Appendix K

Preliminary Geotechnical Feasibility Report

Phase 2 Final SWMF Site Evaluation – Moon Pit

Preliminary Geotechnical Feasibility Report

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Final
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Acronyms and Abbreviations

ANSS	Advanced National Seismic System
ASCE	American Society of Civil Engineers
ASTM	American Society for Testing and Materials
bgs	below ground surface
CEG	Certified Engineering Geologist
CSZ	Cascadia Subduction Zone
DOGAMI	Oregon Department of Geology and Mineral Industries
DSM	digital surface model
EPA	United States Environmental Protection Agency
FEMA	Federal Emergency Management Agency
GIS	geographic information systems
HLP	High Lava Plain
ID	inside diameter
ka	thousand years
km	kilometer
LiDAR	light detection and ranging
M	magnitude
Ma	million years ago
MCE	Maximum Considered Earthquake
mi	mile
MSW	municipal solid waste
NEHRP	National Earthquake Hazard Reduction Program
NSHMP	National Seismic Hazard Mapping Project
OD	outside diameter
OSHA	Occupational Safety and Health Administration
OSSC	Oregon Structural Specialty Code
OWRD	Oregon Water Resources Department
PGA	peak ground acceleration
RCRA	Resource Conservation and Recovery Act
SLIDO	Statewide Landslide Information Database for Oregon
SRTM	Shuttle Radar Topography Mission
SWMF	Solid Waste Management Facility
UAS	unmanned aerial systems
UHS	uniform hazard spectrum
USGS	United States Geological Survey

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Executive Summary

Delve Underground conducted a preliminary geotechnical feasibility assessment related to the siting of a new landfill on an approximately 346-acre portion of the Moon Pit property located in Deschutes County, Oregon. This assessment was performed in support of the Phase 2 Solid Waste Management Facility (SWMF) selection process to assess and compare two potential properties for final selection of the future development of the proposed new Deschutes County SWMF.

The preliminary geotechnical feasibility assessment included a combination of a desktop study and limited geotechnical explorations consisting of test pits to provide a preliminary summary of the subsurface conditions. The subsurface exploration program included 12 test pits excavated to depths ranging from 2.6 to 7.0 feet below ground surface (bgs). All but two test pits were terminated as a result of practical refusal of equipment on shallow bedrock. Bedrock observations were limited to exposures created by quarrying activities, which indicated a variability within the underlying rock mass. No laboratory tests have been performed to assess the adequacy of bedrock for future use as a construction aggregate.

The preliminary assessment of the site did not identify geotechnical critical flaws for future development as a municipal solid waste landfill. However, because of the shallow nature of bedrock encountered, earthwork and site excavation will require extensive drilling and blasting methods to excavate future waste cells to their proposed depths. Additional key summaries include:

- Faults that bound the graben are not included within the USGS Quaternary Fault and Fold Database. Alluvial units and the Newberry Volcano lava flow do not exhibit offsets along the northwest projections of the faults, and thus we interpret the faults as inactive.
- Shallow bedrock is persistent throughout the site and covered with a thin (less than 10-foot thick) veneer of undifferentiated alluvium and loess. Thicker amounts of alluvium may be present where it has not been mined out in the northwestern portion of the site.
- Practical refusal with conventional equipment occurred during the excavation of all test pits resulted in termination less than 10 feet bgs. Shallow bedrock conditions will likely require drilling and blasting techniques to excavate the desired depth of the waste cells.
- Bedrock exposed in quarry exposures in the southern portion of the site consisted of a complex sequence of basaltic lava flows and cinder-filled interbeds. Both lava flow and interbeds generally varied between 2 and 10 feet thick.

- Review of seismic surveys and cross sections compiled by Siemens & Associates within the David Evans and Associates, Inc. report entitled “Deschutes County Landfill Site Evaluation” (prepared for Deschutes County Department of Solid Waste, dated August 7, 1996) indicated an irregular bedrock contact with varying depths of sediment accumulation within the northwest portion of the site. Some drill and blast mining (for basalt rock products) was conducted in this area but was discontinued because of low rock quality.
- Depth to groundwater is anticipated to be well below the bottom of the proposed landfill cells. However, further exploration and study are recommended to confirm the nature and extent of groundwater beneath the site.
- Based on the shallow bedrock conditions and the waste cells excavated into the underlying bedrock, we do not anticipate issues with bearing capacity or settlement associated with future site development.
- On-site materials will require laboratory testing to assess whether materials meet the specification of intended use per Oregon Standard Specifications for Construction (OSSC).
- Site Class B is preliminarily recommended for future seismic design based on the materials encountered in our subsurface exploration program.
- Review of the site development plans by G. Friesen Associates, Inc., dated September 26, 2023, indicate 3H:1V (horizontal to vertical) slopes along the perimeter of the waste cells. These slopes are suitable at this time based on our current understanding of the subsurface conditions and that waste cells will be excavated into the underlying bedrock.

As noted above, the results of this study are based on a limited subsurface investigation and should be considered preliminary in nature. Additional site characterization will be required to complete the geotechnical characterization of this site if it is selected for final design, as well as to determine the quality of rock for potential on-site use.

1.0 Introduction

Delve Underground was retained by Parametrix to conduct a preliminary geotechnical assessment related to the siting of a new landfill on an approximately 346-acre portion of the Moon Pit property (tax lot 1914000000200) located in Deschutes County, Oregon (Figure 1). This assessment was performed in support of the Phase 2 Solid Waste Management Facility (SWMF) selection process to assess and compare two potential properties for final selection of the future development of the proposed new Deschutes County SWMF.

1.1 Project Understanding

Parametrix completed a broad screening of potential landfill sites throughout Deschutes County using geographic information systems (GIS) to identify potential candidates based on geologic hazards and conditions, permitting requirements, environmental impacts, and public input prior to this phase of work. The result of this effort identified two potential properties, referred to as Roth East and Moon Pit. The focus of this report is the Moon Pit property.

The Moon Pit property consists of approximately 440 acres located approximately 16 miles southeast of Bend, Oregon, in Deschutes County (Figure 1). Of the total acreage, a 346-acre area has been identified for use as the potential new Deschutes County SWMF. This portion of land is currently developed and is being used as a surface mine. A preliminary site development plan was completed by G. Friesen Associates, Inc., dated September 26, 2023. The locations of proposed access roads, structures, and the waste cells are shown in Figure 2.

Moon Pit was previously considered for a SWMF in the 1990s. Parametrix completed an initial site characterization and compiled the results in a Site Suitability Analysis and Phase 1 Characterization Report issued in August 1994 (Parametrix, 1994). Subsequently, David Evans and Associates, Inc. issued a final Landfill Site Evaluation report dated August 7, 1996 (DEA, 1996).

1.2 Purpose and Scope of Work

This report presents a summary of the geologic conditions, a preliminary assessment of the geotechnical conditions, and preliminary geotechnical considerations for future development of the site as an SWMF.

This report summarizes preliminary subsurface investigations conducted by means of test pit explorations performed in September 2023. Our scope of services for this work includes the following:

- Desktop study and document review
- Geologic reconnaissance

- Evaluation of current site conditions
- Estimates of soil thickness, soil types, and variations in depth to bedrock
- Preliminary interpretation of subsurface conditions
- Summary of regional and site-specific geology
- Summary of slope conditions
- Regional seismicity and fault hazards
- Preliminary evaluation of design alternatives
- Preliminary construction considerations and limitations

1.3 Authorization

The scope of work presented in this report was authorized under Parametrix Subconsultant Agreement for Professional Services, executed on July 31, 2023, under Deschutes County Services Contract No. 2023-596. The contents of this report have been prepared for the exclusive use of Parametrix on behalf of Deschutes County, and their authorized agents for specific application to the 346-acre portion of the Moon Pit property, herein designated as “the project” or “site.”

2.0 Site Conditions

2.1 Surface Description

The project site is located on the eastern margin of the Deschutes Basin, approximately 15 miles southeast of Bend and northeast of Highway 20. The site is predominantly located on the lower northwest-facing slopes of Bear Creek Buttes, a small upland region that together with the adjacent uplands of Horse Ridge to the west, separates Millican Valley from the Deschutes Basin (Figure 1). The site is located within a fault-bound graben, a down dropped block that forms a depression positioned between two faults that uplift adjacent blocks to create adjacent uplands. The site is sparsely vegetated and currently in use as a quarry, whereas the adjacent fault-bound slopes and associated uplands are undeveloped.

Elevations and slope geometry were assessed using ArcGIS Pro and Global Mapper Pro geographic information systems (GIS). Site-specific elevation data were sourced from an unmanned aerial systems (UAS) flight performed by Parametrix in August 2023. This UAS flight utilized photogrammetry to create a digital surface model (DSM), elevation contours, and orthoimagery. In addition, Shuttle Radar Topography Mission (SRTM) 30-meter digital elevation models, 20-foot elevation contours were acquired from the United States Geological Survey’s (USGS) The National Map portal, and light detection and ranging (LiDAR) data acquired from DOGAMI were assessed.

Elevations of the graben within the site boundary range from approximately 3,870 feet in the southeast to approximately 3,576 feet at the northwest extent of the project site (NAVD 88; Parametrix, 2023). The sparsely vegetated slope of the project site dips gently to the northwest, with a relatively uniform slope of 6 to 18 degrees. The naturally occurring slopes that are adjacent to the graben are typically on the order of 18 to 45 degrees. Surface modifications by quarry activities have led to localized slopes within the site boundary ranging from 26 to 60 degrees.

The site is bound to the north and south by northwest-oriented slopes associated with the uplifted fault blocks. The fault blocks form northwest-trending linear bedrock exposures that transect the Bear Creek Buttes. The slopes associated with the fault blocks are more prominent at the southern extent of the site and taper toward the Deschutes Basin. Although these slopes are predominantly outside of the project area, the toe of the northern slope encroaches into the northern margins of the site. The site is bound to the west by a less prominent northwest-trending uplifted fault block. A subtle drainage network is observed throughout the site that drains the upslope areas of the graben northwest toward the Deschutes Basin.

The site has been significantly impacted by extensive surface mining since the 1990s by Hooker Creek Companies, LLC (Hooker Creek) of Bend, Oregon. Surface mining originally occurred in the northwestern portion of the site that removed the majority of alluvial sands and gravels, lowering the ground surface by as much as 80 to 100 feet. This has created a large closed basin in the northwestern portion of the site. This mining was conducted primarily with mechanical equipment, though some blasting of the underlying bedrock was conducted. In the southeast portion of the site, mining efforts are ongoing and volcanic rock is blasted in this area, producing mining highwalls that locally exceed 20 feet and are over 60 degrees.

Numerous stockpiles of various aggregate products as well as shot rock are present across the site. Most shot rock is located within the active quarry in the southeast part of the site and finished products are present in the northwestern portion of the site. Several fills of apparent mixed construction debris, soil, and rock are also present in several locations.

Stockpiles observed during the site reconnaissance are associated with quarrying activities and locally exceed 30 feet high. Fills associated with mixed construction debris, soil, and rock are up to 10 feet high.

2.2 Regional Geology

The project is located along the eastern margin of the Deschutes Basin within the High Lava Plain (HLP) physiographic province, east of the Cascade Range (Figure 3). The Cascade Range is a north-south oriented volcanic arc that extends from Northern California to British Columbia, Canada, resulting from subduction of the Juan de Fuca plate under the North American plate along the Cascadia subduction zone (CSZ). The interaction of the North American and Pacific plates creates a complex tectonic regime that drives compression, extension, and lateral movement within different regions of the North American plate.

Inland of the CSZ, the tectonic regime transitions from compression west of the Cascade Range to oblique extension east of the Cascade Range. The subducting Juan de Fuca plate is driving clockwise rotation of the Pacific Northwest about a geologic pole located in northeastern Washington (Zandt and Humphreys, 2008; Brocher et al., 2017). The resulting deformation is evident in the faults of Central Oregon, which demonstrate oblique dextral (right-lateral) extensional shear that has been in place for the past 10 million years (Ma) (Zoback, 1989; Waldien et al., 2019). Pezzopane and Weldon (1993) proposed a broad shear zone through Nevada, Oregon, and Washington that may accommodate as much as 10% to 20% of the total Pacific-North American transform motion.

HLP physiographic province is approximately 50 miles wide by 150 miles long and generally oriented east-west. The province is characterized by late Miocene and younger volcanics, forming an elevated desert plateau punctuated by rhyolitic ignimbrites resulting from regional bimodal volcanism of silica-rich effluent lavas and mafic basalt flows (Ford et al., 2013). The silica-rich eruptions formed cinder cones and calderas that pockmark the province and produce a west-northwest age-progressive trend across HLP and the northwest Basin and Range (Jordan et al., 2004). Regional faulting throughout the Quaternary (2.5 Ma) has offset many of the volcanic rocks throughout the HLP and resulted in prominent lineaments observed within the topography (Figure 1, Figure 4, and Figure 5).

Newberry Volcano is a broad shield volcano approximately 600 thousand years (ka) old and located approximately 17 miles southwest of the site (Sherrod et al., 1997; Figure 1 and Figure 4). Newberry Volcano has produced thousands of eruptions since its formation and is the largest volcano in the Cascade volcanic arc. Activity in the past 10 ka involves at least 25 active vents on the flanks and summit, with the most recent eruption known as the Big Obsidian Flow which occurred in the volcano’s crater about 1.3 ka (Sherrod et al., 1997). Basaltic eruptions have also occurred frequently from the flanks and caldera of the Newberry Volcano, most recently along its northwest rift system which formed 7 ka and produced lava flows that in total covered 23 square miles. Newberry Volcano’s most voluminous eruptive events that created the caldera and deposited volcanics throughout the Deschutes Basin occurred approximately 75 and 300 ka (Donnelly-Nolan et al., 2004).

2.3 Local Geology

The geology of the area was mapped at a 1:250,000 regional scale by Walker et al. (1967) and was later compiled with mapping by other investigators in Oregon Department of Geology and Mineral Industries (DOGAMI) Bulletin 89, Geology and Mineral Resources of Deschutes County (Peterson et al., 1976). Subsequent mapping primarily focused on Newberry Volcano was performed by MacLeod et al. (1995). Figure 4 presents a localized view of the mapped geology of the Bear Creek Buttes and Horse Ridge area from the compiled geologic mapping by

Peterson et al. (1976). The geologic conditions that pertain to the future development of the site include the underlying site-specific geologic unit(s), surficial processes, the Brothers fault zone, and the interaction of latest Quaternary faulting within Millican Valley. These are discussed in additional detail as follows.

2.3.1 Relevant Geologic Units

The site is mapped as underlain by Pleistocene (the last 2.58 Ma) age lava flows sourced from Newberry Volcano (map unit Qb) and by Holocene (less than 12,000 years) to Pleistocene age alluvial deposits (map unit Qal) throughout the northwestern half of the site, and by Pliocene (2.58 Ma to 5.3 Ma) age basalt (map unit Tb) throughout the southeastern half of the site (Peterson et al., 1976; Figure 4).

The alluvium is described by Peterson et al. (1976) as unconsolidated gravels, sands, and silts laid by streams with minor wind-deposited silt and ash; pumiceous and cindery at many locations; and includes slope wash, playa deposits, alluvial fans, lakebed deposits, and dune sand. We note that the playa and lakebed deposits were recognized in Millican Valley, southeast of the site, and not along the margin of the Deschutes Basin where the site is located.

The alluvium is overlain by more recent lava flows of the Badlands described by Peterson et al. (1976) as Pleistocene-age basalt flows consisting of olivine basalts and basaltic-andesite lavas originating from the Newberry Volcano. MacLeod et al. (1995) describe the unit as Holocene (?) to Pleistocene in age, slightly to moderately porphyritic, with phenocrysts of plagioclase, olivine and locally clinopyroxene, and note that the unit is unfaulted except for some older flows on the northernmost and southernmost flanks of Newberry Volcano.

The Pliocene age basalt that underlies the southeastern half of the site is described by Peterson et al. (1976) as consisting of gray to black, mostly thin pahoehoe basalt flows within plagioclase and olivine filled vesicles. In addition, MacLeod et al. (1995) note that this unit includes minor rhyolitic to dacite ash-flow tuff and refine the age to Pliocene to Miocene.

Horse Ridge, located southwest of the site and separated from map unit Tb by the Dry River Canyon, is mapped as Miocene to Pleistocene-age mafic vent rocks (map unit QTmv) and described as constructional landforms, lava cones, and shields composed of basalt and basaltic-andesite flows, agglomerates, scoria, and breccia. MacLeod et al. (1995) do not differentiate between QTmv and Tb and lump the two units.

Around 7,700 years ago, a massive eruption at Mount Mazama, now Crater Lake, ejected a massive ash collum that was blown primarily to the northeast across the region, depositing an ash bed as thick as 6 feet thick on Newberry Volcano’s south flank. The ash and pumice blanketed the Badlands and has been transported by wind and water washing it away or concentrating it in dunes. Although the Mazama ash is not a mappable unit in the immediate

Moon Pit site, it serves as an important stratigraphic marker in the region (Donnelly-Nolan et al., 2011).

2.3.1 The Brothers Fault Zone

The Brothers fault zone is one of the dominant tectonic structures within the greater HLP province, forming primarily dextral strike-slip faulting. The faults are generally oriented northwest with less abundant shorter faults oriented northeast, resulting in a left-stepping en echelon pattern (Lawrence, 1976; Ford et al., 2013). The Brothers fault zone terminates west of the site near Bend, Oregon, where it merges with the Sisters fault zone, and to the east at the Steens fault (Pezzopane and Weldon, 1993).

The faults are characterized at the surface by a series of short (6- to 12-mile long), apparent normal faults with a component of dextral slip that displace Miocoene volcanic and sedimentary rocks and Pliocene to Pleistocene volcanics rocks (Pezzopane and Weldon, 1993; Personius, 2002; Vanaman, 2007). Fault blocks are well-defined as northwest- to southeast-oriented lineaments that are readily distinguishable within volcanic rock displacements throughout Horse Ridge, Bear Creek Buttes, and Millican Valley.

A review of the USGS Quaternary Fault and Fold Database indicates relatively few of the faults within the Brothers fault zone are identified as active within the Quaternary, with the nearest fault truncating Horse Ridge approximately 3.3 miles southwest of the site (USGS, 2023a; Figure 6). Faults located within 25 kilometers (km) (approximately 15.5 miles[mi]) of the site and included with USGS Quaternary Fault and Fold Database are presented on Figure 6 and include faults offsetting Horse Ridge, as well as faults near Pine Mountain. Geologic hazard implications related to the faults are discussed in Section 8.1.

The Moon Pit site is located within a fault-bound graben with normal faults located on either side of the graben. These faults continue southeast through Bear Creek Buttes and offset the Pliocene-age basalts (Figure 3 and Figure 5). These faults are not included in the USGS Quaternary Fault and Fold Database (USGS, 2023a). Faults and fault hazards are discussed in detail in Section 4.1.

2.4 Site Geomorphology

SRTM and LiDAR data combined with USGS 20-foot contours were used to assess topographic conditions surrounding the site to understand the geomorphology as it relates to fault structures and geologic conditions within along the eastern margin of the Deschutes Basin and west side of Bear Creek Buttes (Figure 5). As previously discussed, the site is positioned within a fault-bound graben bordered to the north and south by linear ridges. The transition from the graben floor to the adjacent slopes is relatively gentle, forming an approximately 12° slope to the south, and 23° along the north.

The bedrock lineaments formed by faulting are evident throughout the Bear Creek Buttes and follow the same general northwest orientation. However, these lineaments are only observed within the bedrock of Bear Creek Buttes and Horse Ridge and do not extend into the Deschutes Basin or display evident offset within the lava flow.

Approximately 1 mile west of the graben is the meandering Dry River Canyon, which drained Lake Millican and formed a broad fan deposit consisting of gravels that spilled out into the Deschutes Basin (Peterson et al., 1976). Numerous gravel pits are evident within the LiDAR near Horse Ridge, and gravel was historically mined from the northwest portion as well. The alluvial fan protruding from Dry River is poorly incised, indicating the fan is currently inactive with geomorphic overprinting likely from aeolian processes infilling the previously channelized surface.

The Dry River Canyon fan abuts several terraces that are incised with subtle northeast-oriented drainages. The terraces are higher in elevation than the Dry River Canyon fan and slope subtly to the northeast, indicating sediment was sourced from the west. The position of the terraces relative to the gravel quarries at the toe of Horse Ridge indicates gravel was first deposited and sourced from Millican Valley through the Dry River Canyon, before a later episode of sedimentation from the west that allowed for the terraces to form before subsequently being scoured by fluvial processes along the Dry River Canyon fan at a later point.

The lava flows originating from Newberry Volcano were subsequently deposited over the Dry River Canyon fan and terraces. The lava flow has a rough appearance relative to the upslope areas of Horse Ridge and Bear Creek Buttes and the alluvium, and has a well-defined distal edge (Figure 5).

3.0 Subsurface Exploration

The subsurface exploration program included the excavation of 12 test pits on September 26, 2023. The test pit excavations were overseen by a Delve Underground geologist who was on site for the duration of the program. The locations of the test pits are presented in Figure 2. A detailed description of the geotechnical subsurface program is included in Appendix A. Test pits logs are provided in Appendix B, and selected site photographs are included in Appendix C.

4.0 Geologic Hazards

Geologic hazards are conditions associated with the geologic and seismic environment that could adversely influence site development. Geologic hazards for the site were assessed by reviewing publicly available GIS data through the DOGAMI HazVu portal, statewide landslide information database for Oregon (SLIDO), and the USGS Quaternary Fault and Fold Database (DOGAMI, 2023; USGS, 2023a). In addition, Delve Underground reviewed aerial photography and available published geologic maps to evaluate geologic hazards. Relevant geologic hazards identified within DOGAMI HazVu are discussed in detail in Appendix D and summarized in Section 8.1.

Seismic hazards and slope conditions are summarized in the following sections, as they pertain to our understanding of Quaternary faults within the project area and have direct implications for the site geomorphology, age of faulting, and ultimately permitting of the site development.

4.1 Seismic Hazards

4.1.1 Faults

Faults within the DOGAMI HazVu GIS layer are classified as “active faults” without a clear description of the age of the fault or degree of certainty of fault location, and are adopted from the USGS Quaternary Fault and Fold Database. A review of the USGS Quaternary Fault and Fold Database was performed to identify faults within the Brothers fault zone located within 25 km (15.5 mi) of the site to supplement the DOGAMI data and to provide a better understanding of nearby faults and their approximate age (USGS, 2023a; Figure 6).

Three fault zones with a total of 17 individual traces were identified within 25 km (15.5 mi) of the site. The nearest of these fault zones include the unnamed faults near Millican Valley, the Sisters fault zone, and the Metolius fault zone. The fault characteristics of each fault zone and the proximity of the closest traces are summarized in Table 4-1.

Table 4-1. Quaternary Class A Crustal Seismic Sources within 25 Kilometers of Site

USGS Fault ID	Fault/Fault Zone Name	Distance to Site (km / mi)	Fault Length (km / mi)	Type of Fault	Slip Rate Category (mm/yr)
841	Unnamed faults near Millican Valley	5.5 / 3.4	40 / 24.9	Normal, right lateral	0.2
852	Sisters fault zone	15 / 9.3	52 / 32.3	Normal, left lateral	<0.2
853	Metolius fault zone	21.5 / 13.3	94 / 58.4	Normal, right lateral	<0.2

4.1.1.1 Unnamed Faults near Millican Valley

These faults consist of a northwest-trending group of normal, right-lateral faults that are part of the greater Brothers fault zone, an approximately 185-mile-long system of high-angle faults (Personius, 2002). The unnamed faults of Millican Valley fall into two groups: faults truncating Horse Ridge and faults near Pine Mountain. A single fault trace is mapped between the two groups within Millican Valley, and at a more east-west orientation than the northwest-trending faults.

The Horse Ridge and Pine Mountain fault groups offset Miocene to Pliocene volcanics as evidenced by escarpments as high as 650 feet. The faults located near Horse Ridge are classified as active in the middle to late Quaternary (<700–780 ka), and the faults near Pine Mountain are classified as active in the early Quaternary (1.6–1.8 Ma). All faults within the unnamed faults near Millican Valley (Fault ID 841) are designated as middle and late Quaternary in age (<750 ka) within the USGS Quaternary Fault and Fold Database.

4.1.1.2 Sisters Fault Zone

The Sisters fault zone is located approximately 15 km (9.3 mi) west of the site within the Deschutes Basin. These faults are part of a northwest-trending group of normal faults with left lateral motion that form an approximately 52-km (32.3 mi) system that is subparallel to the unnamed faults near Millican Valley (Personius, 2016a). The faults are located along the east side of Bend, Oregon, and are classified as middle and late Quaternary (<750 ka) in age and offset Pleistocene lava flows originating from Newberry Volcano.

4.1.1.3 Metolius Fault Zone

The Metolius fault zone is located approximately 21.5 km (13.3 mi) west of the site within the Deschutes Basin and located along the west side of Bend, Oregon. These faults are also part of a northwest-trending group of normal faults and closely match the orientation of the Sisters fault system, and subparallel to the orientation of the unnamed faults near Millican Valley. However, the Metolius fault zone exhibits right lateral motion as opposed to the left lateral of the Sisters fault zone (Personius, 2016b). The faults near Bend, Oregon, are approximately 45 km (30 mi) in length and are part of a larger 94 km (58.4 mi) long system that extends up to Black Butte and the Metolius River and classified as middle and late Quaternary (<750 ka).

4.2 Historical Seismicity

Regional historical seismicity was acquired from the Advanced National Seismic System (ANSS) comprehensive earthquake catalog, hosted by the USGS Earthquake Hazard Program. Seismicity greater than magnitude (M) 2.5 are presented in presented in Figure 7. Magnitudes within the ANSS dataset are recorded as local magnitude, surface-wave magnitude, body-wave magnitude, moment magnitude, and magnitude of completeness. These data include seismicity within a 150-km (93-mi) radius of the project area and recorded between 1800 and 2022.

5.0 Subsurface Conditions

Subsurface conditions encountered at the Moon Pit site can be grouped into five geotechnical units based on composition and origin: Fill, Loess, Colluvium, Alluvium, and Bedrock. These units are discussed in detail in this section.

Fill: Fill was encountered in TP-10 at the ground surface to a depth of about 1-foot bgs. The fill consisted of dry, gray-brown, well-graded gravel (GW-GM) with silt and fine to coarse sand with trace roots. The gravel clasts were described as coarse and subangular to subrounded.

Loess: Loess is present at the surface and extended to depths of between 1.0 and 1.5 feet bgs. Loess was identified in four test pits (TP-1, TP-2, TP-3, and TP-5) located within the northern portion of the Moon Pit site. Roots and rootlets were present in loess soils. The loess generally consisted of dry, light brown, silty sand (SM) consisting of fine to coarse subangular sand.

Colluvium: Colluvium was encountered in test pit TP-4, at the surface to 6.0 feet bgs; and TP-3, below the loess from 1 to 7 feet bgs. Both test pits were terminated within the colluvium unit. Dense roots were noted in the colluvium of TP-4. The colluvium soil was characterized as dry, light brown, well-graded gravel (GW) with sand, cobbles, and boulders. Clasts were subrounded to subangular. Boulders with a maximum size of 18 inches were present in TP-3 and trace quantities in TP-4. This colluvium is predominantly located along the toe of adjacent slopes.

Alluvium: Alluvium was present in test pits TP-5 through TP-10 and TP-12, most of which were in the southern portion of the site. However, this alluvium is locally sourced from upslope from the subtle drainage network along the site surface, and unlikely related to sediments deposited from the Dry River Canyon. Alluvium was encountered at the surface, except for TP-05 and TP-10 where it was encountered directly under loess or fill, respectively, and to depths of up between 2.5 and 5.5 feet bgs. The alluvium soil was described predominantly as dry or moist, light brown, silty sand (SM) consisting of fine to coarse sand and trace roots. Trace fine to coarse subrounded gravel was described only in TP-08. Additionally, the sand was described as “pumiceous” in TP-12. This alluvium is associated with a northwest-trending drainage.

An additional, minor soil variety that was encountered in one test pit (TP-05) was characterized as dry, blue-gray, well-graded silty sand (SW-SM) consisting of pumice, quartz, and basalt with trace fine to coarse gravel.

Bedrock: The test pits terminated at the contact with bedrock, in TP-03 and TP-04, or within the bedrock unit, in TP-01, TP-02, and TP-05 though TP-12, at final depths of between 2.6 and 7.0 feet bgs. Bedrock encountered consisted of the uppermost weathered zone of the underlying rock mass, and the exposure of rock was limited to the ability to excavate it with conventional equipment. The bedrock unit included:

Dry, light brown, silty sand (SM) with gravel and cobbles. The sand was fine to coarse and the gravel was fine to coarse and subrounded with cementation ranging from none to moderately cemented.

Dry, light brown, well-graded gravel (GW) with varying amounts of silt, sand, and cobbles. Clasts consisted of fine to coarse sand, angular to subrounded gravel, and angular to subangular basalt cobbles.

Dry, light brown, well-graded gravel (GW-GM) with silt and sand. Clasts consisted of uncemented to moderately cemented fine to coarse and subangular to subrounded gravel, fine to coarse sand, and trace cobbles. Minor roots were also noted.

Lava flows observed in outcrop are separated by intervals of flow breccia consisting of well-graded gravels that vary from less than 2 feet thick to greater than 10 feet thick. Clasts consisted of fine to coarse sand, angular gravel to boulder-sized clasts.

5.1 Previous Studies

The David Evans and Associates, Inc. (1996) report includes the following relevant subsurface data:

- Mark V. Herbert & Associates (April 8, 1993). Subsurface descriptions based on 32 test pits (test pit logs not included), and geologic cross sections.
- Siemens & Associates (August 6, 1996). Subsurface conditions based on seismic refraction and 22 borings (boring logs not included).

The subsurface characterization in both reports is similar to those observed during our field investigation, though a primary focus of both previous investigations was to the northwestern extent of the site. Both reports are included in Appendix E.

In both previous exploration programs, sediment accumulation was found typically greater in the northwestern extent of the site where the site opens into the relatively flat Deschutes Basin. Thinning of sediment occurs along the axis of the graben, in the direction of the southeast corner of the site and associated upslope areas. In addition, both investigations identify an irregular bedrock contact underlying sediments.

Sediment accumulation in the northwest portion of the site typically extended to a depth of approximately 8 to 15 feet in the Mark V. Herbert & Associates (1993) investigation, and 3 to 42 feet in the Siemens & Associates (1996) investigation at the time of the investigations. Both investigations noted sands, silts, and gravels overlying bedrock. It is unclear what equipment was used during the Mark V. Herbert & Associates (1993) and we assume some form of test pits given the maximum depths of 15-feet bgs achieved. The Siemens & Associates (1996) investigation used a combination of geophysics and solid auger borings. The approximate locations of the geophysical profiles are presented on Figure 2.

5.2 Groundwater

Groundwater was not encountered at the time of our explorations. Well logs were obtained from the Oregon Water Resources Department (OWRD) web portal to estimate the depth to groundwater within the general vicinity. Three water wells were within the graben occupied by the site and presumed to be within the site boundary. Review of nearby well logs indicate static groundwater is at a depth exceeding 800 feet bgs. The well logs reviewed are summarized in Table 5-1 and included in Appendix F.

Table 5-1. Summary of OWRD Logs

Well ID	Depth to Static Groundwater (feet bgs)	Total Depth (feet bgs)
Desc 56052	970	1,155
Desc 5750	850	915
Desc 9126	852	1,135

Note that the locations of wells are poorly constrained and that reported depth to groundwater should be considered approximate only, *and not to be used for design purposes*.

6.0 Geologic Reconnaissance

Following the completion of the desktop research and literature review, a site reconnaissance was performed by a senior certified engineering geologist (CEG) from Delve Underground on September 14, 2023. Delve Underground was accompanied by Scott Carlson from Hooker Creek during the first part of the reconnaissance and interviewed him regarding site history. The purpose of the reconnaissance was to visually assess the site to confirm interpretations and hypotheses formed during the desktop research phase of the project. A summary of the reconnaissance is as follows:

- The northwestern portion of the site was significantly modified by mining activities starting in the 1990s. Mining activities removed up to 80 to 100 feet of sands and gravels from this area. <u>Some drill and blast mining was conducted in this area but was discontinued because of low rock quality</u>.

- Current mining activities are focused in the southeastern portion of the site. Mining in this area is being primarily performed by drill and blast methods. Reportedly, between 800,000 tons and 1 million tons of rock are excavated and processed for aggregate each year. Highwalls in this quarry exceed 22 feet and are in excess of 60 degrees.
- Much of the undisturbed portions of the site are mantled with several feet of loess deposits. These deposits obscure underlying geologic units; however, mining activities have provided numerous exposures.
- Remnants of sand and gravel deposits are exposed along the sidewalls of the open pit in the northwest portion of the site. Based on visual inspection, these deposits generally consist of gravelly sands to sandy gravels with clasts generally less than 6 inches in diameter.
- Colluvial talus slopes are present along the fault blocks that bound the site to the north and south. These deposits are described above. The lateral extent of these deposits is likely limited to the local apron of deposits extending toward the center of the site and away from the ridges.
- Several minor drainages are present across the site, the largest of these trending northwest down the site. Limited evidence of recent surface flow was observed during the site reconnaissance, consistent with the relatively arid nature of the region.
- Bedrock observed during the site reconnaissance in the quarries consisted of strong to moderately strong, slightly weathered and moderately to intensely fractured basalt flows. Individual flow ranges from a few feet to over 10 feet thick. Flows are separated by intervals of flow breccia consisting of well-graded gravels. Clasts consisted of fine to coarse sand, angular gravel, to boulder-sized clasts.
- An industrial well is located in the northwest portion of the site on the south side of the gravel pit. This well has historically produced 200 to 300 gallons per minute during operation.

7.0 Geologic Discussion

7.1 Subsurface Conditions

Materials encountered within our explorations consist predominantly of silty sand and gravel overlying volcanic bedrock. Equipment refusal was encountered in all 12 explorations, resulting in termination of test pits shallower than 10 feet bgs. The materials encountered at the time of our explorations, are consistent with materials previously observed by Mark V. Herbert & Associates (1993), Siemens & Associates (1996) and observed during our site reconnaissance.

The estimated thickness of subsurface materials encountered at the time of our explorations and the anticipated use of materials is presented in Table 7-1. Across the site, the average thickness of overburden materials (alluvium, loess, and colluvium) is estimated to be 5 feet, plus or minus 3 feet. No laboratory tests have been performed to assess the durability of bedrock for future use as a construction aggregate. Please note that the current coverage of test pits is inadequate for fully assessing the subsurface conditions for a 346-acre development, and lateral variations of materials likely exist.

Table 7-1. Soil Usage Summary

Geologic Unit	ASTM Classification	Estimated Thickness (feet)	Anticipated Use[1]
Alluvium/Loess[2]	Silty SAND (SM)	1 – 5.5	Daily cover
	Well-graded GRAVEL with sand and cobbles (GW)		
	Well-graded SAND with silt (SW-SM)		
Colluvium[3]	Well-graded GRAVEL (GW)	>6	Daily cover
Bedrock (extremely weathered)[4]	Well-graded GRAVEL with silt and SAND (GW-GM)	1 – 4	Daily cover for gravel-sized or finer; crush/screen oversize rock clasts for drain rock, structural fill, and road base
	Well-graded GRAVEL with sand (GW)		
	Silty SAND with gravel and cobbles (SW)		
Bedrock[5] (unweathered)	N/A	Unknown	Crush for drain rock, structural fill, and road base

Notes:

[1] Anticipated uses are assumed. No laboratory testing has been performed and bedrock quality is currently unknown. Laboratory testing is required for approval of on-site use.

[2] Alluvium and loess accumulation throughout the undisturbed areas of the site and overlies bedrock, and old alluvial gravels previously mined in the northwest portion of the site.

[3] Colluvium limited to areas adjacent to fault scarp and only encountered in TP-3 and TP-4.

[4] Bedrock encountered within test pits represents the upper weathering profile and contains varying amounts of sand and fines. Bedrock quality is currently unknown and requires evaluation and laboratory testing to determine durability and quality.

[5] Bedrock quality determination is beyond the scope of this exploration although visual observations of cuts and other exposures suggest high variability ranging from poor to moderate.

7.2 Age of Faulting

The Resource Conservation and Recovery Act (RCRA) Subtitle D – Section 1.1.1, Part 258.13 designates that any landfill or lateral expansion of a landfill may not be located within 200 feet of a fault that has experienced displacement within the Holocene and defines the Holocene as the last 10 to 12 ka (EPA, 1995). Pluvial lakes and alluvial fans are commonly used for determining the age of faulting in arid environments, as they generally have materials that can be used for numerical age dating and often preserve deformation in the form of scarps, drainage offsets, and other lateral and vertical displacements.

The site is positioned within a fault-bound graben, and the associated faults are not identified within the USGS Quaternary Fault and Fold Database as active during the Quaternary. Available LiDAR data provide coverage of the western extent of the site and Horse Ridge, and does not indicate fault offsets within the Newberry Volcano lava flow or alluvial units associated with the faults within the Quaternary Fault and Fold Database that truncate Horse Ridge (Figure 5). The LiDAR coverage extends approximately 3 miles east of Horse Ridge and provides additional coverage extending into Millican Valley. Within this LiDAR coverage, a mapped trace of one of the unnamed faults of Millican Valley would deform a Newberry Volcano lava flow, an alluvial fan, and lake sediments associated with Lake Millican. Deformation features indicative of faulting are not readily distinguishable within the LiDAR data within these units. Therefore, there is no evidence of Holocene faulting within 200 feet of the site.

8.0 Geologic Summary and Preliminary Conclusions

Our understanding of the site conditions indicates the site is favorable to the development of the proposed landfill. Critical flaws related to the site conditions and geohazards were not identified throughout this phase of work, and future site development should be considered. Our findings are summarized as follows:

- Faults that bound the graben are not included within the USGS Quaternary Fault and Fold Database. Alluvial units and the Newberry Volcano lava flow do not exhibit offsets along the northwest projections of the faults and thus we interpret the faults as inactive.
- Shallow bedrock is persistent throughout the site and covered with a thin (less than 10 feet thick) veneer of undifferentiated alluvium and loess. Thicker amounts of alluvium may be present where it has not been mined out in the northwestern portion of the site.
- Practical refusal with conventional equipment occurred during the excavation of all test pits, resulting in termination less than 10 feet bgs. Shallow bedrock conditions will likely require drilling and blasting techniques to excavate the desired depth of the waste cells.
- Bedrock exposed in quarry exposures in the southern portion of the site consisted of a complex sequence of basaltic lava flows and cinder-filled interbeds. Both lava flow and interbeds generally varied between 2 and 10 feet thick.
- Review of seismic surveys and cross sections compiled by Siemens & Associates within the David Evans and Associates, Inc. (1996) report indicated an irregular bedrock contact with varying depths of sediment accumulation within the northwest portion of the site. Some drill and blast mining was conducted in this area but was discontinued because of low rock quality.

- Depth to groundwater is anticipated to be well below the bottom of the proposed landfill cells. However, further exploration and study are recommended to confirm the nature and extent of groundwater beneath the site.
- Based on the shallow bedrock conditions and the waste cells excavated into the underlying bedrock, we do not anticipate issues with bearing capacity or settlement associated with future site development.
- On-site materials are likely suitable for use in site development pending future lab testing to identify the durability of the material.
- On-site materials will require laboratory testing to assess whether materials meet the specification of intended use per Oregon Standard Specifications for Construction (OSSC).
- Site Class B is recommended for future seismic design based on the materials encountered in our subsurface exploration program.
- Review of the site development plans by G. Friesen Associates, Inc., dated September 26, 2023, indicate 3H:1V (horizontal to vertical) slopes along the perimeter of the waste cells. These slopes are suitable at this time based on our current understanding of the subsurface conditions and that waste cells will be excavated into the underlying bedrock.

8.1 Summary of Geologic Hazards

Geologic hazards, based on our review of DOGAMI HazVu combined with site reconnaissance and desktop analysis, are summarized in Table 8-1 as follows:

Table 8-1. Geologic Hazards Summary

Hazard	Assessment
Fault Rupture	The faults that bound the graben are interpreted as inactive. Fault rupture hazard is thus low to none.
National Earthquake Hazard Reduction Program (NEHRP) Site Class	Site Class B is recommended based on subsurface investigation results and is addressed in further detail in Section 9.4.1.
Liquefaction	Groundwater was not encountered within the thin veneer of sediments over the shallow bedrock conditions observed throughout the site. As such, liquefaction susceptibility is negligible.

Hazard	Assessment
Landslide Hazard Areas	On-site slopes characterized as moderate susceptibility within HazVu are attributed to shallow bedrock conditions, or surface modifications from resource development. Adjacent slopes lack geomorphic indicators indicative of landslides and unstable slopes within the currently available elevation models. As such, landslide susceptibility is low to none.
Volcanic Hazards	The site is currently mapped outside of a volcanic hazard area. However, ashfall is likely from near and far sources as documented by the extent of Mazama ash throughout Millican Valley as documented by Vanaman (2007).

9.0 Preliminary Geotechnical Design Considerations

Our preliminary assessment of the site has not identified geotechnical concerns for the future development of the site as a municipal solid waste landfill. Subsurface conditions based on the results of our preliminary exploration program indicate the site is consistently underlain by a shallow veneer of soil overlying bedrock. Groundwater was not encountered within our explorations and is currently estimated at a depth exceeding 800 feet. The current grading and site development plans are preliminary and are subject to change.

9.1 Depth to Groundwater

Groundwater was not encountered at the time of our explorations and a review of OWRD well logs indicate groundwater depth exceeding 800 feet bgs. As such, we do not anticipate groundwater to impact the constructability of the proposed landfill.

9.2 Bearing Pressure and Settlement

The subgrade of the site will likely consist of bedrock. The current plans indicate excavation depths ranging from 10 to 60 feet bgs across the landfill cells (typically ranging from about 30 to 40 feet bgs), and total municipal solid waste (MSW) fill heights/depths of up to 200 feet. Because of the presence of shallow bedrock, we do not anticipate bearing pressure constraints or settlement concerns for future site development.

9.3 Temporary Slopes

In general, the anticipated excavations to facilitate construction of the project will be made within intact rock, with relatively minor excavation depths within the overlying soils. The soil units consist of loess, colluvium, and alluvium and exhibit overall cohesionless soil behavior. In accordance with OSHA, the site soils can preliminarily be classified as Type C. For planning and earthwork volume estimating purposes, excavations up to 20 feet in Type C soils can have a maximum allowable temporary slope of 1.5H:1V (horizontal to vertical) given that groundwater was not encountered.

In general, the basalt present across the project area is considered “stable rock” per OSHA and will stand at a vertical orientation. In general, we recommend the following for planning temporary rock cuts:

- For rock cuts 20 feet in depth or less, cuts may be vertical.
- For rock cuts greater than 20 feet in depth, cuts should be sloped back at an orientation of 0.25H:1V.

However, it is typical for Newberry volcanics basalts to contain soil layers between volcanic flows, as well as vesicular or scoriaceous (i.e., pumice-like) gravel at the tops of volcanic flows that will behave more like cohesionless soil. Depending on the presence and thickness of interflow zones, rock cuts may require flatter slopes.

The site development plan shows maximum cut slope inclinations of 3H:1V around the perimeter of the landfill. Therefore, the proposed maximum cut slope angles are within OSHA temporary cut slope guidelines.

Temporary slope recommendations do not consider site constraints such as groundwater, surcharge, or nearby structures. Temporary slopes should be evaluated on a case-by-case basis and incorporate groundwater conditions, soil classification, and site constraints.

9.4 Seismic Design

The latest available guidelines regarding seismic design criteria for landfills is the United States Environmental Protection Agency (EPA) document RCRA Subtitle D, which states that MSW landfills be designed to resist a maximum horizontal acceleration (i.e., peak ground acceleration, or PGA) based on USGS seismic hazard mapping with a 90 percent probability of nonexceedance in a 250-year period. This corresponds to a 10 percent probability of exceedance in a 250-year period and is the equivalent of the 2 percent probability of exceedance in 50 years (return period of 2,475 years) per 2022 Oregon Structural Specialty Code (OSSC) (ICC, 2022) and American Society of Civil Engineers (ASCE) 7-16 (2017) procedures. For the purposes of this preliminary study, we assume that seismic design for the new MSW landfill will be based on 2022 OSSC and ASCE 7-16 procedures.

9.4.1 Seismic Site Classification

The site is underlain by less than 10 feet of sediments overlying bedrock, and the waste cells will be embedded within bedrock. Therefore, site class B is appropriate per the 2022 OSSC, which references the ASCE/SEI 7-16, Chapter 20 (2017).

9.4.2 Seismic Design Parameters

The 2022 OSSC requires that spectral response accelerations be developed based on the ASCE 7-16 procedures. We developed spectral response accelerations using the online ASCE 7 Hazard Tool, which references ground motion procedures in accordance with ASCE 7-16 and is based on the USGS 2014 National Seismic Hazard Mapping Project (NSHMP) developed for the Maximum Considered Earthquake (MCE) (Petersen et al., 2014). The MCE consists of ground motions (accelerations) with a 2 percent probability of exceedance in 50 years (return period of 2,475 years). The mean earthquake magnitude and the mean site-to-source distance for the zero-second period of vibration (e.g., PGA) are 6.99 and 77.21 km, respectively, for the MCE. The recommended spectral acceleration parameters for use in structural design are provided in Table 9-1.

Table 9-1. 2022 OSSC MCE Spectral Acceleration Parameters for Site Class B

Parameter	0.2-second Period	1-second Period
Mapped MCE_R (Rock Site)	S_S = 0.350g	S_1 = 0.179g
Site Coefficients	F_a = 1.0	F_v = 1.0
Site-adjusted MCE_R	S_{MS} = 0.350g	S_{M1} = 0.179g
Design MCE_R	S_{DS} = 0.234g	S_{D1} = 0.120g
Mapped MCE PGA (Rock Site)	0.159g	
Site Coefficient F_{PGA}	1.0	
Site-adjusted MCE PGA_M	0.159g	

9.4.3 Seismic Sources and Hazard Deaggregation

We used the online USGS Unified Hazard Tool (USGS, 2023b) to perform a deaggregation of the uniform hazard spectrum (UHS) response spectrum for Site Class B-C boundary (i.e., rock site). The deaggregation data identify the earthquake sources, magnitudes, and site-to-source distances that contribute to the mean source event (e.g., the MCE) acceleration parameters. Table 9-2 summarizes the results of the MCE hazard deaggregation for the zero-second period of vibration (e.g., PGA).

Table 9-2. Deaggregation Results for 2,475-year Mean Source Event (MCE), PGA Period

Source	Moment Magnitude, M_W[1]	Site-to-source Distance[2] (km)	% Contribution to Hazard
CSZ Interface	8.96	244.92	23.28
CSZ Intraslab	7.09	149.15	1.84
Crustal Faults[3]	6.18 to 7.07	19.85 to 35.43	74.88

Notes:

[1] M_W values represent the mean value from each type of earthquake source.

[2] Site-to-source distances represent the mean value from each type of earthquake source.

[3] Crustal faults source includes gridded seismic sources that represent earthquakes that do not occur on

9.5 Site Development Considerations

9.5.1 Cell Excavation

Based on the results of our preliminary geotechnical investigation, the site is underlain by less than 10 feet of sediment overlying intact basalt bedrock. Based on the preliminary site development plans, cell excavations will typically be on the order of 20 to 40 feet, and as much as 60 feet in the southern part of the landfill. Since basalt bedrock is generally within about 10 feet of the ground surface at the project site, we anticipate that the majority of the excavations will take place within the basalt. Previous geotechnical investigations done at the project site (Siemens & Associates, 2004) indicate the basalt as highly fractured within the upper few feet, transitioning to typically hard to very hard below. Therefore, we expect that a majority of the basalt will not be excavatable (i.e., rippable) with conventional earthwork equipment, and extensive blasting will be required to achieve the proposed cell subgrade elevations shown on the preliminary site development plans.

9.5.2 Fill Materials for Site Development

We anticipate that the excavated rock, most of which will likely be removed by blasting methods, can be processed on site into the fill materials discussed below. We anticipate that the native on-site soils—relatively minor amounts in comparison to the basalt—are suitable for use in site development, provided they are screened and can be kept free of debris, deleterious materials, and particles larger than 6 inches in diameter, as well as for daily cover. Since most of the material within cell excavations is intact basalt, considerable effort will be required to process the shot rock (by crushing and screening) into the required gradation bands for specific material types.

The use of existing on-site soils and rock should include the following processing recommendations:

- Processed fill should be free of objectionable debris (clay clumps, organic, and/or deleterious material, etc.) and within moisture contents suitable for compaction or as specified based on their intended use (i.e., as general embankment fill or as structural fill);
- Cobbles/boulders or other oversized debris greater than 6 inches should be separated/screened from any processed materials considered for use as fill. This oversized material, provided it is competent/hard cobble and boulder clasts, may subsequently be processed into suitably sized fill material; and
- Prior to filling operations, representative samples of each proposed fill type should be collected. Gradation tests (particle-size analysis) should be performed on the samples to evaluate their suitability for use as fill materials and conformance with project specifications.

Material specifications referenced in this section, with the exception of daily cover, refer to the 2024 OSSC (ODOT, 2024), which is frequently cited in earthwork specifications and referenced by contractors for projects in Oregon. We anticipate that the following material types will be used for the site development:

- Daily Cover: Refers to backfill placed over solid waste consisting of 2-inch minus with <20 percent passing the no. 200 sieve.
- Structural Fill: Refers to backfill placed between subgrade and structural foundations to provide a smooth, uniform surface for foundations or asphalt pavement sections. Structural fill should consist of either 1-inch minus (1″ - 0) or 3/4″ - 0 dense graded aggregate per OSSC §02630.10.
- Open-graded Aggregate: Refers to free-draining backfill placed behind retaining walls and below-grade structures, or used to construct foundation drainage systems. Open-graded aggregate should consist of either 1″ - 0 or 3/4″ - 0 crushed rock per OSSC §02630.11.
- Embankment Fill: Refers to fill placed in the following scenarios: (1) to bring site grades up to design top-of-subgrade elevations (i.e., below structural fill or foundation drainage systems); (2) between subgrade and design pavement sections; and (3) between open-graded aggregate and temporary cuts/excavations behind below-grade structures and walls. Embankment fill should conform to either OSSC §00405.14 for Class A backfill with a maximum rock fragment size of 6 inches or to OSSC §00330.16.
- Pipe Bedding: Backfill zone that includes full trench width and extends from the prepared pipe trench bottom to the bottom of the exterior of the pipe, conduit, cable, or duct bank. Pipe bedding should consist of 3/4″ - 0 dense-graded aggregate per OSSC §02630.10.
- Pipe Zone Material: Backfill zone that includes full trench width and extends from top of pipe bedding to 12 inches above top outside surface of pipe, conduit, cable, or duct

bank. Pipe zone material should consist of 3/4" - 0 dense-graded aggregate per OSSC §02630.10.

- Trench Zone Material: Backfill zone that includes full trench width and extends from top of pipe zone to an upper limit at the bottom of the road subgrade where the trench is below pavement, or the bottom of the topsoil or surface gravel in areas where the trench is outside of paved areas. Trench zone material should consist of either (1) 3/4" - 0 dense graded aggregate per OSSC §02630.10 beneath paved areas or structures; or (2) gravel or crushed rock meeting the requirements for Class B or Class D backfill per OSSC §00405.14.

10.0 Additional Site Characterization

This current phase of work was completed with limited geotechnical explorations consisting of test pits. Additional subsurface characterization will be necessary for final geotechnical engineering and design considerations for the proposed landfill. Future work should be performed under the supervision of a certified engineering geologist and geotechnical engineer and include:

- A comprehensive drilling program to characterize the underlying rock mass extended beyond the depth of the waste cells to check for changes in lithology such as soil layers between volcanic flows or voids related to lava tubes.
- Geophysical surveys coupled with additional test pits to evaluate the thickness of sediments overlying bedrock.
- Additional laboratory testing following the ODOT aggregate suite to identify if on-site gravels and larger clasts can be used as a resource for site development.

11.0 Limitations

This report has been prepared for the SWMF Site Evaluation – Moon Pit project located in Deschutes County, Oregon. The data, analyses, conclusions, and recommendations presented in this report are based on the subsurface conditions at the time that the geotechnical investigation for the project was completed. This report also contains information and data collected from other relevant studies, as well as our site reconnaissance and our professional experience and judgement.

In the performance of geotechnical work, specific information is obtained at specific locations at specific times, and geologic conditions can change over time. It should be acknowledged that variations in soil conditions may exist between exploration and exposed locations, and this report does not necessarily reflect variations between different explorations. The nature and extent of variation may not become evident until construction. Delve Underground is not responsible for the interpretation of the data contained in this report by anyone; as such interpretations are dependent on each person's subjectivity. If, during construction, conditions different from those disclosed by this report are observed or encountered, Delve Underground should be notified at once so we can observe and review these conditions and reconsider our recommendations where necessary.

The site investigation and this report were completed within the limitations of the Delve Underground's approved scope of work, schedule, and budget. The services rendered have been performed in a manner consistent with the level of care and skill ordinarily exercised by members of the profession currently practicing under similar conditions in the same area. Delve Underground is not responsible for the use of this report in connection with anything other than the project at the location described above.

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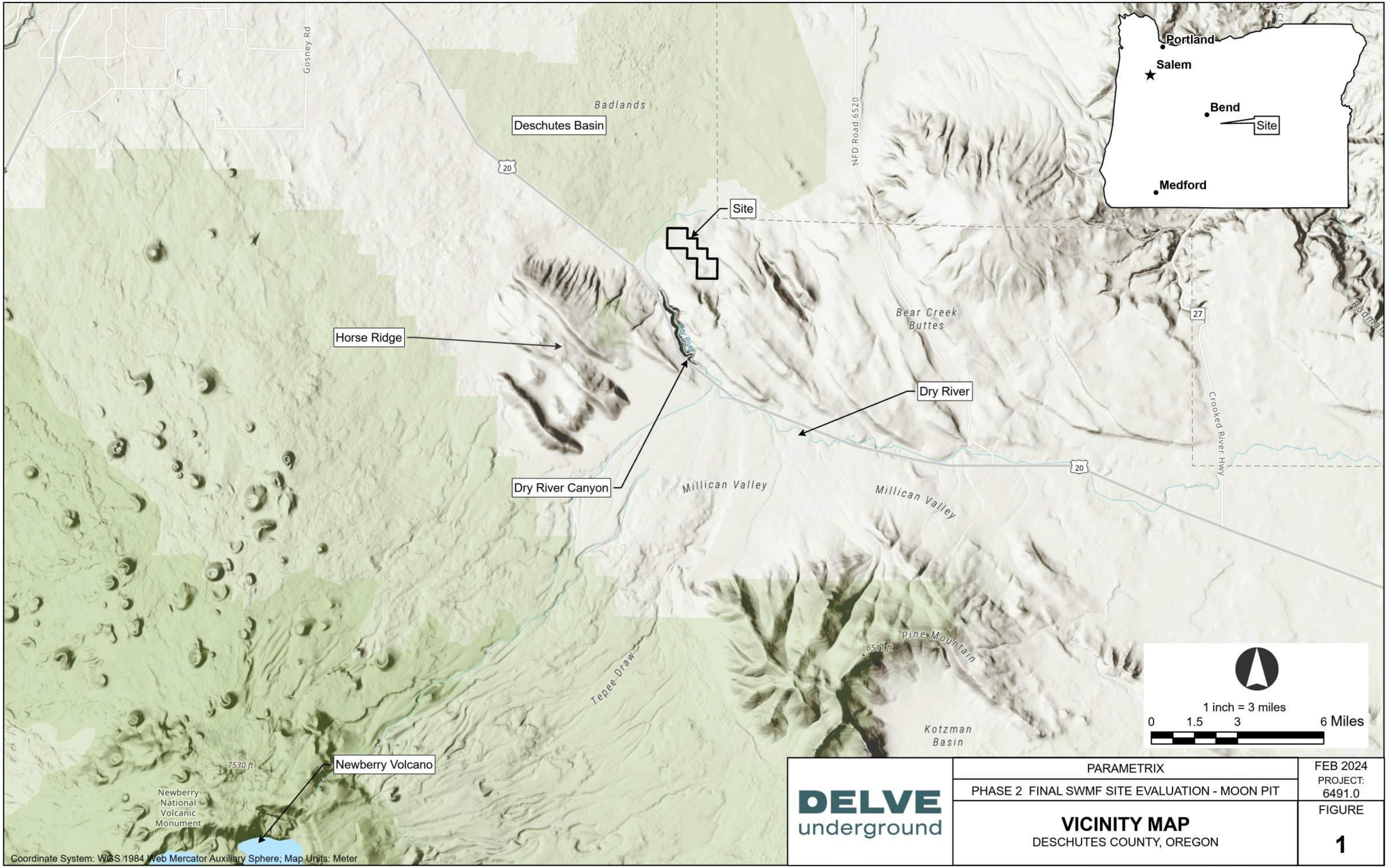
Figures



Coordinate System: WGS 1984 Web Mercator Auxiliary Sphere; Map Units: Meter

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DELVE underground

PARAMETRIX

PHASE 2 FINAL SWMF SITE EVALUATION - MOON PIT

VICINITY MAP

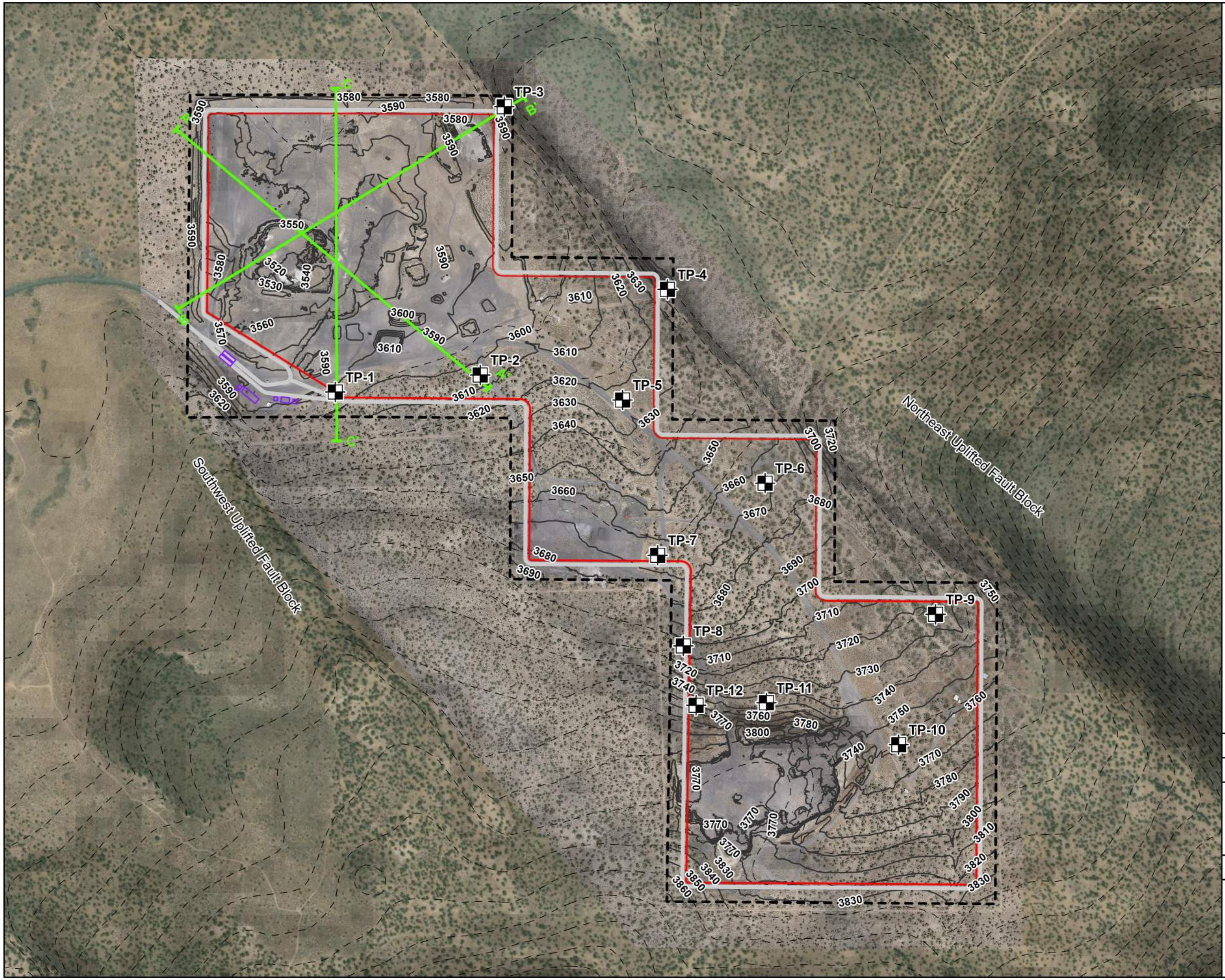
DESCHUTES COUNTY, OREGON

FEB 2024

PROJECT:
6491.0

FIGURE

1



EXPLANATION

- ⊞ TP-1 - Test pit name and approximate location
- — 10-foot elevation contour (Parametrix, 2023)
- – – 20-foot elevation contour (USGS; NAVD 88)
- ⊢⊣ A-A' - Geophysical profile name and approximate location (Siemens & Associates, 1996)

Preliminary Site Layout (Parametrix, 2023)

- — Approximate location of structures
- — Approximate footprint of waste cells
- – – Approximate property boundary
- — Approximate location of proposed access road

Notes:
1. Orthoimagery basemap from Parametrix UAV flight USGS national topo basemap; 20-foot contours (NAVD 88)
2. Linework is approximate and subject to change

1 inch = 800 feet

0 400 800 1,600 Feet

Coordinate System: Central Oregon; Map Units: Foot

PARAMETRIX

PHASE 2 FINAL SWMF SITE EVALUATION - MOON PIT

PRELIMINARY SITE PLAN

DESCHUTES COUNTY, OREGON

DATE: FEB 2024 ▪ PROJECT: 6491.0

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FIGURE

2

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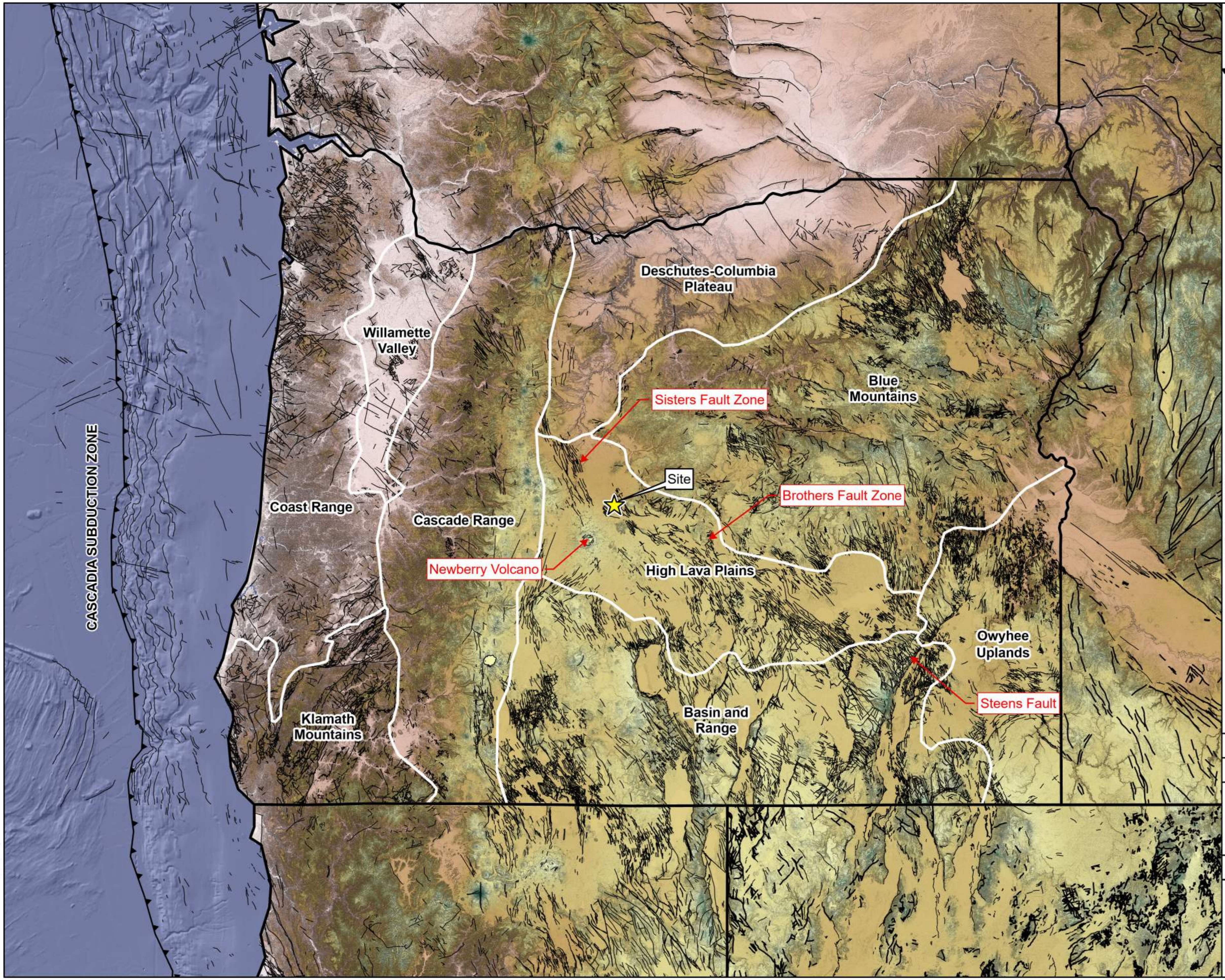

EXPLANATION

☆ Site location

Cascadia Subduction Zone (CSZ)

Fault - Age undifferentiated

Notes:
1. SRTM 30-meter elevation model
2. Faults compiled from USGS Quaternary Fault and Fold d\Database, DOGAMI OGDC-7 (2020), WA DNR DS-18 (2019), USGS OFR-2005-1305 (2007), IGS M-9 (2012)
3. Cascadia Subduction Zone geometry obtained from USGS Cascadia Subduction Zone database (2022)

Coordinate System: WGS 1984 Web Mercator Auxiliary Sphere; Map Units: Meter

PARAMETRIX

PHASE 2 FINAL SWMF SITE EVALUATION - MOON PIT

TECTONIC SETTING AND GEOLOGIC PROVINCE

DESCHUTES COUNTY, OREGON

DATE: FEB 2024 ▪ PROJECT: 6491.0

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FIGURE

3

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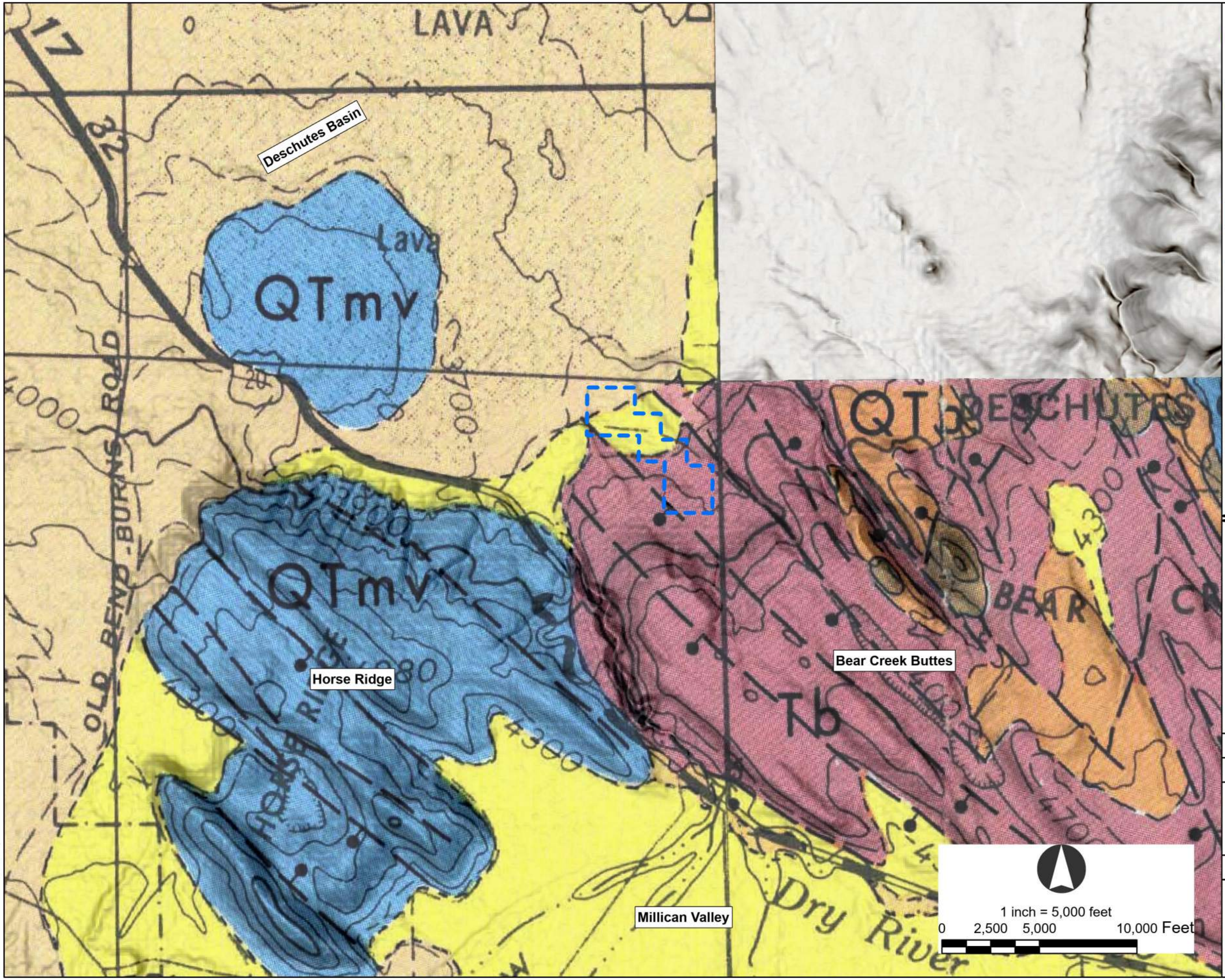

EXPLANATION

🟦 Approximate site boundary

Relevent Geologic Units

Qal	Alluvium and surficial deposits – Holocene to Pleistocene – Unconsolidated gravels, sands, and silt laid by streams, with minor wind-deposited silt and ash. Pumiceous and cindery at many locations. Includes slope wash, playa deposits, alluvial fans, lakebed deposits, and dune sand.
Qb	Pleistocene basalt flows – Pleistocene – Gray, diktytaxitic, olivine basalt originating on and about the flanks of Newberry Volcano and associated Brothers Fault Zone.
QTsv	Silicic vent rocks – Pleistocene to Eocene? – Domes and flow complexes of silicic andesite, dacite, and rhyolite exhibiting uneroded to highly eroded constructional forms.
Tb	Tertiary basalt – Pliocene – Gray to black, mostly thin, pahoehoe, diktytaxitic basalt flows containing small to moderate amounts of olivine. Some flows are platy olivine andesite or basaltic andesite.
QTmv	Mafic vent rocks - Pleistocene to Miocene - Composed of basalt and basaltic andesite flows, agglomerates, scoria, and breccia.
- - -	Contact - Dashed where approximately located; dotted where inferred.
–·–	Fault - Dashed where approximately located; dotted where inferred. Bar and ball on downthrown side.

