# CITY OF THE DALLES, OREGON

CONTRACT NO. 2022-001

# BIDDING REQUIREMENTS
# AND
# CONTRACT DOCUMENTS

for the construction of the

# DOG RIVER PIPELINE REPLACEMENT

## VOLUME 4: REFERENCE INFORMATION

****

****

JACOBS

Corvallis, Oregon

March 2022

Project No. D3504800 Copy No. ___________________

# TABLE OF CONTENTS

## VOLUME 4

REFERENCE INFORMATION

# 1. GEOTECHNICAL DATA REPORT

CITY OF THE DALLES
OREGON

# Dog River Pipeline Replacement
# Geotechnical Data Report

January 2022

Jacobs

Jacobs Engineering Group Inc.
2020 SW 4th Avenue, Suite 300
Portland, Oregon 97201
503.235.5000
www.jacobs.com

# Dog River Pipeline Replacement Geotechnical Data Report

| | |
|---|---|
| Project No: | D3504800 |
| Document Title: | Dog River Pipeline Geotechnical Data Report |
| Revision: | Final |
| Date: | January 2022 |
| Client Name: | City of The Dalles, Oregon |
| Project Manager: | Brady Fuller/Jacobs |
| Authors: | Marcelo Azevedo/Jacobs |
| Reviewed By: | Todd Cotten/Jacobs |

Jacobs Engineering Group Inc.

2020 SW 4th Avenue, Suite 300
Portland, Oregon 97201
United States
T +1.503.235-5000

www.jacobs.com

Digitally signed on
January 13, 2022 by
Marcelo Azevedo, P.E.

# Contents

Tables

Figures (provided at end of report)

Appendix

# Acronyms and Abbreviations

| | |
|---|---|
| AASHTO | American Association of State Highway and Transportation Officials |
| ASTM | ASTM International |
| bgs | below ground surface |
| City | City of The Dalles |
| El | elevation |
| ft | foot/feet |
| GB | grab |
| GDR | Geotechnical Data Report |
| GPS | Global Positioning System |
| ISRM | International Society of Rock Mechanics |
| Jacobs | Jacobs Engineering Group Inc. |
| LL | liquid limit |
| mg/kg | milligrams per kilogram |
| mV | millivolt(s) |
| NAVD88 | National American Vertical Datum of 1988 |
| NR | not recorded |
| ohm-cm | ohms centimeter |
| OCRS | Oregon Coordinate Reference System |
| project | Dog River Pipeline Replacement |

# 1. Introduction

The City of The Dalles (City) retained Jacobs Engineering Group Inc. (Jacobs) to provide engineering consulting services for the design of the Dog River Pipeline Replacement project (project). Authorization for the geotechnical scope of work is provided by the Professional Services Contract between the City and Jacobs effective May 3, 2021. Task 2.2 of the project scope of work requires the development of this Geotechnical Data Report (GDR) summarizing the geotechnical field explorations.

## 1.1 Project Description

The Dog River Pipeline Replacement project is located approximately 7 miles southeast of Parkdale, Oregon within The Dalles Municipal Watershed. The Dog River pipeline conveys water from an existing diversion dam along Dog River and discharges into South Fork Mill Creek. The water provided by the Dog River pipeline is a portion of the City's public drinking water supply. The existing pipeline was constructed approximately 100 years ago and is currently deteriorating as evidenced by a reduced flow volume to South Fork Mill Creek. Exposed and leaking segments of the existing pipeline near the ground surface have also been visually observed.

The overall project design scope includes replacement of approximately 3.5 miles of existing 20-inch diameter wood stave pipeline with a new 24-inch diameter pipeline that is expected to have a service life of 100 years, new fish passage and screening systems at the intake to the pipeline, flow monitoring systems at the intake and outlet, a new aquatic organism passage culvert at Brooks Meadow Creek, and an energy dissipation facility at the discharge into South Fork Mill Creek. The new pipeline is to be constructed within a 25-foot wide corridor through forested lands via open-cut methods. A vicinity map of the project location is presented in Figure 1 (figures are provided at the end of this report).

## 1.2 Pipeline Alignment

The proposed new pipeline alignment will follow a similar alignment to the existing pipeline alignment except that the new pipeline will be located along existing roadways to the maximum extent practical to improve long term maintenance access, reduce construction costs, and reduce pre-construction clearing requirements. The pipeline alignment begins at the existing Dog River diversion dam and follows an existing access road to the northwest until reaching NF-44 road. Upon crossing NF-44, the pipeline will generally follow the alignment of NF-1700014 road, except in a few areas where the pipeline will be shifted off the roadway alignment to maintain the required head for gravity flow to provide the required design flow. NF-1700014 is an approximately 8 to 10-foot-wide access road for a majority of the pipeline alignment. Approximately 400 feet west of and prior to reaching NF-17 road, the pipeline leaves NF-1700014 and proceeds to the north, following the alignment of an existing single-track trail. The alignment will continue north for approximately 2,500 feet on the single-track trail, and will then head east for approximately 1,000 feet until reaching NF-17. The alignment will continue east after crossing NF-17, following an existing access road for an additional approximately 2,000 feet before discharging into South Fork Mill Creek.

The proposed alignment for the new pipeline is presented in Figure 2. The alignment will include an open cut crossing of Brooks Meadow Creek approximately 300 feet west of NF-44. The project will also include the construction of an arch culvert and placement of road embankment fill for the NF-1701114 road crossing of Brooks Meadow Creek.

## 1.3 Objective and Scope of Work

The objective of this GDR is to present findings of the geotechnical and geophysical explorations that were performed in June and July 2021, along with the results of laboratory test data conducted on soil samples recovered during the explorations.

The scope of work for the geotechnical program includes the following:

- Review available geologic information.
- Review data from previous geotechnical explorations.
- Conduct a geotechnical field investigation along the pipeline alignment consisting of geotechnical test pits.
- Conduct a geophysical field investigation consisting of seismic refraction surveys at select locations along the pipeline alignment and electrical resistivity surveys at the diversion dam.
- Develop and perform a laboratory testing program for selected samples collected from the test pits.
- Characterize and develop the general subsurface stratigraphy along the pipeline alignment.
- Prepare this GDR to summarize the results of the field investigations and laboratory testing program.

# 2. Exploration and Testing

This section provides a summary of the field exploration program, laboratory testing program, and results of previous assessments completed in the vicinity of the pipeline alignment.

## 2.1 Geotechnical Field Exploration and Laboratory Testing Program

The geotechnical field exploration program consisted of advancing eighteen test pits between June 14 to 16, 2021. The test pits were excavated with equipment owned and operated by the City. The field explorations were completed in the presence of a Jacobs engineer who directed the work, collected samples, and provided continuous observation and logging of each of the explorations.

Locations of geotechnical explorations were determined using a handheld Global Positioning System (GPS) device (Garmin 62S). Horizontal accuracy of the GPS device is approximately 10 to 15 feet. Vertical elevations for the test pits were determined from a topographic survey completed for this project based on the GPS coordinates. The locations of the explorations are shown on Figure 2.

### 2.1.1 Test Pits

The geotechnical exploration program included completion of eighteen test pits (designated TP-#). The test pits were excavated with a CAT 308D CR excavator equipped with a 2-foot wide toothed bucket and hydraulic thumb. Test pits were excavated to a maximum depth of 10 feet, although most test pits were terminated shallower due to refusal from encountering bedrock, large boulders, or due to raveling soils. Upon completion, the test pits were backfilled with the excavated soil, and compacted in lifts. At select depths, as indicated on the test pit logs, soil samples were recovered by obtaining a grab (GB) sample from the excavated material. Soil recovered in the GB samples were collected in sealable plastic bags. Test pit locations, coordinates, final completion depths, and ground surface elevations at the exploration locations are summarized in Table 2-1.

**Table 2-1. Summary of Test Pits**

| Test Pit | Northing (feet, NAD83)[a] | Easting (feet, NAD83)[a] | Completion Depth (feet, bgs) | Ground Surface Elevation (feet, NGVD29)[b] | Bottom Elevation (feet, NGVD29)[b] |
|---|---|---|---|---|---|
| TP-1A | 331562.4312 | 129083.7890 | 7.0 | 4271 | 4264 |
| TP-1 | 332771.6207 | 128209.5197 | 7.0 | 4224 | 4217 |
| TP-2 | 333384.0958 | 127503.0744 | 5.0 | 4231 | 4226 |
| TP-2A | 333884.4267 | 127180.9118 | 9.0 | 4225 | 4216 |
| TP-3 | 333745.8800 | 127008.6409 | 5.5 | 4244 | 4238.5 |
| TP-4 | 333508.6974 | 126086.7703 | 8.0 | 4235 | 4227 |
| TP-5 | 333326.6456 | 125152.4441 | 7.5 | 4245 | 4237.5 |
| TP-6 | 333333.5849 | 124112.1692 | 5.0 | 4230 | 4225 |
| TP-7 | 335377.4664 | 122948.5298 | 5.0 | 4215 | 4210 |
| TP-8 | 336324.1434 | 123181.9539 | 9.0 | 4237 | 4228 |

**Table 2-1. Summary of Test Pits**

| Test Pit | Northing (feet, NAD83)[a] | Easting (feet, NAD83)[a] | Completion Depth (feet, bgs) | Ground Surface Elevation (feet, NGVD29)[b] | Bottom Elevation (feet, NGVD29)[b] |
|---|---|---|---|---|---|
| TP-9 | 337190.3346 | 123607.1671 | 9.5 | 4214 | 4204.5 |
| TP-10 | 337781.1850 | 124351.5043 | 9.0 | 4223 | 4214 |
| TP-11 | 338035.7061 | 125350.6187 | 10.0 | 4219 | 4209 |
| TP-12 | 338420.6007 | 125988.9992 | 9.5 | 4221 | 4211.5 |
| TP-13 | 340533.8904 | 126277.7076 | 9.5 | 4210 | 4200.5 |
| TP-14 | 340440.9286 | 126549.3135 | 6.0 | 4210 | 4204 |
| TP-15 | 340376.2488 | 127514.3454 | 9.0 | 4156 | 4147 |
| TP-16 | 340275.5301 | 128420.0913 | 5.5 | 4095 | 4089.5 |

[a] Horizontal datum: Oregon Coordinate Reference System (OCRS), Dufur-Madras NSRS11, with units in international feet.

[b] Vertical datum: North American Vertical Datum of 1988 (NAVD88), with units in international feet.

Note:

bgs = below ground surface

Coordinates and ground surface elevations are approximate. Exploration locations were determined using a handheld Global Positioning System (GPS) device (Garmin 62S) and elevations are based on a topographic survey of the project alignment.

Soil classification systems attempt to group soils that have similar engineering behavior (based on index tests). Several classification systems have been developed, usually for a specific application. The system most generally accepted for a wide range of engineering applications is the Unified Soil Classification System (USCS). The use of this method of classification provides a basis for comparison of soils from widespread geographic areas. Soil samples recovered from the test pits were examined and visually classified in accordance with ASTM International (ASTM) D2488, Standard Practice for Description and Identification of Soils (Visual-Manual Procedures), which follows the USCS. Upon receipt of laboratory test data, soil descriptions and classifications were updated in accordance with ASTM D2487, Classification of Soils for Engineering Purposes (USCS).

Sampling intervals, stratigraphy, groundwater occurrence, and descriptions and classifications of soil samples were recorded on the test pit logs presented in Appendix A. The stratigraphic contacts indicated on the logs represent the approximate boundaries between soil types and actual transitions may be more gradual. Photographs of the field explorations are presented in Appendix B.

### 2.1.2 Laboratory Testing

A laboratory testing program was developed to provide classification and engineering properties of the soil samples obtained from the test pits. The soil and corrosion laboratory testing was conducted by FEI Testing & Inspection, Inc. of Corvallis, Oregon.

Soil laboratory testing was performed using the following methods:

- ASTM D422, Standard Test Method for Particle-Size Analysis of Soils

- ASTM D1140, Standard Test Methods for Amount of Material in Soils Finer than the No. 200 (75-µm) Sieve
- ASTM D2216, Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass

Corrosion laboratory testing was performed using the following AASHTO (American Association of State Highway and Transportation Officials) methods:

- AASHTO T288, Standard Method of Test for Determining Minimum Laboratory Soil Resistivity
- AASHTO T289, Standard Method of Test for Determining pH of Soil for Use in Corrosion Testing
- AASHTO T290, Standard Method of Test for Determining Water-Soluble Sulfate Ion Content in Soil
- AASHTO T291, Standard Method of Test for Determining Water-Soluble Chloride Ion Content in Soil

Table 2-2 presents a summary of laboratory testing results completed on representative soil samples collected during the geotechnical explorations. Results of corrosion tests on soil samples are provided in Table 2-3. The complete reports of laboratory tests are included in Appendix C. Select laboratory test results are also included in the “comments” section of the test pit logs in Appendix A.

The gradation test results provided in Table 2-2 may not be representative of the true in situ gradation of the native material. Multiple explorations encountered an abundant quantity of cobbles and boulders. The samples that were collected for laboratory analyses consisted of soil material but generally excluded cobbles and boulders. Therefore, the gradations provided from laboratory testing can be considered approximate for the soil matrix only. Observations of coarser material including cobbles and boulders are noted in the test pit logs.

**Table 2-2. Summary of Laboratory Test Results**

| Exploration | Sample | Depth Interval (feet bgs) | Moisture Content (%) | Fines Content (%)[a] | Sand Content (%)[a] | Gravel Content (%)[a] |
|---|---|---|---|---|---|---|
| TP-1A | GB-1 | 3.5-4 | 10.7 | 11.9 | 34.5 | 65.5 |
| TP-1 | GB-1 | 4-4.5 | 19.3 | 29.1 | 38.5 | 32.4 |
| TP-2A | GB-1 | 4-4.5 | 26.7 | 38.5 | 45.1 | 16.4 |
| TP-4 | GB-1 | 4-4.5 | 25.1 | 26.4 | 44.0 | 29.6 |
| TP-6 | GB-1 | 4-4.5 | 16.5 | 25.8 | 47.3 | 26.9 |
| TP-7 | GB-1 | 3-3.5 | 15.1 | 29.2 | 34.6 | 36.2 |
| TP-9 | GB-1 | 3.5-4 | 14.6 | 29.5 | 39.6 | 30.9 |
| TP-11 | GB-1 | 4.5-5 | 32.7 | 39.3 | 30.4 | 30.3 |
| TP-13 | GB-1 | 3.5-4 | 19.6 | 41.0 | 44.7 | 14.3 |
| TP-14 | GB-1 | 4-4.5 | 19.6 | 30.2 | 54.4 | 15.4 |
| TP-16 | GB-1 | 3.5-4 | 29.2 | 32.0 | 56.2 | 11.8 |

[a] Gradation test results may not be representative of true in situ gradation as samples were obtained from soil matrix between cobbles and boulders.

**Table 2-2. Summary of Laboratory Test Results**

| Exploration | Sample | Depth Interval (feet bgs) | Moisture Content (%) | Fines Content (%)[a] | Sand Content (%)[a] | Gravel Content (%)[a] |
|---|---|---|---|---|---|---|

Notes:
GB = grab sample

**Table 2-3. Summary of Corrosivity Test Results**

| Exploration | Sample | Depth Interval (feet bgs) | pH | Resistivity (ohm-cm) | Water Soluble Chloride (mg/kg) | Water Soluble Sulfate (mg/kg) |
|---|---|---|---|---|---|---|
| TP-2A | GB-1 | 4-4.5 | 6.2 | 9,063 | 10 | 0 |
| TP-9 | GB-1 | 3.5-4 | 6.8 | 19,915 | 20 | 0 |
| TP-14 | GB-1 | 4-4.5 | 6.0 | 14,787 | 0 | 54.1 |

Notes:
mg/kg = milligrams per kilogram
ohm-cm = ohms centimeter

## 2.2 Geophysical Field Exploration

A geophysical exploration was completed along the pipeline alignment in July 2021 to supplement the geotechnical explorations. The geophysical explorations were conducted by Siemens and Associates of Bend, Oregon. The geophysical scope included conducting seismic refraction surveys at eleven locations along the alignment. Electrical resistivity surveys and additional geophysical methods were performed at the diversion dam structure. Data from the geophysical explorations are summarized in a report included in Appendix D.

An additional geophysical investigation was completed by Siemens and Associates in October 2021 to investigate the depth of the existing diversion dam structure. The supplemental geophysical scope included conducting a linear microtremor survey spanning the full length of the dam and a seismic refraction survey perpendicular to the dam structure. Data from the supplemental geophysical explorations are summarized at the end of the geophysical report in Appendix D as Addendum #1. The red outline shown on Figure SR-14 of the geophysical report highlights a possible estimated configuration of the concrete diversion dam structure, as interpreted by Jacobs from the geophysical data.

## 2.3 Previous Investigations

A conceptual design for the project was previously completed by Brown and Caldwell and summarized in the *Dog River Water Pipeline Replacement Conceptual Design* (Brown and Caldwell 2012). The conceptual design report describes a proposed pipeline alignment selected by the City after an alternative evaluation, plan and profile drawings of the selected pipeline alignment, a cost estimate for the project, a geotechnical slope reconnaissance memorandum, and a corrosivity analysis memorandum.

The geotechnical slope reconnaissance memorandum was prepared by Shannon and Wilson and consists of a two-page summary of the conditions of the slopes along the proposed pipeline alignment. The conditions of the slopes were assessed by visual observation by a certified engineering geologist conducting a site walk in October 2011 along the proposed alignment.

The corrosivity analysis memorandum was prepared by Cascade Corrosion Consulting Services, Inc. in 2011. The corrosion investigation included measuring soil resistivity at ten locations along the pipeline alignment. Resistivity tests were performing in accordance with ASTM G57, Field Measurement for Soil Resistivity Using the Wenner Four-Electrode Method. Corrosivity test results indicate that the soil may be slightly corrosive to buried metallic materials. The memorandum discusses recommendations for various pipe materials and liners that may be used as the pipe material for the project.

Both the geotechnical slope reconnaissance memorandum and the corrosivity analysis report are included in Appendix E.

# 3. Geology

This section describes the regional and mapped geology in the vicinity of the proposed pipeline alignment.

## 3.1 Regional Geology

The project site is located within the High Cascades subprovince of the Cascade Range geological province. The Cascade Range is composed of volcanic rocks as old as 45 million years in the deeply eroded Western Cascades subprovince. The High cascades subprovince, however, is minimally eroded as it is composed of relatively younger volcanos which have been active in the last few millions of years. Quaternary volcanic activity has filled canyons and built up the crest of the High Cascades along the axis of the range. Several large volcanos comprise the High Cascades from southern to northern Oregon, with Mount Hood being the largest of the range in Oregon. Mount Hood is a stratovolcano composed of quaternary andesite located to the west of the project site. Numerous small cinder cones and vents have erupted since the Pliocene epoch, producing lava flows covering up to a few square miles around Mount Hood. Volcanic rock units around Mount Hood are predominately comprised of basaltic andesite (Sherrod and Scott 1995).

## 3.2 Mapped Surficial Geology

Multiple surficial geologic units are mapped in the vicinity of the pipeline alignment by Sherrod and Scott (1995) and Ma, Sherrod, and Scott (2014). The 2014 geologic map is an updated version of the 1995 geologic map that has been digitized and colored. Relevant mapped geologic units include: Lookout Mountain Dacite (Tlmd), Lookout Mountain Andesite (Tlma), Basaltic Andesite of Dog River (Qbdr), and Basaltic Andesite and Basalt (QTb). Each of these units was classified according to chemical composition by determining the percent weight of silicon dioxide in the rock. Figure 3 shows the mapped surficial geology within the vicinity of the project site.

**Lookout Mountain Dacite (Tlmd) and Andesite (Tlma)** formed from Pliocene lava flows ranging in composition from basalt to dacite. Dacite is classified as being composed of 63 to 68 percent silicon dioxide while andesite is comprised of 57 to 63 percent silicon dioxide. Dog River Mountain is comprised of dacite, which is slightly porphyritic. Dacite is mapped along the central portion of the pipeline alignment approximately north of Dog River to Surveyors Ridge Road. Andesite is mapped along the southern third of the pipeline alignment approximately south of Dog River to the existing diversion dam.

**Basaltic Andesite of Dog River (Qbdr)** consists of Pleistocene porphyritic lava that erupted from cinder cones near the headwaters of Dog River. Defining features of this unit are a medium gray color and plagioclase phenocrysts with glass inclusions. Basaltic andesite is mapped along the northern third of the pipeline alignment parallel to Surveyors Ridge Road to the existing discharge location into South Fork Mill Creek.

**Basaltic Andesite and Basalt (QTb)** consists of Pleistocene and Pliocene lava flows that erupted from vents near the headwaters of Dog River. This unit contains a small amount of plagioclase and olivine phenocrysts. Basaltic andesite is classified as being composed of 52 to 57 percent silicon dioxide while basalt is comprised of less than 52 percent silicon dioxide. Basaltic andesite and basalt is mapped all around the base of Dog River Mountain.

# 4. Summary of Site Conditions

Results of field explorations as well as information about the regional and local mapped geology described in Section 3 were used to evaluate surface and subsurface soil and groundwater conditions along the pipeline alignment. The following sections summarize the interpretation of available site subsurface information. Readers and users of this GDR should make their own assessment of ground conditions that will be encountered along the project alignment.

## 4.1 Surface Conditions

The ground surface elevation of the southern end of the pipeline alignment, near the existing Dog River diversion dam, is approximately El. 4,270 feet (NAVD88). North of the diversion dam, the pipeline alignment follows a topographic contour around the base of Dog River Mountain, with the ground surface generally remaining within El. 4,210 to 4,240 feet. Once the alignment approaches NF-17, the ground slopes down gently and reaches approximate El. 4,100 feet at the discharge location into South Fork Mill Creek.

## 4.2 Observed Subsurface Conditions

The subsurface soil profile is described below based on the geotechnical data collected during the subsurface exploration program.

### 4.2.1 Silty Sand and Gravel with Cobbles and Boulders

Deposits of silty sand and silty gravel with cobbles and boulders were encountered in all of the explorations along the pipeline alignment. Generally, the soil profile consisted of up to a few feet of material with a higher fines content (up to 40 percent), with fines content decreasing with depth while the amount of coarse-grained material increased with depth. Varying amounts of cobbles and boulders were encountered in all of the explorations starting from the ground surface to a few feet below ground surface. The estimated quantity of cobbles and boulders observed at each test pit location, to the depths of the explorations, are noted on the test pit logs. For soil classified as silt with gravel (ML), minimal cobbles and boulders were observed. For soil classified as silty sand (SM), occasional cobbles and boulders were observed. For soil classified as silty gravel (GM) or poorly graded gravel with silt (GP-GM), abundant cobbles and boulders were observed. Boulders were generally 1 to 3 feet in diameter, although larger boulders up to 6 feet in diameter were encountered as noted in the test pit logs. Boulders having dimensions larger than those observed during the exploration program are expected to be present along the project alignment. The presence of large boulders may result in the inability to complete excavations without the use of a rock hammer.

Material from this soil unit was excavated with a CAT 308D CR equipped with a 2-foot-wide bucket with a thumb. Cobbles and boulders were observed to be loosely deposited within the soil matrix. The presence of boulders made excavation more difficult and significantly reduced the rate of excavation. South of TP-11 and near TP-16, the soil matrix between cobbles and gravels generally was observed to have a fines content of less than 30 percent and raveling was observed on test pit walls. Multiple test pits were terminated above a depth of 10 feet below ground surface (bgs) due to raveling of test pit walls. If the excavation had been widened, the excavation likely could have continued deeper. North of TP-11 and west of TP-15, the soil matrix between cobbles and boulders was observed to have a higher fines content between 30 to 40 percent. Excavations in this area were observed to be mostly vertical with minimal raveling and generally extended deeper to approximately 10 feet bgs before being limited by excavator reach or encountering refusal due to bedrock at a shallower depth.

This soil unit is not mapped on local geologic mapping. The origin of this surficial soil unit is likely a combination of in-place weathering of parent rock, followed by aeolian and fluvial transport from rainfall and streams. Some of the material is also likely colluvium deposited by historic rock falls. Evidence of previous rock falls was noted during the field investigation with the observation of talus slopes and large subangular boulders around portions of Dog River Mountain with steep slopes. A talus slope area was observed on the upslope side of the proposed alignment between TP-8 and TP-9. A large approximately 12-foot-diameter boulder and multiple 3 to 6-foot-diameter were observed at the ground surface between TP-10 and TP-11. Multiple 4 to 5-foot-diameter boulders were observed at the ground surface between TP-15 and TP-16.

### 4.2.2 Residual Soil / Decomposed Bedrock

A layer of reddish-brown residual soil or decomposed bedrock was encountered in TP-5, TP-7, TP-8, TP-9, and TP-10. Residual soil was observed overlying weathered or intact rock in these excavations. The samples collected from this layer consist of soil and weathered rock that is formed due to in-place weathering and chemical leaching of the upper portions of the rock profile. This layer may have the relict structure of the parent rock with the grade of weathering/alteration ranging from residual soil, to completely weathered/decomposed, to highly weathered as defined by the International Society of Rock Mechanics (ISRM, 1978). The degree of weathering varies predominantly in the vertical direction with the mostly highly weathered/decomposed material present closer to the ground surface and becoming less weathered with depth. However, variable weathering also occurs horizontally throughout the layer, resulting in a range of soil and weathered rock properties and particle-size distributions.

Excavation of the residual soil was distinguished from the overlying sand and gravel by a change in color to reddish-brown soil and slower, more difficult excavation. Material from this soil unit could be removed with a CAT 308D CR excavator until reaching refusal at the likely contact with underlying bedrock. It is possible that residual soil was also encountered in TP-11, TP-12, and TP-13 due to the presence of reddish-brown fine-grained soil, although a relict rock structure was not observed and bedrock was not encountered within the limits of the excavation. Excavation in TP-11, TP-12, and TP-13 was also quicker than the other test pits where residual soil was observed.

### 4.2.3 Bedrock

Refusal was encountered in a majority of the test pits above 10 feet bgs including TP-1, TP-2, TP-2A, TP-3, TP-5, TP-6, TP-7, TP-14, and TP-16. Refusal was determined by observing the excavator bucket scrape the bottom of the test pit several times and noting a solid, unyielding surface that the toothed bucket could not penetrate or move. Based on local geologic mapping, it is likely that the depth of refusal corresponds with the top of competent basalt, andesite, or dacite bedrock. It is possible that in some locations where refusal was encountered, such as at TP-1, TP-2, and TP-16, that refusal was due to encountering large boulders instead of the actual bedrock surface.

## 4.3 Groundwater Levels

Groundwater seepage was noted in two of the test pits during the field investigation. Steady water seepage was observed at a depth of 5 feet bgs in TP-1A. The seepage elevation likely corresponds with the water level of Dog River near the existing diversion dam. Slow water seepage was also observed at a depth of 6.5 feet bgs in TP-2A. TP-2A is near Brooks Meadow Creek, which is likely the source of the shallow ground water at this location. No groundwater seepage was observed in any of the other 16 test pits with the native soil observed to be dry to moist, and not wet.

# 5. Limitations

This report has been prepared for the exclusive use of the City of The Dalles and Jacobs for specific application to the design, bidding phase, and services during construction for the Dog River Pipeline Replacement project. The report has been prepared in accordance with generally accepted geotechnical engineering practices. No other warranty, express or implied, is made.

The data contained in this report is based on the test pits excavated during a geotechnical exploration program conducted in 2021. Exploration data indicate subsurface conditions only at specific locations and times, and only to the depths penetrated; they do not reflect strata variations that may exist between such locations. Subsurface conditions and water levels at other locations may differ from conditions occurring at these locations. The nature and extent of variation may not become evident until exposed during construction. The passage of time may result in a change in the conditions at these locations.

The scope of Jacobs's geotechnical services did not include an environmental evaluation regarding the presence or absence of hazardous or toxic materials in the soil, groundwater, on or below the site, nor did it include an evaluation of disposal requirements should these materials be encountered.

This report should be made available to prospective contractors for use as factual data only, and not as a warranty of subsurface conditions. If there are changes in the nature, design, or location of the planned facilities, the data contained in this report should not be considered valid unless the changes are reviewed and the data verified or modified in writing by Jacobs. Jacobs is not responsible for any claims, damages, or liability associated with the interpretations of subsurface data or reuse of the subsurface data without the express written authorization of Jacobs.

# 6. References

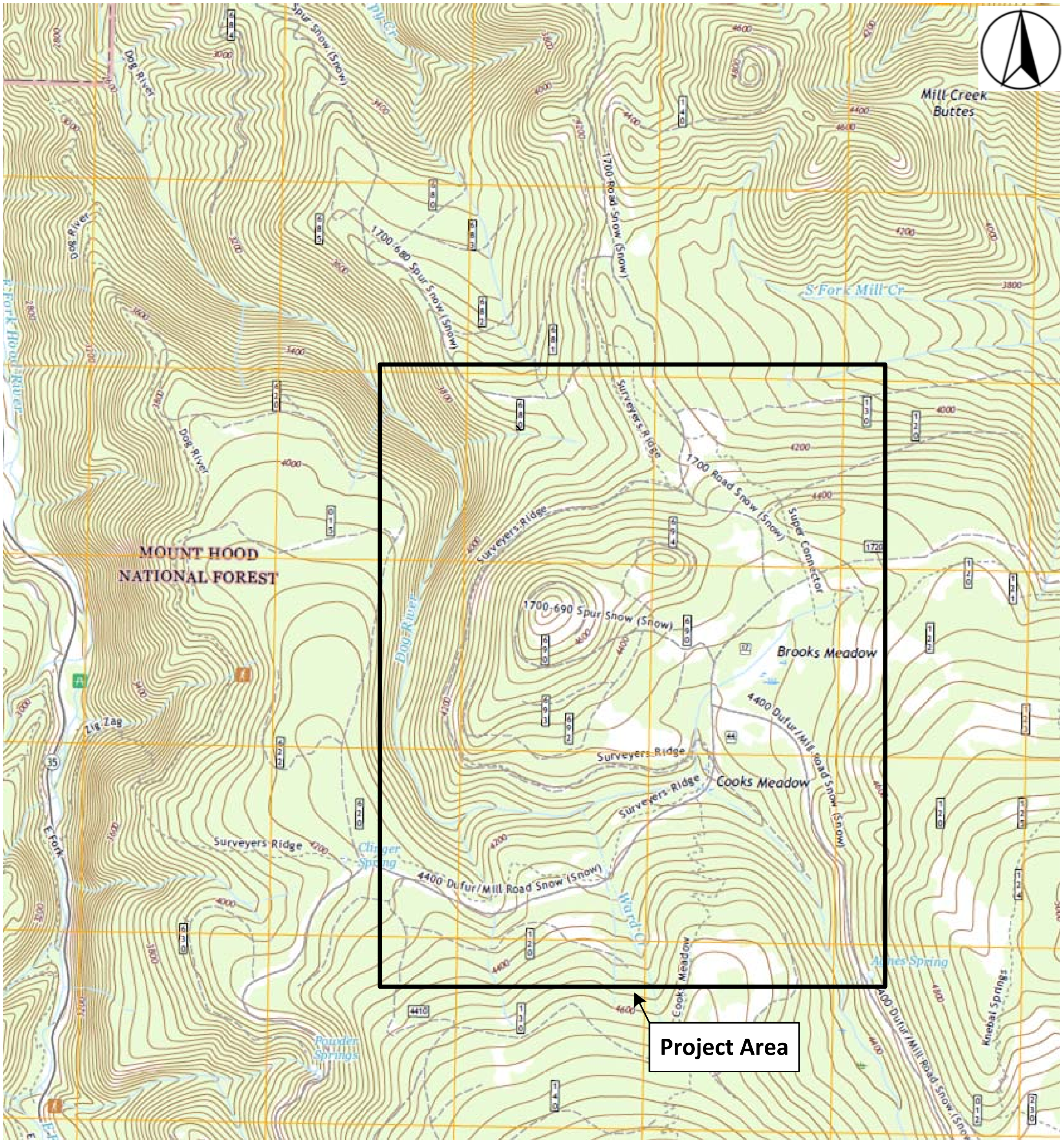
Brown and Caldwell. 2012. *Dog River Water Pipeline Replacement Conceptual Design*. Prepared for City of The Dalles. January.

International Society for Rock Mechanics (ISRM). 1978. *Suggested Methods for the Quantitative Description of Discontinuities in Rock Masses*. International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts, 15, 319-368.

Ma, L., Sherrod, D.R., and Scott, W.E. 2014. *Database for the preliminary geologic map of the Mount Hood 30- by 60-minute quadrangle, northern Cascade Range, Oregon*. U.S. Geological Survey. Data Series DS-906.

Sherrod, D.R., and Scott, W.E. 1995. *Preliminary geologic map of the Mount Hood 30- by 60-minute quadrangle, northern Cascade Range, Oregon*. U.S. Geological Survey. Open-File Report OF-95-219.

# Figures



SCALE: NTS

**FIGURE 1**

PROJECT VICINITY MAP
DOG RIVER PIPELINE REPLACEMENT
CITY OF THE DALLES

Source: USGS US Topo 7.5-Minute Maps for Dog River Quadrangle, 2020

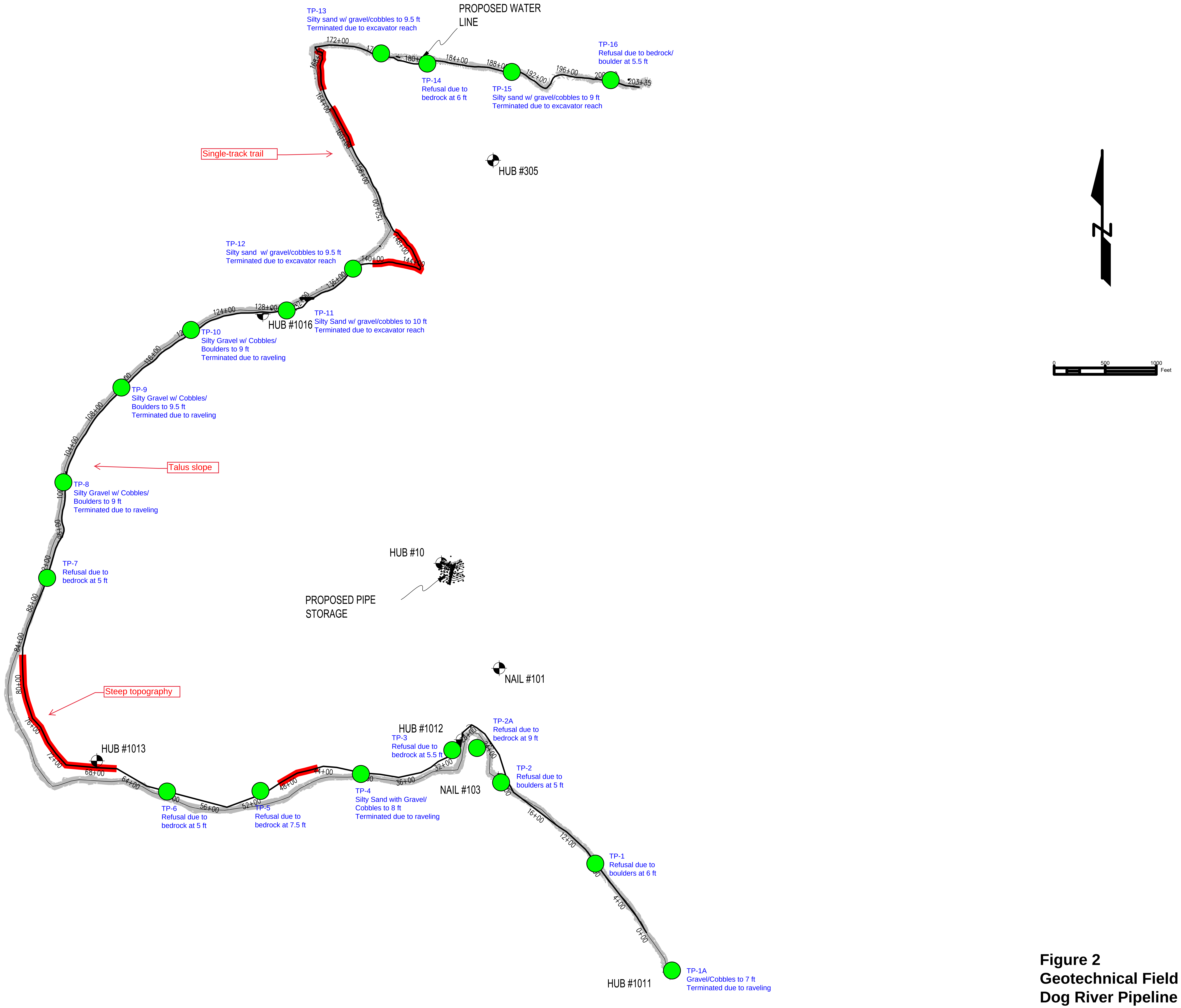
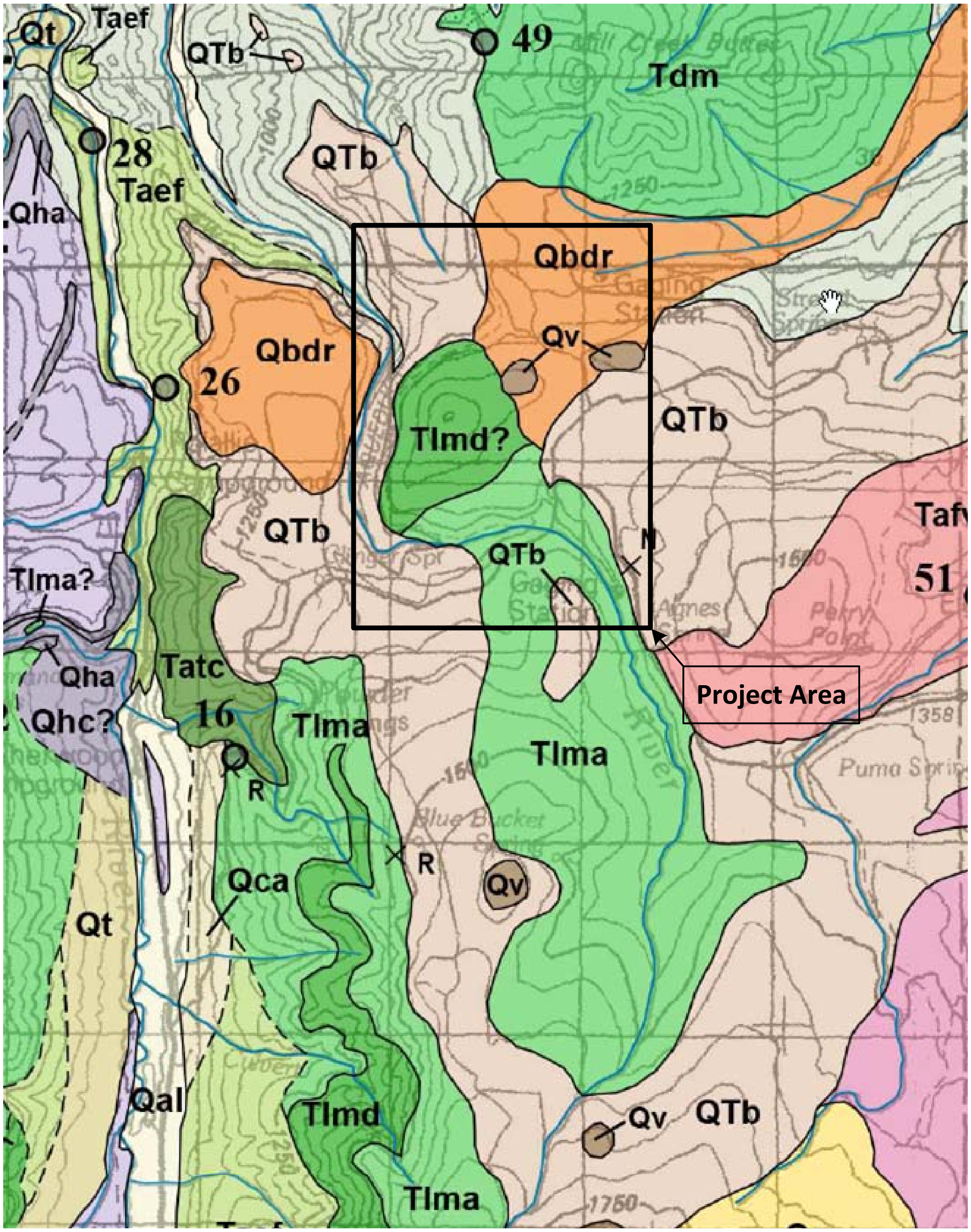


**Figure 2**
**Geotechnical Field Exploration Plan**
**Dog River Pipeline Replacement**



Qv
Cinder Cone or Small Volcano

Qbdr
Basaltic Andesite of Dog River

QTb
Basaltic Andesite and Basalt

Tlma
Lookout Mountain Andesite

Tlmd
Lookout Mountain Dacite

0 2 4 KM

Scale in kilometers
(approximate)

Source: Ma, L., Sherrod, D.R., and Scott, W.E. 2014. *Database for the preliminary geologic map of the Mount Hood 30- by 60-minute quadrangle, northern Cascade Range, Oregon*. U.S. Geological Survey. Data Series DS-906.

