GEOTECHNICAL REPORT

KALAMA CREEK HATCHERY EXPANSION
NISQUALLY INDIAN RESERVATION
OLYMPIA, WA 98513

Project No. 19-384
February, 2020

Prepared for:

PARAMETRIX INC.

PanGEO INCORPORATED

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February 26, 2020
PanGEO Project No. 19-384

Mr. Randy Raymond
Parametrix Inc.
1019 39th Ave SE, #100
Puyallup, WA 98374

Subject: **Geotechnical Report**
Kalama Creek Hatchery Expansion
Nisqually Indian Reservation, Olympia, WA 98513

Dear Mr. Raymond:

As requested, PanGEO, Inc. is pleased to present this geotechnical report for the proposed expansion at the Kalama Creek Hatchery located on the Nisqually Indian Reservation near Olympia, Washington. This report documents the subsurface conditions at the site and our geotechnical engineering recommendations.

In summary, our test borings encountered approximately 2½ to 5 feet of loose forest duff and fill, overlying about 7½ to 10 feet of loose to medium dense sand with silt and gravel (loose alluvium), overlying dense to very dense sand and gravel with silt (dense alluvium). Groundwater was less than 8½ feet deep. Based on the thickness of the loose surficial soils and shallow groundwater, we estimate that about 2 to 4 inches of seismic induced settlement in the lower site and 1 to 3 inches of seismic induced settlement in the upper site could occur during an IBC-level design earthquake. One exception was noted at test boring PG-5 in the upper site where we estimate up to about 9 inches of settlement could occur during the design earthquake.

Based on our understanding of the project, it is our opinion that the proposed structures may be supported on conventional footings or on structural slabs bearing, assuming a few inches of settlements during the design earthquake is acceptable. If a higher level of seismic performance is required for the proposed structures, we can provide additional recommendations for pile foundations or ground improvement.

We appreciate the opportunity to be of service. Should you have any questions, please do not hesitate to call.

Sincerely,

Siew L. Tan, P.E.
Principal Geotechnical Engineer

Encl.: Geotechnical Report

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KALAMA CREEK HATCHERY EXPANSION
NISQUALLY INDIAN RESERVATION
OLYMPIA, WASHINGTON

1.0 GENERAL

PanGEO, Inc. is pleased to present this geotechnical report to assist the project team with the design and construction of the proposed expansion at the Kalama Creek Hatchery located on the Nisqually Indian Reservation near Olympia, Washington. Our scope of services included reviewing readily available geology map, conducting a site reconnaissance, drilling nine geotechnical test borings, installing three groundwater monitoring wells, and developing the conclusions and recommendations presented in this report.

2.0 SITE AND PROJECT DESCRIPTION

The Kalama Creek Hatchery is located within the Nisqually Indian Reservation near Olympia, Washington. The hatchery is situated on the west side of the Nisqually River within the lower river valley and consists of two separate facilities (see Figure 1, Vicinity Map). The two facilities are about a quarter mile apart and can be accessed by dirt roads from Church Kalama Drive Southeast.

The upriver facility, referred to in this report as the “upper site,” consists of an approximate 190-foot-long by 60-foot-wide rectangular holding pond in the middle of the site, a pump house building and incubation building both located on the west side of the pond, a 4-foot tall concrete “linear raceway” structure on the south side of the pond, an approximate 30-foot tall steel headtank near the southeast corner of the pond, and an existing office and shop building located near the entrance gate east of the headtank structure (see Plate 1 on the following page).

The downriver facility, referred to in this report as the “lower site,” consists of an approximate 155-foot-long by 63-foot-wide rectangular adult handling pond, an existing wood-frame pavilion referred to as the spawning facility on the south side of the holding pond, and an existing 25-foot diameter water tank on the west side of the pond (see Plate 2 on the following page).

Plate 1. Upper site with holding pond, headtank, office building, and concrete raceways in view, looking east.

Plate 2. Lower site with adult handling facility and spawning facility in view, looking east.

We understand that there are new developments planned for both the upper and lower sites. The upper site developments will generally consist of a new hatchery building about 190 feet long located along the east side of the existing holding pond, a new clarifier structure northeast of the new hatchery building, and a new filter/UV sump structure located near southwest corner of the existing holding pond by the concrete raceways. The approximate locations of the proposed structures are indicated on the attached Figure 2.

The lower site developments will generally consist of a new gravel driveway loop south of the existing holding pond, a generator and feed building near the west end of the driveway loop, eight new 20-foot diameter water tanks along the sides of the driveway loop, and other smaller support structures for Lox and RAS equipment. The approximate locations of the proposed structures are indicated on the attached Figure 3.

We understand that the finished floors for the new structures will be generally located near the existing grades, with the exception of the filter/UV sump structure on the upper site which we understand may be situated a few feet below grade. However, the proposed finished floor elevations are not available at the time of this report.

The conclusions and recommendations in this report are based on our understanding of the proposed improvements, which is in turn based on the project information provided. If the above project description is incorrect, or the project information changes, we should be consulted to review the recommendations contained in this study and make modifications, if needed. In any case, PanGEO should be retained to provide a review of the final design to confirm that our geotechnical recommendations have been correctly interpreted and adequately implemented in the construction documents.

3.0 SUBSURFACE EXPLORATIONS

3.1 Test Borings

Nine test borings (PG-1 through PG-9) were drilled at the subject sites on December 9 and 10, 2019. The borings were drilled using an EC 95 Track Drill owned and operated by Boretec1, Inc. of Bellevue, Washington. The borings were drilled to depths ranging between 21½ and 31½ feet below the existing grade before drilling refusal was met. The approximate boring locations were taped in the field from on-site features and are shown on the attached Figure 2 for the upper site and Figure 3 for the lower site.

The drill rig was equipped with a nominal 6-inch outside diameter hollow stem augers. Soil samples were obtained from the borings at 2½- and 5-foot depth intervals in general accordance with Standard Penetration Test (SPT) sampling methods (ASTM test method D-1586) in which the samples are obtained using a 2-inch outside diameter split-spoon sampler. The sampler was driven into the soil a distance of 18 inches using a 140-pound weight freely falling a distance of 30 inches. The number of blows required for each 6-inch increment of sampler penetration was recorded. The number of blows required to achieve the last 12 inches of sample penetration is defined as the SPT N-value. The N-value provides an empirical measure of the relative density of cohesionless soil, or the relative consistency of fine-grained soils.

Following the completion of drilling at borings PG-1, PG-5, and PG-8, nominal 2-inch diameter groundwater monitoring wells were installed in the drilled holes. Data loggers were also installed in wells PG-5 and PG-8 to document fluctuations of the groundwater level during the wet season. Details of the well construction are shown on the boring logs.

A geologist from PanGEO was present during the field exploration to observe the drilling, assist in sampling, and to describe and document the soil samples obtained from the borings. The soil samples were described and field classified in general accordance with the symbols and terms outlined in Figure A-1 of Appendix A, and the summary boring logs are included as Figures A-2 through A-10.

3.2 Laboratory Testing

The following laboratory tests were performed on select soil samples collected from the test borings:

- Moisture Content (ASTM D2216)
- Grain Size Distribution (ASTM D6913)

The test results are noted on the test boring logs in Appendix A, where appropriate, and the grain size distribution test results are included in Appendix B.

4.0 SUBSURFACE CONDITIONS

4.1 Site Geology

Based on our review of the *Geologic Map of the Nisqually 7.5-minute Quadrangle, Thurston and Pierce Counties, Washington* (Schasse, et. al. 2003), the project site is underlain by Alluvium (Geologic Map Unit *Qa*). Alluvium generally consists of interbedded silt, sand, gravel, and peat deposited in stream beds and estuaries. The thickness of the Alluvium is noted on the geologic map up to about 150 feet thick overlying Pre-Vashon Cascade Sediments (Geologic Map Unit *Qpc*) within the river delta area about six miles downriver from the subject site.

4.2 Soil Conditions

For a detailed description of the subsurface conditions encountered at each exploration location, please refer to our boring logs provided in Appendix A. The stratigraphic contacts indicated on the boring logs represent the approximate depth to boundaries between soil units. Actual transitions between soil units may be more gradual or occur at different elevations. The descriptions of groundwater conditions and depths are likewise approximate.

The soil conditions at both the lower and upper sites are quite consistent. The following is a generalized description of the soils encountered in the borings.

UNIT 1: **Topsoil** – In test borings PG-1, PG-2 and PG-3, which were drilled in the undeveloped/wooded areas of the upper site, we observed a surficial layer of loose, dark brown organics and silty sand, which we interpreted as forest duff and topsoil. This soil unit was observed to depths of 2 to 3 feet below the ground surface. Forest duff and topsoil was not encountered in borings PG-4 through PG-9 which were generally drilled near the developed areas of the upper and lower sites.

UNIT 2: **Fill** – We observed a surficial layer of loose, brown to dark brown, silty sand with gravel and organics at the upper site test borings PG-4 and PG-5 and all lower site test borings. Based on the loose and mixed consistency, and proximity to developed areas with previous grading activities, we interpret this unit as undocumented fill. At the upper site, the fill was observed to depths of 4 to 5 feet in test borings PG-4 and PG-5. At the lower site, the fill was observed to depth of about 4 to 5 feet in test borings PG-6, PG-7, and PG-9 and about 2½ feet deep in PG-8.

UNIT 3: **Alluvium (Qa)** – Underlying the topsoil and fill in all test borings, we encountered loose to very dense, gray-brown interbedded mix of poorly graded fine to medium-grained sand and gravel with varying silt content. Based on the coloring and interbedded layering of the sand, gravel, and silt, we interpret this soil unit as the mapped alluvium deposits.

Within the upper site test borings (PG-1 to PG-5), this soil unit becomes dense to very dense about 6 feet deep in PG-1, about 10 feet deep in borings PG-2 to PG-4, and about 30 feet deep in PG-5. Within the lower site test borings (PG-6 to PG-9), this soil unit becomes dense to very dense about 10 feet deep in PG-6 and PG-7 and about 15 feet deep in PG-8 and PG-9. The increase in density appears consistent with an increase in gravel content. This soil unit extended to the bottom of all 9 test borings

Our subsurface descriptions are based on the conditions encountered at the time of our exploration. Soil conditions between our exploration locations may vary from those encountered. The nature and extent of variations between our exploratory locations may not become evident until construction. If variations do appear, PanGEO should be requested to reevaluate the recommendations in this report and to modify or verify them in writing prior to proceeding with earthwork and construction.

4.3 GROUNDWATER

Groundwater was observed in all nine test borings at the time of drilling on December 9th and 10th, 2019, ranging from about 5 to 8½ feet below the ground surface. For test borings drilled at the upper site (PG-1 to PG-5) the approximate elevation of the groundwater generally ranged from about 79½ to 81 feet. For test borings drilled at the lower site (PG-6 to PG-9) the approximate elevation of the groundwater generally ranged from 72½ to 73 feet.

We returned to both sites on February 13, 2020, to measure the groundwater levels in monitoring wells PG-1, PG-5, and PG-8, and collect the data loggers installed in wells PG-5 and PG-8. The measured groundwater in the monitoring wells was generally about ¾ to 1 foot higher than the measured readings at the time of drilling.

The data loggers installed in wells at PG-5 and PG-8 measured the hourly groundwater level from the time of drilling (December 9 and 10, respectively) up to February 13, 2020. The chart seen in Plate 3 below shows the measured groundwater levels along with the daily precipitation levels during the monitoring period.

Fluctuations in the groundwater level are generally similar between the two wells. The groundwater levels remained relatively consistent up to January 22 at approximate elevations 80½ feet and 73 feet in borings PG-5 and PG-8, respectively, plus/minus ½-foot. The groundwater level in both wells then steadily rises to the recorded highwater marks on February 7 at approximate elevations 82.5 and 76.2 feet in PG-5 and PG-8, respectively.

We understand the rise in groundwater anecdotally corresponds to a rise in the Nisqually river and flooding of the site.

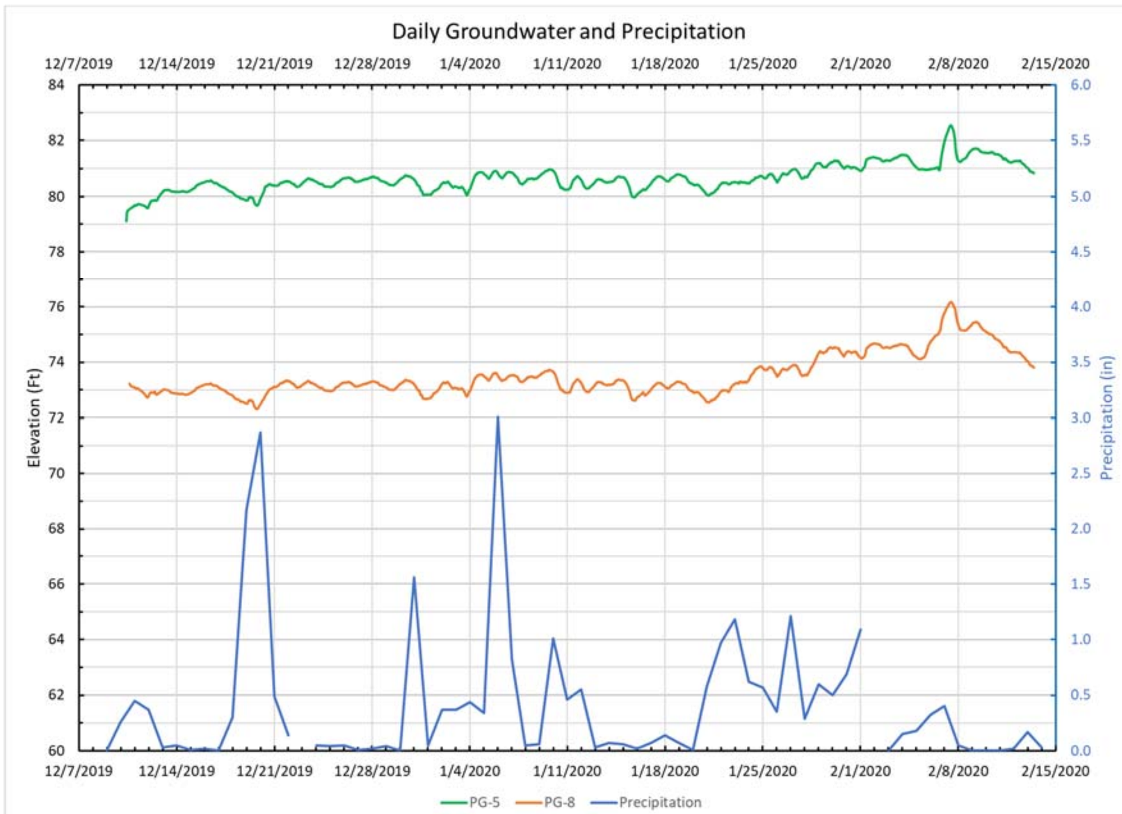


Plate 3. Groundwater monitoring in PG-5 and PG-8 with corresponding daily precipitation totals. Precipitation data taken from NOAA Local Climatological Data Daily Summaries.

It should also be noted that groundwater conditions may vary depending on the season, local subsurface conditions, precipitation, surface water runoff, and other factors. Groundwater levels are typically highest during the winter and early spring.

5.0 SEISMIC CONSIDERATIONS

5.1 SEISMIC SITE CLASS

The 2015/2018 International Building Code (IBC) seismic design section provides a basis for seismic design of structures. Based on the presence of loose to medium dense glacial outwash deposits near the surface, Site Class D should be assumed for design.

Table 1 below provides seismic design parameters for the site that are in conformance with the 2015 and 2018 IBC, which specifies a design earthquake having a 2% probability of occurrence in 50 years (return interval of 2,475 years), and the 2008 USGS seismic hazard maps.

Table 1 –Seismic Design Parameters

IBC	Site Class	Spectral Acceleration at 0.2 sec. [g] S_S	Spectral Acceleration at 1.0 sec. [g] S_1	Site Coefficients		Design Spectral Response Parameters	
				F_a	F_v	S_{DS}	S_{D1}
2015	D	1.274	0.509	1.00	1.50	0.849	0.509
2018	D	1.327	0.478	1.00	1.822	0.883	0.581

The spectral response accelerations were obtained from the USGS Earthquake Hazards Program Interpolated Probabilistic Ground Motion website (2008 data) for the project latitude and longitude.

5.2 SEISMICALLY INDUCED SETTLEMENT

Liquefaction is a process that can occur when soils temporarily lose shear strength due to cyclical loading during a seismic event. Ground shaking of sufficient strength and duration results in the loss of grain-to-grain contact and an increase in pore water pressure, causing the soil to behave as a fluid. Soils with a potential for liquefaction are typically cohesionless, predominately silt and sand sized, generally loose to medium dense, and be below the groundwater table. Soil liquefaction may cause the temporary loss/reduction of foundation capacity and settlement.

The sites are predominantly underlain by 10 to 15 feet of loose to medium dense, poorly graded sand and gravel with a fines content between 10 to 35 percent, overlying dense to very dense sand with silt and gravel. Groundwater was observed during drilling at about 5 to 8½ feet deep in all nine test borings. Based on the presence of submerged loose to medium dense sand and gravel layers, the upper and lower sites are susceptible to liquefaction induced settlement during an IBC-level earthquake. The sites are also susceptible to seismically induced settlement within the surficial loose soils above the groundwater table.

We estimated earthquake-induced settlement using the computer software program LiqSVs, which uses the Boulanger & Idriss (2014) method to calculate vertical settlement from liquefaction and the Pradel (1998) method to calculate vertical settlement for dry sands. The IBC 2018 level earthquake (M 7.5 with a PGA of about 0.53g) was used to calculate the settlement at each boring location.

In general, the test borings drilled in the upper site indicated seismically induced settlements ranging from 1 to 3 inches, with the exception of test boring PG-5 which indicated up to about 9 inches of settlement. Test borings drilled in the lower site indicated seismically induced settlements ranging from 2 to 4 inches. Seismic differential settlements of up to 2 inches should be anticipated in both the upper and lower sites.

For plots of the results from our analysis for each test boring, please refer to Appendix C.

6.0 GEOTECHNICAL RECOMMENDATIONS

6.1 FOUNDATION DESIGN PARAMETERS

We understand that the proposed structures will generally consist of single-story wood-frame buildings, cylindrical water tanks, vaults, and other supporting structures. We anticipate that conventional footings or a mat foundation would be adequate for supporting these structures. Conventional slab-on-grade concrete floors are also considered adequate for buildings.

Presented below are our recommendations for conventional footings and mat foundations.

6.1.1 Conventional Footings

Conventional footings may be designed using an allowable bearing pressure of 3,000 psf, provided the foundation subgrade is prepared as outlined in *Section 6.1.3* below. The allowable bearing pressure should not be increased by one-third for seismic loads due to potential liquefaction risk.

Continuous and individual spread footings should have minimum widths of 18 and 24 inches, respectively. Exterior foundation elements should be placed at a minimum depth of 18 inches below final exterior grade. Interior spread foundations should be placed at a minimum depth of 12 inches below the top of concrete slabs.

6.1.2 Mat Foundation/Structural Slab with Thickened Edges

A mat foundation/structural slab may be considered if a more rigid slab is needed for a structure. The mat foundation/structural slab may be designed using a modulus of subgrade reaction, k_s, of 200 pounds per cubic inch (pci) and an allowable bearing pressure of 2,000 psf, provided the foundation subgrade is prepared as outlined in *Section 6.1.3* below. The allowable bearing pressure should not be increased by one-third for seismic loads due to potential liquefaction risk.

The foundation should be a minimum depth of 18 inches below the adjacent finish grade around the perimeter of the mat. The thickened edges of the structural slabs should have a minimum width of 18 inches.

6.1.3 Foundation Subgrade Preparation

Prior to placing reinforcing steel and concrete formworks, the soils exposed at the bottom of the excavation should be compacted to a dense and unyielding conditions. If the soils cannot be properly compacted due to high fines content and high moisture content, the unstable soils should be removed to at least one foot below the bottom of the foundation and replaced with properly compacted structural fill. The structural fill may consist of on-site soils that are clean (i.e., low fines content), provided that proper compaction can be achieved. Otherwise imported structural fill will be needed.

If the soils at the bottom of the excavation are wet and unstable, a geotextile such as Mirafi 600x should be placed at the bottom of the excavation before placement of structural fill.

6.1.4 Lateral Resistance

Lateral loads acting on the foundations may be resisted by passive earth pressure developed against the embedded portion of the foundation system and by frictional resistance at the bottom of the footings. For footings bearing on the compacted structural fill, a frictional coefficient of 0.35 may be used to evaluate sliding resistance. Passive soil resistance may be calculated using an equivalent fluid unit weight of 350 pcf, assuming properly compacted structural fill will be placed against the foundations. The above values include a factor of safety of 1.5. Unless covered by pavements or slabs, the passive resistance in the upper 12 inches of soil should be neglected.

The values listed above may be increased by one-third for transient loads, except for the seismic condition due to potential soil liquefaction.

6.1.5 Foundation Performance

Under non-seismic conditions, the post-construction settlements for conventional footings and mat foundations designed and constructed in accordance with the above recommendations should be less than about ½ inches total settlement. The potential differential settlement should be less than about ¼ inch over a distance of 50 feet.

At the upper site, we anticipate up to about 1 to 3 inches of total settlement during the IBC-level earthquake, with the exception of the area around the filter/UV sump structure near test boring PG-5, which could settle about 9 inches. At the lower site, we estimate about 2 to 4 inches of total settlement during the IBC-level earthquake.

We anticipate differential settlements in the seismic condition up to 2 inches for both the upper and lower sites.

We anticipate that the proposed structures can tolerate up to 2 inches of differential settlement without collapsing, and not result in a life safety conditions. However, if our assumption is incorrect and a higher level of foundation performance will be needed, the use of piles or ground improvement may be needed. PanGEO can provide additional recommendations for piles and ground improvements if needed.

6.1.6 Perimeter Footing Drains

We anticipate that the most the foundations for the proposed developments may be constructed at or near the ground surface. As such, footing drains are not considered necessary for structures built at-grade. However, footing drains may improve the long-term performance of the building foundations by directing surface water away from the footing subgrades.

For structures with below-grade walls, footing drains should be installed at or just below the invert of the footings (see *Section 5.4.4* below) to avoid an imbalance of hydrostatic pressure.

Under no circumstances should roof downspout drain lines be connected to the footing drain systems. Roof downspouts must be separately tightlined to appropriate discharge locations. Cleanouts should be installed at strategic locations to allow for periodic maintenance of the footing drain and downspout tightline systems.

6.2 Retaining Wall Design Parameters

Retaining walls should be properly designed to resist the lateral earth pressures exerted by the soils behind the wall. Adequate drainage provisions should also be provided behind the walls to intercept and remove groundwater that may be present behind the walls. Our geotechnical recommendations for the design and construction of below-grade walls are presented below.

6.2.1 Lateral Earth Pressures

Concrete cantilever walls should be designed for an equivalent fluid pressure of 40 pcf and 55 pcf for walls with a restraining diaphragm, assuming the backfill behind the wall is level and free draining with adequate drainage provisions.

If the below-grade walls are constructed below the groundwater table and are without permanent dewatering (i.e. a waterproof structure), an equivalent fluid pressure of 90 pcf should be used for the design.

Permanent walls should be designed for an additional uniform lateral pressure of 7H psf for seismic loading, where H corresponds to the buried depth of the wall.

6.2.2 Surcharge

Surcharge loads, where present, should be included in the design of below-grade walls. We recommend that a lateral load coefficient of 0.35 be used to compute the lateral pressure on the wall face resulting from surcharge loads located within a horizontal distance of one-half the wall height.

6.2.3 Lateral Resistance

Lateral forces from seismic loading and unbalanced lateral earth pressures may be resisted by a combination of passive earth pressures acting against the embedded portions of the below-grade walls and by friction acting on the base of the foundation. Passive resistance values for below-grade walls can be seen above in *Section 5.3.4*.

6.2.4 Wall Drainage

Provisions for wall drainage should consist of a 4-inch diameter perforated drainpipe behind and at the base of the wall footings, embedded in clean crushed gravel (minimum 6-inch radius around the pipes), and fully wrapped with nonwoven geotextile fabric. Where applicable, in-lieu of conventional footing drains, weep holes (2-inch diameter and 10 feet on center) may be used for site retaining walls. A minimum 18-inch wide zone of free draining granular soils (i.e. clean gravel or crushed rock) should be placed adjacent to the wall for the full height of the wall. Alternatively, a composite drainage material, such as Miradrain 6000, may be used in lieu of the clean crushed rock or gravel. The drainpipe at the base of the wall should be graded to direct water to a suitable outlet.

6.2.5 Wall Backfill

The on-site soils are generally not suitable as wall backfill, in our opinion. The wall backfill should consist of imported, free draining granular material, such as WSDOT Gravel Borrow, or approved equivalent. In areas where the space is limited between the wall and the face of excavation, clean crushed rock may be used as backfill without compaction.

Wall backfill should be moisture conditioned to within about 3 percent of optimum moisture content, placed in loose, horizontal lifts less than 8 inches in thickness, and systematically compacted to a dense and relatively unyielding condition and to at least 95 percent of the maximum dry density, as determined using test method ASTM D1557. In landscaping areas and within 5 feet of the wall, the wall backfill should be compacted to at least 90 percent of its maximum dry density.

6.3 FLOOR SLABS

Floor slabs may be constructed using conventional concrete slab-on-grade floor construction. The floor slab should be supported by a minimum 1-foot thick layer of compacted structural fill. Within the structural fill layer, the interior concrete slab-on-grade floors should be underlain by a capillary break consisting of at least of 4 inches of ¾-inch, clean crushed rock (less than 3 percent fines). The capillary break material should meet the gradational requirements provided in Table 2, below.

