APPENDIX E
GEOTECHNICAL CONSIDERATIONS

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SECTION 1 PROJECT GEOLOGY

1.1 GEOLOGIC SETTING

Eagle Gorge Reservoir (later renamed Howard A. Hanson Dam) was authorized by the Flood Control Act of 17 May 1950 (Public Law 516, 81st Congress, 2d Session), as a flood control project. Construction began in 1958 and was completed in February 1962. First water was impounded in December 1961. The project provides for a normal maximum reservoir capacity of 106,000 acre-feet of flood pool storage at elevation 1,206 feet which is in excess of the 100 year flood occurrence. During the summer a conservation pool to augment natural low flows and to provide water for the City of Tacoma is impounded at a maximum reservoir elevation of 1,141 (occasionally up to 1,145) feet.

Howard A. Hanson Dam is located on the Green River in western Washington. The dam spans a narrow rock canyon located 5 miles inside the western Cascade margin. To the east, the Cascade Range rises sharply to elevations over 7,000 feet. The Cascades are a complex mountain system composed of sedimentary, metamorphic, and intrusive and extrusive igneous rocks. The ancestral Green River was tributary to the Cedar River drainage prior to the glaciation of the Puget Sound Lowland. Before the last glacial event the river flowed out the North Fork Valley to the Cedar. During the Pleistocene, glacial ice extended eastward up into the alpine valley headwaters. The ice and subsequent moraines diverted the proto-Green River from its North Fork Valley exit to its present course where it emerges from the Cascade Mountain front south of the North Fork Valley. The diverted river flowed on a bedrock floor at elevation 1,000 feet in the river gorge. This gorge is presently buried north of the damsite. The nearest (southwest) rim of the ancestral valley is located several hundred feet northeast of the right abutment of Howard Hanson Dam.

During subsequent interglacial periods, the Green River cut its channel approximately 150 feet deeper resulting in oversteepened side slopes and collapse of the eastern valley side. Several episodes of deposition, erosion, and landsliding may have followed. The present gorge beneath the dam was cut as a result of river blockage by the last massive slide off the northeast valley wall. Today this landslide is a major landform forming part of the right abutment of Howard Hanson Dam, Plates E-1 and E-2.

1.2 TECTONIC AND SEISMIC SETTING

The present North Cascade Range was uplifted during the Late Tertiary by a series of complex folds and faults. One such fault was the Green River fault, see Plate E-1. The fault is a west-northwest trending zone of indefinite width; its map trace is some 1,500 feet north of the dam. Active during the Miocene and/or Pliocene time the fault shows about 4,000 feet of horizontal right lateral movement through combination strike-slip and dip-slip components. Between the area of the dam and mountain front, the Green River exploits the fault zone and parallels its trace. The right abutment landslide obscures the fault trace at the dam. The fault zone probably contributed to the landslide and may be one of its causes (U.S. Army Corps of Engineers, 1983). In this area of the North Cascades, most major faults strike northwest and dip southwest. An exception is a major fault striking northeast across the damsite and dipping at high angle towards the northwest. This fault zone was dominant in the foundation of the dam structure. The dam is located in Seismic Zone 3 which corresponds to a seismic coefficient of 0.10 for the lateral earthquake force. The dam has a design earthquake analysis that identifies dynamic earthquake motions and response (U.S. Army Corps of Engineers, 1983). This engineering seismology study together with its update on page 27 in Position Paper on Seismic Hazard to Corps of Engineers Dams from Cascadian Subduction Zone Earthquakes, June 1994, USACE Seattle, Engineering District is sufficient for new construction.

1.3 SITE GEOLOGY

1.3.1 Bedrock

The Howard Hanson Dam project lies within a series of Tertiary age volcanic rocks. Locally, these rocks are known as the Eagle Gorge Andesite and regionally they correlate with the Fifes Peak formation of early Miocene age. Regional dip of the bedrock is 35° southeast. Bedrock at the project site is composed of andesitic and basaltic flows, tuffs, and breccias with associated basic and acidic dikes and sills. The entire assemblage is so faulted, sheared and hydrothermally altered that it has few mappable structures and stratigraphic patterns (U.S. Army Corps of Engineers, 1963). The Green River channel beneath the dam has been eroded in bedrock to approximately elevation 1,000 feet. The Howard Hanson Dam foundation report lists five distinct rock types found at the dam. These rock types are shown on Plate E-3 and a brief description follows:

- *Basalt*: Hard to moderately hard, dense, blocky, black, generally not badly affected by hydrothermal alteration or weathering, moderately fractured, occurring in the form of thin flows, dikes and sills.

- *Andesite*: Moderately hard, dense, dark green to dark gray, irregular to blocky fractures, sometimes massive, fine-grained to porphyritic, minor hydrothermal alteration.

- *Basalt Pyroclastics (Tuff):* Moderately hard to soft, with medium grained, dark gray tuffaceous matrix with fragments of hard dense basalt. Highly susceptible to hydrothermal alteration and weathering. This rock has a general agglomeratic texture with seams of pure tuff.

- *Andesite Pyroclastics (Tuff):* Soft, light gray, fine-grained matrix with moderately hard fragments, granular to agglomeratic texture. Generally highly altered by hydrothermal action, the rock deteriorates readily upon exposure to the atmosphere.

- *Felsite*: Hard, dense, light gray, occurs as dikes and sills.

(1) Left Abutment. The left abutment contains all of the above rock types. The bedrock is hard to moderately hard, except in the hydrothermally altered zones where the rock is predominantly soft. Bedrock is moderately to intensely fractured. Several fault and shear zones trending east-west and southeast-northwest were mapped in the canyon walls and inside the diversion tunnel during project construction.

(2) Right Abutment. At the dam, the right abutment is a short, sharp, narrow rock ridge dividing the present and ancestral Green River valleys. Bedrock rises steeply to elevation 1,150 feet, see Plate E-4, then drops away to elevation 850 feet into the ancestral valley. Bedrock is predominantly andesitic pyroclastics interspersed with zones of pure tuffs and intrusions of basaltic rocks. The rock is hydrothermally altered and weaker than most of the rock forming the left abutment.

1.3.2 Overburden

The overburden overlying left abutment rock is composed of silty, sandy gravel slopewash. On the right abutment overburden consists of landslide debris and both fluvial and lacustrine sediments.

1.3.3 Eagle Gorge Landslide (Right Abutment)

Landslide materials rest on the right abutment bedrock surface as well as fluvial and lacustrine deposits. Slide materials are composed of a heterogeneous assemblage of rock blocks as much as 20 feet in diameter and varying amounts of interstitial fine-grained material. Blocks are composed of volcanic tuffs and breccias. The slide surface rises northeastward to elevation 1,300 feet.

1.3.4 Groundwater

Rock joints and faults of various spacing and orientations occur in both abutments. Permeability within the rock depends on the width and interconnection of these features.

Groundwater originating from the adjacent hillside above the upstream left abutment has been found to be under moderate pressure. This condition was experienced in 1956 during the initial dam exploration program, again in 1960 during the construction of the existing diversion tunnel, and most recently in May, 1996, within a single exploration boring near the proposed fish passage facility footprint. The latter boring penetrated a pressurized water bearing unit at a depth of 143 feet and produced 40-gallon per minute flow at the surface. The unit was grouted 6 days later and flow was shutoff. The project crew have diverted the minor seepage draining from the overburden covered hillside south of the existing gate tower to prevent erosion of the access road. Within 200 feet south of the gate tower, the overburden covering the bedrock surface is as much as 75 feet thick.

Groundwater also occurs in the right abutment overburden materials, where at least two distinct overburden aquifers have been identified, see Section 3. Aquifer recharge is by precipitation runoff and by direct communication with the reservoir. Seepage through right abutment sediments and landslide debris had been recognized before construction of the dam. A 560-foot-long semi-impervious gravel/rock blanket was placed on the right abutment as part of the original construction to control seepage through the 2,000-foot-long ancient buried river channel (Galster, 1989).

1.4 RESERVOIR AREA

From the dam the reservoir area extends seven miles eastward up the Green River and four miles northerly up the North Fork, Plate E-1. Most of the overburden slope materials are glacial stream and lake deposits. Rocks bordering the reservoir are andesite flows, andesitic tuffs, and breccias which are typically hydrothermally altered and deeply weathered. Reservoir slope stability has not been a serious problem since water was first impounded to the conservation pool at elevation 1,141 feet in December 1961. Since the initial filling of the reservoir there have been four major flood pools that exceeded elevation 1,160 feet. The first flood occurred on 5 December 1975 with a peak of 1,175.8 feet. The second flood peaked at 1,173.6 feet on 4 December 1977. The third flood peaked at 1,167.2 feet on 1 December 1995. The fourth and maximum to date occurred on 10 February 1996 with a peak of 1,183.2 feet.

SECTION 2 RESERVOIR SLOPE STABILITY

2.1 GENERAL

Slope stability issues around the reservoir are not considered to be detrimental as there are no developed lands or structures to be threatened other than a logging road and a railroad line. Reservoir landslides of damaging magnitude are not anticipated. The entire reservoir area was mapped by geologists during the early 1980s as part of a project seismic evaluation. Their original field maps are in Geology Section files. Other available information includes drill hole and test pit data completed in 1955 for the Northern Pacific Railway relocation. This information is available in Design Memorandum No. 4 and Supplements. Project personnel routinely cruise the lake looking for new and renewed slope movement and District geotechnical staff periodically check the reservoir slopes every 5 years and document their findings by memorandum.

The reservoir rim between elevations 1,170 feet and 1,210 feet will be impacted by the proposed additional water storage project. For this reason the Seattle District geotechnical staff have made several boat trips during 1993 through 1995 to assess potential for slope failure within the proposed pool raise area. They identified zones of current and potential instability, but observed no unstable slopes that would negatively impact project safety.

2.2 SLOPE FAILURE CRITERIA

The magnitude and type of slope failures vary with height, steepness, and composition of the slopes. For glaciolacustrine materials, failure is dependent on the sand-silt-clay ratio within the deposit, and on groundwater conditions. Steep slopes in glaciolacustrine deposits tend to fail by slumping, slump-earth flow landsliding and by calving. Slopes in free draining materials such as sand and gravel erode by raveling and tend to achieve stable slopes at 1V on 3H.

2.3 PRE- AND EARLY RESERVOIR LANDSLIDES

In 1995 a literature search was made for reports documenting existing landslides in the vicinity prior to filling of the reservoir. The only slide area documented is located on the west bank of Charley Creek, and is briefly discussed in Design Memorandum 19, Supplement No. 1. Although no as-built documents were found, office correspondence suggests that the Charley Creek slide was buttressed at the toe. Slides have been occurring at this site for many years and are independent of the reservoir's existence.

Soon after initial reservoir filling, a large slide occurred along the east side of the North Fork Green River. It was a quarter-mile-long slump failure of a terrace in glaciolacustrine sediments. Numerous springs were observed at the base of the terrace at elevation 1,125 feet. The slide was in a remote area and caused no damage to the project or private facilities (Galster, 1989).

2.4 RECENT LANDSLIDES

Wave erosion accounts for most of the numerous slip-off slides along the reservoir shoreline. Only one massive rotational slide has been documented since the reservoir filling. This slide occurred in early December 1995 following a period of intense rainfall. The actual causal factor for the slide was man-induced. The crest had been loaded with rock and soil debris trucked from an area further upstream. The rotational slide occurred 1.7 miles upstream of the dam at the downstream end of a rock canyon. The landslide is located on the south bank of the reservoir in the SW1/4 of the SW1/4 of Section 35, Township 21 North , Range 8 East, (W.M.) in King County, Washington. Vehicle access to the slide area is by way of the mainline Weyerhaeuser log haul road. A turnout large enough to park several pickup trucks is located near the mile post 16.5 marker.

During earlier site reconnaissance visits in 1993 and 1994 this landslide had been considered active. It was reported that remnants of an arc failure were found at the downstream end of the gorge, just upstream from the powerline crossing. Materials exposed in the slide headwall did not show any form of bedding, but rather displayed a heterogeneous mix of silt, sand and predominantly small "fist-size" angular rock fragments, similar to materials seen in a pyroclastic mudflow. The headwall materials were noted as unconsolidated and could be easily excavated with a small hand shovel. Project personnel reported that historically, this area was used as a waste site for landslide debris which had slid onto the railroad tracks and log haul road at a point further upstream. The materials were hauled to the site and end dumped. After the waste area had been filled to capacity the area apparently was leveled. Hundreds of small trees had grown on the surface. The waste pile was estimated to be 300 feet in length, 200 feet in width, and 30 feet thick. During 1994 it was concluded that renewed sliding would not threaten the operation of the project.

The landslide may have renewed activity during a medium-sized rainfall between 28 and 30 November, 1995. The reservoir reached maximum elevation 1,167.98 feet at 2100 hours on 1 December 1995. For the 90 hours (flood event period of record) preceding the high pool, the reservoir was above elevation 1,095 feet, and through the following 90 hours the reservoir was above elevation 1,138 feet. Following the peak elevation, the reservoir was lowered at an average rate of 0.05 feet per hour for the first 10 hours. Through the next 10 hours the reservoir was lowered at an average of 0.15 feet per hour.

Maximum rate of reservoir drop averaged 0.5 feet per hour between 70 and 90 hours after the peak elevation. The rapid rate of reservoir drop may have been responsible for failure of the already unstable slope. Turbidity levels increased sharply for 2 days and decreased to normal levels 5 to 7 days following the slide. The Corps concluded that the landslide mass which still partially blocked the Green River would not produce further adverse turbidity in the reservoir. Early in 1996, the City of Tacoma reshaped the slope to avert additional slippage.

2.5 ADDITIONAL WATER STORAGE EFFECT ON RESERVOIR SLOPES

Data collected during the numerous reconnaissance boat trips have been summarized. For descriptive purposes in this document the reservoir rim was divided into topographical distinct segments A through L. See Figure E-2. Each segment is briefly discussed below.

Segment A extends from the dam northward up the North Fork Valley. This segment is characterized by steep relief. A thin veneer of glaciofluvial/lacustrine deposits consisting of silt, sand, gravel, and occasional boulders overlie andesite and basalt rock. These materials may experience minor raveling with increase pool height.

Segment B occupies the flood plain of the North Fork Green River. This area has low relief, containing river deposited sand, gravel, cobbles and boulders. Bank calving should be anticipated, but is of no threat to operation of the project.

Segment C extends from the North Fork floodplain southward to Piling Creek. Relief varies from low to steep. Here, the terraces are composed of silt, clay, sand and gravel. Multiple slumping episodes should be anticipated within the bedded silts and clays. Movement in these materials should pose no threat to operation of the project.

Segment D extends from Piling Creek southward for approximately one mile. Relief varies from low to moderate. Terraces and delta deposits are common. Paragraph 2.3 mentions slump features experienced in this area during the initial pool raise. This segment has a high potential for renewed slumping activity, but as before does not threaten operation of the project.

Segment E relief is predominantly steep. Alluvial sand fills low areas within the massive rock outcrop. Fallout of small rock blocks may occur in the canyon wall. Significant landsliding is not expected.

Segment F is generally low relief. Delta sands and gravels underlie the area. Minor toe calving and slumping are anticipated. Potentially massive slide areas above elevation

1,210 feet along the north side of the valley are considerable horizontal distances from the river, and therefore, do threaten operation of the project.

Segment G extends upstream from the mouth of Gale Creek to the elevation 1,210-foot contour crossing the Green River. Relief ranges from moderate to steep. Alluvial sand and gravel deposits and laminated clay beds conceal much of the tuffaceous bedrock. Even though the terrain is steep, landslides of significant magnitude are not anticipated. Earth and rock slippage throughout this segment should pose no threat to operation of the project.

Segment H extends from the elevation 1,210-foot contour crossing the Green River downstream to the narrow gorge discussed in segment E. Relief ranges from low to moderately steep. Alluvial sand and gravel and laminated lake beds mantle much of the andesitic rock surface. Numerous scars from old slump failures are evident. A higher pool may cause renewed slumps, but these should pose no threat to operation of the project.

Segment I occupies the opposite (south) side of the gorge across from segment E. Relief is very steep. The slope at the upstream end of the gorge is well protected with riprap. A flume on the slope discharges a significant amount of water from the railroad grade above. Further downstream the slope is predominantly rock and is not protected with riprap. Continually raveling sand and gravel should be expected. At the end of the gorge, near the powerline crossing, failure of the wasted materials should be anticipated. Landsliding related to this waste pile can be expected well into the future, but should not pose a threat to operation of the project.

Segment J extends downstream from the rock gorge to the mouth of Charley Creek. Relief throughout this area is moderately steep to very steep. Generally, the reservoir slopes are composed of alluvial sand and gravel deposits overlying laminated silt and clay beds. Bare slopes caused by slip-off slides should be expected. Also, massive shoreline slumping may occur in the initial phases of the pool raise. Both types of slide activity should have no effect on operation of the project.

Segment K comprises Charley Creek and adjacent banks. Relief is steep. Banks are composed of sand and gravel deposits and laminated silt and clay beds. The west side of Charley Creek is characterized by numerous springs. Historically, the area has experienced large slides and slumps resulting from soil saturation during rainstorms. At the same time the sediment load entering the reservoir from the upstream area has been so high that it has masked any turbidity originating in the Charley Creek slide area. As such, sliding at Charley Creek has not impacted turbidity. With an increased pool adjacent slopes will be affected. During initial inundation the temporary suspension of materials is likely, however, the material will settle out and will be diluted as water is exchanged. Charley Creek slopes are not expected to slide routinely during the dry season when water is impounded.

Segment L extends from the mouth of Charley Creek downstream to the left abutment of the dam. Relief is steep. Sand, gravel and rock rubble partially obscure the numerous outcroppings of basalt and andesite. Potential for landsliding appears low.

2.6 RAILROAD BRIDGE NO. 1 (STATION 10602+47), UPPER CROSSING OF GREEN RIVER NEAR HUMPHREY

The upper crossing is located approximately 1 mile from the beginning of the relocated railroad near Humphrey. Preconstruction boring logs are shown on Plate E-5.

2.7 RAILROAD BRIDGE NO. 2 (STATION 10757+40), CHARLEY CREEK CROSSING

Supplement No. 2 to Design Memorandum No. 4 discusses preconstruction design of the Charley Creek crossing. Preconstruction boring logs are shown on Plate E-6. The railroad is located far enough away from the reservoir as to not be considered threatened by any sloughing to occur from the proposed pool raise

SECTION 3 EFFECT OF PROPOSED 1,177-FOOT CONSERVATION POOL ON RIGHT ABUTMENT

3.1 GENERAL

The complex geologic conditions in the right abutment create a complicated reservoir seepage problem which is not totally understood from the standpoint of hydrogeology. Basically, at least two major aquifers are present with the possibility that others exist. The lower aquifer with base elevation at approximately 1,000 feet is found within the buried valley's alluvial materials. Pervious zones in the overlying glacial and slide materials form the upper aquifer. Neither the lower boundary of, nor the material making up the upper aquifer are as well defined as in the lower aquifer. This is particularly true of the slope downstream of the abutment. The lower boundary of the upper aquifer is estimated to be near elevation 1,065 feet.

Stability analyses during design for the upstream and downstream slopes were performed using the slide circle analysis. These analyses showed a minimum factor of safety of 1.41 and 1.25 for two sections through the downstream slope. The upstream slope in the blanketed area had a minimum factor of safety of 1.91 with a pool at elevation 1,080, and a minimum factor of safety of 1.6 under assumed draw-down conditions. The upstream slope in the random fill area had a minimum factor of safety of 1.67 with a pool at elevation 1,120 and a minimum factor of safety under draw-down conditions of 1.30.

3.2 SEEPAGE OBSERVATIONS

Seepage through the right abutment of the dam and its effect on the stability of the downstream right bank slope of the dam have been a basis for continued exploration and studies since the dam became operational in December 1961 (see Exhibit A for logs of wells, piezometers, and horizontal drains, and Plates E-2 and E-4 for locations). The last formal document addressing these issues was a report titled "Right Abutment Seepage", dated 15 June 1992. Initially, seepage in the right abutment was monitored using single stage piezometers. Multiple staged piezometers were introduced in June 1966. Since that time the following modifications and new installations have been completed:

- Multiple stages were installed in single staged piezometers 7, 8, 14, 16, 17, 20, 53, and 54 in 1979.
- Four new wells, 38, 39, 40, and 41, each with 3 piezometers, were installed in 1979.

- In 1986 two multi-stage piezometers (102 and 105) were installed in the right abutment, three multi-stage piezometers (101, 103, and 104) were installed in the dam embankment, and three single stage piezometers (107, 108, and 109) were installed in the downstream toe of the embankment. In addition, an old seismic instrument hole (106) in the dam embankment was converted into a single stage piezometer.

- Twelve new piezometers located in eight wells (110, 111, 112, 113, 114, 115, 117, and 118) were installed in 1993 to provide additional coverage of seepage and to replace non-functional piezometers.

- All piezometers have been automated.

In February 1965, when the pool briefly reached elevation 1,161.8 feet, a spring appeared 460 feet downstream of the dam axis on the right abutment at elevation 1,134 feet. The spring area was blanketed with gravel fill and a crib wall was constructed to support the gravel. In 1968, a 640-foot-long concrete lined drainage tunnel (adit) was constructed into the right abutment at elevation 1,100 feet to improve seepage control. The tunnel is located 200 feet downstream of the dam axis.

During the flood events of December 1995 and February 1996 significant seepage was observed along the downstream right abutment (reference Post Flood Report, Howard A. Hanson Dam Post Flood Report, dated 8 April 1997). During these events seepage was observed further downstream and lower on the slope than reported in 1965. Seepage occurred from a zone extending from weir 1 to 250 feet upstream, and from the slopes behind the two gabion walls, see Plate E-2. Flow quantities were measured from five individual locations for the February 1996 flood. Flows peaked from these locations shortly after the initiation of data collection on 11 February. Weir 1 peaked at nearly 1,000 gallon per minute (gpm) on 9 and 10 February 1996. Based on visual observations of flows running overland and seepage exiting the abutment slope, it is estimated that about 80 percent of the flow through weir 1 was due to seepage and 20 percent due to surface runoff. Weir 2, located farther downstream, peaked at about 550 gpm on 8 and 9 February 1996 with nearly 100 percent of the flow due to surface runoff.

Flows from the drainage tunnel peaked at about 1,150 gpm for the February 1996 flood. Flows measured at well 37 were about 200 gpm, at well 25 were about 11 gpm, at well 34 were about 120 gpm, and at well 35 were about 60 gpm Approximately 800 gpm of the total 1,150 gpm were transmitted through the tunnel gravel floor drain. Water was also observed flowing from the concrete joint just upstream of the tunnel bend and well 25. This water was carrying fines (classified as ML by NPD Laboratory) and had a turbidity of 819 NTU. The data for well 25 exhibits a distinct double peak; the first occurring midday on 10 February and the second at midday on 11 February. It is believed that the first peak is a precipitation response due to infiltration along the rock slope just above the tunnel, and that the second peak is a pool response.

An area of special concern exists between well 25 (elbow of drainage tunnel) and the right abutment/embankment contact. Monitoring of piezometers and wells in the upper aquifer of this area during the February 1996 flood (peak pool elevation of 1,183.2 feet) confirmed the assumption that initial flows through this portion of the abutment are precipitation related. This assumption is validated by the fact that piezometers peak 14 to 18 hours before the flood pool peaks and well 25 peaked 10 hours and again 34.5 hours after the pool peaked. These conclusions are based on the fact that the flows initially are high during the rain storm and infiltration and then once the precipitation stops they reverse direction and flow from the pool towards the drainage tunnel. Precipitation appears to be infiltrating through the rock slope downstream of the administration building parking lot.

3.3 SEEPAGE ANALYSES

Plate E-7 shows phreatic contours for 2 summer conservation pools (reservoirs filled to 1,141 feet), one prior to the installation of the drainage tunnel (6 July 1966) and the other after the tunnel was constructed (19 May 1981). A comparison of these phreatic contours readily shows the effect of the tunnel on the abutment groundwater table. This effect is most evident when the 1,130 foot elevation contours are compared. In the outer (riverward) 600 feet of the abutment, the 1,130 foot contour for the 6 July 1966 pool is about 150 feet downstream of the present tunnel location while for the 19 May 1981 pool this contour is about 250 feet upstream of the tunnel. In the inner (upslope) portion of the abutment the 1,130 foot contour as drawn is very nearly at the same location for both pools. For summer conservation pools to elevation 1,141 feet the tunnel is apparently effective in lowering the groundwater table in the outer, more critical, portion of the abutment but has little effect on the inner part of the abutment.

A summer conservation pool to maximum elevation 1,177 feet (elevation 1,180 feet was used for this analysis) has been proposed. In order to assess the effect of storing this pool on the abutment phreatic levels, the geotechnical staff reviewed the piezometer data for previous summer pools and selected the 1987 and 1989 data as the base from which to model a theoretical projection of the effect of an elevation 1,180 foot conservation pool (reference report titled "Right Abutment Seepage" dated 15 June 1992). The phreatic contours for the upper aquifer for an elevation 1,180 foot conservation pool are shown on Plate E-8. These contours indicate that, at least, some of the pool related seepage will actually pass around the end of the drainage tunnel and some may also pass over the tunnel.

Phreatic contours of the lower aquifer for the February 1996 flood event (1,183.2 feet peak elevation) exhibit no distinct channels. Groundwater flow from the lower aquifer appears to exit into the river channel below elevation 1,025 feet, through the riprap bank or directly into the river. The groundwater flow through the lower aquifer is not considered to be a concern for a conservation pool of 1,177 feet.

The effects of an elevation 1,206 feet flood pool were analyzed in 1992 and found to present no apparent threat to this facility (reference report titled "Right Abutment Seepage", dated 15 June 1992). The results of data analysis from the December 1995 and February 1996 floods made no appreciable changes to this conclusion.

The quantity of water flowing through the abutment for the elevation 1,180 foot conservation pool was calculated to be about 42.8 cubic feet per second (cfs) which is equivalent to about 19,200 gpm; see Figure E-2.

Engineering Pamphlet, EP 1130-2-500 was reviewed to determine the appropriateness of applying the contained criteria to this project for a Risk-based analysis. The following Chapters and Appendixes referenced confirm that a Risk-based analysis for this project is not appropriate.

a. Chapter 3: The proposed seepage control work for the right abutment should not be considered rehabilitation because it would be unnecessary without the additional water storage project. The dam and right abutment are reliable and efficient in their present condition with the current conservation pool level.

b. Appendix B (B-3. d. (1) (d)): The proposed seepage control work is not due to deterioration or degradation in service level.

c. Appendix B (B-3. e. (3) (a)): Alternatives have been developed, but are totally dependent on the reaction of the right abutment to a sustained pool raise.

d. Appendix B (B-3. F. (1) (b)): Failure scenario for this project poses an imminent threat to public safety with a complete dam failure being the worst case.

e. Appendix H: This appendix refers specifically to Hydropower rehabilitation. Howard Hanson dam is a flood control/water supply dam.

The test pool must be accomplished during construction for two reasons: (1) The test pool will be preceded by grouting the area between the drainage tunnel and the embankment. (2) The reservoir may need to be cleared. See paragraph 3.7 for test pool requirements.

3.4 STABILITY ANALYSIS

Stability analyses were performed using the "UTEXAS3 Slope-Stability Program." Parameters for the native slide/abutment materials were:

- Dry unit weight = 120 pounds per cubic foot (pcf)
- Moist unit weight = 134.9 pcf
- Saturated unit weight = 138.5 pcf
- Buoyant unit weight = 76.1 pcf
- Angle of internal friction = 38 degrees
- Cohesion = 0 pounds per square foot (psf)

Parameters for the upstream slope and slope treatment materials were:

- Dry unit weight = 135 pcf
- Moist unit weight = 145 pcf
- Saturated unit weight = 147.6 pcf
- Buoyant unit weight = 85.2 pcf
- Angle of internal friction = 38 degrees
- Cohesion = 0 psf

TABLE E-3-1. CRITICAL ARC FACTORS OF SAFETY

Slope	Pool Condition	Seepage Condition	Critical Arc Factor of Safety
Downstream	1141 Conservation	Steady State	1.113
Downstream	1180 Projected Conservation	Steady State	1.111
Upstream	1141 Conservation	Steady State	2.060
Upstream	1180 Projected Conservation	Steady State	2.215
Upstream	1141 Conservation	Rapid Drawdown	2.060
Upstream	1180 Projected Conservation	Rapid Drawdown	2.215
Upstream	1206 Projected Flood Pool	Steady State	2.308
Upstream	1206 Projected Flood Pool	Rapid Drawdown	2.308

Note: The assumed angle of internal friction (Phi) of 38 degrees and cohesion (c) = 0 are conservative strength parameters for the materials comprising the right abutment of Howard Hanson Dam. These materials are predominately slide debris consisting of large angular rock blocks, boulders, cobbles, and gravel with a matrix of silts, sands, and clays. Historically, a small amount of cohesion has been recognized to be associated with this material, however, because it is practically impossible to accurately sample and test insitu or in a laboratory, the cohesion has been ignored. Instead the upper range of internal friction for gravel has been chosen as the preferred strength parameter for analysis.

3.5 POSSIBLE CORRECTIVE ACTIONS TO DECREASE SEEPAGE AND INCREASE STABILITY OF RIGHT ABUTMENT

As evidenced by the relatively low Factors of Safety derived from this study and the previous seepage studies performed to date, it is apparent that some form of corrective actions must be incorporated into the design of the Additional Storage contract. Several alternatives have been developed and analyzed to address reduction of seepage through the right abutment. The alternatives are briefly described in the following paragraphs.

3.5.1 Drainage Tunnel Extension

This alternative includes extending the existing tunnel approximately 200 lineal feet or more beyond the current end of the tunnel and installing 5 additional relief wells (see Figure E-3 and Plate E-9). Wells would be 10-inch-diameter perforated steel casings spaced at about 40 feet, for a total length of casing of about 1,150 feet.

3.5.2 Additional Feeder Wells at End of Existing Tunnel

This alternative would involve installation of five additional wells at the end of the existing drainage tunnel (see Figure E-4) for drawing down the abutment seepage expected to pass around the end of the tunnel. These would be 10-inch-diameter perforated wells drilled from the ground surface and connected within the drainage tunnel through new feeder pipes and tee connections. Approximately 1,100 feet of drilling and casing will be needed for this option.

3.5.3 Horizontal and Inclined Drains

This alternative would consist of a series of perforated pipes drilled into the abutment from the end of the existing drainage tunnel (see Figure E-5) for an average length of about 150 feet per drain. These drains would be arrayed at various angles from near horizontal to as much as 50 degrees from horizontal. There may be as many as three drain sets each with up to 10 drains.

3.5.4 Cutoff Wall

A positive seepage cutoff wall would be constructed along the top of the impervious blanket (see Figures E-6 and E-7) using a slurry trench method similar to the cutoff wall constructed at Mud Mountain Dam. A temporary fill (approximately 230,000 cubic yards) would be required to provide a working platform (see Figure E-8). Total wall area would be about 250,000 square feet with a maximum depth of 285 feet. The wall would extend to the right canyon wall about 1,400 lineal feet where it would tie into bedrock at approximately elevation 1,190 feet. The bottom of the wall would need to extend at least down to elevation 1,040 feet.

3.5.5 Injection Grouting

This alternative would consist of a series of borings (assumed to be on 3-foot centers and two rows at this time) drilled approximately ten feet into bedrock for a total length of drilling of about 25,500 feet to facilitate placement of grout tubes (see Figures E-9, E-10, and E-11). Casings would be pulled and re-used once grout tubes are in place. Grouting (estimated at about 7,420 cubic yards) would be performed under very low pressures to reduce the chance of hydrofracturing the abutment materials. A work platform will require a temporary fill of approximately 56,000 cubic yards (see Figure E-12).

3.6 RECOMMENDATIONS

It is recommended that the "Injection Grouting" option be incorporated as a work item in the proposed pool raise contract. This option could be further refined during PED. The grouting work would reduce known seepage problems through the abutment adjacent to the dam embankment. If the abutment is left in its present condition serious slope stability problems may occur.

The "Alternatives in paragraphs 3.5.1, 3.5.2, and 3.5.3" are recommended for inclusion as options in the future construction contract. These options would be exercised only if conditions warrant based on results of a test pool raise during the early construction phase. Following test pool analyses it will be possible to determine whether the tunnel extension or a lesser option such as "Horizontal and Inclined Drains" or "Additional Feeder Wells" will be adequate to control additional seepage. It must be recognized that because of the highly variable nature of the right abutment slide materials, an unsuspected anomaly may occur during pool raise that will require development of other remedial measures.

Two additional work items are essential to complete the upgrades to this facility: (1) Three water pressure gauges are recommended, one at the elbow, one at the end, and one at mid point in the existing drainage tunnel. Multiple gauges will be needed for comparison purposes; and (2) since the upstream rock blanket is deteriorating, new rock is recommended to withstand increased erosion caused by a higher wave fetch. Approximately 69,000 cubic yards of rock will be required for this work based on a 3-foot-thick blanket placed directly on the existing rock surface.

3.7 TEST POOL REQUIREMENTS

The test pool is needed in order to monitor groundwater conditions in the right abutment and to design and construct an appropriate modification to the seepage control measures currently in existence, if necessary. Requirements for a test pool are as follows:

1) It is known that precipitation effects the groundwater regime of the upper aquifer, therefore, the test pool will be conducted under conditions of a normal summer conservation pool.

2) The test pool will be conducted in a staged manner; i.e. the pool will be raised in approximately 10-foot increments, allowing time for instruments to stabilize before the initiation step. It is estimated that the test pool will take about three months to accomplish.

3) A complete analysis of the data will follow the completion of the test pool, which is expected to take approximately two months to complete. The design of any new seepage control feature or modification to the existing seepage control features will commence after completion of the analysis.

SECTION 4 INVESTIGATIONS

4.1 PRE-DAM EXPLORATIONS

Exploratory drilling for the damsite consisted of core and cable tool borings. Borings were drilled in the spillway, intake channel, stilling basin, tunnel, right and left abutments, and riverbed. A total of 65 borings were drilled between 1947 and 1958. In addition, five observation wells, four test pits, and two adits, 38 and 55 feet in length, were completed on the right abutment to determine foundation conditions. Exploratory boring locations are shown on Plate E-4. A single core boring (56-DD-27) was drilled in February 1956 at the downstream end of the spillway chute. The boring terminated in rock at elevation 1,068.7 feet. Boring DD-27 is located on/in a 50-foot-wide tabular body of poor rock quality. The body trends northwest on the ground and shows a steep relative dip. Other zones of decomposed rock are present below the spillway chute and in the left bank upstream of the gate tower.

4.2 RECENT INVESTIGATIONS

During March and April 1994, five NQ wireline (3-inch-diameter) core borings numbered 94-DD-80 through 94-DD-84 were drilled to determine subsurface site conditions for the unchosen alternative No. 1 intake tower and tunnel alignment discussed in Exhibit D. Later, during the study, this alternative was redesignated as Alternative 9A7. Following completion of the alternative investigations and after a tentative fish facility tower location was selected in January 1995, the tower site and tunnel configuration were significantly scaled back to reduce costs. The fish facility tower site was moved to the right side of the existing gate tower. The right side of tower alternatives were designated A1, A2, A3, and A4. In December 1995 the site was moved again to the left side of the existing gate tower because of poor foundation conditions on the right side. A single HQ wireline (3.8-inch-diameter) core boring, 96-DD-87, was drilled during May 1996 to affirm the feasibility of the newest site. In late June 1996, the proposed tunnel transition alignment was changed because the local geology indicated probable roof failure while excavating the left wall of the existing diversion tunnel. Loss of the left sluiceway would be a serious dam safety problem, therefore, the new tunnel conduit alignment was redesigned to enter the existing left sluiceway at a higher angle. In January, 1998 the footprint was moved again this time 25 feet south to provide room for a cofferdam next to the existing outlet works. The recommended site has been designated alternative 9A8.

Two core borings located immediately downstream of the existing gate tower, numbered 94-DD-85 and 94-DD-86, were drilled for the gate tower retrofit program. Laboratory test results on rock cores from these and DD-87 are available in Exhibit C. Summary drill logs and hydraulic pressure test data are available in Exhibits A and B, respectively.

4.3 RECOMMENDED FUTURE INVESTIGATIONS

4.3.1 Right Abutment Drainage Tunnel

During feasibility a borehole camera was used to check condition of the perforations in existing drainage tunnel wells. Most were found to be plugged. During PED each of the 10-inch diameter wells will be perforated between elevation 1,090 feet and 1,200 feet. This work coupled with collection of field data during high flood pools will contribute to a better understanding of ground water movement. Approximately 1,100 lineal feet of perforating will be accomplished.

4.3.2 Cofferdam, Fish Passage Facility Footprint, and Entrance Channel

The contact zone between soft pyroclastic rock and a hard porphyritic meta-basalt dike is schematically shown on plate E-3. (Plate 3 is a reproduction of Plate 12 which found in the construction foundation report). The dike appears to be striking east west with a 75° southward dip. Plate 3 illustrates the contact zone at about 25 feet upstream of the existing gate tower. This contact may extend through the proposed wet well/fish lock excavation, see Plate E-10. A important element during initial explorations will be to locate the contact zone and collect representative cores for rock strength tests. The proposed cofferdam appears to straddle the contact zone with one abutment in soft andesite pyroclastics and the other in hard basalt. Recommended sites for exploration borings are shown on Plate E-11. The borings will range in depth from 160 to 215 feet. Purpose of the borings will be to determine overburden thickness, rock type, weathering, hardness, discontinuities, joint spacing, groundwater, and other subsurface characteristics. Hydraulic pressure tests will be conducted to measure joint tightness. Downhole photography will be employed to determine joint condition and orientation. Representative rock cores will be sent to the laboratory for rock strength testing. At least two exploratory relief wells will drilled in the vicinity of the footprint and pumping tests will be accomplished.

4.3.3 Proposed Tunnels

Only a few of the existing exploratory borings are near, within 100 feet, of the proposed tunnel alignment. None extend down to the proposed tunnel grade, therefore additional field explorations are necessary prior to feature design work. A variety of igneous rock types were encountered in 1960 during mining excavation of the present diversion tunnel,

Plate E-12. The construction foundation report provides a brief description of each rock type, but no rock strengths are given. Three of the five reported rock units extend into the fish facility tunnel alignment. One area of concern involves a 25-foot-wide zone of poor quality andesitic pyroclastic rock bounded on both sides by basalt dike rock in the vicinity of the transition to the existing diversion tunnel. This segment of diversion tunnel was strengthened using closely spaced steel supports on 4-foot centers and a collar grouting program to stop build-up of high water pressures outside the concrete lining. An inventory on the number of drain holes and flow from each within the first 200 linear feet of the existing tunnel is planned during feature design.

A minimum of four vertical core borings, varying in depth from 160 to 190 feet, are planned along the proposed tunnel alignment to determine condition of the rock located within two tunnel diameters above the crown of the highest proposed tunnel grade and to one diameter below the invert of the lowest proposed grade. Hydraulic pressure testing will accompany drilling to determine the degree of fracturing. Downhole photography will be used to determine joint orientation. Representative rock cores will be tested in the laboratory to determine rock strengths.

4.3.4 Slope Stability Exploration for Charley Creek Slide

Two slope inclinometer borings, each 200 feet in depth, are proposed for the Charley Creek landslide to evaluate slope stability. The Charley Creek Slide is mentioned in paragraphs 2.3 and 2.5.

4.4 LABORATORY TESTS

Laboratory testing was performed on rock core selected from the core borings referred to in Paragraph 4.2. Most tests were run to obtain rock strengths, including direct tensile strength, grout/rock biaxial direct shear strength and uniaxial (unconfined) compressive strength. Special tests to obtain rock properties particularly related to rock bolting were performed on selected pieces of core from each of the borings; DD-85, DD-86, and DD-87. The most recent test results, dated 22 August 1996, were performed on rock core from boring DD-87. These tests include biaxial direct shear strength tests on 10 sawn rock-grouted joints, 4 samples for dynamic modulus of elasticity, 4 samples for unconfined compressive strength and rock density, and 3 samples for direct tensile strength. Rock samples were tested at NPD Materials Laboratory in Troutdale, Oregon. No laboratory testing was performed on overburden materials. See Exhibit C for laboratory test results on selected rock cores.

SECTION 5 AS-BUILT FOUNDATION TREATMENT FOR EXISTING APPURTENANCES RELEVANT TO PROPOSED FISH FACILITY

5.1 INTAKE CHANNEL

The 460-foot-long intake channel is an open rock cut, leading to the gate tower and diversion tunnel. Rock surface on the high side of the cut ranges in elevation from 1,140 feet to 1,160 feet. At the gate tower the finished floor of the channel is at elevation 1,035 feet with a bottom width of 40 feet. The channel widens upstream. Rock slopes on the left wall of the intake channel are 2 vertical (V) on 1 horizontal (H) while the right wall is 1V on 1H. The right side was revised during construction from 2V on 1H because of the poor quality of the rock. Both slopes were systematically rock-bolted as the excavation proceeded downward from the surface.

Intake channel rock is generally soft. The andesite stays mostly compositionally basic having an agglomerate texture interspersed with tuff seams and dense basaltic sills and dikes. Alteration of the rock is prominent; chloritization of the magnesium minerals and kaolinization of the silicates has softened the entire rock mass. Jointing is prominent on the rock surfaces while the degree of fracture varies from intensely shattered rock to moderately fractured or blocky type rock. Major rock joints and faults are shown on Plates E-13 and E-14. The foundation rock is highly variable, changing from soft, poorly indurated mass, to hard, dense zones. The basalt dikes and sills exposed in open cut slopes are all dense, brittle and sound and constitute the most durable rock found in the intake area.

All intake channel areas were shot in 20-foot lifts except when approaching design grade then lifts were reduced to 5 feet high. Millisecond delays were used extensively in all blasts to maintain neat lines and to control breakage. Powder factors used in the various types of rock ranged from one-half pound in the dense hard rock to three quarters of a pound in the softer rock per cubic yard of rock removal. The shots ranged from 4,000 to 10,000 cubic yards of rock per blast on mass excavation, with minor shots of 100 to 500 cubic yards of rock per blast to complete the required excavation. Five-inch-diameter drill holes on 6-foot centers were drilled an average of 20 feet deep. Holes were generally loaded with ANFO. All neat lines were drilled on 3-foot centers and shot with a light charge to keep overbreak to a minimum. Satisfactory results were obtained in all areas of excavation.

Drain holes were drilled into the exposed rock walls to relieve seepage pressures in the rock. The amount of seepage varied with season of the year. All holes were diamond drilled 20 feet deep from a drilling cage as the excavation proceeded downslope. After the intake channel was essentially complete, holes were drilled to check rock condition in the left wall. Five holes were drilled, 45 feet deep on a 10 percent upward slope at each of the elevations: 1,045 feet, 1,070 feet, and 1,100 feet . The exploration holes were left open to serve as drains. Rock in the left wall varied from hard brittle basalt to soft pyroclastics that could be readily excavated with a shovel.

Rock bolts were used to reinforce the rock cut slopes. Slotted rock bolts of high strength steel varied from 10 feet to 30 feet in length. Plate 14 in the 1963 Foundation Report shows locations and orientations of more than 500 rock bolts installed in the left intake channel wall. Bolts were installed in the direction of maximum compression to reduce fallout due to slip planes, jointing, and shattered rock. Safety netting to alleviate danger from falling rock covered the entire wall of the intake channel and were anchored to the rock bolts or with anchor pins as required. Over the years the slope has held up well, except for minor fallout zones. Most of the netting has deteriorated and has been removed by the project forces.

5.2 GATE TOWER

The gate tower is 40 feet by 50 feet in size with vertical rock slopes of 125 feet on the portal face and left wall. According to the construction foundation report the right wall was to have been vertical, but because of the presence of poor rock, the slope was laid back to a stable angle (degrees not provided) and covered with safety netting to catch raveling from the surface of the slope. In this case the redesign by slope layback allowed the wall rock to stand without support. The right wall, one-half of the gate tower floor, and a section of portal face were composed of soft andesite pyroclastic rock containing relatively hard inclusions, enclosed in a fine, granular, altered matrix. The matrix deteriorated rapidly when exposed to the atmosphere. The soft rock had to be covered with a thin layer of concrete immediately upon excavation to limit air slaking deterioration of the foundation. The zone varies from 20 to 30 feet wide, and is flanked upstream by a dike of dense black basalt. Blocky andesite rock forms a cap over the exposed pyroclastic zone at higher elevations of the gate tower.

The left wall of the portal within the gate tower excavation is firm, dense basalt, moderately hard, with blocky structure. Weathering is very pronounced and the rock is somewhat altered. The poor condition of the rock and excavation geometry made overbreak on the outside corners difficult to avoid. Numerous fracture planes dip into the open cut at angles 45° to 80°. Some fractures were observed to carry groundwater the year round and a definite zone of water seepage from the adjacent hillside was exposed on the left wall of the gate tower. Gate tower excavation was completed in conjunction with the intake channel as one operation.

5.3 UPSTREAM DIVERSION TUNNEL PORTAL AND TRANSITION SECTION

The tunnel portal is 40 feet by 40 feet in size, with a flat roof section through the 35-foot-long transition. This design required an elaborate support structure to hold the flat roof consisting of 24-inch I-beams on 18-inch centers. The soft zone of pyroclastic andesite on the right wall of the gate tower carries into the right side of the upstream transition section and across the floor section of the tunnel, disappearing into the left wall at the downstream end of the transition. The left wall in the transition section, when opened, revealed water bearing faults and three main joint sets all with steeply dipping angles ranging from 50° to 90° toward the east. During tunnel advancement considerable ground water seepage also occurred on the left wall of the tunnel. After placing the concrete lining, seepage built-up substantial pressure and the flow had to be sealed with a grout collar. Grouting for the diversion tunnel collar was done after completion of the tunnel concrete work. The grout collar extended into the foundation rock for a depth of 20 feet and was carried 90 feet downstream from the upstream portal area. Holes were placed in a circular pattern around each of the two water passages (sluices) on 10-foot centers. Grouting was done on a split spacing method in two stages starting at the downstream edge of the collar and progressing upstream to the gate tower. Grout takes ranged from part of a sack to a maximum of 2,046 sacks taken by one of the holes in the right waterway. That particular hole carried grout across the back of the gate tower over the two waterways and up the rock contact on the back side of the gate tower to the 1,141 feet elevation. The collar grouting program successfully sealed the void behind the concrete liner. Drain holes, both upstream and downstream of the grout collar, showed only minor seepage.

5.4 DIVERSION TUNNEL

Water passage is through a concrete-lined 19-foot-diameter tunnel, 900 feet in length in the left abutment rock. A 4-foot-diameter low-flow by-pass tunnel is located beneath the diversion tunnel. The tunnel was driven through volcanics composed of andesite, andesite tuffs, pyroclastics, and dikes of hard, dense basalt and felsite. Extremely variable and abrupt changes of rock types were very common in the exposed tunnel walls. The diversion tunnel was driven full face by conventional drilling and blasting methods employing 10-foot delayed rounds, utilizing a "standard pyramid cut." Progress rate was 10 feet per day. Overbreak was minimal when using a powder factor of 1 pound per cubic yard. The diversion tunnel has vertical sides and a horseshoe shaped crown. One-third of the tunnel was self-supporting where it was driven through moderately hard, irregularly jointed andesite. Two consequential and several minor faults were encountered during excavation of the diversion tunnel. The faults had 2 to 12 inches of gouge and abundant slickensides and almost all were water bearing. One significant fault trends northeast to southwest and dips 75° to 85° northwest and the other strikes N10°E with near vertical dip. The latter was mapped near the left wall of the stilling basin and was encountered in the existing diversion tunnel about 200 feet downstream of the spillway weir. It produced considerable groundwater. Most minor faults were found to strike roughly east-west with dips varying from 70° to 80° south. Nearly 100 feet of tunnel length near the upstream portal and 50 feet near the downstream portal were supported with steel ribs on 4-foot centers. The majority of rib supports were on 6-foot centers. Light loads were experienced, even though the supported sections were in interstratified soft andesitic pyroclastic rock and denser basalt and felsite (Galster, 1989).

Groundwater was encountered in the gate tower excavation, upstream transition section, and at the mid point in the tunnel. Contact grouting was performed during August 1960 beginning at the downstream transition and working upstream through a distance of approximately 800 feet. Embedded grout pipes through the concrete lining were located on 10-foot centers, five feet each side of the centerline, in the arch of the tunnel. The design of the tunnel with no water stops at monolith joints and the use of embedded drain holes was considered a detriment to grouting operations because leakage through the two areas necessitated considerable extra expense to prevent grout loss.

SECTION 6 ENGINEERING CONSIDERATIONS FOR PROPOSED FISH PASSAGE FACILITY SITE

6.1 GENERAL

The recommended fish passage facility site (9A8) was opted late in the study (December, 1995), after several alternatives were evaluated, see Exhibit D. Approximately one month after the drilling of boring 96-DD-87 (May, 1996), the fish passage facility footprint was shifted again (late June, 1996) to accommodate a new tunnel transition angle with the existing left sluiceway. In mid January, 1998 the footprint was moved 25 feet south to provide sufficient room for siting the cofferdam within the existing rock slope bordering the intake channel; see Plate E-11. Currently, no explorations are located within the latest fish passage footprint or within footprints for proposed ancillary structures. Subsurface conditions are unknown, except for some information in the 1963 construction foundation report. The proposed facility is shown on Plates E-10 and E-11. Excavation for the tower and tunnels will be accomplished by both surface and underground mining methods. In the area of the fish passage facility footprint the predominant rock type could be brecciated, porphyritic meta-basalt or could be a narrow lower strength meta-basalt dike. Rock types will be determined during a comprehensive exploratory program intended in the early stages of preconstruction engineering and design (PED). Various elements of work necessary for foundation preparation include:

- strengthen abutments for the cofferdam;
- excavate overburden/rock to shape stable back and side slopes for the fish collector entrance, wet well, fish lock, and tower excavations; install back-slope support elements;
- erect steel sets and excavate turn-under for the gate chamber;
- perform mining excavation for the new conduit tunnel, for the 24-inch diameter fish transport pipe, and for the 48-inch diameter bypass pipe; and
- excavate overburden/rock to widen the existing intake channel and install slope support elements.

6.2 DESIGN CRITERIA

Designs for the surface excavations and tunnels were based on general design criteria presented in Table E-6-1. This table was initially developed using empirical guidelines in EM 1110-2-2901, dated 15 Sep 1978. As a result of recommendations made in the Alternative Formulation Briefing (AFB) in September 1997, Section 6, including Table 6-1 were revised to reflect the new guidance in EM 1110-2-2901, dated 30 May 1997. New guidance emphasizes tunnel excavation by mechanical means in lieu of drill and blast methods especially where existing concrete structures are in close proximity. Regarding the fish passage facility neither method can be adequately designed for until the comprehensive exploration program is underway. The alternative for tunnel excavation by mechanical means such as roadheader was added to this appendix as a result of independent technical review. This alternative will require further research during PED studies. The Rock Mass Rating (RMR) system was used for cursory analysis for feasibility. The RMR system is based on a set of case histories of relatively large tunnels excavated using blasting. Early in PED emphasis will be placed on performing essential tests such as thin section analysis, Schmidt hammer hardness tests, and density, porosity, compressive, and tensile strength tests. These tests and others will be helpful in predicting mechanical excavator performance.

Permanent rock cut slopes as steep as 10V on 1H may be attainable within the fish facility footprint, but will not stand in the intake channel where the rock is much poorer quality. Controlled blasting will be used to minimize overbreak and reduce the vibrations acting on existing structures. Rock slopes will require controlled blasting to attain the excavation neatline. Excavation lifts will be 20 feet or less in height. In no case will explosive amount, pattern, or timing of explosive charge per delay be allowed to exceed blasting criteria shown on Table E-6-1. After each excavation lift all hazardous loose rock and debris will be removed by barring and wedging before installing slope treatment elements such as rock bolts, shotcrete, backfill concrete, rock drains, and chain-link mesh. When large fallout areas occur the resulting cavities will be backfilled with either shotcrete or cast-in-place concrete depending on depth of the cavity. Shotcrete and concrete backfill will be penetrated by inclined rock drains to enable equalization of water pressure during reservoir fluctuations. All excavation slopes will be covered with temporary chain link mesh for worker safety.

TABLE E-6-1. ROCK EXCAVATION GEOTECHNICAL DESIGN CRITERIA

INTAKE CHANNEL SURFACE EXCAVATION

- Maximum rock cut slopes (>10 feet) = 4V on 1 H
- Five-foot bench for every 20 feet of slope height
- Rock bolts, permanent chain link mesh, and drains to provide slope stability and safety

FOOTPRINT EXCAVATION

- Minimize excavation quantities
- Maximum cut slopes (>10 feet) = 10V on 1 H
- Shotcrete, backfill concrete as needed, tensioned rock bolts and drains
- Temporary and permanent chain link mesh

TUNNELS

- Use empirical design criteria in EM 1110-2-2901
- Tunnels driven by light load blasting and/or by mechanical means
- Pre-grouting and rock bolts to strengthen area of transition to existing diversion tunnel
- Pressure grout and drains to control groundwater
- Rock reinforcement by tensioned rock bolts and fiber reinforced shotcrete
- Steel sets, or steel liner construction in critical areas and in portals
- Use spiling as necessary

BLASTING CONTROLS

- Reduced charge weight per delay for low vibration level blasting
- Vibration level to be less than 4 inches per second on existing concrete
- Vibration level to be 2 inches or less per second on newly placed concrete

6.3 BEDROCK ENGINEERING PROPERTIES

The left abutment bedrock consists of a variety of igneous rock types (Plate E-3) with unit weights ranging from 150 to 172 pounds per cubic foot. Table E-6-2 shows characteristics of several rock varieties found at the Howard Hanson Dam Project. Many engineering problems can be related to joints in the rock. Rock in the upstream left abutment has closely and widely spaced fractures depending on location. Prehistoric movement occurred on many secondary fractures as evidenced by gouge and slickensides in local rock exposures.

Rock core from boring 96-DD-87 was field classified as andesite breccia. Actually, the rock is porphyritic meta-basalt. In August 1996, the Corps' Missouri River Division Laboratory in Omaha, Nebraska, completed a petrographic examination of a sample of core from the depth interval 138.5 to 139 feet (elevation 1,027 feet) in boring 96-DD-87. Their results indicate the rock is composed of well fractured (brecciated), altered meta-volcanic rock identified as porphyritic meta-basalt with the majority of principal original volcanic rock mineral constituents altered to chlorite, calcite and mica. The mineral alteration did not appear to have adversely affected rock matrix density. Fractures associated with brecciation were closely spaced, closed and appeared to be well cemented with secondary minerals that included chlorite, carbonate, and microcrystalline silica. The iron ore identified in the sample was composed predominantly of iron sulfide (pyrite) and comprised approximately 15 percent of the rock as determined by modal analysis. Chemical analysis indicated the whole rock sulfate content as less than 0.1 percent and the iron sulfide appeared to be chemically inert based on results from sodium and calcium hydroxide immersion tests. Based on these results no chemical reactions are anticipated between the iron sulfides and the constituents in concrete.

TABLE E-6-2. REPORTED AND OBSERVED ROCK CHARACTERISTICS

Rock Type	Description	Weathering Characteristic	Characteristic of Shot Rock	Specific Gravity Bulk Dry	Unconfined Compressive Strength in est. psi	Modulus of Elasticity in est. psi
Basalt	Hard and dense, fine grained, concoidal fracture, color black, no alteration	Very resistant	Blocky and durable	2.60 to 2.65	4,500 to 14,500	2,900,000 to 7,100,000
Andesite	Moderately hard and dense, medium to fine grained, irregular fracture, color dark green to dark gray, slight hydrothermal alteration	Resistant to normal atmospheric weathering	Massive disintegrates adjacent to shot	2.50 to 2.60		
Basalt Pyroclastics (Tuff)	Matrix. moderately hard and dense, medium grained, color dark gray; Nodules, hard and dense, fine grained, color black hydrothermally altered	Matrix, susceptible to mechanic breakdown Nodules, resistant	Breaks fine to granular particles which weather to a sandy gritty mass	2.30 to 2.35		
Andesitic Pyroclastics (Tuff)	Matrix, soft, color light gray, uniform fine grained, and dense; Nodules, moderately hard, variable granular texture, hydrothermally altered.	Very susceptible to atmospheric weathering, abrasion, and mechanical breakdown	Breaks fine to silty clayey mass with larger particles weathering readily to silty clay. Breaks to plastic mud under construction equipment	2.25 2.33	3,500 to 4,000	1,600,000 to 2,100,000
Felsite	Light gray, hard and dense, fine grained, irregular fracture, small feldspar phenocrysts	Very resistant	Durable and blocky	not tested		

Table E-6-2 modified from Hart Crowser & Assoc., Inc, 1984

6.3.1 Rock Quality Designation (RQD)

The RQD is a modified core recovery logging technique developed at the University of Illinois. This technique is more sensitive to the soundness and quality of rock than is the procedure of simply logging the percentage of core recovery. RQD is useful for estimating rock bolt spacing and lengths. The RQD is based indirectly on the number of fractures and the amount of softening or alteration in the rock as observed in cores from 3-inch diameter borings. RQD is expressed as a percentage of the aggregate length of the 4-inch or longer segments to the total length of the core run. When core is broken by handling or while drilling, the fresh pieces are fitted together and counted as one piece. Table E-6-3 shows RQD percentages used for determining rock quality.

TABLE E-6-3. ROCK QUALITY DESIGNATION

RQD Percentage	**Rock Quality**
0-25	Very Poor
26-50	Poor
51-75	Fair
76-90	Good
91-100	Excellent

The average RQD for boring 96-DD-87 indicates rock of good quality. Fracture spacing ranges from a tenth of a foot to 18 feet. For feasibility the average RQD was used to characterize the overall quality of rock in boring DD-87. Usually, RQD is used as a measure of rock quality for a particular zone of interest such as a portal cut.

6.3.2 Rock Mass Rating (RMR)

RMR is a rock mass classification system used to evaluate ground conditions which a tunnel could encounter and as a means to check initial estimates of tunnel support. This applies to areas with adequate rock cover and strength to develop Terzaghi bridging. Two times the tunnel diameter is needed as adequate cover to fully develop bridging action in jointed rock.

For the fish facility tunnel, ground conditions include the following types of rock: andesite/basalt flow rocks and, andesite pyroclastic rocks. A rating based on historical geologic data, laboratory test results, and drill core logs (RQD, joint spacing and condition, weathering) was developed for these volcanic rock types. Figure E-13 "CSIR Geomechanics Classification of Jointed Rock Masses" was used in generating the values in Table E-6-4. Flow rocks fall into Class II "Good Rock" and pyroclastic rocks are in Class III "Fair Rock."

TABLE E-6-4. ROCK MASS RATING SUMMARY

RATING CATEGORY	AN/BA* FLOW ROCK	PYROCLASTIC** ROCK
Strength of Intact Rock	7	7
RQD	17	13
Spacing of Joints	20	20
Condition of Joints	20	12
Groundwater	4	0
Rating adjustment for Orientation of Joints	-5	-5
Total Rating	73	47
Class	II	III
Average Standup Time (10-ft span)	6 months/12-ft span	1 week/10-ft span

*AN/BA = Andesite/Basalt
**Primary thickness of shotcrete applied after muck-out cycle will raise rock to class II.

6.4 DEWATERING

Groundwater under moderate pressure will be encountered during excavation of the fish facility footprint and at tunnel grade. In boring 96-DD-87, a significant water bearing fracture, dipping 35° (dip direction and strike are unknown) was encountered at a depth of 143.4 feet (elevation 1,022 feet). For 6 days an estimated 40 gpm flowed from the boring at ground surface (elevation 1,166 feet). In May, 1996, the temperature of the flowing artesian water was 48° F., somewhat warmer than the 40° F. temperature at the reservoir surface. A packer was placed in the boring just below elevation 1,030 feet and the boring was pressure grouted, thereby sealing off the water bearing fracture. More exploration is required to adequately design construction and permanent drainage systems. Two exploratory relief wells are planned during PED to further evaluate water problems. For feasibility purposes rock drains will be 2-inch diameter, inclined 5° above horizontal on 12-foot centers, except within the lowermost 15 feet of the excavation, then drains will be more frequent. Field conditions may dictate deviation of lengths, spacings, and orientations of drains. Seepage dewatering will be maintained during the excavation and construction. Once foundation grade has been achieved and mat placed, drain holes on 7-foot by 7 -foot pattern, drilled at least 20 feet deep into the footprint foundation may be needed for uplift pressure relief. Grouting may be necessary to control seepage, particularly if open or continuous joints are present. In addition to the rock drains, systematic grout hole drilling and pressure grouting may be needed around the bottom of the footprint excavation especially between elevations 1,015 and 1,035 feet.

Numerous water bearing rock joints in the area of the proposed tunnels are anticipated. This condition may be exacerbated by high reservoir pools. Therefore, two-inch diameter drains, drilled 20 to 30 feet into the rock on 5-foot centers to relieve pressure. Following tunnel lining installation, additional grouting will be done to restrict high water pressures and seepage.

TABLE E-6-5. GEOTECHNICAL DESIGN FEASIBILITY

Element	Excavation	Support	Dewatering	Reference	Excavation Design Feasibility
Intake Channel	4V:1H	Pattern Rock Bolts 5x2½& Drains, 10x10	Necessary by rock drains		Good
Footprint	10V:1H	Pattern Rock Bolts 6x6 Diagonal & Drains, 12x12	Necessary by rock drains, pumping, and grouting	Plate-E-17	Good
Gate Chamber Portal	Controlled Blasting or Mechanical Means	Steel Sets 5' O.C., Pattern Rock Bolts 5x5 Diagonal, 4" Shotcrete	Necessary by rock drains, pumping, and grouting	Plate-E-18	Good
New Conduit Transition to Existing Diversion	Controlled Blasting by Light Charges, Drilling & Splitting or Mechanical	Steel Sets 4' O.C., Pattern Rock Bolts 5x5, 4" Shotcrete, Drains	Necessary by rock drains, pumping, and grouting	Plate-E-18	Good
New 48" Bypass	Controlled Blasting & Mechanical	None	Necessary by pumping	Plate-E-18	Good
Lock Fish Transport Tunnel	Horizontal Drill small dia. bore	None	None	Plate-E-18	Very Good

6.5 SOUTH WALL REINFORCEMENT FOR COFFERDAM

The south rock wall of the existing intake channel extending from the gate structure to approximately 100 feet upstream will compose part of the proposed cofferdam system. See Appendix A, Design, for the planned cofferdam configuration and cofferdam abutment reinforcement scheme. Also see Plates E-15 and E-16 for as-built reinforcement in the existing south wall.. The cofferdam abutments will be reinforced with post-tensioned cable tendons extending from the ground surface to approximately 35 feet beneath the base of the cofferdam. The tendons will be installed within a series of closely spaced 6-inch diameter vertical borings and grouted full length. In addition to the tendons the abutments will be strengthened with heavy duty Dywidag bolts embedded in resin. The Dywidag bolts will be installed normal to the rock face. Short rod extensometers or some other form of geotechnical instrumentation will be used to measure rock deformation. The rock between the cofferdam abutments will also be left intact and will be grouted to ensure a water tight condition. Construction for the cofferdam will involve access and logistics problems as well as being complicated by a confined work area adjacent to the operating outlet works. Also, the proposed cofferdam area is subject to submergence during flood storage.

6.6 FISH FACILITY FOOTPRINT EXCAVATION AND SLOPE TREATMENT

The fresh rock is anticipated to stand permanently on a 10V on 1H slope. Conventional drill and blast methods can be used to excavate a deep cut or slot in the rock. For ease of construction the near vertical slopes will have 24-inch setbacks for normal air track drills. Since water conveyance channels require permanent protection against rock falls, all exposed rock surfaces will be permanently covered with chain-link mesh. Concrete retaining walls will contain weep holes on 10-foot centers to prevent buildup of water pressure. Overburden on the up slope (south) side of the wet well/lock varies in thickness from several feet to possibly 40 feet. Boring logs 94-DD-80 and DD-81 show overburden consisting of silty, sandy gravel slopewash with numerous cobbles and boulders. No laboratory tests were run on the overburden. An overburden cut slope of 1V on 2H with toe resting on a rock bench 5 to 10 feet from the neatline excavation should allow sufficient room for construction of a temporary barrier fence to catch debris that might otherwise slough into the excavation.

Bedrock fractures are spaced from a few inches to tens of feet. Occasional brecciated zones, several feet thick, are likely to be encountered. Most fractures appear tight. Some fractures contain clay fillings and some are partially or completely rehealed with secondary mineralization. Water bearing fractures are known to occur at foundation grade, elevation 1,030 feet. Water under moderate artesian pressure was encountered in core boring 96-DD-87 and in pre-dam exploratory boring 56-DD-37, see logs in Exhibit A.

The volcanic stratigraphy is very irregular with soft hydrothermally altered zones of incompetent rock. Geotechnical exploration and laboratory testing during feature design studies will be used to determine strength characteristics of some of the questionable rocks. Hydrothermally altered materials destined for disposal will require testing for leachable metals and other suspect specific compounds.

The following conditions could occur: a) joint planes paralleling the excavation cut slope could result in planar sliding; and b) intersecting joint planes may form wedges capable of sliding out of the slope. The following rock bolt-drain hole patterns were selected to support the excavated rock slopes. Treatment will consist of tensioned and grouted rock bolts in a 6-foot by 6-foot diagonal pattern. See Plate E-17 for typical bolt and drain hole configurations. Bolts will be 1-inch diameter, 15 to 30 feet in length and will be installed normal to the slope face. Actual field conditions may dictate deviation of lengths, spacings, and orientations of bolts in order to achieve maximum compression against slip planes and jointing cracks. Rock drains will be 25 feet in length, on 12-foot centers, inclined 5° above horizontal.

6.7 GATE CHAMBER EXCAVATION AND SUPPORT

Portals contain the most unpredictable rock conditions. Two tunnel diameters of sound rock are available at the site for the development of a ground arch over the opening. Rock removal in the portal area will be by the drilling and blasting method. Untensioned rock bolts, shotcrete, and steel mesh will be installed as the excavation advances. Upon achieving turnunder the cut slope will have been thoroughly protected with 30-foot-long rock bolts (#12) on a 5-foot diagonal pattern between elevation 1,076 and 1,096 feet and 4- to 6-inch thick fiber-reinforced shotcrete and welded wire mesh up to elevation 1,160 feet. The gate chamber crown is located at approximately elevation 1,065 feet on the cutslope, see Plate E-18. The portal will be strengthened with a steel set as mining advances. Three more steel sets will be installed in the gate chamber. In addition the chamber crown will be supported with 4-inch thick fiber reinforced shotcrete and embedded rock bolts, 5 feet on center, angled to develop the arch. From the springline down to approximately elevation 1,040 feet the walls will be supported with 4-inches of shotcrete. Consolidation grouting will be accomplished and drains drilled and installed as needed to control water pressure.

Deformation monitoring will be used to provide early warning of potential instability and as a check on the adequacy of installed support. Instruments for this purpose are tape and multiple position borehole extensometers (MPBX). They are effective, relatively low cost and proven reliable. The instruments will be installed during the early stages of the work to optimize their value.

6.8 MINING AND SUPPORT FOR NEW CONDUIT

See Plate E-12 for the existing diversion tunnel geology. Rock quality and hardness vary with rock type and location. Considerable local variation in degree of fracturing is predicted. The rock is anticipated to vary from massive and intact at the proposed tower portal to crushed and altered at the proposed transition. Excessively sheared and/or chemically deteriorated rock could also be encountered. Since rock quality at the tunnel transition is anticipated to be very poor, preconsolidation grouting, rock bolting, and installation of spiling will be installed from within the existing diversion tunnel, between station 16+35 and 16+65, before mining of the new conduit tunnel. The crown and left wall of the existing diversion tunnel will be presupported by consolidation grouting for a distance of 40 feet beyond the existing concrete liner to strengthen the rock. Pattern rock bolts, on 4-foot centers will be drilled and embedded at least 25 feet into the tunnel crown. Bolts will be recessed and holes patched to maintain smoothness of the existing concrete.

Mining for the new conduit and new 48-inch bypass pipe will follow gate chamber excavation and support. The new conduit will start at the rear of the approximately 20-foot-long gate chamber, see Plate E-18. Dimensions of the proposed bore are 15 feet high by 13.5 feet wide with invert at elevation 1,032 feet and crown at approximately 1,047 feet. Rock bolts on 5 feet spacing will be embedded 15 to 25 feet in the crown. Restrictive blasting made up of light loads are necessary within 25 feet (approximately one tunnel diameter) of the existing concrete-lined diversion tunnel. During construction of the existing diversion tunnel the natural state of stress of the rock was affected which resulted in redistribution of stresses and displacements within the surrounding rock. Coincidentally, the 25-foot wide restrictive blasting zone is the reach of soft andesite pyroclastic rocks. Rock load is predicted to change erratically from point to point within this reach, therefore 7 steel sets on 4-foot centers are planned.

6.9 MINING AND SUPPORT FOR 48-INCH DIAMETER BYPASS CONDUIT

The new 48-inch-diameter bypass excavation follows an alignment underneath the proposed intake tower, gate chamber, new conduit tunnel, and beneath the existing sluiceways where it transitions into the existing 48-inch bypass. Rock excavation beneath existing sluiceways will require removal of portions of the concrete floor to gain entry for rock excavation. Blasting will not be allowed beneath the sluiceways, so rock removal will be through mechanical methods such as hydrohammer.

6.10 DRILLING FOR FISH TRANSPORT PIPE

An approximate 20-foot-long permanent 24-inch-diameter continuous steel lining will join the new conduit tunnel approximately 20 feet downgradient from the fish facility radial gate. A 30-inch-diameter micro bore should afford sufficient room for installation of the fish transport pipe as well as construction of an impermeable grout seal.

6.11 INTAKE CHANNEL EXCAVATION AND TREATMENT

An overburden cut slope of 1V on 2H with toe resting on a rock bench 10 feet distance from the neatline will allow ample room for construction of a temporary debris fence. Actual width of the bench will be dependent on the catch points selected during feature design and rock elevations actually encountered during excavation. Overburden removal is planned with common excavation equipment.

In the existing upstream intake channel, rock varies from intensely brecciated to moderately fractured. There are three main joint sets which form the controlling structural feature, see Plates E-13 and E-14. The most critical joint set strikes northeast with easterly dip varying between 40° and 50°. Another set strikes north and dips 70° to 85° east. The third set is nearly horizontal. Regarding stability of the cut, there appears to be no wedge failure problems associated with these joints. These major joints have slickensides and gouge material which varies from a thin veneer to more than 2 inches wide. Hydrothermal alteration minerals have accumulated on some of the exposed joint faces.

Most of the channel widening excavation will be in rock. Systematic drilling and controlled blasting procedures will be employed to prevent damage to final cut slopes and grades. Rock slopes 2V on 1H or steeper will be presplit. The poor quality and fractured nature of the rock dictated a design slope of 4V on 1H with 5-foot-wide horizontal benches every 20 feet in height. Slope treatment elements consisting of tensioned and grouted rock bolts, chain link wire mesh, and drains will be installed in each lift before excavating the next lower lift. Bolt size will be 1-inch diameter (No. 8), 10 to 30 feet in length, and will be spaced in a pattern of 5-foot centers per row and 2-1/2 feet between rows. Chain link mesh will be attached to the cut slope by anchor pins installed midway between each rock bolt. Rock drains will be spaced on 10-foot centers, each a minimum of 30 feet in length and inclined 5° above horizontal.

6.12 DISPOSAL OF EXCAVATED MATERIALS

Materials from excavated areas will be placed in designated areas for disposal or use as borrow. Waste areas will be left reasonably smooth graded and sloped to drain. All of the excavated rock from tunnel mining and from the upstream intake channel widening should be considered waste material.

SECTION 7 CONSTRUCTION MATERIALS

7.1 AGGREGATE SOURCES

Sand and gravel materials for construction of the dam core were borrowed from the Bear Creek Terrace, located one-half mile from the damsite on the left bank, Plate E-1. The Bear Creek gravel was determined unsuitable for concrete aggregate because of the high percentage of soft particles, therefore, concrete aggregate was shipped by railroad from the Glacier Sand and Gravel pit at Steilacoom, WA. The use of existing ready-mix pits in nearby vicinities will require investigation prior to final design.

7.2 ROCK SOURCES

During construction of Howard Hanson Dam Project the rocks produced from the excavation of the spillway cut, tunnel, forebay, and intake channel were intended to be used as rock fill for the embankment dam, but because the rock weathered so severely within the stockpile, a new rock source had to be obtained. The rock at Bear Creek quarry, one mile west of the dam (Plate E-1), was better quality and produced a sufficient supply of durable rock for the entire project. The Bear Creek quarry, now private property, may not be accessible for the Fish Facility construction Since rock need is minimal, several commercial rock quarries within 20 road miles southwest of the project, may be available. Rock testing will be required.