**FIGURE 3**
GEOLOGIC VICINITY MAP
DOG RIVER PIPELINE REPLACEMENT
CITY OF THE DALLES

# Appendix A
# Boring Logs

# SOIL TEST PIT LOG LEGEND

## SOIL LOG ORDER

SOIL NAME, USCS GROUP SYMBOL, COLOR AND MOTTLING/STAINING, MOISTURE, RELATIVE DENSITY (SAND OR GRAVEL) OR CONSISTENCY (SILT OR CLAY), SOIL PARTICLE PERCENTAGE AND SIZES (SIZE THEN SHAPE), PLASTICITY AND DILATENCY, SOIL STRUCTURE, MINERALOGY, CEMENTATION, ORGANICS, HCL REACTION, ODOR, COBBLES AND/OR BOULDERS, FILL DETAILS (BRICK, CONCRETE, ETC.), OTHER DESCRIPTORS, NAME OF UNIT (FILL, ALLUVIUM, COLLUVIUM, RESIDUAL SOIL, NAME OF FORMATION, ETC.)

## DRILLING COMMENTS

TIME BETWEEN SAMPLES (DRILL RATE), DEPTH AND SIZE OF CASING, HOLE CAVING WITH DEPTH, CHANGES IN DRILLING AND MATERIAL, CUTTINGS, DRILLING COMMENTS, ROD CHATTER, DRILLING FLUID LOSS (DEPTH AND AMOUNT),COBBLES/ BOULDERS, PIEZOMETER AND OTHER INSTALLATION INFORMATION, IN SITU TESTING RESULTS, SAMPLES SLECTED FOR LAB TESTING, BACKFILL, SURFACE FINISH, OTHER COMMENTS.

## DRILLING AND SAMPLING ABBREVIATIONS

**SAMPLES:**

**SS**: SPLIT SPOON SAMPLE
**MC**: MODIFIED CALIFORNIA SPLIT SPOON SAMPLE
**BU**: BULK SAMPLE
**ST**: SHELBY TUBE SAMPLE
**OT**: THIN-WALL SHELBY (OSTERBERG) SAMPLE
**BKT**: BUCKET SAMPLE

**LABORATORY TESTING:**

**WC: WATER (MOISTURE) CONTENT (ASTM D2216)**
**SG: SPECIFIC GRAVITY (ASTM D854)**
**UWD: DRY UNIT WEIGHT (ASTM D2937)**
**SA: SIEVE ANALYSIS (ASTM D422)**
**P200: PERCENT FINES, SMALLER THAN NO. 200 SIEVE**
**LL: LIQUID LIMIT, ATTERBERG LIMITS (ASTM D4318)**
**PI: PLASTICITY INDEX, ATTERBERG LIMITS (ASTM D4318)**

**FIELD TESTING:**

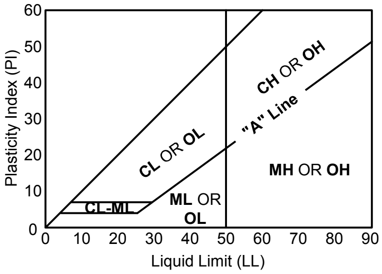
**PP**: UNCONFINED COMPRESSION FROM A POCKET PENETROMETER (TSF)
**TV**: UNDRAINED SHEAR STRENGTH FROM A TORVANE DEVICE (TSF)

**SPT N-VALUE (BLOWCOUNTS)**: THE NUMBER OF BLOWS REQUIRED TO DRIVE THE STANDARD 2-INCH O.D. SPLIT-SPOON SAMPLER (SS) 12 INCHES BEYOND THE FIRST 6 INCH INTERVAL. OF AN 18 INCH DRIVE WITH A 140 LB HAMMER FALLING 30 INCHES. THE BLOWCOUNT VALUES PROVIDED ON THE LOGS HAVE NOT BEEN CORRECTED.

## FINE-GRAINED SOILS (SILTS, CLAYS, ORGANICS):

MORE THAN 50% BY WEIGHT SMALLER THAN THE NO. 200 SIEVE.

**LOW-PLASTICITY (LEAN CLAY OR SILT)**: LIQUID LIMIT LESS THAN 50
**HIGH- PLASTICITY (FAT CLAY OR ELASTIC SILT)**: LIQUID LIMIT GREATER THAN 50
**SILT**: PLASTICITY INDEX BELOW “A” LINE
**CLAY**: PLASTICITY INDEX ABOVE “A” LINE
**OH OR OL**: ORGANIC SOILS
**WITH SAND OR WITH GRAVEL**: WHEN 15% OR MORE BUT LESS THAN 30% SAND OR GRAVEL
**SANDY OR GRAVELLY**: WHEN 30% OR MORE SAND OR GRAVEL
**CONSISTENCY OF COARSE-GRAINED SOILS** (AFTER SOWERS, 1979):



| SPT N-VALUE | CONSISTENCY | PP (TSF) | TORVANE (TSF) | FIELD TEST |
|---|---|---|---|---|
| <2 | VERY SOFT | <0.25 | <0.12 | EASILY PENETRATED SEVERAL INCHES BY FIST |
| 2-4 | SOFT | 0.25 TO 0.50 | <0.12 TO 0.25 | EASILY PENETRATED SEVERAL INCHES BY THUMB |
| 5-8 | FIRM | 0.50 TO 1.0 | 0.25 TO 0.50 | MODERATE EFFORT TO PENETRATE WITH THUMB |
| 9-15 | STIFF | 1.0 TO 2.0 | 0.50 TO 1.0 | INDENTED BY THUMB BUT DIFFICULT TO PENETRATE |
| 16-30 | VERY STIFF | 2.0 TO 4.0 | 1.0 TO 2.0 | READILY INDENTED BY THUMBNAIL |
| >30 | HARD | >4.0 | >2.0 | INDENTED WITH DIFFICULTY BY THUMBNAIL |

## COARSE-GRAINED SOILS (SANDS, GRAVELS, COBBLES, BOULDERS):

MORE THAN 50% BY WEIGHT RETAINED ON THE NO. 200 SIEVE.

**WELL-GRADED**: WIDE RANGE OF PARTICLE SIZES AND SUBSTANTIAL AMOUNTS OF INTERMEDIATE SIZES
**POORLY-GRADED**: PREDOMINATELY ONE SIZE, OR A WIDE RANGE MISSING THE INTERMEDIATE SIZES
**BOULDER**: OVER 12 INCH
**COBBLE**: 3 TO 12 INCH
**GRAVEL**: #4 SIEVE (4.75 MM) TO 3 INCH
**SAND**: #200 SIEVE (0.075 MM) TO #4 SIEVE (4.75 MM)
**WITH SILT OR WITH CLAY**: WHEN 5% OR MORE BUT 12% OR LESS SILT OR CLAY
**SILTY OR CLAYEY**: WHEN MORE THAN 12% SILT OR CLAY
**CONSISTENCY OF COARSE-GRAINED SOILS** (AFTER SOWERS, 1979):

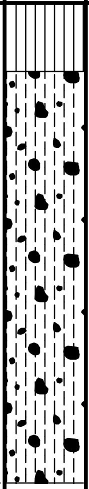
| SPT N-VALUE | RELATIVE DENSITY | FIELD TEST WITH ½-INCH STEEL ROD |
|---|---|---|
| 0-4 | VERY LOOSE | EASILY PENETRATED PUSHED BY HAND |
| 5-10 | LOOSE | EASILY PENETRATED PUSHED BY HAND |
| 11-30 | MEDIUM | EASILY PENETRATED WITH 5-LB HAMMER |
| 31-50 | DENSE | PENETRATED 1 FOOT WITH 5-LB HAMMER |
| >50 | VERY DENSE | PENETRATED ONLY A FEW INCHES WITH 5-LB HAMMER |

ASTM. American Society of Testing and Materials.
Sowers, 1979. *Introductory Soil Mechanics and Foundation: Geotechnical Engineering*. 4th Edition, Macmillan, New York.

| | |
|---|---|
| **PROJECT NUMBER:**<br>**D3504800** | **TEST PIT NUMBER:**<br>**TP-1A** **SHEET 1 OF 1** |

# TEST PIT LOG

PROJECT: Dog River Pipeline
LOCATION: Mt. Hood National Forest, Oregon (331562.43 N, 129083.79 E)
ELEVATION: 4271.00 ft NAVD88
CONTRACTOR: City of The Dalles
EXCAVATION EQUIPMENT: CAT 308D CR with 2-foot wide toothed bucket
DATE EXCAVATED: 6/14/2021
LOGGER: M. Azevedo
WATER LEVELS: 5 feet bgs
LENGTH: 8 feet
WIDTH: 2 feet
DEPTH: 7 feet

| SOIL DESCRIPTION | | | | COMMENTS |
|---|---|---|---|---|
| DEPTH BELOW SURFACE | #TYPE | SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY | GRAPHIC LOG | DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION |
| | | **SILT WITH GRAVEL (ML)**<br>Brown, moist, firm, low plasticity, trace organics consisting of roots |  | Ground surface conditions: weeds and topsoil<br>Root zone: 0 to 1 feet |
| 1 | | **POORLY GRADED GRAVEL WITH SILT, SAND, COBBLES, AND BOULDERS (GP-GM)**<br>Brown and grey, dry to moist, dense to very dense, low plasticity fines, fine to medium sand, subrounded to subangular gravel, cobbles, and boulders | | |
| 2 | | | | |
| 3 | | | | |
| 4 | GB-1 | | | Sides of excavation ravelling below ±4 feet |
| 5 | | Wet below 5 feet, very dense, with larger and more boulders | | Steady water seepage observed from ±5 feet at approximately 1 gal/min. |
| 6 | | | | 2 ft diameter basalt boulder |
| 7 | | Bottom of test pit at 7 ft below ground surface | | Backfilled test pit with excavated material |
| 8 | | | | |
| 9 | | | | |
| 10 | | | | |
| 11 | | | | |
| 12 | | | | |
| 13 | | | | |
| 14 | | | | |
| 15 | | | | |
| 16 | | | | |
| 17 | | | | |
| 18 | | | | |
| 19 | | | | |
| 20 | | | | |

Jacobs

**PROJECT NUMBER:** D3504800

**TEST PIT NUMBER:** TP-1 **SHEET 1 OF 1**

# TEST PIT LOG

PROJECT: Dog River Pipeline

LOCATION: Mt. Hood National Forest, Oregon (332771.62 N, 128209.52 E)

ELEVATION: 4225.00 ft NAVD88

CONTRACTOR: City of The Dalles

EXCAVATION EQUIPMENT: CAT 308D CR with 2-foot wide toothed bucket

DATE EXCAVATED: 6/14/2021

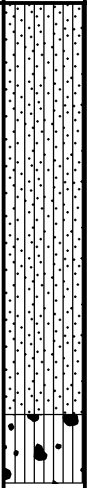
LOGGER: M. Azevedo

WATER LEVELS: ---

LENGTH: 8 feet

WIDTH: 2 feet

DEPTH: 7 feet

| SOIL DESCRIPTION | | | | COMMENTS |
|---|---|---|---|---|
| DEPTH BELOW SURFACE | #TYPE | SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY | GRAPHIC LOG | DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION |
| 1 | | **SILTY SAND (SM)**<br>Brown, moist, loose, ±30% low plasticity fines, fine sand, ±30% coarse angular gravel |  | Ground surface conditions: weeds, shrubs, short trees<br>Root zone: 0 to 4 feet |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | GB-1 | | | |
| 6 | | | | More difficult excavating below 6 feet. |
| 7 | | **SILTY GRAVEL WITH SAND, COBBLES, AND BOULDERS (GM)**<br>Brown, moist, very dense, low plasticity fines, fine sand, subrounded to subangular gravel, cobbles, and boulders | | Large boulders encountered at 6 feet. Excavator was scrapping and could not loosen. Excavation likely could have continued if widened excavation, but would have been difficult. |
| 8 | | Bottom of test pit at 7 ft below ground surface | | Backfilled test pit with excavated material |
| 9 | | | | |
| 10 | | | | |
| 11 | | | | |
| 12 | | | | |
| 13 | | | | |
| 14 | | | | |
| 15 | | | | |
| 16 | | | | |
| 17 | | | | |
| 18 | | | | |
| 19 | | | | |
| 20 | | | | |

Jacobs

**PROJECT NUMBER:** D3504800

**TEST PIT NUMBER:** TP-2 **SHEET** 1 **OF** 1

# TEST PIT LOG

PROJECT: Dog River Pipeline
LOCATION: Mt. Hood National Forest, Oregon (333384.10 N, 127503.07 E)
ELEVATION: 4231.00 ft NAVD88
CONTRACTOR: City of The Dalles
EXCAVATION EQUIPMENT: CAT 308D CR with 2-foot wide toothed bucket
DATE EXCAVATED: 6/14/2021
LOGGER: M. Azevedo
WATER LEVELS: ---
LENGTH: 8 feet
WIDTH: 2 feet
DEPTH: 5 feet

| SOIL DESCRIPTION | | | | COMMENTS |
|---|---|---|---|---|
| DEPTH BELOW SURFACE | #TYPE | SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY | GRAPHIC LOG | DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION |
| 1 | | **SILTY SAND (SM)**<br>Brown, moist, loose, ±30% low plasticity fines, fine sand, ±30% coarse angular gravel | | Ground surface conditions: weeds<br>Root zone: 0 to 2 feet |
| 2 | | | | |
| 3 | | **SILTY GRAVEL WITH SAND, COBBLES, AND BOULDERS (GM)**<br>Brown, moist, medium dense to very dense, low plasticity fines, fine to medium sand, subrounded to subangular gravel, cobbles, and boulders | | Large boulders >2 feet diameter encountered ±2 feet |
| 4 | GB-1 | | | Refusal at 5 feet due to large basalt boulders. Bucket teeth are scrapping boulders and cannot move them. |
| 5 | | Bottom of test pit at 5 ft below ground surface | | Backfilled test pit with excavated material |
| 6 | | | | |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | | |
| 11 | | | | |
| 12 | | | | |
| 13 | | | | |
| 14 | | | | |
| 15 | | | | |
| 16 | | | | |
| 17 | | | | |
| 18 | | | | |
| 19 | | | | |
| 20 | | | | |

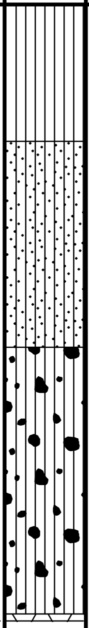
Jacobs

**PROJECT NUMBER:** D3504800

**TEST PIT NUMBER:** TP-2A **SHEET** 1 **OF** 1

# TEST PIT LOG

PROJECT: Dog River Pipeline
LOCATION: Mt. Hood National Forest, Oregon (333884.43 N, 127180.91 E)
ELEVATION: 4225.00 ft NAVD88
CONTRACTOR: City of The Dalles
EXCAVATION EQUIPMENT: CAT 308D CR with 2-foot wide toothed bucket
DATE EXCAVATED: 6/14/2021
LOGGER: M. Azevedo
WATER LEVELS: 6.5 feet bgs
LENGTH: 8 feet
WIDTH: 2 feet
DEPTH: 9 feet



| SOIL DESCRIPTION | | | | COMMENTS |
|---|---|---|---|---|
| DEPTH BELOW SURFACE | #TYPE | SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY | GRAPHIC LOG | DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION |
| | | **SILT WITH SAND (ML)**<br>Brown, moist, firm, low plasticity, fine sand, trace organics consisting of roots | | Ground surface conditions: weeds and short shrubs<br>Root zone: 0 to 2 feet |
| 1 | | | | |
| 2 | | **SILTY SAND WITH GRAVEL, COBBLES, AND BOULDERS (SM)**<br>Brown, moist, loose, low plasticity fines, fine sand, rounded gravel, cobbles, and boulders | | Occasional 1-2 feet diameter boulders from 2 to 5 feet |
| 3 | | | | |
| 4 | GB-1 | | | |
| 5 | | **SILTY GRAVEL WITH SAND, COBBLES, AND BOULDERS (GM)**<br>Brown, moist, medium dense to very dense, low plasticity fines, fine to medium sand, subrounded to subangular gravel, cobbles, and boulders | | |
| 6 | | | | |
| 7 | | | | Water seepage observed from ±6.5 feet.<br>Potentially decomposed basalt bedrock from 7 to 9 feet |
| 8 | | | | |
| 9 | | **BASALT**<br>Bottom of test pit at 9 ft below ground surface | | Refusal at 9 feet due to encountering basalt bedrock<br>Backfilled test pit with excavated material |
| 10 | | | | |
| 11 | | | | |
| 12 | | | | |
| 13 | | | | |
| 14 | | | | |
| 15 | | | | |
| 16 | | | | |
| 17 | | | | |
| 18 | | | | |
| 19 | | | | |
| 20 | | | | |

Jacobs

**PROJECT NUMBER:** D3504800

**TEST PIT NUMBER:** TP-3 **SHEET** 1 **OF** 1

# TEST PIT LOG

PROJECT: Dog River Pipeline

LOCATION: Mt. Hood National Forest, Oregon (333745.88 N, 127008.64 E)

ELEVATION: 4244.00 ft NAVD88

CONTRACTOR: City of The Dalles

EXCAVATION EQUIPMENT: CAT 308D CR with 2-foot wide toothed bucket

DATE EXCAVATED: 6/15/2021

LOGGER: M. Azevedo

WATER LEVELS: ---

LENGTH: 8 feet

WIDTH: 2 feet

DEPTH: 5.5 feet

| SOIL DESCRIPTION | | | | COMMENTS |
|---|---|---|---|---|
| DEPTH BELOW SURFACE | #TYPE | SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY | GRAPHIC LOG | DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION |
| 1 | | **SILTY GRAVEL WITH SAND, COBBLES, AND BOULDERS (GM)**<br>Brown, moist, medium dense, low plasticity fines, fine sand, subrounded to subangular gravel, cobbles, and boulders | | Ground surface conditions: compacted silty gravel<br>Root zone: 0 to 2 feet |
| 2 | | | | Occasional boulders from 0 to 3.5 feet, up to 1.5 feet diameter |
| 3 | GB-1 | | | |
| 4 | | | | No boulders from 3.5 to 5.5 feet, but more difficult excavation with more gravel/cobbles |
| 5 | | | | |
| 6 | | **BASALT**<br>Bottom of test pit at 5.5 ft below ground surface | | Refusal at 5.5 feet due to encountering basalt bedrock<br>Backfilled test pit with excavated material |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | | |
| 11 | | | | |
| 12 | | | | |
| 13 | | | | |
| 14 | | | | |
| 15 | | | | |
| 16 | | | | |
| 17 | | | | |
| 18 | | | | |
| 19 | | | | |
| 20 | | | | |

Jacobs

**PROJECT NUMBER:** **D3504800**

**TEST PIT NUMBER:** **TP-4** **SHEET 1 OF 1**

# TEST PIT LOG

PROJECT: Dog River Pipeline

LOCATION: Mt. Hood National Forest, Oregon (333508.70 N, 126086.77 E)

ELEVATION: 4235.00 ft NAVD88

CONTRACTOR: City of The Dalles

EXCAVATION EQUIPMENT: CAT 308D CR with 2-foot wide toothed bucket

DATE EXCAVATED: 6/15/2021

LOGGER: M. Azevedo

WATER LEVELS: ---

LENGTH: 8 feet

WIDTH: 2 feet

DEPTH: 8 feet

| SOIL DESCRIPTION | | | | COMMENTS |
|---|---|---|---|---|
| DEPTH BELOW SURFACE | #TYPE | SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY | GRAPHIC LOG | DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION |
| | | **SILTY SAND WITH GRAVEL, COBBLES, AND BOULDERS (GM)**<br>Brown, dry to moist, medium dense, low plasticity fines, fine sand, subrounded to subangular gravel, cobbles, and boulders | | Ground surface conditions: compacted silty sand<br>Root zone: 0 to 3 feet<br>>3 feet diameter boulder at 1 foot, broken with excavator bucket |
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | GB-1 | | | |
| 5 | | | | |
| 6 | | | | |
| 7 | | | | Refusal at 8 feet due to ravelling of test pit walls |
| 8 | | Bottom of test pit at 8 ft below ground surface | | Backfilled test pit with excavated material |
| 9 | | | | |
| 10 | | | | |
| 11 | | | | |
| 12 | | | | |
| 13 | | | | |
| 14 | | | | |
| 15 | | | | |
| 16 | | | | |
| 17 | | | | |
| 18 | | | | |
| 19 | | | | |
| 20 | | | | |

Jacobs

PROJECT NUMBER: **D3504800**

TEST PIT NUMBER: **TP-5** SHEET 1 OF 1

# TEST PIT LOG

PROJECT: Dog River Pipeline

LOCATION: Mt. Hood National Forest, Oregon (333326.65 N, 125152.44 E)

ELEVATION: 4245.00 ft NAVD88

CONTRACTOR: City of The Dalles

EXCAVATION EQUIPMENT: CAT 308D CR with 2-foot wide toothed bucket

DATE EXCAVATED: 6/15/2021

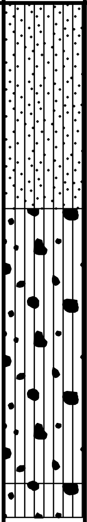
LOGGER: M. Azevedo

WATER LEVELS: ---

LENGTH: 8 feet

WIDTH:

DEPTH: 7.5 feet

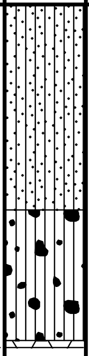
| SOIL DESCRIPTION | | | | COMMENTS |
|---|---|---|---|---|
| DEPTH BELOW SURFACE | #TYPE | SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY | GRAPHIC LOG | DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION |
| 1 | | **SILTY SAND WITH GRAVEL, COBBLES, AND BOULDERS (SM)**<br>Brown, dry to moist, medium dense, low plasticity fines, fine sand, subrounded to subangular gravel, cobbles, and boulders |  | Ground surface conditions: compacted silty sand<br>Root zone: 0 to 3 feet |
| 2 | | | | |
| 3 | | **SILTY GRAVEL WITH SAND, COBBLES, AND BOULDERS (GM)**<br>Brown, dry to moist, dense, low plasticity fines, fine sand, subrounded to subangular gravel, cobbles, and boulders | | Boulders up to 2 feet diameter encountered below ±3 feet. Test pit walls begin ravelling. |
| 4 | GB-1 | | | |
| 5 | | | | |
| 6 | | | | |
| 7 | | **RESIDUAL SOIL / DECOMPOSED BASALT (GM)**<br>Red, very dense<br>Bottom of test pit at 7.5 ft below ground surface | | Color change at ±7 feet to red soil. Refusal at 7.5 feet at likely contact with basalt bedrock.<br>Backfilled test pit with excavated material |
| 8 | | | | |
| 9 | | | | |
| 10 | | | | |
| 11 | | | | |
| 12 | | | | |
| 13 | | | | |
| 14 | | | | |
| 15 | | | | |
| 16 | | | | |
| 17 | | | | |
| 18 | | | | |
| 19 | | | | |
| 20 | | | | |

Jacobs

| PROJECT NUMBER: | TEST PIT NUMBER: |
|---|---|
| D3504800 | TP-6 SHEET 1 OF 1 |

# TEST PIT LOG

PROJECT: Dog River Pipeline
LOCATION: Mt. Hood National Forest, Oregon (333333.58 N, 124112.17 E)
ELEVATION: 4230.00 ft NAVD88
CONTRACTOR: City of The Dalles
EXCAVATION EQUIPMENT: CAT 308D CR with 2-foot wide toothed bucket
DATE EXCAVATED: 6/15/2021
LOGGER: M. Azevedo
WATER LEVELS: ---
LENGTH: 8 feet
WIDTH: 2 feet
DEPTH: 5 feet

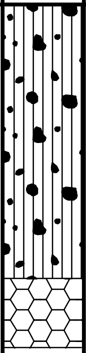
| SOIL DESCRIPTION | | | | COMMENTS |
|---|---|---|---|---|
| DEPTH BELOW SURFACE | #TYPE | SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY | GRAPHIC LOG | DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION |
| | | **SILTY SAND WITH GRAVEL AND COBBLES (SM)**<br>Brown, dry to moist, loose, low plasticity fines, fine sand, subrounded to subangular gravel and cobbles up to 8 inches |  | Ground surface conditions: compacted silty sand<br>Root zone: 0 to 3 feet |
| 1 | | | | |
| 2 | | | | |
| 3 | | **SILTY GRAVEL WITH SAND AND COBBLES (GM)**<br>Brown, dry to moist, dense to very dense, low plasticity fines, fine to medium sand, angular gravel and cobbles | | Gravelly below 3 feet. Most gravel is angular and <6 inches. Potentially fractured or decomposed bedrock. |
| 4 | GB-1 | | | Refusal at 5 feet due to encountering basalt bedrock |
| 5 | | **BASALT**<br>Bottom of test pit at 5 ft below ground surface | | Backfilled test pit with excavated material |
| 6 | | | | |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | | |
| 11 | | | | |
| 12 | | | | |
| 13 | | | | |
| 14 | | | | |
| 15 | | | | |
| 16 | | | | |
| 17 | | | | |
| 18 | | | | |
| 19 | | | | |
| 20 | | | | |

**PROJECT NUMBER:** D3504800

**TEST PIT NUMBER:** TP-7 **SHEET 1 OF 1**

# TEST PIT LOG

PROJECT: Dog River Pipeline
LOCATION: Mt. Hood National Forest, Oregon (335377.47 N, 122948.53 E)
ELEVATION: 4215.00 ft NAVD88
CONTRACTOR: City of The Dalles
EXCAVATION EQUIPMENT: CAT 308D CR with 2-foot wide toothed bucket
DATE EXCAVATED: 6/16/2021
LOGGER: M. Azevedo
WATER LEVELS: ---
LENGTH: 8 feet
WIDTH: 2 feet
DEPTH: 5 feet

| SOIL DESCRIPTION | | | | COMMENTS |
|---|---|---|---|---|
| DEPTH BELOW SURFACE | #TYPE | SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY | GRAPHIC LOG | DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION |
| | | **SILTY GRAVEL WITH SAND, COBBLES, AND BOULDERS (GM)**<br>Brown, dry, dense, low plasticity fines, fine sand, subrounded to subangular gravel, cobbles, and boulders |  | Ground surface conditions: compacted silty gravel<br>Root zone: 0 to 2 feet |
| 1 | | | | |
| 2 | | | | Sides of test pit ravelling below 1.5 feet |
| 3 | GB-1 | | | |
| 4 | | **WEATHERED BASALT** | | More difficult excavation at ±4 feet. Excavator scrapping top of rock and removes multiple flat 3'x2'x3' boulders. |
| 5 | | Bottom of test pit at 5 ft below ground surface | | Refusal at 5 feet due to bedrock<br>Backfilled test pit with excavated material |
| 6 | | | | |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | | |
| 11 | | | | |
| 12 | | | | |
| 13 | | | | |
| 14 | | | | |
| 15 | | | | |
| 16 | | | | |
| 17 | | | | |
| 18 | | | | |
| 19 | | | | |
| 20 | | | | |

| PROJECT NUMBER: | TEST PIT NUMBER: |
|---|---|
| D3504800 | TP-8 SHEET 1 OF 1 |

# TEST PIT LOG

PROJECT: Dog River Pipeline

LOCATION: Mt. Hood National Forest, Oregon (336324.14 N, 123181.95 E)

ELEVATION: 4237.00 ft NAVD88

CONTRACTOR: City of The Dalles

EXCAVATION EQUIPMENT: CAT 308D CR with 2-foot wide toothed bucket

DATE EXCAVATED: 6/16/2021

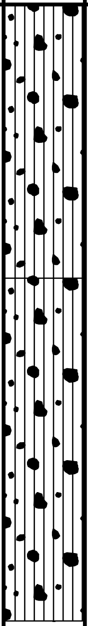
LOGGER: M. Azevedo

WATER LEVELS: ---

LENGTH: 8 feet

WIDTH: 2 feet

DEPTH: 9 feet



| SOIL DESCRIPTION | | | | COMMENTS |
|---|---|---|---|---|
| DEPTH BELOW SURFACE | #TYPE | SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY | GRAPHIC LOG | DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION |
| | | **SILTY GRAVEL WITH SAND, COBBLES, AND BOULDERS (GM)**<br>Brown, dry, medium dense to very dense, low plasticity fines, fine sand, angular gravel, cobbles, and boulders | | Ground surface conditions: compacted silty gravel<br>Root zone: 0 to 4 feet |
| 1 | | | | |
| 2 | | | | Boulders up to 1.5 feet diameter |
| 3 | | | | |
| 4 | GB-1 | **RESIDUAL SOIL / DECOMPOSED BASALT (GM)**<br>Red, dry to moist, medium dense | | Cobbles and boulders up to 1 feet diameter below 4 feet |
| 5 | | | | |
| 6 | | | | |
| 7 | | | | |
| 8 | | | | Denser below 8 feet<br>Terminated test pit due to ravelling of test pit walls |
| 9 | | Bottom of test pit at 9 ft below ground surface | | Backfilled test pit with excavated material |
| 10 | | | | |
| 11 | | | | |
| 12 | | | | |
| 13 | | | | |
| 14 | | | | |
| 15 | | | | |
| 16 | | | | |
| 17 | | | | |
| 18 | | | | |
| 19 | | | | |
| 20 | | | | |

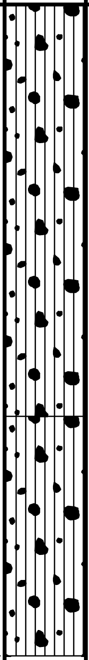
Jacobs

**PROJECT NUMBER:** D3504800

**TEST PIT NUMBER:** TP-9 **SHEET 1 OF 1**

# TEST PIT LOG

PROJECT: Dog River Pipeline
LOCATION: Mt. Hood National Forest, Oregon (337190.33 N, 123607.17 E)
ELEVATION: 4214.00 ft NAVD88
CONTRACTOR: City of The Dalles
EXCAVATION EQUIPMENT: CAT 308D CR with 2-foot wide toothed bucket
DATE EXCAVATED: 6/16/2021
LOGGER: M. Azevedo
WATER LEVELS: ---
LENGTH: 8 feet
WIDTH: 2 feet
DEPTH: 9.5 feet

| SOIL DESCRIPTION | | | | COMMENTS |
|---|---|---|---|---|
| DEPTH BELOW SURFACE | #TYPE | SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY | GRAPHIC LOG | DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION |
| 1 | | **SILTY GRAVEL WITH SAND, COBBLES, AND BOULDERS (GM)**<br>Brown, dry, medium dense to very dense, low plasticity fines, fine sand, angular gravel, cobbles, and boulders |  | Ground surface conditions: compacted silty gravel<br>Root zone: 0 to 3 feet |
| 2 | | | | Boulders up to 2 feet diameter |
| 3 | | | | |
| 4 | GB-1 | | | |
| 5 | | | | |
| 6 | | **RESIDUAL SOIL / DECOMPOSED BASALT (GM)**<br>Red, dry to moist, medium dense | | More difficult excavation below 6 feet |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | Terminated test pit due to ravelling of test pit walls |
| 10 | | Bottom of test pit at 9.5 ft below ground surface | | Backfilled test pit with excavated material |
| 11 | | | | |
| 12 | | | | |
| 13 | | | | |
| 14 | | | | |
| 15 | | | | |
| 16 | | | | |
| 17 | | | | |
| 18 | | | | |
| 19 | | | | |
| 20 | | | | |

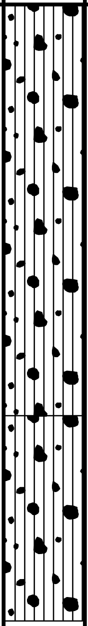
Jacobs

**PROJECT NUMBER:**
**D3504800**

**TEST PIT NUMBER:**
**TP-10** **SHEET 1 OF 1**

# TEST PIT LOG

PROJECT: Dog River Pipeline
LOCATION: Mt. Hood National Forest, Oregon (337781.19 N, 124351.50 E)
ELEVATION: 4223.00 ft NAVD88
CONTRACTOR: City of The Dalles
EXCAVATION EQUIPMENT: CAT 308D CR with 2-foot wide toothed bucket
DATE EXCAVATED: 6/16/2021
LOGGER: M. Azevedo
WATER LEVELS: ---
LENGTH: 8 feet
WIDTH: 2 feet
DEPTH: 9 feet



| SOIL DESCRIPTION | | | | COMMENTS |
|---|---|---|---|---|
| DEPTH BELOW SURFACE | #TYPE | SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY | GRAPHIC LOG | DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION |
| | | **SILTY GRAVEL WITH SAND, COBBLES, AND BOULDERS (GM)**<br>Brown, dry, medium dense to very dense, low plasticity fines, fine sand, angular gravel, cobbles, and boulders | | Ground surface conditions: compacted silty gravel<br>Root zone: 0 to 4 feet |
| 1 | | | | |
| 2 | | | | Cobbles and boulders up to 1 feet diameter, mostly cobbles |
| 3 | GB-1 | | | |
| 4 | | | | More cobbles below 4 feet |
| 5 | | | | |
| 6 | | **RESIDUAL SOIL / DECOMPOSED BASALT (GM)**<br>Red, dry to moist, medium dense | | More difficult excavation below 6 feet |
| 7 | | | | |
| 8 | | | | Terminated test pit due to ravelling of test pit walls |
| 9 | | Bottom of test pit at 9 ft below ground surface | | Backfilled test pit with excavated material |
| 10 | | | | |
| 11 | | | | |
| 12 | | | | |
| 13 | | | | |
| 14 | | | | |
| 15 | | | | |
| 16 | | | | |
| 17 | | | | |
| 18 | | | | |
| 19 | | | | |
| 20 | | | | |

Jacobs

| PROJECT NUMBER: | TEST PIT NUMBER: |
|---|---|
| D3504800 | TP-11 SHEET 1 OF 1 |

# TEST PIT LOG

PROJECT: Dog River Pipeline

LOCATION: Mt. Hood National Forest, Oregon (338035.71 N, 125350.62 E)

ELEVATION: 4219.00 ft NAVD88

CONTRACTOR: City of The Dalles

EXCAVATION EQUIPMENT: CAT 308D CR with 2-foot wide toothed bucket

DATE EXCAVATED: 6/16/2021

LOGGER: M. Azevedo

WATER LEVELS: ---

LENGTH: 8 feet

WIDTH: 2 feet

DEPTH: 10 feet

| SOIL DESCRIPTION | | | | COMMENTS |
|---|---|---|---|---|
| DEPTH BELOW SURFACE | #TYPE | SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY | GRAPHIC LOG | DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION |
| | | **SILTY SAND WITH GRAVEL, COBBLES, AND BOULDERS (SM)**<br>Red-brown, moist, medium dense, low plasticity fines, fine sand, subangular gravel, cobbles, and boulders | | Ground surface conditions: compacted silty sand<br>Root zone: 0 to 1 feet |
| 1 | | | | |
| 2 | | | | Occasional boulders <1.5 feet diameter encountered below ±1 foot |
| 3 | | | | Test pit walls vertical with minimal ravelling |
| 4 | | | | |
| 5 | GB-1 | | | |
| 6 | | | | |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | | Bottom of test pit at 10 ft below ground surface | | Easy excavation to 10 feet. Could have excavator deeper but limited by excavator reach.<br>Backfilled test pit with excavated material |
| 11 | | | | |
| 12 | | | | |
| 13 | | | | |
| 14 | | | | |
| 15 | | | | |
| 16 | | | | |
| 17 | | | | |
| 18 | | | | |
| 19 | | | | |
| 20 | | | | |