Table 2 – Capillary Break Gradation

Sieve Size	Percent Passing
¾-inch	100
No. 4	0 – 10
No. 100	0 – 5
No. 200	0 – 3

The capillary break should be placed on the subgrade that has been compacted to a dense and unyielding condition.

A minimum 6-mil polyethylene vapor barrier should also be placed directly below the slab. Construction joints should be incorporated into the floor slab to control cracking.

6.4 Infiltration Considerations

Groundwater was measured in all nine test borings with the highest groundwater generally observed about 5 feet below the ground surface. We anticipate that the bottom of infiltration facilities would be generally about 3 to 4 feet below the grounds surface for a vertical separation of about 1 to 2 feet. Per Section III-3.3.7 Page 532 of the *Stormwater Management Manual for Western Washington* (2014), "The base of all infiltration basins or trench systems shall be [greater than or equal to] 5 feet above the seasonal high-water mark, bedrock (or hard pan), or other low permeability layer." As such, infiltration facilities are likely not feasible for the project site.

7.0 CONSTRUCTION CONSIDERATIONS

7.1 Temporary Excavations

All temporary excavations deeper than a total height of 4 feet should be sloped or shored. Where space is available, it is our opinion that unsupported open cut excavations are feasible at the site. Based on the soil conditions at the site, for planning purposes, it is our opinion that temporary excavations may be sloped as steep as 1.5H:1V. Where space is limited, the use of L-shaped footings may be considered to reduce the lateral extent of the proposed excavation.

All temporary excavations should be performed in accordance with Part N of WAC (Washington Administrative Code) 296-155. The contractor is responsible for maintaining safe excavation slopes and/or shoring. The temporary excavations and cut slopes should be re-evaluated in the field during construction based on actual observed soil conditions and may need to be flattered in the wet reasons and should be covered with plastic sheets. The cut slopes should be covered with plastic sheets in the raining season. We also recommend that heavy construction equipment, building materials, excavated soil, and vehicular traffic should not be allowed within a distance equal to 1/3 the slope height from the top of any excavation.

7.2 Dewatering Considerations

Groundwater was measured up to about 5 feet below the ground surface in our test borings drilled in the upper site, generally between elevations 79½ to 81 feet. We understand that some of the proposed structures in the upper site, specifically the filter and UV sump structure, may be built near the measured groundwater level and may require temporary dewatering during construction. We understand that the proposed structures in the lower site will be built generally at-grade and therefore the need for dewatering is not anticipated.

The selection and design of the dewatering system should be determined by the contractor and may be determined during construction based on field observations at the time of construction. For the construction of structures with floors below the groundwater table, the need for dewatering can be reduced with the use of a sinking caisson. The groundwater level should be lowered to about 2 feet below the bottom of the excavation.

The rate of groundwater discharge will largely depend on the groundwater level at the time of excavation, the depth of excavation, the size of the excavation, the actual soil conditions (sand vs. silt), the dewatering systems installed by the contractor, and the sequencing of the excavation. The selection of equipment and methods of dewatering should be left up to the contractor provided they are in accordance with the recommendations in this report and the project specifications. The contractor should be aware that modifications to the dewatering system may be required during construction depending on the conditions encountered. The dewatering method selected should have minimal impact on the groundwater level surrounding the proposed excavation.

Grain size analyses were conducted on samples between 5 and 7½ feet deep in borings PG-3, PG-4, and PG-5. The results of the analyses are contained in Appendix B. The contractor may use the information from the boring logs and the laboratory test results to develop a dewatering program for this project.

7.3 Material Reuse and Structural Fill Selection

In the context of this report, structural fill is defined as compacted fill placed under footings, concrete stairs and landings, and slabs, or other load-bearing areas. In our opinion, the on-site soils that are free of organics may be used as structural fill, provided that proper compaction can be achieved. It should be noted that the site soils generally have a relatively high fines content, and will likely be difficult to compact, especially during wet weather.

For planning and budgeting purposes, structural fill, if needed, should consist of imported, well-graded, granular material, such as WSDOT Gravel Borrow (WSDOT 9-03.14(1)), or approved equivalent. The on-site silty soil may be used as general fill in the non-structural and landscaping areas. If the use of the on-site soil is planned, the excavated soil should be stockpiled and protected with plastic sheeting to prevent softening from rainfall in the wet season.

7.4 Structural Fill Compaction

The procedure to achieve proper density of a compacted fill depends on the size and type of compacting equipment, the number of passes, thickness of the lifts being compacted, and certain soil properties. If the excavation to be backfilled is constricted and limits the use of heavy equipment, smaller equipment can be used, but the lift thickness will need to be reduced to achieve the required relative compaction.

Generally, loosely compacted soils are a result of poor construction technique or improper moisture content. Soils with high fines contents are particularly susceptible to becoming too wet and coarse-grained materials easily become too dry, for proper compaction. Silty or clayey soils with a moisture content too high for adequate compaction should be dried as necessary, or moisture conditioned by mixing with drier materials, or other methods.

7.5 Erosion and Drainage Considerations

Surface runoff can be controlled during construction by careful grading practices. Typically, this includes the construction of shallow, upgrade perimeter ditches or low earthen berms in conjunction with silt fences to collect runoff and prevent water from entering excavations or to prevent runoff from the construction area leaving the immediate work site. Temporary erosion control may require the use of hay bales on the downhill side of the project to prevent water from leaving the site and potential stormwater detention to trap sand and silt before the water is discharged to a suitable outlet. All collected water should be directed under control to a positive and permanent discharge system.

Permanent control of surface water should be incorporated in the final grading design. Adequate surface gradients and drainage systems should be incorporated into the design such that surface runoff is collected and directed away from the structure to a suitable outlet. Potential issues associated with erosion may also be reduced by establishing vegetation within disturbed areas immediately following grading operations.

7.6 Wet Weather Construction Considerations

General recommendations relative to earthwork performed in wet weather or in wet conditions are presented below. The following procedures are best management practices recommended for use in wet weather construction:

- Earthwork should be performed in small areas to minimize subgrade exposure to wet weather. Excavation or the removal of unsuitable soil should be followed promptly by the placement and compaction of clean structural fill. The size and type of construction equipment used may have to be limited to prevent soil disturbance.
- During wet weather, the allowable fines content of the structural fill should be reduced to no more than 5 percent by weight based on the portion passing the 0.75-inch sieve. The fines should be non-plastic.
- The ground surface within the construction area should be graded to promote run-off of surface water and to prevent the ponding of water.
- Geotextile silt fences should be installed at strategic locations around the site to control erosion and the movement of soil.

- Excavation slopes and soils stockpiled on site should be covered with plastic sheeting.

8.0 ADDITIONAL SERVICES

To confirm that our recommendations are properly incorporated into the design and construction of the proposed building, PanGEO should be retained to conduct a review of the final project plans and specifications, and to monitor the construction of geotechnical elements. The Island County may require geotechnical construction monitoring services. PanGEO can provide you a cost estimate for construction monitoring services at a later date.

9.0 CLOSURE

We have prepared this report for Parametrix Inc. and the project team. Recommendations contained in this report are based on a site reconnaissance, a subsurface exploration program, review of pertinent subsurface information, and our understanding of the project. The study was performed using a mutually agreed-upon scope of services.

Variations in soil conditions may exist between the locations of the explorations and the actual conditions underlying the site. The nature and extent of soil variations may not be evident until construction occurs. If any soil conditions are encountered at the site that are different from those described in this report, we should be notified immediately to review the applicability of our recommendations. Additionally, we should also be notified to review the applicability of our recommendations if there are any changes in the project scope.

The scope of our work does not include services related to construction safety precautions. Our recommendations are not intended to direct the contractors' methods, techniques, sequences or procedures, except as specifically described in our report for consideration in design. Additionally, the scope of our services specifically excludes the assessment of environmental characteristics, particularly those involving hazardous substances. We are not mold consultants nor are our recommendations to be interpreted as being preventative of mold development. A mold specialist should be consulted for all mold-related issues.

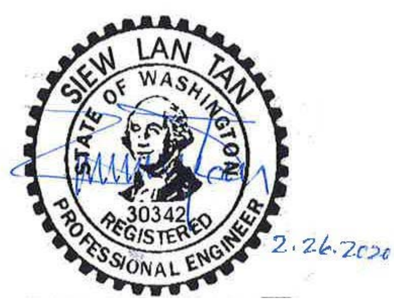
This report has been prepared for planning and design purposes for specific application to the proposed project in accordance with the generally accepted standards of local practice at the time this report was written. No warranty, express or implied, is made.

This report may be used only by the client and for the purposes stated, within a reasonable time from its issuance. Land use, site conditions (both off and on-site), or other factors including advances in our understanding of applied science, may change over time and could materially affect our findings. Therefore, this report should not be relied upon after 24 months from its issuance. PanGEO should be notified if the project is delayed by more than 24 months from the date of this report so that we may review the applicability of our conclusions considering the time lapse.

It is the client's responsibility to see that all parties to this project, including the designer, contractor, subcontractors, etc., are made aware of this report in its entirety. The use of information contained in this report for bidding purposes should be done at the contractor's option and risk. Any party other than the client who wishes to use this report shall notify PanGEO of such intended use and for permission to copy this report. Based on the intended use of the report, PanGEO may require that additional work be performed and that an updated report be reissued. Noncompliance with any of these requirements will release PanGEO from any liability resulting from the use this report.

Sincerely,

PanGEO, Inc.



Bryce C. Townsend, P.E.
Project Geotechnical Engineer

Siew L. Tan, P.E.
Principal Geotechnical Engineer

10.0 REFERENCES

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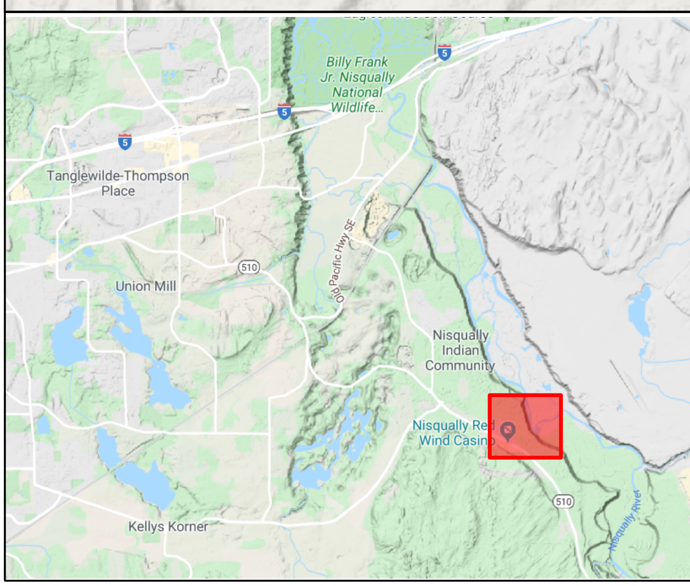


Base Map: Google Terrain Map

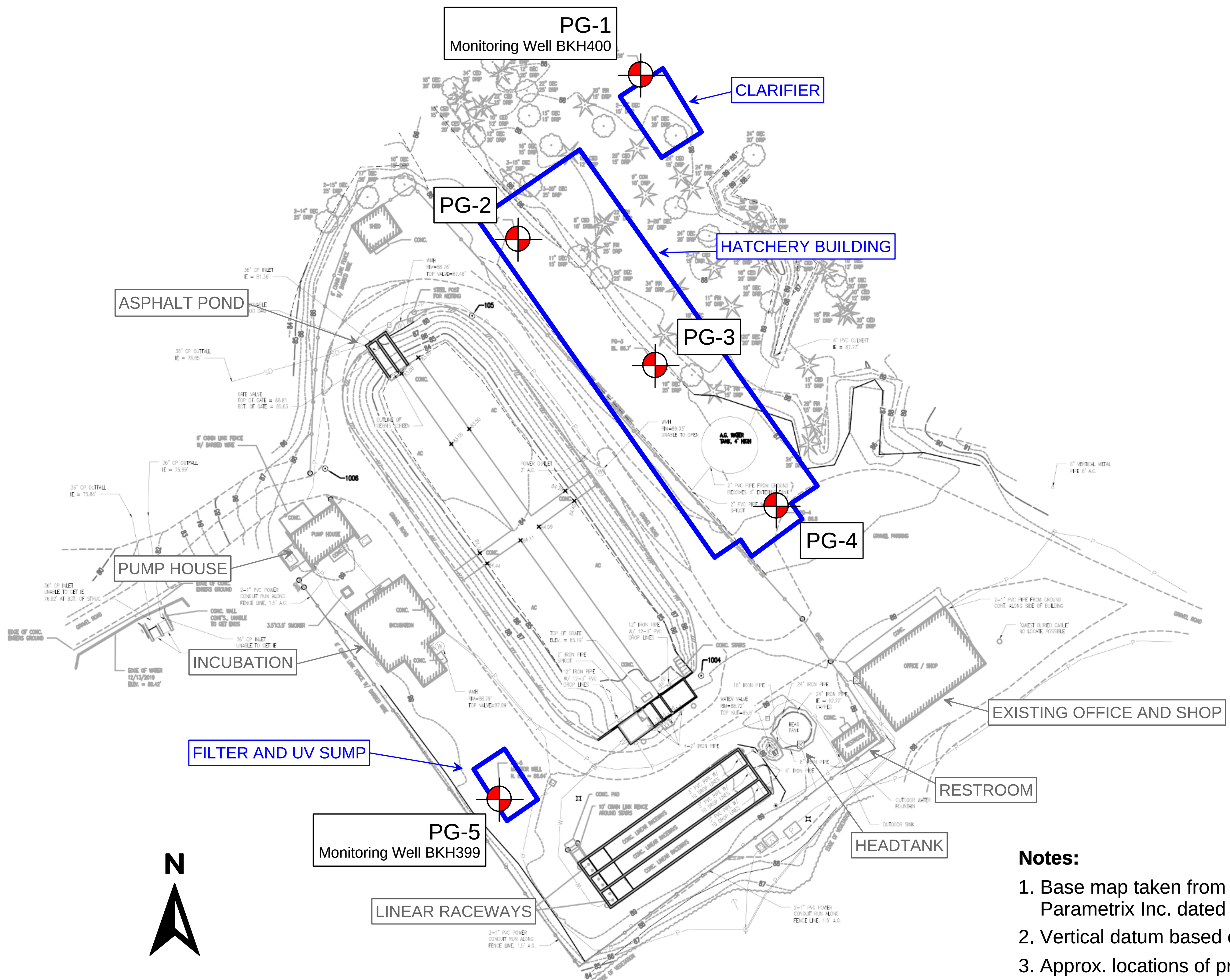
Not to Scale

PanGEO INCORPORATED

Kalama Creek Hatchery Expansion
Nisqually Indian Reservation
Olympia, WA 98513

VICINITY MAP

Project No.	19-384	Figure No.	1



Notes:

1. Base map taken from project survey performed by Parametrix Inc. dated January 2020.
2. Vertical datum based on NAVD88.
3. Approx. locations of proposed structures based on preliminary aerial site plan provided by Parametrix Inc.

Legend:

Approx. Test Boring Location

Approximate Location of Proposed Structures

Scale

Approx. 1" = 50'

0 25' 50'

PanGEO INCORPORATED

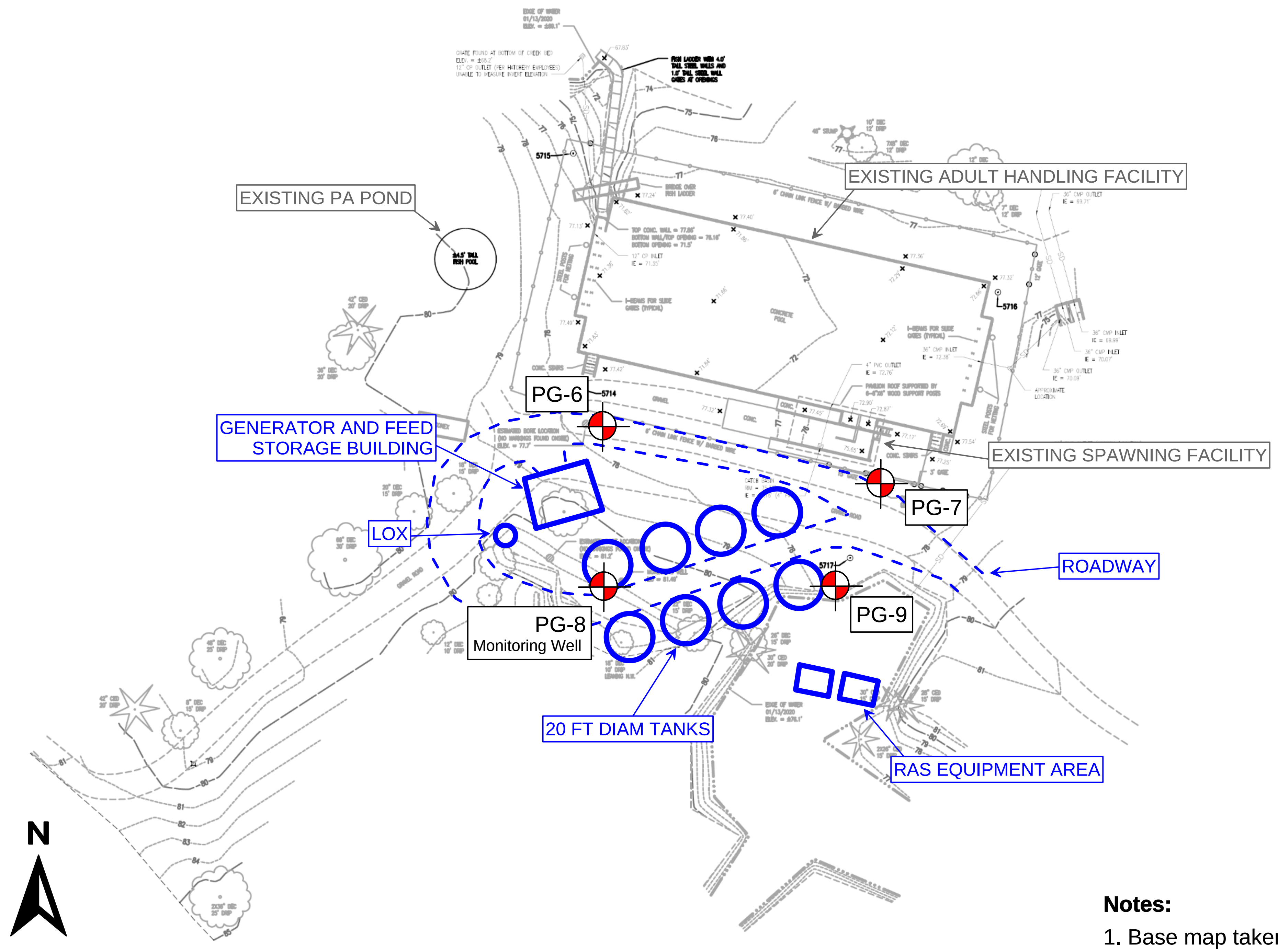
Kalama Creek Hatchery Expansion
Nisqually Indian Reservation
Olympia, WA 98513

SITE AND EXPLORATION PLAN
UPPER SITE

Project No. **19-384**

Figure No. **2**

19-355 Fig 2 (Site Map).grf 2/26/20 (17:15) TEA2



Notes:

1. Base map taken from project survey performed by Parametrix Inc. dated January 2020.
2. Vertical datum based on NAVD88.
3. Approx. locations of proposed structures based on preliminary aerial site plan provided by Parametrix Inc.

Legend:

Approx. Test Boring Location

Approximate Location of Proposed Structures

Scale

Approx. 1" = 50'

0 25' 50'

19-355 Fig 2 (Site Map).grf 2/26/20 (17:16) TEA2

PanGEO INCORPORATED

Kalama Creek Hatchery Expansion
Nisqually Indian Reservation
Olympia, WA 98513

SITE AND EXPLORATION PLAN
LOWER SITE

Project No.	Figure No.
19-384	3

APPENDIX A

SUMMARY BORING LOGS

RELATIVE DENSITY / CONSISTENCY

SAND / GRAVEL			SILT / CLAY		
Density	SPT N-values	Approx. Relative Density (%)	Consistency	SPT N-values	Approx. Undrained Shear Strength (psf)
Very Loose	<4	<15	Very Soft	<2	<250
Loose	4 to 10	15 - 35	Soft	2 to 4	250 - 500
Med. Dense	10 to 30	35 - 65	Med. Stiff	4 to 8	500 - 1000
Dense	30 to 50	65 - 85	Stiff	8 to 15	1000 - 2000
Very Dense	>50	85 - 100	Very Stiff	15 to 30	2000 - 4000
			Hard	>30	>4000

UNIFIED SOIL CLASSIFICATION SYSTEM

MAJOR DIVISIONS		GROUP DESCRIPTIONS	
Gravel 50% or more of the coarse fraction retained on the #4 sieve. Use dual symbols (eg. GP-GM) for 5% to 12% fines.	GRAVEL (<5% fines)	GW	Well-graded GRAVEL
		GP	Poorly-graded GRAVEL
	GRAVEL (>12% fines)	GM	Silty GRAVEL
		GC	Clayey GRAVEL
Sand 50% or more of the coarse fraction passing the #4 sieve. Use dual symbols (eg. SP-SM) for 5% to 12% fines.	SAND (<5% fines)	SW	Well-graded SAND
		SP	Poorly-graded SAND
	SAND (>12% fines)	SM	Silty SAND
		SC	Clayey SAND
Silt and Clay 50%or more passing #200 sieve	Liquid Limit < 50	ML	SILT
		CL	Lean CLAY
		OL	Organic SILT or CLAY
	Liquid Limit > 50	MH	Elastic SILT
		CH	Fat CLAY
		OH	Organic SILT or CLAY
Highly Organic Soils		PT	PEAT

Notes: 1. Soil exploration logs contain material descriptions based on visual observation and field tests using a system modified from the Uniform Soil Classification System (USCS). Where necessary laboratory tests have been conducted (as noted in the "Other Tests" column), unit descriptions may include a classification. Please refer to the discussions in the report text for a more complete description of the subsurface conditions.

2. The graphic symbols given above are not inclusive of all symbols that may appear on the borehole logs. Other symbols may be used where field observations indicated mixed soil constituents or dual constituent materials.

DESCRIPTIONS OF SOIL STRUCTURES

Layered:	Units of material distinguished by color and/or composition from material units above and below	**Fissured:**	Breaks along defined planes
Laminated:	Layers of soil typically 0.05 to 1mm thick, max. 1 cm	**Slickensided:**	Fracture planes that are polished or glossy
Lens:	Layer of soil that pinches out laterally	**Blocky:**	Angular soil lumps that resist breakdown
Interlayered:	Alternating layers of differing soil material	**Disrupted:**	Soil that is broken and mixed
Pocket:	Erratic, discontinuous deposit of limited extent	**Scattered:**	Less than one per foot
Homogeneous:	Soil with uniform color and composition throughout	**Numerous:**	More than one per foot
		BCN:	Angle between bedding plane and a plane normal to core axis

COMPONENT DEFINITIONS

COMPONENT	SIZE / SIEVE RANGE	COMPONENT	SIZE / SIEVE RANGE
Boulder:	> 12 inches	Sand	
Cobbles:	3 to 12 inches	Coarse Sand:	#4 to #10 sieve (4.5 to 2.0 mm)
Gravel		Medium Sand:	#10 to #40 sieve (2.0 to 0.42 mm)
Coarse Gravel:	3 to 3/4 inches	Fine Sand:	#40 to #200 sieve (0.42 to 0.074 mm)
Fine Gravel:	3/4 inches to #4 sieve	Silt	0.074 to 0.002 mm
		Clay	<0.002 mm

TEST SYMBOLS

for In Situ and Laboratory Tests listed in "Other Tests" column.

