**Converse Consultants NW**

**Geotechnical Engineering**
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# SUPPLEMENTAL GEOTECHNICAL DESIGN REPORT

Proposed City of Everett Water Supply
Pipeline No. 2 Rehabilitation Project

Snohomish County, Washington

Two Segments between
Tunnel Portal No. 4 and Panther Creek Screenhouse
(Stations 141+80 to 184+45 and 295+00 to 367+25)

Prepared for:

James M. Montgomery, Consulting Engineers, Inc.

Converse Project No. 87-35205-02

February 2, 1989

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February 2, 1989 87-35205-02

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Project Manager

Subject: **SUPPLEMENTAL GEOTECHNICAL DESIGN REPORT**
Proposed City of Everett Water Supply Pipeline No. 2
Rehabilitation Project
Two Segments between Tunnel Portal No. 4 and
Panther Creek Screenhouse
(Stations 141+80 to 184+45 and 295+00 to 367+25)
Snohomish County, Washington

Enclosed is our supplemental geotechnical report for the referenced project. This report presents the results of our field explorations and laboratory testing, provides geotechnical recommendations for design of the project, and discusses construction considerations as related to the geotechnical aspects of the project. This report supplements our preliminary geotechnical report of November 1, 1988, entitled, "Geotechnical Evaluation - Proposed City of Everett Water Supply Pipeline No. 2 Rehabilitation" for the two sections of pipeline referenced above. The recommendations in this report supersede our preliminary recommendations for the same sections as presented in our previous report. A draft report was presented to you on December 14, 1988. The recommendations in this report supersede our draft report.

We appreciate the opportunity to be of service to you on this project. If you have any questions, or if we can be of additional assistance, please contact us.

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Principal Engineer

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## 1.0 INTRODUCTION AND SCOPE OF WORK

This report summarizes the results of our geotechnical explorations and design recommendations for the proposed rehabilitation of the City of Everett's Water Supply Pipeline No. 2 from station 141+80 to 184+45 (designated herein as eastern alignment section) and station 295+00 to 367+25 (designated herein as western alignment section). These segments of the alignment are located between Tunnel Portal No. 4 and the Panther Creek Screenhouse. The purpose of our work was to explore the subsurface conditions at the site, provide geotechnical engineering recommendations to aid in design, and discuss geotechnical related construction aspects of the project. This report supplements our preliminary report of November 1, 1988, entitled, "Geotechnical Evaluation - Proposed City of Everett Water Supply Pipeline No. 2 Rehabilitation" for the stations referenced above. However, the recommendations in this report supersede our preliminary recommendations as presented in our previous report. This report supersedes our draft report dated December 14, 1988.

Converse Consultants NW (Converse) was retained by James M. Montgomery, Consulting Engineers, Inc. (JMM) to perform the following work:

- Review available information compiled during our preliminary geologic reconnaissance along the referenced sections of the alignment and any additional information obtained from the City of Everett.

- Explore the subsurface conditions along the alignment by excavating between 8 and 12 test pits at selected locations to a minimum of 10 feet below the existing ground surface or to a depth of at least three feet below the existing pipeline No. 2 invert.

- Perform laboratory tests on soil samples obtained in the field to determine soil moisture contents, liquid and plastic Atterberg limits of cohesive samples, grain size distributions for cohesionless soils, and optimum moisture to maximum dry density relationships as defined by ASTM D-1557 (Modified Proctor).

- Provide geotechnical engineering recommendations for pipeline excavation, bedding, backfill and compaction methods, including the suitability for reusing excavated soils as backfill; estimate anticipated settlements for both the replacement pipeline and the existing pipelines on each side of the pipe to be replaced; estimate the difficulty of trench excavation; provide temporary surcharge loads due to traffic and stockpiled materials; discuss the limitations of open cut excavations, appropriate earth pressure parameters for temporary shoring design, and possible impacts of excavation on the adjacent pipelines; discuss the necessity of temporary trench dewatering; and provide soil parameters for design of thrust restraint with the use of restrained joint pipe.

- Prepare and submit three draft copies and five final copies of our report which presents our conclusions and recommendations. The report includes a site plan with field exploration locations, test pit logs, and laboratory test results.

Our work was performed in accordance with our proposal dated November 21, 1988 and our subcontract agreement with JMM dated November 29, 1988.

## 2.0 EXECUTIVE SUMMARY

The following presents a summary of our principal findings and recommendations. The subsequent sections of the report should be consulted for discussion of each point, as well as for other recommendations.

- Subsurface conditions along the eastern segment of the alignment (station 141+80 to 184+45) generally consisted of a thin layer of topsoil underlain by alluvial soils to depths of 6 to at least 15 feet (exploration termination depths) underlain by glacial till. Along the western segment of the alignment (station 295+00 to 367+25) subsurface conditions in our explorations consisted of a thin layer of topsoil, occasionally overlying up to 3.5 feet of fill, overlying glacial till deposits or glacial lacustrine sediments.

- Construction dewatering will likely be required throughout a majority of the design sections of the project, although the level of effort needed will be varied along the alignment. Significant inflows are expected along most of the alignment between station 141+80 to 184+45. Along this eastern portion of the alignment, we anticipate that dewatering can be accomplished with the use of either wells or wellpoints. Seepage is expected to be less severe between station 295+00 to 367+25. Along this western segment of the alignment, cutoff drains and sump pumping from within the excavation may be possible.

- It is anticipated that the soils observed in the test pits may be excavated in a trench configuration using conventional equipment such as rubber-tire backhoes or tracked hydraulic excavators. However, excavation may be slow and difficult where excavations along the same alignment extend to depths greater than the existing No. 2 pipeline or meander off of the existing alignment and extend into the unweathered glacial till and lacustrine soils.

- A movable trench shoring system (trench box) or sloped excavations will most likely be used for shallow excavations in which fill and alluvial soils are not very deep. For deeper excavations or for excavations in loose and soft fills and alluvium, shoring may be required.

- Based on the explorations performed along the alignment, it is our opinion that, in general, the natural soils expected to be encountered at the invert elevations will provide adequate foundation support. Exceptions to this may be at creek crossings and at select locations along the initial section of the alignment where soft and loose alluvium may be encountered.

- Soil from the trench excavation may be used as subsequent backfill provided that the moisture content of the soil is carefully controlled to allow proper compaction. Materials which will not likely be able to be reused without extensive moisture conditioning are the alluvial soils and the cohesive lacustrine sediments which had natural moisture contents which were well above the optimum moisture content for compaction.

- We estimate that only nominal settlements of the new pipeline will occur if good construction procedures are followed. Settlements of the existing No. 3 and No. 4 pipelines is anticipated to be small for the soils observed in the explorations.

- Construction of the proposed pipeline will have some impact on the adjacent existing pipelines, drainage features, existing roads and utilities, and private properties bordering the alignment. Such impacts involve those created by dewatering and excavations.

## 3.0 PROJECT DESCRIPTION

The proposed project consists of the replacement of sections of the existing City of Everett Water Supply Pipeline No. 2 which supplies water from Lake Chaplain (located about seven miles north of Sultan, Washington) to the City of Everett. The current phase of the rehabilitation program is for two sections of the alignment located between Tunnel Portal No. 4 (station 0+00) and the Panther Creek Screenhouse (station 385+53); from station 141+80 to 184+45 and station 295+00 to 367+25. In addition to the No. 2 pipeline, two additional pipelines are located within the same easement and are used for the same purpose. The No. 3 pipeline is located to the north and the No. 4 pipeline is located to the south of the No. 2 pipeline. Figure 1 shows the alignment of the No. 2 pipeline at the referenced sections of the alignment.

We understand that the existing No. 2 pipeline along the referenced sections of the alignment is a 52-inch diameter woodstave pipe that was constructed during the 1920's. The pipeline has required substantial repairs of leaks and breaks in its recent life, necessitating rehabilitation or replacement. Where substantial repairs have been required, the woodstave pipe has been replaced with welded steel pipe or repaired with steel plate.

Except at one location along the study area where the pipeline is supported by a trestle structure (at a creek crossing at station 362+00), the pipeline is buried. The creek crossing at this location will be filled and a culvert placed beneath the new pipeline such that all of the new pipeline will be buried. According to explorations performed by JMM, the top of the existing pipe varies from approximately 1 to 12 feet below the existing ground surface (excluding the creek crossing). The invert of the new pipeline will be located at depths ranging from approximately 7 to 17 feet below the ground surface, generally along the same alignment as the existing pipe. We understand that the final ground surface elevation will be the same as the existing ground elevation except at the trestled creek crossing. At this location, up to 11 feet of fill will be placed to fill in the existing creek. At the

present time, the replacement line is planned to be a 51-inch diameter steel pipe with a mortar lining and coating. Other piping materials may be considered in the final design.

On each side of the No. 2 pipeline are existing 52-inch diameter steel pipelines. The No. 3 pipeline to the north was constructed in the late 1930's and is generally about 20 feet from pipeline No. 2, center to center distance. The No. 4 pipeline to the south was constructed in the early 1960's and is generally spaced 20 feet from pipeline No. 2, center to center distance, except from station 141+80 to about station 168+00 where the pipelines are about 25 feet apart, center to center distance. The invert elevations of the No. 3 and No. 4 pipelines were not known at the time this report was prepared.

Existing information on the layout and profile of the No. 2 pipeline was obtained from a series of sheets prepared by James M. Montgomery, Consulting Engineers, Inc. entitled, "City of Everett - Transmission Line No. 2 Rehabilitation Project". In addition, these sheets provided information on the horizontal distance between the adjacent No. 3 and No. 4 pipelines. Information regarding the grade of the proposed pipeline was obtained through conversations with the staff of JMM.

If there are changes in project design or location, the conclusions and recommendations presented may not be applicable. If changes are made, we request that we be retained to review our conclusions and recommendations and to provide a written modification or verification.

## 4.0 SITE CONDITIONS

Site conditions along the alignment, as observed during a geological reconnaissance on February 1, 1988, were described in our November 1, 1988 report in Section 3.1. This section should be referenced for specific observations of surface conditions.

## 5.0 FIELD EXPLORATION AND LABORATORY TESTING PROGRAMS

Subsurface conditions were explored by excavating 15 test pits. The test pits were excavated to depths ranging from 10 to 15 feet below the existing ground surface on December 1 and 2, 1988. All of the test pits were excavated to the minimum 10-foot depth requirement; however, some of the test pits did not extend to the required depth of three feet below the existing pipe invert because of very hard digging in glacial soil deposits. We were unable to perform any explorations between station 142+00 to 161+00 because wet, marshy ground conditions prohibited equipment access to this area. Approximate locations of the test pits are tabulated on Table 1 below. Soil samples obtained in the field were tested in our laboratory to aid in classifying the soils and to determine pertinent engineering properties. Details and results of the exploration program and laboratory testing are included as Appendix A and Appendix B, respectively, to this report.

TABLE 1

APPROXIMATE EXPLORATION LOCATIONS

| Test Pit* Number | Approximate Right-of-Way Station | Distance From Center of No. 2 Pipeline |
|---|---|---|
| TP-14 | 366+00 | 10 feet left |
| TP-15 | 361+50 | 12 feet right |
| TP-16 | 350+00 | 9 feet left |
| TP-17 | 341+80 | 9 feet left |
| TP-18 | 330+00 | 10 feet left |
| TP-19 | 320+00 | 10 feet left |
| TP-20 | 310+00 | 10 feet left |
| TP-21 | 307+50 | 10 feet right |
| TP-22 | 300+00 | 10 feet left |
| TP-23 | 295+00 | 10 feet left |
| TP-24 | 181+75 | 10 feet left |
| TP-25 | 175+50 | 12 feet left |
| TP-26 | 170+00 | 6 feet left |
| TP-27 | 160+00 | 10 feet left |
| TP-28 | 143+50 | 8 feet left |

*Test pits TP-1 through TP-13 were completed previously for other segments of the alignment

## 6.0 SUBSURFACE CONDITIONS

Regional geology of the site and a general description of the soils along the alignment under consideration were described in Sections 4.1 and 4.2 of our November 1, 1988 report. These sections should be referenced for a detailed discussion. Subsurface conditions, as observed in the explorations performed along the alignment, are described separately in the paragraphs below for station 141+80 to 184+45 and from station 295+00 to 367+25.

### 6.1 Station 141+80 to 184+45

Subsurface conditions as described along this section of the alignment were based on test pits TP-24 through TP-28 and generally consisted of topsoil over alluvium all of which was underlain by glacial till. In particular, about 6 to 12 inches of topsoil was observed in all of the test pits, except for test pit TP-26 which encountered fill soils at the surface. Beneath the topsoil or fill, alluvial deposits were encountered in all of the test pits except for test pit TP-25 which encountered glacial till beneath the topsoil. Alluvial deposits ranged in thickness from 6 feet to at least 15 feet as test pits TP-24 and TP-27 encountered alluvium to the termination depths of 15 feet. Glacial till was observed at depths of 2 to 12 feet below the ground surface in test pits where it was encountered.

Topsoil ranged from very soft to medium stiff silt to loose, silty sand with gravel, organics, and occasional roots and was very moist to wet. The fill which was observed in test pit TP-26 was classified as loose, gravelly silt with occasional roots and was wet.

Alluvial deposits consisted of interbedded clay, silt, sandy silt, sand, silty sand, gravel, and gravelly sand with occasional organic material within the layers. The deposits were wet and ranged in consistency from very soft to stiff and varied in relative density from loose to dense. Generally, the soils graded somewhat stiffer and denser with depth. For the most part, the soils were very soft to medium stiff and loose to

medium dense. Extensive caving was noted in test pits TP-27 and TP-28 in the alluvial deposits. Alluvium is expected to be present along a majority of this section of the alignment.

Glacial till was generally classified as very dense, silty sand with gravel, although occasional zones of very dense sand with trace silt were observed. In addition, occasional cobbles were observed to 12 inches in diameter. The silt content (percentage passing No. 200 sieve, U.S. standard sieve size) was about 30 to 35 percent and the moisture was classified as moist to very moist. The glacial till generally required slow digging and was hard to excavate, especially in the unweathered material.

