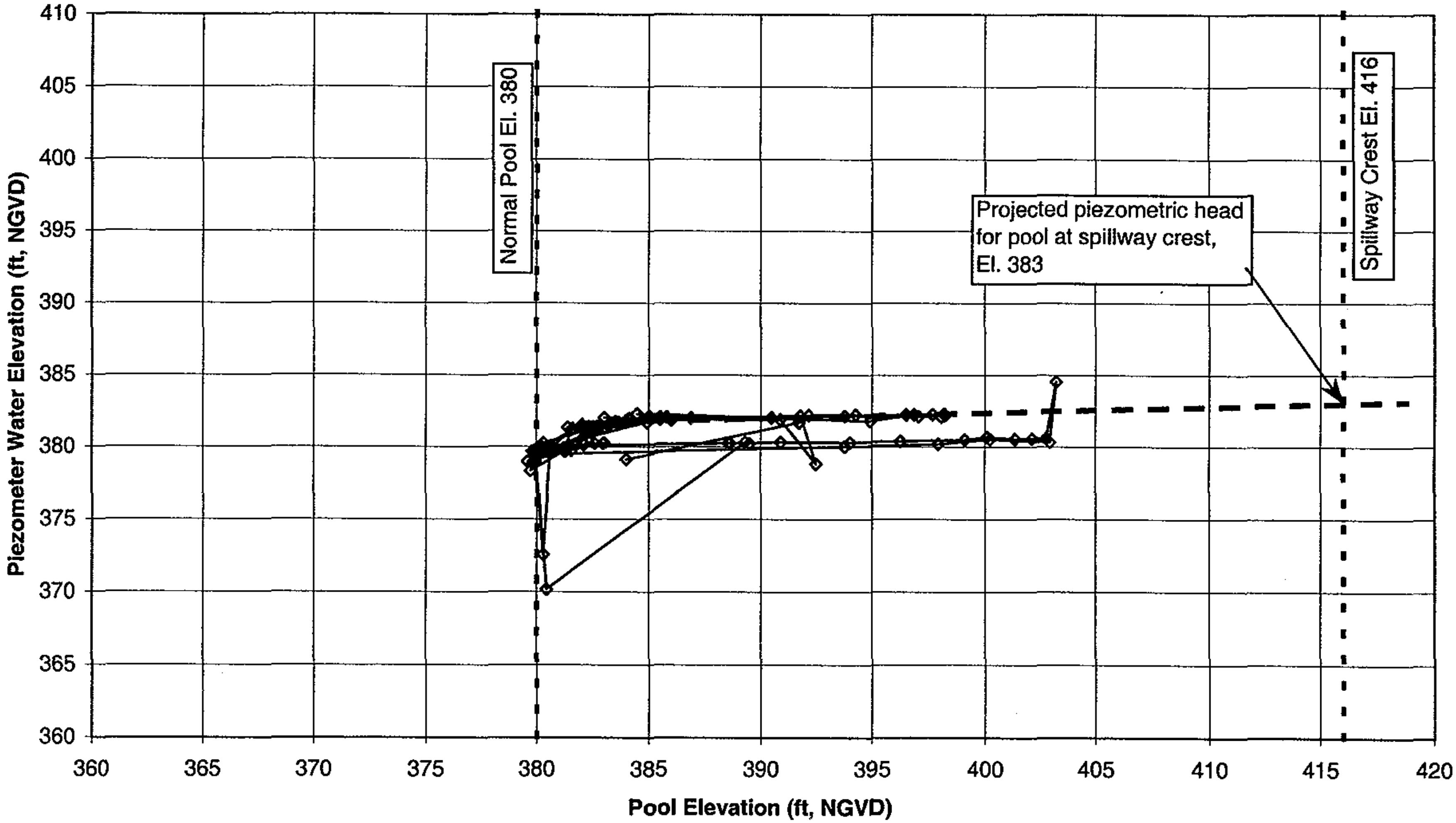
HOPKINTON LAKE DAM
Piezometer Water Level vs Pool Level
PZ-4B

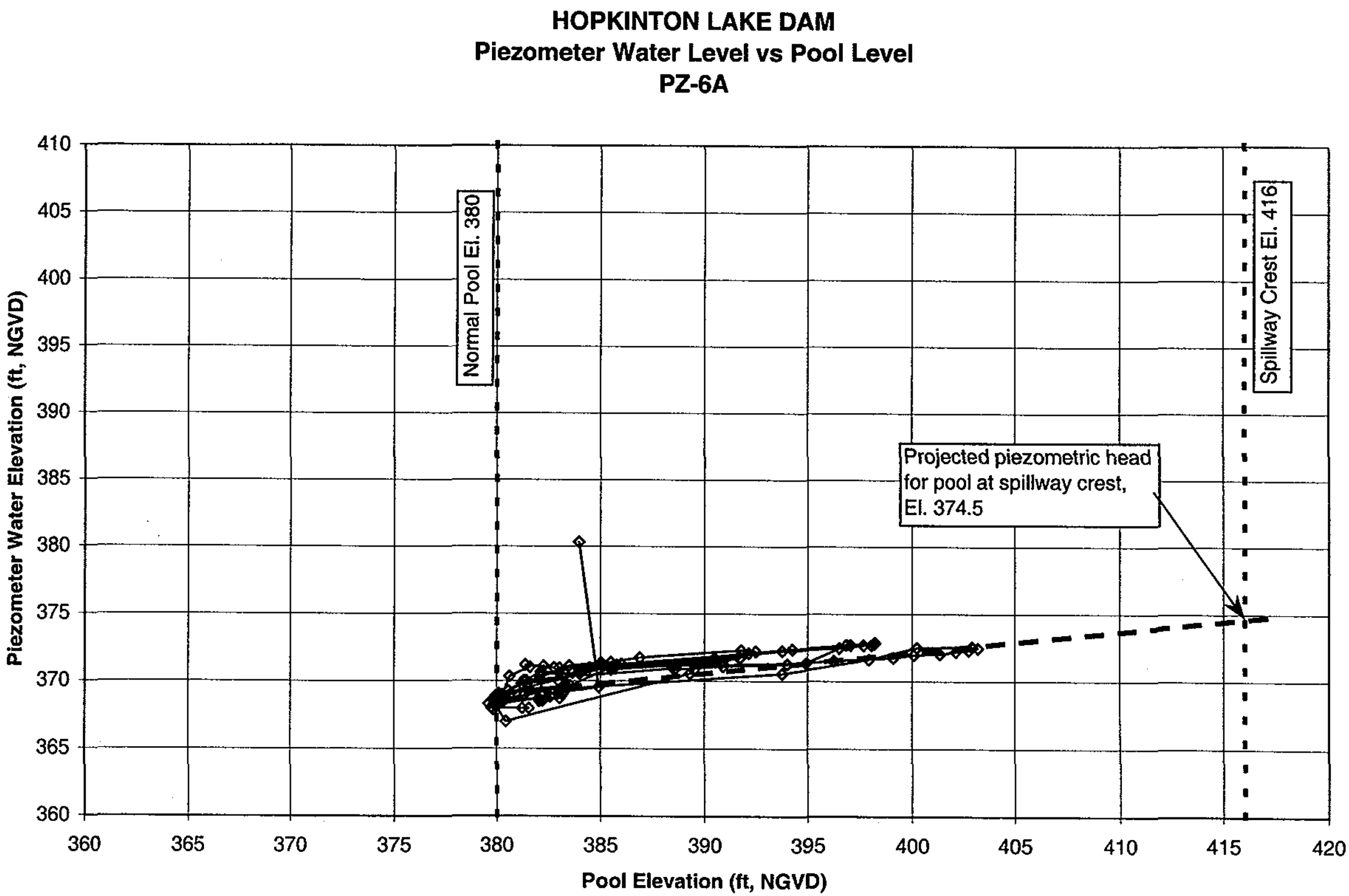


HOPKINTON LAKE DAM
Piezometer Water Level vs Pool Level
PZ-5A



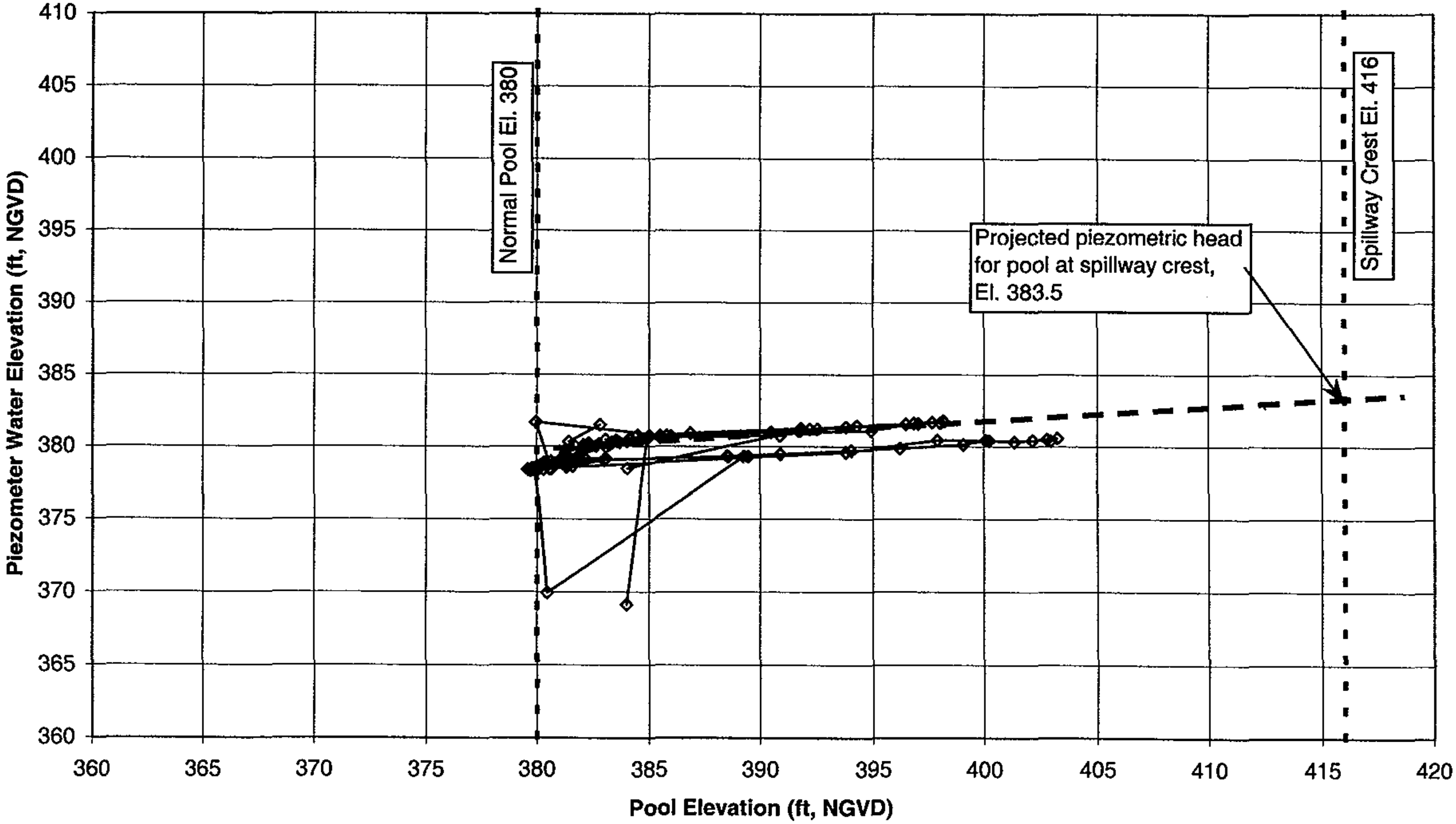
HOPKINTON LAKE DAM
Piezometer Water Level vs Pool Level
PZ-5B

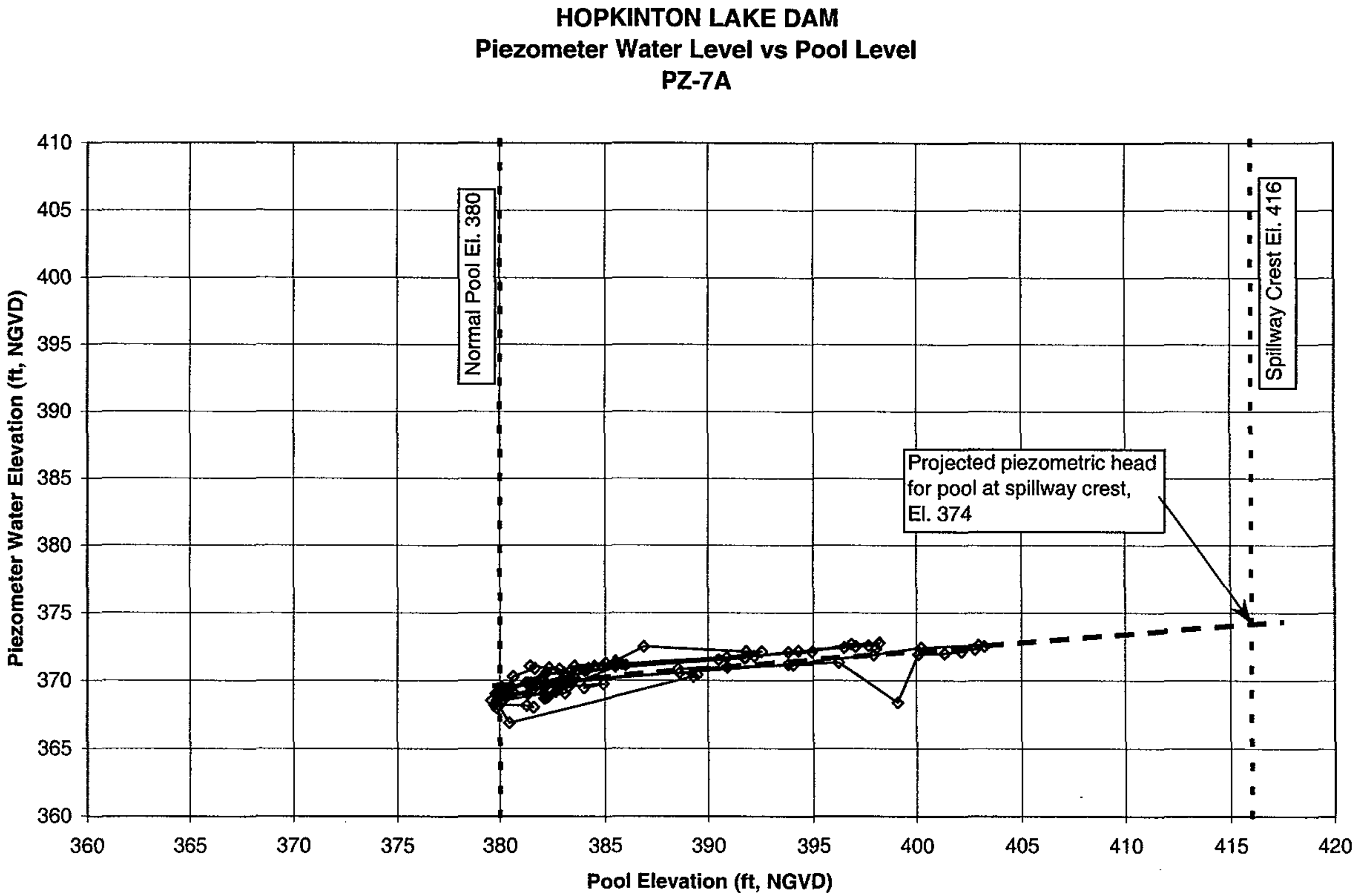




HOPKINTON LAKE DAM
Piezometer Water Level vs Pool Level
PZ-6A
Piezometer Water Elevation (ft, NGVD)
Pool Elevation (ft, NGVD)
Normal Pool El. 380
Spillway Crest El. 416
Projected piezometric head for pool at spillway crest, El. 374.5
410
405
400
395
390
385
380
375
370
365
360
360
365
370
375
380
385
390
395
400
405
410
415
420

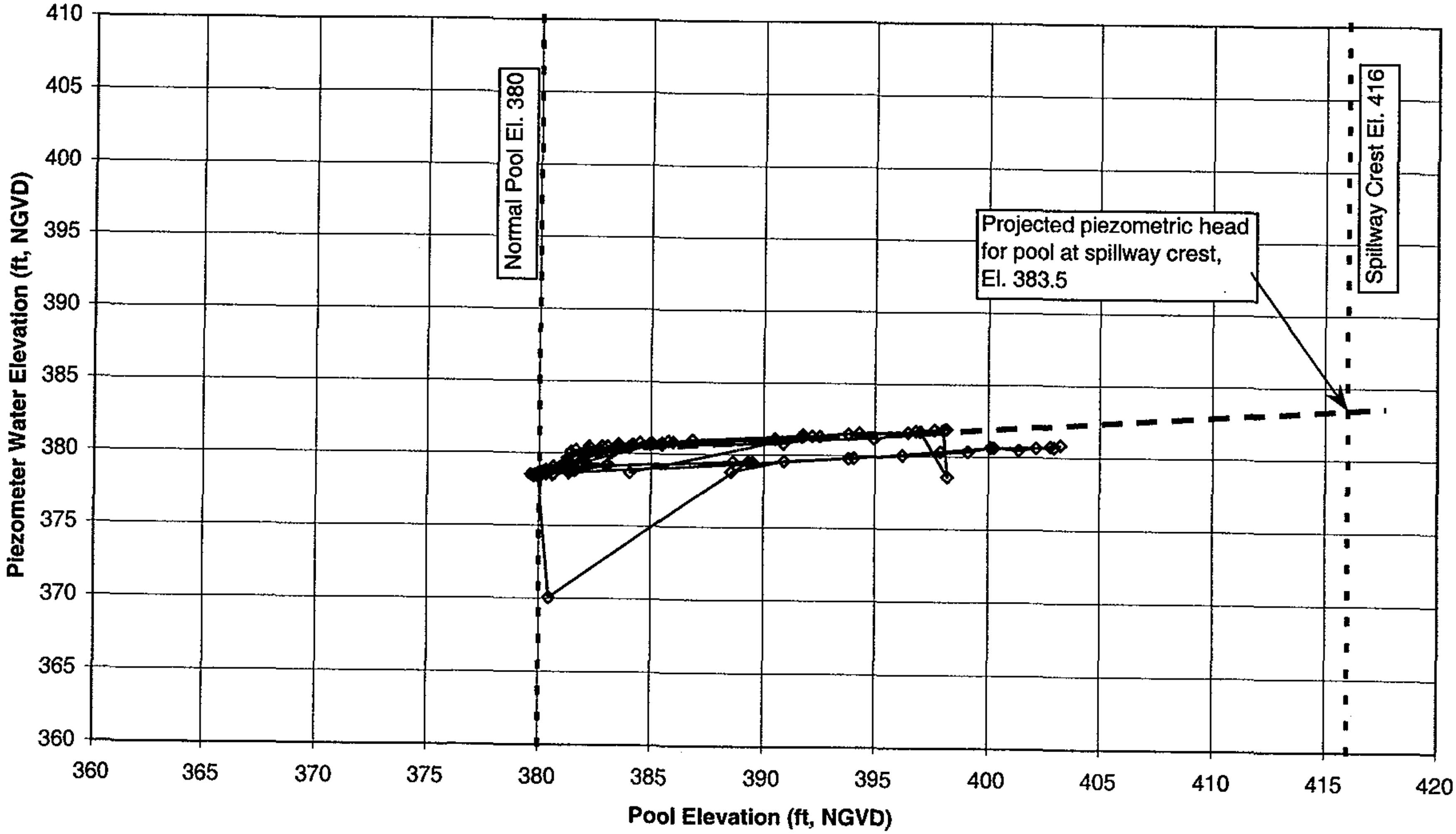
HOPKINTON LAKE DAM
Piezometer Water Level vs Pool Level
PZ-6B

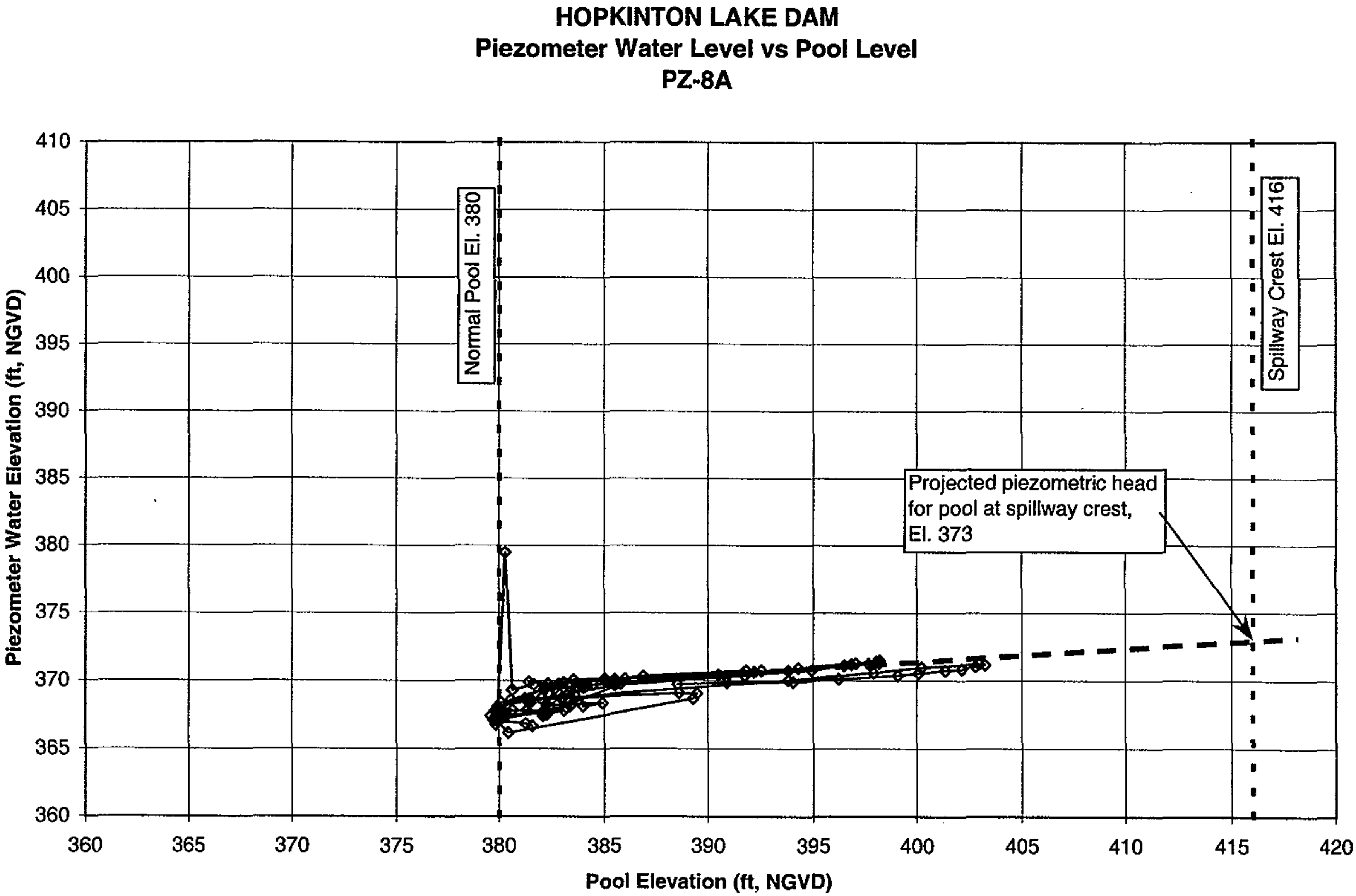




HOPKINTON LAKE DAM
Piezometer Water Level vs Pool Level
PZ-7A
Normal Pool El. 380
Spillway Crest El. 416
Projected piezometric head for pool at spillway crest, El. 374
Piezometer Water Elevation (ft, NGVD)
Pool Elevation (ft, NGVD)
410
405
400
395
390
385
380
375
370
365
360
360
365
370
375
380
385
390
395
400
405
410
415
420