ATT	Atterberg Limit Test
Comp	Compaction Tests
Con	Consolidation
DD	Dry Density
DS	Direct Shear
%F	Fines Content
GS	Grain Size
Perm	Permeability
PP	Pocket Penetrometer
R	R-value
SG	Specific Gravity
TV	Torvane
TXC	Triaxial Compression
UCC	Unconfined Compression

SYMBOLS

Sample/In Situ test types and intervals

- 2-inch OD Split Spoon, SPT (140-lb. hammer, 30" drop)
- 3.25-inch OD Spilt Spoon (300-lb hammer, 30" drop)
- Non-standard penetration test (see boring log for details)
- Thin wall (Shelby) tube
- Grab
- Rock core
- Vane Shear

MONITORING WELL

- Groundwater Level at time of drilling (ATD)
- Static Groundwater Level
- Cement / Concrete Seal
- Bentonite grout / seal
- Silica sand backfill
- Slotted tip
- Slough
- Bottom of Boring

MOISTURE CONTENT

Dry	Dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water

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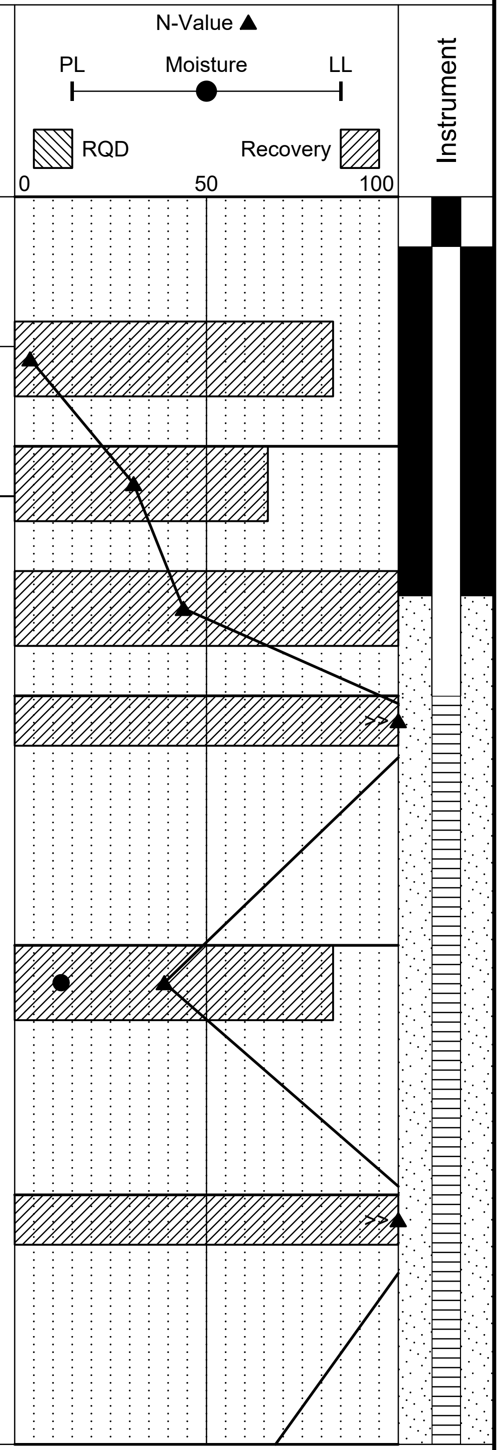
Terms and Symbols for Boring and Test Pit Logs

Figure A-1

Project:	Kalama Creek Hatchery Expansion	Surface Elevation:	Approx. 87.6 ft
Job Number:	19-384	Top of Casing Elev.:	N/A
Location:	Nisqually Indian Reservation, Olympia, WA 98513	Drilling Method:	Hollow Stem Auger
Coordinates:	Northing: , Easting:	Sampling Method:	SPT

Depth, (ft)	Sample No.	Sample Type	Blows / 6 in.	Other Tests	Symbol	MATERIAL DESCRIPTION
0						Ferns, brambles, and forest duff over loose, moist, dark brown silty SAND with organics. **(Topsoil)**.
	1		2 2 2			Loose, moist, brownish-gray, interbedded SILT and silty, fine to medium SAND; thinly laminated to massive. **(Alluvium - Qa)**
5	2		2 2 29			Dense, moist, gray-brown, gravelly and silty SAND; fine to medium sand, angular gravels. **(Alluvium - Qa)**
	3		24 24 20			- Groundwater measured in well at about 8.0 ft deep ATD and 6.9 ft deep on 2/13/2020.
10	4		20 50/6			- Sample S-4: Becomes very dense.
15	5		14 16 23	GS		- Sample S-5: Becomes dense. Gravel = 31.4%, Sand = 34.4%, Fines = 34.2%.
20	6		40 50/6			- Sample S-6: very dense.
25						



Completion Depth:	31.5ft
Date Borehole Started:	12/9/19
Date Borehole Completed:	12/9/19
Logged By:	NER
Drilling Company:	Boretec

Remarks: Standard Penetration Test (SPT) sampler driven with a 140 lb. safety hammer. Hammer operated with a rope and cathead mechanism. Surface elevations taken from project survey provided by Parametrix Inc. dated January 2020.

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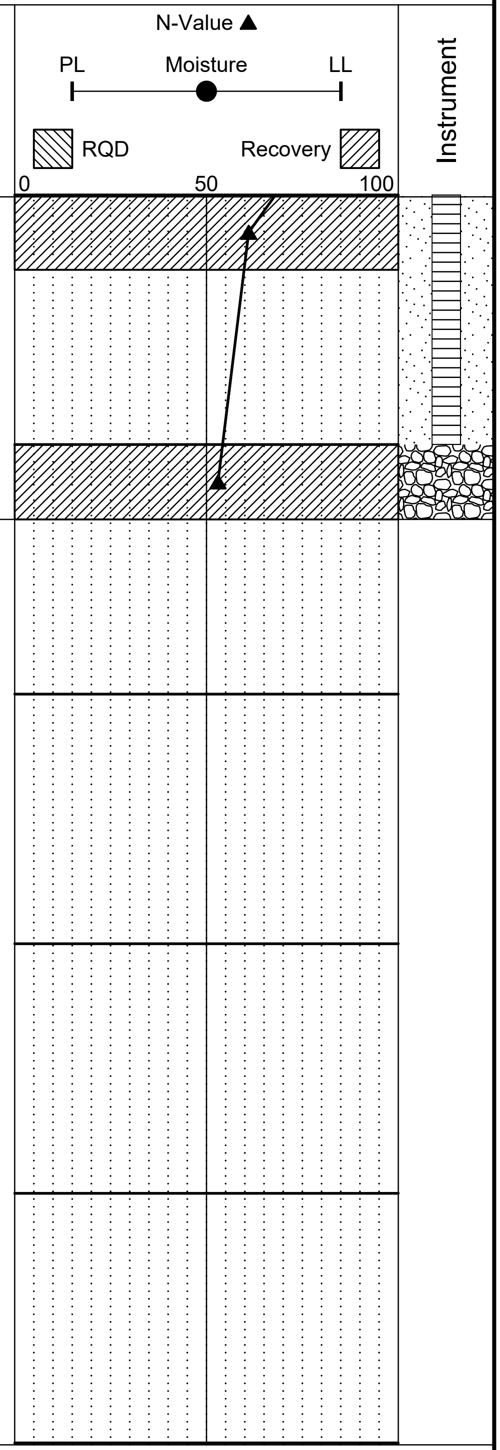
LOG OF TEST BORING PG-1

Figure A-2

The stratification lines represent approximate boundaries. The transition may be gradual.

Project:	Kalama Creek Hatchery Expansion	Surface Elevation:	Approx. 87.6 ft
Job Number:	19-384	Top of Casing Elev.:	N/A
Location:	Nisqually Indian Reservation, Olympia, WA 98513	Drilling Method:	Hollow Stem Auger
Coordinates:	Northing: , Easting:	Sampling Method:	SPT

Depth, (ft)	Sample No.	Sample Type	Blows / 6 in.	Other Tests	Symbol	MATERIAL DESCRIPTION
25	7		20 26 35			Dense, moist, gray-brown, gravelly and silty SAND; fine to medium sand, angular gravels. **(Alluvium - Qa)** *(Continued)*
30	8		20 21 32			
						Bottom of the boring at 31.5 feet below ground surface. Groundwater was measured in well at approximately 8.0 feet deep ATD (12/9/2019) and 6.9 feet deep on 2/13/2020.
35						
40						
45						
50						



Completion Depth:	31.5ft
Date Borehole Started:	12/9/19
Date Borehole Completed:	12/9/19
Logged By:	NER
Drilling Company:	Boretec

Remarks: Standard Penetration Test (SPT) sampler driven with a 140 lb. safety hammer. Hammer operated with a rope and cathead mechanism. Surface elevations taken from project survey provided by Parametrix Inc. dated January 2020.

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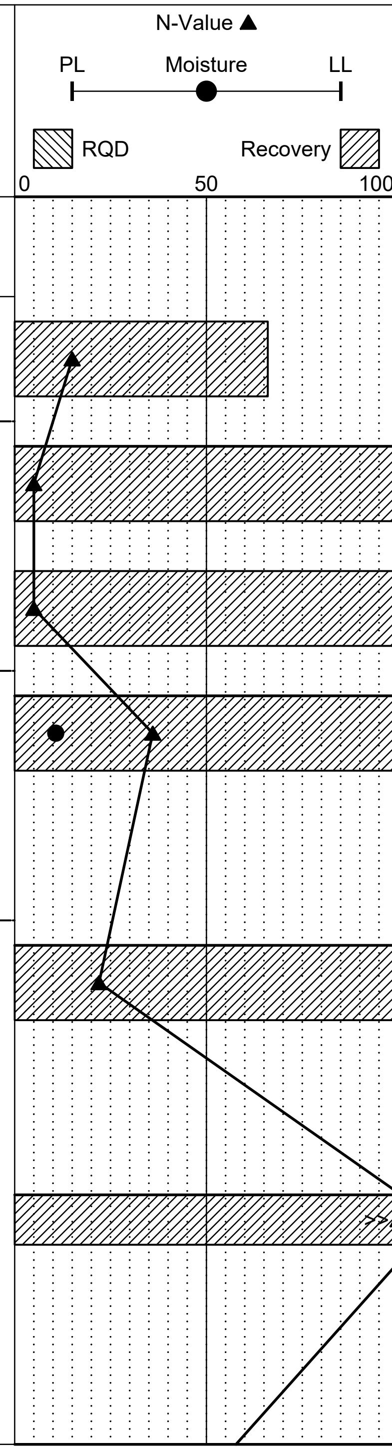
LOG OF TEST BORING PG-1

Figure A-2

The stratification lines represent approximate boundaries. The transition may be gradual.

Project:	Kalama Creek Hatchery Expansion	Surface Elevation:	Approx. 86.6 ft
Job Number:	19-384	Top of Casing Elev.:	N/A
Location:	Nisqually Indian Reservation, Olympia, WA 98513	Drilling Method:	Hollow Stem Auger
Coordinates:	Northing: , Easting:	Sampling Method:	SPT

Depth, (ft)	Sample No.	Sample Type	Blows / 6 in.	Other Tests	Symbol	MATERIAL DESCRIPTION
0						Ferns, brambles, and forest duff over loose, moist, dark brown silty SAND with organics. **(Topsoil)**
	1		8 8 7			Medium dense, moist, brownish-gray, slightly silty to silty, fine to medium SAND; thinly laminated to massive. **(Alluvium - Qa)**
5	2		2 3 2			Medium stiff, wet, brownish-gray, interbedded SILT and silty, fine to medium SAND; occasional fine organics, iron oxide stained, thinly laminated to massive. **(Alluvium - Qa)**
	3		4 3 2			
10	4		11 18 18	GS		Dense, wet, gray-brown, gravelly and silty SAND; angular gravels. **(Alluvium - Qa)** - Sample S-4: Gravel = 38.9%, Sand = 35.5%, Fines = 25.6%.
15	5		9 11 11			Medium dense, wet, gray-brown, fine to medium SAND with silt; slightly gravelly to gravelly. **(Alluvium - Qa)**
20	6		42 50/6			- Sample S-6: Becomes very dense, gravelly.
						- Difficult drilling in gravelly conditions.
25						



Completion Depth:	30.5ft
Date Borehole Started:	12/9/19
Date Borehole Completed:	12/9/19
Logged By:	NER
Drilling Company:	Boretec

Remarks: Standard Penetration Test (SPT) sampler driven with a 140 lb. safety hammer. Hammer operated with a rope and cathead mechanism. Surface elevations taken from project survey provided by Parametrix Inc. dated January 2020.

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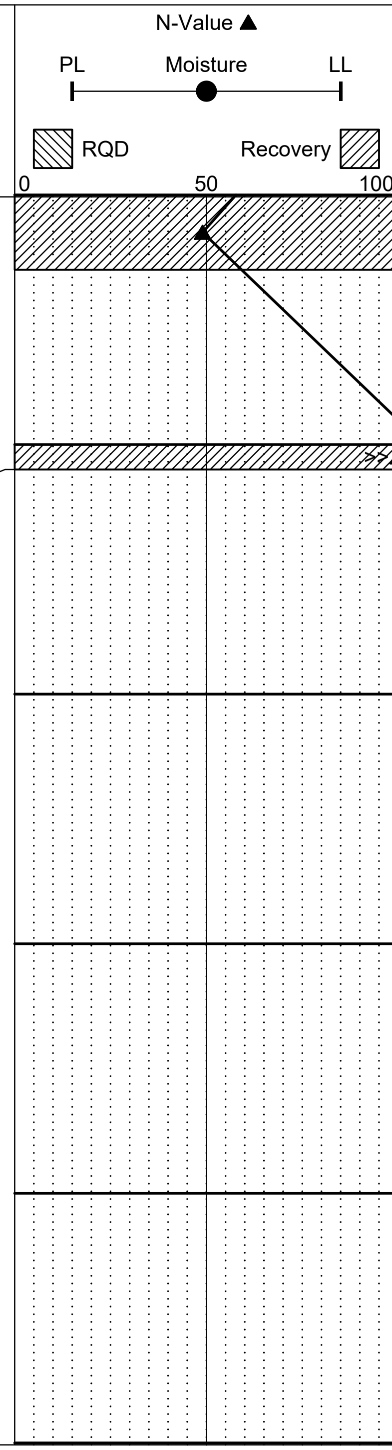
LOG OF TEST BORING PG-2

Figure A-3

The stratification lines represent approximate boundaries. The transition may be gradual.

Project:	Kalama Creek Hatchery Expansion	Surface Elevation:	Approx. 86.6 ft
Job Number:	19-384	Top of Casing Elev.:	N/A
Location:	Nisqually Indian Reservation, Olympia, WA 98513	Drilling Method:	Hollow Stem Auger
Coordinates:	Northing: , Easting:	Sampling Method:	SPT

Depth, (ft)	Sample No.	Sample Type	Blows / 6 in.	Other Tests	Symbol	MATERIAL DESCRIPTION
25	7		19 24 25			Medium dense, wet, gray-brown, fine to medium SAND with silt; slightly gravelly to gravelly. **(Alluvium - Qa)** *(Continued)* - Sample S-7: Becomes dense, decreased gravels.
30	8		50/6			- Sample S-8: Becomes very dense.
						Bottom of the boring at 30.5 feet below ground surface. Groundwater was observed approximately 6 feet deep ATD.
35						
40						
45						
50						



Completion Depth:	30.5ft
Date Borehole Started:	12/9/19
Date Borehole Completed:	12/9/19
Logged By:	NER
Drilling Company:	Boretec

Remarks: Standard Penetration Test (SPT) sampler driven with a 140 lb. safety hammer. Hammer operated with a rope and cathead mechanism. Surface elevations taken from project survey provided by Parametrix Inc. dated January 2020.

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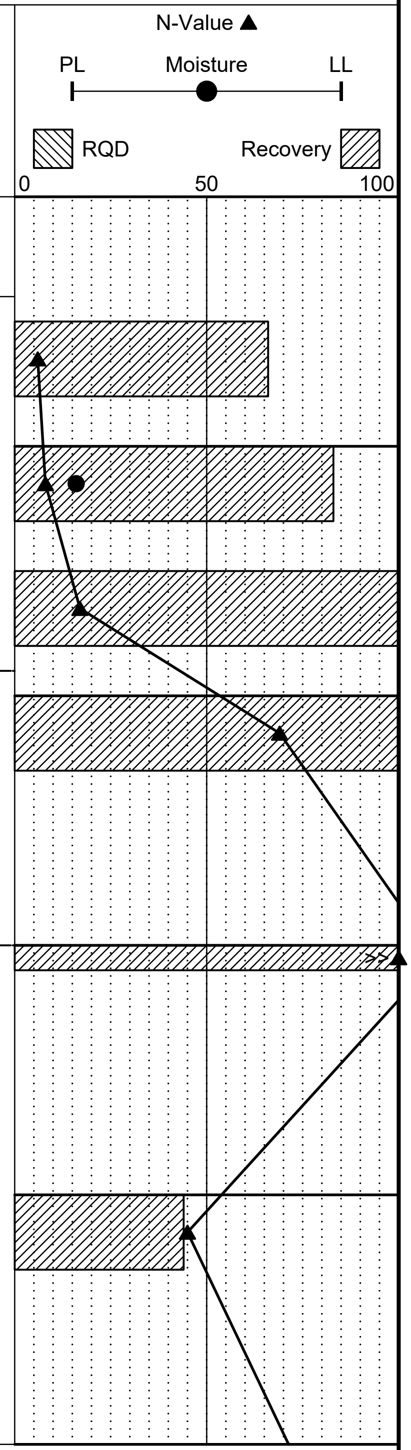
LOG OF TEST BORING PG-2

Figure A-3

The stratification lines represent approximate boundaries. The transition may be gradual.

Project:	Kalama Creek Hatchery Expansion	Surface Elevation:	Approx. 86.7 ft
Job Number:	19-384	Top of Casing Elev.:	N/A
Location:	Nisqually Indian Reservation, Olympia, WA 98513	Drilling Method:	Hollow Stem Auger
Coordinates:	Northing: , Easting:	Sampling Method:	SPT

Depth, (ft)	Sample No.	Sample Type	Blows / 6 in.	Other Tests	Symbol	MATERIAL DESCRIPTION
0						Ferns, brambles, and forest duff over loose, moist, dark brown silty SAND with organics. **(Topsoil)**
						Loose, moist, brownish-gray, silty, fine to medium SAND; thinly laminated to massive, occasional fine organics in upper portion of unit. **(Alluvium - Qa)**
	1		5 3 3			
5	2		3 4 4	GS		Sample S-2: Gravel = 0%, Sand = 76.8%, Silt = 23.2%.
	3		4 4 13			- Sample S-3:Becomes medium dense, wet.
10						Very dense, wet, gray-brown, gravelly and silty SAND; fine to medium sand, angular gravels. **(Alluvium - Qa)**
	4		24 41 28			
						- Difficult drilling in gravelly conditions.
15	5		50/6			Very dense, wet, gray-brown, fine to medium SAND with silt; slightly gravelly to gravelly. **(Alluvium - Qa)**
20	6		20 17 28			- Sample S-6: Becomes dense, gravelly.
						- Difficult drilling in gravelly conditions.
25						



Completion Depth: 31.0ft
Date Borehole Started: 12/9/19
Date Borehole Completed: 12/9/19
Logged By: NER
Drilling Company: Boretec

Remarks: Standard Penetration Test (SPT) sampler driven with a 140 lb. safety hammer. Hammer operated with a rope and cathead mechanism. Surface elevations taken from project survey provided by Parametrix Inc. dated January 2020.

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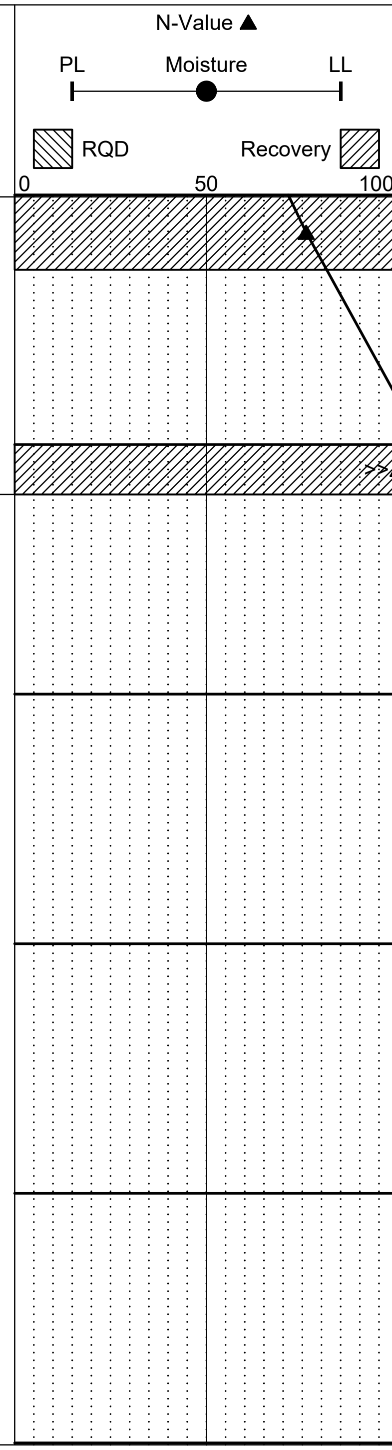
LOG OF TEST BORING PG-3

Figure A-4

The stratification lines represent approximate boundaries. The transition may be gradual.

Project:	Kalama Creek Hatchery Expansion	Surface Elevation:	Approx. 86.7 ft
Job Number:	19-384	Top of Casing Elev.:	N/A
Location:	Nisqually Indian Reservation, Olympia, WA 98513	Drilling Method:	Hollow Stem Auger
Coordinates:	Northing: , Easting:	Sampling Method:	SPT

Depth, (ft)	Sample No.	Sample Type	Blows / 6 in.	Other Tests	Symbol	MATERIAL DESCRIPTION
25	7	X	40 43 33			Very dense, wet, gray-brown, fine to medium SAND with silt; slightly gravelly to gravelly. **(Alluvium - Qa)** *(Continued)* - Sample S-7: Becomes very dense, increased gravels.
30	8	X	29 50/6			
						Bottom of the boring at 31 feet below ground surface. Groundwater was observed approximately 7.5 feet deep ATD.
35						
40						
45						
50						



Completion Depth:	31.0ft
Date Borehole Started:	12/9/19
Date Borehole Completed:	12/9/19
Logged By:	NER
Drilling Company:	Boretec

Remarks: Standard Penetration Test (SPT) sampler driven with a 140 lb. safety hammer. Hammer operated with a rope and cathead mechanism. Surface elevations taken from project survey provided by Parametrix Inc. dated January 2020.

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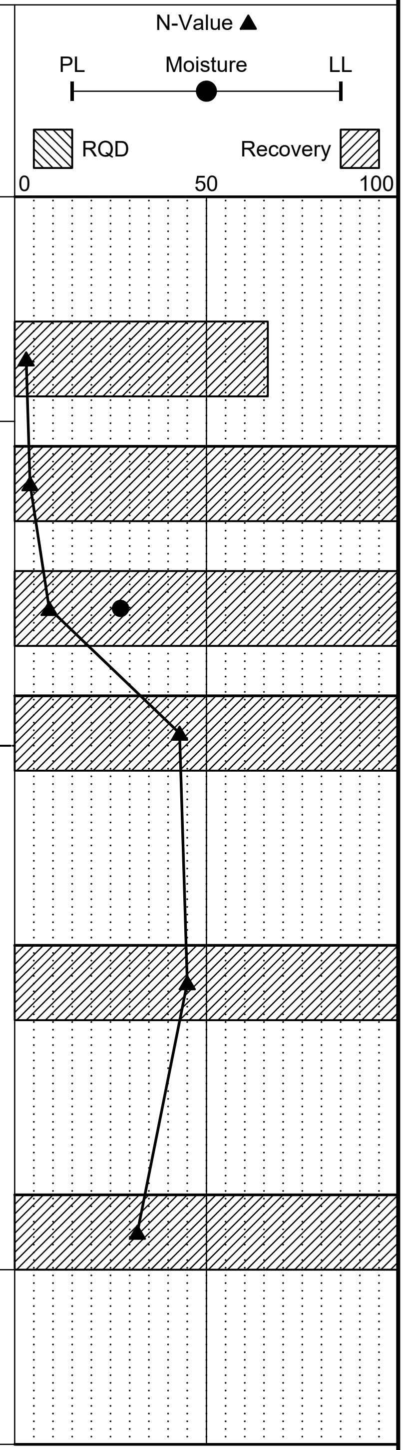
LOG OF TEST BORING PG-3

Figure A-4

The stratification lines represent approximate boundaries. The transition may be gradual.

Project:	Kalama Creek Hatchery Expansion	Surface Elevation:	Approx. 86.8 ft
Job Number:	19-384	Top of Casing Elev.:	N/A
Location:	Nisqually Indian Reservation, Olympia, WA 98513	Drilling Method:	Hollow Stem Auger
Coordinates:	Northing: , Easting:	Sampling Method:	SPT

Depth, (ft)	Sample No.	Sample Type	Blows / 6 in.	Other Tests	Symbol	MATERIAL DESCRIPTION
0						Loose, moist, brown, slightly silty to silty, fine to medium SAND; gravelly in upper portion of unit. **(Fill)**.
	1	X	2 1 2			
5						Loose, wet, brownish-gray, silty SAND; fine to medium sand, thinly laminated to massive, occasional fine organics in upper portion of unit, grading to coarse sand in bottom of unit. **(Alluvium - Qa)**
	2	X	2 2 2		∇	
	3	X	3 4 5	GS		- Sample S-3: Gravel = 2.5%, Sand = 85.6%, Fines = 11.9%.
10	4	X	3 16 27			
						Dense, wet, gray-brown gravelly, slightly silty to silty SAND with gravel; fine to medium sand, angular gravels. **(Alluvium - Qa)**
15	5	X	10 16 29			
						- Difficult drilling in gravelly conditions.
20	6	X	15 15 17			
						Bottom of the boring at 21.5 feet below ground surface. Groundwater was observed approximately 6 feet deep ATD.
25						



Completion Depth:	21.5ft
Date Borehole Started:	12/10/19
Date Borehole Completed:	12/10/19
Logged By:	NER
Drilling Company:	Boretec

Remarks: Standard Penetration Test (SPT) sampler driven with a 140 lb. safety hammer. Hammer operated with a rope and cathead mechanism. Surface elevations taken from project survey provided by Parametrix Inc. dated January 2020.

