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APPENDIX A

SUBSURFACE EXPLORATION

GEOTECHNICAL INTERPRETIVE REPORT

CONTRACT DOCUMENTS

FOR

INTER-ISLAND TUNNEL

CONTRACT PACKAGE NO. 151

DEER ISLAND
BOSTON, MASSACHUSETTS

MWRA CONTRACT NO. 5541
EPA NO. C 259713-18

FOR

MASSACHUSETTS WATER RESOURCES AUTHORITY

WATER RESOURCES AUTHORITY
MASSACHUSETTS

by

SVERDRUP CORPORATION
BOSTON, MASSACHUSETTS

Jacobs Associates
San Francisco, CA

Goldberg - Zoino & Assoc.
Newton Upper Falls, MA

Delon Hampton & Assoc.
Rockville, MD

OCTOBER, 1990

"UNOFFICIAL CONFORMED DOCUMENT"

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1.00 INTRODUCTION

1.10 GENERAL

The Massachusetts Water Resources Authority (MWRA) has undertaken a program to design and construct a Secondary Wastewater Treatment Facility on Deer Island in Boston Harbor. The program is generally referred to as the Boston Harbor - Deer Island Related Facility project and consists of constructing new primary and secondary wastewater treatment facilities at Deer Island, a new headworks facility at Nut Island in Quincy, an Inter-Island Tunnel between Nut and Deer Islands, and an Outfall Tunnel from Deer Island that will discharge into Massachusetts Bay. Refer to Figure 1.1 for the site location plan.

This Geotechnical Interpretive Report describes the geotechnical aspects of the Inter-Island Tunnel and shafts and related structures. It discusses the geologic setting, subsurface conditions, geotechnical issues, and also provides interpretations of the geotechnical data, with respect to design and construction. Two companion documents, entitled "Geotechnical Data Report" and "Geotechnical Design Summary Report" have also been prepared by the PDE. The first report is a presentation of data without interpretation and the latter is a summary of design and construction assumptions.

Additional reference volumes containing data related to this project include:

- "Rock Properties - Secondary Treatment Plant, Deer Island", by New England Research, Inc., January 16, 1989.

- "Boston Harbor Seismic Survey", by Weston Geophysical, Corporation, October 28, 1989.

- "Concept Design - Tunnel Corrosion Engineering", by Metcalf & Eddy, Inc., May 31, 1989.

- "Conceptual Design - Tunnel Seismic Assessment and Design Criteria", by Metcalf & Eddy, Inc., May 31, 1989.

- "Secondary Treatment Facilities Plan - Volume IV - Inter-Island Conveyance System Final Report", by Metcalf & Eddy, Inc., March 7, 1989.

- "Seismic Design Recommendations", by Weston Geophysical, Corporation, May 1989.

- "Coarse-Grid Marine Geophysical Surveys, Deer Island Secondary Treatment Facility", by Weston Geophysical, Corporation, September, 1988.

- "1988 Marine Drilling Summary Report", by Metcalf & Eddy, Inc., February 1, 1989.

- "Boston Harbor Geological and Geotechnical References, Volumes I and II", by Metcalf & Eddy, Inc., May 1989.

- "Conceptual Design, Design Package 5, Inter-Island Tunnel & Shafts", by Metcalf & Eddy, Inc., May 31, 1989.

- "Comprehensive Geotechnical Program Report", by Kaiser Engineers, Inc., June 1989.

- "Geotechnical Interpretive Report - Tunnels, Shafts and Diffuser, Volumes I to IV", by Metcalf & Eddy, Inc., June 16, 1989.

- "Aquifer Test Interpretive Report, Deer Island", by Metcalf & Eddy, Inc., November 30, 1989.

- "Results of the Multichannel Digital Survey for the Boston Harbor Project Inter-Island Area", by Williamson & Associates, Inc., May 1990.

These are available for viewing at the Kaiser Engineers, Inc. (Program/Construction Manager, P/CM) library (Schrafft Center, Charlestown, Massachusetts).

All elevations referenced in this report refer to Metropolitan District Commission (MDC) datum; and all invert elevations refer to top of finished concrete.

1.20 PURPOSE AND SCOPE

The primary objective of this report is to discuss the Project Design Engineer's (PDE's) interpretation of subsurface conditions and their impact on design and construction of the tunnel, shafts and related structures.

The scope of work performed was as follows:

1. Reviewed existing relevant boring and geophysical subsurface data.

2. Developed a subsurface exploration program for the proposed conveyance tunnel alignment consisting of:

   - seventeen borings (14 on water and 3 on land);
   - borehole packer pressure tests in 16 of the borings;
   - downhole geophysics in four of the borings; and
   - a geophysical survey (reflection and refraction) in an area adjacent to Peddocks Island, where previous geophysical surveys and interpretations had suggested that either the top of rock was deep or the rock was of very poor quality.

   The primary purpose of the program was to estimate top of rock and to evaluate the nature and quality of the rock that would be encountered during tunnel excavation.

3. Provided personnel to observe and record data during drilling, packer testing and oriented coring.

4. Developed and executed a laboratory testing program on rock samples consisting of:

   - unconfined compression tests;
   - mineral identification tests (thin-sections);
   - total hardness tests; and
   - point load tests.

5. Analyzed and interpreted the subsurface data with respect to its impact on design and construction.

6. Prepared three reports: the "Geotechnical Interpretive Report", the "Geotechnical Data Report", and the "Geotechnical Design Summary Report".

1.30 PARTICIPANTS

The key members of the Inter-Island Tunnel project team were as follows:

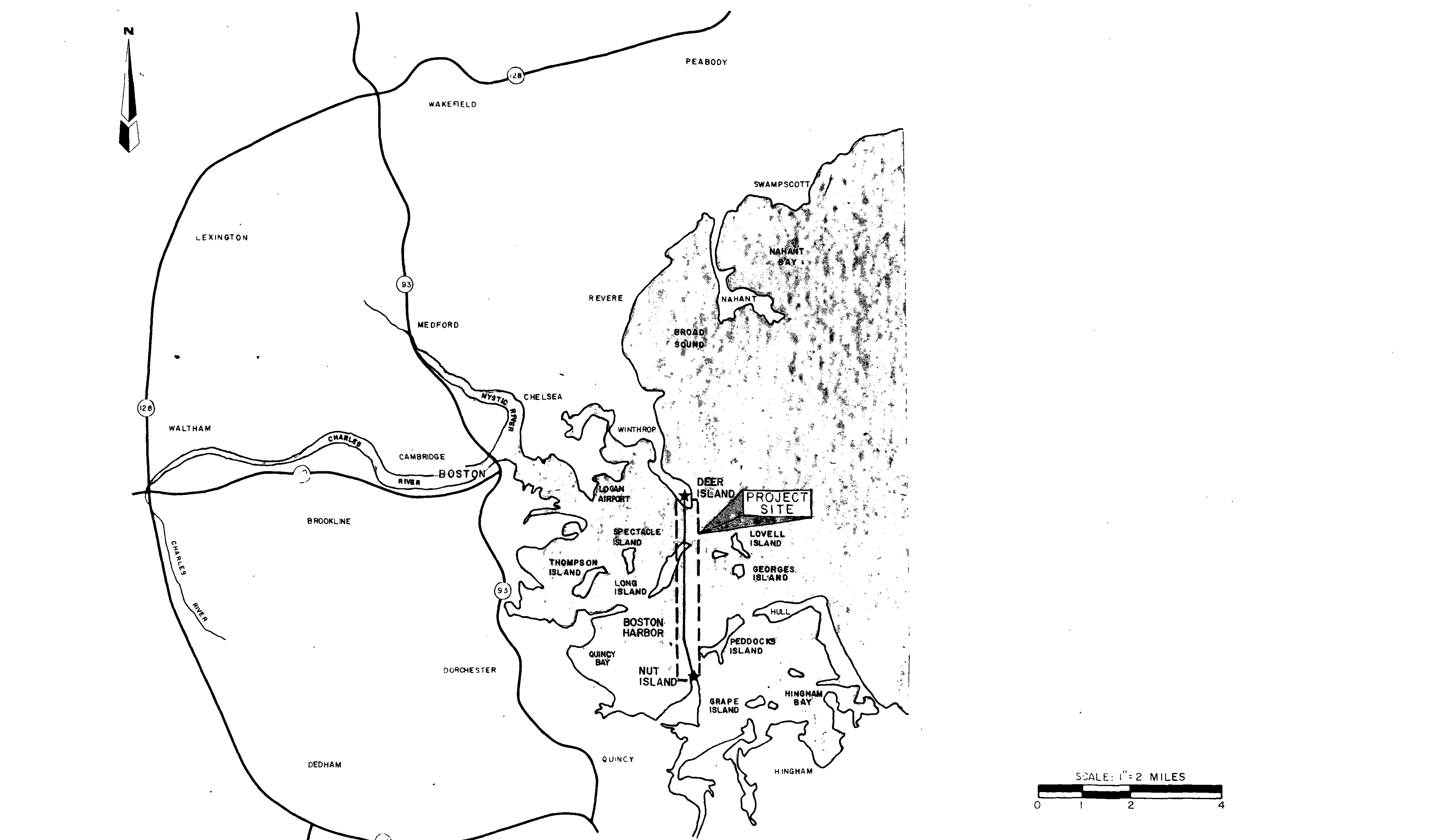
1. The Project Management Division (a department within the MWRA): primarily responsible for transmitting the MWRA's objectives to the Program/Construction Manager and assuring that funding for the investigations was available as needed.

2. The Program/Construction Manager (Kaiser Engineers, Inc. in association with the Maguire Group, Inc. and Howard Needles

Tammen & Bergendoff): responsible for the day-to-day management of the project and the implementation of the Project Management Division's objectives and expectations.

3. The Lead Design Engineer (Metcalf & Eddy, Inc. in association with Mott Hay, Inc.): responsible for obtaining information for conceptual design of the tunnel and land-based facilities; developing geotechnical and geophysical design criteria and standards; and managing PDE during detailed design.

4. The Project Design Engineer (Sverdrup Corporation in association with Jacobs Associates, Goldberg-Zoino & Associates, Inc. and Delon Hampton & Associates): responsible for implementing the 1989 final design subsurface investigation program; performing detailed design; preparing contract documents; and preparing geotechnical interpretive, data, and design summary reports.



FILE No U11305.1

Sverdrup CORPORATION	In Association With **Jacobs Associates** **Goldberg-Zoino & Associates** and **Delon Hampton & Associates**	DP-5 INTER-ISLAND TUNNEL BOSTON HARBOR	PROJECT LOCATION PLAN NOV. 1989 FIGURE No. 1.1

2.00 PROJECT DESCRIPTION

2.10 OVERVIEW

In September 1985, the Federal District Court ruled that the current discharge of "primary" treated effluent into the Boston Harbor, by the MWRA, was unlawful. The Court also ordered the MWRA to provide full "secondary" treatment of all wastewaters before disposing them into the harbor. The MWRA responded by developing the Boston Harbor - Deer Island Related Facilities project and proposed a schedule, containing specific dates for completion of particular design and construction elements, which became legally binding in May 1986.

Currently, the MWRA's wastewater collection system consists of a North Metropolitan Sewerage System and a South Metropolitan Sewerage System. North System flows are collected and transported to the Deer Island Primary Treatment Plant; South System flows are collected and transported to the Nut Island Primary Treatment Plant. Influent flow enters the Deer Island plant via both the Main Pumping Station and the Winthrop Terminal Headworks. The Main Pumping Station pumps from either of two deep rock tunnels (each approximately 300 feet below sea level)-- the approximately 7-mile-long Boston Main Drainage Tunnel (peak capacity of 694 mgd) and the approximately 4-mile-long North Metropolitan Relief Tunnel (peak capacity of 350 mgd). The Winthrop Terminal Headworks screens and pumps influent flow from the North Metropolitan Trunk Sewer (125 mgd peak capacity). Influent flow for the Nut Island plant enters via a High Level Sewer (peak capacity of 360 mgd), which consists of approximately 78 miles of MWRA interceptor sewers. After treatment at each plant, which consists of screening, grit removal, pre-aeration, primary sedimentation and disinfection, the resultant effluent is disposed into the Boston Harbor via a series of short outfalls.

The objective of the proposed MWRA project is to provide primary and secondary treatment of the wastewater conveyed through the MWRA's sewerage collection systems at a single treatment facility to be located on Deer Island. The overall program basically consists of constructing primary and secondary treatment facilities at Deer Island, new headworks (screening and degritting station) at Nut Island in Quincy, a new approximately 25,160-foot-long, 11.5-foot-finished-diameter tunnel to convey South System untreated waste water from Nut Island to Deer Island (Inter-Island Tunnel), and a new approximately 48,000-foot-long, 24.25-foot-finished-diameter outfall tunnel from Deer Island that will discharge into Massachusetts Bay. The new facility will be capable of accepting up to 1.27 billion gallons of waste water per day, removing 85 to 90 percent of the suspended organic material, and discharging the effluent 8 to 10 miles offshore. Both tunnels are expected to be constructed predominantly in Cambridge Argillite using Tunnel Boring Machines (TBMs).

Design of the overall project has been broken up into more than 18 separate design packages, each of which is associated with a particular unit operation. This report addresses geotechnical design and construction issues for the Inter-Island Tunnel (DP-5) design package. The package consists of:

1. a 230-foot-deep, 16-foot-finished-diameter shaft at Nut Island (South Shaft);

2. a 290-foot-deep shaft, with 16- and 11-foot-finished-diameters above and below elevation 80 feet, respectively, at Deer Island (North Shaft);

3. a 25,160-foot-long, 11.5-foot-finished-diameter, conveyance tunnel between Nut Island and Deer Island;

4. an approximately 145-foot-long, 11-foot-finished-diameter connecting conduit to the South System Pumping Station (SSPS) at Deer Island;

5. an approximately 30-foot-long, 12-foot-square connecting concrete conduit to the Grit Removal Facilities Structure (GRFS) at Nut Island;

6. an approximately 135-foot-long stub tunnel at the base of the South Shaft, with an approximately 115-foot-long, 3-foot-diameter pipe, for a future connection to the Fore River wastewater treatment plant in Quincy;

7. an approximately 30-foot-deep, 96-foot by 46-foot, surge storage structure at Deer Island;

8. two 14-inch-internal diameter sludge pipes, from Deer Island to Nut Island, extending approximately 115 feet beyond the South Shaft and into the stub tunnel for future connection to the Fore River wastewater treatment plant in Quincy;

9. a 12-inch-internal diameter ductile iron pipe drop shaft at Long Island, for screened and gritted wastewater from Long Island Hospital's treatment plant.

The in situ volume of excavated material for the Inter-Island Tunnel and its associated shafts will be approximately 148,000 cubic yards. This will result in an estimated bulked muck volume of approximately 250,000 cubic yards. The estimates are based on assumed average excavated diameters of 13.8, 19.0 and 26.0 feet for the tunnel, the South Shaft, and the North Shaft, respectively.

2.20 EXISTING GENERAL SITE CONDITIONS

Deer Island is connected to the southern tip of Winthrop by a man-made causeway fill. It is approximately 200 acres in area, and its dominant natural feature is a drumlin with a summit elevation of 210 feet. Primary active land uses of this island are the Deer Island House of Correction, owned and operated by the City of Boston, and the MWRA primary treatment facility, which take up a combined total area of approximately 60 acres toward the northern side of the island.

The proposed condition of the construction area after the Early Site Preparation Contract is completed is an approximately 74,500-foot-square site levelled to approximately elevation +125 feet (refer to Figure 2.1).

Nut Island, which is a peninsula located on the southern shore of Boston (refer to Figure 2.2), is approximately 17 acres in area, has a flat topography that lies between approximately elevation +125 and +130 feet, and is riprapped at its edges. The site is occupied exclusively by structures associated with the primary treatment facility: tanks are situated at the southern end of the site and major above-grade structures are at the northern end. There is no significant vegetation, and most of the property is covered by either concrete or bituminous pavement.

At the start of DP-5 construction, the condition of this site will be essentially as it exists in December 1989. Pier construction and detour road construction will be completed by others.

2.30 SHAFT CONSTRUCTION

Methods of shaft construction through overburden into bedrock will be up to the Contractor with review by the Construction Manager (CM). Anticipated construction sequence procedures and methods are as follows:

2.31 North Shaft (on Deer Island)

A. Prior to the General Contractor's arrival on site, existing miscellaneous fill will have been removed from the proposed North Shaft location, by the Early Site Preparation Contractor, and replaced with compacted engineered fill up to elevation 125 feet. It is the PDE's understanding that this fill will consist of compacted granular material below the water table and glacial till above.

B. Project mobilization and preparation for shaft sinking.

C. Excavation of soil from the proposed shaft location. This will require a lateral earth support system. The system will probably consist of a concrete diaphragm wall or soil freezing or other possible combinations including ring beam supported liner plates or precast concrete liners with grouting or an appropriate alternative selected by the Contractor and reviewed by the CM. Except for ground freezing, some combination of dewatering and/or grouting will be required to control groundwater within pervious near surface and at depth soil zones and the fractured rock/soil interface.

D. Excavation through bedrock, using drill and blast techniques, and installing temporary rock support as specified. Rock support shall include rock bolts, welded wire fabric (WWF) and shotcrete installed primarily to prevent minor rock fragment fallout that might endanger personnel in the shaft.

E. Excavation of an enlarged bottom station area and tail tunnel, using drill and blast techniques, for installation of the TBM and its muck removal equipment.

F. Construction of underground groundwater pumping station, power facilities, muck handling facilities, and hoisting plant.

G. Lining the shaft with cast-in-place concrete, with the two 14-inch-diameter sludge pipes embedded within the concrete lining; constructing the top of shaft; and tying into the SSPS.

2.32 South Shaft (on Nut Island)

A. Mobilization of shaft sinking equipment to the proposed South Shaft location on Nut Island. As the South Shaft needs to be completed early, as required by specifications, it has to be excavated before tunnel excavation is completed.

B. Excavation of soil from the proposed shaft location. This will require a lateral earth support system. The system will probably consist of soldier piles and lagging, ring beam supported liner plates, or an appropriate alternative selected by the Contractor and reviewed by the CM. Some combination of steel sheeting, dewatering and/or grouting will also be required to control groundwater within the pervious near surface soil zone and the likely fractured rock/soil interface.

C. Excavation through bedrock, using drill and blast techniques, and installing temporary rock support as specified. Rock support shall include rock bolts, WWF and shotcrete installed primarily to prevent minor rock fragment fallout that might endanger personnel in the shaft.

D. Excavation of the 135-foot-long stub tunnel at the base of the South Shaft, using drill and blast techniques, and providing temporary rock support as specified.

E. Installation into the stub tunnel of the 3-foot-diameter wastewater pipe and the two 14-inch-diameter sludge pipes for future connection to the Fore River treatment plant.

F. Lining the shaft with cast-in-place concrete, and constructing the top of shaft.

2.40 TUNNEL CONSTRUCTION

Methods of tunnel construction through bedrock will be up to the Contractor with review by the CM. Anticipated construction procedures and methods are as follows:

1. Mobilization of TBM.

2. Tunnel excavation using a TBM and installing appropriate temporary rock support as specified. The tunnel will be excavated up slope from the North Shaft, primarily to allow gravity drainage of groundwater inflows away from the heading.

3. Lining the tunnel with cast-in-place concrete, installing the two 14-inch-diameter sludge pipes, and backfilling the tail and stub tunnels with concrete.

2.50 OTHER STRUCTURES

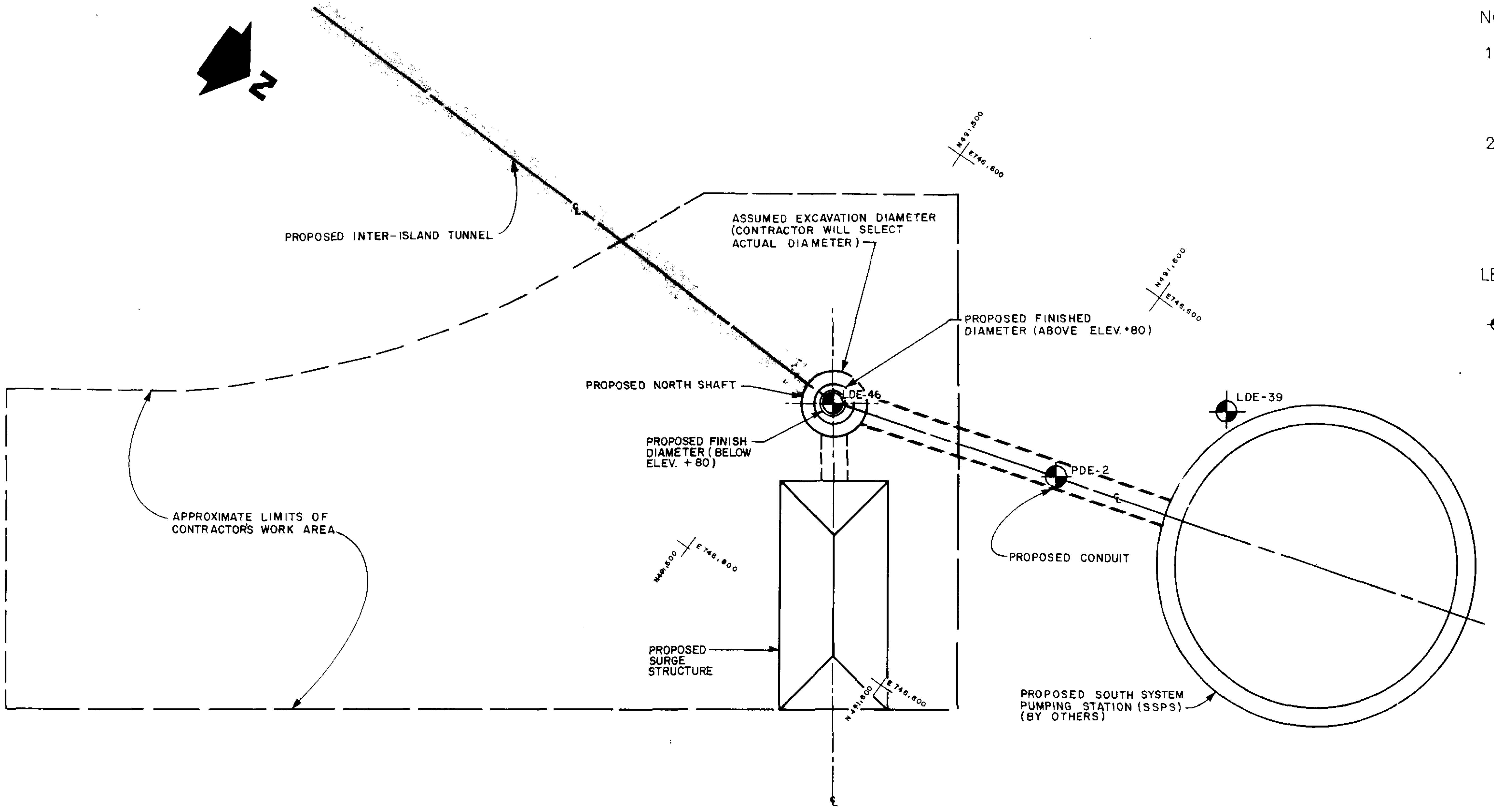
In addition to the North Shaft, the South Shaft, and the tunnel, related structures are to be constructed. Methods of construction will be up to the Contractor with review by the CM. Anticipated construction procedures and methods are as follows:

1. The 11-foot-finished-diameter connecting conduit to the South System Pumping Station (SSPS) at Deer Island will be constructed as a soft ground tunnel using a simple shield and hand-excavation methods. The conduit will be constructed after completion of the SSPS. The PDE assumes that a secondary access shaft will be constructed outside the main shaft to avoid schedule delays.

2. The DP-5 section of the 12-foot-square connecting concrete conduit to the Grit Removal Facilities Structure at Nut Island will probably be constructed using steel sheeting driven into silty clay as a cut-off. It would also be feasible to construct it with soldier piles and lagging in combination with a systematic dewatering system.

3. Soldier piles and lagging or steel sheeting will probably be the lateral soil support system selected for construction of the approximately 30-foot-deep, 96-foot by 46-foot surge storage structure at Deer Island. The storage structure will be constructed either in conjunction with shaft excavation or as a separate operation later, at the Contractor's option.

4. The 12-inch-diameter drop shaft at Long Island will probably be drilled, cased and capped prior to tunnel excavation. Drilling through overburden will be performed using slurry (drilling mud) or other appropriate means of temporary support.



NOTES:

1) BASE MAP DEVELOPED FROM PLANS PROVIDED BY THE LDE, ENTITLED "DEER ISLAND EARLY SITE PREPARATION, EARTHWORKS/ LANDFILL/ ROADWAYS, GRADING PLAN", DATED AUGUST 1989, SHEET No. G-8, 27 OF 61.

2) BORINGS LOCATED BY LDE

LEGEND

LDE-39 BORINGS PERFORMED BY GUILD DRILLING CO., INC. FROM 1/24/89 TO 2/21/89 AND 9/29/89 TO 10/4/89. OBSERVED BY LDE PERSONNEL.

SCALE 1"=40'

0' 20' 40' 80'

Sverdrup CORPORATION	In Association With Jacobs Associates Goldberg-Zoino & Associates and Delon Hampton & Associates	DP-5 INTER-ISLAND TUNNEL BOSTON HARBOR	DEER ISLAND SITE LOCATION PLAN NOV. 1989 FIGURE No. 2.1

FILE No. U-11305.1

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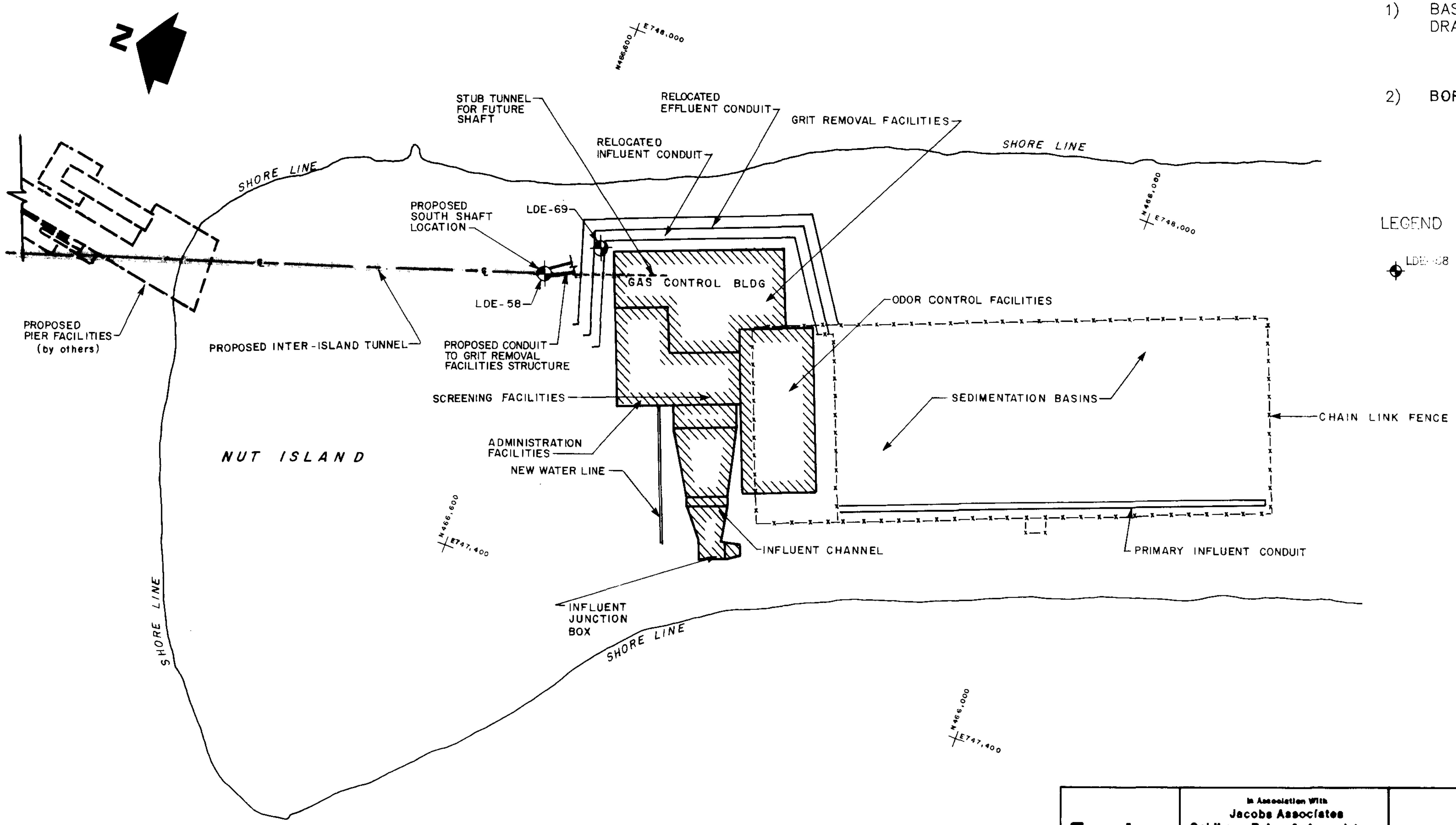


NOTES:

1) BASE MAP DEVELOPED FROM UPDATED CADD DRAWINGS PROVIDED BY THE LDE, DATED 7/15/89.

2) BORINGS LOCATED BY LDE.

LEGEND

LDE-58 BORINGS PERFORMED BY GUILD DRILLING CO., INC. FROM 2/13/89 TO 3/3/89 AND 3/27/89 TO 3/29/89. OBSERVED BY LDE PERSONNEL

Sverdrup CORPORATION	In Association With Jacobs Associates Goldberg-Zoino & Associates and Delon Hampton & Associates	DP-5 INTER-ISLAND TUNNEL BOSTON HARBOR	NUT ISLAND SITE LOCATION PLAN NOV. 1989 FIGURE No.2.2

FILE No. J-11305.1

3.00 GEOLOGIC SETTING

3.10 OVERVIEW OF THE BOSTON BASIN REGIONAL SETTING

Southeastern New England lies astride the eastern border of the Appalachian orogenic belt. This border represents a zone of late-Precambrian and early-Paleozoic collision between Paleo-North American and Paleo-African plates, and now forms the Nashoba Thrust Belt (Barosh, 1984). This zone passes west and northwest of Boston.

Boston is located near the center of the Boston Basin, an east-northeast-trending, triangular-shaped, downfaulted, body of sedimentary-volcanic rock. It is bounded to the north and west by the Northern Border fault and to the south by the Norfolk Basin and Ponkapoag Fault. Onshore, the basin is widest along the coast, where it measures approximately 15 miles, north to south. Offshore, it extends to the east under Massachusetts Bay, where it appears to widen still more (Kaye, 1982). On the west, the basin tapers to a point approximately 18 miles west-south-west of Boston.

Most of the basin is covered by surficial materials consisting predominantly of glacial deposits (Pleistocene in age) which attain a maximum thickness of approximately 300 feet in a few places under the Charles River Basin. Overlying the glacial deposits are recently (Holocene) deposited alluvium, reworked sand and gravel, reworked marine clay, organic silt/peat, and miscellaneous fill materials.

Underlying the glacial deposits are a series of interlayered sedimentary rocks intruded by igneous rocks, mainly diabase. The sedimentary rocks can be divided into three main facies: coarse-grained (conglomerate and sandstone), fine-grained (argillite) and a mixed facies consisting of maroon and green tufaceous siltstone and sandstone. Traditionally, these sedimentary rocks have been called the Boston Bay Group and have been given formational names: Roxbury Conglomerate and Cambridge Argillite.

The upper formation (the Cambridge Argillite) occupies the northern half of the basin and overlies the Roxbury Conglomerate in the southern half. It is characterized by laminated bedding with alternating layers of light gray, sandy and dark gray, clayey argillite. Thicker beds up to about 3 feet also occur, and the composition occasionally grades to sandstone.

The lower formation, the Roxbury Conglomerate, has been traditionally subdivided into three members which are, in descending order: the Squantum Tillite, the Dorchester Shale, and the Brookline Conglomerate. The uppermost member is a poorly-sorted, non-calcareous sedimentary rock with a wide variety of grain sizes (Kaye, 1984). The Dorchester Member is predominantly argillite, with some sandstone and conglomerate; and the Brookline Member is primarily conglomerate, with argillite, sandstone, and basalt.

Underlying the Cambridge Argillite and Roxbury Conglomerate formations are fine-grained volcanic rocks belonging to the Lynn and Mattapan formations. These units are similar lithologically, but are named for their location geographically (Lynn is to the North, Mattapan to the south).

Recent work (Kaye, 1984) indicates that the above simple stratigraphic concept of a layered sequence of decreasing age does not properly portray the complex relations of different facies. This is primarily because the same rock types may have been deposited at different times, and units change composition laterally.

The strike of bedding in the Boston area is typically east-west, but can be oriented in virtually any direction due to local structural changes. In bedrock tunnels, where numerous measurements have been made, strikes range from N65W to N90W and N60E to N90E. According to Rahm (1962) and Kaye (1980), minor folding produces local strikes in a northerly direction.

The structure of the basin is comprised of a series of broad folds with wavelengths on the order of 3 miles (Billings, 1976). However, due to limited subsurface data and differences in geologic interpretation, the number and location of these folds is uncertain. Structural features that intersect the proposed tunnel alignment are shown on Table 3.1 and in Figures 3.1 and 3.2. According to Kaye (1984), three folds will intersect the proposed Inter-Island Tunnel, and according to Billings, two folds will intersect the tunnel.

TABLE 3.1

Structures Along Inter-Island Tunnel Alignment

	Billings, 1976	Kaye, 1984
Folds:	Central Anticline Wollaston Syncline	Hull Syncline Brewster Syncline Central Anticline
Faults:	Mount Hope Fault Neponset Fault	Squantum Fault Long Island Fault Peddocks Island Fault Unnamed Fault (Trends N-NW)

Within the basin, a series of east-northeast trending regional faults dissect the basin into a series of fault blocks. Each block has a fold (anticline, syncline, or homocline), and the average spacing between faults is approximately 500 feet, measured in any direction (Kaye, 1982). Recent mapping by Kaye (1980) indicates that at least eight of these longitudinal faults are 9 miles or more in length. To complicate matters further, the rocks are broken by a complex of later faults, most of which are transverse to the longitudinal faults. The longitudinal faults are mostly high-angle reverse in nature. On many of the transverse faults, slickensides on fault surfaces show a strong strike-slip component of movement. The structural deformation probably occurred during the Ordovician, Permian, and Triassic-Jurassic periods.

Most faults observed in the field and described in tunnels are thin, rehealed and show minor displacements. Fault zones are typically only a few inches wide and contain fragments of rock cemented together by subsequent mineralization. Billings (1976) summarized data on 318 minor faults from three bedrock tunnels. The most frequent strikes were N20E, N10W, and N50W; and dips were typically 80 to 90 degrees, but as low as 50 degrees.

Shear zones have been observed in several of the Boston area tunnels, such as:

1. The Malden tunnel - 40 shears in the *Lynn* Volcanics, striking northeast, with a dip of 45 NW, as well as approximately west, with a steep dip to the south.

2. The MBTA Red Line tunnel - shear zones in the argillite, which were oriented east-northeast, parallel to the regional structural trend.

3. The Dorchester tunnel - large shear zone (approximately 4,800 feet wide), oriented nearly north-south, accompanied by altered bedrock, groundwater inflows, and diabase intrusions.

Joints mapped in bedrock tunnels indicate that orientations are variable, but the most prominent sets are approximately north-south with 80 to 90 degree dips and approximately east-west with 80 to 90 degree dips and 20 to 45 degree dips (bedding planes).

3.20 GEOLOGIC ORIGIN OF SOILS

Much of the topography that is in evidence within the basin was formed during glaciation when massive blocks of ice scoured the bedrock surface, eroding the softer sedimentary rocks that underlie the basin, and subsequently depositing glacial materials over most of the bedrock. More resistant igneous and metamorphic rock formed highlands surrounding the area. The glacial deposits have a maximum thickness of approximately 300 feet in a few places under the Charles River Basin. Most surficial deposits are Pleistocene in age and are related to the last glacial epoch which ended in the late Wisconsian, approximately 12,000 years before present (B.P.)(Hanson, 1984). These deposits include till, sand, gravel, silt, and clay, most of which are glaciomarine in origin (Kaye,1982). In addition, recent (Holocene) processes have deposited alluvium, reworked sand and gravel, reworked marine clay, organic silt/peat, and miscellaneous fill over low areas of the basin.

The following are generalized descriptions of these deposits:

Glacial Till - Typically, this is a very dense, unstratified, variable mixture of clay, silt, sand, gravel, cobbles, and occasional boulders. Till thicknesses typically range between 5 and 30 feet and grain-size distribution curves usually indicate a widely graded material with 10 to 25 percent or more of the grains finer than a No. 200 sieve (Johnson, 1989). As the clasts in the till were moved and deposited by ice rather than water, they are angular to subangular in shape. Some till deposits directly overlie bedrock whereas others overlie older sands, gravels and clays.

Marine Clay - This is glacial rock flour deposited in a quiet marine environment, without the characteristic graded bedding and varves of a lacustrine deposit. It consists of clay-size particles but becomes sandy or silty locally or is interbedded with thin fine sand layers. The clay unit can be over 200 feet thick and is composed primarily of illite, with some chlorite and a little mixed-layered smectite/illite (Kaye, 1979).

Outwash - This unit consists of medium dense deposits that range from stratified coarse gravel through interbedded sand and clay to well-bedded silty clay and silt. The unit was deposited by meltwater streams during retreat of the ice front.

Organic Deposits - As the last glacial epoch waned, there was a drop in sea level. Coastal and nearby lands emerged as salt and freshwater marshes, and poorly drained meadowland, dotted with ponds (Kaye, 1982). Vegetation became established and pond deposits began to collect in these areas. When the sea level began to rise again, approximately 2,000 years later (Kaye, 1982), the vegetation was buried beneath the bay muds, rich in marine life, forming the soft to medium dense, dark brown to black, fine to coarse grained sands which are interbedded with organic silt, shells and peat. This unit can be as much as 20 feet thick and is often used as a marker horizon to indicate the base of fill or top of natural ground.

Alluvium - This unit occurs along stream beds and consists of sand, gravel, and silt, with organic silt or peat in areas of poor drainage. The materials were eroded and transported by runoff to the streams during seasonal rainfall.

Reworked Marine Clay - As the glacial ice retreated/melted, crustal rebounding occurred. This produced a negative sea-level movement that exposed the Boston "blue clay" to wave-base erosion and subaerial erosion. Much of the eroded clay has been deposited on the floor of the Boston Harbor (Kaye, 1982).

Reworked Sand and Gravel - In coastal areas, wave erosion and longshore currents are constantly transporting and redepositing surficial materials, mainly glacial sand and gravel deposits. These processes result in the formation of spits and tombolos. Spits are long, narrow ridges of sand and gravel that extend out from the end of a peninsular or island. Tombolos are spits that connect an island to another island or the mainland. The Winthrop and Nantasket barrier beaches are spits (Hanson, 1984) and Yirrel Beach which connects Deer Island to Winthrop is an example of a tombolo (Fitzgerald, 1984). Nut Island (a drumlin) is connected to Great Hill in Quincy (another drumlin) by a tombolo.

The upper 5 to 10 feet of surface deposits on the seafloor, which shift about due to seasonal storms, are also reworked sand and gravel.

Miscellaneous Fill - The fill consists primarily of excavated and redeposited glacial and alluvial deposits, interbedded with bricks, glass, ash, wood, concrete, granite blocks, and other human-generated debris.

3.30 GEOLOGIC ORIGIN OF BEDROCK

The Boston Basin contains Precambrian to Middle or Late Cambrian and perhaps Ordovician volcanic rocks (Barosh et al., 1989). The rocks appear to have been deposited in a basin complex that was undergoing active block-faulting. The highest relief and source areas lay to the south and west of the basin. Coarse clasts were deposited closer to the source area in alluvial fans, gravel plains, and gravelly marine shelf environments; and finer clastics and occasional conglomerates (diamictites) were moved by gravity transport processes into a basinal environment. The sedimentary rocks, therefore, consist of detritus that was eroded from surrounding highlands and deposited as interfingering facies (Kaye, 1982). Deep erosion of the source areas and concomitant subsidence of the basin resulted in onlapping of finer clastic facies over coarser facies at the basin margin (Bailey, 1987). Consequently, conglomerate, sandstone, argillite and volcaniclastic sediments grade or interfinger into each other laterally and vertically over short distances. Thin limestones interbedded with argillite and sandstone are also locally abundant.

Very late Precambrian volcanic activity was widespread and occurred in at least six intervals (Barosh et al., 1989). Early eruptions were rhyolitic and later were spilitic and keretophyric. The volcanic rocks occur as flows, flow breccias, explosion breccias, pillow lavas, plugs, necks and diatremes.

Based on telltale evidence of submarine sliding and turbidity currents at many stratigraphic levels, it has been concluded that depositional basin bottoms were unstable. The evidence includes convoluted bedding, intraformational breccia, graded-bedding, and large lenticular slumped masses of pebbly to bouldery mudstone. Kaye (1984) suggests that bottom slumps and slides were probably triggered by earthquakes that originated from volcanic eruptions and block faulting.

The following are generalized descriptions of the main rock types that occur within the Boston Basin rock formations:

Argillite - This is perhaps the most common rock type in the basin. It consists of silt-size particles of quartz, feldspar, seritic, chlorite and kaolinite. Darker argillite contains more sericite and chlorite while the lighter argillite contains more kaolinite (Kaye, 1967). The argillite is typically gray, but purple, purplish brown, tan, and green colors also occur. Kaye (1984) describes some mineralogical variations of argillite which include calcareous argillite interbedded with normal argillite, sideritic argillite, gypsiferous and dolomitic argillite, red argillite, and black argillite.

The argillite is typically hard and well indurated, more consolidated than shale but not fissile like shale. According to Kaye (1979), fresh rock tends to break across bedding planes. When partings do occur along bedding, they have smooth, planar surfaces (Rahm, 1962). Bedding is typically laminated, consisting of alternating 0.1- to 0.2-inch-thick light and dark colored layers. Individual beds generally range in thickness from less than 1/16-inch to 4 inches and can be up to 5 feet thick. The individual beds maintain a rather uniform thickness for many feet or tens of feet (Billings and Tierney, 1964). Grain size can vary locally to sandy or silty. Sedimentary structures such as slump folds, ripple marks and cross beds are common in this unit.

Severe alteration of the argillite (known as kaolinization), which results in a soft, whitish rock or even clay, occurs in random areas of the Boston Basin. Thin-section study shows that the normal minerals of the argillite have been replaced by sericite and kaolinite during the alteration process.

Kaolinization is probably the result of thermo-alteration of the argillite, with an igneous intrusion acting as the catalyst (Kaye, 1967).

Sandstone - This rock consists primarily of sand-size particles of quartz, feldspar (up to 35 percent sodic plagioclase) and rock fragments in a matrix of clay-size sericite, kaolinite and chlorite (Rahm, 1962). Sand fragments are mostly subangular in shape and medium to coarse in size. The color is typically tan, green or reddish.

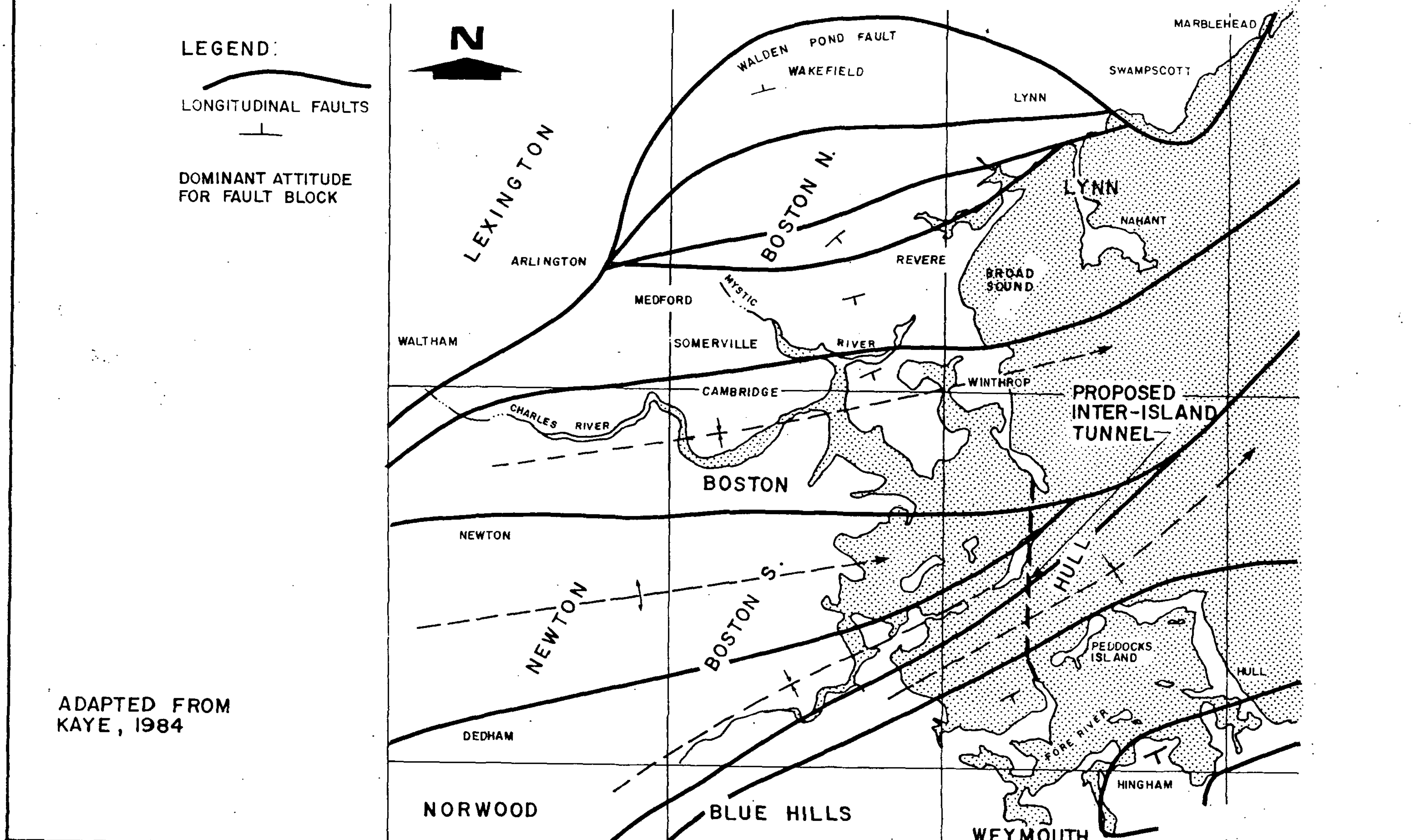
Conglomerates - This rock is typically gray-green, tan, gray or purple and consists of rounded to subrounded, pebble to cobble size clasts (30 to 50 percent (Rahm, 1962)) of felsite, quartzite, granite and basalt in a sandstone matrix (similar to the unit described above). The clasts are 1 to 3 inches in diameter, but can be 12 inches (Tierney et al., 1968). Bedding is sometimes evident from clasts oriented with their long axis parallel (Kaye, 1980). More often, however, the clasts are random and the structure is massive (Tierney et al., 1968; Rahm, 1962; Richardson, 1977).

Tillite/Diamictite - The rock contains clasts of granite, quartzite, felsite, flow-banded volcanics, basalt, slate and siliceous argillite (Bailey, 1976). The clasts are subrounded to subangular in shape and 2 to 24 inches in diameter. The most distinctive characteristics are the poor sorting of clasts and the abundant sand-silt-clay matrix (Bailey, Newman and Genes, 1976).

Diabase - This is the most common intrusive rock in the basin. It is dense, medium to dark gray or greenish gray, and consists of sodium-rich feldspars and mafic silicates (labradorite to oligoclase, dioside, augite, and uralitic amphibole) (Kaye, unpublished). Its most common occurrence is in dikes that cut across other bedrock units.

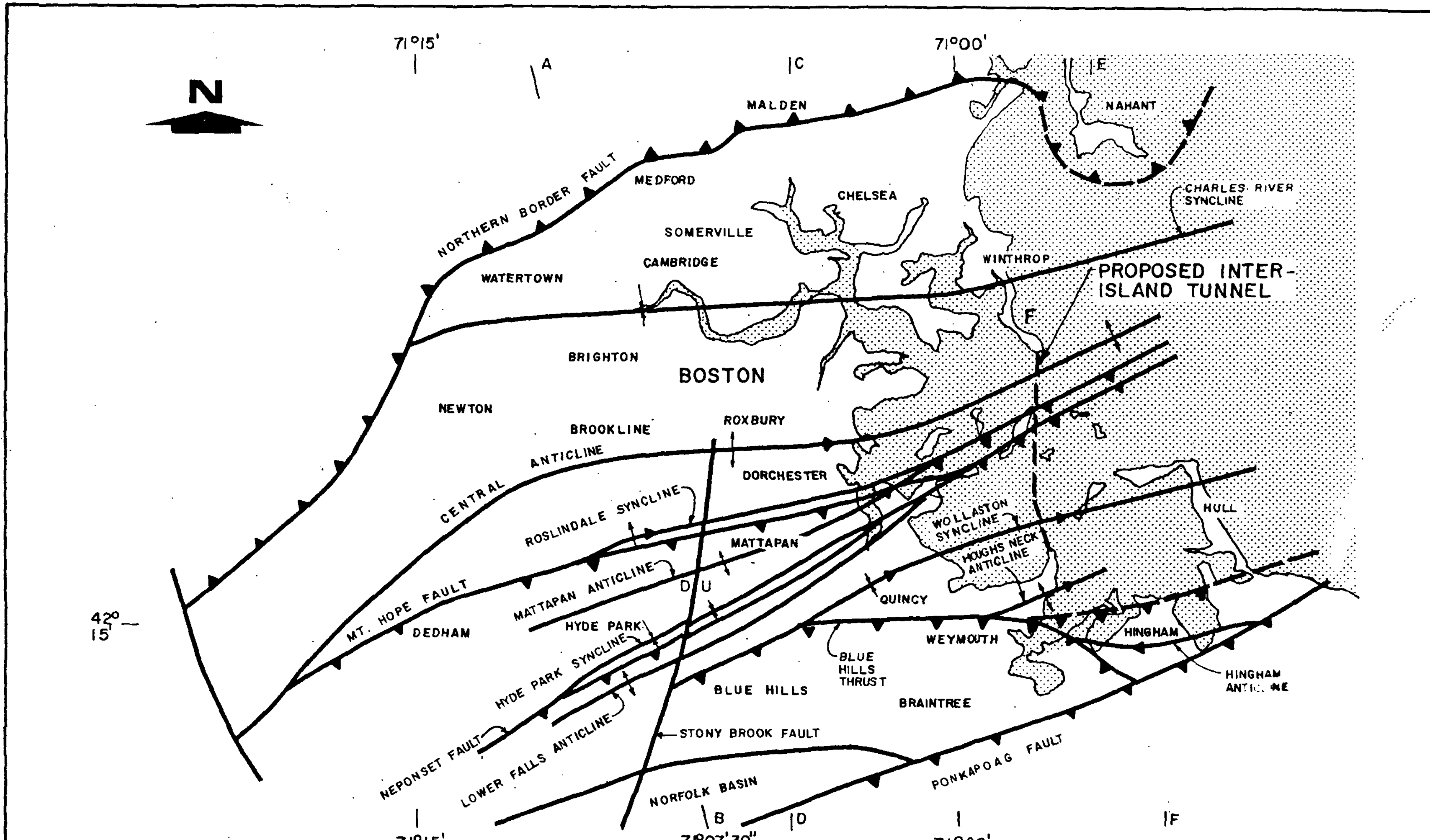
Basalt - This is another common intrusive in the Boston area and commonly occurs both as a sill and a dike. In the City Tunnel Extension, basalt is described as dark green to yellow green and fine grained. In places, it contains small (0.1- to 0.2-inch) vesicles filled with calcite, epidote and chlorite. Petrographic analyses show that the basalt has been extensively altered to secondary minerals - albite, hornblende, chlorite, epidote, and calcite.

FILE No. U-11305.1



Sverdrup CORPORATION	In Association With Jacobs Associates Goldberg-Zoino & Associates and Delon Hampton & Associates	DP-5 INTER-ISLAND TUNNEL BOSTON HARBOR	TECTONIC MAP OF THE BOSTON BASIN NOV. 1989 FIGURE No. 3.1

FILE No. U-11305.1



ADAPTED FROM BILLINGS, 1976

Sverdrup CORPORATION	In Association With **Jacobs Associates** **Goldberg-Zoino & Associates** and **Delon Hampton & Associates**	DP-5 INTER-ISLAND TUNNEL BOSTON HARBOR	TECTONIC MAP OF BOSTON BASIN AND BLUE HILLS NOV. 1989 FIGURE No. 3.2

4.00 SUBSURFACE CONDITIONS

4.10 GENERAL

The proposed conveyance tunnel will be constructed entirely within the Cambridge formation with a minimum of 70 feet of rock cover. Based on the Rock Mass Rating (RMR), Rock Structure Rating (RSR) and Rock Mass Quality (Q) classification systems (described in Section 5.44) used for evaluation, the rock conditions appear to vary from poor to very good for tunnel construction.

The two shafts at Deer Island and Nut Island will penetrate through soil into bedrock. The soil deposits generally consist of fill underlain predominantly by a dense to very dense mixture of clay, silt, sand, gravel, and boulders (glacial till). As is typical of glacial deposits, the proportion of fine- to coarse-grained material is highly variable. However, isolated pockets and lenses of near-homogeneous fine materials can occur within the till.

A boring location plan is attached as Figures 4.1 through 4.3. Initially, the tunnel alignment was to be a straight line between Nut Island and Deer Island. However, due to the results of a seismic reflection and refraction survey, performed in February 1989 by Weston Geophysical Corporation, the alignment was subsequently altered by adding a dog-leg west of Peddocks Island. Interpretation of the data from this survey and other previous geophysical surveys had indicated the existence of a deep depression in the surface of the rock in an area located between Nut and Rainsford Islands, due west of Peddocks Island.

Summary logs for the borings performed within the proposed tunnel alignment area, during both the 1988 and the 1989 subsurface exploration programs, are attached to this report as Appendix A. The complete 1989 boring logs are included in the "Geotechnical Data Report" which is available for purchase separately.

The following sections describe the generalized subsurface profile along the proposed tunnel alignment and at the two shaft locations. All elevations are based on Metropolitan District Commission (MDC) datum.

4.20 SOIL CONDITIONS

4.21 North Shaft

Based on boring LDE-46, which was performed by the LDE, the bedrock at the proposed North Shaft is covered by approximately 134 feet of soil (based on the existing ground surface elevation of 128 feet at the time of drilling). The generalized subsurface soil conditions are as follows, in descending order from ground surface (refer to Figure 4.4 for profile at shaft):

MISCELLANEOUS FILL: Approximately 16 feet of loose to medium dense, sandy clay, pieces of drywall, wire, oily material, and other materials. The Standard Penetration Resistance (SPT) or N values in this material ranged between 5 and 16.

It is the PDE's understanding that prior to commencement of shaft construction, the miscellaneous fill will have been excavated and replaced (by the Early Site Preparation Contractor) with engineered fill (granular material below the groundwater table and till above) up to approximate elevation 125 feet.

GRAVEL: Approximately 7 feet of dense, fine to medium angular gravel, some fine sand, trace silt. One N value of 38 was obtained in this stratum.

SILT: Approximately 15 feet of loose to dense, brownish gray to gray silt, some (20 to 30 percent) fine angular gravel, trace coarse gravel. N values in this stratum were 8 and 45.

GLACIAL TILL: Approximately 68 feet of dense to very dense, brownish gray to gray, clay-silt matrix, some (10 to 30 percent) fine angular gravel, trace coarse gravel. N values ranged from 31 to 129, with values generally being greater than 80 at elevations below 60 feet. No boulders were encountered but cobbles were observed at an approximate elevation of 105.5 to 106 feet. The cobbles are an indication that boulders could be present.

SILTY SAND: Approximately 13 feet of very dense, brown silt and sand, mixed with small fragments of shell. The N values in this stratum were 100 and 108.

BOULDERS: Approximately 15 feet of argillaceous boulders, fragments of argillite, quartzite and igneous rock, cobbles, some fine to coarse gravel, rust staining; with a brown, fine to medium sand layer at elevation 4.3 to -1.2 feet. The sand layer appears to be under hydrostatic pressure and became a "running" sand during drilling.

In boring LDE-46, diabase was encountered below the bouldery deposit. This rock type was encountered at a depth of 134 to 152 feet (elevation -6 to -24 feet) and is a heavily fractured, moderately hard to hard, greenish gray, medium sized crystalline rock, with closely to very closely spaced joints, mostly slickensided joint surfaces, and occasional calcite veins. However, as unweathered to slightly weathered argillite instead of diabase was consistently encountered in the observation well borings (the nearest well was 29.5 feet from LDE-46) for a groundwater pumping test at LDE-46, as well as in boring LDE-39, approximately 165 feet north of LDE-46, the diabase is probably a dike. Therefore, it may not extend over the entire shaft area.

Index property and grain size analysis tests were performed by the LDE on soil samples from boring LDE-46. The results are attached as Appendix L of the LDE's June 1989 Geotechnical Interpretive Report, Volume III.

4.22 South Shaft

Based on boring LDE-58, which was also performed by the LDE, the bedrock at the proposed South Shaft is covered by approximately 95 feet of soil (based on the existing ground surface elevation of 126.2 feet at the time of drilling). The generalized subsurface soil conditions are as follows, in descending order from ground surface (refer to Figure 4.5 for profile at shaft):

GRANULAR FILL: Approximately 26 feet of medium dense to dense, gray, fine to coarse sand and gravel, trace clay, trace organics. The estimated quantity of the sand and the gravel varies between 10 and 40 percent and between 10 and 50 percent, respectively. N values ranged between 10 and 47.

SILTY CLAY: Approximately 13 feet of very stiff, yellowish brown, silty clay, trace fine sand, with medium plasticity. The N value was 24.

CLAYEY SAND: Approximately 4.5 feet of dense, yellowish brown, clayey sand, trace silt, with a low to medium plasticity. The clay content is estimated to be approximately 30 percent and the fine sand is approximately 45 percent. The N value was 39.

GRAVEL: Approximately 7.5 feet of very dense, brown, fine to coarse gravel, some sand, trace clay. The N value was 120.

GLACIAL TILL: Approximately 44 feet of very dense, gray, clayey fine to coarse gravel, some silt, trace sand, with medium plasticity. The N values ranged between 67 and 129, with most of them generally greater than 80. For the till above approximate elevation 55 feet, in boring LDE-69 (approximately 67 feet away from LDE-58), N values range between 42 and 66. The lower N values are probably an indication that there are fewer boulders and/or cobbles within that zone of LDE-69.

Underlying the till, from a depth of approximately 95 to 313 feet (elevation 31 to -187 feet), is slightly weathered, moderately hard, gray, argillite with interbeds of sandy argillite and occasional calcite veins.

Index property and grain size analysis tests were performed by the LDE on soil samples from boring LDE-58. The results are attached as Appendix L of the LDE's June 1989 Geotechnical Interpretive Report, Volume III.

4.23 Tunnel

As the tunnel will be constructed entirely within rock, the characteristics of the surficial deposits overlying bedrock along the proposed tunnel alignment are not of great concern. Consequently, during the 1989 boring program, only a limited number of samples of surficial deposits were obtained. However, the soil/rock interface elevation in all borings was recorded.

Dense marine silty clay and glacial till were the primary deposits encountered along the proposed conveyance tunnel alignment. The generalized subsurface soil conditions along the alignment are as follows, in descending order from ground surface or seabed (refer to Figures 4.6 through 4.8 for profile):

RECENT SEDIMENTS: Approximately 0 to 10 feet of very loose, dark grey to black, sand and/or silt, some clay, trace organics. Boring 89-103 which was performed on land had approximately 9 feet of miscellaneous fill consisting primarily of construction debris such as concrete.

GRAVEL AND/OR SILT: Approximately 0 to 29 feet of loose to dense, fine to medium gravel and/or silt, and some sand.

SILTY CLAY: Approximately 0 to 99 feet of soft to very stiff, gray to yellowish brown silty clay, trace fine sand, with medium plasticity.

GLACIAL TILL: Approximately 6 to 104 feet of dense to very dense, gray sand and gravel, with various quantities of cobbles, silt and clay <u>or</u> hard, gray, clayey silt, with varying quantities of cobbles, gravel, and sand.

The till is generally underlain by Cambridge Argillite. Exceptions are boring 89-116 which is underlain by approximately 60 feet of very dense, grayish-orangish brown, fine to coarse sand, little silt; and boring 89-117 which is underlain by approximately 20 feet of very dense, orange/brown, boulders, cobbles, gravel and sand. The characteristics of the argillite are given in the next section of this report.

4.30 BEDROCK CONDITIONS

4.31 North Shaft

Below the surficial deposits at the proposed North Shaft location, boring LDE-46 encountered the following rock formations, in descending order (refer to Figure 4.6):

Diabase: This formation was encountered at a depth of 134 to 152 feet (elevation -6 to -24 feet) and is a heavily fractured, moderately hard to hard, greenish gray, medium sized crystalline rock, with closely to very closely spaced joints, mostly slickensided joint surfaces, and occasional calcite veins. Drilling core recovery ranged between 90 and 100 percent, and RQDs generally ranged between 50 and 60 percent.

Note that as several observation well borings (the nearest was 29.5 feet away from LDE-46) which were installed for a groundwater pumping test at this location did not encounter the diabase. It is therefore probably a dike. These other borings encountered unweathered to weathered argillite. Boring LDE-39, which is approximately 170 feet north of LDE-46, encountered a medium hard, light gray, unweathered, argillite, with thin and slumped bedding, and occasional calcite veins. Consequently, both diabase and argillite should be expected at this elevation.

Argillite: This formation was encountered at a depth of 152 to 409 feet (elevation -24 to -280 feet) and is slightly weathered, moderately hard, light gray to gray, with occasional calcite veins, typically 35 to 45 degrees opposite bedding. The results of borehole geophysics indicate that there may be some alteration at the contact with the diabase.

Drilling core recovery was generally between 93 and 100 percent (average of 97 percent). RQDs generally ranged between 20 and 75 percent from approximate elevation -24 to -37 feet (area closest to the diabase) and between 83 and 100 percent from elevation -37 to -281 (average of 86 percent). Very few fracture zones were encountered and those present range in thickness from 0.2 to 1.3 feet. All fracture zones appear to be above elevation -80 feet. Below elevation -80 feet, joints are typically widely spaced. Many of the joints are bedding plane separations. Some of the joints were detected by the geophysical logging performed at the site (Appendices M and P of the LDE's 1989 Geotechnical Interpretive (GI) Report, Volume IV).

Oriented core accounted for approximately 50 percent of the core recovered from this boring. The oriented core data indicate that the bedding at the location is highly variable with most of the rock exhibiting slump features below elevation -130 feet.

Orientations of primary and secondary bedding planes and discontinuities for boring LDE-46 have been plotted on Figure 4.9. These data were obtained from oriented rock cores taken by the LDE at select intervals during drilling. A goniometer was used to obtain the strike and dip orientation. Based on the plots, primary bedding planes dip 22 to 48 degrees, at N359° to N033°, and secondary bedding planes dip 30 to 64 degrees, at N315° to N358°. Discontinuity orientation appears to be more variable with primary discontinuities dipping 7 to 77 degrees, at N289° to N066°, and secondary discontinuities dipping 7 to 70 degrees, at N222° to N358°.

Seismic reflection and refraction survey data indicate variable bedrock velocities (13,000 to 16,000 ft/sec.) and top of rock elevations. Furthermore, a southeast trending bedrock trough, with a low point of elevation -35 feet, which is near an area of low velocities, suggests that there may be a fault or shear zone in the vicinity of the proposed shaft. Downhole velocities of the material near the boring are approximately 14,500 ft/sec. However, the velocity of the material in the bottom of boring LDE-46 is irregular due to the number of water bearing fractures. Refer to Appendices E and M of the LDE's 1989 GI Report, Volumes II and IV.

4.32 South Shaft

Below the surficial deposits at the proposed South Shaft location, boring LDE-58 encountered the following rock formations, in descending order (refer to Figure 4.8):

Argillite: This formation was encountered at a depth of approximately 95.3 to 313.0 feet (elevation 30.9 to -186.8 feet) and is slightly weathered, moderately hard, gray, with interbeds of sandy argillite and occasional calcite veins, typically 40 to 60 degrees and 20 to 30 degrees opposite bedding. Within this formation, there is a slightly weathered, hard, green felsite sill at a depth of 262.9 to 263.4 feet (elevation -136.7 to -137.2 feet); and at a depth of 297 to 313 feet (elevation -170.8 to -186.8 feet), the argillite becomes tuffaceous and is interbedded with argillite.

Drilling core recovery was generally between 83 and 100 percent (average of 97 percent). RQDs generally ranged between 78 and 100 percent (average of 93 percent). A fracture zone, 45 to 60 degrees, was observed at a depth of 174.1 to 175.9 feet (elevation -47.9 to -49.7 feet) and a broken zone was observed at a depth of 202.2 to 202.4 feet (elevation -76.0 to -76.2).

Orientation data for boring LDE-58 plotted on Figure 4.10 indicate that primary bedding planes dip 80 to 84 degrees, at N317° to N330°, and secondary bedding planes dip 50 to

70 degrees, at N180° to N195°. Primary discontinuities dip 52 to 55 degrees, at N000° to N007°, and secondary discontinuities dip 2 to 46 degrees, at N155° to N288°.

A land-based seismic refraction survey performed by Weston Geophysical indicates that the argillite is of good quality with bedrock velocities of 16,000 to 17,000 ft/sec. (Appendix E of the LDE's 1989 GI Report, Volume II). The survey was performed on both Nut Island and Deer Island and consisted of approximately 17,900 feet of seismic refraction profiling.

Diabase: This formation was encountered at a depth of approximately 313 to 351 feet (elevation -186.8 to -224.8 feet) and is a slightly weathered, moderately hard, yellowish green to gray, fine to medium sized crystalline rock, with occasional to some yellow/green epidote veins, and occasional to some calcite and quartz veins cutting epidote veins. The contacts with the argillite are brecciated and irregular. Drilling core recovery was 100 percent and RQDs generally ranged between 82 and 97 percent.

Argillite: The lower 78.4 feet (elevation -224.8 to -303.2) of the boring consists of a slightly weathered, moderately hard, gray, argillite, with occasional to numerous hairline calcite veins at various angles. Thin, greenish gray, fine-grained, felsite sills (0.5 to 8 feet thick) and dikes are located within this formation at elevations of approximately -227.8 to -230.0, -235.5 to -242.3, -277.3 to -284.8, and -287.5 to -296.8 feet. Contacts with the argillite are generally brecciated, as if intruded. Drilling core recovery was generally 100 percent. RQDs generally ranged between 82 and 100 percent (average of 87 percent).

4.33 Tunnel

Most of the rock encountered within the proposed tunnel alignment, during both the 1988 and 1989 subsurface investigations, was Cambridge Argillite or diabase/basalt (refer to Figures 4.6 through 4.8). Details of expected rock conditions follow.

4.33.1 Stratigraphy and Structure

The proposed tunnel passes through five lithologic zones. The lateral extent of these zones as described below is approximate. In general, transition between the zones is gradual but there may be abrupt transitions at fault locations. Evidence for such faults is implicit. Nevertheless, where excessive slickensides, gouge and/or abrupt changes in lithology were observed, possible fault zones have been indicated on the subsurface profile.

From north to south, the five zones are as follows:

1. Station 10+00 to 50+00 (Deer Island through President Roads): Massive to regularly bedded, medium hard to hard, gray argillite and sandy argillite, with some calcite veins and an approximately 30-foot-thick diabase sill. The proposed tunnel appears to be entirely within this sill from station 10+50 to 41+00. The sill is below tunnel invert at station 49+00.

2. Station 50+00 to 90+50 (Long Island): Regularly bedded, hard, gray, sandy argillite, argillite and fine sandstone, with pervasive quartz veins.

3. Station 90+50 to 150+00 (south of Long Island): Massive to regularly bedded, medium hard to hard, green banded gray, purple, and black argillite, sandy argillite, tufaceous argillite, and sandstone (color and lithologic transition is from north to south along the alignment). At the northern end of the zone, below the proposed tunnel invert, is a medium hard to very hard green diabase which is in turn underlain by a medium hard to hard, tufaceous sandy argillite.

4. Station 150+00 to 200+00 (anomalous section passing Rainsford Island): Highly sheared or fractured zone consisting of a massive to regularly bedded, medium hard to hard, light to dark gray argillite, sandy argillite, and sandstone at the northern end; a massive to regularly bedded, very soft to medium hard, gray and white argillite and sandstone at the southern end; and massive diabase intrusions around station 170+80 (boring 89-108).

5. Station 200+00 to 261+60 (from Peddocks Island to Nut Island): A regularly bedded, medium hard to hard, purple and gray argillite and sandy argillite, with minor green and red felsite lenses.

<u>ZONE 1 (Station 10+00 to 50+00)</u>: This zone includes borings LDE-46, 89-116, 89-117, 88-26, 89-101, and 89-113. Boring 88-26 is approximately 794 feet off the alignment and not shown on the profile, however, the data from the boring were used in the overall analysis of the rock conditions within this zone. The RQD in the six borings ranges between 0 and 100 percent (poor to excellent) but typical values range between 81 and 100 percent (very good to excellent) for borings LDE-46, 88-26, 89-101 and 89-113; between 63 and 98 percent (good to excellent) for boring 89-117; and between 38 and 100 percent (fair to excellent) in

boring 89-116. Within the tunnel horizon (approximately one tunnel diameter above crown to one tunnel diameter below invert), the RQD ranges between 90 and 100 percent (excellent) in borings LDE-46, 88-26 and 89-113; between 61 and 94 percent (good to excellent) in borings 89-116 and 89-117; and between 33 and 100 percent (fair to excellent) in boring 89-101.

The typically poor condition of the rock core in borings 89-116 and 89-117 is believed to be due in part to drilling breaks along pre-existing discontinuities which had healed. The RQD values reported on the boring logs ignore breaks that appear to have occurred along these discontinuities. This is supported by the fact that all packer pressure tests performed in boring 89-117 did not take significant water. Packer tests were not performed in boring 89-116.

Slickensides and gouge are common in boring 89-116 and bedding plane separations, generally along previously healed/ recemented smooth surfaces, are common in boring 89-117. These observations appear to indicate the existence of a fault and are in agreement with seismic reflection and refraction survey data presented in Appendices E and M of the LDE's 1989 GI Report, Volumes II and IV. Based on these data, the LDE suggests that the presence of a southeast trending bedrock trough, which is near an area of low velocities, may be an indication that there is a fault or shear zone in the vicinity of the proposed North Shaft. Furthermore, Kaye's 1984 map (Figure 3.1) indicates an unnamed fault in this general area.

ZONE 2 (Station 50+00 to 90+50): This zone includes borings 89-102, 89-103 and 89-114. The argillite in zone 1 is fairly similar to that in zone 2. The primary difference is that the argillite in zone 2 is intensely veined (primarily with quartz). The RQD in borings 89-102 and 89-103 ranges between 14 and 100 percent (poor to excellent) but typically ranges between 76 and 100 percent (very good to excellent); and in boring 89-114 it ranges between 30 and 100 percent (fair to excellent) but typically ranges between 59 and 95 percent (good to excellent). Within the tunnel horizon, RQD ranges between 98 and 100 percent (excellent) in borings 89-102 and 89-103; and between 30 and 85 percent (fair to very good) in boring 89-114.

A diabase intrusion, which was encountered approximately 75 feet above the proposed tunnel crown in boring 89-102, may previously have been part of the igneous sill observed in zone 1. Furthermore, the apparently abrupt change in lithology from boring 89-114 to 89-104 and the observation of diabase at approximately the same elevation in zone 3 as in zone 1, may be an indication of a fault area between zones 2 and 3, from approximate station 90+00 to 100+00. These observations appear to suggest that a geological event displaced zone 2 upwards relative to zones 1 and 3 thereby creating two faults at the zone boundaries. The two faults may be those mapped by Kaye and Billings (refer to Figures 3.1 and 3.2). The probable fault north of Long Island might be the one referred to as the Long Island fault by Kaye; and the fault south of Long Island may be the one referred to as the Mount Hope fault by Billings.

<u>ZONE 3 (Station 90+50 to 150+00)</u>: This zone includes borings 89-104, 89-105 and 89-106. The rocks in this zone are coarser-grained than the more northerly argillite and produced fewer drilling breaks. The RQD in the three borings ranges between 19 and 100 percent (poor to excellent) but typically ranges between 81 and 100 percent (very good to excellent). Within the tunnel horizon, RQD ranges between 84 and 100 percent (very good to excellent) in borings 89-104 and 89-105; and between 70 and 100 percent (good to excellent) in boring 89-106.

Slickensides are especially common in boring 89-105 for about a 100-foot zone between elevations -100 and -200 feet (bracketing the tunnel horizon) and gouge is especially common throughout boring 89-104. Kaye mapped the Brewster syncline in this zone, and Billings mapped the Neponset fault (refer to Figures 3.1 and 3.2).

<u>ZONE 4 (Station 150+00 to 200+00)</u>: This zone has a variety of rock types and includes borings 89-107, 89-108, 89-109 and 89-115. It is characterized by extreme development of slickensides, fault gouge, partings along bedding planes, and significantly lower RQDs (0 to 100 percent) than in the more northerly borings. However, within the tunnel horizon, RQD ranges between 29 and 70 percent (fair to good), except in boring 89-109, where RQD ranges between 0 and 10 percent (poor).

In boring 89-107, there is an approximately 5-foot-thick diabase intrusion within the argillite, at approximate elevation -50 feet; and boring 89-108 is intruded by thick flows of highly sheared basaltic diabase (unlike the diabase seen elsewhere in the profile). During oriented coring, the diabase tended to fracture and crumble. In all four borings, slickensides are pervasive from top of rock to approximate elevation -200 feet. The southern borings in this section, 89-109 and 89-115, are an unusual sequence of sandy argillite and sandstone, *with local 3-inch-thick lenses of* a pebble conglomerate (not the Roxbury). Recovery was very poor in these borings, and 2- to 8-inch-thick gouge zones with clay layers are common. Kaye indicates that two faults (Squantum and Peddocks Island) and a syncline (Hull) are in this zone (refer to Figure 3.1).

<u>ZONE 5 (Station 200+00 to 261+60)</u>: This zone includes borings LDE-58, 88-29, 89-110 and 89-112 and extends from Peddocks Island to Nut Island. It has a consistent lithology which is generally softer than the gray or greenish argillite

found to the north. The RQD in the four borings ranges between 0 and 100 percent (poor to excellent) but typically ranges between 51 and 100 percent (good to excellent). Within the tunnel horizon, RQD ranges between 70 and 100 percent (good to excellent), except in boring 89-109, where RQD ranges between 14 and 97 percent (poor to excellent).

No bedding plane partings were observed in the core. The purple argillite contains some felsic volcanic ash and is intruded by very fine (1 to 2 mm) layers of igneous material which have turned the argillite green for 5 mm above and below each intrusion. This gives the rock a peculiar striped appearance but does not significantly affect the hardness of the rock. Borings 89-110 and 89-112 are quite fractured from top of bedrock down to elevation -50 feet; and there are diabase and felsite intrusions approximately 70 feet below proposed tunnel invert. Billings mapped the Wollaston syncline approximately where borings 89-110 and 89-112 are located (refer to Figure 3.2).

Significant quantities of kaolinized argillite were not encountered in any of the borings. However, the poor recovery in boring 89-115, the altered argillite, and the 0.1- to 0.4-inch-thick gouge zones with clay layers which are common in this boring are an indication that severely altered and/or kaolinized argillite could be encountered during tunneling.

The complexity and variability of this formation is consistent with the observations made during a subsurface investigation performed between Devonshire Street and Federal Street in downtown Boston (Errico and von Rosenvinge, 1986). Within this 20,000 square feet parcel, the bedrock consisted of the following three basic units:

1. Badly Decomposed Argillite - Kaolinized argillite, severely to completely weathered to hard clay-like consistency; overlying more competent sandstone and conglomerate, and argillite.

2. Sandstone and Conglomerate - Soft to hard, moderately to severely weathered, argillaceous sandstone and conglomerate.

3. Argillite - Very soft, moderately to severely weathered, argillite; underlies sandstone and conglomerate in northern portion of the site.

4.33.2 Bedding Planes and Discontinuities

The primary and secondary bedding planes and discontinuities have been plotted on Figures 4.11 and 4.12, respectively. These data were obtained from oriented cores taken from approximately 20-foot zones above and below the proposed tunnel crown and invert, respectively. Since the cores were taken, the vertical tunnel alignment has been raised 20 to 30 feet.

The data from each boring is contained in the "Geotechnical Data Report". The discontinuities include joint or fracture planes and cleavage planes. Due to the physical limitations of the goniometer, some of the steeper dipping discontinuities were only estimated. The data obtained in the preliminary boring program (1988) were also used to evaluate the general orientation trend of the rock along the alignment.

Oriented core from boring 89-109 was not considered reliable for determination of the orientation due to the poor quality of the rock and the tendency of the soft rock to rotate during drilling. This same problem occurred in boring 89-115 between elevation -118.7 and -121.2 feet. Hence, even though data from these portions of the oriented core are plotted on Figures 4.11 and 4.12, they were not used in the analysis.

The primary and secondary orientations of the bedding plane and discontinuities was evaluated from lower hemisphere projections of the poles on equal area stereonets. A density plot of the poles by percentage of total discontinuities falling within a counting area was then contoured. A high concentration of poles in a small area generates a cluster. The tighter the cluster the more confidence that can be given to the determination of strike and dip.

Several orientations of bedding planes and other discontinuities were encountered during drilling along the alignment, and it is likely that other orientations of rock discontinuities will be encountered during the tunneling. Several zones of slumped bedding were also encountered during the drilling. These tend to dip more steeply and are generally chaotic.

4.33.3 Intact Rock Properties

To evaluate the rock strength, 13 unconfined compression tests and over 500 point load tests were performed. Representative samples of rock types anticipated to be encountered in the tunnel horizon were selected and sealed immediately upon retrieval from the core barrel. Details of this procedure are provided in the "Geotechnical Data Report". The tunnel elevation has been raised 20 to 30 feet since most of these samples were obtained, however most of the samples are still considered to be representative of the rock at the tunnel depth.

In comparison with the testing performed for the LDE in 1988 (refer to the 1989 New England Research, Inc. report entitled, "Rock Properties - Secondary Treatment Plant, Deer Island") on both DP-5 and DP-6 samples, the recent unconfined compression tests performed by the PDE generally indicate a lower strength rock. Both the low and high values for the 1989 strength data range are lower than those for the 1988 tests. The test results obtained by the PDE compare well with the unconfined testing performed by the Robbins Company (refer to Appendix C of the LDE's 1989 GI Report) on samples supplied to them by the LDE. The 1989 data are summarized on Table 4.1.

The lower unconfined compression strength data range was to be expected since the samples tested by the PDE were of rock cores that exhibited a significantly higher degree of alteration than the 1988 samples. Furthermore, the rock samples tested by the PDE failed along joint surfaces. In several instances these joints were not visible prior to failure. Upon examination of the tested specimen it was noted that the joint surface typically had a very thin clay coating that was slippery to the touch.

Typically along this alignment, the argillite has a low to medium strength, in the typical range of a siltstone. It has bedding planes that have openings of less than 1 to 3 mm wide. These partings vary in space from several per inch to over 10 feet apart. However, it has been observed that bedding plane partings of the rock will occur with time. This is most probably due to stress relief and air drying of the cores.

The point load index strength data can be considered as indices of the unconfined strength of the rock. These data indicate that the corrected index strength ratio of axial tests to tests parallel to the bedding plane is approximately 2.7 to 1. The majority of the tests were parallel to the bedding. The index strength ratio of tests that failed along bedding planes to those that failed along joints is approximately 2 to 1.

Rock having unconfined strengths of 11.5 ksi to 26.6 ksi with corresponding secant moduli of 5,000 to 7,300 ksi was encountered in the northern portion of the alignment from President Roads to Rainsford Island and from south of Peddocks Island southward. A zone of soft rock, i.e. unconfined strengths of 0.9 to 3.9 ksi with corresponding secant moduli of 500 to 1,500 ksi, that was highly altered was found in the area of the bend in the tunnel alignment west of Peddocks Island. Unconfined strengths for the 1988 samples ranged between 0.5 ksi (altered argillite) and 48.5 ksi (diabase).

TABLE 4.1
SUMMARY OF UNCONFINED COMPRESSION TESTS

BORING	DEPTH	SAMPLE NO.	ROCK TYPE	Ht in	Dia in	Ht/Dia Ratio	TOTAL Wt gms	UNIT Wt pcf	FAILURE LOAD lbs	COMPRESSIVE STRENGTH ksi	MODULUS Esec @50% ksi
89-101	211.9	Ur10.1	Argillite	4.97	2.405	2.07	972.32	163.9	22000	4.8	2300
89-101	217.7	Ur10.2	Argillite	5.51	2.405	2.29	1098.54	167.2	9000	2.0	1500
89-102	234.6	Ur6.1	Sandy Argillite	4.97	2.400	2.07	1011.00	171.2	64000	14.2	5300
89-104	241.9	Ur2.1	Tuffaceous Sandy Argillite	5.04	2.404	2.10	1011.56	168.5	93500	20.6	5600
89-105	231.3	Ur8.1	Tuffaceous Sandy Argillite	4.99	2.398	2.08	1003.85	169.8	120000	26.6	7300
89-106	223.5	Ur4.1	Argillite-sandstone	5.01	2.401	2.09	1032.43	173.3	115000	25.4	6500
89-107	231.3	Ur9.1	Argillite	4.97	2.385	2.08	991.54	170.1	27000	6.0	3800
89-109	219.5	Ur7.1	Argillite	4.95	2.390	2.07	888.37	152.5	4000	0.9	500
89-110	191.4	Ur5.1	Argillite	4.98	2.393	2.08	988.65	168.1	17500	3.9	1500
89-111	196.7	Ur11.1	Argillite	4.75	2.400	1.98	908.02	160.9	8800	1.9	1300
89-112	196.9	Ur12.1	Argillite	4.99	2.395	2.08	991.10	168.0	10000	2.2	3000
89-113	222.0	Ur3.1	Diabase	4.92	2.410	2.04	1011.34	171.7	52500	11.5	5000
89-114	211.1	Ur1.1	Sandy Argillite	5.03	2.397	2.10	1008.28	169.2	52000	11.5	5200

Rock hardness indices are shown on Table 4.2. Typically, samples tested in both the 1988 and 1989 programs gave rock hardness values that are consistent with previously reported values for siltstones or argillite in the Boston Basin. However, these index values were very low for the argillite in borings 89-109, 89-110, 89-111 and 89-115. The samples of the igneous rock from borings 88-27, 88-29, 89-104 and 89-113 showed a wide Shore hardness range of 39.5 to 73.4 and a lower total hardness index (by a factor of 2) than the hardness range for a typical diabase (Tarkoy & Hendron, 1975).

Based on observation of thin sections of argillite samples, the quartz content of the rock is estimated to typically range between 15 and 30 percent. The quartz appears to consist mostly of clay or silt size particles which are not distinguishable to the naked eye.

TABLE 4.2
SUMMARY OF ROCK HARDNESS DATA

Sample Number	Bore Hole	Elev. (MDC)	Rock Type	Dia. in.	Shore Sclero-scope (D-Type) HS	Schmidt Hammer (L-type) HR	Modified Taber Abrasion HA	Total Hardness HT
1	89-102	-179.6	Argillite with sandy argillite	2.38	56	44	1.15	47
2	89-104	-152.5	Diabase, light and dark green layers	2.38	50	43	1.82	58
3	89-105	-147.7	Tuffaceous sandy Argillite, thin bedding	2.38	52	45	1.25	50
4	89-106	-150.5	Argillite and sandstone	2.38	54	45	1.03	46
5	89-109	-130.0	Argillite, purple	2.38	16	17	0.20	8
6	89-110	-123.9	Sandy Argillite with thin felsite beds	2.38	31	37	0.49	26
7	89-111	-128.5	Argillite with altered beds	2.38	29	19	0.38	12
8	89-112	-122.2	Argillite, purple with felsite beds	2.38	27	31	0.51	22
9	89-113	-174.4	Felsite	2.38	43	36	1.39	42
10	89-114	-115.5	Sandy Argillite	2.38	33	42	1.23	46
11	89-115	-137.7	Argillaceous Sandstone	2.38	20	20	0.31	11

4.40 GROUNDWATER

4.41 North Shaft

Groundwater was monitored at the proposed North Shaft location in borings LDE-46, LDE-39 and LDE-38. The readings indicate that groundwater fluctuates between approximately elevation 104.5 and 109.5 feet, corresponding to low and high tide, respectively. Groundwater level fluctuation at the shaft lags that of sea level by approximately 30 to 45 minutes.

Packer tests performed in LDE-46 indicate that average permeability within the rock ranges between 2.5 x 10^{-7} and 1.0 x 10^{-5} cm/sec (LDE's 1989 GI Report, Volume I). Falling head test results from an auxiliary borehole, near the shaft boring (LDE's 1989 GI Report, Appendix O, Volume IV), indicate that permeability will range between less than 1 x 10^{-7} and 9.3 x 10^{-4} cm/sec. within the till and between 7.1 x 10^{-5} and 4.1 x 10^{-3} cm/sec. within the outwash, i.e. the non-fill deposits above the till.

Two pump tests were performed (one in soil and the other in bedrock) at this location to evaluate the feasibility of dewatering the area prior to shaft excavation (refer to the LDE's November 30, 1989 report, entitled, "Aquifer Test Interpretive Report, Deer Island", for drawdown data and test details). The drawdown data were analyzed by the LDE using a variety of techniques. A description of the tests and the PDE's interpretation of the major implications of the pumping test data follows.

For the test in soil, pumping was performed at an essentially constant rate of approximately 120 gpm for a period of 49.5 hours (September 5 to September 9, 1989) and groundwater was then monitored for an additional 51 hours after pumping was terminated. For the test in bedrock, pumping was performed at a rate of approximately 43 gpm for a period of 76 hours (October 13 to October 16, 1989) and groundwater was then monitored for an additional period of 72.5 hours during recovery. During those periods, the response of the aquifers during pumping and recovery was monitored using twelve piezometers for the soil test and nine wells for the rock test. Discharge was to the beach about 800 feet from the proposed shaft location.

It is the PDE's opinion that the pump test data indicate that the soil and rock aquifers have a combined transmissivity on the order of 10,000 gallons/day/foot and a storage coefficient as low as 1.0 x 10^{-4}. The Contractor should be prepared to pump approximately 300 to 1,200 gpm of groundwater during excavation if he chooses to utilize a ground support system requiring pumping. The Contractor is given the option of choosing a concrete diaphragm wall or ground freezing support system that would be designed to obviate the need for a dewatering system.

The tests indicate that the lower portion of the overburden (the glacial till stratum) acts as a leaky artesian aquifer. Furthermore, the two aquifers (soil and fractured rock) are well connected hydraulically, and water levels in them exhibit tidal fluctuations that are approximately 50 percent of the amplitude of the corresponding tide. Ground-water withdrawn during the limited period of the tests had no significant salt concentrations. Observations in the piezometers showed tidal influences. Consequently, the PDE believes that pumping rates will stabilize relatively quickly and salinity concentrations may increase with time.

Maximum drawdown in the wells, during the pumping test in the soil, was approximately 46 feet. The aquifer materials are believed to be relatively thin (typically on the order of 10 feet) and approximately 120 feet below ground surface which corresponds to the pervious gravelly silty sand stratum above the rock/soil interface (refer to Section 4.2 for additional subsurface information). Therefore, the aquifer material remained saturated throughout the test. Different conditions will exist during construction and it may not be practical to dewater the soil/rock interface. Consequently, test results should be interpreted with care.

4.42 South Shaft

Groundwater was monitored at the proposed South shaft location in boring LDE-58. The readings indicate that groundwater fluctuates between elevation 107 and 117 feet.

Packer tests performed in LDE-58 indicate that average permeability within the rock ranges between 2.6×10^{-7} and 2.7×10^{-3} cm/sec. (LDE's 1989 GI Report, Volume I). Falling head test results from an auxiliary borehole, near the shaft boring (LDE's 1989 GI Report, Appendix O, Volume IV), indicate that permeability should range between less than 1×10^{-7} and 9.3×10^{-4} cm/sec. within the till; between 7.1×10^{-5} and 4.1×10^{-3} cm/sec. within the outwash, i.e. the non-fill deposits above the till; and approximately 3.6×10^{-4} cm/sec. within the fill.

4.43 Tunnel

The tunnel will be constructed entirely in rock at a depth of approximately 205 to 270 feet below sea level. Since low permeability materials appear to overlie most of the rock, the fact that the proposed tunnel will be constructed beneath the sea need not result in large inflows of water. Groundwater infiltration into the tunnel will be through the rock joints, not intact rock.

The groundwater inflow in the tunnel was estimated using data for packer tests that were conducted during both the 1988 and 1989 marine exploration programs, and the data available regarding the measured water inflow into the Main Drainage Tunnel during its construction in 1956 and 1957 (Hellstrom, 1989).

The data from the packer tests performed in the borings along the proposed alignment have been reduced to permeability values that typically range from $\leq 0.1 \times 10^{-5}$ to 50×10^{-5} cm/sec.

4.44 Groundwater Quality

Groundwater withdrawn during the pump test at the proposed North Shaft had no significant salt concentrations. However, the piezometric levels showed tidal influences. As pumping during construction will be for a much longer period, salt water should be expected.

In addition, water samples were collected and analyzed during the pumping tests at the proposed North Shaft location (refer to Table 5-1 in the LDE's November 30, 1989 report, entitled, "Aquifer Test Interpretive Report, Deer Island", for the water quality test data). The purpose of the analyses was to characterize the groundwater in terms of corrosivity and contamination. Based on the data collected, water from the aquifer should be suitable for discharge to marine waters after siltation control and compliance with discharge permit requirements.

4.50 SEISMICITY

New England is a region of moderate earthquake hazard that experiences a minor earthquake every couple of days (Barosh, 1989). However, this rate of activity is at least an order of magnitude less than that of Southern California. A plot of seismic events in the northeastern United States and adjacent Canada from 1534 to 1977 indicates that most of the seismic activity is concentrated in a seismic area that arcs around Cape Ann, from the south of Boston to southern Maine.

The two principal historic seismic events are the 1755 earthquake of probable epicentral intensity VIII (Modified Mercalli Intensity Scale of 1931, abridged version) and the 1727 event of intensity VII. The 1755 earthquake, which was located about 50 miles offshore of Boston, caused damage across eastern Massachusetts. It apparently thoroughly frightened the inhabitants of Boston, where it reached a high intensity of VII. The smaller 1727 earthquake was similarly located offshore north of Cape Ann and caused minor damage along the coast near Newbury, Massachusetts and adjacent areas in New Hampshire. It greatly startled the residents of Boston but caused little damage (intensity VI).

