BIOLOGICAL ASSESSMENT

(continued)

APPENDIX C

FERC Staff's *Upland Erosion Control, Revegetation, and Maintenance Plan* and *Wetland and Waterbody Construction and Mitigation Procedures*

UPLAND EROSION CONTROL, REVEGETATION, AND MAINTENANCE PLAN

MAY 2013 VERSION

UPLAND EROSION CONTROL, REVEGETATION, AND MAINTENANCE PLAN

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**UPLAND EROSION CONTROL, REVEGETATION,
AND MAINTENANCE PLAN (PLAN)**

I. APPLICABILITY

A. The intent of this Plan is to assist project sponsors by identifying baseline mitigation measures for minimizing erosion and enhancing revegetation. Project sponsors shall specify in their applications for a new FERC authorization and in prior notice and advance notice filings, any individual measures in this Plan they consider unnecessary, technically infeasible, or unsuitable due to local conditions and fully describe any alternative measures they would use. Project sponsors shall also explain how those alternative measures would achieve a comparable level of mitigation.

Once a project is authorized, project sponsors can request further changes as variances to the measures in this Plan (or the applicant's approved plan). The Director of the Office of Energy Projects (Director) will consider approval of variances upon the project sponsor's written request, if the Director agrees that a variance:

1. provides equal or better environmental protection;

2. is necessary because a portion of this Plan is infeasible or unworkable based on project-specific conditions; or

3. is specifically required in writing by another federal, state, or Native American land management agency for the portion of the project on its land or under its jurisdiction.

Sponsors of projects planned for construction under the automatic authorization provisions in the FERC's regulations must receive written approval for any variances in advance of construction.

Project-related impacts on wetland and waterbody systems are addressed in the staff's Wetland and Waterbody Construction and Mitigation Procedures (Procedures).

II. SUPERVISION AND INSPECTION

A. ENVIRONMENTAL INSPECTION

1. At least one Environmental Inspector is required for each construction spread during construction and restoration (as defined by section V). The number and experience of Environmental Inspectors assigned to each construction spread shall be appropriate for the length of the construction spread and the number/significance of resources affected.

2. Environmental Inspectors shall have peer status with all other activity inspectors.

3. Environmental Inspectors shall have the authority to stop activities that violate the environmental conditions of the FERC's Orders, stipulations of other environmental permits or approvals, or landowner easement agreements; and to order appropriate corrective action.

B. RESPONSIBILITIES OF ENVIRONMENTAL INSPECTORS

At a minimum, the Environmental Inspector(s) shall be responsible for:

1. Inspecting construction activities for compliance with the requirements of this Plan, the Procedures, the environmental conditions of the FERC's Orders, the mitigation measures proposed by the project sponsor (as approved and/or modified by the Order), other environmental permits and approvals, and environmental requirements in landowner easement agreements.

2. Identifying, documenting, and overseeing corrective actions, as necessary to bring an activity back into compliance;

3. Verifying that the limits of authorized construction work areas and locations of access roads are visibly marked before clearing, and maintained throughout construction;

4. Verifying the location of signs and highly visible flagging marking the boundaries of sensitive resource areas, waterbodies, wetlands, or areas with special requirements along the construction work area;

5. Identifying erosion/sediment control and soil stabilization needs in all areas;

6. Ensuring that the design of slope breakers will not cause erosion or direct water into sensitive environmental resource areas, including cultural resource sites, wetlands, waterbodies, and sensitive species habitats;

7. Verifying that dewatering activities are properly monitored and do not result in the deposition of sand, silt, and/or sediment into sensitive environmental resource areas, including wetlands, waterbodies, cultural resource sites, and sensitive species habitats; stopping dewatering activities if such deposition is occurring and ensuring the design of the discharge is changed to prevent reoccurrence; and verifying that dewatering structures are removed after completion of dewatering activities;

8. Ensuring that subsoil and topsoil are tested in agricultural and residential areas to measure compaction and determine the need for corrective action;

9. Advising the Chief Construction Inspector when environmental conditions (such as wet weather or frozen soils) make it advisable to restrict or delay construction activities to avoid topsoil mixing or excessive compaction;

10. Ensuring restoration of contours and topsoil;

11. Verifying that the soils imported for agricultural or residential use are certified as free of noxious weeds and soil pests, unless otherwise approved by the landowner;

12. Ensuring that erosion control devices are properly installed to prevent sediment flow into sensitive environmental resource areas (e.g., wetlands, waterbodies, cultural resource sites, and sensitive species habitats) and onto roads, and determining the need for additional erosion control devices;

13. Inspecting and ensuring the maintenance of temporary erosion control measures at least:

    a. on a daily basis in areas of active construction or equipment operation;

    b. on a weekly basis in areas with no construction or equipment operation; and

    c. within 24 hours of each 0.5 inch of rainfall;

14. Ensuring the repair of all ineffective temporary erosion control measures within 24 hours of identification, or as soon as conditions allow if compliance with this time frame would result in greater environmental impacts;

15. Keeping records of compliance with the environmental conditions of the FERC's Orders, and the mitigation measures proposed by the project sponsor in the application submitted to the FERC, and other federal or state environmental permits during active construction and restoration;

16. Identifying areas that should be given special attention to ensure stabilization and restoration after the construction phase; and

17. Verifying that locations for any disposal of excess construction materials for beneficial reuse comply with section III.E.

III. PRECONSTRUCTION PLANNING

The project sponsor shall do the following before construction:

A. CONSTRUCTION WORK AREAS

1. Identify all construction work areas (e.g., construction right-of-way, extra work space areas, pipe storage and contractor yards, borrow and disposal areas, access roads) that would be needed for safe construction. The project sponsor must ensure that appropriate cultural resources and biological surveys are conducted, as determined necessary by the appropriate federal and state agencies.

2. Project sponsors are encouraged to consider expanding any required cultural resources and endangered species surveys in anticipation of the need for activities outside of authorized work areas.

3. Plan construction sequencing to limit the amount and duration of open trench sections, as necessary, to prevent excessive erosion or sediment flow into sensitive environmental resource areas.

B. DRAIN TILE AND IRRIGATION SYSTEMS

1. Attempt to locate existing drain tiles and irrigation systems.

2. Contact landowners and local soil conservation authorities to determine the locations of future drain tiles that are likely to be installed within 3 years of the authorized construction.

3. Develop procedures for constructing through drain-tiled areas, maintaining irrigation systems during construction, and repairing drain tiles and irrigation systems after construction.

4. Engage qualified drain tile specialists, as needed to conduct or monitor repairs to drain tile systems affected by construction. Use drain tile specialists from the project area, if available.

C. GRAZING DEFERMENT

Develop grazing deferment plans with willing landowners, grazing permittees, and land management agencies to minimize grazing disturbance of revegetation efforts.

D. ROAD CROSSINGS AND ACCESS POINTS

Plan for safe and accessible conditions at all roadway crossings and access points during construction and restoration.

E. DISPOSAL PLANNING

Determine methods and locations for the regular collection, containment, and disposal of excess construction materials and debris (e.g., timber, slash, mats, garbage, drill cuttings and fluids, excess rock) throughout the construction process. Disposal of materials for beneficial reuse must not result in adverse environmental impact and is subject to compliance with all applicable survey, landowner or land management agency approval, and permit requirements.

F. AGENCY COORDINATION

The project sponsor must coordinate with the appropriate local, state, and federal agencies as outlined in this Plan and/or required by the FERC's Orders.

1. Obtain written recommendations from the local soil conservation authorities or land management agencies regarding permanent erosion control and revegetation specifications.

2. Develop specific procedures in coordination with the appropriate agencies to prevent the introduction or spread of invasive species, noxious weeds, and soil pests resulting from construction and restoration activities.

3. Develop specific procedures in coordination with the appropriate agencies and landowners, as necessary, to allow for livestock and wildlife movement and protection during construction.

4. Develop specific blasting procedures in coordination with the appropriate agencies that address pre- and post-blast inspections; advanced public notification; and mitigation measures for building foundations, groundwater wells, and springs. Use appropriate methods (e.g., blasting mats) to prevent damage to nearby structures and to prevent debris from entering sensitive environmental resource areas.

G. SPILL PREVENTION AND RESPONSE PROCEDURES

The project sponsor shall develop project-specific Spill Prevention and Response Procedures, as specified in section IV of the staff's Procedures. A copy must be filed with the Secretary of the FERC (Secretary) prior to construction and made available in the field on each construction spread. The filing requirement does not apply to projects constructed under the automatic authorization provisions in the FERC’s regulations.

H. RESIDENTIAL CONSTRUCTION

For all properties with residences located within 50 feet of construction work areas, project sponsors shall: avoid removal of mature trees and landscaping within the construction work area unless necessary for safe operation of construction equipment, or as specified in landowner agreements; fence the edge of the construction work area for a distance of 100 feet on either side of the residence; and restore all lawn areas and landscaping immediately following clean up operations, or as specified in landowner agreements. If seasonal or other weather conditions prevent compliance with these time frames, maintain and monitor temporary erosion controls (sediment barriers and mulch) until conditions allow completion of restoration.

I. WINTER CONSTRUCTION PLANS

If construction is planned to occur during winter weather conditions, project sponsors shall develop and file a project-specific winter construction plan with the FERC application. This filing requirement does not apply to projects constructed under the automatic authorization provisions of the FERC’s regulations.

The plan shall address:

1. winter construction procedures (e.g., snow handling and removal, access road construction and maintenance, soil handling under saturated or frozen conditions, topsoil stripping);

2. stabilization and monitoring procedures if ground conditions will delay restoration until the following spring (e.g., mulching and erosion controls, inspection and reporting, stormwater control during spring thaw conditions); and

3. final restoration procedures (e.g., subsidence and compaction repair, topsoil replacement, seeding).

IV. INSTALLATION

A. APPROVED AREAS OF DISTURBANCE

1. Project-related ground disturbance shall be limited to the construction right-of-way, extra work space areas, pipe storage yards, borrow and disposal areas, access roads, and other areas approved in the FERC's Orders. Any project-related ground disturbing activities outside these areas will require prior Director approval. This requirement does not apply to activities needed to comply with the Plan and Procedures (i.e., slope breakers, energy-dissipating devices, dewatering structures, drain tile system repairs) or minor field realignments and workspace shifts per landowner needs and requirements that do not affect other landowners or sensitive environmental resource areas. All construction or restoration activities outside of authorized areas are subject to all applicable survey and permit requirements, and landowner easement agreements.

2. The construction right-of-way width for a project shall not exceed 75 feet or that described in the FERC application unless otherwise modified by a FERC Order. However, in limited, non-wetland areas, this construction right-of-way width may be expanded by up to 25 feet without Director approval to accommodate full construction right-of-way topsoil segregation and to ensure safe construction where topographic conditions (e.g., side-slopes) or soil limitations require it. Twenty-five feet of extra construction right-of-way width may also be used in limited, non-wetland or non-forested areas for truck turn-arounds where no reasonable alternative access exists.

   Project use of these additional limited areas is subject to landowner or land management agency approval and compliance with all applicable survey and permit requirements. When additional areas are used, each one shall be identified and the need explained in the weekly or biweekly construction reports to the FERC, if required. The following material shall be included in the reports:

   a. the location of each additional area by station number and reference to previously filed alignment sheets, or updated alignment sheets showing the additional areas;

   b. identification of the filing at FERC containing evidence that the additional areas were previously surveyed; and

c. a statement that landowner approval has been obtained and is available in project files.

Prior written approval of the Director is required when the authorized construction right-of-way width would be expanded by more than 25 feet.

B. TOPSOIL SEGREGATION

1. Unless the landowner or land management agency specifically approves otherwise, prevent the mixing of topsoil with subsoil by stripping topsoil from either the full work area or from the trench and subsoil storage area (ditch plus spoil side method) in:

   a. cultivated or rotated croplands, and managed pastures;

   b. residential areas;

   c. hayfields; and

   d. other areas at the landowner's or land managing agency's request.

2. In residential areas, importation of topsoil is an acceptable alternative to topsoil segregation.

3. Where topsoil segregation is required, the project sponsor must:

   a. segregate at least 12 inches of topsoil in deep soils (more than 12 inches of topsoil); and

   b. make every effort to segregate the entire topsoil layer in soils with less than 12 inches of topsoil.

4. Maintain separation of salvaged topsoil and subsoil throughout all construction activities.

5. Segregated topsoil may not be used for padding the pipe, constructing temporary slope breakers or trench plugs, improving or maintaining roads, or as a fill material.

6. Stabilize topsoil piles and minimize loss due to wind and water erosion with use of sediment barriers, mulch, temporary seeding, tackifiers, or functional equivalents, where necessary.

C. DRAIN TILES

1. Mark locations of drain tiles damaged during construction.

2. Probe all drainage tile systems within the area of disturbance to check for damage.

3. Repair damaged drain tiles to their original or better condition. Do not use filter-covered drain tiles unless the local soil conservation authorities and the landowner agree. Use qualified specialists for testing and repairs.

4. For new pipelines in areas where drain tiles exist or are planned, ensure that the depth of cover over the pipeline is sufficient to avoid interference with drain tile systems. For adjacent pipeline loops in agricultural areas, install the new pipeline with at least the same depth of cover as the existing pipeline(s).

D. IRRIGATION

Maintain water flow in crop irrigation systems, unless shutoff is coordinated with affected parties.

E. ROAD CROSSINGS AND ACCESS POINTS

1. Maintain safe and accessible conditions at all road crossings and access points during construction.

2. If crushed stone access pads are used in residential or agricultural areas, place the stone on synthetic fabric to facilitate removal.

3. Minimize the use of tracked equipment on public roadways. Remove any soil or gravel spilled or tracked onto roadways daily or more frequent as necessary to maintain safe road conditions. Repair any damages to roadway surfaces, shoulders, and bar ditches.

F. TEMPORARY EROSION CONTROL

Install temporary erosion controls immediately after initial disturbance of the soil. Temporary erosion controls must be properly maintained throughout construction (on a daily basis) and reinstalled as necessary (such as after backfilling of the trench) until replaced by permanent erosion controls or restoration is complete.

1. Temporary Slope Breakers

   a. Temporary slope breakers are intended to reduce runoff velocity and divert water off the construction right-of-way. Temporary slope breakers may be constructed of materials such as soil, silt fence, staked hay or straw bales, or sand bags.

b. Install temporary slope breakers on all disturbed areas, as necessary to avoid excessive erosion. Temporary slope breakers must be installed on slopes greater than 5 percent where the base of the slope is less than 50 feet from waterbody, wetland, and road crossings at the following spacing (closer spacing shall be used if necessary):

Slope (%)	Spacing (feet)
5 - 15	300
>15 - 30	200
>30	100

c. Direct the outfall of each temporary slope breaker to a stable, well vegetated area or construct an energy-dissipating device at the end of the slope breaker and off the construction right-of-way.

d. Position the outfall of each temporary slope breaker to prevent sediment discharge into wetlands, waterbodies, or other sensitive environmental resource areas.

2. Temporary Trench Plugs

Temporary trench plugs are intended to segment a continuous open trench prior to backfill.

a. Temporary trench plugs may consist of unexcavated portions of the trench, compacted subsoil, sandbags, or some functional equivalent.

b. Position temporary trench plugs, as necessary, to reduce trenchline erosion and minimize the volume and velocity of trench water flow at the base of slopes.

3. Sediment Barriers

Sediment barriers are intended to stop the flow of sediments and to prevent the deposition of sediments beyond approved workspaces or into sensitive resources.

a. Sediment barriers may be constructed of materials such as silt fence, staked hay or straw bales, compacted earth (e.g., driveable berms across travelways), sand bags, or other appropriate materials.

b. At a minimum, install and maintain temporary sediment barriers across the entire construction right-of-way at the base of slopes greater than 5 percent where the base of the slope is less than 50 feet from a waterbody, wetland, or road crossing until revegetation is successful as defined in this Plan. Leave adequate room between the base of the slope and the sediment barrier to accommodate ponding of water and sediment deposition.

c. Where wetlands or waterbodies are adjacent to and downslope of construction work areas, install sediment barriers along the edge of these areas, as necessary to prevent sediment flow into the wetland or waterbody.

4. Mulch

a. Apply mulch on all slopes (except in cultivated cropland) concurrent with or immediately after seeding, where necessary to stabilize the soil surface and to reduce wind and water erosion. Spread mulch uniformly over the area to cover at least 75 percent of the ground surface at a rate of 2 tons/acre of straw or its equivalent, unless the local soil conservation authority, landowner, or land managing agency approves otherwise in writing.

b. Mulch can consist of weed-free straw or hay, wood fiber hydromulch, erosion control fabric, or some functional equivalent.

c. Mulch all disturbed upland areas (except cultivated cropland) <u>before</u> seeding if:

(1) final grading and installation of permanent erosion control measures will not be completed in an area within 20 days after the trench in that area is backfilled (10 days in residential areas), as required in section V.A.1; or

(2) construction or restoration activity is interrupted for extended periods, such as when seeding cannot be completed due to seeding period restrictions.

d. If mulching <u>before</u> seeding, increase mulch application on all slopes within 100 feet of waterbodies and wetlands to a rate of 3 tons/acre of straw or equivalent.

e. If wood chips are used as mulch, do not use more than 1 ton/acre and add the equivalent of 11 lbs/acre available nitrogen (at least 50 percent of which is slow release).

f. Ensure that mulch is adequately anchored to minimize loss due to wind and water.

g. When anchoring with liquid mulch binders, use rates recommended by the manufacturer. Do not use liquid mulch binders within 100 feet of wetlands or waterbodies, except where the product is certified environmentally non-toxic by the appropriate state or federal agency or independent standards-setting organization.

h. Do not use synthetic monofilament mesh/netted erosion control materials in areas designated as sensitive wildlife habitat, unless the product is specifically designed to minimize harm to wildlife. Anchor erosion control fabric with staples or other appropriate devices.

V. RESTORATION

A. CLEANUP

1. Commence cleanup operations immediately following backfill operations. Complete final grading, topsoil replacement, and installation of permanent erosion control structures within 20 days after backfilling the trench (10 days in residential areas). If seasonal or other weather conditions prevent compliance with these time frames, maintain temporary erosion controls (i.e., temporary slope breakers, sediment barriers, and mulch) until conditions allow completion of cleanup.

   If construction or restoration unexpectedly continues into the winter season when conditions could delay successful decompaction, topsoil replacement, or seeding until the following spring, file with the Secretary for the review and written approval of the Director, a winter construction plan (as specified in section III.I). This filing requirement does not apply to projects constructed under the automatic authorization provisions of the FERC's regulations.

2. A travel lane may be left open temporarily to allow access by construction traffic if the temporary erosion control structures are installed as specified in section IV.F. and inspected and maintained as specified in sections II.B.12 through 14. When access is no longer required the travel lane must be removed and the right-of-way restored.

3. Rock excavated from the trench may be used to backfill the trench only to the top of the existing bedrock profile. Rock that is not returned to the trench shall be considered construction debris, unless approved for use as mulch or for some other use on the construction work areas by the landowner or land managing agency.

4. Remove excess rock from at least the top 12 inches of soil in all cultivated or rotated cropland, managed pastures, hayfields, and residential areas, as well as other areas at the landowner's request. The size, density, and distribution of rock on the construction work area shall be similar to adjacent areas not disturbed by construction. The landowner or land management agency may approve other provisions in writing.

5. Grade the construction right-of-way to restore pre-construction contours and leave the soil in the proper condition for planting.

6. Remove construction debris from all construction work areas unless the landowner or land managing agency approves leaving materials onsite for beneficial reuse, stabilization, or habitat restoration.

7. Remove temporary sediment barriers when replaced by permanent erosion control measures or when revegetation is successful.

B. PERMANENT EROSION CONTROL DEVICES

1. Trench Breakers

   a. Trench breakers are intended to slow the flow of subsurface water along the trench. Trench breakers may be constructed of materials such as sand bags or polyurethane foam. Do not use topsoil in trench breakers.

   b. An engineer or similarly qualified professional shall determine the need for and spacing of trench breakers. Otherwise, trench breakers shall be installed at the same spacing as and upslope of permanent slope breakers.

   c. In agricultural fields and residential areas where slope breakers are not typically required, install trench breakers at the same spacing as if permanent slope breakers were required.

   d. At a minimum, install a trench breaker at the base of slopes greater than 5 percent where the base of the slope is less than 50 feet from a waterbody or wetland and where needed to avoid draining a waterbody or wetland. Install trench breakers at wetland boundaries, as specified in the Procedures. Do not install trench breakers within a wetland.

2. Permanent Slope Breakers

a. Permanent slope breakers are intended to reduce runoff velocity, divert water off the construction right-of-way, and prevent sediment deposition into sensitive resources. Permanent slope breakers may be constructed of materials such as soil, stone, or some functional equivalent.

b. Construct and maintain permanent slope breakers in all areas, except cultivated areas and lawns, unless requested by the landowner, using spacing recommendations obtained from the local soil conservation authority or land managing agency.

In the absence of written recommendations, use the following spacing unless closer spacing is necessary to avoid excessive erosion on the construction right-of-way:

Slope (%)	Spacing (feet)
5 - 15	300
>15 - 30	200
>30	100

c. Construct slope breakers to divert surface flow to a stable area without causing water to pool or erode behind the breaker. In the absence of a stable area, construct appropriate energy-dissipating devices at the end of the breaker.

d. Slope breakers may extend slightly (about 4 feet) beyond the edge of the construction right-of-way to effectively drain water off the disturbed area. Where slope breakers extend beyond the edge of the construction right-of-way, they are subject to compliance with all applicable survey requirements.

C. SOIL COMPACTION MITIGATION

1. Test topsoil and subsoil for compaction at regular intervals in agricultural and residential areas disturbed by construction activities. Conduct tests on the same soil type under similar moisture conditions in undisturbed areas to approximate preconstruction conditions. Use penetrometers or other appropriate devices to conduct tests.

2. Plow severely compacted agricultural areas with a paraplow or other deep tillage implement. In areas where topsoil has been segregated, plow the subsoil before replacing the segregated topsoil.

If subsequent construction and cleanup activities result in further compaction, conduct additional tilling.

3. Perform appropriate soil compaction mitigation in severely compacted residential areas.

D. REVEGETATION

1. General

a. The project sponsor is responsible for ensuring successful revegetation of soils disturbed by project-related activities, except as noted in section V.D.1.b.

b. Restore all turf, ornamental shrubs, and specialized landscaping in accordance with the landowner's request, or compensate the landowner. Restoration work must be performed by personnel familiar with local horticultural and turf establishment practices.

2. Soil Additives

Fertilize and add soil pH modifiers in accordance with written recommendations obtained from the local soil conservation authority, land management agencies, or landowner. Incorporate recommended soil pH modifier and fertilizer into the top 2 inches of soil as soon as practicable after application.

3. Seeding Requirements

a. Prepare a seedbed in disturbed areas to a depth of 3 to 4 inches using appropriate equipment to provide a firm seedbed. When hydroseeding, scarify the seedbed to facilitate lodging and germination of seed.

b. Seed disturbed areas in accordance with written recommendations for seed mixes, rates, and dates obtained from the local soil conservation authority or the request of the landowner or land management agency. Seeding is not required in cultivated croplands unless requested by the landowner.

c. Perform seeding of permanent vegetation within the recommended seeding dates. If seeding cannot be done within those dates, use appropriate temporary erosion control measures discussed in section IV.F and perform seeding of permanent vegetation at the beginning of the next recommended seeding season. Dormant seeding or temporary seeding of annual species may also be used, if necessary, to establish cover, as approved by the Environmental Inspector. Lawns may be seeded on a schedule established with the landowner.

d. In the absence of written recommendations from the local soil conservation authorities, seed all disturbed soils within 6 working days of final grading, weather and soil conditions permitting, subject to the specifications in section V.D.3.a through V.D.3.c.

e. Base seeding rates on Pure Live Seed. Use seed within 12 months of seed testing.

f. Treat legume seed with an inoculant specific to the species using the manufacturer's recommended rate of inoculant appropriate for the seeding method (broadcast, drill, or hydro).

g. In the absence of written recommendations from the local soil conservation authorities, landowner, or land managing agency to the contrary, a seed drill equipped with a cultipacker is preferred for seed application.

Broadcast or hydroseeding can be used in lieu of drilling at double the recommended seeding rates. Where seed is broadcast, firm the seedbed with a cultipacker or roller after seeding. In rocky soils or where site conditions may limit the effectiveness of this equipment, other alternatives may be appropriate (e.g., use of a chain drag) to lightly cover seed after application, as approved by the Environmental Inspector.

VI. OFF-ROAD VEHICLE CONTROL

To each owner or manager of forested lands, offer to install and maintain measures to control unauthorized vehicle access to the right-of-way. These measures may include:

A. signs;

B. fences with locking gates;

C. slash and timber barriers, pipe barriers, or a line of boulders across the right-of-way; and

D. conifers or other appropriate trees or shrubs across the right-of-way.

VII. POST-CONSTRUCTION ACTIVITIES AND REPORTING

A. MONITORING AND MAINTENANCE

1. Conduct follow-up inspections of all disturbed areas, as necessary, to determine the success of revegetation and address landowner concerns. At a minimum, conduct inspections after the first and second growing seasons.

2. Revegetation in non-agricultural areas shall be considered successful if upon visual survey the density and cover of non-nuisance vegetation are similar in density and cover to adjacent undisturbed lands. In agricultural areas, revegetation shall be considered successful when upon visual survey, crop growth and vigor are similar to adjacent undisturbed portions of the same field, unless the easement agreement specifies otherwise.

   Continue revegetation efforts until revegetation is successful.

3. Monitor and correct problems with drainage and irrigation systems resulting from pipeline construction in agricultural areas until restoration is successful.

4. Restoration shall be considered successful if the right-of-way surface condition is similar to adjacent undisturbed lands, construction debris is removed (unless otherwise approved by the landowner or land managing agency per section V.A.6), revegetation is successful, and proper drainage has been restored.

5. Routine vegetation mowing or clearing over the full width of the permanent right-of-way in uplands shall not be done more frequently than every 3 years. However, to facilitate periodic corrosion/leak surveys, a corridor not exceeding 10 feet in width centered on the pipeline may be cleared at a frequency necessary to maintain the 10-foot corridor in an herbaceous state. In no case shall routine vegetation mowing or clearing occur during the migratory bird nesting season between April 15 and August 1 of any year unless specifically approved in writing by the responsible land management agency or the U.S. Fish and Wildlife Service.

6. Efforts to control unauthorized off-road vehicle use, in cooperation with the landowner, shall continue throughout the life of the project. Maintain signs, gates, and permanent access roads as necessary.

B. REPORTING

1. The project sponsor shall maintain records that identify by milepost:

    a. method of application, application rate, and type of fertilizer, pH modifying agent, seed, and mulch used;

    b. acreage treated;

    c. dates of backfilling and seeding;

    d. names of landowners requesting special seeding treatment and a description of the follow-up actions;

    e. the location of any subsurface drainage repairs or improvements made during restoration; and

    f. any problem areas and how they were addressed.

2. The project sponsor shall file with the Secretary quarterly activity reports documenting the results of follow-up inspections required by section VII.A.1; any problem areas, including those identified by the landowner; and corrective actions taken for at least 2 years following construction.

    The requirement to file quarterly activity reports with the Secretary does not apply to projects constructed under the automatic authorization, prior notice, or advanced notice provisions in the FERC's regulations.

WETLAND AND WATERBODY CONSTRUCTION AND MITIGATION PROCEDURES

MAY 2013 VERSION

WETLAND AND WATERBODY CONSTRUCTION AND MITIGATION PROCEDURES

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WETLAND AND WATERBODY
CONSTRUCTION AND MITIGATION PROCEDURES (PROCEDURES)

I. APPLICABILITY

A. The intent of these Procedures is to assist project sponsors by identifying baseline mitigation measures for minimizing the extent and duration of project-related disturbance on wetlands and waterbodies. Project sponsors shall specify in their applications for a new FERC authorization, and in prior notice and advance notice filings, any individual measures in these Procedures they consider unnecessary, technically infeasible, or unsuitable due to local conditions and fully describe any alternative measures they would use. Project sponsors shall also explain how those alternative measures would achieve a comparable level of mitigation.

Once a project is authorized, project sponsors can request further changes as variances to the measures in these Procedures (or the applicant's approved procedures). The Director of the Office of Energy Projects (Director) will consider approval of variances upon the project sponsor's written request, if the Director agrees that a variance:

1. provides equal or better environmental protection;

2. is necessary because a portion of these Procedures is infeasible or unworkable based on project-specific conditions; or

3. is specifically required in writing by another federal, state, or Native American land management agency for the portion of the project on its land or under its jurisdiction.

Sponsors of projects planned for construction under the automatic authorization provisions in the FERC's regulations must receive written approval for any variances in advance of construction.

Project-related impacts on non-wetland areas are addressed in the staff's Upland Erosion Control, Revegetation, and Maintenance Plan (Plan).

B. DEFINITIONS

1. “Waterbody” includes any natural or artificial stream, river, or drainage with perceptible flow at the time of crossing, and other permanent waterbodies such as ponds and lakes:

   a. “minor waterbody” includes all waterbodies less than or equal to 10 feet wide at the water’s edge at the time of crossing;

   b. “intermediate waterbody” includes all waterbodies greater than 10 feet wide but less than or equal to 100 feet wide at the water’s edge at the time of crossing; and

   c. “major waterbody” includes all waterbodies greater than 100 feet wide at the water’s edge at the time of crossing.

2. “Wetland” includes any area that is not in actively cultivated or rotated cropland and that satisfies the requirements of the current federal methodology for identifying and delineating wetlands.

II. <u>PRECONSTRUCTION FILING</u>

A. The following information must be filed with the Secretary of the FERC (Secretary) prior to the beginning of construction, for the review and written approval by the Director:

1. site-specific justifications for extra work areas that would be closer than 50 feet from a waterbody or wetland; and

2. site-specific justifications for the use of a construction right-of-way greater than 75-feet-wide in wetlands.

B. The following information must be filed with the Secretary prior to the beginning of construction. These filing requirements do not apply to projects constructed under the automatic authorization provisions in the FERC’s regulations:

1. Spill Prevention and Response Procedures specified in section IV.A;

2. a schedule identifying when trenching or blasting will occur within each waterbody greater than 10 feet wide, within any designated coldwater fishery, and within any waterbody identified as habitat for federally-listed threatened or endangered species. The project sponsor will revise the schedule as necessary to provide FERC staff at least 14 days advance notice. Changes within this last 14-day period must provide for at least 48 hours advance notice;

3. plans for horizontal directional drills (HDD) under wetlands or waterbodies, specified in section V.B.6.d;

4. site-specific plans for major waterbody crossings, described in section V.B.9;

5. a wetland delineation report as described in section VI.A.1, if applicable; and

6. the hydrostatic testing information specified in section VII.B.3.

III. ENVIRONMENTAL INSPECTORS

A. At least one Environmental Inspector having knowledge of the wetland and waterbody conditions in the project area is required for each construction spread. The number and experience of Environmental Inspectors assigned to each construction spread shall be appropriate for the length of the construction spread and the number/significance of resources affected.

B. The Environmental Inspector's responsibilities are outlined in the Upland Erosion Control, Revegetation, and Maintenance Plan (Plan).

IV. PRECONSTRUCTION PLANNING

A. The project sponsor shall develop project-specific Spill Prevention and Response Procedures that meet applicable requirements of state and federal agencies. A copy must be filed with the Secretary prior to construction and made available in the field on each construction spread. This filing requirement does not apply to projects constructed under the automatic authorization provisions in the FERC's regulations.

1. It shall be the responsibility of the project sponsor and its contractors to structure their operations in a manner that reduces the risk of spills or the accidental exposure of fuels or hazardous materials to waterbodies or wetlands. The project sponsor and its contractors must, at a minimum, ensure that:

    a. all employees handling fuels and other hazardous materials are properly trained;

    b. all equipment is in good operating order and inspected on a regular basis;

    c. fuel trucks transporting fuel to on-site equipment travel only on approved access roads;

    d. all equipment is parked overnight and/or fueled at least 100 feet from a waterbody or in an upland area at least 100 feet from a wetland boundary. These activities can occur closer only if the Environmental Inspector determines that there is no reasonable alternative, and the project sponsor and its contractors have taken appropriate steps (including secondary containment structures) to prevent spills and provide for prompt cleanup in the event of a spill;

e. hazardous materials, including chemicals, fuels, and lubricating oils, are not stored within 100 feet of a wetland, waterbody, or designated municipal watershed area, unless the location is designated for such use by an appropriate governmental authority. This applies to storage of these materials and does not apply to normal operation or use of equipment in these areas;

f. concrete coating activities are not performed within 100 feet of a wetland or waterbody boundary, unless the location is an existing industrial site designated for such use. These activities can occur closer only if the Environmental Inspector determines that there is no reasonable alternative, and the project sponsor and its contractors have taken appropriate steps (including secondary containment structures) to prevent spills and provide for prompt cleanup in the event of a spill;

g. pumps operating within 100 feet of a waterbody or wetland boundary utilize appropriate secondary containment systems to prevent spills; and

h. bulk storage of hazardous materials, including chemicals, fuels, and lubricating oils have appropriate secondary containment systems to prevent spills.

2. The project sponsor and its contractors must structure their operations in a manner that provides for the prompt and effective cleanup of spills of fuel and other hazardous materials. At a minimum, the project sponsor and its contractors must:

a. ensure that each construction crew (including cleanup crews) has on hand sufficient supplies of absorbent and barrier materials to allow the rapid containment and recovery of spilled materials and knows the procedure for reporting spills and unanticipated discoveries of contamination;

b. ensure that each construction crew has on hand sufficient tools and material to stop leaks;

c. know the contact names and telephone numbers for all local, state, and federal agencies (including, if necessary, the U. S. Coast Guard and the National Response Center) that must be notified of a spill; and

d. follow the requirements of those agencies in cleaning up the spill, in excavating and disposing of soils or other materials contaminated by a spill, and in collecting and disposing of waste generated during spill cleanup.

B. AGENCY COORDINATION

The project sponsor must coordinate with the appropriate local, state, and federal agencies as outlined in these Procedures and in the FERC's Orders.

V. WATERBODY CROSSINGS

A. NOTIFICATION PROCEDURES AND PERMITS

1. Apply to the U.S. Army Corps of Engineers (COE), or its delegated agency, for the appropriate wetland and waterbody crossing permits.

2. Provide written notification to authorities responsible for potable surface water supply intakes located within 3 miles downstream of the crossing at least 1 week before beginning work in the waterbody, or as otherwise specified by that authority.

3. Apply for state-issued waterbody crossing permits and obtain individual or generic section 401 water quality certification or waiver.

4. Notify appropriate federal and state authorities at least 48 hours before beginning trenching or blasting within the waterbody, or as specified in applicable permits.

B. INSTALLATION

1. Time Window for Construction

Unless expressly permitted or further restricted by the appropriate federal or state agency in writing on a site-specific basis, instream work, except that required to install or remove equipment bridges, must occur during the following time windows:

a. coldwater fisheries - June 1 through September 30; and

b. coolwater and warmwater fisheries - June 1 through November 30.

2. Extra Work Areas

a. Locate all extra work areas (such as staging areas and additional spoil storage areas) at least 50 feet away from water's edge, except where the adjacent upland consists of cultivated or rotated cropland or other disturbed land.

b. The project sponsor shall file with the Secretary for review and written approval by the Director, site-specific justification for each extra work area with a less than 50-foot setback from the water's edge, except where the adjacent upland consists of cultivated or rotated cropland or other disturbed land. The justification must specify the conditions that will not permit a 50-foot setback and measures to ensure the waterbody is adequately protected.

c. Limit the size of extra work areas to the minimum needed to construct the waterbody crossing.

3. General Crossing Procedures

a. Comply with the COE, or its delegated agency, permit terms and conditions.

b. Construct crossings as close to perpendicular to the axis of the waterbody channel as engineering and routing conditions permit.

c. Where pipelines parallel a waterbody, maintain at least 15 feet of undisturbed vegetation between the waterbody (and any adjacent wetland) and the construction right-of-way, except where maintaining this offset will result in greater environmental impact.

d. Where waterbodies meander or have multiple channels, route the pipeline to minimize the number of waterbody crossings.

e. Maintain adequate waterbody flow rates to protect aquatic life, and prevent the interruption of existing downstream uses.

f. Waterbody buffers (e.g., extra work area setbacks, refueling restrictions) must be clearly marked in the field with signs and/or highly visible flagging until construction-related ground disturbing activities are complete.

g. Crossing of waterbodies when they are dry or frozen and not flowing may proceed using standard upland construction techniques in accordance with the Plan, provided that the Environmental Inspector verifies that water is unlikely to flow between initial disturbance and final stabilization of the feature. In the event of perceptible flow, the project sponsor must comply with all applicable Procedure requirements for "waterbodies" as defined in section I.B.1.

4. Spoil Pile Placement and Control

   a. All spoil from minor and intermediate waterbody crossings, and upland spoil from major waterbody crossings, must be placed in the construction right-of-way at least 10 feet from the water's edge or in additional extra work areas as described in section V.B.2.

   b. Use sediment barriers to prevent the flow of spoil or silt-laden water into any waterbody.

5. Equipment Bridges

   a. Only clearing equipment and equipment necessary for installation of equipment bridges may cross waterbodies prior to bridge installation. Limit the number of such crossings of each waterbody to one per piece of clearing equipment.

   b. Construct and maintain equipment bridges to allow unrestricted flow and to prevent soil from entering the waterbody. Examples of such bridges include:

      (1) equipment pads and culvert(s);
      (2) equipment pads or railroad car bridges without culverts;
      (3) clean rock fill and culvert(s); and
      (4) flexi-float or portable bridges.

      Additional options for equipment bridges may be utilized that achieve the performance objectives noted above. Do not use soil to construct or stabilize equipment bridges.

   c. Design and maintain each equipment bridge to withstand and pass the highest flow expected to occur while the bridge is in place. Align culverts to prevent bank erosion or streambed scour. If necessary, install energy dissipating devices downstream of the culverts.

   d. Design and maintain equipment bridges to prevent soil from entering the waterbody.

   e. Remove temporary equipment bridges as soon as practicable after permanent seeding.

   f. If there will be more than 1 month between final cleanup and the beginning of permanent seeding and reasonable alternative access to the right-of-way is available, remove temporary equipment bridges as soon as practicable after final cleanup.

g. Obtain any necessary approval from the COE, or the appropriate state agency for permanent bridges.

6. Dry-Ditch Crossing Methods

a. Unless approved otherwise by the appropriate federal or state agency, install the pipeline using one of the dry-ditch methods outlined below for crossings of waterbodies up to 30 feet wide (at the water's edge at the time of construction) that are state-designated as either coldwater or significant coolwater or warmwater fisheries, or federally-designated as critical habitat.

b. Dam and Pump

(1) The dam-and-pump method may be used without prior approval for crossings of waterbodies where pumps can adequately transfer streamflow volumes around the work area, and there are no concerns about sensitive species passage.

(2) Implementation of the dam-and-pump crossing method must meet the following performance criteria:

(i) use sufficient pumps, including on-site backup pumps, to maintain downstream flows;
(ii) construct dams with materials that prevent sediment and other pollutants from entering the waterbody (e.g., sandbags or clean gravel with plastic liner);
(iii) screen pump intakes to minimize entrainment of fish;
(iv) prevent streambed scour at pump discharge; and
(v) continuously monitor the dam and pumps to ensure proper operation throughout the waterbody crossing.

c. Flume Crossing

The flume crossing method requires implementation of the following steps:

(1) install flume pipe after blasting (if necessary), but before any trenching;

(2) use sand bag or sand bag and plastic sheeting diversion structure or equivalent to develop an effective seal and to divert stream flow through the flume pipe (some modifications to the stream bottom may be required to achieve an effective seal);

(3) properly align flume pipe(s) to prevent bank erosion and streambed scour;

(4) do not remove flume pipe during trenching, pipelaying, or backfilling activities, or initial streambed restoration efforts; and

(5) remove all flume pipes and dams that are not also part of the equipment bridge as soon as final cleanup of the stream bed and bank is complete.

d. Horizontal Directional Drill

For each waterbody or wetland that would be crossed using the HDD method, file with the Secretary for the review and written approval by the Director, a plan that includes:

(1) site-specific construction diagrams that show the location of mud pits, pipe assembly areas, and all areas to be disturbed or cleared for construction;

(2) justification that disturbed areas are limited to the minimum needed to construct the crossing;

(3) identification of any aboveground disturbance or clearing between the HDD entry and exit workspaces during construction;

(4) a description of how an inadvertent release of drilling mud would be contained and cleaned up; and

(5) a contingency plan for crossing the waterbody or wetland in the event the HDD is unsuccessful and how the abandoned drill hole would be sealed, if necessary.

The requirement to file HDD plans does not apply to projects constructed under the automatic authorization provisions in the FERC's regulations.

7. Crossings of Minor Waterbodies

Where a dry-ditch crossing is not required, minor waterbodies may be crossed using the open-cut crossing method, with the following restrictions:

a. except for blasting and other rock breaking measures, complete instream construction activities (including trenching, pipe installation, backfill, and restoration of the streambed contours) within 24 hours.

Streambanks and unconsolidated streambeds may require additional restoration after this period;

b. limit use of equipment operating in the waterbody to that needed to construct the crossing; and

c. equipment bridges are not required at minor waterbodies that do not have a state-designated fishery classification or protected status (e.g., agricultural or intermittent drainage ditches). However, if an equipment bridge is used it must be constructed as described in section V.B.5.

8. Crossings of Intermediate Waterbodies

Where a dry-ditch crossing is not required, intermediate waterbodies may be crossed using the open-cut crossing method, with the following restrictions:

a. complete instream construction activities (not including blasting and other rock breaking measures) within 48 hours, unless site-specific conditions make completion within 48 hours infeasible;

b. limit use of equipment operating in the waterbody to that needed to construct the crossing; and

c. all other construction equipment must cross on an equipment bridge as specified in section V.B.5.

9. Crossings of Major Waterbodies

Before construction, the project sponsor shall file with the Secretary for the review and written approval by the Director a detailed, site-specific construction plan and scaled drawings identifying all areas to be disturbed by construction for each major waterbody crossing (the scaled drawings are not required for any offshore portions of pipeline projects). This plan must be developed in consultation with the appropriate state and federal agencies and shall include extra work areas, spoil storage areas, sediment control structures, etc., as well as mitigation for navigational issues. The requirement to file major waterbody crossing plans does not apply to projects constructed under the automatic authorization provisions of the FERC's regulations.

The Environmental Inspector may adjust the final placement of the erosion and sediment control structures in the field to maximize effectiveness.

10. Temporary Erosion and Sediment Control

Install sediment barriers (as defined in section IV.F.3.a of the Plan) immediately after initial disturbance of the waterbody or adjacent upland.

Sediment barriers must be properly maintained throughout construction and reinstalled as necessary (such as after backfilling of the trench) until replaced by permanent erosion controls or restoration of adjacent upland areas is complete. Temporary erosion and sediment control measures are addressed in more detail in the Plan; however, the following specific measures must be implemented at stream crossings:

a. install sediment barriers across the entire construction right-of-way at all waterbody crossings, where necessary to prevent the flow of sediments into the waterbody. Removable sediment barriers (or driveable berms) must be installed across the travel lane. These removable sediment barriers can be removed during the construction day, but must be re-installed after construction has stopped for the day and/or when heavy precipitation is imminent;

b. where waterbodies are adjacent to the construction right-of-way and the right-of-way slopes toward the waterbody, install sediment barriers along the edge of the construction right-of-way as necessary to contain spoil within the construction right-of-way and prevent sediment flow into the waterbody; and

c. use temporary trench plugs at all waterbody crossings, as necessary, to prevent diversion of water into upland portions of the pipeline trench and to keep any accumulated trench water out of the waterbody.

11. Trench Dewatering

Dewater the trench (either on or off the construction right-of-way) in a manner that does not cause erosion and does not result in silt-laden water flowing into any waterbody. Remove the dewatering structures as soon as practicable after the completion of dewatering activities.

C. RESTORATION

1. Use clean gravel or native cobbles for the upper 1 foot of trench backfill in all waterbodies that contain coldwater fisheries.

2. For open-cut crossings, stabilize waterbody banks and install temporary sediment barriers within 24 hours of completing instream construction activities. For dry-ditch crossings, complete streambed and bank stabilization before returning flow to the waterbody channel.

3. Return all waterbody banks to preconstruction contours or to a stable angle of repose as approved by the Environmental Inspector.

4. Install erosion control fabric or a functional equivalent on waterbody banks at the time of final bank recontouring. Do not use synthetic monofilament

mesh/netted erosion control materials in areas designated as sensitive wildlife habitat unless the product is specifically designed to minimize harm to wildlife. Anchor erosion control fabric with staples or other appropriate devices.

5. Application of riprap for bank stabilization must comply with COE, or its delegated agency, permit terms and conditions.

6. Unless otherwise specified by state permit, limit the use of riprap to areas where flow conditions preclude effective vegetative stabilization techniques such as seeding and erosion control fabric.

7. Revegetate disturbed riparian areas with native species of conservation grasses, legumes, and woody species, similar in density to adjacent undisturbed lands.

8. Install a permanent slope breaker across the construction right-of-way at the base of slopes greater than 5 percent that are less than 50 feet from the waterbody, or as needed to prevent sediment transport into the waterbody. In addition, install sediment barriers as outlined in the Plan.

   In some areas, with the approval of the Environmental Inspector, an earthen berm may be suitable as a sediment barrier adjacent to the waterbody.

9. Sections V.C.3 through V.C.7 above also apply to those perennial or intermittent streams not flowing at the time of construction.

D. POST-CONSTRUCTION MAINTENANCE

1. Limit routine vegetation mowing or clearing adjacent to waterbodies to allow a riparian strip at least 25 feet wide, as measured from the waterbody's mean high water mark, to permanently revegetate with native plant species across the entire construction right-of-way. However, to facilitate periodic corrosion/leak surveys, a corridor centered on the pipeline and up to 10 feet wide may be cleared at a frequency necessary to maintain the 10-foot corridor in an herbaceous state. In addition, trees that are located within 15 feet of the pipeline that have roots that could compromise the integrity of the pipeline coating may be cut and removed from the permanent right-of-way. Do not conduct any routine vegetation mowing or clearing in riparian areas that are between HDD entry and exit points.

2. Do not use herbicides or pesticides in or within 100 feet of a waterbody except as allowed by the appropriate land management or state agency.

3. Time of year restrictions specified in section VII.A.5 of the Plan (April 15 – August 1 of any year) apply to routine mowing and clearing of riparian areas.

VI. WETLAND CROSSINGS

A. GENERAL

1. The project sponsor shall conduct a wetland delineation using the current federal methodology and file a wetland delineation report with the Secretary before construction. The requirement to file a wetland delineation report does not apply to projects constructed under the automatic authorization provisions in the FERC's regulations.

   This report shall identify:

   a. by milepost all wetlands that would be affected;

   b. the National Wetlands Inventory (NWI) classification for each wetland;

   c. the crossing length of each wetland in feet; and

   d. the area of permanent and temporary disturbance that would occur in each wetland by NWI classification type.

   The requirements outlined in this section do not apply to wetlands in actively cultivated or rotated cropland. Standard upland protective measures, including workspace and topsoiling requirements, apply to these agricultural wetlands.

2. Route the pipeline to avoid wetland areas to the maximum extent possible. If a wetland cannot be avoided or crossed by following an existing right-of-way, route the new pipeline in a manner that minimizes disturbance to wetlands. Where looping an existing pipeline, overlap the existing pipeline right-of-way with the new construction right-of-way. In addition, locate the loop line no more than 25 feet away from the existing pipeline unless site-specific constraints would adversely affect the stability of the existing pipeline.

3. Limit the width of the construction right-of-way to 75 feet or less. Prior written approval of the Director is required where topographic conditions or soil limitations require that the construction right-of-way width within the boundaries of a federally delineated wetland be expanded beyond 75 feet. Early in the planning process the project sponsor is encouraged to identify site-specific areas where excessively wide trenches could occur and/or where spoil piles could be difficult to maintain because existing soils lack adequate unconfined compressive strength.

4. Wetland boundaries and buffers must be clearly marked in the field with signs and/or highly visible flagging until construction-related ground disturbing activities are complete.

5. Implement the measures of sections V and VI in the event a waterbody crossing is located within or adjacent to a wetland crossing. If all measures of sections V and VI cannot be met, the project sponsor must file with the Secretary a site-specific crossing plan for review and written approval by the Director before construction. This crossing plan shall address at a minimum:

   a. spoil control;

   b. equipment bridges;

   c. restoration of waterbody banks and wetland hydrology;

   d. timing of the waterbody crossing;

   e. method of crossing; and

   f. size and location of all extra work areas.

6. Do not locate aboveground facilities in any wetland, except where the location of such facilities outside of wetlands would prohibit compliance with U.S. Department of Transportation regulations.

B. INSTALLATION

1. Extra Work Areas and Access Roads

   a. Locate all extra work areas (such as staging areas and additional spoil storage areas) at least 50 feet away from wetland boundaries, except where the adjacent upland consists of cultivated or rotated cropland or other disturbed land.

   b. The project sponsor shall file with the Secretary for review and written approval by the Director, site-specific justification for each extra work area with a less than 50-foot setback from wetland boundaries, except where adjacent upland consists of cultivated or rotated cropland or other disturbed land. The justification must specify the site-specific conditions that will not permit a 50-foot setback and measures to ensure the wetland is adequately protected.

   c. The construction right-of-way may be used for access when the wetland soil is firm enough to avoid rutting or the construction right-of-way has been appropriately stabilized to avoid rutting (e.g., with timber riprap, prefabricated equipment mats, or terra mats).

      In wetlands that cannot be appropriately stabilized, all construction equipment other than that needed to install the wetland crossing shall use access roads located in upland areas. Where access roads in upland areas do not provide reasonable access, limit all other construction equipment to one pass through the wetland using the construction right-of-way.

d. The only access roads, other than the construction right-of-way, that can be used in wetlands are those existing roads that can be used with no modifications or improvements, other than routine repair, and no impact on the wetland.

2. Crossing Procedures

a. Comply with COE, or its delegated agency, permit terms and conditions.

b. Assemble the pipeline in an upland area unless the wetland is dry enough to adequately support skids and pipe.

c. Use "push-pull" or "float" techniques to place the pipe in the trench where water and other site conditions allow.

d. Minimize the length of time that topsoil is segregated and the trench is open. Do not trench the wetland until the pipeline is assembled and ready for lowering in.

e. Limit construction equipment operating in wetland areas to that needed to clear the construction right-of-way, dig the trench, fabricate and install the pipeline, backfill the trench, and restore the construction right-of-way.

f. Cut vegetation just above ground level, leaving existing root systems in place, and remove it from the wetland for disposal.

The project sponsor can burn woody debris in wetlands, if approved by the COE and in accordance with state and local regulations, ensuring that all remaining woody debris is removed for disposal.

g. Limit pulling of tree stumps and grading activities to directly over the trenchline. Do not grade or remove stumps or root systems from the rest of the construction right-of-way in wetlands unless the Chief Inspector and Environmental Inspector determine that safety-related construction constraints require grading or the removal of tree stumps from under the working side of the construction right-of-way.

h. Segregate the top 1 foot of topsoil from the area disturbed by trenching, except in areas where standing water is present or soils are saturated. Immediately after backfilling is complete, restore the segregated topsoil to its original location.

i. Do not use rock, soil imported from outside the wetland, tree stumps, or brush riprap to support equipment on the construction right-of-way.

j. If standing water or saturated soils are present, or if construction equipment causes ruts or mixing of the topsoil and subsoil in wetlands, use low-ground-weight construction equipment, or operate normal equipment on timber riprap, prefabricated equipment mats, or terra mats.

k. Remove all project-related material used to support equipment on the construction right-of-way upon completion of construction.

3. Temporary Sediment Control

Install sediment barriers (as defined in section IV.F.3.a of the Plan) immediately after initial disturbance of the wetland or adjacent upland. Sediment barriers must be properly maintained throughout construction and reinstalled as necessary (such as after backfilling of the trench). Except as noted below in section VI.B.3.c, maintain sediment barriers until replaced by permanent erosion controls or restoration of adjacent upland areas is complete. Temporary erosion and sediment control measures are addressed in more detail in the Plan.

a. Install sediment barriers across the entire construction right-of-way immediately upslope of the wetland boundary at all wetland crossings where necessary to prevent sediment flow into the wetland.

b. Where wetlands are adjacent to the construction right-of-way and the right-of-way slopes toward the wetland, install sediment barriers along the edge of the construction right-of-way as necessary to contain spoil within the construction right-of-way and prevent sediment flow into the wetland.

c. Install sediment barriers along the edge of the construction right-of-way as necessary to contain spoil and sediment within the construction right-of-way through wetlands. Remove these sediment barriers during right-of-way cleanup.

4. Trench Dewatering

   Dewater the trench (either on or off the construction right-of-way) in a manner that does not cause erosion and does not result in silt-laden water flowing into any wetland. Remove the dewatering structures as soon as practicable after the completion of dewatering activities.

C. RESTORATION

1. Where the pipeline trench may drain a wetland, construct trench breakers at the wetland boundaries and/or seal the trench bottom as necessary to maintain the original wetland hydrology.

2. Restore pre-construction wetland contours to maintain the original wetland hydrology.

3. For each wetland crossed, install a trench breaker at the base of slopes near the boundary between the wetland and adjacent upland areas. Install a permanent slope breaker across the construction right-of-way at the base of slopes greater than 5 percent where the base of the slope is less than 50 feet from the wetland, or as needed to prevent sediment transport into the wetland. In addition, install sediment barriers as outlined in the Plan. In some areas, with the approval of the Environmental Inspector, an earthen berm may be suitable as a sediment barrier adjacent to the wetland.

4. Do not use fertilizer, lime, or mulch unless required in writing by the appropriate federal or state agency.

5. Consult with the appropriate federal or state agencies to develop a project-specific wetland restoration plan. The restoration plan shall include measures for re-establishing herbaceous and/or woody species, controlling the invasion and spread of invasive species and noxious weeds (e.g., purple loosestrife and phragmites), and monitoring the success of the revegetation and weed control efforts. Provide this plan to the FERC staff upon request.

6. Until a project-specific wetland restoration plan is developed and/or implemented, temporarily revegetate the construction right-of-way with annual ryegrass at a rate of 40 pounds/acre (unless standing water is present).

7. Ensure that all disturbed areas successfully revegetate with wetland herbaceous and/or woody plant species.

8. Remove temporary sediment barriers located at the boundary between wetland and adjacent upland areas after revegetation and stabilization of adjacent upland areas are judged to be successful as specified in section VII.A.4 of the Plan.

D. POST-CONSTRUCTION MAINTENANCE AND REPORTING

1. Do not conduct routine vegetation mowing or clearing over the full width of the permanent right-of-way in wetlands. However, to facilitate periodic corrosion/leak surveys, a corridor centered on the pipeline and up to 10 feet wide may be cleared at a frequency necessary to maintain the 10-foot corridor in an herbaceous state. In addition, trees within 15 feet of the pipeline with roots that could compromise the integrity of pipeline coating may be selectively cut and removed from the permanent right-of-way. Do not conduct any routine vegetation mowing or clearing in wetlands that are between HDD entry and exit points.

2. Do not use herbicides or pesticides in or within 100 feet of a wetland, except as allowed by the appropriate federal or state agency.

3. Time of year restrictions specified in section VII.A.5 of the Plan (April 15 – August 1 of any year) apply to routine mowing and clearing of wetland areas.

4. Monitor and record the success of wetland revegetation annually until wetland revegetation is successful.

5. Wetland revegetation shall be considered successful if all of the following criteria are satisfied:

   a. the affected wetland satisfies the current federal definition for a wetland (i.e., soils, hydrology, and vegetation);

   b. vegetation is at least 80 percent of either the cover documented for the wetland prior to construction, or at least 80 percent of the cover in adjacent wetland areas that were not disturbed by construction;

   c. if natural rather than active revegetation was used, the plant species composition is consistent with early successional wetland plant communities in the affected ecoregion; and

   d. invasive species and noxious weeds are absent, unless they are abundant in adjacent areas that were not disturbed by construction.

6. Within 3 years after construction, file a report with the Secretary identifying the status of the wetland revegetation efforts and documenting success as defined in section VI.D.5, above. The requirement to file wetland restoration reports with the Secretary does not apply to projects constructed under the automatic authorization, prior notice, or advance notice provisions in the FERC's regulations.

   For any wetland where revegetation is not successful at the end of 3 years after construction, develop and implement (in consultation with a professional wetland ecologist) a remedial revegetation plan to actively revegetate wetlands. Continue revegetation efforts and file a report annually documenting progress in these wetlands until wetland revegetation is successful.

VII. HYDROSTATIC TESTING

A. NOTIFICATION PROCEDURES AND PERMITS

1. Apply for state-issued water withdrawal permits, as required.

2. Apply for National Pollutant Discharge Elimination System (NPDES) or state-issued discharge permits, as required.

3. Notify appropriate state agencies of intent to use specific sources at least 48 hours before testing activities unless they waive this requirement in writing.

B. GENERAL

1. Perform 100 percent radiographic inspection of all pipeline section welds or hydrotest the pipeline sections, before installation under waterbodies or wetlands.

2. If pumps used for hydrostatic testing are within 100 feet of any waterbody or wetland, address secondary containment and refueling of these pumps in the project's Spill Prevention and Response Procedures.

3. The project sponsor shall file with the Secretary before construction a list identifying the location of all waterbodies proposed for use as a hydrostatic test water source or discharge location. This filing requirement does not apply to projects constructed under the automatic authorization provisions of the FERC's regulations.

C. INTAKE SOURCE AND RATE

1. Screen the intake hose to minimize the potential for entrainment of fish.

2. Do not use state-designated exceptional value waters, waterbodies which provide habitat for federally listed threatened or endangered species, or waterbodies designated as public water supplies, unless appropriate federal, state, and/or local permitting agencies grant written permission.

3. Maintain adequate flow rates to protect aquatic life, provide for all waterbody uses, and provide for downstream withdrawals of water by existing users.

4. Locate hydrostatic test manifolds outside wetlands and riparian areas to the maximum extent practicable.

D. DISCHARGE LOCATION, METHOD, AND RATE

1. Regulate discharge rate, use energy dissipation device(s), and install sediment barriers, as necessary, to prevent erosion, streambed scour, suspension of sediments, or excessive streamflow.

2. Do not discharge into state-designated exceptional value waters, waterbodies which provide habitat for federally listed threatened or endangered species, or waterbodies designated as public water supplies, unless appropriate federal, state, and local permitting agencies grant written permission.

APPENDIX D

Pacific Connector's Drilling Fluid Contingency Plan and HDD Failure Mode Procedure

Appendix D.1 Drilling Fluid

Contingency Plan

Pacific Connector Gas Pipeline, LP

Drilling Fluid Contingency Plan for Horizontal Directional Drilling Operations

Pacific Connector Gas Pipeline Project

September 2017

DRILLING FLUID CONTINGENCY PLAN FOR HORIZONTAL DIRECTIONAL DRILLING OPERATIONS

1.0 INTRODUCTION

Pacific Connector Gas Pipeline, LP (Pacific Connector) proposes to construct a 36-inch diameter pipeline beneath Coos Bay, the Coos River, Rogue River, and Klamath River in southwest Oregon. Pacific Connector is proposing to utilize the horizontal directional drilling (HDD) process to install the pipeline underneath these four waterbodies. HDD is an increasingly popular method of installation whereby surface and/or riverbed disturbance may be minimized with proper design and construction procedures. HDD installations may present a potential for surface and/or riverbed disturbance through the inadvertent release of drilling fluid. Contingency planning and prevention control of an inadvertent release of drilling fluid to resources has been a major consideration in selecting and designing the proposed HDD crossings.

Pacific Connector intends to protect public health and safety as well as natural resources in the event of a release of drilling fluid to the ground surface or a waterbody, an event commonly referred to as inadvertent returns or frac-out. The HDD method was identified because it is environmentally conscientious and has been proven a safe and efficient method when feasible for crossing waterbodies. The purpose of this document is to aid Pacific Connector in developing a program designed to minimize the potential for occurrence of adverse effects resulting from an inadvertent release of drilling fluid to the ground surface and/or resources.

2.0 CAUSES OF DRILLING FLUID LOSS

2.1 GENERAL

Drilling fluid utilized in the HDD process is composed primarily of water and bentonite; naturally occurring clay. The primary purposes of this drilling fluid are to suspend and transport cuttings from the borehole, to stabilize the borehole, and to act as a coolant and lubricant during the drilling process. The drilling fluid generally consists of 1 to 5 percent active clays, approximately 0 to 40 percent inert solids, and water. The primary active clay component is bentonite. Bentonite is a naturally occurring, non-hazardous clay product. A material safety data sheet (MSDS) for a bentonite material, as supplied by WYO-BEN Inc. is attached.

Drilling fluid is transported under pressure through the drill string to the cutting bit. The total drilling fluid pressure at the cutting bit is a function of pumping pressures, the elevation difference between the drill rig and the cutting bit, and friction losses. Soil and rock formations around the drill path experience maximum drilling fluid pressures in the immediate proximity of the cutting bit or reaming tools.

Two primary processes by which drilling fluid circulation may be reduced or lost include the following.

1. Formational fluid loss occurs when drilling fluid flows into surrounding permeable soil units within the pore spaces of the soil or along pre-existing fractures or voids.

2. Hydraulic fracturing can occur where the combined resisting force of the available overburden pressure and the shear strength of the overburden soil is less than the hydrostatic pressure applied to the surrounding soil from the drilling fluid at the drill bit.

2.1.1 Formational Fluid Loss

Formational fluid losses typically occur when the drilling fluid flows through the pore spaces in the surrounding formation. Thus, a formation with a higher porosity potentially can lose a larger volume of fluid than a formation with a lower porosity. Silty sands, silts, and clays typically have a low susceptibility to formational fluid losses. Coarse sands and gravels with low percentages of silt and clay have a moderate-to-high susceptibility for fluid loss.

2.1.2 Hydraulic Fracture

Hydraulic fracture is a term typically used to describe the case where the down-hole fluid pressure exceeds the overburden pressure and shear strength of the formation above a drill path. Hydraulic fracture typically occurs when the drill path passes through relatively weak cohesive soils with low shear strength or very loose granular soils. Loose silty sands and soft to medium stiff silts and clays typically have a higher hydraulic fracture potential. Medium dense to dense sands and gravels and very stiff to hard silts and clays have a low to moderate hydraulic fracture potential. Unfractured rock, because of its high shear strength, typically has a low potential for hydraulic fracture. HDD installations with greater depth or in formations with higher shear strength may reduce the potential for hydraulic fracturing.

2.2 Drilling Fluid Releases

Whether by formational fluid loss or hydraulic fracture, there is potential for releasing relatively large volumes of drilling fluid in a short period of time to the ground surface or a waterbody if the fluid pumps are not immediately disengaged.

In practice, drilling fluid releases to the ground surface is most common in close proximity to the entry and exit points where annular pressures are high and soil cover is thin. Drilling fluid releases can also occur at locations along a drill path where there are low shear strength soils, the depth of soil cover is thin or along pre-existing fractures or voids. Other locations where drilling fluid releases can occur include exploratory boring locations, or along the sides of structures such as piles or utility poles.

3.0 DRILLING FLUID RELEASE PREVENTION, CONTAINMENT AND COUNTERMEASURES

3.1 Prevention

3.1.1 Design

The potential for releases of drilling fluid can be reduced through proper HDD design. During design, the HDD crossing locations are selected and a design profile is developed. The primary factors in selecting the HDD profile are the type of surface topographic conditions, subsurface materials, and the desired depth of cover at the proposed pipeline crossing location. Stiff cohesive soils, such as clays, dense sands, and competent rock are considered ideal materials for horizontal drilling. Another important factor to be considered in the design of an HDD profile is an adequate depth of overburden material. The appropriate depth of overburden is determined based on complex calculations, and is different depending on the subsurface conditions.

The following summarizes some of the applicable processes by which each of the proposed HDD crossings are designed:

- Surface Reconnaissance: The proposed HDD site is evaluated for workspace, construction access and topographic relief.

- Subsurface Exploration: Subsurface conditions along a proposed HDD alignment are explored in order to assess drilling feasibility and to select an optimal drill path that passes through the most competent and desirable subsurface strata with the least potential for hydraulic fracture and surface release of drilling fluid.

- Hydraulic Fracture Analysis: Complex analyses are performed to calculate the safety factor against hydraulic fracture along the entire drill path. The analysis is based primarily on research completed by Delft Geotechnics, as discussed in Appendix B of The Army Corps of Engineers Report CPAR-GL-98 (Staheli, et al., 1998, "Installation of Pipelines Beneath Levees Using Horizontal Directional Drilling," US Army Corps of Engineers, Waterways Experiment Station, CPAR-98-1). The input parameters for the model include subsurface material properties, hydrostatic water pressures, drilling fluid properties, penetration rates and pump rates. Based on the assumptions and interpretations utilized during the modeling process, the evaluation may indicate a high potential (low factor of safety) for hydraulic fracture along the drill path. If a higher strength layer is not present above the weaker layer, the design profile may be modified in an attempt at improving the safety factor against hydraulic fracture and/or drilling fluid surface release.

3.1.2 HDD Operations

Another important factor in reducing the potential for drilling fluid surface release is the HDD contractor's construction procedures. Frequently, drilling fluid surface releases can be prevented through proper drilling procedures. The following operational elements, if executed properly, significantly reduce the potential for inadvertent returns:

- Maintaining adequate pump volumes;

- Monitoring and maintaining ideal drilling fluid properties; and,

- Maintaining appropriate penetration rates to maintain proper drilling fluid circulation.

The HDD contractor is responsible for execution of the HDD operation, including actions for detecting and controlling drilling fluid surface releases. Pacific Connector will closely monitor the progress and actions of the HDD contractor.

3.1.3 Monitoring and Detection

HDD is a technically advanced process involving skilled operators. Early detection of hydraulic fracture may prevent or reduce the volume of drilling fluid released to the ground surface. Early detection is highly dependent upon the skill and experience of the HDD contractor. Therefore, Pacific Connector plans to utilize well qualified HDD contractors that specialize in horizontal directional drilling to install the four proposed waterbody crossings. The selection and monitoring of the HDD contractor will be the responsibility of Pacific Connector.

Each drilling situation is unique in that the behavior of the subsurface material is highly variable and difficult to predict. If a drilling fluid release occurs in the river, detection may be difficult due to the high flow rates and turbidity of the river. However, down-hole annular pressure tools that help detect a change or spike in the annular pressure of the drilled hole during pilot hole operations can alert the HDD contractor to impending hydraulic fracture. Detection depends on the proper use of these tools and a proper interpretation of other factors that may indicate hydraulic fracture is imminent. An on-site environmental inspector at each waterway can also aid in identifying a drilling fluid surface release so that corrective actions can be made in an attempt at reducing the amount of fluid released.

3.2 CONTAINMENT

3.2.1 Terrestrial Inadvertent Returns

There is greater potential for drilling fluid surface releases near the entry and exit locations of the HDD crossing. The entry and exit locations for the HDD crossings have dry land segments where drilling fluid surface releases can be easily detected and contained. To isolate and contain potential drilling fluid releases at each of the drill sites, a berm may be built around the entire drilling site area. Hay bales or silt screen may be part of the berm on the river side of the drilling area. To contain and control drilling fluid surface releases on the land area, there will be earth-moving equipment such as backhoes or small bulldozers, portable pumps, hand tools, sand, silt fences, and hay bales available at each of the drilling sites. Drilling fluid will be contained and isolated using dirt berms, hay bales, or silt screens. Drilling fluid releases will be cleaned and hauled or pumped to one of the drilling mud storage pits at the closest drilling site.

Once a drilling fluid release is detected at the ground surface, the HDD contractor will take immediate corrective action. Drilling fluid pumps provide the only source of pressure to the drilling fluid; therefore, the most immediate corrective action is to shut off the drilling fluid pumps. Upon discontinuation of the drilling fluid pumps, the pressure in the hole will quickly dissipate. When the pressure diminishes down-hole, releases of drilling fluid to the surface will slow and eventually stop. The mitigation response process will then be initiated. The drilling fluid released to the ground surface will be contained, where possible, through the use of containment structures; and a determination will be made whether alternative actions will be required prior to resuming the HDD process. If a drilling fluid release occurs in an area where the fluid can be managed within containment structures, drilling activities will immediately resume and the area will be monitored throughout the remainder of the HDD process.

3.2.2 Aquatic Inadvertent Returns

The composition of the drilling fluid is primarily water and bentonite clay. Therefore, a small volume of drilling fluid released into the river will quickly dissipate because of the anticipated high volumes and velocities of the Coos, Rogue, and Klamath Rivers at the proposed time of construction. In the event drilling fluid is detected in a waterbody, agencies will be notified. If corrective measures can be feasibly implemented, an assessment will be made to determine the most appropriate containment structure to be erected to minimize the volume of drilling fluid released into the waterbody. However, it will likely be impractical to erect effective containment structures to extract drilling fluid from rivers.

Coos Bay in the proposed HDD location consists of intertidal mud flats with smaller subtidal areas, namely dredged shipping lanes and natural tidal channels. If drilling fluid is released into Coos Bay, the drilling fluid will not likely mobilize as it would in a rapidly moving river. Coos Bay is relatively shallow throughout much of the HDD alignment. The mudline becomes exposed during low tides across much of the alignment except within the dredged shipping channel. In the event of a drilling fluid release into Coos Bay, the drilling fluid will likely settle onto the bay floor, where it may be contained and removed.

The area downstream of the project site will be monitored to identify areas that may have substantial accumulations of drilling fluid. Potential accumulations will likely only occur in slow flowing areas that allow enough time for the suspended particulates to settle out of the water column. Where possible, drilling fluid volumes that represent significant adverse impacts to aquatic habitat will be removed from the substrate.

Areas where bentonite accumulations are removed will be monitored to assess the need for additional substrate. If the areas identified lack essential substrate materials including spawning gravels, these materials may be added to mitigate the impacts of the bentonite removal activities. These activities will not be conducted if clean-up measures will result in greater damage to the shoreline and watercourse. In areas where clean-up methods are identified to result in greater damage, the area will not be altered and bentonite accumulations will remain in place and likely flush out during periods of high flow. High flow periods are typically associated with naturally occurring elevated turbidity levels and the effect of allowing the bentonite to flush naturally is not expected to significantly alter water quality.

3.3 COUNTERMEASURES

If a drilling fluid surface release occurs, the HDD operation will be stopped temporarily to determine an appropriate response plan. The HDD contractor and Pacific Connector will attempt to determine the cause of the hydraulic fracture and drilling fluid surface release. Pacific Connector will implement procedures which may control the factors causing the hydraulic fracture and/or drilling fluid release to minimize the chance of recurrence. Developing corrective measures will be a joint effort between Pacific Connector and the HDD contractor and will be site and problem specific. A combination of measures may be necessary to control hydraulic fracture and surface releases. Possible corrective measures that may be utilized to control or correct drilling fluid surface releases are as follows:

1. Increase the drilling fluid viscosity in an attempt at sealing the point at which fluid is leaving the drilled hole. The drilling operation may be suspended for a short period (i.e. overnight) to allow the fractured zone to become sealed with the higher viscosity drilling fluid.
2. If increasing the drilling fluid viscosity is ineffective, lost circulation materials (LCM) may be introduced into the hole by incorporating them in the drilling fluid and pumping the material down-hole. The drilling operation may again be suspended for a short period (i.e. overnight) to allow the fractured zone to become sealed with the lost circulation materials.
3. Depending on the location of the fractured zone, a steel casing may be installed that is of sufficient size to receive the largest expected down-hole tools for the crossing. This casing installation provides a temporary conduit for drilling fluids to flow while opening the remaining section of the hole to a diameter acceptable for receiving the proposed pipe sections. To alleviate future concerns with the steel casing after the HDD installation is completed, the casing is generally extracted from the hole prior to or just after completing the HDD installation. However, there have been instances when attempts at extracting the steel casing were unsuccessful.
4. In the event drilling fluid flow is not regained through the annulus of the drilled hole and a steel casing installation is not utilized, the HDD contractor may elect to install a grout mixture into the drilled hole in an attempt to seal the fractured zone. The down-hole drilling assembly is generally extracted and existing hole is re-drilled to the point at which it had previously been drilled prior to having encountered the loss of drilling fluid.

In some instances, it may be determined that the existing hole encountered a zone of unsatisfactory soil material and the hole may have to be abandoned. If the hole is abandoned, it will be filled with cuttings and drilling fluid.

4.0 RISK OF AQUATIC BIOLOGICAL IMPACTS

All four waterbody crossings (Coos Bay, Coos River, Rogue River, and Klamath River) proposed for utilizing the HDD method of construction support resident and anadromous fish species including chinook and coho salmon and steelhead trout. Chinook and coho salmon and steelhead trout use these waterways as spawning, rearing, and migration habitats.

In the event drilling fluid is released into a waterbody, drilling fluid will enter the waterway causing short term, temporary water quality impacts downstream of the project area including sedimentation and turbidity. Sediments discharged into aquatic systems have the potential, depending on the concentrations, to wear down fish gills and impair fish vision making it difficult to feed and also making the fish more susceptible to predation. However, these effects typically occur after relatively long-term exposure to concentrated sedimentation.

If drilling fluid accumulates in the substrate, it can adversely impact the quality and quantity of aquatic habitat available for aquatic species including salmonid spawning habitat and benthic macroinvertebrate rearing habitat. Drilling fluid that accumulates in the substrate may cover up food sources and smother fish eggs and other aquatic life in the riverbed. However, significant impacts to substrate from drilling fluid releases are not likely in the large river systems because of the anticipated high volumes and velocities within these rivers. For example, if drilling fluid is inadvertently released in the Rogue River, the anticipated high volume and velocities of the water is expected to dilute the drilling fluid to a level that is not expected to significantly impact aquatic species or habitats. The rheologic properties of drilling fluid allow it to remain suspended within the water column for prolonged periods of time and would likely settle out in very slow moving water downstream of the release. The distance of expected transport would likely prevent significant concentrations of the fluid from accumulating in one area of the Rogue River. In the event drilling fluid is inadvertently released into any one of the rivers, the behavioral avoidance response of resident and anadromous fish species is presumed to be triggered within the immediate vicinity of the release and the fish are expected to return and utilize the affected area shortly after the inadvertent release has been halted. If significant concentrations are found during monitoring as a result of a release, corrective measures will be taken as described in the previous sections of this report.

Effects to oysters from an inadvertent release would be similar to the increased turbidity resulting from open trenching operations and could include burial or interference with feeding and respiration. However, the effects would be more acute and confined to a much smaller area.

Inadvertent releases could be cleaned up or allowed to naturally attenuate. Clean up options include:

- Removal of material from surface. Mud releases to the surface may be cleaned up by hand, or through the use of vacuum trucks (in the event that a vacuum truck can access the area), or collection sumps and pumps.
- Restoration the area through the placement of clean fill over the excavated inadvertent return,

In the event of a significant release, mitigation may be required. Potential mitigation could include excavation of the released material, replanting of eelgrass beds, and/or financial compensation to oyster growers. Mitigation for native oysters could be done through placement of Pacific oyster shells in the bay. Previous mitigation projects have shown that these shells are quickly colonized by Olympia oysters.

Appendix D.2 HDD

Failure Modes

Pacific Connector Gas Operator, LP

Failure Mode Procedure for the HDD Pipeline Installation Method

Pacific Connector Gas Pipeline Project

September 2017

Failure Mode Procedure for the HDD Pipeline Installation Method

1.0 Horizontal Directional Drill Construction Method

Horizontal Directional Drilling (HDD) is a construction method to install pipelines beneath waterbodies, wetlands, and features that require special attention to environmental and logistical concerns. In the HDD process, there are three basic steps to install a pipeline crossing; pilot hole, hole opening, and pullback. This section will address the HDD process, the different failure modes, and the failure criteria for the three steps of horizontal directional drilling. Further, the process Pacific Connector Gas Pipeline, LP (PCGP) will use to evaluate potential failure of the HDD crossings for the PCGP Project and determine when the HDD method will be abandoned.

1.1 Pilot Hole Process

The pilot hole is the first step in the HDD process. The pilot hole is drilled along a predetermined alignment in which the entry and exit points are located using traditional survey methods. Control of the drill bit is achieved by using a non-rotating drill string with an asymmetrical leading edge. This leading edge creates a steering bias to be held in a precise position during drilling. The pilot hole is surveyed by two separate methods; downhole survey tools using an instrument referred to as a probe and either the Paratrack or TruTracker survey system which uses a wire on the surface creating a magnetic field. Both methods of survey are calculated after each section of drill pipe has been drilled (approximately 30 feet).

The pilot hole consists of drilling the initial hole (typically 12 1/4-inch) beneath the proposed crossing. The pilot hole is drilled using either a tri-cone rotary bit connected to a downhole displacement mud motor or a jetting assembly. Drilling fluid is pumped through the annulus of the drill pipe aiding the mud motor or jetting assembly in cutting the soil or rock strata. The drilling fluid also helps lubricate the drill stem, suspend and carry the drilled cuttings to the surface, and form a wall cake to keep the hole open.

A successful pilot hole will provide pertinent data to aid in determining the possible success of the crossing. Data obtained from the pilot hole includes the rate of penetration to be expected and confirmation of the geotechnical strata. The contractor can then better determine a plan for opening the hole to the required diameter. The diameter required to install a 36-inch pipeline will vary from 48 to 54 inches depending on the confirmed geotechnical strata and the contractor’s judgment.

1.2 Hole Opening Process

The second step consists of one or more hole-opening passes. There are two types of tools that enlarge the pilot hole; flycutters, used for most soil formations, and rock hole opening tools, used for very dense soil or rock formations.

Typically, the flycutter or hole opening tool is attached to the drill pipe string that drilled the pilot hole and is then rotated and pulled back towards the drill rig in what’s also known as a reaming pass.

1. In soil formations, typically there may only be two or three hole opening passes. The first pass will be between a 26-inch and a 32-inch flycutter with the second pass being between a 48-inch and a 54-inch flycutter. Depending on the stability of the hole the contractor may use a barrel

reamer, either a 42-inch or a 48-inch, and pull it through the hole to ensure a good drilling fluid wall cake, a clean hole, and a hole full of drilling fluid immediately prior to pullback.

2. In rock formations, there may be several passes starting typically with a 22 to 34-inch hole opening tool and increasing in steps of 6 to 18-inch increments until the desired diameter is achieved. The diameter of each pre-ream pass will be determined in the field by the HDD contractor.

Drill pipe is usually added behind the tool to keep drill pipe in the hole for the entire length of the crossing. The process of pulling the flycutters or hole opening tools to the drill rig is repeated several times until the hole is at the appropriate diameter to install the pipeline. The contractor may choose to ream away from the drill rig. If so, reamers fitted into the drill string are rotated and thrust toward the exit point and pulled with either a large dozer or trackhoe.

1.3 Pullback Process

The last step to complete a successful installation is the pullback of the prefabricated pipeline into the enlarged hole. The pullback process is the most critical step of the HDD process. A reinforced pullhead is attached to the leading end of the pipe and to a swivel that is connected to the drill pipe. The swivel is placed between the drill rig and the pipe to keep any rotation and minimize torsion from being passed through to the pipeline. The 36-inch pipeline has a positive buoyancy and therefore is filled with a calculated amount of water to keep the pipeline as close to neutral buoyancy as possible. If no water were added to the pipeline during the pullback process, the pipe may float in the drilling mud and press itself against the top of the hole causing the following problems:

- Skin friction of the pipeline would be increased, which would increase the load the drill rig has to pull. The pipeline could be damaged if an excessive amount of pull tension has to be applied to the pipe to continue the pullback process.

- The leading edge of the pullhead could dislodge a cobble or rock fragment, binding the pipeline and making it impossible to move the pipeline in either direction.

- The external coating could be damaged by sharp and/or protruding material and highly abrasive material (coarse sands).

The pull section is supported with a combination of roller stands, pipe handling equipment, or a floatation ditch to minimize tension and prevent the pipe from being damaged.

2.0 Failure Modes

2.1 Hole Instability

One of the most common failure modes that may occur during the HDD operation is hole collapse. Hole collapse can occur if an effective bentonite wall cake is not maintained in loose granular strata or if unfavorable drilling strata is encountered that contains relatively high percentages of gravel, cobbles or highly fractured rock. If the hole collapses on the drill pipe and creates high friction on its surface, the torque required to rotate the drill pipe may increase. The increased friction may either put the drill pipe in a bind in which the drill pipe cannot be moved or if the torque applied to the drill pipe by the drill rig exceeds the strength of the drill pipe, it may cause the drill pipe to either shear or twist into two pieces. Additionally, hole collapse can lead to sinkhole formation at the ground surface which may necessitate the termination of the HDD operations until the condition is mitigated.

Typically, gravel/cobble content above 20 percent presents additional risk for the HDD method of installation. Gravel/cobble content above 50 percent is considered to present a high risk of hole collapse and other complications that can ultimately lead to a failed installation.

In soil formations, if the hole-opening passes take a long time, there is one main type of failure. This failure mode consists of the material falling into the hole due to the lack of a good bentonite wall cake and high drilling mud pressures washing out a cavern in the hole. This may make the hole unstable and can keep the drilling mud from returning to the surface. If the drilling mud is no longer able to carry the drilled cuttings out of the hole, there will be an excess of cuttings in the hole.

2.2 Inadequate Cuttings Removal

An important aspect of the HDD process is the removal of cuttings from the annulus of the hole. If soil and rock cuttings are not adequately removed from the hole, several additional risk factors can negatively impact the likelihood of a successful pipeline installation. When cuttings build up within the hole, rotary torque on the drill string can increase, tool wear is increased, and the risk of drilling fluid loss and subsequent drilling fluid surface release is increased. The increased friction may cause the drill pipe to slow or stop rotation to a point where the drill rig cannot supply enough torque to continue drilling without causing a failure of the drill pipe. The accumulation of cuttings downhole can cause the downhole tooling to become stuck, cause the tooling to twist-off downhole or cause the pipeline to become lodged in the hole during pullback operations.

Several factors can affect the efficiency of cuttings removal from the hole. These factors include the drilling fluid properties, drilling fluid flow and penetration rates, composition of the subsurface soil units (gravel and cobble content), hole geometry and the ability to maintain drilling fluid returns to the entry and exit pits.

Often gravel/cobble clasts cannot be carried out of the drilled/ reamed hole by drilling fluid because drilling fluid does not have enough carrying capacity to suspend and transport the larger, heavier clasts from the drilled or reamed hole. When this occurs, the gravel can accumulate within the lowest section of a drilled or reamed hole and may not be able to be effectively removed from the hole.

2.3 Hole Obstructions

Hole obstructions may consist of a boulder or unexpected man-made structures (piling) or debris in fill. Encountering a boulder or other hard obstruction can deflect the drill bit, stop the forward momentum of the drill bit, and/or impinge on the drill string or other tooling and ultimately prevent the successful installation of the carrier pipe.

If an obstruction is encountered during pullback operations, the pull of the drilling rig may increase to a level causing the drill pipe to fail. This results in the greatest setback, because the only alternative is to abandon the drilled hole and pipeline, relocate the pipeline alignment, and start the drilling process from the beginning. If the pipe becomes lodged in the hole, the contractor may utilize specialized equipment on the exit side to assist in trying to move the pipe.

There is little that can be done to mitigate the risk of hole obstructions short of knowing their general location and avoiding them to the extent possible.

2.4 Mechanical

Mechanical failure can prevent the successful installation of the carrier pipe. If fatigue or failure of downhole tools or drill pipe results in the loss of tools or drill pipe downhole, attempts will be made to retrieve them. However, if the tools/drill pipe retrieval is not successful, the hole will be abandoned, and the HDD will be attempted from the beginning along a new alignment nearby. Frequently, failure of downhole tools is a result of excessive pull forces and wear caused by hole stability and inadequate cuttings removal as described above. Therefore, if the same conditions exist along the new profile that existed in the abandoned hole, similar problems may be encountered and the HDD method of installation may not be feasible.

3.0 HDD Failure Criteria

Pacific Connector considers the following failure criteria as sufficient reason to abandon the HDD process.

3.1 Pilot Hole

The HDD installation method may be considered a failure after several attempts by the CONTRACTOR at completing the pilot hole are unsuccessful. PCGP may determine to consider the pilot hole a failure after two attempts if the actual subsurface materials are determined not to be conducive to the HDD method of installation. If this happens the contractor shall then demobilize their equipment from site after approval from PCGP.

3.2 Hole Opening

The HDD installation method may be considered a failure after several attempts at opening the hole to the required diameter have failed, as long as the failure does not include losing parts of the hole opening tool downhole; or, loss of entire hole opening tool downhole. PCGP may determine to consider the hole-opening process a failure after two attempts if the actual subsurface materials are determined not to be conducive to the HDD method of installation. The contractor will then be allowed 14 working days to attempt retrieving the missing tool or parts from the hole and continue the hole opening process. If failure occurs, the contractor shall then demobilize their equipment from site after approval from PCGP.

3.3 Pullback

The HDD installation method may be considered a failure after several attempts at completing the pullback unless the pipe can be removed from the hole. Then additional attempts will be made after the hole has been reopened and reconditioned with any necessary hole opening passes as determined jointly by the contractor and PCGP. PCGP may determine to consider the pullback process a failure after two attempts if the actual subsurface materials are determined not to be conducive to the HDD method of installation. If failure occurs, the contractor shall then demobilize their equipment from the site after approval from PCGP.

3.4 Mechanical

The HDD installation method may be considered a failure if the contractor has a major breakdown and after either repairing or replacing the broken drilling rig or vital piece of ancillary equipment, the drill pipe, hole opening tool, or pipeline cannot be rotated or pulled. If failure occurs, the contractor shall then demobilize their equipment from site after approval from PCGP.