Seepage was observed in the alluvial soil deposits and ranged from slight to heavy. Seepage was generally encountered above the glacial till soils or above relatively impermeable layers in the alluvial deposits, such as above clay layers. Seepage rates generally were higher in the cleaner sand and gravel soils, and were less in the more silty soils. Heavy seepage was observed at a depth of 14 feet in test pit TP-24 and at a depth of 2 feet in test pit TP-27 which resulted in significant caving of the test pits.

## 6.2 Station 295+00 to 367+25

Subsurface conditions as described along this section of the alignment were based on test pits TP-14 through TP-23. The soil profile along this section generally consisted of a thin layer of topsoil overlying glacial till deposits or glacial lacustrine sediments. Topsoil was encountered in all of the test pits except TP-14, where glacial till was encountered at the surface, and in test pit TP-15 where fill was observed at the surface. Beneath the topsoil was glacial till or lacustrine sediments which extended to the exploration termination depths of 10 to 14 feet. The exceptions to this were in test pits TP-18 and TP-20 where 3.5 feet of fill was encountered, and in test pit TP-21 where 8 feet of fill or alluvium was encountered before encountering glacial soil deposits.

Topsoil appeared to be similar to the topsoil described in the previous section. Fill soils were generally thin except at test pits TP-15 and TP-21. At test pit TP-15 (at the South Fork Dubuque Creek), the fill was classified as medium stiff to very stiff clay with little silt, trace sand and gravel, and trace wood fragments underlain by medium dense, silty sand with trace gravel and trace organic debris. The fill at this location appeared to consist of reworked native, glacial lacustrine which had been placed in this low-lying area for vehicular crossing and was moist to very moist. In the creek, glacial lacustrine soils were noted by our geologist during the field explorations. At test pit TP-21, the upper fill or alluvium soils were classified as loose, silty sand with gravel and dense, wet, sandy silt. It was not possible to distinguish the origin of this material at the time our explorations were performed. The material appeared to be either an alluvial deposition in a low-lying area or fill material which had been imported to raise the grade to serve as a vehicular crossing, and may be a combination of the above. The remainder of the fill which was observed along the alignment was less than 3.5 feet thick and appeared to be similar in grain size to the native glacial till soils.

The glacial till soils were similar in grain size and relative density to the glacial till described in the preceding section, however, some areas of the glacial till contained significantly more silt (up to 60 percent) and were classified as hard, sandy silt with gravel. In addition, in some test pits the upper two to three feet was weathered and noted to be less dense.

The glacial lacustrine sediments were generally encountered in the lower lying areas or on the sides of hills where the glacial till cap was thin and patchy. These soils ranged from cohesive glacial lacustrine soils--hard, moist silt, clay and sandy clay--to granular lacustrine soils--very dense, moist, sandy silt to silty sand, trace to little fine sand, and trace gravel; and dense sand with trace to little silt. The upper one to two feet of the lacustrine sediments were occasionally weathered and were less stiff and very moist.

In addition to the conditions observed in our explorations, we anticipate that shallow fills and alluvial deposits may be encountered in depressions and natural drainage crossings of the alignment. Alluvium and/or fill which was encountered at about station 307+50 may be encountered in other creek crossings, such as at about station 322+00. Occasional swamp areas were observed between about stations 340+00 and 362+00. The test pits which were performed in this area indicated shallow wet topsoil and weathered soils resulting from ponding water perched above the unweathered glacial till soils. Although not observed during our reconnaissance or in our explorations, published information indicates a lobe of sedimentary rock (weathered siltstone) may cross the alignment between about stations 352+00 and 361+00.

Slight to moderate seepage was observed in the fill soils and the weathered glacial soils. This seepage was generally encountered above the unweathered glacial soils.

The lines designating the interface between soil materials on the exploration logs should be considered as reasonably accurate only at the exploration locations. Soil conditions at other locations may differ from conditions occurring at these areas. In addition, the transition between the material types may be abrupt or gradual at other locations.

Seepage levels and rates encountered during our explorations are shown on the logs of the explorations. These levels and rates should only be considered accurate at the locations measured and at the time of measurement. Groundwater fluctuations will occur and will be dependent on the amount of rainfall in the area. During the time of our explorations, above normal rainfall had occurred for the month but was lower than the average year to date total.

## 7.0 DESIGN GEOTECHNICAL RECOMMENDATIONS

It is our opinion, based on the results of our explorations and engineering analyses, that the alignment is suitable for construction of the proposed pipeline. The pipeline may be constructed using conventional soil excavating equipment and trench configurations. Actual trench configurations will be dependent on the location of adjacent pipelines on either side of the proposed pipeline, the depth of the invert below the ground surface, and soil and groundwater conditions.

Some form of dewatering will be necessary along a majority of the alignment for successful installation of the pipeline. Significant inflows are expected along most of the alignment between station 141+80 to 184+45. Seepage is expected to be less between station 295+00 to 367+25. Based on our explorations, it is our opinion that buoyant unit weights should be considered in design above the unweathered glacial soils, where seepage was noted.

In general, native subsoils encountered in the explorations should provide adequate support for the pipe. The exception to this may be in areas where thick alluvial deposits were encountered. The majority of the soils observed in the explorations should be suitable for reuse as subsequent backfill material. The exceptions to this may be where wet alluvial soils were encountered and where cohesive glacial lacustrine soils were encountered. Specific parameters and design recommendations for each of these items are presented in the following sections.

### 7.1 Trench Excavation and Retention

It is anticipated that the soils observed in the test pits may be excavated in a trench configuration using conventional equipment such as rubber-tire backhoes or tracked hydraulic excavators. However, excavation may be slow and difficult where excavations along the same alignment extend to depths greater than the existing No. 2 pipeline or meander off of the existing alignment and extend into the unweathered glacial till and lacustrine soils. In addition, excavation is expected

to be slow and difficult if bedrock is encountered along the alignment approximately between station 352+00 and 361+00. However, based on geological surveys in the area, any bedrock encountered is anticipated to be weathered and rippable with conventional soil excavating equipment.

We recommend that the proposed replacement No. 2 pipeline be placed at an elevation approximately equal to the existing No. 3 and No. 4 pipelines. Excavations deeper than existing pipelines increase the susceptibility of damage to those pipelines during construction. Excavations shallower than the existing pipelines will make future repair of the outside lines more susceptible to causing damage of the new pipeline No. 2. Based on information provided to us by JMM, it is anticipated that the depth of trench excavation for the pipeline will range from approximately 7 to 17 feet. Generally, construction practice in this area on similar projects utilizes a movable trench shoring system ("trench box"), a shored excavation, a sloped excavation, or a partial shoring-backslope (semi-confined) trench depending on depths required, and subsurface soil and groundwater conditions.

Where lateral constraints allow, and proper dewatering and construction techniques are used, sloped excavations may be feasible. However, sloped excavations may not be economical for depths greater than about 10 feet. In addition, it is our opinion that along the first part of the alignment (station 141+80 to 184+45) that sloped excavations will not be economical because of the loose relative density and soft consistency of the subsurface soils and the potential for large groundwater inflows.

For relatively shallow excavations (depths of 8 to 10 feet) in dense to very dense, unweathered glacial soils, a trench box or sloped excavations will likely be most economical. For deeper excavations in dense to very dense soils, a semi-confined trench, or a cantilever or braced shoring system may be necessary. In very dense, unweathered glacial soils, predrilling may be required to allow adequate penetration of soldier piles for cantilever wall systems.

If significant thicknesses of loose or soft soils are expected or encountered, or if excavations encounter a substantial quantity of groundwater seepage, we recommend the use of a cantilever or braced shoring system, or both. We anticipate that loose or soft subsoils deeper than about 8 to 10 feet will be encountered along a majority of the initial section of the alignment (station 141+80 to 184+45) and possibly at other select locations such as at station 307+50 and 322+00 (creek crossings).

We are not aware of any major utilities that cross the alignment except for the drainage culvert which will cross the alignment at station 362+00. At this location, however, the culvert is planned to be placed beneath the pipeline, such that special support considerations will not be necessary.

The design and construction of any required temporary shoring system should be the responsibility of the contractor. The contractor should be required to submit a shoring design for review prior to construction. All excavations should be sloped and/or shored in accordance with the Occupational Safety and Health Act regulations and all applicable state and local requirements. In addition, it is the contractor's responsibility to monitor the stability of shored and/or open cut excavations and take corrective measures if any deficiencies or potentially dangerous conditions are found.

Based on the subsurface exploration program and laboratory test results, the soil engineering properties presented in Table 2 are recommended for evaluating temporary shoring design. Surcharge loads on excavation shoring systems due to sloping ground surfaces outside of the excavation, construction and maintenance equipment, or stockpiled materials should be included in the design of the shoring system.

TABLE 2

SUMMARY OF SOIL PARAMETERS FOR DESIGN OF TEMPORARY SHORING SYSTEMS

| Soil Description | Total Unit Weight (pcf) | Angle of Internal Friction (degrees) | Undrained Shear Strength (psf) |
|---|---|---|---|
| Very loose to loose sand, silty sand, sandy silt, gravel, and gravelly sand (Alluvium, Fill) | 110 | 30 | 0 |
| Medium dense silty sand with gravel, silty sand, sandy silt, and sand (Alluvium, Fill) | 120 | 33 | 0 |
| Dense sand, silty sand, sandy silt with gravel, silty sand with gravel, and gravel (Weathered Glacial Till, Alluvium, Fill) | 125 | 37 | 0 |
| Dense to very dense sand, sandy silt, and silty sand (Unweathered Granular Glacial Lacustrine Sediments) | 130 | 37 | 0 |
| Dense to very dense silty sand with gravel, sandy silt with gravel, and sand (Unweathered Glacial Till) | 140 | 40 | 0 |
| Very soft to soft clay, silt, and sandy clay (Alluvium, Fill) | 110 | 0 | 250 |
| Medium stiff clay, silt, and sandy clay (Alluvium, Fill) | 115 | 0 | 500 |

Table 2 (continued)

| Soil Description | Total Unit Weight (pcf) | Angle of Internal Friction (degrees) | Undrained Shear Strength (psf) |
|---|---|---|---|
| Stiff to very stiff clay, silt, and sandy clay (Alluvium, Fill, Weathered Cohesive Glacial Lacustrine Sediments) | 120 | 0 | 1,000 |
| Hard clay, sandy clay, and silt (Unweathered Cohesive Glacial Lacustrine Sediments) | 125 | 0 | 4,000 |

pcf: pounds per cubic foot
psf: pounds per square foot
Buoyant unit weight = Total unit weight - 62.4 pcf

Bends in the adjacent No. 3 and No. 4 pipelines will produce horizontal stresses in adjacent soils. If trench excavation for the No. 2 pipeline is to extend to or below existing invert elevations of the No. 3 and No. 4 pipelines, it may be necessary to brace excavation walls at pipe bends to resist horizontal pipe forces.

The "safe" slope for the excavation of all soil will depend on the following factors: 1) the presence and abundance of groundwater; 2) the type and density of the soils; 3) the depth of excavation; 4) surcharge loading adjacent to the excavation such as that from excavated material, existing structures, or construction equipment; and 5) the time of construction. Construction slope values required for stability and safety depend on a careful evaluation of all of the above factors. Because of the many variables involved, the actual slope values required for stability in open excavations can only be estimated prior to construction.

Open dewatered excavations to depths of about 20 feet below the ground surface in dense to very dense and very stiff to hard glacial soils are expected to stand at slopes of 0.5H:1V (horizontal to vertical) to 1H:1V, depending on actual dewatering and site conditions. Medium dense to dense and medium stiff to stiff natural soils are expected to stand at slopes of 1H:1V to 1.5H:1V. Medium dense and stiff fill soils and alluvial soils should be made at a 1.5H:1V to 2H:1V slope or flatter. Even with proper dewatering, excavation slopes in silt and fine sand can rapidly erode if wetted (by rain or other causes) and surface sloughing may occur if the trench slopes become dried. Although no organic soils were encountered in our explorations, if such soils are encountered we recommend that shoring be provided.

Consistent with conventional construction practice, actual temporary excavation slopes should be made the responsibility of the contractor. The contractor is able to observe the nature and conditions of the subsurface materials encountered, including groundwater, and has responsibility for methods, sequence, and schedule of construction. If instability is detected, slopes should be flattened or shored. Regardless of the construction method used, all excavation work should be accomplished in compliance with applicable local, state, and federal safety codes.

Excavations for the proposed No. 2 pipeline should be performed so that special backfill material beneath the invert, under the haunches, and above the crown of existing pipelines are not disturbed. Disturbance to the existing pipe backfill material could occur if the invert of the No. 2 pipeline is placed significantly lower than the invert of either the No. 3 or No. 4 backfill and sloped excavations are used or a wide trench is excavated for the new pipeline. As a minimum, we recommend that excavations over existing pipelines be limited so that at least two feet of soil cover is maintained over all pipelines.

## 7.2 Pipe Foundation Support

Based on the explorations performed along the alignment, it is our opinion that, in general, the natural soils expected to be encountered at the invert elevations will provide adequate foundation support. Exceptions to this may be at creek crossings, as listed in the previous section, and at select locations along the initial section of the alignment (station 141+80 to 184+45). In these areas, soft and loose alluvium or fill soils may be encountered.

Most of the soils encountered at the pipe foundation elevations will contain a substantial quantity of silt and fine sand. These soils are generally suitable for foundation support if they are maintained in an undisturbed condition. However, these soils are considered moisture sensitive and are easily disturbed by excavation equipment, especially in a wet condition. Foot traffic should be minimized on the exposed subgrade prior to placing foundation and/or bedding material. Disturbance of soils at the bottom of the trench excavation will affect support of the proposed pipe. The contractor should take all necessary steps to protect the subgrade from becoming disturbed.