Jacobs

**PROJECT NUMBER:** D3504800

**TEST PIT NUMBER:** TP-12 **SHEET 1 OF 1**

# TEST PIT LOG

PROJECT: Dog River Pipeline
LOCATION: Mt. Hood National Forest, Oregon (338420.60 N, 125989.00 E)
ELEVATION: 4221.00 ft NAVD88
CONTRACTOR: City of The Dalles
EXCAVATION EQUIPMENT: CAT 308D CR with 2-foot wide toothed bucket
DATE EXCAVATED: 6/16/2021
LOGGER: M. Azevedo
WATER LEVELS: ---
LENGTH: 8 feet
WIDTH: 2 feet
DEPTH: 9.5 feet

| SOIL DESCRIPTION | | | | COMMENTS |
|---|---|---|---|---|
| DEPTH BELOW SURFACE | #TYPE | SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY | GRAPHIC LOG | DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION |
| | | **SILTY SAND WITH GRAVEL, COBBLES, AND BOULDERS (SM)**<br>Red-brown, moist, medium dense, low plasticity fines, fine sand, subangular gravel, cobbles, and boulders | ▨ | Ground surface conditions: compacted silty sand |
| 1 | | | ▨ | Root zone: 0 to 1 feet |
| 2 | | | ▨ | Occasional boulders <1.5 feet diameter encountered below ±1 foot |
| 3 | | | ▨ | |
| 4 | GB-1 | | ▨ | |
| 5 | | | ▨ | |
| 6 | | | ▨ | Test pit walls mostly vertical. Some ravelling below 6 feet. |
| 7 | | | ▨ | 2 foot diameter boulder at ±7 feet |
| 8 | | | ▨ | |
| 9 | | | ▨ | Terminated test pit due to ravelling and excavator reach. |
| 10 | | Bottom of test pit at 9.5 ft below ground surface | | Backfilled test pit with excavated material |
| 11 | | | | |
| 12 | | | | |
| 13 | | | | |
| 14 | | | | |
| 15 | | | | |
| 16 | | | | |
| 17 | | | | |
| 18 | | | | |
| 19 | | | | |
| 20 | | | | |

Jacobs

**PROJECT NUMBER:**
**D3504800**

**TEST PIT NUMBER:**
**TP-13** **SHEET 1 OF 1**

# TEST PIT LOG

PROJECT: Dog River Pipeline

LOCATION: Mt. Hood National Forest, Oregon (340533.89 N, 126277.71 E)

ELEVATION: 4210.00 ft NAVD88

CONTRACTOR: City of The Dalles

EXCAVATION EQUIPMENT: CAT 308D CR with 2-foot wide toothed bucket

DATE EXCAVATED: 6/16/2021

LOGGER: M. Azevedo

WATER LEVELS: ---

LENGTH: 8 feet

WIDTH: 2 feet

DEPTH: 9.5 feet

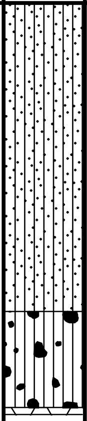
| SOIL DESCRIPTION | | | | COMMENTS |
|---|---|---|---|---|
| DEPTH BELOW SURFACE | #TYPE | SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY | GRAPHIC LOG | DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION |
| | | **SILTY SAND WITH GRAVEL, COBBLES, AND BOULDERS (SM)**<br>Red-brown, dry, medium dense, low plasticity fines, fine sand, subangular gravel, cobbles, and boulders | | Ground surface conditions: compacted silty sand<br>Root zone: 0 to 4 feet |
| 1 | | | | |
| 2 | | | | Occasional boulders <2 feet diameter encountered below ±1 foot |
| 3 | | | | |
| 4 | GB-1 | | | Test pit walls mostly vertical with minimal ravelling |
| 5 | | | | |
| 6 | | | | Denser, more gravels and cobbles below 6 feet |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | Terminated test pit due excavator reach. |
| 10 | | Bottom of test pit at 9.5 ft below ground surface | | Backfilled test pit with excavated material |
| 11 | | | | |
| 12 | | | | |
| 13 | | | | |
| 14 | | | | |
| 15 | | | | |
| 16 | | | | |
| 17 | | | | |
| 18 | | | | |
| 19 | | | | |
| 20 | | | | |

Jacobs

| PROJECT NUMBER: | TEST PIT NUMBER: |
|---|---|
| D3504800 | TP-14 SHEET 1 OF 1 |

# TEST PIT LOG

PROJECT: Dog River Pipeline
LOCATION: Mt. Hood National Forest, Oregon (340440.93 N, 126549.31 E)
ELEVATION: 4210.00 ft NAVD88
CONTRACTOR: City of The Dalles
EXCAVATION EQUIPMENT: CAT 308D CR with 2-foot wide toothed bucket
DATE EXCAVATED: 6/16/2021
LOGGER: M. Azevedo
WATER LEVELS: ---
LENGTH: 8 feet
WIDTH: 2 feet
DEPTH: 6 feet

| SOIL DESCRIPTION | | | | COMMENTS |
|---|---|---|---|---|
| DEPTH BELOW SURFACE | #TYPE | SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY | GRAPHIC LOG | DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION |
| | | **SILTY SAND WITH GRAVEL, COBBLES, AND BOULDERS (SM)**<br>Brown, dry to moist, loose, low plasticity fines, fine sand, angular gravel, cobbles, and boulders |  | Ground surface conditions: compacted silty sand<br>Root zone: 0 to 2 feet |
| 1 | | | | |
| 2 | | | | Boulders up to 1.5 feet diameter |
| 3 | | | | Test pit walls mostly vertical with minimal ravelling |
| 4 | GB-1 | | | |
| 5 | | **SILTY GRAVEL WITH SAND AND COBBLES (GM)**<br>Brown, moist, dense to very dense, low plasticity fines, fine to medium sand, subrounded to subangular gravel and cobbles | | Denser below 4.5 feet, excavator bucket scrapping on rock<br>Refusal at 6 feet due to basalt bedrock. |
| 6 | | **BASALT**<br>Bottom of test pit at 6 ft below ground surface | | Backfilled test pit with excavated material |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | | |
| 11 | | | | |
| 12 | | | | |
| 13 | | | | |
| 14 | | | | |
| 15 | | | | |
| 16 | | | | |
| 17 | | | | |
| 18 | | | | |
| 19 | | | | |
| 20 | | | | |

Jacobs

**PROJECT NUMBER:** **D3504800**

**TEST PIT NUMBER:** **TP-15** **SHEET 1 OF 1**

# TEST PIT LOG

PROJECT: Dog River Pipeline

LOCATION: Mt. Hood National Forest, Oregon (340376.25 N, 127514.35 E)

ELEVATION: 4156.00 ft NAVD88

CONTRACTOR: City of The Dalles

EXCAVATION EQUIPMENT: CAT 308D CR with 2-foot wide toothed bucket

DATE EXCAVATED: 6/16/2021

LOGGER: M. Azevedo

WATER LEVELS: ---

LENGTH: 8 feet

WIDTH: 2 feet

DEPTH: 9 feet

| SOIL DESCRIPTION | | | | COMMENTS |
|---|---|---|---|---|
| DEPTH BELOW SURFACE | #TYPE | SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY | GRAPHIC LOG | DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION |
| | | **SILTY SAND WITH GRAVEL, COBBLES, AND BOULDERS (SM)**<br>Brown, dry to moist, medium dense, low plasticity fines, fine sand, subrounded to subangular gravel, cobbles, and boulders | ▨ | Ground surface conditions: compacted silty sand |
| 1 | | | ▨ | Root zone: 0 to 1 feet |
| 2 | | | ▨ | Multiple boulders <2 feet diameter encountered below ±1 foot |
| 3 | | | ▨ | |
| 4 | GB-1 | | ▨ | Test pit walls mostly vertical with some ravelling near cobbles and boulders. |
| 5 | | | ▨ | |
| 6 | | | ▨ | |
| 7 | | | ▨ | Test pit walls ravelling more below 7 feet. |
| 8 | | | ▨ | Terminated test pit due to ravelling and excavator reach. |
| 9 | | Bottom of test pit at 9 ft below ground surface | | Backfilled test pit with excavated material |
| 10 | | | | |
| 11 | | | | |
| 12 | | | | |
| 13 | | | | |
| 14 | | | | |
| 15 | | | | |
| 16 | | | | |
| 17 | | | | |
| 18 | | | | |
| 19 | | | | |
| 20 | | | | |

**Jacobs**

| PROJECT NUMBER: | TEST PIT NUMBER: |
|---|---|
| D3504800 | TP-16 SHEET 1 OF 1 |

# TEST PIT LOG

PROJECT: Dog River Pipeline

LOCATION: Mt. Hood National Forest, Oregon (340275.53 N, 128420.09 E)

ELEVATION: 4095.00 ft NAVD88

CONTRACTOR: City of The Dalles

EXCAVATION EQUIPMENT: CAT 308D CR with 2-foot wide toothed bucket

DATE EXCAVATED: 6/16/2021

LOGGER: M. Azevedo

WATER LEVELS: ---

LENGTH: 8 feet

WIDTH: 2 feet

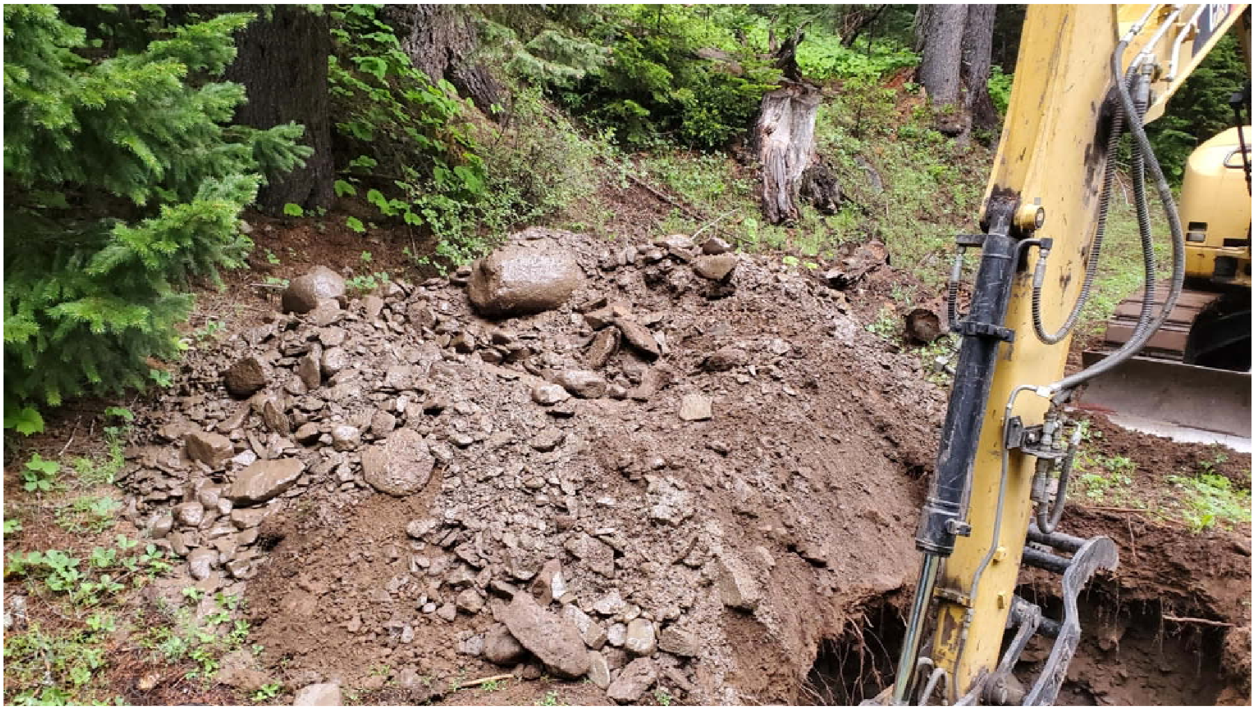
DEPTH: 5.5 feet

| SOIL DESCRIPTION | | | | COMMENTS |
|---|---|---|---|---|
| DEPTH BELOW SURFACE | #TYPE | SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY | GRAPHIC LOG | DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION |
| 1 | | **SILTY SAND WITH GRAVEL, COBBLES, AND BOULDERS (SM)**<br>Brown, moist, loose, low plasticity fines, fine sand, subrounded to subangular gravel, cobbles, and boulders | | Ground surface conditions: compacted silty sand<br>Root zone: 0 to 1 feet |
| 2 | | | | |
| 3 | | | | Multiple large boulders 3 to 5 feet diameter encountered below ±1 foot. Boulders are loose in soil matrix.<br>Test pit walls are ravelling below 3 feet. |
| 4 | GB-1 | | | |
| 5 | | | | |
| 6 | | **BASALT**<br>Bottom of test pit at 5.5 ft below ground surface | | Refusal at 5.5 feet due to large boulder or bedrock surface. Bucket teeth are scrapping rock that will not move.<br>Backfilled test pit with excavated material |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | | |
| 11 | | | | |
| 12 | | | | |
| 13 | | | | |
| 14 | | | | |
| 15 | | | | |
| 16 | | | | |
| 17 | | | | |
| 18 | | | | |
| 19 | | | | |
| 20 | | | | |

# Appendix B

# Geotechnical Exploration Photographs

CAT 308D CR EXCAVATOR
*Geotechnical Data Report*
*Dog River Pipeline Replacement*



TP-1A
*Geotechnical Data Report*
*Dog River Pipeline Replacement*

TP-1

TP-2
*Geotechnical Data Report*
*Dog River Pipeline Replacement*

TP-2A

*Geotechnical Data Report*

*Dog River Pipeline Replacement*

TP-3

*Geotechnical Data Report*

*Dog River Pipeline Replacement*

TP-4

*Geotechnical Data Report*

*Dog River Pipeline Replacement*

TP-5
*Geotechnical Data Report*
*Dog River Pipeline Replacement*

TP-6

*Geotechnical Data Report*

*Dog River Pipeline Replacement*

TP-7
*Geotechnical Data Report*
*Dog River Pipeline Replacement*

TP-8
*Geotechnical Data Report*
*Dog River Pipeline Replacement*

TP-9
*Geotechnical Data Report*
*Dog River Pipeline Replacement*

TP-10

*Geotechnical Data Report*

*Dog River Pipeline Replacement*

TP-11
*Geotechnical Data Report*
*Dog River Pipeline Replacement*

TP-12
*Geotechnical Data Report*
*Dog River Pipeline Replacement*

TP-13

TP-14
*Geotechnical Data Report*
*Dog River Pipeline Replacement*

TP-15

*Geotechnical Data Report*
*Dog River Pipeline Replacement*

TP-16

*Geotechnical Data Report*

*Dog River Pipeline Replacement*

# Appendix C
# Laboratory Test Results

**FEI**
**TESTING & INSPECTION, INC.**
Geotechnical & Construction Services

# LETTER OF TRANSMITTAL

*Date:* August 9, 2021

*Project No.:* 2216130
*Report No.:* C-49760

*Re:* Dog River Pipeline

*To:* Jacobs
2020 SW 4th Ave., Suite 300
Portland, OR 97201

*Attn:* Marcelo Azevedo, PhD, PE

*Enclosed are:*

☐ Report
☐ Copy of Letter
☐ Other
☐ Drawings
☐ Specifications
☑ Test Results (6 Pages Total Incl. Cover)

*These are transmitted as checked below:*

☑ For your use
☑ As requested
☐ For your review/approval
☐ For your files

*Remarks:* Requested laboratory testing results attached. Please call if you have any questions.

Date Sampled: unknown

Sample No.: 8255

*Copy to:*

*Signature:*

Rachel Ray

Rachel Ray
President

**FEI**
**TESTING & INSPECTION, INC.**
Geotechnical & Construction Services

# Percent Fines & Water Content Test
# (ASTM D 1140)

| | | | |
|---|---|---|---|
| *PROJECT NAME* | ***Dog River Pipeline*** | *PROJECT NUMBER* | ***2216130*** |
| RECORDED BY | ***TV/EE*** | *FEI SAMPLE NUMBER* | ***8255*** |
| *CLIENT* | ***Jacobs*** | *DATE* | ***7/14/2021*** |
| *REMARKS* | | *CLIENT PROJECT NUMBER* | ***D3504800*** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| WATER CONTENT DIR or AUX* | ***DIR*** | ***DIR*** | ***DIR*** | ***DIR*** | ***DIR*** | ***DIR*** | ***DIR*** |
| SAMPLE DESIGNATION | **TP-1A, GB-1** | **TP-1, GB-1** | **TP-2A, GB-1** | **TP-4, GB-1** | **TP-6, GB-1** | **TP-7, GB-1** | **TP-9, GB-1** |
| SAMPLE DEPTH | **3.5'-4.0'** | **4.0'-4.5'** | **4.0'-4.5'** | **4.0'-4.5'** | **4.0'-4.5'** | **3.0'-3.5'** | **3.5'-4.0'** |
| Pan Number | 3001 | 20 | 16 | 50 | 51A | 33 | 63 |
| Wt. of Wet Soil + Pan (g) | 1545.04 | 564.31 | 432.26 | 684.30 | 865.43 | 430.59 | 377.14 |
| Wt. of Dry Soil + Pan (g) | 1421.16 | 484.43 | 356.09 | 563.17 | 754.17 | 384.51 | 339.01 |
| Wt. of Water (g) | 123.88 | 79.88 | 76.17 | 121.13 | 111.26 | 46.08 | 38.13 |
| Wt. of Pan (g) | 259.73 | 69.89 | 70.66 | 80.61 | 79.91 | 79.99 | 78.72 |
| Wt. of Dry Soil (g) | 1161.43 | 414.54 | 285.43 | 482.56 | 674.26 | 304.52 | 260.29 |
| Water Content (%) | **10.7%** | **19.3%** | **26.7%** | **25.1%** | **16.5%** | **15.1%** | **14.6%** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| TEST SAMPLE DATA | | | | | | | |
| TEST METHOD A or B | **B** | **B** | **B** | **B** | **B** | **B** | **B** |
| Length of Time Sample Soaked (hrs | **30** | **30** | **30** | **30** | **30** | **30** | **30** |
| Pan Number | 3001 | 20 | 16 | 50 | 51A | 33 | 63 |
| Wet Wt. + Pan (g) | 1545.04 | 564.31 | 356.09 | 684.30 | 865.43 | 430.59 | 377.14 |
| Wet Wt. (g) | 1285.31 | 494.42 | 285.43 | 563.17 | 785.52 | 350.60 | 298.42 |
| Wt. of Pan (g) | 259.73 | 69.89 | 70.66 | 121.13 | 79.91 | 79.99 | 78.72 |
| (A) Dry Soil (g) (Total Sample) | 1161.43 | 414.54 | 285.43 | 482.56 | 674.26 | 304.52 | 260.29 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| AFTER WASHING | | | | | | | |
| Pan Number | 3001 | 20 | 16 | 50 | 51A | 33 | 63 |
| Dry Wt. + Pan (g) | 1282.87 | 363.83 | 246.10 | 435.92 | 580.22 | 295.59 | 262.18 |
| Wt. of Pan (g) | 259.73 | 69.89 | 70.66 | 80.61 | 79.91 | 79.99 | 78.72 |
| (B) Wt. of Dry Soil | 1023.14 | 293.94 | 175.44 | 355.31 | 500.31 | 215.60 | 183.46 |
| (C) Total Loss (g) (No. 200) (C=A-B) | 138.29 | 120.60 | 109.99 | 127.25 | 173.95 | 88.92 | 76.83 |
| % Fines (C/A) | **11.9%** | **29.1%** | **38.5%** | **26.4%** | **25.8%** | **29.2%** | **29.5%** |
| % Gravel (Retained on #4) | **65.5%** | **32.4%** | **16.4%** | **29.6%** | **26.9%** | **36.2%** | **30.9%** |

*DIR=Dry mass was determined directly by drying the test specimen

*AUX=Dry mass was determined using an auxiliary water content specimen

Equipment Used
Oven ID # **6060**
Scale ID # **6067**
Sieve ID # **LS30B**

Reviewed By Rachel Day

**FEI TESTING & INSPECTION, INC.**
Geotechnical & Construction Services

# Percent Fines & Water Content Test
# (ASTM D 1140)

| | | | |
|---|---|---|---|
| *PROJECT NAME* | ***Dog River Pipeline*** | *PROJECT NUMBER* | ***2216130*** |
| RECORDED BY | ***TV/EE*** | *FEI SAMPLE NUMBER* | ***8255*** |
| *CLIENT* | ***Jacobs*** | *DATE* | ***7/14/2021*** |
| *REMARKS* | | *CLIENT PROJECT NUMBER* | ***D3504800*** |

| WATER CONTENT DIR or AUX* | *DIR* | *DIR* | *DIR* | *DIR* | | | |
|---|---|---|---|---|---|---|---|
| SAMPLE DESIGNATION | **TP-11, GB-1** | **TP-13, GB-1** | **TP-14, GB-1** | **TP-16, GB-1** | | | |
| SAMPLE DEPTH | **4.5'-5.0'** | **3.5'-4.0'** | **4.0'-4.5'** | **3.5'-4.0'** | | | |
| Pan Number | 22 | 21 | 64 | #3000 | | | |
| Wt. of Wet Soil + Pan (g) | 598.78 | 623.87 | 415.82 | 1299.73 | | | |
| Wt. of Dry Soil + Pan (g) | 468.61 | 533.21 | 360.61 | 1065.51 | | | |
| Wt. of Water (g) | 130.17 | 90.66 | 55.21 | 234.22 | | | |
| Wt. of Pan (g) | 70.18 | 69.81 | 79.00 | 263.59 | | | |
| Wt. of Dry Soil (g) | 398.43 | 463.40 | 281.61 | 801.92 | | | |
| Water Content (%) | **32.7%** | **19.6%** | **19.6%** | **29.2%** | | | |

| TEST SAMPLE DATA | | | | | | | |
|---|---|---|---|---|---|---|---|
| TEST METHOD A or B | **B** | **B** | **B** | **B** | | | |
| Length of Time Sample Soaked (hrs | **30** | **30** | **30** | **30** | | | |
| Pan Number | 22 | 21 | 64 | #3000 | | | |
| Wet Wt. + Pan (g) | 598.78 | 623.87 | 415.82 | 1299.73 | | | |
| Wet Wt. (g) | 528.60 | 554.06 | 336.82 | 1036.14 | | | |
| Wt. of Pan (g) | 70.18 | 69.81 | 79.00 | 263.59 | | | |
| (A) Dry Soil (g) (Total Sample) | 398.43 | 463.40 | 281.61 | 801.92 | | | |

| AFTER WASHING | | | | | | | |
|---|---|---|---|---|---|---|---|
| Pan Number | 22 | 21 | 64 | #3000 | | | |
| Dry Wt. + Pan (g) | 311.83 | 343.15 | 275.59 | 808.50 | | | |
| Wt. of Pan (g) | 70.18 | 69.81 | 79.00 | 263.59 | | | |
| (B) Wt. of Dry Soil | 241.65 | 273.34 | 196.59 | 544.91 | | | |
| (C) Total Loss (g) (No. 200) (C=A-B) | 156.78 | 190.06 | 85.02 | 257.01 | | | |
| % Fines (C/A) | **39.3%** | **41.0%** | **30.2%** | **32.0%** | | | |
| % Gravel (Retained on #4) | **30.3%** | **14.3%** | **15.4%** | **11.8%** | | | |

*DIR=Dry mass was determined directly by drying the test specimen

*AUX=Dry mass was determined using an auxiliary water content specimen

Equipment Used
Oven ID # **6060**
Scale ID # **6376**
Sieve ID # **6373**

Reviewed By Rachel Day

**OREGON DEPARTMENT OF TRANSPORTATION**
**MATERIALS LABORATORY**
**800 AIRPORT RD. SE SALEM, OR 97301-4792**

Page 1 of 1
(503)986-3000
FAX(503)986-3096

---

**Contract No.: PRIVATE** **EA No.: PRIVATE TESTING: Lab No.: 21-001634**
Project: PRIVATE TESTING - FEI TESTING & INSPECTION INC
Highway: County: **Data Sheet No.: F51291 001**
Contractor: FEI FA No.:
Project Manager: Org Unit: Bid Item:
Submitted By: ESPINOZA GOODMAN Org Unit: FEI Sample No.: TP-2A
Material Source: DOG RIVER Qty Represented: SOIL @ DEPTH
Sampled At: D3504800 4'-4.5' Sampled By:
DATE-Sampled: 21/ 6/14 Received: 21/ 7/28 Tested: 21/ 8/ 6 Date Reported: 21/ 8/ 6

---

Test Results For: **DISTURBED SOIL**

T 89 Liquid Lim:
T 90 Plastic Ind:
T288 Resistivity: 9063 Ω-cm
T289 pH: 6.2
T100 Spec Grav:
TM117
Torvane Shear/ Pocket Pen.

T265 N. Moisture:
Dry Density rec'd:
Wet Density rec'd:
D4644 Slake Durab:
Water Cont:

D2974 Pct Organic:

| Dry Density | Moisture |
|---|---|

Max Density:
Optimum Moisture:

| Sieve | Passing |
|---|---|
| 3 " | |
| 2 | |
| 1.5 | |
| 1 | |
| 3/4 | |
| 1/2 | |
| 3/8 | |
| 1/4 | |
| # 4 | |
| 10 | |
| 40 | |
| 200 | |

| Quantity | Method | Cost |
|---|---|---|
| 1 | T288 | $ 146.00 |
| 1 | T289 | 21.00 |
| 1 | T290 | 76.00 |
| 1 | T291 | 54.00 |
| 1 | R58 | 75.00 |

| Hydrometer Analysis | Subsample | Total Sample |
|---|---|---|
| Coarse Sand= 4.75 to 2.0 mm: | | |
| Medium Sand= 2.0 to .42 mm: | | |
| Fine Sand= .42 to .074 mm: | | |
| Silt= .074 to .02 mm: | | |
| Silt= .02 to .005 mm: | | |
| Clay= .005 to .002 mm: | | |
| Clay= Less Than .002 mm: | | |

---

**TOTAL CHARGES: $ 372.00**

**REMARKS:**
INFORMATION ONLY
Chloride AASHTO T-291 results : 10 ppm
Sulfate AASHTO T-290 results : 0 ppm
*

**KEVIN BROPHY - LABORATORY SERVICES MANAGER**

REPORT SHALL NOT BE REPRODUCED, EXCEPT IN FULL, WITHOUT WRITTEN APPROVAL OF THIS LABORATORY.
'TM' TEST METHODS CAN BE CROSS-REFERENCED WITH AASHTO AND/OR ASTM, CONTACT THIS LAB FOR ASSISTANCE.

C: FILES ; FEI ; R Rodriguez - SOILS
EESPINOZA@FEITESTING.COM

**OREGON DEPARTMENT OF TRANSPORTATION**
MATERIALS LABORATORY
800 AIRPORT RD. SE SALEM, OR 97301-4792

Page 1 of 1
(503)986-3000
FAX(503)986-3096

**Contract No.: PRIVATE** **EA No.: PRIVATE TESTING: Lab No.: 21-001635**
Project: PRIVATE TESTING - FEI TESTING & INSPECTION INC
Highway:
County:
**Data Sheet No.: F51291 001**
Contractor: FEI
FA No.:
Project Manager:
Org Unit:
Bid Item:
Submitted By: ESPINOZA GOODMAN
Org Unit: FEI
Sample No.: TP-9
Material Source: DOG RIVER
Qty Represented: SOIL @ DEPTH
Sampled At: D3504800 3.5'-4'
Sampled By:
DATE-Sampled: 21/ 6/16 Received: 21/ 7/28 Tested: 21/ 8/ 6 Date Reported: 21/ 8/ 6

Test Results For: **DISTURBED SOIL**

T 89 Liquid Lim:
T 90 Plastic Ind:
T288 Resistivity: 19915 Ω-c
T289 pH: 6.8
T100 Spec Grav:
TM117
Torvane Shear/ Pocket Pen.

T265 N. Moisture:
Dry Density rec'd:
Wet Density rec'd:
D4644 Slake Durab:
Water Cont:

D2974 Pct Organic:

| Dry Density | Moisture |
|---|---|

Max Density:
Optimum Moisture:

| Sieve | Passing |
|---|---|
| 3 " | |
| 2 | |
| 1.5 | |
| 1 | |
| 3/4 | |
| 1/2 | |
| 3/8 | |
| 1/4 | |
| # 4 | |
| 10 | |
| 40 | |
| 200 | |

| Quantity | Method | Cost |
|---|---|---|
| 1 | T288 | $ 146.00 |
| 1 | T289 | 21.00 |
| 1 | T290 | 76.00 |
| 1 | T291 | 54.00 |
| 1 | R58 | 75.00 |

| Hydrometer Analysis | Subsample | Total Sample |
|---|---|---|
| Coarse Sand= 4.75 to 2.0 mm: | | |
| Medium Sand= 2.0 to .42 mm: | | |
| Fine Sand= .42 to .074 mm: | | |
| Silt= .074 to .02 mm: | | |
| Silt= .02 to .005 mm: | | |
| Clay= .005 to .002 mm: | | |
| Clay= Less Than .002 mm: | | |

**TOTAL CHARGES: $** 372.00

**REMARKS:**
INFORMATION ONLY
Chloride AASHTO T-291 results : 20 ppm
Sulfate AASHTO T-290 results : 0 ppm
*

**KEVIN BROPHY - LABORATORY SERVICES MANAGER**

REPORT SHALL NOT BE REPRODUCED, EXCEPT IN FULL, WITHOUT WRITTEN APPROVAL OF THIS LABORATORY.
'TM' TEST METHODS CAN BE CROSS-REFERENCED WITH AASHTO AND/OR ASTM, CONTACT THIS LAB FOR ASSISTANCE.

C: FILES ; FEI ; R Rodriguez - SOILS
EESPINOZA@FEITESTING.COM

**OREGON DEPARTMENT OF TRANSPORTATION**
MATERIALS LABORATORY
800 AIRPORT RD. SE SALEM, OR 97301-4792

Page 1 of 1
(503)986-3000
FAX(503)986-3096

**Contract No.: PRIVATE** **EA No.: PRIVATE TESTING: Lab No.:** **21-001636**
Project: PRIVATE TESTING - FEI TESTING & INSPECTION INC
Highway:
County:
**Data Sheet No.:** F51291 001
Contractor: FEI
FA No.:
Project Manager:
Org Unit:
Bid Item:
Submitted By: ESPINOZA GOODMAN
Org Unit: FEI
Sample No.: TP-14
Material Source: DOG RIVER
Qty Represented: SOIL @ DEPTH
Sampled At: D3504800 4'-4.5'
Sampled By:
DATE-Sampled: 21/ 6/16 Received: 21/ 7/28 Tested: 21/ 8/ 6 Date Reported: 21/ 8/ 6

Test Results For: **DISTURBED SOIL**

T 89 Liquid Lim:
T 90 Plastic Ind:
T288 Resistivity: 14787 Ω-c
T289 pH: 6.0
T100 Spec Grav:
TM117
Torvane Shear/ Pocket Pen.

T265 N. Moisture:
Dry Density rec'd:
Wet Density rec'd:
D4644 Slake Durab:
Water Cont:

D2974 Pct Organic:

| Dry Density | Moisture |
|---|---|

Max Density:
Optimum Moisture:

| Sieve | Passing |
|---|---|
| 3 " | |
| 2 | |
| 1.5 | |
| 1 | |
| 3/4 | |
| 1/2 | |
| 3/8 | |
| 1/4 | |
| # 4 | |
| 10 | |
| 40 | |
| 200 | |

| Quantity | Method | Cost |
|---|---|---|
| 1 | T288 | $ 146.00 |
| 1 | T289 | 21.00 |
| 1 | T290 | 76.00 |
| 1 | T291 | 54.00 |
| 1 | R58 | 75.00 |

| Hydrometer Analysis | Subsample | Total Sample |
|---|---|---|
| Coarse Sand= 4.75 to 2.0 mm: | | |
| Medium Sand= 2.0 to .42 mm: | | |
| Fine Sand= .42 to .074 mm: | | |
| Silt= .074 to .02 mm: | | |
| Silt= .02 to .005 mm: | | |
| Clay= .005 to .002 mm: | | |
| Clay= Less Than .002 mm: | | |

**TOTAL CHARGES: $** 372.00

**REMARKS:**
INFORMATION ONLY
Chloride AASHTO T-291 results : 0 ppm
Sulfate AASHTO T-290 results : 54.1 ppm
*

**KEVIN BROPHY - LABORATORY SERVICES MANAGER**

REPORT SHALL NOT BE REPRODUCED, EXCEPT IN FULL, WITHOUT WRITTEN APPROVAL OF THIS LABORATORY.
'TM' TEST METHODS CAN BE CROSS-REFERENCED WITH AASHTO AND/OR ASTM, CONTACT THIS LAB FOR ASSISTANCE.

C: FILES ; FEI ; R Rodriguez - SOILS
EESPINOZA@FEITESTING.COM

# Appendix D
# Geophysical Investigation Report

City of the Dalles, Oregon

# Dog River Pipeline Replacement Design Project

Mt. Hood National Forest, Oregon

## Results of Geophysical Exploration Data Report

**Prepared for Jacobs Engineering Group Inc.**

**Prepared by Siemens & Associates, September 2021**

**September 27, 2021**

**Brady Fuller, P.E.**
Jacobs Engineering Group Inc.
2020 SW Fourth Avenue, #300
Portland, Oregon 97201, US

RE: Dog River Pipeline Replacement Design Project, City of the Dalles, Oregon
Mt. Hood National Forest, Oregon

Hello Brady,

Siemens & Associates is pleased to present the results of this geophysical exploration. The interpretation considers local geology, experience conducting similar exploration, and the benefit of using multiple geophysical methods.

Data were gathered and processed for four geophysical methods: Electrical Resistivity (ER), Seismic Refraction (SR), Linear Microtremor (LM) and Spatial Autocorrelation (SPAC). Only the SR method was applied along the pipeline and all four methods were used to describe the geology through the intake area. The results are presented to describe continuous, 2D profiles through select zones of interest and in the case of the ER, 3D presentation is delivered. Along the pipeline, the interpretation is concentrated on excavation characteristics based on P-wave velocity correlated with Jacob's recent observation during the exploratory exploration program. A broader interpretation is delivered to describe conditions encountered at the Dog River diversion intake.

Siemens & Associates expresses sincere appreciation for the opportunity to conduct this exploration and as new challenges, discoveries and questions arise, we are standing by to offer our assistance.

Prepared by,
**Siemens & Associates**

16,377
J. ANDREW SIEMENS
JAN. 19, 1993

J. Andrew "Andy" Siemens, P.E., G.E.
Principal
siemens@bendcable.com
541.385.6500 (office)
541.480.2527 (cell)

# Contents

# 1 Introduction

## 1.1 Purpose

Siemens & Associates (SA) have completed geophysical services to explore the geotechnical conditions using geophysical methods at select locations along the proposed pipeline route and at the surface water diversion intake on the Dog River. The results are intended to provide guidance in addressing excavation characteristics of materials along the pipeline and information bearing on geology at the intake where various geotechnical assessments are to be completed by others.

## 1.2 Methods

Four geophysical methods were used:

- Electrical Resistivity (ER) in 2D and 3D
- Seismic Refraction (SR) in 2D
- Linear Microtremor Shear-wave (LM) in 1D
- Spatial Autocorrelation Shear-wave (SPAC) in 1D

Details concerning the procedures, the equipment used, and results are presented later in this report.

## 1.3 Project Description

In the 1870s, lumber mill and woolen mill interests designed and constructed a diversion ditch to divert surface water flow from Dog River into South Fork Mill Creek. In 1913-1914, the City of The Dalles municipal water system constructed a new diversion dam and 20-inch-diameter wood stave pipeline to replace the original ditch conveyance. The existing pipeline has experienced many leaks and is beyond the end of its service life. A new pipeline and related improvements are required, and the current project is the culmination of many years of planning, permitting, and operational efforts to maintain the existing system until such time that it can be upgraded. The proposed pipeline length is over 20,000 feet (over 3-1/2 miles) and will generally parallel the existing pipeline alignment, but the new alignment is proposed to be primarily installed in existing US Forest Service roads, except where it must be located off-road due to grade. The new pipeline will be constructed using open-trench methods extending to depths ranging from 3 to 10 feet of cover. The existing pipeline will be abandoned in place.

The Dog River Pipeline Replacement Project will replace the existing pipeline with a new pipeline to restore condition and reliable service, install fish screening and passage systems consistent with Oregon Department of Fish and Wildlife (ODFW) guidance, and provide 0.5 cubic foot per second (cfs) dedicated flow past the diversion dam into Dog River in August, September, and October annually.

Modifications at the Dog River diversion intake are in the 20% design stage, and a dam stability analysis will be performed by Jacobs largely based on geophysical findings as no records exist regarding the dam structure.

## 1.4 Scope

Working under contract with Jacobs Engineering Group Inc. (Jacobs), the SA team completed the services as outlined in the agreement executed on May 3, 2021, prepared by Jacobs. The completed scope is summarized as follows:

- Consultation with the design team
- Review and interpretation of existing documents
- Preparation of a workplan
- Planning operations and safety protocol
- ER, SR, LM and SPAC surveys through zones of interest identified by Jacobs
- Basic surface reconnaissance including line position and elevation verification
- Geophysical data processing and quality control
- Interpretation of the findings
- Preparation of this data report

The line locations were developed through mutual agreement between SA and Jacobs along the pipeline route. SA designed and executed exploration at the intake based on constraints offered by conditions encountered and budget.

## 1.5 Location

The project is in the Cascade Range Geologic Province of Oregon situated in steep to moderately flat timbered terrain. Figures 100 (Geophysical Exploration Plan: Pipeline) and Figure 101 (Geophysical Exploration Plan: Intake) illustrate the extents of the geophysical explorations.

## 1.6 Limitations

This report has been prepared for the exclusive use of Jacobs for specific application to the project known as Dog River Pipeline Replacement Design Project (City of the Dalles, Oregon), Mt, Hood National Forest. This report has been prepared in accordance with generally accepted geophysical practice consistent with similar services performed in the area by geophysical practitioners at this time. No other warranty, express or implied, is made.