3.5 Company/Agency Approval

PCGP will provide a technical consultant on-site during the horizontal directional drill process to keep adequate documentation; daily progress reports, as-built information, etc., describing the events leading up to the failure. PCGP will then submit this documentation to the necessary agencies for their review and approval the drill has failed at the present alignment. The contractor will not demobilize until PCGP's approval has been received.

3.6 Abandoning the Hole

The contractor will grout the top five vertical feet of the hole on both the entry and exit side of the crossing. The grout will be a cement type grout. The top 12-inches of the hole will be filled with native materials or in accordance with the permit requirements.

APPENDIX E

Pacific Connector’s HDD Crossing Plans

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801.307.0216

September 6, 2017

Pacific Connector Gas Pipeline, LP
5615 Kirby Drive, Suite 500
Houston, Texas 77004

Attention: John Walls

Subject: HDD Feasibility Evaluation
Coos Bay East Crossing
Pacific Connector Gas Pipeline Project
Coos County, Oregon
File No. 22708-001-01

INTRODUCTION AND PROJECT UNDERSTANDING

GeoEngineers, Inc. (GeoEngineers) is pleased to present this horizontal directional drilling (HDD) feasibility evaluation for the proposed 36-inch-diameter pipeline installation beneath Coos Bay in Coos Bay, Oregon. The proposed Coos Bay East HDD crossing will be a part of the 229-mile-long Pacific Connector Gas Pipeline (PCGP), beginning at the proposed Jordan Cove Liquefied Natural Gas (LNG) Terminal near Coos Bay, Oregon and terminating near Malin, Oregon. The site is shown with respect to the surrounding area in the Vicinity Map, Figure 1.

Our feasibility evaluation of the proposed Coos Bay East HDD is based on limited subsurface data. Our conclusions should be considered preliminary pending completion of a subsurface exploration program. Table 1 below provides our understanding of the design basis for the proposed HDD.

TABLE 1. BASIS OF DESIGN FOR THE COOS BAY HDD

Product Pipe Data	Design Parameter
Product Pipe Specifications	36 inches x 0.823 inches w.t.[a] API-5L X-70 Steel Pipe
Approximate Horizontal Crossing Length	8,972 feet
Maximum Allowable Operating Pressure	1,600 psig[b]
Maximum Operating Temperature	100 degrees F

Product Pipe Data	Design Parameter
Tie-In Temperature	70 degrees F
Design Factor[c]	0.5

Notes:

[a] w.t. – wall thickness

[b] psig – pounds per square inch gauge

[c] As defined in 49 CFR Parts 195.106 and 192.111

PURPOSE AND SCOPE OF SERVICES

The purpose of our services was to utilize existing subsurface and site survey information in order to evaluate the feasibility of the proposed HDD installation. Our specific scope of services included the following:

1. Reviewed geologic maps and boring logs of previously completed borings in the project area to evaluate geologic conditions along the HDD alignment.
2. Evaluated the feasibility of the proposed HDD from the workspace considerations, subsurface considerations and geometric feasibility standpoints.
3. Prepared conceptual HDD plan and profile drawings using AutoCAD files provided by others.
4. Prepared this HDD feasibility report summarizing HDD feasibility and construction considerations.

SURFACE CONDITIONS

The Coos Bay East HDD extends from North Point in North Bend, Oregon eastward across Coos Bay and ends at the mouth of Kentuck Slough as shown in the Vicinity Map, Figure 1. Surface conditions at North Point at the west end of the HDD consists of a relatively flat ground surface covered with fill stockpiles. The east end of the HDD is located within a flat grass vegetated area in Kentuck Slough Valley. The alignment of the HDD would cross the Coos Bay navigation channel and shallow tidal mud flats east of the navigation channel.

SUBSURFACE SOIL AND GROUNDWATER CONDITIONS

Site Geology

Published geologic mapping shows that the shallow subsurface conditions along the HDD alignment is dominated by young alluvium. Alluvium is described as "…variable amounts of clay, silt, sand, and gravel."

Sedimentary bedrock of the Eocene-age Coaledo Formation is mapped by Baldwin and others (1973) as underlying the uplands surrounding Coos Bay. Baldwin and others (1973) notes that "(t)he Coaledo Formation occupies a north-plunging basin surrounding Coos Bay," implying that the Coaledo forms the bedrock within the Bay and is likely underlying the surficial alluvium.

The most detailed structural geology of the Coaledo Formation in north Coos Bay (Duncan, 1953) includes an east-west cross-section through the Bay, 1 mile north of the HDD alignment. It shows the upper contact of the Coaledo Formation beneath the Bay as an irregular basin deepening to the west to as much as -300 feet mean sea level (MSL). The top of the sedimentary rock is shown rising to approximately -150 feet MSL in the eastern half of the Bay.

SUBSURFACE EXPLORATIONS

GeoEngineers has completed a number of exploratory borings in Coos Bay to investigate various PCGP pipeline alignments. The exploratory boring completed closest to the Coos Bay East HDD alignment is WCB-3, which was completed approximately 1,000 feet south of the alignment at the location shown in Figures 2A and 3A. The boring log of WCB-3 is presented in Figure 5.

Boring WCB-3 was completed to a depth of about 50.5 feet below mudline. The boring encountered approximately 27 feet of very loose to medium dense sand overlying dense sand with silt to a depth of 33 feet where dense to very dense sand was encountered to a depth of 50.5 feet, the maximum depth explored.

Geotechnical Resources, Inc. (GRI) completed a subsurface exploration program in Kentuck Slough valley and reported their findings in a Preliminary Geotechnical Report dated July 2, 2010 (GRI, 2010). Boring B-1 of that report was completed approximately 250 feet southwest of the eastern end of the proposed HDD crossing. B-1 encountered about 10 feet of sandy fill (associated with East Bay Road) overlying soft silt to a depth of 15 feet, where very loose sand was encountered to a depth of 20 feet. Below 20 feet, very soft to soft silt with trace wood debris was encountered to a depth of 100 feet where very loose sand was encountered to 101.5 feet, the maximum depth explored.

PRELIMINARY HDD DESIGN CONSIDERATIONS

General

Due to the substantial length of the proposed HDD, GeoEngineers evaluated two potential alternatives for accomplishing the proposed Coos Bay East 36-inch HDD installation; a single 8,972-foot-long alternative and two shorter HDDs connected by an open cut tie-in located within the tidal flats of Coos Bay. The following describes the basis of design for these two alternatives.

Single HDD Option

We developed a conceptual HDD alignment and profile for the Coos Bay East 36-inch diameter HDD as shown in Figure 2A, with a horizontal design length of approximately 8,972 feet. Due to the substantial length of the HDD, we anticipate that it will be completed using pilot hole intersect methods. The conceptual HDD alignment extends eastward from North Point in North Bend, Oregon, crosses the Coos Bay navigation channel and terminates at the mouth of Kentuck Slough east of East Bay Road. For this conceptual design, the carrier pipe would be strung and fabricated along the Kentuck Slough valley floor on the east end of the crossing as shown in Figure 2B. The bottom tangent was designed with a 25.62-degree horizontal curve, in order to accomplish the necessary alignment to facilitate the pipe string laydown area along Kentuck Slough. Because this crossing would be completed using pilot hole intersect methods, both ends are identified as entry points. We chose a 12-degree entry angle on the west end in order to achieve a suitable depth below the navigation channel. A typical angle of 10 degrees was selected for the east side entry angle, and a radius of curvature of 4,000 feet was selected for both vertical curves and the horizontal curve. The bottom tangent was placed at an elevation of -190 feet, with the assumption that the bottom tangent and horizontal curve will be within bedrock at that depth. This assumption is critical for the feasibility of this option.

Dual HDD with Tie-in Option

GeoEngineers developed two HDD profiles, identified as HDD 1 and HDD 2, to accomplish the Coos Bay east crossing as shown in Figures 3A and 4A, respectively. The east entry point of HDD 1 is located within the tidal mud flats of Coos Bay approximately 250 feet south of Glasgow Point. HDD 1 extends westward a horizontal distance of 5,605 feet, crossing the Coos Bay navigation channel and terminating at the west entry point on land within North Point at the same location as the entry point for the single HDD option. The west entry point of HDD 2 is located about 48 feet from the east entry for HDD 1 and extends eastward a distance of 3,500 feet to the mouth of Kentuck Slough about 300 feet east of East Bay Road as shown in Figure 4A.

Typical entry angles of 10 and 12 degrees were selected for the conceptual profiles of East HDD 1 and East HDD 2. As with the single HDD option, the bottom tangent was placed at an elevation of -190 feet. However, depending on the results of the subsurface exploration program and hydraulic fracture analysis, it may not be necessary for the bottom tangent of HDD 1 and HDD 2 to be in bedrock.

The construction considerations for the single HDD and dual HDD with Tie-in Option are presented in the following section. The discussion for the dual HDD option assumes that both of the HDD 1 and HDD 2 segments will also be completed using pilot hole intersect methods. For discussion purposes, the HDD end points will be identified as east entry and west entry (for the single HDD option) or land side entry and water side entry (for the dual HDD option).

HDD CONSTRUCTION CONSIDERATIONS

General

Based on the information available as presented in this report it is our opinion that the proposed Coos Bay East HDD is technically feasible, pending the results of the subsurface exploration program and provided the considerations in this report are addressed in the design, preconstruction and construction phases of the project.

Site Access

Single HDD Option

Access to the conceptual west side workspace can be gained directly from surface streets servicing an industrial area at North Point in North Bend. The east side workspace could be accessed via a temporary entrance and access road off of East Bay Road west of the workspace. Matting or other subgrade stabilization methods will likely be needed to gain access to the east side entry workspace.

Dual HDD with Tie-In Option

Access to the land side entry points of each drill would be the same as described above for the single HDD option.

Because of the location of the shared in-water entry workspace in Coos Bay for the dual HDD option, access to the tie-in workspace location will have to be provided by barges or other marine vessels, and will be much more difficult than a typical land based HDD site. Because of tidal fluctuations, the tidal flats within the in-water workspace will be exposed at times such that dredging will be required between the navigation channel and the workspace area so that equipment barges can access the workspace. There is an existing shallow natural channel extending from the mouth of Kentuck Slough to the navigation channel that may be incorporated into the access route to the shared workspace to reduce the amount of dredging that would be required. A dredging plan will likely be required to address the dimensions and depth of the access channel, the dredging procedures and placement or disposal of spoils. In addition, the dredging plan will likely need to be permitted through the Army Corps of Engineers, Department of State Lands and/or other state and federal agencies. The HDD contractor can provide details of their plan to access the in-water workspaces as part of their HDD drill plan, and provide input regarding areas to be dredged. However, we assume that the project owner would be responsible for permitting dredging activities.

Workspace Considerations

Single HDD Option

The locations for both the east and west side workspaces are relatively flat and open such the adequate workspace will be available for drilling and installation operations. The east side would be located in a relatively flat low-lying area that may be prone to flooding which should be considered when scheduling and planning for construction.

The proposed carrier pipe stringing area would be located northeast of the east entry point along the Kentuck Slough valley floor. Kentuck Slough and Kentuck Way limit the available pipe string length to 5,293 feet so a tie-in weld will be required during pullback operations. The orientation of the HDD alignment would require two horizontal curves in the pull section, making fabricating and handling the pipe more difficult.

Dual HDD with Tie-In Option

The proposed shared water side entry (tie-in) workspace for both HDD installations is located in a tidal flat area south of Glasgow Point as shown in Figure 3A and 4A. The workspace is approximately 200 feet wide and 450 feet long. As mentioned above, the water side entry workspace will likely have to be dredged in order to stage equipment and provide access to support vessels.

Because of the tidal fluctuations, it will be necessary for the HDD contractor to install steel piles (dolphins) and support brackets (goal posts) to support the drill pipe string during HDD drilling operations. The location and depth of the dolphins is typically selected by the HDD contractor based on the configuration of the HDD equipment.

Workspace considerations for the land side entry points of each drill would be the same as described above for the single HDD option.

The proposed carrier pipe stringing area for HDD 1 would be located through the industrial area west of the land side entry point. The pipe string could pass beneath Highway 101, as the highway is on a raised bridge at the crossing location. The available area across North Point is not sufficiently wide to string the carrier pipe in one continuous section which would require a tie-in weld during pullback operations. The proposed carrier pipe stringing area for HDD 2 would be located northeast of the land side entry point along Kentuck

Slough. This area is of sufficient length to string the carrier pipe in one continuous section prior to pullback operations; however, the orientation of the HDD alignment would require two horizontal curves in the pull section, making fabricating and handling the pipe more difficult.

Drilling Fluid Containment

Single HDD Option

Drilling fluid containment for the Single HDD Option will be via relatively small fluid containment pits excavated adjacent to the entry points of the drill. These pits typically measure approximately 6 to 10 feet square and 4 to 6 feet deep. During drilling operations, drilling fluid returns and cuttings from downhole flow into the pits where the fluid is then pumped to a recycling system where most of the cuttings are removed and the drilling fluid can be recirculated downhole.

Dual HDD with Tie-In Option

By virtue of the fact that both conceptual HDD installations will involve entry points located in water, drilling fluids will be released to the Coos Bay tidal flat during normal operations as a result of drilling fluid circulation if containment measures are not implemented. Drilling fluids may be contained at the water side entry points during pilot hole operations through use of small-diameter conductor casing; however, additional measures will need to be implemented at the water side entry points during reaming operations to contain the drilling fluids.

During reaming operations, it will be preferable to promote drilling fluid returns toward land side entry where they can be more easily contained, recycled, and reused. This may be accomplished by not reaming the pilot hole through the last 200 to 250 feet of the entry tangent until the final reaming pass. Once the entry tangent is reamed to its final diameter, a relatively large drilling fluid returns pit and or containment such as sheet piling may be required at entry to contain drilling fluid returns that surface at the entry point. Containment and recycling operations will need to be executed considering tidal fluctuations. Alternatively, large-diameter casing could be installed prior to reaming operations at the water side entry points to contain drilling fluid on the barge or other containment structure.

Drilling fluid at the land side entry points of both drills could be contained conventionally in shallow pits as described above for the long option HDD.

Pilot Hole Considerations

Based on our experience with similar HDD projects of this length and diameter, we anticipate that the pilot bit diameter will likely range from 9.875 to 12.25 inches. We also anticipate that the pilot hole will most likely be advanced using a jetting assembly through the alluvial soils, and a positive displacement mud motor through the underlying dense to very dense sand and sandstone bedrock, if the proposed HDD profile encounters bedrock.

Single HDD Option

Because of the relatively large degree of horizontal curvature in the alignment of the conceptual HDD and the need to complete a pilot hole intersect within the bay, the use of a magnetic based steering tool may be more advantageous than a gyroscopic steering tool. Currently, the gyroscopic steering tool does not have the secondary survey capabilities offered by the magnetic based steering tool systems. The ability to obtain secondary survey data should aid in advancing the pilot hole within acceptable tolerances and help to complete the pilot hole intersect. For this crossing, the installation and survey of the secondary survey coil wire across the tidal flats will be somewhat more difficult because of the tidal fluctuations. The contractor will need to devise a method of installing the wire given the tidal fluctuations and anchor the wire so that it does not move with the currents. If the wire is not sufficiently anchored, the wire can move which would result in inaccurate survey data. It will not be possible to install the survey coil wire across the navigation channel, so the contractor will have to rely on the downhole steering tool data while crossing the channel.

Dual HDD Option

Because of the difficulty in placing a secondary survey coil wire (used with magnetic based steering tools) along the HDD alignment in the navigation channel and across the tidal flat, it may be preferable for the contractor to use a gyroscopic steering tool to complete the pilot hole. However, the gyroscopic steering tool is sensitive to excessive vibration, particularly when drilling through rock, and requires a skilled surveyor to make constant adjustments to maintain accuracy and account for accumulated error in the survey data. It is typically the HDD contractor's responsibility to choose appropriate means and methods to track the pilot hole.

To accommodate forces generated during pilot hole operations and to maintain drilling fluid returns to the drill barge, support structures (dolphins and goal posts) and an appropriately sized steel casing will likely be required between the drill platform and the entry point for both HDDs.

Reaming Considerations

Single HDD Option

Because of the length of the single HDD option, there is an increased risk of drilling fluid surface release during reaming operations. This risk can be reduced by reaming the hole from both ends of the crossing. This methodology helps reduce downhole annular drilling fluid pressures by shortening the flow path of the drilling fluid through the hole. Although this increased risk doesn't necessarily affect the technical feasibility of the proposed HDD, reaming from both sides of the crossing could potentially have cost impacts that may require consideration.

Dual HDD With Tie-In Option

As discussed in the drilling fluid containment section above, the HDD contractor might elect to not ream the last 200 to 250 feet of entry tangent of the drill profile until the hole is reamed to the final diameter to promote the flow of drilling fluid to the land-side containment pit. This will reduce the volume of drilling fluid that needs to be collected, recycled and pumped downhole from the drill and support barges within the bay.

Pullback

Single HDD Option

As previously described, the fabrication and stringing workspace for the single HDD option would be in the Kentuck Slough valley. The pipe could be fabricated along a straight alignment within the valley but because of the orientation of the HDD alignment relative to that of the valley, the pull section for installation would have to have to be positioned with two horizontal curves for pullback operations. In addition, the practical length of the fabrication and stringing workspace is not sufficient to fabricate the pull section into one continuous section which will require that a minimum of one tie-in weld will be required during pullback operations.

Because of the length of the conceptual HDD, the horizontal curvature in the alignment and the need to make at least one tie-in weld during pullback, it may be necessary to utilize a pipe thruster on the east side of the crossing to help assist the installation process if needed.

Dual HDD With Tie-In Option

The fabrication and stringing workspaces for both conceptual HDDs would be on the land side of each crossing. Because of the tidal flat conditions within the bay, attempting to float the pipe in the bay and installing the pipe from the water side to the land side would be more complex and expensive.

For HDD #1, the stringing and fabrication workspace would be located west of the crossing; however, there is not sufficient workspace to fabricate the pull section into one continuous section which will require that a minimum of one tie-in weld will be required during pullback operations.

For HDD #2, the stringing and fabrication workspace would be located east of the crossing with sufficient workspace to fabricate the pull section into one continuous section prior to pullback operations. The pipe could be fabricated along a straight alignment within the valley but because of the orientation of the HDD alignment relative to that of the valley, the pull section for installation would have to have to be positioned with two horizontal curves for pullback operations.

Because both HDD #1 and HDD #2 would install the pipe from land side to water side, the barge would have to be anchored sufficiently to resist the lateral loads imposed by the drill rig during the installation process.

Drill Hole Stability

The stability of the hole during HDD operations is dependent on a number of factors, including the type and composition of the soils, drilling fluid properties, groundwater conditions and the HDD profile geometry. Holes drilled or reamed through loose soil formations, soil formations with significant gravel content, dry hole sections and fractured rock formations with poor rock quality are prone to exhibiting instabilities.

In general, we expect the risk of drill hole instability along the conceptual HDD drill paths (either option) to be relatively low. Minor hole instabilities may be encountered within the very loose to loose soils expected along the upper portions of the HDD profile at the east end near Kentuck Slough, but we do not anticipate that this condition will jeopardize the successful installation of the product pipe. If hole instabilities are anticipated within the shallow portions of the drill profiles, large-diameter casing can be installed through the tangent sections of the drill profiles to stabilize those areas. The casing would need to be sized sufficiently to allow the reaming tools to pass through it. For the proposed 36-inch carrier pipe and anticipated final ream diameter of 48 inches, we anticipate that the large-diameter casing would need to be a minimum of 56 inches in diameter.

Hydraulic Fracture and Drilling Fluid Surface Release

Drilling fluid loss can occur as a result of either formational fluid loss or hydraulic fracture. The loss of drilling fluid downhole is accompanied by either partial or full loss of drilling fluid returns to the entry and/or exit pits.

Formational drilling fluid losses typically occur when the drilling fluid flows through the pore spaces in the surrounding formation. Thus, a formation with a higher porosity can potentially absorb a larger volume of drilling fluid than a formation with a lower porosity. Coarse sands and gravel units with low percentages of silt and clay and fractured rock formations have a moderate to high susceptibility for drilling fluid loss. Without additional subsurface information along the HDD alignment, it is not currently possible to estimate the risk of substantial formational fluid loss.

Hydraulic fracture is a term typically used to describe the condition in which the downhole drilling fluid pressure exceeds the overburden pressure and shear strength of the formation surrounding a drill path. The risk of hydraulically fracturing subsurface formations during the HDD process generally depends on the type and shear strength of the formation and the downhole drilling fluid pressures. Drilling fluid pressures used for HDD construction are not typically high enough to cause hydraulic fracture of intact bedrock because the shear strength of the rock far exceeds the drilling fluid pressures downhole. Downhole drilling fluid pressures can easily exceed the shear strength of soil formations. In general, fine-grained soils such as silt and clays have a relatively moderate to high risk of hydraulic fracture, whereas granular soils such as sands have a relatively low risk of hydraulic fracture. In general, we expect that there is a relatively low risk of hydraulic fracture occurring during HDD installation because much of the HDD profile passes through sandy soils and potentially bedrock; however, this estimate of risk is contingent on the HDD contractor maintaining drilling fluid returns during all phases of drilling activities.

We anticipate a relatively low risk of drilling fluid surface releases occurring along most of the HDD alignment during construction, primarily because the design intent is to place the bottom tangent of either option within bedrock. However, very soft to soft silt is expected to depth of 100 feet at the east end of the crossing approaching Kentuck Slough. We expect that there is a high risk of hydraulic fracture and drilling fluid surface release along the east side entry tangent of the long, single HDD option and HDD 2 of the Dual HDD with Tie-In option. Large-diameter casing can be utilized to mitigate the potential for hydraulic fracturing. The casing would need to be sized sufficiently to allow the reaming tools to pass through it. For the proposed 36-inch carrier pipe and anticipated final ream diameter of 48 inches, we anticipate that the large-diameter casing would need to be a minimum of 56 inches in diameter.

Installation of oversized casing at the east end of the HDD crossing will require that East HDD 2 be completed as a pilot hole intersect, since the west end of the HDD will also likely utilize casing for drilling fluid containment as describe in more detail below.

For the dual HDD option, drilling fluids will be released to the Coos Bay floor at the conceptual entry points at the tie in location in Coos Bay during normal operations of drilling fluid circulation, unless they are. contained at the water side entry points during pilot hole operations through use of a conductor casing.

Additional measures will need to be implemented during reaming operations to contain the drilling fluids. During reaming operations, the volume of drilling fluid that surfaces at the entry point could be reduced by not reaming the pilot hole through the entry tangent until the final reaming pass. Once the entry tangent is reamed to its final diameter, a relatively large drilling fluid returns pit and or containment such as sheet piling may be required at entry to contain drilling fluid returns that surface at the entry point. Leaving the soil plug at entry through much of the reaming operations promotes drilling fluids returns to land side of the crossings where they can be more easily contained, recycled, and reused. Containment and recycling operations will need to be executed considering tidal fluctuations.

CONCLUSIONS

The following summarizes the primary considerations for the Single HDD and Dual HDD with Tie-In Options.

Single HDD Option

1. Additional subsurface exploration and laboratory testing is required to confirm the construction considerations and feasibility conclusions presented in this report, and to provide subsurface information required for final design of the conceptual HDD. Proposed boring locations and depths are shown in Figure 2A.

2. Due to the substantial length of the HDD, we anticipate that it will be completed using pilot hole intersect methods.

3. It will be necessary to design the HDD to maximize the amount of drill path within bedrock.

4. Oversized casing will likely need to be installed at the eastside entry to assist in efficiently transferring axial loads to the drill bit, and to mitigate against hydraulic fracture and drilling fluid surface releases within the soft silts along the east end of the HDD path.

Dual HDD Option with Tie-In

1. Additional subsurface exploration and laboratory testing is required to confirm the construction considerations and feasibility conclusions presented in this report, and to provide subsurface information required for final design of the conceptual HDDs. Proposed boring locations and depths are shown in Figure 3A and 4A.

2. Due to the length of the HDD 1, we anticipate that it will be completed using pilot hole intersect methods.

3. Dredging will likely be required along the tidal mud flats to provide barge access to the water side entry works space for HDD 1 and HDD 2.

4. Drilling fluids will need to be contained at the water side entry of HDD 1 and HDD 2 during pilot hole operations through use of small-diameter conductor casing; however, additional measures will need to be implemented at the water side entry during reaming operations to contain the drilling fluids.

5. Oversized casing will likely need to be installed at the land side entry of HDD 2 to assist in efficiently transferring axial loads to the drill bit, and to mitigate against hydraulic fracture and drilling fluid surface releases within the soft silts along the east end of the HDD path.

6. Due to the need for casing at both ends of HDD 2, we anticipate that it will be completed using pilot hole intersect methods.

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GRI, July 2, 2010. Preliminary Geotechnical Report, Kentuck Slough Mitigation Site, North Bend, Oregon.

LIMITATIONS

We have prepared this report for use by PCGP and the design team, their authorized agents and other approved members of the design team involved with this project. The report is not intended for use by others, and the information contained herein is not applicable to other sites. The data and report should be provided to prospective contractors, but our report, conclusions and interpretations should not be construed as a warranty of the subsurface conditions. The conclusions and recommendations in this report should be applied in their entirety.

Within the limitations of scope, schedule and budget, our services have been executed in accordance with generally accepted practices in this area at the time the report was prepared. The conclusions, recommendations, and opinions presented in this report are based on our professional knowledge, judgment and experience. No warranty or other conditions, express or implied, should be understood.

Any electronic form, facsimile or hard copy of the original document (email, text, table and/or figure), if provided, and any attachments should be considered a copy of the original document. The original document is stored by GeoEngineers, Inc. and will serve as the official document of record.

CLOSING

We appreciate the opportunity to provide services to PCGP. Please call if you have any questions concerning this report or if we can be of further assistance.

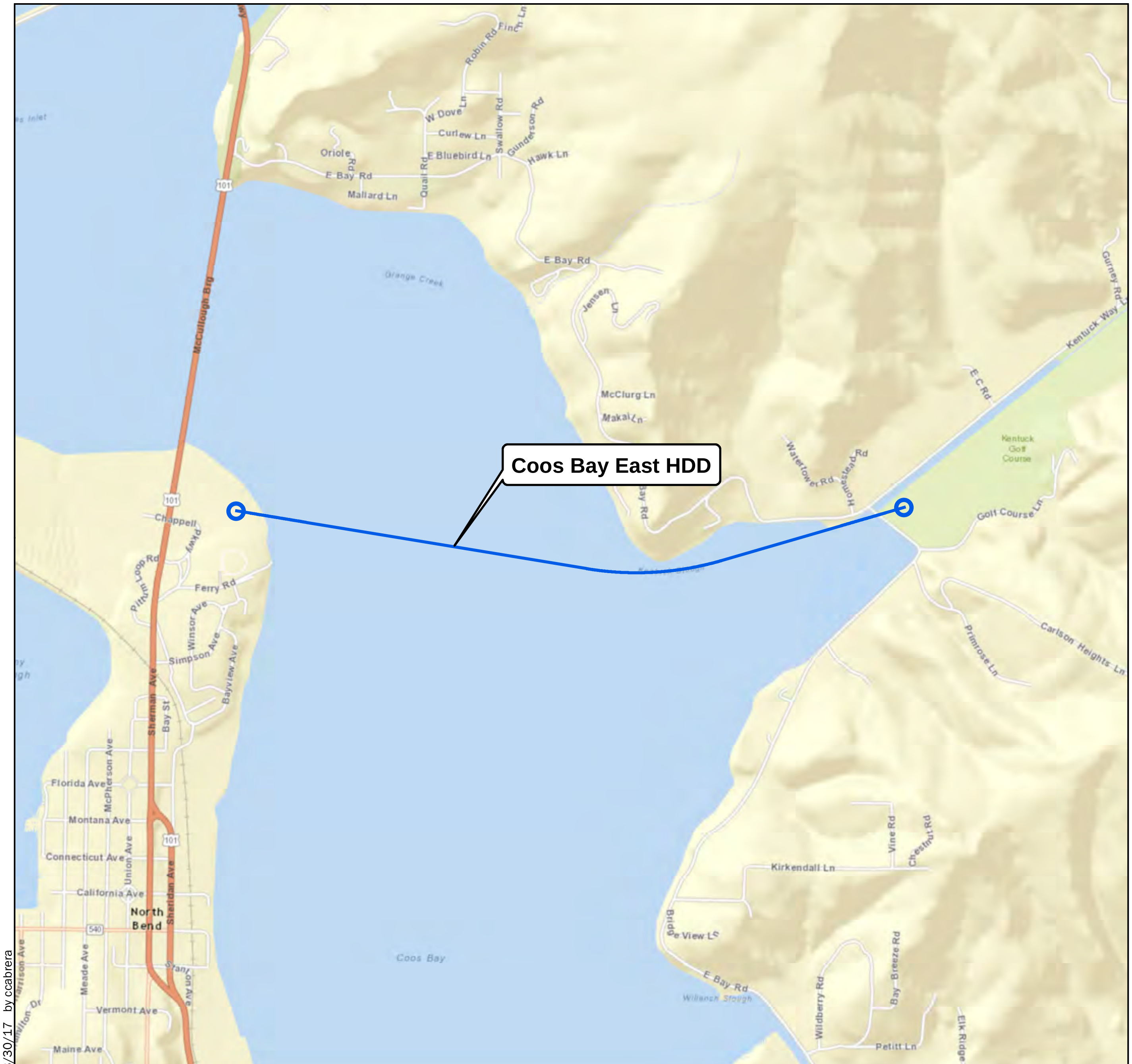
Sincerely,
GeoEngineers, Inc.

Mark Miller, PE
Principal

Trevor N. Hoyles, PE
Principal

AES:MAM:TNH:cje:mlh

List of Figures:



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Feet

Notes:

1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Data Source: Mapbox Open Street Map, 2017

Projection: NAD 1983 UTM Zone 10N

Vicinity Map

COOS BAY EAST HDD
COOS COUNTY, OREGON

GEOENGINEERS

Figure 1

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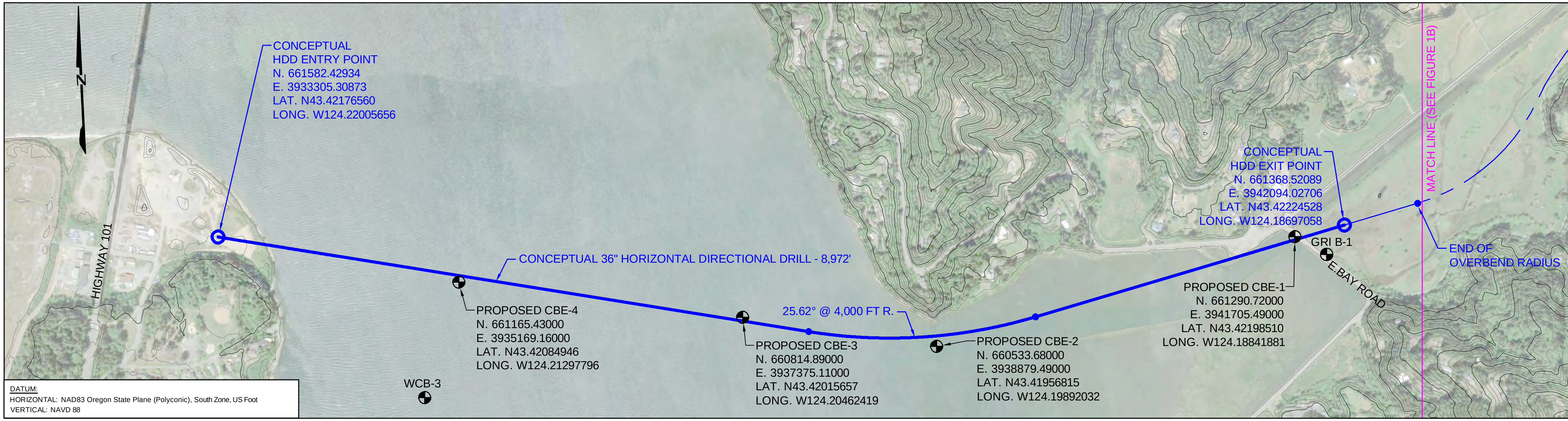

NOT FOR CONSTRUCTION

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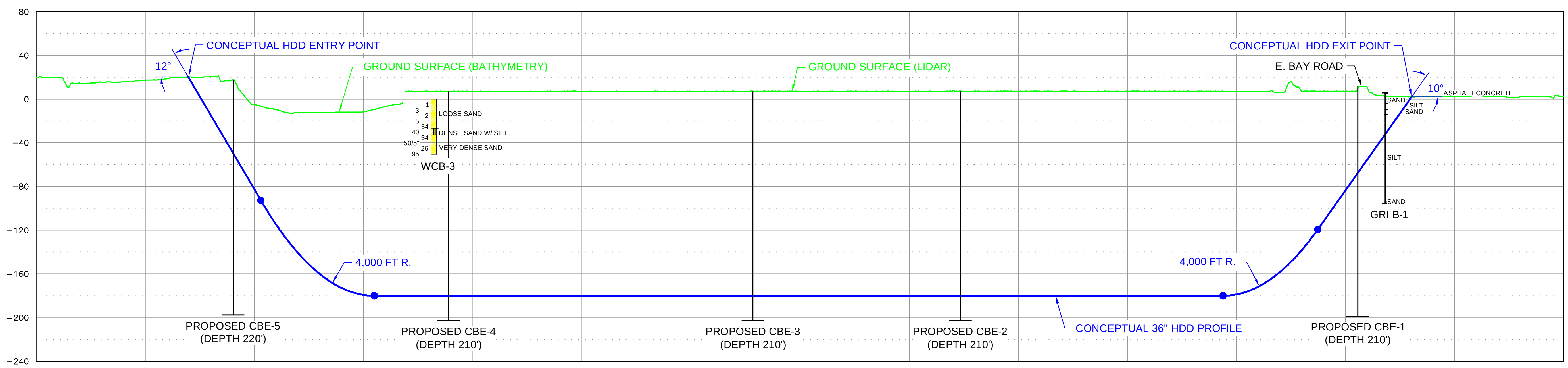

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VERTICAL SCALE IN FEET

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Ground surface bathymetry downloaded from https://www.ngdc.noaa.gov/nos/H10001-H12000/H11745.html

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FOR DISCUSSION ONLY

LEGEND:

Proposed Boring Location
Major Contour - 40' Interval
Minor Contour - 10' Interval

CONCEPTUAL SITE PLAN AND PROFILE

COOS BAY EAST HDD
COOS COUNTY, OREGON

GEOENGINEERS

FIGURE 2A

ISSUED DATE: AUGUST, 2017

TNH : RBM

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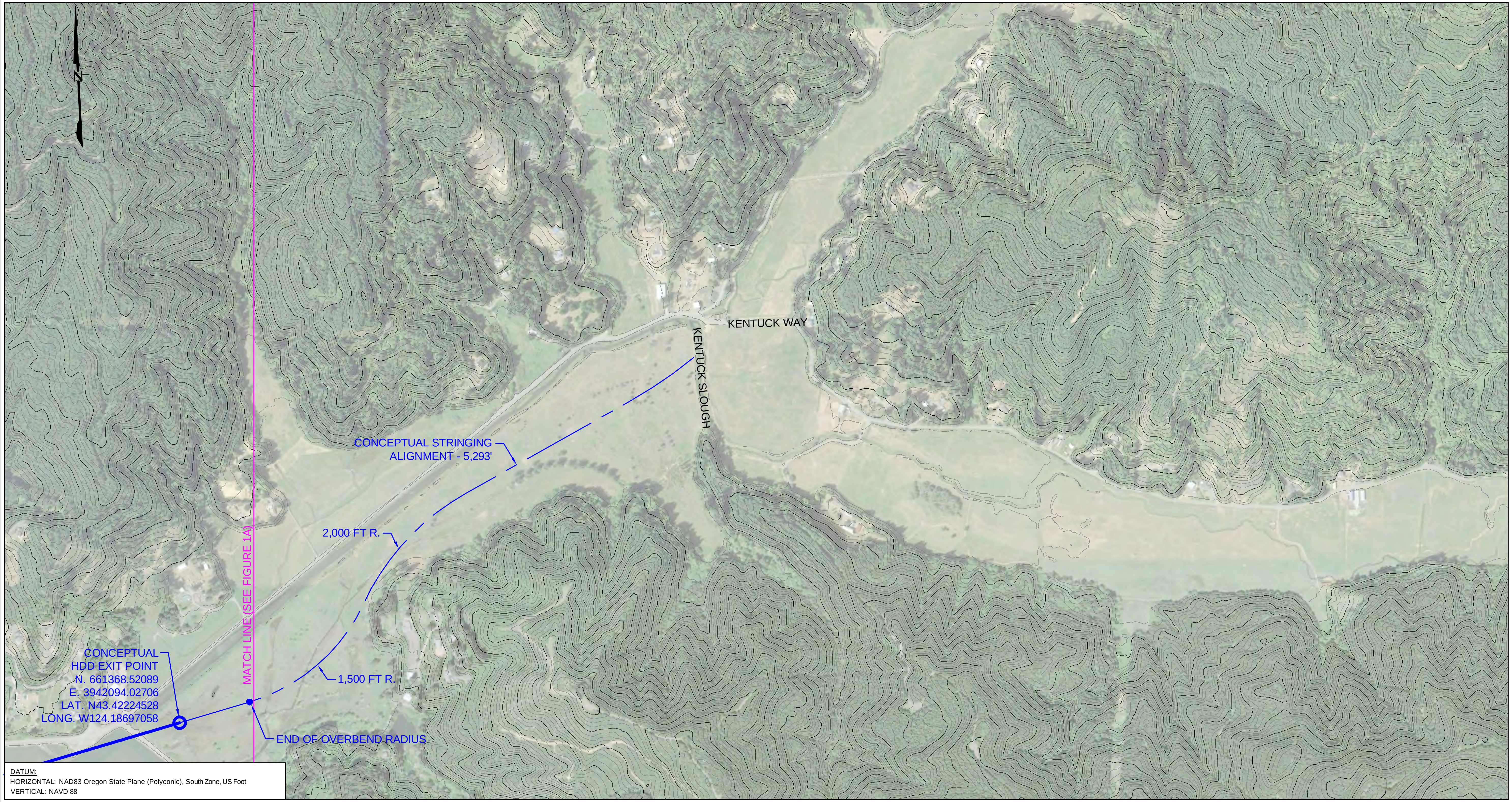

DATUM:
HORIZONTAL: NAD83 Oregon State Plane (Polyconic), South Zone, US Foot
VERTICAL: NAVD 88

Notes:
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PLAN
800 0 800
SCALE IN FEET

NOT FOR CONSTRUCTION
FOR DISCUSSION ONLY

LEGEND:
Major Contour - 40' Interval
Minor Contour - 10' Interval

CONCEPTUAL STRINGING WORKSPACE

COOS BAY EAST HDD
COOS COUNTY, OREGON

GEOENGINEERS

FIGURE 2B

ISSUED DATE: AUGUST, 2017

TNH : RBM

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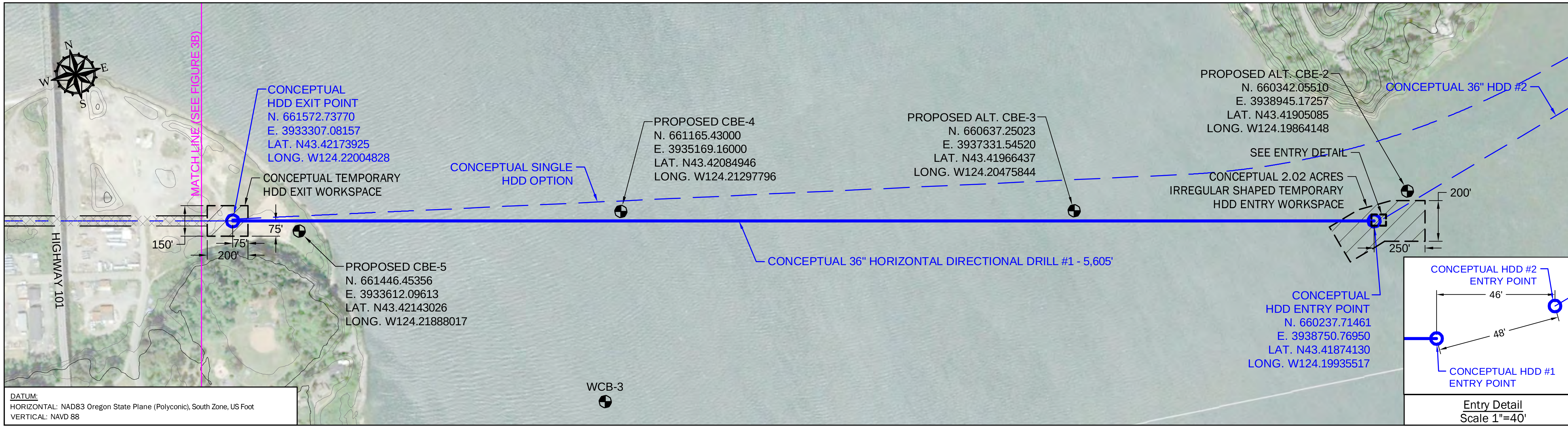
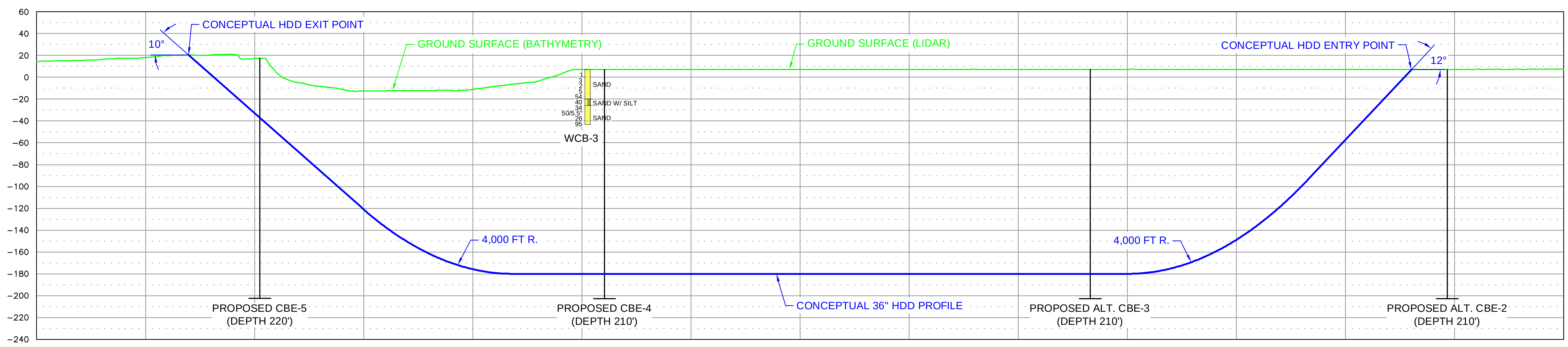
TNH : RBM



Not For Construction

Plan



Profile

Notes:

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Ground surface bathymetry downloaded from https://www.ngdc.noaa.gov/nos/H10001-H12000/H11745.html

Legend

- Proposed Boring Profile
- Proposed Boring Location
- Major Contour - 10' Interval
- Minor Contour - 2' Interval

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Horizontal Scale in Feet

100 0 100
Vertical Scale in Feet
Vertical Exaggeration: 5X

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Conceptual Site Plan and Profile

Coos Bay East HDD #1
Coos County, Oregon

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Figure 3A

Issued Date: August, 2017

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Legend

- Proposed Boring Location
- Major Contour - 10' Interval
- Minor Contour - 2' Interval

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N E S W

500 0 500
Feet

Conceptual Stringing Workspace

Coos Bay East HDD #1
Coos County, Oregon

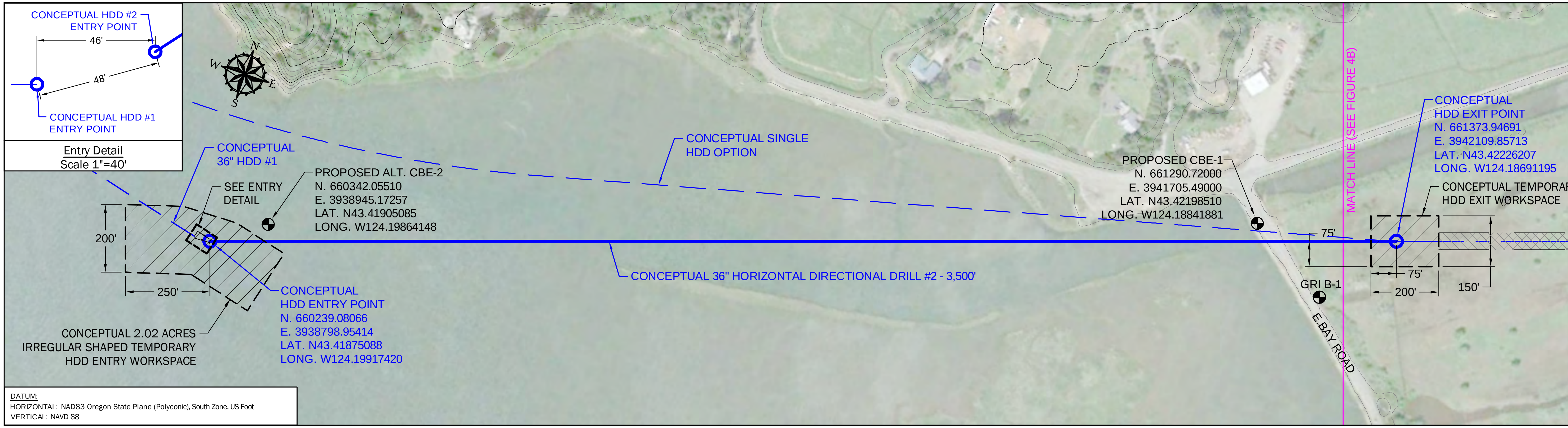
GEOENGINEERS

Figure 3B

Issued Date: August, 2017

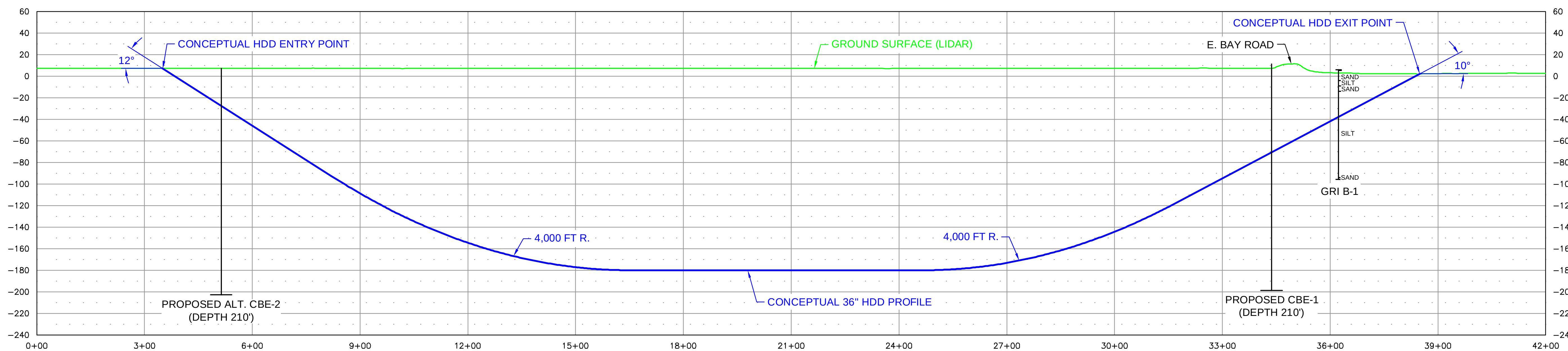
TNH : RBM

P:\22\2270800\1\CAD\Crossings\Kentuck Inlet\Coos Bay East HDD 1.dwg\TAB:Figure 1B modified on Aug 31, 2017 - 9:28am



Not For Construction

Plan



Profile

Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Reference: Ground surface Lidar downloaded from http://www.oregongeology.org/dogamilidarviewer/. Aerial image taken From Google Earth Pro © 2016, licensed to GeoEngineers, Inc., image dated 01/15/16.
Ground surface bathymetry downloaded from https://www.ngdc.noaa.gov/nos/H10001-H12000/H11745.html

Legend

- Proposed Boring Profile
- Proposed Boring Location
- Major Contour - 10' Interval
- Minor Contour - 2' Interval

300 0 300
Horizontal Scale in Feet

100 0 100
Vertical Scale in Feet
Vertical Exaggeration: 3X

NOT FOR CONSTRUCTION
FOR DISCUSSION ONLY

Conceptual Site Plan and Profile

Coos Bay East HDD #2
Coos County, Oregon

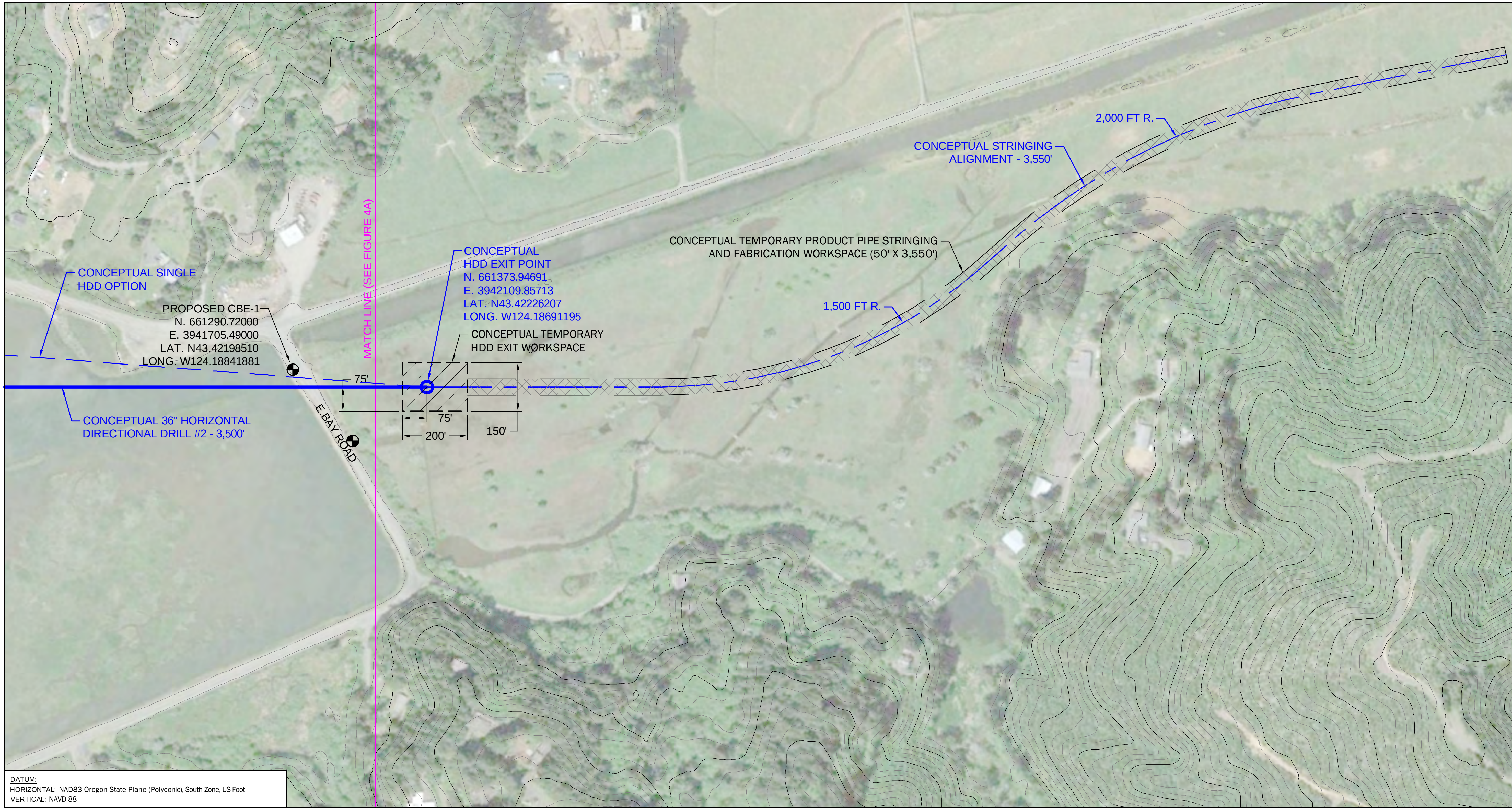
GEOENGINEERS

Figure 4A

Issued Date: August, 2017

TNH : RBM

P:\22\22708001\CAD\Crossings\Kentuck Inlet\Coos Bay East HDD 2.dwg\TAB:Figure 2A modified on Aug 31, 2017 - 9:29am



TNH : RBM

P:\2\2708001\CAD\Crossings\Kentuck Inlet\Coos Bay East HDD 2.dwg\TAB:Figure 2B modified on Aug 31, 2017 - 9:30am

Notes:
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Reference: Ground surface Lidar downloaded from http://www.oregongeology.org/dogamilidarviewer/. Aerial image taken From Google Earth Pro © 2016, licensed to GeoEngineers, Inc., image dated 01/15/16.
Ground surface bathymetry downloaded from https://www.ngdc.noaa.gov/nos/H10001-H12000/H11745.html

Legend

- Proposed Boring Location
- Major Contour - 10' Interval
- Minor Contour - 2' Interval

NOT FOR CONSTRUCTION
FOR DISCUSSION ONLY

N W E S

300 0 300
Feet

Conceptual Stringing Workspace

Coos Bay East HDD #2
Coos County, Oregon

GEOENGINEERS

Figure 4B

Issued Date: August, 2017

Date(s) Drilled	12/18/06	Logged By	John Lawes	Checked By	SRR
Drilling Contractor	Crux	Drilling Method	Mud Rotary	Sampling Methods	SPT/D&M
Auger Data	HWT/HQ-3 casing advancer	Hammer Data	140 lb hammer/30 in drop	Drilling Equipment	DWM-6500 Barge-mounted drilling
Total Depth (ft)	50.5	Surface Elevation (ft)		Groundwater Level (ft. bgs)	Not Encountered
Vertical Datum		Datum/ System		Easting(x): Northing(y):	

Depth feet	SAMPLES: Interval	Recovered (in)	Blows/foot	Sub-Sample Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
0							SP	Dark gray fine poorly graded sand with trace shell (very loose, wet)			
5		10	1	1					24		SA %F=3.5 pH=7.2
10		9	3	2				Some medium sand with abundant shell and trace wood fragments	30		pH=7.7
15		4	2	3				Fine sand with trace shell			%F=3.6 pH=8.1
20			5	4				Becomes loose with abundant broken shell and trace medium sand	28		pH=5.5 Resistivity=310 ohm-cm
25		10	54	5				Becomes medium dense with trace broken shell			
30		8	40	6			SP-SM	Dark gray fine poorly graded sand with silt with trace shell fragments (dense, wet)			%F=6.0
35		7	34	7			SP	Dark gray fine poorly graded sand (dense, wet)			

Note: See Figure A-1 for explanation of symbols.

V6_GTBORING C:\DOCUME~1\JATKINS\LOCALS~1\TEMPOR~1\OLK8\816902107.GPJ GEIV6_1.GDT 2/1/07

LOG OF BORING WCB-3

GEOENGINEERS

Project: Pacific Connector Gas Pipeline
Project Location: Coos Bay, Oregon
Project Number: 8169-021-07 T2

Figure 5
Sheet 1 of 2

Depth feet	Interval	Recovered (in)	Blows/foot	Sub-Sample Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
35											
40		9	50/5½"	8				Becomes very dense			
45		10	26	9				Becomes medium dense			%F=1.8
50			95	10				Becomes very dense			

Heaving sand generally encountered in loose and very loose sand deposits

55

60

65

70

75

LOG OF BORING WCB-3 (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline
Project Location: Coos Bay, Oregon
Project Number: 8169-021-07 T2

GeoEngineers
1200 NW Naito Pkwy., Ste. 180
Portland, Oregon 97209
503.624.9274

September 14, 2017

Pacific Connector Gas Pipeline, LP
5615 Kirby Drive, Suite 500
Houston, Texas 77004

Attention: John Walls

Subject: HDD Feasibility Evaluation
Coos Bay West Crossing
Pacific Connector Gas Pipeline Project
Coos County, Oregon
File No. 22708-001-01

INTRODUCTION AND PROJECT UNDERSTANDING

GeoEngineers, Inc. (GeoEngineers) is pleased to present this horizontal directional drilling (HDD) feasibility evaluation for the proposed 36-inch-diameter pipeline installation beneath Coos Bay in Coos Bay, Oregon. The proposed Coos Bay West HDD crossing will be a part of the 229-mile-long Pacific Connector Gas Pipeline (PCGP), beginning at the proposed Jordan Cove Liquefied Natural Gas (LNG) Terminal near Coos Bay, Oregon and terminating near Malin, Oregon. The site is shown with respect to the surrounding area in the Vicinity Map, Figure 1.

Our feasibility evaluation of the proposed Coos Bay West HDD is based on limited subsurface data. Our conclusions should be considered preliminary pending completion of a subsurface exploration program. Table 1 below provides our understanding of the design basis for the proposed HDD.

TABLE 1. BASIS OF DESIGN FOR THE COOS BAY HDD

Product Pipe Data	Design Parameter
Product Pipe Specifications	36 inches x 0.823 inches w.t.[a] API-5L X-70 Steel Pipe
Approximate Horizontal Crossing Length	5,192 feet
Maximum Allowable Operating Pressure	1,600 psig[b]
Maximum Operating Temperature	100 degrees F

Product Pipe Data	Design Parameter
Tie-In Temperature	70 degrees F
Design Factor[c]	0.5

Notes:

[a] w.t. – wall thickness

[b] psig – pounds per square inch gauge

[c] as defined in 49 CFR Parts 195.106 and 192.111

PURPOSE AND SCOPE OF SERVICES

The purpose of our services was to utilize existing subsurface and site survey information in order to evaluate the feasibility of the proposed HDD installation. Our specific scope of services included the following:

1. Reviewed geologic maps and boring logs of previously completed borings in the project area to evaluate geologic conditions along the HDD alignment.
2. Evaluated the feasibility of the proposed HDD from the workspace considerations, subsurface considerations and geometric feasibility standpoints.
3. Prepared a conceptual HDD plan and profile drawing.
4. Prepared this HDD feasibility report summarizing HDD feasibility and construction considerations.

SURFACE CONDITIONS

The Coos Bay West HDD extends from the North Spit at Milepost 0.0 of the proposed pipeline and extends a distance of approximately 5,192 feet to the southeast, crossing the Coos Bay navigation channel and terminating at North Point in North Bend, Oregon as shown in the Site Plan and Profile, Figure 2A. Surface conditions at both ends of the Coos Bay West HDD consist of a relatively flat ground surface vegetated with sparse grass. The conceptual HDD alignment crosses a railroad trestle bridge within Coos Bay.

SUBSURFACE SOIL AND GROUNDWATER CONDITIONS

Site Geology

Published geologic mapping shows that the shallow subsurface conditions along the HDD alignment is dominated by young alluvium. Alluvium is described as "…variable amounts of clay, silt, sand, and gravel."

Sedimentary bedrock of the Eocene-age Coaledo Formation is mapped by Baldwin et al. (1973) as underlying the uplands surrounding Coos Bay. Baldwin et al. (1973) notes that "(t)he Coaledo Formation occupies a north-plunging basin surrounding Coos Bay," implying that the Coaledo forms the bedrock within Coos Bay and is likely underlying the surficial alluvium.

The most detailed structural geology of the Coaledo Formation in north Coos Bay (Duncan 1953) includes an east-west cross section through Coos Bay, 1 mile north of the HDD alignment. It shows the upper contact of the Coaledo Formation beneath Coos Bay as an irregular basin deepening to the west to as much as

- 300 feet mean sea level (MSL). The top of the sedimentary rock is shown rising to approximately -150 feet MSL in the eastern half of Coos Bay.

SUBSURFACE EXPLORATIONS

GeoEngineers has completed a number of exploratory borings in Coos Bay to investigate various PCGP pipeline alignments. Two exploratory borings have been completed in the vicinity of the Coos Bay West HDD. Boring HIB-2 was completed at the south end of North Spit, approximately 265 feet southwest of the proposed exit point. Boring WCB-1 was completed within Coos Bay, approximately 1,037 feet northeast of the alignment. The boring locations are shown relative to the HDD alignment in Figure 2A. The boring logs of HIB-2 and WCB-3 are presented in Figures 3 and 4, respectively.

Boring HIB-2 encountered loose sand to a depth of 30 feet, where the sand grades to dense to a depth of 35 feet. Below 35 feet, very dense sand was observed to a depth of 90 feet, the maximum depth explored. Boring WCB-1 encountered very loose to loose fine sand with silt to a depth of 25 feet, where loose fine sand (no silt) was observed to 35 feet. At a depth of 35 feet, the sand grades to medium dense consistency and becomes very dense at a depth of 40 feet to 51.5 feet, the maximum depth explored.

HDD PLAN AND PROFILE

We developed a conceptual HDD Plan and Profile of the Coos Bay West HDD as shown in Figure 2A. The conceptual Coos Bay West HDD has a horizontal design length of approximately 5,192 feet. It is likely that the HDD will be completed using pilot hole intersect methods, but for discussion purposes we are referring to the southeast end of the Coos Bay West HDD as the entry point because the proposed pipe stringing and fabrication area is at the northwest end of the HDD. The conceptual entry point is located about 600 feet west of Highway 101, within a relatively flat area covered with sparse grass.

The conceptual exit point is located within a relatively flat area vegetated with sparse grass at the southern end of North Spit. We chose relatively steep entry and exit angles at 12 degrees, and 10 degrees respectively, in order to reach the dense sand layer as quickly as possible. The bottom tangent was placed at an elevation of -180 feet, with the assumption that the bottom tangent and horizontal curve will be within bedrock at that depth. Based on this HDD geometry, the conceptual HDD profile passes approximately 158 feet below the railroad trestle bridge and approximately 138 feet below the deepest part of the navigation channel. The depth and the locations of the railroad trestle foundations are unknown at this time. Although, we anticipate that the foundations are unlikely to conflict with the conceptual HDD alignment at its depth of 138 feet at the crossing location, this will need to be confirmed prior to final design.

HDD FEASIBILITY CONCLUSIONS

Based on our evaluation, it is our opinion that the proposed Coos Bay West HDD is technically feasible, pending the results of the subsurface exploration program and provided the considerations in this report are addressed in the design, preconstruction and construction phases of the project. The following section provides a discussion of considerations for design and construction based on the existing limited subsurface data. The existing boring logs extend to a maximum depth of 91.5 feet below ground surface.

Additional borings are planned to be completed within Coos Bay to 20 feet below the planned bottom tangent elevation, or an approximate depth of 200 feet below the mudline.

Hole Stability

The subsurface conditions anticipated along the conceptual HDD path includes loose sand to depths of about 30 feet along the entry and exit tangents, and dense sand to sandstone bedrock along the remaining portions of the HDD path. The HDD contractor may encounter hole instability and/or steering difficulty through the portions of the entry and exit tangents within the loose sand. Installation of casing at entry can serve to maintain drill hole stability and provide a reaction mass for allowing a greater transfer of axial loads through the drill pipe string to the drill bit during pilot hole drilling. In addition, the installation of casing will reduce the risk of drilling fluid surface release to the ground surface near the entry point. If casing is utilized, upon completion of the pilot hole or prior to reaming the cased section of the hole, the casing is typically removed, but could remain in place through product pipe pullback to maintain drill hole stability within the entry tangent. The specific casing diameter and installation would be determined by the HDD installation contractor.

Hydraulic Fracture and Inadvertent Returns

Drilling fluid loss can occur as a result of either formational fluid loss or hydraulic fracture. The loss of drilling fluid downhole is accompanied by either partial or full loss of drilling fluid returns to the entry and/or exit pits.

Formational drilling fluid losses typically occur when the drilling fluid flows through the pore spaces in the surrounding formation. Thus, a formation with a higher porosity can potentially absorb a larger volume of drilling fluid than a formation with a lower porosity. Coarse sands and gravel units with low percentages of silt and clay and fractured rock formations have a moderate to high susceptibility for drilling fluid loss. The fine to medium sand anticipated along the HDD path will have a low to moderate potential for formational fluid loss.

Hydraulic fracture is a term typically used to describe the condition in which the downhole drilling fluid pressure exceeds the overburden pressure and shear strength of the formation surrounding a drill path. The risk of hydraulically fracturing subsurface formations during the HDD process generally depends on the type and shear strength of the formation and the downhole drilling fluid pressures. Drilling fluid pressures used for HDD construction are not typically high enough to cause hydraulic fracture of intact bedrock because the shear strength of the rock far exceeds the drilling fluid pressures downhole. Downhole drilling fluid pressures can easily exceed the shear strength of soil formations. In general, fine-grained soils such as silt and clays have a relatively moderate to high risk of hydraulic fracture, whereas granular soils such as sands have a relatively low risk of hydraulic fracture. In general, we expect that there is a relatively low risk of hydraulic fracture occurring during HDD installation because much of the HDD profile passes through sandy soils and potentially bedrock; however, this estimate of risk is contingent on the HDD contractor maintaining drilling fluid returns during all phases of drilling activities.

We anticipate a relatively low risk of hydraulic fracture and drilling fluid surface releases occurring along most of the HDD alignment during construction. We expect that there is a high risk of hydraulic fracture and drilling fluid surface release within about 150 feet of either end of the HDD due to the anticipated loose sand and decreased depth of cover. As previously indicated, installation of large diameter conductor casing will reduce the risk of drilling fluid surface releases near entry.

Workspace Considerations

The locations for both the northwest (exit) and southeast (entry) workspaces are relatively flat and open such that adequate workspace will be available for drilling and installation operations. Grading will not be required to prepare entry and exit workspaces in these areas. Because of the loose sandy soils, it may be necessary to provide a stable working platform such as a timber matted or gravel workspace and an entrance road during construction, particularly if construction is completed during the wet winter season, or when heavy prolonged precipitation occurs. In addition, construction roads will be required to access the entry and exit points and the product pipe stringing area.

CONCLUSIONS

The following summarizes the primary considerations for the Coos Bay West HDD.

1. Additional subsurface exploration and laboratory testing is required to confirm the construction considerations and feasibility conclusions presented in this report, and to provide subsurface information required for final design of the conceptual HDD. Proposed boring locations and depths are shown in Figure 2A.
2. The railroad trestle foundation data will need to be obtained and considered for the HDD design.
3. Due to the substantial length of the HDD, we anticipate that it will be completed using pilot hole intersect methods.
4. It will be necessary to design the HDD to maximize the amount of drill path within bedrock.
5. Oversized casing may need to be installed at both ends of the HDD path to assist in efficiently transferring axial loads to the drill bit, and to mitigate against hydraulic fracture and drilling fluid surface releases within the loose sand anticipated in the upper 30 feet.

LIMITATIONS

We have prepared this report for use by PCGP and the design team, their authorized agents and other approved members of the design team involved with this project. The report is not intended for use by others, and the information contained herein is not applicable to other sites. The data and report should be provided to prospective contractors, but our report, conclusions and interpretations should not be construed as a warranty of the subsurface conditions. The conclusions and recommendations in this report should be applied in their entirety.

Within the limitations of scope, schedule and budget, our services have been executed in accordance with generally accepted practices in this area at the time the report was prepared. The conclusions, recommendations, and opinions presented in this report are based on our professional knowledge, judgment and experience. No warranty or other conditions, express or implied, should be understood.

REFERENCES

Baldwin, E.M., et al. 1973. Geology and Mineral Resources of Coos County, Oregon. Department of Geology and Mineral Industries, Bulletin 80.

Bourgoyne, A.T., et al. 1991. "Applied Drilling Engineering," Society of Petroleum Engineers.

Duncan, D.C. 1953. U.S. Geological Survey Bulletin 982-B, Geology and Coal Deposits in Part of the Coos Bay Coal Field, Coos Bay, Oregon.

Pipeline Research Committee International (PRCI) of the American Gas Association. April 15, 1995. "Installation of Pipelines by Horizontal Directional Drilling, An Engineering Design Guide," Contract No. PR-227-9424.

CLOSING

We appreciate the opportunity to provide services to PCGP. Please call if you have any questions concerning this report or if we can be of further assistance.

Sincerely,
GeoEngineers, Inc.

Brian Ranney
Senior Engineering Geologist

Trevor N. Hoyles, PE
Principal

BCR:TNH:cje

List of Figures:
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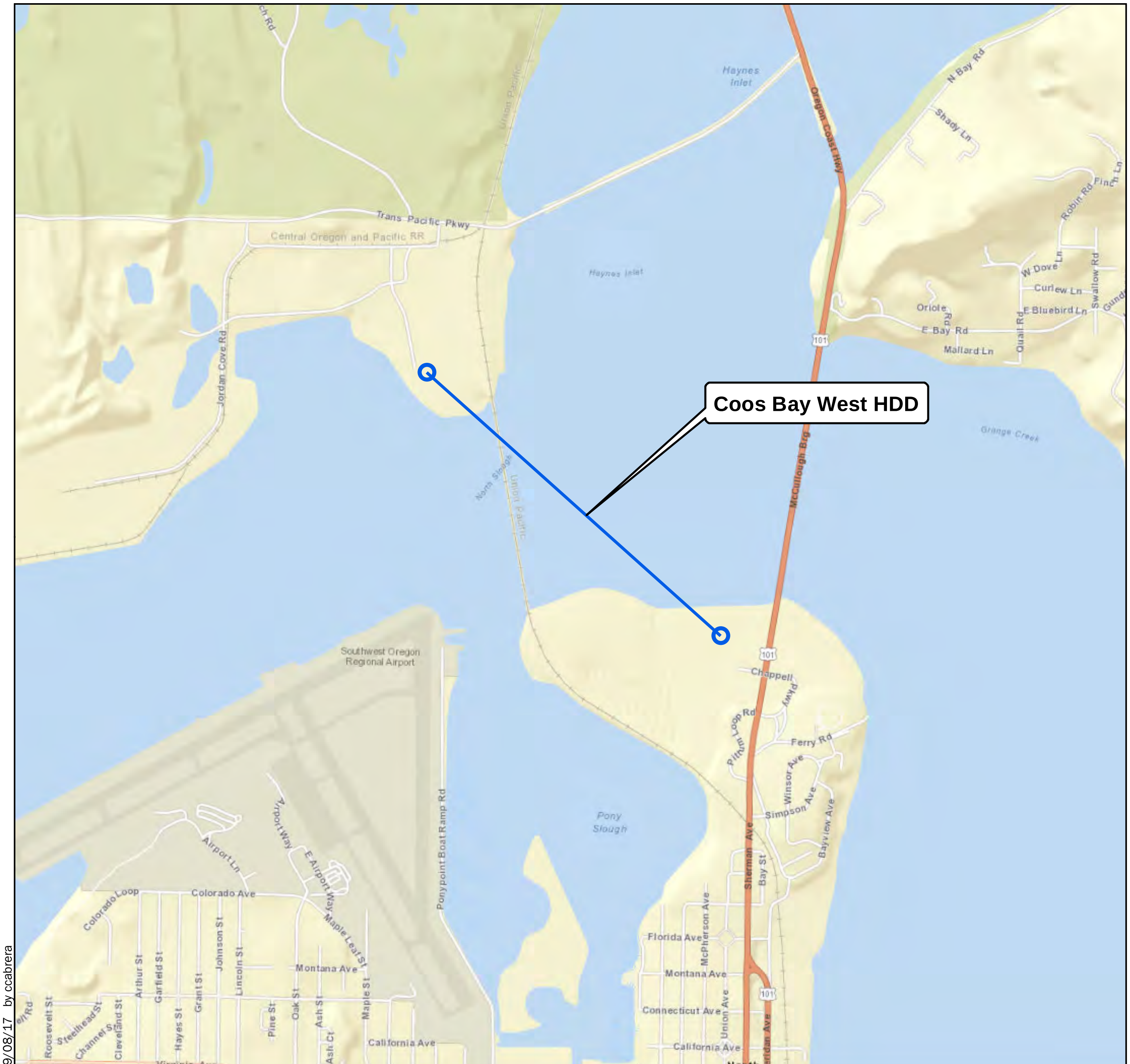
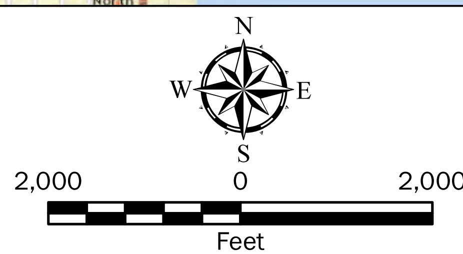
Figure 2A. Conceptual Site Plan and Profile, Coos Bay West HDD
Figure 2B. Conceptual Stringing Workspace, Coos Bay West HDD
Figure 3. HIB-2 Boring Log
Figure 4. WCB-1 Boring Log





Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Data Source: Mapbox Open Street Map, 2017

Projection: NAD 1983 UTM Zone 10N

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Vicinity Map

COOS BAY WEST HDD
COOS COUNTY, OREGON

GEOENGINEERS

Figure 1

TNH : RBM

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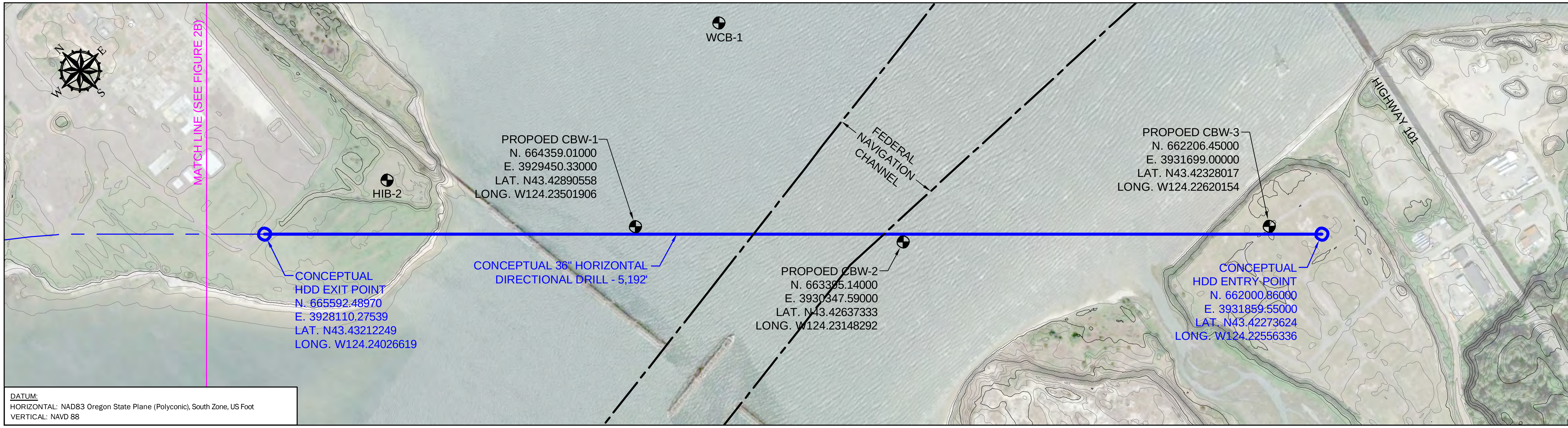

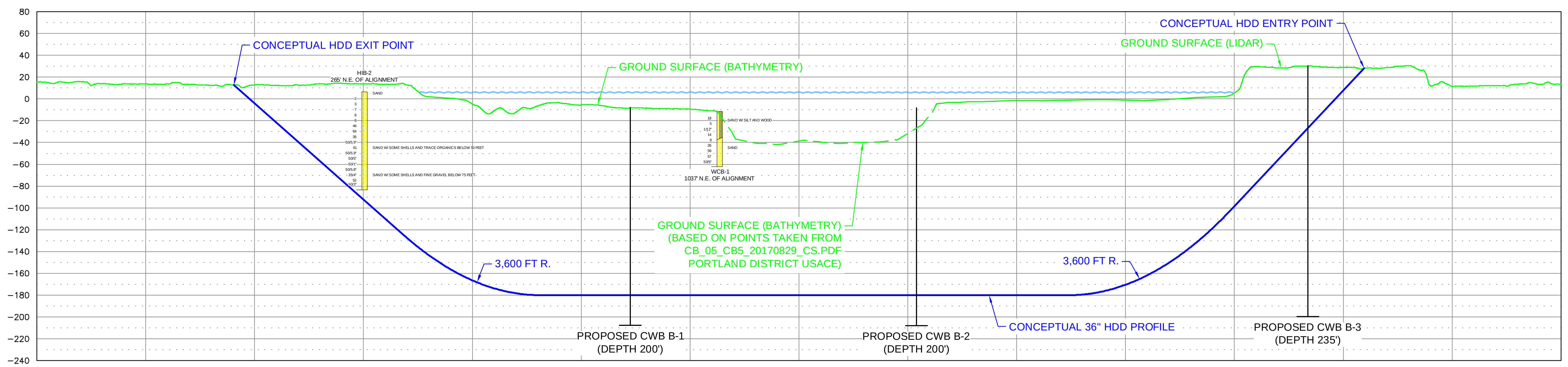

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Ground surface bathymetry downloaded from https://www.ngdc.noaa.gov/nos/H10001-H12000/H11745.html

Legend

- Proposed Boring Profile
- Proposed Boring Location
- Major Contour - 10' Interval
- Minor Contour - 2' Interval

NOT FOR CONSTRUCTION
FOR DISCUSSION ONLY

500 0 500
Horizontal Scale in Feet

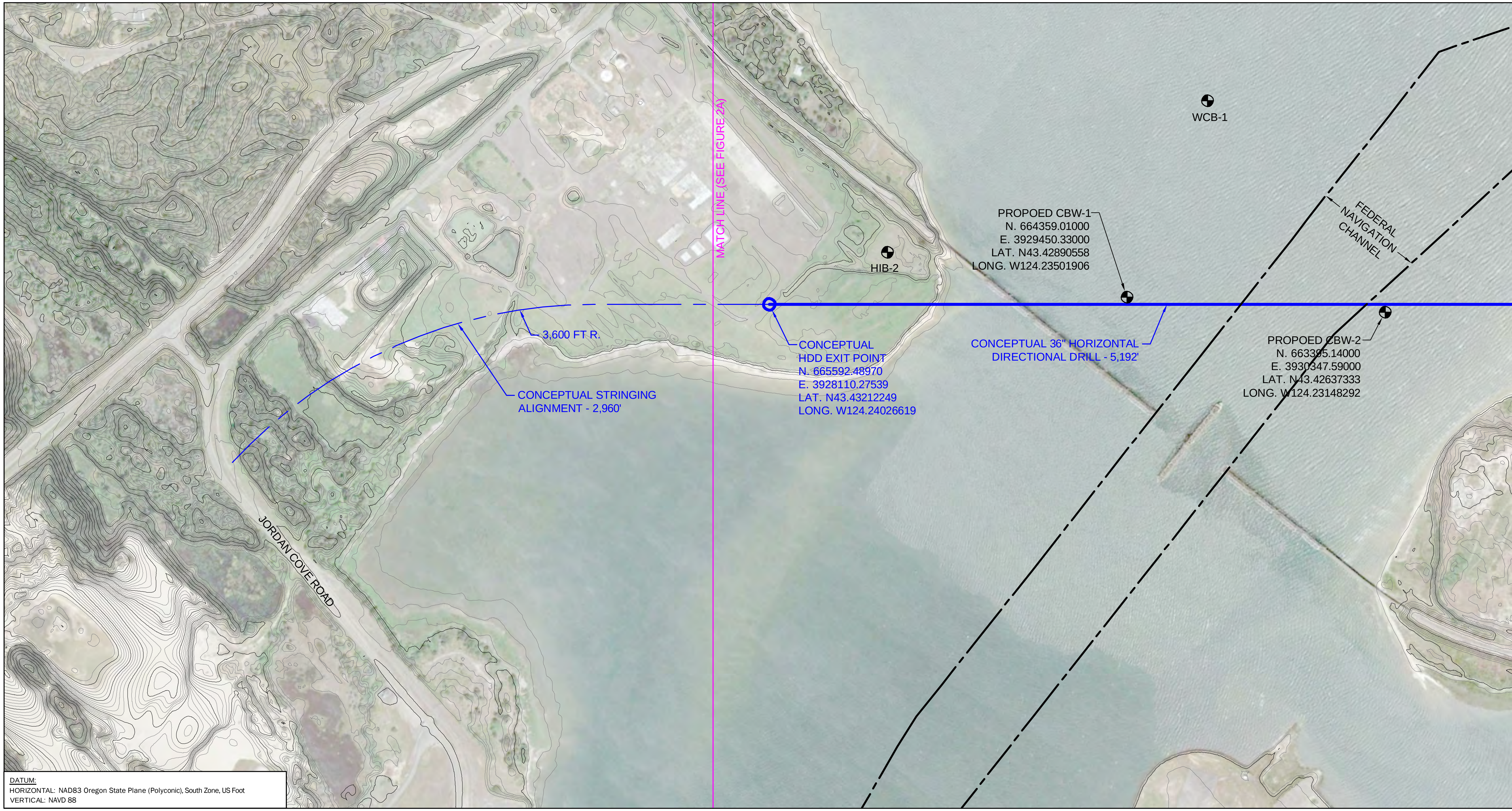
100 0 100
Vertical Scale in Feet
Vertical Exaggeration: 5X

CONCEPTUAL SITE PLAN AND PROFILE

COOS BAY WEST HDD
COOS COUNTY, OREGON

GEOENGINEERS

FIGURE 2A



Notes:

1. The locations of all features shown are approximate.
2. This drawing is for information purposes. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

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Ground surface bathymetry downloaded from https://www.ngdc.noaa.gov/nos/H10001-H12000/H11745.html

Legend

- Proposed Boring Location
- Major Contour - 10' Interval
- Minor Contour - 2' Interval

NOT FOR CONSTRUCTION
FOR DISCUSSION ONLY

500 0 500
Feet

CONCEPTUAL STRINGING WORKSPACE

COOS BAY WEST HDD
COOS COUNTY, OREGON

GEOENGINEERS

FIGURE 2B

P:\22\22708001\CAD\Crossings\Coos Bay West HDD\Coos Bay West HDD.dwg\TAB:Figure 2B modified on Sep 14, 2017 - 3:42pm

TNH : RBM

Date(s) Drilled	11/02/06	Logged By	BCR	Checked By	TNH
Drilling Contractor	Subsurface Technologies, Inc.	Drilling Method	Mud Rotary	Sampling Methods	SPT / Coring
Auger Data		Hammer Data	140 lb hammer/30 in drop	Drilling Equipment	Diedrich D-50 Track
Total Depth (ft)	90	Surface Elevation (ft)		Groundwater Level (ft. bgs)	Not Encountered
Vertical Datum		Datum/ System		Easting(x): Northing(y):	

Depth feet	SAMPLES: Interval	Recovered (in)	Blows/foot	Sub-Sample	Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
0								SP	Gray fine to medium sand (loose, wet)			
5		8	2		1							
10		10	3		2							
15		10	7		3							
20		14	8		4							
25		12	8		5							
30		18	46		6				Dense below 30 feet			
35												

Note: See Figure A-1 for explanation of symbols.

LOG OF BORING HIB-2

GeoEngineers

Project: Pacific Connector Gas Pipeline

Project Location: Coos Bay, Oregon

Project Number: 27708-001-01

Figure: 3

Depth feet	Recovered (in)	Blows/foot	Sample Number	Material Description
35	18	64	7	Very dense below 35 feet
40	18	35	8	Dense below 40 feet
45	18	50/5.9"	9	
50	18	61	10	Very dense; with some shells and trace organics below 50 feet
55	12	50/5.9"	11	
60	18	50/5"	12	
65	18	50/1"	13	
70	12	50/5.8"	14	
75	10	35/4"	15	Becomes medium sand with some shells and occasional fine gravel below 75 feet

Column headings: SAMPLES (Interval, Recovered (in), Blows/foot, Sub-Sample, Sample Number); Water Level; Graphic Log; Group Symbol; MATERIAL DESCRIPTION; Moisture Content %; Dry Unit Weight, lbs/ft^3; OTHER TESTS AND NOTES

LOG OF BORING HIB-2 (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline
Project Location: Coos Bay, Oregon
Project Number: 27708-001-01

Depth feet	Interval	Recovered (in)	Blows/foot	Sub-Sample Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
80		18	52	16							
85											skipped sample #17
90		18	50/3"	18				Bottom of hole at 90 feet Groundwater not encountered during drilling			
95											
100											
105											
110											
115											
120											

LOG OF BORING HIB-2 (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline
Project Location: Coos Bay, Oregon
Project Number: 27708-001-01

Date(s) Drilled	12/18/06	Logged By	John Lawes	Checked By	SRR
Drilling Contractor	Crux	Drilling Method	Mud Rotary	Sampling Methods	SPT
Auger Data	HWT/HQ-3 casing advancer	Hammer Data	140 lb hammer/30 in drop	Drilling Equipment	DWM-6500 Barge-mounted drilling
Total Depth (ft)	51.5	Surface Elevation (ft)		Groundwater Level (ft. bgs)	Not Encountered
Vertical Datum		Datum/ System		Easting(x): Northing(y):	

Depth feet	SAMPLES: Interval	SAMPLES: Recovered (in)	SAMPLES: Blows/foot	SAMPLES: Sub-Sample Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
0							SP-SM	Dark gray poorly graded fine sand with silt and trace wood and shell fragments (very loose, wet) Alluvium bay flat deposit			
5		Trace	18	1							
10		NR	5	2				Becomes loose			
15		5	1/12"	3				Becomes very loose	29		SA %F=7.4
20		5	14	4				Becomes medium dense	32		pH=6.1 Resistivity=620 ohm-cm
25							SP	Dark gray poorly graded fine sand (loose, wet)			
		9	9	5					26		SA %F=3.9
30											
35		10	26	6				Becomes medium dense	28		

Note: See Figure A-1 for explanation of symbols.