According to Barosh (1989), potential earthquakes would have the following effect on eastern Massachusetts:

1. Cape Ann (poses the greatest threat to Boston): A maximum credible event there of intensity IX would cause a general intensity effect in the Boston region with intensity level VIII, and possibly level IX, effects over the extensive areas of filled ground.

2. La Malbaie, Quebec: Large earthquakes may cause average intensities of VII. Long period motions might possibly cause damage to tall buildings and other structures that are susceptible to such motions.

3. Central New Hampshire: May only produce minor damage in eastern Massachusetts.

The effect of earthquakes on underground structures may be broadly grouped into three classes - faulting, ground failure, and shaking.

1. Faulting: This includes direct primary shearing displacements of bedrock which are generally limited to relatively narrow seismically active fault zones. Sliding along a geologic fault introduces stresses that may be significantly higher than the magnitude induced by shaking. It is not practical to design an underground structure to restrain major displacement in the order of several inches to feet. It is more feasible to avoid sensitive areas or to accept displacements, localize the damage, and provide means to accommodate repairs. There is no evidence of recent movement in fault zones which the tunnel will cross.

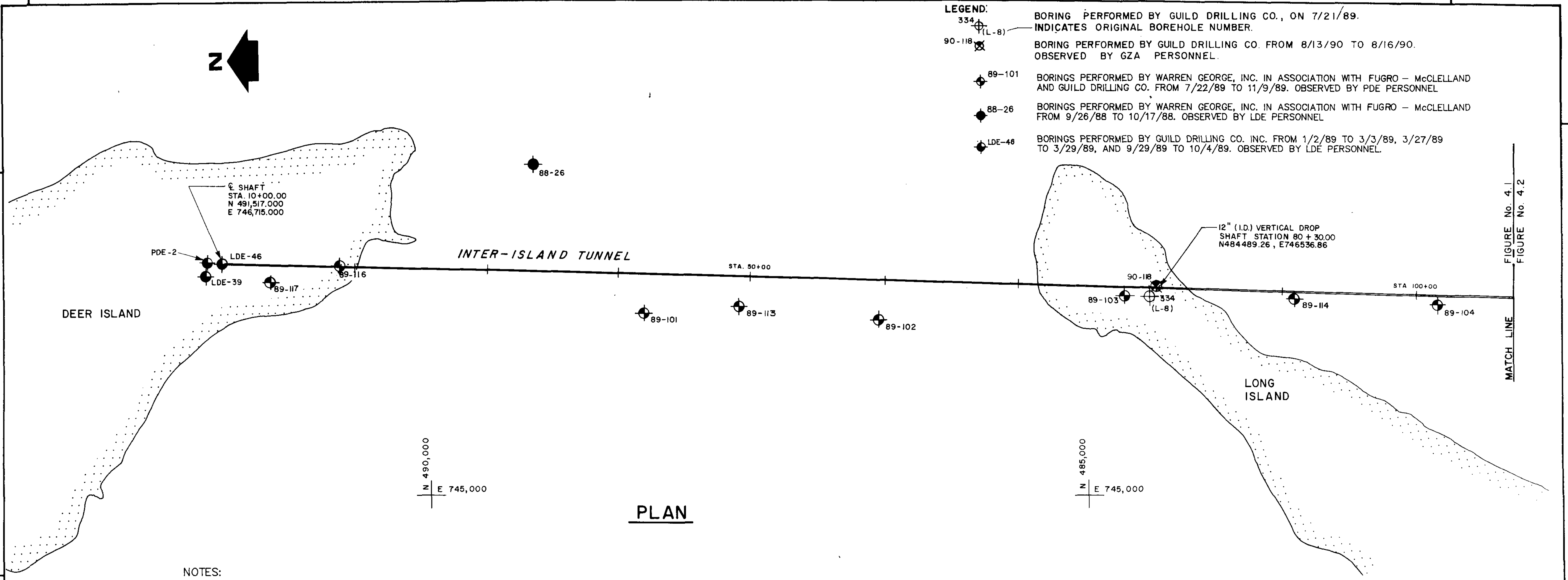
2. Ground Failure: Damage caused by ground failure may be associated with rock or soil slides, liquefaction, soil subsidence and other effects of ground motion. This mode typically affects only shallow structures.

3. Shaking: Damage due to shaking for lined tunnels may include spalling, cracking or failure of the liner. Shaking may also reduce shear strengths of the soil and rock mass above the tunnel and subsequently the tunnel support system may have to withstand additional loads. For unlined tunnels, such vibrating motion may cause block motion, spalling, rock fall, or local opening of joints.

Of these three effects, only shaking is anticipated to be a consideration for the tunnel and shafts.

4.60 GASES

Harmful or explosive gases such as methane, hydrogen sulfide, radon, and/or carbon dioxide are frequently encountered in regions of postvolcanic activities. However, the rock formations along the proposed tunnel alignment are not known as gas producers. Nevertheless, continuous ventilation at the heading should be required to insure the displacement of harmful gases by fresh air and frequent checks for the presence of gas should be made.



NOTES:

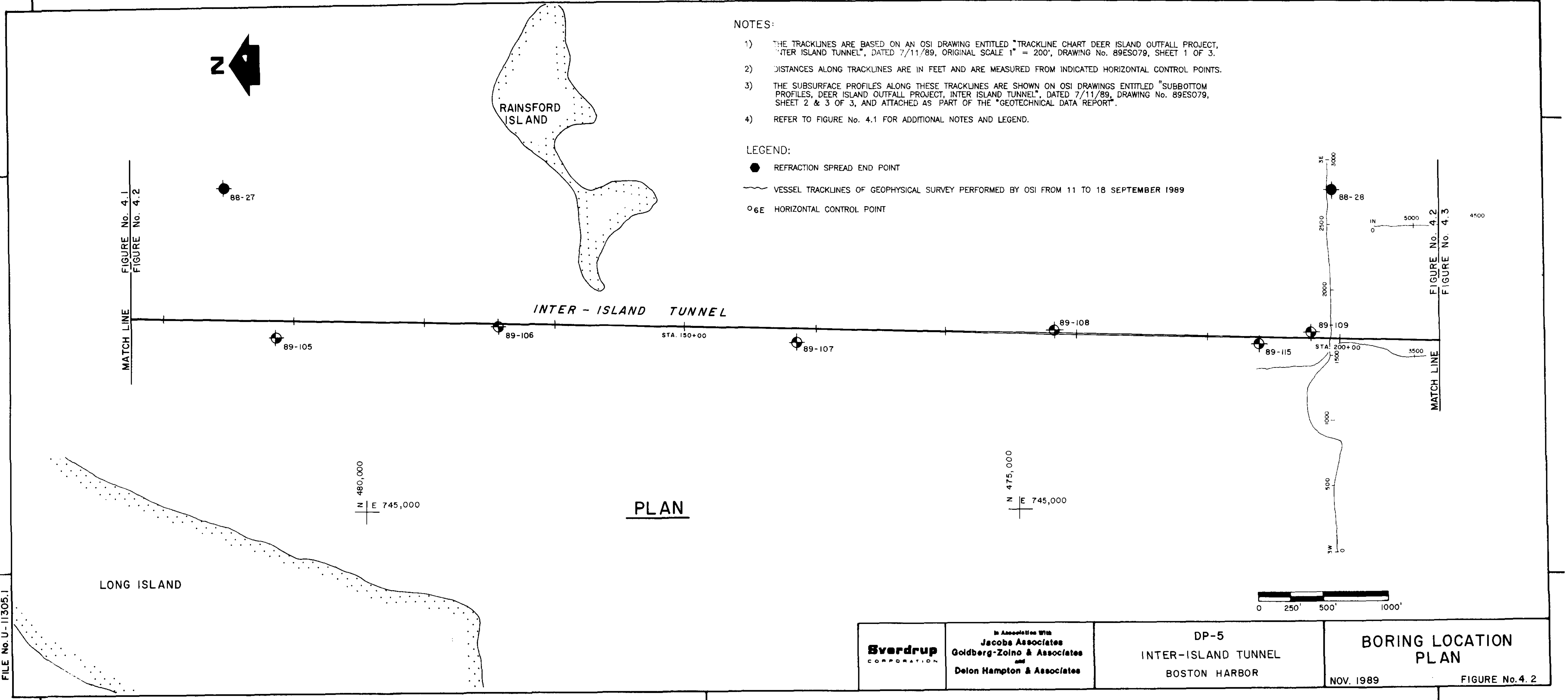
1) BASE MAP DEVELOPED FROM PLAN BY THE U.S. DEPT. OF COMMERCE, NATIONAL OCEANIC & ATMOSPHERIC ADMINISTRATION, NATIONAL OCEAN SERVICE, ENTITLED "UNITED STATES – EAST COAST, MASSACHUSETTS, BOSTON HARBOR", DATED 4/19/86, ORIGINAL SCALE 1: 25,000, MAP No. 13270.

2) BORING LOCATIONS BASED ON SURVEY DATA PROVIDED BY WARREN GEORGE, INC. / FUGRO– McCLELLAND.

Sverdrup CORPORATION	In Association With Jacobs Associates Goldberg-Zoino & Associates and Delon Hampton & Associates	DP-5 INTER-ISLAND TUNNEL BOSTON HARBOR	BORING LOCATION PLAN NOV. 1989 FIGURE No. 4.1

FILE No.U-11305.1

149119 MAKEPEACE



NOTES:

1) THE TRACKLINES ARE BASED ON AN OSI DRAWING ENTITLED "TRACKLINE CHART DEER ISLAND OUTFALL PROJECT, INTER ISLAND TUNNEL", DATED 7/11/89, ORIGINAL SCALE 1" = 200', DRAWING No. 89ES079, SHEET 1 OF 3.

2) DISTANCES ALONG TRACKLINES ARE IN FEET AND ARE MEASURED FROM INDICATED HORIZONTAL CONTROL POINTS.

3) THE SUBSURFACE PROFILES ALONG THESE TRACKLINES ARE SHOWN ON OSI DRAWINGS ENTITLED "SUBBOTTOM PROFILES, DEER ISLAND OUTFALL PROJECT, INTER ISLAND TUNNEL", DATED 7/11/89, DRAWING No. 89ES079, SHEET 2 & 3 OF 3, AND ATTACHED AS PART OF THE "GEOTECHNICAL DATA REPORT".

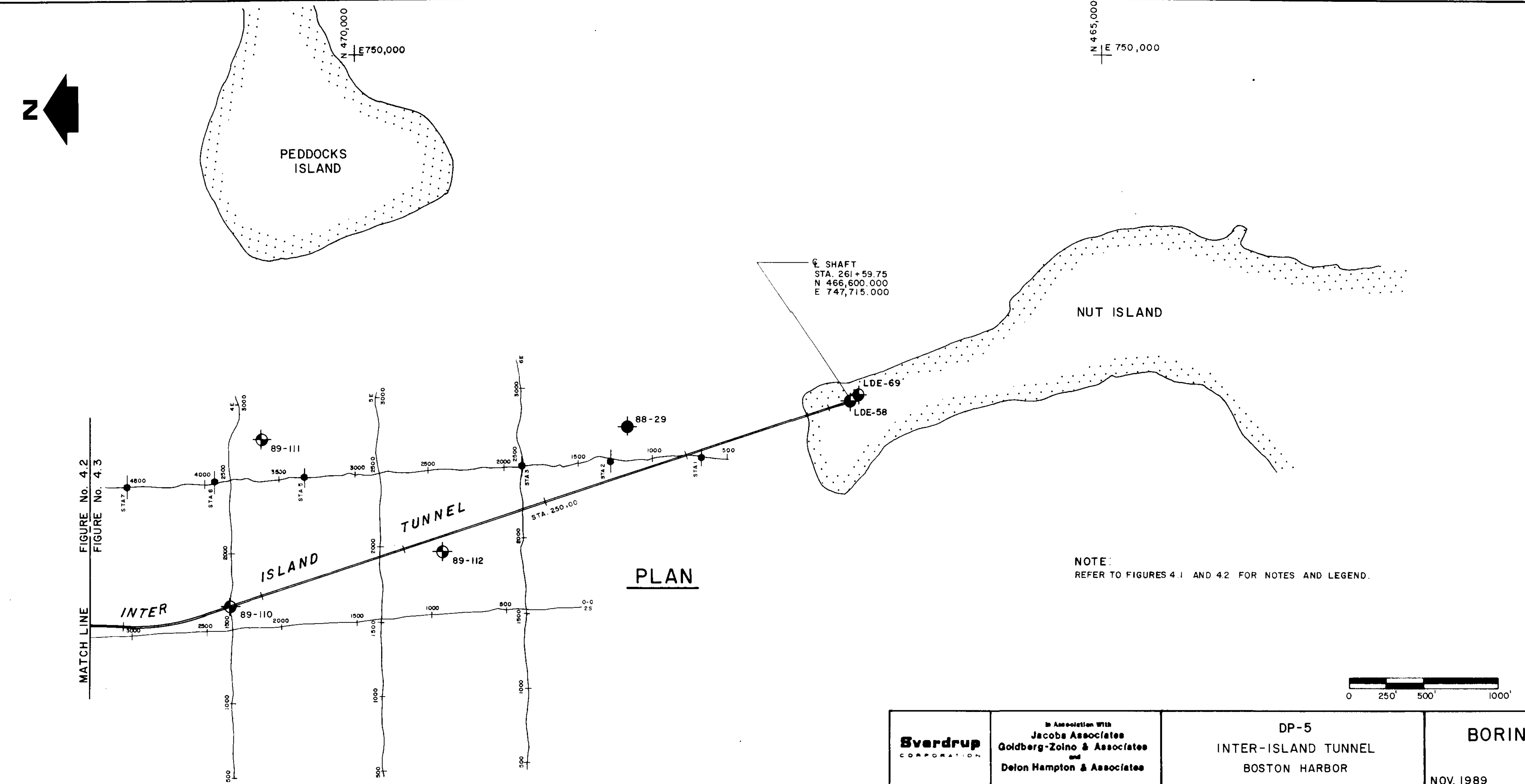
4) REFER TO FIGURE No. 4.1 FOR ADDITIONAL NOTES AND LEGEND.

LEGEND:

- REFRACTION SPREAD END POINT
- VESSEL TRACKLINES OF GEOPHYSICAL SURVEY PERFORMED BY OSI FROM 11 TO 18 SEPTEMBER 1989
- 6E HORIZONTAL CONTROL POINT

PLAN

Sverdrup CORPORATION	In Association With Jacobs Associates Goldberg-Zoino & Associates and Delon Hampton & Associates	DP-5 INTER-ISLAND TUNNEL BOSTON HARBOR	BORING LOCATION PLAN NOV. 1989 FIGURE No. 4.2



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Goldberg-Zoino & Associates
and
Delon Hampton & Associates

DP-5
INTER-ISLAND TUNNEL
BOSTON HARBOR

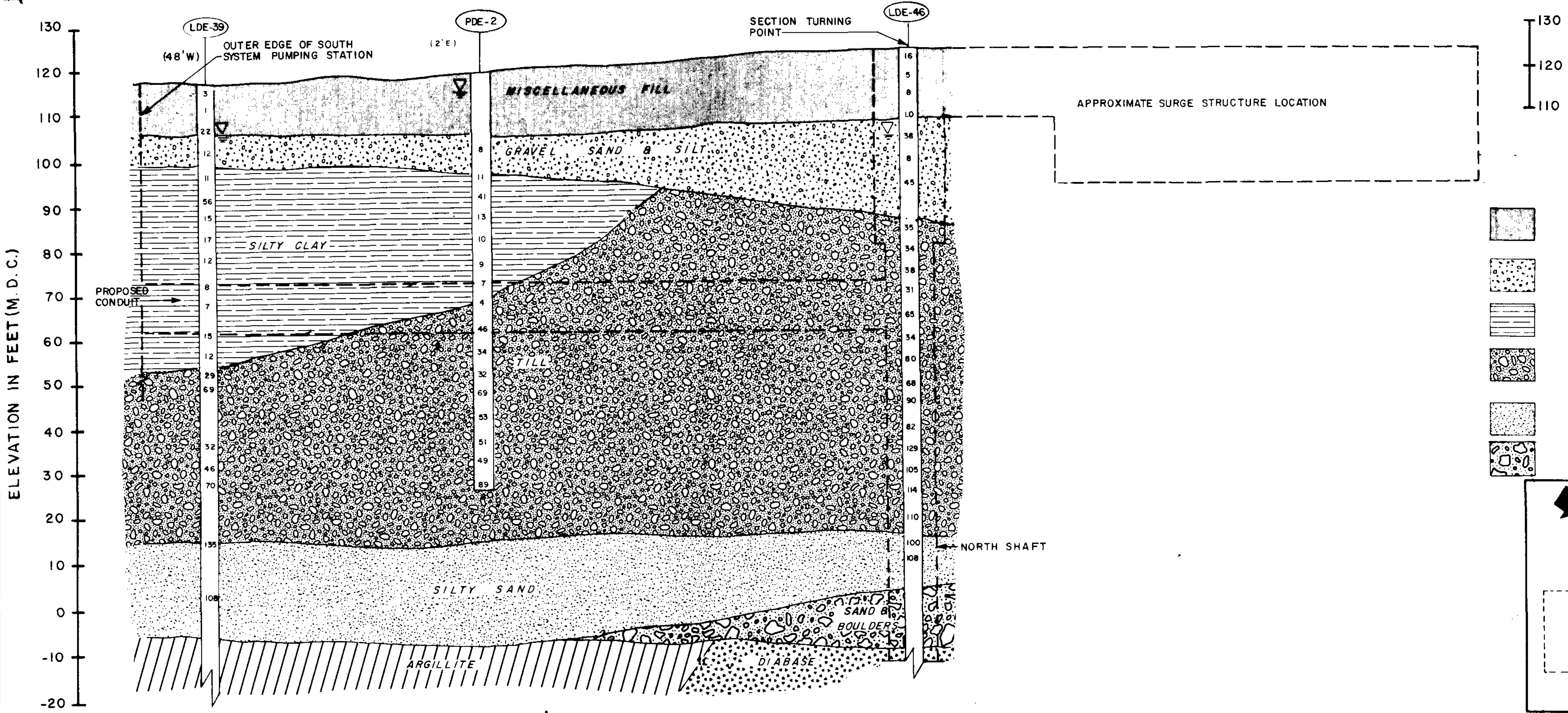
BORING LOCATION PLAN

NOV. 1989

FIGURE No. 4.3

FILE No. C-11305.1

149119 MAKEPEACE



SECTION AA'

MISCELLANEOUS FILL – VERY LOOSE TO MEDIUM DENSE, SAND, GRAVEL, CLAY, OILY MATERIALS, WIRE, DRYWALL, AND OTHER DEBRIS.

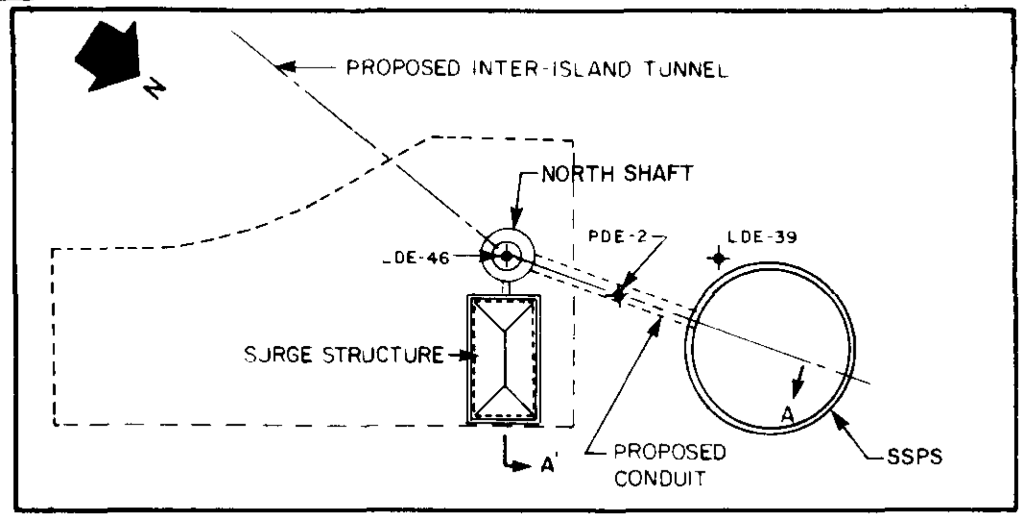
GRAVEL, SAND & SILT – LOOSE TO DENSE, BROWN-GRAY STRATUM CONSISTING OF VARYING QUANTITIES OF GRAVEL, SAND AND SILT, WITH TRACE CLAY.

SILTY CLAY – MEDIUM STIFF TO HARD, GRAY, SILTY CLAY, TRACE TO SOME GRAVEL, TRACE FINE SAND.

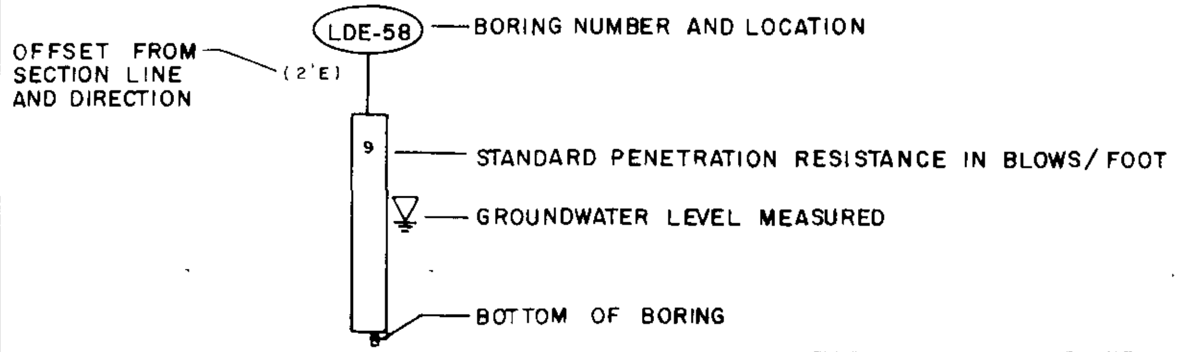
TILL – HARD, BROWNISH GRAY TO GRAY, CLAY AND SILT, LITTLE GRAVEL, LITTLE SAND, OCCASIONAL COBBLES.

SILTY SAND – VERY DENSE, BROWN, FINE TO MEDIUM SAND, SOME SILT, LITTLE GRAVEL, TRACE SHELL FRAGMENTS, OCCASIONAL COBBLES AND BOULDERS.

SAND & BOULDERS – ARGILLACEOUS BOULDERS, FRAGMENTS OF ARGILLITE, QUARTZITE AND IGNEOUS ROCK, COBBLES, SOME SAND AND GRAVEL



LEGEND:



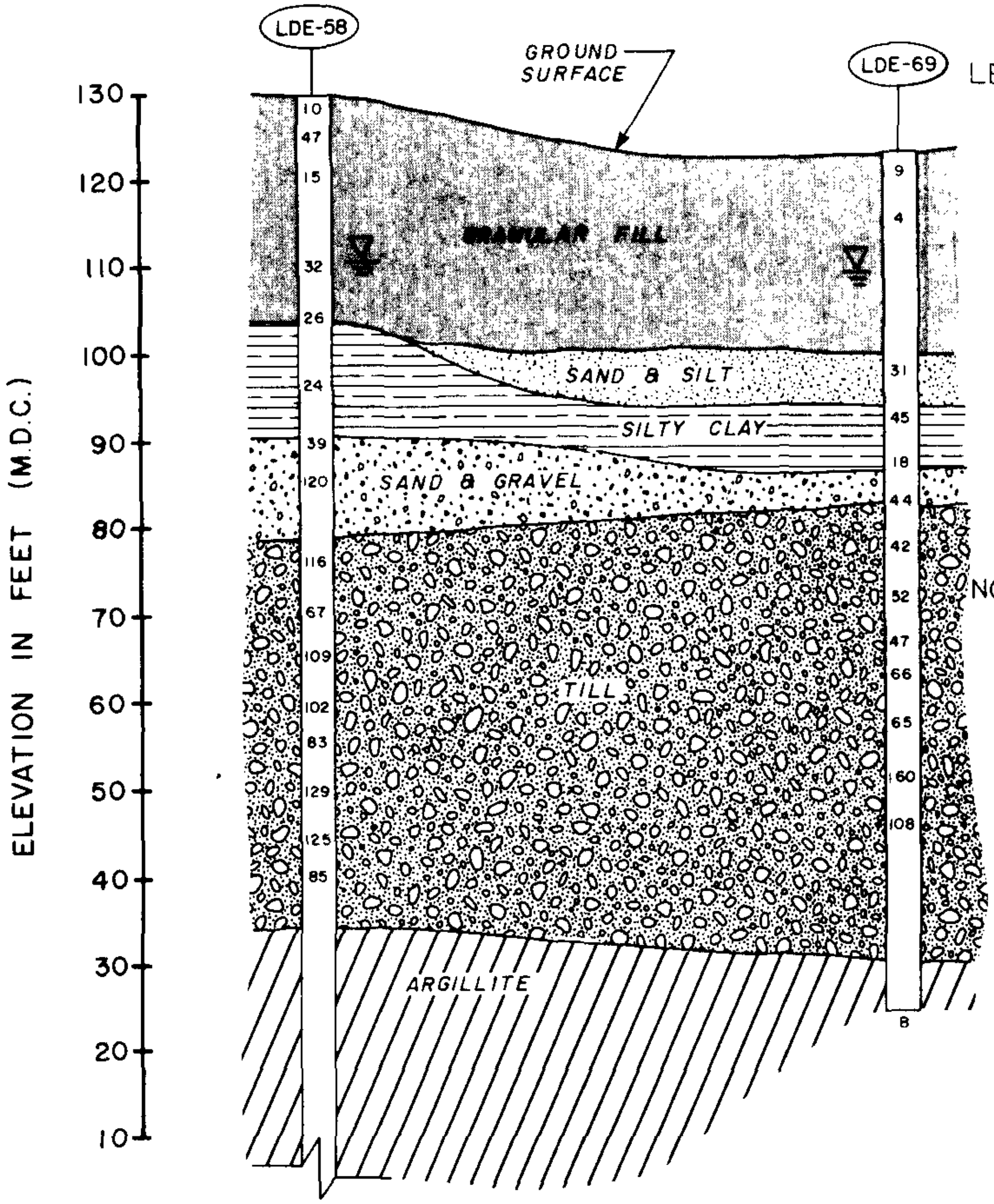
NOTES:

1. THE STRATIFICATION LINES ARE BASED UPON INTERPOLATIONS BETWEEN WIDELY SPACED EXPLORATIONS AND THUS REPRESENT THE APPROXIMATE BOUNDARIES BETWEEN SOIL TYPES. ACTUAL TRANSITIONS MAY VARY FROM THOSE SHOWN.
2. WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT THE TIMES AND UNDER CONDITIONS STATED ON THE LOGS. THESE DATA HAVE BEEN REVIEWED AND INTERPRETATIONS MADE IN THE TEXT OF THIS REPORT. HOWEVER, IT MUST BE STATED THAT FLUCTUATIONS IN THE LEVEL OF THE GROUNDWATER MAY OCCUR DUE TO VARIATIONS IN RAINFALL, TIDES, TEMPERATURE AND OTHER FACTORS SINCE THE TIME OF MEASUREMENT.

0' 10' 20' 40'

FILE No. J-11305.1

Sverdrup CORPORATION	In Association With Jacobs Associates Goldberg-Zoino & Associates and Delon Hampton & Associates	DP-5 INTER-ISLAND TUNNEL BOSTON HARBOR	SUBSURFACE SECTION AT NORTH SHAFT NOVEMBER 1989 FIGURE No.4.4



SECTION A-A'

0' 10' 20' 40'

LEGEND:

LDE-58 — BORING No. & LOCATION

4 — STANDARD PENETRATION RESISTANCE IN BLOWS/FT.

▽ — GROUNDWATER ELEVATION

B — BOTTOM OF BORING

GENERALIZED SOIL DESCRIPTIONS:

GRANULAR FILL – LOOSE TO DENSE, BROWNISH GRAY, FINE TO COARSE GRAVEL AND SAND, WITH VARYING QUANTITIES OF SILT, TRACE CLAY, TRACE ORGANICS, OCCASIONAL BOULDERS.

SAND & SILT – DENSE, GRAY, FINE SAND AND SILT, SOME CLAY, TRACE GRAVEL.

SILTY CLAY – STIFF TO HARD, YELLOW-BROWN TO GRAY, SILTY CLAY, TRACE FINE SAND.

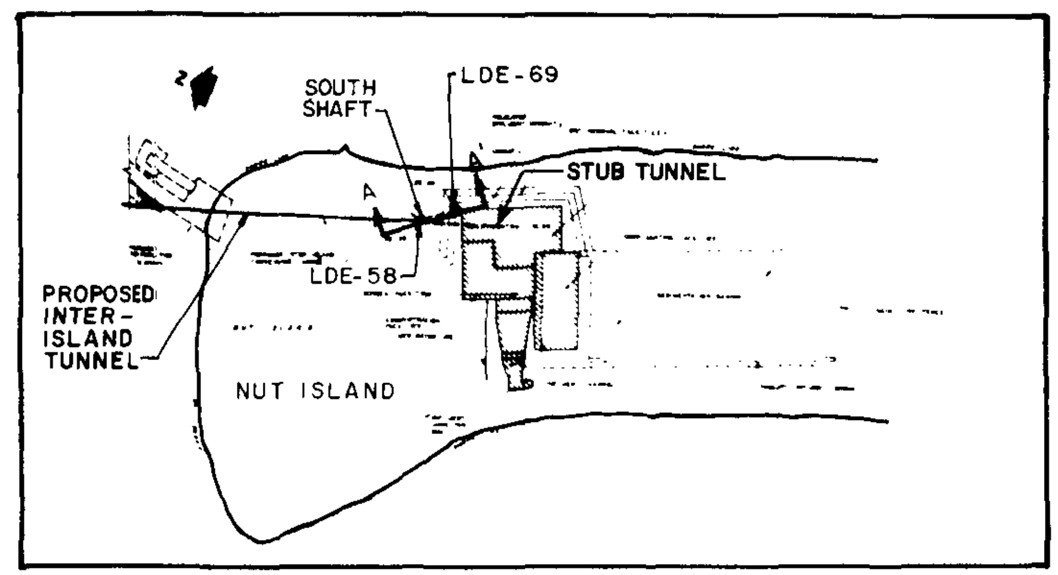
SAND & GRAVEL – DENSE TO VERY DENSE, BROWN, FINE TO COARSE GRAVEL, SOME FINE TO COARSE SAND, WITH TRACE TO SOME SILTY CLAY.

TILL – HARD, GRAY CLAYEY SILT, WITH VARYING QUANTITIES OF GRAVEL, TRACE SAND, OCCASIONAL BOULDERS.

NOTES:

1. THE STRATIFICATION LINES ARE BASED UPON INTERPOLATIONS BETWEEN WIDELY SPACED EXPLORATIONS AND THUS REPRESENT THE APPROXIMATE BOUNDARIES BETWEEN SOIL TYPES. ACTUAL TRANSITIONS MAY VARY FROM THOSE SHOWN.

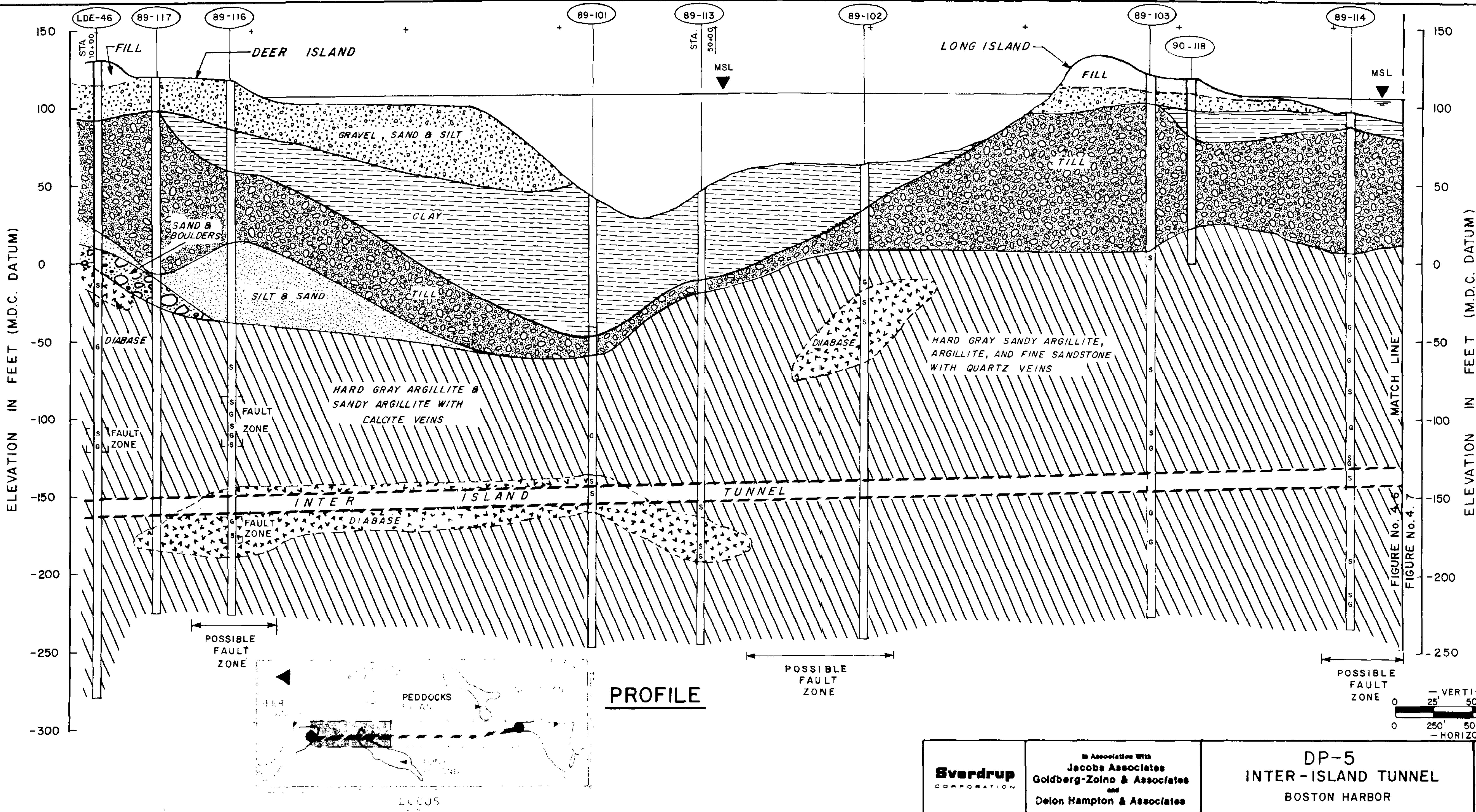
2. WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT THE TIMES AND UNDER CONDITIONS STATED ON THE LOGS. THESE DATA HAVE BEEN REVIEWED AND INTERPRETATIONS MADE IN THE TEXT OF THIS REPORT. HOWEVER, IT MUST BE STATED THAT FLUCTUATIONS IN THE LEVEL OF THE GROUNDWATER MAY OCCUR DUE TO VARIATIONS IN RAINFALL, TIDES, TEMPERATURE AND OTHER FACTORS SINCE THE TIME OF MEASUREMENT.



Sverdrup CORPORATION	In Association With Jacobs Associates Goldberg-Zoino & Associates and Delon Hampton & Associates	DP-5 INTER-ISLAND TUNNEL BOSTON HARBOR	SUBSURFACE SECTION AT SOUTH SHAFT NOV. 1989 FIGURE No. 4.5

149119 FILE No. U-11305.I

MAKEPEACE



NOTE:
REFER TO FIGURE No. 4.6A FOR NOTES AND LEGEND.

FILE No. U-11305.1

Sverdrup CORPORATION	In Association With Jacobs Associates Goldberg-Zoino & Associates and Delon Hampton & Associates	DP-5 INTER-ISLAND TUNNEL BOSTON HARBOR	SUBSURFACE PROFILE ALONG TUNNEL NOV. 1989 FIGURE No. 4.6

149119 MAKEPEACE

FILE No. U-11305.1

GENERALIZED SOIL DESCRIPTION

FILL – LOOSE TO MEDIUM DENSE, MISCELLANEOUS FILL CONSISTING OF SANDY CLAY, PIECES OF DRY WALL, WIRE, AND OTHER CONSTRUCTION DEBRIS; OR MEDIUM DENSE TO DENSE, GRANULAR FILL CONSISTING OF GRAY, FINE TO COARSE SAND AND GRAVEL, TRACE CLAY, TRACE ORGANICS.

GRAVEL, SAND & SILT-DENSE TO VERY DENSE, BROWN-GRAY STRATUM CONSISTING OF VARYING QUANTITIES OF GRAVEL, SAND AND SILT, WITH TRACE CLAY.

CLAY – SOFT TO VERY STIFF, GRAY TO YELLOWISH-BROWN, SILTY CLAY, TRACE FINE SAND.

TILL – DENSE TO VERY DENSE, GRAY SAND AND GRAVEL WITH VARYING QUANTITIES OF COBBLES, SILT AND CLAY; OR HARD, GRAY, CLAYEY SILT, WITH VARYING QUANTITIES OF COBBLES, GRAVEL AND SAND.

SILT & SAND – VERY DENSE, BROWN, FINE TO COARSE SAND AND SILT, TRACE SHELL FRAGMENTS.

SAND & BOULDERS – ARGILLICEOUS BOULDERS, FRAGMENTS OF ARGILLITE, QUARTZITE AND IGNEOUS ROCK, COBBLES, SOME FINE TO COARSE SAND AND GRAVEL.

ARGILLITE

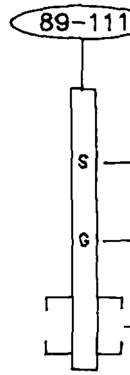
DIABASE

FELSITE

ASH

FOR DESCRIPTION OF THESE ROCKS, REFER TO PROFILE

LEGEND



89-111 — TEST BORING NUMBER AND LOCATION

LOCATION OF SLICKENSIDED DISCONTINUITIES

LOCATION OF GOUGE-FILLED DISCONTINUITIES

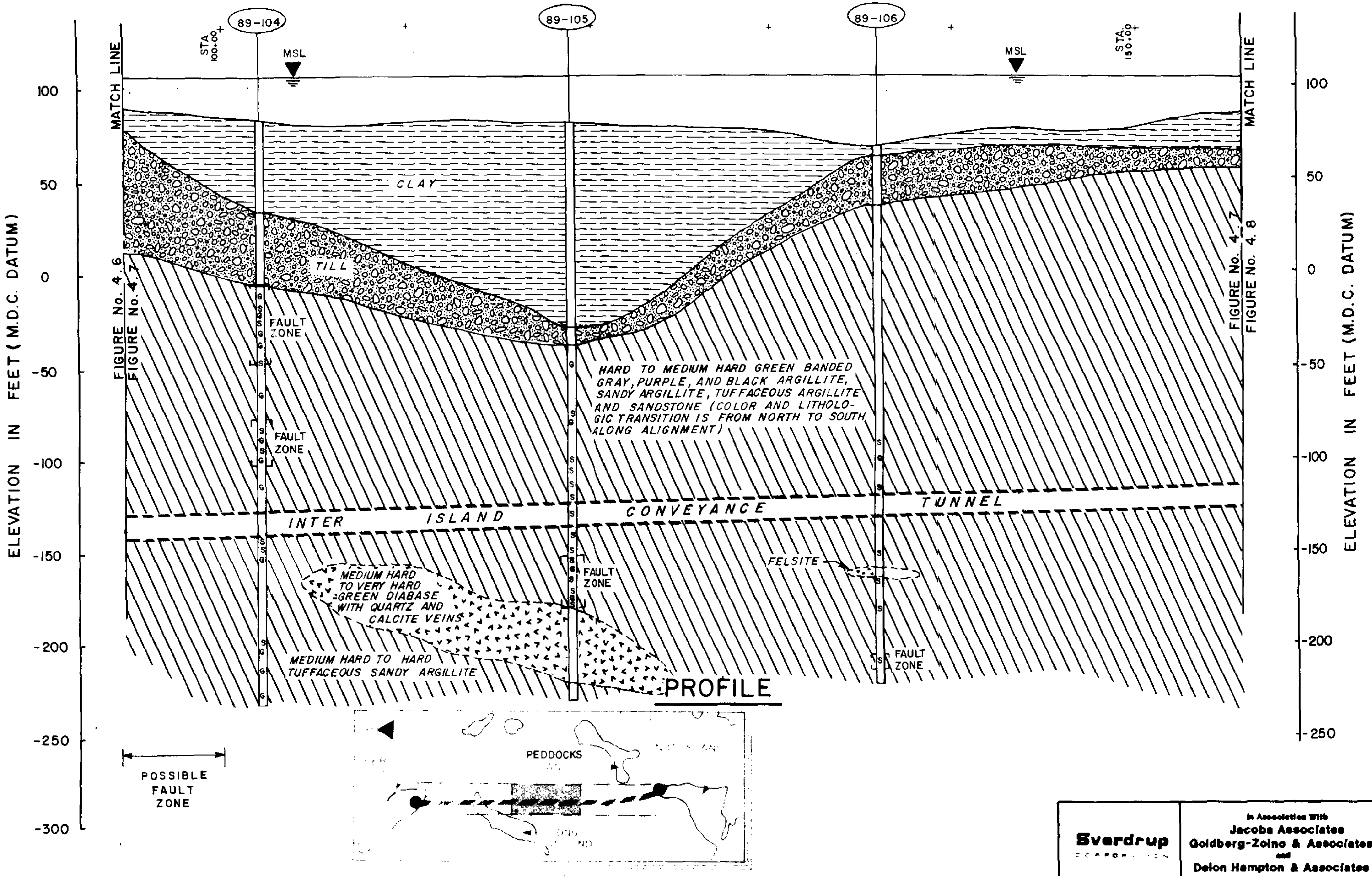
PROBABLE FAULT ZONE

NOTES:

1. THE STRATIFICATION LINES ARE BASED UPON INTERPOLATIONS BETWEEN WIDELY SPACED EXPLORATIONS AND THUS REPRESENT THE APPROXIMATE BOUNDARIES BETWEEN SOIL TYPES. ACTUAL TRANSITIONS MAY VARY FROM THOSE SHOWN.

2. HORIZONTAL TO VERTICAL SCALE DISTORTION FOR PURPOSES OF PRESENTATION CAUSES TRENDS IN STRATA TO APPEAR MORE PRONOUNCED THAN THOSE, WHICH ACTUALLY EXIST.

Sverdrup CORPORATION	In Association With Jacobs Associates Goldberg-Zoino & Associates and Delon Hampton & Associates	DP-5 INTER-ISLAND TUNNEL BOSTON HARBOR	NOTES AND LEGEND FOR FIGURES 4.6, 4.7 & 4.8 NOV. 1989 FIGURE No 4.6A



NOTE:

REFER TO FIGURE No. 46A FOR NOTES AND LEGEND.

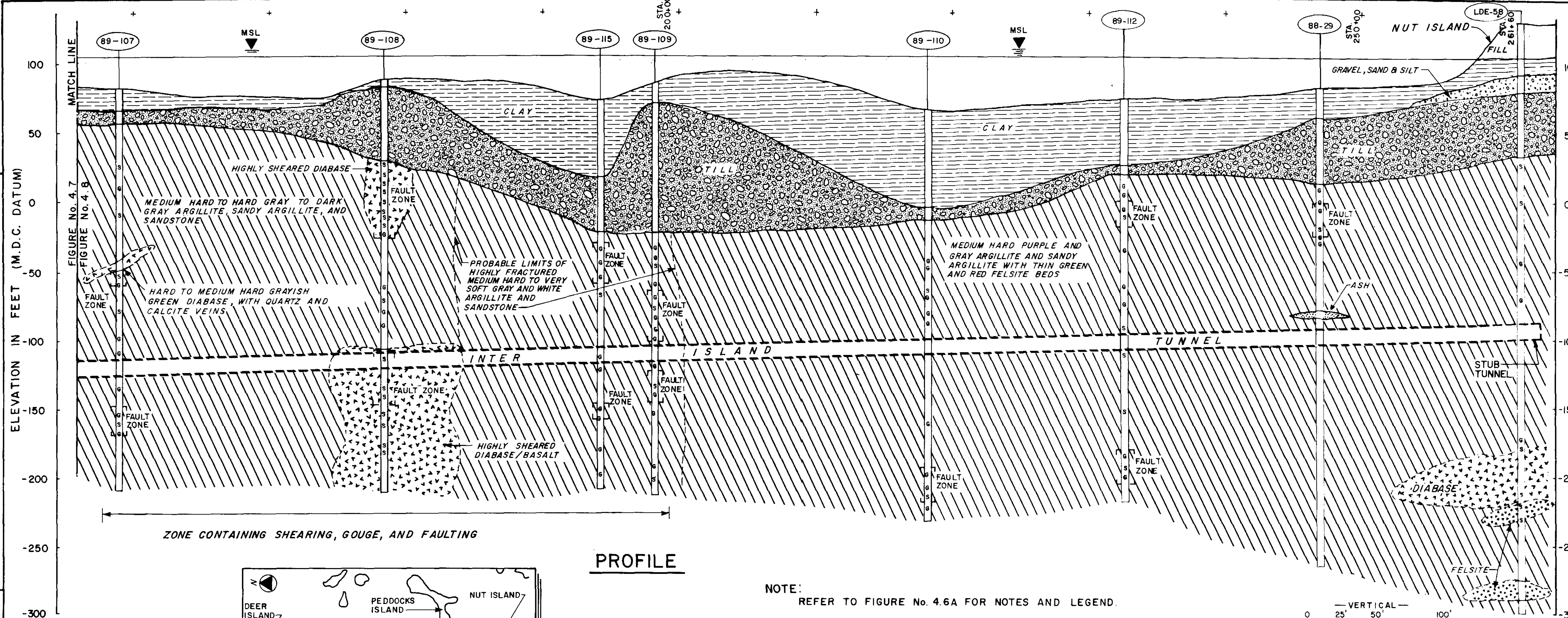
— VERTICAL — 0 25' 50' 100'

0 250' 500' 1000' — HORIZONTAL —

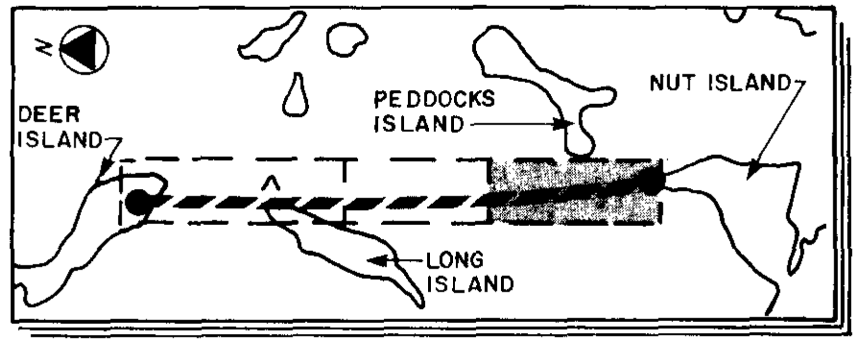
Sverdrup CORPORATION	In Association With Jacobs Associates Goldberg-Zoino & Associates and Deleon Hampton & Associates	DP- 5 INTER - ISLAND TUNNEL BOSTON HARBOR	SUBSURFACE PROFILE ALONG TUNNEL
			NOV. 1989 FIGURE No. 4.7

FILE No. U-11305.1

149119 MAKEPEACE



PROFILE



— LOCUS —
N.T.S.

NOTE:
REFER TO FIGURE No. 4.6A FOR NOTES AND LEGEND.

Sverdrup CORPORATION	In Association With Jacobs Associates Goldberg-Zoino & Associates and Delon Hampton & Associates	DP - 5 INTER - ISLAND TUNNEL BOSTON HARBOR	SUBSURFACE PROFILE ALONG TUNNEL

NOV. 1989 FIGURE No. 4.8

FILE No. D-11305.1

MAKEPEACE

POLE PLOT OF ROCK DISCONTINUITIES FOR SHAFT BORING LDE-46 AT DEER ISLAND

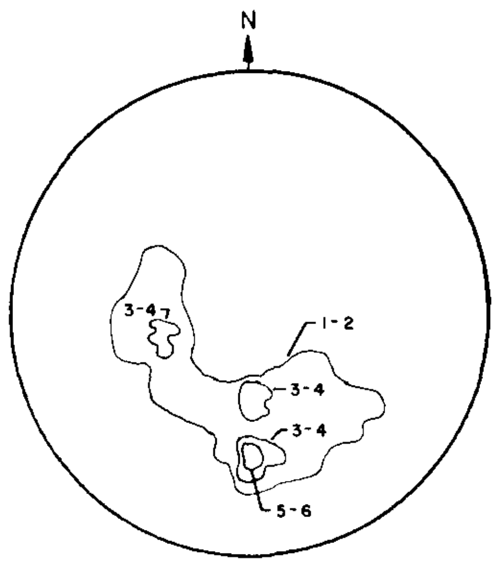
BEDDING PLANE DISCONTINUITIES

NOTES:

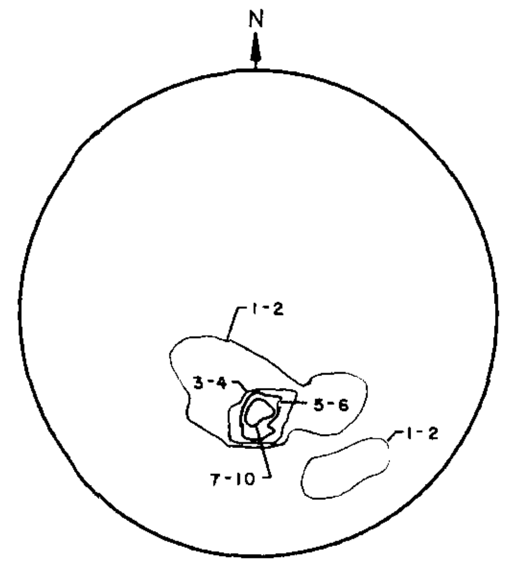
1) ELEVATION MDC DATUM.
2) ALL DIAGRAMS ARE PLOTTED ON EQUAL AREA NETS AND REPRESENT A DENSITY PLOT BY PERCENTAGE OF TOTAL DISCONTINUITIES THAT FELL WITHIN THE COUNTING AREA
3) DATA PLOTTED USING LOWER HEMISPHERE
4) PLOTS BASED ON SUBSURFACE DATA PROVIDED BY LDE.

LEGEND

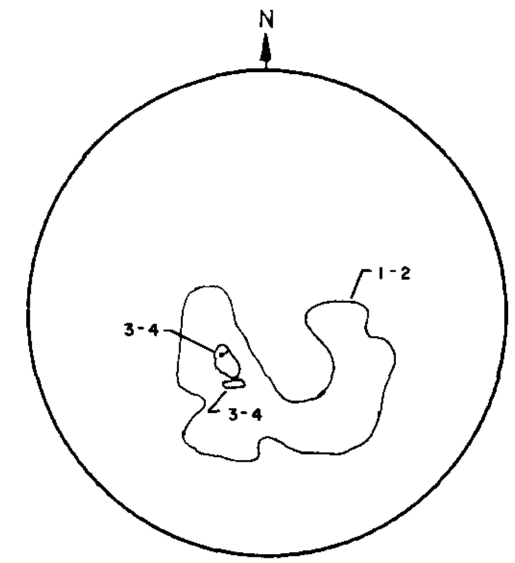
INDICATES CONTOUR INTERVAL BY PERCENTAGE OF TOTAL DISCONTINUITIES THAT FELL WITHIN THE COUNTING AREA.



ELEVATION (ft.) −42.2 TO −92.7
PRIMARY DIP DIRECTION AND DIP
000° 48°
SECONDARY DIP DIRECTION AND DIP
358° 30°

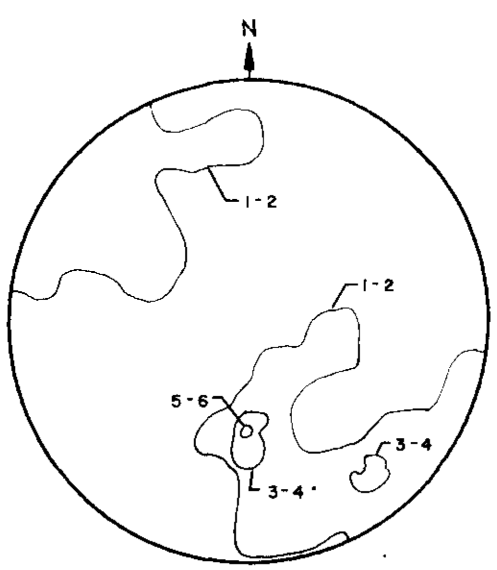


ELEVATION (ft.) −94.7 TO −132.6
PRIMARY DIP DIRECTION AND DIP
359° 33°
SECONDARY DIP DIRECTION AND DIP
331° 64°

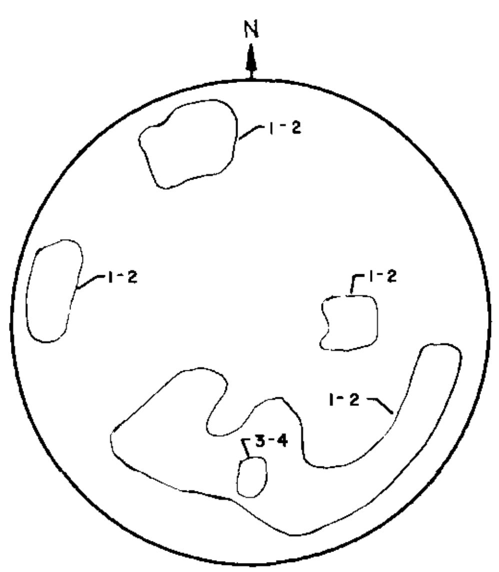


ELEVATION (ft.) −134.4 TO −164.7
PRIMARY DIP DIRECTION AND DIP
033° 22°
SECONDARY DIP DIRECTION AND DIP
315° 39°

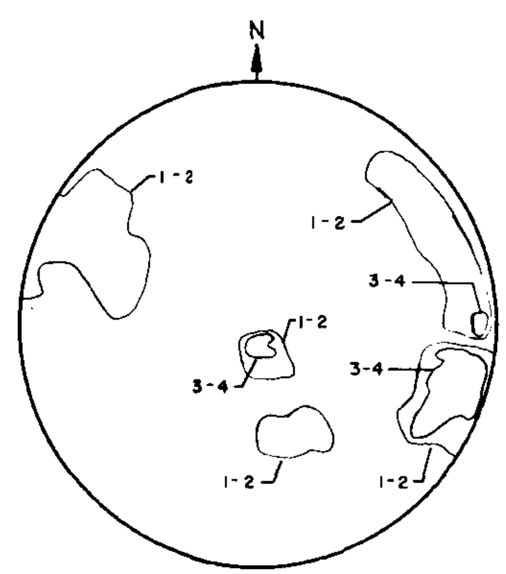
JOINT AND VEIN DISCONTINUITIES



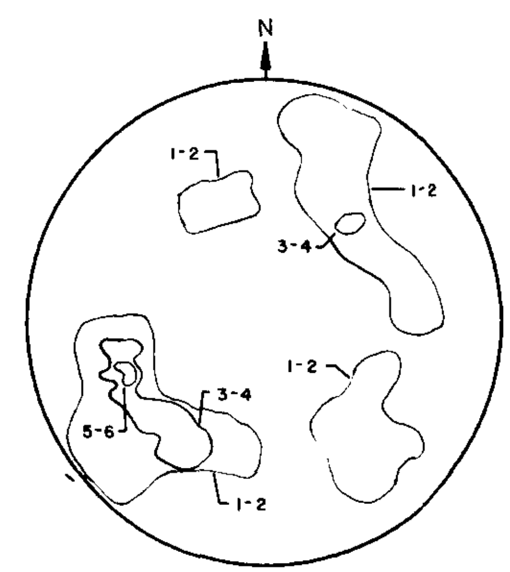
ELEVATION (ft.) −40.9 TO −53.4
PRIMARY DIP DIRECTION AND DIP
001° 37°
SECONDARY DIP DIRECTION AND DIP
322° 70°



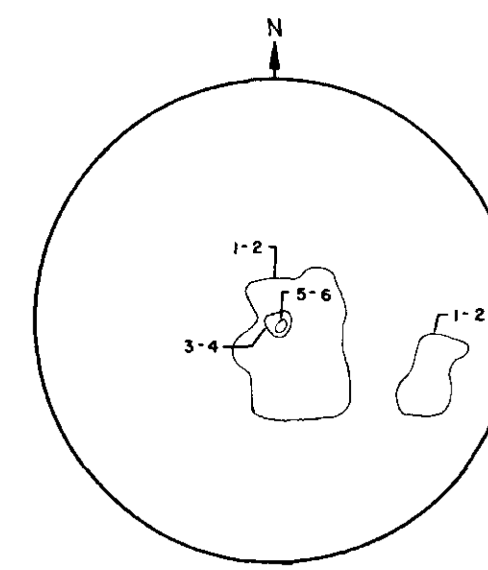
ELEVATION (ft.) −75.5 TO −80.2
PRIMARY DIP DIRECTION AND DIP
000° 52°
SECONDARY DIP DIRECTION AND DIP
308° 68°



ELEVATION (ft.) −91.6 TO −108.5
PRIMARY DIP DIRECTION AND DIP
289° 77°
SECONDARY DIP DIRECTION AND DIP
358° 07°



ELEVATION (ft.) −122.2 TO −138.0
PRIMARY DIP DIRECTION AND DIP
066° 52°
SECONDARY DIP DIRECTION AND DIP
222° 46°



ELEVATION (ft.) −159.3 TO −166.5
PRIMARY DIP DIRECTION AND DIP
304° 07°
SECONDARY DIP DIRECTION AND DIP
288° 59°

Sverdrup CORPORATION	In Association With Jacobs Associates Goldberg-Zoino & Associates and Delon Hampton & Associates	DP-5 INTER-ISLAND TUNNEL BOSTON, HARBOR	ROCK DISCONTINUITIES OF SHAFT BORING LDE-46 NOV. 1989 FIGURE No. 4.9

FILE No. 11305.1

POLE PLOT OF ROCK DISCONTINUITIES FOR SHAFT BORING LDE-58 AT NUT ISLAND

NOTES:

1) ELEVATION MDC DATUM.

2) ALL DIAGRAMS ARE PLOTTED ON EQUAL AREA NETS AND REPRESENT A DENSITY PLOT BY PERCENTAGE OF TOTAL DISCONTINUITIES THAT FELL WITHIN THE COUNTING AREA.

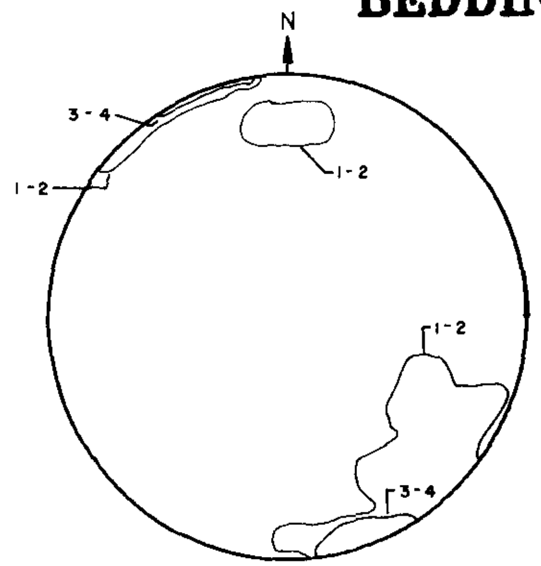
3) DATA PLOTTED USING LOWER HEMISPHERE

4) PLOTS BASED ON SUBSURFACE DATA PROVIDED BY LDE.

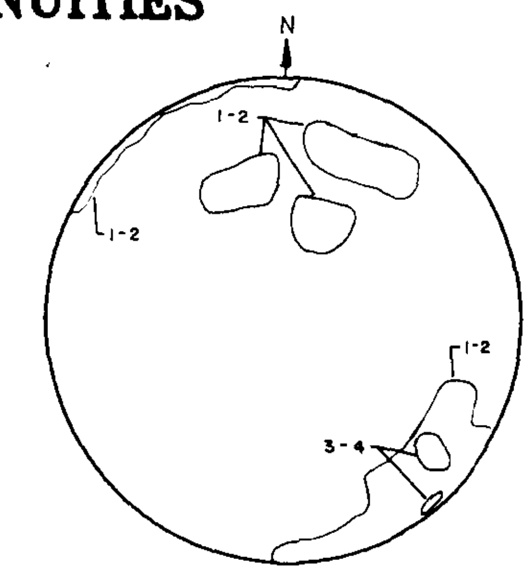
LEGEND:

3-4 INDICATES CONTOUR INTERVAL BY PERCENTAGE OF TOTAL DISCONTINUITIES THAT FELL WITHIN THE COUNTING AREA

BEDDING PLANE DISCONTINUITIES

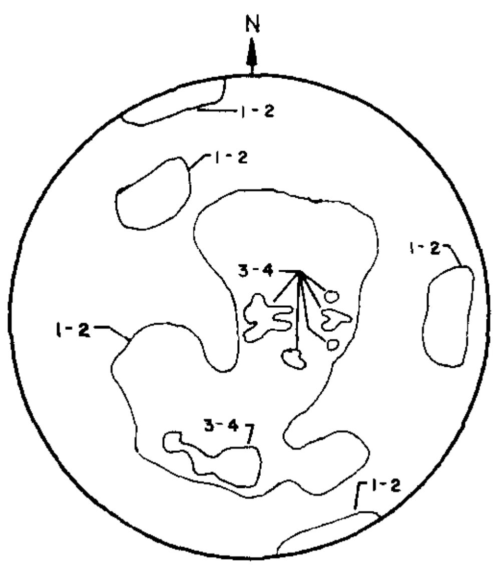


ELEVATION (ft.) −2.5 TO −62.1
PRIMARY DIP DIRECTION AND DIP
330° 84°
SECONDARY DIP DIRECTION AND DIP
180° 70°

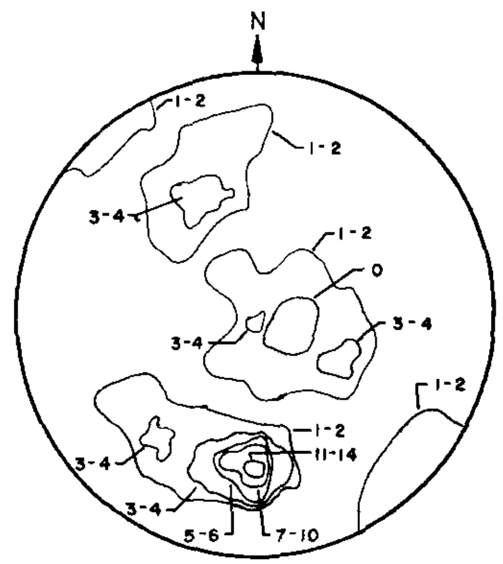


ELEVATION (ft.) −64.5 TO −101.7
PRIMARY DIP DIRECTION AND DIP
317° 80°
SECONDARY DIP DIRECTION AND DIP
195° 50°

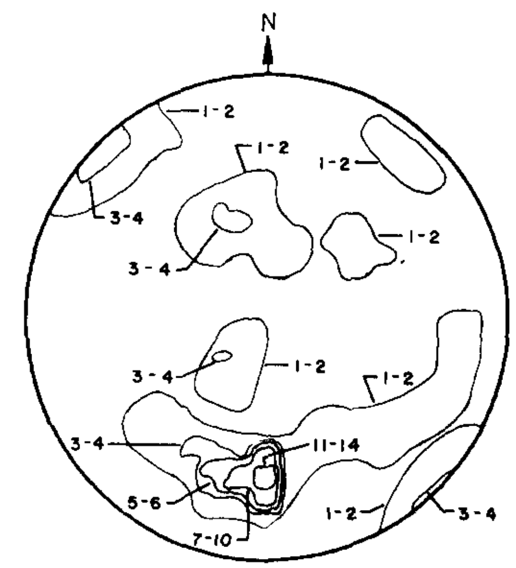
JOINT AND VEIN DISCONTINUITIES



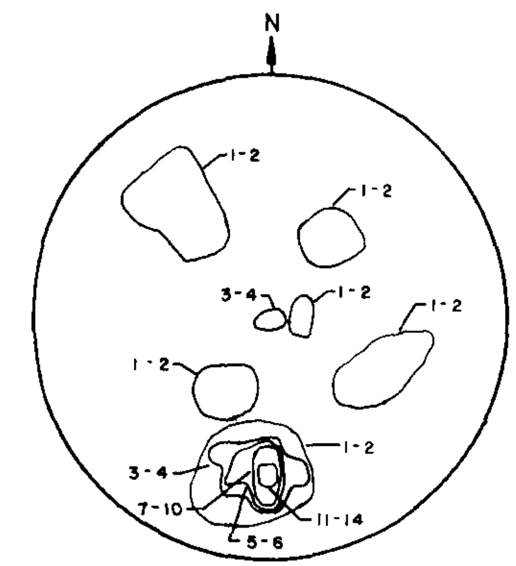
ELEVATION (ft.) −0.6 TO −19.4
PRIMARY DIP DIRECTION AND DIP
007° 52°
SECONDARY DIP DIRECTION AND DIP
263° 04°



ELEVATION (ft.) −30.9 TO −48.1
PRIMARY DIP DIRECTION AND DIP
000° 53°
SECONDARY DIP DIRECTION AND DIP
155° 46°



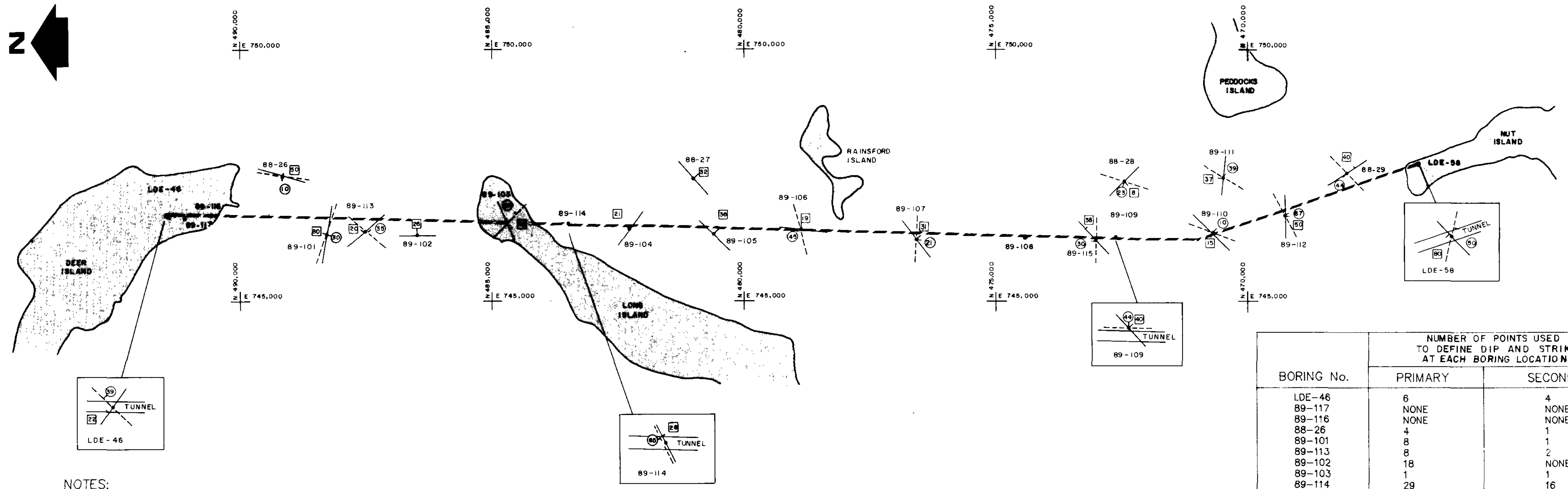
ELEVATION (ft.) −59.5 TO −78.5
PRIMARY DIP DIRECTION AND DIP
002° 55°
SECONDARY DIP DIRECTION AND DIP
161° 38°



ELEVATION (ft.) −92.7 TO −101.0
PRIMARY DIP DIRECTION AND DIP
001° 55°
SECONDARY DIP DIRECTION AND DIP
288° 02°

FILE No. 11305 1

Sverdrup CORPORATION	In Association With Jacobs Associates Goldberg-Zoino & Associates and Delon Hampton & Associates	DP-5 INTER-ISLAND TUNNEL BOSTON HARBOR	ROCK DISCONTINUITIES OF SHAFT BORING LDE-58 NOV. 1989 FIGURE No.4.10



NOTES:

1) ISOLATED BOXES SHOWN FOR CLARITY ONLY

2) DIP AND STRIKE DATA BASED ON ORIENTED CORE OBTAINED WITHIN 30 FEET OF TUNNEL INVERT.

3) BORINGS LDE-39, LDE-69, PDE-2, 329 AND 334 NOT SHOWN.

LEGEND:

70 — DEGREE OF DIP
PRIMARY STRIKE DIRECTION

70 — DEGREE OF DIP
SECONDARY STRIKE DIRECTION

• BORING LOCATION

BORING No.	NUMBER OF POINTS USED TO DEFINE DIP AND STRIKE AT EACH BORING LOCATION	
	PRIMARY	SECONDARY
LDE-46	6	4
89-117	NONE	NONE
89-116	NONE	NONE
88-26	4	1
89-101	8	1
89-113	8	2
89-102	18	NONE
89-103	1	1
89-114	29	16
89-104	8	NONE
88-27	2	NONE
89-105	17	NONE
89-106	15	1
89-107	4	3
89-108	NONE	NONE
89-115	1	1
89-109	2	1
88-28	4	3
89-110	10	NONE
89-111	2	2
89-112	8	5
88-29	1	1
LDE-58	7	4

APPROXIMATE SCALE

0' 1000' 2000' 3000' 4000' 5000'

Sverdrup CORPORATION

In Association With
Jacobs Associates
Goldberg-Zoino & Associates
and
Delon Hampton & Associates

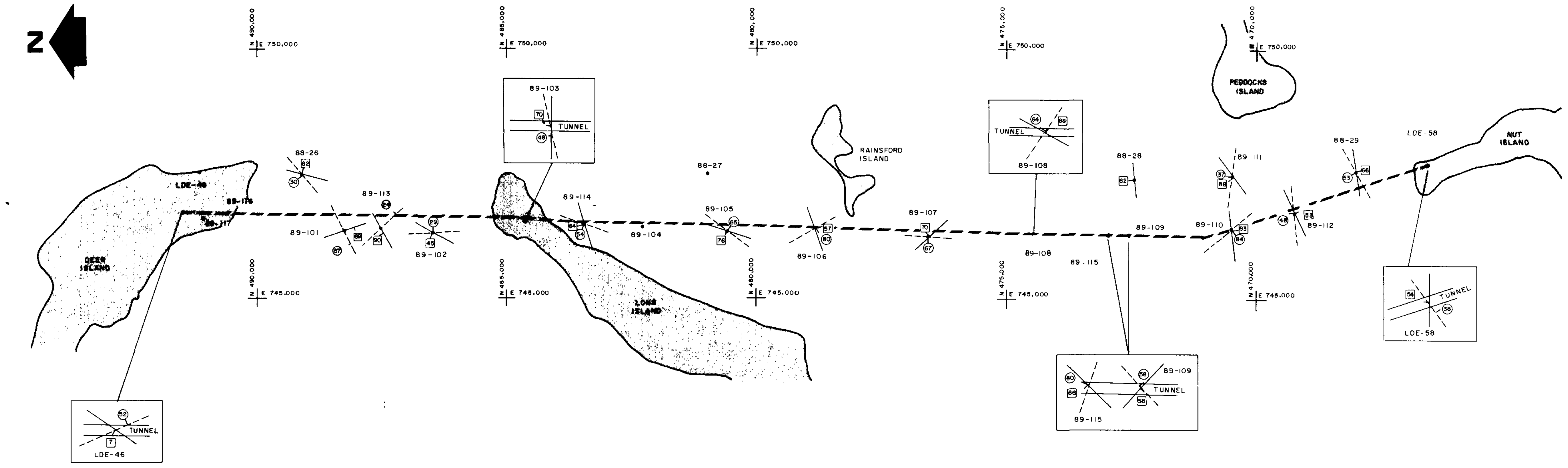
DP-5
INTER-ISLAND TUNNEL
BOSTON HARBOR

PRIMARY & SECONDARY BEDDING PLANES

NOV. 1989 FIGURE No. 4.11

FILE No. U-11305.1

149119 MAKEPEACE



NOTES:

1) ISOLATED BOXES SHOWN FOR CLARITY ONLY

2) DIP AND STRIKE DATA BASED ON ORIENTED CORE OBTAINED WITHIN 30 FEET OF TUNNEL INVERT.

3) BORINGS LDE-39, LDE-69, PDE-2, 329 AND 334 NOT SHOWN.

LEGEND:

70 — DEGREE OF DIP

PRIMARY STRIKE DIRECTION

70 — DEGREE OF DIP

SECONDARY STRIKE DIRECTION

• BORING LOCATION

BORING No.	NUMBER OF POINTS USED TO DEFINE DIP AND STRIKE AT EACH BORING LOCATION	
	PRIMARY	SECONDARY
LDE-46	9	5
89-117	NONE	NONE
89-116	NONE	NONE
88-26	1	1
89-101	6	5
89-113	11	3
89-102	5	2
89-103	10	4
89-114	56	4
89-104	NONE	NONE
88-27	NONE	NONE
89-105	6	3
89-106	3	2
89-107	8	4
89-108	3	3
89-115	5	1
89-109	4	3
88-28	1	NONE
89-110	4	3
89-111	3	2
89-112	13	5
88-29	1	1
LDE-58	13	4

APPROXIMATE SCALE

0' 1000' 2000' 3000' 4000' 5000'

Sverdrup CORPORATION	In Association With Jacobs Associates Goldberg-Zoino & Associates and Delon Hampton & Associates	DP-5 INTER-ISLAND TUNNEL BOSTON HARBOR	PRIMARY & SECONDARY DISCONTINUITY ORIENTATIONS
			NOV. 1989 FIGURE No. 4.12

FILE No. U-11305.1

149119 MAKEPEACE

5.00 GEOTECHNICAL ENGINEERING CONSIDERATIONS

5.10 OVERVIEW

This section presents discussions of geotechnical engineering issues pertaining to design and construction of the tunnel and associated shafts, conduits and surge tank.

The tunnel, with two 14-inch-diameter sludge pipes, will be constructed primarily in Cambridge Argillite. Although the Argillite is expected to be competent (moderately blocky, with widely spaced joints, to blocky and seamy) in most locations, the tunnel will probably also pass through diabase intrusions, fault zones and zones of altered Argillite. Temporary rock support will consist primarily of rock bolts, although more extensive support will also be necessary in some areas. The final lining will primarily be cast-in-place, unreinforced concrete, however, local sections may require reinforcement.

Selection of the method of tunnel excavation will be up to the Contractor. However, due to requirements and anticipated superior advance rate, it is expected that a boring machine (TBM) will be used, rather than drill and blast methods, for most of the tunnel.

The shafts at Deer Island and Nut Island will be excavated through approximately 131 and 95 feet, respectively, of surficial deposits. Hence, carefully designed lateral support systems will be required for retention of the soil during excavation. Possible schemes include: a concrete diaphragm wall, ground freezing, and liner plate or precast concrete segment, with ring beams and grouting, for the North Shaft. Conditions appear to favor a soldier pile and lagging system for the South Shaft, with dewatering or a sheetpile cut-off for the pervious upper zone and grouting for the anticipated fractured top of rock.

If the soil/rock interface is pervious (whether due to a granular stratum or fractured top of rock) and hydraulically connected to the sea, there is the potential for the excavation bottom becoming quick, i.e. upward seepage pressures reducing the vertical effective stress in the soil to zero. It may therefore be prudent to install groundwater pressure relief wells along the outside perimeter of the proposed shaft areas prior to excavation. This would reduce the chances of the excavation bottom becoming unstable.

Shaft excavation will most probably be by clam-shell, or equivalent, in the soil; and by drill and blast techniques in the rock. Rock support measures for shaft walls will consist of rock bolts and welded-wire fabric (WWF) reinforced shotcrete installed primarily to prevent minor rock fragment fallout that might endanger personnel in the shaft. On completion of tunnel excavation, both shafts will be converted into permanent hydraulic structures with concrete lining. At Deer Island, the concrete lining for the shaft will encapsulate the two 14-inch-diameter sludge pipes at an azimuth of 120 degrees.

Tunnel

1. Rock Variability: The Cambridge formation can vary greatly over short distances from a "soil-like" kaolinized Argillite to competent Argillite to hard igneous intrusions. Kaolinized zones, if extensive, could seriously impede the progress of a hard rock TBM by clogging cutters and the muck handling system and failing to provide sufficient bearing capacity for support and advancement. Kaolinized rock was not encountered during subsurface explorations. Hard igneous intrusions may slow TBM progress, but are not expected to halt it.

2. Rock Support: Rock support systems will vary from none to pattern rock bolting to ring beams with steel mat lagging and shotcrete depending on conditions encountered. Pattern bolting is expected to suffice for most of the tunnel.

3. Groundwater Inflow: Estimates of groundwater inflow during excavation have been performed based on borehole packer tests and data from previously excavated tunnels in similar rock formations. The permeability of the rock mass at tunnel depth has been estimated to vary from less than 10^{-6} to 50×10^{-5} cm/sec. Typical groundwater inflows are expected to vary from less than 25 gpm/1,000 feet to 300 gpm/1,000 feet. Locally heavy inflows greater than 300 gpm/1,000 feet are considered to be possible from heavily fractured zones that are believed to have resulted from identified faults in the Cambridge formation.

Shafts

1. Lateral Soil Pressures: Estimates of appropriate design pressures, due to soil and groundwater, for the various lateral soil support systems that the Contractor may adopt have been prepared.

2. Ground Movement: Lateral support systems will have to be designed and constructed to limit ground movements to levels that do not adversely affect existing adjacent structures and/or proposed structures that will be constructed prior to shaft excavation.

3. Groundwater Control: Successfully controlling groundwater during shaft excavation, especially at Deer Island, where there is an approximately 25-foot-thick granular stratum beneath the till which could cause excavation bottom "blow", will be a key concern.

5.20 NORTH SHAFT

5.21 General

Based on information provided by the LDE, the centerline of the North Shaft is to be located at 746,715.00 feet E: 491,517.00 feet N (Mass. Grid, 1927).

The North Shaft will be excavated through approximately 131 feet of soil and 190 feet of rock. The soil will consist of (in descending order from ground surface), compacted replacement engineered fill; granular deposits; glacial till; and a gravelly silty sand, with boulders and rock fragments. It is the PDE's understanding that the miscellaneous fill, which is in place at the time this report is being written (November, 1989), will have been excavated and replaced with engineered fill (by the Early Site Preparation Contractor) up to elevation +125 feet, prior to shaft construction.

Selection of the size of the construction shaft will be at the discretion of the Contractor. For this particular shaft, the TBM will probably be the largest piece of equipment requiring access through it. Furthermore, everything lowered or raised must be able to clear services such as personnel elevators, ventilation ducts, cables and conduits. Based on these considerations, it is anticipated that the construction shaft will have an interior diameter of at least 26 feet. The finished diameter of the permanent shaft will be 11 feet below elevation +80 feet, and 16 feet above elevation +80 feet.

5.22 Geotechnical Design Parameters

The geotechnical design parameters used to compute the lateral pressures on the initial and final support systems are shown on Table 5.1. The parameters were selected based on soil classification, laboratory tests, standard penetration tests (SPTs), and experience. The subsurface profiles for the North Shaft and the Surge Structure are based primarily on boring LDE-46; and the profile for the SSPS conduit is based on borings PDE-2, LDE-39 and LDE-46 (refer to Figure 4.4).

For the initial structures, groundwater elevation was assumed to be 115.3 feet, which is the Federal Emergency Management Agency (FEMA) predicted stillwater storm surge elevation, with a return period of 50 years, for Deer Island; and for final structures, groundwater was assumed to be at elevation

119.5 feet, which is the projected 100-year surge level at Deer Island for the year 2100. These groundwater elevations are the LDE determined maximum flooding conditions.

TABLE 5.1

Lateral Pressure Design Parameters

Soil Parameters:

Soil Description	Unit Weight (pcf)	Friction Angle (Degrees)	Undrained Shear Strength (psf)
Miscellaneous Fill	120	32	0
Granular Fill	125	35	0
Gravelly Silty Sand	120	32	0
Silty Clay	120	23	1,000
Glacial Till	130	38	2,000
Sand, with Boulders, Cobbles and Gravel	125	35	0

Groundwater Parameters:

	*Groundwater Elevation, ft	
	Nut Island	Deer Island
Initial Structures	116.6	115.3
Final Structures	122.3	119.5

*Groundwater elevation for the initial structures is the Federal Emergency Management Agency (FEMA) predicted stillwater storm surge elevation, with a return period of 50 years, and for the final structures, it is the FEMA predicted 100-year surge elevation for the year 2100. These groundwater elevations are the LDE determined maximum flooding conditions.

5.22.1 Shaft Structures

Several theories for estimating lateral earth pressures against shaft linings are discussed by Prater (1977). There is considerable variation in the pressures estimated using these methods. Prater concludes that below a certain depth, earth pressure is probably constant or reaches a maximum and then drops with depth to virtually zero. Similarly, the design pressures recommended in NAVFAC DM-7.1 (1982) for vertical shafts indicate that in granular soils (with friction angles of 30 to 35 degrees), the horizontal pressures become constant from a depth of approximately four times the excavation diameter. In cohesive soils, soil arching and mobilized shear resistance is believed to also cause reduction in lateral pressure for deep shafts. Consequently, considerable engineering judgement is necessary in arriving at safe, economical design pressures for cylindrical shafts, especially in mixed soil conditions.

Temporary Lateral Pressures

For the temporary excavation condition, two cases were evaluated: (a) no dewatering and (b) dewatering down to top of rock. The lateral earth pressure evaluations were performed as follows:

Case (a): No dewatering

Using the parameters shown on Table 5.1 and assuming active conditions, the total lateral pressures due to the soil and groundwater were derived using both drained and undrained analysis and the results plotted on the same graph. The total force due to the pressure envelope from these two analyses was then redistributed into a triangular pressure and assumed to be the pressure that would act on the temporary lateral earth support structure. The recommended lateral earth pressure shown on Figure 5.1 consists of this triangular pressure minus the pressure due to groundwater.

Case (b): Dewatered

The same analyses as outlined for case (a) above were also performed for this case. The main difference was that the excavation was now assumed to be dewatered with groundwater down to bedrock prior to excavation. The recommended design lateral earth pressure is as shown on Figure 5.1.

Permanent Lateral Pressures

Lateral pressures for the final shaft structure were estimated using effective stress analysis. For cohesionless materials, the pressures were assumed to be due to at-rest (K_O) conditions and K_O was estimated using Jaky's equation (refer to

Table 5.1 for values). For cohesive materials, permanent pressures were assumed to be due to an effective horizontal to vertical stress ratio of approximately 0.5 (assuming insignificant soil creep).

The estimated design pressures are shown on Figure 5.1. To account for the reduction in lateral earth pressure due to arching, pressure was assumed to be constant from a depth equal to four times the excavation diameter down to top of rock (Wong and Kaiser, 1988). Estimates were performed for excavation diameters of 18, 22, 26 and 30 feet.

5.22.2 SSPS Conduit

Initial and final lining details are shown on Contract Drawing No. E1 S-06. This structure will be an approximately 145-foot-long, 11-foot-finished-diameter conduit which will connect the North Shaft to the SSPS. It will be constructed as a tunnel within dense to very dense glacial till and stiff to very stiff silty clay at an invert elevation of 61 feet (refer to Figure 4.4).

5.22.3 Surge Storage Structure

A 17.5-foot-long, cast-in-place concrete surge storage structure is to be connected to the North Shaft via a 17.5-foot-long cast-in-place concrete conduit (refer to Figures 2.1 and 4.4). The purpose of the surge storage structure is to store excess effluent from the Inter-Island Tunnel during a sudden surge resulting from effluent momentum after SSPS power outage.

Temporary Lateral Pressures

For the temporary excavation condition, two cases were evaluated: (a) no dewatering and (b) dewatered. Based on boring LDE-46, this structure will be constructed entirely within cohesionless soil. The lateral earth pressure evaluations were performed as follows:

Case (a): No dewatering

Using the parameters shown on Table 5.1 and assuming active conditions, the lateral soil pressure due to the soil was evaluated using effective stress analysis. The total effective force due to the soil pressure was then increased by 30 percent and redistributed into a rectangular pressure, in accordance with Terzaghi and Peck's classic method. This soil pressure and the hydrostatic groundwater pressure were assumed to be the total pressure that would act on the temporary lateral earth support structure. The recommended lateral pressures are shown on Figure 5.2.

Case (b): Dewatered

The same analysis as outlined for case (a) above was also performed for this case. The main difference was that the excavation was now assumed to be dewatered, with groundwater down to bottom of excavation. The recommended design lateral earth pressure is as shown on Figure 5.2.

Permanent Lateral Pressures

Lateral pressure for the final surge structure was also estimated using effective stress analysis. For the cohesionless materials, the pressures were assumed to be due to at-rest (K_O) conditions and K_O was estimated using Jaky's equation (refer to Table 5.1 for values). The recommended design pressure is shown on Figure 5.2.

5.22.4 Surge Storage Structure Conduit

A 17.5-foot-long, cast-in-place concrete conduit, with an 8-foot internal width and variable internal height (maximum of 12.5 feet), will connect the surge structure to the North Shaft (refer to Figure 2.1). The top of the completed conduit will be flush with the ground surface.

Lateral pressure for the conduit was estimated using effective stress analysis. For the cohesionless materials, the pressures were assumed to be due to at-rest (K_O) conditions and K_O was estimated using Jaky's equation (refer to Table 5.1 for values).

5.23 Shaft Excavation in Soil and Rock

Excavation within the soil is expected to be by clam-shell or equivalent using a crane at ground level. Alternatively, the Contractor may elect to use a small hydraulic backhoe or excavator in the shaft to load muck skips which are then hoisted by a crane. Adequate control of groundwater will be critical, especially for the latter method of excavating and mucking. The most critical location will be at the interface between soil and rock. To avoid problems due to groundwater, e.g. excavation bottom instability or surface subsidence due to sloughing of sand as water seeps in, the 25-foot-thick water-bearing pervious stratum below the till at this location must be depressurized or hydraulically isolated prior to excavation.

It is anticipated that excavation of the shaft through rock will be by drill and blast techniques. To provide adequate space for the Contractor's shaft facilities and access for the TBM, it is anticipated that the shaft will be overexcavated to a diameter of approximately 26 feet in the rock section.

5.24 Temporary Lateral Support in Soil - Shaft

Shaft excavation will involve constructing a temporary lateral support wall down to sound bedrock to retain the soil as the excavation proceeds. Selection of a support system should be left to the Contractor, with detailed design by the Contractor subject to review by the CM. Of particular importance will be groundwater control.

The following support systems are considered feasible for the North Shaft:

A. Bolted Precast or Steel Plate Liner - Typically involves removing the top layer of ground to a depth of two to three rings below the proposed level of the top of the finished shaft; creating a level area, approximately 3 feet larger in diameter than the outside diameter of the proposed shaft; constructing the first two rings; and then surrounding them with concrete to form a rigid concrete collar. It is important that these two rings be built level and to a true circle. The concrete collar serves to preserve the shape and level of these two rings, to protect the edge of the shaft from adjacent construction equipment and to provide a firm "anchor" from which the liner can be erected from the top down as excavation proceeds.

   The pumping test which was performed by the LDE at the proposed North Shaft indicates that dewatering of the groundwater within the pervious gravelly silty sand stratum at the rock/soil interface would be feasible using deep wells screened within the fractured rock. However, there would still be residual water that would flow into the shaft excavation, especially from the fractured rock zone. A combination of grouting between the lining and ground and using gasketed liner segments would restrict this seepage.

   The silt and clay content in the till which is as high as 50 percent indicates that the till has a low hydraulic conductivity (refer to Section 4.40). Groundwater control within this material will therefore not be a major issue. However, groundwater within the more pervious granular strata above the till will have to be controlled with shallow wells or steel sheeting driven into the glacial till. Due to the approximately 5-foot groundwater level tide fluctuation, steel sheeting may be more appropriate.

B. Concrete Diaphragm Wall - A closed ring of concrete wall panels built in bentonite slurry supported trenches, with or without encased soldier piles. The wall can be used as part of the final structure thereby reducing cost.

Considerations include:

- Adequate competent rock should be left at the toe of the wall to provide adequate bearing capacity as the excavation continues through rock, below the toe.

- Wall panel excavation may be impeded due to the dense to very dense glacial till. Even though boulders were not encountered within the till during the subsurface investigation, the cobbles that were observed may be an indication that boulders do exist. Boulders within the till could delay construction.

- A flush contact between adjoining panels may be difficult to achieve on a consistent basis. Consequently, leakage at some of the joints should be expected.

- It may be difficult to develop an adequate groundwater seal within the permeable gravelly silty sand stratum at the rock/soil interface, due to the boulders and the weathered, fractured top of rock. Consequently, groundwater pressure relief wells may be necessary within the shaft area prior to excavation. This would limit the chances of the excavation bottom becoming quick. Grouting of the soil/rock interface and the fractured top of rock may be required to achieve an effective seal.

- To avoid trench instability, the slurry should be maintained at least 3 to 5 feet above external groundwater level during construction. The fact that construction in saline water, due to its greater density, requires a greater head of slurry than construction in fresh water should be considered. Furthermore, as groundwater level has a tidal fluctuation of approximately 5 feet, continual monitoring will be necessary.

- Increases in slurry density may make it difficult for the tremie concrete to properly displace the slurry. This may lead to inclusions of bentonite within the concrete, poor bonding to steel, and associated loss of concrete quality. Density tests should be performed, e.g. using a mud scale, on slurry samples taken about a foot above the bottom of the trench prior to concreting.

- Excessive salinity changes the electrolytic properties and may lead to flocculation of the bentonite particles. This could make it more difficult for the slurry to form an effective cake and may lead to fluid loss. The problem would be especially acute in the relatively pervious strata below and above the till. To avoid this problem, the bentonite should be hydrated with fresh water. There are several instances of successful diaphragm wall construction immediately adjacent to bodies of salt water.

C. Ground Freezing - Lowering of the ground temperature to freeze interstitial water in the submerged portion of the overburden and upper portions of the rock. This improves ground behavior due to a decrease in permeability and an increase in mechanical strength. The Contractor may then excavate the frozen soil and fractured rock at the interface using drill and blast techniques. Thereafter, a temporary lining, consisting of cast-in-place concrete or steel liner plate with ring beam or precast liner with ring beam, can be placed and the freezing equipment removed.

Considerations include:

- The actual freezing has to be started well in advance of excavation to enable the method to take effect. Consequently, there may be some delay while waiting for the ground to freeze.

