Geologic Hazards and
Geotechnical Investigation
Tax Lot 1000, Map 07-11-22BD,
SW Bard Loop
Lincoln City, Oregon

Prepared for:

Project #Y224627

July 7, 2022

H.G. Schlicker & Associates, Inc.

H.G. Schlicker & Associates, Inc.
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Project #Y224627 July 7, 2022

To:

Subject: **Geologic Hazards and**
Geotechnical Investigation
Tax Lot 1000, Map 07-11-22BD
SW Bard Loop
Lincoln City, Oregon

Dear Mr. Cromwell:

The accompanying report presents the results of our geologic hazards and geotechnical investigation for the above subject site.

After you have reviewed our report, we would be pleased to discuss it and to answer any questions you might have.

This opportunity to be of service is sincerely appreciated. If we can be of any further assistance, please contact us.

H.G. SCHLICKER & ASSOCIATES, INC.

J. Douglas Gless, MSc, RG, CEG, LHG
President/Principal Engineering Geologist

JDG:mgb

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H.G. Schlicker & Associates, Inc.
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To:

Subject: **Geologic Hazards and Geotechnical Investigation**
Tax Lot 1000, Map 07-11-22BD
SW Bard Loop
Lincoln City, Oregon

Dear Mr. Cromwell:

1.0 Introduction and General Information

At your request and authorization, representatives of H.G. Schlicker and Associates, Inc. (HGSA) visited the subject site on June 10, 16, and 29, 2022, to complete a geologic hazards and geotechnical investigation of Tax Lot 1000, Map 7-11-22BD, Lincoln City, Oregon (Figure 1). We understand that you propose constructing a house at the site.

This report addresses the geologic hazards and engineering geology at the site with respect to constructing a house. The scope of our work consisted of site visits, site observations and measurements, hand augered borings, a slope profile, limited review of the geologic literature, interpretation of topographic maps, lidar, and aerial photographs, and preparation of this report which provides our findings, conclusions, and recommendations.

2.0 Site Description

The site is located on an elevated marine terrace approximately 100 feet east of a 130-foot-high bluff slope (Figure 3). The site consists of a vacant, irregular-shaped lot approximately 70 feet wide and approximately 50 feet deep in the center (Figure 2). The lot is bounded to its north and west by SW Bard Loop and to its east and south by adjacent lots with existing homes.

The area of the site slopes gently to the northwest from 0 to 5 degrees. The bluff west of the site slopes down to the west from approximately 30 to 90 degrees, with an average slope angle of approximately 43 to 45 degrees.

The upper approximately 10 to 25 feet of the bluff is near vertical with a 1 to 2 feet overhang of organic mat and soil along the upper edge of the bluff. Mudstone exposed at the base of the bluff slopes down westerly to the beach.

The area of the site is vegetated, generally with common grasses and weeds. The bluff slope, west of the site, is moderately to densely vegetated with shore pine, spruce, and salal on the middle to upper slope, and European beach grass, salal, and scotch broom on the lower slope. The near-vertical upper-bluff is devoid of vegetation on the bluff face. An oceanfront protective structure is not present at the base of the bluff.

2.1 Proposed Development

Based on the information provided to us, you plan to construct a house at the subject site (Tax Lot 1000). We have provided geotechnical recommendations for design of the house in Sections 8.1 through 8.12 below. HGSA should be contacted to review development plans for the site. There will be additional charges for these services.

2.2 History of The Site and Surrounding Areas

An asphalt driveway, which provides access to the adjacent lot, appears to trend across the northeastern portion of the site (Appendix A).