Notes:
1. Geologic mapping from DOGAMI Bulletin 89 (1976)

Coordinate System: Central Oregon; Map Units: Foot

PARAMETRIX

PHASE 2 FINAL SWMF SITE EVALUATION - MOON PIT

GEOLOGIC MAP
DESCHUTES COUNTY, OREGON

DATE: FEB 2024 • PROJECT: 6491.0

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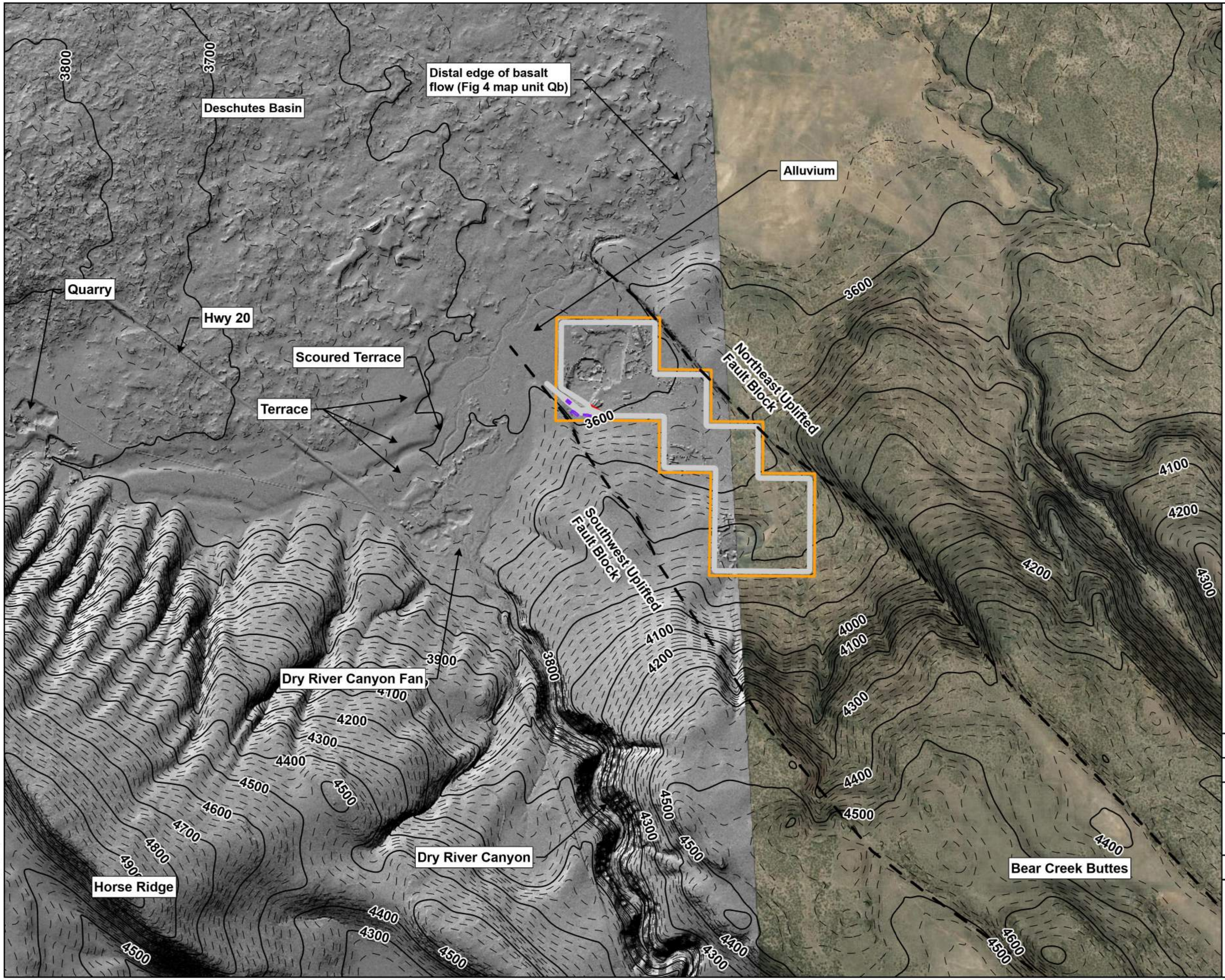
FIGURE
4

Path: \\172.16.6.125\gis\projects\6491.0\6491.0 moon pit\6491.0 moon pit.aprx User: CordesShaun Date Saved: 1/31/2024 5:30 PM



EXPLANATION

- – – 20-foot elevation contour (USGS; NAVD88)
- ― 100-foot elevation contour (USGS; NAVD 88)
- ▬ ▪ Fault - Dashed where approximately located (Walker et al., 1967)

Preliminary Site Layout (Parametrix, 2023)

- 🟥 Approximate footprint of waste cells
- 🟧 Approximate property boundary
- ▬ Approximate location of proposed access road
- 🟪 Approximate location of structures

Notes:
1. LiDAR hillshade limited by extent of data.

1 inch = 2,500 feet
0 1,250 2,500 5,000 Feet

Coordinate System: Central Oregon; Map Units: Foot

PARAMETRIX

PHASE 2 FINAL SWMF SITE EVALUATION - MOON PIT

SITE GEOMORPHOLOGY

DESCHUTES COUNTY, OREGON

DATE: FEB 2024 • PROJECT: 6491.0

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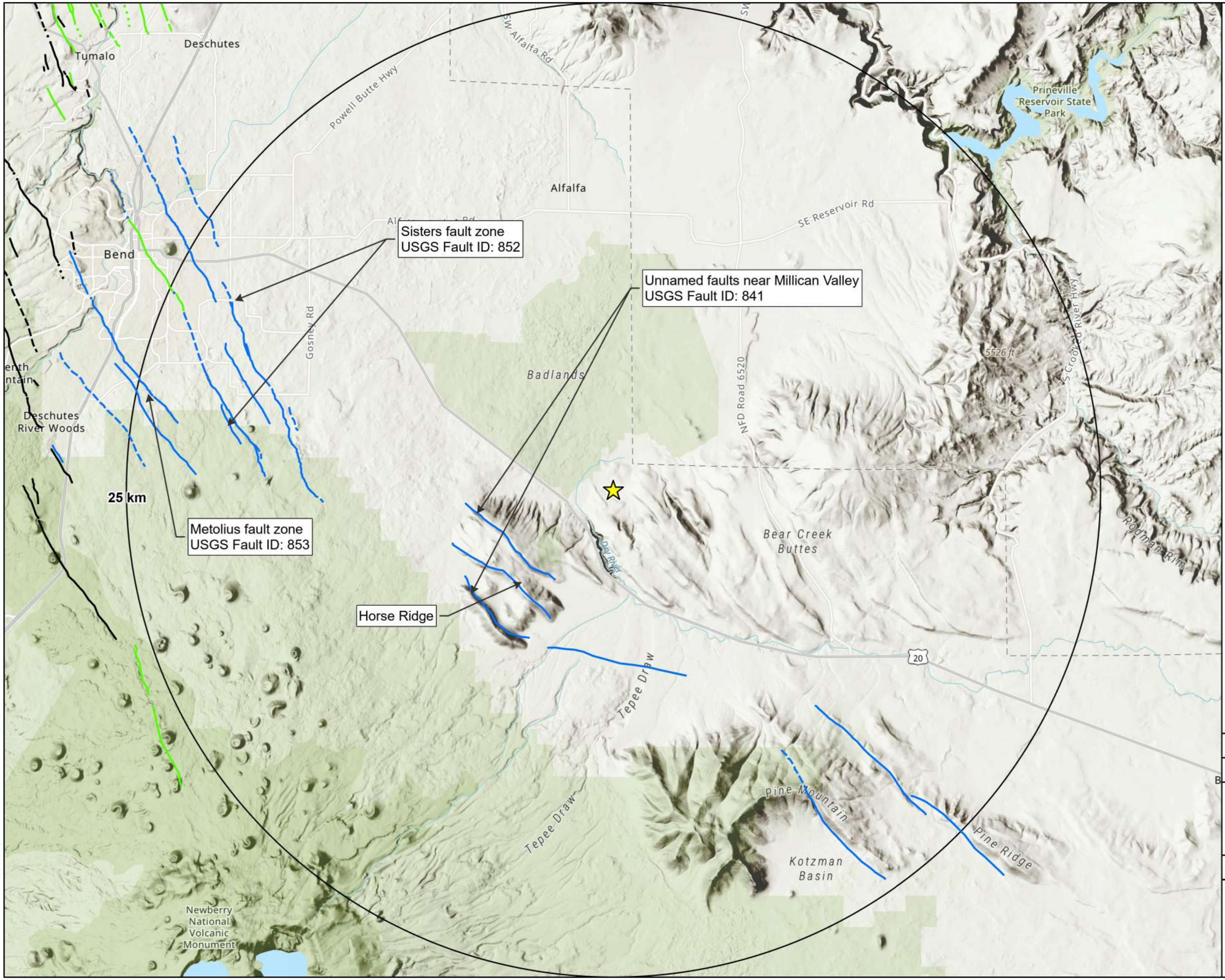
FIGURE

5

Path: \\172.16.6.125\gis\projects\6491.0\6491.0 moon pit\6491.0 moon pit.aprx User: CordesShaun Date Saved: 1/31/2024 5:30 PM



EXPLANATION

★ Site location

○ Site proximity buffer (km)

USGS Quaternary Fault and Fold Database

Fault trace – solid where well constrained, dashed where moderately constrained, and dotted where inferred.

<15,000 years - Latest Quaternary

<130,000 years - Late Quaternary

<750,000 years - Middle and late Quaternary

<1.6 million years - Undifferentiated Quaternary

Notes: ESRI World Topographic basemap, fault traces obtained from USGS Quaternary Fault and Fold Database

1 inch = 5 kilometers

0 2.5 5 10 km

Coordinate System: Central Oregon; Map Units: Foot

PARAMETRIX

PHASE 2 FINAL SWMF SITE EVALUATION - MOON PIT

USGS REGIONAL FAULT MAP

DESCHUTES COUNTY, OREGON

DATE: FEB 2024 ▪ PROJECT: 6491.0

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FIGURE

6

Path: \\172.16.6.125\gis\projects\6491.0\6491.0 moon pit\6491.0 moon pit.aprx User: CordesShaun Date Saved: 1/31/2024 5:30 PM

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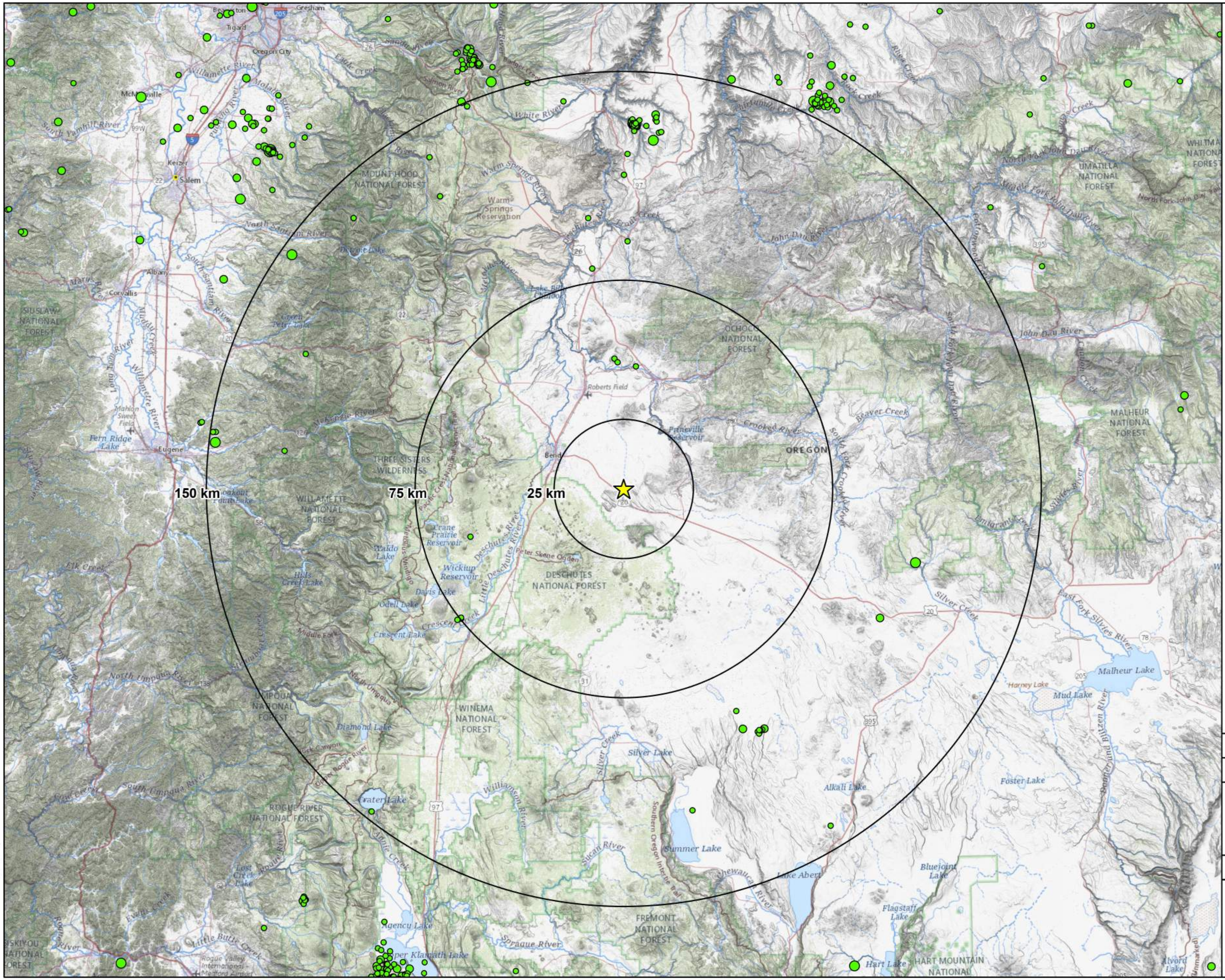

EXPLANATION

☆ Site location

○ Site proximity buffer (km)

ANSS Historical Seismicity (1800-2022)

- ● M 2.5 - 3
- ● M 3 - 4
- ● M 4 - 5
- ● M 6 - 7
- ● M 7 - 8
- ● M 8+

Notes: ESRI World Topographic basemap, historical seismicity obtained through USGS ANSS and filtered by magnitude 4.0 and greater.

1 inch = 35 kilometers

0 17.5 35 70 km

Coordinate System: Central Oregon; Map Units: Foot

PARAMETRIX

PHASE 2 FINAL SWMF SITE EVALUATION - MOON PIT

HISTORICAL SEISMICITY

DESCHUTES COUNTY, OREGON

DATE: FEB 2024 ▪ PROJECT: 6491.0

DELVE underground

FIGURE

7

Appendix A Subsurface Investigation Details

A.1 Subsurface Exploration

Delve Underground performed the subsurface exploration program for the Moon Pit project on September 26, 2023. The investigation included excavating 12 test pits within the Moon Pit site boundary, as shown in Figure 2. The test pits were excavated to depths ranging from 2.6 to 7.0 feet below ground surface (bgs) by Terry Shine Excavating of Bend, Oregon, performed using a CAT 416 C backhoe equipped with a 2-foot-wide toothed bucket. Test pits were terminated at depths where equipment met refusal as a result of increased material hardness. The test pit locations and depths are summarized in Table A-1 below. Test pit logs are provided in Appendix B and photographs in Appendix C.

A Delve Underground geologist was on site to log and photograph subsurface and excavating conditions during the subsurface investigation. Select soil samples were bagged in zipper-type storage bags and delivered to Delve Underground's office for further evaluation. Soils were visually classified according to the American Society for Testing and Materials (ASTM) D2488 Standard Practice for Description and Identification of Soils: Visual-Manual Procedure. Upon completion of the test pits, the trenches were backfilled with excavated soils and restored to the original ground surface level.

Table A-1. Test Pit Summary

Designation	Latitude/Longitude	Ground Surface Elevation (ft)	Final Depth (ft bgs)
TP-01	43.950691 / -121.007276	3,592	2.6
TP-02	43.951063 / -121.002749	3,605	4
TP-03	43.957101 / -121.001974	3,603	7
TP-04	43.952976 / -120.996908	3,655	6
TP-05	43.950349 / -120.998142	3,623	6
TP-06	43.948604 / -120.993887	3,667	4
TP-07	43.94699 / -120.997241	3,655	3.5
TP-08	43.94478 / -120.99637	3,703	4
TP-09	43.94564 / -120.988581	3,721	6
TP-10	43.942705 / -120.989747	3,758	7
TP-11	43.94366 / -120.99387	3,745	2
TP-12	43.94361 / -120.99606	3,762	7

Appendix B Test Pit Logs

MOISTURE CONTENT

DESCRIPTION	CONDITION
Dry	Absence of moisture, dusty, dry to the touch.
Moist	Damp, but no visible water.
Wet	Visible free water, typically below water table.

ABBREVIATIONS

SYMBOL	DEFINITION
⊢⊣	Atterberg Limits
○	Moisture Content
□	Blows per foot (N)
●	WDP Blows per 6 in.

FINE-GRAINED SOIL CONSISTENCY

RELATIVE CONSISTENCY	N, SPT *Blows/foot*	FIELD TEST
Very Soft	0 to 1	Easily penetrated by thumb. Extrudes between thumb and fingers when squeezed.
Soft	2 to 4	Easily penetrated one inch by thumb. Molded by light finger pressure.
Medium stiff	5 to 8	Can be penetrated over ¼ inch with moderate pressure. Molded by strong finger pressure.
Stiff	9 to 15	Indented about ¼ inch by thumb, but penetrated only with great effort.
Very Stiff	16 to 30	Readily indented by thumbnail.
Hard	> 30	Indented with difficulty by thumbnail.

COARSE-GRAINED SOIL DENSITY

Relative Density	N, SPT *Blows/foot*
Very Loose	0 to 4
Loose	5 to 10
Medium Dense	11 to 30
Dense	31 to 50
Very Dense	> 50

PERCENTAGE RANGE TERMS[1,2]

DESCRIPTION	RANGE
Trace	< 5%
Few	5 to 10%
Little	15 to 25%
Some	30 to 45%
Mostly	50 to 100%

1. Gravel, Sand and fines are estimated by mass. Other constituents such as organics, cobbles, and boulders are estimated by volume.
2. Percentages per ASTM D2488.

SOIL CONSTITUENCY DEFINITIONS

CONSTITUENT	COARSE-GRAINED	FINE-GRAINED
Major	Less than 50% fines: **SAND** or **GRAVEL**	More than 50% fines: **SILT, ELASTIC SILT, LEAN CLAY, FAT CLAY, ORGANIC SOIL**
Secondary	12%[1] or more fine-grained: **Silty** or **Clayey**	30% or more coarse-grained: **Sandy** or **Gravelly**
Minor	5 to 12%[1] fine-grained: **with Silt** or **with Clay**	15 to 30% coarse-grained: **with Sand** or **with Gravel**
	15% or more of a second coarse-grained constituent: **with Sand** or **with Gravel**	30% or more total coarse-grained and the lesser coarse constituent is 15% or more: **with Sand** or **with Gravel**

1. ASTM D2488 specifies more than 15% fines

PARTICLE SIZE DEFINITIONS

DESCRIPTON		SIEVE SIZE *PER ASTM D2488*
FINES		< #200 (0.075 mm)
SAND	*Fine*	#200 to #40 (0.075 to 0.4 mm)
	Medium	#40 to #10 (0.4 to 2 mm)
	Coarse	#10 to #4 (0.4 to 4.75 mm)
GRAVEL	*Fine*	#4 to ¾ in. (4.75 to 19 mm)
	Medium	¾ to 3 in. (19 to 76 mm)
COBBLES		3 to 12 in. (76 to 305 mm)
BOULDERS		> 12 in. (305 mm)

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KEY TO SUBSURFACE LOGS

UNIFIED SOIL CLASSIFICATION SYSTEM (USCS)[1]

MAJOR DIVISIONS			SYMBOL		TYPICAL DESCRIPTION	ALTERNATE DESCRIPTIONS
COARSE-GRAINED SOILS (50% OR MORE RETAINED BY NO. 200 SIEVE)	GRAVELS (MORE THAN 50% RETAINED ON NO. 4 SIEVE)	CLEAN GRAVELS (≤ 5% FINES)	GW	▨	WELL-GRADED GRAVEL	WELL-GRADED GRAVEL WITH SAND
			GP	▨	POORLY GRADED GRAVEL	POORLY GRADED GRAVEL WITH SAND
		GRAVELS[2,4] (5 – 12 % FINES)	GW-GM	▨	WELL-GRADED GRAVEL WITH SILT	WELL-GRADED GRAVEL WITH SILT AND SAND
			GW-GC	▨	WELL-GRADED GRAVEL WITH CLAY	WELL-GRADED GRAVEL WITH CLAY AND SAND
			GP-GM	▨	POORLY GRADED GRAVEL WITH SILT	POORLY GRADED GRAVEL WITH SILT AND SAND
			GP-GC	▨	POORLY GRADED GRAVEL WITH CLAY	POORLY GRADED GRAVEL WITH CLAY AND SAND
		GRAVELS WITH FINES[2] (≥ 12% FINES)	GM	▨	SILTY GRAVEL	SILTY GRAVEL WITH SAND
			GC	▨	CLAYEY GRAVEL	CLAYEY GRAVEL WITH SAND
	SANDS (LESS THAN 50% RETAINED ON NO. 4 SIEVE)	CLEAN SANDS (≤ 5% FINES)	SW	⁘	WELL-GRADED SAND	WELL-GRADED SAND WITH GRAVEL
			SP	░	POORLY GRADED SAND	POORLY GRADED SAND WITH GRAVEL
		SANDS[2,4] (5 – 12 % FINES)	SW-SM	▥	WELL-GRADED SAND WITH SILT	WELL-GRADED SAND WITH SILT AND GRAVEL
			SW-SC	▨	WELL-GRADED SAND WITH CLAY	WELL-GRADED SAND WITH CLAY AND GRAVEL
			SP-SM	▥	POORLY GRADED SAND WITH SILT	POORLY GRADED SAND WITH SILT AND GRAVEL
			SP-SC	▨	POORLY GRADED SAND WITH CLAY	POORLY GRADED SAND WITH CLAY AND GRAVEL
		SANDS WITH FINES[3] (> 12% FINES)	SM	▥	SILTY SAND	SILTY SAND WITH GRAVEL
			SC	▨	CLAYEY SAND	CLAYEY SAND WITH GRAVEL
FINE-GRAINED SOILS (50% OR MORE PASSES NO. 200 SIEVE)	SILTS AND CLAYS (LL < 50)	INORGANIC	ML	▥	SILT	SILT WITH SAND OR GRAVEL; SANDY OR GRAVELLY SILT
			CL	▨	LEAN CLAY	LEAN CLAY WITH SAND OR GRAVEL; SANDY OR GRAVELLY LEAN CLAY
		ORGANIC	OL	▧	ORGANIC SOIL	ORGANIC SOIL WITH SAND OR GRAVEL; SANDY OR GRAVELLY ORGANIC SOIL
	SILTS AND CLAYS (LL ≥ 50)	INORGANIC	MH	▥	ELASTIC SILT	ELASTIC SILT WITH SAND OR GRAVEL; SANDY OR GRAVELLY ELASTIC SILT
			CH	▨	FAT CLAY	FAT CLAY WITH SAND OR GRAVEL; SANDY OR GRAVELLY FAT CLAY
		ORGANIC	OH	▧	ORGANIC SOIL	ORGANIC SOIL WITH SAND OR GRAVEL; SANDY OR GRAVELLY ORGANIC SOIL
	SILT/CLAY[2]	INORGANIC	CL-ML	▨	SILTY CLAY	SILTY CLAY WITH SAND OR GRAVEL; SANDY OR GRAVELLY SILTY CLAY
HIGHLY ORGANIC SOILS		ORGANIC	PT	▭	PEAT	

NOTES:

1. The USCS described here is based on ASTM standards D2487 & D2488.
2. Dual symbol materials (e.g., SP-SM) are used for soils between 5% and 12% fines or when liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart, (LL: 12 -25, PI: 4-7).
3. ASTM D2488 specifies the use of dual symbol coarse-grained soils between 5% and 15% fines.

BACKFILL, WELL, AND SAMPLE SYMBOLS					
▦	Bentonite Chips	▧	Grout	⧗	2" OD Split Barrel Sampler
▩	Concrete	◫	Observation Well - Solid	■	Shelby Tube Sample
░	Sand	☰	Observation Well – Screen	✋	Grab Sample
■	Asphalt	▮	Vibrating Wire Piezometer	⋈	3" OD Split Barrel Sampler
⁘	Gravel	▼	Measured Groundwater Level		

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KEY TO SUBSURFACE LOGS

Project: Phase 2 Final SWMF Site Evaluation
Project Location: Deschutes County
Project Number: 6491.0

Log of Test Pit TP-01

Date(s)	Sep 26, 2023	Equipment	CAT 416C Backhoe	Total Depth	2.6 ft
Logged By	J. Siemens	Bucket Type	2-foot toothed	Ground Elev.	3592 ft
Location	Moon Pit	Contractor	Terry Shine	Vert. Datum	NAVD 88
Coordinates	43.95069°, -121.00728°	Coord. Sys.	WGS84 (Latitude/Longitude)		

DEPTH (FT)	USCS GRAPHIC	USCS SYMBOL	MATERIAL DESCRIPTION	SAMPLE	NUMBER	TEST RESULTS 25 50 75	REMARKS
		SM	Dry, light brown, Silty SAND (SM); fine to coarse sand, trace 1/8-inch rootlets. (Loess)				
1		GW	Dry, light brown, Well-graded GRAVEL with Sand (GW); fine to coarse subrounded gravel, fine to coarse sand, calcite cementation, occasional voids observed within unit. (Bedrock) *Equipment met practical refusal.*				
2							
3			Test Pit completed at 2.6 ft. below ground surface (bgs).				
4							
5							
6							
7							
8							
9							

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Sample Symbols

Test Symbols

○ Moisture Content (MC)
❙ Liquid Limit/Plastic Limit (LL/PL)
☐ Fines Content (FC)

Test Pit TP-01

Sheet 1 of 1

Project: Phase 2 Final SWMF Site Evaluation
Project Location: Deschutes County
Project Number: 6491.0

Log of Test Pit TP-02

Date(s)	Sep 26, 2023	Equipment	CAT 416C Backhoe	Total Depth	4.0 ft
Logged By	J. Siemens	Bucket Type	2-foot toothed	Ground Elev.	3605 ft
Location	Moon Pit	Contractor	Terry Shine	Vert. Datum	NAVD 88
Coordinates	43.95106°, -121.00275°	Coord. Sys.	WGS84 (Latitude/Longitude)		

DEPTH (FT)	USCS SYMBOL	MATERIAL DESCRIPTION	SAMPLE	NUMBER	TEST RESULTS 25 50 75	REMARKS
0–1.5	SM	Dry, light brown, Silty SAND (SM); fine to coarse sand, ≤1-inch roots. (Loess)				
1.5–4	GW	Dry, light brown, Well-graded GRAVEL with Sand (GW); fine to coarse subrounded gravel, fine to coarse sand, calcite cementation. (Bedrock?) *Equipment met practical refusal.*	✋	S-1		

Test Pit completed at 4.0 ft. below ground surface (bgs).

Depth scale: 1 2 3 4 5 6 7 8 9

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underground

Sample Symbols

✋ Grab sample

Test Symbols

○ Moisture Content (MC)
| Liquid Limit/Plastic Limit (LL/PL)
☐ Fines Content (FC)

Test Pit TP-02

Sheet 1 of 1

Project: Phase 2 Final SWMF Site Evaluation
Project Location: Deschutes County
Project Number: 6491.0

Log of Test Pit TP-03

Date(s)	Sep 26, 2023	Equipment	CAT 416C Backhoe	Total Depth	7.0 ft
Logged By	J. Siemens	Bucket Type	2-foot toothed	Ground Elev.	3603 ft
Location	Moon Pit	Contractor	Terry Shine	Vert. Datum	NAVD 88
Coordinates	43.95710°, -121.00197°	Coord. Sys.	WGS84 (Latitude/Longitude)		

DEPTH (FT)	USCS SYMBOL	MATERIAL DESCRIPTION	SAMPLE	NUMBER	TEST RESULTS 25 50 75	REMARKS
0–1	SM	Dry, light brown, Silty SAND (SM); fine to coarse sand, rootlets. (Loess)				
1–7	GW	Dry, light brown, Well-graded GRAVEL with cobbles and boulders (GW); ≤18-inch boulders, ≤12-inch cobbles, fine to coarse sub-angular gravel, fine to coarse sand. (Colluvium) *Below 3.5 feet, boulder diameter increases to ≤3 feet.* *Equipment met practical refusal.*				
7		Test Pit completed at 7.0 ft. below ground surface (bgs).				

Sample Symbols

Test Symbols

○ Moisture Content (MC)
| Liquid Limit/Plastic Limit (LL/PL)
☐ Fines Content (FC)

Test Pit TP-03

Sheet 1 of 1

Project: Phase 2 Final SWMF Site Evaluation
Project Location: Deschutes County
Project Number: 6491.0

Log of Test Pit TP-04

Date(s)	Sep 26, 2023	Equipment	CAT 416C Backhoe	Total Depth	6.0 ft
Logged By	J. Siemens	Bucket Type	2-foot toothed	Ground Elev.	3655 ft
Location	Moon Pit	Contractor	Terry Shine	Vert. Datum	NAVD 88
Coordinates	43.95298°, -120.99691°	Coord. Sys.	WGS84 (Latitude/Longitude)		

DEPTH (FT)	USCS GRAPHIC	USCS SYMBOL	MATERIAL DESCRIPTION	SAMPLE	NUMBER	TEST RESULTS 25 50 75	REMARKS
0–6		GW	Dry, light brown, Well-graded GRAVEL with sand and cobbles (GW); fine to coarse subrounded to subangular gravel, fine to coarse sand, subrounded to subangular cobbles, trace boulders, trace silt., dense roots to 0.5 feet bgs. (Colluvium) *Roots from ground surface to 1.5 feet.* *Equipment met practical refusal.*				
6			Test Pit completed at 6.0 ft. below ground surface (bgs).				

Depth scale: 1 2 3 4 5 6 7 8 9

Sample Symbols

Test Symbols

○ Moistue Content (MC)
❙ Liquid Limit/Plastic Limit (LL/PL)
☐ Fines Content (FC)

DELVE
underground

Test Pit TP-04

Sheet 1 of 1

Project: Phase 2 Final SWMF Site Evaluation
Project Location: Deschutes County
Project Number: 6491.0

Log of Test Pit TP-05

Date(s)	Sep 26, 2023	Equipment	CAT 416C Backhoe	Total Depth	6.0 ft
Logged By	J. Siemens	Bucket Type	2-foot toothed	Ground Elev.	3623 ft
Location	Moon Pit	Contractor	Terry Shine	Vert. Datum	NAVD 88
Coordinates	43.95035°, -120.99814°	Coord. Sys.	WGS84 (Latitude/Longitude)		

DEPTH (FT)	USCS GRAPHIC	USCS SYMBOL	MATERIAL DESCRIPTION	SAMPLE	NUMBER	TEST RESULTS 25 50 75	REMARKS
1		SM	Dry, light brown, Silty SAND (SM); fine to coarse sand, trace roots. (Loess)				
2		SW-SM	Dry, blue-gray, Well-graded Silty SAND (SW-SM); fine to coarse, pumice, quartz, and basalt sand, trace fine to coarse gravel. (Alluvium)	✋	S-1		
3 4 5		GW	Dry, light brown, Well-graded GRAVEL with sand and cobbles (GW); subrounded cobbles, fine to coarse subrounded to subangular gravel, fine to coarse sand, trace silt. (Bedrock) *Equipment met practical refusal.*				
6 7 8 9			Test Pit completed at 6.0 ft. below ground surface (bgs).				

DELVE underground

Sample Symbols

✋ Grab sample

Test Symbols

○ Moisture Content (MC)
| Liquid Limit/Plastic Limit (LL/PL)
☐ Fines Content (FC)

Test Pit TP-05

Sheet 1 of 1

Project: Phase 2 Final SWMF Site Evaluation
Project Location: Deschutes County
Project Number: 6491.0

Log of Test Pit TP-06

Date(s)	Sep 26, 2023	Equipment	CAT 416C Backhoe	Total Depth	4.0 ft
Logged By	J. Siemens	Bucket Type	2-foot toothed	Ground Elev.	3667 ft
Location	Moon Pit	Contractor	Terry Shine	Vert. Datum	NAVD 88
Coordinates	43.94860°, -120.99389°	Coord. Sys.	WGS84 (Latitude/Longitude)		

DEPTH (FT)	USCS SYMBOL	MATERIAL DESCRIPTION	SAMPLE	NUMBER	TEST RESULTS 25 50 75	REMARKS
0–2	SM	Dry, light brown, Silty SAND (SM); fine to coarse sand, weakly cemented, roots. (Alluvium)				
2–4	GW-GM	Dry, light brown, Well-graded GRAVEL with silt, sand, and cobbles (GW-GM); subrounded to subangular basalt cobbles, fine to coarse subrounded gravel, fine to coarse sand, trace ≤2-foot boulders, weak to moderate cementation. (Bedrock) *Equipment met practical refusal.*				
4		Test Pit completed at 4.0 ft. below ground surface (bgs).				

Depth scale: 1 2 3 4 5 6 7 8 9

Sample Symbols

Test Symbols

○ Moisture Content (MC)
| Liquid Limit/Plastic Limit (LL/PL)
☐ Fines Content (FC)

DELVE
underground

Test Pit TP-06

Sheet 1 of 1

Project: Phase 2 Final SWMF Site Evaluation
Project Location: Deschutes County
Project Number: 6491.0

Log of Test Pit TP-07

Date(s)	Sep 26, 2023	Equipment	CAT 416C Backhoe	Total Depth	3.5 ft
Logged By	J. Siemens	Bucket Type	2-foot toothed	Ground Elev.	3665 ft
Location	Moon Pit	Contractor	Terry Shine	Vert. Datum	NAVD 88
Coordinates	43.94699°, -120.99724°	Coord. Sys.	WGS84 (Latitude/Longitude)		

DEPTH (FT)	USCS GRAPHIC	USCS SYMBOL	MATERIAL DESCRIPTION	SAMPLE	NUMBER	TEST RESULTS 25 50 75	REMARKS
1 2		SM	Moist, brown, Silty SAND (SM); fine to coarse sand, trace ≤0.5-inch roots. (Alluvium)				
3		SM	Dry, light brown Silty SAND with gravel and cobbles (SW); ≤6-inch basalt cobbles, fine to coarse gravel, fine to coarse sand. (Bedrock) *Equipment met practical refusal.*	✋	S-1		
4 5 6 7 8 9			Test Pit completed at 3.5 ft. below ground surface (bgs).				

DELVE
underground

Sample Symbols

✋ Grab sample

Test Symbols

○ Moisture Content (MC)
| Liquid Limit/Plastic Limit (LL/PL)
☐ Fines Content (FC)

Test Pit TP-07

Sheet 1 of 1

Project: Phase 2 Final SWMF Site Evaluation
Project Location: Deschutes County
Project Number: 6491.0

Log of Test Pit TP-08

Date(s)	Sep 26, 2023	Equipment	CAT 416C Backhoe	Total Depth	4.0 ft
Logged By	J. Siemens	Bucket Type	2-foot toothed	Ground Elev.	3703 ft
Location	Moon Pit	Contractor	Terry Shine	Vert. Datum	NAVD 88
Coordinates	43.94478°, -120.99637°	Coord. Sys.	WGS84 (Latitude/Longitude)		

DEPTH (FT)	USCS GRAPHIC	USCS SYMBOL	MATERIAL DESCRIPTION	SAMPLE	NUMBER	TEST RESULTS 25 50 75	REMARKS
0–2.5		SM	Dry, light brown, Silty SAND (SM); fine to coarse sand, trace fine to coarse subrounded gravel, trace ≤1-inch roots. (Alluvium)				
2.5–4		GW	Dry, light brown, Well-graded GRAVEL with sand (GW); fine to coarse subrounded gravel, fine to coarse sand, trace ≤8-inch basalt cobbles, trace roots to 3 feet bgs. (Bedrock) *Equipment met practical refusal.*				
4			Test Pit completed at 4.0 ft. below ground surface (bgs).				

Depth scale: 1 2 3 4 5 6 7 8 9

Sample Symbols

Test Symbols

○ Moisture Content (MC)
❙ Liquid Limit/Plastic Limit (LL/PL)
☐ Fines Content (FC)

DELVE
underground

Test Pit TP-08

Sheet 1 of 1

Project: Phase 2 Final SWMF Site Evaluation
Project Location: Deschutes County
Project Number: 6491.0

Log of Test Pit TP-09

Date(s)	Sep 26, 2023	Equipment	CAT 416C Backhoe	Total Depth	6.0 ft
Logged By	J. Siemens	Bucket Type	2-foot toothed	Ground Elev.	3721 ft
Location	Moon Pit	Contractor	Terry Shine	Vert. Datum	NAVD 88
Coordinates	43.94564°, -120.98858°	Coord. Sys.	WGS84 (Latitude/Longitude)		

DEPTH (FT)	USCS GRAPHIC	USCS SYMBOL	MATERIAL DESCRIPTION	SAMPLE	NUMBER	TEST RESULTS 25 50 75	REMARKS
0–3.5		SM	Dry, light brown, Silty SAND (SM); fine to coarse sand, trace roots. (Alluvium) *Root mat at 2.5 feet.*				
3.5–6		GW	Dry, brown, Well-graded GRAVEL with silt and cobbles (GW); subangular basalt cobbles, fine to coarse angular to subangular gravel, trace fine to coarse sand. (Bedrock) *Discontinuous root mat at 3.5 feet.* *Equipment met practical refusal.*				
6			Test Pit completed at 6.0 ft. below ground surface (bgs).				

Sample Symbols

Test Symbols

○ Moisture Content (MC)
| Liquid Limit/Plastic Limit (LL/PL)
☐ Fines Content (FC)

DELVE
underground

Test Pit TP-09

Sheet 1 of 1

Project: Phase 2 Final SWMF Site Evaluation
Project Location: Deschutes County
Project Number: 6491.0

Log of Test Pit TP-10

Date(s)	Sep 26, 2023	Equipment	CAT 416C Backhoe	Total Depth	7.0 ft
Logged By	J. Siemens	Bucket Type	2-foot toothed	Ground Elev.	3758 ft
Location	Moon Pit	Contractor	Terry Shine	Vert. Datum	NAVD 88
Coordinates	43.94270°, -120.98975°	Coord. Sys.	WGS84 (Latitude/Longitude)		

DEPTH (FT)	USCS GRAPHIC	USCS SYMBOL	MATERIAL DESCRIPTION	SAMPLE	NUMBER	TEST RESULTS 25 50 75	REMARKS
		GW-GM	Dry, gray-brown, Well-graded GRAVEL with silt and sand (GW-GM); coarse subangular to subrounded gravel, fine to coarse sand, trace roots. (Fill)				
1 2 3 4 5		SM	Moist, brown, Silty SAND (SM); fine to coarse sand, thin to medium fining upward bedding, roots to 3.5 feet bgs. (Alluvium) *Root mat at 3.5 feet.*				
6		GW	Dry, brown, Well-graded GRAVEL with silt and sand (GW); angular 6 to12-inch basalt cobbles, fine to coarse angular to subangular gravel, fine to coarse sand. (Bedrock) *Equipment met practical refusal.*				
7 8 9			Test Pit completed at 7.0 ft. below ground surface (bgs).				

DELVE underground

Sample Symbols

Test Symbols

○ Moisture Content (MC)
| Liquid Limit/Plastic Limit (LL/PL)
☐ Fines Content (FC)

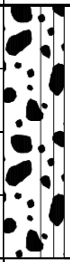
Test Pit TP-10

Sheet 1 of 1

Project: Phase 2 Final SWMF Site Evaluation
Project Location: Deschutes County
Project Number: 6491.0

Log of Test Pit TP-11

Date(s)	Sep 26, 2023	Equipment	CAT 416C Backhoe	Total Depth	2.0 ft
Logged By	J. Siemens	Bucket Type	2-foot toothed	Ground Elev.	3745 ft
Location	Moon Pit	Contractor	Terry Shine	Vert. Datum	NAVD 88
Coordinates	43.94366°, -120.99387°	Coord. Sys.	WGS84 (Latitude/Longitude)		

DEPTH (FT)	USCS GRAPHIC	USCS SYMBOL	MATERIAL DESCRIPTION	SAMPLE	NUMBER	TEST RESULTS 25 50 75	REMARKS
0–2 1		GW-GM	Dry, light brown, Well-graded GRAVEL with silt and sand (GW-GM); fine to coarse subangular gravel, fine to coarse sand, trace ≤10-inch cobbles, roots. (Bedrock) *Equipment met practical refusal.*				
2 3 4 5 6 7 8 9			Test Pit completed at 2.0 ft. below ground surface (bgs).				

Sample Symbols

Test Symbols

○ Moisture Content (MC)
| Liquid Limit/Plastic Limit (LL/PL)
☐ Fines Content (FC)

Test Pit TP-11

Sheet 1 of 1

Project: Phase 2 Final SWMF Site Evaluation
Project Location: Deschutes County
Project Number: 6491.0

Log of Test Pit TP-12

Date(s)	Sep 26, 2023	Equipment	CAT 416C Backhoe	Total Depth	7.0 ft
Logged By	J. Siemens	Bucket Type	2-foot toothed	Ground Elev.	3762 ft
Location	Moon Pit	Contractor	Terry Shine	Vert. Datum	NAVD 88
Coordinates	43.94361°, -120.99606°	Coord. Sys.	WGS84 (Latitude/Longitude)		

DEPTH (FT)	USCS GRAPHIC	USCS SYMBOL	MATERIAL DESCRIPTION	SAMPLE	NUMBER	TEST RESULTS 25 50 75	REMARKS
1 2		SM	Dry, light brown, Silty SAND (SM); fine to coarse pumiceous sand, roots. (Alluvium)				
3 4 5 6		GW-GM	Dry, light brown, Well-graded GRAVEL with silt and sand (GW-GM); fine to coarse subangular to subrounded gravel, fine to coarse sand, trace ≤12-inch cobbles, roots to 4 feet bgs. (Bedrock) *Equipment met practical refusal.*	✋	S-1		
7 8 9			Test Pit completed at 7.0 ft. below ground surface (bgs).				

DELVE underground

Sample Symbols

✋ Grab sample

Test Symbols

○ Moisture Content (MC)
| Liquid Limit/Plastic Limit (LL/PL)
☐ Fines Content (FC)

Test Pit TP-12

Sheet 1 of 1

Appendix C Site Photographs

Photo 1. Example of subsurface materials encountered in TP-4. Gravel to cobble materials within a sandy matrix is the upper weathering profile of bedrock.

Photo 2. Subsurface materials in TP-5 with more of a well-defined interbed appearance.

Photo 3. Spoils from TP-12 with large pumice cobbles and boulder. Tape measure and note case for scale.

Photo 4. Backhoe excavating into the toe of the slope at the location of TP-4. Sandy colluvium with cobbles and boulders from upslope bedrock.

Appendix D Geologic Hazards

D.1 Geologic Hazards

Geologic hazards are conditions associated with the geologic and seismic environment that could adversely influence site development. Geologic hazards for the site were assessed by reviewing publicly available GIS data through the DOGAMI HazVu portal, statewide landslide information database for Oregon (SLIDO), and the USGS Quaternary Fault and Fold Database (DOGAMI, 2023; USGS 2023a). In addition, Delve Underground reviewed aerial photographs and available published geologic maps to evaluate geologic hazards. Relevant geologic hazards identified within DOGAMI HazVu are discussed within this section.

D.1.1 Mapped Landslides

Landslides are caused by a combination of climate, geology, and topography. Primary triggers of landslides are precipitation, earthquakes, and human activity. An important part of determining the risk of a landslide at a given site is to locate existing landslides in the area. Review of SLIDO indicates there are no mapped historical landslides at the site or adjacent slopes (SLIDO, 2021). In addition, inspection of aerial photographs and published geologic maps did not identify any landslide morphology within the project area.

D.1.2 Landslide Susceptibility

Landslide susceptibility is determined by factors such as susceptible geologic units, susceptible geologic contacts, geomorphic indicators, proximity to existing landslides, and slope angles. Landslide susceptibility at the site is estimated generally to be low. Areas of high landslide susceptibility are relatively small and limited to the areas where the steepest slopes are observed.

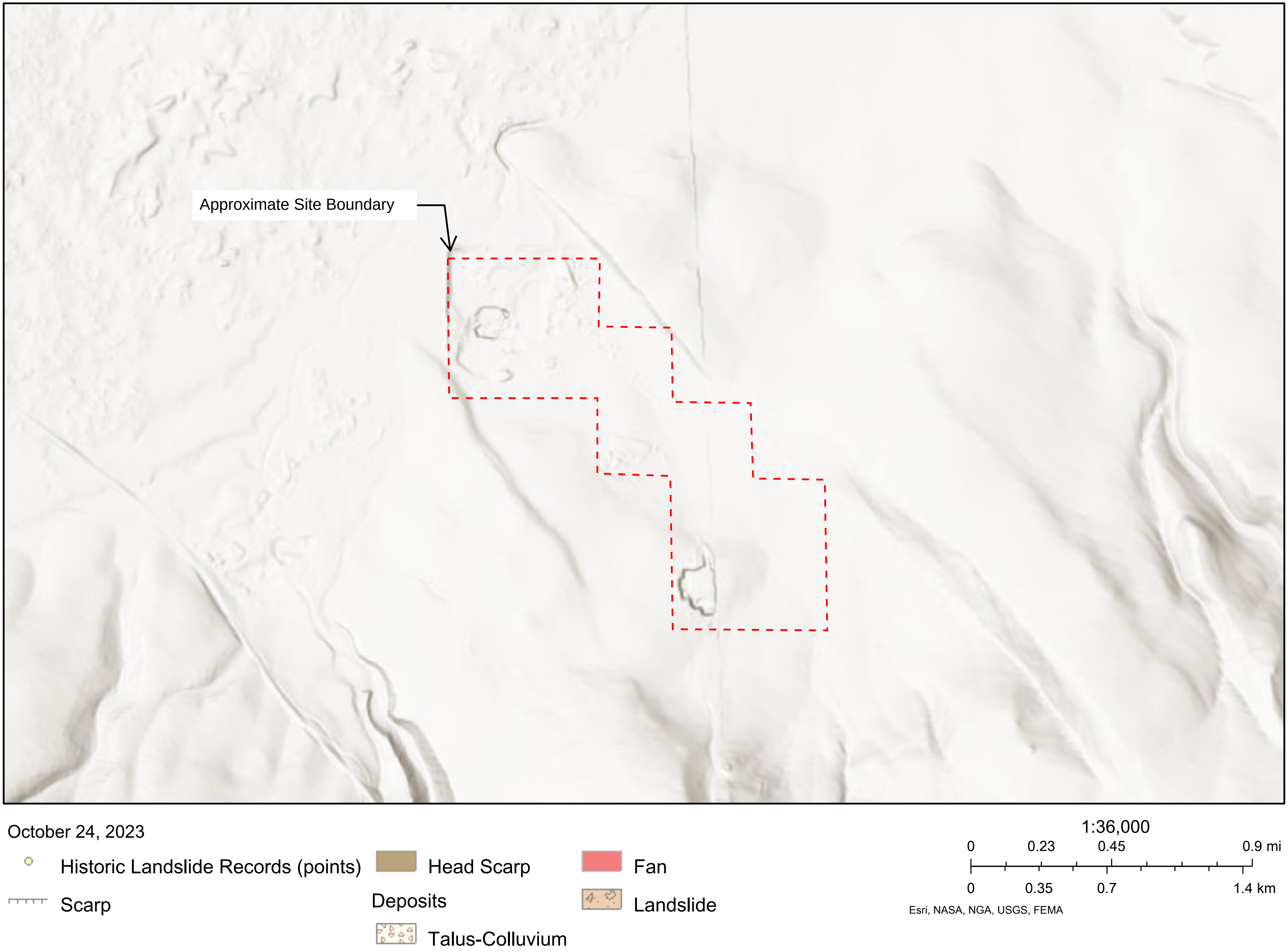
D.1.3 Volcanic Hazards

Volcanic eruptions are likely to occur in Oregon within the Cascade Range. Volcanic hazards can include any combination of the deposition of ash (tephra), lava flows, lahars, avalanches, and pyroclastic flows. The site is mapped outside of a volcanic hazard zone.

D.1.4 Fault Rupture

Fault surface rupture is the expression of surface deformation generated along a fault during an earthquake. Surface ruptures can result in lateral or vertical displacements, or both, and generate visible fractures such as scarps and fissures. Surface ruptures can cause significant damage to roads, structures, and infrastructure intersected by a fault. Surface ruptures are largely dependent on the magnitude of an earthquake along a fault. The larger the magnitude of an earthquake, the more well-defined and destructive a surface rupture may be, while smaller earthquakes may not produce a surface rupture at all.

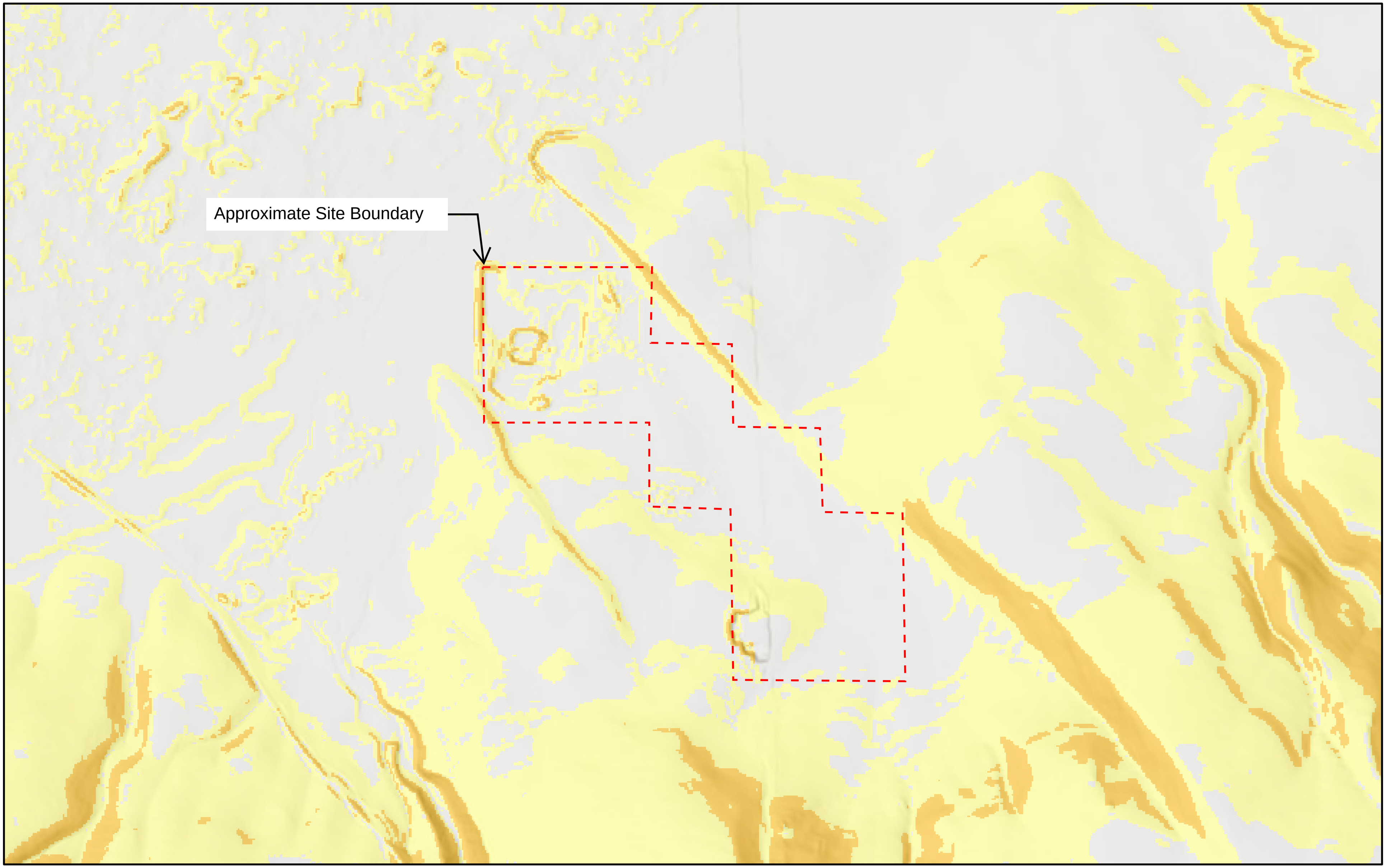
Historic Landslides



October 24, 2023

Esri, NASA, NGA, USGS, FEMA

Statewide Landslide Susceptibility



October 24, 2023

Statewide Landslide Susceptibility Overview Map

⬜ Low

🟨 Moderate

🟧 High

🟥 Very High

○ Historic Landslide Records (points)

┬┬┬┬ Scarp

▨ Head Scarp

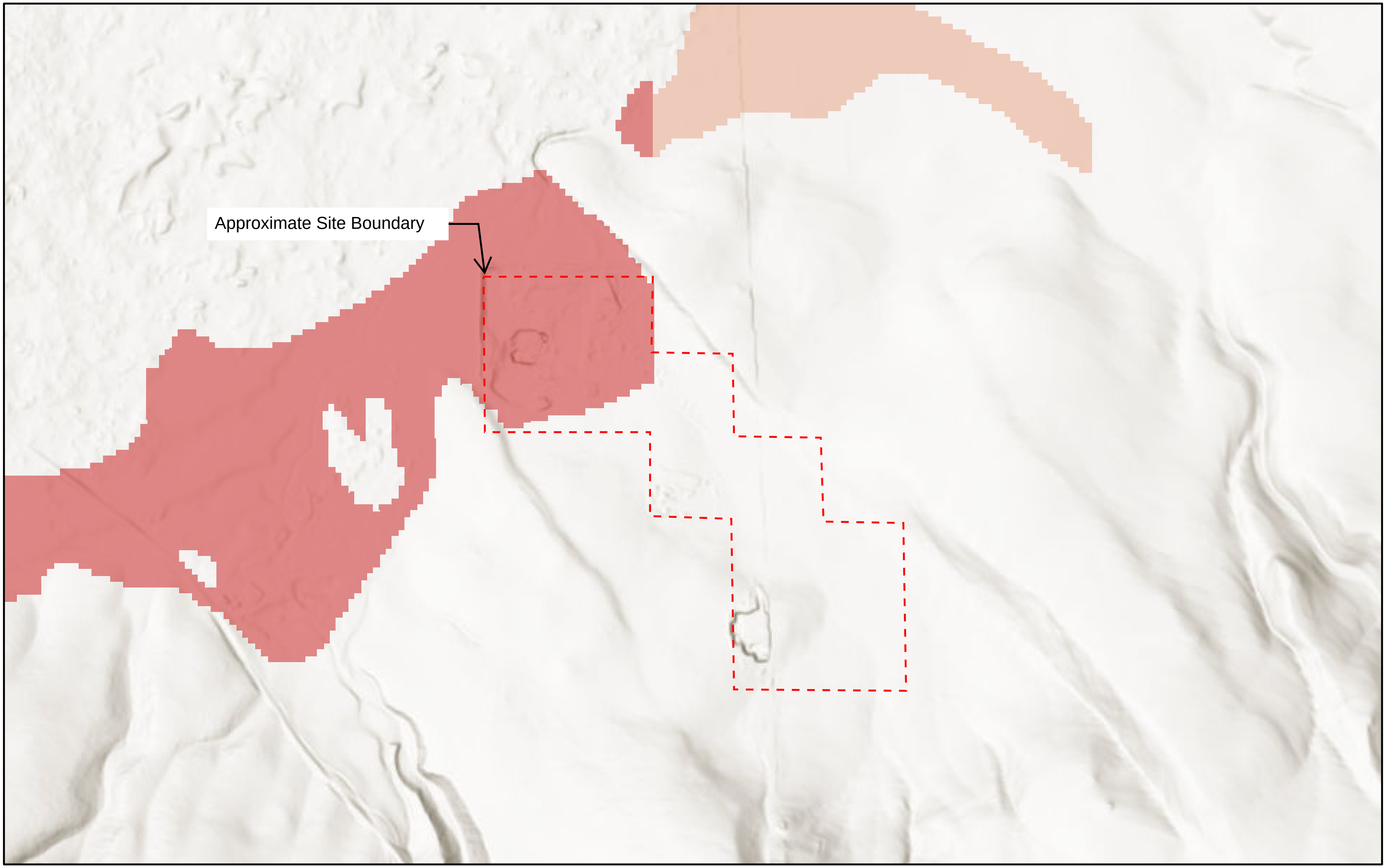
1:36,000

0 0.23 0.45 0.9 mi

0 0.35 0.7 1.4 km

Esri, NASA, NGA, USGS, FEMA

Liquefaction



October 24, 2023

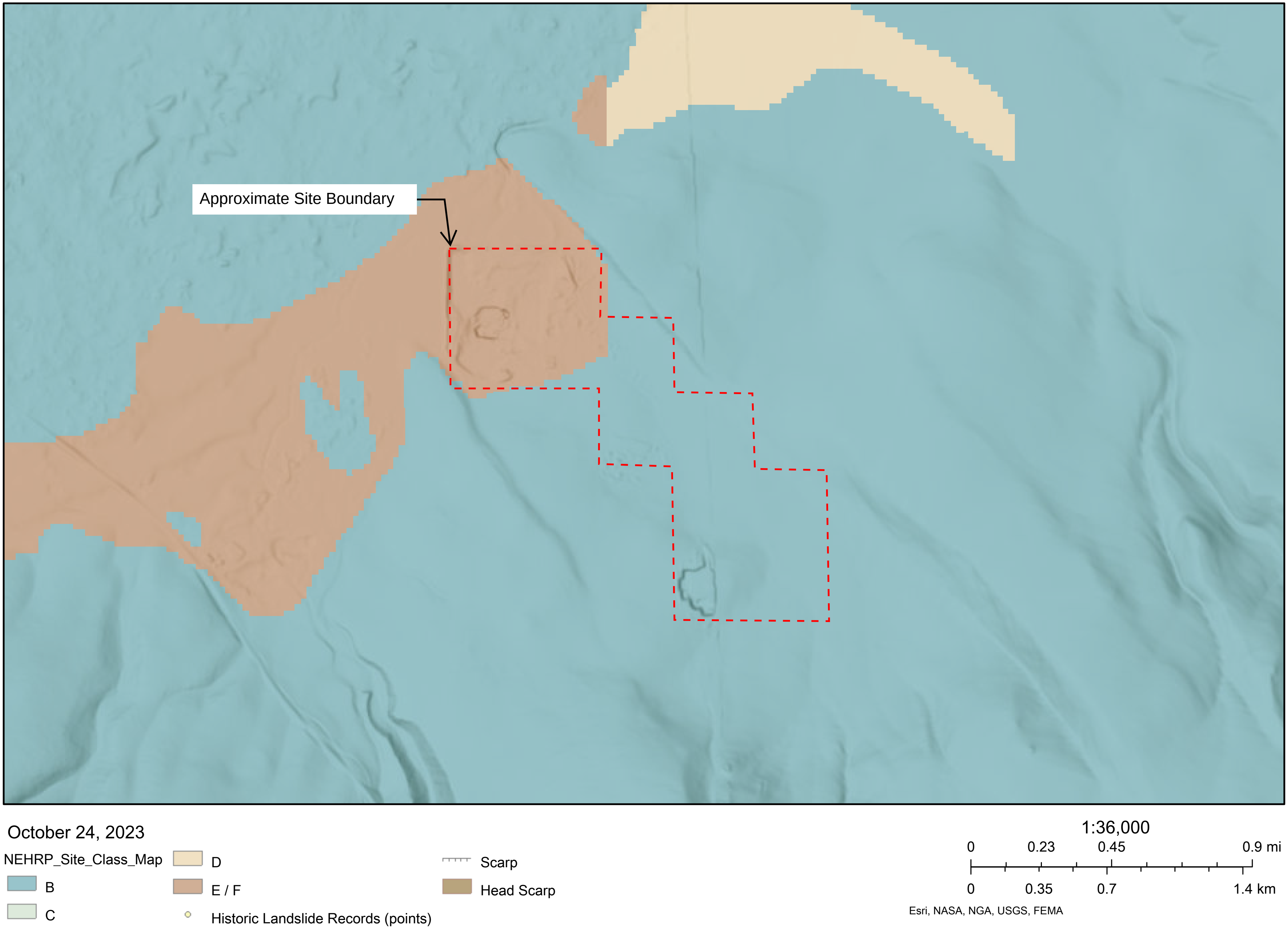
Liquefaction_Susceptibility_Map

- ☐ None
- 🟫 Very Low
- 🟫 Low
- 🟫 Moderate
- 🟥 High
- 🟥 Very High

1:36,000

Esri, NASA, NGA, USGS, FEMA

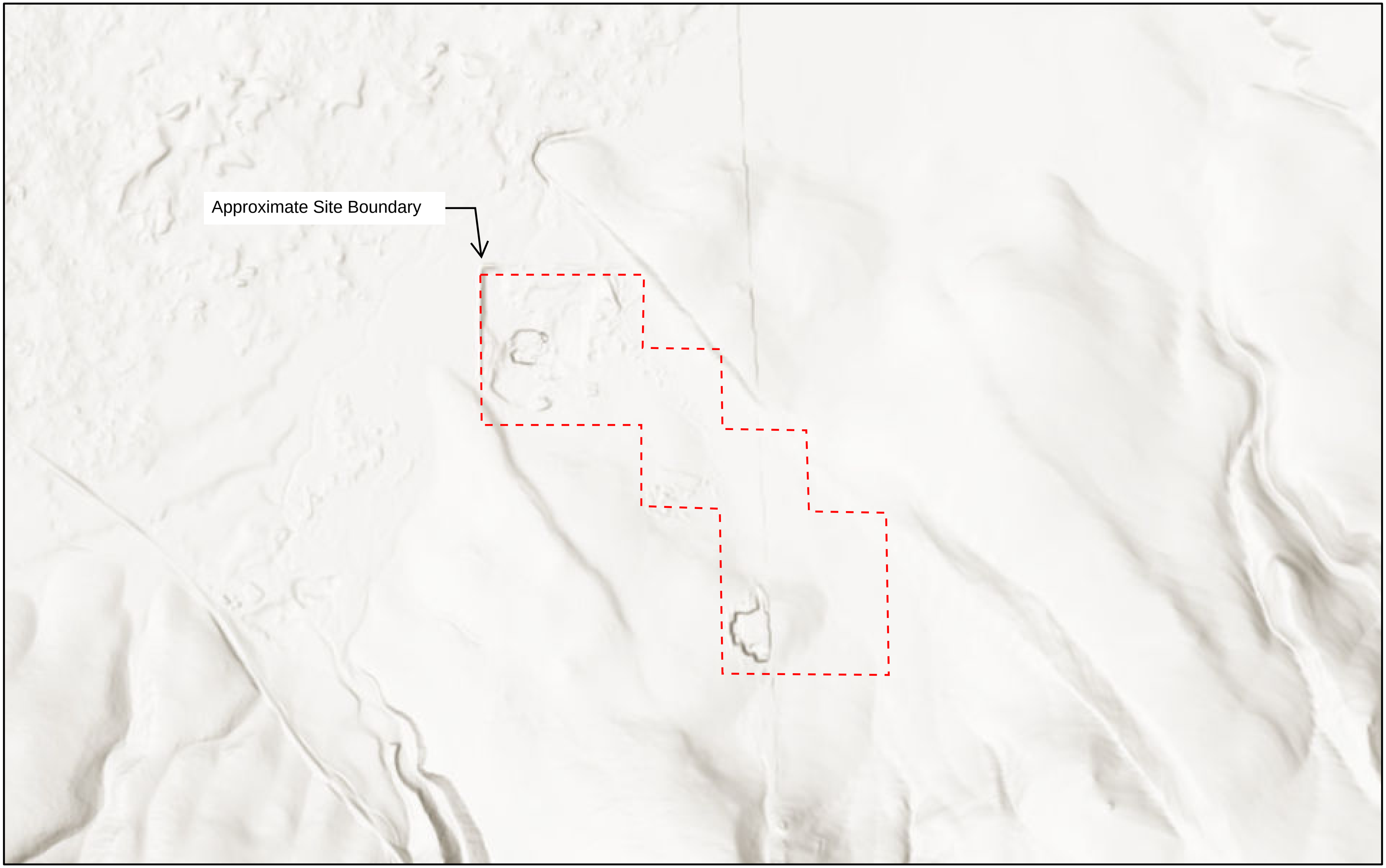
NEHRP SITE CLASS



October 24, 2023

Esri, NASA, NGA, USGS, FEMA

Volcanic Hazard



October 24, 2023

🟥 High Hazard Zone

🟧 Moderate Hazard Zone

1:36,000

0 0.23 0.45 0.9 mi

0 0.35 0.7 1.4 km

Esri, NASA, NGA, USGS, FEMA

No active fault trace is mapped within the site boundary based on review of the USGS Quaternary Fault and Fold Database and DOGAMI HazVu. Given our current understanding of the age of faulting, surface rupture is not a risk to future development.

D.1.5 Ground Shaking

Ground shaking from an earthquake has the potential to damage structures and cause human harm. DOGAMI's Probability of Damaging Shaking map shows the highest shaking level expected at a fixed probability (once in 2,475 years). This is the probability of shaking during the next 50 years at an intensity that weak buildings experience considerable damage and well-built structures have slight to moderate damage. The probability of damaging shaking in the next 50 years from an earthquake the site is estimated to be 10 to 20 percent in the northwest portion and less than 5 percent in the southeast portion (DOGAMI, 2003).

D.1.6 Seismic Site Class (NEHRP)

During an earthquake, soft or loose soil can greatly amplify ground shaking, thereby producing more damage than in areas with firmer or more consolidated soils or bedrock. The National Earthquake Hazard Reduction Program (NEHRP) site classifications can be used to calculate how much amplification will occur during an earthquake and are based on research sponsored by the USGS and Federal Emergency Management Agency (FEMA). The site class for the project is mapped by DOGAMI within a zone of E/F. However, based on the presence of shallow bedrock across the site, we recommend a site class B.

D.1.7 Liquefaction

Liquefaction is a phenomenon affecting saturated, loose, sandy, and low-plasticity silty soils in which cyclic, rapid shearing from an earthquake shaking results in a drastic loss of shear strength and a transformation from a solid mass to a viscous, heavy fluid mass and rapid settlement. The results of soil liquefaction include loss of shear strength, loss of soil materials through sand boils, and post-liquefaction settlement.

The site is classified on HazVu as "very high" susceptibility to liquefaction. However, the presence of shallow bedrock reduces the risk to none in addition the lack of shallow groundwater (see discussion in Section 5.0)

D.1.8 **Other Hazards**

No other significant geologic hazards such as floods, tsunamis, seiches, debris flows, and collapsible soils were identified along the alignments. This is consistent with published hazards and geologic maps for the area.

Appendix E Previous Explorations

MARK V.
HERBERT &
ASSOCIATES
GEOTECHNICAL CONSULTANTS

Attachment 1

April 8, 1993

Mr. Matt Day
65525 Gerking Market Road
Bend, Oregon 97701

Re: Moon Ranch Gravel Pit Evaluation
Deschutes County, Oregon

Dear Matt:

As requested, Mark V. Herbert and Associates has been conducting an evaluation of the Moon Ranch gravel pit. A vicinity map is shown on Figure 1. This letter presents an interim report on data collected thus far, and offers recommendations for the mining operation and further evaluation. The overall purpose of the evaluation is to:

1. Estimate the quantity of the resources available.
2. Assess the quality of the resource.
3. Categorize the different products available.
4. Recommend processing and operational methods.