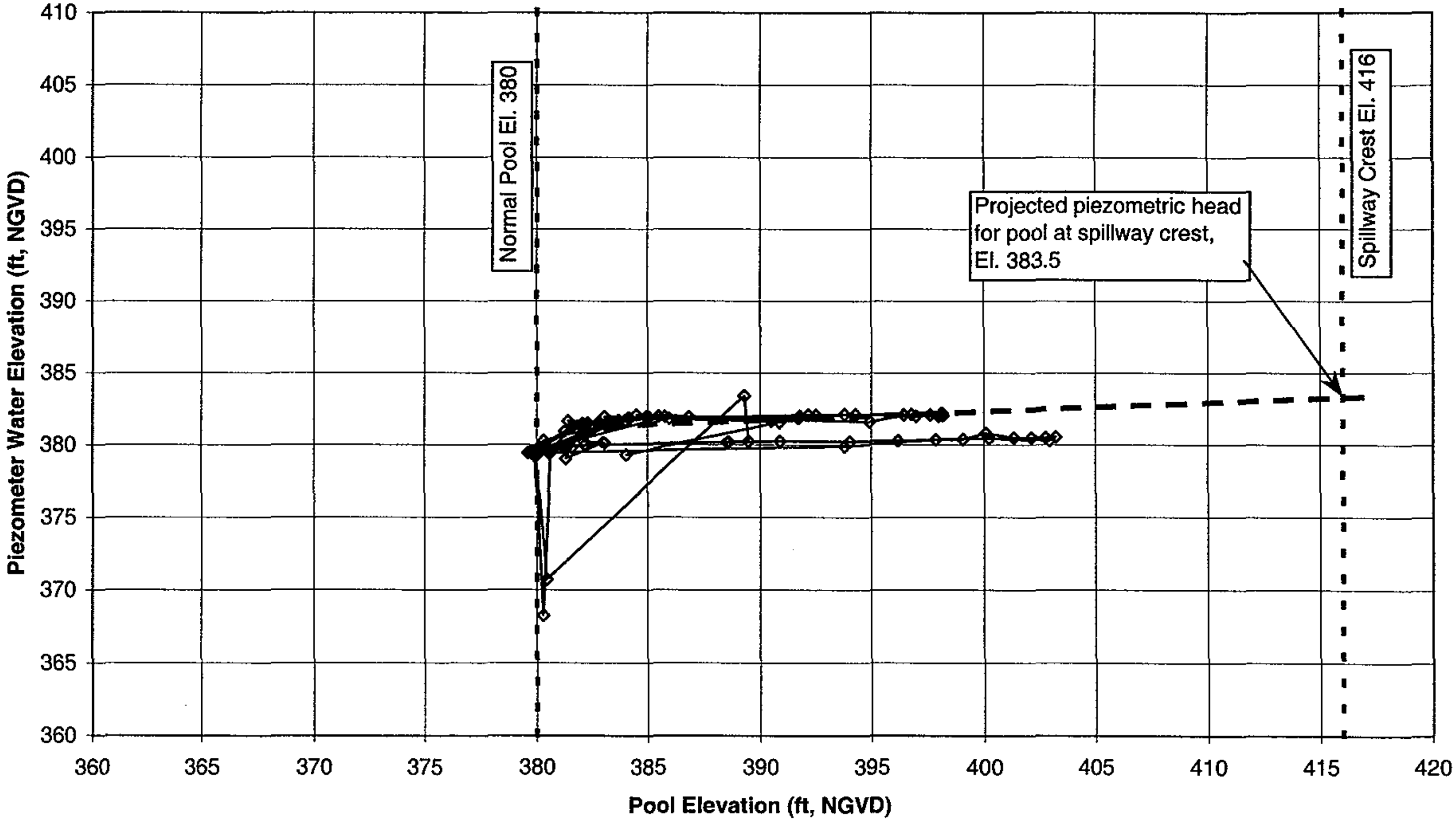
HOPKINTON LAKE DAM
Piezometer Water Level vs Pool Level
PZ-7B



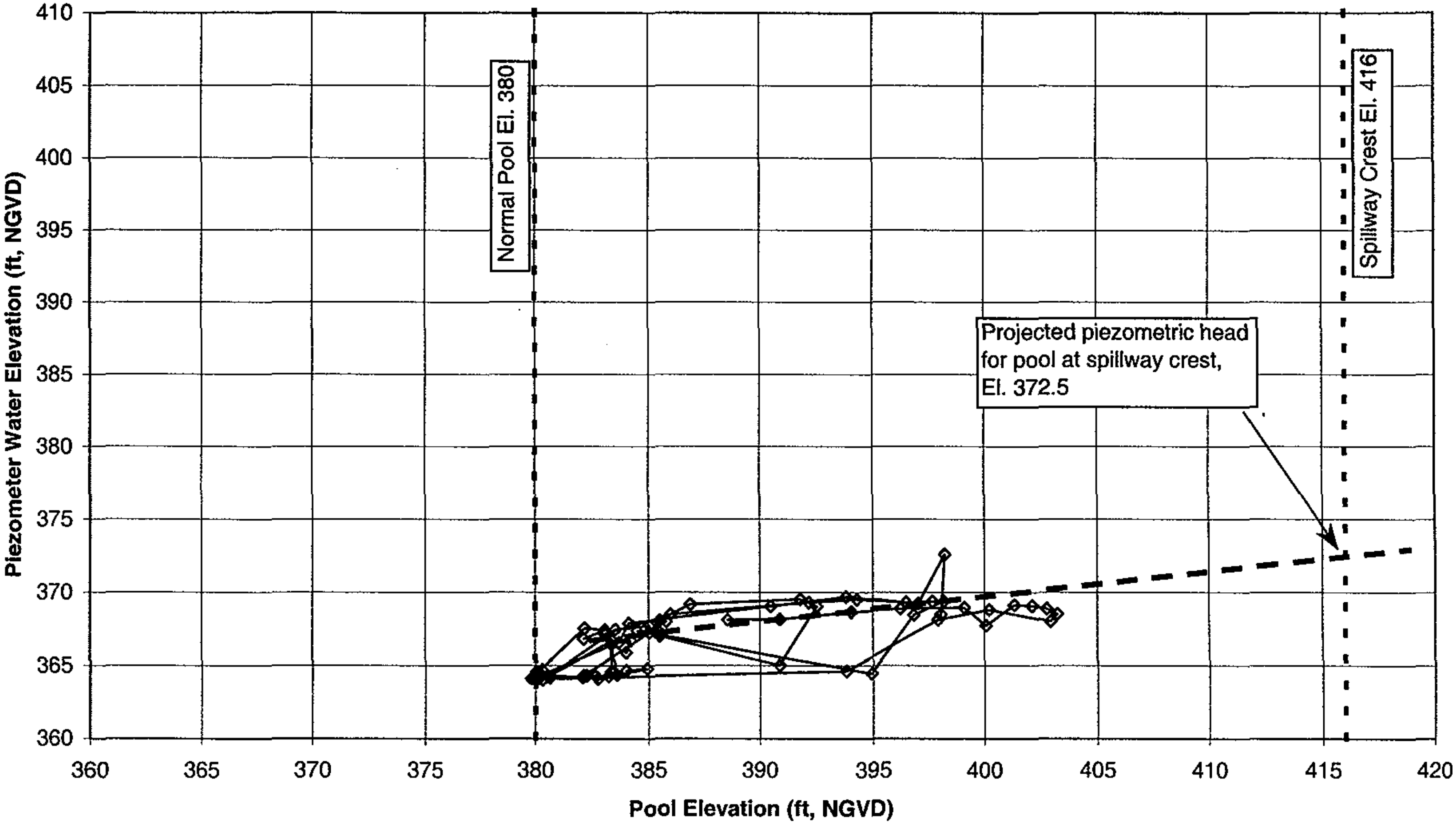


HOPKINTON LAKE DAM
Piezometer Water Level vs Pool Level
PZ-8A
Normal Pool El. 380
Spillway Crest El. 416
Projected piezometric head for pool at spillway crest, El. 373
Piezometer Water Elevation (ft, NGVD)
Pool Elevation (ft, NGVD)
410
405
400
395
390
385
380
375
370
365
360
360
365
370
375
380
385
390
395
400
405
410
415
420

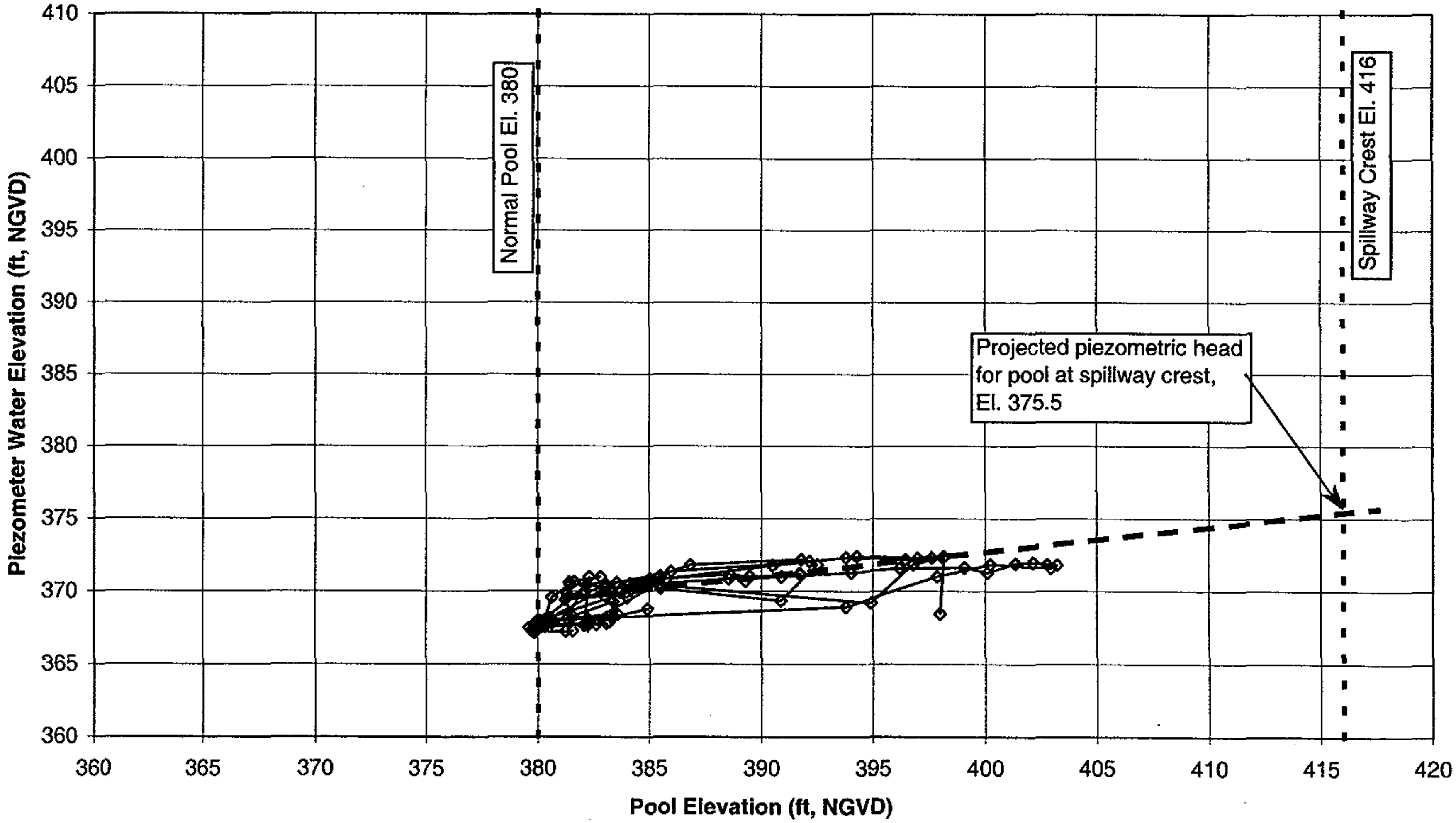
HOPKINTON LAKE DAM
Piezometer Water Level vs Pool Level
PZ-8B



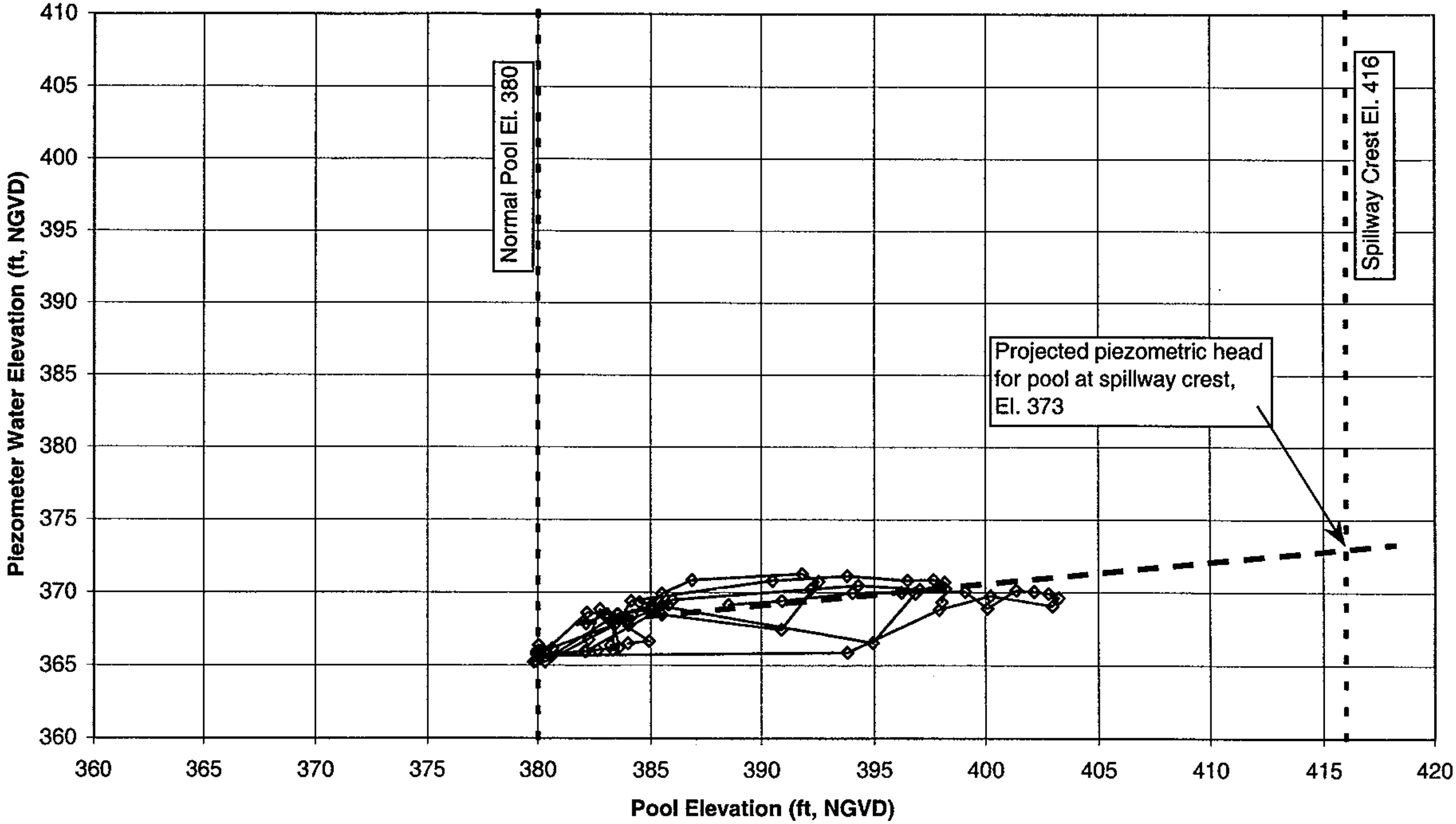
HOPKINTON LAKE DAM
Piezometer Water Level vs Pool Level
PZ-9