The subject property is not oceanfront, according to Lincoln County records. According to the Oregon Coastal Atlas Ocean Shores Data Viewer (http://www.coastalatlas.net/oceanshores, accessed June 2022), the lot is not included in the Goal 18 Eligibility Inventory. The oceanfront lots west of the site do not have an oceanfront protective structure and lie in an area of high bluffs that generally lack oceanfront protective structures. Oceanfront protection is present on lots approximately 450 feet southwest and 2,200 feet north of the subject lot. We expect that this general stretch of coastline, west of the site, will have additional shore protection constructed as bluff recession continues in the future. The oceanfront lots west of the site appear eligible for a beachfront protective structure on the Goal 18 Eligibility Inventory. However, the potential to receive a permit for oceanfront protection is dependent upon meeting certain regulatory requirements in addition to the Goal 18 eligibility requirement.

2.3 Site Topography, Elevations, and Slopes

The area of the site generally slopes down to the west-northwest at approximately 0 to 5 degrees. The bluff west of the site slopes down to the west from approximately 30 degrees to near-vertical, with an average slope angle of approximately 43 to 45 degrees (Figures 3 and 4; Appendix A).

Based on 2016 lidar data from DOGAMI, the area of the site lies at an elevation of approximately 158 feet (NAVD 88), and the beach/dune junction is at an elevation of approximately 20 feet (Figure 3). Based on our review of historical aerial imagery and beach profile data, the elevation of the beach varies from season to season and annually, by a few feet to about 6 feet or more.

2.4 Vegetation Cover

As discussed above in Section 2.0, the area of the site is generally vegetated with grasses, weeds, and a large salal bush. The bluff slope is moderately to densely vegetated with shore pine and salal on the middle to upper slope and European beach grass, salal and scotch broom on the lower slope. The near-vertical upper bluff is devoid of vegetation on the bluff face.

2.5 Subsurface Materials

Detailed descriptions and analyses of geology and subsurface materials at the site are provided in Sections 3.1 and 3.3 below. Interbedded, medium dense to dense, moderately cemented fine-grained sand was exposed on the bluff west of the site. The upper few feet of the bluff exposed slightly organic silty sand with an overhanging mat of vegetation (Appendix A). Mudstone was exposed at the base of the bluff slope (Appendix A).

2.6 Site Oceanfront Conditions

The site is not oceanfront but is located east of an oceanfront bluff slope consisting primarily of marine terrace sands that have undergone recession as a result of wind and rain erosion, sloughing, and shallow landsliding. A detailed description of the fronting beach area is provided in Section 3.2, with oceanfront slope stability and erosion discussed in Section 4.0 below.

2.7 Drift Logs or Flotsam

At the time of our site visit, we observed a moderate accumulation of driftwood and flotsam in the beach area west of the site. Satellite imagery indicates that the accumulation of driftwood and flotsam in the vicinity is generally consistent with greater amounts of accumulation north of the site.

2.8 Streams or Drainage and Influence on Beach Elevations

The nearest major stream is the Siletz River, approximately 1.6 miles south of the site. The nearest stream is Canyon Creek, located approximately 2,800 feet north of the site, and it does not appear to influence the beach elevation at the site.

2.9 Headland Proximity and Influence on Beach Sediment Transport and Elevations

Headlands are not present in this local section of the Oregon Coast and the Lincoln City oceanfront. The site lies within the Lincoln littoral cell. The sands within the Lincoln littoral cell are believed to have little or no transport beyond Cascade Head to the north and Cape Foulweather to the south (Komar, 1997).

Smaller rock outcrops, reefs near the shoreline, and a wave-cut platform appear to have influenced the seasonal/periodic formation of rip currents and rip current embayments along this section of the coast, limiting the ability of rip currents to scour a deep channel to the back-beach area.

2.10 Shore Protection Structures

The nearest oceanfront protective structures are present on lots approximately 450 feet southwest of, and 2,200 feet north of the subject lot.

2.11 Beach Access Pathways

Presently there is no direct access to the beach from the subject site. Public beach access is present approximately 0.5 miles north of the site at the S.W. 11th Drive beach access at Canyon Drive City Park.