- Only the soil below the groundwater table will be frozen. Consequently, the lateral pressure due to the soil above the groundwater must be supported by an alternate method such as steel sheeting or soldier pile and lagging, driven down to an adequate depth below the low tide water level.

- Special care must be taken when drilling the holes and placing the freeze pipes to achieve proper alignment. The pipes must be inserted several feet below the fractured rock zone to accomplish watertight closure of the frozen zone. This is a critical part of the operation, in that if freeze pipes are out of line, closure of the freeze wall might not occur resulting in a leak or concentrated stress condition. The boulders at the soil/rock interface, and probably within the till as well, may cause misalignment of the holes.

- Temperature measurements of the frozen ground must be performed, using thermal transducers in special boreholes, to obtain direct feedback on the efficiency of the system. It is recommended that this be supplemented with a pressure relief hole, drilled near or at the center of the proposed shaft location. When closure of the ice occurs, there would be a surge of water from the hole. This observation, combined with measurements that confirm sub-freezing temperatures, indicate that freezing is continuous around the intended zone of construction (O'Rourke, 1978).

- Freezing may cause a layer of ice to form between the shaft lining and adjacent soil. Furthermore, the frozen soils will resist compression and infiltration when grouting behind the lining. When thawing occurs, voids could form throughout the zone bordering the shaft and possibly cause lining deformation and loss of ground. This problem can be limited by carefully grouting behind the liner in two stages - a short time after the lining is placed and after freezing has been stopped and thermal sensors indicate a return to temperatures above freezing.

- The costs related to ground freezing are cumulative. They increase with the duration of the project as the expense of running the equipment increases, or, in the case of nitrogen, as the nitrogen losses accumulate. Consequently, this method will probably be relatively expensive. Furthermore, the method may be slower than the other two. However, it may be the most positive solution to controlling groundwater at the soil/rock interface.

D. Combined System - This would consist of constructing the upper portion of the shaft in one of several ways, in combination with freezing of the lower portion of the overburden and top of rock. Feasible options for the upper portion include:

1. A slurry wall taken down to just below the top of till. For this case, dewatering would not be necessary. However, the excavation rate may be slow due to the dense to very dense glacial till, which may also contain boulders.

2. A soldier pile and lagging system taken down to a depth of about 70 feet (within the till). The

fill would have to be dewatered using shallow wells or steel sheeting could be driven into the till to serve as a groundwater cut-off.

3. Steel liner plate supported by steel ring beams, or a precast concrete segment liner system. The fill would also have to be dewatered using shallow wells or steel sheeting driven into the till to serve as a groundwater cut-off.

Temporary support in rock shall include rock bolts and shotcrete, with welded wire fabric reinforcement, installed primarily to ensure against minor rock fragment fallout that might endanger personnel in the shaft.

5.25 Groundwater Control - Shaft

The 25-foot-thick stratum of boulders, sand and silt, underlying the till at this site at a depth of 106 to 131 feet (elevation +18.8 to -6.2 feet), is the critical stratum regarding groundwater problems during construction. If this stratum is not properly dewatered or groundwater is not effectively cut off prior to excavation, the pervious nature of the stratum and the high head of water could result in the bottom of the shaft "blowing" during excavation.

Based on the LDE's pumping test results, it is believed that three or more dewatering wells in the immediate vicinity of the shaft will collectively yield less than 1,200 gpm. It is very probable, however, that these wells will not result in a dry condition at the soil/rock interface. This is because the soil appears to have a significantly higher hydraulic conductivity than the rock. Therefore, regardless of the preconstruction dewatering efforts, it is believed that without grouting or other cut-off, such as a slurry wall or freezing, groundwater will flow into the shaft. The volume of flow will be dependent upon a number of factors including: the number and efficiency of dewatering wells, the selected method of construction, and the method of grouting.

Design of the groundwater control system is left up to the Contractor, with review of the proposed method by the CM. The following systems are considered feasible:

- Deep wells: Three or more wells would be screened through the aquifer into the fractured bedrock. The system should be effective in fractured rock and moderately effective in sand and gravel (Guertin and McTigue, 1982). However, to achieve a near dry condition within the shaft excavation, the wells would probably have to be supplemented with grouting, especially at the soil/rock interface.

- Concrete diaphragm wall: The primary problem with this cut-off method is that it may be difficult to develop an adequate groundwater seal within the permeable gravelly silty sand stratum at the rock/soil interface, due to the boulders and the weathered, fractured top of rock.

- Freezing: This method requires highly specialized contractors but if properly performed, it may be a positive solution to controlling groundwater at the soil/rock interface.

Regardless, of the method selected, sumping within the excavation will probably be necessary; it appears that salinity concentrations will increase with time.

5.26 Design of Permanent Lining - Shaft

A combination of reinforced and unreinforced cast-in-place concrete permanent lining would be the most effective alternative over precast concrete segments due to the versatility of continuous steel form construction and ease of forming smooth transition curves and bends at shaft connections to tunnels to reduce hydraulic head loss due to friction. Furthermore, as the North Shaft excavation diameter will be reduced to a finished diameter of 16 feet above and 11 feet below elevation 80 feet, the most viable option for the formation of the resultant thick lining is cast-in-place concrete. Cast-in-place concrete liners also tend to resist groundwater leakage better than precast segments which may leak at the joints if not sealed properly.

The groundwater at the proposed North Shaft location fluctuates between approximately elevation 104.5 and 109.5 feet, and the water surface within the shaft during a surge may rise to a maximum elevation of approximately 120 feet. Surge conditions may therefore create a maximum differential head of approximately 15.5 feet. The permanent concrete lining should therefore be designed to keep stresses due to this surge as well as external soil and groundwater pressures (including when the shafts are empty) within allowable limits.

5.27 SSPS Conduit

An approximately 145-foot-long (from shaft center line to 2 feet into the SSPS), 11-foot-finished-diameter connecting conduit, with an invert elevation of 61 feet, is to be constructed at the North Shaft (refer to Figures 2.1 and 4.4). The conduit will connect the South System Pumping Station (SSPS) to the proposed North Shaft.

Construction of the conduit tunnel is expected to be by hand-mining methods, using a simple shield, or other approved mining method. A shield is basically a steel cylinder which is jacked ahead by thrusting against the in-place liner. The shield provides temporary support of the soil and allows excavation to proceed at the tunnel face. Liner segments are erected in the tail of the shield, in preparation for the next shield advance.

The conduit will be constructed through silty clay and glacial till. Even though boulders were not encountered within the till during the subsurface investigation, the Contractor should be prepared for their existence. Boulders reduce excavation progress, and critical ground losses can occur when the boulders are only partially within the tunnel profile. Unless some method of supporting the irregular opening left by the removal of the boulder is provided, large ground settlements can occur. Boulders can be removed by breaking them up with hydraulic splitters and normal mucking procedures.

For the proposed conduit invert, the glacial till and silty clay have a stability factor (ratio of overburden pressure to undrained shear strength) of approximately 2 to 3. Experience has shown that stability numbers of less than 5 indicate an essentially stable tunnel heading (Cording et al., 1975). Consequently, the stand-up time of the till and clay should be sufficient for installation of the primary liner before significant movement of the soil has occurred. Stand-up time is the time that elapses between the exposure of an unsupported area of soil in the tunnel and the beginning of noticeable movements of the ground at this area. Except for occasional lenses of water-bearing sand, seepage of groundwater into the excavation is not expected to be a problem, especially as the till typically has a high percentage of relatively low permeability clay and silt.

Based on Peck et al. (1976), settlement of the ground surface, due to conduit construction, could be as much as 2 to 3 inches.

5.28 Surge Storage Structure

A cast-in-place concrete surge storage structure is to be constructed near the North Shaft (refer to Figures 2.1 and 4.4). The structure will be 46 feet by 96 feet in plan, at an invert elevation that ranges between approximately 97 and 99 feet. A 17.5-foot-long (from finished face of shaft to surge structure) cast-in-place concrete conduit, with an internal width of 8 feet and an invert elevation ranging between 111.0 and 111.5 feet, will connect the storage structure to the shaft. The purpose of the surge storage structure is to store excess effluent from the Inter-Island Tunnel during a sudden surge.

The subsurface conditions at the proposed surge structure location are based on boring LDE-46 (which is not within the proposed footprint) and are therefore assumed to be similar to those for the proposed North Shaft location. For generalized subsurface soil conditions refer to Figure 4.4 which indicates that the bottom of the excavation will probably be on glacial till.

A boring is to be performed within the proposed surge structure footprint. Data from the boring will not be available prior to issuance of this report. However, the data will be available for the Contractor prior to construction.

If space allows, construction of the storage structure can be performed in an open properly dewatered cut with slopes not exceeding 1.5 horizontal to 1 vertical. Alternatively, steel sheeting with internal bracing or soldier piles and lagging can be used as the lateral soil support system. The support system must be left in place and cut off to approximately 5 feet below proposed finish grade. The estimated lateral earth pressures are as shown in Figure 5.2. Furthermore, this structure has been designed to resist hydrostatic uplift corresponding to a groundwater elevation of 119.5 feet. This groundwater elevation is the LDE determined maximum flooding condition.

The advantage of sheeting is that, provided it is driven into the till, it would cut off the groundwater from the construction area, thereby reducing the need for significant pumping. Soldier piles and lagging would require shallow wells to dewater the pervious soil above the till. Boulders within the till, which would hinder the installation of either system, should be expected. Continuous interlocked steel sheeting can be damaged by obstructions relatively easily, thereby reducing its effectiveness as a groundwater cut-off. Soldier piles, however, can be withdrawn and moved or driven or drilled past boulders. It is therefore a more flexible system for dealing with obstructions.

The connecting conduit is expected to be constructed in a manner similar to the surge storage tank. Concrete for the conduit will probably be cast directly against the lateral soil support system which will be left in place and cut off to approximately 5 feet below proposed finish grade. The top of the finished conduit will be approximately flush with the ground surface.

5.29 Instrumentation

Excavation of the North Shaft could cause horizontal and/or vertical displacement of the surrounding ground. Based on O'Rourke (1989), Goldberg et al. (1976), and assuming good workmanship during shaft excavation, estimates of displacements due to the support systems discussed in Section 5.24 are as shown on Table 5.2 below. These displacements are for ground surface points along a circumference approximately 15 feet from the edge of the shaft excavation.

TABLE 5.2

Estimates of Vertical and Horizontal Displacement
Due to Shaft Construction

Support System	Estimated Displacement, inches.			
	Vertical		Horizontal	
	Settlement	Heave	Towards Excavation	Away From Excavation
Ground Freezing	2.0-4.0	2.0-4.0	2.0-4.0	2.0-4.0
Diaphragm Wall	1.5-3.0	0.0	1.0-2.0	0.0
Liner Plate	2.0-4.0	0.0	2.0-4.0	0.0

Four inclinometers should be installed to monitor horizontal ground displacements. Monitoring of these displacements during shaft excavation will provide a means of assessing whether the earth support system is performing adequately. Proposed locations and depth of installation are as indicated on the contract drawings.

In addition, three piezometers should be installed next to the proposed shaft, prior to construction. The purpose of the piezometers is to monitor that groundwater pore pressures do not exceed anticipated levels during construction. Locations and depth of installation will be as directed by the CM.

The Contractor should monitor these instruments in accordance with the schedule in Section 02295, Part 3.05, of specifications unless otherwise agreed with the CM. Monitoring frequency should be increased if the need arises.

5.30 SOUTH SHAFT

5.31 General

Based on information provided by the LDE, the proposed South Shaft will be located at 747,715.00 feet E; 466,600.00 feet N (Mass. Grid, 1927). As this will not be a primary tunnel construction access shaft, the excavated diameter for the South

Shaft will be governed primarily by the required finished diameter of 16 feet and whether the Contractor elects to remove the TBM via this shaft.

5.32 Geotechnical Design Parameters

The geotechnical design parameters used to compute the lateral pressures on the initial and final support systems are shown on Table 5.1. The parameters were selected based on soil classification, laboratory tests, standard penetration tests (SPTs), and experience. The subsurface profile for structures constructed on Nut Island was based primarily on borings LDE-58 and LDE-69.

For the initial structures, groundwater elevation was assumed to be 116.6 feet, which is the FEMA predicted stillwater storm surge elevation, with a return period of 50 years; and for final structures, groundwater was assumed to be at elevation 122.3 feet, which is the projected 100-year surge level at Nut Island for the year 2100. These groundwater elevations are the LDE determined maximum flooding conditions.

5.32.1 Shaft Structures

The methods of analysis are as outlined in Section 5.22.1 and the recommended design pressures are shown on Figure 5.1. Estimates were performed for excavation diameters of 16, 20, and 24 feet.

5.32.2 Nut Island Conduit

A cast-in-place concrete conduit, with a 12-foot-square internal cross-section, will connect the Grit Removal Facilities Structure (GRFS) to the South Shaft. Based on borings LDE-58 and LDE-69, this structure will be constructed within cohesionless and cohesive soil (refer to Figures 2.2 and 4.5).

Temporary Lateral Pressures

For the temporary excavation condition, two cases were evaluated: (a) no dewatering and (b) dewatered. The lateral earth pressure evaluations were performed as follows:

Case (a): No dewatering

Using the parameters shown on Table 5.1 and assuming active conditions, the total lateral pressures due to the soil and groundwater were derived using both drained and undrained analysis and the results plotted on the same graph. The effective force due to the soil pressure obtained by the drained analysis method was increased by 40 percent and redistributed into a trapezoidal pressure, in accordance with Terzaghi and

Peck's classic method. This soil pressure and the hydrostatic groundwater pressure were assumed to be the total pressure that would act on the initial lateral earth support structure. The recommended lateral pressures are shown on Figure 5.3.

Case (b): Dewatered

The same analysis as outlined for case (a) above was also performed for this case. The main difference was that the excavation was now assumed to be dewatered, with groundwater down to bottom of excavation, and the total force due to the pressure envelope from the two analysis was increased by 30 percent prior to redistribution. The recommended design lateral earth pressure is as shown on Figure 5.3.

Permanent Lateral Pressures

Lateral pressure for the final Nut Island conduit was also estimated using effective stress analysis. For the cohesionless materials, the pressures were assumed to be due to at-rest (K_o) conditions and K_o was estimated using Jaky's equation (refer to Table 5.1 for values). For the cohesive materials, permanent pressures were assumed to be due to an effective horizontal to vertical stress ratio of approximately 0.5 (assuming insignificant creep). The recommended design pressure is shown on Figure 5.3.

Permanent Vertical Pressures

An evaluation of the vertical stress, due to overburden and construction traffic, that would act on the crown of the conduit was performed using the method for shallow pipes and conduits outlined in NAVFAC Design Manual DM-7.1 (May, 1982). As the vertical stress evaluation depends on the excavation width, it was assumed that the excavation for the conduit would extend no more than 1 foot beyond the boundaries of the structure and the walls would be 1-foot-thick.

5.33 Shaft Excavation in Soil and Rock

Excavation considerations in soil and rock are as described in Section 5.23.

5.34 Temporary Lateral Support in Soil - Shaft

Shaft excavation will involve constructing an initial lateral support wall down to sound bedrock to retain the soil as the excavation proceeds. Selection of a support system should be left to the Contractor, with detailed design by the Contractor subject to review by the CM. Of particular importance will be watertightness.

The support systems described in Section 5.24 would also be feasible at this shaft location. However, as the pervious stratum between the till and top of rock at Deer Island was not observed at this location, and the soil overburden is only 95 feet, soldier piles and lagging in the till may be a less expensive system.

Support of the granular fill can probably best be achieved by internally supported steel sheeting driven through the fill into the underlying glacial till. The sheeting will also serve as a groundwater cut-off. Difficulty may be encountered driving steel sheeting through a potentially very dense sand and gravel layer immediately overlying the glacial till.

The use of soldier piles and lagging in conjunction with dewatering of the granular fill and sand and gravel stratum overlying the glacial till will incur risks due to difficulties associated with dewatering pervious strata 70 feet ± from the shoreline. Once the excavation has been successfully advanced into the glacial till, soldier piles and lagging or liner plates could be used to provide support down to the bedrock surface. Some excavation into the rock and grouting will probably be required to seal the soil/rock interface.

5.35 Groundwater Control - Shaft

Unlike the North Shaft, at this location there is no pervious stratum between top of rock and the glacial till. Furthermore, the LDE-58 boring log does not indicate significant fracturing at the top of rock. Nevertheless, as top of rock generally tends to be fractured and waterbearing, the Contractor should be prepared to grout during construction should that be the case.

Design of the groundwater control system should be left up to the Contractor, with review of the proposed method by the CM. It is anticipated that the dewatering system will probably consist of steel sheeting driven into the till to cut off groundwater, supplemented with grouting at the soil/rock interface.

5.36 Design of Permanent Lining - Shaft

Design issues are as outlined in Section 5.26. The primary differences are that the South Shaft excavation diameter will be reduced to one finished diameter of 16 feet; the groundwater at the proposed shaft location fluctuates between approximately elevation 107.0 and 117.0 feet; and the water surface within the shaft during a surge may rise to a maximum elevation of approximately 113 feet, thereby creating a maximum differential head of approximately 6 feet.

5.37 Nut Island Conduit

Thirty feet of an 80-foot-long, 12-foot-square, cast-in-place concrete conduit, with an invert elevation of 95 feet, will be constructed at Nut Island. This conduit will connect the Grit Removal Facilities Structure (GRFS) to the South Shaft (refer to Figures 2.2 and 4.5). The relatively shallow depth of excavation makes this suitable for a soldier pile and lagging or steel sheeting lateral soil support system, with internal bracing.

The advantage of sheeting is that, provided it is driven into the till, it would cut off the groundwater from the construction area, thereby reducing the need for pumping. However, soldier piles and lagging would require shallow wells to dewater the pervious soil above the till. Boulders within the till, which would hinder the installation of either system, should be expected. For the sheeting, boulders could damage the sheeting, thereby reducing its effectiveness as a groundwater cut-off. For the soldier piles, preaugering would become necessary. Concrete for the conduit will probably be cast directly against the lateral soil support system which must be left in place and cut off to approximately 5 feet below proposed finish grade. Removal of lateral support elements from below structure elevation could result in settlements due to lost ground.

5.38 Instrumentation

Four inclinometers and three piezometers should be installed near the proposed South Shaft, and monitored as outlined in Section 5.29.

5.40 INTER-ISLAND TUNNEL

5.41 General

The proposed tunnel will have a minimum excavated diameter of 13.8 feet (the actual excavation size will be determined by the Contractor), a finished diameter of 11.5 feet, two 14-inch-internal diameter, concrete encased sludge pipes clamped every 20 feet along one of the lower quadrants of the tunnel and a 12-inch-internal diameter drop shaft at Long Island (at Station 80+30). The tunnel will extend from Deer Island to Nut Island and will be approximately 25,160 feet long. The proposed alignment has a dog-leg to avoid a depressed, poor quality bedrock area located between Nut Island and Rainsford Island, due, west of Peddocks Island.

The proposed tunnel will pass through five lithologic zones. These zones are described in Section 4.33.1 and illustrated on Figures 4.6 through 4.8.

5.42 Vertical and Horizontal Tunnel Alignment

Initially, the tunnel alignment was to be a straight line between Nut Island and Deer Island. However, due to a subsurface profile developed by Weston Geophysical, Inc. (subcontracted to the LDE) using seismic reflection and refraction survey data which they obtained in February 1989, as well as data obtained by others, the alignment was subsequently altered by adding a dog-leg west of Peddocks Island. The data had indicated the existence of a deep depression (of apparent elevation -180 feet) in the bedrock surface in an area located between Nut Island and Rainsford Island, due west of Peddocks Island.

Ocean Surveys, Inc., as sub-consultant to the PDE, performed additional geophysical surveys (reflection and refraction) within the apparently depressed area. The results confirmed the existence of the major fault/depression that had been disclosed in Weston Geophysical's earlier survey. The data suggest that this "fault" has a westerly strike. However, top of rock within this depressed area appears to be at an approximate elevation of -40 to -85 feet instead of the -180 feet previously implied. For more details, refer to OSI's report which is attached as part of the "Geotechnical Data Report".

Borings 89-110 and 89-111 which were subsequently performed in the area, prior to the OSI geophysical survey, also indicate that top of rock is not that deep (elevation -12 to -47 feet). However, the area has several zones of poor quality rock which gave RQD values of as low as 0 percent (refer to logs for the two borings). These zones may have been the primary cause for the misinterpretation of top of bedrock during previous geophysical surveys. OSI used the data from boring 89-111 to interpret their geophysical survey data.

Under the direction of Appalachian Coal Surveys, Weston Geophysical performed down hole testing using stacked hydrophones in borings 89-105, 89-110, 889-111 and 89-113. The upper sections of the rock in the four borings yielded the following rock velocities: 17,800 feet per second (top 45 feet) in 89-105; 10,100 feet per second (top 17 feet) in 89-110; 12,300 feet per second (top 75 feet) in 89-111; and 11,200 feet per second (top 30 feet) in 89-113. Rock velocities over full depths of the four borings ranged between 10,100 and 20,400 feet per second. This variability and the fact that velocity ranges for soft rock and till appear to overlap also contributes to the difficulty in evaluating top of rock based on an assumed velocity.

Vertical alignment was governed primarily by the following four factors:

- The need to stay, as much as possible, within good quality rock;

- Maintaining an approximately 70-foot minimum rock cover of reasonably sound rock;

- Maintaining a tunnel invert slope of about 0.25 to 0.30 percent for gravity drainage to the North Shaft, the main working shaft during construction and permanent operation; and

- Providing the shallowest depth shafts possible within the above restraints, for economy of shaft construction.

The anticipated tunnel invert elevation along the alignment of between -100 and -165 feet satisfies these three factors.

5.43 Excavation

Drill and blast techniques, tunnel boring machines (TBMs), and point-attack boom type machines, could be used to excavate this tunnel. Each of these methods has advantages and disadvantages in terms of speed, safety, suitability to the ground conditions and flexibility to changes in those ground conditions.

The anticipated rock strengths and length of tunnel would generally preclude use of a point-attack boom type machine except for possible localized special excavations. These types of machines are not considered further in this report.

Drill and Blast

This has been the most commonly used method of excavation in Boston and is known to be effective in these rock conditions. The main advantage over a full-face TBM is that the method has great flexibility and can be used in virtually all rock conditions. However, its main disadvantages include the following:

- A slower rate of advance (estimated at about 25 to 30 feet per day, based on two to three blast and muck cycles).

- Lack of detailed control of the size and shape of the excavation, e.g., overbreak usually results which increases the muck and concrete quantities.

- Blasting process produces an unavoidable loosening of the rock surrounding the opening.

- Generally uneconomical if used to excavate tunnels that are longer than 10,000 feet (Sinha, 1989).

Tunnel Boring Machine

For the subsurface conditions along the proposed tunnel alignment, a TBM would probably provide the fastest rate of excavation (estimated by the PDE to be an average of 95 feet per day for the duration of tunnel excavation). The main advantages of a TBM are:

- Rapid excavation of the tunnel. The quartz content of the argillite is high (estimated to typically range between 15 and 30 percent). However, as the quartz grains appear to be mostly silt or clay size, they will probably not have the high wear rate on cutters suggested by the high content.

- Limited overbreak and disturbance of the surrounding rock.

- Reduced costs over drill and blast methods resulting from greater labor productivity.

- Safer construction than drill and blast methods.

Disadvantages of a TBM are:

- High initial cost. However, this can probably be offset by reduced total labor costs as a result of faster advance rates.

- A TBM is designed for particular ground conditions and should actual ground conditions differ, such as shear or fault zones, the capacity of the TBM to adapt to changes in rock quality can be limited. Hand-mining methods could be needed to overcome such difficulties in extreme cases.

In view of the length of the tunnel (approximately 25,160 feet), the time constraints, and the prevailing rock strengths, a TBM is considered the most appropriate choice for tunnel excavation. Short sections of altered and/or kaolinized argillite may be encountered in which the TBM could experience problems due to slip of gripper pads in weak material or clogging of cutting and mucking systems. This impact is expected to be limited. The data also suggest that blocky ground, which could impede progress, will be encountered.

As the subsurface data for the tunnel indicate that fault zones will probably be encountered during excavation at the locations indicated on the subsurface profile as well as other unidentified locations, contingency plans must be available for advance probing and/or ground treatment ahead of the face (refer to Section 5.45). It is quite possible that within these zones, a combination of high groundwater inflows and poor rock may necessitate the installation of significant amounts of support close to or at the face. Advance probe drilling and forward grouting could reduce the impact of these conditions.

Drill and blast will be appropriate for shaft excavation through rock and for excavation of the bottom station area, tail tunnel and bell out section of the tunnel at the base of the North Shaft; and the stub tunnel at the base of the South Shaft.

Orientation of the rock bedding and discontinuities is variable (refer to Figures 4.11 and 4.12). However, the effect of these features relative to tunnel construction is more pertinent for drill and blast methods than for a TBM excavated tunnel. The orientation of these features is of less concern, but should be considered by the Contractor relative to rock breakage and support requirements.

The PDE anticipates that the Contractor will overbore the tunnel to provide for steering tolerances by increasing the diameter in the order of 4 inches. The lining thickness design accounts for a minimum lining thickness that can be permitted when formwork is set to proper alignment within a wandering actual excavation.

5.44 Rock Support Requirements

The tunnel will be constructed primarily in Cambridge Argillite. Although the Argillite is expected to be competent (moderately blocky, with widely spaced joints, to blocky and seamy) in most locations, the tunnel will probably also pass through diabase intrusions, fault zones and zones of altered Argillite.

Terzaghi (Proctor and White, 1968) defines "moderately blocky" rock as that which contains joints and hair cracks but the blocks between joints are locally grown together or intimately interlocked. "Blocky and seamy" rock consists of chemically intact or almost intact rock fragments which are entirely separated from each other and imperfectly interlocked.

The RQD of the rock at the tunnel horizon was generally good to excellent (61 to 100 percent), from approximate Station 10+00 to 150+00 (Deer Island south to the area west of Rainsford Island) and from approximate Station 200+00 to 261+60 (the bend in the alignment south to Nut Island). In the tunnel sections between these areas the RQD was measured between 0 and 70 percent indicative of a generally fair to locally very poor rock quality.

From the area south of where the tunnel passes under Long Island to the bend in the alignment, the joints in the rock are commonly filled with gouge or are slickensided. The slickensides are more common immediately south of Long Island and at the bend.

For purposes of estimating the required support for tunnels constructed in rock, there are several empirical rock classification methods. It is emphasized that all rock rating systems are approximate. Considerable geologic and engineering judgment must be exercised in applying calculated results to final designs. The three methods described below are considered to be the most common and were reviewed for applicability to this project. Design criteria for the temporary tunnel supports are based on these systems and described in Section 5.46.

Rock Mass Quality (Q)

This method was developed by Barton et al. in 1974 and 1975 by considering data from approximately 200 tunnel and large underground chamber case records (included 13 igneous, 24 metamorphic, and 9 sedimentary rock types). The method assigns indices to the following parameters:

- RQD
- Joint set
- Joint roughness
- Joint alteration
- Joint water (Reduction Factor)
- Stress (Reduction Factor)

to arrive at a combination of these numbers called Q. Q can be related to permanent/temporary crown and wall support in a given tunnel, underground station or shaft. This method is generally applicable to large underground openings.

Rock Structure Rating (RSR)

This method was developed by Wickham et al. in 1974 for rapid transit tunneling using 53 case histories for 8- to 36-foot-diameter tunnels. The RSR is similar to the Q method, but has fewer parameters. RSR is the sum of three parameters, A, B and C which are defined as follows:

A: Represents general geology of rock mass including influences by rock type, strength and geological structure (folds and faults)

B: Represents discontinuity spacing, strike, dip, and the tunnel direction in relation to discontinuity characteristics

C: Represents groundwater and discontinuity characteristics

The RSR number is related to the required steel rib supports (spacing, size), or rock bolts (length, spacing), or shotcrete (thickness).

Rock Mass Rating (RMR)

This method was developed by Bieniawski (originally proposed in 1973) and evaluates 6 parameters which significantly influence behavior of rock mass. For this project, the latest version (Bieniawski, 1988) of the system was evaluated. The six parameters are:

- Uniaxial compressive strength
- Rock quality designation (RQD)
- Joint spacing
- Joint condition
- Groundwater inflow
- Joint orientation relative to proposed excavation

The rock mass is categorized into five classes, indices of parameters are assigned, and a summation of the indices (index for joint orientation has a negative value) defines the rock quality and leads to an estimate of the required rock support.

This classification system is also used for estimates of stand-up time, however, field observations indicate that the estimates are conservative. Assuming this tunnel will be excavated by TBM, stand-up time will not be a significant issue.

Based on this review, it was concluded that the RMR method by Bieniawski was most appropriate for this project, primarily because it is based on tunnels constructed in sedimentary rock formations.

Consequently, the primary method used to evaluate the rock quality for tunnel constructability relative to tunnel excavation and rock support requirements was the latest version (Bieniawski, 1988) of Bieniawski's Rock Mass Rating (RMR) system. A comparison check of the rock ratings was made using the Rock Structure Rating (RSR) developed by Wickham et al. (1974) and Burton's Q system.

The systems provide an index rating of the rock based on various parameters such as strength, joint spacing, joint condition, groundwater inflow, and orientation. The RMR and Q systems also rate the RQD of the rock whereas the RSR system considers the structural geology of the rock. It should be noted, however, that orientation of the rock discontinuities relative to the tunnel has a lesser importance concerning the rock rating when a TBM is used rather than conventional drilling and blasting.

The overall rating of the RSR method, when taking an adjustment factor of 1.19 into account for a TBM as recommended by Skinner (1988), is higher than the RMR method which does not consider the method of excavation in the rating. Nevertheless, the agreement between the two methods was very good when comparing the relative condition of the entire rock along the alignment. A summary of the rating results is shown on Figures 5.4 through 5.6.

The RMR system identifies rock quality classes as follows:

Less than 20 points: Class 5 - very poor rock
21 to 40 points: Class 4 - poor rock
41 to 60 : Class 3 - fair rock
61 to 80: Class 2 - good rock
81 to 100: Class 1 - very good rock

For the overall tunnel length the rock can generally be classified as a fair to good rock for tunneling with overall RMR and RSR ratings averaging 52 and 64, respectively, for the 20 borings that were analyzed. An adjustment factor of 19 percent has been incorporated into the RSR values to account for the tunnel size and use of a TBM and the values have also been weighted by the length of tunnel that the various borings represent. The exceptions are the values for borings LDE-46 and 89-117 which are assumed to be in the area that will be developed using drill and blast techniques instead of a TBM. The rating for the rock at the tunnel horizon at each boring along the route is shown on Figures 5.4 through 5.6.

The averaged rock rating values of the rock for the RMR and RSR systems at the tunnel horizon of each boring are plotted on Figure 5.7. An adjustment factor of 19 percent has been incorporated into both the RMR and RSR values, except for borings LDE-46 and 89-119, to account for the tunnel size and use of a TBM. The figure shows the good overall agreement of the two rating systems. The tunnel rock is anticipated to be very good (RMR of 81-100) at the Nut Island end of the tunnel. In between, generally fair to good tunneling rock conditions (RMR of 41-80) are expected, except the section where the tunnel approaches the bend. In this latter section, the RMR is poor, in the range of 8 to 38. The fair and poor rated rock is anticipated in the areas indicated as fault zones on Figures 4.6, 4.7 and 4.8.

Four types of temporary support systems are anticipated as indicated on the contract drawings. These support systems are described below and illustrated on Figure 5.8. A correlation of rock class to ground support requirements has been developed by the PDE. These correlations have been arrived at based on the collective judgment of the design team.

<u>Type I Support - No Support to Occasional Rock Bolts</u>

Type I support (refer to Figure 5.8) is expected to be utilized along approximately 9 percent of the tunnel, where the RMR rating ranges between 73 and 100. The rock is self-supporting in this condition, and spot rock bolts will be installed for safety only, as needed.

<u>Type II Support - Systematic Rock Bolting with WWF</u>

Type II support (refer to Figure 5.8) is expected to be utilized along approximately 65 percent of the tunnel, where the RMR rating ranges between 57 and 73. Rock bolts with 1/4-inch by 4-inch steel straps, installed 4 feet on center, and WWF are anticipated.

<u>Type III Support - Steel Ribs and Steel Mat Lagging</u>

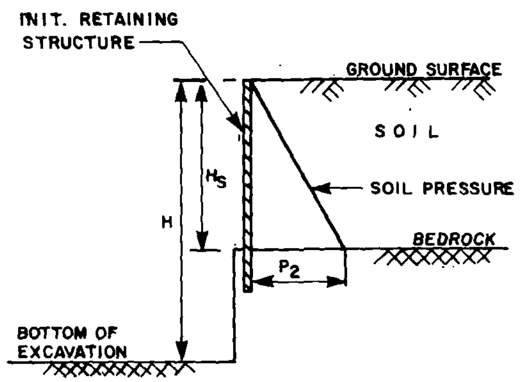
Type III support (refer to Figure 5.8) is expected to be utilized along approximately 21 percent of the tunnel, in areas where the RMR rating ranges between 30 and 57. The use of W5 x 16 steel ribs, installed 4 feet on center, expanded against the rock and preloaded by jacking, is anticipated. The ribs can be installed in three or four segments at the Contractor's option. Rock support between the ribs will be provided by 120-degree coverage with special design steel mat lagging.

<u>Type IV Support - Steel Ribs, Steel Mat Lagging and Shotcrete</u>

Type IV support (refer to Figure 5.8) is expected to be utilized along approximately 5 percent of the tunnel, in areas where the RMR rating is less than 30, e.g. where there is crushed rock, highly altered rock, and where the frictional gripping resistance for the TBM is inadequate. The use of W5 x 16 ribs, installed 4 feet on center, expanded against the rock, and preloaded by jacking, is also anticipated. Rock support between the ribs will be provided by 270 degrees of the same steel mat lagging, plus 2 inches of shotcrete infill between ribs placed as soon as practical behind the TBM.

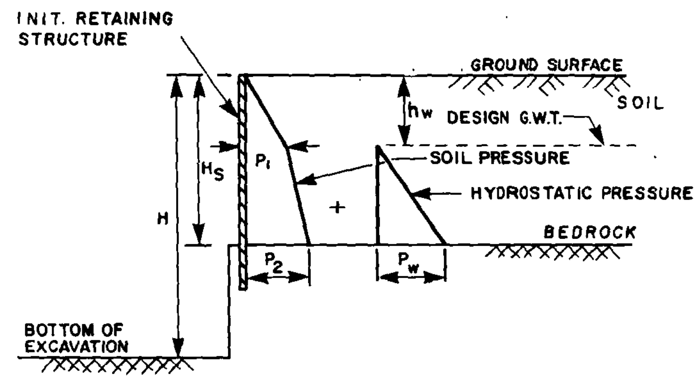
The rock loading on the tunnel for the various classes of rock has been determined using the Barton Q system. These ratings and the corresponding design values are presented in Table 5.3. The corresponding RMR range used in the Q system development of the rock load is also presented in this table along with the other design parameter values used for each support type.

DEWATERED SECTIONS



	H_S (ft)	h_w (ft)	P_2 (ksf)	G.S.E. (ft)
(NORTH) DEER ISLAND	131.2	131.2	7.4	125.0
(SOUTH) NUT ISLAND	95	95	6.2	126.2

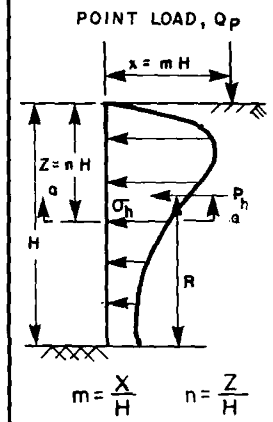
SECTIONS NOT DEWATERED



	H_S (ft)	h_w (ft)	P_1 (ksf)	P_2 (ksf)	P_w (ksf)	G.S.E. (ft)
(NORTH) DEER ISLAND	131.2	9.7	1.0	2.5	7.6	125.0
(SOUTH) NUT ISLAND	95	9.6	1.0	1.7	5.2	126.2

LATERAL PRESSURES DUE TO BUILDING OR CONSTRUCTION LOADS

POINT LOAD OR FOOTING LOAD



FOR $m \leq 0.4$:

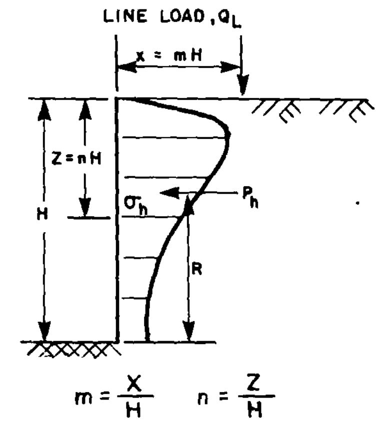
$$\sigma_h\left(\frac{H^2}{Q_P}\right)=\frac{0.28n^2}{(0.16+n^2)^3}$$

FOR $m > 0.4$:

$$\sigma_h\left(\frac{H^2}{Q_P}\right)=\frac{1.77m^2n^2}{(m^2+n^2)^3}$$

$m=\frac{X}{H}$ $n=\frac{Z}{H}$

LINE LOAD PARALLEL TO THE EXCAVATION



FOR $m \leq 0.4$:

$$\sigma_h\left(\frac{H}{Q_L}\right)=\frac{0.20n}{(0.16+n^2)^2}$$

$P_h = 0.55Q_L$

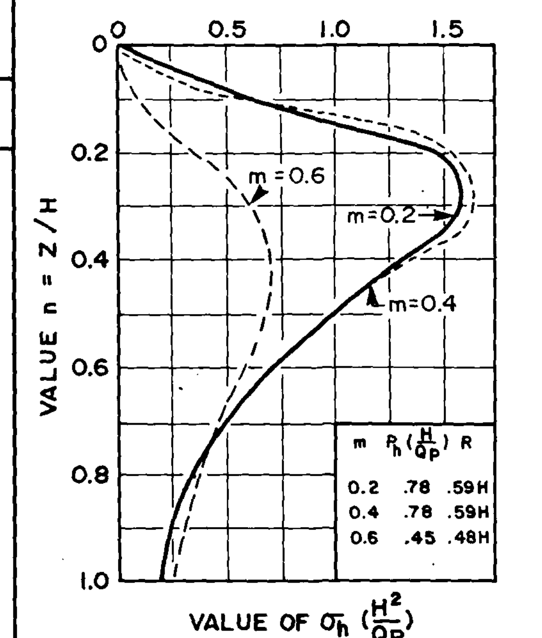
FOR $m > 0.4$:

$$\sigma_h\left(\frac{H}{Q_L}\right)=\frac{1.28m^2n}{(m^2+n^2)^2}$$

$$P_h=\frac{0.64Q_L}{(m^2+1)}$$

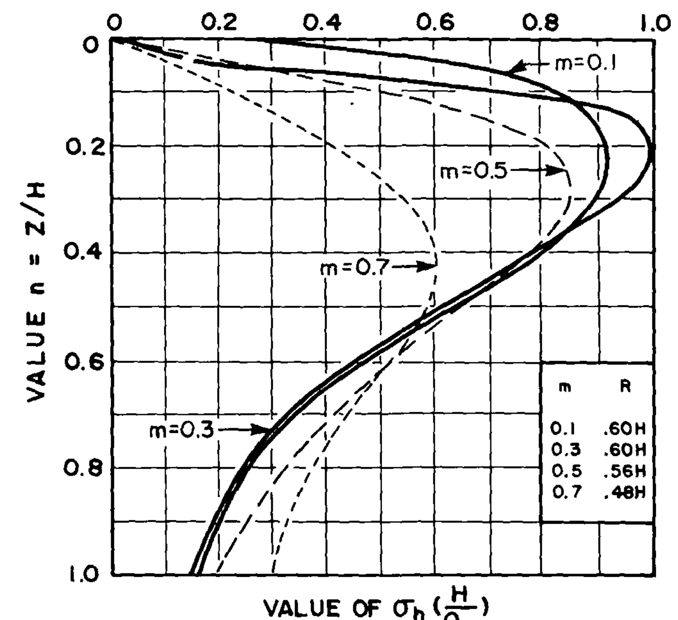
$m=\frac{X}{H}$ $n=\frac{Z}{H}$

SOLUTIONS FOR VARIOUS VALUES OF m & n



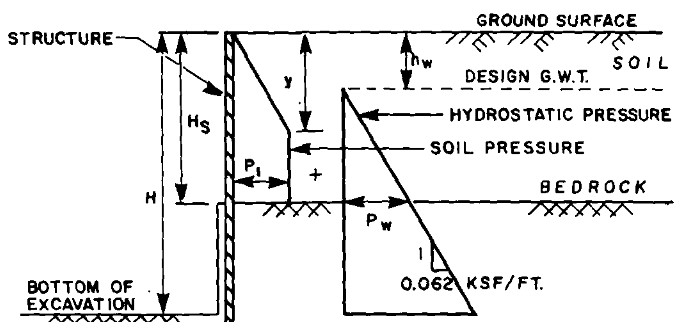
m	$P_h\left(\frac{H}{Q_P}\right)$	R
0.2	.78	.59H
0.4	.78	.59H
0.6	.45	.48H

SOLUTIONS FOR VARIOUS VALUES OF m & n



m	R
0.1	.60H
0.3	.60H
0.5	.56H
0.7	.48H

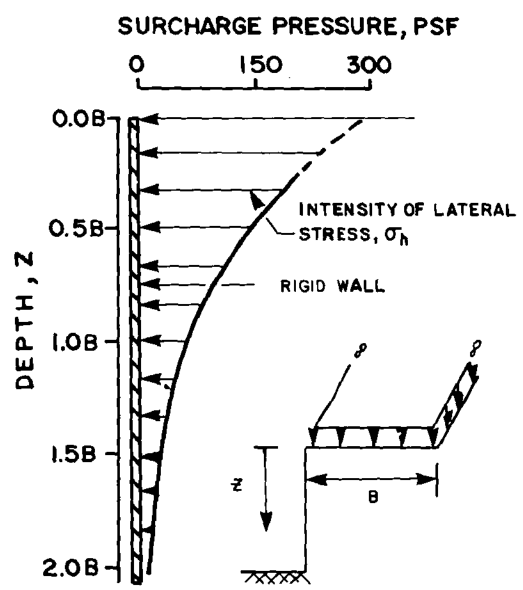
FINAL STRUCTURES



THE PRESSURE DIAGRAMS PRESENTED HEREIN ARE BASED ON SEVERAL SHAFT EXCAVATION DIAMETERS.

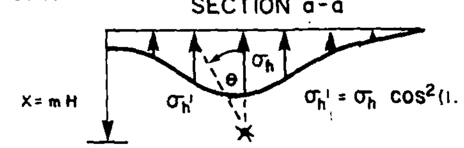
	D (ft)	H_S (ft)	y (ft)	h_w (ft)	P_1 (ksf)	P_w (ksf)	G.S.E. (ft)
DEER ISLAND (NORTH)	18 22 26 30	131.2	69.2 85.2 101.2 117.2	5.5	2.6 3.1 3.6 4.2	7.9	125.0
NUT ISLAND (SOUTH)	16 20 24	97.8	64 80 95	6.7	2.3 2.8 3.3	5.5	129.0

LATERAL PRESSURES DUE TO TRAFFIC & CONSTRUCTION EQUIPMENT



DISTRIBUTION OF HORIZONTAL PRESSURES IN PLAN

SECTION a-a



NOTE:

REFER TO FIGURE No. 5-1A FOR DEFINITIONS AND NOTES.

Sverdrup CORPORATION	In Association With Jacobs Associates Goldberg-Zoino & Associates and Delon Hampton & Associates	DP-5 INTER-ISLAND TUNNEL BOSTON HARBOR	LATERAL PRESSURE FOR NORTH AND SOUTH SHAFTS NOV. 1989 FIGURE No. 5.1

149119 FILE No. U-11305.1

MAKEPEACE

DEFINITIONS:

ksf = KIPS PER SQUARE FOOT.

psf = POUNDS PER SQUARE FOOT.

H = DEPTH FROM GROUND SURFACE TO BOTTOM OF EXCAVATION (ft.).

Hs = DEPTH TO TOP OF BEDROCK.

y = DEPTH TO TOP OF CONSTANT PRESSURE.

G.W.T. = GROUND WATER TABLE.

G.S.E. = GROUND SURFACE ELEVATION.

h_w = ASSUMED GROUNDWATER DEPTH FOR DESIGN: TEMPORARY STRUCTURES, STILLWATER STORM SURGE ELEVATIONS FOR 50-YEAR RETURN PERIOD (FEMA);
FOR THE YEAR 2100 (FEMA).

P_w = HYDROSTATIC PRESSURE BASED ON h_w

P_1, P_2 = CALCULATED LATERAL EARTH PRESSURES TO BE USED IN DESIGN OF INITIAL AND FINAL RETAINING STRUCTURES (kst) VALUES GIVEN ARE FOR THE SPECIFIC DEPTHS INDICATED.

P_h = TOTAL LATERAL FORCE CAUSED BY A POINT OR LINE LOAD (lbs. per ft. of wall).

Z = DEPTH FROM GROUND SURFACE TO SOME POINT BELOW (ft.)

Qp = SURCHARGE LOADING CONSIDERED AS A POINT LOAD AS FROM AN ISOLATED FOOTING OR CONSTRUCTION LOAD (lbs.).

Q_L = SURCHARGE LOAD CONSIDERED AS A LINE LOAD AS FROM A CONTINUOUS FOOTING PARALLEL TO THE EXCAVATION OR A CONSTRUCTION LOAD (lbs.).

X = DISTANCE FROM THE EXCAVATION TO THE APPROPRIATE SURCHARGE LOAD (ft.).

m,n, = DIMENSIONLESS DESIGN PARAMETERS.

σ_h = HORIZONTAL PRESSURE ON A VERTICAL PLANE AT SOME POINT AT OR BELOW THE GROUND SURFACE DUE TO A LINE OR POINT LOAD (psf.).

σ_h' = HORIZONTAL PRESSURE AT SOME POINT ALONG THE SUPPORT WALL DUE TO A POINT OR LINE LOAD SOME DISTANCE AWAY (psf.).

θ = ANGLE BETWEEN THE VERTICAL PLANE OF THE POINT LOAD PERPENDICULAR TO WALL, AND THE POINT ON THE WALL WHERE THE LATERAL PRESSURE IS DESIRED (DEGREES).

D = CONSTRUCTION SHAFT DIAMETER (FT.).

B = WIDTH (20–30 FEET) IN WHICH CONSTRUCTION OR TRAFFIC SURCHARGE IS TO BE CONSIDERED.

R = LOCATION OF RESULTANT (P_h) ABOVE THE BOTTOM OF EXCAVATION (FT.).

NOTES:

1. FOR DESIGN OF INITIAL EXCAVATION SUPPORT SYSTEMS CALCULATIONS MAY BE BASED ON THE ASSUMPTION THAT THE EXCAVATION IS DEWATERED, WHEN CONSTRUCTED WITH SOLDIER PILES AND LAGGING, OR WHEN POSITIVE METHODS OF DRAINING THE SOIL ARE USED.

2. FOR DESIGN OF FINAL SHAFT STRUCTURES, CALCULATIONS ARE BASED ON THE ASSUMPTION THAT AT REST (Ko) CONDITIONS WILL BE ATTAINED AND LATERAL SOIL PRESSURE WILL BE CONSTANT AT DEPTHS GREATER THAN APPROXIMATELY FOUR TIMES THE SHAFT EXCAVATION DIAMETER.

3. FOR DESIGN OF THE FINAL CUT AND COVER CONDUIT STRUCTURE AT NUT ISLAND, CALCULATION ARE BASED ON THE ASSUMPTION THAT AT REST (Ko) CONDITIONS WILL BE ATTAINED.

4. LOADS FROM NEARBY STRUCTURES ARE TO BE DETERMINED BY THE CONTRACTOR AND REVIEWED BY THE ENGINEER. STRUCTURES OUTSIDE A 1:1 INFLUENCE LINE GENERALLY NEED NOT BE CONSIDERED.

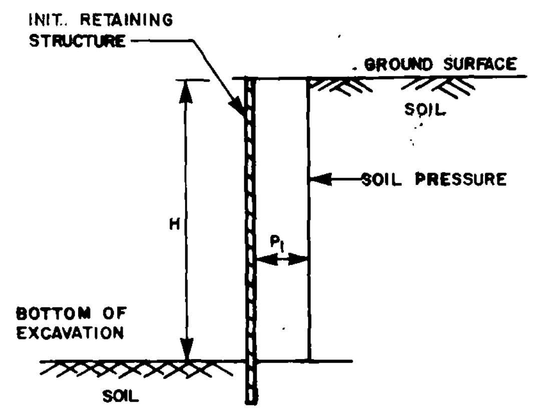
5. FOR EVALUATION OF THE LATERAL PRESSURE UNDER A GIVEN SET OF CONDITIONS, LATERAL PRESSURE FROM SURCHARGE SHALL BE SUPERIMPOSED ON LATERAL PRESSURE DUE TO SOIL AND WATER.

6. IF ANY LOADINGS OCCUR WHICH ARE NOT DESCRIBED HEREIN, ADEQUATE MEASURES MUST BE TAKEN FOR THESE CONDITIONS SUBJECT TO REVIEW BY THE ENGINEER.

7. THE FIGURES SHOWING ADDITIONAL LATERAL PRESSURES DUE TO SURCHARGE LOADS ARE BASED ON THOSE IN "LATERAL SUPPORT SYSTEMS AND UNDERPINNING DESIGN FUNDAMENTALS. VOL.2," BY GOLDBERG ET AL.,1976.

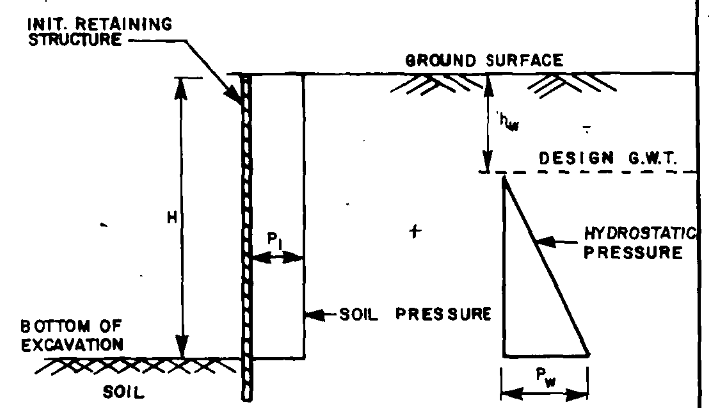
Sverdrup CORPORATION	In Association With Jacobs Associates Goldberg-Zoino & Associates and Delon Hampton & Associates	DP-5 INTER-ISLAND TUNNEL BOSTON, HARBOR	NOTES AND DEFINITIONS FOR FIGURES 5.1,5.2 & 5.3 NOV. 1989 FIGURE No.5.1 A

DEWATERED SECTIONS



	H (ft)	h_w (ft)	P_1 (ksf)	G.S.E. (ft.)
(SURGE STRUCTURE) DEER ISLAND	32.0	32.0	0.80	125.0

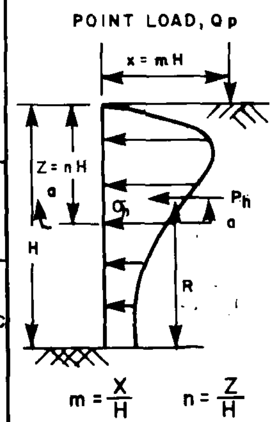
SECTIONS NOT DEWATERED



	H (ft.)	P_1 (ksf)	Pw (ksf)	h_w (ft.)	G.S.E. (ft.)
DEER ISLAND	32.0	0.52	1.39	9.7	125.0

LATERAL PRESSURES DUE TO BUILDING OR CONSTRUCTION LOADS

POINT LOAD OR FOOTING LOAD



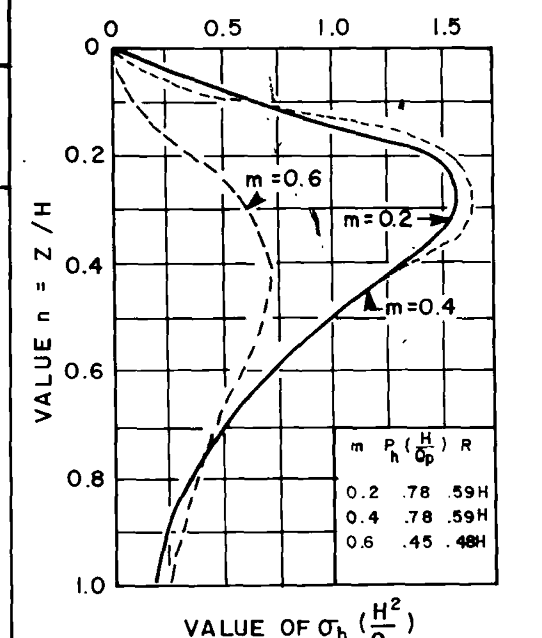
FOR $m \leq 0.4$:

$$\sigma_h \left(\frac{H^2}{Q_p}\right) = \frac{0.28n^2}{(0.16+n^2)^3}$$

FOR $m > 0.4$:

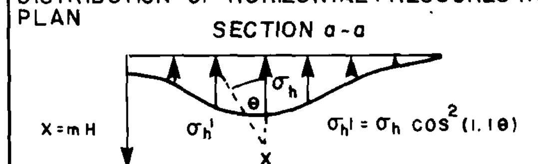
$$\sigma_h \left(\frac{H^2}{Q_P}\right) = \frac{1.77m^2n^2}{(m^2+n^2)^3}$$

SOLUTIONS FOR VARIOUS VALUES OF m & n

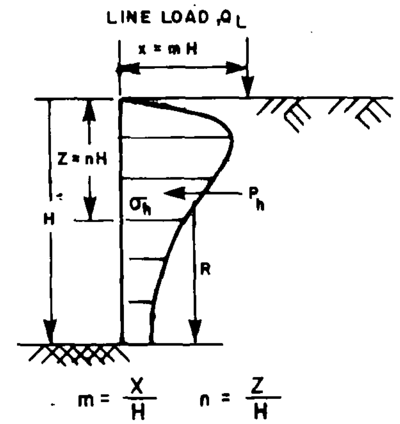


m	$P_h\left(\frac{H}{Q_p}\right)$	R
0.2	.78	.59H
0.4	.78	.59H
0.6	.45	.48H

DISTRIBUTION OF HORIZONTAL PRESSURES IN PLAN



LINE LOAD PARALLEL TO THE EXCAVATION



FOR $m \leq 0.4$:

$$\sigma_h \left(\frac{H}{Q_L}\right) = \frac{0.20n}{(0.16+n^2)^2}$$

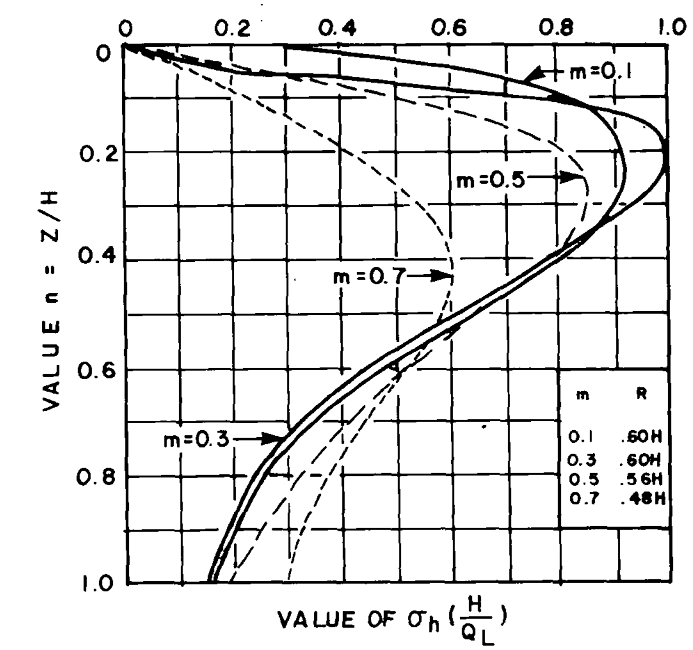
$$P_h = 0.55Q_L$$

FOR $m > 0.4$:

$$\sigma_h \left(\frac{H}{Q_L}\right) = \frac{1.28m^2n}{(m^2+n^2)^2}$$

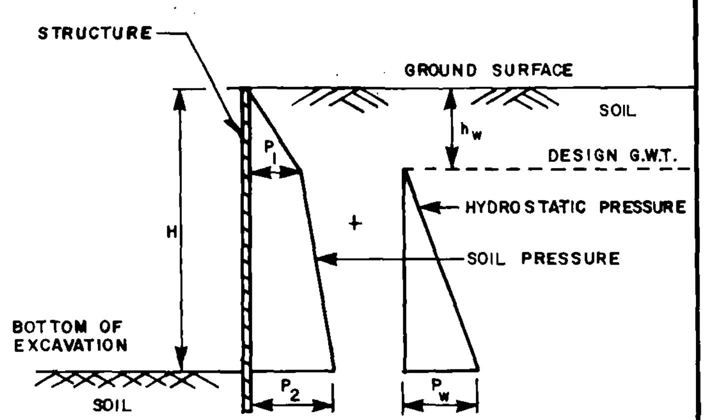
$$P_h = \frac{0.64Q_L}{(m^2+1)}$$

SOLUTIONS FOR VARIOUS VALUES OF m & n



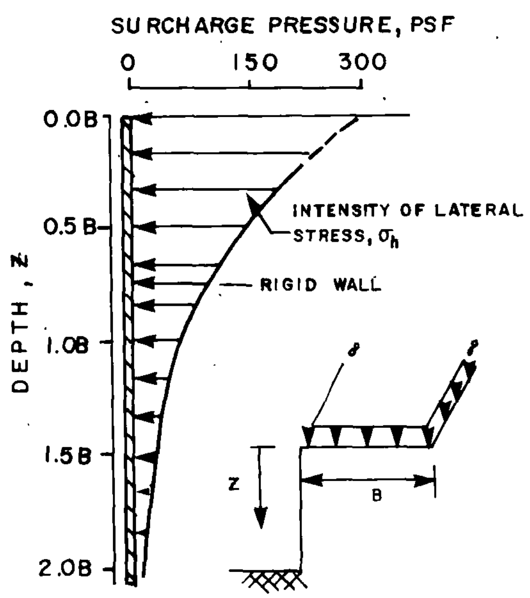
m	R
0.1	.60H
0.3	.60H
0.5	.56H
0.7	.48H

FINAL STRUCTURES



	H (ft.)	h_w (ft.)	P_1 (ksf)	P_2 (ksf.)	P_w (ksf)	G.S.E. (ft.)
DEER ISLAND (SURGE STRUCTURE)	32.0	5.5	0.5	1.2	1.65	125.0

LATERAL PRESSURES DUE TO TRAFFIC & CONSTRUCTION EQUIPMENT

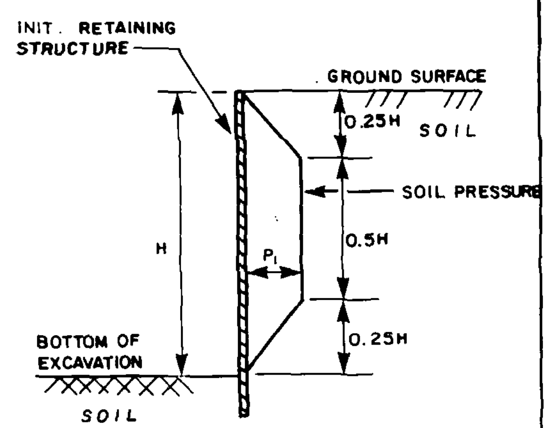


NOTES:

1. THE PRESSURE DIAGRAMS PRESENTED HEREIN ARE BASED ON A MAXIMUM EXCAVATION DEPTH OF 32 FEET. THESE DIAGRAMS MUST BE REVISED IF THE EXCAVATION DEPTH WILL BE EXCEEDED.
2. REFER TO FIGURE No. 5-1A FOR DEFINITIONS AND NOTES.

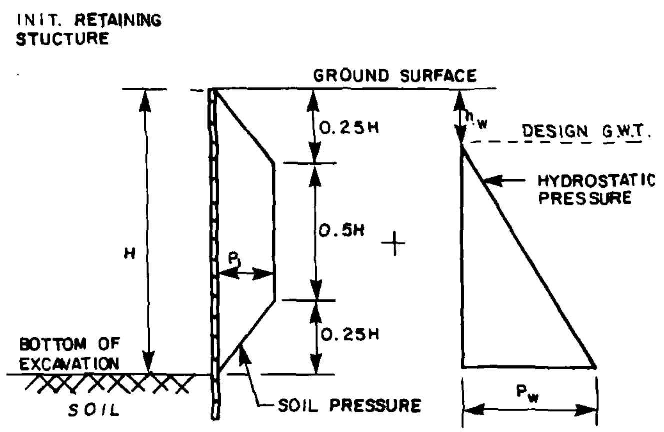
Sverdrup CORPORATION	In Association With Jacobs Associates Goldberg-Zoino & Associates and Delon Hampton & Associates	DP-5 INTER-ISLAND TUNNEL BOSTON HARBOR	LATERAL PRESSURE FOR SURGE STORAGE STRUCTURE AT DEER ISLAND
			NOV. 1989
			FIGURE No. 5.2

DEWATERED SECTIONS



	H (ft)	h_W (ft)	P_1 (ksf)	G.S.E. (ft)
(SOUTH) NUT ISLAND	34.2	34.2	1.4	126.2

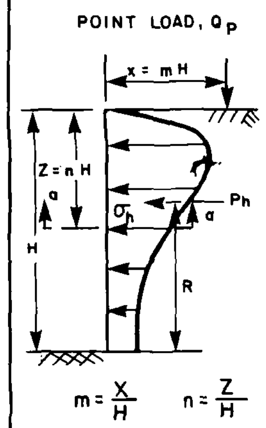
SECTIONS NOT DEWATERED



	H (ft)	P_1 (ksf)	P_W (ksf)	h_W (ft)	G.S.E. (ft)
(SOUTH) NUT ISLAND	34.2	1.1	1.5	9.6	126.2

LATERAL PRESSURES DUE TO BUILDING OR CONSTRUCTION LOADS

POINT LOAD OR FOOTING LOAD



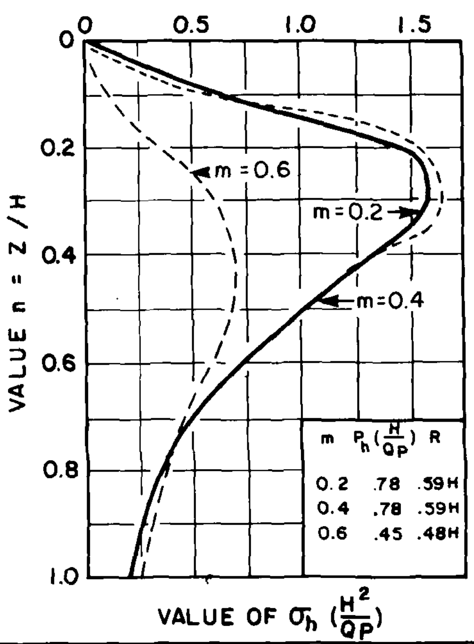
FOR $m \le 0.4$:

$$\sigma_h \left(\frac{H^2}{Q_P}\right) = \frac{0.28n^2}{(0.16+n^2)^3}$$

FOR $m > 0.4$:

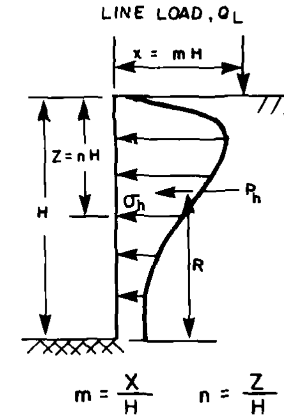
$$\sigma_h \left(\frac{H^2}{Q_P}\right) = \frac{1.77m^2n^2}{(m^2+n^2)^3}$$

SOLUTIONS FOR VARIOUS VALUES OF m & n



m	$P_h\left(\frac{H}{Q_P}\right)$	R
0.2	.78	.59H
0.4	.78	.59H
0.6	.45	.48H

LINE LOAD PARALLEL TO THE EXCAVATION



FOR $m \le 0.4$:

$$\sigma_h \left(\frac{H}{Q_L}\right) = \frac{0.20n}{(0.16+n^2)^2}$$

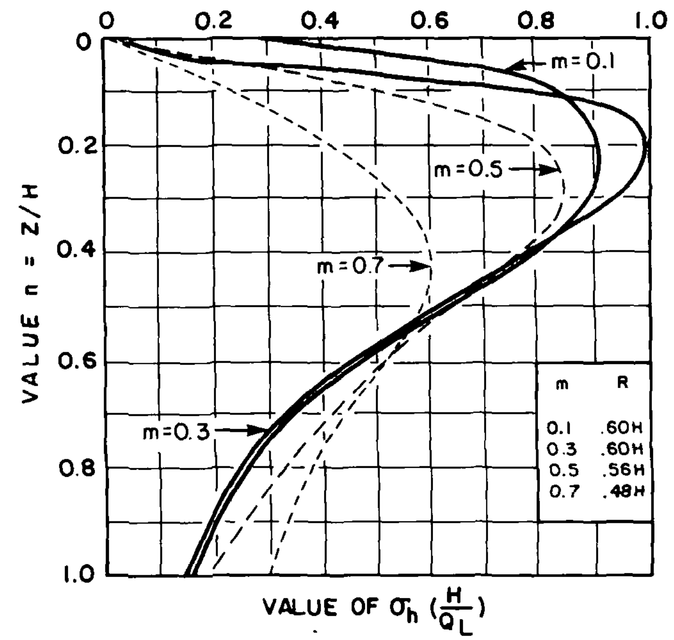
$$P_h = 0.55Q_L$$

FOR $m > 0.4$:

$$\sigma_h \left(\frac{H}{Q_L}\right) = \frac{1.28m^2n}{(m^2+n^2)^2}$$

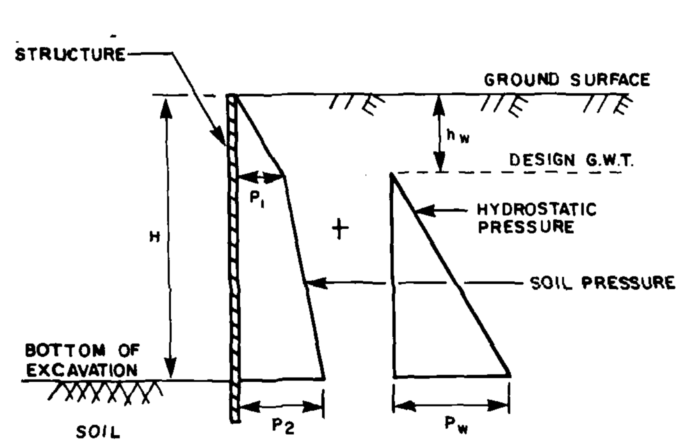
$$P_h = \frac{0.64Q_L}{(m^2+1)}$$

SOLUTIONS FOR VARIOUS VALUES OF m & n



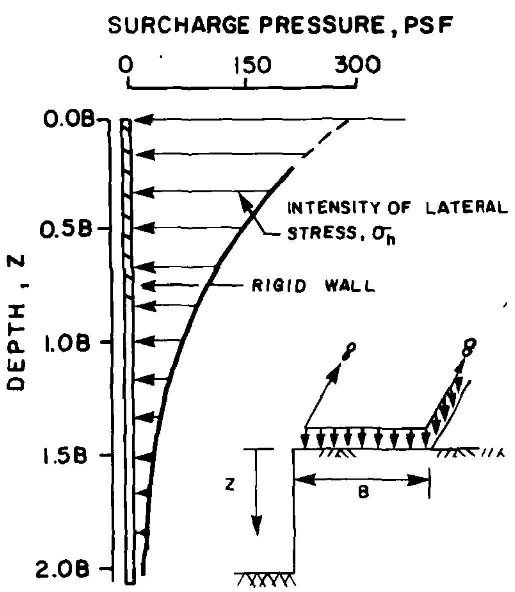
m	R
0.1	.60H
0.3	.60H
0.5	.56H
0.7	.48H

FINAL STRUCTURES

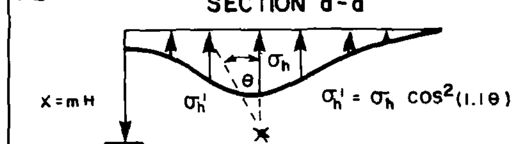


	H (ft)	h_W (ft)	P_1 (ksf)	P_2 (ksf)	P_W (ksf)	G.S.E. (ft)
(SOUTH) NUT ISLAND	37.0	6.7	0.4	1.4	1.9.	129.0

LATERAL PRESSURES DUE TO TRAFFIC & CONSTRUCTION EQUIPMENT



DISTRIBUTION OF HORIZONTAL PRESSURES IN PLAN



NOTES:

1. THE PRESSURE DIAGRAMS PRESENTED HEREIN ARE BASED ON A MAXIMUM EXCAVATION DEPTH OF 37.0 FEET. THESE DIAGRAMS MUST BE REVISED IF THE EXCAVATION DEPTH WILL BE EXCEEDED.
2. REFER TO FIGURE No. 5-1A FOR DEFINITIONS AND NOTES.

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DP-5
INTER-ISLAND TUNNEL
BOSTON HARBOR

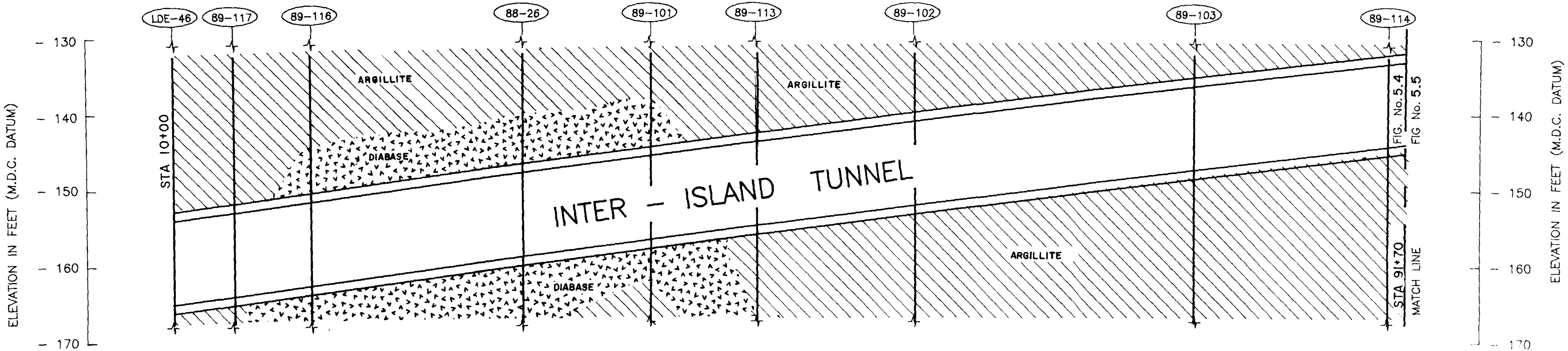
LATERAL PRESSURE FOR CONNECTING CONDUIT AT SOUTH SHAFT

NOV. 1989

FIGURE No. 5.3

149119 FILE No. U-11305.1

MAKEPEACE



	BORING	LDE-46	89-117	89-116	88-26	89-101	89-113	89-102	89-103	89-114
ZONE 15' ABOVE TUNNEL CROWN	RMR	55	43	50	56	34	56	68	65	49
	RQD	100	81	57	100	28	100	99	99	42
	WATER INFLOW	WET	WET	DRIPPING	FLOWING	WET	WET	DAMP	DAMP	WET
	ROCK STRENGTH	VERY HIGH	VERY HIGH	HIGH	HIGH	MODERATE	VERY HIGH	VERY HIGH	VERY HIGH	HIGH
TUNNEL HORIZON	RMR	60	50	45	59	54	43	68	65	45
	RSR	79	58	58	–	46	61	71	79	52
	RQD	100	80	97	100	95	93	100	99	79
	WATER INFLOW	WET	WET	DRIPPING	DRIPPING	WET	WET	DAMP	WET	WET
	ROCK STRENGTH	VERY HIGH	MODERATE	VERY LOW	HIGH	VERY HIGH	VERY HIGH	VERY HIGH	HIGH	LOW
ZONE 15' BELOW TUNNEL INVERT	RMR	60	42	38	52	53	60	56	65	68
	RQD	100	86	41	90	100	87	99	83	96
	WATER INFLOW	WET	WET	DRIPPING	DRIPPING	WET	DAMP	WET	DAMP	DAMP
	ROCK STRENGTH	VERY HIGH	HIGH	MODERATE	MODERATE	HIGH	MODERATE	VERY HIGH	VERY HIGH	HIGH

ROCK STRENGTH

STANDARDIZED POINT LOAD INDEX, I_{50}	DESCRIPTION
<145	VERY LOW
146-290	LOW
291-580	MODERATE
581-1160	HIGH
>1160	VERY HIGH

WATER INFLOW

INFLOW RATE LITER/MIN/10 METERS	DESCRIPTION
0	DRY
<10	DAMP
10-25	WET
25-125	DRIPPING
>125	FLOWING

VERTICAL
0' 5' 10' 20'
0' 250' 500' 1000'
HORIZONTAL

NOTES:

1. RMR – ROCK MASS RATING (NO ADJUSTMENT FOR TBM)
2. RSR – ROCK STRUCTURE RATING WITH ADJUSTMENT FACTOR FOR TBM EXCEPT AT LDE-46 & 89-117
3. PT. LOAD DATA IS CORRECTED TO STANDARD 50 mm DIAMETER
4. RQD–ROCK QUALITY DESIGNATION

FILE NO. 11305.1

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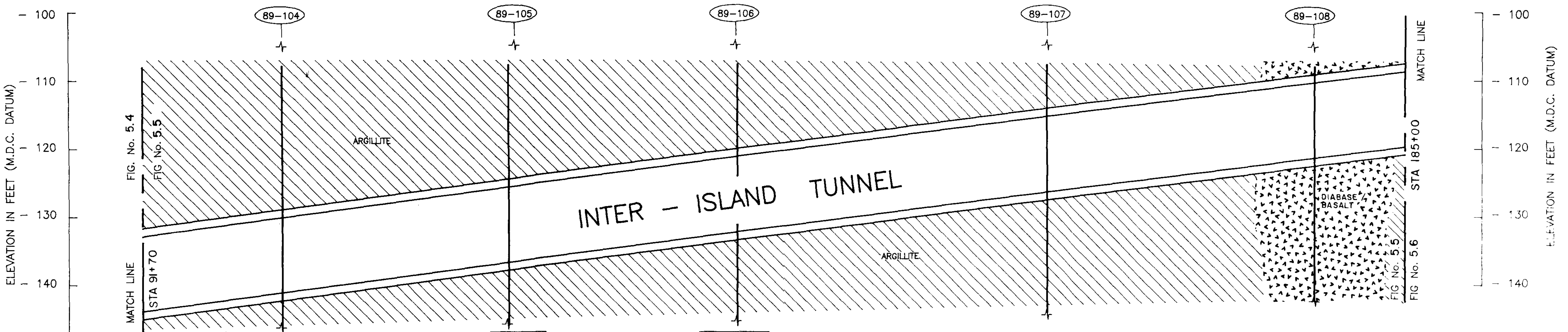
BOSTON HARBOR

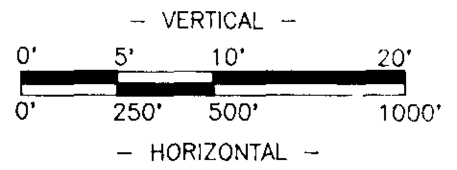
ROCK QUALITY
DATA

NOV. 1989

FIGURE No 5.4



	BORINGS	89-104	89-105	89-106	89-107	89-108
ZONE 15' ABOVE TUNNEL CROWN	RMR	53	52	53	62	47
	RQD	95	88	100	65	54
	WATER INFLOW	WET	DRIPPING	WET	DAMP	WET
	ROCK STRENGTH	HIGH	VERY HIGH	VERY HIGH	VERY HIGH	VERY HIGH
TUNNEL HORIZON	RMR	53	52	52	62	32
	RSR	62	70	74	68	39
	RQD	92	91	84	51	50
	WATER INFLOW	DAMP	WET	WET	DAMP	DAMP
	ROCK STRENGTH	HIGH	HIGH	VERY HIGH	VERY HIGH	VERY LOW
ZONE 15' BELOW TUNNEL INVERT	RMR	44	59	63	49	49
	RQD	87	88	94	69	55
	WATER INFLOW	WET	DAMP	WET	DAMP	WET
	ROCK STRENGTH	DRIPPING	HIGH	VERY HIGH	HIGH	VERY HIGH



REFER TO FIGURE No. 5·4 FOR NOTES.

FILE NO. 11305.1

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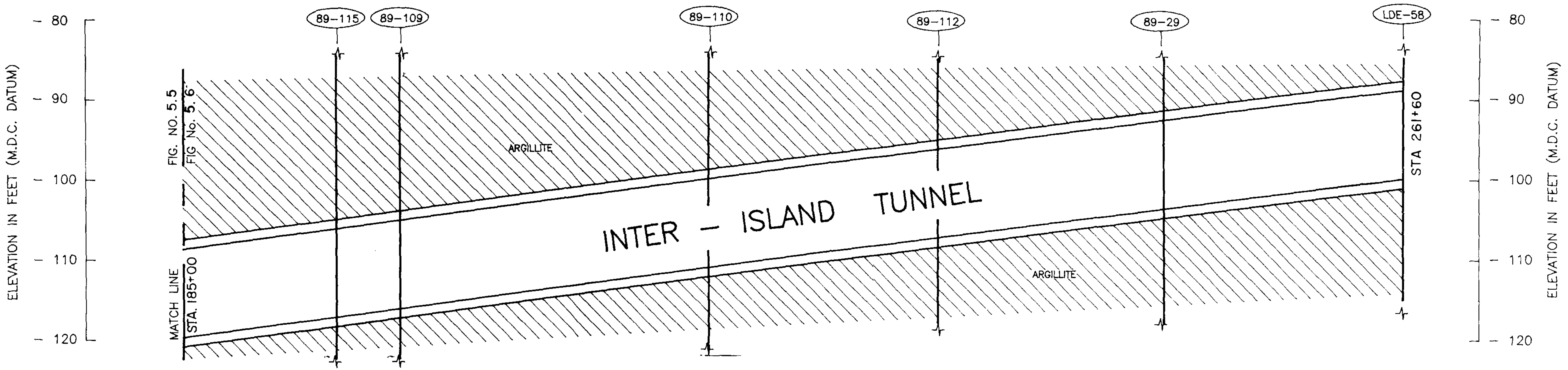
INTER – ISLAND TUNNEL
BOSTON HARBOR

ROCK QUALITY DATA

NOV. 1989

FIGURE No. 5.5



	BORING	89-115	89-109	89-110	89-112	88-29	LDE-58
ZONE 15' ABOVE TUNNEL CROWN	RMR	35	9	53	62	70	72
	RQD	66	50	98	84	94	98
	WATER INFLOW	DAMP	DRIPPING	WET	WET	DAMP	WET
	ROCK STRENGTH	VERY LOW	VERY LOW	HIGH	HIGH	MODERATE	VERY HIGH
TUNNEL HORIZON	RMR	30	0	38	48	67	72
	RSR	54	30	50	64	100	99
	RQD	56	6	89	61	84	95
	WATER INFLOW	WET	DRIPPING	WET	WET	DAMP	WET
	ROCK STRENGTH	VERY LOW	VERY LOW	VERY LOW	HIGH	MODERATE	VERY HIGH
ZONE 15' BELOW TUNNEL INVERT	RMR	32	17	48	62	73	70
	RQD	61	55	65	75	98	99
	WATER INFLOW	WET	DRIPPING	WET	WET	DAMP	WET
	ROCK STRENGTH	VERY LOW	VERY LOW	HIGH	HIGH	HIGH	VERY HIGH

– VERTICAL –
0' 5' 10' 20'
0' 250' 500' 1000'
– HORIZONTAL –

REFER TO FIGURE No 5.4 FOR NOTES

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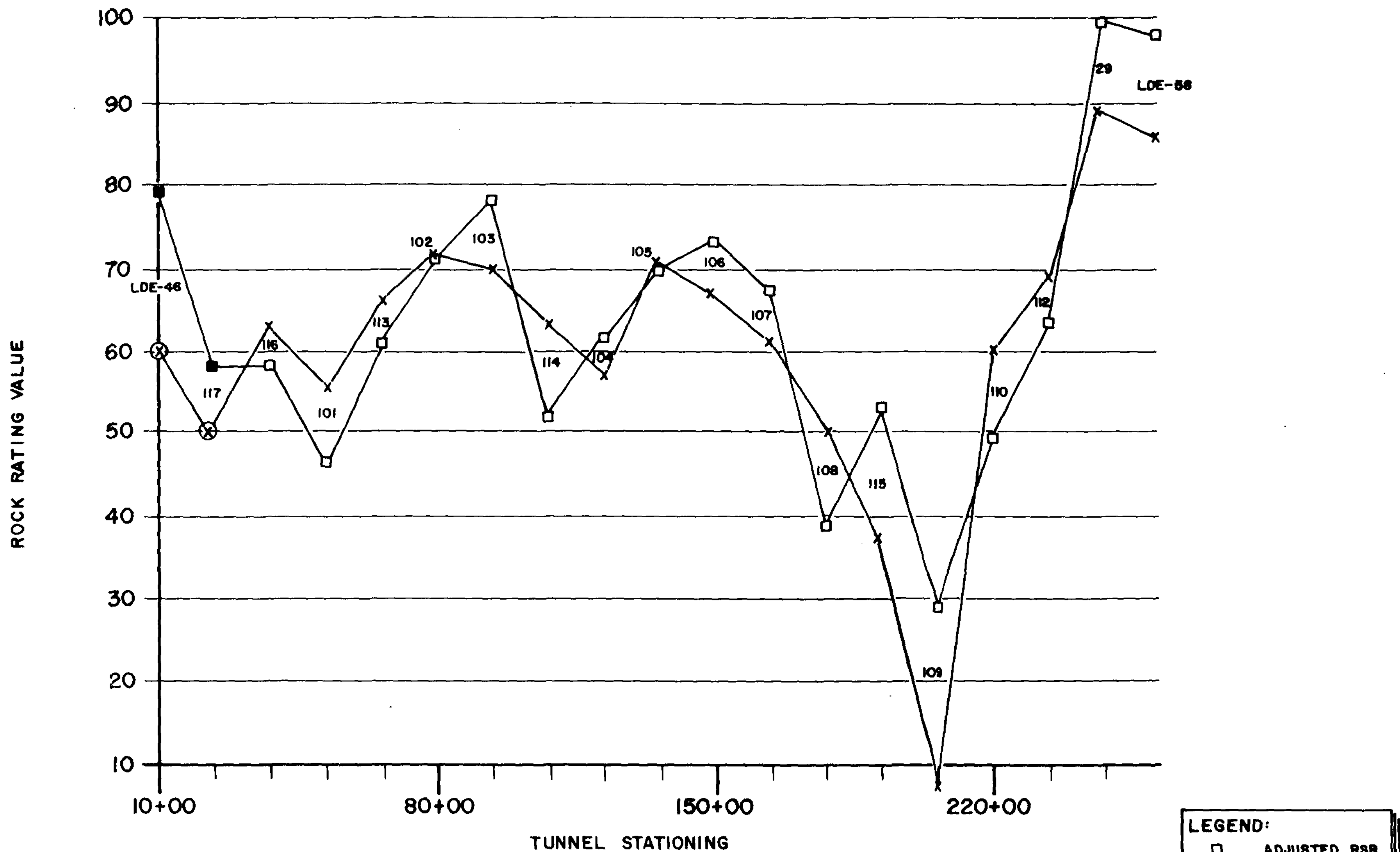
INTER - ISLAND TUNNEL
BOSTON HARBOR

ROCK QUALITY DATA

NOV. 1989

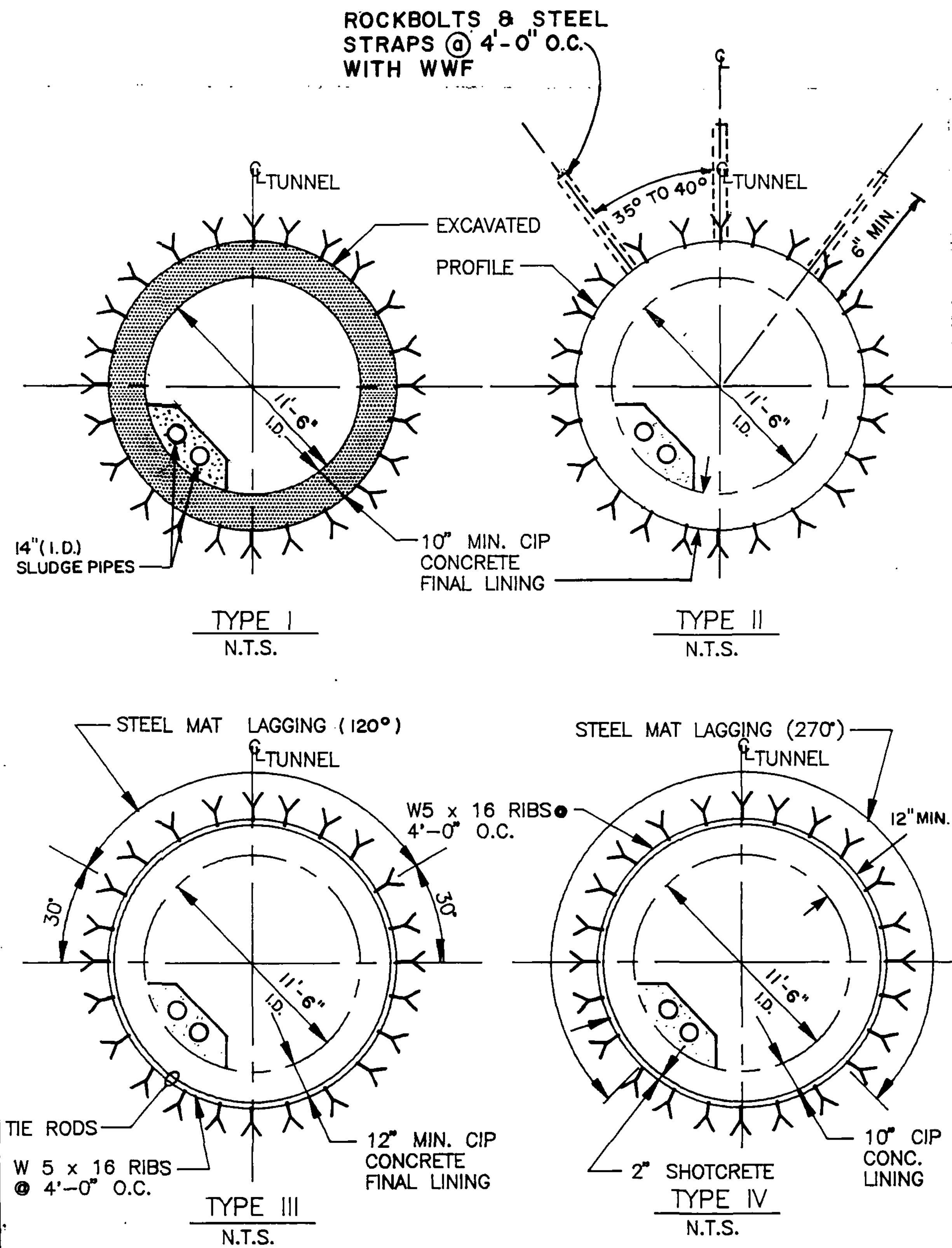
FIGURE No. 5.6

FILE No. U-11305.1



NOTE: NO ADJUSTMENT MADE FOR ROCK RATING VALUES FOR TUNNEL IN BELL-OUT AREA (LDE-46 AND 117)

Sverdrup CORPORATION	In Association With Jacobs Associates Goldberg-Zoino & Associates and Delon Hampton & Associates	DP-5 INTER ISLAND TUNNEL BOSTON HARBOR	ROCK RATINGS ALONG TUNNEL ALIGNMENT NOV. 1989 FIGURE No. 5.7



NOTE:

SEE CONTRACT DRAWINGS E1 S-01 AND E1 S-02 FOR DETAILS OF SUPPORT TYPES AND 14"(I.D.) SLUDGE PIPES.

TUNNEL SUPPORT SYSTEMS
TYPES I, II, III, & IV

NOV. 1989

FIGURE No.5.8

DP-5
INTER-ISLAND TUNNEL
BOSTON HARBOR

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CORPORATION

FILE No. U-11305.1

TABLE 5.3

TUNNEL ROCK LOADING

RMR Rating Range	Support Type	Barton System Rating Q	Jr	Rock Ht. Ft.	Rock Load psf	Modulus of Deformation ksi	Poisson Ratio	K_o
>73 to 100	I	75	3.0	1.8	300	5,000	.25	.33
>57 to 73	II	5.5	2.0	6.7	1,100	650	.30	.43
>30 to 57	III	0.61	1.0	27.0	4,500	200	.32	.47
<30	IV	0.14	1.0	50.0	8,200	60	.34	.52

5.45 Groundwater Control

As the intact rock is relatively impervious, groundwater will infiltrate the tunnel via joints, cracks, shear zones, or faults. If control of this water is inadequate, stability problems and difficulties could arise. For this tunnel, the problems may be related to:

- High volumes of water that are difficult to handle and that can erode the joint filling materials, thereby destabilizing the rock blocks.
- Water pressure that acts on joint surfaces, reduces the effective stress and destabilizes rock blocks, even if the flows are small.
- Water chemistry, e.g., the salinity could cause corrosion of excavation equipment.
- Water so deep in the invert that it interferes with TBM and mucking activities.
- Water pressure around the tunnel causing kaolinized and/or altered argillite to squeeze into the tunnel. This is a possibility only if large zones of kaolinized or altered argillite are encountered.

The groundwater inflow in the tunnel has been estimated using data from packer tests that were conducted during both the 1988 and 1989 marine exploration programs and data reviewed regarding the measured water inflow into the Main Drainage Tunnel during its construction in 1956 and 1957 (Hellstrom, 1989).

The data from the packer testing in the borings have been reduced to the permeability values shown on Figures 5.4 through 5.6. These values typically range from $\leq 0.1 \times 10^{-5}$ to 50×10^{-5} cm/sec. along the alignment.

Estimates of flow into the proposed tunnel were based on a direct relation of packer test surface area to tunnel surface area. This approach is approximate and assumes a hydraulic gradient (i) of 1 and that Darcy's Law is valid. A comparison of the total inflow estimate (56 gpm/1,000 feet) for the proposed tunnel, based on this approximate approach, with an estimate (66 gpm/1,000 feet) based on the inflow data collected during construction of the Main Drainage Tunnel (Hellstrom, 1989), after adjustment for the difference in surface area of the tunnels, indicates that the results are comparable.

In several cases where poor quality rock (RQD less than 50 percent) was encountered, the water inflow was low. This was probably due to clay in-filling of the joints.