The information presented is based on data obtained from the field explorations described in Section 3 of this report. The explorations indicate geophysical conditions only at specific locations and times, and only to the depths penetrated. They do not necessarily reflect variations that may exist between exploration locations. The subsurface at other locations may differ from conditions interpreted at these explored locations. Also, the passage of time may result in a change in conditions. If any changes in the nature, design, or location of the project are implemented, the information contained in this report should not be considered valid unless the changes are reviewed by SA to address the implications and benefit of enhancing the exploration, as necessary. SA is not responsible for any claims, damages, or liability associated with outside interpretation of these results or for the reuse of the information presented in this report for other projects.

The geophysical results discussed herein represent estimated values only. The interpretation provided are not a guarantee of certain soil and rock conditions. The contractor may encounter rock or soil at lower or higher P-wave values than indicated. Ease of excavation may be more difficult than estimated and may require additional time and/or tools/methods.

# 2 Executive Summary: Conditions Encountered

The 2D results developed from the geophysical methods are presented as tomograms; a word derived from the Greek “tomo” meaning to cut or slice. The tomograms are annotated to communicate our interpretation of the character of geomaterials discovered by each geophysical method. ER was processed in 3D at the intake which has the advantage of providing a spatial distribution of the conditions encountered and improved visualization. The following discussions are delivered to summarize conditions along the pipeline and at the Dog River diversion intake separately.

### Pipeline

Ten (10) locations were prescribed by Jacobs for exploration using refraction seismic. The results are presented in the appendix correlating P-wave velocity with excavation characteristics. Jacobs and the City of the Dalles staff performed exploratory excavations in 2021 near most of the geophysical surveys which provide information regarding soil texture and other characteristics not available from seismic refraction results. Logs of the Jacobs explorations are presented in a separate geotechnical data report (Jacobs 2021).

In general, P-wave velocity at each geophysical exploration suggests unconsolidated soils dominating the shallow geology (10 feet and less). The tomograms include a general interpretation of the P-wave velocity correlated to excavation characteristics which consider the Jacobs findings and associated observations during the exploratory excavation process.

The P-wave tomograms compliment the exploratory excavation data by providing information through 120-foot-long profiles illustrating the consistency of stratification. In this case, the geophysical results consistently show high variability in the P-wave velocity through the planned depths of excavation (upper 10 feet). When correlating the geophysical results with the Jacobs observations, SA considers P-wave velocity of 2000 f/s and higher to suggest that excavation is likely to encounter more frequent occurrence of large clast (cobbles and boulders) along with more consolidated soils offering strong resistance to excavation. The 2000 f/s P-wave velocity and sometimes higher is common, though intermittent, throughout the upper 10 feet at most of the explorations. Based on this interpretation, excavation characteristics are anticipated to be erratic in a way that is similar to the P-wave velocity variations illustrated by the tomograms.

Boulders are common in the area geology and only very large ones are likely to be positively interpreted from the seismic refraction results. An example is SR-6 where a very large boulder is interpreted at a depth greater than 10 feet within the extents of the geophysical exploration. Such a condition could be discovered at any depth while trenching between any of the geophysical explorations. Further, the P-wave velocity surrounding the anomaly of SR-6 is judged to be shown lower than reality due to limitations in forward modeling processing.

### Dog River Diversion Intake

The narrow confines of the intake area controlled the exploration pattern. A prime objective is development of information useful for determination of ground behavior given a seismic event. For this reason, SA implemented the SPAC method to define the S-wave velocity profile in 1D to a depth of 100 feet. Data from the north half of the linear seismic array SR-11 was also processed to present a 1D S-wave profile to 100-foot depth. Data from the short seismic line SR-12 which spans a section of the stream and adjacent upland area was used to develop S-wave velocity in 1D to a depth of 30 feet. Results from these three areas provide an effective overview of the soil and rock strength profile in terms of S-wave velocity in the vicinity of the intake.

Electrical methods were used to gain an understanding of the variation in soil texture as the ER method is sensitive to moisture and porosity contrast which range widely in fine to coarse grained soils. When combined with seismic results (both P and S-wave velocity), interpretation is enhanced. The ER models clearly suggest geologic changes within the canyon at the diversion where higher inverted resistivity combined with increased seismic velocities indicate strong, coarse-grained soils begin to dominate at shallower depths.

Upstream of the diversion, lower electrical characteristics combined with slightly lower seismic velocity imply finer-grained materials, probably saturated and possibly some sort of altered rock (heavily fractured, weathered and/or decomposed).

At the intake, the depth to very strong, high velocity rock appears to vary on an upward trend to the north from about 40 feet at the intake to roughly 30 feet at the center of SPAC 1 located about 25 feet north of the intake.

The geophysical findings relate ground conditions to physical properties including inverted electrical resistivity, P-wave velocity, and S-wave velocity. Descriptions of how these properties relate to geology are presented later in this report for an improved understanding.

# 3 Geophysical Data Acquisition

The geophysical explorations were designed to explore the geotechnical conditions through specific zones of interest along the pipeline and the Dog River diversion intake. At the intake, the use of multiple methods improves the confidence of the interpretation as each method is influenced by the geology in different ways and the combined results provide complimentary information that is more valuable than any of the methods individually.

In this section, the geophysical methods, equipment, challenges, and data quality are described.

## 3.1 Geophysical Methods and Equipment

### 3.1.1 Electrical Resistivity (ER)

**How it works:** Electrical resistivity tomography is a geophysical method to illustrate the electrical characteristics of the subsurface by taking measurements on land or in a marine setting. These measurements are then processed using inversion software to develop a 2D or 3D (from a series of parallel 2D lines) electrical resistivity tomogram which is, in turn, related to the likely distribution of geologic or cultural features known to offer similar electrical properties.

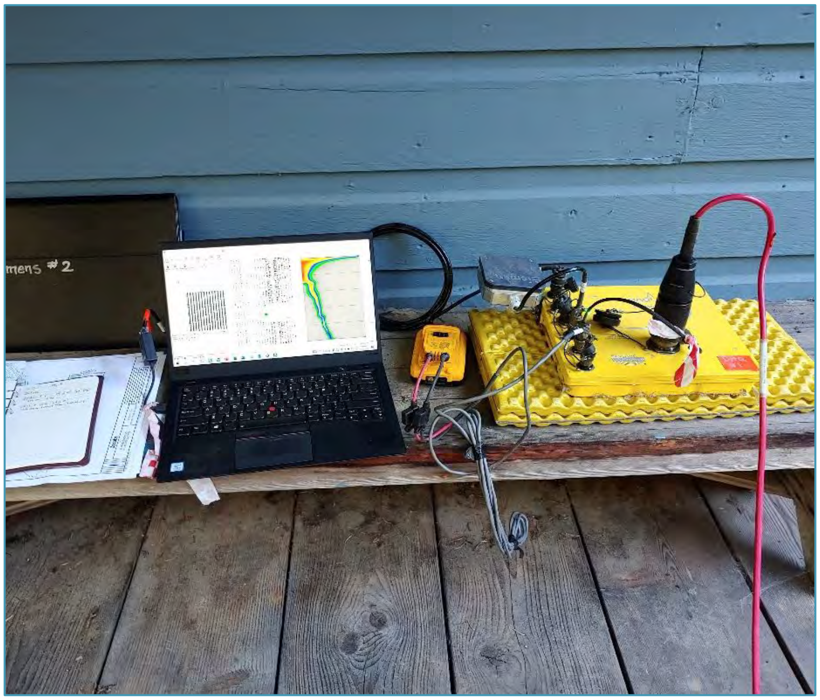
Measurement in an electrical survey involves injecting DC current through two current-carrying electrodes and measuring the resulting voltage difference at two or more potential electrodes. The apparent resistivity is calculated using the value of the injected current, the voltage measured, and a geometric factor related to the arrangement of the four electrodes.

The investigation depth of any measurement is related to the spacing between the electrodes that inject current. Therefore, sampling at different depths can be done by changing the spacing between the electrodes. Measurements are repeated along a survey line with various combinations of electrodes and spacing to produce an inverted resistivity cross-section (tomogram). In this case, SA used the Dipole-Dipole, inverted Schlumberger and Strong Gradient arrays with electrode spacing of 3 m along four lines composed of 21 electrodes each. Depth of exploration was on the order of 40 feet below grade.

Electrical resistivity data were recorded using an R-8 SuperSting with Wi-Fi manufactured by Advanced Geosciences, Inc., Austin, Texas, USA. The instrument is an eight channel, automated system capable of completing several thousand measurements per hour. For this project, the measurement sequence was configured for a high-density data set and data were cautiously filtered during the processing stage.

A marine cable was used and contact with the earth through the water intervals were coupled through the cable without need for electrode pins.

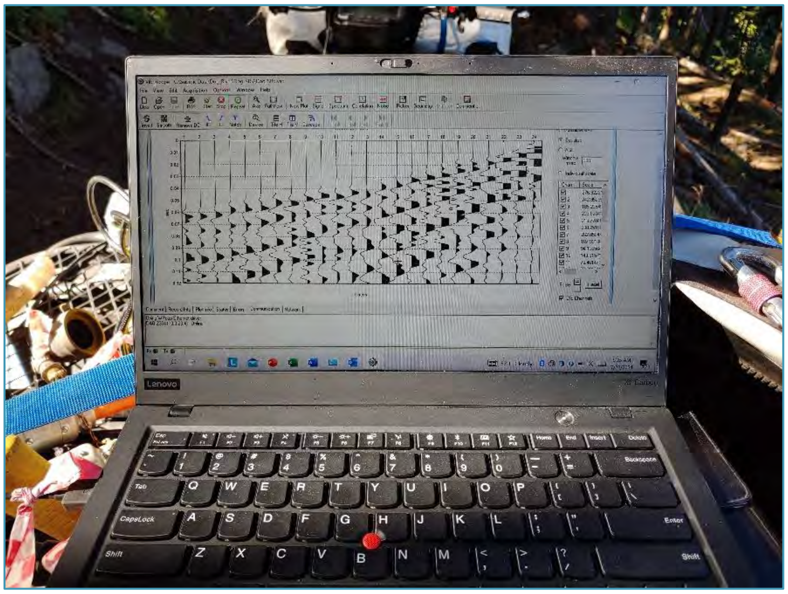
### 3.1.2 Seismic Refraction (SR)



Seismic refraction (SR) is an active seismic method utilizing geophone receivers set along a straight-line gathering data from signals induced by an 18-pound hammer striking an aluminum plate. Data were processed using forward modeling software developed by Geogiga known as DW Tomo 9.3.

**How it works:** When the hammer strikes the plate, the receivers are activated, and the wavelet energy is recorded. The P-wave is the fastest of the various seismic waves that are generated and only the time of the first arrival wave at the receiver is considered in the SR method. These first arrivals are picked for each shot at each receiver. As the energy travels through the ground, the waves are refracted and the arrival time, combined with distance from the source, is related to both the velocity and distance to the layers promoting refraction. This distance is not necessarily vertical depth; rather the nearest refractor and the image can be skewed when oriented along a dipping refractor.

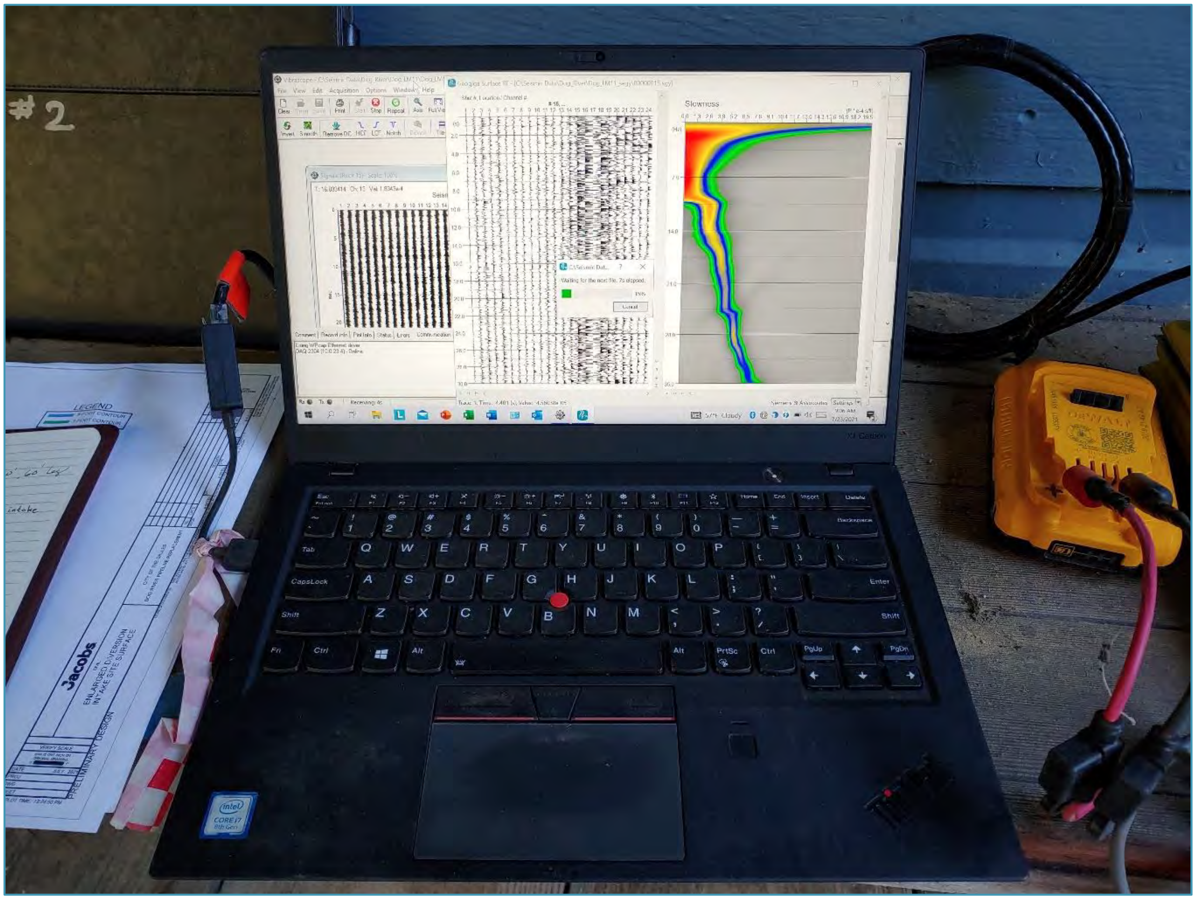
Data were recorded using a DAQ 4 seismograph manufactured by Seismic Source in Ponca City, Oklahoma, USA, connected to an IBM laptop computer. Lines were composed of 12 to 24 receivers on spacing ranging from 5 to 8 feet and shot interval varying from one to two receiver spacing.



### 3.1.3 Linear Microtremor S-wave (LM)

The linear microtremor method, referred to as LM, is a passive, surface-wave analysis technique for obtaining near surface shear-wave velocity models to constrain strength and position of shallow geologic boundaries. These analyses provide information about land and marine soil, and rock properties that are difficult and expensive to obtain through alternative methods. SA recorded passive ambient vibrations (background noise) augmented by an active, un-timed seismic source (plate and hammer) operated along the array to induce higher frequency, rapidly attenuating energy.

On land, surface wave analysis is performed using Rayleigh waves because they can be detected on an air-ground interface (earth surface) using geophones. The low frequency geophones measure the vertical component of the surface wave (Rayleigh) and the results are considered a reasonable estimate of the vertical distance (depth) to layers distinguished by velocity contrast below the receivers.



**How it works:** The LM analysis develops the shear-wave velocity/depth profile using an engineering seismograph, low frequency receivers (geophones or hydrophones) and straight-line array aperture (Louie, 2001). Ambient surface wave energy is recorded using relatively long sample window (30 seconds) recording the ambient wavefield. At this site, quality low frequency signals were consistently recorded, and higher frequency input was provided by untimed hammer blows to an aluminum plate at various positions along the array.

The microtremor records are transformed as a simple, two-dimensional slowness-frequency (p-f) plot where the ray parameter “p” is the horizontal component of slowness (inverse velocity) along the array and “f” is the corresponding frequency (inverse of period). The p-f analysis produces a record of the total spectral power in all records from the site, which plots within the chosen p-f axes. The trend within these axes, where a coherent phase has significant power is “picked.” Then the slowness-frequency picks are transformed to a typical period-velocity diagram for dispersion. Picking the points to be entered into the dispersion curve is performed manually along the low velocity envelope appearing in the p-f image.

### 3.1.4 Spatial Autocorrelation (SPAC)

In support of various engineering endeavors, surface wave analysis is widely utilized for obtaining near surface shear wave velocity models to define geologic conditions in terms of shear wave velocity. The analyses provide information about the variation in shear-wave velocity with depth averaged across a relatively large area (compared to a boring) gaining insight regarding geologic conditions that can be difficult to detect through alternative methods. SPAC is a passive method using ambient vibrations and the Rayleigh waves that these ambient energy sources produce. Since the array occupies a small, 2D footprint, the SPAC method is well suited for this site which is confined within the narrow river channel.

**How it works:** Ambient seismic noise or microtremor observations used in the SPAC method consist of a wide frequency range of surface waves from the frequency of about 3 Hz to several tens of Hz in this survey. The wavelengths (and hence depth sensitivity of such surface waves) allow determination of the site S-wave velocity model from depths of a few feet down to a maximum of several thousand feet with large arrays and low frequency receivers. SPAC is a passive seismic method using only ambient noise as the energy source.

SA utilized a 2D seismic array composed of 24, 4.5 Hz receivers on 10 foot spacing representing a series of nested equilateral triangles (longest leg = 60 feet) to estimate the phase velocity dispersion curve and hence the 1D S-wave velocity depth profile very near the intake and diversion structure. Direct fitting of observed and model SPAC spectra generally provides a bandwidth of useable data like the more common, linear MASW array when linear results from a pair of mutually perpendicular arrays are averaged. Available case histories demonstrate the method with a range of array types including L-shaped multi-station arrays, triangular, and circular arrays. Array sizes from a few feet to thousands of feet in diameter have been successfully deployed in sites ranging from downtown urban settings to rural and remote desert sites.

A fundamental requirement of the method is the ability to average wave propagation over a range of azimuths; this can be achieved with either or both of the wave sources being widely distributed in azimuth, and the use of a 2D array sampling the wave field over a range of azimuths. SA has had best success using dense to moderately dense nested triangular arrays. 2D passive seismic arrays have become the method of choice when characterizing average S-wave velocity to a depth of 100 feet (Vs100) and deeper, with active (or passive) linear seismic methods such as multichannel analysis of surface waves (MASW) being a complementary method for use if and when conditions so require. The use of computer inversion methodology allows estimation of not only the average S-wave velocity profile but also parameter uncertainties in terms of layer thickness and velocity.

The SPAC analysis develops the shear-wave velocity/depth profile using engineering seismographs, low frequency receivers (geophones), and 2D array aperture. Surface wave energies (Rayleigh Waves) are recorded using a relatively long sample window

(120 to 240 seconds) recording the ambient wavefield. For this project, a broad range of low to high frequency signal was consistently recorded from energy and vibrations developed from the rushing river and other sources that were not readily defined. Data were processed using Surface Plus 9.3 software produced by Geogiga Technology Corporation of Calgary, Canada.

In processing, the microtremor records are transformed as a simple, two-dimensional frequency (f) plot. The f analysis produces a record of the total spectral power in all records from the site, which plots within the chosen f axes. The trend within these axes, where a coherent phase has significant power, is “picked”. Then the frequency picks are transformed for dispersion analysis. Picking the points to be entered into the dispersion curve is done manually along the velocity appearing in the f image. The solution is not unique, and a trial-and-error approach is utilized to build a theoretical model that represents a reasonable “fit” with the observations (data).

Data were recorded using a 24 channel DAQ 4 seismograph manufactured by Seismic Source in Ponca City, Oklahoma, USA. The 24-channel system was connected to an IBM laptop computer. The data recorded were strong and the “fit” with the interpretation was exceptionally good with low RMS error. SA judges the model to present an effective representation of the recorded data and actual subsurface conditions.

## 3.2 Horizontal and Vertical Control

During field operations, SA used a hand level and grade rod to determine elevation of explorations along the pipeline with reference to nearby control points previously established by the surveyor (AKS). SA used a theodolite to measure elevation of surveys at the intake which were also referenced to AKS control. The horizontal position of the control points relative to the survey were also recorded and shown on the tomograms. Basis: Oregon Coordinate Reference System, Dufur-Madras NSRS 11.

Following operations, Jacobs provided elevation data for the referenced control points, and this is the basis for the elevations presented with the findings. Basis: North American Vertical Datum of 1988.

Given the methods and short sight distances, elevation is considered accurate to about 0.2 feet and horizontal position accurate to about 2 feet.

The exception to this strategy is SR-4 located a significant distance from any control point. The position of this exploration was staked and flagged, and elevation/position was established by the surveyor.

## 3.3 Summary of Challenges

### 3.3.1 Operations

In general, operations proceeded as planned and no significant challenges were experienced. The tight confines of the intake area limited the possibilities for survey routes although the approach that was designed on site is considered by SA to effectively describe the prevailing geology.

### 3.3.2 Data Quality and Interpretation Challenges

The recorded seismic data are judged to be of excellent quality. Due to the remote nature of the site, SR data were clear and not influenced by background noise leading to accurate definition of first arrival waves. Ambient signal with wide frequency variation was available for the LM and SPAC, again, leading to robust interpretation.

ER data were compromised by difficulty achieving strong electrical contact of electrodes in some areas. As a result, data filtering was necessary and to compensate for this, SA measured three different array types along each line. This practice develops many data points for effective inversion and the results are plausible.

# 4 Processing and Interpretation

## 4.1 General

During the data gather, partial interpretation was completed in the field for quality control purposes, and to assist in setting and confirming proper data acquisition parameters. The instruments were continuously monitored through the data acquisition phase.

Section 2: Executive Summary presents the interpretation of conditions encountered. The locations of the explorations are shown graphically on Figures 100 and 101.

It is worthy to emphasize that most of the geophysical results are presented in 1D or 2D, yet the data collection is influenced by a 3D environment. The results suggest that the character of the subsurface (depth to rock, soil texture, etc.) changes rapidly in some areas. This is especially true at the intake where the ER results clearly suggest variable geology at the intake and diversion structure. In addition, geophysical interpretations are often compared to direct observation of conditions discovered in geotechnical drill holes and exploratory excavations when available.

Note that the drill hole (or exploratory excavation) is a 1D description of the subsurface and represents a very small sampling, unlike the geophysical approach. Correlation and conflict are expected, and both must be considered in context with the complication of the subsurface and the various factors influencing the measurements.

A description of the data processing, interpretation, and results are presented in the following sections.

## 4.2 Electrical Resistivity (ER)

Important factors which affect the resistivity of different geological material are:

- Porosity
- Moisture content
- Dissolved electrolytes
- Rock chemistry
- Rock Character (strong influence from fracture, jointing and alterations due to decomposition and weathering)

Each dataset was filtered to remove spikes, noise, and misfit data through a systematic progression to produce plausible inversion models without excessive iteration. The level of filtering was modest, and most data points were used in the final inversion.

### 4.2.1 ER Processing and Presentation

The data sets were processed using AGI Earth Imager 3DCL software. 2D results were also developed (although not presented) as a quality check on the 3D findings. In the case of 2D inversion, an assumption is made that the electrical current only travels vertically below the electrode array although the current actually goes everywhere. In 3D processing, this assumption is not necessary, and the electrical field is calculated everywhere within the survey grid. The benefit of the 3D approach is a smoother, more realistic model especially when characterizing high or low resistivity anomaly.

ER results are presented in 2D representing slices from the 3D model and select images from the 3D model are also presented. A video has also been prepared and submitted as a separate deliverable for the 3D findings.

### 4.2.2 Considerations in ER Interpretation

As discussed in Section 2: Encountered Conditions, the geophysical results suggest that the geology changes rapidly through the intake area. This is most clearly described by the electrical images that show a higher resistivity area developing at the diversion. It is important to recognize that electrical resistivity cannot be directly related to strength without the benefit of and correlation with other information such as drill data or seismic results. In this case, the higher resistivity is judged to be related to stronger, more coarse soils (possibly weak rock) based on correlation with S-wave velocity. Note that P-wave velocity through saturated soils will reflect the velocity of water. Therefore, the P-wave tomogram of SR-11 does not show contrast below the intake and diversion similar to the electrical findings.

## 4.3 P-wave Seismic Refraction (SR)

Refraction data were processed for each linear array along the pipeline and at the intake.

### 4.3.1 SR Processing and Presentation

Data processing was completed using Geogiga DW Tomo 9.3 software developed by Geogiga Technology Corp. Calgary, Alberta, Canada. The software utilizes a robust grid ray tracing and regularized inversion with constraints in topography and elevation along the seismic array as input for calculations. The software is suitable for strong elevation and lateral velocity variation. Data sets included a moderately dense shot pattern (shots centered at 1X and 2X the receiver spacing). Dr. Satish Pullammanappallil, Ph.D. of SubTerraSeis, LLC, lead the SR data processing effort.

### 4.3.2 Considerations in SR Interpretation

P-wave velocity is often used to predict excavation difficulty (especially rock rippability), and this is one of the objectives of the SR survey along the pipeline. Interpretation associating P-wave velocity with excavation characteristics is provided on each of the tomograms presenting the results of SR surveys along the pipeline.

These associations are subjective estimates developed by SA and consider experience and observations documented by Jacobs during the exploratory excavation program. As described in Section 2, an important consideration in P-wave interpretation is recognizing the method’s ability to illustrate continuity in stratification. The results show rapidly changing conditions over short distances throughout the pipeline excavation.

SR results at the intake are believed to be influenced by saturated soils which carry the P-wave at the speed of water (about 4700 f/s) regardless of how weak or strong the strata. For this reason, contrasts and changes in soil layers are probably not well constrained at the intake by the SR method. Fortunately, S-wave results (no influenced by saturation) are available to overcome this dilemma.

## 4.4 S-wave Linear Microtremor (LM)

LM data were procured along the same routes as the SR surveys although only process from data at the intake. S-wave information is of value as the shear wave velocity is directly related to the strength of a geologic material and is not influenced by a shallow water table and less influenced by structures such as the diversion and intake. The models were produced by Dr. Pullammanappallil, using Geogiga SubsurfacePlus 9.3 software.

Shear-wave velocity, $V_s$ is used to determine the shear modulus, G, of soil or rock:

$G = \rho (V_s^2)$: a valuable measure of soil stiffness and rock strength

Where $\rho$ = mass density (i.e., total unit weight / gravitational acceleration constant, 32.2 ft/$s^2$)

The LM derived $V_s$ is interpreted from small strain measurements produced by non-destructive surface waves (Rayleigh waves) with strain on the order of $10^{-4}$ %. Shear modulus (G) derived from shear-wave velocity measured insitu using surface wave methods is commonly referred to as the small-strain shear modulus $G_{max}$.

### 4.4.1 LM Processing and Presentation

Dr. Pullammanappallil, created the 1D profiles using groups of 12 receivers representing the northern and southern halves of SR-11 and each of the 12 receivers of SR-12. Results from SR-12 only extend to a depth of 30 feet owing to the short array.

### 4.4.2 Considerations in LM Interpretation

The LM results are an excellent means of estimating the strength of soil and rock. LM is a volume averaging method and hence, it is challenging to resolve small variations within high velocity layers. The short array of SR-12 probably presents the best resolution of the shallow geology. Also, the resolving power decreases with depth and thus, variations (particularly velocity reversal) are less likely to be imaged within the deep, higher velocity layers. Comparing the LM results with the ER at this site confirms the geologic change at the intake/diversion area and beyond. This is especially true when adding in the results of the SPAC method.

## 4.5 Spatial Autocorrelation (SPAC)

One-dimensional shear-wave models were produced through the open, flat area just south of the intake and diversion using the SPAC method. The model presents special value as the shear wave velocity is directly related to the strength of a geologic material and is not influenced by saturation since water has no shear strength. The model was produced using Geogiga SubsurfacePlus 9.3 software. The 1D model illustrates the trend in the subsurface in terms of shear-wave velocity and the data measured to produce the model was strong.

### 4.5.1 SPAC Processing and Presentation

The microtremor data were processed to generate 1D shear-wave depth profiles from data collected from a 2D geophone array configured as a nested set of equilateral triangles. As discussed, the method is a passive one using vibrations generated from ambient sources with higher frequency induced outside the array by plate and hammer.

### 4.5.2 Considerations in SPAC Interpretation

The shear-wave velocities observed in the 1D SPAC profile illustrate ground conditions averaged below the triangular SPAC array and are judged to offer a confident representation of actual ground conditions through the upper 100 feet. As a rule of thumb: Vs < 600 f/s suggests weak soils either due to low shear strength or low density or both. Vs > 600 and < 1200 f/s suggest moderate strength soils and or very weak rock. Vs > 1200 f/s suggest weak rock and/or heavily indurated soils, typically cemented sands, and gravels, possibly mixed with cobbles and boulders. S-wave velocity approaching 2500 f/s and higher is likely representative of rock.

Shear-wave velocity, $V_s$ is used to determine the shear modulus, G, of soil or rock:

$G = \rho (V_s^2)$: a valuable measure of soil stiffness and rock strength

Where ρ = mass density (i.e., total unit weight / gravitational acceleration constant, 32.2 $ft/s^2$)

The SPAC derived $V_s$ is interpreted from small strain measurements produced by non-destructive surface waves (Rayleigh waves) with strain on the order of $10^{-4}$ %. Shear modulus (G) derived from shear-wave velocity measured insitu using surface wave methods is commonly referred to as the small-strain shear modulus $G_{max}$.

# 5 Seismic Site Classification (ASCE 7)

Seismic Site Classification, in accordance with ASCE 7, was calculated from data along each of the 2D LM lines. The average shear wave velocities through the upper 100 feet (Vs100) which defines the seismic site classification is calculated as follows:

| Exploration Line | Vs100 | Seismic Site Class |
|---|---|---|
| SPAC-1 | 2052 f/s | **C** |
| SR-11 (north half) | 2183 f/s | **C** |
| SR-11 (south half) | 1696 f/s | **C** |

ASCE 7:

Site Class D: 600 to 1200 f/s

Site Class C: 1200 to 2500 f/s

Site Class B: 2500 to 5000 f/s

# 6 References

John N. Louie, 2001, Faster, better: shear-wave velocity to 100 meters depth from refraction microtremor arrays: Bull. Seismol. Soc. Amer., 91, no. 2 (April), 347-364

A. Pancha, S. K. Pullammanappallil, L. T. West, J. N. Louie, and W. K. Hellmer, 2017, Large scale earthquake hazard class mapping by parcel in Las Vegas Valley, Nevada: Bulletin of the Seismological Society of America, 107, no. 2 (April), 741-749, doi: 10.1785/0120160300. (668 kb PDF journal reprint)

J. Louie, A. Pancha, S. Pullammanappallil, 2017, Applications of Refraction Microtremor done right, and pitfalls of microtremor arrays done wrong: invited presentation at the 16th World Conference on Earthquake Engineering (16WCEE) Paper No. 4947, Santiago, Chile, Jan. 9-13, 12 pp. (14.1 Mb PDF preprint)

Geogiga DW Tomo 9.3 — Refraction Tomography Software operations manual

Geogiga Surface Plus 9.3 — Advanced Surface Wave Data Processing Software, manual

Advanced Geosciences, Inc. 2009
User Manual Earth Imager 2D. Version 2.4.0

Advanced Geosciences, Inc. 2008
User Manual Earth Imager 3DCL Version 1.5.3

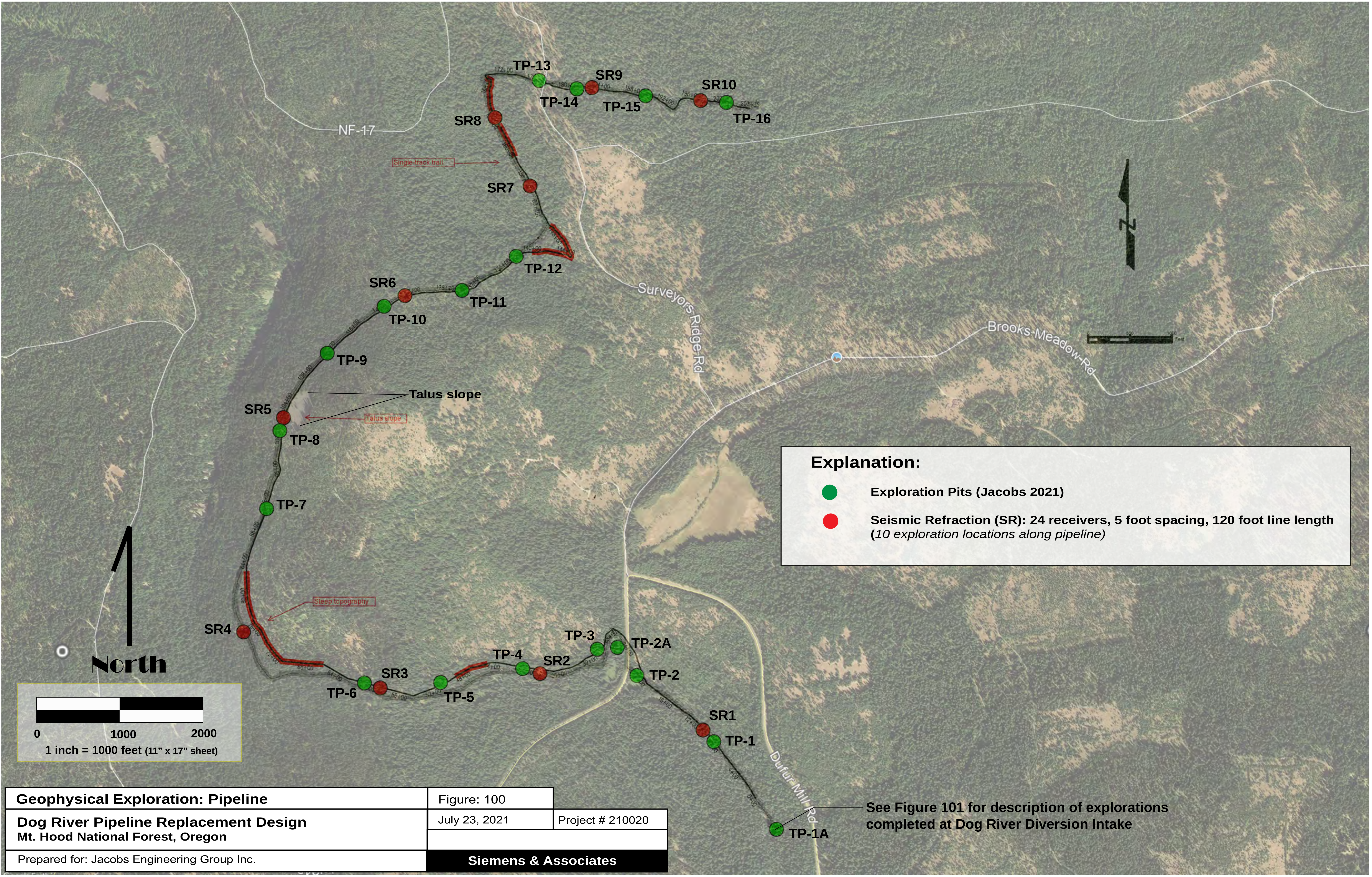
Dog River Pipeline Replacement Geotechnical Data Report, Jacobs, August 2021

Seismic Loads: Guide to the Seismic Load Provisions of ASCE 7-16

# 7 Graphical Presentation of Results

The interpretations are presented in 1D, 2D and 3D with the locations of the exploration lines illustrated on Figures 100 and 101.