SECTION 8 OTHER EVALUATED TOWER/TUNNEL SITES

8.1 GENERAL

Section 6 summarizes geotechnical studies and evaluations of three alternative tower locations and five alternative tunnel alignments. Initially, tower design parameters included a tower base at elevation 1,045 feet, and a 12-foot-diameter finished tunnel having an upstream invert at elevation 1,060 feet, and downstream invert at river level, approximate elevation of 1,005 feet yielding a gradient of 1.6°. A nearly unlimited number of tower/tunnel configurations exist having the above design parameters. The following alternatives sites were thought to be viable by the Seattle District staff and by outside sources. Alternative tower sites Nos. 2 and 3 were studied using the above design parameters. As the feasibility study progressed, design parameters were changed: the upstream tunnel invert was lowered to elevation 1,035 feet; the gradient was flattened to under one degree; and the downstream invert was raised to elevation 1,010 feet. Also, lined 18-foot- and 23-foot-diameter tunnels were considered in order to house multiple conduits and provide for emergency reservoir discharge. For a time alternative tower site No. 1 (now designated as Alternative 9A7) was considered the most suitable location and therefore, minimal field drilling investigations were carried out for that site. Selection of site No. 1 was based on the following factors: favorable to fisheries criteria, favorable rock quality, practicality of tunnel excavation, hydraulically acceptable alignment, favorable proximity to the existing intake structure, availability of surrounding rock for tower stability, natural cofferdam, and overall constructability. See Exhibit A for boring logs, Exhibit C for laboratory test data and Exhibit D for relevant drawings.

8.2 LEFT ABUTMENT INTAKE TOWER SITE NO. 1

Intake tower site No. 1 was sited 150 feet upstream (southeast) of the existing gate tower. The intake structure was located to facilitate debris removal and maintain low risk to equipment operators. Tower site No. 1 would require rock excavation in the left (south) wall of the intake channel. In the immediate vicinity of site No. 1 the rock appeared structurally sound with ample strength for the requirements of slope stability.

8.2.1 Tunnel Alignment No. 1 would be predominantly curved through its 2,000-foot length. It would parallel the existing flood control tunnel at a great separation, therefore, construction controls would be less restrictive than for any of the other alternative tunnel alignment schemes. The formerly proposed 23-foot-diameter tunnel would have been mined in andesitic and basaltic rock types and through a 50-foot-wide zone of very soft pyroclastic rock. Bedrock cover ranges from 30 feet at the diversion portal to a maximum of 150 feet over most of the alignment. The downstream portal and appurtenant structures were located far enough downstream to be protected from spillway discharge and still provide the design tunnel gradient.

8.3 LEFT ABUTMENT INTAKE TOWER SITE NO. 2

Left abutment intake tower site No. 2 (now designated Alternate 9A4) was sited 20 feet northeast (right) of the existing gate tower. Tower site No. 2 would have required excavation into soft pyroclastic rock composing the left abutment of the dam and the right wall of the existing gate tower excavation. During excavation for the existing gate tower special treatment was required due to discovery of a soft hydrothermally altered zone on one side of the excavation. The soft rock had to be covered with a thin layer of concrete immediately upon excavation to limit air slaking deterioration of the foundation. The slope was laid back to a stable angle and covered with safety matting. Based on current knowledge of the area Site No. 2 should be avoided. Should the site be reconsidered at a later date, then an extensive core drilling program together with laboratory analyses will be imperative in order that adequate controls for rock excavation can be instituted to preserve the abutment of the dam. Two tunnel schemes exiting this site were studied and determined to be less feasible than other schemes.

8.3.1 Tunnel Alignment No. 2L

Tunnel alignment No. 2L would be approximately 1,300 feet in length and would be driven in rock. The upstream invert would be at elevation 1,060 feet and downstream invert would exit rock at river level, approximately elevation 1,005 feet. The alignment crosses over the existing diversion tunnel in the vicinity of the spillway weir. Mining along this alignment would require special procedures such as consolidation grouting and/or installation of a tunnel liner in order not jeopardize the existing tunnel operation. Also, the downstream tunnel portal would be in soft hydrothermally altered rock. There is some concern about the integrity of this rock. When the spillway chute passes water, extensive erosion is expected. A tunnel located at the toe of the spillway chute, exiting within this rock mass, should be avoided. Operation of the spillway would probably impact the downstream portal.

8.3.2 Tunnel Alignment No. 2R

Tunnel alignment No. 2R would be a 1,000-foot-long uniform curve into the left abutment between the existing diversion tunnel and the canyon wall. Construction restrictions during mining are recommended to prevent damage to the existing diversion tunnel. The upstream tunnel invert would be at elevation 1,060 feet and downstream invert would be at elevation 1,020 feet where it exits from rock. The tunnel would then transition to a surface flume which would deliver fish downstream to elevation 1,005 feet. The downstream tunnel portal would exit within a few feet of the stilling basin making portal construction and access difficult.

8.4 RIGHT ABUTMENT INTAKE TOWER SITE NO. 3

Site No. 3 was sited about 200 feet upstream (south) of the project office building. This site would require rock excavation into the right abutment of the dam and would require a cofferdam. The intake tower and shaft would be founded in an outcrop of extensively weathered tuff. Right abutment bedrock consists of basalt and andesite in the form of flow deposits and intrusive dikes, and basaltic and andesitic pyroclastics in the form of tuffs. Rock quality was not thoroughly explored during dam construction because the left abutment rock proved best for all the ancillary structures. A major fault, striking E-W and dipping 85° south, was mapped extending from the left abutment across the river canyon into the large bedrock "notch" in the right abutment (Corps of Engineers, 1963). The notch is situated immediately downstream of the dam axis and has since been covered by the dam embankment. Two pre-dam core borings, D-7 and D-8, were drilled in the right bank notch fault zone. Core recovery for the two borings ranged from 75 to 90 percent indicating rock of fair quality. This E-W fault projected across the canyon to the left abutment was encountered in the diversion tunnel and found to transmit considerable groundwater. Groundwater could be a significant problem for tunnel alignments 3L and 3R since two distinct aquifers are known to exist in the right abutment. Two tunnel schemes exiting tower site no. 3 were evaluated. The first significant flood pool occurred in February, 1965 and attained a brief elevation of 1,161.8 feet. At that time a spring abruptly broke out at elevation 1,134 feet, approximately 350 feet downstream from the downstream right abutment toe. The spring flowed as much as 100 gpm and subsequently was controlled by a gravel blanket supported by a crib wall. A drainage adit was constructed in 1968 at elevation 1,100 feet to control abutment leakage through the landslide debris during flood pools. The adit extends 650 feet into the abutment.

8. 4.1 Tunnel Alignment No. 3L

Tunnel Alignment No. 3L would be approximately 500 feet in length, bearing N40°W, and would be driven through 300 feet of volcanic rock, 50 feet of landslide debris, and through 150 feet of rock fill located at the toe of the dam. The upstream tunnel invert would be at elevation 1,060 feet and downstream invert would be at elevation 1,030 feet where it would emerge from the rock fill. The tunnel would transition into a surface flume which would extend downstream along the right bank until reaching river elevation 1,005 feet. Mixed face tunneling is costly and slow. Tunneling into the unconsolidated landslide debris and rockfill may jeopardize the dam and therefore, should be avoided.

8.4.2 Tunnel Alignment No. 3R

Tunnel Alignment No. 3R would be a 600-foot-long straight tunnel, bearing N32°W, and would be driven 500 feet through volcanic rock. The upstream tunnel invert would be at elevation 1,060 feet and downstream invert would be at elevation 1,040 feet where it would emerge from bedrock. Cut and cover would be required for a length of 100 feet through slope treatment materials and bedrock. Upon emerging from the cut the invert would be approximately elevation 1,030 feet, still 25 feet above the river. The tunnel would then transition to a surface flume which would be founded along the right bank to the elevation 1,005 foot contour where it would intersect the river. Approximately midway along tunnel alignment No. 3R, just downstream of the large bedrock notch, the rock cover thins over the tunnel crown. Tunneling through unconsolidated landslide debris directly beneath the embankment dam should be avoided.

A similar alignment, but at a lower tunnel invert (inlet at elevation 1,030 feet) was studied by Hart Crowser & Associates for Tudor Engineering Company in 1984, to supplement a preliminary evaluation for hydroelectric development. They concluded that conditions overall are suitable for construction of hydroelectric facilities. They were concerned that there is the possibility of inadequate rock cover over the tunnel alignment since available information indicates considerable variation in the top of bedrock. The height of rock cover as well as condition of the rock could significantly impact design for a permanent tunnel lining. They concluded that seepage in the abutment may affect design of a tunnel lining, depending on the relative difference in hydraulic head inside and outside the tunnel.

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FIGURES

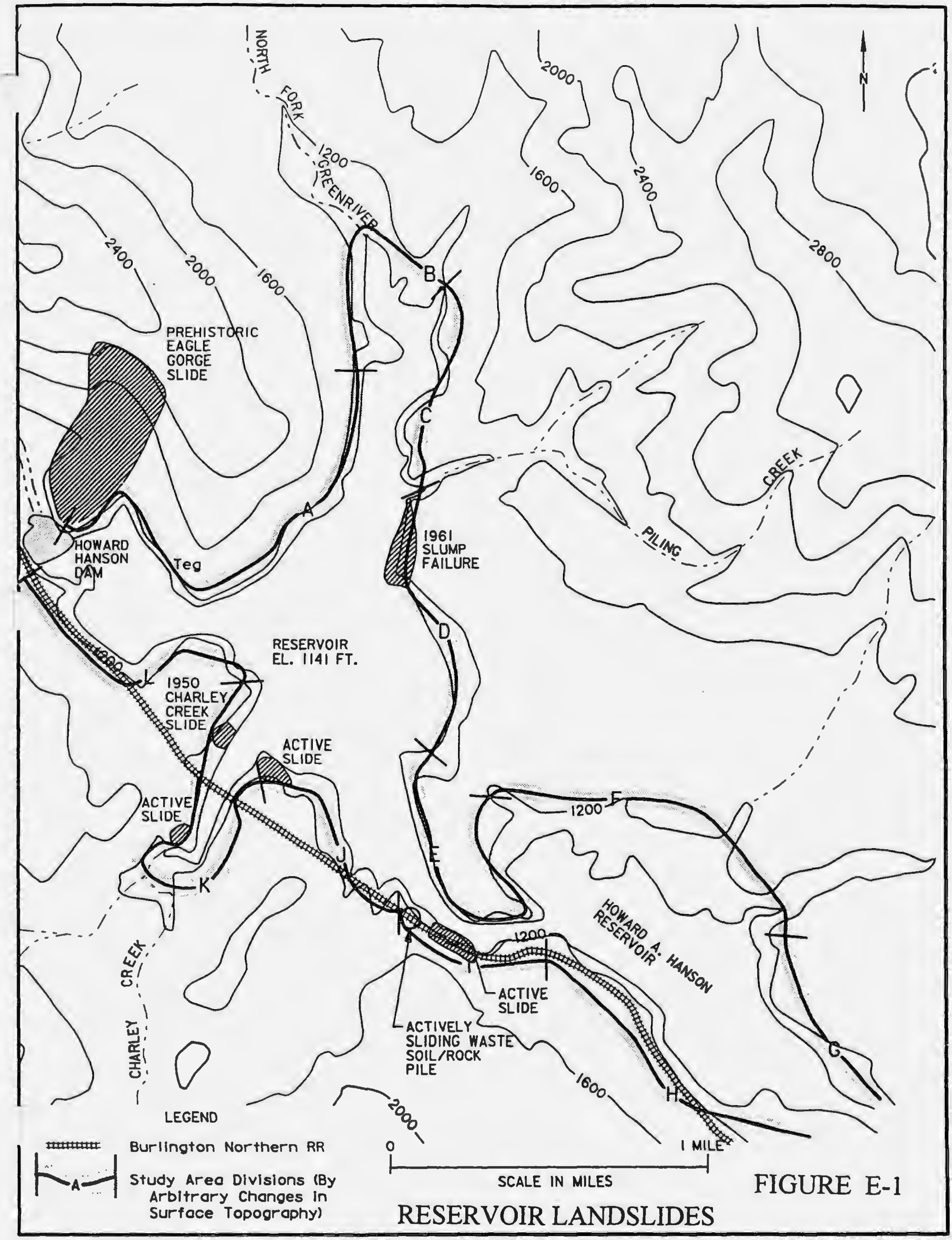


FIGURE E-1

RESERVOIR LANDSLIDES

H_T = TOTAL HEAD LOSS = 1141 − 1085 = 56

$H_T^2 = 56^2 = 3136$

$H_a^2 = \frac{2}{3}(3136) = 2091$ $H_a = \sqrt{2091} = 45.7'$

$H_b^2 = \frac{1}{3}(3136) = 1045$ $H_b = \sqrt{1045} = 32.4'$

$$q_{2A} = K\frac{(56.0-45.7)}{130}\left(\frac{56.0+45.7}{2}\right)$$

$$= K\left(\frac{10.3}{130}\right)\left(\frac{101.7}{2}\right) = 4.02K$$

$Q_{2A} = K4.02(130) = 522K$

$\Sigma Q_{TUNNEL} = 9(522)K = 4698K$

Q_{TUNNEL} FOR K = 100,000 FT/YEAR = .003175 FT/SEC

$Q = 4698(.003175) = 14.9$ FT³/SEC.

POOL AT ELEV. 1160

H_T = TOTAL HEAD LOSS = 1160 − 1085 = 75'

$H_T^2 = 75^2 = 5625$

$H_a^2 = 2/3(5625) = 3750$ $H_a = 61.2'$

$H_b^2 = 1/3(5625) = 1875$ $H_b = 43.3'$

$$q_{2A} = K\frac{(75-61.2)}{130}\frac{(75+61.2)}{2}$$

$$= K\left(\frac{13.8}{130}\right)\left(\frac{136.2}{2}\right) = 7.24K$$

$Q_{2A} = 7.24K(130) = 940K$

$\Sigma Q_{TUNNEL} = 9(940K) = 8460K$

Q_{TUNNEL} FOR K = 100,000 FT/YEAR = .003175 FT/SEC

$Q = 8460(.003175) = 26.8$ FT³/SEC

POOL AT ELEV. 1180

H_T = TOTAL HEAD LOSS = 1180 − 1085 = 95 $H_T^2 = 9025$

$H_a^2 = 2/3(9025) = 6017$ $H_a = 77.6'$

$H_b^2 = 1/3(9025) = 3008$ $H_b = 55'$

$$q_{2A} = K\frac{(95-77.6)}{130}\frac{(95+77.6)}{2} = K\left(\frac{17.4}{130}\right)\left(\frac{172.6}{2}\right) = K\,11.55$$

$Q_{2A} = K(11.55)(130) = 1500K$

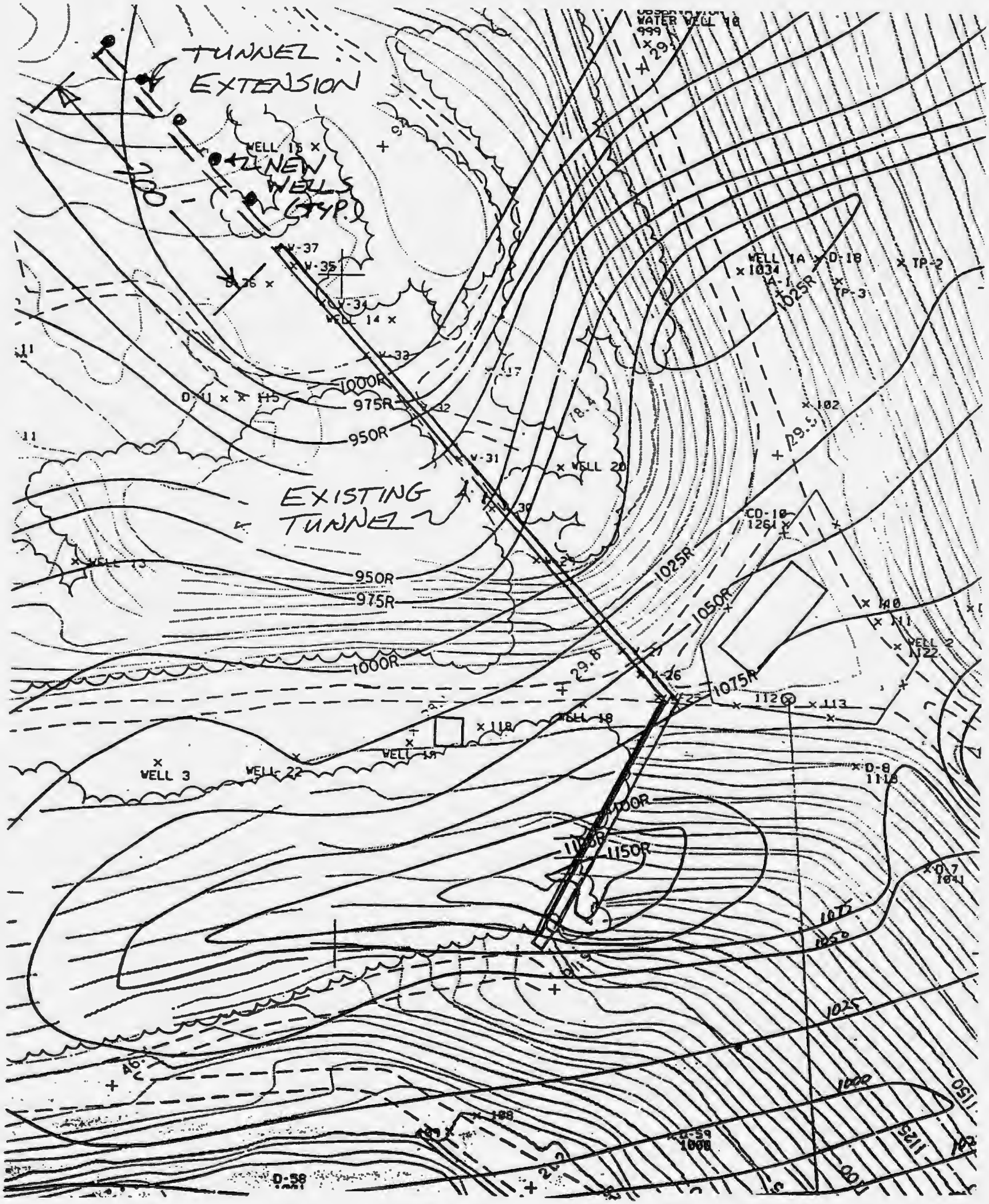
$\Sigma Q_{TUNNEL} = 9(1500K) = 13500K$

Q_{TUNNEL} FOR K = 100,000 FT/YEAR = .003175 FT/SEC

$Q = 13500(.003175) = 42.8$ FT³/SEC = 19,200 GPM

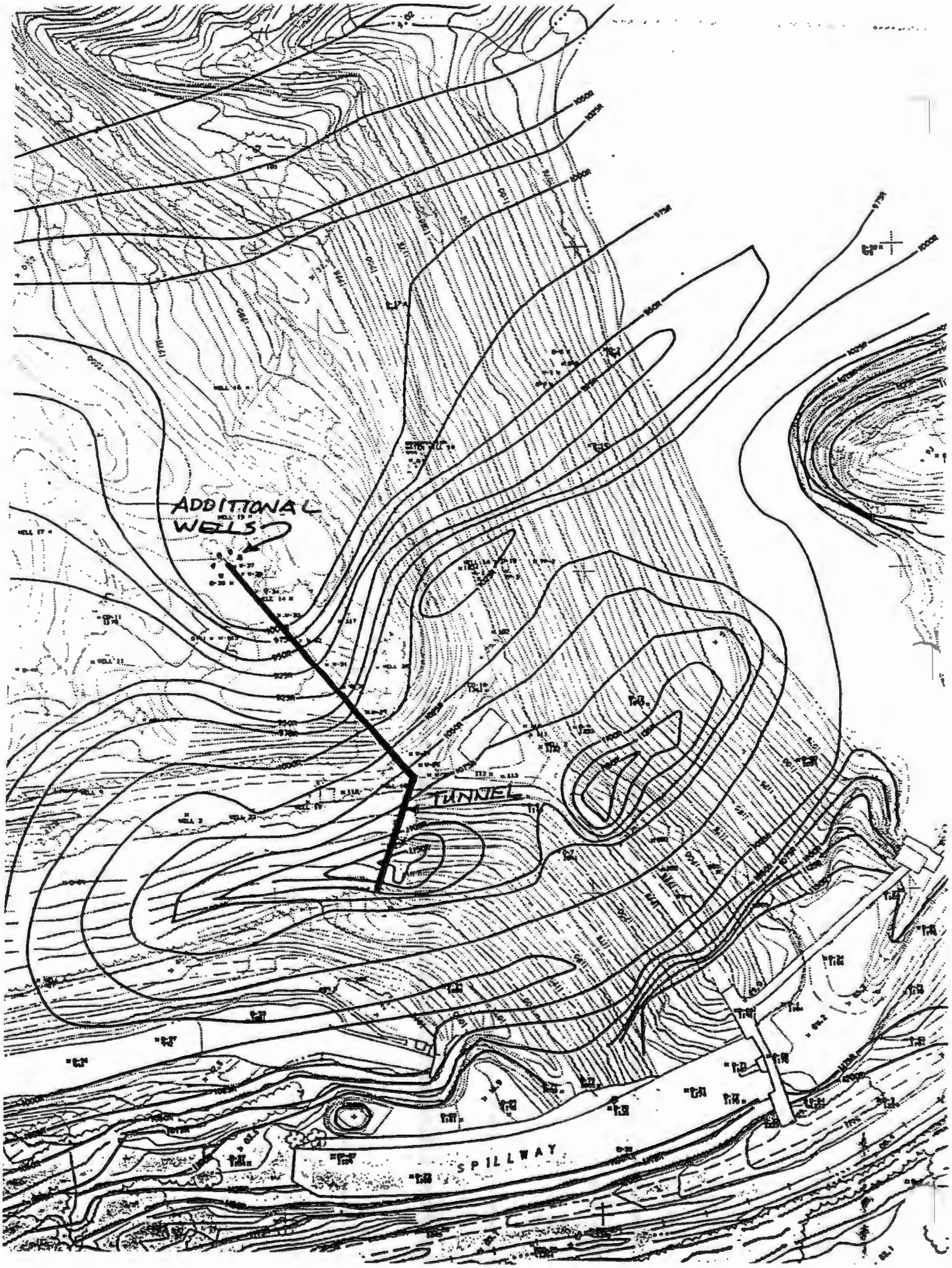
SEEPAGE CALCULATIONS

FIGURE E-2



TUNNEL EXTENSION

FIGURE E-3

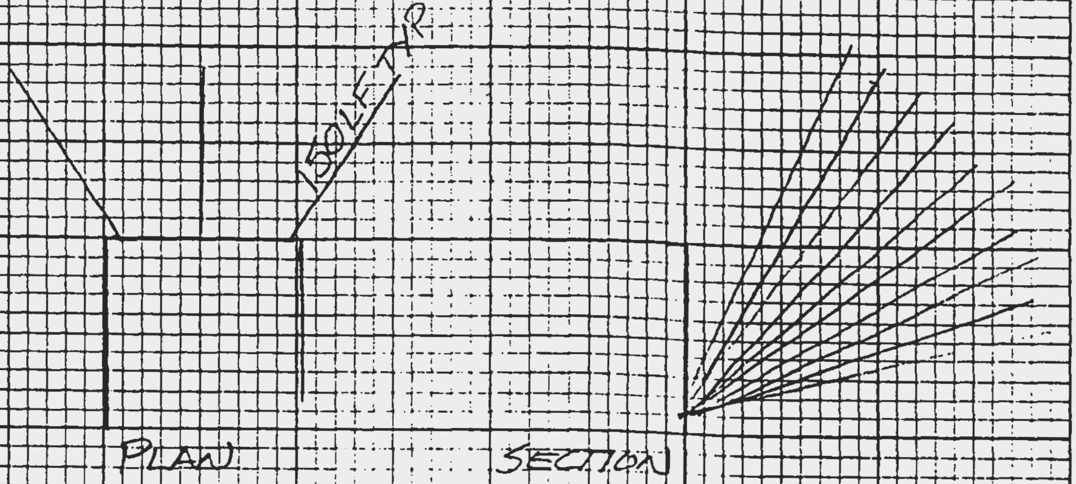


ADDITIONAL WELLS

FIGURE E-4

HORIZONTAL DRAINS DRILLED THROUGH
BACK OF EXISTING TUNNEL.

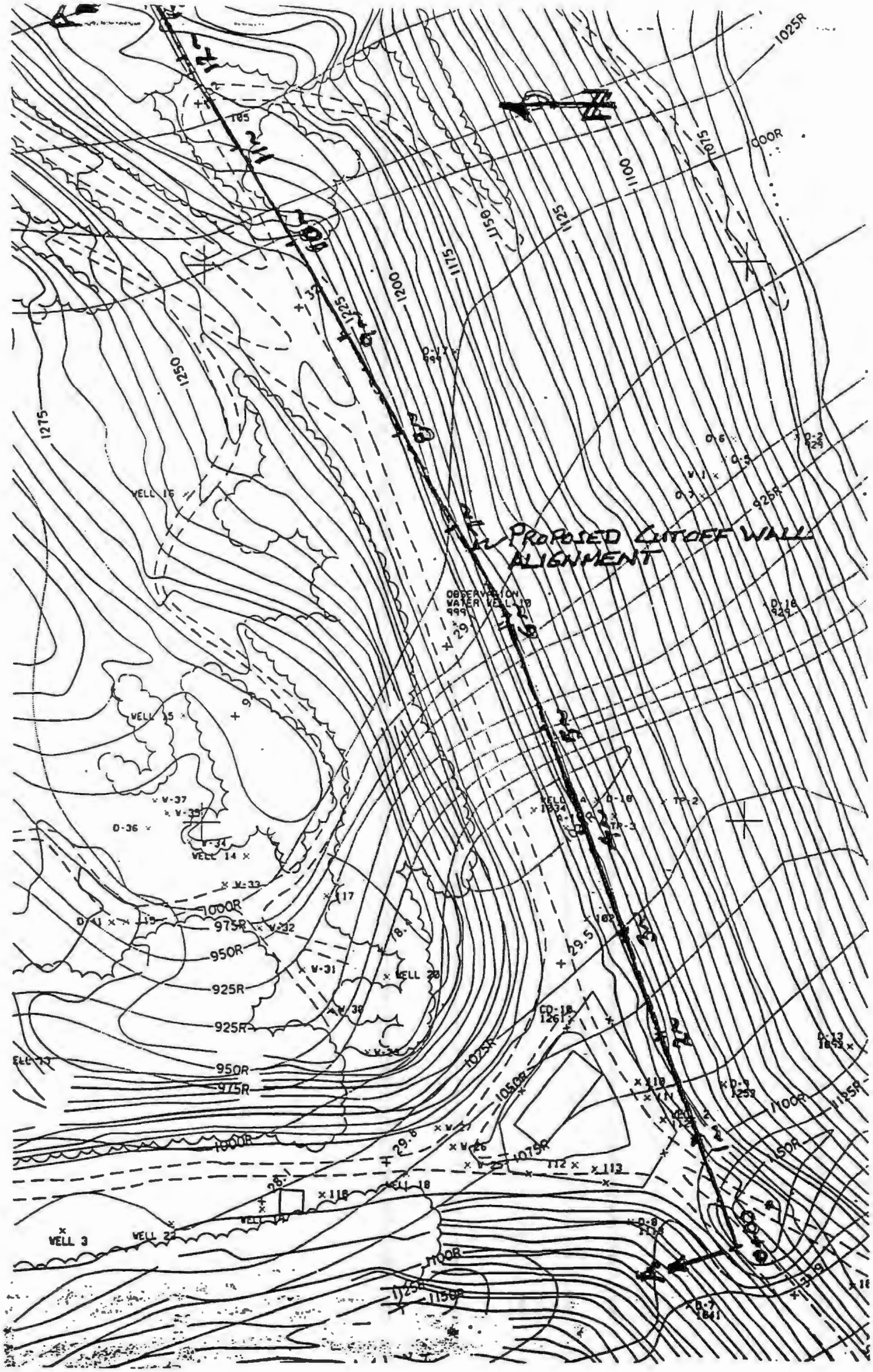
ASSUME THREE SETS:



10 DRAINS PER SET @ 150LF AVERAGE:
30 X 150 = 4500 LF TOTAL

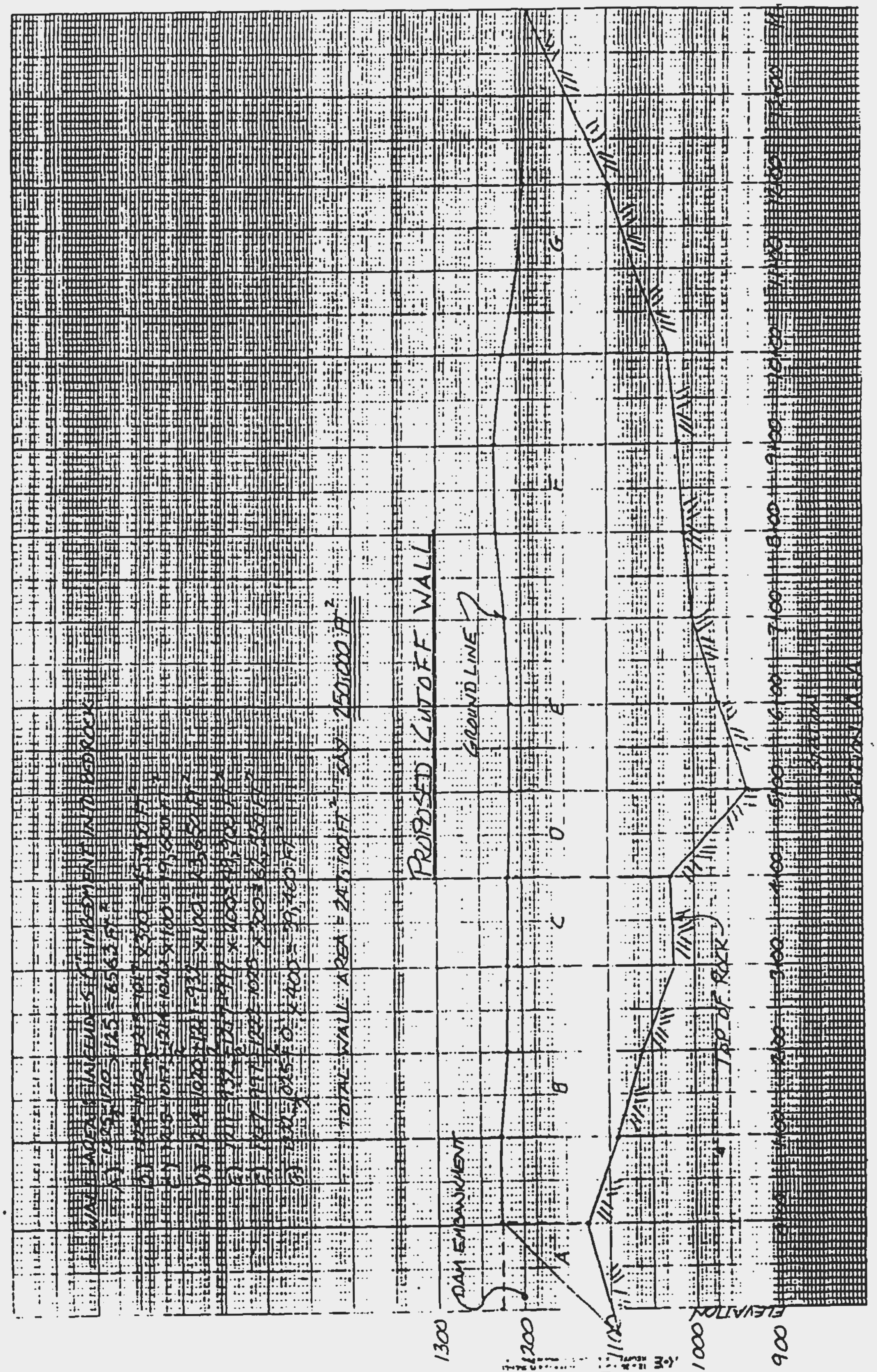
PROPOSED HORIZONTAL WELLS AT
BACK OF EXISTING TUNNEL

FIGURE E-5



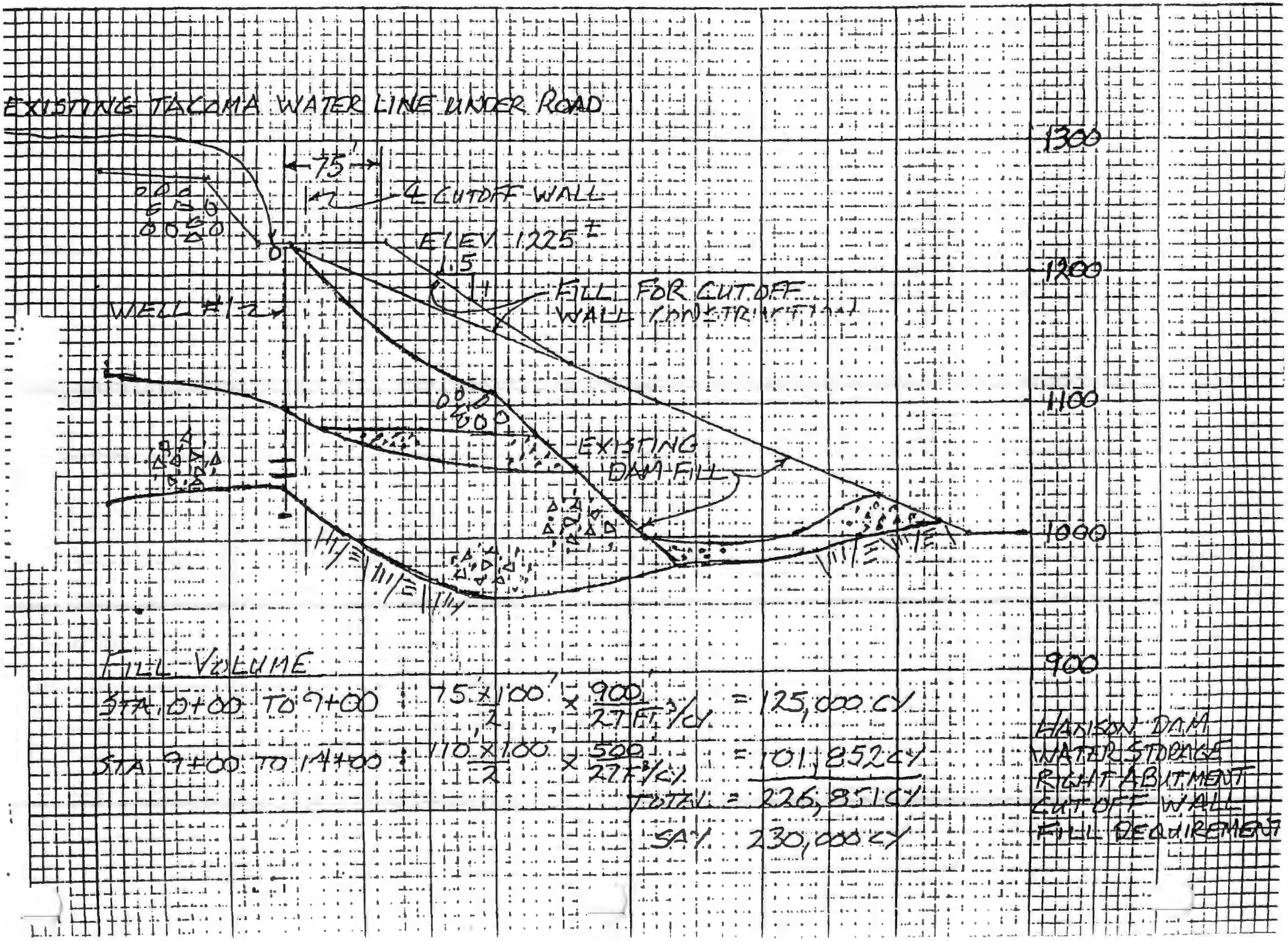
PROPOSED CUTOFF WALL ALIGNMENT

FIGURE F-6



PROPOSED CUTOFF WALL

FIGURE E-7



FILL VOLUME

STA. 0+00 TO 9+00 : $\frac{75' \times 100'}{2} \times \frac{900'}{27 FT^3/CY}$ = 125,000 CY

STA 9+00 TO 14+00 : $\frac{110' \times 100'}{2} \times \frac{500}{27 FT^3/CY}$ = 101,852 CY

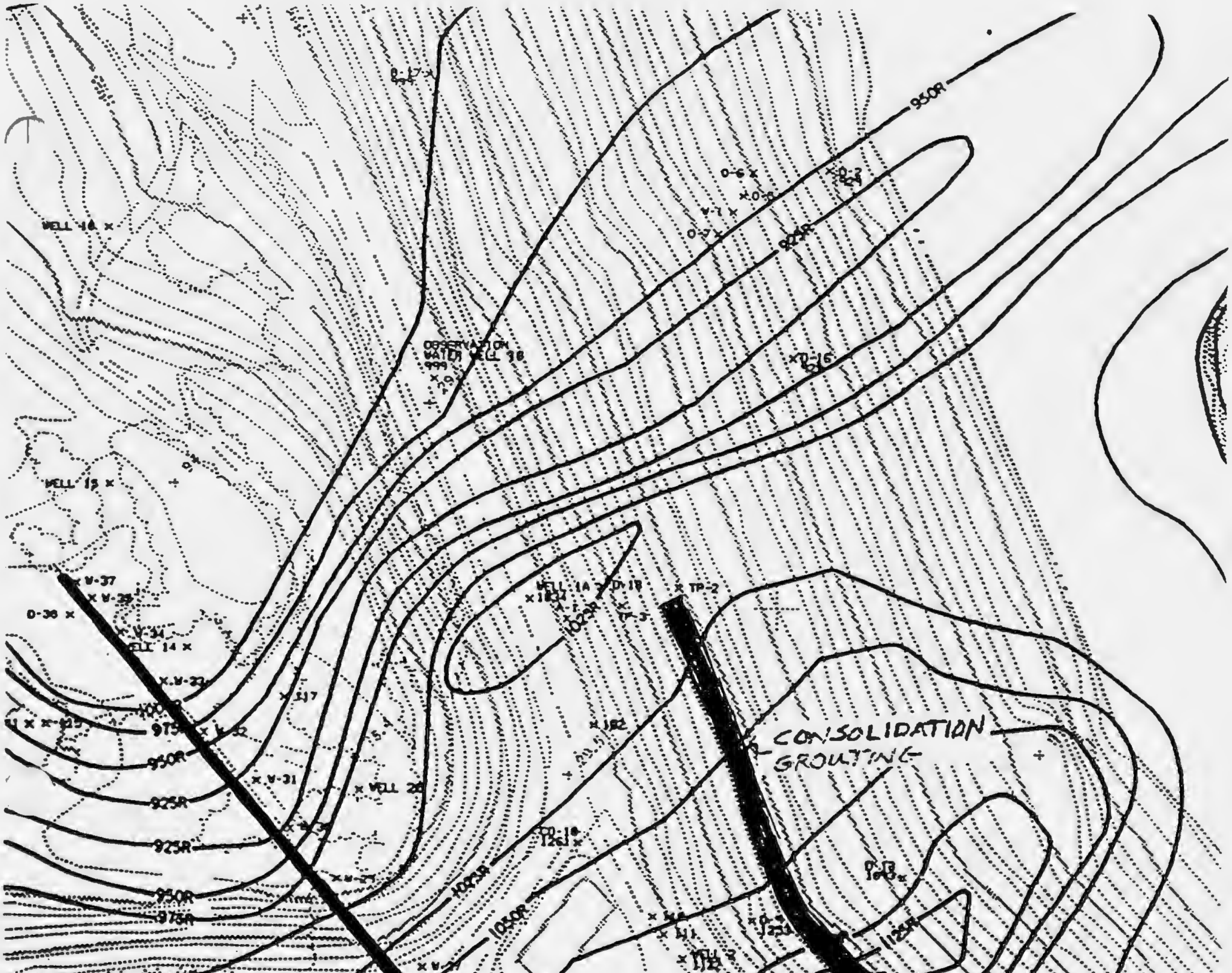
TOTAL = 226,851 CY

SAY 230,000 CY

HANSON DAM
WATER STORAGE
RIGHT ABUTMENT
CUTOFF WALL
FILL REQUIREMENT

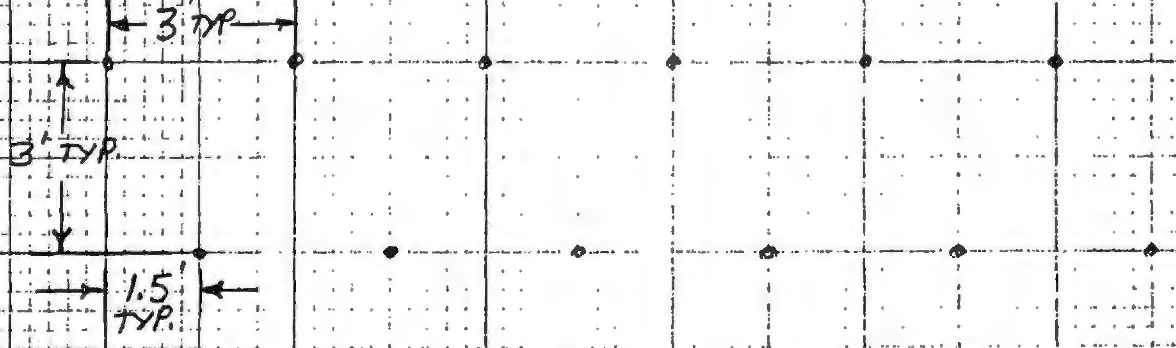
PAD FOR CUTOFF WALL CONSTRUCTION

FIGURE E-8



CONSOLIDATION (INJECTION) GROUTING PLAN

FIGURE E-9



BORINGS ON 3' PATTERN × 2 ROWS

AVERAGE DEPTH	# BORINGS		
60+80÷2 = 70'+10' = 80'	48	=	3840 LF
80+155÷2 = 118'+10' = 128	110	=	14080
155+10' = 165'	46	=	7590
TOTAL LF		=	$\boxed{25,510 \text{ LF}}$

1) ASSUME 6 INCH DIA. CASED BORINGS.
2) CASING TO BE PULLED & RE-USED ONCE GROUT TUBES ARE INSTALLED.

GROUT QUANTITY:

6" DIA. BORING = 0.7854 FT^2

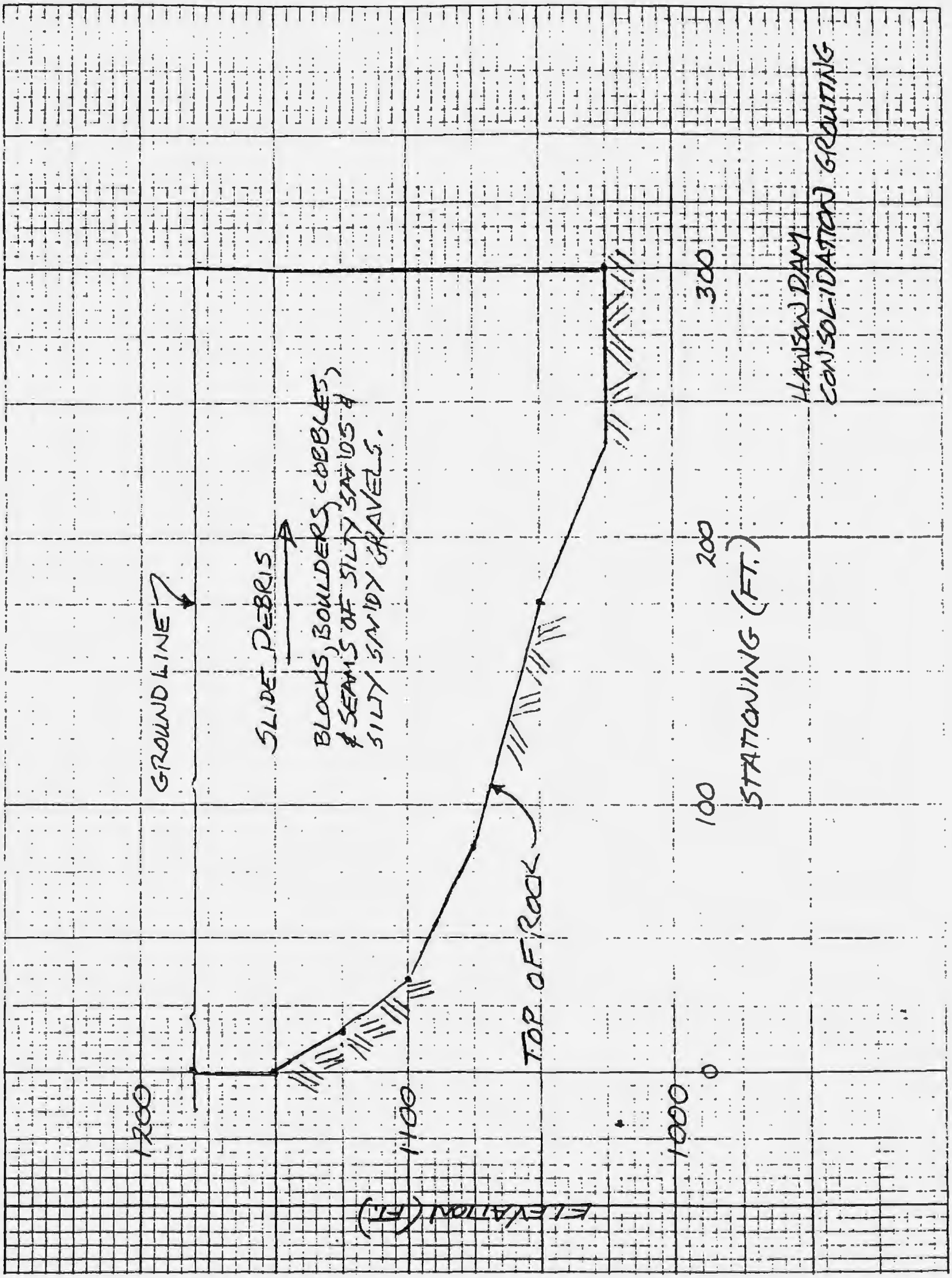
$0.7854 \times 25510 = 20,035 \; FT^3$

$20,035 / 27 \frac{CF}{CY} = 742 \; CY$

BY EXPERIENCE @ MUD MOUNTAIN DAM NEED A FACTOR OF 10 TO FILL VOIDS ∴ NEED $\boxed{7420 \text{ CY}}$

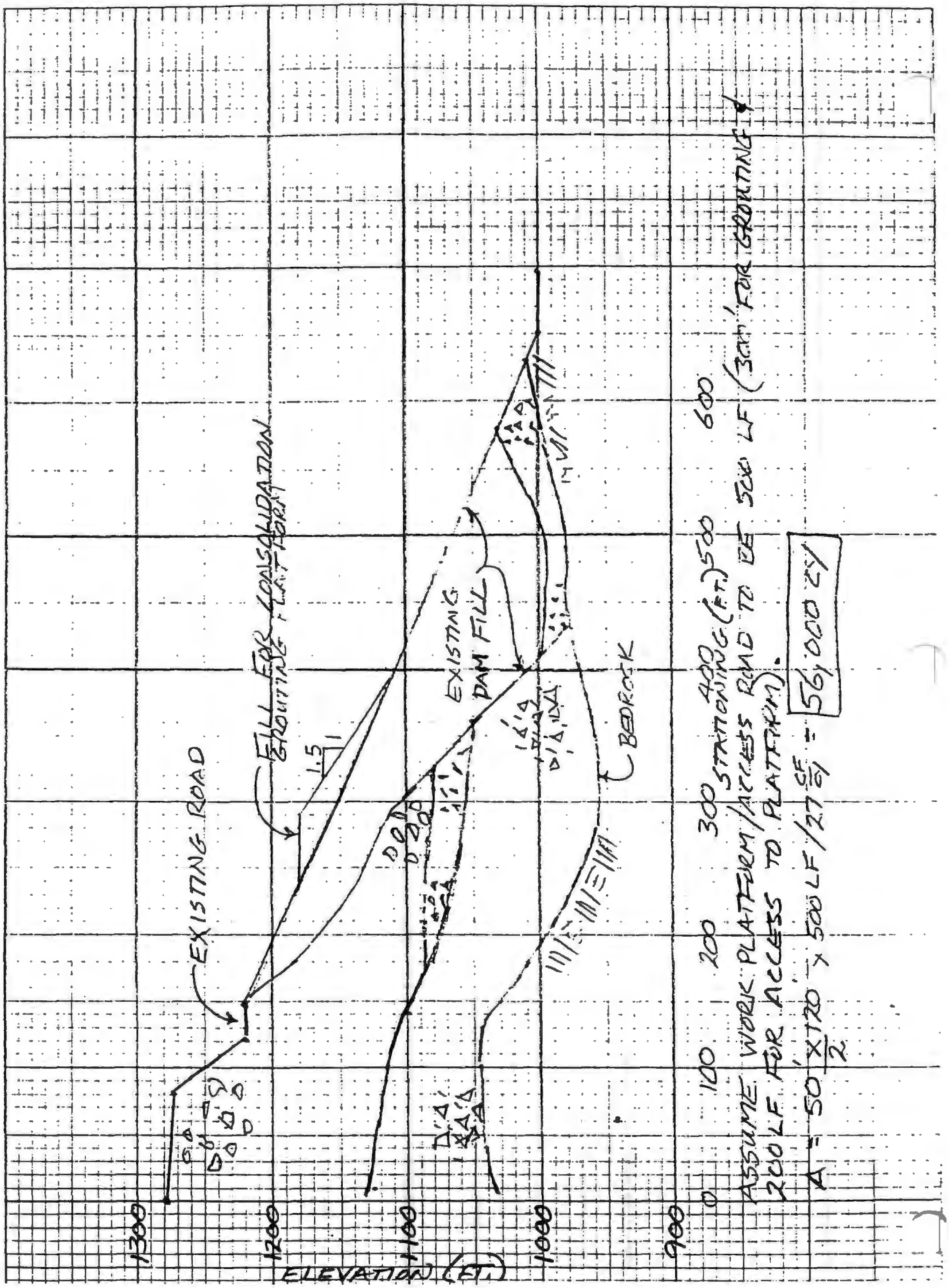
GROUT HOLE PATTERN

FIGURE E-10



INJECTION GROUT PROFILE

FIGURE E-11



ASSUME WORK PLATFORM/ACCESS ROAD TO BE 500 LF (300' FOR GROUTING + 200 LF FOR ACCESS TO PLATFORM).

$A = \frac{50' \times 120'}{2} \times 500\,LF / 27\,\frac{CF}{CY} = \boxed{56,000\ CY}$

WORK PLATFORM

FIGURE E-12

CSIR GEOMECHANICS CLASSIFICATION OF JOINTED ROCK MASSES

A. CLASSIFICATION PARAMETERS AND THEIR RATINGS

	PARAMETER		RANGES OF VALUES						
1	Strength of intact rock material	Point load strength index	>8 MPa	4-8 MPa	2-4 MPa	1-2 MPa	For this low range - uniaxial compressive test is preferred		
		Uniaxial compressive strength	>200 MPa	100-200 MPa	50-100 MPa	25-50 MPa	10-25 MPa	3-10 MPa	1-3 MPa
	Rating		15	12	7	4	2	1	0
2	Drill core quality RQD		90%-100%	75%-90%	50%-75%	25%-50%	<25%		
	Rating		20	17	13	8	3		
3	Spacing of joints		>3 m	1-3 m	0.3-1 m	50-300 mm	<50 mm		
	Rating		30	25	20	10	5		
4	Condition of joints		Very rough surfaces Not continuous No separation Hard joint wall rock	Slightly rough surfaces Separation <1 mm Hard joint wall rock	Slightly rough surfaces Separation <1 mm Soft joint wall rock	Slickensided surfaces or Gouge <5 mm thick or Joints open 1-5mm Continuous joints	Soft gouge >5mm thick or Joints open >5mm Continuous joints		
	Rating		25	20	12	6	0		
5	Ground water	Inflow per 10m tunnel length	None		<25 litres/min.	25-125 litres/min.	>125 litres/min		
		OR Ratio $\frac{\text{joint water pressure}}{\text{major principal stress}}$	0		0.0-0.2	0.2-0.5	>0.5		
		OR General conditions	Completely dry		Moist only (interstitial water)	Water under moderate pressure	Severe water problems		
	Rating		10		7	4	0		

B. RATING ADJUSTMENT FOR JOINT ORIENTATIONS

Strike and dip orientations of joints		Very favourable	Favourable	Fair	Unfavourable	Very unfavourable
Ratings	Tunnels	0	-2	-5	-10	-12
	Foundations	0	-2	-7	-15	-25
	Slopes	0	-5	-25	-50	-60

C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS

Rating	100—81	80—61	60—41	40—21	<20
Class No.	I	II	III	IV	V
Description	Very good rock	Good rock	Fair rock	Poor rock	Very poor rock

D. MEANING OF ROCK MASS CLASSES

Class No.	I	II	III	IV	V
Average stand-up time	10 years for 5m span	6 months for 4 m span	1 week for 3 m span	5 hours for 1.5 m span	10 min. for 0.5m span
Cohesion of the rock mass	>300 kPa	200-300 kPa	150-200 kPa	100-150 kPa	<100 kPa
Friction angle of the rock mass	>45°	40°-45°	35°-40°	30°-35°	<30°

CSIR GE0MECHANICS CLASSIFICATION
OF JOINTED ROCK MASSES (1978)

FIGURE E-13a

Table 7-4
Geomechanics Classification of Jointed Rock Masses

A. CLASSIFICATION PARAMETERS AND THEIR RATINGS

PARAMETER			RANGES OF VALUES						
1	Strength of intact rock material	Point-load strength index	>10 MPa	4-10 MPa	2-4 MPa	1-2 MPa	For this low range - uniaxial compressive test is preferred		
			>250 MPa	100-150 MPa	50-100 MPa	25-50 MPa	5-25 MPa	1-5 MPa	<1 MPa
	Rating		15	12	7	4	2	1	0
2	Drill core quality RQD		90-100%	75-90%	50-75%	25-50%	< 25%		
	Rating		20	17	13	8	3		
3	Spacing of discontinuities		>2 m	0.6-2 m	200-600 mm	60-200 mm	<60 mm		
	Rating		20	15	10	8	5		
4	Condition of discontinuities		Very rough surfaces. Not continuous. No separation. Unweathered wall rock.	Slightly rough surfaces. Separation <1 mm. Slightly weathered walls.	Slightly rough surfaces. Separation < 1 mm. Highly weathered walls.	Slickensided surfaces OR Gouge < 5 mm thick. Separation 1-5 mm. Continuous.	Soft gouge > 5 mm thick OR Separation > 5 mm. Continuous.		
	Rating		30	25	20	10	0		
5	Ground-water	Inflow per 10 m tunnel length	None	<10 L/min	10-25 L/min	25-125 L/min	>125 L/min		
		Ratio: joint water pressure major principal stress	OR 0	OR 0.0-0.1	OR 0.1-0.2	OR 0.2-0.5	OR >0.5		
		General conditions	OR Completely dry	OR Damp	OR Wet	OR Dripping	OR Flowing		
	Rating		15	10	7	4	0		

B. RATING ADJUSTMENT FOR JOINT ORIENTATIONS

Strike and dip orientations and dips		Very favorable	Favorable	Fair	Unfavorable	Very unfavorable
Ratings	Tunnels	0	-2	-5	-10	-12
	Foundations	0	-2	-7	-15	-25
	Slopes	0	-5	-25	-50	-60

C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS

Rating	100 ← 81	80 ← 61	60 ← 41	41 ← 21	<20
Class No.	I	II	III	IV	V
Description	Very good rock	Good rock	Fair rock	Poor rock	Very poor rock

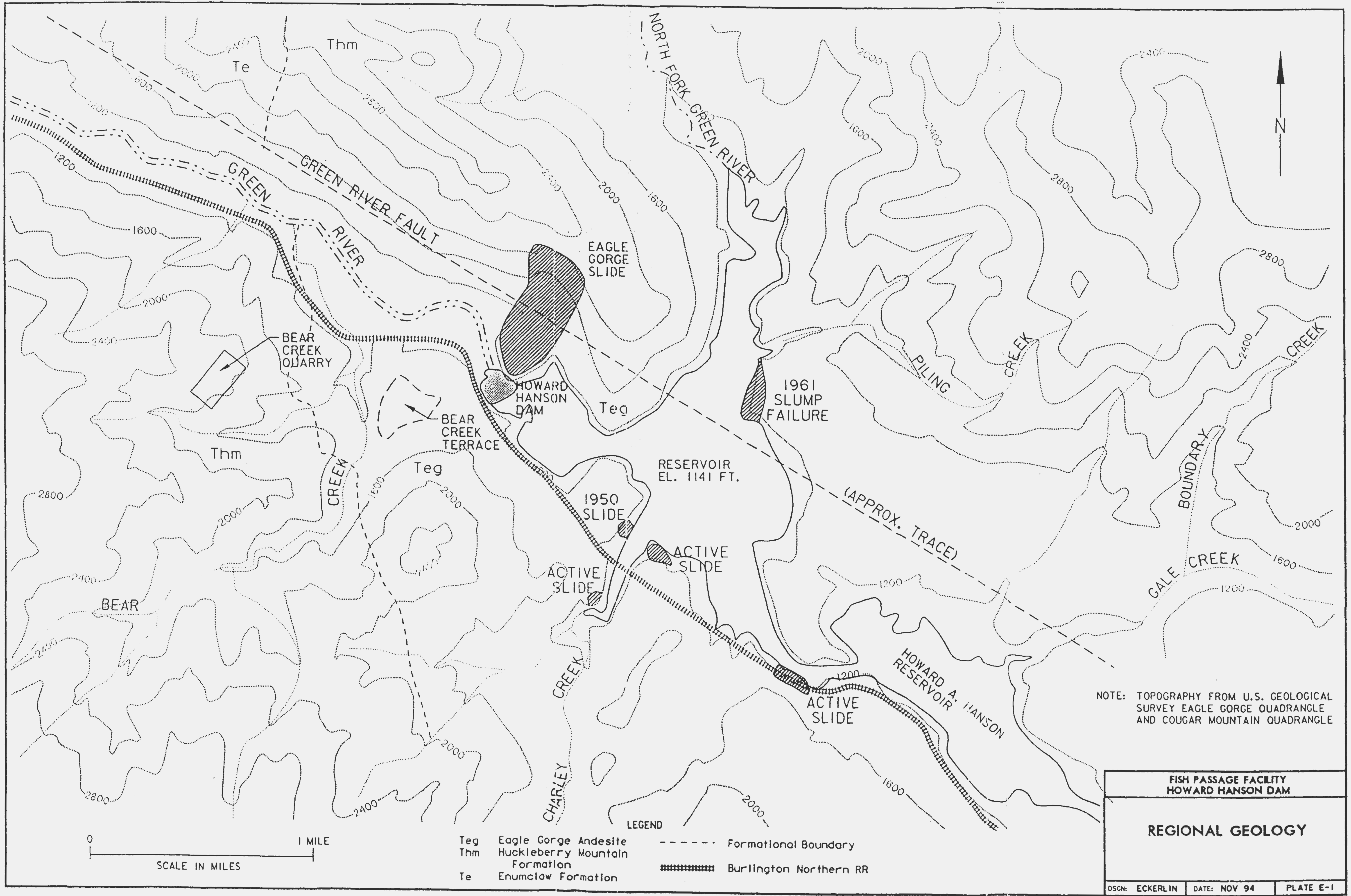
D. MEANING OF ROCK MASS CLASSES

Class No.	I	II	III	IV	V
Average stand-up time	10 years for 15-m span	6 months for 8-m span	1 week for 5-m span	10 hr for 2.5-m span	30 min for 1-m span
Cohesion of the rock mass	>400 kPa	300-400 kPa	200-300 kPa	100-200 kPa	<100 kPa
Friction angle of the rock mass	>45°	35-45°	25-45°	15-25°	<15°

GE0MECHANICS CLASSIFICATION OF JOINTED ROCK MASSES (1997)

FIGURE E-13b

PLATES



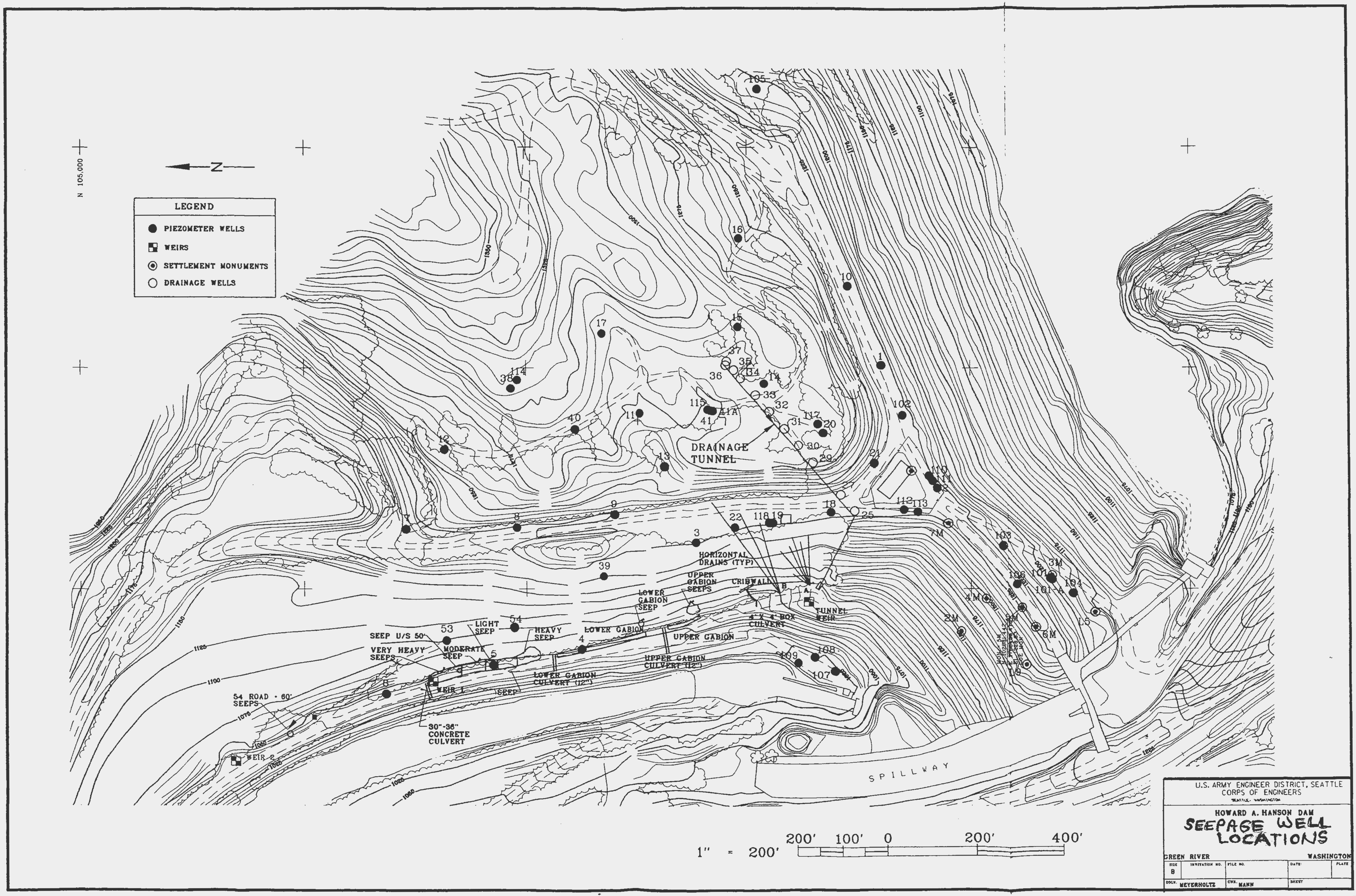
NOTE: TOPOGRAPHY FROM U.S. GEOLOGICAL SURVEY EAGLE GORGE QUADRANGLE AND COUGAR MOUNTAIN QUADRANGLE

FISH PASSAGE FACILITY
HOWARD HANSON DAM

REGIONAL GEOLOGY

DSGN: ECKERLIN | DATE: NOV 94 | PLATE E-1

PLATE E-1



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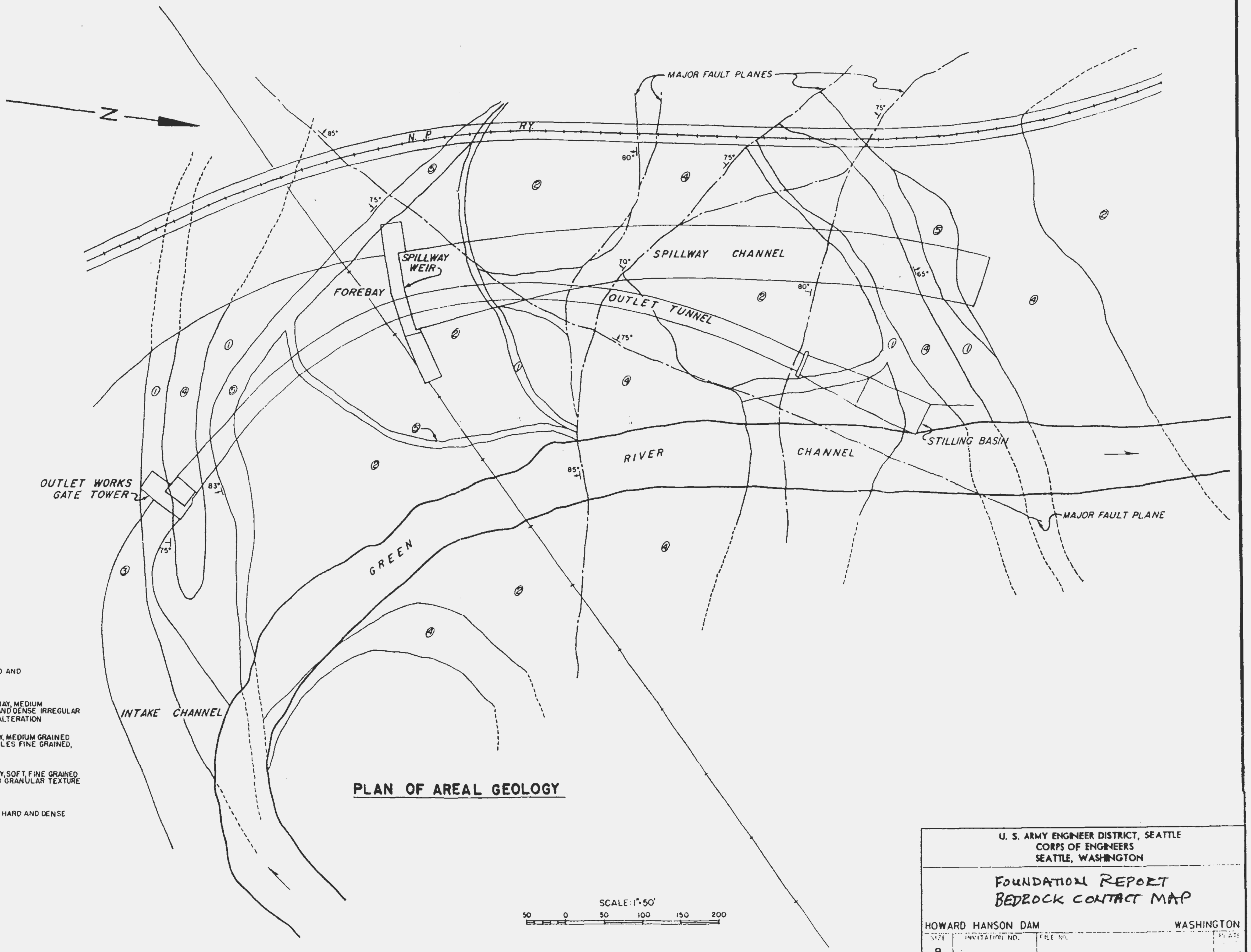
HOWARD A. HANSON DAM
SEEPAGE WELL
LOCATIONS

GREEN RIVER WASHINGTON

SIZE	INVITATION NO.	FILE NO.	DATE:	PLATE
B				
DSGN. MEYERHOLTZ		CHK. MANN	SHEET	

PLATE E-2



PLAN OF AREAL GEOLOGY

LEGEND

1	BASALT BLACK, FINE GRAINED HARD AND DENSE MODERATELY FRACTURED
2	ANDESITE DARK GREEN TO DARK GRAY, MEDIUM TO FINE GRAINED, MODERATELY HARD AND DENSE IRREGULAR FRACTURES MINOR HYDROTHERMAL ALTERATION
3	BASALTIC PYROCLASTICS DARK GRAY, MEDIUM GRAINED MODERATELY HARD AND DENSE NODULES FINE GRAINED, BLACK HARD AND DENSE
4	ANDESITE PYROCLASTICS LIGHT GRAY, SOFT, FINE GRAINED DENSE NODULES MODERATELY HARD GRANULAR TEXTURE
5	FELSITE FINE GRAINED, LIGHT GRAY, HARD AND DENSE

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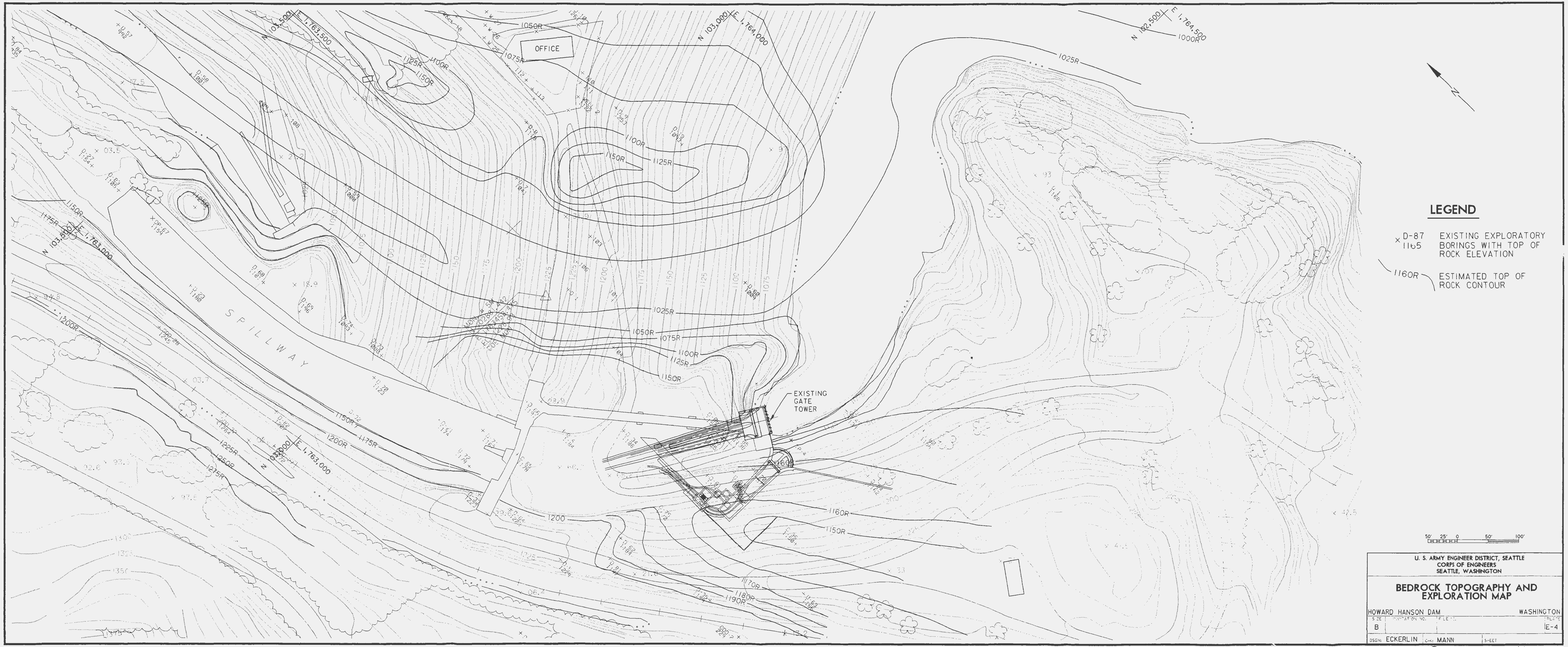
FOUNDATION REPORT
BEDROCK CONTACT MAP