V6_GTBORING C:\DOCUME~1\JATKINS\LOCALS~1\TEMPOR~1\OLK8\816902107.GPJ GEIV6_1.GDT 2/1/07

LOG OF BORING WCB-1

GeoEngineers

Project: Pacific Connector Gas Pipeline
Project Location: Coos Bay, Oregon
Project Number: 27708-001-01

Depth feet	Interval	Recovered (in)	Blows/foot	Sub-Sample Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
35											
40		10	59	7				Becomes very dense			
45		14	57	8							
50		17	50/5"	9							

Heaving sand generally encountered in loose and very loose sand deposits

55

60

65

70

75

LOG OF BORING WCB-1 (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline
Project Location: Coos Bay, Oregon
Project Number: 27708-001-01

Figure 4
Sheet 2 of 2

Geotechnical Engineering Services and Horizontal Directional Drilling Design

Coos River HDD
Pacific Connector Gas Pipeline Project
Coos County, Oregon

for
Pacific Connector Gas Pipeline, LP

September 1, 2017

GeoEngineers
Earth Science + Technology

Geotechnical Engineering Services and Horizontal Directional Drilling Design

Coos River HDD
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September 1, 2017

GeoEngineers

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Geotechnical Engineering Services and Horizontal Directional Drilling Design

Coos River HDD
Pacific Connector Gas Pipeline Project
Coos County, Oregon

File No. 22708-001-01

September 1, 2017

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EXECUTIVE SUMMARY

This report provides geotechnical engineering and horizontal directional drilling (HDD) recommendations and HDD design criteria for the proposed HDD crossing of the Coos River located approximately 4 miles northeast of Coos Bay, Oregon. This HDD crossing consists of installing a new 36-inch-diameter pipeline under the Coos River, Coos River Highway and South Coos River Highway. The river crossing will be a part of the proposed Pacific Connector Gas Pipeline (PCGP).

Based on the results of our site visits, subsurface exploration program, geotechnical engineering evaluations, HDD design, and HDD constructability review, it is our opinion the HDD method of installation is feasible and the proposed crossing of the Coos River can be installed successfully provided the recommendations in this report are incorporated into the installation of the crossing.

The subsurface conditions at the site were evaluated by drilling four borings to depths up to 101.5 feet below the existing ground surface. The soils encountered on the entry (north) side of the river consisted of very soft to stiff fat clay, lean clay, organic clay, organic silt with sand overlying very soft, decomposed to fresh siltstone. Soils encountered on the exit (south) side of the river typically consisted of very soft to soft silt, and very loose to dense fine sand with varying amounts of silt to the maximum depths explored. Soils encountered during exploration had varying amounts of organic matter.

The hydraulic fracture and drilling fluid surface release model indicates the risk of drilling fluid surface release is high along the first approximately 250 feet of the drill path. The risk becomes low from the northern edge of the Coos River Highway and across Coos River to approximate station 17+00. The risk becomes high within approximately 150 feet of the exit point.

The site-specific HDD profile was created utilizing the design guide published by the Pipeline Research Committee International (PRCI) of the American Gas Association. Associated installation and operational stresses were calculated utilizing the PRCI Design Guide and checked to assess compliance with ASTM/ASME B31.8, API Recommended Practice 2A – WSD, and DOT CFR Part 192. The HDD design calculations indicate the stresses incurred during installation and operation should be within the allowable limits.

This Executive Summary should be used only in the context of the full report for which it is intended.

1.0 INTRODUCTION

1.1 General

This report summarizes our geotechnical engineering and HDD design services for the proposed HDD crossing of the Coos River. The site is located approximately 4 miles northeast of Coos Bay, Oregon. The site is shown in the Vicinity Map, Figure 1. The general layout of the site is shown in the Site Plan and Profile, Figure 2.

1.2 Project Description and Basis of Design

The proposed Coos River HDD crossing will be a part of the 229-mile-long PCGP, beginning at the proposed Jordan Cove Liquefied Natural Gas (LNG) Terminal near Coos Bay, Oregon and terminating near Malin, Oregon. The proposed pipeline crossing of the Coos River consists of a single 36-inch-diameter pipe to be installed using HDD installation techniques.

We previously prepared an HDD Feasibility Study for the Coos River HDD in a report titled "HDD Feasibility Study, Coos River HDD, Coos Bay, Oregon," dated January 15, 2013.

The HDD design was completed in accordance with the latest versions of Department of Transportation (DOT) 49 CFR 192, ASME 31.8 and accepted practices within the natural gas industry. The geotechnical and HDD design engineering was completed based on the parameters presented below in Table 1.

TABLE 1. BASIS OF DESIGN FOR THE 36-INCH-DIAMETER COOS RIVER HDD

Product Pipe Data	Design Parameter
Product Pipe Specifications	36 inches x 0.823 inches w.t.[1] API-5L X-70 steel pipe, SAWH or SAWL
Horizontal Crossing Length	1,602 feet
Maximum Allowable Operating Pressure	1,600 psig[2]
Operating Temperature	70 degrees F
Maximum Operating Temperature	100 degrees F
Assumed Tie-In Temperature	50 degrees F

Notes:

[1]w.t. – wall thickness

[2]psig – pounds per square inch gauge

2.0 SCOPE OF SERVICES

The purpose of our services was to evaluate the existing surface and subsurface soil and groundwater conditions and prepare a HDD design for the proposed crossing. The specific scope of services provided by GeoEngineers, Inc. included the following:

1. Prepared preliminary information and maps of the HDD utilizing geographic information system (GIS) data provided by Pacific Gas Connector Pipeline, LP (PCGP, LP) and other available public data sources.

2. Completed a site reconnaissance with PCGP, LP and their authorized representatives to observe surface conditions and locate borings. During our site reconnaissance we collected the following information:
    a. Geologic and environmental surface features that could impact HDD feasibility;
    b. Topography of the site, particularly along the planned alignment;
    c. Potential HDD operational areas such as entry and exit points, staging, site access and pipe stringing;
    d. Number and approximate location of geotechnical borings;
    e. Potential obstacles such as existing utilities, buildings, houses and other surface features within the potential work areas; and
    f. Map surface exposures of geologic materials visible within road cuts and stream banks in order to aid in interpreting potential subsurface conditions along the planned HDD alignment.
3. Coordinated utility locates near the proposed boring locations by the public "One Call" utility locating service.
4. Explored subsurface conditions at the site as follows:
    a. Drilled four brings near the HDD alignment using mud rotary drilling techniques;
    b. Obtained soil samples at representative intervals from the borings using split spoon samples and standard penetration tests (SPT). SPTs were conducted at 5-foot intervals in the soil and soft rock portions of the borings; and
    c. Classified soils encountered in the borings in general accordance with ASTM International (ASTM) Standard Practice D 2488 and maintained a log of the materials encountered in each exploration.
5. Performed index tests necessary to characterize the subsurface materials. Testing included:
    a. Thirteen Atterberg limits determinations in general accordance with ASTM D 4318;
    b. One grain size determination in general accordance with ASTM C 136;
    c. Four percent fines determinations in general accordance with ASTM D 1140; and
    d. Ten sieve analysis in general accordance with ASTM D 422.
6. Prepared and submitted a HDD feasibility study report, which included:
    a. Brief surface description of site conditions that could affect the planned HDD operations;
    b. Summary of subsurface conditions encountered during our fieldwork;
    c. HDD feasibility discussion;
    d. Preliminary HDD profile design length and depth;
    e. Boring logs; and
    f. Site Photographs.
7. Performed a hydraulic fracture and drilling fluid surface release analysis to quantify the risk of hydraulic fracture and drilling fluid surface release.

8. Completed HDD design, including:
    a. Alignment and profile;
    b. Minimum radius;
    c. Installation stresses; and
    d. Operating stresses.
9. Providing this draft HDD design report to the project team for review and comment. The draft report includes:
    a. Analyses and discussion of hydraulic fracture and drilling fluid surface returns potential;
    b. Installation stress calculations;
    c. Operating stress calculations;
    d. HDD design conclusions and recommendations, including:
        i. Drilling fluid loss;
        ii. Minimum allowable product pipe bending radius;
        iii. Pilot hole survey recommendations;
        iv. Anticipated drilling conditions;
        v. Hole collapse conclusions and recommendations;
        vi. Pipe coating specifications conclusions;
        vii. Buoyancy considerations;
        viii. Site access considerations; and
        ix. Noise mitigation techniques.
    e. Geotechnical engineering considerations, including:
        i. Temporary access roads;
        ii. Temporary workspace areas;
        iii. HDD installation
        iv. Temporary excavations;
        v. Construction dewatering; and
        vi. Erosion control.
    f. HDD design drawing, including site-specific construction diagrams that show the location of temporary entry and exit workspaces, pipe assembly areas and areas to be disturbed or cleared for construction.
10. Preparing a final HDD design report incorporating comments from the project team.

3.0 SITE CONDITIONS

3.1 Geologic Setting

3.1.1 Site Geology

The geologic mapping we reviewed (Beaulieu and Baldwin, 1973) shows the site underlain by Quaternary-aged marsh and peat deposits overlying the Tertiary aged Flournoy Formation. The peat and marsh is described as unconsolidated organic soils of silt, clay and sand. The Flournoy Formation is described as rhythmically bedded siltstone and sandstone.

3.2 Surface Conditions

3.2.1 General

We evaluated surface conditions in the vicinity of the site by completing a site reconnaissance during both our preliminary site visits, and our subsurface exploration program conducted on December 6th and 7th, 2012.

3.2.2 Surface Description

The proposed HDD alignment is oriented in a generally northwest-southeast (entry to exit) direction, as shown in Figure 2. The north side (entry) of the proposed HDD is situated on a gently sloping (less than 10 percent) field within the Coos River Valley between approximately Elevation 8 feet and 17 feet above mean sea level (MSL). The south side (exit) is located on a relatively flat alluvial valley floor at about Elevation 5 feet. The north bank of the Coos River is approximately 500 feet south of the entry point and the south bank is approximately 630 feet north of the exit point. Coos River Highway parallels the river on the north side and South Coos River Highway parallels the river on the south side. Both highways are situated on elevated embankments or levees between approximate elevation of 10 to 15 feet.

The open field on the north side of the HDD is located adjacent to the Coos River Highway and is approximately 250 feet wide measured parallel to the highway and is approximately 550 feet long. The proposed entry workspace occupies an irregularly shaped approximately 200-foot by 250-foot area, with the south side of the workspace approximately 100 feet south of the entry point. The area within the entry workspace is vegetated with low grass and a few deciduous trees on the north end. The ground surface at the time of exploration was soft due to recent rains saturating the near surface soils.

The exit workspace occupies an approximately 230-foot by 300-foot area, with the north side of the workspace approximately 125 feet north of the exit point. The area within the exit workspace and stringing area is relatively flat. The ground surface within the stringing area ranges from Elevation 6 feet at the south end to approximately Elevation 3 feet at the west end of the stringing area. The vegetation within the exit workspace and stringing area consists of low grasses.

3.3 Subsurface Conditions

3.3.1 General

We explored subsurface conditions at the site between the dates of December 6th and 7th, 2012 by advancing four drilled borings to maximum depths of 101.5 feet below ground surface (bgs) at the locations shown in Figure 2. A representative from GeoEngineers maintained logs of the materials encountered in each boring and collected disturbed soil samples at 5-foot intervals. Appendix A presents the boring logs and a description of the subsurface exploration and laboratory-testing programs. Laboratory test results are shown in the boring logs in Appendix A.

The materials encountered in our borings were consistent with the geologic mapping for the site. In general, the borings completed on the north side of the crossing encountered fat clay with organic matter, organic clay, and clayey sand overlying siltstone at depths of 48 to 96 feet bgs. The borings completed on the south side of the crossing generally encountered interbedded silt, silty sand, sand with silt, and fat clay to the maximum depths explored. The materials encountered in each boring are described in more detail in the following paragraphs.

3.3.2 Subsurface Conditions Encountered by Borings

Boring CR-1 was completed approximately 125 feet southeast of the entry point and approximately 400 feet northwest of the north bank of the Coos River. Boring CR-1 encountered approximately 48 feet of very soft to stiff fat clay with occasional gravel and varying amounts of organic matter overlying predominantly decomposed, very soft siltstone to a depth of 55.2 feet bgs, the maximum depth explored.

Boring CR-2 was completed approximately 375 feet southeast of the entry point and approximately 150 feet northwest of the north bank of the Coos River. Boring CR-2 encountered 43 feet of very soft organic clay and silt, soft lean clay with sand, and very loose clayey fine to coarse sand overlying soft to very stiff fat clay with varying amounts of sand and gravel to a depth of 96 feet bgs. Very soft, fresh siltstone was encountered from 96 feet bgs to a depth of 101.7 feet bgs, the maximum depth explored.

Boring CR-3 was completed approximately 525 feet northwest of the exit point and approximately 100 feet southeast of the south bank of the Coos River. Boring CR-3 encountered 13 feet of very soft sandy silt and silt with varying amounts of organic matter overlying 10 feet of loose to very loose fine sand with silt. Loose to dense, silty fine sand with trace organic matter was encountered from a depth of 23 feet to a depth of 90 feet bgs, overlying very soft fat clay with trace organic matter to a depth of 101.5 feet bgs, the maximum depth explored.

Boring CR-4 was completed approximately 200 feet northwest of the exit point and approximately 425 feet southeast of the south bank of the Coos River. Boring CR-4 encountered 23 feet of very soft organic clay and very loose silty fine sand overlying very soft to soft, fine sandy silt with loose silty fine sand layers to a depth of about 63 feet, where very loose to medium dense fine sand with varying amounts of silt was encountered to a depth of 76.5 feet bgs, the maximum depth explored.

The subsurface materials encountered in the borings are described in more detail in the boring logs included in Appendix A.

3.3.3 Groundwater Conditions

During our borings, we were not able to measure groundwater levels due to the presence of drilling fluid. However, based on the observed relative moisture content of the samples, and the locations and elevations of the borings relative to the Coos River, we estimate that groundwater was at or near the ground surface at the time of drilling. We anticipate that groundwater levels will fluctuate with precipitation, site utilization and other factors. During heavy prolonged precipitation, and probably during most of the winter months, we expect that groundwater will be near or at the surface of the site.

4.0 HDD ENGINEERING ANALYSES

4.1 Hydraulic Fracture and Drilling Fluid Surface Release Evaluation

4.1.1 Model Input Parameters

The HDD geometry used for our analyses of the Coos River HDD is shown in the HDD Design Drawing in Appendix B. The horizontal length of the HDD is 1,602 feet. The soil units encountered in the vicinity of the HDD are characterized by borings CR-1 through CR-4. A general description of the subsurface conditions encountered in the borings is presented in Section 3.3.2, and the boring logs are presented in Appendix A. Generally, the soils encountered in the borings to the north of Coos River consisted of fat clay with organic matter, organic clay, and clayey sand overlying siltstone. The borings completed on the south side of the crossing generally encountered interbedded silt, silty sand, sand with silt, and fat clay to the maximum depths explored.

Based on the results of the exploration program and subsequent laboratory-testing program, the soil properties used in the evaluation are presented in Table 2 below.

TABLE 2. ESTIMATED SOIL PROPERTIES

Soil Description	Unit Weight (pcf)	Friction Angle (degrees)	Cohesion (psf)
Very Soft Silt and Organic Silt	90	0	100
Soft Fat Clay	90 – 100	0	100 – 350
Medium Stiff to Stiff Fat Clay	100 – 105	0	750 – 1,000
Stiff Fat Clay	105 – 110	0	1,000 – 1,500
Very Stiff Fat Clay	115 – 120	0	2,000 – 3,000
Soft Sandy Silt	100	20	200
Loose Clayey Sand/Soft Sandy Clay	100	24	200
Loose Silty Sand	100 – 110	26 – 28	0
Medium Dense Silty Sand	110 – 115	30 – 32	0

Notes:

pcf = pounds per cubic foot; psf = pounds per square foot

Based on available information and common HDD construction procedures, the tool dimensions and rheological properties used in the evaluation are summarized in Table 3. Because these parameters are dependent upon the HDD contractor's means and methods, the hydraulic fracture and drilling fluid surface release evaluation should be refined during construction of the HDD installations.

TABLE 3. ESTIMATED TOOL DIMENSIONS AND RHEOLOGICAL PROPERTIES

Parameter	Value
Pilot Hole Bit Diameter	9.875 inches
Drill Pipe Diameter	5.0 inches
Drilling Fluid Weight	9.5 ppg
Plastic Viscosity	8 CP
Yield Point	20 lb/100 sf

Notes:

ppg = pounds per gallon; CP = centipoise; lb/100 sf = pounds per 100 square feet

4.1.2 Discussion of Hydraulic Fracture and Drilling Fluid Surface Release

4.1.2.1 GENERAL

During HDD installation, drilling fluid is transported under pressure through the drill pipe string to the cutting tool. For HDD installations like the Coos River HDD, pump pressures of several hundred pounds per square inch (psi) and pump rates of 150 to 400 gallons per minute (gpm) are typical. The drilling fluid typically has a specific gravity ranging from 1.1 to 1.2 (approximately 69 to 75 pounds per cubic foot).

The total drilling fluid pressure at the cutting tool is a function of pumping pressures, the elevation difference between the drill rig and the cutting tool and friction losses. Soil and rock formations along the drill path experience maximum drilling fluid pressures in the immediate proximity of the drill bit or reaming tools. The energy (pressure) of the drilling fluid is steadily diminished along its path from the drill rig to the cutting tool and back to the rig through the annulus of the hole. Thus, the pumping pressure required to circulate the drilling fluid increases as the drill bit advances farther from the drill rig. Typically, the annular drilling fluid pressure at the cutting tool can range from 15 to 25 percent of the pump pressure.

4.1.2.2 DRILLING FLUID LOSS

Drilling fluid circulation may be reduced or lost during HDD operations by drilling fluid loss to the surrounding soil or by the accumulation of cuttings downhole that create a blockage, which may result in hydraulic fracture. These two processes are discussed below:

1. Formational fluid loss occurs when drilling fluid flows into surrounding permeable soil units either within the pore spaces of the soil or along preexisting fractures or voids in the formation.
2. Hydraulic fracturing and subsequent loss of drilling fluid can occur where the combined resisting force of the available overburden pressure and the shear strength of the overburden soil is less than the hydrostatic drilling fluid pressure and the pressures applied to the surrounding soil from the drilling fluid at the cutting tool.

Formational drilling fluid losses typically occur when the drilling fluid flows through the pore spaces in the soil through which the HDD profile passes. Thus, a formation with a higher porosity can potentially absorb a larger volume of drilling fluid than a formation with a lower porosity. Silty sands, silts and clays typically have a low susceptibility to formational drilling fluid losses. Coarse sand and gravel units with low percentages of silt and clay have a moderate to high susceptibility for drilling fluid loss. The proper management of the drilling fluid properties can reduce the volume of formational drilling fluid loss.

4.1.2.3 HYDRAULIC FRACTURE

Hydraulic fracture is a term typically used to describe the condition in which the downhole drilling fluid pressure exceeds the overburden pressure and shear strength of the soil surrounding a drill path. Soils that are most vulnerable to hydraulic fracture include relatively weak cohesive soils or loose granular soils with low shear strength. Medium dense to very dense sands and very stiff to hard silts and clays have a low to moderate hydraulic fracture potential. HDD installations with greater depth or drill paths in formations with higher shear strength may reduce the potential for hydraulic fracturing.

4.1.2.4 DRILLING FLUID SURFACE RELEASE

Drilling fluid surface releases, commonly referred to as "Frac-Outs," occur when drilling fluid emerges at the ground surface or in any other undesired location such as wetlands, utility trenches, basements, roads, railroads, and waterbodies (Photograph 1). In practice, drilling fluid surface releases typically occur in proximity to the entry and exit points where annular pressures are high and soil cover is thin. Drilling fluid surface releases can also occur at locations along a drill path where there are low shear strength soils, where soil cover is relatively thin or along preexisting fractures or voids. Other locations where drilling fluid surface releases can occur are along preferential pathways such as exploratory boring locations, within utility trenches, or along the edges of existing subsurface structures such as piles or utility poles.

The HDD contractor's construction procedures constitute another important factor influencing when and where drilling fluid loss occurs. If the contractor operates with insufficient drilling fluid flow rates, inadequate drilling fluid properties or excessive rates of penetration, the annulus may become blocked through an accumulation of drill cuttings falling out of suspension. This can occur within formations that typically have a low potential for hydraulic fracture. If the accumulation of cuttings creates a blockage downhole, the annulus may become over-pressurized, leading to hydraulic fracturing and potentially drilling fluid surface releases. Our analysis does not account for this over-pressurized condition.

Photograph 1 - Example of Drilling Fluid Surface Release

4.1.2.5 HYDRAULIC FRACTURE CALCULATIONS

The procedures used to evaluate the potential for drilling fluid loss through hydraulic fracturing are based primarily on research completed by Delft Geotechnics, as discussed in Appendix B of the USACE Report CPAR-GL-98 (Staheli, et al., 1998). The methodologies used to estimate the hydraulic fracture potential outlined in the research are based on cavity expansion theory. The cavity expansion model is used to estimate the maximum effective pressure in the drill hole before plastic deformation of the drill hole occurs.

In order to evaluate the hydraulic fracture and drilling fluid surface releases potential for a HDD installation, assumptions must be made when selecting the input parameters. The assumptions used in the model include the extent and uniformity of soil layers, hydrostatic groundwater pressures, drilling fluid properties, penetration rates and drilling fluid flow rates. The soil strength properties are estimated based on interpretations of the boring logs and laboratory test results. The drilling fluid properties, penetration rates and pump rates are estimated based on generally accepted best management practices (BMPs) of the HDD industry. Consequently, the results of the evaluation are only estimates of the potential for hydraulic fracture and drilling fluid surface releases.

In addition, the drilling fluid properties are dependent on the field conditions and the construction practices of the HDD contractor and drilling fluid engineer. Changes in these properties can significantly affect the potential for hydraulic fracture and drilling fluid surface releases.

Based on the soil properties, rheological parameters and anticipated tool dimensions, the model considers the total and effective overburden stresses, shear strengths of the soil, and the estimated drilling fluid pressures along the drill path. A comparison is then made of the estimated drilling fluid pressures immediately behind the drill bit and the ability of the soil to resist plastic deformation. The evaluation considers only the hydraulic fracture potential during pilot hole operations assuming the drilling fluid returns are continuously maintained to the entry point.

The factor of safety against hydraulic fracturing of the soil surrounding the drill bit is defined as the ratio of the formation limit pressure to the estimated annular drilling fluid pressure. The factor of safety against drilling fluid surface releases is defined as the maximum factor of safety against hydraulic fracture calculated for all of the soil units above specified points along the drill path.

In some cases, the evaluation may indicate a high potential for, or a low factor of safety against, hydraulic fracture in the soils surrounding the drill bit; however, a higher-strength layer may be present above the weaker layer that may reduce the migration of drilling fluid toward the ground surface, thus providing a higher factor of safety against drilling fluid surface releases.

Table 4 below shows the relative risk associated with the estimated factors of safety against hydraulic fracture and drilling fluid surface releases.

TABLE 4. RELATIVE HYDRAULIC FRACTURE AND DRILLING FLUID SURFACE RELEASE RISK

Factor of Safety	Relative Risk
Less than 1	Very High
Between 1 and 1.5	High
Between 1.5 and 2	Moderate
Greater than 2	Low

4.1.3 Results of Hydraulic Fracture and Drilling Fluid Surface Release Evaluation

The results of the hydraulic fracture evaluation are presented in Figures 5 through 7. The formation limit pressure, presented in Figure 5, is the ability of the soil to resist plastic deformation and is a function of the shear strength of the soil through which the HDD profile passes. Based on the HDD design, the proposed HDD profile passes through layers of very soft to medium stiff fat clay, organic silt and clay, fine sandy silt and very loose to medium dense silty fine sand. As a result, the formation limit pressure varies depending on the soil encountered along the HDD profile as shown in Figure 5 as the green line. In general, the areas with the higher formation limit pressures are the silty sand and sandy silt soils. The estimated drilling fluid pressure is also shown in Figure 5 as the red line and represents the drilling fluid pressure along the HDD profile based on the anticipated drilling fluid properties shown in Table 3.

When evaluating the risk of hydraulic fracture and drilling fluid surface releases, the analysis computes two types of factors of safety. These are:

- Factor of Safety against localized hydraulic fracture; and
- Factor of Safety against drilling fluid surface release.

Local Hydraulic Fracture: The factor of safety against hydraulic fracture is the ratio of the formation limit pressure to the estimated drilling fluid pressure along the profile, shown as the green line in Figure 6. This represents the factor of safety against hydraulic fracture of the soil immediately surrounding the HDD profile and is a localized condition.

Drilling Fluid Surface Release: The factors of safety against drilling fluid surface release considers the strength of the soil column above the HDD profile that resists drilling fluid migrating to the ground surface. It is computed by comparing the formation limit pressure of the soil units above a specific location along the planned HDD alignment to the anticipated drilling fluid pressure at the same location. The factors of safety against drilling fluid surface releases are shown in Figure 6 at selected points shown as red triangles.

The model indicates that the risk of drilling fluid surface release is generally low when the HDD profile is located within the silty sand units, with calculated factors of safety generally greater than 2, see Figure 6. The factors of safety, however, drop significantly when the HDD passes through the fat clay, organic silt and clay, and shallow sandy silt units as shown in Figure 6 between Stations 4+00 (Entry) and 7+00 and 17+00 and 20+00 (Exit). Figure 6 also shows the factors of safety against hydraulic fracture generally decrease as the HDD progresses towards the exit point as the required drilling fluid pressure increases with length. Most importantly, the factors of safety against drilling fluid surface release are greater than 2 (low risk) along the portion of the HDD path located beneath Coos River.

4.2 Installation Stresses

The analyses of installation loads and stresses are based on the product pipe being installed along the designed path using the BMPs of the HDD industry. The addition of water into the product pipe is the standard method that contractors typically use to control buoyancy of the product pipe during the installation procedure. The proposed 36-inch-diameter product pipe will be positively buoyant in the anticipated drilling fluid weights. Therefore, our analyses include five cases with differing levels of buoyancy and drilling fluid weights.

The five cases analyzed are as follows:

1. The annulus contains 9.5 lb/gal drilling fluid and product pipe is empty.
2. The annulus contains 9.5 lb/gal drilling fluid and product pipe is full of water.
3. The annulus contains 12 lb/gal drilling fluid and product pipe is empty.
4. The annulus contains 12 lb/gal drilling fluid and product pipe is full of water.
5. The annulus contains 10.5 lb/gal drilling fluid and product pipe is filled such that neutral buoyancy is achieved.

The analyses are based upon the methods developed by the Pipeline Research Committee International (PRCI) of the American Gas Association (PR-227-9424, 1995). The only deviation from this guide in calculating the installation stresses is a more conservative allowable tensile stress (F_t).

The equation recommended in the PRCI Design Guide is shown in below in **Equation 1**:

F_t = 0.9 *SMYS (Specified Minimum Yield Strength)

The allowable tensile stress used for our analyses is derived from Sections 2.4.1, 3.1.2 and 3.2 of the American Petroleum Institute (API) Recommended Practice 2A – WSD (WSD Recommended Practice 2A-WSD, 1993).

Section 3.2 of the API Recommended Practice defines the allowable tensile stress of cylindrical members as shown below in **Equation 2**:

F_t = 0.6 *SMYS

Sections 2.4.1 and 3.1.2 of the API Recommended Practice permit the allowable tensile stress, defined in Equation 2, to be increased by one-third, yielding a design factor of 0.8, which is more conservative than 0.9 as listed in the PRCI Design Guide.

The equation used in our analyses is shown below in **Equation 3**:

F_t = 0.8 *SMYS

The following table presents a summary of the calculated installation loads for the HDD.

TABLE 5. INSTALLATION LOADS FOR THE 36-INCH-DIAMETER COOS RIVER HDD[1]

Drilling Fluid Weight (lb/gal)	Buoyancy Condition	Effective Pipe Weight[2] (lb/ft)	Pullback Force[3] (lb)
9.5	Empty	-192	240,000
9.5	Full	209	207,000
12	Empty	-325	316,000
12	Full	77	135,000
10.5	Neutral Buoyancy	0	127,000

Notes:

[1]See Appendix B for detailed calculations.

[2]Negative values indicate upward force (positive buoyancy).

[3]Assumes a fully open drilled hole.

4.3 Operating Stresses

The operating stresses on a pipeline installed by directional drilling include hoop stress from the maximum allowable operating pressure (MAOP), hoop stress from external pressure applied by the groundwater acting on the outside of the product pipe, elastic bending as the product pipe conforms to the shape of the drilled hole, and thermal expansion and contraction stresses resulting from the difference between the constructed temperature and the operating temperature. The following table presents a summary of the operating stresses based on the product pipe specifications and the HDD profile as shown on the HDD Design Drawing in Appendix B.

TABLE 6. SUMMARY OF OPERATING STRESSES FOR THE 36-INCH-DIAMETER COOS RIVER HDD*

Stress Component	Stress (psi)	Percent SMYS[1] (%)	Maximum Allowable Percent SMYS (%)
Longitudinal Bending Stress	16,900	24	-
Hoop Stress	34,990	50	50[2]
Longitudinal Tensile Stress from Hoop Stress	10,500	15	-
Longitudinal Stress from Thermal Expansion	9,500	14	90[3]
Maximum Net Longitudinal Stress	17,900	26	90[4]
Maximum Shear Stress	25,500	36	45[5]
Maximum Combined Effective Stress	50,960	73	90[6]

Notes:

*Operating stress calculations are based on the specified minimum radius of curvature of 2,600 feet and assumed installation and maximum operating temperatures of 50 degrees and 100 degrees Fahrenheit, respectively.

[1]Specified Minimum Yield Strength

[2]Limited by design factor from DOT regulations, Title 49 CFR Part 192.111 for gas.

[3]Limited by Section 402.3.2 of ASME B31.4.

[4]Limited by Section 833.3 of ASME B31.8 for gas.

[5]Limited by Section 402.3.1 of ASME B31.4.

[6]Limited by Section 833.4 of ASME B31.8 for gas.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 HDD Design Considerations and Recommendations

5.1.1 General

The contractor's means and methods during construction are critical to the successful completion of the HDD. Specifically, during pilot hole drilling, only small deviations from the design for horizontal and vertical curvature should be allowed so that pull load forces similar to those estimated by the calculations can be maintained. The HDD contractor's ability to maintain drilling fluid returns, proper drilling fluid properties with appropriate penetration rates, and drilling fluid flow rates will also be important factors to consider during drilling because hole conditions will be directly affected by these operations.

We recommend that PCGP, LP retain a qualified representative to observe and document the drilling process and to advise the project team on areas of concern and recommended actions during drilling activities. We also recommend that PCGP, LP require that a qualified drilling fluid engineer or technician evaluate the drilling fluid properties on a continuous basis during the entire drilling and installation process. Close coordination between the contractor and the drilling fluid engineer or technician to maintain proper drilling fluid properties, penetration rates and drilling fluid flow rates will be instrumental to effectively remove cuttings from the pilot hole and reamed hole.

5.1.2 Drill Hole Stability

In general, the alluvial soils encountered by our borings along the proposed HDD alignment have a low risk of hole instability. However, if hole instability or steering difficulty occur, installation of casing at the entry and exit points can serve to maintain drill hole stability. If casing is utilized, upon completion of the pilot hole or prior to reaming the cased section of the hole, the casing is typically removed but could remain in place through product pipe pullback to maintain drill hole stability within the entry tangent. The specific casing diameter and installation method should be determined by the HDD contractor.

5.1.3 Cuttings Removal

Based on our experience, cuttings removal in fat clay like that encountered by borings underlying the HDD alignment is typically more challenging than in other non-cohesive soils. In some cases, relatively dry fat clays may swell and block the drill hole or the clay cuttings may "ball up" forming large diameter particles that fall out of suspension and are more difficult to remove than smaller clay particles that remain in suspension. Therefore, the potential for the hole to become plugged with cuttings is elevated along the proposed HDD crossing where the drill path is within the fat clay observed in the borings. In the event that the hole becomes plugged, and drilling fluid circulation ceases, downhole annular pressures can increase dramatically. This temporary spike in downhole annular pressure can dramatically increase the risk of hydraulic fracture and drilling fluid surface release. In addition, if cuttings are not effectively removed from the hole during HDD operations, pullback forces could be excessively high during pullback of the 36-inch-diameter product pipe, or the product pipe could become lodged in the hole. The failure to effectively remove cuttings from the hole could potentially result in failure of the HDD installation. Therefore, we recommend that the drilling contractor maintain drilling fluid returns at all times, and use appropriate means and methods (appropriate penetration rates, drilling fluid management, mechanical methods) to ensure that cuttings are adequately removed from the hole during the HDD process.

5.1.4 Drilling Fluid Loss and Drilling Fluid Surface Release

It is our opinion that there is a relatively high risk of hydraulic fracture and drilling fluid surface releases along the first 500 feet and last 300 feet of the HDD, respectively. However, based on our analyses, the risk of drilling fluid surface release to the Coos River is relatively low. As is typical with all HDDs, the risk of drilling fluid surface release is becomes high within approximately 150 feet of the exit. Drilling fluid surface releases may occur within these high risk zones even if the contractor maintains drilling fluid returns during construction and also maintains drilling fluid properties that are conducive to cuttings removal and formation of a "wall cake" to help stabilize the borehole and limit fluid interaction between the borehole and surrounding soils.

Because of the elevated risk of drilling fluid surface release occurring near the entry and exit points during construction, we recommend that the contractor establish a contingency and mitigation plan in the event that drilling fluid surface releases occur; these plans should be reviewed and approved by the project team prior to the start of construction. We recommend the annular drilling fluid pressures be closely monitored during drilling to help identify when the potential for a surface release of drilling fluid may be possible. Annular pressures can be monitored through the use of an annular pressure tool as part of the bottom hole assembly (BHA).

5.1.5 Workspace Considerations

There is not adequate area for a pipe stringing and fabrication workspace on the northwest side of the proposed HDD. Therefore, the Coos River HDD can be drilled from the northwest (entry) side to the southeast (exit) side so that the stringing area will be to the southeast. Depending on temporary workspace that can be obtained on the southeast side of the conceptual HDD, there may be enough linear area for a pipe stringing and fabrication workspace that will allow assembly of a single product pipe string. However, in order to achieve pullback with a single product pipe string, it will need to be curved slightly to the south.

There is adequate area for workspaces at the entry and exit points as shown in Figure 2. Minor grading may be required to prepare entry workspace, but grading is not likely required for the exit workspace. Near the entry and exit points, it will likely be necessary to provide a stable working platform such as a timber matted or gravel workspace and an entrance road during construction, particularly if construction is completed during the wet season, or when heavy prolonged precipitation occurs. In addition, construction roads will be required to access the entry and exit points and the product pipe stringing area, unless construction is completed during the latter part of the dry summer months when precipitation has not recently occurred and groundwater levels are at their lowest point throughout the year.

5.1.6 Minimum Allowable Product Pipe Bending Radius

The design radii for the entry and exit vertical curves are 3,600 feet. The design radii of the vertical curves were chosen based on the industry standard of the design radii being least 100 times the product pipe diameter in inches (for example, 36-inch-diameter pipe x 100 = 3,600-foot design radius), and to provide a reasonable separation of the design radii and the absolute minimum allowable radius calculated based on the product pipe specifications and the anticipated operating conditions. We recommend that the three-joint radius be calculated for each three-joint section of drill pipe during pilot hole operations. Based on the design geometry, subsurface conditions encountered, and proposed product pipe specifications, the minimum allowable three-joint radius over any consecutive three-joint section of drill pipe should not be less than 2,600 feet.

5.1.7 Pilot Hole Survey

We recommend that a secondary survey system (TruTracker, ParaTrack or equivalent) be used along the entire length of the HDD. If the HDD contractor elects to use the wire coil grids with these secondary survey systems, we recommend that the wire grids be placed at least as wide as the survey probe is deep. The placement of the coils is limited to areas where ground surface conditions and agreements with landowners allow.

The HDD design drawing in Appendix B shows two approximate configurations for secondary surface survey coil wires that may be used to track the bottom hole assembly during pilot hole operations. One of the configurations is for the ParaTrack survey system, and the other is for the TruTracker survey system. The secondary surface survey coil wire layouts shown in the design drawing are intended to show the general layout of typical survey coil configurations and are not intended to direct the HDD contractor as to the exact placement of the secondary surface survey coil wires. The final placement of secondary surface survey coil wires is the contractor’s responsibility and may vary from what is shown depending on ground surface conditions at the time of HDD installation, and the HDD contractor’s means and methods. We recommend that the contractor review the project plans and workspace limitations to determine the most appropriate configuration for the secondary survey system.

If secondary surface survey coils will be installed across or within water bodies, we recommend that the HDD contractor sufficiently anchor the coil wires such that the wire does not deviate from the installed location. If the coils are not sufficiently anchored, currents, boat traffic or other influences may deform the coil configuration, resulting in inaccurate downhole survey shots. In addition, accurate downhole survey shots may not be obtained if the coil corners are not properly surveyed.

For pilot hole operations, we recommend that the HDD contractor drill the pilot hole as closely as possible to the designed HDD profile while still maintaining three-joint horizontal and vertical radii equal to or greater than 2,600 feet. We recommend a horizontal tolerance of 5 feet left and 5 feet right of the designed alignment and a vertical tolerance of 2 feet above and 10 feet below the designed profile. We also recommend that, upon completion of the pilot hole, GeoEngineers have the opportunity to review the pilot hole survey data prior to the start of hole opening operations. The contractor should be responsible for producing an as-built drawing of the pilot hole survey data and providing it to PCGP, LP within 2 weeks of the completion of the pilot hole. This as-built drawing should be kept in the project file for future reference as to the location of the installed pipeline.

5.1.8 Product Pipe Coating Specifications

The proposed product pipe coating specifications provided by PCGP, LP specify a nominal thickness of 8 to 10 mils of external Fusion Bonded Epoxy (FBE), and 40 mil thick Abrasion Resistant Overlay (ARO).

5.1.9 Installation Load Considerations

For the proposed HDD crossing, we analyzed the anticipated pull loads based upon different drilling fluid weights in the drilled hole and the proposed pipe specifications. We also evaluated the anticipated pull loads based on using or not using buoyancy control. We recommend that the contractor utilize a rig that provides a factor of safety between the rig capacity and the anticipated pull loads. In addition, the contractor should install a deadman anchor of sufficient capacity to withstand the anticipated pull loads; these aspects are generally left to the contractor's discretion as approved by the owner. Based on our analysis of the installation stresses (see Table 6, in Section 4.3), the pullback force may be as high as 240,000 pounds, without the use of some form of buoyancy control and drilling fluid management. The calculations suggest that the pullback force required to install the product pipe may be reduced to approximately 127,000 pounds, if buoyancy control is used and neutral buoyancy is achieved, and drilling fluid weight is properly managed during construction.

5.1.10 Site Access

Access to the entry workspace can be gained from a gravel drive located southeast of the workspace, which connects with Coos River Highway approximately 0.9 miles northeast of the Chandler Bridge, east of Coos Bay, Oregon. Access to the exit workspace could be gained from a gravel road located off of South Coos River Highway approximately 0.7 miles northeast of Chandler Bridge. We anticipate construction of temporary access roads to the entry and exit workspaces will be necessary, depending on PCGP, LP's approved construction access routes. Recommendations for construction of access roads are provided in Section 5.2.1 below.

5.1.11 Water Sources

A reliable source of water for drilling operations is required during the HDD installation process. In addition, water is also required for the hydrostatic testing of the product pipe. Provided permits can be obtained, the HDD contractor may be able to use water from the Coos River or nearby streams for drilling operations. If local water sources are not available or permissible for access, the water for drilling operations will likely have to be obtained from an approved off-site source and transported to the site.

5.1.12 Noise Mitigation Techniques

Residences are located as close as approximately 300 feet the proposed entry workspace and 700 feet from the exit workspace. We do not anticipate that noise mitigation will be required for exit space operations. However, noise mitigation may be required for entry workspace operations. If noise mitigation is required, diesel power units associated with heavy equipment may be outfitted with noise-reducing mufflers. In addition, the contractor may need to place baffles around the equipment to further reduce noise emissions. The actual placement of the noise reduction measures should be implemented by the selected HDD contractor, when necessary.

5.2 Geotechnical Engineering Considerations

5.2.1 Temporary Site Access

If ground disturbance must be reduced to the extent possible, we recommend the construction of temporary access roads to the HDD work areas. The temporary access roads should consist of either board roads or a minimum 12-inch-thick layer of 4-inch-diameter quarry spalls. If soft or wet near surface soils are encountered, these measures may need to be augmented. If board roads are used, several layers of mats may be necessary to provide adequate support for the heavy equipment entering the site. If quarry spalls are used, the quarry spall thickness may need to be increased or a layer of woven geotextile fabric (TC Mirafi 600X or equivalent) or biaxial geogrid (Tensar BX 1200 or equivalent) may be placed below the quarry spalls. The temporary roads should be constructed with culverts and other improvements necessary to allow surface water runoff to drain without ponding or changing off-site drainage patterns.

5.2.2 Temporary Workspace Areas

Temporary work pad areas for staging drilling equipment, pipeline materials and excavation equipment may be necessary at the entry and exit points depending on the conditions at the time of construction. The size and location of workspace areas to accommodate the HDD and pipeline tie-in activities depend on the available space and right-of-way constraints. The proposed temporary entry, exit and product pipe stringing workspaces for the project are shown in Figure 2.

If necessary, we recommend that the workspace areas be protected with either board mats or a minimum 12-inch-thick layer of 4-inch-diameter quarry spalls. If soft or wet near-surface soils are encountered, these measures may need to be augmented. If board mats are used, several layers of mats may be necessary to provide adequate support for the heavy equipment entering the site. If quarry spalls are used, quarry spall thickness may need to be increased or a layer of woven geotextile fabric (TC Mirafi 600X or equivalent) or biaxial geogrid (Tensar BX 1200 or equivalent) may be placed below the quarry spalls. We also recommend placing an additional 2-inch-thick layer of ¾-inch crushed rock on top of the quarry spalls, which should improve the overall site safety and provide a level surface for light-duty vehicles and foot traffic. The temporary work pads should be removed upon completion of the product pipe installation, and the areas should be restored in accordance with the project site restoration plan.

5.2.3 HDD Installation

Drilling fluid containment pits will be required at the drill entry and exit work areas. Depending on the practices of the HDD contractor, drilling fluid containment pit excavations are typically constructed adjacent to the centerline near the entry and exit point locations and are approximately 20 feet long by 10 feet wide by 6 feet deep.

Based on the completed explorations, soil within the planned excavation depths is anticipated to consist of very soft fat clay and organic silt. Conventional equipment, such as backhoes or excavators, should be suitable for excavation of these soils.

5.2.4 Temporary Excavations

Maintenance of safe working conditions, including temporary excavation stability, is the responsibility of the contractor. All temporary cuts in excess of 4 feet in height should be shored or sloped in accordance with OSHA regulation 1926 Subpart P, Appendix B – Sloping and Benching. For planning purposes, soils encountered within the exploratory borings in the vicinity of the excavation areas should be classified as Type C Soil. Temporary excavations in Type C soil should be inclined no steeper than 1.5H:1V (horizontal to vertical). However, if caving occurs in excavation sidewalls, temporary excavations may need to be laid back to a shallower inclination. These cut slope inclinations are applicable to excavations above the groundwater table only. Dewatering may be required to lower the groundwater table below the base of the excavations. Steeper temporary slope inclinations may be allowed if soil conditions are determined to be suitable by the field geotechnical engineer. For open cuts, we recommend that:

1. No traffic, construction equipment, stockpiles or supplies should be allowed within a distance of at least 5 feet from the top of the cut;
2. Construction activities should be scheduled to reduce the length of time the cuts are left open;
3. Erosion control measures should be implemented as appropriate to limit runoff from the site; and
4. Surface water should be diverted away from the excavations.

5.2.5 Construction Dewatering

The contractor should have the responsibility of determining whether dewatering measures are needed at the time of work. Based on the explorations completed to date, we anticipate that very soft fat clay and organic silt could be encountered in shallow excavations at entry and exit. Groundwater seepage through low plasticity or granular soils may cause caving, making it difficult to keep the excavations open to the required depths. If granular soils and high groundwater conditions are encountered, the contractor may need to implement a well point or pumping well dewatering system. The construction of low berms around excavations should help reduce the volume of surface water runoff entering the excavations.

The contractor should be prepared to handle the effluent that will be generated during any dewatering operations. The effluent may need to be treated in a settlement tank, sediment trap or basin in order to meet discharge permit requirements for sediment content. Additionally, filter bags or filter socks might be necessary at the end of the outfall pipe or hose to reduce sediment discharge.

5.2.6 Erosion Control

To reduce the potential for migration of sediment off site and into adjacent receiving waters during HDD operations, we recommend that state and local regulations be followed during and after construction operations. Proper BMP should be implemented in accordance with the PCGP Project's Erosion Control and Revegetation Plan (ECRP).

6.0 LIMITATIONS

We have prepared this report for use by PCGP, LP. GeoEngineers' report is not intended for use by others, and the information contained herein is not applicable to other sites. The data and report should be provided to prospective contractors, but our report, conclusions and interpretations should not be construed as a warranty of the subsurface conditions. The conclusions and recommendations in this report should be applied in their entirety.

Variations in subsurface conditions are possible between the explorations. Subsurface conditions may also vary with time. A contingency for unanticipated conditions should be included in the project budget and schedule for such an occurrence. We recommend that sufficient monitoring, testing and consultation be provided by GeoEngineers during construction to confirm that the conditions encountered are consistent with those indicated by the explorations, to provide recommendations for design changes should the conditions revealed during the work differ from those anticipated, and to evaluate whether earthwork and pipeline installation activities comply with contract plans and specifications.

The scope of our services does not include services related to construction safety precautions. Our recommendations are not intended to direct the contractor's methods, techniques, sequences or procedures, except as specifically described in our report for consideration in design.

Within the limitations of scope, schedule and budget, our services have been executed in accordance with generally accepted practices in this area at the time the report was prepared. No warranty or other conditions, express, written or implied, should be understood.

Please refer to Appendix C, titled "Report Limitations and Guidelines for Use," for additional information pertaining to use of this report.

7.0 REFERENCES

American Petroleum Institute, Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms – Working Stress Design, API Recommended Practice 2A-WSD, July 1, 1993.

Beaulieu, J.D. and E.M. Baldwin, Geologic Map of the Coos Bay Quadrangle, Oregon. Included in Bulletin 87, Environmental Geology of Western Coos and Douglas Counties, Oregon. State of Oregon Department of Geology and Mineral Industries, Scale 1:62,500, 1973.

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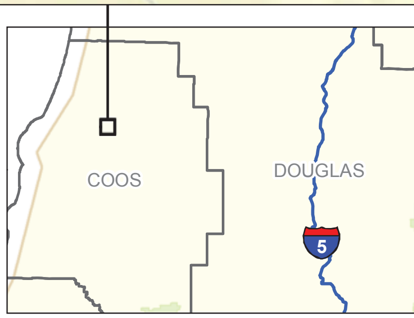
Oregon Department of Transportation Highway Division, Oregon Department of Transportation Soil and Rock Classification Manual, 1987.

Staheli, K., Bennett, D., O'Donnell, H.W., and Hurley, T.J., Installation of Pipelines beneath levees using horizontal directional drilling, Technical Report CPAR-GL-98-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, 1998.

USGS, Spatial Digital Database for the Geologic Map of Oregon. Geology compiled by George W. Walker and Norman S. MacLeod. Spatial database by Robert J. Miller, Gary L. Raines and Katherine A. Connors. United States Geological Survey Open File Report 03-67, 2002.

FIGURES



N
W E
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2,000 0 2,000
Feet

Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.
Data Sources: ESRI Data & Maps, Street Maps 2008.
Base map from ESRI Data Online.
Projection: NAD 1983, UTM Zone 10 North.

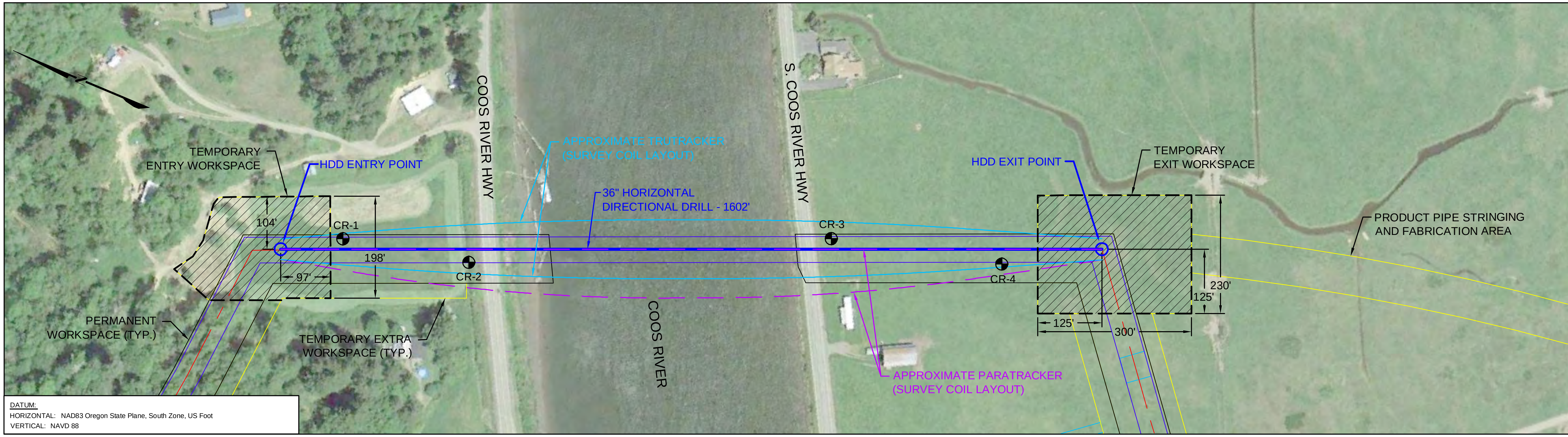
Vicinity Map

Coos River HDD
Coos County, Oregon

GEOENGINEERS

Figure 1

Office: PORT Path: P:\16\16724002\GIS\MXD\Task300\1672400200_Tsk300_CoosR_HDD_VM.mxd Map Revised: 21 July 2014 ccabrera

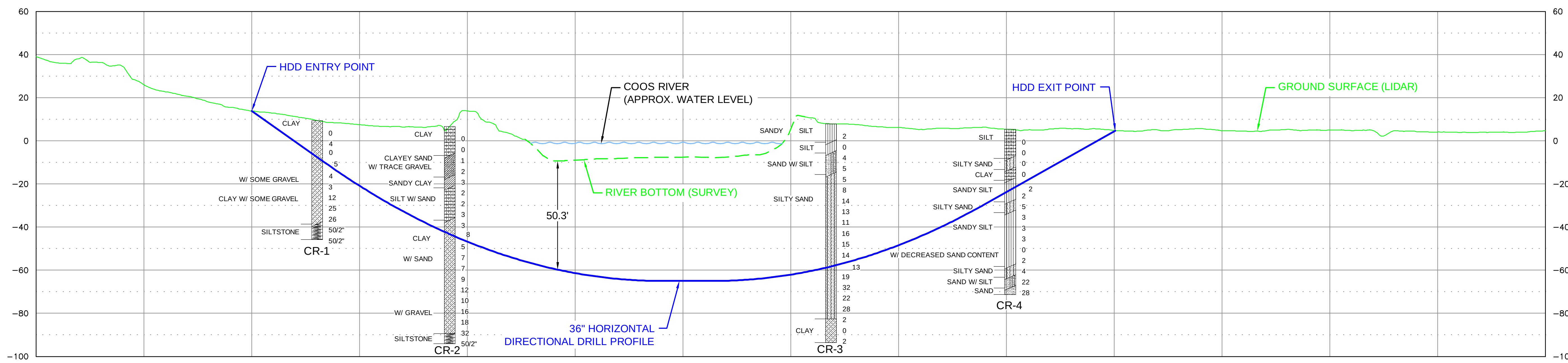


NOT FOR CONSTRUCTION

PLAN

200' 0 200'

SCALE IN FEET



PROFILE

200' 0 200'

HORIZONTAL SCALE IN FEET

50' 0 50'

VERTICAL SCALE IN FEET

Notes:

1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.
3. Refer to the boring logs in the accompanying report for more detailed soil descriptions.
4. GeoEngineers, Inc. has not verified the field location of the existing utilities.

Reference: Aerial image taken from Google Earth Pro, licensed to GeoEngineers, Inc., dated 05-03-13.
Surface lidar data generated from: edited lidar elevation data,
downloaded from http://www.oregongeology.org
River bottom survey provided by Williams Northwest Pipeline, LLC.

LEGEND:

TYPE OF SOIL — SPT (N)

TYPE OF ROCK — RQD/%REC

Boring Location

SITE PLAN AND PROFILE

COOS RIVER HDD
COOS COUNTY, OREGON

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FIGURE 2

AES : RBM

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Entry Looking Southeast Toward Exit

Exit Looking Northwest Toward Entry

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Pacific Connector Gas Pipeline Project
Coos River HDD Site Photos

FIGURE 3

Boring CR-4 Looking Toward Exit

West of Exit Looking Toward Stringing Area

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Pacific Connector Gas Pipeline Project
Coos River HDD Site Photos

FIGURE 4

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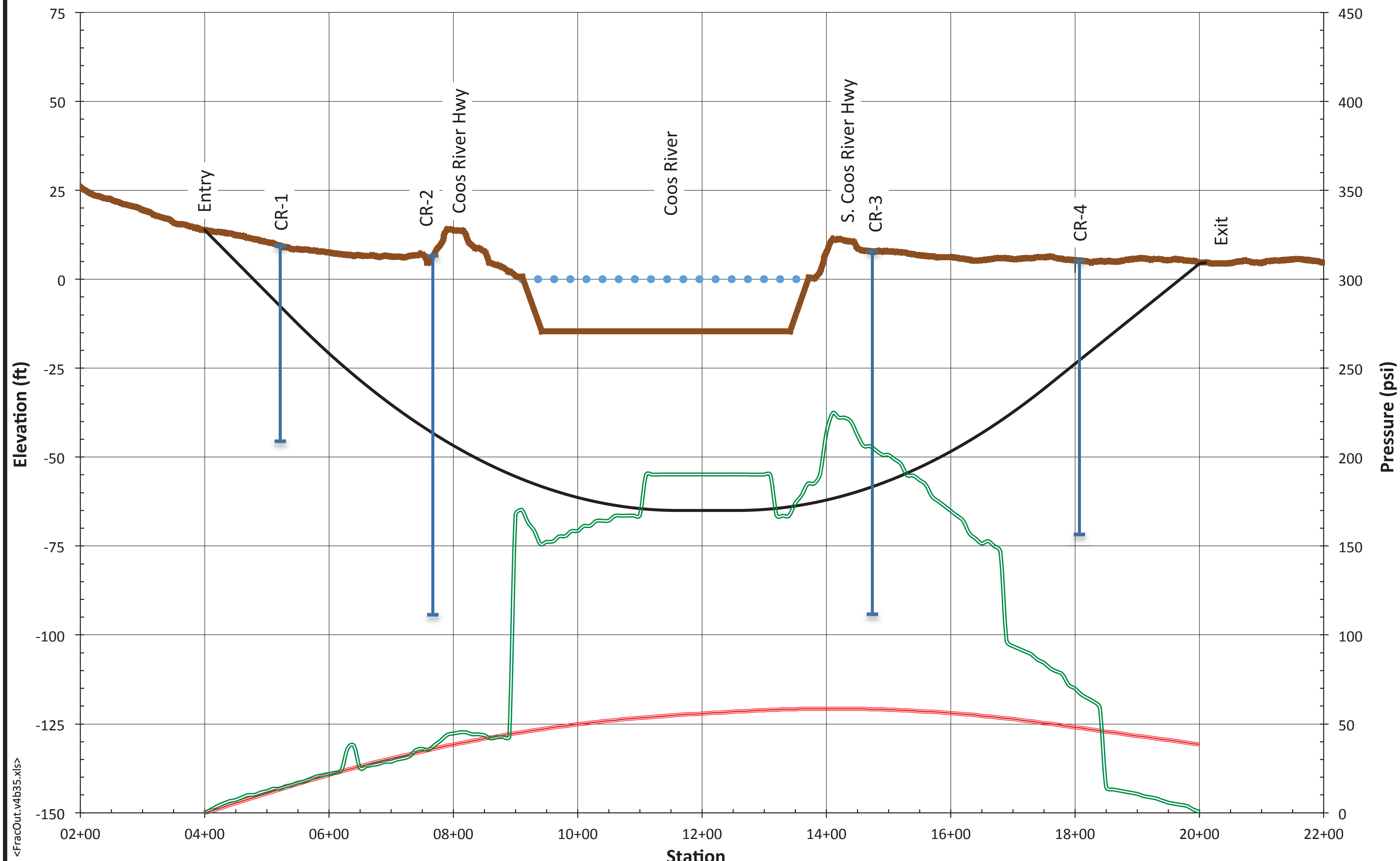

Crossing Length (ft)	1602
Hole Diameter (in)	9.875
Drill Pipe O.D. (in)	5.000
Drilling Fluid Weight (ppg)	9.5
Plastic Viscosity (CP)	8
Yield Point (lb/100 ft)	20

Ground Surface Elevation (ft)
HDD Profile (ft)
Estimated Annular Drilliing Fluid Pressure (psi) for Pilot Hole
Formation Limit Pressure (psi)

ESTIMATED ANNULAR DRILLING FLUID AND FORMATION LIMIT PRESSURES

PCGP - COOS RIVER HDD

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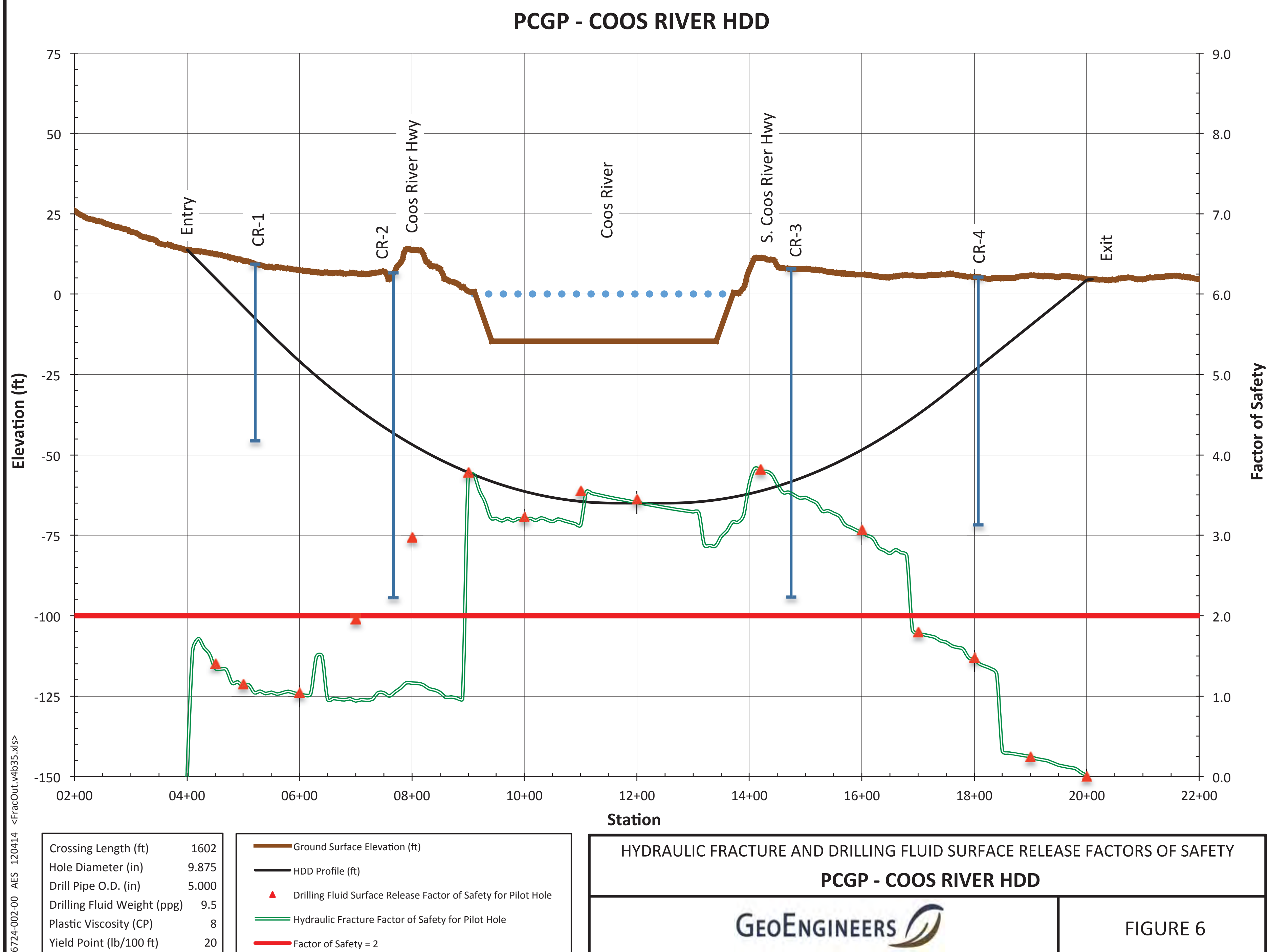
FIGURE 5



Crossing Length (ft)	1602
Hole Diameter (in)	9.875
Drill Pipe O.D. (in)	5.000
Drilling Fluid Weight (ppg)	9.5
Plastic Viscosity (CP)	8
Yield Point (lb/100 ft)	20

HYDRAULIC FRACTURE AND DRILLING FLUID SURFACE RELEASE FACTORS OF SAFETY

PCGP - COOS RIVER HDD

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FIGURE 6

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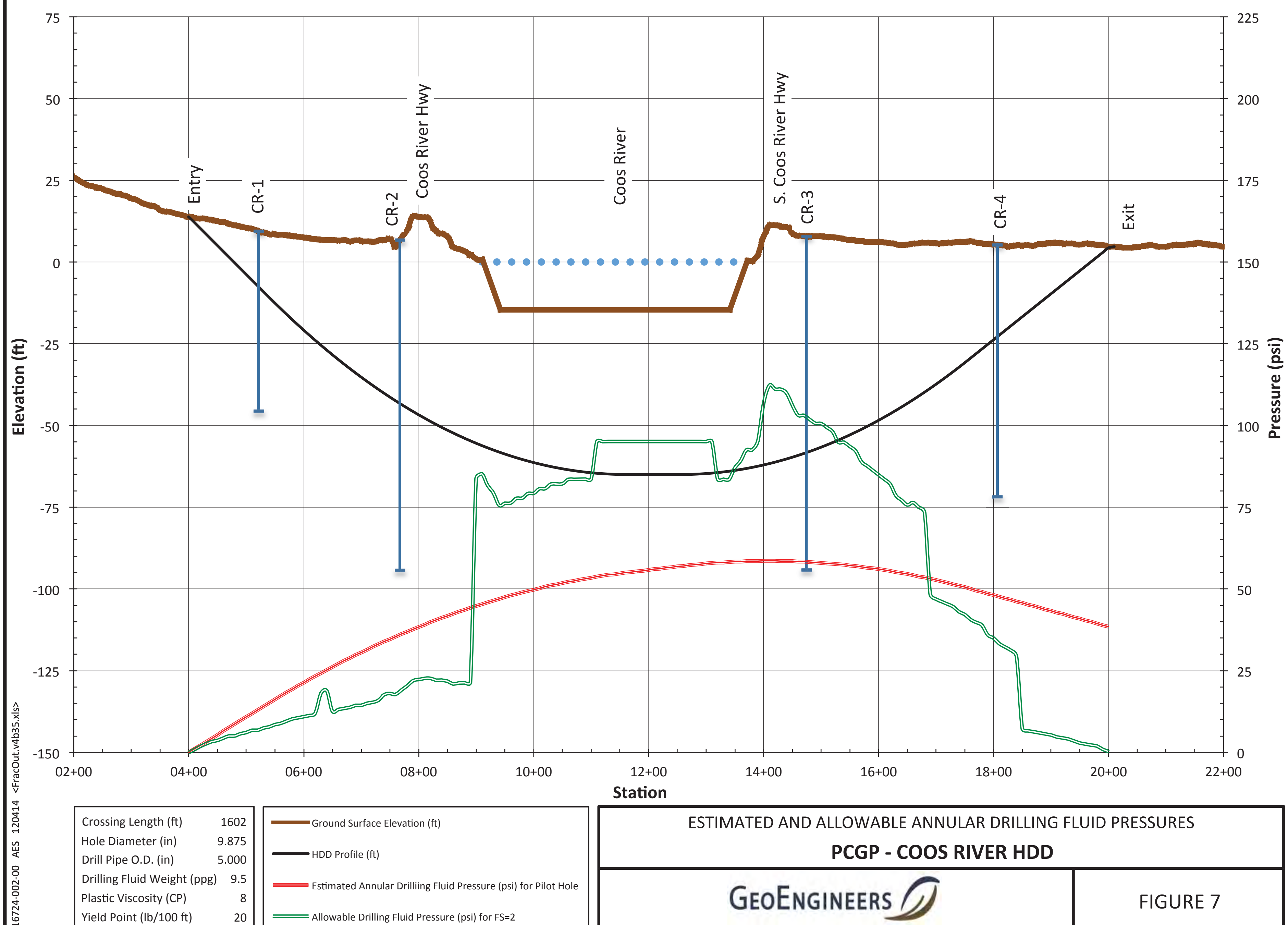
PCGP - COOS RIVER HDD



Crossing Length (ft)	1602
Hole Diameter (in)	9.875
Drill Pipe O.D. (in)	5.000
Drilling Fluid Weight (ppg)	9.5
Plastic Viscosity (CP)	8
Yield Point (lb/100 ft)	20

ESTIMATED AND ALLOWABLE ANNULAR DRILLING FLUID PRESSURES

PCGP - COOS RIVER HDD

GeoEngineers

FIGURE 7

16724-002-00 AES 120414 <FracOut.v4b35.xls>

APPENDICES

APPENDIX A
Field Explorations and Laboratory-Testing Program

APPENDIX A
FIELD EXPLORATION AND LABORATORY-TESTING PROGRAM

We explored subsurface conditions at the site by drilling four borings with a truck-mounted drill rig using mud rotary drilling methods. Western States Drilling of Hubbard, Oregon drilled the borings to depths of up to 101.5 feet bgs. Figure 2 shows the approximate boring locations. A representative from our office observed field activities, classified the soil and rock encountered, obtained representative samples, observed groundwater conditions where possible and prepared a log of each exploration. The borings were backfilled with a bentonite and cement grout mixture at the conclusion of each exploration.

Soil samples were obtained by performing SPTs in general accordance with ASTM Test Method D 1586. The sampler was driven with a 140-pound hammer falling 30 inches. The number of blows required to drive the sampler 1 foot, or as otherwise indicated, into the soils is shown adjacent to the sample symbols on the boring logs. Disturbed samples were obtained from the split barrel sampler for subsequent classification and index testing.

Soils encountered in the borings were classified in the field by a GeoEngineers representative in general accordance with ASTM D 2488, the Standard Practice for the Classification of Soils (Visual-Manual Procedure) which is described in Figure A-1. Rock encountered in the borings was classified in general accordance with the ODOT rock classification system (ODOT, 1987), which is described in Figure A-2. The boring logs are presented in Figures A-3 through A-6. Soil and rock classification and sampling intervals are shown in the boring logs. Inclined lines at the material contacts shown on the log indicate uncertainty as to the exact contact elevation, rather than the inclination of the contact itself.

The relative density of the SPT samples recovered at each interval was evaluated based on correlations with lab and field observations in general accordance with the values outlined in Table A-1 below.

TABLE A-1. CORRELATION BETWEEN BLOW COUNTS AND RELATIVE DENSITY *

Cohesive Soils (Clay/Silt)						
Parameter	Very Soft	Soft	Medium Stiff	Stiff	Very Stiff	Hard
Blows, N	< 2	2 – 4	4 - 8	8 – 16	16 - 32	>32

Cohesionless Soils (Gravel/Sand/Silty Sand) **					
Parameter	Very Loose	Loose	Medium Dense	Dense	Very Dense
Blows, N	0 – 4	4 – 10	10 – 30	30 - 50	> 50

Notes:

*After Terzaghi, K and Peck, R.B., “Soil Mechanics in Engineering Practice,” John Wiley & Sons, Inc., 1962.

**Classification applies to soils containing additional constituents; that is, organic clay, silty or clayey sand, etc.

Laboratory Testing

General

Samples obtained from the explorations were transported to our Portland, Oregon laboratory and examined to confirm or modify field classifications, as well as to evaluate engineering properties of the samples. Representative samples were selected for laboratory testing consisting of moisture content determinations, sieve analyses, fines content, and Atterberg limits tests. The laboratory-testing procedures are discussed in more detail below.

Moisture Content Testing

Moisture content tests were completed for representative samples obtained from the explorations. The results of these tests are presented on the exploration logs in Figures A-3 through A-6 at the depths at which the samples were obtained.

Fines Content Determinations

Fines content determinations were performed on selected soil samples in general accordance with ASTM D 1140. The results of the fines content determinations are shown on the attached boring logs at the depths at which the samples were obtained.

Sieve Analyses

Sieve analyses were performed on selected coarse-grained samples in general accordance with ASTM D 422. The results of the sieve analyses were plotted and classified in general accordance with the Unified Soil Classification System (USCS) and are presented in Figures A-7 through A-11. The percentage passing the U.S. No. 200 sieve is shown on the boring logs at the respective sample depths.

Atterberg Limits Testing

Atterberg Limits tests were performed on selected fine-grained soil samples in general accordance with ASTM D 4318. The tests were used to classify the soil as well as to evaluate its index properties. The results of the Atterberg Limits testing are shown in Figures A-12 through A-17.

SOIL CLASSIFICATION CHART

MAJOR DIVISIONS			SYMBOLS GRAPH	SYMBOLS LETTER	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVELS, GRAVEL - SAND MIXTURES
				GP	POORLY-GRADED GRAVELS, GRAVEL - SAND MIXTURES
	MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	SILTY GRAVELS, GRAVEL - SAND - SILT MIXTURES
				GC	CLAYEY GRAVELS, GRAVEL - SAND - CLAY MIXTURES
MORE THAN 50% RETAINED ON NO. 200 SIEVE	SAND AND SANDY SOILS	CLEAN SANDS (LITTLE OR NO FINES)		SW	WELL-GRADED SANDS, GRAVELLY SANDS
				SP	POORLY-GRADED SANDS, GRAVELLY SAND
	MORE THAN 50% OF COARSE FRACTION PASSING NO. 4 SIEVE	SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	SILTY SANDS, SAND - SILT MIXTURES
				SC	CLAYEY SANDS, SAND - CLAY MIXTURES
FINE GRAINED SOILS	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS, ROCK FLOUR, CLAYEY SILTS WITH SLIGHT PLASTICITY
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
MORE THAN 50% PASSING NO. 200 SIEVE	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS SILTY SOILS
				CH	INORGANIC CLAYS OF HIGH PLASTICITY
				OH	ORGANIC CLAYS AND SILTS OF MEDIUM TO HIGH PLASTICITY
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

NOTE: Multiple symbols are used to indicate borderline or dual soil classifications

ADDITIONAL MATERIAL SYMBOLS

SYMBOLS GRAPH	SYMBOLS LETTER	TYPICAL DESCRIPTIONS
	AC	Asphalt Concrete
	CC	Cement Concrete
	CR	Crushed Rock/ Quarry Spalls
	TS	Topsoil/ Forest Duff/Sod

Groundwater Contact

Measured groundwater level in exploration, well, or piezometer

Measured free product in well or piezometer

Graphic Log Contact

Distinct contact between soil strata or geologic units

Approximate location of soil strata change within a geologic soil unit

Material Description Contact

Distinct contact between soil strata or geologic units

Approximate location of soil strata change within a geologic soil unit

Sampler Symbol Descriptions

2.4-inch I.D. split barrel

Standard Penetration Test (SPT)

Shelby tube

Piston

Direct-Push

Bulk or grab

Blowcount is recorded for driven samplers as the number of blows required to advance sampler 12 inches (or distance noted). See exploration log for hammer weight and drop.

A "P" indicates sampler pushed using the weight of the drill rig.

Laboratory / Field Tests

%F	Percent fines
AL	Atterberg limits
CA	Chemical analysis
CP	Laboratory compaction test
CS	Consolidation test
DS	Direct shear
HA	Hydrometer analysis
MC	Moisture content
MD	Moisture content and dry density
OC	Organic content
PM	Permeability or hydraulic conductivity
PI	Plasticity index
PP	Pocket penetrometer
PPM	Parts per million
SA	Sieve analysis
TX	Triaxial compression
UC	Unconfined compression
VS	Vane shear

Sheen Classification

NS	No Visible Sheen
SS	Slight Sheen
MS	Moderate Sheen
HS	Heavy Sheen
NT	Not Tested

NOTE: The reader must refer to the discussion in the report text and the logs of explorations for a proper understanding of subsurface conditions. Descriptions on the logs apply only at the specific exploration locations and at the time the explorations were made; they are not warranted to be representative of subsurface conditions at other locations or times.

KEY TO EXPLORATION LOGS

GeoEngineers

FIGURE A-1

Scale of Relative Rock Weathering (ODOT, 1987)

Designation	Field Identification
Fresh	Crystals are bright. Discontinuities may show some minor surface staining. No discoloration in rock fabric.
Slightly Weathered	Rock mass is generally fresh. Discontinuities are stained and may contain clay. Some discoloration in rock fabric. Decomposition extends up to 1 inch into rock.
Moderately Weathered	Rock mass is decomposed 50% or less. Significant portions of rock show discoloration and weathering effects. Crystals are dull and show visible chemical alteration. Discontinuities are stained and may contain secondary mineral deposits.
Predominantly Decomposed	Rock mass is more than 50% decomposed. Rock can be excavated with geologist's pick. All discontinuities exhibit secondary mineralization. Complete discoloration of rock fabric. Surface of core is friable and usually pitted due to washing out of highly altered minerals by drilling water.
Decomposed	Rock mass is completely decomposed. Original rock "fabric" may be evident. May be reduced to soil with hand pressure.

Scale of Relative Rock Hardness (ODOT, 1987)

Term	Hardness Designation	Field Identification	Approximate Unconfined Compressive Strength
Extremely Soft	R0	Can be indented with difficulty by thumbnail. May be moldable or friable with finger pressure.	< 100 psi
Very Soft	R1	Crumbles under firm blows with point of a geology pick. Can be peeled by a pocket knife. Scratched with fingernail.	100-1000 psi
Soft	R2	Can be peeled by a pocket knife with difficulty. Cannot be scratched with fingernail. Shallow indentation made by firm blow of geology pick.	1000-4000 psi
Medium Hard	R3	Can be scratched by knife or pick. Specimen can be fractured with a single firm blow of hammer/geology pick.	4000-8000 psi
Hard	R4	Can be scratched with knife or pick only with difficulty. Several hard hammer blows required to fracture specimen.	8000-16000 psi
Very Hard	R5	Cannot be scratched by knife or sharp pick. Specimen requires many blows of hammer to fracture or chip. Hammer rebounds after impact.	> 16000 psi

Rock Quality Designation (RQD)

RQD (Percent)	Description of Rock Quality
0 to 25	Very Poor
25 to 50	Poor
50 to 75	Fair
75 to 90	Good
90 to 100	Excellent

RQD is a modified core recovery measurement which expresses the number of hard and sound rock pieces of 4" or more in size as a percentage of the total length of core run.

Discontinuity Spacing (ODOT, 1987)

Description for Bedding, Foliation, or Flow Banding	Spacing	Description of Joints, Faults, or Other Fractures
Very Thickly	>10 feet	Very Widely
Thickly	3-10 feet	Widely
Medium	1-3 feet	Moderately Close
Thinly	2-12 inches	Closely
Very Thinly	< 2 inches	Very Closely

EXPLANATION OF BEDROCK TERMS

GeoEngineers

FIGURE A-2

Drilled	Start 12/6/2012	End 12/7/2012	Total Depth (ft)	55.2	Logged By KWW / Checked By AES	Driller	Western States Drilling	Drilling Method	Mud Rotary

Surface Elevation (ft) / Vertical Datum	24	Hammer Data	Auto 140 (lbs) / 30 (in) Drop	Drilling Equipment	CME 75
Latitude / Longitude	43° 22' 32.016" N / 124° 8' 28.968" W	System / Datum	Geographic / WGS84	Groundwater	

Groundwater — Date Measured | Depth to Water (ft) | Elevation (ft): Not encountered

Notes: Boring backfilled with cement-bentonite grout upon completion.

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	0								CH	Grayish brown fat clay with occasional organic matter (very soft, wet)			
20													
	5		12	0		1 / AL					52		AL; PI = 31
15													
	10		6	4		2				Becomes soft			
10													
	15		12	0		3 / AL				With trace organic matter, very soft	51		AL; PI = 44
5													
	20		18	5		4				Becomes medium stiff			
0													
	25		12	4		5 / AL					45		AL; PI = 28
										Becomes blue-gray with occasional gravel, soft			
-5													
	30		12	3		6							
-10													
	35												

Note: See Figure A-1 for explanation of symbols

Log of Boring CR-1

GeoEngineers

Project: PCGP Pacific Connector Pipeline
Project Location: Coos County, Oregon
Project Number: 16724-002-00

Figure A-3
Sheet 1 of 2

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	35		6	12		7			CH	Blue-gray fat clay with occasional gravel and organic matter (stiff, wet)			
-15										Becomes orange-gray-blue mottled, very stiff (weakly to moderately cemented)			
	40		12	25		8 / AL					37		AL; PI = 38
-20													
	45		12	26		9							
-25									SLST	Orange-gray siltstone; predominantly decomposed, very soft			
	50		2	50/2"		10							
-30													
	55		2	50/2"		11				Becomes gray, fresh			

Note: See Figure A-1 for explanation of symbols

Log of Boring CR-1 (continued)

GeoEngineers

Project: PCGP Pacific Connector Pipeline
Project Location: Coos County, Oregon
Project Number: 16724-002-00

Drilled	Start 12/7/2012	End 12/7/2012	Total Depth (ft) 100.7	Logged By KWW / Checked By AES	Driller Western States Drilling	Drilling Method Mud Rotary

Surface Elevation (ft) / Vertical Datum	14	Hammer Data	Auto, 140 (lbs) / 30 (in) Drop
Drilling Equipment	CME 75		
Latitude	43° 22' 29.564" N	System	Geographic
Longitude	124° 8' 28.108" W	Datum	WGS84

Groundwater: Date Measured / Depth to Water (ft) / Elevation (ft) — Not encountered

Notes: Boring backfilled with cement-bentonite grout upon completion.

Elevation (feet)	Depth (feet)	Recovered (in)	Blows/foot	Sample Name / Testing	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	0				OH	Dark brown organic clay (very soft, wet)			
	5	12	0	1 / AL			138		AL; PI = 188
	10	12	0	2		Woody debris from 10 to 11 feet			
					SC	Gray clayey fine to coarse sand with trace fine gravel (very loose, wet)			
	15	12	1	3 / SA			59		SA; %F = 47 %Gravel = 1
	20	12	2	4					
					CL	Gray fine to coarse sandy lean clay (soft, wet)			
	25	18	3	5 / %F			85		%F = 56
					OH	Dark brown organic silt with sand (woody debris) (soft, wet)			
	30	18	2	6					burn?
	35								

Elevation scale: 10, 5, 0, -5, -10, -15, -20

Note: See Figure A-1 for explanation of symbols

Portland: Date:10/2/14 Path:C:\USERS\KJANC\DESKTOP\1672400200.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_STANDARD

Log of Boring CR-2

GEOENGINEERS

Project: PCGP Pacific Connector Pipeline
Project Location: Coos County, Oregon
Project Number: 16724-002-00

Elevation (feet)	Depth (feet)	Interval Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	35	3	2		7			OH	Dark brown organic silt with sand (woody debris) (soft, wet)			
-25												
	40	18	3		8 / AL					94		AL; PI = 67
-30								CH	Gray fat clay with trace organic matter (soft, wet)			
	45	18	3		9							
-35												
	50	8	8		10 / AL				Becomes medium stiff	41		AL; PI = 36
-40												
	55	18	5		11							
-45												
	60	18	7		12 / AL				With fine sand	44		AL; PI = 34
-50												
	65	18	7		13							
-55												
	70	12	9		14				Becomes orange-gray mottled, stiff (weakly to moderately cemented)			
-60												
	75	12	12		15 / AL					39		AL; PI = 35

Note: See Figure A-1 for explanation of symbols

Portland: Date:10/2/14 Path:C:\USERS\KJANCI\DESKTOP\1672400200.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_STANDARD

Log of Boring CR-2 (continued)

GeoEngineers

Project: PCGP Pacific Connector Pipeline
Project Location: Coos County, Oregon
Project Number: 16724-002-00

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
									OH	Orange-gray mottled fat clay with fine sand and trace organic matter (stiff, wet) (weakly to moderately cemented)			
-65													
	80		12	10		16							
-70													
	85		5	16		17 / AL				With gravel, very stiff			AL; PI = 40
-75													
	90		10	18		18				Becomes gray			
-80													
	95		12	32		19							
									SLST	Brown-gray siltstone; fresh, very soft			
-85													
	100		2	50/2"		20							

Note: See Figure A-1 for explanation of symbols

Log of Boring CR-2 (continued)

GeoEngineers

Project: PCGP Pacific Connector Pipeline

Project Location: Coos County, Oregon

Project Number: 16724-002-00

Drilled	Start 12/7/2012	End 12/7/2012	Total Depth (ft)	101.5	Logged By KWW / Checked By AES	Driller	Western States Drilling	Drilling Method	Mud Rotary

Surface Elevation (ft) / Vertical Datum	2	Hammer Data	Auto 140 (lbs) / 30 (in) Drop	Drilling Equipment	CME 75
Latitude / Longitude	43° 22' 23.484" N / 124° 8' 23.352" W	System / Datum	Geographic / WGS84	Groundwater	

Groundwater: Date Measured | Depth to Water (ft) | Elevation (ft) — Not encountered

Notes: Boring backfilled with cement-bentonite grout upon completion.

Elevation (feet)	Depth (feet)	Recovered (in)	Blows/foot	Sample Name / Testing	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	0				ML	Brown sandy silt with organic matter (woody debris) (very soft, wet)			
0									
	5	6	2	1					
-5									
					ML	Brownish gray silt with occasional organic matter (very soft, wet)			
	10	18	0	2					
-10									
					SP-SM	Gray fine sand with silt (loose, wet)			
	15	12	4	3 SA			34		SA; %F = 12
-15									
	20	8	5	4		With organic matter (woody debris)			
-20									
					SM	Gray silty fine sand with trace organic matter (loose, wet)			
	25	10	5	5					
-25									
	30	12	8	6 SA			42		SA; %F = 40
-30									
	35								

Note: See Figure A-1 for explanation of symbols

Log of Boring CR-3

GEOENGINEERS

Project: PCGP Pacific Connector Pipeline
Project Location: Coos County, Oregon
Project Number: 16724-002-00

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	35		12	14		7			SM	Gray silty fine sand with trace organic matter (medium dense, wet)			
-35													
	40		12	13		8 / SA				Lacks organic matter	34		SA; %F = 19
-40													
	45		12	11		9							
-45													
	50		12	16		10 / SA					36		SA; %F = 19
-50													
	55		18	15		11							
-55													
	60		18	14		12 / SA					46		SA; %F = 29
-60													
	65		18	13		13							
-65													
	70		12	19		14 / SA					33		SA; %F = 23
-70													
	75		12	32		15				Becomes dense			

Note: See Figure A-1 for explanation of symbols

Log of Boring CR-3 (continued)

GeoEngineers

Project: PCGP Pacific Connector Pipeline
Project Location: Coos County, Oregon
Project Number: 16724-002-00

Elevation (feet)	Depth (feet)	Interval Recovered (in)	Blows/foot	Collected Sample / Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
-75							SM	Gray silty fine sand (dense, wet)			
	80	12	22	16 SA				Becomes medium dense	37		SA; %F = 19
-80											
	85	18	28	17							
-85											
	90	12	2	18			CH	Grayish brown fat clay with trace organic matter (very soft, wet)			
-90											
	95	18	0	19 AL					55		AL; PI = 32
-95											
	100	18	2	20							

Note: See Figure A-1 for explanation of symbols

Log of Boring CR-3 (continued)

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Project: PCGP Pacific Connector Pipeline
Project Location: Coos County, Oregon
Project Number: 16724-002-00

Figure A-5
Sheet 3 of 3

Drilled	Start 12/7/2012	End 12/7/2012	Total Depth (ft)	76.5	Logged By KWW Checked By AES	Driller	Western States Drilling	Drilling Method	Mud Rotary

Surface Elevation (ft) Vertical Datum	8	Hammer Data	Auto 140 (lbs) / 30 (in) Drop	Drilling Equipment	CME 75
Latitude Longitude	43° 22' 20.316" N 124° 8' 21.984" W	System Datum	Geographic WGS84	Groundwater: Date Measured / Depth to Water (ft) / Elevation (ft)	Not encountered

Notes: Boring backfilled with cement-bentonite grout upon completion.