2.12 Human Impacts and Influence on Site Resistance to Ocean Wave Attack

The site is not listed as an oceanfront property, according to Lincoln County records. Based on our observations, direct human impacts are not contributing to the alteration of the resistance of the bluff to wave attack at this site.

3.0 Geologic Mapping, Investigation and Descriptions

3.1 Geology

The site lies in an area which has been mapped as Quaternary marine terrace deposits consisting of semi-consolidated, fine- to medium-grained sand commonly overlain by fine-grained stabilized dune deposits (Schlicker et al., 1973; Priest and Allan, 2004). The uplifted marine terrace sediments are typically high-energy nearshore marine deposits capped by beach sand (Kelsey et al., 1996).

The bluff exposed interbedded, medium dense to dense, moderately cemented, fine-grained sand. The upper few feet of the bluff exposed slightly organic silty sand with an overhanging mat of vegetation. Colluvium and sloughed materials mantle the central and lower parts of the bluff.

The marine terrace deposits mantle wave-cut benches of westerly dipping strata of the lower Eocene Nestucca Formation. The Nestucca Formation consists of thin-bedded, tuffaceous siltstone and sandstone, with ash and glauconitic sandstone interbeds. We observed the Nestucca Formation exposed along the lower portion of the bluff. Miocene intrusive basalts have been mapped along the beach and shoreline southwest of the site, forming a rocky beach zone (Priest and Allan, 2004). Sandy colluvial materials and transient low dunes can mantle the lower part of the bluff but are typically not present in the back-beach area. Colluvial materials are deposited along the lower bluff as the result of past erosion, sloughing and shallow landsliding along the middle and upper bluff (Appendix A).

3.2 Description of the Fronting Beach

3.2.1 Summer and Winter Average Beach Widths

The beach at the site has a width of approximately 100 feet to more than 300 feet in this area during the winter and summer, respectively, depending upon sand transport in any given year. The beach here is very dynamic and frequently changes, primarily due to rip current formation and El Niño and La Niña ocean conditions. Typically, the beach is broad and dissipative in summer, becoming narrower and steeper in winter, particularly during prolonged storm cycles.

3.2.2 Beach Sediment Median Grain Size

Beach sediment west of the site is comprised of primarily fine-grained to lesser medium-grained sand.

3.2.3 Summer and Winter Beach Elevations and Average Slopes

West of the site the beach slopes at approximately 7 degrees in the winter and a few degrees in the summer. Based on our review of beach morphology monitoring data available for this section of Oregon's coast from 1997 to 2002, beach elevations varied by 0 to 6 feet from minimum to maximum, with a minor change at the beach-bluff junction (Allan and Hart, 2005). The beach elevation can change substantially associated with El Niño and La Niña events, with the sand being stripped off, exposing the wave-cut platform beneath. Topographic contours derived from 2016 lidar data provided by NOAA show the elevation above mean sea level of the beach-bluff junction west of the subject property as approximately 20 feet (NAVD 88), which generally agrees with data from Allan and Hart (2005).

3.2.4 Rip Currents or Embayments

Rip currents and rip current embayments have formed in the area of the site frequently, as evidenced by our review of historical aerial and satellite imagery.

3.2.5 Offshore Rock Outcrops and Sea Stacks

A basaltic dike is present along the beach southwest of the site, and exposures of Nestucca Formation mudstone create a rocky reef in the wave swash zone of the beach in the area west of the site (Schlicker et al., 1973; Priest and Allan, 2004) (Appendix A).

3.2.6 Depth of Beach Sand to Bedrock

Exposed mudstone bedrock was observed at the base of the bluff slope (Appendix A). We estimate sand depths along the beach at this time to be up to about 6 feet thick.