HOWARD HANSON DAM WASHINGTON

SIZE	INVITATION NO.	FILE NO.	PLATE
B			

DSGN: ECKERLIN CHK: MANN SHEET

PLATE E-3



LEGEND

× D-87 1165	EXISTING EXPLORATORY BORINGS WITH TOP OF ROCK ELEVATION
1160R	ESTIMATED TOP OF ROCK CONTOUR

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SEATTLE, WASHINGTON

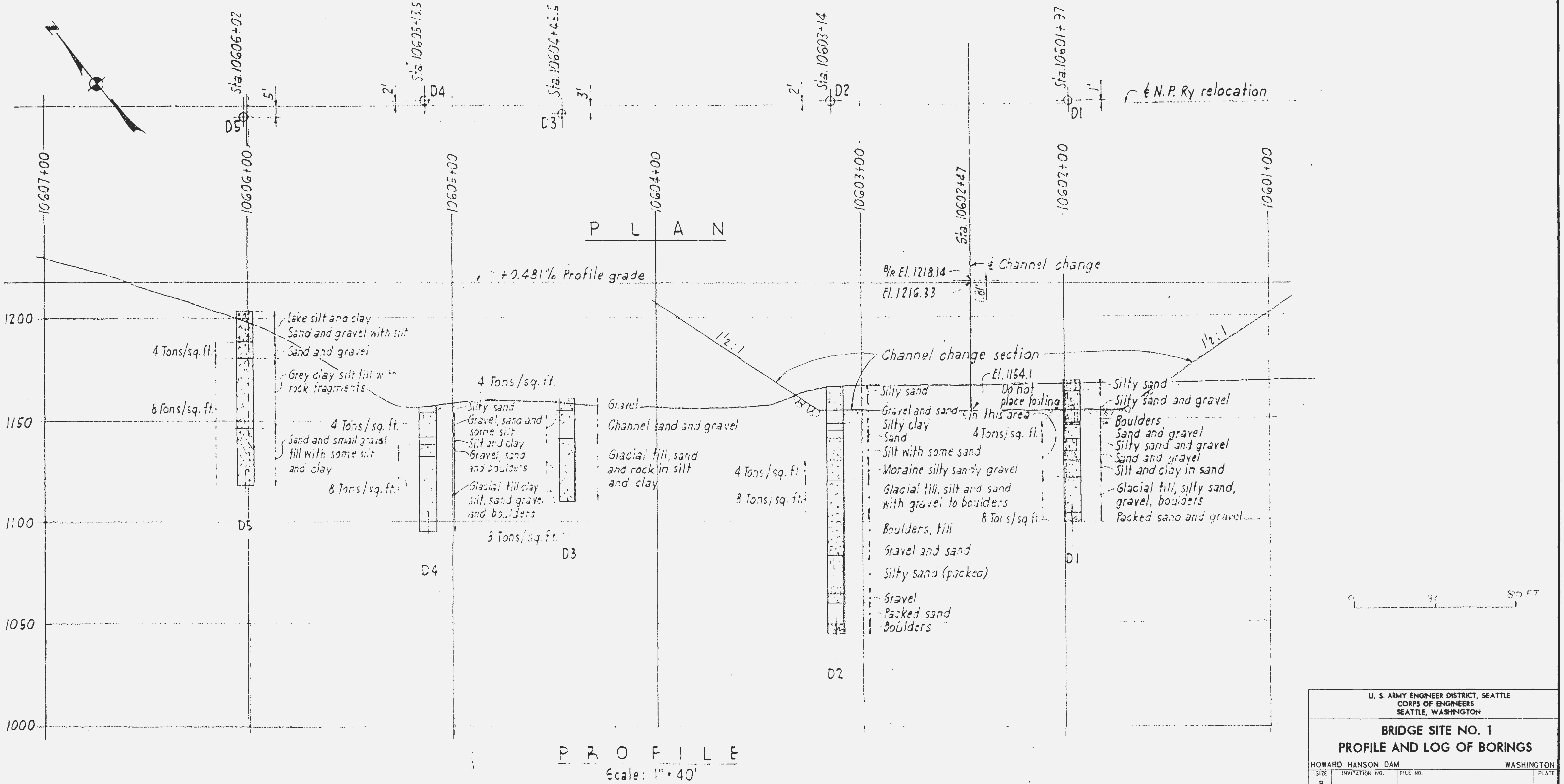
BEDROCK TOPOGRAPHY AND EXPLORATION MAP

HOWARD HANSON DAM WASHINGTON

SIZE	INVITATION NO.	FILE NO.	PLATE
B			E-4

DSGN: ECKERLIN CHK: MANN SHEET

PLATE E-4



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BRIDGE SITE NO. 1
PROFILE AND LOG OF BORINGS

HOWARD HANSON DAM			WASHINGTON
SIZE B	INVITATION NO.	FILE NO.	PLATE
DSGN: ECKERLIN	CKD: MANN	SHEET	

PLATE E-5

U. S. ARMY ENGINEER DISTRICT, SEATTLE
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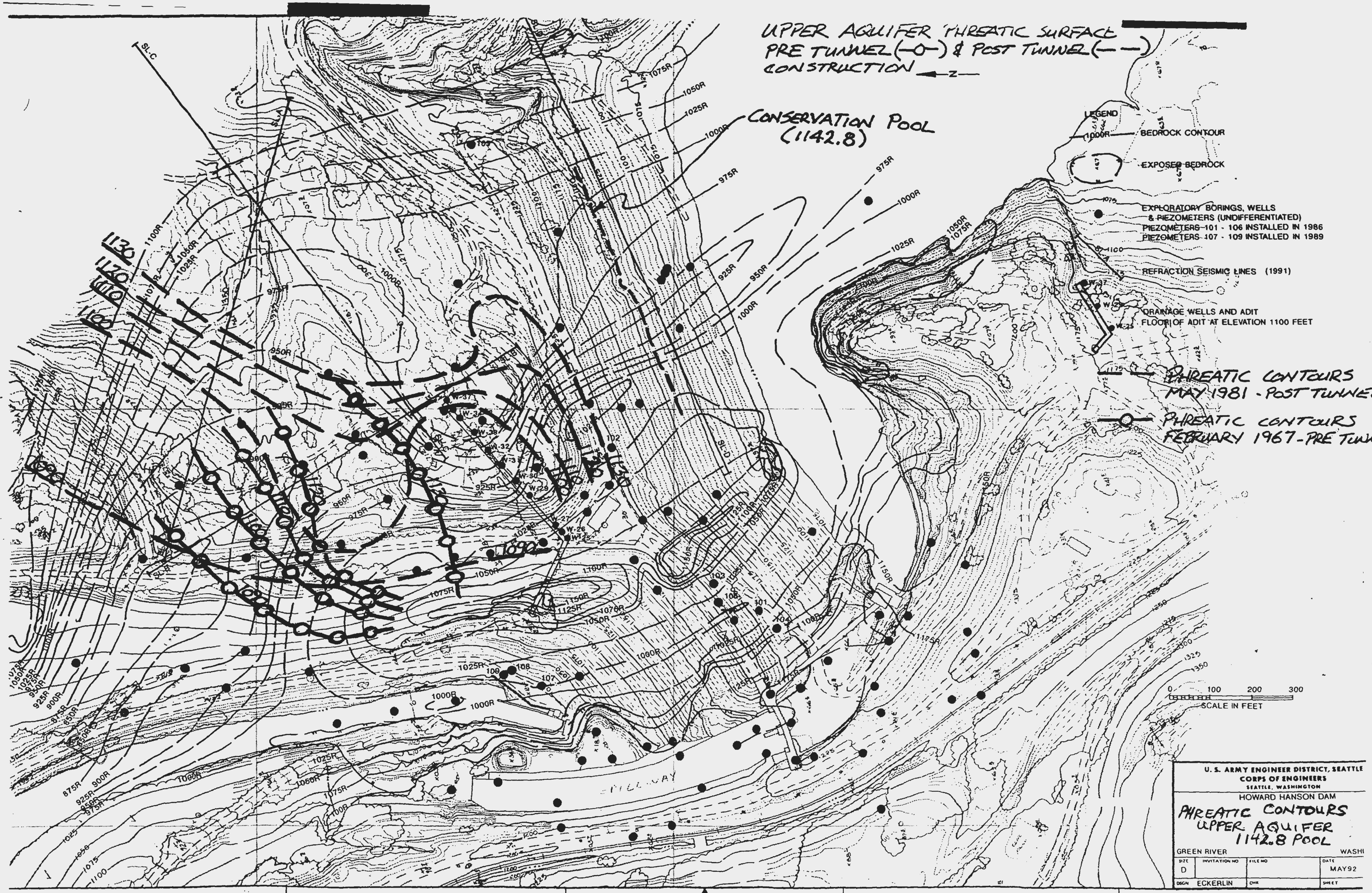
BRIDGE SITE NO. 2
PROFILE AND LOG OF BORINGS

HOWARD HANSON DAM WASHINGTON

SIZE B

DSGN. ECKERLIN CH'K'D MANN SHEET

PLATE · E-6



U. S. ARMY ENGINEER DISTRICT, SEATTLE
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SEATTLE, WASHINGTON

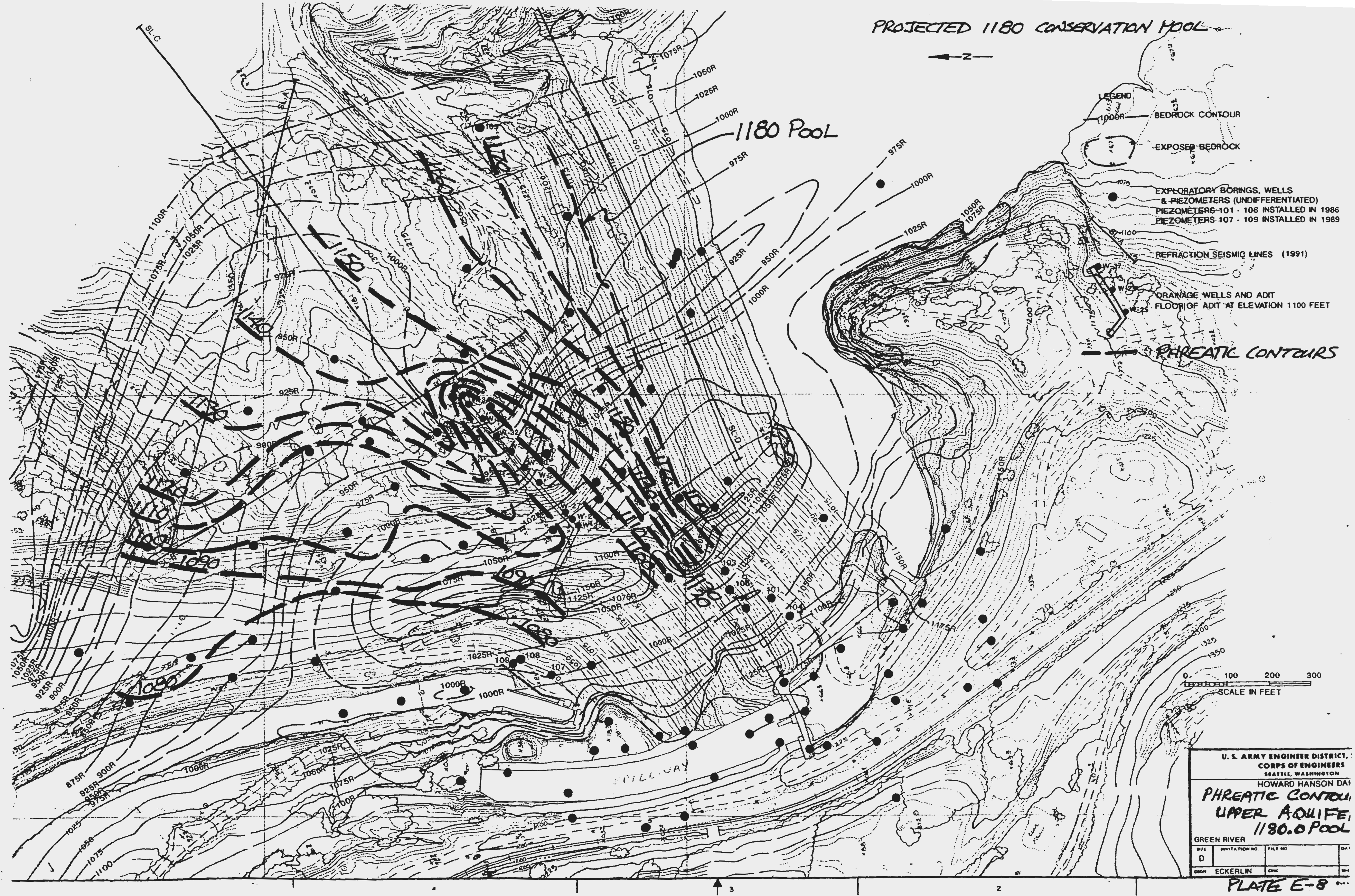
HOWARD HANSON DAM

PHREATIC CONTOURS
UPPER AQUIFER
1142.8 POOL

GREEN RIVER WASHI

SIZE	INVITATION NO	FILE NO	DATE
D			MAY92
DSGN ECKERLIN		CHK	SHEET

PLATE E-7



U. S. ARMY ENGINEER DISTRICT,
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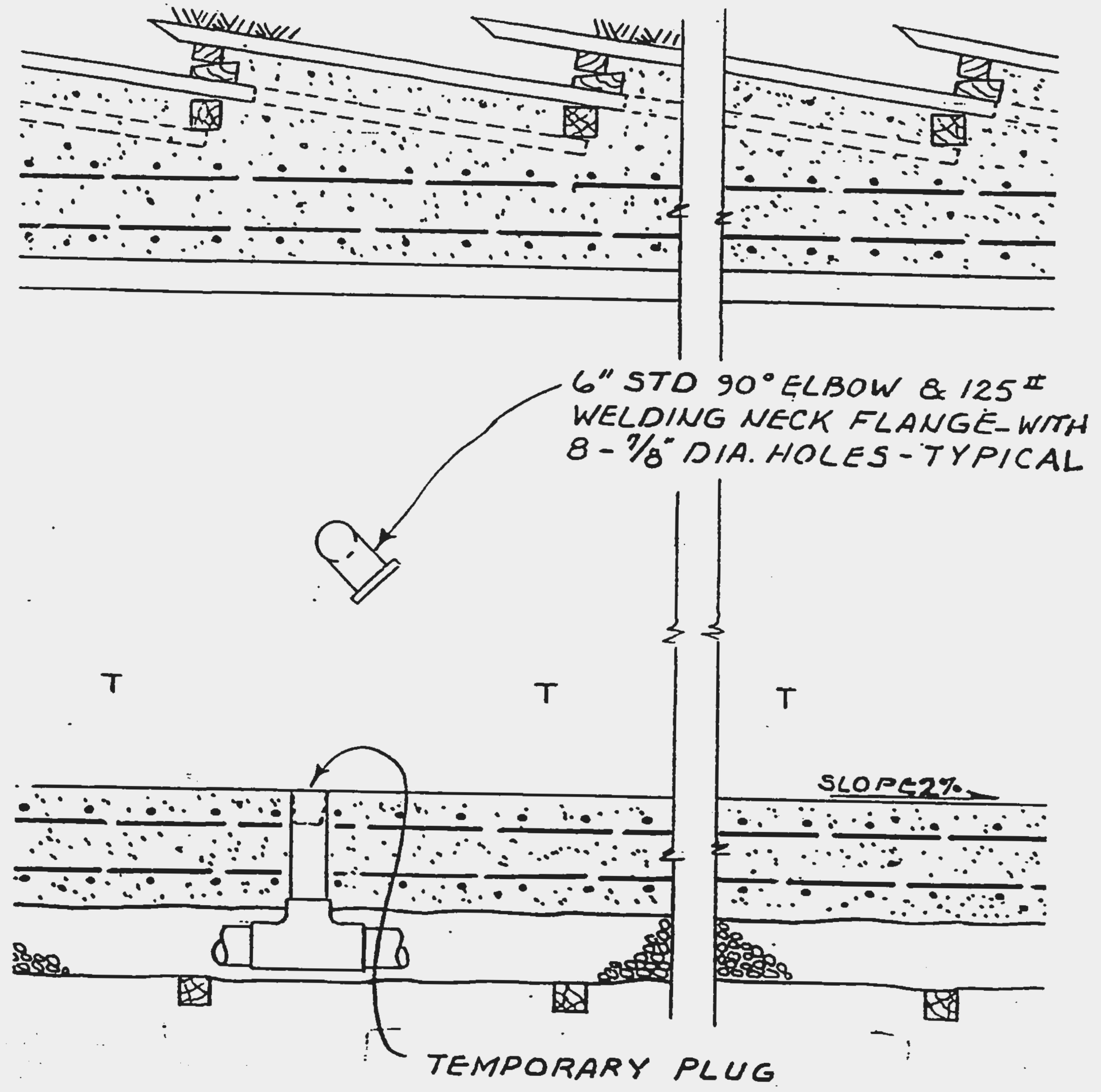
SEATTLE, WASHINGTON

HOWARD HANSON DAM
PHREATIC CONTOU
UPPER AQUIFE
1180.0 POOL

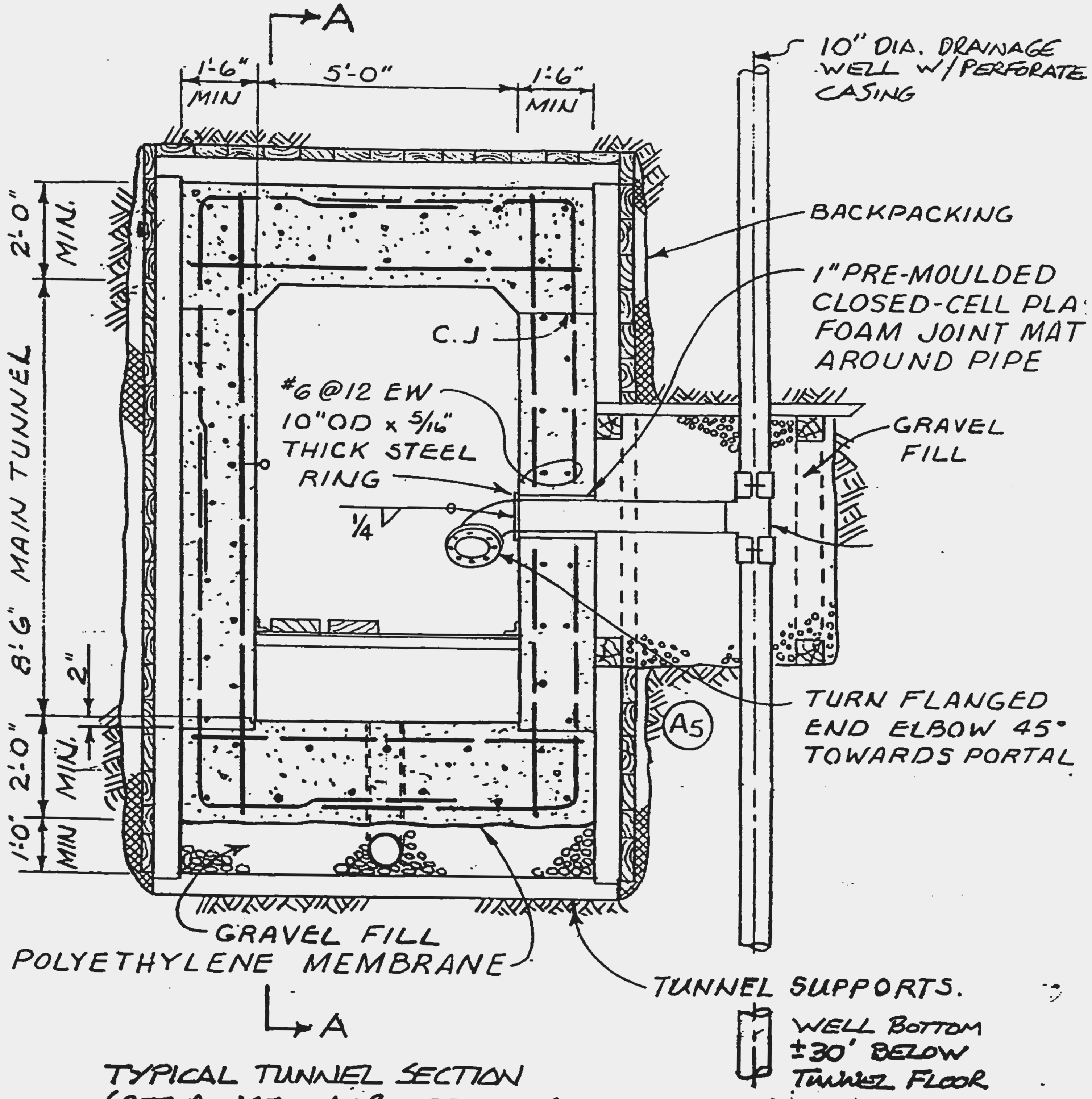
GREEN RIVER

SIZE	INVITATION NO.	FILE NO	DA
D			
DSGN ECKERLIN	CHK.		SH

PLATE E-8



SECTION A-A

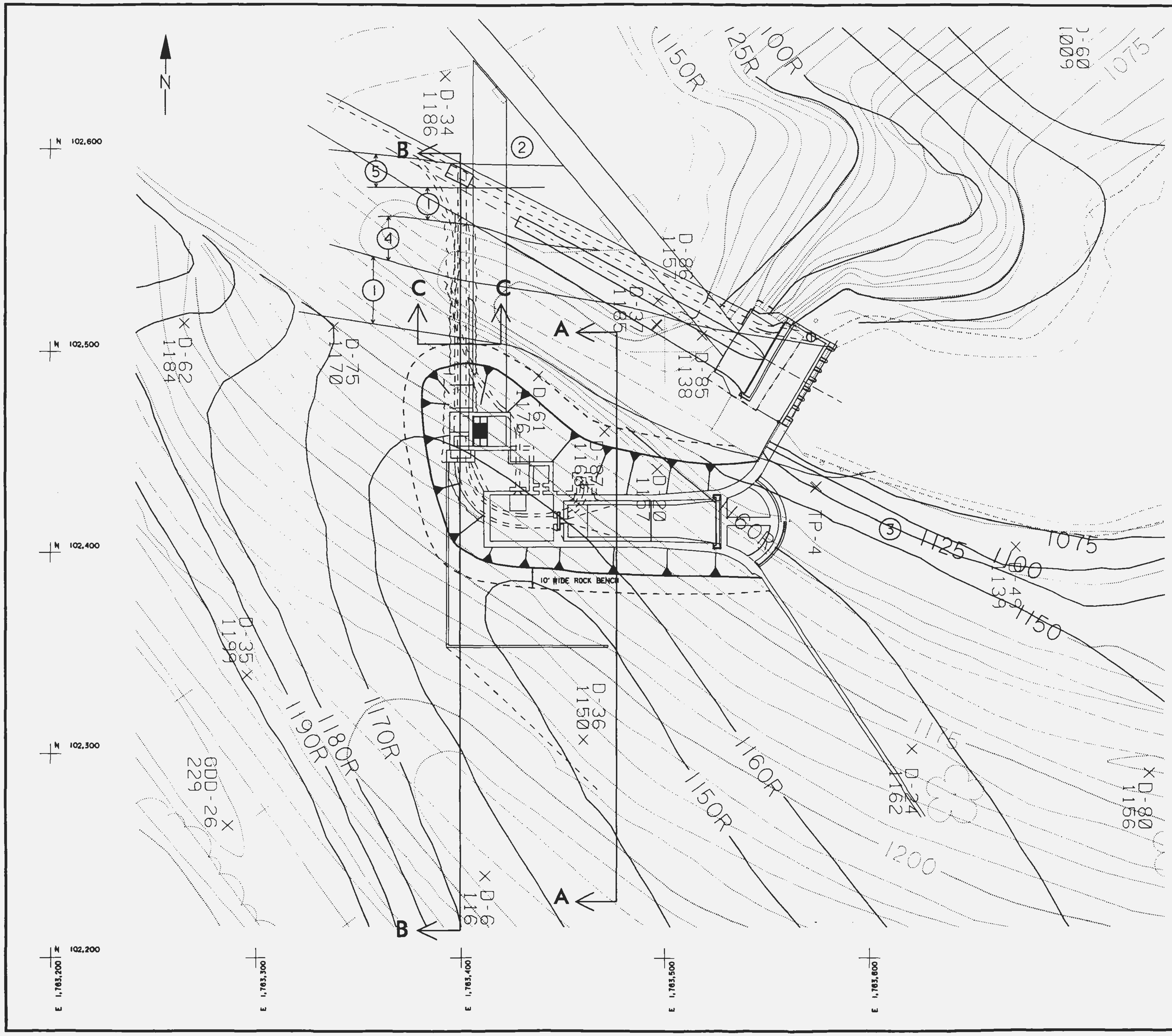


TYPICAL TUNNEL SECTION
(REFERENCE - AS BUILT DRAWING
FOR EXISTING TUNNEL - E-56-11-53)

WORK PLATFORM

ASSUME WELL SPACING
OF 40 FT. ∴ 5 WEL
@ 238', 235', 230', 223'
& 217'
TOTAL = 1143 SAY 11

PLATE E-9



LEGEND

① - BASALT

② - ANDESITE

③ - BASALT PYROCLASTICS

④ - ANDESITE PYROCLASTICS

⑤ - FELSITE

1160R - APPROXIMATE BEDROCK CONTOUR

NOTES:

1. ROCK CONTACTS ARE ESTIMATED USING FOUNDATION REPORT PLATES. THESE ESTIMATED CONTACTS ARE AT THE ELEVATION OF THE DIVERSION TUNNEL.
2. ROCK TYPES FOR THE FISH PASSAGE FACILITY EXCAVATION WILL BE EXPLORED DURING FUTURE EXPLORATORY DRILLING CONTRACTS.
3. SECTION A-A SHOWN ON PLATE E-17 AND SECTIONS B-B AND C-C ARE SHOWN ON PLATE E-18.
4. TUNNEL ALIGNMENT AND TRANSITION TO BE REORIENTED DURING PED.

50' 25' 0 50' 100'

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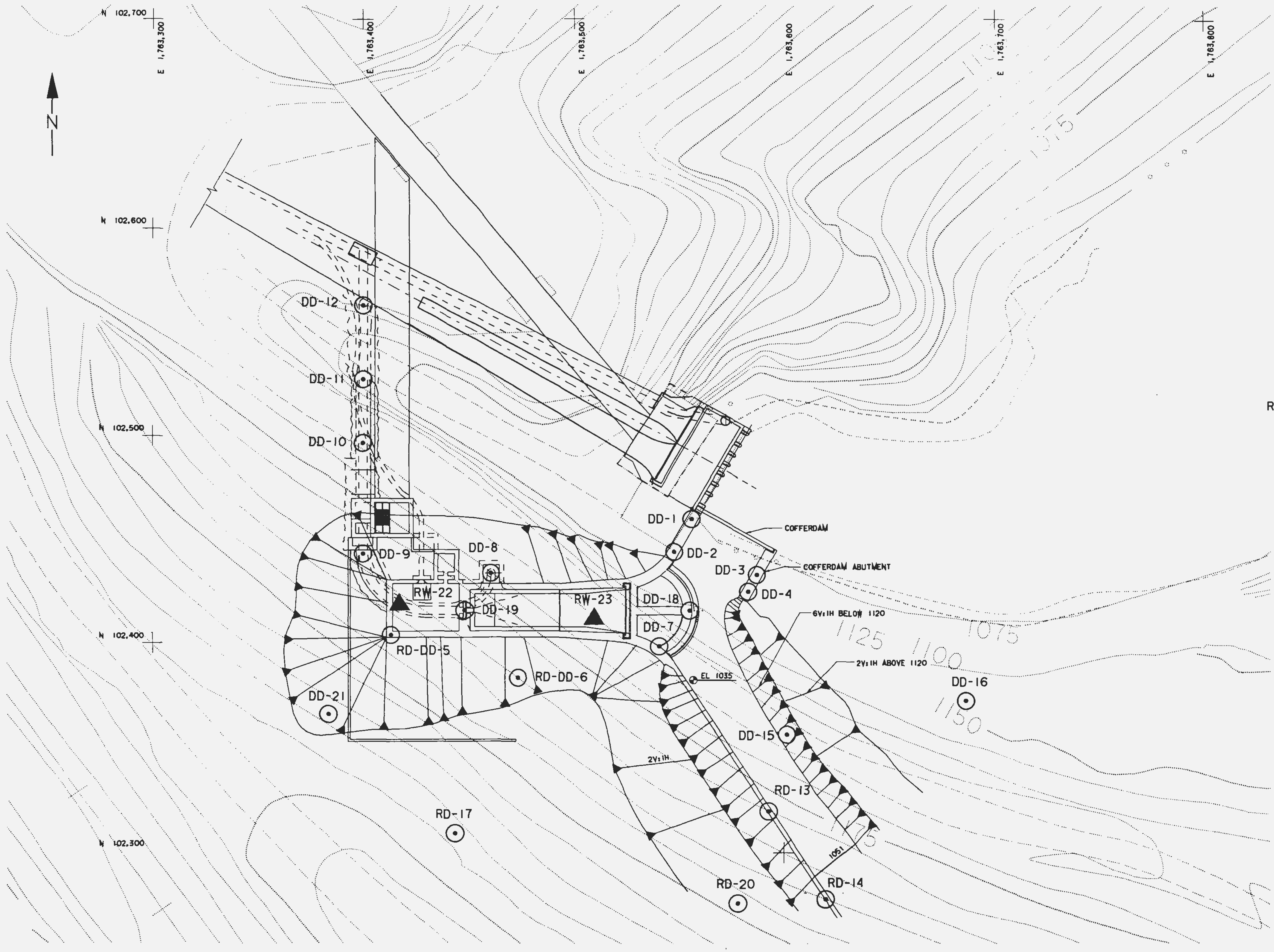
BEDROCK EXCAVATION

HOWARD HANSON DAM WASHINGTON

SIZE	INVITATION NO.	FILE NO.	PLATE
B			E-10

DSGN: ECKERLIN CHK: MANN SHEET

PLATE E-10



LEGEND

⊙ PROPOSED EXPLORATORY BORING
DD = DIAMOND DRILLED CORE BORING
RD = ROTARY DRILLED SOILS BORING

RW-22
▲ PROPOSED RELIEF WELL

0 50' 100'

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PROPOSED EXPLORATION

HOWARD HANSON DAM WASHINGTON

SIZE	INVITATION NO.	FILE NO.	PLATE
B			E-11

DSGN: ECKERLIN CHK: MANN SHEET

PLATE E-11

LEGEND

1	BASALT BLACK, HARD AND DENSE APHANTIC TEXTURE CONCHOIDAL FRACTURE
2	ANDESITE, LIGHT TO DARK GRAY, MODERATELY HARD FINE GRAINED, IRREGULAR FRACTURE.
4	ANDESITE PYROCLASTICS, (TUFF) SOFT, LIGHT GRAY FINE GRAINED, IRREGULAR FRACTURE, BREAKS DOWN RAPIDLY
5	FELSITE LIGHT GRAY, HARD DENSE. APHANTIC TEXTURE, IRREGULAR FRACTURE
	MAJOR FAULT

OUTLET WORKS TUNNEL

NO SCALE

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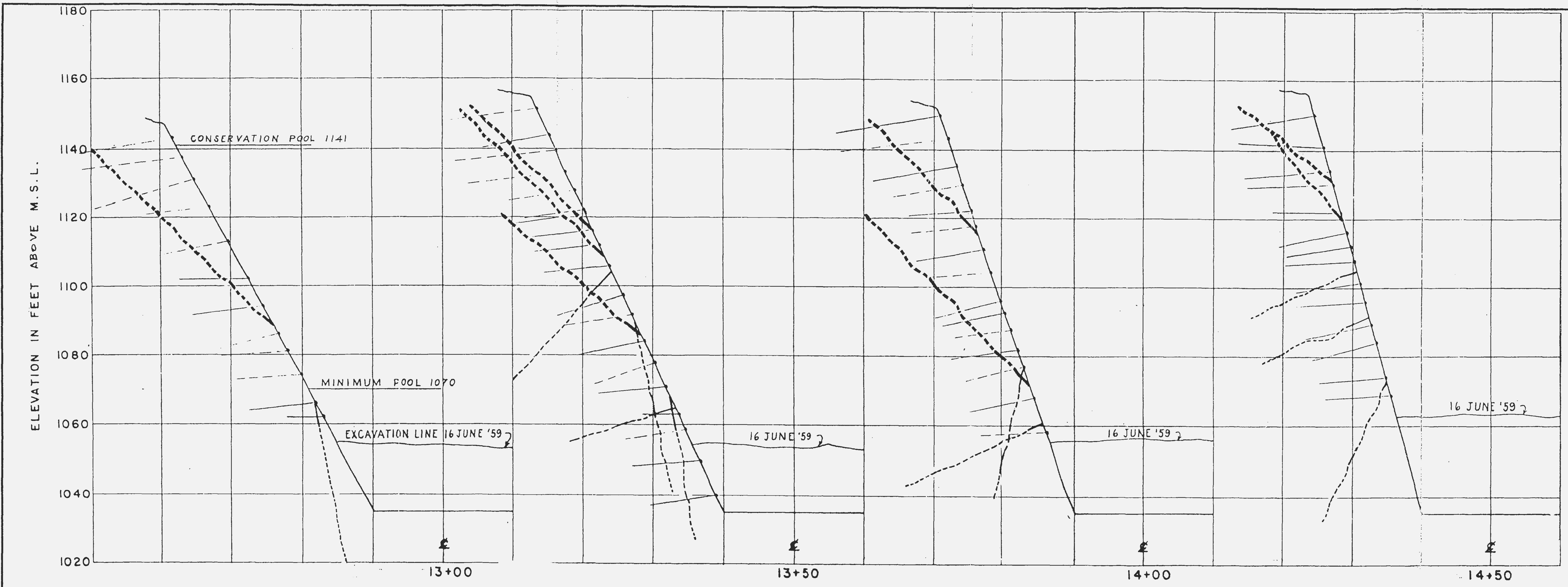
EXISTING OUTLET TUNNEL GEOLOGY

HOWARD HANSON DAM WASHINGTON

SIZE	INVITATION NO.	FILE NO.	PLATE
B			E-12

DSGN: ECKERLIN CHK: MANN SHEET

PLATE E-12



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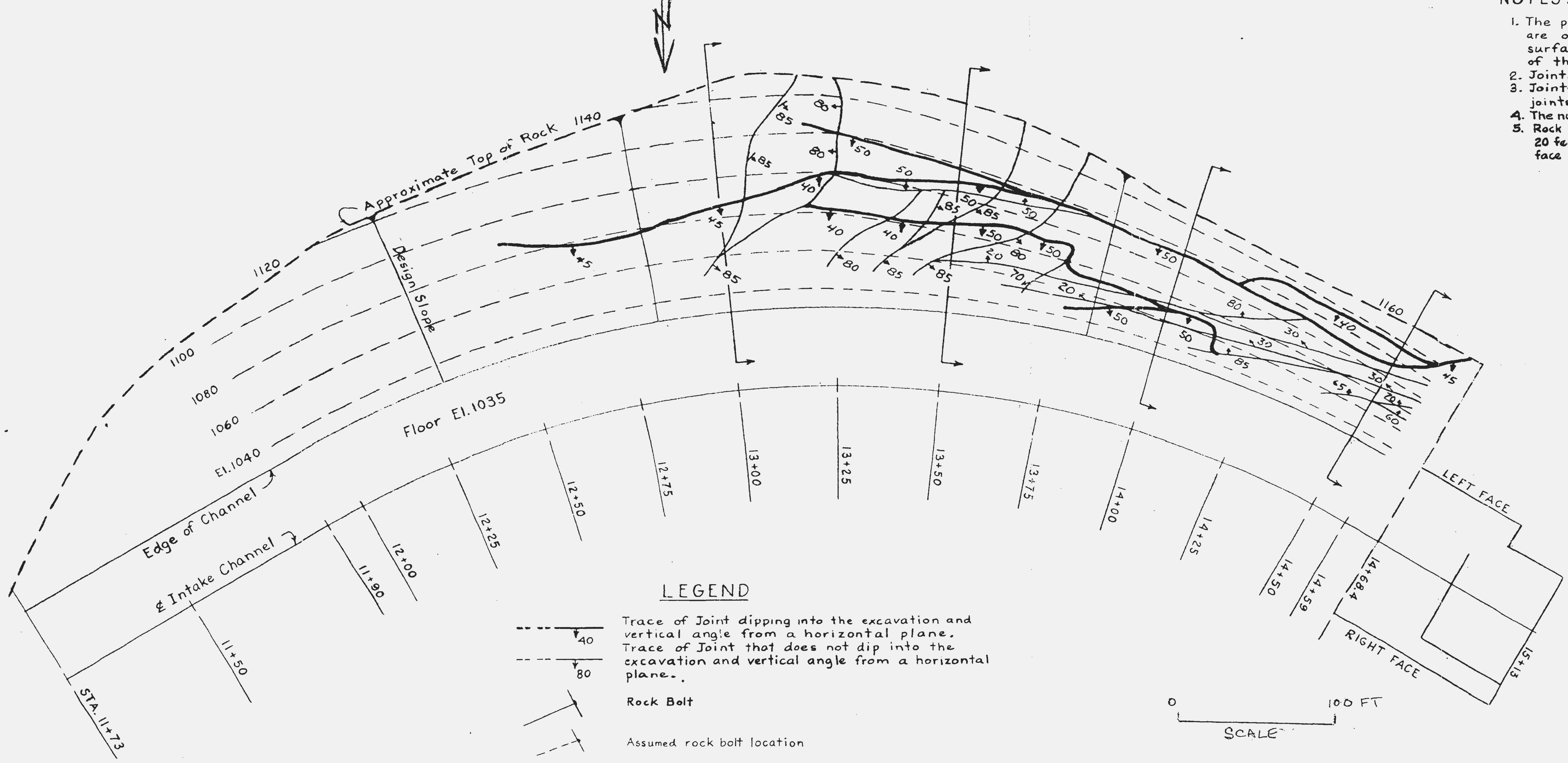
MAJOR JOINTS ON LEFT ROCKWALL OF EXISTING INTAKE CHANNEL

HOWARD HANSON DAM WASHINGTON

SIZE B | INVITATION NO. | FILE NO. | PLATE

DSGN: ECKERLIN | CHK: MANN | SHEET

PLATE E-13



LEGEND

Trace of Joint dipping into the excavation and vertical angle from a horizontal plane. 40

Trace of Joint that does not dip into the excavation and vertical angle from a horizontal plane. 80

Rock Bolt

Assumed rock bolt location

NOTES:

1. The potential slippage surfaces shown on the plan and sections are overemphasized for purposes of illustration. These surfaces, however, can be located by careful observation of the excavation.
2. Joints and faults are not differentiated.
3. Joints are shown in approximate position and attitude of joints is estimated from bottom of excavation.
4. The numerous minor fractures and joints are not shown.
5. Rock bolts are placed on about five (5) foot centers. The bolts in the upper 20 feet of the face are 30 feet long and the lower portion of the face is secured by rock bolts 20 feet long.

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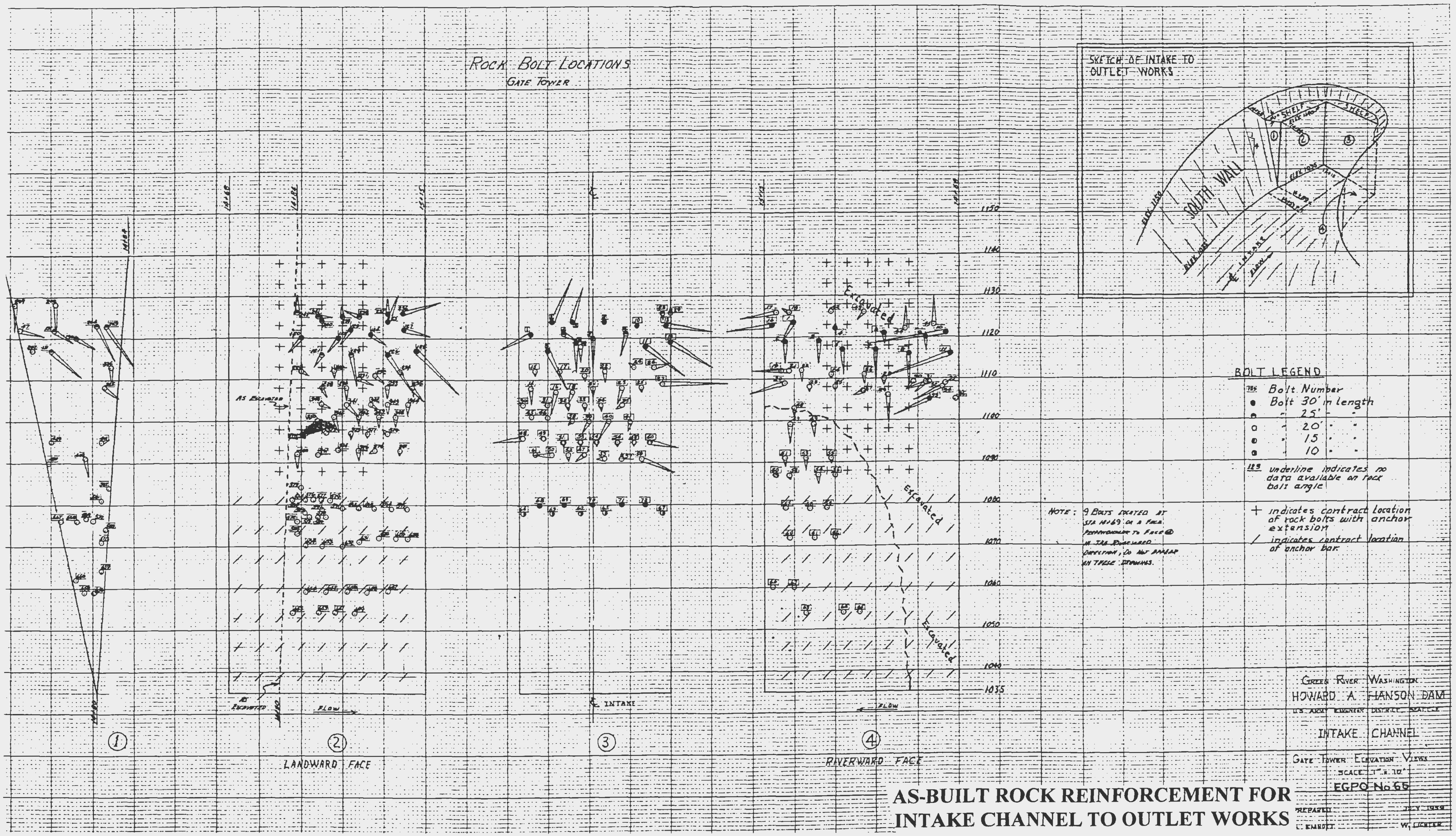
GEOLOGIC SECTIONS ALONG LEFT ROCKWALL OF EXISTING INTAKE CHANNEL

HOWARD HANSON DAM WASHINGTON

SIZE B INVITATION NO. FILE NO. PLATE

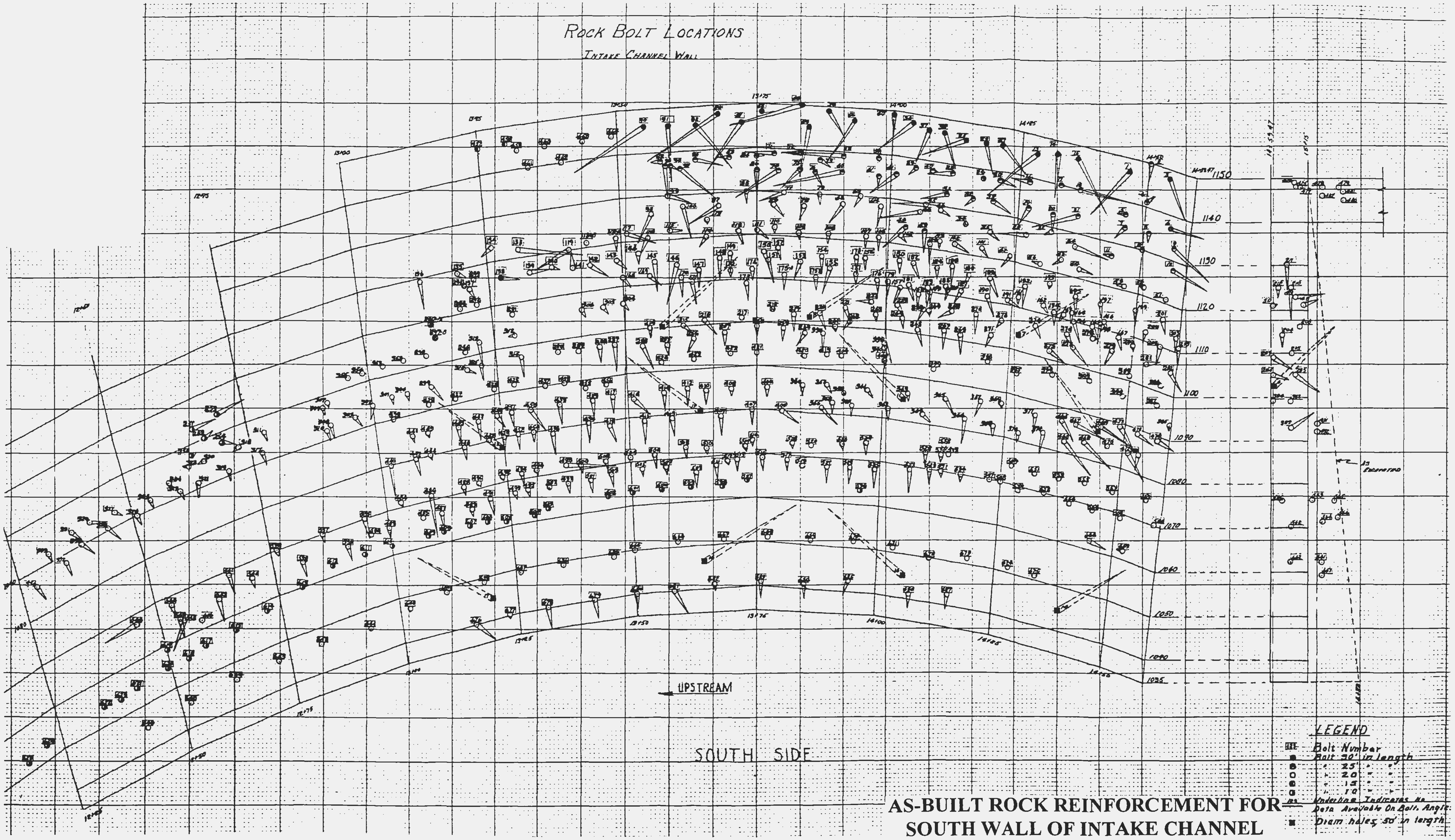
DSGN: ECKERLIN CHK: MANN SHEET

PLATE E-14



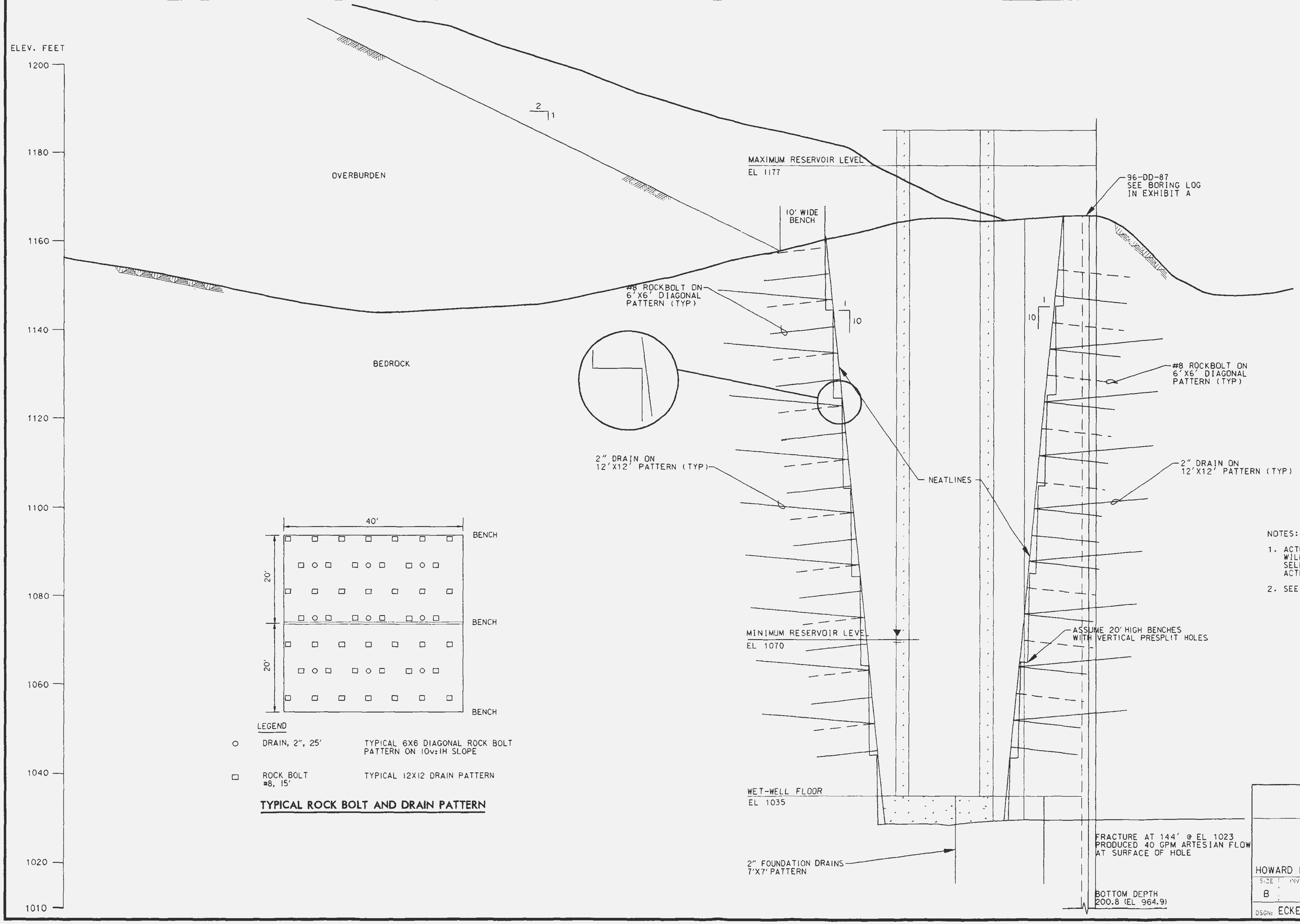
AS-BUILT ROCK REINFORCEMENT FOR INTAKE CHANNEL TO OUTLET WORKS

PLATE E-15



AS-BUILT ROCK REINFORCEMENT FOR SOUTH WALL OF INTAKE CHANNEL

PLATE E-16



NOTES:

1. ACTUAL WIDTH OF BENCH AT TOP OF ROCK CUT SLOPE WILL BE DEPENDENT ON THE CATCH POINTS SELECTED DURING DESIGN AND ROCK ELEVATIONS ACTUALLY ENCOUNTERED DURING EXCAVATION.
2. SEE PLATE E-10 FOR PLAN.

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SEATTLE, WASHINGTON

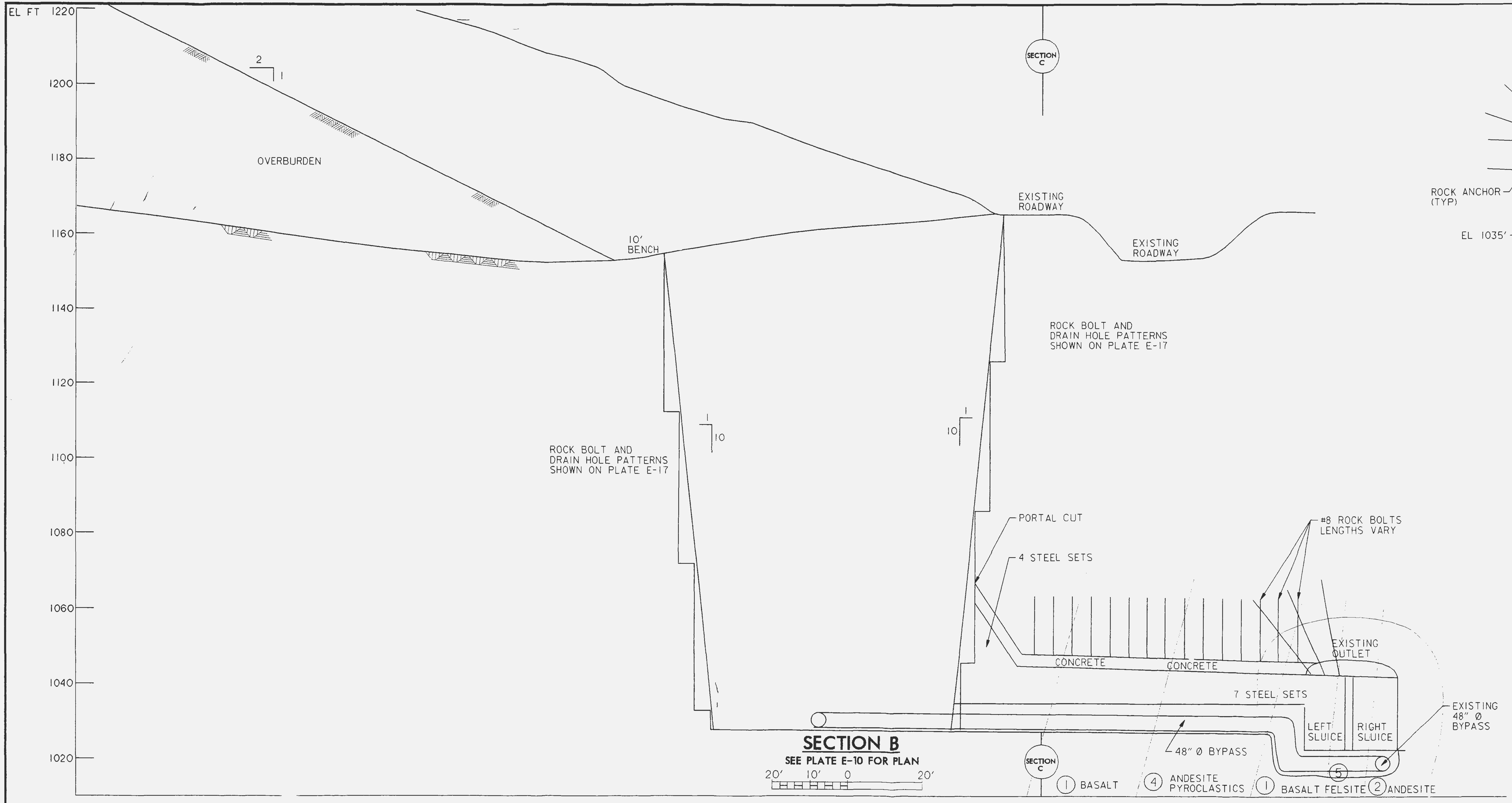
FISH FACILITY
GEOLOGIC SECTION A

HOWARD HANSON DAM WASHINGTON

SIZE	INVITATION NO.	FILE NO.	PLATE
B			E-17

DSGN: ECKERLIN CHK: MANN SHEET

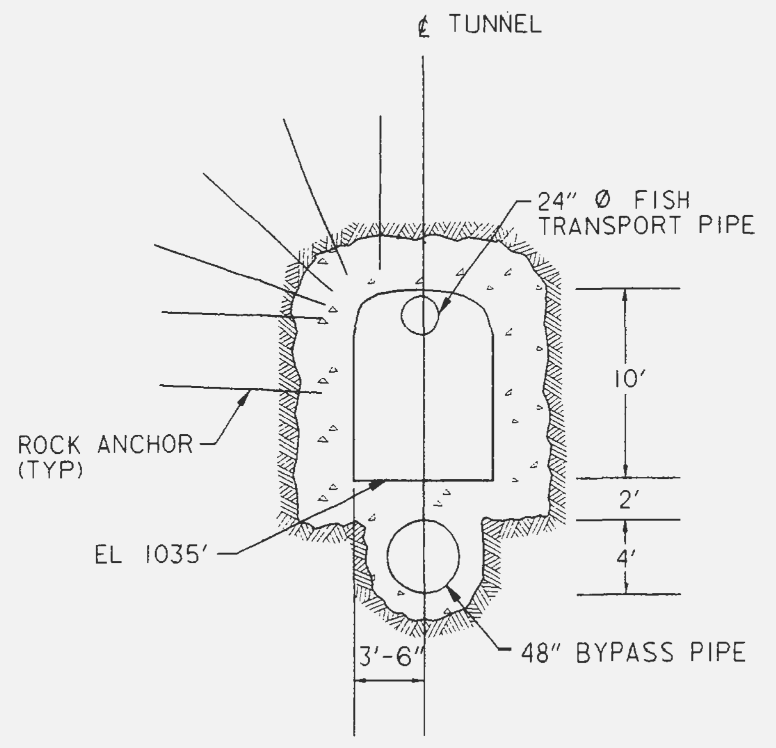
PLATE E-17



SECTION B

SEE PLATE E-10 FOR PLAN

20' 10' 0 20'



SECTION C

SEE PLATE E-10 FOR PLAN

10' 5' 0 10'

① - BASALT
② - ANDESITE
③ - BASALT PYROCLASTICS
④ - ANDESITE PYROCLASTICS
⑤ - FELSITE

NOTES:

1. ROCK CONTACTS ARE ESTIMATED USING FOUNDATION REPORT PLATES.
2. ACTUAL WIDTH OF BENCH CUT AT TOP OF ROCK CUTSLOPE WILL BE DEPENDENT ON THE CATCH POINTS SELECTED DURING DESIGN AND ROCK ELEVATIONS ACTUALLY ENCOUNTERED DURING EXCAVATION.

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SEATTLE, WASHINGTON

FISH FACILITY
GEOLOGIC SECTIONS B AND C

HOWARD HANSON DAM WASHINGTON
SIZE B | INVITATION NO. | FILE NO. | PLATE E-18
DSGN: ECKERLIN CHKD: MANN SHEET

PLATE E-18

EXHIBIT A

SUMMARY DRILL LOGS

DRILLING LOG

DIVISION NPD

INSTALLATION NPS

SHEET 1 OF 2 SHEETS

1. PROJECT HHD Fish Passage Study
2. LOCATION (Coordinates or Station) N 102,291.016 E 1,763,737.800
3. DRILLING AGENCY Ruen Drilling (Clark Fork, Idaho)
4. HOLE NO. (As shown on drawing title and file number) 94-DD-80
5. NAME OF DRILLER LYLE BALLINGER
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN 8.4 FT.
8. DEPTH DRILLED INTO ROCK 156.6 FT.
9. TOTAL DEPTH OF HOLE 165.0 FT.
10. SIZE AND TYPE OF BIT NWC3 Wireline
11. DATUM FOR ELEVATION SHOWN (TBM or MSL) NGVD 1929
12. MANUFACTURER'S DESIGNATION OF DRILL Longyear 44
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN DISTURBED - UNDISTURBED -
14. TOTAL NUMBER CORE BOXES 12
15. ELEVATION GROUND WATER 1153.8
16. DATE HOLE STARTED 4/5/94 COMPLETED 4/8/94
17. ELEVATION TOP OF HOLE 1164.767
18. TOTAL CORE RECOVERY FOR BORING 98.3% %
19. SIGNATURE OF INSPECTOR

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY 0 .100	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
1164.8			GM, Silty Sandy GRAVEL with boulders.			NWC3 - OD = 2.980" ID = 1.875" SPLIT INNER TUBE 4/5/94
			TOP OF ROCK @ 8.4 FT	RQD %		
1156.4			ANDESITE, soft, weathered, rusty-red to gray in color.	75.0	A	4/6/94
▼ 1153.8	10					
				80.8	B	
1149.8			ANDESITE BRECCIA, moderately hard, dense, weathered, rusty-red.		1	40 psig/6.7 gpm/15 min 40-21/5 sec 21-7/120 sec.
				96.1	C	
	20			100	D	
1139.7			Color change to gray-green	84.4	E	
	30				2	40 psig/15.5 gpm/15 min 40-17/5 sec 17-4/120 sec.
				98.4	F	
				100	G	
	40			80.0	H	40 psig/8.1 gpm/15 min 40-22/5 sec 22-8/120 sec.
				84.4	I	
					3	
	50		From 47.4 to 57 core is soft, slicken sides on joints 47.4 to 48.4 clay gouge, soft, gray	64.5	J	4/6/94
				77.8	K	4/7/94
1107.7					4	80 psig/8.0 gpm/15 min 80-58/5 sec 58-33/120 sec.
	60		ANDESITE BRECCIA, moderately hard, dense, dark gray to black	88.3	L	
				90.0	M	
				97.0	N	80 psig/9.7 gpm/15 min 80-47/5 sec 47-13/120 sec.
1091.9	70		Color change to light gray-green @ 71.0', with slickensides on joints: 75.0' to 76.0', clayey gouge.	87.6	O	
					5	
				86.1	P	
	80			88.0	Q	80 psig/1.5 gpm/15 min 80-25/5 sec 25-0/120 sec.
				98.4	R	
				92.0	S	
					6	
	90			98.4	T	80 psig/0 gpm/15 min 80-49/5 sec 49-21/120 sec.
				90.0	U	
					7	
1064.8	100					

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71

PROJECT FISH PASSAGE STUDY

HOLE NO. 94-DD-80

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 1164.76	Hole No. 94-DD-80
PROJECT HHD Fish Passage Study	INSTALLATION	SHEET 2 OF 2 SHEETS

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth weathering, etc., if significant)
1064.3	100		ANDESITE BRECCIA, soft to hard, green to gray, slickensides on joint surfaces.	65.8	V 7	
	105			50.0	W	4/7/94
	110			93.2	X 8	80 psig/0 gpm/15 min 80-40/5 sec 40-19/120 sec.
	115			100	Y	
	120			100	Z	80 psig/0 gpm/15 min 30-43/5 sec 43-21/120 sec.
	125			96.6	AA 9	
	130			100	AB	
				91.2	AC	80 psig/0 gpm/15 min 80-70/5 sec 70-50/120 sec.
	135		NPD laboratory test, conducted on core 139.3 - 140.3'. Results reported 7/13/94: Specific Gravity 2.42 unit Weight 150.8 pcf Absorption 6.8% Unconfined Compressive Strength = 5,410 psi	100	AD	
	140			100	AE 10	
1020.4	145		ANDESITE BRECCIA, clayey, soft, altered gray to green, slickensides on joints.	51	AF	80 psig/5.3 gpm/ 80-75/5 sec 75-60/120 sec.
	150			62.5	AG 11	
	155			77.1	AH	
	160			86.2	AI 12	80 psig/5.7 gpm/ 80-70/5 sec 70-51/120 sec.
			hard @ 163 ft	94.3	AJ	4/8/94
999.8	165		Bottom of boring @ 165 ft			

NOTE: Ruen Drilling Company is subcontractor to Andrew Drilling Co., Idaho Falls, Idaho under contrat DACA 67-93-D-1012 Delivery Order No. 9

*NOTE

Water test data corresponds to interval shown.

Abbreviations used:
80 psig/9.7 gpm/15 min
80-40/5 sec
40-19/120 sec

80 psig = 80 pounds water pressure per inch measaured by a gauge at ground level

9.7 gpm/15 min = 9.7 gallons of water per minute measured with a flow meter for the stated period

80-40 /5sec = water pressre drop in system from 80 to 40 psig in 5 seconds.