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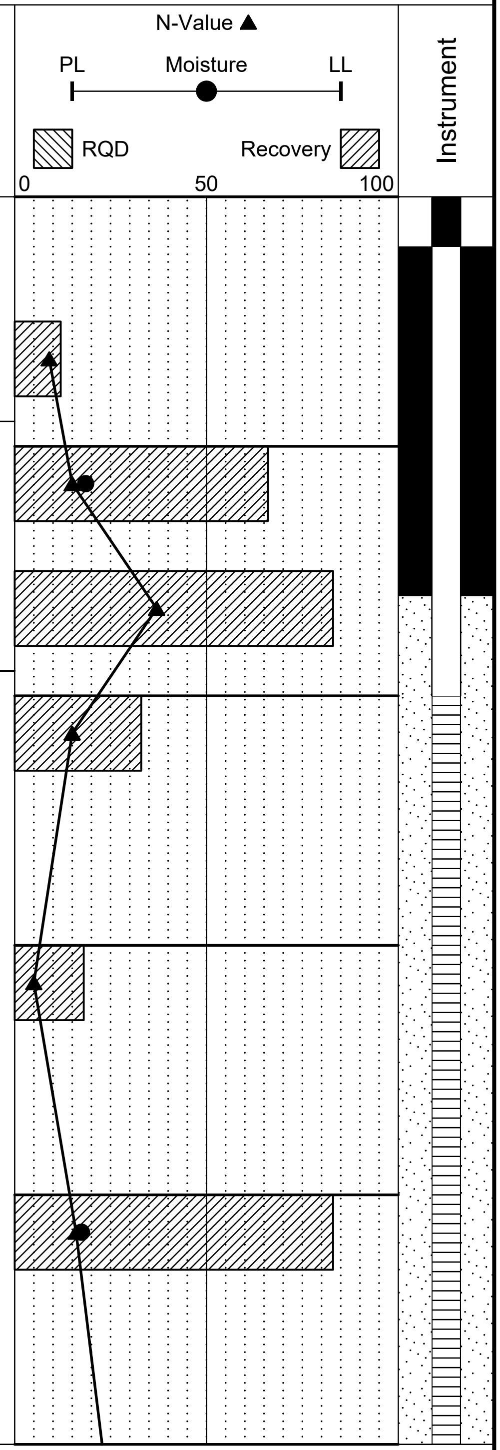
LOG OF TEST BORING PG-4

Figure A-5

The stratification lines represent approximate boundaries. The transition may be gradual.

Project:	Kalama Creek Hatchery Expansion	Surface Elevation:	Approx. 88.6 ft
Job Number:	19-384	Top of Casing Elev.:	N/A
Location:	Nisqually Indian Reservation, Olympia, WA 98513	Drilling Method:	Hollow Stem Auger
Coordinates:	Northing: , Easting:	Sampling Method:	SPT

Depth, (ft)	Sample No.	Sample Type	Blows / 6 in.	Other Tests	Symbol	MATERIAL DESCRIPTION
0						Grass and a thin layer of topsoil over loose, moist, dark brown silty SAND with gravel and organics. **(Fill)**.
	1		7 5 4			
5	2		2 3 12	GS		Medium dense, moist, brownish-gray, slightly silty to silty SAND; fine to medium sand, thinly laminated to massive. **(Alluvium - Qa)** - Sample S-2: Gravel = 23.3%, Sand = 44.9%, Fines = 31.8%.
	3		16 20 17			- Sample S-3: Becomes dense. - Groundwater measured in well at about 8.5 ft deep ATD and 7.8 ft deep on 2/13/2020.
10	4		6 10 5			Medium dense, wet, gray-brown, SAND with silt and gravel; fine to medium sand, angular gravels. **(Alluvium - Qa)**.
15	5		2 2 3			- Sample S-5: Becomes loose.
20	6		7 8 8	GS		- Sample S-6: Becomes medium dense, increased gravel. Gravel = 18.6%, Sand = 77.8%, Fines = 3.6%.
25						



Completion Depth:	31.0ft	Remarks: Standard Penetration Test (SPT) sampler driven with a 140 lb. safety hammer. Hammer operated with a rope and cathead mechanism. Surface elevations taken from project survey provided by Parametrix Inc. dated January 2020.
Date Borehole Started:	12/9/19	
Date Borehole Completed:	12/9/19	
Logged By:	NER	
Drilling Company:	Boretec	

PanGEO INCORPORATED

LOG OF TEST BORING PG-5

Figure A-6

The stratification lines represent approximate boundaries. The transition may be gradual.

Project:	Kalama Creek Hatchery Expansion	Surface Elevation:	Approx. 88.6 ft
Job Number:	19-384	Top of Casing Elev.:	N/A
Location:	Nisqually Indian Reservation, Olympia, WA 98513	Drilling Method:	Hollow Stem Auger
Coordinates:	Northing: , Easting:	Sampling Method:	SPT

Depth, (ft)	Sample No.	Sample Type	Blows / 6 in.	Other Tests	Symbol	MATERIAL DESCRIPTION	N-Value ▲ PL Moisture LL RQD Recovery 0 50 100	Instrument
25	7		12 10 14			Medium dense, wet, gray-brown, SAND with silt and gravel; fine to medium sand, angular gravels. **(Alluvium - Qa)**. *(Continued)* - Sample S-7: Organic layers and woody debris present. - Difficult drilling in gravelly conditions.		
30	8		44 50/6			- Sample S-8: Becomesvery dense, gravelly.	>>	
						Bottom of the boring at 31 feet below ground surface. Groundwater was measured in well at approximately 8.5 feet deep ATD and 7.8 feet deep on 2/13/2020.		
35								
40								
45								
50								

Completion Depth:	31.0ft
Date Borehole Started:	12/9/19
Date Borehole Completed:	12/9/19
Logged By:	NER
Drilling Company:	Boretec

Remarks: Standard Penetration Test (SPT) sampler driven with a 140 lb. safety hammer. Hammer operated with a rope and cathead mechanism. Surface elevations taken from project survey provided by Parametrix Inc. dated January 2020.

PanGEO INCORPORATED

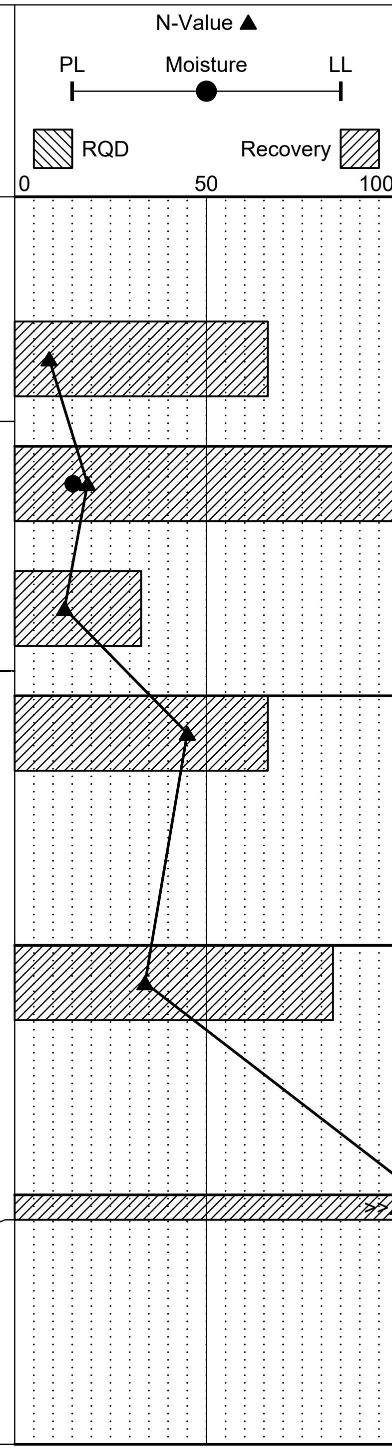
LOG OF TEST BORING PG-5

Figure A-6

The stratification lines represent approximate boundaries. The transition may be gradual.

Project:	Kalama Creek Hatchery Expansion	Surface Elevation:	Approx. 77.7 ft
Job Number:	19-384	Top of Casing Elev.:	N/A
Location:	Nisqually Indian Reservation, Olympia, WA 98513	Drilling Method:	Hollow Stem Auger
Coordinates:	Northing: , Easting:	Sampling Method:	SPT

Depth, (ft)	Sample No.	Sample Type	Blows / 6 in.	Other Tests	Symbol	MATERIAL DESCRIPTION
0						Gravel drive surface over loose, moist, dark brown silty SAND with gravel and organics. **(Fill)**.
	1		4 5 4			
5	2		9 10 9	GS		Medium dense, wet, brownish-gray, slightly silty to silty SAND; fine to medium sand, some gravelly layers, thinly laminated to massive. **(Alluvium - Qa)** - Sample S-2: Gravel = 42.0%, Sand = 32.2%, Fines = 25.8%.
	3		5 5 8			
10	4		44 18 27			Dense, wet, gray-brown, slightly silty, gravelly SAND; fine to medium sand. **(Alluvium - Qa)**
15	5		14 13 21			
20	6		50/6			Sample S-6: Becomes very dense, increased gravel.
						Bottom of the boring at 20.5 feet below ground surface. Groundwater was observed approximately 5 feet deep ATD.
25						



Completion Depth:	20.5ft
Date Borehole Started:	12/10/19
Date Borehole Completed:	12/10/19
Logged By:	NER
Drilling Company:	Boretec

Remarks: Standard Penetration Test (SPT) sampler driven with a 140 lb. safety hammer. Hammer operated with a rope and cathead mechanism. Surface elevations taken from project survey provided by Parametrix Inc. dated January 2020.

PanGEO INCORPORATED

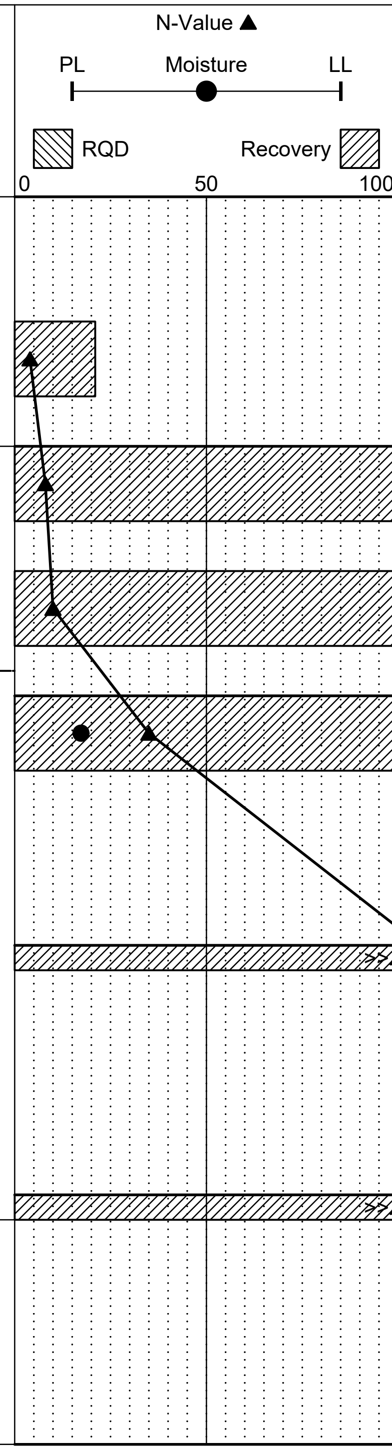
LOG OF TEST BORING PG-6

Figure A-7

The stratification lines represent approximate boundaries. The transition may be gradual.

Project:	Kalama Creek Hatchery Expansion	Surface Elevation:	Approx. 77.8 ft
Job Number:	19-384	Top of Casing Elev.:	N/A
Location:	Nisqually Indian Reservation, Olympia, WA 98513	Drilling Method:	Hollow Stem Auger
Coordinates:	Northing: , Easting:	Sampling Method:	SPT

Depth, (ft)	Sample No.	Sample Type	Blows / 6 in.	Other Tests	Symbol	MATERIAL DESCRIPTION
0						Gravel drive surface over loose, moist, dark brown silty SAND with gravel and organics. **(Fill)**.
	1		4 3 1			
5	2		3 4 4			Loose, wet, brownish-gray, interbedded silty SAND and SILT; trace fine organics, thinly laminated to massive. **(Alluvium - Qa)**
	3		8 5 5			
10	4		7 22 13	GS		Dense, wet, gray-brown, slightly silty, gravelly SAND; fine to medium sand. **(Alluvium - Qa)** - Sample S4: Gravel = 17.8%, Sand = 76.9%, Fines = 5.3%.
15	5		50/6			Sample S-5: Becomes very dense, increased gravel.
20	6		50/6			
						Bottom of the boring at 20.5 feet below ground surface. Groundwater was observed approximately 5 feet deep ATD.
25						



Completion Depth:	26.5ft
Date Borehole Started:	12/10/19
Date Borehole Completed:	12/10/19
Logged By:	NER
Drilling Company:	Boretec

Remarks: Standard Penetration Test (SPT) sampler driven with a 140 lb. safety hammer. Hammer operated with a rope and cathead mechanism. Surface elevations taken from project survey provided by Parametrix Inc. dated January 2020.

PanGEO INCORPORATED

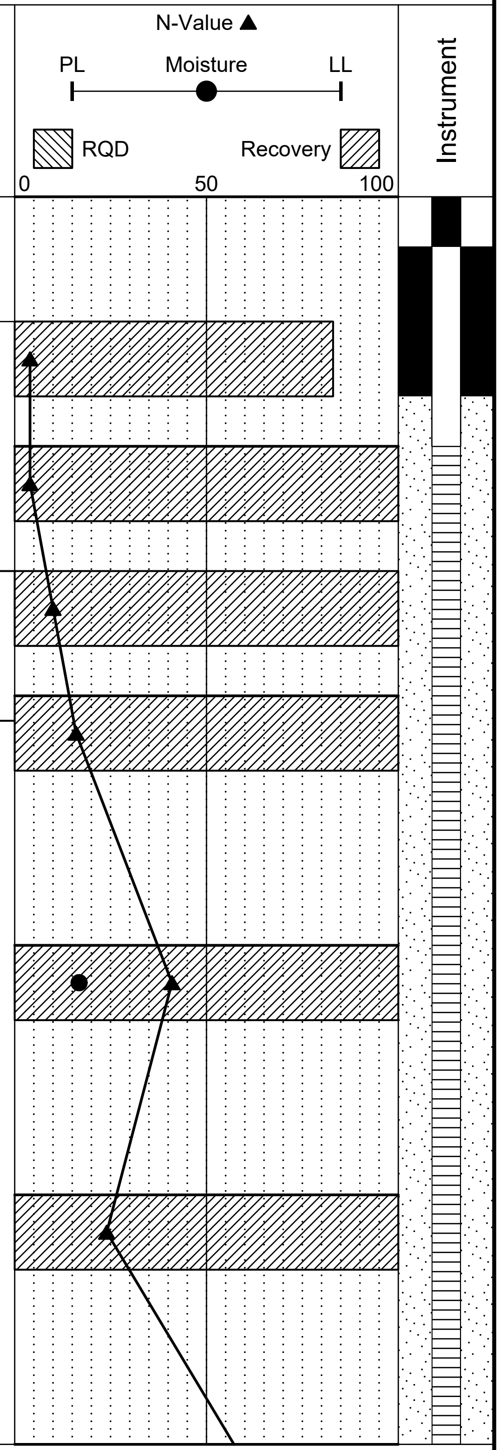
LOG OF TEST BORING PG-7

Figure A-8

The stratification lines represent approximate boundaries. The transition may be gradual.

Project:	Kalama Creek Hatchery Expansion	Surface Elevation:	Approx. 81.5 ft
Job Number:	19-384	Top of Casing Elev.:	N/A
Location:	Nisqually Indian Reservation, Olympia, WA 98513	Drilling Method:	Hollow Stem Auger
Coordinates:	Northing: , Easting:	Sampling Method:	SPT

Depth, (ft)	Sample No.	Sample Type	Blows / 6 in.	Other Tests	Symbol	MATERIAL DESCRIPTION
0						Grass and a thin layer of topsoil over loose, moist, dark brown silty SAND with gravel and organics. **(Fill)**.
	1		3 2 2			Loose, moist, brownish-gray, slightly silty to silty, fine to medium SAND; occasional fine organics and small roots, thinly laminated to massive. **(Alluvium - Qa)**
5	2		2 2 2			
	3		2 3 7			Medium stiff, wet, brownish-gray, SILT with fine sand; occasional fine organics and small roots, thinly laminated to massive. **(Alluvium - Qa)** - Groundwater measured in well at about 8.6 ft deep ATD and 7.7 ft deep on 2/13/2020.
10	4		4 5 11			Medium dense, wet, gray-brown, gravelly SAND with silt; fine to medium sand. **(Alluvium - Qa)**
15	5		17 20 21	GS		- Sample S-5: Becomes dense, increased silt. Gravel = 42.0%, Sand = 41.6%, Fines = 16.4%.
20	6		14 12 12			- Sample S-6: Becomes medium dense.
25						



Completion Depth:	26.5ft
Date Borehole Started:	12/10/19
Date Borehole Completed:	12/10/19
Logged By:	NER
Drilling Company:	Boretec

Remarks: Standard Penetration Test (SPT) sampler driven with a 140 lb. safety hammer. Hammer operated with a rope and cathead mechanism. Surface elevations taken from project survey provided by Parametrix Inc. dated January 2020.

PanGEO INCORPORATED

LOG OF TEST BORING PG-8

Figure A-9

The stratification lines represent approximate boundaries. The transition may be gradual.

Project:	Kalama Creek Hatchery Expansion	Surface Elevation:	Approx. 81.5 ft
Job Number:	19-384	Top of Casing Elev.:	N/A
Location:	Nisqually Indian Reservation, Olympia, WA 98513	Drilling Method:	Hollow Stem Auger
Coordinates:	Northing: , Easting:	Sampling Method:	SPT

Depth, (ft)	Sample No.	Sample Type	Blows / 6 in.	Other Tests	Symbol	MATERIAL DESCRIPTION	N-Value ▲ / PL Moisture LL / RQD Recovery (0 50 100)	Instrument
25	7		44 40 23			Medium dense, wet, gray-brown, gravelly SAND with silt; fine to medium sand. **(Alluvium - Qa)** *(Continued)* - Sample S-7: Becomes very dense, very gravelly.		
						Bottom of the boring at 26.5 feet below ground surface. Groundwater was measured in well at approximately 8.6 feet deep ATD and 7.7 feet deep on 2/13/2020.		
30								
35								
40								
45								
50								

Completion Depth: 26.5ft
Date Borehole Started: 12/10/19
Date Borehole Completed: 12/10/19
Logged By: NER
Drilling Company: Boretec

Remarks: Standard Penetration Test (SPT) sampler driven with a 140 lb. safety hammer. Hammer operated with a rope and cathead mechanism. Surface elevations taken from project survey provided by Parametrix Inc. dated January 2020.

PanGEO INCORPORATED

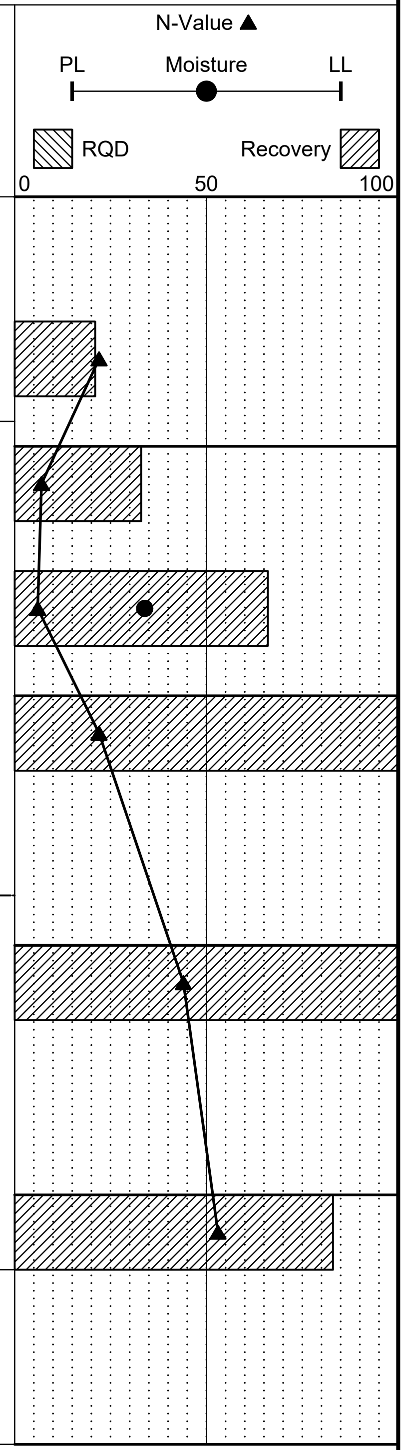
LOG OF TEST BORING PG-8

Figure A-9

The stratification lines represent approximate boundaries. The transition may be gradual.

Project:	Kalama Creek Hatchery Expansion	Surface Elevation:	Approx. 78 ft
Job Number:	19-384	Top of Casing Elev.:	N/A
Location:	Nisqually Indian Reservation, Olympia, WA 98513	Drilling Method:	Hollow Stem Auger
Coordinates:	Northing: , Easting:	Sampling Method:	SPT

Depth, (ft)	Sample No.	Sample Type	Blows / 6 in.	Other Tests	Symbol	MATERIAL DESCRIPTION
0						Grass and topsoil at the surface over medium dense, moist, dark brown silty SAND with gravel and organics. **(Fill)**.
	1		18 14 8			
5						Loose, wet, brownish-gray, slightly silty GRAVEL with sand; fine to medium sandoccasional organics and wood debris. **(Alluvium - Qa)**
	2		4 3 4			
	3		7 4 2	GS		Sample S-3: Gravel 51.3%, Sand 40.4%, Fines = 8.3%.
10	4		6 7 15			Sample S-4: Becomes medium dense.
						Dense, wet, gray-brown, gravelly SAND with silt; fine to medium sand, angular gravels. **(Alluvium - Qa)**
15	5		24 20 24			
20	6		18 33 20			Sample S-6: Becomes very dense, increased gravel.
						Bottom of the boring at 21.5 feet below ground surface. Groundwater was observed from below approximately 5 feet at the time of drilling.
25						



Completion Depth:	21.5ft
Date Borehole Started:	12/10/19
Date Borehole Completed:	12/10/19
Logged By:	NER
Drilling Company:	Boretec

Remarks: Standard Penetration Test (SPT) sampler driven with a 140 lb. safety hammer. Hammer operated with a rope and cathead mechanism. Surface elevations taken from project survey provided by Parametrix Inc. dated January 2020.

PanGEO INCORPORATED

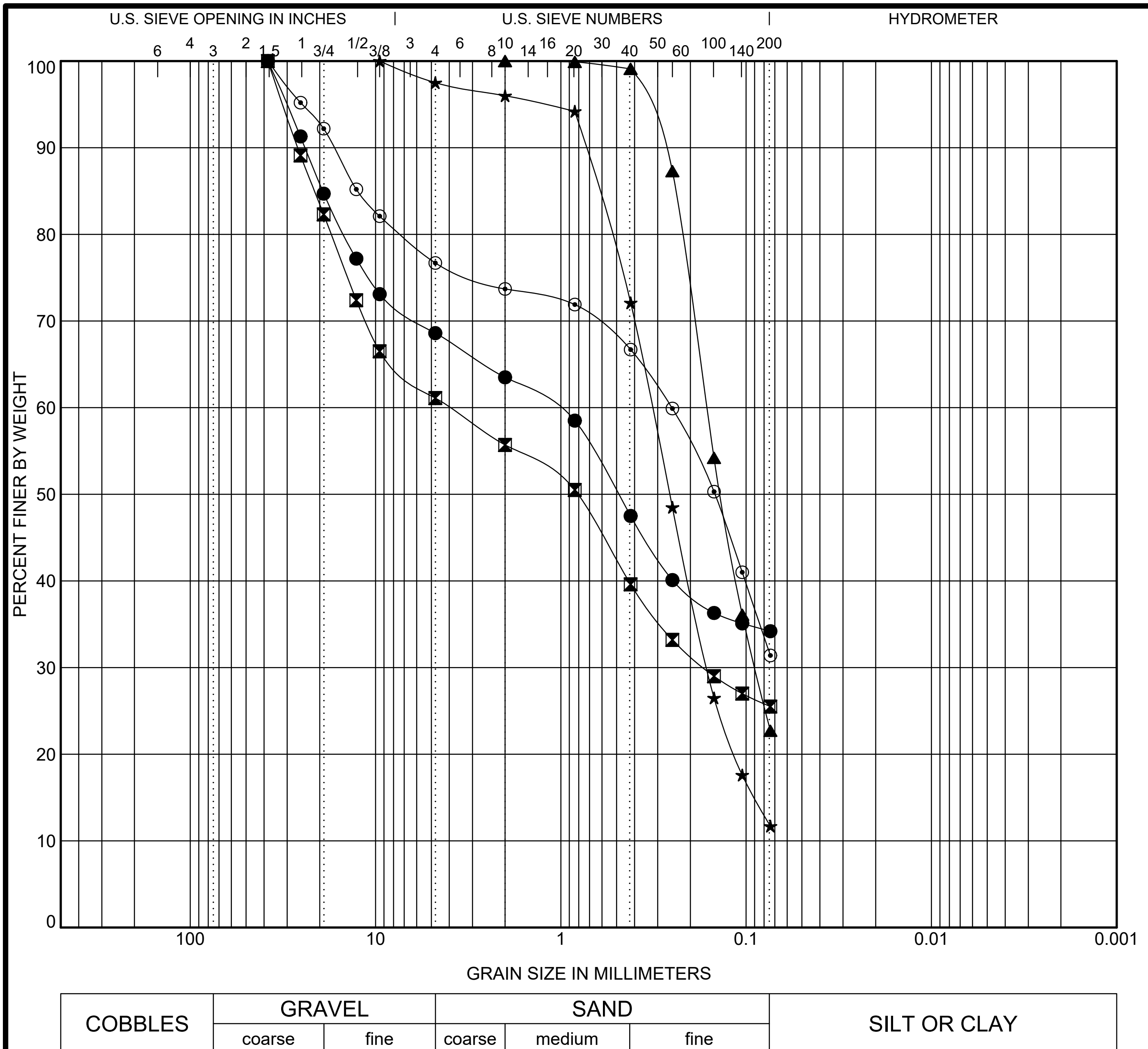
LOG OF TEST BORING PG-9

Figure A-10

The stratification lines represent approximate boundaries. The transition may be gradual.