## 7.1 Geophysical Exploration: Pipeline



See Figure 101 for description of explorations completed at Dog River Diversion Intake

**Explanation:**

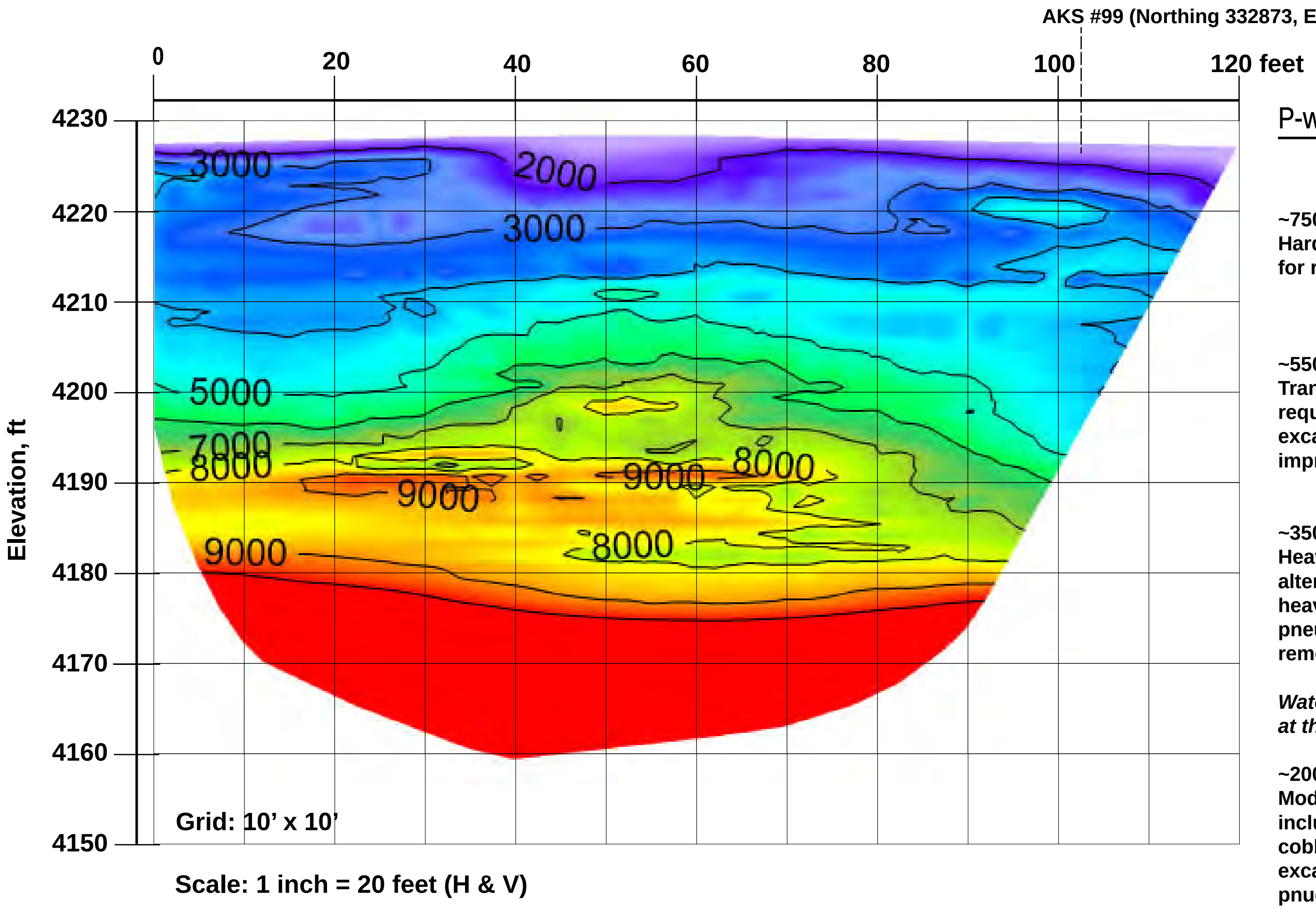
🟢 **Exploration Pits (Jacobs 2021)**

🔴 **Seismic Refraction (SR): 24 receivers, 5 foot spacing, 120 foot line length**
(*10 exploration locations along pipeline)*

| | |
|---|---|
| **Geophysical Exploration: Pipeline** | Figure: 100 |
| **Dog River Pipeline Replacement Design**<br>**Mt. Hood National Forest, Oregon** | July 23, 2021 — Project # 210020 |
| Prepared for: Jacobs Engineering Group Inc. | **Siemens & Associates** |

# P-wave Seismic Refraction: SR-1

(24, 4.5 Hz. receivers on 5 foot spacing, 13 shots on 10 foot spacing)



## P-wave velocity interpretation

**~7500 f/s and higher:**
**Hard Rock - drilling and blasting required for removal.**

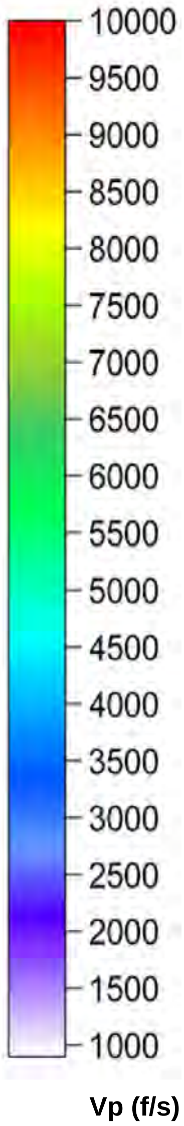
**~5500 to 7500:**
**Transition to hard rock - pneumatic chisel required for removal and powerful excavator, large dozer. Drill and blast for improved production.**

**~3500 to 5500 f/s:**
**Heavily consolidated soil and/or altered rock (decomposed, weathered, heavily fractured). Powerful excavator with pneumatic chisel assistance required for removal.**

***Water Vs ~ 4700 f/s: possible saturation at this velocity and higher.***

**~2000 to 3500 f/s:**
**Moderately heavy consolidation (could include many boulders and cemented cobbles/gravel assemblages). Slow excavation with powerful excavator and pnuematic chisel assist, possible raveling.**

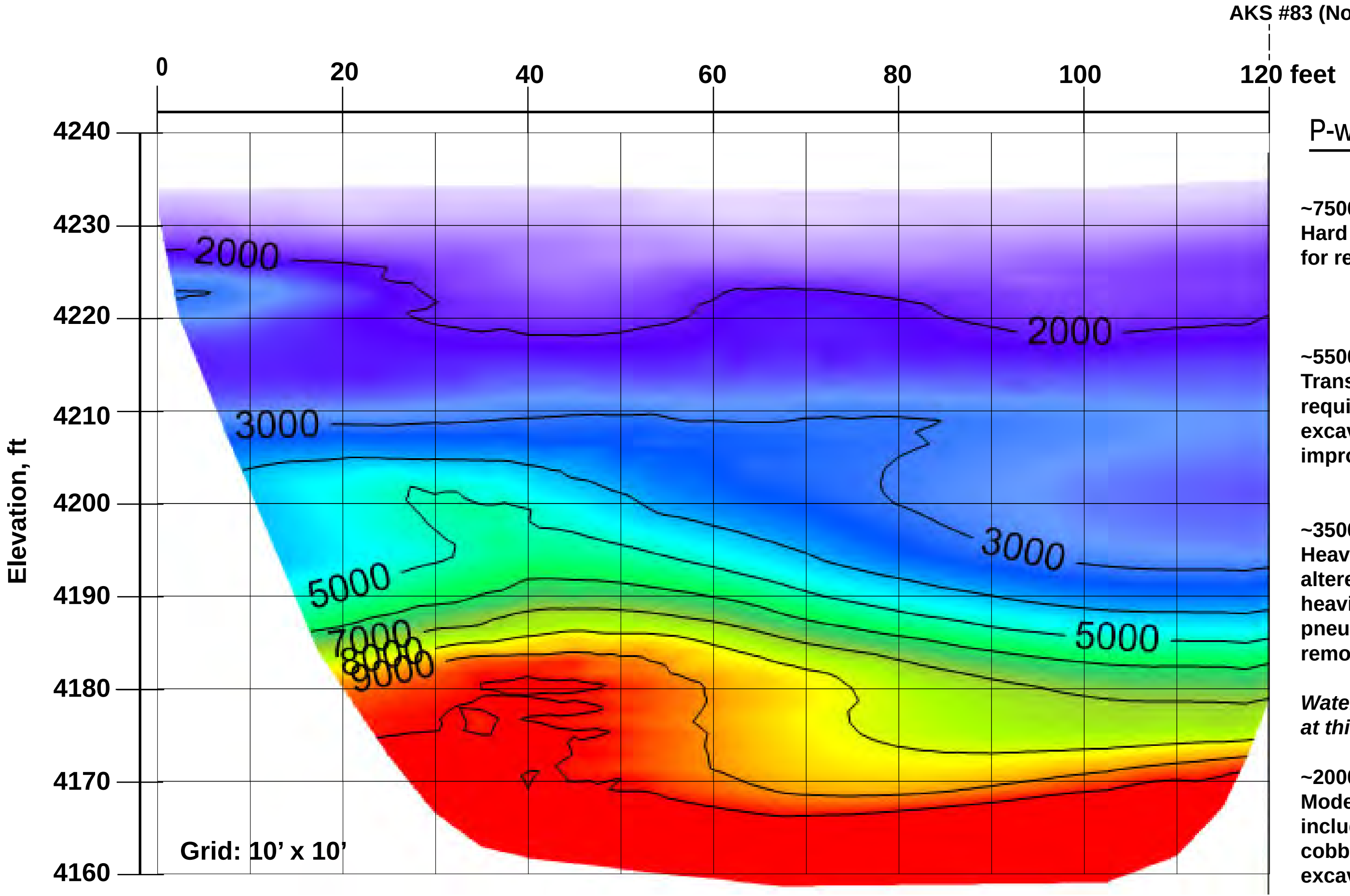
**~2000 f/s and lower:**
**Moderate to difficult excavation with conventional equipment: moderate sized excavator, small dozer, etc. Possible raveling, complications from large boulders and cobble/boulder assemblages possible.**



| | | |
|---|---|---|
| **P-wave Seismic Refraction: Line SR-1** | Figure: SR-1 | |
| **Dog River Pipeline Replacement Design Project**<br>**Mt. Hood National Forest, Oregon** | July 22, 2021 | Project # 210020 |
| Prepared for: Jacobs Engineering GroupInc. | **Siemens & Associates** | |

# P-wave Seismic Refraction: SR-2

**(24, 4.5 Hz. receivers on 5 foot spacing, 13 shots on 10 foot spacing)**



Scale: 1 inch = 20 feet (H & V)

## P-wave velocity interpretation

**~7500 f/s and higher:**
**Hard Rock - drilling and blasting required for removal.**

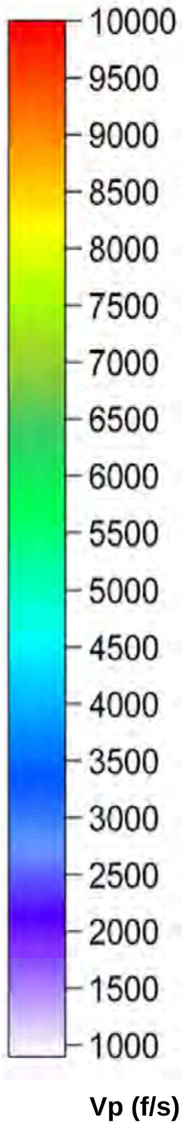
**~5500 to 7500:**
**Transition to hard rock - pneumatic chisel required for removal and powerful excavator, large dozer. Drill and blast for improved production.**

**~3500 to 5500 f/s:**
**Heavily consolidated soil and/or altered rock (decomposed, weathered, heavily fractured). Powerful excavator with pneumatic chisel assistance required for removal.**

***Water Vs ~ 4700 f/s: possible saturation at this velocity and higher.***

**~2000 to 3500 f/s:**
**Moderately heavy consolidation (could include many boulders and cemented cobbles/gravel assemblages). Slow excavation with powerful excavator and pnuematic chisel assist, possible raveling.**

**~2000 f/s and lower:**
**Moderate to difficult excavation with conventional equipment: moderate sized excavator, small dozer, etc. Possible raveling, complications from large boulders and cobble/boulder assemblages possible.**



**P-wave Seismic Refraction: Line SR-2**

Figure: SR-2

**Dog River Pipeline Replacement Design Project**
**Mt. Hood National Forest, Oregon**

July 22, 2021

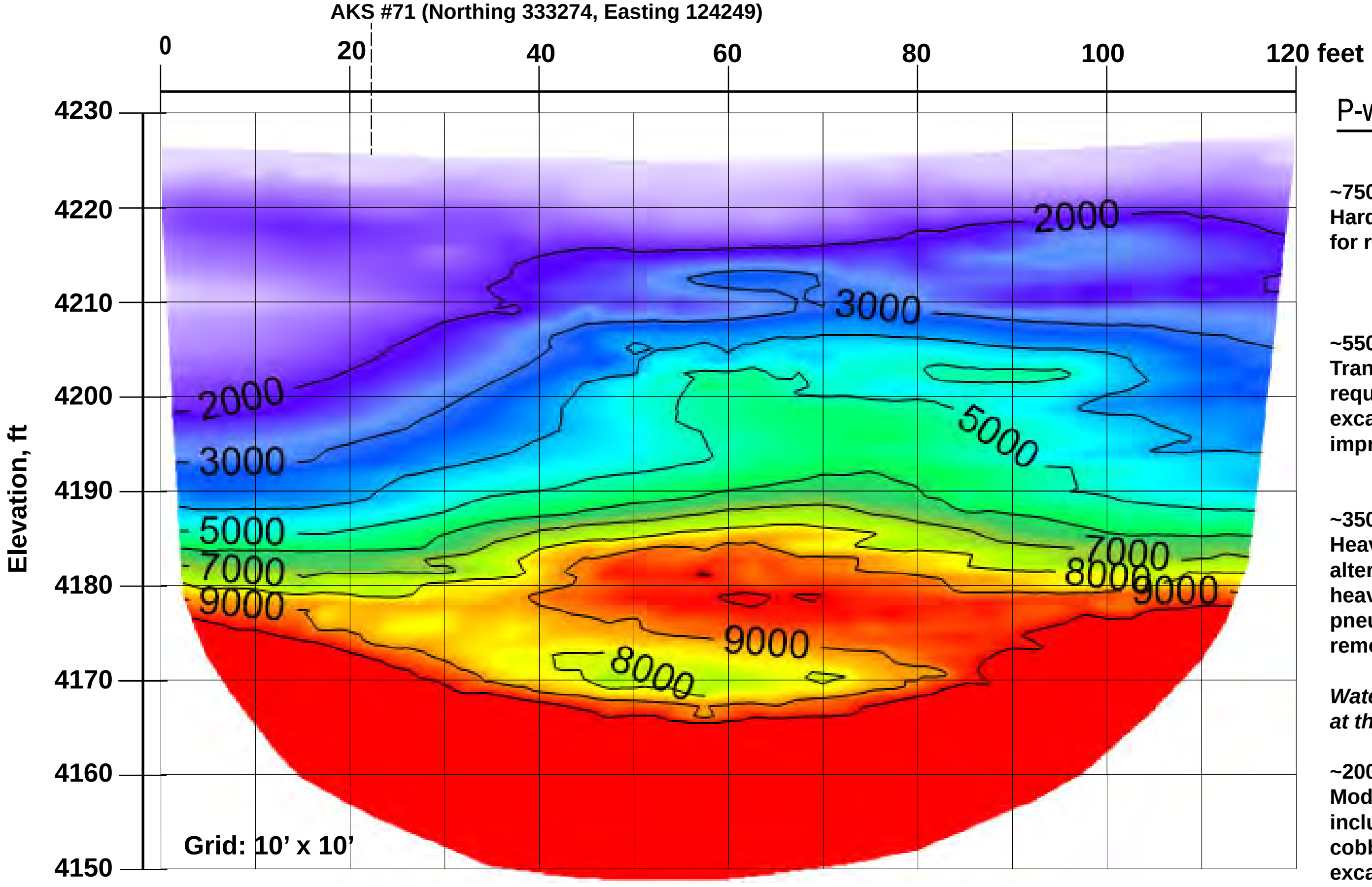
Project # 210020

Prepared for: Jacobs Engineering Group Inc.

**Siemens & Associates**

# P-wave Seismic Refraction: SR-3

(24, 4.5 Hz. receivers on 5 foot spacing, 13 shots on 10 foot spacing)



Scale: 1 inch = 20 feet (H & V)

## P-wave velocity interpretation

**~7500 f/s and higher:**
**Hard Rock - drilling and blasting required for removal.**

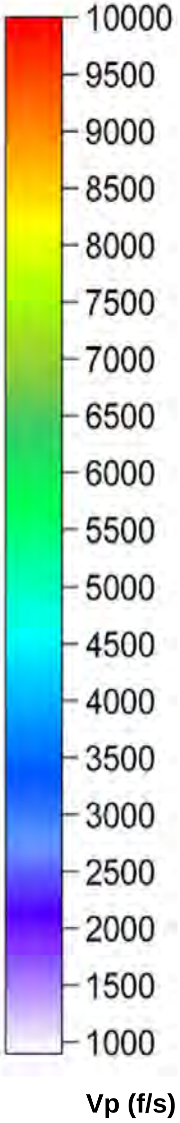
**~5500 to 7500:**
**Transition to hard rock - pneumatic chisel required for removal and powerful excavator, large dozer. Drill and blast for improved production.**

**~3500 to 5500 f/s:**
**Heavily consolidated soil and/or altered rock (decomposed, weathered, heavily fractured). Powerful excavator with pneumatic chisel assistance required for removal.**

***Water Vs ~ 4700 f/s: possible saturation at this velocity and higher.***

**~2000 to 3500 f/s:**
**Moderately heavy consolidation (could include many boulders and cemented cobbles/gravel assemblages). Slow excavation with powerful excavator and pnuematic chisel assist, possible raveling.**

**~2000 f/s and lower:**
**Moderate to difficult excavation with conventional equipment: moderate sized excavator, small dozer, etc. Possible raveling, complications from large boulders and cobble/boulder assemblages possible.**



**P-wave Seismic Refraction: Line SR-3**

Figure: SR-3

**Dog River Pipeline Replacement Design Project**
**Mt. Hood National Forest, Oregon**

July 22, 2021

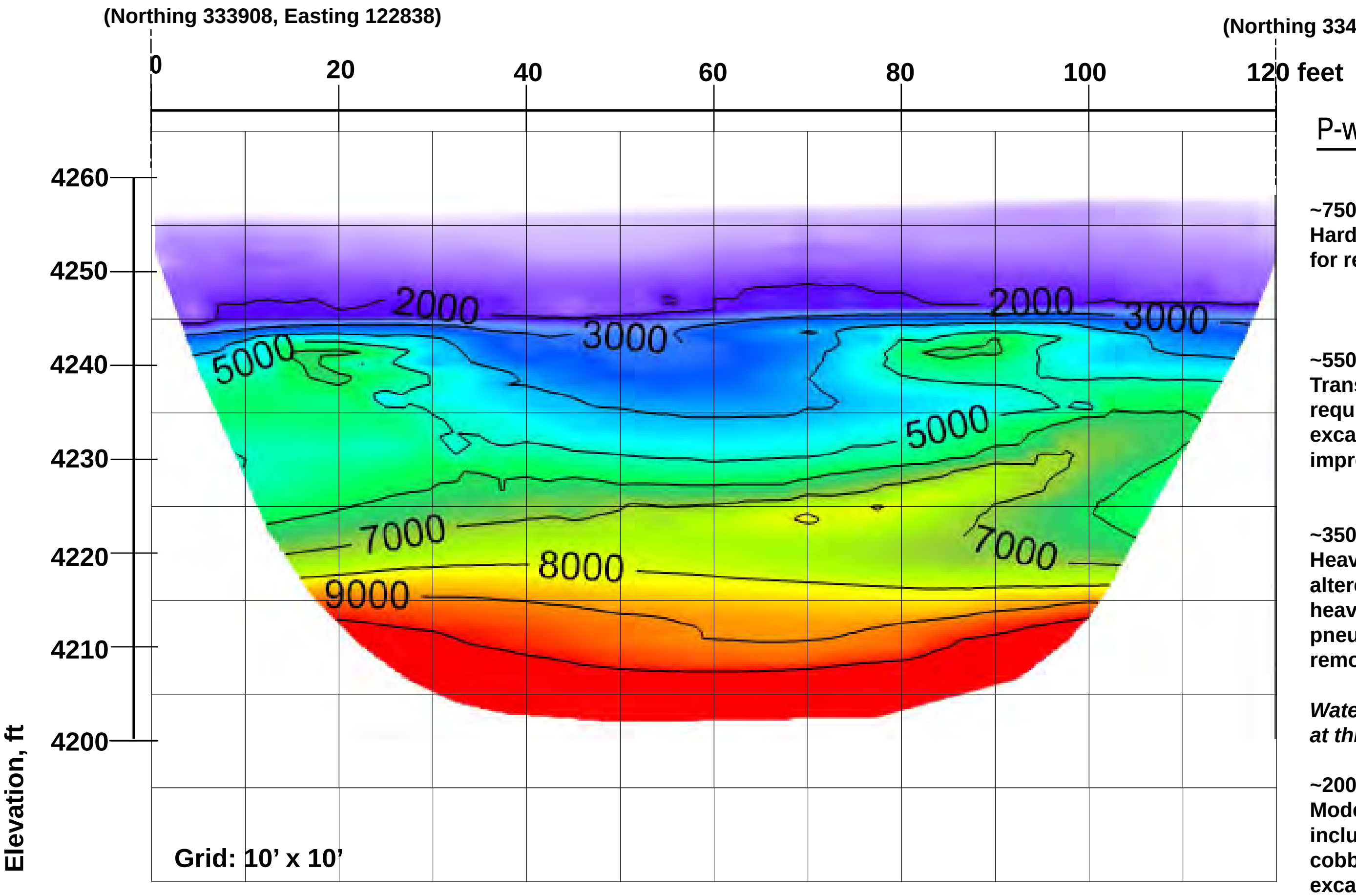
Project # 210020

Prepared for: Jacobs Engineering Group Inc.

**Siemens & Associates**

# P-wave Seismic Refraction: SR-4

(24, 4.5 Hz. receivers on 5 foot spacing, 13 shots on 10 foot spacing)



Scale: 1 inch = 20 feet (H & V)

## P-wave velocity interpretation

**~7500 f/s and higher:**
**Hard Rock - drilling and blasting required for removal.**

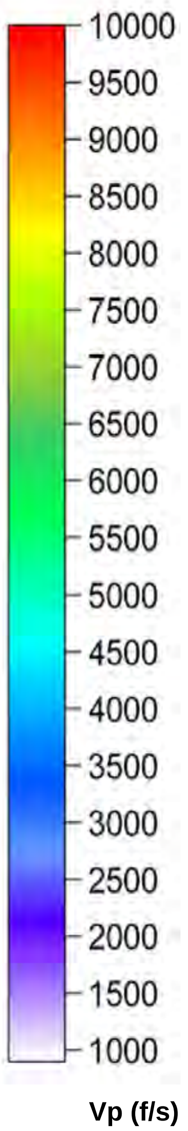
**~5500 to 7500:**
**Transition to hard rock - pneumatic chisel required for removal and powerful excavator, large dozer. Drill and blast for improved production.**

**~3500 to 5500 f/s:**
**Heavily consolidated soil and/or altered rock (decomposed, weathered, heavily fractured). Powerful excavator with pneumatic chisel assistance required for removal.**

***Water Vs ~ 4700 f/s: possible saturation at this velocity and higher.***

**~2000 to 3500 f/s:**
**Moderately heavy consolidation (could include many boulders and cemented cobbles/gravel assemblages). Slow excavation with powerful excavator and pnuematic chisel assist, possible raveling.**

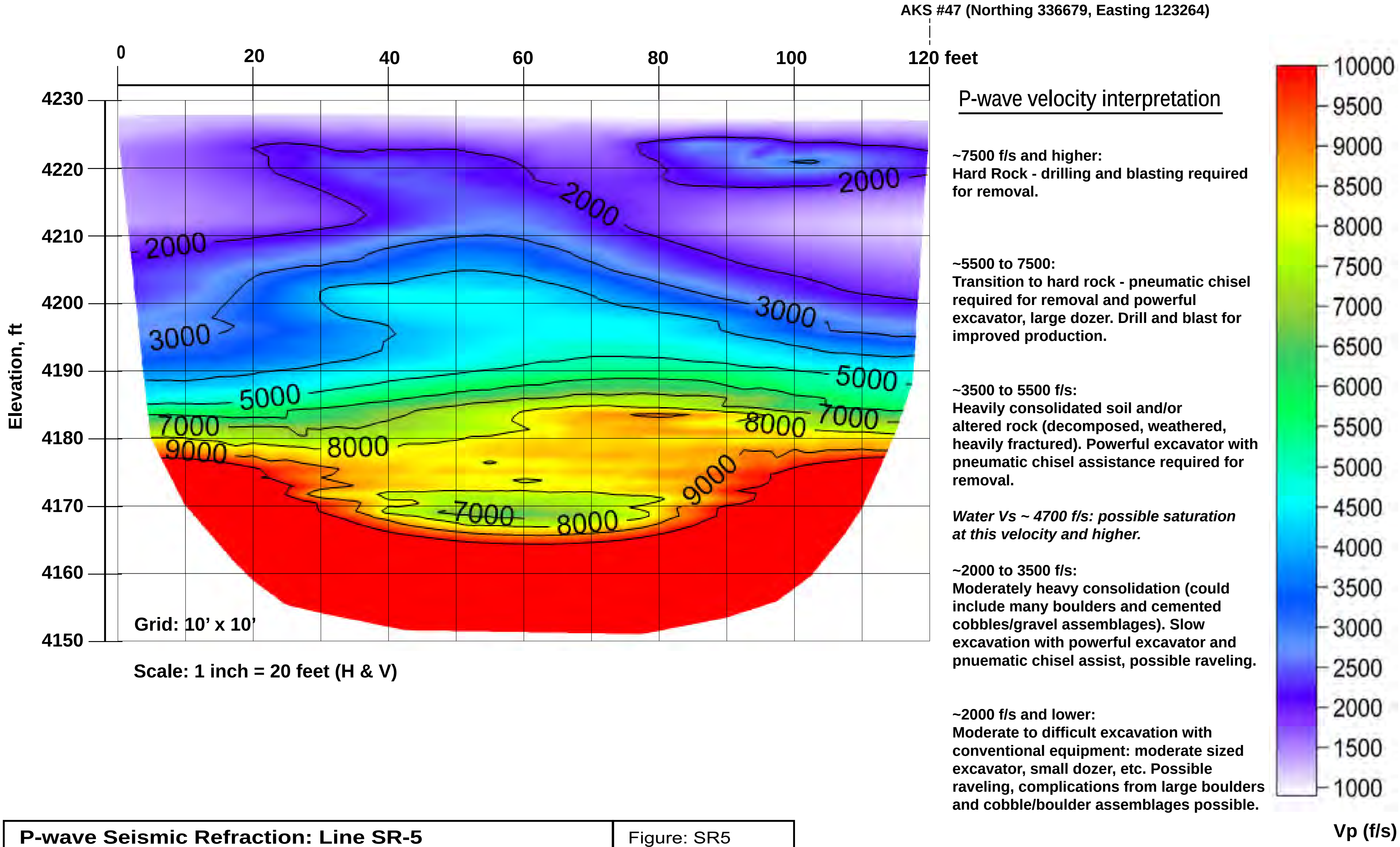
**~2000 f/s and lower:**
**Moderate to difficult excavation with conventional equipment: moderate sized excavator, small dozer, etc. Possible raveling, complications from large boulders and cobble/boulder assemblages possible.**



| | | |
|---|---|---|
| **P-wave Seismic Refraction: Line SR-4** | Figure: SR-4 | |
| **Dog River Pipeline Replacement Design Project**<br>**Mt. Hood National Forest, Oregon** | July 22, 2021 | Project # 210020 |
| Prepared for: Jacobs Engineering Group Inc. | **Siemens & Associates** | |

# P-wave Seismic Refraction: SR-5

(24, 4.5 Hz. receivers on 5 foot spacing, 13 shots on 10 foot spacing)



Scale: 1 inch = 20 feet (H & V)

## P-wave velocity interpretation

**~7500 f/s and higher:**
**Hard Rock - drilling and blasting required for removal.**

**~5500 to 7500:**
**Transition to hard rock - pneumatic chisel required for removal and powerful excavator, large dozer. Drill and blast for improved production.**

**~3500 to 5500 f/s:**
**Heavily consolidated soil and/or altered rock (decomposed, weathered, heavily fractured). Powerful excavator with pneumatic chisel assistance required for removal.**

***Water Vs ~ 4700 f/s: possible saturation at this velocity and higher.***

**~2000 to 3500 f/s:**
**Moderately heavy consolidation (could include many boulders and cemented cobbles/gravel assemblages). Slow excavation with powerful excavator and pnuematic chisel assist, possible raveling.**

**~2000 f/s and lower:**
**Moderate to difficult excavation with conventional equipment: moderate sized excavator, small dozer, etc. Possible raveling, complications from large boulders and cobble/boulder assemblages possible.**

**P-wave Seismic Refraction: Line SR-5**

**Dog River Pipeline Replacement Design Project**
**Mt. Hood National Forest, Oregon**

Prepared for: Jacobs Engineering Group Inc.

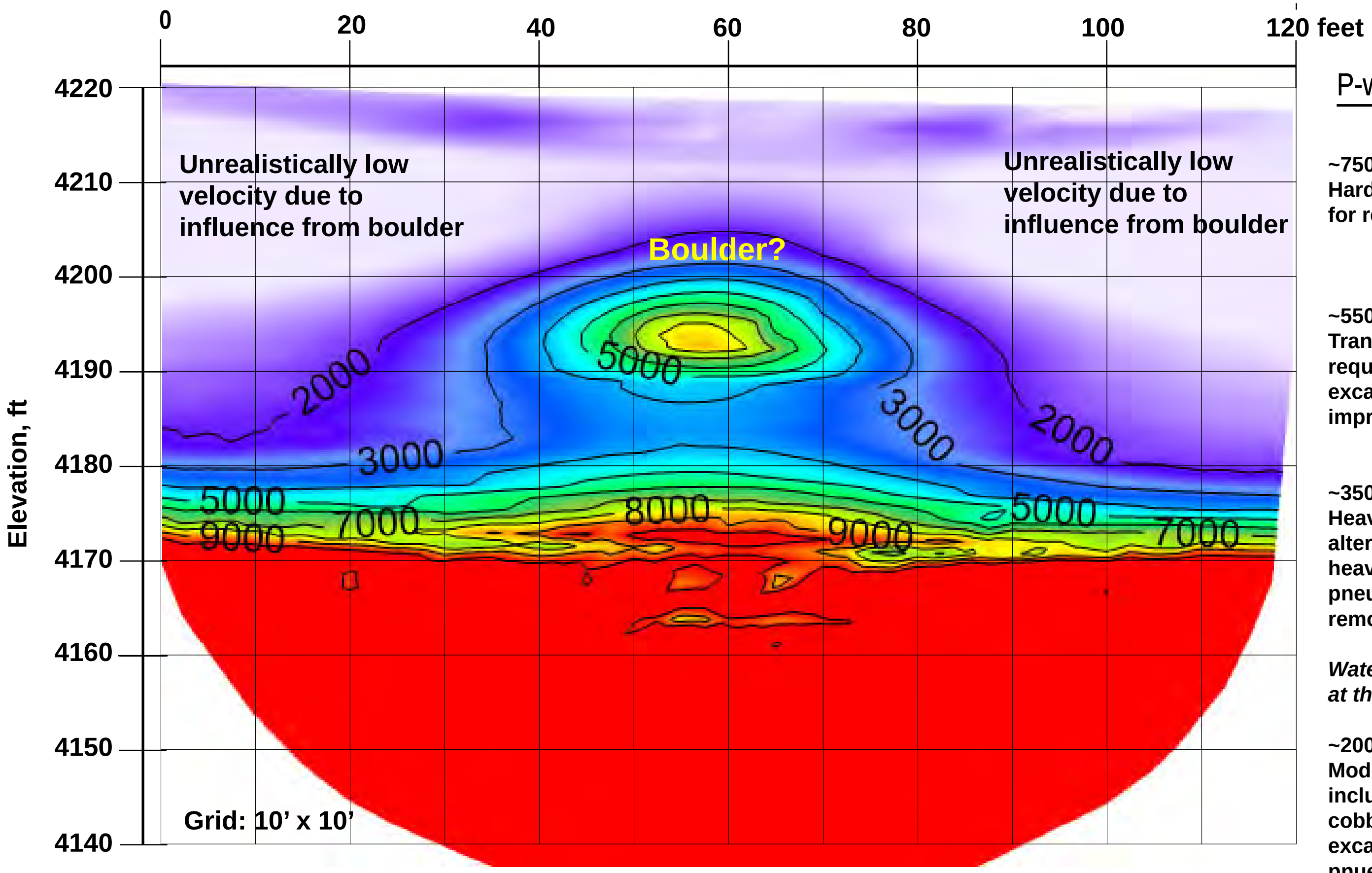
Figure: SR5
July 22, 2021
Project # 210020

**Siemens & Associates**

# P-wave Seismic Refraction: SR-6

(24, 4.5 Hz. receivers on 5 foot spacing, 13 shots on 10 foot spacing)

AKS #39 (Northing 337997, Easting 124774)



Unrealistically low velocity due to influence from boulder

Unrealistically low velocity due to influence from boulder

Grid: 10’ x 10’

Scale: 1 inch = 20 feet (H & V)

## P-wave velocity interpretation

**~7500 f/s and higher:**
**Hard Rock - drilling and blasting required for removal.**

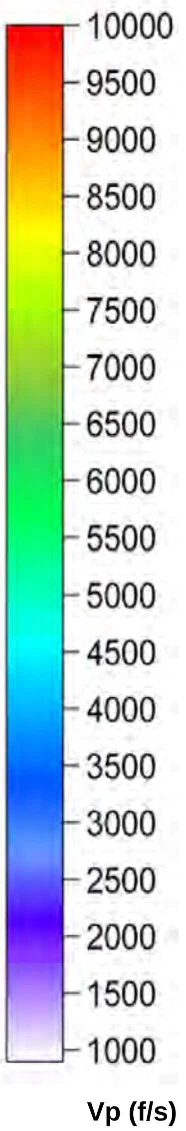
**~5500 to 7500:**
**Transition to hard rock - pneumatic chisel required for removal and powerful excavator, large dozer. Drill and blast for improved production.**

**~3500 to 5500 f/s:**
**Heavily consolidated soil and/or altered rock (decomposed, weathered, heavily fractured). Powerful excavator with pneumatic chisel assistance required for removal.**

***Water Vs ~ 4700 f/s: possible saturation at this velocity and higher.***

**~2000 to 3500 f/s:**
**Moderately heavy consolidation (could include many boulders and cemented cobbles/gravel assemblages). Slow excavation with powerful excavator and pnuematic chisel assist, possible raveling.**

**~2000 f/s and lower:**
**Moderate to difficult excavation with conventional equipment: moderate sized excavator, small dozer, etc. Possible raveling, complications from large boulders and cobble/boulder assemblages possible.**



**P-wave Seismic Refraction: Line SR-6**

Figure: SR6

**Dog River Pipeline Replacement Design Project**
**Mt. Hood National Forest, Oregon**

July 22, 2021

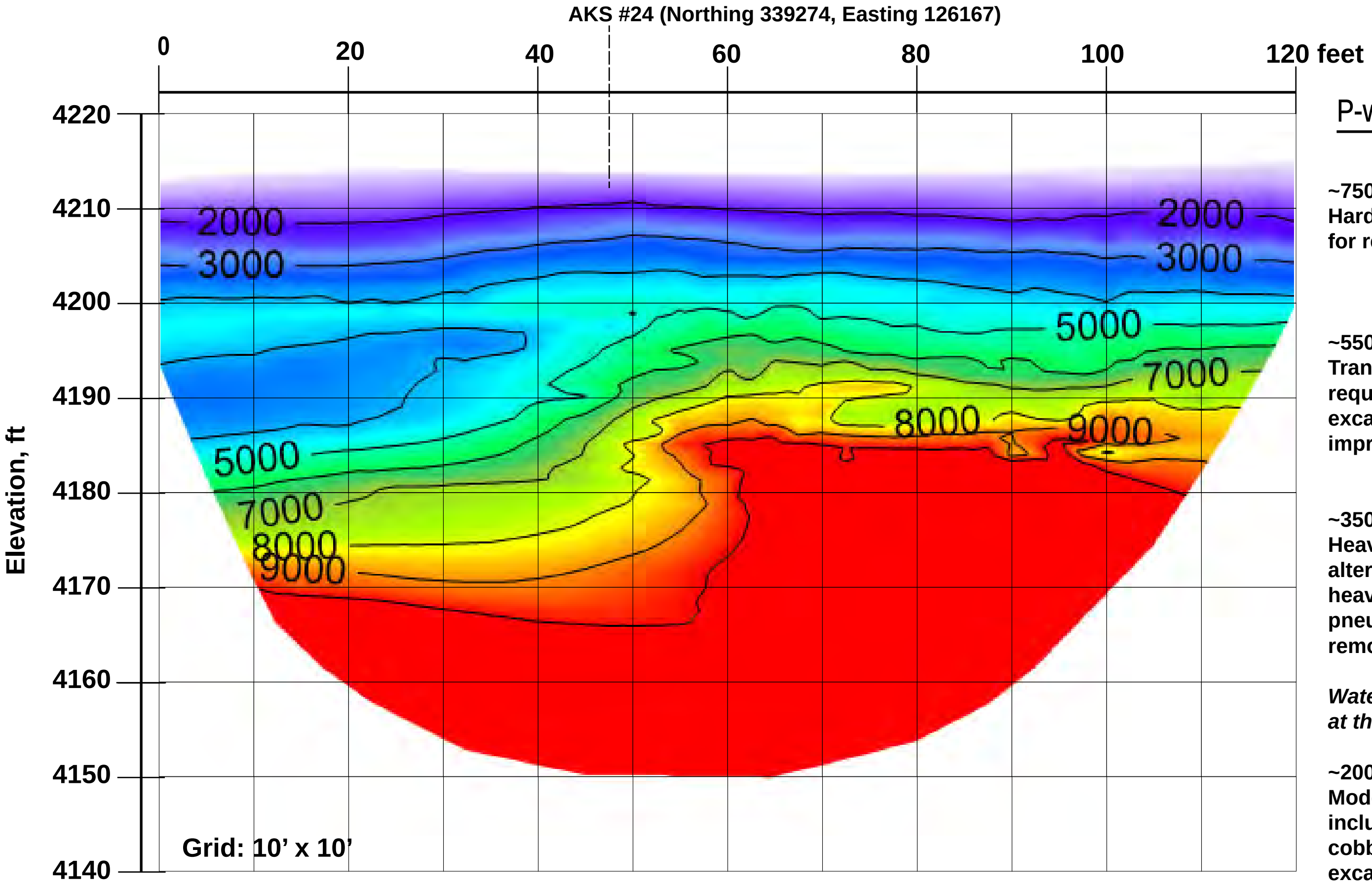
Project # 210020

Prepared for: Jacobs Engineering Group Inc.