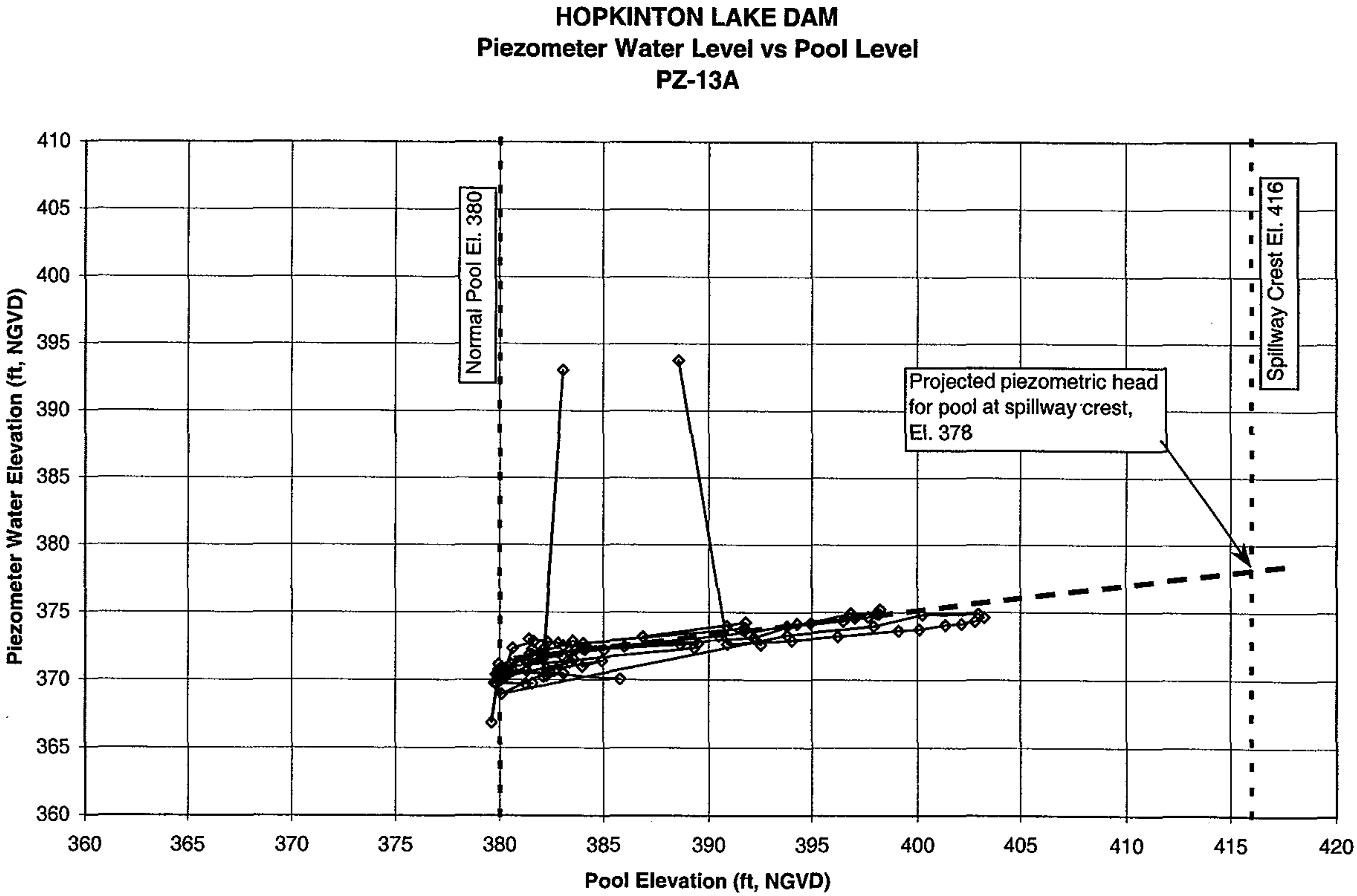


HOPKINTON LAKE DAM
Piezometer Water Level vs Pool Level
PZ-10

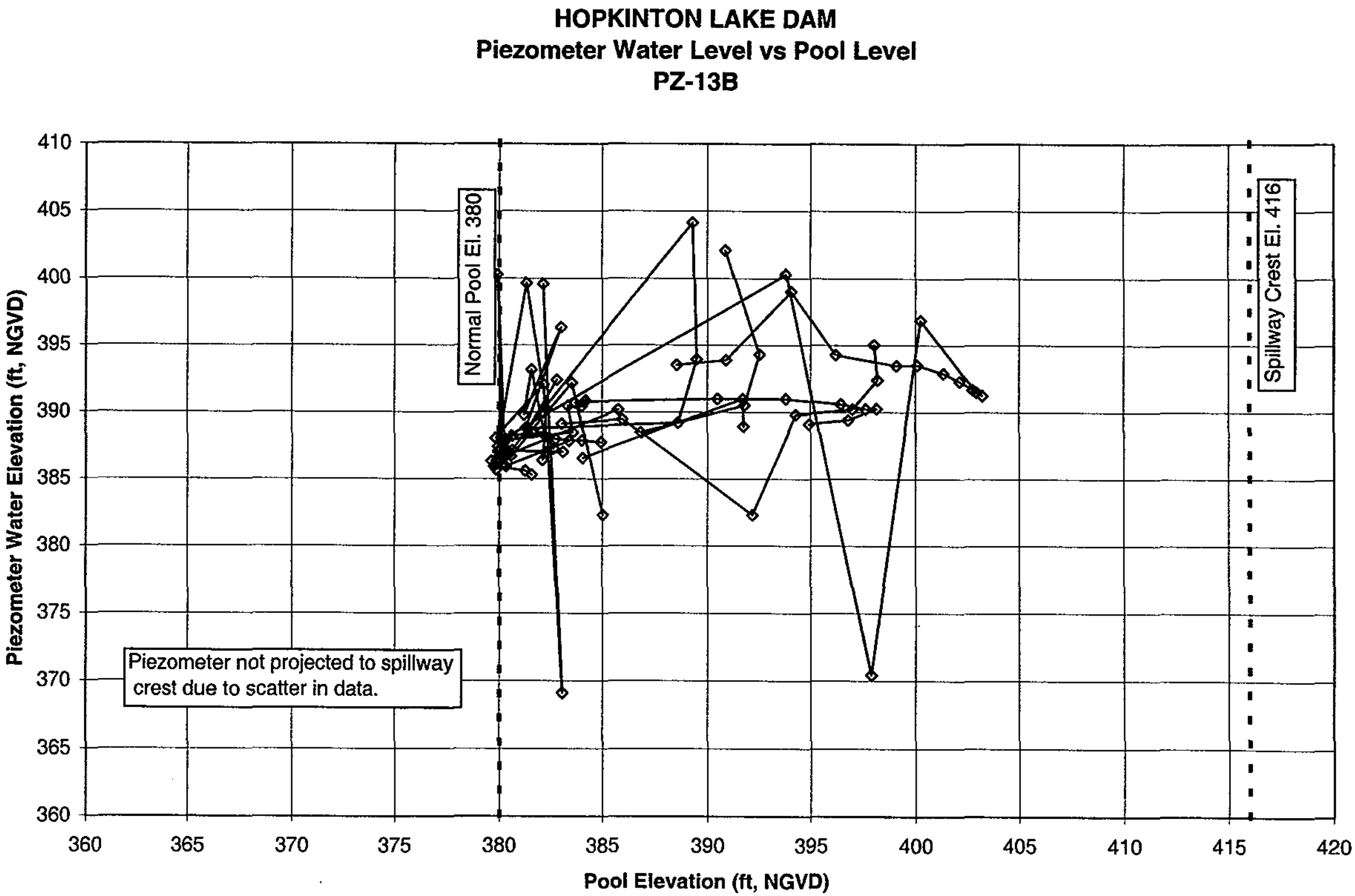


HOPKINTON LAKE DAM
Piezometer Water Level vs Pool Level
PZ-11

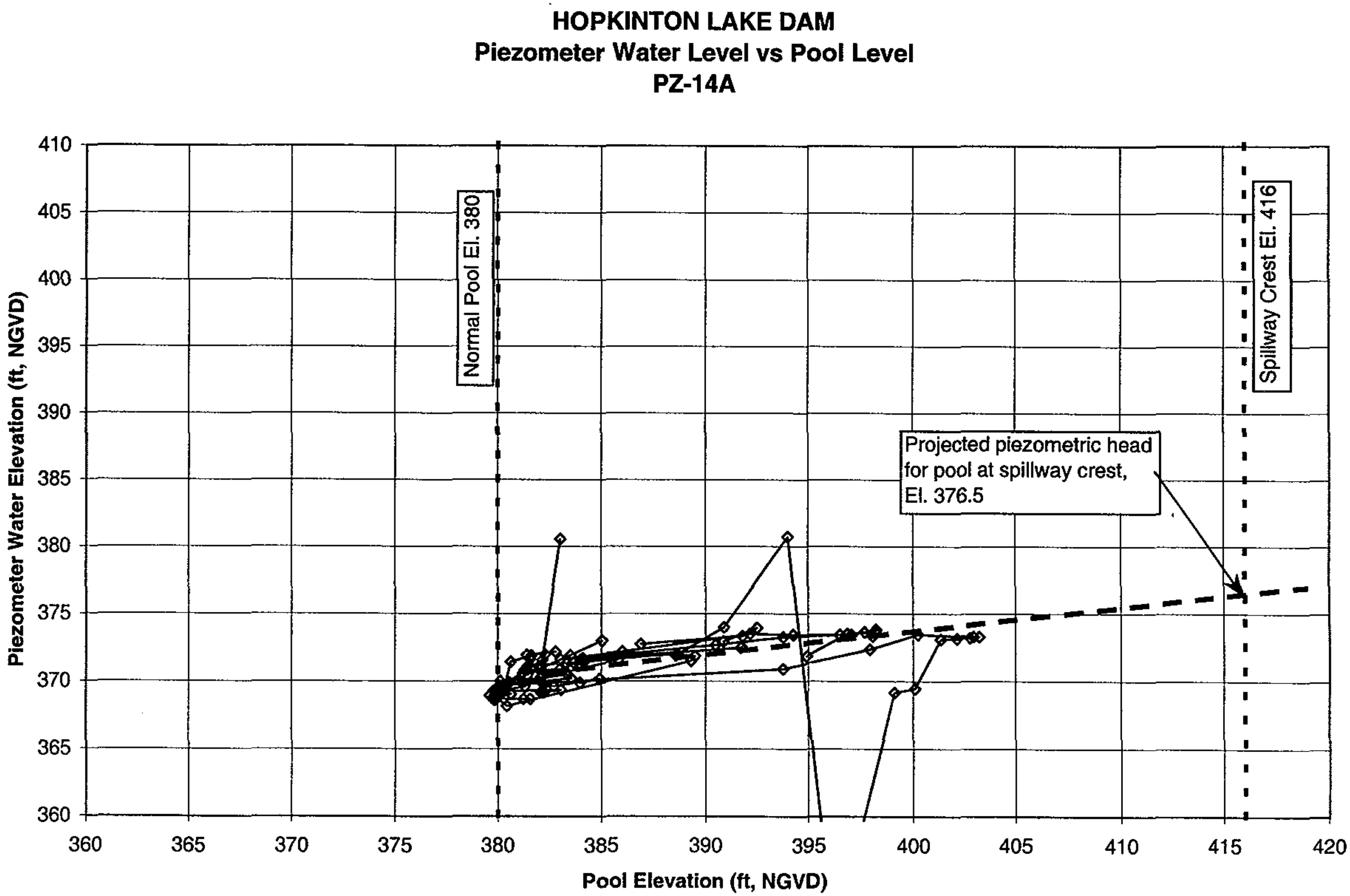




HOPKINTON LAKE DAM
Piezometer Water Level vs Pool Level
PZ-13A
Normal Pool El. 380
Spillway Crest El. 416
Projected piezometric head for pool at spillway crest, El. 378
Piezometer Water Elevation (ft, NGVD)
Pool Elevation (ft, NGVD)
410
405
400
395
390
385
380
375
370
365
360
360
365
370
375
380
385
390
395
400
405
410
415
420

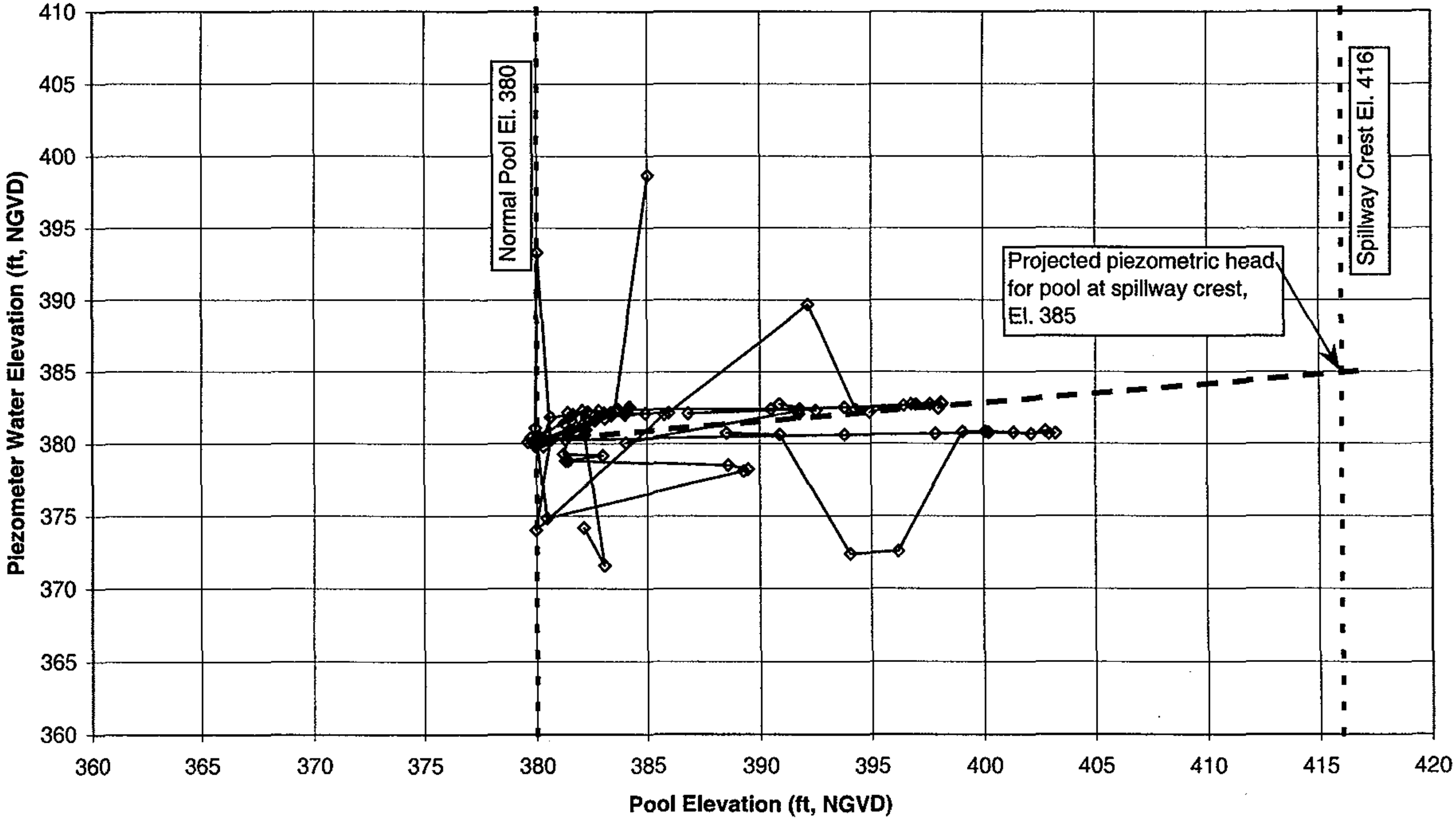


HOPKINTON LAKE DAM
Piezometer Water Level vs Pool Level
PZ-13B
Piezometer Water Elevation (ft, NGVD)
Pool Elevation (ft, NGVD)
Normal Pool El. 380
Spillway Crest El. 416
Piezometer not projected to spillway crest due to scatter in data.
410
405
400
395
390
385
380
375
370
365
360
360
365
370
375
380
385
390
395
400
405
410
415
420

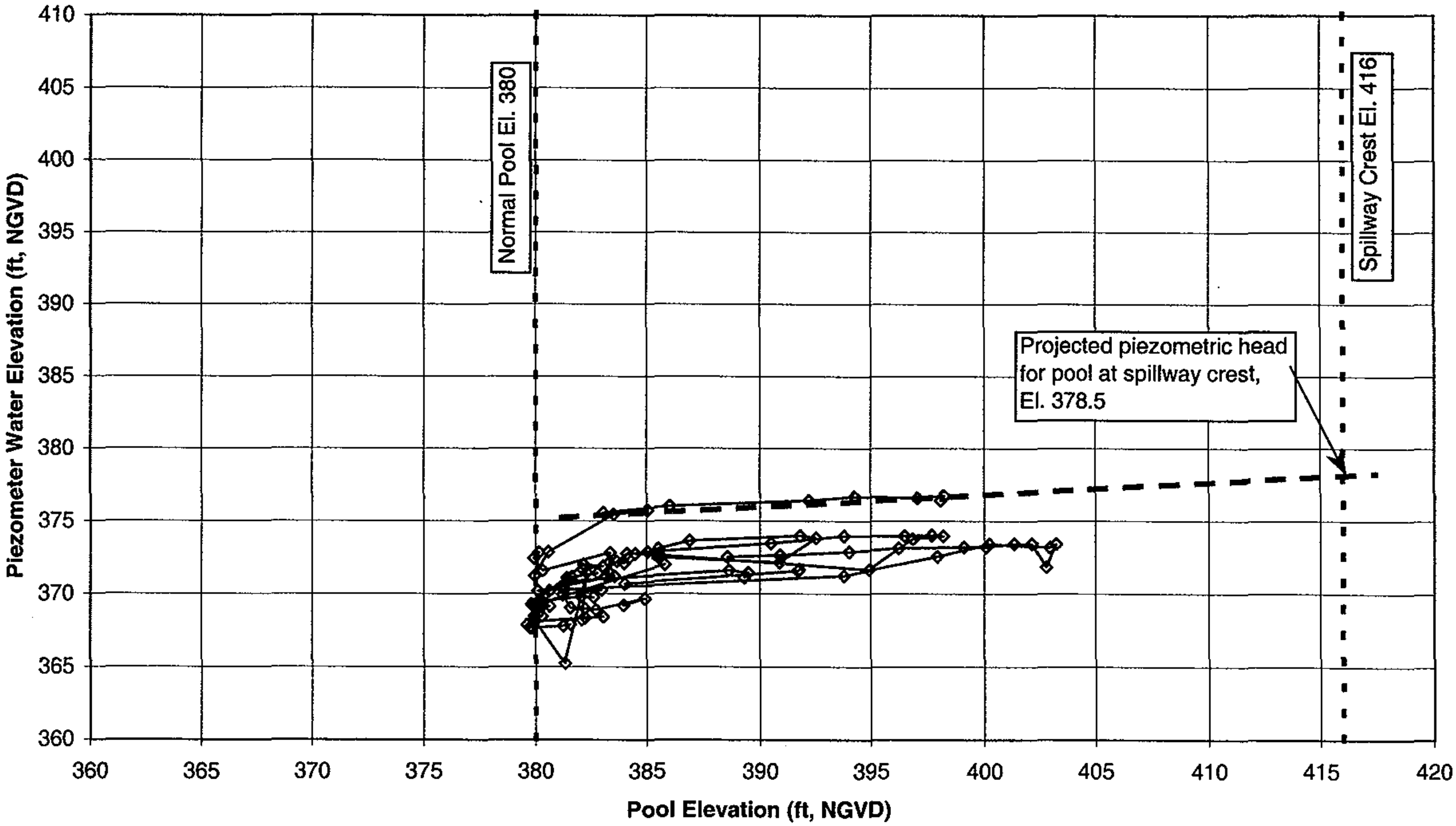


HOPKINTON LAKE DAM
Piezometer Water Level vs Pool Level
PZ-14A
Normal Pool El. 380
Spillway Crest El. 416
Projected piezometric head for pool at spillway crest, El. 376.5
Piezometer Water Elevation (ft, NGVD)
Pool Elevation (ft, NGVD)
410
405
400
395
390
385
380
375
370
365
360
360
365
370
375
380
385
390
395
400
405
410
415
420