For cohesionless soils such as silty sand, sand, and gravel, if the bottom of the trench is maintained in a dry condition, disturbance may be repaired by recompacting the subgrade, provided soils are within a moisture content range which permits the required compaction. It is our opinion that this moisture range varies from 2 points below to 2 points above the optimum moisture content, as determined by ASTM D-1557, for cohesionless soil.

If fine-grained sandy silt and/or cohesive subgrade soils become wet or disturbed, they should be overexcavated to expose undisturbed soils and replaced with suitable imported foundation material as described below. It is generally not practical to stabilize these materials once they are disturbed. If excavation reveals soft cohesive soils, organic soils, or existing fill at the bottom of the trench, we recommend overexcavation of these soils to a depth of at least 12 inches.

Overexcavated foundation soil should be replaced with foundation material meeting the gradational requirements specified in Section 9-30.7(2)A, foundation material class A, of the 1988 Washington State Department of Transportation and American Public Works Association (WSDOT/APWA) Standard Specifications and brought up to the bedding grade. This material should be placed in maximum eight-inch lifts and compacted to at least 90 percent of the maximum dry density as determined by ASTM D-1557. Bedding material, which should be placed as described below, should not be considered as providing adequate support if the underlying soils have been disturbed. Thus, the trench bottom should be evaluated prior to placing the required bedding material to determine its suitability of support. As an alternative to using foundation material class A, imported quarry spalls (from four to six inches in diameter) may be used as backfill in areas requiring overexcavation.

## 7.3 Pipe Bedding

We recommend that the pipe be bedded with imported granular material meeting the gradational requirements of "Bedding Material for Flexible Pipe" as specified in Section 9-30.7(1)B of the 1988 WSDOT/APWA Standard Specifications. Bedding should extend at least 6 inches below the bottom of the pipe, and should extend up the pipe to the 120 degree arc of the pipe (a distance equal to 0.25 times the outside diameter above the bottom of the pipe), as shown in Figure 2.

Initial backfill should extend from the bedding up to at least 12 inches over the top of the pipe. Initial backfill material should meet the gradational requirements provided above for bedding material and be brought up evenly around the pipe. The initial backfill should be placed in maximum lift thicknesses of six inches and carefully worked under the pipe by means of slicing with a shovel, vibration, or other approved procedure.

## 7.4 Backfill and Compaction Requirements

Subsequent backfill (placed over initial backfill) under paved areas should conform to the gradational requirements of Section 9-03.14, gravel borrow, of the 1988 WSDOT/APWA Standard Specifications except that the maximum particle size may be increased to 2 inches. In all remaining areas, soil from the trench excavation may be used as subsequent backfill provided that the moisture content of the soil is carefully controlled to allow proper compaction. The majority of the soils encountered in the test pits contained a significant percentage of silt and are considered moisture sensitive. These soils are expected to be difficult to compact should they remain wet or become wet due to rain or careless surface water control during construction. Organic materials, such as peat, topsoil, organic silt, wood and other deleterious material should not be used as subsequent backfill. We anticipate that most of the soils excavated from the trench along the western segment of the alignment (station 295+00 to 367+50) will be suitable for reuse as subsequent backfill. Exceptions to this may be at creek crossings, and when cohesive glacial lacustrine sediments are encountered.

As shown on Figure B-4, in Appendix B, the natural moisture content for the glacial till sample was approximately three percent above the optimum moisture content for compaction. The range of natural moisture contents for all of the glacial till samples was about 1 to 8 percent above the optimum moisture content for the sample on Figure B-4. It is our opinion, that this material can be compacted at the natural moisture contents for the relative compaction required. Some drying of the material may be necessary, however. In addition, if the material becomes wet it will be difficult to place and compact to the required relative densities.

As shown on Figure B-5, the natural moisture content for the cohesive glacial lacustrine sample was approximately 14 percent above the optimum moisture content for compaction. The range of natural moisture contents for all of the cohesive lacustrine samples was 9 to 25 percent above the optimum moisture content for the sample on Figure B-5. This material

will not likely meet the required relative compaction at its natural moisture content and drying will be required. However, because this material is fine-grained, disking and drying for extended periods may be required which may make this material impractical for reuse.

Along the eastern segment of the alignment, the alluvial soils were classified as wet and had natural moisture contents which were well above the optimum moisture content as shown in Figure B-6. The natural moisture contents ranged from approximately 7 to 25 percent above the optimum moisture content for the silty sand and sand soils. These soils will require spreading and drying to lower the moisture contents into a range suitable for compaction. Although these soils are above the optimum moisture content, they can be moisture conditioned if work is performed during dry weather months and there is room available for spreading and drying. We recommend that the occasional layers of clay and silt which were encountered within the alluvial deposits not be used as subsequent backfill.

If soils excavated from the trench are found to be unsuitable for backfilling, then gravel borrow, as specified above, should be used. Regardless of the type of backfill used, the first lift should not be compacted until the backfill has been placed a distance of one foot above the crown of the pipe.

All foundation material, bedding material, and initial backfill material should be compacted to 90 percent of the maximum dry density as determined by ASTM D-1557. Subsequent backfill should be compacted to 90 percent of the maximum dry density except in paved areas where the upper two feet should be compacted to 95 percent of the ASTM D-1557 maximum dry density.

### 7.5 Loads on Buried Pipe

Based on the explorations performed for this project and our experience with similar projects, the modulus of lateral soil reaction (E′) values presented in Table 3 are recommended for design of the pipeline if the

pipe material selected is considered flexible. In order for trench backfill material to control the design of the pipe, we estimate that backfill material must extend beyond the edge of the pipe approximately one pipe diameter. For trenches which are narrower, the existing soil conditions will control pipe deflection.

TABLE 3

RECOMMENDED MODULUS OF LATERAL SOIL REACTION (E′) VALUES

| Major Soil Type | Density or Consistency | Estimated E′, psi |
|---|---|---|
| Silty Sand, Sandy Silt, and Sand | Loose | 400 |
| Silty Sand, Sandy Silt, and Sand | Medium Dense, Dense | 600 |
| Sand, Sand and Gravel, Sandy Gravel | Loose | 700 |
| Silty Sand, Sandy Silt, and Sand | Very Dense | 1,000 |
| Sand, Sand and Gravel, Sandy Gravel | Medium Dense, Dense | 1,000 |
| Sand, Sand and Gravel, Sandy Gravel | Very Dense | 1,500 |
| Clay, Silt, and Sandy Clay | Very Soft, Soft | 200 |
| Clay, Silt, and Sandy Clay | Medium Stiff, Stiff | 300 |
| Clay, Silt, and Sandy Clay | Very Stiff, Hard | 500 |

psi = pounds per square inch

The soil load that will be imposed on a vertical pipe will depend on the subsurface conditions, the height of the backfill above the pipe, the method of installation, the relative rigidity of the pipe, and the trench conditions. Figure 3 presents backfill loads on a 51-inch inside diameter flexible pipe assuming a semi-confined trench width of 100

inches. This trench width was determined by selecting the approximate maximum width permissible in accordance with Section 7-10.3(7) of the 1988 WSDOT/APWA Standard Specifications.

Consideration should also be given to the effect of traffic loadings on pipes for that portion of the alignment within traffic areas. Figure 4 presents the pressure on buried pipes from a H-20 AASHTO truck loading. This pressure should be added to the backfill pressure under road crossings. Stockpiled soil and equipment material and traffic loads should be minimized over existing pipelines so additional loads will not be induced on the existing pipes.

## 7.6 Riser Structures

Foundation soils for manholes should be analyzed, as described under the section of this report entitled, "Pipe Foundation Support" to determine their suitability to provide support and be overexcavated and replaced as appropriate. Manholes should be underlain by a minimum of six inches of material meeting the gradational requirements of Section 9-30.7(1)B to act as a bedding material and to protect foundation soils.

We recommend that backfill adjacent to manholes and riser structures meet the gradational requirements specified under the "Backfill and Compaction Requirements" section of this report for paved and unpaved areas, respectively. Compaction of backfill around riser structures should conform to the recommendations presented in that section. Backfill placed against riser structures should be brought up evenly around the structures so that unbalanced earth pressures do not develop.

Riser structures should be designed to withstand lateral earth pressures as would be exerted by a fluid having an equivalent density of 55 pounds per cubic foot (pcf) above the groundwater level. Below the groundwater level (in buoyant weight areas), riser structures should be designed to withstand lateral earth pressures in combination with a hydrostatic head, as exerted by a fluid with an equivalent density of 95 pcf.

Uplift should be evaluated on actual manhole dimensions to determine if there is a potential for buoyancy with high groundwater levels. Uplift may be resisted by increasing the weight of the manhole or providing the base of the manhole with an exterior flange so that the overlying soils resist uplift. Uplift should only be evaluated where the base of the manhole will not penetrate the relatively impermeable glacial soils.

## 7.7 Settlements

We understand that final ground elevations will be near the existing ground elevations along a majority of the alignment. Calculation of the volumes and weights of materials removed and replaced during installation of the proposed pipe and any manholes indicates that there should be very little, if any, net increase in stresses transmitted to the soils provided ground elevations are not raised. Therefore, it is anticipated that only nominal settlement of the pipe should occur due to installation provided foundation soils are not disturbed. It is our understanding that the only place where the ground surface elevation will be significantly changed is at station 362+00 where over 11 feet of fill will be placed in a creek crossing. During our explorations, we noted glacial lacustrine soils exposed in this crossing. Thus we anticipate only nominal settlements due to raising the grade in this area.

We recommend that stockpiles of excavated soil be kept off of newly installed pipes. As a general rule, the stockpile should be as far from the pipeline (laterally) as the base width of the stockpile. In addition, stockpiles should not be placed on top of the existing pipelines so as to induce additional settlement of the foundation soils below these pipes.

## 7.8 Thrust Restraint

The lateral thrust that develops from liquid flowing through bends in the pipeline must be absorbed by the soil. Resistance to lateral thrust for a pipe with restrained joints will develop by longitudinal frictional resistance acting between the pipe and the trench backfill soils,

and by passive soil resistance. To evaluate the longitudinal thrust force resistance that will develop along pipe, we recommend that a soil to pipe friction angle of 22 degrees be used for mortar-coated pipe and 18 degrees be used for steel pipe. These friction angles are based on imported granular bedding and backfill around the pipe as specified previously in this report. Passive pressures at pipe bend locations or thrust blocks should be based on an equivalent fluid density of 200 pcf above the groundwater level and 110 pcf below the groundwater level.

## 7.9 Construction Dewatering

Construction dewatering will likely be required throughout a majority of the design sections of the project, although the level of effort needed will be varied along the alignment. Along the eastern segment of the alignment (station 141+80 to 184+45), seepage was observed in four of the five test pits performed. This seepage varied from slight to moderate to heavy and was generally observed to be perched on the unweathered glacial till soils, although in two of the test pits alluvium was encountered for the entire depth (15 feet) with associated water inflows. Along the western segment of the alignment (station 295+00 to 367+25) seepage was observed in five of the ten test pits completed. Seepage ranged from slight to moderate along this section and was generally shallow and perched on the relatively unweathered glacial till and glacial lacustrine soils.

Dewatering of shallow perched water is usually effectively performed by installation of cutoff drains or trenches upslope of the pipe trench excavation. Cutoff drains should extend through the seepage zone and into the relatively impermeable glacial till deposits or to the depth of the proposed pipe trench excavation, whichever is deeper. Cutoff trenches should be constructed on the outside of the upslope outer pipeline, if space permits. For the portion of the alignment on side hill cuts, it may be possible to use the outer pipe backfill as a cutoff drain, provided that the existing bedding and backfill for the upslope outside pipeline is free-draining. For this case, wells could be installed that penetrate through the existing backfill and bedding. If

construction is performed in drier summer months, where excavations encounter only light seepage, or where seepage occurs over a thin section of the trench, it may be possible to sump pump water from the excavated pipe trench.

Along the eastern segment of the alignment, station 141+80 to 184+45, excavations are expected to encounter deep alluvial deposits. We anticipate that dewatering can be accomplished with the use of either wells or wellpoints, the latter used for shallower excavations.

Excavation for the existing waterline originally intercepted the interface between the relatively impermeable unweathered glacial soils and the overlying soils along a majority of the alignment. We anticipate that the existing pipe trench will act as a conduit, conveying water to the trench as it is excavated. This condition will be more pronounced when the new pipeline is bedded with free-draining granular soils. These expected flows may be reduced by installing wells or deep sump pumps in the existing and future trench bedding and backfill upslope of excavations.

Where the alignment is located on steep slopes, such as between stations 178+00 to 180+00, 307+00 to 312+00, and 360+00 to 361+00, we recommend that trench cutoff walls be installed to intercept flow through the pipe bedding and initial backfill and reduce velocities which could lead to scouring of this material or the subgrade soils. Trench cutoff walls should consist of cast-in-place concrete collars which replace bedding and initial backfill material. Trench cutoff walls should be located on maximum center spacings of 40 feet. Lean-mix concrete may be used to form the collars. A perforated drain pipe should extend along the length of the alignment in these sections to carry groundwater volumes. The pipe should be at least four inches in diameter and placed on top of the bedding material on each side of the proposed pipe. At the base of the slopes, the pipes should be connected to laterals which drain into roadside ditches or existing ravines.

## 8.0 GEOTECHNICAL IMPACTS

Construction of the proposed pipeline will have some impact on the adjacent existing pipelines, drainage features, existing roads and utilities, and private properties bordering the alignment. Such impacts involve those created by dewatering and excavations. Comments and recommendations concerning these impacts are provided below.

In general, where right-of-way embankments cross ravines or creeks, culverts should be sized to adequately convey flood-condition flows without washing out fills and/or exposing the pipe. In addition, we did not observe any signs of major slope instability along the alignment in the study area. We conclude that long-term static slope stability will not be a problem for this project. Regarding construction, it is our opinion that access along the alignment will be difficult from station 142+00 to 161+00. During our explorations, we were unable to mobilize a Case 580E backhoe to this area because of wet, swampy ground surface conditions. Based on visual reconnaissance of this area, we anticipate that fine-grained alluvium will be encountered. In addition, groundwater is expected near the existing ground surface. In order to mobilize equipment in this area, the contractor may have to place plywood or timber mats to act as a working platform. Heavier equipment may need a working mat consisting of a reinforcement geotextile and a gravel fill. Backfill material excavated from the trench is anticipated to be fine-grained and wet and will not likely be suitable for reuse as fill. Imported backfill material should be expected along this section.