Along the alignment, a high inflow of water of approximately 200 to 300 gpm/1,000 feet of tunnel, can be expected from the southern end of Deer Island to the northern approach to Long Island. Similar high inflows can be expected in the vicinity of boring 89-106.

More moderate inflows of 50 to 100 gpm/1,000 feet of tunnel can be expected along the alignment just south of Long Island. A lesser inflow of 25 to 50 gpm/1,000 feet is expected in the section from the bend southward.

In other sections of the alignment the groundwater inflow is expected to be less than 25 gpm/1,000 feet.

Potential groundwater inflow problems can be identified prior to excavation by probe drilling in advance of the excavation face. However, the requirement of carrying an advance bore hole at all times would cause substantially lower progress and increase costs. It is probably advisable to probe ahead in identified critical areas. Consequently, it is proposed that probe drilling be performed at the probable fault areas indicated on the subsurface profile (Figures 4.6 through 4.8) and other areas of concern to be designated by the CM or Contractor.

Based on the evaluation of groundwater inflow data for tunnels constructed in the same rock formation around Boston and the packer test results along the alignment, total inflows of approximately 1,900 to 3,200 gpm are expected during excavation. The most efficient way of handling the water inflow may be to accept the flow during excavation and then drain it to the North Shaft by gravity. A tunnel invert slope of 0.25835 percent has been designed to facilitate gravity drainage of the expected inflows and maintain water depths to manageable levels. With a lesser grade, it might be necessary to use a series of sumps from the heading to the shaft, pumping from one to the next. In a bored tunnel, it is difficult to excavate such sumps, as the drill-and-blast excavation requires substantial protection for installed power cables, ventilation pipes, and other facilities and thus must be performed during TBM shutdowns.

Though the overall average pumping is expected to be manageable, local inflows at the heading may be severe enough to affect TBM operations. If the problem is foreseen during the progress of the tunneling operation, it might be possible to overcome by cement or chemical grouting techniques ahead of the tunnel face. If the problem occurs unexpectedly, a quick-set cement-chemical or acrylate grout may be effective in halting the flow.

It should also be noted that local flows may affect concrete lining placement. In such an event, the Contractor will have to fissure grout such areas in order to reduce water inflow to an extent that it can be diverted away from the pour area. Where ponding, panning, or other means can be used to keep the concrete area free from standing water, fissure grouting is not essential.

Note that borings 89-110 and 89-114 are within the limits of the proposed tunnel excavation and borings 89-106, 89-108 and 89-116 are approximately 16 to 25 feet off the center line of the proposed alignment. These holes along with all the others were grouted on completion. However, if the grouting was not fully effective, seepage could occur at those locations that are intersected by the tunnel. The Contractor should therefore be prepared for such a possibility.

5.46 Design of Permanent Lining

The LDE identified three types of permanent liners: cast-in-place concrete (CIPC), precast concrete segmental lining, and a composite of a CIPC lining and precast concrete segments.

The primary advantage of precast concrete segments is that the casting and curing of the concrete in a yard produces a stronger, more dense and water-resistant concrete than can possibly be placed in the tunnel. However, segments have the following drawbacks:

A. Heavy erection equipment is required to handle the heavy segments and this results in more difficulty in the limited space of the tunnel. This is particularly true in a medium size tunnel of significant length such as this one.

B. Precast segments are prone to leak through cracks caused by improper handling (during transportation and/or setting) and TBM jacking loads.

C. While gaskets may help seal the segments, it may be difficult to keep the gaskets from ripping or contamination when handling and placing segments.

CIPC lining is superior from the viewpoint of hydraulic head friction loss and for sealing off groundwater infiltration by grouting methods. Furthermore, CIPC is believed to at least be equal in overall costs to the unbolted precast segmental lining due to the much slower TBM progress to be expected with that system. Its main disadvantage is the concrete placement time constraint which depends on the set time and haul distance within the tunnel.

Nevertheless, CIPC liners have already proved to be trouble-free for about 30 years on the Boston Main Drainage Tunnel and for 80 years on water supply tunnels in New York City. Given the criteria of a 100-year design life and desired zero operational downtime, a CIPC lining with contact grouting is considered to be the best option for this tunnel.

Circumferential shrinkage cracks at more or less regular intervals of 20 to 30 feet should be expected in a CIPC liner. Most of these cracks will be surficial and not extend through the lining. Others will undoubtedly show signs of leakage, but can be sealed by grouting if the leakage is excessive. It is believed that these cracks will not be harmful to the service life of the tunnel, especially as shrinkage is to a considerable extent almost reversible. Therefore, no special measures, e.g. longitudinal crack-control reinforcement steel, mandatory spacing of vertical construction joints, or waterstops in construction joints, are required to control them. Experience shows that shrinkage-control reinforcing steel is only moderately successful and is quite expensive.

Steel fibers can reliably inhibit cracking and improve material deterioration from shrinkage and/or thermal stresses by limiting the width of CIPC shrinkage-temperature cracks. However, due to high costs and placement difficulties, it is the PDE's opinion that its use for this tunnel is not warranted. Consequently, it is proposed that the tunnel lining be unreinforced except in areas where substantial zones of kaolinized argillite or fractured rock are encountered.

Where a substantial zone of kaolinized argillite or a fault zone with clayey gouge is encountered, the concern is that the internal hydraulic pressure will cause the concrete lining to expand and fail. This is because both the kaolinized argillite (a stiff clay) and the fault zones have much lower subgrade moduli than rock. In these areas, type IV support (refer to Figure 5.8) will be installed and the CIPC liner will be reinforced (as shown on Contract Drawing No. E1 S-01 and E1 S-02) with steel to:

1. Reduce crack width from internal pressure, and

2. Strengthen the lining to resist bending moments caused by vertical rock loads.

The circumferential lining reinforcement has been chosen to resist the design condition of maximum internal water pressure and assumed zero external hydrostatic pressure.

Ground successfully excavated as Type III support, may subsequently show signs of distress prior to placement of final lining. Based on field observations and judgment, the CM may require installation of steel reinforcement. In this case, payment for the reinforcement steel will be at the unit price established in the contract for the reinforcement required in type IV support ground.

5.47 Long Island Drop Shaft

The Long Island drop shaft will be constructed at Station 80+30. It will consist of a 12-inch (I.D.) ductile iron pipe grouted into a hole that will have minimum excavation diameters of 24 and 20 inches in the soil and rock, respectively. Drilling through overburden will be performed using slurry (drilling mud) or other appropriate means of temporary support. The shaft will probably be constructed prior to tunnel excavation.

Boring 90-118 was performed at the proposed drop shaft location. The boring indicates that the subsurface conditions consist of (in descending order): 7.5 feet of fill; 13 feet of gravelly sand; 15.5 feet of silty clay; 54.3 feet of till; all underlain by argillite.

5.50 SEISMIC DESIGN CONSIDERATIONS

Portions of Weston Geophysical's May 1989 report entitled, "Seismic Design Recommendations" and the LDE's May 1989 report entitled, "Conceptual Design - Tunnel Seismic Assessment and Design Criteria" were reviewed. In addition, Adhya's (1989) chapter on "Underground Structures through Seismic Zones" was also reviewed.

For the design of the DP-5 tunnel, two earthquakes have been defined in the LDE's document: The Maximum Design Earthquake (MDE), which has a mean return period of several thousand years, and the Operating Design Earthquake (ODE) which has a mean return period of several hundred years. Peak ground motion for the ODE is specified as 0.125g acceleration and 2 inches/second velocity. Peak ground motion for the MDE is specified as 0.25g acceleration and 4 inches/second velocity.

5.51 Shafts

Reports of damage to shafts due to earthquake effects are few. Based on the limited information available, Schmidt and Richardson (1989) draw the following conclusions:

- Shafts are inherently more resistant to earthquake effects than are surface structures.
- The effect of earthquakes on shafts diminishes with depth. Shaft damage near the surface, when it occurs, is often caused by shifting of earth or liquefaction.
- The damage typically experienced is predominantly circumferential cracking, with less common cracking in axial and diagonal directions.
- Though fallout of plaster and loosened brick has been observed, shaft structures tend to resist collapse.
- No shaft liner distress has been reported for Modified Mercalli intensities below VIII.

The soil at the proposed shaft locations is not expected to fail during an earthquake. Furthermore, as indicated in Section 4.50, a maximum credible event at Cape Ann (which poses the greatest threat to Boston) of intensity IX would cause a general intensity effect in the Boston region with intensity level VIII.

Based on the above information, it has been concluded that seismic criteria do not control the design of the proposed shafts.

5.52 Tunnel

The response of an underground structure to shaking will be influenced by the shape, depth of excavation, the properties of soil and rock mass around the opening, and the intensity of ground motion. Based on data compiled by Dowding and Rozen (1978), no damage should be experienced by an underground structure in rock if the particle velocity due to ground motion is below 20 cm/sec.

Furthermore, the following observations have been made concerning the damage due to shaking:

- Of the damage modes which can occur during shaking of concrete-lined tunnels, only the cracking of the lining is possible.

- No damage has occurred to lined or unlined tunnels at surface accelerations below 0.19g which is greater than the assumed ODE value of 0.125g.

- Little damage has occurred to rock tunnels at surface accelerations of less than 0.4g which is greater than the MDE value of 0.25g.

Based on the above information, it has also been concluded that seismic criteria do not control the design of the proposed Inter-Island Tunnel.

5.60 DISPOSAL AND USE OF EXCAVATED MATERIALS

The construction of the Inter-Island Tunnel will produce a bulked muck volume of approximately 250,000 cubic yards (c.y.). Most of the muck will be removed via the North Shaft with only approximately 7,000 c.y. being removed via the South Shaft. The muck removed via the North Shaft will be temporarily stored at a central location on Deer Island. The muck disposal will be performed under a separate contract.

Based on Kaiser Engineers, Inc.'s "Comprehensive Geotechnical Program Report", dated June 1989, the excavated muck is expected to have the following grain size distribution:

gravel size	:	30-50 percent by weight
sand size	:	40-50 percent by weight
silt size	:	10-20 percent by weight

The gravel size portion of the muck is not expected to be suitable for use as concrete aggregate primarily because it is anticipated that it will contain a significantly larger quantity of thin, flat, elongated rock pieces than is permitted by the Massachusetts Department of Public Works Specifications.

However, this does not preclude its use in construction on Deer Island. The excavated muck is expected to be of sufficient consistency and uniformity to serve as a good pavement subbase. The material is easily spread and requires no extraordinary effort to attain sufficient in-place density. It is expected that earth-moving equipment will be able to move over this material readily.

The muck may also be used on site as unspecified fill to raise grade and as fill for sight and noise barriers, between settling ponds and clarifiers, etc.

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Barosh, P.J., 1989: "The Hazard From Earthquakes in the Boston Area", Civil Engineering Practice: Journal of the Boston Society of Civil Engineers Section/ASCE, Vol.4, No.1, pp. 65-78.

Barosh, P.J., Kaye, C.A. and Woodhouse, D., 1989: "Geology of the Boston Basin & Vicinity", Civil Engineering Practice: Journal of the Boston Society of Civil Engineers Section/ASCE, Vol.4, No.1, pp. 39-52.

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APPENDIX A

SUMMARY BORING LOGS

FIELD TEST BORING RECORD COVER SHEET

SITE	J.O. NO.	BORING NO. 89-101 / SHEET
Inter Island Tunnel - Boston Harbor	U11305	1 OF 1

COORIDNATES N-S 488331.9 E-W 746331.2

SEAFLOOR ELEVATION 42.5

INCLINATION Vertical INSPECTOR Grimes, Watson

DATE: START/FINISH 7/22/89 / 7/22/89

CONTRACTOR/DRILLER Warren George/Peltier, Laurenza

DRILLING BARGE Southern Cross

WATER DEPTH 63.2 (FT) DRILL RIG TYPE Failing 1500

ELEVATION TOP OF BEDROCK -57.5 (FT)

TOTAL DEPTH DRILLED 287.7 (FT)

METHODS:
- DRILLING SOIL Tri-cone rollerbit
- SAMPLING SOIL Split-spoon sampler
- DRILLING ROCK Roller bit, continuous HQ wireline coring
- SPECIAL TESTING OR INSTRUMENTATION Oriented coring, Packer testing.

SUMMARY

SOIL DRILLED 100.0 (FT) ROCK CORED 187.7 (FT)
NUMBER SPLIT BARREL SAMPLES 10

NOTES

1. The coordinate system used is the 1927 MASS GRID.
2. Datum is M.D.C.
3. In water borings, the split spoon sampler was driven into the soil by dropping a 175-pound sliding down hole hammer a distance of 4 feet within the borehole.
4. In land based borings the soil sampling method used was the STD Penetration Resistance using a 140 lb. hammer dropping a distance of 30 inches.

APPROVED	DATE
[signature]	1/2/90

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

BORING 89-101
SHEET 1 OF 5

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 488331.95ft. E: 746331.18ft.**

Sea Floor Elevation: **42.5 ft.**
Total Depth Drilled: **287.7 ft.**

DESCRIPTION: MAIN	DESCRIPTION: DETAIL	Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load I_{s} 50	Pressure Test K = cm/sec (x 0.00001)
		0	42.5			**	
			40				
			35				
SILTY CLAY, very soft, gray to olive green (CL).		10	30			WOH 0-0-1 R8	
			25				
SILTY CLAY, soft, gray to olive green (CL).		20	20			1-1-2 R18	
			15				
SILTY CLAY, soft, gray to olive green (CL).		30	10			1-1-1 R18	
			5				
SILTY CLAY, 2% fine sand, very soft, gray to olive green (CL).		40	0			1-1-0 R18	
			-5				
SILTY CLAY, soft, gray to olive green (CL).		50	-10			2-2-2 R11	
			-15				
SILTY CLAY, soft, gray to olive green (CL).		60	-20			1-1-1 R18	
			-25				
SILTY CLAY, soft, gray to olive green (CL), trace shell fragments.		70	-30			1-1-2 R18	

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

GZA

BORING SUMMARY LOG

BORING 89-101
SHEET 2 OF 5

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 488331.95ft. E: 746331.18ft.**

Sea Floor Elevation: **42.5 ft.**
Total Depth Drilled: **287.7 ft.**

DESCRIPTION

MAIN

SILTY CLAY, soft, gray to olive green (CL), trace shell fragments.

TILL, SILTY GRAVEL, very angular gravel, 35% clayey silt, 15% fine sand, dense, gray and black (GM).

ARGILLITE INTERBEDDED WITH SANDY ARGILLITE, dark gray to light gray, med. hard to hard, slightly weathered; thin bedding, 20 to 30 deg., slumped bedding common; fabric generally massive where argillite is sandy (105 to 110 ft., 130 to 135 ft.), joints moderately closely spaced, 30 to 80 deg.; cleavage at 60 to 90 deg; veins, joints, and bedding plane separations generally infilled with quartz and calcite.
111.0-119.0 ft.: Mod. closely spaced joints and bedding plane separations.

116.5 ft.: *Shoe of core barrel coming off, blocked core run.*

120.5-130.5 ft.: Two cleavages (60 and 90 deg.) visible on bedding plane separations.
121.5-130.0 ft.: Mod. closely spaced joints.

- - - - - - - - - - - - - - - -

148.0-150.5 ft.: Discontinuities filled with Clay or Gouge.

DETAIL

TOP OF BEDROCK 100 FT.

Roller bit to 105.8 ft.
105.8-108.9 ft.: 20 deg. calcite-filled joint, crosscut bedding.
107.0 ft.: 60 deg. clay filled joint.
109.0 ft.: 20 deg. bedding.
111.0 ft.: 75 deg. calcite-filled joint.
116.0 ft.: 75 deg. calcite-filled joint.
119.0 ft.: 75 deg. calcite-filled joint.
119.7 ft.: Conglomeratic breccia.
121.5 ft.: 70 deg. calcite and quartz-filled joint.
123.6 ft.: 70 deg. calcite and quartz-filled joint.
128.6 ft.: 70 deg. calcite-filled joint.
129.9 ft.: 70 deg. calcite and quartz-filled joint.
131.5 ft.: 60 deg. calcite-filled joint.
132.7 ft.: 60 deg. calcite-filled joint.
133.7 ft.: Two cleavages (30 and 60 deg.).
134.1-134.7 ft.: Slumped bedding.
137.6 ft.: 70 deg. calcite-filled joint.
139.9 ft.: 70 deg. calcite-filled joint.
142.0 ft.: 50 deg. calcite-filled joint.
142.5 ft.: 45 deg. calcite-filled joint.

Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load I_{s} 50	Pressure Test K = cm/sec (x 0.00001)
	-35				
80				1-1-2 R18	
	-40				
	-45				
90				18-18-22 R4	
	-50				
	-55				
100				50/5 R.75	
	-60				
		96	75		
	-65				
110				2569	
		100	100		
	-70			2364	
	-75			1871	
120		100	100		
	-80				
				2169	5.1 @ 65 psi
	-85				
130				2030	
		99	99		
	-90			1681	
					3.0 @ 70 psi
	-95			1649	
140		95	95		
	-100				
				1649	2.0 @ 75 psi
	-105				

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

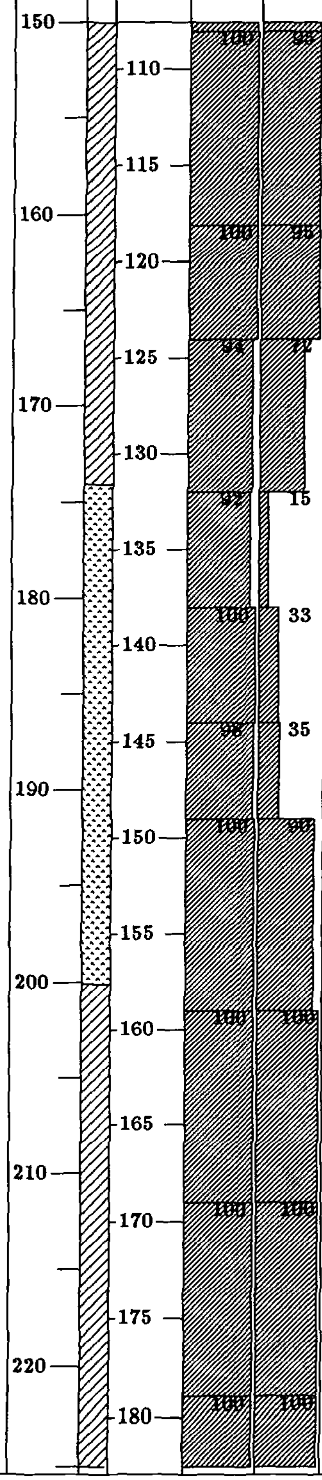
BORING SUMMARY LOG

BORING 89-101
SHEET **3 OF 5**

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
Sea Floor Elevation: **42.5 ft.**
CLIENT: **Massachusetts Water Resources Authority**
Total Depth Drilled: **287.7 ft.**
Coordinates: **N: 488331.95ft. E: 746331.18ft.**

DESCRIPTION

MAIN	DETAIL
ARGILLITE INTERBEDDED WITH SANDY ARGILLITE, and fine Sandstone, gray to light gray, hard to med. hard, slightly weathered; thin bedding 15 to 35 deg.; joints moderately closely spaced 45 to 75 deg. 160.5-166.5 ft.: Sandy argillite. 166.5-171.1 ft.: Bedded Argillite and Sandstone dip 40 deg. at 166.5 grading to horizontal at 169 ft.	142.7 ft.: 40 deg. calcite-filled joint. 143.0-144.0 ft.: Graded beds (possibly turbidibes). 146.5 ft.: 55 deg. calcite-filled joint. 147.1 ft.: 70 deg. calcite-filled joint. 147.2 ft.: 70 deg. calcite-filled joint. 156.7 ft.: Bedding nearly horizontal. 157.0-158.0 ft.: 75 deg. calcite-filled joints. 158.8-160.3 ft.: *Discontinuities up to 6 mm wide filled with clay or gouge.* 160.5-163.0 ft.: 75 deg. calcite-filled joints, clay in bedding plane separations. 163.0-165.0 ft.: Slumped bedding. 166.5 ft.: Drilling stopped because shoe of core barrel was coming off.
FELSITE (Diorite), gray to grayish green, mottled; med. hard, slightly weathered, generally closely jointed throughout, many joints are slickensided or filled with quartz; generally fractured rock. 191.5-211.5 ft.: Oriented core.	170.5 ft.: 70 deg. quartz-filled joint. 171.1-174.5 ft.: Kaolinized argillite adjacent to 70 deg. calcite-filled joints. 175.3 ft.: 30 deg. quartz-filled joint. 176.5 ft.: 80 deg. slickensided joint. 177.4-178.3 ft.: Pyrite mineralization. 177.4 ft.: 20 deg. quartz-filled joint. 178.4 ft.: 80 deg. quartz-filled joint. 178.6 ft.: 80 deg. quartz-filled joint. 180.6 ft.: 40 deg. quartz-filled joint. 181.3 ft.: 80 deg. *quartz-filled joint.*
ARGILLITE, gray, med. hard, slightly weathered; bedding thin to laminar, subhorizontal to 30 deg., occasionally 35-55 deg.; mod. closely spaced joints generally 30-45 deg., parallel/subparallel to bedding; most joints filled with quartz and calcite. 201.5-206.4 ft.: Many bedding plane separations. 211.5-212.6 ft.: Preserved core. 217.3-217.9 ft.: Preserved core. 221.5-237.5 ft.: Oriented core.	182.3 ft.: 40 deg. quartz-filled joint. 184.5 ft.: Occasional coarse quartz veins and quartz-filled vugs 185.2 ft.: 10 deg. slickensided joint. *186.0 ft.:* 80 deg. slickensided joint. 187.5 ft.: 70 deg. slickensided joint. 188.3 ft.: 70 deg. slickensided joint. 189.1 ft.: 30 deg. quartz-filled joint. 191.5 ft.: 20 deg. slickensided joint. 192.1 ft.: 45 deg. slickensided *joint.* 193.1 ft.: 70 deg. quartz-filled joint. 194.4 ft.: 20 deg. slickensided joint. 195.6 ft.: 70 deg.



Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
1205*	
	1.1 @ 80 psi
<200	
888*	
1269	9.3 @ 86 psi
492	
1459*	
<200	6.2 @ 91 psi
<200	
349	6.3 @ 97 psi
1522	0.2 @ 102 psi
1269	
1269	1.5 @ 108 psi
808	0≈<0.1 @ 57 psi

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

GZA

BORING SUMMARY LOG

BORING 89-101
SHEET 4 OF 5

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR** Sea Floor Elevation: **42.5 ft.**
CLIENT: **Massachusetts Water Resources Authority** Total Depth Drilled: **287.7 ft.**
Coordinates: **N: 488331.95ft. E: 746331.18ft.**

DESCRIPTION

MAIN

ARGILLITE INTERBEDDED WITH SANDY ARGILLITE, dark gray to light gray, hard, fresh appearance; bedding thin; 10-25 deg. bedding massive in sandy zone. 237.7-241.0 ft.; widely spaced to moderately close joints, 30 to 70 deg.; two cleavages, dominant cleavage nearly 90 deg., second cleavage nearly parallel to bedding.

ARGILLITE, dark gray, hard, fresh to slightly weathered; bedding thin to laminar ocassionally massive; same two cleavages as above.

273.0-287.7 ft.: Argillite shows chlorite alteration, rock quality deteriorates below 283.0 ft.

287.7 FT.: END OF BORING

DETAIL

quartz-filled joint.
196.7 ft.: 45 deg. slickensided joint.
197.2 ft.: 50 deg. quartz-filled joint, 15 mm wide.
198.4 ft.: 85 deg. quartz-filled joint.
210.3 ft.: 60 deg. quartz-filled joint.
214.7 ft.: Network of quartz veins.
215.5 ft.: 45 deg. calcite-filled joint.
223.0 ft.: 70 deg. calcite-filled joint.
223.0-223.5 ft.: Slumped bedding.
224.0 ft.: 70 deg. calcite-filled joint.
225.5-225.9 ft.: Small offset along joint.
225.5 ft.: 45 deg. calcite-filled joints.
228.0 ft.: 70 deg. calcite-filled joint.
230.1 ft.: Two conjugate 50 deg. joints.
235.5-236.4 ft.: Slumped bedding.
237.2-237.7 ft.: Slumped bedding, pyrite mineralization.
239.5 ft.: 70 deg. calcite-filled joint.
241.0-243.0 ft.: Slumped bedding.
241.0 ft.: Two cleavages; primary is 90 deg., secondary is 30 deg.
245.7 ft.: 30 deg. calcite-filled joint.
247.7-267.7 ft.: Only three joints, 55 to 70 deg.
251.1-252.1 ft.: Brecciated argillite.
252.4-252.6 ft.: Network of calcite veins.
252.7 ft.: Coarse calcite veins.
256.5 ft.: 60 deg. calcite joint.
264.5-266.5 ft.: Chlorite alteration.
269.3 ft.: 30 deg. joint.
273.4 ft.: 60 deg. calcite-filled joint.
274.5 ft.: 50 deg. calcite-filled joint.
276.2-277.0 ft.: Four 70 deg. calcite-filled joints.
279.0 ft.: 60 deg. calcite-filled joint.
279.5 ft.: 60 deg. iron stained joint.
281.1 ft.: 20 deg. calcite-filled joint.
281.2 ft.: 20 deg. calcite-filled joint.
281.7 ft.: 60 deg. calcite-filled joint.
282.5 ft.: 30 deg.

Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
	185	100	100		
230	190				9.1 @ 118 psi
	195	100	98		
240	200			888 1565 952	1.6 @ 123 psi
	205	100	100		
250	210			1522 634 1935	24.1 @ 128 psi
	215	100	100	1522 603 1332	
260	220				
	225	100	100		
270	230			1078 1412 888	
	235	100	88		
280	240				
	245				

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

BORING 89-101
SHEET 5 OF 5

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 488331.95ft. E: 746331.18ft.**

Sea Floor Elevation: **42.5 ft.**
Total Depth Drilled: **287.7 ft.**

DESCRIPTION MAIN	DESCRIPTION DETAIL	Depth (ft.)		Elev. (ft.)	REC	RQD	Point Load $I_{s\ 50}$	Pressure Test K = cm/sec (x 0.00001)
	quartz-filled joint. 282.5-282.8 ft.: Extensive calcite veining. 283.3-285.2 ft.: Alteration zones adjacent to calcite veins. 286.8-287.7 ft.: Alteration zones adjacent to calcite veins.							

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

FIELD TEST BORING RECORD COVER SHEET

SITE	J.O. NO.	BORING NO. / SHEET
		BORING NO. 89-102
Inter Island Tunnel - Boston Harbor	U11305	SHEET 1 OF 1

COORIDNATES N-S 486563.2 E-W 746285.9

SEAFLOOR ELEVATION 61.4

INCLINATION Vertical INSPECTOR Grimes, Zilinskas

DATE: START/FINISH 7/29/89 / 7/31/89

CONTRACTOR/DRILLER Warren George/Marney, Laurenza

DRILLING BARGE Southern Cross

WATER DEPTH 44.3 (FT) DRILL RIG TYPE Failing 1500

ELEVATION TOP OF BEDROCK 10.4 (FT)

TOTAL DEPTH DRILLED 301.7 (FT)

METHODS:
- DRILLING SOIL Tri-cone rollerbit
- SAMPLING SOIL Wash cuttings
- DRILLING ROCK Roller bit, continuous HQ wireline coring
- SPECIAL TESTING OR INSTRUMENTATION Oriented coring, Packer testing.

SUMMARY

SOIL DRILLED 51.0 (FT) ROCK CORED 250.7 (FT)
NUMBER SPLIT BARREL SAMPLES ---

NOTES

1. The coordinate system used is the 1927 MASS GRID.
2. Datum is M.D.C.
3. In water borings, the split spoon sampler was driven into the soil by dropping a 175-pound sliding down hole hammer a distance of 4 feet within the borehole.
4. In land based borings the soil sampling method used was the STD Penetration Resistance using a 140 lb. hammer dropping a distance of 30 inches.

APPROVED	DATE
M Gilbert	1/2/90

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

BORING 89-102
SHEET 1 OF 5

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 486563.24ft. E: 746285.95ft.**

Sea Floor Elevation: **61.4 ft.**
Total Depth Drilled: **301.7 ft.**

DESCRIPTION — MAIN	DESCRIPTION — DETAIL	Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
SILTY CLAY (no samples taken)		0, 10, 20	61.4, 60, 55, 50, 45, 40				
CLAYEY TILL (no samples taken).		30, 40, 50	35, 30, 25, 20, 15, 10				
ARGILLITE, gray, medium hard, slightly to moderately weathered; bedding very thin to medium, 25 to 40 deg.; abundant amount of slumped bedding; joints are generally closely spaced, 1 to 10 mm wide, filled with calcite and clay, dip 40 deg. to nearly vertical.	TOP OF BEDROCK 51.0 FT. Roller bit to 56.0 ft. 59.0 ft.: 80 deg. iron stained joint. 60.8 ft.: 80 deg. clay-filled joint. 61.0 ft.: 90 deg. iron stained joint. 62.3-62.9 ft.: Fracture zone. 62.9 ft.: 85 deg. clay-filled joint. 69.0 ft.: Shoe of core barrel jammed. 73.4 ft.: 70 deg. weak cleavage.	60, 70	5, 0, -5, -10	92 100 100	60 100 78	1368 <200 302 223 <200 <200	

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test correct to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

BORING 89-102
SHEET 2 OF 5

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: N: **486563.24ft.** E: **746285.95ft.**

Sea Floor Elevation: **61.4 ft.**
Total Depth Drilled: **301.7 ft.**

DESCRIPTION

MAIN	DETAIL
	76.0-81.5 ft.: Fracture zone with substantial alteration to clay 77.0-78.0 ft.: Fracture zone. 80.0 ft.: 70 deg. clay-filled joint.
DIABASE/BASALT, dark green to grayish green, medium hard to hard, slightly weathered; joints are closely to very closely spaced, filled with calcite clay, quartz and infrequent pyrite, 20 to 70 deg.; small scale *movement* evidenced by slickensides and microfaulting. 91.5-101.5 ft.: Abundant calcite veins, various orientations.	82.0-84.0 ft.: Calcite veins 5 to 25 mm wide various orientations. 83.0 ft.: Calcite vein 35 mm wide. 84.0-85.5 ft.: Argillite clasts in diabase. 89.0 ft.: Fracture with clay surfaces. 95.0 ft.: Texture abruptly becomes finer. 100.0-101.5 ft.: Near vertical vein filled with grantic material
TUFFACEOUS ARGILLITE, pale green, hard to med. hard, slightly weathered; med. to thinly bedded, 35 to 70 deg.; joints moderately closely spaced, 45 to 70 deg.; abundant bedding plane separations with clay coating.	113.8 ft.: 40 deg. quartz filled vein, 10 mm wide. 117.0 ft.: 50 deg. joint, rough surfaces. 118.0 ft.: 70 deg. joint, rough surfaces. 123.0 ft.: 70 deg. joint, rough surfaces 124.0-125.0 ft.: Nearly vertical bedding crosscut by hairline (<1 mm wide) faults. 126.0 ft.: 75 deg. cleavage.
SANDY ARGILLITE and **ARGILLITE**, gray, medium hard, fresh to slightly weathered; bedding varies from very thin to massive with occasional slump features and micro-faulting, 25 to 35 deg.; joints are closely spaced, filled with calcite, quartz and clay, generally 45 to 70 deg. 131.5-151.5 ft.: 70 to 85 deg. cleavage becomes more prominent with increase in depth.	128.0 ft.: 75 deg. joint, 2 mm wide. 131.5 ft.: Cleavage development; increases between 131.5 to 151.5 ft., 70 to 85 deg. 136.0 ft.: 50 deg. calcite-filled joint. 138.0 ft.: 80 deg. calcite-filled joint. 140.6 ft.: 70 deg. joint, 3 mm wide. 141.7 ft.: 70 deg. calcite-filled joint.

Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
	-15			223	
		80	14		
80	-20	100	100		
	-25			1885	
				732	
90	-30	100	100	827	
	-35				
100	-40	100	100	1519	
	-45			955	
110	-50	98		1177	
	-55				
120	-60	100	100		
	-65				
130	-70	98	98	1400	
	-75			1018	
140				700	
	-80	100	100		
	-85			605 622	

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test correct to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

BORING 89-102
SHEET **3 OF 5**

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR** Sea Floor Elevation: **61.4 ft.**
CLIENT: **Massachusetts Water Resources Authority** Total Depth Drilled: **301.7 ft.**
Coordinates: **N: 486563.24ft. E: 746285.95ft.**

DESCRIPTION

MAIN

SANDY ARGILLITE and **ARGILLITE**, gray, medium hard, fresh to slightly weathered; bedding varies from very thin to massive with occasional slump features and micro-faulting, 25 to 35 deg.; joints are closely spaced, filled with calcite, quartz and clay, generally 45 to 70 deg.
151.5-156.5 ft.: Massive fabric.
151.5-161.5 ft.: Many bedding plane separations.
156.5-161.5 ft.: Laminar bedding.
161.5-171.5 ft.: 25 to 30 deg. bedding and 60 deg. cleavage.

181.5-191.5 ft.: Many 30 deg. bedding plane separations with smooth surfaces.

ARGILLITE INTERBEDDED WITH SANDY ARGILLITE, gray or light gray or light green (sandy layers lighter color), hard, fresh to slightly weathered, bedding thin to very thin, 15 to 45 deg.; some slumped bedding; most joints are healed and very closely to moderately closely spaced, filled with calcite or clay, dipping 20 to 40 deg.; occasional hairline joints; most breaks in core are due to drilling and occur along hairline healed fractures and/or bedding plane separations.
210.4-230.4 ft.: Oriented core.
217.0 ft.: Broke core to fit into core box.

221.5-231.5 ft.: Numerous 25 to 30 deg. bedding plane separations.

DETAIL

153.0 ft.: 85 deg. cleavage.
154.0-155.6 ft.: Massive fabric.
156.5-158.0 ft.: Slumped bedding.
157.1 ft.: 25 deg. bedding with clasts of sandy argillite.
160.1 ft.: 25 deg. bedding with clasts of sandy argillite.

166.0 ft.: 40 deg. joint.

169.0-170.6 ft.: Slumped bedding.
169.0 ft.: 60 deg. joint, smooth surfaces.
170.0 ft.: 70 deg. joint.
171.0 ft.: 40 deg. joint.
172.0 ft.: 60 deg. cleavage.

184.2-184.7 ft.: Sandy argillite bed.

190.5 ft.: 45 deg. joint, crosscutting bedding.

194.8 ft.: Two 35 deg. joints.
197.0 ft.: Pyrite mineralization.
199.3 ft.: Pyrite mineralization.

214.3 ft.: Pyrite mineralization.
214.7 ft.: 45 deg. calcite-filled joint, smooth surfaces.
215.8-216.0 ft.: Slumped bedding.
217.4-220.0 Some bedding plane separations.
217.6 ft.: 30 deg.

Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
150					
	-90	100	97		
				1082	
	-95				
				1010* <200	
160					
	-100	99	99		
	-105			1400	
170					
	-110	100	100	1527* 923	
	-115			891	6.8 @ 197.5 psi
				1225	
180					
	-120	98	98		
	-125			1591* 525	0=<0.1 @208psi
190					
	-130	100	100	891	
	-135			1432 1830	0=<0.1 @218psi
200				1018	
	-140	100	100		
	-145			1440	0=<0.1 @229psi
210					
	-150	100	100	1782	
	-155				0.1 @ 240 psi
220					
	-160	100	99		

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test correct to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

BORING 89-102
SHEET **4 OF 5**

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: N: **486563.24ft.** E: **746285.95ft.**

Sea Floor Elevation: **61.4 ft.**
Total Depth Drilled: **301.7 ft.**

DESCRIPTION

MAIN

ARGILLITE INTERBEDDED WITH SANDY ARGILLITE, gray or light gray or light green (sandy layers *lighter color*), hard, *fresh to slightly* weathered; bedding thin to very thin, 15 to 45 deg.; some slumped bedding; most joints are healed and are very closely to moderately closely spaced, filled with calcite or clay, dipping 20 to 40 deg.; occasional hairline joints; most breaks in core are due to drilling and occur along hairline healed fractures and/or bedding planes separations.
233.3-235.4 ft.: Preserved core.
240.4-260.4 ft.: Oriented core.

243.0-250.9 ft.: Many healed calcite fractures, each less than 2 mm wide.

247.5-251.5 ft.: Core was dropped before logged. Most breaks are due to the drop.

273.4-280.9 ft.: Closely spaced joints dipping 30 to 50 deg.

ARGILLITE, dark gray to light gray, hard, fresh to slightly weathered; thinly bedded, 10 to 45 deg. with some slumped bedding; joints are close to very closely spaced, filled with calcite, 20 to 50 deg.

DETAIL

calcite-filled joint parallel to bedding.
218.8-219.0 ft.: Slumped bedding.
220.0-221.5 ft.: Conglomeratic argillite.
221.7 ft.: 85 deg. hairline calcite-filled vein.
223.0 ft.: 30 deg. calcite-filled bedding plane separation.
223.2-224.9 ft.: Six hairline joints, 40 to 55 deg.
231.5-232.1 ft.: Slumped bedding.
236.0 ft.: 25 deg. calcite vein.
236.3 ft.: 25 deg. calcite vein.
238.2 ft.: 40 deg. clay coated joint.
240.8-241.5 ft.: Fracture zone.
240.8 ft.: 25 deg. calcite vein.
240.8-241.5 ft.: Slumped bedding with brecciated argillite.
246.3 ft.: 25 deg. calcite and pyrite filled joint.
248.6 ft.: Calcite vein 55 mm thick.
249.0 ft.: Conjugate 30 and 40 deg. joints.
251.5-252.5 ft.: Bedding plane separations, with no filling.
251.8 ft.: 30 deg. calcite vein, 3 mm wide.
253.5-255.7 ft.: Slumped bedding with clasts of argillite.
257.4 ft.: 25 deg. calcite veins.
263.6 ft.: 25 deg. clay-filled bedding plane separation.
263.9 ft.: 80 deg. calcite-filled joint.
266.6-271.0 ft.: Slumped bedding with argillite clasts.
271.2 ft.: 40 deg. calcite/clay vein, 6 mm wide.
276.6-277.1 ft.: *Sandstone bed with* calcite.
286.5 ft.: 50 deg. joint.
287.5 ft.: 45 deg. joint.
287.7-288.7 ft.: Zone of calcite-rich lenses.
288.5 ft.: 70 deg. joint.
291.0 ft.: 85 deg. cleavage.
293.0-295.3 ft.: Conglomeratic argillite.
294.7-298.2 ft.: Slumped bedding.
296.5 ft.: 50 deg. joint.

Depth (ft.)	Elev. (ft.)	REC	RQD
	-165		
230	-170	100	97
	-175		
240	-180	99	89
	-185		
250	-190	100	99
	-195		
260	-200	100	99
	-205		
270	-210	100	100
	-215		
280	-220	100	100
	-225		
290	-230	100	100
	-235		

Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
	0.4 @ 250 psi
1782	0.1 @ 260.5 psi
	3.3 @ 281.5 psi
1814	
1018	
	0=<0.1 @ 292psi
780	
1432	
1130	

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test correct to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

BORING 89-102
SHEET **5 OF 5**

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: N: **486563.24ft.** E: **746285.95ft.**

Sea Floor Elevation: **61.4 ft.**
Total Depth Drilled: **301.7 ft.**

DESCRIPTION MAIN	DESCRIPTION DETAIL	Depth (ft.)		Elev. (ft.)	REC	RQD	Point Load I_s 50	Pressure Test K = cm/sec (x 0.00001)
301.7 FT.: END OF BORING	300.5 ft.: 75 deg. joint. 301.6 ft.: 40 deg. calcite-filled joint, 4 mm wide.							

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test correct to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

FIELD TEST BORING RECORD COVER SHEET

SITE	J.O. NO.	BORING NO. / SHEET
		BORING NO. 89-103
Inter Island Tunnel - Long Island	U11305	SHEET 1 OF 1

COORIDNATES N-S 484737.4 E-W 746487.6

GROUND ELEVATION 119.8

INCLINATION Vertical INSPECTOR Gillen, Sheridan

DATE: START/FINISH 9/19/89 / 9/27/89

CONTRACTOR/DRILLER Guild/Texeira, Eastwood

DRILL RIG TYPE Acker AD II (Soil), Longyear HC150 (Rock)

WATER DEPTH ϕ (Land Based Boring

ELEVATION TOP OF BEDROCK 6.8 (FT)

TOTAL DEPTH DRILLED 332.5 (FT)

METHODS:
- DRILLING SOIL Tri-cone rollerbit
- SAMPLING SOIL Split-spoon sampler
- DRILLING ROCK Roller bit, continuous HQ wireline coring
- SPECIAL TESTING OR INSTRUMENTATION Oriented coring, Packer testing.

SUMMARY

SOIL DRILLED 113.0 (FT) ROCK CORED 231.5 (FT)
NUMBER SPLIT BARREL SAMPLES 12

NOTES

1. The coordinate system used is the 1927 MASS GRID.
2. Datum is M.D.C.
3. In water borings, the split spoon sampler was driven into the soil by dropping a 175-pound sliding down hole hammer a distance of 4 feet within the borehole.
4. In land based borings the soil sampling method used was the STD Penetration Resistance using a 140 lb. hammer dropping a distance of 30 inches.

APPROVED	DATE
M Setter	1/2/90

GOLDBERG-ZOINO & ASSOCIATES, INC.

GZA

BORING SUMMARY LOG

BORING 89-103

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 484737.40ft. E: 746487.60ft.**

Sea Floor Elevation: **119.8 ft.**
Total Depth Drilled: **332.5 ft.**

DESCRIPTION — MAIN	DESCRIPTION — DETAIL	Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load I_{s} 50	Pressure Test K = cm/sec (x 0.00001)
			119.8				
FILL, concrete rubble.		0				**	
			115				
GRAVELLY SAND, fine to medium sand, 35% gravel, 5% cobbles, very dense, brown (SP).		10	110			12-37 40-32 R12	
			105				
TILL, CLAYEY SILT, 35% fine sand, 25% gravel, hard, gray (ML).		20	100			27-36 40-36 R12	
			95				
TILL, CLAYEY SILT, 35% fine sand, 25% gravel, hard, gray (ML).		30	90			20-23 33-29 R18	
			85				
TILL, CLAYEY SILT, 35% fine sand, 25% gravel, 5% cobbles hard, gray (ML).		40	80			20-29 120 R9	
			75				
TILL, CLAYEY SILT, 35% fine sand, 25% gravel, hard, gray (ML).		50	70			23-54 60-66 R12	
			65				
TILL, CLAYEY SILT, 35% gravel, hard, gray (ML).		60	60			38-32 33-64 R8	
			55				
TILL, CLAYEY SILT, 35% gravel, hard, gray (ML). **BOULDER OF ARGILLITE.**		70	50			38-54-80 R9 80 R4	
			45				

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 50 mm standard, diametric except * indicates axial. ** = SOIL, SPT/Recovery in inches.

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 484737.40ft. E: 746487.60ft.**

Sea Floor Elevation: **119.8 ft.**
Total Depth Drilled: **332.5 ft.**

DESCRIPTION: MAIN	DESCRIPTION: DETAIL	Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
TILL, CLAYEY SILT, 35% gravel, hard, grayish brown (ML).		80	40			38-39 66-80/3 R8	
			35				
TILL, CLAYEY SILT, 35% gravel, hard, brownish gray (ML).		90	30			28-49-82 R8	
			25				
TILL, CLAYEY SILT, 35% gravel, hard, greenish gray (ML).		100	20			50-47 115 R12	
Boulder.			15				
TILL, GRAVELLY SILT, 35% gravel, very dense, gray (GM).		110	10			43-112 101 R10	
ARGILLITE, dark gray, hard, slightly weathered; bedding very thin to laminar, 20 to 30 deg., occasionally slumped bedding 50 to 60 deg.; joints close to very closely spaced, 50 to 70 deg.; some bedding plane separations and veins, generally infilled with quartz.	TOP OF BEDROCK 113 FT.		5				
	Roller bit to 116.9 ft.			100	76	1233	
117.0-122.5 ft.: Few bedding plane separations, joints generally slickensided.	120.0 ft.: 60 deg. joint crosscutting bedding.	120	0			1473	
117.5-142.5 ft.: Many quartz filled veins random orientations.				100	95		
	124.0 ft.: 60 deg. joint crosscutting bedding.		-5			961	
		130	-10			1313	
132.5-142.5 ft.: Pyrite and quartz mineralization.				97	77		
	134.0 ft.: 50 deg. joint crosscutting bedding.		-15			1201	
	137.5-138.0 ft.: Quartz veins with random orientations.					977	
	140.0-142.5 ft.: Numerous bedding plane separations, 20 to 30 deg. dip.	140	-20				
				96	54		
	142.5-146.7 ft.: Fracture zone.		-25				
	144.0 ft.: 60 deg. clay filled joint.					1153	
	149.0 ft.: 60 deg. joint		-30				

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 50 mm standard, diametric except * indicates axial. ** = SOIL, SPT/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

GZA

BORING SUMMARY LOG

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: ***Massachusetts Water Resources Authority***
Coordinates: N: **484737.40ft.** E: **746487.60ft.**

Sea Floor Elevation: **119.8 ft.**
Total Depth Drilled: **332.5 ft.**

DESCRIPTION – MAIN	DESCRIPTION – DETAIL	Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\ 50}$	Pressure Test K = cm/sec (x 0.00001)
	crosscutting bedding.	150				1618	
	153.0-157.0 ft.: Massive fabric.		-35	100	96	1345	
ARGILLITE, dark gray, hard, slightly weathered; bedding very thin to lmainar, 60 to 90 deg., often slumped; joints close to very closely spaced, generally 40 to 60 deg., occasionally 10 to 30 deg. and 85 deg.; some bedding plane separations and veins, generally infilled with quartz, occasionally calcite. 162.5-172.5 ft.: Slumped bedding 80 to 90 deg dip.	157.0 ft.: 70 deg. joint parallel to bedding. 159.0 ft.: 70 deg. joint crosscutting bedding.	160	-40				
	162.0 ft.: 70 deg. joint crosscutting bedding. 164.0 ft.: 40 deg. joint crosscutting bedding.		-45	100	99	2146	
	167.0-171.0 ft.: 85 deg. joints parallel to bedding.	170	-50				
	172.5-202.5 ft.: 60 to 70 deg. bedding. 174.2 ft.: 30 deg. slickensided joint.		-55	100	100	1313 641	
	179.0 ft.: 50 deg. joint crosscutting bedding. 180.0 ft: 90 deg. joint sub-parallel to bedding.	180	-60			705	
	184.0-185.0 ft.: 60 deg. joints parallel to bedding. 186.8 ft.: 60 deg. slickensided joint, parallel to bedding, quartz and calcite infilling.	190	-65 -70	97	97	641 897	
192.5-202.5 ft.: Few veins.	194.0 ft.: Quartz veins parallel to bedding. 195.0 ft.: 60 deg. joint parallel to bedding.		-75	100	85	1377	
	198.5-199.5 ft.: Fracture zone.	200	-80			1345	
ARGILLITE, dark gray, hard, slightly weathered; bedding very thin to medium, 202.5-225.0 bedding dips at 60 to 90 deg, 225.0-252.5 bedding dips at 25 to 60 deg.; joints moderately close to closely spaced, generally 30 to 60 deg.; quartz and calcite veins less frequent than in previous core. 212.5-222.5 ft.: Quartz and calcite veins closely spaced, generally parallel to bedding.	204.0 ft.: 30 and 60 deg. joints crosscutting bedding. 206.3-206.5 ft.: 25 mm wide zone of argillite and calcite parallel to bedding. 209.0-211.0 ft.: 60 deg. joint crosscutting bedding.	210	-85 -90	100	100	1265 929	
	214.0-222.5 ft.: Slumped, nearly vertical bedding.		-95	100	100	1249	
	219.0 ft.: 60 deg. joint crosscutting bedding.	220	-100			705	
			-105	100	94		

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 50 mm standard, diametric except * indicates axial. ** = SOIL, SPT/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 484737.40ft. E: 746487.60ft.**

Sea Floor Elevation: **119.8 ft.**
Total Depth Drilled: **332.5 ft.**

DESCRIPTION

MAIN

232.5-242.5 ft.: Occasional bedding plane separations.

252.0 ft.: Lost drilling shoe down hole.
252.8-272.8 ft.: Oriented core.

ARGILLITE, dark gray, hard, slightly weathered; bedding medium to very thin, occasionally massive, generally 20 to 30 deg. occasionally slumped bedding with nearly vertical orientation; joints moderately close to closely spaced, generally 20 to 60 deg.; occasional quartz and calcite veins generally locally concentrated, various orientations.
252.5-262.5 ft.: Lost shoe in hole and one scribe came loose, 20 perent of core is overdilled and has no scribe marks or 4 scribe marks.
262.5-282.5 ft.: Fabric generally massive.

280.0-282.1 ft.: Preserved core.

282.8-292.8 ft.: Oriented core.

ARGILLITE, dark gray, hard, slightly weathered; bedding thin to very thin, 20 to 50 deg., occasionally slumped bedding with nearly vertical orientation; joints moderately close to very closely spaced, 40 to 65 deg., rarely 90 deg.; numerous harline quartz veins, various orientations.
292.5-302.5 ft.: Numerous vertical quartz veins.

DETAIL

227.0 ft.: Two intersecting cleavages at 10 and 20 deg.; 20 deg. cleavage is parallel to bedding.
229.0 ft.: Two intersecting cleavages at 10 and 20 deg.; 20 deg. cleavage is parallel to bedding.
230.2 ft.: 65 deg. slickensided joint.
234.0 ft.: 50 deg. joint crosscutting bedding.
241.2-241.8 ft.: Fracture zone.
244.0-245.0 ft.: Numerous quartz veins, some clay.
245.5 ft.: Two intersecting cleavages at 30 and 50 deg., 30 deg. cleavage is parallel to bedding.
246.5 ft.: Two intersecting cleavages at 30 and 50 deg., 30 deg. cleavage is parallel to bedding.
248.0 ft.: 20 deg. joint parallel to bedding.
251.0 ft.: 75 deg. joint parallel to bedding.
254.0 ft.: 30 deg. joint parallel to bedding.
254.1-245.3 ft.: Numerous quartz veins, 10 to 30 deg. dip.
255.0 ft.: 30 deg. joint.
259.0 ft.: 45 deg. joint.
264.0 ft.: 50 deg. joints.
266.0 ft.: Two crossing joints 50 and 60 deg.
267.0 ft.: Two crossing joints 30 and 60 deg.
269.0-272.5 ft.: Slumped bedding, 80 deg.
273.0 ft.: 90 deg. joint.
276.0 ft.: Slumped bedding.
277.0 ft.: 90 deg. quartz veins with random orientation.
278.0-282.5 ft.: Joints have substantial amount of chloritic infilling.
279.0 ft.: Two crossing joints at 60 and 70 deg.
283.5 ft.: Fracture zone.
284.0 ft.: 80 deg. joint.
285.0 ft.: 30 deg. joint parallel to bedding.
294.0 ft.: 60 deg. joint crosscutting bedding.
296.0-298.0 ft.: Fracture zone with network of hairline quartz veins and 60 deg.

Depth (ft.)	Elev. (ft.)
230	-110
	-115
240	-120
	-125
250	-130
	-135
260	-140
	-145
270	-150
	-155
280	-160
	-165
290	-170
	-175
	-180

REC	RQD
100	78
100	100
100	98
98	98
100	100
80	48
100	70

Point Load $I_{s\,50}$
913
673
929
833
1714
865*
1281
705
961
1089

Pressure Test K = cm/sec (x 0.00001)
18.0 @ 82 psi
0=<0.1 @ 93 psi
0=<0.1 @ 93 psi
7.1 @ 103 psi
0=<0.1 @ 103psi
1.8 @ 114 psi
2.1 @ 114 psi

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 50 mm standard, diametric except * indicates axial. ** = SOIL, SPT/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

GZA

BORING SUMMARY LOG

BORING 89-103

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 484737.40ft. E: 746487.60ft.**

Sea Floor Elevation: **119.8 ft.**
Total Depth Drilled: **332.5 ft.**

DESCRIPTION – MAIN	DESCRIPTION – DETAIL	Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
ARGILLITE, dark gray, hard, slightly weathered; bedding thin to very thin, 20 to 50 deg., occasionally slumped bedding with nearly vertical orientation; joints moderately close to very closely spaced, 40 to 65 deg., rarely 90 deg.; numerous harline quartz veins, various orientations.	joints.	300					
302.5-312.5 ft.: Numerous 1 mm wide quartz veins, also very closely spaced joints 40 to 75 deg.			185	100	100	1650	0=<0.1 @ 124psi
		310	190			961	
312.5-322.5 ft.: Numerous vertical quartz veins.	314.0 ft.: 80 deg. joint crosscutting bedding.		195	100	100	1633	
	317.0 ft.: 40 deg. joint crosscutting bedding.	320	200				
322.5-332.5 ft.: Bedding generally 30 deg.; closely spaced veins, various orientations.	321.0 ft.: 60 deg. joint crosscutting bedding.		205	100	90	1121	
	328.0 ft.: 60 deg. joint crosscutting bedding.	330	210			849	
332.5 ft.: END OF BORING	332.0 ft.: 40 deg. joint crosscutting bedding.					561	

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 50 mm standard, diametric except * indicates axial. ** = SOIL, SPT/Recovery in inches.

FIELD TEST BORING RECORD COVER SHEET

		BORING NO. 89-104
SITE Inter Island Tunnel - Boston Harbor	J.O. NO. U11305	SHEET 1 OF 1

COORIDNATES N-S 482330.1 E-W 746407.4

SEAFLOOR ELEVATION 88.5

INCLINATION Vertical INSPECTOR Grimes, Watson

DATE: START/FINISH 8/09/89 / 8/12/89

CONTRACTOR/DRILLER Warren George/Gregory

DRILLING BARGE WGI 90

WATER DEPTH 17.2 (FT) DRILL RIG TYPE Failing 1500

ELEVATION TOP OF BEDROCK -1.0 (FT)

TOTAL DEPTH DRILLED 318.1 (FT)

METHODS:
- DRILLING SOIL Tri-cone rollerbit
- SAMPLING SOIL Wash cuttings
- DRILLING ROCK Roller bit, continuous HQ wireline coring
- SPECIAL TESTING OR INSTRUMENTATION Oriented coring, Packer testing.

SUMMARY

SOIL DRILLED 89.5 (FT) ROCK CORED 228.6 (FT)
NUMBER SPLIT BARREL SAMPLES ---

NOTES

1. The coordinate system used is the 1927 MASS GRID.
2. Datum is M.D.C.
3. In water borings, the split spoon sampler was driven into the soil by dropping a 175-pound sliding down hole hammer a distance of 4 feet within the borehole.
4. In land based borings the soil sampling method used was the STD Penetration Resistance using a 140 lb. hammer dropping a distance of 30 inches.

APPROVED	DATE
M Gilbert	1/2/90

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

BORING 89-104
SHEET **1 OF 5**

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: N: **482330.10ft.** E: **746407.38ft.**

Sea Floor Elevation: **88.5 ft.**
Total Depth Drilled: **318.1 ft.**

DESCRIPTION — MAIN	DETAIL	Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load I_s 50	Pressure Test K = cm/sec (x 0.00001)
No samples taken, soil descriptions are from cuttings.		0	88.5				
			85				
SILTY CLAY, 5% gravel, gray and light green (CL).			80				
		10					
			75				
			70				
		20					
SILTY CLAY, 5% medium sand, greenish gray (CL).			65				
			60				
		30					
			55				
SILTY CLAY, greenish gray (CL).			50				
		40					
			45				
			40				
TILL, CLAYEY GRAVEL, coarse to fine gravel, 40% silty clay, greenish gray (GC).		50					
			35				
TILL, CLAYEY GRAVEL, coarse to fine gravel, 5% clay, gray (GC).			30				
		60					
			25				
			20				
		70					
TILL, GRAVEL, coarse to fine gravel, 60% clasts of mudstone, dark gray (GW).			15				

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial.

GOLDBERG-ZOINO & ASSOCIATES, INC.

GZA

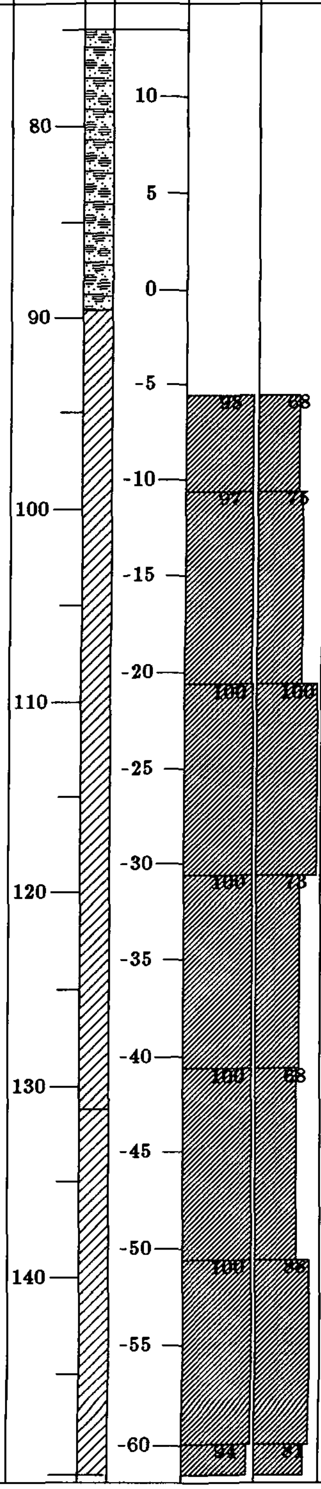
BORING SUMMARY LOG

BORING 89-104
SHEET **2 OF 5**

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 482330.10ft. E: 746407.38ft.**

Sea Floor Elevation: **88.5 ft.**
Total Depth Drilled: **318.1 ft.**

DESCRIPTION — MAIN	DESCRIPTION — DETAIL
TILL, CLAYEY GRAVEL, coarse to fine gravel, 35% silty clay, gray (GC).	
ARGILLITE INTERBEDDED WITH SANDY ARGILLITE, greenish-gray to gray, mottled, med. hard, slightly weathered; bedding very thin to laminar, 40 to 60 deg.; joints moderately closely spaced, 50 to 75 deg.; joints, veins, and bedding plane separations generally infilled with clay, quartz, and calcite; occasional green tuffaceous sandy beds, 5 to 10 mm thick; occasional slickensided joint surfaces with microfaulting.	TOP OF BEDROCK 89.5 FT. Roller bit to 94.1 ft. 96.3-97.4 ft.: Fracture zone. 98.3-99.1 ft.: Fracture zone with clay infilling. 102.4-102.7 ft.: Fracture zone. 103.7 ft.: 45 deg. slickensided joints and fractures. 105.0 ft.: 20 deg. slickensided joints and fractures. 107.0 ft.: 50 deg. slickensided joints and fractures. 116.8 ft.: Fracture zone infilled with clay. 123.0 ft.: 70 deg. joint. 125.9-126.6 ft.: Healed fracture zone. 126.0 ft.: 60 deg. joint. 127.0 ft.: 70 deg. joint. 128.2-129.1 ft.: Holes 1 to 3 mm wide in rock core.
ARGILLITE INTERBEDDED WITH SANDY ARGILLITE, purplish gray, medium hard, slightly weathered; bedding very thin to laminar 10 to 50 deg.; joints very closely spaced, 45 to 90 deg.; most joints, veins, fractures infilled with clay, quartz and calcite.	130.1-130.7 ft.: Fracture zone. 131.0 ft.: Fracture filled with clay. 131.0-134.5 ft.: Slumped bedding. 133.0 ft.: 65 deg. joint with prominent slickensides. 134.5 ft.: 90 deg. joint with prominent slickensides. 137.1 ft.: Tuffaceous argillite. 139.1-148.4 ft.: Abundant slumped bedding and



Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
<200	
<200	
<200	
1365	
1206	
698	
<200	
1762	
1000	
1428	

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial.

GOLDBERG-ZOINO & ASSOCIATES, INC.

GZA

BORING SUMMARY LOG

BORING 89-104
SHEET **3 OF 5**

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 482330.10ft. E: 746407.38ft.**

Sea Floor Elevation: **88.5 ft.**
Total Depth Drilled: **318.1 ft.**

DESCRIPTION

MAIN

ARGILLITE INTERBEDDED WITH SANDY ARGILLITE, purplish gray, medium hard, slightly weathered; bedding very thin to laminar 10 to 50 deg.; joints very closely spaced, 45 to 90 deg.; most joints, veins, fractures infilled with clay, quartz and calcite.

168.4-178.4 ft.: Green and white tuffaceous sandstone beds, 3 to 35 mm wide.

188.4 ft.: Correction in depth of borehole, subtracted 0.4 ft.

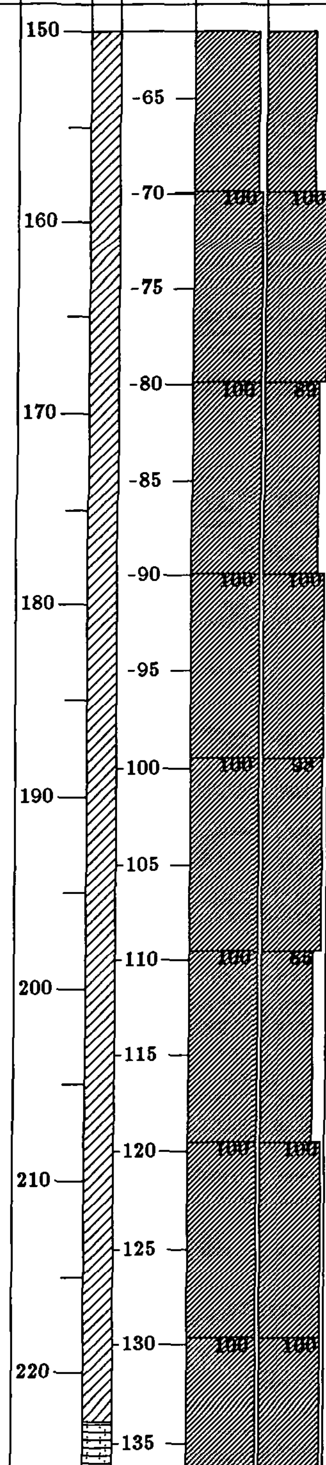
209.1-216.7 ft.: 25 to 35 deg. bedding plane separations infilled with quartz and chlorite, 2 to 10 mm wide.

213.0-222.2 ft.: Closely spaced 65 to 75 deg. joints, generally clean or infilled with quartz.

217.5-237.5 ft.: Oriented core.

DETAIL

microfaulting.
142.0 ft.: 55 deg. joint.
143.4 ft.: 70 deg. cleavage.
143.7-144.0 ft.: Green and white tuffaceous sandstone beds.
148.0 ft.: 70 deg. joint.
148.0-148.3 ft.: Fracture zone.
148.9-149.7 ft.: Holes 1 mm wide in core.
152.1 ft.: 30 deg. quartz-filled joint, 15 to 20 mm wide.
152.3 ft.: 60 deg. quartz-filled joint, 15 to 20 mm wide.
155.5-156.5 ft.: Green and white tuffaceous sandstone beds.
157.0-157.3 ft.: Green and white tuffaceous sandstone beds.
163.2 ft.: 15 deg. calcite-filled bedding plane separation.
164.8-168.3 ft.: Green and white tuffaceous sandstone beds, 5 to 10 mm wide.
170.8 ft.: Fracture zone.
173.0 ft.: 30 deg. slickensided joint.
175.0 ft.: 30 deg. joint, rough surfaces.
175.8-176.3 ft.: Brecciated zone with quartz infilling.
178.0 ft.: 75 deg. joint.
179.8-180.4 ft.: Fracture zone.
181.7 ft.: Microfaulting offsets bedding 3 to 6 mm.
184.1 ft.: Microfaulting offsets bedding by 3 to 6 mm.
185.1 ft.: Microfaulting offsets bedding by 3 to 6 mm.
188.6 ft.: Fracture zone, healed fractures.
189.1 ft.: Vein of calcite and quartz, 10 to 30 mm wide.
194.0 ft.: 90 deg. joint.
196.0-197.2 ft.: Fractures infilled with quartz.
198.0 ft.: 15 deg. quartz-filled joint, 7 mm wide.
198.0-198.6 ft.: Quartz veins 6 to 25 mm wide.
201.0-202.0 ft.: Fracture zone.
203.2 ft.: 30 deg. quartz-filled joint, 20 mm wide.
207.6 ft.: 30 deg. quartz-filled joint, 6 to 10 mm wide.
207.8 ft.: 30 deg. quartz-filled joint, 7 mm



Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
1460	
1283	
1999*	
<200	
603	
1428	3.0 @ 60 psi
1730	
825	
	0.2 @ 65 psi
<200	
<200	
	2.3 @ 120 psi
1111	
649	
1016	
	0.7 @ 76 psi
857	
	0.7 @ 81 psi

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial.

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 482330.10ft. E: 746407.38ft.**

Sea Floor Elevation: **88.5 ft.**
Total Depth Drilled: **318.1 ft.**

DESCRIPTION

MAIN

TUFFACEOUS SANDY ARGILLITE, dark green to light green, medium hard to hard, slightly weathered; flow banded appearance, thin to very thinly spaced bands, generally 10 to 35 deg.; joints moderately closely spaced, 45 to 80 deg., 1 to 10 mm wide, generally infilled with quartz and chlorite.

238.9-240.0 ft.: Preserved core.

241.2-242.5 ft.: Preserved core.

247.5-267.5 ft.: Oriented core.

271.6-276.3 ft.: Moderately closely spaced 70 and 80 deg. joints, 2 to 3 mm thick, infilled with quartz and chlorite.

290.1 ft.: Some pyrite.
290.5-296.0 ft.: Fracture zone with very closely spaced joints.

DETAIL

wide.
222.2-224.0 ft.: 55 to 60 deg. slickensided joints.
227.5-227.8 ft.: 65 to 75 deg. slickensided joints infilled with quartz.
228.1 ft.: Pyrite mineralization.
230.0 ft.: 55 deg. quartz-filled joint.
233.1-234.0 ft.: Fracture zone adjacent to 85 deg. joint.
233.5 ft.: 85 deg. quartz and calcite-filled joint.
236.0-238.0 ft.: Fracture zone and joints infilled with quartz.
237.4 ft.: Pyrite mineralization.
244.8-246.1 ft.: 75 deg. fault and fracture zone infilled with brecciated quartz.

252.0-252.4 ft.: Felsite clast 4 to 5 inches in diameter.
253.0 ft.: 55 deg. joint.
253.6 ft.: 65 deg. joint.

261.0-261.6 ft.: Argillite clast 6 inches in diameter.

265.0 ft.: Pyrite mineralization.

281.3 ft.: 80 deg. quartz and calcite-filled joint, 2 to 3 mm wide.
282.6 ft.: 50 deg. quartz and chlorite-filled joint, 2 to 3 mm wide.
286.0-287.0 ft.: Fracture zone, 30 deg. joints infilled with quartz and chlorite.
290.1 ft.: Pyrite mineralization.
290.5-296.0 ft.: Fracture zone with very closely spaced joints, infilled with quartz and chlorite.

Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
					0=<0.1 @ 86 psi
	-140	100	84		
230					
	-145				
					24.1 @ 92 psi
	-150	100	88		
240				571	
	-155			952	
				<200	0=<0.1 @ 97 psi
	-160	100	100		
250					
	-165				
	-170	100	100		
260					
	-175				
	-180	100	100		151.8 @ 107 psi
270					
				405	
	-185				
				1444	
	-190	100	90		0=<0.1 @ 112psi
280					
	-195			1762	
	-200	100	84	762	
290				1587	
	-205				
				841	
	-210	100	100		

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial.

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 482330.10ft. E: 746407.38ft.**

Sea Floor Elevation: **88.5 ft.**
Total Depth Drilled: **318.1 ft.**

DESCRIPTION — MAIN	DESCRIPTION — DETAIL	Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
TUFFACEOUS SANDY ARGILLITE, dark green to light green, medium hard to hard, slightly weathered; flow banded appearance, thin to very thinly spaced bands, generally 10 to 35 deg.; joints moderately close to closely spaced 45 to 80 deg., 1 to 10 mm wide, generally infilled with quartz and chlorite. Numerous drilling breaks parallel to joints and flow banding.	301.3-301.8 ft.: Fracture zone, 65-70 deg. quartz-filled joints. 302.0 ft.: Pyrite mineralization. 303.0 ft.: 70 deg. joint. 304.0 ft.: 50 deg. joint.	300	215			810 <200	
	310.0 ft.: 80 deg. quartz and chlorite-filled joint. 311.0 ft.: 30 deg. joint.	310	220	100	98	1063	
	314.7 ft.: Brecciated joint 5 mm wide. 316.5-318.1 ft.; Fracture zone with very closely spaced quartz filled joints, dipping 30 to 60 deg.		225			714	
318.1 FT.: END OF BORING							

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial.

FIELD TEST BORING RECORD COVER SHEET

		BORING NO. 89-105
SITE Inter Island Tunnel - Boston Harbor	J.O. NO. U11305	SHEET 1 OF 1

COORIDNATES N-S 480642.8 E-W 746306.8

SEAFLOOR ELEVATION 84.3

INCLINATION Vertical INSPECTOR Richters, Sheridan

DATE: START/FINISH 8/26/89 / 8/29/89

CONTRACTOR/DRILLER Warren George/Gregory

DRILLING BARGE Katherine G

WATER DEPTH 21.4 (FT) DRILL RIG TYPE Failing 1500

ELEVATION TOP OF BEDROCK -30.7 (FT)

TOTAL DEPTH DRILLED 307.5 (FT)

METHODS:
- DRILLING SOIL Tri-cone rollerbit
- SAMPLING SOIL Split-spoon sampler
- DRILLING ROCK Roller bit, continuous HQ wireline coring
- SPECIAL TESTING OR INSTRUMENTATION Oriented coring, Packer testing, downhole geophysics.

SUMMARY

SOIL DRILLED 115.0 (FT) ROCK CORED 192.5 (FT)
NUMBER SPLIT BARREL SAMPLES 12

NOTES

1. The coordinate system used is the 1927 MASS GRID.
2. Datum is M.D.C.
3. In water borings, the split spoon sampler was driven into the soil by dropping a 175-pound sliding down hole hammer a distance of 4 feet within the borehole.
4. In land based borings the soil sampling method used was the STD Penetration Resistance using a 140 lb. hammer dropping a distance of 30 inches.

APPROVED	DATE
M Gilbert	1/2/90

GOLDBERG-ZOINO & ASSOCIATES, INC.

GZA

BORING SUMMARY LOG

BORING 89-105
SHEET 1 OF 5

PROJECT: INTER-ISLAND TUNNEL, BOSTON HARBOR
CLIENT: Massachusetts Water Resources Authority
Coordinates: N: 480642.79ft. E: 746306.76ft.

Sea Floor Elevation: 84.3 ft.
Total Depth Drilled: 307.5 ft.

DESCRIPTION — MAIN	DESCRIPTION — DETAIL	Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
ORGANIC SILT, 15% sand, 3% gravel, very loose, black (OL). **SILTY CLAY**, moderately plastic, 5% sand, very soft, gray (CH).		0	84.3 80			** 1-1-1-1 R6	
SILTY CLAY, slightly plastic, very stiff, green (CL).		10	75 70			13-13 13-15 R24	
SILTY CLAY, slightly plastic, very stiff, green (CL).		20	65 60			10-12 7-9 R24	
SILTY CLAY, slightly plastic, stiff, green (CL).		30	55 50			4-6-8-9 R24	
SILTY CLAY, slightly plastic, stiff, green (CL).		40	45 40			2-3-5-8 R16	
SILTY CLAY, slightly plastic, stiff, green (CL).		50	35 30			4-4-6-8 R20	
SILTY CLAY, slightly plastic, stiff, green (CL).		60	25 20			7-7-7-9 R20	
SILTY CLAY, slightly plastic, stiff, green (CL).		70	15 10			5-5-5-5 R20	

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

GZA

BORING SUMMARY LOG

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 480642.79ft. E: 746306.76ft.**

Sea Floor Elevation: **84.3 ft.**
Total Depth Drilled: **307.5 ft.**

DESCRIPTION: MAIN	DESCRIPTION: DETAIL	Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load I_{s} 50	Pressure Test K = cm/sec (x 0.00001)
SILTY CLAY, slightly plastic, stiff, green (CL).		80	5			3-3-6-8 R17	
			0				
SILTY CLAY, slightly plastic, firm, green (CL).		90	-5			3-3-3-6 R24	
			-10				
SILTY CLAY, slightly plastic, firm, green (CL).		100	-15			2-3-3-9 R24	
			-20				
TILL, SANDY GRAVEL, mostly coarse gravel, 35% fine to coarse sand, 20% silt, dense, gray (GM).		110	-25			4-13 16-37 R6	
			-30				
TUFFACEOUS SANDY ARGILLITE, greenish gray, hard, slightly weathered; bedding very thin generally 40 deg.; widely spaced joints 40 to 85 deg.; veins infilled with quartz.	TOP OF BEDROCK 115.0 FT. Roller bit to 117.5 ft. 118.6-119.0 ft.: Fracture zone adjacent to joints.	120	-35	100	96	<200 1179*	
			-40			940	
127.0-147.0 ft.: Numerous bedding plane separations.	129.0-132.0 ft.: 95 deg. slickensided joints 3 to 4 mm wide, some infilled with quartz, pyrite and chlorite.	130	-45	100	19	1657 1402	
	131.4-132.3 ft.: 90 deg. fracture zone with slickensides.		-50				
137.5-157.5 ft.: Very widely spaced joints.	133.0-134.0 ft.: 60 deg. bedding. 133.0-136.0 ft.: 90 deg. fracture zone with gouge. 135.0 ft.: 80 deg. cleavage.	140	-55	100	68	2087	
	138.5 ft.: Bedding plane separations filled with clay and pyrite.		-60			1338	
	146.0-146.3 ft.: Soft sediment deformation. 146.5-147.2 ft.:		-65	100	100		

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

BORING 89-105
SHEET 3 OF 5

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 480642.79ft. E: 746306.76ft.**

Sea Floor Elevation: **84.3 ft.**
Total Depth Drilled: **307.5 ft.**

DESCRIPTION

MAIN

TUFFACEOUS SANDY ARGILLITE, greenish gray, hard, slightly weathered; bedding very thin, generally 40 deg.; joints moderately close to widely spaced 50 to 85 deg.; veins infilled with quartz, pyrite, and chlorite; slickensides on many bedding plane separations.

187.5-197.5 ft.: Joints are moderately closely spaced, generally 2 to 3 mm wide, and crosscutting bedding.

207.3-227.3 ft.: Oriented core.

TUFFACEOUS SANDY ARGILLITE, greenish gray, hard, slightly weathered to fresh; bedding very thin to laminar 30 to 40 deg.; joint spacing generally moderately closely, 50 to 75 deg.; slickensides present on many joint and bedding plane surfaces.
207.5-217.5 ft.: Moderately closely spaced joints.

DETAIL

Fracture zone.
147.7-149.0 ft.: 70 deg. quartz filled joint.

160.5-161.5 ft.: Slumped bedding.
160.5: 60 deg. slickensided joint.

164.5-165.4 ft.: Fracture zone, highly weathered, closely spaced 80 deg. quartz veins and bedding plane separations.

177.5-178.5 ft.: Fracture zone with abundant quartz veins, brecciation, and pyrite.
179.0 ft.: Pyrite mineralization.
180.0 ft.: 75 deg. joint with slickensides, crosscutting bedding.
181.0 ft.: Pink quartz-rich sandstone bed.
183.0 ft.: Two 60 deg. joints.
183.5 ft.: Soft sediment deformation.
190.5 ft.: 70 deg. slickensided joint.
194.5 ft.: 70 deg. calcite filled joint.
195.0 ft.: 70 deg. calcite filled joint.
195.0-196.0 ft.: Numerous 90 deg. calcite veins.
197.0-197.8 ft.: Fracture zone.
200.2-201.0 ft.: Pitted with a network of calcite stringers and pyrite mineralization.
207.0 ft.: 80 deg. slickensided joint.

212.5-214.5 ft.: Numerous thin interbedded quartz rich sandstone beds.

224.0 ft.: Pyrite

Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
150					
	-70				
		100	64	1227	
160	-75				
				797	
				1848*	
	-80				
				781	
		100	99		
170	-85				
				972	
	-90				
				1227	0=<0.1 @ 51 psi
		100	81		
				<200	
180	-95				
	-100			669	
		100	85		
190	-105				
				1529	
	-110			605	14.2 @ 62 psi
		100	84		
200	-115				
	-120				
				<200	0=<0.1 @ 67 psi
		100	96		
210	-125				
	-130				
		100	85		0.5 @ 72 psi
220	-135				
	-140				

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

GZA

BORING SUMMARY LOG

BORING 89-105

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: N: **480642.79ft.** E: **746306.76ft.**

Sea Floor Elevation: **84.3 ft.**
Total Depth Drilled: **307.5 ft.**

DESCRIPTION

MAIN	DETAIL
TUFFACEOUS SANDY ARGILLITE, greenish gray, hard, slightly weathered to fresh; bedding very thin to laminar 30 to 40 deg.; joint spacing generally moderately closely, 50 to 75 deg.; slickensides present on many joint and bedding plane surfaces. 231.0-232.2 ft.: Preserved core. 237.3-257.3 ft.: Oriented core. 237.5-247.5 ft.: Very widely spaced joints. 247.5-257.5 ft.: Widely spaced joints.	mineralization along joints and bedding plane separation. 225.8 ft.: Chlorite and pyrite mineralization along joint and bedding plane separations. 230.0-231.0 ft.: Slumped bedding. 235.0-236.0 ft.: 70 deg. slickensided joint. 243.0-244.0 ft.: Slumped bedding. 249.2-252.2 ft.: Massive fabric. 252.8-258.3 ft.: 45 deg. bedding.
DIABASE, dark green, very hard, fresh; massive; joints closely spaced, 30 to 80 deg.; veins infilled with quartz and calcite; disseminated pyrite present throughout. 287.5-292.5: Quartz veins, 1 to 7 mm wide, various orientations.	264.7 ft.: 60 deg. slickensided joint. 265.3-265.5 ft.: 60 deg. calcite filled joint, 50 mm wide. 278.0 ft.: 60 deg. slickensided joint. 279.3 ft.: 40 deg. slickensided joint. 280.5 ft.: 80 deg. slickensided joint. 287.2 ft.: 50 deg. slickensided joint. 288.0 ft.: 80 deg. slickensided joint. 289.0 ft.: 70 deg. slickensided joint. 294.0 ft.: 85 deg. slickensided joint.

Depth (ft.)	Elev. (ft.)
	-145
230	
	-150
	-155
240	
	-160
	-165
250	
	-170
	-175
260	
	-180
	-185
270	
	-190
	-195
280	
	-200
	-205
290	
	-210
	-215

REC	RQD
100	90
100	97
100	90
100	70
100	95
100	92
100	88
100	98

Point Load $I_{s\,50}$
797
<200
2326
2135
2549
1004
1243

Pressure Test K = cm/sec (x 0.00001)
0.6 @ 78 psi
0=<0.1 @ 83 psi
0=<0.1 @ 88 psi
0=<0.1 @ 93 psi
0.1 @ 98 psi
18.9 @ 56 psi

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 480642.79ft. E: 746306.76ft.**

Sea Floor Elevation: **84.3 ft.**
Total Depth Drilled: **307.5 ft.**

DESCRIPTION: MAIN	DESCRIPTION: DETAIL	Depth (ft.)		Elev. (ft.)	REC	RQD	Point Load $I_{s\ 50}$	Pressure Test K = cm/sec (x 0.00001)
		300						
TUFFACEOUS SANDY ARGILLITE, greenish-gray, hard, fresh to slightly weathered; bedding thin to very thin, generally 40 deg.; joints moderately closely spaced 50 to 85 deg.; veins infilled with calcite and quartz.	303.0-305.0 ft.: Slumped bedding.			220			908 1004	
307.5 FT.: END OF BORING								

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

FIELD TEST BORING RECORD COVER SHEET

		BORING NO. 89-106
SITE Inter Island Tunnel - Boston Harbor	J.O. NO. U11305	SHEET 1 OF 1

COORIDNATES N-S 478934.8 E-W 746371.3

SEAFLOOR ELEVATION 72.5

INCLINATION Vertical INSPECTOR Zilinskas, Grimes

DATE: START/FINISH 8/19/89 / 8/23/89

CONTRACTOR/DRILLER Warren George/Gregory

DRILLING BARGE Katherine G

WATER DEPTH 33.2 (FT) DRILL RIG TYPE Failing 1500

ELEVATION TOP OF BEDROCK 40.0 (FT)

TOTAL DEPTH DRILLED 292.0 (FT)

METHODS:
- DRILLING SOIL Tri-cone rollerbit
- SAMPLING SOIL Split-spoon sampler
- DRILLING ROCK Roller bit, continuous HQ wireline coring
- SPECIAL TESTING OR INSTRUMENTATION Oriented coring, Packer testing.

SUMMARY

SOIL DRILLED 32.5 (FT) ROCK CORED 259.5 (FT)
NUMBER SPLIT BARREL SAMPLES 5

NOTES

1. The coordinate system used is the 1927 MASS GRID.
2. Datum is M.D.C.
3. In water borings, the split spoon sampler was driven into the soil by dropping a 175-pound sliding down hole hammer a distance of 4 feet within the borehole.
4. In land based borings the soil sampling method used was the STD Penetration Resistance using a 140 lb. hammer dropping a distance of 30 inches.

APPROVED	DATE
M Gilbert	1/2/90

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

BORING 89-106

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: N: **478934.77ft.** E: **746371.33ft.**

Sea Floor Elevation: **72.5 ft.**
Total Depth Drilled: **292.0 ft.**

DESCRIPTION

MAIN	DETAIL
SILTY SAND, fine to medium sand, 35% silt, 5% clay, very loose, gray and black (SM), abundant shell fragments.	
TILL, CLAYEY SILT, 35% fine to coarse gravel, angular clasts, 5% medium sand, very dense, olive gray (ML).	
TILL, SANDY GRAVEL, mostly fine to coarse gravel, angular clasts, 35% medium to coarse sand, 25% clayey silt, very dense, olive gray (GP).	
TILL, CLAYEY SILT, 40% medium to coarse sand, 5% fine gravel, very dense, olive gray (ML).	TOP OF BEDROCK 32.5 FT.
ARGILLITE INTERBEDDED WITH SANDSTONE, black to light gray, medium hard to hard, slightly weathered to fresh; bedding very thin to laminar 30 to 45 deg., except generally massive in sandy light gray areas; joints moderately closely spaced, 45 to 80 deg.; soft sediment deformation (slumped bedding) common throughout; joints, veins, and bedding plane partings generally infilled with calcite, quartz, and clay.	Roller bit to 37.5 ft. 37.5-39.3 ft.: Slumped bedding. 38.0 ft.: 80 degree cleavage. 41.0 ft.: Tuffaceous argillite. 42.0-51.3 ft.: Slumped bedding. 47.0 ft.: 70 deg. cleavage. 49.0-51.5 ft.: Network of calcite veining. 52.8 ft.: 60 deg. clay filled joint.
55.0-58.0 ft.: Altered Diabase, light grayish green, medium hard.	60.5 ft.: 70 deg. cleavage. 63.0 ft.: 90 deg. calcite vein. 64.9-65.4 ft.: Slumped bedding. 66.0 ft.: 45 deg. clay filled joint. 66.3 ft.: 70 deg. slickensided calcite vein. 68.3-70.3 ft.: Sandstone; slumped bedding with Argillite clasts.

Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\ 50}$	Pressure Test K = cm/sec (x 0.00001)
0	72.5			** 1-1-0-1 R5	
	70				
	65				
10	60				
	55			100/4 R4	
20	50			100/2 R2	
	45				
30	40			100/1 R1	
				75/3 R0	
	35	100	100		
40				1463	
	30	100	100	1272	
	25				
50	20	95	91	<200 1256	
	15				
60				620	
	10	100	95		
				2194	
	5				
70				636	
	0	100	100	541*	

NOTES: Packer Test, transducer monitored double packer, K, 10-5 cm/sec at pressure indicated; Point Load Test corrected to 50 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer, Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

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BORING SUMMARY LOG

BORING 89-106
SHEET 2 OF 4

PROJECT: INTER-ISLAND TUNNEL, BOSTON HARBOR Sea Floor Elevation: **72.5 ft.**
CLIENT: **Massachusetts Water Resources Authority** Total Depth Drilled: **292.0 ft.**
Coordinates: **N: 478934.77ft. E: 746371.33ft.**

DESCRIPTION

MAIN

ARGILLITE INTERBEDDED WITH SANDSTONE, black to light gray, medium hard, fresh to slightly weathered; bedding very thin to laminar except generally massive in sandy light gray areas, 25 to 35 deg.; joints moderately close to widely spaced, generally 60 deg.; joints, veins and bedding plane separations generally infilled with calcite or clay.
82.0-89.7 ft.: Felspathic Sandstone, light grayish green, medium hard, massive.

142.0-152.0 ft.: Slumped bedding common, most core breaks along bedding plane separations.

DETAIL

71.5-71.8 ft.: Coarse Sandstone bed.
77.0 ft.: 80 deg. cleavage
77.0-78.0 ft.: Massive Sandstone beds contain Argillite clasts.
78.8-80.0 ft.: 75 deg. calcite veins up to 10 mm thick.
82.0 ft.: 60 deg. calcite filled joint, crosscutting bedding.
83.0 ft.: 60 deg. calcite filled joint, crosscutting bedding.
89.7-92.0 ft.: 70-90 deg. calcite filled joints, crosscutting bedding

97.0 ft.: Pyrite mineralization.

99.8-100.0 ft. & 105.2-106.4 ft.: Sandstone with argillite clasts.
102.0-112.0 ft.: Widely spaced joints.
103.0 ft.: 50 deg. calcite filled joint, crosscutting bedding.
104.5-107.0 ft.: Massive sandstone with argillite clasts.
105.2-106.4 ft.: Sandstone with argillite clasts.
114.0-117.0 ft.: Slumped bedding.
115.8 ft.: 80 deg. cleavage
117.0-118.6 ft.: Sandstone with argillite clasts.
120.7-122.0 ft.: Slumped Sandstone bedding with argillite clasts.
123.0-131.4 ft.: Slumped bedding.
126.8-127.0 ft.: Coarse Sandstone bed.
129.8 ft.: 80 deg. cleavage.

135.0 ft.: 80 deg. pyrite and calcite coated joint.
137.0 ft: 60 deg. joint, crosscutting bedding.
138.1 ft.: 60 deg. joint, crosscutting bedding.

143.0 ft.: Calcite filled bedding plane partings, 1to 7 mm thick.
146.0 ft.: Calcite filled bedding plane partings 1 to 7 mm thick.
148.5 ft.: 60 deg. joint,

Depth (ft.)

80, 90, 100, 110, 120, 130, 140

Elev. (ft.) / REC / RQD

Elev. (ft.)	REC	RQD
-5		
-10	100	100
-15		
-20	100	100
-25		
-30	100	100
-35		
-40	100	100
-45		
-50	100	100
-55		
-60	100	74
-65		
-70	100	94
-75		

Point Load I_{s} 50

<200
1359
795
1272
1097
1121
1542
2067
<200
<200
1065

Pressure Test K = cm/sec (x 0.00001)

NOTES: Packer Test, transducer monitored double packer, K, 10-5 cm/sec at pressure indicated; Point Load Test corrected to 50 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer, Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 478934.77ft. E: 746371.33ft.**

Sea Floor Elevation: **72.5 ft.**
Total Depth Drilled: **292.0 ft.**

DESCRIPTION

MAIN

ARGILLITE INTERBEDDED WITH SANDSTONE, black to light gray, medium hard, fresh to slightly weathered; bedding thin to laminar except generally massive in sandy light gray areas, 25 to 35 deg.; joints moderately close to widely spaced, generally 60 deg.; joints, veins and bedding plane separations generally infilled with calcite or clay.

162.0-182.0 ft.: Core is more massive.
162.4-168.8 ft.: Many sandstone beds with argillite clasts.

182.0-192.0 ft.: Widely spaced joints with many bedding plane separations.

187.0-190.5 ft.: Sandstone beds with argillite clasts.

192.5-217.5 ft.: Oriented core.

202.0-217.0 ft.: Few bedding plane separations.

209.5-227.0 ft.: No natural joints.

222.5-223.8 ft.: Preserved core.

DETAIL

crosscutting bedding.

156.0-162.0 ft.: Slumped bedding with calcite filled fractures.
157.7-158.8 ft.: Brecciated zone with numerous ennechelon joints
158.5 ft.: 70 deg. joint, crosscutting bedding.
161.0 ft.: 70 deg. joint, crosscutting bedding.