HOPKINTON LAKE DAM
Piezometer Water Level vs Pool Level
PZ-14B

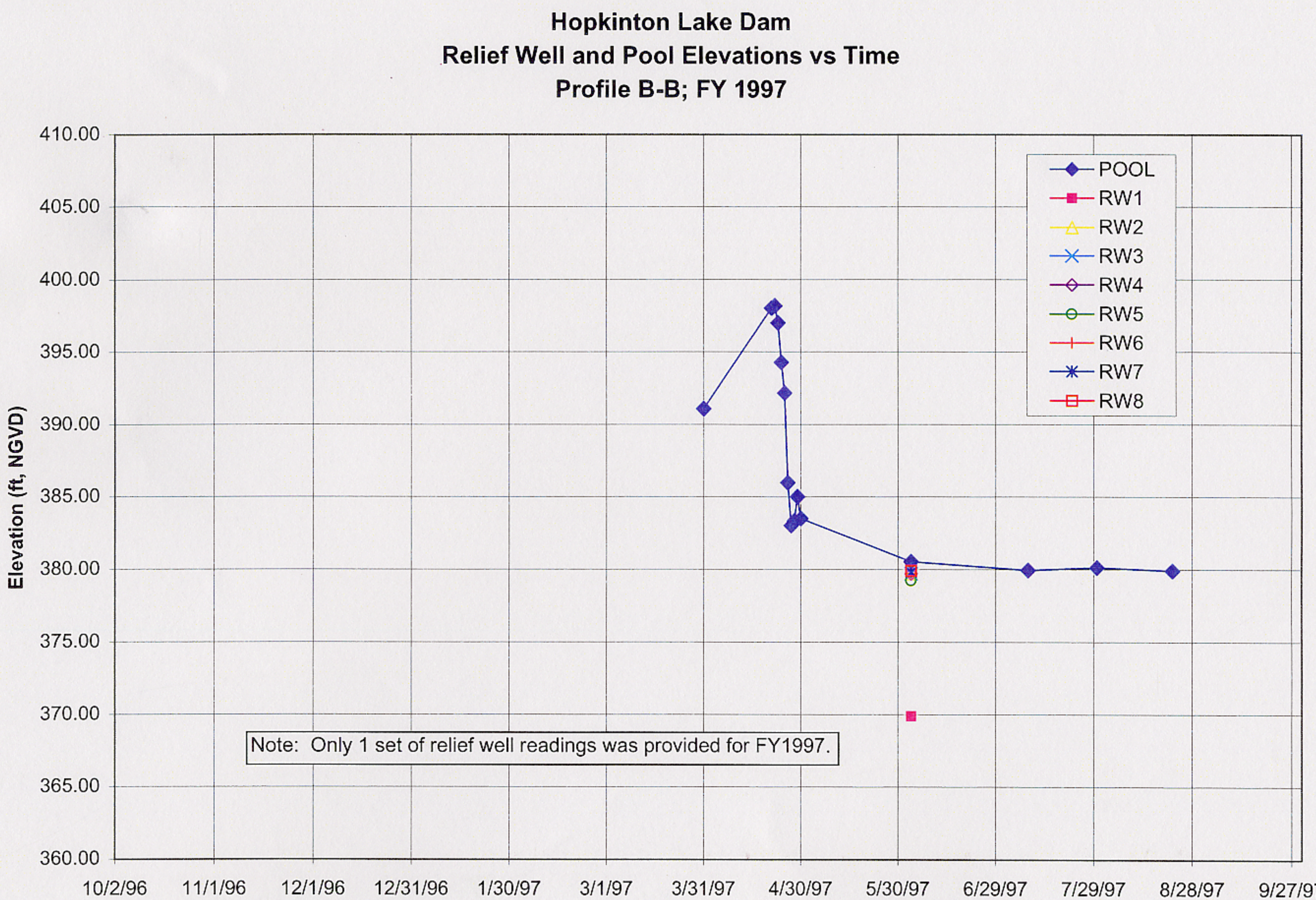


HOPKINTON LAKE DAM
Piezometer Water Level vs Pool Level
PZ-15



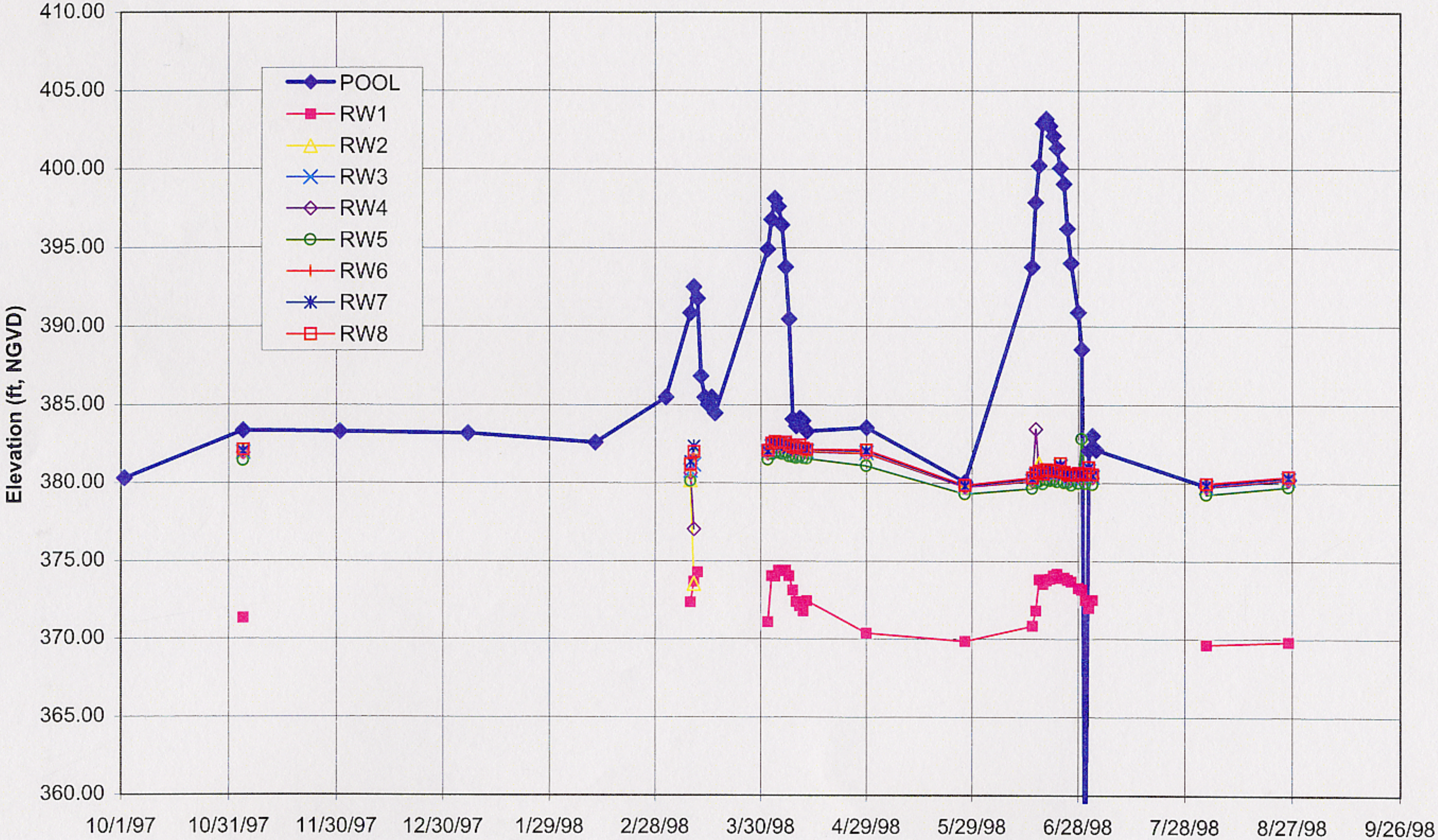
Appendix E

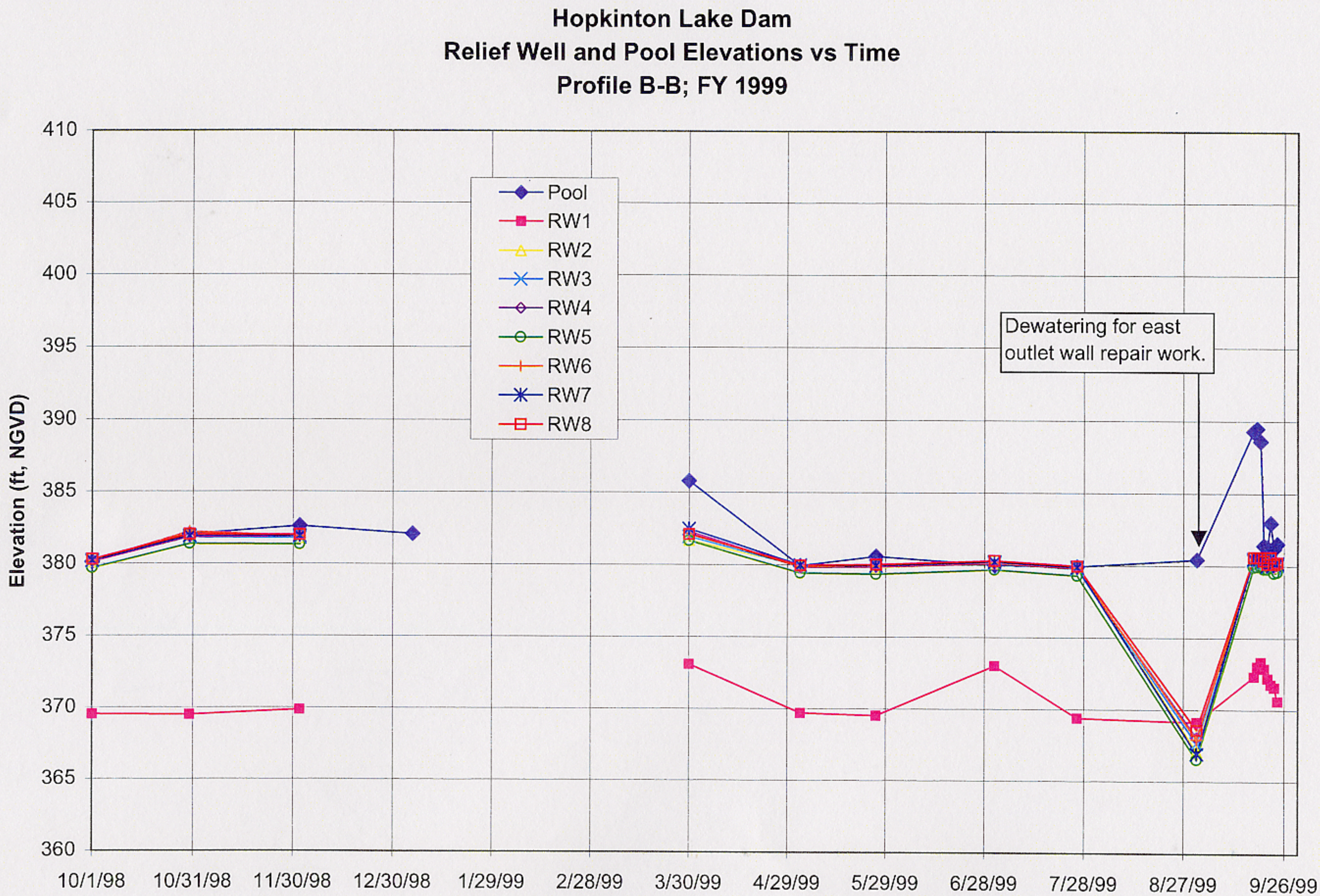
Relief Well Data, Time-History Plots



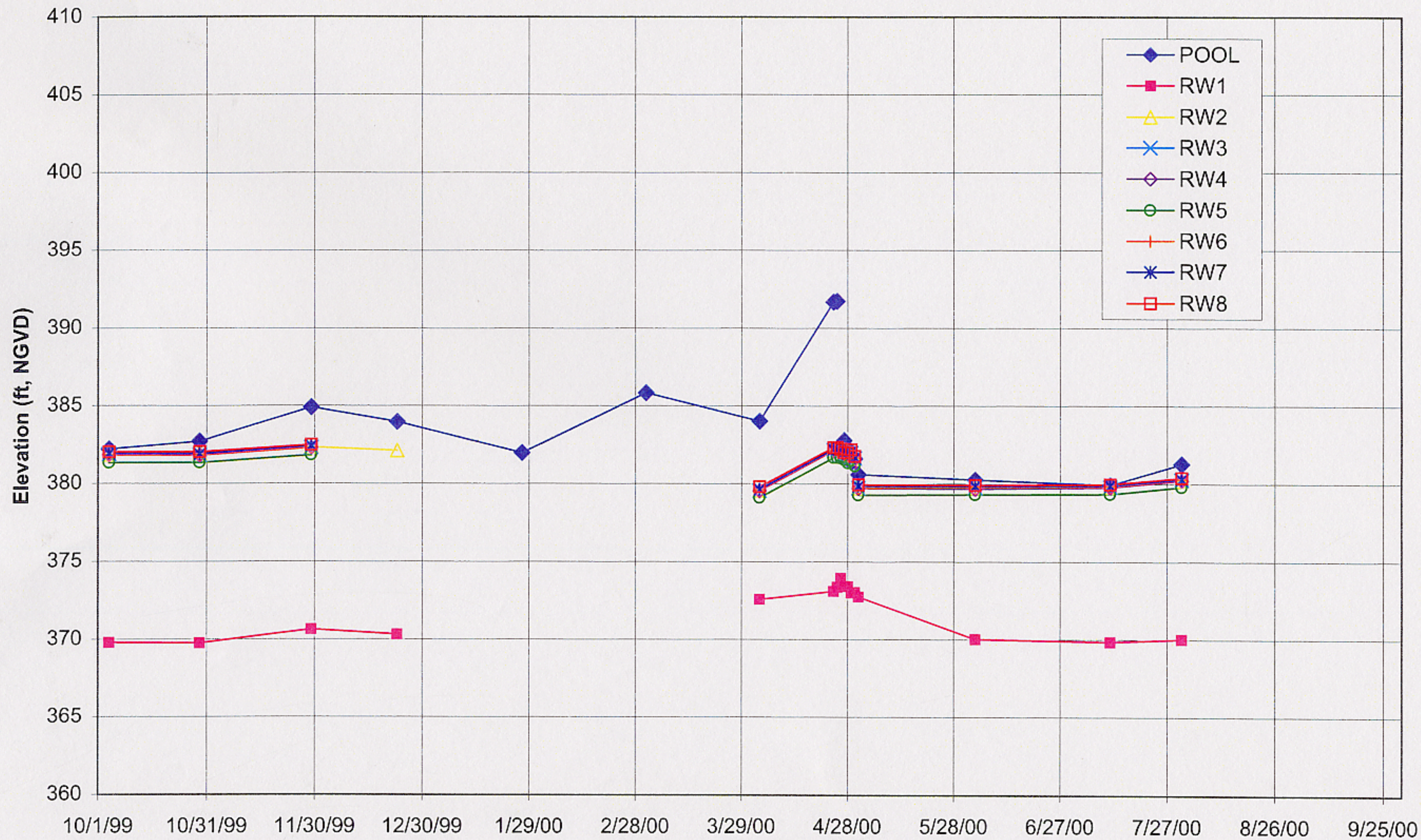
Hopkinton Lake Dam
Relief Well and Pool Elevations vs Time
Profile B-B; FY 1997
Elevation (ft, NGVD)
410.00
405.00
400.00
395.00
390.00
385.00
380.00
375.00
370.00
365.00
360.00
10/2/96
11/1/96
12/1/96
12/31/96
1/30/97
3/1/97
3/31/97
4/30/97
5/30/97
6/29/97
7/29/97
8/28/97
9/27/97
POOL
RW1
RW2
RW3
RW4
RW5
RW6
RW7
RW8
Note: Only 1 set of relief well readings was provided for FY1997.

Hopkinton Lake Dam
Relief Well and Pool Elevations vs Time
Profile B-B; FY 1998

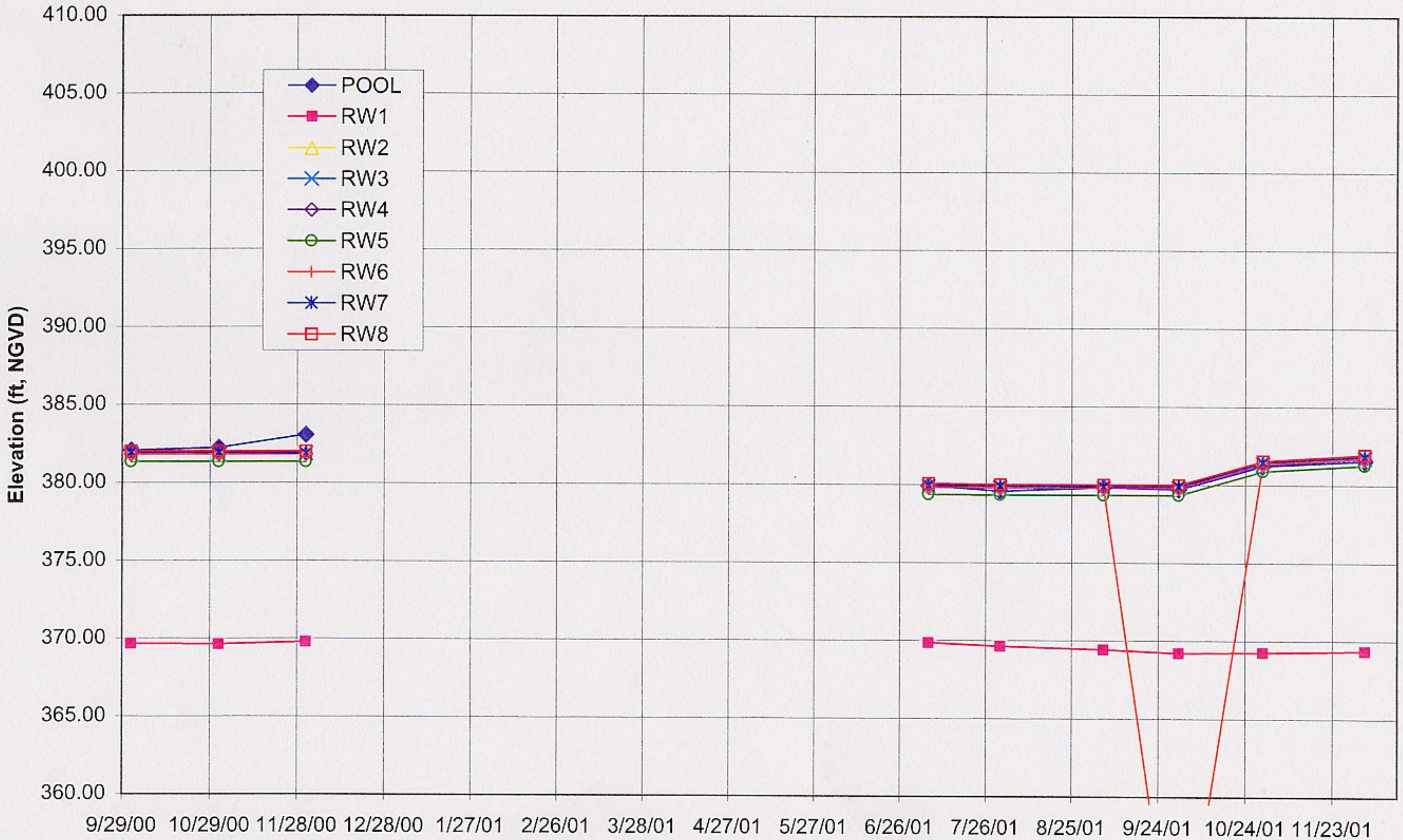



Hopkinton Lake Dam
Relief Well and Pool Elevations vs Time
Profile B-B; FY 1999
Elevation (ft, NGVD)
410
405
400
395
390
385
380
375
370
365
360
10/1/98
10/31/98
11/30/98
12/30/98
1/29/99
2/28/99
3/30/99
4/29/99
5/29/99
6/28/99
7/28/99
8/27/99
9/26/99
Pool
RW1
RW2
RW3
RW4
RW5
RW6
RW7
RW8
Dewatering for east outlet wall repair work.

Hopkinton Lake Dam
Relief Well and Pool Elevations vs Time
Profile B-B; FY 2000

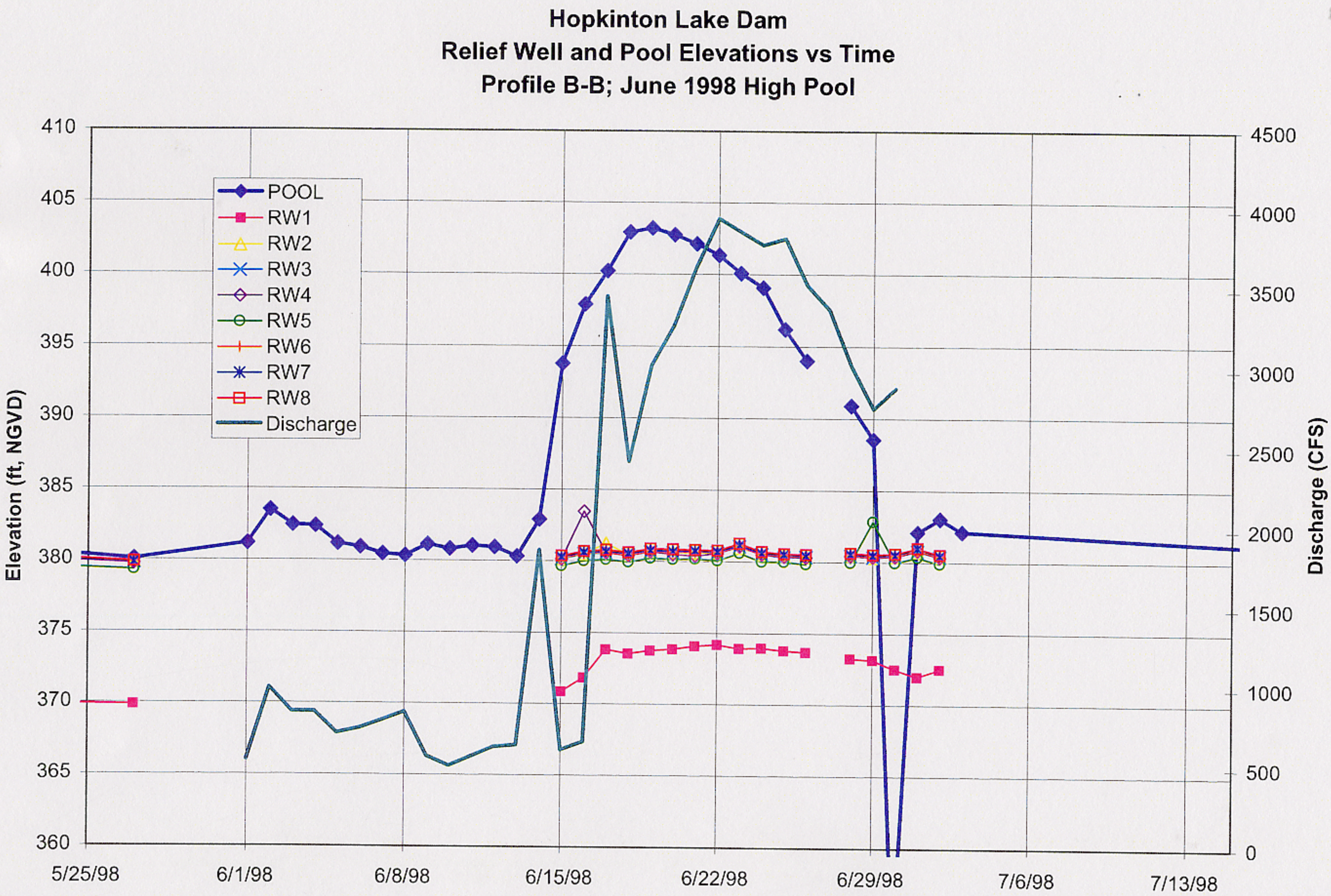


Hopkinton Lake Dam
Relief Well and Pool Elevations vs Time
Profile B-B; FY 2001



Appendix F

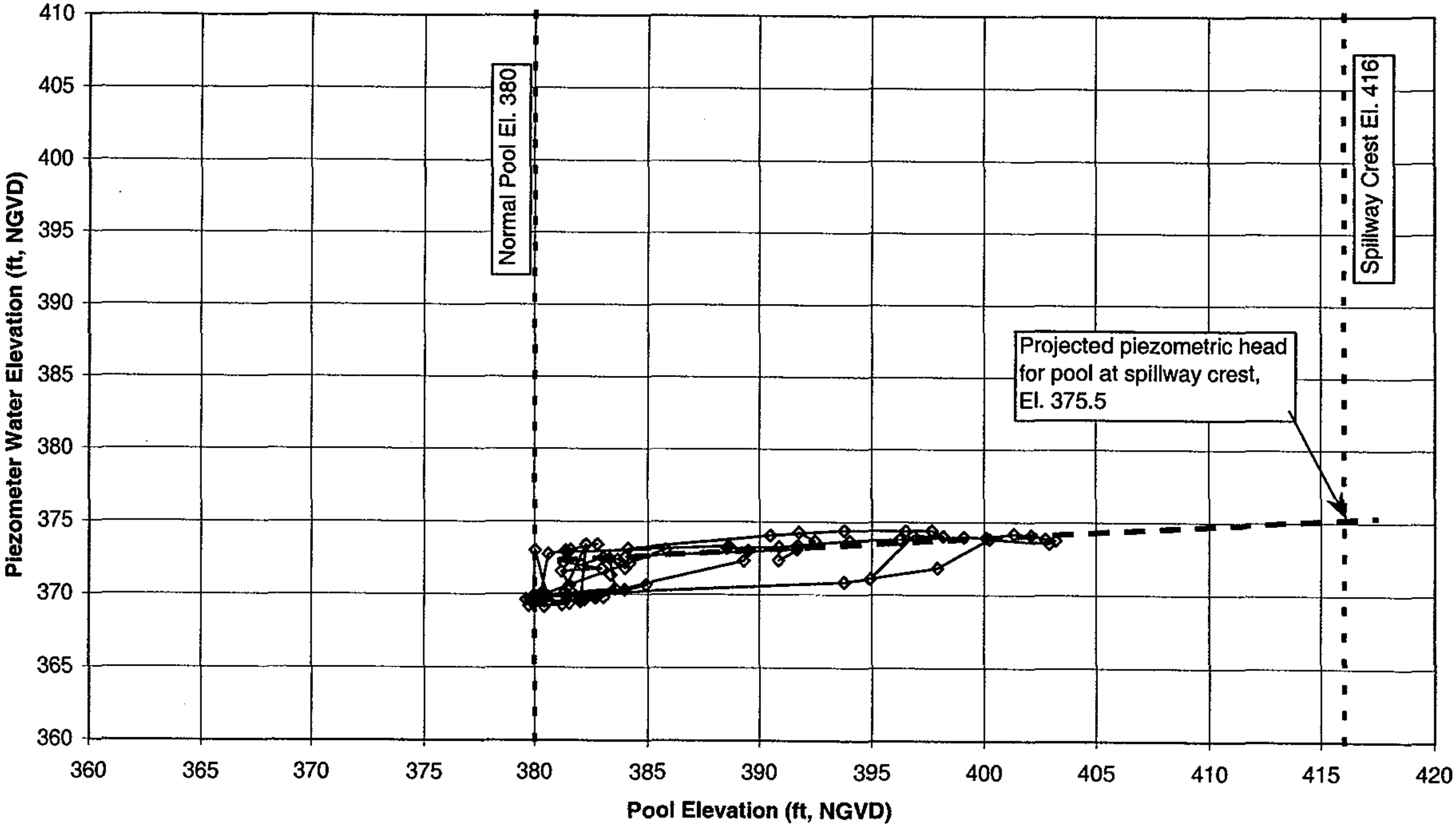
Relief Well Data, June 1998 Event Plots


Hopkinton Lake Dam
Relief Well and Pool Elevations vs Time
Profile B-B; June 1998 High Pool
POOL
RW1
RW2
RW3
RW4
RW5
RW6
RW7
RW8
Discharge
Elevation (ft, NGVD)
Discharge (CFS)
410
405
400
395
390
385
380
375
370
365
360
4500
4000
3500
3000
2500
2000
1500
1000
500
0
5/25/98
6/1/98
6/8/98
6/15/98
6/22/98
6/29/98
7/6/98
7/13/98

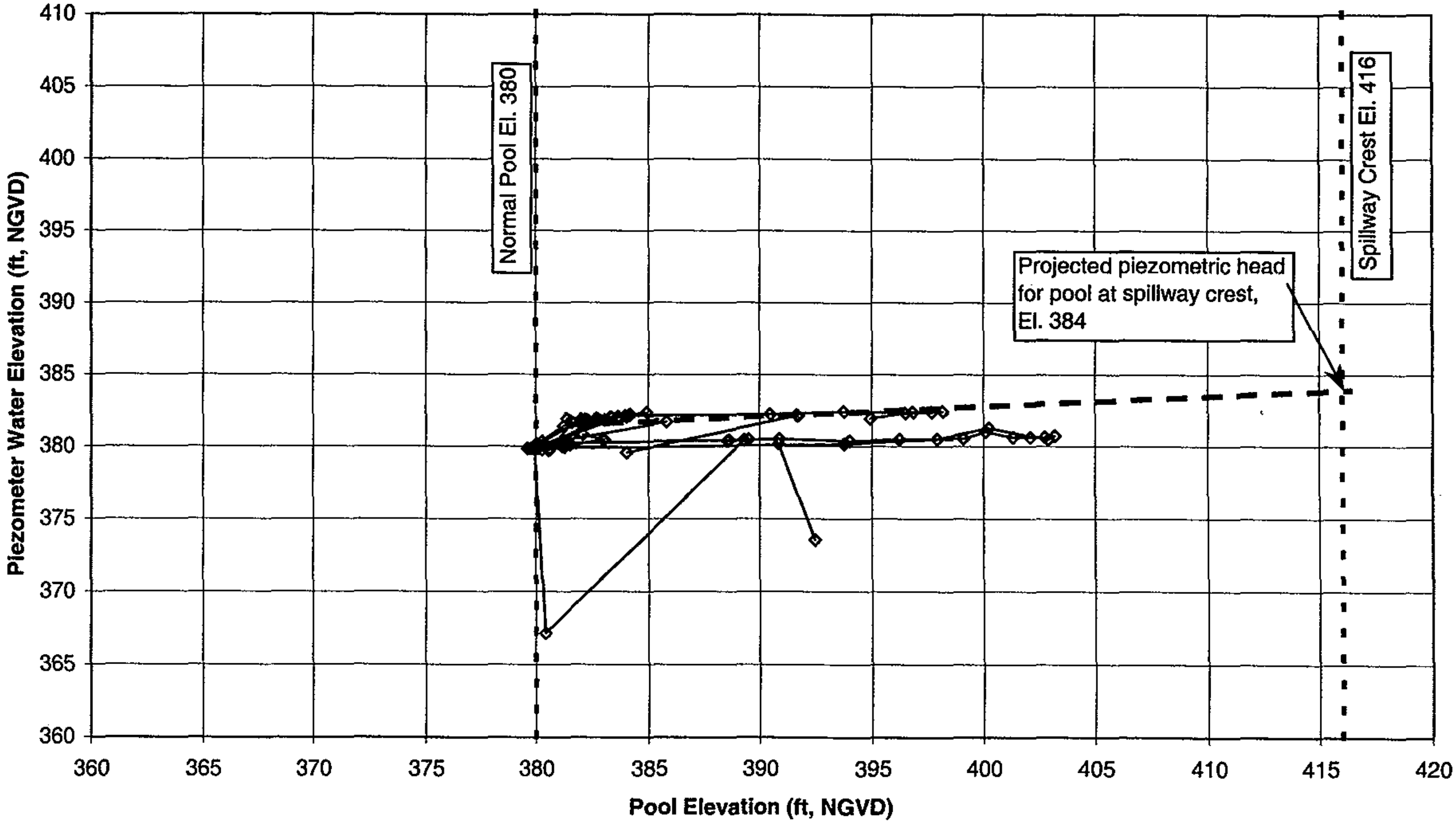
Appendix G

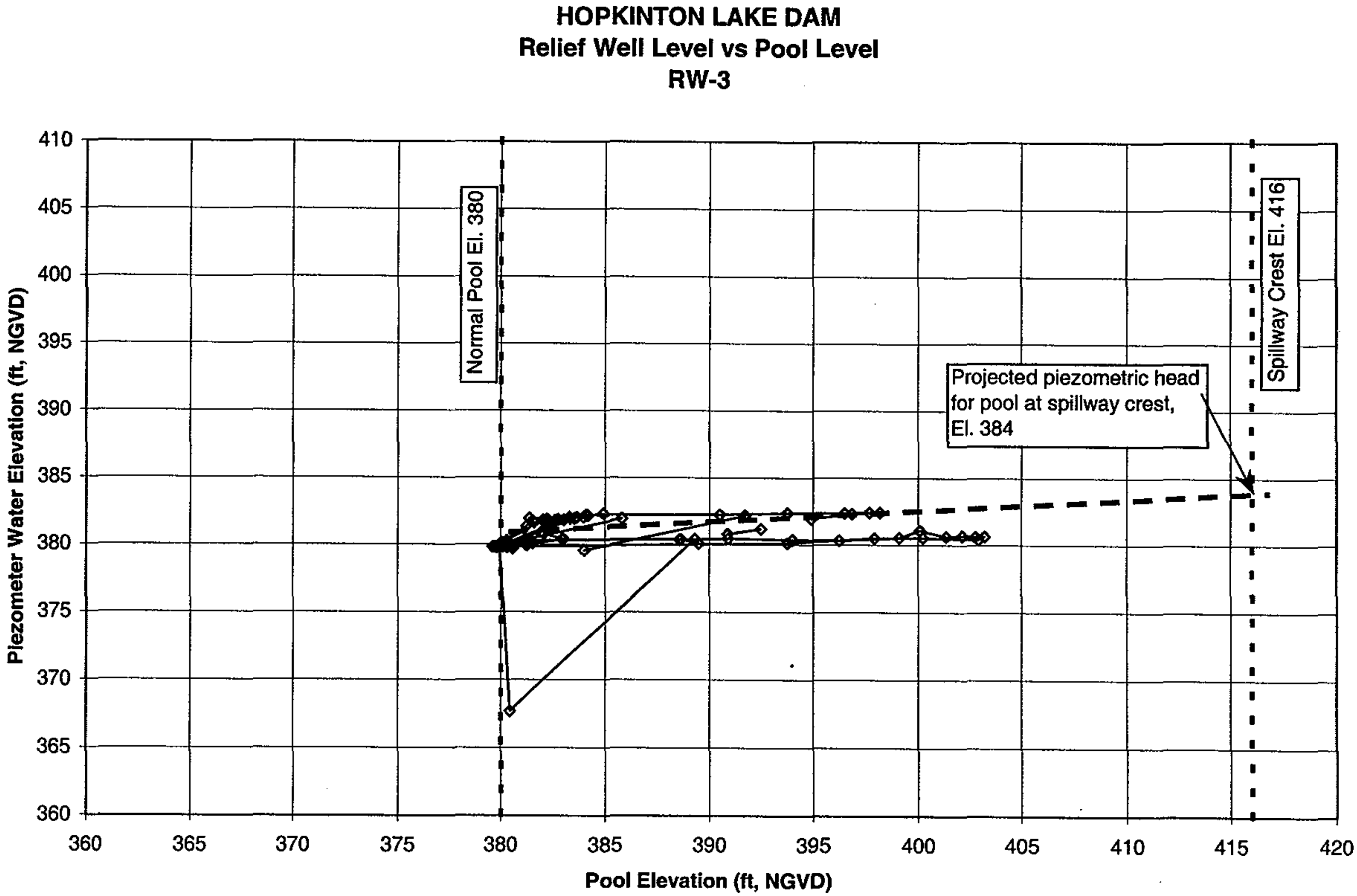
Relief Well Elevations vs. Pool Elevations