Additional reports will be submitted as the resource is further defined and laboratory and field data are collected.

Summary

1. Our preliminary estimates of the resources, in cubic yards, are tabulated below:

Topsoil	Sand and Gravel	Silty, Gravelly Sand	Crushable Rock
630,000	725,000	807,000	240,000

How these estimates were determined is described later in the report.

2. The quality of the sand and gravel deposits and crushable rock material appears to be good based on visual evaluation. Laboratory testing will be required if the aggregate is to be used on Oregon State Highway Department projects.

   A laboratory standard Proctor test (ASTM D698) and gradation analysis were conducted on the silty, gravelly sand material. The maximum density was determined to be 100.5 pounds per cubic foot. The gradation analysis showed 4.6 percent passing a No. 200 sieve.

3. Potential marketable products include topsoil, drain rock, pea gravel, coarse concrete aggregate, concrete sand, asphalt aggregate and select structural backfill.

4. In general, the topsoil appears to be more concentrated in the easterly portion of the site. The sand and gravel is of greater thickness in the westerly portion of the site. The silty sand and gravel is of variable thickness across the site and is generally located beneath the coarser sand and gravel. A possible source of crushable rock is located in the far easterly portion of the site.

It is recommended that operations such as crushing, screening and washing be located in the area south of the existing road that travels in an east-west direction through the site. There appears to be little gravel resource south and east of the existing pit. Setting up operations in a "no-resource" area would mean that it would not be necessary to move equipment as aggregate extraction proceeds. Other alternatives are presented in the report.

Washing of the aggregate will be needed for various products, such as concrete sand and pea gravel. This will require the installation of water storage tanks and construction of a waste water sump.

Field Exploration

The resource was explored by making 32 test pit excavations on March 15 and 16, 1993. Test pit locations are shown on Figure 2 and are approximate. Most of the exploration was confined to the 160 acres that is presently approved for surface mining. Twenty-two of the test pits were excavated on a grid pattern, enabling cross-sections of the substrata to be shown graphically. The remaining test pits were excavated in areas further east and south on the property. The test pit logs are shown on Figures 3 thorough 9 attached.

Representative samples of the subsoils were retrieved from selected test pits. The locations of sampling is shown on the test pit logs. The samples were generally scraped from the sides of the test pits at various depths. The samples are believed to be representative of the areas chosen for sampling.

Laboratory Testing

At the present time, laboratory testing has been limited to Proctor and gradation tests on a sample of the silty, gravelly sand beneath the coarser sand and gravel. The test results are shown on Figure 12. In our opinion, the material is suitable as select structural fill and as trench backfill. Other uses are possible.

In order for the pit to be approved for Oregon State Highway Department projects, it will be necessary for standard pit qualification tests to be conducted. These include Los Angeles abrasion, Oregon air degradation and sodium sulfate soundness. In addition, lightweight particles tests must be conducted for ODOT approved concrete sand.

Subsurface Conditions and Quantities

Topsoil

The depth of topsoil encountered in the test pits was quite variable and ranged from 1.5 to 5 feet. In Test Pit Nos. 1, 11 and 12 the topsoil is underlain by a fine, silty sand with some fine pumice mixed in. This material was also included in our estimate of the topsoil available.

In general, the top 2 feet, approximately, of topsoil is moist and more loamy and organic than the underlying material. The top 2 feet would likely be classified as No. 1 topsoil. The deeper material is more sandy and contains scattered gravels with occasional cobbles. This material, after screening out the large particles, would probably be classified as No. 2.

The areas considered to be good for topsoil extraction include Areas A, B and C on Figure 2. Area A is where the primary gravel resource is located. The topsoil will need to be removed to reach the gravel. Little aggregate is available in Area B, however, the depth of topsoil is greater. The topsoil depth is shallow in Area C, however, the easterly portion of Area C is where some crushable size rock is located.

My estimate of the total topsoil resource in Areas A, B and C is 855,000 cubic yards. Assuming that 12 inches of topsoil is needed for reclamation over the entire area, estimated at 140 acres, 225,000 cubic yards should be saved. This leaves 630,000 cubic yards of topsoil available for sale.

Coarse Sand and Gravel

Area A (approximately 100 acres) is where the primary sand and gravel source is located. In most areas, it is located directly beneath the topsoil. The thickness of the coarse sand and gravel deposit in Area A ranges from 3 to 8 feet, and averages about 5 feet. In general, the thicker sand and gravel deposits are located in the northwesterly portion of Area A.

Based on the test pits, my estimate of the sand and gravel resource in Area A is 800,000 cubic yards. No gradation tests have been conducted on this material, however, visual observations of the soils removed from the test pits revealed that approximately 10 percent, or 80,000 cubic yards is larger than 3 inches. Rock particles larger than 3 inches are considered to be of crushable size. The 80,000 cubic yards is included in estimates of crushable rock given later in the report.

Fine Sand and Gravel

Beneath the coarse sand and gravel in most areas is a finer sand and gravel. This material is generally confined to Area A. The material is predominantly a 1 -inch minus and contains minor amounts of silt and clay. The thickness is variable and ranges from 2 to 10 feet. At deeper elevations the material is more damp and is slightly cemented. This resulted in the excavated material being somewhat chunky.

Based on the depths exposed in the test pits, my estimate of the quantity of the finer sand and gravel on the site is 800,000 cubic yards.

Crushable Rock

As mentioned previously, crushable size rock in Area A is limited in quantity. Approximately 10 percent or 80,000 cubic yards may be of crushable size.

Several test pits were excavated in the far easterly portion of the 160-acre permitted area, and also in a pasture southeast of the permitted area. Large, crushable size rock was encountered in Test Pit No's. 25 and 29 through 33. No samples were collected, however, my estimate was that 50 percent of the excavated material was of crushable size. Some of the material was vesicular (porous) basalt and cinder-rock, however, most of the rock appeared to be hard and durable. Pit qualification tests should be conducted on this material.

The average thickness of the crushable rock layer in these test pits was 5 feet. Applying a 50 percent factor to the layer for plus 3-inch size rock, about 4,000 cubic yards per acre can be extracted.

It is my opinion that this area of the site warrants further exploration. It is possible that exploration heading southeast up the wide valley could yield greater depth and size of rock. Locating 40 acres of crushable rock deposits in this area of the site would yield an additional 160,000 cubic yards of crushable rock. Adding this to the crushable size rock in Area A gives 240,000 cubic yards of potential crushable rock resource.

Resource Quality

The coarse sand and gravel layer, as shown on the logs, appears to be of good quality. Pit qualification tests on the plus 3-inch rock in Area No. 1 and the larger rock in the easterly portion of the site will need to be conducted to confirm the quality. A series of lightweight particle tests are in order to approve the material for concrete sand.

The underlying finer sand and gravel contains considerable pumice and other lightweight particles. This material is probably not suitable for processing into ODOT quality concrete sand. The laboratory standard Proctor test (ASTM D698) showed a density of 100.5 pounds per cubic foot. The sample was collected from the side of the existing pit. This material would be suitable for trench backfill, select structural fill and meets Deschutes County's requirement of 100-lb unit weight material on certain applications.

The quantity of fines (-#200 sieve material) is 4.6 percent. The material is not as desirable as ordinary cinders for winter-time roadway applications. It may be an acceptable alternate, in my opinion, for lesser traveled roadways. Most of the sample submitted was fine to medium sand. The quantity of fines would not make for muddy or slippery conditions, however, some murky water runoff would probably occur.

Potential Products and Uses

Topsoil

Good quality topsoil is becoming scarce in Deschutes County. Topsoil could be the most valuable commodity on the property. At $12-$15/cubic yard as reported by Jim Bussard, the available topsoil on the site has a retail value of $7.5 to 9.5 million.

Coarse Sand and Gravel

Products available from this material include drain rock, concrete and asphalt aggregate, pea gravel, concrete sand and crushed aggregate base course. A series of gradation tests would show the breakdown of various particle sizes and help determine the yield for each product. The quantity of each produced depends to a large extent on market conditions. Prices for these materials are probably in the $6-$12/cubic yard range.

Finer Sand and Gravel

Because of the lightweight particles content, uses for this material are limited, and were described in the preceding section. Value of ordinary pit-run sand and gravel is in the $2-4/cubic yard range. The Bend Parkway project will require about one million cubic yards of fill according to ODOT field personnel. I believe this material would be an acceptable fill for the parkway project.

Pit Operation

Perimeter Enclosure

It is my understanding that a perimeter fence or enclosure is proposed. A fence is less costly than an earthen berm but would be subject to vandalism. If the fence is constructed of wood, range fires are also a concern.

An earthen berm constructed 8 feet high with 1:1 side slopes would require about 4 cubic yards of earth per foot. If the berm were constructed along the north and west sides of the site, between two existing rocky ridges, the berm would be approximately 4,800 feet long. Earth required is on the order of 20,000 cubic yards. An earthen berm would be a good way to stockpile a portion of the reclamation material needed, and may be more acceptable to the Oregon Department of Fish and Wildlife.

Processing Area

It is my opinion that a suitable equipment area is south of the existing road and generally east of Test Pit No. 18. This area has no aggregate resource and only a few feet of topsoil. This area would be a good choice if a semi-permanent crushing, screening and washing area were set up. The equipment would not have to be moved in order to extract a resource. This area is also closest to the existing water well. Water tanks will be needed for washing certain types of aggregate.

A disadvantage of the location is that the most likely mining scheme is from south to north, or away from the proposed operations area. Raw material hauls would become increasingly greater as the pit moves to the north. If a large source of crushable rock is located in the southeasterly area of the site, however, the proposed location would be more central in the overall scheme of things. A suggested layout is shown on Figure 10.

An alternative would be to utilize the existing pit for operations. The equipment could be moved north as the resource is extracted. This approach may be more suitable for a portable, self contained operation. The equipment could be mobilized to the site every few years as stockpiles are depleted. New stockpiles could be placed in designated areas along the existing road, or even placed in the bottom of the advancing pit.

This approach would place equipment somewhat farther away from the crushable rock source. I visited a local pit operation a few years ago, however, and observed the screening/washing and crushing operations in two different areas. For the Moon Pit, screening and washing could be located in or near the existing pit and crushing closer to the rock source. This alternative is shown on Figure 11. There are probably other operational plans that may be more efficient as the pit expands.

Washing Waste Sump

Washing of aggregate will produce clay and silt particles that must be disposed of. Generally a shallow sump or pit can be excavated to store the waste. If the mined aggregate has an average of 2 percent silt and clay-size particles, a sump 50 feet by 50 feet by 3 feet deep would hold the waste for approximately 350,000 cubic yards of raw material.

This letter has presented an interim, but detailed report of findings, conclusions and recommendations completed to date. If you have questions please call.

Sincerely,

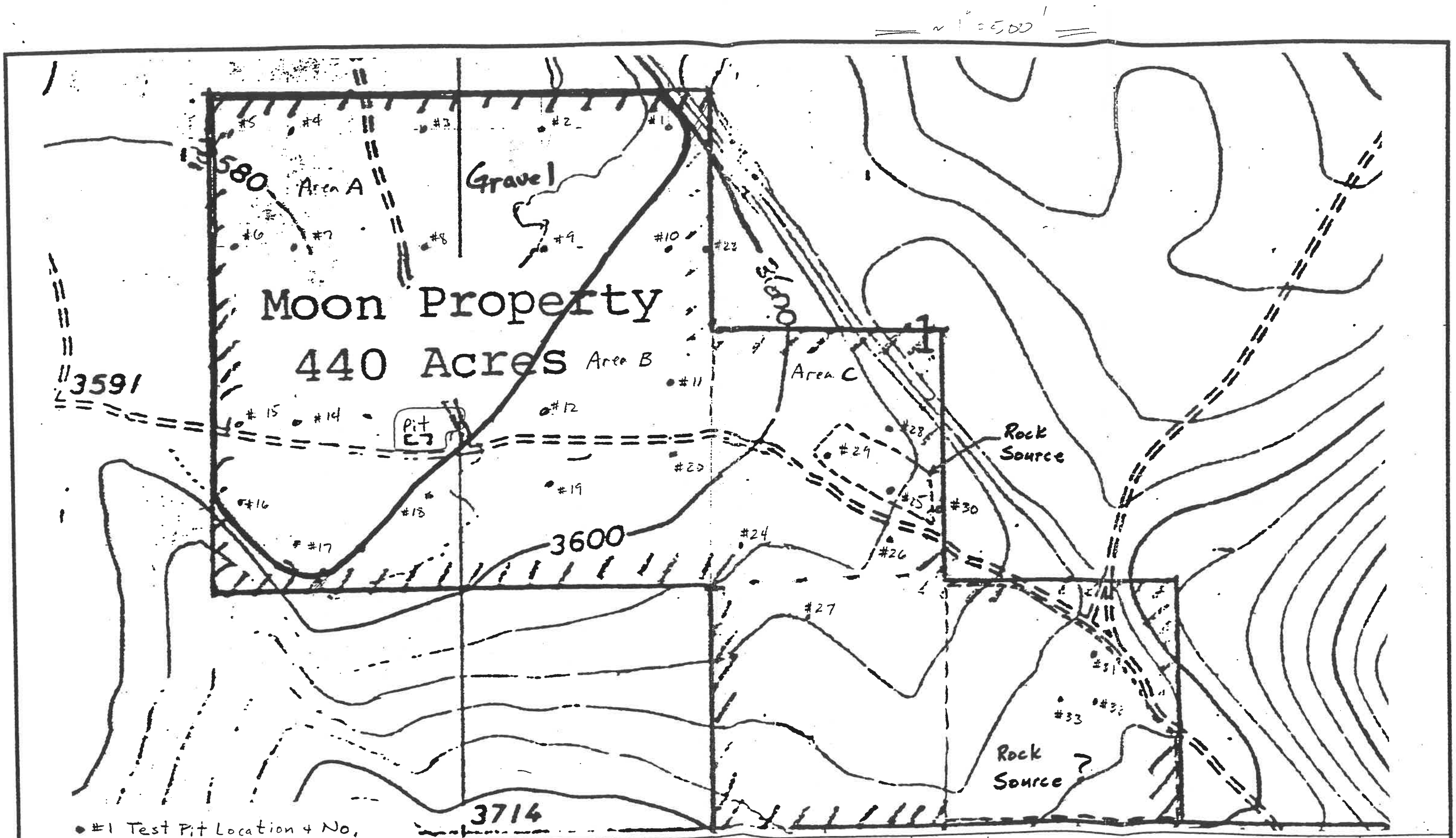
Mark V. Herbert

Mark V. Herbert, P.E.

Geotechnical Engineer

skh

14227
NOV 29, 1988
MARK V. HERBERT



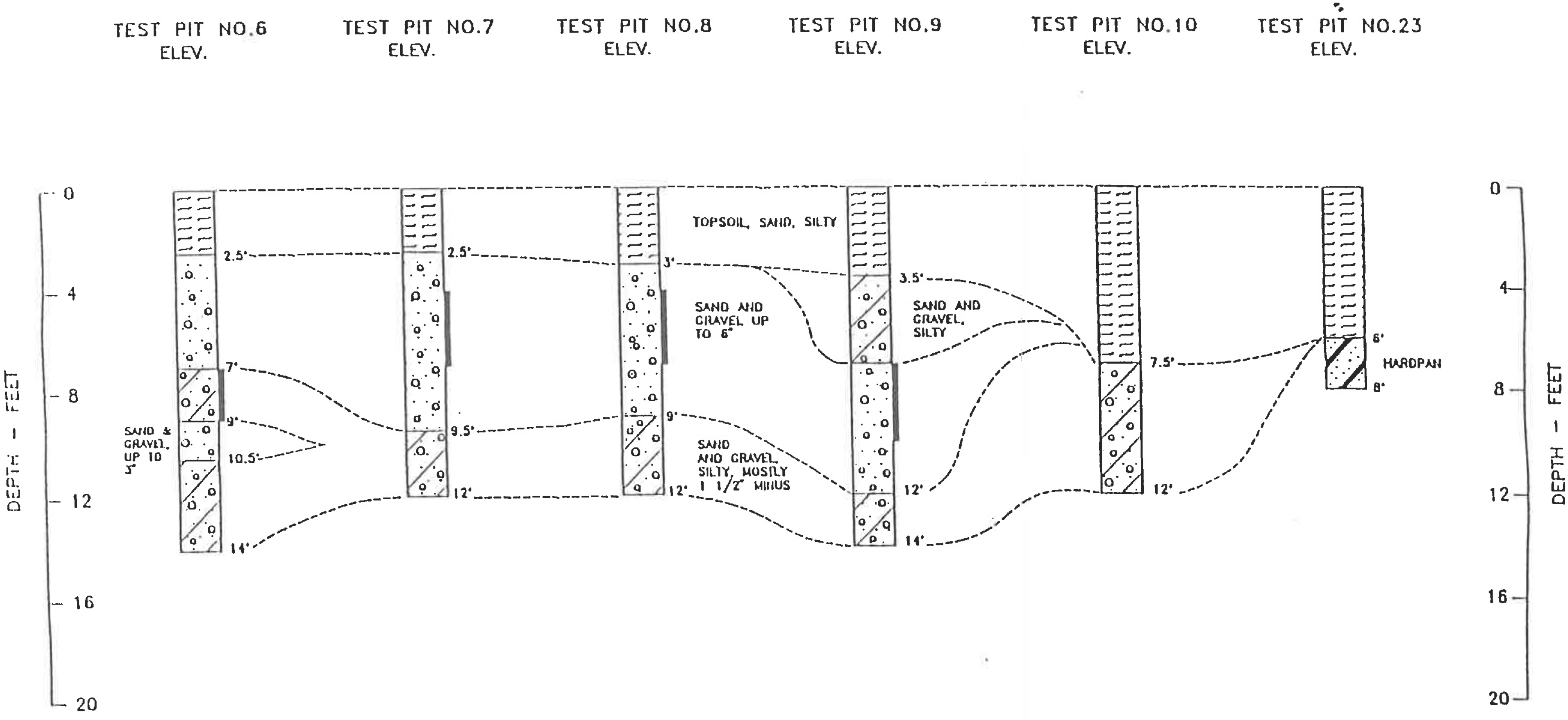
DESIGN BY: MVH
DRAWN BY: PAM
DATE: APRIL - 1993
DWG FILE: \EXAMPLE

MARK V. HERBERT & ASSOCIATES
GEOTECHNICAL CONSULTANTS

SITE MAP
LOCATIONS OF EXPLORATORY TEST PITS
MOON GRAVEL PIT

FIGURE
2

Appendix E



Appendix E

NOTE:
FOR LEGEND AND NOTES,
SEE FIGURE 9.

DESIGN BY: MVH
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DATE: 3-24-93
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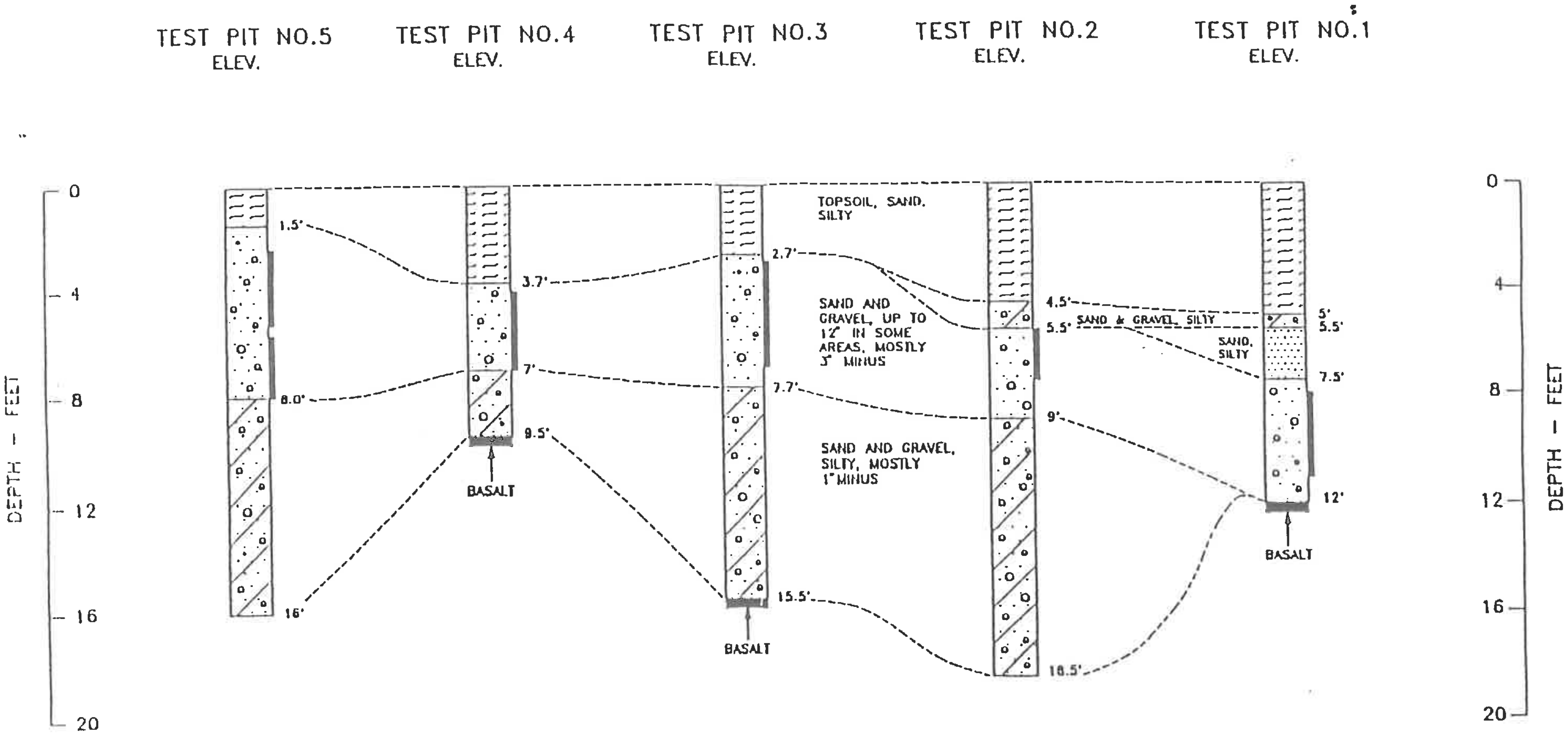
PROJECT NO. 93-011

MARK V. HERBERT & ASSOCIATES
GEOTECHNICAL CONSULTANTS

LOGS OF EXPLORATORY TEST PITS
MOON PIT EVALUATION
DESCHUTES COUNTY, OREGON
FOR: MATT DAY

FIGURE
4



NOTE:
FOR LEGEND AND NOTES,
SEE FIGURE 9.

Appendix E

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DATE:	3-24-93
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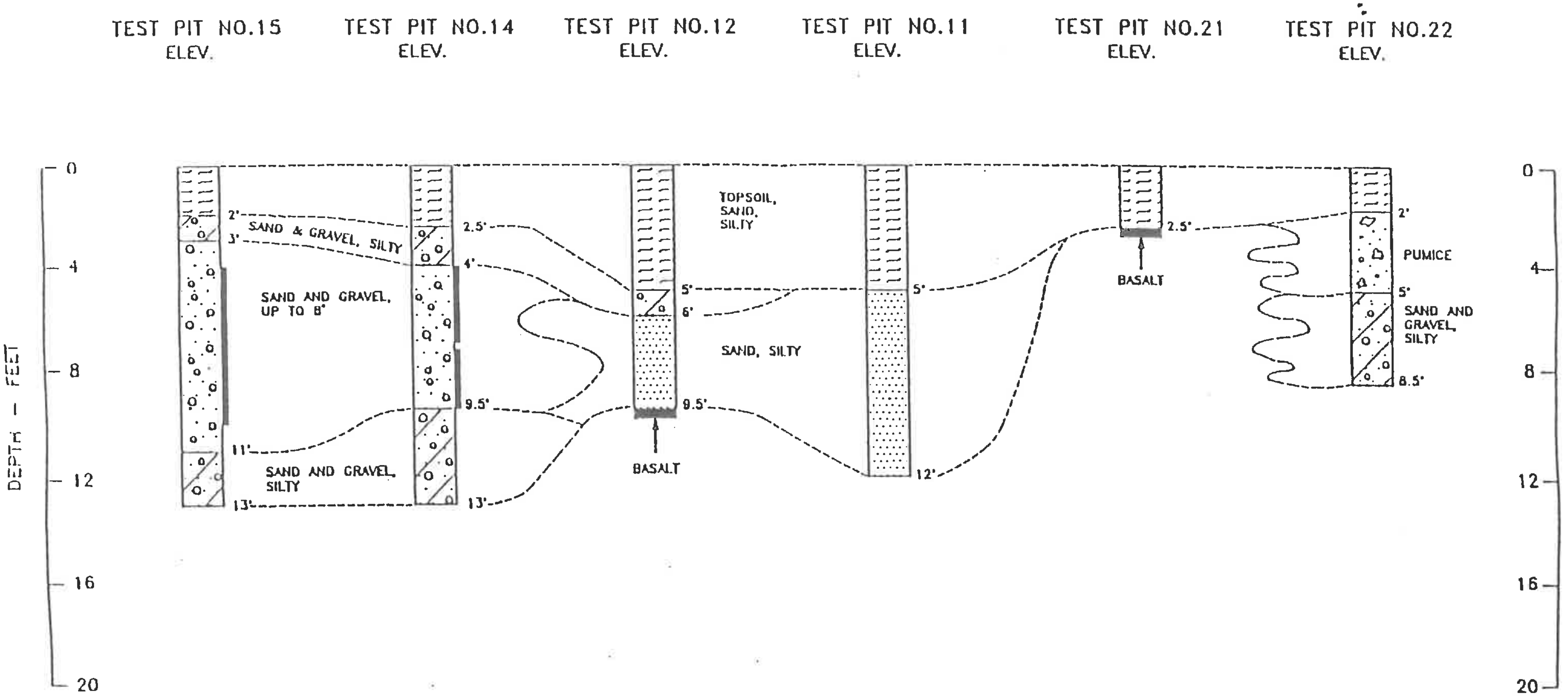
PROJECT NO.	93-011

MARK V.
HERBERT &
ASSOCIATES
GEOTECHNICAL CONSULTANTS

LOGS OF EXPLORATORY TEST PITS
MOON PIT EVALUATION
DESCHUTES COUNTY, OREGON
FOR: MATT DAY

FIGURE
3



NOTE:
FOR LEGEND AND NOTES,
SEE FIGURE 9.

Appendix E

DESIGN BY: MVH
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PROJECT NO. 93-011

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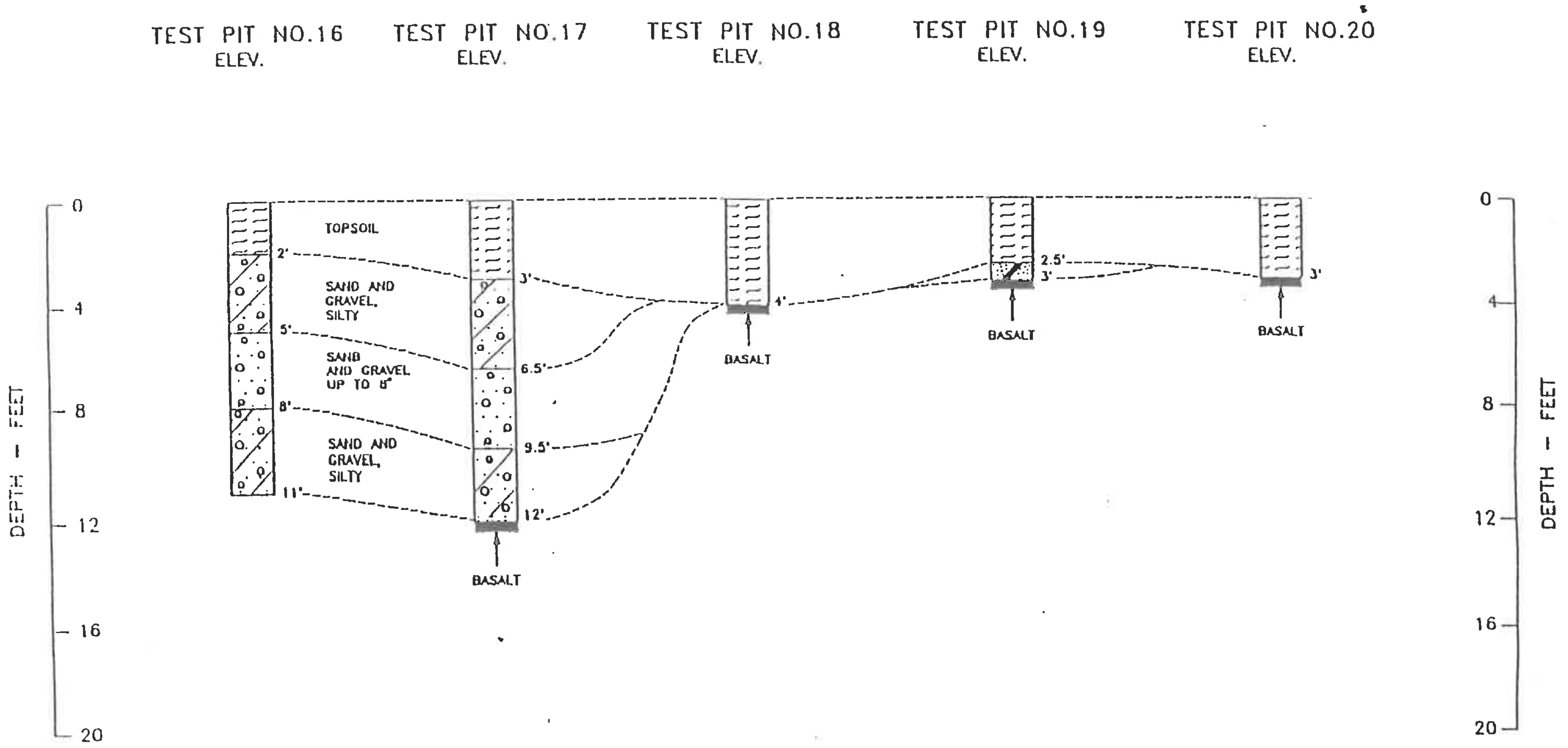
GEOTECHNICAL CONSULTANTS

LOGS OF EXPLORATORY TEST PITS
MOON PIT EVALUATION
DESCHUTES COUNTY, OREGON
FOR: MATT DAY

FIGURE
5



Appendix E

NOTE:
FOR LEGEND AND NOTES,
SEE FIGURE 9.

DESIGN BY: MVH
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DATE: 3-24-93
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PROJECT NO. 93-011

MARK V.
HERBERT &
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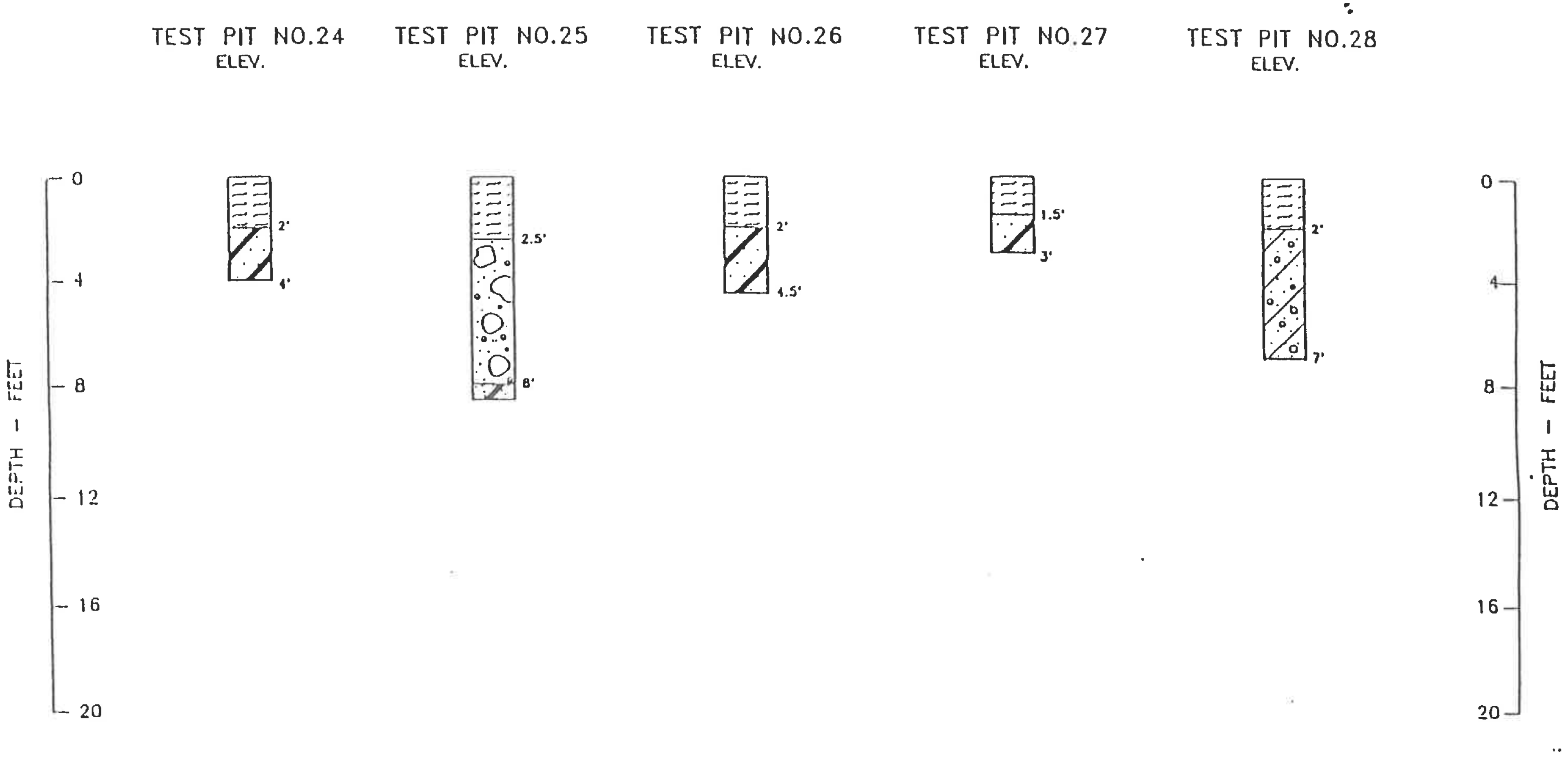
GEOTECHNICAL CONSULTANTS

LOGS OF EXPLORATORY TEST PITS
MOON PIT EVALUATION
DESCHUTES COUNTY, OREGON
FOR: MATT DAY

FIGURE
6



NOTE:
FOR LEGEND AND NOTES,
SEE FIGURE 9.

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DATE: 3-24-93
DWG FILE: \93-011D
PROJECT NO. 93-011

MARK V.
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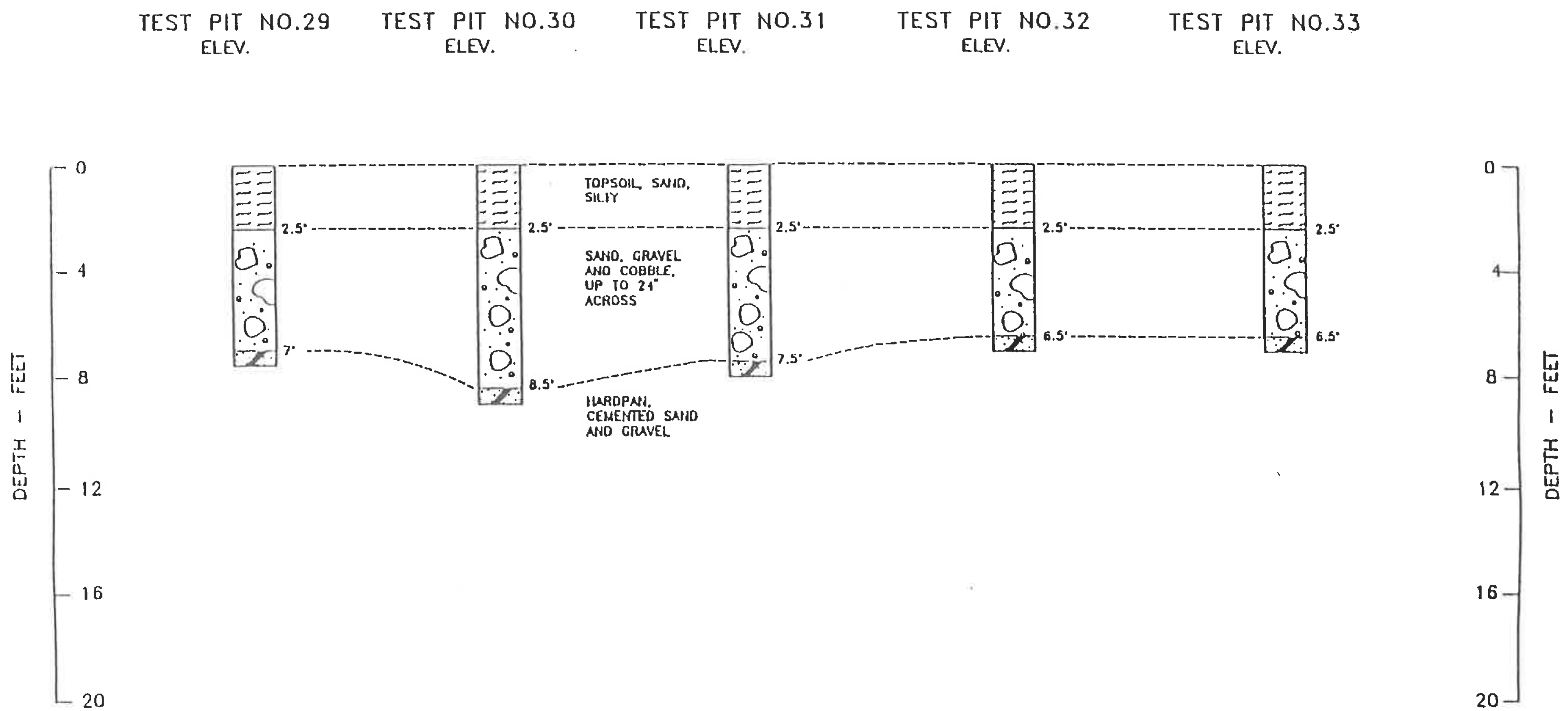
GEOTECHNICAL CONSULTANTS

LOGS OF EXPLORATORY TEST PITS
MOON PIT EVALUATION
DESCHUTES COUNTY, OREGON
FOR: MATT DAY

FIGURE
7

Appendix E



NOTE:
FOR LEGEND AND NOTES, SEE FIGURE 9.

Appendix E

DESIGN BY: MVH
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DATE: 3-24-93
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PROJECT NO. 93-011

MARK V. HERBERT & ASSOCIATES
GEOTECHNICAL CONSULTANTS

LOGS OF EXPLORATORY TEST PITS
MOON PIT EVALUATION
DESCHUTES COUNTY, OREGON
FOR: MATT DAY

FIGURE
8

LEGEND

▤	TOPSOIL, sand, silty, occasional chunks of rock and small gravels, organic in upper foot of material, dry to moist, light brown to brown (OL, SM)
░	SAND, silty, occasional chunks of rock and small gravels, moderate quantities of pumice sand mixed in, dry, light brown (SM)
⁘	SAND and GRAVEL, clean to slightly silty, some cobbles up to 12 inches, occasional rounded pumice gravel lenses, dry, dark grayish-brown (SW, GW)
▧	SAND and GRAVEL, silty, slightly cemented in some areas, trace of clay mixed in, predominantly 1 1/2-inch minus, lots of pumice sand and fine pumice gravels, damp, light brown to brown (SM, GM)
▒	PUMICE, loose, dry, light gray, relatively clean
▣	SAND, GRAVEL, COBBLE and ROCK, up to 24 inches across, rounded to subrounded, mostly basaltic rock with some reddish cinder-rock mixed in, some rock is vesicular, estimate 50% of material is plus 3-inch in size, dry to damp, grayish-brown
▨	HARDPAN, cemented sand, gravel and cobble, calcium or carbonate on rock surfaces, dry, light brown
■	BASALT, rock, very hard, vesicular, fractured, could not be penetrated with backhoe
┃	Depth at which a bulk sample of soils was taken
┬	Depth at which refusal was encountered with a Cat 320L backhoe

NOTES

1. Test pits were excavated March 15 and 16, 1993 with a Caterpillar 320L backhoe.
2. Test pit locations were determined in the field by Jim Bussard, Consultant and/or Mark V. Herbert and Assoc.
3. Test pit logs shown are representative of the locations explored. Interpolations between logs are approximate.

Appendix E

DESIGN BY:	MVH
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DATE:	3-24-93
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PROJECT NO.	93-011

MARK V. HERBERT & ASSOCIATES
GEOTECHNICAL CONSULTANTS

LEGEND AND NOTES
MOON PIT EVALUATION
DESCHUTES COUNTY, OREGON
FOR: MATT DAY

FIGURE
9

SIEMENS & ASSOCIATES

BEND OR.

Geotechnical Engineering and Laboratory Services

David Evans And Associates, Inc
709 NW Wall, Suite 102
Bend, Oregon 97701
Attn. George Holroyd

August 6, 1996

Project No. 966021

Project: Deschutes County Final Landfill Site Evaluation **Site "L"**
Horse Ridge, Oregon

Subject: Results of Onsite Soil and Rock Investigation
(Task 3, Geological Investigation) *Final*

Dear George:

As requested, we have completed the subject investigation with the results presented in the following six (6) chapters and three (3) appendices.

The results identify a variety of soil and rock types, some of which possess special characteristics identifying them as especially valuable for use in the development of a modern landfill. In many areas, rock was discovered at shallow depths which effectively limits the economical depth of excavation. The results are summarized in Chapter 3 and presented graphically by cross sections A-A' through C-C'.

It has been a pleasure to be of service on this project and if you or your client have questions or require additional interpretation, evaluation or testing, please call.

Respectfully Submitted:

SIEMENS & ASSOCIATES

J. Andrew Siemens, P. E.

Addressee: 1 original

19134 River Woods Drive – Bend, Oregon 97702
Telephone & Fax 541/385-6500
J. Andrew Siemens, P.E.

Appendix E

TABLE OF CONTENTS

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1. CONTEXT

1.0 This Report presents an evaluation of the distribution and character of the soil and rock to be anticipated throughout the excavation proposed for the landfill as conceptually laid out on Site L. The work has been conducted under contract with Deschutes County's Engineering Consultant, David Evans And Associates, Inc. with specific authorization provided by George Holroyd.

1.1 SCOPE

1.1.0 This report is to provide technical information regarding the quality, quantity and potential uses for the soil and rock occurring naturally on-site. The work has been performed in accordance with the scope identified as Task #3, outlined in the subcontract agreement dated May 29, 1996.

The report presents our professional opinion based upon information gained from the reconnaissance of the general area, a subsurface exploration program, and our review of readily available existing data. The extent of the study excludes areas of the property that are obviously underlain by shallow rock as limiting rock excavation is a primary project objective.

A standard outline is followed in this report to obtain uniformity among our projects. Consequently, the numbering system is not necessarily consecutive.

2.4 SUBSURFACE CONDITIONS

2.4.0 The subsurface conditions comprise an alluvial/aeolian (wind blown) topsoil underlain by various assemblages of alluvial sand, gravel and extrusive basalt of several ages.

2.4.1 STRATIFICATION

For engineering purposes, we divide the soils into varying strata differentiated by their engineering properties as they affect this project. To maintain uniformity among our reports, Stratum 1 is used to designate in-place, existing fill materials, Stratum 2 to designate native soils, while Stratum 3 is used to identify various types of rock. In this case, we have defined five strata, each with unique characteristics as summarized in the following table:

TABLE 2.4.1
STRATIFICATION

STRATUM	THICKNESS	DEPOSIT	MATERIAL
2m	0 to 5'	Alluvial/Aeolian	Sand w/Silt (Topsoil)
2g	0 to 12'	Alluvial	Gravel w/ Sand, Cobbles
2s	0' - 45'	Alluvial	Sand w/ Gravel
3q	0 to 20'+ ??	Extrusive	Quaternary Basalt
3p	100'+ ??	Extrusive	Pleistocene Basalt

2.4.1.2m STRATUM 2m ALLUVIAL/AEOLIAN SAND w/ Silt (Top Soil)

This stratum represents the topsoil which has been stripped and stockpiled as a perimeter berm flanking the site's northwestern corner. The material is in its natural state, throughout the remainder of the site with a thickness up to about 4 feet. Stratum 2m is a light-weight, pumiceous, wind-blown sandy soil with a modest quantity of silt (about 20%).

2.4.1.2g STRATUM 2g ALLUVIAL GRAVEL w/ Sand & Cobbles

This sub-rounded gravel appears to have once covered roughly 70% of the site as a horizontally bedded deposit about 8 to 12 feet thick. We estimate that nearly half of this stratum has been processed for select washed gravel products and either stockpiled on site or deported. Stratum 2g remains in place throughout the site's northeastern and eastern areas.

2.4.1.2s STRATUM 2s ALLUVIAL SAND w/ fine Gravel

Stratum 2s appears to be the predominate soil type and was found to occur in horizontally bedded layers to depths as great as 42 feet. This soil is presently being developed as a general fill material and is favored for its ease in excavation and tendency to compact readily at native moisture content.

2.4.1.3q STRATUM 3q EXTRUSIVE QUATERNARY BASALT (about 10,000 years old)

Underlying the majority of the site, we encountered a flow of a relatively young basalt with its origin believed to be the Newberry Caldera. This is a very common rock type in Central Oregon and often is quite vesicular and inflated as evident at this and surrounding sites. The rock contact with overlying soils is typically quite irregular as indicated by the subsurface data presented in Chapter 6 of this report. An existing exposure (working face) indicates that the thickness is about 20 feet and seismic data indicates Stratum 3q to be underlain by another, basalt.

Stratum 3q has apparently been drilled, shot and processed to construct specialty crushed rock products such as pavement base course although recent test results were not available for our review. Our observations of the existing exposure indicate that the quality of this basalt improves dramatically with depth such that the best quality rock is bound by the lower half of the deposit. The upper part of the deposit (top 5 to 10 feet) is in our opinion a relatively low quality rock due to its vesicular and inflated nature.

Stratum 3q controls the practical depth of excavation and is expected to be encountered in each of the leachate trench bottoms as conceptually designed. When encountered, difficult excavation (drill and blast) is indicated by seismic data and on site experience.

2.4.1.3m STRATUM 3p EXTRUSIVE PLEISTOCENE BASALT (.01 to 2 million years old)

The slopes of the Bear Creek Buttes which flank the site's southern and eastern margins are believed to represent basalt dating to the Pleistocene epoch (.01 to 2 million years ago). Stratum 3p outcrops in numerous places exposing a massive, crystalline basalt and is currently being processed in the far southeastern portion of the site (off of the conceptual landfill footprint).

Through seismic investigation, Stratum 3p was found to predominate at a shallow depth (0 to about 12 feet) throughout the 40 acre parcel off of the sites southeast corner, effectively excluding the conceptual footprint from that area.

This Pleistocene basalt controls the practical depth of excavation in some areas and is expected to be encountered in each of the leachate trench bottoms as conceptually designed. When encountered, difficult excavation (drill and blast) is indicated by seismic data and on site experience.

3. CONCLUSIONS

3.0 EXECUTIVE SUMMARY

The following conclusions are based upon the results of the field and laboratory investigations presented in Chapter 6 (prepared by us) and Appendix 1 and 2 which present previous subsurface and laboratory analysis done by others relative to the subject site. This data is interpreted through Chapter 2 of this Onsite Soils Investigation.

The available data indicates that the site can be readily developed to accommodate a solid waste landfill utilizing onsite materials to construct many of the components common to state of the art landfill liner and final cover system design. The economical depth of excavation is judged to be limited by the depth to Stratum 3q (Quaternary Basalt) and Stratum 3p (Pleistocene Basalt).

Stratification

For practical purposes, it is our opinion that the materials influencing conceptual landfill design and operation can be simplified to 4 Strata:

Stratum 2m:	SAND w/ Silt (Topsoil)	■ Closure, Reclamation
2s:	SAND w/ fine Gravel	■ Construction and Operations
2g:	GRAVEL w/ Sand	■ Construction and Operations
3q, 3p:	BASALTS	■ Limits Depth of Excavation

Of these materials, the most abundant is judged to be Stratum 2s which is a soil that can be readily excavated and has significant value when considering the design, development and daily operation of a Subtitle D Landfill. Stratum 2g represents sub-rounded gravel, cobbles and sand that, when screened and washed provide an excellent, multi-use aggregate for a variety of uses. Although Strata 3q and 3p can be crushed and screened to produce useful construction materials, the cost of excavation and processing is judged to exceed the value of the landfill volume generated by hard rock removal. Deposits of Stratum 2m (topsoil) are present to facilitate an effective, naturally vegetated final cover utilizing the economics of a water balance design.

Depth to Rock

Depth to rock has been interpreted from refraction seismic data, auger drilling and direct observation in trackhoe pits (excavated and observed by others). Drilling methods and backhoe pit exploration only provide 'spot' data and unless many borings and pits are excavated, there is no way to know if the rock contact is representative of a high point, low point or some place in between. However, the interpretation of the refraction seismic information tends to average out the abrupt peaks and valleys common to Stratum 3q and thus provides a reasonable approximation of the "average" depth to rock across the length of the seismic spread (typically 150 to 250 feet).

Consequently, where we must rely solely on existing drilling or trackhoe pit data to define the depth to rock, error, probably on the order of 15% to 25% of the depth estimate can be expected. Where seismic information is available, our experience indicates that the depth to rock can be considered accurate to 5% to 10% of the actual contact.

Rock Excavation

Due to the irregularity of the soil/rock contact, some rock excavation is necessary to develop a reasonably long lived landfill based on current state of the art design which includes a series of cells draining to a common collection sump. Based upon the available data, rock excavation is estimated to make up about 24% of the cut along the proposed leachate collection trenches. Rock cuts as deep as 20 feet can be expected although most are less than 10 feet. In most places, the bottom grade quickly rises to above rock elevations, but, the data indicates that rock will be encountered given the conceptual layout. Based on the available data, limiting rock excavation to a significantly greater degree would, necessitate significant reduction in site capacity. Based on the conseptual design, about 8% of the total cut is estimated to involve rock excavation.

Based on the information at hand, it is our opinion that the layout, as proposed, presents a good fit with the existing topography and subsurface occurrence of rock. A more efficient layout probably exists, but would necessitate a basis of considerably more detailed subsurface information than is currently available.

Specific Usage of Onsite Soils and *Volume Estimates*
Our conclusions regarding the suitability of the various strata identified in context with traditional components of a modern landfill are summarized through Table 3.0.

Volume estimates are based on a summation of the stratification that occurs above the bottom grade interpreted from 200 foot interval slices along each of the geologic cross sections presented in Chapter 6 combined with an estimate of total earthwork volume calculated by the average end area and prismoidal methods.

Table 3.0

SOILS USAGE SUMMARY / VOLUME ESTIMATES

STRATUM	Estimated Total Volume Million C.Y. / % of Cut	**ANTICIPATED USES**
2m **SAND w/ Silt** (Topsoil)	0.27 / 13%	Final Cover (Suitable for Water Balance Design), Daily Cover,General Site Reclamation and Grading
2s **Sand w/ fine Gravel**	1.25 / 61%	Liner System: Protective Layer, Drainage Layer, Leveling Layer, Cushioning Layer Daily Cover, General Grading and Embankment Construction Final Cover: Coarse Grained Capillary Break (Water Balance Design), Shaping, Grading
2g **Gravel & Cobbles** (Alluvial)	0.37 / 18%	General Grading and Embankment Construction, Crush/Screen for Leachate Collection Gravel, Coarse Grained Capillary Break (Water Balance Final Cover)
3q **Quatemary Basalt**	0.10 / 5%	Crush/Screen for Daily Cover, Leachate Collection Gravel and Onsite Road Construction
3m **Miocene Basalt**	--	Not Encountered
3p **Pleistocene Basalt**	0.06 / 3%	Crush/Screen for Daily Cover, Leachate Collection Gravel and Onsite Road Construction

Gross Earthwork Volume = *Approx. 2.05 Million C.Y. (Cut)

* Gross earthwork volumes provided by DEA

4. RECOMMENDATIONS

4.0 EXECUTIVE SUMMARY

Prior to final landfill design, we recommend that the data presented in this report be supplemented with additional information developed specifically for solid waste landfill design and construction. Specifically, more detailed subsurface information should be developed and an in-depth laboratory testing program should be executed to provide more definitive uses and specifications for the various soils and rock occurring on site.

5. LIMITATIONS

5.0 Site exploration interprets subsurface conditions from evidence valid only at those points sampled or tested. Data obtained through sampling and subsequent laboratory testing are then extrapolated by the Geotechnical Engineer who renders an opinion concerning quality, quantity, significance, etc.

Even where least expected, actual site conditions could differ significantly from those inferred, because no Geotechnical Engineer (no matter how qualified) and no subsurface exploration program (no matter how comprehensive) can reveal everything hidden by earth, rock, and time. Actual conditions in the areas not sampled or tested may differ from our logs.

This investigation was conducted in accordance with generally accepted geotechnical engineering practices executed to achieve, at a minimum, an ordinary standard of care. The Report presents our professional findings of investigation data developed to meet or exceed the standards of the geotechnical profession in this area, and we make no other warranties express or implied.

6. FIELD INVESTIGATION

6.0 The field work, which consisted of research, geologic reconnaissance, refraction seismic exploration and the drilling of test borings was conducted during late spring and early summer 1996. The field investigation was organized and executed by J. Andrew Siemens, P.E. with drilling services provided by Mathers Drilling, Bend, Oregon.

The subsurface results are summarized on the Cross Sections (Figures 6.0.2). Boring elevations and depth to rock are summarized on Table 6.2.1. The boring and seismic lines locations are depicted on the Site Plan (Figure 6.0.1). Seismic data is presented in a graphic format as Figures 6.7.

6.1 RESEARCH AND RECONNAISSANCE

Readily available existing data was limited to information on file with Deschutes County Planning Division which related to data that had been submitted to permit and rezone the area as a surface mine. This information is include in this report as appendix.

A quick reconnaissance of the property combined with a review of the existing data indicated that consistently significant thicknesses of soil only occurred in the site's northwestern, 160 acres. Consequently, exiting information and reconnaissance provided the focus to establish the conceptual landfill footprint.

6.2 AUGER DRILLING

A total of 22 borings were advanced utilizing a Mobil B-40 drill equipped with 6 inch O.D. solid stem continuous flight auger. This equipment was capable of rapidly penetrating the soils and was soundly refused by rock after a few feet of penetration. The borings are numbered in a fashion consecutive with previous work that was done on site by others. The results are summarized through Table 6.2.1. Individual logs for each boring are not presented.

6.7 GEOPHYSICAL

6.7.1 REFRACTION SEISMIC SURVEYS

Seismic refraction is generally considered to be one of the most reliable indicators of "average" rock depth since a large boulder, or anomaly will not be confused with a solid rock surface as it can be in drilling or backhoe exploration. In our experience, the seismic data tends to predict the depth to rock, on average, slightly deeper than auger refusal and is a much better indicator than backhoe refusal.

A total of 17 seismic spreads were laid out in a strategic fashion in an effort to delineate depth to and quality of rock. Each geophone spread represents a straight line, 12-channel array utilizing a 10 to 16-foot geophone spacing with at least three shot points along the alignment, two of which extend beyond the end points of the geophone spread. Dynamic compression ("P" waves) were induced utilizing a sixteen pound maul striking an aluminum plate effectively transferring the hammer energy to the ground. The resulting seismic waves were perceived by the geophones with the wave traces recorded digitally on our Smart Seis seismograph manufactured by Geometrics, Inc.

As the seismic waves travel vertically and horizontally through the strata, they are refracted when a material of a different nature is encountered, such as Strata 3q or 3p (basalt) which can carry the wave at a higher velocity. From the resulting transit time from the shot point to the geophones, the velocity of the wave and the depth at which refraction is occurring can be mathematically calculated.

The digitally recorded data was interpreted in our office utilizing software (SIPT 2) developed by Rimrock Geophysics, Inc. The data is presented graphically as seismic profiles (Figures 6.7.1) which identify the depth and orientation of the strata interpreted from the seismic data as well as the respective seismic "P" wave or velocity of each layer interpretation. In general, unconsolidated, or soil-like materials offer a seismic velocity less than or slightly greater than 3000 fps, inflated basalts can be indicated by velocities as low as 3500 fps while competent, hard basalt is indicated by velocities in excess of 9000 fps.

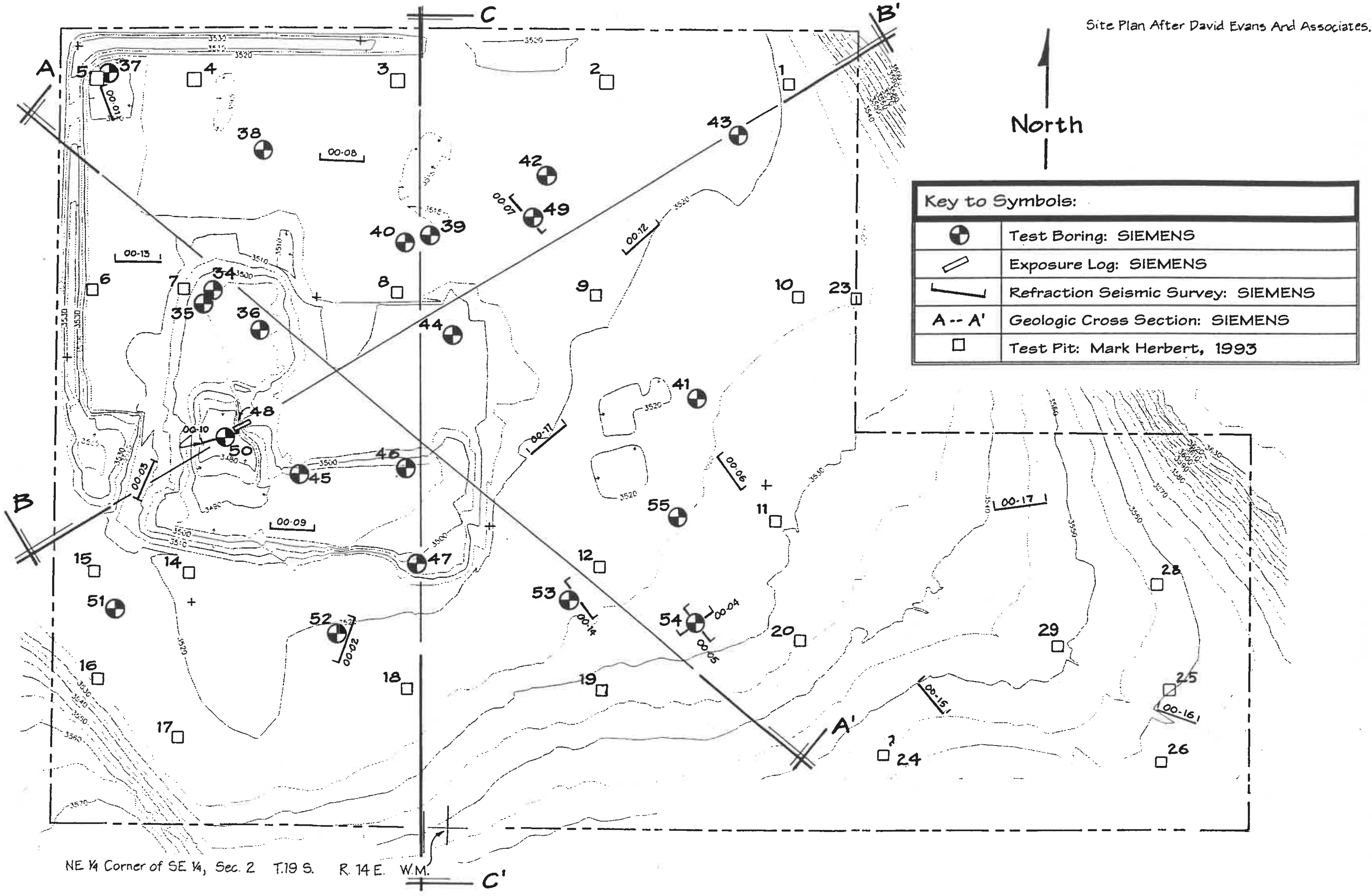
6.8 LOCATIONS

6.8.1 HORIZONTAL CONTROL

A series of control points labeled Day 1 through 5 were set out by the project engineer (David Evans And Associates, Inc.). Utilizing these points, we located each of the exploration test sites utilizing our K&E Transit providing angle control to the nearest minute. As such, the boring and seismic line locations, as shown on the plan may be considered accurate to the nearest 10 feet.

6.8.2 VERTICAL CONTROL

Elevations of the test sites were established from the control points utilizing stadia techniques. As such, the elevations as presented on the logs of the various borings and seismic profiles may be considered accurate to the nearest one-half foot relative to the aforementioned control standard.



Site Plan After David Evans And Associates, Inc.

Scale: Horiz. 1" = 400'

Site Plan: SITE "L"

Deschutes Co. Final Landfil Site Evaluation

Horse Ridge, Oregon

For: David Evans And Associates, Inc.

FIGURE 6.0.1

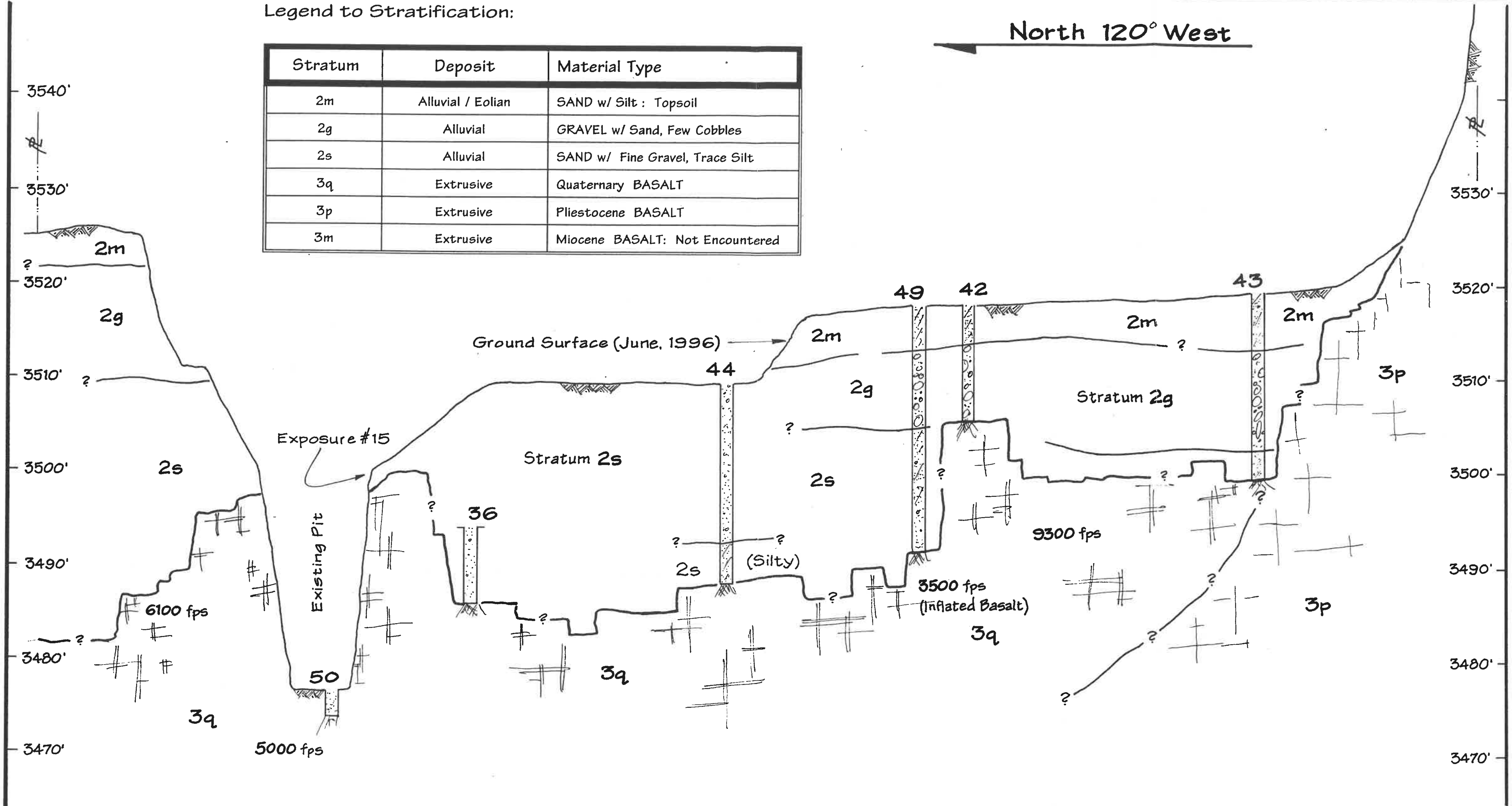
July 1996

Project No. 966021

SIEMENS & ASSOCIATES

Legend to Stratification:

Stratum	Deposit	Material Type
2m	Alluvial / Eolian	SAND w/ Silt : Topsoil
2g	Alluvial	GRAVEL w/ Sand, Few Cobbles
2s	Alluvial	SAND w/ Fine Gravel, Trace Silt
3q	Extrusive	Quaternary BASALT
3p	Extrusive	Pliestocene BASALT
3m	Extrusive	Miocene BASALT: Not Encountered



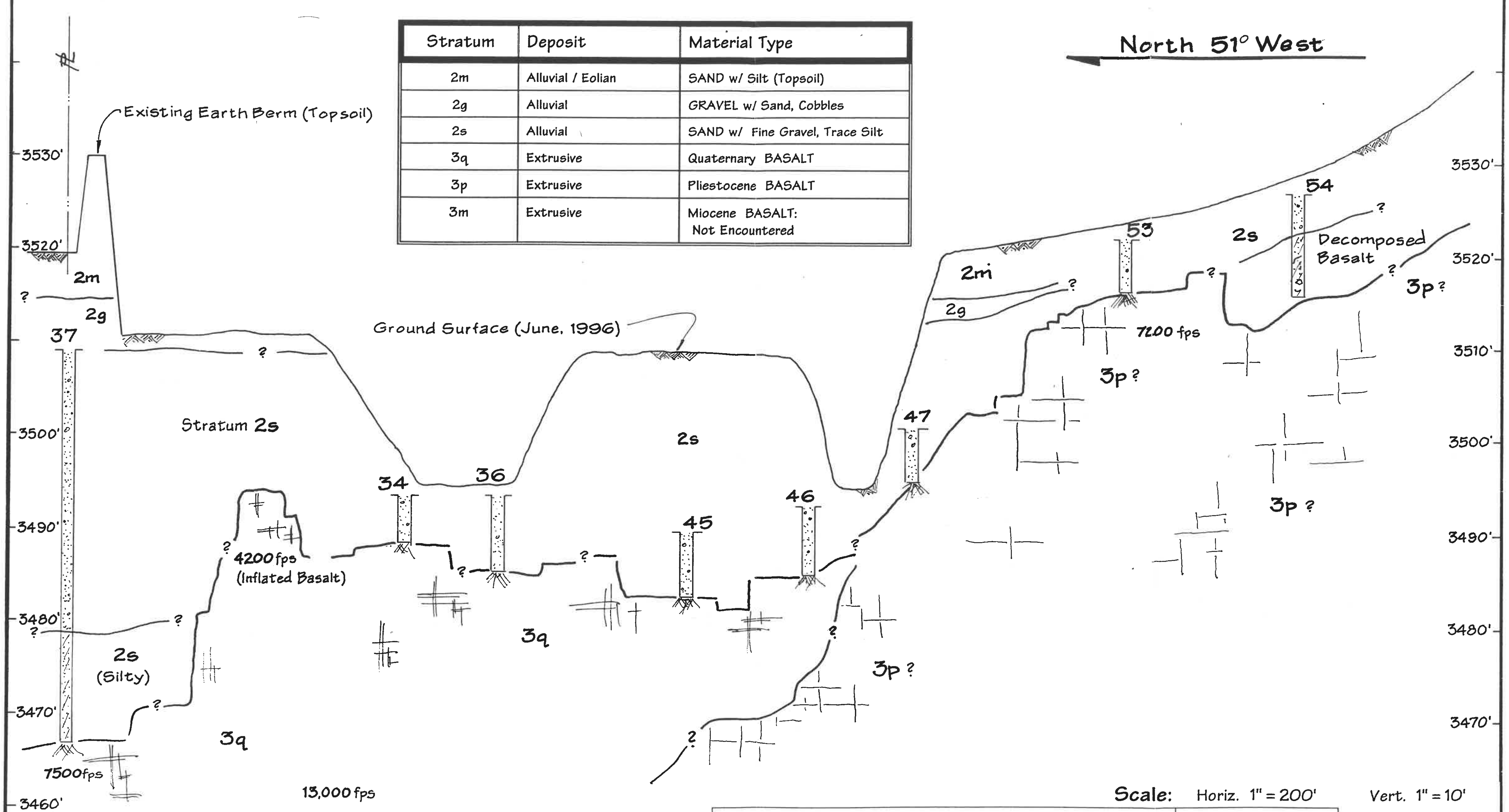
Scale: Horiz. 1" = 200' Vert. 1" = 10'

Soil and rock classification should be considered accurate only at boring and pit locations. For engineering purposes, stratification is interpolated between test sites and may not necessarily reflect true subsurface conditions.