169.5-170.3 ft.: Closely spaced joints, 1 to 3 mm wide, approximately 65 deg.
173.0 ft.: 50 deg. joint, crosscutting bedding.
176.0 ft.: 50 deg. joint, crosscutting bedding.
178.0 ft.: 80 deg. joint, crosscutting bedding.
179.0-180.0 ft.: Slumped bedding.
179.5-181.4 ft.: Closely spaced calcite filled joints, 70 to 80 deg.
180.6 ft.: 60 deg. joint, crosscutting bedding.
182.5 ft.: 70 deg. joint, crosscutting bedding.
183.5 ft.: 75 deg. joint with slickensides.
184.3 ft.: 60 deg. joint, crosscutting bedding.
186.0 ft.: 60 deg. joint, crosscutting bedding.
193.4 ft.: 60 deg. calcite filled joint, crosscutting bedding.
193.5 ft.: 60 deg. calcite filled joint, crosscutting bedding.
199.5-201.5 ft.: Numerous bedding plane separations.
200.5-202.0 ft.: Fracture zone with 80 deg. cleavage.
203.7 ft.: 4 mm thick bedding plane parting infilled with calcite.
207.0 ft.: 80 deg. calcite filled joint, crosscutting bedding.
207.5 ft.: 60 deg. calcite filled joint, crosscutting bedding.
212.5-214.8 ft.: Slumped bedding.
214.8-215.0 ft.: 50 deg. vein, 20 mm wide infilled with calcite and brecciated argillite.
215.0-217.0 ft.: Slumped bedding.
218.0-219.8 ft.:

Depth (ft.)	Elev. (ft.)
150	
	-80
	-85
160	
	-90
	-95
170	
	-100
	-105
180	
	-110
	-115
190	
	-120
	-125
200	
	-130
	-135
210	
	-140
	-145
220	
	-150

Elev. (ft.) at top of run	REC	RQD
-80	100	98
-90	100	98
-100	100	100
-110	100	100
-120	98	70
-130	100	99
-137	99	96
-145	100	97

Point Load $I_{s\,50}$
1145*
1320
493
1956
842
700
1511
1701
2274
1685

Pressure Test K = cm/sec (x 0.00001)
0.1 @ 69 psi
6.5 @ 74 psi
32.2 @ 80 psi
1.4 @ 85 psi
2.4 @ 90 psi
4.5 @ 96 psi

NOTES: Packer Test, transducer monitored double packer, K, 10-5 cm/sec at pressure indicated; Point Load Test corrected to 50 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer, Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

BORING 89-106
SHEET **4 OF 4**

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 478934.77ft. E: 746371.33ft.**

Sea Floor Elevation: **72.5 ft.**
Total Depth Drilled: **292.0 ft.**

DESCRIPTION

MAIN	DETAIL
227.5-242.5 ft.: Oriented core.	Conglomeratic bed. 220.8-221.4 ft.: 70 deg. joints, many have slickensided surfaces. 228.6 ft.: 60 deg. joint.
FELSITE, light grayish green, medium hard, massive, contact conformable with argillite bedding. Closely spaced, calcite-filled joints, 70 to 80 deg.	231.0 ft.: 70 deg. calcite filled joint, with slickensides.
ARGILLITE INTERBEDDED WITH SANDSTONE, light gray to dark gray, medium hard to hard, slightly weathered to fresh; bedding medium to very thin, generally 15 to 30 deg., except up to 55 deg. in areas of slumped bedding; joints widely to closely spaced, 40 to 85 deg. 242.0-260.7 ft.: Slumped bedding common.	234.3-236.2 ft.: Slumped bedding. 235.09-235.2 ft.: 40 deg. joint, crosscutting bedding. 237.5 ft.: 60 deg. joint, crosscutting bedding. 241.8 ft.: 60 deg. joint, infilled with clay and pyrite. 243.6 ft.: 60 deg. joint. 243.8 ft.: 60 deg. joint, crosscutting bedding. 244.3 ft.: 40 deg. joint, crosscutting bedding. 246.3 ft.: Pyrite mineralization. 248.5-250.8 ft.: 45 deg. bedding with numerous bedding plane separations and frequent slickensides. 248.8 ft.: Fracture zone, adjacent to 80 deg. calcite coated joint. 250.2 ft.: 70 deg. cleavage. 258.0 ft.: 70 deg. cleavage. 258.6-260.9 ft.: Pyrite mineralization. 263.9-269.1 ft.: Fracture zone, 80 deg. cleavage. 265.6-268.0 ft.: Sandstone beds. 269.7 ft.: 70 deg. joint, stained with iron oxide.
272.0-292.0 ft.: Generally massive fabric with few bedding plane separations.	271.8 ft.: 50 deg. calcite filled joints. 277.0 ft.: 80 deg. cleavage. 281.6-281.8 ft.: Coarse sandstone beds. 283.6 ft.: 90 deg. calcite vein. 285.4-289.5 ft.: Fracture zone with 75 deg. fault off-setting bedding.
292.0 ft.: END OF BORING	

Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s}50$	Pressure Test K = cm/sec (x 0.00001)
	-155	100	68		
230	-160				42.4 @ 96 psi
	-165	98	78		
240	-170	100	63	1272	5.6 @ 106 psi
	-175			827	
250	-180	100	97		0=<0.1 @ 120psi
	-185			1526	
				1113	
260	-190	100	91	2321	8.4 @ 125 psi
	-195			2393	
270	-200	100	97		
	-205			1797	
280	-210	100	88	1781	
	-215				
290				1590	

NOTES: Packer Test, transducer monitored double packer, K, 10-5 cm/sec at pressure indicated; Point Load Test corrected to 50 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer, Recovery in inches.

FIELD TEST BORING RECORD COVER SHEET

		BORING NO. 89-107
SITE Inter Island Tunnel - Boston Harbor	J.O. NO. U11305	SHEET 1 OF 1

COORIDNATES N-S 476641.1 E-W 746227.7

SEAFLOOR ELEVATION 85.6

INCLINATION Vertical INSPECTOR Watson, Grimes

DATE: START/FINISH 9/01/89 / 9/04/89

CONTRACTOR/DRILLER Warren George/Gregory

DRILLING BARGE Katherine G

WATER DEPTH 20.1 (FT) DRILL RIG TYPE Failing 1500

ELEVATION TOP OF BEDROCK 60.6 (FT)

TOTAL DEPTH DRILLED 303.7 (FT)

METHODS:
- DRILLING SOIL Tri-cone rollerbit
- SAMPLING SOIL Split-spoon sampler
- DRILLING ROCK Roller bit, continuous HQ wireline coring
- SPECIAL TESTING OR INSTRUMENTATION Oriented coring, Packer testing.

SUMMARY

SOIL DRILLED 25.0 (FT) ROCK CORED 278.7 (FT)
NUMBER SPLIT BARREL SAMPLES 3

NOTES

1. The coordinate system used is the 1927 MASS GRID.
2. Datum is M.D.C.
3. In water borings, the split spoon sampler was driven into the soil by dropping a 175-pound sliding down hole hammer a distance of 4 feet within the borehole.
4. In land based borings the soil sampling method used was the STD Penetration Resistance using a 140 lb. hammer dropping a distance of 30 inches.

APPROVED	DATE
M Gilbert	1/2/90

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

BORING 89-107
SHEET 1 OF 5

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: N: **476641.05ft.** E: **746227.69ft.**

Sea Floor Elevation: **85.6 ft.**
Total Depth Drilled: **303.7 ft.**

DESCRIPTION – MAIN	DESCRIPTION – DETAIL
ORGANIC SILT, 15% sand, medium dense, black (OL). **SILTY CLAY**, hard, gray to light brown (CL).	
SILTY CLAY, 5% gravel, very stiff, gray to light brown (CL).	
TILL, CLAYEY GRAVEL, 20% clay and silt, 5% sand, medium dense, light brown to gray (GC).	
ARGILLITE INTERBEDDED WITH SANDY ARGILLITE, gray, medium hard, slightly weathered; bedding very thin to laminar, 20 to 35 deg, sandy beds are generally calcareous from depth of 25.0 to 62.3 ft.; jonts moderately close to very closely spaced 50 to 85 deg; bedding plane partings, joints, and veins (discontinuities) generally infilled with calcite and minor quartz.	TOP OF BEDROCK 25.0 FT. Roller bit to 32.0 ft. 33.5 ft.: 60 deg. cleavage. 38.0-39.0 ft.: 75 deg. joints, crosscutting bedding.
42.0-52.0 ft.: Numerous 45 deg. calcite veins, crosscutting bedding.	42.8 ft.: Slumped bedding. 48.5 ft.: 85 deg. joint, crosscutting bedding. 51.0-52.0 ft.: 80 deg. calcite filled joint. 53.0 ft.: 75 deg. cleavage. 54.5-55.5 ft.: 75 deg. slickensided joint; core is brecciated adjacent to joint 57.8-58.6 ft.: Slumped bedding altered (chloritic) argillite. 61.6-62.0 ft.: Slumped bedding. 65.9-66.2 ft.: Slumped bedding. 73.5 ft.: 3 cm wide calcite vein, 60 deg.

Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
0	85.6				
	85			** 8-14-18 R12	
	80				
10	75			5-7-9 R18	
	70				
20	65			11-9-14 R5	
	60				
30	55				
		100	71	2474	
	50				
				1574	
40	45				
		100	87	1976 <200	
	40			1896	
50	35				
		100	55		
	30			1687	
60	25	100	61	771	
	20			1285	
70	15	100	34		
				996	

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 50 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 476641.05ft. E: 746227.69ft.**

Sea Floor Elevation: **85.6 ft.**
Total Depth Drilled: **303.7 ft.**

DESCRIPTION

MAIN

ARGILLITE WITH OCCASIONAL SANDSTONE BEDS, gray, medium hard, slightly weathered; bedding very thin to laminar, 0 to 35 deg.; sandy beds are generally calcareous; joints moderately closely spaced, 60 to 85 deg.; occasional calcite veins, various dip angles; calcite throughout core.

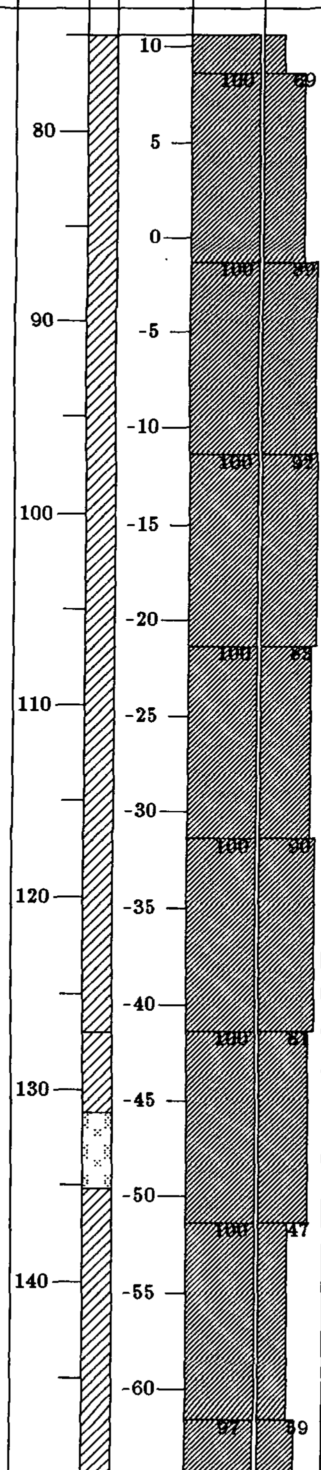
ARGILLITE WITH OCCASIONAL SANDSTONE BEDS, dark gray, medium hard, slightly weathered; bedding very thin to laminar, 10 to 45 deg.; joints moderately close to very closely spaced, 50 to 70 deg.; occasional veins at various angles; veins, joints and bedding plane separations generally infilled with calcite and minor quartz.

DIABASE, grayish green, hard, massive, numerous calcite veins. 4 cm wide calcite veins at contact of felsite and argillite.

137.0-147.0 ft.: Slumped bedding common.

DETAIL

74.0-74.5 ft.: Fracture zone with numerous voids.
74.7-74.9 ft.: Fracture zone recemented with calcite.
75.0-76.7 ft.: Massive fabric.
76.7-77.0 ft.: Horizontal bedding.
79.0 ft.: 60 deg. calcite filled joint.
84.5 ft.: 60 deg. joint, crosscutting bedding.
87.5-90.6 ft.: Slumped bedding.
89.0 ft.: 70 deg. slickensided joint.
92.0 ft.: 85 deg. joint.
94.9 ft.: Slumped bedding with some calcite/clay beds.
101.0-106.0 ft.: Slumped bedding.
106.0-107.0 ft.: Massive fabric.
107.5-108.2 ft.: 70 deg. calcite filled joint.
110.8 ft.: Clay bed.
111.0-111.8 ft.: Slumped bedding.
117.0-121.0 ft.: Massive fabric.
126.0-127.0 ft.: Massive fabric.
127.0-127.7 ft.: Numerous voids.
129.0 ft.: Fractures give core a blocky fabric.
136.0-137.0 ft.: 70 deg. calcite filled joint.
137.8-139.0 ft.: Numerous voids.
138.5-139.0 ft.: 55 deg. fault zone with slickensides.
140.1-140.3 ft.: Gouge zone.



Point Load $I_{s\,50}$: 835, 1414, 1237, 1109, 1366, 1334, <200, 2217, 996, 1366, 1349, 1526, <200, 1077

Pressure Test K = cm/sec (x 0.00001)

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 50 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

BORING 89-107
SHEET 3 OF 5

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: N: **476641.05ft.** E: **746227.69ft.**

Sea Floor Elevation: **85.6 ft.**
Total Depth Drilled: **303.7 ft.**

DESCRIPTION

MAIN

ARGILLITE WITH OCCASIONAL SANDSTONE BEDS, dark gray, medium hard, slightly weathered; bedding very thin to laminar, 10 to 45 deg.; joints moderately close to very closely spaced, 50 to 70 deg.; occasional veins at various angles; veins, joints and bedding plane separations generally infilled with calcite and minor quartz.

- - - - - - - - - - - - - - -

ARGILLITE WITH OCCASIONAL SANDSTONE BEDS, dark gray to black, medium hard, slightly weathered; bedding very thin to laminar, 10 to 35 deg.; joints moderately close to closely spaced, 50 to 80 deg.; occasional calcite veins 40 to 80 deg.

193.0-197.0 ft.: 70 deg. joints, 2 to 4 mm wide crosscutting bedding, calcite infilling.

206.6-226.6 ft.: Oriented core.

DETAIL

151.5 ft.: 60 deg. clay filled joint, crosscutting bedding.
152.0 ft.: 5 mm wide bedding plane separation infilled with calcite and argillite breccia.
158.3-159.6 ft.: Slumped bedding.

162.5 ft.: 50 deg. slickensided joint.

171.2-171.8 ft.: Calcareous sandy beds.

174.0-177.0 ft.: Slumped bedding with argillite clasts.
175.0 ft.: 90 deg. fault, recemented with calcite.

181.0-181.2 ft.: Gouge zone.

187.0-189.0 ft.: Calcite veins, various orientations.
190.0-190.8 ft.: Soft argillite.
190.9-191.1 ft.: Sandstone bed.
192.0-194.0 ft.: Calcite veins, various orientations.
197.7-198.5 ft.: 60 deg. fracture zone with numerous voids and slickensides.
200.3-201.0 ft.: Fracture zone, recemented with calcite.
201.0-203.2 ft.: Slumped bedding with calcite clasts.
205.6-206.8 ft.: Slumped bedding with calcite clasts.
206.4 ft.: Closely spaced 60 to 70 deg. joints.
210.0-210.5 ft.: Brecciated zone.
211.0 ft.: 45 deg slickensided bedding plane separation.
213.8-214.9 ft.: Slumped bedding with calcite clasts.
215.9-216.6 ft.: Brecciated zone.
220.8-221.5 ft.: Slumped bedding.

Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
150	-65			1189	
				1173	
	-70	100	91	1912	
160	-75				
	-80	100	70		
170	-85				0.8 @ 69 psi
				<200	
	-90	100	35		
180	-95			<200	0=<0.1 @ 75 psi
				<200	
	-100	100	70		
190	-105				0=<0.1 @ 80 psi
				2474	
	-110	100	56	482	
200	-115			1285	0=<0.1 @ 85 psi
	-120	100	48	<200	
210	-125				0=<0.1 @ 90 psi
	-130	100	78		
220	-135				0.1 @ 96 psi

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 50 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

GZA

BORING SUMMARY LOG

BORING 89-107
SHEET **4 OF 5**

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 476641.05ft. E: 746227.69ft.**

Sea Floor Elevation: **85.6 ft.**
Total Depth Drilled: **303.7 ft.**

DESCRIPTION — MAIN	DESCRIPTION — DETAIL	Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s}50$	Pressure Test K = cm/sec (x 0.00001)
	223.3-225.7 ft.: Slumped bedding. 226.2 ft.: 60 deg. clay filled joint, 10 mm wide. 226.40-226.9 ft.: Brecciated zone.		140	98	51		
231.1-231.8 ft.: Preserved core	226.9-230.5 ft.: Fracture zone, recemented with calcite. 231.1-231.8 ft.: Preserved core.	230	145			529	0.2 @ 101 psi
236.6-253.6 ft.: Oriented core.	232.3-232.5 ft.: Fractured zone, recemented with calcite.		150	97	28	<200	
ARGILLITE WITH OCCASIONAL SANDSTONE BEDS, light gray to dark gray, medium hard, slightly weathered; bedding variable: generally slumped, to massive, rarely very thin; 45 to 80 deg; joints wide to moderately closely spaced, 45 to 80 deg.	234.7-236.4 ft.: Fracture zone with numerous voids. 237.8-238.3 ft.: Gouge zone with 60 deg. slickensides.	240	155				0=<0.1 @ 107psi
	241.0 ft.: 80 deg. curved joint with slickensides. 242.1-242.5 ft.: Fracture zone infilled with calcite.		160	100	82		
	243.6-245.0 ft.: Fracture zone with conjugate joint sets at 50 to 60 deg.	250	165				
	248.0-249.0 ft.: 65 deg. calcite filled joint crosscutting bedding.		170	100	92	<200	0=<0.1 @ 111psi
	257.4 ft.: 55 deg. calcite filled joint crosscutting bedding, 5 mm wide.	260	175			<200	
			180	100	97		0=<0.1 @ 117psi
		270	185			879 619	
			190	100	97		
	279.5-280.0 ft.: Calcareous sandy beds.	280	195			1159* 554	
			200	100		417	
	287.0 ft.: 85 deg. joint, crosscutting bedding. 289.3-289.7 ft.: Slumped bedding.	290	205			1628	
	209.6 ft.: 46 deg. joint with altered argillite adjacent to joint. 290.6-293.7 ft.: Slumped bedding. 296.0-299.0 ft.: 85 deg. joint, crosscutting bedding.		210	100	100	543	

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 50 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 476641.05ft. E: 746227.69ft.**
Sea Floor Elevation: **85.6 ft.**
Total Depth Drilled: **303.7 ft.**

DESCRIPTION: MAIN	DESCRIPTION: DETAIL	Depth (ft.)		Elev. (ft.)	REC	RQD	Point Load I_{s} 50	Pressure Test K = cm/sec (x 0.00001)
	297.0 ft.: 45 deg. cleavage.	300		-215			1177	
303.7 ft: END OF BORING								

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 50 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

FIELD TEST BORING RECORD COVER SHEET

		BORING NO. 89-108
SITE Inter Island Tunnel - Boston Harbor	J.O. NO. U11305	SHEET 1 OF 1

COORIDNATES N-S 474651.3 E-W 746305.4

SEAFLOOR ELEVATION 91.4

INCLINATION Vertical INSPECTOR Zilinskas, Grimes

DATE: START/FINISH 9/01/89 / 9/04/89

CONTRACTOR/DRILLER Warren George/Gregory

DRILLING BARGE Katherine G

WATER DEPTH 14.3 (FT) DRILL RIG TYPE Failing 1500

ELEVATION TOP OF BEDROCK 32.4 (FT)

TOTAL DEPTH DRILLED 300.2 (FT)

METHODS:
- DRILLING SOIL Tri-cone rollerbit
- SAMPLING SOIL Split-spoon sampler
- DRILLING ROCK Roller bit, continuous HQ wireline coring
- SPECIAL TESTING OR INSTRUMENTATION Oriented coring, Packer testing.

SUMMARY

SOIL DRILLED 59.0 (FT) ROCK CORED 241.2 (FT)
NUMBER SPLIT BARREL SAMPLES 7

NOTES

1. The coordinate system used is the 1927 MASS GRID.
2. Datum is M.D.C.
3. In water borings, the split spoon sampler was driven into the soil by dropping a 175-pound sliding down hole hammer a distance of 4 feet within the borehole.
4. In land based borings the soil sampling method used was the STD Penetration Resistance using a 140 lb. hammer dropping a distance of 30 inches.

APPROVED	DATE
M Gilbert	1/2/90

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

BORING 89-108
SHEET 1 OF 5

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 474651.33ft. E: 746305.36ft.**

Sea Floor Elevation: **91.4 ft.**
Total Depth Drilled: **300.2 ft.**

DESCRIPTION: MAIN	DESCRIPTION: DETAIL	Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
SANDY SILT, 35% fine to medium sand, 15% clay, 2% organics (seaweed), very loose, olive green and black (ML).		0	91.4 90			** WOR R16/24	
TILL, CLAYEY SILT, 15% fine to coarse sand (subangular to rounded), 5% fine gravel, very dense, olive green (ML).		10	85 80			18-30 40-46 R16	
TILL, CLAYEY SILT, 15% fine to coarse sand (subangular to rounded), 15% fine gravel (subaugular to rounded), very dense, olive green (ML).		20	75 70			26-14 23-40 R10	
TILL, CLAYEY SILT, 40% medium to coarse sand (subaugular to rounded), 5% fine gravel, very dense, olive green (ML).		30	65 60			14-26 50-75 R12	
TILL, SANDY SILT, 35% fine to medium sand, 5% gravel, 5% clay, very dense, olive gray (ML).		40	55 50			36-44 60-73 R6	
TILL, CLAYEY SILT, 15% medium to coarse sand (subaugular to rounded), 10% gravel, very dense, olive green (ML).		50	45 40 35			105/6 R5	
DIABASE, yellowish green to gray with very light gray areas, medium hard, slightly weathered; joints closely to moderately closely spaced, 10 to 85 deg.; occasional chlorite, quartz and calcite veins; pyrite present throughout, many joint surfaces are slickensided.	TOP OF BEDROCK 59.0 FT. Roller bit to 66.5 ft. 66.5-67.5 ft.: 65 deg. cleavage. 70.4 ft.: 60 deg. quartz *filled joint, 5 mm thick.* 74.0 ft.: Fault 55 deg.	60 70	30 25 20	100 96	43 26	75/1 R0 1080	

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: ***Massachusetts Water Resources Authority***
Coordinates: **N: 474651.33ft. E: 746305.36ft.**

Sea Floor Elevation: **91.4 ft.**
Total Depth Drilled: **300.2 ft.**

DESCRIPTION

MAIN

DIABASE, yellowish green to gray with very light gray areas, medium hard, slightly weathered; joints closely to moderately closely spaced, 10 to 85 deg.; occasional chlorite, quartz and calcite veins; pyrite present throughout, many joint surfaces are slickensided.

88.5-96.0 ft.: Fault zone, roller bit, cuttings are clay and gravel, no core recovered.

ARGILLITE, gray to black, medium hard, fresh to slightly weathered; bedding very thin to laminar, 10 to 30 deg. from 99.7 to 124 feet and 50 to 65 deg. from 124 to 138 feet, medium close bedding plane separations; joints moderately close to closely spaced, 55 to 85 deg; abundant pyrite.

ARGILLITE, gray to black, medium hard, fresh to slightly weathered; bedding very thin to laminar, 10 to 30 deg., medium close bedding plane separations; joints moderately close to closely spaced, 55 to 85 deg; abundant pyrite.

146.0-152.0 ft.: Numerous bedding plane separations infilled with calcite.

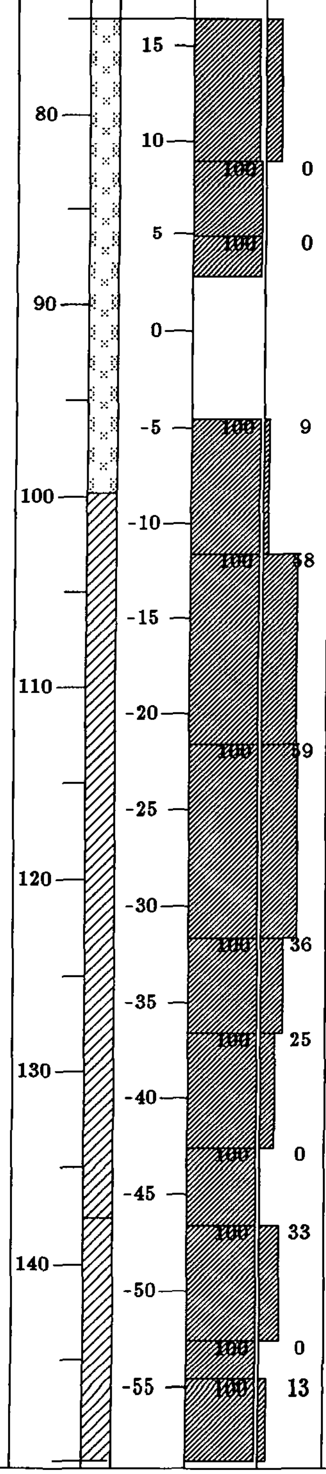
DETAIL

75.5-78.6 ft.: Fracture zone adjacent to 50 deg. quartz vein, 1 cm wide.
76.0 ft.: Fracture zone with iron stained surfaces.
79.0-80.0 ft.: 90 deg. quartz vein, 1.5 mm wide.
81.5-82.5 ft.: 90 deg. basaltic dike 13 mm wide.
82.0 ft.: 75 deg. joint.
82.5-88.5 ft.: 13 mm wide quartz vein; also quartz filled vugs.
82.5-83.2 ft.: Fracture zone adjacent to 55 deg. quartz vein.
84.9-85.4 ft.: Fracture zone with quartz filling.
87.0-88.0 ft.: Pyrite mineralization.
88.0 ft.: 55 deg. fault.
97.2 ft.: 80 deg. joint.
100.0-103.0 ft.: Fracture zone sheared and slickensided adjacent to 80 deg. fracture.
100.0 ft.: 90 deg. quartz vein, 2 cm wide.
101.0 ft.: 85 deg. joint, rough surfaces.
101.0-103.0 ft.: Fracture zone.
103.4 ft.: Pyrite mineralization.
106.8 ft.: Pyrite mineralization.
109.0 ft.: 80 deg. joint.
109.5-109.8 ft.: Clay and gouge zone along 20 deg. bedding plane separations.
114.0 ft.: 70 deg. joint, crosscutting bedding.
118.9 ft.: Fracture zone adjacent to 40 deg. joint.
120.0 ft.: 75 deg. joint, crosscutting bedding.
123.9 ft.: Pyrite mineralization.

136.0 ft.: Bedding plane separations infilled with calcite.

143.0 ft.: 75 deg. clay filled joint.

Depth (ft.) | Elev. (ft.) | REC | RQD



Point Load I_s 50: <200, <200, <200, <200, <200, 935, <200, 1596, 677, <200, 1435, <200

Pressure Test K = cm/sec (x 0.00001)

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

GZA

BORING SUMMARY LOG

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 474651.33ft. E: 746305.36ft.**

Sea Floor Elevation: **91.4 ft.**
Total Depth Drilled: **300.2 ft.**

DESCRIPTION

MAIN

ARGILLITE, gray to black, medium hard, fresh to slightly weathered; bedding very thin to laminar, 10 to 30 deg., medium close bedding plane separations; joints moderately close to closely spaced, 55 to 85 deg; abundant pyrite.
152.0-159.3 ft.: Most joints are healed.

181.3-191.3 ft.: Numerous calcite filled veins.

DIABASE-BASALT, dark green to greenish gray, medium hard to hard, fresh to slightly weathered; grain size coarsens with increasing depth; joints closely spaced; crosscutting quartz and calcite veins, pervasive slickensides on most joint and fracture surfaces.
201.4-218.4 ft.: Oriented core.

208.1-215.7 ft.: Generally fractured adjacent to 30 to 45 deg. joints.

215.7-218.7 ft.: Core barrel blocked three times during core run.

224.2-224.8 ft.: Preserved core.

DETAIL

149.5-150.0 ft.: Fractured zone.
151.8 ft.: 85 deg. quartz filled joint.
152.0 ft.: 25 deg. closed joint.
154.0 ft.: 35 deg. closed joint.
157.0 ft.: 85 deg. quartz filled joint.

161.0 ft.: 75 deg. joint with slickensides, crosscutting bedding
163.0 ft.: Bedding plane separation, 50 deg. dip.

167.8 ft.: Fracture zone, joints infilled with calcite.
168.4 ft.: 80 deg. fault.
169.6-170.4 ft.: Fracture zone, joints infilled with calcite.
170.8-172.9 ft.: Numerous voids in rock core, voids up to 7 mm wide.
175.7 ft.: 75 deg. calcite filled joint.
176.2 ft.: Intersecting 70 and 20 deg. joints.
177.5-177.9 ft.: Fracture zone.

185.2 ft.: 40 deg. clay filled joint.
186.3-187.4 ft.: Fracture zone, joints infilled with calcite.
188.2-189.0 ft.: Slumped bedding.
189.0-190.2 ft.: Fracture zone, joints infilled with calcite.
190.0 ft.: 60 deg. quartz filled joint, 6 mm wide.
192.6-193.4 ft.: Network of quartz veins, healed fracture zone, calcite cementation.
199.0 ft.: 45 deg. slickensided joint.

204.0 ft.: 80 deg. slickensided joint.
205.0-205.8 ft.: Fracture zone.
206.0-206.9 ft.: Fracture zone with slickensides.
207.0 ft.: 45 deg. quartz vein, 4 mm wide.
210.0-211.0 ft.: Two parallel 80 deg. quartz veins.
215.7-218.7 ft.: Fracture zone, core barrel blocked three times during drilling.

220.4 ft.: 15 mm offset of quartz vein along 75 deg. joint.

Depth (ft.) / Elev. (ft.)

Depth (ft.)	150	160	170	180	190	200	210	220

Elev. (ft.)	-60	-65	-70	-75	-80	-85	-90	-95	-100	-105	-110	-115	-120	-125	-130

REC / RQD

REC	RQD
100	55
93	36
100	36
100	23
98	43
100	54
100	54
88	29
100	69
76	20
100	64

Point Load $I_{s\,50}$

1128
1741
741
1402
597
645
645
<200
<200
2128
<200
<200

Pressure Test K = cm/sec (x 0.00001)

7.8 @ 64 psi
0.2 @ 70 psi
0.5 @ 75 psi
0=<0.1 @ 80 psi
0.1 @ 85 psi
0.2

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

GZA

BORING SUMMARY LOG

BORING 89-108
SHEET **4 OF 5**

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 474651.33ft. E: 746305.36ft.**

Sea Floor Elevation: **91.4 ft.**
Total Depth Drilled: **300.2 ft.**

DESCRIPTION: MAIN	DESCRIPTION: DETAIL	Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
DIABASE-BASALT, dark green to greenish gray, medium hard to hard, fresh to slightly weathered; grain-size coarsens with increasing depth; joints closely spaced; crosscutting quartz and calcite veins, pervasive slickensides on most joint and fracture surfaces. 228.4-245.4 ft.: Oriented core.	224.5-225.2 ft.: 60 deg. slickensided joint.		135			1274	@ 91 psi
	228.4 ft.: 10 mm offset of quartz vein adjacent to 70 deg. slickensided joint.			100	69	<200	
	229.5-229.9 ft.: Fracture zone.	230	140				
	234.2-234.5 ft.: 40 deg. calcite filled joint.		145	100	79		0.1 @ 96 psi
		240	150				
	242.0-243.0 ft.: 70 deg. slickensided joint.						
			155	100	87		0.1 @ 101 psi
	246.6 ft.: 70 deg. slickensided joint. 247.0 ft.: 75 deg. slickensided joint, 15 mm wide. 249.0 ft.: 40 deg. slickensided joint.	250	160				
	254.4 ft.: 35 deg. quartz vein.		165	100	81		0.1 @ 106 psi
	258.0-259.0 ft.: 20 to 50 deg. calcite veins.	260	170				
	264.1 ft.: 60 deg. slickensided joint.		175	100	83		0=<0.1 @ 112psi
	266.6 ft.: 10 deg. quartz veins.					<200	
	269.9 ft.: 50 deg. slickensided joint with calcite and quartz infilling.	270	180			854	
	270.5 ft.: 50 deg. slickensided joint. 271.0 ft.: 50 deg. slickensided joint. 274.0 ft.: 70 deg. slickensided joint.		185	100	79	<200	
	277.0 ft.: Two 50 deg. slickensided joints. 282.0-284.0 ft.: Numerous 50 deg. joints.	280	190				
			195	100	84	1289	
	288.0-289.5 ft.: Quartz veins, various orientations.	290	200				
	291.5-298.0 ft.: Four 50 deg. slickensided joints.					<200	
			205	100	38		
	297.6 ft.: Conjugate 60 deg. joints with slickensides.						

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

BORING 89-108
SHEET 5 OF 5

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 474651.33ft. E: 746305.36ft.**

Sea Floor Elevation: **91.4 ft.**
Total Depth Drilled: **300.2 ft.**

DESCRIPTION MAIN	DESCRIPTION DETAIL	Depth (ft.)		Elev. (ft.)	REC	RQD	Point Load $I_{s\ 50}$	Pressure Test K = cm/sec (x 0.00001)
300.2 ft.: END OF BORING							<200	

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

FIELD TEST BORING RECORD COVER SHEET

		BORING NO. 89-109
SITE Inter Island Tunnel - Boston Harbor	J.O. NO. U11305	SHEET 1 OF 1

COORIDNATES N-S 472679.2 E-W 746274.6

SEAFLOOR ELEVATION 89.0

INCLINATION Vertical INSPECTOR Watson, Grimes

DATE: START/FINISH 9/14/89 / 9/19/89

CONTRACTOR/DRILLER Warren George/Gregory, Laurenza

DRILLING BARGE Katherine G

WATER DEPTH 16.7 (FT) DRILL RIG TYPE Failing 1500

ELEVATION TOP OF BEDROCK -19.0 (FT)

TOTAL DEPTH DRILLED 301.5 (FT)

METHODS:
DRILLING SOIL Tri-cone rollerbit
SAMPLING SOIL Split-spoon sampler
DRILLING ROCK Roller bit, continuous HQ wireline coring
SPECIAL TESTING OR INSTRUMENTATION Oriented coring, Packer testing.

SUMMARY

SOIL DRILLED 108.0 (FT) ROCK CORED 193.5 (FT)
NUMBER SPLIT BARREL SAMPLES 11

NOTES

1. The coordinate system used is the 1927 MASS GRID.
2. Datum is M.D.C.
3. In water borings, the split spoon sampler was driven into the soil by dropping a 175-pound sliding down hole hammer a distance of 4 feet within the borehole.
4. In land based borings the soil sampling method used was the STD Penetration Resistance using a 140 lb. hammer dropping a distance of 30 inches.

APPROVED	DATE
M Gilbert	1/2/90

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

BORING 89-109
SHEET **1 OF 5**

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: N: **472679.22ft.** E: **746274.62ft.**

Sea Floor Elevation: **89.0 ft.**
Total Depth Drilled: **305.5 ft.**

DESCRIPTION – MAIN	DESCRIPTION – DETAIL	Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load I_s 50	Pressure Test K = cm/sec (x 0.00001)
		0	89.0				
SILTY CLAY, very stiff greenish-gray (CL).			85			** 7-12 9-12 R19	
SILTY CLAY, 5% fine sand, very stiff greenish-gray (CL).		10	80 / 75			5-7-9-8 R18	
		20	70			12-15 18-21 R7	
TILL, CLAYEY GRAVEL, fine to coarse gravel, 15% silty clay, 10% fine sand, dense, greenish gray, (GC).			65 / 60				
TILL, CLAYEY GRAVEL, fine to coarse gravel, 5% silty clay, very dense (GP).		30	55			18-32 42-64 R2	
TILL, CLAYEY GRAVEL, fine to coarse gravel, 5% silty clay, very dense (GP).		40	50 / 45			15-23 27-47 R1	
TILL, CLAYEY GRAVEL, fine to coarse gravel, 40% silty clay, 5% fine sand, very dense, greenish gray (GC).		50	40 / 35			49-52 52-61 R8	
TILL, GRAVELLY CLAY, mostly silty clay, 40% fine to coarse gravel, 5% fine sand, very dense, greenish gray (CL).		60	30 / 25			21-35 49-56 R7	
TILL, GRAVELLY CLAY, mostly silty clay, 40% fine to coarse gravel, 5% fine to medium sand, very dense, greenish gray (CL).		70	20 / 15			23-43 51-54 R8	

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

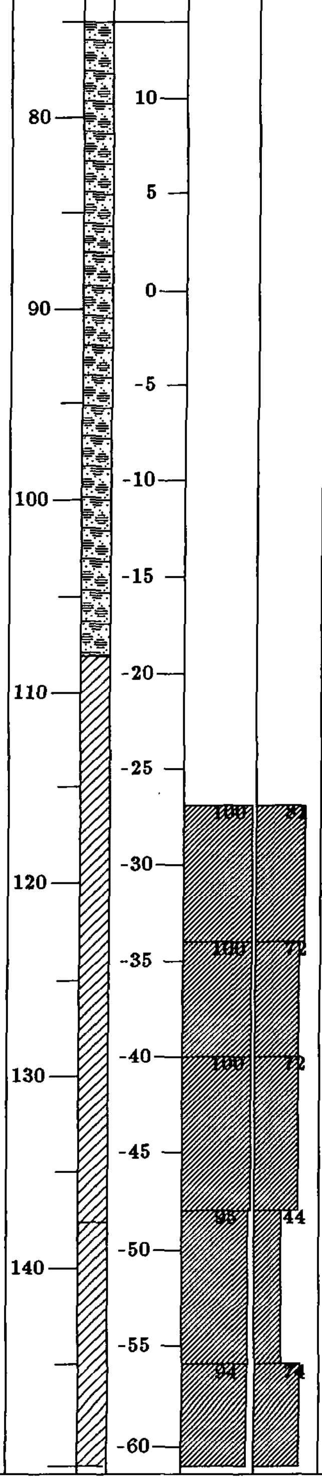
BORING SUMMARY LOG

BORING 89-109

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 472679.22ft. E: 746274.62ft.**

Sea Floor Elevation: **89.0 ft.**
Total Depth Drilled: **305.5 ft.**

DESCRIPTION – MAIN	DESCRIPTION – DETAIL	Point Load $I_{s\ 50}$	Pressure Test K = cm/sec (x 0.00001)
TILL, GRAVEL, fine to coarse, very dense (GP).		25-58 63-73 R4	
TILL, GRAVELLY CLAY, mostly silty clay, 40% fine to coarse gravel, 5% fine to coarse sand, very dense, greenish gray (CL).		61-79 81-81 R10	
TILL, GRAVELLY CLAY, mostly silty clay, 40% fine to coarse gravel, 5% fine sand, very dense, greenish gray (CL).		65-106 R5	
ARGILLITE WITH OCCASIONAL SANDY ARGILLITE, purplish gray, medium hard, slightly weathered; bedding difficult to see; some healed fractures with many fractures having offsets of up to 10 mm in length; moderately close to closely spaced joints generally 60 to 90 deg.; many joints and fractures are infilled with calcite and clay; some quartz and calcite veins.	TOP OF BEDROCK 108.0 FT. Roller bit to 116.0 ft. 120.0-123.0 ft.: Fracture zone, some clay and kaolinite. 120.0 ft.: 45 deg. cleavage.	<200 <200 <200	
130.5-132.0 ft.: Bedding plane separations coated with kaolinite.	128.2-128.6 ft.: Fracture zone. 129.6 ft.: Clay zone. 131.0 ft.: 35 deg. cleavage. 135.0-136.0 ft.: 80 deg. calcite vein. 136.5 ft.: Clay zone.	512 <200	
	137.5-140.7 ft.: Fracture zone and 10 to 15 mm wide veins of quartz, calcite, and kaolinite. 144.0-145.5 ft.: Fracture zone. 146.5-147.5 ft.: Fracture zone. 148.4-149.3 ft.:	<200 208 <200	



NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

BORING 89-109
SHEET **3 OF 5**

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 472679.22ft. E: 746274.62ft.**

Sea Floor Elevation: **89.0 ft.**
Total Depth Drilled: **305.5 ft.**

DESCRIPTION

MAIN

ARGILLITE WITH OCCASIONAL SANDY ARGILLITE, purplish gray medium hard, slightly to highly weathered; weakly bedded to massive; generally fractured with many fractures healed; some coarse quartz and calcite veins; close to very closely spaced joints generally 40 to 70 deg., some joints 25 to 30 deg. and 90 deg.

183.3-187.5 ft.: Very fractured, gouge zone, poor recovery.

192.0-197.5 ft.: Soft rock.

198.0-218.5 ft.: Oriented core.

ARGILLITE WITH OCCASIONAL SANDY ARGILLITE, purple to reddish gray, soft to medium hard, slightly weathered; bedding very thin to laminar, 25 to 60 deg.; closely spaced joints, 35 to 80 deg.; veins and joints are generally infilled with quartz, chlorite, clay and kaolinite.

218.5-220.1 ft.: Preserved core.

222.8-223.5 ft.: Preserved core.

DETAIL

Fracture zone.
150.3-151.9 ft.: Fracture zone with 30 deg. clay-filled joints.
151.1-151.5 ft.: 70 deg. clay-filled joints up to 4 mm thick.
154.6-158.3 ft.: Fracture zone with some clay and gouge filling.
159.0-159.9 ft.: Most breaks due to drilling.
161.3 ft.: 55 deg. slickensided joint.
163.1-163.4 ft.: Fracture zone with clay and gouge filling.
163.1-163.5 ft.: Gouge zone.
164.9-167.5 ft.: Very fractured zone.
169.8-170.1 ft.: Very fractured zone.
170.4-171.0 ft.: Very fractured zone, with gouge.
172.0 ft.: 70 deg. joint.
175.0 ft.: 60 deg. joint.
176.0 ft.: 80 deg. joint.
177.0-177.3 ft.: Chlorite filled joints.

190.0-191.7 ft.: Very fractured, gouge zone.

193.0 ft.: 85 deg. cleavage.

200.7-201.3 ft.: Soft rock.

208.5-209.6 ft.: 85 deg. gypsum-filled joint, 5 mm wide.

214.5 ft.: 75 deg. joint.

218.0 ft.: 50 deg. joint.

220.0 ft.: 60 deg. clay filled joint.
221.0 ft.: 55 deg. clay filledjoint.
221.5 ft.: 50 deg. clay

Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
150				<200	
		84	34	224	
	-65				
	-70	78	30		
160					
				<200	
	-75				
		72	9		12.7 @ 49 psi
	-80				
170					
		57	30		
	-85				
				<200	
		58	0		
	-90				
180					
	-95				
		42	0		
	-100				
190					
	-105				
		76	10		
	-110				
200					
		70	8		
	-115				
		42	0		
	-120				
210					
	-125	100	64		
	-130	100	100		
220				<200	
				<200	
	-135	50	24		

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

GZA

BORING SUMMARY LOG

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 472679.22ft. E: 746274.62ft.**

Sea Floor Elevation: **89.0 ft.**
Total Depth Drilled: **305.5 ft.**

DESCRIPTION

MAIN

224.0-254.0 ft.: Oriented core. **ARGILLITE WITH SANDY ARGILLITE** and occasional thin **FELSITE** bed, reddish gray to dark gray, medium hard, slightly weathered; bedding very thin to laminar, 15 to 40 deg.; close to very closely spaced joints, 50 to 80 deg.; joints and veins are generally infilled with quartz, chlorite, calcite, and kaolinite; Felsite beds are green, red, or dark purple, 1 to 7 mm wide, and occasionally are alterated to chlorite.
228.5-248.5 ft.: Inner core barrel rotated during oriented core runs; therefore, scribe marks drifted from vertical line orientation.
233.5-238.5 ft.: Thin bedded with green chlorite-rich beds.

263.5-265.3 ft.: Purple argillite with dark purple beds (white in center) 5 to 15 mm thick.

DETAIL

filled joint.
223.0 ft.: 50 deg. quartz filled joint.
225.0-226.0 ft.: Brecciated argillite in clay matrix.
226.0-228.5 ft.: No recovery.
231.0 ft.: 40 deg. joint filled with quartz and minor calcite.
231.5 ft.: 80 deg. joint filled with quartz and minor calcite.
232.5 ft.: 75 deg. joint filled with quartz and minor calcite.
234.9-237.0 ft.: Red felsite beds 1 to 2 mm wide.
235.0 ft.: 85 deg. joint.
236.0 ft.: 50 deg. joint.
237.3 ft.: 85 deg. joint.
240.0 ft.: 40 deg. quartz-filled joint.
240.5 ft.: 65 deg. quartz-filled joint.
241.2 ft.: 40 deg. quartz-filled joint.
243.0 ft.: 80 deg. quartz-filled joint.
244.5 ft.: 70 deg. quartz-filled joint.
245.0 ft.: 70 deg. quartz-filled joint.
250.0 ft.: 60 deg. slickensided joint.
252.0 ft.: 65 deg. slickensided joint.
253.0 ft.: 50 deg. slickensided joint.
254.8 ft.: 80 deg. slickensided joint.
255.5 ft.: 75 deg. quartz-filled joint.
256.5 ft.: 70 deg. quartz-filled joint.
259.7 ft.: 70 deg. quartz-filled joint.
265.3-283.5 ft.: Light green, dark green and white (chlorite) beds (1 to 7 mm thick) parallel to bedding.
266.0 ft.: 80 deg. slickensided joint.
267.3 ft.: 60 deg. slickensided joint.
268.0 ft.: 60 deg. cleavage.
268.9 ft.: 55 deg. slickensided joint.
270.0 ft.: 65 deg. slickensided joint.
270.1-270.3 ft.: Quartz and feldspar-rich layer parallel to bedding.
272.5 ft.: 70 deg. slickensided joint.
275.0 ft.: 65 deg. slickensided joint.
276.5 ft.: 65 deg. slickensided joint.
277.0 ft.: 60 deg. slickensided joint.

Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
	140	98	75		0.3 @ 80 psi
230					
	145	100	100		
	150	97	97		0.2 @ 86 psi
240					
	155				
	160	100	100		
250					2.9 @ 91 psi
	165	99	96		
				<200	
	170				
260					2.3 @ 96 psi
	175	98	88	<200	
				<200	
	180				
270					3.2 @ 102 psi
	185	100	94	<200 318	
	190				
280					
	195	100	100	<200	
		100	100	<200	
	200				
290					
		96	80		
	205			<200	
	210				

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: N: **472679.22ft.** E: **746274.62ft.**

Sea Floor Elevation: **89.0 ft.**
Total Depth Drilled: **305.5 ft.**

DESCRIPTION: MAIN	DESCRIPTION: DETAIL	Depth (ft.)		Elev. (ft.)	REC	RQD	Point Load I_s 50	Pressure Test K = cm/sec (x 0.00001)
301.5 FT.: END OF BORING	278.7 ft.: 80 deg. slickensided joint. 281.5-281.8 ft.: Slumped bedding with three closely spaced tuffaceous sandstone beds. 282.0 ft.: Gouge zone offset by 80 deg. joints. 285.0 ft.: 70 deg. slickensided joint. 286.0 ft.: 65 deg. slickensided joint. 287.5 ft.: 80 deg. slickensided joint. 290.5 ft.: 55 deg. slickensided joint. 291.6-292.2 ft.: Clay-rich zone adjacent to crosscutting 55 deg. joints. 293.6 ft.: 60 deg. 295.5 ft.: 90 deg. slickensided joint. 296.1 ft.: 50 deg. slickensided joint. 296.9-297.7 ft.: Kaolinized zone. 298.5 ft.: 50 deg. slickensided joint. 300.0 ft.: 60 deg. slickensided joint.						<200	

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

FIELD TEST BORING RECORD COVER SHEET

		BORING NO. 89-110
SITE Inter Island Tunnel - Boston Harbor	J.O. NO. U11305	SHEET 1 OF 1

COORIDNATES N-S 470759.2 E-W 746341.6

SEAFLOOR ELEVATION 68.1

INCLINATION Vertical INSPECTOR Watson, Zilinskas

DATE: START/FINISH 7/24/89 / 7/26/89

CONTRACTOR/DRILLER Warren George/Laurenza, Peltier

DRILLING BARGE Southern Cross

WATER DEPTH 37.6 (FT) DRILL RIG TYPE Failing 1500

ELEVATION TOP OF BEDROCK -11.9 (FT)

TOTAL DEPTH DRILLED 305.5 (FT)

METHODS:
DRILLING SOIL Tri-cone rollerbit
SAMPLING SOIL Split-spoon sampler
DRILLING ROCK Roller bit, continuous HQ wireline coring
SPECIAL TESTING OR INSTRUMENTATION Oriented coring, Packer testing, downhole geophysics.

SUMMARY

SOIL DRILLED 80.0 (FT) ROCK CORED 225.5 (FT)
NUMBER SPLIT BARREL SAMPLES 8

NOTES

1. The coordinate system used is the 1927 MASS GRID.
2. Datum is M.D.C.
3. In water borings, the split spoon sampler was driven into the soil by dropping a 175-pound sliding down hole hammer a distance of 4 feet within the borehole.
4. In land based borings the soil sampling method used was the STD Penetration Resistance using a 140 lb. hammer dropping a distance of 30 inches.

APPROVED	DATE
M Gilbert	1/2/90

GOLDBERG-ZOINO & ASSOCIATES, INC.

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BORING SUMMARY LOG

BORING 89-110
SHEET **1 OF 6**

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 470759.20ft. E: 746341.59ft.**

Sea Floor Elevation: **68.1 ft.**
Total Depth Drilled: **305.5 ft.**

DESCRIPTION — MAIN	DESCRIPTION — DETAIL	Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
		0	68.1				
			65				
			60				
		10				**	
SILTY CLAY, moderately plastic, firm, yellow gray (CL).			55			2-1-3 R15	
			50				
		20					
SILTY CLAY, moderately plastic, firm, yellow gray (CL).			45			3-4-6 R18	
			40				
		30					
SILTY CLAY, moderately plastic, firm, yellow gray to gray (CL).			35			4-4-5 R18	
			30				
		40					
SILTY CLAY, moderately plastic, firm, yellow gray (CL).			25			2-2-3 R18	
			20				
		50					
SILTY CLAY, moderately plastic, firm, yellow gray (CL).			15			1-1-3 R18	
			10				
		60					
SILTY CLAY, moderately plastic, firm, yellow gray (CL).			5			2-2-3 R18	
			0				
		70				13-17-22 R6	
TILL, CLAYEY SILT, 15% gravel, 5% coarse sand, hard, brownish gray			-5				

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

GZA

BORING SUMMARY LOG

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 470759.20ft. E: 746341.59ft.**

Sea Floor Elevation: **68.1 ft.**
Total Depth Drilled: **305.5 ft.**

DESCRIPTION

MAIN

to gray (CL).

ARGILLITE, purplish-gray with occasional thin green felsite beds (6 to 50 mm thick); medium hard with *occasional soft chlorite zones*, slightly weathered; bedding very thin, 15-20 deg.; joints closely spaced, occasionally microfaulted, filled with chlorite/clay material, 60 to 90 deg.; generally 60-80 deg. cleavage.
88.0-99.0 ft.: Drilling pressure of 50 psi to 100 psi were used during coring.

101.9-107.8 ft.: Several thin horizons of altered (chlorite) Argillite with 60 to 80 deg. cleavage.

111.0 ft.: Shoe of core barrel plugged up due to weak circulation.

118.0-148.0 ft.: Numerous 15 to 20 deg. bedding plane separations.
118.0 ft.: Core barrel blocked.

138.0-148.0 ft.: Core HQ8 was bumped and badly disturbed before logging.
138.0-168.0 ft.: Green chlorite beds (4 to 6 mm thick) spaced approximately 0.75 feet apart.

147.0 ft.: Core barrel blocked.

DETAIL

TOP OF BEDROCK 80.0 FT.

Roller bit to 89.3 ft.
89.3-89.9 ft.: Green (chlorite) altered argillite.
89.5-90.5 ft.: Very thin (1 mm wide) 70 deg. joints.
90.0 ft.: 80 deg. cleavage.
90.6-91.1 ft.: Green (chlorite) altered argillite.
93.0 ft.: 75 deg. joint.
95.5 ft.: 75 deg. cleavage.
96.0 ft.: 60 deg. joint.
99.0 ft.: 75 deg. joint.
100.0 ft.: 75 deg. joint.
108.5-108.7 ft.: Only rock fragments recovered.
108.5 ft.: 80 deg. cleavage.
109.9-110.8 ft.: Clay coated fractures adjacent to 80 deg. joints.
111.1-111.5 ft.: Clay zone.
112.0 ft.: Shoe of core barrel jammed.
113.3-117.4 ft.: 80 deg. fracture zone and 80 deg. cleavage with micro faulting along bedding.
118.0 ft.: Shoe of core barrel jammed.
118.0 ft.: 80 deg. clay coated joint.
118.4-118.9 ft.: Altered (chloritic) argillite.
120.6-122.9 ft.: 90 deg. clay coated joint.
122.4-123.0 ft.: 90 deg. joint.
123.0-123.5 ft.: 80 deg. fracture zone adjacent to 80 deg. clay coated joint.
124.3-125.5 ft.: Green and pink felsite beds.
128.3-128.5 ft.: Chlorite zone parallel to 20 deg. bedding.
129.0 ft.: 20 deg. slickensides.
130.9 ft.: Iron stained bedding plane separation adjacent to 20 deg.

Depth (ft.) / Elev. (ft.) scale

Depth (ft.)	Elev. (ft.)
	-10
80	
	-15
	-20
90	
	-25
	-30
100	
	-35
	-40
110	
	-45
	-50
120	
	-55
	-60
130	
	-65
	-70
140	
	-75
	-80

REC / RQD

Run top (Elev. ft.)	REC	RQD
-20	100	32
-25	100	54
-30	100	33
-40	90	0
-45	96	44
-50	100	100
-60	98	81
-70	100	60
-79.5	98	98

Point Load $I_{s\,50}$

Approx. Elev. (ft.)	Point Load $I_{s\,50}$
-16	20-50 R4
-27	352
-30	464
-34	384
-40	<200
-58	511
-61	511
-64	256
-77	543

Pressure Test K = cm/sec (x 0.00001)

Pressure Test
0=<0.1 @ 56 psi
33.4 @ 61 psi
17.4 @ 66 psi
1.8 @ 72 psi
1.4 @ 77 psi

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

GZA

BORING SUMMARY LOG

BORING 89-110
SHEET **3 OF 6**

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 470759.20ft. E: 746341.59ft.**

Sea Floor Elevation: **68.1 ft.**
Total Depth Drilled: **305.5 ft.**

DESCRIPTION

MAIN

167.1-181.1 ft.: Oriented core.

170 ft.: Water stopped circulating.
170.0-180.0 ft.: Many green (chlorite) and white (calcite) beds, 3 to 6 mm thick.

ARGILLITE, gray and light green, med. hard, slightly weathered; bedding thin with occasional green chlorite or felsite beds, 10 to 20 deg.; joints closely spaced, 40 to 80 deg.; joints and bedding plane separations generally infilled with calcite or chlorite.
191.0-192.5 ft.: Preserved core.

194.6-195.3 ft.: Preserved core.
196.0-280.0 ft.: Oriented core.
196.0-201.5 ft.: Very closely spaced 65 to 75 deg. joints, 1 to 2 mm wide, parallel to 70 deg. cleavage.

221.0 ft.: Core barrel plugged.
222.0 ft.: Core barrel plugged.

223.5-233.5 ft.: Calcite veins

DETAIL

fracture.
131.8-132.7 ft.: Severely fractured chloritized zone.
133.8-134.0 ft.: Green and red colored argillite.
138.0-141.0 ft.: 90 deg. clay coated joint.
138.0-141.9 ft.: Near vertical joint.
139.2-140.0 ft.: Bedding plane separations 3 to 6 mm thick with soft chloritic material.
142.6 ft.: Severely weathered.
144.6 ft.: Bedding plane separations with soft chloritic material along surface.
147.0 ft.: Shoe of core barrel jammed.
148.0 ft.: 90 deg. cleavage.
148.5 ft.: 60 deg. clay coated joint, crosscutting bedding.
151.1 ft.: Chloritized zone, highly fractured.
154.2 ft.: 60 deg. clay coated joint, crosscutting bedding.
155.8 ft.: 60 deg. clay coated joint, crosscutting bedding.
157.8 ft.: 70 deg. chlorite filled joint, closed.
159.0-159.8 ft.: Chlorite filled bedding plane separations dipping 20 deg., microfaulted with 6 mm displacement.
162.5 ft.: 70 deg. chlorite filled joint, closed.
165.3 ft.: 70 deg. chlorite filled joint, closed.
166.0 ft.: 70 deg. chlorite filled joint, closed.
167.5-169.5 ft.: Green felsite beds 3 to 6 mm thick, parallel to 20 deg. bedding.
171.0 ft.: Shoe of core barrel jammed.
172.0 ft.: 60 deg. calcite filled joint.
175.0 ft.: 85 deg. calcite filled joint.
176.0 ft.: 60 deg. cleavage.
176.7-179.9 ft.: Bedding offset by 70 to 80 deg. joints.
178.0 ft.: 80 deg. chlorite and calcite filled joint.
179.0 ft.: 70 deg. chlorite and calcite filled joint.
181.0 ft.: 80 deg. calcite and chlorite

Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
150	-85				
	-90	100	100	1047	2.9 @ 82 psi
160	-95			<200	
	-100	93	75		
170	-105	100	93		1.9 @ 87 psi
180	-110				4.7 @ 92 psi
	-115	100	85		
	-120	100	83	<200, 767, 767	
190	-125				6.2 @ 98 psi
	-130	92	51	<200	
200	-135	100	71		21.0 @ 103 psi
	-140				
210	-145	89	73		2.9 @ 108 psi
	-150				
220	-155	100	67		1.0 @ 113 psi
		100	0		
		99	95		

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

GZA

BORING SUMMARY LOG

BORING 89-110

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 470759.20ft. E: 746341.59ft.**

Sea Floor Elevation: **68.1 ft.**
Total Depth Drilled: **305.5 ft.**

DESCRIPTION

MAIN

generally parallel, 15 deg. bedding.
ARGILLITE, gray to dark gray; hard to med. hard, slightly weathered; bedding very thin, 5-15 deg.; joints closely to very closely spaced, filled with calcite or chloritic material, 30-80 deg.; numerous calcite veins.

265.5-269.0 ft.: Vuggy argillite with closely spaced 70 deg. joints filled with quartz, chlorite, and minor pyrite.
266.0 ft.: Core run H025 was overdrilled.

295.5 ft.: Drill hole taking a lot of water.

DETAIL

filled joint.
182.2-187.0 ft.: Green argillite with 3 mm thick chlorite and calcite beds.
182.6-182.9 ft.: Green argillite, some curved joints dipping 40 to 70 deg.
184.2-185.2 ft.: Green argillite with many curved joints dipping 40 to 70 deg.
185.0 ft.: 60 deg. chlorite filled joint.
189.1-195.8 ft.: Sporadic wavy bedding.
192.5-192.9 ft.: Altered green argillite, soft, moderately weathered.
202.0 ft.: 75 deg. calcite filled joint.
202.3 ft.: Contact of green argillite to gray argillite.
203.5 ft.: Shoe of core barrel jammed.
204.0-205.2 ft.: 75 deg. calcite filled joint.
205.0 ft.: 65 deg. cleavage.
207.0 ft.: 80 deg. calcite and chlorite filled joint.
209.0 ft.: 50 deg. calcite filled joint.
210.6-211.0 ft.: Slightly altered gray argillite.
212.7-212.9 ft.: Gradational change from gray to green argillite.
213.0 ft.: 70 deg. calcite filled joint.
216.0 ft.: 80 deg. calcite and chlorite filled joint.
218.0 ft.: 70 deg. calcite and chlorite filled joint.
218.0-219.0 ft.: 25 to 55 mm wide, med. hard to soft, altered argillite, layers spaced 75 to 150 mm apart.
221.0-222.3 ft.: Slightly weathered, med. hard to soft argillite with thin layers of pyrite and clay.
225.0 ft.: 45 deg. calcite filled joint.
225.8 ft.: Fracture zone with clay coating.
226.0 ft.: 45 deg. calcite filled joint.
226.5 ft.: Soft gray calcareous material 5 mm thick parallel to 15 deg. bedding.
227.5 ft.: Fracture zone.
232.0 ft.: 80 deg. cleavage.
233.2 ft.: Tuffaceous material.
234.0 ft.: 80 deg. calcite and chlorite filled joint.

Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load I_{s} 50	Pressure Test K = cm/sec (x 0.00001)
				831	
	-160				
				895	
230					
					4.4 @ 120 psi
	-165	100	96		
				<200	
	-170				
240				975	
					2.0 @ 124 psi
	-175	100	100		
	-180				
250					
	-185	100	100	1311	12.2 @ 130 psi
	-190				
260		85	84	592	
	-195			831	
					38.0 @ 134 psi
		100	70		
	-200				
270					
	-205				
					40.9 @ 105 psi
		98	91	1103	
	-210				
				<200	
280				496	
	-215				
					0=<0.1 @ 145psi
		99	99		
	-220				
290					
				<200	
	-225				
		97	97		
	-230			1279	

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 470759.20ft. E: 746341.59ft.**

Sea Floor Elevation: **68.1 ft.**
Total Depth Drilled: **305.5 ft.**

DESCRIPTION MAIN	DESCRIPTION DETAIL	Depth (ft.)		Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
305.5 FT.: END OF BORING	235.0-237.0 ft.: 80 deg. calcite filled joint offsets 10 mm wide 15 deg. calcite vein. 236.0 ft.: 65 deg. calcite and chlorite filled joint. 238.0 ft.: 80 deg. cleavage. 240.0 ft.: Clay zone. 244.5 ft.: 60 deg. clay coated joint. 247.3 ft.: 60 deg. clay coated joint. 248.0-248.5 ft.: 70 deg. fracture with clay coating. 249.6-250.0 ft.: Reddish-purple beds, 5 to 6 mm wide. 252.2-252.5 ft.: Purple sandy argillite. 255.0 ft.: Conjugate (30 deg. and 70 deg.) joints. 257.8-258.7 ft.: 80 deg. clay coated joint. 260.3-260.5 ft.: Fracture zone, clay coating. 260.5-261.3 ft.: No recovery. 261.3-266.5 ft.: 70 deg. quartz and chlorite filled vein, 1 to 3 mm wide. 261.5 ft.: 10 deg. slickensided bedding plane separation. 263.5 ft.: 80 deg. cleavage. 265.3-265.5 ft.: 70 deg. very closely spaced joints filled with quartz and chlorite. 272.6-273.0 ft.: Clay coated 15 deg. bedding plane separations. 273.4 ft.: 70 deg. conjugate joints. 274.4-275.5 ft.: Numerous voids adjacent to 80 deg. calcite filled joint. 276.7 ft.: Soft gray 16 mm thick, parallel to bedding with microfaulting, 10 mm displacement. 278.8 ft.: 20 deg. quartz vein (1 mm) microfaulted with 10 mm displacement. 280.0 ft.: 70 deg. slickensided joint, pyrite mineralization. 284.6 ft.: 60 deg. joint with brown clay on surface, parallel to bedding. 286.7-288.3 ft.: Very closely spaced 80 deg. joint. 289.0 ft.: 80 deg. clay filled joint. 291.0-295.0 ft.: 70 deg. healed fractures.						735	

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

BORING 89-110
SHEET **6 OF 6**

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 470759.20ft. E: 746341.59ft.**

Sea Floor Elevation: **68.1 ft.**
Total Depth Drilled: **305.5 ft.**

DESCRIPTION: MAIN	DESCRIPTION: DETAIL	Depth (ft.)		Elev. (ft.)	REC	RQD	Point Load I_{s} 50	Pressure Test K = cm/sec (x 0.00001)
	295.5 ft.: Driller indicated large water take in borehole. 297.8 ft.: Subhorizontal red, iron-rich bed. 298.8 ft.: Subhorizontal red, iron-rich bed. 300.4 ft.: 70 deg. cleavage. 302.7 ft.: 60 deg. clay and calcite filled joint. 305.5 ft.: Subhorizontal red, iron-rich bed.							

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

FIELD TEST BORING RECORD COVER SHEET

SITE	J.O. NO.	BORING NO. 89-111
Inter Island Tunnel - Boston Harbor	U11305	SHEET 1 OF 1

COORIDNATES N-S 470553.6 E-W 747451.0

SEAFLOOR ELEVATION 68.5

INCLINATION Vertical INSPECTOR Zilinskas, Grimes

DATE: START/FINISH 8/01/89 / 8/05/89

CONTRACTOR/DRILLER Warren George/Gregory

DRILLING BARGE Katherine G

WATER DEPTH 37.2 (FT) DRILL RIG TYPE Failing 1500

ELEVATION TOP OF BEDROCK -46.5 (FT)

TOTAL DEPTH DRILLED 395.4 (FT)

METHODS:
- DRILLING SOIL Tri-cone rollerbit
- SAMPLING SOIL Split-spoon sampler
- DRILLING ROCK Roller bit, continuous HQ wireline coring
- SPECIAL TESTING OR INSTRUMENTATION Oriented coring, Packer testing, downhole geophysics.

SUMMARY

SOIL DRILLED 114.5 (FT) ROCK CORED 281.0 (FT)
NUMBER SPLIT BARREL SAMPLES 13

NOTES

1. The coordinate system used is the 1927 MASS GRID.
2. Datum is M.D.C.
3. In water borings, the split spoon sampler was driven into the soil by dropping a 175-pound sliding down hole hammer a distance of 4 feet within the borehole.
4. In land based borings the soil sampling method used was the STD Penetration Resistance using a 140 lb. hammer dropping a distance of 30 inches.

APPROVED	DATE
M Gilbert	1/2/90

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 470553.58ft. E: 747451.00ft.**

Sea Floor Elevation: **68.5 ft.**
Total Depth Drilled: **395.4 ft.**

DESCRIPTION: MAIN	DESCRIPTION: DETAIL	Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load I_{s} 50	Pressure Test K = cm/sec (x 0.00001)
CLAYEY SAND, fine to medium sand, 35% clay, 15% fine gravel, very loose, dark gray to black (SC), foul odor.		0	68.5 65			** 1-0-1-2 R5	
SILTY CLAY, 5% slightly to moderately plastic, medium to coarse sand, very stiff, gray (CL).		10	60 55			8-12 13-12 R3	
SILTY CLAY, slightly to moderately plastic, stiff, greenish gray (CL).		20	50 45			3-3-4-4 R13	
SILTY CLAY, slightly to moderately plastic, stiff, greenish gray (CL).		30	40 35			2-3-5-5 R14	
SILTY CLAY, slightly to moderately plastic, very stiff, greenish gray (CL).		40	30 25			7-8-8-9 R18	
SILTY CLAY, slightly to moderately plastic, stiff, greenish gray (CL).		50	20 15			2-4-6-7 R18	
SILTY CLAY, slightly to moderately plastic, stiff, greenish gray (CL).		60	10 5			5-5-5-7 R16	
SILTY CLAY, slightly to moderately plastic, stiff, greenish gray (CL).		70	0 -5			5-6-6-5 R17	

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

BORING 89-111

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 470553.58ft. E: 747451.00ft.**

Sea Floor Elevation: **68.5 ft.**
Total Depth Drilled: **395.4 ft.**

DESCRIPTION – MAIN	DESCRIPTION – DETAIL	Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
			-10				
SILTY CLAY, slightly to moderately plastic, stiff, greenish gray (CL).		80				7-6-8-7 R12	
			-15				
			-20				
SILTY CLAY, slightly to moderately plastic, stiff, greenish gray (CL).		90				4-5-3-4 R19	
			-25				
			-30				
TILL: CLAYEY GRAVEL, fine to coarse gravel, subrounded gray mudstone; 35% clay and silt, 5% medium sand, very dense (GC).		100				35-37 38-40 R5	
			-35				
			-40				
TILL: CLAYEY GRAVEL, fine to coarse gravel, various colors; 30% gray clay and silt, 20% fine to coarse sand, 3% orange clay, very dense (GC).		110				33-35 38-40 R9	
			-45				
ARGILLITE, gray, med. hard, slightly weathered, with fractures in highly localized zones; evenly bedded thin to very thin, 35 to 50 deg.; closely spaced joints filled with clay and chlorite, up to 5 mm wide, 65 to 80 deg.; some joints with slickensides; 80 deg. cleavage.	TOP OF BEDROCK 114.5 FT.						
			-50				
	119.5-120.0 ft.: Kaolinitic argillite.	120				100 R3	
			-55				
	Roller bit to 125.8 ft.						
	127.0 ft.: 70 deg. cleavage. 128.0-128.3 ft.: Fracture zone. 128.7 ft.: 75 deg. *chlorite and quartz filled* joint. 129.6 ft.: 85 deg. chlorite and quartz filled joint.	130	-60	100	92	2768	
			-65				
	130.2 ft.: 60 deg. chlorite and quartz filled joint, 2 mm wide. 130.6 ft.: Fracture zone with kaolinite and chlorite filling.	140	-70	96	45	<200	
	134.1 ft.: 60 deg. chlorite and quartz filled joint. 136.1 ft.: 65 deg. quartz filled joint, 3 mm wide. 137.0 ft.: 80 deg. cleavage.		-75	100	91	<200	
			-80				

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

BORING 89-111
SHEET 3 OF 6

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: N: **470553.58ft.** E: **747451.00ft.**

Sea Floor Elevation: **68.5 ft.**
Total Depth Drilled: **395.4 ft.**

DESCRIPTION

MAIN

ARGILLITE, gray, med. hard to soft; slight to moderate weathering; thin to very thin bedding 30 to 40 deg.; 40 to 80 deg. joints, crosscut bedding, filled with 1 to 5 mm of very soft kaolinite, chlorite, or iron oxide; local zones of intense fracturing associated with alteration.

172.0 ft.: Correction in depth of borehole, added 2.6 ft.

196.4-197.4 ft.: Preserved core.

213.5-225.5 ft.: Oriented core.

DETAIL

137.5 ft.: Fracture zone with clay and quartz.
138.2 ft.: 65 deg. slickensided joint.
139.6-140.6 ft.: 70 to 90 deg. slickensided joints.
141.1 ft.: 40 deg. clay and chlorite filled bedding plane separation.
142.0 ft.: 70 deg. calcite filled joint.
144.5 ft.: 80 deg. cleavage.
145.4 ft.: 70 deg. calcite filled joint.
147.3 ft.: 50 deg. clay and chlorite filled joint.
148.2-148.4 ft.: Fracture zone with chlorite filling.
150.5-159.5 Ft.: Fracture zone.
159.6 ft.: 40 deg. calcite filled joint.
161.1-161.3 ft.: Gouge zone, clay filling adjacent to 80 deg. joint.
161.4-165.8 ft.: Fracture zone with kaolinite and chlorite filling.
167.0-169.0 ft.: Very fractured, clay filled joint.
169.6-171.1 ft.: Fracture zone w/kaolinite and chlorite filling.
175.7-178.2 ft.: Altered argillite.
176.0 ft.: 60 deg. cleavage.
177.3 ft.: 70 deg. chlorite filled joint.
183.0 ft.: 70 deg. clay filled joint.
188.3 ft.: 70 deg. clay filled joint.
190.3-191.9 ft.: Fracture zone with clay and gouge.
192.5 ft.: 60 deg. chlorite filled joint, 7 mm wide.
196.0 ft.: Altered argillite, chlorite zone.
199.3-200.1 ft.: Fracture zone, clay and gouge filling.
205.9-211.5 ft.: Cavities in joint fillings.
207.0 ft.: 70 deg. cleavage.
209.5 ft.: 60 deg. chlorite filled joint.
213.1 ft.: 60 deg. iron stained joint.
215.6 ft.: 45 deg. clay filled joint.
217.0 ft.: Clay zone.
218.1-218.3 ft.: Green ash layer.
218.3 ft.: Clay zone.

Depth (ft.) / Elev. (ft.) / REC / RQD

Depth marks: 150, 160, 170, 180, 190, 200, 210, 220

Elev. marks: -85, -90, -95, -100, -105, -110, -115, -120, -125, -130, -135, -140, -145, -150, -155

REC	RQD
99	60
100	52
89	38
97	72
100	91
100	71
100	77
74	29
54	16

Point Load $I_{s\,50}$

<200
509
<200
<200
<200
<200
318
477
318
382
<200
318
382

Pressure Test K = cm/sec (x 0.00001)

39.1 @ 32 psi
25.7 @ 49 psi
19.4 @ 35 psi
2.1 @ 59 psi
1.3 @ 64 psi
22.7 @ 70 psi
14.2 @ 38 psi

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

GZA

BORING SUMMARY LOG

BORING 89-111
SHEET **4 OF 6**

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR** | Sea Floor Elevation: **68.5 ft.**
CLIENT: **Massachusetts Water Resources Authority** | Total Depth Drilled: **395.4 ft.**
Coordinates: **N: 470553.58ft. E: 747451.00ft.**

DESCRIPTION

MAIN

225.1 ft.: Correction in depth of borehole, added 0.6 ft.
ARGILLITE with occasional layers of ash; gray to light purple, med. hard; slightly weathered; bedding poorly defined, 30 to 40 deg.; closely spaced joints with adjacent alteration zones 3 to 10 mm wide, 40 to 80 deg.; cavities in joint fillings and slickensides along steep (75 to 80 deg.) joints; small offsets (3 to 10 mm) along many joints; cleavage 60 to 70 deg.

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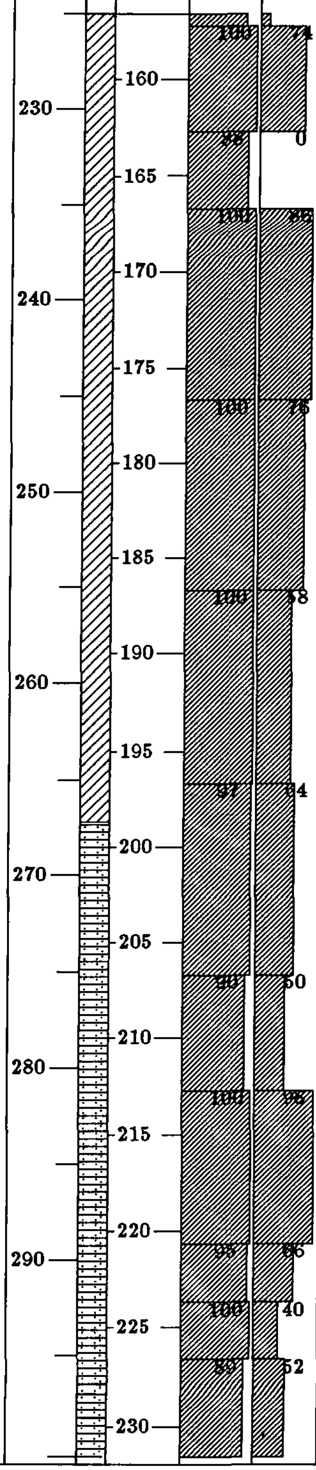
TUFFACEOUS ARGILLITE, gray to green and pink, med. hard, slightly weathered; very thinly bedded, 20 to 30 deg., with small offsets; closely to very closely spaced joints filled with clay, quartz, and chlorite, 50 to 85 deg.

298.1-299.0 ft.: Shear folding adjacent to 70 deg. cleavage.

DETAIL

219.4 ft.: Clay zone.
220.1-221.0 ft.: 80 deg. clay filled joint.
223.0 ft.: 20 deg. joint.
226.4 ft.: 40 deg. chlorite filled joint, 2 mm wide.
226.6-226.8 ft.: Pink ash layer.
228.5 ft.: Tuffaceous argillite.
229.0 ft.: 90 deg. cleavage.
230.0 ft.: 80 deg.
232.1 ft.: 40 deg. chlorite filled joint.
233.5-234.2 ft.: Clay-rich zone.
235.4 ft.: 80 deg. slickensided joint.
237.3 ft.: 60 deg. joint.
238.1 ft.: 60 deg. cleavage.
241.3 ft.: 90 deg. cleavage.
242.6 ft.: 80 deg. slickensided joint.
243.2 ft.: 60 deg. slickensided joint.
247.0 ft.: 80 deg. joint.
249.2-250.1 ft.: Fracture zone with clay filling.
250.1 ft.: 30 deg. joint.
252.0 ft.: 70 deg. cleavage.
255.6 ft.: 75 deg. clay filled joint.
256.7 ft.: 75 deg. cleavage.
257.1 ft.: 80 deg. clay filled joint, 4 mm wide.
258.1 ft.: 60 deg. cleavage.
260.5-261.7 ft.: Fracture zone with shear folding.
265.0 ft.: 70 deg. clay filled joint.
265.6-265.8 ft.: Ash layer.
267.0 ft.: Ash layer.
270.0 ft.: 80 deg. cleavage.
273.0-174.6 ft.: Kaolinized argillite.
275.3 ft.: 70 deg. cleavage.
276.1 ft.: 60 deg. joint.
277.7 ft.: 85 deg. joint.
278.3-279.1 ft.: Fracture zone.
282.1 ft.: 80 deg. joint.
285.3 ft.: 70 deg. joint.
287.1 ft.: 60 deg. chlorite filled joint, 3 mm wide.
291.1-295.2 ft.: Fracture zone.
291.3 ft.: 50 deg. joint.
292.4 ft.: 70 deg. joint.
292.8-294.0 ft.: Quartz vein 10 mm wide.
294.0 ft.: 75 deg. cleavage.



Point Load $I_{s\,50}$

477
573
605
310
573
445
318
350
339
<200
318
613
716
1035
<200
700
<200
<200
605

Pressure Test K = cm/sec (x 0.00001)

0.1 @ 80 psi
0.3 @ 85 psi
3.0 @ 91 psi
2.5 @ 96 psi
0.4 @ 101 psi
1.4 @ 106 psi
1.1 @ 112 psi

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

GZA

BORING SUMMARY LOG

BORING 89-111

SHEET **5 OF 6**

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR** | Sea Floor Elevation: **68.5 ft.**

CLIENT: ***Massachusetts Water Resources Authority*** | *Total Depth Drilled:* ***395.4 ft.***

Coordinates: **N: 470553.58ft. E: 747451.00ft.**

DESCRIPTION

MAIN

DIABASE, green, med. hard, slightly weathered; very closely spaced joints 25 to 30 deg. and 60 to 80 deg., filled with 1 to 2 mm clay, quartz, and calcite, and iron stained.
330.0-333.3 ft.: 50 to 80 deg. joints, very closely spaced, generally infilled with quartz and calcite.

ARGILLITE, greenish gray, med. hard, slightly weathered; weak thin bedding, 20 to 30 deg.; two sets of crosscutting, very closely spaced steep joints, 75 deg., filled with 2 to 6 mm of quartz, chlorite, and iron oxides.

DETAIL

295.0 ft.: 80 deg. joint.
298.0 ft.: 50 deg. chlorite filled joint.
300.4 ft.: 70 deg. joint.
302.6-302.9 ft.: Fracture zone.
302.7 ft.: Quartz vein 20 mm wide.
303.6 ft.: 50 deg. joint.
306.5-308.5 ft.: Slightly fractured zone.
310.0-312.0 ft.: Numerous 75 to 85 deg. joints that offset 45 deg. bedding.
310.0-311.0 ft.: 85 deg. clay filled joint.
313.8 ft.: 80 deg. chlorite and clay filled joint.
316.0 ft.: 60 deg. calcite and quartz filled joint.
316.2-316.3 ft.: 85 deg. calcite filled joint.
317.2-317.3 ft.: 85 deg. calcite filled joint.
318.2 ft.: 50 deg. calcite filled joint.
318.9 ft.: 65 deg. calcite filled joint.
320.0 ft.: 85 deg. calcite filled joint.
322.5 ft.: 75 deg. calcite filled joint.
323.1 ft.: 75 deg. calcite and quartz filled joint to 8 mm wide.
326.0 ft.: 35 deg. joint.
327.1 ft.: 75 deg. quartz and calcite filled joint.
328.3 ft.: 70 deg. quartz and calcite filled joint.
330.3-331.0 ft.: Fractured and slickensided 60 deg. cleavage.
335.2 ft.: 65 deg. calcite filled joint.
335.7-336.1 ft.: Fracture zone adjacent to 65 deg. joints, clay infilling.
338.2-339.0 ft.: Fracture zone adjacent to 70 deg. joint, clay infilling.
343.4-344.5 ft.: 75 deg. quartz and calcite filled joint.
345.5 ft.: 65 and 75 deg. quartz and calcite filled joints.
350.2 ft.: 50 deg. joint.
350.4-351.3 ft.: Quartz vein 5 to 20 mm wide.
351.6 ft.: 60 deg. clay filled joint.
352.4 ft.: 75 deg. joint.
353.5 ft.: Fault zone adjacent to 70 deg. iron stained and slickensided joint.
354.3 ft.: 65 deg. joint with clay filling.

Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
300				<200	0.8 @ 117 psi
	-235			780	
		100	41		
	-240				
310				859	
	-245			636	
		100	51		
				<200	
				764	
	-250				
320					
	-255				
		82	40	223	
	-260				
		82	0		
330					
	-265				
		50	4		
				318*	
				<200	
	-270				
340					
	-275				
		55	5		
	-280				
		100	23		
350					
	-285	95	18	<200	
				<200	
	-290				
		80	8		
360				<200	
		94	0		
	-295				
		94	37		
	-300			589	
370					
		97	53	<200	
	-305				

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

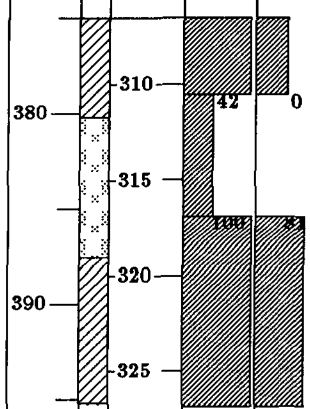
GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 470553.58ft. E: 747451.00ft.**

Sea Floor Elevation: **68.5 ft.**
Total Depth Drilled: **395.4 ft.**

DESCRIPTION — MAIN	DESCRIPTION — DETAIL
	354.9 ft.: 60 deg. joint with clay filling. 355.5 ft.: 80 deg. joint with clay filling. 357.8 ft.: 70 deg. joint with clay filling.
DIABASE, green, med. hard, slightly weathered; very closely spaced joints, 60 to 70 deg. filled with calcite and iron oxide.	358.8-361.2 ft.: Fracture zone with clay and quartz filling. 362.0 ft.: 65 deg. clay filled joint. 364.0-364.7 ft.: 80 deg. joint.
ARGILLITE, gray, med. hard, slightly weathered, with thin layers of tuffaceous argillite; very thin bedding, 25 to 30 deg.; smooth, closely spaced joints, lined with clay.	365.4 ft.: 65 deg. joint. 366.5-369.7 ft.: Two veins, 60 deg. and 70 deg. 369.0-370.2 ft.: Fracture zone. 370.8-371.6 ft.: Fracture zone. 371.4 ft.: 75 deg. joint. 373.4 ft.: 60 deg. joint. 374.7-376.6 ft.: 75 deg. joint. 376.0 ft.: 45 deg. joint. 377.4 ft.: 80 deg. joint. 380.2-385.4 ft.: Fracture zone, poor recovery. 380.5 ft.: 70 deg. joint. 390.4-391.5 ft.: 85 deg. smooth and clay filled joint. 392.4-394.0 ft.: 85 deg. smooth and clay filled joint. 395.0 ft.: 60 deg. clay filled joint.
395.4 FT.: END OF BORING	



Point Load I_s 50	Pressure Test K = cm/sec (x 0.00001)
<200	
748	

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

FIELD TEST BORING RECORD COVER SHEET

		BORING NO. 89-112
SITE Inter Island Tunnel - Boston Harbor	J.O. NO. U11305	SHEET 1 OF 1

COORIDNATES N-S 469336.2 E-W 746707.3

SEAFLOOR ELEVATION 74.8

INCLINATION Vertical INSPECTOR Watson, Sheridan

DATE: START/FINISH 8/21/89 / 8/24/89

CONTRACTOR/DRILLER Warren George/Laurenza, Gregory

DRILLING BARGE Katherine G

WATER DEPTH 30.9 (FT) DRILL RIG TYPE Failing 1500

ELEVATION TOP OF BEDROCK 22.5 (FT)

TOTAL DEPTH DRILLED 291.0 (FT)

METHODS:
- DRILLING SOIL Tri-cone rollerbit
- SAMPLING SOIL Split-spoon sampler
- DRILLING ROCK Roller bit, continuous HQ wireline coring
- SPECIAL TESTING OR INSTRUMENTATION Oriented coring, Packer testing.

SUMMARY

SOIL DRILLED 52.3 (FT) ROCK CORED 238.7 (FT)
NUMBER SPLIT BARREL SAMPLES 6

NOTES

1. The coordinate system used is the 1927 MASS GRID.
2. Datum is M.D.C.
3. In water borings, the split spoon sampler was driven into the soil by dropping a 175-pound sliding down hole hammer a distance of 4 feet within the borehole.
4. In land based borings the soil sampling method used was the STD Penetration Resistance using a 140 lb. hammer dropping a distance of 30 inches.

APPROVED	DATE
M Gilbert	1/2/90

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

BORING 89-112

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 469336.18ft. E: 746707.27ft.**

Sea Floor Elevation: **74.8 ft.**
Total Depth Drilled: **291.0 ft.**

DESCRIPTION – MAIN	DESCRIPTION – DETAIL	Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
SILTY CLAY, 3% fine sand, stiff green (CL).		0	74.8, 70			** 6-6-9-31 R24	
SILTY CLAY, 3% fine sand, very stiff green (CL).		10	65, 60			12-12 13-18 R24	
SILTY CLAY, 3% fine sand, stiff green (CL).		20	55, 50			10-8 7-10 R16	
SILTY CLAY, 3% fine sand, very stiff green (CL).		30	45, 40			9-11 12-15 R18	
SILTY CLAY, 3% fine sand, very stiff green (CL).		40	35, 30			5-7-9-12 R23	
TILL, GRAVELLY CLAY, fine to coarse gravel, 10% silt, 5% fine sand, hard, green (CL).		50	25			15-17 30-42 R6	
ARGILLITE, purple with occasional 2 to 25 mm thick pale pink tuffaceous (felsite) beds, med. hard, slightly weathered; bedding 40 deg.; moderately closely spaced joints, 30 to 85 deg.; joints and veins generally infilled with calcite, clay, quartz, and chlorite. 55.0-63.0 ft.: 40 deg. joints are slickensided. 63.0 ft.: Core barrel blocked after 6.5 ft. of core run.	TOP OF BEDROCK 52.3 FT. Roller bit to 55.0 ft. 56.0 ft.: 60 deg. clay coated joint. 56.8 ft.: Sandstone bed 30 mm thick. 57.0 ft.: 85 deg. joint. 60.8 ft.: Sandstone bed 5 mm thick.	60	20, 15, 10	90 94	56	1277 351 1245 2100	
69.5-78.0 ft.: Vertical fractures.	67.7-68.5 ft.: Fracture zone with gouge. 68.0 ft.: 30 deg. joint with soft clay filling, 20 mm thick. 71.0 ft.: 50 deg. joint. 72.0 ft.: 85 deg. joint.	70	5, 0	100		<200	

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

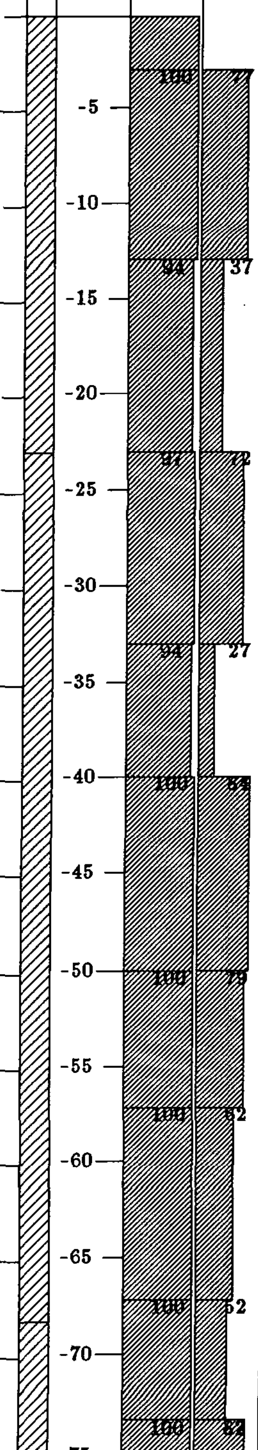
BORING SUMMARY LOG

BORING 89-112
SHEET 2 OF 5

PROJECT: INTER-ISLAND TUNNEL, BOSTON HARBOR
CLIENT: Massachusetts Water Resources Authority
Coordinates: N: 469336.18ft. E: 746707.27ft.

Sea Floor Elevation: **74.8 ft.**
Total Depth Drilled: **291.0 ft.**

DESCRIPTION — MAIN	DESCRIPTION — DETAIL
	75.0-75.6 ft.: Closely spaced felsite beds.
77.8 ft.: Correction in depth of borehole, subtracted 2.2 ft. 77.8-97.8 ft.: Purple argillite interbedded tuffaceous (felsite) (2 to 6 mm thick).	79.0 ft.: 45 deg. slickensided and clay filled joint. 80.5 ft.: Fault with gouge, 4 mm thick.
87.8-97.8 ft.: Felsite inclusionS (5 to 30 mm long).	90.0-91.5 ft.: Fracture zone, with clay and quartz in joints.
ARGILLITE with 20 mm thick Felsite beds; purplish gray, hard, slightly weathered; bedding thin to very thin, 40 to 60 deg., mod close to closely spaced joints 30 to 60 deg.; joints generally stained, slickensided or infilled with clay and quartz.	99.0 ft.: 30 deg. joint. 99.2-100.0 ft.: Fracture zone. 100.0 ft.: 60 deg. joint.
	107.8-114.8 ft.: 85 deg. cleavage. 109.0 ft.: 65 deg. slickensided joint. 110.5-111.5 ft.: Fracture zone with 80 deg. cleavage.
	115.4 ft.: Quartz vein 10 mm thick. 117.2 ft.: Crenulation folds in felsite bed.
	122.0 ft.: Sandstone bed 12 mm thick with felsite fragments.
	126.0 ft.: 60 deg. quartz filled joint. 127.2 ft.: 40 deg. clay coated joint.
131.6 ft.: Correction in depth of borehole, added 0.4 ft. 132.0-142.0 ft.: Felsite beds with microfaulting.	133.4 ft.: 60 deg. clay filled joint. 135.0-136.2 ft.: Fracture zone.
	143.3 ft.: 40 deg. clay coated joint. 144.1 ft.: 60 deg. clay coated joint. 148.6 ft.: 80 deg. clay coated joint.



Depth (ft.)	Elev. (ft.)
80	-5
	-10
90	-15
	-20
100	-25
	-30
110	-35
	-40
120	-45
	-50
130	-55
	-60
140	-65
	-70
	-75

REC	RQD
100	77
94	37
97	72
94	27
100	84
100	79
100	62
100	52
100	82

Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
<200	
351	
<200	
926	
<200	
<200	
<200	
734	
1517	
974*	
575	
862	
1102	
<200	36.1 @ 53 psi

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 469336.18ft. E: 746707.27ft.**

Sea Floor Elevation: **74.8 ft.**
Total Depth Drilled: **291.0 ft.**

DESCRIPTION

MAIN

ARGILLITE and sandy argillite beds, purplish gray, hard, slightly weathered; bedding thin when present, 60 to 85 deg.; moderately close to closely spaced joints 40 to 60 deg.; joints generally stained or filled with clay and quartz.

172.8-192.8 ft.: Oriented core.
173.0-183.0 ft.: Vertically bedded argillite with few felsite inclusions.

193.0-201.0 ft.: Interbedded argillite and thin felsite beds with crenulation cleavage.
196.0-197.0 ft.: Preserved core.

200.8-230.8 ft.: Oriented core.

- - - - - - - - - - - - - - - - - - - -

ARGILLITE, purple, gray and dark gray, hard to medium hard, slightly weathered; bedding medium to thin; 30 to 70 deg.; joints widely to moderately closely spaced generally 30 to 75 deg.; joints, veins, and bedding partings generally infilled with quartz, calcite, or chlorite.

221.0-241.0 ft.: Very thin (1 to 3 mm) joints.

DETAIL

149.9-151.7 ft.: Fracture zone.
151.0 ft.: Clay zone 20 mm thick.
153.0 ft.: 60 deg. quartz filled joint.

159.0 ft.: 60 deg. quartz filled joint.
160.0 ft.: 40 deg. clay coated joint.
162.0 ft.: 20 deg. clay coated joint.
165.0 ft.: 55 deg. quartz filled joint.
165.2 ft.: 55 deg. slickensided felsite bed.
169.0 ft.: 40 deg. clay coated joint.
171.1 ft.: 50 deg. clay coated joint.

174.3 ft.: 50 deg. clay coated joint.

181.5-183.0 ft.: Fracture zone with slickensided vertical joint.
184.20 ft.: 40 deg. joint.
186.5 ft.: Pink felsite bed, 10 mm thick.
187.5 ft.: Pink felsite bed, 10 mm thick.
191.9 ft.: 30 deg. clay filled joint, 10 mm thick.
193.2 ft.: 60 deg. clay filled joint.