40-19/120 sec = water pressure drop in system from 40 to 19 psig in 2 minutes

ENG FORM 1836-A PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71

PROJECT	HOLE NO.
FISH PASSAGE STUDY	94-DD-80

Y-7

DRILLING LOG	DIVISION NPD	INSTALLATION NPS	SHEET 1 OF 2 SHEETS

1. PROJECT
HHD FISH PASSAGE STUDY

2. LOCATION *(Coordinates or Station)*
N 102,503.562 E 1,763,228.777

3. DRILLING AGENCY
RUEN DRILLING (CLARK FORK, IDAHO)

4. HOLE NO. *(As shown on drawing title and file number)* 94-00-31

5. NAME OF DRILLER
LYLE BALLINGER

6. DIRECTION OF HOLE
☒ VERTICAL ☐ INCLINED ________ DEG. FROM VERT.

7. THICKNESS OF OVERBURDEN 23.0 FT.

8. DEPTH DRILLED INTO ROCK 167.0 FT.

9. TOTAL DEPTH OF HOLE 190.0 FT.

10. SIZE AND TYPE OF BIT NWC3 (WIRELINE)

11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)*
NGVD 1929

12. MANUFACTURER'S DESIGNATION OF DRILL
LONGYEAR 44

13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED	UNDISTURBED
	-	-

14. TOTAL NUMBER CORE BOXES 13

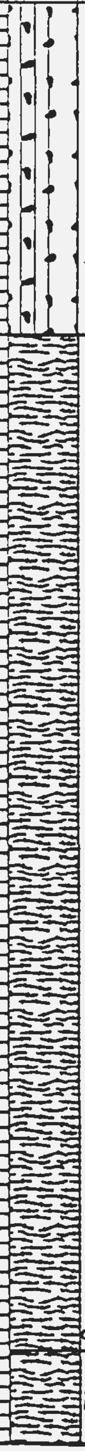
15. ELEVATION GROUND WATER 1189.7

16. DATE HOLE	STARTED	COMPLETED
	4/21/94	4/234/94

17. ELEVATION TOP OF HOLE 1220.307

18. TOTAL CORE RECOVERY FOR BORING 99 %

19. SIGNATURE OF INSPECTOR



ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS *(Description)* d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)* g
1220.3			GM, Silty sandy gravel			
	10					
						Legend for joint spacing: widely >1.5 ft moderately 0.5 to 1.5 ft closely 0.1 to 0.5 ft highly fractured=brecciated
	20			RQD		
			Top of rock @ 23.0 ft	%		
1197.3				87	A	
			ANDESITE BRECCIA: Altered dark green to gray, soft zones, calcite			
▼				89	B 1	
1189.7	30		FeO			
				91	C	
				97	D	
	40			98	E	
					2	
				100	F	
	50			91	G	
				88	H 3	
	60			92	I	4/21/94 SWL 23.6 bgs
						4/22/94 7.1 bgs
				100	J 4	
	70			98	K	
				98	L	
	80			100	M	
					5	
				88	N	
	90			100	O	
			Clayey Joints	98	P	
1126.5					6	
			ANDESITE BRECCIA, altered FeO, Pyrite, CaCo on joints			
1120.3	100			91	Q	

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71

PROJECT
HHD FISH PASSAGE

HOLE NO.
94-00-81 X-3

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 1220.307	Hole No. 94-00-81
PROJECT HHD FISH PASSAGE	INSTALLATION NPS	SHEET 2 OF 2 SHEETS

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY 0 .100	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
1120.3	100		ANDESITE BREDCCIA, altered, clayey zones, FeO, Pyrite, Calcite, slickensides.	RQD % 84	R 6	
				88	S 7	
	110			100	T	
				100	U	
	120			100	V 8	SEE NOTE ON SHEET 2 LOG 94-00-80
				94	W	
	130		@ 130' Slickensides on joint surfaces	71	X	80 psi/0 gpm/15 min 80-61 psi/120 sec
				89	Y 9	
	140			88	Z	
				100	AA	80 psi/27.8 gpm/13.5 min 80-0 psi/5 sec
	150			71	AB 10	
1065.3				61	AC	
			ANDESITE BRECCIA, highly altered, intact	60	AD	80 psi/30.7 gpm/15 min 80-0 psi/5 sec
1054.1	160			88	AE 11	
			ANDESITE BRECCIA, altered - soft, broken, discolored, local, clay, FeO, Calcite	74	AF	
	170			74	AG	80 psi/25.7 gpm/15 min 80-17 psi/5 sec 17 - 0 psi /60 sec
				96	AH 12	
	180			96	AI	80 psi /12.9 gpm/15min 80-40 psi/5 sec 40-13psi/120 sec
				91	AJ 13	
				100	AK	
1030.3	190		Bottom of boring at 190.0' NPD lab results 7/13/94 conducted on core 175.2-175.6 Sp. Gravity 2.81 Unit Weight 162.8 pcf Absorption 2.0% Unconfined CompStr 8,790 psi Conducted on core 187.5 - 188.0 Sp. Gravity 2.85 Unit Weight 165.1 pcf Absorption 1.6% Unconfined CompStr 9,170 psi			NOTES: End of shift 4/22 cored to 170.1 SWL 23.8' Began Shift 4/23 SWL 30.6'

ENG FORM 1836-A PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71

PROJECT	HOLE NO.
HHD FISH PASSAGE	94-00-81

X - 4

DRILLING LOG	DIVISION NPD	INSTALLATION NPS	SHEET 1 OF 2 SHEETS

1. PROJECT HHD FISH PASSAGE
2. LOCATION (Coordinates or Station) N 103,055.429 E 1,763,015.934
3. DRILLING AGENCY RUEN DRILLING (CLARK FORK, IDAHO)
4. HOLE NO. (As shown on drawing title and file number) 94-DD-82
5. NAME OF DRILLER LYLE BALLINGER
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ________ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN 4.2'
8. DEPTH DRILLED INTO ROCK 205.8'
9. TOTAL DEPTH OF HOLE 210.0'
10. SIZE AND TYPE OF BIT NWC3 (WIRELINE)
11. DATUM FOR ELEVATION SHOWN (TBM or MSL) NGVD, 1929
12. MANUFACTURER'S DESIGNATION OF DRILL LONGYEAR 44
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN | DISTURBED | UNDISTURBED
14. TOTAL NUMBER CORE BOXES 16
15. ELEVATION GROUND WATER 1170.8 FT
16. DATE HOLE STARTED 4/18/94 COMPLETED 4/20/94
17. ELEVATION TOP OF HOLE 1206.396 ft
18. TOTAL CORE RECOVERY FOR BORING 97.2 %
19. SIGNATURE OF INSPECTOR

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
1206.4			GM, Silty Sandy Gravel			
			Top of rock @ 4.2 ft	RQD		
1202.2			ANDESITE BRECCIA. Altered, maroon to green-gray, broken, clay in places. FeO, $CaCO_3$	21	A	
	10			80	B	
					1	
				80	C	Legend for Joint Spacing
				23	D	
						Widely >1.5 ft
	20			42	E	Moderately 0.5 to 1.5 ft
						Closely 0.1 to 0.5 ft
					2	Highly Fractured = brecciated
			0.4' Loss	47	F	
					G	
	30			90		
				100	H	
1170.8 ▼						
1168.9					3	
	40		ANDESITE BRECCIA. Highly altered, clayey, gouge, discoloration, slickensides, $CaCO_3$, FeO	80	I	
				78	J	
	50		1.3' loss	47	K	
					4	
			2.0' loss	0	L	
	60		2.1' loss	0	M	
1143.5			ANDESITE BRECCIA. Altered but intact, with zones of heavy alteration, green to gray, calcite, and pyrite mineralization	74	N	
					5	
	70			65	O	
				91	P	
				89	O	
	80				6	
			Slickensides on joints	80	R	
1112.0	90			89	S	
					7	
			ANDESITE/ANDESITE BRECCIA, hard, dark green	99	T	
1106.4	100			100	U	

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PROJECT HH FISH PASSAGE

HOLE NO. 94-DD-82

X-5

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 1206.396	Hole No. 94-00-82
PROJECT HHD FISH PASSAGE	INSTALLATION NPS	SHEET 2 OF 2 SHEETS

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
1106.4	100		ANDESITE/ANDESITE BRECCIA, hard, dark green, minor alteration FeO and slickensides on joints	99	V	
				100	W 8	
	110			92	X	
				96	Y	
	120			90	Z 9	
				100	AA	SEE NOTE ON SHEET 2 LOG 94-00-80
	130			100	AB 10	
				96	AC	
				100	AD	
	140					80 psig/0 gpm/15 min 80-46 psig/120 sec
				100	AE 11	
				100	AF	
	150			100	AG	80 psig/0 gpm/15 min 80 - 48 psig/5 sec 48 - 18 psi /120 sec
				100	AH	
	160			100	AI 12	
				100	AJ	
				100	AK	80 psig/0 gpm/15 min 80-40 psig/5 sec 40 - 26 psig/120 sec
	170		NPO lab results 7/13/94 conducted on core 179.9' - 180.7'	98	13 AL	
				100	AM	80 psig/0 gpm/15 min 80-59 psig/120 sec
	180		Sp. Gravity 2.59 Unit Weight 181.4 pcf Absorption 2.1% Unconfined CompStr 21,920 psi	100	AN	
				100	14 AO	
	190			91	AP	
				98	AQ 15	80 psig/0 gpm/15 min 80-49 psig/120 sec
	200			96	AR	
				100	AS 16	80 psig/0 gpm/15 min 80-40 psig/5 sec 40 - 30 psig/120 sec
				100	AT	
998.4	210		Bottom of Boring @ 210'			Hole cemented

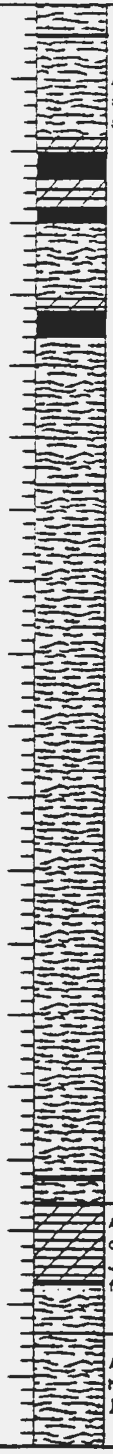
ENG FORM 1836-A PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71

PROJECT
HHD FISH PASSAGE

HOLE NO.
94-00-82

DRILLING LOG DIVISION NPD INSTALLATION NPS SHEET 1 OF 2 SHEETS

1. PROJECT HHD FISH PASSAGE STUDY
2. LOCATION *(Coordinates or Station)* N 103,494.837 E 1,763,093.729
3. DRILLING AGENCY RUEN DRILLING (CLARK FORK, IDAHO)
4. HOLE NO. *(As shown on drawing title and file number)* 94-00-83
5. NAME OF DRILLER LYLE BALLINGER
6. DIRECTION OF HOLE ☐ VERTICAL ☒ INCLINED 20° DOWN DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN 0
8. DEPTH DRILLED INTO ROCK 220 ft
9. TOTAL DEPTH OF HOLE 220 ft
10. SIZE AND TYPE OF BIT NWC3 (Wireline)
11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)* NGVD 1929
12. MANUFACTURER'S DESIGNATION OF DRILL LONGYEAR 44
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN DISTURBED - UNDISTURBED -
14. TOTAL NUMBER CORE BOXES 17
15. ELEVATION GROUND WATER 1051.8
16. DATE HOLE STARTED 3/29/94 COMPLETED 4/2/94
17. ELEVATION TOP OF HOLE 1104.810
18. TOTAL CORE RECOVERY FOR BORING 96.6 %
19. SIGNATURE OF INSPECTOR



ELEVATION a	DEPTH b	CLASSIFICATION OF MATERIALS *(Description)* d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)* g
1104.8		ANDESITE, hard, black	RQD% 16.7	A	NWC3 OD = 2.980" ID = 1.875" SOLID INNER TUBE TYPE WIRELINE BARREL
1101.0			63.0	B	
		ANDESITE BRECCIA, clayey, altered, soft, gray, closely to moderately spaced joints	30.0	C 1	
	10		0	D	
			0	E	3/29/94
			15.4	F	Legend for Joint Spacing: Widely = >1.5 ft Moderately = 0.5 - 1.5 ft Closely = 0.1 -0.5 ft Highly Fractured = Brecciated
	20		41.7	G 2	
			84.8	H	
			81.1	I	
	30		52.4	J 3	
			24.8	K	
	40		32.7	L 4	
			50.0	M	
	50		35.0	N	
▼ 1051.8			15.0	O 5	
	60		23.3	P	
			0.0	Q	
	70		79.2	R 6	
			80.0	S	
	80		19.2	T 7	
1026.8		ANDESITE BRECCIA, altered with clayey gouge, FeO at 86'-87'. Joints closely spaced to highly fractured.	0.0	U	
	90		25.0	V	
1017.9		ANDESITE BRECCIA, dark green, altered highly fractured to closely spaced joints	31.5	W 8	
1010.8	100		44.4	X	

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71

PROJECT HHD FISH PASSAGE HOLE NO. 94-00-83

X-1

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 1104.810	Hole No. 94-DD-83
PROJECT HHD FISH PASSAGE	INSTALLATION NPS	SHEET 2 OF 2 SHEETS

ELEVATION	DEPTH	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
1010.8	100	ANDESITE, hard, gray, closely to moderately spaced joints	7.7	X Y 9	
			23.5	Z	SEE NOTE ON SHEET 2 LOG 94-00-80
	110		56 .1	9 AA	3/30/94
			85.2	AB	
	120		76.2	AC	
			38.0	AD 10	80 psig/12.5gm/15 min 80-60/5 sec 60 - 30/120 sec
	130		47.4	AE	
			78.2	AF	
	140		91.2	11 AG	80 psig/0.9 gpm/15 min 80-50 /5 sec 50 - 0/120 sec
970.4		ANDESITE BRECCIA, altered, light gray to green, soft, crumbles NPD lab results 7/13/94 on core 147.5 to 148.0 ft Sp. Gravity 2.42 UnitWgt 150.8 pcf Absorption 6.1% Unconf. Compstr 13.510 psi	78.2	AH	3/31/94
	150		82.1	AI	
			51.0	12 AJ	80 psig/8.3 gpm/15 mi 80-60 /5 sec 60 - 0 /60 sec
		On core 150.2 to 1510.0 ft Sp. Gravity 2.39 Unit Wgt 148.9 pcf Absorption 6.5% Unconf. Compstr 8.900 psi	22.2	AK	
	160		47.6	AL	
949.8		ANDESITE BRECCA, hard, dark green, some clcyey zones, moderately to widely spaced joints	96.5	13 AM	80 psig/9.3 gpm/15 min 80-75 /5 sec 75 - 32 /120 sec
	170		100.0	AN	
			78.3	AO	
	180		85.0	14 AP	80 psig/3.0 gpm/15 min 80-65 /5 sec 65 - 12 /120 sec
			93.0	AQ	
	190		40.7	AR	4/1/94
		FeO on joint	61.9	AS 15	80 psig/11.5gpm/15 min 80-58/5 sec 58-34/120 sec
			92.2	AT	
	200		93.1	AU	80 psig/5 gpm/10 min 80-60 /5 sec 63- 18/120 sec
			94.8	16 AV	
	210		88.7	AW	
			92.9	AX 17	80 psig/0.1 gpm/5 min 80-63 /5 sec 63- 9/120 sec
898.1	220		92.0	AY	Hole Cemented

ENG FORM 1836-A PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71

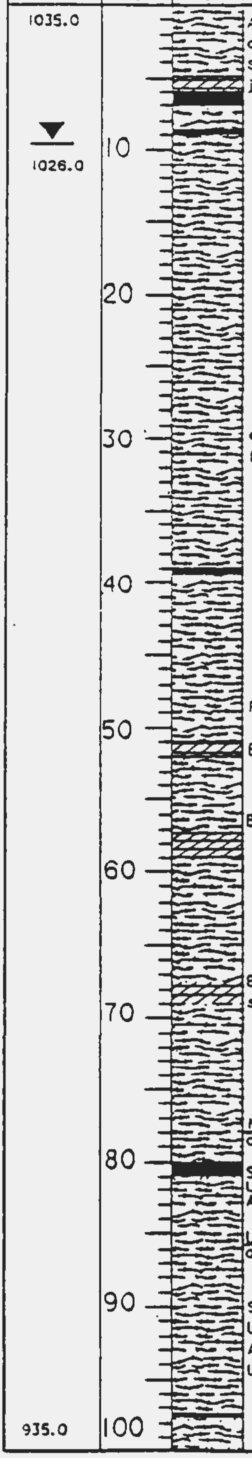
PROJECT
HHD FISH PASSAGE

HOLE NO.
94-DD-83

X-8

DRILLING LOG
DIVISION NPD
INSTALLATION NPS
SHEET 1 OF 1 SHEETS

1. PROJECT HHD FISH PASSAGE STUDY
2. LOCATION *(Coordinates or Station)* N 103,792.632 E 1,763,150.124
3. DRILLING AGENCY RUEN DRILLING (CLARK FORK, IDAHO)
4. HOLE NO. *(As shown on drawing title and file number)* 94-00-84
5. NAME OF DRILLER LYLE BALLENGER
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN 0
8. DEPTH DRILLED INTO ROCK 100 FT
9. TOTAL DEPTH OF HOLE 100 FT
10. SIZE AND TYPE OF BIT NWC3 (WIRELINE)
11. DATUM FOR ELEVATION SHOWN (TBM or MSL) SOLID INNER TUBE NGVD, 1929
12. MANUFACTURER'S DESIGNATION OF DRILL LONGYEAR 44
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN DISTURBED UNDISTURBED
14. TOTAL NUMBER CORE BOXES 8
15. ELEVATION GROUND WATER 1026.0 FT
16. DATE HOLE STARTED 4/3/94 COMPLETED 4/5/94
17. ELEVATION TOP OF HOLE 1035.044 FT
18. TOTAL CORE RECOVERY FOR BORING 97.6 %
19. SIGNATURE OF INSPECTOR



ELEVATION	DEPTH	CLASSIFICATION OF MATERIALS *(Description)*
1035.0	0	ANDESITE BRECCIA, altered with clayey gouge on joint surfaces, soft, gray green, closely spaced joints to highly brecciated (0-30 ft).
1026.0		
	30	@30 ft joint spacing close to moderate
		FeO on jt surfaces
		Brecciated
		Brecciated, FeO on jts
		Brecciated, FeO on jt surfaces
		NPD lab results 7/13/94 on core 35-35.4
	80	Sp. Gravity 2.72 Unit Wgt 169.5 pcf Absorption 0.8%
		Unconf. Comp. Str. 18,010 on core 53.1 - 53.5
	90	Sp. Gravity 2.76 Unit Wgt 171.9 pcf Absorption 0.9% Unconf. Comp. Str. 8,320 psi
935.0	100	

% CORE RECOVERY	BOX OR SAMPLE NO.	
RQD 54	A	1
10.8	B	1
0	C	1
33	D	1
[illegible]	E	1
33.7	F	1
48.7	G	2
48.1	H	2
25.4	I	2
0	J	2
33.9	K	3
77.7	L	3
48.7	M	3
30.8	N	4
31.7	O	4
42.7	P	4
0	Q	4
91.2	R	5
0	S	5
62.5	T	5
39.2	U	5
94.1	V	6
89.6	W	6
94.0	X	6
51.1	Y	7
60.2	Z	7
94.5	AA	7
99.7	AB	8
88.7	AC	8

REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)*

Core Bite = NWC3
OD = 2.980 - inch
ID = 1.875 - inch
SEE NOTE ON SHEET 2 LOG 94-00-80

40 PSIG/4.6 GPM/15 MIN
40-19/5 SEC
19-8/120 SEC

40 PSIG/7 GPM/15 MIN
40-8/5 SEC
8-0/30 SEC

80 PSIG/23.7 GPM/15 MIN
80-10/5 SEC
10-0/60 SEC

80 PSIG/17.7 GPM/15 MIN
80-0/ 5 SEC

80 PSIG/20 GPM/15 MIN
80-0/5 SEC

80 PSIG/26 GPM/17 MIN
80-0/5 SEC

80 PSIG/24.7 GPM/15 MIN
80-10/5 SEC
10-0/60 SEC

Hole Cemented

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71

PROJECT HH FISH PASSAGE STUDY
HOLE NO. 94-00084

X-9

DRILLING LOG
DIVISION NPD
INSTALLATION SEATLE DISTRICT
SHEET 1 OF 3 SHEETS

1. PROJECT HOWARD HANSEN DAM INTAKE TOWER
2. LOCATION (Coordinates or Station) N102,508.19 E 1,763,518.22
3. DRILLING AGENCY KERR DRILLING CO.
4. HOLE NO. (As shown on drawing title and file number) 94-DD-85
5. NAME OF DRILLER RANDY PAINTER
6. DIRECTION OF HOLE VERTICAL ☒ INCLINED ☐ ____________ DEG. FROM VERT
7. THICKNESS OF OVERBURDEN 2.0
8. DEPTH DRILLED INTO ROCK 54.0
9. TOTAL DEPTH OF HOLE 56
10. SIZE AND TYPE OF BIT HQ DIAMOND
11. DATUM FOR ELEVATION SHOWN (TBM OR MSL) NGVD 1929
12. MANUFACTURER'S DESIGNATION OF DRILL MOBILE B-53
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN DISTURBED 0 UNDISTURBED 0
14. TOTAL NUMBER CORE BOXES 6
15. ELEVATION GROUND WATER 1133
16. DATE HOLE STARTED 09-18-94 COMPLETED 09-20-94
17. ELEVATION TOP OF HOLE 1140.1
18. TOTAL CORE RECOVERY FOR BORING 96
19. SIGNATURE OF INSPECTOR

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant) g
1140.1	0	▨	ROCK FILL	63	1	RUN A TO 4.0' D 4.0: C2.5: L1.5 RQD 12.. 5%
1138.1	2.0	▨	ANDESITE,breccia, gray,hard broken w/qtz and pyrite mineralization high angle joint			
1137.1	3.0	▨	70 degree 3.5 to 4.9 ft broken zone	100		RUN B TO 6.0' D 2.0: C 2.0: L 0.0 RQD 55 %
1135.2	4.9	▨	50 degree 45 degree 40 degree 65 degree, pyrite mineralizaton, some slickensides 45 degree	100		RUN C TO 11.0' D 5.0:C 5.0:L 0 RQD 85% w.t. 9/18 9/19
1130.1	10	▨	ANDESITE, breccia, hard 70 degree, pyrite fill flat joint, fresh hard rock 10 degree 45 degree 30 degree	100	1 2	BOX 1 Fm 0.0 to 11.0' RUN D TO 16.0 D5.0:C5.0:L0.0 RQD 96%
1124.1	16.0	▨	broken zone to 18 ft. 20 degree group of 3	90		RUN E TO 21.0 D5.0:C4.5:L0.5 RQD 63%
1123.1	17	▨	Andesite lapallie tuff,			

DRILLING LOG (Cont Sheet)

ELEVATION TOP OF HOLE 1140.1

Hole No. 94-DD-85

1. PROJECT HOWARD HANSEN DAM INTAKE TOWER

INSTALLATION SEATLE DISTRICT

SHEET 2 OF 3 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant) g
			30 degree thin calcite crust rock is crumbly 30 degree,calcite fill			
			60 degree, calcite			lost return water, water exiting slope drain at elev 1132 ft.
1120.1	20		35 degree, thick calcite infill, crumbly rock		2	
			Andesite, brecia, gray,hard		-----	BOX 2 Fm 11.0 TO 21 FT
			45 degree	100	3	RUN F TO 26.0' D5.0:C5.0:L0.0 RQD 60%
			70 degree			
			22.4 to 24.0 ft, broken zone			
			flat joint			
			26.3 to 26.8 ft., broken zone	100		RUN G TO 31.0' D5.0:C5.0:L0.0 RQD 86%
			5 degree 27.8 to 28.4 ft., broken zone			
			10 degree			
			30 degree, some slickensides			
1110.1	30.00		Andesite, breccia, gray, hard		3	
			5 degree, several close fractures		----- 4	BOX 3 TO 30.6' RUN H TO 36.0' D5.0:C5.0:L0.0 RQD 96%
			35 degree same 5 degree	100		
			6 & 20 degree			
			5 degree, minor calcite			
			soft zone			
			50·degree, soft infill			
			35.9 to 36.7 ft.,broken, crumbly rock, slicks present			RUN I TO 41.0' D5.0:C5.0:L0.0 RQD 80%
			50 degree, pyrite, qtz infill	100	4	
1100.1	40.0		30 degree, soft		----- 5	BOX 4 Fm 30.6 To 39.6 FT.

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PROJECT HOWARD HANSEN DAM INTAKE TOWER

HOLE NO. 94-DD-85

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 1140.1	Hole No. 94-DD-85

1. PROJECT HOWARD HANSEN DAM INTAKE TOWER	INSTALLATION SEATLE DISTRICT	SHEET 3 OF 3 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant) g
1099.6	40.5	▨	40.5 to 42.0 ft., broken zone, rock is soft, crumbly with silickensides			RUN J TO 46.0' D5.0:C5.0:L0.0 RQD 90%
1098.1	42	▨	Andesite Lapallie tuff, hardcompetent rock 30 degree, Qtz, pyrite soft infill	100		
			30 degree		5	
				100	-----	BOX 5 Fm 39.6 To 48.5 FT.
					6	
1090.1	50	▨	30 degree			RUN L TO 56.0 D5.0:C5.0:L0.0 RQD 84%
			40 degree	100		
			shallow joint set			
			30 & 35 degree conjugate set			
			40 degree, slight broken zone			
			20 degree		6	
1084.1	56.0		btm of hole@ 56 ft.		-----	BOX 6 Fm 48.5 To 56.0 FT.

DRILLING LOG	DIVISION NPD	INSTALLATION SEATLE DISTRICT	SHEET 1 OF 3 SHEETS

1. PROJECT HOWARD HANSEN DAM INTAKE TOWER

TION (Coordinates or Station) N102,525.236 E1,763496.572

3. ING AGENCY KERR DRILLING CO.

4. HOLE NO. (As shown on drawing title and file number) 94-DD-86

5. NAME OF DRILLER R. PAINTER

6. DIRECTION OF HOLE VERTICAL ☒ INCLINED ☐ ________ DEG. FROM VERT

7. THICKNESS OF OVERBURDEN 2.6

8. DEPTH DRILLED INTO ROCK 38.4

9. TOTAL DEPTH OF HOLE 41.1

10. SIZE AND TYPE OF BIT 6" DIAMOND

11. DATUM FOR ELEVATION SHOWN (TBM OR MSL) NGVD 1929

12. MANUFACTURER'S DESIGNATION OF DRILL MOBILE B-53

13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED	UNDISTURBED
	0	0

14. TOTAL NUMBER CORE BOXES 6

15. ELEVATION GROUND WATER 1146.3

16. DATE HOLE	STARTED	COMPLETED
	09/16/94	09/17/94

17. ELEVATION TOP OF HOLE 1159.7

18. TOTAL CORE RECOVERY FOR BORING 92

19. SIGNATURE OF INSPECTOR

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant) g
1159.7	0	■	CONCRETE	66	1	RUN A TO 3.0' D3.0:C2.0:L1.0:RQD N/A Initial advance w/HQ bit
1157.7	2.0	▥	SUBGRADE, (1/4"-) gravels			
1157.1	2.6	▨	ANDESITE, gray-green, Mod.hard core highly broken, crumbly crumbly	71		RUN B TO 6.5' D3.5:C2.5:L1.0 RQD 0% Return water leaking to pool in subsurface
			rock highly broken vertical joint w/slickensides 40 degrees 20 degrees 70 degrees	100		RUN C TO 8.0' D1.5:C1.5:L0 RQD 25% reamed HQ pilot hole to 6" dia for next run.
				72		RUN D TO 13.0 D5.0:C3.6:L1.4 RQD 19 % water return 80% 0-
					1	BOX 1 FM 0.0 TO 9.7 FT.
1149.7	10	▨	ANDESITE, gray, hard calcite infill, soft, highly broken to 15.1 Ft. 0 degres watertable flat jointed	100	2	RUN E TO 18.0' D5.0:C5.0:L0 RQD 54% w.t 9/17
5	15.1	▨	Andesite, gray, hard 10 degree flat joint 45 degree joint		2	BOX 2 Fm 9.7'To 17.0'

PROJECT

HOLE NO.

DRILLING LOG (Cont Sheet)

ELEVATION TOP OF HOLE 1159.7

Hole No. 94-DD-86

1. PROJECT HOWARD HANSEN DAM INTAKE TOWER

INSTALLATION SEATLE DISTRICT

SHEET 2 OF 3 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOV-ERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant) g
					3	
1141.7	18.0		ANDESITE BRECCIA,gray,amgdules pink/maroon broken, crumbly,soft breccia. 1/8 to 4 " pieces. Pyrite and calcite	100	3	RUN F TO 23.0' D5.0:C5.0:10 RQD 64%
1138.7	21		highly breciated and broken to 23 ft.		-----	BOX 3 Fm 17.0' To 22.5'
1136.7	23.0		40 degree 70 degree rehealed fracture, qts filling 70 degree dark coating flat pocket of qtz 50 degree soft zone 90 degree, qts infill 30 degree, Qtz. and pyrite mineralizaton 40 degree, thin qtz infill	100 100	4 4 ----- 5	RUN G TO 28.0 D 5.0:C5.0:L0 RQD 86% BOX 4 Fm 22.5' To 28.0' RUN H TO 34.5 D 6.5:C 6.5:L 0 RQD 28%
1129.7	30		Andesite, breccia, hard broken, crumbly, soft clayey grouge high angle jointing high angle jointing high angle jointing broken zone 1 to 2" pieces high angle and flat jnt.	100	5 ----- 6	BOX 5 To 34.5 FT. RUN I TO 41.0' D 6.5:C6.5:L0.0 RQD 20%
1123.7	36.0		clay gouge zone, clay, grey,soft			
1122.2	37.5		Andesite breccia, hard			
.121.3	38.4		60 degree, broken to 38.5 ft. Andesite, lapillie tuff 70 degree		6	

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PROJECT HOWARD HANSEN DAM INTAKE TOWER

HOLE NO. 94-DD-86

DRILLING LOG (Cont Sheet)

ELEVATION TOP OF HOLE 1159.7

Hole No. 94-DD-86

1. PROJECT HOWARD HANSEN DAM INTAKE TOWER

INSTALLATION SEATLE DISTRICT

SHEET 3 OF 3 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant) g
		▨	40-41 ft. high angle joint zone rock highly broken	______	-----	BOX 6 TO 41.0 ft.
1118.6	41.1		BTM of HOLE			

PROJECT

HOLE NO.

DRILLING LOG | NPD | NPS | OF 2 SHEETS

1. PROJECT
HHD FISH PASSAGE STUDY

2. LOCATION (Coordinates or Station)
N102,462 E1,763,470 (TOPO)

3. DRILLING AGENCY
JOHNSON DRILLING for R&R DRILLING

4. HOLE NO. (As shown on drawing title and file number) : 96-00-87

5. NAME OF DRILLER
BOB JOHNSON

6. DIRECTION OF HOLE
☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.

7. THICKNESS OF OVERBURDEN 1.0'

8. DEPTH DRILLED INTO ROCK 199.8'

9. TOTAL DEPTH OF HOLE 200.8'

10. SIZE AND TYPE OF BIT HQ WIRELINE

11. DATUM FOR ELEVATION SHOWN (TBM or MSL)

12. MANUFACTURER'S DESIGNATION OF DRILL
JOY 22

13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN : DISTURBED N/A : UNDISTURBED N/A

14. TOTAL NUMBER CORE BOXES 20

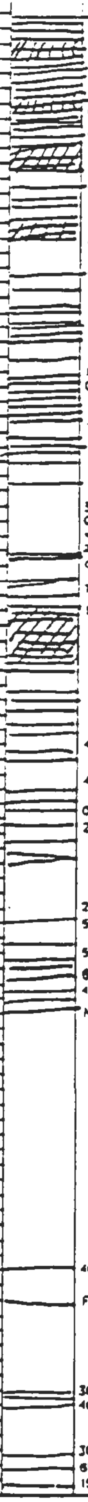
15. ELEVATION GROUND WATER FLOWING ARTESIAN

16. DATE HOLE : STARTED 29 APR 96 COMPLETED 3 MAY 96

17. ELEVATION TOP OF HOLE 1165.7

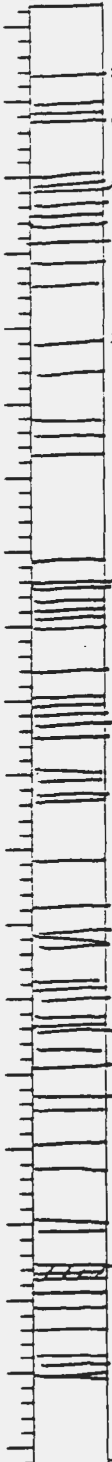
18. TOTAL CORE RECOVERY FOR BORING 99.9 %

19. SIGNATURE OF INSPECTOR
RICHARD ECKERLIN



ELEVATION	DEPTH	CLASSIFICATION OF MATERIALS (Description)	RQD	RUN/BOX	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
1165.7		GM: Silty Sandy Gravel	0	A	Drilled to 5.3 in 3 runs, then reamed 4"-I.D. (HW) casing to 4.8'. Removed 4" casing and took off diamond reaming shoe, then set back in hole so that top is 3" bgs. Top is threaded for cap.
1164.7		TOP OF ROCK ANDESITE BRECCIA, mod hard to hard, black to green to reddish green, closely to widely fractured		B	
			100	C 1	
			35	D	NOTE: Petrographic Examination of core by MRD Lab - see 10 Oct 96 Memorandum in Exhibit C
		60°, with calcite			
		55°	35	E	
	10				
			51	F	
1152.9		35°, FeO, water course (12.8-13.0) 50°, FeO			
		75°, FeO, Calcite at 16' vesicules filled with zeolites to 1/8" dia.	71	G 2	
1145.4	20	55° 75° 75°, possible water course (20.3)			11 27 gpm/10 minutes 15 - 0 psi/instantaneous
		FeO, silt	77	H	
			70	I 3	
		FeO Green Gauge, pyrite vein, calcite	84	J	
	30				10 26.1 gpm/10 minutes 20 - 2 psi/30 sec
			100	K	
		34-38° Core is mottled red, green black with calcite, vesicules filled with zeolites (1/8") at 37' chlorite on Jt., fault gouge		4	
			90	L	
		75° traces, 50°			
	40	Intensely fractured 39.8-43.3'	0	M	9 0.23 gpm/10 minutes 52 - 20 psi/2 min
			57	N 5	
	50	45°	96	O	
					8 0.19 gpm/10 minutes 50 - 20 psi/2 min
		45°	44	P	4/30 1730
		0.2' loss 25°			5/1 0700 SWL 18.5' bgs
			96	Q 6	
	60				
		25° 59.7-70.3' core sent to NPD Lab.	100	R	7 0.58 gpm/10 minutes 52 - 14 psi/2 min
		55° 55°, 60°	100	S	
		65° 45° No joints 67.3-65.2'	96	T 7	
	70				
			100	U	6 0.65 gpm/10 minutes 55 - 16 psi/2 min
				8	
			100.	V	
	80				
			96	W	5 2.4 gpm/10 minutes 65 - 40 psi/2 min
		40°			
1078.8		FeO Taking Jt. Water Course		9	
			98	X	
	90				
					4 3.1 gpm/10 minutes 64 - 36 psi/2 min
			98	Y	
		30°, FeO, Clay 40°		10	
		30°, FeO 65°	96	Z	3
1065.7	100	15°			

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 1165.7		Hole No. 96-00-87
PROJECT HHD FISH PASSAGE STUDY	INSTALLATION NPS		SHEET 2 OF 2 SHEETS



ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	RQD	RUN/ BOX	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
1065.7	100		ANDESITE BRECCIA, moderately hard to hard, black to green to reddish green, medium to widely fractured			
				100	AA	2.8 gpm/5 mi. 50 - 10 psi/2 min
					11	
			20°	81	AB	
	110					
			111.7-117.5' core tested at NPD Lab			1.1 gpm/5 mi. 45 - 10 psi/2 min
				100	AC	
			50°		12	
				98	AD	
	120					5/1 1730 SWL 9.0 bgs SWL 14.5 bgs 5/2 0700
			75°	96	AE	
1040.0			35°		13	1.3 gpm/5 mi. 45 - 12 psi/2 min
			45°	100	AF	
	130		65° 50° 45°			
1030.0			135.1-139.7' core tested at NPD Lab	100	AG	BASE OF PROPOSED EXCAVATION
					14	At 137' Set Grout Packer
				100	AH	
	140		35°			
1022.9			35° FeO, Water Course at 142.8			On 8 May, grouted hole 137-200 ± using 10 sacks cement grout.
1022.0			30°, 35°, FeO Artesian Zone 143.4-143.7			
			60°	82	AI	NOTE: Core from interval 138.5-139' classified as porphyritic metabasalt (see 10 Oct 96 Memorandum in Exhibit C)
					15	
			40°	76	AJ	
	150		30° 30° 30° 45°	76	AK	
1009.8			155.9-156.4 Fault at 156.1 green gauge on jt., pyrite vein	92	AL 16	
	160		70°	100	AM	
			65° 85°			
				33	AN 17	
	170		65° 65° 35°	78	AO	
			0° at 174.5' possibly fault			
			55°	100	AP 18	
	180		40°, 45° 45°			
				75	AQ	5/2 1730 Artesian 40 gpm 5/3 0700 Artesian Pool 40° F, Artesian 48° F
			50° 75°	68	AR 19	
	190		35° 0° 20°	94	AS	
			50° 60° 80°	81	AT 20	
				98	AU	
984.9	200		Bottom of Hole at 200.8'			

LEGEND FOR JOINT SPACING

Widely	=	>1.5 ft
Moderately	=	0.5 to 1.5 ft
Closely	=	0.1 to 0.5 ft
Highly Fractured	=	brecciated

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PROJECT HHD FISH PASSAGE STUDY | HOLE NO. 96-00-87

GRAVELS

GW	WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES.
GP	POORLY GRADED GRAVELS OR GRAVEL-SAND MIXTURES, LITTLE OR NO FINES.
GM	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURE.
GC	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES.

SANDS

SW	WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES.
SP	POORLY GRADED SANDS OR GRAVELLY SNADS, LITTLE OR NO FINES.
SM	SILTY SANDS, SAND-SILT MIXTURES.
SC	CLAYEY SANDS, SAND-CLAY MIXTURES.

FINES

ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTIC PLASTICITY.
CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS.
OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY.
MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS, ELASTIC SILTS.
CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS.
OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS.
PT	PEAT AND OTHER HIGHLY ORGANIC SOILS.

BOUNDARY CLASSIFICATIONS: SOILS POSSESSING CHARACTERISTICS OF TWO GROUPS ARE DESIGNATED BY COMBINATIONS OF GROUP SYMBOLS. FOR EXAMPLE GW-GC, WELL-GRADED GRAVEL-SAND MIXTURE WITH CLAY BINDER.

▮	LOCATION OF PERFORATED ZONES IN WELL CASING.
WL	WATER LEVEL AT COMPLETION OF HOLE .
S ▮	LOCATION OF SEAL.
T ▶◼	LOCATION OF PIEZOMETER TIP.

HOLE NUMBER WELL I

PROJECT HANSON DAM
SEEPAGE STUDIES

LOCATION

N 103,199 E 1,764,0C

DATE STARTED	DATE COMPLETED
18 November 1961	17 Januar, 1962

2 STAGE PIEZ COM 25 MAY 66

ELEVATION	DEPTH	DESCRIPTION OF MATERIALS TOP OF CASING EL 229.23'
1227.3		
1212.3		SAND AND GRAVEL FILL
5.3	20 40 60	COARSE, ANGULAR ROCK FRAGMENTS w/sand, gravel and clay
1122.3	80 100	LARGE, ANGULAR ROCK BLOCKS w/sand and clay
1087.3	120 140	LARGE, ANGULAR ROCK BLOCKS w/interstitial silt
1057.3	160	* COARSE, ANGULAR ROCK FRAGMENTS w/silt and clay S W. L., Jan. 1962
[illegible].3		
1034.7	180	COARSE, ANGULAR ROCK FRAGMENTS w/minor gravel, water bearing
1034.3		Top of Bedrock
1027.3	200	ANDESITE: soft

HOLE NUMBER WELL 2

PROJECT HANSON DAM
SEEPAGE STUDIES

LOCATION

N 103,076 E 1,763,729

DATE STARTED	DATE COMPLETED
~~19 January 1962~~ 25 July 1963	~~1 February 1962~~ 1 August 1963

ELEVATION	DEPTH	DESCRIPTION OF MATERIALS TOP OF CASING EL 1230.70
1228.2		
1210.2		SAND AND GRAVEL FILL
1195.2		COARSE, ANGULAR ROCK FRAGMENTS w/sand, gravel and silt
1180.2	40	LARGE, ANGULAR ROCK FRAGMENTS w/sand, gravel and silt
1158.2	60	ANGULAR ROCK FRAGMENTS w/interstitial sand, silt and clay, minor gravel and intercalated lenticular sand and silt W. L., Feb. 1962
	80 100 120	Bottom of boring, Feb. 1962
1102.2		
1091.2		SANDY GRAVEL w/boulders
1077.2	140	SILTY SAND w/gravel
1076.2		CLAY
1064.2		Top of bedrock ANDESITE BRECCIA

NOTE: Bottom perforation is to pick up water in void between 4" casing and 6" hole.

HOLE NUMBER	WELL 3
PROJECT	HANSON DAM SEEPAGE STUDIES
LOCATION	N 103,617 E1,763,606
DATE STARTED	1 March 1962 8 July 1963
DATE COMPLETED	16 March 1962 24 July 1963

2 STAGE PIEZ COMP 24 MAY 66

ELEVATION	DEPTH	DESCRIPTION OF MATERIALS TOP OF CASING EL 1225.70
1223.3		
1213.3		FILL MATERIAL
	20	
1193.3		
1190.3		BOULDER
	40	COARSE TO LARGE ANGULAR ROCK FRAGMENTS w/interstitial sand, silt, clay and minor gravel
	60	
1143.3	80	
1126.3		LARGE ANGULAR ROCK FRAGMENTS
1123.3	100	VOLCANIC ASH, lt. gray
1110.3		LARGE, ANGULAR ROCK FRAGMENTS
1103.3		COARSE, ANGULAR ROCK FRAGMENTS AND GRAVEL
	130	COARSE, ANGULAR ROCK FRAGMENTS w/minor sand, gravel and silt
		Bottom of boring, Mar. 1962
1071.3	150	
1063.3		SILTY SANDY GRAVEL
1060.3		SANDY GRAVEL, water
1054.3	170	COARSE TO FINE ANGULAR ROCK FRAGMENTS and clay
1052.3		SANDY GRAVEL, water
1'		SILTY SANDY GRAVEL
	180	Top of bedrock
1036.3		HIGHLY FRACTURED BRECCIA
1028.3		BRECCIA

HOLE NUMBER	WELL 4
PROJECT	HANSON DAM SEEPAGE STUDIES
LOCATION	N 103,878 E1,763,366
DATE STARTED	6 February 1962
DATE COMPLETED	9 February 1962

ELEVATION	DEPTH	DESCRIPTION OF MATERIALS TOP OF CASING EL 1047.70
1044.7		
1038.7		COARSE, ANGULAR ROCK FRAGMENTS w/silt and sand
1031.7		SAND AND GRAVEL w/trace clay
1022.7	20	SANDY SILTY GRAVEL
	30	SILTY GRAVEL
1009.7		W. L. Feb 1962
1005.7		
1002.7		GRAVEL, water bearing
997.7		SILT w/gravel
	50	Top of bedrock
989.7		ANDESITE: soft, blue gray, pyrochastic

HOLE NUMBER WELL 5

PROJECT HANSON DAM SEEPAGE STUDIES

LOCATION

N 104,074 E 1,763,329

DATE STARTED 18 January 1962

DATE COMPLETED 5 February 1962

ELEVATION 1042.6	DEPTH	DESCRIPTION OF MATERIALS TOP OF CASING EL 1046.38
		SAND AND GRAVEL w/minor clay, water bearing
1030.6		SILTY GRAVEL, fine w/sand, compact, minor rock fragments
	20	
1011.4		W. L. Feb 1962
1000.6	40	SANDY GRAVEL, coarse, w/cobbles and sand lenses, water bearing
	60	
964.5		SILTY CLAY w/gravel
962.6		SANDY CLAY
		INTERBEDDED FINE SAND AND SILT
948.6		SAND
942.6	100	SILT w/sand and gravel lenses
930.6		
924.6		SILT w/decomposed rock and gravel
922.6		BEDROCK

HOLE NUMBER WELL 6

PROJECT HANSON DAM SEEPAGE STUDIES

LOCATION

N 104,315 E 1,763,265

DATE STARTED 2 February 1962

DATE COMPLETED 9 February 1962

ELEVATION 1040.0	DEPTH	DESCRIPTION OF MATERIALS TOP OF CASING EL 1043.29
		SANDY, CLAYEY SILT w/rock fragments
1020.0	20	SANDY, SILTY, CLAYEY GRAVEL w/rock fragments
1011.0		
1005.0		BOULDER
	40	SILTY, SANDY GRAVEL, water bearing
994.0		GRAVEL: water bearing
985.0		SAND AND GRAVEL w/silt and clay lenses
	60	
965.0		CLEAN SAND AND GRAVEL
960.0		SAND AND GRAVEL w/minor silt
940.0		INTERBEDDED SANDS, GRAVEL, SILT AND ROCK FRAGMENTS
	120	
	140	
894.0		

HOLE NUMBER WELL 7

PROJECT HANSON DAM SEEPAGE STUDIES

LOCATION

N 104,271 E 1,763,636

DATE STARTED 26 August 1963

DATE COMPLETED 18 September 1963

2 STAGE PIEZ COMP 20 JUN 66

TOP OF CASING EL 1213.10

ELEVATION	DEPTH	DESCRIPTION OF MATERIALS
1210.6		
1161.6	20 40	ANGULAR ROCK FRAGMENTS AND CLAY
.6	60	ANGULAR ROCK FRAGMENTS, occasional boulders w/interstitial clay
1094.6	80 100	SANDY CLAYEY ANGULAR ROCK FRAGMENTS w/occasional boulders
1076.6	120	GRAVELLY CLAYEY SAND
1075.6		CLEAN SAND
1072.6		SANDY CLAY
1060.6		GRAVEL AND BROKEN ROCK, water bearing
1050.6	160	ROCK FRAGMENTS
1042.6		CLAYEY SANDY GRAVEL
1039.6		CLEAN GRAVEL, water
	180	CLAYEY SANDY GRAVEL
1024.6		CLEAN SAND
		SANDY GRAVEL, water bearing

HOLE NUMBER WELL 7

ELEVATION	DEPTH	DESCRIPTION OF MATERIALS
1000.6 1001.6		SANDY GRAVEL
999		BROKEN ROCK & GRAVEL
990.6	220	ROCK FRAGMENTS AND CLAY
989.6		CLEAN SAND
952.6	240	ROCK FRAGMENTS w/interstitial clay
930.6	280	CLAY, SAND AND GRAVEL
913.6		CLAY
904.6	300	SANDY CLAY
858.6	320 340	SANDY GRAVEL w/boulders
855.6		SAND, GRAVEL AND ROCK FRAGMENTS

HOLE NUMBER WELL 8

ECT HANSON DAM SEEPAGE STUDIES

LOCATION

N 104,022 E1,763,640

DATE STARTED 20 September 1963

DATE COMPLETED 1 October 1963

2 STAGE PIEZ COMP 18 MAY 66

TOP OF CASING EL 1227.59

ELEVATION	DEPTH	DESCRIPTION OF MATERIALS
1225.4		BROKEN ROCK AND CLAY
1208.4	20	CLAY AND BROKEN ROCK
1184.4	40	BLOCKY ROCK W/CLAY
1175.4	60	CLAY AND BROKEN ROCK
1152.4	80	BLOCKY ROCK W/CLAY
1139.4		CLAY W/BROKEN ROCK
1126.4		SANDY CLAYEY GRAVEL AND ROCK FRAGMENTS
T S	120	
1100.4	140	SILTY SANDY GRAVEL AND ROCK FRAGMENTS
T S	160	
1062.4		BROKEN ROCK, water bearing
1c	180	BROKEN ROCK w/clay
1039.4		SAND, water bearing
	200	SANDY GRAVEL w/cobbles

HOLE NUMBER WELL 8

ELEVATION	DEPTH	DESCRIPTION OF MATERIALS
		SANDY GRAVEL w/cobbles, water bearing at depth 206 ft.
1005.4	220	SAND w/gravel and silt
1000.0 T 995.4	240	SANDY GRAVEL, water bearing
975.4 974.4		CLAY AND BROKEN ROCK

HOLE NUMBER WELL 9

PROJECT HANSON DAM SEEPAGE STUDIES

LOCATION

N 103,803 E 1,763,669

DATE STARTED	DATE COMPLETED
2 August 1963	23 August 1963

2 STAGE PIEZ COMP 28 APR 66

TOP OF CASING EL 1230.01

ELEVATION	DEPTH	DESCRIPTION OF MATERIALS
1227.5		
		ANGULAR ROCK FRAGMENTS w/sand and clay
	20	
1197.5		
		BROKEN ROCK w/clay, scattered large blocks
	40	
	60	
	80	
1139.5		
		BROKEN ROCK
	100	
1117.5		
		BROKEN ROCK w/clay and sand
1107.5		
1102.5		SANDY, BROKEN ROCK
		BROKEN ROCK w/sand and clay
	140	
	160	
S		
	180	GRAVELLY CLAY
1033.5		
1032.5		GRAVEL, water bearing
	200	CLAYEY GRAVEL

HOLE NUMBER WELL 9

ELEVATION	DEPTH	DESCRIPTION OF MATERIALS
		CLAYEY GRAVEL
	220	
1005.5		
		SANDY GRAVEL AND broken rock
997.5		
991.5		GRAVEL w/sand, water
987.0	240	
982.5		CLAY
		BEDROCK
	260	
963.5		

HOLE NUMBER	WELL 10
F‌ ‌CT	HANSON DAM SEEPAGE STUDIES
LOCATION N 103,275	E 1,764,190
DATE STARTED 15 October 1961	DATE COMPLETED 14 November 1961

ELEV-ATION	DEPTH	DESCRIPTION OF MATERIALS
228.6		TOP OF CASING EL 1223.51
210.6		BROKEN ROCK w/sand, gravel and fines
1178.6	80	BROKEN ROCK w/sand and gravel
1150.6	60	BLOCKY ROCK w/sand, gravel and clay
1099.6	100 120	BOULDERS in a sand, clay and gravel matrix
1074.6	140	SILT, SAND AND GRAVEL w/broken rock
1063.6	160	LARGE FRAGMENTS OF BROKEN ROCK (clean) W. L., Nov. 1961
1044.6	180	COARSE SAND AND GRAVEL w/broken rock
	200	CLEAN COARSE SAND AND GRAVEL

HOLE NUMBER	WELL 10

ELEV-ATION	DEPTH	DESCRIPTION OF MATERIALS
1013.6		CLEAN COARSE SAND AND GRAVEL (Well screen)
1001.6	220	SAND, GRAVEL, CLAY AND SILT
998.6		SILT AND CLAY
992.6		BEDROCK

HOLE NUMBER	WELL II
PROJECT	HANSON DAM SEEPAGE STUDIES
LOCATION	N 103,748 E 1,763,881
DATE STARTED 29 August 1963	DATE . COMPLETED 17 September 1963

ELEVATION	DEPTH	2 STAGE PIEZ COMP 2 JUN 66 DESCRIPTION OF MATERIALS TOP OF CASING EL 1274.26
1271.7		
1268.7		GRAVELLY SILTY SAND
		ANGULAR BROKEN ROCK w/sand, gravel & clay
	20	
	40	
	60	
	80	
	100	
	120	
	140	
	160	
1101.7		BROKEN ROCK (water seepage)
1081.7		SANDY CLAYEY GRAVEL w/occasional boulders
	200	

HOLE NUMBER	WELL II

ELEVATION	DEPTH	DESCRIPTION OF MATERIALS
		SANDY CLAYEY GRAVEL w/occasional boulders
9	220	
1033.7		CLEAN GRAVEL, water
1026.7		SAND AND GRAVEL
1010.7	260	CLEAN GRAVEL, water
1006.7		CLAYEY GRAVEL
1004.7		CEMENTED GRAVEL
1001.7		
997.7	280	BROKEN ROCK w/clay
981.7		

X-2

HOLE NUMBER CD-12

PROJECT HANSON DAM SEEPAGE STUDIES

LOCATION

N 104,184 E1,763,816

DATE STARTED	DATE COMPLETED
	June 1953

ELEVATION	DEPTH	DESCRIPTION OF MATERIALS
1256.6		TOP OF CASING 1260.1
1255.6		SANDY ORGANIC SILT
		BROKEN ROCK and sandy silt
	20	
	40	
1211.6		
		BROKEN ROCK w/interstitial sandy silt
	60	
	80	
	100	
	120	
	140	
1100.6		
	160	BROKEN ROCK, gravel size, in matrix of sandy clay and silt
1085.6		
		BROKEN ROCK
	180	
	200	

HOLE NUMBER CD-12

ELEVATION	DEPTH	DESCRIPTION OF MATERIALS
		BROKEN ROCK
	220	
1024.6		
1019.6		SANDY GRAVEL
1018.6		GRAVELLY SAND
		SANDY GRAVEL
	260	
991.6		
		SANDY GRAVEL w/boulders
976.6	280	
		CLAYEY SANDY GRAVEL w/boulders
963.6		
		CLAYEY SAND w/boulders
954.6	300	
951.6		CLAYEY SANDY GRAVEL w/boulders

HOLE NUMBER	WELL 13
ECT	HANSON DAM SEEPAGE STUDIES
LOCATION N 103,689	E 1,763,778
DATE STARTED 14 September 1963	DATE COMPLETED 28 September 1963

ELEVATION	DEPTH	DESCRIPTION OF MATERIALS
1253.2		TOP OF CASING 1255.7
	20 40 60 80	BROKEN ROCK w/sand, gravel and silt
1162.2		
1155.2		BROKEN ROCK
T S	120	* BROKEN ROCK w/sand and silt
1128.2		
	140	* BROKEN ROCK
1102.2		
T S	160 180 200	* SILTY SANDY GRAVEL AND BROKEN ROCK, water at 155 & 173-185 ft

HOLE NUMBER	WELL 13

ELEVATION	DEPTH	DESCRIPTION OF MATERIALS
1047.2		SILTY SANDY GRAVEL AND BROKEN ROCK
1040.2		CLAY
1034.2		SILTY SANDY GRAVEL
1032.2		SANDY GRAVEL WATER
1026.2		SILTY SANDY GRAVEL
1009.2	240	SANDY GRAVEL
974.2	260	SILTY SANDY GRAVEL
958.2		BEDROCK

X-2

HOLE NUMBER WELL 14

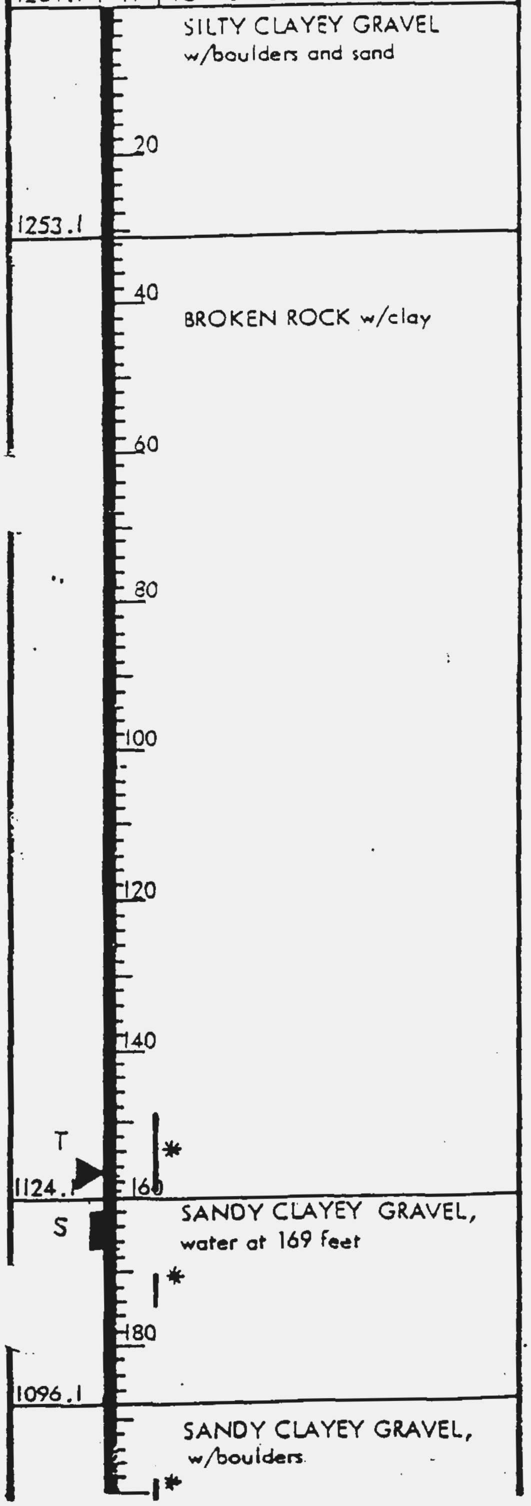
ROJECT HANSON DAM SEEPAGE STUDIES

LOCATION

N 103,462 E 1,763,965

DATE STARTED	DATE COMPLETED
10 July 1963	31 July 1963

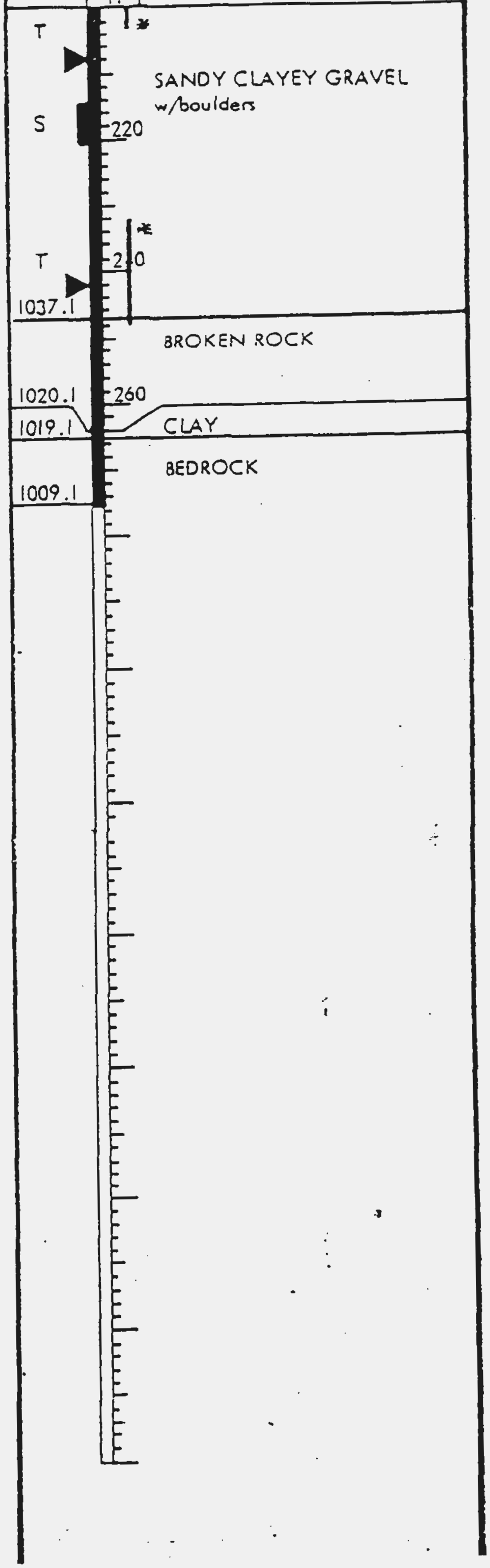
ELEVATION	DEPTH	DESCRIPTION OF MATERIALS
1284.1		TOP OF CASING 1286.8



ELEVATION	DESCRIPTION OF MATERIALS
	SILTY CLAYEY GRAVEL w/boulders and sand
1253.1	BROKEN ROCK w/clay
1124.1	SANDY CLAYEY GRAVEL, water at 169 feet
1096.1	SANDY CLAYEY GRAVEL, w/boulders

HOLE NUMBER WELL 14

ELEVATION	DEPTH	DESCRIPTION OF MATERIALS



ELEVATION	DESCRIPTION OF MATERIALS
	SANDY CLAYEY GRAVEL w/boulders
1037.1	BROKEN ROCK
1020.1	CLAY
1019.1	BEDROCK
1009.1	

X-2a

HOLE NUMBER WELL 15

OJECT HANSON DAM
SEEPAGE STUDIES

LOCATION

N 103,521 E 1,764,095

DATE STARTED 24 June 1963

DATE COMPLETED 9 July 1963

ELEVATION	DEPTH	DESCRIPTION OF MATERIALS
1287.4		TOP OF CASING 1290.0
		SILTY SAND w/gravel
	20	
	40	
1237.4		
	60	
		BROKEN ROCK w/clayey sand
	80	
1187.4	100	
		BROKEN ROCK w/clay
	120	
1157.4		
		BROKEN ROCK w/sand
	140	
1137.4		
		BROKEN ROCK w/sandy clay
	160	
1123.9		W. L. 10 July 1963
	*	SILTY SANDY GRAVEL, water bearing
	180	
		SANDY CLAYEY GRAVEL
1087.4	*	

HOLE NUMBER WELL 15

ELEVATION	DEPTH	DESCRIPTION OF MATERIALS
		SANDY CLAYEY GRAVEL
	220	
S		
	240	
1037.4		
		SANDY GRAVEL
	260	water bearing
1021.4	*	
1017.4		GRAVELLY SANDY CLAY
1014.4	*	SANDY GRAVEL, water
T	280	BROKEN ROCK w/clay
1002.4		
		BEDROCK
988.4		

X-30

HOLE NUMBER WELL 16

JECT HANSON DAM
SEEPAGE STUDIES

LOCATION

N 103,518 E 1,764,296

DATE STARTED	DATE COMPLETED
5 June 1963	21 June 1963

ELEVATION	DEPTH	DESCRIPTION OF MATERIALS
1257.0		TOP OF CASING 1259.3
		ANGULAR ROCK FRAGMENTS w/clay and sand
	20	
	40	
1212.0		
		BROKEN ROCK w/clay
	60	
S		
1177.0	80	
		BROKEN ROCK w/clay and sand
1167.0		
		BROKEN ROCK w/clay, silt and sand
1157.0	100	
		CLAYEY SANDY BROKEN ROCK
T	120	
S		
		Water at 140 - 142 feet
	160	Water at 162 - 163 feet
	180	
S	200	

HOLE NUMBER WELL 16

ELEVATION	DEPTH	DESCRIPTION OF MATERIALS
1049.0		CLAYEY SANDY BROKEN ROCK
1046.0		SANDY GRAVEL, water
		CLAYEY SANDY ANGULAR GRAVEL
1037.0	220	
T		SANDY GRAVEL w/clay lenses, water bearing
1011.0		
		BEDROCK
995.0	260	

HOLE NUMBER WELL 17

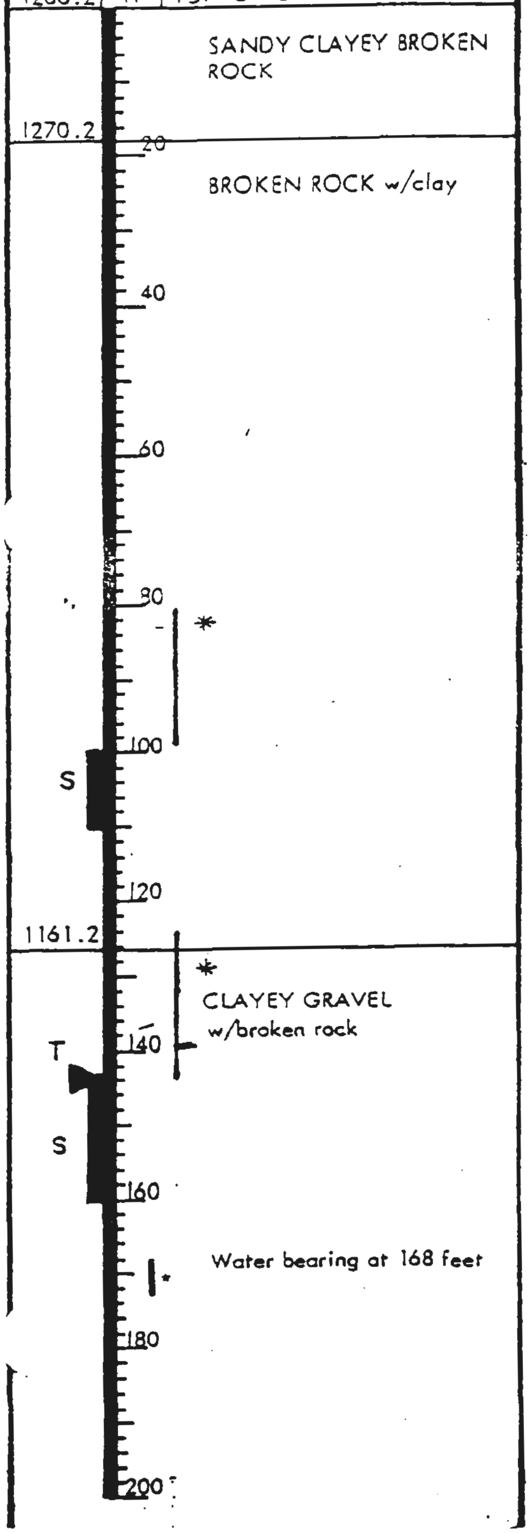
PROJECT HANSON DAM SEEPAGE STUDIES

LOCATION

N 103,833 E 1,764,080

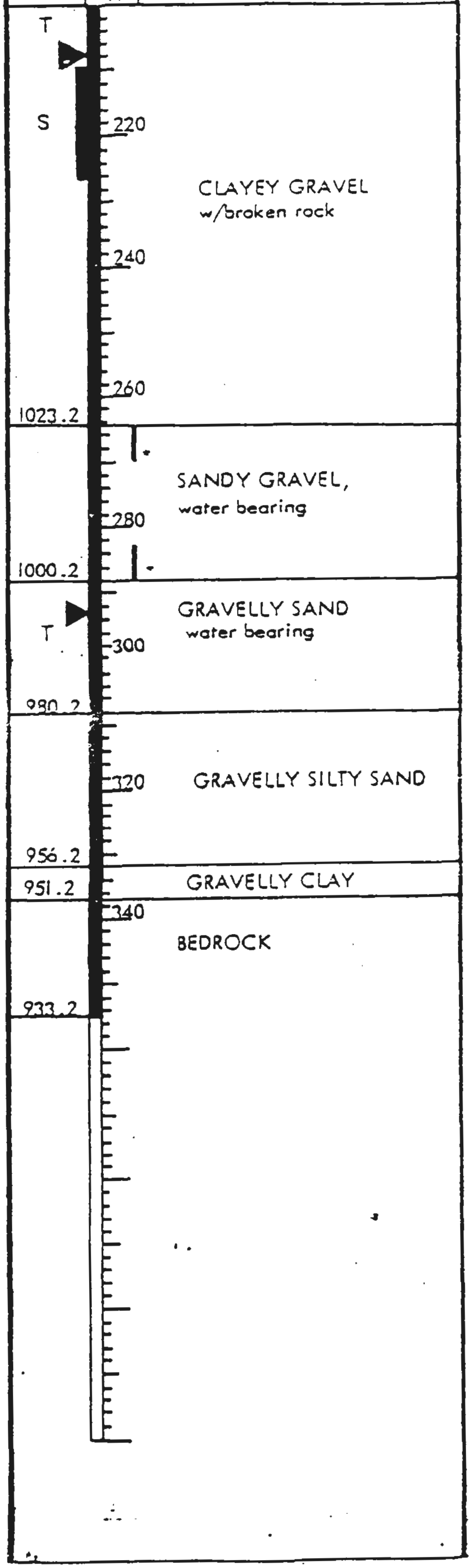
DATE STARTED	DATE COMPLETED
5 August 1963	28 August 1963

ELEVATION	DEPTH	DESCRIPTION OF MATERIALS
1288.2		TOP OF CASING 1290.7
		SANDY CLAYEY BROKEN ROCK
1270.2		BROKEN ROCK w/clay
1161.2		CLAYEY GRAVEL w/broken rock
		Water bearing at 168 feet



HOLE NUMBER WELL 17

ELEVATION	DEPTH	DESCRIPTION OF MATERIALS
		CLAYEY GRAVEL w/broken rock
1023.2		SANDY GRAVEL, water bearing
1000.2		GRAVELLY SAND water bearing
980.2		GRAVELLY SILTY SAND
956.2		GRAVELLY CLAY
951.2		BEDROCK
933.2		



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HOLE NUMBER WELL 18

PROJECT HANSON DAM
SEEPAGE STUDIES

LOCATION

N 103,314 E 1,763,675

DATE STARTED	DATE COMPLETED
11 May 1965	3 June 1965

ELEV-ATION 1228.1	DEPTH	DESCRIPTION OF MATERIALS TOP OF CASING 1230.7
1210.1		CLAYEY ANGULAR GRAVEL AND ROCK FRAGMENTS
1206.1	20	SILTY SANDY GRAVEL
1175.1	40	CLAYEY ANGULAR GRAVEL AND ROCK FRAGMENTS
1142.1	60 80	SILTY SANDY ANGULAR GRAVEL AND ROCK FRAGMENTS *Lost drill water, 76 to 86'
S 1131.1		CLAYEY SANDY GRAVEL w/broken rock
1112.1	100	SILTY SANDY GRAVEL w/broken rock
1083.1	120 140	SILTY SANDY GRAVEL w/broken rock. Water bearing zones at 133' - 134' and 139' - 140'. *S.W.L. 130'
1072.1		CLAY
1071.		*SANDY GRAVEL, water S.W.L. 135'
1068.1	160	CLAY
1062.1		SILTY SANDY GRAVEL & boulder
1058.1		CLAY
T 1041.1	180	BEDROCK ANDESITE

HOLE NUMBER WELL 19

PROJECT HANSON DAM SEEPAGE STUDIES

LOCATION

N 103,444 E 1,763,650

DATE STARTED	DATE COMPLETED
4 June 1965	16 July 1965

ELEVATION	DEPTH	DESCRIPTION OF MATERIALS
1226.9		TOP OF CASING 1229.5
1224.9		FILL MATERIAL
1195.9	20	CLAYEY ANGULAR GRAVEL AND ROCK FRAGMENTS
.9	40 60	SILTY SANDY ANGULAR GRAVEL AND ROCK FRAGMENTS Lost drill water, 63 - 64'
1128.9	80	BROKEN ROCK w/clay. Lost drill water *
1116.9	100	SANDY SILTY GRAVEL AND ROCK FRAGMENTS
1065.9	120 140 160	SANDY SILTY GRAVEL w/cobbles, boulders and broken rock Lost drill water, 123 - 124' Water bearing zones intermittent between 133 and 153'. S.W.L. 128'
1060.9		SANDY CLAYEY GRAVEL w/broken rock
S .9	180	CLAY
T 1026.9		SANDY GRAVEL AND SANDY SILTY GRAVEL, interbedded, water bearing to 197'. S.W.L. 182'

HOLE NUMBER WELL 19

ELEVATION	DEPTH	DESCRIPTION OF MATERIALS
1016.9		SANDY GRAVEL w/ broken rock
1011.9		SANDY SILTY GRAVEL
1001.9		BEDROCK

HOLE NUMBER WELL 20

OJECT HANSON DAM
DRAINAGE TUNNEL

LOCATION

N 103,330 E 1,763,854

DATE STARTED	DATE COMPLETED
15 June 1965	2 Aug 1965

ELEVATION 1277.4	DEPTH	2 Stage piez. comp. 25 Mar. 1966 DESCRIPTION OF MATERIALS Top of Casing El. 1280.0
1275.4		SILT
S T S 1105.4	20 40 60 80 100 120 140 160	SANDY SILTY ANGULAR GRAVEL AND ROCK FRAGMENTS
1089.4	180	BROKEN ROCK SAND, 1' thick @ 176-7' Water 172' - 188' S.W.L. 168'
1083.4		SANDY SILTY GRAVEL
1078.4		*FINE SAND & BROKEN ROCK water
	200	SANDY SILTY GRAVEL

HOLE NUMBER WELL 20

ELEVATION	DEPTH	DESCRIPTION OF MATERIALS
1075.4		SANDY SILTY GRAVEL
1064.4		BROKEN ROCK, *water
1062.4		SAND, water, S.W.L. 169'
1057.4	220	BROKEN ROCK, water
S 1050.4		BOULDER
1041.4		SILT
1037.4	240	*SAND, water, S.W.L. 204'
1034.4		SANDY GRAVEL
1027.4		BROKEN ROCK
1024.4		CLAYEY GRAVELLY SAND
1016.4	260	*GRAVELLY SAND, water, S.W.L. 204'
1013.0 T 987.4	280	CLAY w/sand lenses
979.4		SANDY GRAVELLY CLAY
967.4	300	BEDROCK
	320	

HOLE NUMBER WELL 21

PROJECT HANSON DAM DRAINAGE TUNNEL

LOCATION

N 103,215 E 1,763,786

DATE STARTED	DATE COMPLETED
16 July 1965	19 Aug 1965

2 Stage piez. comp. 28 March 1966

Top of Casing El. 1230.8

ELEVATION	DEPTH	DESCRIPTION OF MATERIALS
1228.0		
	20	
	40	CLAYEY SANDY ANGULAR GRAVEL AND ROCK FRAGMENTS
	60	
1150.0	80	
		SILTY SANDY ANGULAR GRAVEL AND ROCK FRAGMENTS
	100	
1119.0		
		BROKEN ROCK w/ clayey sandy gravel
	120	
		Water bearing zone 131' to 139'
	140	S.W.L.: 123 to 126' during drilling to depth 216'
1069.0	160	
		SILT
.0	180	
S		SANDY GRAVELLY CLAY
1032.0		
		BROKEN ROCK
	200	

HOLE NUMBER WELL 21

ELEVATION	DEPTH	DESCRIPTION OF MATERIALS
1027.0		BEDROCK VOLCANIC BRECCIA
	220	
999.0		
	240	

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HOLE NUMBER WELL 22

JECT HANSON DAM DRAINAGE TUNNEL

LOCATION

N 103,529 E 1,763,640

DATE STARTED 11 May 1965

DATE COMPLETED 2 June 1965

ELEVATION 1225.4	DEPTH	2 Stage piez comp. 10 May 1966 DESCRIPTION OF MATERIALS Top of Casing El. 1227.6
.?	20 40 60	CLAYEY ANGULAR GRAVEL AND ROCK FRAGMENTS
1124.4	80 100	SILTY SANDY ROCK FRAGMENTS AND GRAVEL *
1109.4		BOULDERS AND BROKEN ROCK w/sandy clay
1101.4	120	SILTY SANDY GRAVEL
1091.4		SANDY GRAVELLY CLAY
1085.4	140	SILTY SANDY GRAVEL, water bearing. S.W.L. 124'
1055.4	160	SILT & CLAY
S 1036.4	180	SILT & FINE SAND
1026.4		SILTY SANDY GRAVEL

HOLE NUMBER WELL 22

ELEVATION	DEPTH	DESCRIPTION OF MATERIALS
1020.4		GRAVELLY SAND, water S.W.L. 193'
1015.4 ▸ T 1006.2	220	BEDROCK ANDESITE Water in open joint at depth 219' S.W.L. 189'

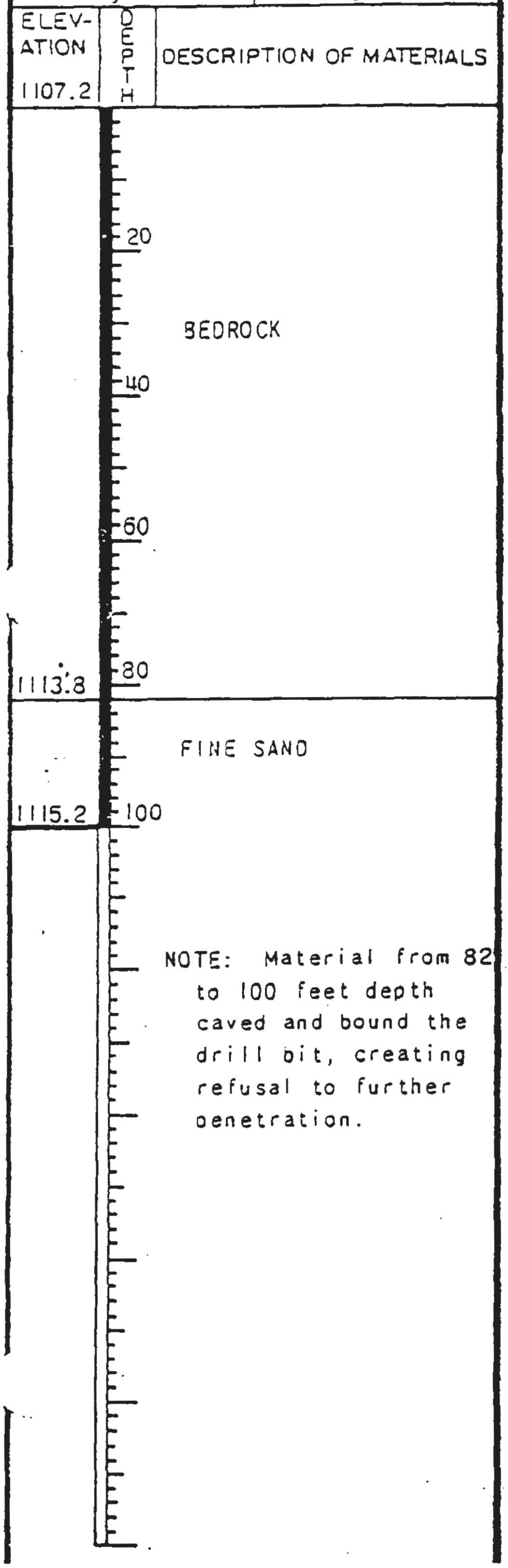
HOLE NUMBER HORIZ. DRAIN A-1

JECT HANSON DAM DRAINAGE TUNNEL

LOCATION

N 103,360 E 1,763,510

DATE STARTED	DATE COMPLETED
16 August 1967	17 August 1967



NOTE: Material from 82 to 100 feet depth caved and bound the drill bit, creating refusal to further penetration.

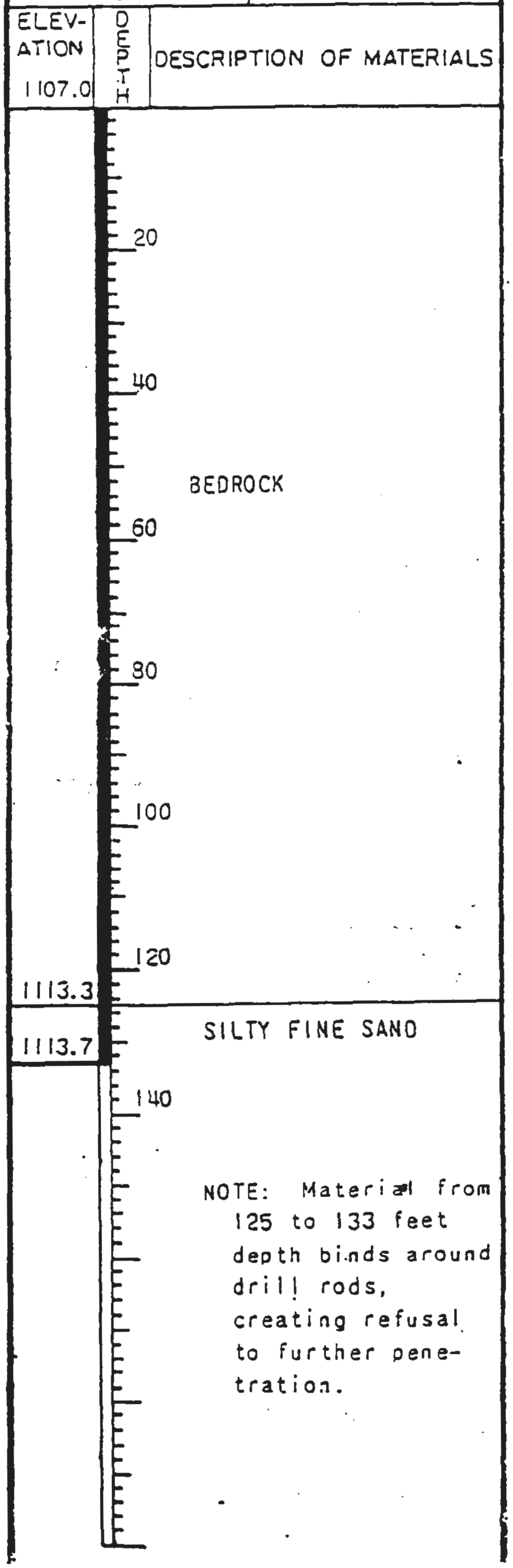
HOLE NUMBER HORIZ. DRAIN A-2

PROJECT HANSON DAM DRAINAGE TUNNEL

LOCATION

N 103,360 E 1,763,510

DATE STARTED	DATE COMPLETED
14 August 1967	16 August 1967



NOTE: Material from 125 to 133 feet depth binds around drill rods, creating refusal to further penetration.

HOLE NUMBER HORIZ. DRAIN A-3

PROJECT HANSON DAM
DRAINAGE TUNNEL

LOCATION
N 103,360 E 1,763,510

DATE STARTED 14 August 1967

DATE COMPLETED 14 August 1967

ELEVATION 1107.2	DEPTH	DESCRIPTION OF MATERIALS
		BROKEN ROCK
	20	
1108.0		
	40	
	60	BEDROCK: Jointed w/clay seams
	80	
1110.2	100	
		SAND & BROKEN ROCK
1110.5		
	120	
		BORING MADE 90 GPM UPON COMPLETION WITH RESERVOIR AT ELEV. 1133 FT.

HOLE NUMBER HORIZ. DRAIN A-4

PROJECT HANSON DAM
DRAINAGE TUNNEL

LOCATION
N 103,360 E 1,763,510

DATE STARTED 9 August 1967

DATE COMPLETED 14 August 1967

ELEVATION 1107.8	DEPTH	DESCRIPTION OF MATERIALS
	20	
	40	BEDROCK: Fractured w/clay seams
	60	
	80	
1120.9	100	
		BEDROCK: Sound
1122.9		
		SILTY SAND
1124.0	120	
		SILTY SANDY GRAVEL w/ rock fragments
1125.4		
	140	BORING MADE 30 GPM UPON COMPLETION WITH RESERVOIR AT ELEV. 1133 FT.