Cross Section B - B': SITE "L"	FIGURE 6.0.2(B)	
Deschutes Co. Final Landfil Site Evaluation	July 1996	Project No. 966021
Horse Ridge, Oregon		
For: David Evans And Associates, Inc.	SIEMENS & ASSOCIATES	

Legend to Stratification:

Stratum	Deposit	Material Type
2m	Alluvial / Eolian	SAND w/ Silt (Topsoil)
2g	Alluvial	GRAVEL w/ Sand, Cobbles
2s	Alluvial	SAND w/ Fine Gravel, Trace Silt
3q	Extrusive	Quaternary BASALT
3p	Extrusive	Pliestocene BASALT
3m	Extrusive	Miocene BASALT: Not Encountered



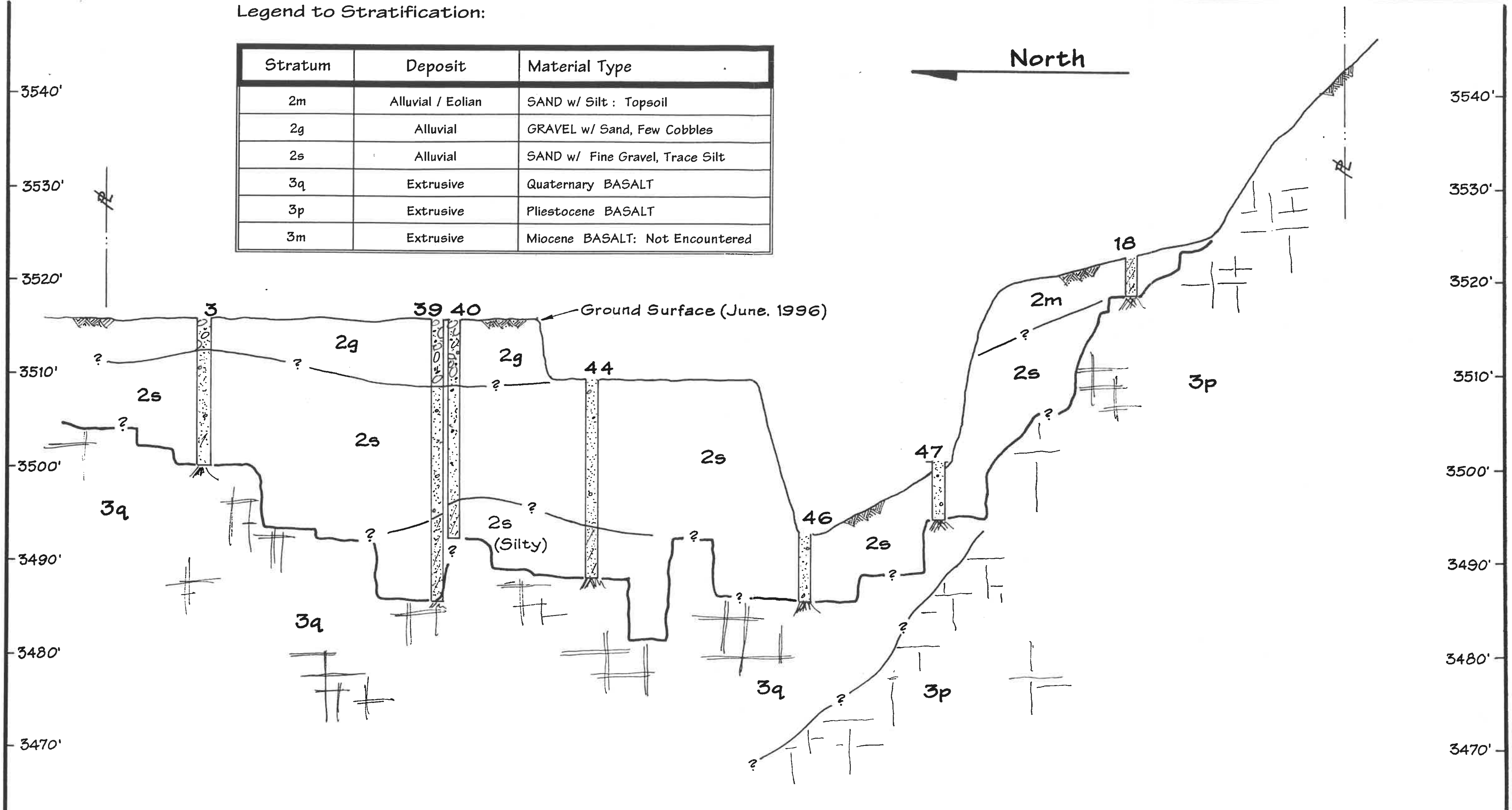
Scale: Horiz. 1" = 200' Vert. 1" = 10'

Soil and rock classification should be considered accurate only at boring and pit locations. For engineering purposes, stratification is interpolated between test sites and may not necessarily reflect true subsurface conditions.

Cross Section A - A': SITE "L"	FIGURE 6.0.2(A)	
Deschutes Co. Final Landfil Site Evaluation	July 1996	Project No. 966021
Horse Ridge, Oregon	Appendix E	
For: David Evans And Associates, Inc.	SIEMENS & ASSOCIATES	

Legend to Stratification:

Stratum	Deposit	Material Type
2m	Alluvial / Eolian	SAND w/ Silt : Topsoil
2g	Alluvial	GRAVEL w/ Sand, Few Cobbles
2s	Alluvial	SAND w/ Fine Gravel, Trace Silt
3q	Extrusive	Quaternary BASALT
3p	Extrusive	Pliestocene BASALT
3m	Extrusive	Miocene BASALT: Not Encountered



Scale: Horiz. 1" = 200' Vert. 1" = 10'

Soil and rock classification should be considered accurate only at boring and pit locations. For engineering purposes, stratification is interpolated between test sites and may not necessarily reflect true subsurface conditions.

Cross Section C - C': SITE "L"	FIGURE 6.0.2(C)	
Deschutes Co. Final Landfil Site Evaluation	July 1996	Project No. 966021
Horse Ridge, Oregon		
For: David Evans And Associates, Inc.	SIEMENS & ASSOCIATES	

Appendix E

Table 6.2.1
Boring Log Summary

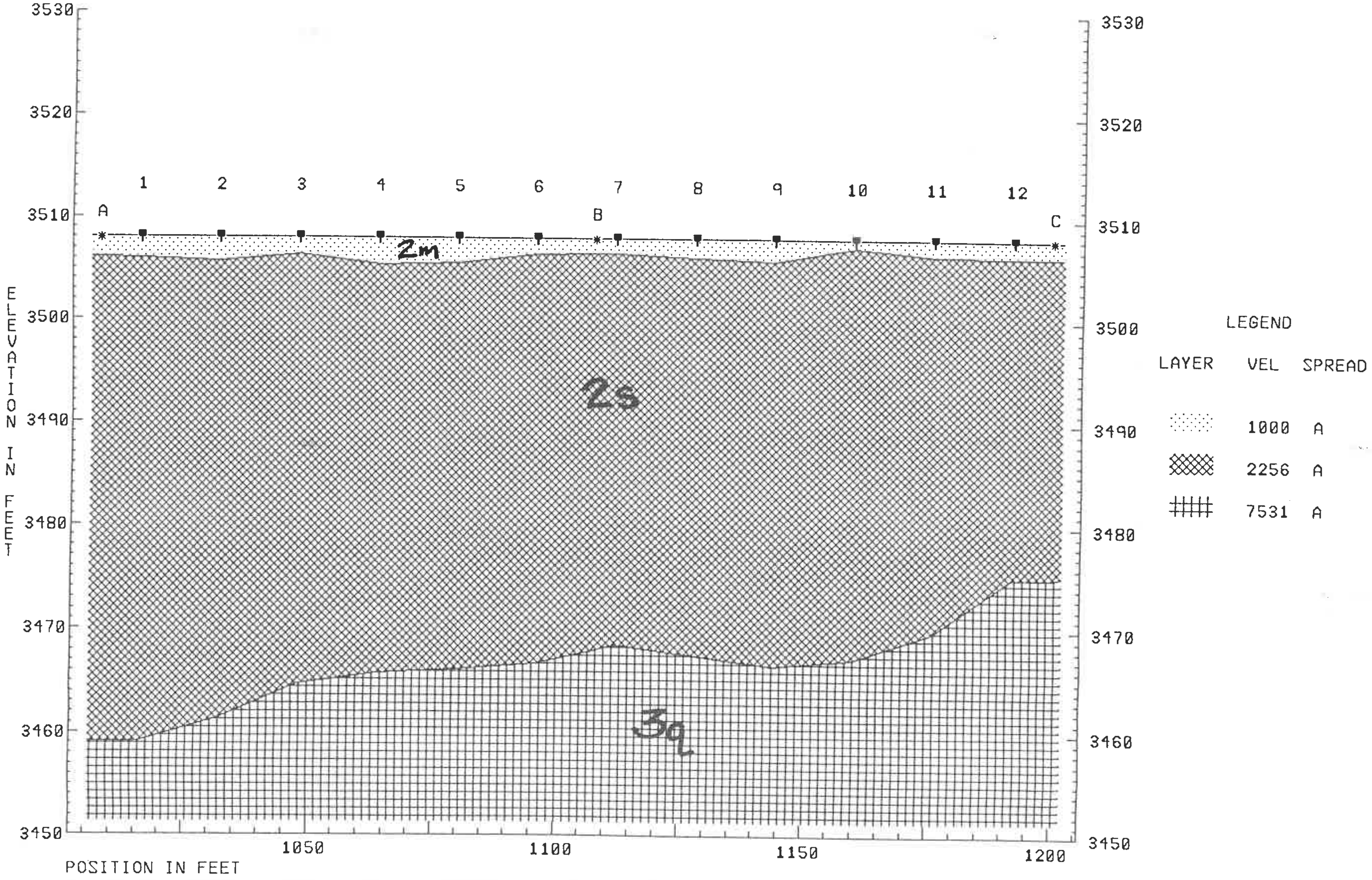
Boring #	Location	Ground Elevation	Est. Depth to Basalt (feet)	Remarks
34	W. Central Area	3494'	5	Stratum 3q
35	W. Central Area	3494'	4½	Stratum 3q
36	W. Central Area	3494'	8	Stratum 3q
37	N.W. Corner Area	3509'	42	Stratum 3q
38	N.W. Central Area	3516'	12	Stratum 3q
39	N. Central Area	3516'	30	Stratum 3q
40	N. Central Area	3516'	23	Stratum 3q
41	E. Central Area	3523'	23	Stratum 3q
42	N. Central Area	3518'	12	Stratum 3q
43	N.E Area	3519'	20	Stratum 3q ?
44	Central Area	3509'	22	Stratum 3q
45	S.W. Area	3490'	7	Stratum 3q
46	S.W. Central Area	3493'	7	Stratum 3q
47	S. Central Area	3501'	6	Stratum 3p
48	W. Central Area	3498'	3	Stratum 3q
49	N. Central	3518'	26	Stratum 3q
50	W. Central	3477'	3	Stratum 3q
51	S.W. Area	3522'	27	Stratum 3q
52	S.W. Area	3521'	17	Stratum 3q ?
53	S.E. Area	3522'	5½	Stratum 3p
54	S.E. Area	3527'	11	Stratum 3p
55	E. Central Area	3524'	12½	Stratum 3q

Deschutes County Final Landfill Site Evaluation: Site L
Horse Ridge, Oregon

Project No. 966021

FILE 00-01.SIP
SITE L: SEISMIC LINE 00-01, NW AREA

SPREAD A



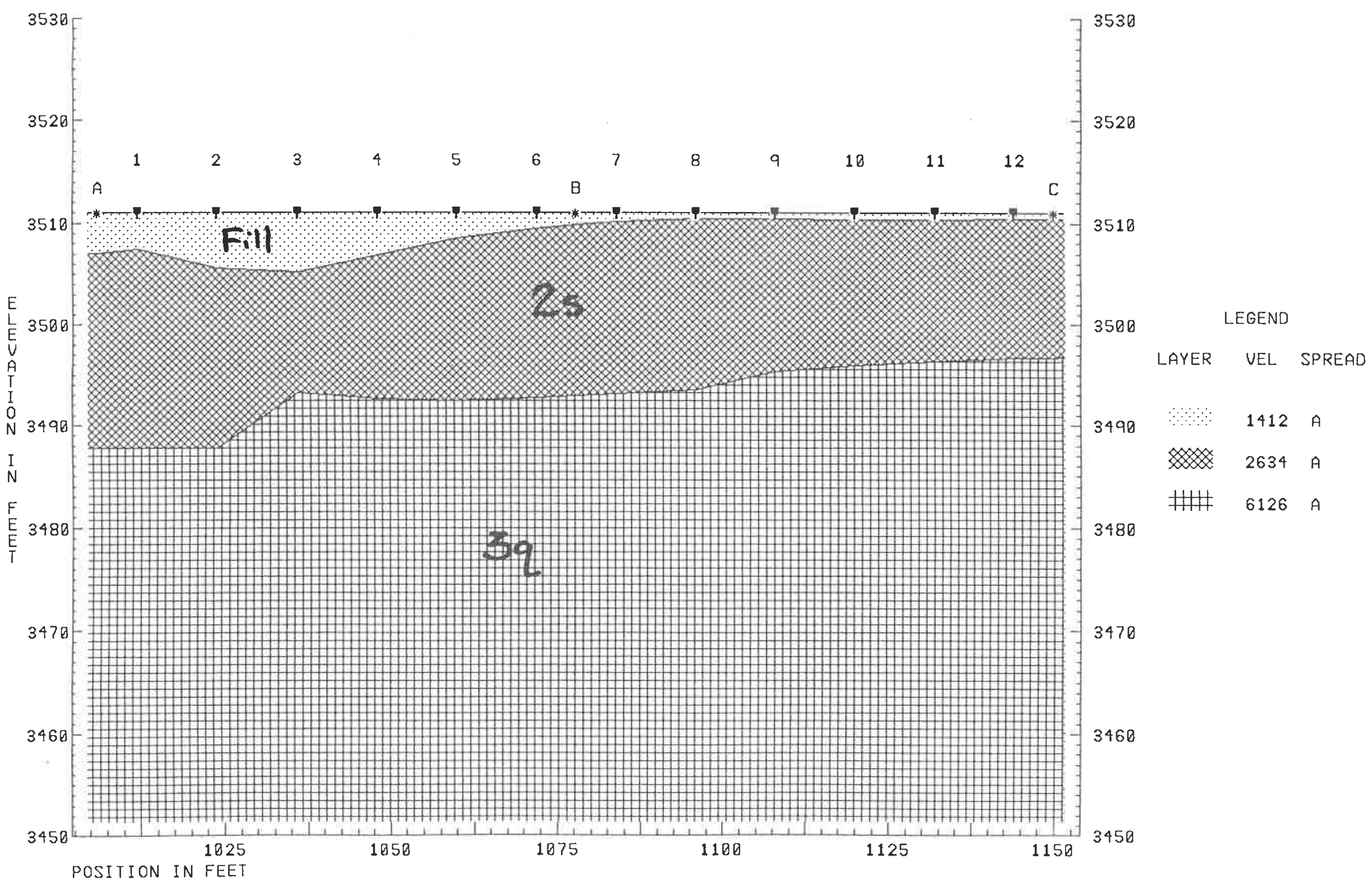
Appendix E

Deschutes County Final Landfill Site Evaluation: Site L
Horse Ridge, Oregon

Project No. 966021

Appendix E

FILE 00-03.SIP
SITE L: SEISMIC LINE 00-03, WEST, CENTER AREA
SPREAD A



F' e 6.

Deschutes County Final Landfill Site Evaluation: Site L
Horse Ridge, Oregon

Project No. 966021

Appendix E

FILE 00-02.SIP
SITE L: SEISMIC LINE 00-02, SW AREA
SPREAD A

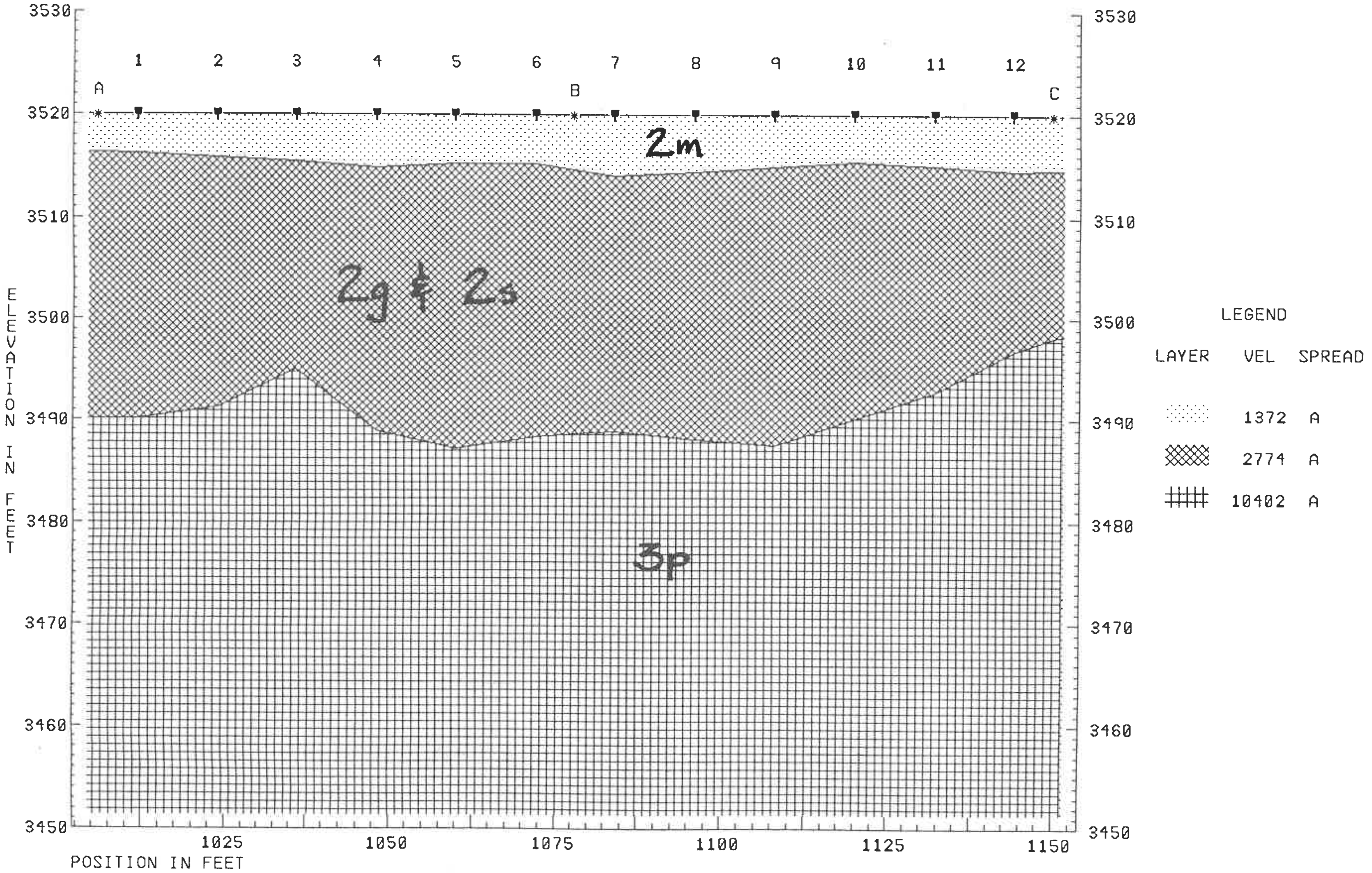


Figure 6.7(2)

Deschutes County Final Landfill Site Evaluation: Site L
Horse Ridge, Oregon

Project No. 966021

FILE 00-04.SIP
SITE L: SEISMIC LINE 00-04, SE AREA
SPREAD A

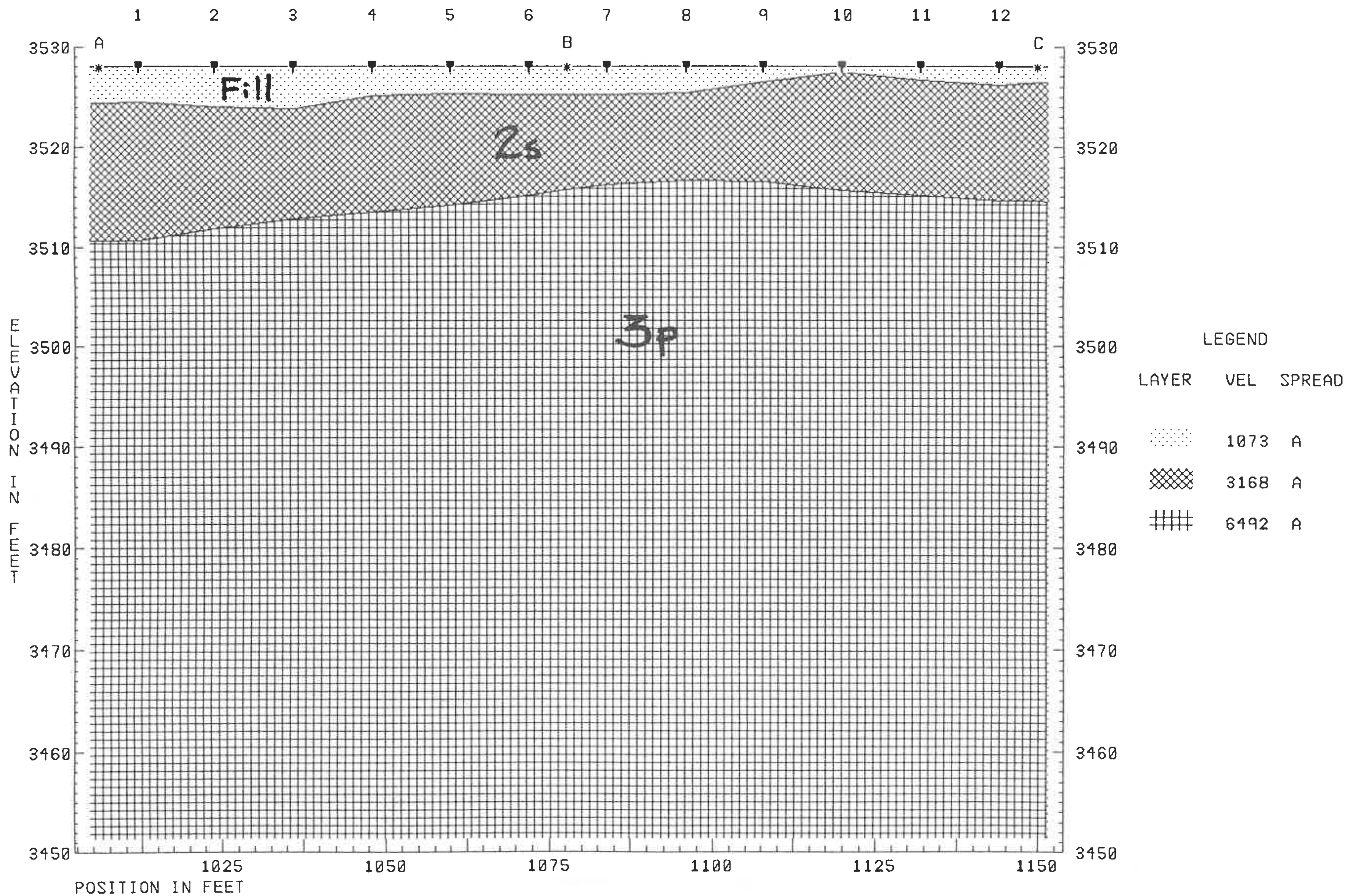


Figure 6.7(4)

Appendix E

Deschutes County Final Landfill Site Evaluation: Site L
Horse Ridge, Oregon

Project No. 966021

FILE 00-05.SIP
SITE L: SEISMIC LINE 00-05 , SE AREA

SPREAD A

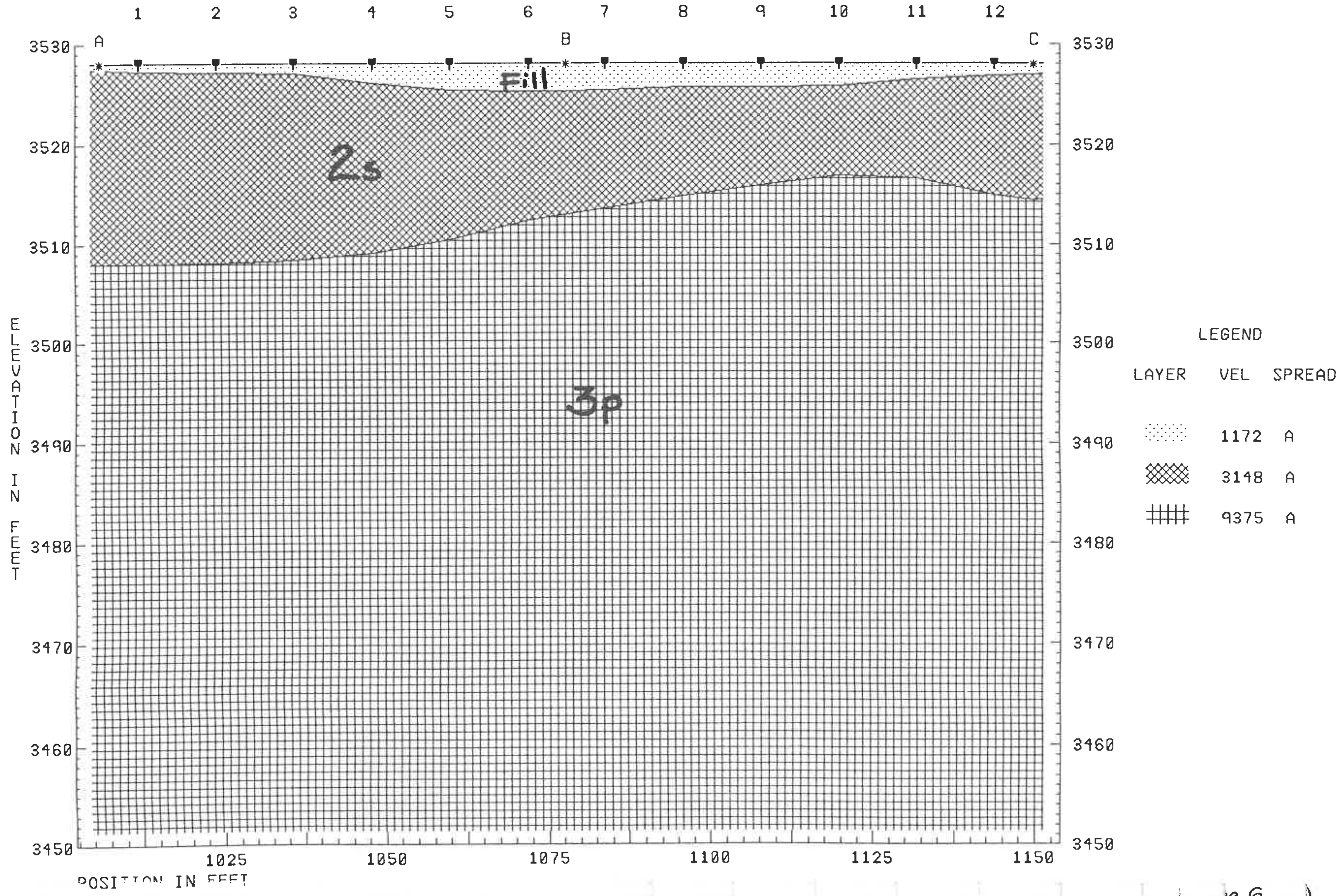


Figure 6. ...)

FILE 00-06.SIP
SITE L: SEISMIC LINE 00-06, EAST, CENTER AREA
SPREAD A

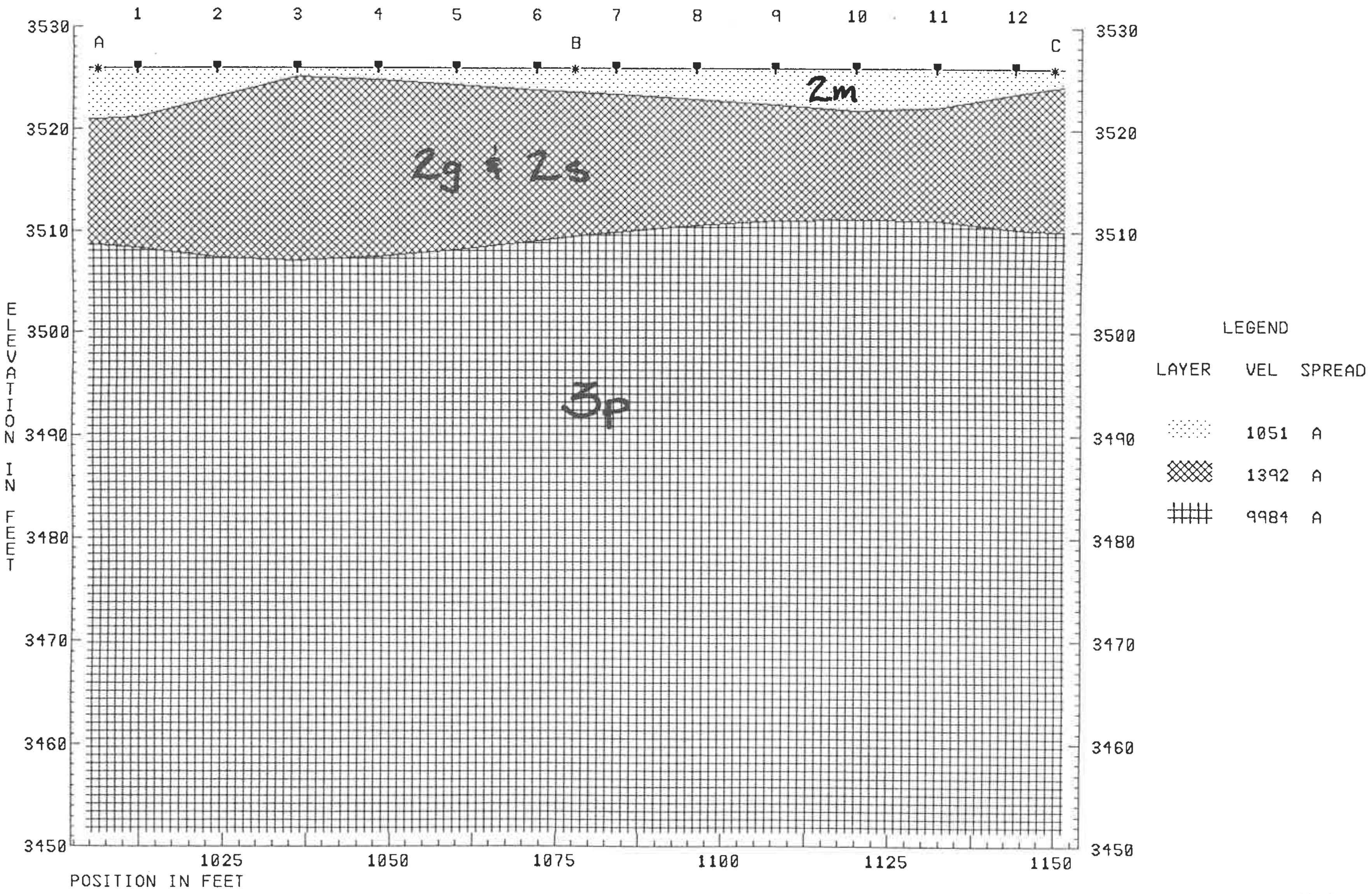
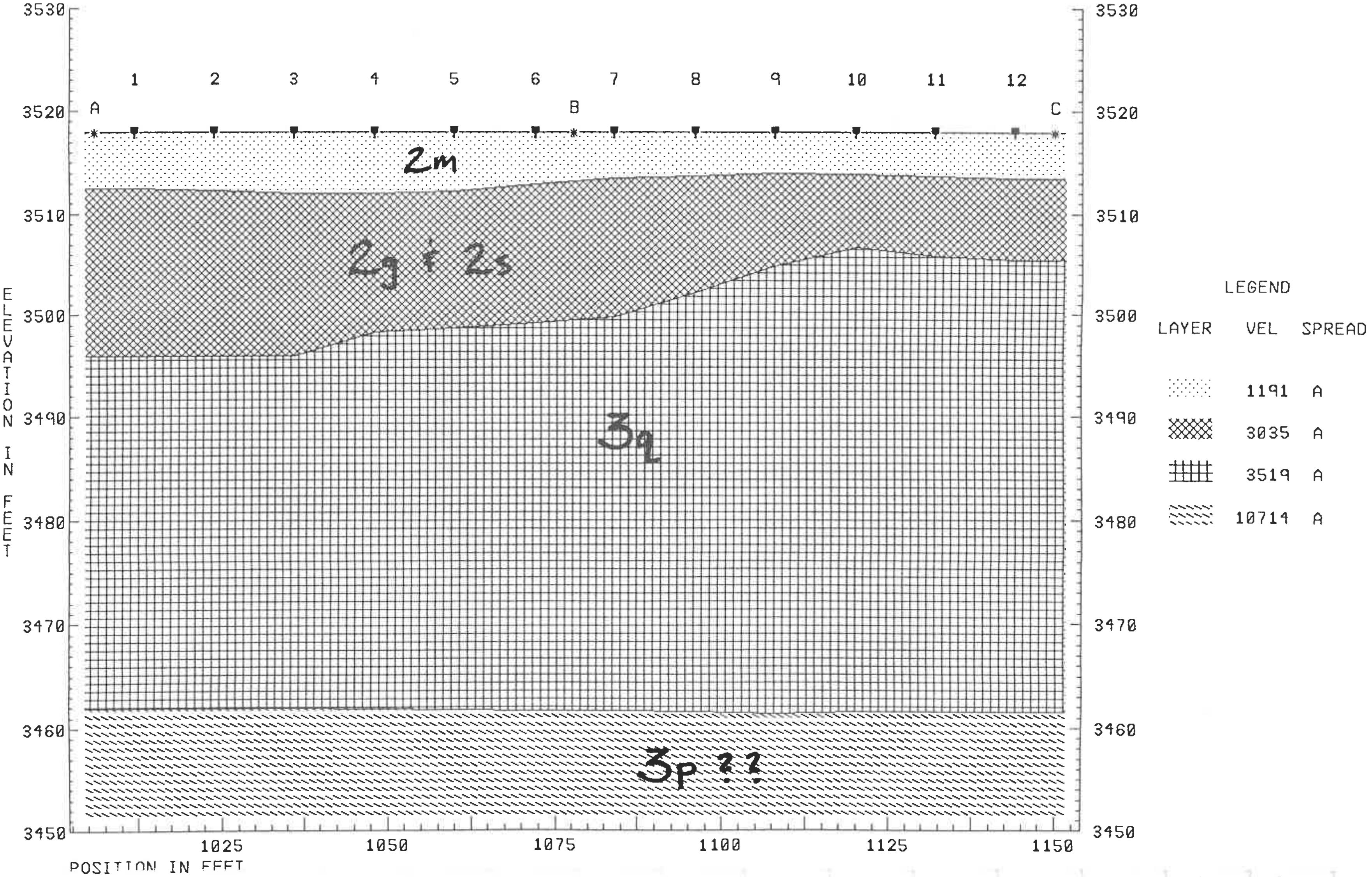


Figure 6.7(6)

Deschutes County Final Landfill Site Evaluation: Site L
Horse Ridge, Oregon

Project No. 966021

```
FILE     00-07.SIP
SITE L:   SEISMIC LINE 00-07,   NORTH, CENTRAL AREA
                                          SPREAD A
```



F...e 6.

Deschutes County Final Landfill Site Evaluation: Site L
Horse Ridge, Oregon

Project No. 966021

Appendix E

FILE 00-08.SIP
SITE L: SEISMIC LINE 00-08, NW AREA
SPREAD A

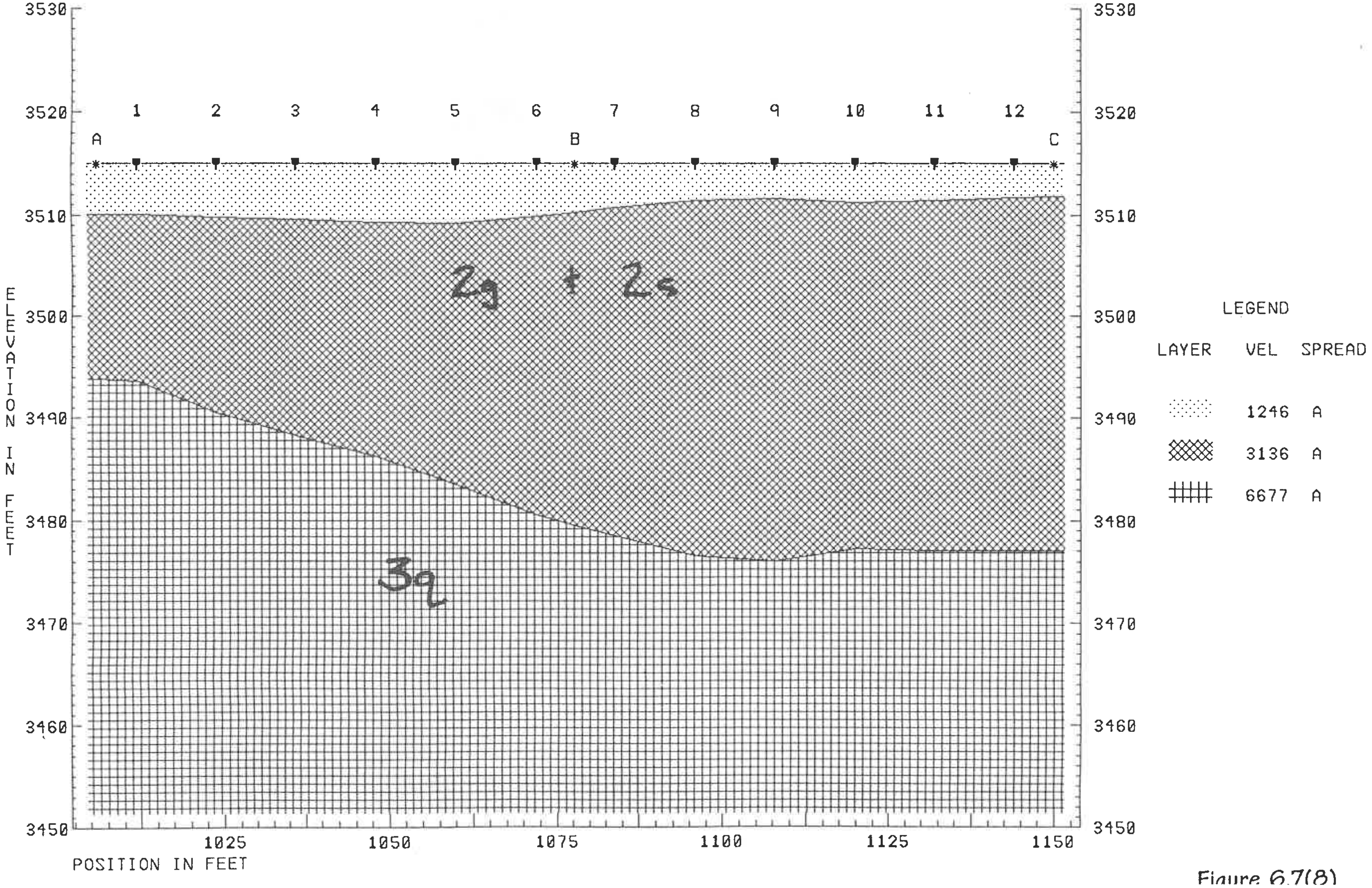


Figure 6.7(8)

FILE 00-10.SIP
SITE L: SEISMIC LINE 00-10, WEST CENTER AREA (BOTTOM OF PIT)
SPREAD A

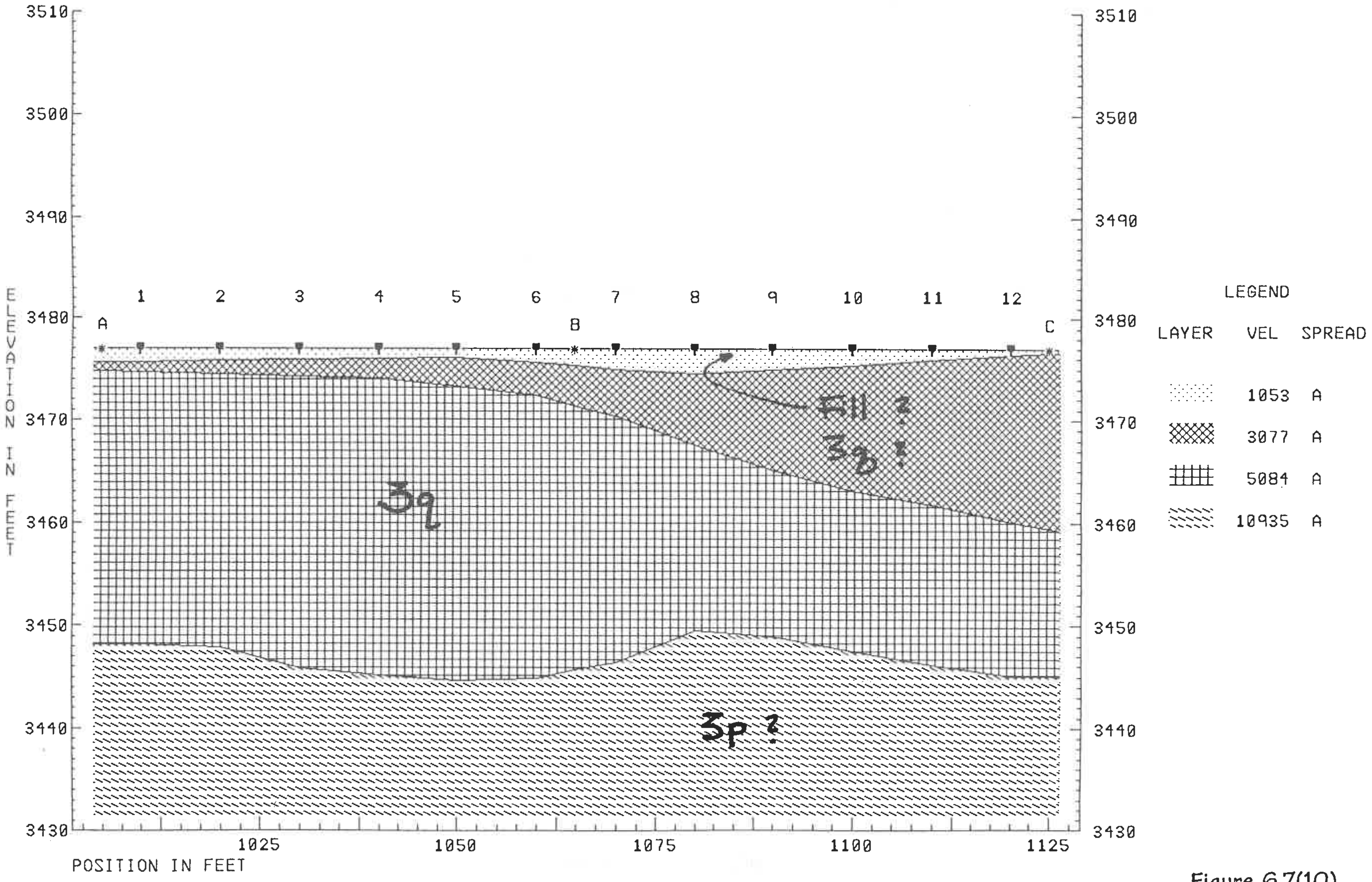


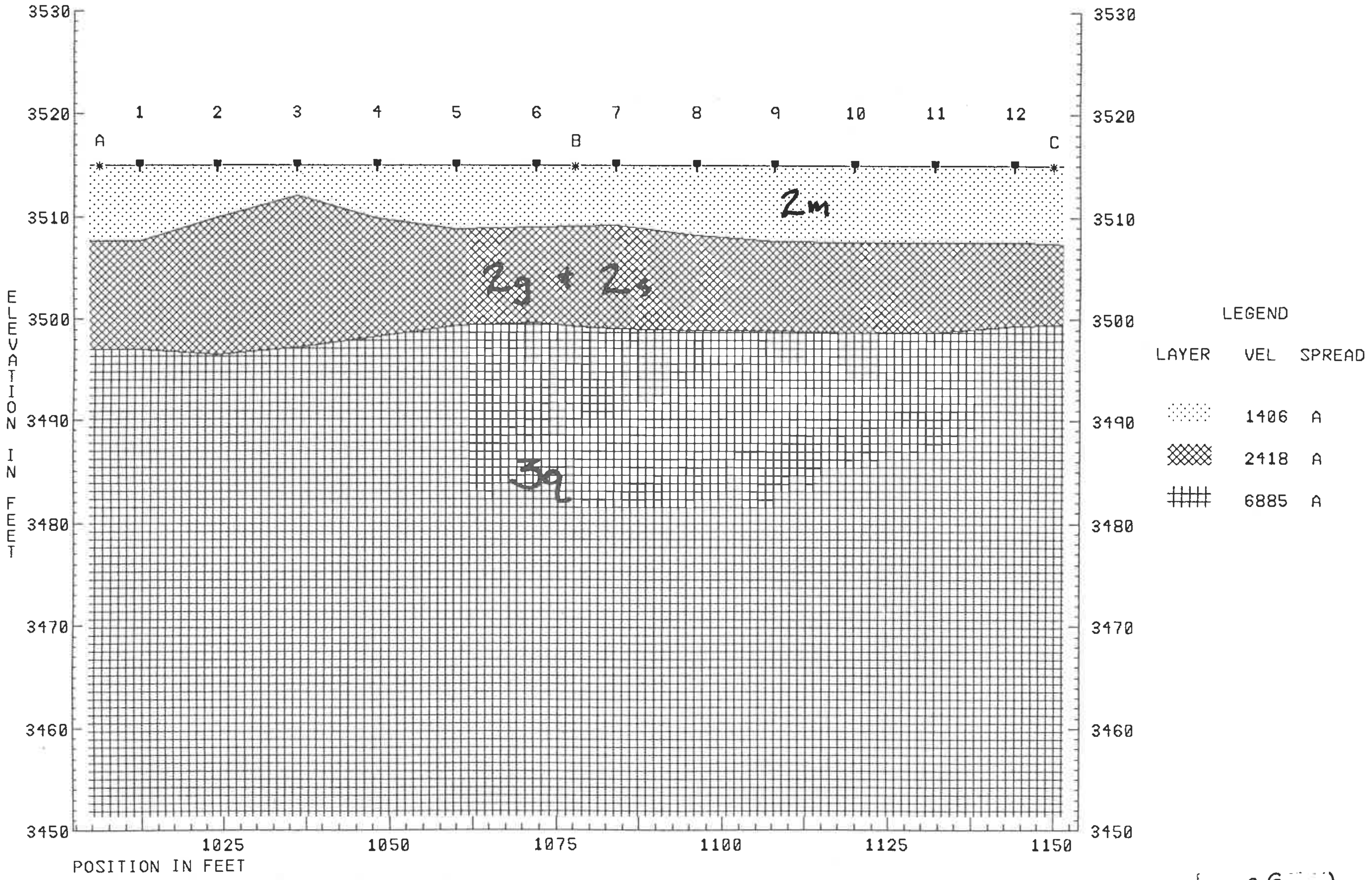
Figure 6.7(10)

Deschutes County Final Landfill Site Evaluation: Site L
Horse Ridge, Oregon

Project No. 966021

Appendix E

FILE 00-11.SIP
SITE L: SEISMIC LINE 00-11, CENTRAL AREA
SPREAD A



Deschutes County Final Landfill Site Evaluation: Site L
Horse Ridge, Oregon

Project No. 966021

Appendix E

FILE 00-09.SIP
SITE L: SEISMIC LINE 00-09, SW CENTER AREA
SPREAD A

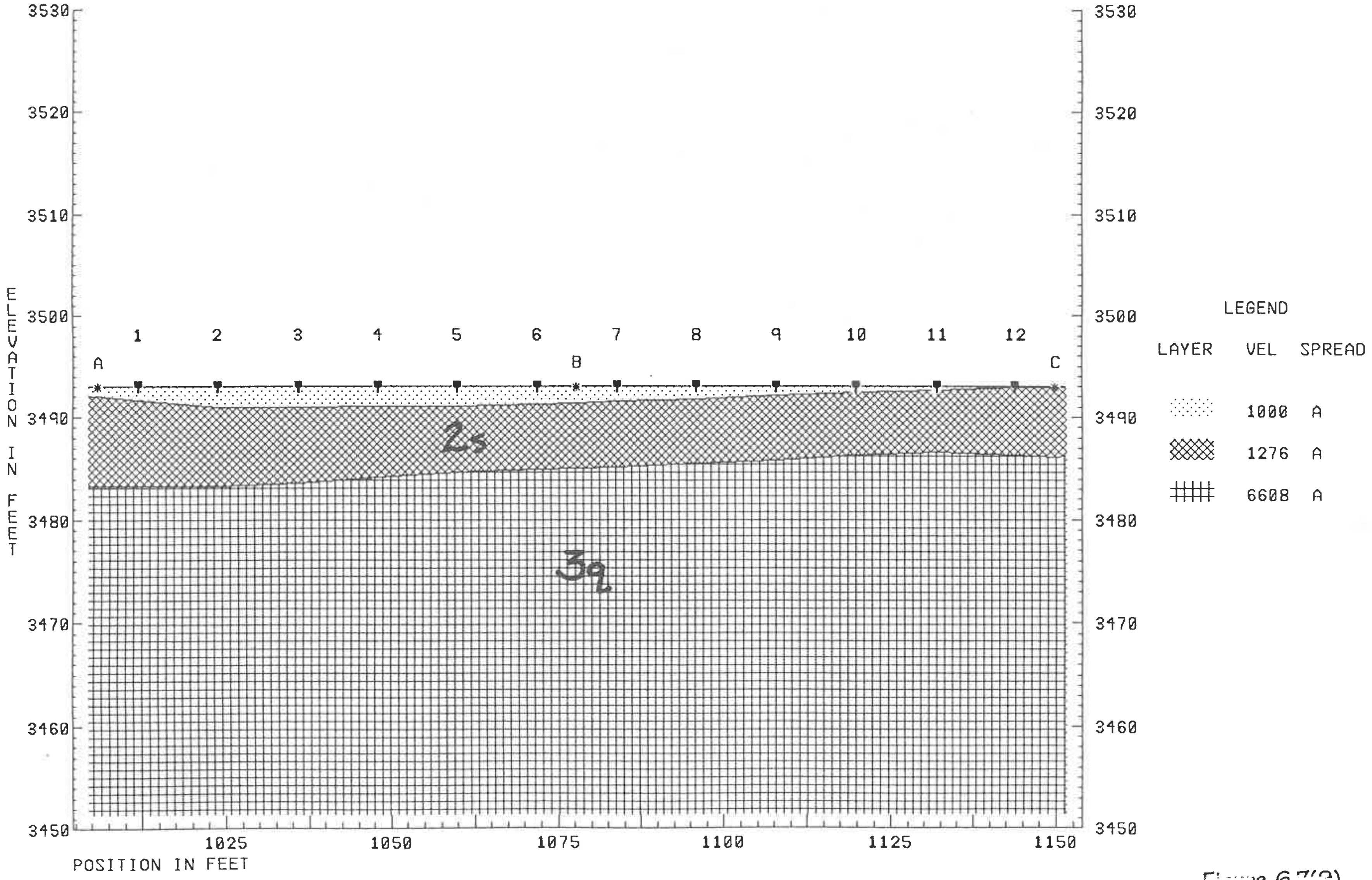
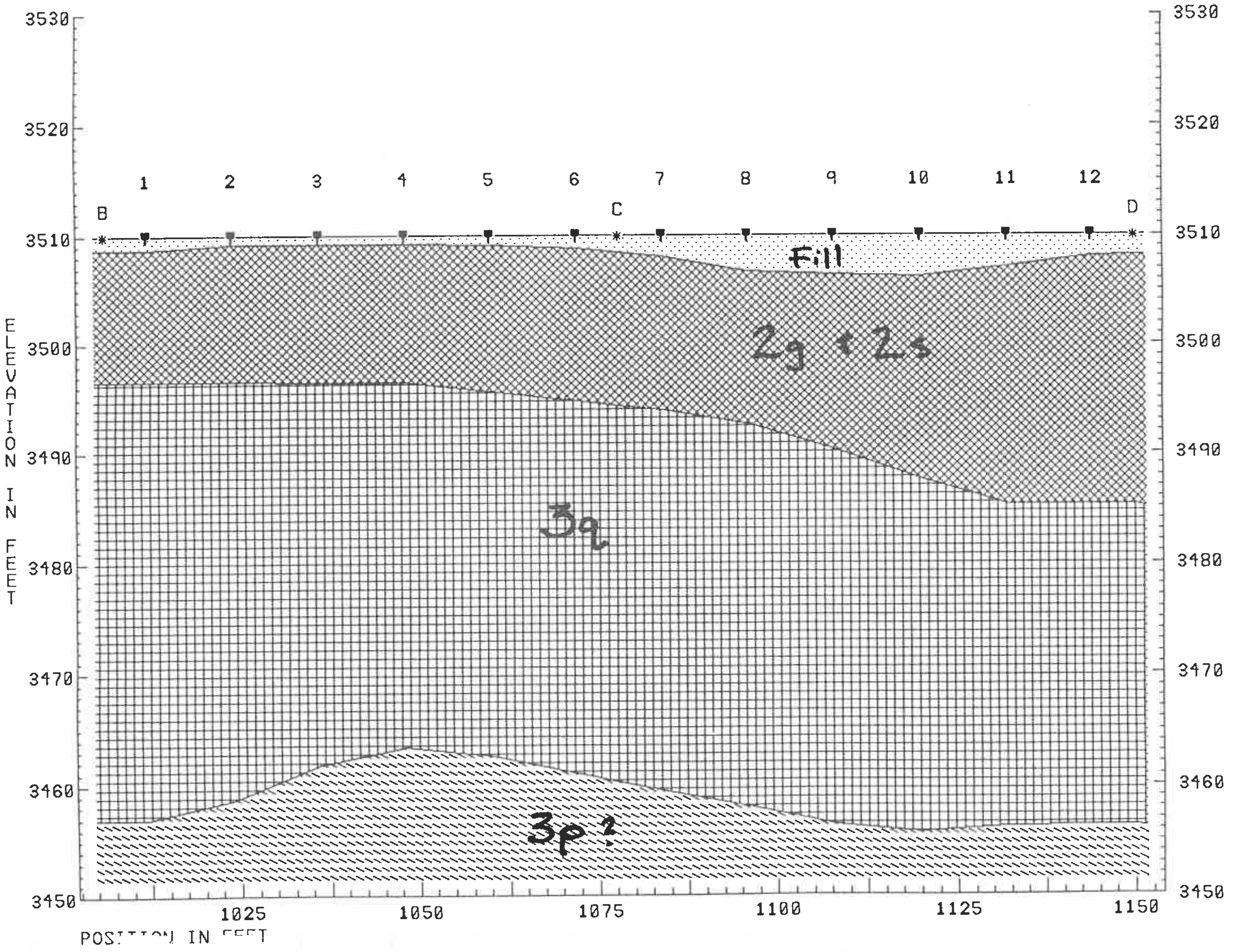


Figure 6.7(2)

Deschutes County Final Landfill Site Evaluation: Site L
Horse Ridge, Oregon

Project No. 966021

FILE 00-13.SIP
SITE L: SEISMIC LINE 00-13, W. CENTRAL AREA
SPREAD A



LEGEND

LAYER	VEL	SPREAD
░	1836	A
▩	2232	A
▦	4202	A
▧	13408	A

Figure 6.[illegible])

Deschutes County Final Landfill Site Evaluation: Site L
Horse Ridge, Oregon

Project No. 966021

Appendix E

FILE 00-14.SIP
SITE L: SEISMIC LINE 00-14, SE CENTRAL AREA
SPREAD A

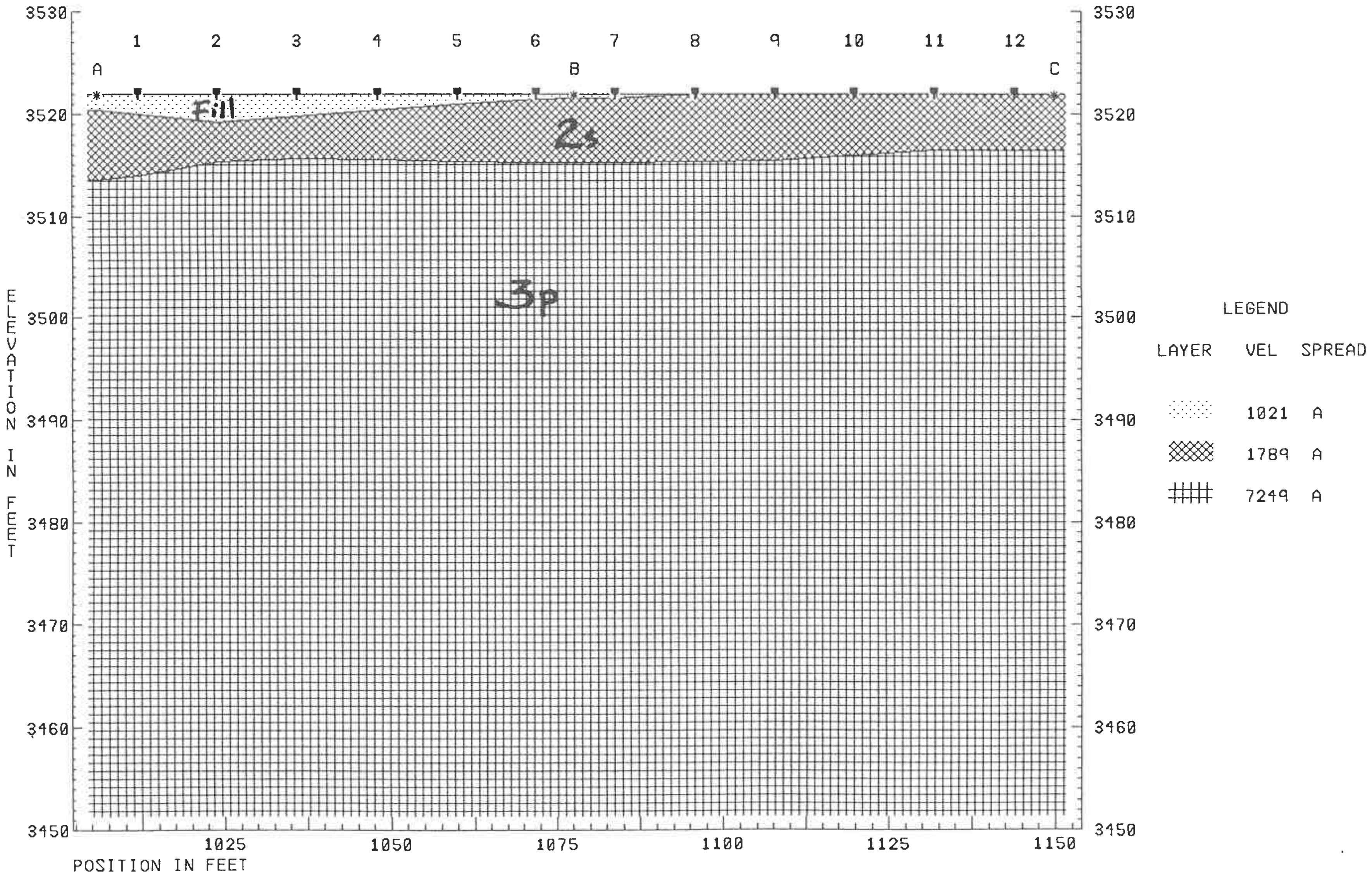


Figure 6.7(14)

Deschutes County Final Landfill Site Evaluation: Site L
Horse Ridge, Oregon

Project No. 966021

Appendix E

FILE 00-15.SIP
SITE L: SEISMIC LINE 00-15, SE AREA

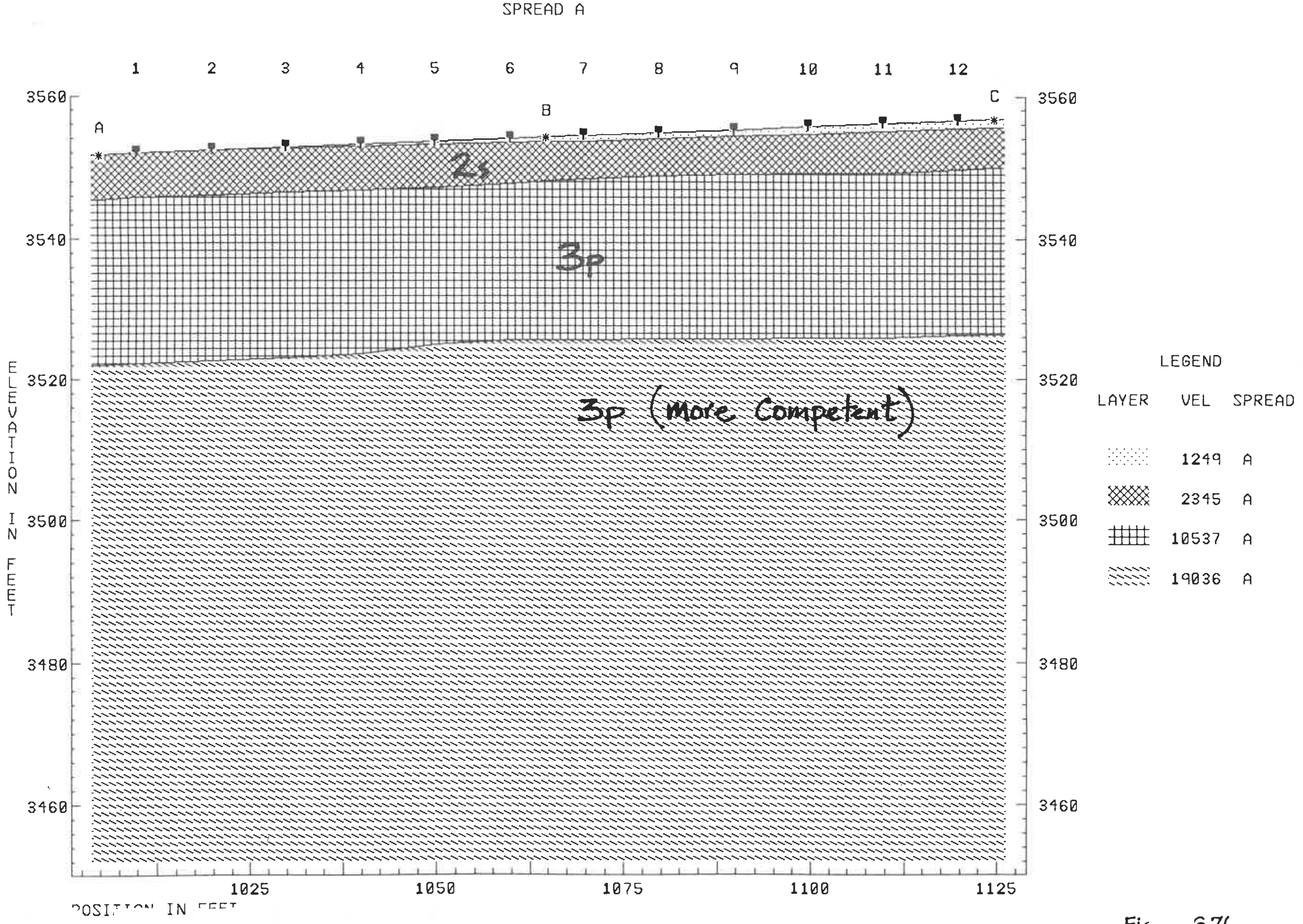


Figure 6.7(

Deschutes County Final Landfill Site Evaluation: Site L
Horse Ridge, Oregon

Project No. 966021

FILE 00-12.SIP
SITE L: SEISMIC LINE 00-12, NE AREA
SPREAD A

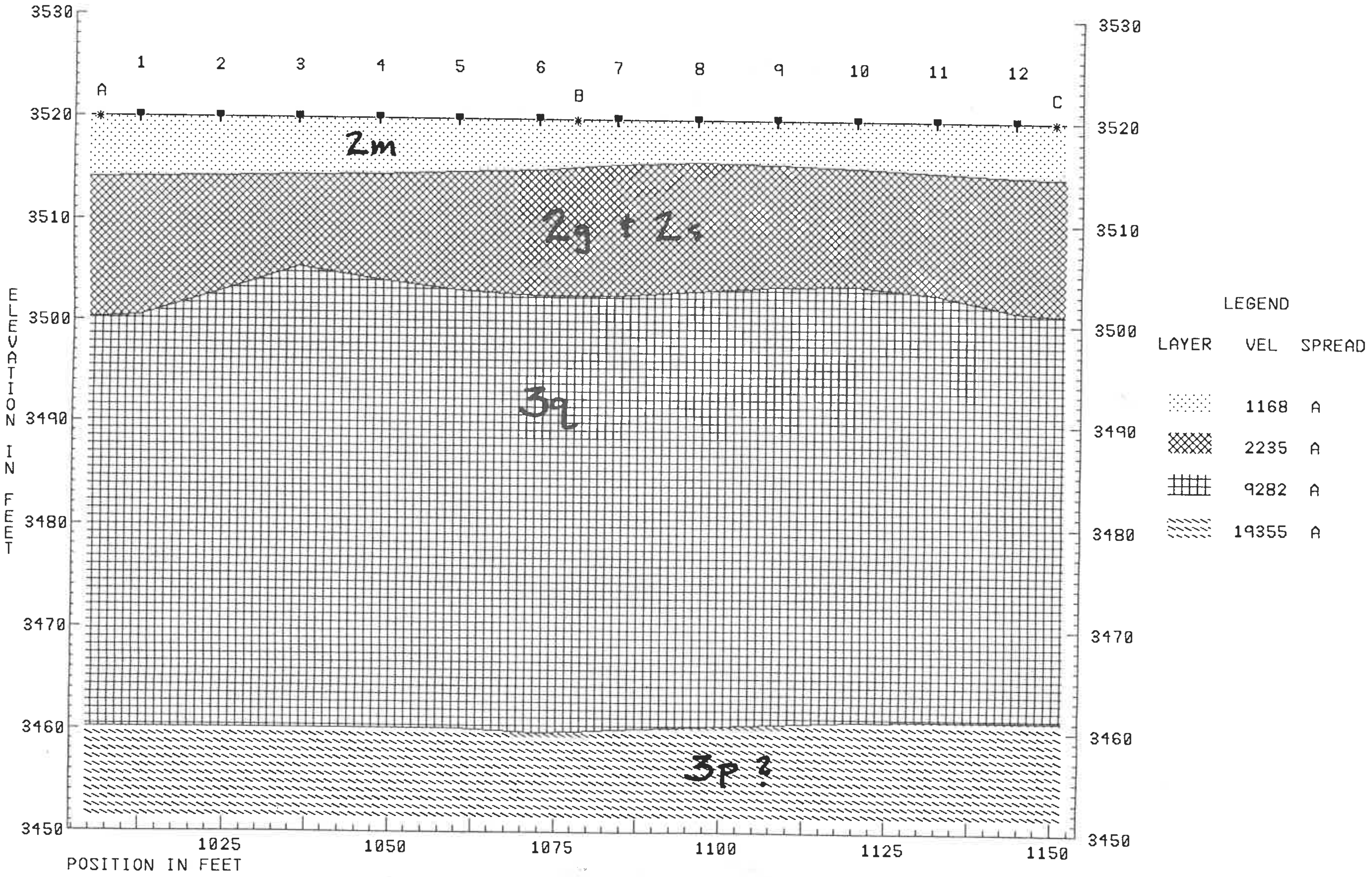
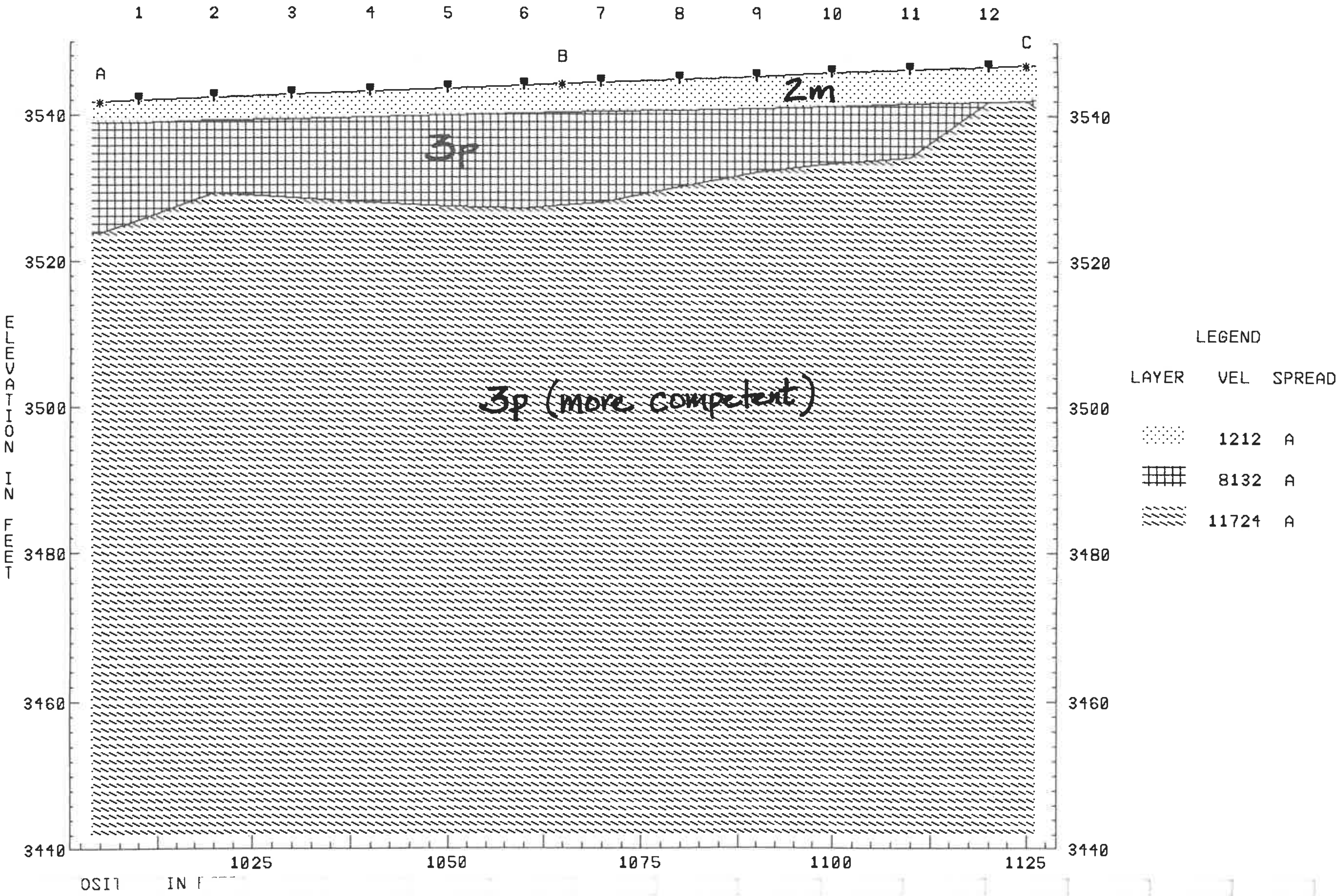


Figure 6.7(12)

Deschutes County Final Landfill Site Evaluation: Site L
Horse Ridge, Oregon

Project No. 966021

FILE 00-17.SIP
SITE L: SEISMIC LINE 00-17, SE AREA
SPREAD A



Appendix E

Deschutes County Final Landfill Site Evaluation: Site L
Horse Ridge, Oregon

Project No. 966021

FILE 00-16.SIP
SITE L: SEISMIC LINE 00-16 , SE AREA
SPREAD A

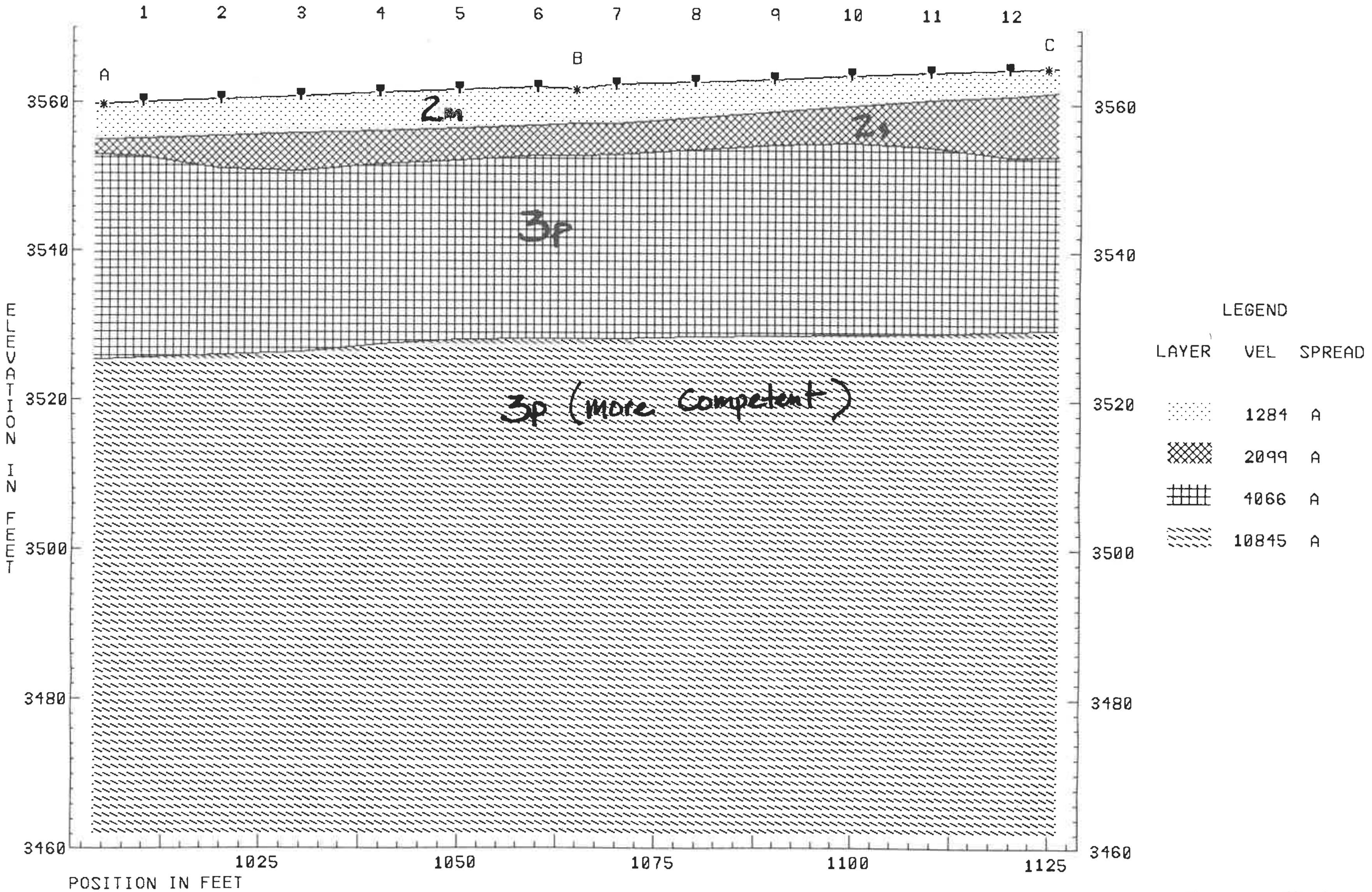


Figure 6.7(16)

Appendix E

Appendix F OWRD Well Logs

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WATER RESOURCES DEPT.
SALEM, OREGON

DESC 5750

Pg. 1 of 2

19/14E 2

STATE OF OREGON
WATER WELL REPORT
(as required by ORS 537.765)

(1) OWNER:
Owner's Well Number:
Name **Eugene Moon**
Address **[illegible] (P.O. Box) 5952**
City **Bend** State **Oregon** Zip **97708**

(2) TYPE OF WORK:
☒ New Well ☐ Deepen ☐ Recondition ☐ Abandon

(3) DRILL METHOD:
☒ Rotary Air ☐ Rotary Mud ☐ Cable ☐ Other

(4) PROPOSED USE:
☒ Domestic ☐ Community ☐ Industrial ☐ Irrigation
hermal ☐ Injection ☐ Other

) BORE HOLE CONSTRUCTION:
Depth of Completed Well **915** ft.
Special Standards date of approval

HOLE			SEAL			
meter	From	To	Material	From	To	Amount sacks or pounds
"	0	19½	Bentonite			16 sacks

How was seal placed? Method ☐ A ☐ B ☐ C ☐ D ☐ E
☒ Other **Poured down dry**
Backfill placed from ____ ft. to ____ ft. Material
Gravel placed from ____ ft. to ____ ft. Size of gravel

(6) CASING/LINER:

	Diameter	From	To	Gauge	Steel	Plastic	Welded	Threaded
Casing:	8"	+1½	19½	.250	☒	☐	☐	☐
					☐	☐	☐	☐
					☐	☐	☐	☐
					☐	☐	☐	☐
Liner:					☐	☐	☐	☐
					☐	☐	☐	☐

l location of shoe(s)

) PERFORATIONS/SCREENS:
☐ Perforations Method ---------
☐ Screens Type Material

om	To	Slot size	Number	Diameter	Tele/pipe size	Casing	Liner
						☐	☐
						☐	☐
						☐	☐
						☐	☐
						☐	☐
						☐	☐

(8) WELL TESTS: Minimum testing time is 1 hour
☐ Pump ☒ Bailer ☐ Air ☐ Flowing Artesian

Yield gal/min	Pumping level	Drill stem at	Time
10	[illegible]	905	½ hr
10		905	1 hr

Temperature of water **62*** Depth Artesian Flow Found
Was a water analysis done? ☐ Yes By whom **no**
Did any strata contain water not suitable for intended use? ☐ Too little **no**
☐ Salty ☐ Muddy ☐ Odor ☐ Colored ☐ Other
Depth of strata:

(9) LOCATION OF WELL by legal description:
County **Deschutes** Latitude ____ ' " Longitude ____ ' "
Township **19S** N or S, Range **14E** E or W, WM.
Section **2** ____ ¼ ____ ¼
Tax Lot ____ Lot ____ Block ____ Subdivision
Street Address of Well (or nearest address) **26300 Bend-Burns Hwy.**
Star Rte. 97701

(10) STATIC WATER LEVEL:
850 ft. below land surface. Date **12-20-86**
Artesian pressure ____ lb. per square inch. Date

(11) WELL LOG:
Ground elevation **unknown**

Material	From	To	WB?	SWL
Sand	0	8		
Broken Lava	8	10		
Hard Grey Lava	10	25		
Broken Lava	25	29		
Mild Lava	29	55		
Mild Lava	55	58		
Broken Lava	58	87		
Cinders	87	95		
Broken Lava	95	105		
Hard Red Lava	105	122		
Broken Red Lava	122	128		
Mild Brown Lava	128	153		
Hard Grey Lava	153	168		
Broken Lava	168	185		
Hard Brown Lava	185	215		
Hard Grey Lava	215	225		
Broken Red Lava	225	228		
Mild Red Lava	228	241		
Broken Red Lava	241	246		
Hard Red Lava	246	253		
Broken Red Lava	253	256		
Mild Red Lava	256	267		
Red Conglomerate	267	273		
Mild Brown Lava	273	305		
Hard Grey Clay	305	308		
Broken Red Lava	308	315		
Hard Grey Lava	315	361		
Red Broken Lava	361	373		
Mild Red Lava	373	385		
Mild Grey Lava	385	396		
Broken Red Lava	396	402		

Date started **Oct. 10-86** Completed **Dec. 20-86**

(unbonded) Water Well Constructor Certification:

I constructed this well in compliance with Oregon well construction standards. Materials used and information reported above are true to my best knowledge and belief.