Elevation (feet)	Depth (feet)	Interval Recovered (in)	Blows/foot	Collected Sample	Sample Name Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	0							OH	Dark brown organic clay (very soft, wet)			
5		14	0		1							
	5											
0												
	10	18	0		2 AL					111		AL; PI = 102
-5								SM	Gray silty fine sand with trace organic matter (very loose, wet)			
	15	18	0		3 SA					56		SA; %F = 41
-10								OH	Brownish gray organic clay (very soft, wet)			
	20	18	0		4 AL					106		AL; PI = 78
-15								ML	Gray fine sandy silt with trace organic matter (very soft to soft, wet)			
	25	18	2		5							
-20												
	30	18	2		6 %F					52		%F = 58
-25								SM	Gray silty fine sand with trace organic matter (loose, wet)			
	35											

Note: See Figure A-1 for explanation of symbols

Log of Boring CR-4

GeoEngineers

Project: PCGP Pacific Connector Pipeline
Project Location: Coos County, Oregon
Project Number: 16724-002-00

Figure A-6
Sheet 1 of 2

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	35		18	5		7 / SA			SM	Gray silty fine sand with trace organic matter (loose, wet)	53		SA; %F = 49
-30									ML	Gray fine sandy silt (soft, wet)			
	40		18	3		8							
-35													
	45		18	3		9 / %F					53		%F = 53
-40													
	50		18	3		10							
-45													
	55		18	0		11 / %F				Becomes very soft with decreased sand content	57		%F = 76
-50										Becomes brownish gray			
	60		18	2		12							
-55									SM	Gray silty fine sand (very loose, wet)			
	65		18	4		13							
-60									SP-SM	Gray fine sand with silt (medium dense, wet)			
	70		18	22		14							
-65									SP	Gray fine to medium sand (medium dense, wet)			
	75		12	28		15							

Note: See Figure A-1 for explanation of symbols

Log of Boring CR-4 (continued)

GeoEngineers

Project: PCGP Pacific Connector Pipeline
Project Location: Coos County, Oregon
Project Number: 16724-002-00

Figure A-6
Sheet 2 of 2

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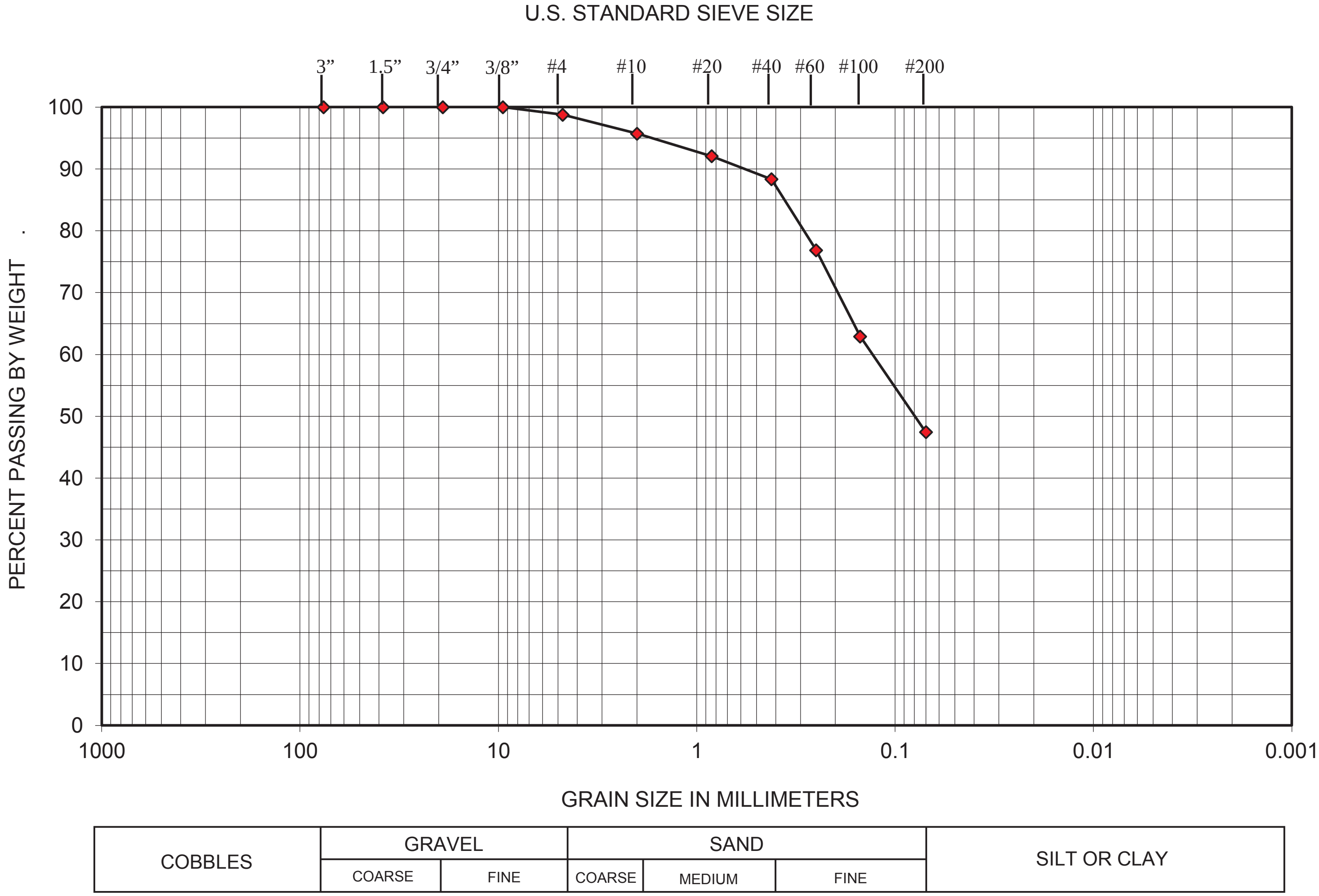

Symbol	Exploration Number	Sample Depth (feet)	Soil Classification
♦	CR-2	15.0 – 16.5	Gray Clayey Fine To Coarse SAND With Trace Fine Gravel (SC)

Sieve Analysis Results

Coos River HDD
Coos County, Oregon

GeoEngineers

Figure A-7

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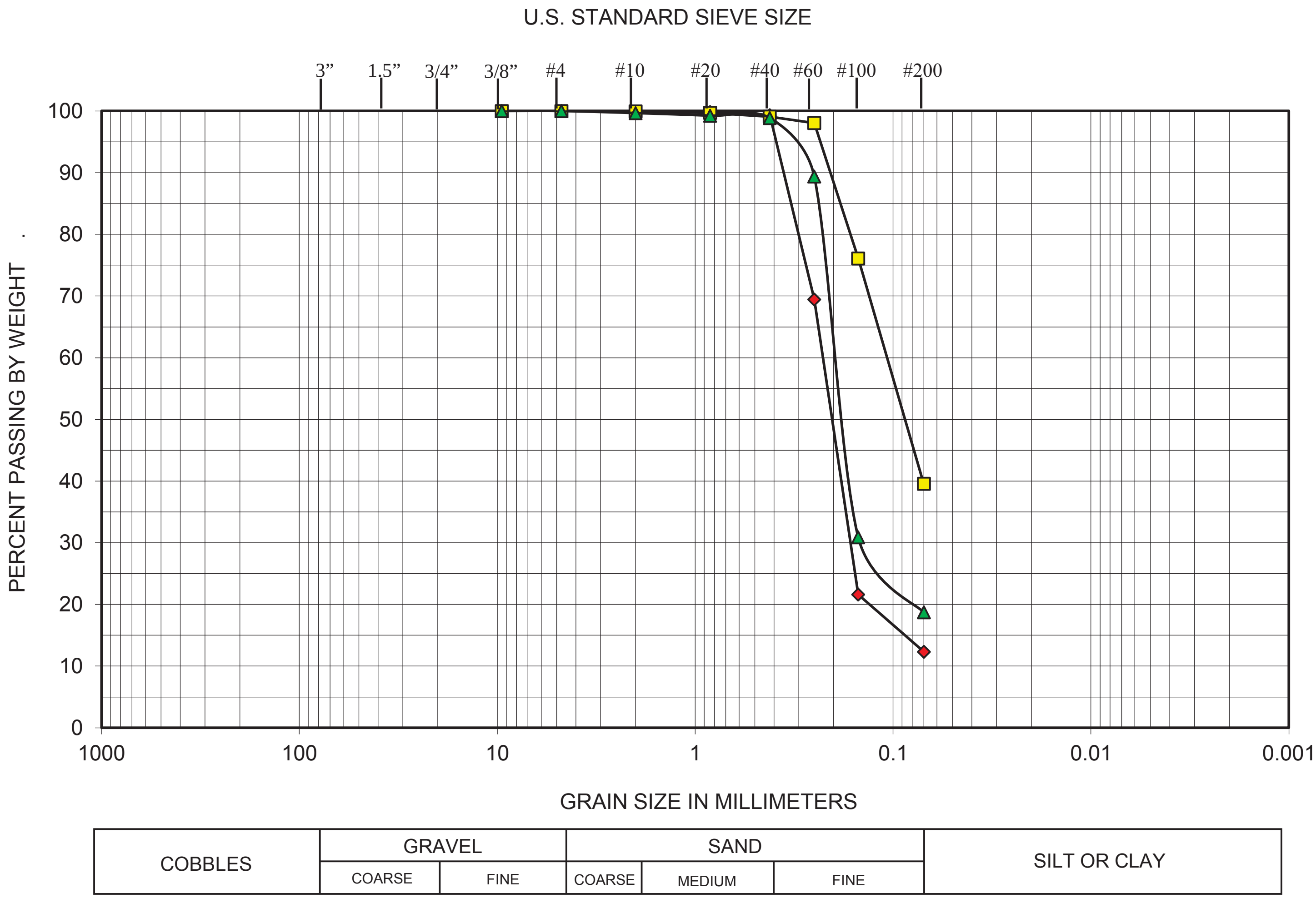


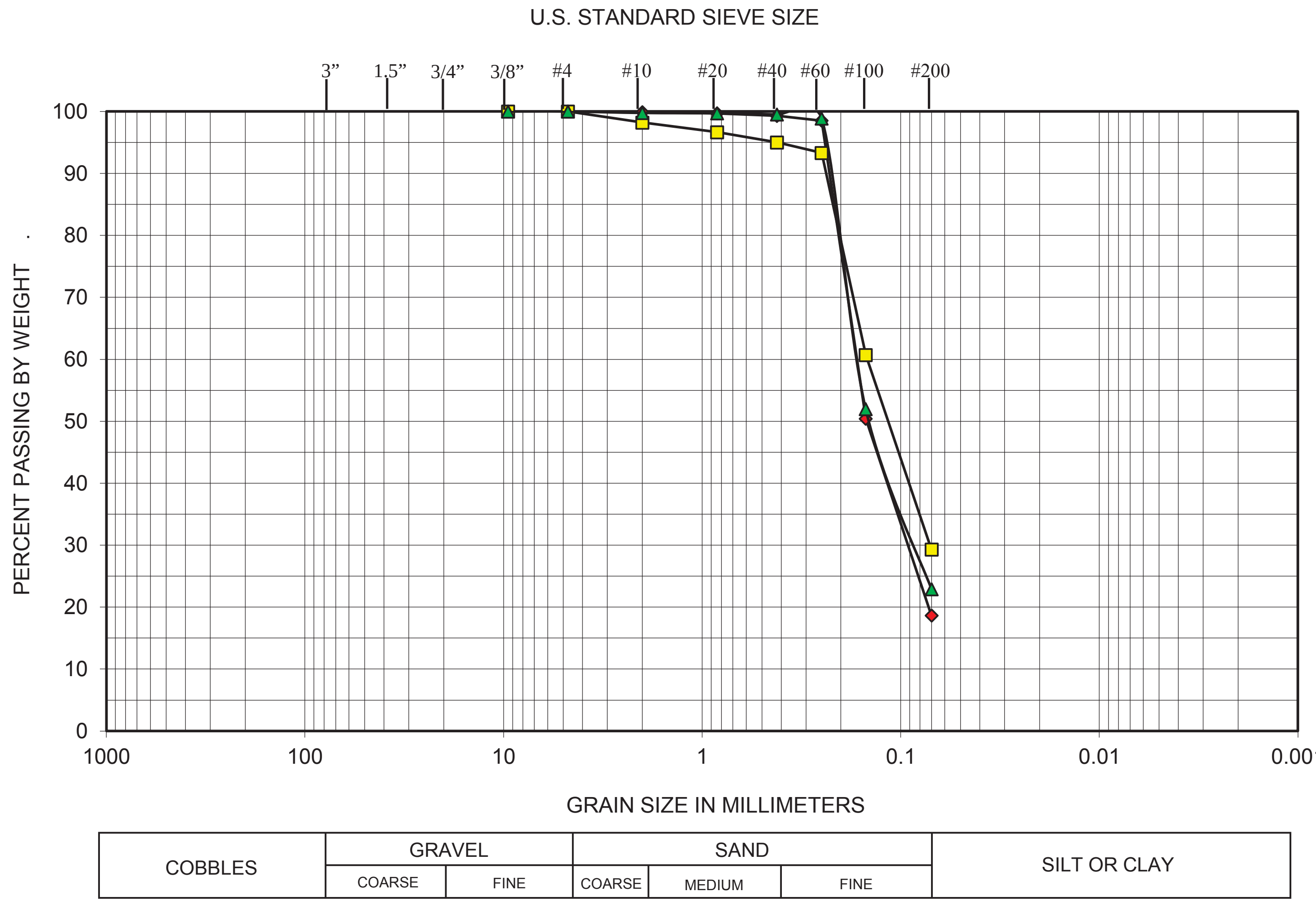
Symbol	Exploration Number	Sample Depth (feet)	Soil Classification
♦ (red diamond)	CR-3	15.0 – 16.5	Gray Fine SAND With Silt (SP-SM)
■ (yellow square)	CR-3	30.0 – 31.5	Gray Silty Fine SAND (SM)
▲ (green triangle)	CR-3	40.0 – 41.5	Gray Silty Fine SAND (SM)

Sieve Analysis Results

Coos River HDD
Coos County, Oregon

GeoEngineers

Figure A-8



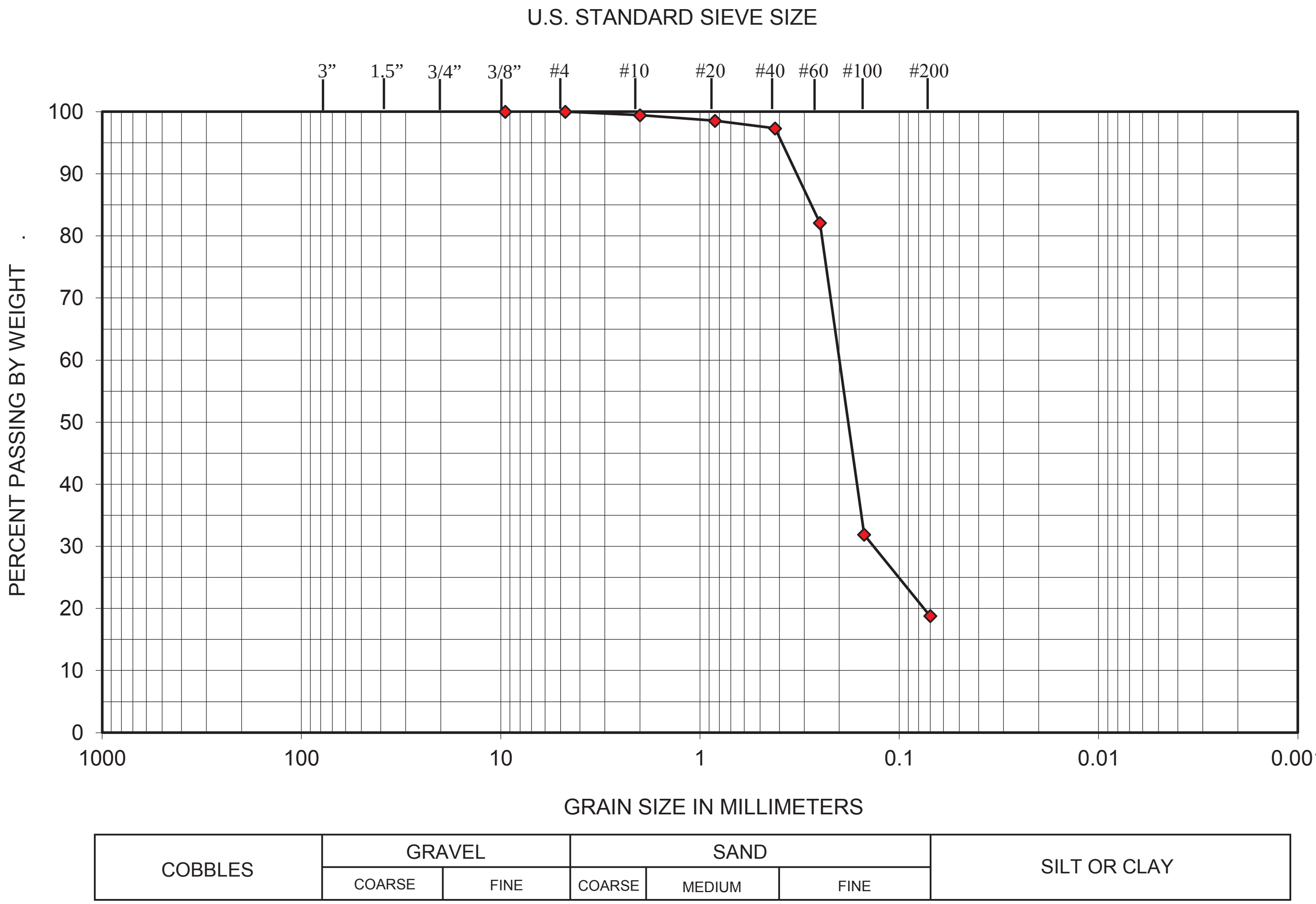
Symbol	Exploration Number	Sample Depth (feet)	Soil Classification
◆ (red diamond)	CR-3	50.0 – 51.5	Gray Silty Fine SAND (SM)
■ (yellow square)	CR-3	60.0 – 61.5	Gray Silty Fine SAND (SM)
▲ (green triangle)	CR-3	70.0 – 71.5	Gray Silty Fine SAND (SM)

Sieve Analysis Results

Coos River HDD
Coos County, Oregon

GEOENGINEERS

Figure A-9



Symbol	Exploration Number	Sample Depth (feet)	Soil Classification
♦	CR-3	80.0 – 81.5	Gray Silty Fine SAND (SM)

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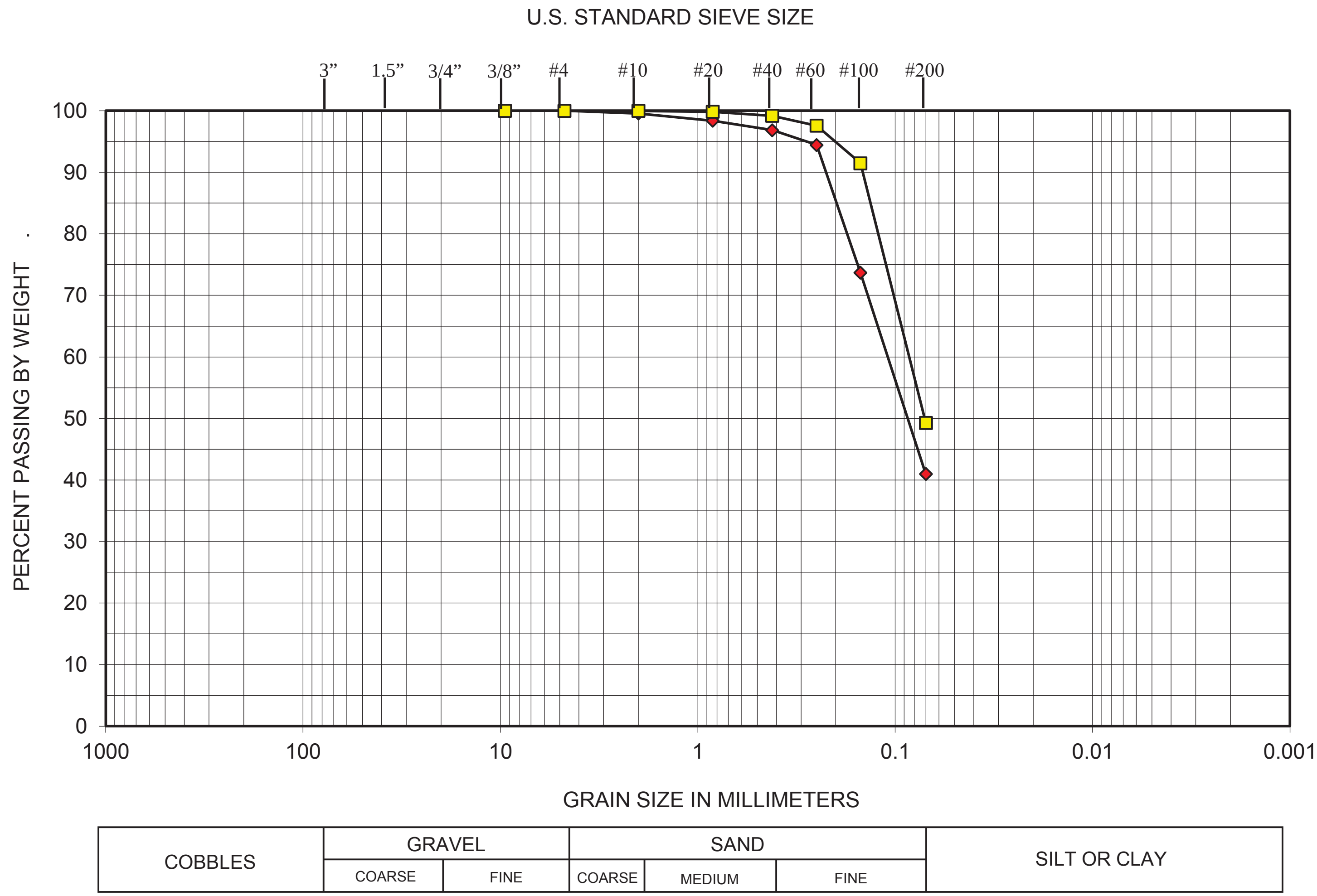
Sieve Analysis Results

Coos River HDD
Coos County, Oregon

GEOENGINEERS

Figure A-10



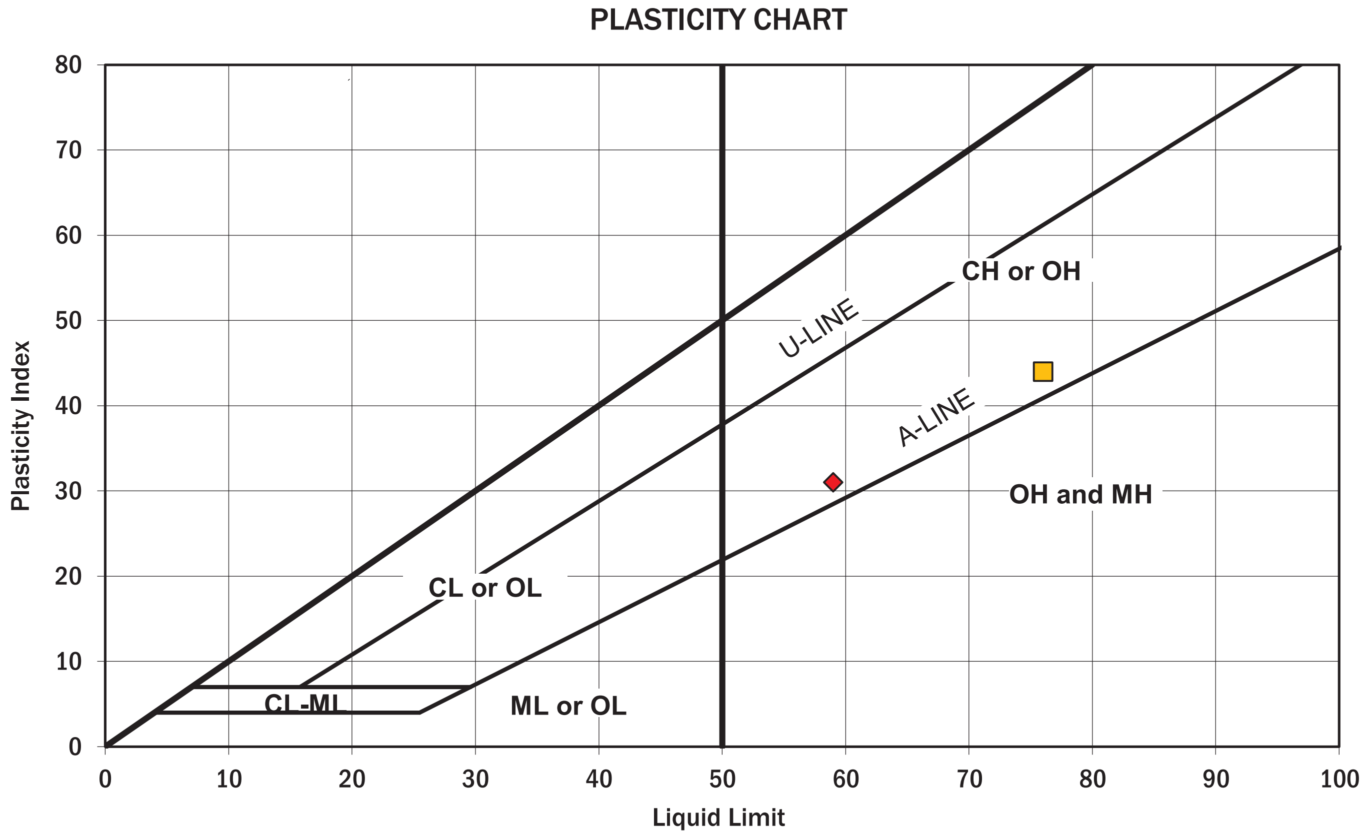
Symbol	Exploration Number	Sample Depth (feet)	Soil Classification
◆	CR-4	15.0 – 16.5	Gray Silty Fine SAND (SM)
■	CR-4	35.0 – 36.5	Gray Silty Fine SAND (SM)

Sieve Analysis Results

Coos River HDD
Coos County, Oregon

GeoEngineers

Figure A-11



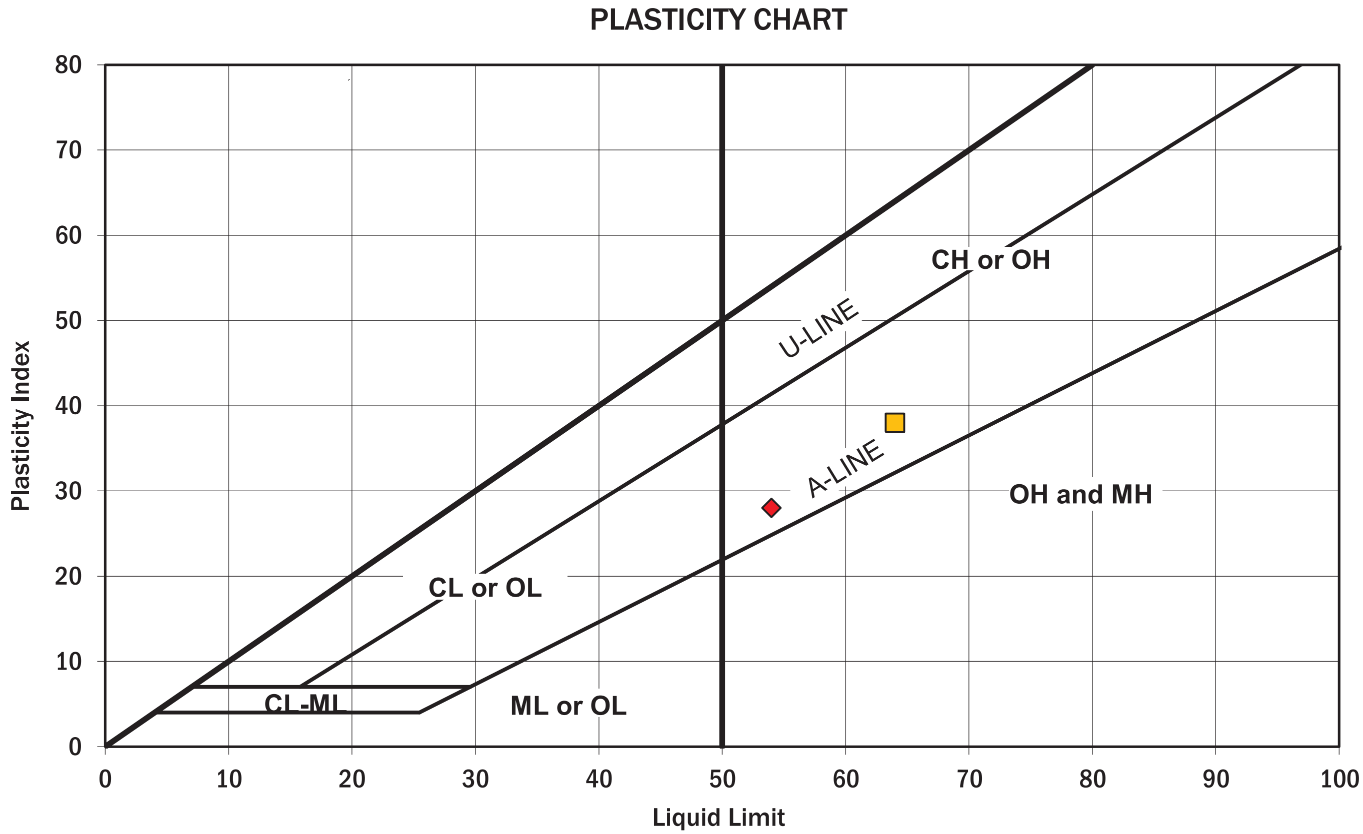
Symbol	Exploration Number	Sample Depth (feet)	Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	Soil Description
♦	CR-1	5.0 – 6.5	52	59	31	Grayish Brown Fat CLAY (CH)
□	CR-1	15.0 – 16.5	51	76	44	Grayish Brown Fat CLAY (CH)

Atterberg Limits Test Results

Coos River HDD
Coos County, Oregon

GEOENGINEERS

Figure A-12



Symbol	Exploration Number	Sample Depth (feet)	Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	Soil Description
♦	CR-1	25.0 – 26.5	45	54	28	Blue-Gray Fat CLAY With Occasional Gravel (CH)
■	CR-1	40.0 – 41.5	37	64	38	Orange-Gray-Blue Mottled Fat CLAY With Occasional Gravel (CH)

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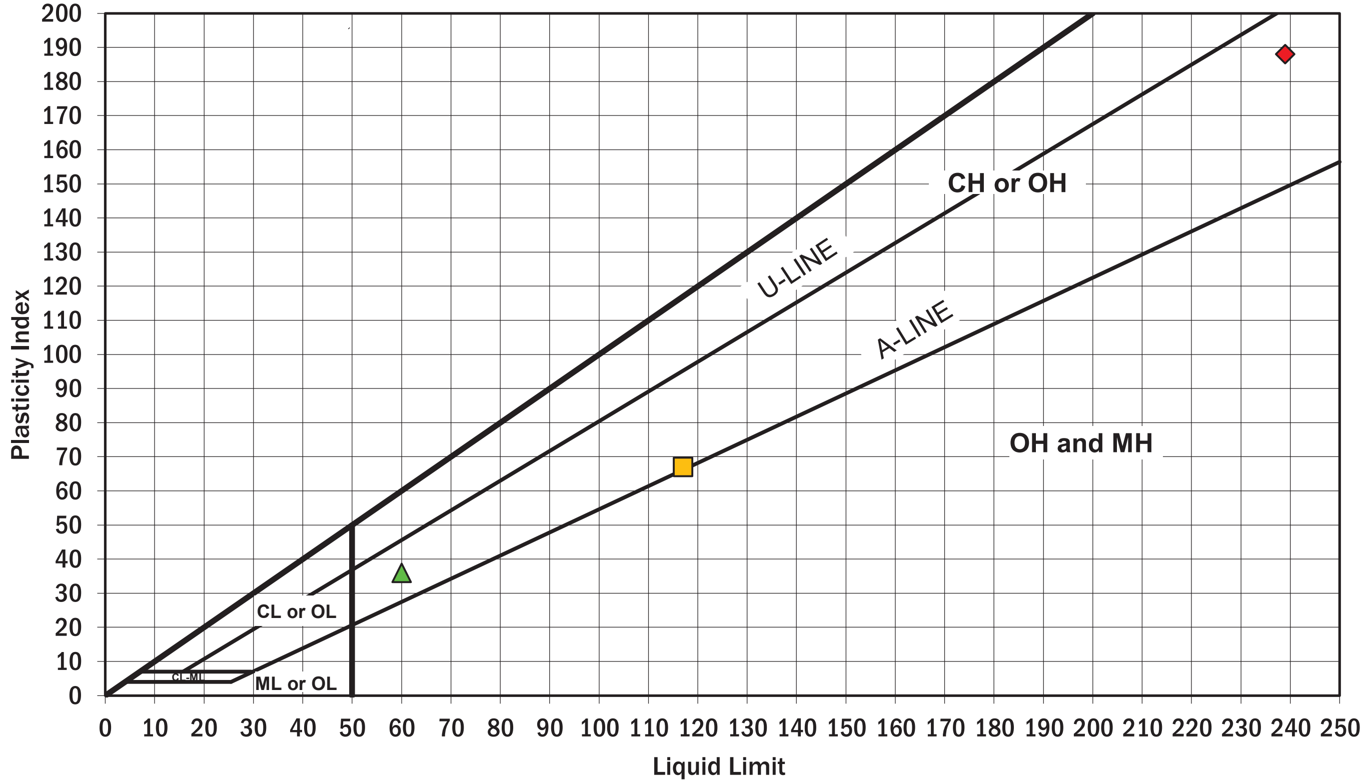
Atterberg Limits Test Results

Coos River HDD
Coos County, Oregon

GeoEngineers

Figure A-13

PLASTICITY CHART



Symbol	Exploration Number	Sample Depth (feet)	Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	Soil Description
◆	CR-2	5.0 – 6.5	138	239	188	Dark Brown Organic CLAY (OH)
■	CR-2	40.0 – 41.5	94	117	67	Dark Brown Organic SILT With Sand (OH)
▲	CR-2	50.0 – 51.5	41	60	36	Gray Fat CLAY (CH)

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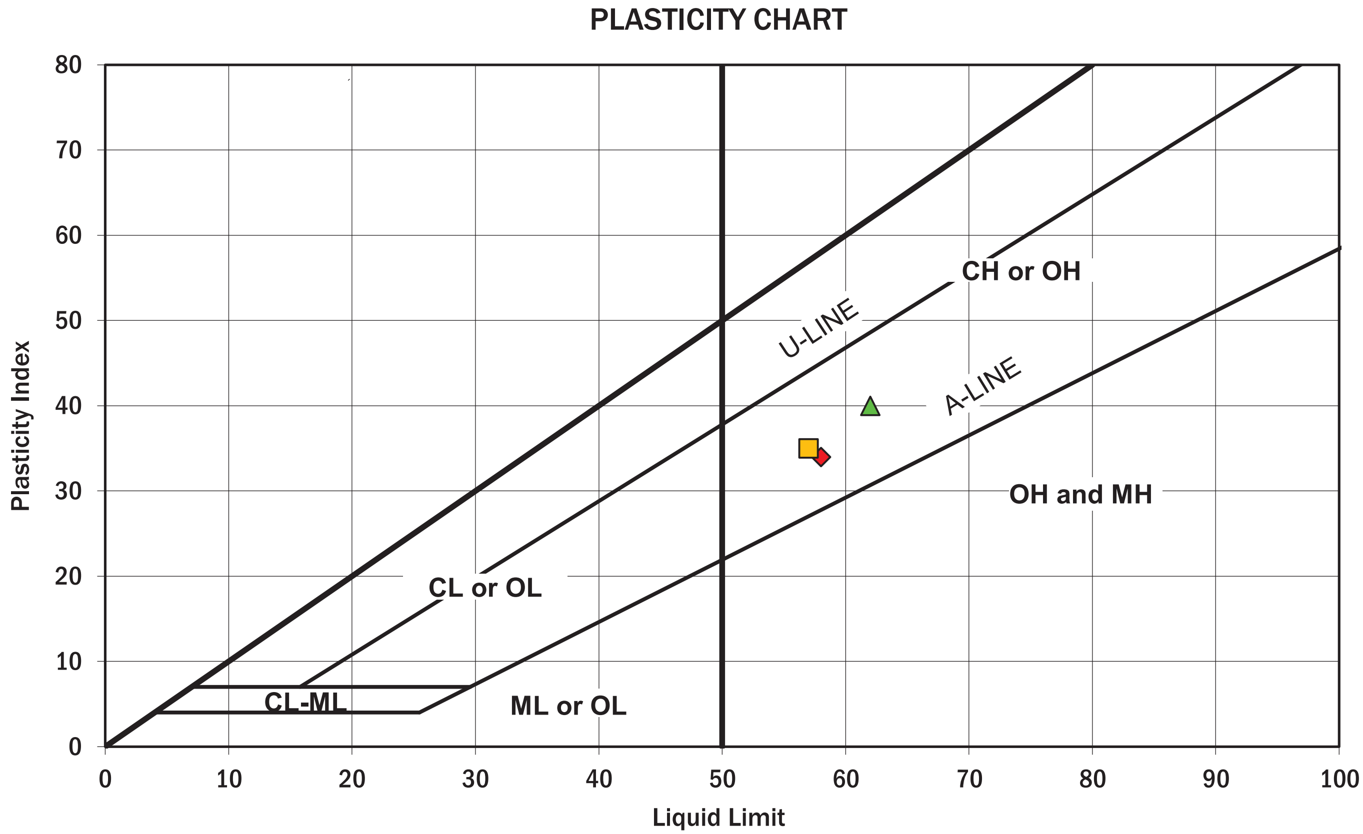
Atterberg Limits Test Results

Coos River HDD
Coos County, Oregon

GeoEngineers

Figure A-14



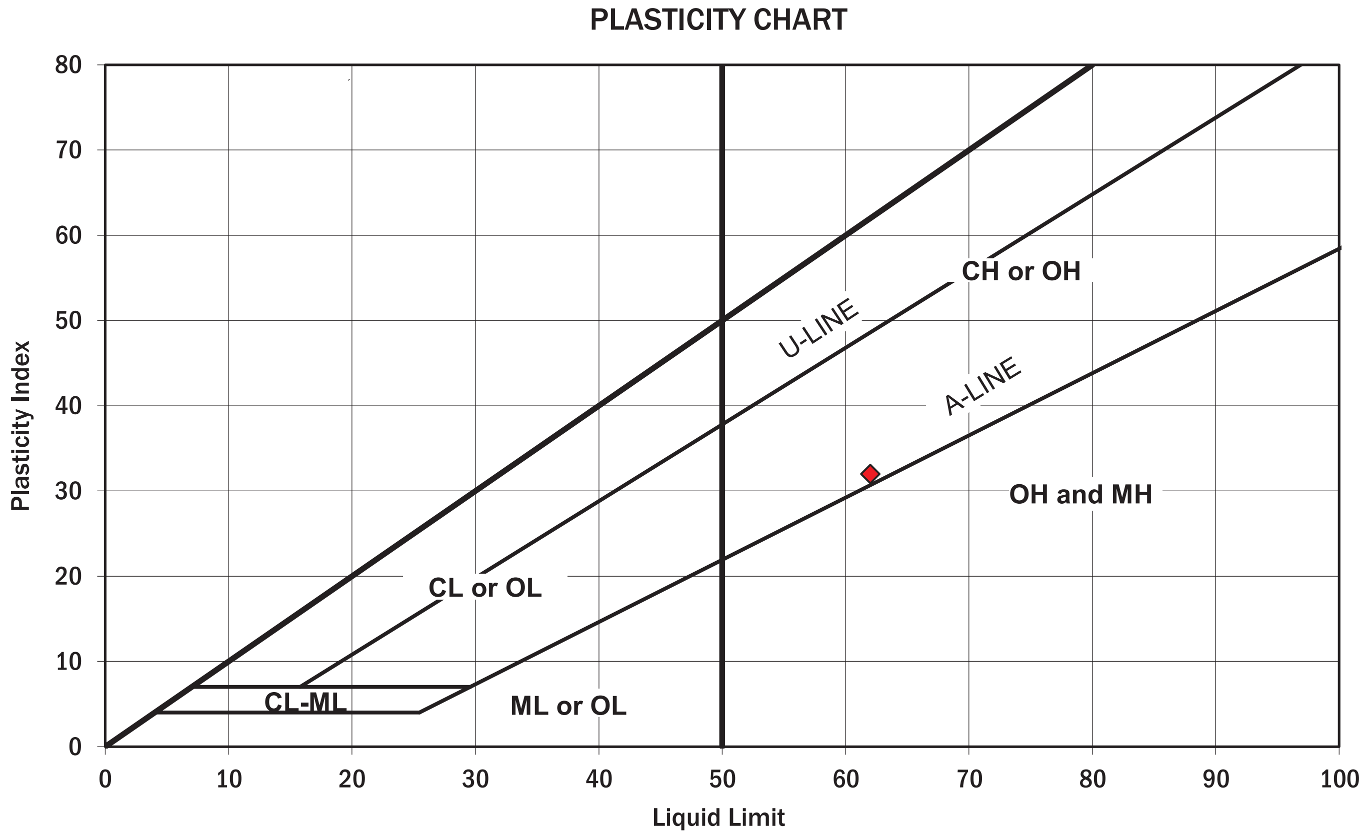
Symbol	Exploration Number	Sample Depth (feet)	Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	Soil Description
◆ (red diamond)	CR-2	60.0 – 61.5	44	58	34	Gray Fat CLAY With Fine Sand (CH)
■ (yellow square)	CR-2	75.0 – 76.5	39	57	35	Orange-Gray Mottled Fat CLAY With Fine Sand (CH)
▲ (green triangle)	CR-2	85.0 – 86.5	-	62	40	Orange-Gray Mottled Fat CLAY With Fine Sand And Gravel (CH)

Atterberg Limits Test Results

Coos River HDD
Coos County, Oregon

GeoEngineers

Figure A-15



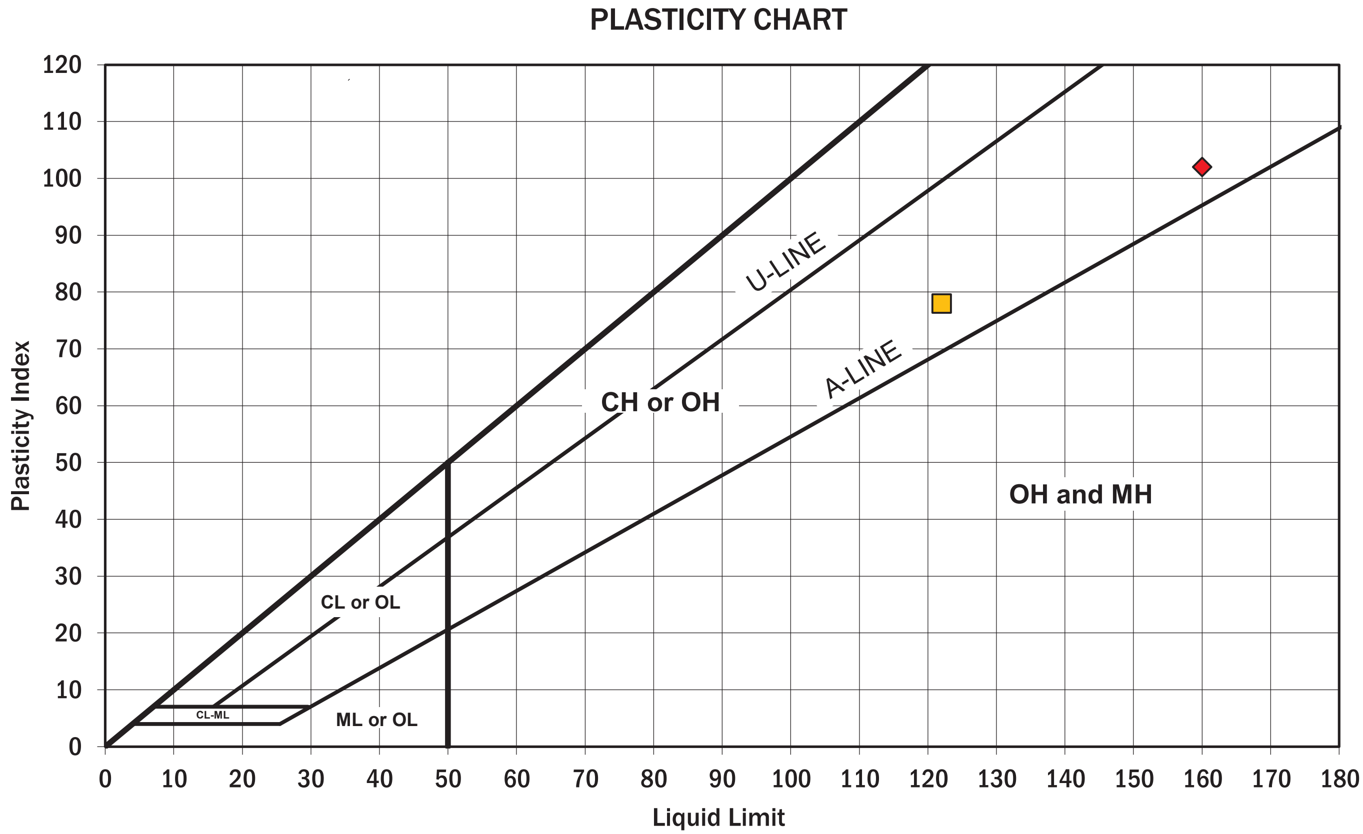
Symbol	Exploration Number	Sample Depth (feet)	Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	Soil Description
♦	CR-3	95.0 – 96.5	55	62	32	Grayish Brown Fat CLAY (CH)

Atterberg Limits Test Results

Coos River HDD
Coos County, Oregon

GeoEngineers

Figure A-16



Symbol	Exploration Number	Sample Depth (feet)	Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	Soil Description
◆	CR-4	10.0 – 11.5	111	160	102	Dark Brown Organic CLAY (OH)
■	CR-4	20.0 – 21.5	106	122	78	Brownish Gray Organic CLAY (OH)

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Atterberg Limits Test Results

Coos River HDD
Coos County, Oregon

GeoEngineers

Figure A-17

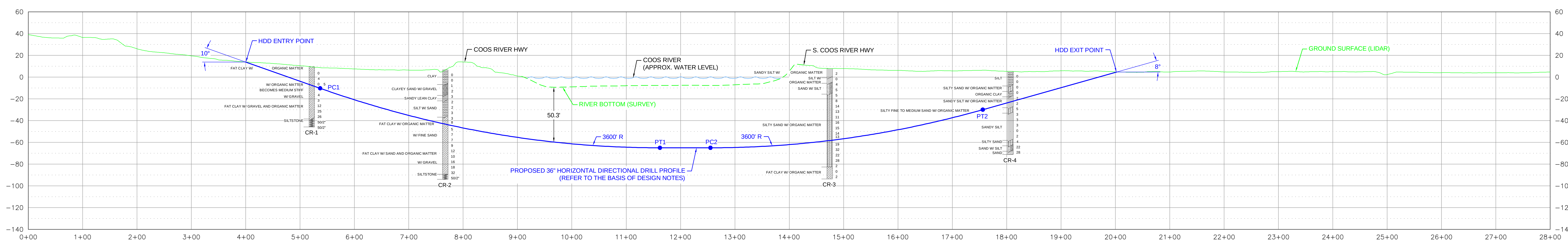
APPENDIX B
HDD Design Drawing and Calculations

DATUM:
HORIZONTAL: NAD83 Oregon State Plane, South Zone, US Foot
VERTICAL: NAVD 88

NOTE: THIS IS A FULL SIZE DRAWING THAT IS INTENDED TO BE PRINTED ON A 24" X 36" SHEET OF PAPER.

PLAN

100 0 100
SCALE IN FEET



DIRECTIONAL DRILL DATA COOS RIVER HDD		
DESCRIPTION	STATION * (FT)	ELEVATION (FT)
ENTRY @ 10°	4+00.00	13.84
P C 1 (10.00° @ 3,600 FT R.)	5+36.92	-10.31
P T 1	11+62.05	-65.00
P C 2 (8.00° @ 3,600 FT R.)	12+54.98	-65.00
P T 2	17+56.00	-29.97
EXIT @ 8°	20+02.24	4.64
HORIZONTAL DISTANCE = 1,602.24 FT		
DIRECTIONAL DRILL PIPE LENGTH = 1,611.59 FT		

* THE STATIONING IS BASED ON AN ARBITRARY REFERENCE POINT

RECOMMENDED TOLERANCES	
ITEM	TOLERANCE
PILOT HOLE ENTRY ANGLE	INCREASE ANGLE UP TO 1º (STEEPER), BUT NO DECREASE IN ANGLE ALLOWED.
PILOT HOLE ENTRY LOCATION	AS PER COORDINATES PROVIDED BY COMPANY WITH NO CHANGES WITHOUT COMPANY APPROVAL.
PILOT HOLE EXIT ANGLE	INCREASE ANGLE UP TO 1º (STEEPER) OR DECREASE UP TO 2º (FLATTER).
PILOT HOLE EXIT LOCATION	UP TO 20 FEET BEYOND OR 10 FEET SHORT OF THE EXIT STAKE. BETWEEN 5 FEET LEFT AND 5 FEET RIGHT OF CENTERLINE.
PILOT HOLE DEPTH	UP TO 2 FEET ABOVE THE DESIGN DRILL PROFILE ALLOWED. UP TO 10 FEET BELOW THE DESIGN DRILL PROFILE ALLOWED.
PILOT HOLE ALIGNMENT	SHALL REMAIN WITHIN 5 FEET LEFT OR RIGHT OF THE HDD ALIGNMENT.

BORING LEGEND

TYPE OF SOIL — SPT (N)
TYPE OF ROCK — RQD/%REC
Boring Location

PROFILE

100 0 100
HORIZONTAL SCALE IN FEET
50 0 50
VERTICAL SCALE IN FEET

BASIS OF DESIGN:

1. PRODUCT PIPE WILL CONSIST OF 36" O.D. X 0.823" W.T., API-5L X-70 SAWL OR SAWH PIPE WITH 8-10 MILS OF FUSION BONDED EPOXY (FBE) AND A MINIMUM OF 40 MILS OF ABRASION RESISTANT OVERLAY (ARO).
2. MAXIMUM ALLOWABLE OPERATING PRESSURE (MAOP) = 1,600 psi
3. ASSUMED MAXIMUM OPERATING TEMPERATURE = 100° FAHRENHEIT.
4. ASSUMED AVERAGE OPERATING TEMPERATURE = 70° FAHRENHEIT.
5. THE MINIMUM ALLOWABLE THREE JOINT RADIUS SHALL NOT BE LESS THAN 2,600 FEET.

ISSUED FOR PERMIT

NOTES:

1. CONTRACTOR SHALL ADHERE TO THE SPECIFICATIONS AND REQUIREMENTS PER PACIFIC CONNECTOR GAS PIPELINE, LP SPECIFICATIONS, CONTRACT DOCUMENTS AND SPECIAL PERMIT CONDITIONS, EXCEPT AS NOTED ON THIS DRAWING.
2. CONTRACTOR IS RESPONSIBLE FOR CALLING OREGON ONE-CALL AND LOCATING ALL UNDERGROUND UTILITIES PRIOR TO BEGINNING CONSTRUCTION. IF ANY UTILITY IS LOCATED WITHIN 15 FEET OF THE DESIGNED HDD PROFILE AND ALIGNMENT, CONTRACTOR SHALL OBTAIN APPROVAL FROM PACIFIC CONNECTOR GAS PIPELINE, LP PRIOR TO INITIATING HDD OPERATIONS.
2. IT IS THE CONTRACTORS RESPONSIBILITY TO IDENTIFY AND PROTECT ANY FOREIGN UTILITY THAT MAY BE AFFECTED BY THE HDD OPERATIONS.
3. PLACEMENT OF THE HDD RIG IS NOT FIXED BY THE DESIGNATION OF THE ENTRY AND EXIT POINTS. THE USE OF DUAL HDD RIGS DURING CONSTRUCTION MAY BE AT THE DISCRETION OF THE HDD CONTRACTOR, TO BE APPROVED BY THE PROJECT TEAM.
4. ALL EQUIPMENT MUST ACCESS THE SITE ALONG THE CONSTRUCTION RIGHT-OF-WAY OR FROM APPROVED ACCESS ROADS.
5. WORK SPACE: MAXIMUM WORK SPACE LIMITS ARE DEPICTED. RESTRICT CLEARING TO THE WORK SPACE INDICATED AT THE ENTRY AND EXIT POINTS AND PRODUCT PIPE STRINGING AND FABRICATION AREA ALONG THE CONSTRUCTION RIGHT-OF-WAY. CLEARING BETWEEN THE ENTRY AND EXIT POINTS REQUIRES PRIOR APPROVAL FROM THE ENVIRONMENTAL INSPECTOR AND IS LIMITED TO THE AMOUNT NECESSARY TO STRING SURVEY WIRES AND INSTALL PUMPS AND PIPING TO OBTAIN WATER (WHERE APPROVED).
6. WATER SOURCE: DRILL WATER AND HYDROSTATIC TEST WATER SHALL BE OBTAINED FROM AN APPROVED SOURCE.
7. HYDROSTATIC TEST: PRE-INSTALLATION AND POST-INSTALLATION HYDROSTATIC TESTS SHALL BE CONDUCTED IN ACCORDANCE WITH THE HYDROSTATIC TEST PLAN. TEST WATER SHALL BE SAMPLED AND TESTED IN ACCORDANCE WITH PERMIT REQUIREMENTS. THE TEST WATER SHALL BE DISCHARGED IN AN UPLAND AREA INTO AN EROSION CONTROL STRUCTURE OF STRAW BALES AND/OR SILT FENCES, GEOTEXTILE FILTER BAG, OR COLLECTED IN A TRUCK AND HAULED TO AN APPROVED DISPOSAL SITE. UPON COMPLETION OF DEWATERING AND DRYING, A CALIPER PIG SURVEY SHALL BE COMPLETED IN ACCORDANCE WITH THE CONTRACT DOCUMENTS.
8. SPILL-PREVENTION: REFUELING OF ALL EQUIPMENT SHALL BE COMPLETED IN ACCORDANCE WITH THE SPCC PLAN.
9. EROSION AND SEDIMENT CONTROL: CONTRACTOR SHALL SUPPLY, INSTALL AND MAINTAIN SEDIMENT CONTROL STRUCTURES IN ACCORDANCE WITH CONTRACT DOCUMENTS. CONTRACTOR SHALL INSTALL ADDITIONAL EROSION CONTROL STRUCTURES AS DIRECTED BY THE ENVIRONMENTAL INSPECTOR.
10. INSTALLATION: THE PIPE SECTION FOR THE DRILLED CROSSING SHALL BE MADE UP WITHIN THE APPROVED CONSTRUCTION RIGHT-OF-WAY AT THE DRILL EXIT POINT AS SHOWN. AFTER THE PILOT HOLE IS COMPLETE, CONTRACTOR'S ACTUAL DRILL PROFILE SHALL BE SUBMITTED TO PACIFIC CONNECTOR GAS PIPELINE, LP FOR APPROVAL. CONTRACTOR SHALL ASSESS THE NEED FOR AND SUPPLY APPROPRIATE BALLAST DURING PULLBACK.
11. DRILLING FLUID DISPOSAL: CONTRACTOR SHALL DISPOSE OF EXCESS DRILLING FLUID AS DIRECTED BY THE COMPANY REPRESENTATIVE IN ACCORDANCE WITH PERMIT CONDITIONS. UNDER NO CIRCUMSTANCES SHALL DRILLING FLUID BE DISPOSED OF IN WATER BODIES OR WETLANDS. ANY DRILLING FLUID WHICH INADVERTENTLY SURFACES AT POINTS OTHER THAN THE ENTRY OR EXIT POINTS SHALL BE CONTAINED AND COLLECTED TO THE EXTENT PRACTICAL AND DISPOSED OF AS DIRECTED BY THE COMPANY REPRESENTATIVE IN ACCORDANCE WITH PERMIT CONDITIONS.
12. CLEANUP/STABILIZATION/RESTORATION: ALL DISTURBED AREAS SHALL BE RETURNED TO THE ORIGINAL CONTOURS. DISTURBED AREAS SHALL BE SEEDED AS SPECIFIED IN THE CLEAN-UP AND RESTORATION REQUIREMENTS. IF THE TERRAIN ALLOWS AND ACCESS IS PERMITTED, CONTRACTOR SHALL UTILIZE LOW GROUND PRESSURE EQUIPMENT OR OTHER EQUIPMENT APPROVED BY OWNER, TO FACILITATE CONTAINMENT AND CLEAN-UP OF ANY INADVERTENT RETURNS THAT OCCUR DURING THE HDD INSTALLATION PROCESS.
13. GEOTECHNICAL DATA: BORE HOLES ARE OFFSET FROM THE PIPELINE CENTERLINE AS SHOWN ON THE PLAN VIEW. THE GEOTECHNICAL INFORMATION PROVIDED ON THIS DRAWING IS A GENERAL SUMMARY. REFER TO THE APPLICABLE GEOTECHNICAL REPORT IN THE CONTRACT DOCUMENTS FOR MORE DETAILED INFORMATION.
14. GROUND SURFACE LIDAR DATA GENERATED FROM: EDITED LIDAR ELEVATION DATA, DOWNLOADED FROM HTTP://WWW.OREGONGEOLOGY.ORG. AERIAL IMAGE TAKEN FROM GOOGLE EARTH PRO, LICENSED TO GEOENGINEERS, INC., DATED 05-03-13.
15. RIVER BOTTOM SURVEY PROVIDED BY WILLIAMS NORTHWEST PIPELINE, LLC.
16. THE SECONDARY SURFACE SURVEY COIL LAYOUTS SHOWN ON THIS DRAWING ARE APPROXIMATE AND INTENDED TO SHOW THE GENERAL LAYOUT OF TYPICAL SECONDARY SURFACE SURVEY COIL WIRES THAT MAY BE PLACED TO TRACK THE BOTTOM HOLE ASSEMBLY DURING PILOT HOLE OPERATIONS. THE APPROXIMATE LOCATIONS OF THE COIL WIRES SHOWN ON THIS DRAWING ARE NOT INTENDED TO DIRECT THE HDD CONTRACTOR AS TO THE EXACT PLACEMENT OF THE COIL WIRES. THE FINAL PLACEMENT OF SOIL WIRES IS THE CONTRACTOR'S RESPONSIBILITY AND MAY VARY FROM WHAT IS SHOWN DEPENDING ON GROUND SURFACE CONDITIONS AT THE TIME OF HDD INSTALLATION, AND THE HDD CONTRACTORS MEANS AND METHODS.

REFERENCES

DRAWING NUMBER	REFERENCE DRAWING TITLE
	PCGP_IP_Right_of_Way.dwg

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK'D	APP'D
0	ISSUED FOR PERMIT (MODIFIED PIPE SPECS)	RBM	08/24/17	BCR	TNH

AES Design	03/05/14 Date
RBM Drawn	03/04/17 Date
BCR Checked	07/09/15 Date
TNH Approved	08/24/17 Date

GEOENGINEERS
317 East Main Street,
American Fork, UT 84003
Telephone (801) 307-0216

36" PACIFIC CONNECTOR GAS PIPELINE PROJECT

COOS RIVER HDD
COOS COUNTY, OREGON

Project No. 22708-001-01
Drawing No. P1-000-CIV-HDD-GEI-00003-01
Sheet 1 of 1

HDD Design Summary

Project Name: Pacific Connector Gas Pipeline **HDD Name:** Coos River HDD **Owner:** PCGP, LP

Project No: 22708-001-01 **By:** AES **Ck'd By:** BCR/ JAH **Location:** Coos County, Oregon **Date:** Friday, September 1, 2017

Design Parameters

Pipe Diameter = 36.000 in

Pipe Material = Steel

Yield Stress = 70,000 psi

Wall Thickness = 0.823 in

Assumed Installation Temp = 50 °F

Assumed Operating Temp= 100 °F

Design Factor = 0.5

MAOP = 1,600 psi

Drill Data Box

Point	Station (ft)	Elevation (ft)
ENTRY @ 10°	400.00	13.84
P C 1 (10.00° @ 3,600 ft R.)	536.92	-10.31
P T 1	1,162.05	-65.00
P C 2 (8.00° @ 3,600 ft R.)	1,254.98	-65.00
P T 2	1,756.00	-29.97
EXIT @ 8°	2,002.24	4.64
Horizontal Alignment Length = 1,602.24 ft		

Profile Segment Information

Segment Name	Segment Type	Segment Length (ft)
ENTRY TANGENT	Straight	139.03
ENTRY CURVE	Vertical Curve	628.32
BOTTOM TANGENT	Straight	92.92
EXIT CURVE	Vertical Curve	502.65
EXIT TANGENT	Straight	248.66
Pipe Length = 1,611.59 ft		

Installation Load Summary

Drilling Fluid Weight (lb/gal)	Buoyancy Condition	Buoyancy Control (lb/ft)	Effective Pipe Weight (lb/ft)	Total Installation Force (lb)
9.50	Empty	0.00	-192.37	240,000
9.50	Full	401.67	209.30	207,000
12.00	Empty	0.00	-324.56	316,000
12.00	Full	401.67	77.11	135,000
10.50	Neutral	245.24	0.00	127,000

GeoEngineers

Minimum Radius Calculations

Project Name:	Pacific Connector Gas Pipeline	**HDD Name:**	Coos River HDD	**Owner:**	PCGP, LP
Project No:	22708-001-01 **By:** AES **Ck'd By:** BCR/ JAH	**Location:**	Coos County, Oregon	**Date:**	Friday, September 1, 2017

Design Parameters:

Pipe Diameter = 36.000 in
MAOP = 1,600 psi
Factor of Safety = 2.00
Wall Thickness = 0.823 in
SMYS = 70,000 psi
D/t Ratio = 43.74
Modulus of Elasticity (E) = 2.93E+007 psi

Hoop Stress:

Calculated Hoop Stress = (MAOP * Pipe Diameter) / (2 * Wall Thickness) = 34,994 psi

Longitudinal Stress:

Calculated Longitudinal Stress = Hoop Stress / 2 = 17,497 psi

Allowable Stress:

Calculated Allowable Stress = SMYS / Factor of Safety = 35,000 psi

Bending Stress:

Calculated Bending Stress = Allowable Stress - Longitudinal Stress = 17,503 psi

Minimum Radius:

Calculated Minimum Radius = (E * Pipe Diameter) / (2 * Bending Stress) = 2,485 ft

Operating Stress Summary

Project Name:	Pacific Connector Gas Pipeline	**HDD Name:**	Coos River HDD	**Owner:**	PCGP, LP
Project No:	22708-001-01 **By:** AES **Ck'd By:** BCR/ JAH	**Location:**	Coos County, Oregon	**Date:**	Friday, September 1, 2017

Design Parameters

Pipe diameter =	36.000 in	**Minimum Radius of Curvature =**	2,600 ft
Wall Thickness =	0.823 in	**Coefficient of Thermal Expansion =**	6.5E-06 in/in/°F
SMYS =	70,000 psi	**Assumed Installation Temperature =**	50 °F
MAOP =	1,600 psi	**Assumed Operating Temperature =**	100 °F
Poissons's Ratio =	0.30	**Temperature Derating Factor =**	1.00
Young's Modulus (E) =	2.93E+007 psi	**Groundwater Table Head =**	0.00 ft
Design Factor =	0.5		

Stress Analyses

Longitudinal Stress from Bending =	16,929 psi	
Percent SMYS =	24.18 %	
Hoop Stress =	34,994 psi	
Percent SMYS =	49.99 %	Limited by Design Factor (0.5) according to 49 CFR 192.111
Longitudinal Tensile Stress from Hoop Stress =	10,498 psi	
Percent SMYS =	15.00 %	
Longitudinal Stress from Thermal Expansion =	-9,537 psi	
Percent SMYS =	13.62 %	Limited to 90% SMYS by ASME/ANSI B31.4 section 402.3.2
Net Longitudinal Stress (Comp. side of Curve) =	-15,968 psi	
Percent SMYS =	22.81 %	Limited to 90% SMYS by ASME/ANSI B31.8 section 833.3
Net Longitudinal Stress (Tension side of Curve) =	17,891 psi	
Percent SMYS =	25.56 %	Limited to 90% SMYS by ASME/ANSI B31.8 section 833.3
Maximum Shear Stress =	25,481 psi	
Percent SMYS =	36.40 %	Limited to 45% SMYS by ASME/ANSI B31.4 section 402.3.1
Combined Biaxial Stress Check =	50,962 psi	
Percent SMYS =	72.80 %	Limited to 90% SMYS by ASME/ANSI B31.8 section 833.4

Operating Stress Summary

Project Name: Pacific Connector Gas Pipeline **HDD Name:** Coos River HDD **Owner:** PCGP, LP

Project No: 22708-001-01 **By:** AES **Ck'd By:** BCR/ JAH **Location:** Coos County, Oregon **Date:** Friday, September 1, 2017

Installation Load Calculations

Project Name: Pacific Connector Gas Pipeline	**HDD Name:** Coos River HDD	**Owner:** PCGP, LP
Project No: 22708-001-01 **By:** AES **Ck'd By:** BCR/ JAH	**Location:** Coos County, Oregon	**Date:** Friday, September 1, 2017

Installation Case:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty

Product Pipe Parameters	
Pipe Diameter =	36.000 in
Wall Thickness =	0.823 in
SMYS =	70,000 psi
Young's Modulus =	2.90E+007 psi
Total Pipe Length =	1,612 ft
Moment of Inertia =	14,076 in⁴
Pipe Face Area =	90.95 in²
D/t Ratio =	43.74
Poisson Ratio =	0.30
Coefficient of Soil Friction =	0.30
Fluid Drag Coefficient =	0.05

Effective Weight Calculations	
Total Empty Pipe Weight In Air=	309.96 lb/ft
Pipe Interior Volume =	6.44 ft³
Coating Thickness =	0.00 in
Coating Density =	0.00 lb/ft³
Pipe Exterior Volume =	7.07 ft³/ft
Displaced Fluid Weight =	502.33 lb/ft
B.C. Line(s) Weight =	0.00 lb/ft
B.C. Line(s) Volume =	0.00 ft³/ft
Unit Weight of B.C. Fluid =	62.40 lb/ft³
Effective Weight of Pipe =	-192.37 lb/ft

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 1 of 5

Segment Parameters			
Segment Name =	EXIT TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	248.66 ft	Center Displacement =	0.00 ft

Segment Force Components	
Normal Force =	0 lb
Drag Force =	16,874 lb
Friction Force =	14,211 lb
Segment Weight =	6,657 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	37,742 lb
Cumulative Force =	**37,742 lb**

Stress Component	Calculated	Allowable
Segment Axial Stress =	415 psi	
Cumulative Axial Stress =	415 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	473 psi	8,892 psi
Combined Stress =	0.0074	< 1.0
Total Stress =	0.0029	< 1.0

GeoEngineers

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 2 of 5

Segment Parameters

Segment Name =	EXIT CURVE	Radius of Curvature =	3,600 ft
Segment Type =	Vertical Curve	Angle Turned =	8.00 deg
Segment Length =	502.65 ft	Center Displacement =	8.77 ft

Segment Force Components

Normal Force =	75,730 lb
Drag Force =	34,109 lb
Friction Force =	22,719 lb
Segment Weight =	6,745 lb
Tension =	124,034 lb
Average Tension =	80,888 lb
Segment Force =	86,292 lb
Cumulative Force =	**124,034 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	949 psi	
Cumulative Axial Stress =	1,364 psi	56,000 psi
Bending Stress =	16,731 psi	46,113 psi
Hoop Stress =	851 psi	8,892 psi
Combined Stress =	0.3872	< 1.0
Total Stress =	0.1268	< 1.0

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 3 of 5

Segment Parameters

Segment Name =	BOTTOM TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	92.92 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	6,306 lb
Friction Force =	5,363 lb
Segment Weight =	0 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	11,668 lb
Cumulative Force =	**135,702 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	128 psi	
Cumulative Axial Stress =	1,492 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	851 psi	8,892 psi
Combined Stress =	0.0266	< 1.0
Total Stress =	0.0106	< 1.0

Installation Load Calculations

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 4 of 5

Segment Parameters			
Segment Name =	ENTRY CURVE	Radius of Curvature =	3,600 ft
Segment Type =	Vertical Curve	Angle Turned =	10.00 deg
Segment Length =	628.32 ft	Center Displacement =	13.70 ft

Segment Force Components	
Normal Force =	98,840 lb
Drag Force =	42,637 lb
Friction Force =	29,652 lb
Segment Weight =	-10,534 lb
Tension =	227,109 lb
Average Tension =	181,406 lb
Segment Force =	91,407 lb
Cumulative Force =	**227,109 lb**

Stress Component	Calculated	Allowable
Segment Axial Stress =	1,005 psi	
Cumulative Axial Stress =	2,497 psi	56,000 psi
Bending Stress =	16,731 psi	46,113 psi
Hoop Stress =	851 psi	8,892 psi
Combined Stress =	0.4074	< 1.0
Total Stress =	0.1412	< 1.0

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 5 of 5

Segment Parameters			
Segment Name =	ENTRY TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	139.03 ft	Center Displacement =	0.00 ft

Segment Force Components	
Normal Force =	0 lb
Drag Force =	9,435 lb
Friction Force =	7,902 lb
Segment Weight =	-4,644 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	12,692 lb
Cumulative Force =	**239,801 lb**

Stress Component	Calculated	Allowable
Segment Axial Stress =	140 psi	
Cumulative Axial Stress =	2,637 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	261 psi	8,892 psi
Combined Stress =	0.0471	< 1.0
Total Stress =	0.0036	< 1.0

Installation Load Calculations

Project Name: Pacific Connector Gas Pipeline		**HDD Name:** Coos River HDD		**Owner:** PCGP, LP	
Project No: 22708-001-01	**By:** AES	**Ck'd By:** BCR/ JAH	**Location:** Coos County, Oregon	**Date:** Friday, September 1, 2017	

Installation Case:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full

Product Pipe Parameters	
Pipe Diameter =	36.000 in
Wall Thickness =	0.823 in
SMYS =	70,000 psi
Young's Modulus =	2.90E+007 psi
Total Pipe Length =	1,612 ft
Moment of Inertia =	14,076 in⁴
Pipe Face Area =	90.95 in²
D/t Ratio =	43.74
Poisson Ratio =	0.30
Coefficient of Soil Friction =	0.30
Fluid Drag Coefficient =	0.05

Effective Weight Calculations	
Total Empty Pipe Weight In Air=	309.96 lb/ft
Pipe Interior Volume =	6.44 ft³
Coating Thickness =	0.00 in
Coating Density =	0.00 lb/ft³
Pipe Exterior Volume =	7.07 ft³/ft
Displaced Fluid Weight =	502.33 lb/ft
B.C. Line(s) Weight =	0.00 lb/ft
B.C. Line(s) Volume =	0.00 ft³/ft
Unit Weight of B.C. Fluid =	62.40 lb/ft³
Effective Weight of Pipe =	209.30 lb/ft

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 1 of 5

Segment Parameters			
Segment Name =	EXIT TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	248.66 ft	Center Displacement =	0.00 ft

Segment Force Components	
Normal Force =	0 lb
Drag Force =	16,874 lb
Friction Force =	15,461 lb
Segment Weight =	-7,243 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	25,092 lb
Cumulative Force =	**25,092 lb**

Stress Component	Calculated	Allowable
Segment Axial Stress =	276 psi	
Cumulative Axial Stress =	276 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	145 psi	8,892 psi
Combined Stress =	0.0049	< 1.0
Total Stress =	0.0003	< 1.0

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 2 of 5

Segment Parameters

Segment Name =	EXIT CURVE	Radius of Curvature =	3,600 ft
Segment Type =	Vertical Curve	Angle Turned =	8.00 deg
Segment Length =	502.65 ft	Center Displacement =	8.77 ft

Segment Force Components

Normal Force =	-51,211 lb
Drag Force =	34,109 lb
Friction Force =	15,363 lb
Segment Weight =	-7,339 lb
Tension =	82,590 lb
Average Tension =	53,841 lb
Segment Force =	57,497 lb
Cumulative Force =	**82,590 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	632 psi	
Cumulative Axial Stress =	908 psi	56,000 psi
Bending Stress =	16,731 psi	46,113 psi
Hoop Stress =	191 psi	8,892 psi
Combined Stress =	0.3790	< 1.0
Total Stress =	0.1026	< 1.0

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 3 of 5

Segment Parameters

Segment Name =	BOTTOM TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	92.92 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	6,306 lb
Friction Force =	5,835 lb
Segment Weight =	0 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	12,140 lb
Cumulative Force =	**94,730 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	133 psi	
Cumulative Axial Stress =	1,042 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	191 psi	8,892 psi
Combined Stress =	0.0186	< 1.0
Total Stress =	0.0010	< 1.0

Installation Load Calculations

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 4 of 5

Segment Parameters			
Segment Name =	ENTRY CURVE	Radius of Curvature =	3,600 ft
Segment Type =	Vertical Curve	Angle Turned =	10.00 deg
Segment Length =	628.32 ft	Center Displacement =	13.70 ft

Segment Force Components	
Normal Force =	-57,925 lb
Drag Force =	42,637 lb
Friction Force =	17,378 lb
Segment Weight =	11,462 lb
Tension =	183,583 lb
Average Tension =	139,157 lb
Segment Force =	88,854 lb
Cumulative Force =	**183,583 lb**

Stress Component	Calculated	Allowable
Segment Axial Stress =	977 psi	
Cumulative Axial Stress =	2,018 psi	56,000 psi
Bending Stress =	16,731 psi	46,113 psi
Hoop Stress =	191 psi	8,892 psi
Combined Stress =	0.3989	< 1.0
Total Stress =	0.1157	< 1.0

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 5 of 5

Segment Parameters			
Segment Name =	ENTRY TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	139.03 ft	Center Displacement =	0.00 ft

Segment Force Components	
Normal Force =	0 lb
Drag Force =	9,435 lb
Friction Force =	8,597 lb
Segment Weight =	5,053 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	23,085 lb
Cumulative Force =	**206,668 lb**

Stress Component	Calculated	Allowable
Segment Axial Stress =	254 psi	
Cumulative Axial Stress =	2,272 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	119 psi	8,892 psi
Combined Stress =	0.0406	< 1.0
Total Stress =	0.0021	< 1.0

Installation Load Calculations

Project Name: Pacific Connector Gas Pipeline **HDD Name:** Coos River HDD **Owner:** PCGP, LP

Project No: 22708-001-01 **By:** AES **Ck'd By:** BCR/ JAH **Location:** Coos County, Oregon **Date:** Friday, September 1, 2017

Installation Case:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty

Product Pipe Parameters	
Pipe Diameter =	36.000 in
Wall Thickness =	0.823 in
SMYS =	70,000 psi
Young's Modulus =	2.90E+007 psi
Total Pipe Length =	1,612 ft
Moment of Inertia =	14,076 in⁴
Pipe Face Area =	90.95 in²
D/t Ratio =	43.74
Poisson Ratio =	0.30
Coefficient of Soil Friction =	0.30
Fluid Drag Coefficient =	0.05

Effective Weight Calculations	
Total Empty Pipe Weight In Air=	309.96 lb/ft
Pipe Interior Volume =	6.44 ft³
Coating Thickness =	0.00 in
Coating Density =	0.00 lb/ft³
Pipe Exterior Volume =	7.07 ft³/ft
Displaced Fluid Weight =	634.52 lb/ft
B.C. Line(s) Weight =	0.00 lb/ft
B.C. Line(s) Volume =	0.00 ft³/ft
Unit Weight of B.C. Fluid =	62.40 lb/ft³
Effective Weight of Pipe =	-324.56 lb/ft

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 1 of 5

Segment Parameters			
Segment Name =	EXIT TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	248.66 ft	Center Displacement =	0.00 ft

Segment Force Components	
Normal Force =	0 lb
Drag Force =	16,874 lb
Friction Force =	23,976 lb
Segment Weight =	11,232 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	52,082 lb
Cumulative Force =	**52,082 lb**

Stress Component	Calculated	Allowable
Segment Axial Stress =	573 psi	
Cumulative Axial Stress =	573 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	597 psi	8,892 psi
Combined Stress =	0.0102	< 1.0
Total Stress =	0.0047	< 1.0

Installation Load Calculations

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 2 of 5

Segment Parameters

Segment Name =	EXIT CURVE	Radius of Curvature =	3,600 ft
Segment Type =	Vertical Curve	Angle Turned =	8.00 deg
Segment Length =	502.65 ft	Center Displacement =	8.77 ft

Segment Force Components

Normal Force =	118,745 lb
Drag Force =	34,109 lb
Friction Force =	35,623 lb
Segment Weight =	11,380 lb
Tension =	168,818 lb
Average Tension =	110,450 lb
Segment Force =	116,736 lb
Cumulative Force =	**168,818 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	1,284 psi	
Cumulative Axial Stress =	1,856 psi	56,000 psi
Bending Stress =	16,731 psi	46,113 psi
Hoop Stress =	1,075 psi	8,892 psi
Combined Stress =	0.3960	< 1.0
Total Stress =	0.1419	< 1.0

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 3 of 5

Segment Parameters

Segment Name =	BOTTOM TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	92.92 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	6,306 lb
Friction Force =	9,048 lb
Segment Weight =	0 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	15,353 lb
Cumulative Force =	**184,172 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	169 psi	
Cumulative Axial Stress =	2,025 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	1,075 psi	8,892 psi
Combined Stress =	0.0362	< 1.0
Total Stress =	0.0172	< 1.0

Installation Load Calculations

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 4 of 5

Segment Parameters			
Segment Name =	ENTRY CURVE	Radius of Curvature =	3,600 ft
Segment Type =	Vertical Curve	Angle Turned =	10.00 deg
Segment Length =	628.32 ft	Center Displacement =	13.70 ft

Segment Force Components	
Normal Force =	153,970 lb
Drag Force =	42,637 lb
Friction Force =	46,191 lb
Segment Weight =	-17,773 lb
Tension =	301,417 lb
Average Tension =	242,794 lb
Segment Force =	117,245 lb
Cumulative Force =	**301,417 lb**

Segment Installation Stress Checks		
Stress Component	Calculated	Allowable
Segment Axial Stress =	1,289 psi	
Cumulative Axial Stress =	3,314 psi	56,000 psi
Bending Stress =	16,731 psi	46,113 psi
Hoop Stress =	1,075 psi	8,892 psi
Combined Stress =	0.4220	< 1.0
Total Stress =	0.1612	< 1.0

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 5 of 5

Segment Parameters			
Segment Name =	ENTRY TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	139.03 ft	Center Displacement =	0.00 ft

Segment Force Components	
Normal Force =	0 lb
Drag Force =	9,435 lb
Friction Force =	13,332 lb
Segment Weight =	-7,836 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	14,931 lb
Cumulative Force =	**316,348 lb**

Segment Installation Stress Checks		
Stress Component	Calculated	Allowable
Segment Axial Stress =	164 psi	
Cumulative Axial Stress =	3,478 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	329 psi	8,892 psi
Combined Stress =	0.0621	< 1.0
Total Stress =	0.0062	< 1.0

Installation Load Calculations

Project Name: Pacific Connector Gas Pipeline		**HDD Name:** Coos River HDD	**Owner:** PCGP, LP
Project No: 22708-001-01	**By:** AES **Ck'd By:** BCR/ JAH	**Location:** Coos County, Oregon	**Date:** Friday, September 1, 2017

Installation Case:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full

Product Pipe Parameters	
Pipe Diameter =	36.000 in
Wall Thickness =	0.823 in
SMYS =	70,000 psi
Young's Modulus =	2.90E+007 psi
Total Pipe Length =	1,612 ft
Moment of Inertia =	14,076 in⁴
Pipe Face Area =	90.95 in²
D/t Ratio =	43.74
Poisson Ratio =	0.30
Coefficient of Soil Friction =	0.30
Fluid Drag Coefficient =	0.05

Effective Weight Calculations	
Total Empty Pipe Weight In Air=	309.96 lb/ft
Pipe Interior Volume =	6.44 ft³
Coating Thickness =	0.00 in
Coating Density =	0.00 lb/ft³
Pipe Exterior Volume =	7.07 ft³/ft
Displaced Fluid Weight =	634.52 lb/ft
B.C. Line(s) Weight =	0.00 lb/ft
B.C. Line(s) Volume =	0.00 ft³/ft
Unit Weight of B.C. Fluid =	62.40 lb/ft³
Effective Weight of Pipe =	77.11 lb/ft

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 1 of 5

Segment Parameters

Segment Name =	EXIT TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	248.66 ft	Center Displacement =	0.00 ft

Segment Force Components	
Normal Force =	0 lb
Drag Force =	16,874 lb
Friction Force =	5,696 lb
Segment Weight =	-2,668 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	19,901 lb
Cumulative Force =	**19,901 lb**

Segment Installation Stress Checks		
Stress Component	Calculated	Allowable
Segment Axial Stress =	219 psi	
Cumulative Axial Stress =	219 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	269 psi	8,892 psi
Combined Stress =	0.0039	< 1.0
Total Stress =	0.0009	< 1.0

Installation Load Calculations

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 2 of 5

Segment Parameters

Segment Name =	EXIT CURVE	Radius of Curvature =	3,600 ft
Segment Type =	Vertical Curve	Angle Turned =	8.00 deg
Segment Length =	502.65 ft	Center Displacement =	8.77 ft

Segment Force Components

Normal Force =	-11,408 lb
Drag Force =	34,109 lb
Friction Force =	3,422 lb
Segment Weight =	-2,704 lb
Tension =	58,152 lb
Average Tension =	39,027 lb
Segment Force =	38,251 lb
Cumulative Force =	**58,152 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	421 psi	
Cumulative Axial Stress =	639 psi	56,000 psi
Bending Stress =	16,731 psi	46,113 psi
Hoop Stress =	415 psi	8,892 psi
Combined Stress =	0.3742	< 1.0
Total Stress =	0.1047	< 1.0

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 3 of 5

Segment Parameters

Segment Name =	BOTTOM TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	92.92 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	6,306 lb
Friction Force =	2,150 lb
Segment Weight =	0 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	8,455 lb
Cumulative Force =	**66,607 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	93 psi	
Cumulative Axial Stress =	732 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	415 psi	8,892 psi
Combined Stress =	0.0131	< 1.0
Total Stress =	0.0025	< 1.0

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 4 of 5

Segment Parameters

Segment Name =	ENTRY CURVE	Radius of Curvature =	3,600 ft
Segment Type =	Vertical Curve	Angle Turned =	10.00 deg
Segment Length =	628.32 ft	Center Displacement =	13.70 ft

Segment Force Components

Normal Force =	-12,405 lb
Drag Force =	42,637 lb
Friction Force =	3,722 lb
Segment Weight =	4,223 lb
Tension =	120,910 lb
Average Tension =	93,758 lb
Segment Force =	54,303 lb
Cumulative Force =	**120,910 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	597 psi	
Cumulative Axial Stress =	1,329 psi	56,000 psi
Bending Stress =	16,731 psi	46,113 psi
Hoop Stress =	415 psi	8,892 psi
Combined Stress =	0.3866	< 1.0
Total Stress =	0.1127	< 1.0

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 5 of 5

Segment Parameters

Segment Name =	ENTRY TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	139.03 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	9,435 lb
Friction Force =	3,167 lb
Segment Weight =	1,862 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	14,464 lb
Cumulative Force =	**135,373 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	159 psi	
Cumulative Axial Stress =	1,488 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	187 psi	8,892 psi
Combined Stress =	0.0266	< 1.0
Total Stress =	0.0014	< 1.0

Installation Load Calculations

Project Name: Pacific Connector Gas Pipeline	**HDD Name:** Coos River HDD	**Owner:** PCGP, LP
Project No: 22708-001-01 **By:** AES **Ck'd By:** BCR/ JAH	**Location:** Coos County, Oregon	**Date:** Friday, September 1, 2017

Installation Case:10.50 lb/gal Drilling Fluid With Neutral Pipe Buoyancy

Product Pipe Parameters	
Pipe Diameter =	36.000 in
Wall Thickness =	0.823 in
SMYS =	70,000 psi
Young's Modulus =	2.90E+007 psi
Total Pipe Length =	1,612 ft
Moment of Inertia =	14,076 in⁴
Pipe Face Area =	90.95 in²
D/t Ratio =	43.74
Poisson Ratio =	0.30
Coefficient of Soil Friction =	0.30
Fluid Drag Coefficient =	0.05

Effective Weight Calculations	
Total Empty Pipe Weight In Air=	309.96 lb/ft
Pipe Interior Volume =	6.44 ft³
Coating Thickness =	0.00 in
Coating Density =	0.00 lb/ft³
Pipe Exterior Volume =	7.07 ft³/ft
Displaced Fluid Weight =	555.21 lb/ft
B.C. Line(s) Weight =	0.00 lb/ft
B.C. Line(s) Volume =	0.00 ft³/ft
Unit Weight of B.C. Fluid =	62.40 lb/ft³
Effective Weight of Pipe =	0.00 lb/ft

Installation:10.50 lb/gal Drilling Fluid With Neutral Pipe Buoyancy — Segment 1 of 5

Segment Parameters

Segment Name =	EXIT TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	248.66 ft	Center Displacement =	0.00 ft

Segment Force Components	
Normal Force =	0 lb
Drag Force =	16,874 lb
Friction Force =	0 lb
Segment Weight =	0 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	16,874 lb
Cumulative Force =	**16,874 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	186 psi	
Cumulative Axial Stress =	186 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	523 psi	8,892 psi
Combined Stress =	0.0033	< 1.0
Total Stress =	0.0035	< 1.0

Installation Load Calculations

Installation:10.50 lb/gal Drilling Fluid With Neutral Pipe Buoyancy — Segment 2 of 5

Segment Parameters			
Segment Name =	EXIT CURVE	Radius of Curvature =	3,600 ft
Segment Type =	Vertical Curve	Angle Turned =	8.00 deg
Segment Length =	502.65 ft	Center Displacement =	8.77 ft

Segment Force Components

Normal Force =	12,567 lb
Drag Force =	34,109 lb
Friction Force =	3,770 lb
Segment Weight =	0 lb
Tension =	58,523 lb
Average Tension =	37,699 lb
Segment Force =	41,650 lb
Cumulative Force =	**58,523 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	458 psi	
Cumulative Axial Stress =	643 psi	56,000 psi
Bending Stress =	16,731 psi	46,113 psi
Hoop Stress =	940 psi	8,892 psi
Combined Stress =	0.3743	< 1.0
Total Stress =	0.1215	< 1.0

Installation:10.50 lb/gal Drilling Fluid With Neutral Pipe Buoyancy — Segment 3 of 5

Segment Parameters			
Segment Name =	BOTTOM TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	92.92 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	6,306 lb
Friction Force =	0 lb
Segment Weight =	0 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	6,306 lb
Cumulative Force =	**64,829 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	69 psi	
Cumulative Axial Stress =	713 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	940 psi	8,892 psi
Combined Stress =	0.0127	< 1.0
Total Stress =	0.0115	< 1.0

Installation Load Calculations

Installation:10.50 lb/gal Drilling Fluid With Neutral Pipe Buoyancy — Segment 4 of 5

Segment Parameters			
Segment Name =	ENTRY CURVE	Radius of Curvature =	3,600 ft
Segment Type =	Vertical Curve	Angle Turned =	10.00 deg
Segment Length =	628.32 ft	Center Displacement =	13.70 ft

Segment Force Components	
Normal Force =	16,931 lb
Drag Force =	42,637 lb
Friction Force =	5,079 lb
Segment Weight =	0 lb
Tension =	117,624 lb
Average Tension =	91,227 lb
Segment Force =	52,795 lb
Cumulative Force =	**117,624 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	580 psi	
Cumulative Axial Stress =	1,293 psi	56,000 psi
Bending Stress =	16,731 psi	46,113 psi
Hoop Stress =	940 psi	8,892 psi
Combined Stress =	0.3859	< 1.0
Total Stress =	0.1293	< 1.0

Installation:10.50 lb/gal Drilling Fluid With Neutral Pipe Buoyancy — Segment 5 of 5

Segment Parameters			
Segment Name =	ENTRY TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	139.03 ft	Center Displacement =	0.00 ft

Segment Force Components	
Normal Force =	0 lb
Drag Force =	9,435 lb
Friction Force =	0 lb
Segment Weight =	0 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	9,435 lb
Cumulative Force =	**127,059 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	104 psi	
Cumulative Axial Stress =	1,397 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	288 psi	8,892 psi
Combined Stress =	0.0249	< 1.0
Total Stress =	0.0020	< 1.0

APPENDIX C
Report Limitations and Guidelines for Use

APPENDIX C
REPORT LIMITATIONS AND GUIDELINES FOR USE[1]

This appendix provides information to help you manage your risks with respect to the use of this report.

