



December 28, 2018

Colin McArthur
Cameron McCarthy
160 East Broadway
Eugene, Oregon 97401

Via email: colin@cameronmccarthy.com

Regarding: Additional Geotechnical Engineering Services
Port of Port Orford Redevelopment
300 Dock Road
Port Orford, Oregon
PBS Project 73422.000

Dear Mr. McArthur:

PBS Engineering and Environmental Inc. (PBS) is pleased to submit this letter report summarizing additional geotechnical engineering services for the proposed Port of Port Orford Redevelopment project located off Dock Road at Graveyard Point in Port Orford, Oregon. The general site location is shown on the Vicinity Map, Figure 1. The locations of existing site features is shown on the Site Plan, Figure 2.

BACKGROUND

PBS previously provided a feasibility letter report for the Port Orford Cannery Redevelopment.¹ PBS understands the Port of Port Orford plans to construct new buildings at the toe of a mapped landslide. This site is exposed to numerous geologic hazards, as previously identified by PBS in 2016, such as coastal erosion, tsunami, seismically induced strong ground motions, and fault surface rupture. The purpose of PBS' current scope of services is to provide a better understanding of the risks associated with slope stability at this site and of the feasibility of various risk mitigation measures. For discussion of additional hazards, please refer to our previous report (PBS, 2016).

SCOPE OF SERVICES

PBS completed the following geotechnical scope of services.

Geologic Map Review

Geologic maps of the site area were reviewed for information regarding geologic conditions and hazards at or near the site.

Aerial Photo Review

Available historical aerial photos were reviewed to identify historical changes to the adjacent slopes.

¹ PBS Engineering and Environmental Inc. (February 26, 2016). Feasibility Geotechnical Engineering Services, Port of Port Orford Cannery Redevelopment. Prepared for Crow/Clay Associates, Inc., PBS Project 90321.000.

Site Reconnaissance

A certified engineering geologist (CEG) from PBS conducted a walking site reconnaissance to observe and map the slopes adjacent to the proposed structure location and the length of Dock Road. The hillside adjacent to Dock Road, existing cannery building, and dry dock are herein referred to as "the site." Mapping was performed by traversing accessible areas of the slopes and noting visible geologic features such as outcrops, scarps, cracks, springs, etc., that are indicative of recent slope movement. These features were photo-documented and identified on a base map.

Geological and Geotechnical Engineering Evaluation

The data collected during the literature research and site reconnaissance was reviewed and used to develop an opinion regarding the risks associated with potential geologic hazards at the site.

Deliverable

This letter report was prepared containing the results of our work, including the following information:

- Field reconnaissance photos and maps
- Discussion of aerial photo review
- Discussion of geologic hazards, including the impact of changes reportedly implemented at the top of the slope, below the Castaway Motel, and associated risks for the proposed building location
- General discussion of feasible mitigation measures such as improved drainage, slope and road maintenance, and rock slope reinforcement options, as well as input on relative costs and visual impact
- Recommendations for future exploration, analyses, and slope monitoring

SITE DESCRIPTION

The site is located at the west end of Dock Road near the existing cannery building and dry dock located at Graveyard Point (Figure 2). Review of available LiDAR (light detection and ranging) data acquired through the DOGAMI LiDAR Viewer,² indicates the existing cannery building and end of Dock Road are at an elevation of 24 feet above mean sea level (amsl; NAVD88). Dock Road is bordered to the west and north by a steep hillside mapped as an existing landslide deposit (identified in dashed red in Figure 2) and to the south by the beach and dunes. The road traverses the toe of the landslide and increases in elevation from west to east. An old road, located upslope of Dock Road, is currently being used as a walking trail and can be easily identified on the LiDAR hillshade (Figure 3). The existing cannery is located at the west end of the mapped landslide and the dry dock is bordered to the west by the cliff face.

The cliff located at the western end of Dock Road is composed of bedrock capped by coastal terrace sediments (this will be described in more detailed below). The cliff forms the topographic highpoint within the immediate site vicinity, with a summit elevation of 224 amsl that decreases from west to east to an elevation of 74 amsl due to changes in geologic conditions.

The hillside along Dock Road is convex shaped, with a hummocky surface and a steep, well-defined head scarp readily distinguishable by the inclination of slope (Figure 2). Some of the hummocks form steep fronts, with slope inclination upward of 27 degrees (Figure 2). The hillside is vegetated by grass, brush, and small trees, with some low-lying areas located near the center of the slope and between hummocks.

² Oregon Department of Geology and Mineral Industries (DOGAMI), 2018. DOGAMI LiDAR Viewer.
<https://gis.dogami.oregon.gov/maps/lidarviewer/>

GEOLOGIC SETTING

Regional Geology

The site is located in southwestern Oregon within the northwestern margin of the Klamath Mountains physiographic province; a mountainous region along the Pacific coast that extends from the Middle Fork Coquille River, Oregon, to the South Fork Trinity River, California. Bedrock geology along southwestern coastal Oregon consists of complexly folded, faulted, and metamorphosed rock assigned to tectonostratigraphic terranes.³ These terranes record a history of volcanic arc and continental sedimentation, magmatism, and terrane accretion during the Late Jurassic and Cretaceous. Ongoing subduction along the Cascadia subduction zone (CSZ), where oceanic rock is subducting beneath continental rock, have accreted and overthrust these terranes to their present-day positions (McCloughry et al., 2013a).