Signed Date **12-22-86**

(bonded) Water Well Constructor Certification:

I accept responsibility for construction of this well and its compliance with all Oregon water well standards. This report is true to the best of my knowledge and belief.

Signed Date 12-22-86

Company **Orvail Buckner Well Drill'g. Inc.**

9809C 10/85

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DEC 24 1986

~~WATER RESOURCES DEPT.~~
~~SALEM, OREGON~~

Page 2 of 2

19S/14E-2

STATE OF OREGON
WATER WELL REPORT
(as required by ORS 537.765)

(1) OWNER:
Name **Eugen Moon**
Address **P.O. Box 5952**
City **Bend** State **Oregon** Zip **97708**

(2) TYPE OF WORK:
☒ New Well ☐ Deepen ☐ Recondition ☐ Abandon

(3) DRILL METHOD:
☒ Rotary Air ☐ Rotary Mud ☐ Cable ☐ Other

(4) PROPOSED USE:
☒ Domestic ☐ Community ☐ Industrial ☐ Irrigation
hermal ☐ Injection ☐ Other

) BORE HOLE CONSTRUCTION:
Depth of Completed Well ______ ft.
Special Standards date of approval ______

HOLE			SEAL			Amount
meter	From	To	Material	From	To	sacks or pounds
2"	0	19½	Bentonite			16 sacks

How was seal placed? Method ☐ A ☐ B ☐ C ☐ D ☐ E
☒ Other **Poured down dry**
Backfill placed from ______ ft. to ______ ft. Material ______
Gravel placed from ______ ft. to ______ ft. Size of gravel ______

(6) CASING/LINER:

	Diameter	From	To	Gauge	Steel	Plastic	Welded	Threaded
Casing:	8"	+1½	19½	.250	☒	☐	☐	☐
					☐	☐	☐	☐
					☐	☐	☐	☐
					☐	☐	☐	☐
Liner:					☐	☐	☐	☐
					☐	☐	☐	☐

l location of shoe(s) ______

) PERFORATIONS/SCREENS:
☐ Perforations Method ------------
☐ Screens Type ______ Material ______

om	To	Slot size	Number	Diameter	Tele/pipe size	Casing	Liner
						☐	☐
						☐	☐
						☐	☐
						☐	☐
						☐	☐
						☐	☐

(8) WELL TESTS: Minimum testing time is 1 hour
☐ Pump ☒ Bailer ☐ Air ☐ Flowing Artesian

Yield gal/min	Pumping level	Drill stem at	Time
10		905	½ hr
10		905	1 hr
10		905	

Temperature of water ______ Depth Artesian Flow Found ______
Was a water analysis done? ☐ Yes By whom ______
Did any strata contain water not suitable for intended use? ☐ Too little
☐ Salty ☐ Muddy ☐ Odor ☐ Colored ☐ Other ______
Depth of strata: ______

(9) LOCATION OF WELL by legal description:
County **Deschutes** Latitude ______ ' " Longitude ______ ' "
Township **19S** N or S, Range **14E** E or W, WM.
Section **2** ______ ¼ ______ ¼
Tax Lot ______ Lot ______ Block ______ Subdivision ______
Street Address of Well (or nearest address) **26300 Bend-Burns Hwy. Star Rte. 97701....**

(10) STATIC WATER LEVEL:
850 ft. below land surface. Date **12-20-86**
Artesian pressure ______ lb. per square inch. Date ______

(11) WELL LOG:
Ground elevation **unknown**

Material	From	To	WB?	SWL
Mild Brown Lava	402	412		
Hard Grey Lava	412	429		
Broken Red Lava	429	432		
Broken Red Lava	432	445		
Broken Sandstone	445	515		
Broken Grey Lava	515	535		
Broken Red Lava	535	570		
Broken Grey Lava	570	680		
Hard Grey Lava	680	722		
Mild Broken Lava	722	735		
Hard Grey Lava	735	745		
Broken Lava	745	753		
Hard Grey Lava	753	769		
Broken Lava	769	771		
Hard Grey Lava	771	883		
Red Cinder Conglomerate	883	893		
Hard Black Lava	893	905		
W/B Red Cinder Gravels	905	913		
Mild Red Lava	913	920		
Red Cinder Gravels W/B	920	931		

Date started **Oct. 10-86** Completed **Dec. 20-86**

(unbonded) Water Well Constructor Certification:

I constructed this well in compliance with Oregon well construction standards. Materials used and information reported above are true to my best knowledge and belief.

Signed ______ Date **12-22-86**

(bonded) Water Well Constructor Certification:

I accept responsibility for construction of this well and its compliance with all Oregon water well standards. This report is true to the best of my knowledge and belief.

Signed ______ Date **12-22-86**

Company **Orvail Buckner Well Drill'g. Inc.** Co. No.

9809C 10/86

11

Desc 9126

19S/14E/2da

STATE OF OREGON

WATER WELL REPORT

(as required by ORS 537.765)

MAR 15 1994
WATER RESOURCES DEPT
SALEM, OREGON

(START CARD) # 58111

(1) OWNER:

Well Number

Name Hooker Creek Ranch

Address 65525 Gerking Market Road

City Bend State OR Zip 97702

(2) TYPE OF WORK:

☒ New Well ☐ Deepen ☐ Recondition ☐ Abandon

(3) DRILL METHOD

☐ Rotary Air ☐ Rotary Mud ☒ Cable

☐ Other

(4) PROPOSED USE:

☒ Domestic ☐ Community ☒ ~~Industrial~~ ☐ Irrigation

☐ Thermal ☐ Injection ☐ Other

(5) BORE HOLE CONSTRUCTION:

Special Construction approval Yes ☐ No ☒ Depth of Completed Well 1135 ft.

Explosives used Yes ☐ No ☒ Type --- Amount ---

HOLE			SEAL			Amount
Diameter	From	To	Material	From	To	sacks or pounds
20	0	162	XXXXXXXX	0	55	14.5 yards
			Cement			
14"	162	1135				

How was seal placed: Method ☐ A ☐ B ☒ C ☐ D ☐ E

☐ Other

Backfill placed from -- ft. to -- ft. Material ----

Gravel placed from -- ft. to -- ft. Size of gravel ----

(6) CASING/LINER:

	Diameter	From	To	Gauge	Steel	Plastic	Welded	Threaded
Casing:	14	+3	1007	.375	☒	☐	☒	☐
					☐	☐	☐	☐
					☐	☐	☐	☐
					☐	☐	☐	☐
Liner:	12	1000	1048	.250	☒	☐	☒	☐
	10	1048	1135	.250	☒	☐	☒	☐

Final location of shoe(s) 14" 1007

(7) PERFORATIONS/SCREENS:

☒ Perforations Method Machine

☐ Screens Type ---- Material ------

From	To	Slot size	Number	Diameter	Tele/pipe size	Casing	Liner
870	970	1/8x3	5320	14		☒	☐
1095	1135	1/8x3	1520	10		☐	☒
						☐	☐
						☐	☐
						☐	☐
						☐	☐

(8) WELL TESTS: Minimum testing time is 1 hour

☐ Pump ☒ Bailer ☐ Air ☐ Flowing Artesian

Yield gal/min	Drawdown	Drill stem at	Time
50	0		1 hr.

Temperature of water 56 Depth Artesian Flow Found ----

Was a water analysis done? ☐ Yes By whom ----

Did any strata contain water not suitable for intended use? ☐ Too little

☐ Salty ☐ Muddy ☐ Odor ☐ Colored ☐ Other ----

Depth of strata: -----

(9) LOCATION OF WELL by legal description:

County Deschutes Latitude ' " Longitude ' "

Township 19 S N or S. Range 14E E or W. WM.

Section 2 NE 1/4 SE 1/4

Tax Lot Unknown Lot Block Subdivision

Street Address of Well (or nearest address) 18 miles on Burns Highway

(10) STATIC WATER LEVEL:

852 ft. below land surface. Date 1/30/94

Artesian pressure --- lb. per square inch. Date ----

(11) WATER BEARING ZONES:

Depth at which water was first found 890

From	To	Estimated Flow Rate	SWL
890	895	50	852
1090	1130	50	852

(12) WELL LOG:

Ground elevation

Material	From	To	SWL
SEE ATTACHED SHEET			

Date started 8/30/93 Completed 2/14/94

(unbonded) Water Well Constructor Certification:

I certify that the work I performed on the construction, alteration, or abandonment of this well is in compliance with Oregon well construction standards. Materials used and information reported above are true to my best knowledge and belief.

Signed WWC Number 758

Date

(bonded) Water Well Constructor Certification:

I accept responsibility for the construction, alteration, or abandonment work performed on this well during the construction dates reported above. all work performed during this time is in compliance with Oregon well construction standards. This report is true to the best of my knowledge and belief.

WWC Number 723

Signed Date

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DESC.
9126

MAR 15 1994
WATER RESOURCES DEPT
SALEM, OREGON

Hooker Creek Ranch
65525 Gerking Market Rd
Bend, OR 97702

Start Card #
58111

(12) WELL LOG

MATERIAL	FROM	TO
Pumice brown	0	4
Clay sand gravel	4	12
Lava rock black	12	42
Basalt	42	46
Lava rock red	46	64
Broken lava rock	64	70
Lava black	70	75
Red lava	75	91
Cinders	91	95
Lava rock hard	95	100
Lava rock broken	100	110
Lava rock black	110	125
Lava rock brown	125	135
Black lava and red cinders	135	148
Basalt gray	148	163
Lava rock black and red layers	163	182
Cinders red and black layers	182	202
Lava rock black	202	208
:Lave rock brown	208	237
Andesite basalt	237	247
Lava and basalt layers black	247	277
Red lava	277	285
Lava brown pumice layers	285	305
Lava red	305	330
Gray tuffstone	330	355
Gray basalt soft	355	374
Red cinders and lava rock	374	385
Pumice	385	390
Red gray lava layers with cinders	390	429
Andesite basalt	429	440
Red lava	440	487
Basalt gray hard	487	501
Lava rock brown	501	528
Red basalt	528	536
Weathered rock yellow	536	565

DESC
9126

Hooker Creek Ranch
Well Log
Page 2

Gray basalt	565	612	
Pumice	612	615	
Black basalt	615	634	
Gray basalt	634	732	
Basalt with lava layers	732	865	
Lava broken red	865	882	
Lava rock solid	882	898	
Lava pourous	898	935	852
Lava broken	935	945	
Layers of pumice brown clay with red fibers	945	990	
Weathered rock yellow	990	1010	
Gray basalt	1010	1075	
Lava red black	1075	1090	
Pourous lava rock	1090	1105	852
Red lava rock	1105	1115	
Pourous lava	1115	1128	852
Gray basalt	1128	1135	

DESC 56052

1 of 2

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MAY 10 2004

WATER RESOURCES DEPT
SALEM, OREGON

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OVER THE COUNTER

DESC 56052

STATE OF OREGON
WATER SUPPLY WELL REPORT
(as required by ORS 537.765)

WELL ID # L 68135
START CARD # 82082

(1) OWNER:

Well Number: Horse Ridge Pit

Name: 4 R Equipment
Address: P.O. Box 5006
City: Bend State: OR Zip: 97708

(2) TYPE OF WORK:
☒ New Well ☐ Deepening ☐ Alteration (repair/recondition) ☐ Abandonment

(3) DRILL METHOD:
☒ Rotary Air ☐ Rotary Mud ☐ Cable ☐ Auger
☐ Other:

(4) PROPOSED USE:
☒ Domestic ☐ Community ☐ Industrial ☐ Irrigation
☐ Thermal ☐ Injection ☐ Livestock ☐ Other

(5) BORE HOLE CONSTRUCTION:
Special Construction approval ☐ Yes ☒ No
Depth of Completed Well 1155'
Explosives Used ☐ Yes ☒ No Type = Amount —

HOLE Diameter	From	To	Material	SEAL From	To	sacks or pounds
15	0	40	Cement	0	40	70 sacks
10	-40	1150	—	—	—	—
8	1150	1155	—	—	—	—

How was seal placed: Method ☐ A ☐ B ☒ C ☐ D ☐ E
☒ Other
Backfill placed from = to = Material =
from = to = Material =
Gravel placed from — to = Size of gravel =

(6) CASING/LINER:

CASING:

Diameter	From	To	Gauge	Steel	Plastic	Welded	Threaded
12	+1	40	.250	☒	☐	☒	☐
				☐	☐	☐	☐
				☐	☐	☐	☐
				☐	☐	☐	☐

LINER:

Diameter	From	To	Gauge	Steel	Plastic	Welded	Threaded
8	-6	1150	.250	☒	☐	☒	☐
				☐	☐	☐	☐

Final location of Shoe(s):

(7) PERFORATIONS/SCREENS:
☒ Perforations Method: Fact Slot
☐ Screen Type: Material:

From	To	Slot Size	No.	Diameter	Tele/pipe size	Casing	Liner
990	1150	1/8x3	2560		P	☐	☐
						☐	☐
						☐	☐
						☐	☐
						☐	☐

(8) WELL TESTS: Minimum testing time is 1 hour
☐ Pump ☐ Bailer ☒ Air ☐ Flowing Artesian

Yield gal/min	Drawdown	Drill Stem at	Time
			1 hr.
100		1050	

Temperature of water 50 Depth Artesian Flow Found =
Was a water analysis done? = By whom: =
Did any strata contain water not suitable for intended use? (explain)
=
Depth of Strata: =

(9) LOCATION OF WELL by legal description:
County: Deschutes Latitude: Longitude: 2
Township: 19S Range: 14E
Section: 2 SE ¼ NE ¼
Tax Lot: 191402700 Block: Subdivision:
700
Street Address of Well (or nearest address)
3 Miles off Hwy 20 on Old Burns loop Rd / 15425 Address

(10) STATIC WATER LEVEL:
970 Ft. below land surface Date 3-7-04
Artesian pressure lb. per sq. in. Date

(11) WATER BEARING ZONES:
Depth at which water was first found

From	To	Est. Flow Rate	SWL
1070	1086	20	970
1126	1128	50	970
1131	1134	25	970
1144	1147	25	970

(12) WELL LOG: Ground Elevation

Material	From	To	SWL
Rubble brn	0	2	
Broken Conglomerate brn	2	23	
Basalt Lava Mix	23	32	
Basalt Med Gray	32	70	
Cinder Blk Red	70	92	
Basalt Med Gray	92	161	
Lava Gray	161	180	
Lava & Basalt Layers Blk	180	276	
Red Lava	276	310	
Lava Gray	310	320	
Lava Cinder Red Brown	320	410	
Conglomet Brown-Red-Black Volcanic	410	462	
Conglomet basalt Rubble Blk-Red	462	490	
Cinder Red Med	490	515	
Lava Gray Med Hard	515	601	
Cinder Red Med Soft	601	640	
Lava Gray Red	640	649	
Cinder Gray Red	649	702	
Lava Gray	702	740	
Cinder Red	740	774	
Basalt Black	774	807	
Lava Gray Hard	807	822	
Basalt Hard Gray Smooth	822	833	
Lava Cinder Mix Red Gray	833	844	
Basalt Hard Gray	844	893	
Lava Cinder Red Gray	893	919	
Soft Lava Cinder Rubble All Color	919	932	

Date Started: 6-1-03 Completed: 3-7-04

(unbonded) Water Well Constructor Certification:

I certify that the work I performed on the construction, alteration, or abandonment of this well is in compliance with Oregon water supply well construction standards. Materials used and information reported above are true to the best of my knowledge and belief.

WWC Number 723
Signed Date 3/20/04

(bonded) Water Well Constructor Certification:

I accept responsibility for the construction, alteration, or abandonment work performed on this well during the construction dates reported above. All work performed during this time is in compliance with Oregon water supply well construction standards. This report is true to the best of my knowledge and belief.

WWC Number 723
Signed Date 4-6-04

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JUN 15 2004

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SALEM, OREGON

F10 DESC 56052

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PAGE 2 of 2

STATE OF OREGON
WATER SUPPLY WELL REPORT
(as required by ORS 537.765)

WELL ID # L ____
START CARD # ____

(1) OWNER: Well Number: ____
Name: ____
Address: ____
City: ____ State: ____ Zip: ____

(2) TYPE OF WORK:
☐ New Well ☐ Deepening ☐ Alteration (repair/recondition) ☐ Abandonment

(3) DRILL METHOD:
☐ Rotary Air ☐ Rotary Mud ☐ Cable ☐ Auger
☐ Other: ____

(4) PROPOSED USE:
☐ Domestic ☐ Community ☐ Industrial ☐ Irrigation
☐ Thermal ☐ Injection ☐ Livestock ☐ Other ____

(5) BORE HOLE CONSTRUCTION:
Special Construction approval ☐ Yes ☐ No
Depth of Completed Well ____
Explosives Used ☐ Yes ☐ No Type ____ Amount ____

HOLE				SEAL		
Diameter	From	To	Material	From	To	sacks or pounds

How was seal placed: Method ☐ A ☐ B ☐ C ☐ D ☐ E
☐ Other ____
Backfill placed from ____ to ____ Material ____
from ____ to ____ Material ____
Gravel placed from ____ to ____ Size of gravel ____

(6) CASING/LINER:
CASING:

Diameter	From	To	Gauge	Steel	Plastic	Welded	Threaded
				☐	☐	☐	☐
				☐	☐	☐	☐
				☐	☐	☐	☐
				☐	☐	☐	☐
LINER:							
				☐	☐	☐	☐
				☐	☐	☐	☐

Final location of Shoe(s): ____

(7) PERFORATIONS/SCREENS:
☐ Perforations Method: ____
☐ Screen Type: ____ Material: ____

From	To	Slot Size	No.	Diameter	Tele/pipe size	Casing	Liner
						☐	☐
						☐	☐
						☐	☐
						☐	☐
						☐	☐

(8) WELL TESTS: Minimum testing time is 1 hour
☐ Pump ☐ Bailer ☐ Air ☐ Flowing Artesian

Yield gpm	Drawdown	Drill Stem at	Time
			1 hr.

Temperature of water ____ Depth Artesian Flow Found ____
Was a water analysis done? ____ By whom: ____
Did any strata contain water not suitable for intended use? (explain)
____
Depth of Strata: ____

(9) LOCATION OF WELL by legal description:
County: ____ Latitude: ____ Longitude: ____
Township: ____ Range: ____
Section: ____ ____ ¼ ____ ¼
Tax Lot: ____ Lot: ____ Block: ____ Subdivision: ____
Street Address of Well (or nearest address) ____

(10) STATIC WATER LEVEL:
____ Ft. below land surface Date ____
Artesian pressure ____ lb. per sq. in. Date ____

(11) WATER BEARING ZONES:
Depth at which water was first found ____

From	To	Est. Flow Rate	SWL

(12) WELL LOG: Ground Elevation: ____

Material	From	To	SWL
Lava Gray Med Hard	932	940	
Lava Cinder Conglom Red Gray	940	990	
Lava Gray Hard	990	1059	
Basalt Hard Gray	1059	1070	
Lava Cinder	1070	1086	
Basalt Very Hard Gray	1086	1104	
Rubble Loose Red brown Gray	1104	1110	
Basalt Hard Gray Smooth	1110	1116	
Rubble Red Gray	1116	1120	
Basalt Hard Gray	1120	1126	
Rubble Red	1126	1128	
Baslt Hard Red	1128	1131	
Loose Cinder Red	1131	1135	
Basalt Hard Gray	1135	1144	
Cinder Red Broken	1144	1147	
Lava Gray Med Hard	1147	1155	
Well was Temp Capped from 6-10-03			
to 12-31-03 due to equipment Comp.			
restarted and completed in 2004			

Date Started: ____ Completed: ____

(unbonded) Water Well Constructor Certification:
I certify that the work I performed on the construction, alteration, or abandonment of this well is in compliance with Oregon water supply well construction standards. Materials used and information reported above are true to the best of my knowledge and belief.
WWC Number ____
Signed ____ Date 3-26-04

(bonded) Water Well Constructor Certification:
I accept responsibility for the construction, alteration, or abandonment work performed on this well during the construction dates reported above. All work performed during this time is in compliance with Oregon water supply well construction standards. This report is true to the best of my knowledge and belief.
WWC Number 723
Signed ____ Date 3-26-04

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Phase 2 Final SWMF Site Evaluation – Roth East

Preliminary Geotechnical Feasibility Report

February 2024

Rev. No. 1
Final

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Document QA/QC Check Form

Project Number and Name:	Project 6491.0 Deschutes County Phase 2 Final SWMF Site Evaluation – Roth East					
Document Title:	Preliminary Geotechnical Feasibility Report- Roth East					
Rev. No.	**Document Date**	**Description / Design Phase:**	**Preliminary geotechnical assessment of the Roth East site**			
0	11/29/2023	**Draft**	**Prepared by**	**Checked by**	**Technical Editor Review by**	**Approved by**
		Name	Annie Havekost, Shaun Cordes, Jeff Quinn	Bryan Duevel, Jamie Schick	Lucy Campos	Jamie Schick
		Date	11/28/2023	11/28/2023	11/28/2023	11/28/2023
1	2/2/2024	**Final**	**Prepared by**	**Checked by**	**Technical Editor Review by**	**Approved by**
		Name	Annie Havekost, Shaun Cordes, Jeff Quinn	Bryan Duevel	Annie Havekost	Jamie Schick
		Date	2/1/2024	2/2/2024	2/1/2024	2/2/2024

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Appendices

Acronyms and Abbreviations

ANSS	Advanced National Seismic System
ASCE	American Society of Civil Engineers
ASTM	American Society for Testing and Materials
bgs	below ground surface
CEG	Certified Engineering Geologist
CSZ	Cascadia Subduction Zone
DC	direct current
Delve	Delve Underground
DOGAMI	Oregon Department of Geology and Mineral Industries
DSM	digital surface model
EPA	United States Environmental Protection Agency
ER	electrical resistivity
FEI	FEI Testing and Inspection, Inc.
FEMA	Federal Emergency Management Agency
ft/s	feet per second
GIS	geographic information systems
HLP	High Lava Plain
ID	inside diameter
ka	thousand years ago
LL	liquid limit
Ma	million years ago
MCE	Maximum Considered Earthquake
MSW	municipal solid waste
NEHRP	National Earthquake Hazard Reduction Program
NSHMP	National Seismic Hazard Mapping Project
N-value	Number of blows to penetrate the final 12-inches of an SPT
OD	outside diameter
OSSC	Oregon Structural Specialty Code
OWRD	Oregon Water Resources Department
PGA	peak ground acceleration
PI	plasticity index
PL	plasticity limit
RCRA	Resource Conservation and Recovery Act
SLIDO	Statewide Landslide Information Database for Oregon
SR	seismic resistivity
SRTM	shuttle radar topography mission
SPT	Standard Penetration Test
SWMF	Solid Waste Management Facility
UAS	unmanned aerial system
UHS	uniform hazard spectrum
USGS	United States Geological Survey

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Exp. 7/1/2024

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Delve Underground

59847PE
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Date: 2024.03.11 17:27:38 -07'00'
JULY 14, 2009
BRYAN J. DUEVEL
EXPIRES: 12/31/2024

Bryan Duevel, PE, GE
Delve Underground

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Executive Summary

Delve Underground conducted a preliminary geotechnical feasibility assessment related to the siting of a new landfill on an approximately 382-acre portion of the Roth East property located in Deschutes County, Oregon. This assessment was performed in support of the Phase 2 Solid Waste Management Facility (SWMF) selection process to assess and compare two potential properties for final selection of the future development of the proposed new Deschutes County SWMF.

The preliminary geotechnical feasibility assessment included a combination of a desktop study and limited geotechnical explorations consisting of four geotechnical borings, and two parallel geophysical surveys utilizing electrical resistivity and seismic resistivity. Borings were advanced to depths ranging from between 46.5 to 150 feet below ground surface (bgs) and were terminated in predominantly gravelly alluvial fan deposits. Bedrock was not encountered within the borings and is estimated to be at a depth of approximately 400 feet based on the results of the geophysical surveys.

Disturbed soil samples were collected in conjunction with standard penetration tests (SPT) using a standard split-spoon sampler and a modified California split-barrel sampler. However, because of the relatively small sampler opening sizes (i.e., 1.375 to 2.4 inches), they do not provide an adequate sample size to accurately describe a predominantly gravel soil type.

The preliminary assessment of the site did not identify geotechnical critical flaws for future development as a municipal solid waste landfill. Additional key summaries include the following:

- The unnamed faults near Millican Valley (USGS fault ID 841) have an age constraint of <750 thousand years (ka); considerably older than the 12 ka Holocene age defined by Resource Conservation and Recovery Act (RCRA) Subtitle D.
- The Pine Mountain catchment basin now drains to the northwest of Pine Mountain, and the paleochannel that previously supplied sediment for the alluvial fan beneath the site is now separated from the upslope catchment basin, and thus inactive. The elimination of this sediment supply likely resulted from faulting of the linear ridge with a poor age constraint but is likely older than mid Quaternary (>750 ka), and considerably older than the Holocene.
- The geomorphic relationship between the alluvial fan and surrounding topography suggests that the fan is mid Quaternary or older in age, and that the upslope sediment supply for the fan was disconnected around the same time, or before the faulting and uplift of the knob by the unnamed faults near Millican Valley.

- Faulting of the knob is likely older than the Holocene (12 ka) and not a hazard for the future development of the site. However, a lack of Holocene deposition of sediments within the site makes the age constraint relative to preliminary observations elsewhere within Millican Valley.
- Preliminary review of the limited extent of LiDAR within the western extent of Millican Valley near Horse Ridge does not indicate any offsets of Newberry Volcano lava flows, alluvial fans, or sediments associated with Lake Millican. All units within this area are late Pleistocene in age, thus indicating faulting along the unnamed faults of Millican Valley is older than 12 ka, and not active by the RCRA Subtitle D definition of Holocene (10 ka to 12 ka). However, the lack of deformation and offset within these units may indicate (1) a lack of deformation within the last 100 ka, (2) geomorphic overprinting as a result of a prolonged recurrence interval, and (3) discontinuous fault structures across the basin.
- Preliminary geotechnical drilling encountered coarse-grained soils to a maximum depth of 150 feet bgs that largely consist of gravels of varying sizes, consistent with materials generally encountered within an alluvial fan. The materials appear to be predominantly gravels, but SPT samples limit the ability to quantify the amount of gravel because of sampling intervals and the limited size of what can enter the sampling tube.
- Geophysical surveys indicate up to 400 feet of what we interpret as coarse-grained soils within the limits of the survey profiles. We note that the boundary of the site changed from the time of original planning of the subsurface program and has since moved farther to the southwest, which currently lacks coverage from the geophysical survey. Shallowing of bedrock should be anticipated toward the south of the site near the linear ridge.
- Based on the materials encountered, conventional earth-moving equipment for mass grading and excavation of soil is anticipated; however, large boulders on the order of 4-foot diameter may be encountered.
- Based on the materials encountered, we do not expect issues with bearing capacity or settlement associated with future site development.
- On-site materials are likely suitable for use in site development pending future lab testing to identify the durability of the material.
- Site Class C is recommended for future seismic design based on the materials encountered in our subsurface exploration program.
- Site development plans by G. Friesen Associates, Inc., dated September 26, 2023, indicate 3H:1V (horizontal to vertical) slopes along the perimeter of the waste cells. These slopes are suitable at this time based on our current understanding of the subsurface conditions but may require additional input as plans for site development progress.

- Site development plans by G. Friesen Associates, Inc., dated September 26, 2023, indicate excavation extending to close proximity of the linear ridge. This area lacks subsurface information because of the limitation of our exploration program, and shallow bedrock may be encountered. To reduce cost overrun, we recommend a comprehensive geotechnical exploration program be completed as a future phase of work if this site is selected for future development.

As noted above, the results of this study are based on a very limited subsurface investigation and should be considered preliminary in nature. Additional site characterization will be required to complete the geotechnical characterization of this site if it is selected for final design, as well as to determine the quality of gravels within the alluvial fan deposit for potential on-site use.

1.0 Introduction

Delve Underground (Delve) was retained by Parametrix to conduct a preliminary geotechnical assessment related to the siting of a new landfill on an approximately 300-acre portion of Roth East property (tax lot 2015000000301) located in Deschutes County, Oregon (Figure 1). This assessment was performed in support of the Phase 2 Solid Waste Management Facility (SWMF) selection process to assess and compare two potential properties for final selection of the future development of the proposed new Deschutes County SWMF.

1.1 Project Understanding

Parametrix completed a broad screening of potential landfill sites throughout Deschutes County using geographic information systems (GIS) to identify potential candidates based on geologic hazards and conditions, permitting requirements, environmental impacts, and public input prior to this phase of work. The result of this effort identified two potential properties referred to as the Roth East property and Moon Pit. The focus of this report is the Roth East property.

The Roth East property consists of approximately 382 acres located approximately 24 miles east of Bend, Oregon, just south of Highway 20 in Millican Valley, Oregon (Figure 1). This portion of land is currently undeveloped and has been historically used for ranching. A preliminary site development plan was completed by G. Friesen Associates, Inc., dated September 26, 2023. The location of proposed access roads, structures, and the waste cells is shown in Figure 2.

1.2 Purpose and Scope of Work

This report presents a summary of the geologic conditions, a preliminary assessment of the geotechnical conditions, and preliminary geotechnical considerations for future development of the site as an SWMF.

This report summarizes preliminary subsurface investigations conducted by means of geophysics and geotechnical drilling performed between August and September 2023. Our scope of services for this work includes the following:

- Desktop study and document review
- Geologic reconnaissance
- Evaluation of current site conditions
- Estimates of soil thickness, soil types, and variations in depth to bedrock
- Preliminary interpretation of subsurface conditions
- Summary of regional and site-specific geology
- Summary of slope conditions

- Regional seismicity and fault hazards
- Preliminary evaluation of design alternatives
- Preliminary construction considerations and limitations

1.3 Authorization

The scope of work presented in this report was authorized under Parametrix Subconsultant Agreement for Professional Services, executed on July 31, 2023, under the Deschutes County Services Contract No. 2023-596. The contents of this report have been prepared for the exclusive use of Parametrix on behalf of Deschutes County, and their authorized agents for specific application to the 300-acre portion of the Roth East property, herein designated as “the project” or “site.”

2.0 Site Conditions

2.1 Surface Description

The project site is located in Millican Valley, Oregon, and is approximately 24 miles southeast of Bend, Oregon, and 16 miles northeast of Newberry Volcano. The site is positioned on a low-relief and relatively flat alluvial fan south of Highway 20 and is currently undeveloped and sparsely vegetated with sagebrush (Figure 2). Alluvial fans are geomorphic features that form when upslope sediments are transported downslope to a confined drainage and then conveyed by surface water to an unconfined basin where the sediments are dispersed in a fan-like shape. The alluvial fan extends outward from a northwest-trending linear ridge positioned on the north side of Pine Mountain that topographically bounds the site, and ultimately slopes northeastward toward Highway 20.

Elevations and slope geometry were assessed using ArcGIS Pro and Global Mapper Pro geographic information systems (GIS). Site-specific elevation data was sourced from an unmanned aerial systems (UAS) flight performed by Parametrix in August 2023. This UAS flight utilized photogrammetry to create a digital surface model (DSM), elevation contours, and orthoimagery. In addition, shuttle radar topography mission (SRTM) 30-meter digital elevation models, and 20-foot USGS (United States Geological Survey) elevation contours were acquired from the USGS National Map portal because available LiDAR within the project vicinity were lacking.

Surface elevations along the alluvial fan and within the site boundary range from approximately 4,710 feet in the southwest at the head of the fan, to approximately 4,512 feet in the northeast at the toe of the fan, with a relatively uniform slope of 3° (NAVD 88; Parametrix, 2023). Near the northeast corner of the site, the toe of the alluvial fan is bounded by a subtle northwest to southeast oriented “knob” that has a maximum elevation of 4,546 feet at the apex, with a slope inclination of less than 10° on its flanks.

The head of the alluvial fan in the southwest corner of the site is bounded by the slope associated with the northwest-trending linear ridge. The ridge is incised by a water gap formed by a paleochannel (remnant of a once active stream), and composed of the ”north ridge” and “south ridge” identified on Figure 2. The linear ridge forms the site-specific local topographic high point with a maximum relief of approximately 320 feet with a corresponding elevation of approximately 4,970 feet along the north ridge, and 386 feet with a corresponding elevation of 5,096 feet along south ridge. Slope inclinations along the northeast-facing flank of the ridge line range from 10° to 16°.

2.2 Regional Geology

The project is located within Millican Valley, Oregon, and within the High Lava Plain (HLP) physiographic province to the east of the Cascade Range (Figure 3. The Cascade Range is a north-south oriented volcanic arc that extends from Northern California to British Columbia resulting from subduction of the Juan de Fuca plate under the North American plate along the Cascadia subduction zone (CSZ). The interaction of the North American and Pacific plates creates a complex tectonic regime that drives compression, extension, and lateral movement within different regions of the North American plate.

Inland of the CSZ, the tectonic regime transitions from compression west of the Cascade Range to oblique extension east of the Cascade Range. The subducting Juan de Fuca plate is driving clockwise rotation of the Pacific Northwest about a geologic pole located in northeastern Washington (Zandt and Humphreys, 2008; Brocher et al., 2017). The resulting deformation is evident in the faults of Central Oregon, which demonstrate oblique dextral (right-lateral) extensional shear that has been in place for the past 10 million years (Zoback, 1989; Waldien et al., 2019). Pezzopane and Weldon (1993) proposed a broad shear zone through Nevada, Oregon, and Washington that may accommodate as much as 10% to 20% of the total Pacific-North American transform motion.

HLP physiographic province is approximately 50 miles wide by 150 miles long and generally oriented east-west. The province is characterized by late Miocene and younger volcanics, forming an elevated desert plateau punctuated by rhyolitic ignimbrites resulting from regional bimodal volcanism of silica-rich effluent lavas and mafic basalt flows (Ford et al., 2013). The silica rich eruptions formed cinder cones and calderas which pockmark the province and produce a west-northwest age-progressive trend across HLP and the northwest Basin and Range (Jordan et al., 2004). Regional faulting throughout the Quaternary (2.5 million years) has offset many of the volcanic rocks throughout the HLP and resulted in prominent lineaments observed within the topography (Figure 1).

Newberry Volcano is a broad shield volcano approximately 600 thousand years (ka) old and located approximately 16 miles southwest of Millican Valley (Sherrod et al., 1997; Figure 1). Newberry Volcano has produced thousands of eruptions since its formation and is the largest volcano in the Cascade volcanic arc. Activity in the past 10 ka involves at least 25 active vents on the flanks and summit, with the most recent eruption known as the Big Obsidian Flow which occurred in the volcano's crater about 1.3 ka (Sherrod et al., 1997). Basaltic eruptions have also occurred frequently from the flanks and caldera of the Newberry Volcano, most recently along its northwest rift system which formed 7 ka and produced lava flows that in total covered 23 square miles. Newberry Volcano's most voluminous eruptive events that created the caldera and deposited volcanics in Millican Valley occurred approximately 75 and 300 ka (Donnelly-Nolan et al., 2004).

2.3 Local Geology

The geology of the area was mapped at a 1:250,000 regional scale by Walker et al. (1967) and was later compiled with mapping by other investigators in Oregon Department of Geology and Mineral Industries (DOGAMI) Bulletin 89, Geology and Mineral Resources of Deschutes County (Peterson et al., 1976). Figure 4 presents a localized view of the mapped geology of Millican Valley from the compiled geologic mapping by Peterson et al. (1976). The geologic conditions that pertain to the future development of the site include the underlying site-specific geologic unit(s), surficial processes, the Brothers fault zone, and the interaction of latest Quaternary faulting within Millican Valley. These are discussed in additional detail as follows.

2.3.1 Relevant Geologic Units

The site is positioned on an alluvial fan that is mapped as Holocene (less than 12,000 years) to Pleistocene (2.58 million years) age alluvium and surficial deposits (map unit Qal). The alluvium is described by Peterson et al. (1976) as unconsolidated gravels, sands, and silts laid by streams with minor wind-deposited silt and ash; pumiceous and cindery at many locations; and includes slope wash, playa deposits, alluvial fans, lakebed deposits, and dune sand.

Pliocene (2.58 million years to 5.3 million years) age basalt (map unit Tb) is mapped as separating Pine Mountain from the alluvial fan. The basalt consists of gray to black, mostly thin pahoehoe basalt flows with plagioclase and olivine filled vesicles. The basalt unit is a fault bound block that forms a narrow northwest to southeast oriented finger ridge that separates the alluvial fan underlying the site from Pine Mountain (Figure 4). The geomorphic implications for fan development and faulting are described in additional detail within the site surface conditions and geomorphology, section 2.4.

Pine Mountain is a large rhyolitic dome composed of Pleistocene to Eocene(?) (56 million years) age silicic vent rocks (map unit Qtsv). This unit is described as domes and flow complexes of silicic andesite, dacite, and rhyolite exhibiting uneroded to highly eroded constructional forms.

Within Pine Mountain, this unit predominantly consists of rhyolite and dacite vitrophyre, massive, and flow banded.

2.3.2 The Brothers Fault Zone

The Brothers fault zone is the dominant tectonic structure within Millican Valley and the greater HLP province, forming primarily dextral strike-slip faulting. The faults are generally oriented northwest with less abundant shorter faults oriented northeast, resulting in a left-stepping en echelon pattern (Lawrence, 1976; Ford et al., 2013). The Brothers fault zone terminates west of Millican Valley where it merges with the Sisters fault zone, and to the east at the Steens fault (Pezzopane and Weldon, 1993).

The faults in Millican Valley are characterized at the surface by a series of short (6- to 12-mile long), apparent normal faults with a component of dextral slip that displace Miocoene volcanic and sedimentary rocks and Pliocene to Pleistocene volcanics rocks (Pezzopane and Weldon, 1993; Personius, 2002; Vanaman, 2007). Fault blocks are well-defined as northwest- to southeast-oriented lineaments that are readily distinguishable within volcanic rock displacements throughout Millican Valley. Within Millican Valley, the Brothers fault zone can be subdivided into faults that offset Horse Ridge, and faults near Pine Mountain.

A review of the USGS Quaternary Fault and Fold Database indicates relatively few of the faults within the Brothers fault zone are identified as active within the Quaternary. One such fault is located immediately adjacent to and southeast of the site (USGS, 2023a; Figure 5). Faults located within 25 kilometers (km) (approximately 15.5 miles) of the site and included with USGS Quaternary Fault and Fold Database are presented on Figure 6A and include faults offsetting Horse Ridge, as well as faults near Pine Mountain. Geologic hazard implications related to the faults are discussed in section 4.1.1.

A single fault trace is mapped between the two groups within the USGS Quaternary Fault and Fold Database, and at a more east-west orientation than the northwest-trending faults (Figure 6A). The significance of this fault is addressed in additional detail in Section 7.2 – Age of Faulting.

2.3.3 Surficial Processes

Millican Valley was occupied by a sizeable pluvial lake, Lake Millican, for at least some portion of the Pleistocene (Peterson et al., 1976; Vanaman, 2007). Lake sediments have accumulated from Horse Ridge to approximately 15 miles eastward with approximately 50 feet of layered sand, gravel, and silt, exposed in roadcuts, borrow pits, and lake terraces along Highway 20. Vanaman (2007) identified a maximum lake level elevation of approximately 4,297 feet based on the interaction of lake deposits with Newberry Volcano lava flows and alluvial fans sourced from Newberry Volcano along the south side of Millican Valley. Lake sediments poorly preserved within Millican Valley are only observed along Highway 20 and near the interaction of volcanic flows sourced from Newberry Volcano, suggesting the lake was short lived (Vanaman, 2007). The oldest possible age for the lake is estimated at ~300 ka, with a favorable estimated age of 110 to 225 ka (Vanaman, 2007).

Dry River Canyon is an approximately 3-mile-long steep-walled canyon that formed the spillover for Lake Millican and controlled the maximum lake level during the Pleistocene. The incision of Dry River Canyon is attributed to the drainage of Lake Millican and subsequent breaching and outburst flooding of Lake Millican into the greater Deschutes Basin (Peterson et al., 1976; Vanaman, 2007). The canyon separates the Deschutes Basin to the west, from Millican Valley to the east, and has incised into the underlying Pliocene age basalt (map unit Tb) mapped immediately adjacent east of Horse Ridge (Peterson et al., 1976). The canyon deepens from approximately 20 feet on the east, to more than 300 feet before shallowing up at its western terminus and accommodates approximately 500 feet of elevation relief along its reach. The terminus of the canyon consists of a large gravel fan where the Dry River enters the Deschutes Basin. This fan extended out from the Dry River Canyon into the Deschutes Basin, with finer sediments distributed extensively to the north and west and subsequently buried from younger Badlands lava flows originating from Newberry Volcano (Peterson et al., 1976).

Lake sediments and alluvium throughout Millican Valley were incised by the Dry River with prominent evidence of a meandering channel that extends from Dry River Canyon approximately 37 miles eastward to Hampton Butte. Mazama Ash from an eruption of Crater Lake 6.9 ka was observed throughout Millican Valley in low lying dune fields and throughout alluvial fans by Vanaman (2007). The presence of Mazama Ash provides a primary marker bed that could be used for Holocene age correlations and stratigraphic interpretations throughout Millican Valley.

Several prominent alluvial fans are present on the south side of Millican Valley extending northeastward from Newberry Volcano (Figure 1). The Evans Well fan is the westernmost fan and is adjacent to Horse Ridge, and the Teepee Draw alluvial fan is the easternmost fan and is located adjacent to Pine Mountain. The two fans are separated by the Smith Well lava flow that extended into Millican Valley from Newberry Volcano, with an approximate age of 300 ka as part of one of the caldera-forming volcanic events. The Teepee Draw fan aggradation may date back to the Micoene with aggradation continuing between 80 ka and 300 ka (Vanaman, 2007). The Teepee Draw alluvial fan is considerably more incised, indicating it is likely older than the Evans Well fan but likely still active into the late Pleistocene based on the correlation of basalt gravels sourced from Newberry Volcano and observed in both fans (Vanaman, 2007).

The Evans Well fan and Teepee Draw fan are blanketed by Mazama Ash, while lacking gravel deposition above the ash, thus indicating that alluvial processes were not a primary source of sediment transport throughout the Holocene.

2.4 Site Geomorphology

SRTM data combined with USGS 20-foot contours were used to assess topographic conditions surrounding the site to understand the geomorphology as it relates to fault structures and geologic conditions within Millican Valley (Figure 5). As previously discussed, the site consists of an alluvial fan protruding outward from a near linear ridgeline oriented northwest to southeast and subdivided as the north and south ridge in Figure 2 and Figure 5. The alluvial fan is bounded at its toe by a knob with a parallel orientation to the ridgeline. These orientations match the general trend of fault-bound blocks within the Brothers fault zone, as mapped by Peterson et al. (1976). As such, we interpret the knob as a fault-bound structure and likely a continuation of an unnamed fault of Millican Valley trace located less than 3,000 feet from eastern site boundary.

The linear ridgeline is truncated by a water gap formed by a paleochannel. The paleochannel under current conditions is disconnected from the upslope catchment basin and drainage network located on the north side of Pine Mountain, and incapable of delivering sediments to the alluvial fan to allow propagation and aggradation of the fan. Surface runoff and sedimentation derived from Pine Mountain is currently conveyed to the northwest and into Millican Valley.

An additional water gap is located within the linear ridge approximately 1 mile to the southeast of the paleochannel. Earlier mapping by Walker et al. (1967) indicates both water gaps truncating the ridgeline are fault bounded, but the Peterson et al. (1976) iteration did not include all of the previous faults within the linear ridgeline. The complex geomorphic conditions at the site are difficult to comprehend without the presence of the Walker et al. (1967) faults and as such have been included on Figure 5 for discussion. The age of faulting is unconstrained, and we assume these faults were likely interpreted as inactive and ancient bedrock faults at the time of mapping.

Faulting of the water gap likely predates the middle to late Quaternary faulting of the unnamed faults of Millican Valley, as continued sediment delivery to the alluvial fan would likely have overprinted the structural development of the knob, or alternatively, created a stronger geomorphic signature of drainage deflection around the knob. The implication for this is that the alluvial fan underlying the site is likely very old, as northeast-oriented Quaternary faults are not identified within the USGS Quaternary Fault and Fold Database within the Brothers fault zone, and only suspected of being Quaternary in age by Weldon et al. (2003).

3.0 Subsurface Exploration

The subsurface exploration program included a combination of geophysical surveys performed between August 21 and August 25, 2023, and four geotechnical borings completed between September 12 and 14, 2023. Both exploration programs were overseen by a Delve Underground geologist who was on site for the duration of the programs. The locations of the geotechnical borings' geophysical profiles are presented on Figure 2. A detailed description of the geotechnical boring program, including laboratory testing, is included in Appendix A. Boring logs are provided in Appendix B and laboratory data are included in Appendix C.

Geophysical testing was conducted by Siemens and Associates of Bend, Oregon. The survey consisted of electrical resistivity (ER) and seismic refraction (SR) surveys along two parallel lines that extended through the site, designed to be perpendicular to the trend of faults that are mapped in Millican Valley and the Brothers fault zone. The survey locations designated A-A' and B-B' are shown in Figure 2. The procedures and results of the geophysical survey are summarized in section 5.2, Geophysics, and included as Appendix D.

4.0 Geologic Hazards

Geologic hazards are conditions associated with the geologic and seismic environment that could adversely influence site development. Geologic hazards for the site were assessed by reviewing publicly available GIS data through the DOGAMI HazVu portal, statewide landslide information database for Oregon (SLIDO), and the USGS Quaternary Fault and Fold Database (DOGAMI, 2023; USGS 2023a). In addition, Delve Underground reviewed aerial photography and available published geologic maps to evaluate geologic hazards. Relevant geologic hazards identified within DOGAMI HazVu are discussed in detail in Appendix E and summarized in section 8.1.

Seismic hazards are summarized in the following sections, as they pertain to our understanding of Quaternary faults within the project area and have direct implications for the site geomorphology, age of faulting, and ultimately permitting of the site development.

4.1 Seismic Hazards

Seismic hazards are hazards associated with earthquakes that can generate strong shaking and deformation. Earthquakes throughout the Pacific Northwest can result from CSZ interface earthquakes, intraslab earthquakes, crustal faults, and volcanic sources.

4.1.1 Faults

Faults within the DOGAMI HazVu GIS layer are classified as "active faults" without a clear description of the age of the fault or degree of certainty of fault location and are adopted from the USGS Quaternary Fault and Fold Database. A review of the USGS Quaternary Fault and Fold Database was performed to identify faults within the Brothers fault zone located within 25 km (15.5 miles) of the site to supplement the DOGAMI data and to provide a better understanding of nearby faults and their approximate age (USGS, 2023a; Figure 6A).

Two fault zones with a total of 11 individual traces were identified within 25 km of the site. These fault zones include the unnamed faults near Millican Valley and the Southeast Newberry fault zone. The fault characteristics of each fault zone and the proximity of the closest traces are summarized in Table 4-1.

Table 4-1. Quaternary Class A Crustal Seismic Sources within 25 Kilometers

USGS Fault ID	Fault/Fault Zone Name	Distance to Site (km/miles)	Fault Length (km/miles)	Type of Fault	Slip Rate Category (mm/yr)
841	Unnamed faults near Millican Valley	0.5 / 0.3	40 / 24.9	Normal, right lateral	0.2
835	Southeast Newberry fault zone	19 / 11.8	58 / 36.0	Normal, left lateral	0.2–1.0

In addition to the USGS Fault and Fold Database review, a review of the USGS open-file report (OFR) 02-301, An Update of Quaternary Faults of Central and Eastern Oregon (Weldon et al., 2003) and a leading contributor to the succeeding USGS Quaternary Fault and Fold Database was performed to further understand the age of faults within Millican Valley. Faults within the OFR 02-301 database located within 25 km of the site are presented on Figure 6B. These faults are typically identified as older than faults within the USGS Quaternary Fault and Fold Database presented on Figure 6A. Many of the faults within OFR 02-301 were excluded from the USGS Quaternary Fault and Fold Database or further refined, as identified in Figure 6B.

4.1.1.1 Unnamed Faults near Millican Valley

These faults consist of a northwest-trending group of normal, right-lateral faults that are part of the greater Brothers fault zone, an approximately 185-mile-long system of high-angle faults (Personius, 2002). The unnamed faults of Millican Valley fall into two groups: faults truncating Horse Ridge and faults near Pine Mountain. A single fault trace is mapped between the two groups within Millican Valley, and at a more east-west orientation than the northwest-trending faults.

The Horse Ridge and Pine Mountain fault groups offset Miocene to Pliocene volcanics as evidenced by escarpments as high as 650 feet. The faults located near Horse Ridge are classified as active in the middle to late Quaternary (<700–780 ka), and the faults near Pine Mountain are classified as active in the early Quaternary (1.6–1.8 million years [Ma]). All faults within the unnamed faults near Millican Valley (Fault ID 841) are designated as middle and late Quaternary in age (<750 ka) within the USGS Quaternary Fault and Fold Database.

4.1.1.2 Southeast Newberry Fault Zone

The Southeast Newberry fault zone located approximately 12.4 miles southeast of the site is a series of normal faults, with a component of left-lateral slip, that have displaced Plio-Pleistocene volcanics and Pleistocene-Holocene sediments (Personius, 2016). Paleoseismic studies along the fault indicate Holocene displacement that occurred in the early to middle Holocene. All faults within the Southeast Newberry fault zone are designated as latest Quaternary (<15 ka) in age.

4.1.2 Historical Seismicity

Regional historical seismicity was acquired from the Advanced National Seismic System (ANSS) comprehensive earthquake catalog, hosted by the USGS Earthquake Hazard Program. Seismicity greater than magnitude (M) 2.5 is presented on Figure 7. Magnitudes within the ANSS dataset are recorded as local magnitude, surface-wave magnitude, body-wave magnitude, moment magnitude, and magnitude of completeness. These data include seismicity within a 150-km (93 miles) radius of the project area and recorded between 1800 and 2022.

5.0 Subsurface Conditions

Subsurface conditions encountered at the project site can be grouped into two geologic units: alluvial fan deposits and bedrock. The geotechnical boring program did not penetrate the bottom of the alluvial fan deposits, and depth to bedrock is inferred from the geophysical data as discussed in the sections below.

5.1 Alluvial Fan Deposits

Alluvial fan deposits were encountered in all four geotechnical borings from the surface to terminal depths of up to 150 feet below ground surface (bgs). These deposits generally consisted of silt, sand, gravel, and cobble deposits and are summarized as:

- Dense to very dense, moist, brown, or red-brown **silty sand (SM)** with varying amounts of subangular to subrounded gravel composed of basalt and tuff and trace basalt cobbles.
- Dense to very dense, moist, brown **well-graded sand (SW-SM)** with varying amounts of silt and fine to coarse subangular to subrounded gravel composed of basalt and tuff.
- Very dense, moist, brown **silty gravel (GM) with sand** and consisting of fine to coarse subrounded or rounded basalt and tephra gravels and trace amounts of cobbles.
- Very dense, moist, brown, or red-brown **well-graded gravel with silt and sand (GW-GM)** containing variable amounts of fine to coarse sand and fine to coarse subrounded basalt and tuff gravels.

- Very dense, moist, brown, or gray-brown **well-graded gravel with sand (GW)** consisting of fine to coarse subrounded to rounded basalt and tuff gravels and sometimes containing cobbles.

SPT N-values in the alluvial fan deposits ranged from 19 to refusal (50 blows within a 6-inch drive with a 2-inch sampler, or 75 blows within a 6-inch drive with a 3-inch sampler).

Laboratory test results for materials within the alluvial fan are summarized as follows:

- A single Atterberg limits test was conducted on the fine-grained portion of sample S-1 taken from boring B-2 at 5 feet bgs, resulting in a plastic limit (PL) of 34, liquid limit (LL) of 43, and plasticity index (PI) of 9 indicating a soil property identification of silt.
- 18 moisture content tests results ranged from 12.3 to 25.3 percent.
- 18 fines percentage (P200) tests results ranged from 6.8 to 47.6 percent fines.

Soil boring logs include laboratory results and can be found in Appendix B and a laboratory summary table is provided in Appendix C.

A void was encountered in boring B-3A that resulted in drilling fluid circulation loss at 45 feet bgs. The drill team attempted to plug the void to continue advancing the boring, but eventually abandoned the hole and began drilling B-3B, approximately 20 feet from the location of B-3A. Sampling for B-3B commenced at 45 feet bgs. Although these logs are presented separately, they are within close enough proximity to be considered continuous.

5.2 Geophysics

The results of the ER and SR geophysical surveys indicated similar subsurface conditions between the two profiles. P-wave values less than 5,000 feet per second (ft/s) are interpreted as alluvial fan materials, as confirmed by the borings to depths of 100 to 150 feet bgs. P-wave values exceeding 5,000 ft/s are interpreted as bedrock. Alluvial fan materials persist to a depth of upward of 400 feet bgs in both profiles. In profile A, several anomalies that exceed 5,000 ft/s are present, and thus reduce the thickness of alluvial fan materials, but are shallower than 150 feet within the profiles.

The alluvial fan deposits are interpreted to be generally layered, unconsolidated dense to very dense soils with zones of inferred heavy cementation and regions of greater percentage of coarse-grained constituents, unconfirmed at this time for geotechnical drilling for the upper 150-feet.

The depth to bedrock is estimated from the SR tomographs to range from approximately 300 to greater than 400 feet bgs. The depth to bedrock could not be interpreted by the ER results because the bedrock was deeper than the extent of the ER survey. See Appendix D for the complete geophysics data report. Definitive indications of fault-related offsets in the bedrock were not observed.

5.3 Groundwater

Groundwater was not encountered at the time of our explorations. Well logs were obtained from the Oregon Water Resources Department (OWRD) web portal to estimate the depth to groundwater within the general vicinity. Wells selected for review shared similar topographic and inferred geologic conditions as the site (e.g., located northwest of Pine Mountain and within the mapped alluvium). Review of nearby well logs indicate static groundwater is at a depth exceeding 400 feet bgs. The well logs reviewed are summarized in Table 5-1. Summary of OWRD Logs, and included in Appendix F.

Table 5-1. Summary of OWRD Logs

Well ID	Depth to Static Groundwater (feet bgs)	Total Depth (feet bgs)
Desc 6477	485	495
Desc 6479	450	655
Desc 52142	435	610
Desc 54733	495	545
Desc 62152	480	630

Note that the locations of wells are poorly constrained and that reported depth to groundwater should be considered approximate only, *and not to be used for design purposes*.

6.0 Geologic Reconnaissance

Following the completion of the desktop research, literature review, and subsurface explorations, a site reconnaissance was performed by a certified engineering geologist (CEG) on November 15, 2023. The purpose of the reconnaissance was to visually assess the site to confirm interpretations and hypotheses formed during the desktop research phase of the project. A summary of the reconnaissance is as follows:

- The surficial materials observed along the alluvial fan surface consisted of a silty sand matrix with gravels, cobbles, and boulders, consistent with what was observed within the borings and what would be expected for an alluvial fan. Boulders were infrequent and upward of 3 to 4 feet in diameter, but more commonly less than 2 feet in diameter. Gravel, cobble, and boulder clasts were subrounded to subangular, and the larger boulders were irregularly observed throughout the fan surface. Piles of cobbles and boulders were observed along the side of access rounds from prior historical agricultural uses.

- The surficial materials throughout the knob are consistent with materials observed throughout the fan and consisted of silty sand matrix with gravel to boulder-sized clasts, thus supporting the interpretation that the knob is an uplifted toe of the fan.

- Drainages observed within the site topography are difficult to identify in the field. We interpret the lack of definitive and easily recognizable surface expression as a result of geomorphic overprinting by aeolian processes, supporting the interpretation that the fan is exceptionally old and possibly early Quaternary in age.

- The paleochannel lacks surficial deposits consistent with streamflow, likely indicating a much older landform that has been overprinted by aeolian and local slope processes. Several bedrock outcrops were observed in slopes adjacent to the paleochannel, as well as boulders that appeared to be protruding out of the slopes.

7.0 Geologic Discussion

7.1 Subsurface Conditions

Materials encountered within our borings consist of predominantly gravel soils with varying amounts of silt and sand. The variation of materials observed during the time of drilling is consistent with alluvial fan formation. Geophysical profiles indicate the materials encountered likely extend to a maximum depth of 400 feet and indicate high velocity anomalies at the northern extent in profile A-A’ (Appendix D).

The variation of drilling conditions observed by our staff at the time of drilling explorations suggests variable subsurface conditions consistent with alluvial fan formation where intermittent fining sequences are common. The lack of full recovery, particularly within gravels, indicates particle sizes exceeding the opening diameter of the sampler. Cobbly and boulder material are found along the surface of the fan, and likely persists at depth as well.

The estimated thickness of subsurface materials encountered at the time of our explorations and the anticipated use of materials is presented on Table 7-1. Across the site, the average thickness of overburden materials (alluvial fan deposits) is estimated to be greater than 150 feet. No laboratory tests have been performed to assess the durability of gravels within the overburn materials for future use as a construction aggregate. Please note that the current coverage of borings and geophysical surveys is inadequate for fully assessing the subsurface conditions for a 382-acre development, and lateral variations of materials likely exists.

Table 7-1. Soil Usage Summary

Geologic unit	ASTM Classification	Estimated Thickness	Anticipated Use [1]
Alluvial Fan Deposits [2]	Silty SAND (SM)	>150 feet	Daily cover; crush/screen for drain rock, structural fill, and road base
	Well-graded SAND with silt (SW-SM)		
	Silty GRAVEL (GM)		
	Well-graded GRAVEL with silt and sand (GW-GM)		
	Well-graded GRAVEL with sand (GW)		
Bedrock [3]	N/A	Unknown	Unknown

Notes:

[1] Anticipated uses are assumed. No laboratory testing has been performed to determine the durability of onsite gravel. Durability tests will be required before final approval of onsite use.

[2] Gravel percentage poorly constrained due to the limited opening diameter within the SPT and ModCal sampling tube.

[3] Bedrock was not encountered in the geotechnical drilling exploration and estimated at around 400 feet below grade by geophysical exploration.

7.2 Age of Faulting

The Resource and Conservation Recovery Act (RCRA) Subtitle D – Section 1.1.1 Part 258.13 designates that any landfill or lateral expansion of a landfill may not be located within 200 feet of a fault that has experienced displacement within the Holocene and defines the Holocene as the last 10 to 12 ka (EPA, 1995). Pluvial lakes and alluvial fans are commonly used for determining the age of faulting in arid environments as they generally have materials that can be used for numerical age dating, and often preserve deformation in the form of scarps, drainage offsets, and other lateral and vertical displacements.

The formation of the alluvial fan at the site was dependent on upslope sediment sourced from Pine Mountain and deposited within the valley by a paleochannel that is currently discontinuous from a sediment source. The linear ridge was mapped as a fault bounded block by Walker et al. (1967) and Peterson et al. (1976) and truncated by a fault within the paleochannel by Walker et al. (1967). The faults that bound the linear ridge are not identified within the USGS Fault and Fold Database or USGS OFR 02-301 (Walker et al., 1967; USGS, 2023a; Weldon et al., 2003), indicating that these faults are suspected as early Quaternary or older in age. As such, this would suggest that the alluvial fan is also of similar age or older, as the fan would need to first be formed prior to being cut off from its upslope sediment source by faulting.

We interpret the knob at the toe of the fan as a geomorphic indicator of fault deformation that uplifted the toe of the fan to its current position, and a continuation of the unnamed fault of

Millican Valley (<750 ka) immediately east of the site boundary. Review of the geophysical surveys indicates similarities within the fan sediments where the profiles cross the knob and confirmed by field reconnaissance and observations of fan materials on the surface of the knob. However, it is unlikely that this structure is Holocene in age, given the presumed age of the alluvial fan.