**Siemens & Associates**

# P-wave Seismic Refraction: SR-7

(24, 4.5 Hz. receivers on 5 foot spacing, 13 shots on 10 foot spacing)



Scale: 1 inch = 20 feet (H & V)

## P-wave velocity interpretation

**~7500 f/s and higher:**
**Hard Rock - drilling and blasting required for removal.**

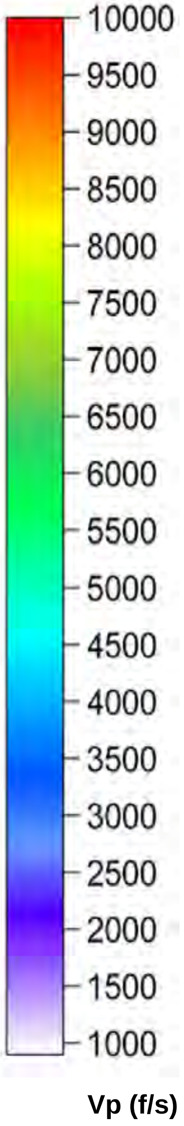
**~5500 to 7500:**
**Transition to hard rock - pneumatic chisel required for removal and powerful excavator, large dozer. Drill and blast for improved production.**

**~3500 to 5500 f/s:**
**Heavily consolidated soil and/or altered rock (decomposed, weathered, heavily fractured). Powerful excavator with pneumatic chisel assistance required for removal.**

***Water Vs ~ 4700 f/s: possible saturation at this velocity and higher.***

**~2000 to 3500 f/s:**
**Moderately heavy consolidation (could include many boulders and cemented cobbles/gravel assemblages). Slow excavation with powerful excavator and pnuematic chisel assist, possible raveling.**

**~2000 f/s and lower:**
**Moderate to difficult excavation with conventional equipment: moderate sized excavator, small dozer, etc. Possible raveling, complications from large boulders and cobble/boulder assemblages possible.**



**P-wave Seismic Refraction: Line SR-7**

Figure: SR7

**Dog River Pipeline Replacement Design Project**
**Mt. Hood National Forest, Oregon**

July 22, 2021

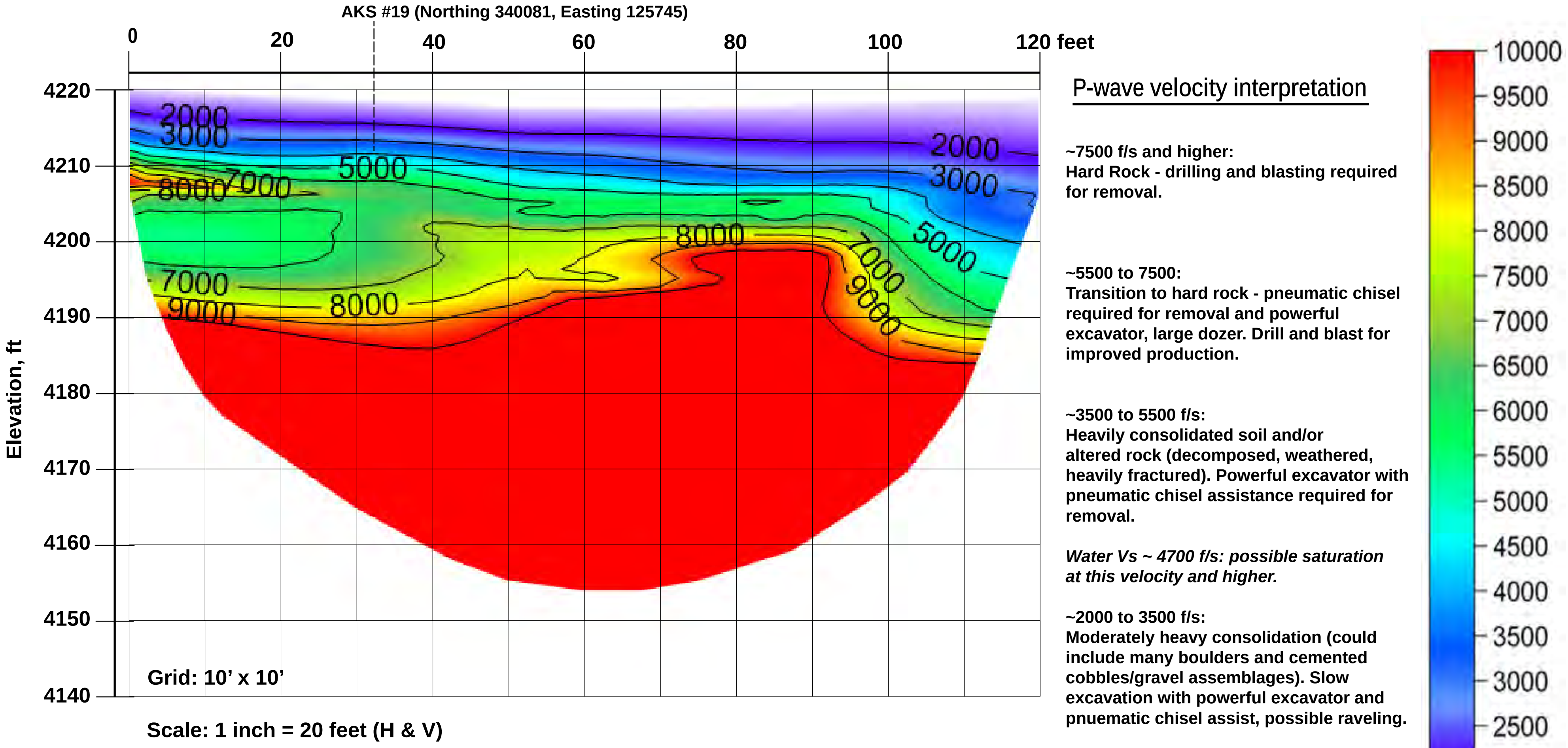
Project # 210020

Prepared for: Jacobs Engineering Group Inc.

**Siemens & Associates**

# P-wave Seismic Refraction: SR-8

(24, 4.5 Hz. receivers on 5 foot spacing, 13 shots on 10 foot spacing)



Scale: 1 inch = 20 feet (H & V)

## P-wave velocity interpretation

**~7500 f/s and higher:**
**Hard Rock - drilling and blasting required for removal.**

**~5500 to 7500:**
**Transition to hard rock - pneumatic chisel required for removal and powerful excavator, large dozer. Drill and blast for improved production.**

**~3500 to 5500 f/s:**
**Heavily consolidated soil and/or altered rock (decomposed, weathered, heavily fractured). Powerful excavator with pneumatic chisel assistance required for removal.**

***Water Vs ~ 4700 f/s: possible saturation at this velocity and higher.***

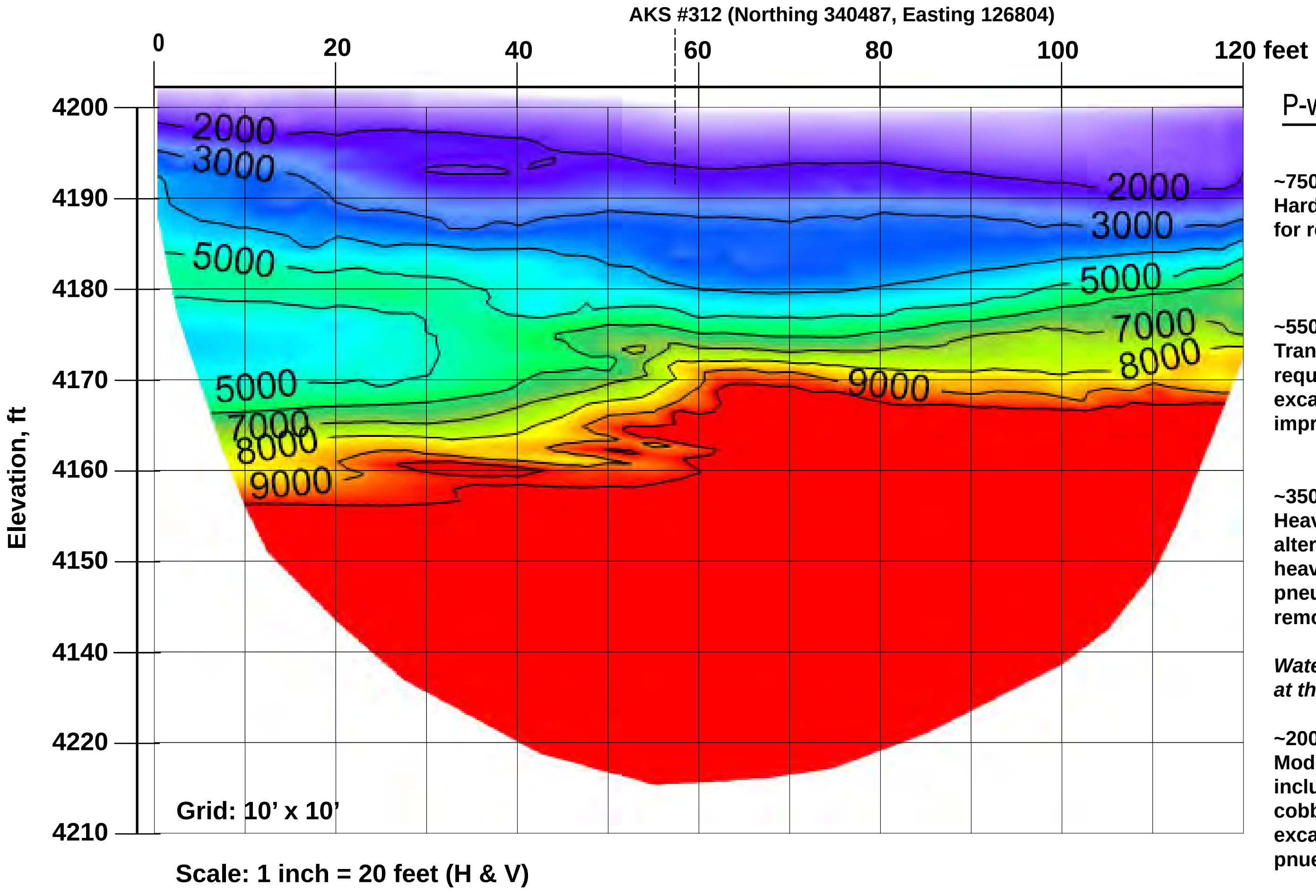
**~2000 to 3500 f/s:**
**Moderately heavy consolidation (could include many boulders and cemented cobbles/gravel assemblages). Slow excavation with powerful excavator and pnuematic chisel assist, possible raveling.**

**~2000 f/s and lower:**
**Moderate to difficult excavation with conventional equipment: moderate sized excavator, small dozer, etc. Possible raveling, complications from large boulders and cobble/boulder assemblages possible.**

| | | |
|---|---|---|
| **P-wave Seismic Refraction: Line SR-8** | Figure: SR8 | |
| **Dog River Pipeline Replacement Design Project**<br>**Mt. Hood National Forest, Oregon** | July 22, 2021 | Project # 210020 |
| Prepared for: Jacobs Engineering Group Inc. | **Siemens & Associates** | |

# P-wave Seismic Refraction: SR-9

(24, 4.5 Hz. receivers on 5 foot spacing, 13 shots on 10 foot spacing)



Scale: 1 inch = 20 feet (H & V)

## P-wave velocity interpretation

**~7500 f/s and higher:**
**Hard Rock - drilling and blasting required for removal.**

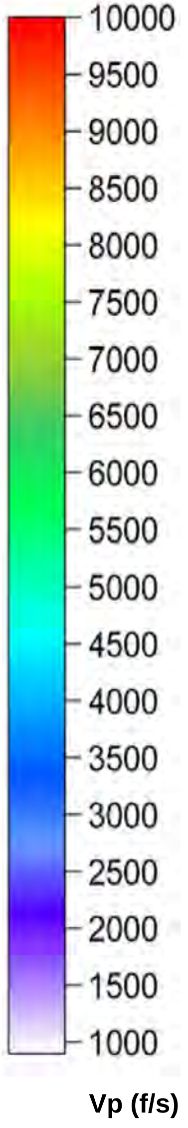
**~5500 to 7500:**
**Transition to hard rock - pneumatic chisel required for removal and powerful excavator, large dozer. Drill and blast for improved production.**

**~3500 to 5500 f/s:**
**Heavily consolidated soil and/or altered rock (decomposed, weathered, heavily fractured). Powerful excavator with pneumatic chisel assistance required for removal.**

***Water Vs ~ 4700 f/s: possible saturation at this velocity and higher.***

**~2000 to 3500 f/s:**
**Moderately heavy consolidation (could include many boulders and cemented cobbles/gravel assemblages). Slow excavation with powerful excavator and pnuematic chisel assist, possible raveling.**

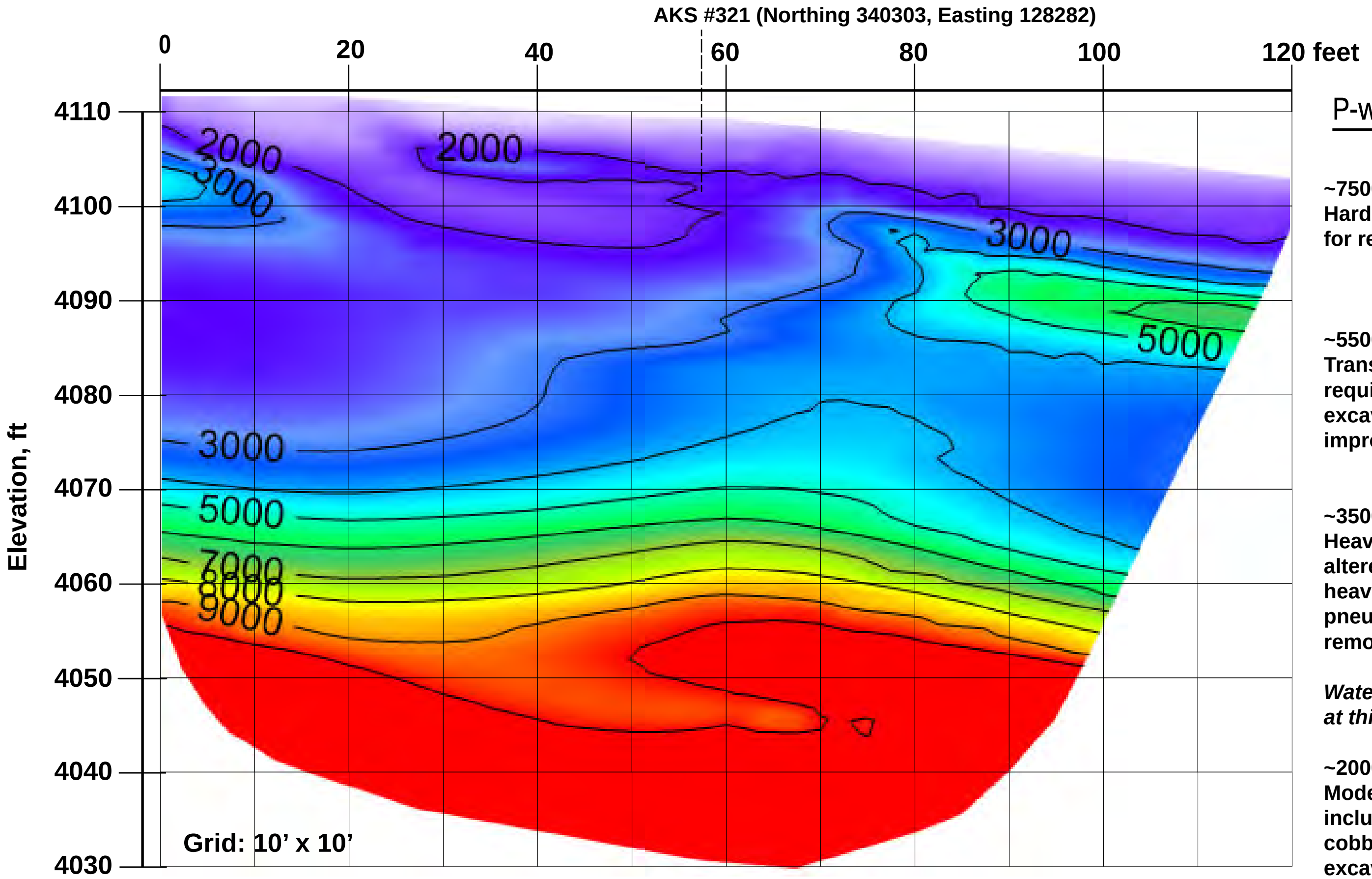
**~2000 f/s and lower:**
**Moderate to difficult excavation with conventional equipment: moderate sized excavator, small dozer, etc. Possible raveling, complications from large boulders and cobble/boulder assemblages possible.**



| | | |
|---|---|---|
| **P-wave Seismic Refraction: Line SR-9** | Figure: SR9 | |
| **Dog River Pipeline Replacement Design Project**<br>**Mt. Hood National Forest, Oregon** | July 21, 2021 | Project # 210020 |
| Prepared for: Jacobs Engineering Group Inc. | **Siemens & Associates** | |

# P-wave Seismic Refraction: SR-10

(24, 4.5 Hz. receivers on 5 foot spacing, 13 shots on 10 foot spacing)



Grid: 10' x 10'

Scale: 1 inch = 20 feet (H & V)

## P-wave velocity interpretation

**~7500 f/s and higher:**
**Hard Rock - drilling and blasting required for removal.**

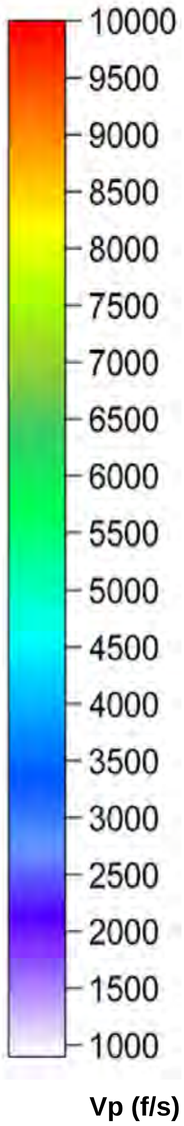
**~5500 to 7500:**
**Transition to hard rock - pneumatic chisel required for removal and powerful excavator, large dozer. Drill and blast for improved production.**

**~3500 to 5500 f/s:**
**Heavily consolidated soil and/or altered rock (decomposed, weathered, heavily fractured). Powerful excavator with pneumatic chisel assistance required for removal.**

***Water Vs ~ 4700 f/s: possible saturation at this velocity and higher.***

**~2000 to 3500 f/s:**
**Moderately heavy consolidation (could include many boulders and cemented cobbles/gravel assemblages). Slow excavation with powerful excavator and pnuematic chisel assist, possible raveling.**

**~2000 f/s and lower:**
**Moderate to difficult excavation with conventional equipment: moderate sized excavator, small dozer, etc. Possible raveling, complications from large boulders and cobble/boulder assemblages possible.**



**P-wave Seismic Refraction: Line SR-10**

Figure: SR10

**Dog River Pipeline Replacement Design Project**
**Mt. Hood National Forest, Oregon**

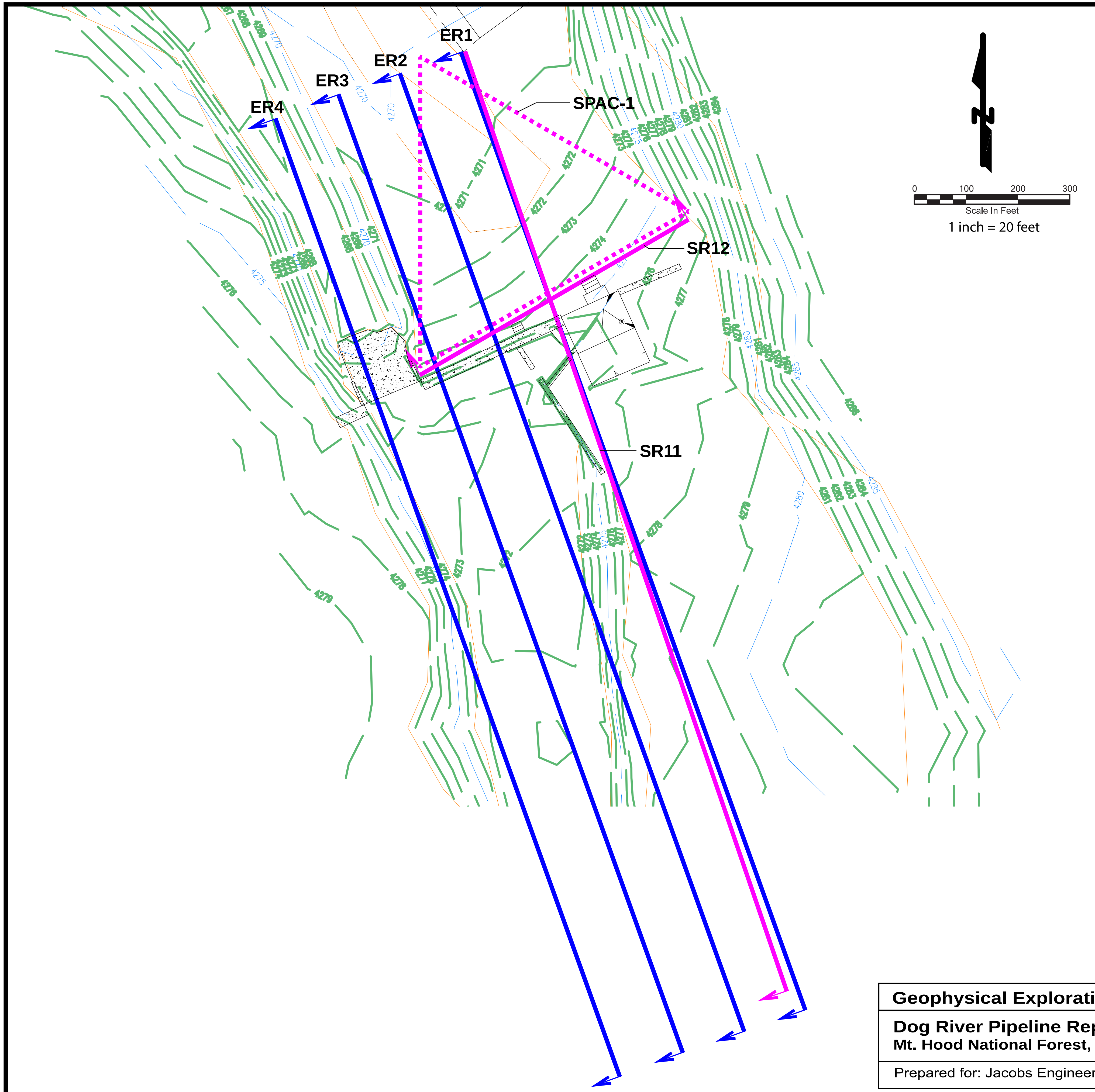
July 21, 2021

Project # 210020

Prepared for: Jacobs Engineering Group Inc.

**Siemens & Associates**

## 7.2 Geophysical Exploration: Dog River Diversion Intake



**Explanation:**

- Seismic Refraction (SR) and LM (S-wave)
- Electrical Resistivity (ER)
- Spatial Auto Acceleration (SPAC) S-wave

**Geophysical Exploration at Dog River Diversion Intake**

Figure: 101

**Dog River Pipeline Replacement Design**
**Mt. Hood National Forest, Oregon**

July 23, 2021

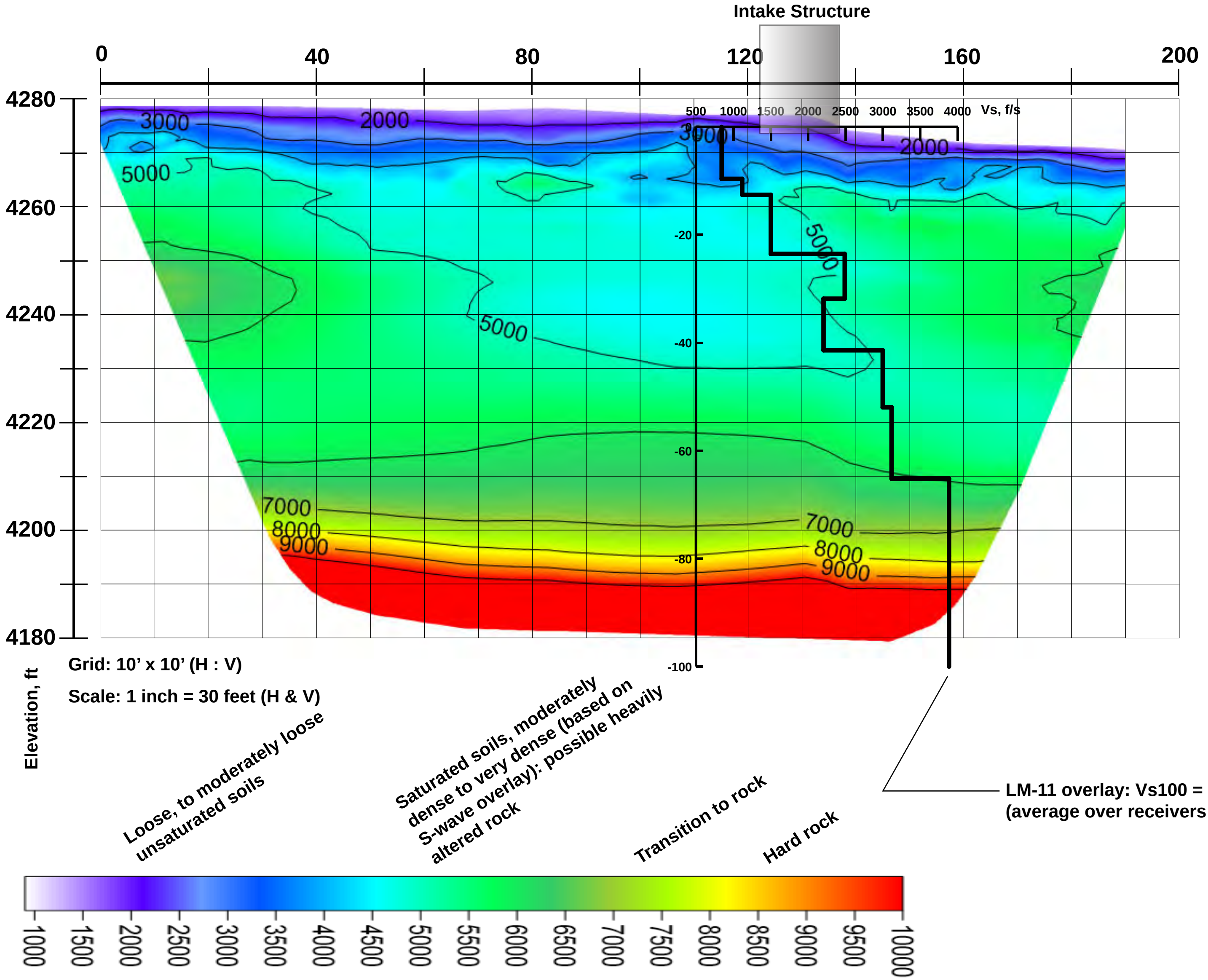
Project # 210020

Prepared for: Jacobs Engineering Group Inc.

**Siemens & Associates**

# SR-11: P-wave Seismic Refraction: through intake and diversion

**(24, 4.5 Hz. receivers on 8 foot spacing, 13 shots on 16 foot spacing)**



Grid: 10’ x 10’ (H : V)

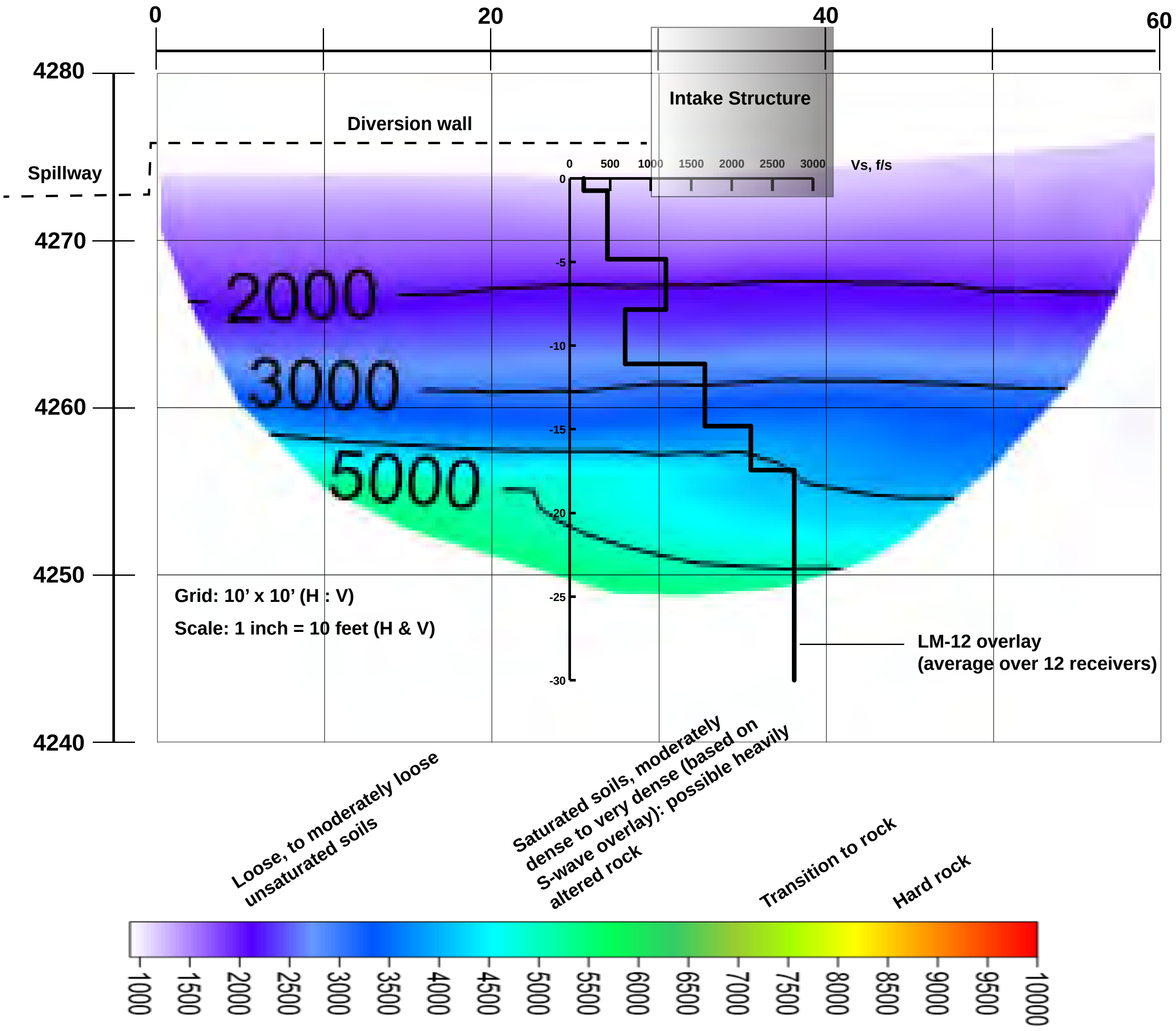
Scale: 1 inch = 30 feet (H & V)

LM-11 overlay: Vs100 = 2183 f/s (Seismic Site Class C)
(average over receivers 13 to 24)

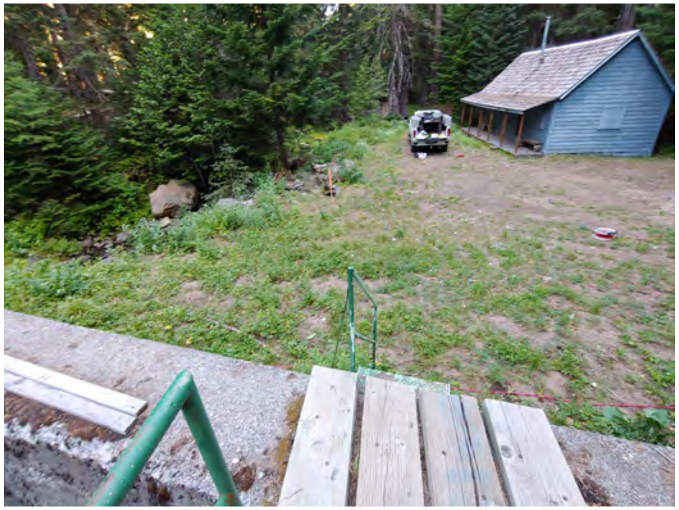
| | | |
|---|---|---|
| **P-wave Seismic Refraction: Line SR-11** | Figure: SR-11 | |
| **Dog River Pipeline Replacement Design Project**<br>**Mt. Hood National Forest, Oregon** | July 23, 2021 | Project # 210020 |
| Prepared for: Jacobs Engineering Group Inc. | **Siemens & Associates** | |

# SR-12: P-wave Seismic Refraction: adjacent intake and diversion

(12, 4.5 Hz. receivers on 5 foot spacing, 13 shots on 5 foot spacing)



Azimuth ~60 degrees



**P-wave Seismic Refraction: Line SR-12**

Figure: SR-12

**Dog River Pipeline Replacement Design Project**
**Mt. Hood National Forest, Oregon**

July 23, 2021

Project # 210020

Prepared for: Jacobs Engineering Group Inc.

**Siemens & Associates**

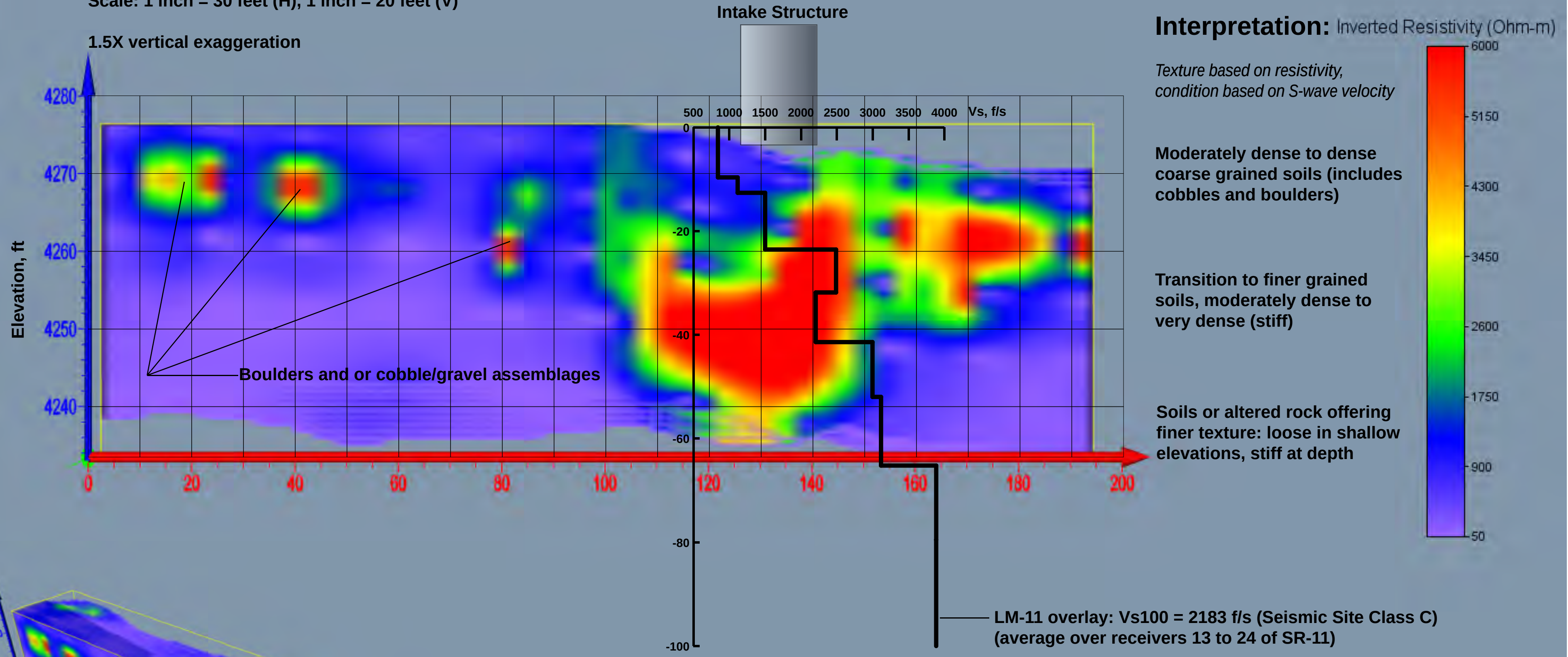
# ER-1: Electrical Resistivity Tomography through intake and diversion

**(21 electrodes on 3 m spacing: combined Dipole-Dipole, inverted Schlumberger and Strong Gradient arrays)**

**Grid: 10’ x 10’ (H : V)**

**Scale: 1 inch = 30 feet (H), 1 inch = 20 feet (V)**

**1.5X vertical exaggeration**



**Interpretation:**

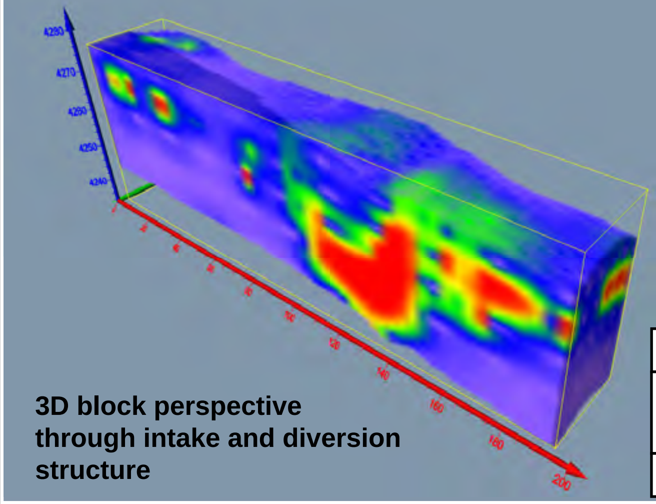
*Texture based on resistivity, condition based on S-wave velocity*

**Moderately dense to dense coarse grained soils (includes cobbles and boulders)**

**Transition to finer grained soils, moderately dense to very dense (stiff)**

**Soils or altered rock offering finer texture: loose in shallow elevations, stiff at depth**

**LM-11 overlay: Vs100 = 2183 f/s (Seismic Site Class C) (average over receivers 13 to 24 of SR-11)**

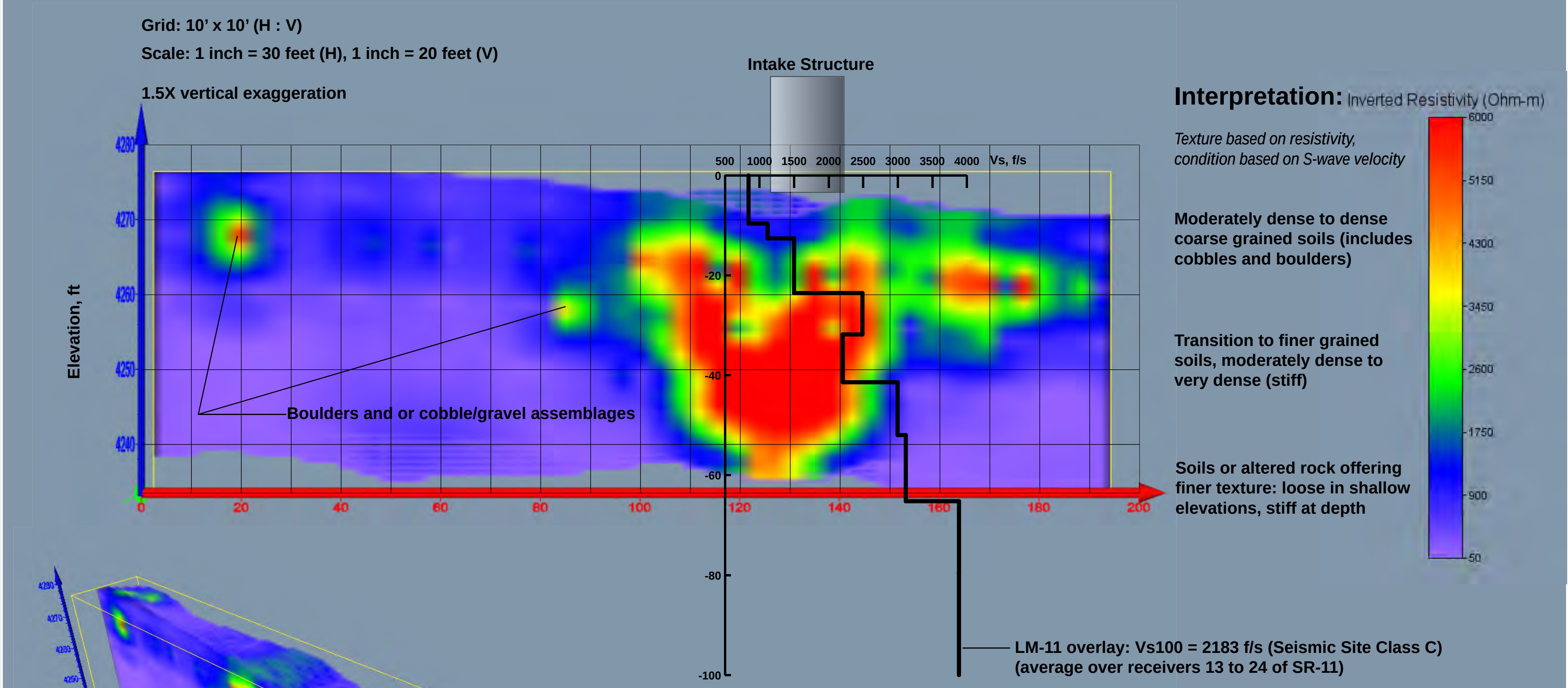


**3D block perspective through intake and diversion structure**

| | | |
|---|---|---|
| **Electrical Resistivity Tomography: Line ER-1** | Figure: ER-1 | |
| **Dog River Pipeline Replacement Design Project**<br>**Mt. Hood National Forest, Oregon** | July 23, 2021 | Project # 210020 |
| Prepared for: Jacobs Engineering Group Inc. | **Siemens & Associates** | |

# ER-2: Electrical Resistivity Tomography through intake and diversion

**(21 electrodes on 3 m spacing: combined Dipole-Dipole, inverted Schlumberger and Strong Gradient arrays)**



**Grid: 10’ x 10’ (H : V)**

**Scale: 1 inch = 30 feet (H), 1 inch = 20 feet (V)**

**1.5X vertical exaggeration**

**Intake Structure**

**Boulders and or cobble/gravel assemblages**

## Interpretation:

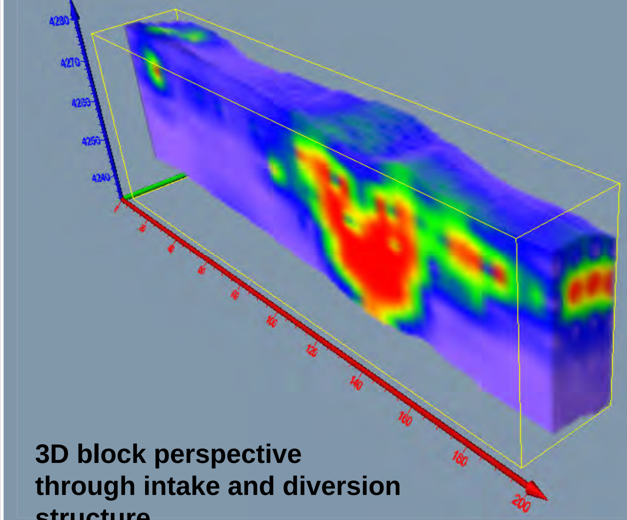
*Texture based on resistivity, condition based on S-wave velocity*

**Moderately dense to dense coarse grained soils (includes cobbles and boulders)**

**Transition to finer grained soils, moderately dense to very dense (stiff)**

**Soils or altered rock offering finer texture: loose in shallow elevations, stiff at depth**

**LM-11 overlay: Vs100 = 2183 f/s (Seismic Site Class C)**
**(average over receivers 13 to 24 of SR-11)**



**3D block perspective through intake and diversion structure**

**Electrical Resistivity Tomography: Line ER-2**

Figure: ER-2

**Dog River Pipeline Replacement Design Project**
**Mt. Hood National Forest, Oregon**

July 23, 2021

Project # 210020

Prepared for: Jacobs Engineering Group Inc.