The bedrock geology of the Port Orford area consists of marine sedimentary rock of the Gold Beach Terrane to the west, which is juxtaposed and fault-bounded with marine sedimentary rock of the Western Klamath Terrane to the east by the Battle Rock fault zone.⁴

Along much of coastal Oregon, these older accreted rocks are overlain by a sequence of younger Pleistocene age coastal terraces (McCloughry et al., 2013b). These sediments were deposited by beach and dune processes during fluctuations in sea level and subsequently uplifted by regional tectonic activity associated with CSZ. Within the vicinity of Port Orford, a sequence of four terraces are recognized from youngest to oldest: Pioneer terrace (map unit Qmtp), Silver Butte terrace (not shown on Figure 3), Indian Creek terrace (map unit Qmti), and Poverty Ridge terrace (not shown on Figure 3). The terraces form broad, flat surfaces, with varying degrees of incision and degradation correlated to age.

Local Geology

Dock Road is located between a mapped landslide deposit (map unit Qls) forming the convex hillslope to the north and west of the road, and beach and dunes (map units Ads and Abs) to the south (Figure 3).⁵ Map unit Qls is the largest landslide within the site and contains several smaller Anthropocene age landslide deposits mapped within it (map unit Als). Burns et al. (2014) identify this landslide as historical or active, with movement less than 150 years ago or currently moving, and classify this slide as a rock flow. We herein adopt the title of this slide as "rock flow" and assume all Anthropocene landslide deposits mapped by McCloughry et al. (2013b) are active slides, as identified by Burns et al. (2014), unless engineered measures have been implemented or monitoring has proven otherwise.

The morphology of the rock flow is readily distinguishable with well-developed hummocks visible in the LiDAR hillshade and slope measurements (Figures 2 and 3).

The western-most end of Dock Road is bordered to the west by a cliff consisting of Otter Point Sandstone (map unit KJos), capped with younger Indian Creek terrace sediments (map unit Qmti). This cliff forms the highest

³ McCloughry, J. D., Ma, L., Jones, C. B., Michelson, K. A., Wiley, T. J., 2013a, Geologic Map of the Southwestern Oregon Coast between Crook Point and Port Orford, Curry County, Oregon. Oregon Department of Geology and Mineral Industries, Open-File Report O-13-21.

⁴ McCloughry, J. D., Ma, L., Jones, C. B., Michelson, K. A., Wiley, T. J., 2013b, Geologic Map of the Port Orford OE W 7.5' Quadrangle, Port Orford 7.5' Quadrangle, and Part of the Father Mountain 7.5' Quadrangle, Curry County, Oregon, Oregon Department of Geology and Mineral Industries, Open-File Report O-13-21, Plate 4, 1:24,000.

⁵ Burns, W. J., Mickelson, K. A., and Stimely, L. L., 2014. Landslide Inventory Map for Coastal Curry County, Oregon, Port Orford to Lookout Rock. Oregon Department of Geology and Mineral Industries, Open-File Report O-14-10, Plate 3, 1:14,000.

topographic point at the site, with a maximum elevation of 265 feet amsl, and wraps around approximately half of the rock flow before terminating near existing residences. The cliff forms a readily distinguishable head scarp in the LiDAR and hillshade slope measurements and represents the greatest topographic relief between the crest of the slope and mapped rock flow (Figures 2 and 3). The Otter Point sandstone is mapped as wrapping around the entire extent of the of the rock flow but is only cliff-forming along the western half of the slide.

A notable decrease in elevation at the crest of the hillside occurs from west to east, with a change in elevation from 265 feet to the west to 74 feet amsl to the east. This elevation gradient is the result of a change in geology along the crest from older terrace sediments to the west (Qmti), to younger terraces sediments to the east (Qmtp), with mapped bedrock (KJos) creating an interface between the two terraces.

Battle Rock Fault Zone

Several splays of the Battle Rock fault zone (USGS No. 896) are mapped as cutting across the rock flow. The Battle Rock fault zone is identified as active by Oregon HazVu and included within the USGS Quaternary Faults and Folds Database.^{6,7} The USGS estimates the most recent prehistoric deformation occurred along this fault zone within the last 750,000 years (middle to late Quaternary) based on deformation of the Indian Creek marine terrace near Port Orford (USGS, 2006). In addition, the USGS does include an earthquake scenario for this within its Earthquake Hazards Program, a collaborative research effort to report, monitor, research, and assess earthquake hazards.⁸ The magnitude 7.0 (M 7.0) scenario earthquake estimates severe shaking at the site.⁹

RECONNAISSANCE

A certified engineering geologist (CEG) from PBS performed a walking site reconnaissance on November 27 and 28, 2018. The purpose of the reconnaissance was to document existing site conditions by traversing the slopes above Dock Road. Photos taken during the site reconnaissance can be found on Figure 4; the locations of the photos are indicated on Figure 2.