LiDAR coverage is currently limited to an extent of approximately 3 miles east of Horse Ridge (Figure 8). While this limits our ability to look for fault displacement throughout Millican Valley, the coverage does provide enough detail to observe high resolution elevation data where at least part of one of the unnamed faults of Millican Valley is mapped and would deform a Newberry Volcano lava flow, an alluvial fan, and lake sediments. Deformation features indicative of faulting are not readily distinguishable within the LiDAR data.

The lava flow sourced from Newberry Volcano immediately adjacent and east of Horse Ridge between Evans Well fan is less than 100 ka in age (MacLeod et al., 1995; Vanaman, 2007) and possibly as young as 12 ka (Donelly-Nolan, 2004; Figure 8). Vanaman (2007) identified that deposition of Evans Well fan began in the early Pleistocene during the formation of Newberry Volcano and continued into the late Pleistocene, but has not been active during the Holocene based on the preservation of Mazama Ash (6.7 ka). In addition, this alluvial fan postdates the formation and aggradation of the Teepee Draw fan, indicating an age range of 12 ka to 300 ka. Mazama Ash observed within the fan only displayed signs of disturbance by windblown processes, indicating that the fan was largely inactive during the Holocene as the ash would have been easily eroded (Vanaman, 2007).

The lack of deformation and offset without these geologic units indicates that the unnamed faults within Millican Valley (1) have not deformed units and geomorphic features in more than 100,000 years and thus not active as defined by RCRA, (2) have been geomorphically overprinted due to a prolonged recurrence interval, and (3) are discontinuous across the basin as currently mapped. While these features are not located directly on site, they are geologic datapoints for interpreting the faulting history throughout the late Pleistocene within Millican Valley and understanding of the Brothers fault zone and Quaternary age faults within it.

The age of these deposits is significant as our current understanding is that all of these features would be blanketed by Mazama Ash and would act as a primary Holocene marker bed with an age of 6.7 ka, and prime for preserving fault offset within the Holocene.

8.0 Geologic Summary and Preliminary Conclusions

Our understanding of the site conditions indicates the site is favorable to the development of the proposed landfill. Critical flaws related to the site conditions and geohazards were not identified throughout this phase of work, and future site development should be considered. We have summarized our findings as follows:

- The unnamed faults near Millican Valley (USGS fault ID 841) have an age constraint of <750 thousand years (ka); considerably older than the 12 ka Holocene age defined by Resource Conservation and Recovery Act (RCRA) Subtitle D.
- The Pine Mountain catchment basin now drains to the northwest of Pine Mountain, and the paleochannel that previously supplied sediment for the alluvial fan beneath the site is now separated from the upslope catchment basin, and thus inactive. The elimination of this sediment supply likely resulted from faulting of the linear ridge with a poor age constraint but is likely older than mid Quaternary (>750 ka), and considerably older than the Holocene.
- The geomorphic relationship between the alluvial fan and surrounding topography suggests that the fan is mid Quaternary or older in age, and that the upslope sediment supply for the fan was disconnected around the same time, or before the faulting and uplift of the knob by the unnamed faults near Millican Valley.
- Faulting of the knob is likely older than the Holocene (12 ka) and not a hazard for the future development of the site. However, a lack of Holocene deposition of sediments within the site makes the age constraint relative to preliminary observations elsewhere within Millican Valley.
- Preliminary review of the limited extent of LiDAR within the western extent of Millican Valley near Horse Ridge does not indicate any offsets of Newberry Volcano lava flows, alluvial fans, or sediments associated with Lake Millican. All units within this area are late Pleistocene in age, thus indicating faulting along the unnamed faults of Millican Valley is older than 12 ka, and not active by the RCRA Subtitle D definition of Holocene (10 ka to 12 ka). However, the lack of deformation and offset within these units may indicate (1) a lack of deformation within the last 100 ka, (2) geomorphic overprinting as a result of a prolonged recurrence interval, and (3) discontinuous fault structures across the basin.
- Preliminary geotechnical drilling encountered coarse-grained soils to a maximum depth of 150 feet bgs that largely consist of gravels of varying sizes, consistent with materials generally encountered within an alluvial fan. The materials appear to be predominantly gravels, but SPT samples limit the ability to quantify the amount of gravel because of sampling intervals and the limited size of what can enter the sampling tube.
- Geophysical surveys indicate up to 400 feet of what we interpret as coarse-grained soils within the limits of the survey profiles. We note that the boundary of the site changed from the time of original planning of the subsurface program and has since moved farther to the southwest, which currently lacks coverage from the geophysical survey. Shallowing of bedrock should be anticipated toward the south of the site near the linear ridge.
- Based on the materials encountered, conventional earth-moving equipment for mass grading and excavation of soil is anticipated; however, large boulders on the order of 4-foot diameter may be encountered.

- Based on the materials encountered, we do not expect issues with bearing capacity or settlement associated with future site development.
- On-site materials are likely suitable for use in site development pending future lab testing to identify the durability of the material.
- Site Class C is recommended for future seismic design based on the materials encountered in our subsurface exploration program.
- Site development plans by G. Friesen Associates, Inc., dated September 26, 2023, indicate 3H:1V (horizontal to vertical) slopes along the perimeter of the waste cells. These slopes are suitable at this time based on our current understanding of the subsurface conditions but may require additional input as plans for site development progress.
- Site development plans by G. Friesen Associates, Inc., dated September 26, 2023, indicate excavation extending to close proximity of the linear ridge. This area lacks subsurface information because of the limitation of our exploration program, and shallow bedrock may be encountered. To reduce cost overrun, we recommend a comprehensive geotechnical exploration program be completed as a future phase of work if this site is selected for future development.

8.1 Summary of Geologic Hazards

Based on our review of DOGAMI HazVu combined with site reconnaissance, and desktop analysis, we have summarized geologic hazards for the site in Table 8-1 as follows:

Table 8-1. Geologic Hazards Summary

Hazard	Assessment
Fault Rupture	The unnamed faults near Millican Valley (USGS fault ID 841) and identified trace within the project boundary are assumed to be older than Holocene in age. Fault rupture hazard is thus low to none.
National Earthquake Hazard Reduction Program (NEHRP) Site Class	Site Class C is recommended based on subsurface investigation results and is addressed in further detail in section 9.1.4.1.
Liquefaction	Groundwater was not encountered at the time of drilling. Review of nearby well logs identified groundwater greater than a depth of 400 feet and liquefaction susceptibility is low to none.
Landslide Hazard Areas	Adjacent slopes lack geomorphic indicators indicative of landslides and unstable slopes within the currently available elevation models. As such, landslide susceptibility is low to none.

Hazard	Assessment
Volcanic Hazards	The site is currently mapped outside of a volcanic hazard area. However, ashfall is likely from near and far sources as documented by the extent of Mazama Ash throughout Millican Valley.

9.0 Preliminary Geotechnical Design Considerations

Our preliminary assessment of the site has not identified geotechnical concerns for the future development of the site as a municipal solid waste landfill. Subsurface conditions based on the results of our preliminary exploration program indicate the site is consistently underlain by dense to very dense, predominantly gravel soils with varying amounts of silt and sand. Groundwater was not encountered within our explorations and is currently estimated at a depth exceeding 400 feet. The current grading and site development plans are preliminary and are subject to change.

9.1.1 Depth to Groundwater

Groundwater was not encountered at the time of our explorations and review of OWDR well logs indicate groundwater depth exceeding 400-feet bgs. As such, we do not anticipate groundwater to impact the constructability of the proposed landfill.

9.1.2 Bearing Pressure & Settlement

Review of G. Friesen Associates, Inc., site development plan dated September 26, 2023, indicate the landfill cells will be placed on a 6-inch cushioning layer positioned between the liner and subgrade. The plans show excavation depths ranging from 30 to 90 feet across the landfill cells (typically ranging from about 50 to 60 feet), and total MSW fill heights/depths of up to 340 feet. A maximum fill height of 340 feet with a corresponding excavation depth of 50 feet is proposed at the approximate center of the landfill. At this location, we anticipate a maximum effective stress increase of about 15,000 pounds per square foot (psf), assuming a unit weight of 65 pounds per cubic foot (pcf) for the MSW fill materials and 130 pcf for the native, predominately gravel soils. We anticipate the magnitude of the effective stress increase will decrease proportionally with the decrease in finished slope heights as they descend away from the center of the landfill.

Although the magnitude of effective stress increase is relatively significant within the central area of the landfill, the overall very dense, predominately gravel soils will provide competent bearing support. We anticipate maximum vertical settlement on the order of 3 inches or less, occurring within the central portion of the landfill, and decreasing to 1 inch or less along the outer perimeter of the landfill. We anticipate the total and differential settlements can be accommodated by the landfill liner system. Therefore, we do not anticipate any design issues of the landfill from a bearing capacity and settlement standpoint.

It should be noted that the net effective stress increase and settlement calculations summarized above are preliminary and are based on assumptions that require verification in the future design stages.

9.1.3 Temporary Slopes

In general, soil within the anticipated excavation depths in the Project area consists of dense sand and gravel with varying amounts of silt, cobbles, and boulders, and temporary cuts can be utilized. In accordance with OSHA, the site soils can be preliminarily classified as Type C. For planning and earthwork volume estimating purposes, excavations up to 20 feet in Type C soils can have a maximum allowable temporary slope of 1.5H:1V (horizontal: vertical) given the lack of groundwater encountered. The site development plan shows a maximum cut slope inclinations of 3H:1V around the perimeter of the landfill. Therefore, the proposed maximum cut slope angles are well within OSHA temporary cut slope guidelines.

Temporary slope recommendations do not consider site constraints such as groundwater, surcharge, or nearby structures. Temporary slopes should be evaluated on a case-by-case basis and incorporate groundwater conditions, soil classification, and site constraints.

The Contractor should monitor temporary cut slope stability and adjust the slope inclination accordingly. Temporary excavation stability is the responsibility of the Contractor and must comply with current federal, state, and local requirements.

9.1.4 Seismic Design

The latest available guidelines regarding seismic design criteria for landfills is the United States Environmental Protection Agency (EPA) document RCRA Subtitle D, which states that municipal solid waste (MSW) landfills be designed to resist a maximum horizontal acceleration (i.e., peak ground acceleration, or PGA) based on USGS seismic hazard mapping with a 90 percent probability of nonexceedance in a 250-year period. This corresponds to a 10 percent probability of exceedance in a 250-year period and is the equivalent of the 2 percent probability of exceedance in 50 years (return period of 2,475 years) per 2022 Oregon Structural Specialty Code (OSSC) (ICC, 2022) and American Society of Civil Engineers (ASCE) 7-16 (2017) procedures. For the purposes of this preliminary study, we assume that seismic design for the new MSW landfill will be based on 2022 OSSC and ASCE 7-16 procedures.

9.1.4.1 Seismic Site Classification

The site is underlain by dense to very dense, predominantly gravel soils with varying amounts of silt and sand and should assume a site class of C based on the code-based procedures in Section 1613.2.2 of the 2022 OSSC, which references the ASCE/SEI 7-16, Chapter 20 (2017). Site classification is used to categorize common subsurface conditions into broad classes to which ground motion attenuation and amplification effects are assigned. Site classification is based on the weighted average of the shear wave velocity or Standard Penetration Test (SPT) blow counts (N-value) in the upper 100 feet of subsurface profile. Based on the N-values from our geotechnical exploration, Site Class C is appropriate for design purposes.

9.1.4.2 Seismic Design Parameters

The 2022 OSSC requires that spectral response accelerations be developed based on the ASCE 7-16 procedures. We developed spectral response accelerations using the online ASCE 7 Hazard Tool, which references ground motion procedures in accordance with ASCE 7-16 and is based on the USGS 2014 National Seismic Hazard Mapping Project (NSHMP) developed for the Maximum Considered Earthquake (MCE) (Petersen et al., 2014). The MCE consists of ground motions (accelerations) with a 2 percent probability of exceedance in 50 years (return period of 2,475 years). The mean earthquake magnitude and the mean site-to-source distance for the zero-second period of vibration (e.g., PGA) are 6.95 and 65.61 km, respectively, for the MCE. The recommended spectral acceleration parameters for use in structural design are provided in Table 9-1Table 9-1.

Table 9-1. 2022 OSSC MCE Spectral Acceleration Parameters for Site Class C

Parameter	0.2-second Period	1-second Period
Mapped MCE_R (Rock Site)	S_S = 0.368g	S_1 = 0.181g
Site Coefficients	F_a = 1.3	F_v = 1.5
Site-adjusted MCE_R	S_{MS} = 0.478g	S_{M1} = 0.272g
Design MCE_R	S_{DS} = 0.319g	S_{D1} = 0.181g
Mapped MCE PGA (Rock Site)	0.167g	
Site Coefficient F_{PGA}	1.233	
Site-adjusted MCE PGA_M	0.206g	

9.1.4.3 Seismic Sources and Hazard Deaggregation

We used the online USGS Unified Hazard Tool (USGS, 2023b) to perform a deaggregation of the uniform hazard spectrum (UHS) response spectrum for Site Class C. The deaggregation data identify the earthquake sources, magnitudes, and site-to-source distances that contribute to the mean source event (e.g., the MCE) acceleration parameters. Table 9-2 Table 9-1. Table 9-2 summarizes the results of the MCE hazard deaggregation for the zero-second period of vibration (e.g., PGA).

Table 9-2: Deaggregation Results for 2,475-year Mean Source Event (MCE), PGA Period

Source	Moment Magnitude, M_W[1]	Site-to-source Distance[2] (km)	% Contribution to Hazard
CSZ Interface	8.97	253.19	18.31
CSZ Intraslab	7.12	155.34	1.12
Crustal Faults[3]	6.18 to 7.04	19.16 to 26.21	80.57

Notes:

[1] M_W values represent the mean value from each type of earthquake source.

[2] Site-to-source distances represent the mean value from each type of earthquake source.

[3] Crustal faults source includes gridded seismic sources that represent earthquakes that do not occur on known, mapped faults.

9.1.5 Site Development Considerations

Based on the results of our preliminary geotechnical investigation, the site is underlain by predominantly gravel soils with varying amounts of silt and sand. In addition, cobbles (e.g., particle size ranging from 3 to 12 inches or greater) were frequently encountered during our exploration and observed at the surface, as well as occasional boulders (e.g., particle size greater than 12 inches). This particle size variation observed during our geotechnical investigation is typical of alluvial fan deposits and should be anticipated when sourcing on-site materials used for site development.

9.1.5.1 Fill Materials for Site Development

We anticipate that the native on-site soils are suitable for use in site development, provided they are screened and can be kept free of debris, deleterious materials, and particles larger than 6 inches in diameter, as well as for daily cover.

The use of existing on-site materials should include the following processing recommendations:

- Processed fill should be free of objectionable debris (clay clumps, organic, and/or deleterious material, etc.) and within moisture contents suitable for compaction or as specified based on their intended use (i.e., as general embankment fill or as structural fill);
- Cobbles/boulders or other oversized debris greater than 6 inches should be separated/screened from any processed materials considered for use as fill. This oversized material, provided it is competent/hard cobble and boulder clasts, may subsequently be processed into suitably sized fill material; and
- Prior to filling operations, representative samples of each proposed fill type should be collected. Gradation tests (particle-size analysis) should be performed on the samples to evaluate their suitability for use as fill materials and conformance with project specifications.

Material specifications referenced in this section, with the exception of daily cover, refer to the 2024 OSSC (ODOT, 2024), which is frequently cited in earthwork specifications and referenced by contractors for projects in Oregon. We anticipate that the following material types will be used for the site development:

- Daily Cover: Refers to backfill placed over solid waste consisting of 2-inch minus with <20% passing the no. 200 sieve.
- Structural Fill: Refers to backfill placed between subgrade and structural foundations to provide a smooth, uniform surface for foundations or asphalt pavement sections. Structural fill should consist of either 1-inch minus (1″ - 0) or ¾″ - 0 dense graded aggregate per OSSC §02630.10.
- Open-graded Aggregate: Refers to free-draining backfill placed behind retaining walls and below-grade structures, or used to construct foundation drainage systems. Open-graded aggregate should consist of either 1″ - 0 or ¾″ - 0 crushed rock per OSSC §02630.11.
- Embankment Fill: Refers to fill placed in the following scenarios: (1) to bring site grades up to design top-of-subgrade elevations (i.e., below structural fill or foundation drainage systems); (2) between subgrade and design pavement sections; and (3) between open-graded aggregate and temporary cuts/excavations behind below-grade structures and walls. Embankment fill should conform to either OSSC §00405.14 for Class A backfill with a maximum rock fragment size of 6 inches or to OSSC §00330.16.
- Pipe Bedding: Backfill zone that includes full trench width and extends from the prepared pipe trench bottom to the bottom of the exterior of the pipe, conduit, cable, or duct bank. Pipe bedding should consist of ¾″ - 0 dense-graded aggregate per OSSC §02630.10.
- Pipe Zone Material: Backfill zone that includes full trench width and extends from top of pipe bedding to 12 inches above top outside surface of pipe, conduit, cable, or duct bank. Pipe zone material should consist of ¾″ - 0 dense-graded aggregate per OSSC §02630.10.
- Trench Zone Material: Backfill zone that includes full trench width and extends from top of pipe zone to an upper limit at the bottom of the road subgrade where the trench is below pavement, or the bottom of the topsoil or surface gravel in areas where the trench is outside of paved areas. Trench zone material should consist of either (1) ¾″ - 0 dense graded aggregate per OSSC §02630.10 beneath paved areas or structures; or (2) gravel or crushed rock meeting the requirements for Class B or Class D backfill per OSSC §00405.14.

10.0 Additional Site Characterization

This current phase of work was completed with limited geotechnical explorations consisting of geotechnical borings and geophysical surveys. Additional subsurface characterization will be necessary for final geotechnical engineering and design considerations for the proposed landfill. Future work should be performed under the supervision of a certified engineering geologist and geotechnical engineer and include:

- Test pits to assess near-surface conditions including cementation of soils, distribution of gravel-sized particles or larger, and the architecture of the alluvial fan.

- Additional geophysical profiles extending from the existing profiles to the linear ridge, and oriented perpendicular to the existing profiles to further estimate and constrain the depth to bedrock.

- Additional borings (using sonic drilling methods to obtain adequate soil sample volumes for laboratory testing) to confirm the depth of bedrock compared to the geophysical profiles, and to identify the lithology of bedrock as well as groundwater conditions (if encountered).

- Additional laboratory testing following the ODOT aggregate suite to identify if on-site gravels and larger clasts can be used as a resource for site development.

11.0 Limitations

This report has been prepared for the exclusive use by Deschutes County and the design team consisting of engineers and architects as an aid and for design of the proposed solid waste landfill, and is not to be relied upon by other parties. It is not to be photographed, photocopied, or similarly reproduced, in total or in part, without the express written consent of Deschutes County and Delve Underground. It is the responsibility of the addressee to provide this report to the appropriate design professionals to ensure the correct implementation of the preliminary recommendations.

The opinions, comments, conclusions, and recommendations are based upon information derived from our literature review, limited field explorations, limited laboratory testing, and it is possible that soil, rock, and groundwater conditions vary throughout the site.

The preliminary geotechnical investigation consisted of four borings advanced to depths ranging from 100 to 150 feet bgs. The proximity and distribution of boreholes are insufficient for the characterization of 300 acres of land for development, despite the similarities of materials encountered in all borings. Additional borings will be necessary for final design. Disturbed soil samples were collected in conjunction with standard penetration tests (SPTs) using a standard split-spoon sampler (2-inch outside diameter [OD] and 1.375-inch inside diameter [ID]) and a modified California split-barrel sampler (3-inch OD and 2.4-inch ID). Both types of samplers provide adequate data to describe the relative density for predominantly gravel soils (i.e., SPT N-values). However, because of the relatively small sampler opening sizes (i.e., 1.375 to 2.4 inches), they do not provide an adequate sample size to accurately describe a predominantly gravel soil type.

In the performance of geotechnical work, specific information is obtained at specific locations at specific times, and geologic conditions can change over time. It should be acknowledged that variations in soil conditions may exist between exploration and exposed locations and this report does not necessarily reflect variations between different explorations. The nature and extent of variation may not become evident until construction. Delve Underground is not responsible for the interpretation of the data contained in this report by anyone; as such interpretations are dependent on each person’s subjectivity. If, during construction, conditions different from those disclosed by this report are observed or encountered, Delve Underground should be notified at once so we can observe and review these conditions and reconsider our recommendations where necessary.

The site investigation and this report were completed within the limitations of the Delve Underground’s approved scope of work, schedule, and budget. The services rendered have been performed in a manner consistent with the level of care and skill ordinarily exercised by members of the profession currently practicing under similar conditions in the same area. Delve Underground is not responsible for the use of this report in connection with anything other than the project at the location described above.

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Figures

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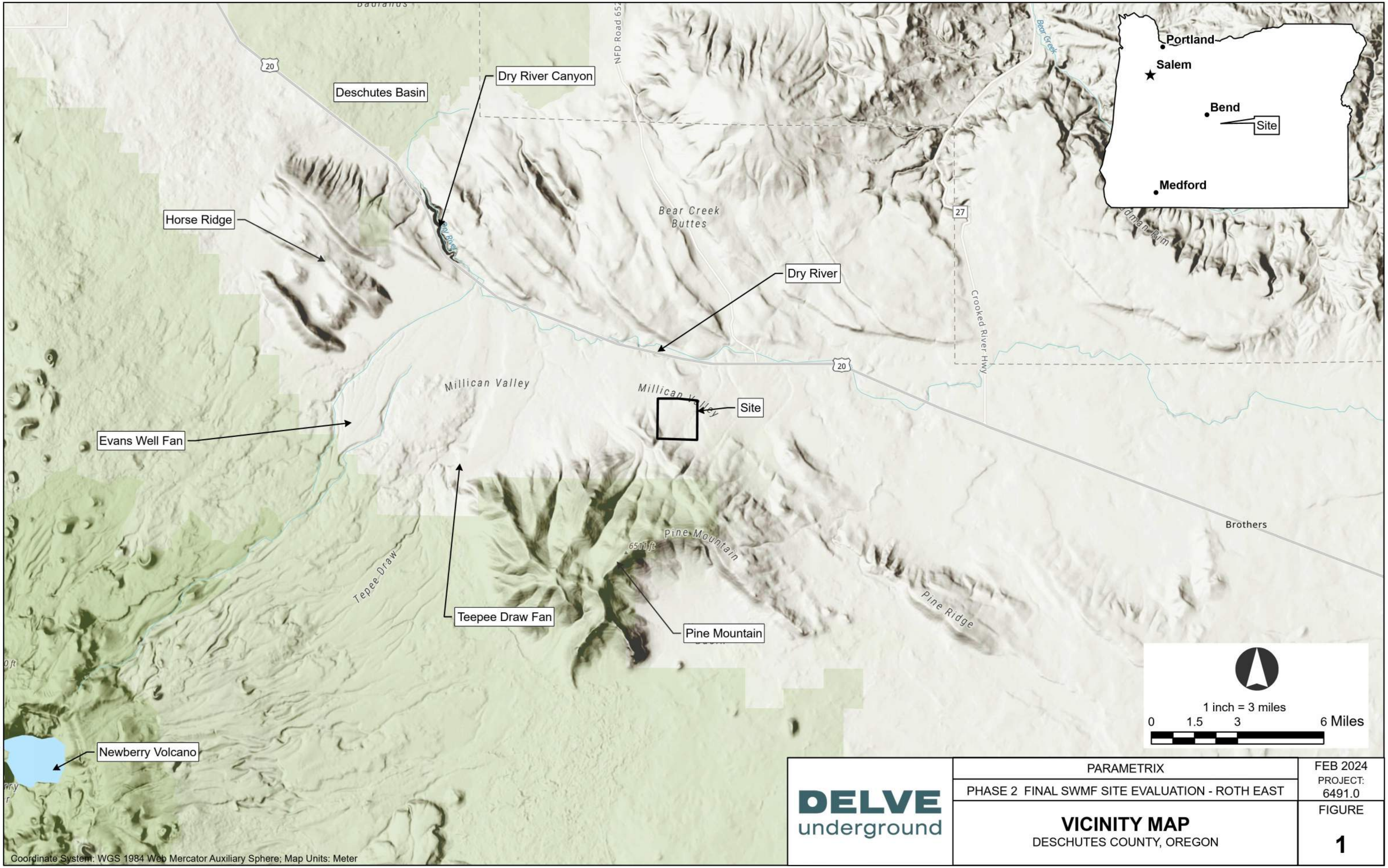

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DELVE underground

PARAMETRIX

PHASE 2 FINAL SWMF SITE EVALUATION - ROTH EAST

VICINITY MAP

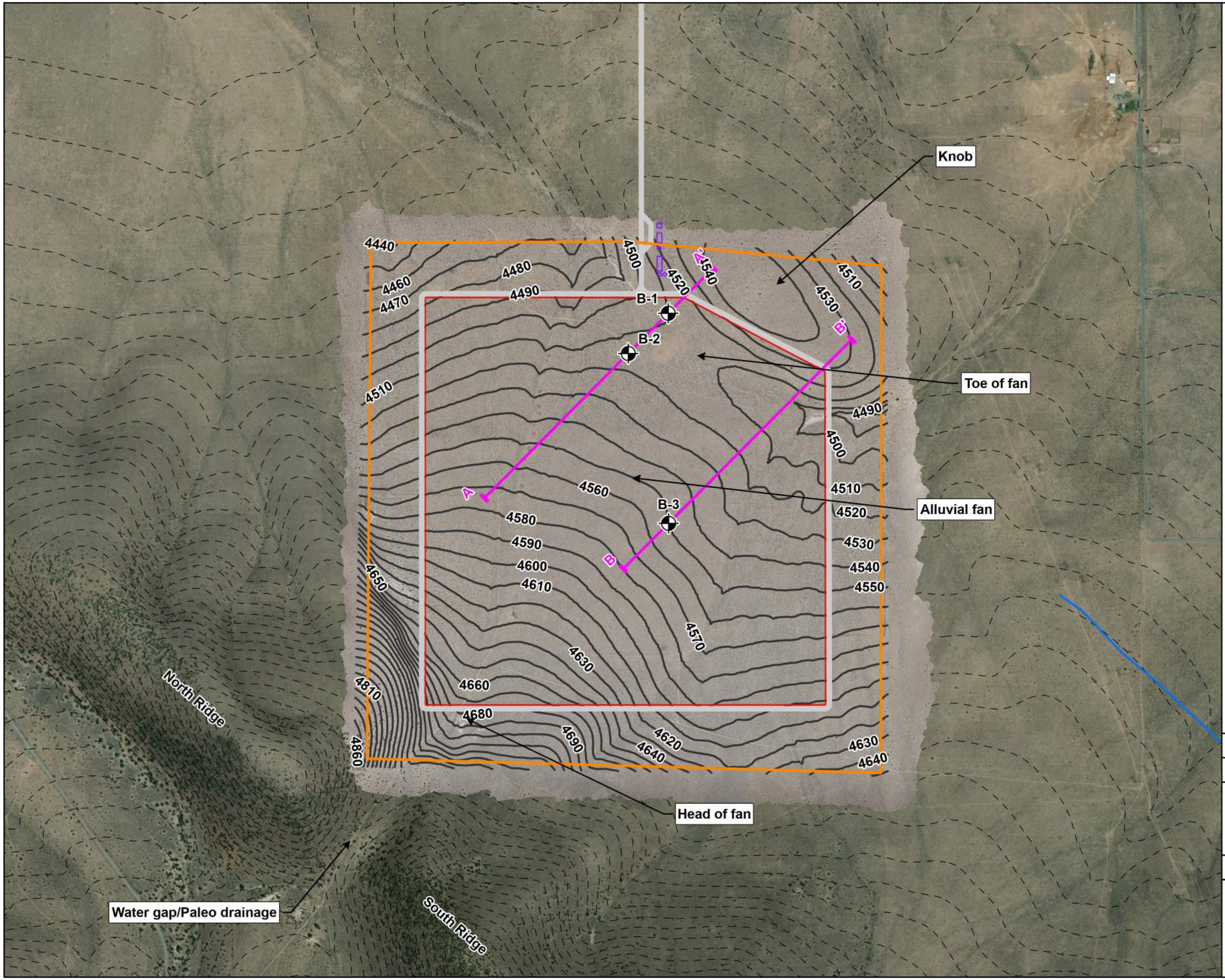
DESCHUTES COUNTY, OREGON

FEB 2024

PROJECT:
6491.0

FIGURE

1



EXPLANATION

⊕	B-1 - Boring name and approximate location
⊢⊣	Approximate location of geophysical profiles
—	10-foot elevation contour (Parametrix, 2023)
- - -	20-foot elevation contour (USGS; NAVD 88)

USGS Quaternary Fault and Folds Database

—	middle and late Quaternary (<750,000 years), well constrained location

Preliminary Site Layout (Parametrix, 2023)

—	Approximate footprint of waste cells
—	Approximate property boundary
—	Approximate location of proposed access road
—	Approximate location of structure

Notes:
1. Orthoimagery basemap from Parametrix UAV flight USGS national topo basemap; 20-foot contours (NAVD 88)
2. Linework is approximate and subject to change

1 inch = 1,000 feet
0 500 1,000 2,000 Feet

Coordinate System: Central Oregon; Map Units: Foot

PARAMETRIX

PHASE 2 FINAL SWMF SITE EVALUATION - ROTH EAST

PRELIMINARY SITE PLAN
DESCHUTES COUNTY, OREGON

DATE: FEB 2024 • PROJECT: 6491.0

DELVE underground

FIGURE
2

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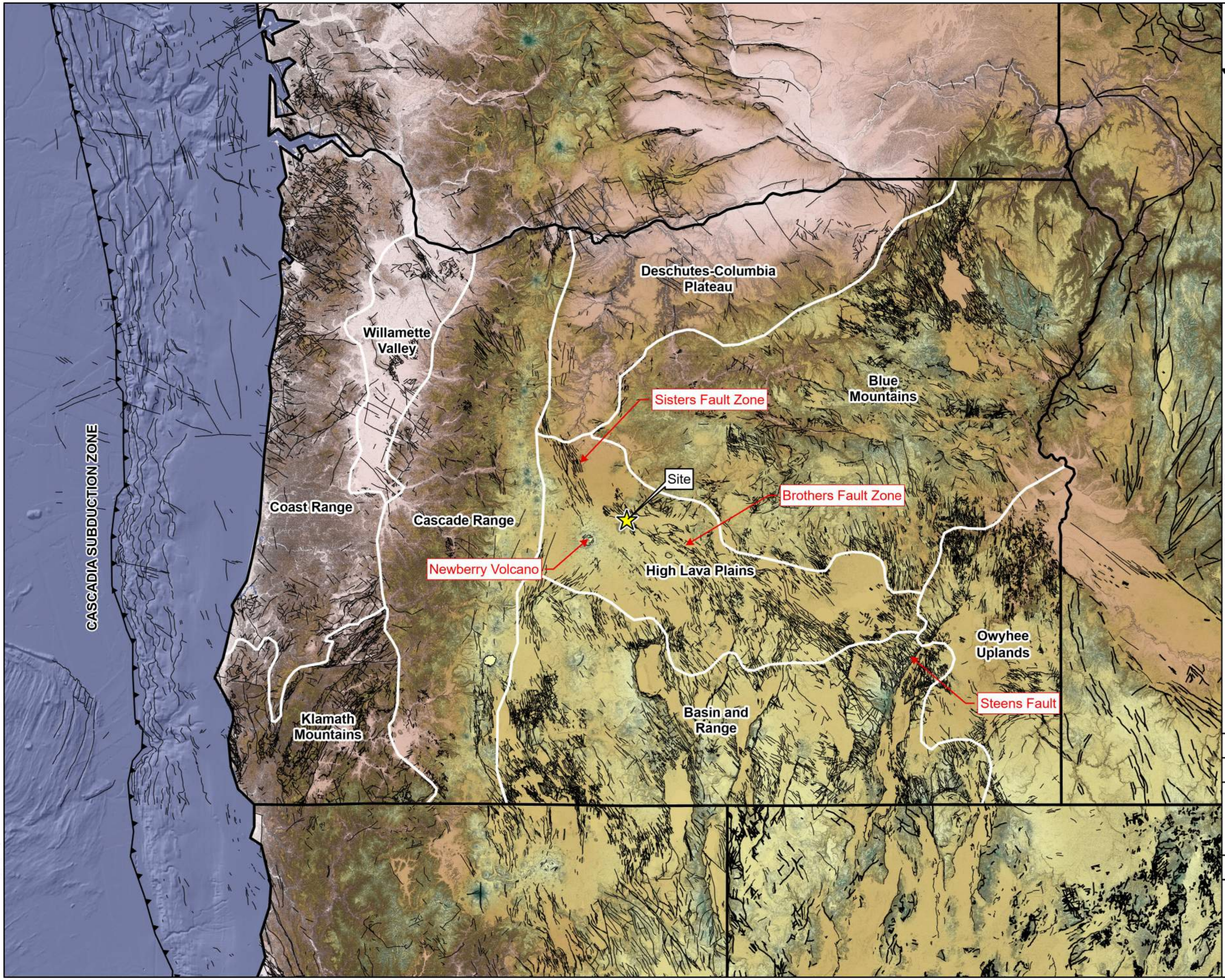

EXPLANATION

☆ Site location

▼— Cascadia Subduction Zone (CSZ)

— Fault - Age undifferentiated

Notes:
1. SRTM 30-meter elevation model
2. Faults compiled from USGS Quaternary Fault and Fold database, DOGAMI OGDC-7 (2020), WA DNR DS-18 (2019), USGS OFR-2005-1305 (2007), IGS M-9 (2012)
3. Cascadia Subduction Zone geometry obtained from USGS Cascadia Subduction Zone database (2022)

1 inch = 60 miles

0 30 60 120 Miles

Coordinate System: WGS 1984 Web Mercator Auxiliary Sphere; Map Units: Meter

PARAMETRIX

PHASE 2 FINAL SWMF SITE EVALUATION - ROTH EAST

TECTONIC SETTING AND GEOLOGIC PROVINCE

DESCHUTES COUNTY, OREGON

DATE: FEB 2024 ▪ PROJECT: 6491.0

DELVE underground

FIGURE

3

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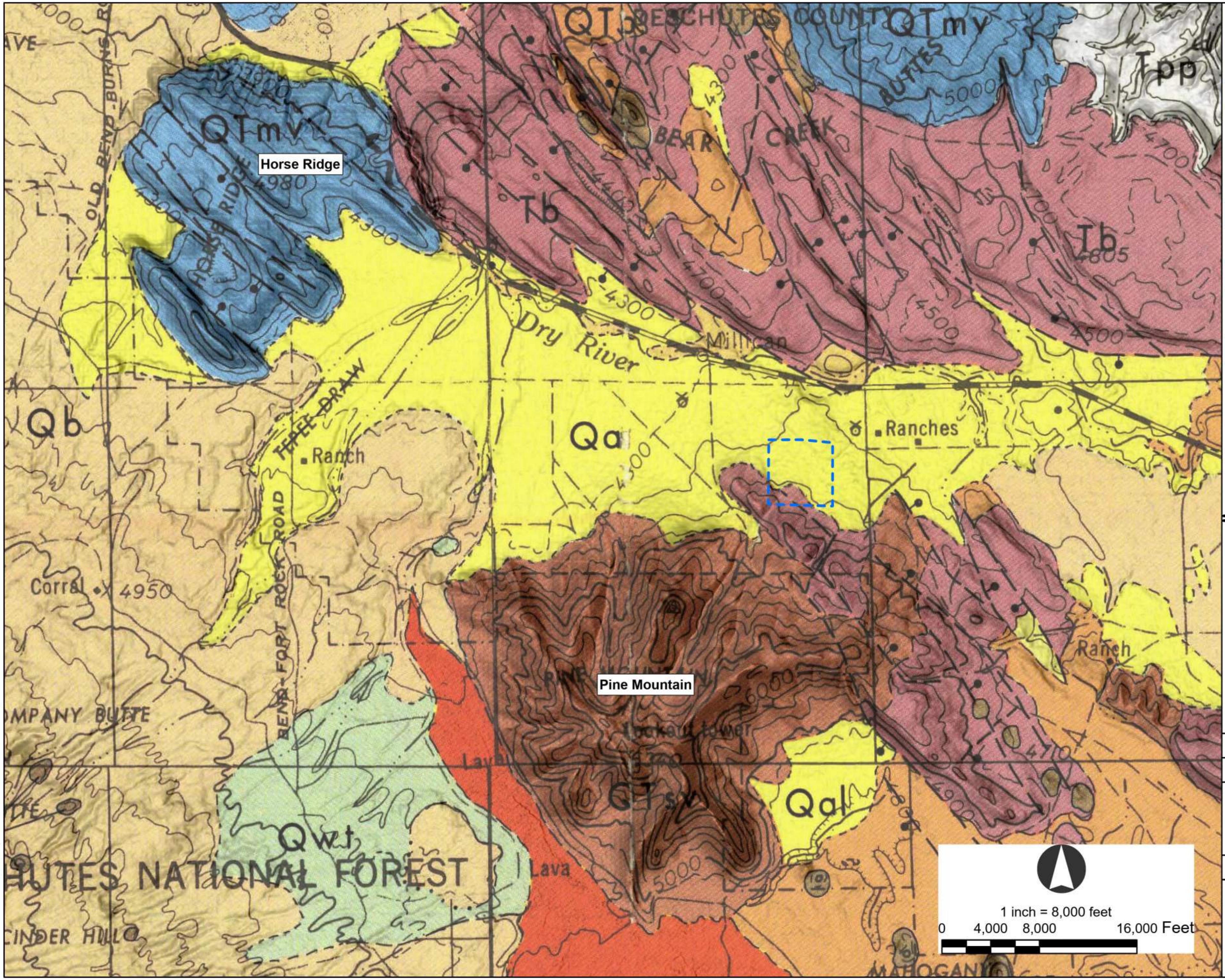

EXPLANATION

- - - Approximate site boundary (Parametrix, 2023)

Relevant Geologic Units

Qal	Alluvium and surficial deposits – Holocene to Pleistocene – Unconsolidated gravels, sands, and silt laid by streams, with minor wind-deposited silt and ash. Pumiceous and cindery at many locations. Includes slope wash, playa deposits, alluvial fans, lake bed deposits, and dune sand.
Qb	Pleistocene basalt flows – Pleistocene – Gray, diktytaxitic, olivine basalt originating on and about the flanks of Newberry Volcano and associated Brothers Fault Zone.
QTsv	Silicic vent rocks – Pleistocene to Eocene? – Domes and flow complexes of silicic andesite, dacite, and rhyolite exhibiting uneroded to highly eroded constructional forms.
Tb	Tertiary basalt – Pliocene – Gray to black, mostly thin, pahoehoe, diktytaxitic basalt flows containing small to moderate amounts of olivine. Some flows are platy olivine andesite or basaltic andesite.
QTmv	Mafic vent rocks - Pleistocene to Miocene - Composed of basalt and basaltic andesite flows, agglomerates, scoria, and breccia.
- - - -	Contact - Dashed where approximately located; dotted where inferred.
—-—-—	Fault - Dashed where approximately located; dotted where inferred. Bar and ball on downthrown side.

Notes:
1. Geologic mapping from DOGAMI Bulletin 89 (1976)

Coordinate System: Central Oregon; Map Units: Foot

PARAMETRIX

PHASE 2 FINAL SWMF SITE EVALUATION - ROTH EAST

GEOLOGIC MAP

DESCHUTES COUNTY, OREGON

DATE: FEB 2024 • PROJECT: 6491.0

DELVE underground

FIGURE

4

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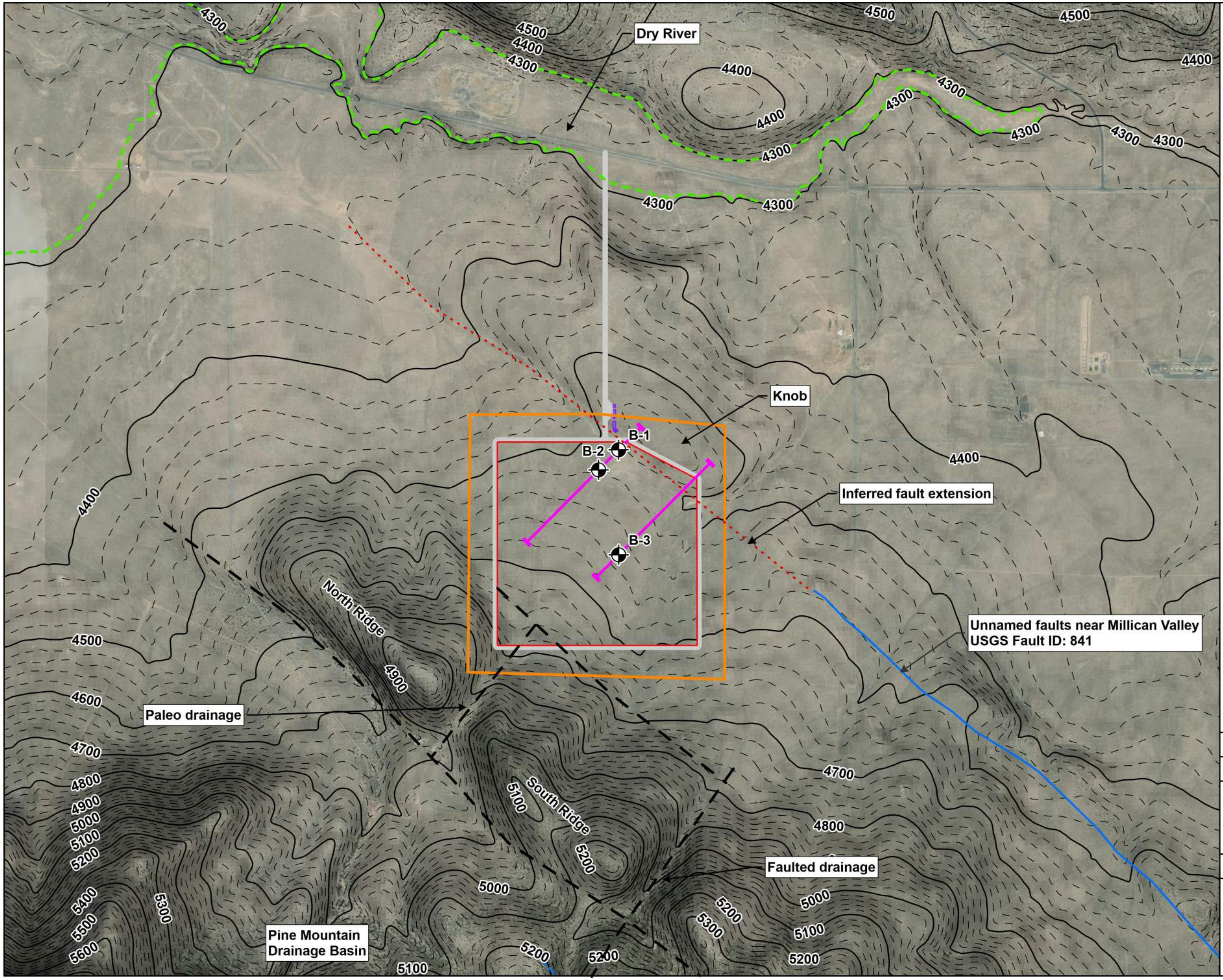

EXPLANATION

Lake Millican shoreline (Vanaman, 2007)

20-foot elevation contour (USGS; NAVD 88)

100-foot elevation contour (USGS; NAVD 88)

USGS Quaternary Fault and Folds Database

middle and late Quaternary (<750,000 years), well constrained location

middle and late Quaternary (<750,000 years), moderately constrained location

B-1 - Boring name and approximate location

Approximate location of geophysical profiles

Preliminary Site Layout (Parametrix, 2023)

Approximate footprint of waste cells

Approximate property boundary

Approximate location of proposed access road

Approximae location of structure

Fault - Dashed where approximately located (Walker et al., 1967)

1 inch = 2,000 feet

0 1,000 2,000 4,000 Feet

Coordinate System: Central Oregon; Map Units: Foot

PARAMETRIX

PHASE 2 FINAL SWMF SITE EVALUATION - ROTH EAST

SITE GEOMORPHOLOGY

DESCHUTES COUNTY, OREGON

DATE: FEB 2024 • PROJECT: 6491.0

DELVE underground

FIGURE

5

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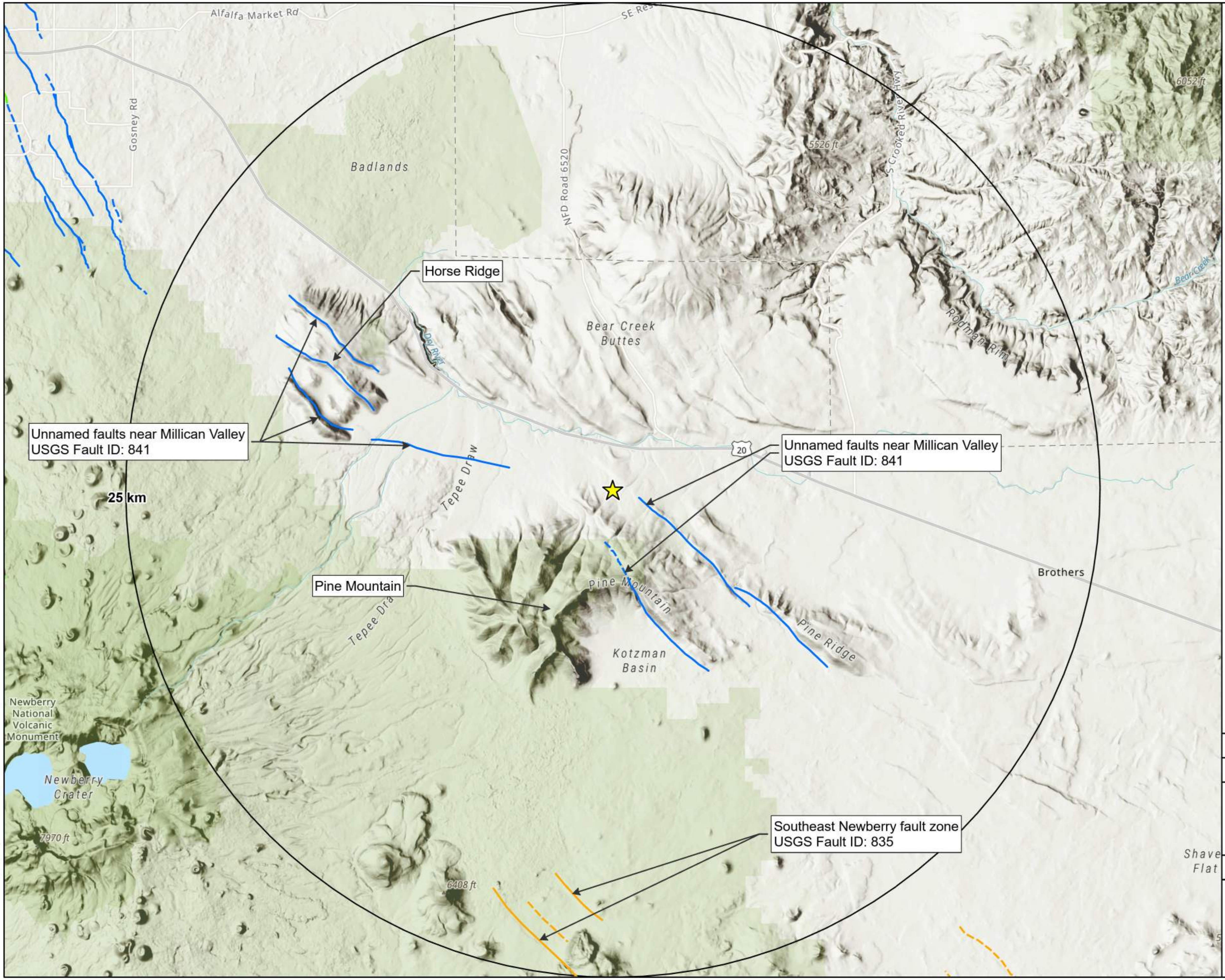

EXPLANATION

☆ Site location

○ Site proximity buffer (km)

USGS Quaternary Fault and Fold Database

Fault trace – solid where well constrained, dashed where moderately constrained, and dotted where inferred.

<15,000 years - Latest Quaternary

<750,000 years - Middle and late Quaternary

Notes: ESRI World Topographic basemap, fault traces obtained from USGS Quaternary Fault and Fold Database

1 inch = 5 kilometers

0 2.5 5 10 km

Coordinate System: Central Oregon; Map Units: Foot

PARAMETRIX

PHASE 2 FINAL SWMF SITE EVALUATION - ROTH EAST

USGS QUATERNARY FAULT AND FOLD DATABASE

DESCHUTES COUNTY, OREGON

DATE: FEB 2024 ▪ PROJECT: 6491.0

DELVE underground

FIGURE

6A

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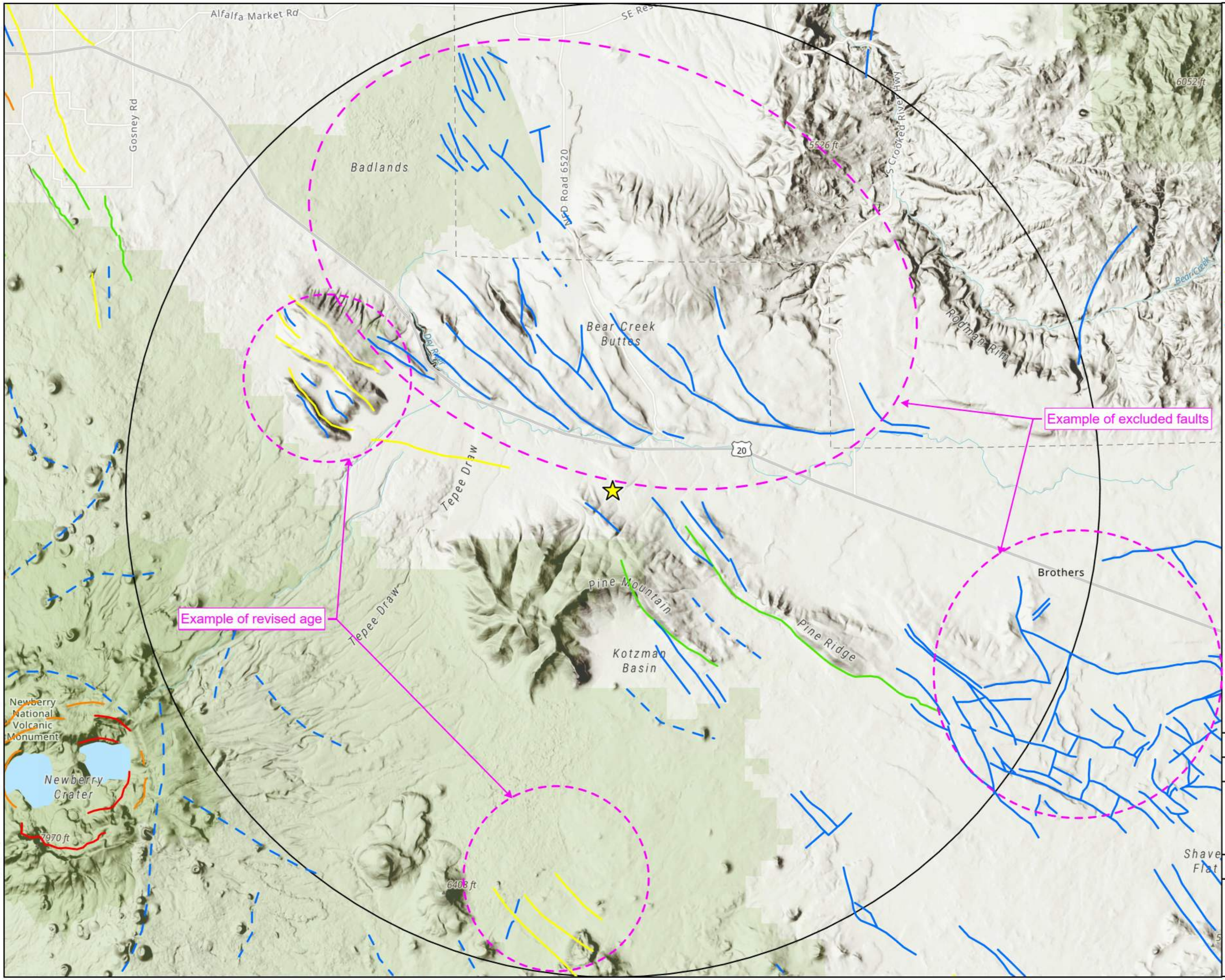

EXPLANATION

★ Site location

○ Site proximity buffer (km)

USGS OFR 02-301 Faults

Fault trace – solid where well constrained, dashed where moderately constrained, and dotted where inferred.

- Active during the Holocene or post glacial (<10 ka -<18 ka)
- Active during the latest Quaternary (<120 ka)
- Active during the middle to late Quaternary (<0.78 Ma)
- Active during the Quaternary (<1.6 Ma)
- Possibly active during the Quaternary

1 inch = 5 kilometer

0 2.5 5 10 Kilometers

Coordinate System: Central Oregon; Map Units: Foot

PARAMETRIX

PHASE 2 FINAL SWMF SITE EVALUATION - ROTH EAST

USGS OFR 02-301 REGIONAL FAULT MAP

DESCHUTES COUNTY, OREGON

DATE: FEB 2024 ▪ PROJECT: 6491.0

DELVE underground

FIGURE

6B

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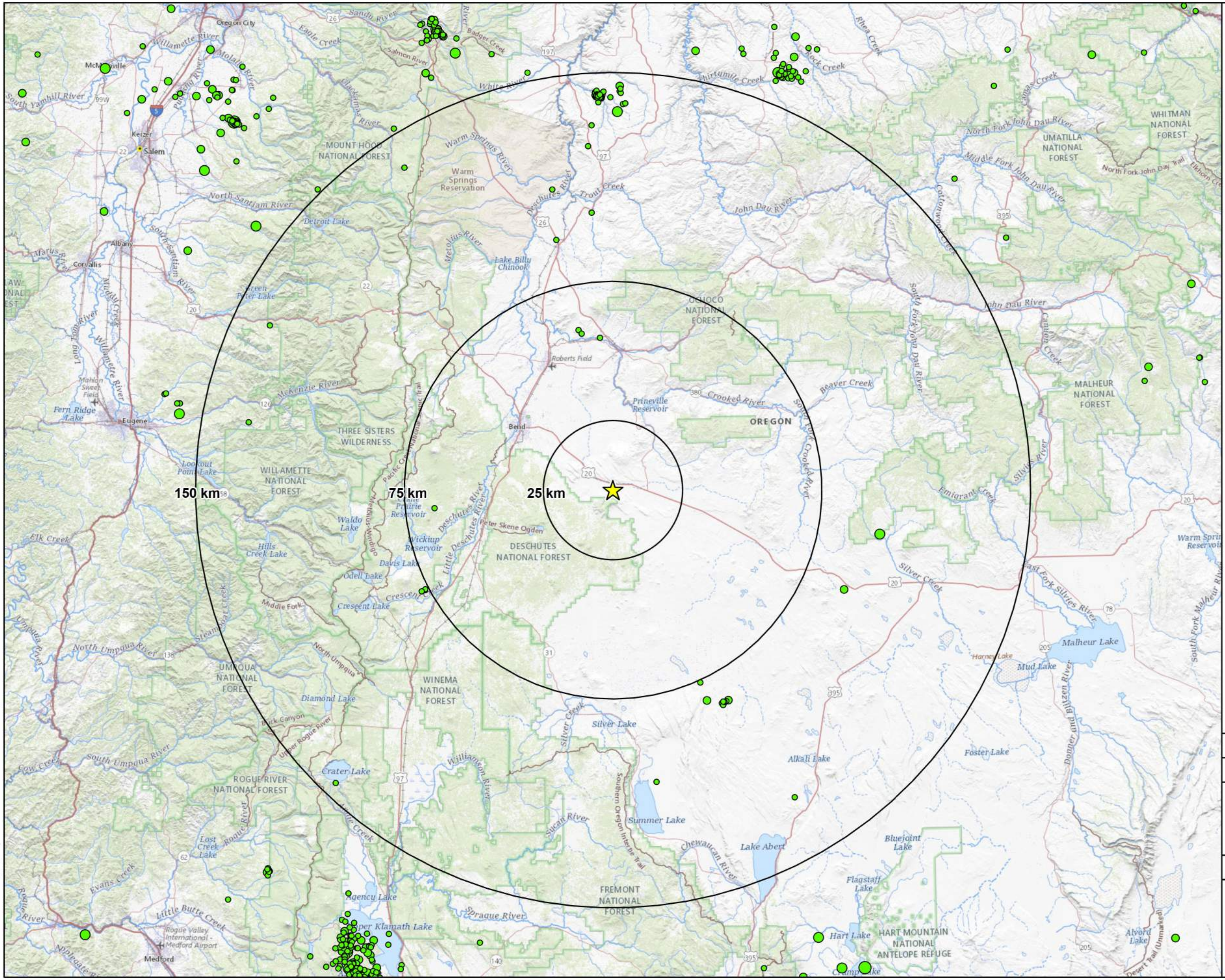


EXPLANATION

☆ Site location

○ Site proximity buffer (mi)

ANSS Historical Seismicity (1800-2022)

- ● M 2.5 - 3
- ● M 3 - 4
- ● M 4 - 5
- ● M 6 - 7
- ● M 7 - 8
- ● M 8+

Notes: ESRI World Topographic basemap, historical seismicity obtained through USGS ANSS and filtered by magnitude 4.0 and greater.

1 inch = 35 kilometers

0 17.5 35 70 km

Coordinate System: Central Oregon; Map Units: Foot

PARAMETRIX

PHASE 2 FINAL SWMF SITE EVALUATION - ROTH EAST

HISTORICAL SEISMICITY

DESCHUTES COUNTY, OREGON

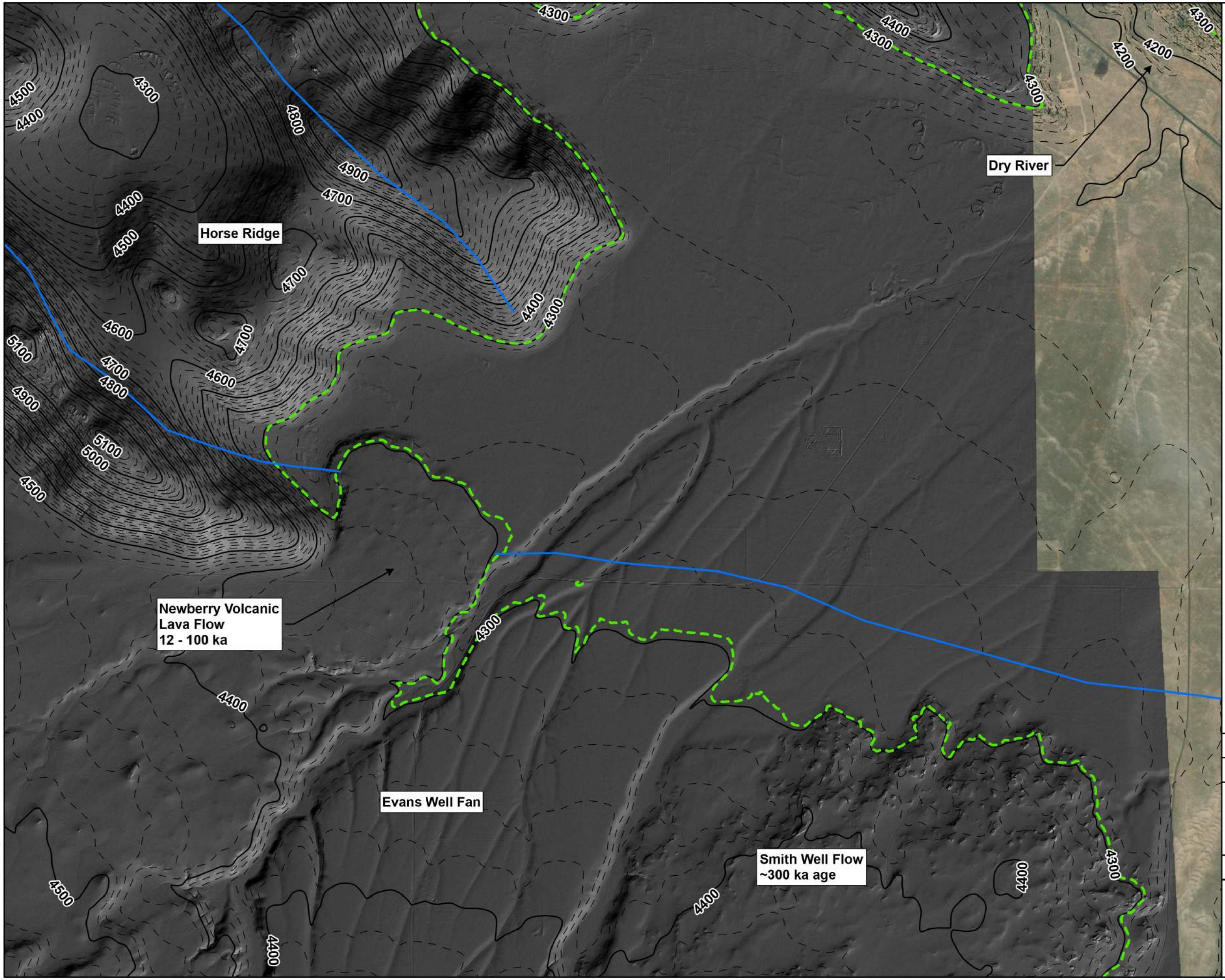
DATE: FEB 2024 ▪ PROJECT: 6491.0

DELVE underground

FIGURE

7

Path: \\172.16.6.125\gis\projects\6491.0\6491.0.aprx User: CordesShaun Date Saved: 1/31/2024 10:06 AM



EXPLANATION

- - 20-foot elevation contour (USGS; NAVD 88)

— 100-foot elevation contour (USGS; NAVD 88)

- - Lake Millican shoreline (Vanaman, 2007)

USGS Quaternary Fault and Fold Database

— middle and late Quaternary (<750,000 years), well constrained location

1 inch = 2,000 feet

0 1,000 2,000 4,000 Feet

Coordinate System: Central Oregon; Map Units: Foot

PARAMETRIX

PHASE 2 FINAL SWMF SITE EVALUATION - ROTH EAST

MILLICAN VALLEY LIDAR

DESCHUTES COUNTY, OREGON

DATE: FEB 2024 • PROJECT: 6491.0

DELVE underground

FIGURE

8

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Appendix A Subsurface Investigation Details

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A.1 Subsurface Exploration

The subsurface exploration program included a combination of geophysical surveys performed between August 21 and 25, 2023, and geotechnical borings completed between September 12 and 14, 2023. Both exploration programs were overseen by a Delve Underground geologist who was on site for the duration of the programs. The locations of the geotechnical borings geophysical profiles are presented in Figure 2. Details of the subsurface exploration program are presented below.

A.1.1 Geophysical Survey

Geophysical testing was conducted by Siemens and Associates of Bend, Oregon. The survey consisted of Electrical Resistivity (ER) and Seismic Refraction (SR) surveys along two parallel lines that extended through the site designed to be perpendicular to the trend of faults that are mapped in Millican Valley and the Brothers fault zone. The survey locations designated A-A’ and B-B’ are shown in Figure 2. The procedures and results of the geophysical survey are included as Appendix D.

ER tomography is a geophysical method that is used to illustrate the electrical characteristics of the subsurface. A direct current (DC) is injected into the ground through a series of electrodes, and the resulting voltage difference is measured at two or more potential electrodes along the survey line. The results were processed using software that compares the data to known resistivity values for specific rock or soil types to create a 2-dimensional electrical resistivity tomogram, or cross section of the subsurface. Similarly, SR surveys measure the energy of P-waves propagated through the subsurface materials as generated by an artificial blast and collected by geophone receivers along the survey line. These data are also correlated with known values to characterize the subsurface materials and create an SR tomogram. The use of both ER and SR surveys concurrently improves the interpretation by providing benefits achieved through comparison of the two tomograms.

A.1.2 Geotechnical Borings

Four geotechnical borings, designated B-1, B-2, B-3A, and B-3B, were advanced to depths ranging from 46.5 to 150 feet below ground surface (bgs) between September 12 and 14, 2023. Drilling was performed by Western States Soil Conservation, Inc. (WSSC) of Hubbard, Oregon, with a CME 850 track-mounted drilling rig (drill rig #12) using mud-rotary drilling techniques. The geotechnical borings area summarized in Table A-1 below and boring logs are provided in Appendix B.

A Delve Underground geologist was on site to log subsurface, observe drilling conditions, and to collect soil samples. Soils were visually classified according to the American Society for Testing and Materials (ASTM) D2488, “Standard Practice for Description and Identification of Soils

(Visual-Manual Procedures).” Select soil samples were chosen for laboratory testing as described in Section A.4.

Table A-1. Geotechnical Borings

Exploration	Latitude/Longitude	Ground Surface Elevation (ft)	Total Depth (ft bgs)
B-1	45.85684/-120.88570	4,514	151.5
B-2	43.85572/-120.88731	4,519	101.5
B-3A	45.85093/-122.88572	4,553	46.5
B-3B[1]	45.85098/-122.88567	4,522	101.5

Note:

[1] Began sampling B-3B at 45 ft bgs.

A void was encountered in boring B-3A that resulted in drilling fluid circulation loss at 45 feet bgs. The drill team attempted to plug the void to continue advancing the boring but eventually abandoned the hole and began drilling B-3B, approximately 20 feet from the location of B-3A. Sampling for B-3B commenced at 45 feet bgs. Although these logs are presented separately, they are within close enough proximity to be treated as continuous.

A.2 Soil Sampling

The geotechnical boring program included the collection of disturbed soil in conjunction with Standard Penetration Tests (SPTs) at 5- or 10-foot intervals using a standard 2-inch and 3-inch diameter split-barrel sampler and a 140-pound automatic hammer system. For each SPT, the sampler was advanced 18 inches by dropping the hammer 30 inches for each blow in accordance with ASTM D1586, “Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils.” The number of hammer-blows for each 6 inches of penetration was recorded. The standard penetration resistance (designated as the N-value) of the soil is the sum of the number of blows required for the final 12 inches of sampler penetration. The N-value is an indication of the relative density of granular soils and the relative consistency of cohesive soils.

The WSSC drill rig was equipped with an automatic safety hammer for performing the SPTs. WSSC provided automatic hammer calibration reports of SPT Hammer Energies (NV5, 2022) for its fleet of drilling equipment. Table A-2 summarizes the hammer calibration data for the WSSC drill rig # 12 used in the project investigations. Uncorrected, field-recorded N-values are presented in the boring logs in Appendix B.

Table A-2. SPT Hammer Efficiency Summary

Drill Type, Make, and Model	WSSC Drill ID/SN	SPT Hammer Energy Transfer Ratio	SPT Hammer Correction Factor	Borings
Track-mounted CME-850	Rig #2 / 417612	81.4	1.357	All Borings

Notes: SPT = Standard Penetration Test; WSSC = Western States Soil Conservation.

A.3 Exploration Hole Abandonment

Upon completion, the boreholes were abandoned in accordance with OWRD Regulations (OAR 690-240) to prevent vertical migration of surface water. The boreholes were backfilled with granular bentonite to the ground surface.

A.4 Laboratory Testing

A geotechnical laboratory index testing program was performed by FEI Testing and Inspection, Inc. (FEI) of Corvallis, Oregon.

The following soil index property tests were performed on select soil samples:

- Moisture Content: ASTM D2216, “Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass.”
- Atterberg Limits: ASTM D4318, “Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.”
- Percent Fines (passing No. 200 sieve or P200): ASTM D1140, “Standard Test Methods for Determining the Amount of Material Finer than 75-µm (No. 200) Sieve in Soils by Washing,” and ASTM C117, “Standard Test Method for Materials Finer than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing.”

The laboratory test results are presented in Appendix C as well as in the boring logs in Appendix B.

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Appendix B Boring Logs

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MOISTURE CONTENT

DESCRIPTION	CONDITION
Dry	Absence of moisture, dusty, dry to the touch.
Moist	Damp, but no visible water.
Wet	Visible free water, typically below water table.

ABBREVIATIONS

SYMBOL	DEFINITION
⊢⊣	Atterberg Limits
○	Moisture Content
□	Blows per foot (N)
●	WDP Blows per 6 in.

FINE-GRAINED SOIL CONSISTENCY

RELATIVE CONSISTENCY	N, SPT *Blows/foot*	FIELD TEST
Very Soft	0 to 1	Easily penetrated by thumb. Extrudes between thumb and fingers when squeezed.
Soft	2 to 4	Easily penetrated one inch by thumb. Molded by light finger pressure.
Medium stiff	5 to 8	Can be penetrated over ¼ inch with moderate pressure. Molded by strong finger pressure.
Stiff	9 to 15	Indented about ¼ inch by thumb, but penetrated only with great effort.
Very Stiff	16 to 30	Readily indented by thumbnail.
Hard	> 30	Indented with difficulty by thumbnail.

COARSE-GRAINED SOIL DENSITY

Relative Density	N, SPT *Blows/foot*
Very Loose	0 to 4
Loose	5 to 10
Medium Dense	11 to 30
Dense	31 to 50
Very Dense	> 50

PERCENTAGE RANGE TERMS^{1,2}

DESCRIPTION	RANGE
Trace	< 5%
Few	5 to 10%
Little	15 to 25%
Some	30 to 45%
Mostly	50 to 100%

1. Gravel, Sand and fines are estimated by mass. Other constituents such as organics, cobbles, and boulders are estimated by volume.
2. Percentages per ASTM D2488.