### 8.1 Dewatering

It is anticipated that water pumped from dewatering wells or from open sumps in the excavation may be discharged into surface streams and drainage features. When pumping from properly installed wells, the silt content of the water being discharged should be insignificant. However, when pumping from open sumps it may be necessary to filter the water to remove silt prior to discharging the water off-site.

Settlement may result from dewatering due to an increase in effective stress in the soil with a decrease in pore water pressures. Along the proposed alignment we anticipate that this may be a concern over the eastern segment of the alignment in areas where deep alluvial soils extend below the invert of the proposed existing pipelines No. 3 and No. 4 and the proposed No. 2 pipeline. Where shallow fill or alluvial soils are encountered dewatering should not effect the pipelines. Even in areas with deep alluvial soils, dewatering subsidence is expected to be relatively minor as most of the soils were coarse-grained. If significant thicknesses of clay, peat or silt are found within the alluvial soils, dewatering subsidence could affect the performance of the existing pipes.

Dewatering is not expected to affect the proposed pipeline as long as the contractor employs good construction techniques, such as drawing down the groundwater level well in advance of laying the pipe and maintaining the drawdown condition until the backfill has been properly placed and compacted. The majority of any settlement should occur prior to placing the pipe. We know of no structures or other features that would be affected by dewatering along this part of the alignment.

Possible solutions to reduce settlements of existing improvements (should dewatering settlements become a concern) include: designing the pipeline for shallow depths, thus reducing the extent of dewatering; using a tight sheetpile shoring system that allows dewatering from within the trench only; or using smaller diameter closely spaced wells to reduce the cone of influence of dewatering.

## 8.2 Excavations

In order to provide adequate support to roadway and utility crossings, shoring should be used. Preliminary discussions of the types of shoring that may be appropriate are presented in a previous section of this report, "Trench Excavation and Retention". With properly designed and installed shoring systems, movement of adjacent improvements may be controlled to within tolerable limits. Removal of passive resistance at

bends in the existing No. 3 and No. 4 pipelines by excavation for the new pipeline may cause horizontal movements in the existing pipelines. Braced excavations may be necessary to prevent horizontal movements at pipe bends, as discussed in the "Trench Excavation and Retention" section of this report.

## 8.3 Seismicity and Liquefaction

The project lies within a seismically active area of the Pacific Northwest classified within Seismic Zone 3 by the Uniform Building Code, which is described as a zone of major risk potential in conjunction with earthquakes having intensities of VIII or higher on the Modified Mercalli Intensity (MM) Scale. Several earthquakes in recent historic times have occurred in the Pacific Northwest with MM intensity greater than or equal to VIII. During one such earthquake, the 1965 Seattle-Tacoma earthquake of MM intensity VIII (Richter Magnitude 6.5), centered near Federal Way, Washington, breaks occurred in two of the City of Everett water supply pipelines at the Ebey Slough crossing (U.S. Geological Survey, 1975).

Liquefaction can occur in loose, saturated sand and silty sand deposits due to earthquake ground motions causing a sudden buildup of pore water pressures and a subsequent loss of effective stress. The consequences of a liquefaction occurrence are loss of soil strength and settlements which could cause cracks to develop or separation of the pipe at joints.

Generally, the most susceptible material to liquefaction is clean, fine to medium sand. Larger grain size material, such as gravel, will have higher permeabilities and thus will be able to dissipate cyclic induced pore water pressures faster. Silty materials are inherently more stable against liquefaction, and clayey soils are generally regarded as non-liquefiable. Along the alignment, soils which have the potential to liquefy were noted in the alluvial deposits from station 141+80 to 184+45. The alluvial soils were noted to be loose and saturated in this section. However, consistent with alluvial deposition, the material was variable and ranged from clay to silt to sand and gravel, with layering

evident. Generally, layers of loose sand or silty sand (the most susceptible material) were thin and it is our experience that layers are not continuous in alluvial deposits with interfingering of soils between layers. In our opinion, a liquefaction occurrence would only result in localized ground settlement and loss of pipe support.

Alluvial deposits were noted to extend below the proposed pipeline invert in only about one-half of the test pits in this area. For the areas where the pipeline extends into the underlying glacial soils, the consequences of liquefaction in the overlying soils would not effect the performance of the pipe.

## 9.0 DOCUMENT REVIEW AND CONSTRUCTION OBSERVATIONS

We recommend that we be retained to review those portions of the plans and specifications that pertain to foundations and earthwork to determine whether they are consistent with the recommendations in this report.

We recommend that monitoring, testing, and consultation be provided by our firm during construction to confirm that the conditions encountered are consistent with those indicated by our explorations, to provide expedient recommendations should conditions be revealed during construction which differ from those anticipated, and to evaluate whether earthwork activities comply with contract plans and specifications. Such activities would include subgrade preparation for pipe foundations, fill placement and compaction, and other geotechnical related earthwork activities.

## 10.0 USE OF THIS REPORT

This report was prepared for the exclusive use of the owner and engineer for specific application to the design of the project at this site as it relates to the geotechnical aspects discussed herein. The data and report should be provided to prospective contractors for their information, but our report, conclusions and interpretations should not be construed as a warranty of subsurface conditions included in this report.

Within the limitations of scope, schedule and budget, the analyses, conclusions, and recommendations presented in this report were prepared in accordance with generally accepted professional geotechnical engineering principles and practice in this area at the time this report was prepared. We make no other warranty, either express or implied. These conclusions and recommendations were based on our understanding of the project as described in this report and the site conditions as observed at the time of our explorations.

If there is a substantial lapse of time between the submittal of this report and the start of construction at the site, or if conditions have changed due to natural causes or construction operations at or adjacent to the site, or appear to be different from those described in our report, we recommend that we review our report to determine the applicability of the conclusions and recommendations considering the changed conditions and time lapse.

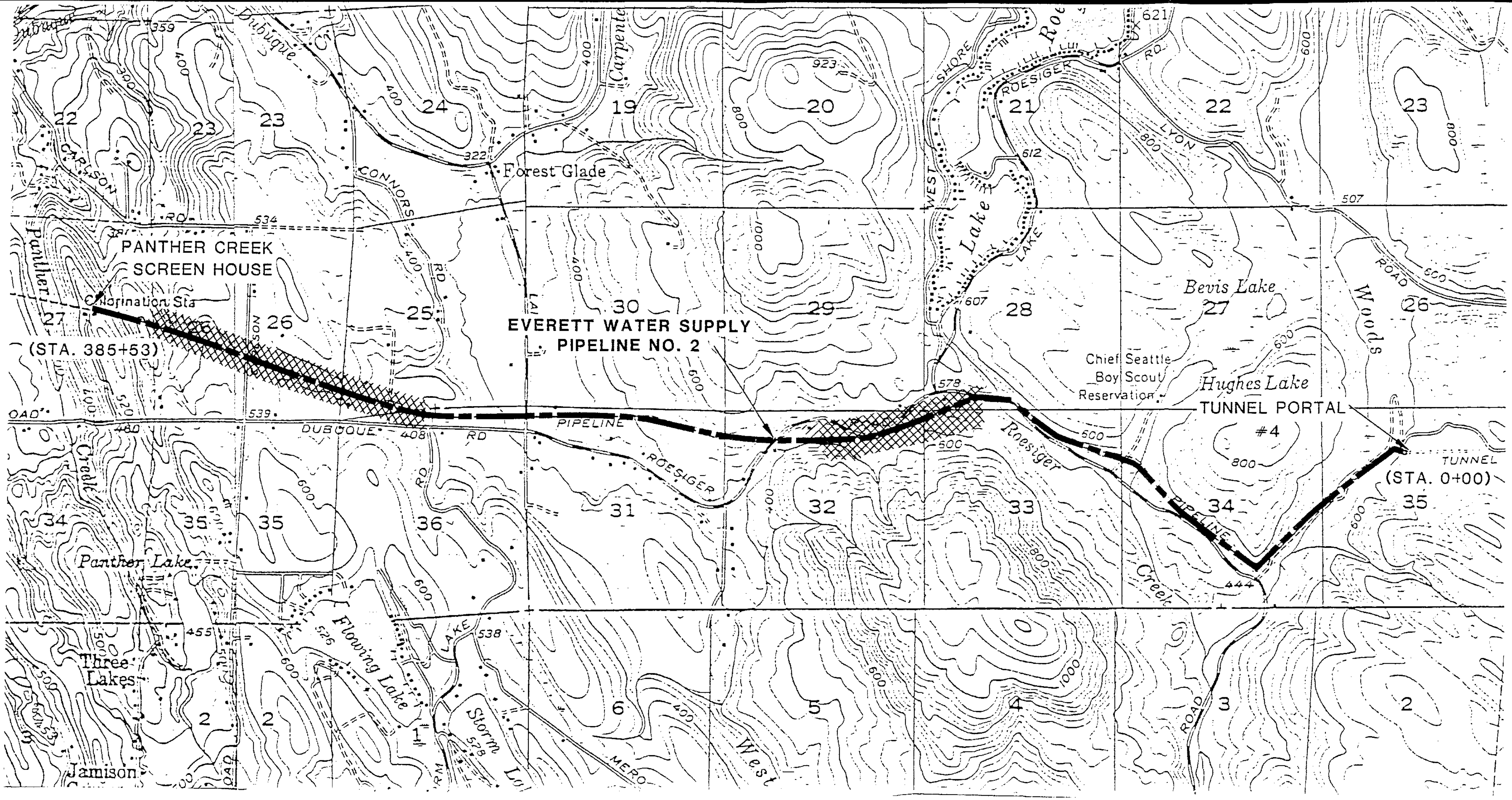
We appreciate the opportunity to be of continued service on this project, and look forward to continued involvement. If you have any questions, or require additional services, please do not hesitate to contact us.

CONVERSE CONSULTANTS NW

Gregory R. Fischer
Geotechnical Engineer

Dean E. Ryden
Principal Engineer

GRF6/DER/kpp




0 1/2 1
SCALE IN MILES

LEGEND:

FINAL DESIGN SEGMENT

REFERENCE: U.S.G.S. 15' QUADRANGLE MAPS - "EVERETT, WASHINGTON" AND "MONROE, WASHINGTON".

N

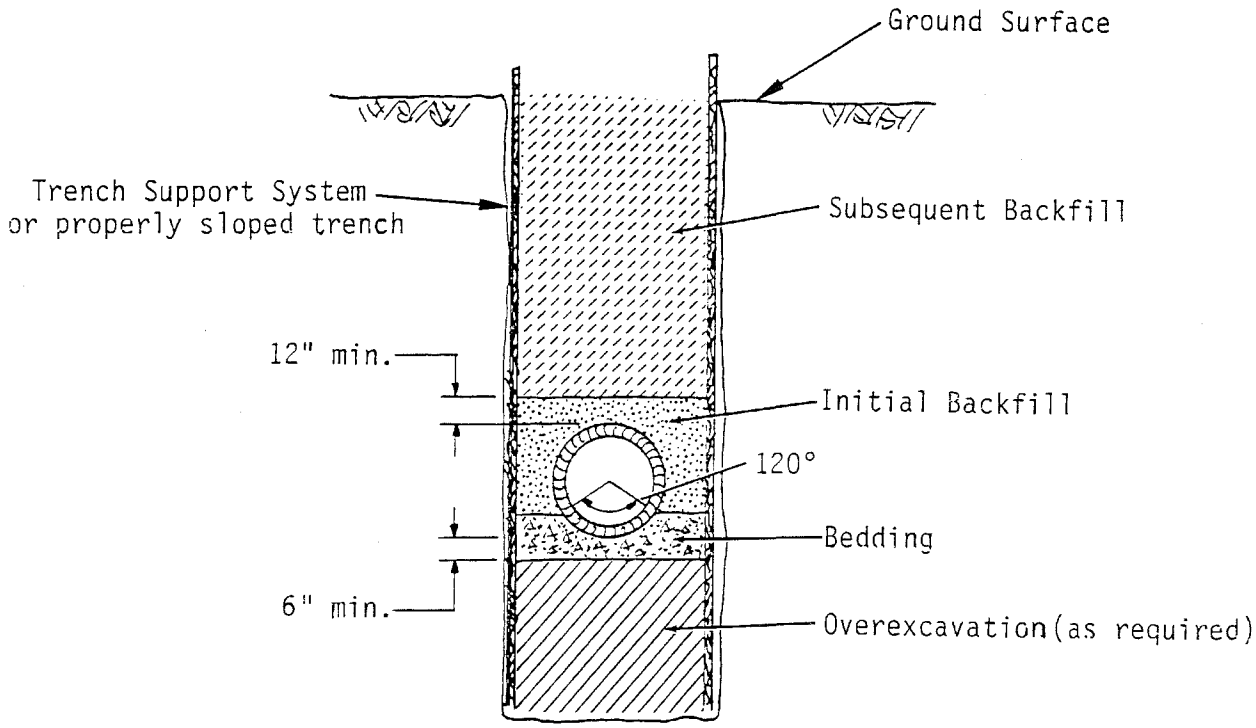
## SITE PLAN - SNOHOMISH VALLEY

PROPOSED WATER SUPPLY PIPELINE NO. 2
Everett, Washington
for James M. Montgomery, Consulting Engineers

Converse Consultants NW — Geotechnical Engineering and Applied Earth Sciences

| | |
|---|---|
| Scale | NOTED |
| Date | DEC 1988 |
| Prepared by | JM |
| Checked by | GRF |
| Approved By | DER |
| Project No. | 87-35205-03 |
| Figure No. | 1 |