APPENDIX B

LABORATORY TESTING



	Specimen Identification		Classification	LL	PL	PI	Cc	Cu
●	**PG-1**	**@ 15.0 ft.**	**Silty SAND with Gravel (SM)**					
⧗	**PG-2**	**@ 10.0 ft.**	**Silty SAND with Gravel (SM)**					
▲	**PG-3**	**@ 5.0 ft.**	**Silty SAND (SM)**					
★	**PG-4**	**@ 7.5 ft.**	**Poorly Graded SAND with Silt (SP-SM)**				**1.22**	**4.81**
⊙	**PG-5**	**@ 5.0 ft.**	**Silty SAND with Gravel (SM)**					

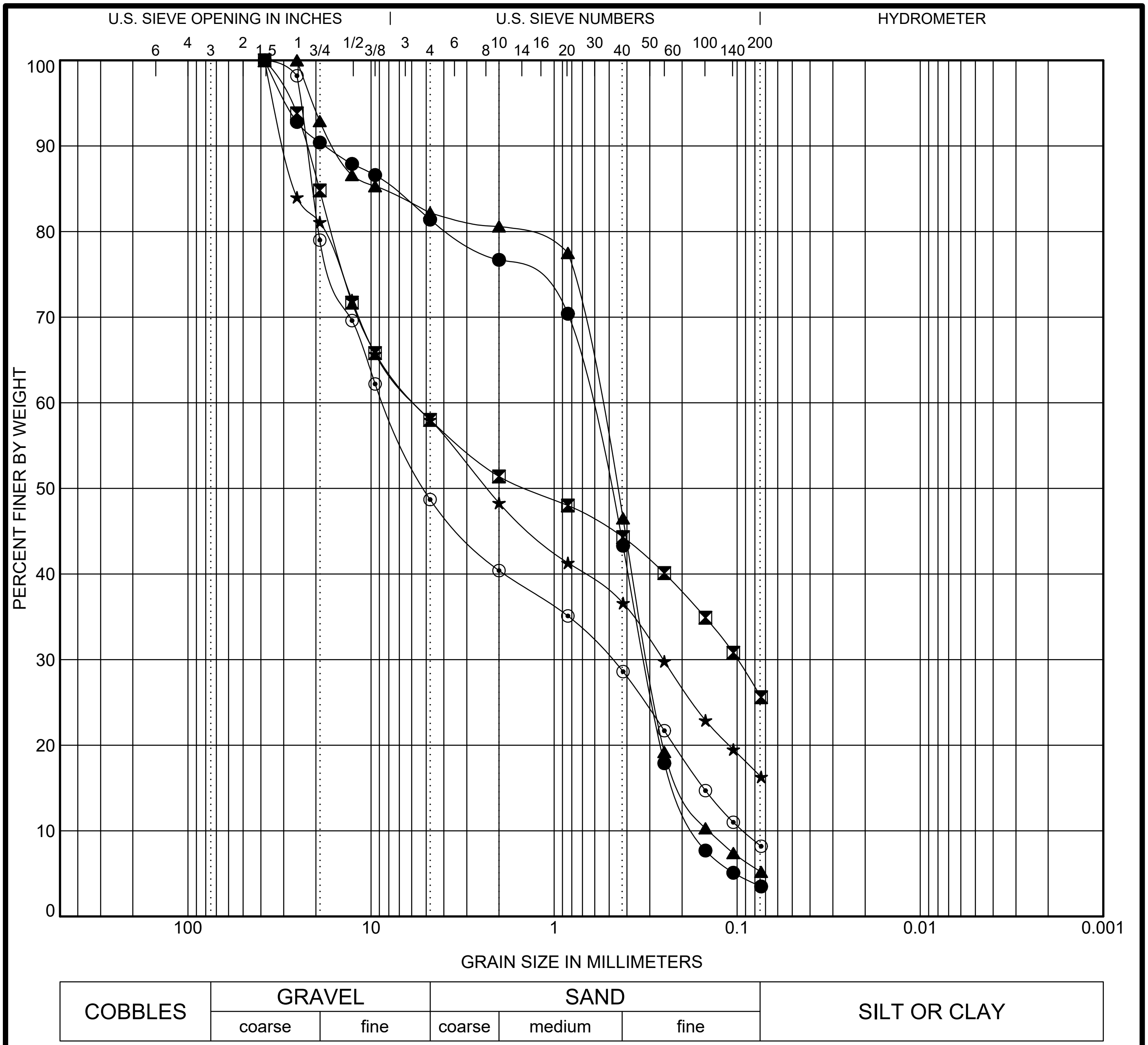
	Specimen Identification		D100	D90	D60	D10	%Gravel	%Sand	%Silt	%Clay
●	**PG-1**	**15.0**	**38.1**	**24.001**	**1.091**		**31.4**	**34.4**	**34.2**	
⧗	**PG-2**	**10.0**	**38.1**	**26.265**	**3.989**		**38.9**	**35.5**	**25.6**	
▲	**PG-3**	**5.0**	**2**	**0.282**	**0.163**		**0.0**	**76.8**	**23.2**	
★	**PG-4**	**7.5**	**9.5**	**0.737**	**0.322**		**2.5**	**85.6**	**11.9**	
⊙	**PG-5**	**5.0**	**38.1**	**16.771**	**0.252**		**23.3**	**44.9**	**31.8**	

GRAIN SIZE DISTRIBUTION

PanGEO INCORPORATED
Phone: 206.262.0370

Project: Kalama Creek Hatchery Expansion
Job Number: 19-384
Location: Nisqually Indian Reservation, Olympia, WA 98513

Figure B-1



Specimen Identification		Classification	LL	PL	PI	Cc	Cu
● PG-5	@ 20.0 ft.	**Poorly Graded SAND with Gravel (SP)**				**0.95**	**3.85**
⧗ PG-6	@ 5.0 ft.	**Silty SAND with Gravel (SM)**					
▲ PG-7	@ 10.0 ft.	**Poorly Graded SAND with Silt and Gravel (SP-SM)**				**1.15**	**3.95**
★ PG-8	@ 15.0 ft.	**Silty SAND with Gravel (SM)**					
⊙ PG-9	@ 7.5 ft.	**Poorly Graded GRAVEL with Sand and Silt (GP-GM)**				**0.30**	**91.60**

Specimen Identification		D100	D90	D60	D10	%Gravel	%Sand	%Silt	%Clay
● PG-5	20.0	38.1	17.853	0.644	0.167	18.6	77.8	3.6	
⧗ PG-6	5.0	38.1	22.495	5.683		42.0	32.2	25.8	
▲ PG-7	10.0	25.4	15.807	0.568	0.144	17.8	76.9	5.3	
★ PG-8	15.0	38.1	29.571	5.696		42.0	41.6	16.4	
⊙ PG-9	7.5	38.1	22.463	8.488	0.093	51.3	40.4	8.3	

GRAIN SIZE DISTRIBUTION

PanGEO INCORPORATED
Phone: 206.262.0370

Project: Kalama Creek Hatchery Expansion
Job Number: 19-384
Location: Nisqually Indian Reservation, Olympia, WA 98513

Figure B-1

APPENDIX C

SEISMICALLY INDUCED SETTLEMENT ANALYSIS

PanGEO INCORPORATED

Geotechnical & Earthquake Engineering Consultants
206.262.0370

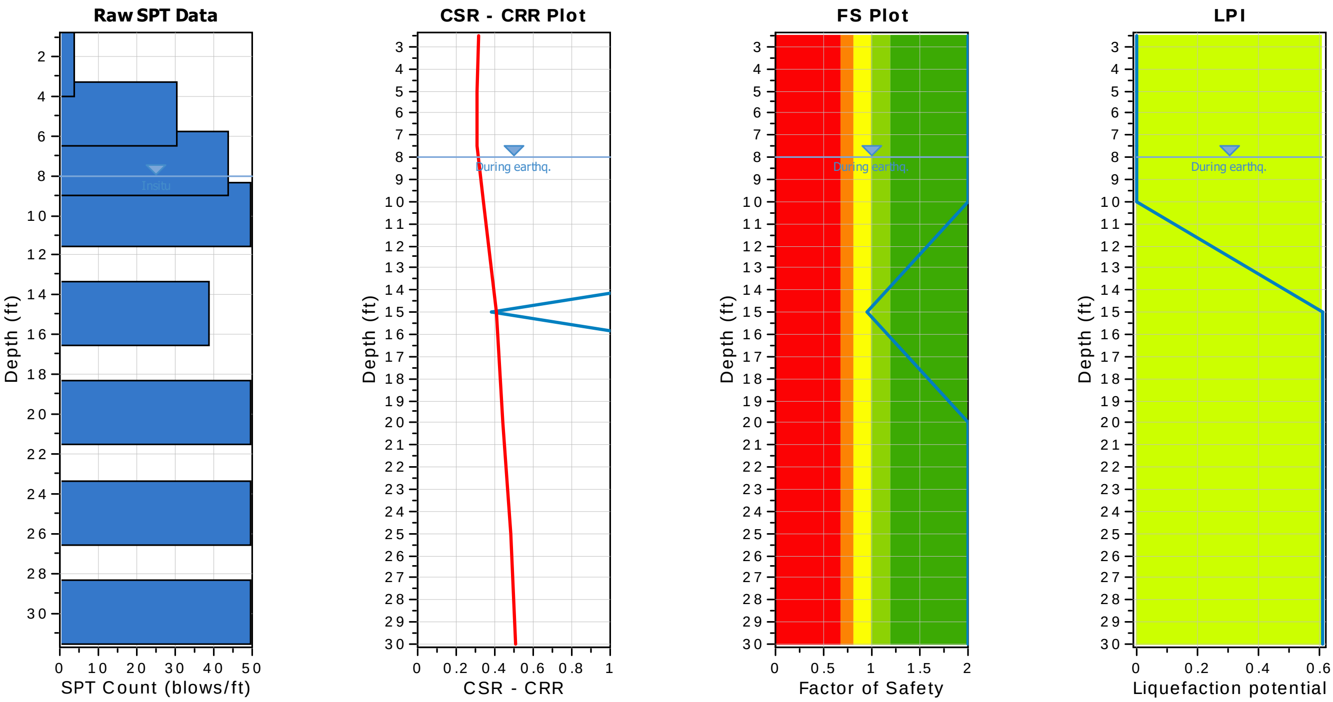
SPT BASED LIQUEFACTION ANALYSIS REPORT

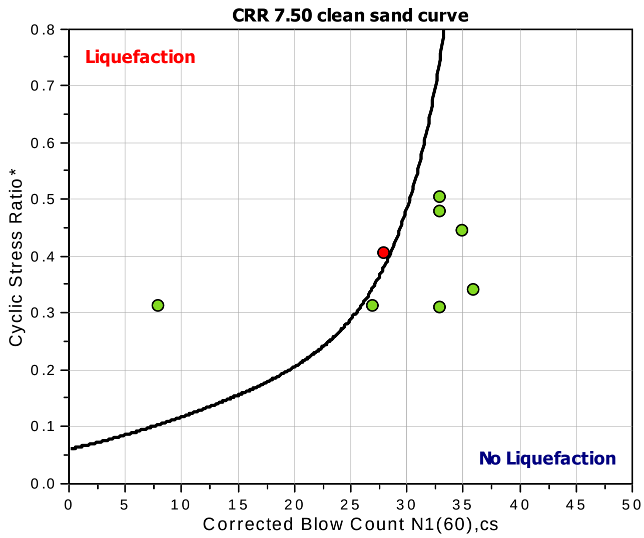
Project title : 19-384 Kalama Creek Hatchery Expansion **SPT Name: PG-1**

Location : Nisqually Indian Reservation

:: Input parameters and analysis properties ::

Analysis method:	Boulanger & Idriss, 2014	G.W.T. (in-situ):	8.00 ft
Fines correction method:	Boulanger & Idriss, 2014	G.W.T. (earthq.):	8.00 ft
Sampling method:	Standard Sampler	Earthquake magnitude M_w:	7.50
Borehole diameter:	65mm to 115mm	Peak ground acceleration:	0.53 g
Rod length:	3.30 ft	Eq. external load:	0.00 tsf
Hammer energy ratio:	0.60		





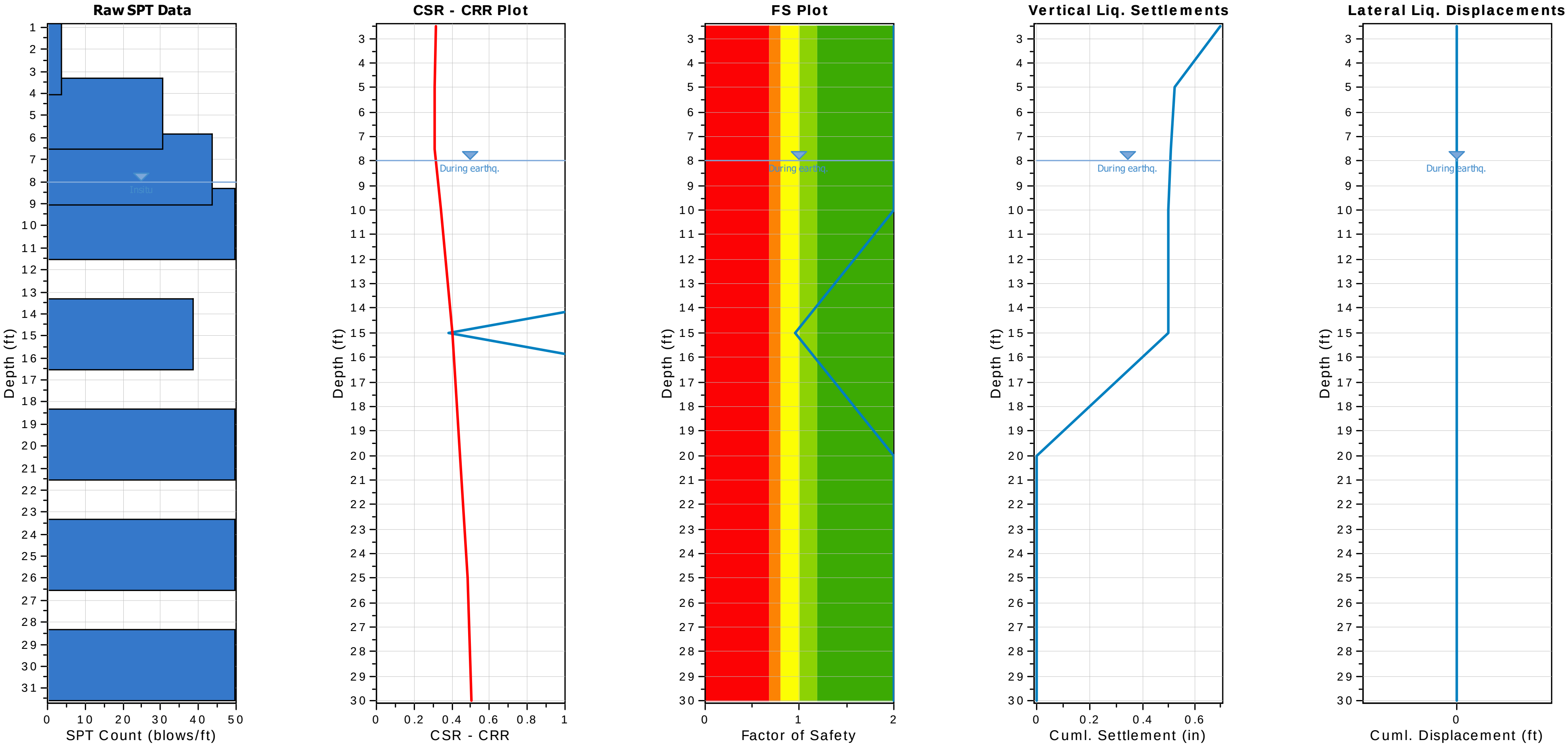
F.S. color scheme

- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

LPI color scheme

- Very high risk
- High risk
- Low risk

:: Overall Liquefaction Assessment Analysis Plots ::



:: Vertical settlements estimation for dry sands ::

Depth (ft)	$(N_1)_{60}$	τ_{av}	p	G_{max} (tsf)	α	b	γ	ε_{15}	N_c	ε_{Nc} (%)	Δh (ft)	ΔS (in)

Cumulative settlemetns: 0.197

Abbreviations

τ_{av}: Average cyclic shear stress
p: Average stress
G_{max}: Maximum shear modulus (tsf)
α, b: Shear strain formula variables
γ: Average shear strain
ε_{15}: Volumetric strain after 15 cycles
N_c: Number of cycles
ε_{Nc}: Volumetric strain for number of cycles N_c (%)
Δh: Thickness of soil layer (in)
ΔS: Settlement of soil layer (in)

:: Vertical & Lateral displ.acements estimation for saturated sands ::

Depth (ft)	$(N_1)_{60cs}$	γ_{lim} (%)	F_α	FS_{liq}	γ_{max} (%)	e_v (%)	dz (ft)	S_{v-1D} (in)	LDI (ft)
10.00	36	1.86	-0.51	2.000	0.00	0.00	5.00	0.000	0.00
15.00	28	6.08	0.04	0.948	3.89	0.83	5.00	0.497	0.00
20.00	35	2.20	-0.44	2.000	0.00	0.00	5.00	0.000	0.00
25.00	33	3.01	-0.29	2.000	0.00	0.00	5.00	0.000	0.00
30.00	33	3.01	-0.29	2.000	0.00	0.00	1.50	0.000	0.00

Cumulative settlements: 0.497 0.00

Abbreviations

γ_{lim}: Limiting shear strain (%)
F_α/N: Maximun shear strain factor
γ_{max}: Maximum shear strain (%)
e_v:: Post liquefaction volumetric strain (%)
S_{v-1D}: Estimated vertical settlement (in)
LDI: Estimated lateral displacement (ft)

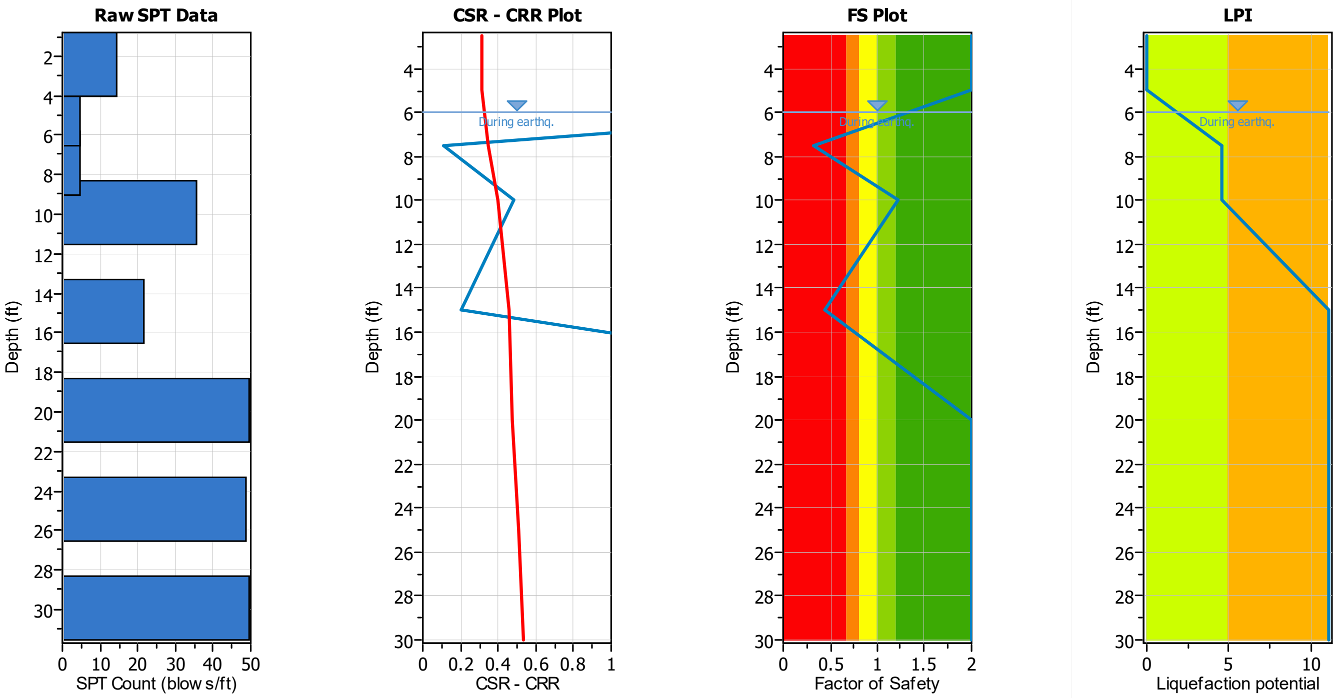
SPT BASED LIQUEFACTION ANALYSIS REPORT

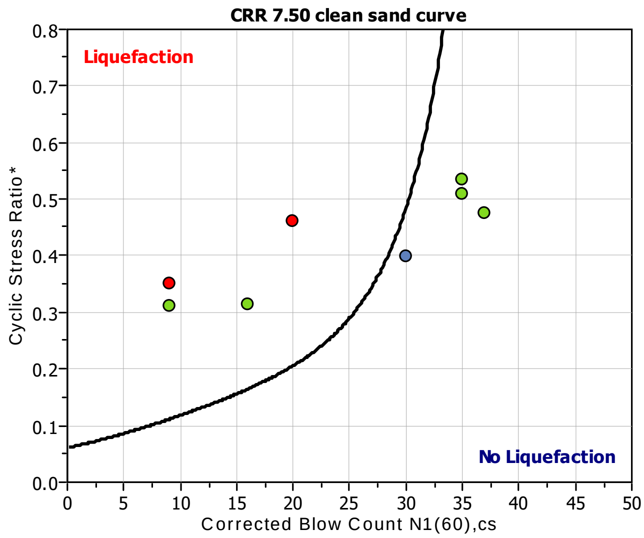
Project title : 19-384 Kalama Creek Hatchery Expansion **SPT Name: PG-2**

Location : Nisqually Indian Reservation

:: Input parameters and analysis properties ::

Analysis method:	Boulanger & Idriss, 2014	G.W.T. (in-situ):	6.00 ft
Fines correction method:	Boulanger & Idriss, 2014	G.W.T. (earthq.):	6.00 ft
Sampling method:	Standard Sampler	Earthquake magnitude M_w:	7.50 ft
Borehole diameter:	65mm to 115mm	Peak ground acceleration:	0.53 g
Rod length:	3.30 ft	Eq. external load:	0.00 tsf
Hammer energy ratio:	0.60		





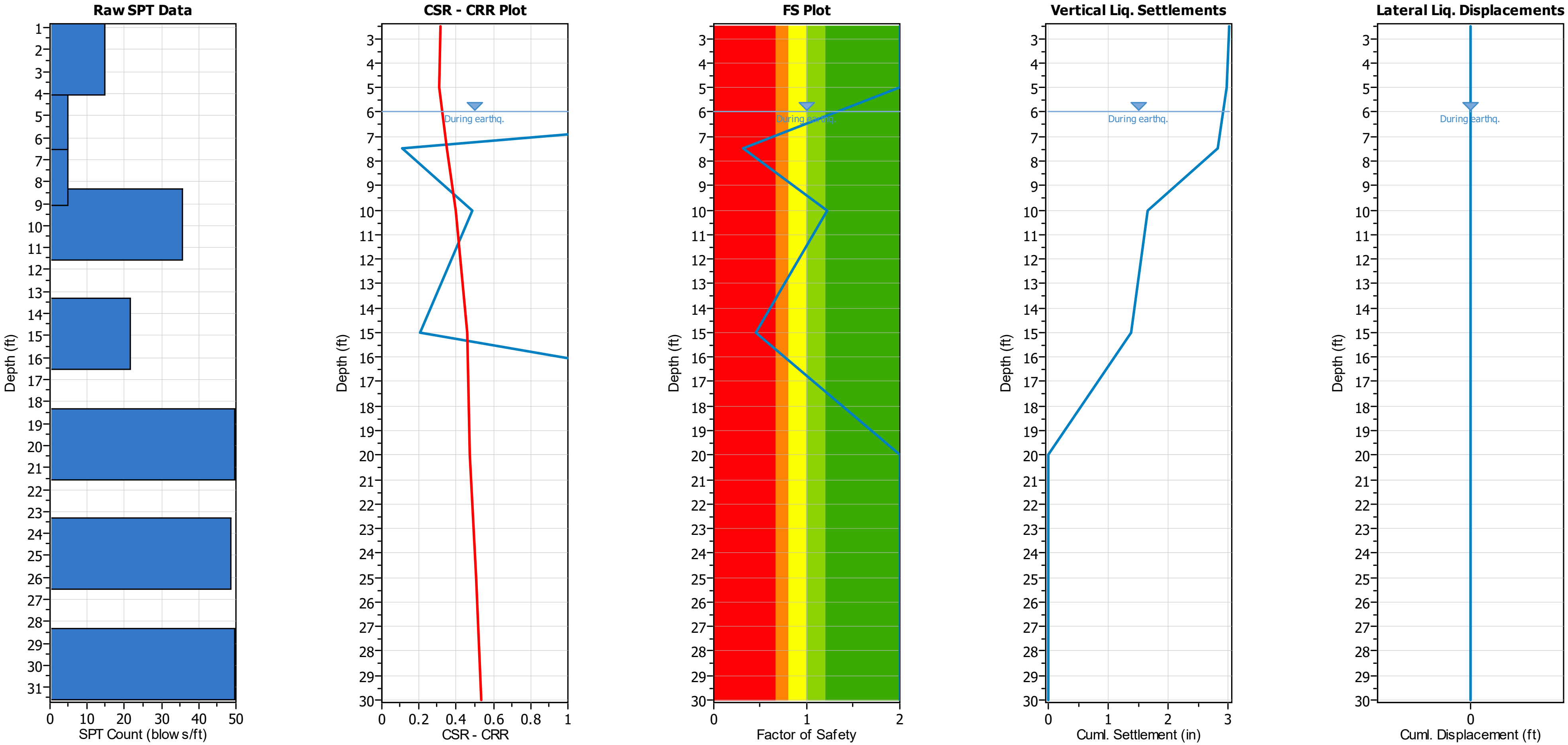
F.S. color scheme

- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

LPI color scheme

- Very high risk
- High risk
- Low risk

:: Overall Liquefaction Assessment Analysis Plots ::