198.0 ft.: 85 deg. clay filled joint.

202.0 ft.: 20 deg. clay filled joint.
203.2 ft.: 70 deg. clay filled joint.

208.6 ft.: 40 deg. joint, 2 mm wide.

211.4 ft.: Clasts of felsite 15 to 22 mm long.
212.0 ft.: 45 deg. quartz filled joint.
213.1 ft.: 30 deg. thin (1 to 3 mm) joints parallel to 30 deg. cleavage; joints infilled with chlorite.
215.1 ft.: 45 deg. calcite and quartz filled joint.
216.2 ft.: Clasts of felsite 15 to 20 mm long.

LOG DATA

Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
150				415	
	-80			<200	
		100	85	<200	
160	-85				
	-90			1245	
		100	14	1133	
170	-95				3.9 @ 63 psi
		100	82	974* / 974	
	-100				
180	-105				0.4 @ 69 psi
		100	97		
	-110				
190	-115				5.1 @ 74 psi
		88	53		
	-120			<200	
				687	
200	-125				4.7 @ 79 psi
		100	91		
	-130				
210	-135				4.2 @ 85 psi
		100	100		
	-140				
220	-145				
		100	100		4.2 @ 90 psi
	-150				

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

BORING 89-112
SHEET **4 OF 5**

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR** Sea Floor Elevation: **74.8 ft.**
CLIENT: **Massachusetts Water Resources Authority** Total Depth Drilled: **291.0 ft.**
Coordinates: **N: 469336.18ft. E: 746707.27ft.**

DESCRIPTION

MAIN

ARGILLITE, purple, gray and dark gray, hard to medium hard, slightly weathered; bedding medium to thin; 30 to 70 deg.; joints widely to moderately closely spaced generally 30 to 75 deg.; joints, veins, and bedding partings generally infilled with quartz, calcite, or chlorite.

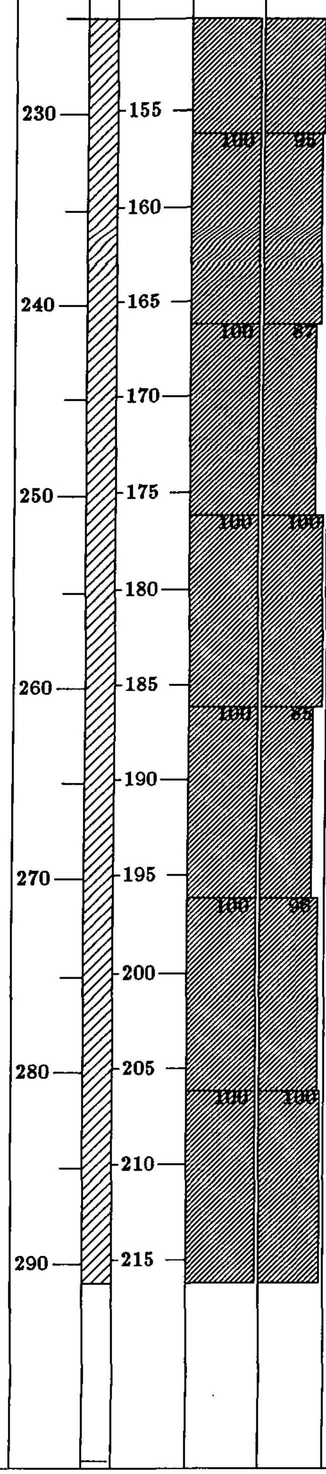
262.6-269.5 ft.: Zone of very closely spaced 40 to 45 deg. calcite filled and iron stained joints.

271.0-281.0 ft.: Numerous thin beds of white to pink felsite; parallel to bedding and 2 mm thick. Bedding commonly offset by very thinly spaced en echelon joints that have no infilling.

291.0 FT.: END OF BORING

DETAIL

218.4 ft.: 60 deg. quartz and calcite filled joint.
222.1 ft.: 30 deg. joint.
223.4 ft.: 30 deg. chlorite and quartz filled joint.
225.6-225.7 ft.: 50 deg. cleavage.
226.0 ft.: 35 deg. joint.
231.3 ft.: Ash bed with some calcite.
232.1 ft.: 75 deg. quartz and calcite filled joint.
234.0 ft.: 40 deg. quartz and calcite filled joint.
235.7 ft.: Granitic clast 70 mm long.
237.5 ft.: 25 deg. calcite and quartz filled joint.
238.5 ft.: 30 deg. cleavage.
240.0 ft.: Quartz filled vug, 30 mm in diameter.
242.6 ft.: 35 deg. joint, 1 mm wide.
244.1-246.6 ft.: 80 deg. calcite and quartz filled joint.
246.5 ft.: 45 deg. joint.
248.0 ft.: 70 deg. calcite and quartz filled joint.
248.5 ft.: 70 deg. cleavage.
248.9 ft.: Red (felsite) lens 5 mm thick parallel to bedding.
250.0 ft.: Prominent 30 deg. cleavage.
253.5 ft.: 80 deg. joint.
254.0 ft.: Red (felsite) lens offset by 75 deg. joints that are parallel to cleavage.
256.0-256.6 ft.: Very closely spaced 55 to 75 deg. joints; some infilled with pyrite and calcite.
258.5 ft.: 30 deg. cleavage.
261.8-262.7 ft.: 75 deg. calcite filled joint.
271.5 ft.: 40 deg. joint.
274.0 ft.: 30 deg. cleavage.
274.0 ft.: 60 deg. joint.
275.4-275.8 ft.: Fracture zone with numerous joints.
278.0 ft.: 50 deg. joint.
281.0-291.0 ft.: Cleavage cuts bedding at 65 deg. Bedding, as above, cut by en echelon very closely spaced joints.
282.5 ft.: 65 deg. joint.
285.0 ft.: 75 deg. quartz with minor calcite filled joint.
287.6 ft.: 65 deg. calcite and quartz filled joint.
289.0 ft.: 90 deg.



Point Load $I_{s\,50}$

<200
415
702
1309
1229
479
1006
<200
319
846
958

Pressure Test K = cm/sec (x 0.00001)

0=<0.1 @ 95 psi
0=<0.1 @ 100psi
3.4 @ 106 psi
78.2 @ 58 psi

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

BORING 89-112

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 469336.18ft. E: 746707.27ft.**

Sea Floor Elevation: **74.8 ft.**
Total Depth Drilled: **291.0 ft.**

DESCRIPTION MAIN	DESCRIPTION DETAIL	Depth (ft.)		Elev. (ft.)	REC	RQD	Point Load I_{s} 50	Pressure Test K = cm/sec (x 0.00001)
	bedding. 290.3 ft.: 70 deg. calcite filled joint. 290.9 ft.: Felsite bed 2 mm thick cut by en echelon joints.							

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

FIELD TEST BORING RECORD COVER SHEET

		BORING NO. 89-113
SITE Inter Island Tunnel - Boston Harbor	J.O. NO. U11305	SHEET 1 OF 1

COORIDNATES N-S 487612.2 E-W 746384.3

SEAFLOOR ELEVATION 47.6

INCLINATION Vertical INSPECTOR Watson, Zilinskas

DATE: START/FINISH 7/31/89 / 8/02/89

CONTRACTOR/DRILLER Warren George/Kurzynowski, Marney

DRILLING BARGE Southern Cross

WATER DEPTH 58.1 (FT) DRILL RIG TYPE Failing 1500

ELEVATION TOP OF BEDROCK -18.4 (FT)

TOTAL DEPTH DRILLED 292.0 (FT)

METHODS:
DRILLING SOIL Tri-cone rollerbit
SAMPLING SOIL Split-spoon sampler
DRILLING ROCK Roller bit, continuous HQ wireline coring
SPECIAL TESTING OR INSTRUMENTATION Oriented coring, Packer testing, downhole geophysics.

SUMMARY

SOIL DRILLED 66.0 (FT) ROCK CORED 226.0 (FT)
NUMBER SPLIT BARREL SAMPLES 7

NOTES

1. The coordinate system used is the 1927 MASS GRID.
2. Datum is M.D.C.
3. In water borings, the split spoon sampler was driven into the soil by dropping a 175-pound sliding down hole hammer a distance of 4 feet within the borehole.
4. In land based borings the soil sampling method used was the STD Penetration Resistance using a 140 lb. hammer dropping a distance of 30 inches.

APPROVED	DATE
M Gilbert	1/2/90

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

BORING 89-113
SHEET 1 OF 5

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 487612.25ft. E: 746384.27ft.**

Sea Floor Elevation: **47.6 ft.**
Total Depth Drilled: **292.0 ft.**

DESCRIPTION: MAIN	DESCRIPTION: DETAIL	Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
SILTY CLAY, slightly to moderately plastic, 3% fine gravel, stiff, greenish gray (CH).		0	47.6 45 40			** 2-3-5 R15	
SILTY CLAY, slightly to moderately plastic, stiff, greenish gray (CH).		10	35 30			5-5-5 R17	
SILTY CLAY, slightly to moderately plastic, soft, greenish gray (CH).		20	25 20			1-1-2 R18	
SILTY CLAY, slightly to moderately plastic, soft, greenish gray (CH).		30	15 10			1-2-2 R18	
SILTY CLAY, slightly to moderately plastic, soft, greenish gray (CH).		40	5 0			1-1-2 R18	
SILTY CLAY, slightly to moderately plastic, soft, greenish gray (CH).		50	-5 -10			1-1-1 R18	
TILL, GRAVELLY CLAY, fine to coarse gravel, angular to subrounded; 35% coarse sand, hard greenish gray (GC).		60	-15				
ARGILLITE, gray to light gray and greenish gray, med. hard, fresh to moderately weathered; bedding thin, 35 to 85 deg., some soft sediment deformational features; joints very closely spaced, 1 to 3 mm wide, filled with calcite, clay, quartz, occasionally iron stained, 20 to 85	TOP OF BEDROCK 66.0 FT. Roller bit to 70.0 ft. 70.0-74.1 ft.: Many thin (1 to 3 mm wide) joints infilled with calcite and quartz dipping 5 to 50	70	-20 -25	100	95	11-30+/3 R9	

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

BORING 89-113
SHEET 2 OF 5

PROJECT: INTER-ISLAND TUNNEL, BOSTON HARBOR Sea Floor Elevation: **47.6 ft.**
CLIENT: **Massachusetts Water Resources Authority** Total Depth Drilled: **292.0 ft.**
Coordinates: **N: 487612.25ft. E: 746384.27ft.**

DESCRIPTION — MAIN	DESCRIPTION — DETAIL
deg. 73.7 ft.: Circulation problems, correspond to drill breaks. 78.2 ft.: Circulation problems, correspond to drill breaks. 80.0-88.8 ft.: Joints with iron oxide staining/weathering. 88.8-98.8 ft.: Numerous bedding plane separations filled with calcite. **ARGILLITE INTERBEDDED WITH SANDY ARGILLITE**, gray to light gray, hard to med. hard, fresh to slightly weathered; bedding thin to very thin 20 to 40 deg., frequent soft sediment deformation; joints widely to closely spaced, 1 to 5 mm wide, filled with calcite or clay, 20 to 70 deg. 111.9-112.3 ft.: Fractured zone, with clay, pyrite and numerous joints. 119.1-127.1 ft.: 45 deg. hairline joints filled with calcite. 129.0-139.0 ft.: All core breaks due to drilling or hammering. 139.0-149.0 ft.: Numerous clay filled bedding plane separations. 139.5-143.8 ft.: 50 to 70 deg. clay filled joints.	deg. 70.0-71.0 ft.: Slumped bedding. 72.0-74.7 ft.: Slumped bedding. 77.0-79.7 ft.: 30 deg. calcite and quartz filled joints, 1 to 2 mm wide. 78.4 ft.: Slumped bedding. 80.8-82.2 ft.: Fracture zone with numerous filled fractures. 83.0 ft.: 70 deg. quartz and calcite filled joint. 86.5 ft.: 25 deg. calcite filled joint. 87.1 ft.: 60 deg. calcite filled joint. 90.4 ft.: Clasts of light gray argillite in matrix of dark gray argillite. 92.1 ft.: 35 deg. calcite filled joint. 94.0 ft.: 85 deg. calcite filled joint. 95.1 ft.: 85 deg. calcite filled joint. 96.0 ft.: 30 deg. calcite filled joint. 96.9-97.6 ft.: Argillite, slightly altered with iron oxide staining along closely spaced 50 deg. bedding plane separations. 98.0 ft.: 30 deg. calcite filled joint. 100.0 ft.: 20 deg. calcite filled joints. 100.9-101.4 ft.: Eight 30 to 35 deg. joints coated with clay. 102.9 ft.: Slumped bedding. 104.6 ft.: 35 deg. calcite and pyrite coated joint. 105.4 ft.: 65 deg. cleavage. 107.8-108.5 ft.: Fracture zone. 111.1 ft.: 30 deg. numerous joints. 112.2 ft.: 45 deg. clay coated joint. 114.2-114.8 ft.: Closed joint with calcite filling. 115.7 ft.: 50 deg. calcite filled joint. 119.5 ft.: Slumped bedding. 120.3 ft.: 45 deg. joint with smooth surfaces. 120.8 ft.: Slumped bedding. 123.1 ft.: Slumped bedding. 126.5 ft.: Slumped bedding. 135.1 ft.: 45 deg. calcite filled joint. 135.7 ft.: 35 deg. calcite filled joint.

Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load I_{s} 50	Pressure Test K = cm/sec (x 0.00001)
	-30			<200*	
80		95	35		
	-35				
	-40			<200	
		100	90	<200	
90				<200	
	-45				
				632	
	-50	100	91	1992	
100					
	-55				
				1391	
	-60	100	93		
110					
	-65				
				1091	
	-70			1518	
		100	100		
120					
	-75			1241	
				1154*	
	-80	100	100	1723	
130					
	-85			996	
	-90			1857	
		100	100	988	
140					
	-95			537	
	-100			1328*	
		100	100	933	

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test *corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.*

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

BORING 89-113

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 487612.25ft. E: 746384.27ft.**

Sea Floor Elevation: **47.6 ft.**
Total Depth Drilled: **292.0 ft.**

DESCRIPTION

MAIN

ARGILLITE, gray, med. hard to hard, fresh to slightly weathered; bedding very thin, 10 to 60 deg., occasional soft sediment deformation and interbedded sandy argillite; joints moderately close to closely spaced, 1 to 3 mm wide, filled with calcite, clay and occasionally quartz, 10 to 70 deg., occasional healed micro-faults.

193.5-197.0 ft.: Argillite interbedded with sandy argillite.

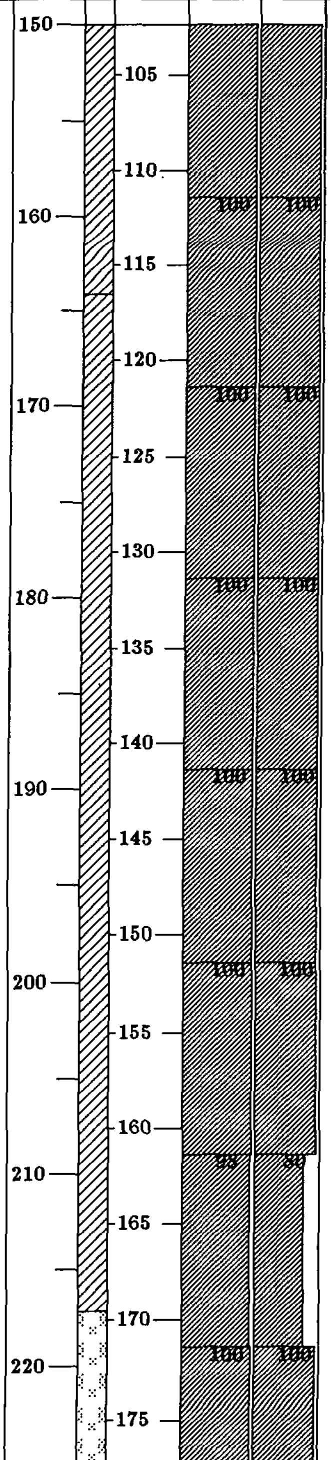
197.0-207.0 ft: Slumped bedding common.
198.6-218.6 ft.: Oriented core.

DIABASE, light gray to gray, hard to very hard, fresh to slightly weathered; joints close to very close, 1 to 5 mm wide, filled with calcite, clay and quartz, 10 to 40 deg., and 60 to 90 deg.
222.1-223.8 ft.: Preserved core.

DETAIL

137.7 ft.: 40 deg. calcite filled joint.
139.5 ft.: 70 deg. calcite filled joint.
140.0 ft.: 70 deg. calcite filled joint.
143.2 ft.: 60 deg. calcite filled joint.
143.8 ft.: 50 deg. calcite filled joint.
144.6-144.8 ft.: 60 deg. *fine sandstone bed.*
144.6-148.8 ft.: 30 deg. clay filled bedding plane separations.
156.0-156.6 ft.: Calcite filled fractures crosscutting bedding.

171.0 ft.: 75 deg. calcite filled joint crosscutting bedding.
173.1 ft.: 75 deg. calcite filled joint crosscutting bedding.
175.3 ft.: 65 deg. calcite filled joint crosscutting bedding.
176.6 ft.: 75 deg. calcite filled joint crosscutting bedding.
177.0 ft.: Bedding orientation changes direction, calcite filled joints, 75 deg. crosscut beds.
179.0 ft.: Vertical cleavage.
182.3 ft.: 75 deg. calcite filled joint.
182.7 ft.: 30 deg. calcite filled bedding plane separations, 2 to 3 mm wide.
184.1 ft.: 70 deg. calcite filled joint.
184.6 ft.: 30 deg. calcite filled bedding plane separations, 2 to 3 mm wide.
185.2 ft.: 60 deg. calcite filled joint.
187.7 ft.: 30 deg. calcite filled bedding plane separations, 2 to 3 mm wide.
191.0 ft.: 25 deg. calcite filled joint.
191.5 ft.: 60 deg. calcite filled bedding plane separation.
197.0 ft.: 45 deg. calcite and quartz filled joint.
198.5 ft.: 60 deg. calcite vein 10 mm wide.
199.2 ft.: 60 deg. calcite filled bedding plane separation.
200.0 ft.: 20 deg. calcite and quartz filled joint.
202.1 ft.: 20 deg.



Point Load $I_{s\,50}$
395
696
618
1415
1075
2387
2063
618
1731*
964

Pressure Test K = cm/sec (x 0.00001)
2.4 @ 71 psi
0.4 @ 76 psi
0.2 @ 82 psi
0.1 @ 87 psi
3.9 @ 92 psi
0.1 @ 97 psi

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 487612.25ft. E: 746384.27ft.**
Sea Floor Elevation: **47.6 ft.**
Total Depth Drilled: **292.0 ft.**

DESCRIPTION

MAIN

228.6-248.6 ft.: Oriented core.

ARGILLITE, light gray, hard, fresh to slightly weathered; bedding very thin, 20 to 30 deg.; joints closely spaced, 1 to 8 mm wide, filled with quartz, 30 to 90 deg.

259.0-269.0 ft.: ARGILLITE interbedded with SANDY ARGILLITE.

292.0 FT.: BOTTOM OF BORING

DETAIL

calcite and quartz filled joint.
202.8 ft.: 10 deg. calcite and quartz filled joint.
205.1 ft.: 30 deg. calcite and quartz filled joint.
209.0 ft.: 90 deg. calcite and quartz filled joint.
211.0 ft.: 90 deg. calcite and quartz filled joint.
215.3 ft.: 90 deg. calcite and quartz filled joint.
217.1 ft.: 70 deg. calcite and quartz filled joint.
220.0 ft.: 90 deg. calcite filled joint.
221.3 ft.: 80 deg. calcite filled joint.
222.0 ft.: 20 deg. calcite filled joint.
225.3 ft.: 90 deg. calcite and quartz filled joint.
225.9 ft.: 80 deg. calcite and quartz filled joint.
227.6 ft.: 80 deg. calcite and quartz filled joint.
228.1 ft.: 80 deg. calcite and quartz filled joint.
229.4 ft.: 10 deg. calcite and quartz filled joint.
230.0 ft.: 40 deg. calcite and quartz filled joint.
232.6 ft.: 65 deg. calcite filled joint.
234.5-235.0 ft.: Vertical joints (1 to 10 mm) filled with calcite. Drill breaks along joints.
235.4 ft.: 70 deg. calcite filled joint.
236.1 ft.: 90 deg. calcite filled joint.
242.0 ft.: 30 deg. calcite filled bedding plane separation.
244.7 ft.: 45 deg. quartz filled joint.
245.0 ft.: 40 deg. quartz filled joint.
248.0 ft.: 60 deg. quartz filled joint.
251.0 ft.: 80 deg. clay filled joint.
252.3 ft.: 30 deg. quartz filled joint.
255.1 ft.: 45 deg. quartz filled joint.
258.1 ft.: 80 deg. clay filled joint.
264.0 ft.: 40 deg. quartz filled joint.
272.0 ft.: 30 deg. quartz filled joint.

Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
	180			1573 2466* 2426	
230		100	100		6.3 @ 103 psi
	185				
	190				
240		100	100		13.5 @ 108 psi
	195				
	200				
250		100	100	751	47.6 @ 100 psi
	205				
	210			996	
260		100	100		17.4 @ 118 psi
	215			1549	
	220				
270		100	100	854	
	225				
				1162	
	230				
280		100	100	948 <200 1304*	
	235				
	240				
290		100	87	553 490	

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 487612.25ft. E: 746384.27ft.**

Sea Floor Elevation: **47.6 ft.**
Total Depth Drilled: **292.0 ft.**

DESCRIPTION		Depth (ft.)		Elev. (ft.)	REC	RQD	Point Load $I_{s\ 50}$	Pressure Test K = cm/sec (x 0.00001)
MAIN	DETAIL							
	281.0 ft.: 30 deg. quartz filled joint. 283.0-286.0 ft.: Slumped bedding. 291.3 ft.: 80 deg. calcite filled joint.							

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

FIELD TEST BORING RECORD COVER SHEET

SITE Inter Island Tunnel - Boston Harbor	J.O. NO. U11305	BORING NO. 89-114 SHEET 1 OF 1

COORIDNATES N-S 483446.6 E-W 746503.7

SEAFLOOR ELEVATION 96.5

INCLINATION Vertical INSPECTOR Watson, Zilinskas

DATE: START/FINISH 9/11/89 / 9/15/89

CONTRACTOR/DRILLER Warren George/Smith, Tirro, Gregory

DRILLING BARGE WGI 90

WATER DEPTH 9.2 (FT) DRILL RIG TYPE Failing 1500

ELEVATION TOP OF BEDROCK 18.5 (FT)

TOTAL DEPTH DRILLED 333.4 (FT)

METHODS:
- DRILLING SOIL Tri-cone rollerbit
- SAMPLING SOIL Split-spoon sampler
- DRILLING ROCK Roller bit, continuous HQ wireline coring
- SPECIAL TESTING OR INSTRUMENTATION Oriented coring, Packer testing.

SUMMARY

SOIL DRILLED 78.0 (FT) ROCK CORED 255.4 (FT)
NUMBER SPLIT BARREL SAMPLES 8

NOTES

1. The coordinate system used is the 1927 MASS GRID.
2. Datum is M.D.C.
3. In water borings, the split spoon sampler was driven into the soil by dropping a 175-pound sliding down hole hammer a distance of 4 feet within the borehole.
4. In land based borings the soil sampling method used was the STD Penetration Resistance using a 140 lb. hammer dropping a distance of 30 inches.

APPROVED	DATE
M. Gilbert	

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 483446.60ft. E: 746503.70ft.**

Sea Floor Elevation: **96.5 ft.**
Total Depth Drilled: **333.4 ft.**

DESCRIPTION – MAIN	DESCRIPTION – DETAIL	Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load I_{s} 50	Pressure Test K = cm/sec (x 0.00001)
SANDY SILT, slightly plastic, 35% fine to coarse sand, 25% gravel, very loose, black (OL). **CLAYEY SILT**, slightly plastic, 20% fine to coarse sand, 15% gravel, 3% organics, hard blue and reddish *brown (CL).*		0	96.5 / 95			** 1-8-14 R12	
			90				
TILL, SILTY CLAY, 35% fine to coarse sand, 25% gravel, moderately plastic fines, dense, light gray to blue gray (SC).		10	85			8-14-17 R1	
			80				
TILL, CLAYEY GRAVEL, 25% clay, 20% fine to coarse sand, 10% *silt*, very dense, gray; *gravel consists* of angular pieces of green, purple, and dark gray argillite (GC).		20	75			21-25-37 R8	
			70				
TILL, SILTY SAND, well graded, 35% silt, 15% clay, 3% gravel, slightly plastic fines, very dense, gray (SM).		30	65			23-34-41 R14	
			60				
TILL, SANDY GRAVEL, 35% sand, 20% silt, 15% clay, very dense, gray (GM).		40	55			32-34-27 R8	
			50				
TILL, SANDY GRAVEL, 35% sand, 20% silt, 15% clay, very dense, gray (GM).		50	45			19-28-50 R7	
			40				
TILL, CLAYEY SAND, poorly sorted, fine to coarse sand, 35% clay, 25% silt, 3% gravel, very dense, gray (SC).		60	35			39-50 R9	
			30				
TILL, SANDY GRAVEL, 35% fine to coarse sand, 15% silt, 10% clay, very dense, gray; gravel consists of weathered pieces of argillite (GC).		70	25			42-50+/2 R4	

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

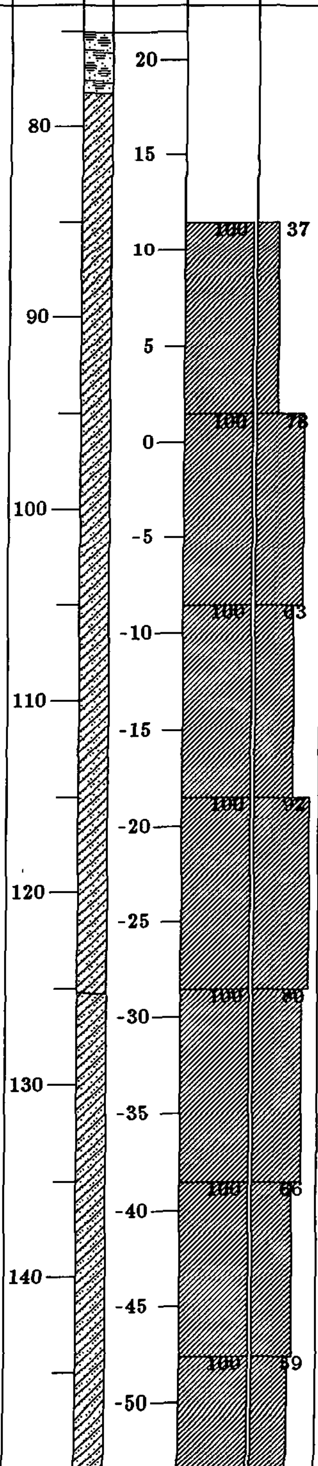
GZA

BORING SUMMARY LOG

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 483446.60ft. E: 746503.70ft.**

Sea Floor Elevation: **96.5 ft.**
Total Depth Drilled: **333.4 ft.**

DESCRIPTION: MAIN	DESCRIPTION: DETAIL
SANDY ARGILLITE INTERBEDDED WITH FINE SANDSTONE, light greenish gray to *dark gray with 2 to 5 mm wide* orange-brown layers parallel to bedding, hard to med. hard, slightly weathered; bedding thin to laminar, 30 to 45 deg., slumped bedding *common; joints moderately close to* closely spaced, 50 to 75 deg.; some quartz veins, various orientations; numerous bedding plane separations infilled with quartz. 105.0-115.0 ft.: Numerous quartz veins, 3 to 25 mm wide, generally dipping 45 to 70 deg.	TOP OF BEDROCK 78.0 FT. Roller bit to 85 ft.: 85.0 ft.: 55 deg. cleavage w/iron staining along cleavage planes 88.0 ft.: 45 deg. slickensided joint. 89.5 ft.: 60 deg. slumped bedding with slickensides. 90.0 ft.: 65 deg. slickensided joint. 91.0 ft.: 70 deg. slickensided joint. 92.0-92.5 ft.: 10 to 20 deg. quartz veins. 94.0 ft.: Slumped bedding. 96.0 ft.: 70 deg. cleavage. 98.5 ft.: 75 deg. slickensided joint. 99.2-100.0 ft.: Fracture zone. 100.6-100.8 ft.: Fracture zone. 102.7-102.9 ft.: Moderate alteration of argillite. 103.5-104.0 ft.: Pyrite mineralization parallel - 40 deg. bedding 103.5-103.8 ft.: Gouge zone. 106.2-106.3 ft.: Moderate alteration of argillite. 107.5 ft.: 55 deg. cleavage. 110.0 ft.: 50 deg. joint. 110.1 ft.: 45 deg. quartz vein, 25 mm wide.
SANDY ARGILLITE INTERBEDDED WITH FINE SANDSTONE, light greenish gray to dark gray with 2 to 5 mm wide orange-brown layers parallel to bedding, hard to very hard, slightly weathered to moderately weathered; bedding thin to very thin, 35 to 60 deg., slumped bedding common; joints moderately close to closely spaced, 60 to 85 deg.; some quartz veins (with minor amounts of calcite); numerous bedding plane separations infilled with quartz. 125.0-154.1 ft.: Lighter, sandy quartz rich beds are very hard and the darker, clayey silt, beds are hard to medium hard. 130.7-131.1 ft.: Preserved core. 136.0-142.7 ft.: Numerous quartz veins, 3 to 15 mm wide, various orientations.	111.3 ft.: 70 deg. quartz vein, 12 mm wide. 112.0 ft.: 50 deg. cleavage. 115.6-117.9 ft.: Numerous quartz veins 7 to 15 mm wide, various *orientations, turncate* bedding. 117.0 ft.: 60 deg. quartz filled joint. 118.8 ft.: Tuffaceous argillite. 119.5 ft.: 15 deg. joint. 120.0 ft.: 70 deg. cleavage. 121.3 ft.: 80 deg. quartz filled joint. 123.2 ft.: 70 deg. quartz filled joint. 124.6-124.7 ft.: Pyrite mineralization parallel to 50 deg. bedding. 127.0 ft.: 70 deg. quartz



Point Load I_s 50	Pressure Test K = cm/sec (x 0.00001)
<200	
<200	
1169	
<200	
542	
<200	
446	
813	
1291	
<200	
654	
510 1498*	
701	

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

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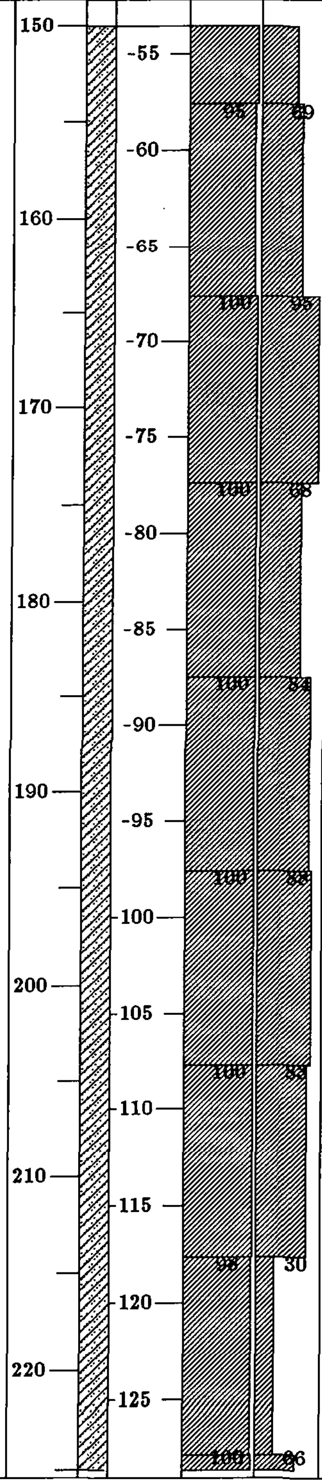
BORING SUMMARY LOG

BORING 89-114
SHEET **3 OF 6**

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: N: **483446.60ft.** E: **746503.70ft.**

Sea Floor Elevation: **96.5 ft.**
Total Depth Drilled: **333.4 ft.**

DESCRIPTION — MAIN	DESCRIPTION — DETAIL
SANDY ARGILLITE INTERBEDDED WITH FINE SANDSTONE, light greenish gray to dark gray with 2 to 5 mm wide orange-brown layers parallel to bedding, hard to very hard, slightly weathered to moderately weathered; bedding thin to very thin, 35 to 60 deg., slumped bedding common; joints moderately close to closely spaced, 60 to 85 deg.; some quartz veins (with minor amounts of calcite); numerous bedding plane separations infilled with quartz. 161.0-161.9 ft.: Preserved core. 165.0 ft.: When drilling pressure raised above 250 PSI bit chattered, therfore, driller used lower PSI during drilling. 165.9-172.4 ft.: 55 to 70 deg. joints dip, 2 mm wide, infilled with quartz, generally crosscutting bedding. 184.0 ft.: New drill bit installed. 188.7-193.5 ft.: Bedding plane separations 2 to 5 mm wide, infilled with quartz. 210.6-211.8 ft.: Preserved core.	filled joint. 131.7 ft.: 75 deg. quartz and chlorite filled joint. 132.7-132.9 ft.: Moderately alterated zone parallel to 50 deg. bedding. 133.8-134.1 ft.: Gouge zone. 136.0 ft.: 70 deg. quartz filled joint. 137.5 ft.: 70 deg. quartz filled joint. 139.5 ft.: 85 deg. quartz filled joint. 141.1 ft.: Kinked bedding adjacent to joints. 142.4-144.1 ft.: Slight alteration of argillite. 143.0 ft.: 65 deg. joint. 144.1 ft.: Clay zone, blocked core barrel. 144.3-144.5 ft.: Fracture zone. 146.0 ft.: 85 deg. quartz filled joint. 147.9 ft.: Quartz vein parallel to 55 deg. bedding. 148.5 ft.: 80 deg. quartz and chlorite filled joint. 152.0-154.1 ft.: Many hairline veins of organge-brown mineral (iron-rich) along 75 deg. cleavage. 155.5 ft.: 60 deg. quartz filled joint. 156.5 ft.: 75 deg. joint. 158.1-158.7 ft.: Gouge zone, moderate alteration. 159.5 ft.: Pyrite mineralization. 159.9 ft.: Quartz veins 2 to 3 mm wide. 161.0 ft.: 65 deg. cleavage. 172.2 ft.: Altered chloritic argillite. 174.0 ft.: 70 deg. joint. 175.0 ft.: 75 deg. joint. 176.4-175.0 ft.: 75 deg. quartz filled joint parallel to bedding 176.5-177.4 ft.: 80 deg. slickensided joint infilled with quartz. 177.0 ft.: 80 deg. joint. 179.9 ft.: 90 deg. bedding. 181.0 ft.: 65 deg. cleavage. 181.5 ft.: 90 deg. bedding. 182.5 ft.: 65 deg. joint. 186.5 ft.: 70 deg. cleavage. 190.3 ft.: Bedding plane separations 2-5mm wide infilled w/quartz 194.1-196.0 ft.: Bedding massive. 195.0 ft.: 65 deg.



Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
1339	
781	
973	
478	
797	
1275	
1753	
765	
542	
	12.4 @ 97 psi
1004	
431	
<200	
	2.5 @ 103 psi
1148	
686	
	5.8 @ 109 psi

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

PROJECT: INTER-ISLAND TUNNEL, BOSTON HARBOR
CLIENT: Massachusetts Water Resources Authority
Coordinates: N: 483446.60ft. E: 746503.70ft.

Sea Floor Elevation: 96.5 ft.
Total Depth Drilled: 333.4 ft.

DESCRIPTION

MAIN

234.5-254.5 ft.: Oriented core.

SANDY ARGILLITE INTERBEDDED WITH FINE SANDSTONE, greenish gray to gray, hard, slightly weathered; bedding thin to medium, 5 to 55 deg. occasional slumped bedding with steeper dip angle; joints moderately closely spaced, 55 to 80 deg.; occasional quartz veins; numerous bedding plane separations.
262.9-263.8 ft.: Preserved core.
264.5-284.5 ft.: Oriented core.

287.0-294.4 ft.: Very hard sandstone.

295.4-303.5 ft.: Slumped bedding with quartz infilling slump folds.

DETAIL

cleavage.
195.5 ft.: 65 deg. chlorite and quartz filled joint.
195.5 ft.: 70 deg. cleavage.
199.2-203.6 ft.: 45 to 65 deg. quartz filled joints, 5-7 mm wide
200.0-200.6 ft.: Fracture zone with abundant quartz.
201.0-204.2 ft.: Quartz veins, various orientations.
202.0 ft.: 55 deg. quartz filled joint.
203.5 ft.: 60 deg. cleavage.
204.2-208.3 ft.: Slumped bedding.
204.5-205.1 ft.: Quartz veins parallel to bedding.
206.5 ft.: 75 deg. quartz vein.
208.5 ft.: 70 deg. quartz filled joint.
210.0 ft.: 75 deg. joint.
211.5 ft.: 70 deg. joint.
213.5 ft.: 65 deg. joint.
216.0 ft.: 65 quartz filled joint.
217.0-223.8 ft.: 85 deg. fracture with slickensides.
219.0 ft.: 75 deg. cleavage.
220.5 ft.: 85 deg. cleavage.
222.5 ft.: 75 deg. cleavage.
225.2-229.2 ft.: Quartz veins various orientations.
225.8 ft.: Quartz filled vug.
226.0 ft.: 65 deg. quartz filled joint.
227.0 ft.: 75 deg. quartz filled joint.
228.0 ft.: 85 deg. quartz filled joint.
232.0 ft.: 60 deg. slickensided joint.
234.2-236.0 ft.: Bedding massive.
235.0 ft.: 85 deg. cleavage.
236.0 ft.: 65 deg. joint.
239.0 ft.: 75 deg. cleavage.
239.6-240.9 ft.: Bedding massive.
241.5-242.5 ft.: Bedding massive.
242.0 ft.: 75 deg. joint.
244.2 ft.: 70 deg. cleavage.
245.0 ft.: 50 deg. quartz filled joint.
247.0 ft.: 90 deg. bedding.
252.0 ft.: 65 deg. cleavage.

Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
	-130			<200	
230	-135			223	
	-140	100	85		12.2 @ 115 psi
240	-145				
	-150	100	100		0=<0.1 @ 120psi
250	-155				
	-160	100	87		1.6 @ 127 psi
260	-165			765	
	-170	100	73	1100	2.6 @ 132 psi
270	-175				
	-180	97	40		22.8 @ 138 psi
280	-185				
	-190	100	61	797	17.3 @ 144 psi
290	-195				
	-200	100	61	431	5.9 @ 158 psi

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

GZA

BORING SUMMARY LOG

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 483446.60ft. E: 746503.70ft.**

Sea Floor Elevation: **96.5 ft.**
Total Depth Drilled: **333.4 ft.**

DESCRIPTION

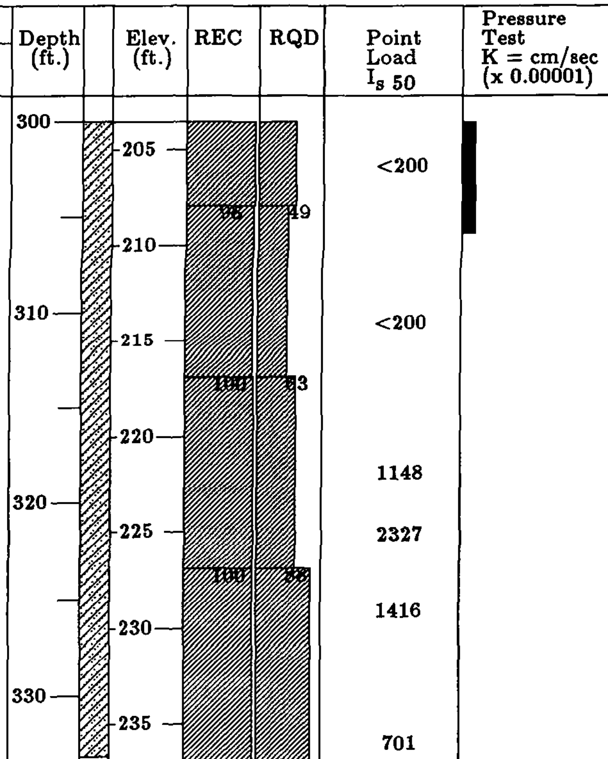
MAIN

SANDY ARGILLITE INTERBEDDED WITH FINE SANDSTONE, light greenish gray to dark gray, hard to very hard, slightly weathered; bedding thin to medium, 35 to 55 deg. slumped bedding common with steeper dips; joints moderately close, 55 to 80 deg.; occasional quartz veins, various orientations; numerous bedding plane separations.

333.4 FT.: END OF BORING

DETAIL

253.0 ft.: Sandy bed.
255.0 ft.: 60 deg. cleavage.
256.3 ft.: 60 deg. quartz filled joint, 4 mm wide, crosscutting bedding.
256.4-257.2 ft.: Fracture zone.
257.1 ft.: 60 deg. quartz filled joint, 4 mm wide, crosscutting bedding.
260.0-264.0 ft.: Many sandstone beds.
262.6-264.2 ft.: 60 deg. calcite filled joints.
264.4-264.8 ft.: Slumped bedding.
266.4-267.4 ft.: Sandstone bed.
268.0 ft.: 60 deg. cleavage.
272.0 ft.: 55 deg. cleavage.
273.3-274.0 ft.: Fracture zone.
277.0-280.0 ft.: Numerous sandstone beds.
280.7-282.0 ft.: 80 deg. joint, 15 mm wide, infilled with quartz and calcite.
282.0-283.0 ft.: 70 deg. quartz filled joint.
284.2 ft.: 45 deg. slickensided bedding plane separations.
285.5 ft.: 60 deg. cleavage.
286.6-289.0 ft.: Slumped bedding.
289.0 ft.: 65 deg. cleavage.
293.5 ft.: 45 deg. cleavage.
295.0 ft.: 45 deg. cleavage.
299.0 ft.: Vertical sandstone bed 20 mm wide.
304.4-308.0 ft.: Numerous sandstone beds.
306.9 ft.: 10 deg. calcite and quartz vein.
307.0-308.0 ft.: 85 deg. fracture zone with slickensides.
310.0 ft.: 75 deg. quartz and calcite filled joint.
311.0-313.4 ft.: Fracture zone adjacent to 75 deg. joints.
313.0-317.0 ft.: 85 deg. fracture zone with quartz and calcite infilling.
315.4 ft.: Fracture zone.
316.0 ft.: 50 deg. cleavage.
317.0-323.4 ft.: Conglomeratic sandstone, slumped bedding.
319.0 ft.: 45 deg.



NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

GZA

BORING SUMMARY LOG

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 483446.60ft. E: 746503.70ft.**

Sea Floor Elevation: **96.5 ft.**
Total Depth Drilled: **333.4 ft.**

DESCRIPTION MAIN	DESCRIPTION DETAIL	Depth (ft.)		Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
	cleavage. 322.0 ft.: 40 deg. cleavage. 323.4-333.4 ft.: Conglomeratic sandstone. 324.0 ft.: 75 deg. cleavage. 326.0 ft.: 20 deg. calcite filled joint. 329.0 ft.: 75 deg. cleavage. 330.0 ft.: 70 deg. bedding. 330.0 ft.: 25 deg. joint.							

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

FIELD TEST BORING RECORD COVER SHEET

SITE	J.O. NO.	SHEET	BORING NO.
Inter Island Tunnel - Boston Harbor	U11305	1 OF 1	89-115

COORIDNATES N-S 473079.7 E-W 746187.6

SEAFLOOR ELEVATION 74.3

INCLINATION Vertical INSPECTOR Watson, Grimes

DATE: START/FINISH 9/05/89 / 9/09/89

CONTRACTOR/DRILLER Warren George/Gregory, Tirro

DRILLING BARGE WGI 90

WATER DEPTH 31.4 (FT) DRILL RIG TYPE Failing 1500

ELEVATION TOP OF BEDROCK -20.7 (FT)

TOTAL DEPTH DRILLED 288.0 (FT)

METHODS:
- DRILLING SOIL Tri-cone rollerbit
- SAMPLING SOIL Split-spoon sampler
- DRILLING ROCK Roller bit, continuous HQ wireline coring
- SPECIAL TESTING OR INSTRUMENTATION Oriented coring, Packer testing.

SUMMARY

SOIL DRILLED 95.0 (FT) ROCK CORED 193.0 (FT)
NUMBER SPLIT BARREL SAMPLES 11

NOTES

1. The coordinate system used is the 1927 MASS GRID.
2. Datum is M.D.C.
3. In water borings, the split spoon sampler was driven into the soil by dropping a 175-pound sliding down hole hammer a distance of 4 feet within the borehole.
4. In land based borings the soil sampling method used was the STD Penetration Resistance using a 140 lb. hammer dropping a distance of 30 inches.

APPROVED	DATE
M Gilbert	1/2/90

GOLDBERG-ZOINO & ASSOCIATES, INC.

GZA

BORING SUMMARY LOG

BORING 89-115

SHEET 1 OF 4

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 473079.72ft. E: 746187.63ft.**

Sea Floor Elevation: **74.3 ft.**
Total Depth Drilled: **288.0 ft.**

DESCRIPTION MAIN	DESCRIPTION DETAIL	Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
ORGANIC SILT, 15% sand, very loose, black (OL). **SILTY CLAY** 15% sand, 5% gravel, 3% organics, olive gray (CL).		0	74.3, 70			** 1-1-2 R15	
SILTY CLAY, slightly to moderately plastic, 5% sand, 3% organics, stiff, gray (CL-CH).		10	65, 60			7-6-8 R18	
SILTY CLAY, slightly to moderately plastic, 5% sand, stiff, olive gray (CL-CH).		20	55, 50			3-6-4 R18	
SILTY CLAY, slightly to moderately plastic, 2% fine to coarse sand, stiff, olive gray (CL-CH).		30	45, 40			6-4-4 R18	
SILTY CLAY, slightly to moderately plastic, 5% fine sand, medium stiff, olive gray (CL-CH).		40	35, 30			2-3-4 R18	
SILTY CLAY, slightly to moderately plastic, stiff, olive gray (CL-CH).		50	25, 20			3-4-6 R12	
TILL, GRAVELLY CLAY, fine to coarse gravel, 35% fine to coarse sand and silt, very dense, gray to olive gray (GC). 62.0-72.0 ft.: HQ wireline cored, driller thought this was top or rock, was boulders, 70 percent recovery of gabbro, diabase, purple argillite in a till matrix same as above description, sample numbers 8 and 9.		60, 70	15, 10, 5, 0			5-38-23 R5	

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

BORING 89-115
SHEET 2 OF 4

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 473079.72ft. E: 746187.63ft.**

Sea Floor Elevation: **74.3 ft.**
Total Depth Drilled: **288.0 ft.**

DESCRIPTION — MAIN	DESCRIPTION — DETAIL	Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load I_{s} 50	Pressure Test K = cm/sec (x 0.00001)
TILL, very dense, gray to olive gray, fine to coarse GRAVEL and CLAY, some fine to coarse Sand and Silt.		80	-5			17-31 50+/1 R5	
			-10				
		90	-15			11-32-65 R9	
	TOP OF BEDROCK 95.0 FT.		-20				
ARGILLACEOUS SANDSTONE TO CONGLOMERATIC SANDSTONE, dark gray to light gray, medium hard to very soft, slightly to highly weathered; bedding very thin to medium, 35 to 70 deg., occasionally slumped; joints moderately close to closely spaced 60 to 85 deg.; occasional quartz veins various orientations.	Roller bit to 101.5 ft.	100	-25	100	44	<200	
	103.0 ft.: 90 deg. joint.		-30				
	106.0 ft.: 70 deg. cleavage.					<200	
	108.8 ft.: Argillite altered to clay.	110	-35				
	110.0 ft.: Brecciated zone, 60 deg. joint crosscutting bedding.			100	32		
	112.5-113.5 ft.: Coarse sandstone to conglomeratic sandstone bed.		-40			<200	
	115.1 ft.: 80 deg. cleavage; clay alteration.					<200	
	119.8 ft.: 30 to 35 deg. fractures coated with clay.	120	-45				
121.5-126.5 ft.: Core not recovered. Fracture zone infilled with clay above this interval suggests that this is a fault zone.	121.5 ft.: 30 to 35 deg. fractures coated with clay.			51	4		
			-50				
		130	-55				
131.5-133.6 ft.: Fault zone with clay and poor recovery.				56	11		
	134.6 ft.: 75 mm wide quartz vein.		-60			<200	
	134.9-137.0 ft.: Black shaly sandstone.			97	8		
	135.0 ft.: 80 deg. cleavage.	140	-65			<200	
	140.8-142.4 ft.: Slumped bedding.					<200	
	141.0 ft.: 70 deg. cleavage.		-70				
	143.3-143.7 ft.: Slumped bedding.						0.2 @ 56 psi
	144.6 ft.: Clay zone.			99	38		
	145.4-146.0 ft.: Slumped bedding.		-75			<200	

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**

CLIENT: **Massachusetts Water Resources Authority**

Coordinates: **N: 473079.72ft. E: 746187.63ft.**

Sea Floor Elevation: **74.3 ft.**

Total Depth Drilled: **288.0 ft.**

DESCRIPTION

MAIN

ARGILLACEOUS SANDSTONE TO CONGLOMERATIC SANDSTONE, dark gray to light gray, medium hard to very soft, slightly to highly weathered; bedding very thin to medium, 35 to 70 deg., *occasionally slumped; joints* moderately close to closely spaced 60 to 85 deg.; occasional quartz veins various orientations.

177.8 ft.: Measurement gives 0.8 ft. error which was probably distributed over last several recoveries.

188.3-208.3 ft.: Oriented core.

208.0-218.0 ft.: 60 to 70 deg. cleavage.

211.8-212.6 ft.: Preserved core.

218.0 ft.: Bit being used is for harder rock and may result in longer drilling times through intervals of softer rock.

DETAIL

147.0-151.9 ft.: 75 deg. joints crosscutting beds; bedding offsets up to 10 mm along joints.
153.0 ft.: 70 deg. cleavage.
153.3-153.8 ft.: Fracture zone.
156.4 ft.: Calcite infilling of bedding plane separation.
158.8-159.4 ft.: Fracture zone with clay filling.
159.2 ft.: 25 mm wide quartz vein.
164.5 ft.: Coarse sandstone bed.
167.8-168.9 ft.: Coarse sandstone to fine conglomerate.
168.1-169.0 ft.: Slumped bedding.
171.5-171.6 ft.: Coarse sandstone bed.

176.3 ft.: Coarse sandstone bed.
178.0-179.2 ft.: *Conglomeratic sandstone bed.*
181.2 ft.: 30 deg. cleavage.

187.4-187.6 ft.: Clay zone.
187.9-188.0 ft.: Clay zone.
188.9-189.1 ft.: Clay zone.
190.6-191.0 ft.: Clay zone.
191.8-192.0 ft.: Clay zone.
192.0 ft.: 80 deg. cleavage.
194.4 ft.: 70 deg. cleavage.
196.6-196.8 ft.: Clay zone.
200.0 ft.: 70 deg. cleavage.
202.0-202.5 ft.: Fracture zone.
205.0 ft.: 50 deg. cleavage.
208.2 ft.: 2 to 3 cm diameter *granitic clast.*

216.7 ft.: 1 to 2 cm diameter sandstone clast.
219.0 ft.: 80 deg. calcite vein.
220.0 ft.: 75 deg. cleavage.

Depth (ft.)	Elev. (ft.)
150	
	-80
	-85
160	
	-90
	-95
170	
	-100
	-105
180	
	-110
	-115
190	
	-120
	-125
200	
	-130
	-135
210	
	-140
	-145
220	
	-150

REC	RQD
94	51
100	67
99	65
93	47
95	58
98	47
56	15

Point Load $I_{s\ 50}$: <200, <200, <200, <200, <200, <200, <200, <200, <200, <200, <200

Pressure Test K = cm/sec (x 0.00001):
- 0.5 @ 41 psi
- 0=<0.1 @ 60 psi
- 0.6 @ 66 psi
- 0.4 @ 63 psi
- 0=<0.1 @ 90 psi
- 0.2 @ 90 psi

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

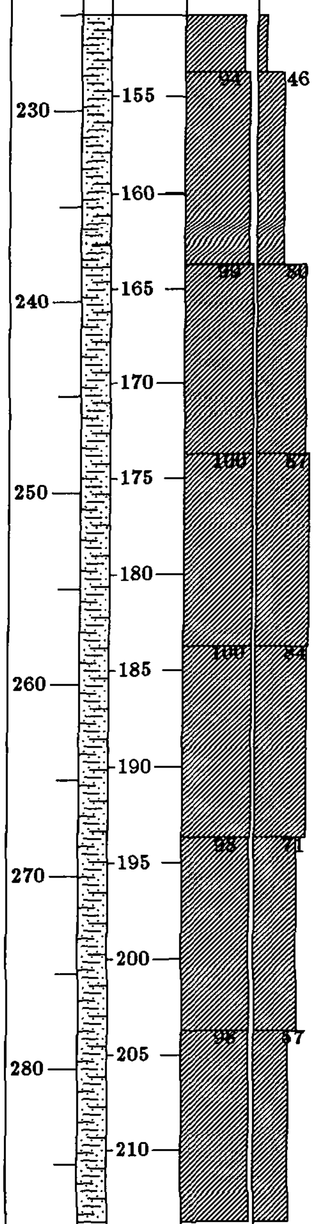
BORING SUMMARY LOG

BORING 89-115
SHEET 4 OF 4

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 473079.72ft. E: 746187.63ft.**

Sea Floor Elevation: **74.3 ft.**
Total Depth Drilled: **288.0 ft.**

DESCRIPTION — MAIN	DESCRIPTION — DETAIL
225.0-228.0 ft.: Fault zone with gouge and poor recovery.	225.0-228.0 ft.: Fault zone with gouge and poor recovery. 231.0-233.0 ft.: Zone of calcite crystals filling voids. 232.0-238.0 ft.: Conglomeratic bed with argillite and sandstone.
ARGILLACEOUS SANDSTONE TO CONGLOMERATIC SANDSTONE, gray to grayish green, medium hard to soft, slightly weathered; bedding very thin to medium, 5 to 35 deg., occasionally slumped; joints close to moderately closely spaced, 60 to 80 deg. 238.0-248.0 ft.: Slumped bedding common.	241.0 ft.: 85 deg. cleavage. 248.0 ft.: 80 deg. cleavage. 256.5-256.8 ft.: Gouge zone, clay filling. 261.9 ft.: 65 deg. joint, 4 mm wide, infilled with calcite and quartz. 263.7 ft.: 75 deg. joint, 3 mm wide, infilled with calcite and quartz. 265.0-268.0 ft.: Slumped bedding. 265.7 ft.: 85 deg. joint crosscutting bedding, up to 20 mm offset of beds along joint. 270.0-272.0 ft.: 85 deg. calcite vein, 3 mm wide. 271.4-272.2 ft.: Conglomeratic sandstone. 272.3-272.8 ft.: Soft rock, friable. 274.0 ft.: 75 deg. cleavage. 276.4-267.6 ft.: Soft rock, friable. 276.8-277.0 ft.: Gouge zone, clay filling. 278.0 ft.: 65 deg. cleavage. 280.0-281.0 ft.: Soft rock, friable.
288.0 ft.: BOTTOM OF BORING	



Point Load $I_{s\,50}$: <200, <200, <200, 324, <200, <200, <200, <200, <200, <200

Pressure Test K = cm/sec (x 0.00001): 0.2 @ 102 psi; 0=<0.1 @ 95 psi

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, Down Hole Hammer/Recovery in inches.

FIELD TEST BORING RECORD COVER SHEET

		BORING NO. 89-116
SITE Inter Island Tunnel - Deer Island	J.O. NO. U11305	SHEET 1 OF 1

COORIDNATES N-S 490630.9 E-W 746709.3

GROUND ELEVATION 116.3

INCLINATION Vertical INSPECTOR Gillen

DATE: START/FINISH 9/27/89 / 10/18/89

CONTRACTOR/DRILLER Guild/Texeira

DRILL RIG TYPE Acker AD II (Soil), Longyear HC150 (Rock)

WATER DEPTH ϕ (Land Based Boring)

ELEVATION TOP OF BEDROCK -39.7 (FT)

TOTAL DEPTH DRILLED 342.5 (FT)

METHODS:
- DRILLING SOIL Tri-cone rollerbit
- SAMPLING SOIL Split-spoon sampler
- DRILLING ROCK Roller bit, continuous HQ wireline coring
- SPECIAL TESTING OR INSTRUMENTATION Oriented coring

SUMMARY

SOIL DRILLED 156.6 (FT) ROCK CORED 186.5 (FT)
NUMBER SPLIT BARREL SAMPLES 15

NOTES

1. The coordinate system used is the 1927 MASS GRID.
2. Datum is M.D.C.
3. In water borings, the split spoon sampler was driven into the soil by dropping a 175-pound sliding down hole hammer a distance of 4 feet within the borehole.
4. In land based borings the soil sampling method used was the STD Penetration Resistance using a 140 lb. hammer dropping a distance of 30 inches.

APPROVED	DATE
M Gilbert	1/2/90

GOLDBERG-ZOINO & ASSOCIATES, INC.

GZA

BORING SUMMARY LOG

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 490630.90ft. E: 746709.30ft.**

Sea Floor Elevation: **116.3 ft.**
Total Depth Drilled: **342.5 ft.**

DESCRIPTION: MAIN	DESCRIPTION: DETAIL	Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
		0	116.3				
			115				
			110				
SANDY GRAVEL, 5% sand, compact (GP).		10	105			8-7-9-9 R2	
			100				
SANDY GRAVEL, 5% sand, compact (GP).		20	95			5-5 19-27 R3	
			90				
SILTY SAND, mostly coarse sand with spotted layers of organic silt, dense, gray (SM).		30	85			8-9-9-7 R18	
CLAY, medium stiff, greenish-gray CLAY (CL).			80				
SILTY CLAY, slightly to moderately plastic, firm to stiff, greenish gray (CL).		40	75			5-6-8-17 R24	
			70				
SILTY CLAY, slightly to moderately plastic, very soft to soft, greenish gray (CL).		50	65			WOR 11-14 R16	
			60				
TILL, GRAVELLY CLAYEY SILT, 30% gravel, 20% fine sand, very dense, gray (GM).		60	55			70-23 28-35 R16	
			50				
TILL, GRAVELLY CLAYEY SILT, 30% gravel, 20% fine sand, dense, gray (GM).		70	45			17-16 22-41 R16	

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected at 55 mm standard, diametric except * indicates axial. ** = SOIL, SPT/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

GZA

BORING SUMMARY LOG

BORING 89-116
SHEET **2 OF 6**

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 490630.90ft. E: 746709.30ft.**

Sea Floor Elevation: **116.3 ft.**
Total Depth Drilled: **342.5 ft.**

DESCRIPTION MAIN	DESCRIPTION DETAIL	Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\ 50}$	Pressure Test K = cm/sec (x 0.00001)
			40				
TILL, GRAVELLY CLAYEY SILT, 30% gravel, very dense, gray (GM).		80	35			29-40 45-60 R18	
			30				
TILL, GRAVELLY CLAYEY SILT, 30% gravel, very dense, greenish-gray and no sand.		90	25			32-33 49-78 R18	
			20				
SAND, mostly coarse sand, very dense, grayish brown (SW).		100	15			18-23 30-31 R18	
			10				
SAND, mostly coarse sand, very dense, grayish brown (SW).		110	5			29-37 44-46 R12	
			0				
SILTY SAND, mostly fine sand; silt occurs as lenses, very dense; brown, orange and rust (SM).		120	-5			30-30 33-39 R20	
			-10				
SILTY SAND, mostly fine sand; silt occurs as lenses, very dense; brown, orange and rust (SM).		130	-15			40-40 39-83 R18	
			-20				
SILTY SAND, mostly fine sand; silt occurs as lenses, very dense; brown, orange and rust (SM).		140	-25			26-24 33-47 R24	
			-30				
SAND, mostly medium sand, very						41-44 49-70	

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected at 55 mm standard, diametric except * indicates axial. ** = SOIL, SPT/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

GZA

BORING SUMMARY LOG

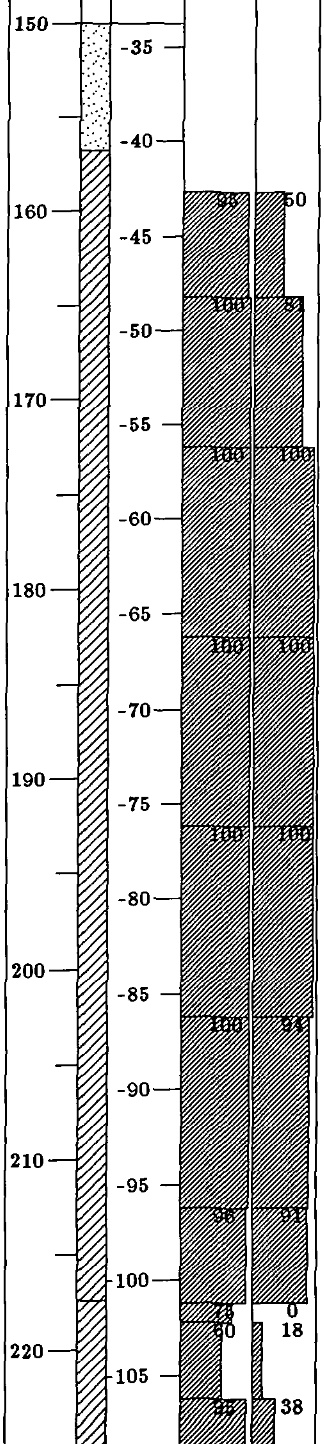
BORING 89-116
SHEET 3 OF 6

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 490630.90ft. E: 746709.30ft.**

Sea Floor Elevation: **116.3 ft.**
Total Depth Drilled: **342.5 ft.**

DESCRIPTION — MAIN	DESCRIPTION — DETAIL
dense, brown (SW). 151.0-182.5 ft.: Sand washing into hole during drilling, therefore, grouted hole to hold back sand and drilled through grout.	
ARGILLITE, dark gray, hard, slightly weathered; bedding thin to laminar, 20 to 50 deg., occasional slumped bedding with steeper dips, up to 90 deg.; joints mod. close to closely spaced, 20 to 60 deg., occasionally steeper to 90 deg.; many core breaks are along bedding plane separations and have clean surfaces. Most joints are filled with calcite. 158.0 ft.: Metal from roller bit in hole; chewed up coring bit. 164.5-172.5 ft.: Many bedding plane separations, are slickensided dip at 20 to 40 deg. 172.5-182.5 ft.: Abundant slumped bedding dips 60 to 90 deg. 202.5-212.5 ft.: Most core breaks due to drilling. 216.9-217.1 FT.: No recovery.	TOP OF BEDROCK 156.6 FT. Roller bit to 158.0 ft. 159.6-160.4 ft.: 40 deg. calcite vein. 160.0 ft.: 20 deg. calcite filled joint, crosscutting bedding. 160.5 ft.: 50 deg. iron stained bedding plane separation. 161.5-164.5 ft.; 70 deg. cleavage. 165.1 ft.: 85 deg. calcite filled joint. 169.3-170.4 ft.: microfaulting adjacent to 1 to 2 mm wide joints 171.3 ft.: 90 deg. calcite filled joint. 171.5 ft.: 30 deg. calcite vein, 5 mm wide. 172.5-174.5 ft.: 80 deg. calcite filled and slickensided joint. 174.7 ft.: 45 deg. iron stained joint. 176.2 ft.: Conjugate 40 deg. calcite and pyrite filled joints. 177.9 ft.: 80 deg. calcite filled joint. 184.0 ft.: 25 deg. calcite filled joint. 185.2 ft.: 50 deg. calcite filled joint. 186.0 ft.: 70 deg. calcite filled joint with microfaulting and slickensided subsidiary joints. 189.4 ft.: 50 deg. calcite filled joint. 191.4 ft.: 90 deg. cleavage. 191.6 ft.: 60 deg. calcite filled joint. 193.4 ft.: 80 deg. cleavage. 193.5 ft.: 90 deg. slumped bedding. 194.0-196.5 ft.: 40-45 deg. calcite filled joints crosscutting bedding. 199.5 ft.: 55 deg. calcite filled joint. 200.3 ft.: 50 deg. calcite filled joint. 203.1 ft.: 70 deg. calcite filled joint. 205.1 ft.: 30 deg. calcite filled joint. 206.4 ft.: 60 deg. calcite filled joint. 207.0 ft.: Slumped bedding. 207.4 ft.: 60 deg. joint
217.1-218.3 ft.: FELSITE, green, massive, mod. weathered, pyrite mineralization. 218.3-222.5 ft.: Poor recovery, missing 2.5 ft. of core. 222.5-232.5 ft.: Broken core with clay	

Depth (ft.) | Elev. (ft.) | REC | RQD



Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
R24	
1623	
700	
505	
1421	
1273	
1920	
1336	
1336	
1305	
1400	
713	
1527	

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected at 55 mm standard, diametric except * indicates axial. ** = SOIL, SPT/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

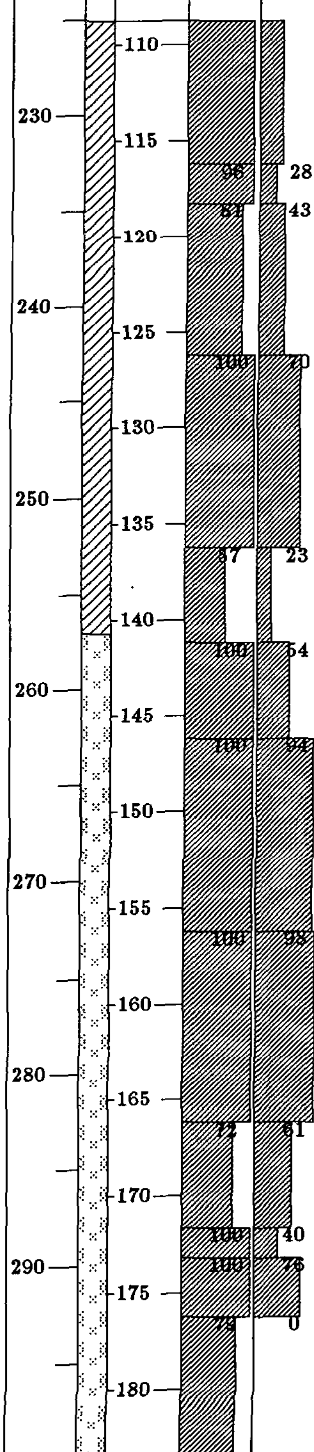
BORING SUMMARY LOG

BORING 89-116
SHEET **4 OF 6**

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR** Sea Floor Elevation: **116.3 ft.**
CLIENT: **Massachusetts Water Resources Authority** Total Depth Drilled: **342.5 ft.**
Coordinates: **N: 490630.90ft. E: 746709.30ft.**

DESCRIPTION — MAIN	DESCRIPTION — DETAIL
and pyrite (fault zone). **ARGILLITE**, dark gray, hard, slightly to mod. weathered; bedding thin to laminar, 25 to 60 deg., occasionally massive; joints close to very closely spaced, 35 to 90 deg.; most joints are filled with calcite and most bedding plane separations have rough surfaces. 234.0-236.5 ft.: FELSITE, light greenish gray, massive, broken core. 242.5-252.5 ft.: Argillite interbedded with Sandy Argillite beds (1 to 2 cm thick). 253.7-255.0 ft.: Light greenish gray, diabase with chlorite alteration.. 255.0 ft.: 1.5 feet of core not recovered. **DIABASE**, dark green to black, hard, slightly weathered; massive; joints closely spaced, 30 to 50 deg. and 60 to 80 deg. 271.0-304.7 ft.: Most joints are infilled with calcite and chloritoid and are slickensided. 283.3-287.3 ft.: Oriented core. 293.3-295.3 ft.: Oriented core.	with clean surfaces. 207.7 ft.: 40 deg. slickensided joint with adjacent calcite veins, various orientations. 207.9 ft.: 50 deg. clay coated joint. 209.9 ft.: 30 deg. calcite vein parallel to bedding. 210.4 ft.: 30 deg. calcite vein parallel to bedding. 212.5 ft.: 35 deg. clay coated bedding plane separation. 213.5 ft.: Pyrite mineralization. 213.6 ft.: 25 deg. clay coated bedding plane separation. 214.0 ft.: 90 deg. slumped bedding. 217.9 ft.: 40 deg. clay and pyrite coated joint. 219.4 ft.: 70 deg. calcite filled joint. 220.1 ft.: 50 deg. calcite filled joint. 223.3 ft.: 40 deg. slickensided bedding plane separation. 224.5 ft.: 70 deg. slumped bedding. 225.1 ft.: 35 deg. calcite filled joint. 226.2 ft.: 90 deg. calcite filled joint. 226.8 ft.: 65 deg. calcite filled joint. 227.3 ft.: 60 deg. calcite filled joint. 228.3 ft.: Fracture zone adjacent to 80 deg. iron stained and clay filled joint. 229.3 ft.: 65 deg. calcite filled joint. 230.1 ft.: 60 deg. calcite filled joint. 231.4 ft.: 50 deg. calcite filled joint. 232.3 ft.: 55 deg. calcite filled joint. 232.5-234.8 ft.: 70 to 85 deg. clay and pyrite coated joints. 235.8 ft.: 70 deg. calcite filled joint. 238.8 ft.: 75 deg. calcite filled joint. 239.4 ft.: 40 deg. calcite filled joint. 240.1 ft.: 65 deg. calcite filled joint. 241.3 ft.: 60 deg. calcite filled joint. 243.5 ft.: 45 deg. calcite filled joint. 244.2 ft.: Felsite clast. 244.3 ft.: 45 deg. slickensided bedding plane separation. 245.1 ft.: 60 deg. calcite filled joint.

Depth (ft.) | Elev. (ft.) | REC | RQD



Point Load I_s 50	Pressure Test K = cm/sec (x 0.00001)
874	
827	
477	
636	
<200	
552	
1538	

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected at 55 mm standard, diametric except * indicates axial. ** = SOIL, SPT/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

GZA

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 490630.90ft. E: 746709.30ft.**

Sea Floor Elevation: **116.3 ft.**
Total Depth Drilled: **342.5 ft.**

DESCRIPTION — MAIN	DESCRIPTION — DETAIL
304.7-312.5 ft.: Core breaks are along bedding plane separations and 15 deg. joints. **ARGILLITE**, dark gray to black with occasional light gray (Sandy Argillite) beds, hard, slightly weathered; bedding thin to very thin, 35 to 60 deg., occasional slumped bedding with steeper dips up to 90 deg.; joints moderately to very closely spaced, dip angles, generally 15 to 35 deg. and 65 to 90 deg.; most joints filled with calcite. 342.5 ft.: END OF BORING	246.6 ft.: 70 deg. calcite filled joint. 247.3 ft.: 50 deg. calcite filled joint. 248.1 ft.: 40 deg. calcite band, parallel to bedding. 250.0 ft.: Calcite and pyrite bed parallel to 40 deg. bedding, 12 mm thick. 250.3 ft.: 65 deg. clay and pyrite coated joint. 250.6 ft.: 50 deg. quartz and calcite vein, 12 mm wide. 251.2 ft.: 85 deg. calcite filled joint. 252.4 ft.: 85 deg. calcite filled joint. 253.1 ft.: 60 deg. calcite filled joint with smooth surfaces. 263.1 ft.: 65 deg. calcite filled joint. 264.2 ft.: 65 deg. calcite filled joint. 267.5 ft.: 60 deg. clay coated joint. 273.0 ft.: 70 deg. joint. 274.5 ft.: 30 deg. mylonitic joint. 276.1 ft.: 45 deg. joint. 277.5 ft.: 60 deg. joint. 279.8 ft.: 45 deg. joint. 281.0 ft.: 45 deg. joint. 283.0 ft.: 40 deg. joint. 283.6 ft.: 40 deg. joint. 284.1 ft.: 90 deg. joint. 285.3 ft.: 40 deg. mylonitic joint. 286.0 ft.: 30 deg. joint. 287.1 ft.: 60 deg. joint. 288.0 ft.: 90 deg. joint. 289.0 ft.: 30 deg. joint. 289.1 ft.: 60 deg. joint. 290.1 ft.: 20 deg. joint. 290.3 ft.: 50 deg. joint. 291.5 ft.: 20 deg. joint. 291.8 ft.: 30 deg. joint. 292.5-295.8 ft.: 30 deg. joints with smooth surfaces. 295.8-296.5 ft.: 30 to 45 deg. joints. 299.0 ft.: 75 deg. joint. 300.3 ft.: 30 deg. mylonitic joint. 301.0-302.5 ft.: Very close crossing 45 deg. joints. 302.8 ft.: 65 deg. calcite filled joint. 303.4 ft.: 60 deg. calcite filled joint. 304.7 ft.: 65 deg. calcite and pyrite filled joint, 10 mm wide; occurs at contact of diabase and argillite. 306.1 ft.: 60 deg. calcite and quartz filled joint. 308.1 ft.: 70 deg. calcite and quartz filled

Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
300	-185	100	81		
310	-190, -195	100	100		
320	-200, -205	100	100	1385	
330	-210, -215	100	83	1623	
340	-220, -225			2355	

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected at 55 mm standard, diametric except * indicates axial. ** = SOIL, SPT/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC. **BORING SUMMARY LOG** **BORING 89-116**

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR** Sea Floor Elevation: **116.3 ft.**
CLIENT: **Massachusetts Water Resources Authority** Total Depth Drilled: **342.5 ft.**
Coordinates: **N: 490630.90ft. E: 746709.30ft.**

DESCRIPTION		Depth (ft.)		Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
MAIN	DETAIL							
	joint. 309.6 ft.: 65 deg. calcite and quartz filled joint cuts across 80 deg. joint at 310.2 ft. 310.1-312.5 ft.: 90 deg. bedding. 310.2 ft.: 85 deg. calcite and quartz filled joint, 2-4 mm wide. 311.4 ft.: 15 deg. calcite and quartz filled joint. 312.1 ft.: 15 deg. calcite and quartz filled joint. 312.7 ft.: 35 deg. calcite filled joint, 12 mm wide. 313.0 ft.: 35 deg. quartz and calcite filled joint, 5 mm wide. 313.3 ft.: 55 deg. slumped bedding. 313.8 ft.: 35 deg. quartz filled joint, 35 mm wide. 317.5 ft.: 80 deg. calcite filled joint. 318.6 ft.: 50 deg. calcite and quartz filled joint, 10 mm wide. 319.4 ft.: 60 deg. calcite filled joint. 320.1 ft.: 70 deg. quartz filled joint. 322.5 ft.: 70 deg. calcite filled joint. 322.9-323.1 ft.: Calcite bed. 323.1 ft.: 80 deg. calcite filled joint. 323.9 ft.: 90 deg. calcite filled joint. 325.1 ft.: 40 deg. calcite filled joint. 326.2 ft.: 30 deg. calcite filled joint. 327.1 ft.: 30 deg. calcite and quartz filled joint. 328.5 ft.: 50 deg. calcite filled joint. 329.4 ft.: 30 deg. calcite and quartz filled joint. 331.0 ft.: 35 deg. calcite filled joint. 332.1 ft.: 30 deg. calcite filled joint. 332.5 ft.: 60 deg. calcite filled joint. 333.4 ft.: 70 deg. calcite filled joint, 3 mm wide. 333.7-334.3 ft.: 50 deg. fracture w/calcite and clay infilling. 338.8-342.0 ft.: 40-85 deg. calcite filled joints, 4-10 mm wide.							

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected at 55 mm standard, diametric except * indicates axial. ** = SOIL, SPT/Recovery in inches.

FIELD TEST BORING RECORD COVER SHEET

SITE	J.O. NO.	BORING NO. 89-117 / SHEET
Inter Island Tunnel - Deer Island	U11305	1 OF 1

COORIDNATES N-S 491149.6 E-W 746593.5

GROUND ELEVATION 116.3

INCLINATION Vertical INSPECTOR Gillen, Richters

DATE: START/FINISH 10/18/89 / 11/09/89

CONTRACTOR/DRILLER Guild/Texeira, Eastwood

DRILL RIG TYPE Acker AD II (Soil), Longyear HC150 (Rock)

WATER DEPTH ϕ (Land Based Boring)

ELEVATION TOP OF BEDROCK -28.7 (FT)

TOTAL DEPTH DRILLED 326.3 (FT)

METHODS:
- DRILLING SOIL Tri-cone rollerbit
- SAMPLING SOIL Split-spoon sampler
- DRILLING ROCK Roller bit, continuous HQ wireline coring
- SPECIAL TESTING OR INSTRUMENTATION Oriented coring, Packer testing.

SUMMARY

SOIL DRILLED 145.0 (FT) ROCK CORED 181.3 (FT)
NUMBER SPLIT BARREL SAMPLES 15

NOTES

1. The coordinate system used is the 1927 MASS GRID.
2. Datum is M.D.C.
3. In water borings, the split spoon sampler was driven into the soil by dropping a 175-pound sliding down hole hammer a distance of 4 feet within the borehole.
4. In land based borings the soil sampling method used was the STD Penetration Resistance using a 140 lb. hammer dropping a distance of 30 inches.

APPROVED	DATE
M Gilbert	1/2/90

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

BORING 89-117

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 491149.60ft. E: 746593.50ft.**

Sea Floor Elevation: **116.3 ft.**
Total Depth Drilled: **326.3 ft.**

DESCRIPTION – MAIN	DESCRIPTION – DETAIL	Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load I_s 50	Pressure Test K = cm/sec (x 0.00001)
		0	116.3				
			115				
			110				
GRAVEL, 3% sand, dense (GP).		10	105			15-14 16-28 R10	
			100				
TILL, SANDY SILT, 30% sand, 5% clay, moderately plastic fines, very stiff, gray (ML).		20	95			13-20 21-37 R8	
			90				
TILL, SANDY SILT, 30% sand, 5% clay, 3% gravel, moderately plastic fines, very stiff, gray (ML).		30	85			10-17 38-21 R18	
			80				
TILL, SANDY SILT, 35% sand, 5% clay, moderately plastic fines, very stiff, gray (ML)		40	75			13-15 21-20 R18	
			70				
TILL, SANDY SILT, 30% sand, 5% clay, moderately plastic fines, very stiff, gray (ML).		50	65			19-22 30-31 R15	
			60				
TILL, SANDY SILT, 30% sand, 5% clay, moderately plastic fines, very stiff, gray (ML).		60	55			23-34 38-37 R12	
			50				
TILL, SANDY SILT, 30% sand, 5% clay, moderately plastic fines, very stiff, gray (ML). 70.0-71.0 ft.: Used 140 lb. hammer. 71.0-72.0 ft.: Used 300 lb. hammer.		70	45			42-60 36-32 R18	

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, SPT/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

GZA

BORING SUMMARY LOG

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 491149.60ft. E: 746593.50ft.**

Sea Floor Elevation: **116.3 ft.**
Total Depth Drilled: **326.3 ft.**

DESCRIPTION: MAIN	DESCRIPTION: DETAIL	Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
			40				
TILL, CLAYEY SILT, slightly plastic, 15% gravel, hard, gray (ML).		80	35			26-39 48-88 R18	
			30				
TILL, CLAYEY SILT, slightly plastic, 30% gravel, hard, gray (ML).		90	25			31-42 69-71 R24	
			20				
100.0-101.5 ft.: No recovery.		100	15			60-67-79 R0	
			10				
TILL, CLAYEY SILT, slightly plastic, 15% gravel and cobbles, hard, gray (ML).		110	5			46-65-83 R1	
			0				
TILL, CLAYEY SILT, slightly plastic, 15% gravel, hard, gray (ML).		120	-5			100/6 R3	
			-10				
SANDY GRAVEL, 55% mostly fine sand, very dense, orange (GP).		130	-15			71-87 R8	
			-20				
BOULDERS	140.0 ft.: Refusal, no recovery.	140	-25			100/0 R0	
SAND, GRAVEL AND COBBLES, mostly coarse sand, 5% fines, very dense, brown (SP). 144.0-144.5 ft.: Used 140 lb. hammer. 144.5-145.0 ft.: Used 300 lb. hammer.	TOP OF BEDROCK 145.0 FT.		-30			80-100 R4	
	Roller bit to 148.0 ft. 148.0 ft.: 90 deg.			100	100	1114	

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, SPT/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

BORING 89-117
SHEET 3 OF 6

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 491149.60ft. E: 746593.50ft.**

Sea Floor Elevation: **116.3 ft.**
Total Depth Drilled: **326.3 ft.**

DESCRIPTION

MAIN

ARGILLITE, dark gray, hard, slightly weathered; bedding thin to laminar, 30 to 45 deg., occasionally up to 60 deg. dip; joints mod. close to closely spaced, 45 to 90 deg.; numerous bedding plane separations that apparently re-opened during drilling; many bedding plane separations show cleavage and have smooth surfaces.
153.0-167.0 ft.: Most breaks are a result of drilling.
160.5-161.8 ft.: Felsite, light greenish-gray, hard, slightly weathered.

177.3-181.9 ft.: 30 to 45 deg. bedding plane separations spaced 50 to 65 mm apart, appear to have been recemented prior to drilling.

184.0-192.0 ft.: Numerous 30 to 40 deg. bedding plane separations, spaced 50 to 75 mm apart.
184.3-186.3 ft.: Numerous 90 deg. calcite veins, 1 to 4 mm wide.

191.0 ft.: Broken core jammed core barrel.
192.0-202.0 ft.: Numerous 30 deg. bedding plane separations with smooth and iron stained surfaces, spaced 25 to 100 mm apart.

200.0 ft.: Broken core jammed core barrel.

212.0-222.0 ft.: Numerous bedding plane separations generally along previously healed smooth surfaces.

DETAIL

cleavage.
148.0-149.5 ft.: 30 deg. calcite filled and smooth surfaced bedding plane separations.
149.5-151.2 ft.: 60 deg. calcite filled joints.
151.2-153.0 ft.: 45 to 60 deg. calcite and quartz filled joints.
152.0-153.0 ft.: Calcite veins, various orientations.
153.0-154.5 ft.: 45 and 80 deg. calcite and quartz filled joints
154.5-156.0 ft.: Horizontal to 10 deg. bedding.
156.0-158.0 ft.: 70 deg. calcite and quartz filled joints.
158.0-160.2 ft.: Slumped bedding.
161.3 ft.: 45 deg. slickensided and calcite filled joint.
161.4 ft.: 30 deg. iron stained bedding plane separation.
162.0-163.0 ft.: 90 deg. calcite filled fracture with 5 mm displacement
163.3-164.0 ft.: 90 deg. calcite and quartz filled joint, up to 12 mm wide.
164.5-165.0 ft.: 70 deg. iron stained joint.
168.0 ft.: 60 deg. iron stained joint.
170.1 ft.: Fracture zone, healed.
173.5-175.8 ft.: 90 deg. fractures and joints, up to 4 mm wide with some smooth surfaces.
177.3 ft.: 40 deg. slickensided bedding plane separation.
185.5 ft.: 40 deg. clay coated bedding plane separation.
189.0-190.1 ft.: Closely spaced 70 deg. smooth, iron stained joints.
190.4 ft.: Gouge zone with clay filling.
192.5-193.0 ft.: High angle calcite veins.
196.4-198.0 ft.: 90 deg. calcite and quartz filled joint with 2 mm displacement of bedding planes adjacent to joint.
199.7-202.2 ft.: 80 to 90 deg. slickensided joint.
207.5-209.0 ft.: 90 deg. calcite and quartz filled joint.
212.0-212.7 ft.: 90 deg. calcite quartz filled joint, 1 to 3 mm wide, some fractures adjacent to joint.

Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
150					
	-35				
		100	91		
	-40				
160				668	
	-45				
		98	86		
				636	
	-50				
170					
	-55				
		99	98	1273	
	-60				
180					
	-65				
		100	85		
					0=<0.1 @ 72 psi
	-70				
190					
	-75				
		100	88		
	-80			923	0=<0.1 @ 78 psi
200					
	-85			1241	
		100	96	1241	
	-90				0=<0.1 @ 82 psi
210					
	-95				
		100	85	1336	
	-100				0=<0.1 @ 88 psi
220					
	-105				
		100	88		

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, SPT/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

BORING 89-117

SHEET 4 OF 6

PROJECT: INTER-ISLAND TUNNEL, BOSTON HARBOR
CLIENT: Massachusetts Water Resources Authority
Coordinates: N: 491149.60ft. E: 746593.50ft.

Sea Floor Elevation: **116.3 ft.**
Total Depth Drilled: **326.3 ft.**

DESCRIPTION

MAIN

ARGILLITE, dark gray, hard, slightly weathered; bedding very thin to laminar, generally 30 to 40 deg., occasionally bedding is massive with 45 to 90 deg. dip; joints mod. close to closely spaced, 40 to 90 deg.,rarely 10 to 30 deg. Numerous bedding plane separations are along smooth, previously healed surfaces that appear to have re-opened during drilling.

262.0 ft.: Oriented core run aborted, core too broken.
263.3-267.2 ft.: Massive fabric.
265.6-266.8 ft.: Preserved core.

271.2-272.0 ft.: Preserved core.

282.0-292.0 ft.: Very thin bedding generally 30 to 45 deg. dip except 10 deg. dip at 284.0-285.0 ft. and 289.0-289.5 ft.

DIABASE, green, hard, slightly weathered, massive with many calcite veins.

DETAIL

213.4 ft.: 30 deg. calcite filled bedding plane separation, 5 mm wide.
214.1 ft.: 45 deg. quartz and calcite filled joint, crosscutting bedding.
215.8 ft.: 30 deg. calcite filled bedding plane separation, 7 mm wide.
216.6-216.8 ft.: 90 deg. clean fractures.
217.0 ft.: 60 deg. iron stained joint, crosscutting bedding.
217.7-218.5 ft.: 45 deg. calcite filled joints, crosscutting bedding, 1 to 3 mm wide.
220.3-221.7 ft.: 90 deg. clean fractures.
222.2 ft.: 30 deg. clean joint, crosscutting bedding.
223.1 ft.: 80 deg. cleavage.
227.4-229.7 ft.: Closely spaced 30 deg. calcite filled bedding plane separations.
230.0 ft.: 50 deg. calcite filled joint, crosscutting bedding.
231.5 ft.: 20 and 70 deg. crosscutting joint sets, calcite filled
231.5 ft.: 60 deg. calcite filled fracture, up to 15 mm of displacement.
231.8 ft.: 60 deg. calcite and quartz filled joint.
232.4-234.5 ft.: Many closely spaced low angle calcite veins, crosscutting bedding.
233.2 ft.: 60 deg. calcite filled joint, crosscutting bedding.
234.2 ft.: 10 deg. calcite and quartz filled joint with slickensides.
235.2-235.7 ft.: 90 deg. calcite and quartz filled joint.
235.7 ft.: 30 deg. calcite filled bedding plane separation, 3 mm thick.
239.0-239.4 ft.: 60 deg. calcite filled fracture with rough surfaces.
241.0 ft.: 70 deg. fracture with trace of clay filling.
241.4-241.8 ft.: Very closely spaced calcite filled joints and veins.
242.0-242.7 ft.: 90 deg. fracture with rough surfaces; also, 60 deg. very closely spaced calcite and quartz filled

Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
	-110				0=<0.1 @ 94 psi
230	-115	100	84	1082 509	
	-120				0=<0.1 @ 100psi
240	-125	91	68		
	-130			1718	0=<0.1 @ 104psi
250	-135	100	87	891	
	-140				0=<0.1 @ 112psi
260	-145	100	63	1623	
	-150	100	84		0=<0.1 @ 114psi
270	-155	100	80	477	0=<0.1 @ 118psi
	-160				
280	-165	100	75		
	-170			668	
290	-175	98	97		
	-180			1018	

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, SPT/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

BORING 89-117
SHEET 5 OF 6

PROJECT: INTER-ISLAND TUNNEL, BOSTON HARBOR
CLIENT: Massachusetts Water Resources Authority
Coordinates: N: 491149.60ft. E: 746593.50ft.

Sea Floor Elevation: 116.3 ft.
Total Depth Drilled: 326.3 ft.

DESCRIPTION

MAIN

302.3-312.3 ft.: Oriented core. **ARGILLITE**, interbedded, dark gray Argillite and light gray Sandy Argillite, hard to med. hard, slightly weathered, bedding very thin, 30 to 75 deg.; joints close to very closely spaced, 30 to 80 deg.

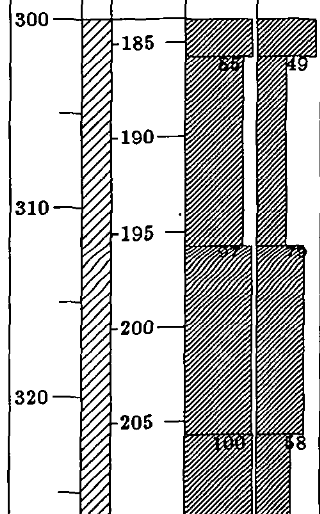
326.3 ft.: 20 ft. of rod and 10 ft. of core barrel fell into hole.

326.3 FT.: END OF BORING

DETAIL

joints.
242.8-244.4 ft.: Quartz veins, various orientations.
242.9 ft.: 60 deg. fractured joint with rough surfaces.
244.9-245.0 ft.: Fracture zone.
246.0 ft.: 30 deg. calcite and quartz vein, 12 mm wide.
246.6 ft.: 30 deg. calcite and quartz vein, 25 mm wide.
247.0-248.9 ft.: Slumped bedding.
249.7 ft.: 60 deg. fractured joint.
252.0-253.0 ft.: 90 deg. calcite filled fracture, 3 mm displacement; also, 90 deg. calcite veins.
252.3 ft.: 70 deg. calcite and quartz filled joint.
254.5 ft.: 60 deg. closely spaced calcite filled veins and joints; 90 deg. fracture with 4 mm displacement.
257.1 ft.: 30 deg. bedding plane separation infilled with 10 mm of recemented brecciated argillite.
258.9 ft.: 60 deg. fracture with 5 mm of displacement.
259.0-262.0 ft.; 60 deg. closely spaced joints w/smooth surfaces
262.0-263.3 ft.: Very thin bedding with 45 to 60 deg. dip.
262.3-263.2 ft.: 30 deg. closely spaced calcite veins, 1 to 3 mm wide and crosscutting 30 deg. calcite filled joint.
265.1-265.6 ft.: 70 deg. joint with smooth, clean surfaces.
268.1-268.6 ft.: 80 deg. calcite filled fracture, 9 mm wide.
268.9-270.6 ft.: 90 deg. calcite filled fracture with 14 mm displacement.
270.7 ft.: 60 deg. calcite filled joint.
272.9 ft.: 90 deg. clay filled joint with smooth surfaces.
273.7 ft.: 90 deg. clean fracture with 14 mm displacement.
276.9 ft.: 80 deg. calcite vein, 10 mm wide.
277.2-279.5 ft.: 45 to 60 deg. clean joints with smooth surfaces
278.0-279.5 ft.: 30 to 75

Depth (ft.) | Elev. (ft.) | REC | RQD



Point Load I_s 50

923

923

Pressure Test K = cm/sec (x 0.00001)

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, SPT/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

GZA

BORING SUMMARY LOG

PROJECT: INTER-ISLAND TUNNEL, BOSTON HARBOR
CLIENT: Massachusetts Water Resources Authority
Coordinates: N: 491149.60ft. E: 746593.50ft.