BRUNING 40 107




SCHEMATIC ONLY
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RECOMMENDED BEDDING AND BACKFILL CONFIGURATION

PROPOSED WATER SUPPLY PIPELINE NO. 2
Everett, Washington
for James M. Montgomery, Consulting Engineers

Project No.
87-35205

Figure No.
2

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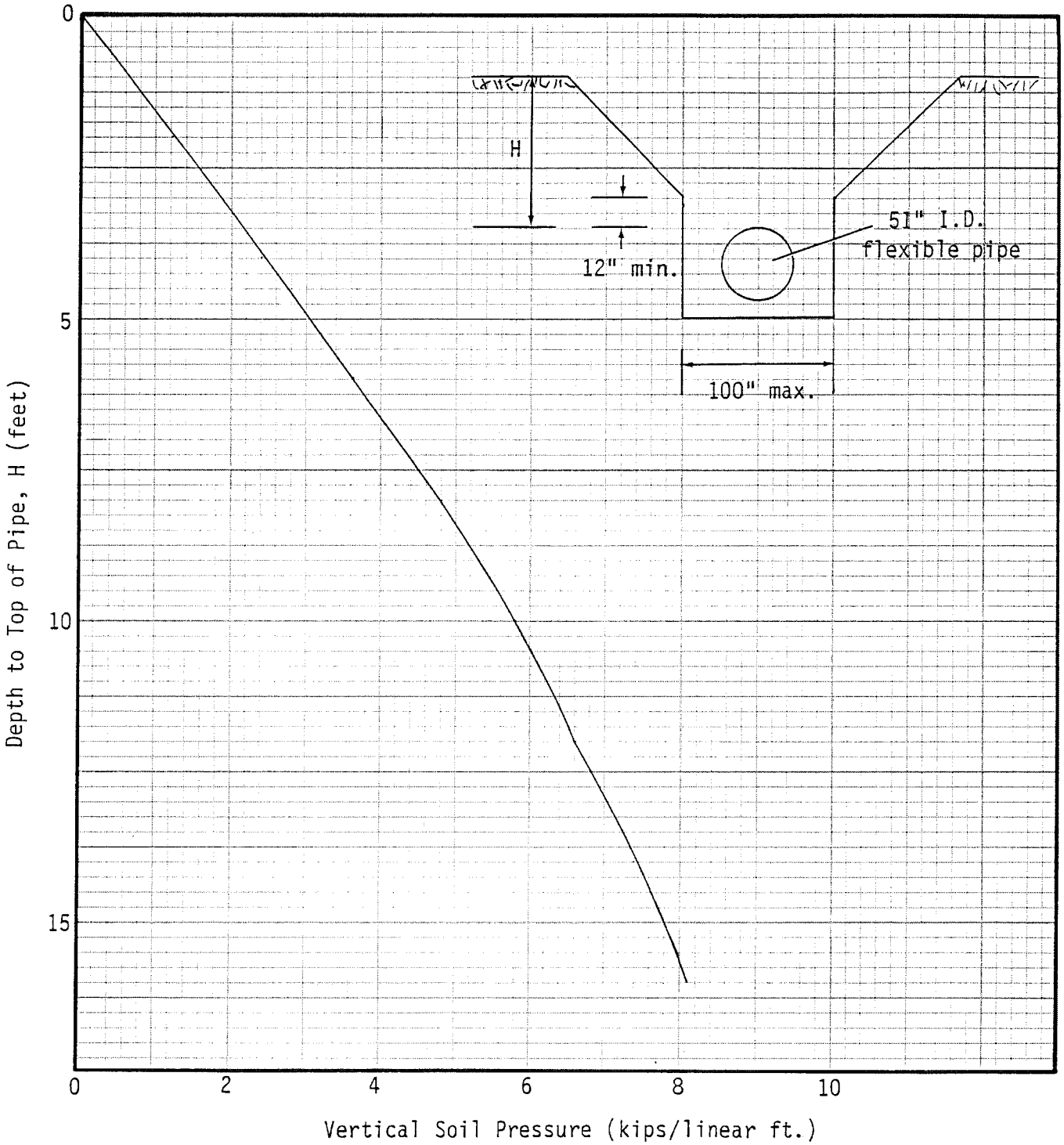


VERTICAL SOIL PRESSURE FOR SEMI-CONFINED TRENCH CONDITION - FLEXIBLE PIPE

PROPOSED WATER SUPPLY PIPELINE NO. 2
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Project No.
87-35205

Figure No.
3

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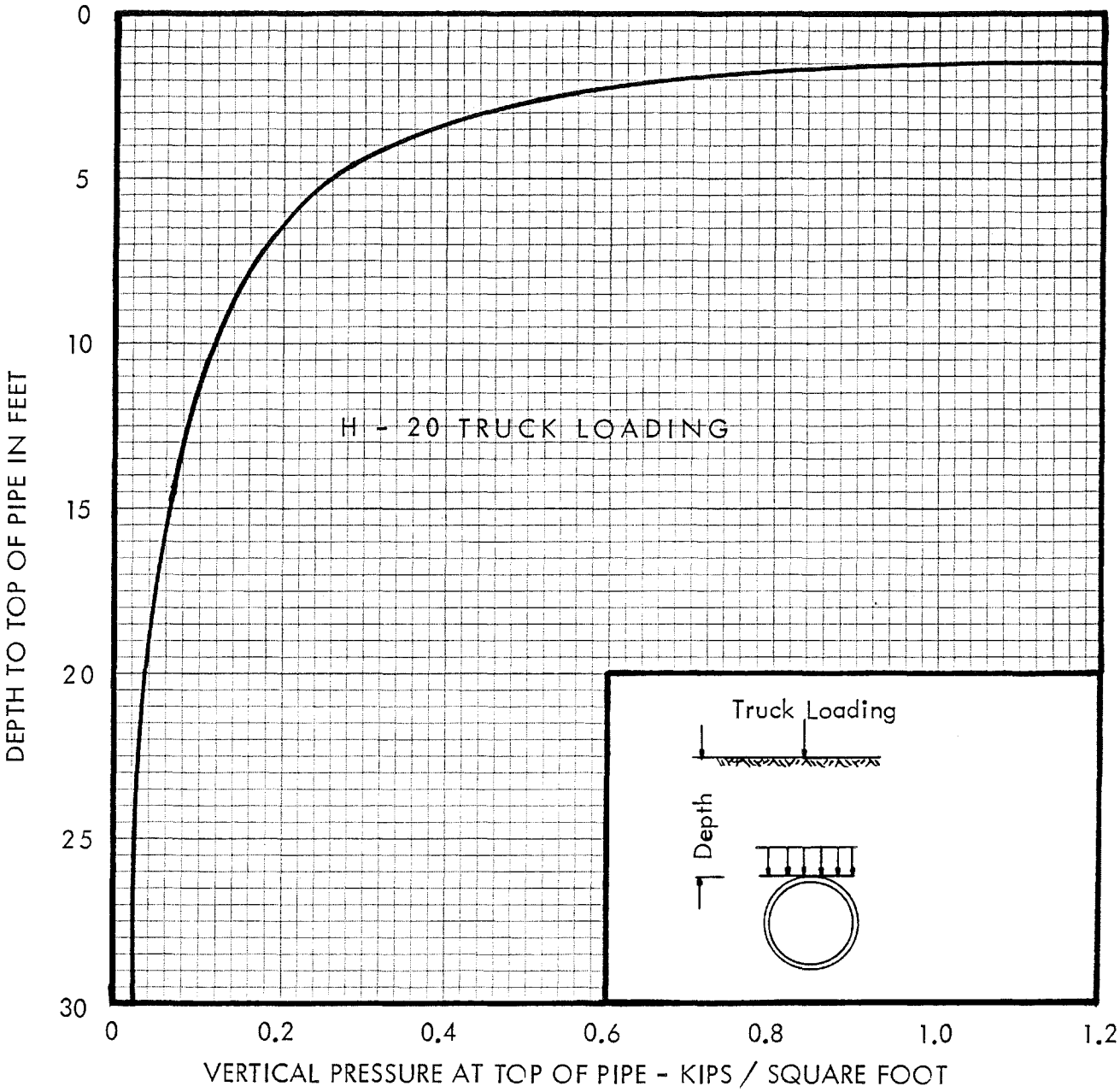


1.) For traffic loads multiply curve value by pipe O.D. in feet.

2.) Curve is corrected for following values:

| Depth in feet | Impact factor |
|---|---|
| 1 | 30% |
| 2 | 20% |
| 3 | 10% |
| 4 or more | 0% |

3.) Backfill loads must be added to traffic load.

TRAFFIC LOADS ON PIPES

PROPOSED WATER SUPPLY PIPELINE NO. 2
Everett, Washington
for James M. Montgomery, Consulting Engineers

Project No.
87-35205

Figure No.
4

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# APPENDIX A

## FIELD EXPLORATION PROGRAM

Subsurface conditions for this project were explored by excavating 15 test pits at the approximate locations shown on the Site and Exploration Plan, Figure 1 and are summarized in Table 1 in this report. The explorations were performed on December 1 and 2, 1988 and advanced to depths ranging from 10 to 15 feet below the existing ground surface. The results of our exploration program are presented on the exploration logs at the end of this appendix on Figures A-1 through A-15.

The explorations were located in the field by hand taping and pacing relative to the existing right-of-way stationing monuments. The location of the explorations are referenced parallel to the alignment by the stationing and perpendicular to the alignment by the distance from the center of pipeline No. 2, as described on the individual logs. The approximate ground surface elevations at the exploration locations, as presented on the exploration logs, were interpolated from the plan and profile sheets prepared by JMM. The location and elevation of the explorations should be considered accurate to the degree implied by the method used.

The test pits were excavated with a Case 580E rubber-tire backhoe. Test pits allow direct visual observation of the subsurface soils on the sides of an excavated trench. Representative samples of soil types encountered were placed in plastic bags, sealed, and transported to our laboratory for further classification and testing. The relative density and consistency of the soils were estimated by our field geologist.

A geologist from our firm was present throughout the field work program to observe the explorations, assist in sampling, and to prepare descriptive logs of the explorations. Soils were classified in general accordance with ASTM D-2488, "Standard Recommended Practice for Description of Soils (Visual-Manual Procedure)". The final exploration logs represent our interpretation of the contents of the field logs and the results of laboratory testing.

# LOG OF TEST PIT NO. TP-14

Location: Sta. 366+00, 10′ L. of ℄ No. 2 Pipeline Elevation: approx. 495

Surface Conditions: flat

| Depth in feet | Moisture Content-% | Sample | Symbol | DESCRIPTION | REMARKS |
|---|---|---|---|---|---|
| 1 | | | SM | GLACIAL TILL<br>SILTY SAND WITH GRAVEL; yellow-brown, fine to medium sand, little gravel, trace cobbles, (weathered); dense, moist | digs very hard |
| 2 | | | | | |
| 3 | | | | grades to gray-brown and unweathered, becomes very dense | |
| 4 | | | | | |
| 5 | | | | | |
| 6 | | | | | |
| 7 | 10 | 1 | SM | | |
| 8 | | | | | |
| 9 | | | | | |
| 10 | | | | | |
| 11 | | | | | |
| 12 | | | | Bottom of test pit at depth 12.0 feet<br>Completed and backfilled on 12/1/88<br>No groundwater encountered | |

Approved for publication _____ by _____

PROPOSED WATER SUPPLY PIPELINE NO. 2
Everett, Washington
for James M. Montgomery, Consulting Engineers

Project No.
87-35205-03

Converse Consultants NW Geotechnical Engineering and Applied Earth Sciences

Figure No.
A-1

# LOG OF TEST PIT NO. TP-15

Location: Sta. 361+50, 12′ R. of ℄ No. 2 Pipeline Elevation: approx. 465

Surface Conditions: edge of creek, slight slope, grassy

| Depth in feet | Moisture Content-% | Sample | Symbol | DESCRIPTION | REMARKS |
|---|---|---|---|---|---|
| 1<br>2<br>3<br>4<br>5<br>6 | 30 | 1 | CL | FILL<br>CLAY; brown, little silt, trace sand and gravel, trace wood fragments, medium plasticity; medium stiff to very stiff, moist | digs very easy<br><br>trench walls stand vertical. |
| 7<br>8 | 42 | 2 | SM | SILTY SAND; gray-green, fine sand, thinly bedded with clay, little silt, trace organic debris, trace gravel; medium dense, very moist | |
| 9<br>10<br>11<br>12<br>13 | 39 | 3 | MH | LACUSTRINE SEDIMENTS<br>SILT; gray-brown mottled, some clay, silt, trace fine sand, trace gravel, laminated, highly plastic; hard, moist<br><br>grades to very hard | digs harder |
| 14 | | | | Bottom of test pit at depth 14.0 feet<br>Completed and backfilled on 12/1/88<br>Slight seepage at depth 7.0 feet | |

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PROPOSED WATER SUPPLY PIPELINE NO. 2
Everett, Washington
for James M. Montgomery, Consulting Engineers

Project No.
87-35205-03

Converse Consultants NW Geotechnical Engineering and Applied Earth Sciences

Figure No.
A-2

# LOG OF TEST PIT NO. TP-16

Location: Sta. 350+00, 9′ L. of ℄ No. 2 Pipeline  Elevation: approx. 512

Surface Conditions: flat, grassy

| Depth in feet | Moisture Content-% | Sample | Symbol | DESCRIPTION | REMARKS |
|---|---|---|---|---|---|
| 1 | | | SM | TOPSOIL<br>SILTY SAND WITH GRAVEL; dark brown, fine to medium sand, little gravel, trace roots; loose, very moist | |
| 2 | | | ML | GLACIAL TILL<br>SANDY SILT WITH GRAVEL; yellow-brown, little sand and gravel, trace clay, weathered; very dense, very moist | digs very hard |
| 3 | | | | | |
| 4 | | | ML | SANDY SILT WITH GRAVEL; gray-brown, little gravel, trace clay, scattered cobbles to 12-inch dia., weathered, medium plasticity, locally fissured, fractures iron stained; very dense, moist<br>- grades to unweathered | |
| 5 | 16 | 1 | | | |
| 6 | | | | | |
| 7 | | | SM | SILTY SAND WITH GRAVEL; gray-brown, fine to medium, sand, little gravel, trace clay, scattered cobbles to 8-inch dia.; very dense, moist | |
| 8 | | | | | |
| 9 | | | | | |
| 10 | | | | | |
| 11 | | | | Bottom of test pit at depth 11.0 feet<br>Completed and backfilled on 12/1/88<br>No groundwater encountered | |