Fill

Fill was observed near the Castaway by the Sea hotel located above the Dock Road (Figure 4, photo 1). The fill was placed at an undermined date and consists of angular, 1- to 4-inch diameter sandstone gravel. The crest of the fill was at the same grade as the surrounding ground surface at the time of our visit. The fill was mapped (map unit Af) with a known contact (Figure 3). Corrugated pipes were observed along the slope below the fill and across the old road. To where these pipes extend is unclear, and we are uncertain whether these pipes are part of an improvised dewatering system or some sort of stormwater drainage for the hotel.

Additional fill may exist along the north side of Dock Road at the eastern end of the road. At this location, the geometry of the slope relative to Dock Road and the old road suggest that the old road was cut into the hillside and the excavated material was pushed downslope. This fill was mapped with an inferred contact (Figure 3).

⁶ Oregon HazVu website: <http://www.oregongeology.org/hazvu/>

⁷ USGS. 2006, Quaternary fault and fold database for the United States, accessed 11/30/2018, from USGS web site: <http://earthquake.usgs.gov/hazards/qfaults/>.

⁸ USGS, Earthquake Hazards Program, accessed 12/26/18, from USGS web site: <https://earthquake.usgs.gov/>

⁹ BSSC2014. M 7.0 Scenario Earthquake – Battle Rock fault zone. Accessed 12/26/18, from USGS web site: https://earthquake.usgs.gov/scenarios/eventpage/bssc2014896_m7p_se/executive

Evidence of Slope Movement

The gravel fill near the hotel was placed at the head of what PBS has interpreted as an active slump. The slump consists of a hummocky surface with a distinctive distal edge located along the old road (identified in Figures 3 and 4), and freshly exposed soil free of vegetation was observed along the western flank. This feature was mapped by PBS (map unit Als) with an approximate contact and can be found on Figure 3.

Immediately north of the existing cannery building, a vertical, corrugated pipe was observed protruding out of the toe of the hillside (Figure 4, photo 2). The purpose of this pipe is unclear. However, it appears it is being "slowly engulfed" within a soil mass from up slope and periodically cleaned. This location was in proximity to an Anthropocene age landslide (map unit Als) by McClaughry et. al (2013b). As such, we have modified the extent of the Als boundary in Figure 3 to include the area identified in Figure 4, photo 1.

Rock Flow

Traversing the rock flow proved to be difficult due to thick vegetation (Figure 4, photos 3 and 4). Lower-lying areas were overgrown with dense Equisetum (commonly known as horsetail or snake grass) and teasel, and the ground surface had a soft, spongy feel underfoot that may be indicative of shallow groundwater or seasonal springs. We note that no surface water or seepage was observed at the time of our site reconnaissance. In the center of the mapped rock flow, hummocks had the same ground feel and vegetation as the low-lying areas (Figure 4, photo 4). No visible surface features indicative of recent slope movement (e.g., tension cracks, potholes, exposed soil, etc.) were observed while traversing the rock flow. However, we note that this does not exempt the rock flow from being classified as active.

Cliff Face

The cliff face adjacent to the dry dock is subvertical, with vertical and overhanging blocks. Three prominent joint sets intersect approximately half way up the rock exposure producing a V-shaped wedge with a vertical face. A debris cone is located at the toe of the wedge, with the majority of the debris consisting of angular gravel less than 1 inch in diameter to boulder-sized sandstone blocks upward of 1 foot in diameter, within a sandy matrix. This was mapped as colluvium (map unit Hfr) and is likely the result of continuous shedding of upslope debris and not the result of a singular catastrophic rock fall. Two massive blocks that exceed 4 feet in diameter are present along the eastern margin of the colluvium.

CONCLUSIONS AND DISCUSSION

Based on review of available data and our site reconnaissance, we have drawn the following conclusions regarding the stability of the existing landslide deposits and feasibility of development at the site.

- Current conditions of the rock flow:
 - Based on the lack of field indicators of recent movement (tension cracks, exposed soil scarps, etc.), it is unclear if the slide mass is currently in equilibrium or creeping at a rate slow enough to have little or no impact to the site.
 - The stability of the rock flow cannot be determined without installation of slope monitoring instruments and ongoing monitoring.
 - Seepage and surface water was not observed at the time of our exploration, however the presence of dense Equisetum growth and the spongy feel when walking over the surface of some areas may indicate shallow groundwater conditions.

- Groundwater levels cannot be determined without the installation of piezometers and the presence of seepage or springs cannot be determined without a future site visit at the end of the rainy season.
- Slope movement
 - Smaller surficial failures have been observed at the site within the mapped extent of the rock flow and along the hillside above Dock Road.
 - Without the installation of slope monitoring instruments and ongoing monitoring, we cannot determine the magnitude of these slope movements, nor can we determine if they may be indicative of deep-seated movement within the rock flow or the level of risk they may pose to the site.
- Fill placed at the hotel
 - Gravel fill was placed at the top of the slope by the hotel above what PBS has identified as an active slump.
 - It appears that the fill placed at the top of the slope did not include efforts to buttress or stabilize the slide mass upon which it was placed, and we interpret this to be an unengineered repair.
- Coseismic landslides
 - The Battle Rock fault zone is mapped through the center of the rock flow; however, the recurrence interval for an event along this fault zone is unknown.
 - Scenario earthquakes for the Cascadia subduction zone^{10,11} and Battle Rock fault zone model the site within a zone of very strong to severe ground shaking (Modified Mercalli Scale 7.5 to 8). It is reasonable to assume that this degree of ground shaking would trigger slope movements.