HOPKINTON LAKE DAM
Relief Well Level vs Pool Level
RW-1



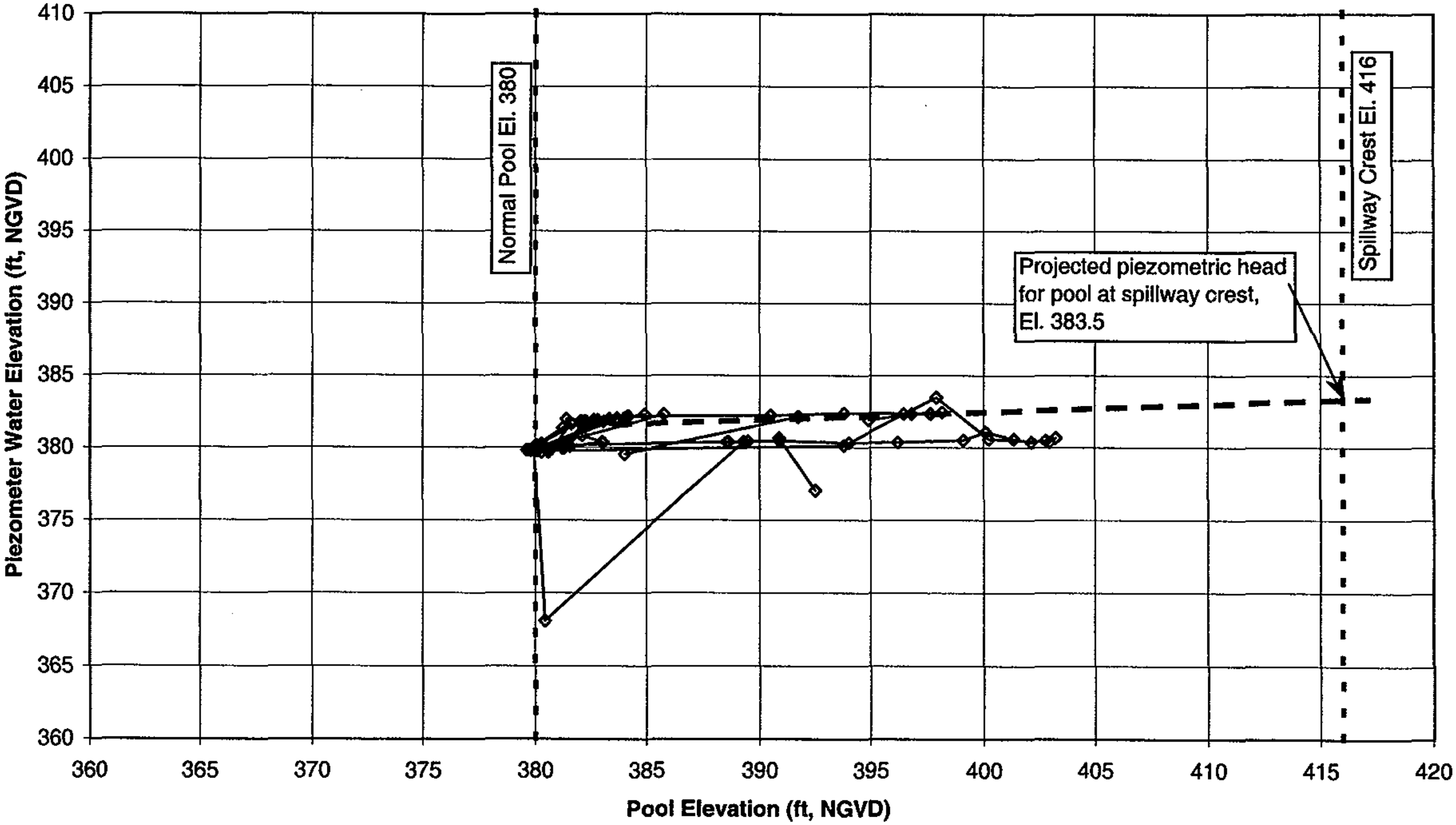
HOPKINTON LAKE DAM
Relief Well Level vs Pool Level
RW-2

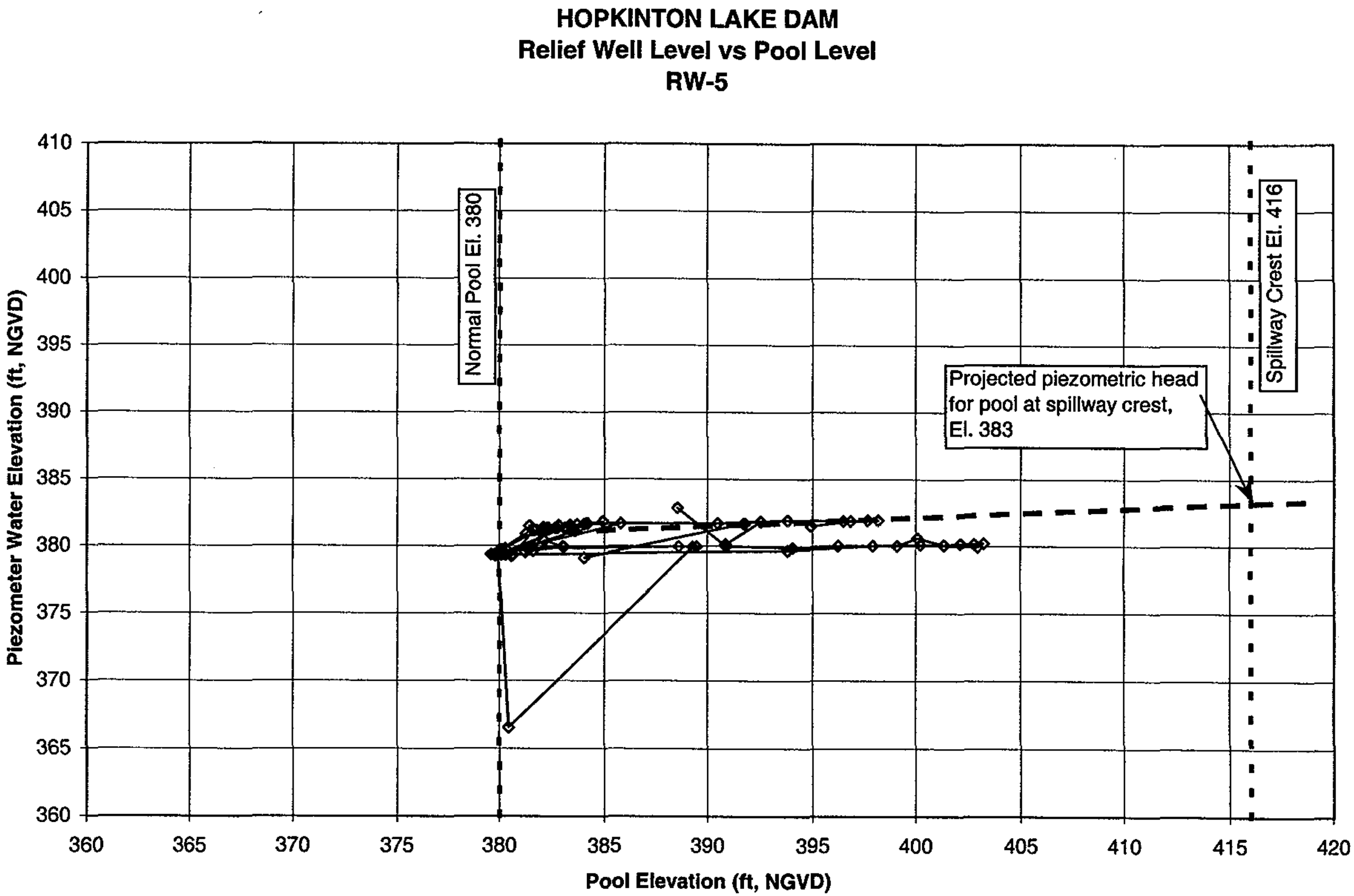




HOPKINTON LAKE DAM
Relief Well Level vs Pool Level
RW-3
Piezometer Water Elevation (ft, NGVD)
Pool Elevation (ft, NGVD)
410
405
400
395
390
385
380
375
370
365
360
360
365
370
375
380
385
390
395
400
405
410
415
420
Normal Pool El. 380
Spillway Crest El. 416
Projected piezometric head for pool at spillway crest, El. 384

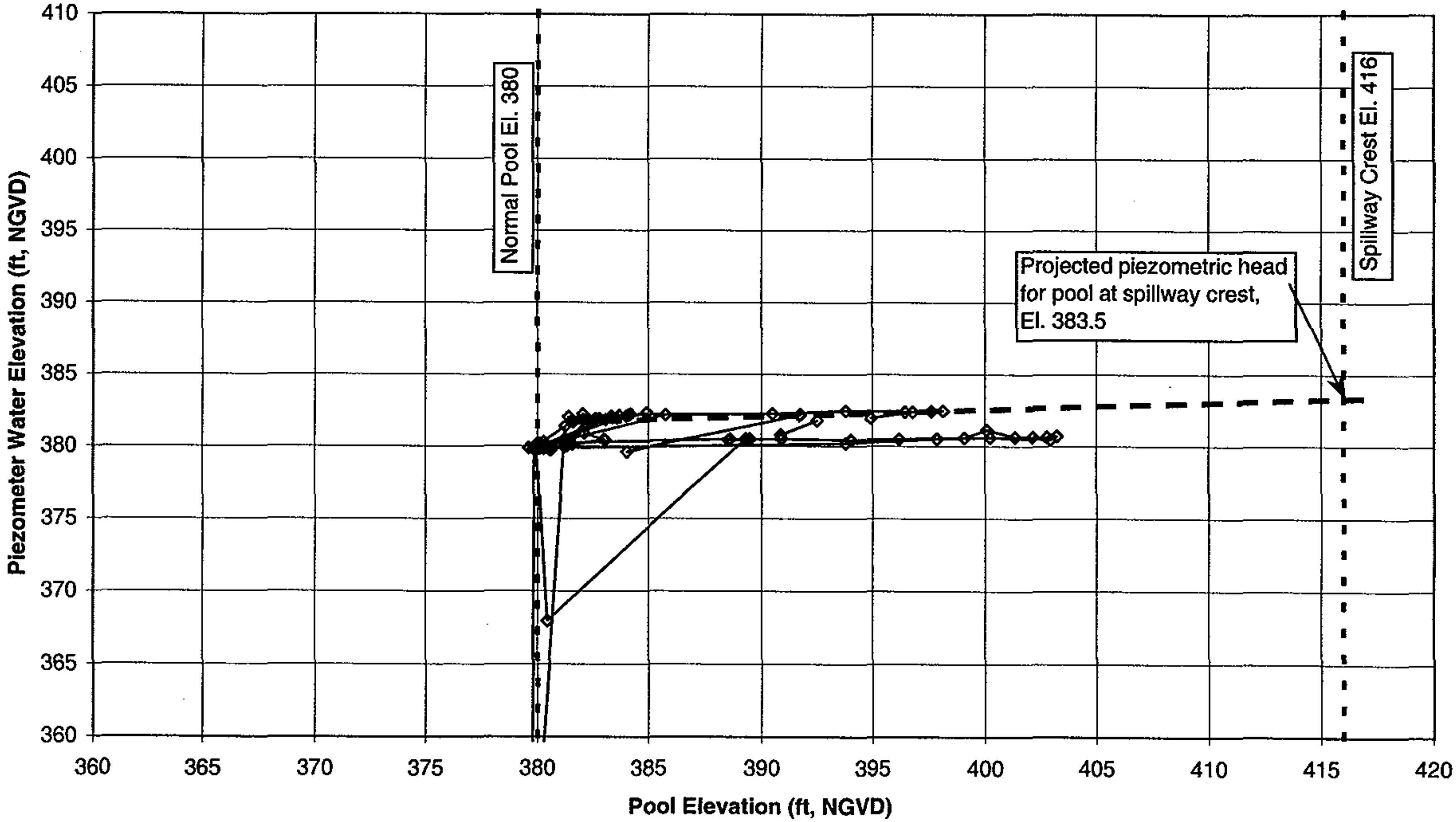
HOPKINTON LAKE DAM
Relief Well Level vs Pool Level
RW-4

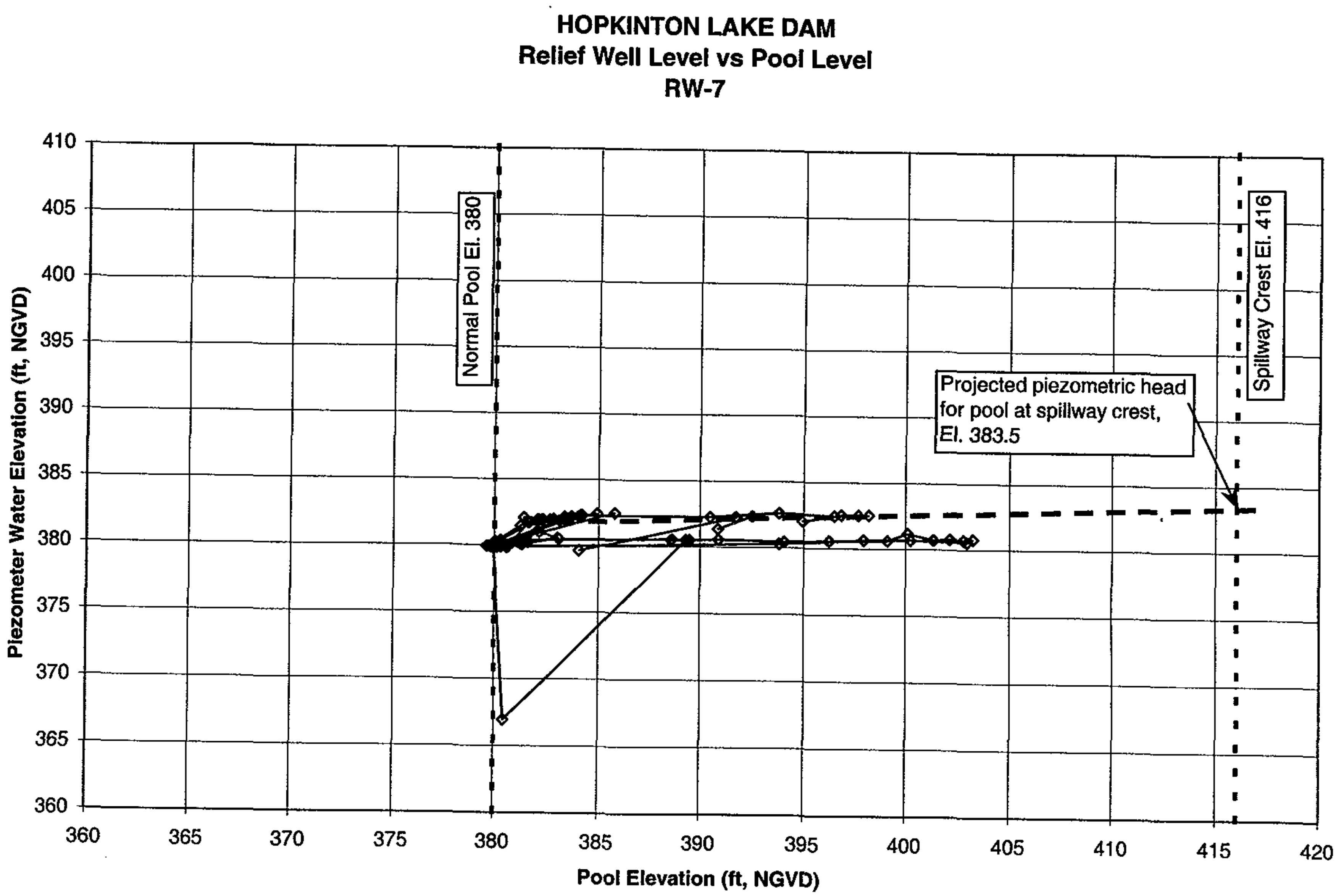




HOPKINTON LAKE DAM
Relief Well Level vs Pool Level
RW-5
Piezometer Water Elevation (ft, NGVD)
Pool Elevation (ft, NGVD)
410
405
400
395
390
385
380
375
370
365
360
360
365
370
375
380
385
390
395
400
405
410
415
420
Normal Pool El. 380
Spillway Crest El. 416
Projected piezometric head for pool at spillway crest, El. 383

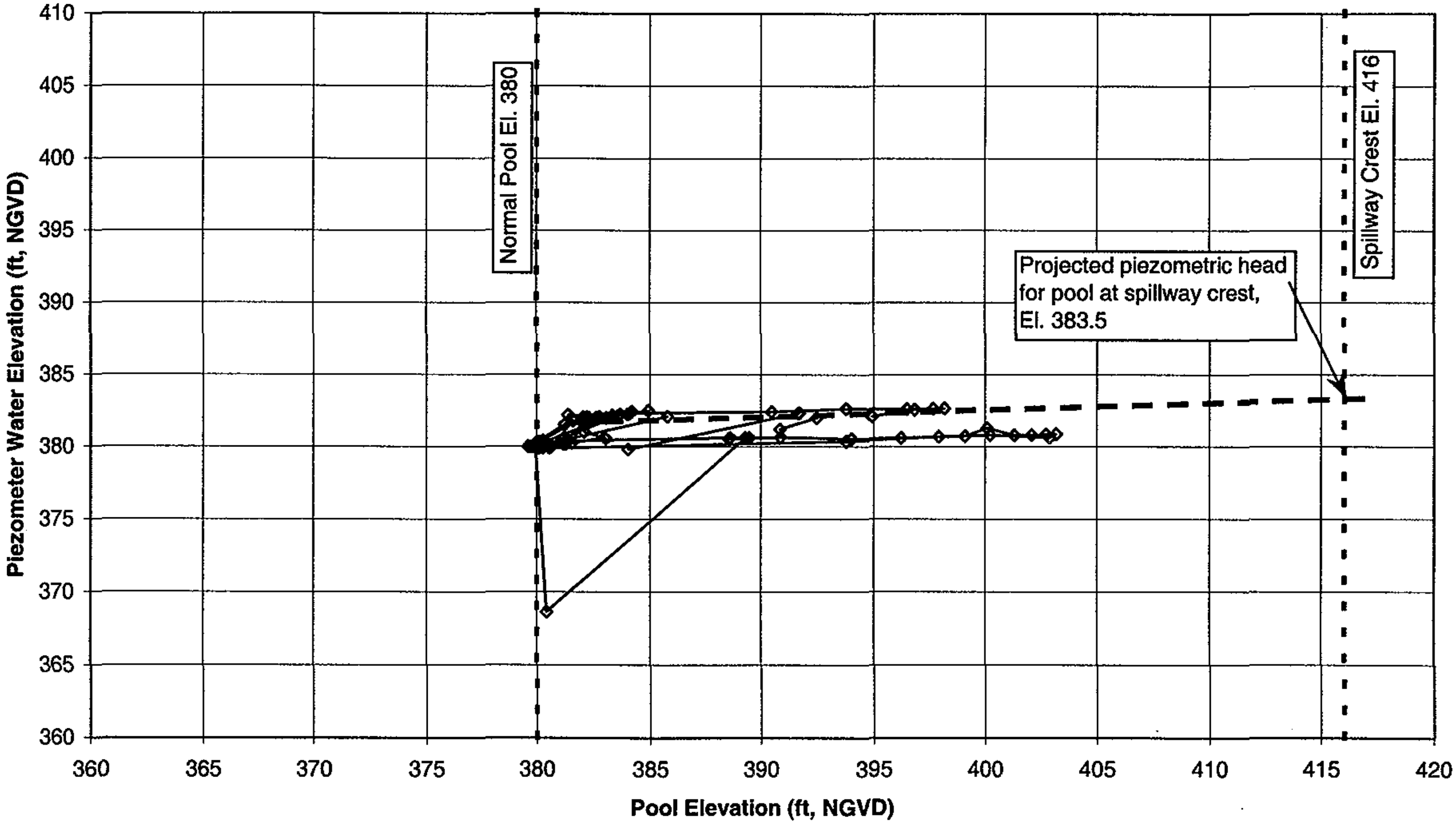
HOPKINTON LAKE DAM
Relief Well Level vs Pool Level
RW-6





HOPKINTON LAKE DAM
Relief Well Level vs Pool Level
RW-7
Piezometer Water Elevation (ft, NGVD)
410
405
400
395
390
385
380
375
370
365
360
Pool Elevation (ft, NGVD)
360
365
370
375
380
385
390
395
400
405
410
415
420
Normal Pool El. 380
Spillway Crest El. 416
Projected piezometric head for pool at spillway crest, El. 383.5

HOPKINTON LAKE DAM
Relief Well Level vs Pool Level
RW-8



APPENDIX VIII

RESULTS OF CRACK SURVEYS

PERIODIC INSPECTION REPORT NO. 6
HOPKINTON LAKE
RESULTS OF CRACK SURVEY

1. PURPOSE

This crack survey is intended to identify the location and the size of cracks in concrete features at Hopkinton Lake. It is important to monitor cracks to determine the cause of cracking, the severity of the crack in relation to the concrete feature, and the remedial measures that may be required to strengthen the feature. Two types of cracks are structural and non-structural cracks. This crack survey was conducted on 4 June 2002 by John Kedzierski from the Design Branch, Engineering/Planning Division of New England District.