Geotechnical Services Are Performed for Specific Purposes, Persons and Projects

This report has been prepared for the exclusive use of PCGP, LP and their authorized agents. This report is not intended for use by others, and the information contained herein is not applicable to other sites.

GeoEngineers structures our services to meet the specific needs of our clients. For example, a geotechnical or geologic study conducted for a civil engineer or architect may not fulfill the needs of a construction contractor or even another civil engineer or architect that are involved in the same project. Because each geotechnical or geologic study is unique, each geotechnical engineering or geologic report is unique, prepared solely for the specific client and project site. Our report is prepared for the exclusive use of our Client. No other party may rely on the product of our services unless we agree in advance to such reliance in writing. This is to provide our firm with reasonable protection against open-ended liability claims by third parties with whom there would otherwise be no contractual limits to their actions. Within the limitations of scope, schedule and budget, our services have been executed in accordance with our Agreement with the Client and generally accepted geotechnical practices in this area at the time this report was prepared. This report should not be applied for any purpose or project except the one originally contemplated.

A Geotechnical Engineering or Geologic Report Is Based on a Unique Set of Project-specific Factors

This report has been prepared for PCGP, LP for the Coos River HDD in Coos County, Oregon. GeoEngineers considered a number of unique, project-specific factors when establishing the scope of services for this project and report. Unless GeoEngineers specifically indicates otherwise, do not rely on this report if it was:

- not prepared for you.
- not prepared for your project.
- not prepared for the specific site explored.
- completed before important project changes were made.

For example, changes that can affect the applicability of this report include those that affect:

- the function of the proposed structure.
- elevation, configuration, location, orientation or weight of the proposed structure.
- composition of the design team.
- project ownership.

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[1] Developed based on material provided by ASFE, Professional Firms Practicing in the Geosciences; www.asfe.org.

If important changes are made after the date of this report, GeoEngineers should be given the opportunity to review our interpretations and recommendations and provide written modifications or confirmation, as appropriate.

Subsurface Conditions Can Change

This geotechnical or geologic report is based on conditions that existed at the time the study was performed. The findings and conclusions of this report may be affected by the passage of time, by manmade events such as construction on or adjacent to the site, or by natural events such as floods, earthquakes, slope instability or groundwater fluctuations. Always contact GeoEngineers before applying a report to determine if it remains applicable.

Most Geotechnical and Geologic Findings Are Professional Opinions

Our interpretations of subsurface conditions are based on field observations from widely spaced sampling locations at the site. Site exploration identifies subsurface conditions only at those points where subsurface tests are conducted or samples are taken. GeoEngineers reviewed field and laboratory data and then applied our professional judgment to render an opinion about subsurface conditions throughout the site. Actual subsurface conditions may differ, sometimes significantly, from those indicated in this report. Our report, conclusions and interpretations should not be construed as a warranty of the subsurface conditions.

Geotechnical Engineering Report Recommendations Are Not Final

Do not over-rely on the preliminary construction recommendations included in this report. These recommendations are not final, because they were developed principally from GeoEngineers' professional judgment and opinion. GeoEngineers' recommendations can be finalized only by observing actual subsurface conditions revealed during construction. GeoEngineers cannot assume responsibility or liability for this report's recommendations if we do not perform construction observation.

Sufficient observation, testing and consultation by GeoEngineers should be provided during construction to confirm that the conditions encountered are consistent with those indicated by the explorations, to provide recommendations for design changes should the conditions revealed during the work differ from those anticipated, and to evaluate whether or not earthwork activities are completed in accordance with our recommendations. Retaining GeoEngineers for construction observation for this project is the most effective method of managing the risks associated with unanticipated conditions.

A Geotechnical Engineering or Geologic Report Could Be Subject to Misinterpretation

Misinterpretation of this report by other design team members can result in costly problems. You could lower that risk by having GeoEngineers confer with appropriate members of the design team after submitting the report. Also, retain GeoEngineers to review pertinent elements of the design team's plans and specifications. Contractors can also misinterpret a geotechnical engineering or geologic report. Reduce that risk by having GeoEngineers participate in pre-bid and preconstruction conferences, and by providing construction observation.

Do Not Redraw the Exploration Logs

Geotechnical engineers and geologists prepare final boring and testing logs based upon their interpretation of field logs and laboratory data. To prevent errors or omissions, the logs included in a geotechnical

engineering or geologic report should never be redrawn for inclusion in architectural or other design drawings. Only photographic or electronic reproduction is acceptable, but recognize that separating logs from the report can elevate risk.

Give Contractors a Complete Report and Guidance

Some owners and design professionals believe they can make contractors liable for unanticipated subsurface conditions by limiting what they provide for bid preparation. To help prevent costly problems, give contractors the complete geotechnical engineering or geologic report, but preface it with a clearly written letter of transmittal. In that letter, advise contractors that the report was not prepared for purposes of bid development and that the report's accuracy is limited; encourage them to confer with GeoEngineers and/or to conduct additional study to obtain the specific types of information they need or prefer. A pre-bid conference can also be valuable. Be sure contractors have sufficient time to perform additional study. Only then might an owner be in a position to give contractors the best information available, while requiring them to at least share the financial responsibilities stemming from unanticipated conditions. Further, a contingency for unanticipated conditions should be included in your project budget and schedule.

Contractors Are Responsible for Site Safety on Their Own Construction Projects

Our geotechnical recommendations are not intended to direct the contractor's procedures, methods, schedule or management of the work site. The contractor is solely responsible for job site safety and for managing construction operations to minimize risks to on-site personnel and to adjacent properties.

Read These Provisions Closely

Some clients, design professionals and contractors may not recognize that the geoscience practices (geotechnical engineering or geology) are far less exact than other engineering and natural science disciplines. This lack of understanding can create unrealistic expectations that could lead to disappointments, claims and disputes. GeoEngineers includes these explanatory "limitations" provisions in our reports to help reduce such risks. Please confer with GeoEngineers if you are unclear how these "Report Limitations and Guidelines for Use" apply to your project or site.

Geotechnical, Geologic and Environmental Reports Should Not Be Interchanged

The equipment, techniques and personnel used to perform an environmental study differ significantly from those used to perform a geotechnical or geologic study and vice versa. For that reason, a geotechnical engineering or geologic report does not usually relate any environmental findings, conclusions or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. Similarly, environmental reports are not used to address geotechnical or geologic concerns regarding a specific project.

Biological Pollutants

GeoEngineers' Scope of Work specifically excludes the investigation, detection, prevention or assessment of the presence of Biological Pollutants. Accordingly, this report does not include any interpretations, recommendations, findings, or conclusions regarding the detecting, assessing, preventing or abating of Biological Pollutants and no conclusions or inferences should be drawn regarding Biological Pollutants, as they may relate to this project. The term "Biological Pollutants" includes, but is not limited to, molds, fungi, spores, bacteria, and viruses, and/or any of their byproducts.

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Geotechnical Engineering Services and Horizontal Directional Drilling Design

Rogue River HDD
Pacific Connector Gas Pipeline Project
Jackson County, Oregon

for

Pacific Connector Gas Pipeline, LP

September 1, 2017

GeoEngineers
Earth Science + Technology

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Geotechnical Engineering Services and Horizontal Directional Drilling Design

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Pacific Connector Gas Pipeline Project
Jackson County, Oregon

File No. 22708-001-01

September 1, 2017

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EXECUTIVE SUMMARY

This report provides geotechnical engineering and horizontal directional drilling (HDD) recommendations and horizontal directional drilling design criteria for the proposed HDD crossing of the Rogue River located near Shady Cove, Oregon. The HDD portion of the project consists of installing a new 36-inch diameter pipeline under the river. The river crossing will be a part of the proposed Pacific Connector Gas Pipeline (PCGP).

Based on the results of our site visits, subsurface exploration program, geotechnical engineering evaluations, HDD design, and HDD constructability review, it is our opinion the HDD method of installation is feasible and the proposed crossing of the Rogue River can be installed successfully provided the recommendations in this report are incorporated into the installation of the crossing.

The subsurface conditions at the site were evaluated by drilling seven borings, to depths up to 250 feet below the existing ground surface. The soils encountered in the explorations typically consisted of up to 27 feet of dense fine to coarse gravel with cobbles near entry and approximately 15 feet of very stiff to hard clay near exit. Bedrock was encountered below the soil in each of the borings. The bedrock consisted primarily of basalt and breccia.

Original plans called for a compressor station to be optionally located at the top of the hill on the west side of the river. The initial HDD profile had the HDD entry point at the top of the hill. Subsequent to the completion of the field explorations, the decision was made to locate the compressor station at an alternate site. In an attempt to reduce topographic relief between the entry and exit points and reduce potential construction difficulties, the original HDD profile was lengthened such that the proposed workspace on the west side of the river is now located further west, near the base of the hill. Because of the change in the HDD profile, boring B-6 was drilled near the proposed HDD exit point to characterize the subsurface conditions within the western third of the proposed HDD alignment.

The site-specific HDD profile was created utilizing the design guide published by the Pipeline Research Committee International (PRCI) of the American Gas Association. Associated installation and operational stresses were calculated utilizing the PRCI Design Guide and checked to assess compliance with ASTM / ASME B31.8, API Recommended Practice 2A – WSD, and DOT CFR Part 192. The HDD design calculations indicate the stresses incurred during installation and operation should be within the allowable limits.

This Executive Summary should be used only in the context of the full report for which it is intended.

1.0 INTRODUCTION

1.1 General

This report summarizes our geotechnical engineering and HDD design services for the proposed HDD crossing of the Rogue River. The site is located near Shady Cove in Jackson County, Oregon. The site is approximately shown in the Vicinity Map, Figure 1. The general layout of the site is shown in the Site Plan and Profile, Figure 2.

1.2 Project Description and Basis of Design

The proposed Rogue River HDD crossing will be a part of the 229-mile-long PCGP, beginning at the proposed Jordan Cove Liquefied Natural Gas (LNG) Terminal near Coos Bay, Oregon and terminating near Malin, Oregon. The proposed pipeline crossing of the Rogue River consists of a single 36-inch diameter pipe to be installed using HDD techniques. The proposed crossing is located approximately 2 miles north of Shady Cove in Jackson County, Oregon.

The HDD design was completed in accordance with the latest versions of Department of Transportation (DOT) 49 CFR 192, ASME 31.8 and accepted practices within the natural gas industry. The geotechnical and HDD design engineering was completed based on the parameters presented below in Table 1.

TABLE 1. BASIS OF DESIGN FOR THE 36-INCH-DIAMETER ROGUE RIVER HDD

Product Pipe Data	Design Parameter
Product Pipe Specifications	36 inches x 0.823 inches w.t.[1] API-5L X-70 steel pipe, SAWH or SAWL
Horizontal Crossing Length	3,050 feet
Maximum Allowable Operating Pressure	1,600 psig[2]
Operating Temperature	70 degrees F
Maximum Operating Temperature	100 degrees F
Assumed Tie-In Temperature	50 degrees F

Notes:

[1] w.t. – wall thickness

[2] psig – pounds per square inch gauge

2.0 SCOPE OF SERVICES

The purpose of our services was to evaluate the existing surface and subsurface soil and groundwater conditions and prepare a HDD design for the proposed crossing. The specific scope of services provided by GeoEngineers, Inc. included the following:

1. Preparing preliminary information and maps of the HDD utilizing geographic information system (GIS) data provided by Pacific Connector Gas Pipeline, LP (PCGP, LP) and other available public data sources.
2. Completing a site reconnaissance with PCGP, LP and their authorized representatives to observe surface conditions and locate borings. During our site reconnaissance, we collected the following information:
    a. Geologic and environmental surface features that could impact HDD feasibility;

   b. Topography of the site, particularly along the planned alignment;
   c. Potential HDD operational areas such as entry and exit points, staging, site access and pipe stringing;
   d. Number and approximate location of geotechnical borings;
   e. Potential obstacles such as existing utilities, buildings, houses and other surface features within the potential work areas; and
   f. Map surface exposures of geologic materials visible within road cuts and stream banks in order to aid in interpreting potential subsurface conditions along the planned HDD alignment.
3. Preparing and submitting a technical memorandum to PCGP, LP, including:
   a. Brief surface description of site conditions that could affect the planned HDD operations;
   b. Summary of subsurface conditions encountered during our fieldwork;
   c. HDD feasibility discussion;
   d. Preliminary HDD profile design length and depth;
   e. Draft bore logs; and
   f. Site Photographs.
4. Coordinating utility locating near our proposed boring locations by the public "One Call" utility locating service.
5. Exploring subsurface conditions by drilling seven borings near the HDD alignment using mud rotary and rock core drilling techniques. Our drilling subcontractor drilled the borings to total depths ranging between 31.5 and 250 feet below ground surface (bgs). During drilling, we:
   a. Obtained soil samples at representative intervals from the borings using split spoon samples and also conducted standard penetration tests (SPT) at 5-foot intervals in the soil portion of the borings. We obtained continuous rock core samples of rock encountered in the borings; and
   a. Classified soils encountered in the borings in general accordance with ASTM International (ASTM) Standard Practice D 2488. We classified rock encountered in the borings in general accordance with the Oregon Department of Transportation (ODOT) rock classification system. We maintained a log of the materials encountered in each exploration.
6. Performing index tests necessary to characterize the subsurface materials. Testing included:
   a. Unconfined compressive strength tests in general accordance with ASTM D 7012.
7. Performing a qualitative hydraulic fracture and drilling fluid surface release analysis to characterize the risk of hydraulic fracture and drilling fluid surface release. A numerical analysis was not conducted because the vast majority of the HDD path is located within bedrock and the numerical analysis method (cavity expansion theory) generally applies to soil materials rather than hard rock.
8. Completing HDD design, including:
   a. Alignment and profile;
   b. Minimum radius;

c. Installation stresses; and

d. Operating stresses.

9. Providing a draft HDD design report to the project team for review and comment. The draft report included:

    a. Analyses and discussion of hydraulic fracture and drilling fluid surface returns potential;

    b. Installation stress calculations;

    c. Operating stress calculations;

    d. HDD design conclusions and recommendations including:

        i. Drilling fluid loss;

        ii. Minimum allowable product pipe bending radius;

        iii. Pilot hole survey recommendations;

        iv. Anticipated drilling conditions;

        v. Hole collapse conclusions and recommendations;

        vi. Pipe coating specifications conclusions;

        vii. Buoyancy considerations;

        viii. Site access considerations; and

        ix. Nose mitigation techniques.

    e. Geotechnical engineering considerations, including:

        i. Temporary access roads;

        ii. Temporary workspace areas;

        iii. HDD installation

        iv. Temporary excavations;

        v. Construction dewatering; and

        vi. Erosion control.

    f. HDD design drawings, including site-specific construction diagrams that show the location of temporary entry and exit workspaces, pipe assembly areas and areas to be disturbed or cleared for construction.

10. Preparing a final HDD design report incorporating comments from the project team (to be completed).

3.0 SITE CONDITIONS

3.1 Geologic Setting

3.1.1 Site Geology

Based on the geologic maps we reviewed for the area (USGS, 2002) and our geotechnical explorations, the site is underlain by alluvial soils and weathered bedrock overlying basaltic and pyroclastic breccia, Tertiary-aged basalt flows, tuffaceous sedimentary rocks and volcanic ash.

3.2 Surface Conditions

3.2.1 General

We evaluated surface conditions in the vicinity of the site by completing a site reconnaissance during both our preliminary site visits and our subsurface exploration program conducted during May and June of 2006.

3.2.2 Surface Description

The proposed HDD crossing is located approximately 2 miles north of Shady Cove, Oregon where the PCGP alignment crosses the Rogue River from east to west, entry to exit, (see Figure 2). The proposed HDD entry workspace is located on the east side of the river on relic point bar sediments deposited by the river. The workspace is located in a relatively flat wooded area approximately 650 feet from the east river bank. The entry point is located in close proximity (200–400 feet) to existing single-family residences. The exit workspace and stringing area are located within uplands approximately 2,100 feet west of the river within a drainage basin that drains to the river south of the crossing.

The ground surface on the east (entry) side of the river is generally flat but slopes gently down toward the west and ranges from approximately Elevation 1,426 feet at the entry point to approximately Elevation 1,410 feet at the riverbank. The proposed entry workspace occupies a 200-foot by 250-foot area just east of the entry point. The area within the entry workspace is vegetated primarily with grasses and scattered trees. No surface water features are located within the entry workspace.

The ground surface within the exit workspace slopes down toward the west and ranges in elevation from approximately 1,499 feet at the exit point to approximately Elevation 1,492 feet at the west end of the workspace. The exit workspace occupies a 200-foot by 250-foot area west of the exit point in a relatively undeveloped area. The stringing area west of the exit workspace slopes gently up toward the west. The ground surface within the stringing area ranges from Elevation 1,492 feet at the east end to approximately Elevation 1,635 feet at the west end of the stringing area. The vegetation within the exit workspace and stringing area consists of grasses, brush and scattered trees.

3.3 Subsurface Conditions

3.3.1 General

We explored subsurface conditions at the site in May, June and October 2006 by advancing seven drilled borings to maximum depths of 250 feet bgs at the locations shown in Figure 2. A representative from GeoEngineers maintained logs of the materials encountered in each boring and collected disturbed soil samples at 5-foot intervals and continuous rock core samples of rock encountered by the borings. Appendix A presents the boring logs and a description of the subsurface exploration and laboratory-testing programs.

The materials encountered in our borings were consistent with the geologic mapping for the site. In general, borings completed within upland areas on the west side of the Rogue River encountered hard lean clay, medium dense sand and very dense gravel that we interpret as colluvium and weathered bedrock overlying bedrock consisting of sandstone, claystone, breccia and basalt. A few ash layers were encountered interbedded with the breccia. Borings completed in the valley floor segment of the alignment east of the Rogue River generally encountered very dense gravel alluvium (river deposits) overlying breccia. The materials encountered in each boring are described in more detail in the following paragraphs.

3.3.2 Subsurface Conditions Encountered by Borings

Boring B-1 was completed within the upland portion of the HDD alignment approximately 700 feet east of the exit point. Boring B-1 encountered approximately 7 feet of hard clay with gravel and occasional cobbles overlying very dense gravel to approximately 17 feet bgs. Below 17 feet bgs, the boring encountered hard sandy clay to about 27 feet bgs, where decomposed to predominately decomposed, very soft to medium hard and closely fractured sandstone was encountered to 59 feet bgs. Below 59 feet bgs, the boring encountered generally fresh, very soft to medium hard and closely to medium fractured breccia to a depth of 101 feet bgs, the maximum depth explored. Rock Quality Designation (RQD) values in the sandstone ranged from 25 to 80 percent. RQD values in the breccia typically ranged from 73 to 100 percent except between depths of 76 to 81 feet where the RQD value was 37 percent. The tested unconfined compressive strength in one sample of the breccia we collected was 990 pounds per square inch (psi).

Boring B-2 was completed near Ragsdale Road approximately near the midpoint of the HDD alignment. Boring B-2 encountered 3 feet of sandy gravel overlying slightly weathered to fresh, medium hard to hard and close to medium fractured basalt to a depth of 101 feet bgs, the maximum depth explored. RQD values in the basalt typically ranged from 57 to 85 percent except for three isolated zones of rock between 2 to 4 feet in thickness where the RQD values ranged from 0 to 47 percent. The tested unconfined compressive strength for one sample of the basalt we collected was 12,660 psi.

Boring B-3 was completed in the shoulder of State Highway 62 above the west bank of the Rogue River. Boring B-3 encountered 7 feet of medium dense silty sand overlying moderately weathered to fresh, moderately strong and very closely to closely fractured basalt to a depth of 29 feet bgs. Below 29 feet bgs, the boring encountered completely weathered to fresh, soft to medium hard breccia with close to wide fracturing to a depth of 101 feet bgs, the maximum depth explored. The RQD values in the basalt typically ranged from 59 to 96 percent except for the upper 2 feet of the unit where the RQD was 0 percent. RQD values in the breccia below 29 feet typically ranged from 62 to 99 percent except for the zone between depths of 71 and 76 feet where the RQD was 38 percent. The tested unconfined compressive strength in two of the breccia samples we collected ranged from 2,410 psi to 4,040 psi.

Boring B-4 was completed within the valley floor near the east bank of the Rogue River. Boring B-4 encountered 13 feet of alluvium consisting of very dense gravel with cobbles and boulders overlying slightly weathered, soft to medium hard breccia with medium to wide fracturing to a depth of 101 feet bgs, the maximum depth explored. RQD values in the breccia ranged from 73 to 99 percent. The tested unconfined compressive strength in the breccia ranged from 3,220 psi to 3,430 psi.

Boring B-5 was completed within the valley floor approximately 400 feet west of the entry point. Boring B-5 encountered 27 feet of alluvium consisting of very dense gravel with cobbles and boulders overlying predominately decomposed to slightly weathered, soft breccia with very close to close fracturing to a depth of 31.5 feet bgs, the maximum depth explored. The RQD value for the one core run completed in the breccia was 51 percent.

Boring B-6 was completed within the uplands near the west (exit) end of the HDD alignment. Boring B-6 encountered 15 feet of very stiff to hard clay overlying decomposed claystone to a depth of approximately 19 feet bgs. Below 19 feet bgs, the boring encountered predominately decomposed to fresh, very soft to soft breccia with close to wide fracturing to a depth of 101 feet bgs, the maximum depth explored. RQD values in the breccia typically ranged from 60 to 93 percent except for the two coring runs between depths of 91 and 101 feet where the RQD was 30 percent or less. The tested unconfined compressive strength for one sample of the breccia we collected from a depth of approximately 37 feet was 467 psi.

Boring B-7 was completed within the uplands segment of the alignment approximately 900 feet east of the exit point. Boring B-7 encountered approximately 8 feet of hard sandy clay with gravel overlying slightly weathered basalt to a depth of 11 feet bgs. Below 11 feet bgs, the boring encountered silty gravel with sand and occasional cobbles to a depth of approximately 24 feet where sandy clay residual soil (decomposed basalt) was encountered to a depth of 35 feet bgs. Below 35 feet bgs, the boring encountered highly weathered, closely fractured to medium fractured and very soft to soft volcanic breccia with some interbedded ash layers to a depth of 250 feet bgs, the maximum depth explored. RQD values in the breccia generally ranged between 45 and 100 percent; however, RQDs within several depth intervals were significantly lower as shown on the boring log in Appendix B.

The subsurface materials encountered by the borings are described in more detail in the boring logs included in Appendix A.

3.3.3 Groundwater Conditions

We did not measure groundwater levels upon completion of the borings because of the presence of drilling fluid in the holes at the time of drilling. We anticipate that groundwater levels will mimic the elevation of the Rogue River around 1,410 feet mean sea level (MSL). We anticipate that groundwater levels will fluctuate with precipitation, site utilization and other factors. During heavy prolonged precipitation, and probably during most of the winter months, we expect that groundwater will be near or at the surface of the site on the east side of the Rogue River.

4.0 HDD ENGINEERING ANALYSES

4.1 Drilling Fluid Loss

4.1.1 General

Drilling fluid is pumped through the drill pipe string to the cutting tool and returns through the drilled hole annulus. For HDD installations like the Rogue River HDD, pump pressures of several hundred psi and pump rates of 100 to 400 gallons per minute (gpm) are typical. The drilling fluid typically has a specific gravity ranging from 1.1 to 1.2 (approximately 69 to 75 pounds per cubic foot [pcf]).

Drilling fluid circulation may be reduced or lost primarily by either or both of the following two processes:

1. Formational fluid loss occurs when drilling fluid flows into preexisting fractures, voids and/or pore spaces in the surrounding soil or rock. Sand and gravel soil layers and highly fractured rock are typically more susceptible to formational fluid loss than cohesive soils like clay and silt.
2. Hydraulic fracturing can occur where the combined resisting force of the overburden pressure and the shear strength of the overburden soil is less than the hydrostatic pressure applied by the drilling fluid at the cutting tool.

4.2 Hydraulic Fracture and Drilling Fluid Surface Releases

Hydraulic fracture is a term typically used to describe the situation in which the downhole fluid pressure exceeds the overburden pressure and shear strength of the formation above a drill path. Hydraulic fracture typically occurs when the drill path passes through relatively weak cohesive soils or loose granular soils with low shear strength. Very loose to loose sands and silty sands and soft to medium stiff silts and clays typically have a higher hydraulic fracture potential. Medium dense to very dense sands typically have a low to moderate hydraulic fracture potential. Bedrock, because of its high shear strength, typically has a low potential for hydraulic fracture. Moreover, cavity expansion theory used in calculating the safety factor against hydraulic fracture cannot be applied to bedrock conditions. Because most of the Rogue River HDD path is situated within bedrock, we did not perform a numerical hydraulic fracture analysis. The following section describes our qualitative evaluation of the potential for drilling fluid surface releases along the Rogue River HDD.

Our qualitative hydraulic fracture and drilling fluid surface release evaluation considers the material types encountered in the borings completed at the site, the relative density or consistency of the soils and relative pumping pressures required to move drilling fluid from the cutting tool to the entry point.

Drilling fluid can be released to the ground surface as a result of hydraulic fracture of the soil formation or by following preexisting voids or fractures in the subsurface as described further below. This release of drilling fluid is commonly referred to as a “frac-out.” Relatively large volumes of drilling fluid can be released over a short time period, particularly if the high-pressure drilling fluid pumps are not immediately disengaged.

In practice, drilling fluid releases commonly occur in close proximity to the entry and exit points where depth of cover decreases and at the exit point where annular pressures are at their greatest. Potential for releases also increase at locations along a drill path where there are low strength soils, where the alignment is at a relatively shallow depth, or along preexisting fractures or voids. Other locations where potential for drilling fluid release is elevated include preferential pathways such as exploratory boring locations, along the sides of existing structures such as piles or utility poles.

The HDD contractor’s construction procedures constitute another important factor influencing when and where fluid loss occurs. If the contractor operates with inadequate pump volumes, less than ideal drilling fluid properties or excessive rates of penetration, the annulus may become blocked through an accumulation of drill cuttings falling out of suspension. If the accumulation creates a blockage downhole, the annulus may become over-pressurized, leading to hydraulic fracturing and potentially release of drilling fluid.

Our qualitative evaluation considers materials encountered by exploratory borings, and the susceptibility of those material types to hydraulic fracture, and/or difficulty removing cuttings of those materials from the drilled hole. We also consider the relative pump pressures that will be required to move solids laden with drilling fluid from the cutting to the drilling fluid recycling system. Based on these considerations, and our HDD construction experience, we developed a qualitative opinion on the relative risk of drilling fluids being released to the ground surface along the proposed HDD. The results of our evaluation are provided in the conclusions section of this report.

4.3 Installation Stresses

The analyses of installation loads and stresses are based on the product pipe being installed along the designed path using the best management practices (BMP) of the HDD industry. The addition of water into the product pipe is the standard method that contractors typically use to control buoyancy of the product pipe during the installation procedure. The proposed 36-inch-diameter product pipe will be positively buoyant in the anticipated drilling fluid weights. Therefore, our analyses include five cases with differing levels of buoyancy and drilling fluid weights.

The five cases analyzed are as follows:

1. The annulus contains 9.5 lb/gal drilling fluid and product pipe is empty.
2. The annulus contains 9.5 lb/gal drilling fluid and product pipe is full of water.
3. The annulus contains 12 lb/gal drilling fluid and product pipe is empty.
4. The annulus contains 12 lb/gal drilling fluid and product pipe is full of water.
5. The annulus contains 10.5 lb/gal drilling fluid and product pipe is filled such that neutral buoyancy is achieved.

The analyses are based upon the methods developed by the Pipeline Research Committee International (PRCI) of the American Gas Association (PR-227-9424, 1995). The only deviation from this guide in calculating the installation stresses is a more conservative allowable tensile stress (F_t).

The equation recommended in the PRCI Design Guide is shown in below in **Equation 1**:

F_t = 0.9 *SMYS (Specified Minimum Yield Strength)

The allowable tensile stress used for our analyses is derived from Sections 2.4.1, 3.1.2 and 3.2 of the American Petroleum Institute (API) Recommended Practice 2A – WSD (WSD Recommended Practice 2A-WSD, 1993).

Section 3.2 of the API Recommended Practice defines the allowable tensile stress of cylindrical members as shown below in **Equation 2**:

F_t = 0.6 *SMYS

Sections 2.4.1 and 3.1.2 of the API Recommended Practice permit the allowable tensile stress, defined in Equation 2, to be increased by one-third, yielding a design factor of 0.8, which is more conservative than 0.9 as listed in the PRCI Design Guide.

The equation used in our analyses is shown below in **Equation 3**:

$$F_t = 0.8 * SMYS$$

The following table presents a summary of the calculated installation loads for the HDD.

TABLE 2. INSTALLATION LOADS FOR THE 36-INCH-DIAMETER ROGUE RIVER HDD[1]

Drilling Fluid Weight (lb/gal)	Buoyancy Condition	Effective Pipe Weight[2] (lb/ft)	Pullback Force[3] (lb)
9.5	Empty	-192	453,000
9.5	Full	209	365,000
12	Empty	-324	603,000
12	Full	77	252,000
10.5	Neutral Buoyancy	0	233,000

Notes:

[1] See Appendix B for detailed calculations.

[2] Negative values indicate upward force (positive buoyancy).

[3] Assumes a fully open drilled hole.

4.4 Operating Stresses

The operating stresses on a pipeline installed by directional drilling include hoop stress from the maximum allowable operating pressure (MAOP), hoop stress from external pressure applied by the groundwater acting on the outside of the product pipe, elastic bending as the product pipe conforms to the shape of the drilled hole, and thermal expansion and contraction stresses resulting from the difference between the constructed temperature and the operating temperature. The following table presents a summary of the operating stresses based on the product pipe specifications and the HDD profile as shown on the HDD Design Drawing in Appendix B.

TABLE 3. SUMMARY OF OPERATING STRESSES FOR THE 36-INCH-DIAMETER ROGUE RIVER HDD*

Stress Component	Stress (psi)	Percent SMYS[1] (%)	Maximum Allowable Percent SMYS (%)
Longitudinal Bending Stress	16,900	24	-
Hoop Stress	34,990	50	50[2]
Longitudinal Tensile Stress from Hoop Stress	10,500	15	-
Longitudinal Stress from Thermal Expansion	9,500	14	90[3]
Maximum Net Longitudinal Stress	17,900	26	90[4]
Maximum Shear Stress	25,500	36	45[5]
Maximum Combined Effective Stress	50,960	73	90[6]

Notes:

* Operating stress calculations are based on the specified minimum radius of curvature of 2,600 feet and assumed installation and maximum operating temperatures of 100 degrees Fahrenheit.

[1] Specified Minimum Yield Strength

[2] Limited by design factor from DOT regulations, Title 49 CFR Part 192.111 for gas.

[3] Limited by Section 402.3.2 of ASME B31.4.

[4] Limited by Section 833.3 of ASME B31.8 for gas.

[5] Limited by Section 402.3.1 of ASME B31.4.

[6] Limited by Section 833.4 of ASME B31.8 for gas.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 HDD Design Considerations and Recommendations

5.1.1 General

The contractor's means and methods during construction are critical to the successful completion of the HDD. Specifically, during pilot hole drilling, only small deviations from the design for horizontal and vertical curvature should be allowed so that pull load forces similar to those estimated by the calculations can be maintained. The HDD contractor's ability to maintain drilling fluid returns, proper drilling fluid properties with appropriate penetration rates, and drilling fluid flow rates will also be important factors to consider during drilling because hole conditions will be directly affected by these operations.

We recommend that PCGP, LP retain a qualified representative to observe and document the drilling process and to advise the project team on areas of concern and recommended actions during drilling activities. We also recommend that PCGP, LP require that a qualified "Mud Engineer" evaluate the drilling fluid properties on a continuous basis during the entire drilling and installation process. Close coordination between the contractor and the "Mud Engineer" to maintain proper drilling fluid properties, penetration rates and drilling fluid flow rates will be instrumental to effectively remove cuttings from the pilot hole and reamed hole.

5.1.2 Drill Hole Stability

In general, we expect that there is a relatively low risk of drill hole instability within most of the proposed HDD profile. However, the contractor should be prepared to encounter approximately 27 feet of very dense gravel with occasional cobbles and boulders near the entry point. If hole instability or steering difficulty is anticipated by the contractor, installation of casing at the entry and exit points can serve to maintain drill hole stability. If casing is utilized, upon completion of the pilot hole or prior to reaming the cased section of the hole, the casing is typically removed, but could remain in place through product pipe pullback to maintain drill hole stability within the entry tangent. The specific casing diameter and installation method should be determined by the HDD contractor.

Depending on the contractor's means and methods, and the ability of the contractor to keep the pilot hole within acceptable tolerances, the contractor may elect to complete the entry tangent portion of the pilot hole and then install casing of sufficient diameter over the drill pipe that would allow for hole opening operations to be completed without removing the casing. The contractors' proposed drill hole stability mitigation measures should be presented as part of the HDD bid proposals and included in the evaluation prior to contractor selection.

RQDs observed in borings that encounter the proposed HDD profile generally range between about 75 and 98 percent, which indicates a relatively low risk of drill hole collapse along the portions of the HDD profile that are located within the bedrock. However, there are localized zones along the planned HDD profile that have RQD values of less than 25 percent. Therefore, there is a moderate risk for localized hole instability along the HDD profile. The contractor should pay special attention to the area between approximate stations 25+00 and 20+00 during pilot hole operations, and reaming and swabbing operations. If hole collapse does occur, additional reaming and swabbing passes may be necessary to clean the hole prior to attempting installation of the product pipe.

5.1.3 Cuttings Removal

The gravels and cobbles encountered within the upper 27 feet near the HDD entry point present unique cuttings removal challenges. Often gravel and cobble clasts cannot be carried out of the drilled/reamed hole by drilling fluid because the weight of the clasts preclude the ability for the gravel and cobble to remain in suspension. When this occurs, the gravel and cobble can accumulate within the lowest section of a drilled or reamed hole, and may not be able to be effectively removed from the hole without mechanical means of extraction. If gravels and cobbles accumulate within the hole, the contractor will need to be prepared to attempt to either extract the over-sized material by mechanical means such as a "junk basket" or cut a larger than typical hole to accommodate the product pipe, given that some of the hole is plugged with gravels and/or cobbles.

If cuttings are not effectively removed from the hole during HDD operations, pullback forces could be excessively high during pullback of the 36-inch-diameter product pipe, or the product pipe could become lodged in the hole. The failure to effectively remove cuttings from the hole could potentially result in failure of the HDD installation. Therefore, we recommend that the drilling contractor maintain drilling fluid returns at all times, and use appropriate means and methods (appropriate penetration rates, drilling fluid management, mechanical methods) to ensure that cuttings are adequately removed from the hole during the HDD process.

5.1.4 Drilling Fluid Loss and Drilling Fluid Surface Release

It is our opinion that relatively little formational fluid loss should be expected along most of the proposed HDD profile provided the contractor maintains drilling fluid returns during construction and also maintains drilling fluid properties that are conducive to cuttings removal and formation of a "wall cake" to help stabilize the bore hole and limit fluid interaction between the bore hole and surrounding soils. However, some drilling fluid loss should be expected especially as the HDD profile passes through gravelly soil layers near the entry point and low RQD zones within the bedrock where the rock is very closely to closely fractured.

It is our opinion that there is a low risk of drilling fluid surface release along the proposed HDD profile, except within about 50 to 100 feet of the entry and exit points where the HDD profile passes through alluvial and colluvial soils, and the cover between the HDD profile and the ground surface is relatively thin. As is typical with most HDD installations, the risk of drilling fluid surface release within about 100 feet of the entry and exit points is relatively high.

Because of the elevated risk of drilling fluid surface release occurring near the entry and exit points during construction, we recommend that the contractor establish a contingency and mitigation plan in the event that drilling fluid surface releases occur; these plans should be reviewed and approved by the project team prior to the start of construction. We recommend the annular drilling fluid pressures be closely monitored during drilling to help identify when the potential for a surface release of drilling fluid may be possible. Annular pressures can be monitored through the use of an annular pressure tool as part of the bottom hole assembly (BHA).

5.1.5 Workspace Considerations

The proposed entry workspace for the HDD measures roughly 250 feet by 200 feet as shown in Figure 2, and also in the HDD Design Drawing in Appendix B. The workspace is located within an area with relatively little topographic relief and scattered trees. We anticipate that clearing of trees and some minor grading may be required to provide a suitable workspace for drilling operations.

The exit workspace is located within an area with sparsely spaced trees. The ground surface slopes gently to moderately westward within the exit workspace. Some cutting of trees and grading may be required to provide a suitable workspace for exit side HDD operations.

The proposed product pipe stringing and fabrication area is located west of the exit point. The workspace near the exit point slopes gently to moderately westward, then traverses a hill with gentle to moderate east and west facing slopes. Clearing of trees should be expected to prepare the workspace. We do not anticipate that significant grading will be required to prepare the product pipe stringing and fabrication workspace.

5.1.6 Minimum Allowable Product Pipe Bending Radius

Based on the design geometry, subsurface conditions encountered, and proposed product pipe specifications, the minimum allowable three-joint radius over any consecutive three-joint section of drill pipe should not be less than 2,600 feet. We recommend that the three-joint radius be calculated for each three-joint section of drill pipe drilled during pilot hole operations. The design radii for the entry and exit vertical curves are 3,600 feet. The design radii of the vertical curves were chosen based on the industry standard of the design radii being least 100 times the product pipe diameter in inches (for example, 36-inch-diameter pipe x 100 = 3,600-foot design radius), and to provide a reasonable separation of the design radii and the absolute minimum allowable radius calculated based on the product pipe specifications and the anticipated operating conditions.

5.1.7 Pilot Hole Survey

We recommend that a secondary survey system (TruTracker, ParaTrack or equivalent) be used along the entire length of the HDD. If the HDD contractor elects to use the wire coil grids with these secondary survey systems, we recommend that the wire grids be placed at least as wide as the survey probe is deep. The placement of the coils is limited to areas where ground surface conditions and agreements with landowners allow.

The HDD design drawing in Appendix B shows two conceptual configurations for secondary surface survey coil wires that may be used to track the bottom hole assembly during pilot hole operations. One of the configurations is for the ParaTrack survey system, and the other is for the TruTracker survey system. The secondary surface survey coil wire layouts shown on the drawing are intended to show the general layout of typical survey coil configurations and are not intended to direct the HDD contractor as to the exact placement of the secondary surface survey coil wires. The final placement of secondary surface survey coil wires is the contractor's responsibility and may vary from what is shown depending on ground surface conditions at the time of HDD installation, and the HDD contractor's means and methods. We recommend that the contractor review the project plans and workspace limitations to determine the most appropriate configuration for the secondary survey system.

If secondary surface survey coils will be installed across or within water bodies, we recommend that the HDD contractor sufficiently anchor the coil wires such that the wire does not deviate from the installed location. If the coils are not sufficiently anchored, currents, boat traffic or other influences may deform the coil configuration, resulting in inaccurate downhole survey shots. In addition, accurate downhole survey shots may not be obtained if the coil corners are not properly surveyed.

For pilot hole operations, we recommend that the HDD contractor drill the pilot hole as closely as possible to the designed HDD profile while still maintaining three-joint horizontal and vertical radii equal to or greater than 2,600 feet. We recommend a horizontal tolerance of 5 feet left and 5 feet right of the designed alignment and a vertical tolerance of 2 feet above and 10 feet below the designed profile. We also recommend that, upon completion of the pilot hole, GeoEngineers have the opportunity to review the pilot hole survey data prior to the start of hole opening operations. The contractor should be responsible for producing an as-built drawing of the pilot hole survey data and providing it to PCGP, LP within 2 weeks of the completion of the pilot hole. This as-built drawing should be kept in the project file for future reference as to the location of the installed pipeline.

5.1.8 Product Pipe Coating Specifications

The proposed product pipe coating specifications provided by PCGP, LP specify a nominal thickness of 8 to 10 mils of external Fusion Bonded Epoxy (FBE), and 40 mil thick Abrasion Resistant Overlay (ARO). In our opinion, the ARO coating should be increased to between 50 and 60 mils to provide added protection to the product pipe as it is pulled back through the breccia and basalt bedrock.

5.1.9 Installation Load Considerations

For the proposed HDD crossing, we analyzed the anticipated pull loads based upon different drilling fluid weights in the drilled hole and the proposed pipe specifications. We also evaluated the anticipated pull loads based on using or not using buoyancy control. We recommend that the contractor utilize a rig that provides a factor of safety between the rig capacity and the anticipated pull loads. In addition, the contractor should install a deadman anchor of sufficient capacity to withstand the anticipated pull loads; these aspects are generally left to the contractor's discretion as approved by the owner. Based on our analysis of the installation stresses (see Table 2, in Section 4.3), the pullback force may be as high as 603,000 pounds, without the use of some form of buoyancy control and drilling fluid management. The calculations suggest that the pullback force required to install the product pipe may be reduced to approximately 233,000 pounds, if buoyancy control is used and neutral buoyancy is achieved, and drilling fluid weight is properly managed during construction.

5.1.10 Site Access

Access to the entry workspace can be gained from Old Ferry Road and River Bottom Road, which connect with Highway 62 in the town of Shady Cove, Oregon. Access to the exit workspace could be gained via Old Highway 62 off Highway 227, and Ragsdale Road. We do not anticipate that improvement of these roads will be necessary. However, construction of temporary access roads from Ragsdale Road and River Bottom Road to the workspaces may be necessary, depending on PCGP, LP's approved construction access routes. Recommendations for construction of access roads are provided in Section 5.2.1 below.

5.1.11 Water Sources

A reliable source of water for drilling operations is required during the HDD installation process. In addition, water is also required for the hydrostatic testing of the product pipe. Water for drilling operations will likely have to be obtained from an approved off-site source and transported to the site.

5.1.12 Noise Mitigation Techniques

Residences are located as close as about 250 feet from the proposed entry workspace and 1,000 feet from the exit workspace. We do not anticipate that noise mitigation will be required for exit space operations. However, noise mitigation may be required for entry workspace operations. If noise mitigation is required, diesel power units associated with heavy equipment may be outfitted with noise-reducing mufflers. In addition, the contractor may need to place baffles around the equipment to further reduce noise emissions. The actual placement of the noise reduction measures should be implemented by the selected HDD contractor, when necessary.

5.2 Geotechnical Engineering Considerations

5.2.1 Temporary Site Access

If ground disturbance must be reduced to the extent possible, we recommend the construction of temporary access roads to the HDD work areas. The temporary access roads should consist of either board roads or a minimum 12-inch-thick layer of 4-inch quarry spalls. If soft or wet near surface soils are encountered, these measures may need to be augmented. If board roads are used, several layers of mats may be necessary to provide adequate support for the heavy equipment entering the site. If quarry spalls are used, the quarry spall thickness may need to be increased or a layer of woven geotextile fabric (TC Mirafi 600X or equivalent) or biaxial geogrid (Tensar BX 1200 or equivalent) may be placed below the quarry spalls. The temporary roads should be constructed with culverts and other improvements necessary to allow surface water runoff to drain without ponding or changing off-site drainage patterns.

5.2.2 Temporary Workspace Areas

Temporary work pad areas for staging drilling equipment, pipeline materials and excavation equipment may be necessary at the entry and exit points depending on the conditions at the time of construction. The size and location of workspace areas to accommodate the HDD and pipeline tie-in activities depend on the available space and right-of-way constraints. The proposed temporary entry, exit and product pipe stringing workspaces for the project are shown in Figure 2.

If necessary, we recommend that the workspace areas be protected with either board mats or a minimum 12-inch-thick layer of 4-inch quarry spalls. If soft or wet near-surface soils are encountered, these measures may need to be augmented. If board mats are used, several layers of mats may be necessary to provide adequate support for the heavy equipment entering the site. If quarry spalls are used, quarry spall thickness may need to be increased or a layer of woven geotextile fabric (TC Mirafi 600X or equivalent) or biaxial geogrid (Tensar BX 1200 or equivalent) may be placed below the quarry spalls. We also recommend placing an additional 2-inch-thick layer of ¾-inch crushed rock on top of the quarry spalls, which should improve the overall site safety and provide a level surface for light-duty vehicles and foot traffic. The temporary work pads should be removed upon completion of the product pipe installation, and the areas should be restored in accordance with the project site restoration plan.

5.2.3 HDD Installation

Drilling fluid containment pits will be required at the drill entry and exit work areas. Depending on the practices of the HDD contractor, drilling fluid containment pit excavations are typically constructed adjacent to the centerline near the entry and exit point locations and are approximately 20 feet long by 10 feet wide by 6 feet deep.

Based on the completed explorations, soil within the planned excavation depths is anticipated to consist of hard clay and very dense gravel with occasional cobbles and possibly boulders. Conventional equipment, such as backhoes or excavators, should be suitable for excavation of these soils.

5.2.4 Temporary Excavations

Maintenance of safe working conditions, including temporary excavation stability, is the responsibility of the contractor. All temporary cuts in excess of 4 feet in height should be shored or sloped in accordance with OSHA regulation 1926 Subpart P, Appendix B – Sloping and Benching. For planning purposes, soils encountered within the exploratory borings in the vicinity of the excavation areas should be classified as Type C Soil. Temporary excavations in Type C soil should be inclined no steeper than 1.5H:1V (horizontal to vertical). However, if caving occurs in excavation sidewalls, temporary excavations may need to be laid back to a shallower inclination. These cut slope inclinations are applicable to excavations above the groundwater table only. Dewatering will not likely be required to lower the groundwater table below the base of the excavations. Steeper temporary slope inclinations may be allowed if soil conditions are determined to be suitable by the field geotechnical engineer. For open cuts, we recommend that:

1. No traffic, construction equipment, stockpiles or supplies should be allowed within a distance of at least 5 feet from the top of the cut;
2. Construction activities should be scheduled to reduce the length of time the cuts are left open;
3. Erosion control measures should be implemented as appropriate to limit runoff from the site; and

4. Surface water should be diverted away from the excavations.

5.2.5 Construction Dewatering

The contractor should have the responsibility of determining whether dewatering measures are needed at the time of work. Based on the explorations completed to date, we anticipate that hard clay and very dense gravel with occasional cobbles and possibly boulders could be encountered in shallow excavations at entry and exit. Groundwater seepage through the granular soils may cause caving, making it difficult to keep the excavations open to the required depths. If granular soils and high groundwater conditions are encountered, the contractor may need to implement a well point or pumping well dewatering system. The construction of low berms around excavations should help reduce the volume of surface water runoff entering the excavations.

The contractor should be prepared to handle the effluent that will be generated during any dewatering operations. The effluent may need to be treated in a settlement tank, sediment trap or basin in order to meet discharge permit requirements for sediment content. Additionally, filter bags or filter socks might be necessary at the end of the outfall pipe or hose to reduce sediment discharge.

5.2.6 Erosion Control

To reduce the potential for migration of sediment off site and into adjacent receiving waters during HDD operations, we recommend that state and local regulations be followed during and after construction operations. Proper BMP should be implemented in accordance with the PCGP Project's Erosion Control and Revegetation Plan (ECRP).

6.0 LIMITATIONS

We have prepared this report for use by PCGP, LP. GeoEngineers' report is not intended for use by others, and the information contained herein is not applicable to other sites. The data and report should be provided to prospective contractors, but our report, conclusions and interpretations should not be construed as a warranty of the subsurface conditions. The conclusions and recommendations in this report should be applied in their entirety.

Variations in subsurface conditions are possible between the explorations. Subsurface conditions may also vary with time. A contingency for unanticipated conditions should be included in the project budget and schedule for such an occurrence. We recommend that sufficient monitoring, testing and consultation be provided by GeoEngineers during construction to confirm that the conditions encountered are consistent with those indicated by the explorations, to provide recommendations for design changes should the conditions revealed during the work differ from those anticipated, and to evaluate whether earthwork and pipeline installation activities comply with contract plans and specifications.

The scope of our services does not include services related to construction safety precautions. Our recommendations are not intended to direct the contractor's methods, techniques, sequences or procedures, except as specifically described in our report for consideration in design.

Within the limitations of scope, schedule and budget, our services have been executed in accordance with generally accepted practices in this area at the time the report was prepared. No warranty or other conditions, express, written or implied, should be understood.

Please refer to Appendix C, titled "Report Limitations and Guidelines for Use," for additional information pertaining to use of this report.

7.0 REFERENCES

Installation of Pipelines by Horizontal Directional Drilling, an Engineering Design Guide, and Contract No. PR-227-9424, May 3, 1995.

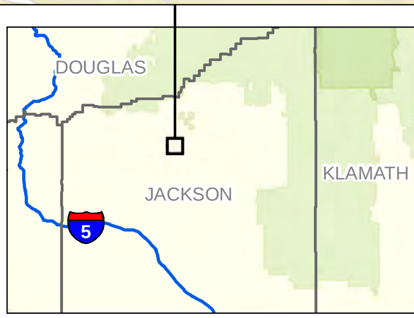
Oregon Department of Transportation Highway Division, Oregon Department of Transportation Soil and Rock Classification Manual, 1987.

Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms – Working Stress Design, API Recommended Practice 2A-WSD, July 1, 1993.

Staheli, K., Bennett, D., O'Donnell, H.W., and Hurley, T.J., Installation of Pipelines beneath levees using horizontal directional drilling, Technical Report CPAR-GL-98-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, 1998.

USGS, Spatial Digital Database for the Geologic Map of Oregon. Geology compiled by George W. Walker and Norman S. MacLeod. Spatial database by Robert J. Miller, Gary L. Raines and Katherine A. Connors. United States Geological Survey Open File Report 03-67, 2002.

FIGURES



N
W E
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2,000 0 2,000
Feet

Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.
Data Sources: ESRI Data & Maps, Street Maps 2008.
Base map from ESRI Data Online.
Projection: NAD 1983, UTM Zone 10 North.

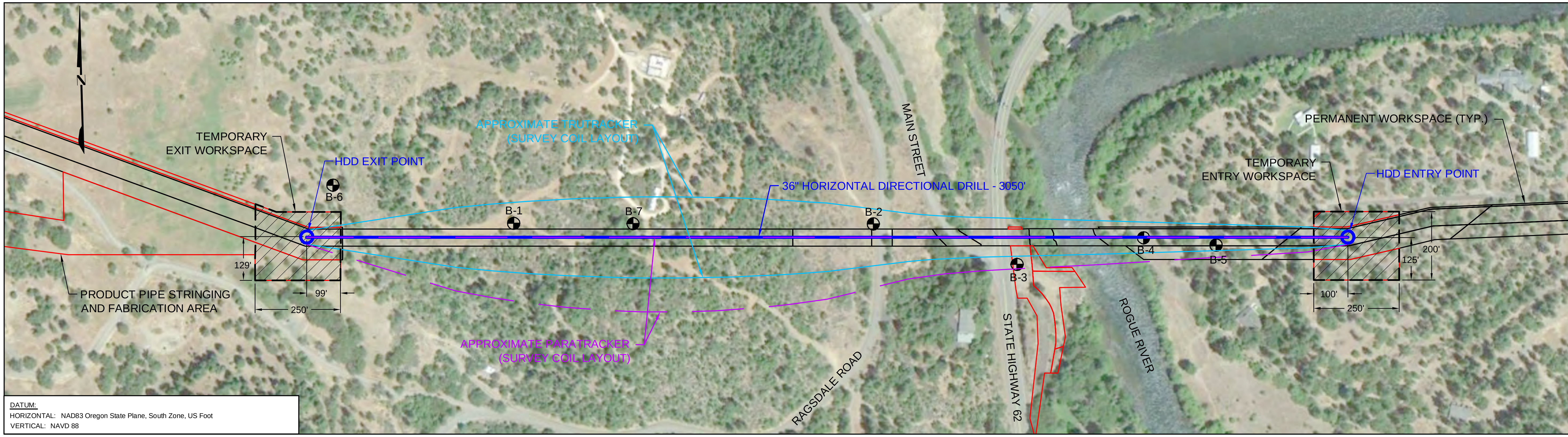
Vicinity Map

Rogue River HDD
Jackson County, Oregon

GEOENGINEERS

Figure 1

Office: PORT Path: P:\16\1672400200\GIS\MXD\Task2_4\1672400200_Tsk400_VM.mxd Map Revised: 22 April 2014 ccabrera

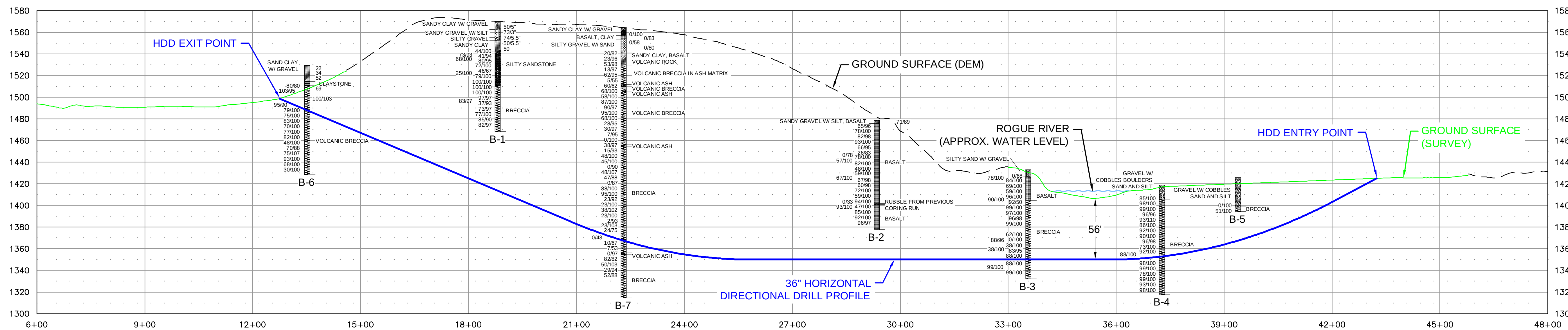


NOT FOR CONSTRUCTION:

PLAN

300' 0 300'

SCALE IN FEET



PROFILE

300' 0 300'

HORIZONTAL SCALE IN FEET

100' 0 100'

VERTICAL SCALE IN FEET

Notes:

1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.
3. Refer to the boring logs in the accompanying report for more detailed soil descriptions.
4. GeoEngineers, Inc. has not verified the field location of the existing utilities.

Reference: Ground surface survey provided by Pacific Connector Gas Pipeline, LP.
Ground surface dem (1/9 arc second) downloaded from http://www.usgs.gov/.
Aerial Image taken from Google Earth Pro licensed to GeoEngineers, Inc., image dated 07/04/14.

LEGEND:

TYPE OF SOIL — SPT (N)

RQD/%REC — TYPE OF ROCK

Boring Location

SITE PLAN AND PROFILE

ROGUE RIVER HDD
JACKSON COUNTY, OREGON

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FIGURE 2

AES : RBM

P:\16\16724002\00\CAD\Rogue River HDD\Rogue River HDD Figure 2.dwg\TAB:Figure 2 modified on Dec 03, 2014 - 8:24am

Looking east across river from turnout on Hwy 62

Photograph of east side of river near entry

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ROGUE RIVER HDD – SITE PHOTOS

FIGURE 3

Looking east toward entry from Ragsdale Rd

Looking west from Hwy 62 toward exit and Ragsdale Rd

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ROGUE RIVER HDD – SITE PHOTOS

FIGURE 4

APPENDIX A
Field Explorations and Laboratory Testing

APPENDIX A
FIELD EXPLORATION AND LABORATORY TESTING PROGRAM

We explored subsurface conditions at the site by drilling seven borings with a track-mounted drill rig using mud rotary and HQ wire line rock coring drilling methods. Subsurface Technologies of North Plains, Oregon and Crux Subsurface Inc. of Spokane, Washington drilled the borings to depths of up to 250 feet bgs. Figure 2 shows the approximate boring locations. A representative from our office observed field activities, classified the soil and rock encountered, obtained representative samples, observed groundwater conditions where possible and prepared a log of each exploration. The borings were backfilled with a bentonite and cement grout mixture at the conclusion of each exploration.

Soil samples were obtained by performing SPTs in general accordance with ASTM Test Method D 1586. The sampler was driven with a 140-pound hammer falling 30 inches. The number of blows required to drive the sampler 1 foot, or as otherwise indicated, into the soils is shown adjacent to the sample symbols on the boring logs. Disturbed samples were obtained from the split barrel sampler for subsequent classification and index testing. Continuous rock core samples were obtained using HQ wireline rock coring techniques.

Soils encountered in the borings were classified in the field by a GeoEngineers representative in general accordance with ASTM D 2488, the Standard Practice for the Classification of Soils (Visual-Manual Procedure) which is described in Figure A-1. Rock encountered in the borings was classified in general accordance with the ODOT rock classification system (ODOT, 1987), which is described in Figure A-2. The boring logs are presented in Figures A-3 through A-9. Soil and rock classification and sampling intervals are shown in the boring logs. Inclined lines at the material contacts shown on the log indicate uncertainty as to the exact contact elevation, rather than the inclination of the contact itself.

The relative density of the SPT samples recovered at each interval was evaluated based on correlations with lab and field observations in general accordance with the values outlined in Table A-1 below.

TABLE A-1. CORRELATION BETWEEN BLOW COUNTS AND RELATIVE DENSITY *

Cohesive Soils (Clay/Silt)						
Parameter	Very Soft	Soft	Medium Stiff	Stiff	Very Stiff	Hard
Blows, N	< 2	2 – 4	4 - 8	8 – 16	16 - 32	>32

Cohesionless Soils (Gravel/Sand/Silty Sand) **					
Parameter	Very Loose	Loose	Medium Dense	Dense	Very Dense
Blows, N	0 – 4	4 – 10	10 – 30	30 - 50	> 50

Notes:

*After Terzaghi, K and Peck, R.B., "Soil Mechanics in Engineering Practice," John Wiley & Sons, Inc., 1962.

**Classification applies to soils containing additional constituents; that is, organic clay, silty or clayey sand, etc.

Laboratory Testing

General

Samples obtained from the explorations were transported to our Portland, Oregon laboratory and examined to confirm or modify field classifications, as well as to evaluate engineering properties of the samples.

Representative rock core samples were selected for laboratory testing consisting of unconfined compressive strength testing. The laboratory testing procedures are discussed in more detail below.

Unconfined Compression (UC) Tests

Seven unconfined compressive (UC) tests were completed on rock core samples obtained from the borings. The UC tests were completed in general accordance with ASTM Test Method D 7012-04. The results of the UC tests are presented in the attached boring logs at their respective depths.

SOIL CLASSIFICATION CHART

MAJOR DIVISIONS			SYMBOLS GRAPH	SYMBOLS LETTER	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVELS, GRAVEL - SAND MIXTURES
				GP	POORLY-GRADED GRAVELS, GRAVEL - SAND MIXTURES
	MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	SILTY GRAVELS, GRAVEL - SAND - SILT MIXTURES
				GC	CLAYEY GRAVELS, GRAVEL - SAND - CLAY MIXTURES
MORE THAN 50% RETAINED ON NO. 200 SIEVE	SAND AND SANDY SOILS	CLEAN SANDS (LITTLE OR NO FINES)		SW	WELL-GRADED SANDS, GRAVELLY SANDS
				SP	POORLY-GRADED SANDS, GRAVELLY SAND
	MORE THAN 50% OF COARSE FRACTION PASSING NO. 4 SIEVE	SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	SILTY SANDS, SAND - SILT MIXTURES
				SC	CLAYEY SANDS, SAND - CLAY MIXTURES
FINE GRAINED SOILS	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS, ROCK FLOUR, CLAYEY SILTS WITH SLIGHT PLASTICITY
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
MORE THAN 50% PASSING NO. 200 SIEVE	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS SILTY SOILS
				CH	INORGANIC CLAYS OF HIGH PLASTICITY
				OH	ORGANIC CLAYS AND SILTS OF MEDIUM TO HIGH PLASTICITY
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

NOTE: Multiple symbols are used to indicate borderline or dual soil classifications

ADDITIONAL MATERIAL SYMBOLS

SYMBOLS GRAPH	SYMBOLS LETTER	TYPICAL DESCRIPTIONS
	AC	Asphalt Concrete
	CC	Cement Concrete
	CR	Crushed Rock/ Quarry Spalls
	TS	Topsoil/ Forest Duff/Sod

Groundwater Contact

Measured groundwater level in exploration, well, or piezometer

Measured free product in well or piezometer

Graphic Log Contact

Distinct contact between soil strata or geologic units

Approximate location of soil strata change within a geologic soil unit

Material Description Contact

Distinct contact between soil strata or geologic units

Approximate location of soil strata change within a geologic soil unit

Sampler Symbol Descriptions

2.4-inch I.D. split barrel

Standard Penetration Test (SPT)

Shelby tube

Piston

Direct-Push

Bulk or grab

Blowcount is recorded for driven samplers as the number of blows required to advance sampler 12 inches (or distance noted). See exploration log for hammer weight and drop.

A "P" indicates sampler pushed using the weight of the drill rig.

Laboratory / Field Tests

%F Percent fines
AL Atterberg limits
CA Chemical analysis
CP Laboratory compaction test
CS Consolidation test
DS Direct shear
HA Hydrometer analysis
MC Moisture content
MD Moisture content and dry density
OC Organic content
PM Permeability or hydraulic conductivity
PI Plasticity index
PP Pocket penetrometer
PPM Parts per million
SA Sieve analysis
TX Triaxial compression
UC Unconfined compression
VS Vane shear

Sheen Classification

NS No Visible Sheen
SS Slight Sheen
MS Moderate Sheen
HS Heavy Sheen
NT Not Tested

NOTE: The reader must refer to the discussion in the report text and the logs of explorations for a proper understanding of subsurface conditions. Descriptions on the logs apply only at the specific exploration locations and at the time the explorations were made; they are not warranted to be representative of subsurface conditions at other locations or times.

KEY TO EXPLORATION LOGS

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FIGURE A-1

EXPLANATION OF BEDROCK TERMS

Scale of Relative Rock Weathering (ODOT; 1987)

Designation	Field Identification
Fresh	Crystals are bright. Discontinuities may show some minor surface staining. No discoloration in rock fabric.
Slightly Weathered	Rock mass is generally fresh. Discontinuities are stained and may contain clay. Some discoloration in rock fabric. Decomposition extends up to 1 inch into rock.
Moderately Weathered	Rock mass is decomposed 50% or less. Significant portions of rock show discoloration and weathering effects. Crystals are dull and show visible chemical alteration. Discontinuities are stained and may contain secondary mineral deposits.
Predominantly Decomposed	Rock mass is more than 50% decomposed. Rock can be excavated with geologist's pick. All discontinuities exhibit secondary mineralization. Complete discoloration of rock fabric. Surface of core is friable and usually pitted due to washing out of highly altered minerals by drilling water.
Decomposed	Rock mass is completely decomposed. Original rock "fabric" may be evident. May be reduced to soil with hand pressure.

Scale of Relative Rock Hardness (ODOT, 1987)

Term	Hardness Designation	Field Identification	Approximate Unconfined Compressive Strength
Extremely Soft	R0	Can be indented with difficulty by thumbnail. May be moldable or friable with finger pressure.	< 100 psi
Very Soft	R1	Crumbles under firm blows with point of a geology pick. Can be peeled by a pocket knife. Scratched with fingernail.	100-1000 psi
Soft	R2	Can be peeled by a pocket knife with difficulty. Cannot be scratched with fingernail. Shallow indentation made by firm blow of geology pick.	1000-4000 psi
Medium Hard	R3	Can be scratched by knife or pick. Specimen can be fractured with a single firm blow of hammer/geology pick.	4000-8000 psi
Hard	R4	Can be scratched with knife or pick only with difficulty. Several hard hammer blows required to fracture specimen.	8000-16000 psi
Very Hard	R5	Cannot be scratched by knife or sharp pick. Specimen requires many blows of hammer to fracture or chip. Hammer rebounds after impact.	> 16000 psi

Rock Quality Designation (RQD)

RQD (Percent)	Description of Rock Quality
0 to 25	Very Poor
25 to 50	Poor
50 to 75	Fair
75 to 90	Good
90 to 100	Excellent

RQD is a modified core recovery measurement which expresses the number of hard and sound rock pieces of 4" or more in size as a percentage of the total length of core run.

Discontinuity Spacing (ODOT; 1987)

Description for Bedding, Foliation, or Flow Banding	Spacing	Description of Joints, Faults, or Other Fractures
Very Thickly	>10 feet	Very Widely
Thickly	3-10 feet	Widely
Medium	1-3 feet	Moderately Closely
Thinly	2-12 inches	Closely
Very Thinly	< 2 inches	Very Closely

Drilled	Start 5/22/2006	End 5/23/2006	Total Depth (ft)	101	Logged By BCR Checked By TNH	Driller Crux Drilling	Drilling Method HWT/HQ-3

Surface Elevation (ft) Vertical Datum	1569.25	Hammer Data	140 (lbs) / 30 (in) Drop
Drilling Equipment	Burley 4000 Track Rig		
Latitude Longitude	42° 38' 44.05" N 122° 48' 53.39" W	System Datum	Geographic WGS84

Groundwater

Date Measured	Depth to Water (ft)	Elevation (ft)
	Not Measured	

Notes: Boring backfilled with cement-bentonite grout upon completion.

FIELD DATA

Interval	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level
	0	1	50/0.5"		
	9	2	73/3"		
	11.6	3	74/5.5"		
	5	4	50/5.5"		
	18	5	31		
	18	1			
	20	2		44	
	28	3		73	
	17	4		41	

Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
CL	Red sandy clay with gravel and occasional cobbles (hard, moist) No Recovery			
GP	Gray sandy gravel with some silt and occasional cobbles (very dense, moist)			
GM	Brown and red silty gravel (very dense, moist)			
CL	Brown-orange-white mottled sandy clay (hard, moist)			
Siltstone	Brown and red silty sandstone; predominantly decomposed, soft, closely fractured Very soft from 28.5 to 29 feet			

Elevation (feet): 1565, 1560, 1555, 1550, 1545, 1540, 1535

Depth (feet): 0, 5, 10, 15, 20, 25, 30, 35

Note: See Figure A-1 for explanation of symbols; A-2 for explanation of bedrock terms

Log of Boring B-1

GeoEngineers

Project: PCGP-Rogue River HDD
Project Location: Jackson County, Oregon
Project Number: 16724-002-00

Elevation (feet)	Depth (feet)	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	35	12	5		68			Gray below 35 feet			
		57	6		80						
								Brown and soft to medium hard below 37 feet			
1530											
	40										
		60	7		72						
1525											
	45							Red, decomposed and very soft from 45 to 46.1 feet			
		16	8		46			Soft and clayey below 46.1 feet			
		36	9		25						
1520											
	50										
		60	10		79						
								Gray and medium hard below 52 feet			
1515											
	55										
		60	11		100						
1510							Breccia	Gray pyroclastic breccia; fresh, medium hard, closely to moderately close fractured			
	60										
		60	12		100						
1505											
	65										
		60	13		100			Moderately close fractured below 66 feet			
1500											
	70										
		29	14		97						
1495		29	15		83			Closely fractured below 74 feet			
	75										
		56	16		37						

Note: See Figure A-1 for explanation of symbols; A-2 for explanation of bedrock terms

Log of Boring B-1 (continued)

GEOENGINEERS

Project: PCGP-Rogue River HDD
Project Location: Jackson County, Oregon
Project Number: 16724-002-00

Figure A-3
Sheet 2 of 3

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
1490	80		58	17		73				Very soft to soft, moderately close fractured below 81 feet			
1485	85									Closely fractured below 84 feet			
			60	18		77				Very closely fractured between 87.5 and 89 feet			
1480	90		54	19		85				Closely to moderately close fractured below 91 feet			
1475	95		58	20		82							
1470	100												

Bottom of hole at 101 feet
Groundwater not measured during drilling

Note: See Figure A-1 for explanation of symbols; A-2 for explanation of bedrock terms

Log of Boring B-1 (continued)

GEOENGINEERS

Project: PCGP-Rogue River HDD
Project Location: Jackson County, Oregon
Project Number: 16724-002-00

Drilled	Start 5/25/2006	End	Total Depth (ft) 101	Logged By BCR / Checked By TNH	Driller Crux Drilling	Drilling Method HWT/HQ-3

Surface Elevation (ft) / Vertical Datum: 1479.49	Hammer Data: 140 (lbs) / 30 (in) Drop	Drilling Equipment: Burley 4000 Track Rig	
Latitude: 42° 38' 44.17" N / Longitude: 122° 48' 39.30" W	System: Geographic / Datum: WGS84	Groundwater — Date Measured / Depth to Water (ft) / Elevation (ft)	Not Measured

Notes: Boring backfilled with cement-bentonite grout upon completion.

Elevation (feet)	Depth (feet)	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	0						GP-GM	Light brown fine to coarse gravel with silt and basalt particles			No samples taken, observed drill behavior and cuttings
		34	1		71		Basalt	Gray basalt; slightly weathered, hard, medium fractured			
1475	5										
		54	2		65						
1470	10										
		60	3		78			Fresh and closely fractured below 11 feet			
1465	15										
		59	4		82						
1460	20										
		60	5		93			Moderately close fractured below 21.5 feet			
1455	25										
		57	6		66						
1450	30							Closely fractured from 31 to 34.5 feet			
		20	7		26						
		23	8		0						
1445	35	48	9		79						

Note: See Figure A-1 for explanation of symbols; A-2 for explanation of bedrock terms

Log of Boring B-2

GeoEngineers

Project: PCGP-Rogue River HDD
Project Location: Jackson County, Oregon
Project Number: 16724-002-00

Elevation (feet)	Depth (feet)	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	35										
1440		30	10		57						
	40							Closely to moderately close fractured below 39.5 feet			
		58	11		82						
1435											
	45	48	12		48						
1430											
	50	54	13		59						
1425		24	14		67						
	55	51	15		67						
1420											
	60							Becomes gray-brown and moderately weathered			
		59	16		60						
1415											
	65	60	17		72						
1410											
	70										UC = 12,660 psi
		60	18		59			Closely fractured below 71 feet			
1405											
	75	18	19		94						

Note: See Figure A-1 for explanation of symbols; A-2 for explanation of bedrock terms

Log of Boring B-2 (continued)

GeoEngineers

Project: PCGP-Rogue River HDD

Project Location: Jackson County, Oregon

Project Number: 16724-002-00

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
			4	20		0			Rubble	Rubble from previous coring run Very closely fractured from 77.5 to 78.2 feet			
1400	80		30	21		47			Basalt				
			60	22		93				Widely fractured below 81.3 feet			
1395	85		60	23		85							
1390	90									Gray basaltic flow breccia; fresh, hard, closely fractured			
			60	24		92				Gray basalt; fresh, hard to very hard, closely fractured Widely fractured below 91.5 feet Closely fractured from 93.9 to 94.2 feet			
1385	95		58	25		96							
1380	100												

Bottom of hole at 101 feet
Groundwater not measured during drilling

Note: See Figure A-1 for explanation of symbols; A-2 for explanation of bedrock terms

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Log of Boring B-2 (continued)

GEOENGINEERS

Project: PCGP-Rogue River HDD
Project Location: Jackson County, Oregon
Project Number: 16724-002-00

Drilled	Start 5/31/2006	End 6/1/2006	Total Depth (ft) 101	Logged By ABA / Checked By TNH	Driller Crux Drilling	Drilling Method HWT/HQ-3

Surface Elevation (ft) / Vertical Datum: 1432.53	Hammer Data: 140 (lbs) / 30 (in) Drop	Drilling Equipment: Burley 4000 Track Rig	
Latitude: 42° 38' 43.06" N / Longitude: 122° 48' 33.63" W	System: Geographic / Datum: WGS84	Groundwater — Date Measured / Depth to Water (ft) / Elevation (ft)	Not Measured

Notes: Boring backfilled with cement-bentonite grout upon completion.

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	0		6	1					SM	Brown to red-brown silty fine to coarse sand with gravel (medium dense, moist)			
1430													
	5		0	2									
1425			16	1		0			Basalt	Dark gray medium grained basalt; moderately weathered, medium hard to hard, closely fractured Crushed zone from 6.6 to 8.5 feet with red silt and sand infilling			
			30	2		78							
	10		60	3		84				Very closely fractured from 11 to 12 feet Becomes moderately close fractured below 12 feet			
1420													
	15		60	4		69				Closed high angle fractures from 16.5 to 18.5 feet Very closely fractured from 17 to 18 feet			
1415													
	20		60	5		59				Very closely fractured from 22 to 23 feet with silt infilling			
1410													
	25		30	6		96				Very dark gray fine-grained basalt; fresh, hard, moderately close fractured			
1405			30	7		90			Breccia	Dark blue-gray breccia; fresh, medium hard, widely fractured			
	30		60	8		92				Closed, quartz-filled fracture at 36.5 feet			
1400	35												

Note: See Figure A-1 for explanation of symbols; A-2 for explanation of bedrock terms

Log of Boring B-3

GeoEngineers

Project: PCGP-Rogue River HDD
Project Location: Jackson County, Oregon
Project Number: 16724-002-00

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	35												
			60	9		99							
1395													
	40												
			60	10		97							
1390													
										80 degree fracture with calcite mineralization at 43.5 feet			
	45									25 to 40 degree very thin quartz-filled veins			
			59	11		96							
1385													
										Closely fractured at 48.7 feet			
	50												
			60	12		99							
1380													
	55												
			60	13		74							
1375													
										Becomes decomposed, very soft and very closely fractured from 59.8 to 60 feet			
	60									Multi-colored breccia, moderately weathered, soft, moderately close fractured			
			54	14		62				Sheared/highly fractured zone from 60 to 61 feet Highly fractured/sheared zone from 61 to 61.7 feet			
1370													
	65									Decomposed zone from 65 to 65.5 feet			
			6	14.5		0							
			58	15		88							
1365													
										Sheared fractures from 68.2 to 68.5 feet			
	70												
			42	16		38				Decomposed zone from 71 to 72.2 feet			
1360													
										Predominantly decomposed from 72.2 to 73.5 feet			
			18	17		38				Gray breccia; slightly weathered, soft to medium hard, closely fractured			
	75												
			57	18		83							

Note: See Figure A-1 for explanation of symbols; A-2 for explanation of bedrock terms

Log of Boring B-3 (continued)

GeoEngineers

Project: PCGP-Rogue River HDD
Project Location: Jackson County, Oregon
Project Number: 16724-002-00

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
1355													
	80									Crushed zone from 79.2 to 80 feet fracture faces slickensided			UC = 2,410 psi
			60	19		88							
1350													
	85									Becomes dark blue altered breccia; slightly weathered, medium hard, moderately close fractured			
			60	20		88							
1345													
	90												
			60	21		99							
1340													
	95									Widely spaced fractures below 96 feet			
			60	22		99							
1335													
	100												UC = 4,040 psi

Bottom of hole at 101 feet
Groundwater not measured during drilling

Note: See Figure A-1 for explanation of symbols; A-2 for explanation of bedrock terms

Log of Boring B-3 (continued)

GeoEngineers

Project: PCGP-Rogue River HDD
Project Location: Jackson County, Oregon
Project Number: 16724-002-00

Drilled	Start 6/2/2006	End 6/3/2006	Total Depth (ft)	101	Logged By ABA / Checked By TNH	Driller	Crux Drilling	Drilling Method	HWT/HQ-3

Surface Elevation (ft) / Vertical Datum	1417.68	Hammer Data	140 (lbs) / 30 (in) Drop	Drilling Equipment	Burley 4000 Track Rig
Latitude / Longitude	42° 38' 43.87" N / 122° 48' 28.68" W	System / Datum	Geographic / WGS84	Groundwater	

Groundwater:

Date Measured	Depth to Water (ft)	Elevation (ft)
Not Measured		

Notes: Boring backfilled with cement-bentonite grout upon completion.

FIELD DATA

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	0		6	1					GW-GM	Medium brown fine to coarse gravel with silt, sand, cobbles and boulders (very dense, moist)			
1415													
	5		6	2									
			6	3									
1410													
	10		6	4									
1405			3	5									
			36	1		85			Breccia	Dark gray altered breccia; slightly weathered, soft to medium hard, moderately close fractured			
	15												
			60	2		98							
1400													
	20												
			60	3		99				Becomes widely to very widely fractured			
1395													
	25												
			58	4		96							
1390													
										Becomes widely fractured			
	30												
			60	5		93				Becomes moderately close fractured			
1385													
	35									Fracture with 1/2-inch thick crushed zone at			

Note: See Figure A-1 for explanation of symbols; A-2 for explanation of bedrock terms

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Log of Boring B-4

GEOENGINEERS

Project: PCGP-Rogue River HDD
Project Location: Jackson County, Oregon
Project Number: 16724-002-00

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	35									34.8 feet			
			60	6		86							
1380													
										Sheared fracture at 38.5 feet			
	40									Sheared/highly fractured zone (40 degree angle) from 39.3 to 39.9 feet			
			60	7		92				Becomes moderately close to widely fractured			
1375													
	45												
			60	8		90							
1370													
										Crushed zone from 48.3 to 48.5 feet			
	50												
			59	9		96							
1365													
										Fracture with 1/2-inch thick crushed zone at 54 feet			
	55												
			60	10		73				Becomes closely to moderately close fractured; 2-inch thick crushed zone at 56.2 feet; 1-inch thick crushed zone at 56.7 feet			
1360													
	60									Becomes moderately close fractured			
			60	11		92							
1355													
										Becomes moderately close to widely fractured			
	65												
			60	12		88				1.5-inch thick zone of crushed rock at 66.6 feet			
1350													
										Becomes widely fractured			UC = 3,220 psi
	70												
			60	13		98							
1345													
	75												
										Crushed rock infilling fractures at 75.5 feet			
			60	14		99							

Note: See Figure A-1 for explanation of symbols; A-2 for explanation of bedrock terms

Log of Boring B-4 (continued)

Project: PCGP-Rogue River HDD
Project Location: Jackson County, Oregon
Project Number: 16724-002-00

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
1340													
	80												
			60	15		78							
1335													
										Becomes moderately close fractured			
	85												
			60	16		99				Becomes widely fractured			
1330													
	90												
			60	17		93							
1325													
													UC = 3,430 psi
	95												
			60	18		98							
1320													
	100												

Bottom of hole at 101 feet
Groundwater not measured during drilling

Note: See Figure A-1 for explanation of symbols; A-2 for explanation of bedrock terms

Log of Boring B-4 (continued)

GEOENGINEERS

Project: PCGP-Rogue River HDD
Project Location: Jackson County, Oregon
Project Number: 16724-002-00

Drilled	Start 6/3/2006	End 6/5/2006	Total Depth (ft)	31.5	Logged By ABA / Checked By TNH	Driller	Crux Drilling	Drilling Method	HWT/HQ-3

Surface Elevation (ft) / Vertical Datum	1425.23	Hammer Data	140 (lbs) / 30 (in) Drop	Drilling Equipment	Burley 4000 Track Rig
Latitude / Longitude	42° 38' 43.69" N / 122° 48' 25.84" W	System / Datum	Geographic / WGS84	Groundwater: Date Measured / Depth to Water (ft) / Elevation (ft)	Not Measured

Notes: Boring backfilled with cement-bentonite grout upon completion.

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
1425	0								GW-GM	Light brown fine to coarse gravel with silt, sand, cobbles, and 6" boulders (very dense, moist) (alluvium)			
1420	5		18	1									
			18	2									
			18	3									
1415	10		12	4									
1410	15		6	5									
1405	20		18	6									
			12	7									
1400	25		6	8									
			36	1		0							
									Breccia	Dark blue breccia; predominantly decomposed, soft, very closely to closely fractured			
			42	2		51							
1395	30									Sheared fracture at 31 feet			

Bottom of hole at 31.5 feet
Groundwater not measured during drilling

Note: See Figure A-1 for explanation of symbols; A-2 for explanation of bedrock terms

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Log of Boring B-5

GeoEngineers

Project: PCGP-Rogue River HDD
Project Location: Jackson County, Oregon
Project Number: 16724-002-00

Figure A-7
Sheet 1 of 1

Drilled — Start: 6/26/2006, End:	Total Depth (ft): 101	Logged By: BCR Checked By: TNH	Driller: Crux Drilling	Drilling Method: HWT/HQ-3
Surface Elevation (ft) / Vertical Datum: 1524.2	Hammer Data: 140 (lbs) / 30 (in) Drop		Drilling Equipment: Burley 4000 Track Rig	
Latitude: 42° 38' 44.89" N Longitude: 122° 49' 00.47" W	System: Geographic Datum: WGS84		Groundwater — Date Measured / Depth to Water (ft) / Elevation (ft): Not Measured	

Notes: Boring backfilled with cement-bentonite grout upon completion.

Elevation (feet)	Depth (feet)	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	0						CL	Brown-yellow sandy clay with some fine gravel (very stiff, moist) (residual claystone?)			
1520	5	18	1	11				Tan to light gray below 5.5 feet			
1515	10	18	2	18				Brown-yellow below 11 feet (hard)			
1510	15	18	3	31			Claystone	Light gray to tan completely decomposed claystone (hard, moist)			
1505							Breccia	Brown-green breccia; predominantly decomposed, very soft to soft, closely fractured			
	20	18	4	48							
		25	1		73			Becomes moderately weathered			
1500		30	2		67			Soft below 23.5 feet			
	25	18	3		61						
		40	4		83						
1495	30	60	5		83						
1490								Becomes blue-gray, slightly weathered to fresh, very soft to soft below 33.2 feet			
	35										

Note: See Figure A-1 for explanation of symbols; A-2 for explanation of bedrock terms

Log of Boring B-6

GEOENGINEERS

Project: PCGP-Rogue River HDD
Project Location: Jackson County, Oregon
Project Number: 16724-002-00

Figure A-8
Sheet 1 of 3

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	35												
			37	6		79				Blue below 36 feet			
													UC = 470 psi
1485													
	40		18	7									
			60	8		75				Fresh below 41 feet			
1480													
	45												
			60	9		83							
										Widely fractured from 47 to 49.5 feet			
1475													
	50												
			60	10		70							
1470													
	55									Very closely fractured from 54 to 55 feet			
			60	11		77							
1465													
	60												
			60	12		82							
										Becomes soft and closely fractured			
1460													
	65												
			60	13		48							
										Very closely fractured from 67.8 to 69.5 feet			
1455													
	70												
			60	14		70							
1450													
	75									Very closely fractured from 75.5 to 76 feet			
			53	15		75				Widely fractured below 76 feet			

Note: See Figure A-1 for explanation of symbols; A-2 for explanation of bedrock terms

Log of Boring B-6 (continued)

GEOENGINEERS

Project: PCGP-Rogue River HDD
Project Location: Jackson County, Oregon
Project Number: 16724-002-00

Figure A-8
Sheet 2 of 3

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
1445													
	80												
			60	16		93							
1440													
	85									Very soft to soft below 85 feet			
			60	17		68							
										Closely fractured below 88.8 feet			
1435													
	90												
			60	18		30							
										Very closely to closely fractured below 92.5 feet			
1430													
	95									Soft below 95 feet			
			60	19						Closely fractured below 96 feet			
1425										Very closely fractured from 99.3 to 99.6 feet			
	100												

Bottom of hole at 101 feet
Groundwater not measured during drilling

Note: See Figure A-1 for explanation of symbols; A-2 for explanation of bedrock terms

Log of Boring B-6 (continued)

GEOENGINEERS

Project: PCGP-Rogue River HDD
Project Location: Jackson County, Oregon
Project Number: 16724-002-00

Drilled	Start 10/18/2006	End	Total Depth (ft)	250	Logged By BCR Checked By APB	Driller	Subsurface Technologies, inc.	Drilling Method	HQ Wire Line

Surface Elevation (ft) Vertical Datum	Undetermined	Hammer Data	140 (lbs) / 30 (in) Drop	Drilling Equipment	Diedrich D-50 Turbo Track Rig
Latitude Longitude	42° 38' 44.09" N 122° 48' 48.71" W	System Datum	Geographic WGS84	Groundwater	Date Measured / Depth to Water (ft) / Elevation (ft): Not Measured

Notes: Boring backfilled with cement-bentonite grout upon completion.