3.3 Subsurface Conditions

At the time of our site visits, we explored the subsurface by advancing two hand-augered borings to depths up to approximately 5 feet below the ground surface (bgs). The approximate locations of the borings are shown on Figures 3 and 4. A geologist from our office visually classified the soils encountered according to the Unified Soil Classification System (USCS) as follows:

B-1	**Depth (ft.)**	**USCS**	**Description**
	0.0 – 2.0	ML	Sandy SILT; dark brown, dry, loose; Organic-rich.
	2.0 – 4.5	SM	Silty SAND; brown, dry, loose to medium dense. Increasing density with depth. Generally non-cemented.

B-2	**Depth (ft.)**	**USCS**	**Description**
	0.0 - 0.5	OL/PT	Organic SILT; dark brown, moist, loose. With decayed wood/peat.
	0.5 - 1.0	ML	SILT; dark brown, wet, loose/soft.
	1.0 – 5.0	ML	Sandy SILT; brown, wet, loose to medium dense. Increasing density with depth.

We generally encountered soft, silty soils to depths up to approximately 1 to 2 feet, overlying loose to medium dense silty and sandy soils. Probing the site met little resistance to a depth of approximately 2.5 to 3.5 feet.

3.4 Structures

Structural deformation and faulting along the Oregon Coast is dominated by the Cascadia Subduction Zone (CSZ), which is a convergent plate boundary extending for approximately 680 miles from northern Vancouver Island to northern California. This convergent plate boundary is defined by the subduction of the Juan de Fuca plate beneath the North America Plate and forms an offshore north-south trench approximately 60 miles west of the Oregon coast shoreline. A resulting deformation front consisting of north-south oriented reverse faults is present along the western edge of an accretionary wedge east of the trench, and a zone of margin-oblique folding and faulting extends from the trench to the Oregon Coast (Geomatrix, 1995).

The nearest fault is a northeast-trending normal fault, indicated on mapping as an inferred fault, approximately ¼ mile south of the subject site with its northeasternmost mapped extent at the south end of Devils Lake approximately 1.25 miles to the northeast (Schlicker et al., 1973). Several other generally parallel faults which trend in a southwesterly direction toward Siletz Bay have been mapped within 1 to 2 miles east and southeast of the site. These are normal faults with their upthrown sides to the northwest and cut Tertiary aged deposits with no indications of recent movement.

The nearest mapped potentially active faults are the Yaquina Head Fault located approximately 19 miles south of the site, and the Yaquina Bay Fault located approximately 22 miles south of the site. The Yaquina Head Fault is an east-trending oblique fault with left-lateral strike-slip and either contractional or extensional dip-slip offset components (Personius et al., 2003). It offsets the 80,000-year-old Newport marine terrace by approximately 5 feet, indicating a relatively low rate of slip, if still active (Schlicker et al., 1973; Personius et al., 2003). The Yaquina Bay Fault is a generally east-northeast trending oblique fault that also has left-lateral strike-slip and either contractional or extensional dip-slip offset components (Personius et al., 2003). This fault is believed to extend offshore for approximately 7 to 8 miles and may be a structurally controlling feature for the mouth of Yaquina Bay (Goldfinger et al., 1996; Geomatrix, 1995). At Yaquina Bay, a 125,000-year-old platform has been displaced approximately 223 feet up-on-the-north by the Yaquina Bay Fault. This fault has the largest component of vertical slip (as much as 2 feet per 1,000 years) of any active fault in coastal Oregon or Washington (Geomatrix, 1995). Although the age for the last movement of the Yaquina Bay Fault is not known, the fault also offsets 80,000-year-old marine terrace sediments.

4.0 Erosion and Slope Stability

The site is located approximately 100 feet east of a high and steep bluff slope that is undergoing erosion and sloughing as the result of wind, rain and ocean wave activity. Several landslides were observed along the bluff in the area of the site. These landslides appear to have failed back from the bluff edge from 5 to 15 feet. The upper oversteepened bluff is more susceptible to sloughing and landsliding than the lower bluff due to the steepness of the upper bluff segment and the poorly consolidated nature of the sediments. A review of Google Earth satellite imagery indicates that a landslide occurred on the bluff slope west of the site between July 2015 and August 2016.