MITIGATION MEASURES, CONSIDERATIONS, AND RELATIVE COSTS

Slope stability is influenced by various factors including: (1) the geometry of the soil mass and subsurface materials, (2) the weight of soils overlying the failure surface, (3) the shear strength of soils and/or rock along the failure surface, and (4) the hydrostatic pressure (groundwater levels) along the failure surface. The stability of a slope is expressed in terms of factor of safety (FS), which is defined as the ratio of resisting forces to driving forces. At equilibrium, the FS is equal to 1.0 and the driving forces are balanced by the resisting forces. Failure occurs when the driving forces exceed the resisting forces, i.e., FS less than 1.0. An increase in the FS above 1.0, whether by increasing the resisting forces and/or decreasing the driving forces, reflects a corresponding increase in the stability of the mass. The actual FS may differ from the calculated FS due to uncertainty in soil strengths, subsurface geometry, failure surface location and orientation, groundwater levels, and other factors that are not completely known or understood.

Due to the complex nature and size of the mapped rock flow, mitigation measures should be carefully planned prior to implementation to avoid disturbance that could increase the risk of future failure. Any mitigation measure will require site-specific exploration and monitoring through a representative wet season prior to design and construction of the desired mitigation measures. Slope stabilization efforts typically include slope stability analysis and incorporate one or more of the following: dewatering, installing some form of buttressing material or

¹⁰ BSSC2014. M 9.3 Scenario Earthquake – Cascadia Megathrust – whole CSZ Characteristic Largest M Branch. Accessed 12/26/18, from USGS web site: https://earthquake.usgs.gov/scenarios/eventpage/bssc2014cascadia_sub0_m9p34_se/executive

¹¹ GLEGACY. M 9.0 Scenario Earthquake – Cascadia M9.0 Scenario (mean value). Accessed 12/26/18, from USGS web site: https://earthquake.usgs.gov/scenarios/eventpage/gllegacycasc9p0expanded_se/executive

engineered structure, or removing the slide mass. However, without the necessary data to quantify the depth of the slide plane(s), magnitude of movement, or groundwater levels, we cannot determine the best approach at this time.

At the time of our reconnaissance, no obvious signs of seepage in accessible areas were observed. We note that very little rainfall had occurred at the site prior to our reconnaissance, and we expect seepage will occur during the wet season. In addition, the presence of aquatic plants could indicate the presence of relatively shallow, perched groundwater. Due to limited amount of water observed and the presence of fine-grained soils, widespread implementation of drainage elements, such as trench drains, horizontal drains, or surface modifications, would likely be extensive, and possibly have limited impact on reducing the risk of movement. Without the installation of piezometers and continued monitoring, our current opinion is that drainage improvements may not significantly reduce the risk of slope movement.

It appears that relatively shallow, ongoing slope movement (creep) has been occurring over the mapped slide areas. Regular maintenance that includes digging out and around existing utilities, repairing damaged utility lines, and removing debris from Dock Road has been sufficient for maintaining access to the dry dock area and existing cannery. However, this type of maintenance should take care to not adversely impact site slopes with excavation into the toe or removing large amounts of soil from the toe, as this may further destabilize the slope. The ongoing maintenance may be sufficient to maintain access along Dock Road.

The magnitude of slope displacement from ground shaking generated by an earthquake is unknown, and the ability to prevent slope movement from an earthquake is unlikely. Given some movement of portions of the landslide mass has occurred or is occurring, the FS is likely very close to 1.0. Subsequently, the additional force associated with an earthquake would likely result in a larger magnitude of movement than is occurring in the current, static conditions. In the event of an earthquake, additional hazards such as tsunami waves and liquefaction will likely impact the site, as well as slope movement.

The following table includes the relative costs for various methods of slope stabilization and the associated considerations impacting those costs.

Mitigation Measure	Relative Cost*	Notes
Removing slide mass	Low	Can be performed with conventional equipment, and local materials and contractors
Rock buttress	Moderate	Can be performed with conventional equipment, using local materials and contractors, but will require slope stability analysis and engineering
Engineered structure (walls, shafts, anchors, etc.)	Very high	Requires specialty equipment, specialty subcontractors, and extensive engineering analyses
Trench drains	Low	Can be performed with conventional equipment, and local materials and contractors
Improved surface water drainage	Low	Can be performed with conventional equipment, and local materials and contractors

Mitigation Measure	Relative Cost*	Notes
Horizontal drains	High	Requires specialty equipment, specialty subcontractors, and extensive engineering analyses

*Actual costs should be determined based on selected mitigation measure and subsequent design analyses

ADDITIONAL SERVICES

Prior to developing design and construction recommendations, site-specific exploration and/or monitoring should be completed. Monitoring could be a combination of slope inclinometers, which can be used to determine the rate and depth of slope movement, and installation of survey monitoring points. Survey points provide data over a larger area and can be obtained for a smaller cost, but they are limited to monitoring surface movement only.