HOLE NUMBER HORIZ. DRAIN A-5

ECT HANSON DAM
DRAINAGE TUNNEL

LOCATION

N 103,360 E 1,763,510

DATE STARTED	DATE COMPLETED
8 August 1967	8 August 1967

ELEV-ATION 1107.0	DEPTH	DESCRIPTION OF MATERIALS
1107.4		BEDROCK: Sound
		BROKEN BEDROCK w/seams of silty & clayey sand
1108.7	20	
	40	SILTY SANDY FINE GRAVEL w/rock fragments
	60	
		- BORING MAKING 1.2 GPM FROM DEPTH OF 70 FT.
1112.7	80	
		SILTY SANDY COARSE GRAVEL & BROKEN ROCK
1114.4	100	
		BORING MADE 60 GPM UPON COMPLETION WITH RESERVOIR AT ELEV. 1137 FT.
	120	

HOLE NUMBER HORIZ. DRAIN A-6

PROJECT HANSON DAM
DRAINAGE TUNNEL

LOCATION

N 103,360 E 1,763,510

DATE STARTED	DATE COMPLETED
17 August 1967	18 August 1967

ELEV-ATION 1107.6	DEPTH	DESCRIPTION OF MATERIALS
		BEDROCK: Sound
1109.4	20	
	40	
	60	BROKEN BEDROCK w/ seams of silty and clayey sand
	80	
1115.0	100	
1115.3		FINE SAND
1116.0	120	SILTY SANDY GRAVEL. w/rock fragments
		BORING MADE 37 GPM UPON COMPLETION WITH RESERVOIR AT ELEV. 1130 FT.

HOLE NUMBER HORIZ. DRAIN 8-1A

JECT HANSON DAM
DRAINAGE TUNNEL

LOCATION

N 103,425 E 1,763,498

DATE STARTED	DATE COMPLETED
6 Sept. 1967	11 Sept. 1967

ELEVATION	DEPTH	DESCRIPTION OF MATERIALS
1081.3		
	20	
	40	BEDROCK
	60	
	80	
1094.4		BORING MAKING WATER BELOW DEPTH 82 FT.
	100	CLAYEY SANDY GRAVEL
1099.8	120	
	140	
	160	BROKEN ROCK: Weathered w/clay & silt filled seams. HARD BETWEEN DEPTH 160 & 180 FT.
	180	
	200	

HOLE NUMBER HORIZ. DRAIN 8-1A

ELEVATION	DEPTH	DESCRIPTION OF MATERIALS
	220	BROKEN ROCK: Weathered w/clay and silt filled seams.
	240	BORING MADE 60 GPM UPON COMPLETION WITH RESERVOIR AT ELEV. 1121 FT.
1120.8	260	

HOLE NUMBER HORIZ. DRAIN B-2

P CT HANSON DAM
DRAINAGE TUNNEL

LOCATION
N 103,425 E 1,763,498

DATE STARTED 11 Sept. 1967
DATE COMPLETED 13 Sept. 1967

ELEVATION 1082.4	DEPTH	DESCRIPTION OF MATERIALS
	20	
		BEDROCK
	40	
	60	
	80	
		CLAYEY SANDY GRAVEL
	100	
1100.4	120	
		CLAYEY SANDY GRAVEL AND BROKEN ROCK w/ sand lenses
	140	
1105.7		
	160	
		BROKEN ROCK w/interstitial clay, silt and sand
	180	
1110.9		
		CLAYEY & SILTY GRAVEL & ROCK FRAGMENTS w/ sand lenses
1112.4	200	

BORING MADE 70 GPM UPON COMPLETION WITH RESERVOIR AT ELEV. 1121 FT.

HOLE NUMBER HORIZ. DRAIN B-3

PROJECT HANSON DAM
DRAINAGE TUNNEL

LOCATION
N 103,425 E 1,763,498

DATE STARTED 15 Sept. 1967
DATE COMPLETED 17 Sept. 1967

ELEVATION 1081.3	DEPTH	DESCRIPTION OF MATERIALS
	20	
		BEDROCK
	40	
	60	
1085.9		
	80	
	100	
		BROKEN ROCK w/interstitial clayey and silty sandy gravel and occasional sand lenses
	120	
	140	BORING MADE 90 GPM UPON COMPLETION w/ RESERVOIR AT ELEV. 1120 FT.
	160	
1092.9		
	180	

HOLE NUMBER 79-CD-38

PROJECT Howard Hanson Dam
1979 Piezometer installation

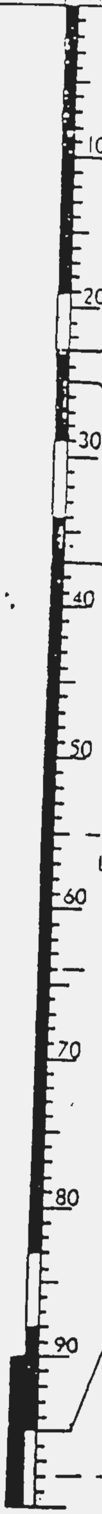
LOCATION Right Abutment

N 104,036.28 E. 763,956.34

DATE STARTED	DATE COMPLETED
23 Aug 1979	27 Oct 1979

ELEVATION 1308 | DEPTH | DESCRIPTION OF MATERIALS

Top of Casing 1311.3



Boulders & broken rock - all angular - w/silt & sand.

GM, Silty Sandy GRAVEL (ang.) w/boulders (ang.) & minor clay or decomposed rock, medium w/dense zones, brown w/minor gray.

BOULDER

GM, Cemented Sands & Gravels w/silt, clay & broken rock, medium, brownish gray.

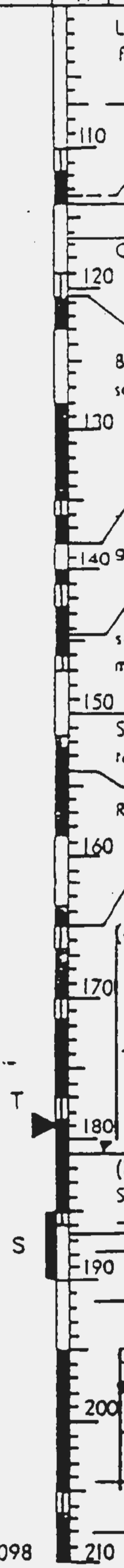
GM, Cemented Sands & Gravels w/silt, clay, broken rock & occ. boulders (ang.), medium, brownish gray.

Lost Drill Water from -55 to -64

GM, Cemented Sands & Gravels w/clay, medium to dense, gray.

HOLE NUMBER 79-CD-38

ELEVATION 1208 | DEPTH | DESCRIPTION OF MATERIALS



Lost Drill Water from -95 to -107

Water Bearing Zone from -113.5 to -114

BOULDER

GM, Cemented Sands & Gravels w/clay, broken rock & boulders (ang.), dense, gray

Boulders (nest of) w/clay & minor sand & silt between boulders & broken rock.

SP-SM, Gravelly SAND w/silt, very dense, NP, moist, gray.

GM, Clayey GRAVEL w/sand, silt & broken rock, very dense, moist, gray.

SM, Clayey Silty SAND (med. to fine), dense, gray.

Rock Slab (Lost Drill Water from -152 to -153.5)

GM, Silty Sandy GRAVEL (coarse to fine, ang.) w/boulders & clay, dense, gray w/traces of brown.
Less boulders w/depth.

*

W.L.
(Hit Ground Water, Did Not Seal Off Until Casing Reached -320±)

→ 9/24/79 p.m. : hole @ 187', W.L. @ 176'

→ 9/25/79 a.m. : hole @ 187', W.L. @ 173'

GM, Broken rock w/silt, sand, gravel (ang.) & minor clay, dense, gray w/brown.

*

→ 9/25/79 p.m. : hole @ 193', W.L. @ 181'

→ 9/26/79 a.m. : hole @ 193', W.L. @ 181'

→ 9/26/79 p.m. : hole @ 205', W.L. @ 176.5'

→ 9/27/79 a.m. : hole @ 205', W.L. @ 176.5'

HOLE NUMBER 79-CD-38

ELEV- ION	DEPTH	DESCRIPTION OF MATERIALS
J98		→ 10/4/79 p.m. : hole : 220', W.L. 180 → 10/5/79 a.m. : hole : 220', W.L. : 181
T	220	*
		GM, Broken Rock w/silt, sand, gravel (ang.), decomposed rock & boulders (ang.), dense, gray w/brown.
	230	
S		NOTE: W.L. STATIC : -181' until 10/17/79
	240	
	250	*
	260	
		SM, Silty SAND (med. to fine) [w/minor gravel (fine) to -264'], medium to dense, grayish brown.
	270	
T		GM, Broken Rock w/silt, sand & gravel (ang.), dense, gray w/ brown.
	280	*
	290	
		∇ STATIC WATER LEVEL
	300	
		GM, Silty Sandy GRAVEL (coarse to fine, ang.) w/ boulders & clay, dense, gray w/brown.
	310	
988	320	→ 10/17/79 p.m. : hole : 321.5', W.L. : 295.5' → 10/18/79 a.m. : hole : 321.5', W.L. : 295.5'

HOLE NUMBER 79-CD-38

ELEV- ATION	DEPTH	DESCRIPTION OF MATERIALS
988		Less Boulders w/depth.
	330	Hit possible water bearing zone -330' to -340±.
		→ 10/18/79 p.m. : hole : 340', W.L. : 280'
	340	→ 10/19/79 a.m. : hole : 340', W.L. : 320' → 10/20/79 p.m. : hole : 351', W.L. : 320'
	350	BOULDER → 10/24/79 a.m. : hole : 351', W.L. : 288'
	360	SP-GP, Gravelly (coarse to fine) SAND (coarse to fine) w/ minor silt & num. boulders (rounded), medium to dense, brownish gray.
	370	GP-GM, Silty Sandy GRAVEL w/boulders, medium to dense, brownish gray. → 10/26/79 p.m. : hole : 365', W.L. : 302.5'
923		
	380	Bottom : -375' → 10/27/79 p.m. : hole : 380', W.L. : 295.5' NOTE: Casing : -361.5

X-4

HOLE NUMBER 79-CD-39

?OJECT Howard Hanson Dam
1979 Piezometer Installation

LOCATION ?ight Abutment

N 103,829.0[illegible]   E 1,7[illegible],[illegible]29.97

DATE STARTED	DATE COMPLETED
29 Aug. 1979	25 Sept. 1979

ELEVATION	DEPTH	DESCRIPTION OF MATERIALS
1176.4		Top of casing = 1178.9

CASING STICKUP = 2.5'

BACKFILL MATERIAL PLACED AUGUST 1981

10

GM, Silty Sandy GRAVEL (ang.) BROKEN ROCK-w/occ. boulders, med. to loose w/dense zones, brown.

20

30

GM, Silty Sandy GRAVEL (a[illegible] w/occ. boulders, broken [illegible] & minor organic debris, m[illegible]dium, brown.

40

50

BROKEN ROCK w/silt, sand & Gravel, med. to dense, brown to brownish gray.

60

BROKEN ROCK & boulders (ang.) w/silt, sand, gravel & minor clay, dense, brownish gray to tan.

70

*

BROKEN ROCK & boulders (ang.) w/silt, sand, clay & gravel, dense, grayish brown.

80

T

water bearing zone from 90.1 to 91.1

90

BROKEN ROCK & boulders (ang.) w/silt, sand, clay & decomposed rock, dense, blue-gray

100

HOLE NUMBER 79-CD-39

ELEVATION	DEPTH	DESCRIPTION OF MATERIALS
1176.4		

water level @ -101.1 until sealed by casing into clay zone below.

*

T

110

CL, CLAY, very stiff, moist, gray.

120

S

130

SP, SAND (med. to fine, clean) w/minor gravel (fine), medium to dense, gray.

140

GP-GM, Silty Sandy (coa[illegible] to fine) GRAVEL (1½"-), dense, brownish gray.

150

BOULDER

GM, Silty Sandy (coars[illegible] to fine) GRAVEL (coars[illegible] fine, ang.) w/num. boulders, dense, gray w/mi[illegible] brown & reddish gravel.

160

*

GM, Silty Sandy GRAVEL (ang.) to sub-round) w/Occ bldrs., dense, brown.

170

T

GP, Sandy GRAVEL (med. to coarse, sub-round) clean, loose to medium, wet, gray

HIT WATER @ - 165.1
STATIC LEVEL @ - 152.1

180

ROCK - SOLID w/possible fracture zones.

190

200

973.3

Bottom @ - 203^{1} in bedrock.

210

HOLE NUMBER 79-CD-40

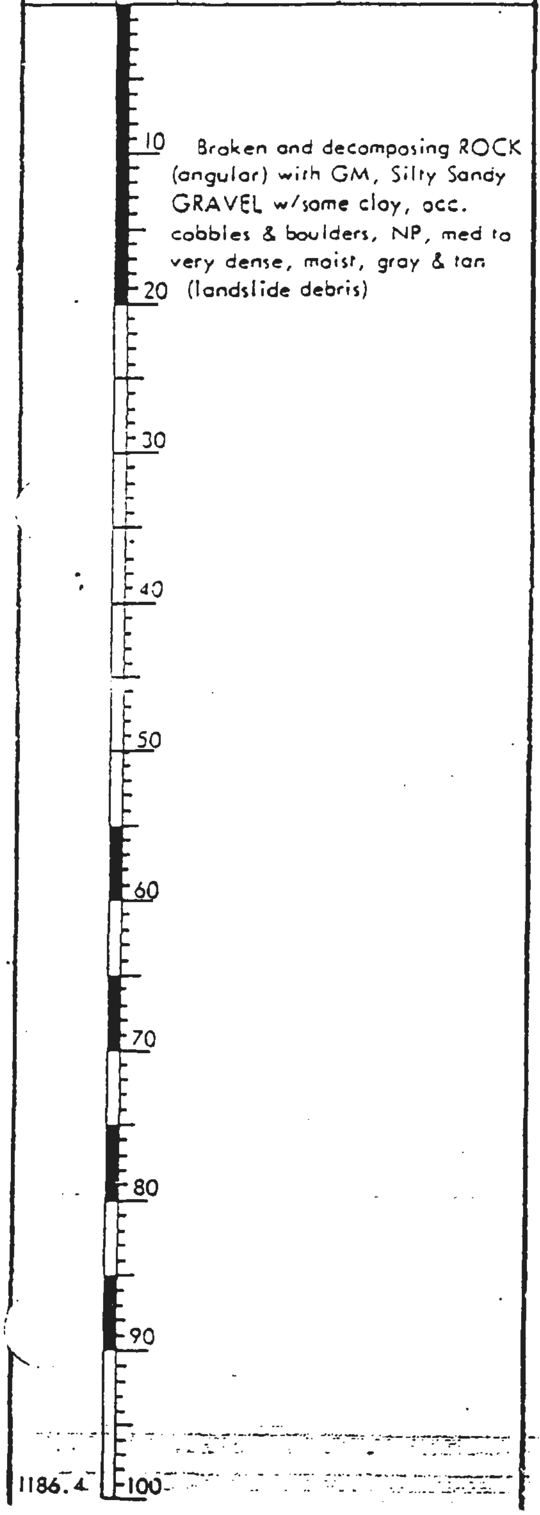
PROJECT Howard Hanson Dam
1979 Piezometer Installations

LOCATION Right Abutment

N 103,891.20 E 1,763,861.25

DATE STARTED	DATE COMPLETED
31 Aug 1979	27 Sep 1979

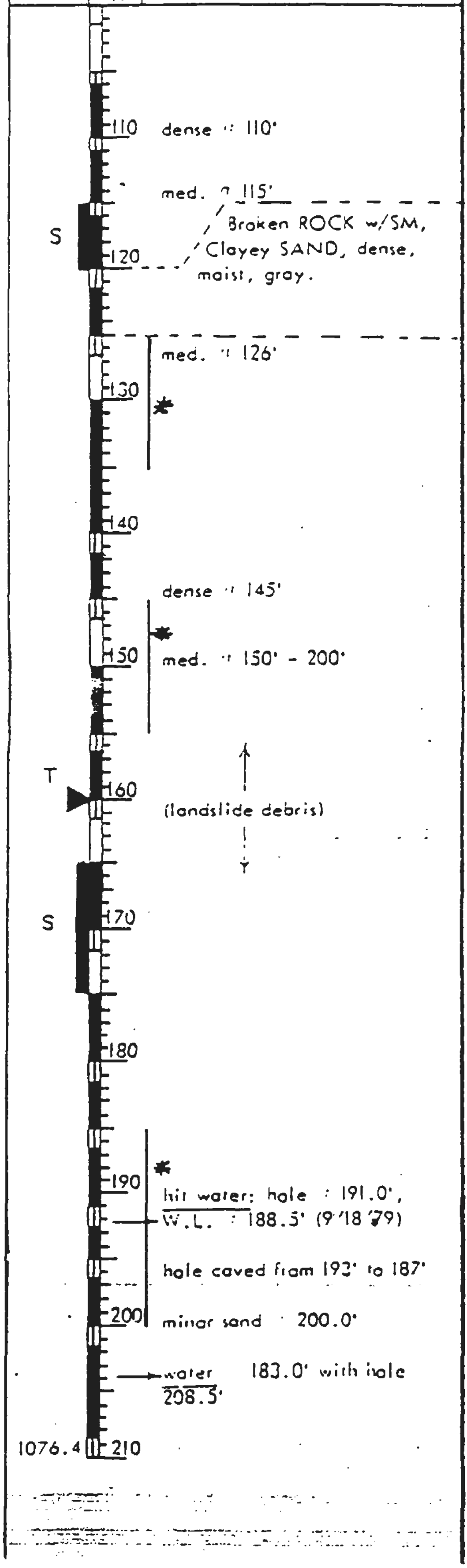
ELEVATION 1286.4 | DEPTH | DESCRIPTION OF MATERIALS
Top of Casing = 1289.4



Broken and decomposing ROCK (angular) with GM, Silty Sandy GRAVEL w/some clay, occ. cobbles & boulders, NP, med to very dense, moist, gray & tan (landslide debris)

HOLE NUMBER 79-CD-40

ELEVATION 1186.4 | DEPTH | DESCRIPTION OF MATERIALS



dense @ 110'

med. @ 115'

Broken ROCK w/SM, Clayey SAND, dense, moist, gray.

med. @ 126'

*

dense @ 145'

*

med. @ 150' - 200'

(landslide debris)

*

hit water: hole @ 191.0', W.L. @ 188.5' (9/18/79)

hole caved from 193' to 187'

minor sand @ 200.0'

water 183.0' with hole 208.5'

X-46

HOLE NUMBER 79-CD-40

ELEVATION
5.4

DEPTH

DESCRIPTION OF MATERIALS

9/19/79 a.m. : hole : 208.5', W.L. : 189.3'

9/21/79 a.m. : hole : 226.5', W.L. : 189.3'

*

very dense 225'

dense : 230'

9/24/79 a.m. : hole : 231.5', W.L. : 188.8'

CL, CLAY, medium, moist gray

GP, Sandy GRAVEL (rounded) w/minor silt, NP, med. to dense, moist to wet, gray

GM, Silty Sandy GRAVEL w/some clay, NP, med. to dense, wet, brown & gray. (rounded gravels)

9/24/79 1200 hrs : hole : 242.0', W.L. : 195.0'

9/25/79 a.m. : hole : 251.5', W.L. 192.5'

GP, Sandy GRAVEL w/occ. cobbles, NP, loose, saturated, gray.

*

9/26/79, a.m. : hole 271.5', W.L. 191.5'

9/27/79, a.m. : hole 285.0', W.L. 264.3'

10/1/79, a.m. : hole 300.0', W.L. 264.5'

986.4

Bottom of Hole : 300.0'

HOLE NUMBER 79-CD-41A

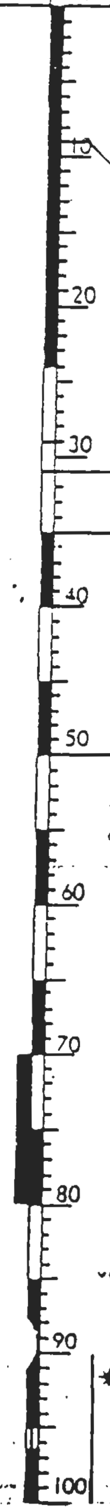
PROJECT Howard Hanson Dam
1979 Piezometer Installation

LOCATION Right Abutment

N 103,586.77 E 1,703,904.70

DATE STARTED	DATE COMPLETED
4 Sep 1979	31 Oct 1979

ELEVATION 1274.2 DEPTH DESCRIPTION OF MATERIALS
Top of Casing =1277.0



GM, Silty Sandy GRAVEL w/ cobbles & boulders (all ang.), medium, brown.

GM, Silty Sandy GRAVEL w/ clay & occ. boulders, medium to dense, tan.

LOST DRILL WATER FROM -9 to -11 & FROM -15 to -17.

BOULDER

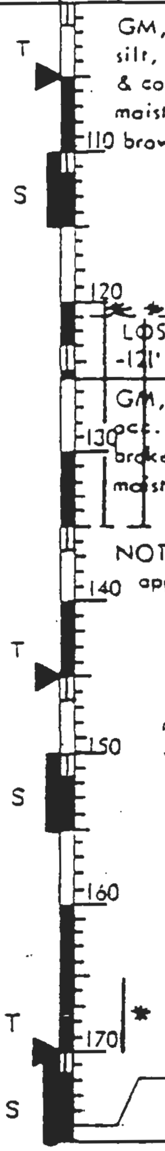
GM, Silty Sandy GRAVEL w/ clay & occ. boulders, dense, tan.

GM, Clayey Sandy GRAVEL w/silt, occ. boulders & cobbles dense, tan.

very dense w/ depth.

HOLE NUMBER 79-CD-41A

ELEVATION 1174.2 DEPTH DESCRIPTION OF MATERIALS



GM, Clayey Sandy GRAVEL w/ silt, broken rock, occ. boulders & cobbles, medium to very dense, moist, brown & gray w/reddish brown in clayey material.

LOST DRILL WATER FROM -121' to -135'.

GM, Silty Sandy GRAVEL w/clay occ. cobbles &/or boulders & broken rock, medium to dense, moist, gray & reddish brown.

NOTE: reddish brown material appears to be decomposed rock.

medium to very dense w/depth.

Bottom @ 176' Lost Bailer

X-48

HOLE NUMBER 79-CD-41

JECT Howard Hanson Dam
1979 Piezometer Installation

LOCATION Right Abutment

N 103,586.77 E 1,763,904.70

DATE STARTED	DATE COMPLETED
4 Sep 1979	31 Oct 1979

ELEVATION	DEPTH	DESCRIPTION OF MATERIALS
1274.2		Top of Casing =1277.0
		GM, Silty Sandy GRAVEL w/ cobbles & boulders (all ang.), medium, brown.
	10	
		GM, Silty Sandy GRAVEL w/ clay & occ. boulders, medium to dense, tan.
	20	LOST DRILL WATER FROM -9 to -11 & FROM -15 to -17.
	30	
		BOULDER
		GM, Silty Sandy GRAVEL w/ clay & occ. boulders, dense, tan.
	40	
	50	
		GM, Clayey Sandy GRAVEL w/silt, occ. boulders & cobbles, dense, tan.
	60	
	70	
	80	
		very dense w/depth.
	90	
	100	

HOLE NUMBER 79-CD-41

ELEVATION	DEPTH	DESCRIPTION OF MATERIALS
1174.2		
		GM, Clayey Sandy GRAVEL w/ silt, broken rock, occ. boulders & cobbles, medium to very dense, moist, brown & gray w/reddish brown in clayey material.
	110	
	120	
		LOST DRILL WATER FROM -121' to - 135'.
		GM, Silty Sandy GRAVEL w/clay occ. cobbles &/or boulders & broken rock, medium to dense, moist, gray & reddish brown.
	130	
		NOTE: reddish brown material appears to be decomposed rock.
	140	
	150	medium to very dense w/depth.
	160	
S	170	
		POSSIBLE SAND SEAM
		GM, Silty Sandy GRAVEL (ang.) &/or broken rock w/clay, num. boulders & cobbles, medium to dense, grayish brown.
	180	
	*	
	▽190	
		More cobbles & gravel & less clay w/depth.
T	200	
		ROCK SLAB
		Hit Ground Water @ -205'
		Static Water Level @ -190'.
1064.2	210	
		Bottom @ -210

HOLE NUMBER	CD-53	
PROJECT	HANSON DAM SEEPAGE STUDIES	
LOCATION N 104,180	E 1,763,385	
DATE STARTED	DATE COMPLETED 1955	

ELEVATION 1086.6	DEPTH	DESCRIPTION OF MATERIALS TOP OF CASING 1087.5
		SANDY SILT w/broken rock
1069.6		
		SANDY SILTY CLAY w/rock fragments
T		*
1052.6		
S		SANDY CLAY w/rock fragments
1050.6		
	40	SANDY GRAVEL w/clay and silt
1035.6		
		GRAVELLY SAND w/broken rock
	60	
1006.6	80	W. L.
		*
939.6		
		SILTY CLAY w/broken rock
975.6		
		SAND w/rock fragments
	120	
961.1		
T		SILTY SANDY GRAVEL
955.6		
		SAND
948.1		
		SAND, GRAVEL, SILT AND CLAY, interbedded
925.6	160	
		SAND, SILT AND CLAY, interbedded
	180	
394.6		
		BEDROCK
836.6	200	

HOLE NUMBER	CD-54	
PROJECT	HANSON DAM SEEPAGE STUDIES	
LOCATION N 104,029	E 1,763,414	
DATE STARTED	DATE COMPLETED 1955	

ELEVATION 1093.3	DEPTH	DESCRIPTION OF MATERIALS TOP OF CASING 1094.6
		BROKEN ROCK w/sandy silt
	20	*
1064.3		
		BOULDER
T 1048.8	40	
S 1046.8		CLAY
1045.3		BOULDER
1038.3		SANDY SILTY GRAVEL
1032.8	60	SAND
1026.8		SANDY SILTY GRAVEL
		SANDY SILTY GRAVEL w/broken rock
	80	
	100	*
992.3		GRAVEL w broken rock, some sand and silt
986.3		
981.8		SANDY GRAVEL
979.3		SAND
974.3		SILTY SANDY GRAVEL
	140	INTERBEDDED SANDS, GRAVELS, SILTY GRAVELS, AND GRAVELLY SANDS w occasional rock fragments
	160	
T	180	*
903.3		
700.3		WEATHERED ROCK
893.3	200	BEDROCK

NPD

NPS

SHEET 1 OF 3 SHEETS

1. PROJECT HOWARD HANSON DAM

2. LOCATION (Coordinates or Station) N102,795 E1,763,510 [TOPO]

3. DRILLING AGENCY JENSEN DRILLING CO.

4. HOLE NO. (As shown on drawing title and file number) 86-CD-101/101A

5. NAME OF DRILLER ART GWIN

6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.

7. THICKNESS OF OVERBURDEN 192'

8. DEPTH DRILLED INTO ROCK 6'

9. TOTAL DEPTH OF HOLE 198'

10. SIZE AND TYPE OF BIT 0-10'[8"] 10'-198'[6"]

11. DATUM FOR ELEVATION SHOWN (TBM or MSL)

12. MANUFACTURER'S DESIGNATION OF DRILL BUCYRUS ERIE 22W CABLE TOOL

13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN DISTURBED 2 UNDISTURBED 19

14. TOTAL NUMBER CORE BOXES 0

15. ELEVATION GROUND WATER

16. DATE HOLE STARTED 10/30/86 COMPLETED

17. ELEVATION TOP OF HOLE 1194 [TOPO]

18. TOTAL CORE RECOVERY FOR BORING %

19. SIGNATURE OF INSPECTOR R. ECKERLIN

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
1194			GM GRAVEL LOOSE			DRILLED WITH BUCYRUS ERIE CABLE TOOL. 6" BIT 4" ID SAMPLER WITH 2,000 LB. WT 1.5' LONG
			APPROX. CORE OF DAM			N=* BLOWS TO DRIVE SAMPLER 6"
	10		GM. SILTY SANDY GRAVEL WITH COBBLES [6"]. DENSE		A	SAMPLE A REFUSAL. 0% REC.
			SANDY AT 18'			
	20		GM. SILTY SANDY GRAVEL WITH COBBLES. DENSE BROWN WITH MOTTLED GRAY		B	N=48,36,50 70% REC. 10/30/86 10/31/86
	30				C	N=65,69,50 60% REC. 10/31/86 11/3/86
	40		GM. SILTY SANDY GRAVEL WITH COBBLES [6"] DENSE MOIST. BROWN		D	N=43,42,33 100% REC.
						11/3/86 11/4/86
	50				E	N=20,24,30 100% REC
	60		LARGE COBBLE AT 62.5'		F	N=49,28,28 100% REC.
						11/4/86 11/5/86
	70				G	N=37,40,36 75% REC.
	80				H	N=63,67,75 50% REC 11/5/86 11/6/86
	90				I	N=38,66,60 75% REC 11/6/86 11/18/86
	100					11/18/86

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71

PROJECT HHD

HOLE NO. 86-CD-101/101A

X-51

HOLE NO. 86 CD-101/101A

PROJECT	INSTALLATION	SHEET
HOWARD HANSON DAM	NPSEN-GT	SHEET 2 OF 3 SHEETS

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
1094'	100		GM. SILTY SANDY GRAVEL. COBBLES, MOIST, BROWN		J	N=31,42,38 100% REC.
						SWL 105.7 11/19/86
	110					SWL 104.9 11/20/86
			LOOSE GRAVELS [SOME CAVING]. MOIST TO WET		K	N=34.40.63 100% REC.
						SWL 104.9 11/20/86
						SWL 104.9 11/21/86
	120				L	
			AT 124' CASING BENT			SWL 120 11/21/86
			MOVE TO NEW LOCATION 5' TOWARD LEFT ABUTMENT FROM 101 11/25/86 START NEW HOLE 86-CD-101A			SWL 118.5 11/24/86 12/18/86
	130				M	N= 42.43.39 SWL 129.6 12/18/86
			GP-GM, SILTY SANDY GRAVEL. WITH COBBLES DENSE.MOIST.BROWN			SWL 129.3 12/19/86
	140				N	N= 42.43.47 100% REC.
						SWL 145.2 12/19/86
	150		COBBLE @ 152			SWL 146.2 1/6/87
					O	N=45.45.REFUSAL 100% REC. 2 JARS
	160				P	N= 24.55.39 60% REC. 1/6/87
						SWL 161 1/7/87
	170		GP-GM. LESS SILT THAN PREVIOUS SAMPLE		Q	N= 41,43,68 90% REC. 1/7/87
						SWL 163.6 1/8/87
	180		GM. SILTY SANDY GRAVEL WITH COBBLES. VERY DENSE.MOIST.BROWN		R	N= 32.60.44 75% REC. 1/8/87
						SWL 165.5 1/9/87
			FINE GRNED. WITH COARSE SAND TO GM		S	BAILER SAMPLE
	190		TOP ROCK		T	N= 40.56.REFUSAL 100% REC. 2 JARS SWL-BAIL DRY 1/9/87
1002'			SOFT-HARD HARD ANDESITE, BLACK			SWL 183.4 1/13/87
996'						
	200		TD 198' [ELV. 996']			TD 198' CASING TO 192.5' [6"ID]

101
101A

ENG FORM 1836-A PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71

PROJECT HHD

HOLE NO. 86-CD-101/101A

X-52

DRILLING LOG | NPD | NPS | SHEET ___ OF ___ SHEETS

1. PROJECT HOWARD HANSON DAM
2. LOCATION (Coordinates or Station) N103,150 E1,763,905 [TOPO]
3. DRILLING AGENCY JENSEN DRILLING CO.
4. HOLE NO. (As shown on drawing title and file number) 87-RD-102
5. NAME OF DRILLER TED MERYDITH
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN 208'
8. DEPTH DRILLED INTO ROCK 12'
9. TOTAL DEPTH OF HOLE 220'
10. SIZE AND TYPE OF BIT 6" ODEX
11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
12. MANUFACTURER'S DESIGNATION OF DRILL CP 650 AIR ROTARY DRILL
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN DISTURBED 22 UNDISTURBED 10
14. TOTAL NUMBER CORE BOXES
15. ELEVATION GROUND WATER
16. DATE HOLE STARTED JAN. 21, 1987 COMPLETED JAN. 29, 1987
17. ELEVATION TOP OF HOLE APPROX. 1225 [TOPO]
18. TOTAL CORE RECOVERY FOR BORING %
19. SIGNATURE OF INSPECTOR RICK ECKERLIN

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
1225		▨	CLAYEY-SILTY CRUSHED ROCK. WET, TAN-BROWN [FILL?]			DRILLED WITH AIR USING ODEX HAMMER CASING CONCURRENT WITH DRLG. USED OVERHEAD CASING DRIVE THRU HAMMER TO DRIVE SAMPLER
	10					
	20			75%	A	DRIVE SAMPLE A N= 8,10,12
1223		▒	GM, SILTY SANDY GRAVEL WITH COBBLES AND BOULDERS			
	30			75%	B	1/21/87 1/22/87 DRIVE SAMPLE B N= 8,10,10
1191		▓	ANDESITE BLOCK, HARD, LIGHT GREEN [34-42']			
	40				C	CHIP SAMPLE
			SILT			
		▓	ANDESITE BLOCK, HARD, LIGHT GREEN [43-65']			
	50				D	CHIP SAMPLE
	60				E	CHIP SAMPLE
					F	CHIP SAMPLE
			SILT AND COBBLES, LOOSE, BROWN		G	CHIP SAMPLE
	70			0%	H	DRIVE SAMPLE H N= 20/2, REFUSAL
		▓	ANDESITE BLOCK, HARD, GREEN 70-78'			
					I	CHIP SAMPLE
		▒	SAND AND COBBLES			
	80				J	CHIP SAMPLE
		▓	ANDESITE BLOCK, HARD GREEN 79-99'			
					K	CHIP SAMPLE
	90				L	CHIP SAMPLE
1125	100				N	CHIP SAMPLE JAN 22, 1730 HRS

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71

PROJECT HHD

HOLE NO. 87-RD-102

X-53

Hole No. 87-RD-102

PROJECT HOWARD HANSON DAM | INSTALLATION NPS | SHEET 2 OF 3 SHEETS

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
1125			99', SILTY SANDY ROCK FRAGMENTS [1'- 1, MED SOFT, MOIST, GREEN	100%	O	DRIVE SAMPLE O 1/23/87 N= 11,14,15
1117	110		ANDESITE BLOCK, HARD, GREEN 108-113'		P	CHIP SAMPLE
1112			SILTY SAND AND ROCK FRAGMENTS			
1108	120		ANDESITE BLOCK, 113-124		Q	CHIP SAMPLE
1101	130		ROCK FRAGMENTS IN SILTY SAND MATRIX, MOIST ,GREEN		R	CHIP SAMPLE
				100%	S	DRIVE SAMPLE S N= 4,6,6
					T	CHIP SAMPLE 1/23/87
	140			75%	U	DRIVE SAMPLE U 1/27/87 N= 10,8,9
	150				V	CHIP SAMPLE
					W	CHIP SAMPLE
					X	CHIP SAMPLE
1065	160		GC, CLAYEY SANDY GRAVEL, WITH COBBLES,, DENSE, MOIST , BROWN, OCCASIONAL BOULDER	100%	Y	DRIVE SAMPLE Y N= 10,12,15
1057	170		GC, CLAYEY GRAVEL, MOIST, CHARCOAL GRAY			
1053			CL, SANDY CLAY, SOFT, MOIST, CHARCOAL GRAY [VARVED] SM, SILTY SAND [FINE], WITH OCCASIONAL GRAVEL, SOFT, MOIST, BROWN			1/27/87
	180			100%	Z	SWL=171.6 1/28/87 DRIVE SAMPLE Z N= 2,4,10
1043	190		GP, SANDY GRAVEL WITH COBBLES AND BOULDERS		AA	CHIP SAMPLE
					AB	CHIP SAMPLE
	200			100%	AC	DRIVE SAMPLE AC N= 12,12 SWL=181.0 1/28/87
						SWL=182.3 1/29/87
1017			TOP OF BEDROCK @ 208			
	210		RESIDUUM 208-209 ANDESITE, MED. SOFT, GRAY	0%	AD	DRIVE SAMPLE AD N=15/3 REFUSAL
1005	220		TO 220'		AE	CHIP SAMPLE 1/29/87

ENG FORM 1836-A PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71

PROJECT HHD | HOLE NO. 87-RD-102

X-54

OF 3 SHEETS

1. PROJECT HOWARD HANSON DAM	10. SIZE AND TYPE OF BIT 8"-12' ; 6"-178'
2. LOCATION (Coordinates or Station) N 102,905 E1,763,905	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY JENSEN DRILLING CO.	12. MANUFACTURER'S DESIGNATION OF DRILL BUCYRUS ERIE 22W CABLE TOOL
4. HOLE NO. (As shown on drawing title and file number) 87-CD-103	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN DISTURBED 0 UNDISTURBED 15
5. NAME OF DRILLER ART GWIN	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE STARTED JAN. 14, 1987 COMPLETED FEB. 3, 1987
	17. ELEVATION TOP OF HOLE 1217'
7. THICKNESS OF OVERBURDEN 173'	18. TOTAL CORE RECOVERY FOR BORING %
8. DEPTH DRILLED INTO ROCK 5'	19. SIGNATURE OF INSPECTOR RICK ECKERLIN
9. TOTAL DEPTH OF HOLE 178'	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
1217			FILL FOR DRILLING PAD [CRUSHED GRAVEL]			PAD PREPARED. RIG-UP DRILLED 8' AND SET 8" CASING 2,000 LB. TOOL WT. FOR SAMPLING; 4" ID- LS' LONG 1/14/87
			GM. SILTY SANDY GRAVEL WITH COBBLES. LOOSE TO MEDIUM., MOIST BROWN			1/15/87
	10					N= * BLOWS TO DRIVE SAMPLER 6" 1/15/87
						1/16/87
	20			50%	A	N= 14.17.23
				100%	B	N= 20.21.33
	30					1/16/87
						1/20/87
	40			100%	C	N= 48.23.32
						1/20/87
						1/21/87
	50		GP-GM	100%	D	N= 20.15 88
	60			100%	E	N= 20.20.32
						1/21/87
						1/22/87
	70			100%	F	N= 30.30.18
	80			90%	G	N= 20.30.36
	90			75%	H	N= 39.+50 REFUSAL 1/22/87
						1/23/87
1117	100					

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71

PROJECT HHD

HOLE NO. 87-CD-103

X-55

1217' [1080]

Hole No. 87-CD-103

PROJECT HOWARD HANSON DAM	INSTALLATION NPS	SHEET 2 OF 3 SHEETS

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
	100		GP-GM, SILTY SANDY GRAVEL WITH COBBLES, MEDIUM, MOIST, BROWN		I	N= 34,50.53 100% RECOVERY 1/23/87
						1/27/87
	110					
					J	N= 35,46.71 100% RECOVERY 1/27/87
	120					SWL= 111 1/28/87
					K	N= 50.60. REFUSAL
	130					
						SWL= 135.5 1/28/87
						SWL= 129.9 1/29/87
	140				L	N= 37.53.57 90% RECOVERY
						SWL 1/29/87
	150		GP-GM, SILTY SANDY GRAVEL WITH COBBLES, LIGHT BRN. AND WET			SWL= 141.3 1/30/87
					M	N= 32.50.42 100% RECOVERY
						SWL= BAILED DRY 1/30/87
	160				N	SWL= 152 2/2/87 N= 33.31.33 60% RECOVERY
						SWL= BAILED DRY 2/2/87
						SWL= DRY 2/3/87
	170		BEDROCK		O	N= 50/1" REFUSAL 1 JAR SAMPLE
1044			ANDESITE, GREEN, HARD			
1039						TD= 178' 2/3/87
	180		BOTTOM OF HOLE AT 178' [ELV. 1039]			HOLE DRY DURING DRILLING 6" CASING TO 172.5'
	190					
	200					

X-5

DRILLING LOG	DIVISION NPD	INSTALLATION NPS	SHEET 1 OF 3 SHEETS

1. PROJECT HOWARD HANSON DAM
2. LOCATION (Coordinates or Station) N 102.750 E 1,763.470
3. DRILLING AGENCY JENSEN DRILLING CO.
4. HOLE NO. (As shown on drawing title and file number) 87-CD-104
5. NAME OF DRILLER GLEN WHITE
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN 121'
8. DEPTH DRILLED INTO ROCK 6'
9. TOTAL DEPTH OF HOLE 127'
10. SIZE AND TYPE OF BIT 6" CABLE TOOL
11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
12. MANUFACTURER'S DESIGNATION OF DRILL BUCYRUS ERIE 22W
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN DISTURBED 0 UNDISTURBED 8
14. TOTAL NUMBER CORE BOXES
15. ELEVATION GROUND WATER
16. DATE HOLE STARTED 2/4/87 COMPLETED 2/20/87
17. ELEVATION TOP OF HOLE 1185 [TOPO]
18. TOTAL CORE RECOVERY FOR BORING %
19. SIGNATURE OF INSPECTOR BILL GOSS

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
			FILL [CRUSHED GRAVEL] FOR DRILLING PAD			DRILLED WITH BUCYRUS ERIE 22W CABLE DRILL USING 2,000 LB. TOOL WEIGHT FOR DRIVE SAMPLING. SAMPLER= 1.5' LONG, 4" ID 2/4/87
	10		GP-GM: SANDY GRAVEL WITH SILT AND COBBLES			2/5/87 N= # OF BLOWS TO DRIVE SAMPLER 6".
	20				A	N= 44,34,50 66% RECOVERY 2/5/87
	30					2/9/87
			GM: SILTY SANDY GRAVEL DENSE, BROWN, MOIST		B	N= 8,6,16 100% RECOVERY 2/9/87
	40					2/10/87
	50				C	N= 40,29,29 80% RECOVERY 2/10/87
						2/11/87
	60				D	N= 26,25,33 66% RECOVERY 2/11/87
	70					2/12/87
			GM: SILTY SANDY GRAVEL WITH COBBLES, DENSE, BROWN, MOIST		E	N= 24,56,62 80% RECOVERY 2/12/87
	80					2/17/87
	90				F	N= 31,35,50 90% RECOVERY 2/17/87
	100					2/18/87

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE.

PROJECT HOWARD HANSON DAM HOLE NO. 87-CD-104

X-57

1185' [TOPO]

Hole No. 87-CD-104

PROJECT	INSTALLATION	SHEET 2
HOWARD HANSON DAM	NPS	OF 3 SHEETS

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
1085	100	▨	GM: SILTY SANDY GRAVEL DENSE, BROWN, MOIST			2/18/87
					G	N= 20.34.50 95% RECOVERY
	110					2/18/87 2/19/87 SWL 105
					H	N= 16.24.30 70% RECOVERY
	120				I	BAILER SAMPLE SWL 119.5 2/19/87
1064		▩	ANDESITE- GREEN, HARD			SWL 119.5 2/20/87 SAMPLE I- BAILER SAMPLE I JAR ANDESITE AND GRAVEL
1058 TD	130					TD 127' 125' OF 6" CASING CASING SEATED IN BEDROCK AT 123.5' HOLE DRY DURING DRILLING

81

X-58

ENG FORM 1836-A PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71

PROJECT	HOLE NO.
HOWARD HANSON DAM	87-CD-104

NPS

SHEET 1 OF 3 SHEETS

1. PROJECT HOWARD HANSON DAM	10. SIZE AND TYPE OF BIT 6" ODEX
2. LOCATION (Coordinates or Station) N 103,485 E 1,764,630	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY JENSEN DRILLING CO	12. MANUFACTURER'S DESIGNATION OF DRILL CP 650 AIR ROTARY DRILL
4. HOLE NO. (As shown on drawing title and file number) 87-80-105	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN DISTURBED UNDISTURBED
5. NAME OF DRILLER TED MEREDITH	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE STARTED 3/17/87 COMPLETED 3/25/87
7. THICKNESS OF OVERBURDEN 132'	17. ELEVATION TOP OF HOLE 1205 GROUND
8. DEPTH DRILLED INTO ROCK 54'	18. TOTAL CORE RECOVERY FOR BORING %
9. TOTAL DEPTH OF HOLE 186'	19. SIGNATURE OF INSPECTOR BILL GOSS

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
			GM: SILTY SANDY GRAVEL			DRILLED WITH AIR USING ODEX HAMMER CASING CONCURRENT WITH DRILLING
	10		BOULDER 8-10'			USED OVERHEAD CASING DRIVE THRU HAMMER TO DRIVE SAMPLER
			GM			FIRST LENGTH OF 6" CASING 21' WITH SHOE AT 21.2'
	20		BOULDER 20-25'		A	BIT 6" AHEAD OF CASING SHOE 3/18/87 CHIP SAMPLE A 1 JAR
	30		GM		B	DRIVE SAMPLE B N= 5,5,8 90% REC
			BOULDER 33'-36'			
	40		GM: SILTY SANDY GRAVEL, WET, ANGULAR, RUST BRN.-WEATHERED GRAYISH GRN.-FRESH SMALL AMOUNT OF WATER ENCOUNTERED		C	CHIP SAMPLE C 1 JAR
	50				D	DRIVE SAMPLE D N= 4,9,3 70% REC 3/18/87 3/18/87
			BOULDER 52'-55'			
	60				E	DRIVE SAMPLE E N= 2,5,7 60% REC
			GM			
	70				F	DRIVE SAMPLE F N= 2,2,4 65% REC
	80				G	DRIVE SAMPLE N= 6,15, REFUSAL 50% REC
	90				H	DRIVE SAMPLE H N= 15/4", REFUSAL 30% REC 3/19/87
	100				I	3/23/87 DRIVE SAMPLE N= 20,20/4", REFUSAL 50%REC

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71

PROJECT HOWARD HANSON DAM

HOLE NO. 87-80-105

X-59

1 1205_[1080]

Hole No. 87-RD-105

PROJECT HOWARD_HANSON_DAM	INSTALLATION NPS	SHEET 2 OF 3 SHEETS

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
			GM: SANDY SILTY GRAVEL			
	110				J	DRIVE SAMPLE J N= 3,8,10 100% REC
	120				K	CHIP SAMPLE
	130		GM		L	DRIVE SAMPLE L N= 4,3,5 70% REC 3/23/87 3/24/87
1073			ANDESITE: BLACK, FRESH . SHARP ANGULAR DRILL CUTTINGS			
	140				M	CHIP SAMPLE
	150				N	CHIP SAMPLE
	160				O	CHIP SAMPLE
						3/24/87 3/25/87
			DRILLING ON GROUND WATER			
	170				P	CHIP SAMPLE
						WATER IN HOLE-- DRILLING ON GRNDWATER
	160				O·	CHIP SAMPLE
					[illegible]	CHIP SAMPLE
			TD=186'			
	190					
1005	200					

ENG FORM 1836-A PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71

PROJECT HOWARD_HANSON_DAM

HOLE NO. 87-RD-105

X-60

DATE AND TIME PLOTTED: 28-SEP-1993 10:07

Hole No. 92-RD-110

DRILLING LOG	DIVISION CENPS-EN-GT	INSTALLATION HOWARD HANSON DAM	SHEET 1 OF 2 SHEETS

1. PROJECT PIEZOMETER INSTALLATION
2. LOCATION (COORDINATES OR STATION)
3. DRILLING AGENCY ANDREW WELL DRILLING
4. HOLE NO. (AS SHOWN ON DRAWING TITLE AND FILE NUMBER)
5. NAME OF DRILLER ROBERT DEWILD
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ________ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN
8. DEPTH DRILLED INTO ROCK 16'
9. TOTAL DEPTH OF HOLE 199'
10. SIZE AND TYPE OF BIT 8" ODEX
11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)
12. MANUFACTURER'S DESIGNATION OF DRILL
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN : DISTURBED : UNDISTURBED
14. TOTAL NUMBER CORE BOXES
15. ELEVATION GROUND WATER
16. DATE HOLE : STARTED : COMPLETED
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING
19. NAME AND SIGNATURE OF INSPECTOR

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (DESCRIPTION) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (DRILLING TIME, WATER LOSS, DEPTH OF WEATHERING, ETC., IF SIGNIFICANT) g
			ROCK SPALLS (3") W/GRAVEL & SANDY CLAY, BROWN			
			RIP RAP (3") AND LOOSE BOULDERS			
	5					
	10					
	15		SILTY SAND, FINE, DRY, BROWN			5 NOV 92
	20					
	25					
			SILTY SAND, MED.- FINE, DRY, GREY.			
	30					
			SILTY SAND W/ OCC GRAVELS, MED. DRY-MOIST, BROWN			
	35					
			SILTY SAND W/ OCC GRAVELS MED., DRY, GREY			
	40		SILTY SAND, MED.-COARSE, DRY, BROWNISH GREY			
	45					
			SILTY SAND, FINE, DRY, BROWN			
	50					
	55					
	60					
			SAND (COARSE, MED) W/ SOME SILT, DRY-MOIST, GREY. (GRANULES ARE UNIFORM W/ FRACTURED FACES, PROBABLY BOULDERS)			
	65					
	70					
			SILTY SAND, FINE, DRY BROWN			
	75		ANDESITE BOULDERS W/ INTERSTITIAL SAND, SILT, AND CLAY WITH MINOR GRAVEL, DRY, GREEN ROCK FRAGMENTS W/ BROWN CLAY AND SILT. (CONT.)			6 NOV 92
	80					
	85					
	90					
	95					
	100					

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71
SEP 90 MODIFIED FOR CADD BY CENPS

PROJECT PIEZOMETER INSTALLATION

HOLE NO. 92-RD-110

X-41

DRILLING LOG (Cont Sheet)

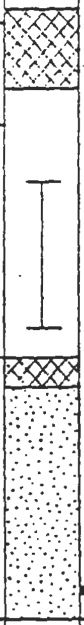
ELEVATION TOP OF HOLE

Hole No. 92-RD-110

PROJECT

INSTALLATION HOWARD HANSON DAM

SHEET 2 OF 2 SHEETS



ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (DESCRIPTION)		BOX OR SAMPLE NO.	REMARKS (DRILLING TIME, WATER LOSS, DEPTH OF WEATHERING, ETC., IF SIGNIFICANT)
a	b	c	d	e	f	g
	100		(CONT.) ANDESITE BOULDERS W/ INTERSTITIAL SAND, SILT, AND CLAY WITH MINOR GRAVEL, DRY, GREEN ROCK FRAGMENTS W/ BROWN CLAY AND SILT			
	105					
	110					
	115					7 NOV 92
	120					
	125					
	130		FRACTURED ANDESITE W/ INTERSTITIAL SILT & CLAY. GROUNDWATER AT 127'			
	135					
	140		BOULDER?			8 NOV 92
	145					
	150					
	155		CLAY/SOME SANDS			
	160		ANDESITE BRECCIA - BLUE/GREEN FLAKES			
	165		COARSE, ANGULAR ROCK FRAGMENTS, BLUE/GREEN CHIPS W/ BROWN FLAKES			9 NOV 92
	170					
	175					
	180		ANDESITE - SOFT			
	185					
	190					
	195					10 NOV 92
	200					

ENG FORM 1836-A PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71
SEP 90 MODIFIED FOR CADD BY CENPS

PROJECT

HOLE NO. 92-RD-110

V-62

U.S. ARMY CORPS OF ENGINEERS, SEATTLE DISTRICT

WELL COMPLETION REPORT

Project PIEZOMETER INSTALLATION, HANSON DAM
Completion date 12-18-92
Contractor ANDREW WELL DRILLING SERVICE
Rig IR AIR ROTARY - T4W
Operator ROBERT DEWILD
Inspector BEN LAZO
Depth 199' Datum GROUND SURFACE

HOLE DATA
Size: 8 in. to 199 ft.
in. to ft.

CASING
Type STEEL (SEE COMMENTS)
Mfr.
Ht. above gnd. surf.
Drive shoe
Size: 8 ¼ in. to 199 ft.

SCREEN
Type SCH 80 MONOFLEX -0.020 IN. SLOT
Mfr. CAMPBELL
Composition PVC Dia. 2"

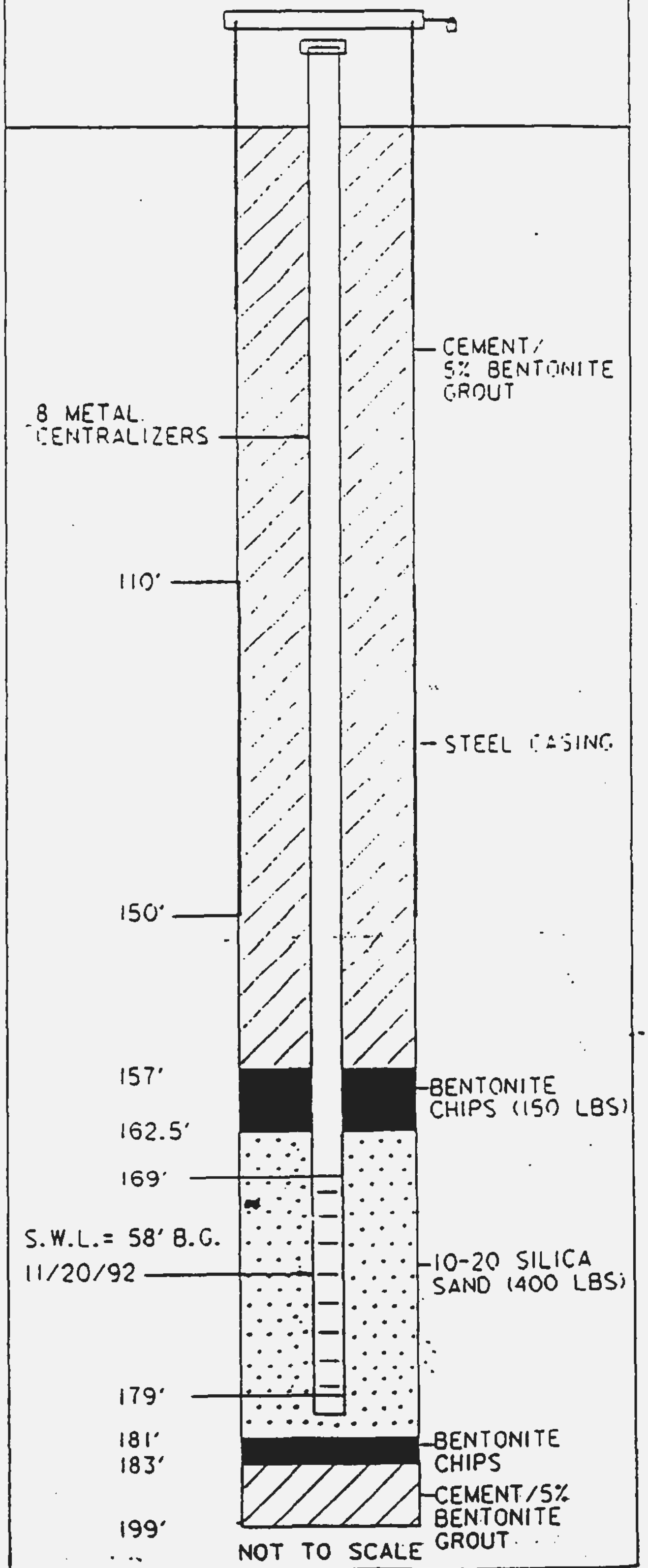
Fittings:	Length	Dia.
Riser		
Tailpipe		

FILTER
Source BAGS (100 LBS) COLORADO SILICA SAND, INC.
Composition CLEAN SILICA SAND
Gradation 10-20
Inst. method POUR DOWN HOLE
Volume used 4 FT^3
Depth 162.5 to 181 ft.
to ft.

GROUT
Composition CEMENT/BENTONITE (5% BENTONITE)
Volume used
Inst. method TREMMIE
Depth 0.0 to 157 ft.
183 to 199 ft.

REMARKS: 40 FEET OF CASING (WITH DRIVE SHOE) LEFT IN HOLE FROM 110 FEET TO 150 FEET. ALL OTHER CASING REMOVED FROM HOLE.

WELL DETAIL (AS BUILT)
92-RD-110
NOT TO SCALE



DESIGN FILE:

Hole No. 92-RD-111

DRILLING LOG	DIVISION CENPS-EN-GT
INSTALLATION HOWARD HANSON DAM	SHEET 1 OF 2 SHEETS
1. PROJECT PIEZOMETER INSTALLATION	10. SIZE AND TYPE OF BIT 8" ODEX
2. LOCATION (COORDINATES OR STATION)	11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)
3. DRILLING AGENCY ANDREW WELL DRILLING	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (AS SHOWN ON DRAWING TITLE AND FILE NUMBER)	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN : DISTURBED : UNDISTURBED
5. NAME OF DRILLER ROBERT DEWILD	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.	15. ELEVATION GROUND WATER
7. THICKNESS OF OVERBURDEN	16. DATE HOLE : STARTED : COMPLETED
8. DEPTH DRILLED INTO ROCK	17. ELEVATION TOP OF HOLE
9. TOTAL DEPTH OF HOLE 150'	18. TOTAL CORE RECOVERY FOR BORING %
	19. NAME AND SIGNATURE OF INSPECTOR

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (DESCRIPTION) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (DRILLING TIME, WATER LOSS, DEPTH OF WEATHERING, ETC., IF SIGNIFICANT) g
			ROCK SPALLS (3") W/GRAVEL			
	5		RIP RAP (3") AND LOOSE BOULDERS			
	10					
	15		SILTY SAND, FINE, BROWN			
	20					
			SILTY SAND, FINE W/GRAVELS, TAN			
	25		BOULDERS 1-2' 0			
	30					
	35					
			CLAYEY SAND W/GRAVEL (1/2") AND COBBLES (3") TAN			
	40					
	45					
	50					
			SILTY SAND W/GRAVELS (1/2"), BROWN			
	55					
	60		FRACTURED ROCK AND GRAVELS, GREEN, W/SILT			
	65					
	70					
	75					
	80					
	85					
	90					
	95					
	100					

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PROJECT PIEZOMETER INSTALLATION

HOLE NO. 92-RD-111

X-6

DRILLING LOG (Cont Sheet)

ELEVATION TOP OF HOLE

Hole No. 92-RD-111

PROJECT PIEZOMETER INSTALLATION

INSTALLATION HOWARD HANSON DAM

SHEET 2 OF 2 SHEETS

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (DESCRIPTION)		BOX OR SAMPLE NO.	REMARKS (DRILLING TIME, WATER LOSS, DEPTH OF WEATHERING, ETC., IF SIGNIFICANT)
	100		ANDESITE BOULDERS W/INTERSTITIAL SAND, SILT, AND CLAY. OCCASIONAL GRAVELS. DRY. GREEN ROCK FRAGMENTS WITH BROWN-TAN SILT AND CLAY			
	105					
	110					
	115					
	120					
	125					
	130		FRACTURED ANDESITE W/INTERSTITIAL SILT AND CLAY LAYERS. WATER GENERATED AT 127 FEET			
	135					
	140		FRACTURED ANDESITE ROCK FRAGMENTS APPEAR UNIFORM IN SIZE			
	145					
	150					

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PROJECT

HOLE NO. 92-RD-111

X-105

U.S. ARMY CORPS OF ENGINEERS, SEATTLE DISTRICT

WELL COMPLETION REPORT

Project PIEZOMETER INSTALLATION, HANSON DAM
Completion date 12/18/93
Contractor ANDREW WELL DRILLING SERVICE
Rig IR AIR ROTARY - T4W
Operator ROBERT DEWILD
Inspector BEN LAZO, CHARLES IFFT
Depth 150' Datum GROUND SURFACE

HOLE DATA
Size: 8 in. to 150' ft.
in. to ft.

CASING
Type STEEL (REMOVED)
Mfr.
Ht. above gnd. surf.
Drive shoe
Size: 8 1/4 in. to 150' ft.

SCREEN
Type SCH 80 MONOFLEX -0.020 IN. SLOT
Mfr. CAMPBELL
Composition PVC Dia. 2"

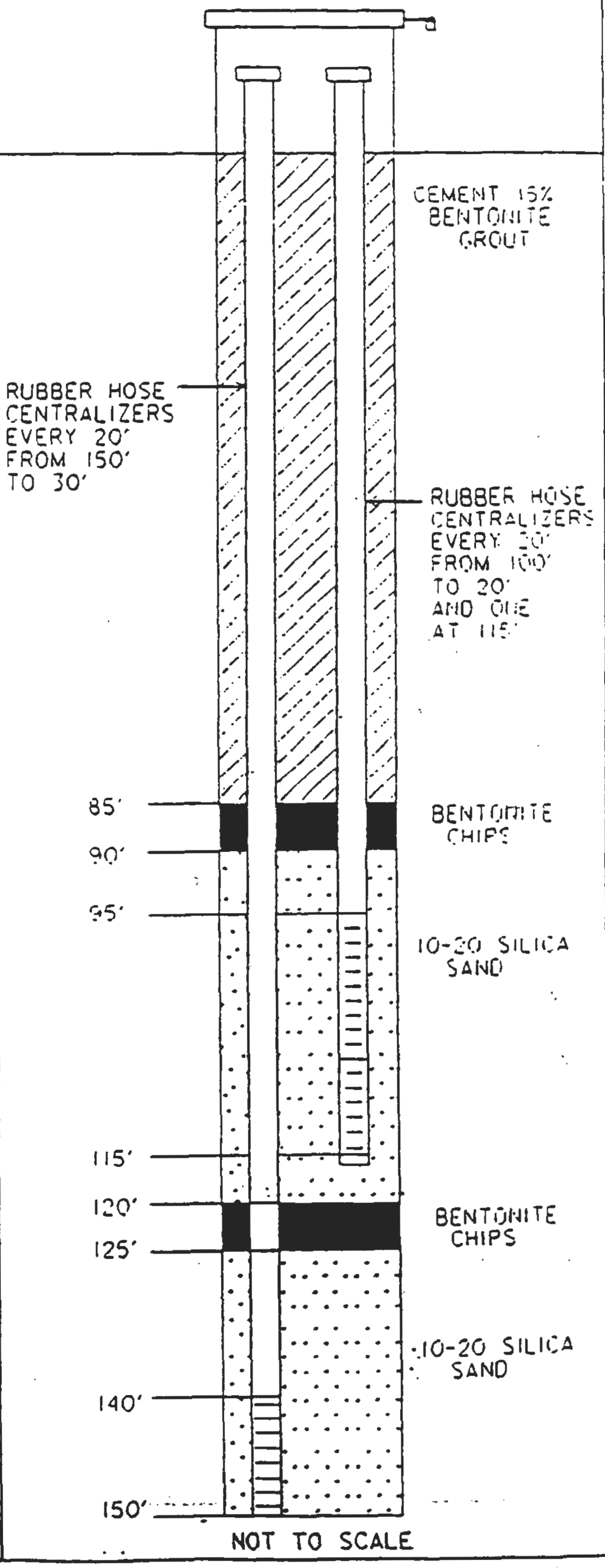
Fittings:	Length	Dia.
Riser		
Tailpipe		

FILTER
Source BAGS (100 LBS) COLORADO SILICA SAND, INC.
Composition CLEAN SILICA SAND
Gradation 10-20
Inst. method POUR DOWN HOLE
Volume used
Depth 90 to 120 ft.
125' to 150' ft.

GROUT
Composition CEMENT/BENTONITE (5% BENTONITE)
Volume used
Inst. method TREMMIE
Depth 0.0 to 85 ft.
to ft.

REMARKS:

WELL DETAIL (AS BUILT)
92-RD-111
NOT TO SCALE



DATE AND TIME PLOTTED: 28-SEP-[illegible]

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X-66

HOLE NO. 92 RD-112

DRILLING LOG	DIVISION CENPS-EN-GT	INSTALLATION HOWARD HANSON DAM	SHEET 1 OF 2 SHEETS

1. PROJECT PIEZOMETER INSTALLATION
2. LOCATION (COORDINATES OR STATION)
3. DRILLING AGENCY ANDREW WELL DRILLING
4. HOLE NO. (AS SHOWN ON DRAWING TITLE AND FILE NUMBER) 92-RD-112
5. NAME OF DRILLER ROBERT DEWILD
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN 138
8. DEPTH DRILLED INTO ROCK 22
9. TOTAL DEPTH OF HOLE 160
10. SIZE AND TYPE OF BIT 8" ODEX
11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)
12. MANUFACTURER'S DESIGNATION OF DRILL IR AIR ROTARY - T4W
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN : DISTURBED : UNDISTURBED
14. TOTAL NUMBER CORE BOXES
15. ELEVATION GROUND WATER
16. DATE HOLE : STARTED 7 OCT 92 : COMPLETED
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING %
19. NAME AND SIGNATURE OF INSPECTOR

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (DESCRIPTION) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (DRILLING TIME, WATER LOSS, DEPTH OF WEATHERING, ETC., IF SIGNIFICANT) g
			GRAVEL WEARING COURSE (3/4" MINUS)			
	5		SILTY SAND, DRY, TAN			
	10					
	15					7 OCT 92
	20					
	25					
	30		SANDY CLAY W/GRAVEL, MOIST, BROWN			
	35		SANDY SILT, DRY, TAN			
	40					
	45		SILTY SAND, DRY, TAN-LT GREY			
	50		SILT W/SAND, DRY LT GREY (ASH-LIKE)			
	55					
	60					
	65		GRAVELLY SAND W/SILT, TAN-LT GREY, DRY			
	70					
	75		SILTY SAND W/GRAVEL TAN-LT GREY, DRY			
	80		GRAVEL W/SILT, LT GREY, DRY, (POSSIBLE BOULDER)			
	85					
	90		SILTY SAND W/GRAVEL, DRY, TAN-LT GREY (CONT.)			
	95					8 OCT 92
	100					

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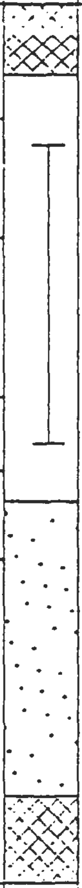
PROJECT PIEZOMETER INSTALLATION

HOLE NO. 92-RD-112

X-6

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE		Hole No. 92-RD-112	
PROJECT PIEZOMETER INSTALLATION		INSTALLATION HANSON DAM		SHEET 2 OF 2 SHEETS



ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (DESCRIPTION) d	e	BOX OR SAMPLE NO. f	REMARKS (DRILLING TIME, WATER LOSS, DEPTH OF WEATHERING, ETC., IF SIGNIFICANT) g
	100 105		(CONT.) SILTY SAND W/GRAVEL, DRY, TAN-LT-GREY			
	110 115		LOSS OF CUTTINGS IN THIS ZONE, LARGE VOID OR FRACTURE, CASING DROVE EASILY.			9 OCT 92
	120 125		FRACTURED ANDESITE WATER GENERATED BETWEEN ZONES (1 GALLON/MINUTE)			
	130		SANDY GRAVEL W/SILT MOIST, TAN-LT GREY			18 OCT 92
	135		CLAY, MOIST, GREY			19 OCT 92
	140 145 150 155		BEDROCK (ANDESITE CUTTINGS BECAME UNIFORM IN SIZE AND COLOR)			20 OCT 92
	160					

X-4

U.S. ARMY CORPS OF ENGINEERS, SEATTLE DISTRICT

WELL COMPLETION REPORT

Project PIEZOMETER INSTALLATION, HANSON DAM
Completion date 10/23/92
Contractor ANDREW WELL DRILLING SERVICE
Rig IR AIR ROTARY - T4W
Operator ROBERT DEWILD
Inspector
Depth 160' Datum GROUND SURFACE

HOLE DATA

Size: 8 in. to 160' ft.
in. to ft.

CASING

Type STEEL (REMOVED)
Mfr.
Ht. above gnd. surf.
Drive shoe
Size: 8 1/4 in. to 160' ft.

SCREEN

Type SCH 80 MONOFLEX -0.020 IN. SLOT
Mfr. CAMPBELL
Composition PVC Dia. 2"

Fittings:	Length	Dia.
Riser		
Tailpipe		

FILTER

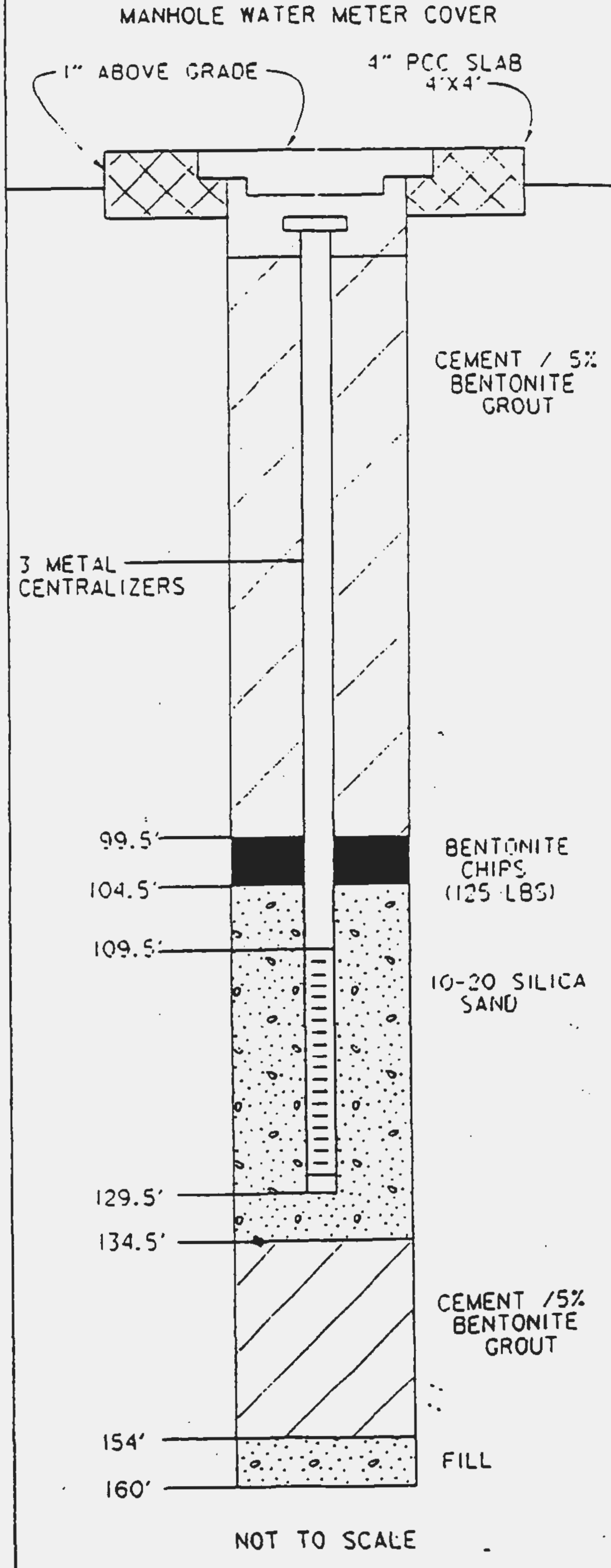
Source BAGS (100 LBS) COLORADO SILICA SAND, INC.
Composition CLEAN SILICA SAND
Gradation 10-20
Inst. method POUR DOWN HOLE
Volume used 9 FT^3
Depth 104.5 to 134.5 ft.

GROUT

Composition CEMENT/BENTONITE (5% BENTONITE)
Volume used
Inst. method TREMMIE
Depth 0.0 to 99.5 ft.
134.5 to 154 ft.