**Siemens & Associates**

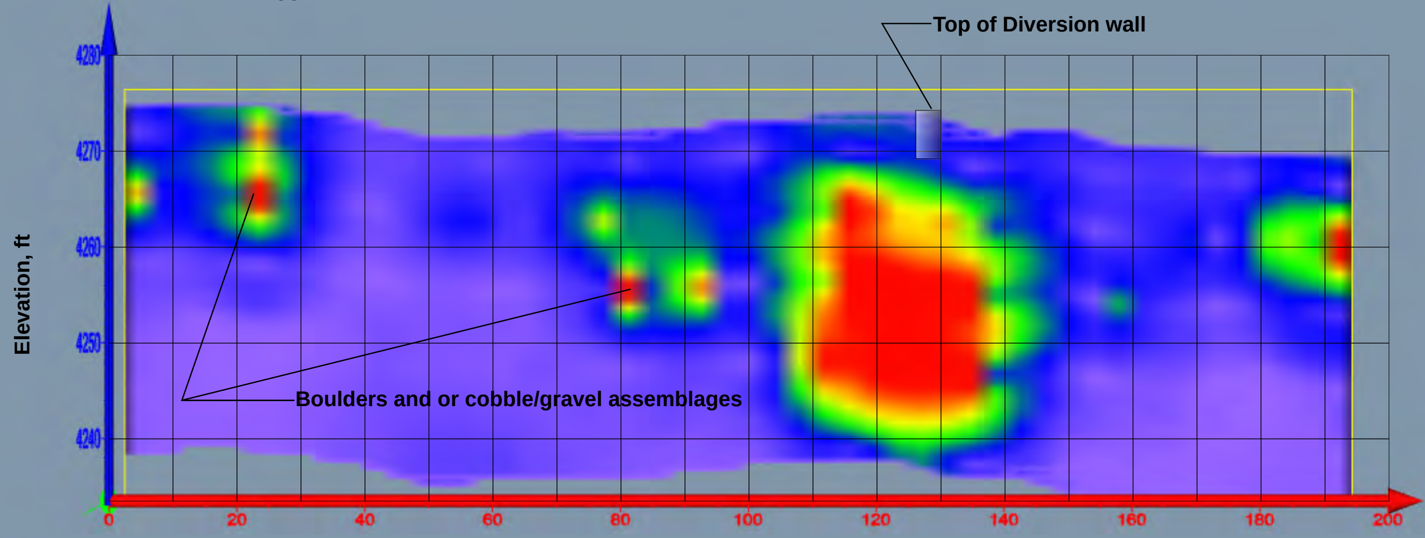
# ER-3: Electrical Resistivity Tomography through intake and diversion

**(21 electrodes on 3 m spacing: combined Dipole-Dipole, inverted Schlumberger and Strong Gradient arrays)**

**Grid: 10’ x 10’ (H : V)**

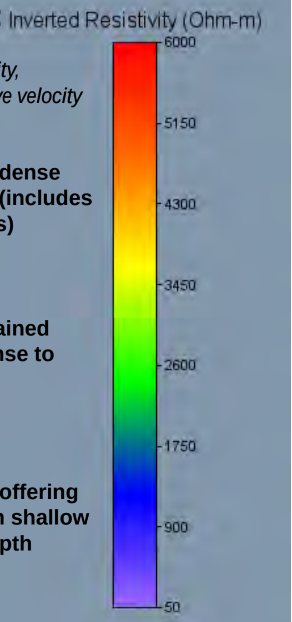
**Scale: 1 inch = 30 feet (H), 1 inch = 20 feet (V)**

**1.5X vertical exaggeration**



## Interpretation:

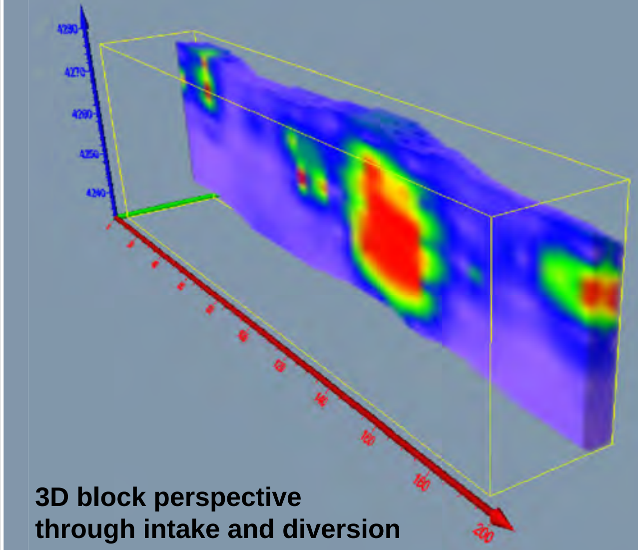
*Texture based on resistivity, condition based on S-wave velocity*



**Moderately dense to dense coarse grained soils (includes cobbles and boulders)**

**Transition to finer grained soils, moderately dense to very dense (stiff)**

**Soils or altered rock offering finer texture: loose in shallow elevations, stiff at depth**



**3D block perspective through intake and diversion structure**

| | | |
|---|---|---|
| **Electrical Resistivity Tomography: Line ER-3** | Figure: ER-3 | |
| **Dog River Pipeline Replacement Design Project**<br>**Mt. Hood National Forest, Oregon** | July 23, 2021 | Project # 210020 |
| Prepared for: Jacobs Engineering Group Inc. | **Siemens & Associates** | |

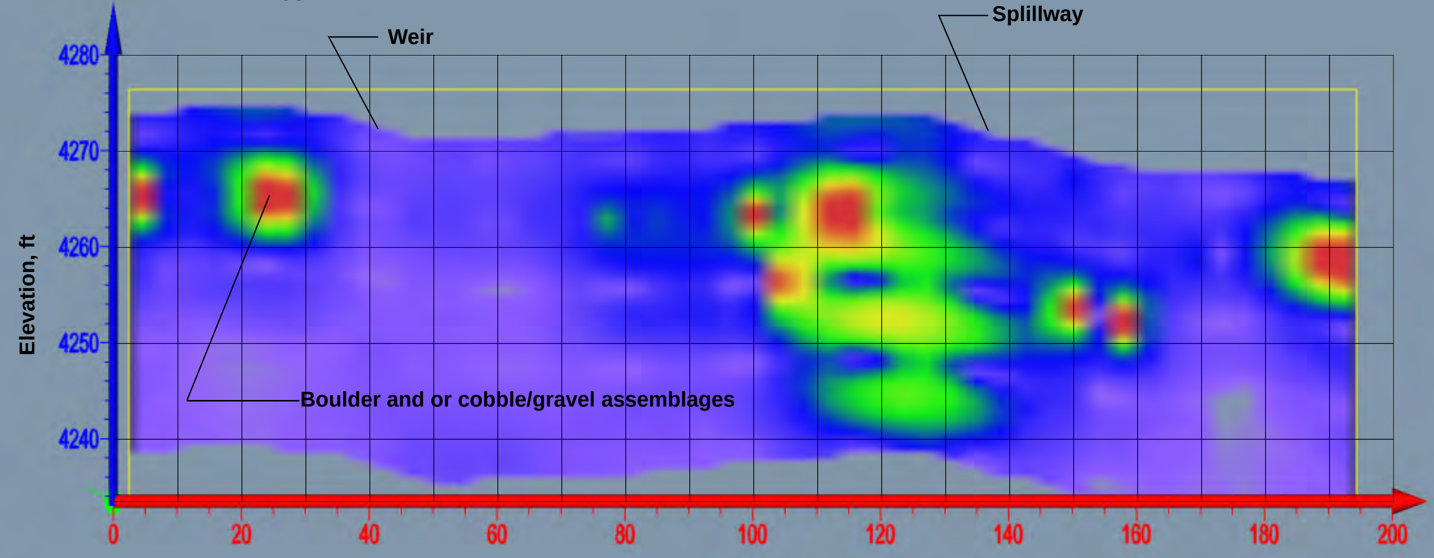
# ER-4: Electrical Resistivity Tomography through intake and diversion

## (21 electrodes on 3 m spacing: combined Dipole-Dipole, inverted Schlumberger and Strong Gradient arrays)

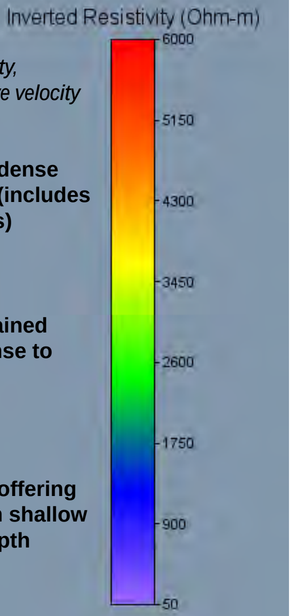
**Grid: 10’ x 10’ (H : V)**

**Scale: 1 inch = 30 feet (H), 1 inch = 20 feet (V)**

**1.5X vertical exaggeration**



**Interpretation:**

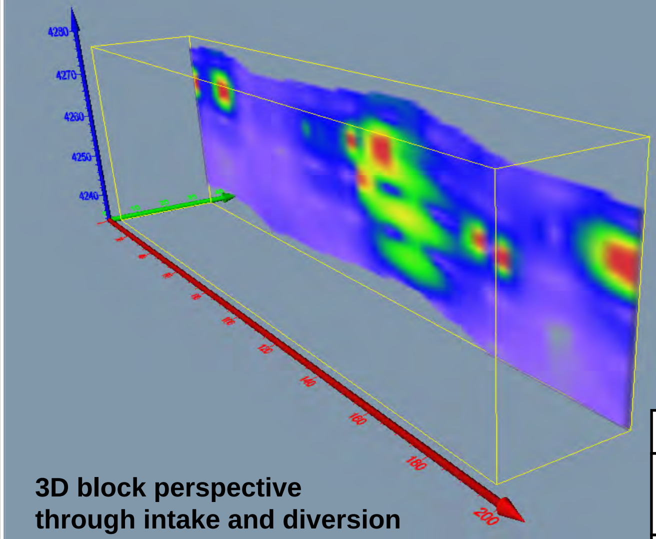


*Texture based on resistivity, condition based on S-wave velocity*

**Moderately dense to dense coarse grained soils (includes cobbles and boulders)**

**Transition to finer grained soils, moderately dense to very dense (stiff)**

**Soils or altered rock offering finer texture: loose in shallow elevations, stiff at depth**



**3D block perspective through intake and diversion structure**

**Electrical Resistivity Tomography: Line ER-4**

Figure: ER-4

**Dog River Pipeline Replacement Design Project**
**Mt. Hood National Forest, Oregon**

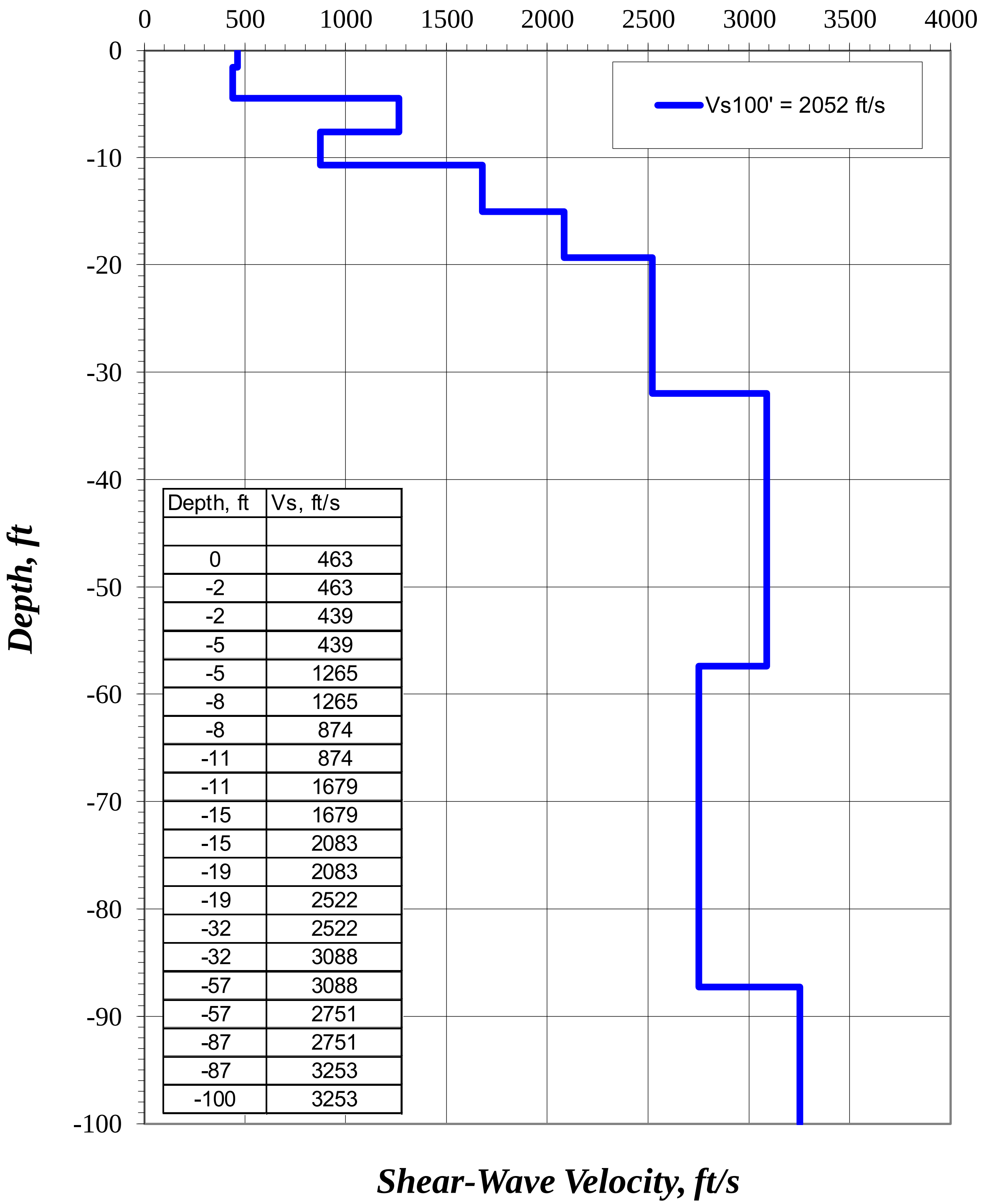
July 23, 2021

Project # 210020

Prepared for: Jacobs Engineering Group Inc.

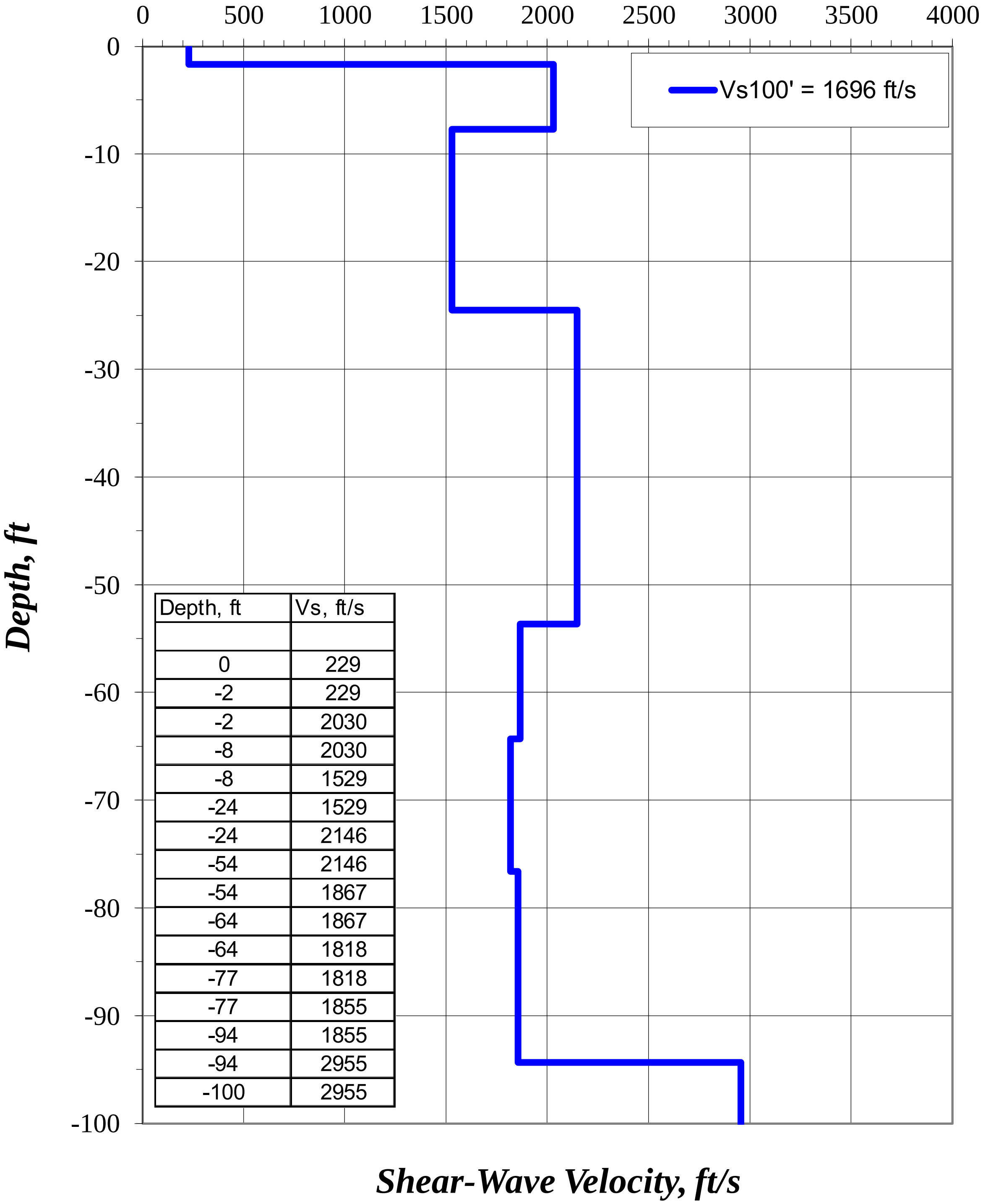
**Siemens & Associates**

# SPAC - 1: Vs Model



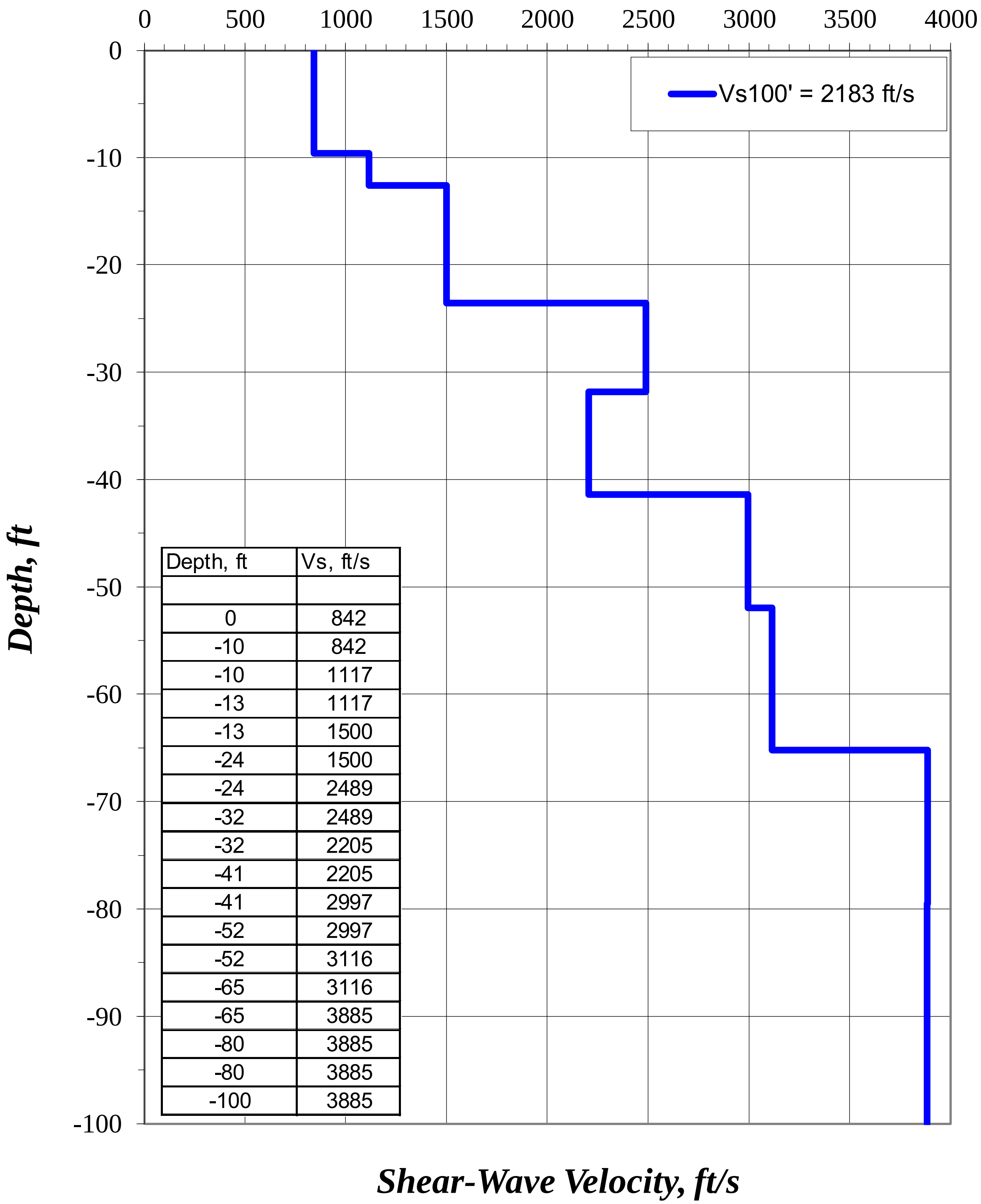
| Depth, ft | Vs, ft/s |
|---|---|
| | |
| 0 | 463 |
| -2 | 463 |
| -2 | 439 |
| -5 | 439 |
| -5 | 1265 |
| -8 | 1265 |
| -8 | 874 |
| -11 | 874 |
| -11 | 1679 |
| -15 | 1679 |
| -15 | 2083 |
| -19 | 2083 |
| -19 | 2522 |
| -32 | 2522 |
| -32 | 3088 |
| -57 | 3088 |
| -57 | 2751 |
| -87 | 2751 |
| -87 | 3253 |
| -100 | 3253 |

# LM11, Ch 1-12: Vs Model



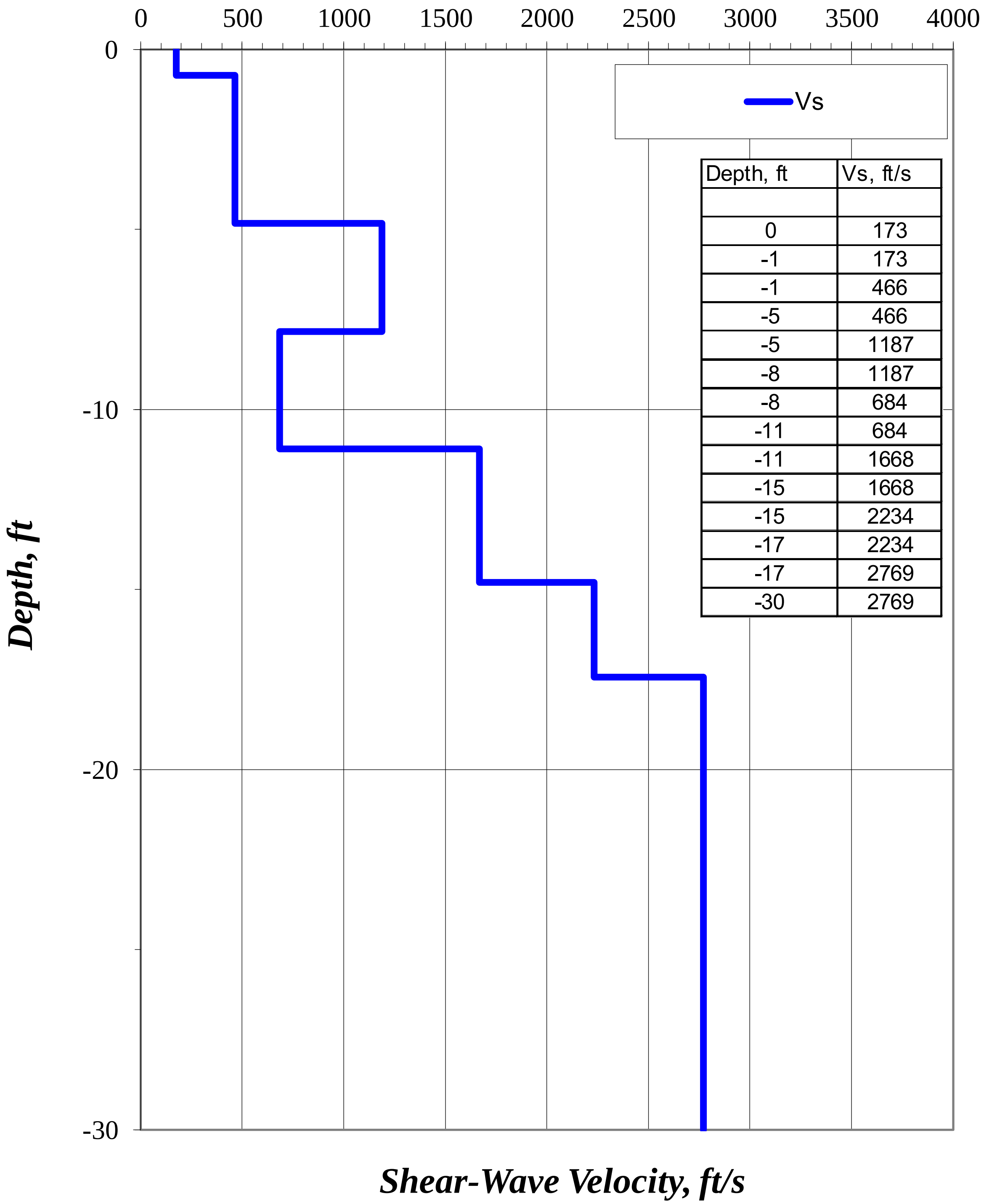
| Depth, ft | Vs, ft/s |
|---|---|
| | |
| 0 | 229 |
| -2 | 229 |
| -2 | 2030 |
| -8 | 2030 |
| -8 | 1529 |
| -24 | 1529 |
| -24 | 2146 |
| -54 | 2146 |
| -54 | 1867 |
| -64 | 1867 |
| -64 | 1818 |
| -77 | 1818 |
| -77 | 1855 |
| -94 | 1855 |
| -94 | 2955 |
| -100 | 2955 |

# *LM11, Ch 13-24: Vs Model*



| Depth, ft | Vs, ft/s |
|---|---|
| | |
| 0 | 842 |
| -10 | 842 |
| -10 | 1117 |
| -13 | 1117 |
| -13 | 1500 |
| -24 | 1500 |
| -24 | 2489 |
| -32 | 2489 |
| -32 | 2205 |
| -41 | 2205 |
| -41 | 2997 |
| -52 | 2997 |
| -52 | 3116 |
| -65 | 3116 |
| -65 | 3885 |
| -80 | 3885 |
| -80 | 3885 |
| -100 | 3885 |

# *LM 12: Vs Model*



| Depth, ft | Vs, ft/s |
|---|---|
| | |
| 0 | 173 |
| -1 | 173 |
| -1 | 466 |
| -5 | 466 |
| -5 | 1187 |
| -8 | 1187 |
| -8 | 684 |
| -11 | 684 |
| -11 | 1668 |
| -15 | 1668 |
| -15 | 2234 |
| -17 | 2234 |
| -17 | 2769 |
| -30 | 2769 |

SIEMENS & ASSOCIATES

**November 5, 2021**

**Brady Fuller, P.E.**
Jacobs Engineering Group, Inc.
2020 SW Fourth Avenue, #300
Portland, Oregon 97201, US

RE: Dog River Pipeline Replacement Design Project, City of the Dalles, Oregon
Addendum #1

Mt. Hood National Forest, Oregon

Hello Brady,

This letter presents the results of the geophysical exploration recently completed to evaluate the depth of the concrete diversion dam at the Dog River Intake. The exploration was completed on October 27, 2021, authorized within the existing agreement.

### Scope

The agreed upon and completed scope is summarized as follows:

- Consultation with the geotechnical team
- Review and interpretation of existing information
- Preparation of a workplan
- Planning operations and safety protocol
- Geophysical surveys through zones of interest
- Geophysical data processing and quality control
- Interpretation of the findings
- Preparation of this data report

### Project Understanding

Siemens & Associates (SA) understands that evaluations underway by the Jacobs team will benefit from information that bears on the depth of the concrete diversion dam. SA mobilized to conduct two different geophysical surveys offering potential to provide the desired information.

## Executive Summary

The linear microtremor (LM) and seismic refraction (SR) methods were used to accomplish the task. Theory and implementation associated with these geophysical methods are discussed in the original report and are not repeated with this addendum.

The task is a challenging one and the results are plausible, and the two methods are in general agreement within the expected resolution. The LM results show a distinct S-wave velocity decrease that corresponds with a similar depth of P-wave velocity decrease and these transitions are interpreted to represent the depth extent of the concrete diversion dam.

Assuming that the top of the diversion dam is at elevation 4276 feet, the results of this exploration suggest that the base of the dam is likely between elevations 4261 and 4264 feet such that the total height of the structure is on the order of 12 to 15 feet.

Graphical results are presented in the appendix to this letter and are discussed as follows:

*Linear Microtremor (LM-13):*

Twelve receivers were coupled to the top of the dam using a 2.5 foot spacing for an array that essentially spanned the full dam length. Data were processed to develop a 1D shear-wave profile representing the average conditions within the array. The LM method is challenged by the unusual conditions and wide swings in S-wave velocity are illustrated in the shallow regions that are judged to be promoted by the dam itself although not necessarily descriptive of the dam's character. However, at a depth of roughly 12 feet below the top of the dam, the model suggests a velocity reversal to lower strength material. This reversal is well constrained by the data and, in the opinion of SA, represents the transition from the concrete structure to native foundation soils probably composed of granular, unconsolidated materials.

*Seismic Refraction (SR-14):*

The two-dimensional SR model includes an overlay of the 1D LM model and agreement within the expected resolution is demonstrated. Resolution is estimated to be on the order of the receiver spacing which ranges from 2.5 feet (LM) and 3 feet (SR). Due to abrupt changes in surface elevation (vertical walls of the dam), P-wave arrivals were unusual and difficult to model. However, the best fit clearly illustrates two high velocity regions and the lower elevation, high velocity transition to lower velocity layers is interpreted as the base of the diversion dam.

The higher elevation high velocity region located just inside the dam at ground level is constrained by the data and could be some sort of concrete extension of the dam or possibly an artifact caused by the extreme elevation transitions and other factors that have not been recognized. Note that the receivers approaching the upstream side of the diversion dam were coupled to the ground and extended above the water level using extension rods. These rods were hammered into the ground and hard conditions were encountered preventing more than a few inches penetration near the dam. This observation supports the theory that some sort of extension may be present in the area of the upper high velocity region.

While the application of the methods used is unusual, it is the opinion of SA that the results are plausible and the fact that two different methods deliver similar results adds to the confidence in the interpretations.

## Limitations

Limitations as outlined in the original report apply to this addendum.

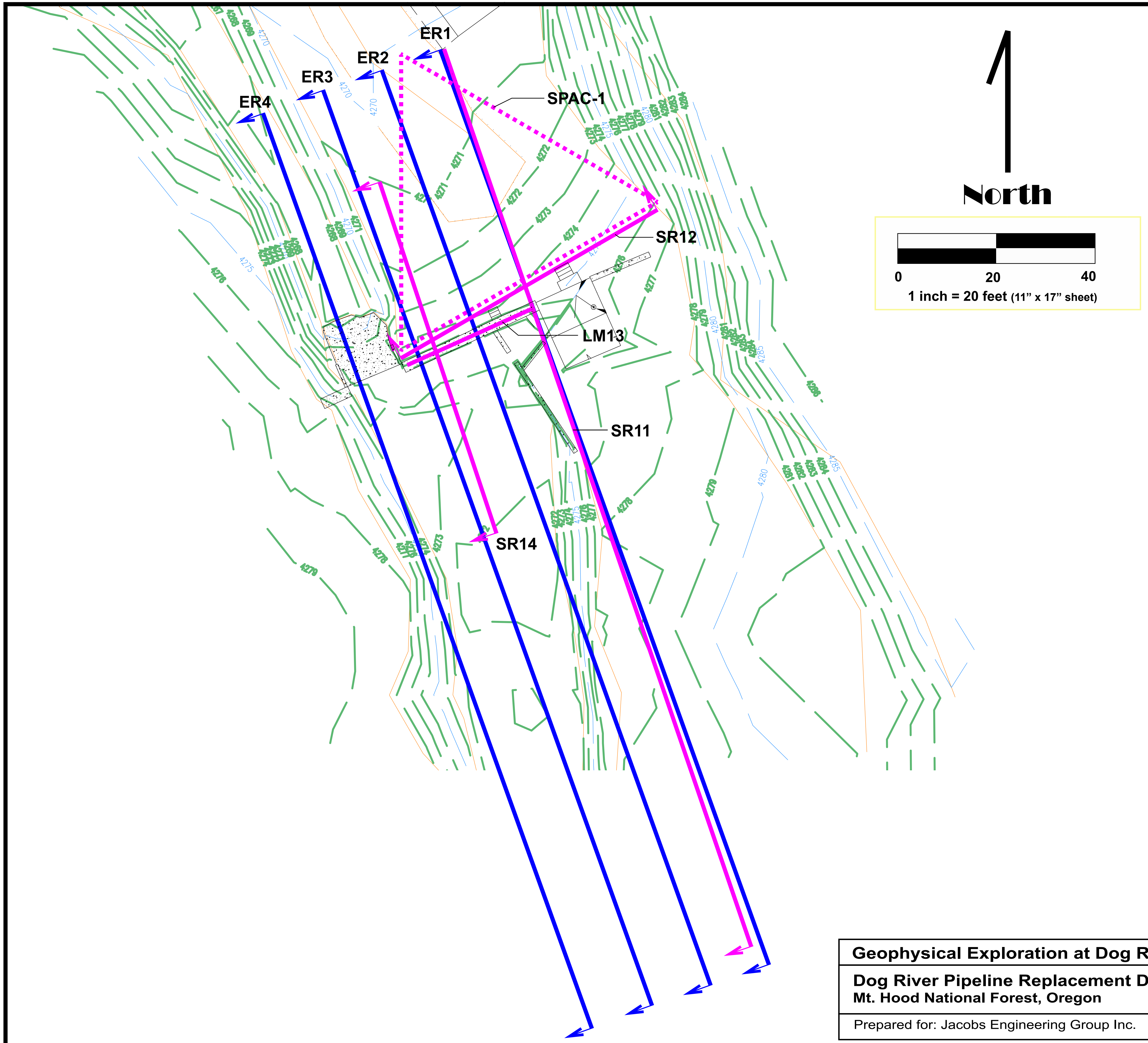
SA appreciates the opportunity to conduct this exploration and trust that the services are in line with your expectation.