At a minimum, we recommend installing a network of survey monuments over areas of concern, and monitoring those through a representative wet, winter season to determine the magnitude and direction of ongoing slope movement.

LIMITATIONS

Our conclusions are based upon limited observations during a site reconnaissance on the date mentioned above. No subsurface explorations have been completed to verify soil, bedrock, and groundwater conditions within the mapped landslide deposits. Variations in these slope components can have a substantial effect on the long-term stability of slopes. Off-site changes due to excavation, construction, or placement of fills can also impact long-term slope stability. PBS should be contacted to review any site changes to evaluate their possible effect on the subject property.

CLOSING

We trust this letter meets your current needs. Please feel free to contact Shaun Cordes at 503.935.5517 or shaun.cordes@pbsusa.com with any questions or comments.

Sincerely,

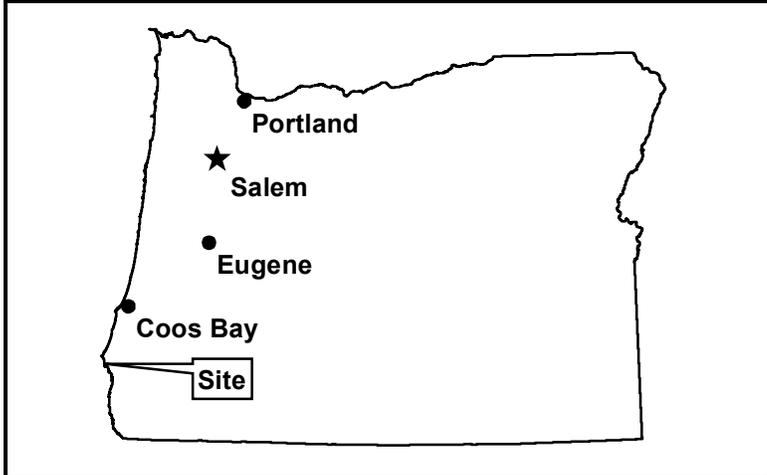
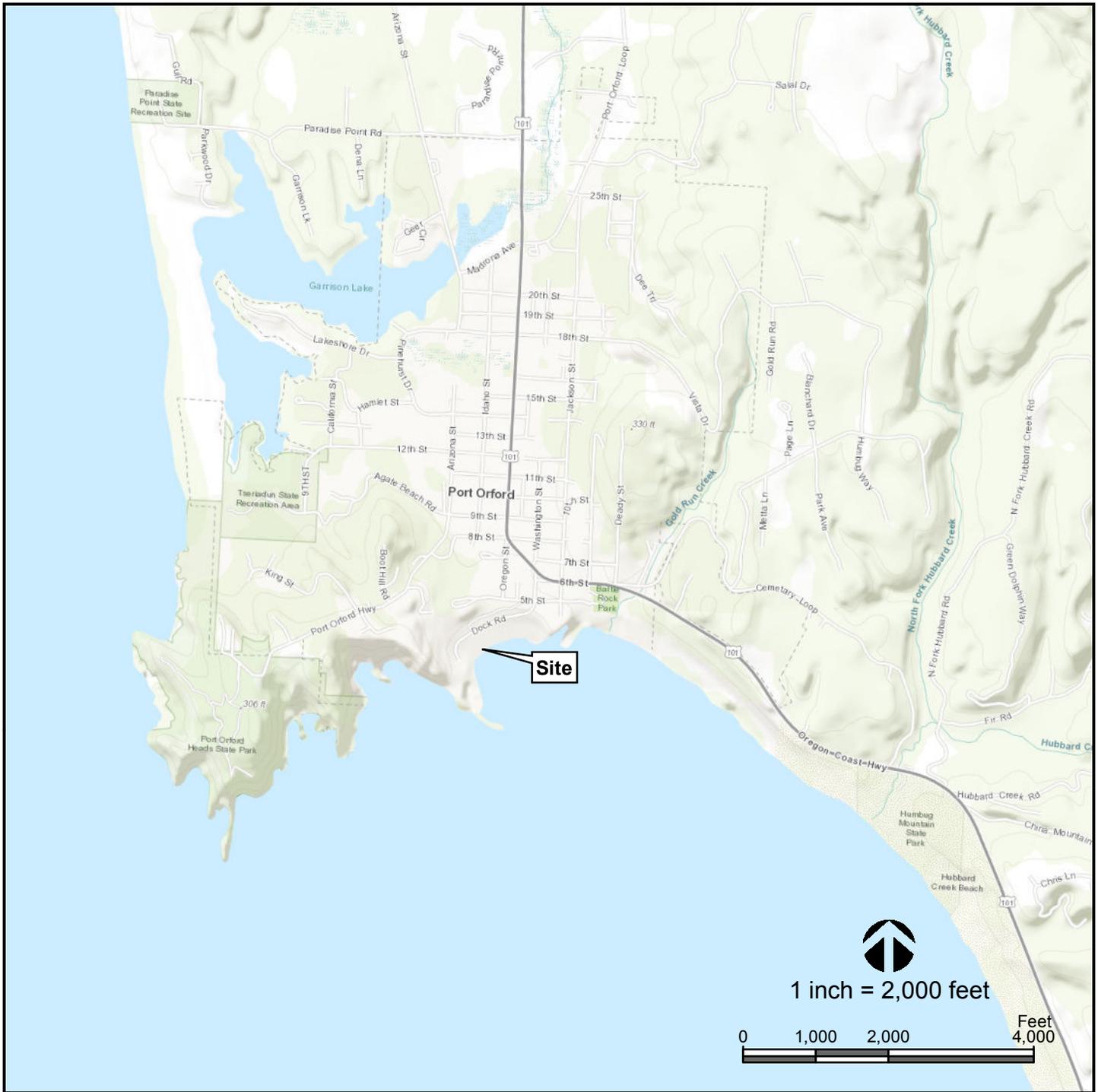