REMARKS:

WELL DETAIL (AS BUILT)
92-RD-112
NOT TO SCALE



DATE AND TIME PLOTTED: 28-SEP-1992

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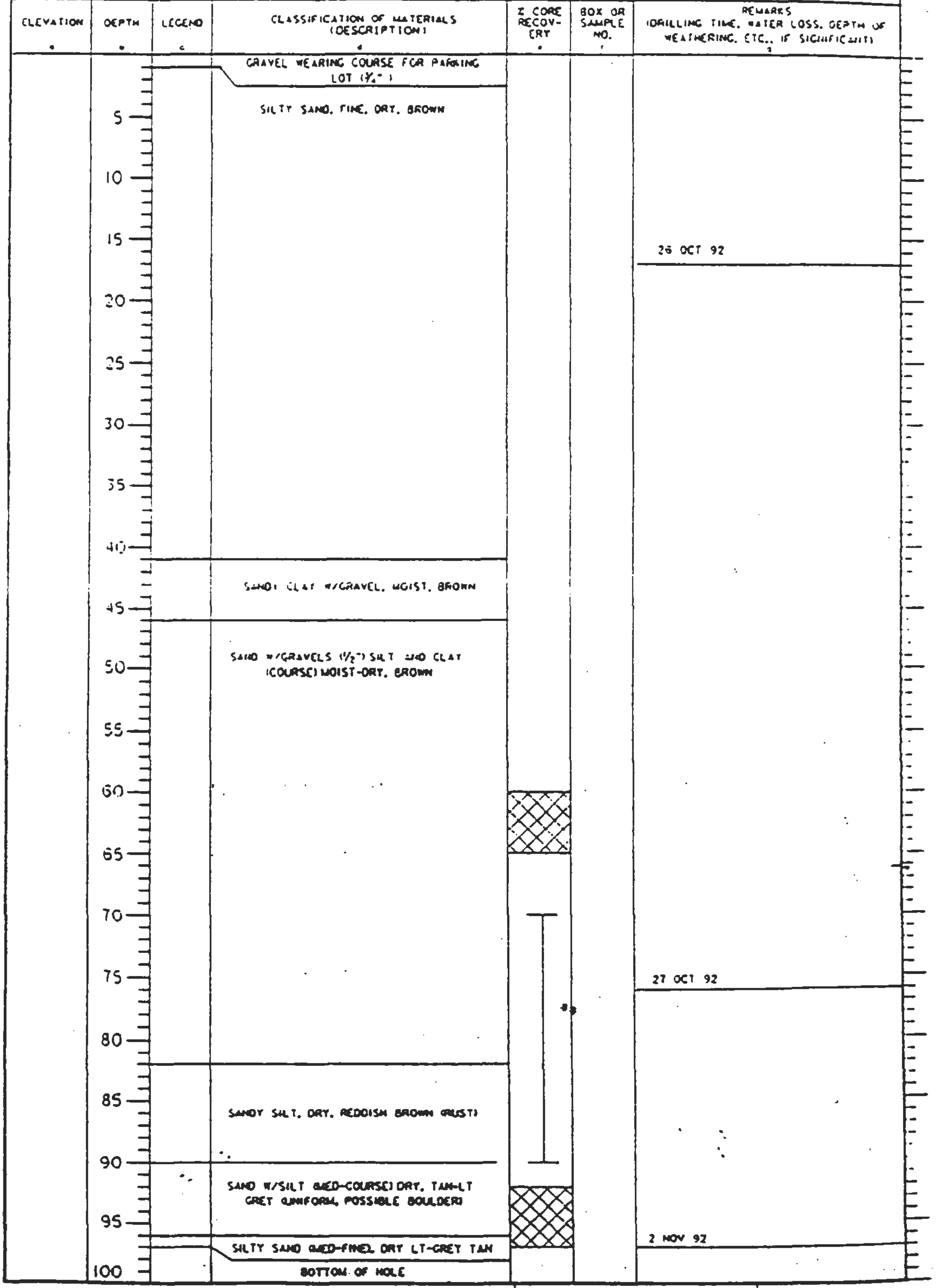
DATE AND TIME PLOTTED: 06-OCT-1993 12:46

Hole No.92-RD-113

DRILLING LOG
DIVISION: CENPS-EN-GT
INSTALLATION: 92-RD-113
SHEET 1 OF 1 SHEETS

1. PROJECT: PIEZOMETER INSTALLATION
2. LOCATION (COORDINATES OR STATION): HOWARD HANSON DAM
3. DRILLING AGENCY: ANDREW WELL DRILLING
4. HOLE NO. (AS SHOWN ON DRAWING TITLE AND FILE NUMBER): 92-RD-113
5. NAME OF DRILLER: ROBERT DEWILD
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED ________ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: 97
8. DEPTH DRILLED INTO ROCK: 0
9. TOTAL DEPTH OF HOLE: 97
10. SIZE AND TYPE OF BIT: 8" ODEX
11. DATUM FOR ELEVATION SHOWN (TBM OR MSL):
12. MANUFACTURER'S DESIGNATION OF DRILL: IR AIR ROTARY - T4W
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED: UNDISTURBED:
14. TOTAL NUMBER CORE BOXES:
15. ELEVATION GROUND WATER:
16. DATE HOLE: STARTED 26 OCT 92 COMPLETED 4 NOV 92
17. ELEVATION TOP OF HOLE:
18. TOTAL CORE RECOVERY FOR BORING: %
19. NAME AND SIGNATURE OF INSPECTOR:



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PROJECT: PIEZOMETER INSTALLATION
HOLE NO.: 92-RD-112

U.S. ARMY CORPS OF ENGINEERS, SEATTLE DISTRICT

WELL COMPLETION REPORT

Project PIEZOMETER INSTALLATION, HANSON DAM
Completion date 11/04/92
Contractor ANDREW WELL DRILLING SERVICE
Rig IR AIR ROTARY - T4W
Operator ROBERT DEWILD
Inspector BEN LAZO, STEVE MYERHOLTZ
Depth 97' Datum GROUND SURFACE

HOLE DATA
Size: 8 in. to 97' ft.
in. to ft.

CASING
Type STEEL (ALL BUT 10' REMOVED)
Mfr.
Ht. above gnd. surf.
Drive shoe YES - LEFT IN HOLE
Size: 8 ½ in. to 97' ft.

SCREEN
Type SCH 80 MONOFLEX -0.020 IN. SLOT
Mfr. CAMPBELL
Composition PVC Dia. 2"

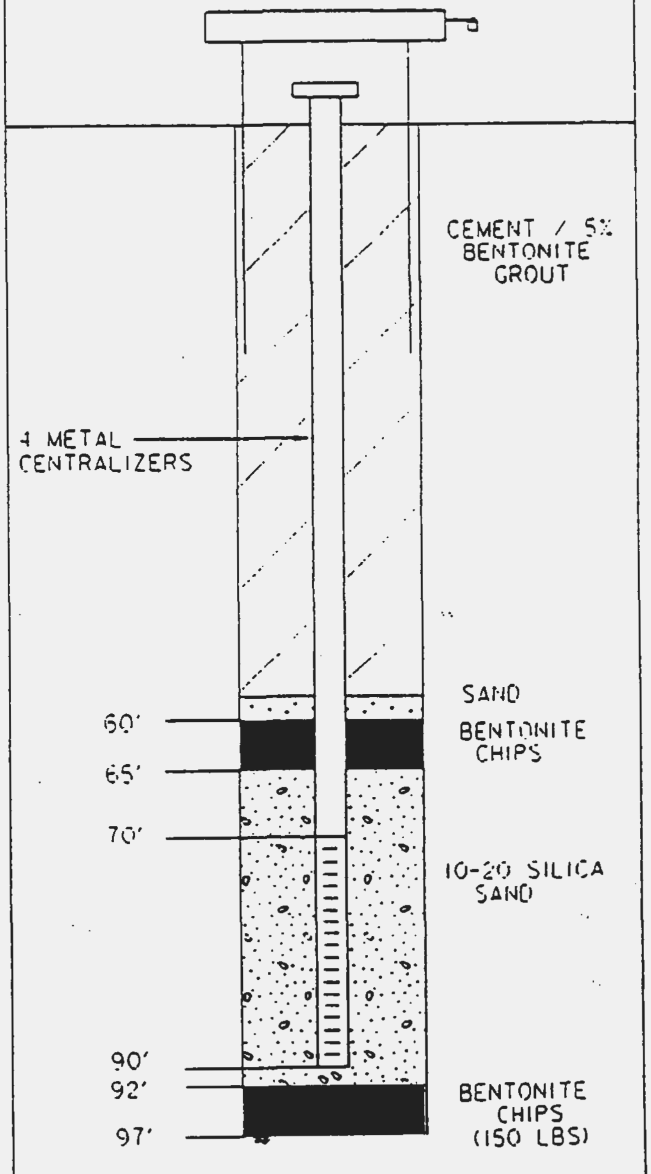
Fittings:	Length	Dia.
Riser		
Tailpipe		

FILTER
Source BAGS (100 LBS) COLORADO SILICA SAND, INC.
Composition CLEAN SILICA SAND
Gradation 10-20
Inst. method POUR DOWN HOLE
Volume used
Depth 65 to 92 ft.

GROUT
Composition CEMENT/BENTONITE (5% BENTONITE)
Volume used
Inst. method TREMMIE
Depth to ft.
to ft.

REMARKS: GROUT LOSS @ 30' STOPPED BY ADDING SAND AND BENTONITE CHIIPS TO GROUT

WELL DETAIL (AS BUILT)
92-RD-113
NOT TO SCALE



NOT TO SCALE

DATE AND TIME PLOTTED: 28-SEP-19

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HOLE NO. 93-RD-114

DRILLING LOG	DIVISION CENPS-EN-GT-GE	INSTALLATION HOWARD HANSON DAM	SHEET 1 OF 3 SHEETS

1. PROJECT PIEZOMETER INSTALLATION
2. LOCATION (COORDINATES OR STATION)
3. DRILLING AGENCY ANDREW WELL DRILLING
4. HOLE NO. (AS SHOWN ON DRAWING TITLE AND FILE NUMBER) 93-RD-114
5. NAME OF DRILLER ROBERT DEWILD
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN 336.5
8. DEPTH DRILLED INTO ROCK 0
9. TOTAL DEPTH OF HOLE 336.5
10. SIZE AND TYPE OF BIT 8" ODEX
11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)
12. MANUFACTURER'S DESIGNATION OF DRILL I R AIR ROTARY-T4W
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN : DISTURBED 8 : UNDISTURBED
14. TOTAL NUMBER CORE BOXES -
15. ELEVATION GROUND WATER -
16. DATE HOLE : STARTED 6-7-93 : COMPLETED 7-3-93
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING - %
19. NAME AND SIGNATURE OF INSPECTOR RICHARD E. SMITH

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (DESCRIPTION)	SAMPLE INTER-VAL	BOX OR SAMPLE NO.	REMARKS (DRILLING TIME, WATER LOSS, DEPTH OF WEATHERING, ETC. IF SIGNIFICANT)
			BROWN CLAY/SILT AND CLAYEY GRAVEL CONSISTING OF WEATHERED ANGULAR ANDESITE PEBBLES AND ROCK CUTTINGS; LOOSE, MOIST			DRILLED WITH 8" ODEX BIT CONCURRENT WITH 8¼" ID STEEL CASING BY DOWN-THE-HOLE HAMMER DRILLING FLUID RETURN SUMMARY 0-19 FT: AIR ONLY 19-31 FT: NO RETURN 31-37 FT: 25-50% RETURN 37-42 FT: NO RETURN 42-115 FT: 100% RETURN 115-120 FT: NO RETURN 120-150 FT: 100% RETURN 150-159.5 FT: NO RETURN 159.5-170 FT: 100% RETURN 170-172 FT: NO RETURN 172-193 FT: 100% RETURN 193-195 FT: NO RETURN 195-260 FT: 100% RETURN 260-277 FT: <20% RETURN 277-336.5 FT: 100% RETURN
			GREY/BROWN SILT/CLAY AND SILTY, CLAYEY GRAVEL AS ABOVE; LOOSE AND DRY			
	10		ANDESITE BOULDER			
	20 30 40		LARGE COBBLES OF FRACTURED ANDESITE, LOOSE			
	50 60 70 80 90		CUTTINGS OF ANDESITE COBBLES, GRAVELS AND BOULDERS WITH GREY/BROWN TO BROWN SILT/CLAY, LOOSE TO DENSE		①	S.W.L. - DRY 6/7/93 (@77 FT) S.W.L. - DRY 6/8/93 (@77 FT)
	100		CUTTINGS OF ANDESITE COBBLES AND BOULDERS WITH SOME GREY CLAY/SILT, DENSE		②	

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PROJECT PIEZOMETER INSTALLATION

HOLE NO. 93-RD-114

Y-7

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DATE AND TIME PLOTTED: 16-AUG-1993 12:38

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE		Hole No. 93-RD-114
PROJECT PIEZOMETER INSTALLATION	INSTALLATION HOWARD HANSON DAM		SHEET 2 OF 3 SHEETS

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (DESCRIPTION)	SAMPLE INTER-VAL	BOX OR SAMPLE NO.	REMARKS (DRILLING TIME, WATER LOSS, DEPTH OF WEATHERING, ETC, IF SIGNIFICANT)
	100					
	110					
			CUTTINGS OF ANDESITE W/ NO SILT OR CLAY, LOOSE			
	120		BOULDER OR ROCK SLAB			
	130		CUTTINGS OF LARGER ANDESITE COBBLES WITH VARYING AMOUNTS OF CLAY AND SILT (GREY/BROWN); OCCASIONAL LOOSE OPEN ZONES WHERE FLUID LOSS OCCURED; ALSO, SUB-ANGULAR, WEATHERED ANDESITE PEBBLES UP TO 1" BELOW 157', DENSE.			
	140					
	150					
						S.W.L. = DRY 6/8/93 (@ 157') S.W.L. = DRY 6/9/93 (@ 157')
	160					
WATER LEVEL UPPER STAGE (7-6-93) ▼ 171.3' B.G.	170					
			CUTTINGS OF LARGE ANDESITE COBBLES/BOULDERS AND SUB-ANGULAR WEATHERED ANDESITE PEBBLES AS ABOVE WITH MORE CLAY/SILT AND THIN LENSES OF SANDY, BROWN CLAY/SILT, DENSE			
	180		ANDESITE BOULDER			
			CONTINUED			
	190					
	200					FORMATION WATER @ 200'-205.5'
	210					FORMATION WATER @ 210.5'-214.5'
						S.W.L. = 179.0' 6/16/93 (@216.5')
	220					

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PROJECT PIEZOMETER INSTALLATION
HOLE NO. 93-RD-114

DATE AND TIME PLOTTED= 16-AUG-1993 13:13

DRILLING LOG (Cont Sheet)

ELEVATION TOP OF HOLE

Hole No. 93-RD-114

PROJECT: PIEZOMETER INSTALLATION

INSTALLATION: HOWARD HANSON DAM

SHEET 3 OF 3 SHEETS

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (DESCRIPTION)	SAMPLE INTER-VAL	BOX OR SAMPLE NO.	REMARKS (DRILLING TIME, WATER LOSS, DEPTH OF WEATHERING, ETC. IF SIGNIFICANT)
	220		FRACTURED SLAB OR BOULDERS OF GREEN, PINK AND WHITE ANDESITE, VERY HARD AND DENSE, WITH COBBLES OF THE SAME ROCK AT THE TOP AND BOTTOM OF THIS INTERVAL.		③	ZONE 218-256 MAY OR MAY NOT BE WATER BEARING
	230					
	240					6/18/93
	250					
			CLAYEY, VERY SILTY (BROWN) SANDY, ANGULAR GRAVEL (ANDESITE) AND ROUNDED GRAVEL (MIXED VOLCANICS) WITH NUMEROUS BROWN AND GREY SILT/CLAY BALLS		④ ⑤	S.W.L. = DRY 6/18/93 (@258')
	260		SLIGHTLY (?) SILTY (BROWN) WELL-ROUNDED GRAVELS OF MIXED IGNEOUS ORIGIN UP TO 2" ACROSS, AND CUTTINGS OF POSSIBLY LARGER GRAVELS, AND THIN LAYERS OF MEDIUM SAND; MEDIUM TO LOOSE, POSSIBLY DRY TO 277'. ALSO SOME THIN SILT/CLAY LENSES, AND CLAYEY GRAVEL NEAR BOTTOM		⑥	
	270					S.W.L. = DRY 6/18/93 (@ 278')
WATER LEVEL LOWER STAGE (7/6/93) ▼ 280.85' B.G.	280				⑦ ⑧	
	290					S.W.L. = 280.0' 6/18/93 (@ 295') S.W.L. = 279.3' 6/19/93 (@ 295')
	300					
	310					S.W.L. = 280.1' 6/19/93 (@ 317')
	320					
	330		BOTTOM = 336.5' B.G.			S.W.L. = DRY 6/19/93 (ABOVE 300') S.W.L. = 282.3' 6/20/93 (@ 336.5')
	340					

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PROJECT: PIEZOMETER INSTALLATION

HOLE NO. 93-RD-114

V-7

U.S. ARMY CORPS OF ENGINEERS, SEATTLE DISTRICT

WELL COMPLETION REPORT

Project PIEZOMETER INSTALLATION, HANSON DAM
Completion date 7-3-93
Contractor ANDREW WELL DRILLING SERVICE
Rig IR AIR ROTARY - T4W
Operator ROBERT DEWILD
Inspector RICHARD E. SMITH
Depth 336.5' Datum GROUND SURFACE

HOLE DATA
Size: 8 in. to 336.5 ft.
in. to ft.

CASING
Type STEEL (REMOVED ALL BUT 10')
Mfr.
Ht. above gnd. surf.
Drive shoe YES (REMOVED DURING COMPLETION)
Size: 8 ¼ in. to 336.2 ft.

SCREEN
Type SCH 80 MONOFLEX
Mfr. CAMPBELL
Composition PVC Dia. 2"

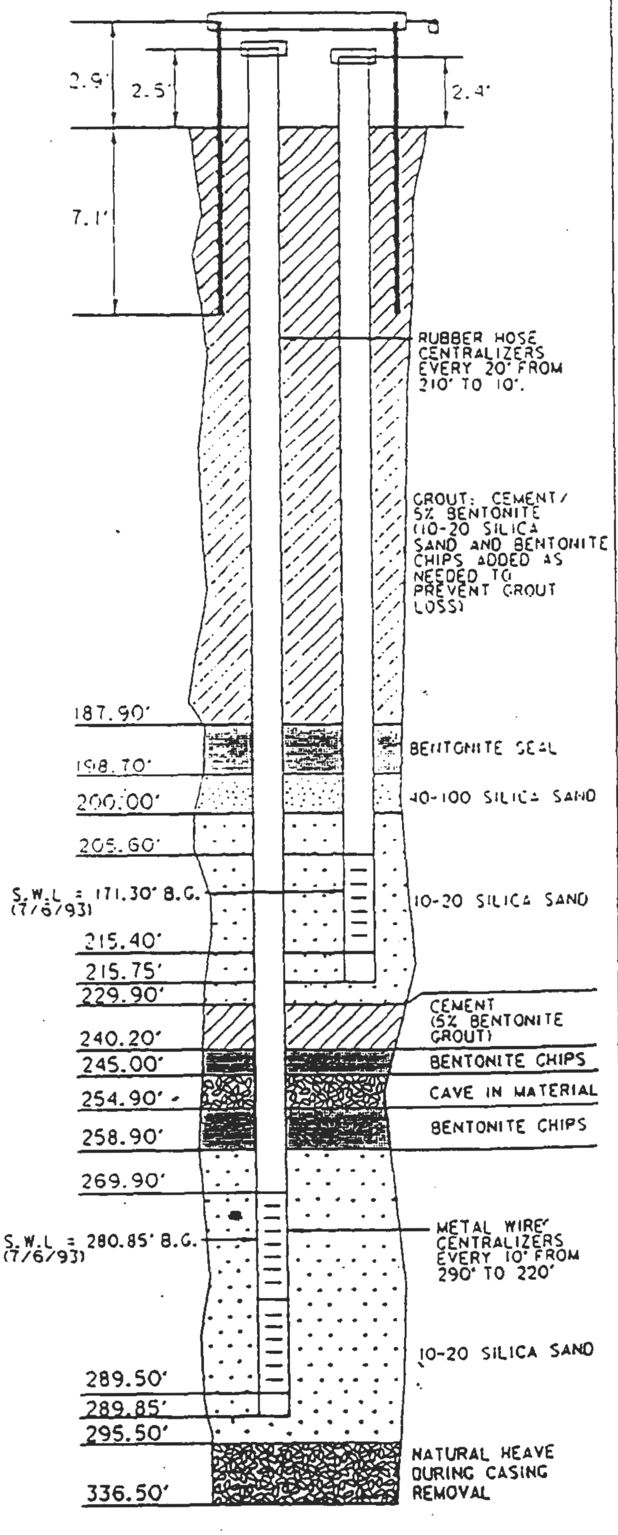
Fittings:	Length	Dia.
Riser		2"
Tailpipe	0.35"	2"

FILTER
Source BAGS (100 LBS) COLORADO SILICA SAND, INC.
Composition CLEAN SILICA SAND
Gradation 10-20
Inst. method POUR DOWN HOLE
Volume used 20.5 FT³ / 18 FT³
Depth 200 to 229.9 ft.
259 to 295.5 ft.

GROUT
Composition CEMENT/BENTONITE (5% BENTONITE)
Volume used 600 GALLONS/50 GALLONS
Inst. method TREMMIE
Depth 0.0 to 187.9 ft.
229.9 to 240.2 ft.

REMARKS: PULLING CASING WAS VERY DIFFICULT AND COULD NOT ADD GROUT AT BOTTOM UNTIL CASING PULLED, BUT FORMATION COLLAPSED INTO THE HOLE AS FAST AS CASING WAS REMOVED. 270' OF WIRE LOST IN HOLE AT 257' AND WIRE BUNCHED AROUND STABILIZER AT 220'. 281.5' OF WIRE AND 1.5' OF REBAR LOST IN HOLE AT 271' B.G.

WELL DETAIL (AS BUILT)
93-RD-114
NOT TO SCALE



DATE AND TIME PLOTTED: 30-JUL-199

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DATE AND TIME PLOTTED: 16-AUG-1993 13:41

Hole No.93-RD-115

DRILLING LOG

DIVISION CENPS-EN-GT-GE

INSTALLATION HOWARD HANSON DAM

SHEET 1 OF 4 SHEETS

1. PROJECT PIEZOMETER INSTALLATION
2. LOCATION (COORDINATES OR STATION)
3. DRILLING AGENCY ANDREW WELL DRILLING
4. HOLE NO. (AS SHOWN ON DRAWING TITLE AND FILE NUMBER) 93-RD-115
5. NAME OF DRILLER ROBERT DEWILD
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ________ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN 251'
8. DEPTH DRILLED INTO ROCK 143'
9. TOTAL DEPTH OF HOLE 394'
10. SIZE AND TYPE OF BIT 8" ODEX/6 5/8" TRICONE
11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)
12. MANUFACTURER'S DESIGNATION OF DRILL IR AIR ROTARY - T4W
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN DISTURBED 12 UNDISTURBED
14. TOTAL NUMBER CORE BOXES
15. ELEVATION GROUND WATER
16. DATE HOLE STARTED 5-18-93 COMPLETED 6-5-93
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING %
19. NAME AND SIGNATURE OF INSPECTOR RICHARD E. SMITH

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (DESCRIPTION) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (DRILLING TIME, WATER LOSS, DEPTH OF WEATHERING, ETC., IF SIGNIFICANT) g
			SILTY, SLIGHTLY CLAYEY, SLIGHTLY SANDY GRAVEL, MOIST TO DRY, BECOMING DRY WITH DEPTH, LOOSE, BROWN TO TAN, OCCASIONAL ZONES OF LARGE COBBLES.			DRILLED WITH ODEX BUTTON BIT DRIVEN BY DOWN-THE-HOLE HAMMER CONCURRENT WITH 6 1/4" ID STEEL CASING DRILLING FLUID RETURN SUMMARY 0-48 FT: AIR CIRCULATION 48-70 FT: 50-60% RETURN 70-217FT: 100% RETURN 217-230FT: AIR CIRCULATION 230-242FT: 100% RETURN 242-248FT: AIR CIRCULATION 248-394FT: 100% RETURN
	10					
	20					
	30					
			GRAVEL WITH A LITTLE SAND, SOME SILT AND CLAY, DRY CHANGING TO MOIST WITH DEPTH, GREY-BROWN; MAY BE WET AT 48'; GRAVEL ARE ANGULAR PEBBLES AND CUTTINGS OF ANDESITE AND OTHER VOLCANIC ROCKS.			
	40					
	50					
			ANGULAR GRAVEL (PEBBLES AND CUTTINGS OF ANDESITE AND OTHER VOLCANICS) WITH COARSE SAND AND SOME SILT, TAN.			
	60					
			POSSIBLE WEATHERED HORIZON			
			SILTY, SANDY GRAVEL AND CLAY, ORANGE-BROWN, GRAVELS ARE WEATHERED ANGULAR ANDESITE AND BASALT CUTTINGS AND PEBBLES. LARGE COBBLES ARE PRESENT NEAR THE BASE OF THIS UNIT.			
	70					
					①	
	80					
			SLIGHTLY SILTY/CLAYEY GRAVEL (AS ABOVE, EXCEPT NUMEROUS SUB-ROUNDED PEBBLES LOCATED NEAR THE TOP OF THIS UNIT), ORANGE-BROWN TO BROWN, CLAY AND SILT CONTENT DECREASES DOWNWARD.			
	90					
					②	

DATE AND TIME PLOTTED: 16-AUG-1993 13:46

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE	Hole No. 93-RD-115
PROJECT PIEZOMETER INSTALLATION	INSTALLATION HOWARD HANSON DAM	SHEET 2 OF 4 SHEETS

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (DESCRIPTION)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (DRILLING TIME, WATER LOSS, DEPTH OF WEATHERING, ETC. IF SIGNIFICANT
			SILTY, SLIGHTLY SANDY GRAVEL AND CLAY, BROWN. GRAVEL CONSISTS OF ANGULAR PEBBLES AND CUTTINGS OF ANDESITE AND OTHER VOLCANIC ROCKS. LAYERS OF DARK BROWN TO BROWN CLAY/SILT ALSO PRESENT.			
	110					
	120				③	
	130					
						S.W.L = DRY 5/26/93 @ 137'
	140					
	150					
						S.W.L = DRY 5/26/93 @ 157'
			BOULDER			
	160		SLIGHTLY SILTY AND SLIGHTLY CLAYEY TO CLAYEY ANGULAR GRAVEL AND CUTTINGS OF GRAY-GREEN PYRITE-RICH ANDESITE, BROWN. LARGER GRAVELS POSSIBLE 173'-228.5'			
WATER LEVEL UPPER STAGE ▼	170					
175.45' B.G.						S.W.L = DRY 5/26/93 @ 177'
						S.W.L = DRY 5/27/93 @ 177'
			SLIGHTLY SILTY CUTTINGS OF LARGER GRAVELS AS DESCRIBED ABOVE, LIGHT BROWN			
	180					
			CLAY AND CUTTINGS OF GRAY-GREEN PYRITE-RICH ANDESITE COBBLES, GRAY TO GRAY-BROWN		④	
	190					
			SILT WITH MINOR CLAY AND CUTTINGS OF WEATHERED GRAY-GREEN ANDESITE (PYRITE-RICH) COBBLES, GRAY TO GRAY-BROWN.			
	200					
			LESS SILT WITH DEPTH AND COLOR CHANGES TO BROWN AT 202' AND OCCASIONAL GRAY CLAY BALLS AFTER 202'.			FORMATION WATER AFTER 202'
						DENSE DRILLING PAST 206'
	210					
			COLOR OF SILT CHANGES BACK TO GRAY-BROWN AT 212' AND TO GRAY AT 215'			
						S.W.L = 175' 5/28/93 @ 217'

ENG FORM 1836-A PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71
SEP 90 MODIFIED FOR CADD BY CENPS

PROJECT	HOLE NO.
PIEZOMETER INSTALLATION	93-RD-115

DESIGN FILE: [illegible]
DATE AND TIME PLOTTED: 16-AUG-1993 13:52

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE	Hole No. 93-RD-115
PROJECT PIEZOMETER INSTALLATION	INSTALLATION HOWARD HANSON DAM	SHEET 3 OF 4 SHEETS

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (DESCRIPTION)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (DRILLING TIME, WATER LOSS, DEPTH OF WEATHERING, ETC. IF SIGNIFICANT)
a	b	c	d	e	f	g
WATER LEVEL LOWER STAGE ▼ 225.00' B.G.						
	230		DENSE, DRY TO MOIST, SILT/CLAY, DARK GRAY.		⑤	NO FORMATION WATER 228.5'-238'
			CLAY/SILT AS ABOVE AND ROUNDED FINE TO COARSE PEBBLE GRAVEL OF MIXED IGNEOUS ORIGIN, DRY AND DENSE.			
	240		CLEAN RIVER GRAVELS (ROUNDED MIXED IGNEOUS AND CUTTINGS OF SAME), MINOR GRAY-BROWN SILT, LOOSE.		⑥	WATER 238'-245'
			LARGE COBBLES OF DARK GREEN ANDESITE AND RED-ORANGE CLAY/SILT BALLS, DENSE.		⑦	NO FORMATION WATER 245'-294'
	250		CUTTINGS OF DARK GREEN ANDESITE BOULDER/ROCK SLAB.			
	260				⑧	S.W.L = 220.4' 5-29-93 (@ 251') DRILLED WITH 6 ¾"-TRICONE BIT AND NO CASING ADVANCED PAST 257.6'
	270					
	280					
	290		MEDIUM TO VERY FINE GRAINED GREY, GREEN, WHITE, AND RED SAND AND GRAY SILT. OCCASIONAL CUTTINGS OF DECOMPOSED GRAY ROCK WITH DECAYED RED AND GREEN MINERALS. VARYING AMOUNTS OF CLAY AND SILT WITH OCCASIONAL THIN CLAY/SILT LAYERS. ROCK IS DENSE AND CEMENTED. POSSIBLE GLACIAL TILL.		⑨	
	300					
	310				⑩	
	320					
	330					S.W.L. = 225.5' 5/29/93 (@ 334')
	340					

ENG FORM 1836-A PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71

PROJECT	HOLE NO.
PIEZOMETER INSTALLATION	93-RD-115

X-7

DESIGN FILE: /CENPS/PROJECTS/CW/HH/GEOTECH/HHG
DATE AND TIME PLOTTED: 16-AUG-1993 13:53

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE		Hole No. 93-RD-115
PROJECT PIEZOMETER INSTALLATION	INSTALLATION HOWARD HANSON DAM		SHEET 4 OF 4 SHEETS

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (DESCRIPTION)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (DRILLING TIME, WATER LOSS, DEPTH OF WEATHERING, ETC. IF SIGNIFICANT)
			CONTINUED			
	350					
					⑪	
	360					
	370		FINE TO MEDIUM SAND, GRAY AND WHITE, WITH VARYING AMOUNTS OF GRAY SILT AND CLAY AND FLAT ANGULAR CUTTINGS OF GRAY, BRITTLE SILTSTONE (?) WITH OCCASIONAL SAND SIZED GRAINS EMBEDDED WITHIN			
	380					
	390					
			POSSIBLE ANDESITE BOULDER AT 292'-293.5'		⑫	
			BOTTOM OF HOLE = 394'			S.W.L = 225.7' 5-30-93 (@ 394')
	400					

ENG FORM 1836-A PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71
SEP 90 MODIFIED FOR CADD BY CENPS

PROJECT	HOLE NO.
PIEZOMETER INSTALLATION	93-RD-115

X-8

U.S. ARMY CORPS OF ENGINEERS, SEATTLE DISTRICT

WELL COMPLETION REPORT

Project PIEZOMETER INSTALLATION, HANSON DAM
Completion date 6-5-93
Contractor ANDREW WELL DRILLING SERVICE
Rig INGERSOL RAND T-4W
Operator ROBERT DEWILD
Inspector RICHARD E. SMITH
Depth 394' Datum BELOW GROUND

HOLE DATA
Size: 8 in. to 257.6 ft.
7 in. to 394.0 ft.

CASING
Type STEEL
Mfr.
Ht. above gnd. surf. 2.95'
Drive shoe YES (REMOVED DURING COMPLETION)
Size: 8 1/4 in. to 257.6 ft.

SCREEN - 10' THREADED
Type SCH 80 MONOFLEX
Mfr. CAMPBELL
Composition PVC Dia. 2" ID

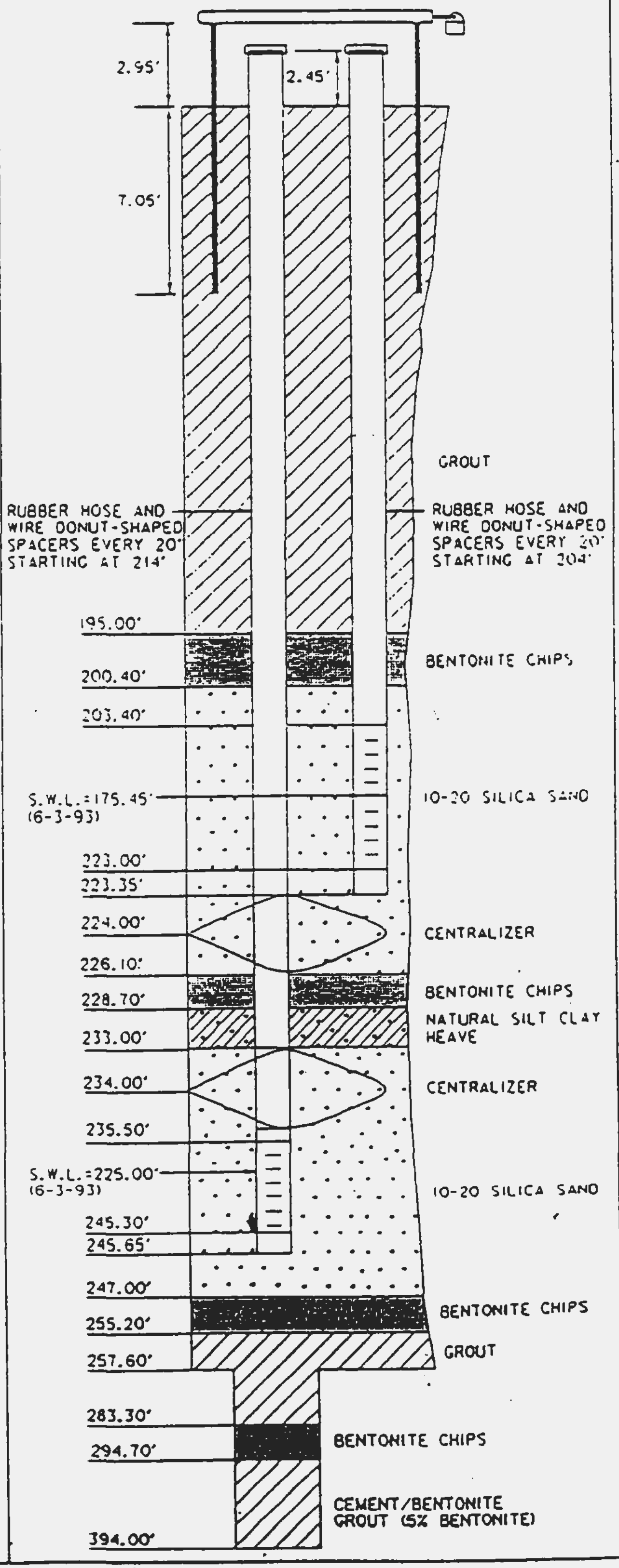
Fittings:	Length	Dia.
Riser		
Tailpipe	0.35"	2" ID

FILTER
Source BAGS (100 LBS) COLORADO SILICA SAND, INC.
Composition CLEAN SILICA SAND
Gradation 10-20
Inst. method POUR DOWN HOLE
Volume used 12.5 FT^3 / 5.5 FT^3
Depth 200.4 to 226.1 ft.
233.0 to 247.0 ft.

GROUT
Composition CEMENT/BENTONITE (5% BENTONITE)
Volume used 1000 GALLONS/250 GALLONS
Inst. method TREMMIE
Depth 0.0 to 195.0 ft.
255.2 to 394.0 ft.

REMARKS: THE NATURAL SEAL AT 228.5' TO 231.0' (SILT/CLAY) EXPANDED AND FILLED THE VOID LEFT DURING CASING REMOVAL. BENTONITE CHIPS WERE FORCED INTO AND ON TOP OF THIS LAYER BY ADDING 400 GALLONS OF WATER WHILE ADDING BENTONITE. GROUT LOSS AT 80', 55', AND 35' WAS STOPPED BY ADDING SAND AND BENTONITE CHIPS.

WELL DETAIL (AS BUILT)
93-RD-115
NOT TO SCALE



DATE AND TIME PLOTTED: 06-AUG-1993

DESIGN FILE: /cenps/projects/cw/hh/geotech hhg115.dgn

X-81

Hole No.93-RD-117

DRILLING LOG

DIVISION CENPS-EN-GT-GE

INSTALLATION HOWARD HANSON DAM

SHEET 1 OF 4 SHEETS

1. PROJECT PIEZOMETER INSTALLATION
2. LOCATION (COORDINATES OR STATION)
3. DRILLING AGENCY ANDREW WELL DRILLING
4. HOLE NO. (AS SHOWN ON DRAWING TITLE AND FILE NUMBER) 93-RD-117
5. NAME OF DRILLER ROBERT DE WILD
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN 320'
8. DEPTH DRILLED INTO ROCK 19'
9. TOTAL DEPTH OF HOLE 349'
10. SIZE AND TYPE OF BIT 8" ODEX/6$^5/_8$" TRICONE
11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)
12. MANUFACTURER'S DESIGNATION OF DRILL IR AIR ROTARY -T4W
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN DISTURBED 13 UNDISTURBED
14. TOTAL NUMBER CORE BOXES
15. ELEVATION GROUND WATER
16. DATE HOLE STARTED 4-16-93 COMPLETED 5-17-93
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING %
19. NAME AND SIGNATURE OF INSPECTOR RICHARD E. SMITH

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (DESCRIPTION)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (DRILLING TIME, WATER LOSS, DEPTH OF WEATHERING, ETC., IF SIGNIFICANT)
			CLAYEY SILT WITH OCCASIONAL PEBBLES. MOIST AND LOOSE. TAN/BROWN			DRILLED WITH ODEX BUTTON BIT DRIVEN BY DOWN-THE-HOLE HAMMER CONCURRENT WITH 8¼" ID STEEL CASING. SAMPLES SAVED WERE PLACED IN PLASTIC JARS.
	10 20		SILTY SANDY, CLAYEY GRAVEL (FINE TO MEDIUM ROUNDED PEBBLE GRAVEL), DRY AND LOOSE. TAN/LIGHT BROWN		①	DRILLING FLUID RETURN SUMMARY 0-17FT: AIR CIRCULATION 17-45 FT: 100% RETURN 45-47 FT: NO RETURN 47-170 FT: 100% RETURN 170-175 FT: AIR CIRCULATION 175-285 FT: 100% RETURN 285-349 FT: AIR CIRCULATION
	30		AS ABOVE EXCEPT GRAVELS ARE ANGULAR CUTTINGS OF LARGER GRAVELS (ANDSITE).			
	40 50 60 70 80		SLIGHTLY CLAYEY, SLIGHTLY SILTY, SLIGHTLY SANDY GRAVEL CONSISTING OF PEBBLES AND CUTTINGS OF ANDESITE AND BASALT. OCCASIONAL THIN LENSES OF BROWN CLAY/SILT PRESENT, AND OCCASIONAL ZONES OF LARGE COBBLES.		② ③	
	90		AS ABOVE EXCEPT MANY ROCK FRAGMENTS ARE OXIDIZED AND NUMEROUS ORANGISH BROWN CLAY/SILT BALLS ARE PRESENT.			POSSIBLE WEATHERED HORIZON @ 85'
	100		SAME AS 35'-85' INTERVAL, SILT AND SAND CONTENT VARIES SLIGHTLY THROUGHOUT			

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71
SEP 90 MODIFIED FOR CADD BY CENPS

PROJECT PIEZOMETER INSTALLATION

HOLE NO. 93-RD-117

X-8

DESIGN FILE: /CENPS/PROJECTS/[illegible]/GEOTECH/[illegible]
DATE AND TIME PLOTTED: 06-AUG-1993 13:04

DRILLING LOG (Cont Sheet)

ELEVATION TOP OF HOLE: PIEZOMETER INSTALLATION

Hole No. 93-RD-117

PROJECT: PIEZOMETER INSTALLATION

INSTALLATION: HOWARD HANSON DAM

SHEET 2 OF 4 SHEETS

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (DESCRIPTION)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (DRILLING TIME, WATER LOSS, DEPTH OF WEATHERING, ETC., IF SIGNIFICANT)
	100		CONTINUED			
	110					
	120					
	130					
	140				④	
	150					
	160					
	170					
WATER LEVEL UPPER STAGE 5/17/93 ▼ 181.8' B.G.	180					
	190					BEGAN MAKING WATER @ 190'
	200					S.W.L = 181.8' 5/17/93 (@ 214')
WATER LEVEL LOWER STAGE 5/17/93 ▼ 214.1' B.G.	210				⑤	
	220					

ENG FORM 1836-A PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71
SEP 90 MODIFIED FOR CADD BY CENPS

PROJECT: PIEZOMETER INSTALLATION

HOLE NO. 93-RD-117

X-4

DATE AND TIME PLOTTED: 16-AUG-1993 16:28

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE PIEZOMETER INSTALLATION	Hole No. 93-RD-117
PROJECT PIEZOMETER INSTALLATION	INSTALLATION HOWARD HANSON DAM	SHEET 3 OF 4 SHEETS

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (DESCRIPTION)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (DRILLING TIME, WATER LOSS, DEPTH OF WEATHERING, ETC., IF SIGNIFICANT)
	220		CONTINUED			
			SILTY GRAVEL(SUB-ANGULAR TO SUB ROUNDED ANDESITE AND BASALT) AND CLAY, GREY.		⑥	
	230		CLAYEY SILT OR SILTY CLAY, DENSE, DRY TO MOIST, DARK GREY		⑦	
	240		CLEAN, ROUNDED GRAVELS OF MIXED INGEOUS ORIGIN AND ANGULAR CUTTINGS OF SAME, MINOR SAND		⑧	
	250		SILTY, SLIGHTLY CLAYEY, SANDY GRAVELS (ANGULAR CUTTINGS AND ROUNDED PEBBLES OF MIXED IGNEOUS ORIGIN) AND BROWN CLAYEY SILT OR SILTY CLAY		⑨	
	260		SILTY SAND, FINE SUB-ROUNDED GRAVELS OF MIXED IGNEOUS ORIGIN, BROWN			
	270		ALTERNATING LAYERS OF SLIGHTLY SILTY, SLIGHTLY SANDY ROUNDED GRAVEL AND ANGULAR GRAVEL OF MIXED IGNEOUS ORIGIN AND SLIGHTLY SILTY GRAVELLY SAND, GREY.			
	280 290		CUTTINGS OF LARGER GRAY IGNEOUS ROCK (DESCRIBED AS BEDROCK BELOW) WITH SOME GREY SILT; DENSE. A FEW ROUNDED PEBBLES OF MIXED IGNEOUS ORIGIN ARE PRESENT THROUGHOUT, INCREASING IN QUANTITY DOWNWARD.		⑩	
	300 310		ALTERNATING LAYERS OF GREY CLAYEY SILT, GREY SILTY SAND AND GREY SILTY GRAVEL CONSISTING OF PEBBLES AND/OR CUTTINGS OF GREY IGNEOUS ROCK DESCRIBED AS BEDROCK BELOW; POSSIBLE GLACIAL TILL		⑪ ⑫ ⑬	
	320 330 340		BEDROCK: GREY IGNEOUS ROCK (ANDESITE?) WITH ELONGATE GREEN XTLS AND PYRITE IN A GREY MATRIX			BEGAN DRILLING WITH A 6⅝" TRICONE BIT WITHOUT ADVANCING CASING @ 320'

ENG FORM 1836-A PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71
SEP 90 MODIFIED FOR CADD BY CENPS

PROJECT PIEZOMETER INSTALLATION	HOLE NO. 93-RD-117

X-9

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE	Hole No. 93-RD-117
PROJECT PIEZOMETER INSTALLATION	INSTALLATION HOWARD HANSON DAM	SHEET 4 OF 4 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (DESCRIPTION) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (DRILLING TIME, WATER LOSS, DEPTH OF WEATHERING, ETC., IF SIGNIFICANT) g
	340		BEDROCK CONTINUED			
	349					SWL = 213' 5/6/93 (@ 349')
			BOTTOM = 349' BELOW GROUND			SWL = 212' 5/7/93 (@ 349')

ENG FORM 1836-A PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71
SEP 90 MODIFIED FOR CADD BY CENPS

PROJECT	HOLE NO.
PIEZOMETER INSTALLATION	93-RD-117

U.S. ARMY CORPS OF ENGINEERS, SEATTLE DISTRICT

WELL COMPLETION REPORT

WELL DETAIL (AS BUILT)

93-RD-117

Project HOWARD HANSON DAM PIEZOMETER INSTALLATION
Completion date 5/17/93
Contractor ANDREW WELL DRILLING SERVICE
Rig IR AIR ROTARY - T4W, 8" ODEX & 6⅝" TRICONE
Operator ROBERT DEWILD
Inspector RICHARD E. SMITH:CENPS-EN-GT-GE
Depth 349' Datum GROUND SURFACE

HOLE DATA
Size: 8.5 in. to 320 ft.
7 in. to 349 ft.

CASING
Type STEEL
Mfr.
Ht. above gnd. surf. 3.0'
Drive shoe YES - REMOVED
Size: 8¼ID in. to 320' ft.

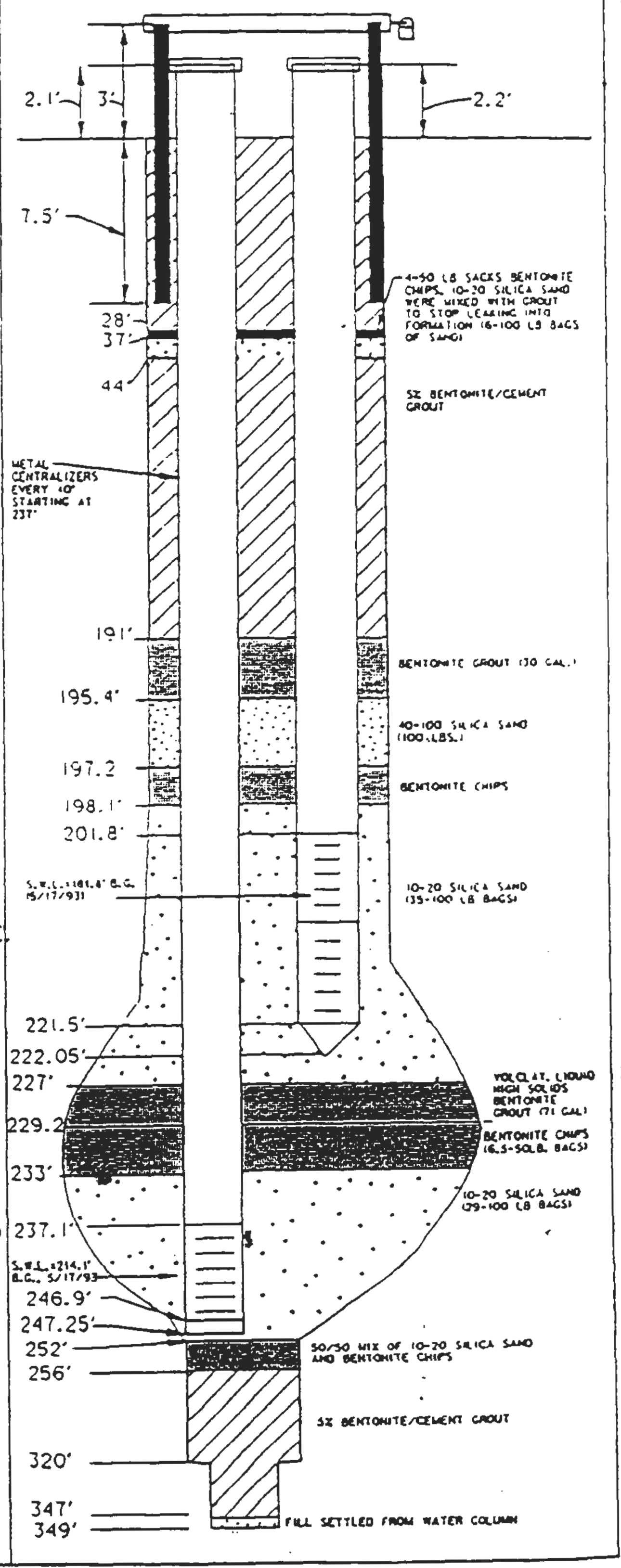
SCREEN
Type MONOFLEX, SCHEDULE 80
Mfr. CAMPBELL
Composition PVC Dia. 2" ID

Fittings:	Length	Dia.
Packer	NONE	
Riser		
Tailpipe	0.55"/0.35"	2"

FILTER
Source BAGS (100 LBS.) COLORADO SILICA SAND INC.
Composition CLEAN SILICA SAND
Gradation 10-20
Inst. method POURED DOWN HOLE
Volume used 35 FT³(197-227)/29 FT³(233-252)
Depth 197.2 to 227 ft.
233 to 252

GROUT
Composition 5% BENTONITE CEMENT
Volume used 1200 GAL (0-191)/210 GAL (256-347)
Inst. method TREMMIE
Depth 0 to 191 ft.
256 to 347 ft.

REMARKS: ALL STEEL CASING REMOVED DURING WELL COMPLETION. LARGE CAVITY SUSPECTED AROUND LOWER SCREEN FROM CASING REMOVAL AND SUBSEQUENT REDRILLING (SEE DRILLING LOG). CENTRALIZERS INSTALLED ON LOWER STAGE EVERY 40' BEGINNING AT 197'. 10.5' OF STEEL CASING ADDED DURING SURFACE COMPLETION AS WELL PROTECTION.



NOT DRAWN TO SCALE

DESIGN FI /cenps/projects/cw/hh/geotech/hh93117.dgn DATE AND TIME PLOTTED: 19-AUG-1993

DRILLING LOG
DIVISION CENPS-EN-GT
INSTALLATION HOWARD HANSON DAM
SHEET 1 OF 2 SHEETS

1. PROJECT PIEZOMETER INSTALLATION
2. LOCATION (COORDINATES OR STATION)
3. DRILLING AGENCY ANDREW WELL DRILLING
4. HOLE NO. (AS SHOWN ON DRAWING TITLE AND FILE NUMBER) 92-RD-118
5. NAME OF DRILLER ROBERT DEWILD
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN
8. DEPTH DRILLED INTO ROCK 15'
9. TOTAL DEPTH OF HOLE 216'
10. SIZE AND TYPE OF BIT 8" ODEX
11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)
12. MANUFACTURER'S DESIGNATION OF DRILL AIR ROTARY
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN : DISTURBED : UNDISTURBED
14. TOTAL NUMBER CORE BOXES
15. ELEVATION GROUND WATER
16. DATE HOLE : STARTED 12/3/92 : COMPLETED
17. ELEVATION TOP OF HOLE 1227
18. TOTAL CORE RECOVERY FOR BORING %
19. NAME AND SIGNATURE OF INSPECTOR

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (DESCRIPTION) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (DRILLING TIME, WATER LOSS, DEPTH OF WEATHERING, ETC., IF SIGNIFICANT) g
			SILTY SAND, COARSE, DRY, BROWN			12/3/92 SET-UP 12/4/92 0-50'
	5					
	10					
	15					
	20					
	25		SANDY GRAVELS (2"), DRY, GREY			
	30					
			BOULDER 2', GREY/GREEN			
	35		SANDY GRAVELS (2"), DRY, GREY			
	40					
	45					11 HRS. DRILL TIME 12/4/92 END
	50					12/5/92 START
	55					
	60					
	65		SILTY SAND, MED., DRY, LT. BROWN			
	70		SILTY SAND, MED. COARSE, DRY, LT. GREY			
	75					4 HRS. DRILL TIME 6 HRS. DOWN TIME (3PM) BROKE HYDRAULIC LINE
	80					
	85					12/5/92 END 12/6/92 START (2 PM)
	90					SLOW DRILLING BIT LOCKS UP
	95					
	100					

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71
SEP 90 MODIFIED FOR CADD BY CENPS

PROJECT PIEZOMETER INSTALLATION
HOLE NO. 92-RD-118

1-4

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE Hole No. 92-RD-118	
PROJECT PIEZOMETER INSTALLATION	INSTALLATION HOWARD HANSON DAM	SHEET 2 OF 2 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (DESCRIPTION) d	e	BOX OR SAMPLE NO. f	REMARKS (DRILLING TIME, WATER LOSS, DEPTH OF WEATHERING, ETC., IF SIGNIFICANT) g
	100		(CONT.)			SIX HRS. DRILL TIME THREE HRS. DOWN TIME 12/6/92 END
	105		SILTY SAND, MED.-COARSE, DRY, GREY W/ INTERMITTENT LARGER ROCK FRAGMENTS LAYERS INDICATING MED.-LARGE BOULDERS			12/7/92 START
	110					
	115					
	120					
	125					
	130					
	135					
	140		SILTY SAND INDICATES MOISTURE (VERY LITTLE)			
	145		SILTY SAND BECOMES DRY AGAIN W/ INTERMITTENT ROCK FRAGMENT LAYERS (BOULDERS)			12/7/92 END
	150					12/8/92 START
	155					
	160					
	165					
	170					
	175		CLAYEY SAND W/ GRAVEL			12/8/92 END 12/9/92 START @ 180' SLOW DRILLING IN CLAY
	180					SANDY GRAVEL
	185					
	190		SILTY, SANDY GRAVEL			12/9/92 END DRILL DOWN 11:30 - BROKEN HYDRAULIC LINE
	195		CLAYEY SAND W/ GRAVEL AND ROCK FRAGMENTS (1")			
	200		BEDROCK			201'-216' DRILLED WITH 6" TRI-CONE. 8" CASING RESTS @ 201' (TOP OF BEDROCK)
	205					
	210		BEDROCK (VERY FRACTURED) @ 210'			WATER WAS PRODUCED @ 210' ROCK DRILLS WATER SOUNDED IN AM ON 12/12/92 @ 200 FT.
	215		BOTTOM OF HOLE @ 216"			
	220					

ENG FORM 1836-A PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71
SEP 90 MODIFIED FOR CADD BY CENPS

PROJECT PIEZOMETER INSTALLATION | HOLE NO. 92-RD-118

U.S. ARMY CORPS OF ENGINEERS, SEATTLE DISTRICT

WELL COMPLETION REPORT

Project PIEZOMETER INSTALLATION, HANSON DAM
Completion date 12/16/92
Contractor ANDREW WELL DRILLING SERVICE
Rig IR AIR ROTARY - T4W
Operator ROBERT DEWILD
Inspector BEN LAZO, STEVE MEYERHOLTZ
Depth 216' Datum GROUND SURFACE

HOLE DATA
Size: 8 in. to 201 ft.
7 in. to 216 ft.

CASING
Type STEEL (ALL REMOVED BUT 10')
Mfr.
Ht. above gnd. surf.
Drive shoe
Size: 8 ¼ in. to 201 ft.

SCREEN
Type SCHEDULE 80 MONOFLEX -0.020 IN. SLOT
Mfr. CAMPBELL
Composition PVC Dia. 2"

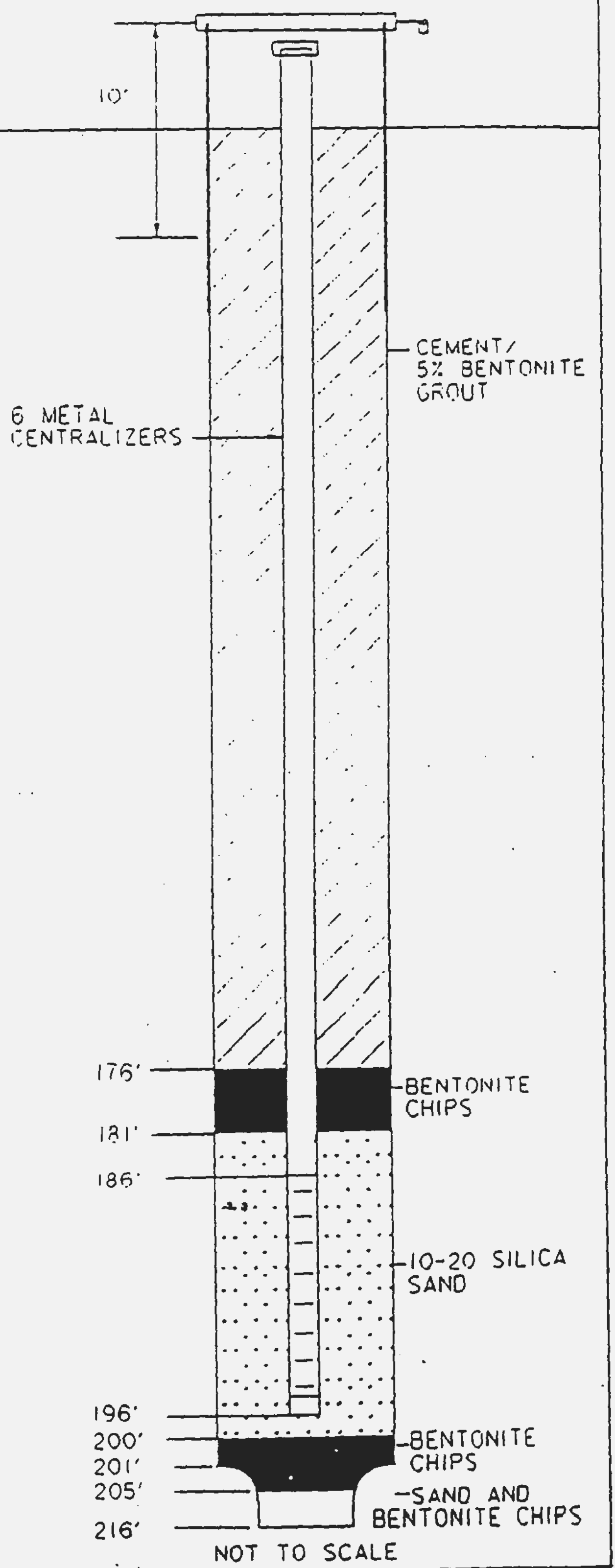
Fittings:	Length	Dia.
Riser		
Tailpipe		

FILTER
Source BAGS (100LB) COLORADO SILICA SAND, INC.
Composition CLEAN SILICA SAND
Gradation 10-20
Inst. method POUR DOWN HOLE
Volume used
Depth 181 to 200 ft.
to ft.

GROUT
Composition CEMENT /5% BENTONITE
Volume used
Inst. method TREMMIE
Depth 0 to 176 ft.
to ft.

REMARKS: GROUT LOSS AT BOTTOME OF HOLE STOPPED BY ADDING SAND AND BENTONITE CHIPS. VOLUMINOUS GROUT LOSS IN UPPER ZONES STOPPED BY MIXING IN 20 BAGS OF SAND STARTING AT 105' AND INCREASING THE PERCENTAGE BENTONITE IN THE GROUT

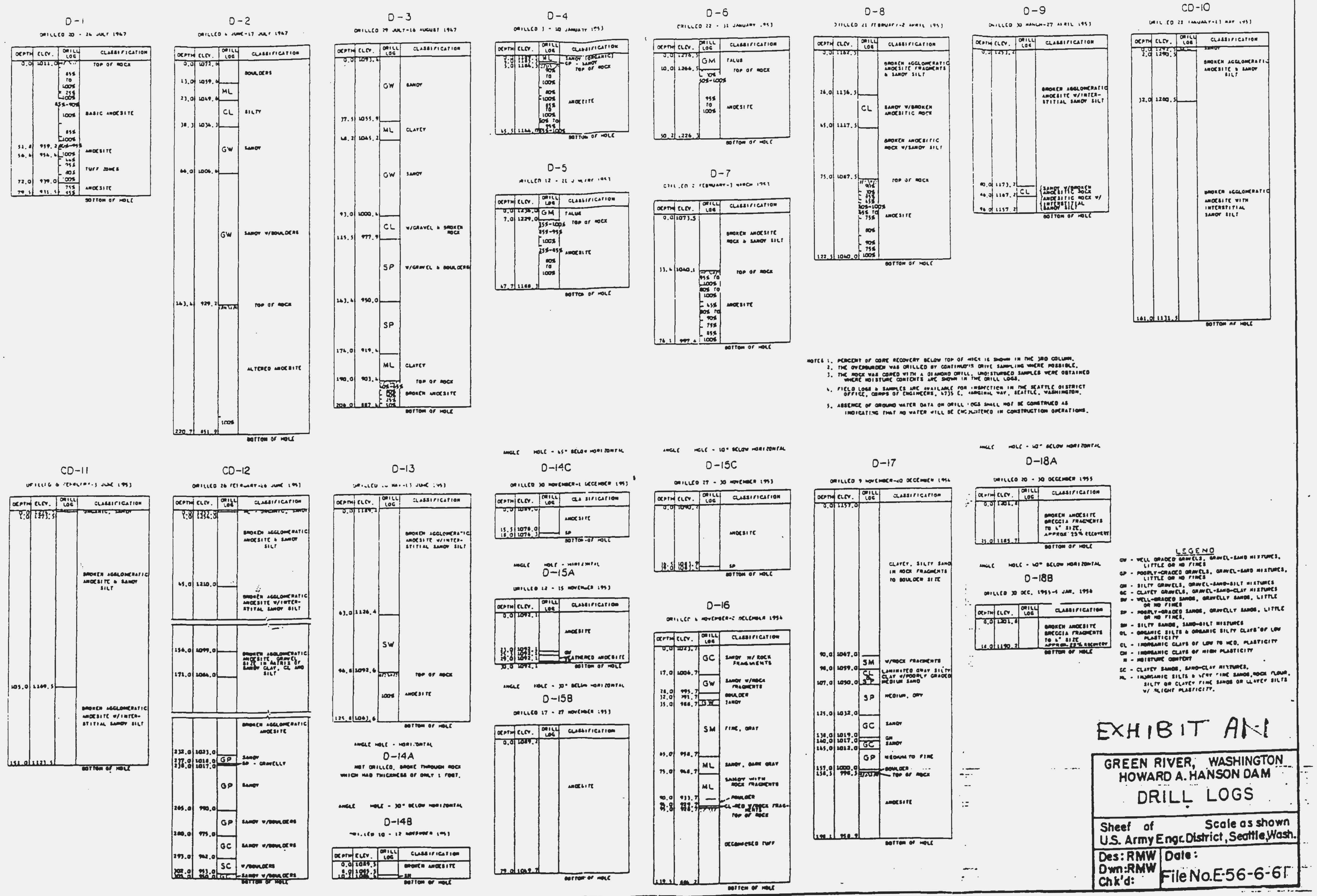
WELL DETAIL (AS BUILT)
92-RD-118
NOT TO SCALE



DATE AND TIME PLOTTED: 28-SEP-1993

DESIGN FILE: /cenps/projects/cw/hh/geotech/hhg118.dgn

X-8



D-14A NOT DRILLED, BROKE THROUGH ROCK WHICH HAD THICKNESS OF ONLY 1 FOOT.

NOTES 1. PERCENT OF CORE RECOVERY BELOW TOP OF ROCK IS SHOWN IN THE 3RD COLUMN.
2. THE OVERBURDEN WAS DRILLED BY CONTINUOUS DRIVE SAMPLING WHERE POSSIBLE.
3. THE ROCK WAS CORED WITH A DIAMOND DRILL. UNDISTURBED SAMPLES WERE OBTAINED WHERE MOISTURE CONTENTS ARE SHOWN IN THE DRILL LOGS.
4. FIELD LOGS & SAMPLES ARE AVAILABLE FOR INSPECTION IN THE SEATTLE DISTRICT OFFICE, CORPS OF ENGINEERS, 4735 E. MARGINAL WAY, SEATTLE, WASHINGTON.
5. ABSENCE OF GROUND WATER DATA ON DRILL LOGS SHALL NOT BE CONSTRUED AS INDICATING THAT NO WATER WILL BE ENCOUNTERED IN CONSTRUCTION OPERATIONS.

LEGEND

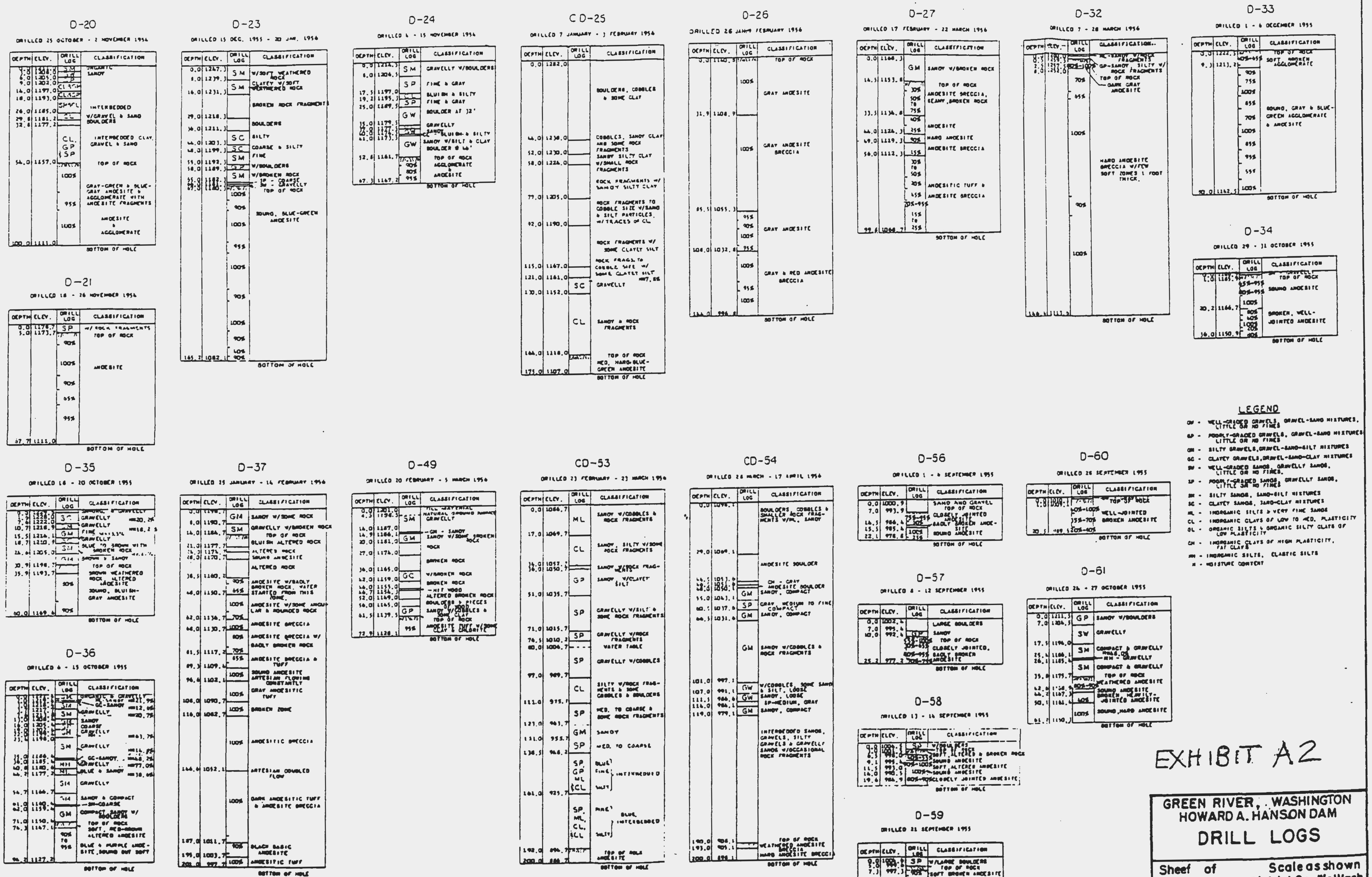
GW - WELL GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
GP - POORLY-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
GM - SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES
GC - CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES
SW - WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
SP - POORLY-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES.
SM - SILTY SANDS, SAND-SILT MIXTURES
OL - ORGANIC SILTS & ORGANIC SILTY CLAYS OF LOW PLASTICITY
CL - INORGANIC CLAYS OF LOW TO MED. PLASTICITY
CH - INORGANIC CLAYS OF HIGH PLASTICITY
M - MOISTURE CONTENT
SC - CLAYEY SANDS, SAND-CLAY MIXTURES.
ML - INORGANIC SILTS & VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS W/ SLIGHT PLASTICITY.

EXHIBIT AN

GREEN RIVER, WASHINGTON
HOWARD A. HANSON DAM
DRILL LOGS

Sheet of
Scale as shown
U.S. Army Engr. District, Seattle, Wash.

Des: RMW
Dwn: RMW
Chk'd:
Date:
File No. E-56-6-61



THE ARTESIAN WATER IN D-37 HAS A STEADY FLOW OF 10 GAL. PER MIN. AND ROSE IN A STANDPIPE 16 FT. ABOVE THE CASING DURING DRILLING. WATER IS ASSUMED TO BE COMING FROM THE 2 ZONES SHOWN IN LOG.

NOTES. 1. PERCENT OF CORE RECOVERY BELOW TOP OF ROCK IS SHOWN IN THE LOG COLUMN.
2. THE OVERBURDEN WAS DRILLED BY CONTINUOUS DRIVE SAMPLING WHERE POSSIBLE.
3. THE ROCK WAS CORED WITH A DIAMOND DRILL. UNDISTURBED SAMPLES WERE OBTAINED WHERE MOISTURE CONTENTS ARE SHOWN IN THE DRILL LOGS.
4. FIELD LOGS & SAMPLES ARE AVAILABLE FOR INSPECTION IN THE SEATTLE DISTRICT OFFICE, CORPS OF ENGINEERS, 4735 E. MARGINAL WAY, SEATTLE, WASHINGTON.
5. ABSENCE OF GROUND WATER DATA ON DRILL LOGS SHALL NOT BE CONSTRUED AS INDICATING THAT NO WATER WILL BE ENCOUNTERED IN CONSTRUCTION OPERATIONS.

LEGEND

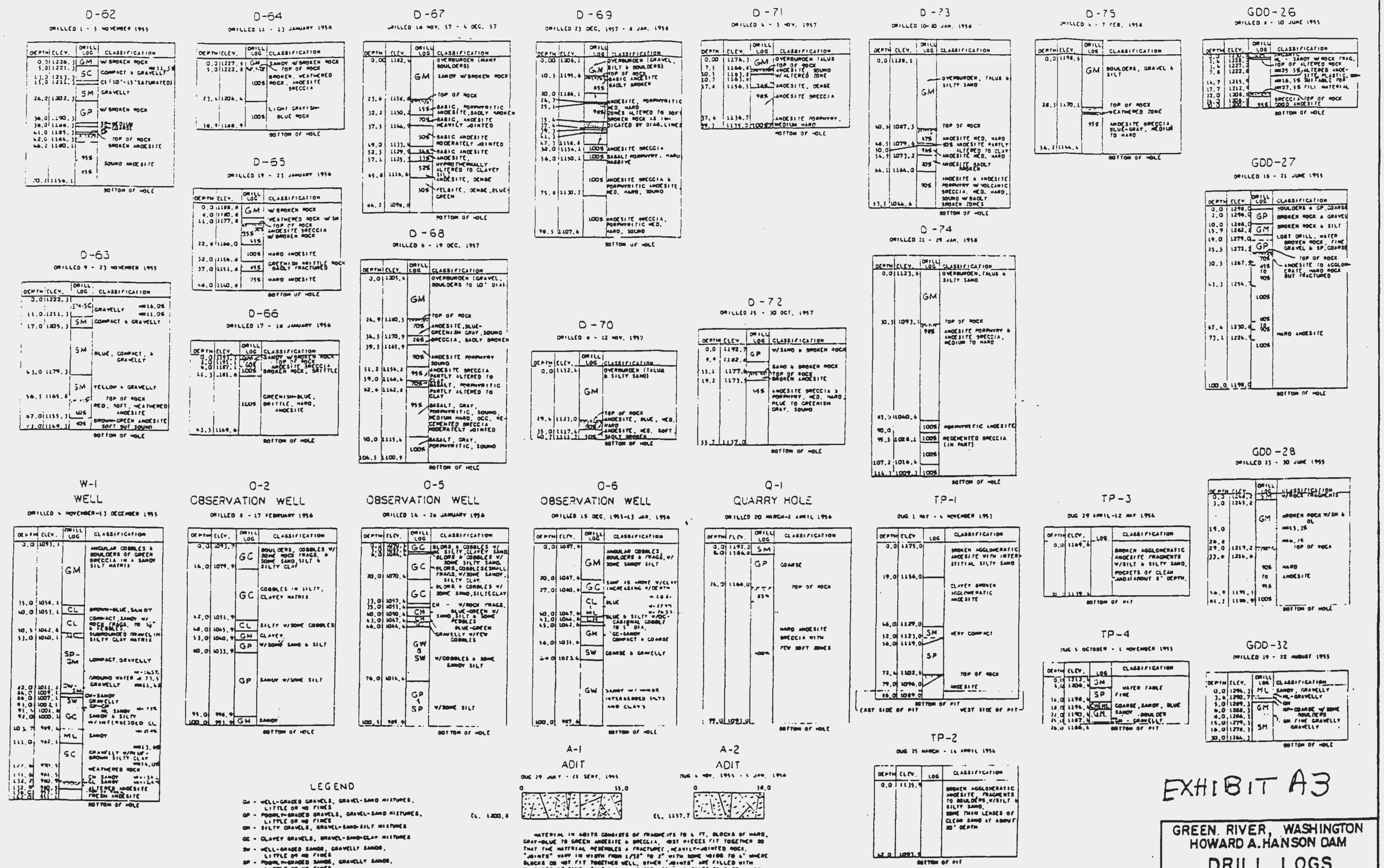
GW - WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
GP - POORLY-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
GM - SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES
GC - CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES
SW - WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES.
SP - POORLY-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
SM - SILTY SANDS, SAND-SILT MIXTURES
SC - CLAYEY SANDS, SAND-CLAY MIXTURES
ML - INORGANIC SILTS & VERY FINE SANDS
CL - INORGANIC CLAYS OF LOW TO MED. PLASTICITY
OL - ORGANIC SILTS & ORGANIC SILTY CLAYS OF LOW PLASTICITY
CH - INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
MH - INORGANIC SILTS, ELASTIC SILTS
M - MOISTURE CONTENT

EXHIBIT A2

GREEN RIVER, WASHINGTON
HOWARD A. HANSON DAM
DRILL LOGS

Sheet of
Scale as shown
U.S. Army Engr. District, Seattle, Wash.
Des: RMW
Dwn: RMW
Chk'd:
Date:
File No. E-56-6-61

X-92



MATERIAL IN ADITS CONSISTS OF FRAGMENTS TO 4 FT. BLOCKS OF HARD, GRAY-BLUE TO GREEN ANDESITE & BRECCIA. MOST PIECES FIT TOGETHER SO THAT THE MATERIAL RESEMBLES A FRACTURED, HEAVILY-JOINTED ROCK. "JOINTS" VARY IN WIDTH FROM 1/32" TO 2" WITH SOME VOIDS TO 6" WHERE BLOCKS DO NOT FIT TOGETHER WELL. OTHER "JOINTS" ARE FILLED WITH MIXTURES OF SAND, SILT & CLAY. THERE ARE ALSO ZONES TO 2 FT. WIDE WHICH ARE COMPOSED OF A HETROGENEOUS MIXTURE OF FRAGMENTS, WELL-GRADED FROM SAND SIZE UPWARD.