:: Vertical settlements estimation for dry sands ::

Depth (ft)	$(N_1)_{60}$	τ_{av}	p	G_{max} (tsf)	α	b	γ	ε_{15}	N_c	ε_{Nc} (%)	Δh (ft)	ΔS (in)
2.50	11	0.05	0.09	0.34	0.13	21047.40	0.00	0.00	15.16	0.05	2.50	0.033
5.00	4	0.09	0.18	0.40	0.13	13886.10	0.00	0.00	15.16	0.25	2.50	0.150

Cumulative settlemetns: 0.183

Abbreviations

τ_{av}: Average cyclic shear stress
p: Average stress
G_{max}: Maximum shear modulus (tsf)
α, b: Shear strain formula variables
γ: Average shear strain
ε_{15}: Volumetric strain after 15 cycles
N_c: Number of cycles
ε_{Nc}: Volumetric strain for number of cycles N_c (%)
Δh: Thickness of soil layer (in)
ΔS: Settlement of soil layer (in)

:: Vertical & Lateral displ.acements estimation for saturated sands ::

Depth (ft)	$(N_1)_{60cs}$	γ_{lim} (%)	F_α	FS_{liq}	γ_{max} (%)	e_v (%)	dz (ft)	S_{v-1D} (in)	LDI (ft)
7.50	9	52.88	0.93	0.317	52.88	3.97	2.50	1.190	0.00
10.00	30	4.65	-0.09	1.220	2.27	0.45	5.00	0.271	0.00
15.00	20	15.90	0.52	0.447	15.90	2.30	5.00	1.382	0.00
20.00	37	1.56	-0.58	2.000	0.00	0.00	5.00	0.000	0.00
25.00	35	2.20	-0.44	2.000	0.00	0.00	5.00	0.000	0.00
30.00	35	2.20	-0.44	2.000	0.00	0.00	1.50	0.000	0.00

Cumulative settlements: 2.843 0.00

Abbreviations

γ_{lim}: Limiting shear strain (%)
F_α/N: Maximun shear strain factor
γ_{max}: Maximum shear strain (%)
e_v:: Post liquefaction volumetric strain (%)
S_{v-1D}: Estimated vertical settlement (in)
LDI: Estimated lateral displacement (ft)

PanGEO INCORPORATED

Geotechnical & Earthquake
Engineering Consultants
206.262.0370

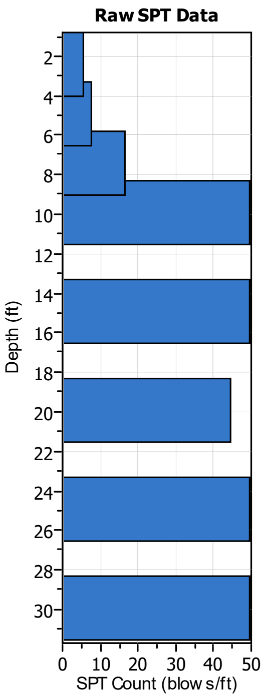
SPT BASED LIQUEFACTION ANALYSIS REPORT

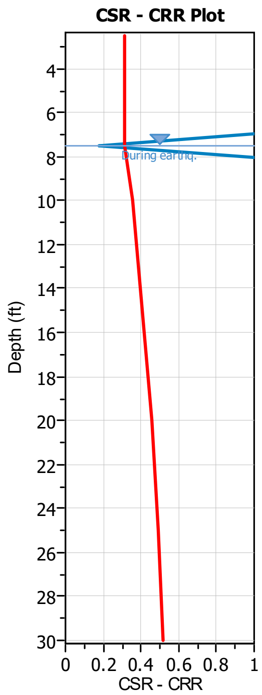
Project title : 19-384 Kalama Creek Hatchery Expansion **SPT Name: PG-3**

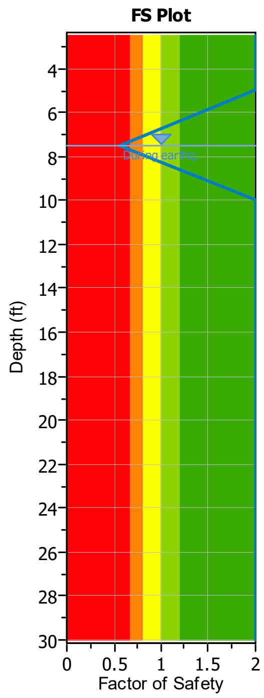
Location : Nisqually Indian Reservation

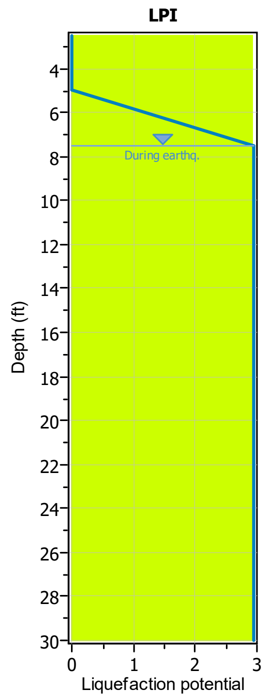
:: Input parameters and analysis properties ::

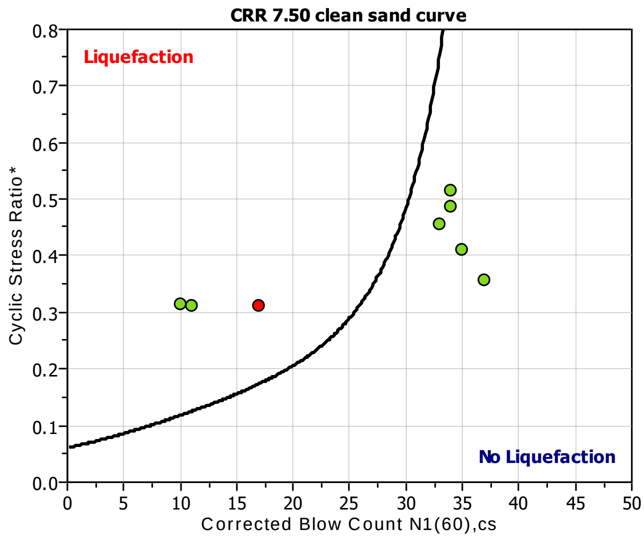
Analysis method:	Boulanger & Idriss, 2014	G.W.T. (in-situ):	7.50 ft
Fines correction method:	Boulanger & Idriss, 2014	G.W.T. (earthq.):	7.50 ft
Sampling method:	Standard Sampler	Earthquake magnitude M_w:	7.50 ft
Borehole diameter:	65mm to 115mm	Peak ground acceleration:	0.53 g
Rod length:	3.30 ft	Eq. external load:	0.00 tsf
Hammer energy ratio:	0.60		











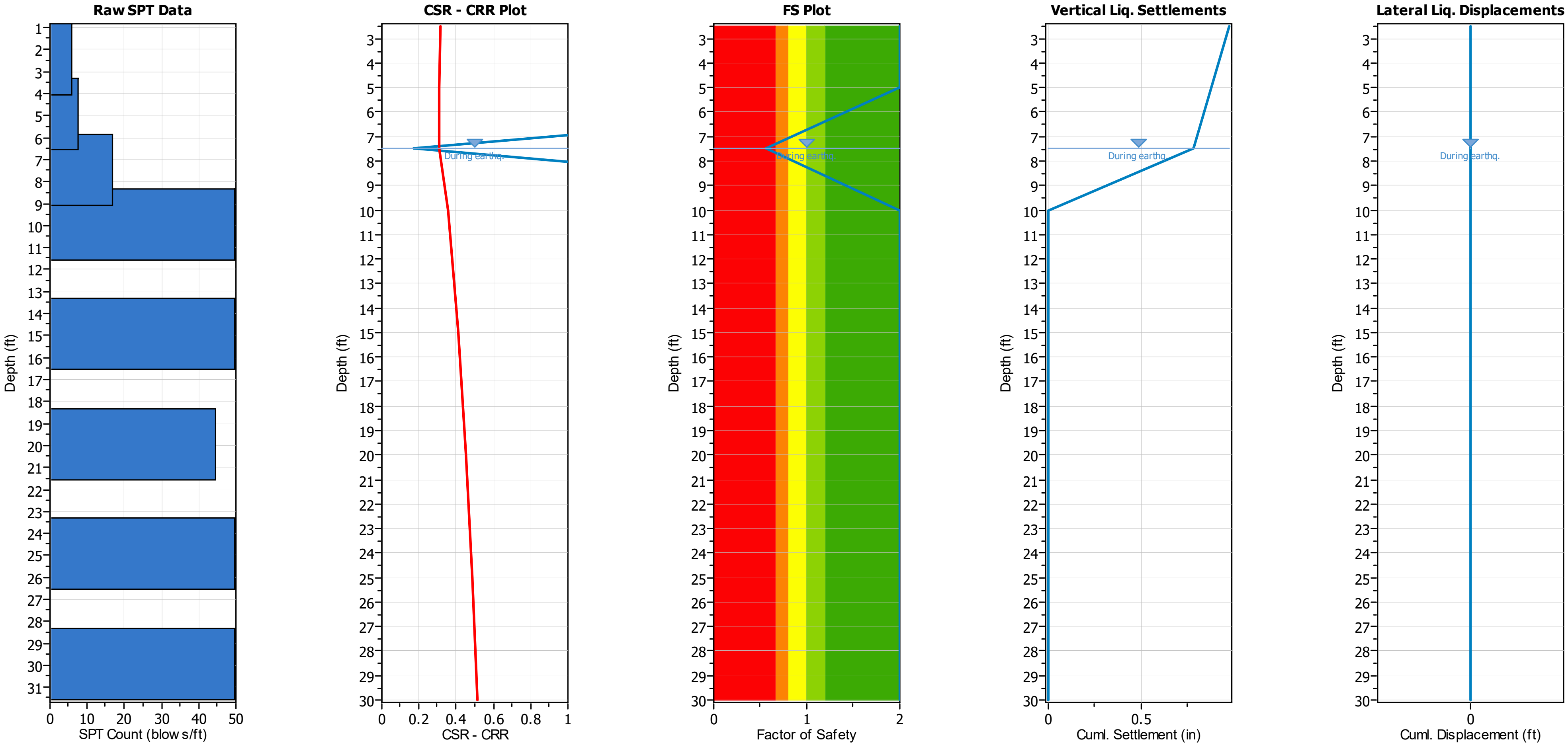
F.S. color scheme

- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

LPI color scheme

- Very high risk
- High risk
- Low risk

:: Overall Liquefaction Assessment Analysis Plots ::



:: Vertical settlements estimation for dry sands ::

Depth (ft)	$(N_1)_{60}$	τ_{av}	p	G_{max} (tsf)	α	b	γ	ε_{15}	N_c	ε_{Nc} (%)	Δh (ft)	ΔS (in)
2.50	5	0.05	0.09	0.29	0.13	21047.40	0.00	0.00	15.16	0.16	2.50	0.098
5.00	6	0.09	0.18	0.43	0.13	13886.10	0.00	0.00	15.16	0.16	2.50	0.094

Cumulative settlemetns: 0.192

Abbreviations

τ_{av}: Average cyclic shear stress
p: Average stress
G_{max}: Maximum shear modulus (tsf)
α, b: Shear strain formula variables
γ: Average shear strain
ε_{15}: Volumetric strain after 15 cycles
N_c: Number of cycles
ε_{Nc}: Volumetric strain for number of cycles N_c (%)
Δh: Thickness of soil layer (in)
ΔS: Settlement of soil layer (in)

:: Vertical & Lateral displ.acements estimation for saturated sands ::

Depth (ft)	$(N_1)_{60cs}$	γ_{lim} (%)	F_α	FS_{liq}	γ_{max} (%)	e_v (%)	dz (ft)	S_{v-1D} (in)	LDI (ft)
7.50	17	22.15	0.67	0.562	22.15	2.62	2.50	0.786	0.00
10.00	37	1.56	-0.58	2.000	0.00	0.00	5.00	0.000	0.00
15.00	35	2.20	-0.44	2.000	0.00	0.00	5.00	0.000	0.00
20.00	33	3.01	-0.29	2.000	0.00	0.00	5.00	0.000	0.00
25.00	34	2.58	-0.36	2.000	0.00	0.00	5.00	0.000	0.00
30.00	34	2.58	-0.36	2.000	0.00	0.00	1.50	0.000	0.00

Cumulative settlements: 0.786 0.00

Abbreviations

γ_{lim}: Limiting shear strain (%)
F_α/N: Maximun shear strain factor
γ_{max}: Maximum shear strain (%)
e_v:: Post liquefaction volumetric strain (%)
S_{v-1D}: Estimated vertical settlement (in)
LDI: Estimated lateral displacement (ft)

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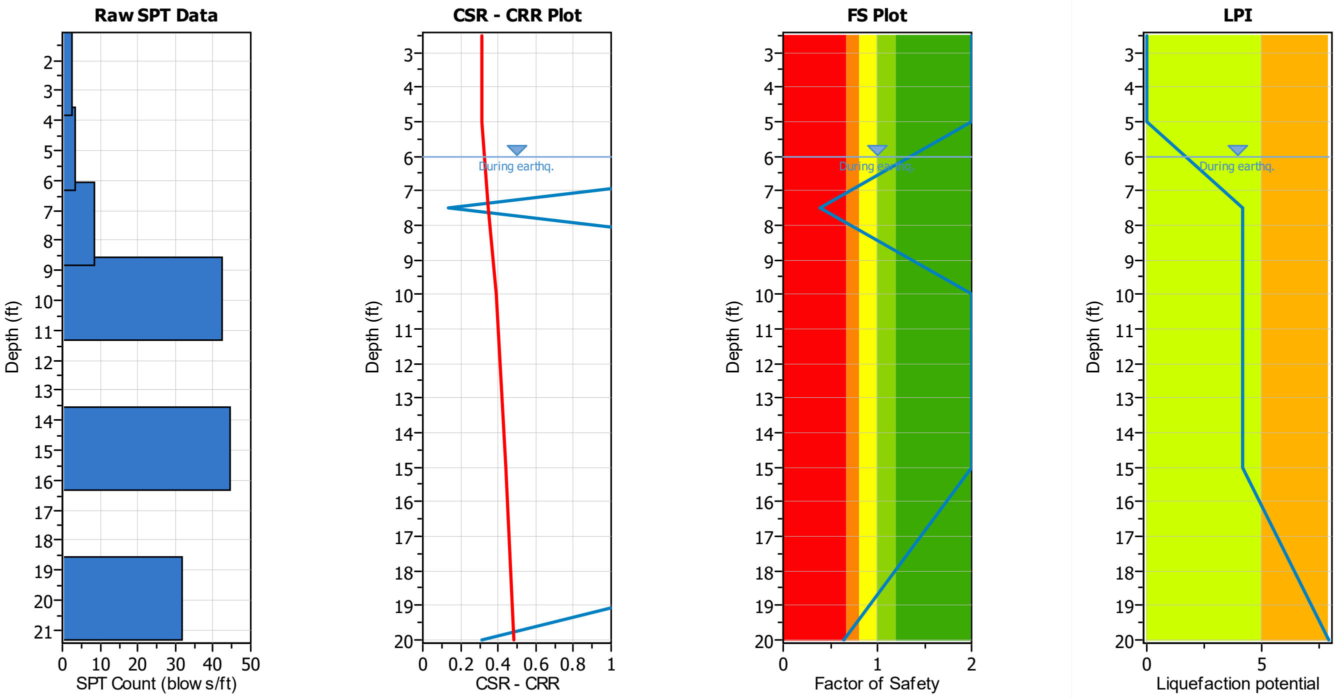
SPT BASED LIQUEFACTION ANALYSIS REPORT

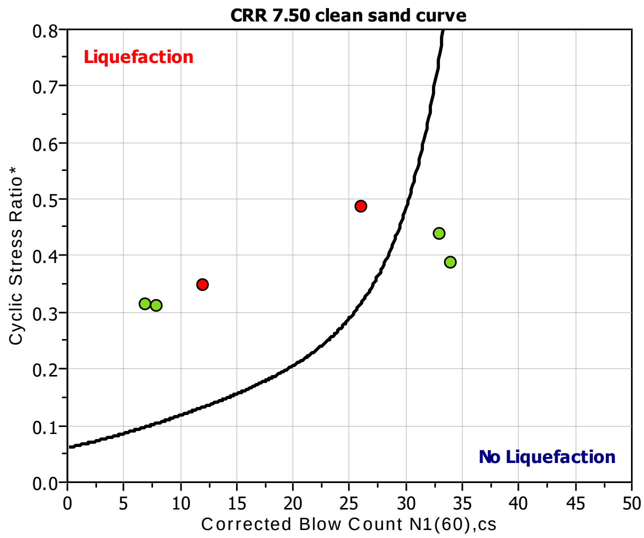
Project title : 19-384 Kalama Creek Hatchery Expansion **SPT Name: PG-4**

Location : Nisqually Indian Reservation

:: Input parameters and analysis properties ::

Analysis method:	Boulanger & Idriss, 2014	G.W.T. (in-situ):	6.00 ft
Fines correction method:	Boulanger & Idriss, 2014	G.W.T. (earthq.):	6.00 ft
Sampling method:	Standard Sampler	Earthquake magnitude M_w:	7.50 ft
Borehole diameter:	65mm to 115mm	Peak ground acceleration:	0.53 g
Rod length:	3.30 ft	Eq. external load:	0.00 tsf
Hammer energy ratio:	0.60		





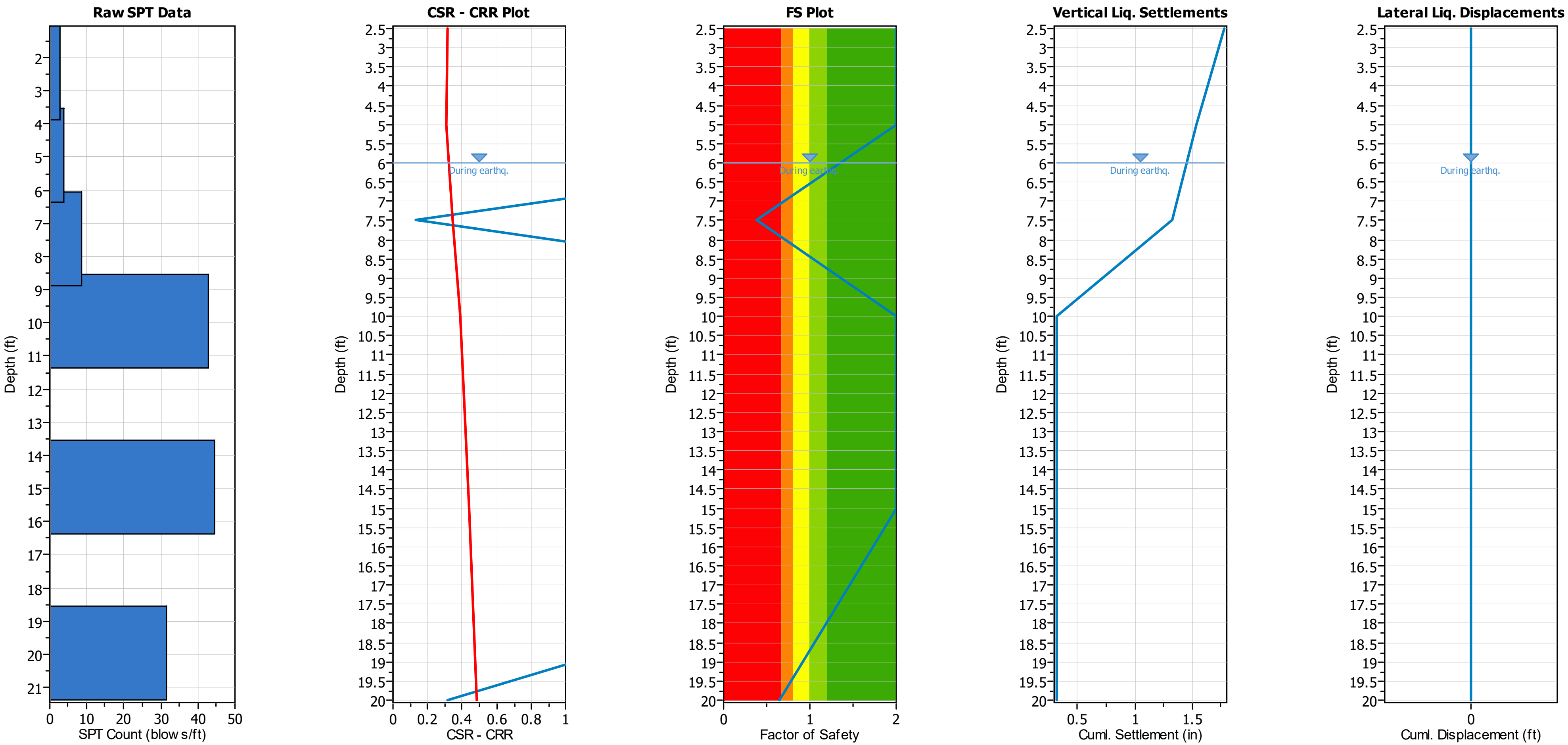
F.S. color scheme

- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

LPI color scheme

- Very high risk
- High risk
- Low risk

:: Overall Liquefaction Assessment Analysis Plots ::



:: Vertical settlements estimation for dry sands ::

Depth (ft)	$(N_1)_{60}$	τ_{av}	p	G_{max} (tsf)	α	b	γ	ε_{15}	N_c	ε_{Nc} (%)	Δh (ft)	ΔS (in)
2.50	2	0.05	0.10	0.27	0.13	19976.77	0.00	0.00	15.16	0.41	2.50	0.247
5.00	3	0.10	0.20	0.40	0.14	13179.75	0.00	0.00	15.16	0.34	2.50	0.204

Cumulative settlemetns: 0.451

Abbreviations

τ_{av}: Average cyclic shear stress
p: Average stress
G_{max}: Maximum shear modulus (tsf)
α, b: Shear strain formula variables
γ: Average shear strain
ε_{15}: Volumetric strain after 15 cycles
N_c: Number of cycles
ε_{Nc}: Volumetric strain for number of cycles N_c (%)
Δh: Thickness of soil layer (in)
ΔS: Settlement of soil layer (in)

:: Vertical & Lateral displ.acements estimation for saturated sands ::

Depth (ft)	$(N_1)_{60cs}$	γ_{lim} (%)	F_α	FS_{liq}	γ_{max} (%)	e_v (%)	dz (ft)	S_{v-1D} (in)	LDI (ft)
7.50	12	38.03	0.86	0.382	38.03	3.34	2.50	1.003	0.00
10.00	34	2.58	-0.36	2.000	0.00	0.00	5.00	0.000	0.00
15.00	33	3.01	-0.29	2.000	0.00	0.00	5.00	0.000	0.00
20.00	26	7.85	0.17	0.649	7.85	1.79	1.50	0.323	0.00

Cumulative settlements: 1.325 0.00

Abbreviations

γ_{lim}: Limiting shear strain (%)
F_α/N: Maximun shear strain factor
γ_{max}: Maximum shear strain (%)
e_v:: Post liquefaction volumetric strain (%)
S_{v-1D}: Estimated vertical settlement (in)
LDI: Estimated lateral displacement (ft)

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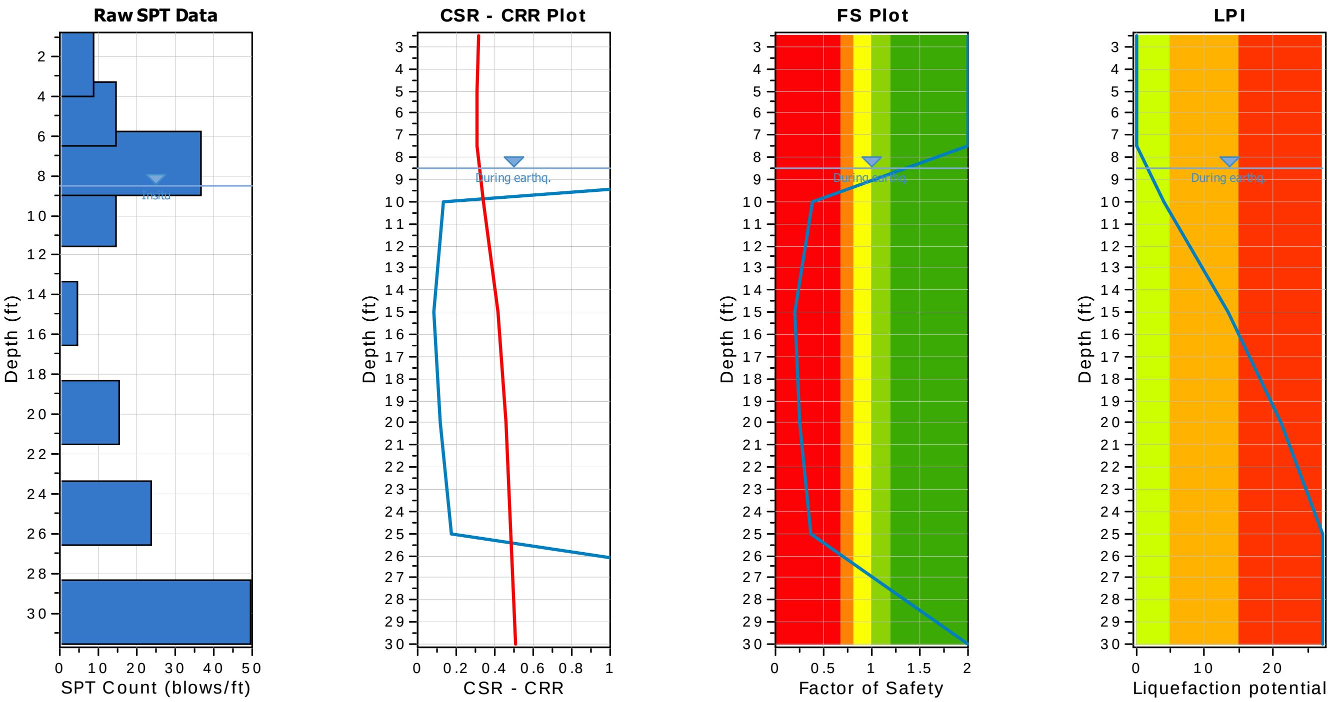
SPT BASED LIQUEFACTION ANALYSIS REPORT