Renewal Date 7/1/2019

Shaun Cordes, RG, CEG
 Project Engineering Geologist

Ryan White, PE, GE
 Geotechnical Engineering Group Manager

- Attachments: Figure 1. Vicinity Map
 Figure 2. Site Plan and Field Notes
 Figure 3. Geologic Map
 Figure 4. Reconnaissance Photographs



VICINITY MAP

**PORT OF PORT ORFORD
REDEVELOPMENT
PORT ORFORD, OREGON**

DATE: DEC 2018 · PROJECT: 73422.000



FIGURE
1



EXPLANATION

-  B-1 - Boring name and approximate location (PBS, 2016)
-  Rock flow, historical and/or active (Burns et al., 2014)
-  Approximate location of proposed structures, plan L-1.0 (Cameron McCarthy, 12/4/18)
-  Approximate site location

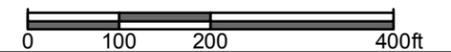
Slope (degrees)

-  20 - 27
-  27 - 36
-  36 - 46
-  46 - 61
-  61 - 85

Notes:
 Google Earth 2016 imagery, slope and contours derived from DOGAMI LiDAR DEM, 10-foot contour interval



1 inch = 200 feet



SITE PLAN

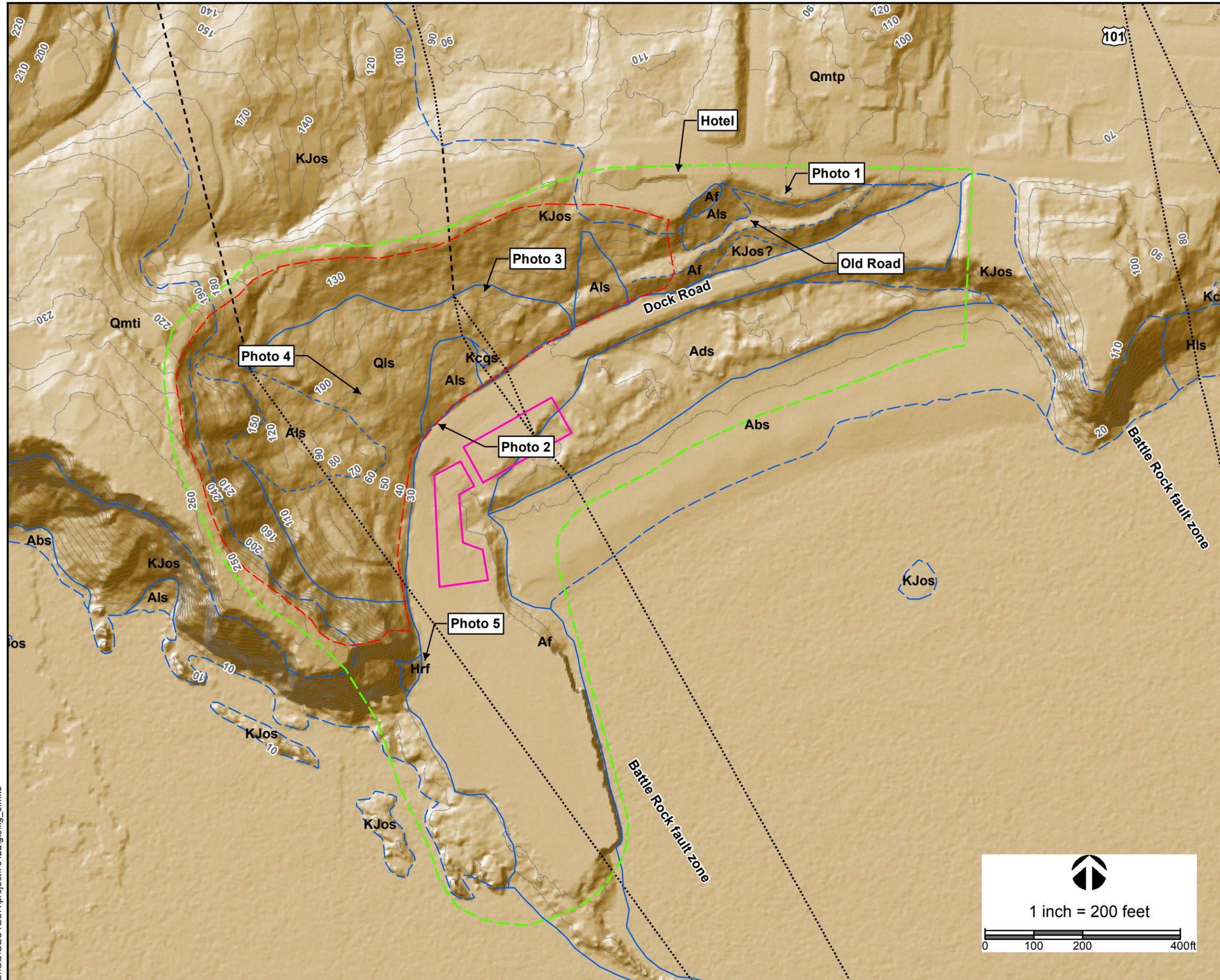
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FIGURE