LEGEND

▨	ANDESITE BLOCKS
▨	ROCK FRAGMENTS

LEGEND

GW - WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
GP - POORLY-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
GM - SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES
GC - CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES
SW - WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
SP - POORLY-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
SM - SILTY SANDS, SAND-SILT MIXTURES
SC - CLAYEY SANDS, SAND-CLAY MIXTURES
ML - INORGANIC SILTS & VERY FINE SANDS
CL - INORGANIC CLAYS OF LOW TO MED. PLASTICITY, LEAN CLAYS
OL - ORGANIC SILTS & ORGANIC SILTY CLAYS OF LOW PLASTICITY
CH - INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
w - MOISTURE CONTENT

NOTES:

1. PERCENT OF CORE RECOVERY BELOW TOP OF ROCK IS SHOWN IN THE 3RD COLUMN.
2. THE OVERBURDEN WAS DRILLED BY CONTINUOUS DRIVE SAMPLING WHERE POSSIBLE.
3. THE ROCK WAS CORED WITH A DIAMOND DRILL. UNDISTURBED SAMPLES WERE OBTAINED WHERE MOISTURE CONTENTS ARE SHOWN IN THE DRILL LOGS.
4. FIELD LOGS & SAMPLES ARE AVAILABLE FOR INSPECTION IN THE SEATTLE DISTRICT OFFICE, CORPS OF ENGINEERS, 1519 S. ALASKAN WAY, SEATTLE, WASHINGTON.
5. ABSENCE OF GROUND WATER DATA ON DRILL LOGS SHALL NOT BE CONSTRUED AS INDICATING THAT NO WATER WILL BE ENCOUNTERED IN CONSTRUCTION EXCAVATIONS.

EXHIBIT A3

GREEN. RIVER, WASHINGTON
HOWARD A. HANSON DAM
DRILL LOGS

Sheet of
Scale as shown
U.S. Army Engr. District, Seattle, Wash.
Des: RMW
Dwn: RMW
Chk'd:
Date:
File No. E-56-6-61

V-93

EXHIBIT B

WATER PRESSURE TESTING DATA

REPORT OF WATER PRESSURE TESTING

Project HHD FISH PASSAGE STUDY

Hole No. 94-DD-80
Location
Coordinates N 102,291,016
E 4,763,737.800

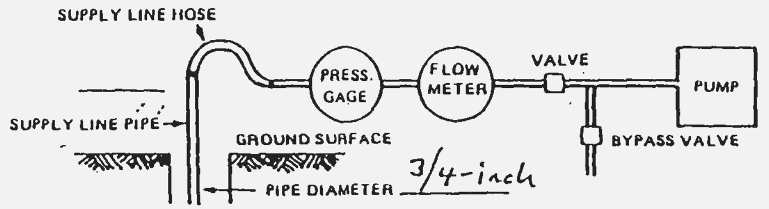
Angle (from Horiz.) 90° (Vertical)
Bearing —
Casing Size 4-inch
Static Water Level (1) 11 ft (bgs) 1153.8'

Surface Elevation 1164.767
Bedrock Elevation 1156.4
Meter Type

Date 4/ /94
Inspector Anna Campbell
Sheet 1 of 2

Test No.	Test Interval ☒ ft ☐ m (2)			Packer P.S.I.	Water Meter ☐ cfm ☒ gal ☐ liters			Time			Gage P.S.I.	Pressure Dropoff Test (P.S.I. Gage) seconds						Total pipe (3)	Casing Depth	Supply Line Press. (4)	Rate of Flow G.P.M. (5)	Column P.S.I. (6)	Net Press. P.S.I. (7)	COMMENTS
	Top	Btm	Lng		Start	End	Total	Start	End	Total Min		5	10	15	30	60	120	Ft	Ft					
1a	12.5	25.1	12.6	375	208992	209093	101	1140	1155	15	40	21	19	18	14	10	7	13	8.4		6.7			Pump 15 gpm
1b	12.5	25.1	12.6	375	209111	209155	44	1205	1220	15	20	13	12	10	9	6	4	13	8.4		3			" 15 "
2a	24	38.2	14.2	375	209168	209400	232	1400	1415	15	40	17	17	13	11	9	4	24.5	8.4		15.5			" 24.5 "
2b	24	38.2	14.2	375	209732	209896	164	1434	1441.5	7½	80	20	19	17	10	9	7	24.5	8.4		21.9			" 24.5 "
3a	36.5	51.6	15.1	375	209913	210034	121	1630	1645	15	40	22	19	19	18	12	8	37	8.4		8.1			" 25.2 "
3b	36.5	51.6	15.1	375	210056	210126	70	1650	1705	15	80	39	30	22	19	9	4	37	8.4		4.7			" 24.3 "
4a	50	64.4	14.4	325	210100	210195	95	0835	0850	15	40	21	19	17	14	9	4	50.5	8.4		6.3			" 13.2 "
4b	50	64.4	14.4	325	210270	210390	120	0857	0912	15	80	58	50	48	44	39	33	50.5	8.4		8			" 13.1 "
5a	63.5	76.6	13.1	325	210425	210482	57	1140	1155	15	40	20	18	13	9	7	4	64	8.4		3.2			" 14.4 "
5b	63.5	76.6	13.1	320	210560	210700	140	1200	1215	15	80	47	36	28	19	16	13	64	8.4		9.7			" 14.4 "
6a	75	89.5	14.5	325	210711	210718	7	1355	1410	15	40	29	24	21	17	11	8	90	8.4		0.5			" 15.2 "
6b	75	89.5	14.5	325	210719	210741	22	1420	1435	15	80	25	19	15	9	3	0	90	8.4		1.5			" 15.5 "
7a	87.5	103.1	15.6	350	210746	210746	0	1610	1625	15	40	40	39	37	30	24	20	88	8.4		0			" 15.6 "
7b	87.5	103.1	15.6	350	210747	210747	0	1635	1650	15	80	49	43	41	38	29	21	88	8.4		0			" 15.6 "
8a	102.5	117	14.5	300	210751	210751	0	0845	0900	15	40	31	27	24	21	18	15	103	8.4		0			
8b	102.5	117	14.5	300	210751	210751	0	0915	0930	15	80	40	37	34	29	22	19	103	8.4		0			
9a	116.5	130.8	14.3	300	210754	210754	0	1030	1045	15	40	27	24	22	21	21	21	103	8.4		0			

TYPICAL EQUIPMENT SKETCH



NOTES

(1) Use comments space if changes occur in the static water level during testing.

(2) Test each interval at two different gage pressures.

(3) Give accumulative total length of supply line pipe exclusive of supply line hose and packer assy.

(4) Connect packer to supply line hose on horiz. surface. Record gage pressure for flow in 5g. p.m. increments to 30 g.p.m. on back of this form. Repeat each time

(4) Cont. · the supply line diameter or length, or packer is changed. This data will be used later in the office to calculate supply line pressure.

(5) Gallon = ft³ ÷ 7.48 = liter x 3.79

(6) Column Pressure (P.S.I.) = Vertical dist. from gage to the smaller of packer or static water level x (0.433 P.S.I./ft)

(7) Net Pressure (P.S.I.) = Gage Press. + Column Press. − Supply Line Press. (This is the actual internal pressure.)

NPS FORM 140 (EM 1110-1-1801)
JUNE 1981

EX-1

REPORT OF WATER PRESSURE TESTING

Project *HHD Fish Passage Study*

Hole No. 94-DD-80
Location
Coordinates N 102,291.016
E 1,763,737.800

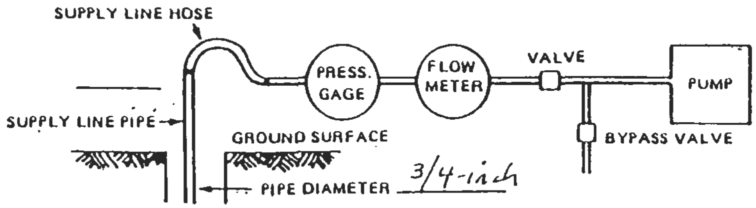
Angle (from Horiz.) 90° (Vertical)
Bearing —
Casing Size 4-inch
Static Water Level (1) 11-feet bgs

Surface Elevation 1164.767
Bedrock Elevation 1156.4
Meter Type

Date 4/ /94
Inspector Anna Campbell
Sheet 2 of 2

Test No.	Test Interval ☒ ft __ m(2)			Packer P.S.I.	Water Meter __ cfm ☒ gal __ liters			Time			Gage P.S.I.	Pressure Dropoff Test (P.S.I. Gage) seconds						Total pipe (3)	Casing Depth	Supply Line Press. (4)	Rate of Flow G.P.M. (6)	Column P.S.I. (6)	Net Press. P.S.I. (7)	COMMENTS
	Top	Btm	Lng		Start	End	Total	Start	End	Total Min		5	10	15	30	60	120							
9b	116.5	130.8	14.3	300	210754	210754	0	1100	1115	15	80	43	38	35	21	21	21	117	8.4		0			
10a	127.5	144.4	16.9	300	210757	210757	0	1217	1222	15	40	35	31	31	31	30	30	128	8.4		0			
10b	127.5	144.4	16.9	300	210760	210760	0	1228	1233	15	80	70	67	63	60	57	50	128	8.4		0			
11a	143.5	157.9	14.4	300	210790	210811	21	1430	1445	15	40	31	30	30	29	28	26	144	8.4		1.4			
11b	143.5	157.9	14.4	300	210857	210936	79	1457	1512	15	80	75	75	75	70	67	60	144	8.4		5.3			
12a	156	165	9	300	210967	210991	24	0710	0725	15	40	24	22	21	21	20	18	156.5	8.4		1.6			Fluctuating gage 20-60psi range
12b	156	165	9	300	211051	211136	85	0735	0750	15	80	70	68	68	63	59	51	156.5	8.4		5.7			

TYPICAL EQUIPMENT SKETCH



PIPE DIAMETER 3/4-inch

NOTES

(1) Use comments space if changes occur in the static water level during testing.

(2) Test each interval at two different gage pressures.

(3) Give accumulative total length of supply line pipe exclusive of supply line hose and packer assy.

(4) Connect packer to supply line hose on horiz. surface. Record gage pressure for flow in 5g. p.m increments to 30 g.p.m. on back of this form. Repeat each time

(4) Cont. - the supply line diameter or length, or packer is changed. This data will be used later in the office to calculate supply line pressure.

(5) Gallon - ft³ + 7.48 - liter x 3.79

(6) Column Pressure (P.S.I.) = Vertical dist. from gage to the smaller of packer or static water level x (0.433 P.S.I./ft)

(7) Net Pressure (P.S.I.) = Gage Press. + Column Press. - Supply Line Press. (This is the actual internal pressure.)

NPS FORM 140 (EM 1110-1-1801)
JUNE 1981

B-2

REPORT OF WATER PRESSURE TESTING

Project *HHD Fish Passage Study*

Hole No. 94-DD-81
Location LEFT ABUTMENT
Coordinates N 102 503.562
E 1,763,228.777

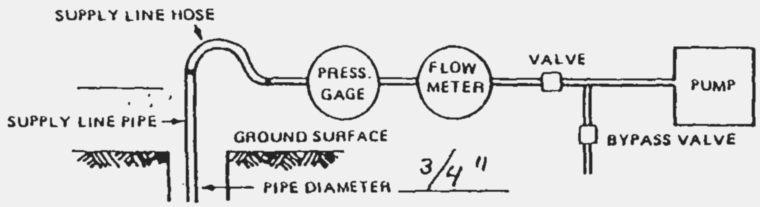
Angle (from Horiz.) 90° (Vertical)
Bearing —
Casing Size 4-inch ID
Static Water Level (1) 30.6 1189.7

Surface Elevation 1220.3FT
Bedrock Elevation 1197.3FT
Meter Type

Date 22 Apr 94
Inspector Anna Campbell
Sheet 1 of 1

Test No.	Test Interval ___ft ___m(2)			Packer P.S.I.	Water Meter ___ cfm ___ gal ___ liters			Time			Gage P.S.I.	Pressure Dropoff Test (P.S.I. Gage) seconds						Total pipe (3)	Casing Depth	Supply Line Press. (4)	Rate of Flow G.P.M. (6)	Column P.S.I. (6)	Net Press. P.S.I. (7)	COMMENTS
	Top	Btm	Lng		Start	End	Total	Start	End	Total Min		6	10	15	30	60	120	*	FT					
1a	129.5	143.6	14.1	325	211174	211174	0	1220	1235	15	40	39	32	30	29	29	29	130	23		0	56		16.6 Pump GPM
1b	129.5	143.6	14.1	325	211175	211175	0	1245	1300	15	80	77	77	74	70	66	61	130	23		0	56		16.3 Pump GPM
2a	143.0	156.2	13.2	325	211400	211695	295	1430	1445	15	40	0						143.5	23		19.7	62		Test terminated at 13.5 min because
2b	143.0	156.2	13.2	325	211875	212250	375	1455	1508.5	13.5	80	0						143.5	23		27.8	62		pump can't meet demand
3a	155.5	170.1	14.6	325	212420	212683	263	1655	1710	15	40	0						156	23		17.5	67		
3b	155.5	170.1	14.6	325	213300	213760	460	0715	0730	15	80	0						156	23		30.7	67		
4a	169.5	178.8	9.3	325	213925	214200	275	0855	0910	15	40	0						170	23		18.3	73		
4b	169.5	178.8	9.3	325	214365	214750	385	0920	0935	15	80	17	10	8	6	0		170	23		25.7	73		
5a	177.5	190	12.5	325	214781	214800	19	1040	1055	15	40	36	31	30	26	21	19	178	23		1.3	77		
5b	177.5	190	12.5	325	214855	215048	193	1110	1125	15	80	40	39	36	31	21	13	178	23		12.9	77		
																								*Estimated 4/28/94

TYPICAL EQUIPMENT SKETCH



NOTES

(1) Use comments space if changes occur in the static water level during testing.

(2) Test each interval at two different gage pressures.

(3) Give accumulative total length of supply line pipe exclusive of supply line hose and packer assy.

(4) Connect packer to supply line hose on horiz. surface. Record gage pressure for flow in 5g. p.m. increments to 30 g.p.m. on back of this form. Repeat each time

(4) Cont. - the supply line diameter or length, or packer is changed. This data will be used later in the office to calculate supply line pressure.

(5) Gallon = $ft^3 \div 7.48$ = liter x 3.79

(6) Column Pressure (P.S.I.) = Vertical dist. from gage to the smaller of packer or static water level x (0.433 P.S.I./ft)

(7) Net Pressure (P.S.I.) = Gage Press. + Column Press. - Supply Line Press. (This is the actual internal pressure.)

NPS FORM 140 (EM 1110 1-1801)
JUNE 1981

REPORT OF WATER PRESSURE TESTING

Project *HHD FISH PASSAGE STUDY*

Hole No. *94-DD-82*
Location
Coordinates N *103055.429*
E *1,763,015.934*

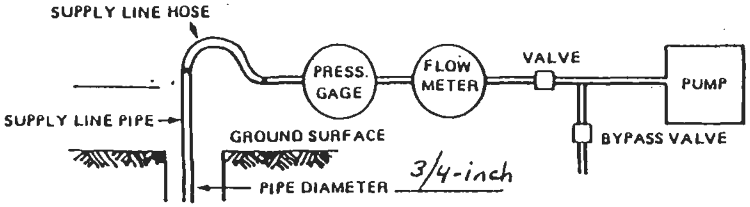
Angle (from Horiz.) *90° (Vertical)*
Bearing *—*
Casing Size *4"*
Static Water Level (1) *35.6* *1170.8'*

Surface Elevation *1206.396*
Bedrock Elevation *1202.2*
Meter Type

Date *4/19/94*
Inspector *Anna Campbell*
Sheet *1* of *1*

Test No.	Test Interval X ft __ m (2)			Packer P.S.I.	Water Meter __ cfm X gal __ liters			Time			Gage P.S.I.	Pressure Dropoff Test (P.S.I. Gage) seconds						Total pipe (3)	Casing Depth	Supply Line Press. (4)	Rate of Flow G.P.M. (5)	Column P.S.I. (6)	Net Press. P.S.I. (7)	COMMENTS
	Top	Btm	Lng		Start	End	Total	Start	End	Total Min		6	10	16	30	60	120							
1a	140	153.5	13.5	270	211135	21135	0	1600	1615	15	40	38	34	34	32	29	26	154	4		0			Pump 15 gpm
1b	140	153.5	13.5	270	211135	211B5	0	1625	1640	15	80	63	61	60	58	53	46	154	4		0			" 15 "
2a	152	166.1	14.1	300	211144	211144	0	0735	0810	15	40	32	32	30	27	22	18	162.5	4		0			" 14.3 "
2b	152	166.1	14.1	300	211144	211144	0	0820	0835	15	80	48	42	38	34	27	18	152.5	4		0			" 14.3 "
3a	165.5	179.4	13.9	300	211149	211149	0	1010	1025	15	40	38	38	37	34	31	23	166	4		0			" 14.3 "
3b	165.5	179.4	13.9	300	211149	211149	0	1035	1050	15	80	40	38	34	31	30	26	166	4		0			" 11.0 "
4a	177.5	192.5	15.0	300	211155	211155	0	1220	1235	15	40	36	32	32	30	30	30	178	4		0			" 13.7 "
4b	177.5	192.5	15.0	300	211155	211155	0	1245	1300	15	80	64	62	62	61	61	59	178	4		0			" 13.5 "
5a	188.5	202.4	13.9	300	211160	211160	0	1415	1430	15	40	30	28	25	23	22	22	189	4		0			" 13.5 "
5b	188.5	202.4	13.9	300	211160	211160	0	1440	1455	15	80	59	59	59	55	52	49	189	4		0			" 17.3 "
6a	197.5	210	12.5	275	211166	211166	0	1610	1625	15	40	24	22	21	20	19	18	198	4		0			" 14.0 "
6b	197.5	210	12.5	275	211167	211167	0	1640	1655	15	80	40	39	38	37	37	30	198	4		0			" 13.8 "

TYPICAL EQUIPMENT SKETCH



NOTES

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(2) Test each interval at two different gage pressures.

(3) Give accumulative total length of supply line pipe exclusive of supply line hose and packer assy.

(4) Connect packer to supply line hose on horiz. surface. Record gage pressure for flow in 5g. p.m. increments to 30 g.p.m. on back of this form. Repeat each time

(4) Cont. - the supply line diameter or length, or packer is changed. This data will be used later in the office to calculate supply line pressure.

(5) Gallon = ft³ ÷ 7.48 = liter x 3.79

(6) Column Pressure (P.S.I.) = Vertical dist. from gage to the smaller of packer or static water level x (0.433 P.S.I./ft)

(7) Net Pressure (P.S.I.) = Gage Press. + Column Press. - Supply Line Press. (This is the actual internal pressure.)

NPS FORM 140 (EM 1110-1-1801)
JUNE 1981

REPORT OF WATER PRESSURE TESTING

Project HHD FISH PASSAGE STUDY

Hole No. 94-DD-83
Location SPILLWAY
Coordinates N 109,494.837
E 1,763,093.729

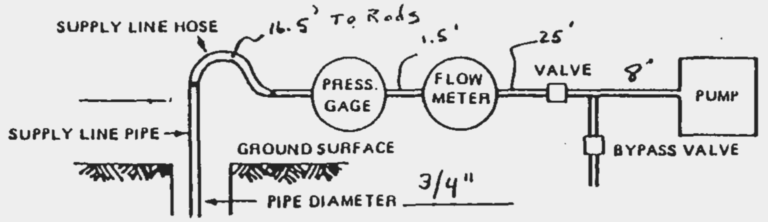
Angle (from Horiz.) 70°
Bearing Due West
Casing Size 4-inch
Static Water Level (1) 56.8' downhole = 53' vertical EL 1051.8'

Surface Elevation 1104.810
Bedrock Elevation 1104. 810
Meter Type

Date 3/31/94
Inspector Anna Campbell
Sheet 1 of 1

Test No.	Test Interval X ft __ m(2) Angle Depth			Packer P.S.I.	Water Meter __ cfm X gal __ liters			Time			Gage P.S.I.	Pressure Dropoff Test (P.S.I. Gage) seconds						Total pipe (3)	Casing Depth	Supply Line Press. (4)	Rate of Flow G.P.M. (5)	Column P.S.I. (6)	Net Press. P.S.I. (7)	COMMENTS
	Top	Btm	Lng		Start	End	Total	Start	End	Total Min		6	10	16	30	60	120	Ft	Ft					
1a	120	133.7	13.7	225	19	64	45	1403	1418	15	40	40	40	40	39	38	25	51	3.5		3	23		Pump 16 gpm
1b	120	133.7	13.7	225	46	231	185	1422	1437	15	80	60	50	45	40	30	30	51	3.5		12.5	23		" 15 "
2a	133	147.5	14.5	275	60	64	4	1640	1649	9	40	30	20	18	5	0	0	51	3.5		0.4	23		" 16 "
2b	133	147.5	14.5	275	89	102.5	13.5	0720	0735	15	80	50	40	38	20	0	0	51	3.5		0.9	23		" 13 "
3a	146	160.5	14.5	275	41	96.	55	0935	0950	15	40	0	0	0	0	0	0	51	3.5		3.7	23		" 13 "
3b	146	160.5	14.5	275	49	181	132	0955	1010	15	80	60	30	20	15	0	0	51	3.5		8.8	23		" 13 "
4a	160	173.3	13.3	300	55	184	129	1230	1245	15	40	25	18	18	15	10	10	51	3.5		8.6	23		" 16 "
4b	160	173.3	13.3	300	43.5	183	139.5	1250	1305	15	80	75	60	40	37	37	32	51	3.5		9.3	23		" 16 "
5a	173	187.6	14.6	325	21	50	29	1530	1545	15	40	20	18	15	10	5	0	51	3.5		2	23		" 13 "
5b	173	187.6	14.6	325	69	111	42	1550	1605	15	80	65	60	56	42	20	12	51	3.5		3	23		" 13 "
6a	187	200.9	13.9	275	79	152.5	73.5	0850	0905	15	40	30	25	22	22	19	14	51	3.5		5	23		" 13 "
6b	187	200.9	13.9	275	97	270	173	0915	0930	15	80	58	52	52	48	42	34	51	3.5		11.5	23		" 11 "
7a	200	210.5	10.5	275	77	142.5	65.5	1114	1124	10	40	22	21	19	17	10	0	51	3.5		6.5	23		" 16 "
7b	200	210.5	10.5	275	4	80.5	76.5	1129	1139	10	80	60	42	30	27	22	18	51	3.5		5	23		" 16 "
8a	207	220	13	325	89.5	89.5	0	1347	1352	5	40	27	21	20	18	12	7	51	3.5		0	23		" 13 "
8b	207	220	13	325	90	90.5	0.5	1358	1403	5	80	63	39	31	21	18	9	51	3.5		0.1	23		" 13 "

TYPICAL EQUIPMENT SKETCH



NOTES

(1) Use comments space if changes occur in the static water level during testing.

(2) Test each interval at two different gage pressures.

(3) Give accumulative total length of supply line pipe exclusive of supply line hose and packer assy.

(4) Connect packer to supply line hose on horiz. surface. Record gage pressure for flow in 5g. p.m. increments to 30 g.p.m. on back of this form. Repeat each time

(4) Cont. - the supply line diameter or length, or packer is changed. This data will be used later in the office to calculate supply line pressure.

(5) Gallon = $ft^3 \div 7.48$ = liter x 3.79

(6) Column Pressure (P.S.I.) = Vertical dist. from gage to the smaller of packer or static water level x (0.433 P.S.I./ft)

(7) Net Pressure (P.S.I.) = Gage Press. + Column Press. - Supply Line Press (This is the actual internal pressure)

REPORT OF WATER PRESSURE TESTING

Project HHD Fish Passage Study

Hole No. 94-DD-84
Location
Coordinates N 103,792.632
E 1,763,150.124

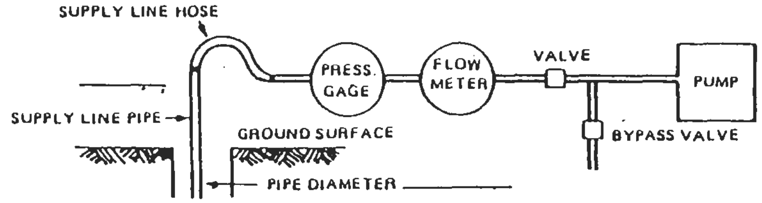
Angle (from Horiz.) 90° (Vertical)
Bearing —
Casing Size
Static Water Level (1) 9' bgs; 12' below gage

Surface Elevation 1035.044
Bedrock Elevation 1035.044
Meter Type EL 1026

Date 4/3/94
Inspector Anna Campbell
Sheet 1 of 1

Test No.	Test Interval ___ft ___m (2)			Packer P.S.I.	Water Meter ___ cfm X gal ___ liters			Time			Gage P.S.I.	Pressure Dropoff Test (P.S.I. Gage) seconds						Total pipe (3)	Casing Depth	Supply Line Press. (4)	Rate of Flow G.P.M. (5)	Column P.S.I. (6)	Net Press. P.S.I. (7)	COMMENTS
	Top	Btm	Lng		Start	End	Total	Start	End	Total Min		6	10	15	30	60	120							
1a	6.5	24.8	18.3	200	203885	203954	69	1515	1530	15	40	19	18	13	11	10	8	7.0			4.6	1.6		Pump 9.5 gpm
1b	6.5	24.8	18.3	200	204066	204066	0	1543	1558	15	20	18	12	9	6	4	0	7.0			0	1.6		Pump 16.0 gpm
2a	24	39.1	15.1	200	204172	204277	105	0718	0733	15	40	8	3	1	0			24.5			7	5.2		Pump 13 "
2b	24	39.1	15.1	200	2043205	204412	91.5	0740	0755	15	20	9	4	0				24.5			6.1	5.2		Pump 8 "
3a	37.5	51.2	14.7	325	204525	204668	143	0950	1005	15	40	0						38			9.5	5.2		Pump 12 "
3b	37.5	51.2	14.7	325	204824	205179	355	1012	1027	15	80	10	9	6	4	0		38			23.7	5.2		Pump 28 "
4a	49.5	63.7	14.2	300	205319	205501	182	1215	1230	15	40	0						50			12	5.2		Pump 15 "
4b	49.5	63.7	14.2	300	205700	205967	267	1245	1300	15	80	0						50			17.7	5.2		Pump 23 "
5a	63	79.1	16.1	325	206193	206397	204	1455	1510	15	40	0						63.5			13.7	5.2		Pump 17.5 "
5b	63	79.1	16.1	325	206470	206768	298	1520	1535	15	80	0						63.5			20	5.2		Pump 22 "
6a	78	88.1	10.1	300	207100	207312	212	0707	0722	15	40	0						78.5			14	5.2		Leak - Packer not sealed
6b	78	88.1	10.1	300	207401	207805	394	0730	0747	15	80	0						78.5			26	5.2		
7a	87.5	100	12.5	300	207411	208299	254	1020	1035	15	40	0						88	—		16.9	5.2		Pump 22.6 gpm
7b	87.5	100	12.5	300	208460	208830	370	1045	1100	15	80	10	7	3	0			88	—		24.7	5.2		Pump 30 gpm

TYPICAL EQUIPMENT SKETCH



NOTES

(1) Use comments space if changes occur in the static water level during testing.

(2) Test each interval at two different gage pressures.

(3) Give accumulative total length of supply line pipe exclusive of supply line hose and packer assy.

(4) Connect packer to supply line hose on horiz. surface. Record gage pressure for flow in 5g. p.m. increments to 30 g.p.m. on back of this form. Repeat each time

(4) Cont. - the supply line diameter or length, or packer is changed. This data will be used later in the office to calculate supply line pressure.

(5) Gallon - ft³ ÷ 7.48 - liter x 3.79

(6) Column Pressure (P.S.I.) = Vertical dist. from gage to the smaller of packer or static water level x (0.433 P.S.I./ft)

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NPS FORM 140 (EM 1110-1-1801)
JUNE 1981

REPORT OF WATER PRESSURE TESTING

Project HUD TOWER STUDY

Hole No. 94-00-85
Location HUD
Coordinates N 102,508.189
E 1,763,518.223

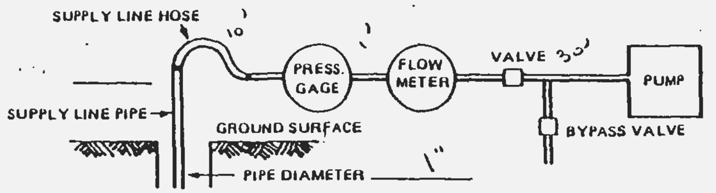
Angle (from Horiz.) 90° (Vertical)
Bearing ——
Casing Size 3½"
Static Water Level (1) 4.5-7.0' bgs

Surface Elevation 1140.095
Bedrock Elevation 1138.095
Meter Type Rockwell [illegible]

Date 9/19/94 - 9/20/94
Inspector [illegible]
Sheet 1 of 1

Test No.	Test Interval X ft __ m (2)			Packer P.S.I.	Water Meter __ cfm X gal __ liters			Time			Gage P.S.I.	Pressure Dropoff Test (P.S.I. Gage) seconds						Total pipe (3)	Casing Depth	Supply Line Press. (4)	Rate of Flow G.P.M. (5)	Column P.S.I. (6)	Net Press. P.S.I. (7)	COMMENTS
	Top	Btm	Lng		Start	End	Total	Start	End	Total Min		6	10	15	30	60	120							
1a	6	16	10	120	00192544	[illegible]	0	1047	1057	10	15	0					→	7	4		0	2.4		
1b	6	16	10	120	00192544	[illegible]	0	1054	1104	10	30	0						7	4		0	2.4		
2a	15	26	11	150	00193544	00193544	0	1408	1418	10	15	0					→	18	13		0	3.0		Water @ 7' bgs
2b	15	26	11	150	00193544	00193544	0	1423	1433	10	30	0					→	18	13		0	3.0		
3a	25	36	11	150	00193544	00193544	0	1639	1649	10	20	0					→	28	23		0	3.0		
3b	25	36	11	150	00193544	00193544	0	1655	1705	10	40	10	0					28	23		0	3.0		
4a	35	46	11	150	00193546	00193546	0	0945	0955	10	20	10	0				→	38	33		0	1.9		Water @ 4.5' bgs
4b	35	46	11	150	00193546	00193546	0	0956	1006	10	40	12	0				→	38	33		0	1.9		
5a	45	56	11	150	00193548	00193548	0	1212	1222	10	20	8	0				→	49	43		0	1.9		
5b	45	56	11	150	00193550	00193550	0	1226	1236	10	40	14	0				→	49	43		0	1.9		

TYPICAL EQUIPMENT SKETCH



NOTES

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NPS FORM 140 (EM 1110-1-1801)
JUNE 1981

REPORT OF WATER PRESSURE TESTING

Project HHD TOWER STUDY

Hole No. 94-DD-86
Location HHD TOWER
Coordinates N 102,525.236
E 1,763,496.572

Angle (from Horiz.) 90° (Vertical)
Bearing —
Casing Size 6"
Static Water Level (1) 10'-13' bgs

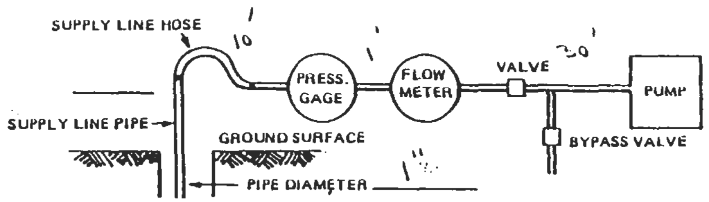
Surface Elevation 1159.7
Bedrock Elevation 1157.1'
Meter Type ROCKWELL INTERNATIONAL

Date 9/13/94
Inspector ANNA CAMPBELL
Sheet 1 of 1

Test Interval 10 ft ___ m(2)
Water Meter ___ cfm X gal ___ liters

Test No.	Test Interval Top	Btm	Lng	Packer P.S.I.	Water Meter Start	End	Total	Time Start	End	Total Min	Gage P.S.I.	Pressure Dropoff Test (P.S.I. Gage) seconds 6	10	16	30	60	120	Total pipe (3)	Casing Depth	Supply Line Press. (4)	Rate of Flow G.P.M. (5)	Column P.S.I. (6)	Net Press. P.S.I. (7)	COMMENTS
1a	27	37	10	150	0019335	0019335	0	0815	0825	10	15	10	0	—	—	—	→	23	21.5		0	4.3		water at 10' bgs
1b	27	37	10	150	0019336	0019336	0	0830	0840	10	30	15	0	—	—	—	→	23	21.5		0	4.3		"
2a	18	28	10	150	0019334	0019334	0	0930	0940	10	15	0	—	—	—	—	→	16	0		0	5.6		water level drops to 12'
2b	18	28	10	150	0019334	0019334	0	0945	0955	10	20	0	—	—	—	—	→	16	0		0	5.6		bgs when casing removed
3a	9	19	10	150							15							5	0			1.7		TEST TERMINATED;
																								WATER FLOWING OUT
																								OF HOLE

TYPICAL EQUIPMENT SKETCH



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NPS FORM 140 (EM 1110-1-1801)
JUNE 1981

REPORT OF WATER PRESSURE TESTING

Project *Fish Facility Tower/Tunnel*

Hole No. 96-DD-87
Location Howard Hanson Dam
Coordinates N
E

Angle (from Horiz.) N/A
Bearing N/A
Casing Size 4" ID to 3'
Static Water Level (1) 11.8 bgs

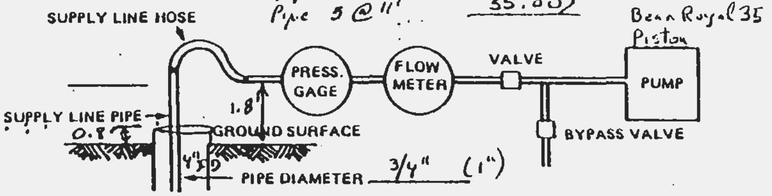
Surface Elevation 1165.7
Bedrock Elevation 1164.7
Meter Type 3/4 x 3/4 Neptune - Trident Triseal
S/N 20889675
(Neptune Meter Co, N.Y.)

Date 5/9/96
Inspector Eckerlin
Sheet 1 of 2

Test No.	Test Interval X ft __ m(2)			Packer P.S.I.	Water Meter __ cfm X gal __ liters			Time			Gage P.S.I.	Pressure Dropoff Test (P.S.I. Gage) seconds						Total pipe (3)	Casing Depth	Supply Line Press. (4)	Rate of Flow G.P.M (5)	Column P.S.I. (6)	Net Press P.S.I. (7)	COMMENTS			
	Top	Btm	Lng		Start	End	Total	Start	End	Total Min		6	10	15	30	60	120							Above G.S.	SWL Begin Test	Pressure Packers (5min)	End Test Packers Pr
1	114.1	129.7	15.6	110	1814.0	1820.4	6.4	1541:25	1546:25	5	45	32	28	26	22	18	12	118.8			1.3			S/4 = 4.7	11.0	—	—
2	104.4	120.0	15.6	110	1825.0	1830.6	5.6	1607:38	16:1238	5	45	32	29	26	21	15	10	108.7			1.1			S/4 = 4.3	11.7	—	—
3A	94.3	109.6	15.6	110	1842.0	1855.2	13.2	1627:27	1632:27	5	50	37	34	30	25	17	10	98.7			2.6			S/4 = 4.4	—	—	12.4
3B	94.3	109.6	15.6	110	1856.0	1862.4	6.4	1635:06	1640.06	5	25	20	18	16	13	10	6	98.7			1.3			S/4 4.4			
4A	84.1	99.7	15.6	110	1870.0	1900.7	30.7	1652:35	1702:35	10	64	62	59	57	52	46	36	88.6			3.1			S/4 4.6	—	—	8.7
4B	84.1	99.7	15.6	110	1910.0	1923.7	13.7	1705:47	1715:47	10	32	30	29	28	26	25	21	88.6			1.4			S/4 4.5	—	—	—
5A	74.1	89.7	15.6	110	1930.0	1953.7	23.7	1731:25	1741:25	10	65	64	60	58	55	49	40	78.6			2.4			S/4 4.5	8.7	13.6	—
5B	74.1	89.7	15.6	110	1953.7	1958.0	4.3	1747:10	1752:10	5	30	30	30	29	27	25	21	78.6			0.8			S/4 4.5	—	14.1	—

TYPICAL EQUIPMENT SKETCH

Top Packer length =	2.8	Supply Line
Nipple	0.4	
Couplings (ea)	0.05	
Pipe 6 @ 10'	60.00	
Pipe 5 @ 11'	55.00	



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NPS FORM 140 (EM 1110-1-1801)
JUNE 1981

REPORT OF WATER PRESSURE TESTING

Project Fish Facility Tower/Tunnel

Hole No. 96-DD-87
Location Howard Hanson Dam
Coordinates N
E

Angle (from Horiz.) N/A
Bearing N/A
Casing Size 4" ID to 8'
Static Water Level (1) 11.0 bgs

Surface Elevation 1165.7
Bedrock Elevation 1164.7
Meter Type 3/4x3/4 Neptune Trident Triseal

Date 5/10/96 (F)
Inspector Eckerlin
Sheet 2 of 2

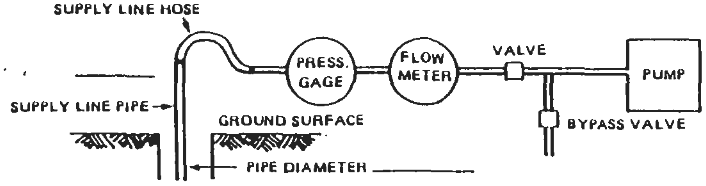
Begin Shift 0730

Test No.	Test Interval ☒ ft ☐ m(2)			Packer P.S.I.	Water Meter ☐ cfm ☒ gal ☐ liters			Time			Gage P.S.I.	Pressure Dropoff Test (P.S.I. Gage) seconds						Total pipe (3)	Casing Depth	Supply Line Press. (4)	Rate of Flow G.P.M (5)	Column P.S.I. (6)	Net Press. P.S.I. (7)	COMMENTS			
	Top	Btm	Lng		Start	End	Total	Start	End	Total Min		6	10	15	30	60	120							Above G.S.	Begin Test	SWL 5min into Packer Inflat	Following Dropoff
6A	64.3	79.9	15.6	110	1960.0	1966.5	6.5	0813:00	0823:00	10	55	48	44	40	33	24	16	68.5			0.65			s/u = 4.2	11.0	13.3	14.6
6B	64.3	79.9	15.6	110	1967.0	1970.8	3.8	082646	083646	10	35	30	28	26	21	16	12	68.5			0.38			s/u = 4.2	→	15.3	15.8
7A	55.0	70.6	15.6	100	1972.3	1978.1	5.8	084917	085917	10	52	41	37	35	28	20	14	58.4			0.58			s/u = 3.4	10.0	14.2	15.2
7B	55.0	70.6	15.6	100	1978.9	1981.0	1.1	090321	090921	6	36	29	26	25	20	16	10	58.4			0.18			s/u = 3.4	←	15.7	16.1
8A	44.0	59.6	15.6	100	1981.9	1983.8	1.9	0920:30	0930:30	10	50	45	42	39	34	26	20	47.4			0.19			s/u = 3.4	11.0	13.9	14.6
8B	44.0	59.6	15.6	100	1984.0	1984.5	0.5	093445	094045	6	25	25	24	23	22	19	16	47.4			0.10			s/u = 3.4	←	15.2	15.5
9A	32.8	48.4	15.6	100	1985.3	1987.6	2.3	0953:00	1003:00	10	52	48	45	42	36	28	20	36.3			0.23			s/u = 3.5	10.9	13.7	14.4
9B	32.8	48.4	15.6	100	1987.7	1988.3	0.6	1007:00	1013:00	6	26	23	22	22	20	19	16	36.3			0.10			s/u = 3.5	—	14.8	15.2
10A	21.9	37.5	15.6	80	2030	Terminated		1025:30	—	—	25	—	—	—	—	—	—	25.3			—			s/u = 3.4	11.0	Suspected leakage	
10B	21.9	37.5	15.6	100	2200	2461.5	261.5	103345	1043:45	10	20	8	7	5	2	0	—	25.3			26.1			s/u = 3.4	11.0	11.7	—
																								Water Vented on Slope			
11	10.8	26.4	15.6	80	2510.0	2780.0	270	1055:35	1105:35	10	15	0	—	—	—	—	—	14.2			27.0			s/u = 3.4	—	4.8	—
								1115:00																Packers out SWL 12.3 bgs			

Water Vented on slope → Sec to 1115

TYPICAL EQUIPMENT SKETCH

See Sheet 1



NOTES

(1) Use comments space if changes occur in the static water level during testing.

(2) Test each interval at two different gage pressures.

(3) Give accumulative total length of supply line pipe exclusive of supply line hose and packer assy.

(4) Connect packer to supply line hose on horiz. surface. Record gage pressure for flow in ~~5 gpm~~ 5gpm increments to 30. g.p.m. on back of this form. Repeat each time

(4) Cont. - the supply line diameter or length, or packer is changed. This data will be used later in the office to calculate supply line pressure.

(5) Gallon = ft^3 ÷ 7.48 = liter x 3.79

(6) Column Pressure (P.S.I.) = Vertical dist. from gage to the smaller of packer or static water level x (0.433 P.S.I./ft)

(7) Net Pressure (P.S.I.) = Gage Press. + Column Press. - Supply Line Press. (This is the actual internal pressure)

NPS FORM 140 (EM 1110-1-1801)
JUNE 1981

EXHIBIT C

LABORATORY RESULTS

DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION LABORATORY
CORPS OF ENGINEERS
1491 N.W. GRAHAM ROAD
TROUTDALE, OREGON 97060-9508

REPLY TO
ATTENTION OF:

CENPP-PE-L (1110-1-8100c) 10-Oct-96

MEMORANDUM FOR: Commander, Seattle District ATTN: CENPS-EN-GT-GE (Eckerlin)

SUBJECT: W.O.# 96-245, Report of Tests on Rock Cores

Project: Howard Hanson Dam Fish Facility Feasibility Study
Intended Use: Stabilization of turn under at tunnel portal
Source of Material: Rock slope above tunnel portal, Drill Hole No. 96-DD-87
Submitted by: CENPS-EN-GT-GE
Date Sampled: -- Date Received: 28 May 96
Method of Test or Specification: ASTM, CRD, RTH
Reference: a) DD Form 448, MIPR No. E86-96-3105 dated 30 May 96.
b) Our report, this subject, dated 22 Aug 96.

1. Enclosed is report of Petrographic Examination made on a portion of rock core sample No. 3. The petrographic examination was performed by the Corps of Engineers, Missouri River District Laboratory, Omaha, Nebraska.

2. Results indicate the rock is composed of well fractured altered meta-volcanic porphyritic meta-basalt.

3. This completes all work requested.

Enclosure

JAMES K. HINDS, PE
Deputy Director

RECEIV

SEP 26 1996

MR LAB NO. 4116

Sheet 1 of 1

13 SEP 1996

DEPARTMENT OF THE ARMY
MISSOURI RIVER LABORATORY
CORPS OF ENGINEERS
OMAHA, NEBRASKA 68102

Subject: Petrographic Analysis of Rock Core - Final
Project: Howard Hanson Dam Fish Facility Feasibility Study
Intended Use: Investigation
Source of Material: 2. 3 inch Diameter Rock Core
Submitted by: Chief. CENPDL
Date Sampled: ______________, Date Received: 27 June. 1996
Method of Test or Specification: See "Test Method"
References: North Pacific Division Lab MIPR No. 96-0245 dated 06/19/96

SUMMARY

1. Sample identification and test methods are provided in Appendix A. Test results and discussion are presented in Appendix B. Documentation photographs and photomicrographs are presented in Figure Nos. 1 through 7.

2. Petrographic analysis to determine bulk rock mineralogy and to determine sulfate and sulfide mineral content was performed on a 2.3 in. dia. rock core from the Howard Hanson Dam Fish_Facility Feasibility Study Project submitted by North Pacific Division Lab. Test results indicate the rock is composed of well fractured (brecciated), altered meta-volcanic rock identified as porphyritic meta-basalt with the majority of principal original volcanic rock mineral constituents altered to chlorite, calcite and mica. The fractures associated with brecciation are closely spaced, closed and healed with secondary minerals that include chlorite, carbonate and microcrystalline silica. Iron ore identified in the sample is composed predominately of iron sulfide (pyrite) and comprises approximately 15 % of the rock as determined by modal analysis. Chemical analysis indicates whole rock sulfate content is less than 0.1 % and the iron sulfide appears to be chemically inert based on results from sodium and calcium hydroxide immersion tests.

Submitted by:

Douglas B. Taggart

Douglas B. Taggart
Director, MR Laboratory

CX-2

MR LAB No. 4116
Sheet 1 of 1

APPENDIX A

SAMPLE IDENTIFICATION

1. One rock core from the Howard Hanson Dam - Fish Facility Feasibility Study Project was submitted by North Pacific Division for petrographic and chemical analysis. The core is identified as CENPDL # 5547 (138.5 - 139.0 ft.) based on sample identification information provided in the sample transmittal document submitted with the core sample.

TEST METHOD

2. The analysis was conducted in accordance with the following test methodology:

The subject rock core sample was examined with stereo- and polarized light microscope (PLM) instrumentation using powder mounts and thin section techniques in accordance with CRD-C 57 (ASTM -856-83), -C 127 (ASTM C 295-85), -C 139 (ASTM C 294-86) to determine gross composition, general condition, to select zones for further analysis and to document the as-received condition of the sample. Specimen dimensional measurements were taken and unique features recorded. Thin section modal analysis was performed to determine iron sulfide mineral distribution. Whole rock representative subsamples were obtained and comminuted to produce samples for chemical analysis (sulfate test) in accordance with CRD-C 403-71 "Method of Test for Determination of Sulfate Ions in Water and Soil" and to provide powder mounts for x-ray diffraction analysis. Both random and oriented powder mounts were used to determine bulk mineralogy and were scanned with a GE 500 x-ray diffractometer interfaced with a Siemens D-500 automation system using monochromatic CuK alpha x-radiation with an Ni filter at a stepping rate of 2 degrees/two-theta per minute. All external instrumental variables were not altered to increase precision and reduce experimental error. Selected rock polished sections were immersed in 1 N sodium hydroxide and saturated calcium hydroxide solutions for 2 weeks to assess sulfide mineral chemical stability (Method after Dolar-Mantuani).

APPENDIX B

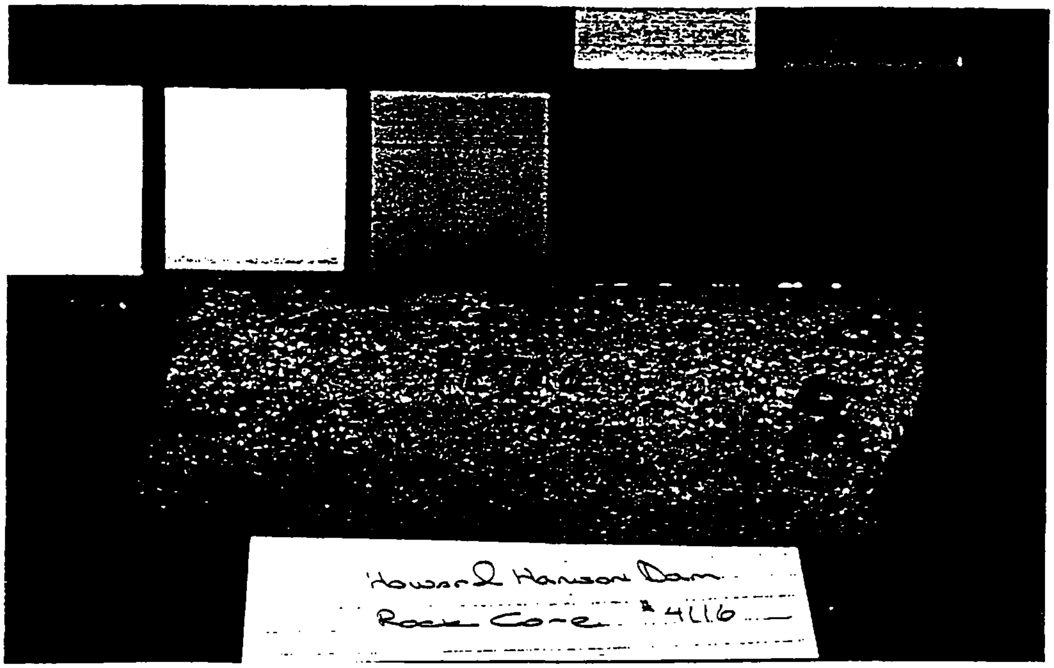
TEST RESULTS

1. Petrographic analysis to determine rock type and sample condition reveals the following information;

Sample No. CENPDL # 5547 (138.5 - 139.0 ft.). This core sample measures approximately 7.0 inches in length by 2.3 inches in diameter (Figure No. 1) and is composed of dense, dark greenish black (5G 4/1, Munsell Color Classification-wet) rock containing grayish olive green (5 GY 3/2) brecciated zones. The fractures associated with brecciation are closely spaced, closed and healed with secondary minerals that include chlorite, carbonate and microcrystalline silica (Figure No. 5). Thin section analysis indicates the rock type is classified as a dense, porphyritic meta-volcanic rock (porphyritic meta-basalt) with coarse, well-formed, occasionally oscillatory-zoned feldspar phenocrysts of andesite / labradorite composition in a fine grain matrix of fine plagioclase feldspar microlites (showing flow structure), devitrified volcanic glass and abundant black, opaque iron ore (pyrite - iron sulfide dominant, See Figure No. 7)). The majority of plagioclase phenocrysts are corroded, having been replaced with mica and calcite which complicated the determination of the original composition of plagioclase and the rock classification. The original matrix (especially in the brecciated zones) is partially to extensively altered or replaced by secondary minerals such as chlorite, quartz and calcite. Granulation of the parent rock is visible both on a macro and microscopic scale and voids created by the brecciation (Figure No. 3) are partially to completely in-filled with similar secondary minerals (Figure Nos. 4 and 6). Bulk x-ray diffraction analysis confirms the presence of plagioclase feldspar, quartz, calcite, ferromagnesian minerals, mica and chlorite group minerals and iron ore (magnetite and pyrite) minerals but did not detect significant quantities of expansive clay minerals present in the rock that would have been derived from the weathering of glassy, volcanic matrices. Thin section modal analysis indicate iron sulfide minerals (predominantly pyrite) comprises approximately 15.4 % of the rock. Selected rock polished sections were immersed in a 1 N sodium hydroxide and saturated calcium hydroxide solutions for 2 weeks (Method after Dolar-Mantuani) to visually assess sulfide mineral chemical stability. The sulfide minerals showed only minor tarnishing after the immersion tests, with no conversion to ferrous sulfate (bluish-green gelatinous precipitate). Bulk chemical analysis indicated sulfate content of the rock is 0.07 % (normally reported as less than 0.1 %).

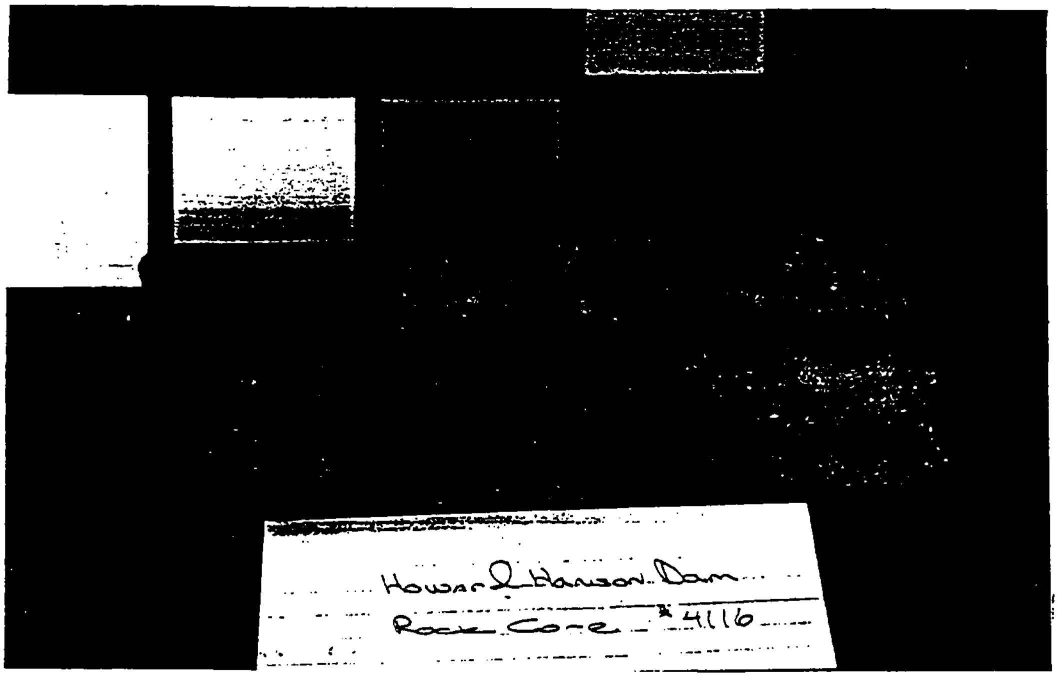
DEPARTMENT OF THE ARMY
MISSOURI RIVER LABORATORY
CORPS OF ENGINEERS
OMAHA, NEBRASKA 68102

Figure No. 1



Core Sample No. CENPDL # 5547. Profile view of the subject core showing condition and identification information (core top - left side of photo). Core Dia. 2.3 inches.

Figure No. 2



Core Sample No. CENPDL # 5547. Profile view of surface cut parallel to the core axis detailing variable textural nature of the rock due to brecciation. Core Dia. 2.3 inches.

Plate No. 1

Figure No. 3

Core Sample No. CENPDL # 5547. Thin section photomicrograph detailing texture of rock classified as a porphyritic meta-basalt. Note the elongate greenish structure (arrow) in center of photo representing void in-filled with radially fibrous chlorite crystals. Magnification 63 X.

Figure No. 4

Core Sample No. CENPDL # 5547. Further magnification of previous view showing radially fibrous nature of chlorite (arrow) filling void. Gold-colored zone (same arrow) is secondary carbonate (calcite) precipitate lining same void. Crossed polarized light. 115 X Mag.

Plate No. 2

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OMAHA, NEBRASKA 68102

Figure No. 5

Core Sample No. CENPDL # 5547. Thin section photomicrograph detailing fractures (arrows) healed with chlorite and carbonate (calcite-gold-colored) secondary precipitate. Crossed polarized light. 63 X Magnification.

Figure No. 6

Core Sample No. CENPDL # 5547. Thin section photomicrograph detailing void in-filled with radially fibrous chlorite secondary precipitate. Crossed polarized light. 115 X Mag.

Plate No. 3

CX-1

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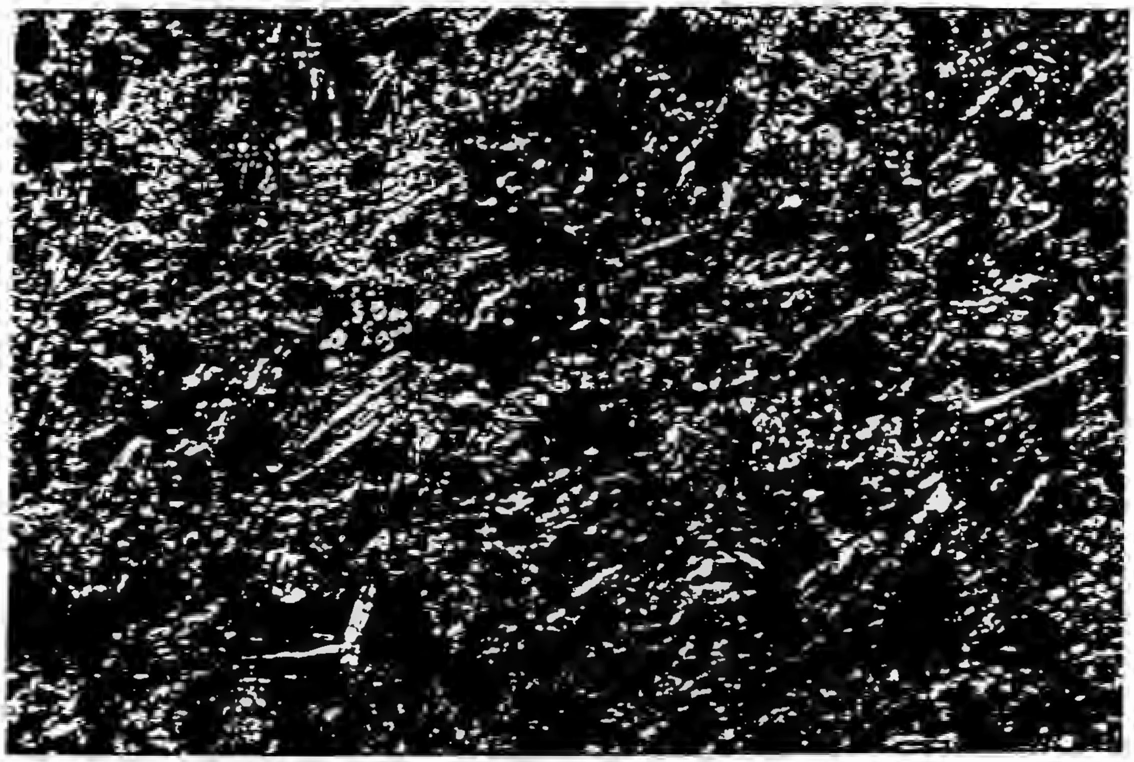
OMAHA, NEBRASKA 68102

Figure No. 7



Core Sample No. CENPDL # 5547. **Thin section photomicrograph detailing the distribution of opaque iron ore particles (black particles) in the rock matrix. Light colored, elongated crystals are plagioclase microlites. Magnification 190 X.**

Plate No. 4

1x8

APPENDIX B

DISCUSSION

2. Petrographic analysis performed on the subject core sample from Howard Hanson Dam Fish Facility Feasibility Study Project submitted by North Pacific Division Laboratory indicates the sample represents rock classified as a brecciated, porphyritic meta-basalt, with the original mineral constituents extensively altered to secondary minerals such as chlorite, microcrystalline silica and calcite. The fractures associated with the brecciation appear to be well cemented and the mineral alteration does not appear to have adversely affected rock matrix density. The bulk rock sulfate content is 0.07 % and sulfide minerals common in the matrix appear chemically stabile as these minerals did not produce significant reaction or alteration to ferrous sulfate during immersion in sodium or calcium hydroxide (saturated lime) solutions.

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION LABORATORY
CORPS OF ENGINEERS
1491 N.W. GRAHAM AVENUE
TROUTDALE, OREGON 97060-9503

CENPP-PE-L (1110-1-8100c) 22 Aug 96

MEMORANDUM FOR: Commander, Seattle District ATTN: CENPS-EN-GT-GE (Eckerlin)

SUBJECT: W.O.# 96-245, Report of Tests on Rock Cores

Project: Howard Hanson Dam Fish Facility Feasibility Study
Intended Use: Stabilization of turn under at tunnel portal
Source of Material: Rock slope above tunnel portal, Drill Hole No: 96-DD-87
Submitted by: CENPS-EN-GT-GE
Date Sampled: -- Date Received: 28 May 96
Method of Test or Specification: ASTM, CRD, RTH
Reference: a) DD Form 448, MIPR No. E86-96-3105 dated 30 May 96.
b) NPD Form 300, Transmittal of Materials Samples, dated 28 May 96.
c) Telephone conversations 22 May through 7 Aug 96 with Mr. Rick Eckerlin, wherein test program and costs were discussed.
d) Facsimile report of preliminary data dated 9 Aug 96, wherein results to date were reported.

1. Enclosed is report of tests made on rock cores taken from the vicinity of the tunnel portal of the Howard Hanson Dam. Included are:

a) Enclosure 1, Table I, Report of Unconfined Compressive and Direct Tensile Strength Tests on Andesite Breccia Rock Cores.

b) Enclosure 2, Table II, Report of Specific Gravity, Absorption, Unit Weight, and Dynamic Modulus of Elasticity Tests on Andesite Breccia Rock Cores.

c) Enclosure 3, Table III, Report of Bi-Axial Direct Shear Strength Tests on Sawn Rock-Grouted Joints.

d) Enclosure 4, Figure I, Graphical Report of Bi-Axial Direct Shear Strength Tests on Sawn Rock-Grouted Joints.

2. Approximately 20 linear feet of andesite breccia HQ rock core was received on 28 May 96 for compressive strength, direct tensile strength, unit weight, sonic tests, and bi-axial direct shear tests on sawn rock-grouted joints.

3. A petrographic examination is currently being performed on a portion of Sample No. 3. Results will be forwarded when available.

Enclosures

JAMES K. HINDS, PE
Deputy Director

CENPP-PE-L (96-245)

Howard Hanson Dam Fish Facility Feasibility Study

Table I
Report of Unconfined Compressive and Direct Tensile Strength Tests on Andesite Breccia Rock Cores [1/], Drill Hole No. 96-DD-87

1. Compressive Strength Test Data

Sample No.	Depth, ft.	Diameter, in.	Height, in.	Moisture Content [2/], %	Compressive Strength, psi	Modulus of Elasticity, [3/] Ec x 10^6 psi	Poisson's Ratio, μ [3/]
1	$61^{\underline{9}}$ - $62^{\underline{2}}$	2.39	5.13	2.1	4010	4.55	0.172
2	$113^{\underline{2}}$ - $113^{\underline{5}}$	2.40	4.98	0.8	8670	3.73	0.152
2	$113^{\underline{7}}$ - $114^{\underline{0}}$	2.39	4.97	1.3	7200	1.44	0.155
3	$136^{\underline{5}}$ - $136^{\underline{8}}$	2.39	4.90	0.7	11190	4.06	0.167

2. Direct Tensile Strength Data

Sample No.	Depth, ft.	Diameter, in.	Height, in.	Direct Tensile Strength, psi
1	$61^{\underline{2}}$ - $61^{\underline{5}}$	2.39	4.82	45 [4/]
2	$112^{\underline{8}}$ - $113^{\underline{1}}$	2.40	4.85	200
3	$137^{\underline{1}}$ - $137^{\underline{4}}$	2.39	4.93	740

Notes: 1/ Tested in accordance with Rock Testing Handbook, RTH Methods 111 and 112.

2/ Moisture content of sample at time of test.

3/ Modulus of Elasticity and Poisson's Ratio tests made using glue-on electrical resistance strain gauges.

4/ Examination of Sample No. 1 after test indicates failure occurred along an existing slicken-sided seam comprising approximately 50% of the total failure plane.

CENPDL No. 5547; samples received 28 May 96.

CENPP-PE-L (96-245)

Howard Hanson Dam Fish Facility Feasibility Study

Table II
Report of Specific Gravity, Absorption, Unit Weight, and Sonic Tests on Andesite Breccia Cores*, Drill Hole No. 96-DD-87

Sample No.	Depth, ft.	Specific Gravity	Absorption, %	Unit Weight, lb/ft^3	Longitudinal Dynamic Modulus of Elasticity, E x 10^6 psi	Sonic Velocity, V, ft/sec.	
						Longitudinal	Transverse
1	$59^{\underline{7}}$ - $70^{\underline{3}}$	2.66	1.7	165.7	--	--	--
2	$111^{\underline{4}}$ - $117^{\underline{5}}$	2.50	5.3	155.8	--	--	--
3	$135^{\underline{1}}$ - $139^{\underline{7}}$	2.54	3.8	158.2	--	--	--
3	$137^{\underline{1}}$ - $138^{\underline{1}}$	--	--	--	0.513	3960	2540

* Tested in accordance with Rock Testing Handbook, RTH Methods 107 and 110.

CENPDL No. 5547; samples received 28 May 96.

Howard Hanson Dam Fish Facility Feasibility Study

Table III
Summary of Bi-Axial Direct Shear Strength Tests on Sawn Rock-Grout Joints, Drill Hole No. 96-DD-87

1. Bi-Axial Direct Shear Strength, Grout-Rock Bond [1/]

Sample No.	Depth, ft	Shear Strength, psi Confining Pressure, psi 5	50	100	Angle of Internal Friction, Φ, degrees	Cohesion, psi
2	$111^{\underline{7}}$	75	--	--	--	--
2	$111^{\underline{9}}$	--	440	--	--	--
2	$115^{\underline{7}}$	--	--	365	--	--
2	$115^{\underline{9}}$	230	--	--	--	--
2	$115^{\underline{9}}$	--	435	--	--	--
2	$117^{\underline{6}}$	--	390	--	--	--
2	117^{4}	--	--	505	--	--
	Average:	155	420	435	71.0	187
3	$135^{\underline{5}}$	85	--	--	--	--
3	$137^{\underline{7}}$	--	240	--	--	--
3	$138^{\underline{3}}$	--	--	390	--	--
	Average:	85	240	390	72.7	73

2. Compressive Strength of Neat Cement Grout Cubes [2/]

Test Age, days	Compressive Strength, psi
3	3340
7	4710
10	5120
28	6260

Notes: 1/ Grout/rock bi-axial direct shear tests made at grout age 10 days. All tests performed in accordance with Rock Testing Handbook Method 203

2/ Grout batched with laboratory blend Type II cement (CENPDL No. 4959) at a water:cement ratio of 0.49 with 20.0 seconds flow.

CENPDL No. 5547; samples received 28 May 96.

Howard Hanson Dam Fish Facility Feasibility Study
Figure I
Bi-Axial Direct Shear Strength versus Confining Pressure, Sawn Rock-Grout Joints

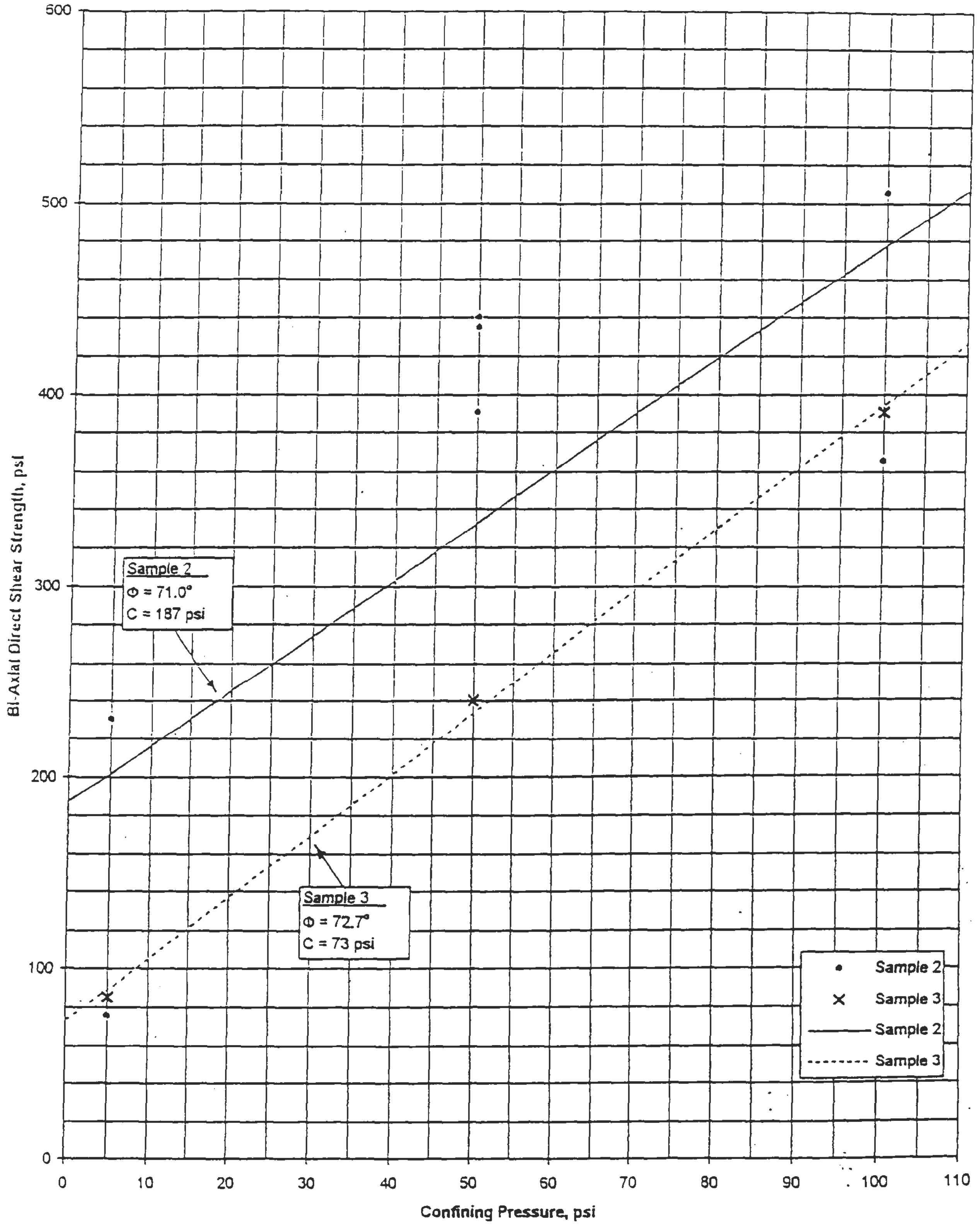


Figure I

CENPDL
Aug 96

CX-12

DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION LABORATORY
CORPS OF ENGINEERS
1491 N.W. GRAHAM AVENUE
TROUTDALE, OREGON 97060-9503

CENPD-ET-P-L (1110-1-8100c) April 10, 1995

MEMORANDUM FOR Commander, Seattle District, ATTN: CENPS-EN-GT (Hancock)

SUBJECT: W.O. # 95-099, Report of Tests on Foundation Rock Cores

Project: HOWARD HANSEN DAM INTAKE TOWER RETROFIT
Intended Use: Stabilization of intake tower buttress
Source of Material: Intake tower vicinity foundation
Submitted by: CENPS-EN-GT (Hancock)
Date Sampled: 16-20 Sep 94 Date Received: 21 Nov 94
Method of Test or Specification: CRD, ASTM, RTH
Reference: a) DD Form 448, MIPR No. E86-95-3065, dated 14 Nov 94
b) NPD Form 300, Transmittal of Materials Samples, dated 15 Nov 94
c) Telephone conversations 22 Nov 94 - 12 Jan 95 with Mr. Bill Hancock, wherein test program and costs were discussed
d) Facsimile report dated 29 Dec 94, wherein results to date were reported

1. Enclosed is report of tests made on foundation rock cores taken from the vicinity of the intake tower of the Howard Hansen Dam. Included are:

a) Enclosure 1, Table I, Report of Unconfined Compressive and Direct Tensile Strength Tests on Andesite Rock Cores

b) Enclosure 2, Table II, Report of Point Load Strength Tests on Andesite Rock Cores

c) Enclosure 3, Table III, Summary of Bi-Axial Direct Shear Strength Tests on Rock Cores and Sawn Rock-Grouted Joints

d) Enclosure 4 a-d, Figures I through IV, Graphical Report of Compressive Strength versus strain, one for each of four cores tested.

2. Approximately 90 lineal feet of andesite HQ and 4-inch diameter rock core was received 21 Nov 94 for unconfined compressive strength, direct tensile strength, point load, and bi-axial direct shear strength tests. The cores were received in an air-dry, unsealed condition, and were tested in accordance with Rock Testing Handbook Methods 111, 112, 203 and 325.

CX-15

3. Several tests were requested to be made within the section of core at depth 15' to 20' in Drill Hole No. 95-CC-85. In general, the core within this zone was heavily fractured, and tests were rescheduled to be performed as closely as possible in adjacent areas.

4. This completes all work requested.

James K. Hinds, PE
Deputy Director

Enclosures

Copy Furnished: CENPD-ET-P

CENPD-ET-P-L (95-099)

HOWARD HANSEN DAM INTAKE TOWER

Table I

Report of Unconfined Compressive and Direct Tensile Strength Tests on Andesite Rock Cores[1]

1. Compressive Strength Test Data

Drill Hole No.	Depth, feet	Diameter, inches	Height, inches	Moisture[2] Content, %	Unconfined Compressive Strength			
					Ultimate Load, lbs.	psi	Corrected[3] psi	x10^6 psi Modulus of Elasticity
94-DD-85	6.5-6.8	2.38	4.87	1.7	16,300	3,660	3,670[4]	0.67
	13.6-13.9	2.39	5.17	2.0	20,600	4,590	4,630[4]	2.11
	15.0-15.4	2.40	5.15	2.2	39,200	8,670	8,740	---
	19.0-19.4	2.40	4.87	0.9	122,500	27,080	27,130	---
	24.7-25.0	2.39	4.67	1.8	56,000	12,480	12,440	3.26
	25.0-25.3	2.38	4.72	1.3	53,700	12,070	12,060	3.42
94-DD-86	24.0-24.7	3.97	8.16	1.8	84,000	6,790	6,830	---
	39.3-40.0	3.98	7.59	2.3	93,500	7,920	7,870	---

2. Direct Tensile Strength Data

Drill Hole No.	Depth, feet	Diameter, inches	Height, inches	Direct Tensile Strength	
				Ultimate Load, lbs.	psi
94-DD-85	10.1-10.5	2.40	4.83	2,260	500[5]
	10.5-10.8	2.39	4.82	1,960	440
	11.7-12.0	2.38	4.63	480	110[5]

Notes: 1/ Tested in accordance with Rock Testing Handbook, RTH Methods 111, 112, and 201.