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Figure No.
A-3

# LOG OF TEST PIT NO. TP-17

Location: Sta. 341+80, 9′ L. of ℄ No. 2 Pipeline  Elevation: approx. 498

Surface Conditions: flat, grassy, with surface water

| Depth in feet | Moisture Content-% | Sample | Symbol | DESCRIPTION | REMARKS |
|---|---|---|---|---|---|
| 1 | | | SM | TOPSOIL<br>SILTY SAND WITH GRAVEL; dark brown, fine to medium sand, little gravel, trace roots; loose, very moist | digs easy |
| 2 | | | SM | SILTY SAND WITH GRAVEL; dark brown, fine to medium sand, little gravel, trace roots, thinly bedded with sand at 2′-3′; dense, wet | |
| 3 | | | | | |
| 4 | 12 | 1 | ML/SM | GLACIAL TILL<br>SANDY SILT W/ GRAVEL TO SILTY SAND W/GRAVEL; gray-brown mottled rust, little clay, little gravel, thinly laminated with sand, medium plasticity; very dense, very moist<br><br>- grades with scattered cobbles to 12" dia. | caving moderately to depth 5′ |
| 5 | | | | | |
| 6 | | | | | |
| 7 | | | | | |
| 8 | 14 | 2 | SM | SILTY SAND W/GRAVEL; gray, fine to medium, little gravel, trace cobbles; dense, wet | |
| 9 | 28 | 3 | CH | LACUSTRINE SEDIMENTS/GLACIAL TILL<br>SANDY CLAY; gray, some sand, some silt, very thinly bedded with fine to medium sand, with trace gravel, high plasticity; very stiff to hard, very moist | |
| 10 | | | | | |
| 11 | | | | | |
| 12 | | | | Bottom of test pit at depth 12.0 feet<br>Completed and backfilled on 12/1/88<br>Seepage encountered from depth 2′ to 3′; inflow approximately 2 gallons per minute | |

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Figure No.
A-4

# LOG OF TEST PIT NO. TP-18

Location: Sta. 330+00, 10′ L. of ℄ No. 2 Pipeline Elevation: approx. 478

Surface Conditions: edge of creek, slight slope, grassy

| Depth in feet | Moisture Content-% | Sample | Symbol | DESCRIPTION | REMARKS |
|---|---|---|---|---|---|
| 1 | | | SM | TOPSOIL<br>SILTY SAND W/GRAVEL; dark brown, fine to medium sand, little gravel, trace roots; loose, very moist | digs easy |
| 2 | 27 | 1 | SM | FILL<br>SILTY SAND W/GRAVEL; fine to medium sand, little gravel, trace organics; medium dense, very moist. | digs very easy |
| 3 | | | | | |
| 4 | | | SM | GLACIAL TILL<br>SILTY SAND W/GRAVEL; gray-brown, fine to medium sand, little gravel, trace to scattered cobbles to 6" dia.; very dense, moist | trench walls standing vertical |
| 5 | | | | | |
| 6 | | | | | |
| 7 | 14 | 2 | | | digs very hard and slow |
| 8 | | | | | |
| 9 | | | | | |
| 10 | | | | | |
| 11 | | | | | |
| 12 | | | | Bottom of test pit at depth 12.0 feet completed and backfilled on 12/1/88<br>Slight seepage at depth 4′; approximately 0.5 gallons per minute | |

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Figure No.
A-5

# LOG OF TEST PIT NO. TP-19

Location: Sta. 320+00, 10′ L. of ℄ No. 2 Pipeline Elevation: approx. 485

Surface Conditions: flat, grassy

| Depth in feet | Moisture Content-% | Sample | Symbol | DESCRIPTION | REMARKS |
|---|---|---|---|---|---|
| 1 | 37 | 1 | SM | TOPSOIL<br>SILTY SAND W/GRAVEL; dark brown, fine to medium, little gravel, trace roots; loose, very moist | |
| 2<br>3 | | | | GLACIAL TILL<br>SILTY SAND W/GRAVEL; brown, fine to medium sand, gravel, trace cobbles; medium dense, moist<br>- grades to unweathered | digs very hard<br><br>trench walls stand vertical |
| 4<br>5<br>6<br>7<br>8 | 10 | 2 | SM | SILTY SAND W/GRAVEL; gray-brown, fine to medium, little gravel; very dense, moist | |
| 9 | 9 | 3 | SM | SILTY SAND W/GRAVEL; gray, fine to coarse, little to some silt, little gravel; very dense, moist | |
| 10 | | | | Bottom of test pit at depth 10.0 feet<br>Completed and backfilled on 12/1/88<br>No groundwater encountered | |

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Figure No.
A-6

# LOG OF TEST PIT NO. TP-20

Location: Sta. 310+00, 10′ L. of ℄ No. 2 Pipeline  Elevation: approx. 465

Surface Conditions: approximate 3:1 slope, grassy

| Depth in feet | Moisture Content-% | Sample | Symbol | DESCRIPTION | REMARKS |
|---|---|---|---|---|---|
| 1 | | | SM | TOPSOIL<br>SILTY SAND W/GRAVEL; dark brown, fine to medium sand, little gravel, trace roots; loose, very moist | |
| 2<br>3 | 21 | 1 | SM | FILL<br>SILTY SAND W/GRAVEL; gray-brown, mottled rust, fine to medium sand, little gravel, trace roots; medium dense, moist | trench walls stand vertical |
| 4<br>5<br>6 | 15 | 2 | SM | GLACIAL TILL<br>SILTY SAND W/GRAVEL; gray-brown, fine to medium sand, little gravel, scattered cobbles to 4" dia.; dense, moist | digs hard |
| 7<br>8<br>9<br>10<br>11 | 23 | 3 | CH | LACUSTRINE SEDIMENTS<br>SANDY CLAY; gray-brown, mottled rust, little fine sand, some silt, laminated with sand and silt, high plasticity; hard, moist<br>- grades to gray green, micaceous | |
| 12<br>13 | | | ML | SANDY SILT; gray-green, fine sand, trace clay, laminated; very dense, moist | |
| 14 | | | | Bottom of test pit at depth 14.0 feet<br>Completed and backfilled on 12/1/88<br>No groundwater encountered | |

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Figure No.
A-7

# LOG OF TEST PIT NO. TP-21

Location: Sta. 307+50, 10′ R. of ℄ No. 2 Pipeline Elevation: approx. 425

Surface Conditions: edge of creek, vegetated with swamp grass, wet

| Depth in feet | Moisture Content-% | Sample | Symbol | DESCRIPTION | REMARKS |
|---|---|---|---|---|---|
| 1 | | | SM | TOPSOIL<br>SILTY SAND W/GRAVEL; dark brown, fine to medium sand, little gravel, trace roots; loose, very moist | digs easy |
| 2<br>3<br>4 | | | SM | FILL/ALLUVIUM<br>SILTY SAND W/GRAVEL; gray-brown mottled rust, fine to medium sand, little gravel, trace roots; loose, moist | trench walls caving slightly to depth 5′ |
| 5 | 31 | 1 | | - grades to laminated with sandy silt | |
| 6<br>7 | | | | | |
| 8 | | | ML | SANDY SILT W/GRAVEL; gray-green, fine to medium sand, laminated silt and clay; dense, wet. | |
| 9<br>10 | 14 | 2 | SM | GLACIAL TILL<br>SILTY SAND W/GRAVEL; gray-green, fine to medium sand, little gravel, trace clay, thinly laminated with sand and clay layers; dense, very moist | |
| 11 | | | | Bottom of test pit at depth 11.0 feet<br>Completed and backfilled on 12/1/88<br>Seepage encountered from depth 2′ to 5′; inflow approximately 2 gallons per minute | |

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Figure No
A-8

# LOG OF TEST PIT NO. TP-22

Location: Sta. 300+00, 10′ L. of ℄ No. 2 Pipeline  Elevation: approx. 435

Surface Conditions: flat, grassy, wet

| Depth in feet | Moisture Content-% | Sample | Symbol | DESCRIPTION | REMARKS |
|---|---|---|---|---|---|
| 1 | | | SM | TOPSOIL<br>SILTY SAND W/GRAVEL; dark brown, fine to medium sand, little gravel, trace roots; loose, very moist | digs easy |
| 2<br>3<br>4 | | | MH | LACUSTRINE SEDIMENTS<br>SILT; gray-brown mottled rust, some to little clay, trace sand and gravel, weathered; very stiff, very moist<br>- grades to unweathered | trench walls stand vertical |
| 5<br>6<br>7<br>8<br>9 | 27 | 1 | SM | SILTY SAND; brown mottled rust, laminated with clay and sand; very dense, moist | |
| 10<br>11<br>12 | 28 | 2 | SP | SAND; brown, fine to medium, trace silt, thinly bedded; very dense, moist | |
| 13 | | | | Bottom of test pit at depth 13.0 feet completed and backfilled on 12/1/88<br>Seepage at depth 2′; inflow approximately 2 gallons per minute | |

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Figure No. A-9

# LOG OF TEST PIT NO. TP-23

Location: Sta. 295+00, 10′ L. of ℄ No. 2 Pipeline Elevation: approx. 435

Surface Conditions: slight slope, grassy wet; change from ~~wooden to metal pipe at approx. sta. 294+25~~

| Depth in feet | Moisture Content-% | Sample | Symbol | DESCRIPTION | REMARKS |
|---|---|---|---|---|---|
| | | | | TOPSOIL | |
| 1 | | | SM | SILTY SAND W/GRAVEL; dark brown, fine to medium sand, little gravel, trace roots; loose, very moist | digs easy |
| 2 | | | | LACUSTRINE SEDIMENTS | |
| 3 | | | MH | SILT; gray-brown mottled rust, some to little clay, trace sand and gravel, bedded with 2′ layers of till, weathered; stiff, moist | trench walls stand vertical |
| 4 | | | | | |
| 5 | | | SP/SM | SAND; gray, fine to coarse, little to trace silt; dense, moist | |
| 6 | | | | | |
| 7 | 21 | 1 | | | |
| 8 | | | | | |
| 9 | | | | | |
| 10 | | | | | |
| 11 | | | | | |
| 12 | | | | | |
| 13 | | | | Bottom of test pit at depth 13.0 feet<br>Completed and backfilled on 12/1/88<br>No groundwater encountered | |

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Figure No. A-10

# LOG OF TEST PIT NO. TP-24

Location: Sta. 181+75, 10′ L. of ℄ No. 2 Pipeline Elevation: approx. 450

Surface Conditions: slight slope, grassy, pasture

| Depth in feet | Moisture Content-% | Sample | Symbol | DESCRIPTION | REMARKS |
|---|---|---|---|---|---|
| 1 | | | SM | TOPSOIL<br>SILTY SAND W/GRAVEL; dark brown, fine to medium sand, little gravel, trace roots; loose, very moist | digs easy |
| 2 | | | SM | RECENT ALLUVIUM<br>SILTY SAND; brown, fine to medium sand, thinly bedded to laminated with sand and scattered laminations of silt; loose to medium dense, wet | |
| 3 | 34 | 1 | | | |
| 4 | | | | | |
| 5 | | | | | |
| 6 | 54 | 2 | CL | CLAY; brown, trace organics, med. plasticity; very soft, wet | |
| 7 | 19 | 3 | GW | SAND & GRAVEL; gray-brown, fine to coarse sand; loose, wet | |
| 8 | | | SM | SILTY SAND W/GRAVEL; brown, fine to coarse, little gravel; loose, wet | |
| 9 | 28 | 4 | ML | SANDY SILT; gray, fine sand, very thinly laminated to bedded with silty sand; dense, wet | |
| 10 | | | SM | SILTY SAND; gray, fine to medium sand, trace organics, micaceous; medium dense, wet | |
| 11 | | | | | |
| 12 | | | | | |
| 13 | | | | | |
| 14 | 21 | 5 | GW | SAND & GRAVEL; gray, fine to coarse sand, few to little silt; medium dense to loose, wet | |
| 15 | | | | Bottom of test pit at depth 14.0 feet<br>Completed and backfilled on 12/2/88<br>Heavy seepage at 14′; seepage moderate from 3′ to 6′ inflow approximately 5 gallons per minute | |

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Figure No. A-11

# LOG OF TEST PIT NO. TP-25

Location: Sta. 175+50, 12′ L. of ℄ No. 2 Pipeline  Elevation: approx. 505

Surface Conditions: flat, grassy, top of slope

| Depth in feet | Moisture Content-% | Sample | Symbol | DESCRIPTION | REMARKS |
|---|---|---|---|---|---|
| | | | | TOPSOIL | |
| 1 | | | SM | SILTY SAND W/GRAVEL; dark brown, fine to medium sand, little gravel, trace roots; loose, very moist | |
| 2 | | | SM | SILTY SAND W/GRAVEL; brown, fine to medium sand, little gravel, trace roots; dense, wet | digs very hard |
| 3 | | | | GLACIAL TILL | |
| 4 | | | ML | SILTY SAND W/GRAVEL; gray-brown, little gravel, trace to scattered cobbles to 6" dia.; very dense, moist | |
| 5 | | | | | |
| 6 | | | | - grades to gray in color | |
| 7 | | | | | |
| 8 | | | | | |
| 9 | | | | | |
| 10 | | | | | |
| 11 | | | | Bottom of test pit at depth 11.0 feet<br>Completed and backfilled on 12/2/88<br>No groundwater encountered | |