The site is also mapped in an area of moderate landslide susceptibility based on the DOGAMI methodology (Burns, Mickelson, and Madin, 2016). The nearest mapped landslides are approximately 120 feet and 175 feet west and northwest of the site on the bluff slope (DOGAMI Unique IDs Lincoln_396 and Lincoln_395).

Mudstone of the Nestucca Formation is exposed at the base of the bluff near the beach level. This mudstone is hard and is generally more resistant to ocean wave erosion than the overlying terrace sands. However, the mudstone does not extend very high up the bluff, and ocean waves are still able to erode the sands overlying the mudstone unit.

The site lies in an area mapped as undergoing critical erosion of marine terraces and sediments (Schlicker et al., 1973). Priest (1994) and Priest et al. (1994) have determined the average annual erosion rate for the bluff segments west of the site as 0.27 ± 0.34 feet per year. This erosion rate was calculated by measuring the distance between existing structures and the bluff and compared to distances measured on a 1939 or 1967 vertical aerial photograph.

Based on mapping completed by Priest and Allan (2004), the beach and bluff slope west of the site lie within the Active Erosion Hazard Zone. The area from the upper bluff edge to approximately 55 feet eastward lies in the High-Risk Coastal Erosion Hazard Zone, and the next approximately 30 feet east to S.W. Bard Loop lies in the Moderate-Risk Coastal Erosion Hazard Zone. The western portion of the site, along S.W. Bard Loop, lies within the Low-Risk Coastal Erosion Hazard Zone. Coastal erosion hazard zone definitions and methodology are provided below.

The methodology provided by Priest and Allan (2004) defines four coastal erosion hazard zones for bluffs of Lincoln County, Oregon, as follows:

"*The basic techniques used here are modified from Gless and others (1998), Komar and others (1999), and Allan and Priest (2001). The zones are as follows:*

1) <u>Active hazard zone:</u> The zone of currently active mass movement, slope wash, and wave erosion.

2) The other three zones define high-, moderate-, and low-risk scenarios for expansion of the active hazard zone by bluff top retreat. Similar to the dune-backed shorelines, the three hazard zones depict decreasing levels of risk that they will become active in the future. These hazard zone boundaries are mapped as follows:

a. <u>High-risk hazard zone:</u> The boundary of the high-risk hazard zone will represent a best case for erosion. It will be assumed that erosion proceeds gradually at a mean erosion rate for 60 years, maintaining a slope at the angle of repose for talus of the bluff materials.

b. <u>Moderate-risk hazard zone:</u> The boundary of the moderate-risk hazard zone will be drawn at the mean distance between the high- and low-risk hazard zone boundaries.

c. <u>Low-risk hazard zone:</u> The low-risk hazard zone boundary represents a "worst case" for bluff erosion. The worst case is for a bluff to erode gradually at a maximum erosion rate for 100 years, maintaining its slope at the angle of repose for talus of the bluff materials. The bluff will then be assumed to suffer a maximum slope failure (slough or landslide). For bluffs composed of poorly consolidated or unconsolidated sand, another worst-case scenario will be mapped that assumes that the bluff face will reach a 2:1 slope as rain washes over it and sand creeps downward under the forces of gravity. For these sand bluffs, whichever method produces the most retreat will be adopted"

It should be noted that mapping done for the 2004 study was intended for regional planning use, not for site-specific hazard identification.

The subject site is not an oceanfront site but lies in an area of high bluffs that do not have an oceanfront protective structure. According to the Ocean Shores Viewer (http://www.coastalatlas.net/oceanshores/, accessed June 2022), the site is not included in the Goal 18 eligibility inventory.

4.1 Analyses of Erosion and Flooding Potential

4.1.1 DOGAMI Beach Monitoring Data

Discussed in Section 3.2.3 above, beach monitoring data for the section of Oregon's coast west of the site shows that beach elevations varied by several feet from minimum to maximum over the monitored period of 1997 to 2002 (Allan and Hart, 2005).