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	0								CL	Red with green, black and gray mottled residual sandy clay with gravel (hard, moist)			
	5		6	1	50/6"								
			32	1		0			Basalt	Black basalt; slightly weathered, hard, closely to very closely fractured, abundant clay filled fractures			
	10		50	2		0							
									GM	Brown-gray silty gravel with sand			
	15		35	3		0				With occasional cobbles			
	20		48	4		0							
									CL	Light brown sandy clay, residual basalt (?) very soft, very closely fractured			
	25		49	5		20				Becomes brown and closely fractured			
	30		58	6		23							
										Becomes light brown-gray, predominantly decomposed, soft, very closely fractured Closely fractured from 32 to 34 feet			
	35									Very closely fractured from 34 to 35 feet			

Note: See Figure A-1 for explanation of symbols; A-2 for explanation of bedrock terms

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Log of Boring B-7

GeoEngineers

Project: PCGP-Rogue River HDD
Project Location: Jackson County, Oregon
Project Number: 16724-002-00

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	35		58	7		37			Breccia	Grayish-green breccia; moderately weathered, soft, closely fractured			
	40		57	8		13							
										Reddish-pink between 41.5 and 49.5'			
										Very closely fractured from 43 to 44.3 feet			
										Dark gray to below 44 feet			
	45		58	9		62				Green and slightly weathered below 45 feet			
										Moderately close fractured from 47.2 to 49.4 feet			
	50		55	10		51				Moderately weathered below 50 feet			
										Highly to completely weathered below 53 feet			
									Ash	Grayish-blue volcanic ash; slightly weathered, very soft, closely fractured			
	55		62	11		60			Breccia	Gray breccia; slightly weathered, soft, closely fractured			
										Very closely fractured from 57.5 to 57.8 feet			
									Ash	Grayish-blue volcanic ash; slightly weathered to fresh, very soft, closely fractured			
	60		60	12		68			Breccia	Gray breccia; fresh, soft, very closely fractured			
										Moderately close fractured spacing below 61.3 feet			
	65		60	13		58				Very closely fractured from 65.9 to 66.7 feet			
										Dark pink and closely fractured below 69 feet			
	70		60	14		86							
										Moderately close fractured below 72.5 feet			
										Grayish-blue below 73.4 feet			
	75		58	15		90							

Note: See Figure A-1 for explanation of symbols; A-2 for explanation of bedrock terms

Log of Boring B-7 (continued)

GEOENGINEERS

Project: PCGP-Rogue River HDD
Project Location: Jackson County, Oregon
Project Number: 16724-002-00

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	80		60	16		95				Widely fractured from 80.2 to 83.3 feet			
	85		60	17		68				Closely fractured below 85 feet Pinkish-red from 87 to 89.2 feet Pinkish-red below 89.9 feet			
	90		57	18		28				Very closely fractured 91.5 to 92 feet Very closely fractured below 94 feet			
	95		58	19		30				Closely fractured below 97 feet Moderately weathered, very soft and very closely fractured below 99 feet			
	100		57	20		7				Closely fractured below 100 feet			
	105		60	21		42				Grades to fresh and soft to medium hard at 105.8 feet Very closely fractured from 107.2 to 108.1 feet			
									Ash	Grayish-blue volcanic ash; fresh, very soft, closely fractured			
	110		58	22		38			Breccia	Blue-gray breccia; fresh, soft, closely fractured Very soft and closely fractured from 113.3 to 114 feet			
	115		56	23		15				Soft below 115 feet Very closely fractured from 116 to 117 feet			

Note: See Figure A-1 for explanation of symbols; A-2 for explanation of bedrock terms

Log of Boring B-7 (continued)

GeoEngineers

Project: PCGP-Rogue River HDD
Project Location: Jackson County, Oregon
Project Number: 16724-002-00

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	120		60	24		48							
										Very closely fractured from 122.8 to 123 feet			
										Very closely fractured from 124 to 125 feet			
	125		60	25		45				Very closely fractured from 125 to 125.7 feet			
										Very closely fractured from 127.8 to 129 feet			
	130		54	26		57				Widely fractured from 130 to 132 feet			
	135		54	27		45				Soft to medium hard below 135 feet			
	140		53	28		47							
										Widely fractured from 141 to 143 feet			
	145		54	29		86				Very closely fractured below 145 feet			
										Widely fractured below 146.2 feet			
	150		60	30 31		88							
										Becomes red-pink			
	155		60	32		95							
	160												

Note: See Figure A-1 for explanation of symbols; A-2 for explanation of bedrock terms

Log of Boring B-7 (continued)

GeoEngineers

Project: PCGP-Rogue River HDD
Project Location: Jackson County, Oregon
Project Number: 16724-002-00

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
			55	33		11				Closely fractured below 160 feet			
	165		60	34		23				Very soft and very closely fractured below 164 feet Becomes gray, fresh, medium hard and closely fractured			
	170		61	35		38				Slightly weathered and very closely fractured below 170 feet Hard and closely fractured below 171.7 feet			
	175		60	36		23				Fresh below 176.5 feet			
	180		56	37		37				Moderately weathered below 183.5 feet			
	185		62	38		23				Very closely fractured from 188 to 189 feet			
	190		41	39		18				Moderately weathered from 190 to 191 feet Very closely fractured from 192 to 192.5 feet			
	195		26	40		0				Very closely fractured below 195 feet			
	200		40	41		10							

Note: See Figure A-1 for explanation of symbols; A-2 for explanation of bedrock terms

Log of Boring B-7 (continued)

GEOENGINEERS

Project: PCGP-Rogue River HDD
Project Location: Jackson County, Oregon
Project Number: 16724-002-00

Figure A-9
Sheet 5 of 7

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
										Fresh, soft to medium hard and closely fractured below 202 feet			
										Very soft below 204.5 feet			
	205		32	42		7							
									Ash	Volcanic ash; moderately weathered, very soft to soft, closely fractured			
	210		58	43		75			Breccia	Blue-gray breccia, fresh, soft to medium hard, moderately close fractured			
										Very closely fractured from 213.5 to 214 feet			
	215		49	44		100							
										Widely fractured below 216 feet			
	220		56	45		50				Moderately close fractured below 220 feet			
										Closely fractured from 221 to 222 feet			
										Very closely fractured from 223.5 to 224.5 feet			
	225		62	46		29							
										Very closely fractured from 226.5 to 227.3 feet			
										Soft to medium hard from 228 to 229.5 feet Very closely fractured from 228.5 to 229 feet			
	230		53	47		53							
	235												
	240												

Note: See Figure A-1 for explanation of symbols; A-2 for explanation of bedrock terms

Log of Boring B-7 (continued)

GEOENGINEERS

Project: PCGP-Rogue River HDD
Project Location: Jackson County, Oregon
Project Number: 16724-002-00

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	245												
	250									Bottom of hole at 250 feet Groundwater not measured during drilling			

Note: See Figure A-1 for explanation of symbols; A-2 for explanation of bedrock terms

Portland: Date:7/23/14 Path:C:\USERS\KJANCI\DESKTOP\167240020.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Log of Boring B-7 (continued)

GeoEngineers

Project: PCGP-Rogue River HDD
Project Location: Jackson County, Oregon
Project Number: 16724-002-00

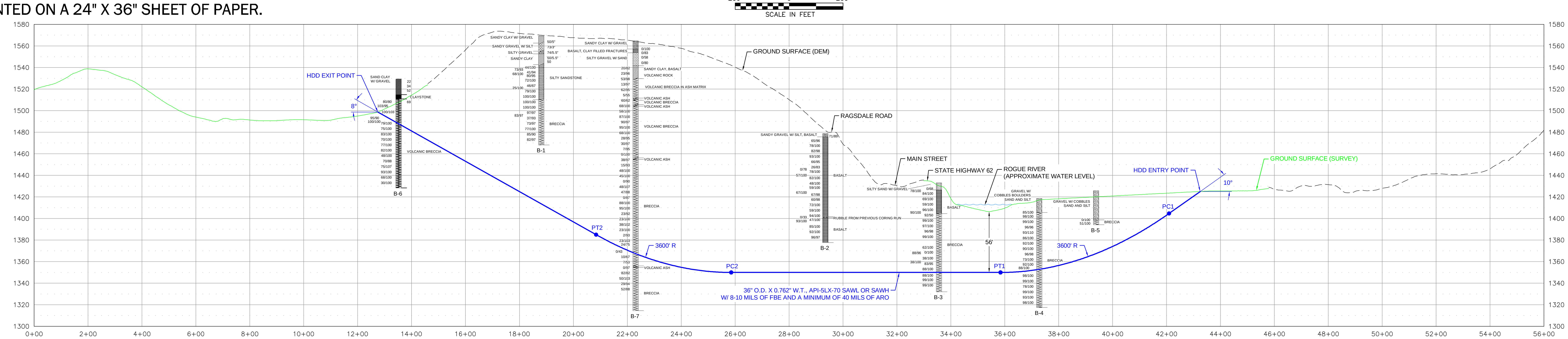
Appendix B
HDD Design Drawing and Calculations

DATUM:
HORIZONTAL: NAD83 Oregon State Plane, South Zone, US Foot
VERTICAL: NAVD 88

NOTE: THIS IS A FULL SIZE DRAWING THAT IS INTENDED TO BE PRINTED ON A 24" X 36" SHEET OF PAPER.

PLAN

200' 0 200'
SCALE IN FEET



PROFILE

200' 0 200'
HORIZONTAL SCALE IN FEET
50' 0 50'
VERTICAL SCALE IN FEET

DIRECTIONAL DRILL DATA ROGUE RIVER HDD		
DESCRIPTION	STATION * (ft)	ELEVATION (ft)
ENTRY @ 10°	43+25.00	1425.09
P C 1 (10.00° @ 3,600 ft R.)	42+09.34	1404.69
P T 1	35+84.21	1350.00
P C 2 (8.00° @ 3,600 ft R.)	25+85.23	1350.00
P T 2	20+84.20	1385.03
EXIT @ 8°	12+75.00	1498.76
HORIZONTAL DISTANCE = 3050.00 ft		
DIRECTIONAL DRILL PIPE LENGTH = 3064.55 ft		

* THE STATIONING IS BASED ON AN ARBITRARY REFERENCE POINT

RECOMMENDED TOLERANCES	
ITEM	TOLERANCE
PILOT HOLE ENTRY ANGLE	INCREASE ANGLE UP TO 1º (STEEPER), BUT NO DECREASE IN ANGLE ALLOWED.
PILOT HOLE ENTRY LOCATION	AS PER COORDINATES PROVIDED BY COMPANY WITH NO CHANGES WITHOUT COMPANY APPROVAL.
PILOT HOLE EXIT ANGLE	INCREASE ANGLE UP TO 1º (STEEPER) OR DECREASE UP TO 2º (FLATTER).
PILOT HOLE EXIT LOCATION	UP TO 20 FEET BEYOND OR 10 FEET SHORT OF THE EXIT STAKE. BETWEEN 5 FEET LEFT AND 5 FEET RIGHT OF CENTERLINE.
PILOT HOLE DEPTH	UP TO 2 FEET ABOVE THE DESIGN DRILL PROFILE ALLOWED. UP TO 10 FEET BELOW THE DESIGN DRILL PROFILE ALLOWED.
PILOT HOLE ALIGNMENT	SHALL REMAIN WITHIN 5 FEET LEFT OR RIGHT OF THE HDD ALIGNMENT.

BORING LEGEND

TYPE OF SOIL — SPT (N)
RQD/%REC — TYPE OF ROCK
Boring Location

BASIS OF DESIGN:

1. PRODUCT PIPE WILL CONSIST OF 36" O.D. X 0.823" W.T., API-5L X-70 SAWL OR SAWH PIPE WITH 8-10 MILS OF FUSION BONDED EPOXY (FBE) AND A MINIMUM OF 40 MILS OF ABRASION RESISTANT OVERLAY (ARO).
2. MAXIMUM ALLOWABLE OPERATING PRESSURE (MAOP) = 1,600 psi
3. ASSUMED MAXIMUM OPERATING TEMPERATURE = 100° FAHRENHEIT.
4. ASSUMED AVERAGE OPERATING TEMPERATURE = 70° FAHRENHEIT.
5. THE MINIMUM ALLOWABLE THREE JOINT RADIUS SHALL NOT BE LESS THAN 2,600 FEET.

ISSUED FOR PERMIT

NOTES:

1. CONTRACTOR SHALL ADHERE TO THE SPECIFICATIONS AND REQUIREMENTS PER PACIFIC CONNECTOR GAS PIPELINE, LP SPECIFICATIONS, CONTRACT DOCUMENTS AND SPECIAL PERMIT CONDITIONS, EXCEPT AS NOTED ON THIS DRAWING.
2. CONTRACTOR IS RESPONSIBLE FOR CALLING OREGON ONE-CALL AND LOCATING ALL UNDERGROUND UTILITIES PRIOR TO BEGINNING CONSTRUCTION. IF ANY UTILITY IS LOCATED WITHIN 15 FEET OF THE DESIGNED HDD PROFILE AND ALIGNMENT, CONTRACTOR SHALL OBTAIN APPROVAL FROM PACIFIC CONNECTOR GAS PIPELINE, LP PRIOR TO INITIATING HDD OPERATIONS.
2. IT IS THE CONTRACTORS RESPONSIBILITY TO IDENTIFY AND PROTECT ANY FOREIGN UTILITY THAT MAY BE AFFECTED BY THE HDD OPERATIONS.
3. PLACEMENT OF THE HDD RIG IS NOT FIXED BY THE DESIGNATION OF THE ENTRY AND EXIT POINTS. THE USE OF DUAL HDD RIGS DURING CONSTRUCTION MAY BE AT THE DISCRETION OF THE HDD CONTRACTOR, TO BE APPROVED BY THE PROJECT TEAM.
4. ALL EQUIPMENT MUST ACCESS THE SITE ALONG THE CONSTRUCTION RIGHT-OF-WAY OR FROM APPROVED ACCESS ROADS.
5. WORK SPACE: MAXIMUM WORK SPACE LIMITS ARE DEPICTED. RESTRICT CLEARING TO THE WORK SPACE INDICATED AT THE ENTRY AND EXIT POINTS AND PRODUCT PIPE STRINGING AND FABRICATION AREA ALONG THE CONSTRUCTION RIGHT-OF-WAY. CLEARING BETWEEN THE ENTRY AND EXIT POINTS REQUIRES PRIOR APPROVAL FROM THE ENVIRONMENTAL INSPECTOR AND IS LIMITED TO THE AMOUNT NECESSARY TO STRING SURVEY WIRES AND INSTALL PUMPS AND PIPING TO OBTAIN WATER (WHERE APPROVED).
6. WATER SOURCE: DRILL WATER AND HYDROSTATIC TEST WATER SHALL BE OBTAINED FROM AN APPROVED SOURCE.
7. HYDROSTATIC TEST: PRE-INSTALLATION AND POST-INSTALLATION HYDROSTATIC TESTS SHALL BE CONDUCTED IN ACCORDANCE WITH THE HYDROSTATIC TEST PLAN. TEST WATER SHALL BE SAMPLED AND TESTED IN ACCORDANCE WITH PERMIT REQUIREMENTS. THE TEST WATER SHALL BE DISCHARGED IN AN UPLAND AREA INTO AN EROSION CONTROL STRUCTURE OF STRAW BALES AND/OR SILT FENCES, GEOTEXTILE FILTER BAG, OR COLLECTED IN A TRUCK AND HAULED TO AN APPROVED DISPOSAL SITE. UPON COMPLETION OF DEWATERING AND DRYING, A CALIPER PIG SURVEY SHALL BE COMPLETED IN ACCORDANCE WITH THE CONTRACT DOCUMENTS.
8. SPILL-PREVENTION: REFUELING OF ALL EQUIPMENT SHALL BE COMPLETED IN ACCORDANCE WITH THE SPCC PLAN.
9. EROSION AND SEDIMENT CONTROL: CONTRACTOR SHALL SUPPLY, INSTALL AND MAINTAIN SEDIMENT CONTROL STRUCTURES IN ACCORDANCE WITH CONTRACT DOCUMENTS. CONTRACTOR SHALL INSTALL ADDITIONAL EROSION CONTROL STRUCTURES AS DIRECTED BY THE ENVIRONMENTAL INSPECTOR.
10. INSTALLATION: THE PIPE SECTION FOR THE DRILLED CROSSING SHALL BE MADE UP WITHIN THE APPROVED CONSTRUCTION RIGHT-OF-WAY AT THE DRILL EXIT POINT AS SHOWN. AFTER THE PILOT HOLE IS COMPLETE, CONTRACTOR'S ACTUAL DRILL PROFILE SHALL BE SUBMITTED TO PACIFIC CONNECTOR GAS PIPELINE, LP FOR APPROVAL. CONTRACTOR SHALL ASSESS THE NEED FOR AND SUPPLY APPROPRIATE BALLAST DURING PULLBACK.
11. DRILLING FLUID DISPOSAL: CONTRACTOR SHALL DISPOSE OF EXCESS DRILLING FLUID AS DIRECTED BY THE COMPANY REPRESENTATIVE IN ACCORDANCE WITH PERMIT CONDITIONS. UNDER NO CIRCUMSTANCES SHALL DRILLING FLUID BE DISPOSED OF IN WATER BODIES OR WETLANDS. ANY DRILLING FLUID WHICH INADVERTENTLY SURFACES AT POINTS OTHER THAN THE ENTRY OR EXIT POINTS SHALL BE CONTAINED AND COLLECTED TO THE EXTENT PRACTICAL AND DISPOSED OF AS DIRECTED BY THE COMPANY REPRESENTATIVE IN ACCORDANCE WITH PERMIT CONDITIONS.
12. CLEANUP/STABILIZATION/RESTORATION: ALL DISTURBED AREAS SHALL BE RETURNED TO THE ORIGINAL CONTOURS. DISTURBED AREAS SHALL BE SEEDED AS SPECIFIED IN THE CLEAN-UP AND RESTORATION REQUIREMENTS. IF THE TERRAIN ALLOWS AND ACCESS IS PERMITTED, CONTRACTOR SHALL UTILIZE LOW GROUND PRESSURE EQUIPMENT OR OTHER EQUIPMENT APPROVED BY OWNER, TO FACILITATE CONTAINMENT AND CLEAN-UP OF ANY INADVERTENT RETURNS THAT OCCUR DURING THE HDD INSTALLATION PROCESS.
13. GEOTECHNICAL DATA: BORE HOLES ARE OFFSET FROM THE PIPELINE CENTERLINE AS SHOWN ON THE PLAN VIEW. THE GEOTECHNICAL INFORMATION PROVIDED ON THIS DRAWING IS A GENERAL SUMMARY. REFER TO THE APPLICABLE GEOTECHNICAL REPORT IN THE CONTRACT DOCUMENTS FOR MORE DETAILED INFORMATION.
14. GROUND SURFACE SURVEY PROVIDED BY PACIFIC CONNECTOR GAS PIPELINE, LP. GROUND SURFACE DEM (1/9 ARC SECOND) DOWNLOADED FROM HTTP://WWW.USGS.GOV/. AERIAL IMAGE TAKEN FROM GOOGLE EARTH PRO LICENSED TO GEOENGINEERS, INC., IMAGE DATED 07/04/14.
15. THE SECONDARY SURFACE SURVEY COIL LAYOUTS SHOWN ON THIS DRAWING ARE APPROXIMATE AND INTENDED TO SHOW THE GENERAL LAYOUT OF TYPICAL SECONDARY SURFACE SURVEY COIL WIRES THAT MAY BE PLACED TO TRACK THE BOTTOM HOLE ASSEMBLY DURING PILOT HOLE OPERATIONS. THE APPROXIMATE LOCATIONS OF THE SECONDARY SURFACE SURVEY COIL WIRES SHOWN ON THIS DRAWING ARE NOT INTENDED TO DIRECT THE HDD CONTRACTOR AS TO THE EXACT PLACEMENT OF THE SECONDARY SURFACE SURVEY COIL WIRES. THE FINAL PLACEMENT OF SECONDARY SURFACE SURVEY COIL WIRES IS THE CONTRACTOR'S RESPONSIBILITY AND MAY VARY FROM WHAT IS SHOWN DEPENDING ON GROUND SURFACE CONDITIONS AT THE TIME OF HDD INSTALLATION, AND THE HDD CONTRACTOR'S MEANS AND METHODS.

REFERENCES

DRAWING NUMBER	REFERENCE DRAWING TITLE
	PCGP_IP_Right_of_Way.dwg

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK'D	APP'D
0	ISSUED FOR PERMIT (MODIFIED PIPE SPECS)	RBM	08/24/17	BCR	TNH

AES Design	03/05/14 Date
RBM Drawn	03/04/17 Date
BCR Checked	07/09/15 Date
TNH Approved	08/24/17 Date

GEOENGINEERS
317 East Main Street,
American Fork, UT 84003
Telephone (801) 307-0216

36" PACIFIC CONNECTOR GAS PIPELINE PROJECT

ROGUE RIVER HDD
JACKSON COUNTY, OREGON

Project No. 22708-001-01
Drawing No. P1-000-CIV-HDD-GEI-00005-01
Sheet 1 of 1

HDD Design Summary

Project Name: Pacific Connector Gas Pipeline **HDD Name:** Klamath River HDD **Owner:** PCGP, LP

Project No: 22708-001-01 **By:** AES **Ck'd By:** BCR/ JAH **Location:** Klamath County, Oregon **Date:** Wednesday, August 30, 2017

Design Parameters

Pipe Diameter = 36.000 in

Pipe Material = Steel

Yield Stress = 70,000 psi

Wall Thickness = 0.823 in

Assumed Installation Temp = 50 °F

Assumed Operating Temp= 100 °F

Design Factor = 0.5

MAOP = 1,600 psi

Drill Data Box

Point	Station (ft)	Elevation (ft)
ENTRY @ 12°	2,700.00	4,085.91
P C 1 (12.00° @ 3,600 ft R.)	2,374.23	4,016.67
P T 1	1,625.75	3,938.00
P C 2 (12.00° @ 3,600 ft R.)	1,515.87	3,938.00
P T 2	767.39	4,016.67
EXIT @ 12°	400.00	4,094.76

Horizontal Alignment Length = 2,300.00 ft

Profile Segment Information

Segment Name	Segment Type	Segment Length (ft)
ENTRY TANGENT	Straight	333.05
ENTRY CURVE	Vertical Curve	753.98
BOTTOM TANGENT	Straight	109.88
EXIT CURVE	Vertical Curve	753.98
EXIT TANGENT	Straight	375.59

Pipe Length = 2,326.49 ft

Installation Load Summary

Drilling Fluid Weight (lb/gal)	Buoyancy Condition	Buoyancy Control (lb/ft)	Effective Pipe Weight (lb/ft)	Total Installation Force (lb)
9.50	Empty	0.00	-192.37	345,000
9.50	Full	401.67	209.30	294,000
12.00	Empty	0.00	-324.56	457,000
12.00	Full	401.67	77.11	197,000
10.50	Neutral	245.24	0.00	179,000

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Minimum Radius Calculations

Project Name: Pacific Connector Gas Pipeline **HDD Name:** Klamath River HDD **Owner:** PCGP, LP

Project No: 22708-001-01 **By:** AES **Ck'd By:** BCR/ JAH **Location:** Klamath County, Oregon **Date:** Wednesday, August 30, 2017

Design Parameters:

Pipe Diameter = 36.000 in **MAOP =** 1,600 psi **Factor of Safety =** 2.00

Wall Thickness = 0.823 in **SMYS =** 70,000 psi

D/t Ratio = 43.74 **Modulus of Elasticity (E) =** 2.93E+007 psi

Hoop Stress:

Calculated Hoop Stress = (MAOP * Pipe Diameter) / (2 * Wall Thickness) = 34,994 psi

Longitudinal Stress:

Calculated Longitudinal Stress = Hoop Stress / 2 = 17,497 psi

Allowable Stress:

Calculated Allowable Stress = SMYS / Factor of Safety = 35,000 psi

Bending Stress:

Calculated Bending Stress = Allowable Stress - Longitudinal Stress = 17,503 psi

Minimum Radius:

Calculated Minimum Radius = (E * Pipe Diameter) / (2 * Bending Stress) = 2,485 ft

Operating Stress Summary

Project Name:	Pacific Connector Gas Pipeline	**HDD Name:**	Klamath River HDD	**Owner:**	PCGP, LP
Project No:	22708-001-01 **By:** AES **Ck'd By:** BCR/ JAH	**Location:**	Klamath County, Oregon	**Date:**	Wednesday, August 30, 2017

Design Parameters

Pipe diameter = 36.000 in

Wall Thickness = 0.823 in

SMYS = 70,000 psi

MAOP = 1,600 psi

Poissons's Ratio = 0.30

Young's Modulus (E) = 2.93E+007 psi

Design Factor = 0.5

Minimum Radius of Curvature = 2,600 ft

Coefficient of Thermal Expansion = 6.5E-06 in/in/°F

Assumed Installation Temperature = 50 °F

Assumed Operating Temperature = 100 °F

Temperature Derating Factor = 1.00

Groundwater Table Head = 0.00 ft

Stress Analyses

Longitudinal Stress from Bending = 16,929 psi

Percent SMYS = 24.18 %

Hoop Stress = 34,994 psi

Percent SMYS = 49.99 % Limited by Design Factor (0.5) according to 49 CFR 192.111

Longitudinal Tensile Stress from Hoop Stress = 10,498 psi

Percent SMYS = 15.00 %

Longitudinal Stress from Thermal Expansion = -9,537 psi

Percent SMYS = 13.62 % Limited to 90% SMYS by ASME/ANSI B31.4 section 402.3.2

Net Longitudinal Stress (Comp. side of Curve) = -15,968 psi

Percent SMYS = 22.81 % Limited to 90% SMYS by ASME/ANSI B31.8 section 833.3

Net Longitudinal Stress (Tension side of Curve) = 17,891 psi

Percent SMYS = 25.56 % Limited to 90% SMYS by ASME/ANSI B31.8 section 833.3

Maximum Shear Stress = 25,481 psi

Percent SMYS = 36.40 % Limited to 45% SMYS by ASME/ANSI B31.4 section 402.3.1

Combined Biaxial Stress Check = 50,962 psi

Percent SMYS = 72.80 % Limited to 90% SMYS by ASME/ANSI B31.8 section 833.4

GeoEngineers

Operating Stress Summary

Project Name:	Pacific Connector Gas Pipeline	**HDD Name:**	Klamath River HDD	**Owner:**	PCGP, LP
Project No:	22708-001-01 **By:** AES **Ck'd By:** BCR/ JAH	**Location:**	Klamath County, Oregon	**Date:**	Wednesday, August 30, 2017

Installation Load Calculations

Project Name:	Pacific Connector Gas Pipeline	**HDD Name:**	Klamath River HDD	**Owner:**	PCGP, LP
Project No:	22708-001-01 **By:** AES **Ck'd By:** BCR/ JAH	**Location:**	Klamath County, Oregon	**Date:**	Wednesday, August 30, 2017

Installation Case:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty

Product Pipe Parameters

Pipe Diameter =	36.000 in
Wall Thickness =	0.823 in
SMYS =	70,000 psi
Young's Modulus =	2.90E+007 psi
Total Pipe Length =	2,326 ft
Moment of Inertia =	14,076 in^4
Pipe Face Area =	90.95 in^2
D/t Ratio =	43.74
Poisson Ratio =	0.30
Coefficient of Soil Friction =	0.30
Fluid Drag Coefficient =	0.05

Effective Weight Calculations

Total Empty Pipe Weight In Air=	309.96 lb/ft
Pipe Interior Volume =	6.44 ft^3
Coating Thickness =	0.00 in
Coating Density =	0.00 lb/ft^3
Pipe Exterior Volume =	7.07 ft^3/ft
Displaced Fluid Weight =	502.33 lb/ft
B.C. Line(s) Weight =	0.00 lb/ft
B.C. Line(s) Volume =	0.00 ft^3/ft
Unit Weight of B.C. Fluid =	62.40 lb/ft^3
Effective Weight of Pipe =	-192.37 lb/ft

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 1 of 5

Segment Parameters

Segment Name =	EXIT TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	375.59 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	25,487 lb
Friction Force =	21,202 lb
Segment Weight =	15,022 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	61,711 lb
Cumulative Force =	**61,711 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	679 psi	
Cumulative Axial Stress =	679 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	843 psi	8,892 psi
Combined Stress =	0.0121	< 1.0
Total Stress =	0.0093	< 1.0

GeoEngineers

Installation Load Calculations

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 2 of 5

Segment Parameters

Segment Name =	EXIT CURVE	Radius of Curvature =	3,600 ft
Segment Type =	Vertical Curve	Angle Turned =	12.00 deg
Segment Length =	753.98 ft	Center Displacement =	19.72 ft

Segment Force Components

Normal Force =	109,124 lb
Drag Force =	51,164 lb
Friction Force =	32,737 lb
Segment Weight =	15,161 lb
Tension =	193,511 lb
Average Tension =	127,611 lb
Segment Force =	131,800 lb
Cumulative Force =	**193,511 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	1,449 psi	
Cumulative Axial Stress =	2,128 psi	56,000 psi
Bending Stress =	16,731 psi	46,113 psi
Hoop Stress =	1,692 psi	8,892 psi
Combined Stress =	0.4008	< 1.0
Total Stress =	0.1764	< 1.0

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 3 of 5

Segment Parameters

Segment Name =	BOTTOM TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	109.88 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	7,456 lb
Friction Force =	6,341 lb
Segment Weight =	0 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	13,797 lb
Cumulative Force =	**207,308 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	152 psi	
Cumulative Axial Stress =	2,279 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	1,692 psi	8,892 psi
Combined Stress =	0.0407	< 1.0
Total Stress =	0.0398	< 1.0

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 4 of 5

Segment Parameters

Segment Name =	ENTRY CURVE	Radius of Curvature =	3,600 ft
Segment Type =	Vertical Curve	Angle Turned =	12.00 deg
Segment Length =	753.98 ft	Center Displacement =	19.72 ft

Segment Force Components

Normal Force =	123,041 lb
Drag Force =	51,164 lb
Friction Force =	36,912 lb
Segment Weight =	-15,161 lb
Tension =	317,136 lb
Average Tension =	262,222 lb
Segment Force =	109,828 lb
Cumulative Force =	**317,136 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	1,208 psi	
Cumulative Axial Stress =	3,487 psi	56,000 psi
Bending Stress =	16,731 psi	46,113 psi
Hoop Stress =	1,692 psi	8,892 psi
Combined Stress =	0.4251	< 1.0
Total Stress =	0.1954	< 1.0

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 5 of 5

Segment Parameters

Segment Name =	ENTRY TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	333.05 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	22,600 lb
Friction Force =	18,800 lb
Segment Weight =	-13,321 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	28,080 lb
Cumulative Force =	**345,216 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	309 psi	
Cumulative Axial Stress =	3,796 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	843 psi	8,892 psi
Combined Stress =	0.0678	< 1.0
Total Stress =	0.0160	< 1.0

Installation Load Calculations

Project Name:	Pacific Connector Gas Pipeline	**HDD Name:**	Klamath River HDD	**Owner:**	PCGP, LP
Project No:	22708-001-01 **By:** AES **Ck'd By:** BCR/ JAH	**Location:**	Klamath County, Oregon	**Date:**	Wednesday, August 30, 2017

Installation Case:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full

Product Pipe Parameters	
Pipe Diameter =	36.000 in
Wall Thickness =	0.823 in
SMYS =	70,000 psi
Young's Modulus =	2.90E+007 psi
Total Pipe Length =	2,326 ft
Moment of Inertia =	14,076 in⁴
Pipe Face Area =	90.95 in²
D/t Ratio =	43.74
Poisson Ratio =	0.30
Coefficient of Soil Friction =	0.30
Fluid Drag Coefficient =	0.05

Effective Weight Calculations	
Total Empty Pipe Weight In Air=	309.96 lb/ft
Pipe Interior Volume =	6.44 ft³
Coating Thickness =	0.00 in
Coating Density =	0.00 lb/ft³
Pipe Exterior Volume =	7.07 ft³/ft
Displaced Fluid Weight =	502.33 lb/ft
B.C. Line(s) Weight =	0.00 lb/ft
B.C. Line(s) Volume =	0.00 ft³/ft
Unit Weight of B.C. Fluid =	62.40 lb/ft³
Effective Weight of Pipe =	209.30 lb/ft

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 1 of 5

Segment Parameters			
Segment Name =	EXIT TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	375.59 ft	Center Displacement =	0.00 ft

Segment Force Components	
Normal Force =	0 lb
Drag Force =	25,487 lb
Friction Force =	23,068 lb
Segment Weight =	-16,344 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	32,211 lb
Cumulative Force =	**32,211 lb**

Stress Component	Calculated	Allowable
Segment Axial Stress =	354 psi	
Cumulative Axial Stress =	354 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	103 psi	8,892 psi
Combined Stress =	0.0063	< 1.0
Total Stress =	0.0002	< 1.0

GeoEngineers

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 2 of 5

Segment Parameters

Segment Name =	EXIT CURVE	Radius of Curvature =	3,600 ft
Segment Type =	Vertical Curve	Angle Turned =	12.00 deg
Segment Length =	753.98 ft	Center Displacement =	19.72 ft

Segment Force Components

Normal Force =	-80,602 lb
Drag Force =	51,164 lb
Friction Force =	24,181 lb
Segment Weight =	-16,495 lb
Tension =	115,241 lb
Average Tension =	73,726 lb
Segment Force =	83,030 lb
Cumulative Force =	**115,241 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	913 psi	
Cumulative Axial Stress =	1,267 psi	56,000 psi
Bending Stress =	16,731 psi	46,113 psi
Hoop Stress =	206 psi	8,892 psi
Combined Stress =	0.3854	< 1.0
Total Stress =	0.1071	< 1.0

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 3 of 5

Segment Parameters

Segment Name =	BOTTOM TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	109.88 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	7,456 lb
Friction Force =	6,899 lb
Segment Weight =	0 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	14,355 lb
Cumulative Force =	**129,596 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	158 psi	
Cumulative Axial Stress =	1,425 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	206 psi	8,892 psi
Combined Stress =	0.0254	< 1.0
Total Stress =	0.0014	< 1.0

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 4 of 5

Segment Parameters

Segment Name =	ENTRY CURVE	Radius of Curvature =	3,600 ft
Segment Type =	Vertical Curve	Angle Turned =	12.00 deg
Segment Length =	753.98 ft	Center Displacement =	19.72 ft

Segment Force Components

Normal Force =	-65,361 lb
Drag Force =	51,164 lb
Friction Force =	19,608 lb
Segment Weight =	16,495 lb
Tension =	236,472 lb
Average Tension =	183,034 lb
Segment Force =	106,876 lb
Cumulative Force =	**236,472 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	1,175 psi	
Cumulative Axial Stress =	2,600 psi	56,000 psi
Bending Stress =	16,731 psi	46,113 psi
Hoop Stress =	206 psi	8,892 psi
Combined Stress =	0.4092	< 1.0
Total Stress =	0.1232	< 1.0

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 5 of 5

Segment Parameters

Segment Name =	ENTRY TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	333.05 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	22,600 lb
Friction Force =	20,455 lb
Segment Weight =	14,493 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	57,548 lb
Cumulative Force =	**294,021 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	633 psi	
Cumulative Axial Stress =	3,233 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	103 psi	8,892 psi
Combined Stress =	0.0577	< 1.0
Total Stress =	0.0038	< 1.0

Installation Load Calculations

Project Name: Pacific Connector Gas Pipeline **HDD Name:** Klamath River HDD **Owner:** PCGP, LP

Project No: 22708-001-01 **By:** AES **Ck'd By:** BCR/ JAH **Location:** Klamath County, Oregon **Date:** Wednesday, August 30, 2017

Installation Case:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty

Product Pipe Parameters	
Pipe Diameter =	36.000 in
Wall Thickness =	0.823 in
SMYS =	70,000 psi
Young's Modulus =	2.90E+007 psi
Total Pipe Length =	2,326 ft
Moment of Inertia =	14,076 in⁴
Pipe Face Area =	90.95 in²
D/t Ratio =	43.74
Poisson Ratio =	0.30
Coefficient of Soil Friction =	0.30
Fluid Drag Coefficient =	0.05

Effective Weight Calculations	
Total Empty Pipe Weight In Air=	309.96 lb/ft
Pipe Interior Volume =	6.44 ft³
Coating Thickness =	0.00 in
Coating Density =	0.00 lb/ft³
Pipe Exterior Volume =	7.07 ft³/ft
Displaced Fluid Weight =	634.52 lb/ft
B.C. Line(s) Weight =	0.00 lb/ft
B.C. Line(s) Volume =	0.00 ft³/ft
Unit Weight of B.C. Fluid =	62.40 lb/ft³
Effective Weight of Pipe =	-324.56 lb/ft

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 1 of 5

Segment Parameters

Segment Name =	EXIT TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	375.59 ft	Center Displacement =	0.00 ft

Segment Force Components	
Normal Force =	0 lb
Drag Force =	25,487 lb
Friction Force =	35,772 lb
Segment Weight =	25,345 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	86,604 lb
Cumulative Force =	**86,604 lb**

Segment Installation Stress Checks		
Stress Component	Calculated	Allowable
Segment Axial Stress =	952 psi	
Cumulative Axial Stress =	952 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	1,065 psi	8,892 psi
Combined Stress =	0.0170	< 1.0
Total Stress =	0.0149	< 1.0

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 2 of 5

Segment Parameters

Segment Name =	EXIT CURVE	Radius of Curvature =	3,600 ft
Segment Type =	Vertical Curve	Angle Turned =	12.00 deg
Segment Length =	753.98 ft	Center Displacement =	19.72 ft

Segment Force Components

Normal Force =	173,471 lb
Drag Force =	51,164 lb
Friction Force =	52,041 lb
Segment Weight =	25,579 lb
Tension =	267,430 lb
Average Tension =	177,017 lb
Segment Force =	180,826 lb
Cumulative Force =	**267,430 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	1,988 psi	
Cumulative Axial Stress =	2,940 psi	56,000 psi
Bending Stress =	16,731 psi	46,113 psi
Hoop Stress =	2,137 psi	8,892 psi
Combined Stress =	0.4153	< 1.0
Total Stress =	0.2160	< 1.0

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 3 of 5

Segment Parameters

Segment Name =	BOTTOM TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	109.88 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	7,456 lb
Friction Force =	10,699 lb
Segment Weight =	0 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	18,155 lb
Cumulative Force =	**285,585 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	200 psi	
Cumulative Axial Stress =	3,140 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	2,137 psi	8,892 psi
Combined Stress =	0.0561	< 1.0
Total Stress =	0.0645	< 1.0

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 4 of 5

Segment Parameters

Segment Name =	ENTRY CURVE	Radius of Curvature =	3,600 ft
Segment Type =	Vertical Curve	Angle Turned =	12.00 deg
Segment Length =	753.98 ft	Center Displacement =	19.72 ft

Segment Force Components

Normal Force =	190,787 lb
Drag Force =	51,164 lb
Friction Force =	57,236 lb
Segment Weight =	-25,579 lb
Tension =	425,641 lb
Average Tension =	355,613 lb
Segment Force =	140,057 lb
Cumulative Force =	**425,641 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	1,540 psi	
Cumulative Axial Stress =	4,680 psi	56,000 psi
Bending Stress =	16,731 psi	46,113 psi
Hoop Stress =	2,137 psi	8,892 psi
Combined Stress =	0.4464	< 1.0
Total Stress =	0.2421	< 1.0

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 5 of 5

Segment Parameters

Segment Name =	ENTRY TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	333.05 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	22,600 lb
Friction Force =	31,720 lb
Segment Weight =	-22,474 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	31,846 lb
Cumulative Force =	**457,487 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	350 psi	
Cumulative Axial Stress =	5,030 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	1,065 psi	8,892 psi
Combined Stress =	0.0898	< 1.0
Total Stress =	0.0266	< 1.0

Installation Load Calculations

Project Name: Pacific Connector Gas Pipeline	**HDD Name:** Klamath River HDD	**Owner:** PCGP, LP
Project No: 22708-001-01 **By:** AES **Ck'd By:** BCR/ JAH	**Location:** Klamath County, Oregon	**Date:** Wednesday, August 30, 2017

Installation Case:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full

Product Pipe Parameters	
Pipe Diameter =	36.000 in
Wall Thickness =	0.823 in
SMYS =	70,000 psi
Young's Modulus =	2.90E+007 psi
Total Pipe Length =	2,326 ft
Moment of Inertia =	14,076 in⁴
Pipe Face Area =	90.95 in²
D/t Ratio =	43.74
Poisson Ratio =	0.30
Coefficient of Soil Friction =	0.30
Fluid Drag Coefficient =	0.05

Effective Weight Calculations	
Total Empty Pipe Weight In Air=	309.96 lb/ft
Pipe Interior Volume =	6.44 ft³
Coating Thickness =	0.00 in
Coating Density =	0.00 lb/ft³
Pipe Exterior Volume =	7.07 ft³/ft
Displaced Fluid Weight =	634.52 lb/ft
B.C. Line(s) Weight =	0.00 lb/ft
B.C. Line(s) Volume =	0.00 ft³/ft
Unit Weight of B.C. Fluid =	62.40 lb/ft³
Effective Weight of Pipe =	77.11 lb/ft

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 1 of 5

Segment Parameters

Segment Name =	EXIT TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	375.59 ft	Center Displacement =	0.00 ft

Segment Force Components	
Normal Force =	0 lb
Drag Force =	25,487 lb
Friction Force =	8,498 lb
Segment Weight =	-6,021 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	27,964 lb
Cumulative Force =	**27,964 lb**

Segment Installation Stress Checks		
Stress Component	Calculated	Allowable
Segment Axial Stress =	307 psi	
Cumulative Axial Stress =	307 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	325 psi	8,892 psi
Combined Stress =	0.0055	< 1.0
Total Stress =	0.0014	< 1.0

GeoEngineers

Installation Load Calculations

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 2 of 5

Segment Parameters			
Segment Name =	EXIT CURVE	Radius of Curvature =	3,600 ft
Segment Type =	Vertical Curve	Angle Turned =	12.00 deg
Segment Length =	753.98 ft	Center Displacement =	19.72 ft

Segment Force Components	
Normal Force =	-22,174 lb
Drag Force =	51,164 lb
Friction Force =	6,652 lb
Segment Weight =	-6,077 lb
Tension =	86,356 lb
Average Tension =	57,160 lb
Segment Force =	58,391 lb
Cumulative Force =	**86,356 lb**

Stress Component	Calculated	Allowable
Segment Axial Stress =	642 psi	
Cumulative Axial Stress =	949 psi	56,000 psi
Bending Stress =	16,731 psi	46,113 psi
Hoop Stress =	652 psi	8,892 psi
Combined Stress =	0.3798	< 1.0
Total Stress =	0.1150	< 1.0

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 3 of 5

Segment Parameters			
Segment Name =	BOTTOM TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	109.88 ft	Center Displacement =	0.00 ft

Segment Force Components	
Normal Force =	0 lb
Drag Force =	7,456 lb
Friction Force =	2,542 lb
Segment Weight =	0 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	9,998 lb
Cumulative Force =	**96,354 lb**

Stress Component	Calculated	Allowable
Segment Axial Stress =	110 psi	
Cumulative Axial Stress =	1,059 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	652 psi	8,892 psi
Combined Stress =	0.0189	< 1.0
Total Stress =	0.0061	< 1.0

Installation Load Calculations

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full **Segment 4 of 5**

Segment Parameters			
Segment Name =	ENTRY CURVE	Radius of Curvature =	3,600 ft
Segment Type =	Vertical Curve	Angle Turned =	12.00 deg
Segment Length =	753.98 ft	Center Displacement =	19.72 ft

Segment Force Components	
Normal Force =	-12,900 lb
Drag Force =	51,164 lb
Friction Force =	3,870 lb
Segment Weight =	6,077 lb
Tension =	161,335 lb
Average Tension =	128,844 lb
Segment Force =	64,981 lb
Cumulative Force =	**161,335 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	714 psi	
Cumulative Axial Stress =	1,774 psi	56,000 psi
Bending Stress =	16,731 psi	46,113 psi
Hoop Stress =	652 psi	8,892 psi
Combined Stress =	0.3945	< 1.0
Total Stress =	0.1250	< 1.0

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full **Segment 5 of 5**

Segment Parameters			
Segment Name =	ENTRY TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	333.05 ft	Center Displacement =	0.00 ft

Segment Force Components	
Normal Force =	0 lb
Drag Force =	22,600 lb
Friction Force =	7,536 lb
Segment Weight =	5,339 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	35,475 lb
Cumulative Force =	**196,810 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	390 psi	
Cumulative Axial Stress =	2,164 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	325 psi	8,892 psi
Combined Stress =	0.0386	< 1.0
Total Stress =	0.0034	< 1.0

Installation Load Calculations

Project Name:	Pacific Connector Gas Pipeline	**HDD Name:**	Klamath River HDD	**Owner:**	PCGP, LP
Project No:	22708-001-01 **By:** AES **Ck'd By:** BCR/ JAH	**Location:**	Klamath County, Oregon	**Date:**	Wednesday, August 30, 2017

Installation Case:10.50 lb/gal Drilling Fluid With Neutral Pipe Buoyancy

Product Pipe Parameters	
Pipe Diameter =	36.000 in
Wall Thickness =	0.823 in
SMYS =	70,000 psi
Young's Modulus =	2.90E+007 psi
Total Pipe Length =	2,326 ft
Moment of Inertia =	14,076 in⁴
Pipe Face Area =	90.95 in²
D/t Ratio =	43.74
Poisson Ratio =	0.30
Coefficient of Soil Friction =	0.30
Fluid Drag Coefficient =	0.05

Effective Weight Calculations	
Total Empty Pipe Weight In Air=	309.96 lb/ft
Pipe Interior Volume =	6.44 ft³
Coating Thickness =	0.00 in
Coating Density =	0.00 lb/ft³
Pipe Exterior Volume =	7.07 ft³/ft
Displaced Fluid Weight =	555.21 lb/ft
B.C. Line(s) Weight =	0.00 lb/ft
B.C. Line(s) Volume =	0.00 ft³/ft
Unit Weight of B.C. Fluid =	62.40 lb/ft³
Effective Weight of Pipe =	0.00 lb/ft

Installation:10.50 lb/gal Drilling Fluid With Neutral Pipe Buoyancy — Segment 1 of 5

Segment Parameters

Segment Name =	EXIT TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	375.59 ft	Center Displacement =	0.00 ft

Segment Force Components	
Normal Force =	0 lb
Drag Force =	25,487 lb
Friction Force =	0 lb
Segment Weight =	0 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	25,487 lb
Cumulative Force =	**25,487 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	280 psi	
Cumulative Axial Stress =	280 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	932 psi	8,892 psi
Combined Stress =	0.0050	< 1.0
Total Stress =	0.0112	< 1.0

Installation:10.50 lb/gal Drilling Fluid With Neutral Pipe Buoyancy — Segment 2 of 5

Segment Parameters

Segment Name =	EXIT CURVE	Radius of Curvature =	3,600 ft
Segment Type =	Vertical Curve	Angle Turned =	12.00 deg
Segment Length =	753.98 ft	Center Displacement =	19.72 ft

Segment Force Components

Normal Force =	13,088 lb
Drag Force =	51,164 lb
Friction Force =	3,926 lb
Segment Weight =	0 lb
Tension =	84,504 lb
Average Tension =	54,995 lb
Segment Force =	59,017 lb
Cumulative Force =	**84,504 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	649 psi	
Cumulative Axial Stress =	929 psi	56,000 psi
Bending Stress =	16,731 psi	46,113 psi
Hoop Stress =	1,870 psi	8,892 psi
Combined Stress =	0.3794	< 1.0
Total Stress =	0.1711	< 1.0

Installation:10.50 lb/gal Drilling Fluid With Neutral Pipe Buoyancy — Segment 3 of 5

Segment Parameters

Segment Name =	BOTTOM TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	109.88 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	7,456 lb
Friction Force =	0 lb
Segment Weight =	0 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	7,456 lb
Cumulative Force =	**91,960 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	82 psi	
Cumulative Axial Stress =	1,011 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	1,870 psi	8,892 psi
Combined Stress =	0.0181	< 1.0
Total Stress =	0.0444	< 1.0

Installation Load Calculations

Installation:10.50 lb/gal Drilling Fluid With Neutral Pipe Buoyancy — Segment 4 of 5

Segment Parameters			
Segment Name =	ENTRY CURVE	Radius of Curvature =	3,600 ft
Segment Type =	Vertical Curve	Angle Turned =	12.00 deg
Segment Length =	753.98 ft	Center Displacement =	19.72 ft

Segment Force Components	
Normal Force =	21,453 lb
Drag Force =	51,164 lb
Friction Force =	6,436 lb
Segment Weight =	0 lb
Tension =	155,996 lb
Average Tension =	123,978 lb
Segment Force =	64,036 lb
Cumulative Force =	**155,996 lb**

Stress Component	Calculated	Allowable
Segment Axial Stress =	704 psi	
Cumulative Axial Stress =	1,715 psi	56,000 psi
Bending Stress =	16,731 psi	46,113 psi
Hoop Stress =	1,870 psi	8,892 psi
Combined Stress =	0.3934	< 1.0
Total Stress =	0.1815	< 1.0

Installation:10.50 lb/gal Drilling Fluid With Neutral Pipe Buoyancy — Segment 5 of 5

Segment Parameters			
Segment Name =	ENTRY TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	333.05 ft	Center Displacement =	0.00 ft

Segment Force Components	
Normal Force =	0 lb
Drag Force =	22,600 lb
Friction Force =	0 lb
Segment Weight =	0 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	22,600 lb
Cumulative Force =	**178,596 lb**

Stress Component	Calculated	Allowable
Segment Axial Stress =	248 psi	
Cumulative Axial Stress =	1,964 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	932 psi	8,892 psi
Combined Stress =	0.0351	< 1.0
Total Stress =	0.0134	< 1.0

APPENDIX C
Report Limitations and Guidelines for Use

APPENDIX C
REPORT LIMITATIONS AND GUIDELINES FOR USE[1]

This appendix provides information to help you manage your risks with respect to the use of this report.

Geotechnical Services Are Performed for Specific Purposes, Persons and Projects

This report has been prepared for the exclusive use of PCGP, LP and their authorized agents. This report is not intended for use by others, and the information contained herein is not applicable to other sites.

GeoEngineers structures our services to meet the specific needs of our clients. For example, a geotechnical or geologic study conducted for a civil engineer or architect may not fulfill the needs of a construction contractor or even another civil engineer or architect that are involved in the same project. Because each geotechnical or geologic study is unique, each geotechnical engineering or geologic report is unique, prepared solely for the specific client and project site. Our report is prepared for the exclusive use of our Client. No other party may rely on the product of our services unless we agree in advance to such reliance in writing. This is to provide our firm with reasonable protection against open-ended liability claims by third parties with whom there would otherwise be no contractual limits to their actions. Within the limitations of scope, schedule and budget, our services have been executed in accordance with our Agreement with the Client and generally accepted geotechnical practices in this area at the time this report was prepared. This report should not be applied for any purpose or project except the one originally contemplated.

A Geotechnical Engineering or Geologic Report Is Based on a Unique Set of Project-specific Factors

This report has been prepared for PCGP, LP for the Rogue River HDD in Jackson County, Oregon. GeoEngineers considered a number of unique, project-specific factors when establishing the scope of services for this project and report. Unless GeoEngineers specifically indicates otherwise, do not rely on this report if it was:

- not prepared for you.
- not prepared for your project.
- not prepared for the specific site explored.
- completed before important project changes were made.

For example, changes that can affect the applicability of this report include those that affect:

- the function of the proposed structure.
- elevation, configuration, location, orientation or weight of the proposed structure.
- composition of the design team.
- project ownership.

[1] Developed based on material provided by ASFE, Professional Firms Practicing in the Geosciences; www.asfe.org.

If important changes are made after the date of this report, GeoEngineers should be given the opportunity to review our interpretations and recommendations and provide written modifications or confirmation, as appropriate.

Subsurface Conditions Can Change

This geotechnical or geologic report is based on conditions that existed at the time the study was performed. The findings and conclusions of this report may be affected by the passage of time, by manmade events such as construction on or adjacent to the site, or by natural events such as floods, earthquakes, slope instability or groundwater fluctuations. Always contact GeoEngineers before applying a report to determine if it remains applicable.

Most Geotechnical and Geologic Findings Are Professional Opinions

Our interpretations of subsurface conditions are based on field observations from widely spaced sampling locations at the site. Site exploration identifies subsurface conditions only at those points where subsurface tests are conducted or samples are taken. GeoEngineers reviewed field and laboratory data and then applied our professional judgment to render an opinion about subsurface conditions throughout the site. Actual subsurface conditions may differ, sometimes significantly, from those indicated in this report. Our report, conclusions and interpretations should not be construed as a warranty of the subsurface conditions.

Geotechnical Engineering Report Recommendations Are Not Final

Do not over-rely on the preliminary construction recommendations included in this report. These recommendations are not final, because they were developed principally from GeoEngineers' professional judgment and opinion. GeoEngineers' recommendations can be finalized only by observing actual subsurface conditions revealed during construction. GeoEngineers cannot assume responsibility or liability for this report's recommendations if we do not perform construction observation.

Sufficient observation, testing and consultation by GeoEngineers should be provided during construction to confirm that the conditions encountered are consistent with those indicated by the explorations, to provide recommendations for design changes should the conditions revealed during the work differ from those anticipated, and to evaluate whether or not earthwork activities are completed in accordance with our recommendations. Retaining GeoEngineers for construction observation for this project is the most effective method of managing the risks associated with unanticipated conditions.

A Geotechnical Engineering or Geologic Report Could Be Subject to Misinterpretation

Misinterpretation of this report by other design team members can result in costly problems. You could lower that risk by having GeoEngineers confer with appropriate members of the design team after submitting the report. Also, retain GeoEngineers to review pertinent elements of the design team's plans and specifications. Contractors can also misinterpret a geotechnical engineering or geologic report. Reduce that risk by having GeoEngineers participate in pre-bid and preconstruction conferences, and by providing construction observation.

Do Not Redraw the Exploration Logs

Geotechnical engineers and geologists prepare final boring and testing logs based upon their interpretation of field logs and laboratory data. To prevent errors or omissions, the logs included in a geotechnical

engineering or geologic report should never be redrawn for inclusion in architectural or other design drawings. Only photographic or electronic reproduction is acceptable, but recognize that separating logs from the report can elevate risk.

Give Contractors a Complete Report and Guidance

Some owners and design professionals believe they can make contractors liable for unanticipated subsurface conditions by limiting what they provide for bid preparation. To help prevent costly problems, give contractors the complete geotechnical engineering or geologic report, but preface it with a clearly written letter of transmittal. In that letter, advise contractors that the report was not prepared for purposes of bid development and that the report's accuracy is limited; encourage them to confer with GeoEngineers and/or to conduct additional study to obtain the specific types of information they need or prefer. A pre-bid conference can also be valuable. Be sure contractors have sufficient time to perform additional study. Only then might an owner be in a position to give contractors the best information available, while requiring them to at least share the financial responsibilities stemming from unanticipated conditions. Further, a contingency for unanticipated conditions should be included in your project budget and schedule.

Contractors Are Responsible for Site Safety on Their Own Construction Projects

Our geotechnical recommendations are not intended to direct the contractor's procedures, methods, schedule or management of the work site. The contractor is solely responsible for job site safety and for managing construction operations to minimize risks to on-site personnel and to adjacent properties.

Read These Provisions Closely

Some clients, design professionals and contractors may not recognize that the geoscience practices (geotechnical engineering or geology) are far less exact than other engineering and natural science disciplines. This lack of understanding can create unrealistic expectations that could lead to disappointments, claims and disputes. GeoEngineers includes these explanatory "limitations" provisions in our reports to help reduce such risks. Please confer with GeoEngineers if you are unclear how these "Report Limitations and Guidelines for Use" apply to your project or site.

Geotechnical, Geologic and Environmental Reports Should Not Be Interchanged

The equipment, techniques and personnel used to perform an environmental study differ significantly from those used to perform a geotechnical or geologic study and vice versa. For that reason, a geotechnical engineering or geologic report does not usually relate any environmental findings, conclusions or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. Similarly, environmental reports are not used to address geotechnical or geologic concerns regarding a specific project.

Biological Pollutants

GeoEngineers' Scope of Work specifically excludes the investigation, detection, prevention or assessment of the presence of Biological Pollutants. Accordingly, this report does not include any interpretations, recommendations, findings, or conclusions regarding the detecting, assessing, preventing or abating of Biological Pollutants and no conclusions or inferences should be drawn regarding Biological Pollutants, as they may relate to this project. The term "Biological Pollutants" includes, but is not limited to, molds, fungi, spores, bacteria, and viruses, and/or any of their byproducts.

If Client desires these specialized services, they should be obtained from a consultant who offers services in this specialized field.

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GeoEngineers

Geotechnical Engineering Services and Horizontal Directional Drilling Design

Klamath River HDD
Pacific Connector Gas Pipeline Project
Klamath County, Oregon

for
Pacific Connector Gas Pipeline, LP

September 1, 2017

GeoEngineers
Earth Science + Technology

Geotechnical Engineering Services and Horizontal Directional Drilling Design

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September 1, 2017

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Geotechnical Engineering Services and Horizontal Directional Drilling Design

Klamath River HDD
Pacific Connector Gas Pipeline Project
Klamath County, Oregon

File No. 22708-001-01

September 1, 2017

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GeoEngineers

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EXECUTIVE SUMMARY

This report provides geotechnical engineering and horizontal directional drilling (HDD) recommendations and HDD design criteria for the proposed HDD crossing of the Klamath River located approximately 4 miles south of Klamath Falls, Oregon. This HDD crossing consists of installing a new 36-inch-diameter pipeline under the Klamath River. The river crossing will be a part of the proposed Pacific Connector Gas Pipeline (PCGP).

Based on the results of our site visits, subsurface exploration program, geotechnical engineering evaluations, HDD design, and HDD constructability review, it is our opinion the HDD method of installation is feasible and the proposed crossing of the Klamath River can be installed successfully provided the recommendations in this report are incorporated into the installation of the crossing.

The subsurface conditions at the site were evaluated by drilling eight borings, to depths ranging between 91.5 feet below ground surface (bgs) and 165.1 feet bgs. In general, borings completed on the west side of the river (B-1, B-2) encountered about 15 feet of silt, clay, peat and sand soil overburden overlying sandstone bedrock, whereas borings completed on the east side of the river (B199.6-1, B-3, B-4) encountered sandy silt, elastic silt and clay to the maximum depths explored. The three borings completed in the river (B199.33-1, B199.41-1 and B199.43-1) encountered between 85 feet and 112 feet of elastic silt with a few sand layers overlying decomposed siltstone bedrock or fresh siltstone.

The hydraulic fracture and drilling fluid surface release model indicates that the risks of localized hydraulic fracture and drilling fluid surface release are generally low when the HDD profile is located within the sandstone and siltstone formations, with calculated factors of safety generally greater than 9. The factors of safety, however, drop significantly when the HDD passes through the silt, elastic silt, peat and lean clay units between Stations 18+00 through 26+00 and 4+00 through 4+25, indicating a moderate to high risk between these stations (east of the river, and near the exit point). Within about 100 feet of the entry point (Stations 27+00 to 26+00), the factors of safety against hydraulic fracture and drilling fluid surface releases are greater than 2, indicating a low risk. Most importantly, the factors of safety against drilling fluid surface release are greater than 9 (low risk) along the portion of the HDD path located beneath the Klamath River. We modeled the location where the HDD profile will pass the rock/soil interface at Station 18+00 based on information collected in borings completed at the site; however, the location of this contact is an estimate only and should not be construed as a warranty of where the HDD profile will pass the rock/soil interface. As is typical of HDD installations, we anticipate that there is a relatively high risk of hydraulic fracture and drilling fluid surface release within about 100 feet of the entry and exit points.

The site-specific HDD profile was created utilizing the design guide published by the Pipeline Research Committee International (PRCI) of the American Gas Association. Associated installation and operational stresses were calculated utilizing the PRCI Design Guide and checked to assess compliance with ASTM/ASME B31.8, API Recommended Practice 2A – WSD, and DOT CFR Part 192. The HDD design calculations indicate the stresses incurred during installation and operation should be within the allowable limits.

This Executive Summary should be used only in the context of the full report for which it is intended.

1.0 INTRODUCTION

1.1 General

This report summarizes our geotechnical engineering and HDD design services for the proposed HDD crossing of the Klamath River. The site is located approximately 4 miles south of Klamath Falls, Oregon. The site location is shown with respect to the surrounding area in the Vicinity Map, Figure 1. The general layout of the site is shown in the Site Plan and Profile, Figure 2.

1.2 Project Description and Basis of Design

The proposed Klamath River HDD crossing will be a part of the 229-mile-long PCGP, beginning at the proposed Jordan Cove Liquefied Natural Gas (LNG) Terminal near Coos Bay, Oregon and terminating near Malin, Oregon. The proposed pipeline crossing of the Klamath River consists of a single 36-inch-diameter pipe to be installed using HDD techniques.

The HDD design was completed in accordance with the latest versions of Department of Transportation (DOT) 49 CFR 192, ASME 31.8 and accepted practices within the natural gas industry. The geotechnical and HDD design engineering was completed based on the parameters presented below in Table 1.

TABLE 1. BASIS OF DESIGN FOR THE 36-INCH-DIAMETER KLAMATH RIVER HDD

Product Pipe Data	Design Parameter
Product Pipe Specifications	36 inches x 0.823 inches w.t.[1] API-5L X-70 steel pipe, SAWH or SAWL
Horizontal Crossing Length	2,300 feet
Maximum Allowable Operating Pressure	1,600 psig[2]
Average Operating Temperature	70 degrees F
Maximum Operating Temperature	100 degrees F
Assumed Tie-In Temperature	50 degrees F

Notes:

[1] w.t. – wall thickness

[2] psig – pounds per square inch gauge

2.0 SCOPE OF SERVICES

The purpose of our services was to evaluate the existing surface and subsurface soil and groundwater conditions and prepare a HDD design for the proposed crossing. The specific scope of services provided by GeoEngineers, Inc. included the following:

1. Prepared Oregon Department of State Lands (DSL) General Authorization (GA) form for borings within the Klamath River.
2. Prepared supplement to GA form, including:
    a. Project description;
    b. Resource characteristics; and

c. Project location map, photos and drawings (plan view and cross section).

3. Coordinated with DSL to address comments and/or data requests.
4. Coordinated utility locates near the proposed boring locations by the public "One Call" utility locating service.
   a. Explored subsurface conditions at the Klamath River HDD crossing by means of eight drilled borings to depths ranging between 91.5 and 165.5 feet bgs;
   b. Placed drill cuttings in drums and remove them off site;
   c. Obtained samples at representative intervals from the borings using a combination of thin-walled samplers or standard penetration tests (SPTs) in soil, or obtain continuous rock core in bedrock; and
   d. Classified soils encountered in the borings in general accordance with ASTM International (ASTM) Standard Practices Test Method D 2488. We classified rock encountered in the borings in general accordance with the Oregon Department of Transportation (ODOT) soil and rock classification manual. We maintained a detailed log of each boring.
5. Performed index tests necessary to characterize the subsurface materials. Testing included:
   a. Twenty-seven Atterberg limits determinations in general accordance with ASTM D 4318;
   b. Two percent fines determinations in general accordance with ASTM D 1140
   c. One sieve analysis in general accordance with ASTM D 422; and
   d. Two unconfined compression tests in general accordance with ASTM D 7012.
6. Prepared and submitted a HDD feasibility study report, which included:
   a. Brief surface description of site conditions that could affect the planned HDD operations;
   b. Summary of subsurface conditions encountered during our fieldwork;
   c. HDD feasibility discussion;
   d. Preliminary HDD profile design length and depth;
   e. Boring logs; and
   f. Site Photographs.
7. Performed a hydraulic fracture and drilling fluid surface release analysis to quantify the risk of hydraulic fracture and drilling fluid surface release.
8. Completed HDD design, including:
   a. Alignment and profile;
   b. Minimum radius;
   c. Installation stresses; and
   d. Operating stresses.
9. Providing this draft HDD design report to the project team for review and comment. The draft report included:

a. Analyses and discussion of hydraulic fracture and drilling fluid surface release potential;

b. Installation stress calculations;

c. Operating stress calculations;

d. HDD design conclusions and recommendations, including:

    i. Drilling fluid loss;

    ii. Minimum allowable product pipe bending radius;

    iii. Pilot hole survey recommendations;

    iv. Anticipated drilling conditions;

    v. Hole collapse conclusions and recommendations;

    vi. Pipe coating specifications conclusions;

    vii. Buoyancy considerations;

    viii. Site access considerations; and

    ix. Noise mitigation techniques.

e. Geotechnical engineering considerations, including:

    i. Temporary access roads;

    ii. Temporary workspace areas;

    iii. HDD installation

    iv. Temporary excavations;

    v. Construction dewatering; and

    vi. Erosion control.

f. HDD design drawing, including site-specific construction diagrams that show the location of temporary entry and exit workspaces, pipe assembly areas and areas to be disturbed or cleared for construction.

10. Prepare a final HDD design report incorporating comments from the project team.

3.0 SITE CONDITIONS

3.1 Geologic Setting

3.1.1 Site Geology

The site is mapped as Quaternary-aged lacustrine and fluvial sedimentary deposits overlying Pliocene and upper Miocene-aged mudstone and sandstone bedrock (Walker and MacLeod, 1991). The sedimentary deposits are described as unconsolidated lacustrine clay, silt and sand with localized portions containing mudflow and fluvial deposits as well as discontinuous layers of peat. The mudstone and sandstone bedrock is described as thin to medium-bedded sandstone, siltstone and laminated mudstone with minor conglomerate beds.

3.2 Surface Conditions

3.2.1 General

We evaluated surface conditions in the vicinity of the site during an initial site reconnaissance in June 2006, and also while conducting our subsurface exploration program between June 7 and June 16, 2006, July 29 and July 31, 2014, November 11, 2014, and January 13 and January 14, 2015. Site photographs are presented in Figures 3 and 4.

3.2.2 Surface Description

The proposed HDD alignment is oriented in a generally east-west (entry to exit) direction, as shown in Figure 2. The east side (entry) of the proposed HDD is located on a relatively flat agricultural field with approximately Elevation 4,085 feet above mean sea level (MSL). The west side (exit) is located within an open space that gently slopes down toward the river to the east and ranges from approximately Elevation 4,115 feet at the west end of the stringing area to Elevation 4,090 feet at the west river bank. The west bank of the river is approximately 370 feet east of the exit point and the east bank of the river is approximately 950 feet west of the entry point. State Highway 97 is approximately 420 feet west of the entry point.

The proposed entry workspace occupies a rectangular shaped 200-foot by 250-foot area situated within a larger temporary extra work area (TEWA) for the project. The area within the entry workspace is vegetated with agricultural crops. The entry workspace is located approximately 400 feet southwest of an existing single-family residence. The portion of the alignment between the east bank of the river and State Highway 97 will likely be delineated as a wetland during upcoming phases of the project.

The exit workspace occupies a 180-foot by 250-foot area, with the south side of the workspace approximately 75 feet south of the exit point. The area within the exit workspace and stringing area are vegetated with grasses. A pond approximately 100 feet in diameter is located adjacent to the stringing area on the west side of the crossing.

3.3 Subsurface Conditions

3.3.1 General

We explored subsurface conditions at the site between June 7 and June 16, 2006, July 29 and July 31, 2014, November 11, 2014, and January 13 and January 14, 2015 by advancing a total of eight drilled borings to depths ranging between 91.5 feet bgs and 165.1 feet bgs. The approximate boring locations are presented in Figure 2. A representative from GeoEngineers maintained logs of the materials encountered in each boring and collected disturbed soil samples at 5-foot intervals using split spoon samplers during SPT. In bedrock, cores were taken using an HQ-3 core barrel. Appendix A presents the boring logs, a description of the subsurface exploration, and laboratory-testing programs. Laboratory test results are shown in the boring logs and laboratory test result figures in Appendix A.

The materials encountered in our borings were generally consistent with the geologic mapping for the site. In general, borings completed on the west side of the river encountered about 15 feet of silt, sand and peat overlying sandstone bedrock. Borings completed in the river encountered between approximately 90 to 110 feet of elastic silt overlying weathered siltstone bedrock (where rock was encountered). Borings completed on the east side of the river encountered elastic silt. The materials encountered in each boring are described in more detail in the following paragraphs.

3.3.2 Subsurface Conditions Encountered by Borings

3.3.2.1 BORINGS COMPLETED ON THE WEST SIDE OF KLAMATH RIVER

Boring B-1 was located in a flat open area on the west side of the crossing, approximately 335 feet west of the Klamath River. Boring B-1 encountered loose granular fill soil to a depth of about 6 feet bgs where a unit of very soft peat approximately 3 feet in thickness was encountered. Below the peat, very stiff to hard silt and clay, and medium dense clayey sand, was encountered between depths of approximately 9 and 15 feet bgs. Fresh, medium hard, very closely to medium fractured sandstone was encountered to the bottom of the boring at 101 feet bgs. Rock Quality Designation (RQD) values in the sandstone generally ranged from 65 to 100 percent except for a zone between depths of approximately 36 to 45 feet (Runs 6 and 7) where RQD values of 40 percent were recorded. The unconfined compressive strength of one sample of the sandstone was 2,660 pounds per square inch (psi).

Boring B-2 was also located in an open area on the west side of the crossing, approximately 100 feet west of the Klamath River. The boring encountered 8 feet of very soft organic silt overlying very stiff silt to a depth of approximately 15 feet where sandstone bedrock was encountered. The sandstone was generally slightly weathered to fresh and medium strong with very close to medium fracturing. RQD values in the sandstone typically ranged from 61 to 97 percent except for one zone of rock at depths between 36 and 41 feet (Run 6) where an RQD value of 59 percent was recorded. The unconfined compressive strength for one sandstone sample was 5,400 psi.

3.3.2.2 BORINGS COMPLETED ON THE EAST SIDE OF KLAMATH RIVER

Boring B-3 was located on the east side of the crossing adjacent the east side of Highway 97, approximately 500 feet east of the Klamath River. The boring encountered soft silt to a depth of approximately 6 feet bgs overlying medium dense silty sand to a depth of about 10 feet bgs. Below the silty sand, the boring encountered stiff to very stiff silt and elastic silt to the completion depth of the boring at 100 feet.

Boring B-4 was located on the east side of crossing approximately 1,100 feet east of the Klamath River. The boring encountered soft silt to a depth of approximately 5 feet bgs overlying loose silty sand to a depth of about 9 feet bgs. The boring then encountered stiff to very stiff silt to the completion depth of the boring at 101 feet bgs.

Boring B199.6-1 was completed adjacent to the east side of Highway 97, approximately 550 feet east of the Klamath River. Boring B199.6-1 encountered 4 feet of medium dense gravel (road fill) overlying very soft to very stiff elastic silt with various sand content to the completion depth of the boring at approximately 165 feet bgs.

3.3.2.3 BORINGS COMPLETED WITHIN THE KLAMATH RIVER

Boring B199.33-1 was completed approximately 720 feet west of the east bank of the Klamath River. Boring B199.33-1 encountered stiff to very stiff elastic silt to a depth of approximately 90.5 feet bgs with two layers of medium dense silty sand between 16 feet bgs and 19 feet bgs, and between 40.5 feet bgs and 43.5 feet bgs. Below 90.5 feet bgs, the boring encountered decomposed bedrock consisting of dense silty sand to the completion depth of the boring at 91.5 feet bgs.

Boring B199.41-1 was completed approximately 240 feet west of the east bank of the Klamath River. Boring B199.41-1 encountered stiff to very stiff silt to the completion depth of the boring at 91.5 feet bgs.

Boring B199.43-1 was completed approximately 160 feet west of the east bank of the Klamath River. Boring B199.43-1 generally encountered stiff to very stiff elastic silt to a depth of 112 feet bgs overlying siltstone to the completion depth of the boring at approximately 115 feet bgs. RQD value in the siltstone core we obtained was 100 percent.

The subsurface materials encountered in the borings are described in more detail in the boring logs included in Appendix A.

3.3.3 Groundwater Conditions

We did not measure groundwater levels upon completion of the borings because of the presence of drilling fluid in the holes at the time of drilling. We anticipate that groundwater levels will mimic the elevation of the Klamath River around 4,092 feet MSL. We anticipate that groundwater levels will fluctuate with precipitation, site utilization and other factors.

4.0 HDD ENGINEERING ANALYSES

4.1 Hydraulic Fracture and Drilling Fluid Surface Release Evaluation

4.1.1 Model Input Parameters

The HDD geometry used for our analyses of the Klamath River HDD is shown in the HDD Design Drawing in Appendix B. The horizontal length of the HDD is 2,300 feet. The soil units encountered in the vicinity of the HDD are characterized by borings B-1 through B-4, B199.33-1, B199.41-1, B199.43-, and B199.6-1. A general description of the subsurface conditions encountered in the borings is presented in Section 3.3.2, and the boring logs are presented in Appendix A.

Based on the results of the exploration program and subsequent laboratory-testing program, the soil properties used in the evaluation are presented in Table 2 below.

TABLE 2. ESTIMATED SOIL PROPERTIES

Soil Description	Unit Weight (pcf)	Friction Angle (degrees)	Cohesion (psf)
Stiff to Very Stiff Elastic Silt	110	0	500
Stiff Sandy Silt and Clayey Sand	110	10	500
Peat	80	0	100
Siltstone/Sandstone	140	25	4,000-4,200

Notes:

pcf = pounds per cubic foot; psf = pounds per square foot

Based on available information and common HDD construction procedures, the tool dimensions and rheological properties used in the evaluation are summarized in Table 3. Because these parameters are dependent upon the HDD contractor's means and methods, the hydraulic fracture and drilling fluid surface release evaluation should be refined during construction of the HDD installations.

TABLE 3. ESTIMATED TOOL DIMENSIONS AND RHEOLOGICAL PROPERTIES

Parameter	Value
Pilot Hole Bit Diameter	12.25 inches
Drill Pipe Diameter	5.5 inches
Drilling Fluid Weight	9.5 ppg
Plastic Viscosity	10 CP
Yield Point	20 lb/100 sf

Notes:

ppg = pounds per gallon; CP = centipoise; lb/100 sf = pounds per 100 square feet

4.1.2 Discussion of Hydraulic Fracture and Drilling Fluid Surface Release

4.1.2.1 GENERAL

During HDD installation, drilling fluid is transported under pressure through the drill pipe string to the cutting tool. For HDD installations like the Klamath River HDD, pump pressures of several hundred psi and pump rates of 150 to 400 gallons per minute (gpm) are typical. The drilling fluid typically has a specific gravity ranging from 1.1 to 1.2 (approximately 69 to 75 pounds per cubic foot).

The total drilling fluid pressure at the cutting tool is a function of pumping pressures, the elevation difference between the drill rig and the cutting tool and friction losses. Soil and rock formations along the drill path experience maximum drilling fluid pressures in the immediate proximity of the drill bit or reaming tools. The energy (pressure) of the drilling fluid is steadily diminished along its path from the drill rig to the cutting tool and back to the rig through the annulus of the hole. Thus, the pumping pressure required to circulate the drilling fluid increases as the drill bit advances farther from the drill rig. Typically, the annular drilling fluid pressure at the cutting tool can range from 15 to 25 percent of the pump pressure.

4.1.2.2 DRILLING FLUID LOSS

Drilling fluid circulation may be reduced or lost during HDD operations by drilling fluid loss to the surrounding soil or by the accumulation of cuttings downhole that create a blockage, which may result in hydraulic fracture. These two processes are discussed below:

1. Formational fluid loss occurs when drilling fluid flows into surrounding permeable soil units either within the pore spaces of the soil or along preexisting fractures or voids in the formation.
2. Hydraulic fracturing and subsequent loss of drilling fluid can occur where the combined resisting force of the available overburden pressure and the shear strength of the overburden soil is less than the hydrostatic drilling fluid pressure and the pressures applied to the surrounding soil from the drilling fluid at the cutting tool.

Formational drilling fluid losses typically occur when the drilling fluid flows through the pore spaces in the soil through which the HDD profile passes. Thus, a formation with a higher porosity can potentially absorb a larger volume of drilling fluid than a formation with a lower porosity. Silty sands, silts and clays typically have a low susceptibility to formational drilling fluid losses. Coarse sand and gravel units with low percentages of silt and clay have a moderate to high susceptibility for drilling fluid loss. The proper management of the drilling fluid properties can reduce the volume of formational drilling fluid loss.

4.1.2.3 HYDRAULIC FRACTURE

Hydraulic fracture is a term typically used to describe the condition in which the downhole drilling fluid pressure exceeds the overburden pressure and shear strength of the soil surrounding a drill path. Soils that are most vulnerable to hydraulic fracture include relatively weak cohesive soils or loose granular soils with low shear strength. Medium dense to very dense sands and very stiff to hard silts and clays have a low to moderate hydraulic fracture potential. Rock, due to its high shear strength, typically has a low potential for hydraulic fracture. HDD installations with greater depth or drill paths in formations with higher shear strength may reduce the potential for hydraulic fracturing.

4.1.2.4 DRILLING FLUID SURFACE RELEASE

Drilling fluid surface releases, commonly referred to as “Frac-Outs,” occur when drilling fluid emerges at the ground surface or in any other undesired location such as wetlands, utility trenches, basements, roads, railroads, and waterbodies (Photograph 1). In practice, drilling fluid surface releases typically occur in proximity to the entry and exit points where annular pressures are high and soil cover is thin. Drilling fluid surface releases can also occur at locations along a drill path where there are low shear strength soils, where soil cover is relatively thin or along preexisting fractures or voids. Other locations where drilling fluid surface releases can occur are along preferential pathways such as exploratory boring locations, within utility trenches, or along the edges of existing subsurface structures such as piles or utility poles.

The HDD contractor’s construction procedures constitute another important factor influencing when and where drilling fluid loss occurs. If the contractor operates with insufficient drilling fluid flow rates, inadequate drilling fluid properties or excessive rates of penetration, the annulus may become blocked through an accumulation of drill cuttings falling out of suspension. This can occur within formations that typically have a low potential for hydraulic fracture. If the accumulation of cuttings creates a blockage downhole, the annulus may become over-pressurized, leading to hydraulic fracturing and potentially drilling fluid surface releases. Our analysis does not account for this over-pressurized condition.

Photograph 1 - Example of Drilling Fluid Surface Release

4.1.2.5 HYDRAULIC FRACTURE CALCULATIONS

The procedures used to evaluate the potential for drilling fluid loss through hydraulic fracturing are based primarily on research completed by Delft Geotechnics, as discussed in Appendix B of the USACE Report CPAR-GL-98 (Staheli, et al., 1998). The methodologies used to estimate the hydraulic fracture potential outlined in the research are based on cavity expansion theory. The cavity expansion model is used to estimate the maximum effective pressure in the drill hole before plastic deformation of the drill hole occurs.

In order to evaluate the hydraulic fracture and drilling fluid surface releases potential for a HDD installation, assumptions must be made when selecting the input parameters. The assumptions used in the model include the extent and uniformity of soil layers, hydrostatic groundwater pressures, drilling fluid properties, penetration rates and drilling fluid flow rates. The soil strength properties are estimated based on interpretations of the boring logs and laboratory test results. The drilling fluid properties, penetration rates and pump rates are estimated based on generally accepted best management practices (BMPs) of the HDD industry. Consequently, the results of the evaluation are only estimates of the potential for hydraulic fracture and drilling fluid surface releases.

In addition, the drilling fluid properties are dependent on the field conditions and the construction practices of the HDD contractor and drilling fluid engineer. Changes in these properties can significantly affect the potential for hydraulic fracture and drilling fluid surface releases.

Based on the soil properties, rheological parameters and anticipated tool dimensions, the model considers the total and effective overburden stresses, shear strengths of the soil, and the estimated drilling fluid pressures along the drill path. A comparison is then made of the estimated drilling fluid pressures immediately behind the drill bit and the ability of the soil to resist plastic deformation. The evaluation considers only the hydraulic fracture potential during pilot hole operations assuming the drilling fluid returns are continuously maintained to the entry point.

The factor of safety against hydraulic fracturing of the soil surrounding the drill bit is defined as the ratio of the formation limit pressure to the estimated annular drilling fluid pressure. The factor of safety against drilling fluid surface releases is defined as the maximum factor of safety against hydraulic fracture calculated for all of the soil units above specified points along the drill path.

In some cases, the evaluation may indicate a high potential for, or a low factor of safety against, hydraulic fracture in the soils surrounding the drill bit; however, a higher-strength layer may be present above the weaker layer that may reduce the migration of drilling fluid toward the ground surface, thus providing a higher factor of safety against drilling fluid surface releases.

Table 4 below shows the relative risk associated with the estimated factors of safety against hydraulic fracture and drilling fluid surface releases.

TABLE 4. RELATIVE HYDRAULIC FRACTURE AND DRILLING FLUID SURFACE RELEASE RISK

Factor of Safety	Relative Risk
Less than 1	Very High
Between 1 and 1.5	High
Between 1.5 and 2	Moderate
Greater than 2	Low

4.1.3 Results of Hydraulic Fracture and Drilling Fluid Surface Release Evaluation

The results of the hydraulic fracture evaluation are presented in Figures 5 through 7. The formation limit pressure, presented in Figure 5, is the ability of the soil to resist plastic deformation and is a function of the shear strength of the soil through which the HDD profile passes. Based on subsurface conditions encountered in the borings and the HDD design, the proposed HDD profile (from entry to exit) passes through stiff to very stiff elastic silt, stiff silt, sandstone and siltstone. As a result, the formation limit pressure varies depending on the soil and rock encountered along the HDD profile as shown in Figure 5 as the green line. The areas with the higher formation limit pressures are the sandstone and siltstone. The estimated drilling fluid pressure is also shown in Figure 5 as the red line and represents the drilling fluid pressure along the HDD profile based on the anticipated drilling fluid properties shown in Table 3.

When evaluating the risk of hydraulic fracture and drilling fluid surface releases, the analysis computes two types of factors of safety. These are:

- Factor of Safety against localized hydraulic fracture; and
- Factor of Safety against drilling fluid surface release.

Local Hydraulic Fracture: The factor of safety against hydraulic fracture is the ratio of the formation limit pressure to the estimated drilling fluid pressure along the profile, shown as the green line in Figure 6. This represents the factor of safety against hydraulic fracture of the soil immediately surrounding the HDD profile and is a localized condition.

Drilling Fluid Surface Release: The factors of safety against drilling fluid surface release considers the strength of the soil column above the HDD profile that resists drilling fluid migrating to the ground surface. It is computed by comparing the formation limit pressure of the soil units above a specific location along the planned HDD alignment to the anticipated drilling fluid pressure at the same location. The factors of safety against drilling fluid surface releases are shown in Figure 6 at selected points shown as red triangles.

The model indicates that the risks of localized hydraulic fracture and drilling fluid surface release are very low when the HDD profile is located within the sandstone and siltstone bedrock, with calculated factors of safety greater than 9 (see Figure 6). The factors of safety, however, drop significantly when the HDD passes through the elastic silt, silt, lean clay and peat units as shown in Figure 6 between Stations 18+00 through 26+00 (east side river) and 4+00 through 4+25 (close to exit point), indicating a moderate to high risk between these stations. Most importantly, the factors of safety against drilling fluid surface release are greater than 9 (very low risk) along the portion of the HDD path located beneath the Klamath River. We modeled the location where the HDD profile will pass the rock/soil interface at Station 18+00 (about 100 feet east of the river) based on information collected in borings completed at the site; however, the location of this contact is an estimate only and should not be construed as a warranty of where the HDD profile will pass the rock/soil interface.

In general, we consider that the risk of hydraulic fracture and drilling fluid surface release is high within approximately 100 feet of the HDD entry and exit points. This is a result of relatively thin soil cover near the entry and exit points. Near the exit point, the risk is also increased because of the relatively high drilling fluid pressures required to move drilling fluid from the cutting head back to the entry point as the pilot hole nears the exit point.

4.2 Installation Stresses

The analyses of installation loads and stresses are based on the product pipe being installed along the designed path using the BMPs of the HDD industry. The addition of water into the product pipe is the standard method that contractors typically use to control buoyancy of the product pipe during the installation procedure. The proposed 36-inch-diameter product pipe will be positively buoyant in the anticipated drilling fluid weights. Therefore, our analyses include five cases with differing levels of buoyancy and drilling fluid weights.