2



EXPLANATION

- Af** - Artificial fill
 - Abs** - Beach deposits (Anthropocene) - Unconsolidated sands and gravels deposited in active ocean beaches.
 - Ads** - Back-beach dune deposits (Anthropocene) - Unconsolidated sand deposited by wind in near-shore and back-beach settings parallel to shoreline.
 - Als** - Landslide deposits (Anthropocene) - Unconsolidated chaotically mixed masses of rock and soil deposited by landslides, slumps, debris flows and rock fall.
 - Hrf** - Rock fall and colluvium (Anthropocene to Holocene?) - Unconsolidated mixture of rocks and soil deposited in rockfall and talus cones beneath steep slopes.
 - Hls** - Landslide deposits (Holocene) - Unconsolidated chaotically mixed masses of rock and soil deposited by landslides, slumps, debris flows, and rock fall with well-defined hummocks.
 - Qls** - Landslide deposits (Quaternary) - Unconsolidated chaotically mixed masses of rock and soil deposited by landslides, slumps, debris flows, and rock fall with well-defined hummocks. May consist of individual slides or large complexes resulting from multiple slides.
 - Qmp** - Pioneer terrace sediments (Upper Pleistocene) - Slightly dissected terrace sediments forming a regional extensive platform with a maximum thickness of approximately 70 feet.
 - Qmti** - Indian Creek terrace sediments (Upper or lower Pleistocene) - Moderately to deeply dissected terrace sediments, moderately warped and faulted with a maximum thickness of 100 feet.
 - KJos** - Otter Point Formation sandstone and mudstone (Lower Cretaceous and Jurassic) - well-indurated sandstone with less common siltstone, shale, and conglomerate.
-
- Contact — Solid where known, dashed where approximate, short-dashed where inferred
 - Rock flow, historic and/or active (Burns et al., 2014)
 - Fault - Dotted where concealed, dashed where inferred
 - Approximate location of proposed structures, plan L-1.0 (Cameron McCarthy, 12/4/18)
 - Approximate site location
- Notes:
 Geologic map modified from McClaughry et al. (2013), contours and hillshade basemap produced from DOGAMI LiDAR DEM, 20-foot contour interval

GEOLOGIC MAP

**PORT OF PORT ORFORD
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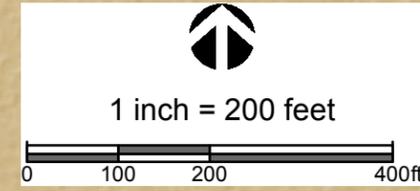


	FIGURE
	3

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Photo 1: Undocumented fill and slump with evidence of recent creep