4.1.2 Human Activities Affecting Shoreline Erosion

Human activities have not significantly altered the resistance of the bluff to wave attack at this site.

4.1.3 Mass Wasting

Weathering, landsliding, recession rates, and other erosional processes at this oceanfront site are discussed in Section 4.0 above and Section 4.2.3 below. The rate used in our setback analysis was 0.6 feet per year.

4.1.4 Erosion Potential From Wave Runup Beyond Mean Water Elevation

Coastal erosion rates and hazard zones (as referenced in Priest and Allan, 2004) are presented in Section 4.0 above. In the bluff-backed shoreline recession methodology applicable to the subject site, wave erosion at the bluff toe and associated parameters (rock composition, vegetative/protective cover, ballistics of debris, bluff slope angle of repose, etc.) are more critical to erosion zone and rate estimates than calculating wave runup elevation which changes with many variables such as changing beach elevations, presence of transient dunes, etc. It is the chronic nature of the wave attack hazard that undercuts the toe of the bluff, creating bluff instability.

4.1.5 Frequency of Erosion-Inducing Processes

As discussed in Section 4.0 above, the average annual erosion rate for the bluff at the site is 0.27 ± 0.34 feet per year (Priest and Allan, 2004), and as also discussed in Section 4.1.3 above, is currently estimated at 0.6 feet per year for the calculation of setbacks from the upper bluff edge. Ocean wave, wind, and rain erosion are continuous and ongoing processes that impact bluff recession. Future landsliding near the subject site would cause additional recession of the upper bluff. We anticipate that future landslides could fail back 5 to 15 feet at a time if not mitigated; however, these would be very infrequent and impossible to predict when they will occur.

4.1.6 Bluff-Backed Shoreline Erosion Potential

Discussed in Section 4.0 above, including the methodology in Priest and Allan (2004).

4.1.7 Sea Level Rise

Information from NOAA's Garibaldi and Newport/South Beach monitoring stations provides an average sea level rise of approximately 2.11 ± 0.65 mm/year between 1967 and 2021 (NOAA Tides & Currents Sea Level Trends, http://tidesandcurrents.noaa.gov/sltrends). Global climate change can also influence rates of sea-level rise (refer to Section 7.0).

4.1.8 Estimated Annual Erosion Rate

A detailed discussion of recession and estimated erosion rates is in Section 4.0 above; Priest (1994) and Priest et al. (1994) have determined the average annual erosion rate for the bluff at the site as 0.27 ± 0.34 feet per year. The rate used in our setback analysis was 0.6 feet per year.

4.2 Assessment of Potential Reactions to Erosion Episodes

4.2.1 Legal Restrictions of Shoreline Protective Structures

According to Lincoln County records, the site is not listed as an oceanfront property and is therefore not eligible for a shoreline protective structure. According to the Ocean Shores Viewer (http://www.coastalatlas.net /oceanshores/, accessed June 2022), the tax lots west of the site appear to be Goal 18 eligible for beachfront protective structures; however, the potential to receive a permit for oceanfront protection is dependent upon meeting certain regulatory requirements in addition to the Goal 18 eligibility requirement.

4.2.2 Potential Reactions to Erosion Events and Future Erosion Control Measures

Site geologic hazards conclusions and development recommendations are presented in Section 8.0 below, which includes recommended oceanfront setback for foundations along with a discussion of inherent risks to development in coastal areas with characteristics such as those at the site, as presented and analyzed in Section 4.0 above. Deep foundations, oceanfront protective structures, retaining walls, underpinning of foundations, vegetation management, relocation of structures, and bioengineering can all be potential reactions and control measures to erosion events.

4.2.3 Annual Erosion Rate for the Property

An average annual erosion rate of 0.6 feet per year is used in the determination of oceanfront setbacks for the subject site. A five feet psychological setback is added to the average annual erosion rate. For further information, please refer to Sections 4.0 and 4.1.8 above.