The five cases analyzed are as follows:

1. The annulus contains 9.5 pounds per gallon (lb/gal) drilling fluid and product pipe is empty.

2. The annulus contains 9.5 lb/gal drilling fluid and product pipe is full of water.
3. The annulus contains 12 lb/gal drilling fluid and product pipe is empty.
4. The annulus contains 12 lb/gal drilling fluid and product pipe is full of water.
5. The annulus contains 10.5 lb/gal drilling fluid and product pipe is filled such that neutral buoyancy is achieved.

The analyses are based upon the methods developed by the PRCI of the American Gas Association (PR-227-9424, 1995). The only deviation from this guide in calculating the installation stresses is a more conservative allowable tensile stress (F_t).

The equation recommended in the PRCI Design Guide is shown in below in **Equation 1**:

F_t = 0.9 *SMYS (Specified Minimum Yield Strength)

The allowable tensile stress used for our analyses is derived from Sections 2.4.1, 3.1.2 and 3.2 of the American Petroleum Institute (API) Recommended Practice 2A – WSD (WSD Recommended Practice 2A-WSD, 1993).

Section 3.2 of the API Recommended Practice defines the allowable tensile stress of cylindrical members as shown below in **Equation 2**:

F_t = 0.6 *SMYS

Sections 2.4.1 and 3.1.2 of the API Recommended Practice permit the allowable tensile stress, defined in Equation 2, to be increased by one-third, yielding a design factor of 0.8, which is more conservative than 0.9 as listed in the PRCI Design Guide.

The equation used in our analyses is shown below in **Equation 3**:

F_t = 0.8 *SMYS

The following table presents a summary of the calculated installation loads for the HDD.

TABLE 5. INSTALLATION LOADS FOR THE 36-INCH-DIAMETER KLAMATH RIVER HDD[1]

Drilling Fluid Weight (lb/gal)	Buoyancy Condition	Effective Pipe Weight[2] (lb/ft)	Pullback Force[3] (lb)
9.5	Empty	-192	345,000
9.5	Full	209	294,000
12	Empty	-324	457,000
12	Full	77	197,000
10.5	Neutral Buoyancy	0	179,000

Notes:

[1] See Appendix B for detailed calculations.

[2] Negative values indicate upward force (positive buoyancy).

[3] Assumes a fully open drilled hole.

4.3 Operating Stresses

The operating stresses on a pipeline installed by directional drilling include hoop stress from the maximum allowable operating pressure (MAOP), hoop stress from external pressure applied by the groundwater acting on the outside of the product pipe, elastic bending as the product pipe conforms to the shape of the drilled hole, and thermal expansion and contraction stresses resulting from the difference between the constructed temperature and the operating temperature. The following table presents a summary of the operating stresses based on the product pipe specifications and the HDD profile as shown on the HDD Design Drawing in Appendix B.

TABLE 6. SUMMARY OF OPERATING STRESSES FOR THE 36-INCH-DIAMETER KLAMATH RIVER HDD*

Stress Component	Stress (psi)	Percent SMYS[1] (%)	Maximum Allowable Percent SMYS (%)
Longitudinal Bending Stress	16,900	24	-
Hoop Stress	34,990	50	50[2]
Longitudinal Tensile Stress from Hoop Stress	10,500	15	-
Longitudinal Stress from Thermal Expansion	-9,500	14	90[3]
Maximum Net Longitudinal Stress	17,900	26	90[4]
Maximum Shear Stress	25,500	36	45[5]
Maximum Combined Effective Stress	50,960	73	90[6]

Notes:

* Operating stress calculations are based on the specified minimum radius of curvature of 2,600 feet and assumed installation and maximum operating temperatures of 50 degrees and 100 degrees Fahrenheit, respectively.

[1] Specified Minimum Yield Strength

[2] Limited by design factor from DOT regulations, Title 49 CFR Part 192.111 for gas.

[3] Limited by Section 402.3.2 of ASME B31.4.

[4] Limited by Section 833.3 of ASME B31.8 for gas.

[5] Limited by Section 402.3.1 of ASME B31.4.

[6] Limited by Section 833.4 of ASME B31.8 for gas.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 HDD Design Considerations and Recommendations

5.1.1 General

The contractor's means and methods during construction are critical to the successful completion of the HDD. Specifically, during pilot hole drilling, only small deviations from the design for horizontal and vertical curvature should be allowed so that pull load forces similar to those estimated by the calculations can be maintained. The HDD contractor's ability to maintain drilling fluid returns, proper drilling fluid properties with appropriate penetration rates, and drilling fluid flow rates will also be important factors to consider during drilling because hole conditions will be directly affected by these operations.

Based on the results of our exploration and analyses, it is our opinion that the proposed Klamath River HDD crossing is constructible; however, differing subsurface conditions were observed between the entry and exit points of the crossing. On the east side of the river, we observed over 160 feet of alluvial soils consisting of stiff to very stiff elastic silt while on the west side of the river we observed sandstone bedrock from depths of approximately 15 feet to the completion depth of the borings at 101 feet. Borings indicate that the contact between the soil and bedrock dips steeply toward the east, particularly between borings B-2 and B199.33-1. The contractor should be prepared to encounter differing subsurface conditions and be prepared to amend drilling procedures and tooling for the differing subsurface conditions. The soil/bedrock interface is discussed further in Section 5.1.4 below.

We recommend that Pacific Gas Connector Pipeline, LP (PCGP, LP) retain a qualified representative to observe and document the drilling process and to advise the project team on areas of concern and recommended actions during drilling activities. We also recommend that PCGP, LP require that a qualified drilling fluid engineer evaluate the drilling fluid properties on a continuous basis during the entire drilling and installation process. Close coordination between the contractor and the drilling fluid technician to maintain proper drilling fluid properties, penetration rates and drilling fluid flow rates will be instrumental to effectively remove cuttings from the pilot hole and reamed hole.

5.1.2 Drill Hole Stability

In general, the alluvial soils and rock encountered by our borings along the proposed HDD alignment present a relatively low risk of hole instability during HDD operations.

5.1.3 Cuttings Removal

Based on our experience, cuttings removal in elastic silt like that encountered by borings completed along the HDD alignment, is typically more challenging than in other non-cohesive soils. In some cases, relatively dry elastic silts may swell and block the drill hole or the high plasticity cuttings may "ball up" forming large diameter particles that fall out of suspension and are more difficult to remove than smaller clay particles that remain in suspension. Therefore, the potential for the hole to become plugged with cuttings is elevated along the proposed HDD crossing where the drill path is within the elastic silt observed in the borings. In the event that the hole becomes plugged, and drilling fluid circulation ceases, downhole annular pressures can increase dramatically. This temporary spike in downhole annular pressure can dramatically increase the risk of hydraulic fracture and drilling fluid surface release. In addition, if cuttings are not effectively removed from the hole during HDD operations, pullback forces could be excessively high during pullback of the 36-inch-diameter product pipe, or the product pipe could become lodged in the hole. The failure to effectively remove cuttings from the hole could potentially result in failure of the HDD installation. Therefore, we recommend that the drilling contractor maintain drilling fluid returns at all times, and use appropriate means and methods (appropriate penetration rates, drilling fluid management, mechanical methods) to ensure that cuttings are adequately removed from the hole during the HDD process.

5.1.4 Soil/Bedrock Interface

During the reaming process, the soil/bedrock interface (estimated to be near Station 18+00) can be a location where an excessive vertical offset (dogleg) in the hole profile can form as a result of the heavy rock hole openers over-mining the bottom portion of the hole. This condition can induce excessive stresses in the downhole tooling, increasing the risk for stuck tooling, a twist-off downhole and stuck pipe during pullback operations. This risk will likely be most pronounced within the entry curve or the first few joints of the bottom tangent of the HDD profile, where we expect that the soil/bedrock interface will be contacted during HDD operations.

Reaming the hole from exit to entry would allow the reamers to pass from rock into soil, which creates less chance for the hole openers to over-mine the bottom of the hole at the interface. If it is suspected that a severe hole offset exists at the soil/bedrock interface, the hole can be reamed to a larger diameter than typically required to allow more annular space for the carrier pipe to conform to the hole and pass through the interface without becoming lodged in the hole. We recommend that the HDD contractor be required to submit with their HDD Work Plan an assessment of the potential for excessive hole offset at the soil/bedrock interface and their proposed mitigation procedures to reduce this risk.

5.1.5 Drilling Fluid Loss and Drilling Fluid Surface Release

It is our opinion that little formational fluid loss should be expected within the subsurface conditions encountered along the crossing. The total volume of formational fluid loss will be small relative to the total volume of fluid required for the project.

The HDD profile was designed to be within the sandstone/siltstone bedrock under the river in order to reduce the risk of drilling fluid releases to the river during HDD operations. Our analysis indicates a moderate to high risk of hydraulic fracture and drilling fluid surface releases while the HDD profile is within the stiff silt alluvium from the entry point (27+00) to approximate Station 18+00. We estimate a low risk of hydraulic fracture and drilling fluid releases within the bedrock from approximate Station 18+00 to 4+25. Then the risk increases to high within 250 feet of the exit point (4+00) as the drill profile emerges from the bedrock and is located with variable overburden soils including peat.

Because of the elevated risk of drilling fluid surface release occurring near the entry and exit points, and between Stations 18+00 and 27+00, and 4+00 and 4+25 during construction, we recommend that the contractor establish a contingency and mitigation plan in the event that drilling fluid surface releases occur; these plans should be reviewed and approved by the project team prior to the start of construction. We recommend the annular drilling fluid pressures be closely monitored during drilling to help identify when the potential for a surface release of drilling fluid may be possible. Annular pressures can be monitored through the use of an annular pressure tool as part of the bottom hole assembly (BHA).

5.1.6 Workspace Considerations

There is not adequate area for a pipe stringing and fabrication workspace on the east side of the proposed HDD. Therefore, the Klamath River HDD can be drilled from the east (entry) side to the west (exit) side so that the stringing area will be to the west. Depending on temporary workspace that can be obtained on the west side of the conceptual HDD, there may be enough linear area for a pipe stringing and fabrication workspace that will allow assembly of a single product pipe string. However, in order to achieve pullback with a single product pipe string, it will need to be curved slightly to the south.

There is adequate area for workspaces at the entry and exit points as shown in Figure 2. Significant grading will not likely be required for the entry and exit workspaces. Near the entry and exit points, it will likely be necessary to provide a stable working platform such as a timber matted or gravel workspace and an entrance road during construction, particularly if construction is completed during the wet season, or when heavy prolonged precipitation occurs. In addition, construction roads will be required to access the entry and exit points and the product pipe stringing area, unless construction is completed during the latter part of the dry summer months when precipitation has not recently occurred and groundwater levels are at their lowest point throughout the year.

5.1.7 Minimum Allowable Product Pipe Bending Radius

The design radii for the entry and exit vertical curves are 3,600 feet. The design radii of the vertical curves were chosen based on the industry standard of the design radii being least 100 times the product pipe diameter in inches (for example, 36-inch-diameter pipe x 100 = 3,600-foot design radius), and to provide a reasonable separation of the design radii and the absolute minimum allowable radius calculated based on the product pipe specifications and the anticipated operating conditions. We recommend that the three-joint radius be calculated for each three-joint section of drill pipe during pilot hole operations. Based on the design geometry, subsurface conditions encountered, and proposed product pipe specifications, the minimum allowable three-joint radius over any consecutive three-joint section of drill pipe should not be less than 2,600 feet.

5.1.8 Pilot Hole Survey

We recommend that a secondary survey system (TruTracker, ParaTrack or equivalent) be used along the entire length of the HDD. If the HDD contractor elects to use the wire coil grids with these secondary survey systems, we recommend that the wire grids be placed at least as wide as the survey probe is deep. The placement of the coils is limited to areas where ground surface conditions and agreements with landowners allow. Conceptual configurations for both TruTracker and ParaTrack setups are shown in the design drawing. However, we recommend that the contractor review the project plans and workspace limitations to determine the most appropriate configuration for the secondary survey system at the time of construction.

For pilot hole operations, we recommend that the HDD contractor drill the pilot hole as closely as possible to the designed HDD profile while still maintaining three-joint horizontal and vertical radii equal to or greater than 2,600 feet. We recommend a horizontal tolerance of 5 feet left and 5 feet right of the designed alignment and a vertical tolerance of 2 feet above and 10 feet below the designed profile. We also recommend that, upon completion of the pilot hole, GeoEngineers have the opportunity to review the pilot hole survey data prior to the start of hole opening operations. The contractor should be responsible for producing an as-built drawing of the pilot hole survey data and providing it to PCGP, LP within 2 weeks of the completion of the pilot hole. This as-built drawing should be kept in the project file for future reference as to the location of the installed pipeline.

5.1.9 Product Pipe Coating Specifications

The proposed product pipe coating specifications provided by PCGP, LP specify a nominal thickness of 8-10 mils of external Fusion Bonded Epoxy (FBE), and 40 mil thick Abrasion Resistant Overlay (ARO). In our opinion, the ARO thickness should be increased to provide added protection for the product pipe during pullback when the product pipe passes through the rock/soil interface.

5.1.10 Installation Load Considerations

For the proposed HDD crossing, we analyzed the anticipated pull loads based upon different drilling fluid weights in the drilled hole and the proposed pipe specifications. We also evaluated the anticipated pull loads based on using or not using buoyancy control. We recommend that the contractor utilize a rig that provides a factor of safety between the rig capacity and the anticipated pull loads. In addition, the contractor should install a deadman anchor of sufficient capacity to withstand the anticipated pull loads; these aspects are generally left to the contractor's discretion as approved by the owner. Based on our analysis of the installation stresses (see Table 6, in Section 4.3), the pullback force may be as high as 457,000 pounds, without the use of some form of buoyancy control and drilling fluid management. The calculations suggest that the pullback force required to install the product pipe may be reduced to approximately 179,000 pounds, if buoyancy control is used and neutral buoyancy is achieved, and drilling fluid weight is properly managed during construction.

5.1.11 Site Access

Access to the entry workspace on the east side of the river can be obtained from a temporary access road across open agricultural land. The access road may reach the entry workspace from either a private drive north of the site or from Highway 97 to the west. The use of traffic control devices, including flaggers along Highway 97 may be necessary to mobilize large equipment into and out of the site.

Access to the workspace on the west side of the river can be obtained from existing access roads on the west side of the river. We do not envision any difficulties with site access to this side of the river.

5.1.12 Water Sources

A reliable source of water for drilling operations is required during the HDD installation process. In addition, water is also required for the hydrostatic testing of the product pipe. Provided permits can be obtained, the HDD contractor may be able to use water from the Klamath River or nearby streams for drilling operations. If local water sources are not available or permissible for access, the water for drilling operations will likely have to be obtained from an approved off-site source and transported to the site.

5.1.13 Noise Mitigation Techniques

The workspace on the east side of the river is located in close proximity (between 300 feet to 400 feet) to a single-family residence. The workspace on the west side of the river is located near an industrial area where noise pollution should not be a concern. The lack of natural ground cover and short distance to the residence on the east side of the river is such that noise suppression may be required during 24-hour operations. If noise suppression is required for permitting, diesel power units associated with heavy equipment may be outfitted with noise reducing mufflers. In addition, the workspace can be muffled by strategically placed baffles to further reduce noise emissions. The actual placement of the noise reduction measures should be implemented by the selected HDD contractor, when necessary.

5.2 Geotechnical Engineering Considerations

5.2.1 Temporary Site Access

If ground disturbance must be reduced to the extent possible, we recommend the construction of temporary access roads to the HDD work areas. The temporary access roads should consist of either board roads or a minimum 12-inch-thick layer of 4-inch-diameter quarry spalls. If soft or wet near surface soils are encountered, these measures may need to be augmented. If board roads are used, several layers of mats may be necessary to provide adequate support for the heavy equipment entering the site. If quarry spalls are used, the quarry spall thickness may need to be increased or a layer of woven geotextile fabric (TC Mirafi 600X or equivalent) or biaxial geogrid (Tensar BX 1200 or equivalent) may be placed below the quarry spalls. The temporary roads should be constructed with culverts and other improvements necessary to allow surface water runoff to drain without ponding or changing off-site drainage patterns.

5.2.2 Temporary Workspace Areas

Temporary work pad areas for staging drilling equipment, pipeline materials and excavation equipment may be necessary at the entry and exit points depending on the conditions at the time of construction. The size and location of workspace areas to accommodate the HDD and pipeline tie-in activities depend on the available space and right-of-way constraints. The proposed temporary entry, exit and product pipe stringing workspaces for the project are shown in Figure 2.

If necessary, we recommend that the workspace areas be protected with either board mats or a minimum 12-inch-thick layer of 4-inch-diameter quarry spalls. If soft or wet near-surface soils are encountered, these measures may need to be augmented. If board mats are used, several layers of mats may be necessary to provide adequate support for the heavy equipment entering the site. If quarry spalls are used, quarry spall thickness may need to be increased or a layer of woven geotextile fabric (TC Mirafi 600X or equivalent) or biaxial geogrid (Tensar BX 1200 or equivalent) may be placed below the quarry spalls. We also recommend placing an additional 2-inch-thick layer of ¾-inch crushed rock on top of the quarry spalls, which should improve the overall site safety and provide a level surface for light-duty vehicles and foot traffic. The temporary work pads should be removed upon completion of the product pipe installation, and the areas should be restored in accordance with the project site restoration plan.

5.2.3 HDD Installation

Drilling fluid containment pits will be required at the drill entry and exit work areas. Depending on the practices of the HDD contractor, drilling fluid containment pit excavations are typically constructed adjacent to the centerline near the entry and exit point locations and are approximately 20 feet long by 10 feet wide by 6 feet deep.

Based on the completed explorations, soil within the planned excavation depths is anticipated to consist of loose gravel, soft peat, soft silt and medium dense sand. Conventional equipment, such as backhoes or excavators, should be suitable for excavation of these soils.

5.2.4 Temporary Excavations

Maintenance of safe working conditions, including temporary excavation stability, is the responsibility of the contractor. All temporary cuts in excess of 4 feet in height should be shored or sloped in accordance with OSHA regulation 1926 Subpart P, Appendix B – Sloping and Benching. For planning purposes, soils encountered within the exploratory borings in the vicinity of the excavation areas should be classified as Type C Soil. Temporary excavations in Type C soil should be inclined no steeper than 1.5H:1V (horizontal to vertical). However, if caving occurs in excavation sidewalls, temporary excavations may need to be laid back to a shallower inclination. These cut slope inclinations are applicable to excavations above the groundwater table only. Dewatering may be required to lower the groundwater table below the base of the excavations. Steeper temporary slope inclinations may be allowed if soil conditions are determined to be suitable by the field geotechnical engineer. For open cuts, we recommend that:

1. No traffic, construction equipment, stockpiles or supplies should be allowed within a distance of at least 5 feet from the top of the cut;
2. Construction activities should be scheduled to reduce the length of time the cuts are left open;
3. Erosion control measures should be implemented as appropriate to limit runoff from the site; and
4. Surface water should be diverted away from the excavations.

5.2.5 Construction Dewatering

The contractor should have the responsibility of determining whether dewatering measures are needed at the time of work. Based on the explorations completed to date, we anticipate that loose gravel, soft peat, soft silt and medium dense sand could be encountered in shallow excavations at entry and exit. Groundwater seepage through low plasticity or granular soils may cause caving, making it difficult to keep the excavations open to the required depths. If granular soils and high groundwater conditions are encountered, the contractor may need to implement a well point or pumping well dewatering system. The construction of low berms around excavations should help reduce the volume of surface water runoff entering the excavations.

The contractor should be prepared to handle the effluent that will be generated during any dewatering operations. The effluent may need to be treated in a settlement tank, sediment trap or basin in order to meet discharge permit requirements for sediment content. Additionally, filter bags or filter socks might be necessary at the end of the outfall pipe or hose to reduce sediment discharge.

5.2.6 Erosion Control

To reduce the potential for migration of sediment off site and into adjacent receiving waters during HDD operations, we recommend that state and local regulations be followed during and after construction operations. Proper BMPs should be implemented in accordance with the PCGP Project's Erosion Control and Revegetation Plan (ECRP).

Potential sources or causes of erosion and sedimentation depend upon construction methods, slope length and gradient, amount of soil exposed and/or disturbed, soil type, construction sequencing and weather. We recommend that the following erosion control measures be included in construction planning:

- Scheduling excavation and construction to minimize soil exposure;
- Retaining existing vegetation whenever feasible;
- Revegetating or mulching denuded areas;
- Directing runoff away from denuded areas;
- Preparing drainage ways and outlets to handle concentrated or increased runoff;

- Using sediment traps/stilling basins/filter socks to collect, detain, and settle sediment from surface water runoff or water pumped from the exit and entry pit excavations;
- Confining sediment to the project site with silt fences and straw bales;
- Inspecting and maintaining control measures frequently;
- Temporarily covering soil stockpiles during construction when necessary;
- Conducting routine inspections of the construction site to ensure effectiveness of the measures and to determine the need for maintenance or additional measures;
- Collecting, containing, and disposing of drilling spoil at a predetermined approved site;
- Re-vegetating all disturbed surfaces to provide erosion protection after construction is complete.

Construction procedures should be designed to minimize the opportunity for erosion to occur. Clearing, excavation, and grading should be limited to those areas necessary for construction of temporary improvements. The construction limits should be clearly marked in the field and equipment should not be allowed outside the work area. Prompt grading, mulching, and revegetation will help to limit erosion.

Silt fences should be constructed around the perimeter of the work areas to reduce the possibility of transport of sediment off site. Straw bales should also be incorporated as necessary to augment the silt fences.

Stockpiles of excavated materials or erodible raw material such as soil, sand, backfill and drill cutting materials should be covered during wet weather and small diversion berms used to prevent stormwater runoff from entering or eroding stockpiles. Excavated soil should be reused as much as possible. After final grading is complete, soil in graded or disturbed areas should be tracked in place with the equipment running perpendicular to slope contours so that the track grouser marks provide a texture to help resist erosion. Any excess material disposed of offsite should be handled in accordance with applicable regulations at authorized disposal facilities.

The drilling fluid containment pits should be configured to reduce the potential of transport of sediment off site. Any excess excavated or drilling materials to be disposed of offsite should be handled in accordance with applicable regulations.

Until permanent erosion protection is established and stabilized, periodic monitoring should be performed to evaluate the effectiveness of post-construction erosion control measures and repair and/or modify them as appropriate. Areas of observed significant erosion should be repaired using an appropriate combination of the methods discussed above.

6.0 LIMITATIONS

We have prepared this report for use by PCGP, LP. GeoEngineers' report is not intended for use by others, and the information contained herein is not applicable to other sites. The data and report should be provided to prospective contractors, but our report, conclusions and interpretations should not be construed as a warranty of the subsurface conditions. The conclusions and recommendations in this report should be applied in their entirety.

Variations in subsurface conditions are possible between the explorations. Subsurface conditions may also vary with time. A contingency for unanticipated conditions should be included in the project budget and schedule for such an occurrence. We recommend that sufficient monitoring, testing and consultation be provided by GeoEngineers during construction to confirm that the conditions encountered are consistent with those indicated by the explorations, to provide recommendations for design changes should the conditions revealed during the work differ from those anticipated, and to evaluate whether earthwork and pipeline installation activities comply with contract plans and specifications.

The scope of our services does not include services related to construction safety precautions. Our recommendations are not intended to direct the contractor's methods, techniques, sequences or procedures, except as specifically described in our report for consideration in design.

Within the limitations of scope, schedule and budget, our services have been executed in accordance with generally accepted practices in this area at the time the report was prepared. No warranty or other conditions, express, written or implied, should be understood.

Please refer to Appendix C, titled "Report Limitations and Guidelines for Use," for additional information pertaining to use of this report.

7.0 REFERENCES

American Petroleum Institute, Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms – Working Stress Design, API Recommended Practice 2A-WSD, July 1, 1993.

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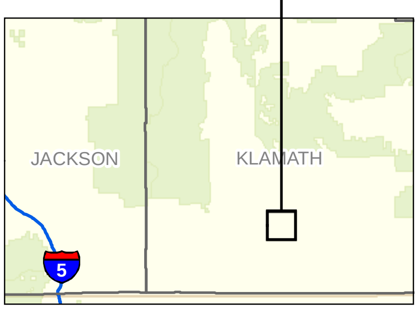

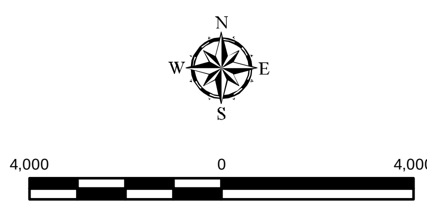

Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.
Data Sources: ESRI Data & Maps, Street Maps 2008.
Base map from ESRI Data Online.
Projection: NAD 1983, UTM Zone 10 North.

Vicinity Map

Klamath River HDD
Klamath County, Oregon

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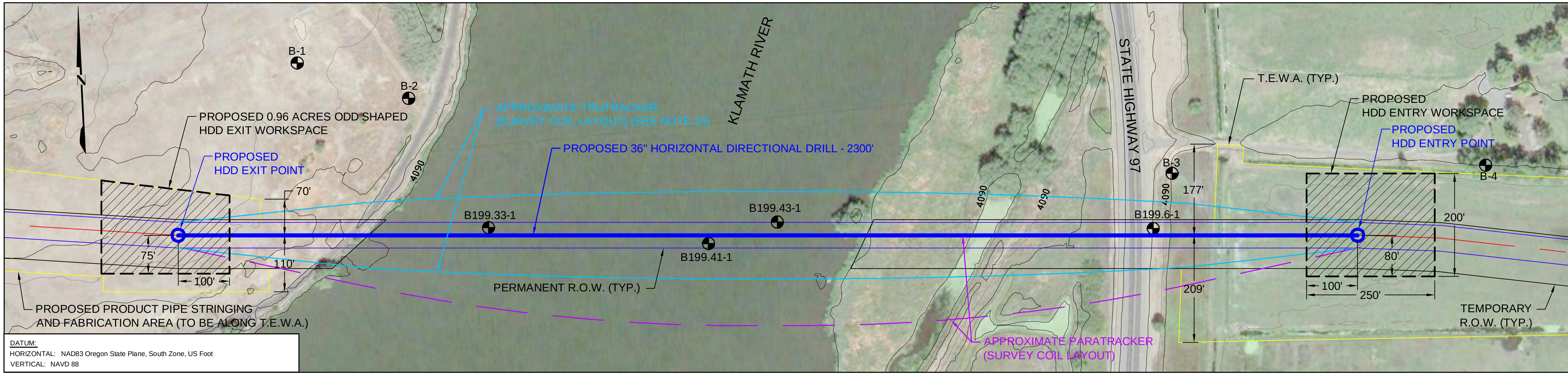
Figure 1

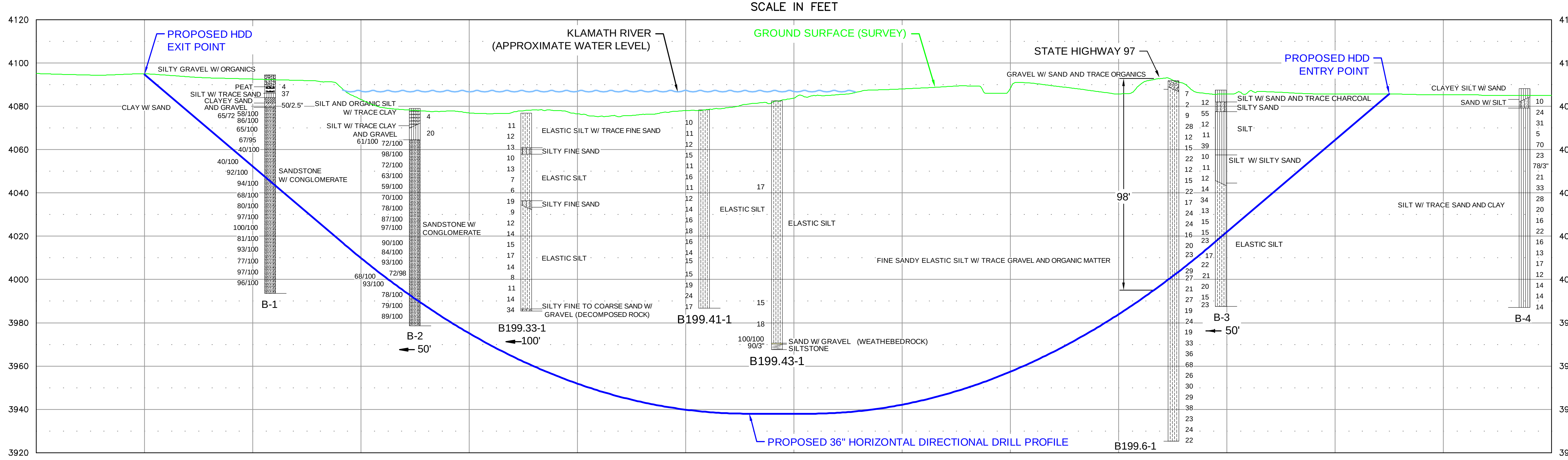
Office: PORT Path: P:\16\16724002\GIS\MXD\Task2_4\1672400200_Tsk400_KlamathHDD_VM.mxd Map Revised: 26 January 2015 ccabrera



PLAN

200' 0 200'

SCALE IN FEET



Notes:

1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.
3. Refer to the boring logs in the accompanying report for more detailed soil descriptions.
4. GeoEngineers, Inc. has not verified the field location of the existing utilities.

Reference: Ground surface survey provided by Pacific Connector Gas Pipeline, LP.
Image taken from Google Earth Pro © 2015, licensed to GeoEngineers, Inc., Image dated 08/26/13.

PROFILE

200' 0 200'

HORIZONTAL SCALE IN FEET

50' 0 50'

VERTICAL SCALE IN FEET

ISSUED FOR PERMIT

LEGEND:

TYPE OF SOIL — SPT (N)

RQD/%REC — TYPE OF ROCK

Boring Location

Major Contour - 10' Interval

Minor Contour - 2' Interval

SITE PLAN AND PROFILE

KLAMATH RIVER HDD
KLAMATH COUNTY, OREGON

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FIGURE 2

AES : RBM

D:\Blakes\16\16724002\Klamath River HDD\Klamath River HDD_IFP_Figure 2.dwg\TAB:Figure 2 modified on Mar 02, 2015 - 8:44am

Entry Looking East Toward Entry Workspace

Looking Northwest at Exit Workspace

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Site Photos
Klamath River HDD

FIGURE 3

RTB: 072114

Looking Northeast from Exit Workspace Towards Klamath River

Looking West Towards Pipe Stringing and Fabrication Workspace

SP:\16742002\00\Working\Task 0300-Coos River HDD\Coos River HDD_Site Photos

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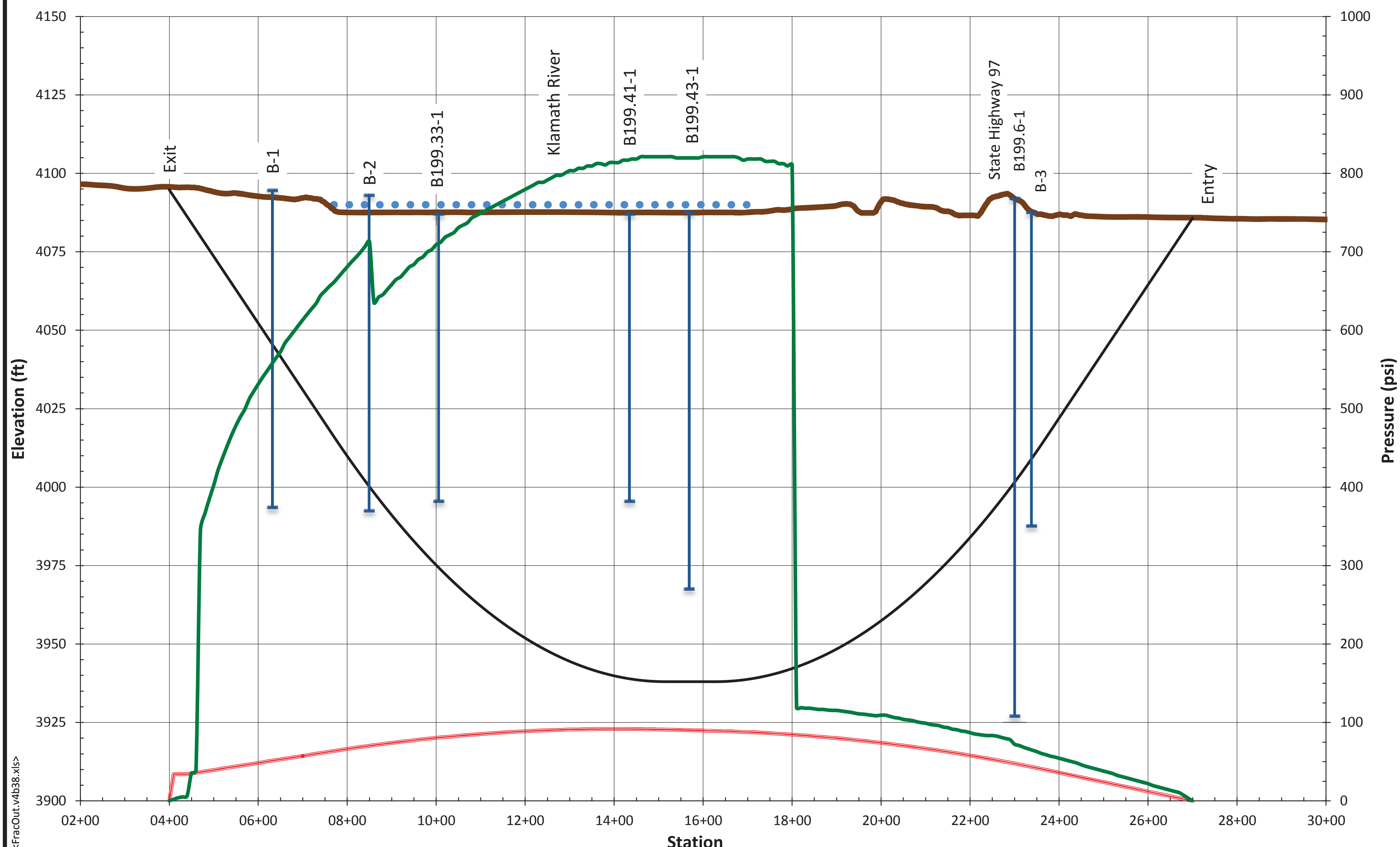
Site Photos
Klamath River HDD

FIGURE 4

PCGP - KLAMATH RIVER HDD - EAST TO WEST



Crossing Length (ft)	2300
Hole Diameter (in)	12.250
Drill Pipe O.D. (in)	5.500
Drilling Fluid Weight (ppg)	9.5
Plastic Viscosity (CP)	10
Yield Point (lb/100 ft)	20

- Ground Surface Elevation (ft)
- HDD Profile (ft)
- Estimated Annular Drilliing Fluid Pressure (psi) for Pilot Hole
- Formation Limit Pressure (psi)

ESTIMATED ANNULAR DRILLING FLUID AND FORMATION LIMIT PRESSURES

PCGP - KLAMATH RIVER HDD - EAST TO WEST

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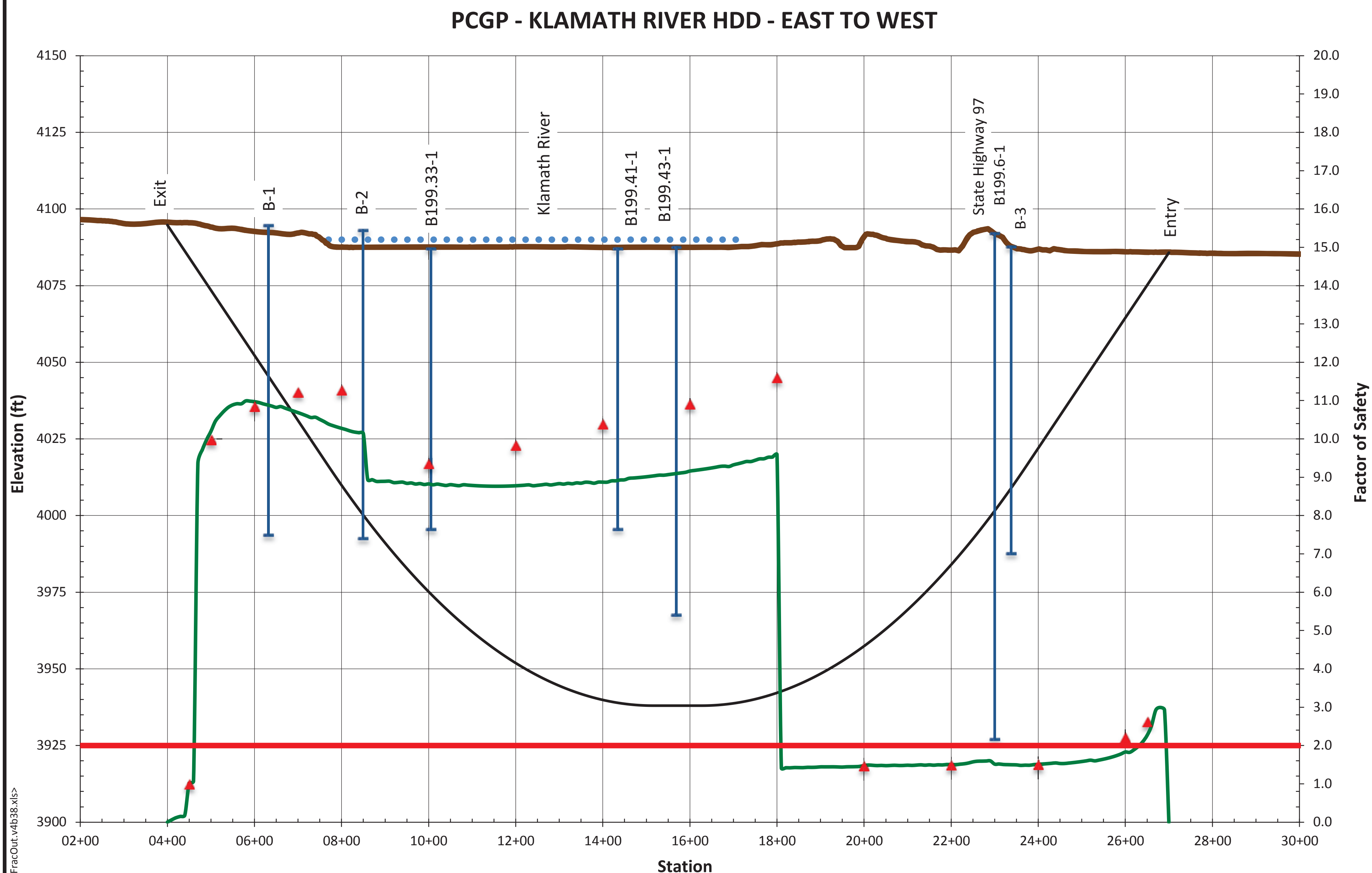
FIGURE 5

16724-002-00 IDB 022715 <FracOut.v4b38.xls>



Crossing Length (ft)	2300
Hole Diameter (in)	12.250
Drill Pipe O.D. (in)	5.500
Drilling Fluid Weight (ppg)	9.5
Plastic Viscosity (CP)	10
Yield Point (lb/100 ft)	20

HYDRAULIC FRACTURE AND DRILLING FLUID SURFACE RELEASE FACTORS OF SAFETY

PCGP - KLAMATH RIVER HDD - EAST TO WEST

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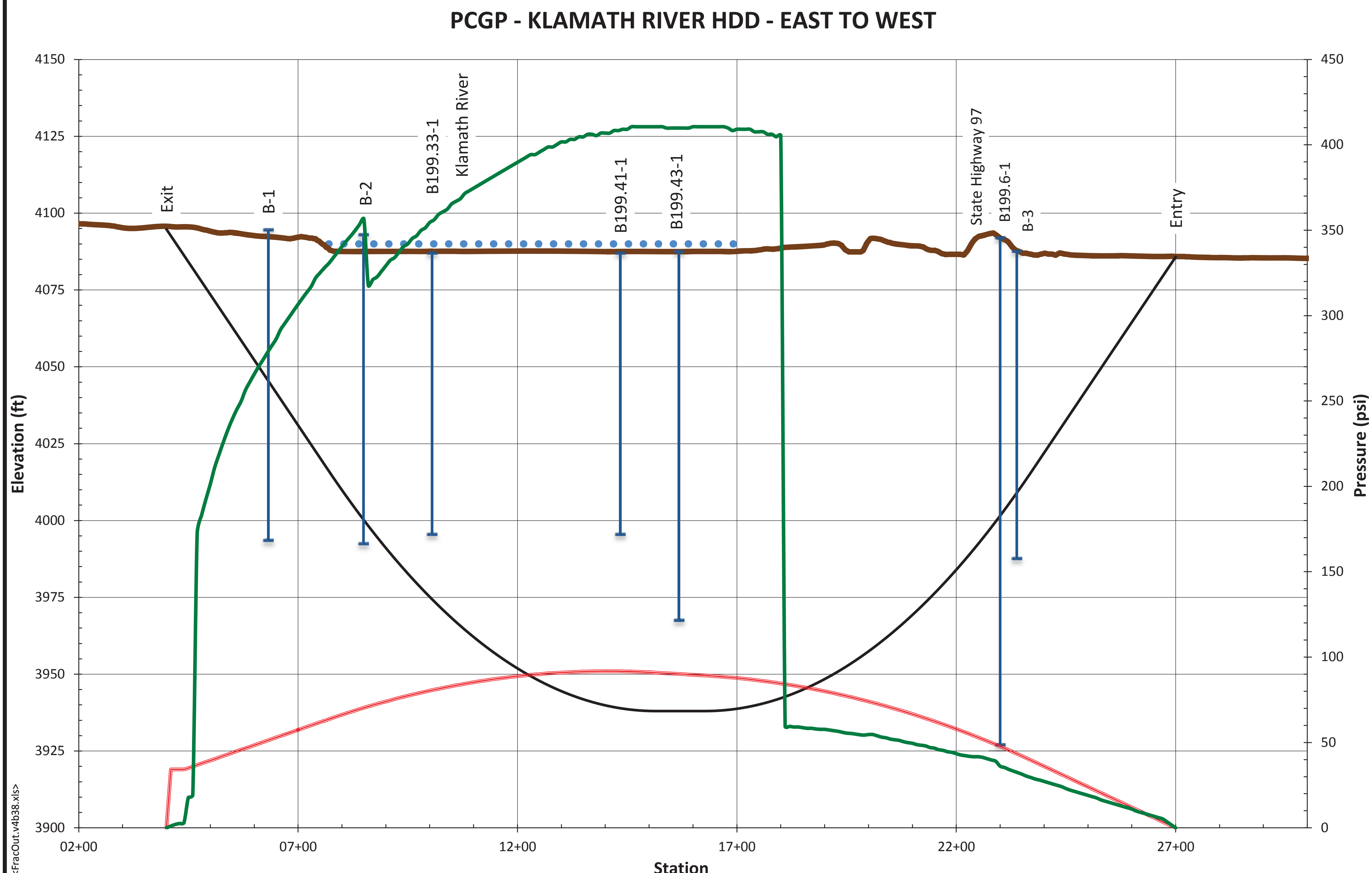
FIGURE 6

16724-002-00 IDB 022715 <FracOut.v4b38.xls>



Crossing Length (ft)	2300
Hole Diameter (in)	12.25
Drill Pipe O.D. (in)	5.500
Drilling Fluid Weight (ppg)	9.5
Plastic Viscosity (CP)	10
Yield Point (lb/100 ft)	20

Ground Surface Elevation (ft)

HDD Profile (ft)

Estimated Annular Drilliing Fluid Pressure (psi) for Pilot Hole

Allowable Drilling Fluid Pressure (psi) for FS=2

ESTIMATED AND ALLOWABLE ANNULAR DRILLING FLUID PRESSURES

PCGP - KLAMATH RIVER HDD - EAST TO WEST

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FIGURE 7

16724-002-00 IDB 022715 <FracOut.v4b38.xls>

APPENDICES

APPENDIX A
Field Explorations and Laboratory-Testing Program

APPENDIX A
FIELD EXPLORATION AND LABORATORY-TESTING PROGRAM

We explored subsurface conditions at the site by drilling a total of eight borings with track-mounted and truck-mounted drill rigs. Borings completed in the river were completed by a truck-mounted drill rig atop a barge platform. Crux Subsurface Inc. of Spokane, Washington and Subsurface Technologies of North Plains, Oregon drilled the borings to depths of up to 165 feet bgs. The borings were drilled using mud rotary and HQ rock coring techniques. Figure 2 shows the approximate boring locations. A representative from our office observed field activities, classified the soil and rock encountered, obtained representative samples, observed groundwater conditions where possible and prepared a log of each exploration. The borings were backfilled with a bentonite and cement grout mixture at the conclusion of each exploration.

Soil samples were obtained by performing SPTs in general accordance with ASTM Test Method D 1586. The sampler was driven with a 140-pound hammer falling 30 inches. The number of blows required to drive the sampler 1 foot, or as otherwise indicated, into the soils is shown adjacent to the sample symbols on the boring logs. Disturbed samples were obtained from the split barrel sampler for subsequent classification and index testing.

When bedrock was encountered in the borings, rock core samples were taken using a HQ-3 rock core barrel mounted to a track-mounted Burley 4000 drill rig and/or Mobile B-57 drill rig. The rock core samples were examined and classified in the field before being transported to our laboratory facilities for testing. RQD values also were measured in the field prior to transport.

Soils encountered in the borings were classified in the field by a GeoEngineers representative in general accordance with ASTM D 2488, the Standard Practice for the Classification of Soils (Visual-Manual Procedure) which is described in Figure A-1. Rock encountered in the borings was classified in general accordance with the ODOT rock classification system (ODOT, 1987), which is described in Figure A-2. The boring logs are presented in Figures A-3 through A-10. Soil classifications and sampling intervals are shown in the boring logs. Inclined lines at the material contacts shown on the log indicate uncertainty as to the exact contact elevation, rather than the inclination of the contact itself.

The relative density of the SPT samples recovered at each interval was evaluated based on correlations with lab and field observations in general accordance with the values outlined in Table A-1 below.

TABLE A-1. CORRELATION BETWEEN BLOW COUNTS AND RELATIVE DENSITY *

Cohesive Soils (Clay/Silt)						
Parameter	Very Soft	Soft	Medium Stiff	Stiff	Very Stiff	Hard
Blows, N	< 2	2 – 4	4 - 8	8 – 16	16 - 32	>32

Cohesionless Soils (Gravel/Sand/Silty Sand) **					
Parameter	Very Loose	Loose	Medium Dense	Dense	Very Dense
Blows, N	0 – 4	4 – 10	10 – 30	30 - 50	> 50

Notes:

*After Terzaghi, K and Peck, R.B., "Soil Mechanics in Engineering Practice," John Wiley & Sons, Inc., 1962.

**Classification applies to soils containing additional constituents; that is, organic clay, silty or clayey sand, etc.

Laboratory Testing

General

Samples obtained from the explorations were transported to our Portland, Oregon laboratory and examined to confirm or modify field classifications, as well as to evaluate engineering properties of the samples. Representative samples were selected for laboratory testing consisting of sieve analysis, Atterberg limits tests, and unconfined compression test. The laboratory-testing procedures are discussed in more detail below.

Sieve Analyses

Sieve analyses were performed on selected coarse-grained samples in general accordance with ASTM D 422. The results of the sieve analyses were plotted and classified in general accordance with the Unified Soil Classification System (USCS) and are presented in Figure A-11. The percentage passing the U.S. No. 200 sieve is shown on the boring logs at the respective sample depths.

Atterberg Limits Testing

Atterberg Limits tests were performed on selected fine-grained soil samples in general accordance with ASTM D 4318. The tests were used to classify the soil as well as to evaluate its index properties. The results of the Atterberg Limits testing are shown in Figures A-12 through A-20.

Percent Fines Determinations

Percent fines determinations were performed on soil samples obtained from the borings. The tests were used to evaluate the relative amounts of coarse and fine grained particles present in the samples and were completed in general accordance with the ASTM D 1140. The results of the testing are presented on the boring logs at their respective sample depths.

Unconfined Compression Test

Unconfined compression (UC) tests were completed on two rock core samples obtained from borings in general accordance with ASTM D 7012-04. The results of these tests are presented on the exploration logs in Figures A-3 and A-4 at the depths at which the samples were obtained.

SOIL CLASSIFICATION CHART

MAJOR DIVISIONS			SYMBOLS GRAPH	SYMBOLS LETTER	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVELS, GRAVEL - SAND MIXTURES
				GP	POORLY-GRADED GRAVELS, GRAVEL - SAND MIXTURES
	MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	SILTY GRAVELS, GRAVEL - SAND - SILT MIXTURES
				GC	CLAYEY GRAVELS, GRAVEL - SAND - CLAY MIXTURES
MORE THAN 50% RETAINED ON NO. 200 SIEVE	SAND AND SANDY SOILS	CLEAN SANDS (LITTLE OR NO FINES)		SW	WELL-GRADED SANDS, GRAVELLY SANDS
				SP	POORLY-GRADED SANDS, GRAVELLY SAND
	MORE THAN 50% OF COARSE FRACTION PASSING NO. 4 SIEVE	SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	SILTY SANDS, SAND - SILT MIXTURES
				SC	CLAYEY SANDS, SAND - CLAY MIXTURES
FINE GRAINED SOILS	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS, ROCK FLOUR, CLAYEY SILTS WITH SLIGHT PLASTICITY
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
MORE THAN 50% PASSING NO. 200 SIEVE	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS SILTY SOILS
				CH	INORGANIC CLAYS OF HIGH PLASTICITY
				OH	ORGANIC CLAYS AND SILTS OF MEDIUM TO HIGH PLASTICITY
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

NOTE: Multiple symbols are used to indicate borderline or dual soil classifications

ADDITIONAL MATERIAL SYMBOLS

SYMBOLS GRAPH	SYMBOLS LETTER	TYPICAL DESCRIPTIONS
	AC	Asphalt Concrete
	CC	Cement Concrete
	CR	Crushed Rock/ Quarry Spalls
	TS	Topsoil/ Forest Duff/Sod

Groundwater Contact

Measured groundwater level in exploration, well, or piezometer

Measured free product in well or piezometer

Graphic Log Contact

Distinct contact between soil strata or geologic units

Approximate location of soil strata change within a geologic soil unit

Material Description Contact

Distinct contact between soil strata or geologic units

Approximate location of soil strata change within a geologic soil unit

Sampler Symbol Descriptions

2.4-inch I.D. split barrel

Standard Penetration Test (SPT)

Shelby tube

Piston

Direct-Push

Bulk or grab

Blowcount is recorded for driven samplers as the number of blows required to advance sampler 12 inches (or distance noted). See exploration log for hammer weight and drop.

A "P" indicates sampler pushed using the weight of the drill rig.

Laboratory / Field Tests

%F Percent fines
AL Atterberg limits
CA Chemical analysis
CP Laboratory compaction test
CS Consolidation test
DS Direct shear
HA Hydrometer analysis
MC Moisture content
MD Moisture content and dry density
OC Organic content
PM Permeability or hydraulic conductivity
PI Plasticity index
PP Pocket penetrometer
PPM Parts per million
SA Sieve analysis
TX Triaxial compression
UC Unconfined compression
VS Vane shear

Sheen Classification

NS No Visible Sheen
SS Slight Sheen
MS Moderate Sheen
HS Heavy Sheen
NT Not Tested

NOTE: The reader must refer to the discussion in the report text and the logs of explorations for a proper understanding of subsurface conditions. Descriptions on the logs apply only at the specific exploration locations and at the time the explorations were made; they are not warranted to be representative of subsurface conditions at other locations or times.

KEY TO EXPLORATION LOGS

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FIGURE A-1

Scale of Relative Rock Weathering (ODOT, 1987)

Designation	Field Identification
Fresh	Crystals are bright. Discontinuities may show some minor surface staining. No discoloration in rock fabric.
Slightly Weathered	Rock mass is generally fresh. Discontinuities are stained and may contain clay. Some discoloration in rock fabric. Decomposition extends up to 1 inch into rock.
Moderately Weathered	Rock mass is decomposed 50% or less. Significant portions of rock show discoloration and weathering effects. Crystals are dull and show visible chemical alteration. Discontinuities are stained and may contain secondary mineral deposits.
Predominantly Decomposed	Rock mass is more than 50% decomposed. Rock can be excavated with geologist's pick. All discontinuities exhibit secondary mineralization. Complete discoloration of rock fabric. Surface of core is friable and usually pitted due to washing out of highly altered minerals by drilling water.
Decomposed	Rock mass is completely decomposed. Original rock "fabric" may be evident. May be reduced to soil with hand pressure.

Scale of Relative Rock Hardness (ODOT, 1987)

Term	Hardness Designation	Field Identification	Approximate Unconfined Compressive Strength
Extremely Soft	R0	Can be indented with difficulty by thumbnail. May be moldable or friable with finger pressure.	< 100 psi
Very Soft	R1	Crumbles under firm blows with point of a geology pick. Can be peeled by a pocket knife. Scratched with fingernail.	100-1000 psi
Soft	R2	Can be peeled by a pocket knife with difficulty. Cannot be scratched with fingernail. Shallow indentation made by firm blow of geology pick.	1000-4000 psi
Medium Hard	R3	Can be scratched by knife or pick. Specimen can be fractured with a single firm blow of hammer/geology pick.	4000-8000 psi
Hard	R4	Can be scratched with knife or pick only with difficulty. Several hard hammer blows required to fracture specimen.	8000-16000 psi
Very Hard	R5	Cannot be scratched by knife or sharp pick. Specimen requires many blows of hammer to fracture or chip. Hammer rebounds after impact.	> 16000 psi

Rock Quality Designation (RQD)

RQD (Percent)	Description of Rock Quality
0 to 25	Very Poor
25 to 50	Poor
50 to 75	Fair
75 to 90	Good
90 to 100	Excellent

RQD is a modified core recovery measurement which expresses the number of hard and sound rock pieces of 4" or more in size as a percentage of the total length of core run.

Discontinuity Spacing (ODOT, 1987)

Description for Bedding, Foliation, or Flow Banding	Spacing	Description of Joints, Faults, or Other Fractures
Very Thickly	>10 feet	Very Widely
Thickly	3-10 feet	Widely
Medium	1-3 feet	Moderately Close
Thinly	2-12 inches	Closely
Very Thinly	< 2 inches	Very Closely

EXPLANATION OF BEDROCK TERMS

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FIGURE A-2

Drilled	Start 6/14/2006	End 6/15/2006	Total Depth (ft) 101	Logged By BCR / Checked By TNH	Driller Crux Drilling	Drilling Method HWT/HQ-3

Surface Elevation (ft) / Vertical Datum	4094.74	Hammer Data: 140 (lbs) / 30 (in) Drop	Drilling Equipment: Burley 4000 Track Rig
Latitude / Longitude	42.17196 / -121.80393	System: Geographic / Datum: WGS84	Groundwater — Date Measured / Depth to Water (ft) / Elevation (ft): Not observed
Notes:			

Elevation (feet)	Depth (feet)	Interval / Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
	0						GM	Brown silty gravel with abundant organics (loose, moist) (fill)			
4090	5	6	1	4							
							PT	Brown peat (very soft, moist to wet)			
4085							ML	Brown with slight orange mottling silt with trace sand (very stiff, moist)			
	10	18	2	37							
							SC	Gray to green clayey sand (medium dense, moist)			
4080							CH	Gray clay with sand and gravel (hard, moist)			
	15	12	3	50/2.5"			SSTN	Gray and green sandstone; medium grained with conglomerate lenses; fresh, medium hard, very closely fractured			
		8.4	1		58						
		43.2	2		65			Moderately close fractured, very strong below 16 feet			
4075	20	48	3		86						
4070								Closely fractured below 23.8 feet			
	25	60	4		65						
								Medium hard below 26.5 feet Very closely fractured between 26.5 and 27.2			
4065	30	62.7	5		67			Moderately close fractured and soft below 30.2 feet Very closely fractured between 31.5 and 32.5 feet	21		UC=2,660 psi
4060	35										

Note: See Figure A-1 for explanation of symbols and Figure A-2 for explanation of rock terms.

Log of Boring B-1

GEOENGINEERS

Project: PCGP-Klamath River HDD
Project Location: Klamath County, Oregon
Project Number: 16724-002-00

Figure A-3
Sheet 1 of 3

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
	35		54	6		40			SSTN	Gray and green sandstone; medium grained with conglomerate lenses; fresh, soft, closely fractured			
										Very closely fractured between 37.5 and 38 feet			
4055	40		60	7		40				Moderately close fractured between 41.8 and 43.4 feet			
4050	45		60	8		92				Very closely fractured between 45 and 45.3 feet Moderately close fractured, medium hard below 45.3 feet			
4045	50		66	9		94				Widely fractured between 50.3 and 54 feet			
4040	55		60	10		68				Closely fractured between 57 and 57.8 feet			
4035	60		60	11		80							
4030	65		60	12		97				Widely fractured below 65.7 feet			
4025	70		60	13		100				Very closely fractured between 70.6 and 71 feet			
4020	75		60	14		81							

Note: See Figure A-1 for explanation of symbols and Figure A-2 for explanation of rock terms.

Log of Boring B-1 (continued)

GeoEngineers

Project: PCGP-Klamath River HDD
Project Location: Klamath County, Oregon
Project Number: 16724-002-00

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
									SSTN	Gray and green sandstone; medium grained with conglomerate lenses; fresh, medium hard, widely fractured			
4015	80		54	15		93							
										Moderately close fractured below 82.6 feet			
4010	85		60	16		77				Widely fractured between 86 and 89 feet			
4005	90		60	17		97				Very closely fractured between 90.6 and 91 feet Widely fractured below 91 feet			
4000	95		60	18		96							
3995	100												

Bottom of hole at 101 feet
Groundwater not determined due to drilling fluid

Note: See Figure A-1 for explanation of symbols and Figure A-2 for explanation of rock terms.

Log of Boring B-1 (continued)

GeoEngineers

Project: PCGP-Klamath River HDD
Project Location: Klamath County, Oregon
Project Number: 16724-002-00

Drilled	Start 6/15/2006	End 6/16/2006	Total Depth (ft)	100.5	Logged By BCR / Checked By TNH	Driller	Crux Drilling	Drilling Method	HWT/HQ-3

Surface Elevation (ft) / Vertical Datum	4093.2	Hammer Data	140 (lbs) / 30 (in) Drop	Drilling Equipment	Burley 4000 Track Rig
Latitude / Longitude	42.17176 / -121.80313	System / Datum	Geographic / WGS84	Groundwater	
Notes:				Date Measured / Depth to Water (ft) / Elevation (ft)	Not observed

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
	0								OL	Brown and gray interbedded silt and organic silt with trace clay (very soft, wet)			
4090													
	5		14	1	4								
4085									ML	Gray silt with trace clay and gravel and organics (very stiff, moist)			
	10		18	2	20								
4080													
	15		100	1		61			SSTN	Dark gray to olive green sandstone; medium grained with conglomerate lenses; slightly weathered, medium hard, closely fractured			
			100	2		72							
4075										Gray below 17 feet			
	20												
			100	3		98							
4070													
	25												
			100	4		72				Fresh below 26 feet			
4065													
	30												
			100	5		63							
4060													
	35												

Note: See Figure A-1 for explanation of symbols and Figure A-2 for explanation of rock terms.

Log of Boring B-2

GEOENGINEERS

Project: PCGP-Klamath River HDD
Project Location: Klamath County, Oregon
Project Number: 16724-002-00

Elevation (feet)	Depth (feet)	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
	35						SSTN	Gray sandstone; medium grained with conglomerate lenses; fresh, medium hard, closely fractured			
		100	6		59						
								Very closely fractured between 36 and 36.5 feet			
4055								Very closely fractured between 38.9 and 39.1 feet			
	40										
		100	7		70						
4050								Moderately close fractured between 42.5 and 44.5 feet			
	45										
		100	8		78						
								Very closely fractured between 46.5 and 47.1 feet			
4045								Very closely fractured between 47.8 and 48 feet			
	50										
		100	9		87						
								Very closely fractured between 52 and 52.3 feet			
4040								Widely fractured below 53 feet			
	55										
		100	10		97				18		UC=5,400 psi
4035											
	60							Closely fractured below 59.5 feet			
		100	11		90			Moderately close fractured below 61 feet; medium hard			
4030											
	65										
		100	12		84						
4025											
	70										
		100	13		93			Widely fractured below 71 feet			
4020											
	75										
		98	14		72						

Note: See Figure A-1 for explanation of symbols and Figure A-2 for explanation of rock terms.

Log of Boring B-2 (continued)

GeoEngineers

Project: PCGP-Klamath River HDD
Project Location: Klamath County, Oregon
Project Number: 16724-002-00

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
4015			100	15		68			SSTN	Gray sandstone; medium grained with conglomerate lenses; fresh, medium hard, widely fractured			
	80		100	16		93							
4010													
	85		100	17		78							
4005													
	90									Very closely fractured between 89.8 and 90 feet			
			90	18		79							
4000										Closely fractured below 93 feet			
	95												
			100	19		89				Very closely fractured between 96 and 96.3 feet			
3995										Very closely fractured between 98.2 and 98.3 feet			
	100												

Bottom of hole at 100.5 feet
Groundwater not determined due to drilling fluid

Note: See Figure A-1 for explanation of symbols and Figure A-2 for explanation of rock terms.

Log of Boring B-2 (continued)

GEOENGINEERS

Project: PCGP-Klamath River HDD
Project Location: Klamath County, Oregon
Project Number: 16724-002-00

Drilled	Start 6/7/2006	End 6/7/2006	Total Depth (ft)	100	Logged By BCR / Checked By TNH	Driller	Crux Drilling	Drilling Method	HWT

Surface Elevation (ft) Vertical Datum	4086.38	Hammer Data	140 (lbs) / 30 (in) Drop
Latitude Longitude	42.17129 -121.79753	System Datum	Geographic WGS84
Drilling Equipment	Burley 4000 Track Rig		
Notes:			

Groundwater

Date Measured	Depth to Water (ft)	Elevation (ft)
	Not observed	

FIELD DATA

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
	0								ML	Light tan silt with occasional fine sand, trace charcoal and organics			
4085													
4080	5		12	1	12				SM	Tan-brown silty fine to coarse sand (medium dense, wet)			
4075	10		12	2	55				ML	Light tan-gray silt (very stiff, moist)			
4070	15		12	3	12					Grades to gray, becomes stiff			
4065	20		18	4	11					Grades to green-gray			
4060	25		6	5	39					Becomes very stiff			
4055	30		18	6	10				ML	Gray silt with interbedded layers of silty fine to coarse sand (stiff, moist)			
	35												

Note: See Figure A-1 for explanation of symbols and Figure A-2 for explanation of rock terms.

Log of Boring B-3

GeoEngineers

Project: PCGP-Klamath River HDD
Project Location: Klamath County, Oregon
Project Number: 16724-002-00

Elevation (feet)	Depth (feet)	Interval Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
4050	35	18	7	11				ML	Gray silt with interbedded layers of silty fine to coarse sand (stiff, moist)			
4045	40	18	8	12								
								MH	Gray elastic silt (stiff, moist)			
4040	45	18	9	14								
4035	50	18	10	34								
4030	55	12	11	13								
4025	60	18	12	15					Light green-gray lean clay (stiff, moist)			
4020	65	18	13	15					Grades to blue gray			
4015	70	18	14	23					Becomes very stiff			
4010	75	18	15	17					Grades to gray and weakly cemented			

Note: See Figure A-1 for explanation of symbols and Figure A-2 for explanation of rock terms.

Log of Boring B-3 (continued)

GeoEngineers

Project: PCGP-Klamath River HDD
Project Location: Klamath County, Oregon
Project Number: 16724-002-00

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
									MH	Gray elastic silt, weakly cemented (very stiff, moist)			
4005	80		18	16	22					Grades to light green-gray and weakly cemented			
4000	85		18	17	21								
3995	90		18	18	20								
3990	95		18	19	15								
			18	20	23								
	100												

Bottom of hole at 100 feet
Groundwater not determined due to drilling fluid

Note: See Figure A-1 for explanation of symbols and Figure A-2 for explanation of rock terms.

Log of Boring B-3 (continued)

GeoEngineers

Project: PCGP-Klamath River HDD
Project Location: Klamath County, Oregon
Project Number: 16724-002-00

Drilled	Start 6/13/2006	End 6/13/2006	Total Depth (ft)	101	Logged By BCR / Checked By TNH	Driller	Crux Drilling	Drilling Method	HWT

Surface Elevation (ft) / Vertical Datum	4088.59	Hammer Data	140 (lbs) / 30 (in) Drop	Drilling Equipment	Burley 4000 Track Rig
Latitude / Longitude	42.17129 / -121.79541	System / Datum	Geographic / WGS84	Groundwater	
Notes:				Date Measured / Depth to Water (ft) / Elevation (ft)	Not observed

FIELD DATA

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
	0								ML	Light brown clayey silt with sand (soft, moist to wet)			
4085													
	5		8	1	10				SM	Dark brown fine to medium sand with trace to some silt (loose, moist to wet)			
4080													
	10		18	2	24				ML	Light brown fine sandy silt (very stiff, moist)			
										Grades to silt with trace sand and clay below 11 feet			
4075													
	15		18	3	31					Becomes dark gray, lack sand and clay below 15 feet			
4070													
	20		18	4	5					Becomes soft			
4065													
	25		18	5	70					Becomes hard with trace clay below 25 feet			
4060													
	30		18	6	23					Becomes very stiff			
										1 inch thick sand seam at 31.3 feet			
4055													
	35												

Note: See Figure A-1 for explanation of symbols and Figure A-2 for explanation of rock terms.

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Log of Boring B-4

GEOENGINEERS

Project: PCGP-Klamath River HDD
Project Location: Klamath County, Oregon
Project Number: 16724-002-00

Figure A-6

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
	35		18	7	78/3"				ML	Dark gray silt (very stiff, moist)			Switch to HQ casing with wireline
4050													
	40		18	8	21								
4045													
	45		18	9	33					With trace clay below 45 feet			
4040													
	50		18	10	30								
4035													
	55		18	11	20								
4030													
	60		18	12	16								
4025													
	65		18	13	22								
4020													
	70		18	14	16								
4015													
	75		18	15	13					Becomes stiff			

FIELD DATA

Note: See Figure A-1 for explanation of symbols and Figure A-2 for explanation of rock terms.

Log of Boring B-4 (continued)

GeoEngineers

Project: PCGP-Klamath River HDD
Project Location: Klamath County, Oregon
Project Number: 16724-002-00

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
4010									ML	Dark gray silt with trace clay (stiff, moist)			
	80		18	16	17					Becomes very stiff			
4005													
	85		18	17	12					Becomes stiff			
4000													
	90		18	18	14					Gray to dark olive green below 90 feet			
3995													
	95		18	19	14					Dark gray below 95 feet			
3990													
	100		12	20	14								

Bottom of hole at 101 feet
Groundwater not determined due to drilling fluid

Note: See Figure A-1 for explanation of symbols and Figure A-2 for explanation of rock terms.

Log of Boring B-4 (continued)

GEOENGINEERS

Project: PCGP-Klamath River HDD
Project Location: Klamath County, Oregon
Project Number: 16724-002-00

Drilled	Start 1/13/2015	End 1/14/2015	Total Depth (ft) 166.5	Logged By IDB / Checked By TNH	Driller Subsurface Technologies	Drilling Method Mud Rotary

Surface Elevation (ft) / Vertical Datum	4086	Hammer Data	140 (lbs) / 30 (in) Drop
Latitude / Longitude	42.17098 / -121.79780	System / Datum	Geographic / WGS84

Drilling Equipment: Diedrich D-50 Truck Mounted Drill Rig

Groundwater — Date Measured | Depth to Water (ft) | Elevation (ft): Not observed

Notes:

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
4085	0								GW	Gray and red mottled well graded gravel with sand and trace organics (medium dense, moist) (fill)			
4080	5		9	7		1			MH	Gray fine sandy elastic silt with trace gravel and organic matter (very soft, wet)			
4075	10		5	2		2 / %F				Becomes soft with increasing sand content	86	67	
										Becomes light gray, stiff and moist			
4070	15		18	9		3 / AL				Becomes light brown	152		AL; PI = 80
4065	20		18	28		4				Becomes gray and very stiff			
4060	25		18	12		5				Becomes stiff			
4055	30		18	15		6				With trace sand			
	35												

Note: See Figure A-1 for explanation of symbols and Figure A-2 for explanation of rock terms.

Log of Boring B199.6-1

GeoEngineers

Project: PCGP-Klamath River HDD
Project Location: Klamath County, Oregon
Project Number: 16724-002-00

Elevation (feet)	Depth (feet)	Recovered (in)	Blows/foot	Sample Name / Testing	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
4050	35	18	22	7	MH	Gray fine sandy elastic silt with trace gravel, trace sand and organic matter (very stiff, wet)			
4045	40	18	12	8		Becomes stiff			
4040	45	18	15	9					
4035	50	18	22	10		Becomes very stiff			
4030	55	18	17	11					
4025	60	18	24	12					
4020	65	18	24	13					
4015	70	18	16	14 / AL		Beomes green-gray	181		AL; PI = 57
4010	75	18	20	15					

Note: See Figure A-1 for explanation of symbols and Figure A-2 for explanation of rock terms.

Log of Boring B199.6-1 (continued)

GeoEngineers

Project: PCGP-Klamath River HDD
Project Location: Klamath County, Oregon
Project Number: 16724-002-00

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
									MH	Green-gray fine elastic silt with trace gravel, trace sand and organic matter (very stiff, wet)			
4005	80		18	23		16							
4000	85		18	29		17 / %F				With trace fine sand	149	96	
3995	90		18	27		18							
3990	95		18	21		19				Greenish gray 2.5 inch thick sand seam			
3985	100		18	27		20							
3980	105		18	19		21							
3975	110		18	24		22							
3970	115		18	19		23							

Note: See Figure A-1 for explanation of symbols and Figure A-2 for explanation of rock terms.

Log of Boring B199.6-1 (continued)

GeoEngineers

Project: PCGP-Klamath River HDD
Project Location: Klamath County, Oregon
Project Number: 16724-002-00

Elevation (feet)	Depth (feet)	Interval / Recovered (in)	Blows/foot	Collected Sample / Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
							MH	Green-gray elastic silt with trace gravel, trace fine sand and organic matter (very stiff, wet)			
3965	120	18	33	24				Becomes gray			
3960	125	18	36	25 / AL				Becomes hard	94		AL; PI = 62
3955	130	18	68	26							
								Becomes green and very stiff			
3950	135	18	26	27							
3945	140	18	30	28 / AL				With trace sand	148		AL; PI = 49
3940	145	18	29	29							
3935	150	18	38	30				Becomes hard and lacks sand			
3930	155	18	23	31				Becomes gray and very stiff			
	160										

Note: See Figure A-1 for explanation of symbols and Figure A-2 for explanation of rock terms.

Log of Boring B199.6-1 (continued)

GEOENGINEERS

Project: PCGP-Klamath River HDD
Project Location: Klamath County, Oregon
Project Number: 16724-002-00

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
3925			18	24		32 / AL			MH	Gray elastic silt with trace gravel and organic matter (very stiff, wet)	132		AL; PI = 64
3920	165		18	22		33							

Note: See Figure A-1 for explanation of symbols and Figure A-2 for explanation of rock terms.

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Log of Boring B199.6-1 (continued)

GEOENGINEERS

Project: PCGP-Klamath River HDD
Project Location: Klamath County, Oregon
Project Number: 16724-002-00

Drilled	Start 7/29/2014	End 7/30/2014	Total Depth (ft)	91.5	Logged By IDB Checked By BCR	Driller	Subsurface Technologies	Drilling Method	Mud Rotary

Surface Elevation (ft) Vertical Datum	4077	Hammer Data	140 (lbs) / 30 (in) Drop	Drilling Equipment	Mobile B-57 Truck Mounted
Latitude Longitude	42.17106 -121.80258	System Datum	Geographic WGS84	Groundwater	
Notes:				Date Measured / Depth to Water (ft) / Elevation (ft)	Not observed

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
	0								MH	Gray and brown mottled elastic silt with trace fine sand (stiff, moist)			
4075													
4070	5		18	11		1 AL					144		AL; LL = 179, PI = 89
4065	10		18	12		2							
4060	15		18	13		3 AL					161		AL; LL = 170, PI = 80
									SM	Gray silty fine sand (medium dense, moist)			
									MH	Greenish gray elastic silt (stiff, moist)			
4055	20		18	10		4 AL					168		AL; LL = 187, PI = 71
4050	25		18	13		5							
4045	30		18	7		6 AL				Becomes medium stiff with trace fine sand	160		AL; LL = 175, PI = 85
	35												

Note: See Figure A-1 for explanation of symbols and Figure A-2 for explanation of rock terms.

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Log of Boring B199.33-1

GeoEngineers

Project: PCGP-Klamath River HDD
Project Location: Klamath County, Oregon
Project Number: 16724-002-00

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
	35		18	6		7			MH	Greenish gray elastic silt with trace fine sand (medium stiff, moist)			
4040													
	40		18	19		8 / AL					154		AL; LL = 206, PI = 99
									SM	Gray and light gray mottled silty fine sand (medium dense, moist)			
4035													
									MH	Gray and brown mottled elastic silt (stiff, moist)			
	45		18	9		9 / AL					164		AL; LL = 197, PI = 91
4030													
	50		18	12		10 / AL					149		AL; LL = 187, PI = 80
4025													
	55		18	14		11							
4020													
	60		18	15		12 / AL					146		AL; LL = 200, PI = 111
4015													
	65		18	17		13				Becomes very stiff and greenish gray			
4010													
	70		18	14		14 / AL				Becomes stiff	177		AL; LL = 246, PI = 130
4005													
	75		18	8		15							

Note: See Figure A-1 for explanation of symbols and Figure A-2 for explanation of rock terms.

Log of Boring B199.33-1 (continued)

GeoEngineers

Project: PCGP-Klamath River HDD
Project Location: Klamath County, Oregon
Project Number: 16724-002-00

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
4000									MH	Gray and brown mottled elastic silt (stiff, moist)			
	80		18	11		16 / AL					243		AL; LL = 300, PI = 117
3995													
	85		18	14		17 / AL					287		AL; LL = 329, PI = 178
3990													
	90		10	34		18 / SA					64		SA; %F = 18 %Gravel = 28
									SM	Dark gray silty fine to coarse sand with gravel (decomposed rock) (dense, moist)			

Note: See Figure A-1 for explanation of symbols and Figure A-2 for explanation of rock terms.

Log of Boring B199.33-1 (continued)

GEOENGINEERS

Project: PCGP-Klamath River HDD
Project Location: Klamath County, Oregon
Project Number: 16724-002-00

Drilled	Start 7/30/2014	End 7/31/2014	Total Depth (ft) 91.5	Logged By IDB / Checked By BCR	Driller: Subsurface Technologies	Drilling Method: Mud Rotary

Surface Elevation (ft) / Vertical Datum	4078	Hammer Data	140 (lbs) / 30 (in) Drop
Latitude / Longitude	42.17095 / -121.80100	System / Datum	Geographic / WGS84
Drilling Equipment	Mobile B-57 Truck Mounted		
Notes:			

Groundwater

Date Measured	Depth to Water (ft)	Elevation (ft)
	Not observed	

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
	0								MH	Gray and brown mottled elastic silt (stiff, moist)			
4075													
	5		18	10		1 / AL					174		AL; LL = 193, PI = 89
4070													
	10		18	11		2 / AL					138		AL; LL = 171, PI = 84
4065													
	15		18	12		3							
4060										Becomes greenish gray			
	20		18	15		4							
4055													
	25		18	11		5 / AL					165		AL; LL = 176, PI = 78
4050										Becomes very stiff and brown			
	30		18	16		6				Becomes greenish gray			
4045													
	35												

Note: See Figure A-1 for explanation of symbols and Figure A-2 for explanation of rock terms.

Log of Boring B199.41-1

GeoEngineers

Project: PCGP-Klamath River HDD
Project Location: Klamath County, Oregon
Project Number: 16724-002-00

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
	35		18	11		7 / AL			MH	Gray-brown elastic silt (stiff, moist)	133		AL; LL = 160, PI = 79
4040													
	40		18	12		8 / AL					134		AL; LL = 164, PI = 69
4035													
	45		18	14		9							
4030													
	50		18	16		10				Becomes very stiff			
4025													
	55		18	18		11 / AL					139		AL; LL = 159, PI = 69
4020													
	60		18	16		12							
4015													
	65		18	14		13 / AL				Becomes stiff	144		AL; LL = 182, PI = 91
4010													
	70		18	15		14				Becomes greenish gray			
4005													
	75		18	15		15 / AL				With trace fine sand	148		AL; LL = 181, PI = 92

Note: See Figure A-1 for explanation of symbols and Figure A-2 for explanation of rock terms.

Log of Boring B199.41-1 (continued)

GeoEngineers

Project: PCGP-Klamath River HDD
Project Location: Klamath County, Oregon
Project Number: 16724-002-00

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
4000									MH	Greenish gray elastic silt with trace fine sand (stiff, moist)			
	80		16	19		16				Becomes very stiff			
3995													
	85		16	24		17 / AL				Lacks sand	157		AL; LL =191 , PI = 75
3990													
	90		16	17		18				With trace fine sand			

Note: See Figure A-1 for explanation of symbols and Figure A-2 for explanation of rock terms.

Log of Boring B199.41-1 (continued)

GEOENGINEERS

Project: PCGP-Klamath River HDD
Project Location: Klamath County, Oregon
Project Number: 16724-002-00

Drilled	Start 11/11/2014	End 11/11/2014	Total Depth (ft) 115	Logged By MK / Checked By TNH	Driller Subsurface Technologies	Drilling Method Mud Rotary/Wireline

Surface Elevation (ft) / Vertical Datum	4082	Hammer Data	140 (lbs) / 30 (in) Drop
Drilling Equipment	Mobile B-57 Truck Mounted		
Latitude / Longitude	42.17106 / -121.80050	System / Datum	Geographic / WGS84
Notes:			

Groundwater

Date Measured	Depth to Water (ft)	Elevation (ft)
	Not observed	

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
	0								MH	Greenish gray elastic silt (very stiff, moist)			Soil description from 0 to 42 feet based on visual observation of cuttings
4080													
	5												
4075													
	10												
4070													
	15												
4065													
	20												
4060													
	25												
4055													
	30												
4050													
	35												

Note: See Figure A-1 for explanation of symbols and Figure A-2 for explanation of rock terms.

Log of Boring B199.43-1

GEOENGINEERS

Project: PCGP-Klamath River HDD
Project Location: Klamath County, Oregon
Project Number: 16724-002-00

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
	35								MH	Greenish gray elastic silt (very stiff, moist)			
4045													
	40												
4040				1	17						152		AL; PI = 80
													Soil description from 43.5 to 92 feet based on visual observation of cuttings
	45												
4035													
	50												
4030													
	55												
4025													
	60												
4020													
	65												
4015													
	70												
4010													
	75												

Note: See Figure A-1 for explanation of symbols and Figure A-2 for explanation of rock terms.

Log of Boring B199.43-1 (continued)

GeoEngineers

Project: PCGP-Klamath River HDD
Project Location: Klamath County, Oregon
Project Number: 16724-002-00

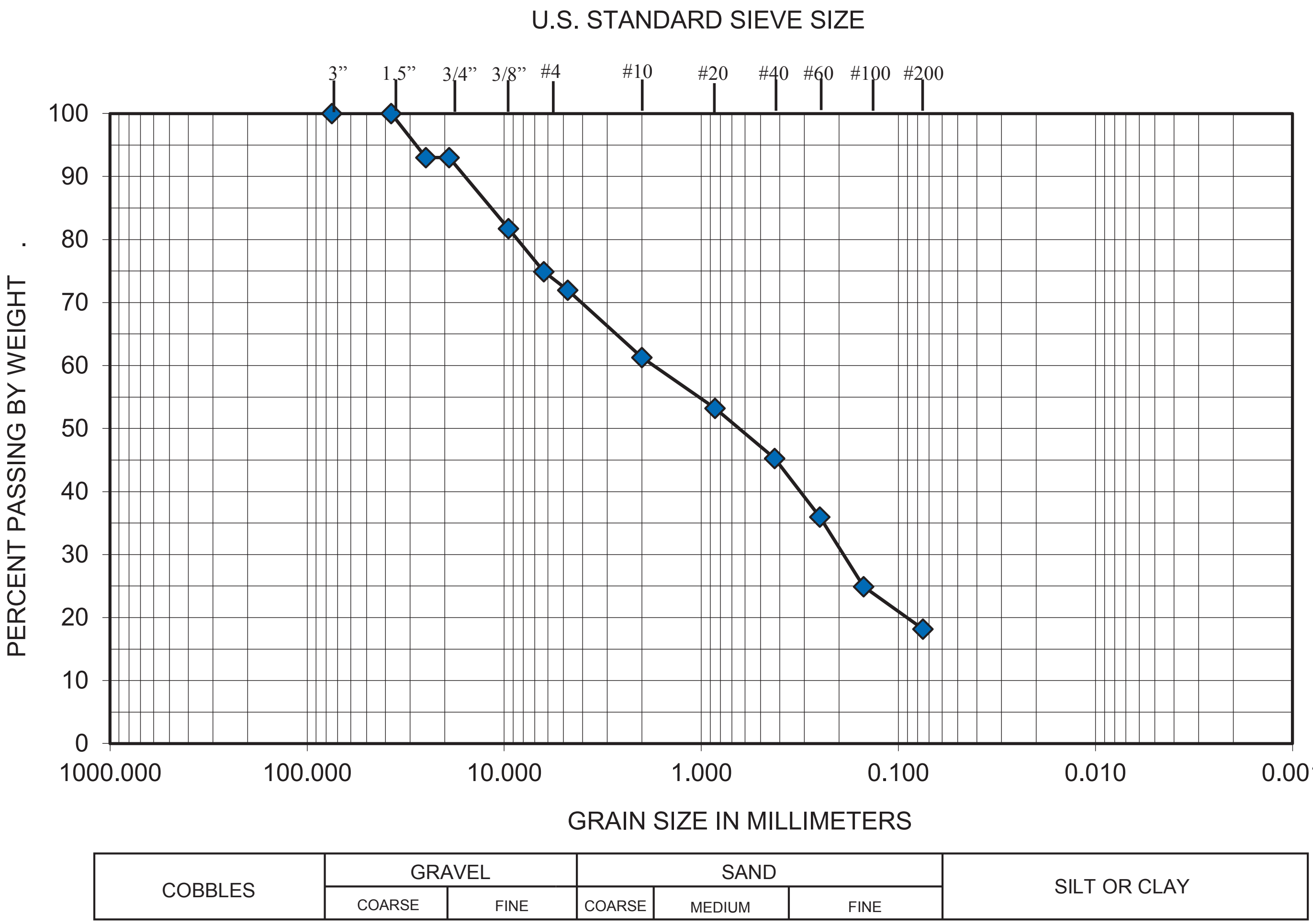
Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
4005									MH	Greenish gray elastic silt (very stiff, moist)			
	80												
4000													
	85												
3995													
	90												
3990			18	2	15					Becomes stiff	148		AL; PI = 49 Soil description from 93.5 to 102 feet based on visual observation of cuttings
	95												
3985													
	100												
3980				3	18					Becomes grayish green (very stiff, dry to moist)			Soil description from 103.5 to 112 feet based on visual observation of cuttings
	105												
3975													
	110												
3970			3	4	90/3"				SP	Black medium sand with gravel (very dense, moist) (weathered bedrock)			
			100	R1		100			SLST	Dark gray siltstone; fresh, medium hard, closely fractured			
	115												

Note: See Figure A-1 for explanation of symbols and Figure A-2 for explanation of rock terms.