SOIL CONSTITUENCY DEFINITIONS

CONSTITUENT	COARSE-GRAINED	FINE-GRAINED
Major	Less than 50% fines: **SAND** or **GRAVEL**	More than 50% fines: **SILT, ELASTIC SILT, LEAN CLAY, FAT CLAY, ORGANIC SOIL**
Secondary	12%^{1} or more fine-grained: **Silty** or **Clayey**	30% or more coarse-grained: **Sandy** or **Gravelly**
Minor	5 to 12%^{1} fine-grained: **with Silt** or **with Clay**	15 to 30% coarse-grained: **with Sand** or **with Gravel**
	15% or more of a second coarse-grained constituent: **with Sand** or **with Gravel**	30% or more total coarse-grained and the lesser coarse constituent is 15% or more: **with Sand** or **with Gravel**

1. ASTM D2488 specifies more than 15% fines

PARTICLE SIZE DEFINITIONS

DESCRIPTON		SIEVE SIZE *PER ASTM D2488*
FINES		< #200 (0.075 mm)
SAND	*Fine*	#200 to #40 (0.075 to 0.4 mm)
	Medium	#40 to #10 (0.4 to 2 mm)
	Coarse	#10 to #4 (0.4 to 4.75 mm)
GRAVEL	*Fine*	#4 to ¾ in. (4.75 to 19 mm)
	Medium	¾ to 3 in. (19 to 76 mm)
COBBLES		3 to 12 in. (76 to 305 mm)
BOULDERS		> 12 in. (305 mm)

DELVE
underground

KEY TO SUBSURFACE LOGS

UNIFIED SOIL CLASSIFICATION SYSTEM (USCS)[1]

MAJOR DIVISIONS			SYMBOL		TYPICAL DESCRIPTION	ALTERNATE DESCRIPTIONS
COARSE-GRAINED SOILS (50% OR MORE RETAINED BY NO. 200 SIEVE)	GRAVELS (MORE THAN 50% RETAINED ON NO. 4 SIEVE)	CLEAN GRAVELS (≤ 5% FINES)	GW	▩	WELL-GRADED GRAVEL	WELL-GRADED GRAVEL WITH SAND
			GP	▩	POORLY GRADED GRAVEL	POORLY GRADED GRAVEL WITH SAND
		GRAVELS[2,4] (5 – 12 % FINES)	GW-GM	▩	WELL-GRADED GRAVEL WITH SILT	WELL-GRADED GRAVEL WITH SILT AND SAND
			GW-GC	▩	WELL-GRADED GRAVEL WITH CLAY	WELL-GRADED GRAVEL WITH CLAY AND SAND
			GP-GM	▩	POORLY GRADED GRAVEL WITH SILT	POORLY GRADED GRAVEL WITH SILT AND SAND
			GP-GC	▩	POORLY GRADED GRAVEL WITH CLAY	POORLY GRADED GRAVEL WITH CLAY AND SAND
		GRAVELS WITH FINES[2] (≥ 12% FINES)	GM	▩	SILTY GRAVEL	SILTY GRAVEL WITH SAND
			GC	▩	CLAYEY GRAVEL	CLAYEY GRAVEL WITH SAND
	SANDS (LESS THAN 50% RETAINED ON NO. 4 SIEVE)	CLEAN SANDS (≤ 5% FINES)	SW	▒	WELL-GRADED SAND	WELL-GRADED SAND WITH GRAVEL
			SP	░	POORLY GRADED SAND	POORLY GRADED SAND WITH GRAVEL
		SANDS[2,4] (5 – 12 % FINES)	SW-SM	▥	WELL-GRADED SAND WITH SILT	WELL-GRADED SAND WITH SILT AND GRAVEL
			SW-SC	▨	WELL-GRADED SAND WITH CLAY	WELL-GRADED SAND WITH CLAY AND GRAVEL
			SP-SM	▥	POORLY GRADED SAND WITH SILT	POORLY GRADED SAND WITH SILT AND GRAVEL
			SP-SC	▨	POORLY GRADED SAND WITH CLAY	POORLY GRADED SAND WITH CLAY AND GRAVEL
		SANDS WITH FINES[3] (> 12% FINES)	SM	▥	SILTY SAND	SILTY SAND WITH GRAVEL
			SC	▨	CLAYEY SAND	CLAYEY SAND WITH GRAVEL
FINE-GRAINED SOILS (50% OR MORE PASSES NO. 200 SIEVE)	SILTS AND CLAYS (LL < 50)	INORGANIC	ML	▥	SILT	SILT WITH SAND OR GRAVEL; SANDY OR GRAVELLY SILT
			CL	▨	LEAN CLAY	LEAN CLAY WITH SAND OR GRAVEL; SANDY OR GRAVELLY LEAN CLAY
		ORGANIC	OL	▧	ORGANIC SOIL	ORGANIC SOIL WITH SAND OR GRAVEL; SANDY OR GRAVELLY ORGANIC SOIL
	SILTS AND CLAYS (LL ≥ 50)	INORGANIC	MH	▥	ELASTIC SILT	ELASTIC SILT WITH SAND OR GRAVEL; SANDY OR GRAVELLY ELASTIC SILT
			CH	▨	FAT CLAY	FAT CLAY WITH SAND OR GRAVEL; SANDY OR GRAVELLY FAT CLAY
		ORGANIC	OH	▧	ORGANIC SOIL	ORGANIC SOIL WITH SAND OR GRAVEL; SANDY OR GRAVELLY ORGANIC SOIL
	SILT/CLAY[2]	INORGANIC	CL-ML	▨	SILTY CLAY	SILTY CLAY WITH SAND OR GRAVEL; SANDY OR GRAVELLY SILTY CLAY
HIGHLY ORGANIC SOILS		ORGANIC	PT	⩊	PEAT	

NOTES:

1. The USCS described here is based on ASTM standards D2487 & D2488.
2. Dual symbol materials (e.g., SP-SM) are used for soils between 5% and 12% fines or when liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart, (LL: 12 -25, PI: 4-7).
3. ASTM D2488 specifies the use of dual symbol coarse-grained soils between 5% and 15% fines.

BACKFILL, WELL, AND SAMPLE SYMBOLS					
▦	Bentonite Chips	▧	Grout	⧗	2” OD Split Barrel Sampler
▒	Concrete	◫	Observation Well - Solid	■	Shelby Tube Sample
░	Sand	▤	Observation Well – Screen	✋	Grab Sample
■	Asphalt	▮	Vibrating Wire Piezometer	⋈	3” OD Split Barrel Sampler
⁘	Gravel	▼	Measured Groundwater Level		

DELVE underground

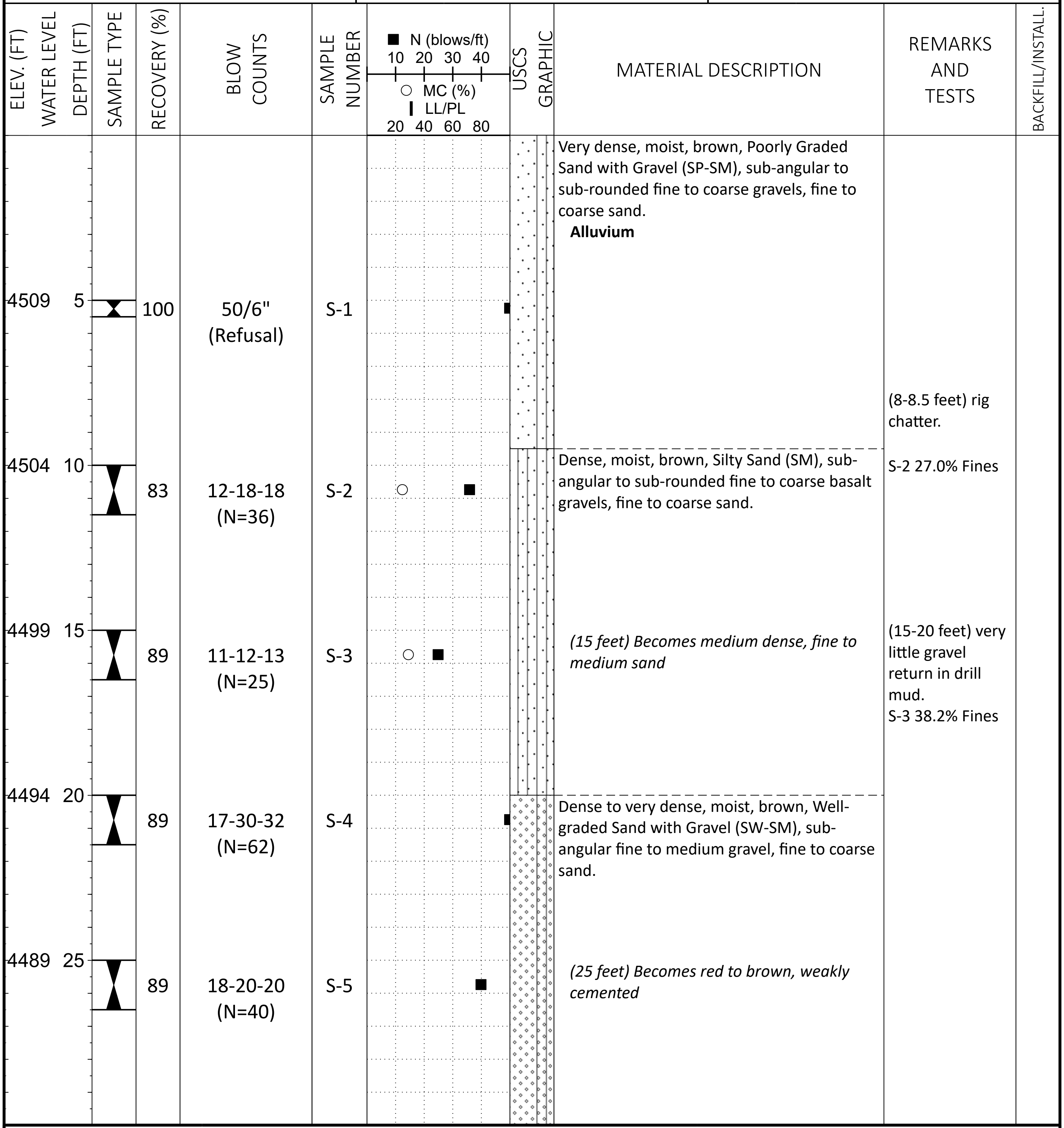
KEY TO SUBSURFACE LOGS

Project: Phase 2 Final SWMF Site Evaluation
Project Location: Deschutes County
Project Number: 6491.0

Log of Boring

B-1

Date(s) Drilled	**09/11/2023 - 09/12/2023**	Client	**Deschutes County**	Final Depth	**150.0 ft bgs**
Coordinates	**Lat. 43.85684°, Lon. -120.88570°**	Geotechnical Consultant	**Delve Underground**	Method/ Rig Type	**Mud Rotary** **CME 850 Track Mounted**
Surface Elevation	**4514.0 ft.**	Drilling Contractor	**Western States Soil Conservation, Inc.**	Hole Diameter	**4.88 in**
Location	**Roth East**	Logged by/ Checked by	**J. Siemens / S. Cordes**	Hammer Type	**140 lb / 30 in / Automatic**



ELEV. (FT)	DEPTH (FT)	RECOVERY (%)	BLOW COUNTS	SAMPLE NUMBER	MATERIAL DESCRIPTION	REMARKS AND TESTS
					Very dense, moist, brown, Poorly Graded Sand with Gravel (SP-SM), sub-angular to sub-rounded fine to coarse gravels, fine to coarse sand. **Alluvium**	
4509	5	100	50/6" (Refusal)	S-1		
						(8-8.5 feet) rig chatter.
4504	10	83	12-18-18 (N=36)	S-2	Dense, moist, brown, Silty Sand (SM), sub-angular to sub-rounded fine to coarse basalt gravels, fine to coarse sand.	S-2 27.0% Fines
4499	15	89	11-12-13 (N=25)	S-3	*(15 feet) Becomes medium dense, fine to medium sand*	(15-20 feet) very little gravel return in drill mud. S-3 38.2% Fines
4494	20	89	17-30-32 (N=62)	S-4	Dense to very dense, moist, brown, Well-graded Sand with Gravel (SW-SM), sub-angular fine to medium gravel, fine to coarse sand.	
4489	25	89	18-20-20 (N=40)	S-5	*(25 feet) Becomes red to brown, weakly cemented*	

DELVE
underground

NOTES:N: Penetration resistance; MC: Moisture Content; LL/PL: Atterberg liquid/plastic limits
Location and Elevation Source:
Vertical Datum:
Coordinate System: WGS84

Boring B-1

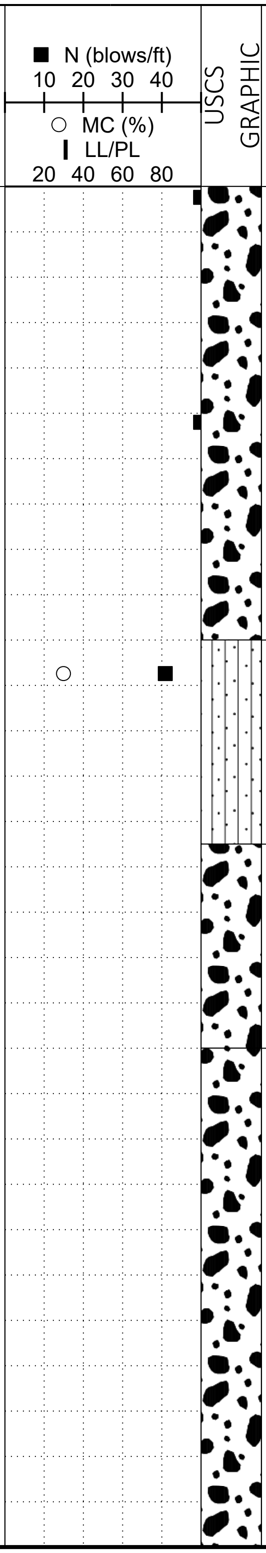
Project: Phase 2 Final SWMF Site Evaluation
Project Location: Deschutes County
Project Number: 6491.0

Log of Boring

B-1

Date(s) Drilled	09/11/2023 - 09/12/2023	Client	Deschutes County	Final Depth	150.0 ft bgs
Coordinates	Lat. 43.85684°, Lon. -120.88570°	Geotechnical Consultant	Delve Underground	Method/ Rig Type	Mud Rotary CME 850 Track Mounted
Surface Elevation	4514.0 ft.	Drilling Contractor	Western States Soil Conservation, Inc.	Hole Diameter	4.88 in
Location	Roth East	Logged by/ Checked by	J. Siemens / S. Cordes	Hammer Type	140 lb / 30 in / Automatic

ELEV. (FT)	WATER LEVEL	DEPTH (FT)	SAMPLE TYPE	RECOVERY (%)	BLOW COUNTS	SAMPLE NUMBER	MATERIAL DESCRIPTION	REMARKS AND TESTS	BACKFILL/INSTALL.
				100	50/6" (Refusal)	S-6	Very dense, moist, gray to brown, Well-graded Gravel with Sand (GW), fine to coarse rounded gravel, medium to coarse sand.	(30 feet) rig chatter.	
4479		35		79	50/5" (Refusal)	S-7	*(35 feet) trace silt*		
4474		40		89	15-20-21 (N=41)	S-8	Dense, moist, brown, Silty SAND (SM); fine to coarse sand.	(40-49 feet) smooth drilling with occasional rig chatter. S-8 32.6% Fines	
4469		45		84	100/6" (Refusal)	S-9	Very dense, moist, gray to brown, Well-graded Gravel with sand (GW), fine to coarse sub-rounded gravel, medium to coarse sand, trace silt.		
							Very dense, moist, gray to brown, Well-graded Gravel with Sand (GW), fine to coarse rounded gravel, medium to coarse sand.	(49-50 feet) some rig chatter.	
4464		50		84	100/6" (Refusal)	S-10		(50-55 feet) moderate rig chatter.	
4459		55		92	72-100/6" (Refusal)	S-11		(55 feet) Switched to Modified California 3-inch sampler.	



NOTES:N: Penetration resistance; MC: Moisture Content; LL/PL: Atterberg liquid/plastic limits
Location and Elevation Source:
Vertical Datum:
Coordinate System: WGS84

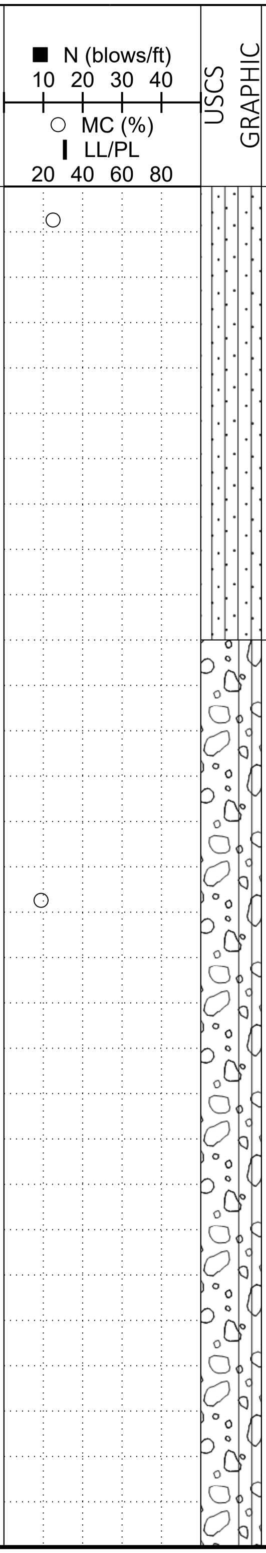
Project: Phase 2 Final SWMF Site Evaluation
Project Location: Deschutes County
Project Number: 6491.0

Log of Boring

B-1

Date(s) Drilled	**09/11/2023 - 09/12/2023**	Client	**Deschutes County**	Final Depth	**150.0 ft bgs**
Coordinates	**Lat. 43.85684°, Lon. -120.88570°**	Geotechnical Consultant	**Delve Underground**	Method/ Rig Type	**Mud Rotary** **CME 850 Track Mounted**
Surface Elevation	**4514.0 ft.**	Drilling Contractor	**Western States Soil Conservation, Inc.**	Hole Diameter	**4.88 in**
Location	**Roth East**	Logged by/ Checked by	**J. Siemens / S. Cordes**	Hammer Type	**140 lb / 30 in / Automatic**

ELEV. (FT)	WATER LEVEL	DEPTH (FT)	SAMPLE TYPE	RECOVERY (%)	BLOW COUNTS	SAMPLE NUMBER	MATERIAL DESCRIPTION	REMARKS AND TESTS	BACKFILL/INSTALL.
			⧗	95	60-60-62	S-12	Very dense, moist, red to brown, Silty SAND (SM), fine rounded basalt and tuff gravel, fine to coarse sand.	S-12 24.2% Fines	
4449		65	⧗	59	31-40-46	S-13			
4444		70	⧗	88	46-95-100/4" (Refusal)	S-14	Very dense, moist, red to brown, Well-graded Gravel with Silt and Sand (GW-GM), fine to coarse sub-rounded gravel, fine to coarse sand.	(70-72 feet) rig chatter. (72-74 feet) smooth drilling. (74-75 feet) rig chatter and hard drilling; driller notes cobbles.	
4439		75	⧗	67	58-80-97	S-15	*(75 feet) increase in sand and silt*	S-15 12.9% Fines (78-79 feet) very hard drilling.	
4434		80	⧗	138	100/3" (Refusal)	S-16	*(80 feet) Becomes brown, 4-inch gravel clasts*	(80-90 feet) driller notes 6- to 12-inch interbedded layers of smooth to hard drilling with rig chatter.	
4429		85							



DELVE underground

NOTES:N: Penetration resistance; MC: Moisture Content; LL/PL: Atterberg liquid/plastic limits
Location and Elevation Source:
Vertical Datum:
Coordinate System: WGS84

Project: Phase 2 Final SWMF Site Evaluation
Project Location: Deschutes County
Project Number: 6491.0

Log of Boring

B-1

Date(s) Drilled	09/11/2023 - 09/12/2023	Client	Deschutes County	Final Depth	150.0 ft bgs
Coordinates	Lat. 43.85684°, Lon. -120.88570°	Geotechnical Consultant	Delve Underground	Method/ Rig Type	Mud Rotary CME 850 Track Mounted
Surface Elevation	4514.0 ft.	Drilling Contractor	Western States Soil Conservation, Inc.	Hole Diameter	4.88 in
Location	Roth East	Logged by/ Checked by	J. Siemens / S. Cordes	Hammer Type	140 lb / 30 in / Automatic

ELEV. (FT)	WATER LEVEL	DEPTH (FT)	SAMPLE TYPE	RECOVERY (%)	BLOW COUNTS	SAMPLE NUMBER	■ N (blows/ft) 10 20 30 40 ○ MC (%) ▌ LL/PL 20 40 60 80	USCS	GRAPHIC	MATERIAL DESCRIPTION	REMARKS AND TESTS	BACKFILL/INSTALL.
				100	100/3" (Refusal)	S-17				Very dense, moist, red to brown, Well-graded Gravel with Silt and Sand (GW-GM), fine to coarse sub-rounded gravel, fine to coarse sand. *(90 feet) no recovery*	(91-92 feet) rig chatter and hard drilling; driller notes cobbles. (94-98 feet) hard drilling; driller notes cobbles.	
4419		95										
4414		100		0	100/0" (Refusal)	S-18				*(100 feet) no recovery*	(100-105 feet) hard to smooth drilling; driller notes cobbles and fine-grained layers.	
4409		105									(107-109 feet) smooth driling.	
4404		110										
4399		115	⧗	129	36-100/1" (Refusal)	S-19				Very dense, moist, brown, Well-graded Gravel with Sand (GW), fine to coarse gravel, trace cobbles?, fine to coarse sand, trace silt.		

DELVE underground

NOTES:N: Penetration resistance; MC: Moisture Content; LL/PL: Atterberg liquid/plastic limits
Location and Elevation Source:
Vertical Datum:
Coordinate System: WGS84

Boring B-1

Project: Phase 2 Final SWMF Site Evaluation
Project Location: Deschutes County
Project Number: 6491.0

Log of Boring

B-1

Date(s) Drilled	**09/11/2023 - 09/12/2023**	Client	**Deschutes County**	Final Depth	**150.0 ft bgs**
Coordinates	**Lat. 43.85684°, Lon. -120.88570°**	Geotechnical Consultant	**Delve Underground**	Method/ Rig Type	**Mud Rotary** **CME 850 Track Mounted**
Surface Elevation	**4514.0 ft.**	Drilling Contractor	**Western States Soil Conservation, Inc.**	Hole Diameter	**4.88 in**
Location	**Roth East**	Logged by/ Checked by	**J. Siemens / S. Cordes**	Hammer Type	**140 lb / 30 in / Automatic**

ELEV. (FT)	WATER LEVEL	DEPTH (FT)	SAMPLE TYPE	RECOVERY (%)	BLOW COUNTS	SAMPLE NUMBER	■ N (blows/ft) 10 20 30 40 ○ MC (%) ❙ LL/PL 20 40 60 80	USCS GRAPHIC	MATERIAL DESCRIPTION	REMARKS AND TESTS	BACKFILL/INSTALL.
				100	100/2" (Refusal)	S-20			Very dense, moist, brown, Well-graded Gravel with Sand (GW), fine to coarse gravel, trace cobbles?, fine to coarse sand, trace silt.	(120 feet) 3-inch tuff clasts obstructing shoe.	
4389		125									
4384		130		100	100/1" (Refusal)	S-21				(130-135 feet) hard to smooth drilling; driller notes cobbles and sand layers.	
4379		135								(135-140 feet) driller notes increasing sand.	
4374		140		100	100/2" (Refusal)	S-22					
4369		145									
									(150 feet) no recovery		

DELVE
underground

NOTES:N: Penetration resistance; MC: Moisture Content; LL/PL: Atterberg liquid/plastic limits
Location and Elevation Source:
Vertical Datum:
Coordinate System: WGS84

Boring B-1

Project: Phase 2 Final SWMF Site Evaluation
Project Location: Deschutes County
Project Number: 6491.0

Log of Boring

B-1

Date(s) Drilled	**09/11/2023 - 09/12/2023**	Client	**Deschutes County**	Final Depth	**150.0 ft bgs**
Coordinates	**Lat. 43.85684°, Lon. -120.88570°**	Geotechnical Consultant	**Delve Underground**	Method/ Rig Type	**Mud Rotary** **CME 850 Track Mounted**
Surface Elevation	**4514.0 ft.**	Drilling Contractor	**Western States Soil Conservation, Inc.**	Hole Diameter	**4.88 in**
Location	**Roth East**	Logged by/ Checked by	**J. Siemens / S. Cordes**	Hammer Type	**140 lb / 30 in / Automatic**

ELEV. (FT)	WATER LEVEL	DEPTH (FT)	SAMPLE TYPE	RECOVERY (%)	BLOW COUNTS	SAMPLE NUMBER	■ N (blows/ft) 10 20 30 40 ○ MC (%) ❙ LL/PL 20 40 60 80	USCS GRAPHIC	MATERIAL DESCRIPTION	REMARKS AND TESTS	BACKFILL/INSTALL.
				0	100/0" (Refusal)	S-23				Borehole completed at 150 feet below ground surface (bgs).	
4359		155									
4354		160									
4349		165									
4344		170									
4339		175									

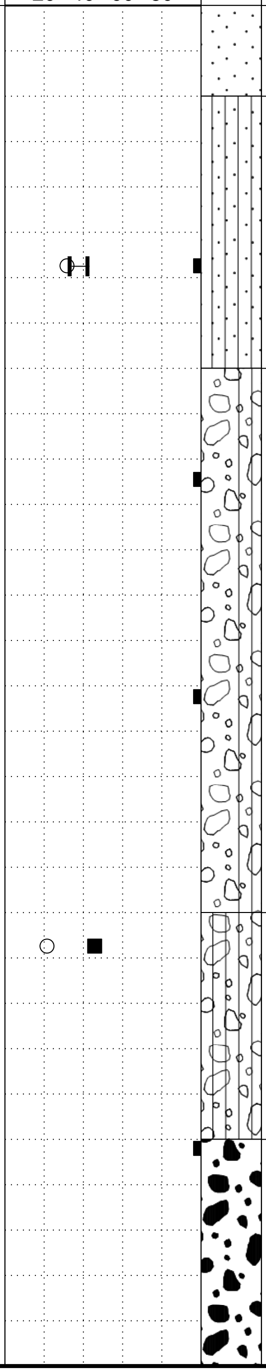
NOTES:N: Penetration resistance; MC: Moisture Content; LL/PL: Atterberg liquid/plastic limits
Location and Elevation Source:
Vertical Datum:
Coordinate System: WGS84

Project: Phase 2 Final SWMF Site Evaluation
Project Location: Deschutes County
Project Number: 6491.0

Log of Boring

B-2

Date(s) Drilled	09/13/2023	Client	Deschutes County	Final Depth	100.0 ft bgs
Coordinates	Lat. 43.85572°, Lon. -120.88731°	Geotechnical Consultant	Delve Underground	Method/ Rig Type	Mud Rotary CME 850 Track Mounted
Surface Elevation	4519.0 ft.	Drilling Contractor	Western States Soil Conservation, Inc.	Hole Diameter	4.88 in
Location	Roth East	Logged by/ Checked by	J. Siemens / S. Cordes	Hammer Type	140 lb / 30 in / Automatic



ELEV. (FT)	WATER LEVEL	DEPTH (FT)	SAMPLE TYPE	RECOVERY (%)	BLOW COUNTS	SAMPLE NUMBER	BACKFILL/INSTALL.
4514		5		100	18-29-27 (N=56)	S-1	
4509		10		109	36-50/5" (Refusal)	S-2	
4504		15		84	50/6" (Refusal)	S-3	
4499		20		45	12-11-12 (N=23)	S-4	
4494		25		100	50/5" (Refusal)	S-5	

MATERIAL DESCRIPTION

Dense, dry, brown, Poorly Graded SAND with Gravel (GP); few 6-inch cobbles.
Alluvium

Hard, moist, brown, Silty SAND (SM); fine to medium sand, trace fine sub-rounded gravel.

Very dense, moist, brown, Well-graded GRAVEL with Silt and Sand (GP-GM); little fine to coarse sand, fine to coarse sub-rounded basalt and tuff gravels with weathered surfaces.

Medium dense, moist, brown, Silty GRAVEL (GM); few fine to medium sand, fine to coarse sub-rounded gravel.

Very dense, moist, brown, Well-graded GRAVEL with Sand (GW); little fine to coarse sand, fine to coarse rounded basalt and tuff gravels.

REMARKS AND TESTS

(0-2 feet) moderate rig hatter; driller notes cobbles and boulders.
(2-5 feet) smooth drilling.

S-1 28.1% Fines

(8-10 feet) slight rig chatter; driller notes gravel.

(13-15 feet) rapid drilling; driller notes fine-grained zone.
(15-20 feet) intermittent moderate rigchatter; driller notes small cobbles to layers of gravel with sand.
S-4 18.9% Fines

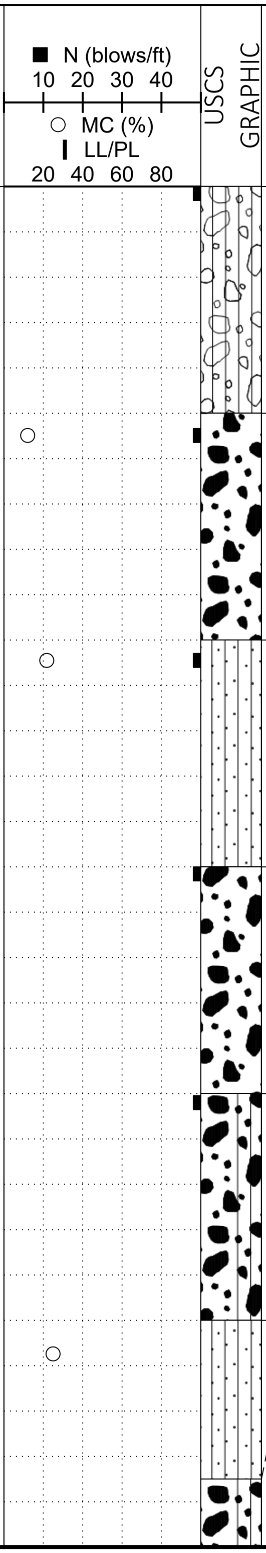
NOTES:N: Penetration resistance; MC: Moisture Content; LL/PL: Atterberg liquid/plastic limits
Location and Elevation Source:
Vertical Datum:
Coordinate System: WGS84

DELVE underground

Project: Phase 2 Final SWMF Site Evaluation
Project Location: Deschutes County
Project Number: 6491.0

Log of Boring
B-2

Date(s) Drilled	**09/13/2023**	Client	**Deschutes County**	Final Depth	**100.0 ft bgs**
Coordinates	**Lat. 43.85572°, Lon. -120.88731°**	Geotechnical Consultant	**Delve Underground**	Method/ Rig Type	**Mud Rotary** **CME 850 Track Mounted**
Surface Elevation	**4519.0 ft.**	Drilling Contractor	**Western States Soil Conservation, Inc.**	Hole Diameter	**4.88 in**
Location	**Roth East**	Logged by/ Checked by	**J. Siemens / S. Cordes**	Hammer Type	**140 lb / 30 in / Automatic**



ELEV. (FT)	WATER LEVEL	DEPTH (FT)	SAMPLE TYPE	RECOVERY (%)	BLOW COUNTS	SAMPLE NUMBER	MATERIAL DESCRIPTION	REMARKS AND TESTS	BACKFILL/INSTALL.
				100	50/4" (Refusal)	S-6	Very dense, moist, brown, GRAVEL with Silt and Sand (GM); little fine to coarse sand, fine to coarse gravel.	(30-40 feet) intermittent rig chatter; driller notes interbedded gravels with smoother layers about 6-12-inch thick.	
4484		35		100	42-50/6" (Refusal)	S-7	Very dense, moist, brown, Well-graded GRAVEL with Sand (GW); little fine to coarse sand, fine to coarse sub-rounded gravel, trace <6-inch cobbles. *(35 feet) few coarse to medium sand, trace <6-inch cobbles.*	S-7 6.8% Fines	
4479		40		109	37-50/5" (Refusal)	S-8	Very dense, moist, brown, Silty SAND with Gravel (SM); some fine to coarse sub-rounded gravel, fine to coarse sand.	S-8 18.5% Fines	
4474		45		127	50/4" (Refusal)	S-9	Very dense, moist, brown, Well-graded GRAVEL with Sand (GW); little fine to coarse sand, fine to coarse sub-rounded basalt gravels.		
4469		50		219	50/5" (Refusal)	S-10	Very dense, moist, brown, Well-graded GRAVEL with Silt and Sand (GW-GM); some fine to coarse sand, fine to coarse rounded gravel, trace cobbles.		
4464		55		95	51-80-84	S-11	Very dense, moist, red-brown, Silty SAND (SM); few fine sub-angular gravel, fine to coarse, sand, weakly cemented.	(55-58.5 feet) rapid smooth drilling. S-11 23.9% Fines	
							Very dense, moist, brown, Well-graded SAND with Silt and Gravel (GW-GM); little fine to coarse rounded basalt gravel, fine to coarse sand.		

DELVE
underground

NOTES:N: Penetration resistance; MC: Moisture Content; LL/PL: Atterberg liquid/plastic limits
Location and Elevation Source:
Vertical Datum:
Coordinate System: WGS84

Project: Phase 2 Final SWMF Site Evaluation
Project Location: Deschutes County
Project Number: 6491.0

Log of Boring

B-2

Date(s) Drilled	09/13/2023	Client	Deschutes County	Final Depth	100.0 ft bgs
Coordinates	Lat. 43.85572°, Lon. -120.88731°	Geotechnical Consultant	Delve Underground	Method/ Rig Type	Mud Rotary CME 850 Track Mounted
Surface Elevation	4519.0 ft.	Drilling Contractor	Western States Soil Conservation, Inc.	Hole Diameter	4.88 in
Location	Roth East	Logged by/ Checked by	J. Siemens / S. Cordes	Hammer Type	140 lb / 30 in / Automatic

ELEV. (FT)	WATER LEVEL	DEPTH (FT)	SAMPLE TYPE	RECOVERY (%)	BLOW COUNTS	SAMPLE NUMBER	■ N (blows/ft) 10 20 30 40 ○ MC (%) ❙ LL/PL 20 40 60 80	USCS GRAPHIC	MATERIAL DESCRIPTION	REMARKS AND TESTS	BACKFILL/INSTALL.
				89	48-58-100/6" (Refusal)	S-12			Very dense, moist, brown, Well-graded SAND with Silt and Gravel (GW-GM); little fine to coarse rounded basalt gravel, fine to coarse sand.	(60-65 feet) rapid smooth drilling.	
4454		65		100	54-100/5" (Refusal)	S-13			Very dense, moist, brown, Well-graded GRAVEL with Sand (GW); little fine to coarse sand, fine to coarse sub-rounded gravel, trace 6-inch cobbles.	(65-70 feet) moderate rig chatter; driller notes gravels and small cobbles.	
4449		70		100	100/6" (Refusal)	S-14				(73-75 feet) smooth and rapid drilling.	
4444		75		100	79-100/4" (Refusal)	S-15	○		Very dense, moist, red-brown, Well-graded GRAVEL with Sand and Silt (GW-GM); little fine to coarse sand, fine to coarse sub-rounded gravel, red-brown iron-oxide stained matrix.	(75-80 feet) intermittent rig chatter; driller notes gravel/ cobbles interbedded with fine-grained beds 6-12-inches thick. S-15 13.0% Fines	
4439		80		100	100/4" (Refusal)	S-16			*(80 feet) becomes brown, basalt and tuff clasts.*	(80-85 feet) strong rig chatter; driller notes clast size increases.	
4434		85		100	100/2" (Refusal)	S-17			*(85-90 feet) few 3- to 4-inch cobbles.*	(85-90 feet) strong rig chatter; driller notes possible cobbles or coarse-size gravels.	

DELVE underground

NOTES:N: Penetration resistance; MC: Moisture Content; LL/PL: Atterberg liquid/plastic limits
Location and Elevation Source:
Vertical Datum:
Coordinate System: WGS84

Boring B-2

Project: Phase 2 Final SWMF Site Evaluation
Project Location: Deschutes County
Project Number: 6491.0

Log of Boring

B-2

Date(s) Drilled	**09/13/2023**	Client	**Deschutes County**	Final Depth	**100.0 ft bgs**
Coordinates	**Lat. 43.85572°, Lon. -120.88731°**	Geotechnical Consultant	**Delve Underground**	Method/ Rig Type	**Mud Rotary** **CME 850 Track Mounted**
Surface Elevation	**4519.0 ft.**	Drilling Contractor	**Western States Soil Conservation, Inc.**	Hole Diameter	**4.88 in**
Location	**Roth East**	Logged by/ Checked by	**J. Siemens / S. Cordes**	Hammer Type	**140 lb / 30 in / Automatic**

ELEV. (FT)	WATER LEVEL	DEPTH (FT)	SAMPLE TYPE	RECOVERY (%)	BLOW COUNTS	SAMPLE NUMBER	■ N (blows/ft) 10 20 30 40 ○ MC (%) ❙ LL/PL 20 40 60 80	USCS GRAPHIC	MATERIAL DESCRIPTION	REMARKS AND TESTS	BACKFILL/INSTALL.
				100	100/2" (Refusal)	S-18			Very dense, moist, brown, Well-graded GRAVEL with Sand; little fine to coarse sand, fine to coarse rounded gravel, trace cobbles.	(90-95 feet) driller notes interbedded cobbles with gravels.	
4424		95		100	100/3" (Refusal)	S-19					
									Very dense, moist, brown, Well-graded SAND with Silt and Gravel (SW-SM); some fine to medium rounded basalt and tuff gravels, fine to coarse sand.	(97-100 feet) smooth drilling. S-20 9.6% Fines	
4419		100		95	37-66-66	S-20	○			Borehole completed at 100 feet below ground surface (bgs).	
4414		105									
4409		110									
4404		115									

DELVE underground

NOTES:N: Penetration resistance; MC: Moisture Content; LL/PL: Atterberg liquid/plastic limits
Location and Elevation Source:
Vertical Datum:
Coordinate System: WGS84

Boring B-2

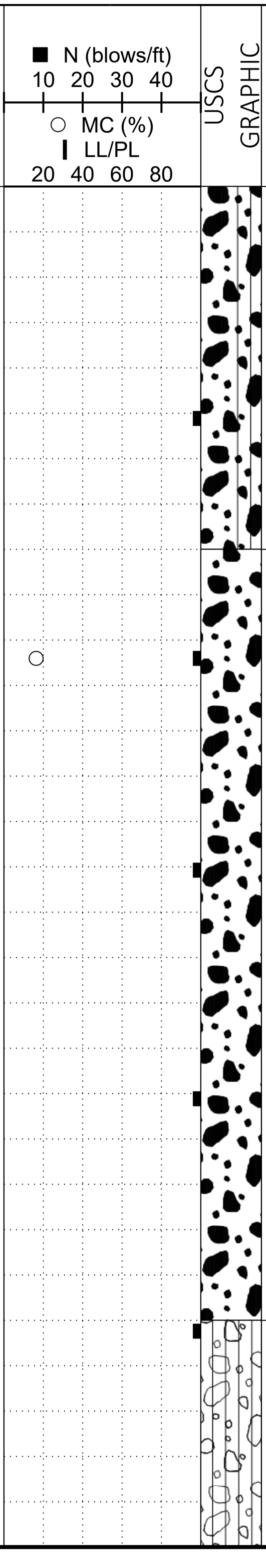
Project: Phase 2 Final SWMF Site Evaluation
Project Location: Deschutes County
Project Number: 6491.0

Log of Boring

B-3A

Date(s) Drilled	**09/13/2023 - 09/14/2023**	Client	**Deschutes County**	Final Depth	**46.5 ft bgs**
Coordinates	**Lat. 45.85093°, Lon. -122.88572°**	Geotechnical Consultant	**Delve Underground**	Method/ Rig Type	**Mud Rotary** **CME 850 Track Mounted**
Surface Elevation	**4553.0 ft.**	Drilling Contractor	**Western States Soil Conservation, Inc.**	Hole Diameter	**4.88 in**
Location	**Roth East**	Logged by/ Checked by	**J. Siemens / S. Cordes**	Hammer Type	**140 lb / 30 in / Automatic**

ELEV. (FT)	WATER LEVEL	DEPTH (FT)	SAMPLE TYPE	RECOVERY (%)	BLOW COUNTS	SAMPLE NUMBER	MATERIAL DESCRIPTION	REMARKS AND TESTS	BACKFILL/INSTALL.
							Very dense, moist, brown, Well-graded Sandy GRAVEL with Silt and Cobbles (GW-GM); sub-rounded clasts, 6-12-inch cobbles. **Alluvium**	(0-8 feet) strong rod chatter; driller notes many cobbles.	
4548		5		0	50/3" (Refusal)	S-1			
							Very dense, moist, brown, Well-graded GRAVEL with Sand (GW); little fine to coarse sand, fine to coarse rounded gravel, few cobbles.	(8.5 feet) intermittent rig chatter; driller notes interbedding. (10-15 feet) intermittent rig chatter: driller notes 1-2-foot-thick interbedded gravels and sands. S-2 10.0% Fines (16-19.5 feet) smooth rapid drilling.	
4543		10		90	45-50/4" (Refusal)	S-2			
4538		15		47	50/2" (Refusal)	S-3			
4533		20		32	50/3" (Refusal)	S-4			
4528		25		100	50/6" (Refusal)	S-5	Very dense, moist, brown, Silty GRAVEL (GM); few fine to coarse sand, fine to coarse rounded tuff and basalt gravels.	(25-30 feet) driller notes gravel/sand layers 1- to 1.5-feet thick, no large cobbles.	



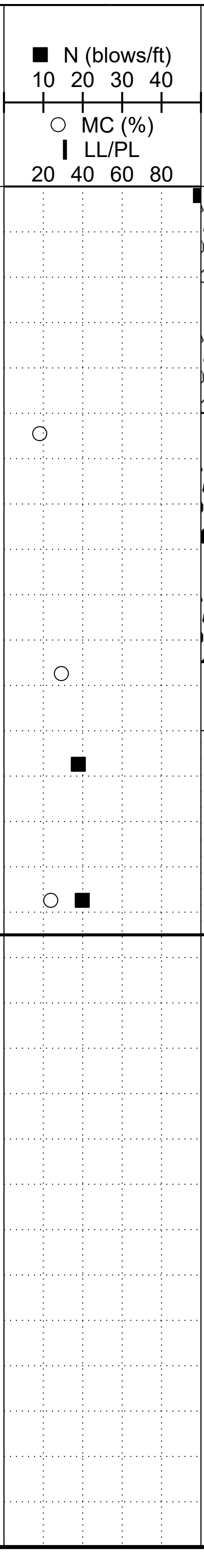
DELVE underground

NOTES:N: Penetration resistance; MC: Moisture Content; LL/PL: Atterberg liquid/plastic limits
Location and Elevation Source:
Vertical Datum: NAVD 88
Coordinate System: WGS84

Project: Phase 2 Final SWMF Site Evaluation
Project Location: Deschutes County
Project Number: 6491.0

Log of Boring
B-3A

Date(s) Drilled	**09/13/2023 - 09/14/2023**	Client	**Deschutes County**	Final Depth	**46.5 ft bgs**
Coordinates	**Lat. 45.85093°, Lon. -122.88572°**	Geotechnical Consultant	**Delve Underground**	Method/ Rig Type	**Mud Rotary** **CME 850 Track Mounted**
Surface Elevation	**4553.0 ft.**	Drilling Contractor	**Western States Soil Conservation, Inc.**	Hole Diameter	**4.88 in**
Location	**Roth East**	Logged by/ Checked by	**J. Siemens / S. Cordes**	Hammer Type	**140 lb / 30 in / Automatic**



ELEV. (FT)	WATER LEVEL	DEPTH (FT)	SAMPLE TYPE	RECOVERY (%)	BLOW COUNTS	SAMPLE NUMBER	USCS GRAPHIC	MATERIAL DESCRIPTION	REMARKS AND TESTS	BACKFILL/INSTALL.
				100	50/5" (Refusal)	S-6		Very dense, moist, brown, Silty GRAVEL (GM); few fine to coarse sand, fine to coarse rounded tuff and basalt gravels.	(30-35 feet) driller notes lenses 1-2-feet thick. (32 feet) circulation loss; possible void.	
4518		35		90	60-100/5" (Refusal)	S-7		Very dense, moist, brown, Well-graded GRAVEL with Silt and Sand (GW-GM); little fine to coarse sand, fine to coarse rounded gravel, trace <6-inch cobbles.	(35 feet) switched to Modified California 3-inch sampler. S-7 9.2% Fines	
4513		40		17	31-1-0	S-8		Void.	S-8B 9.3% Fines	
				100	3-8-11 (N=19)	S-9		Very dense, moist, brown, Well-graded SAND with Silt and Gravel (SW-SM); little fine to coarse sub-angular gravel, fine to coarse sand. *Continued on Log of Boring B-3B.*	(42 feet) switched back to SPT sampler. Hole abandoned at 45 feet due to void and circulation loss, moved to advance B-3B. S-10 11.9% Fines Borehole completed at 46.5 feet below ground surface (bgs).	
4508		45		50	6-11-9 (N=20)	S-10				
4503		50								
4498		55								

DELVE underground

NOTES:N: Penetration resistance; MC: Moisture Content; LL/PL: Atterberg liquid/plastic limits
Location and Elevation Source:
Vertical Datum: NAVD 88
Coordinate System: WGS84

Boring B-3A

Project: Phase 2 Final SWMF Site Evaluation
Project Location: Deschutes County
Project Number: 6491.0

Log of Boring

B-3B

Date(s) Drilled	**09/14/2023**	Client	**Deschutes County**	Final Depth	**100.0 ft bgs**
Coordinates	**Lat. 45.85098°, Lon. -122.88567°**	Geotechnical Consultant	**Delve Underground**	Method/ Rig Type	**Mud Rotary** **CME 850 Track Mounted**
Surface Elevation	**4552.0 ft.**	Drilling Contractor	**Western States Soil Conservation, Inc.**	Hole Diameter	**4.88 in**
Location	**Roth East**	Logged by/ Checked by	**J. Siemens / S. Cordes**	Hammer Type	**140 lb / 30 in / Automatic**

ELEV. (FT)	WATER LEVEL	DEPTH (FT)	SAMPLE TYPE	RECOVERY (%)	BLOW COUNTS	SAMPLE NUMBER	■ N (blows/ft) 10 20 30 40 ○ MC (%) ❙ LL/PL 20 40 60 80	USCS GRAPHIC	MATERIAL DESCRIPTION	REMARKS AND TESTS	BACKFILL/INSTALL.
									(0-45 feet) See Log of Boring B-3A; no sampling from 0-45 feet.	Continued from Log of Boring B-3A that was abandoned due to void and circulation loss. Sampling begins at 45 feet. (0-26 feet) driller notes layered gravels and sands in 1-2-foot thick beds.	
4547		5									
4542		10									
4537		15									
4532		20									
4527		25									
										(26-30 feet) rapid drilling.	

NOTES:N: Penetration resistance; MC: Moisture Content; LL/PL: Atterberg liquid/plastic limits
Location and Elevation Source:
Vertical Datum:
Coordinate System: WGS84

Project: Phase 2 Final SWMF Site Evaluation
Project Location: Deschutes County
Project Number: 6491.0

Log of Boring

B-3B

Date(s) Drilled	09/14/2023	Client	Deschutes County	Final Depth	100.0 ft bgs
Coordinates	Lat. 45.85098°, Lon. -122.88567°	Geotechnical Consultant	Delve Underground	Method/ Rig Type	Mud Rotary CME 850 Track Mounted
Surface Elevation	4552.0 ft.	Drilling Contractor	Western States Soil Conservation, Inc.	Hole Diameter	4.88 in
Location	Roth East	Logged by/ Checked by	J. Siemens / S. Cordes	Hammer Type	140 lb / 30 in / Automatic

ELEV. (FT)	WATER LEVEL	DEPTH (FT)	SAMPLE TYPE	RECOVERY (%)	BLOW COUNTS	SAMPLE NUMBER	■ N (blows/ft) 10 20 30 40 ○ MC (%) ❙ LL/PL 20 40 60 80	USCS GRAPHIC	MATERIAL DESCRIPTION	REMARKS AND TESTS	BACKFILL/INSTALL.
									(0-45 feet) See Log of Boring B-3A; no sampling from 0-45 feet.		
4517		35									
4512		40									
4507		45		100	27-50/2" (Refusal)	S-1	■		Very dense, moist, brown, Well-graded GRAVEL with sand (GW); little fine to coarse sand, fine to coarse sub-rounded tuff and basalt gravels. **Alluvium**	(45-50 feet) rig chatter; driller notes consistent gravels.	
4502		50		72	50/11" (Refusal)	S-2	■		Very dense, moist, brown, Well-graded GRAVEL with Silt and Sand (GW-GM); little fine to coarse sand, fine to coarse sub-rounded basalt gravels.	(50-55 feet) intermittent rig chatter; driller notes layered 4-6-inch cobbles with 6-12-inch-thick gravels and sands.	
4497		55		132	100/3" (Refusal)	S-3			Very dense, moist, brown, Silty GRAVEL with Sand (GM); little fine to coarse sand, fine to coarse sub-rounded gravel, trace 3-inch basalt cobbles.	(55 feet) switched from 4 7/8 inch to 3 7/8 inch bit and to Modified California Sampler.	
									Very dense, moist, brown, Silty SAND (SM); few fine to coarse rounded gravel, fine to coarse sand, trace basalt cobbles.	(57-59 feet) hard	

NOTES:N: Penetration resistance; MC: Moisture Content; LL/PL: Atterberg liquid/plastic limits
Location and Elevation Source:
Vertical Datum:
Coordinate System: WGS84

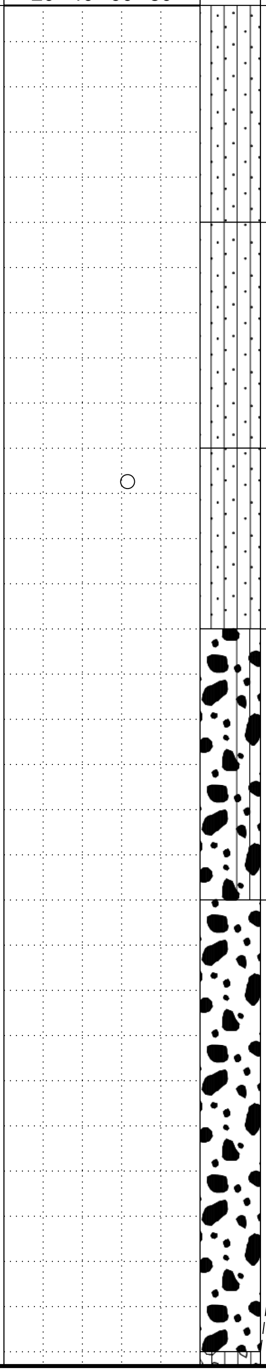
Project: Phase 2 Final SWMF Site Evaluation
Project Location: Deschutes County
Project Number: 6491.0

Log of Boring

B-3B

Date(s) Drilled	09/14/2023	Client	Deschutes County	Final Depth	100.0 ft bgs
Coordinates	Lat. 45.85098°, Lon. -122.88567°	Geotechnical Consultant	Delve Underground	Method/ Rig Type	Mud Rotary CME 850 Track Mounted
Surface Elevation	4552.0 ft.	Drilling Contractor	Western States Soil Conservation, Inc.	Hole Diameter	4.88 in
Location	Roth East	Logged by/ Checked by	J. Siemens / S. Cordes	Hammer Type	140 lb / 30 in / Automatic

ELEV. (FT)	WATER LEVEL	DEPTH (FT)	SAMPLE TYPE	RECOVERY (%)	BLOW COUNTS	SAMPLE NUMBER	MATERIAL DESCRIPTION	REMARKS AND TESTS	BACKFILL/INSTALL.
				168	100/3" (Refusal)	S-4	Very dense, moist, brown, Silty SAND (SM); few fine to coarse rounded gravel, fine to coarse sand, trace basalt cobbles.	drilling; driller notes cobbles. (61-65 feet) driller notes 6-inch layers of gravel/sand without cobbles.	
4487		65		112	62-100/2" (Refusal)	S-5	Very dense, moist, brown, Silty SAND (SM); few fine to medium gravel, few cobbles, fine to coarse sand.	(65-70 feet) rapid drilling; driller notes interbedded 1-foot-thick gravel and sand.	
4482		70		100	8-11-12	S-6	Stiff, moist, brown, Silty SAND (SM); few fine to coarse sand, trace fine to medium gravel, low plasticity, no dilatancy.	(70-74 feet) rapid and smooth drilling. S-6 47.6% Fines	
4477		75		127	100/4" (Refusal)	S-7	Very dense, moist, brown, Well-graded GRAVEL with Silt and Sand (GW-GM); little fine to coarse sand, fine to coarse sub-rounded basalt and tuff gravels.	(74-75 feet) driller notes "gravel feel". (75-80 feet) intermittent rig chatter; driller notes interbedded 6-12-inch thick gravel and silty sand.	
4472		80		132	100/3" (Refusal)	S-8	Very dense, moist, brown Well-graded GRAVEL with Sand (GW); little fine to coarse sand, fine to coarse rounded basalt and tuff gravels.		
4467		85		100	100/2" (Refusal)	S-9	*(85 feet) very poor recovery: recovered a single 2-inch by 3-inch tuff cobble.*		
							Very dense, moist, brown, Silty GRAVEL with Sand (GM); some fine to coarse sand, fine to coarse sub-rounded basalt gravel.		



DELVE underground

NOTES:N: Penetration resistance; MC: Moisture Content; LL/PL: Atterberg liquid/plastic limits
Location and Elevation Source:
Vertical Datum:
Coordinate System: WGS84

Project: Phase 2 Final SWMF Site Evaluation
Project Location: Deschutes County
Project Number: 6491.0

Log of Boring

B-3B

Date(s) Drilled	**09/14/2023**	Client	**Deschutes County**	Final Depth	**100.0 ft bgs**
Coordinates	**Lat. 45.85098°, Lon. -122.88567°**	Geotechnical Consultant	**Delve Underground**	Method/ Rig Type	**Mud Rotary** **CME 850 Track Mounted**
Surface Elevation	**4552.0 ft.**	Drilling Contractor	**Western States Soil Conservation, Inc.**	Hole Diameter	**4.88 in**
Location	**Roth East**	Logged by/ Checked by	**J. Siemens / S. Cordes**	Hammer Type	**140 lb / 30 in / Automatic**

ELEV. (FT)	WATER LEVEL	DEPTH (FT)	SAMPLE TYPE	RECOVERY (%)	BLOW COUNTS	SAMPLE NUMBER	■ N (blows/ft) 10 20 30 40 ○ MC (%) ❙ LL/PL 20 40 60 80	USCS GRAPHIC	MATERIAL DESCRIPTION	REMARKS AND TESTS	BACKFILL/INSTALL.
				132	100/3" (Refusal)	S-10			Very dense, moist, brown, Silty GRAVEL with Sand (GM); some fine to coarse sand, fine to coarse sub-rounded basalt gravel.	(92-93.5 feet) hard drilling; driller notes large cobbles.	
4457		95	⧗	133	41-100/3" (Refusal)	S-11	○		Very dense, moist, brown, Silty GRAVEL with Sand (GW-GM); fine to coarse sand, fine to coarse rounded gravel.	S-11 29.4% Fines	
4452		100		100	100/1" (Refusal)	S-12				Borehole completed at 100 feet below ground surface (bgs).	
4447		105									
4442		110									
4437		115									
4432		120									

NOTES:N: Penetration resistance; MC: Moisture Content; LL/PL: Atterberg liquid/plastic limits
Location and Elevation Source:
Vertical Datum:
Coordinate System: WGS84

Appendix C Laboratory Testing Results

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Laboratory Test Results Summary

Project Phase 2 Solid Waste Management Facility (SWMF)
Project # 6491.0
Date Updated October 23, 2023
Updated By A Havekost

DELVE
underground

Sample Location/ID			Soil Description			Other Soil Tests		Atterberg Limits		
Exploration ID	Sample No.	Sample Depth (feet)	Geologic Unit[a]	Soil Description	USCS[b]	Fines (%)	Moisture (%)	Plastic Limit (%)	Liquid Limit (%)	Plasticity Index (%)
B-1	S-2	10	Alluvial Fan Deposits	Brown Silty SAND	SM	27.0	25.0			
B-1	S-3	15	Alluvial Fan Deposits	Brown Silty SAND	SM	38.2	29.2			
B-1	S-8	40	Alluvial Fan Deposits	Brown Silty SAND	SM	32.6	30.1			
B-1	S-12	60	Alluvial Fan Deposits	Red to brown Silty SAND	SM	24.2	25.2			
B-1	S-15	75	Alluvial Fan Deposits	Well-graded GRAVEL with Silt and Sand	GW-GM	12.9	19.1			
B-2	S-1	5	Alluvial Fan Deposits	Brown Silty SAND	SM	28.1	31.9	34	43	9
B-2	S-4	20	Alluvial Fan Deposits	Brown Silty GRAVEL	GM	18.9	21.7			
B-2	S-7	35	Alluvial Fan Deposits	Well-graded GRAVEL with Sand	GW	6.8	12.3			
B-2	S-8	40	Alluvial Fan Deposits	Brown Silty SAND with Gravel	SM	18.5	22.0			
B-2	S-11	55	Alluvial Fan Deposits	Red-brown Silty SAND	SM	23.9	25.2			
B-2	S-15	75	Alluvial Fan Deposits	Well-graded GRAVEL with Sand and Silt	GW-GM	13.0	18.0			
B-2	S-20	100	Alluvial Fan Deposits	Well-graded SAND with Silt and Gravel	SW-SM	9.6	24.1			
B-3A	S-2	10	Alluvial Fan Deposits	Well-graded GRAVEL with Sand	GW	10.0	16.6			
B-3A	S-7	35	Alluvial Fan Deposits	Well-graded GRAVEL with Silt and Sand	GW-GM	9.2	18.4			
B-3A	S-8	40	Alluvial Fan Deposits	Well-graded GRAVEL with Silt and Sand	GW-GM	9.3	29.4			
B-3A	S-10	45	Alluvial Fan Deposits	Well-graded SAND with Silt and Gravel	SW-SM	11.9	24.0			
B-3B	S-6	70	Alluvial Fan Deposits	Brown Silty SAND	SM	47.6	63.3			
B-3B	S-11	95	Alluvial Fan Deposits	Silty GRAVEL with Sand	GM	29.4	23.9			

Notes:

a. Quaternary Alluvium Fan Deposits.

b. Soil Description and USCS based on reported geologic conditions, ASTM D2488, laboratory testing results, and drilling reactions observed.

Appendix D Geophysical Survey Results

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Deschutes County Solid Waste Management Facility Siting
Roth East

near Millican, Oregon

Results of Geophysical Exploration
Data Report

Prepared for Delve Underground

Prepared by Siemens & Associates

September 30, 2023

Shaun Cordes, RG, CEG
Delve Underground
2000 SW 1st Avenue
Portland, Oregon 97201

RE: Deschutes County Solid Waste Management Facility Siting: Roth East
near Millican, Oregon

Hello Shaun,

Siemens & Associates is pleased to present the results of this geophysical exploration. This report presents the findings which describe a broad look at geologic conditions along two long exploration lines extending through the Roth East property and beyond.

Data were gathered and processed for two geophysical methods: Electrical Resistivity (ER) and Seismic Refraction (SR). The use of multiple methods improves the interpretation as each method responds to geology in its own way providing benefits achieved through comparison. The results are presented to describe continuous, 2D profiles along two lines that extend through the property on parallel azimuths designed to be perpendicular to the trend of faults that are mapped in the general area.

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

J. Andrew “Andy” Siemens, P.E., G.E.
Principal
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541.385.6500 (office)
541.480.2527 (cell)

Contents

1 Introduction

1.1 Purpose

Siemens & Associates (SA) have completed services to explore geotechnical conditions using geophysical methods at select locations through the zone of interest associated with the property known as Roth East near Millican, Oregon. The intent is to provide a broad look at geology along transects oriented to define characteristics of the soil and rock across the site and identify area faults if present and suited for definition using the geophysical methods that were applied.

1.2 Methods

Two geophysical methods were used:

- Electrical Resistivity (ER) in 2D
- Seismic Refraction (SR) in 2D

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

1.3 Project Description

Roth East is one of two areas currently under consideration as a new solid waste management facility (SWMF) for Deschutes County. Roth East is identified in early screening documents as Site ID: 201500-301 with total of ~300 acres. The site is roughly square and is vegetated by light to moderate native shrubs including sage, bitter brush, rabbit brush, and a few small Juniper trees. The terrain is undisturbed range land and is fairly flat with a gradual slope down to the northeast.

1.4 Scope

Working under contract with Delve Underground (DU), the SA team completed the services as outlined in the agreement prepared by DU. 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 and SR surveys through zones of interest
- Basic surface reconnaissance including line position and elevation verification

- Geophysical data processing and quality control
- Consultation with the DU team and limited interpretation
- Preparation of this data report

The line locations were developed through a mutual agreement between SA and DU and field operations were completed as planned with the assistance of DU.

1.5 Location

The project is located roughly 2-½ miles southeast of Millican, Oregon and about 1-½ miles south of Highway 20. Specifically, the project is in the vicinity of Lat. 43.852415° and Long. -120.886414°.

1.6 Limitations

This report has been prepared for the exclusive use of DU and select associates for specific application to the project known as Deschutes County SWMF: Roth East, near Millican, Oregon. This report has been prepared in accordance with 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 SA reviews the changes 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.

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

The findings suggest a great thickness of unconsolidated soils extending far deeper than the design limits of a new waste disposal facility. Further, the seismic P-wave velocity of these materials suggests favorable excavation characteristics and predictable sequence of stratification. This finding is unexpected as thick sequences of unconsolidated materials such as this in Central Oregon are rare.

The results do not identify disruption or significant offset in stratification or other indication that the exploration lines crossed any of the area faults which are believed to be oriented roughly perpendicular to the exploration line azimuth. Although this is a positive observation, in the view of SA, it is quite possible that disruption in the thick sequence of unconsolidated materials due to faulting could be too subtle for the geophysical methods that were used to reveal. The bedrock located roughly 400 feet below grade appears to be an abrupt, smooth surface with no offset suggesting faulting. However, it is important to recognize that this layer is deep and at the base of the P-wave model where resolution is lowest. Just because the image suggests a smooth bedrock surface does not mean that minor vertical relief on the order of 20 to 50 feet does not exist. Had the bedrock surface been encountered at a shallower depth, say less than 200 feet, SA would have much more confidence in the modeled character of the transition from soil to rock.

The electrical models expose minor electrical contrast within the thick overburden and the ER models do not extend deep enough to identify or characterize the bedrock which, based on P-wave velocity, occurs very near the base of the ER tomograms. Again, the electrical nature of the thick unconsolidated layer is too uniform to define minor disruption that may have occurred due to area faulting.

3 Geophysical Data Acquisition

The geophysical explorations were designed to explore geotechnical conditions through the site along a specific azimuth judged to be roughly perpendicular to the orientation of known regional faults. The use of multiple methods improves the confidence of the interpretation as each method is influenced by 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: ER 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 direct current (DC) 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 merged data from two arrays: Dipole-Dipole and Strong Gradient with electrode spacing of 10.25 m along lines composed of 56 electrodes. The array was extended by sliding the cable forward leaving a 25 percent overlap then merging data files for final processing. Depth of exploration was greater than 400 feet below grade.

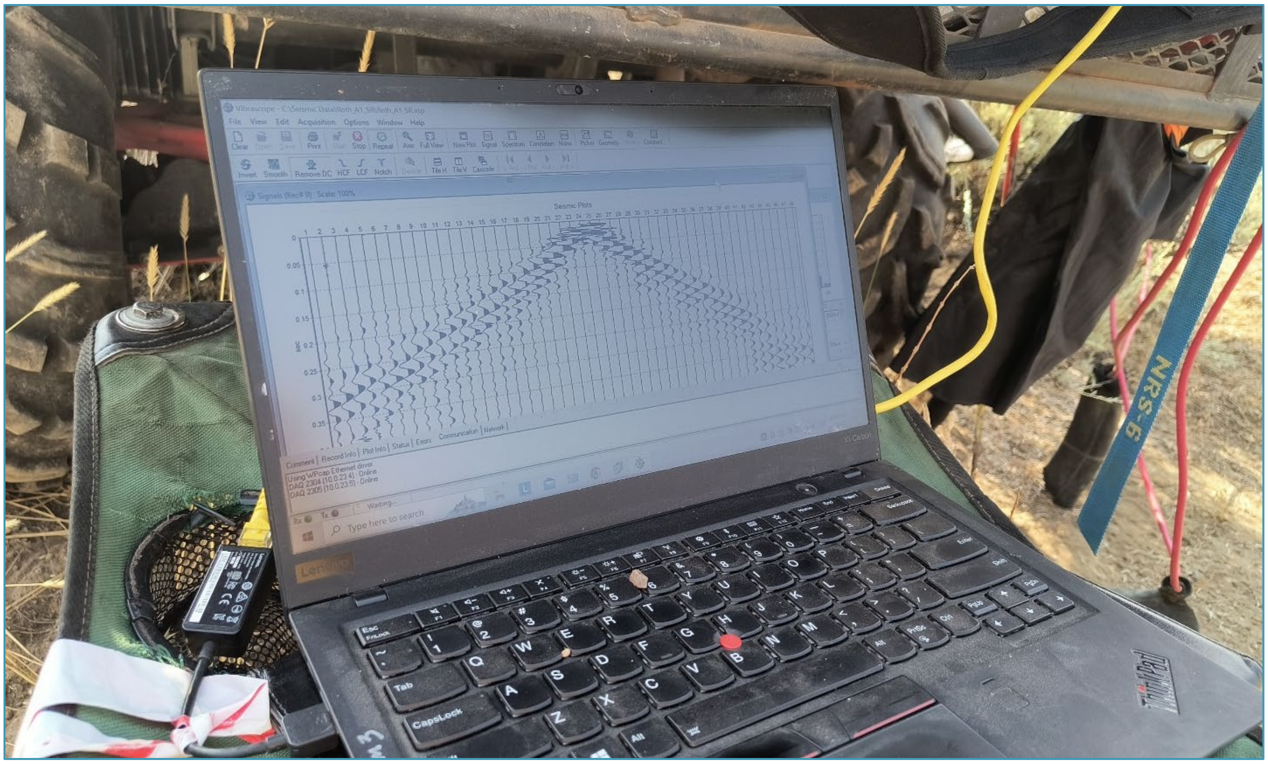
Electrical resistivity data were recorded using an R-8 SuperSting with Wi-Fi manufactured by Advanced Geosciences, Inc., Austin, Texas, USA. The instrument is an eight channel, automated system capable of completing several thousand measurements per hour. For this project, the measurement sequence was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

3.1.2 Seismic Refraction (SR)

SR is an active seismic method utilizing geophone receivers set along a straight-line gathering data from signals induced by an explosive source or impact source. In this case, the source was a 500-grain black powder charge detonated with a Besty Seisgun. Data were processed using forward modeling software developed by Geogiga known as DW Tomo 10.

How it works: When the charge is detonated, the receivers are activated and the wavelet energy is recorded. The P-wave is the fastest of the various seismic waves generated and only the time of the first arrival P-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. This effect can be appeased by surveys that employ mutually perpendicular lines.

Data were recorded using networked DAQ 4 seismographs manufactured by Seismic Source in Ponca City, Oklahoma, USA, connected to an IBM computer laptop. The lines were set up with receiver spacing of 20 feet for greater depth of exploration and line length was extended by moving the 48-channel array forward 36 receivers and including overlapping shots. Shots were induced at 60-foot intervals along each line.



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. The technique is like the more common MASW (multi-channel analysis of surface waves) method and uses the same array as SR.

Note that LM data were recorded and have been archived for future use such as establishing the seismic site classification in accordance with ASTM 7.

3.2 Horizontal and Vertical Control

The beginning and end of each line was set in the field using hand-held GPS (Garmin 755t) based on coordinates derived from interpretation from Google Earth Pro. These points offered visual targets to effectively advance the line segments along the specified azimuth.

SA was provided elevations along each line derived from the recent LiDAR data delivered to DU by Parametrix. A similar map is used to illustrate the positions of the geophysical lines along with the property boundaries (Figure 100).

Given these techniques, the line positions and elevations shown on the various deliverables are estimated to be accurate to approximately 10 feet horizontal and one foot vertical.

The end positions of each line along with intermediate points were marked with lath and flagging.

3.3 Summary of Challenges

3.3.1 Operations

Few difficulties were experienced and field data collection operations progressed as planned. The primary challenge was the sheer size of the property and the long distances involved associated with coordinating activities of the crew which were often split up for efficiency. The crew was in constant radio contact and a pair of ATVs were mobilized to schlep equipment across the long distances and rough terrain. Afternoon winds, although light promoted some challenges with the long-distance shots during the P-wave data collection.

3.3.2 Data Quality and Interpretation Challenges

The recorded seismic and electrical data are judged to be of excellent quality. SR data were clear although recording was sometimes delayed due to wind noise. LM data were enhanced by adding higher frequency vibrations using an untimed plate and hammer in the vicinity of the receivers and is of extraordinarily good quality.

4 Processing and Interpretation

4.1 General

During the data acquisition, 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.

It is worthy to emphasize that the geophysical results are presented in 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.) is remarkably uniform across the site. And this observation suggests that there is probably not a great deal of 3D effect in the tomograms presented. In addition, geophysical interpretations are often compared to direct observation of conditions discovered in geotechnical drill holes and exploratory excavations. Note that the drill hole (or exploratory excavation) is a 1D description of the subsurface and represents a 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.