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Figure No.
A-12

# LOG OF TEST PIT NO. TP-26

Location: Sta. 170+00, 6′ L. of ℄ No. 2 Pipeline  Elevation: approx. 538

Surface Conditions: flat pasture, muddy

| Depth in feet | Moisture Content-% | Sample | Symbol | DESCRIPTION | REMARKS |
|---|---|---|---|---|---|
| 1, 2 | | | ML | FILL<br>GRAVELLY SILT; gray-brown mottled brown, few fine to medium, little gravel, trace roots; loose, wet | trench walls stand vertical<br>top of pipe encountered at 3′<br>digs easy |
| 3, 4 | | | SM | RECENT ALLUVIUM<br>SILTY SAND W/GRAVEL; gray-brown, fine to medium sand, little gravel; medium dense, wet | |
| 5, 6 | 43 | 1 | CL/CH | CLAY; brown mottled and streaked gray, little to trace fine sand, trace organics, medium to high plasticity; very soft to medium stiff, wet | |
| 7, 8 | | | SM | SILTY SAND; brown, fine to coarse, trace gravel; medium dense, wet | |
| 9, 10, 11 | 15 | 2 | SM | SILTY SAND TO SILTY SAND W/GRAVEL; gray, fine to coarse sand, little gravel, trace cobbles to 12" dia.; dense, wet | |
| 12, 13 | 10 | 3 | SM | GLACIAL TILL<br>SILTY SAND W/GRAVEL; gray-green, fine to medium sand, little gravel; very dense, moist | digs very hard |

Bottom of test pit at depth 13.0 feet
Completed and backfilled on 12/2/88
Slight seepage at depth 5.0 feet

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Figure No. A-13

# LOG OF TEST PIT NO. TP-27

Location: Sta. 160+00, 10′ L. of ℄ No. 2 Pipeline Elevation: approx. 555

Surface Conditions: flat, pasture, swampy with 6" standing water at surface

| Depth in feet | Moisture Content-% | Sample | Symbol | DESCRIPTION | REMARKS |
|---|---|---|---|---|---|
| | | | | RECENT ALLUVIUM | |
| 1 | | | OL | ORGANIC SILT; brown; very soft, wet | digs very easy |
| 2 | | | SM | SILTY SAND W/GRAVEL; gray-brown, fine to medium, little gravel, trace roots to 4′; loose to medium dense, wet | |
| 3 | | | | | |
| 4 | 36 | 1 | SW | GRAVELLY SAND; brown, fine to medium sand, trace to few silt; medium dense, wet | caving badly entire depth |
| 5 | | | | | |
| 6 | | | SM | SILTY SAND; brown, fine to medium sand, very thinly bedded with clay, silt, and gravel; medium dense, wet | |
| 7 | | | | | |
| 8 | | | | | |
| 9 | | | | | |
| 10 | | | | | |
| 11 | 35 | 2 | ML | SANDY SILT; gray-green, fine, very thinly laminated with clay and sand; dense, wet | |
| 12 | | | | | |
| 13 | | | | | |
| 14 | 44 | 3 | | | |
| 15 | | | SP | SAND; gray-green, fine to coarse, trace gravel, very thinly bedded with silty sand; dense, wet | |
| 16 | | | | | |
| | | | | Bottom of test pit at depth 15.0 feet<br>Completed and backfilled on 12/2/88<br>Heavy seepage entire depth | |

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Figure No. A-14

# LOG OF TEST PIT NO. TP-28

Location: Sta. 143+50, 8′ L. of ℄ No. 2 Pipeline  Elevation: approx. 510

Surface Conditions: swampy area, grassy and wet

| Depth in feet | Moisture Content-% | Sample | Symbol | DESCRIPTION | REMARKS |
|---|---|---|---|---|---|
| | | | ML | TOPSOIL<br>SILT; gray-brown mottled brown, trace roots; med. stiff, wet | |
| 1 | | | | | |
| 2 | | | SM | RECENT ALLUVIUM<br>SILTY SAND W/GRAVEL; gray-green, fine to medium sand, little gravel, trace organics, thinly bedded with organics scattered cobbles to 6" dia.; medium dense, wet | digs easy |
| 3 | | | | | |
| 4 | | | | | caving badly |
| 5 | | | | | |
| 6 | | | | | |
| 7 | | | | | |
| 8 | | | SM | GLACIAL TILL<br>SILTY SAND W/GRAVEL; gray-green, fine to coarse sand, little gravel, trace to scattered cobbles; very dense, moist | digs very hard |
| 9 | | | | | |
| 10 | | | | - grades to yellow-brown in color | |
| 11 | | | | | |
| 12 | | | SP | SAND; brown, fine to coarse, trace silt and fine gravel; very dense, very moist | |
| | | | | Bottom of test pit at depth 12.0 feet<br>completed and backfilled on 12/2/88<br>Moderate seepage from depth 2′ to 7′ | |

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Figure No.
A-15

# APPENDIX B

## GEOTECHNICAL LABORATORY TESTING

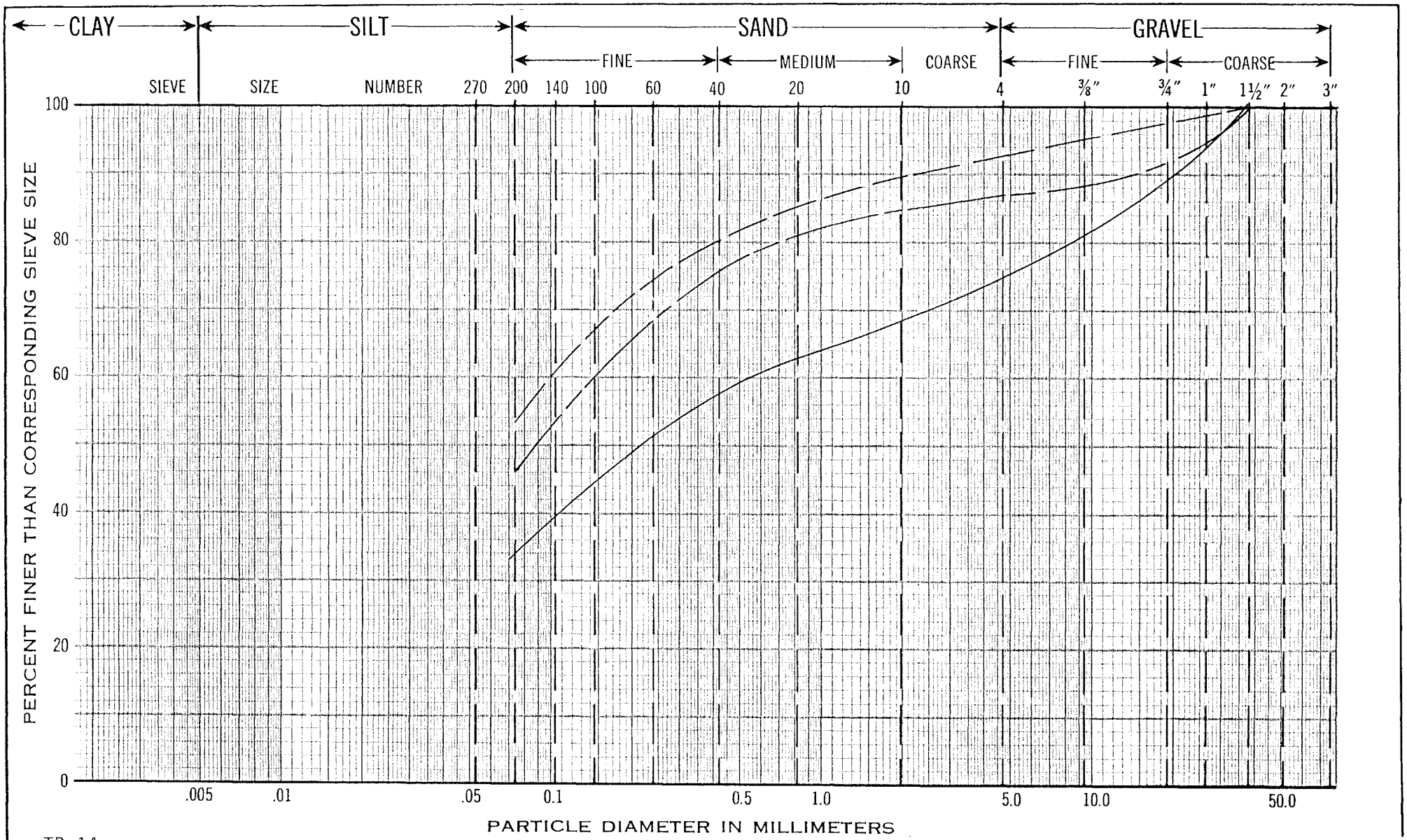
Classification tests were performed on selected soil samples to develop parameters for use in evaluating subsurface conditions, to permit correlation of engineering properties of tested samples with similar soil types, and to prepare geotechnical engineering recommendations for the proposed project. The soils which were tested were checked against the field log classifications and updated where appropriate in general accordance with ASTM D-2488, "Standard Test Method for Classification of Soils for Engineering Purposes". The laboratory testing program included moisture content determinations, grain size analyses, liquid and plastic Atterberg limit determinations, and compaction testing. All tests were performed in our laboratory and in general accordance with the American Society of Testing and Materials (ASTM) standard test procedures.

Moisture content determinations were performed on selected soil samples in general accordance with ASTM D-2216. The test results are used in classification and correlation of the various soils encountered at the site. They were also used to provide quantitative approximations regarding soil strength characteristics for cohesive soils. The results of these tests are shown on the individual logs of the explorations.

Sieve analyses were performed on selected samples to determine grain size distributions. The tests were performed in general accordance with ASTM D-422. The grain size curves are shown at the end of this appendix on Figures B-1 and B-2.

Liquid and plastic Atterberg limits were determined for selected samples of the cohesive soils encountered in the explorations. The tests were performed in accordance with ASTM D-4318 to aid in classification and correlation, and to provide qualitative information concerning engineering parameters of the soils. The results of these tests are shown on Figure B-3.

A dry density versus moisture content curve was developed for prevalent soil types encountered in the test pits. One curve was developed for the glacial till soil deposits, the lacustrine deposits, and the alluvial deposits. The tests were performed in accordance with ASTM D-1557. The resulting curves are shown on Figures B-4 through B-6.




TP-14 ———
Sample 1, depth 6'-7

TP-16 — — —
Sample 1, depth 5'-6'

TP-17 — — —
Sample 1, depth 5'-6'

## GRAIN-SIZE DISTRIBUTION CHART

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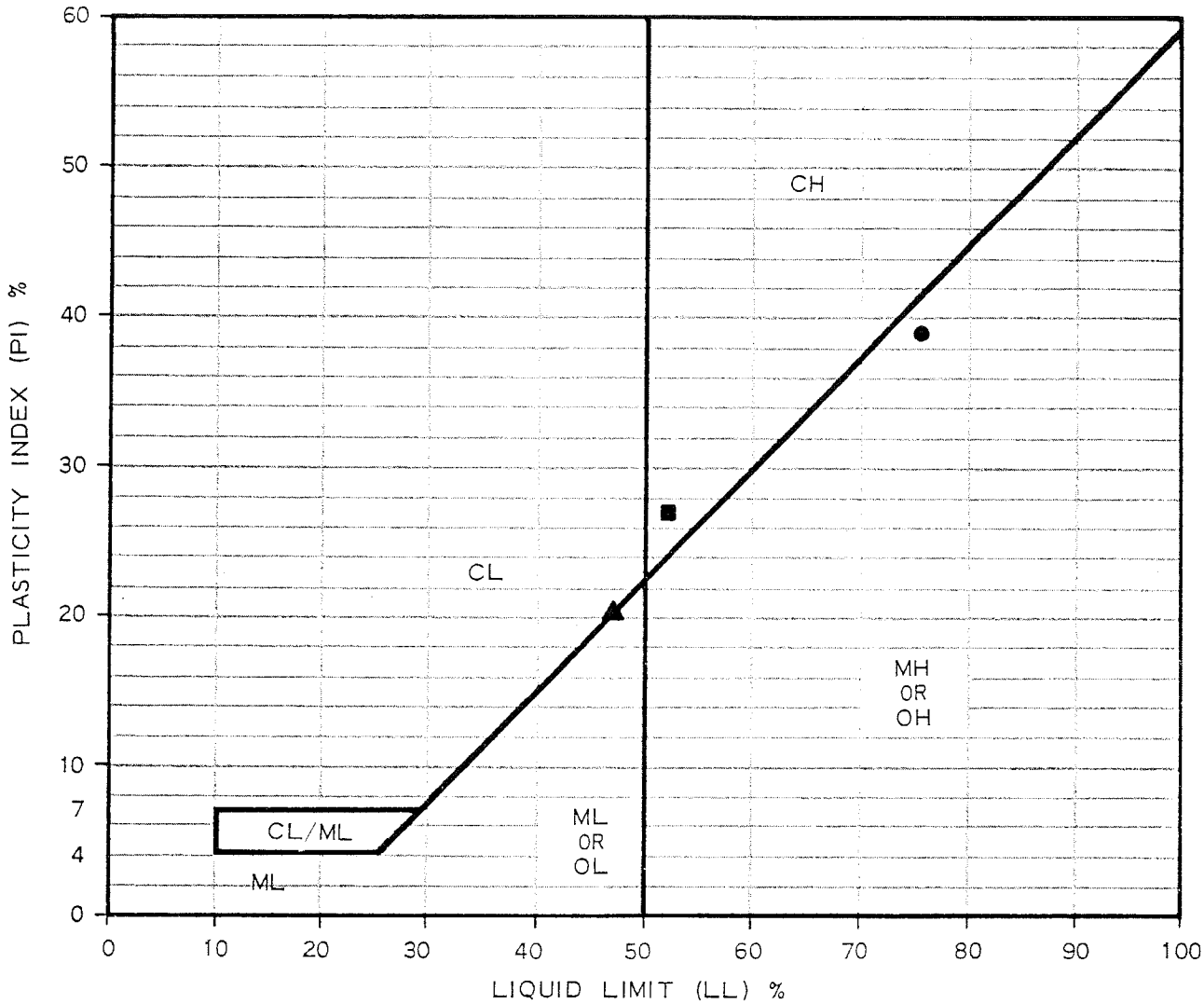
Figure No.
B-1




| Symbol | Classification and Source | Liquid Limit (%) | Plastic Limit (%) | Plasticity Index (%) | % Passing No. 200 Seive |
|---|---|---|---|---|---|
| ● | TP-15, S-3, depth 9'-10' | 75 | 36 | 39 | |
| ■ | TP-17, S-3, depth 9'-10' | 52 | 25 | 27 | |
| ▲ | TP-26, S-1, depth 5'-6' | 46 | 26 | 20 | |