Sea Floor Elevation: 116.3 ft.
Total Depth Drilled: 326.3 ft.

DESCRIPTION MAIN	DESCRIPTION DETAIL	Depth (ft.)		Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
	deg. calcite veins. 280.3-280.8 ft.: Occasional calcite veins, various orientations. 280.4-282.0 ft.: Slumped bedding. 282.0-283.0 ft.: Slumped bedding. 282.5 ft.: 60 deg. calcite filled joint. 283.2-284.6 ft.: 45 deg. closely spaced joints, calcite infilling 284.8-286.4 ft.: 90 deg. iron stained fracture. 290.3-292.0 ftl: Numerous calcite veins, various orientations. 291.3 ft.: 45 deg. joint with rough surfaces. 292.0-296.5 ft.: 60 to 90 deg. slickensided calcite veins. 292.2 ft.: 90 deg. fracture with 22 mm displacement. 294.7-297.0 ft.: 40 deg. closely spaced joints with smooth, iron stained surfaces. 296.7-299.0 ft.: 60 to 90 deg. calcite veins. 299.0-299.9 ft.: 90 deg. fracture with 8 mm displacement. 301.5 ft.: 60 deg. calcite filled joint. 302.7-303.7 ft.: Some calcite veins, various orientations. 303.7-304.0 ft.: 30 deg. iron stained joints. 305.0-309.8 ft.: Massive fabric. 308.3-309.3 ft.: 90 deg. fracture with clean, smooth surfaces. 313.9-314.6 ft.: 75 deg. calcite vein. 314.2 ft.: 90 deg. fractures with 12 mm displacement. 316.2-317.6 ft.: 75 deg. calcite filled joint. 318.3-319.2 ft.: 60 deg. crossing calcite veins, 1 to 3 mm wide. 320.5-321.7 ft.: 80 deg. crossing calcite veins, 1 to 3 mm wide. 322.0 ft.: 90 deg. cleavage. 322.0-322.5 ft.: Slumped bedding. 324.7-325.9 ft.: 75 deg. calcite filled joint.							

NOTES: Packer Test, transducer monitored double packer, K=10-5 cm/sec at pressure indicated; Point Load Test corrected to 55 mm standard, diametric except * indicates axial. ** = SOIL, SPT/Recovery in inches.

GOLDBERG-ZOINO & ASSOCIATES, INC.

GZA

BORING SUMMARY LOG

BORING 90-118
SHEET 1 OF 2

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR** Sea Floor Elevation: **116.5 ft.**
CLIENT: **Massachusetts Water Resources Authority** Total Depth Drilled: **115.0 ft.**
Coordinates: N: **484488.85ft.** E: **746536.59ft.**

DESCRIPTION — MAIN	DETAIL	Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
		0	116.5				
FILL, fine to coarse sand, 30% gravel, 5% silt, brick fragments, medium dense			115			6-13 13-9 R2	
FILL, medium to coarse sand, 30% gravel, 5% silt, 5% brick fragments, medium dense, brown.			110			5-5 5-9 R13	
GRAVELLY SAND, medium to coarse sand, 40% gravel, 5% silt, medium dense, brown.		10	105			10-12 8-9 R11	
No Recovery			100			14-9 10-10 R0	
CLAYEY SAND, fine to medium sand, 30% gravel, 30% silty clay, medium dense, brownish gray.		20	95			16-13 12-16 R12	
SILTY CLAY, 10% fine to coarse sand, 5% gravel, very stiff, brownish gray No Recovery			90			16-16 18-27 R0	
SILTY CLAY, moderately plastic, stiff, olive-gray.						3-7 7-8 R24	
SILTY CLAY, moderately plastic, stiff, olive-gray.		30	85			6-4 8-10 R24	
SILTY CLAY, moderately plastic, hard, olive-gray			80			6-11 44-120 R18	
TILL, CLAYEY SILT, 20% fine to medium sand, 20% gravel, hard. **TILL**, CLAYEY SILT, 30% fine to medium sand, 20% gravel, hard, greenish brown.		40	75			47-32 40-49 R15	
TILL, CLAYEY SILT, 20% fine to coarse sand, 25% gravel, hard, greenish brown to olive-gray.			70			52-45 113-48 R16	
TILL, CLAYEY SILT, 20% fine to coarse sand, 20% gravel, hard, olive-gray.		50	65			24-26 46-73 R15	
TILL, CLAYEY SILT, 15% fine to medium sand, 15% gravel, hard, olive-gray.			60			22-29 49-64 R14	
TILL, CLAYEY SILT, 15% fine to medium sand, 30% gravel, hard, olive-gray.		60	55			22-59 35-82 R14	
TILL, CLAYEY SILT, 10% fine to medium sand, 35% gravel, hard, olive-gray.			50			36-60 54-60 R15	
TILL, CLAYEY SILT, 15% fine to medium sand, 20% gravel, hard, olive-gray.		70	45			24-35 59-55 R16	

NOTES: 1. *Dashed lines in description column indicate approximate vertical location of change in sample description when the change is gradual.* 2. *Asterisk (*) indicates not a standard (300# hammer used).*

GOLDBERG-ZOINO & ASSOCIATES, INC.

BORING SUMMARY LOG

BORING 90-118
SHEET **2 OF 2**

PROJECT: **INTER-ISLAND TUNNEL, BOSTON HARBOR** — Sea Floor Elevation: **116.5 ft.**
CLIENT: **Massachusetts Water Resources Authority** — Total Depth Drilled: **115.0 ft.**
Coordinates: **N: 484488.85ft. E: 746536.59ft.**

DESCRIPTION

MAIN

TILL, CLAYEY SILT, 15% fine to medium sand, 15% gravel, hard, olive-gray.

TILL, CLAYEY SILT, 35% gravel, 10% fine to medium sand, hard, olive gray.

TILL, CLAYEY SILT, 15% fine to medium sand, 20% gravel, hard, olive-gray.

TILL, CLAYEY SILT, 15% fine to coarse sand, 25% gravel, hard, olive-gray.

90.3 ft.: Top of Bedrock
ARGILLITE, dark gray, medium hard to hard, slightly weathered; bedding very thin to laminar, 20 to 60 deg. Joints very closely spaced, hairline to 5 mm in thickness, 10 to 90 deg. with random orientations of joint planes; few bedding plane separations and some veins, generally infilled with calcite, occassionally iron-stained and clay coated. Microfaulting of veins and joints are common.
96.0-106.0 ft.: Microfaulting common.
101.0-101.7 ft.: Joints are iron-stained and slightly clay coated. Calcite appears to have "dissolved" giving a vuggy appearance.
102.9-103.5 ft.: Alternating bands of light and dark gray ARGILLLITE.
109.5-110.6 ft.: Grayish green ARGILLITE.

115.0 ft.: END OF BORING

DETAIL

TOP OF BEDROCK 90.3 FT.

95.0-96.0 ft.: Calcite infilled joints and veins with random orientations, hairline to 5 mm in thickness.
97.2 ft.: Iron-stained joint with thin film of clay coating,dipping 85 deg.
98.0 ft.: Iron-stained, calcite infilled joint dipping 20 deg.
100.0-101.0 ft.: Steeply dipping iron-stained partially opened joints.
107.1-107.3 ft.: Fracture zone partially recemented with calcite, upper portion is iron-stained.
108.5-110.5 ft.: Open joint and bedding parting surfaces, spaced approximately 2 to 5 inches apart, are iron-stained and thinly coated with clay, dipping 30 to 60 deg.
109.5-109.7 ft.: Soft, severely weathered, highly fractured ARGILLITE with 20 mm wide zone of clayey material at 109.5 ft.
110.6 ft.: Soft, severely weathered, highly fractured ARGILLITE with 25 to 50 mm wide zone of clayey-brecciated material.
113.0 ft.: Iron-stained joint dipping 40 deg. with 2mm clay coating on joint surface.

Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load I_{s} 50	Pressure Test K = cm/sec (x 0.00001)
	40			30-36 56-49 R15	
80	35			57-86 66-98 R12	
	30			43-30 135-120 R20	
90	25			60 100/4" R10	
	20	83	83	40/0" R0	
		92	38		
100	15	100	93		
	10	100	57		
110	5	92	83		

NOTES: 1. Dashed lines in description column indicate approximate vertical location of change in sample description when the change is gradual. 2. Asterisk (*) indicates not a standard (300# hammer used).

Metcalf & Eddy, Inc.	BORING LOG	BORING PDE-2 J.O. 4128-0013-3 SHEET: 1 OF 5

Project: 1989 PDE BORINGS - DEER ISLAND (DP-5)
Client: MASSACHUSETTS WATER RESOURCE AUTHORITY
Logged by: PA
Date Start - Finish: 9/29/89 - 10/4/89
Coordinates: N: 491609.69 ft. E: 746689.25 ft. (NAD 27)
Ground Elevation: 123.1 ft.
Ground Water Elev.: 114.7 ft.
Depth to Bedrock: N/A ft.
Total Depth Drilled: 96.0 ft.
Drill Contractor: GUILD DRILLING
Driller: AW
Rig Type: CME-75

Methods:
Casing Used: HW casing used to 30.0 ft.
Drilling Soil: 3.75" Roller Bit
Sampling Soil: 2" Split Spoon (SPT) & one Shelby Tube
Drilling Rock: None

Comments: Vane Shear Test-performed @ 52.0 ft. Drilled under Health & Safety Plan/modified level D from surface to 40 ft. Grouted hole after completion. Fill placed on slope in order to position rig for drilling.

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY / RQD	SPT N VALUE	USC SYMBOL OR PEN. RATE	SAMPLE DESCRIPTION
123.1	0						
							FILL: Gray SAND & GRAVEL from surface to about 10 ft. (on site material brought in on 9/29/89 for construction of access road into PDE-2).
120							
	5						
115							
	10						BOTTOM of NEW FILL @ 10.0 ft.
							FILL: Sandy clay, peices of dry wall, fiberous & organic oily material, garbage, debris & landfill material (description of wash).
110							

LEGEND/NOTES:

Datum is MDC sewer Datum (USGS datum plus 105.62 ft)

Blows = number of blows required to drive sample spoon 6" or distance shown.

r = inches of soil sample recovery.

RECOVERY = % of rock core recovery.

RQD = Rock Quality Designation

SPT N = Standard Penetration Test resistance to driving, blows/ft.

USC = Unified Soil Classification system.

Coordinates are in the 1927 Massachusetts State Plane Grid System.

Pen. Rate = coring penetration rate in min./ft.

SAMPLE TYPE:
SS = Standard Split Spoon
S3 = 3" Split Spoon
UO = Osterberg
NX = Rock Core
NQ = Wireline Rock Core
OR = Oriented Core
US = Shelby
UF = Fixed Piston

Approved/Date
12/11/89

Metcalf & Eddy, Inc.	BORING LOG	BORING PDE-2 J.O. 4128-0013-3 SHEET: 2 OF 5

Project: 1989 PDE BORINGS - DEER ISLAND (DP-5) Logged by: PA
Client: MASSACHUSETTS WATER RESOURCE AUTHORITY

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY / RQD	SPT N VALUE	USC SYMBOL OF PEN. RATE	SAMPLE DESCRIPTION
	15						
							BOTTOM of FILL @ 17.0 ft.
							17.0 ft. - SAND: Gray fine to medium SAND w/a trace of coarse sand & trace shell fragments (description of wash).
105							
		SS	1	4-4 4 r4	8	SW	SAND & GRAVEL: Dark gray fine to coarse SAND & fine GRAVEL, trace silt & shell fragments.
	20						
100							TOP of PEAT @ 23.5 ft.
		SS	2	3-2 9 r13	11	PT/ CL	PEAT: First 0.3 ft. of sample - Brown to black organic PEAT.
							TOP of CLAY @ 24.4 ft. CLAY: Remainder of sample - Gray CLAY, little fine to coarse SAND (more sand @ base) w/traces of silt & fine to coarse gravel & wood fragments. POCKET PENETROMETER: 2.0 tsf POCKET TORVANE: 0.2 tsf
	25						
95							
		SS	3	26-19 22-23 r10	41	CL- ML	CLAY: Light brown-tan CLAY, some SILT & some fine GRAVEL w/traces of coarse sand & coarse gravel. POCKET PENETROMETER:>4.5 tsf POCKET TORVANE: 0.6 tsf
	30						
90							
		SS	4	8-6 7-11 r14	13	CL	CLAY: Gray CLAY, little SILT & fine to medium SAND w/traces of coarse sand & fine gravel. POCKET PENETROMETER: 2.0 tsf POCKET TORVANE: 0.25 tsf
	35						
85							
		SS	5	4-4 6-5 r20	10	CL	CLAY: Gray CLAY, some SILT, traces of fine sand & fine gravel (moderate plasticity).

NOTES: Vane Shear Test-performed @ 52.0 ft. Drilled under Health & Safety Plan/modified level D from surface to 40 ft. Grouted hole after completion. Fill placed on slope in order to position rig for drilling.

Metcalf & Eddy, Inc.	BORING LOG	BORING PDE-2 J.O. 4128-0013-3 SHEET: 3 OF 5

Project: 1989 PDE BORINGS - DEER ISLAND (DP-5) Logged by: PA
Client: MASSACHUSETTS WATER RESOURCE AUTHORITY

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY ------- RQD	SPT N VALUE	USC SYMBOL OF PEN. RATE	SAMPLE DESCRIPTION
	40						CLAY: Gray CLAY, some SILT w/traces of fine sand & fine gravel (moderate plasticity). POCKET PENETROMETER: 1.5 tsf POCKET TOTVANE: 0.15 tsf
80							
		SS	6	2-4 5-5 r24	9	CL	CLAY: Gray CLAY, little SILT & traces of coarse sand & fine to coarse gravel. (moderate plasticity). POCKET PENETROMETER: 1.25 tsf POCKET TORVANE: 0.2 tsf
	45						
		US	7	PUSHED r24		CL	CLAY: Gray CLAY, little SILT & trace fine to coarse sand. POCKET PENETROMETER: 1.5 tsf POCKET TORVANE: 0.1 tsf
75							
		SS	8	2-3 4-7 r23	7	CL	CLAY: Gray CLAY, little SILT & traces of fine to coarse sand and fine gravel (high plasticity). POCKET PENETROMETER: 1.0 tsf POCKET TORVANE: 0.15 tsf
	50						
							VANE SHEAR TEST @ 52.0 ft.
70							TOP of TILL @ 53.5 ft.
		SS	9	148-22 r10		CL	TILL: Gray CLAY, some SILT, little fine GRAVEL & traces of fine to coarse sand & coarse gravel (Coarse gravel @ bottom of spoon; stopped after penetrating 12 in. to prevent damaging spoon.). POCKET PENETROMETER: 3.2 tsf POCKET TORVANE: 0.25 tsf
	55						
65							
		SS	10	20-18 28-46 r7	46	CL	TILL: As above, except w/trace oxidation stains. POCKET PENETROMETER: 3.5 tsf POCKET TORVANE: 0.3 tsf
	60						
60							
		SS	11	14-14 20-34 r7	34	CL	TILL: Gray CLAY, some SILT, little fine to coarse SAND, little fine GRAVEL & trace coarse gravel.

NOTES: Vane Shear Test-performed @ 52.0 ft. Drilled under Health & Safety Plan/modified level D from surface to 40 ft. Grouted hole after completion. Fill placed on slope in order to position rig for drilling.

Metcalf & Eddy, Inc.	BORING LOG	BORING PDE-2 J.O. 4128-0013-3 SHEET: 4 OF 5

Project: 1989 PDE BORINGS - DEER ISLAND (DP-5) Logged by: PA
Client: MASSACHUSETTS WATER RESOURCE AUTHORITY

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY ------- RQD	SPT N VALUE	USC SYMBOL OF PEN. RATE	SAMPLE DESCRIPTION
	65						TILL: Gray CLAY, some SILT, little fine to coarse SAND, little fine GRAVEL & trace coarse gravel. POCKET PENETROMETER: 1.5 tsf POCKET TORVANE: 0.2 tsf
55							
	70	SS	12	15-14 18-23 r8	32	CL	TILL: As above. POCKET PENETROMETER: 4.0 tsf POCKET TORVANE: 0.35 tsf
50							
	75	SS	13	21-30 39-50 r11	69	CL	TILL: As above. POCKET PENETROMETER:>4.3 tsf POCKET TORVANE: 0.4 tsf
45							
	80	SS	14	24-25 28-44 r12	53	CL	TILL: As above. POCKET EPNETROMETER:>4.5 tsf POCKET TORVANE: 0.3 tsf
40							
	85	SS	15	20-20 31-38 r11	51	CL	TILL: As above, except w/a trace of shell fragments & fine to coarse sand. POCKET PENETROMETER:>4.5 tsf POCKET TORVANE: 0.4 tsf
35							
		SS	16	32-24 25-38 r12	49	CL	TILL: As above. POCKET PENETROMETER:>4.5 tsf

NOTES: Vane Shear Test-performed @ 52.0 ft. Drilled under Health & Safety Plan/modified level D from surface to 40 ft. Grouted hole after completion. Fill placed on slope in order to position rig for drilling.

Metcalf & Eddy, Inc.	BORING LOG	BORING PDE-2 J.O. 4128-0013-3 SHEET: 5 OF 5

Project: 1989 PDE BORINGS - DEER ISLAND (DP-5) Logged by: PA
Client: MASSACHUSETTS WATER RESOURCE AUTHORITY

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY / RQD	SPT N VALUE	USC SYMBOL or PEN. RATE	SAMPLE DESCRIPTION
	90						TILL: Gray CLAY, some SILT, little fine GRAVEL & traces of fine to coarse SAND, coarse gravel & shell fragments. POCKET PENETROMETER:>4.5 tsf
30							
	95	SS	17	39-43 46-50 r14	89	CL	TILL: As above. POCKET PENETROMETER:>4.5 tsf POCKET TORVANE: 0.4 tsf
							END of BORING @ 96.0 ft.

NOTES: Vane Shear Test-performed @ 52.0 ft. Drilled under Health & Safety Plan/modified level D from surface to 40 ft. Grouted hole after completion. Fill placed on slope in order to position rig for drilling.

Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-39 J.O. 004128-0013 SHEET: 1 OF 7

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT
Client: Massachusetts Water Resources Authority

Logged by: CF
Date Start - Finish: 2/2/89 - 2/13/89

Coordinates: N: 491653.74 ft. E: 746622.52 ft. (NAD 27)
Ground Elevation: 117.8 ft.
Ground Water Elev.: 105.8 ft.
Depth to Bedrock: 124.5 ft.
Total Depth Drilled: 157.8 ft.
Drill Contractor: GUILD DRILLING
Driller: JP
Rig Type: CME-75

Methods:
Casing Used: HW to 34.0 ft., then NW to 128 ft.
Drilling Soil: 3.75" Roller Bit
Sampling Soil: 2" Split Spoons (SPT), 3" Split Spoons & 3" Osterberg Tubes
Drilling Rock: NX Diamond Core Bit

Comments: Asterisk (*) indicates the particular blow count interval not to standard (300# hammer used). Packer Tests performed. Observation Well installed to a depth of 157.85 ft. (1.25 in. Sch. 40 PVC).

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY ------- RQD	SPT N VALUE	USC SYMBOL OR PEN. RATE	SAMPLE DESCRIPTION
117.8	0	SS	1	2-1 2-2 r5	3	FILL	**FILL**: Dry fiberous, organic, material & garbage.
115							
	5	SS	2	1/12" 1/12" r8	1	FILL	**FILL**: As above.
110							
	10	SS	3	11-14 8-6 r8	22	FILL	**FILL**: Fine to coarse **GRAVEL**, fine **SAND**, trace silt, light gray **CLAY** & oil.
105							
		SS	4	8-6 6-4 r11	12	SW/ SM	**SAND**: Fine **SAND & SILT**, fine to coarse **GRAVEL** w/trace clay (little to no cohesion).

LEGEND/NOTES:

Datum is MDC sewer Datum (USGS datum plus 105.62 ft)

Blows = number of blows required to drive sample spoon 6" or distance shown.

r = inches of soil sample recovery.

RECOVERY = % of rock core recovery.

RQD = Rock Quality Designation

SPT N = Standard Penetration Test resistance to driving, blows/ft.

USC = Unified Soil Classification system.

Coordinates are in the 1927 Massachusetts State Plane Grid System.

Pen. Rate = coring penetration rate in min./ft.

SAMPLE TYPE:

SS = Standard Split Spoon
S3 = 3" Split Spoon
UO = Osterberg
NX = Rock Core
NQ = Wireline Rock Core
OR = Oriented Core
US = Shelby
UF = Fixed Piston

Approved/Date
F. Risitano 7/18/89

Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-39 J.O. 004128-0013 SHEET: 2 OF 7

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT   Logged by: CF
Client: Massachusetts Water Resources Authority

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY / RQD	SPT N VALUE	USC SYMBOL OF PEN. RATE	SAMPLE DESCRIPTION
	15						**SAND**: Fine **SAND & SILT**, fine to coarse **GRAVEL** w/trace clay (little to no cohesion).
100							
	20	SS	5	3-5 6-14 r22	11	CL/PT	**CLAY w/GRAVEL**: Gray sandy CLAY, some fine to trace coarse GRAVEL. NOTE: A 4in. layer of **PEAT** with wood material & a 3in. layer of gray **CLAY**.
95							WASH TURNED BROWN @ 23 ft.
	25	SS	6	14-25 31-29 r12	56	CL	**CLAY w/GRAVEL**: Brown silty CLAY, 10-20% fine GRAVEL, trace of coarse gravel.
90							
	30	SS	7	6-7 8-10 r13	15	CL	**CLAY**: Gray CLAY w/a trace of fine sand & gravel.
85		UF	7A	PUSH r5		CL	
	35	SS	8	6-8 9-11 r14	17	CL	**CLAY**: Gray CLAY w/a trace of fine GRAVEL 0-5%. POCKET PENTETROMETER: 0.5 tsf POCKET TORVANE: 0.15 tsf
80							
		SS	9	3-5 7-7 r11	12	CL	**CLAY**: Gray CLAY w/a trace of gravel 0-5%.

NOTES: Asterisk (*) indicates the particular blow count interval not to standard (300# hammer used). Packer Tests performed. Observation Well installed to a depth of 157.85 ft. (1.25 in. Sch. 40 PVC).

Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-39 J.O. 004128-0013 SHEET: 3 OF 7

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT　　Logged by: CF
Client: Massachusetts Water Resources Authority

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY .... RQD	SPT N VALUE	USC SYMBOL OF PEN. RATE	SAMPLE DESCRIPTION
	40						CLAY: Gray CLAY w/a trace of gravel 0-5%.
75		UF	9A	PUSH r24		CL	
	45	SS	10	7-4 4-6 r24	8	CL	CLAY: Gray stiff plastic CLAY w/ a trace of fine gravel. POCKET PENETROMETER: 0.75 tsf POCKET TORVANE: 0.4 tsf
70							
		UO	10 A	PUSH r0			
	50	SS	11	2-3 4-6 r18	7	CL	CLAY: Gray stiff plastic CLAY. POCKET PENETROMETER: 0.5 tsf POCKET TORVANE: 0.4 tsf
65							
	55	UO	11 A	PUSH r23		CL	
60		SS	12	3-6 9-11 r18	15	CL	CLAY: Gray CLAY. POCKET PENETROMETER: 1.0 tsf POCKET TORVANE: 0.5 tsf
	60	SS	13	6-3 9-11 r18	12	CL	CLAY: Gray stiff plastic CLAY w/a trace of fine gravel. POCKET PENETROMETER: 0.75 tsf POCKET TORVANE: 0.5 tsf
55							
		SS	14	9-12 17-37 r11	29	CL	TILL: CLAY, 10-20% silty SANDw/10-20% fine GRAVEL.

NOTES: Asterisk (*) indicates the particular blow count interval not to standard (300# hammer used). Packer Tests performed. Observation Well installed to a depth of 157.85 ft. (1.25 in. Sch. 40 PVC).

Metcaf & Eddy, Inc.	BORING LOG	BORING LDE-39 J.O. 004128-0013 SHEET: 4 OF 7

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT   Logged by: CF
Client: Massachusetts Water Resources Authority

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY ------- RQD	SPT N VALUE	USC SYMBOL OF PEN. RATE	SAMPLE DESCRIPTION
	65						TILL: CLAY, 10-20% silty SANDw/10-20% fine GRAVEL.
50							
	70	SS	15	17-32 37-52 r4	69	CL	TILL: As above.
45							
	75	SS	16	*9-*24 *29 r13		CL	TILL: As above.
40							
	80	SS	17	8-13 19-35 r12	32	CL	TILL: As above.
35							COBBLE from 82.5 ft. to 83.5 ft.
	85	SS	18	12-18 28-36 r12	46	CL	TILL: As above.
30							
		SS	19	20-30 40-46 r9	70	CL	TILL: CLAY,10-20% silty SAND,10-20% fine GRAVEL.

NOTES: Asterisk (*) indicates the particular blow count interval not to standard (300# hammer used). Packer Tests performed. Observation Well installed to a depth of 157.85 ft. (1.25 in. Sch. 40 PVC).

Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-39 J.O. 004128-0013 SHEET: 5 OF 7

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT   Logged by: CF
Client: Massachusetts Water Resources Authority

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY ------- RQD	SPT N VALUE	USC SYMBOL OF PEN. RATE	SAMPLE DESCRIPTION
	90						TILL: CLAY,10-20% silty SAND,10-20% fine GRAVEL.
25							
	95	SS	20	*15-*30 *39 r10		CL	TILL: As above
20							
	100	SS	21	*15-*30 *67 r16		CL	TILL: As above.
15							
	105	SS	22	52-70 67-55 r19	137	SM	SAND: Fine to medium brown SAND, shell fragments. A 1-2in. piece of gravel in shoe of spoon (WET).
10							
	110	SS	23	100/2" *51/3"-*		SM	SAND: Fine to coarse GRAVEL in top 3in. Remainder fine to medium SAND, some SILT (wet). SS 23, recovery of soil sample r=16 in. Remaining blow count intervals: *35,*32-*30.
5							
		SS	24	44-56 52-60 r19	108	SM	SAND: Fine to medium brown,more coarse at top of spoon, bedded with SILT at bottom of spoon.

NOTES: Asterisk (*) indicates the particular blow count interval not to standard (300# hammer used). Packer Tests performed. Observation Well installed to a depth of 157.85 ft. (1.25 in. Sch. 40 PVC).

Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-39 J.O. 004128-0013 SHEET: 6 OF 7

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT   Logged by: CF
Client: Massachusetts Water Resources Authority

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY ------- RQD	SPT N VALUE	USC SYMBOL OF PEN. RATE	SAMPLE DESCRIPTION
	115						SAND: Fine to medium brown,more coarse at top of spoon, bedded with SILT at bottom of spoon.
0							
	120	SS	25	100/5"-* r16		SM	SAND: Medium to coarse brown, fine & coarse GRAVEL 10-20%. Two-2 in. pieces of gravel. SS 25,remaining blow count intervals: *18/1",*60,*70-*75
-5							
		SS	26	100/3"-* r6		SM	SAND: Brown silty layer 0.2ft, then 0.3ft of Argillite. SS 26,remaining blow count intervals: *69/3", *100/0".
	125						TOP of BEDROCK @ 124.5 ft.
							ROLLER BIT from 124.5 ft. to 128.0 ft.
-10		NX	1	100 ---- 100		5.0	ARGILLITE: Medium hard, light gray, unweathered, thin bedding, slumped. Occasional CALCITE veins.
	130						FALLING HEAD PERM TEST from 128.0 to 133.0 ft.
-15		NX	2	100 ---- 100		3.5	
	135						
-20		NX	3	100 ---- 100		3.0	ARGILLITE: Medium hard, light gray, unweathered, bedding thin to laminar & one thin CALCITE vertical vein through entire core.

NOTES: Asterisk (*) indicates the particular blow count interval not to standard (300# hammer used). Packer Tests performed. Observation Well installed to a depth of 157.85 ft. (1.25 in. Sch. 40 PVC).

Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-39 J.O. 004128-0013 SHEET: 7 OF 7

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT   Logged by: CF
Client: Massachusetts Water Resources Authority

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY / RQD	SPT N VALUE	USC SYMBOL OF PEN. RATE	SAMPLE DESCRIPTION
	140						**ARGILLITE**: Medium hard, light gray, unweathered, bedding thin to laminar & one thin CALCITE vertical vein through entire core.
-25		NX	4	100 / 98		3.0	**ARGILLITE**: As above.
	145						
-30		NX	5	98 / 98		3.0	**ARGILLITE**: As above with slumped bedding.
	150						Vertical CALCITE vein ends @ 152ft.
-35		NX	6	98 / 98		3.0	
	155						**END OF BORING @ 157.8ft**
-40							

NOTES: Asterisk (*) indicates the particular blow count interval not to standard (300# hammer used). Packer Tests performed. Observation Well installed to a depth of 157.85 ft. (1.25 in. Sch. 40 PVC).

Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-46 J.O. 004128-0013 SHEET: 1 OF 17

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT
Client: Massachusetts Water Resources Authority

Logged by: CF
Date Start - Finish: 1/24/89 - 2/21/89

Coordinates: N: 491516.95 ft. E: 746714.66 ft. (NAD 27)
Ground Elevation: 128.1 ft.
Ground Water Elev.: 105.8 ft.
Depth to Bedrock: 134.0 ft.
Total Depth Drilled: 408.5 ft.
Drill Contractor: Guild Drilling
Driller: RE & JP
Rig Type: CME-75;HC-150

Methods:
Casing Used: 134 ft. of NW casing left in ground
Drilling Soil: 3.75" Tricone Roller bit
Sampling Soil: Stanard Penetration Tests
Drilling Rock: 33 ft. of NX core, 328 ft. of NQ wireline core

Comments: Packer Testing - Performed over length of rock boring. Asterisk (*) indicates not to standard (300# hammer used). Preserved core 10.2 ft. Insitu testing 8 ft. away in LDE-46A. PMT- Menard Pressuremeter Test.

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY ------- RQD	SPT N VALUE	USC SYMBOL OR PEN. RATE	SAMPLE DESCRIPTION
128.1	0	SS	1	11-7 9-15 r2	16	FILL	FILL: Oily material pieces of drywall, sandy CLAY material, wire & other materials.
125							
	5	SS	2	3-3 2-4 r9	5	FILL	FILL: As above.
120							
	10	SS	3	7-4 4-4 r8	8	FILL	FILL: As above.
115							
		SS	4	12-7 3-7 r12	10	FILL	FILL: As above.

LEGEND/NOTES:

Datum is MDC sewer Datum (USGS datum plus 105.62 ft)

Blows = number of blows required to drive sample spoon 6" or distance shown.

r = inches of soil sample recovery.

RECOVERY = % of rock core recovery.

RQD = Rock Quality Designation

SPT N = Standard Penetration Test resistance to driving, blows/ft.

USC = Unified Soil Classification system.

Coordinates are in the 1927 Massachusetts State Plane Grid System.

Pen. Rate = coring penetration rate in min./ft.

SAMPLE TYPE:
SS = Standard Split Spoon
S3 = 3" Split Spoon
UO = Osterberg
NX = Rock Core
NQ = Wireline Rock Core
OR = Oriented Core
US = Shelby
UF = Fixed Piston

Approved/Date
John Pastore 6/8/89

Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-46 J.O. 004128-0013-00 SHEET: 2 OF 17

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT   Logged by: CF
Client: Massachusetts Water Resources Authority

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY / RQD	SPT N VALUE	USC SYMBOL OF PEN. RATE	SAMPLE DESCRIPTION
	15						FILL: Oily material pieces of drywall, sandy CLAY material, wire & other materials.
110							
	20	SS	5	10-17 21-18 r11	38	GW-GM	GRAVEL: Brown angular fine to medium gravel, fine sandy binder, trace silt.
105							
	25	SS	6	10-4 4-7 r11	8	ML/PT	SILT: Gray SILT , some fine GRAVEL, little fine sand, clay & a 2-3 in. layer of peat.
100							LDE-46A PMT #1 @ 28 ft.
	30	SS	7	43-18 27-57 r12	45	ML	SILT:30% mottled brown brownish-gray CLAY-SILT matrix. FALLING HEAD PERM TEST from 30.5 ft. to 32.0 ft.
95							
	35	SS	8	67-100/4" r15		ML	SILT: Brownish-gray SILT-CLAY matrix with 10-20 % fine angular GRAVEL. SS 8,remaining blow count intervals: *5/2",*14-*19 POCKET PENETROMETER: 4.5 tsf POCKET TORVANE: 1.6 tsf
90							
		SS	9	10-15 20-25 r15	35	CL	TILL: Gray silty CLAY, 10-20% fine GRAVEL, trace medium sub-angular gravel and trace fine-medium sand.

NOTES: Packer Testing - Performed over length of rock boring. Asterisk (*) indicates not to standard (300# hammer used).
Preserved core 10.2 ft. Insitu testing 8 ft. away in LDE-46A. PMT- Menard Pressuremeter Test.

Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-46 J.O. 004128-0013 SHEET: 3 OF 17

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT   Logged by: CF
Client: Massachusetts Water Resources Authority

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY / RQD	SPT N VALUE	USC SYMBOL OF PEN. RATE	SAMPLE DESCRIPTION
	40						TILL:Gray silty CLAY, 10-20% fine GRAVEL, trace medium sub-angular gravel and trace fine -medium sand.
85							
	45	SS	10	10-15 19-35 r8	34	CL	TILL:Gray silty CLAY,20-30% fine GRAVEL, trace of rounded angular medium gravel and trace fine-medium sand. FALLING HEAD PERM TEST from 44.0 ft. to 45.5 ft.
80							
	50	SS	11	10-16 22-30 r9	38	CL	TILL: As above.
75							
	55	SS	12	8-8 23-27 r14	31	CL	TILL: As above. LDE-46A PMT #2 @ 55.0 ft.
70							
	60	SS	13	20-26 39-53 r12	65	CL	TILL: As above. LDE-46A PMT #3 @ 60.3 ft.
65							
		SS	14	12-17 17-27 r5	34	CL	FALLING HEAD PERM TEST from 64.0 ft. to 65.5 ft.

NOTES: Packer Testing - Performed over length of rock boring. Asterisk (*) indicates not to standard (300# hammer used).
Preserved core 10.2 ft. Insitu testing 8 ft. away in LDE-46A. PMT- Menard Pressuremeter Test.

Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-46 J.O. 004128-0013 SHEET: 4 OF 17

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT Logged by: CF
Client: Massachusetts Water Resources Authority

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY ------- RQD	SPT N VALUE	USC SYMBOL OF PEN. RATE	SAMPLE DESCRIPTION
	65						TILL: Gray silty CLAY matrix, 20-30% fine GRAVEL; trace medium gravel and trace fine-medium sand.
60							
	70	SS	15	30-30 50-60 r16	80	CL	TILL: As above.
55							
	75	SS	16	23-30 38-45 r22	68	CL	TILL: As above.
50							
	80	SS	17	18-32 58-54 r13	90	CL	LDE-46A, 79 ft. to 104 ft.: Core Till (Face discharge bit w/Split triple tube NX barrel. Recovered & preserved 3.3 ft. Penetration rate of 1 min./ft.). TILL: As above.
45							
	85	SS	18	38-44 38-43 r18	82	CL	TILL: As above.
40							
		SS	19	15-30 99-55 r13	129	CL	TILL: As above.

NOTES: Packer Testing - Performed over length of rock boring. Asterisk (*) indicates not to standard (300# hammer used). Preserved core 10.2 ft. Insitu testing 8 ft. away in LDE-46A. PMT- Menard Pressuremeter Test.

Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-46 J.O. 004128-0013 SHEET: 5 OF 17

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT   Logged by: CF
Client: Massachusetts Water Resources Authority

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY ------- RQD	SPT N VALUE	USC SYMBOL OF PEN. RATE	SAMPLE DESCRIPTION
	90						TILL: Gray silty CLAY matrix, 20-30% fine GRAVEL; trace medium gravel and trace fine-medium sand.
35							
		SS	20	23-55 50-60 r11	105	CL	TILL: As above.
	95						
30							
		SS	21	23-45 69-70 r24	114	CL	
	100						TILL: As above.
25							
		SS	22	25-50 60-200/0"	110	CL	**FALLING HEAD PERM TEST** from 104.0 ft. to 104.5 ft. *SS 22, recovery of sample r=11 in.*
	105						6 in. COBBLE from 105.5 ft. to 106.0 ft.
							LDE-46A, 105.2 ft. to 109 ft.: Core Till (Face discharge bit w/Split triple tube NX barrel. Recovered & preserved 0.7 ft. Penetration rate 1 min./ft.)
20							
		SS	23	50-50 50-58 r18	100	SM	SILT & SAND: Brown & mixed with crumbly fragments of shell (wet).
	110						**FALLING HEAD PERM TEST** from 110.5 ft. to 112.0 ft.
15							
		SS	24	45-60 48-43 r11	108	SM	SAND & SILT: As above. **FALLING HEAD PERM TEST** from 114.0 ft. to 115.5 ft.

NOTES: Packer Testing - Performed over length of rock boring. Asterisk (*) indicates not to standard (300# hammer used).
Preserved core 10.2 ft. Insitu testing 8 ft. away in LDE-46A. PMT- Menard Pressuremeter Test.

Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-46 J.O. 004128-0013 SHEET: 6 OF 17

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT Logged by: CF
Client: Massachusetts Water Resources Authority

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY / RQD	SPT N VALUE	USC SYMBOL OF PEN. RATE	SAMPLE DESCRIPTION
	115						**SAND & SILT**: Brown & mixed with small fragments of shell (wet).
10							
		SS	25	100/4"-*		SP-SM	SS 25, recovery of soil sample r=4 in. Remaining blow count interval: *100/0".
	120						**FALLING HEAD PERM TEST** from **120.5 ft.** to **122.0 ft.**
		NX	1	50 / 0		3.0	**BOULDERS**: Argillite, Quartsite, medium grained Igneous & FeO2 stains.
5							
		SS	26	r0		SP	**SAND**: Brown fine to medium **SAND**. **FALLING HEAD PERM TEST** *from* **124 ft.** *to* **124.3 ft.** SS 26:Running **SAND**. No blow counts or recovery.
	125						Clean-out with tricore bit (125.9 ft. to 129 ft.).
0							**END OF SAND @ 129 ft.**
		NX	2	50 / 0		4.5	**BOULDERS**: Argillite; some cobbles, trace gravel (3" to 4" diameter) & FeO2 stains.
	130						Drilled with roller bit (132.5 ft. to 134.0 ft.) ***TOP of BEDROCK @ 133.0 ft.***
-5							
		NX	3	90 / 18		5.0	**DIABASE**, greenish gray med. grained; very closely spaced joints, surfaces coated with clay and FeO2 stains. **FALLING HEAD PERM TEST** from **134.0 ft.** to **140.25 ft.**
	135	NX	4	100 / 70		4.0	**DIABASE**, greenish gray med. grained; ocasional calcite veins; close to very closely spaced joints, surfaces coated with clay and FeO2 stains.
-10							

NOTES: Packer Testing - Performed over length of rock boring. Asterisk (*) indicates not to standard (300# hammer used). Preserved core 10.2 ft. Insitu testing 8 ft. away in LDE-46A. PMT- Menard Pressuremeter Test.

Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-46 J.O. 004128-0013 SHEET: 7 OF 17

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT Logged by: CF
Client: Massachusetts Water Resources Authority

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY ------- RQD	SPT N VALUE	USC SYMBOL OR PEN. RATE	SAMPLE DESCRIPTION
	140	NX	5	100 ---- 50		4.0	DIABASE, greenish gray, med. grained; close to very closely spaced joints. 140.6 - 30 deg. joint, curved, smooth, slickensides, sl. FeO2 stain on surfaces. 141.0 - 30 deg. joint, curved, smooth, slickensides, sl. FeO2 stain on surfaces. 142.3 to 142.5 - Fracture zone, slickensides on surfaces.
-15							144.0 - 40 deg. joint, rough, FeO2 stains on surfaces. 145.0 - 60 deg. joint, rough, chlorite on surface.
	145	NX	6	98 ---- 68		4.0	DIABASE, greenish gray, med. grained; close to very closely spaced joints. 146.2 - Joint, smooth, rock fragments and slickensides. 146.8 - 60 deg. joint, rough, calcite and chlorite on surfaces.
-20							147.9 - joint, smooth, slickensides. 148.2 - 60 deg. joint, rough, calcite and chlorite on surfaces. 148.7 - joint, smooth, slickensides. 148.9 - 60 deg. joint, rough, calcite and chlorite on surfaces.
	150	NX	7	100 ---- 60		3.5	DIABASE, greenish gray, med. grained, occasional calcite veins.
-25							152.0 to 155.0 - ARGILLITE, lt. gray, mod. hard, unweathered; bedding thin to laminar, 60 deg.; quartz vein with alteration.
	155	NX	8	100 ---- 20		4.0	ARGILLITE, lt. gray, mod. hard, unweathered; bedding thin to laminar, 60 deg.. 155.6 - 2 intersecting joints, 70 deg. opp. bedding and 60 deg. same as bedding. 156.4 - 2 intersecting joints, 70 deg. opp. bedding and 60 deg. same as bedding. 156.7 - 2 intersecting joints, 70 deg. opp. bedding and 60 deg. same as bedding. 157.8 - 2 intersecting joints, 70 deg. opp. bedding and 60 deg. same as bedding.
-30		NX	9	100 ---- 55		3.5	ARGILLITE, lt. gray, mod. hard, unweathered; bedding thin to laminar, 60 deg..
	160						
-35							
		NX	10	100 ---- 75		2.0	ARGILLITE, lt. gray, mod. hard, unweathered; bedding thin to laminar, 60 deg..
		NQ	11	100		2.5	

NOTES: Packer Testing - Performed over length of rock boring. Asterisk (*) indicates not to standard (300# hammer used). Preserved core 10.2 ft. Insitu testing 6 ft. away in LDE-46A. PMT- Menard Pressuremeter Test.

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT   Logged by: CF
Client: Massachusetts Water Resources Authority

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY / RQD	SPT N VALUE	USC SYMBOL OF PEN. RATE	SAMPLE DESCRIPTION
	165			---- / 100			ARGILLITE, same as above, occasional high angle quartz veins.
-40		NQ	12	100 / 83		2.5	ARGILLITE, lt. gray, mod. hard, unweathered; bedding thin to laminar, 60 deg.; occasional quartz veins. 169.8 - 60 deg. joint, sl. chlorite and qtz. coating; slickensides. 170.3 - 60 deg. joint, sl. chlorite and quartz coating. 170.6 - 60 deg. joint, sl. chlorite and quartz coating.
	170						
-45							NOTE: bottom of core broken up by drilling, jammed up.
	175	NQ	13	100 / 100		2.5	ARGILLITE, lt. gray, mod. hard, unweathered; bedding thin to laminar, 60 deg.; occasional quartz veins. 175.0 to 175.2- qtz. healed fracture zone.
-50		NQ	14	100 / 100		2.5	ARGILLITE, lt. gray, mod. hard, unweathered; bedding thin to laminar, 60 deg..
	180						181.4 - 70 deg. fracture, partially open, opp. bedding.
-55							
	185						186.5 - scribe jumped, right after stop.
-60		NQ	15	100 / 90		2.5	ARGILLITE, lt. gray, mod. hard, unweathered; bedding thin to laminar, 60 deg..

NOTES: Packer Testing - Performed over length of rock boring. Astersk (*) indicates not to standard (300# hammer used).
Preserved core 10.2 ft. Insitu testing 6 ft. away in LDE-46A. PMT- Menard Pressuremeter Test.

Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-46 J.O. 004128-0013 SHEET: 9 OF 17

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT Logged by: CF
Client: Massachusetts Water Resources Authority

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY / RQD	SPT N VALUE	USC SYMBOL OF PEN. RATE	SAMPLE DESCRIPTION
	190						
-65							
	195						196.8 - 60 deg. joint, smooth, qts. coating.
-70							197.8 - 60 deg. joint, smooth, qts. coating. 198.0 - 60 deg. joint, smooth, qts. coating.
		NQ	16	100 / 33		3.0	ARGILLITE, lt. gray, mod. hard, unweathered; bedding thin to laminar, 60 deg.; close to very closely spaced joints. 198.8 to 199.5 - 4 50 deg. joints, opp. bedding, smooth, chlorite and pyrite coatings.
	200						199.9 - 60 deg. joint, opp. bedding, chlorite on surfaces. 201.2 to 202.5 - fracture sone, all surfaces coated with chlorite and some pyrite. 202.5 - core barrel blocked up.
-75		OR	17	90 / 90		3.0	ARGILLITE, lt. gray, mod. hard, unweathered; bedding thin to laminar, 202.5 to 207.0 - bedding slumped, 207.0 to 208.5 - 50 deg.; some fractures partially open, some of these showing mineralisation.
	205						
-80							
		NQ	18	70 / 35		7.0	ARGILLITE, lt. gray, mod. hard, unweathered; bedding thin to laminar, 208.5 to 211.0 - 50 deg., 211.0 to 215.5 - slumped. NOTE: rock heavily broken by drilling, drilling rate slowed due to fracturing, core barrel blocked up.
	210						
-85							

NOTES: Packer Testing - Performed over length of rock boring. Asterisk (*) indicates not to standard (300# hammer used).
Preserved core 10.2 ft. Insitu testing 6 ft. away in LDE-46A. PMT- Menard Pressuremeter Test.

Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-46 J.O. 004128-0013 SHEET: 10 OF 17

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT Logged by: CF
Client: Massachusetts Water Resources Authority

SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY / RQD	SPT N VALUE	USC SYMBOL OF PEN. RATE	SAMPLE DESCRIPTION
NQ	19	85 / 85		5.0	ARGILLITE, lt. gray, mod. hard, unweathered; bedding thin to laminar, 50 deg.. NOTE: Top of core broken during drilling.
OR	20	98 / 98		3.0	ARGILLITE, lt. gray, mod. hard, unweathered; bedding thin to laminar, 218.5 to 220.0 bedding slumped, 220.0 to 228.5 - 40 deg.; occasional calcite veins parallel to bedding; no natural fractures.
OR	21	100 / 100		2.5	ARGILLITE, lt. gray, mod. hard, unweathered; bedding thin to laminar, 228.5 to 237.5 - bedding slumped, 237.5 to 238.5 - 45 deg.; no natural fractures.
NQ	22	100 / 94		2.5	ARGILLITE, lt. gray, mod. hard, unweathered; bedding thin to laminar, 238.5 to 241.5 - slumped bedding, 241.5 to 246.0 - 40 deg., 246.0 to 248.5 - slumped bedding; wide to very close fracture spacing

ELEV. (ft.): -90, -95, -100, -105, -110
DEPTH (ft.): 215, 220, 225, 230, 235

NOTES: Packer Testing - Performed over length of rock boring. Asterisk (*) indicates not to standard (300# hammer used).
Preserved core 10.2 ft. Insitu testing 6 ft. away in LDE-46A. PMT- Menard Pressuremeter Test.

Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-46 J.O. 004128-0013 SHEET: 11 OF 17

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT Logged by: CF
Client: Massachusetts Water Resources Authority

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY / RQD	SPT N VALUE	USC SYMBOL OF PEN. RATE	SAMPLE DESCRIPTION
	240						
-115							243.3 to 243.7 - Broken zone.
	245						
-120							
		OR	23	100 / 100		2.5	ARGILLITE, lt. gray, mod. hard, unweathered; bedding thin to laminar, 248.5 to 251.7 - slumped bedding, 251.7 to 258.5 - 35 deg.; occasional calcite veins parallel and perpendicular to bedding.
	250						
-125							253.0 to 254.0 - SANDY ARGILLITE
	255						
-130							
		OR	24	100 / 100		2.5	ARGILLITE, lt. gray, mod. hard, unweathered; bedding thin to laminar, slumped. No natural fractures.
	260						
-135							

NOTES: Packer Testing - Performed over length of rock boring. Astersk (*) indicates not to standard (300# hammer used).
Preserved core 10.2 ft. Insitu testing 6 ft. away in LDE-46A. PMT- Menard Pressuremeter Test.

Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-46 J.O. 004128-0013 SHEET: 12 OF 17

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT Logged by: CF
Client: Massachusetts Water Resources Authority

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY / RQD	SPT N VALUE	USC SYMBOL OR PEN. RATE	SAMPLE DESCRIPTION
	265						
-140							
		NQ	25	100 / 90		2.5	ARGILLITE, lt. gray, mod. hard, unweathered; bedding to laminar & slumped. No natural fractures.
	270						
-145							
	275						
-150							
		OR	26	100 / 100		2.5	
	280						
-155							
	285						
-160							
		OR	27	100 / 100		2.5	

NOTES: Packer Testing - Performed over length of rock boring. Asterisk (*) indicates not to standard (300# hammer used).
Preserved core 10.2 ft. Insitu testing 6 ft. away in LDE-46A. PMT- Menard Pressuremeter Test.

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT   Logged by: CF
Client: Massachusetts Water Resources Authority

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY / RQD	SPT N VALUE	USC SYMBOL OR PEN. RATE	SAMPLE DESCRIPTION
	290						ARGILLITE, same as above, no natural fractures.
-165							
	295						
-170							
		NQ	28	100 / 100		2.5	
	300						
-175							
	305						
-180							
		OR	29	100 / 100		3.0	ARGILLITE, lt. gray, mod. hard, unweathered; bedding thin to laminar, slumped; occasional calcite veins, 35 deg.; no natural fractures.
	310						
-185							

NOTES: Packer Testing - Performed over length of rock boring. Asterak (*) indicates not to standard (300# hammer used). Preserved core 10.2 ft. Insitu testing 6 ft. away in LDE-46A. PMT- Menard Pressuremeter Test.

Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-46 J.O. 004128-0013 SHEET: 14 OF 17

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT   Logged by: CF
Client: Massachusetts Water Resources Authority

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY / RQD	SPT N VALUE	USC SYMBOL OF PEN. RATE	SAMPLE DESCRIPTION
	315						
-190		OR	30	100 / 100		3.0	ARGILLITE, lt. gray, mod. hard, unweathered; bedding thin to laminar, 318.5 to 320.5 - slumped bedding, 320.5 to 328.5 - 35 deg.; occasional calcite veins, 35 deg. similar to bedding, all breaks due to drilling, along calcite veins.
	320						
-195							
	325						
-200		NQ	31	93 / 93		4.0	ARGILLITE, lt. gray, mod. hard, unweathered; bedding thin to laminar, slumped. 228.5 to 330.0 - 2 weak planes, 75 deg.
	330						
-205							
	335						
		NQ	32	100 / 100		3.0	ARGILLITE, lt. gray, mod. hard, unweathered; bedding thin to laminar, slumped.
-210							
		OR	33	100 / 90		2.5	ARGILLITE, same as above.

NOTES: Packer Testing - Performed over length of rock boring. Astersk (*) indicates not to standard (300# hammer used).
Preserved core 10.2 ft. Insitu testing 6 ft. away in LDE-46A. PMT- Menard Pressuremeter Test.

Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-46 J.O. 004128-0013 SHEET: 15 OF 17

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT   Logged by: CF
Client: Massachusetts Water Resources Authority

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY / RQD	SPT N VALUE	USC SYMBOL OF PEN. RATE	SAMPLE DESCRIPTION
	340						
-215							
	345						346.6 to 347.3 - core broken by drilling next to plane of weakness, 70 deg.
-220							347.9 to 348.4 - core broken by drilling, next to plane of weakness, 70 deg.
		OR	34	100 / 100		2.5	ARGILLITE, lt. gray, mod. hard, unweathered; bedding thin to laminar, 348.5 to 357.4 - 35 deg., 357.4 to 358.4 - slumped bedding; occasional calcite veins parallel to bedding; widely spaced joints.
	350						
-225							
	355						
-230							357.8 - 70 deg. joint, smooth, calcite coating.
		NQ	35	100 / 100		2.5	ARGILLITE, lt. gray, mod. hard, unweathered; bedding thin to laminar, slumped.
	360						
-235							

NOTES: Packer Testing - Performed over length of rock boring. Asterisk (*) indicates not to standard (300# hammer used).
Preserved core 10.2 ft. Insitu testing 6 ft. away in LDE-46A. PMT- Menard Pressuremeter Test.

Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-46 J.O. 004128-0013 SHEET: 16 OF 17

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT Logged by: CF
Client: Massachusetts Water Resources Authority

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY / RQD	SPT N VALUE	USC SYMBOL OF PEN. RATE	SAMPLE DESCRIPTION
	365						
							366.8 - 2 intersecting joints, 50 deg. and 60 deg., sl. calcite coating on surfaces.
-240							
		OR	36	100 / 100		2.5	ARGILLITE, slightly sandy, lt. gray, mod. hard, unweathered; bedding thin to laminar, 368.5 to 372.5 - slumped bedding, 372.5 to 378.5 - 20 deg., some slumped beds near vertical; occasional calcite veins 40 deg. opp. bedding; no natural fractures.
	370						
-245							
	375						
-250							
		OR	37	98 / 98		2.5	ARGILLITE, lt. gray, mod. hard, unweathered; bedding thin to laminar, slumped; occasional calcite veins, 40 deg. opp. bedding; all breaks due to drilling, breaks easily along bedding.
	380						
-255							
	385						
-260							
		NQ	38	100 / 90		3.0	ARGILLITE, lt. gray, mod. hard, unweathered; bedding thin to laminar, slumped; core appears porous; most breaks due to *drilling*, breaks *easily along bedding*. 389.1 to 389.5 - bedding plane separations, faint slickensides, calcite coating.

NOTES: Packer Testing - Performed over length of rock boring. Asterisk (*) indicates not to standard (300# hammer used).
Preserved core 10.2 ft. Insitu testing 6 ft. away in LDE-46A. PMT- Menard Pressuremeter Test.

Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-46 J.O. 004128-0013 SHEET: 17 OF 17

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT   Logged by: CF
Client: *Massachusetts Water Resources Authority*

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY / RQD	SPT N VALUE	USC SYMBOL OF PEN. RATE	SAMPLE DESCRIPTION
	390						
-265							
		NQ	39	100 / 100		2.5	ARGILLITE, sl. sandy, lt. gray, mod. hard, unweathered; bedding thin to laminar, 40 deg. sl. slumped; occasional calcite veins parallel to bedding; rock seems porous.
	395						
-270							398.0 - bedding plane separation, 2-3mm thick broken zone, slickensides.
		OR	40	98 / 85		3.0	ARGILLITE, lt. gray, mod. hard, unweathered; bedding thin to laminar, 399.0 to 405.0 - 40 deg. sl. slumped, 405.0 to 408.5 - 40 - 50 deg. other direction; some bedding plane separation; core breaks easily along bedding.
	400						
-275							
	405						
-280							END OF BORING @ 408.5 ft.

NOTES: Packer Testing - Performed over length of rock boring. Astersk (*) indicates not to standard (300# hammer used).
Preserved core 10.2 ft. Insitu testing 6 ft. away in LDE-46A. PMT- Menard Pressuremeter Test.

GOLDBERG-ZOINO & ASSOCIATES, INC.

GZA

BORING SUMMARY LOG

BORING PDE-46
SHEET 1 OF 1

PROJECT: INTER-ISLAND TUNNEL, BOSTON HARBOR
CLIENT: *Massachusetts Water Resources Authority*
Coordinates: N: 491572.94ft. E: 746808.67ft.

Sea Floor Elevation: **123.4 ft.**
Total Depth Drilled: **51.0 ft.**

DESCRIPTION — MAIN	DETAIL	Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load I_s 50	Pressure Test K = cm/sec (x 0.00001)
FILL, fine to coarse SAND, 35% gravel, 20% silt, brown		0	123.4				
FILL, fine to coarse GRAVEL, 35% *clayey silt, 20% fine to coarse sand,* medium dense, gray			120			17-13 8-12 R9	
FILL, fine to coarse GRAVEL, 35% fine to coarse sand, 20% silt, dense, gray		10	115			24-29 19-28 R10	
FILL, fine to coarse Gravel, 35% fine to coarse sand, 20% silt, dense, gray.			110			36-31 18-18 R14	
FILL, fine to coarse Sand, 10% fine gravel, 10% silt.			105				
FILL, fine to coarse SAND, 25% fine gravel, medium dense, gray.		20				22-11 13-8 R1	
ORGANIC SILT, 20% fine Sand, 5% fine gravel, 3% *shells, dense,* brown.			100			6-16 16-27 R15	
FINE SAND AND SILT, 20% Gravel, dense, gray.			95				
SILT AND FINE SAND, 5% fine to coarse Gravel, dense, yellow.		30				24-27 18-26 R12	
SILT AND CLAY, 5% fine to coarse Sand, 5% gravel, dense, yellow.			90			17-16 15-18 R3	
SILTY CLAY, 2% Gravel, stiff, olive-gray.			85			4-4 5-6 R24	
SILTY CLAY, 5% Gravel, 5% fine sand, medium stiff, olive-gray.		40				4-3 4-4 R24	
SILTY CLAY, medium stiff, olive-gray.			80			3-3 3-4 R16	
SILTY CLAY, 5% Gravel, medium stiff, olive-gray, several 1/2 in. to 1 in. pieces of gravel.		50	75			2-4 4-5 R24	
51.0 ft.: END OF BORING							

NOTES: Observation well, 30 feet deep, installed in borehole by Guild under direction of *HMM. Groundwater level is* affected by tide.

ADD. 4

Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-58 J.O. 004128-0013 SHEET: 1 OF 18

Project: **1989 LAND BORINGS - DEER ISLAND PROJECT** Logged by: **CS**
Client: **Massachusetts Water Resources Authority** Date Start - Finish: **2/13/89 - 3/3/89**

Coordinates: **N: 466599.39 ft. E: 747713.46 ft. (NAD 27)** Ground Elevation: **126.2 ft.**
Ground Water Elev.: **107.7 ft.** Depth to Bedrock: **95.3 ft.** Total Depth Drilled: **429.4 ft.**
Drill Contractor: **Guild Drilling** Driller: **JP/RE/PB** Rig Type: **CME-75;HC-150**

Methods: Casing Used: **50.5 ft. HW casing & 97.5 ft. NW casing left in hole.**
Drilling Soil: **Tricone Roller Bit**
Sampling Soil: **Standard Penetration Tests**
Drilling Rock: **NX core to 127.0; NQ wireline and oriented core to 429.4**

Comments: Packer Testing - Performed over length of rock boring. LDE-58 is located on Nut Island; elevation estimated. Astersk (*) indicates not to standard (300# hammer used). Insitu testing 6 ft. away in LDE-58A. Preserved core 18.8 ft.

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY ------- RQD	SPT N VALUE	USC SYMBOL OR PEN. RATE	SAMPLE DESCRIPTION
126.2	0	SS	1	1-3 7-9 r12	10	FILL	**FILL**: Brown organic gravelly **SILT**; 15% fine to coarse **GRAVEL** (1.5 in. MAX); 10% fine to coarse **SAND**; 5% organic fiber; loamy material.
125							
	5	SS	2	10-21 26-29 r12	47	FILL	Remaing blow count intervals: 100/3",*60/3",*16 **GRAVEL-SAND**: Grey, compact, fine to coarse **GRAVEL** (1.25 in MAX); 40% fine to coarse **SAND**; 5% silt & 5% clay.
120							
	10	SS	3	7-8 7-7 r7	15	FILL	**FILL**: **GRAVEL-CLAY**, Yellow-brown; 15% fine GRAVEL (3/4 in MAX); 20% fine to coarse **SAND**; 5% silt; medium plasticity.
115							
		SS	4	12-30 * r20		FILL	**FILL**: **GRAVEL-SAND**, brown & loose; 30% fine to coarse **GRAVEL** (1.5 in. MAX); 10% silt & < 5% clay.

LEGEND/NOTES:

Datum is MDC sewer Datum (USGS datum plus 105.62 ft)

Blows = number of blows required to drive sample spoon 6" or distance shown.

r = inches of soil sample recovery.

RECOVERY = % of rock core recovery.

RQD = Rock Quality Designation

SPT N = Standard Penetration Test resistance to driving, blows/ft.

USC = Unified Soil Classification system.

Coordinates are in the 1927 Massachusetts State Plane Grid System.

Pen. Rate = coring penetration rate in min./ft.

SAMPLE TYPE:
SS = Standard Split Spoon
S3 = 3" Split Spoon
UO = Osterberg
NX = Rock Core
NQ = Wireline Rock Core
OR = Oriented Core

Approved/Date
6/6/89

Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-58 J.O. 004128-0013 SHEET: 2 OF 18

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT — Logged by: CS
Client: Massachusetts Water Resources Authority

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY ------- RQD	SPT N VALUE	USC SYMBOL OF PEN. RATE	SAMPLE DESCRIPTION
	15						SS 4,remaing blow count intervals: 100/3",*60/3"-*16
110							
	20	SS	5	17-16 16-11 r8	32	FILL	FILL: GRAVEL-SAND, Gray 50% fine to coarse GRAVEL, broken by drilling (1.5 in. MAX), fine to coarse SAND, < 5% silt & < 1% clay; loose. FALLING HEAD PERM TEST from 20 ft.to 22.0 ft.
105							FALLING HEAD PERM TEST from 23.0 ft. to 25.0 ft.
	25	SS	6	14-14 12-38 r11	26	FILL	
100							CLAY: Silty, yellow-brown, stiff, 5% sand, 35 % SILT & medium plasticity.
	30	SS	7	*4-*6 *6-*8 r18		CL	NOTE:PMT-Menard Pressuremeter Test LDE-58A PMT #1 @ 30.7 ft. POCKET PENETROMETER: 2.0 tsf POCKET TORVANE: 0.7 tsf
95							FALLING HEAD PERM TEST from 33.0 ft. to 35.9 ft.
	35	SS	8	6-12 12-12 r23	24	CL	LDE-58A PMT#2 @ 35.2 ft. POCKET PENETROMETER: 2.5 tsf POCKET TORVANE: 0.7 tsf
90							FALLING HEAD PERM TEST from 39.0 ft. to 40.0 ft.
		SS	9	9-17 22-30 r23	39	SC/CL	SAND: Clayey yellow brown, trace silt low to medium plasticity.

NOTES: Packer Testing - Performed over length of rock boring. LDE-58 is located on Nut Island; elevation estimated. Asterak (*) indicates not to standard (300# hammer used). Insitu testing 6 ft. away in LDE-58A. Preserved core 18.8 ft.

Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-58 J.O. 004128-0013 SHEET: 3 OF 18

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT   Logged by: CS
Client: Massachusetts Water Resources Authority

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY / RQD	SPT N VALUE	USC SYMBOL OF PEN. RATE	SAMPLE DESCRIPTION
	40						SAND: As above. LDE-58A PMT #3 @ 40.5 ft.
85							
		SS	10	61-59 61-98 r18	120	GP-GM	GRAVEL, fine to coarse with some fine to coarse SAND, trace silty clay; very dense.
	45						FALLING HEAD PERM TEST from 44.5 ft. to 46.5 ft.
80							
							FALLING HEAD PERM TEST from 48.5 ft. to 50.5 ft.
		SS	11	60-100 *50-*59		GP-GM	As above. SS 11,recovery of soil sample r=12 in.
	50						
75							TILL: Grey gravelly CLAY, 20-30% fine to coarse GRAVEL, 20-30% SILT; trace sand; moderate plasticity.
		SS	12	36-51 65-87 r19	116	CL-ML	
	55						
70							
		SS	13	19-24 43-47 r14	67	CL-ML	
	60						LDE-58A PMT #4 @ 60.5 ft.
65							
		SS	14	24-32 77-89 r12	109	CL-ML	TILL: As above. LDE-58A PMT #5 @ 65.0 ft.

NOTES: Packer Testing - Performed over length of rock boring. LDE-58 is located on Nut Island; elevation estimated. Asterisk (*) indicates not to standard (300# hammer used). Insitu testing 6 ft. away in LDE-58A. Preserved core 18.8 ft.

Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-58 J.O. 004128-0013 SHEET: 4 OF 18

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT   Logged by: CS
Client: Massachusetts Water Resources Authority

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY / RQD	SPT N VALUE	USC SYMBOL OF PEN. RATE	SAMPLE DESCRIPTION
	65						TILL: As above 20-30% CLAY & 20-30% SILT, trace of SAND; moderate plasticity.
60							
							FALLING HEAD PERM TEST from 68.5 ft. to 70.5 ft.
	70	SS	15	23-41 61-49 r13	102	CL-ML	
55							
	75	SS	16	41-46 37-25 r10	83	CL-ML	TILL: Gray silty CLAY, as above.
50							
	80	SS	17	43-53 76-85 r18	129	CL-ML	
45							
	85	SS	18	36-44 81-87 r24	125	CL-ML	
40							
		SS	19	34-38 47-62 r24	85	CL-ML	TILL: As above with layered portions, 10% fine GRAVEL.

NOTES: Packer Testing - Performed over length of rock boring. LDE-58 is located on Nut Island; elevation estimated. Astersk (*) indicates not to standard (300# hammer used). Insitu testing 6 ft. away in LDE-58A. Preserved core 18.8 ft.

Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-58 J.O. 004128-0013 SHEET: 5 OF 18

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT Logged by: CS
Client: Massachusetts Water Resources Authority

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY ------- RQD	SPT N VALUE	USC SYMBOL OR PEN. RATE	SAMPLE DESCRIPTION
	90						**TILL:** As above.
35							
							FALLING HEAD PERM TEST from 94.0 ft to 95.3 ft.
		SS	20	100-*35 *150/4"		CL-ML	SS 20,recovery of soil sample r=13 in. **TOP OF BEDROCK @ 95.3 ft.**
	95						
							Roller Bit from 95.3 ft. to 97.0 ft.
30							
		NX	1	92 ---- 92		2.4	**FALLING HEAD PERM TEST** from 97.0 ft. to 102.0 ft. **ARGILLITE**, gray, mod. hard, sl. weathered; bedding laminar, 45 - 50 deg., some bedding slumped, 70 - 90 deg., some bedding offset along various hairline calcite veins; occasional calcite veins, 25 - 60 deg.; close to widely spaced joints. 97.5 - 40 deg. joint, rough, weathered mineral (qtz?) coating. 98.1 - 30 deg. joint, rugh, weathered mineral (qtz?) coating.
	100						
25							
		NX	2	100 ---- 92		2.0	**ARGILLITE**, gray, mod. hard, sl. weathered; bedding laminar, 45 - 60, some bedding slumped with bedding offset in slumped areas along 70 deg. calcite vein; occasional to some calcite veins, usually parallel to bedding, and 15 - 75 deg. opp. bedding; mod. close to closely spaced joints. 103.7 - 40 deg. joint, along calcite vein, rough, sl. brown clay. 104.4 - 35-55 deg. joint, rough, sl. discoloration of calcite. 104.7 - 40 deg. joint, rough, sl. gray clay. 104.8 - 30 deg. joint, opp. bedding, rough, sl. pyrite.
	105						
20							
		NX	3	100 ---- 100		1.8	**ARGILLITE**, gray, mod. hard, sl. weathered; bedding laminar, 107.0 to 109.7 45 - 40 deg., 109.7 to 112.0 30 - 35 deg.; occasional to some calcite veins, parallel to bedding and 40 - 85 deg. opp. bedding; occasional separations along calcite veins; mod. close to closely spaced joints. 108.1 - 60 deg. joint, opp. bedding, along calcite vein, rough, partial pyrite coating. 109.4 - 50 deg. joint, opp. bedding, rough, partial pyrite coating. 110.5 - 35 deg. joint, opp. bedding, smooth, sl. pyrite.
	110						
							111.5 - 50 deg. joint, opp. bedding, smooth, sl. pyrite.
15							
		NX	4	100 ---- 98		1.9	**ARGILLITE**, gray, mod. hard, sl. weathered; bedding laminar, 35 deg.; numerous calcite veins, parallel to bedding and 50 - 55 deg. opp. bedding; occasional separations along calcite veins; wide to closely spaced joints. 112.5 - 35 deg. joint, smooth, sl. pyrite and clay. 112.6 - 40 deg. joint, opp. bedding, smooth, sl. pyrite.

NOTES: Packer Testing - Performed over length of rock boring. LDE-58 is located on Nut Island; elevation estimated. Astersk (*) indicates not to standard (300# hammer used). Insitu testing 6 ft. away in LDE-58A. Preserved core 18.8 ft.

Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-58 J.O. 004128-0013 SHEET: 6 OF 18

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT Logged by: CS
Client: Massachusetts Water Resources Authority

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY / RQD	SPT N VALUE	USC SYMBOL OR PEN. RATE	SAMPLE DESCRIPTION
	115						116.0 - 30 deg. joint, along calcite vein, smooth, sl. gray clay.
10							
		NX	5	100 / 86		2.0	**ARGILLITE**, occasional to some interbeds of **SANDY ARGILLITE**, gray, mod. hard, sl. weatherd; bedding laminar, 35 deg.; occasional to some hairline calcite veins, parallel to bedding, 50 deg. and 70 deg. opp. bedding; closely spaced joints. 118.7 - 60 deg. joint, opp. bedding, rough, sl. gray clay. 118.7 - 35 deg. joint, smooth, sl. pyrite. 119.0 - 55 deg. joint, opp. bedding, smooth, sl. gray clay. 119.8 - 50 deg. joint, opp. bedding, rugh, sl. gray clay. 120.0 - 40 deg. joint, opp. bedding, rough sl. gray clay.
	120						
		NX	6	100 / 78		2.0	**ARGILLITE**, with interbeds of **SANDY ARGILLITE**, gray, mod. hard, sl. weatherd; bedding laminar, 120.5 to 124.2 - 40 - 45 deg., 124.2 to 125.0 - 60 deg.; occasional hairline calcite veins, usually 45 - 55 deg. opp. bedding, some parallel to bedding and 15 - 25 deg. opp. bedding; very close to mod. closely spaced joints. 120.9 - 70 deg. joint, opp. bedding, rough, sl. pyrite. 121.3 - 85 - 90 deg. joint, rough, sl. pyrite
5							
							124.3 - 20 deg. joint, rough, sl. pyrite, sl. discoloration.
	125	NX	7	100 / 85		2.0	**ARGILLITE**, gray, mod. hard, unweathed; bedding irregular, with 180 deg. change in dip direction 125.3 to 126.3, 126.3 to 127 - 65 - 70 deg.; some bedding plane separations; close to mod. close joint spacing. 125.3 - 35 deg. joint, smooth, sl. pyrite 125.6 - 35 deg. joint, smooth, sl. pyrite.
0							
		NQ	8	83 / 83		2.5	**ARGILLITE**, gray, mod. hard, sl. weathered; bedding slumped and overturned; occasional to some calcite veins, 30 - 45 deg.; mod. closely spaced joints.
							129.0 - 40 deg. joint, smooth, sl. pyrite coating.
	130	OR	9	89 / 85		3.6	**ARGILLITE**, with interbeds of **SANDY ARGILLITE**, gray, mod. hard, sl. weathered; bedding thin to laminar, irregular, 90 - 70 and 0 - 35 deg., overturns between 132.6 and 138.7; numerous to occasional calcite veins, 50 - 60 deg. joints; mod. closely spaced joints with some very closely spaced. 130.1 - 45 deg. joint, rough, partial pyrite coating.
-5							
							133.3 - 15 deg. joint, rough, sl. pyrite.
	135						135.5 - 25 deg. joint, along calcite vein, rough, sl. clay coating.
-10							137.2 - 50 deg. joint, smooth, sl. pyrite. 137.6 - 25 deg. joint, smooth, sl.pyrite. 138.6 - 50 deg. joint, rough, sl. discoloration.

NOTES: Packer Testing - Performed over length of rock boring. LDE-58 is located on Nut Island; elevation estimated. Astersk (*) indicates not to standard (300# hammer used). Insitu testing 6 ft. away in LDE-58A. Preserved core 18.8 ft.

Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-58 J.O. 004128-0013 SHEET: 7 OF 18

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT Logged by: CS
Client: Massachusetts Water Resources Authority

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY / RQD	SPT N VALUE	USC SYMBOL OF PEN. RATE	SAMPLE DESCRIPTION
	140	OR	10	100 / 99		*2.5	**ARGILLITE**, with interbeds of **SANDY ARGILLITE**, gray, mod. hard, sl. weatherd ; bedding very thin to laminar, irregular, 0 - 90 deg.; occasional to numerous calcite veins, parallel to bedding and 45 and 60 deg. opp. bedding; mod. close to closely spaced joints. 141.6 - 10 deg. joint, rough, sl. pyrite. 141.9 - 50 deg. joint, smooth, sl. pyrite. 143.0 - 0 - 20 deg. joint, rough, sl. pyrite 144.7 - 30 deg. joint, along calcite vein, sl. pyrite. 146.3 - 30 deg. joint, opp. bedding, rough, pyrite coating. 146.4 - 65 deg. joint, opp. bedding, rough, pyrite coating. 148.8 - 30 deg. joint, opp. bedding, rough, sl. pyrite. 150.0 - 10 deg. joint, rough, sl. pyrite.
-15	145						
-20							
	150	NQ	11	100 / 97		*2.5	**ARGILLITE, w/SANDY ARGILLITE** - similar to above bedding laminar, 150-36-45; 153.5 to 156.5 - 25 deg. Some to numerous calcite veins 45-50-60-80 opp bdg w/ parrallel to bdg; occassional bdg slumped; 75 - 85 deg.; mod. close to closely spaced joints.
-25	155						
		NQ	12	100 / 100		*2.5	**ARGILLITE,w/SANDY ARGILLITE**- Same as above; bedding laminar to irregular with most bedding slumped. Numerous calcite veins, 35-50 deg. & 75-80 deg.; close to moderately spaced joints.
-30							
	160	OR	13	100 / 93		2.3	**ARGILLITE**, gray, mod. hard, sl. weathered; bedding faintly laminar to thin, 75 - 90 deg. ; numerous to occasional calcite veins, 50 deg., 10 - 15 deg. and 75 deg.; occasional separations along planes 10 - 20 deg.; mod. closely spaced joints. 160.4 to 170.0 - 90 - 75 deg. joint, parallel to bedding, rough, sl. pyrite. 163.6 - 50 deg. joint, along calcite vein, rough, lt. gray clay. * **NOTE**: bit pressure 1100 psi.
-35							

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Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-58 J.O. 004128-0013 SHEET: 8 OF 18

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT — Logged by: CS
Client: Massachusetts Water Resources Authority

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY / RQD	SPT N VALUE	USC SYMBOL OR PEN. RATE	SAMPLE DESCRIPTION
	165						
-40							166.1 - 15 deg. joint, along calcite vein, smooth, sl. pyrite. 167.5 - 50 deg. joint, rough, sl. gray clay. 168.7 - core barrel blocked up.
		NQ	14	100 / 100			ARGILLITE, gray, mod. hard, sl. weathered; bedding faintly laminar, 75 - 90 deg.; some hairline calcite veins, usually 80 deg.; No natural joints.
	170	OR	15	89 / 86			ARGILLITE, gray, mod. hard, sl. weathered; bedding faintly laminar, 169.9 to 171.9 - 75-90 deg., 171.9 to 173.5 - bedding slumped and overturned, 173.5 to 174.7 - 70-90 deg., 174.7 to 176.4, 35-50 deg., 176.4 to 179.1 - 70-90 deg.; occasional to numerous calcite veins, conjugate set 40 deg., and 10 - 30 deg.; rock tends to separate along low angle veins; mod. closely spaced joints. 170.5 - 10 deg. joint, along calcite vein, rough, sl. pyrite. 172.8 - 40 deg. joint, along calcite vein, smooth, sl. pyrite.
-45							
	175						174.9 to 175.1 - Fracture zone, main joint 45 - 60 deg. along calcite vein, rough, sl. pyrite.
-50							176.2 - 15 deg. joint, intersecting calcite vein, 35 deg. rough, sl. pyrite. 179.1 - 75 deg. joint, along calcite vein, sl. pyrite.
		NQ	16	100 / 100		2.5	ARGILLITE, gray, mod. hard, sl. weathered; bedding slumped; some calcite veins; core separates along calcite veins; No natural joints.
	180						
-55							
	185						
-60							
		OR	17	100 / 90		3.0	ARGILLITE, gray, mod. hard, sl. weathered; bedding slumped; some calcite veins, high angle; core separates along calcite veins; mod. closely spaced joints. 188.0 - 80 deg. joint, rough, calcite coating. 189.5 - 80 deg. joint, rough, sl. pyrite.

NOTES: Packer Testing - Performed over length of rock boring. LDE-58 is located on Nut Island; elevation estimated. Astersk (*) indicates not to standard (300# hammer used). Insitu testing 6 ft. away in LDE-58A. Preserved core 18.8 ft.

Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-58 J.O. 004128-0013 SHEET: 9 OF 18

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT Logged by: CS
Client: Massachusetts Water Resources Authority

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE NO.	BLOWS OR RECOVERY / RQD	SPT N VALUE	USC SYMBOL OR PEN. RATE	SAMPLE DESCRIPTION
	190						
-65							192.0 - core barrel blocked up.
		OR	18	100 / 90			ARGILLITE, gray, mod. hard, sl. weathered; bedding slumped; some calcite veins; widely spaced joints. 193.0 - Two subparallel joints, opp. bedding, calcite coated.
	195						
-70							
	200	OR	19	100 / 95		2.5	ARGILLITE, gray, mod. hard, sl. weathered; bedding slumped; some calcite veins; wide to closely spaced joints.
-75							202.2 to 202.4 - Broken zone 202.4 - 10 deg. fractured layer, some signs of movement 203.1 - 60 deg. joint, semi planar, calcite, faint slickensides.
	205						
-80							
	210	NQ	20	100 / 100		2.0	ARGILLITE, gray, mod. hard, sl. weathered; bedding slumped; some calcite veins; widely spaced joints.
-85							212.0 - 65 deg. joint, smooth, calcite coated.

NOTES: Packer Testing - Performed over length of rock boring. LDE-58 is located on Nut Island; elevation estimated. Asterisk (*) indicates not to standard (300# hammer used). Insitu testing 6 ft. away in LDE-58A. Preserved core 18.8 ft.

Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-58 J.O. 004128-0013 SHEET: 10 OF 18

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT   Logged by: CS
Client: Massachusetts Water Resources Authority

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY ------- RQD	SPT N VALUE	USC SYMBOL OF PEN. RATE	SAMPLE DESCRIPTION
	215						
-90							
	220	OR	21	100 ---- 85		2.5	ARGILLITE, gray, mod. hard, sl. weathered; bedding slumped; some calcite veins; Most breaks due to drilling, along weak planes.
-95							
	225						
-100							226.9 - Two subparallel joints, 45 deg., weathered calcite coating.
							228.5 - Core barrel blocked up.
		OR	22	100 ---- 100			ARGILLITE, gray, mod. hard, sl. weathered; bedding slumped to 229.4, 229.4 to 230.0 - 55 deg.. Note: from 228.8 to 230.0 - core is doubly scribed. 228.8 - 25 deg. joint, along calcite vein, smooth, sl. pyrite
	230	OR	23	100 ---- 100		2.0-2.5	ARGILLITE, gray, mod. hard, sl. weathered; bedding very thin to medium, irregular, 45- 65 deg., some slumped; numerous intersecting calcite veins, 40 deg. , and 50 deg. opp. bedding, other veins 20 - 45 deg. and 50 - 65 deg.; occasional separations along veins; mod. closely spaced joints. 230.4 - 40 deg. joint, rough, sl. pyrite. 231.9 - 50 deg. joint, smooth, sl. pyrite.
-105							233.3 - 70 - 60 deg. joint, along calcite vein, sl. gray clay.
	235						
-110							236.7 - 45 deg. joint, along calcite vein, rough, lt. gray clay coating. 237.3 - Core barrel blocked up.
		NQ	24	100 ---- 100			ARGILLITE, gray, mod. hard, sl. weathered; bedding thin to laminar, 50 deg. and slumped up to 90 deg. ; occasional hairline calcite veins, 45 - 85 deg.; No natural joints.

NOTES: Packer Testing - Performed over length of rock boring. LDE-58 is located on Nut Island; elevation estimated. Asterisk (*) indicates not to standard (300# hammer used). Insitu testing 6 ft. away in LDE-58A. Preserved core 18.8 ft.

Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-58 J.O. 004128-0013 SHEET: 11 OF 18

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT Logged by: CS
Client: Massachusetts Water Resources Authority

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY / RQD	SPT N VALUE	USC SYMBOL OF PEN. RATE	SAMPLE DESCRIPTION
	240	NQ	25	100 / 97			ARGILLITE, with occasional SANDY ARGILLITE beds; gray, mod. hard, sl. weathered ; bedding thin to medium, bedding irregular with slumping; occasional to numerous calcite veins, 40 - 55 deg.; mod. close to closely spaced joints.
-115							242.3 - 5 deg. joint, rough, sl. pyrite.
							243.0 - 15 deg. joint, rough, sl. pyrite. 243.3 - 0-35 deg. joint, rough, sl.pyrite.
	245						
-120							247.7 - 0-45 deg. joint, rough, sl. pyrite.
							249.6 - 40-50 deg. joint, rough, sl. gray clay.
	250	NQ	26	100 / 100		1.5-2.0	ARGILLITE, with some SANDY ARGILLITE beds; gray, mod. hard, sl. weathered; bedding medium to very thin, slumped, where not slumped 35 - 55 deg.; occasional to numerous calcite veins, 35-45 deg. and 65 - 70 deg. same as bedding and 30 - 45 deg. opp. bedding; mod. close joint spacing.
-125							
							254.7 - 40 deg. joint, rough, sl. gray clay coating.
	255						255.5 - 35 deg. joint, along calcite vein, sl. pyrite.
-130							257.3 - 35 deg. joint, rough, gray clay coating.
	260	OR	27	100 / 89			ARGILLITE, with occasional SANDY ARGILLITE beds; gray, mod. hard, sl. weathered; bedding faintly laminar to medium, irregular with most slumped, non slumped bedding 50 - 55 deg.; occasional to numerous calcite veins, 25 - 40 deg.; mod. close joint spacing. 261.0 - 45 deg. joint, along calcite vein, smooth, pyrite coating. 261.7 to 262.5 - 80 deg. joint, along calcite vein, smooth, pyrite coating. 262.9 to 269.4 - FELSITE, grayish green, hard, sl. weathered, cut across high angle to bedding, contact 40 - 45 deg.; contacts offset slightly along hairline calcite vein, 80 deg.. 263.2 to 263.5 - 80-85deg. joint, along calcite vein, rough, sl. pyrite. 263.5 to 263.7 - Euhedral pyrite crystals in argillite.
-135							

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Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-58 J.O. 004128-0013 SHEET: 12 OF 18

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT Logged by: CS
Client: Massachusetts Water Resources Authority

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY / RQD	SPT N VALUE	USC SYMBOL OF PEN. RATE	SAMPLE DESCRIPTION
	265						
-140							
	270	NQ	28	100 / 100			**ARGILLITE**, with **SANDY ARGILLITE** beds; gray, mod. hard, sl. weathered; bedding very thin to medium, 30 - 50 deg., some bedding offset by calcite veins; occasional to numerous calcite veins, 40 - 60 deg. opp. bedding and 70 - 75 deg.; No natural joints.
-145							
	275						
-150							
	280	OR	29	100 / 89			**ARGILLITE**, gray, mod. hard, sl. weathered; bedding laminar to medium, slumped and occasionally folded, 60 - 90 deg.; occasional to numerous calcite veins, 60 - 80 deg. same as bedding or 0 - 40 deg.; mod. close to very closely spaced joints. 283.1 - horizontal joint, rough, sl. pyrite. 283.5 - 5 deg. joint, rough, pyrite coating. 283.6 - 20 deg. joint, rough, pyrite coating. 283.7 - 20 deg. joint, opp. joint above, smooth, sl. pyrite 284.5 - 20 deg. joint, along calcite vein, smooth, sl. pyrite. 284.8 - 30 deg. joint, rough, sl. pyrite.
-155							
	285						
-160							286.9 - 20 deg. joint, rough, sl. pyrite. 287.3 - 50 deg. joint, chlorite coating, sl. pyrite. 287.3 to 287.9 - 80 deg. joint, rough, lt. gray clay coating, sl. pyrite. 289.0 - 40 deg. joint, steeped, sl. pyrite.

NOTES: Packer Testing - Performed over length of rock boring. LDE-58 is located on Nut Island; elevation estimated. Astersk (*) indicates not to standard (300# hammer used). Insitu testing 6 ft. away in LDE-58A. Preserved core 18.8 ft.

Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-58 J.O. 004128-0013 SHEET: 13 OF 18

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT Logged by: CS
Client: Massachusetts Water Resources Authority

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY / RQD	SPT N VALUE	USC SYMBOL OR PEN. RATE	SAMPLE DESCRIPTION
-165	290	OR	30	100 / 97			ARGILLITE, gray, mod. hard, sl. weathered; bedding laminar, 75 deg.; some to numerous hairline calcite and qts. veins, parallel to bedding ot 60 - 75 deg. opp. bedding; closely spaced joints. 290.9 - 40 deg. joint, rough, sl. pyrite. 291.7 - 40 deg. joint, along calcite vein, smooth, sl. pyrite. 292.5 - 45 deg. joint, steeped, sl.pyrite. 292.7 - 20 deg. joint, rough, sl. pyrite. 293.6 - 40 deg. joint, along calcite vein, smooth, sl. gray clay. 294.9 - 45 deg. joint aong calcite vein, rough, sl. gray clay.
-170	295						295.9 - 30 deg. joint, along calcite vein, rough, sl. gray clay. Note: core barrel jammed at 297.0
		OR	31	100 / 100			TUFFACEOUS ARGILLITE, greenish gray and gray, mottled, mod. hard, sl. weathered, unbedded 297.4 - contact with ARGILLITE, gray, mod. hard; faintly laminar, 65 - 75 deg.; 297.3 - 65 deg. joint, along calcite vein, smooth, sl. gray clay coating, sl. pyrite. 299.2 - ARGILLITE grades into TUFFACEOUS ARGILLITE, same as above; numerous low angle calcite veins. 299.5 - 40 deg joint, rough, sl. pyrite.
-175	300	NQ	32	100 / 100			TUFFACEOUS ARGILLITE, greenish gray to gray, mottled, mod.hard, sl. weathered; laminar to med. bedded, 35 deg.; qts. and calcite veins, 70 deg. occasionally 40 deg. 300.6 - 10 deg. joint and 40 deg. joint, rough, sl. pyrite. 301.2 - 45 deg. joint, along calcite vein, smooth, sl. pyrite.
-180	305	NQ	33	47 / 47			Note: core barrel blocked at 304.2 TUFFACEOUS ARGILLITE, greenish gray to gray, mottled, mod. hard, sl. weathered; bedding laminar to med., 35 deg.; grading into ARGILLACEOUS TUFF, greenish gray, mod. hard, sl. weathered; core badly broken by drilling, core jammed in bit during length of run.
-185	310	OR	34	100 / 97		2.4	ARGILLACEOUS TUFF, yellowish-greenish gray, mod. hard, sl. weathered. 311.1 - ARGILLITE, gray, mod. hard, sl. weathered; bedding laminar, 50 - 55 deg.. 311.5 - 50 deg. joint, rough, slickensides. 311.8 - 55 deg. joint, rough, slickensides. 312.2 to 313.5 - ARGILLITE grades into TUFFACEOUS ARGILLITE, same as above, some to numerous qts. veins, varous directions. 312.3 - 45 deg. joint, rough, slickensides, sl. pyrite. 313.5 - DIABASE, yellow-greenish gray, pillowed and brecciated at contact; numerous qts. veins, dip 50 - 60 deg. and other directions. 314.2 - 30 deg. joint, rough, sl. pyrite.

NOTES: Packer Testing - Performed over length of rock boring. LDE-58 is located on Nut Island; elevation estimated. Asterak (*) indicates not to standard (300# hammer used). Insitu testing 6 ft. away in LDE-58A. Preserved core 18.8 ft.

Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-58 J.O. 004128-0013 SHEET: 14 OF 18

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT Logged by: CS
Client: Massachusetts Water Resources Authority

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY / RQD	SPT N VALUE	USC SYMBOL OF PEN. RATE	SAMPLE DESCRIPTION
	315						315.6 - 25-20 deg. joint, rough, sl. pyrite.
-190							316.5 - 45 deg. joint, along qts. vein, rough, chlorite coating. 318.0 to 320.0 - numerous greenish yellow veins of epidote, chlorite, serpentine and qts., concentrated in two bands, 30 deg. and 50 deg. opp. direction of the first band. 318.2 - 30 deg. joint, along calcite vein, rough, sl. pyrite.
	320	NQ	35	100 / 93			DIABASE, gray, fine grained to med. grained, hard, sl. weathered; numerous greenish yellow epidotised parallel veins, generally 30 - 40 deg. and 50 - 65 deg.; occasional to some qts. and calcite veins, 40 deg., cross cutting epidotised veins or layers; Mod. close to closely spaced joints.
-195							
	325						325.3 - 40 deg. joint, rough, serpentine coating.
-200							329.1 to 329.5 - 90-80 deg. joint, rough, sl. pyrite. 329.8 - 40 deg. joint, rough, sl. pyrite coating.
	330	NQ	36	100 / 82			DIABASE, gray, med. grained, hard, sl. weathered; occasional greenish yellow epidote-chloritised veins, very thin, 0 - 40 deg.; occasional to some calcite veins, 50 - 70 deg.; closely spaced joints. 330.6 - 25 deg. joint, rough, sl. pyrite. 330.7 - 25 deg. joint, rough, sl. pyrite 331.2 - 60 deg. joint, smooth, slickensides. 331.8 - horizontal joint, rough, sl. pyrite. 332.4 - 5 deg. joint, rough, sl. pyrite. 333.1 - horizontal joint, rough, sl. epidote.
-205							
	335						335.5 - 30 deg. joint, rough, sl. pyrite 335.7 - 35 deg. joint, rough, sl. epidote. 335.7 to 336.7 - 3 parallel joints, 70 - 90 deg., rough, slickensides. 336.7 - 10 deg. joint, rough, sl.pyrite.
-210							338.9 - 70 deg. joint, intersecting 45 deg. joint, rough, slickensides, epidote. 339.2 - 80 deg. joint, along qts. vein, rough, slickensides. 340.0 - 5 deg. joint, rough, along weathered calcite vein.

NOTES: Packer Testing - Performed over length of rock boring. LDE-58 is located on Nut Island; elevation estimated. Asterak (*) indicates not to standard (300# hammer used). Insitu testing 6 ft. away in LDE-58A. Preserved core 18.8 ft.

Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-58 J.O. 004128-0013 SHEET: 15 OF 18

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT Logged by: CS
Client: Massachusetts Water Resources Authority

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY / RQD	SPT N VALUE	USC SYMBOL OR PEN. RATE	SAMPLE DESCRIPTION
	340	OR	37	100 ---- 90			**DIABASE**, gray, med. grained, hard, sl. weathered; occasional greenish yellow epidote-chloritised veins, very thin; occasional to numerous qts. and calcite veins, 60 - 70 deg.; mod. close to closely spaced joints. 340.9 - horizontal joint, rough, sl. pyrite.
-215							342.5 - 35 deg. joint, rough, slickensides. 343.6 - 35 deg. joint, slickensides, chlorite.
	345						
-220							347.3 - 70 deg. joint, rough, slickensides 348.6 - 70 deg. joint, sl. pyrite. 349.0 - 45 deg. joint, rough, slickensides. 349.1 to 349.7 - 70-85 deg. joint, rough, slickensides. **DIABASE**, gray, med. grained, hard, sl. weathered; some black veins, 60 deg.
	350	NQ	38	100 ---- 82		4.0- 4.5	350.9 - **ARGILLITE**, gray, mod. hard, sl. weathered; bedding laminar, 40 - 55 deg.; some calcite and qts. veins, parallel to bedding or 35 - 50 deg. opp. bedding; upper contact broken by drilling. 351.3 - 40 deg. joint, smooth, slickensides. 351.5 - 30 deg. joint, smooth, slickensides. 351.6 - 35 deg. joint, smooth, slickensides. 351.9 - 30 deg. joint, smooth, slickensides. 352.1 - 40 deg. joint, smooth, slickensides. 352.4 to 353.1 - core badly broken by drilling 353.7 - 30 deg. joint, smooth, slickensides.
-225	355						354.0 - **FELSITE**, greenish gray, fine grained, mod. hard, sl. weathered; brecciated from contact to 356.2; contact with argillite is 50 deg.. 354.0 to 354.4 - Core badly broken by drilling.
-230		NQ	39	100 ---- 57		2.0- 2.5	**ARGILLITE**, gray, mod. hard, sl. weathered; bedding laminar, 80 deg.; contact with felsite above, not observed; numerous hairthin calcite veins; closely spaced joints. 357.3 - 50 deg. joint, smooth, slickensides. 357.5 - 40 deg. joint, smooth, slickensides. 358.1 - 30 deg. joint, smooth, sl. discoloration. 358.9 - 30 deg. joint, smooth, sl. discoloration. 359.0 to 360.0 - core badly broken by drilling.
	360	OR	40	99 ---- 93		10.0	**ARGILLITE**, gray, mod. hard, sl. weathered; bedding laminar, irregular, slumped, 45-60, and 70 deg.; occasional to some calcite veins, parallel to bedding. 360.0 to 360.4 - 75 deg. joint, rough, chlorite coating. 360.5 - 35 deg. joint, smooth, sl. pyrite, sl. chlorite coating. 361.0 - 40 deg. joint, smooth, slickensides.
-235							361.7 to 367.5 - **FELSITE SILL**, greenish gray, fine grained, mod. hard, sl. weathered; contact with argillite, 50 deg., sl. brecciated; numerous qts. veins, 60 - 80 deg., tends to fracture along veins.

NOTES: Packer Testing - Performed over length of rock boring. LDE-58 is located on Nut Island; elevation estimated. Astersk (*) indicates not to standard (300# hammer used). Insitu testing 6 ft. away in LDE-58A. Preserved core 18.8 ft.

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT Logged by: CS
Client: Massachusetts Water Resources Authority

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY ------- RQD	SPT N VALUE	USC SYMBOL OF PEN. RATE	SAMPLE DESCRIPTION
	365						365.5 - 45 deg. joint, along calcite vein, smooth, sl. pyrite.
-240							
		OR	41	100 ---- 60		5.0	FELSITE, greenish gray, fine grained, mod. hard, sl. weathered.
							368.5 to 370.0 - ARGILLITE, gray, mod. hard, sl weathered; bedding laminar, 55- 45 deg.; numerous breaks due to drilling. 369.1 - 25 deg. joint, sl. gray green mineralization. 369.5 - 40 deg. joint, rough, weathered qts. coating
	370	OR	42	100 ---- 100		2.5	ARGILLITE, gray, mod. hard, sl. weathered; bedding laminar to very thin, 40 - 60 deg.; some bedding slumped and offset along calcite veins; occasional to numerous calcite and qts. veins, parallel to bedding and 25 - 40 deg. opp. bedding and 80 - 90 deg.; widely spaced joints. 371.75 - 45 deg. joint, opp. bedding, green mineralization.
-245							
	375						
-250							
	380	NQ	43	100 ---- 98			ARGILLITE, gray, mod. hard, sl. weathered; bedding laminar to very thin, 380.0 to 385.4 - 50-55 deg.; 385.4 to 388.5 - 50-60 deg.; 388.5 to 390.0 - 70-80 deg.; some bedding slumped; some bedding offset; occasional calcite veins, parallel to bedding, and 30-45 deg. opp. bedding; mod. close to closely spaced joints. 380.3 - 20 deg. joint, rough, pyrite coating. 380.5 - 25 deg. joint, rough, sl. pyrite coating.
-255							
							383.3 - 15 deg. joint, smooth, sl. pyrite.
	385						
-260							386.1 - 1/2" wide Felsite vein, pyrite rich.
							389.8 - 25 deg. joint, smooth, pyrite coating.

NOTES: Packer Testing - Performed over length of rock boring. LDE-58 is located on Nut Island; elevation estimated. Asterisk (*) indicates not to standard (300# hammer used). Insitu testing 6 ft. away in LDE-58A. Preserved core 18.8 ft.

Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-58 J.O. 004128-0013 SHEET: 17 OF 18

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT Logged by: CS
Client: Massachusetts Water Resources Authority

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY ------- RQD	SPT N VALUE	USC SYMBOL OR PEN. RATE	SAMPLE DESCRIPTION
-265 -270	390 395	OR	44	98 ---- 96		2.0	**ARGILLITE**, gray, mod. hard, sl. weathered; bedding laminar, 390.0 to 390.7 - 70-80 deg.; 391.9 to 393.1 - 70-50 deg.; 393.1 to 395.0 - 50-45 deg.; 395.0 bedding reverses 180 deg., 25 deg., 395.0 to 400.0 25-40 deg. and slumped; some bedding offsets along hairline calcite veins, 35-50 deg. and 10-15 deg.; occasional to numerous calcite and qts. veins, 40-60 deg. opp. bedding or parallel to bedding, mod. closely spaced joints. 390.0 - 60 deg. joint, rough, along calcite and qts. vein, sl. pyrite. 398.6 - horizontal joint, rough, sl. pyrite. 398.9 - 10 deg. joint, rough, sl.pyrite.
-275 -280	400 405	NQ	45	100 ---- 97		3.0	**ARGILLITE**, gray, mod. hard, sl. weathered; bedding laminar, 30 - 60 deg.; some to numerous calcite and qts. veins, paralllel to bedding. 403.4 - 85 deg. joint, stepped, chalky. 403.5 to 403.7 - Fracture zone, weathered calcite, sl. pyrite. 403.7 to 410.0 - **FELSITE**, greenish gray, mod. hard, sl. weathered; contact with argillite, 10 deg opp. bedding; numeous qts. and calcite veins, 10 - 30 deg. and 50 - 60 deg. 404.4 - 90 deg. joint, stepped, chalky. 404.4 - 35 deg. joint, rough, sl. pyrite. 406.8 - 55 deg. joint, rough, slickensides, sl. gray clay coating. **FELSITE**, same as above, occasional qts. veins.
-285	410	OR	46	100 ---- 93			410.6 to 411.0 - contact of FELSITE with ARGILLITE, 80 deg., offset along qts. veins. **ARGILLITE**, gray, mod. hard, sl. weathered; bedding laminar but mostly slumped, some 30 deg.; some calcite veins. 410.9 - 20 deg. joint, along qts. vein, rough, sl. pyrite. 412.3 - 30 deg. joint, along calcite vein, rough, sl. pyrite. 412.45 - 30 deg. joint, along calcite vein, rough, sl. pyrite. 412.7 - 30 deg. joint, along calcite vein, smooth, sl. pyrite 413.0 - 20 deg. joint, along calcite vein, rough, pyrite coatin. 413.7 to 419.4 - **FELSITE**, greenish gray, mod. hard, sl. weathered; contact distinct, 30 deg. same as argillite bedding; some to numerous qts. and calcite veins, 10 - 15 deg.

NOTES: Packer Testing - Performed over length of rock boring. LDE-58 is located on Nut Island; elevation estimated. Astersk (*) indicates not to standard (300# hammer used). Insitu testing 6 ft. away in LDE-58A. Preserved core 18.8 ft.

Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-58 J.O. 004128-0013 SHEET: 18 OF 18

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT Logged by: CS
Client: Massachusetts Water Resources Authority

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY ------- RQD	SPT N VALUE	USC SYMBOL OF PEN. RATE	SAMPLE DESCRIPTION
	415						and 50 - 60 deg.
-290							417.0 - 1" qts. vein, 50 - 75 deg.
							FELSITE, same as above.
		NQ	47	100 ---- 99			419.7 to 422.4 - FELSITE and ARGILLITE, same as above, in fault contact, dipping 70 - 90 deg., vertical fracture occasionaly offset by calcite veins. 420.6 - 70 deg. joint, rough, sl. pyrite. 421.1 - 20 deg. joint, rough, sl. pyrite.
	420						
-295							422.3 - 15 deg. joint, stepped along contact, sl. pyrite. 422.4 - 15 deg. joint, smooth, sl. pyrite.
	425						
-300							ARGILLITE, gray, mod. hard, sl. weathered; bedding laminar, 15 deg. to 60 deg., bedding is dragged along contact with FELSITE and fracture at 428.8; numerous qts. and calcite veins, 0-20 deg. or parallel to bedding; mod. closely spaced joints.
							END OF BORING @ 429.4 ft.

NOTES: Packer Testing - Performed over length of rock boring. LDE-58 is located on Nut Island; elevation estimated. Asterak (*) indicates not to standard (300# hammer used). Insitu testing 6 ft. away in LDE-58A. Preserved core 18.8 ft.

Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-69 J.O. 004128-0013 SHEET: 1 OF 5

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT
Client: Massachusetts Water Resources Authority

Logged by: CS
Date Start - Finish: 3/27/89 - 3/29/89

Coordinates: N: 466553.19 ft. E: 747762.54 ft. (NAD 27)
Ground Elevation: 123.5 ft.
Ground Water Elev.: 110.4 ft.
Depth to Bedrock: 92.5 ft.
Total Depth Drilled: 103.0 ft.
Drill Contractor: GUILD DRILLING
Driller: GB
Rig Type: CME-55

Methods:
Casing Used:
Drilling Soil: 3 7/8" Tricone Roller Bit; 2 7/8" Tricone Roller Bit.
Sampling Soil: 2" Split Spoon (SPT), 3" Split Spoon
Drilling Rock: NX Diamond Drill & NX Double Core Barrel

Comments: An astersk indicates not to standard (300# hammer used). Observation well installed to 103.0 ft.; One falling head permeability test.

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY .... RQD	SPT N VALUE	USC SYMBOL OR PEN. RATE	SAMPLE DESCRIPTION
123.5	0	SS	1	2-3 6-11 r6	9	FILL	**FILL**: Brown sandy **SILT**, with 40-50% fine to coarse **SAND**; 5% fine to coarse gravel.
120	5	SS	2	2-2 2-1 r2	4	FILL	**FILL**: Brownish-gray **GRAVEL & SAND**: fine to coarse gravel; 10-15% fine to coarse sand. S3 2, recovery for a 3 in. spoon sample (second attempt to improve recovery) was r=10 in.
115	10	S3	3	*6-*5 *6-*7 r4		FILL	**FILL**: as above except 5% sand.
110		S3	4	*8-*6 *7 r6		FILL	**FILL**: Yellowish-brown fine **SAND** with 40% **SILT**; 5-10% coarse sand; 5% fine to coarse gravel.

LEGEND/NOTES:

Datum is MDC sewer Datum (USGS datum plus 105.62 ft)

Blows = number of blows required to drive sample spoon 6" or distance shown.

r = inches of soil sample recovery.

RECOVERY = % of rock core recovery.

RQD = Rock Quality Designation

SPT N = Standard Penetration Test resistance to driving, blows/ft.

USC = Unified Soil Classification system.

Coordinates are in the 1927 Massachusetts State Plane Grid System.

Pen. Rate = coring penetration rate in min./ft.

SAMPLE TYPE:
- SS = Standard Split Spoon
- S3 = 3" Split Spoon
- UO = Osterberg
- NX = Rock Core
- NQ = Wireline Rock Core
- OR = Oriented Core
- US = Shelby
- UF = Fixed Piston

Approved/Date
7/28/89

Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-69 J.O. 004128-0013 SHEET: 2 OF 5

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT   Logged by: CS
Client: Massachusetts Water Resources Authority

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE NO.	BLOWS OR RECOVERY ------- RQD	SPT N VALUE	USC SYMBOL OF PEN. RATE	SAMPLE DESCRIPTION
	15						FILL: Yellowish-brown fine SAND with 40% SILT; 5-10% coarse sand; 5% fine to coarse gravel. 15.5 - BOULDER
105		SS	5	*30-*12 *12-*11		FILL	FILL: Yellowish-brown fine to coarse SAND: 5% fine to coarse gravel. FILL: Yellowish-brown SAND; 15-20% silt; 15% medium sand; 5% coarse sand; trace gravel. SS 5, recovery of soil sample r=8 in.
	20						
100							Silty gray SAND @ 23.0 ft.
		SS	6	16-15 16-17 r22	31	SM/ ML	SAND: gray, fine grained; 50% SILT; trace fine to coarse gravel. Gray & olive brown mottled, sandy clayey SILT: 30% fine to medium sand; 20% clay; trace fine gravel.
	25						CLAY CONTENT INCREASES AS SAND CONTENT DECREASES FROM 26 TO 29 FT.
95		SS	7	14-20 25-43 r22	45	CL	CLAY: Gray, silty, areas oxidized brown; 45-65% SILT; marine CLAY. CLAY: gray, silty, as above; much more highly oxidized to brown.
	30						CHANGE FROM VERY STIFF TO STIFF CLAY AT 32.0 FT.
90		SS	8	11-7 6-7 r24	13	ML- CL	CLAY: Olive gray clayey SILT; 20-35% clay; a few oxidized brown planes.
	35	UF	9	PUSHED r6		ML/ GC	Yellowish-brown clayey silty SAND & GRAVEL; 40% fine gravel; 30% fine to coarse sand; 15% clay and silt.
85		SS	10	20-23 21-19 r10	44	GC	SAND & GRAVEL: as above; 35% fine gravel; 20% clay.

NOTES: An astersk indicates not to standard (300# hammer used). Observation well installed to 103.0 ft.; One falling head permeability test.

Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-69 J.O. 004128-0013 SHEET: 3 OF 5

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT   Logged by: CS
Client: Massachusetts Water Resources Authority

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY ------- RQD	SPT N VALUE	USC SYMBOL OF PEN. RATE	SAMPLE DESCRIPTION
	40					CL	TILL: Olive gray silty CLAY to clayey SILT: 45-55% SILT; 35% CLAY; 10-20% fine sand; trace fine gravel; trace medium to coarse sand.
80							
	45	SS	11	12-18 24-26 r12	42	CL	TILL: Silty CLAY to clayey SILT, gray; little fine to coarse gravel; trace medium to coarse sand; gravel lens @ 44.0, 3" thick.
75							
	50	SS	12	31-26 26-50 r8	52	CL	TILL: as above; 10-20% gravel.
70							
	55	SS	13	16-21 26-57 r11	47	CL	TILL: as above, 5-10% gravel.
65							
	60	SS	14	26-26 40-66 r14	66	CL	TILL: as above, 20-25% fine to coarse gravel.
60							
		SS	15	25-30 35-44 r24	65	CL	TILL: as above, a few highly weathered pieces of coarse gravel.

NOTES: An astersk indicates not to standard (300# hammer used). Observation well installed to 103.0 ft.; One falling head permeability test.

Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-69 J.O. 004128-0013 SHEET: 4 OF 5

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT   Logged by: CS
Client: Massachusetts Water Resources Authority

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY ------- RQD	SPT N VALUE	USC SYMBOL or PEN. RATE	SAMPLE DESCRIPTION
	65						TILL: Silty CLAY to clayey SILT, gray; little fine to coarse gravel; trace medium to coarse sand; a few highly weathered pieces of coarse gravel.
55							
		SS	16	31-40 120 r7	160	CL	TILL: olive gray, silty CLAY to clayey SILT
	70						BOULDER from 70.5-71.5 ft. (roller bit)
50							
		SS	17	41-53 55-57 r17	108	CL	TILL: olive gray, silty CLAY to clayey SILT FALLING HEAD PERM TEST from 74.0 ft.to 76.0 ft.
	75						
45							
		SS	18	150/6" r2		ML-CL	TILL: as above, 50-60% GRAVEL; coarse gravel obstructing spoon.
	80						
40							
		SS	19	56-33 50-49 r24	94	ML-CL	TILL: as above, a few highly weathered pieces of coarse gravel.
	85						
35							
		SS	20	36-41 51-101	94	ML-CL	TILL: olive gray, silty CLAY to clayey SILT

NOTES: An astersk indicates not to standard (300# hammer used). Observation well installed to 103.0 ft.; One falling head permeability test.

Metcalf & Eddy, Inc.	BORING LOG	BORING LDE-69 J.O. 004128-0013 SHEET: 5 OF 5

Project: 1989 LAND BORINGS - DEER ISLAND PROJECT   Logged by: CS
Client: Massachusetts Water Resources Authority

ELEV. (ft.)	DEPTH (ft.)	SAMPLE TYPE	SAMPLE No.	BLOWS OR RECOVERY / RQD	SPT N VALUE	USC SYMBOL OF PEN. RATE	SAMPLE DESCRIPTION
	90						**TILL**: Silty CLAY, olive gray; trace gravel; trace medium to coarse sand; bottom 4" laminated clay and sand, 10% fine sand.
							TOP OF BEDROCK @ 92.5 FT.
30		NX	1	98 / 90		4.0	**ARGILLITE**, gray, medium hard, sl. weathered; bedding laminar, 75 - 90 deg.; very close to mod. closely spaced fractures; fissured.
	95						
25		NX	2	92 / 74		4.0	**ARGILLITE**: as above, some slumping, soft sediment brecciation, slight bedding offset, fractured; 0.2 ft. *of highly weathered* argillite, decomposed to sandy CLAY.
	100						
							END OF BORING @ 103.0 ft.

NOTES: An astersk indicates not to standard (300# hammer used). Observation well installed to 103.0 ft.; One falling head permeability test.

METCALF & EDDY, Inc	BORING SUMMARY LOG	BORING 88-26 SHEET 1 OF 6

PROJECT: INTER-ISLAND CONVEYANCE TUNNEL
CLIENT: Massachusetts Water Resources Authority
Coordinates: N: 2949841.90 ft. E: 803749.70 ft.

Sea Floor Elevation: 98.4 ft.
Total Depth Drilled: 442.0 ft.

DESCRIPTION: MAIN	DESCRIPTION: DETAIL	Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load I_s 50	Pressure Test K = cm/sec (x 0.00001)
TILL, gravel, angular to sub-rounded; sand, brownish gray to gray, mostly coarse.		0, 10, 20, 30, 40, 50	98.4, 95, 90, 85, 80, 75, 70, 65, 60, 55, 50, 45, 40				
CLAY, olive green to gray, high plasticity, mod. firm; some silty clay.		60, 70	35, 30, 25				

NOTES: Nine 21 ft. packer tests, injection pressures of 50, 100, and 200 p.s.i. below 300 ft., 30, 60, and 120 p.s.i. above 300 ft.; Point load tests were diametral, * indicates test perpendicular to bedding, + indicates axial

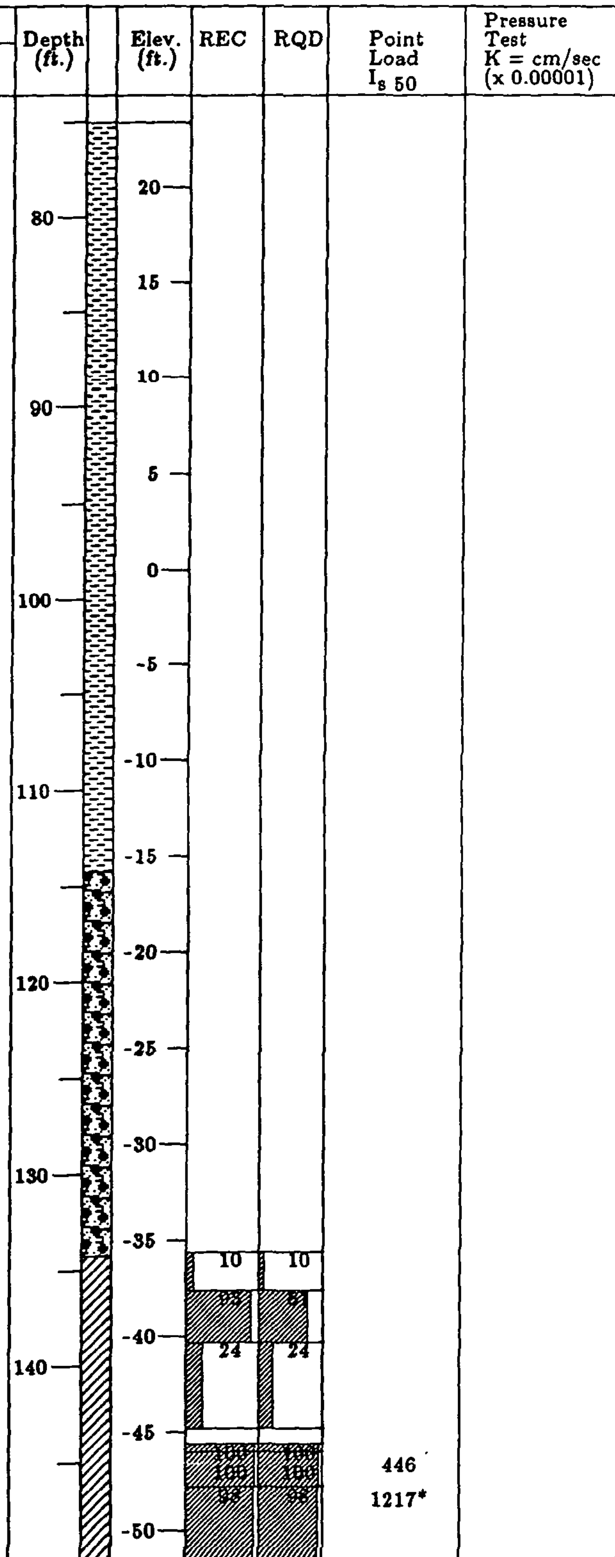
METCALF & EDDY, Inc

BORING SUMMARY LOG

PROJECT: **INTER-ISLAND CONVEYANCE TUNNEL**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 2949841.90 ft. E: 803749.70 ft.**

Sea Floor Elevation: 98.4 ft.
Total Depth Drilled: 442.0 ft.

DESCRIPTION — MAIN	DESCRIPTION — DETAIL
CLAY, olive green to gray, high plasticity, mod. firm; some silty clay. (same as previous page)	
TILL, gravel and coarse sand, medium to fine sand; some to little clay.	
ARGILLITE, dk. gray, mod. hard, unweathered; bedding thin to laminar, 5 - 20 deg., some is slumped; some calcite veins, 70 - 90 deg., offset by some 40 - 60 deg. 134.0 to 139.0 - Mod. close to very closely spaced joints. 139.0 to 197.0 - Only one joint, all other breaks due to drilling, some of which break along calcite veins.	TOP OF BEDROCK 143.2 to 144.0 - Drill with roller bit.



NOTES: Nine 21 ft. packer tests, injection pressures of 50, 100, and 200 p.s.i. below 300 ft., 30, 60, and 120 p.s.i. above 300 ft.; Point load tests were diametral, * indicates test perpendicular to bedding, + indicates axial

METCALF & EDDY, Inc	BORING SUMMARY LOG	BORING 88-26 SHEET 3 OF 6

PROJECT: INTER-ISLAND CONVEYANCE TUNNEL — Sea Floor Elevation: 98.4 ft.
CLIENT: Massachusetts Water Resources Authority — Total Depth Drilled: 442.0 ft.
Coordinates: N: 2949841.90 ft. E: 803749.70 ft.

DESCRIPTION

MAIN

ARGILLITE, dk. gray, mod. hard, unweathered; bedding thin to laminar, 5 - 20 deg., some is slumped; some calcite veins, 70 - 90 deg., offset by some 40 - 60 deg. (same as sheet 2)
139.0 to 197.0 - only one joint, all other breaks due to drilling, some of which break along calcite veins.

197.0 to 214.2 - Mod. close to very closely spaced joints and bedding plane separations; generally joints are 30 - 40 deg. opposite bedding.

214.2 to 248.0 - No natural fractures.

DETAIL

166.8 to 167.0 - Sandy Argillite, some argillite clasts

185.8 to 185.9 - Pyrite rich zone.

Elev. (ft.) (approx.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
-58	100	100		
-61			1725*	
-64	100	100		
-68	82	75	1952	
-77	100	100	624 670*	
-78	90	90		
-89	96	96	373 1321*	
-99	100	100	328	
-104	99	99		
-109			1613 530*	
-114	100	92		
-117			688 554*	
-124	100	100		50.0

Depth (ft.): 150, 160, 170, 180, 190, 200, 210, 220
Elev. (ft.): -55, -60, -65, -70, -75, -80, -85, -90, -95, -100, -105, -110, -115, -120, -125

NOTES: Nine 21 ft. packer tests, injection pressures of 50, 100, and 200 p.s.i. below 300 ft., 30, 60, and 120 p.s.i. above 300 ft.; Point load tests were diametral, * indicates test perpendicular to bedding, + indicates axial

METCALF & EDDY, Inc

BORING SUMMARY LOG

PROJECT: *INTER-ISLAND CONVEYANCE TUNNEL*
CLIENT: Massachusetts Water Resources Authority
Coordinates: N: 2949841.90 ft. E: 803749.70 ft.

Sea Floor Elevation: 98.4 ft.
Total Depth Drilled: 442.0 ft.

DESCRIPTION — MAIN	DETAIL
ARGILLITE, dk. gray, mod. hard, unweathered; bedding thin to laminar, 5 - 20 deg., some is slumped; some calcite veins, 70 - 90 deg., offset by some 40 - 60 deg. (same as sheet 2)	
248.0 to 256.0 - Mod. closely spaced joints.	
256.0 to 269.0 - No natural joints.	
269.0 to 277.0 - Very close to mod. closely spaced joints and bedding plane separations.	
ARGILLITE, dk. gray, mod. hard, unweathered; bedding mostly slumped; apparent dip quite variable, usually 20 - 50 deg. and 60 - 90 deg.; occasional to some calcite veins, various directions, usually 10 - 30 deg. and 50 - 60 deg. opposite bedding. 277.0 to 376.0 - Mod. close to closely spaced joints and bedding plane separations, pyrite and FeO2 stain on surfaces; joints generally 30 - 50 deg. opposite bedding.	

Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
	-130	100	100	835 413*	
230					
	-135				
	-140	100	100	183 1508*	
240					
	-145				50.0
	-150	100	100	210 1688*	
250					
	-155	100	100		
	-160	100	100		
260					
	-165				30.0
	-170	100	85	732	
270					
	-175				
	-180	100	100	150	
280					
	-185				20.0
	-190	100	85	559 774*	
290					
	-195	100	100		
	-200			380 1050*	

NOTES: Nine 21 ft. packer tests, injection pressures of 50, 100, and 200 p.s.i. below 300 ft., 30, 60, and 120 p.s.i. above 300 ft.; Point load tests were diametral, * indicates test perpendicular to bedding, + indicates axial

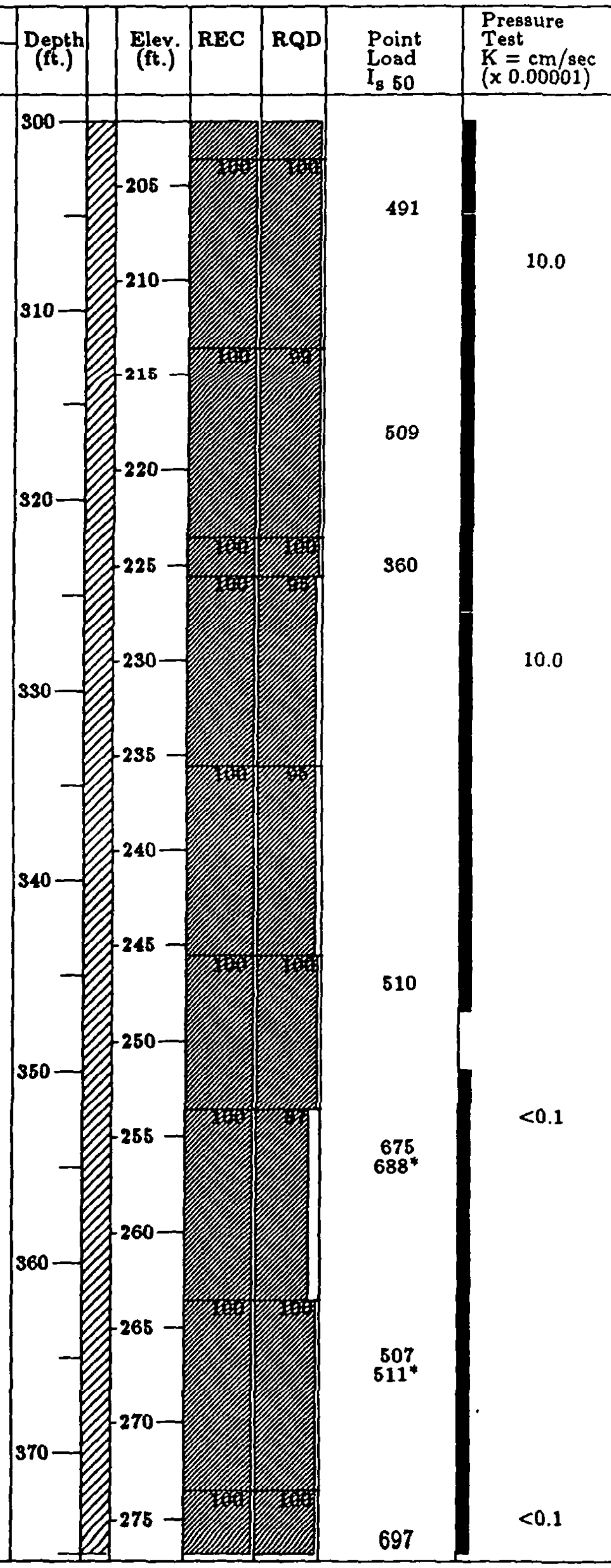
METCALF & EDDY, Inc

BORING SUMMARY LOG

PROJECT: INTER-ISLAND CONVEYANCE TUNNEL
CLIENT: Massachusetts Water Resources Authority
Coordinates: N: 2949841.90 ft. E: 803749.70 ft.

Sea Floor Elevation: 98.4 ft.
Total Depth Drilled: 442.0 ft.

DESCRIPTION — MAIN	DESCRIPTION — DETAIL
ARGILLITE, dk. gray, mod. hard, unweathered; bedding mostly slumped; apparent dip quite variable, usually 20 - 50 deg. and 60 - 90 deg.; occasional to some calcite veins, various directions, usually 10 - 30 deg. and 50 - 60 deg. opposite bedding. (same as sheet 4) 277.0 to 376.0 - Mod. close to closely spaced joints and bedding plane separations, pyrite and FeO2 stain on surfaces; joints generally 30 - 50 deg. opposite bedding.	302.0 to 322.0 - Argillite with Sandy Argillite, dk. gray, mod. hard, unweathered, bedding similiar as argillite.



NOTES: Nine 21 ft. packer tests, injection pressures of 50, 100, and 200 p.s.i. below 300 ft., 30, 60, and 120 p.s.i. above 300 ft.; Point load tests were diametral, * indicates test perpendicular to bedding, + indicates axial

METCALF & EDDY, Inc

BORING SUMMARY LOG

PROJECT: INTER-ISLAND CONVEYANCE TUNNEL
CLIENT: Massachusetts Water Resources Authority
Coordinates: N: 2949841.90 ft. E: 803749.70 ft.

Sea Floor Elevation: 98.4 ft.
Total Depth Drilled: 442.0 ft.

DESCRIPTION — MAIN	DESCRIPTION — DETAIL	Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
ARGILLITE, dk. gray, mod. hard, unweathered; bedding mostly slumped; apparent dip quite variable, usually 20 - 50 deg. and 60 - 90 deg.; occasional to some calcite veins, various directions, usually 10 - 30 deg. and 50 - 60 deg. opposite bedding. (same as sheet 4) 376.0 to 404.0 - No natural fractures.		380	280			539	
			285	100	100	263 2176*	<0.1
	387.5 to 388.0 - Coarser grained beds with pyrite throughout; similar beds at 396.9 to 397.3, 400.6 to 401.1, and 403.0 to 404.0.	390	290				
			295	100	100	477	
		400	300				
404.0 to 440.0 - Closely spaced bedding plane separations with slight clay coating, mod. close to widely spread apart groups.			305	100	94	429 1491*	
		410	310				
			315	100	100	409	
		420	320			673	
			325	100	100		
		430	330				
			335	100	100		
		440	340				
442.0 - END OF BORING							

NOTES: Nine 21 ft. packer tests, injection pressures of 50, 100, and 200 p.s.i. below 300 ft., 30, 60, and 120 p.s.i. above 300 ft.; Point load tests were diametral, * indicates test perpendicular to bedding, + indicates axial

METCALF & EDDY, Inc

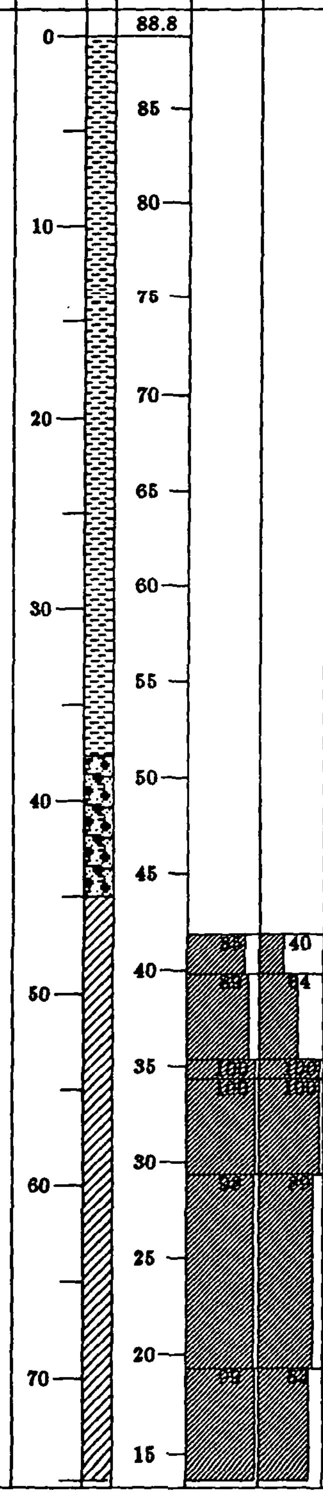
BORING SUMMARY LOG

BORING 88-27
SHEET 1 OF 6

PROJECT: INTER-ISLAND CONVEYANCE TUNNEL
CLIENT: Massachusetts Water Resources Authority
Coordinates: N: 2941696.90 ft. E: 803751.70 ft.

Sea Floor Elevation: 88.8 ft.
Total Depth Drilled: 395.0 ft.

DESCRIPTION — MAIN	DESCRIPTION — DETAIL	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
CLAY, gray, some silt, trace fine sand, plastic.			
TILL, medium to coarse gravel in gray clay matrix with some coarse sand.			
ARGILLITE, gray, mod. hard, unweathered; bedding laminar 0 - 20 deg., some slumped bedding; closely spaced joints and bedding plane separations, occasional joints near vertical.	TOP OF BEDROCK	530 663*	
		868 754*	
		1209 1043*	



NOTES: Seven 21 ft. packer tests, injection pressures of 50, 100, and 200 psi below 300 ft., 30, 60, and 120 psi. above 300 ft.; Point Load tests were diametral, * indicates test perpendicular to bedding, + indicates axial.

METCALF & EDDY, Inc

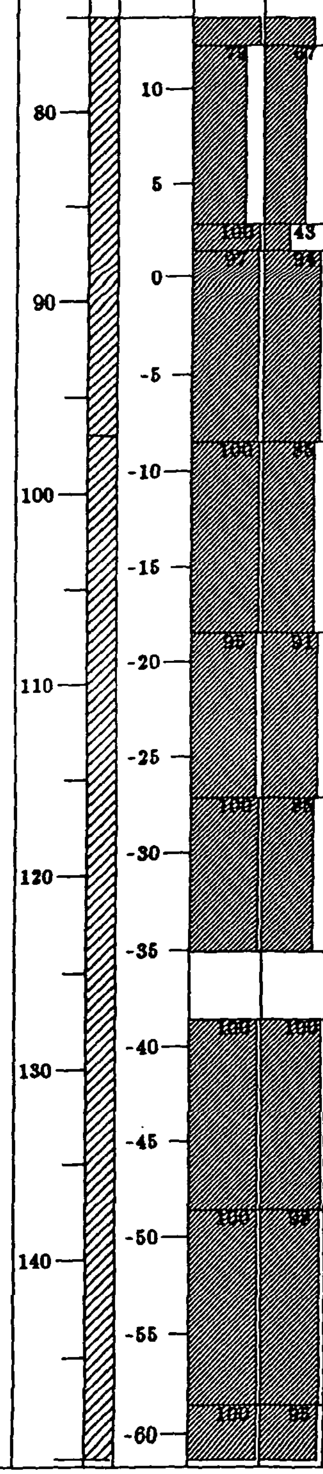
BORING SUMMARY LOG

BORING 88-27
SHEET 2 OF 6

PROJECT: INTER-ISLAND CONVEYANCE TUNNEL
CLIENT: Massachusetts Water Resources Authority
Coordinates: N: 2941696.90 ft. E: 803751.70 ft.

Sea Floor Elevation: 88.8 ft.
Total Depth Drilled: 395.0 ft.

DESCRIPTION — MAIN	DESCRIPTION — DETAIL	Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
						930 394*	
						652 1600	
ARGILLITE, gray, mod. hard, unweathered; bedding laminar 10 - 40 deg., mostly 20 - 30 deg.; occasional to some calcite veins, 40 - 80 deg. across bedding. *97.0 to 141.0* - mod. close to widely spaced joints.						1021 854*	
						527 622*	
						156 756*	
ARGILLITE, gray, mod. hard, unweathered; bedding laminar 10 - 40 deg., mostly 20 - 30 deg.; occasional to some calcite veins, 40 - 80 deg. across bedding. (same as sheet 2)						1608 630*	
141.0 to 206.1 - Mod. close to widely spaced weathered bedding plane separations, sl. clay coatings.	140.5 to 140.7 - Fracture zone, some clay.					1232 516*	



NOTES: Seven 21 ft. packer tests, injection pressures of 50, 100, and 200 psi below 300 ft., 30, 60, and 120 psi. above 300 ft.; Point Load tests were diametral, * indicates test perpendicular to bedding, + indicates axial.

METCALF & EDDY, Inc

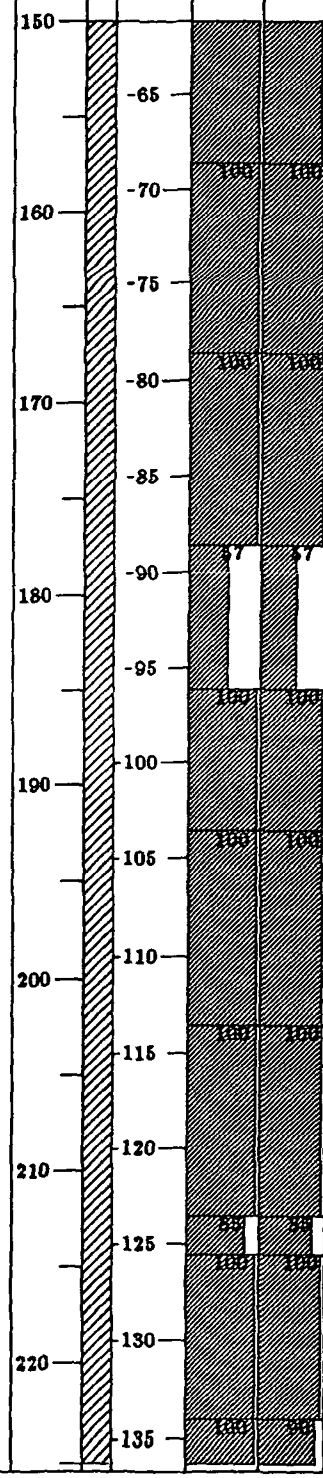
BORING SUMMARY LOG

BORING 88-27
SHEET 3 OF 6

PROJECT: INTER-ISLAND CONVEYANCE TUNNEL
CLIENT: Massachusetts Water Resources Authority
Coordinates: N: 2941696.90 ft. E: 803751.70 ft.

Sea Floor Elevation: 88.8 ft.
Total Depth Drilled: 395.0 ft.

DESCRIPTION — MAIN	DESCRIPTION — DETAIL	Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
206.1 to 239.0 - closely spaced joints, 10 - 20 deg. and 65 to 70 deg., opp. bedding, sl. clay coatings; mod. close bedding plane separations, clay coatings.		150–225				600 851 905* 1123 1438 773 256 128* 1019 675 542*	



NOTES: Seven 21 ft. packer tests, injection pressures of 50, 100, and 200 psi below 300 ft., 30, 60, and 120 psi. above 300 ft.; Point Load tests were diametral, * indicates test perpendicular to bedding, + indicates axial.

METCALF & EDDY, Inc

M&E

BORING SUMMARY LOG

BORING 88-27
SHEET 4 OF 6

PROJECT: INTER-ISLAND CONVEYANCE TUNNEL
CLIENT: Massachusetts Water Resources Authority
Coordinates: N: 2941696.90 ft. E: 803751.70 ft.

Sea Floor Elevation: 88.8 ft.
Total Depth Drilled: 395.0 ft.

DESCRIPTION

MAIN	DETAIL
ARGILLITE, gray, mod. hard, unweathered; bedding laminar 10 - 40 deg., mostly 20 - 30 deg.; occasional to some calcite veins, 40 - 80 deg. across bedding. (same as sheet 2)	
239.0 to 256.0 - wide to mod. closely spaced joints, 20 deg., gray clay coatings; close to medium spaced bedding plane separations, weathered.	
256.0 to 300.0 - no natural fractures, all breaks due to drilling, some opened along previously healed fractures.	SANDY ARGILLITE beds at 257.2 , 258.8 to 259.4, and 267.6.

Depth (ft.): 230, 240, 250, 260, 270, 280, 290

Elev. (ft.): 140, 145, 150, 155, 160, 165, 170, 175, 180, 185, 190, 195, 200, 205, 210

REC	RQD
100	98
100	100
100	100
100	97
100	97
100	100
100	100
100	100
100	80

Point Load $I_{s\,50}$: 176, 643*, 81, 1705*, 796, 585, 1503, 307, 647

Pressure Test K = cm/sec (x 0.00001): 20.0, 30.0, 2.0, 10.0

NOTES: Seven 21 ft. packer tests, injection pressures of 50, 100, and 200 psi below 300 ft., 30, 60, and 120 psi. above 300 ft.; Point Load tests were diametral, * indicates test perpendicular to bedding, + indicates axial.

METCALF & EDDY, Inc

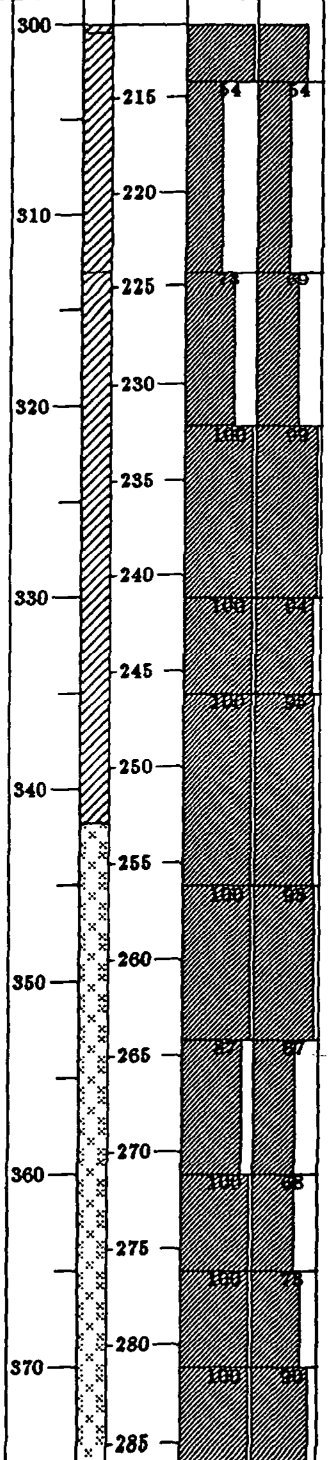
BORING SUMMARY LOG

PROJECT: INTER-ISLAND CONVEYANCE TUNNEL
CLIENT: *Massachusetts Water Resources Authority*
Coordinates: N: 2941696.90 ft. E: 803751.70 ft.

Sea Floor Elevation: 88.8 ft.
Total Depth Drilled: 395.0 ft.

DESCRIPTION — MAIN	DESCRIPTION — DETAIL
ARGILLITE, gray, mod. hard, unweathered; bedding thin to laminar, 60 - 75 deg., some slumped bedding; some calcite and quartz veins; mod. close bedding plane separations, occasionally sl. weathering; mod. close to closely spaced joints, 60 - 70 deg. same as bedding.	
ARGILLITE, gray, mod. hard, unweathered; bedding thin to laminar, 60 - 75 deg., some slumped bedding; occasional to some calcite veins, 40 - 70 deg.; close to mod. closely spaced joints and bedding plane separations, some with clay coatings, joints generally 60 deg. opp. bedding.	
DIABASE, gray, aphanitic but coarsens with depth, massive, mod. hard to hard, unweathered; numerous qtz. and calcite veins; layers of argillite interbedded, 3 - 5 ft. wide.	353.0 to 354.4 - Fracture zone, planar and rough, some clay. 366.0 to 368.0 - ARGILLITE, gray, mod. hard, unweathered. 368.0 to 371.3 - ALTERED ARGILLITE AND DIABASE, near vertical contact, some qtz. veins.

Depth (ft.) | Elev. (ft.) | REC | RQD



Point Load $I_{s\,50}$: 176; 325; 225, 1118*; 1645, 1051; 875, 1452; 91, 1230

Pressure Test K = cm/sec (x 0.00001): >100.0; >100.0; 0.5

NOTES: Seven 21 ft. packer tests, injection pressures of 50, 100, and 200 psi below 300 ft., 30, 60, and 120 psi. above 300 ft.; Point Load tests were diametral, * indicates test perpendicular to bedding, + indicates axial.

METCALF & EDDY, Inc

BORING SUMMARY LOG

BORING 88-27
SHEET 6 OF 6

PROJECT: INTER-ISLAND CONVEYANCE TUNNEL
CLIENT: Massachusetts Water Resources Authority
Coordinates: N: 2941696.90 ft. E: 803751.70 ft.

Sea Floor Elevation: 88.8 ft.
Total Depth Drilled: 395.0 ft.

DESCRIPTION — MAIN	DETAIL	Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
DIABASE, gray aphanitic but coarsens with depth, massive, mod. hard to hard, unweathered. (same as sheet 5)		380	-290, -295	100, 100	100, 98	662, 1360, 785, 2194	
ARGILLITE, gray, mod. hard, unweathered; bedding laminar, 45 deg., some bedding altered, easily separated along bedding planes.		390	-300, -305	100	30	425	
395.0 - END OF BORING							

NOTES: Seven 21 ft. packer tests, injection pressures of 50, 100, and 200 psi below 300 ft., 30, 60, and 120 psi. above 300 ft.; Point Load tests were diametral, * indicates test perpendicular to bedding, + indicates axial.

METCALF & EDDY, Inc

BORING SUMMARY LOG

BORING 88-28

PROJECT: **INTER-ISLAND CONVEYANCE TUNNEL**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 2933179.60 ft. E: 803656.50 ft.**

Sea Floor Elevation: **82.7 ft.**
Total Depth Drilled: **307.0 ft.**

DESCRIPTION — MAIN	DESCRIPTION — DETAIL	Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
			82.7				
		0	80				
CLAY, greenish gray, dense, plastic.			75				
		10	70				
			65				
		20	60				
			55				
		30	50				
			45				
		40	40				
			35				
TILL, hard angular gravel, coarse to fine sand, some silt, loose.		50	30				
			25				
		60	20				
			15				
		70	10				

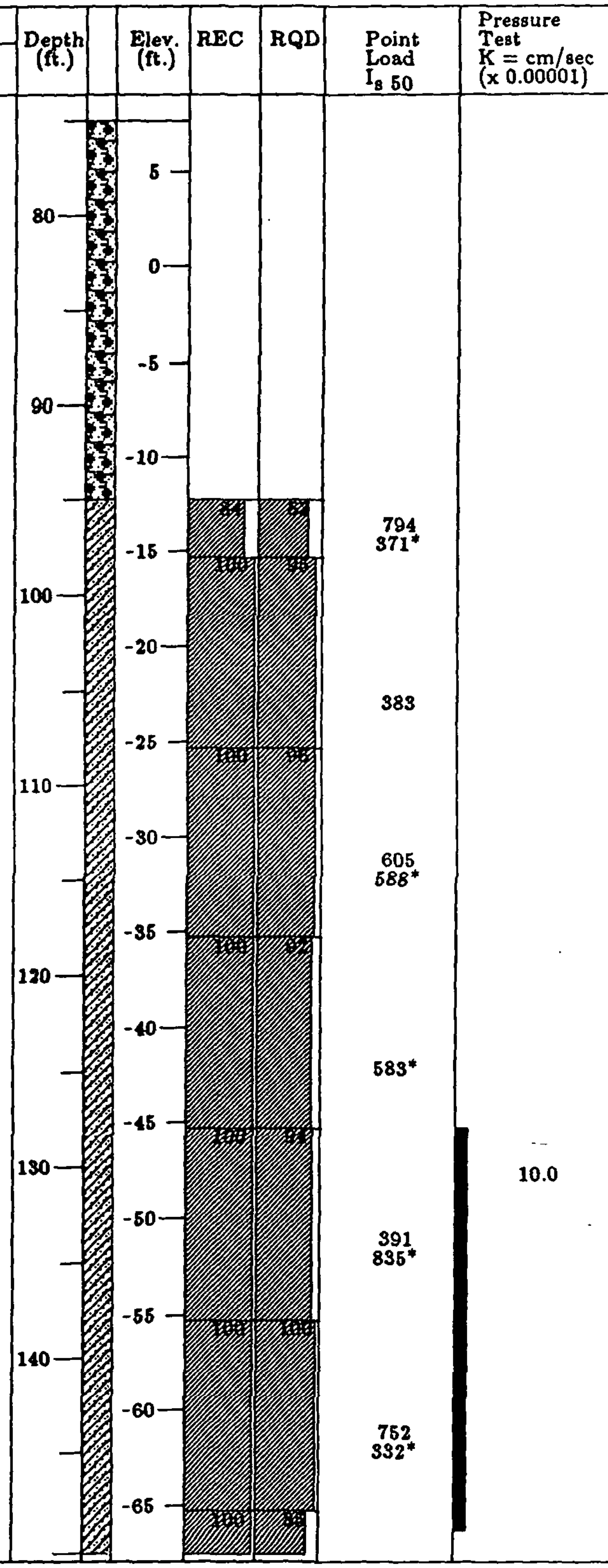
NOTES: Four 21 ft. packer tests, injection pressures of 50, 100, and 200 psi below 300 ft., 30, 60, and 120 psi above 300 ft.; Point Load Tests were diametral, * indicates test perpendicular to bedding, + indicates axial test.

METCALF & EDDY, Inc	BORING SUMMARY LOG	BORING 88-28 SHEET 2 OF 5

PROJECT: INTER-ISLAND CONVEYANCE TUNNEL
CLIENT: Massachusetts Water Resources Authority
Coordinates: N: 2933179.60 ft. E: 803656.50 ft.

Sea Floor Elevation: 82.7 ft.
Total Depth Drilled: 307.0 ft.

DESCRIPTION — MAIN	DESCRIPTION — DETAIL
ARGILLITE WITH SANDY ARGILLITE, gray, mod. hard, unweathered; bedding very thin to laminar, 5 - 25 deg.; occasional quarts veins, irregular. 95.0 to 151.7 - close to very closely spaced joints, mostly bedding plane separations; joints 50 -75 deg.; clay coated and stained surfaces.	TOP OF BEDROCK



NOTES: Four 21 ft. packer tests, injection pressures of 50, 100, and 200 psi below 300 ft., 30, 60, and 120 psi above 300 ft.; Point Load Tests were diametral, * indicates test perpendicular to bedding, + indicates axial test.

METCALF & EDDY, Inc M&E	BORING SUMMARY LOG	BORING 88-28 SHEET 3 OF 5

PROJECT: INTER-ISLAND CONVEYANCE TUNNEL
CLIENT: Massachusetts Water Resources Authority
Coordinates: N: 2933179.60 ft. E: 803656.50 ft.

Sea Floor Elevation: 82.7 ft.
Total Depth Drilled: 307.0 ft.

DESCRIPTION

MAIN	DETAIL
ARGILLITE WITH SANDY ARGILLITE, gray, mod. hard, unweathered; sandy argillite is medium grained with clear to white qtz. and green chlorite; bedding very thin to laminar, 5 - 25 deg.; occasional quartz veins, irregular. (same as previous page) 151.7 to 182.5 - mod. close to closely spaced joints and bedding plane separations; 50 - 70 deg., some in conjugate sets.	
ARGILLITE INTERBEDDED WITH SANDY ARGILLITE, purplish gray, mod. hard; bedding thin to laminar, 10 - 20 deg.; occasional to some healed fractures, clay filled; some coarse qtz. veins; mod. close bedding plane separations, clay coated; mod. close joints, 60 to 70 deg.	193.2 to 193.7 - Sl. Kaolinized zone, coarse sandy layer at base.

Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
150					
	-70	100	100	481*	
	-75	100	100		
160	-80			774	
	-85	100	100		
170	-90			683 316*	4.0
	-95	100	95		
180				301*	
	-100				
	-105				
190	-110	90	80	398 444*	
	-115	100	99		
200	-120				
	-125	100	100		
210	-130			412	
	-135	100	98		
220	-140				

NOTES: Four 21 ft. packer tests, injection pressures of 50, 100, and 200 psi below 300 ft., 30, 60, and 120 psi above 300 ft.; Point Load Tests were diametral, * indicates test perpendicular to bedding, + indicates axial test.

METCALF & EDDY, Inc

BORING SUMMARY LOG

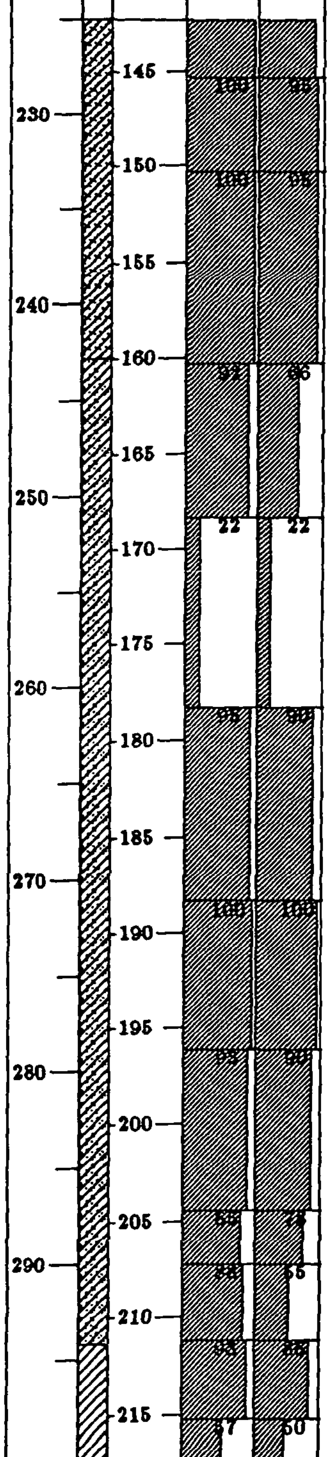
BORING 88-28
SHEET 4 OF 5

PROJECT: INTER-ISLAND CONVEYANCE TUNNEL
CLIENT: Massachusetts Water Resources Authority
Coordinates: N: 2933179.60 ft. E: 803656.50 ft.

Sea Floor Elevation: 82.7 ft.
Total Depth Drilled: 307.0 ft.

DESCRIPTION

MAIN	DETAIL
ARGILLITE INTERBEDDED WITH SANDY ARGILLITE, purplish gray, mod. hard; bedding thin to laminar, 10 - 20 deg.; occasional to some healed fractures, clay filled; some coarse qts. veins; mod. close bedding plane separations, clay coated; mod. close joints, 60 to 70 deg. (same as sheet 3)	228.9 to 229.4 - IGNEOUS INTRUSION, along bedding surface, 70 deg., kaolinized boundaries.
ARGILLITE with SANDY ARGILLITE, interbedded; mod. hard, unweathered; bedding very thin to laminar, irregular: 10 - 45 deg.; occasional hairline quartz veins; mod. close to closely spaced joints, generally 50 - 70 deg. 261.0 to 285.0 - close to moderately close spaced bedding plane separations, clay coatings, usually between argillite and sandy argillite layers.	246.0 to 246.4 - Fracture Zone, weathered, some clay. 281.0 to 281.1 - WEATHERED ARGILLITE, pinkish purple, parallel to bedding. 287.1 - LOST CIRCULATION.
ARGILLITE, gray, mod. hard, unweathered; bedding very thin to laminar, 30 - 60 deg.; closely spaced clay filled bedding plane separations; mod. close to closely	



Point Load I_{s} 50	Pressure Test K = cm/sec (x 0.00001)
388 353*	
358 633*	<0.1
478	
	<0.1
576 422*	
	20.0
336 565*	

NOTES: Four 21 ft. packer tests, injection pressures of 50, 100, and 200 psi below 300 ft., 30, 60, and 120 psi above 300 ft.; Point Load Tests were diametral, * indicates test perpendicular to bedding, + indicates axial test.

METCALF & EDDY, Inc

BORING SUMMARY LOG

BORING 88-28
SHEET 5 OF 5

PROJECT: INTER-ISLAND CONVEYANCE TUNNEL
CLIENT: Massachusetts Water Resources Authority
Coordinates: N: 2933179.60 ft. E: 803656.50 ft.

Sea Floor Elevation: 82.7 ft.
Total Depth Drilled: 307.0 ft.

DESCRIPTION		Depth (ft.)		Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
MAIN	DETAIL							
spaced joints, 30 deg. across bedding, with chlorite.		300		220			402	
307.0 - END OF BORING								

NOTES: Four 21 ft. packer tests, injection pressures of 50, 100, and 200 psi below 300 ft., 30, 60, and 120 psi above 300 ft.; Point Load Tests were diametral, * indicates test perpendicular to bedding, + indicates axial test.

METCALF & EDDY, Inc

M&E

BORING SUMMARY LOG

PROJECT: **INTER-ISLAND CONVEYANCE TUNNEL**
CLIENT: **Massachusetts Water Resources Authority**
Coordinates: **N: 2928759.90 ft. E: 803838.90 ft.**

Sea Floor Elevation: **83.4 ft.**
Total Depth Drilled: **347.0 ft.**

DESCRIPTION: MAIN	DESCRIPTION: DETAIL	Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
CLAY, blue gray, stiff, plastic; some silt.		0, 10	83.4, 80, 75, 70, 65				
TILL, boulders and hard gravel, angular to subangular; some silty clay, firm.		20, 30, 40, 50, 60	60, 55, 50, 45, 40, 35, 30, 25, 20				
ARGILLITE see next sheet for description		70	15, 10	72 56	46 60	114 318*	

NOTES: Eight packer 21 ft. packer tests, injection pressures of 50, 100, and 200 psi below 300 ft., 30, 60, and 120 psi. above 300 ft.; Point Load tests were diametral, * indicates test perpendicular to bedding, + indicates axial.

METCALF & EDDY, Inc

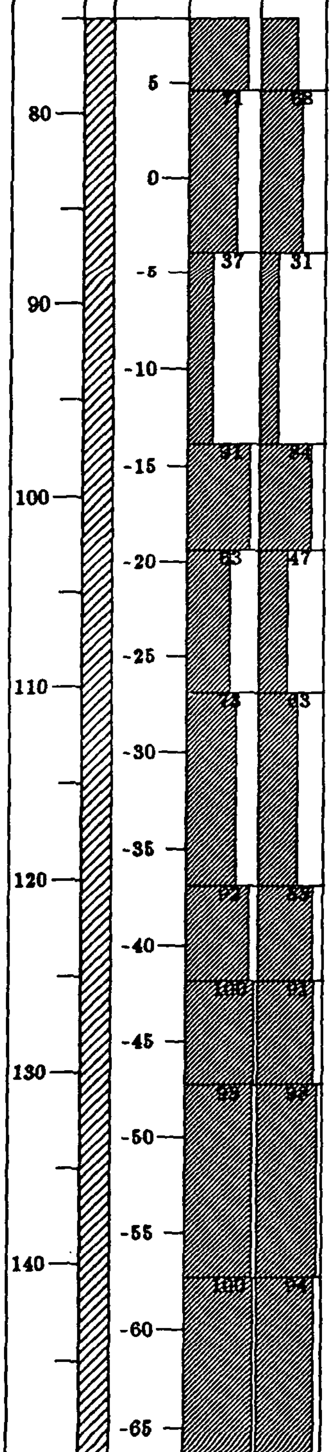
M&E

BORING SUMMARY LOG

PROJECT: INTER-ISLAND CONVEYANCE TUNNEL
CLIENT: Massachusetts Water Resources Authority
Coordinates: N: 2928759.90 ft. E: 803838.90 ft.

Sea Floor Elevation: 83.4 ft.
Total Depth Drilled: 347.0 ft.

DESCRIPTION — MAIN	DESCRIPTION — DETAIL	Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\ 50}$	Pressure Test K = cm/sec (x 0.00001)
ARGILLITE, gray green with small zones altered to white, mod. hard with softer material in "white zones", mostly unweathered; bedding very thin to laminar, 50 - 70 deg with some irregular zones up to 90 deg. and hard to distinguish; some to numerous hairline quartz veins, 20 - 70 deg.; mod. close to closely spaced joints, 65 - 90 deg. and 0 - 20 deg., greenish gray clay coating, occasional pyrite and chlorite. (same as sheet 1).	76.2 to 77.7 - Fracture Zone, 65 - 90 deg. dominant joints,/ significant green gray clay.					99 217*	
	83.1 to 83.2 - Fracture Zone, green gray clay.					137*	
						114*	
	102.0 to 102.3 - Fracture Zone.					150 152*	
	116.7 to 117.6 - Fracture Zone.					172 161*	
	132.9 to 133.3 and 137.2 to 137.6 - Argillite altered to white.					395 497*	
						250	



NOTES: Eight packer 21 ft. packer tests, injection pressures of 50, 100, and 200 psi below 300 ft., 30, 60, and 120 psi. above 300 ft.; Point Load tests were diametral, * indicates test perpendicular to bedding, + indicates axial.

METCALF & EDDY, Inc	BORING SUMMARY LOG	BORING 88-29 SHEET 3 OF 5

PROJECT: INTER-ISLAND CONVEYANCE TUNNEL — Sea Floor Elevation: 83.4 ft.
CLIENT: Massachusetts Water Resources Authority — Total Depth Drilled: 347.0 ft.
Coordinates: N: 2928759.90 ft. E: 803838.90 ft.

DESCRIPTION

MAIN

ARGILLITE, greenish gray to gray, *mod. hard; unweathered;* bedding thin to laminar, when visible, 60 - 90 deg.; numerous high angle quartz veins.
151.0 to 198.0 - Mod. close to widely spaced joint sets with *some joint* spacing very close, typically 40 - 60 deg., many with quartz and chlorite on surfaces.

198.0 to 219.0 - Widely spaced joints.

219.0 to 228.0 - Closely spaced joints, 60 to 75 deg., pyrite coatings and FeO2 stains.

DETAIL

162.4 to 167.0 - VOLCANIC ASH, lt. gray, extremely fine grained near contact with argillite.

205.6 to 206.8 - IGNEOUS LAYER, very fine grained, qtz, *feldspar contact is not* conformable with bedding.

Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load I_{s} 50	Pressure Test K = cm/sec (x 0.00001)
150		100	100		5.0
	-70			242	
	-75	100	100		
160		100	98		
	-80			337	
	-85	100	94		
170					<0.1
	-90				
		94	94	705*	
	-95				
180					
	-100	98	70		
	-105				
190		94	94		
	-110			496	<0.1
		98	98		
	-115				
200					
	-120	100	100		
		100	100	707 716*	
	-125				
210					
	-130			573	<0.1
		97	97		
	-135				
220				586 870*	
	-140	100	85		

NOTES: Eight packer 21 ft. packer tests, injection pressures of 50, 100, and 200 psi below 300 ft., 30, 60, and 120 psi. above 300 ft.; Point Load tests were diametral, * indicates test perpendicular to bedding, + indicates axial.

METCALF & EDDY, Inc

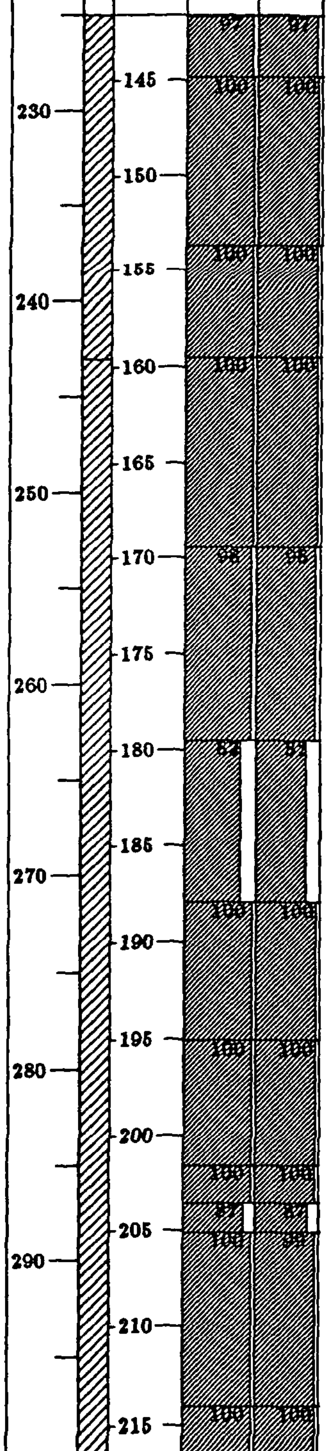
BORING SUMMARY LOG

BORING 88-29
SHEET 4 OF 5

PROJECT: INTER-ISLAND CONVEYANCE TUNNEL
CLIENT: Massachusetts Water Resources Authority
Coordinates: N: 2928759.90 ft. E: 803838.90 ft.

Sea Floor Elevation: 83.4 ft.
Total Depth Drilled: 347.0 ft.

DESCRIPTION — MAIN	DESCRIPTION — DETAIL
ARGILLITE, gray green with small zones altered to white, mod. hard with softer material in "white zones", mostly unweathered; bedding very thin to laminar, 50 - 70 deg with some irregular zones up to 90 deg. and hard to distinguish; some to numerous hairline quartz veins, 20 - 70 deg.; mod. close to closely spaced joints, 65 - 90 deg. and 0 - 20 deg., greenish gray clay coating, occasional pyrite and chlorite. (same as sheet 3) 228.0 to 243.0 - No natural joints, all breaks due to drilling.	
ARGILLITE, greenish gray, mod. hard, unweathered; bedding thin to laminar, when distinct, 60 - 90 deg., generally 90 deg., but variable; occasional to so;me thin to very thin layers of igneous material; occasional to some hairline quartz, and calcite veins. 243.0 to 285.0 - mod. close to widely spaced joints	247.3 to 248.6 - IGNEOUS INTRUSION 259.0 to 260.8 - ALTERED ARGILLITE, lt. greenish gray, small veins of igneous material, baked contact. 260.8 to 262.0 - IGNEOUS INTRUSION, fine grained, lt. tan, large pyrite crystals.
285.0 to 302.0 - widely spaced joints.	283.3 to 284.3 - two FELSITE layers, 0.4 ft., fine grained, abundant fine pyrite.



Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
671 591*	<0.1
781 1132*	
677 783*	0.9
432 767*	0.3
528	
469 330*	<0.1

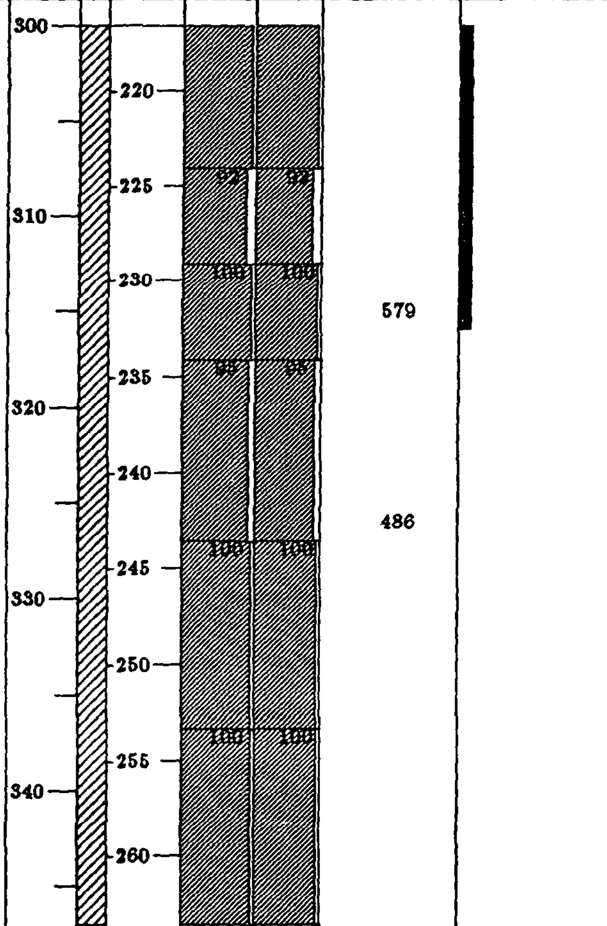
NOTES: Eight packer 21 ft. packer tests, injection pressures of 50, 100, and 200 psi below 300 ft., 30, 60, and 120 psi. above 300 ft.; Point Load tests were diametral, * indicates test perpendicular to bedding, + indicates axial.

METCALF & EDDY, Inc	BORING SUMMARY LOG	BORING 88-29 SHEET 5 OF 5

PROJECT: INTER-ISLAND CONVEYANCE TUNNEL
CLIENT: Massachusetts Water Resources Authority
Coordinates: N: 2928759.90 ft. E: 803838.90 ft.

Sea Floor Elevation: 83.4 ft.
Total Depth Drilled: 347.0 ft.

DESCRIPTION		Depth (ft.)		Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
MAIN	DETAIL							
302.0 to 347.0 - Mod. close to closely spaced joints, typically 30 deg with lt. brown to gray stain.								
							579	
							486	
	327.5 to 327.8 - ASH LAYER, sl. chill zone at base, indications of slumping at the top.							
	337.4 to 337.8 - IGNEOUS LAYER, lt. green, fine grained, small blocks of argillite, some chlorite.							
347.0 - END OF BORING								



NOTES: Eight packer 21 ft. packer tests, injection pressures of 50, 100, and 200 psi below 300 ft., 30, 60, and 120 psi. above 300 ft.; Point Load tests were diametral, * indicates test perpendicular to bedding, + indicates axial.

GOLDBERG-ZOINO & ASSOCIATES, INC.

GZA

BORING SUMMARY LOG

BORING PDE-46
SHEET 1 OF 1

PROJECT: INTER-ISLAND TUNNEL, BOSTON HARBOR — Sea Floor Elevation: 123.4 ft.
CLIENT: Massachusetts Water Resources Authority — Total Depth Drilled: 51.0 ft.
Coordinates: N: 491572.94ft. E: 746808.67ft.

DESCRIPTION: MAIN	DETAIL	Depth (ft.)	Elev. (ft.)	REC	RQD	Point Load $I_{s\,50}$	Pressure Test K = cm/sec (x 0.00001)
FILL, fine to coarse SAND, 35% gravel, 20% silt, brown		0	123.4				
FILL, fine to coarse GRAVEL, 35% clayey silt, 20% fine to coarse sand, medium dense, gray			120			17-13 8-12 R9	
FILL, fine to coarse GRAVEL, 35% fine to coarse sand, 20% silt, dense, gray		10	115			24-29 19-28 R10	
FILL, fine to coarse Gravel, 35% fine to coarse sand, 20% silt, dense, gray.			110			36-31 18-18 R14	
FILL, fine to coarse Sand, 10% fine gravel, 10% silt.			105				
FILL, fine to coarse SAND, 25% fine gravel, medium dense, gray.		20				22-11 13-8 R1	
ORGANIC SILT, 20% fine Sand, 5% fine gravel, 2% shells, dense, brown.			100			6-16 16-27 R15	
FINE SAND AND SILT, 20% Gravel, dense, gray.			95				
SILT AND FINE SAND, 5% fine to coarse Gravel, dense, yellow.		30				24-27 18-26 R12	
SILT AND CLAY, 5% fine to coarse Sand, 5% gravel, dense, yellow.			90			17-16 15-18 R3	
SILTY CLAY, 2% Gravel, stiff, olive-gray.			85			4-4 5-6 R24	
SILTY CLAY, 5% Gravel, 5% fine sand, medium stiff, olive-gray.		40				4-3 4-4 R24	
SILTY CLAY, medium stiff, olive-gray.			80			3-3 3-4 R16	
SILTY CLAY, 5% Gravel, medium stiff, olive-gray, several 1/2 in. to 1 in. pieces of gravel.		50	75			2-4 4-5 R24	
51.0 ft.: *END OF BORING*							

PDE #3

NOTES: Observation well, 30 feet deep, installed in borehole by Guild under direction of HMM. Groundwater level is affected by tide.

GUILD DRILLING CO., INC.

100 WATER STREET EAST PROVIDENCE, R I

SHEET	1 OF 2
DATE	
HOLE NO.	L-3
LINE & STA.	
OFFSET	#329
SURF. ELEV.	113.7

TO Metcalf & Eddy, Inc. ADDRESS Boston, Mass.
PROJECT NAME Land & Water Borings for /Islands LOCATION " "
REPORT SENT TO above PROJ. NO.
SAMPLES SENT TO Taken at Site OUR JOB NO 82-24

GROUND WATER OBSERVATIONS

At ________ after ______ Hours

At ________ after ______ Hours

Rods-"BW"

	CASING	SAMPLER	CORE BAR
Type	HW	S/S	
Size I D	4"	1 3/8"	
Hammer Wt	300#	140#	BIT
Hammer Fall	24"	30"	

	Date	Time
START	7/17/81	a.m. p.m.
COMPLETE	7/21/81	a.m. p.m.
TOTAL HRS.		
BORING FOREMAN	G.Brouillette	
INSPECTOR		
SOILS ENGR.		

LOCATION OF BORING Long Island

DEPTH	Casing Blows per foot	Sample Depths From - To	Type of Sample	Blows per 6" on Sampler From 0-6	To 6-12	12-18	Moisture Density or Consist	Strata Change Elev	SOIL IDENTIFICATION Remarks include color, gradation, Type of soil etc. Rock-color, type, condition, hardness, Drilling time, seams and etc	SAMPLE No	Pen	Rec
		0'-1'6"	D	10	7	8	Dry medium dense	4'	6" Topsoil - Brown fine to medium Sand - FILL	1	18"	12"
		4'-5'6"	D	3	1	6	Wet loose	6'	Brown fine to medium SAND & course gravel, some root matter	2	18"	2"
		9'-10'6"	D	10	4	6	"		Brownsilty fine to coarse SAND & gravel	3	18"	12"
		14'-15'6"	D	7	8	7	"			4	18"	9"
		19'-20'6"	D	20	19	20	Wet dense		W/cobbles	5	18"	9"
		24'-25'6"	D	15	28	11			Fine to coarse gravel fine to coarse sand, rock fragments; silty	6	18"	0"
		29'-30'6"	D	41	31	29				7	18"	18"
				300# Weight				33'				
		34'-35'	D	11	15		Moist/ stiff	35'	Gray Br. SILTY, clay F-M sand and gravel	8	12"	9"
		35'-35'6"	D			20			Gray silty CLAY no layering	8A	6"	-
		39'-40'6"	D	5	5	7	Moist stiff			9	18"	18"

GROUND SURFACE TO 35' USED HW "CASING THEN Open to Bottom

Sample Type
D=Dry C=Cored W=Washed
UP=Undisturbed Piston
TP=Test Pit A=Auger V=Vane Test

Proportions Used
trace 0 to 10%
little 10 to 20%
some 20 to 35%

140 lb Wt. x 30" fall on 2" O D Sampler

Cohesionless Density
0-10 Loose
10-30 Med Dense
30-50 Dense

Cohesive Consistency
0-4 Soft
4-8 M/Stiff
8-15 Stiff
30 + Hard

SUMMARY
Earth Boring 75'6"
Rock Coring
Samples 17

GUILD DRILLING CO., INC.

100 WATER STREET EAST PROVIDENCE, R I

SHEET 2 OF 2
DATE
HOLE NO. L-3
LINE & STA.
OFFSET # 329
SURF. ELEV. 113.7

TO | ADDRESS
PROJECT NAME | LOCATION
REPORT SENT TO | PROJ. NO.
SAMPLES SENT TO | OUR JOB NO

GROUND WATER OBSERVATIONS		CASING	SAMPLER	CORE BAR		Date	Time
At ___ after ___ Hours	Type				START		a.m. p.m.
	Size I D				COMPLETE		a.m. p.m.
At ___ after ___ Hours	Hammer Wt			BIT	TOTAL HRS.		
	Hammer Fall				BORING FOREMAN		
					INSPECTOR		
					SOILS ENGR.		

LOCATION OF BORING

DEPTH	Casing Blows per foot	Sample Depths From - To	Type of Sample	Blows per 6" on Sampler From 0-6	To 6-12	12-18	Moisture Density or Consist	Strata Change Elev	SOIL IDENTIFICATION Remarks include color, gradation, Type of soil etc. Rock-color, type, condition, hardness, Drilling time, seams and etc	SAMPLE No	Pen	Rec
		41'-43'	UP	Shelby						UP10	24'	-
		44'-45'6"	D	3	4	5	Moist stiff		Green & Gray CLAY	11	18"	18"
		49'-51'	UP	Shelby						UP12	24'	15"
		54'-55'6"	D	1	2	5	Moist medium stiff			13	18"	18"
		59'-61'	UP	Shelby						-	24"	0"
		61'-62'6"	D	2	2	5	"			14	18"	18"
		64'-66'	UP	Shelby					Trace pebbles	15	24'	18"
		69'-70'6"	D	1	4	5	Moist stiff			16	18"	18"
								72'				
		74'-75'6"	D	15	20	56	Moist very dense	75'6"	Gray fine to coarse SAND & Gravel, some silty clay	17	18"	6"
									Bottom of Boring 75'6"			

GROUND SURFACE TO ______ USED ______ " CASING: THEN ______

Sample Type
D=Dry C=Cored W=Washed
UP=Undisturbed Piston
TP=Test Pit A=Auger V=Vane Test
UT=Undisturbed Thinwall

Proportions Used
trace 0 to 10%
little 10 to 20%
some 20 to 35%
and 35 to 50%

140 lb Wt. x 30" fall on 2" O.D. Sampler

Cohesionless Density
0-10 Loose
10-30 Med. Dense
30-50 Dense

Cohesive Consistency
0-4 Soft
4-8 M/Stiff
8-15 Stiff
30 + Hard

SUMMARY:
Earth Boring
Rock Coring
Samples

GUILD DRILLING CO., INC.

100 WATER STREET EAST PROVIDENCE, R I

SHEET 1 OF 1
DATE
HOLE NO. L-8
LINE & STA.
OFFSET #334
SURF. ELEV. 113.9

TO Metcalf & Eddy, Inc. ADDRESS Boston, Mass.
PROJECT NAME Land & Water Boring for LOCATION " "
REPORT SENT TO above /Islands PROJ. NO
SAMPLES SENT TO Taken at Site OUR JOB NO. 82-24

GROUND WATER OBSERVATIONS
At ______ after ______ Hours
At ______ after ______ Hours

Rods-"BW"	CASING	SAMPLER	CORE BAR
Type	NW	S/S	
Size: D	3"	1 3/8"	
Hammer Wt	300#	140#	BIT
Hammer Fall	24"	30"	

	Date	Time
START	7/21/81	a.m. p.m.
COMPLETE	7/21/81	a.m. p.m.

TOTAL HRS.
BORING FOREMAN G.Brouillette
INSPECTOR
SOILS ENGR.

LOCATION OF BORING Long Island

DEPTH	Casing Blows per foot	Sample Depths From - To	Type of Sample	Blows per 6" on Sampler From 0-6	6-12	To 12-18	Moisture Density or Consist	Strata Change Elev	SOIL IDENTIFICATION Remarks include color, gradation, Type of soil etc. Rock-color, type, condition, hardness, Drilling time, seams and etc	SAMPLE No	Pen	Rec
		0'-1'6"	D	4	5	14	Dry medium dense		6" Topsoil - Brown silty fine to medium Sand & Gravel FILL and rock frag.	1	18"	12"
		4'-5'6"	D	11	14	15	"		or-br silt, f-m sand, broken rock	2	18"	12"
		9'-10'6"	D	5	1	6	Wet loose	12'	br. silty f-crse sand, gravel, trace organics	3	18"	4"
		14'-15'6"	D	20	30	31	Moist very dense	18'	Brown fine to medium SAND, Gravel & Silt tr. shells, broken rock	4	18"	16"
		19'-20'6"	D	15	20	30	Moist Hard		Brown & Green silty CLAY	5	18"	18"
		24'-25'6"	D	5	7	15	Moist very stiff			6	18"	18"
		29'-30'6"	D	4	4	6	Moist stiff			7	18"	18"
		34'-35'6"	D	5	6	7	"			8	18"	18"
								38'	Boulder			
									Bottom of Boring 38'			

GROUND SURFACE TO 20' USED NW CASING THEN Open to 38'

Sample Type
D=Dry C=Cored W=Washed
UP=Undisturbed Piston
TP=Test Pit A=Auger V=Vane Test

Proportions Used
trace 0 to 10%
little 10 to 20%
some 20 to 35%

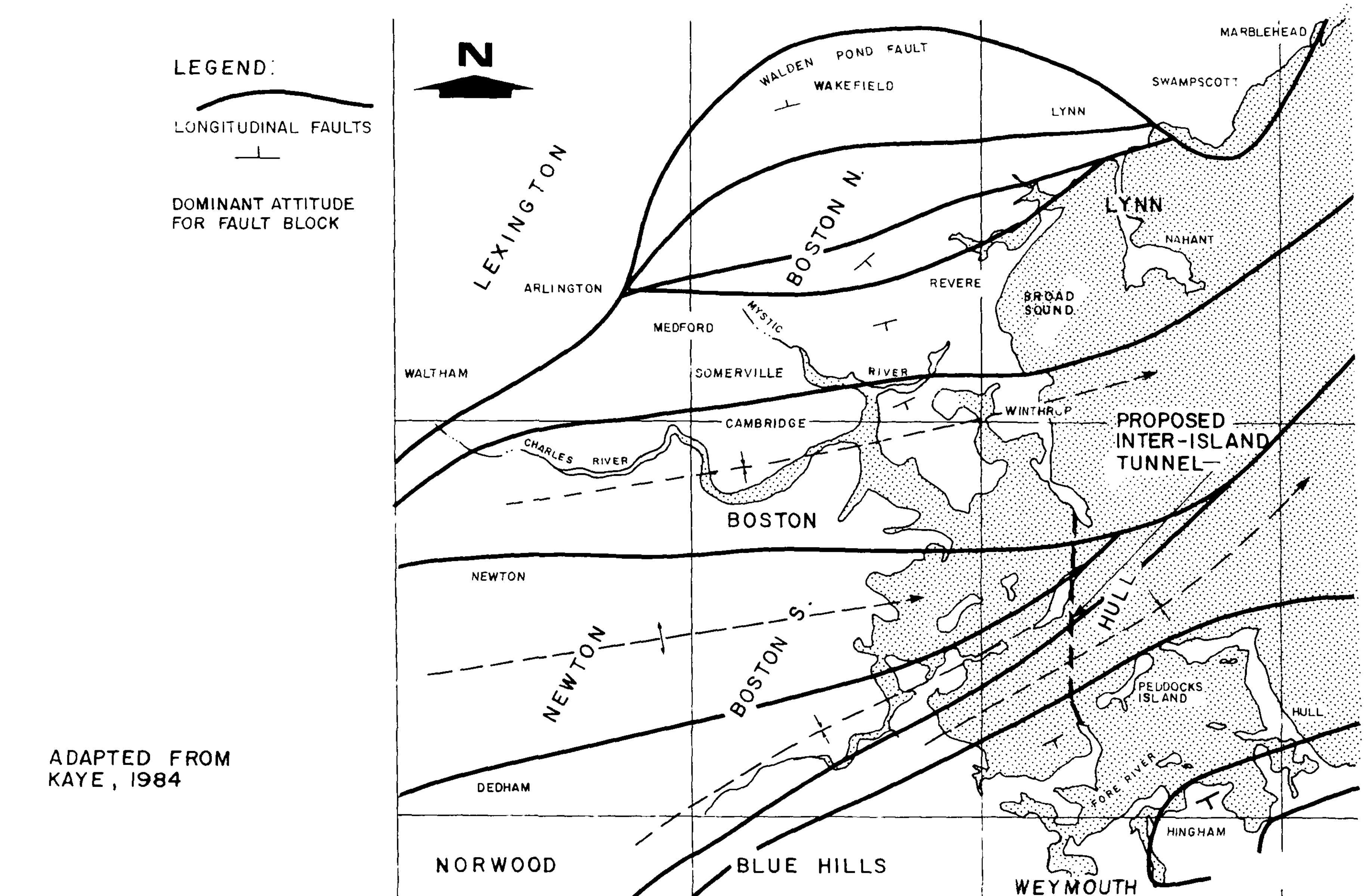
140 lb Wt. x 30" fall on 2" O.D. Sampler

Cohesionless Density
0-10 Loose
10-30 Med. Dense
30-50 Dense

Cohesive Consistency
0-4 Soft
4-8 M/Stiff
8-15 Stiff
30 + Hard

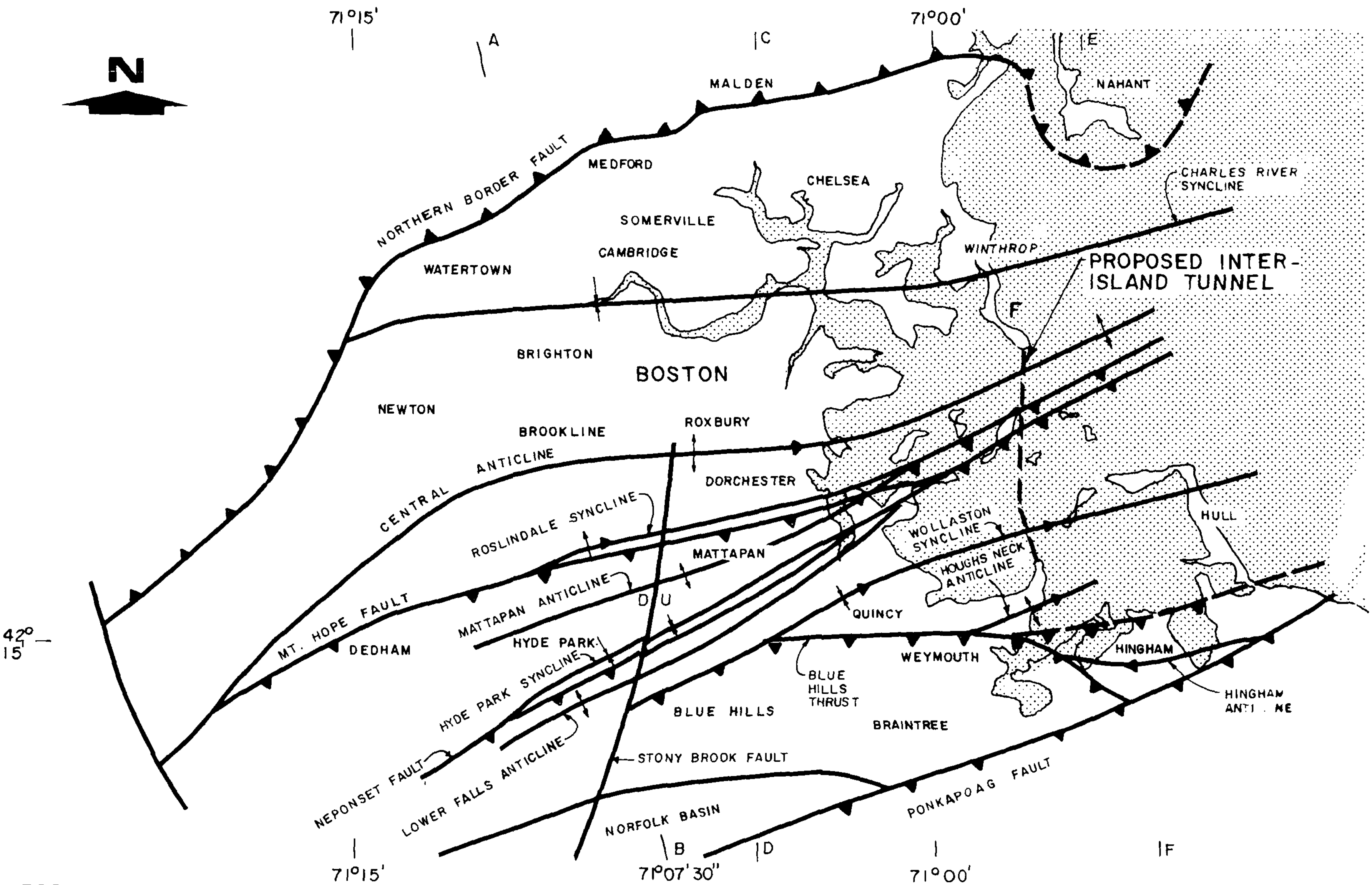
SUMMARY
Earth Boring 38'
Rock Coring
Samples 8

FILE No. U-11305.1



Sverdrup CORPORATION	In Association With Jacobs Associates Goldberg-Zoino & Associates and Delon Hampton & Associates	DP-5 INTER-ISLAND TUNNEL BOSTON HARBOR	TECTONIC MAP OF THE BOSTON BASIN NOV. 1989 FIGURE No. 3.1

FILE No. U-11305.1



ADAPTED FROM BILLINGS, 1976

Sverdrup CORPORATION	In Association With Jacobs Associates Goldberg-Zoino & Associates and Delon Hampton & Associates	DP-5 INTER-ISLAND TUNNEL BOSTON HARBOR	TECTONIC MAP OF BOSTON BASIN AND BLUE HILLS NOV. 1989 FIGURE No. 3.2