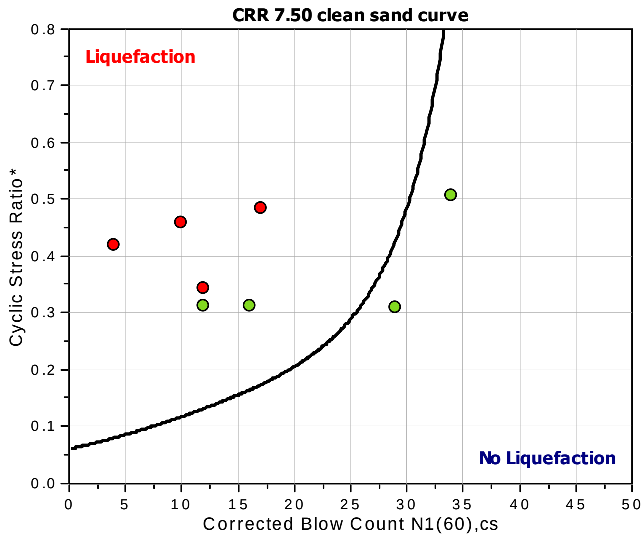
Project title : 19-384 Kalama Creek Hatchery Expansion **SPT Name: PG-5**

Location : Nisqually Indian Reservation

:: Input parameters and analysis properties ::

Analysis method:	Boulanger & Idriss, 2014	G.W.T. (in-situ):	8.50 ft
Fines correction method:	Boulanger & Idriss, 2014	G.W.T. (earthq.):	8.50 ft
Sampling method:	Standard Sampler	Earthquake magnitude M_w:	7.50
Borehole diameter:	65mm to 115mm	Peak ground acceleration:	0.53 g
Rod length:	3.30 ft	Eq. external load:	0.00 tsf
Hammer energy ratio:	0.60		





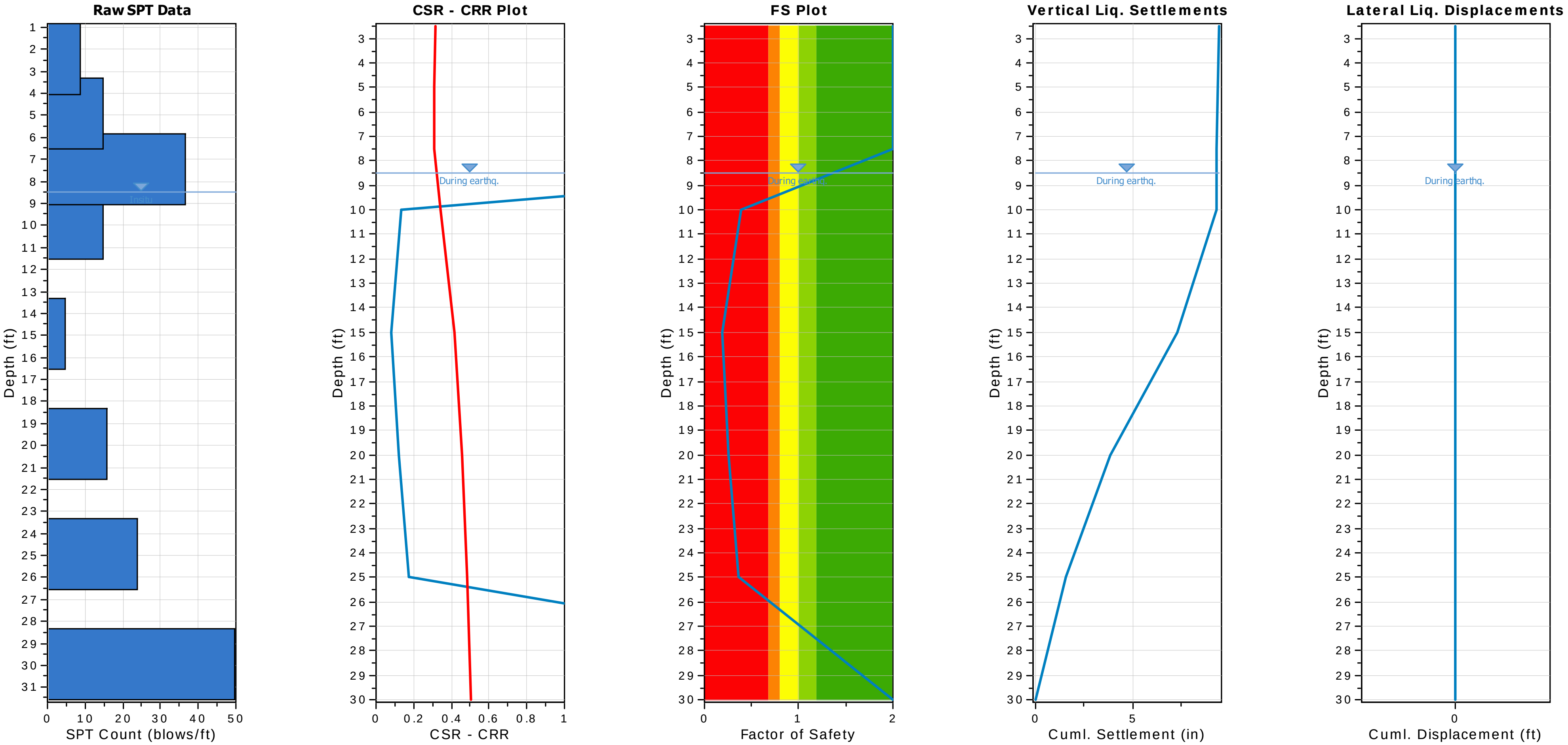
F.S. color scheme

- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

LPI color scheme

- Very high risk
- High risk
- Low risk

:: Overall Liquefaction Assessment Analysis Plots ::



:: Vertical settlements estimation for dry sands ::

Depth (ft)	$(N_1)_{60}$	τ_{av}	p	G_{max} (tsf)	α	b	γ	ε_{15}	N_c	ε_{Nc} (%)	Δh (ft)	ΔS (in)

Cumulative settlemetns: 0.119

Abbreviations

τ_{av}: Average cyclic shear stress
p: Average stress
G_{max}: Maximum shear modulus (tsf)
α, b: Shear strain formula variables
γ: Average shear strain
ε_{15}: Volumetric strain after 15 cycles
N_c: Number of cycles
ε_{Nc}: Volumetric strain for number of cycles N_c (%)
Δh: Thickness of soil layer (in)
ΔS: Settlement of soil layer (in)

:: Vertical & Lateral displ.acements estimation for saturated sands ::

Depth (ft)	$(N_1)_{60cs}$	γ_{lim} (%)	F_α	FS_{liq}	γ_{max} (%)	e_v (%)	dz (ft)	S_{v-1D} (in)	LDI (ft)
10.00	12	38.03	0.86	0.385	38.03	3.34	5.00	2.005	0.00
15.00	4	97.02	0.95	0.192	97.02	5.74	5.00	3.442	0.00
20.00	10	47.32	0.91	0.258	47.32	3.74	5.00	2.242	0.00
25.00	17	22.15	0.67	0.358	22.15	2.62	5.00	1.572	0.00
30.00	34	2.58	-0.36	2.000	0.00	0.00	1.50	0.000	0.00

Cumulative settlements: 9.262 0.00

Abbreviations

γ_{lim}: Limiting shear strain (%)
F_α/N: Maximun shear strain factor
γ_{max}: Maximum shear strain (%)
e_v:: Post liquefaction volumetric strain (%)
S_{v-1D}: Estimated vertical settlement (in)
LDI: Estimated lateral displacement (ft)

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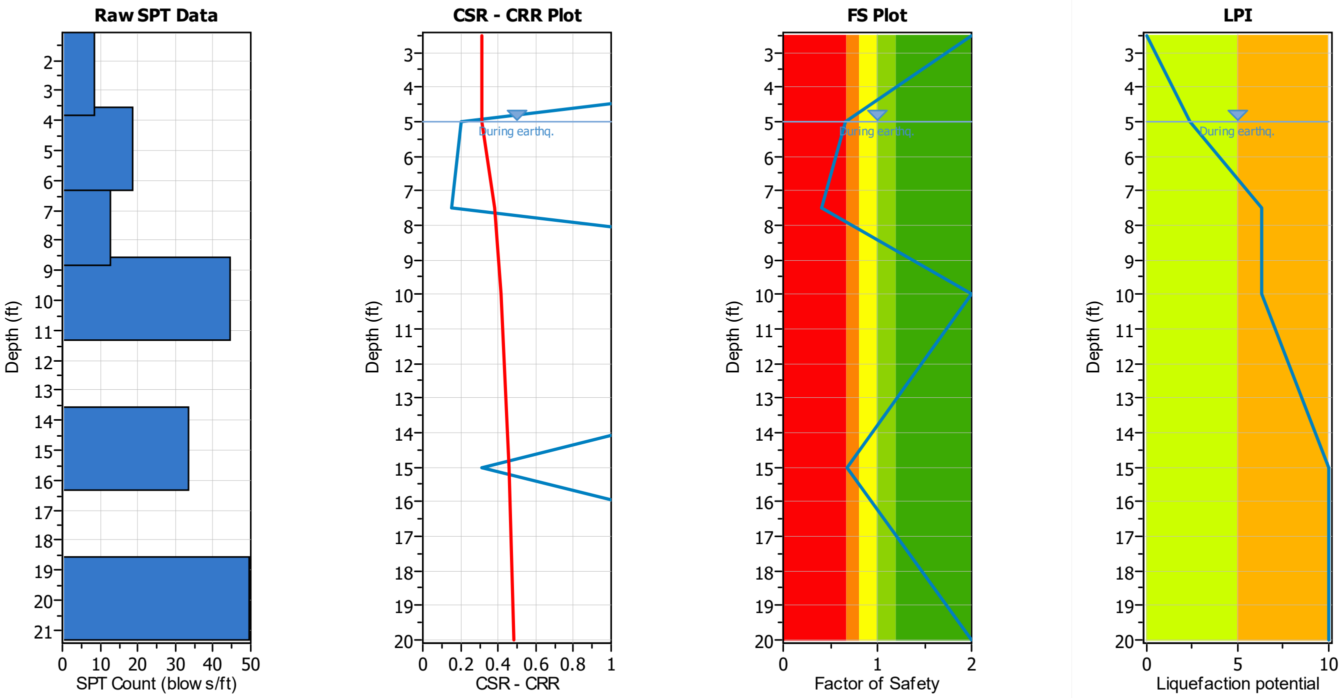
SPT BASED LIQUEFACTION ANALYSIS REPORT

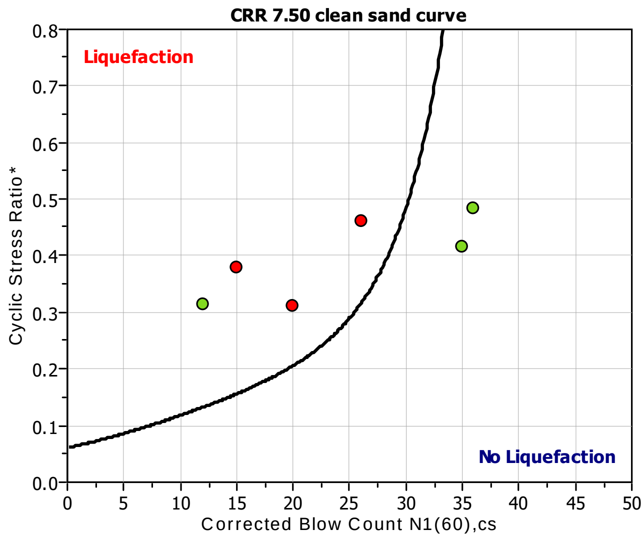
Project title : 19-384 Kalama Creek Hatchery Expansion **SPT Name: PG-6**

Location : Nisqually Indian Reservation

:: Input parameters and analysis properties ::

Analysis method:	Boulanger & Idriss, 2014	G.W.T. (in-situ):	5.00 ft
Fines correction method:	Boulanger & Idriss, 2014	G.W.T. (earthq.):	5.00 ft
Sampling method:	Standard Sampler	Earthquake magnitude M_w:	7.50 ft
Borehole diameter:	65mm to 115mm	Peak ground acceleration:	0.53 g
Rod length:	3.30 ft	Eq. external load:	0.00 tsf
Hammer energy ratio:	0.60		





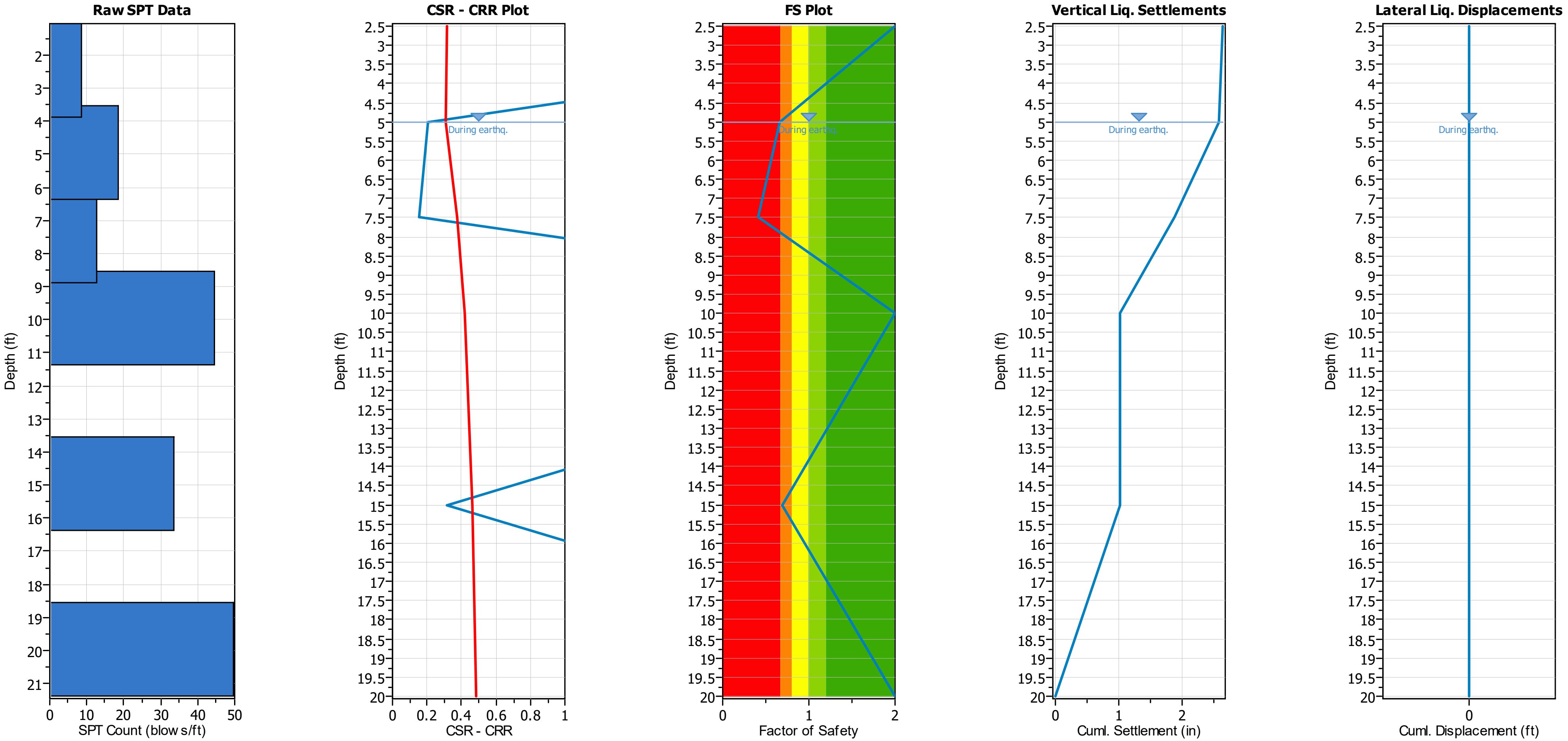
F.S. color scheme

- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

LPI color scheme

- Very high risk
- High risk
- Low risk

:: Overall Liquefaction Assessment Analysis Plots ::



:: Vertical settlements estimation for dry sands ::

Depth (ft)	$(N_1)_{60}$	τ_{av}	p	G_{max} (tsf)	α	b	γ	ε_{15}	N_c	ε_{Nc} (%)	Δh (ft)	ΔS (in)
2.50	7	0.05	0.10	0.32	0.13	20493.46	0.00	0.00	15.16	0.11	2.50	0.064

Cumulative settlemetns: 0.064

Abbreviations

τ_{av}: Average cyclic shear stress
p: Average stress
G_{max}: Maximum shear modulus (tsf)
α, b: Shear strain formula variables
γ: Average shear strain
ε_{15}: Volumetric strain after 15 cycles
N_c: Number of cycles
ε_{Nc}: Volumetric strain for number of cycles N_c (%)
Δh: Thickness of soil layer (in)
ΔS: Settlement of soil layer (in)

:: Vertical & Lateral displ.acements estimation for saturated sands ::

Depth (ft)	$(N_1)_{60cs}$	γ_{lim} (%)	F_α	FS_{liq}	γ_{max} (%)	e_v (%)	dz (ft)	S_{v-1D} (in)	LDI (ft)
5.00	20	15.90	0.52	0.661	15.83	2.30	2.50	0.691	0.00
7.50	15	27.51	0.75	0.413	27.51	2.87	2.50	0.862	0.00
10.00	35	2.20	-0.44	2.000	0.00	0.00	5.00	0.000	0.00
15.00	26	7.85	0.17	0.686	7.40	1.69	5.00	1.015	0.00
20.00	36	1.86	-0.51	2.000	0.00	0.00	1.50	0.000	0.00

Cumulative settlements: 2.568 0.00

Abbreviations

γ_{lim}: Limiting shear strain (%)
F_α/N: Maximun shear strain factor
γ_{max}: Maximum shear strain (%)
e_v:: Post liquefaction volumetric strain (%)
S_{v-1D}: Estimated vertical settlement (in)
LDI: Estimated lateral displacement (ft)

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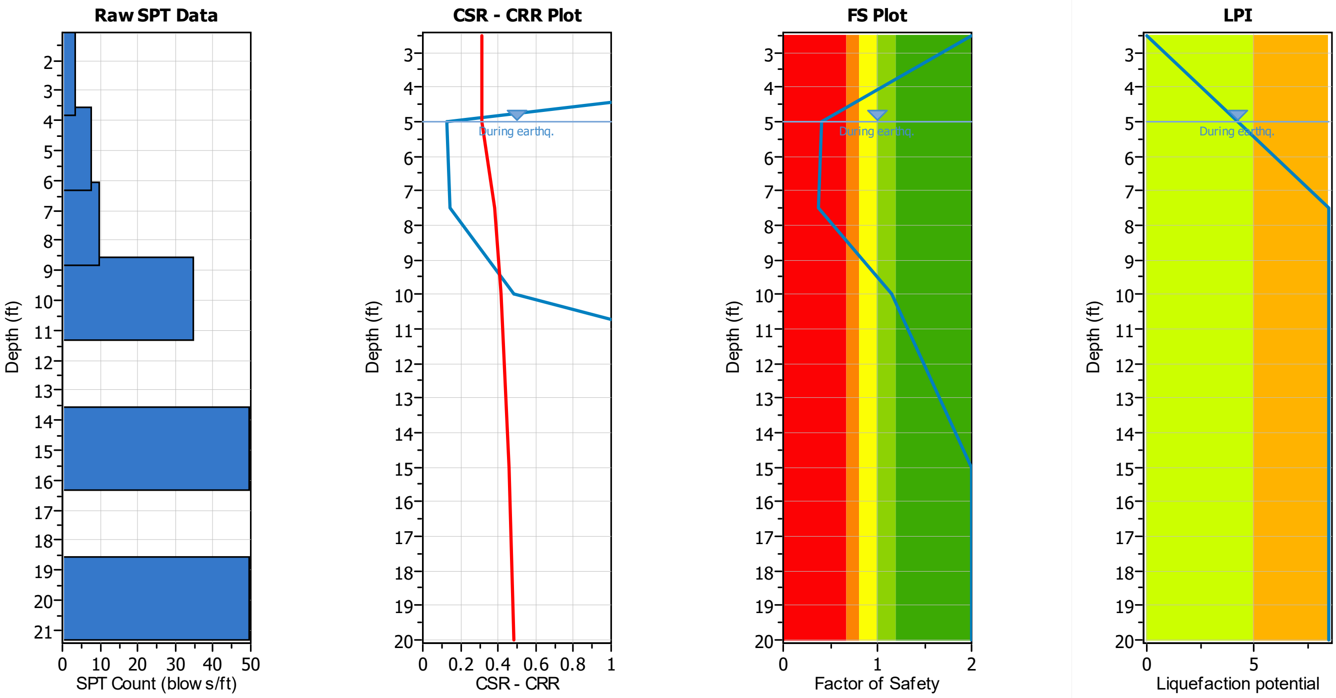
SPT BASED LIQUEFACTION ANALYSIS REPORT

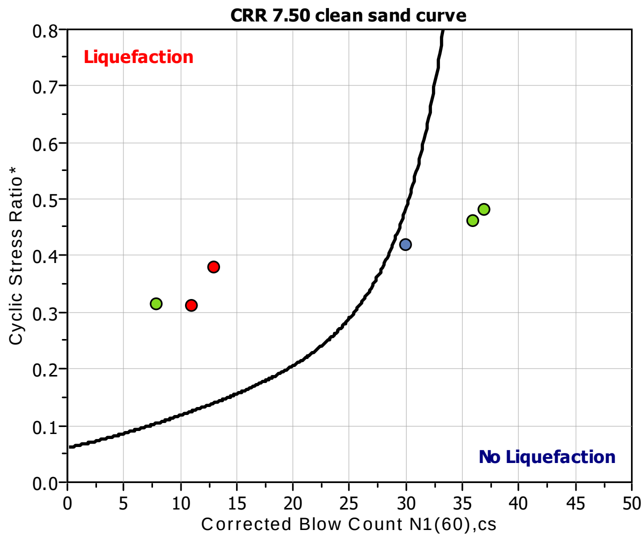
Project title : 19-384 Kalama Creek Hatchery Expansion **SPT Name: PG-7**

Location : Nisqually Indian Reservation

:: Input parameters and analysis properties ::

Analysis method:	Boulanger & Idriss, 2014	G.W.T. (in-situ):	5.00 ft
Fines correction method:	Boulanger & Idriss, 2014	G.W.T. (earthq.):	5.00 ft
Sampling method:	Standard Sampler	Earthquake magnitude M_w:	7.50 ft
Borehole diameter:	65mm to 115mm	Peak ground acceleration:	0.53 g
Rod length:	3.30 ft	Eq. external load:	0.00 tsf
Hammer energy ratio:	0.60		