2/ Moisture content of sample at time of test.

3/ Corrected for length-to-diameter ratio.

4/ Specimen had hairline crack before test

5/ Specimen had hyperbolic open seam before test.

CENPDL No. 5087, Received 21 Nov 94

CX-17

HOWARD HANSEN DAM INTAKE TOWER

Table II

Report of Point Load Strength Tests on Andesite Rock Cores[1]

Drill Hole No.	Depth, feet	Diameter,[2] inches	Length, inches	Ultimate Load, lbs	Point Load Index, psi
85	15.3	2.36	3.00	2550	460
	18.8	2.24	3.00	5050	1005[3]
	20.4	2.38	3.00	530	95[4]
	25.7	1.97	3.00	2450	630
	30.3	2.22	3.00	2730	555
	35.1	1.87	3.00	1600	460[3]
	39.9	2.16	3.00	1680	360
	45.5	2.20	3.00	1070	220[3]
	45.3	1.76	3.00	2440	790[3]
	48.7	2.15	3.00	2150	465
	50.3	2.10	3.00	3990	905[3]
86	10.0	3.95	5.00	1800	115
	15.3	3.92	4.00	2020	130[3]
	16.2	3.92	4.00	2090	135[3,5]
	16.4	3.82	4.00	2700	185[3]
	19.6	3.96	4.00	1430	90[3]
	24.7	3.97	4.00	2040	130[3]
	25.5	3.79	4.00	1520	105[3]
	25.8	3.42	4.00	4320	370[3]
	29.5	3.97	4.00	950	60[5]
	29.7	3.97	4.00	1350	85[4]
	38.0	3.60	5.00	200	15

Notes:
1/ Specimens tested diametrically, in accordance with RTH-325 requirements
2/ Diameter used for calculation of Point Load Index, based on distance between points of point load apparatus at the time of failure.
3/ Specimen did not break through both points of point load apparatus
4/ Specimen tested with points parallel to weak planes/seams
5/ Specimen tested with points normal to weak planes/seams

HOWARD HANSEN DAM INTAKE TOWER

Table III

Summary of Bi-Axial Direct Shear Strength Tests Intact Rock Cores and Sawn Rock-Grout Joints

1. Intact Rock Core

Drill Hole No.	Depth, Feet	Ultimate Load, lbs.	Area Inches^2	Shear Strength, psi Confining Load, psi 10	50	100	Angle of Internal Friction, degrees	Cohesion, psi
86	24.3	12020	12.379	970	--	--	--	--
86	28.4	7700	12.316	625	--	--	--	--
86	23.3	13300	12.130	--	1095	--	--	--
86	19.0	11560	12.316	--	--	940	--	--
86	27.4	9700	12.316	--	--	790	--	--
			Average	800	1095	865	33.0	887

2. Grout-Rock Bond*

Drill Hole No.	Depth, Feet	Ultimate Load, lbs	Area Inches^2	Shear Strength, psi Confining Load, psi 10	25	50	100	Angle of Internal Friction, degrees	Cohesion, psi
85	10.8	840	4.486	185	--	--	--	--	--
85	19.5	1160	4.449	--	260	--	--	--	--
85	26.1	900	4.486	--	--	200	--	--	--
86	27.8	3250	12.629	--	--	--	--	--	--
86	16.1	2050	12.629	255	160	--	--	--	--
86	15.7	3220	12.629	--	--	255	--	--	--
85	13.0	820	4.524	--	--	180	--	--	--
85	12.0	1320	4.524	--	--	--	285	--	--
			Average	220	210	210	285	38.2	195

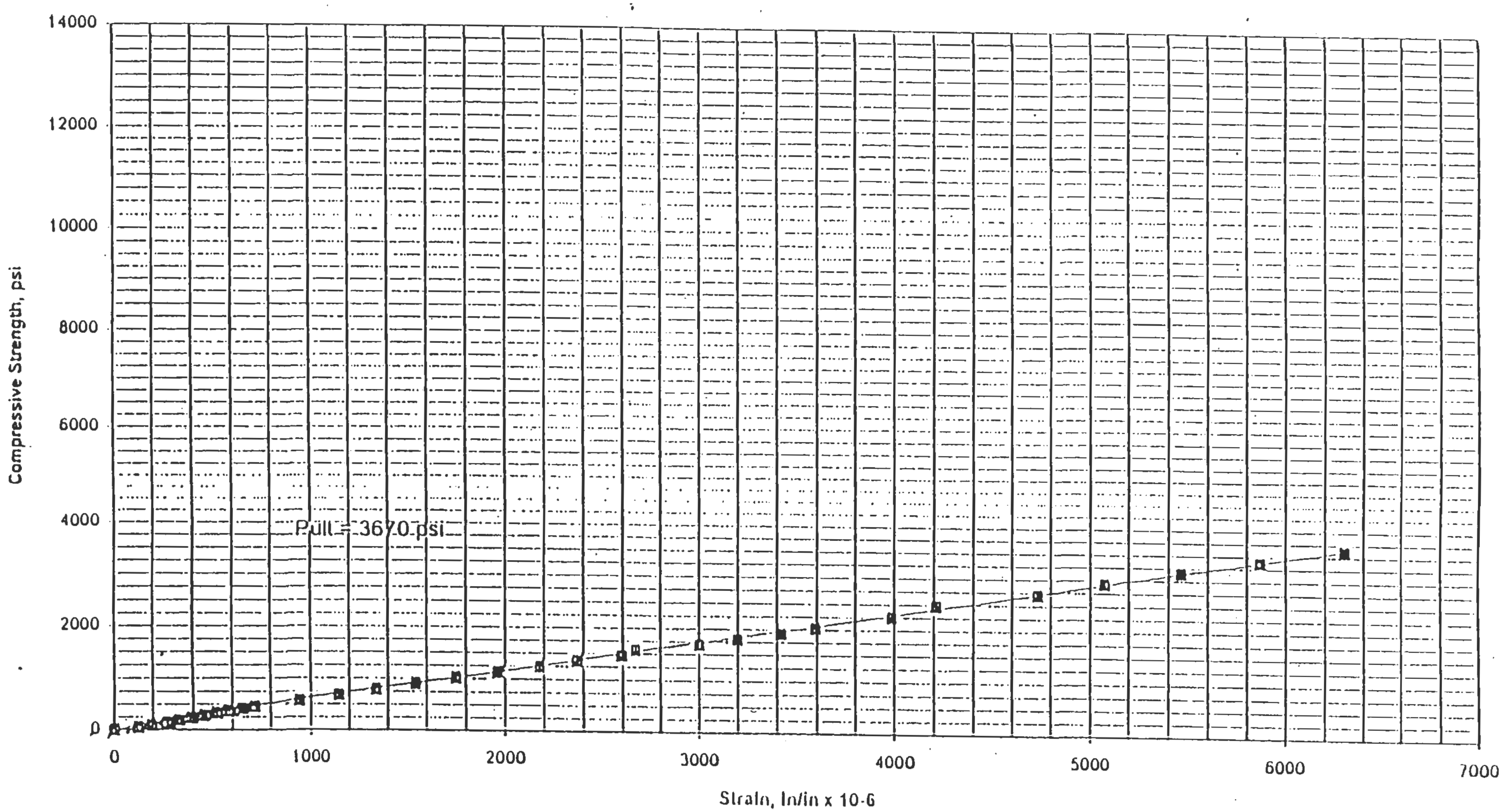
*Grout/rock biaxial direct shear tests made at grout age 7-days. All tests made in accordance with Rock Testing Handbook Method 203. Compressive Strength of Neat Cement Grout Cubes as follows:

Test Age, days	Compressive Strength, psi
4	4530
7	5490
28	9140

Grout batched with laboratory blend Type II cement at a water:cement ratio of 0.42, and 22.4 second flow.

Figure I

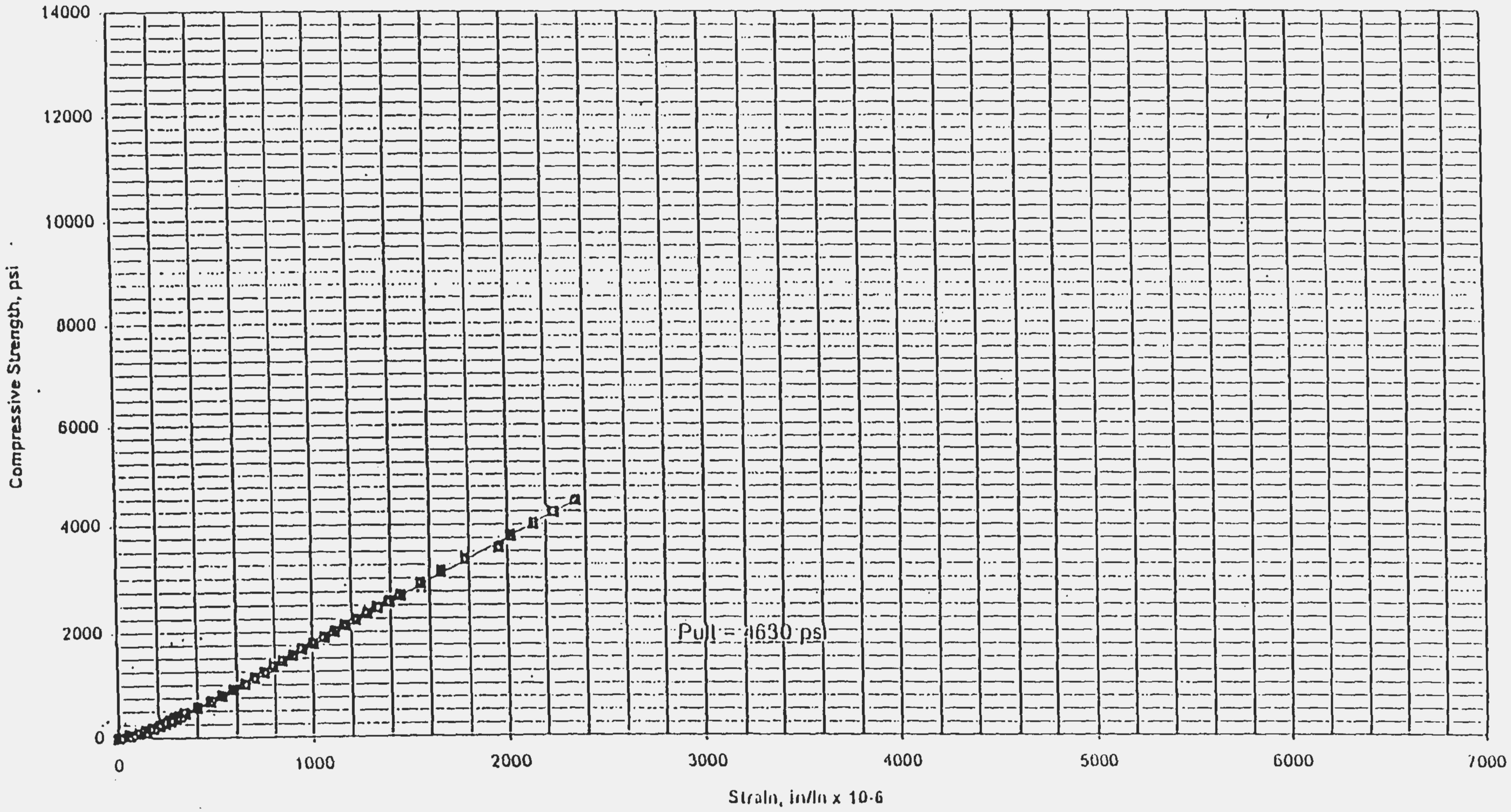
Unconfined Compressive Strength versus Strain
Nominal 2-inch Diameter Rock Core
Drill Hole No. 94-DD-85, Depth 6.5'-6.8'



CX-20

Figure II

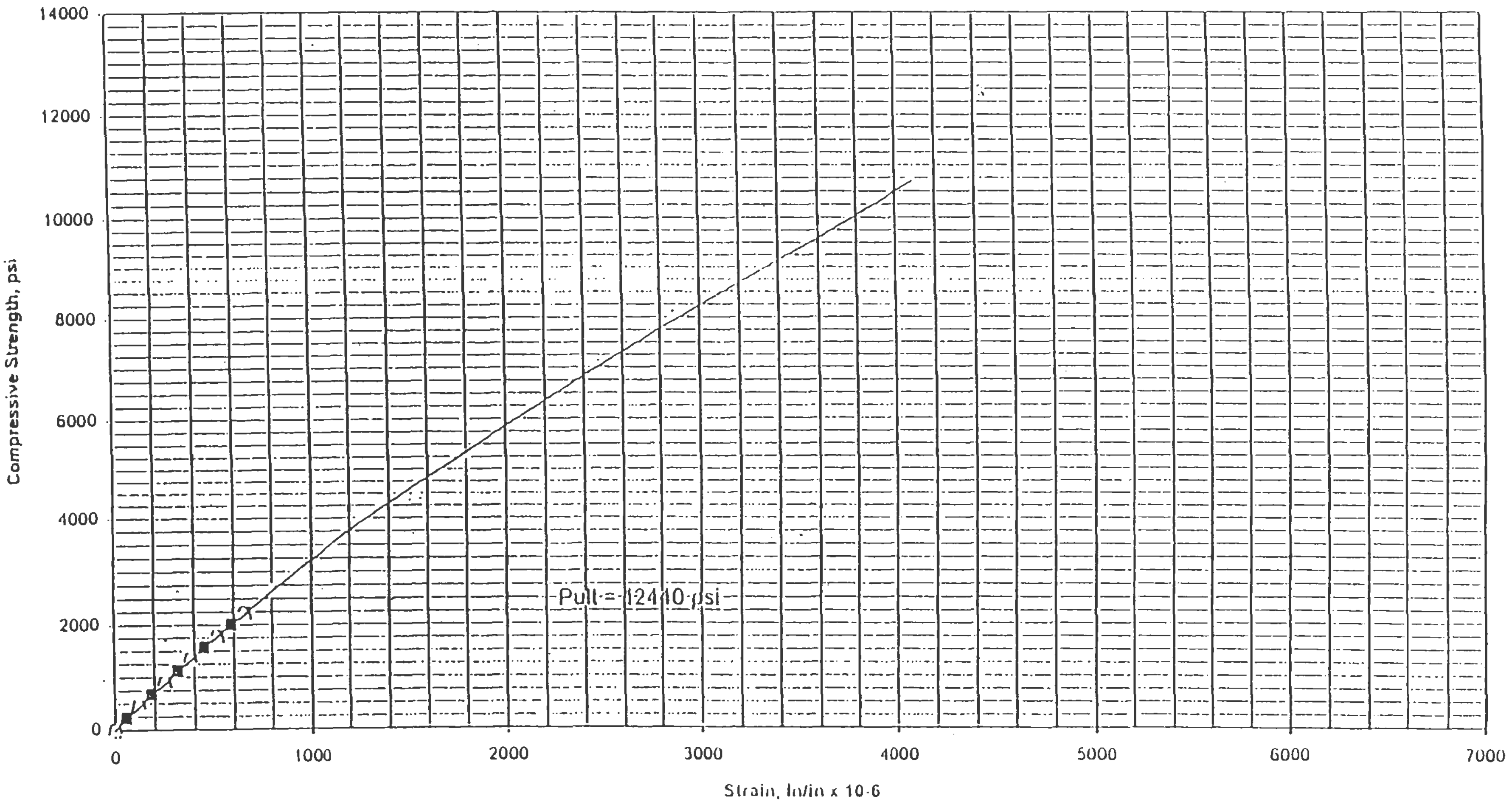
Unconfined Compressive Strength versus Strain
Nominal 2-inch Diameter Rock Core
Drill Hole No. 95-DD-95, Depth 13.6'-13.9'



HOWARD HANSEN DAM INTAKE TOWER

Figure III

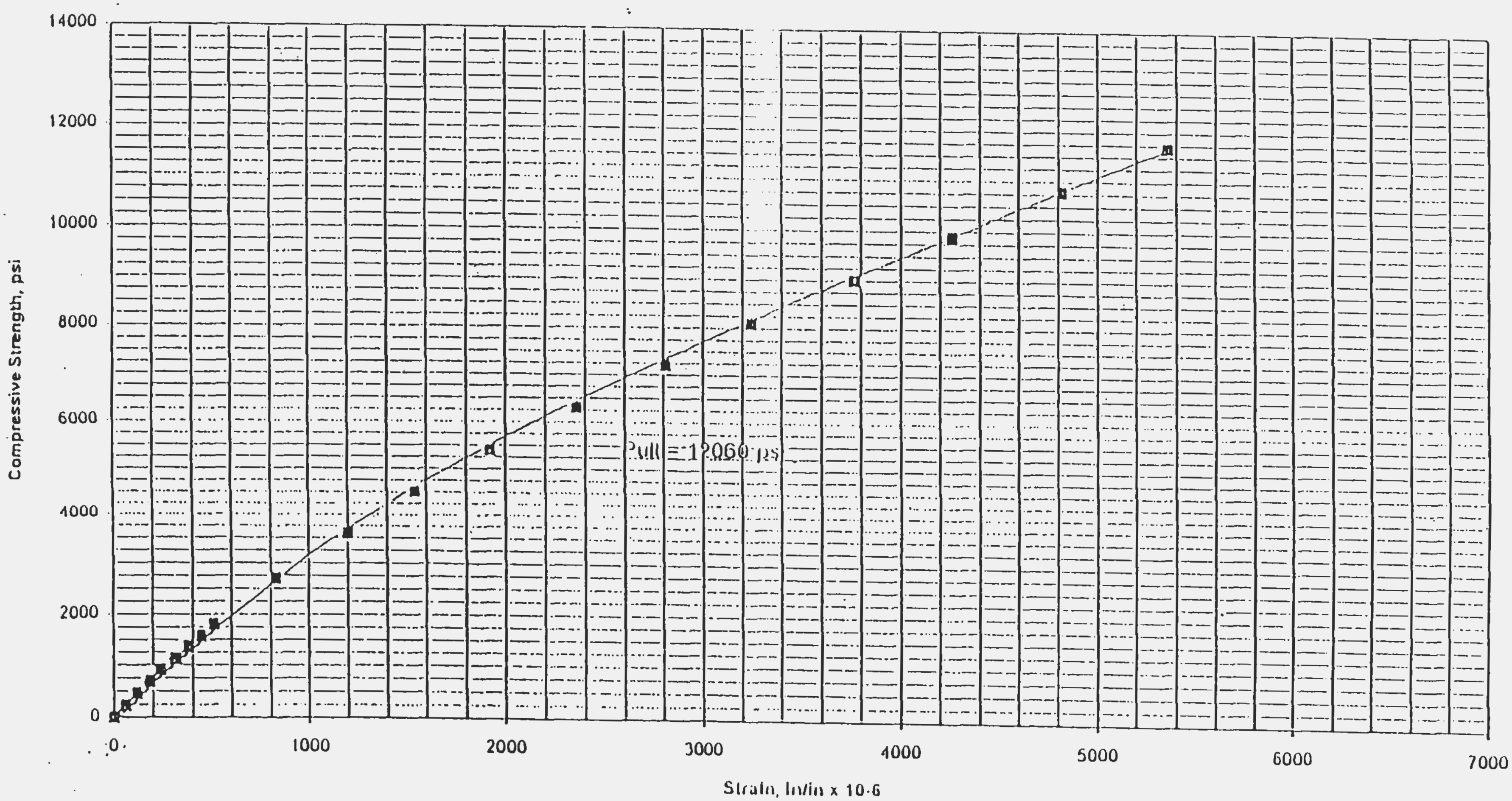
Unconfined Compressive Strength versus Strain
Nominal 2-inch Diameter Rock Core
Drill Hole No. 94-DD-85, Depth 24.7'-25.0'



HOWARD HANSEN DAM INTAKE TOWER

Figure IV

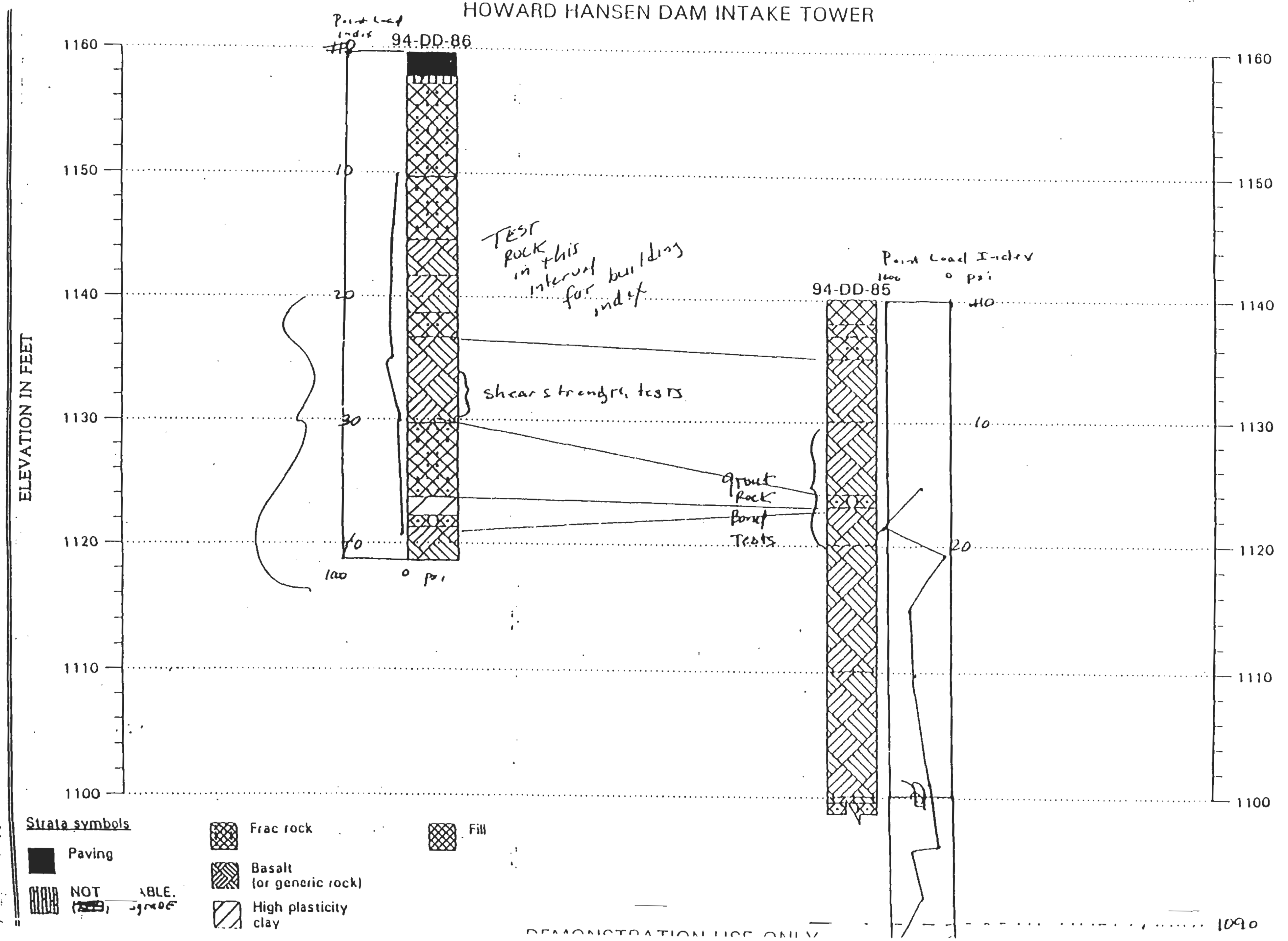
Unconfined Compressive Strength versus Strain
Nominal 2-Inch Diameter Rock Core
Drill Hole No. 95-DD-85, Depth 25.0'-25.3'



DX-2

Figure IV

LOG OF BORINGS
HOWARD HANSEN DAM INTAKE TOWER



Test rock in this interval for building index

shear strength tests

Grout Rock Bond Tests

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION LABORATORY
CORPS OF ENGINEERS
1491 N.W. GRAHAM AVENUE
TROUTDALE, OREGON 97060-9503

CENPD-PE-GE-L (1110 - 1 - 8100c) July 13, 1994

MEMORANDUM FOR Commander, Seattle District, ATTN: CENPS-EN-GT-GE (Eckerlin)

SUBJECT: W.O. # 94-314, Report of Tests on Foundation Rock Cores.

Project: Howard Hanson Dam Fish Passage Study
Intended Use: Foundation Investigation
Source of Material: Left abutment of Howard Hanson Dam

Submitted by: CENPS-EN-GT-GE
Date Sampled: ------ Date Received: 4 May 94
Method of Test or Specification: ASTM, Rock Testing Handbook (WES)
Reference: a) MIPR No. E86-94-3101 dated 4 May 94
b) NPD Form 300, Transmittal of Rock Cores, dated 18 Apr 94
c) Telecon 14 Apr 94 with Mr. Rick Eckerlin wherein test program was discussed.

1. Attached is report of tests on foundation rock cores from the above source.

2. This completes all work requested.

Timothy J. Seeman

TIMOTHY J. SEEMAN
Director

Enclosures

Copy Furnished: CENPD-PE-GE

CENPD-PE-GE-L (94-314)

HOWARD HANSON DAM FISH PASSAGE STUDY
Report of Tests on Foundation Rock Cores

CENPS Sample No.	Rock Type	Depth 1/ ft.	Moisture 2/ Content, %	Specific Gravity	Absorption %	Unit Weight pcf	Unconfined 3/ Compressive Strength, psi
94-DD-80	Andesite Breccia	139.3	1.1	2.42	6.6	150.8	5410
94-DD-81A	Andesite Breccia	175.2	0.9	2.61	2.0	162.6	8790
94-DD-81B	Andesite	187.5	2.0	2.65	1.6	165.1	9170
94-DD-82A	Andesite Breccia	179.9	0.5	2.59	2.1	161.4	21920
94-DD-83A	Andesite Breccia	147.5	0.5	2.42	6.1	150.8	13510
94-DD-83B	Andesite Breccia	150.2	0.5	2.39	6.5	148.9	8900
94-DD-84A	Andesite Breccia	35.0	0.4	2.72	0.8	169.5	18010
94-DD-84B	Andesite Breccia	53.1	0.8	2.76	0.9	171.9	8320

1/ Depth to top of core.
2/ Moisture content at time of unconfined compressive strength test.
3/ Compressive Strength corrected in accordance with ASTM D-2938 for cores with length to diameter ratio of less than 2.

CENPDL No. 4936 Received 4 May 94

EXHIBIT D

EVALUATED ALTERNATIVE SITES

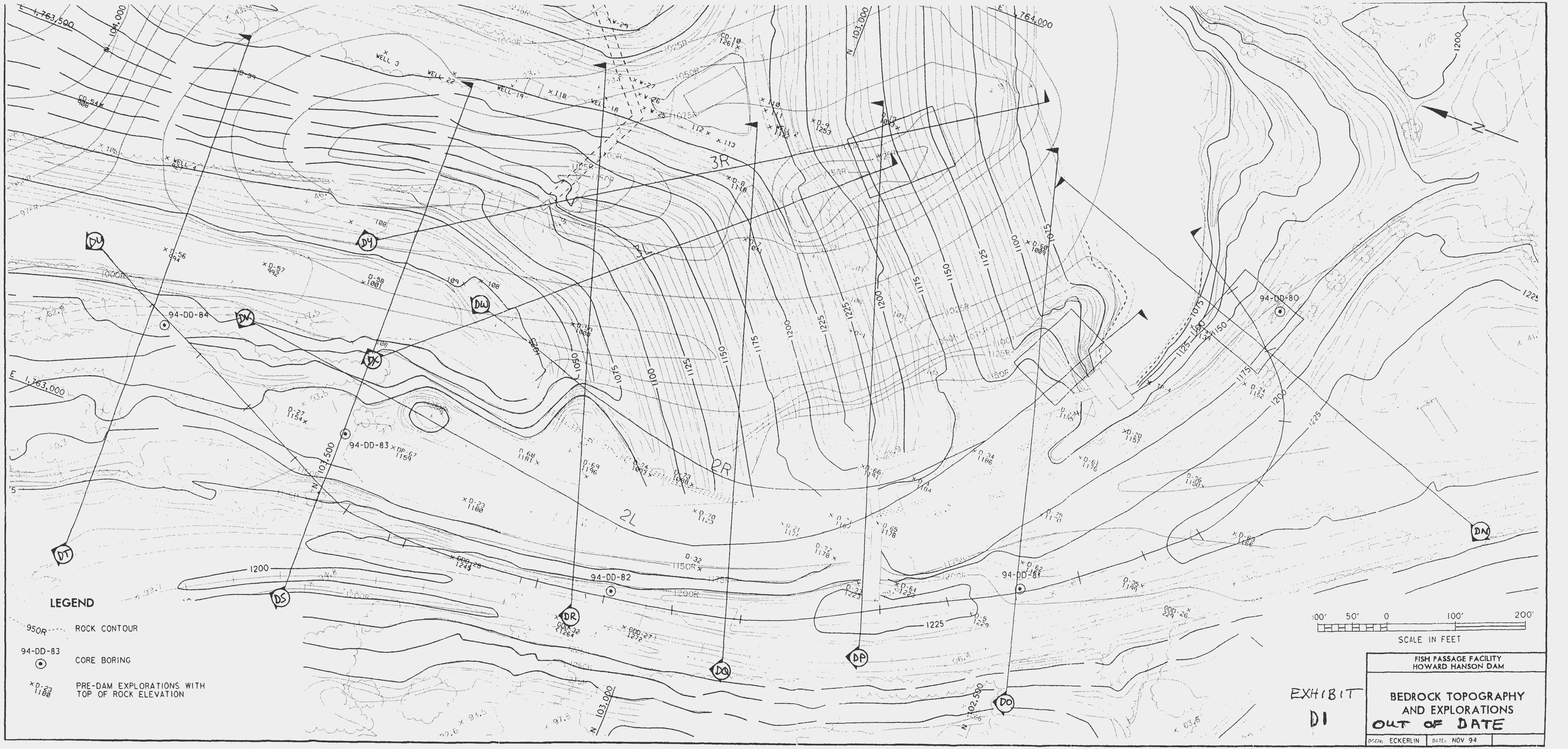


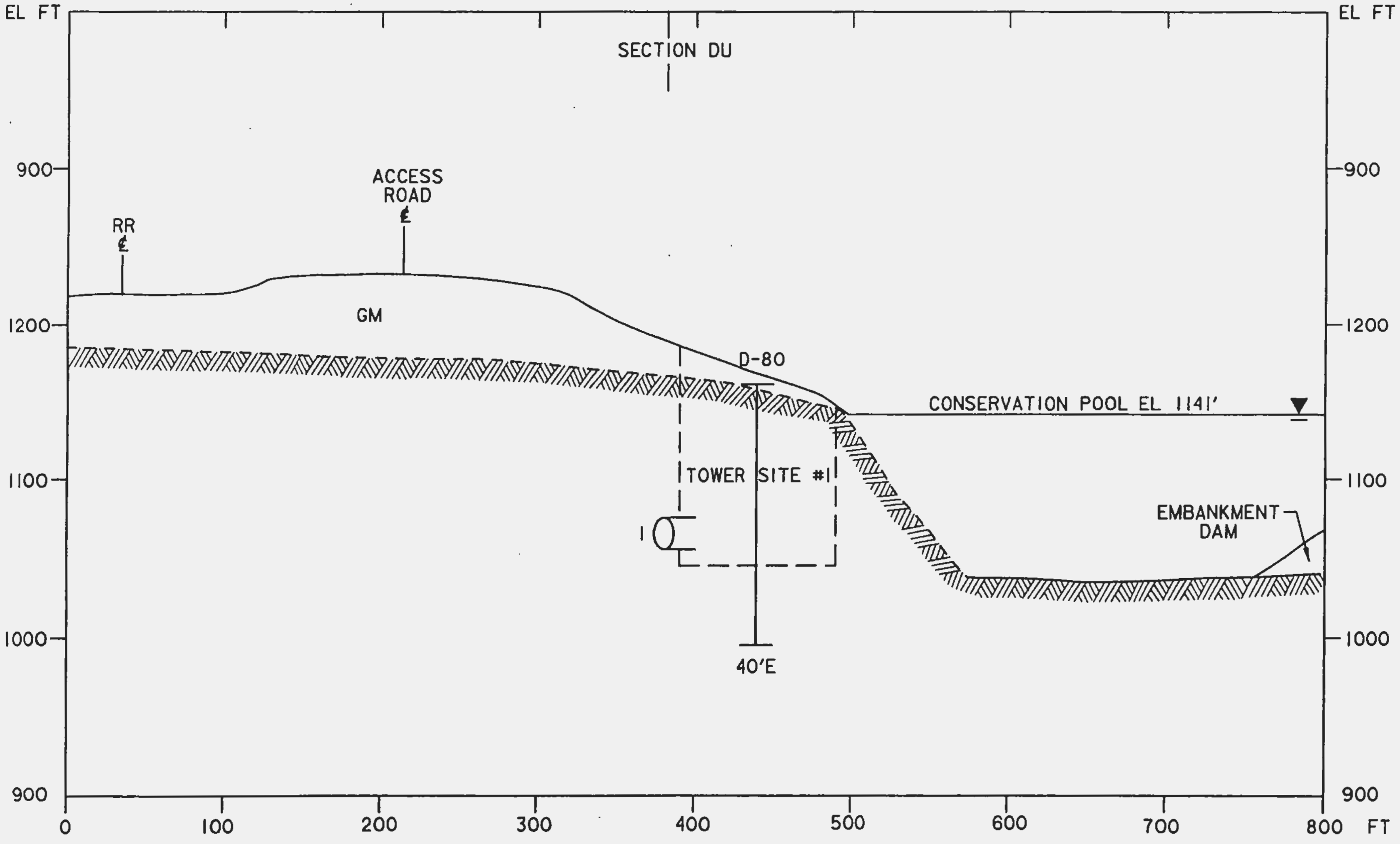
EXHIBIT
D1

FISH PASSAGE FACILITY
HOWARD HANSON DAM

BEDROCK TOPOGRAPHY
AND EXPLORATIONS

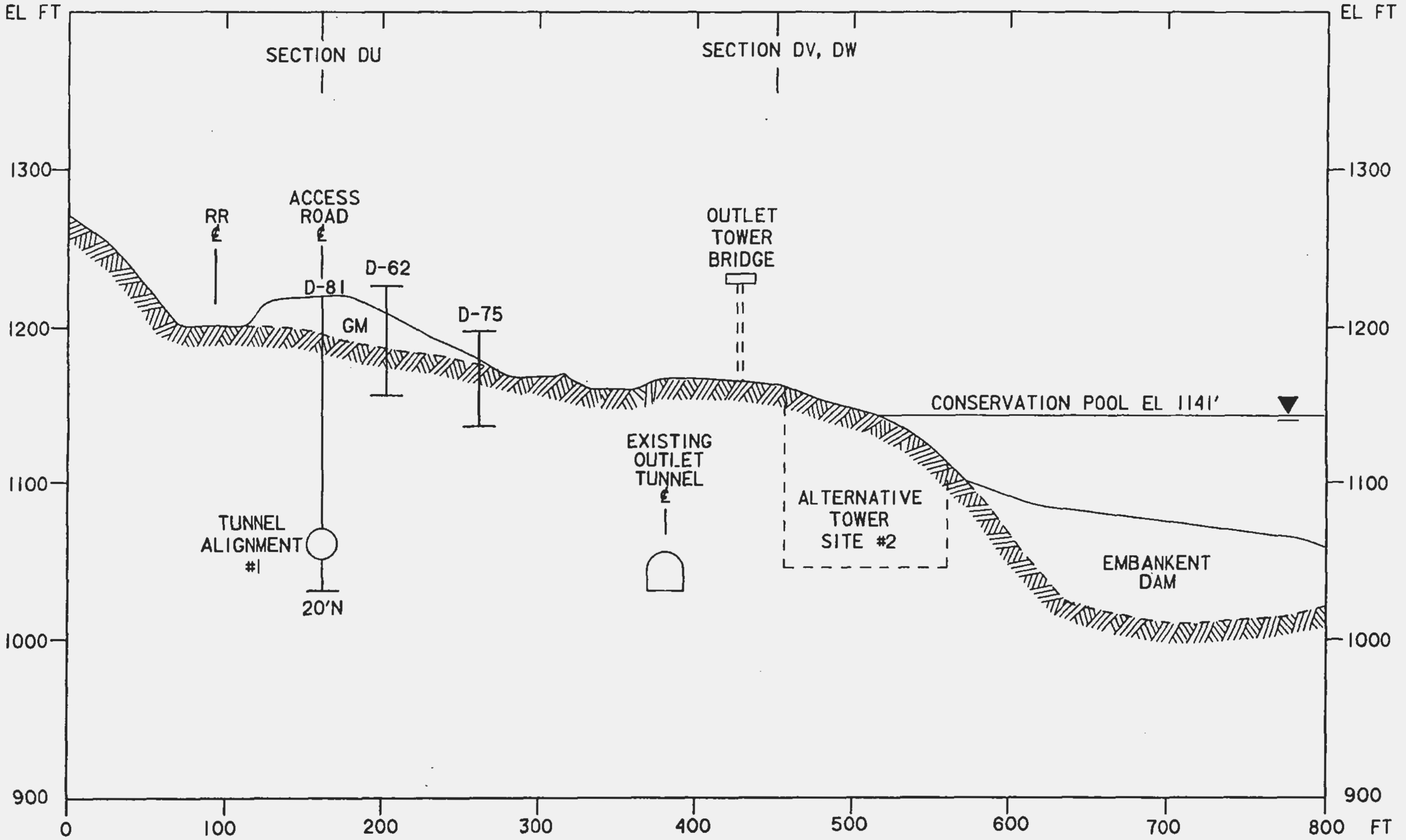
OUT OF DATE

DSGN: ECKERLIN | DATE: NOV 94



SECTION DN
DOWNSTREAM VIEW

EXHIBIT D2



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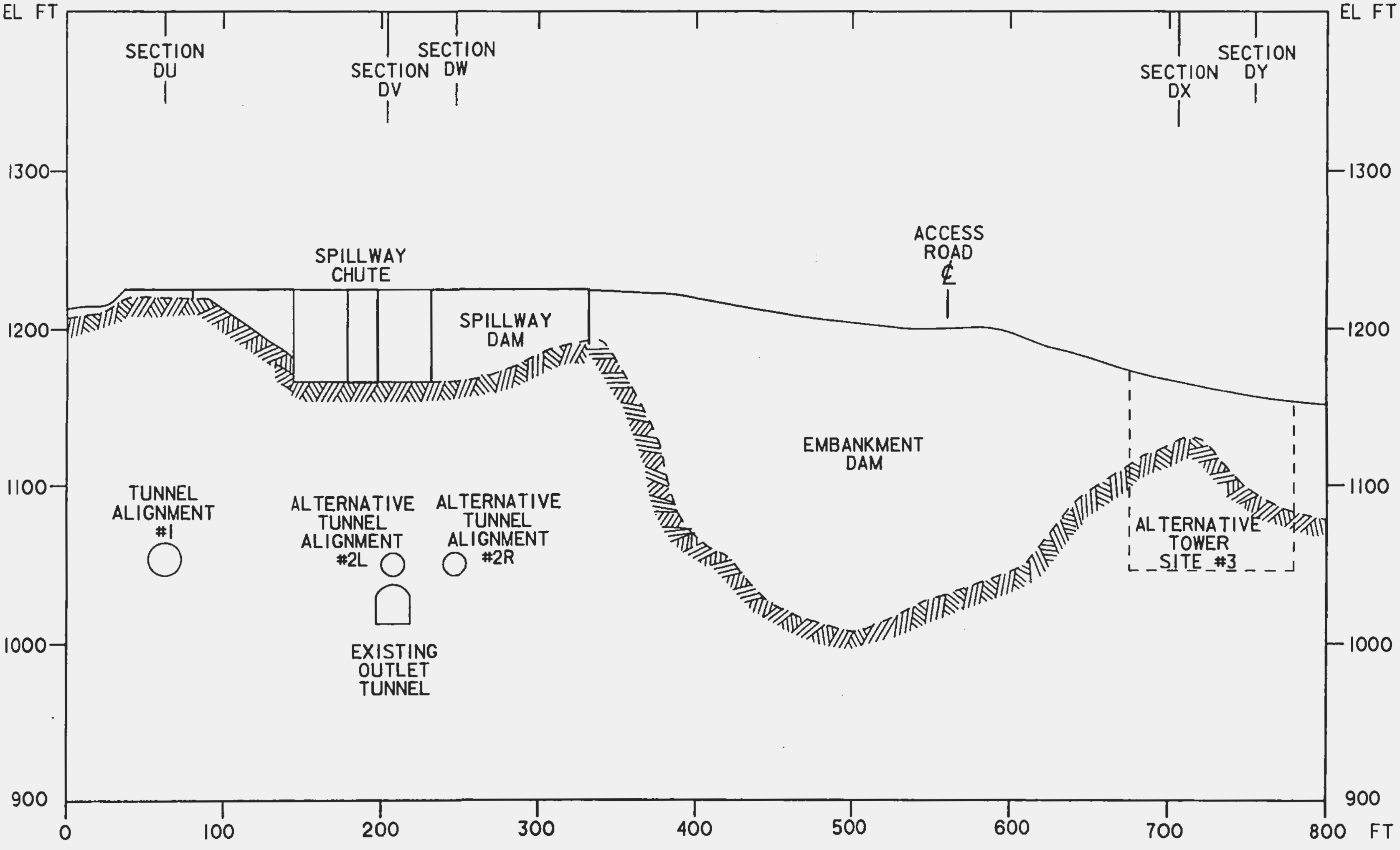
SECTION DO
DOWNSTREAM VIEW

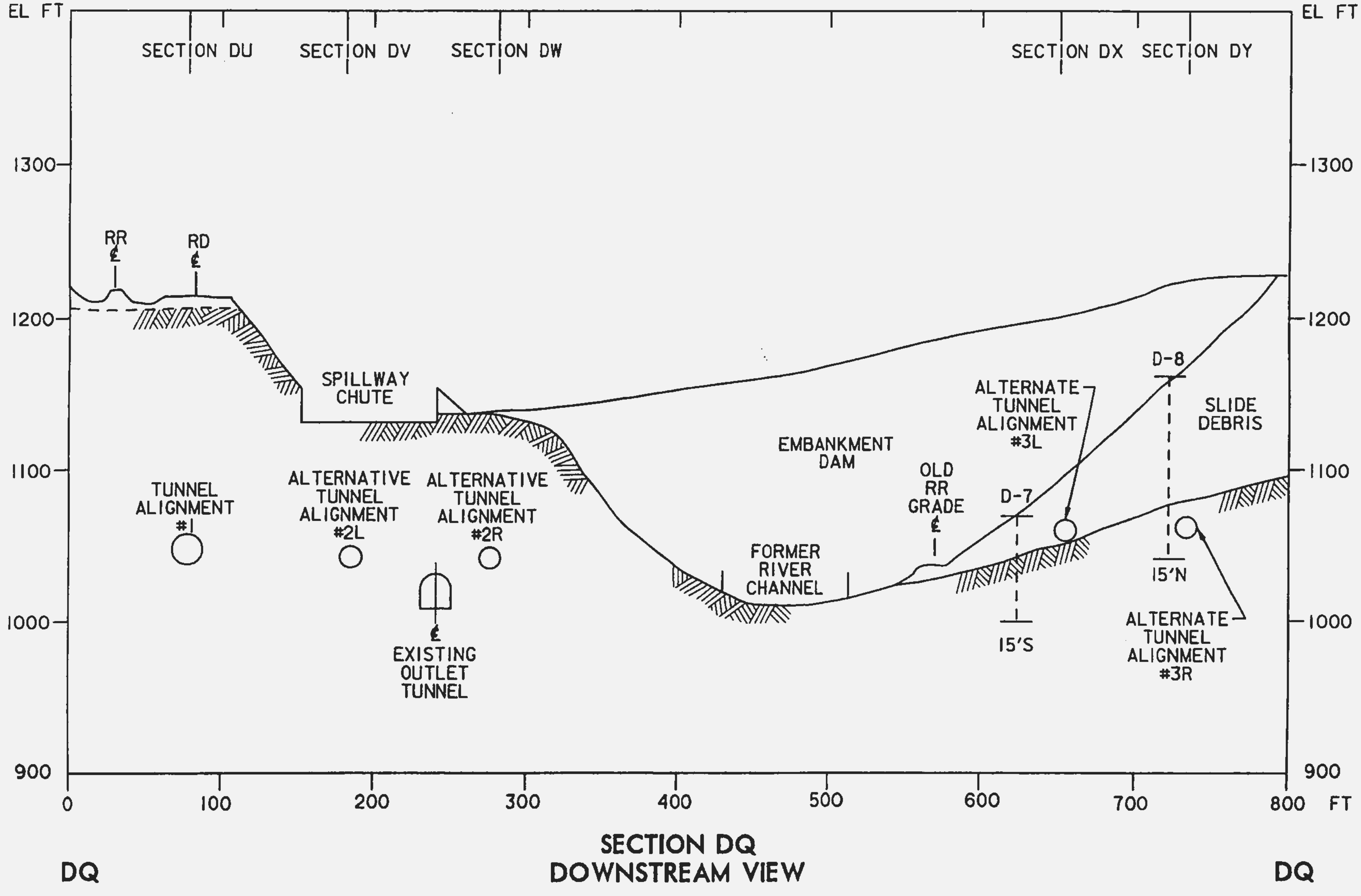
DO

EXHIBIT D3



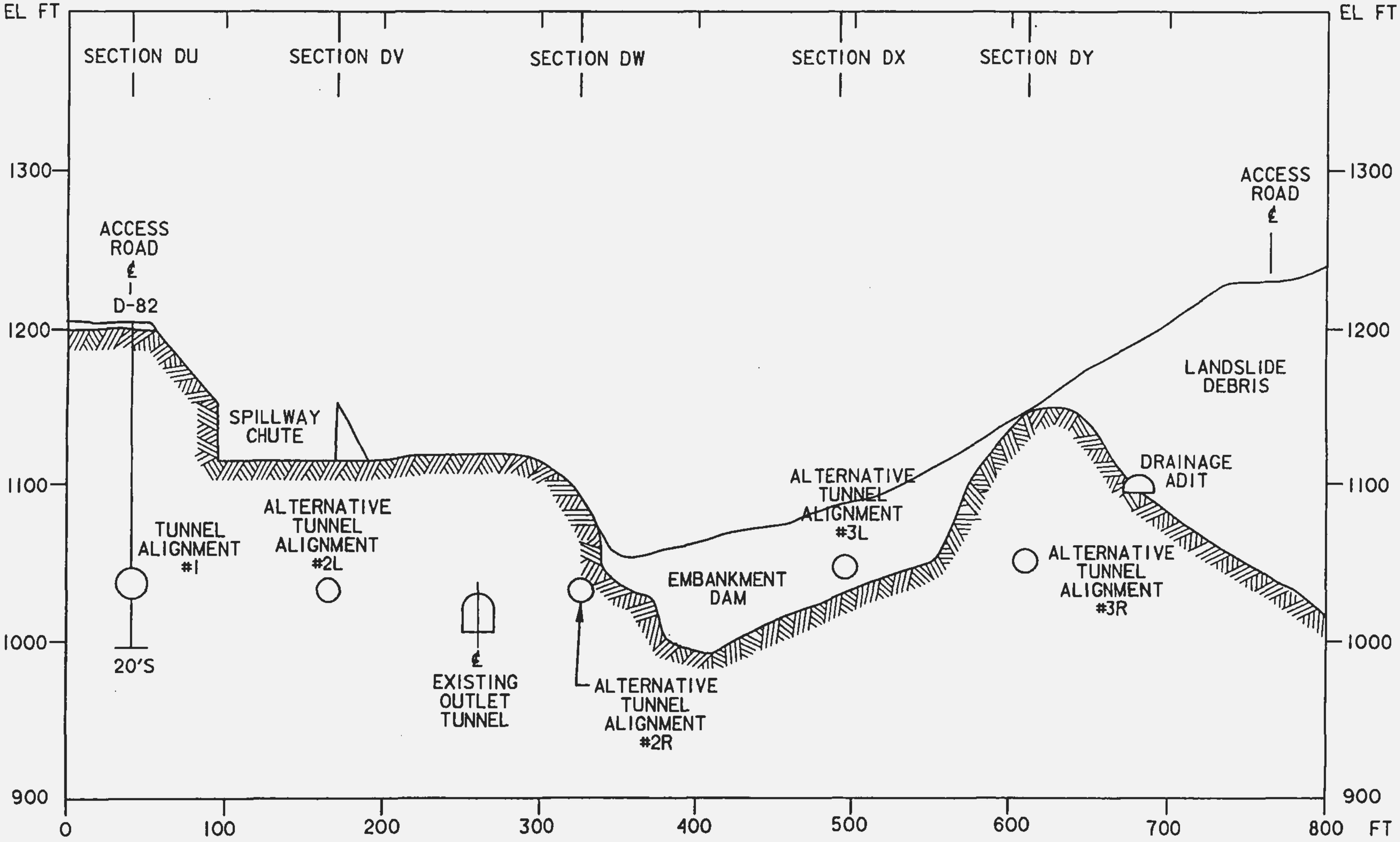
SECTION DP
DOWNSTREAM VIEW

EXHIBIT D4



SECTION DQ
DOWNSTREAM VIEW

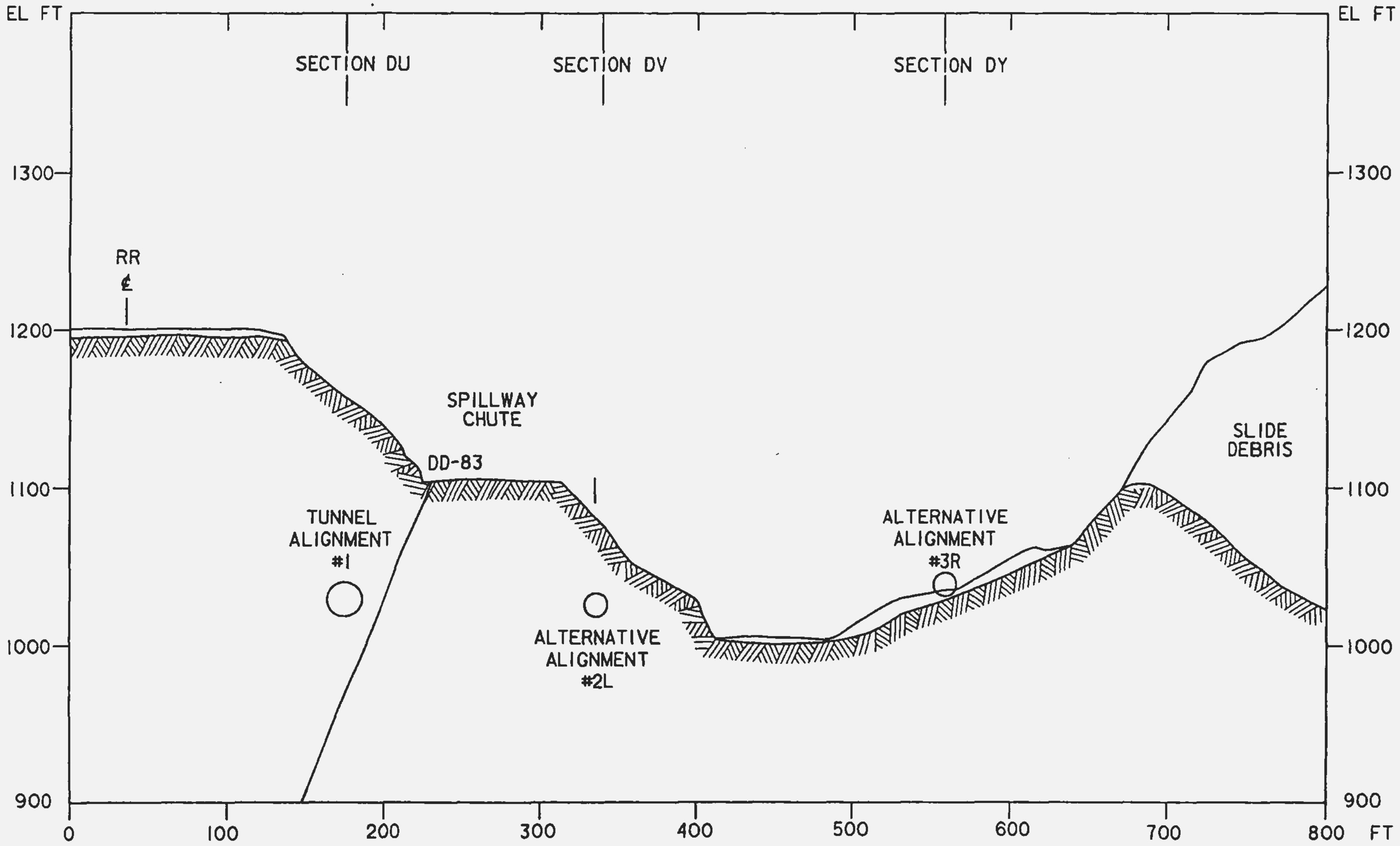
EXHIBIT D5



SECTION DR
DOWNSTREAM VIEW

DR **DR**

EXHIBIT D6

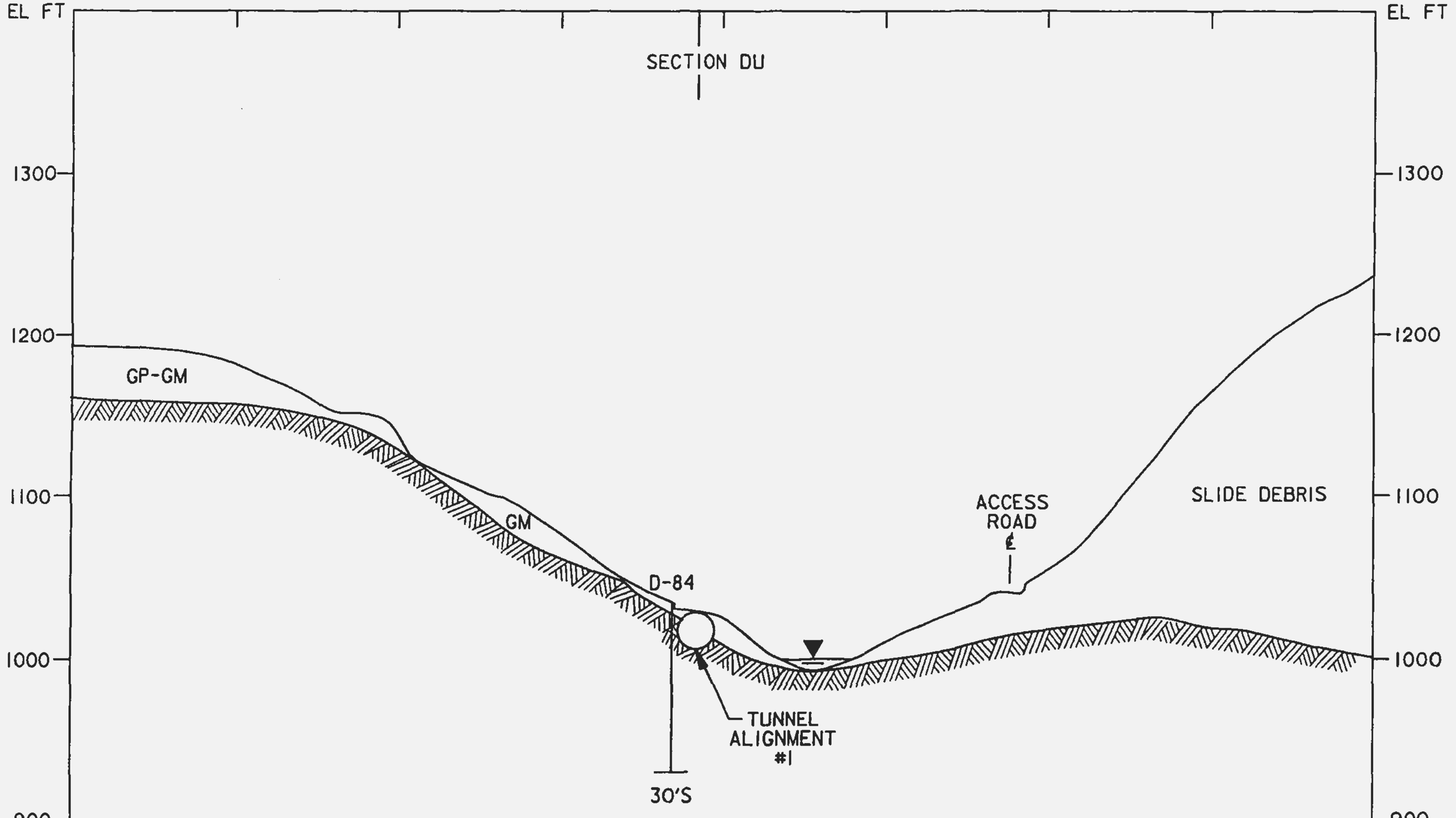


SECTION DS
DOWNSTREAM VIEW

DS

DS

EXHIBIT D7

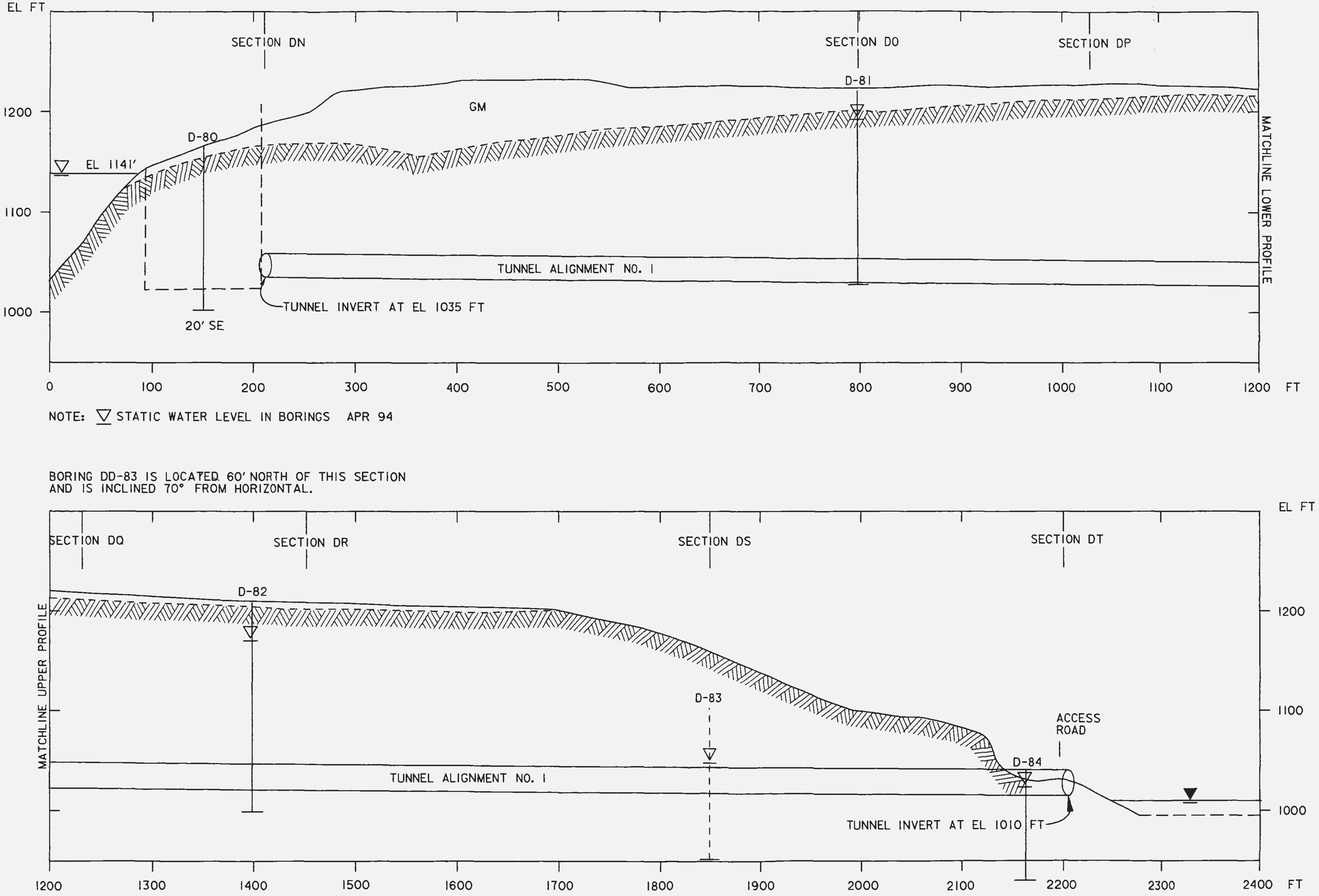


SECTION DT
DOWNSTREAM VIEW

DT

DT

EXHIBIT D8



NOTE: ▽ STATIC WATER LEVEL IN BORINGS APR 94

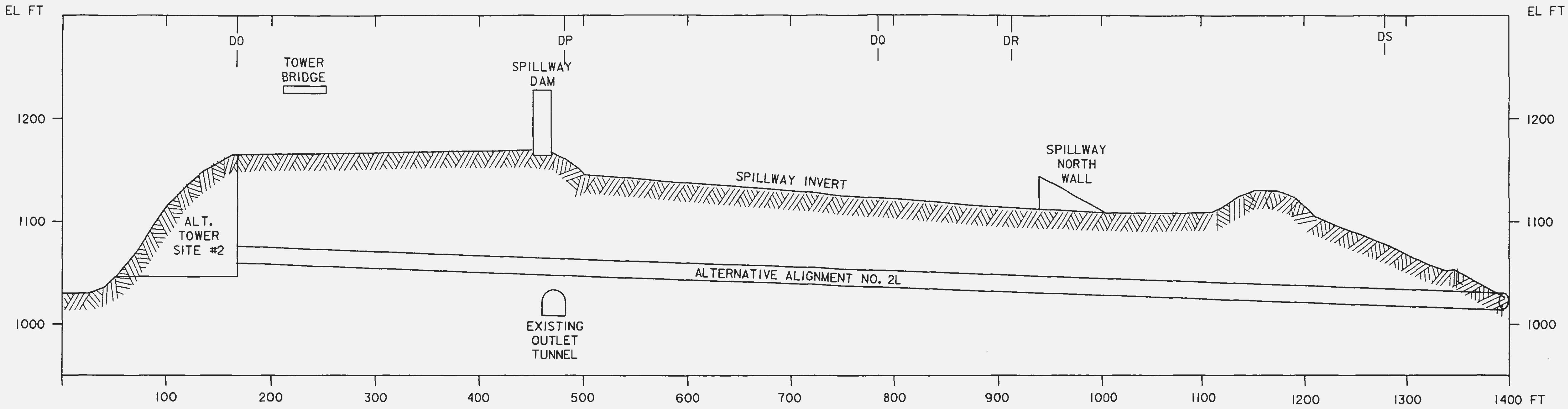
BORING DD-83 IS LOCATED 60' NORTH OF THIS SECTION
AND IS INCLINED 70° FROM HORIZONTAL.

DU SECTION DU **DU**
SOUTH ABUTMENT VIEW

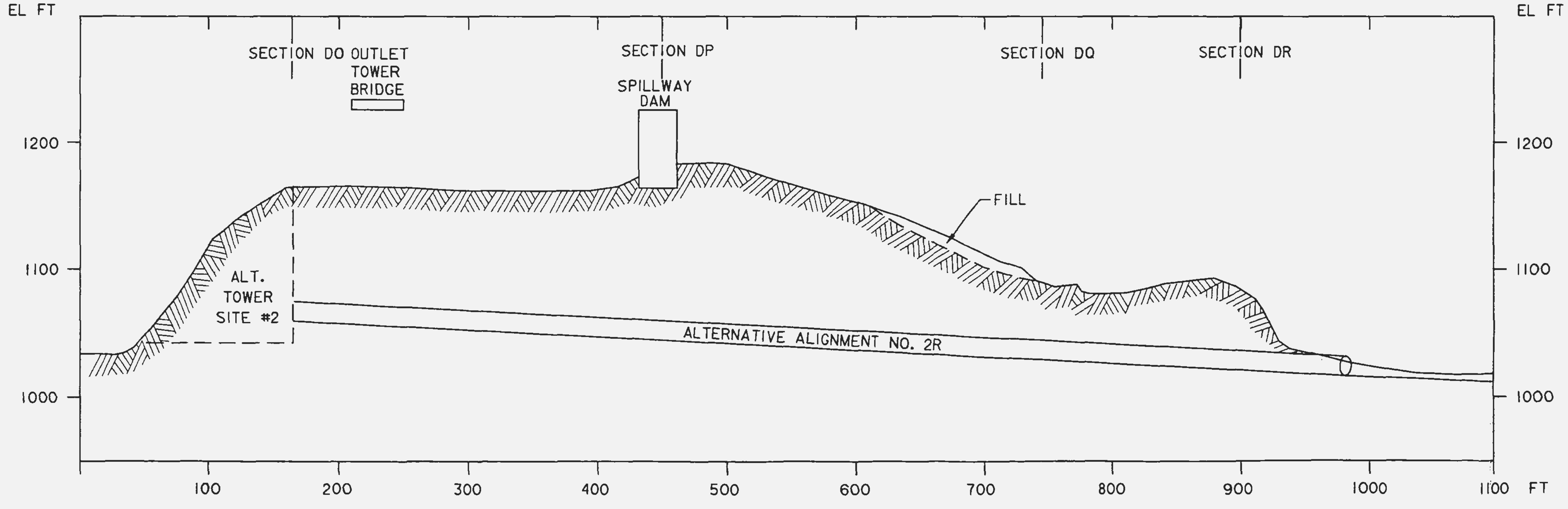
FISH PASSAGE FACILITY
HOWARD HANSON DAM

GEOLOGIC SECTION DU
TUNNEL ALIGNMENT NO. 1

DSGN: ECKERLIN | DATE: 94 NOV 4 | EXHIBIT D9



SECTION DV
SOUTH ABUTMENT VIEW

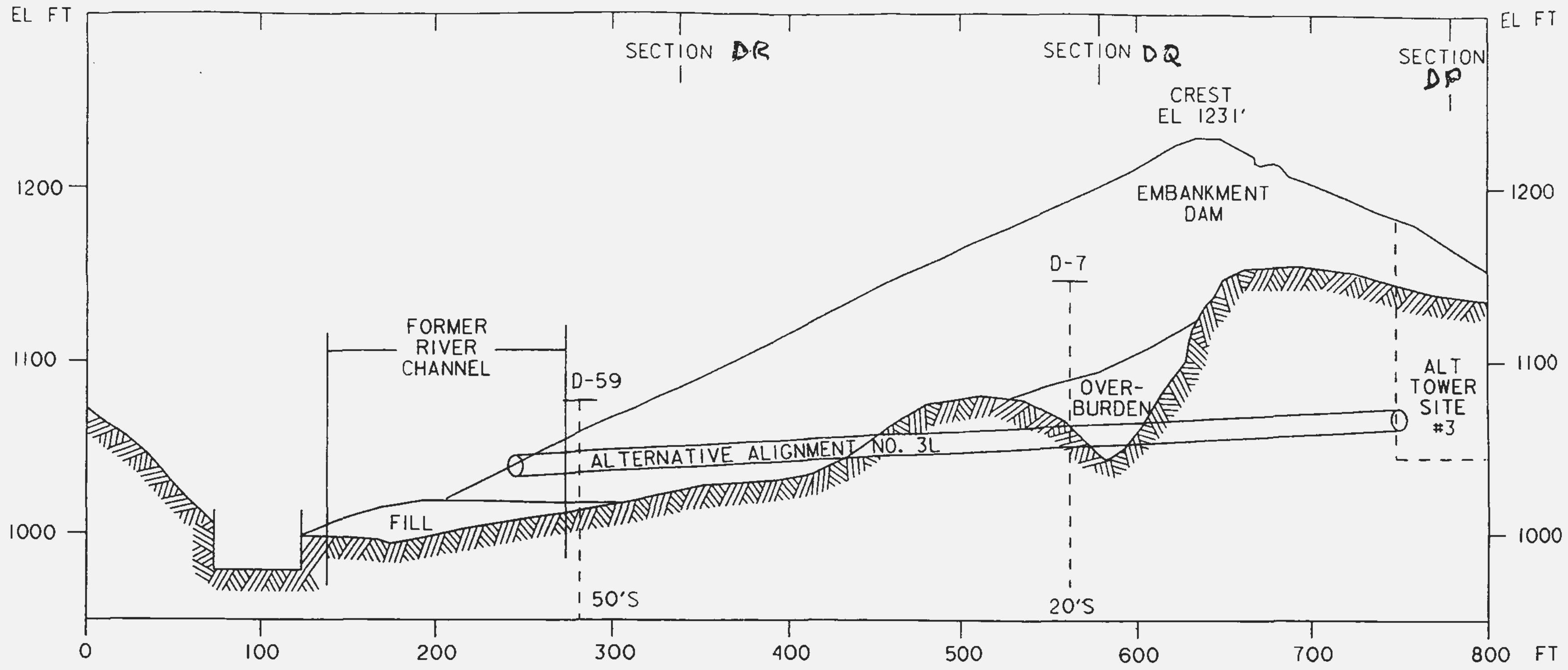


SECTION DW
SOUTH ABUTMENT VIEW

FISH PASSAGE FACILITY
HOWARD HANSON DAM

GEOLOGIC SECTIONS DV & DW
TUNNEL ALIGNMENT NO. 2

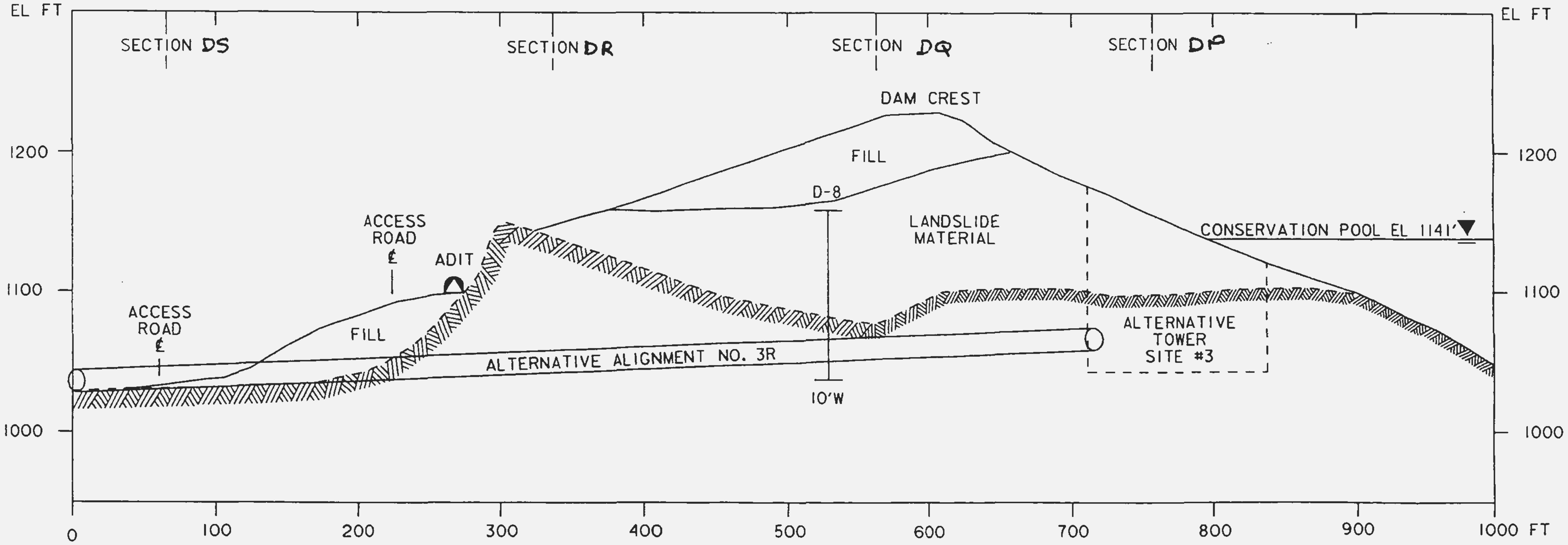
DSGN: ECKERLIN | DATE: NOV 94 | EXHIBIT D10



DX

SECTION DX
NORTH ABUTMENT VIEW

DX.



DY

SECTION DY
NORTH ABUTMENT VIEW

DY

FISH PASSAGE FACILITY
HOWARD HANSON DAM

GEOLOGIC SECTIONS DX & DY
TUNNEL ALIGNMENT NO. 3

EXHIBIT D1

DSGN: ECKERLIN | DATE: NOV 94