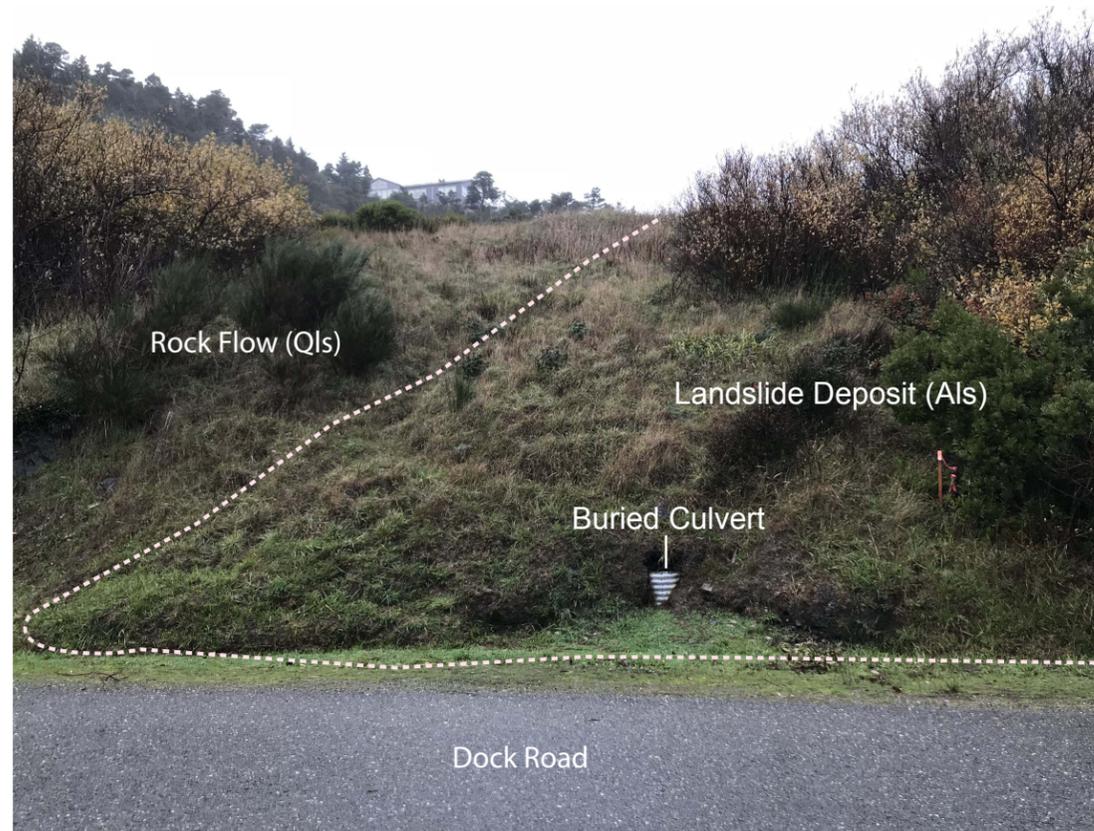


Photo 2: Toe of mapped Als landslide with evidence of recent creep

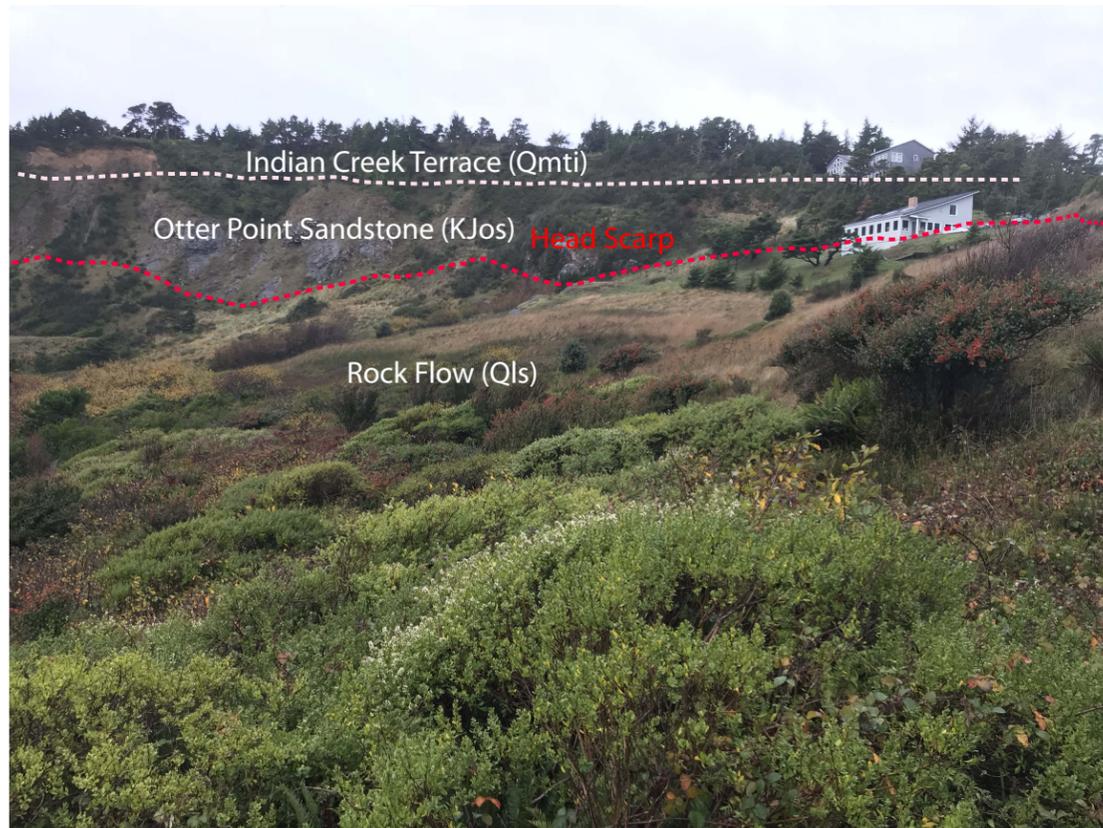


Photo 3: Westward view of rock flow



Photo 4: Eastward view of rock flow

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FIGURE

4

SITE PHOTOGRAPHS
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