Figures A and B present the tomograms for each method along each line with no vertical exaggeration. 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 soil, rock, and water are:

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

The data were 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 set was processed using AGI Earth Imager 2D software. As discussed, Dipole-Dipole and strong gradient arrays were surveyed and merged together for processing.

4.2.2 Considerations in ER Interpretation

When interpreting electrical results, it is the opinion of SA that contrast is the primary feature recognizing transitions in soil texture, moisture, and rock type. It is important to understand that ER cannot be related to strength without the benefit of and correlation with other information such as drill data or seismic results.

Even though the ER tomograms extend greater than 400 feet, hard rock is not interpreted. This opinion is based on several observations including the SR which clearly defines a hard rock layer at an elevation at the base and deeper than the extents of the ER surveys. Further, the highest inverted resistivity is on the order of 600 Ohm-m, near surface basalt near Millican occurring at similar elevation has been measured by SA to offer an inverted resistivity on the order of 4000 Ohm-m and higher which is far greater than interpreted within the upper 400 feet at Roth East.

4.3 P-wave Seismic Refraction (SR)

Refraction data were gathered and processed in 2D along the same lines as ER. The results are robust. Shots were induced along the full length of the geophone spreads and beyond using a Betsy Seisgun.

4.3.1 SR Processing and Presentation

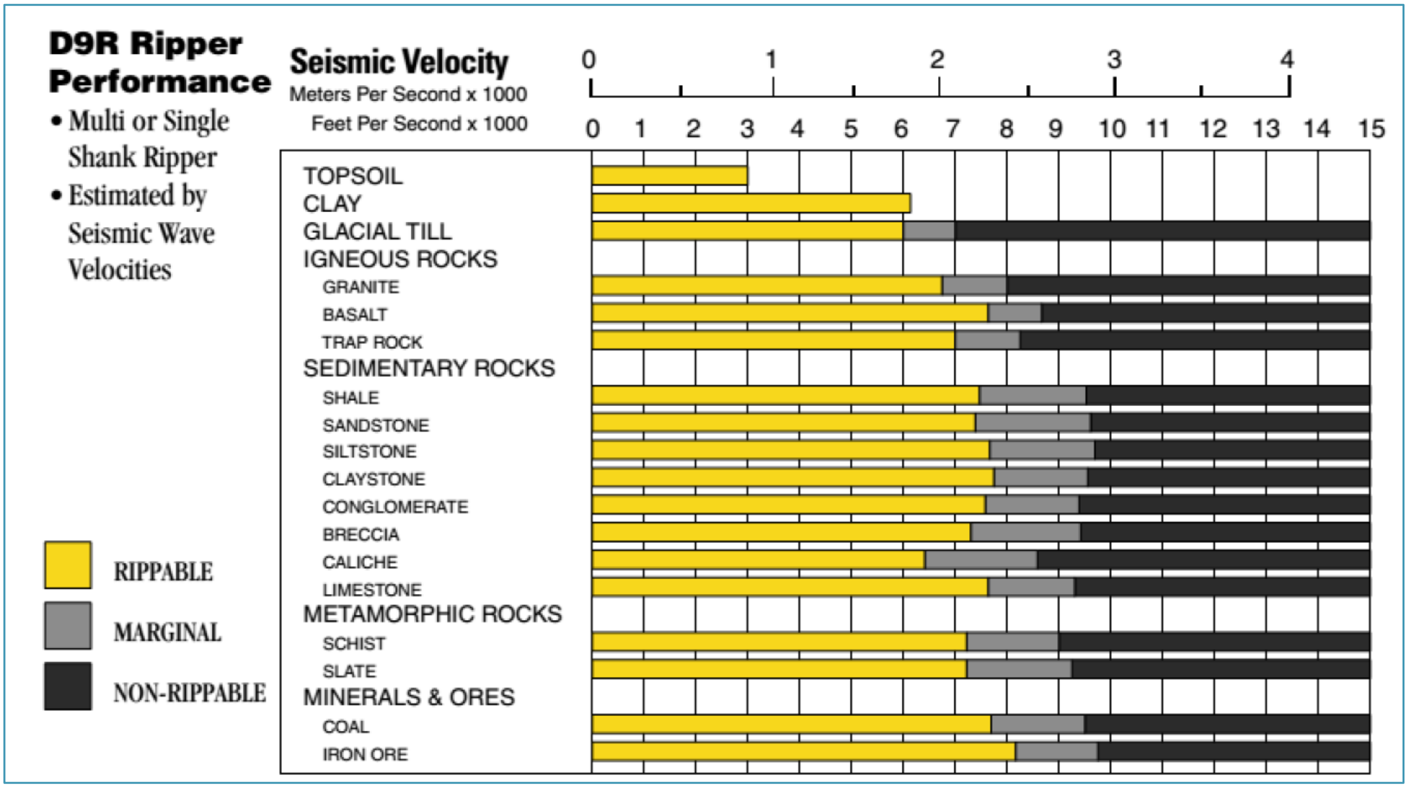
Data processing was completed using Geogiga DW Tomo 10.0 software developed by Geogiga Technology Corp. Calgary, Alberta, Canada. The software utilizes robust grid ray tracing and regularized inversion with constraints in topography and elevation along the seismic array as input for calculations. The software is suitable for strong elevation and lateral velocity variation. Data sets included a moderately dense shot pattern (shots centered at 3X the receiver spacing). Dr. Satish Pullammanappallil, Ph.D., led the SR data processing effort.

4.3.2 Considerations in SR Interpretation

The long receiver spacing and 48 receiver arrays, combined with the existence of a deep refractor, promote SR results that delve well beyond 500 feet below grade. The depth to rock (defined at the transition velocity of about 8000 ft/s) is clearly defined as are the characteristics of the overburden soils.

Overburden soil velocities are consistently higher than 2000 ft/s and generally at or lower than 4000 ft/s. These P-wave velocities represent dense to very dense soils which likely offer a variable degree of cementation. The DU borings are presented as overlay on both the ER and SR tomograms and these borings were positioned to target shallow zones of variability in P-wave velocity. Since both 2000 ft/s and 4000 ft/s soils are quite strong, it is difficult to discern differences using traditional procedures such as SPT (standard penetration test) blow counts since the resistance is so high as to promote penetration refusal in either layer.

To provide an understanding of the excavation characteristics of this thick unconsolidated layer, SA presents findings published by Caterpillar Inc. describing excavation characteristics relative to P-wave velocity and various types of rock and soil:



The chart presents simplistic material descriptions and many uncertainties, albeit the P-wave velocities interpreted at Roth East are typically at or below 4000 ft/s within the upper 200 feet suggesting successful excavation using rippers and/or powerful excavators.

4.4 S-wave Linear Microtremor (LM)

As discussed, S-wave data has been recorded and archived for processing at a later date if deemed valuable.

5 Seismic Site Classification (ASCE 7)

Seismic Site Classification, in accordance with ASCE 7, can be calculated from the archived data upon request and scope revision.

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 10.0 — Refraction Tomography Software operations manual

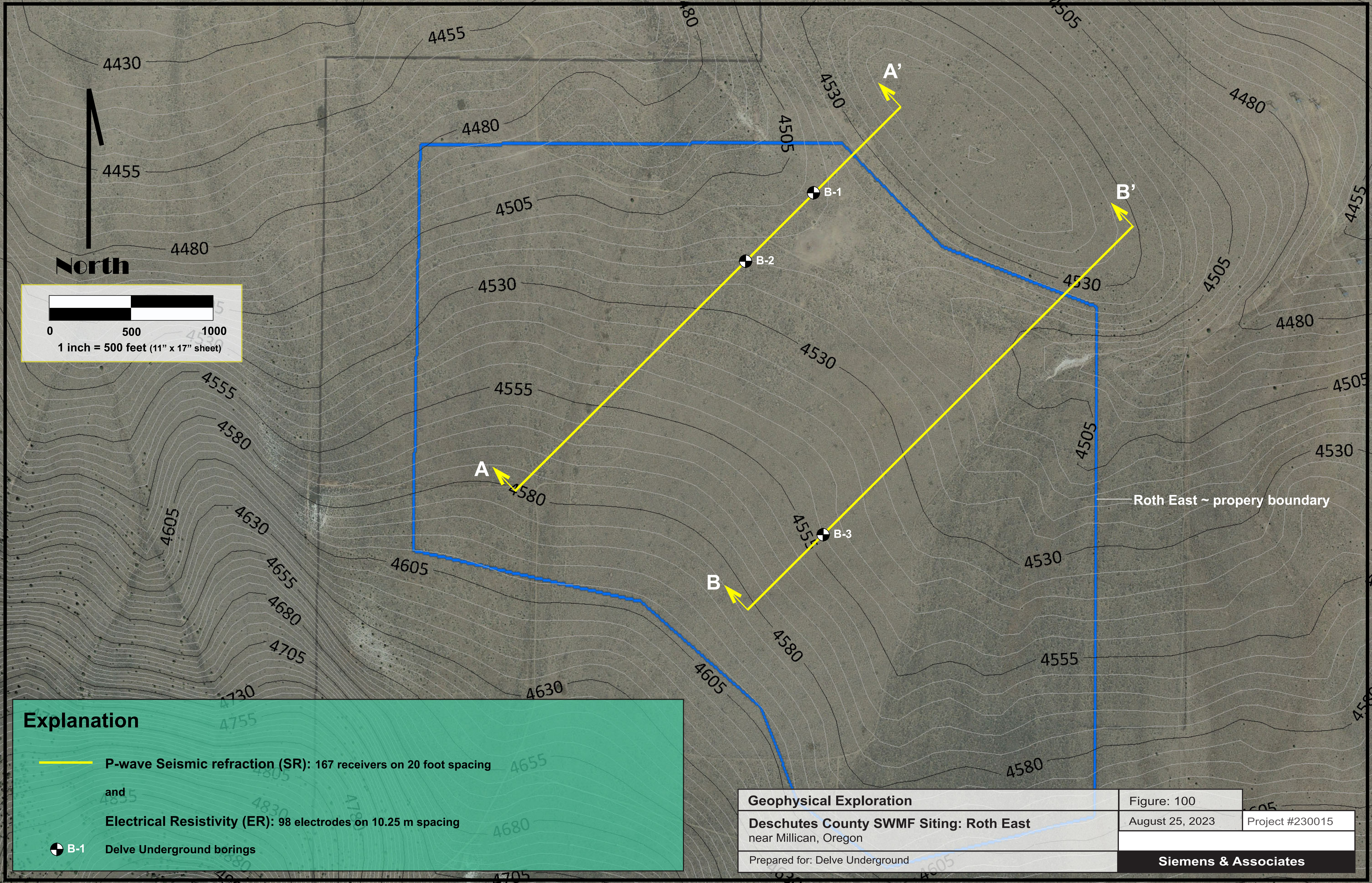
Geogiga Surface Plus 10.0 — Advanced Surface Wave Data Processing Software, manual

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

7 Graphical Presentation of Results

The interpretations are presented in 2D with the locations of the exploration lines illustrated by the following exhibit (Figure 100) prepared by SA using input from DU.

7.1 Figure 100 Geophysical Exploration: Site Plan



Explanation

P-wave Seismic refraction (SR): 167 receivers on 20 foot spacing

and

Electrical Resistivity (ER): 98 electrodes on 10.25 m spacing

● B-1 **Delve Underground borings**

Geophysical Exploration

Deschutes County SWMF Siting: Roth East
near Millican, Oregon

Prepared for: Delve Underground

Figure: 100

August 25, 2023

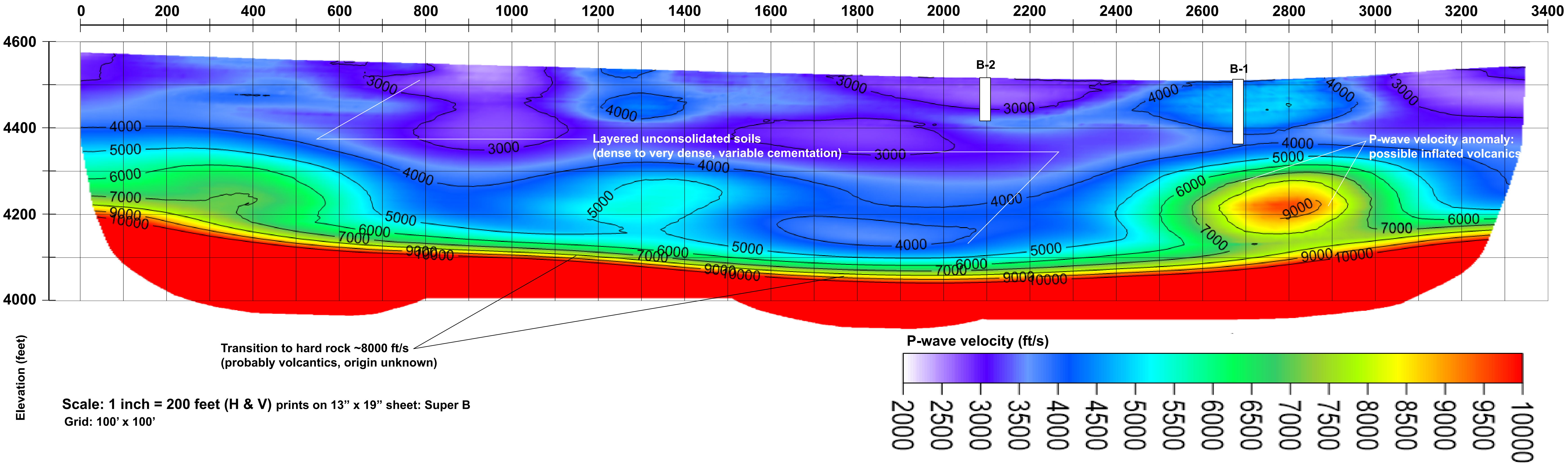
Project #230015

Siemens & Associates

7.2 Geophysical Exploration: Summary of Results in 2D

P-wave Seismic Refraction Tomography: Line A

(167 receivers on 20 foot spacing, 81 shots)



Layered unconsolidated soils
(dense to very dense, variable cementation)

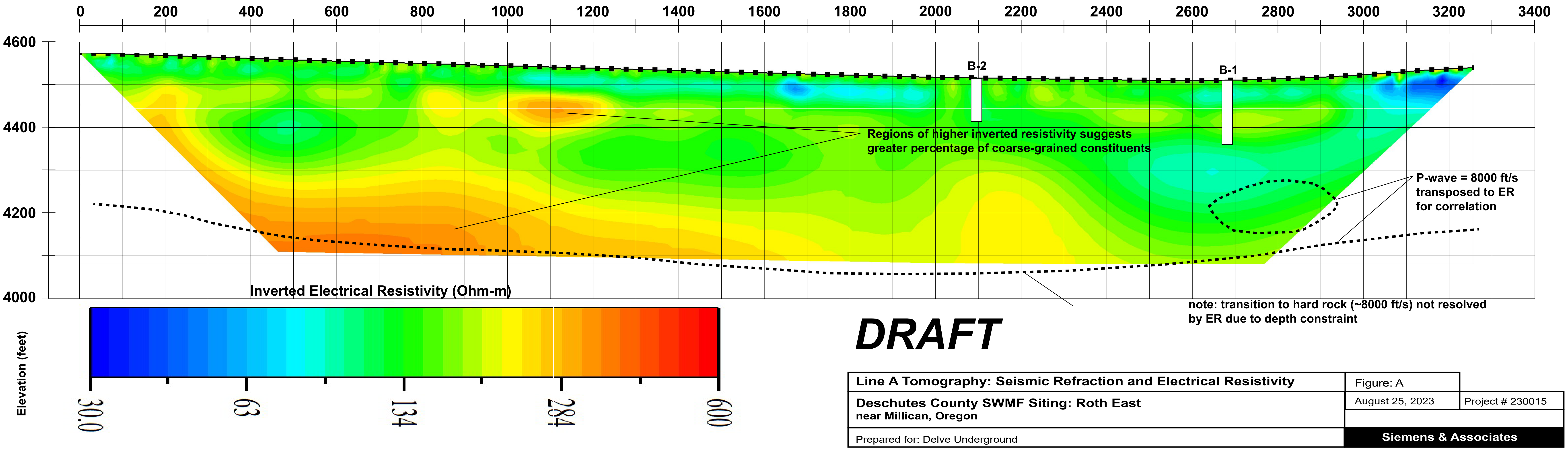
P-wave velocity anomaly:
possible inflated volcanics

Transition to hard rock ~8000 ft/s
(probably volcantics, origin unknown)

Scale: 1 inch = 200 feet (H & V) prints on 13” x 19” sheet: Super B
Grid: 100’ x 100’

Electrical Resistivity Tomography: Line A

(98 electrodes on 10.25 m spacing: combined Dipole-Dipole and Strong Gradient arrays)



Regions of higher inverted resistivity suggests
greater percentage of coarse-grained constituents

P-wave = 8000 ft/s
transposed to ER
for correlation

note: transition to hard rock (~8000 ft/s) not resolved
by ER due to depth constraint

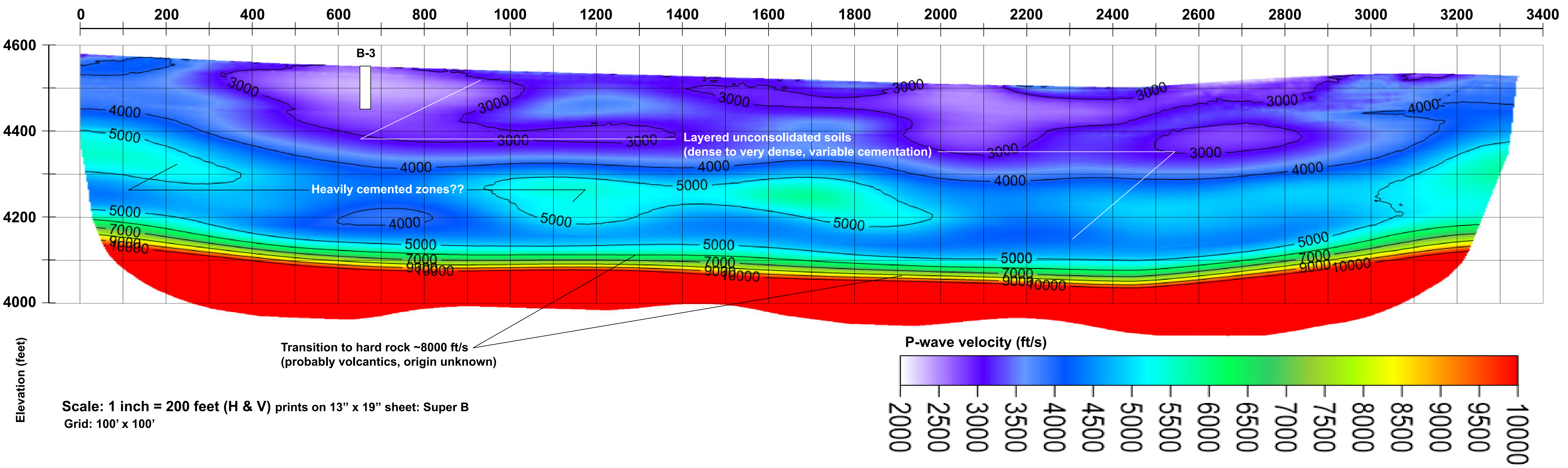
DRAFT

Line A Tomography: Seismic Refraction and Electrical Resistivity | Figure: A
Deschutes County SWMF Siting: Roth East
near Millican, Oregon
August 25, 2023 | Project # 230015
Prepared for: Delve Underground
Siemens & Associates

P-wave Seismic Refraction Tomography: Line B

(167 receivers on 20 foot spacing, 81 shots)

Azimuth ~45 degrees



Layered unconsolidated soils (dense to very dense, variable cementation)

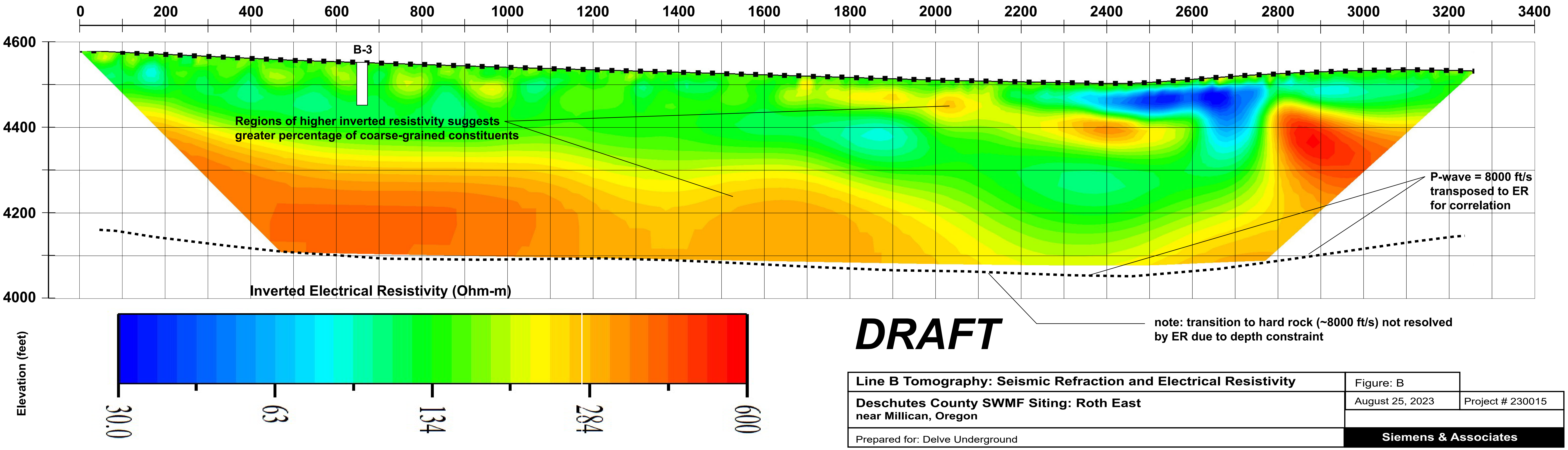
Heavily cemented zones??

Transition to hard rock ~8000 ft/s (probably volcantics, origin unknown)

Scale: 1 inch = 200 feet (H & V) prints on 13" x 19" sheet: Super B
Grid: 100' x 100'

Electrical Resistivity Tomography: Line B

(98 electrodes on 10.25 m spacing: combined Dipole-Dipole and Strong Gradient arrays)



Regions of higher inverted resistivity suggests greater percentage of coarse-grained constituents

P-wave = 8000 ft/s transposed to ER for correlation

note: transition to hard rock (~8000 ft/s) not resolved by ER due to depth constraint

DRAFT

Line B Tomography: Seismic Refraction and Electrical Resistivity	Figure: B	
Deschutes County SWMF Siting: Roth East **near Millican, Oregon**	August 25, 2023	Project # 230015
Prepared for: Delve Underground	**Siemens & Associates**	

Appendix E Geologic Hazards

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E.1 Geologic Hazards

Geologic hazards are conditions associated with the geologic and seismic environment that could adversely influence site development. Geologic hazards for the site were assessed by reviewing publicly available GIS data through the DOGAMI HazVu portal, statewide landslide information database for Oregon (SLIDO), and the USGS Quaternary Fault and Fold Database (DOGAMI, 2023; USGS 2023a). In addition, Delve Underground reviewed aerial photography and available published geologic maps to evaluate geologic hazards. Relevant geologic hazards identified within DOGAMI HazVu are discussed within this section.

E.1.1 Mapped Landslides

Landslides are caused by a combination of climate, geology, and topography. Primary triggers of landslides are precipitation, earthquakes, and human activity. An important part of determining the risk of a landslide at a given site is to locate existing landslides in the area. Review of SLIDO indicates there are no mapped historic landslides at the site or adjacent slopes (SLIDO, 2021). In addition, inspection of aerial photographs and published geologic maps did not identify any landslide morphology within the project area.

E.1.2 Landslide Susceptibility

Landslide susceptibility is determined by factors such as susceptible geologic units, susceptible geologic contacts, geomorphic indicators, proximity to existing landslides, and slope angles. The alluvial fan is mapped within a zone of low to moderate landslide susceptibility, and the knob and linear ridgeline is mapped within zones of low to high landslide susceptibility. Areas of high landslide susceptibility are relatively small and limited to the areas where the steepest slopes are observed.

E.1.3 Volcanic Hazards

Volcanic eruptions are likely to occur in Oregon within the Cascade Range. Volcanic hazards can include any combination of the deposition of ash (tephra), lava flows, lahars, avalanches, and pyroclastic flows. The site is mapped outside of a volcanic hazard zone.

E.1.4 Fault Rupture

Fault surface rupture is the expression of surface deformation generated along a fault during an earthquake. Surface ruptures can result in lateral or vertical displacements, or both, and generate visible fractures such as scarps and fissures. Surface ruptures can cause significant damage to roads, structures, and infrastructure intersected by a fault. Surface ruptures are largely dependent on the magnitude of an earthquake along a fault. The larger the magnitude of an earthquake, the more well-defined and destructive a surface rupture may be, while smaller earthquakes may not produce a surface rupture at all.

An active fault trace is not mapped within the site boundary based on review of the USGS Quaternary Fault and Fold Database, and DOGAMI HazVu. However, there is strong geomorphic evidence of a continuation of the closest unnamed faults of Millican Valley through the northwest extent of the site (Figure 5). Given our current understanding of the age of faulting, surface rupture is not a risk to future development.

E.1.5 Seismic Site Class (NEHRP)

During an earthquake, soft or loose soil can greatly amplify ground shaking, thereby producing more damage than in areas with firmer or more consolidated soils or bedrock. The National Earthquake Hazard Reduction Program (NEHRP) site classifications can be used to calculate how much amplification will occur during an earthquake and are based on research sponsored by the USGS and Federal Emergency Management Agency (FEMA). The site class for the project is mapped by DOGAMI within a zone of E/F.

Based on our subsurface investigation at the site, soil was found to consist of dense to very dense gravels and sands and no groundwater was encountered within the upper 150 feet. Site classification is based on the weighted average of the shear wave velocity or Standard Penetration Test (SPT) blow counts (N-value) in the upper 100 feet of subsurface profile. Based on the N-values from our geotechnical exploration, Site Class C is appropriate for design purposes.

E.1.6 Liquefaction

Liquefaction is a phenomenon affecting saturated, loose, sandy and low-plasticity silty soils in which cyclic, rapid shearing from an earthquake shaking results in a drastic loss of shear strength and a transformation from a solid mass to a viscous, heavy fluid mass and rapid settlement. The results of soil liquefaction include loss of shear strength, loss of soil materials through sand boils, and post liquefaction settlement.

The site is classified on HazVu as “very high” susceptibility to liquefaction. However, groundwater at the site is estimated to be greater than 400 feet bgs (see discussion in Section 5.3) and therefore liquefaction is not a risk at the site.

E.1.7 Other Hazards

No other significant geologic hazards such as floods, tsunamis, seiches, debris flows, and collapsible soils were identified at the site. This is consistent with published hazards and geologic maps for the area.

Historical Landslide

October 26, 2023

- ● Historic Landslide Records (points)
- ┬┬┬┬ Scarp
- 🟫 Head Scarp Deposits
- ▨ Talus-Colluvium
- 🟥 Fan
- ▨ Landslide

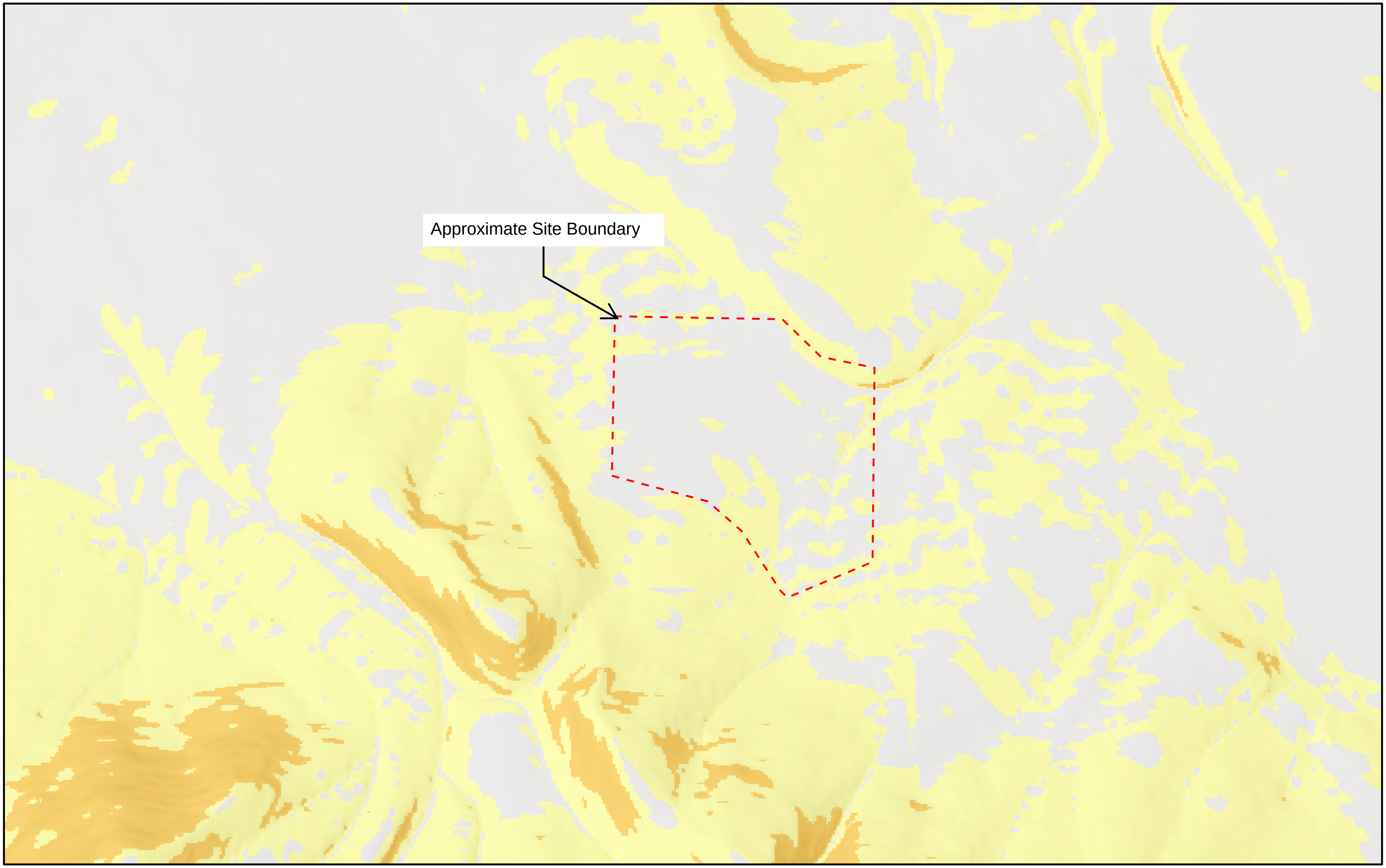
1:36,000

0 0.23 0.45 0.9 mi

0 0.35 0.7 1.4 km

Esri, NASA, NGA, USGS, FEMA

Landslide Susceptibility



October 26, 2023

Statewide Landslide Susceptibility Overview Map

⬜ Low

🟨 Moderate

🟧 High

🟥 Very High

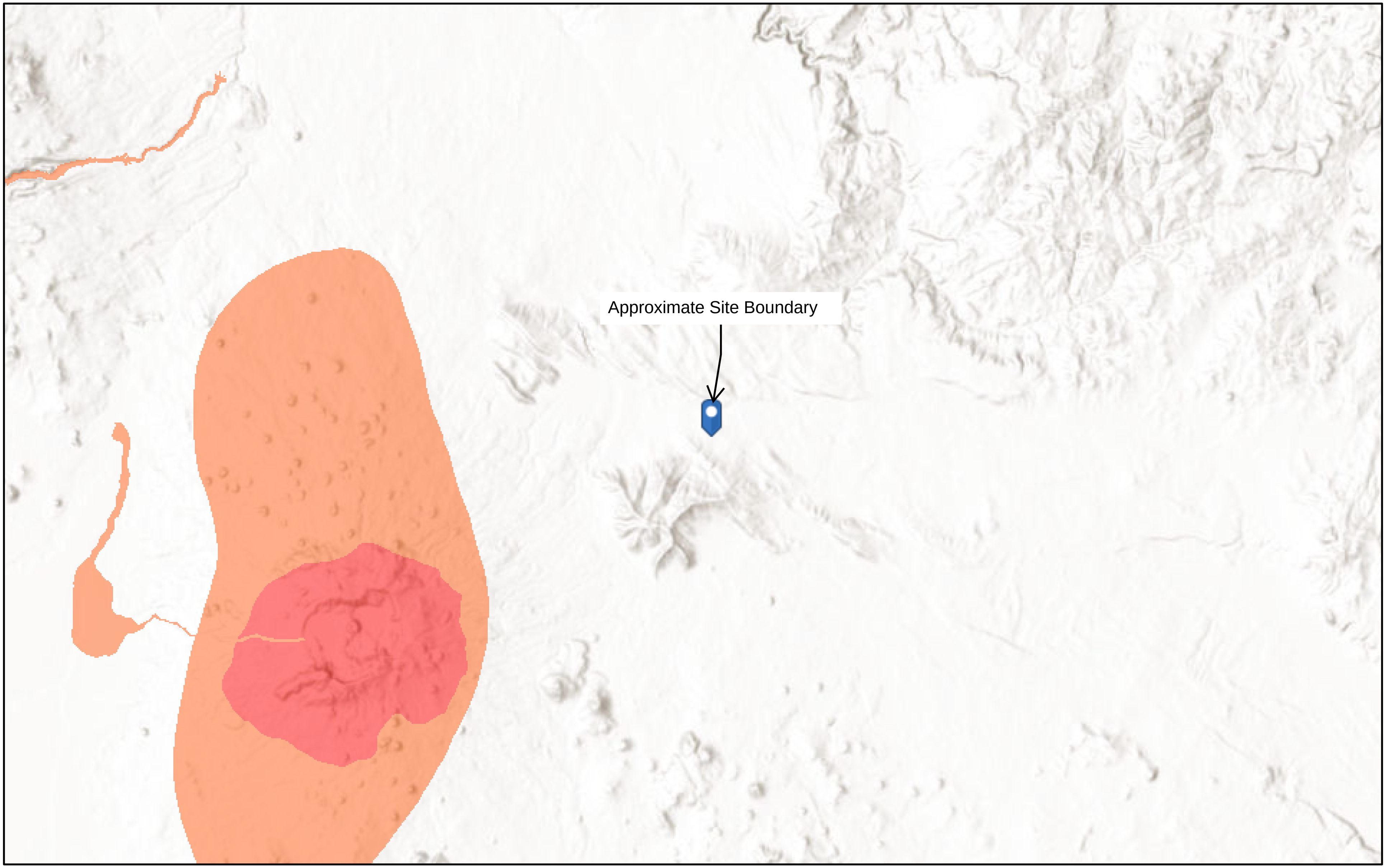
1:36,000

0 0.23 0.45 0.9 mi

0 0.35 0.7 1.4 km

Esri, NASA, NGA, USGS, FEMA

Volcanic Hazard Zones



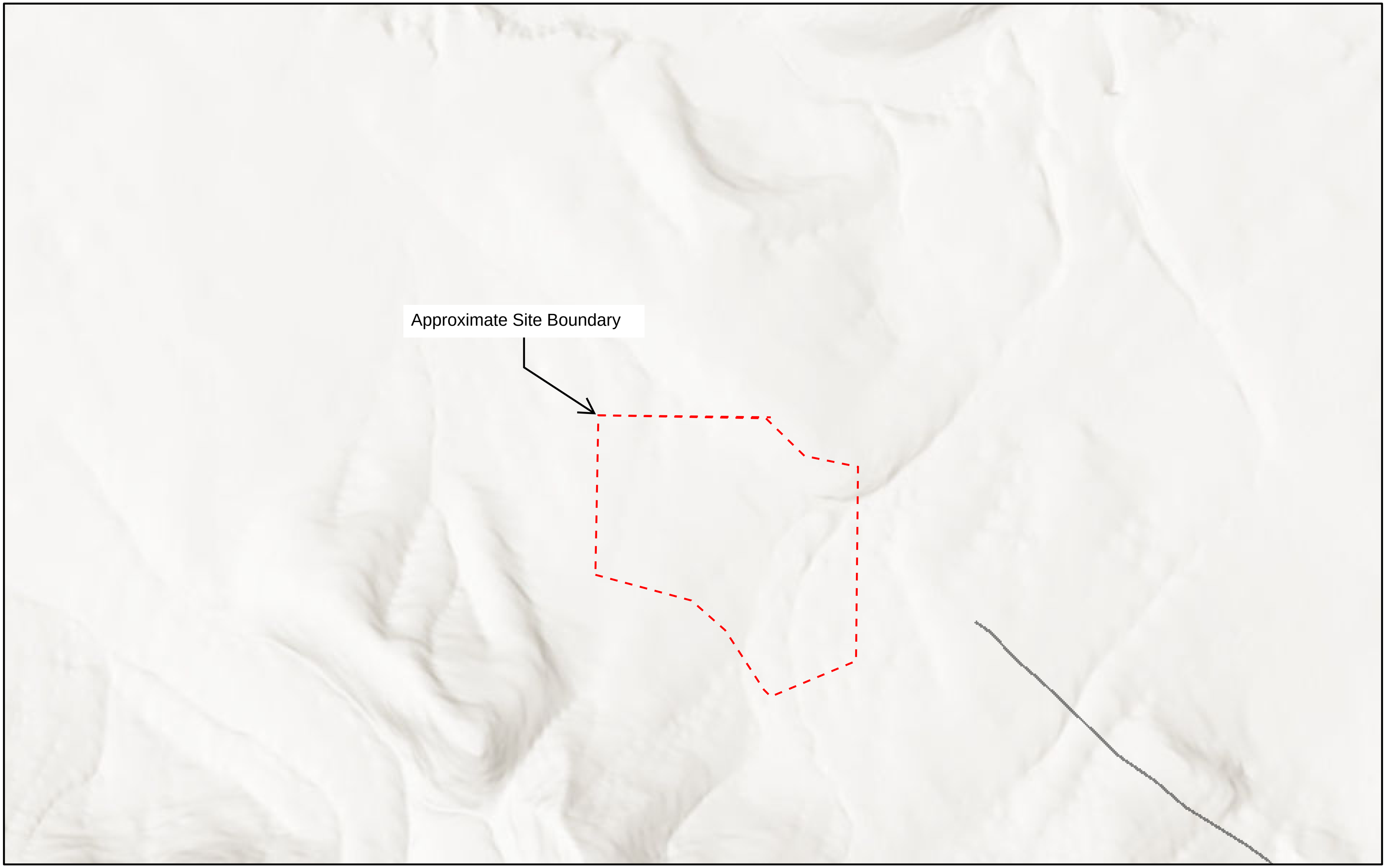
October 10, 2023

🟥 High Hazard Zone

🟧 Moderate Hazard Zone

Esri, CGIAR, USGS, Sources: Esri, USGS

"Active" Faults

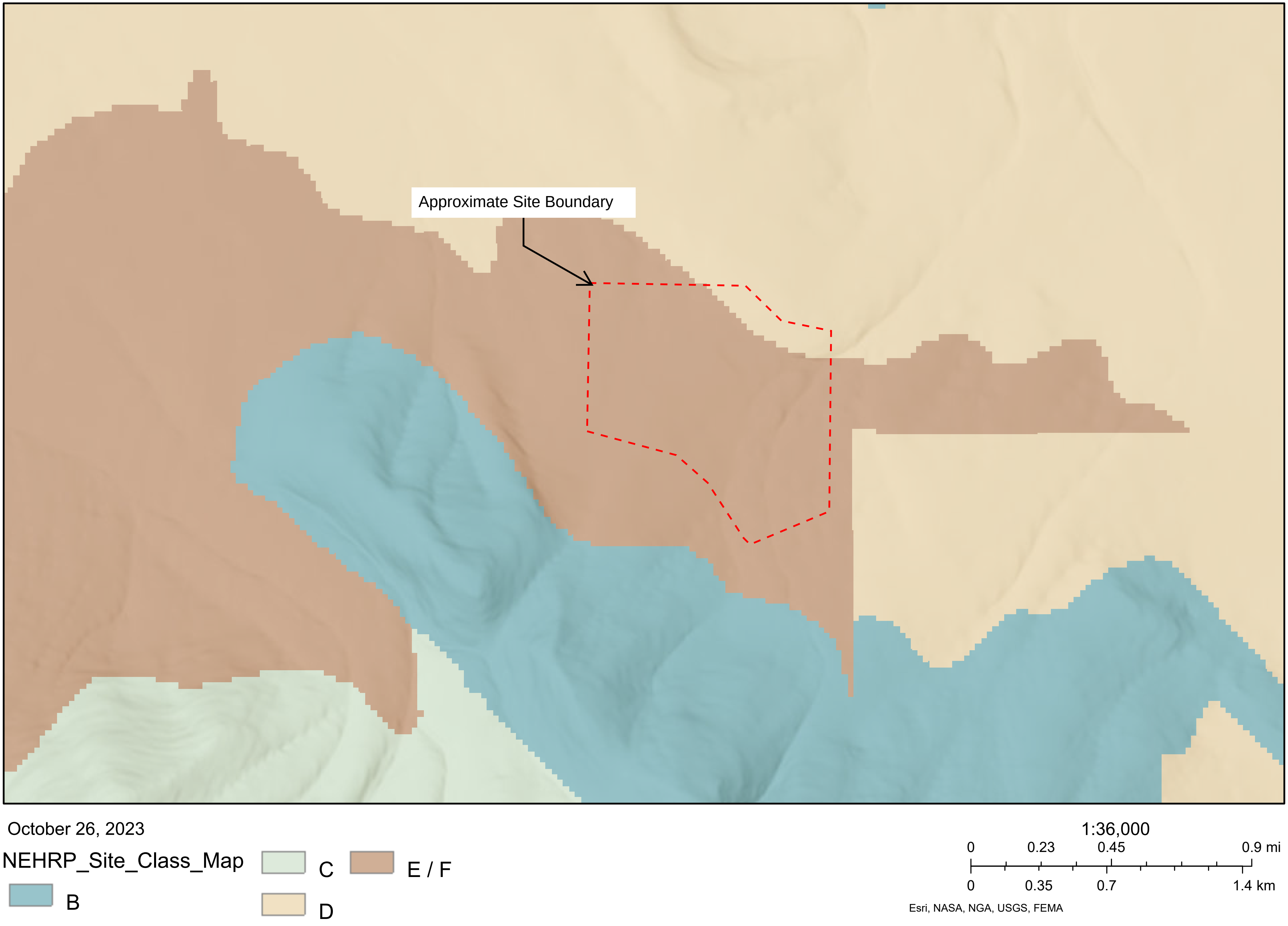


October 26, 2023

— Active_Faults

Esri, NASA, NGA, USGS, FEMA, Sources: Esri, USGS

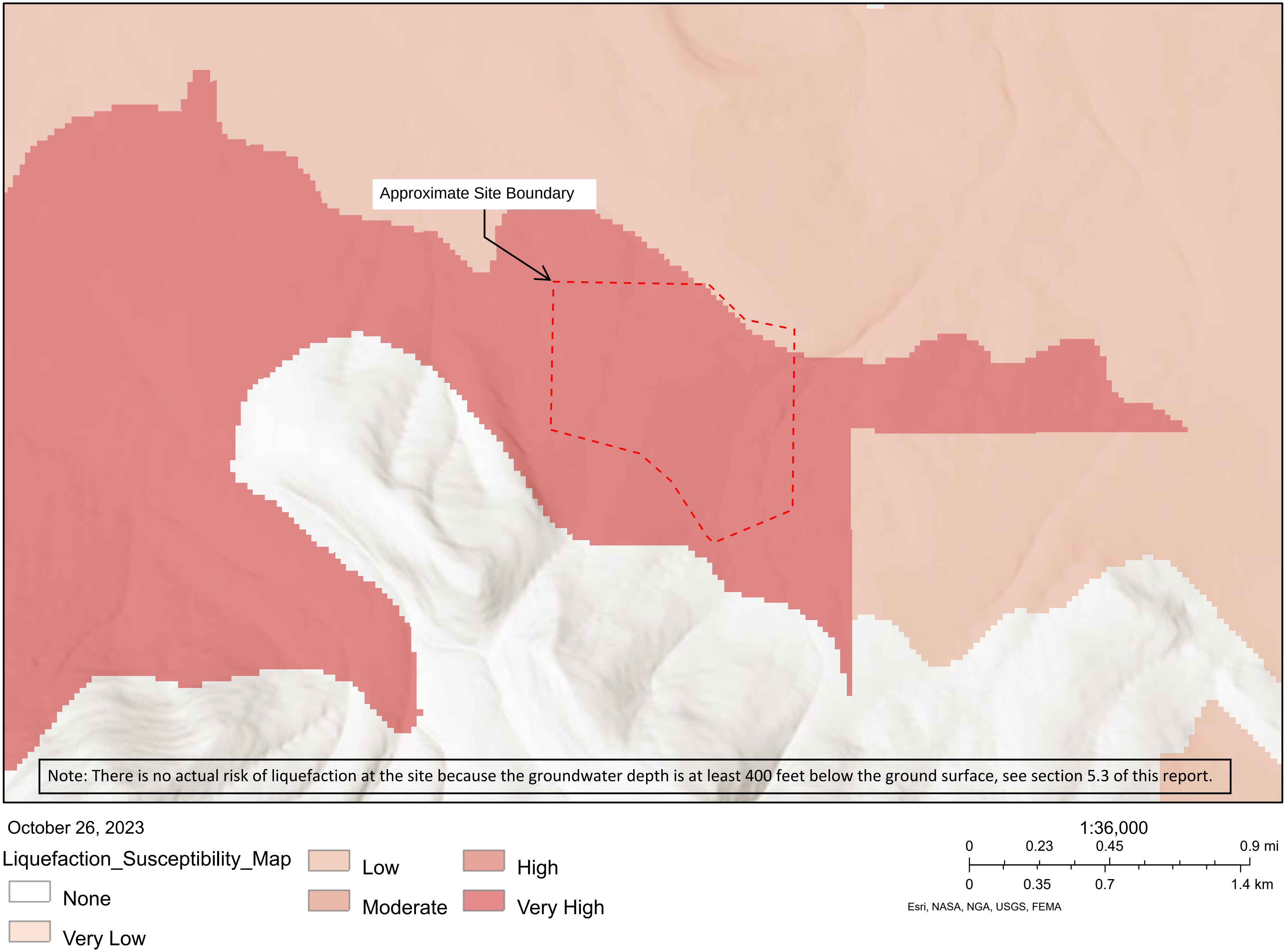
NEHRP Site Class



October 26, 2023

Esri, NASA, NGA, USGS, FEMA

Liquefaction Susceptibility



Note: There is no actual risk of liquefaction at the site because the groundwater depth is at least 400 feet below the ground surface, see section 5.3 of this report.

October 26, 2023

Esri, NASA, NGA, USGS, FEMA

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Appendix F OWRD Well Logs

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STATE OF OREGON
WATER SUPPLY WELL REPORT
(as required by ORS 537.765 & OAR 690-205-0210)

DESC 62152
8/4/2020

WELL I.D. LABEL# L 138630
START CARD # 1048033
ORIGINAL LOG #

(1) LAND OWNER

Owner Well I.D.
First Name MARK & ANN Last Name MALLOT
Company
Address PO BOX 127
City POWELL BUTTE State OR Zip 97753

(2) TYPE OF WORK

☒ New Well ☐ Deepening ☐ Conversion
☐ Alteration (complete 2a & 10) ☐ Abandonment(complete 5a)

(2a) PRE-ALTERATION

	Dia	+	From	To	Gauge	Stl	Plstc	Wld	Thrd
Casing:		☐				○	○	☐	☐

	Material	From	To	Amt	sacks/lbs
Seal:					

(3) DRILL METHOD

☒ Rotary Air ☐ Rotary Mud ☐ Cable ☐ Auger ☐ Cable Mud
☐ Reverse Rotary ☐ Other

(4) PROPOSED USE

☒ Domestic ☐ Irrigation ☐ Community
☐ Industrial/ Commericial ☒ Livestock ☐ Dewatering
☐ Thermal ☐ Injection ☐ Other

(5) BORE HOLE CONSTRUCTION

Special Standard ☐ (Attach copy)
Depth of Completed Well 630.00 ft.

BORE HOLE

Dia	From	To
12	0	18.5
8	18.5	590
6	590	630

SEAL

Material	From	To	Amt	sacks/ lbs
Bentonite Chips	0	18.5	20	S
		Calculated	11.94	
		Calculated		

How was seal placed: Method ☐ A ☐ B ☐ C ☐ D ☐ E
☒ Other POURED DRY
Backfill placed from ft. to ft. Material
Filter pack from ft. to ft. Material Size
Explosives used: ☐ Yes Type Amount

(5a) ABANDONMENT USING UNHYDRATED BENTONITE

Proposed Amount Actual Amount

(6) CASING/LINER

Casing	Liner	Dia	+	From	To	Gauge	Stl	Plstc	Wld	Thrd
●	○	8	☒	1.5	18.5	.250	●	○	☐	☐
○	●	6	☐	0	590	.188	●	○	☒	☐
○	○		☐				○	○	☐	☐
○	○		☐				○	○	☐	☐
○	○		☐				○	○	☐	☐

Shoe ☐ Inside ☐ Outside ☐ Other Location of shoe(s)
Temp casing ☐ Yes Dia From + ☐ To

(7) PERFORATIONS/SCREENS

Perforations Method FACTORY
Screens Type Material

Perf/ Screen	Casing/ Screen Liner	Dia	From	To	Scrn/slot width	Slot length	# of slots	Tele/ pipe size
Perf	Liner	6	570	590	.125	3	228	

(8) WELL TESTS: Minimum testing time is 1 hour

○ Pump ○ Bailer ● Air ○ Flowing Artesian

Yield gal/min	Drawdown	Drill stem/Pump depth	Duration (hr)
10		630	1

Temperature 60 °F Lab analysis ☐ Yes By
Water quality concerns? ☐ Yes (describe below) TDS amount 166 ppm

From	To	Description	Amount	Units

(9) LOCATION OF WELL (legal description)

County DESCHUTES Twp 20.00 S N/S Range 16.00 E E/W WM
Sec 6 SW 1/4 of the NW 1/4 Tax Lot 1000
Tax Map Number Lot
Lat ° ' " or DMS or DD
Long ° ' " or DMS or DD
○ Street address of well ● Nearest address
27201 HWY 20

(10) STATIC WATER LEVEL

	Date	SWL(psi)	+	SWL(ft)
Existing Well / Pre-Alteration			☐	
Completed Well	7/9/2020		☐	480

Flowing Artesian? ☐ Dry Hole? ☐

WATER BEARING ZONES Depth water was first found 460.00

SWL Date	From	To	Est Flow	SWL(psi)	+	SWL(ft)
7/9/2020	480	630	10		☐	480
					☐	
					☐	
					☐	
					☐	

(11) WELL LOG

Ground Elevation

Material	From	To
TOP SOIL	0	3
BROWN CLAYSTONE	3	275
BROWN CLAYSTONE CONGLOMERATE	275	310
BASALT CLAYSTONE SEAMS	310	445
BROWN CLAYSTONE	445	460
W/B FRACTURED BROWN BASALT	460	505
W/B FRATURED BASALT W/ CLAYSTONE	505	555
W/B BROWN CONGLOMERATE	555	630

Date Started 7/6/2020 Completed 7/9/2020

(unbonded) Water Well Constructor Certification

I certify that the work I performed on the construction, deepening, alteration, or abandonment of this well is in compliance with Oregon water supply well construction standards. Materials used and information reported above are true to the best of my knowledge and belief.

License Number Date

Signed

(bonded) Water Well Constructor Certification

I accept responsibility for the construction, deepening, alteration, or abandonment work performed on this well during the construction dates reported above. All work performed during this time is in compliance with Oregon water supply well construction standards. This report is true to the best of my knowledge and belief.

License Number 1720 Date 8/4/2020

Signed JACK ABBAS (E-filed)
Contact Info (optional) JACK ABBAS

ORIGINAL - WATER RESOURCES DEPARTMENT
THIS REPORT MUST BE SUBMITTED TO THE WATER RESOURCES DEPARTMENT WITHIN 30 DAYS OF COMPLETION OF WORK Form Version:

NOTICE TO WATER WELL CONTRACTOR
The original and first copy
of this report are to be
filed with the
STATE ENGINEER, SALEM, OREGON 97310
within 30 days from the date
of well completion.

RECEIVED
OCT 4 1972
STATE ENGINEER
SALEM. OREGON

RECEIVED
NOV 30 1972
STATE ENGINEER
SALEM, OREGON

WATER WELL REPORT
STATE OF OREGON
(Please type or print)
(Do not write above this line)

State Well No. 20S/15E-1 bc

State Permit No.

DESC 6477

(1) OWNER:
Name Jack Vogt
Address Bend Ore. 97701

(2) TYPE OF WORK (check):
New Well ☐ Deepening ☐ Reconditioning ☒ Abandon ☐
If abandonment, describe material and procedure in Item 12.

(3) TYPE OF WELL:
Rotary ☐ Driven ☐
Cable ☒ Jetted ☐
Dug ☐ Bored ☐

(4) PROPOSED USE (check):
Domestic ☒ Industrial ☐ Municipal ☐
Irrigation ☐ Test Well ☐ Other ☐

[illegible]) CASING INSTALLED:
Threaded ☐ Welded ☐
" Diam. from ft. to ft. Gage
" Diam. from ft. to ft. Gage
" Diam. from ft. to ft. Gage

[illegible]) PERFORATIONS:
Perforated? ☐ Yes ☒ No.
Type of perforator used
Size of perforations in. by in.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.

(7) SCREENS:
Well screen installed? ☐ Yes ☒ No
Manufacturer's Name
Type Model No.
Diam. Slot size Set from ft. to ft.
Diam. Slot size Set from ft. to ft.

(8) WELL TESTS:
Drawdown is amount water level is lowered below static level
Was a pump test made? ☐ Yes ☒ No If yes, by whom?
Yield: gal./min. with ft. drawdown after hrs.
" " "
" " "
Bailer test ~~none~~ 3 gal./min. with 0 ft. drawdown after 1 hrs.
Artesian flow g.p.m.
[illegible]mperature of water 57 Depth artesian flow encountered ft.

(9) CONSTRUCTION:
Well seal—Material used undisturbed
Well sealed from land surface to ft.
Diameter of well bore to bottom of seal in.
Diameter of well bore below seal in.
Number of sacks of cement used in well seal sacks
Number of sacks of bentonite used in well seal sacks
Brand name of bentonite
Number of pounds of bentonite per 100 gallons of water lbs./100 gals.
Was a drive shoe used? ☐ Yes ☒ No Plugs Size: location ft.
Did any strata contain unusable water? ☐ Yes ☒ No
Type of water? depth of strata
Method of sealing strata off
Was well gravel packed? ☐ Yes ☒ No Size of gravel:
Gravel placed from ft. to ft.

(10) LOCATION OF WELL:
County Deschutes Driller's well number
SW ¼ NW ¼ Section 1 T. 20 R. 15E W.M.
Bearing and distance from section or subdivision corner 2340' south and 200' east of the NW corner of section 1

(11) WATER LEVEL: Completed well.
Depth at which water was first found ft.
Static level 485 ft. below land surface. Date 9/1/72
Artesian pressure lbs. per square inch. Date

(12) WELL LOG:
Diameter of well below casing 6
Depth drilled 6 ft. Depth of completed well 495 ft.

Formation: Describe color, texture, grain size and structure of materials; and show thickness and nature of each stratum and aquifer penetrated, with at least one entry for each change of formation. *Report each change in position of Static Water Level and indicate principal water-bearing strata.*

MATERIAL	From	To	SWL
The is an old well that was aupposed to be 495'deep. We hit sand at 492'-drilled to 498'- cleaned it out to our satisfaction and left the seal undisturbed.			485

Work started 8/28 1972 Completed 9/1 1972
Date well drilling machine moved off of well 9/1 1972

Drilling Machine Operator's Certification:
This well was constructed under my direct supervision. Materials used and information reported above are true to my best knowledge and belief.
[Signed] Larry Crawford Date 9/14, 1972
(Drilling Machine Operator)
Drilling Machine Operator's License No. 678

Water Well Contractor's Certification:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.
Name Crawford Well Drilling
(Person, firm or corporation) (Type or print)
Address Box 17 Terrebonne, Ore97760
[Signed] Dale Crawford
(Water Well Contractor)
Contractor's License No. 451 Date 9/14, 1972

(USE ADDITIONAL SHEETS IF NECESSARY)

NOTICE TO WATER WELL CONTRACTOR
The original and first copy
of this report are to be
filed with the
STATE ENGINEER, SALEM, OREGON 97310
within 30 days from the date
of well completion.

RECEIVED
DEC 10 1969
STATE ENGINEER
SALEM, OREGON

RECEIVED
DEC 1[illegible] 1969
STATE ENGINEER
SALEM, OREGON

DESC 6479

WATER WELL REPORT
STATE OF OREGON
(Please type or print)
(Do not write above this line)

State Well No. 20/15-12
State Permit No.

(1) OWNER: #2
Name Hershel Haley
Address Rte 1 Box Hillsboro, Oregon

(2) TYPE OF WORK (check):
New Well ☒ Deepening ☐ Reconditioning ☐ Abandon ☐
If abandonment, describe material and procedure in Item 12.

(3) TYPE OF WELL:
Rotary ☒ Driven ☐
Cable ☐ Jetted ☐
[illegible] ☐ Bored ☐

(4) PROPOSED USE (check):
Domestic ☒ Industrial ☐ Municipal ☐
Irrigation ☐ Test Well ☐ Other ☐

(5) CASING INSTALLED:
Threaded ☐ Welded ☒
xxxx 6" Diam. from 0 ft. to ~~22~~ 22' Gage 1/4 wall
" Diam. from ft. to ft. Gage
" Diam. from ft. to ft. Gage

[illegible]) PERFORATIONS:
Perforated? ☐ Yes ☒ No.
Type of perforator used
Size of perforations in. by in.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.

(7) SCREENS:
Well screen installed? ☐ Yes ☒ No
Manufacturer's Name
Type Model No.
Diam. Slot size Set from ft. to ft.
Diam. Slot size Set from ft. to ft.

(8) WATER LEVEL: Completed well.
[illegible]tic level 450 ft. below land surface Date 11-19-69
Artesian pressure lbs. per square inch Date

(9) WELL TESTS:
Drawdown is amount water level is lowered below static level
Was a pump test made? ☐ Yes ☒ No If yes, by whom?
[illegible]ld: gal./min. with ft. drawdown after hrs.
" " " "
~~air~~ " " "
~~Bailer~~ test 12 gal./min. with 150 ft. drawdown after 1 hrs.
Artesian flow g.p.m. Date
Temperature of water Was a chemical analysis made? ☐ Yes ☒ No

(10) CONSTRUCTION:
Well seal—Material used cement
Depth of seal 20 feet ft.
Diameter of well bore to bottom of seal 9 in.
Were any loose strata cemented off? ☐ Yes ☒ No Depth
Was a drive shoe used? ☐ Yes ☒ No
Did any strata contain unusable water? ☐ Yes ☒ No
Type of water? depth of strata
Method of sealing strata off
Was well gravel packed? ☐ Yes ☒ No Size of gravel:
Gravel placed from ft. to ft.

(11) LOCATION OF WELL:
County Dechutes Driller's well number
1/4 E 1/2 Section 12 T. 20-S R. 15-E W.M.
Bearing and distance from section or subdivision corner

(12) WELL LOG:
Diameter of well below casing 6 inch
Depth drilled 655 ft. Depth of completed well 655 ft.

Formation: Describe color, texture, grain size and structure of materials; and show thickness and nature of each stratum and aquifer penetrated, with at least one entry for each change of formation. Report each change in position of Static Water Level as drilling proceeds. Note drilling rates.

MATERIAL	From	To	SWL
Brown sand and rock	0	7	
Brown rock	7	15	
Light grey soft rock	15	20	
Brown rock	20	150	
Soft brown rock	150	275	
Hard grey rock	275	320	
Red lava	320	350	
Brown rock	350	390	
Light brown & yellow rock	390	440	
Hard dark grey rock	440	565	
Med. brown lava rock	565	620	
Light brown ,red rock	620	635	
Hard grey rock with seams	635	655	

Work started 11-15-69 19 Completed 11-19-69 19
Date well drilling machine moved off of well 11-19-69 19

Drilling Machine Operator's Certification:
This well was constructed under my direct supervision. Materials used and information reported above are true to my best knowledge and belief.
[Signed] Martin Brest (Drilling Machine Operator) Date 12-8 1969
Drilling Machine Operator's License No. 566

Water Well Contractor's Certification:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.
NAME Ralph Turner Drilling Co. (Person, firm or corporation) (Type or print)
Address Rte 1 Box 141 Hillsboro, Oregon
[Signed] Ralph Turner (Water Well Contractor)
Contractor's License No. 247 Date 12-8 1969

(USE ADDITIONAL SHEETS IF NECESSARY)

DESC
52142

JAN 21 1999
WATER RESOURCES DEPT.
SALEM, OREGON

WELL I.D. # L24901

(START CARD) # 115347

STATE OF OREGON
WATER SUPPLY WELL REPORT
(as required by ORS 537.765)

Instructions for completing this report are on the last page of this form.

(1) OWNER: Well Number 1

Name LARRY WAUSMAN
Address 64120 JOHNSON RANCH RD.
City PRINEVILLE State OR Zip 97701

(2) TYPE OF WORK

☒ New Well ☐ Deepening ☐ Alteration (repair/recondition) ☐ Abandonment

(3) DRILL METHOD:

☒ Rotary Air ☐ Rotary Mud ☐ Cable ☐ Auger
☐ Other

(4) PROPOSED USE:

☐ Domestic ☐ Community ☐ Industrial ☒ Irrigation
☐ Thermal ☐ Injection ☐ Livestock ☒ Other TEST HOLE

(5) BORE HOLE CONSTRUCTION:

Special Construction approval ☐ Yes ☒ No Depth of Completed Well 610 ft.
Explosives used ☐ Yes ☒ No Type Amount

HOLE			SEAL			
Diameter	From	To	Material	From	To	Sacks or pounds
12"	0	19	BENTONITE	0	19	16 SACKS
8"	19	505				
6"	505	610				

How was seal placed: Method ☐ A ☐ B ☐ C ☐ D ☐ E
☒ Other BENTONITE POURED DRY
Backfill placed from — ft. to — ft. Material
Gravel placed from — ft. to — ft. Size of gravel

(6) CASING/LINER:

	Diameter	From	To	Gauge	Steel	Plastic	Welded	Threaded
Casing:	8"	+1	19	.250	☒	☐	☒	☐
					☐	☐	☐	☐
					☐	☐	☐	☐
					☐	☐	☐	☐
Liner:	6"	5	505		☒	☐	☒	☐
					☐	☐	☐	☐

Final location of shoe(s)

(7) PERFORATIONS/SCREENS:

☒ Perforations Method FACTORY
☐ Screens Type Material

From	To	Slot size	Number	Diameter	Tele/pipe size	Casing	Liner
425	505	1/8	1,056	1/8x6"	6"x.188	☐	☒
						☐	☐
						☐	☐
						☐	☐
						☐	☐

(8) WELL TESTS: Minimum testing time is 1 hour

☐ Pump ☐ Bailer ☒ Air ☐ Flowing Artesian

Yield gal/min	Drawdown	Drill stem at	Time
20+	0	610'	1 hr.

Temperature of water 64° Depth Artesian Flow Found
Was a water analysis done? ☐ Yes By whom
Did any strata contain water not suitable for intended use? ☐ Too little
☐ Salty ☐ Muddy ☐ Odor ☐ Colored ☐ Other
Depth of strata:

(9) LOCATION OF WELL by legal description:

County DESCHUTES Latitude Longitude
Township 20 N or [✓ S] Range 16 [✓ E] or W. WM.
Section 6 SW 1/4 NW 1/4
Tax Lot 1000 Lot Block Subdivision
Street Address of Well (or nearest address) 29201 Hwy 20

(10) STATIC WATER LEVEL:

435 ft. below land surface. Date 1/16/99
Artesian pressure 0 lb. per square inch. Date 1/16/99

(11) WATER BEARING ZONES:

Depth at which water was first found 465'

From	To	Estimated Flow Rate	SWL
465'	470'	20+ gpm	435

(12) WELL LOG:

Ground Elevation

Material	From	To	SWL
TOP SOIL	0	2	
BROWN CLAY W/CEMENTED GRAVEL	2	12	
COARSE TAN SANDSTONE	12	26	
BROWN SANDSTONE	26	34	
MED BROWN SANDSTONE	34	73	
LIGHT BROWN SANDSTONE	73	191	
MED BROWN SANDSTONE	191	435	
MED DARK GRAY SANDSTONE	435	505	435
MED LAVA GRAY	505	523	
MILD LAVA BROWN	523	560	
MILD GRAY LAVA	560	610	

Date started 1/9/99 Completed 1/16/99

(unbonded) Water Well Constructor Certification:

I certify that the work I performed on the construction, alteration, or abandonment of this well is in compliance with Oregon water supply well construction standards. Materials used and information reported above are true to the best of my knowledge and belief.

WWC Number
Date
Signed

(bonded) Water Well Constructor Certification:

I accept responsibility for the construction, alteration, or abandonment work performed on this well during the construction dates reported above. All work performed during this time is in compliance with Oregon water supply well construction standards. This report is true to the best of my knowledge and belief.

WWC Number 1555
Date 1/20/99
Signed

ORIGINAL & FIRST COPY-WATER RESOURCES DEPARTMENT SECOND COPY-CONSTRUCTOR THIRD COPY-CUSTOMER

DESC 54733

1-25525

STATE OF OREGON

WATER SUPPLY WELL REPORT

(as required by ORS 537.765)

Instructions for completing this report are on the last page of this form.

Desc
54733

WELL I.D. # L 142750

START CARD #

(1) LAND OWNER Well Number

Name Pieratt Bros, Inc

Address 21350 Stevens Rd.

City Bend State OR Zip 97702

(2) TYPE OF WORK

☐ New Well ☒ Deepening ☐ Alteration (repair/recondition) ☐ Abandonment

(3) DRILL METHOD:

☒ Rotary Air ☐ Rotary Mud ☐ Cable ☐ Auger

☐ Other

(4) PROPOSED USE:

☒ Domestic ☐ Community ☐ Industrial ☐ Irrigation

☐ Thermal ☐ Injection ☐ Livestock ☐ Other

(5) BORE HOLE CONSTRUCTION:

Special Construction approval ☐ Yes ☒ No Depth of Completed Well 545 ft.

Explosives used ☐ Yes ☐ No Type Amount

HOLE			SEAL			
Diameter	From	To	Material	From	To	Sacks or pounds
5 3/4	487	545				

How was seal placed: Method ☐ A ☐ B ☐ C ☐ D ☐ E

☐ Other undisturbed (original well drilled pre-1935)

Backfill placed from ft. to ft. Material

Gravel placed from ft. to ft. Size of gravel

(6) CASING/LINER:

	Diameter	From	To	Gauge	Steel	Plastic	Welded	Threaded
Casing:					☐	☐	☐	☐
					☐	☐	☐	☐
					☐	☐	☐	☐
					☐	☐	☐	☐
Liner:	4 1/2	+1	545	SDR21	☐	☒	☒	☐
					☐	☐	☐	☐

Drive Shoe used ☐ Inside ☐ Outside ☐ None

Final location of shoe(s)

(7) PERFORATIONS/SCREENS:

☒ Perforations Method Saw cut

☐ Screens Type 1/8 X 6 Material

From	To	Slot size	Number	Diameter	Tele/pipe size	Casing	Liner
545	505	1/8x6	100	4 1/2	pipe	☐	☒
						☐	☐
						☐	☐
						☐	☐

(8) WELL TESTS: Minimum testing time is 1 hour

☐ Pump ☐ Bailer ☒ Air ☐ Flowing Artesian

Yield gal/min	Drawdown	Drill stem at	Time
15	0	540	1 hr.

Temperature of water 57° Depth Artesian Flow Found

Was a water analysis done? ☐ Yes By whom

Did any strata contain water not suitable for intended use? ☐ Too little

☐ Salty ☐ Muddy ☐ Odor ☐ Colored ☐ Other

Depth of strata:

(9) LOCATION OF WELL by legal description:

County Des Latitude Longitude

Township 20 N or [✓ S] Range 16 [✓ E] or W. WM.

Section 6 SE 1/4 SW 1/4

Tax Lot 1203 Lot Block Subdivision /

Street Address of Well (or nearest address) none assigned

(10) STATIC WATER LEVEL:

495 ft. below land surface. Date Feb 28/02

Artesian pressure lb. per square inch Date

(11) WATER BEARING ZONES:

Depth at which water was first found 495

From	To	Estimated Flow Rate	SWL
495	545	15+	495

(12) WELL LOG:

Ground Elevation

Material	From	To	SWL
Broken Rock (NR)	495	545	495

RECEIVED
JUN 05 2002
WATER RESOURCES DEPT.
SALEM, OREGON

RECEIVED
JUN 13 2005
WATER RESOURCES DEPT.
SALEM, OREGON

Date started 2/16/02 Completed 2/28/02

(unbonded) Water Well Constructor Certification:

I certify that the work I performed on the construction, alteration, or abandonment of this well is in compliance with Oregon water supply well construction standards. Materials used and information reported above are true to the best of my knowledge and belief.

WWC Number 1371

Signed Date 2/28/02

(bonded) Water Well Constructor Certification:

I accept responsibility for the construction, alteration, or abandonment work performed on this well during the construction dates reported above. All work performed during this time is in compliance with Oregon water supply well construction standards. This report is true to the best of my knowledge and belief.

WWC Number 1371

Signed Date 2/28/02

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