PLASTICITY CHART

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Figure No.
B-3

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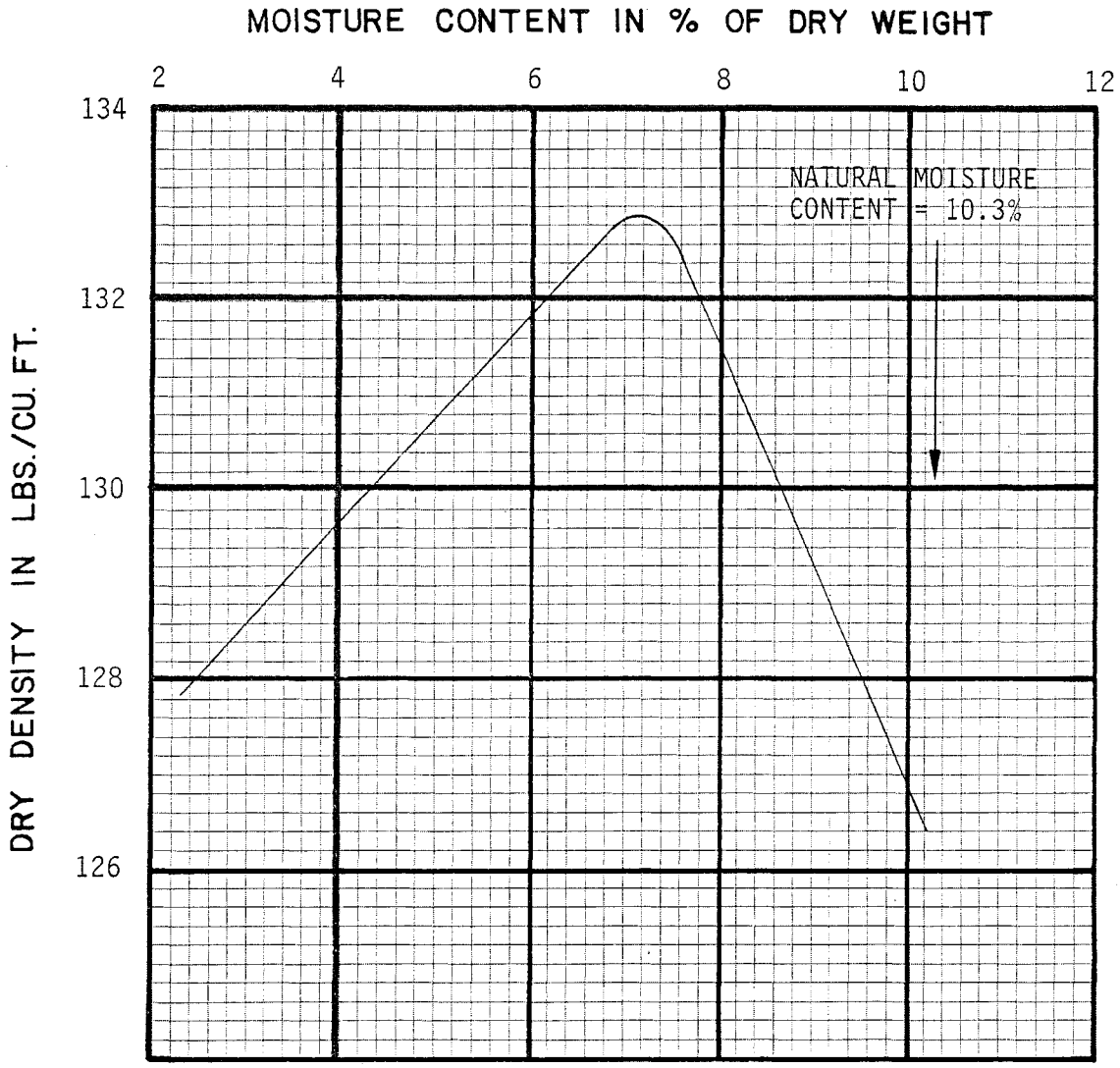
# COMPACTION TEST RESULTS




TEST PROCEDURE: ASTM D1557, method C

| CURVE NUMBER | SAMPLE LOCATION | SAMPLE DEPTH (FT.) | SOIL DESCRIPTION | OPTIMUM MOISTURE CONTENT (%) | MAX. DRY DENSITY (PCF) |
|---|---|---|---|---|---|
| | TP-14, S-1 | 6'-7' | Brown SILTY SAND; fine to coarse, with some fine to coarse gravel | 7 | 133 |

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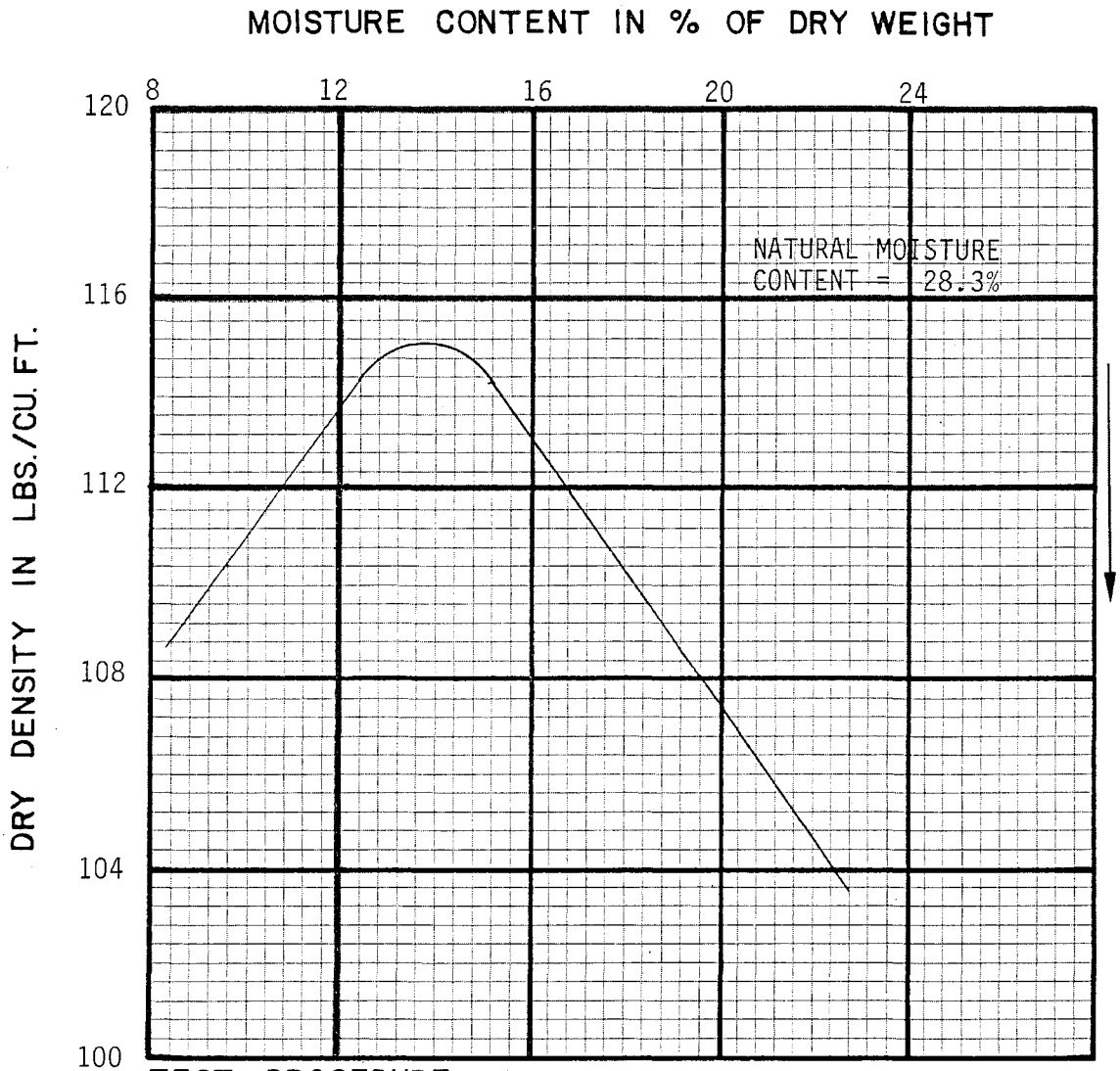
Figure No.
B-4

# COMPACTION TEST RESULTS




TEST PROCEDURE: ASTM D1557, method A

| CURVE NUMBER | SAMPLE LOCATION | SAMPLE DEPTH (FT.) | SOIL DESCRIPTION | OPTIMUM MOISTURE CONTENT (%) | MAX. DRY DENSITY (PCF) |
|---|---|---|---|---|---|
| | TP-17 S-3 | 9' | Blue-gray SILTY CLAY, with trace fine to medium sand | 14 | 115 |

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Figure No.
B-5

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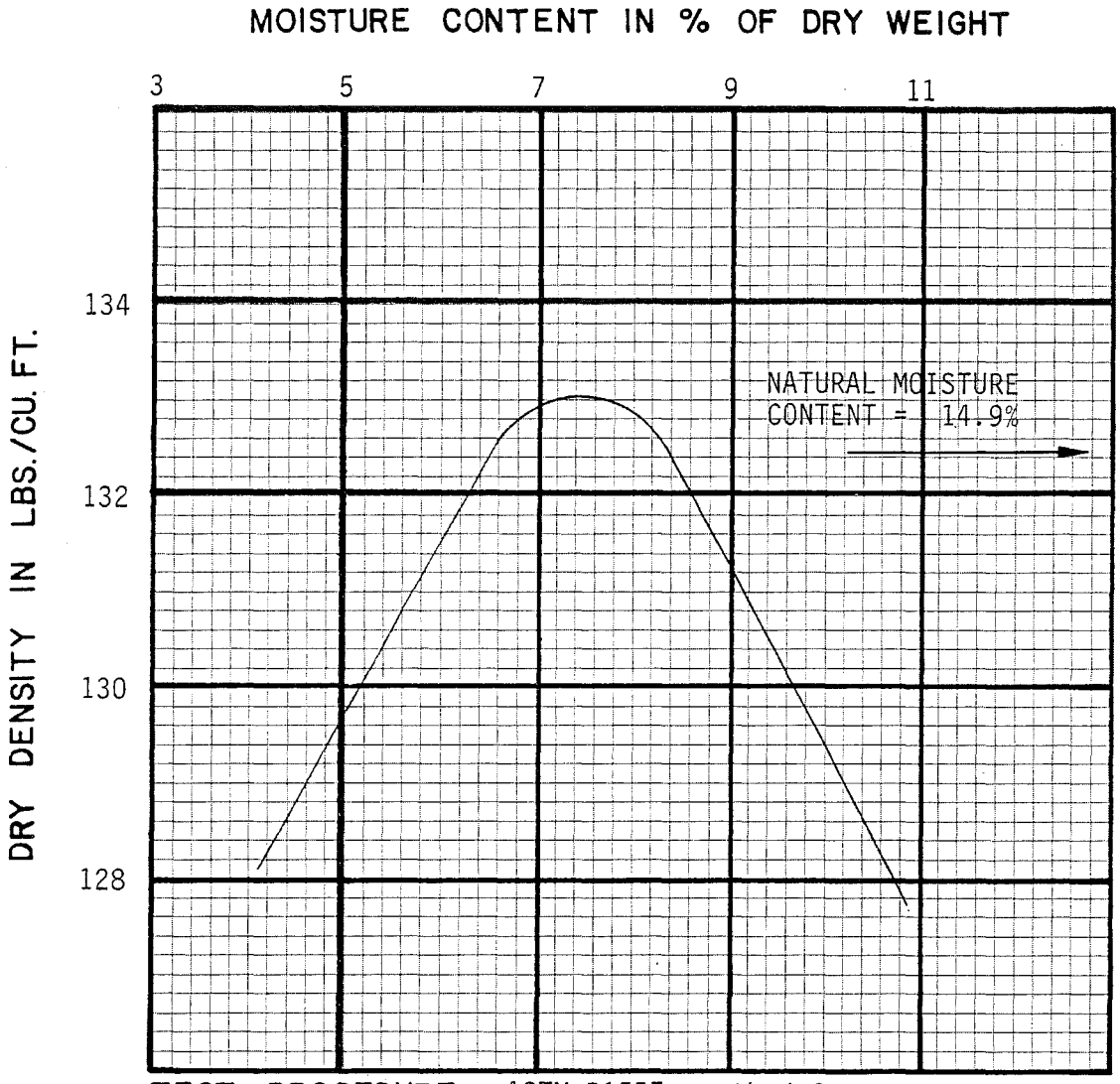
# COMPACTION TEST RESULTS




TEST PROCEDURE: ASTM D1557, method C

| CURVE NUMBER | SAMPLE LOCATION | SAMPLE DEPTH (FT.) | SOIL DESCRIPTION | OPTIMUM MOISTURE CONTENT (%) | MAX. DRY DENSITY (PCF) |
|---|---|---|---|---|---|
| | TP-26 S-2 | 9'-10' | Gray SILTY SAND, fine to medium, with little fine to coarse gravel | 8 | 133 |

PROPOSED WATER SUPPLY PIPELINE NO. 2
Everett, Washington
for James M. Montgomery, Consulting Engineers

Project No.
87-35205-03

Converse Consultants NW Geotechnical Engineering and Applied Earth Sciences

Figure No.
B-6

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