2. STRUCTURAL CRACKS

Structural cracks are developed due to over stressing of a concrete member or differential movement or settlement within a member or monolith. Structural cracks will typically be located in tensile zones of members subject to bending (flexural cracks), in shear zones of beams or walls (shear cracks), and in walls or foundations due to differential movement or settlement (settlement cracks). No structural cracks were found in the conduit or other features at Hopkinton Lake during Periodic Inspection No. 6, except for a ¼" wide crack at the inlet of the North Weir Stop Log structure (see Photo A-12).

3. NON-STRUCTURAL CRACKS

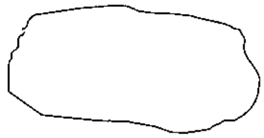
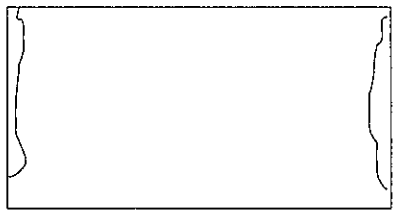
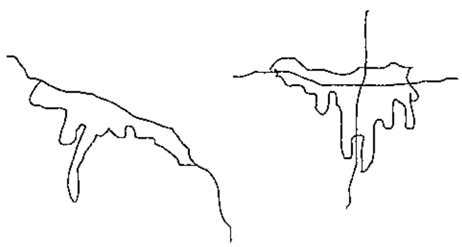
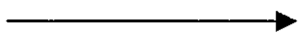
Non-structural cracks are developed typically due to improper placement and curing techniques during construction (shrinkage and pattern cracks) or inadequate spacing of expansion/contraction joints to allow for thermal movement of concrete members (temperature cracks). Because non-structural cracks are not caused by over stressing of a concrete member, they are of lesser concern. Non-structural cracks were found at the spillway and retaining walls, the inlet and outlet structures, the conduit, and in the control tower. The majority of these cracks were hairline cracks and a description of them is provided in the Concrete/Structural section of the main report.

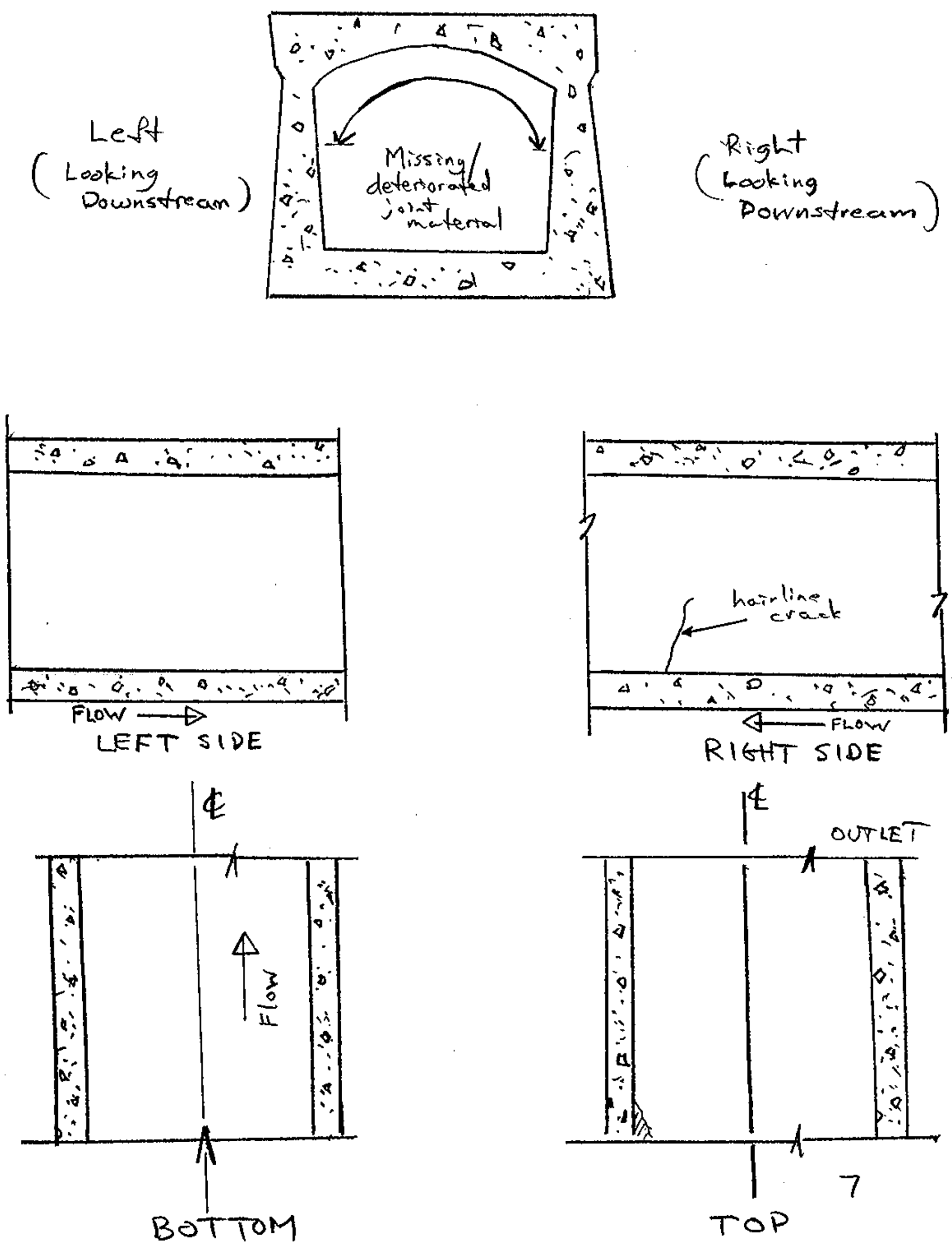
4. RESULTS OF CRACK SURVEYS

There are currently no structural cracks at Hopkinton Lake that require monitoring. The crack at the North Weir Stop Log structure is not critical to the overall function of the structure but should be inspected during subsequent periodic inspections. All of the other cracks found during Periodic Inspection No. 6 are non-structural and do not affect the structural integrity of the project.

Non-structural cracks are located in various areas of the project and are described in the main report. The concrete in the transition and conduit is in overall good condition, except for joint deterioration between the monoliths. There are hairline cracks in various other features such as the spillway retaining walls, and the inlet and outlet structures. Sketches provided below illustrate the general location and extent of cracking and concrete deterioration in the conduits.

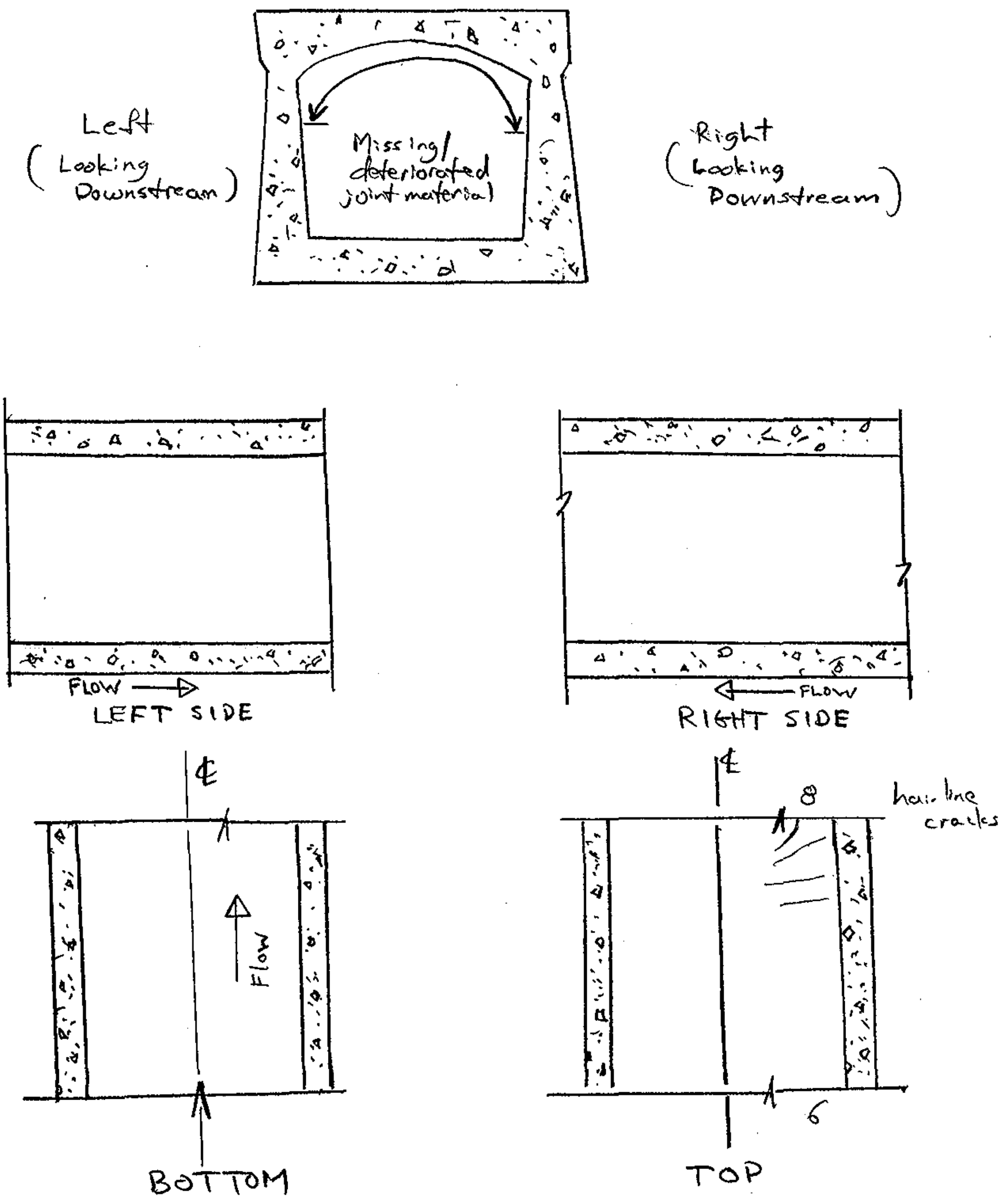
PERIODIC INSPECTION REPORT NO. 6
HOPKINTON LAKE
RESULTS OF CRACK SURVEYS

DESCRIPTION OF SYMBOLS	
DESCRIPTION	SYMBOL
SPALL OR DETERIORATION	
JOINT DETERIORATION	
HAIRLINE CRACKS	
EFFLORESCENCE	
CRACKS WITH EFFLORESCENCE	
DIRECTION OF FLOW	