Prepared by,
**Siemens & Associates**

16,377
JAN. 19, 1993
J. ANDREW SIEMENS

J. Andrew Siemens, P.E., G.E.

| | |
|---|---|
| Addressee: | 1 electronic |
| Encl. | Figure 101: Exploration Site Plan<br>Figures LM-13 and SR-14 |



**Explanation:**

| | |
|---|---|
| 🟪 | Seismic Refraction (SR) and LM (S-wave) |
| 🟦 | Electrical Resistivity (ER) |
| △ | Spatial Auto Acceleration (SPAC) S-wave |

**Geophysical Exploration at Dog River Diversion Intake**

Figure: 101

**Dog River Pipeline Replacement Design**
**Mt. Hood National Forest, Oregon**

October 27, 2021

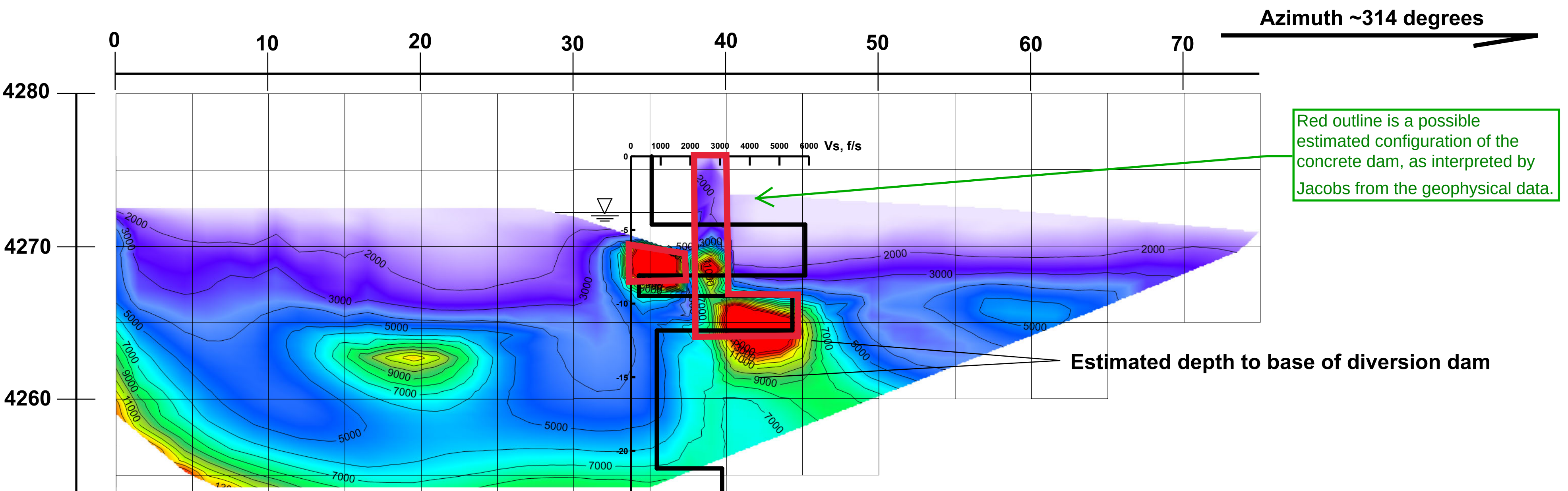
Project # 210020

Prepared for: Jacobs Engineering Group Inc.

**Siemens & Associates**

# SR-14: P-wave Seismic Refraction: over the diversion dam

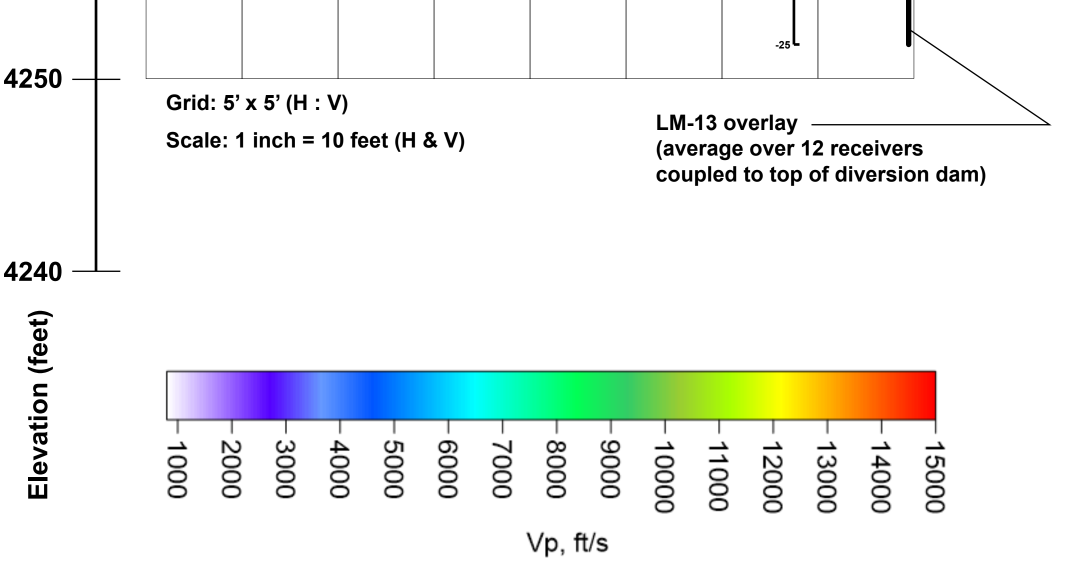
**(24, 4.5 Hz. receivers on 3 foot spacing, 12 shots on 6 foot spacing)**



**Azimuth ~314 degrees**

Red outline is a possible estimated configuration of the concrete dam, as interpreted by Jacobs from the geophysical data.

**Estimated depth to base of diversion dam**



**Grid: 5' x 5' (H : V)**

**Scale: 1 inch = 10 feet (H & V)**

**LM-13 overlay**
**(average over 12 receivers**
**coupled to top of diversion dam)**

**P-wave Seismic Refraction: Line SR-14**

**Dog River Pipeline Replacement Design Project**
**Mt. Hood National Forest, Oregon**

Prepared for: Jacobs Engineering Group Inc.

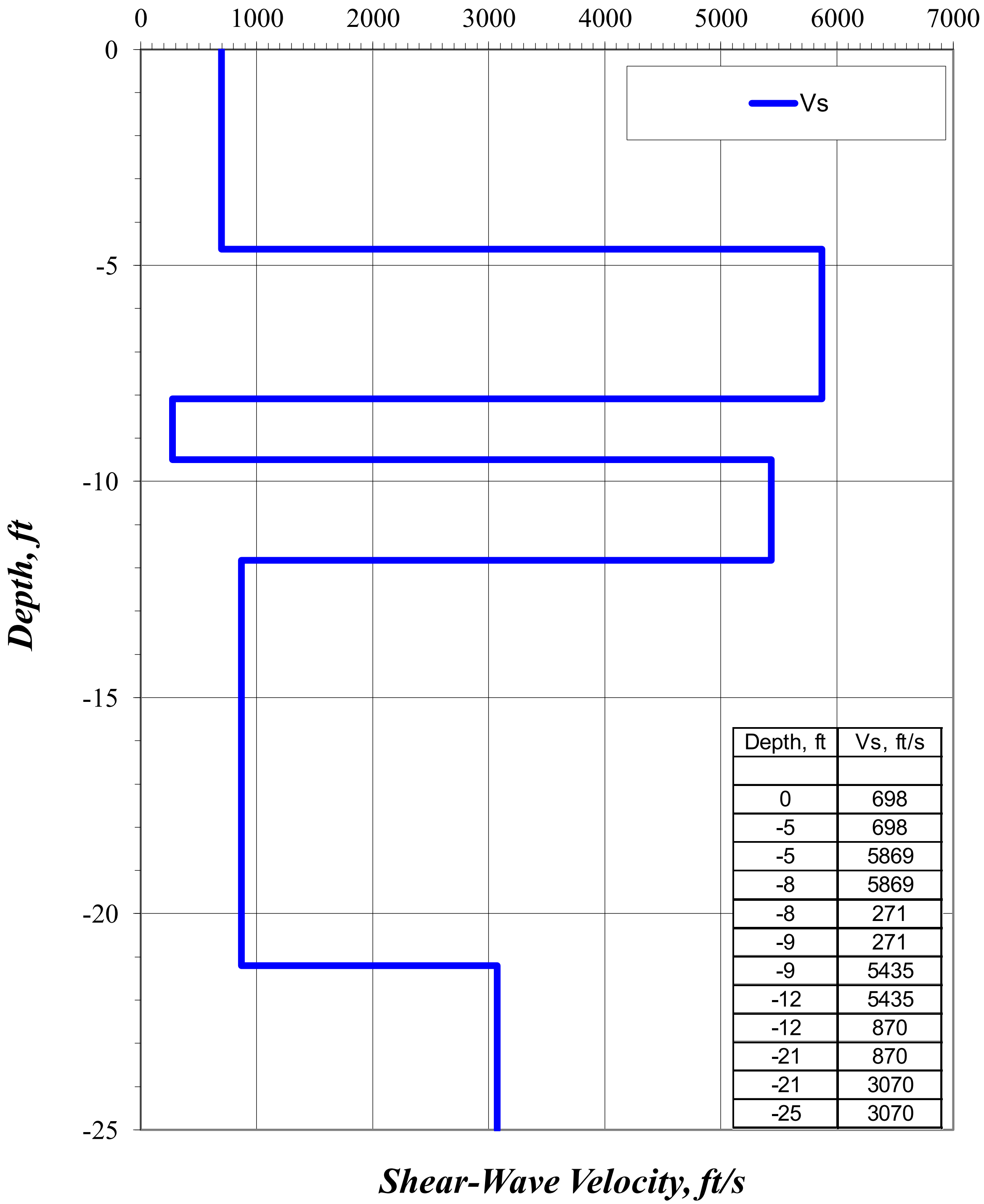
Figure: SR-14

October 27, 2021

Project # 210020

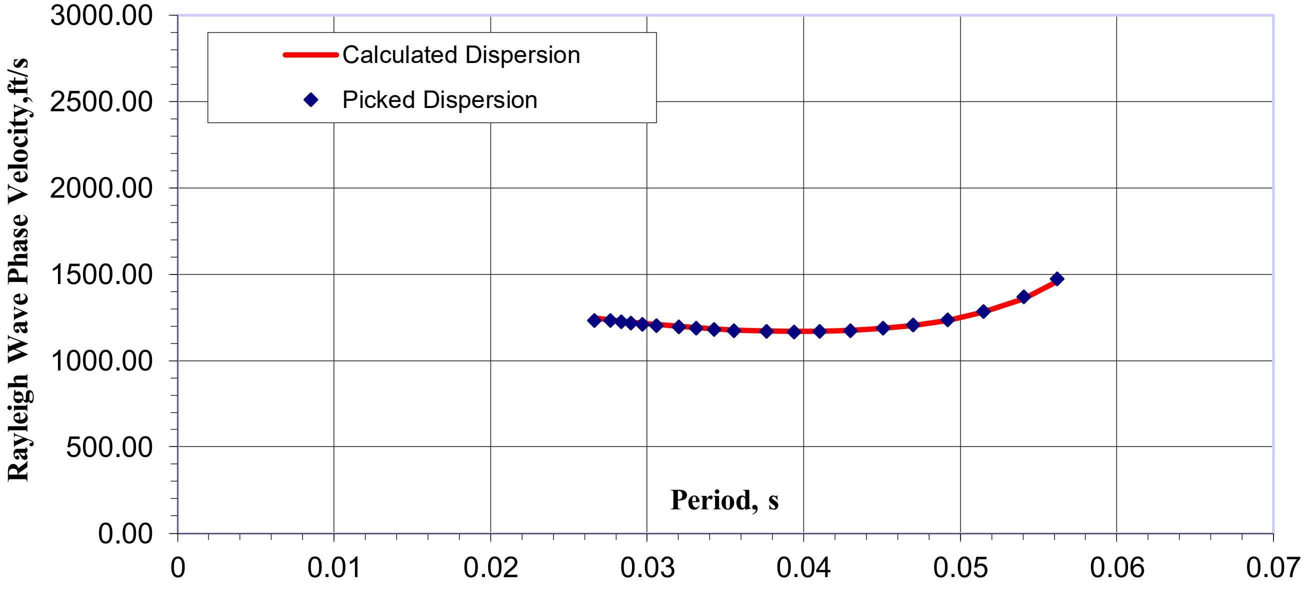
**Siemens & Associates**

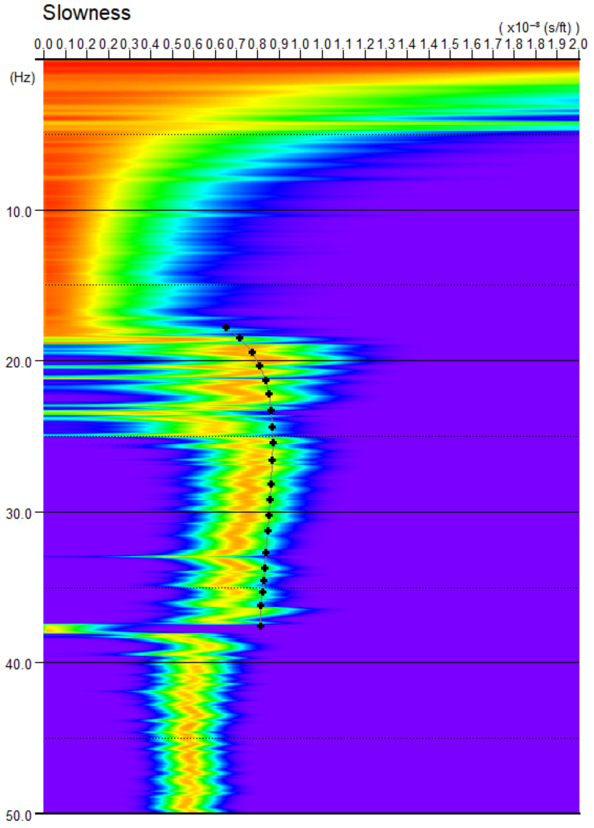
# LM 13: Vs Model



| Depth, ft | Vs, ft/s |
|---|---|
| | |
| 0 | 698 |
| -5 | 698 |
| -5 | 5869 |
| -8 | 5869 |
| -8 | 271 |
| -9 | 271 |
| -9 | 5435 |
| -12 | 5435 |
| -12 | 870 |
| -21 | 870 |
| -21 | 3070 |
| -25 | 3070 |

# *LM13*


Rayleigh Wave Phase Velocity,ft/s
3000.00
2500.00
2000.00
1500.00
1000.00
500.00
0.00
Calculated Dispersion
Picked Dispersion
Period, s
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07


Slowness
( x10⁻³ (s/ft) )
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
(Hz)
10.0
20.0
30.0
40.0
50.0

# Appendix E
# Previous Investigation Data

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

ALASKA
CALIFORNIA
COLORADO
FLORIDA
MINNESOTA
MISSOURI
OREGON
WASHINGTON

October 26, 2011

City of The Dalles
Public Works Department
1215 West 1st Street
The Dalles, Oregon 97058

Attn: Dave Anderson

**RE: DOG RIVER PIPELINE**
**SLOPE RECONNAISSANCE**
**HOOD RIVER COUNTY, OREGON**

I performed reconnaissance of slopes adjacent to the Dog River Aqueduct Pipeline between the headworks at Dog River dam and Surveyors Ridge Road on October 18, 2011. I was accompanied by Philip Roppo, PE, with Brown and Caldwell. Phil and I walked the Dog River Aqueduct Pipeline alignment from Brook Meadow Road north to Surveyors Ridge Road, and used vehicles to shuttle between the entry and exit point along the roadway, see attached survey. After returning to the entry point where the aqueduct crosses Brook Meadow Road, we walked up the aqueduct pipeline alignment to the dam at the headworks. We did not walk the section of pipeline alignment between Surveyors Ridge Road and the aqueduct outlet at Mill Creek because the pipeline runs parallel with a gentle slope and a low risk for slope instability. The sections of pipeline alignment we walked consisted of an 18-inch-diameter buried wooden aqueduct. The soil backfill cover ranged in thickness from 0 to approximately 2 feet.

The aqueduct pipeline between Brook Meadow Road and Surveyors Ridge Road runs around the south, west, and north faces of Dog River Mountain. Between Brooks Meadow Road and Dog River Mountain, near-surface geology is mapped as volcanic intrusive andesite. Dog River Mountain is made up of volcanic intrusive dacite bedrock. North of Dog River Mountain to Surveyors Ridge Road, surface geology is mapped as basaltic andesite lava flows. The slopes are perpendicular to the pipeline and range from near flat on the south face to approximately between 1½ horizontal to 1 vertical (1½H:1V) and 4H:1V on the west and north faces. Bedrock and residual soil were exposed on the ground surface on most slope faces. In some areas there appeared to be a thin layer of colluvium overlying the bedrock and residual soil. Based on surface observations, I did not observe any indications of shallow or deep-seated slope instability along the pipeline alignment. I also did not observe any indication of active or past surface erosion of the native soils immediately adjacent to the pipeline. In some areas drainages bisect the pipeline, but there were no indications of active erosion or incised channels in the drainage. The soil backfill cover over the pipeline also appeared stable and there were no indications of erosion. In some areas the pipeline was leaking slightly, or there were indications of past leaks that had been repaired, and the fill cover had been eroded and washed out. In these areas there was no sign of erosion on the adjacent native soils.

The area between the headworks at the Dog River dam and Brooks Meadow Road is also mapped as volcanic intrusive andesite. In this area, the aqueduct pipeline is within a small tight valley paralleling the Dog River creek bed. The valley slopes range between 3H:1V and 4H:1V. Based on surface observations, I did not observe any indications of shallow or deep-seated slope instability or active erosion. The pipeline is completely buried below the access road to the headworks dam.

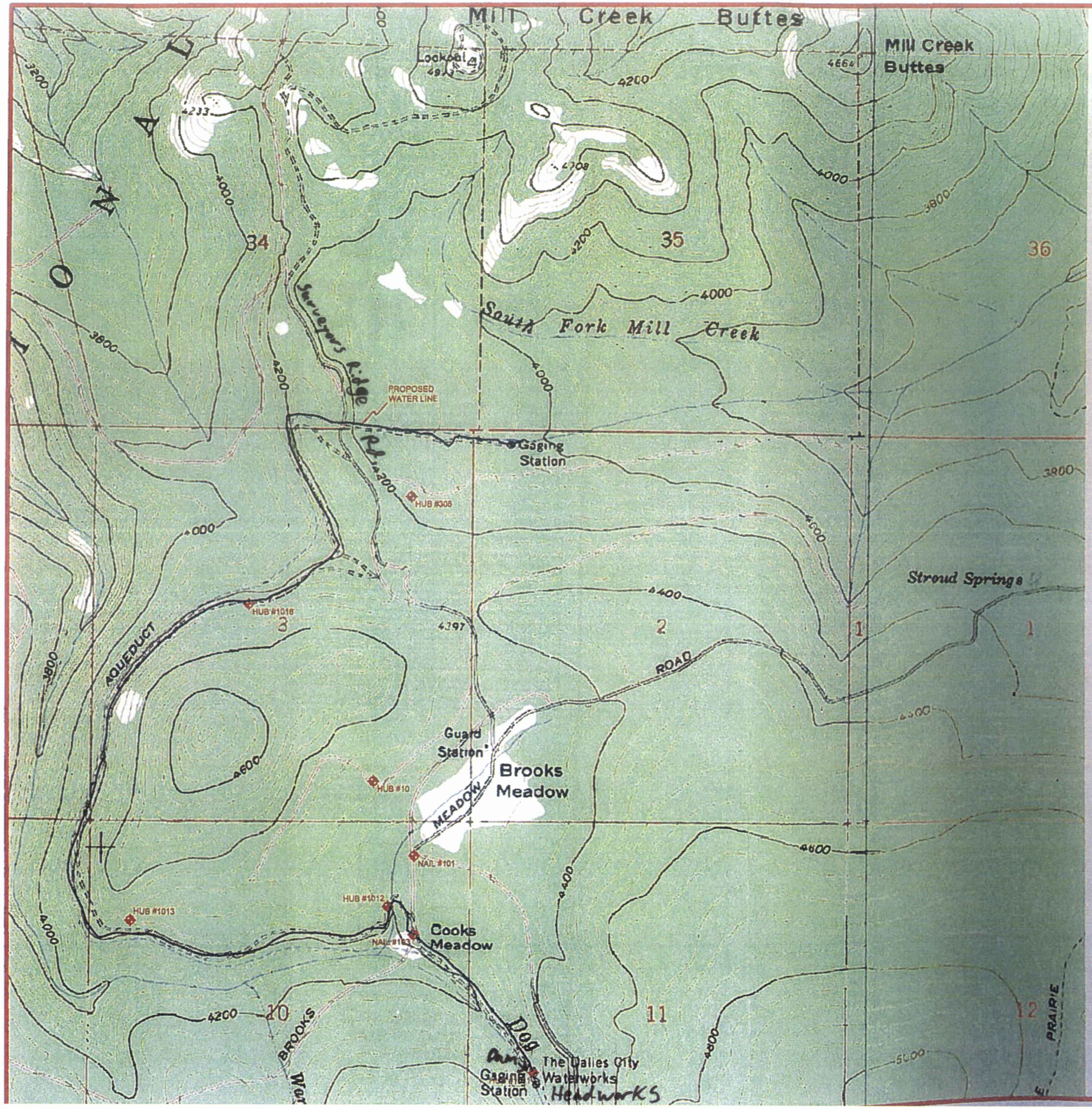
Sincerely,

**SHANNON & WILSON, INC.**

David J. Higgins, CEG
Senior Principal Engineering Geologist

DJH/jsw

Enclosure: Dog River Pipeline Survey



# DOG RIVER PIPELINE SURVEY

## MT HOOD NATIONAL FOREST,
## HOOD RIVER COUNTY OREGON.

JUNE TO SEPTEMBER, 2010

SHEET 1 OF 16

N
W E
S

0' 1000' 2000' 3000'

SCALE 1 INCH = 1000 FEET

**NARRATIVE:**

THE PURPOSE OF THIS SURVEY IS TO LOCATE THE PROPOSED NEW ROUTE FOR THE CITY OF THE DALLES DOG RIVER DEVIATION WATER PIPE LINE AS STAKED IN THE FIELD BY BROWN & CALDWELL ENGINEERS. ALSO TREES POTENTIALLY IMPACTING THE ROUTE WERE IDENTIFIED BY A THIRD PARTY AND THIS SURVEY SHOWS THE LOCATION AND CORRESPONDING NUMBER AS PAINTED ON THE TREES. ELEVATION INFORMATION WAS NOT OBSERVED FOR THE TREES.

A SUITABLE SITE WAS CHOSEN FOR AN R.T.K. G.P.S. BASE STATION AND ITS LOCATION WAS ESTABLISHED BY THE NATIONAL GEODETIC SURVEY (N.G.S.) ON-LINE POSITIONING USER SERVICE (O.P.U.S.). ADDITIONAL CONTROL POINTS WERE THEN ESTABLISHED BY R.T.K. OBSERVATIONS WITH CLOSED TERRESTRIAL TRAVERSES OBSERVED BETWEEN THESE POINTS AND ADJUSTED BY A LEAST SQUARES SOLUTION.

THE TOPOGRAPHIC QUAD MAP SHOWN ON THIS SHEET IS THE "DOG RIVER, OREG." SHEET No.45121-D5-TF-024, DATED 1962 AND PHOTOREVISED 1979. IT IS SHOWN AS A BEST FIT TO THE DATA AND SHOULD BE CONSIDERED APPROXIMATE FOR LOCATION. THE SECTION CORNER MONUMENTS WERE NOT LOCATED BY THIS SURVEY.

**HORIZONTAL DATUM:**

N.A.D.83 (CORS96) (EPOCH 2002) OREGON STATE PLANE, NORTH ZONE.
TO CONVERT THE STATE PLANE DISTANCES OF THIS SURVEY TO GROUND DISTANCES DIVIDE BY THE SCALE FACTOR OF 0.99970069.

**VERTICAL DATUM:**

N.A.V.D.88. (GEOID 09).

REGISTERED
PROFESSIONAL
LAND SURVEYOR

OREGON
JANUARY 15, 2002
BRADLEY J. CROSS
60061

RENEWAL DATE: 12/31/2011

PROJECT NUMBER: 2010010.
DATE OF DRAWING: OCTOBER 25, 2010.

**COLUMBIA RIVER SURVEYING & MAPPING**

1767 12th St, #191
HOOD RIVER, OREGON, 97031
PHONE: 541-386-9002
EMAIL: INFO@COLUMBIASURVEYING.COM

Cascade Corrosion Consulting Services, Inc.

P.O. Box 20432
Keizer, OR 97307

george.richards6@msn.com

(503) 463-9409 – office
(503) 463-9413 – fax

# Technical Memorandum

**To:** Phil Roppo / B&C

**From:** George Richards / CCCS

**Cc:** Dennis Kessler / B&C

**Subject:** The Dalles – Dog River Deviation Water Pipeline Project
Corrosion Control Requirements

**Date:** December 7, 2011

**Project No.:** OR402.11.01

The narrative description provides preliminary corrosion control recommendations for the City of The Dalles – Dog River Deviation Water Pipeline Project. The purpose of this technical memorandum is to provide preliminary recommendation on corrosion protection criteria for the buried pipeline. It is assumed the following materials may be considered for this pipeline:

- Steel
- Ductile iron
- Concrete Cylinder
- Polyvinyl Chloride (PVC)
- Fiberglass – reinforced pipe (FRP)
- High density polyethylene (HDPE)

The required protection for the buried metallic piping will be based on the soil resistivity and pipe wall thickness.

## CRITERIA AND CONSTRAINTS

Because of soil's ability to conduct current, its electrical resistance controls the rate of the electrochemical process of corrosion. Measuring the resistance of soil provides information about corrosivity. The lower the soil resistivity, the better the electrical current is conducted and greater the corrosion rate.

Soil resistivity was measured in accordance with ASTM standard G51 (*Field Measurement for Soil Resistivity Using the Wenner Four-Electrode Method*). This method allows measurements to any depth and provides the average resistivity from ground level to that depth. If measured at various depths the average resistivity for each layer can then be calculated using the Barnes layer technique.

The criteria used to evaluate the corrosivity of soil with respect to soil resistivity values vary somewhat from source to source but are generally similar. Test Performed by the National Bureau of Standards has determined that steel, ductile iron (DI) and cast iron (CI) generally corrode at the same rate in low resistivity. Therefore the various sources use the same criteria for all buried ferrous metal.

**Table 1**
**ANTICIPATED CORROSION ACTIVITIES**

| Reference | Resistivity Range (ohm-cm) | Anticipated Corrosion Activity |
|---|---|---|
| CCCS | 0-1,000 | Very Corrosive |
| | 1,000-5,000 | Corrosive |
| | 5,000-10,000 | Moderately Corrosive |
| | Over 10,000 | Slightly Corrosive |

*This guide line is the combination of other published guide lines and CCCS experience*

The soil resistivity was performed along the pipeline route on November 2, 2011. The measurements indicate the soil is slightly corrosive to buried metallic structures. The test is for external corrosion and does not cover any internal corrosion due to the water. It is been our experience that most of the ground water in Oregon has been corrosive to metallic structures.

While considering the corrosion protection, we also look at anticipated corrosion rate, to help determine if additional thickness is required for a corrosion allowance. In the 60’s the National Bureau of Standards (NBS) performed a study and came up with a formula to help predict the corrosion rate of metallic structure exposed to soil environment. In the late 60’s John R. Rossum used the electrochemical theory of underground corrosion to refine the equation for pit depth to include a constant for poor, fair, and well aerated soils. NBS than expanded the formula to include resistivity, pH, and other factors that influence corrosion. The equation was finally expanded by G.H. Scott to include the relationship of structures surface area. The formula it is based on the structure’s surface being bare, no bimetallic couples (causing galvanic corrosion), and no concentration cell corrosion due to dissimilar electrolyte.

## RECOMMENDATIONS

The general pipe recommendations are shown below. In addition to these recommendations the steel and ductile iron pipe needs to be isolated from all other metallic pipe, or structures to prevent galvanic corrosion.

***Steel Pipe:*** Steel pipe should lined with mortar, epoxy, or polyurethane coating. The resistivity does not indicate any additional external corrosion is required. The corrosion rate calculations indicate a leak would not happen for 100 plus years as long as the wall thickness is 3/16 inch or thicker. However, CCCS has never recommended installing steel pipe without some type of coating (tight bonded or mortar), even if the test indicates it does not require it, therefore we recommend a coating to be installed, just incase additional protection is required in the future. If this was a Bureau of Reclamation project they would require mortar coating.

***Ductile Iron (DI):*** Ductile iron pipe should be mortar lined. The resistivity does not indicate any additional external corrosion is required. The corrosion rate calculations indicate a leak would not happen for 100 plus years as long as the pipe was class 50 or higher. If this was a Bureau of Reclamation project they would require polyethylene encasement.

***Polyvinyl Chloride (PVC):*** Buried PVC pipe requires no extra protection except the metallic fittings should be fusion-bonded coated and lined.

***Fiberglass-Reinforced (FRP):*** Buried FRP pipe requires no extra protection except the metallic fittings should be fusion-bonded coated and lined.

***High Density Polyethylene (HDPE):*** Buried HDPE pipe requires no extra protection except the metallic fittings should be fusion-bonded coated and lined.

The recommendations for material selection and additional corrosion protection are shown in Table 1, Material Selection Requirements shown below. It is assumed the City prefers materials with the least maintenance requirements. Therefore, if the equipment, etc. can be made out of non-metallic material or requires little or no coating, it is preferred, as long as the cost is not excessive.

## Table 1

## Material Section Requirements

| Pipe Type | Lining | Coating | Isolation | Corrosion Monitoring |
|---|---|---|---|---|
| Steel | Yes(1) | Yes(2) | Yes(3) | No |
| DI | Yes(1) | Yes(4) | Yes(3) | No |
| PVC(5) | Valves/Fittings(6) | Valves/Fittings(6) | N/A | N/A |
| FRP(5) | Valves/Fittings(6) | Valves/Fittings(6) | N/A | N/A |
| HDPE(5) | Valves/Fittings(6) | Valves/Fittings(6) | N/A | N/A |

***Notes:***

1. *Mortar lining*
2. *Mortar coating*
3. *From all other metallic pipe and structures*

4. *Polyethylene encasement, if following Bureau of Reclamation requirements*
5. *To be buried deep enough that forest fires will not affect the pipe structure*
6. *Fusion bonded epoxy coated and lined*

Do not hesitate to contact me if you have any questions.

CORROSION
NACE
INTERNATIONAL
GEORGE E. RICHARDS
2083
SPECIALIST

**CCCS**
Cascade Corrosion Consulting Services, Inc.

**CLIENT:** Brown & Caldwell
**LOCATION:** Dog River Pipeline
**PORJ. NO.:** OR402.11.01

**DATE:** 11/2/2011
**BY:** Geo. Richards
Philip Roppo

# SOIL RESISTIVITY

| Test NO. | Location | AVG. Depth (feet) | Resistance (ohm) | Avg. Soil Resistivity (ohm-cm) | Soil Layer (feet) | Layer Resistivity (ohm-cm) |
|---|---|---|---|---|---|---|
| 1 | 0+20 | 2.5 | 410 | 196,288 | 0 - 2.5 | 196,288 |
| North of the Diverson Dam | | 5.0 | 170 | 162,775 | 2.5 - 5.0 | 139,037 |
| 2 | 27+00 | 2.5 | 1100 | 526,625 | 0 - 2.5 | 526,625 |
| North of Meadow Rd. | | 5.0 | 350 | 335,125 | 2.5 - 5.0 | 245,758 |
| 3 | 42+00 | 2.5 | 1300 | 622,375 | 0 - 2.5 | 622,375 |
| By tree 94 | | 5.0 | 430 | 411,725 | 2.5 - 5.0 | 307,611 |
| 4 | 60+00 | 2.5 | 4100 | 1,962,875 | 0 - 2.5 | 1,962,875 |
| By tree 157 | | 5.0 | 820 | 785,150 | 2.5 - 5.0 | 490,719 |
| 5 | 74+00 | 2.5 | 1800 | 861,750 | 0 - 2.5 | 861,750 |
| By tree 201 | | 5.0 | 330 | 315,975 | 2.5 - 5.0 | 193,454 |
| 6 | 94+50 | 2.5 | 1100 | 526,625 | 0 - 2.5 | 526,625 |
| By Tree 255 | | 5.0 | 150 | 143,625 | 2.5 - 5.0 | 83,151 |
| 7 | 117+00 | 2.5 | 1200 | 574,500 | 0 - 2.5 | 574,500 |
| | | 5.0 | 200 | 191,500 | 2.5 - 5.0 | 114,900 |
| 8 | 145+00 | 2.5 | 730 | 349,488 | 0 - 2.5 | 349,488 |
| | | 5.0 | 460 | 440,450 | 2.5 - 5.0 | 595,423 |
| 9 | 152+00 | 2.5 | 1400 | 670,250 | 0 - 2.5 | 670,250 |
| By bend | | 5.0 | 215 | 205,863 | 2.5 - 5.0 | 121,607 |
| 10 | 180+00 | 2.5 | 1500 | 718,125 | 0 - 2.5 | 718,125 |
| North of Gorest Rd #17 | | 5.0 | 350 | 335,125 | 2.5 - 5.0 | 218,560 |

**CCCS**

**Cascade Corrosion Consulting Services, Inc.**

**CLIENT:** Brown & Caldwell
**LOCATION:** Dog River Pipeline
**PORJ. NO.:** Corrosion Considerations

**DATE:** 12/1/2011
**BY:** Geo. Richards

***EQUATION:*** $T_L$ = (P/10-pH) $(Z/KnKa)^{1/n}$ $(1/A)^{a/n}$

$T_L$= Time-to-first Penetration, years

P = Soil resistivity, ohm-cm
Z = Wall thickness, mils
A = Surface area, square feet

Kn= Soil aeration constant
n = Aeration constant
Ka= Relative pit depth constant
a = Material constant

| **Soil Layer** | ***2.5 to 5.0 - foot*** | | | |
|---|---|---|---|---|
| | | | | |
| **Pipe type** | Stl | Stl | Stl | Stl |
| **Pipe class** | 3/16 | 1/4 | 3/16 | 52 |
| **Pipe size (in)** | 18 | 18 | 24 | 24 |
| **Outside diameter (in)** | 19.5 | 19.5 | 25.8 | 25.8 |
| **Length (ft)** | 40 | 40 | 40 | 40 |
| **Surface Area (A)** | 204.2 | 204.2 | 270.2 | 270.2 |
| **Wall thickness (Z)** | 350 | 410 | 350 | 410 |
| **Soil Resistivity (P)** | 83151 | 83151 | 83151 | 83151 |
| **Soil Aeration** | Fair | Fair | Fair | Fair |
| **pH** | 6.5 | 6.5 | 6.5 | 6.5 |
| **Kn** | 222 | 222 | 222 | 222 |
| **n** | 0.333333 | 0.333333 | 0.333333 | 0.333333 |
| **Ka** | 1.06 | 1.06 | 1.06 | 1.06 |
| **a** | 0.16 | 0.16 | 0.16 | 0.16 |

| **Soil Layer** | ***2.5 to 5.0 - foot*** | | | |
|---|---|---|---|---|
| **$T_L$ =** | 100+ | 100+ | 100+ | 100+ |

Note: Used the lowest soil resivitity meausrement

CCCS
Cascade Corrosion Consulting Services, Inc.

**CLIENT:** Brown & Caldwell
**LOCATION:** Dog River Pipeline
**PORJ. NO.:** Corrosion Considerations

**DATE:** 12/1/2011
**BY:** Geo. Richards

***EQUATION:*** $T_L = (P/10\text{-pH})\ (Z/KnKa)^{1/n}\ (1/A)^{a/n}$

$T_L$= Time-to-first Penetration, years

P = Soil resistivity, ohm-cm
Z = Wall thickness, mils
A = Surface area, square feet

Kn= Soil aeration constant
n = Aeration constant
Ka= Relative pit depth constant
a = Material constant

**Soil Layer** ***2.5 to 5.0 - foot***

| | | | | |
|---|---|---|---|---|
| **Pipe type** | DI | DI | DI | DI |
| **Pipe class** | 50 | 52 | 50 | 52 |
| **Pipe size (in)** | 18 | 18 | 24 | 24 |
| **Outside diameter (in)** | 19.5 | 19.5 | 25.8 | 25.8 |
| **Length (ft)** | 18 | 18 | 18 | 18 |
| **Surface Area (A)** | 91.9 | 91.9 | 121.6 | 121.6 |
| **Wall thickness (Z)** | 350 | 410 | 350 | 410 |
| **Soil Resistivity (P)** | 83151 | 83151 | 83151 | 83151 |
| **Soil Aeration** | Fair | Fair | Fair | Fair |
| **pH** | 6.5 | 6.5 | 6.5 | 6.5 |
| **Kn** | 222 | 222 | 222 | 222 |
| **n** | 0.333333 | 0.333333 | 0.333333 | 0.333333 |
| **Ka** | 1.35 | 1.35 | 1.35 | 1.35 |
| **a** | 0.205 | 0.205 | 0.205 | 0.205 |

**Soil Layer** ***2.5 to 5.0 - foot***

| | | | | |
|---|---|---|---|---|
| **$T_L$ =** | 100+ | 100+ | 100+ | 100+ |

Note: Used the lowest soil resivitity meausrement