Log of Boring B199.43-1 (continued)

GeoEngineers

Project: PCGP-Klamath River HDD
Project Location: Klamath County, Oregon
Project Number: 16724-002-00



Symbol	Sample ID	Sample Depth (feet)	Moisture Content (%)	Gravel (%)	Sand (%)	Fines (%)	USCS	Soil Description
◆	B4-1 S-18	90	64	28	54	18	SM	Silty fine to coarse sand with gravel

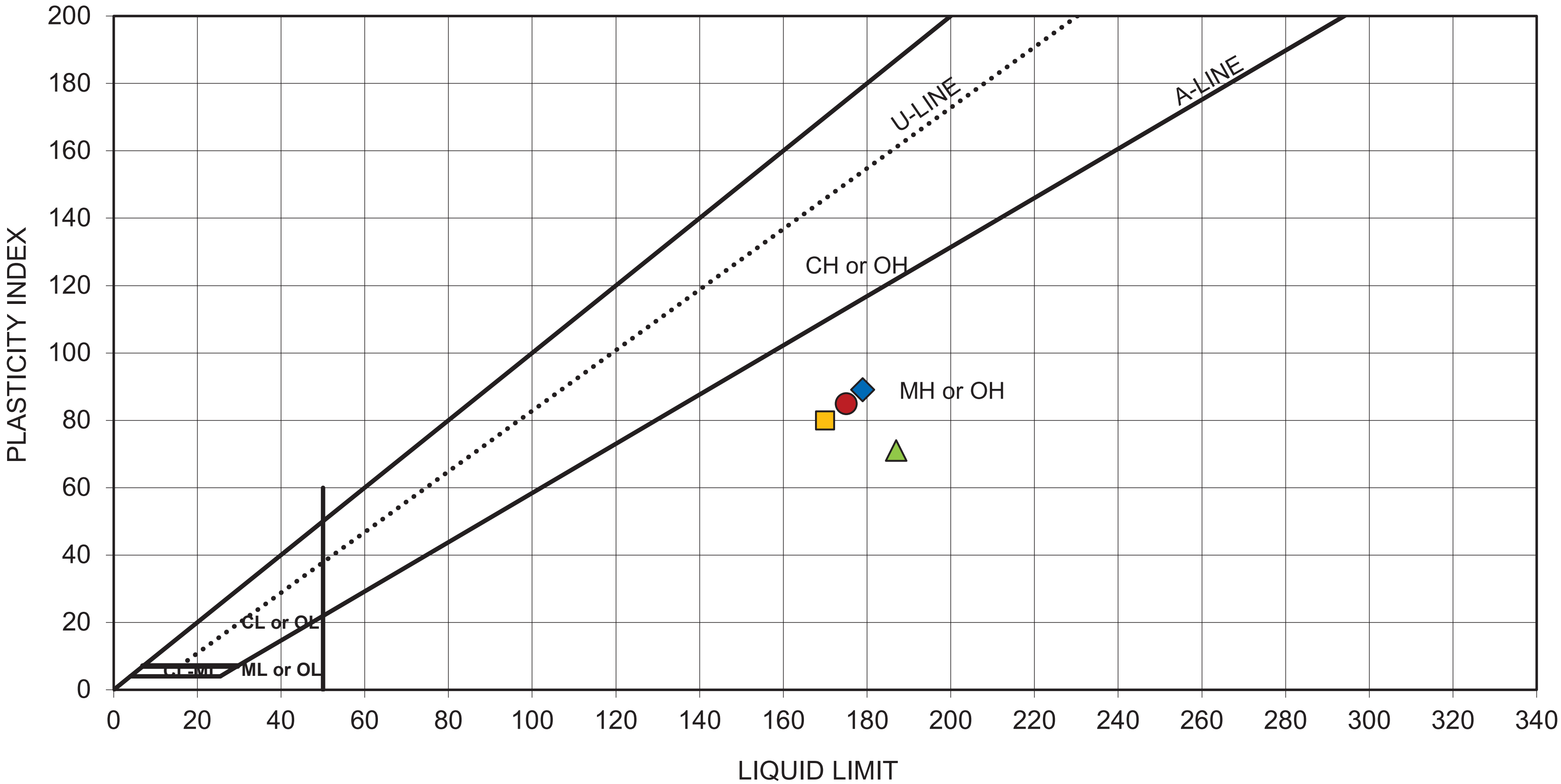
Sieve Analysis Results

PCGP – Klamath River HDD
Klamath County, Oregon

GeoEngineers

Figure A-11

PLASTICITY CHART



Symbol	Sample ID	Sample Depth (feet)	Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	USCS	Soil Description
◆	B199.33-1 S-1	5	144	179	89	MH	Elastic silt
■	B199.33-1 S-3	15	161	170	80	MH	Elastic silt
▲	B199.33-1 S-4	20	168	187	71	MH	Elastic silt
●	B199.33-1 S-6	30	160	175	85	MH	Elastic silt

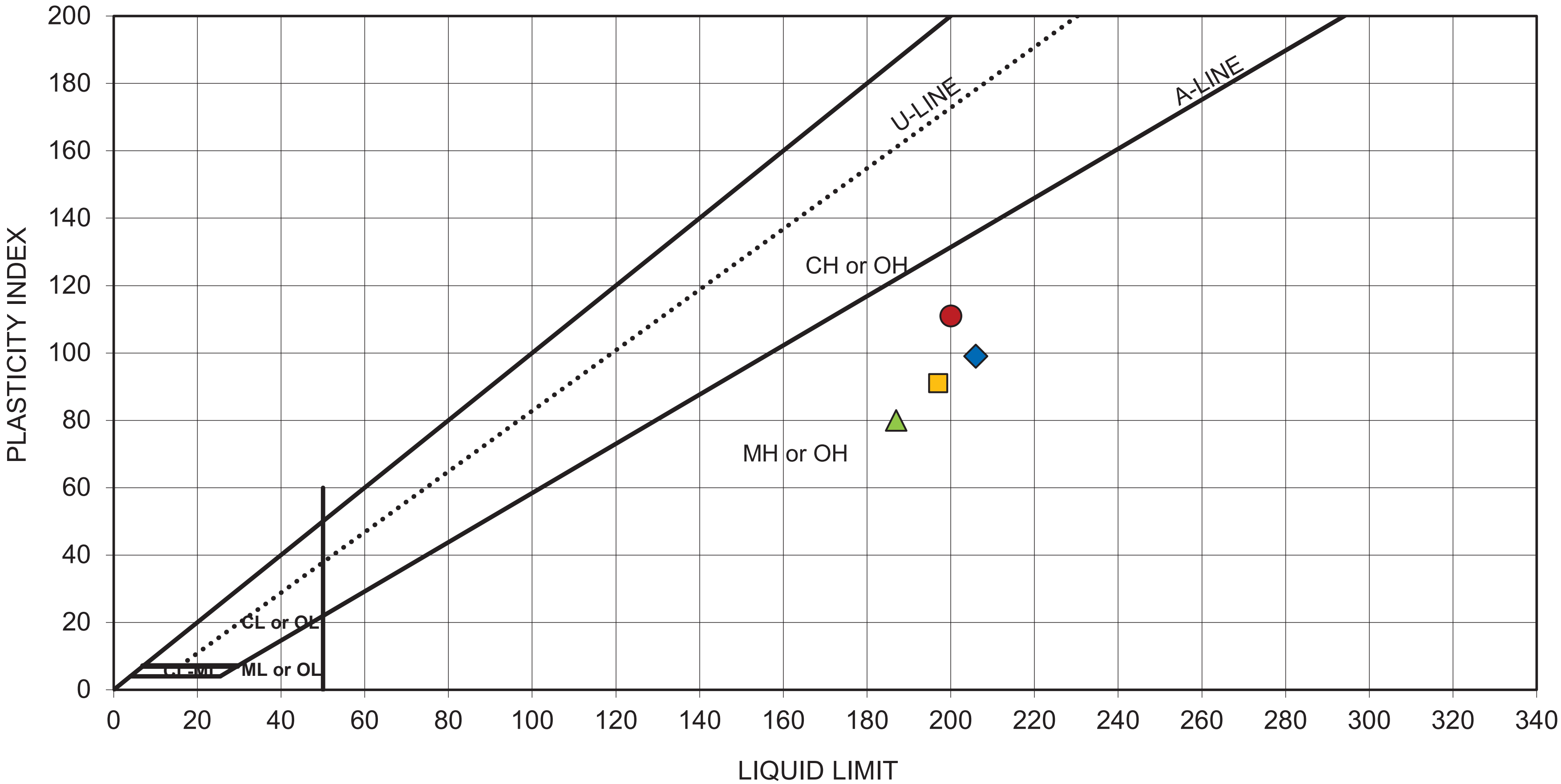
Atterberg Limits Test Results

PCGP – Klamath River HDD
Klamath County, Oregon

GeoEngineers

Figure A - 12

PLASTICITY CHART



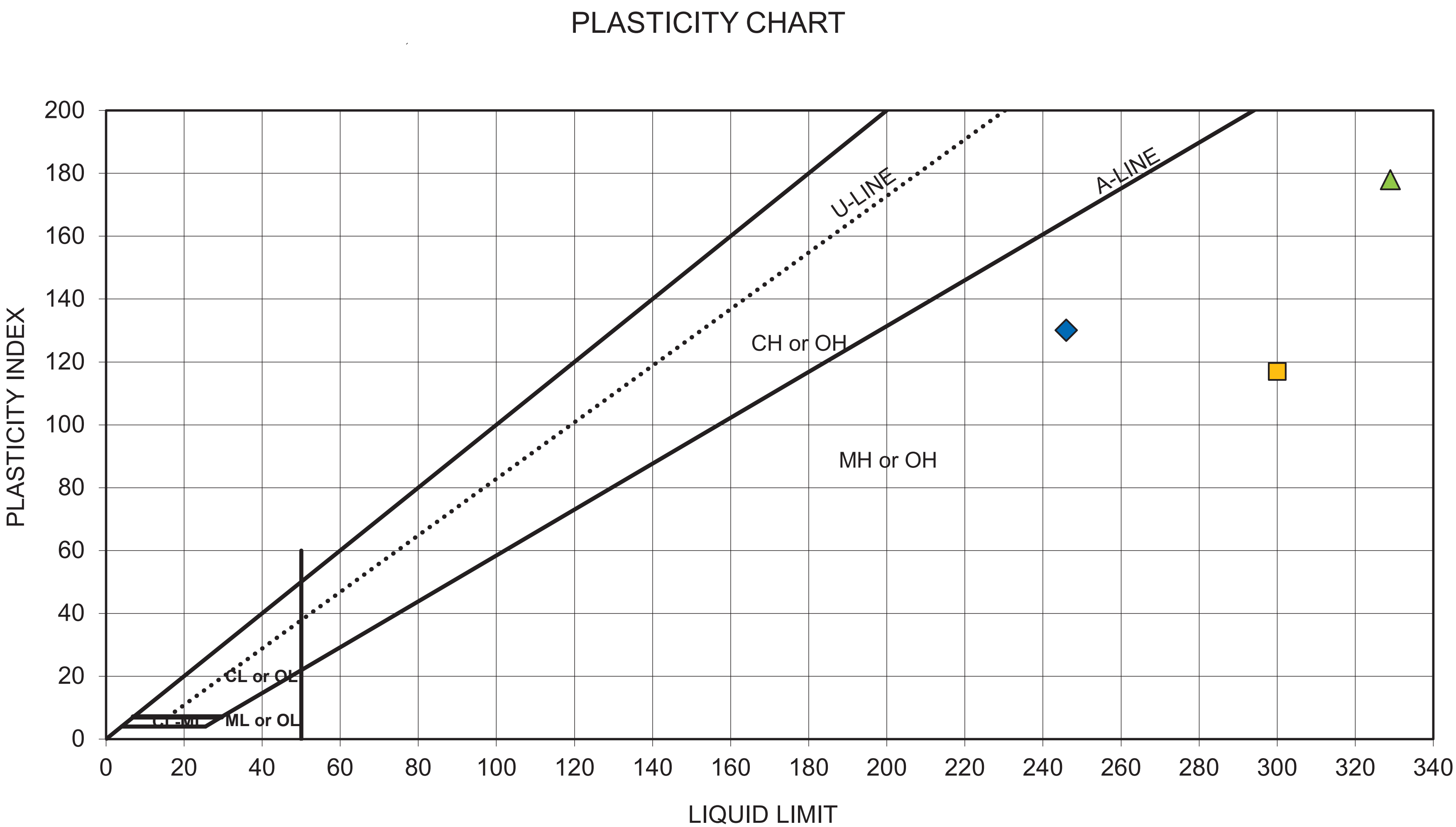
Symbol	Sample ID	Sample Depth (feet)	Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	USCS	Soil Description
◆	B199.33-1 S-8	40	154	206	99	MH	Elastic silt
■	B199.33-1 S-9	45	164	197	91	MH	Elastic silt
▲	B199.33-1 S-10	50	149	187	80	MH	Elastic silt
●	B199.33-1 S-12	60	146	200	111	MH	Elastic silt

Atterberg Limits Test Results

PCGP – Klamath River HDD
Klamath County, Oregon

GeoEngineers

Figure A - 13



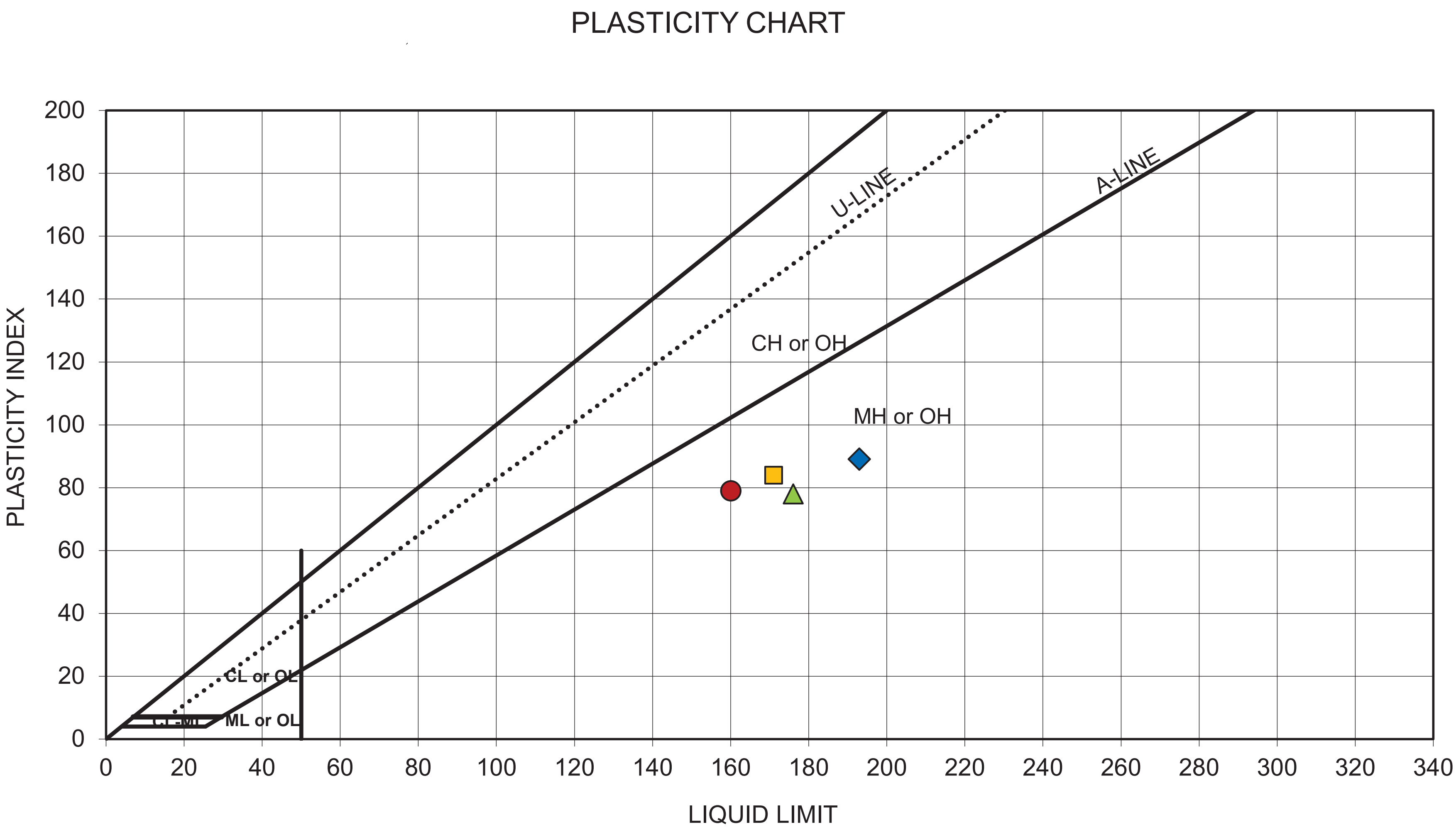
Symbol	Sample ID	Sample Depth (feet)	Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	USCS	Soil Description
◆	B199.33-1 S-14	70	177	246	130	MH	Elastic silt
■	B199.33-1 S-16	80	243	300	117	MH	Elastic silt
▲	B199.33-1 S-17	85	287	329	178	MH	Elastic silt

Atterberg Limits Test Results

PCGP – Klamath River HDD
Klamath County, Oregon

GEOENGINEERS

Figure A - 14



Symbol	Sample ID	Sample Depth (feet)	Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	USCS	Soil Description
◆	B199.41-1 S-1	5	174	193	89	MH	Elastic silt
■	B199.41-1 S-2	10	138	171	84	MH	Elastic silt
▲	B199.41-1 S-5	25	165	176	78	MH	Elastic silt
●	B199.41-1 S-7	35	133	160	79	MH	Elastic silt

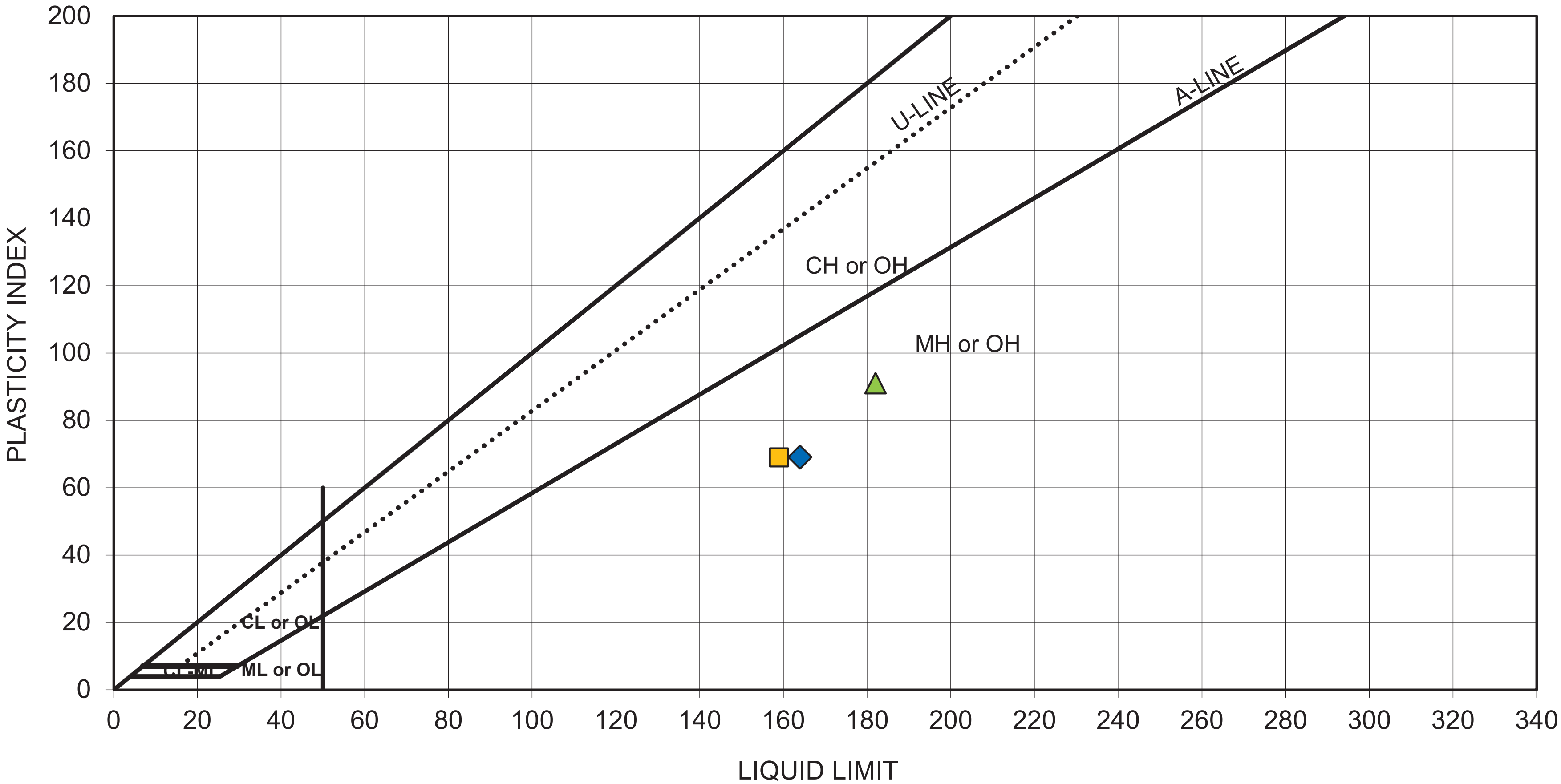
Atterberg Limits Test Results

PCGP – Klamath River HDD
Klamath County, Oregon

GeoEngineers

Figure A - 15

PLASTICITY CHART



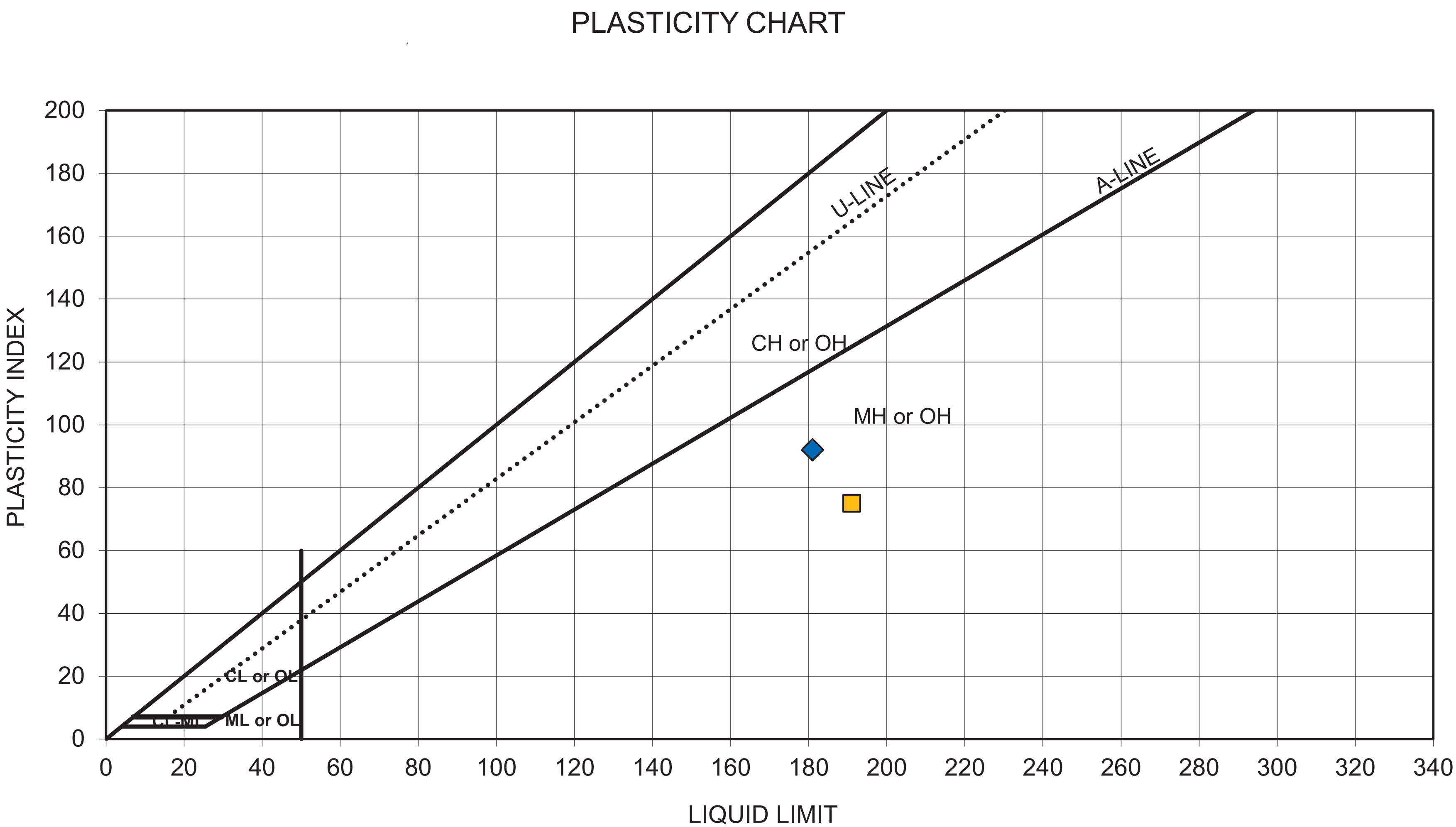
Symbol	Sample ID	Sample Depth (feet)	Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	USCS	Soil Description
◆	B199.41-1 S-8	45	134	164	69	MH	Elastic silt
■	B199.41-1 S-11	55	139	159	69	MH	Elastic silt
▲	B199.41-1 S-13	65	144	182	91	MH	Elastic silt

Atterberg Limits Test Results

PCGP – Klamath River HDD
Klamath County, Oregon

GEOENGINEERS

Figure A - 16



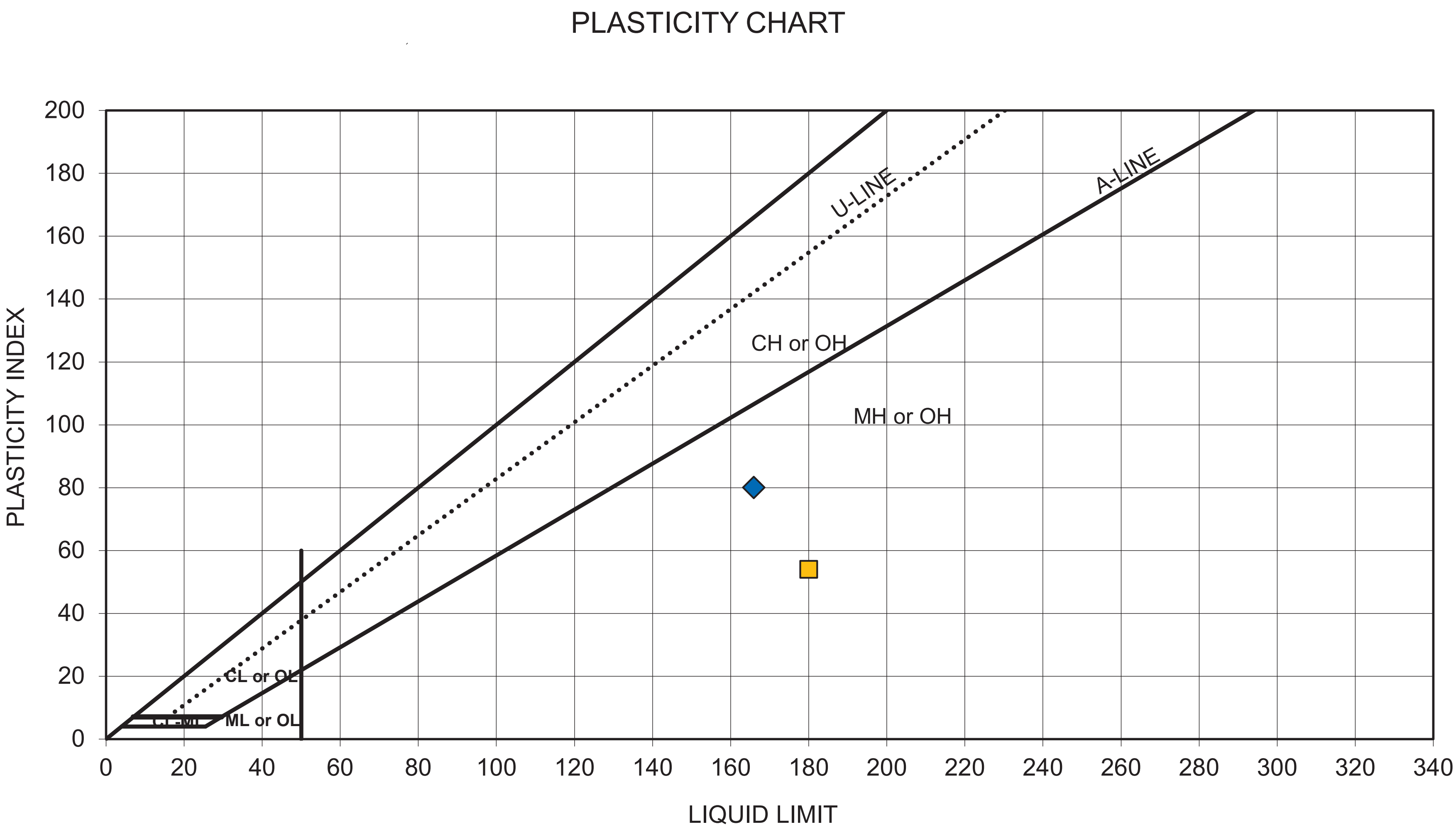
Symbol	Sample ID	Sample Depth (feet)	Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	USCS	Soil Description
◆	B199.41-1 S-15	75	148	181	92	MH	Elastic silt
■	B199.41-1 S-17	85	157	191	75	MH	Elastic silt

Atterberg Limits Test Results

PCGP – Klamath River HDD
Klamath County, Oregon

GeoEngineers

Figure A - 17



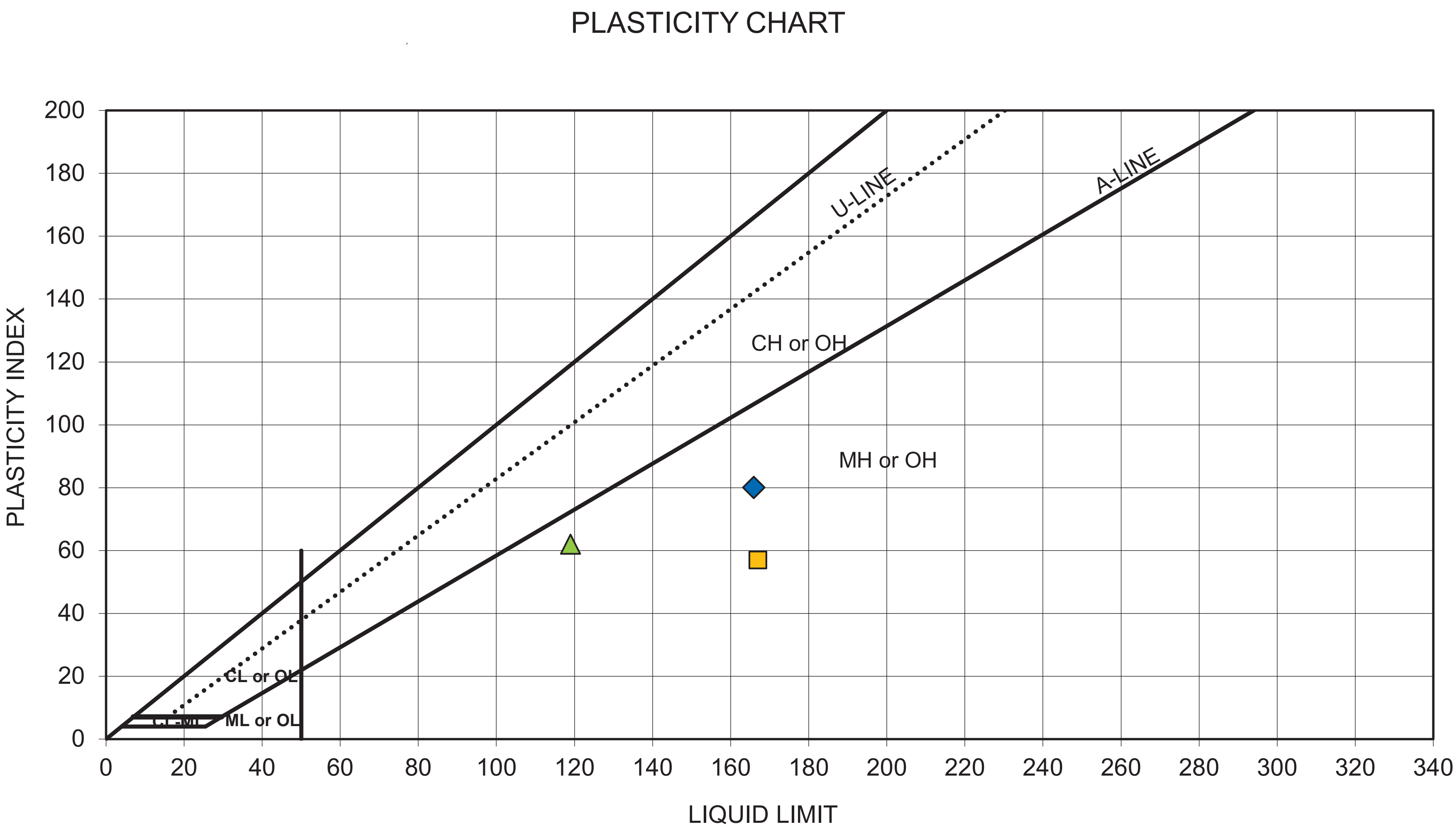
Symbol	Sample ID	Sample Depth (feet)	Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	USCS	Soil Description
◆	B199.43-1 S-1	42	152	166	80	MH	Elastic silt
■	B199.43-1 S-2	92	178	180	54	MH	Elastic silt

Atterberg Limits Test Results

PCGP – Klamath River HDD
Klamath County, Oregon

GeoEngineers

Figure A - 18



Symbol	Sample ID	Sample Depth (feet)	Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	USCS	Soil Description
◆	B199.6-1 S-3	15	152	166	80	MH	Elastic silt
■	B199.6-1 S-14	70	181	167	57	MH	Elastic silt
▲	B199.6-1 S-25	125	94	119	62	MH	Elastic silt

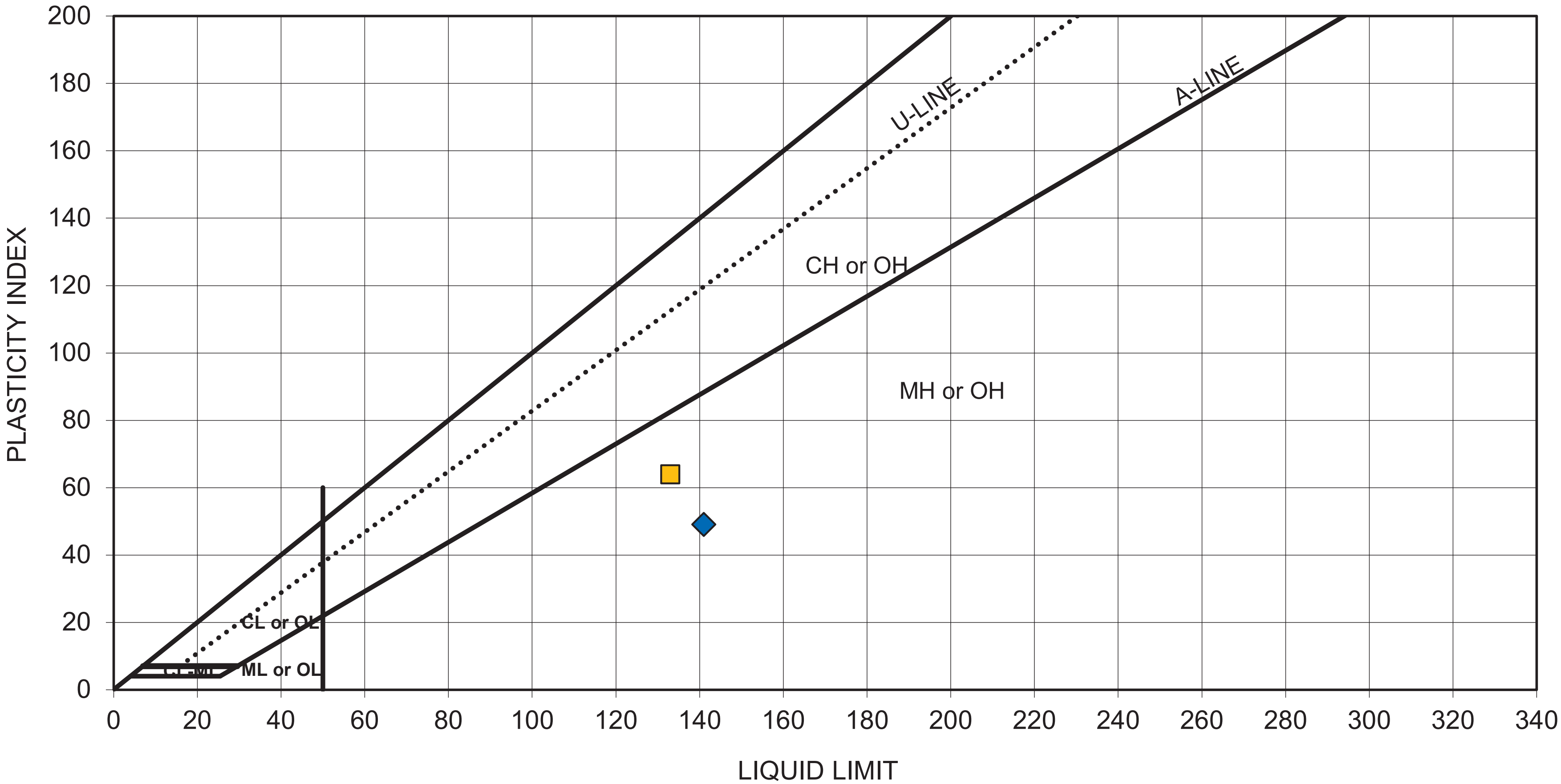
Atterberg Limits Test Results

PCGP – Klamath River HDD
Klamath County, Oregon

GEOENGINEERS

Figure A - 19

PLASTICITY CHART



Symbol	Sample ID	Sample Depth (feet)	Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	USCS	Soil Description
◆	B199.6-1 S-28	140	148	141	49	MH	Elastic silt
■	B199.6-1 S-32	160	132	133	64	MH	Elastic silt

Atterberg Limits Test Results

PCGP – Klamath River HDD
Klamath County, Oregon

GeoEngineers

Figure A - 20

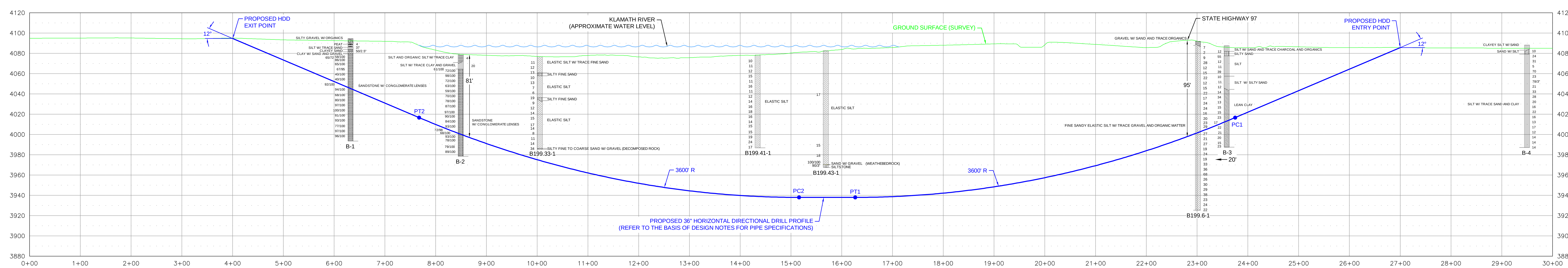
APPENDIX B
HDD Design Drawing and Calculations

DATUM:
HORIZONTAL: NAD83 Oregon State Plane, South Zone, US Foot
VERTICAL: NAVD 88

NOTE: THIS IS A FULL SIZE DRAWING THAT IS INTENDED TO BE PRINTED ON A 24" X 36" SHEET OF PAPER.

PLAN

100 0 100
SCALE IN FEET



PROFILE

100 0 100
HORIZONTAL SCALE IN FEET
50 0 50
VERTICAL SCALE IN FEET

DIRECTIONAL DRILL DATA KLAMATH RIVER HDD		
DESCRIPTION	STATION * (ft)	ELEVATION (ft)
ENTRY @ 12°	27+00.00	4085.91
P C 1 (12.00° @ 3,600 ft R.)	23+74.23	4016.67
P T 1	16+25.75	3938.00
P C 2 (12.00° @ 3,600 ft R.)	15+15.87	3938.00
P T 2	7+67.39	4016.67
EXIT @ 12°	4+00.00	4094.76
HORIZONTAL DISTANCE = 2300.00 ft		
DIRECTIONAL DRILL PIPE LENGTH = 2326.49 ft		

* THE STATIONING IS BASED ON AN ARBITRARY REFERENCE POINT

BASIS OF DESIGN:

1. PRODUCT PIPE WILL CONSIST OF 36" O.D. X 0.823" W.T., API-5L X-70 SAWL OR SAWH PIPE WITH 8-10 MILS OF FUSION BONDED EPOXY (FBE) AND A MINIMUM OF 40 MILS OF ABRASION RESISTANT OVERLAY (ARO).
2. MAXIMUM ALLOWABLE OPERATING PRESSURE (MAOP) = 1,600 psi
3. ASSUMED MAXIMUM OPERATING TEMPERATURE = 100° FAHRENHEIT.
4. ASSUMED AVERAGE OPERATING TEMPERATURE = 70° FAHRENHEIT.
5. THE MINIMUM ALLOWABLE THREE JOINT RADIUS SHALL NOT BE LESS THAN 2,600 FEET.

RECOMMENDED TOLERANCES	
ITEM	TOLERANCE
PILOT HOLE ENTRY ANGLE	INCREASE ANGLE UP TO 1° (STEEPER), BUT NO DECREASE IN ANGLE ALLOWED.
PILOT HOLE ENTRY LOCATION	AS PER COORDINATES PROVIDED BY COMPANY WITH NO CHANGES WITHOUT COMPANY APPROVAL.
PILOT HOLE EXIT ANGLE	INCREASE ANGLE UP TO 1° (STEEPER) OR DECREASE UP TO 2° (FLATTER).
PILOT HOLE EXIT LOCATION	UP TO 20 FEET BEYOND OR 10 FEET SHORT OF THE EXIT STAKE. BETWEEN 5 FEET LEFT AND 5 FEET RIGHT OF CENTERLINE.
PILOT HOLE DEPTH	UP TO 2 FEET ABOVE THE DESIGN DRILL PROFILE ALLOWED. UP TO 10 FEET BELOW THE DESIGN DRILL PROFILE ALLOWED.
PILOT HOLE ALIGNMENT	SHALL REMAIN WITHIN 5 FEET LEFT OR RIGHT OF THE HDD ALIGNMENT.

LEGEND

TYPE OF SOIL — SPT (N)
RQD/%REC — TYPE OF ROCK
Boring Location
Major Contour - 10' Interval
Minor Contour - 2' Interval

ISSUED FOR PERMIT

NOTES:

1. CONTRACTOR SHALL ADHERE TO THE SPECIFICATIONS AND REQUIREMENTS PER PACIFIC CONNECTOR GAS PIPELINE, LP SPECIFICATIONS, CONTRACT DOCUMENTS AND SPECIAL PERMIT CONDITIONS, EXCEPT AS NOTED ON THIS DRAWING.
2. CONTRACTOR IS RESPONSIBLE FOR CALLING OREGON ONE-CALL AND LOCATING ALL UNDERGROUND UTILITIES PRIOR TO BEGINNING CONSTRUCTION. IF ANY UTILITY IS LOCATED WITHIN 15 FEET OF THE DESIGNED HDD PROFILE AND ALIGNMENT, CONTRACTOR SHALL OBTAIN APPROVAL FROM PACIFIC CONNECTOR GAS PIPELINE, LP PRIOR TO INITIATING HDD OPERATIONS.
2. IT IS THE CONTRACTORS RESPONSIBILITY TO IDENTIFY AND PROTECT ANY FOREIGN UTILITY THAT MAY BE AFFECTED BY THE HDD OPERATIONS.
3. PLACEMENT OF THE HDD RIG IS NOT FIXED BY THE DESIGNATION OF THE ENTRY AND EXIT POINTS. THE USE OF DUAL HDD RIGS DURING CONSTRUCTION MAY BE AT THE DISCRETION OF THE HDD CONTRACTOR, TO BE APPROVED BY THE PROJECT TEAM.
4. ALL EQUIPMENT MUST ACCESS THE SITE ALONG THE CONSTRUCTION RIGHT-OF-WAY OR FROM APPROVED ACCESS ROADS.
5. WORK SPACE: MAXIMUM WORK SPACE LIMITS ARE DEPICTED. RESTRICT CLEARING TO THE WORK SPACE INDICATED AT THE ENTRY AND EXIT POINTS AND PRODUCT PIPE STRINGING AND FABRICATION AREA ALONG THE CONSTRUCTION RIGHT-OF-WAY. CLEARING BETWEEN THE ENTRY AND EXIT POINTS REQUIRES PRIOR APPROVAL FROM THE ENVIRONMENTAL INSPECTOR AND IS LIMITED TO THE AMOUNT NECESSARY TO STRING SURVEY WIRES AND INSTALL PUMPS AND PIPING TO OBTAIN WATER (WHERE APPROVED).
6. WATER SOURCE: DRILL WATER AND HYDROSTATIC TEST WATER SHALL BE OBTAINED FROM AN APPROVED SOURCE.
7. HYDROSTATIC TEST: PRE-INSTALLATION AND POST-INSTALLATION HYDROSTATIC TESTS SHALL BE CONDUCTED IN ACCORDANCE WITH THE HYDROSTATIC TEST PLAN. TEST WATER SHALL BE SAMPLED AND TESTED IN ACCORDANCE WITH PERMIT REQUIREMENTS. THE TEST WATER SHALL BE DISCHARGED IN AN UPLAND AREA INTO AN EROSION CONTROL STRUCTURE OF STRAW BALES AND/OR SILT FENCES, GEOTEXTILE FILTER BAG, OR COLLECTED IN A TRUCK AND HAULED TO AN APPROVED DISPOSAL SITE. UPON COMPLETION OF DEWATERING AND DRYING, A CALIPER PIG SURVEY SHALL BE COMPLETED IN ACCORDANCE WITH THE CONTRACT DOCUMENTS.
8. SPILL-PREVENTION: REFUELING OF ALL EQUIPMENT SHALL BE COMPLETED IN ACCORDANCE WITH THE SPCC PLAN.
9. EROSION AND SEDIMENT CONTROL: CONTRACTOR SHALL SUPPLY, INSTALL AND MAINTAIN SEDIMENT CONTROL STRUCTURES IN ACCORDANCE WITH CONTRACT DOCUMENTS. CONTRACTOR SHALL INSTALL ADDITIONAL EROSION CONTROL STRUCTURES AS DIRECTED BY THE ENVIRONMENTAL INSPECTOR.
10. INSTALLATION: THE PIPE SECTION FOR THE DRILLED CROSSING SHALL BE MADE UP WITHIN THE APPROVED CONSTRUCTION RIGHT-OF-WAY AT THE DRILL EXIT POINT AS SHOWN. AFTER THE PILOT HOLE IS COMPLETE, CONTRACTOR'S ACTUAL DRILL PROFILE SHALL BE SUBMITTED TO PACIFIC CONNECTOR GAS PIPELINE, LP FOR APPROVAL. CONTRACTOR SHALL ASSESS THE NEED FOR AND SUPPLY APPROPRIATE BALLAST DURING PULLBACK.
11. DRILLING FLUID DISPOSAL: CONTRACTOR SHALL DISPOSE OF EXCESS DRILLING FLUID AS DIRECTED BY THE COMPANY REPRESENTATIVE IN ACCORDANCE WITH PERMIT CONDITIONS. UNDER NO CIRCUMSTANCES SHALL DRILLING FLUID BE DISPOSED OF IN WATER BODIES OR WETLANDS. ANY DRILLING FLUID WHICH INADVERTENTLY SURFACES AT POINTS OTHER THAN THE ENTRY OR EXIT POINTS SHALL BE CONTAINED AND COLLECTED TO THE EXTENT PRACTICAL AND DISPOSED OF AS DIRECTED BY THE COMPANY REPRESENTATIVE IN ACCORDANCE WITH PERMIT CONDITIONS.
12. CLEANUP/STABILIZATION/RESTORATION: ALL DISTURBED AREAS SHALL BE RETURNED TO THE ORIGINAL CONTOURS. DISTURBED AREAS SHALL BE SEEDED AS SPECIFIED IN THE CLEAN-UP AND RESTORATION REQUIREMENTS. IF THE TERRAIN ALLOWS AND ACCESS IS PERMITTED, CONTRACTOR SHALL UTILIZE LOW GROUND PRESSURE EQUIPMENT OR OTHER EQUIPMENT APPROVED BY OWNER, TO FACILITATE CONTAINMENT AND CLEAN-UP OF ANY INADVERTENT RETURNS THAT OCCUR DURING THE HDD INSTALLATION PROCESS.
13. GEOTECHNICAL DATA: BORE HOLES ARE OFFSET FROM THE PIPELINE CENTERLINE AS SHOWN ON THE PLAN VIEW. THE GEOTECHNICAL INFORMATION PROVIDED ON THIS DRAWING IS A GENERAL SUMMARY. REFER TO THE APPLICABLE GEOTECHNICAL REPORT IN THE CONTRACT DOCUMENTS FOR MORE DETAILED INFORMATION.
14. GROUND SURFACE SURVEY PROVIDED BY PACIFIC CONNECTOR GAS PIPELINE, LP. IMAGE TAKEN FROM GOOGLE EARTH PRO © 2015, LICENSED TO GEOENGINEERS, INC., IMAGE DATED 08/26/13.
15. THE SECONDARY SURFACE SURVEY COIL LAYOUTS SHOWN ON THIS DRAWING ARE APPROXIMATE AND INTENDED TO SHOW THE GENERAL LAYOUT OF TYPICAL SECONDARY SURFACE SURVEY COIL WIRES THAT MAY BE PLACED TO TRACK THE BOTTOM HOLE ASSEMBLY DURING PILOT HOLE OPERATIONS. THE APPROXIMATE LOCATIONS OF THE SECONDARY SURFACE SURVEY COIL WIRES SHOWN ON THIS DRAWING ARE NOT INTENDED TO DIRECT THE HDD CONTRACTOR AS TO THE EXACT PLACEMENT OF THE SECONDARY SURFACE SURVEY COIL WIRES. THE FINAL PLACEMENT OF SECONDARY SURFACE SURVEY COIL WIRES IS THE CONTRACTOR'S RESPONSIBILITY AND MAY VARY FROM WHAT IS SHOWN DEPENDING ON GROUND SURFACE CONDITIONS AT THE TIME OF HDD INSTALLATION, AND THE HDD CONTRACTOR'S MEANS AND METHODS.

REFERENCES	
DRAWING NUMBER	REFERENCE DRAWING TITLE
	PCGP_IP_Right_of_Way.dwg

REVISIONS					
NO.	DESCRIPTION	BY	DATE	CHK'D	APP'D
0	ISSUED FOR PERMIT (MODIFIED PIPE SPECS)	RBM	08/24/17	AES	TNH

AES Design	03/05/14 Date
RBM Drawn	03/25/14 Date
AES Checked	06/30/15 Date
TNH Approved	08/24/17 Date

GEOENGINEERS
317 East Main Street,
American Fork, UT 84003
Telephone (801) 307-0216

36" PACIFIC CONNECTOR GAS PIPELINE PROJECT

KLAMATH RIVER HDD
KLAMATH COUNTY, OREGON

Project No.
22708-001-01

Drawing No.
P1-000-CIV-HDD-GEI-00001-06

Sheet
1 of 1

P:\...\Klamath River HDD\Klamath River HDD_IFP.dwg\TAB:HDD Drawing modified on Aug 24, 2017 - 4:06pm

HDD Design Summary

Project Name: Pacific Connector Gas Pipeline **HDD Name:** Klamath River HDD **Owner:** PCGP, LP

Project No: 22708-001-01 **By:** AES **Ck'd By:** BCR/ JAH **Location:** Klamath County, Oregon **Date:** Wednesday, August 30, 2017

Design Parameters

Pipe Diameter = 36.000 in

Pipe Material = Steel

Yield Stress = 70,000 psi

Wall Thickness = 0.823 in

Assumed Installation Temp = 50 °F

Assumed Operating Temp= 100 °F

Design Factor = 0.5

MAOP = 1,600 psi

Drill Data Box

Point	Station (ft)	Elevation (ft)
ENTRY @ 12°	2,700.00	4,085.91
P C 1 (12.00° @ 3,600 ft R.)	2,374.23	4,016.67
P T 1	1,625.75	3,938.00
P C 2 (12.00° @ 3,600 ft R.)	1,515.87	3,938.00
P T 2	767.39	4,016.67
EXIT @ 12°	400.00	4,094.76

Horizontal Alignment Length = 2,300.00 ft

Profile Segment Information

Segment Name	Segment Type	Segment Length (ft)
ENTRY TANGENT	Straight	333.05
ENTRY CURVE	Vertical Curve	753.98
BOTTOM TANGENT	Straight	109.88
EXIT CURVE	Vertical Curve	753.98
EXIT TANGENT	Straight	375.59

Pipe Length = 2,326.49 ft

Installation Load Summary

Drilling Fluid Weight (lb/gal)	Buoyancy Condition	Buoyancy Control (lb/ft)	Effective Pipe Weight (lb/ft)	Total Installation Force (lb)
9.50	Empty	0.00	-192.37	345,000
9.50	Full	401.67	209.30	294,000
12.00	Empty	0.00	-324.56	457,000
12.00	Full	401.67	77.11	197,000
10.50	Neutral	245.24	0.00	179,000

GeoEngineers

Minimum Radius Calculations

Project Name:	Pacific Connector Gas Pipeline	**HDD Name:**	Klamath River HDD	**Owner:**	PCGP, LP
Project No:	22708-001-01 **By:** AES **Ck'd By:** BCR/ JAH	**Location:**	Klamath County, Oregon	**Date:**	Wednesday, August 30, 2017

Design Parameters:

Pipe Diameter = 36.000 in

Wall Thickness = 0.823 in

D/t Ratio = 43.74

MAOP = 1,600 psi

SMYS = 70,000 psi

Modulus of Elasticity (E) = 2.93E+007 psi

Factor of Safety = 2.00

Hoop Stress:

Calculated Hoop Stress = (MAOP * Pipe Diameter) / (2 * Wall Thickness) = 34,994 psi

Longitudinal Stress:

Calculated Longitudinal Stress = Hoop Stress / 2 = 17,497 psi

Allowable Stress:

Calculated Allowable Stress = SMYS / Factor of Safety = 35,000 psi

Bending Stress:

Calculated Bending Stress = Allowable Stress - Longitudinal Stress = 17,503 psi

Minimum Radius:

Calculated Minimum Radius = (E * Pipe Diameter) / (2 * Bending Stress) = 2,485 ft

Operating Stress Summary

Project Name: Pacific Connector Gas Pipeline **HDD Name:** Klamath River HDD **Owner:** PCGP, LP

Project No: 22708-001-01 **By:** AES **Ck'd By:** BCR/ JAH **Location:** Klamath County, Oregon **Date:** Wednesday, August 30, 2017

Design Parameters

Pipe diameter = 36.000 in

Wall Thickness = 0.823 in

SMYS = 70,000 psi

MAOP = 1,600 psi

Poissons's Ratio = 0.30

Young's Modulus (E) = 2.93E+007 psi

Design Factor = 0.5

Minimum Radius of Curvature = 2,600 ft

Coefficient of Thermal Expansion = 6.5E-06 in/in/°F

Assumed Installation Temperature = 50 °F

Assumed Operating Temperature = 100 °F

Temperature Derating Factor = 1.00

Groundwater Table Head = 0.00 ft

Stress Analyses

Longitudinal Stress from Bending = 16,929 psi

Percent SMYS = 24.18 %

Hoop Stress = 34,994 psi

Percent SMYS = 49.99 % Limited by Design Factor (0.5) according to 49 CFR 192.111

Longitudinal Tensile Stress from Hoop Stress = 10,498 psi

Percent SMYS = 15.00 %

Longitudinal Stress from Thermal Expansion = -9,537 psi

Percent SMYS = 13.62 % Limited to 90% SMYS by ASME/ANSI B31.4 section 402.3.2

Net Longitudinal Stress (Comp. side of Curve) = -15,968 psi

Percent SMYS = 22.81 % Limited to 90% SMYS by ASME/ANSI B31.8 section 833.3

Net Longitudinal Stress (Tension side of Curve) = 17,891 psi

Percent SMYS = 25.56 % Limited to 90% SMYS by ASME/ANSI B31.8 section 833.3

Maximum Shear Stress = 25,481 psi

Percent SMYS = 36.40 % Limited to 45% SMYS by ASME/ANSI B31.4 section 402.3.1

Combined Biaxial Stress Check = 50,962 psi

Percent SMYS = 72.80 % Limited to 90% SMYS by ASME/ANSI B31.8 section 833.4

Operating Stress Summary

Project Name: Pacific Connector Gas Pipeline **HDD Name:** Klamath River HDD **Owner:** PCGP, LP

Project No: 22708-001-01 **By:** AES **Ck'd By:** BCR/ JAH **Location:** Klamath County, Oregon **Date:** Wednesday, August 30, 2017

Installation Load Calculations

Project Name: Pacific Connector Gas Pipeline **HDD Name:** Klamath River HDD **Owner:** PCGP, LP

Project No: 22708-001-01 **By:** AES **Ck'd By:** BCR/ JAH **Location:** Klamath County, Oregon **Date:** Wednesday, August 30, 2017

Installation Case:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty

Product Pipe Parameters

Pipe Diameter =	36.000 in
Wall Thickness =	0.823 in
SMYS =	70,000 psi
Young's Modulus =	2.90E+007 psi
Total Pipe Length =	2,326 ft
Moment of Inertia =	14,076 in^4
Pipe Face Area =	90.95 in^2
D/t Ratio =	43.74
Poisson Ratio =	0.30
Coefficient of Soil Friction =	0.30
Fluid Drag Coefficient =	0.05

Effective Weight Calculations

Total Empty Pipe Weight In Air=	309.96 lb/ft
Pipe Interior Volume =	6.44 ft^3
Coating Thickness =	0.00 in
Coating Density =	0.00 lb/ft^3
Pipe Exterior Volume =	7.07 ft^3/ft
Displaced Fluid Weight =	502.33 lb/ft
B.C. Line(s) Weight =	0.00 lb/ft
B.C. Line(s) Volume =	0.00 ft^3/ft
Unit Weight of B.C. Fluid =	62.40 lb/ft^3
Effective Weight of Pipe =	-192.37 lb/ft

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 1 of 5

Segment Parameters

Segment Name =	EXIT TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	375.59 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	25,487 lb
Friction Force =	21,202 lb
Segment Weight =	15,022 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	61,711 lb
Cumulative Force =	**61,711 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	679 psi	
Cumulative Axial Stress =	679 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	843 psi	8,892 psi
Combined Stress =	0.0121	< 1.0
Total Stress =	0.0093	< 1.0

Installation Load Calculations

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 2 of 5

Segment Parameters

Segment Name =	EXIT CURVE	Radius of Curvature =	3,600 ft
Segment Type =	Vertical Curve	Angle Turned =	12.00 deg
Segment Length =	753.98 ft	Center Displacement =	19.72 ft

Segment Force Components

Normal Force =	109,124 lb
Drag Force =	51,164 lb
Friction Force =	32,737 lb
Segment Weight =	15,161 lb
Tension =	193,511 lb
Average Tension =	127,611 lb
Segment Force =	131,800 lb
Cumulative Force =	**193,511 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	1,449 psi	
Cumulative Axial Stress =	2,128 psi	56,000 psi
Bending Stress =	16,731 psi	46,113 psi
Hoop Stress =	1,692 psi	8,892 psi
Combined Stress =	0.4008	< 1.0
Total Stress =	0.1764	< 1.0

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 3 of 5

Segment Parameters

Segment Name =	BOTTOM TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	109.88 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	7,456 lb
Friction Force =	6,341 lb
Segment Weight =	0 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	13,797 lb
Cumulative Force =	**207,308 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	152 psi	
Cumulative Axial Stress =	2,279 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	1,692 psi	8,892 psi
Combined Stress =	0.0407	< 1.0
Total Stress =	0.0398	< 1.0

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 4 of 5

Segment Parameters

Segment Name =	ENTRY CURVE	Radius of Curvature =	3,600 ft
Segment Type =	Vertical Curve	Angle Turned =	12.00 deg
Segment Length =	753.98 ft	Center Displacement =	19.72 ft

Segment Force Components

Normal Force =	123,041 lb
Drag Force =	51,164 lb
Friction Force =	36,912 lb
Segment Weight =	-15,161 lb
Tension =	317,136 lb
Average Tension =	262,222 lb
Segment Force =	109,828 lb
Cumulative Force =	**317,136 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	1,208 psi	
Cumulative Axial Stress =	3,487 psi	56,000 psi
Bending Stress =	16,731 psi	46,113 psi
Hoop Stress =	1,692 psi	8,892 psi
Combined Stress =	0.4251	< 1.0
Total Stress =	0.1954	< 1.0

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 5 of 5

Segment Parameters

Segment Name =	ENTRY TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	333.05 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	22,600 lb
Friction Force =	18,800 lb
Segment Weight =	-13,321 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	28,080 lb
Cumulative Force =	**345,216 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	309 psi	
Cumulative Axial Stress =	3,796 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	843 psi	8,892 psi
Combined Stress =	0.0678	< 1.0
Total Stress =	0.0160	< 1.0

Installation Load Calculations

Project Name:	Pacific Connector Gas Pipeline	**HDD Name:**	Klamath River HDD	**Owner:**	PCGP, LP
Project No:	22708-001-01 **By:** AES **Ck'd By:** BCR/ JAH	**Location:**	Klamath County, Oregon	**Date:**	Wednesday, August 30, 2017

Installation Case:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full

Product Pipe Parameters

Parameter	Value
Pipe Diameter =	36.000 in
Wall Thickness =	0.823 in
SMYS =	70,000 psi
Young's Modulus =	2.90E+007 psi
Total Pipe Length =	2,326 ft
Moment of Inertia =	14,076 in⁴
Pipe Face Area =	90.95 in²
D/t Ratio =	43.74
Poisson Ratio =	0.30
Coefficient of Soil Friction =	0.30
Fluid Drag Coefficient =	0.05

Effective Weight Calculations

Parameter	Value
Total Empty Pipe Weight In Air=	309.96 lb/ft
Pipe Interior Volume =	6.44 ft³
Coating Thickness =	0.00 in
Coating Density =	0.00 lb/ft³
Pipe Exterior Volume =	7.07 ft³/ft
Displaced Fluid Weight =	502.33 lb/ft
B.C. Line(s) Weight =	0.00 lb/ft
B.C. Line(s) Volume =	0.00 ft³/ft
Unit Weight of B.C. Fluid =	62.40 lb/ft³
Effective Weight of Pipe =	209.30 lb/ft

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 1 of 5

Segment Parameters

Segment Name =	EXIT TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	375.59 ft	Center Displacement =	0.00 ft

Segment Force Components

Component	Value
Normal Force =	0 lb
Drag Force =	25,487 lb
Friction Force =	23,068 lb
Segment Weight =	-16,344 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	32,211 lb
Cumulative Force =	**32,211 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	354 psi	
Cumulative Axial Stress =	354 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	103 psi	8,892 psi
Combined Stress =	0.0063	< 1.0
Total Stress =	0.0002	< 1.0

GeoEngineers

Installation Load Calculations

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 2 of 5

Segment Parameters

Segment Name =	EXIT CURVE	Radius of Curvature =	3,600 ft
Segment Type =	Vertical Curve	Angle Turned =	12.00 deg
Segment Length =	753.98 ft	Center Displacement =	19.72 ft

Segment Force Components

Normal Force =	-80,602 lb
Drag Force =	51,164 lb
Friction Force =	24,181 lb
Segment Weight =	-16,495 lb
Tension =	115,241 lb
Average Tension =	73,726 lb
Segment Force =	83,030 lb
Cumulative Force =	**115,241 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	913 psi	
Cumulative Axial Stress =	1,267 psi	56,000 psi
Bending Stress =	16,731 psi	46,113 psi
Hoop Stress =	206 psi	8,892 psi
Combined Stress =	0.3854	< 1.0
Total Stress =	0.1071	< 1.0

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 3 of 5

Segment Parameters

Segment Name =	BOTTOM TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	109.88 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	7,456 lb
Friction Force =	6,899 lb
Segment Weight =	0 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	14,355 lb
Cumulative Force =	**129,596 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	158 psi	
Cumulative Axial Stress =	1,425 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	206 psi	8,892 psi
Combined Stress =	0.0254	< 1.0
Total Stress =	0.0014	< 1.0

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 4 of 5

Segment Parameters

Segment Name =	ENTRY CURVE	Radius of Curvature =	3,600 ft
Segment Type =	Vertical Curve	Angle Turned =	12.00 deg
Segment Length =	753.98 ft	Center Displacement =	19.72 ft

Segment Force Components

Normal Force =	-65,361 lb
Drag Force =	51,164 lb
Friction Force =	19,608 lb
Segment Weight =	16,495 lb
Tension =	236,472 lb
Average Tension =	183,034 lb
Segment Force =	106,876 lb
Cumulative Force =	**236,472 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	1,175 psi	
Cumulative Axial Stress =	2,600 psi	56,000 psi
Bending Stress =	16,731 psi	46,113 psi
Hoop Stress =	206 psi	8,892 psi
Combined Stress =	0.4092	< 1.0
Total Stress =	0.1232	< 1.0

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 5 of 5

Segment Parameters

Segment Name =	ENTRY TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	333.05 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	22,600 lb
Friction Force =	20,455 lb
Segment Weight =	14,493 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	57,548 lb
Cumulative Force =	**294,021 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	633 psi	
Cumulative Axial Stress =	3,233 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	103 psi	8,892 psi
Combined Stress =	0.0577	< 1.0
Total Stress =	0.0038	< 1.0

Installation Load Calculations

Project Name:	Pacific Connector Gas Pipeline				**HDD Name:**	Klamath River HDD	**Owner:**	PCGP, LP
Project No:	22708-001-01	**By:** AES	**Ck'd By:**	BCR/ JAH	**Location:**	Klamath County, Oregon	**Date:**	Wednesday, August 30, 2017

Installation Case:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty

Product Pipe Parameters	
Pipe Diameter =	36.000 in
Wall Thickness =	0.823 in
SMYS =	70,000 psi
Young's Modulus =	2.90E+007 psi
Total Pipe Length =	2,326 ft
Moment of Inertia =	14,076 in^4
Pipe Face Area =	90.95 in^2
D/t Ratio =	43.74
Poisson Ratio =	0.30
Coefficient of Soil Friction =	0.30
Fluid Drag Coefficient =	0.05

Effective Weight Calculations	
Total Empty Pipe Weight In Air=	309.96 lb/ft
Pipe Interior Volume =	6.44 ft^3
Coating Thickness =	0.00 in
Coating Density =	0.00 lb/ft^3
Pipe Exterior Volume =	7.07 ft^3/ft
Displaced Fluid Weight =	634.52 lb/ft
B.C. Line(s) Weight =	0.00 lb/ft
B.C. Line(s) Volume =	0.00 ft^3/ft
Unit Weight of B.C. Fluid =	62.40 lb/ft^3
Effective Weight of Pipe =	-324.56 lb/ft

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 1 of 5

Segment Parameters

Segment Name =	EXIT TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	375.59 ft	Center Displacement =	0.00 ft

Segment Force Components	
Normal Force =	0 lb
Drag Force =	25,487 lb
Friction Force =	35,772 lb
Segment Weight =	25,345 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	86,604 lb
Cumulative Force =	**86,604 lb**

Segment Installation Stress Checks		
Stress Component	**Calculated**	**Allowable**
Segment Axial Stress =	952 psi	
Cumulative Axial Stress =	952 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	1,065 psi	8,892 psi
Combined Stress =	0.0170	< 1.0
Total Stress =	0.0149	< 1.0

GeoEngineers

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 2 of 5

Segment Parameters

Segment Name =	EXIT CURVE	Radius of Curvature =	3,600 ft
Segment Type =	Vertical Curve	Angle Turned =	12.00 deg
Segment Length =	753.98 ft	Center Displacement =	19.72 ft

Segment Force Components

Normal Force =	173,471 lb
Drag Force =	51,164 lb
Friction Force =	52,041 lb
Segment Weight =	25,579 lb
Tension =	267,430 lb
Average Tension =	177,017 lb
Segment Force =	180,826 lb
Cumulative Force =	**267,430 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	1,988 psi	
Cumulative Axial Stress =	2,940 psi	56,000 psi
Bending Stress =	16,731 psi	46,113 psi
Hoop Stress =	2,137 psi	8,892 psi
Combined Stress =	0.4153	< 1.0
Total Stress =	0.2160	< 1.0

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 3 of 5

Segment Parameters

Segment Name =	BOTTOM TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	109.88 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	7,456 lb
Friction Force =	10,699 lb
Segment Weight =	0 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	18,155 lb
Cumulative Force =	**285,585 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	200 psi	
Cumulative Axial Stress =	3,140 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	2,137 psi	8,892 psi
Combined Stress =	0.0561	< 1.0
Total Stress =	0.0645	< 1.0

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 4 of 5

Segment Parameters

Segment Name =	ENTRY CURVE	Radius of Curvature =	3,600 ft
Segment Type =	Vertical Curve	Angle Turned =	12.00 deg
Segment Length =	753.98 ft	Center Displacement =	19.72 ft

Segment Force Components

Normal Force =	190,787 lb
Drag Force =	51,164 lb
Friction Force =	57,236 lb
Segment Weight =	-25,579 lb
Tension =	425,641 lb
Average Tension =	355,613 lb
Segment Force =	140,057 lb
Cumulative Force =	**425,641 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	1,540 psi	
Cumulative Axial Stress =	4,680 psi	56,000 psi
Bending Stress =	16,731 psi	46,113 psi
Hoop Stress =	2,137 psi	8,892 psi
Combined Stress =	0.4464	< 1.0
Total Stress =	0.2421	< 1.0

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 5 of 5

Segment Parameters

Segment Name =	ENTRY TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	333.05 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	22,600 lb
Friction Force =	31,720 lb
Segment Weight =	-22,474 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	31,846 lb
Cumulative Force =	**457,487 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	350 psi	
Cumulative Axial Stress =	5,030 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	1,065 psi	8,892 psi
Combined Stress =	0.0898	< 1.0
Total Stress =	0.0266	< 1.0

Installation Load Calculations

Project Name: Pacific Connector Gas Pipeline	HDD Name: Klamath River HDD	Owner: PCGP, LP
Project No: 22708-001-01 By: AES Ck'd By: BCR/ JAH	Location: Klamath County, Oregon	Date: Wednesday, August 30, 2017

Installation Case:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full

Product Pipe Parameters

Pipe Diameter =	36.000 in
Wall Thickness =	0.823 in
SMYS =	70,000 psi
Young's Modulus =	2.90E+007 psi
Total Pipe Length =	2,326 ft
Moment of Inertia =	14,076 in^4
Pipe Face Area =	90.95 in^2
D/t Ratio =	43.74
Poisson Ratio =	0.30
Coefficient of Soil Friction =	0.30
Fluid Drag Coefficient =	0.05

Effective Weight Calculations

Total Empty Pipe Weight In Air=	309.96 lb/ft
Pipe Interior Volume =	6.44 ft^3
Coating Thickness =	0.00 in
Coating Density =	0.00 lb/ft^3
Pipe Exterior Volume =	7.07 ft^3/ft
Displaced Fluid Weight =	634.52 lb/ft
B.C. Line(s) Weight =	0.00 lb/ft
B.C. Line(s) Volume =	0.00 ft^3/ft
Unit Weight of B.C. Fluid =	62.40 lb/ft^3
Effective Weight of Pipe =	77.11 lb/ft

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 1 of 5

Segment Parameters

Segment Name =	EXIT TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	375.59 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	25,487 lb
Friction Force =	8,498 lb
Segment Weight =	-6,021 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	27,964 lb
Cumulative Force =	**27,964 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	307 psi	
Cumulative Axial Stress =	307 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	325 psi	8,892 psi
Combined Stress =	0.0055	< 1.0
Total Stress =	0.0014	< 1.0

GeoEngineers

Installation Load Calculations

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 2 of 5

Segment Parameters

Segment Name =	EXIT CURVE	Radius of Curvature =	3,600 ft
Segment Type =	Vertical Curve	Angle Turned =	12.00 deg
Segment Length =	753.98 ft	Center Displacement =	19.72 ft

Segment Force Components

Normal Force =	-22,174 lb
Drag Force =	51,164 lb
Friction Force =	6,652 lb
Segment Weight =	-6,077 lb
Tension =	86,356 lb
Average Tension =	57,160 lb
Segment Force =	58,391 lb
Cumulative Force =	**86,356 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	642 psi	
Cumulative Axial Stress =	949 psi	56,000 psi
Bending Stress =	16,731 psi	46,113 psi
Hoop Stress =	652 psi	8,892 psi
Combined Stress =	0.3798	< 1.0
Total Stress =	0.1150	< 1.0

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 3 of 5

Segment Parameters

Segment Name =	BOTTOM TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	109.88 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	7,456 lb
Friction Force =	2,542 lb
Segment Weight =	0 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	9,998 lb
Cumulative Force =	**96,354 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	110 psi	
Cumulative Axial Stress =	1,059 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	652 psi	8,892 psi
Combined Stress =	0.0189	< 1.0
Total Stress =	0.0061	< 1.0

Installation Load Calculations

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 4 of 5

Segment Parameters

Segment Name =	ENTRY CURVE	Radius of Curvature =	3,600 ft
Segment Type =	Vertical Curve	Angle Turned =	12.00 deg
Segment Length =	753.98 ft	Center Displacement =	19.72 ft

Segment Force Components

Normal Force =	-12,900 lb
Drag Force =	51,164 lb
Friction Force =	3,870 lb
Segment Weight =	6,077 lb
Tension =	161,335 lb
Average Tension =	128,844 lb
Segment Force =	64,981 lb
Cumulative Force =	**161,335 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	714 psi	
Cumulative Axial Stress =	1,774 psi	56,000 psi
Bending Stress =	16,731 psi	46,113 psi
Hoop Stress =	652 psi	8,892 psi
Combined Stress =	0.3945	< 1.0
Total Stress =	0.1250	< 1.0

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 5 of 5

Segment Parameters

Segment Name =	ENTRY TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	333.05 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	22,600 lb
Friction Force =	7,536 lb
Segment Weight =	5,339 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	35,475 lb
Cumulative Force =	**196,810 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	390 psi	
Cumulative Axial Stress =	2,164 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	325 psi	8,892 psi
Combined Stress =	0.0386	< 1.0
Total Stress =	0.0034	< 1.0

Installation Load Calculations

Project Name:	Pacific Connector Gas Pipeline	**HDD Name:**	Klamath River HDD	**Owner:**	PCGP, LP
Project No:	22708-001-01 **By:** AES **Ck'd By:** BCR/ JAH	**Location:**	Klamath County, Oregon	**Date:**	Wednesday, August 30, 2017

Installation Case:10.50 lb/gal Drilling Fluid With Neutral Pipe Buoyancy

Product Pipe Parameters	
Pipe Diameter =	36.000 in
Wall Thickness =	0.823 in
SMYS =	70,000 psi
Young's Modulus =	2.90E+007 psi
Total Pipe Length =	2,326 ft
Moment of Inertia =	14,076 in⁴
Pipe Face Area =	90.95 in²
D/t Ratio =	43.74
Poisson Ratio =	0.30
Coefficient of Soil Friction =	0.30
Fluid Drag Coefficient =	0.05

Effective Weight Calculations	
Total Empty Pipe Weight In Air=	309.96 lb/ft
Pipe Interior Volume =	6.44 ft³
Coating Thickness =	0.00 in
Coating Density =	0.00 lb/ft³
Pipe Exterior Volume =	7.07 ft³/ft
Displaced Fluid Weight =	555.21 lb/ft
B.C. Line(s) Weight =	0.00 lb/ft
B.C. Line(s) Volume =	0.00 ft³/ft
Unit Weight of B.C. Fluid =	62.40 lb/ft³
Effective Weight of Pipe =	0.00 lb/ft

Installation:10.50 lb/gal Drilling Fluid With Neutral Pipe Buoyancy — Segment 1 of 5

Segment Parameters

Segment Name =	EXIT TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	375.59 ft	Center Displacement =	0.00 ft

Segment Force Components	
Normal Force =	0 lb
Drag Force =	25,487 lb
Friction Force =	0 lb
Segment Weight =	0 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	25,487 lb
Cumulative Force =	**25,487 lb**

Stress Component	Calculated	Allowable
Segment Axial Stress =	280 psi	
Cumulative Axial Stress =	280 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	932 psi	8,892 psi
Combined Stress =	0.0050	< 1.0
Total Stress =	0.0112	< 1.0

GeoEngineers

Installation Load Calculations

Installation:10.50 lb/gal Drilling Fluid With Neutral Pipe Buoyancy — Segment 2 of 5

Segment Parameters

Segment Name =	EXIT CURVE	Radius of Curvature =	3,600 ft
Segment Type =	Vertical Curve	Angle Turned =	12.00 deg
Segment Length =	753.98 ft	Center Displacement =	19.72 ft

Segment Force Components

Normal Force =	13,088 lb
Drag Force =	51,164 lb
Friction Force =	3,926 lb
Segment Weight =	0 lb
Tension =	84,504 lb
Average Tension =	54,995 lb
Segment Force =	59,017 lb
Cumulative Force =	**84,504 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	649 psi	
Cumulative Axial Stress =	929 psi	56,000 psi
Bending Stress =	16,731 psi	46,113 psi
Hoop Stress =	1,870 psi	8,892 psi
Combined Stress =	0.3794	< 1.0
Total Stress =	0.1711	< 1.0

Installation:10.50 lb/gal Drilling Fluid With Neutral Pipe Buoyancy — Segment 3 of 5

Segment Parameters

Segment Name =	BOTTOM TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	109.88 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	7,456 lb
Friction Force =	0 lb
Segment Weight =	0 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	7,456 lb
Cumulative Force =	**91,960 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	82 psi	
Cumulative Axial Stress =	1,011 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	1,870 psi	8,892 psi
Combined Stress =	0.0181	< 1.0
Total Stress =	0.0444	< 1.0

Installation Load Calculations

Installation:10.50 lb/gal Drilling Fluid With Neutral Pipe Buoyancy — Segment 4 of 5

Segment Parameters			
Segment Name =	ENTRY CURVE	Radius of Curvature =	3,600 ft
Segment Type =	Vertical Curve	Angle Turned =	12.00 deg
Segment Length =	753.98 ft	Center Displacement =	19.72 ft

Segment Force Components	
Normal Force =	21,453 lb
Drag Force =	51,164 lb
Friction Force =	6,436 lb
Segment Weight =	0 lb
Tension =	155,996 lb
Average Tension =	123,978 lb
Segment Force =	64,036 lb
Cumulative Force =	**155,996 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	704 psi	
Cumulative Axial Stress =	1,715 psi	56,000 psi
Bending Stress =	16,731 psi	46,113 psi
Hoop Stress =	1,870 psi	8,892 psi
Combined Stress =	0.3934	< 1.0
Total Stress =	0.1815	< 1.0

Installation:10.50 lb/gal Drilling Fluid With Neutral Pipe Buoyancy — Segment 5 of 5

Segment Parameters			
Segment Name =	ENTRY TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	333.05 ft	Center Displacement =	0.00 ft

Segment Force Components	
Normal Force =	0 lb
Drag Force =	22,600 lb
Friction Force =	0 lb
Segment Weight =	0 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	22,600 lb
Cumulative Force =	**178,596 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	248 psi	
Cumulative Axial Stress =	1,964 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	932 psi	8,892 psi
Combined Stress =	0.0351	< 1.0
Total Stress =	0.0134	< 1.0

APPENDIX C
Report Limitations and Guidelines for Use

APPENDIX C
REPORT LIMITATIONS AND GUIDELINES FOR USE[1]

This appendix provides information to help you manage your risks with respect to the use of this report.

Geotechnical Services Are Performed for Specific Purposes, Persons and Projects

This report has been prepared for the exclusive use of PCGP, LP and their authorized agents. This report is not intended for use by others, and the information contained herein is not applicable to other sites.

GeoEngineers structures our services to meet the specific needs of our clients. For example, a geotechnical or geologic study conducted for a civil engineer or architect may not fulfill the needs of a construction contractor or even another civil engineer or architect that are involved in the same project. Because each geotechnical or geologic study is unique, each geotechnical engineering or geologic report is unique, prepared solely for the specific client and project site. Our report is prepared for the exclusive use of our Client. No other party may rely on the product of our services unless we agree in advance to such reliance in writing. This is to provide our firm with reasonable protection against open-ended liability claims by third parties with whom there would otherwise be no contractual limits to their actions. Within the limitations of scope, schedule and budget, our services have been executed in accordance with our Agreement with the Client and generally accepted geotechnical practices in this area at the time this report was prepared. This report should not be applied for any purpose or project except the one originally contemplated.

A Geotechnical Engineering or Geologic Report Is Based on a Unique Set of Project-specific Factors

This report has been prepared for PCGP, LP for the Klamath River HDD in Klamath County, Oregon. GeoEngineers considered a number of unique, project-specific factors when establishing the scope of services for this project and report. Unless GeoEngineers specifically indicates otherwise, do not rely on this report if it was:

- not prepared for you.
- not prepared for your project.
- not prepared for the specific site explored.
- completed before important project changes were made.

For example, changes that can affect the applicability of this report include those that affect:

- the function of the proposed structure.
- elevation, configuration, location, orientation or weight of the proposed structure.
- composition of the design team.
- project ownership.

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[1] Developed based on material provided by ASFE, Professional Firms Practicing in the Geosciences; www.asfe.org.

If important changes are made after the date of this report, GeoEngineers should be given the opportunity to review our interpretations and recommendations and provide written modifications or confirmation, as appropriate.

Subsurface Conditions Can Change

This geotechnical or geologic report is based on conditions that existed at the time the study was performed. The findings and conclusions of this report may be affected by the passage of time, by manmade events such as construction on or adjacent to the site, or by natural events such as floods, earthquakes, slope instability or groundwater fluctuations. Always contact GeoEngineers before applying a report to determine if it remains applicable.

Most Geotechnical and Geologic Findings Are Professional Opinions

Our interpretations of subsurface conditions are based on field observations from widely spaced sampling locations at the site. Site exploration identifies subsurface conditions only at those points where subsurface tests are conducted or samples are taken. GeoEngineers reviewed field and laboratory data and then applied our professional judgment to render an opinion about subsurface conditions throughout the site. Actual subsurface conditions may differ, sometimes significantly, from those indicated in this report. Our report, conclusions and interpretations should not be construed as a warranty of the subsurface conditions.

Geotechnical Engineering Report Recommendations Are Not Final

Do not over-rely on the preliminary construction recommendations included in this report. These recommendations are not final, because they were developed principally from GeoEngineers' professional judgment and opinion. GeoEngineers' recommendations can be finalized only by observing actual subsurface conditions revealed during construction. GeoEngineers cannot assume responsibility or liability for this report's recommendations if we do not perform construction observation.

Sufficient observation, testing and consultation by GeoEngineers should be provided during construction to confirm that the conditions encountered are consistent with those indicated by the explorations, to provide recommendations for design changes should the conditions revealed during the work differ from those anticipated, and to evaluate whether or not earthwork activities are completed in accordance with our recommendations. Retaining GeoEngineers for construction observation for this project is the most effective method of managing the risks associated with unanticipated conditions.

A Geotechnical Engineering or Geologic Report Could Be Subject to Misinterpretation

Misinterpretation of this report by other design team members can result in costly problems. You could lower that risk by having GeoEngineers confer with appropriate members of the design team after submitting the report. Also, retain GeoEngineers to review pertinent elements of the design team's plans and specifications. Contractors can also misinterpret a geotechnical engineering or geologic report. Reduce that risk by having GeoEngineers participate in pre-bid and preconstruction conferences, and by providing construction observation.

Do Not Redraw the Exploration Logs

Geotechnical engineers and geologists prepare final boring and testing logs based upon their interpretation of field logs and laboratory data. To prevent errors or omissions, the logs included in a geotechnical

engineering or geologic report should never be redrawn for inclusion in architectural or other design drawings. Only photographic or electronic reproduction is acceptable, but recognize that separating logs from the report can elevate risk.

Give Contractors a Complete Report and Guidance

Some owners and design professionals believe they can make contractors liable for unanticipated subsurface conditions by limiting what they provide for bid preparation. To help prevent costly problems, give contractors the complete geotechnical engineering or geologic report, but preface it with a clearly written letter of transmittal. In that letter, advise contractors that the report was not prepared for purposes of bid development and that the report's accuracy is limited; encourage them to confer with GeoEngineers and/or to conduct additional study to obtain the specific types of information they need or prefer. A pre-bid conference can also be valuable. Be sure contractors have sufficient time to perform additional study. Only then might an owner be in a position to give contractors the best information available, while requiring them to at least share the financial responsibilities stemming from unanticipated conditions. Further, a contingency for unanticipated conditions should be included in your project budget and schedule.

Contractors Are Responsible for Site Safety on Their Own Construction Projects

Our geotechnical recommendations are not intended to direct the contractor's procedures, methods, schedule or management of the work site. The contractor is solely responsible for job site safety and for managing construction operations to minimize risks to on-site personnel and to adjacent properties.

Read These Provisions Closely

Some clients, design professionals and contractors may not recognize that the geoscience practices (geotechnical engineering or geology) are far less exact than other engineering and natural science disciplines. This lack of understanding can create unrealistic expectations that could lead to disappointments, claims and disputes. GeoEngineers includes these explanatory "limitations" provisions in our reports to help reduce such risks. Please confer with GeoEngineers if you are unclear how these "Report Limitations and Guidelines for Use" apply to your project or site.

Geotechnical, Geologic and Environmental Reports Should Not Be Interchanged

The equipment, techniques and personnel used to perform an environmental study differ significantly from those used to perform a geotechnical or geologic study and vice versa. For that reason, a geotechnical engineering or geologic report does not usually relate any environmental findings, conclusions or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. Similarly, environmental reports are not used to address geotechnical or geologic concerns regarding a specific project.

Biological Pollutants

GeoEngineers' Scope of Work specifically excludes the investigation, detection, prevention or assessment of the presence of Biological Pollutants. Accordingly, this report does not include any interpretations, recommendations, findings, or conclusions regarding the detecting, assessing, preventing or abating of Biological Pollutants and no conclusions or inferences should be drawn regarding Biological Pollutants, as they may relate to this project. The term "Biological Pollutants" includes, but is not limited to, molds, fungi, spores, bacteria, and viruses, and/or any of their byproducts.

If Client desires these specialized services, they should be obtained from a consultant who offers services in this specialized field.

Have we delivered World Class Client Service?

Please let us know by visiting **www.geoengineers.com/feedback**.

GeoEngineers