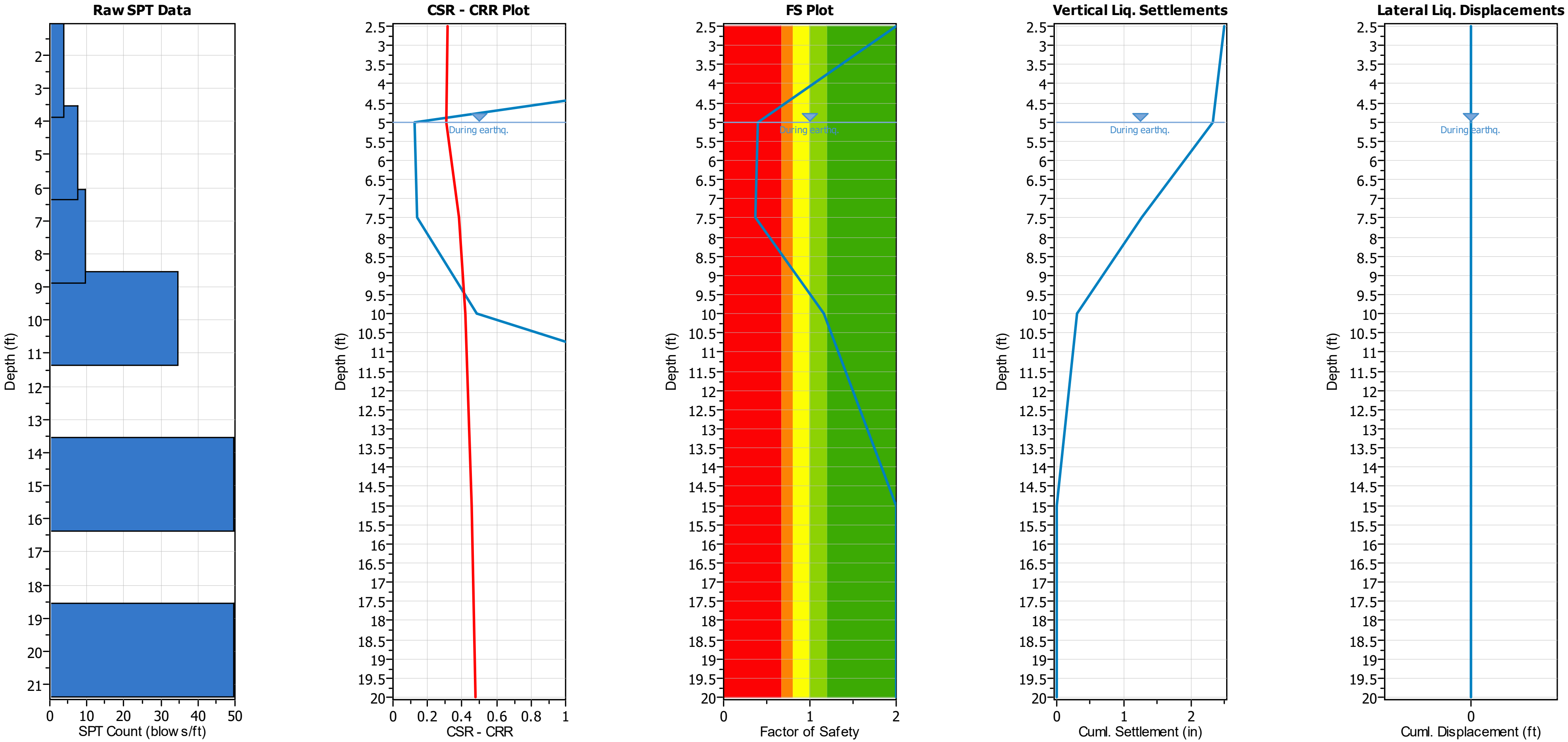
F.S. color scheme

- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

LPI color scheme

- Very high risk
- High risk
- Low risk

:: Overall Liquefaction Assessment Analysis Plots ::



:: Vertical settlements estimation for dry sands ::

Depth (ft)	$(N_1)_{60}$	τ_{av}	p	G_{max} (tsf)	α	b	γ	ε_{15}	N_c	ε_{Nc} (%)	Δh (ft)	ΔS (in)
2.50	3	0.05	0.09	0.27	0.13	21047.40	0.00	0.00	15.16	0.29	2.50	0.171

Cumulative settlemetns: 0.171

Abbreviations

τ_{av}: Average cyclic shear stress
p: Average stress
G_{max}: Maximum shear modulus (tsf)
α, b: Shear strain formula variables
γ: Average shear strain
ε_{15}: Volumetric strain after 15 cycles
N_c: Number of cycles
ε_{Nc}: Volumetric strain for number of cycles N_c (%)
Δh: Thickness of soil layer (in)
ΔS: Settlement of soil layer (in)

:: Vertical & Lateral displ.acements estimation for saturated sands ::

Depth (ft)	$(N_1)_{60cs}$	γ_{lim} (%)	F_α	FS_{liq}	γ_{max} (%)	e_v (%)	dz (ft)	S_{v-1D} (in)	LDI (ft)
5.00	11	42.40	0.89	0.402	42.40	3.53	2.50	1.059	0.00
7.50	13	34.14	0.83	0.369	34.14	3.17	2.50	0.952	0.00
10.00	30	4.65	-0.09	1.159	2.57	0.51	5.00	0.306	0.00
15.00	36	1.86	-0.51	2.000	0.00	0.00	5.00	0.000	0.00
20.00	37	1.56	-0.58	2.000	0.00	0.00	1.50	0.000	0.00

Cumulative settlements: 2.317 0.00

Abbreviations

γ_{lim}: Limiting shear strain (%)
F_α/N: Maximun shear strain factor
γ_{max}: Maximum shear strain (%)
e_v:: Post liquefaction volumetric strain (%)
S_{v-1D}: Estimated vertical settlement (in)
LDI: Estimated lateral displacement (ft)

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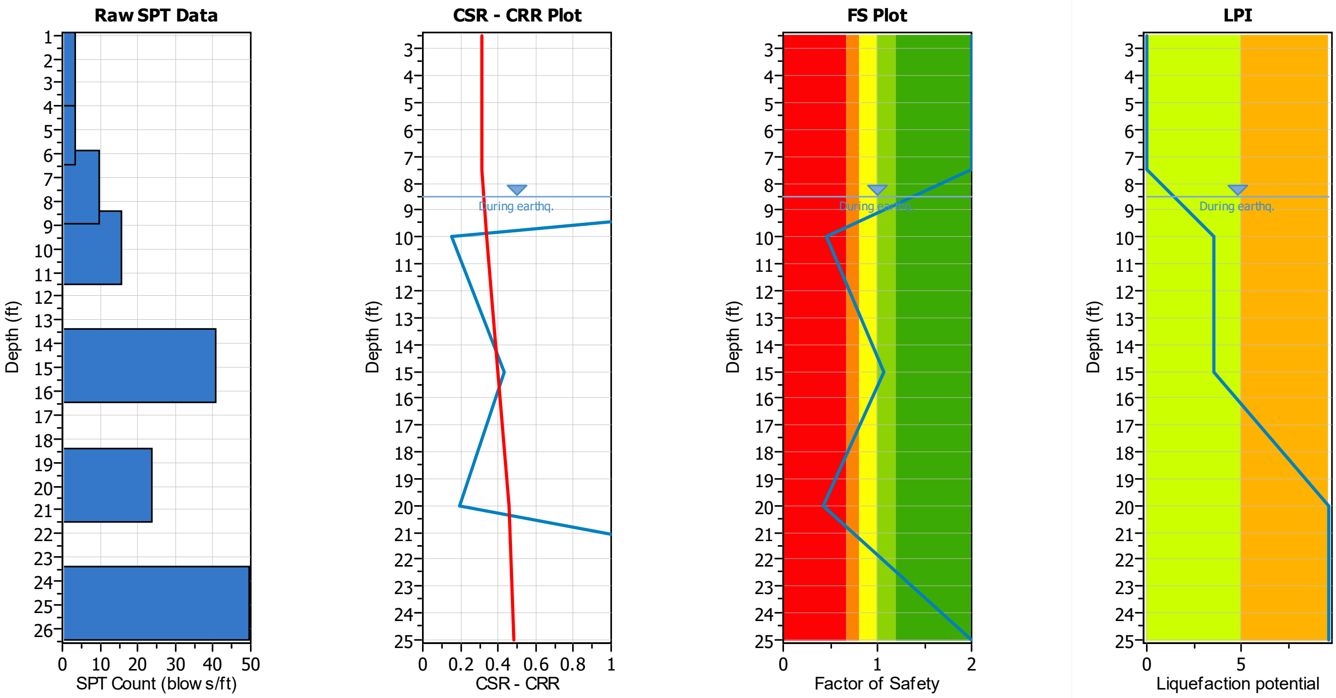
SPT BASED LIQUEFACTION ANALYSIS REPORT

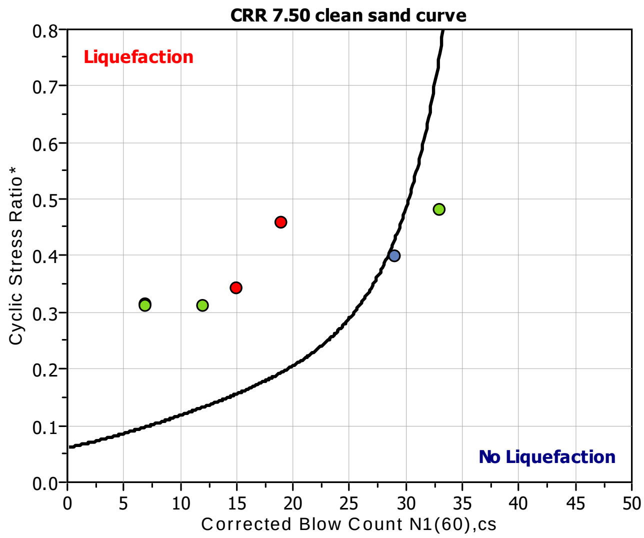
Project title : 19-384 Kalama Creek Hatchery Developments **SPT Name: PG-8**

Location : Nisqually Indian Reservation

:: Input parameters and analysis properties ::

Analysis method:	Boulanger & Idriss, 2014	G.W.T. (in-situ):	8.50 ft
Fines correction method:	Boulanger & Idriss, 2014	G.W.T. (earthq.):	8.50 ft
Sampling method:	Standard Sampler	Earthquake magnitude M_w:	7.50 ft
Borehole diameter:	65mm to 115mm	Peak ground acceleration:	0.53 g
Rod length:	3.30 ft	Eq. external load:	0.00 tsf
Hammer energy ratio:	0.60		





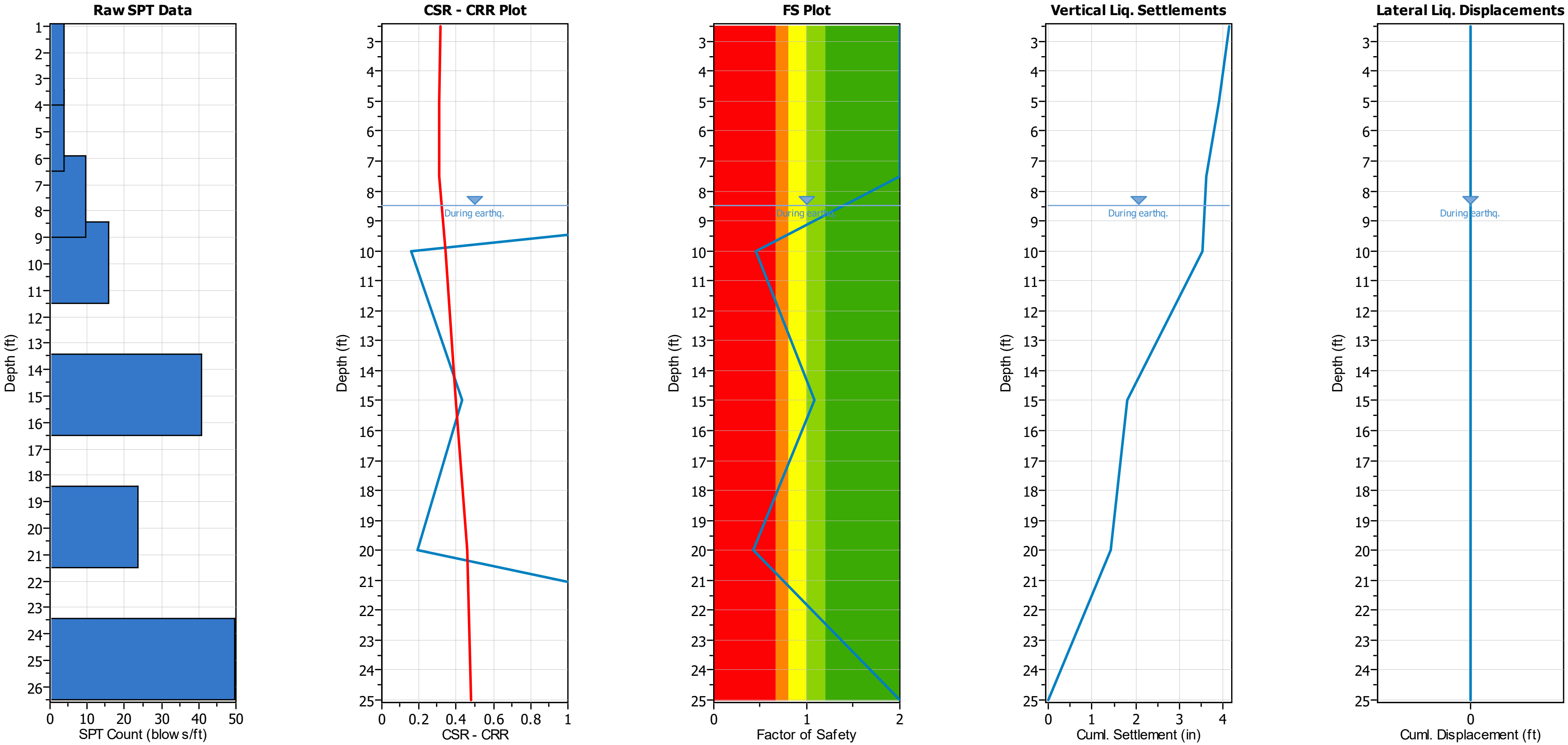
F.S. color scheme

- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

LPI color scheme

- Very high risk
- High risk
- Low risk

:: Overall Liquefaction Assessment Analysis Plots ::



:: Vertical settlements estimation for dry sands ::

Depth (ft)	$(N_1)_{60}$	τ_{av}	p	G_{max} (tsf)	α	b	γ	ε_{15}	N_c	ε_{Nc} (%)	Δh (ft)	ΔS (in)
2.50	3	0.05	0.09	0.26	0.13	21047.40	0.00	0.00	15.16	0.40	2.50	0.242
5.00	3	0.09	0.18	0.37	0.13	13886.10	0.00	0.00	15.16	0.46	2.50	0.277
7.50	8	0.14	0.28	0.54	0.14	10887.44	0.00	0.00	15.16	0.14	2.50	0.087

Cumulative settlemetns: 0.606

Abbreviations

τ_{av}: Average cyclic shear stress
p: Average stress
G_{max}: Maximum shear modulus (tsf)
α, b: Shear strain formula variables
γ: Average shear strain
ε_{15}: Volumetric strain after 15 cycles
N_c: Number of cycles
ε_{Nc}: Volumetric strain for number of cycles N_c (%)
Δh: Thickness of soil layer (in)
ΔS: Settlement of soil layer (in)

:: Vertical & Lateral displ.acements estimation for saturated sands ::

Depth (ft)	$(N_1)_{60cs}$	γ_{lim} (%)	F_α	FS_{liq}	γ_{max} (%)	e_v (%)	dz (ft)	S_{v-1D} (in)	LDI (ft)
10.00	15	27.51	0.75	0.457	27.51	2.87	5.00	1.725	0.00
15.00	29	5.33	-0.02	1.076	3.01	0.62	5.00	0.372	0.00
20.00	19	17.78	0.57	0.425	17.78	2.40	5.00	1.441	0.00
25.00	33	3.01	-0.29	2.000	0.00	0.00	1.50	0.000	0.00

Cumulative settlements: 3.538 0.00

Abbreviations

γ_{lim}: Limiting shear strain (%)
F_α/N: Maximun shear strain factor
γ_{max}: Maximum shear strain (%)
e_v:: Post liquefaction volumetric strain (%)
S_{v-1D}: Estimated vertical settlement (in)
LDI: Estimated lateral displacement (ft)

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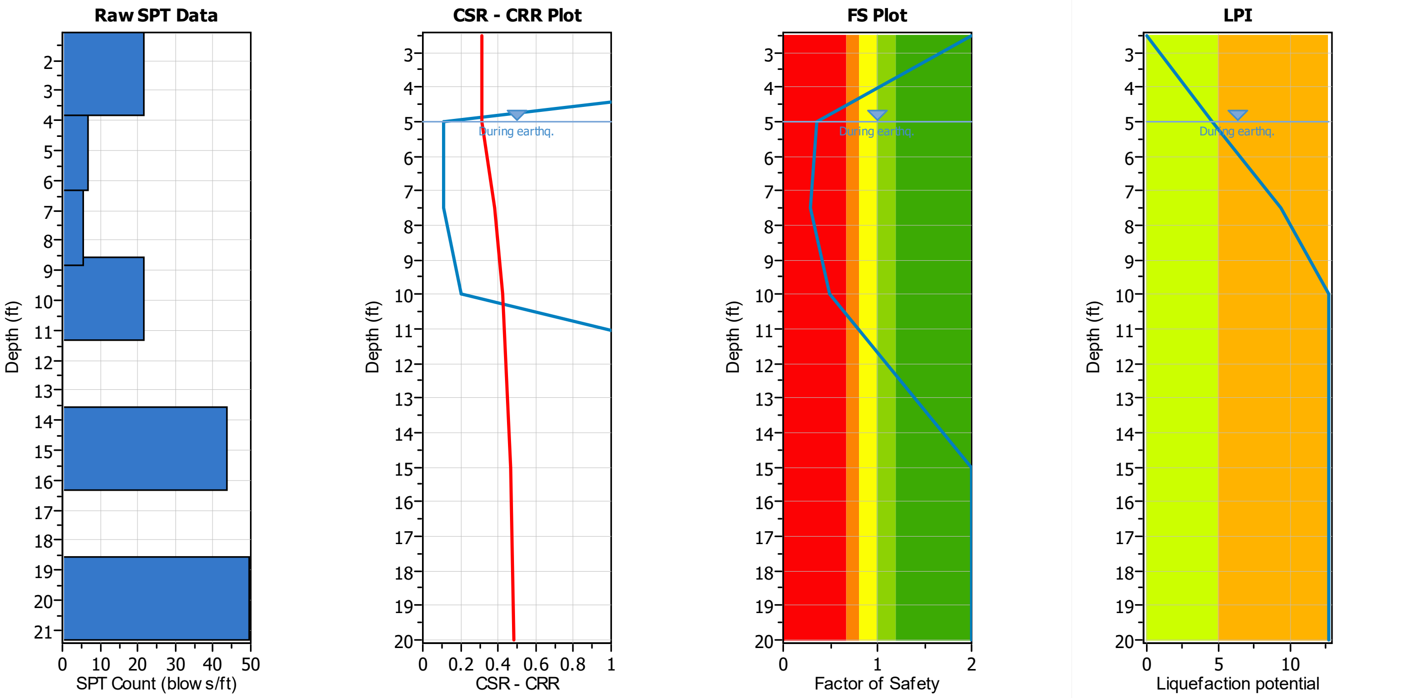
SPT BASED LIQUEFACTION ANALYSIS REPORT

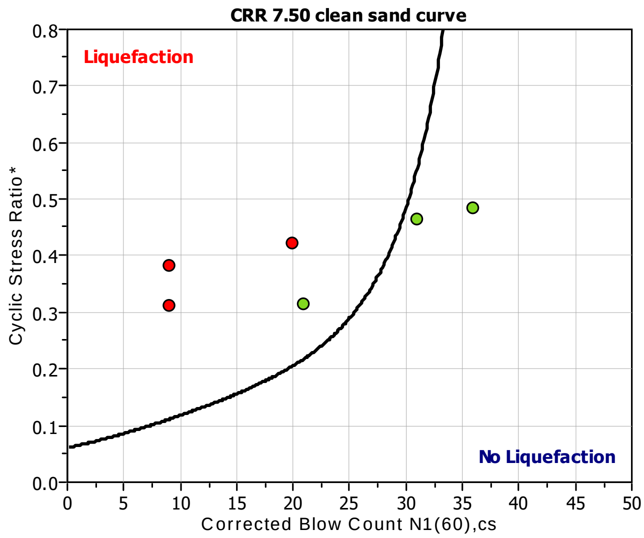
Project title : 19-384 Kalama Creek Hatchery Expansion **SPT Name: PG-9**

Location : Nisqually Indian Reservation

:: Input parameters and analysis properties ::

Analysis method:	Boulanger & Idriss, 2014	G.W.T. (in-situ):	5.00 ft
Fines correction method:	Boulanger & Idriss, 2014	G.W.T. (earthq.):	5.00 ft
Sampling method:	Standard Sampler	Earthquake magnitude M_w:	7.50 ft
Borehole diameter:	65mm to 115mm	Peak ground acceleration:	0.53 g
Rod length:	3.30 ft	Eq. external load:	0.00 tsf
Hammer energy ratio:	0.60		





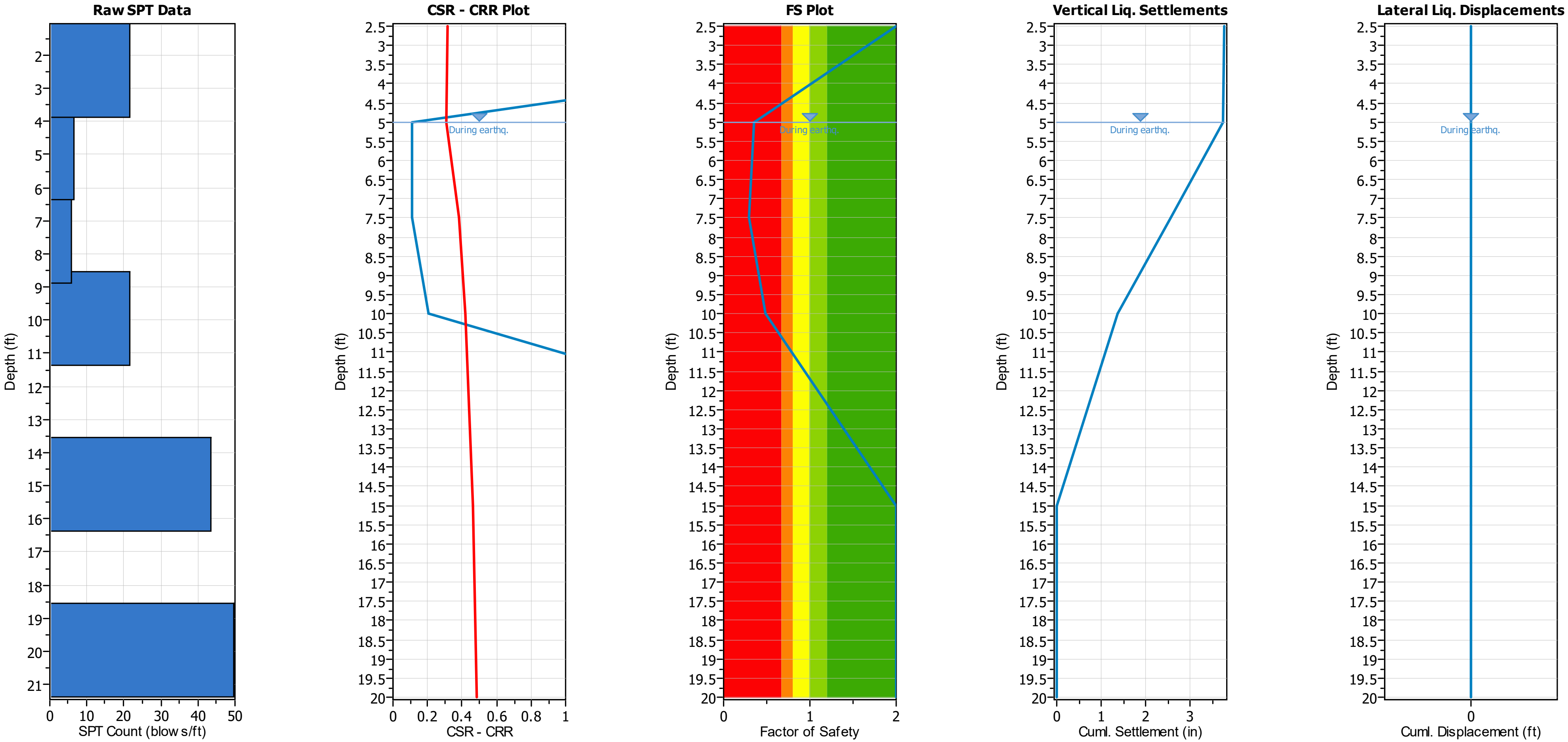
F.S. color scheme

- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

LPI color scheme

- Very high risk
- High risk
- Low risk

:: Overall Liquefaction Assessment Analysis Plots ::



:: Vertical settlements estimation for dry sands ::

Depth (ft)	$(N_1)_{60}$	τ_{av}	p	G_{max} (tsf)	α	b	γ	ε_{15}	N_c	ε_{Nc} (%)	Δh (ft)	ΔS (in)
2.50	17	0.05	0.09	0.37	0.13	21047.40	0.00	0.00	15.16	0.03	2.50	0.018

Cumulative settlemetns: 0.018

Abbreviations

τ_{av}: Average cyclic shear stress
p: Average stress
G_{max}: Maximum shear modulus (tsf)
α, b: Shear strain formula variables
γ: Average shear strain
ε_{15}: Volumetric strain after 15 cycles
N_c: Number of cycles
ε_{Nc}: Volumetric strain for number of cycles N_c (%)
Δh: Thickness of soil layer (in)
ΔS: Settlement of soil layer (in)

:: Vertical & Lateral displ.acements estimation for saturated sands ::

Depth (ft)	$(N_1)_{60cs}$	γ_{lim} (%)	F_α	FS_{liq}	γ_{max} (%)	e_v (%)	dz (ft)	S_{v-1D} (in)	LDI (ft)
5.00	9	52.88	0.93	0.357	52.88	3.97	2.50	1.190	0.00
7.50	9	52.88	0.93	0.291	52.88	3.97	2.50	1.190	0.00
10.00	20	15.90	0.52	0.488	15.90	2.30	5.00	1.382	0.00
15.00	31	4.04	-0.16	2.000	0.00	0.00	5.00	0.000	0.00
20.00	36	1.86	-0.51	2.000	0.00	0.00	1.50	0.000	0.00

Cumulative settlements: 3.762 0.00

Abbreviations

γ_{lim}: Limiting shear strain (%)
F_α/N: Maximun shear strain factor
γ_{max}: Maximum shear strain (%)
e_v:: Post liquefaction volumetric strain (%)
S_{v-1D}: Estimated vertical settlement (in)
LDI: Estimated lateral displacement (ft)