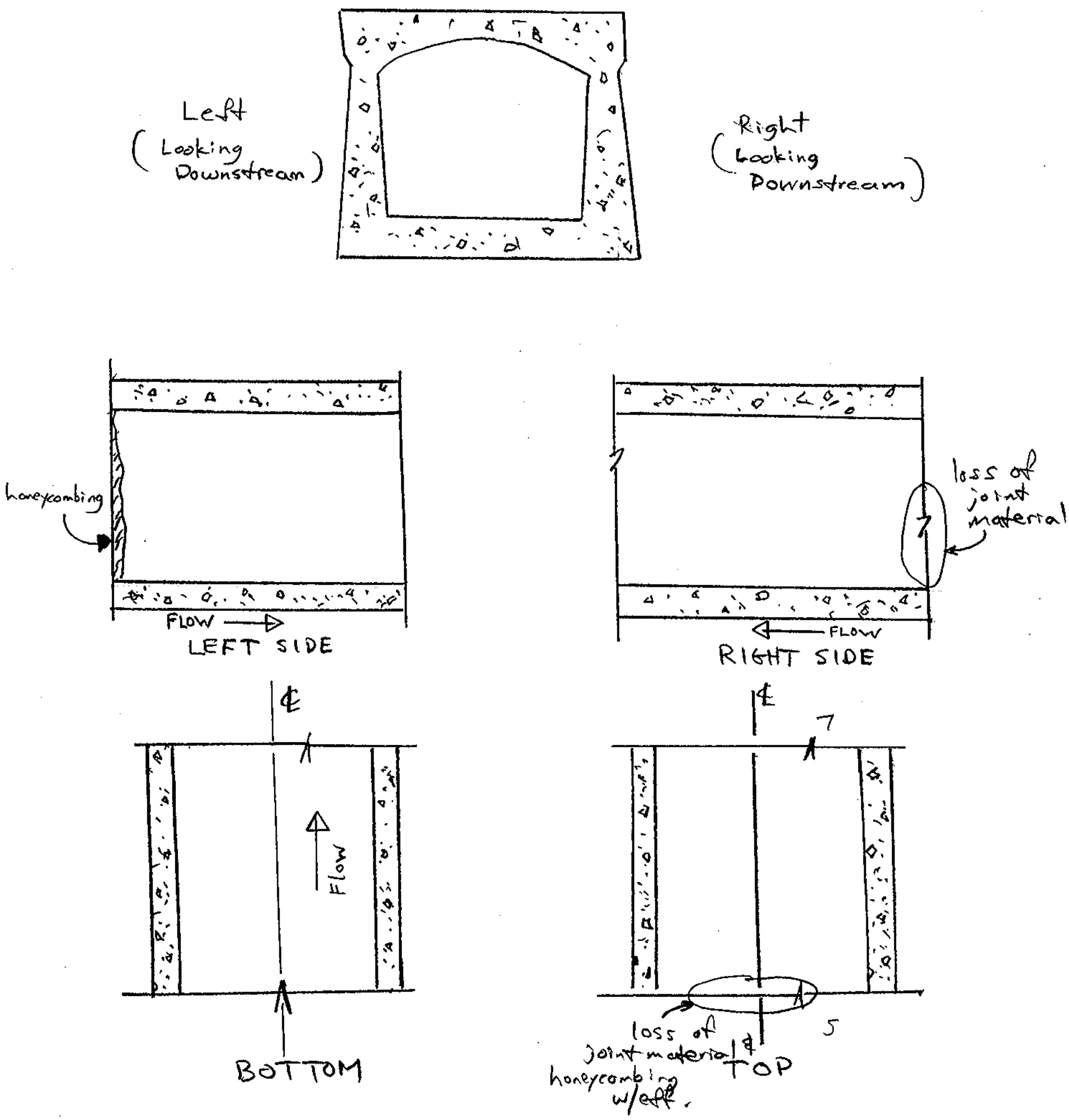
Conduit 1

Monolith 8



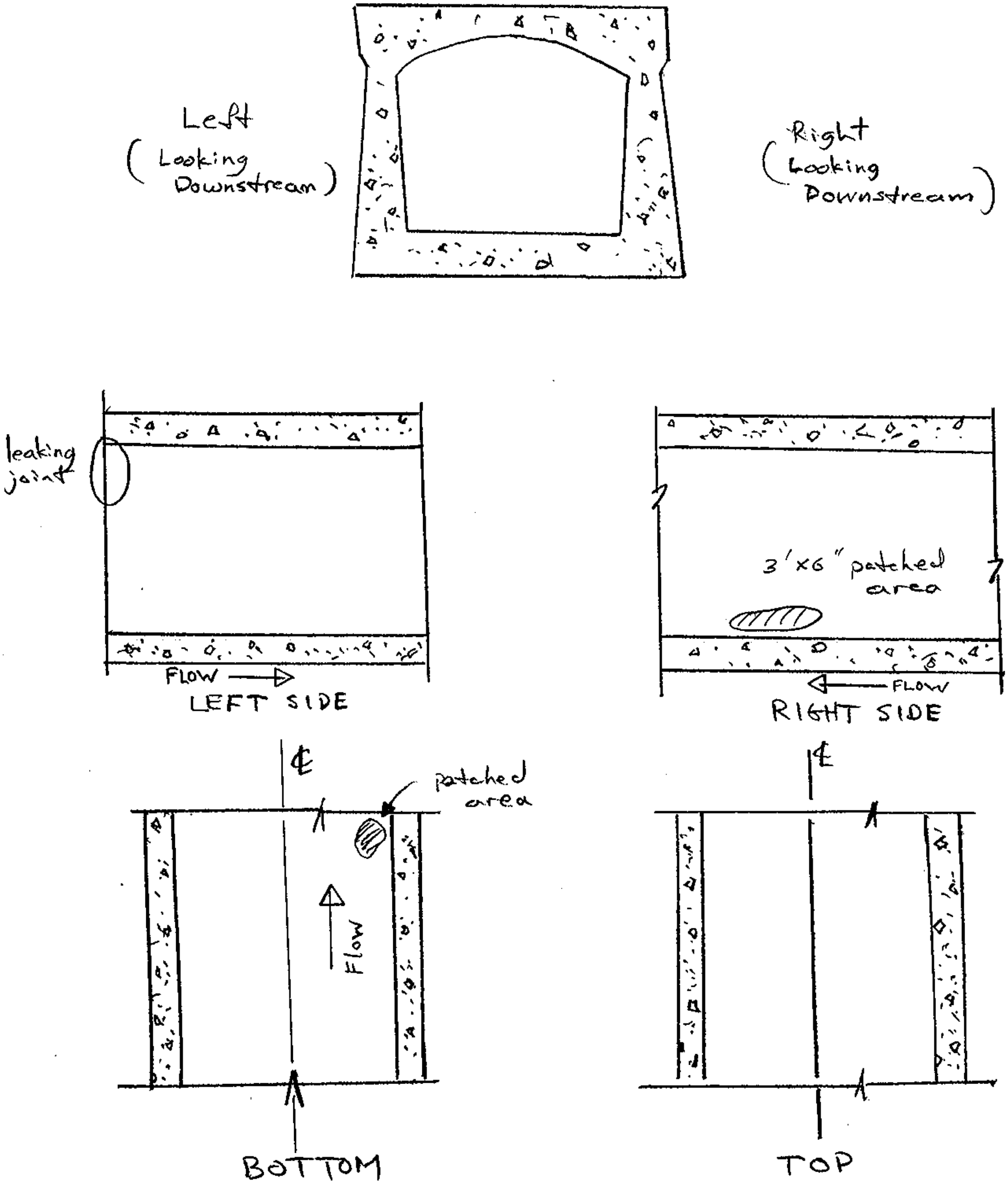
Conduit 1

Monolith 7



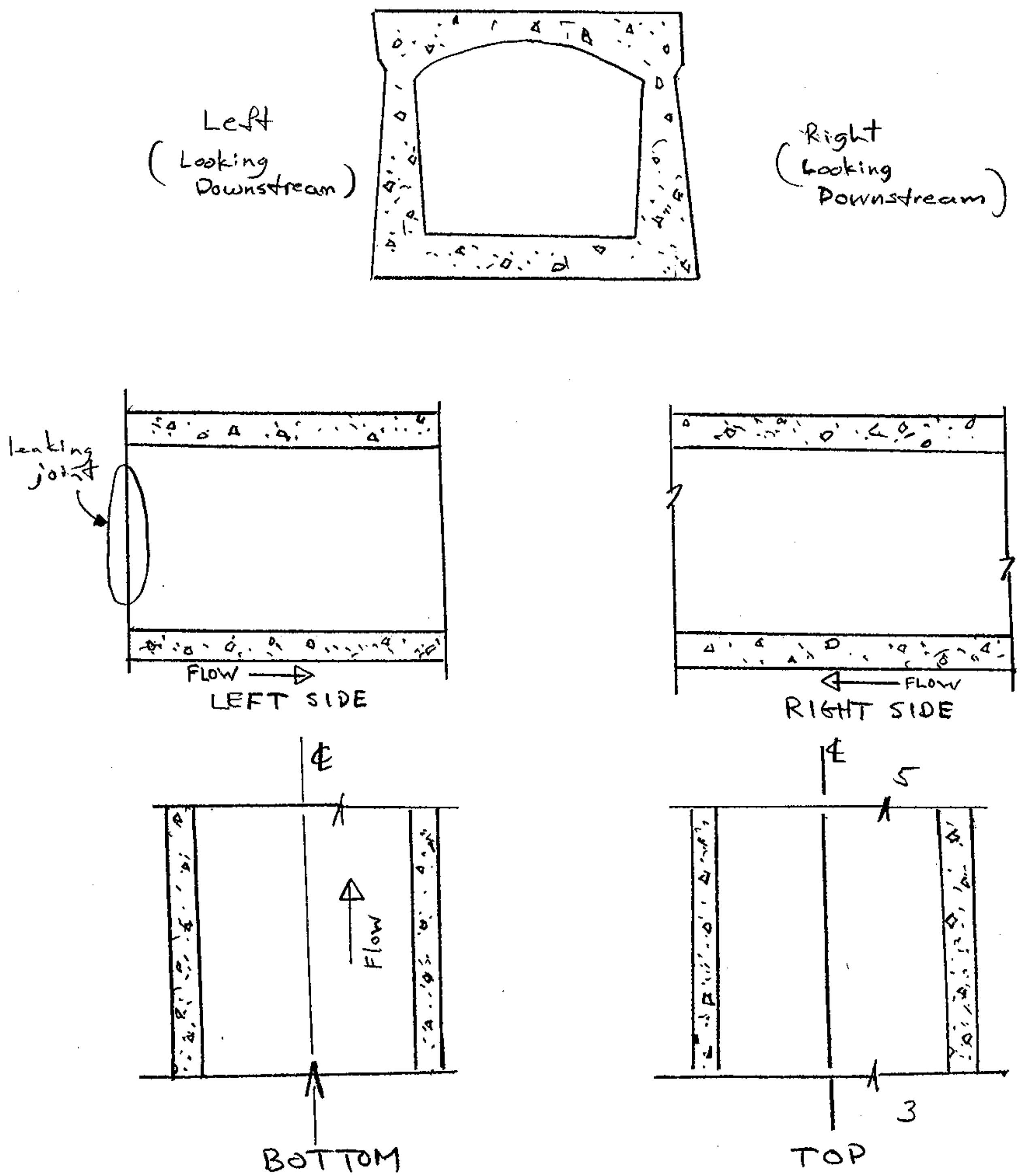
Conduit 1

Monolith 6



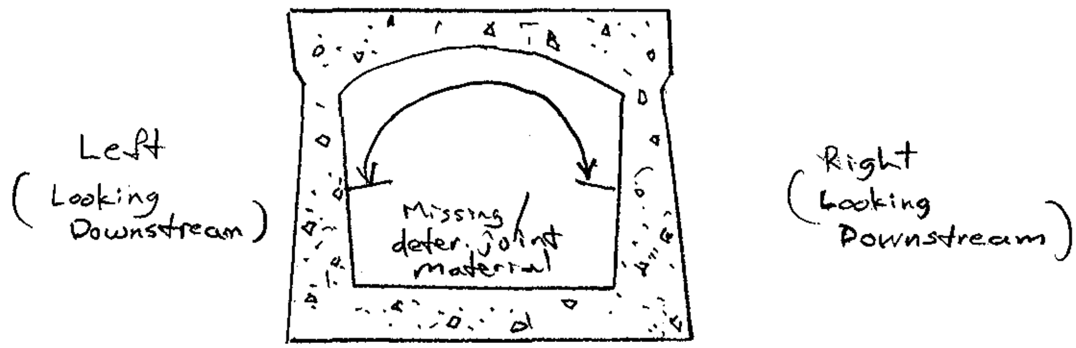
Conduit 1

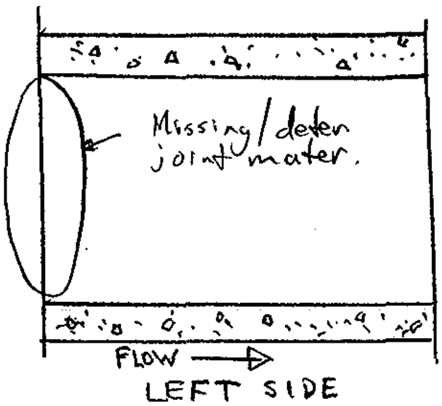
Monolith 5

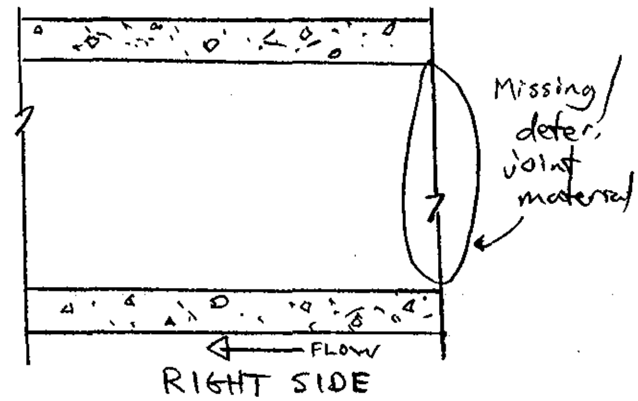


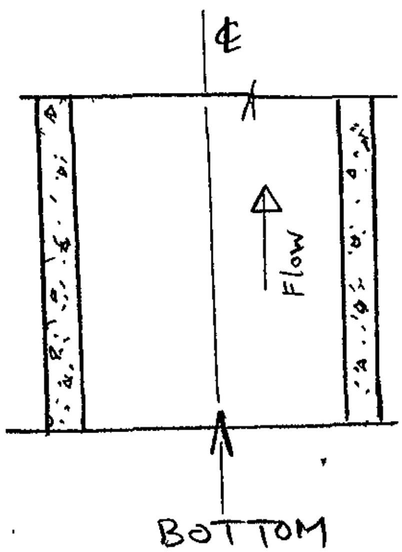
Conduit 1

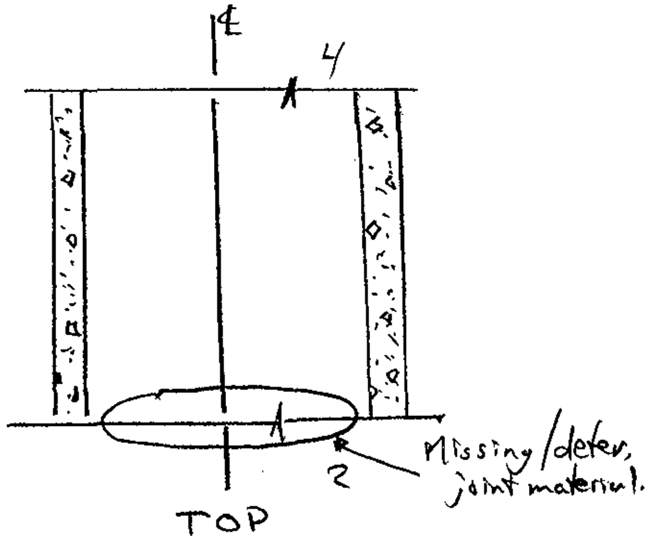
Monolith 4





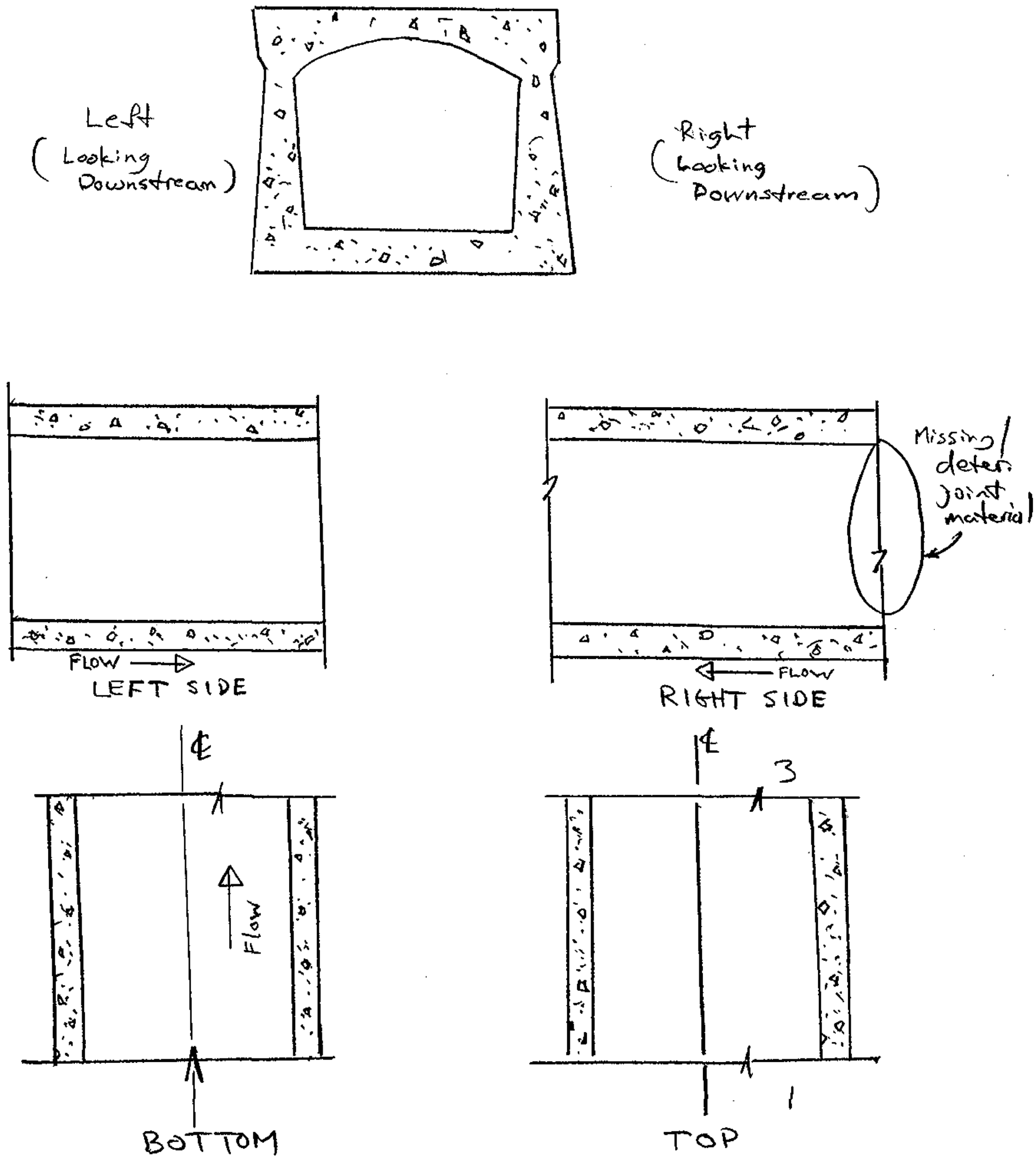






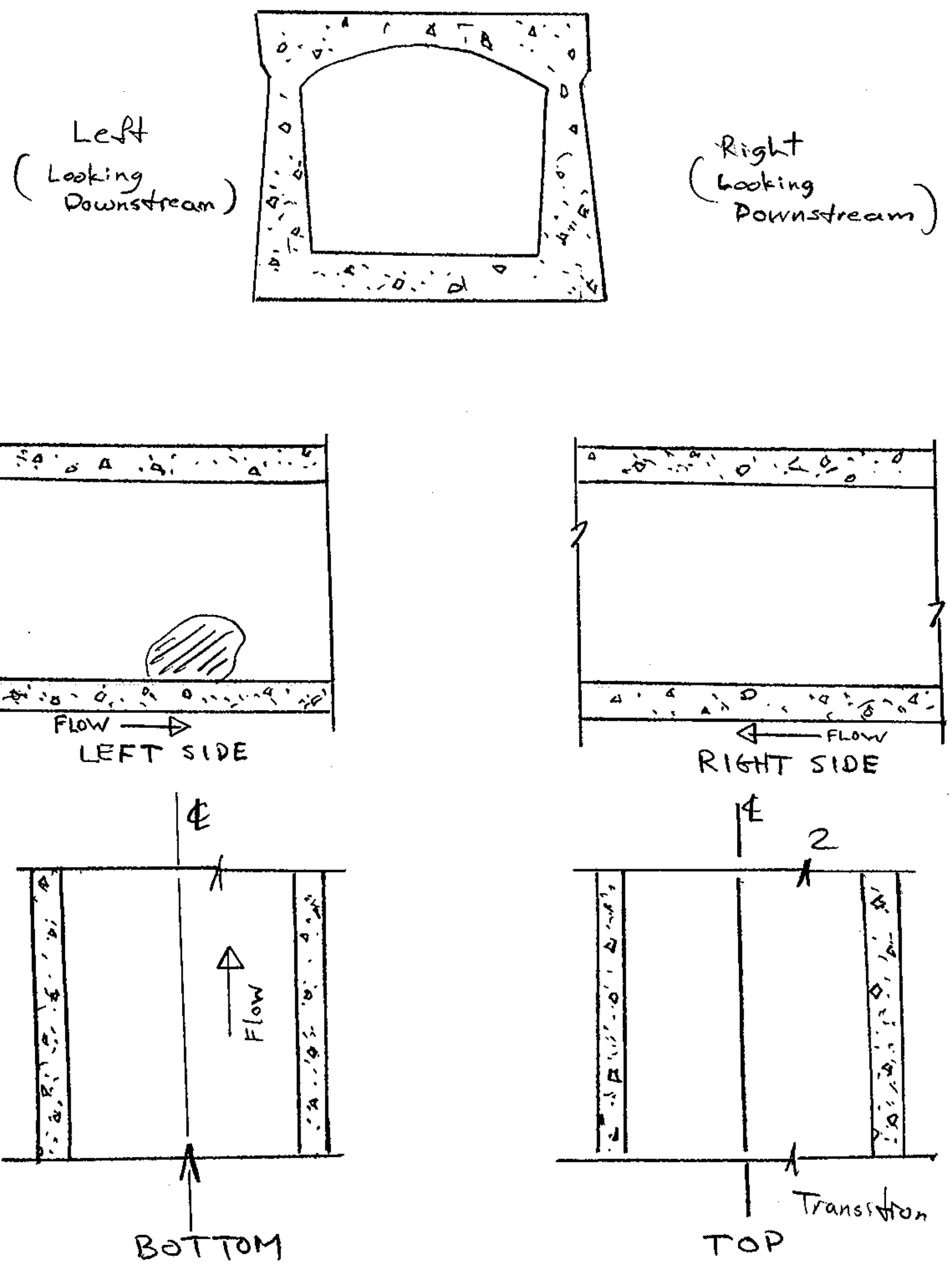
Conduit 1

Monolith 3



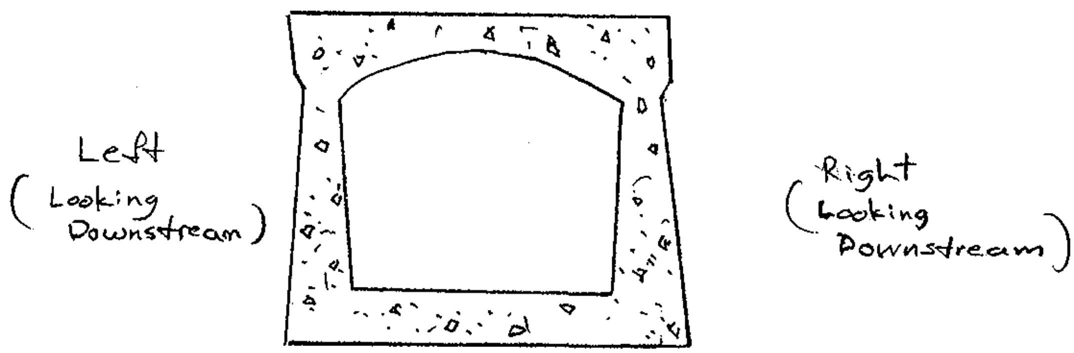
Conduit 1

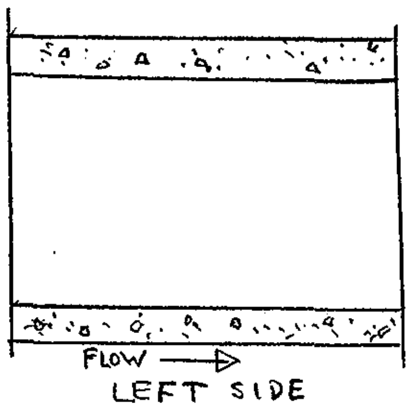
Monolith 2

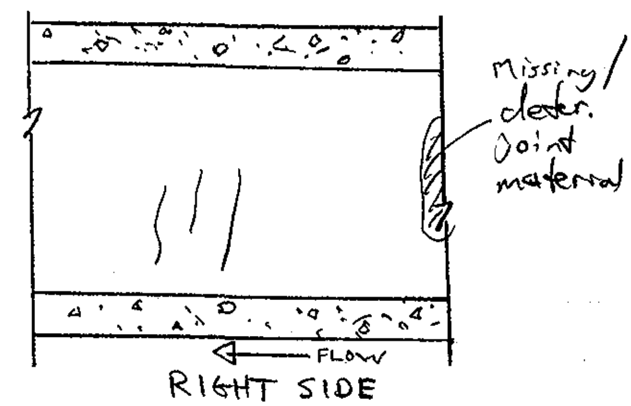


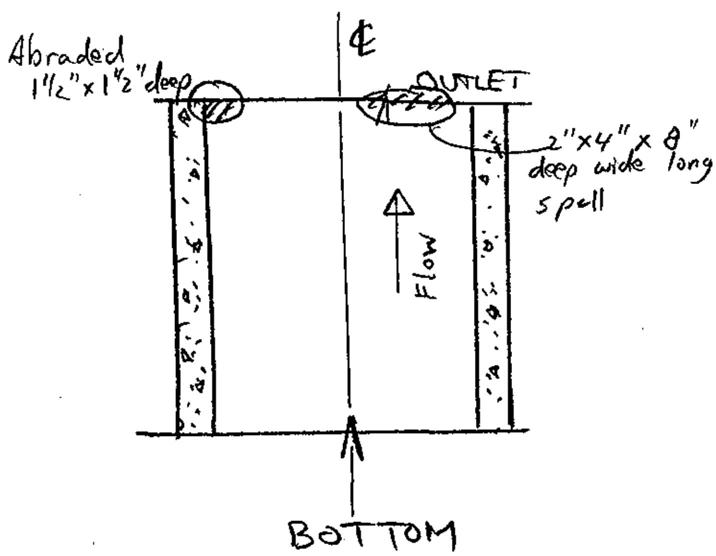
Conduit 1

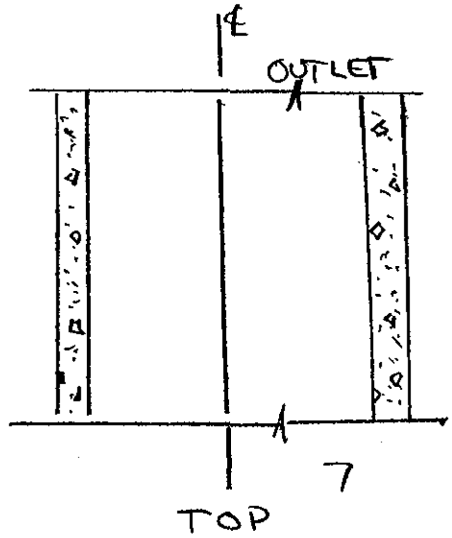
Monolith 1 (Splitter wall not shown.)





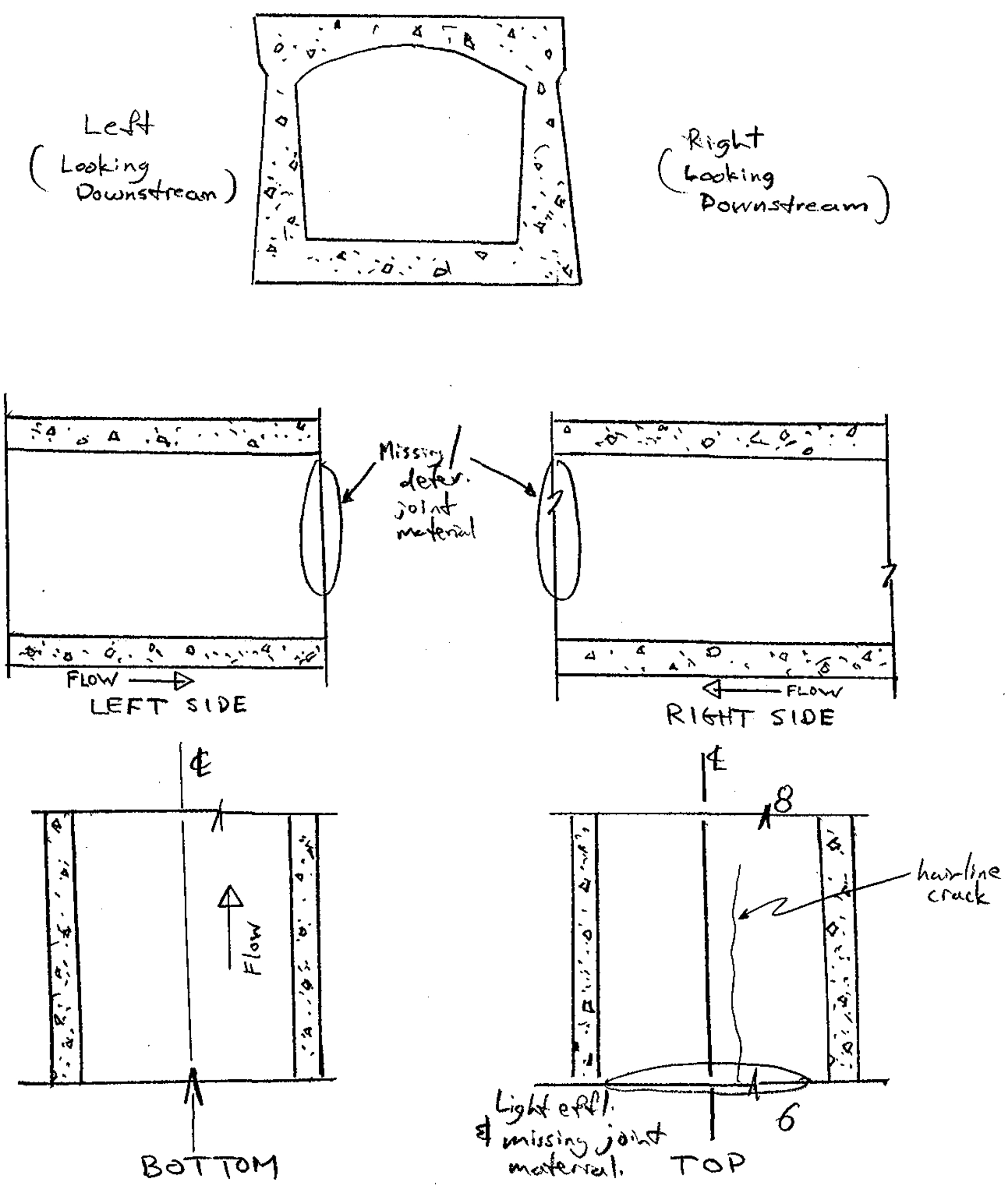






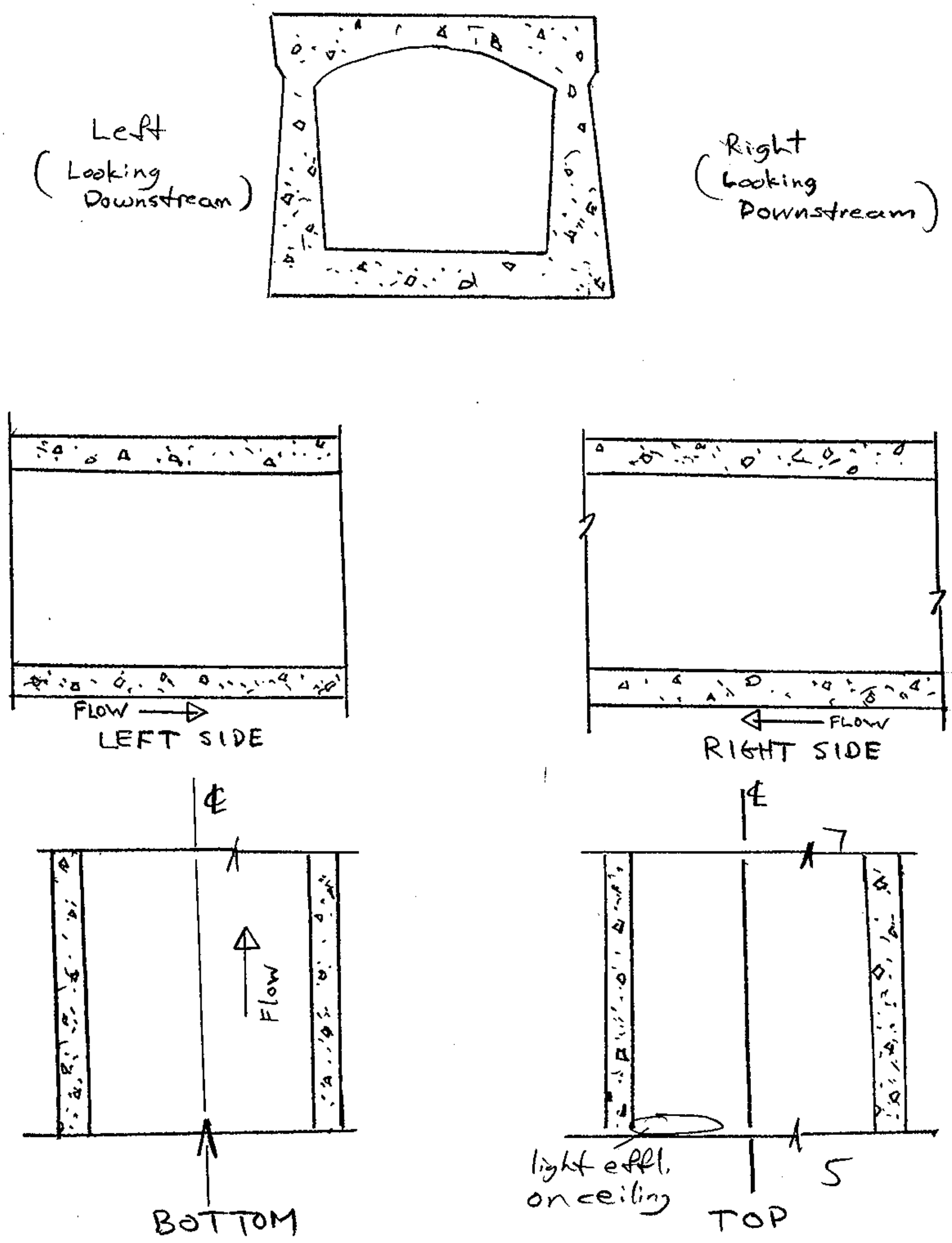
Conduit 2

Monolith 8



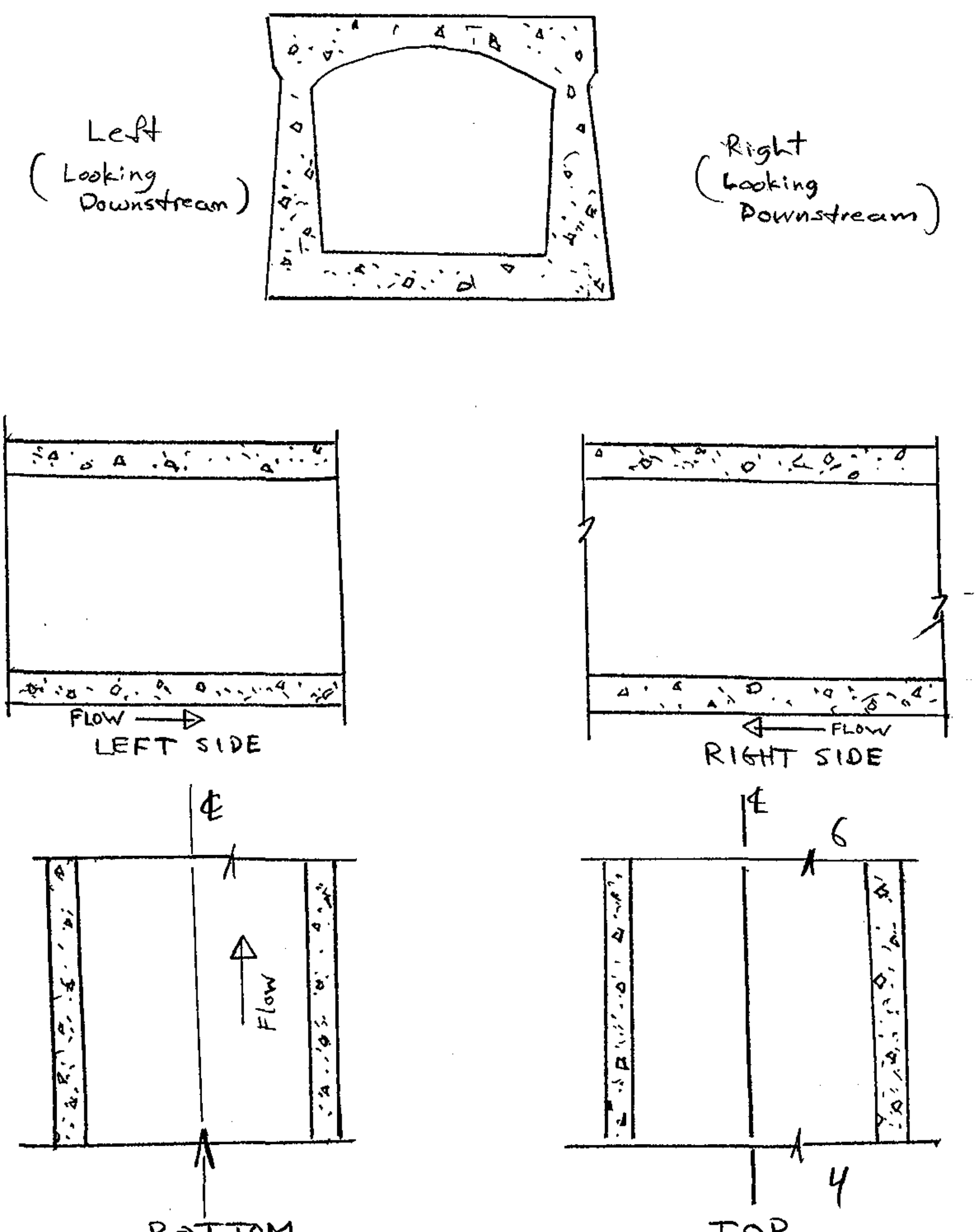
Conduit 2

Monolith 7



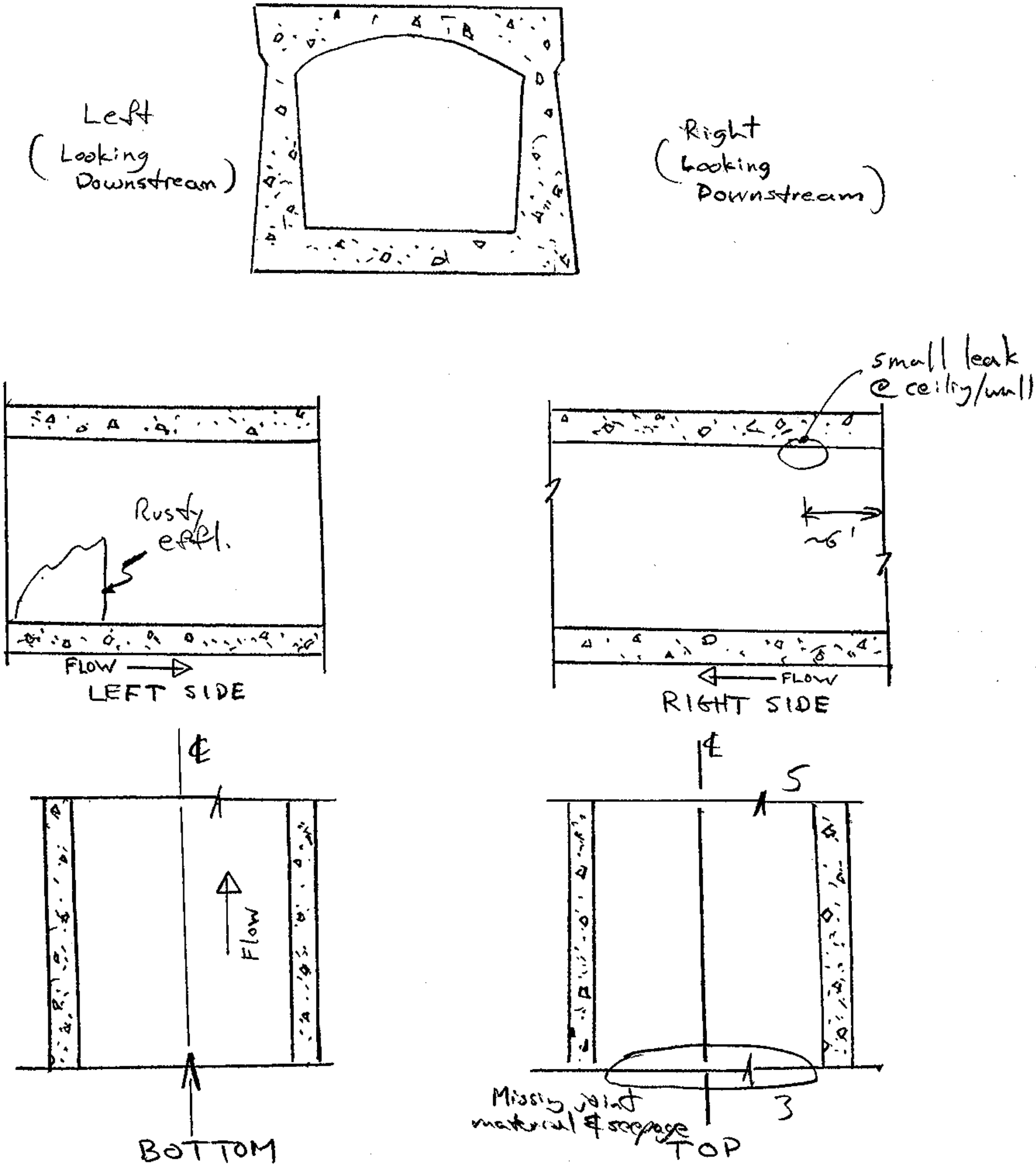
Conduit 2

Monolith 6



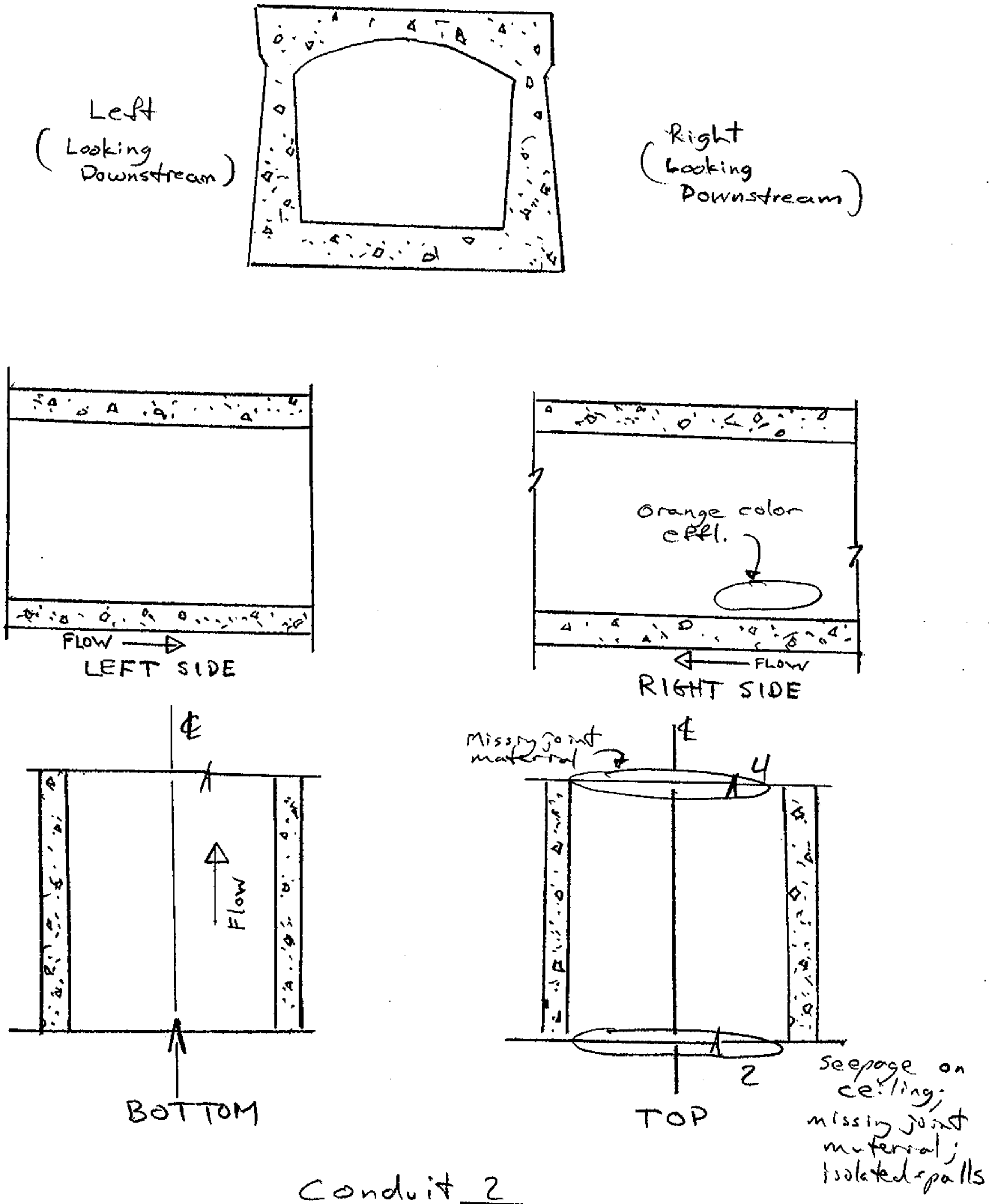
Conduit 2

Monolith 5



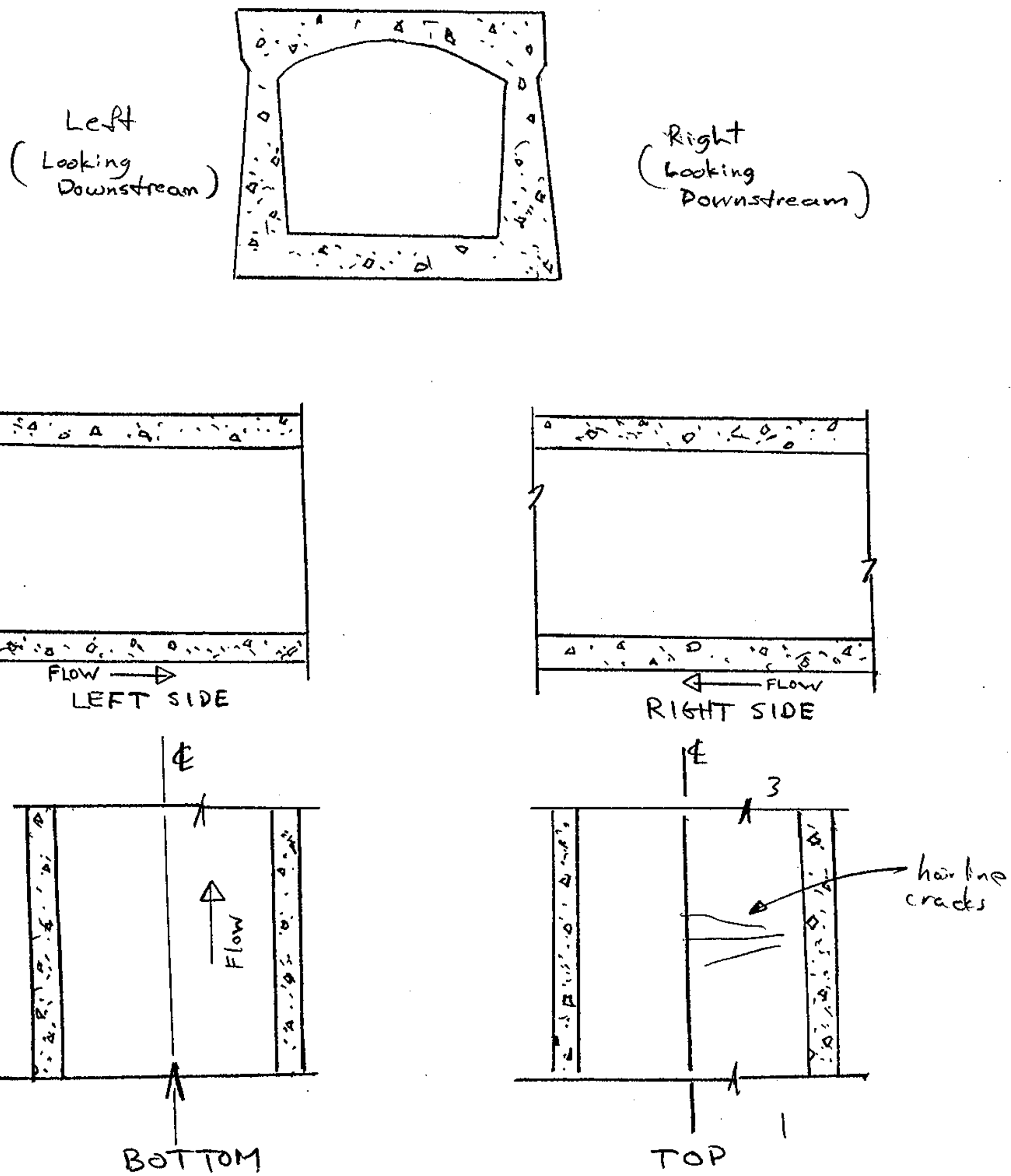
Conduit 2

Monolith 4



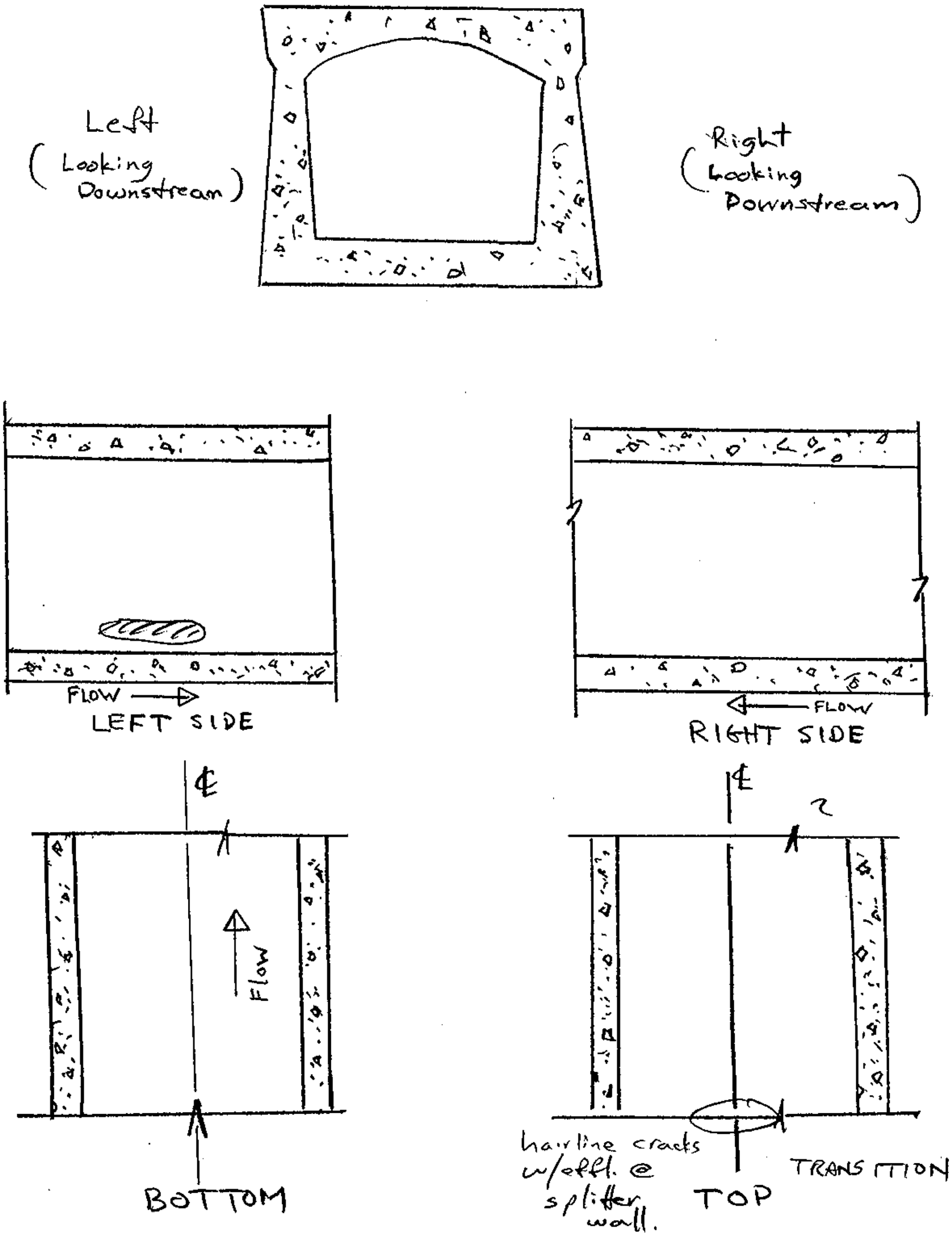
Conduit 2

Monolith 3



Conduit 2

Monolith 2



Conduit 2

Monolith 1 (splitter wall not shown)

APPENDIX IX

STATUS OF PROJECT DOCUMENTATION

PERIODIC INSPECTION REPORT NO. 6
HOPKINTON LAKE
HOPKINTON, NEW HAMPSHIRE

PROJECT DOCUMENTATION

a. Engineering data related to project features will be collected and permanently retained in accessible, appropriate files at the project site. The data should consist of, but not be limited to, design memoranda, subsurface exploration results, as-built drawings and pertinent construction records including foundations and embankment criteria reports, contract specifications, emergency plans, etc. Project data, listed on the attached tabulation, are accessible at the project office.

PROJECT NAME Hopkinton

CONSTRUCTION PLANS Yes

POST CONSTRUCTION REPAIRS AND MODS. Yes

OPERATIONS AND MAINT. MANUALS Yes

CONSTRUCTION PHOTOGRAPHS Yes

WATER CONTROL MANUALS Yes

WATER CONTROL APPENDIX Yes

DAM BREAK FLOOD ANALYSIS Yes

FLOOD EMERGENCY PLAN Yes

PERIODIC INSPECTION NO. 1 Yes

PERIODIC INSPECTION NO. 2 Yes

PERIODIC INSPECTION NO. 3 Yes

PERIODIC INSPECTION NO. 4 Yes

PERIODIC INSPECTION NO. 5 Yes

CIVIL EMERGENCY MGMT PROGRAM Yes

EMERGENCY COMMUNICATIONS MANUAL Instructions contained in FEP

FED'L GUID. OF DAM SAFETY Yes

ANALYSIS OF DESIGN N/A

DESIGN MEMORANDUM

NO. 1 Yes

NO. 2 Yes

NO. 3 Yes

NO. 4 Yes

NO. 5 Yes

NO. 6 Yes

NO. 7 Yes

NO. 8 Yes

NO. 9 Yes

NO. 10 Yes

NO. 11 Yes

NO. 12 N/A

AERIAL PHOTOGRAPHS Yes

BRIDGE INSPECTION REPORT Yes

STATIC ANALYSIS OF STRUCTURE No

DYNAMIC ANALYSIS OF STRUCTURE N/A

/s/ Alister Shanks, Project Manager
Aug 13, 2002

APPENDIX X

STATUS OF DAM OPERATION MANAGEMENT POLICY (DOMP) TRAINING

PERIODIC INSPECTION REPORT NO. 6
HOPKINTON LAKE
HOPKINTON, NEW HAMPSHIRE

STATUS OF DAM OPERATION MANAGEMENT POLICY (DOMP) TRAINING

a. Division Engineers are directed to implement a dam safety training program for O&M personnel, with retraining every four years, that will address the following:

(1) Discussion of basic typical design considerations for various types of construction, including hydraulic considerations, foundation factors, etc.

(2) Procedures for monitoring potential problem areas.

(3) Dam safety features in design and construction.

(4) Normal operation, surveillance, monitoring and reporting procedures.

(5) Emergency Operations, surveillance, monitoring and reporting procedures.

b. DOMP training for the Merrimack River Basin, which includes Hopkinton Lake personnel, was last conducted in November 1997. Additional dam safety training is scheduled for FY03.