5.0 Regional Seismic Hazards

Abundant evidence indicates that a series of geologically recent large earthquakes related to the Cascadia Subduction Zone have occurred along the coastline of the Pacific Northwest. Evidence suggests that more than 40 great earthquakes of magnitude 8 and larger have struck western Oregon during the last 10,000 years. The calculated odds that a Cascadia earthquake will occur in the next 50 years range from 7–15 percent for a great earthquake affecting the entire Pacific Northwest, to about a 37 percent chance that the southern end of the Cascadia Subduction Zone will produce a major earthquake in the next 50 years (OSSPAC, 2013; OSU News and Research Communications, 2010; Goldfinger et al., 2012). Evidence suggests the last major earthquake occurred on January 26, 1700, and may have been of magnitude 8.9 to 9.0 (Clague et al., 2000; DOGAMI, 2013).

There is now increasing recognition that great earthquakes do not necessarily result in a complete rupture along the full 1,200 km fault length of the Cascadia subduction zone. Evidence in the paleorecords indicates that partial ruptures of the plate boundary have occurred due to smaller earthquakes with moment magnitudes (Mw) < 9 (Witter et al., 2003; Kelsey et al., 2005). These partial segment ruptures appear to occur more frequently on the southern Oregon coast, as determined from paleotsunami studies. Furthermore, the records have documented that local tsunamis from Cascadia earthquakes recur in clusters (~250–400 years) followed by gaps of 700–1,300 years, with the highest tsunamis associated with earthquakes occurring at the beginning and end of a cluster (Allan et al., 2015).

These major earthquake events were accompanied by widespread subsidence of a few centimeters to 1–2 meters (Leonard et al., 2004). Tsunamis appear to have been associated with many of these earthquakes. In addition, settlement, liquefaction, and landsliding of some earth materials are believed to have been commonly associated with these seismic events.

Other earthquakes related to shallow crustal movements or earthquakes related to the Juan de Fuca plate have the potential to generate magnitude 6.0 to 7.5 earthquakes. The recurrence interval for these types of earthquakes is difficult to determine from present data, but estimates of 100 to 200 years have been given in the literature (Rogers et al., 1996).

Based on the 1999 Relative Earthquake Hazard Map of the Lincoln City area (Madin and Wang, 1999), the subject site lies in an area designated as Zone C, which represents areas having low to intermediate relative hazards associated with earthquakes. The degree of relative hazard was based on the factors of ground motion amplification, liquefaction, and slope instability, with slope instability being the most critical factor at the subject site.

The subject site is also mapped in an area of very strong expected earthquake shaking during an earthquake in a 500-year period (DOGAMI Oregon HazVu website, accessed June 2022). “Very Strong” is the third-highest level of a six-level gradation from “Light” to “Violent” in this mapping system.

6.0 Flooding Hazards

Based on the 2019 Flood Insurance Rate Map (FIRM, Panel #41041C0109E), the site lies in an area rated as Zone X, which is defined as an area determined to be outside the 0.2% annual chance floodplain. The lower bluff slope and beach area west of the site is rated as Zone VE (EL 29) (NAVD 88), which is defined as a coastal flood zone with velocity hazard (wave action); Base Flood Elevations determined.

Based on Oregon Department of Geology and Mineral Industries mapping (DOGAMI, 2013), the beach and bluff slope west of the site lies within the tsunami inundation zone resulting from a 9.1 and greater magnitude Cascadia Subduction Zone (CSZ) earthquake. The site lies outside the mapped CSZ tsunami inundation zones. The 2013 DOGAMI mapping is based upon five computer-modeled scenarios for shoreline tsunami inundation caused by potential CSZ earthquake events ranging in magnitude from approximately 8.7 to 9.1. The January 1700 earthquake event (discussed in Section 5.0 above) has been rated as an approximate 8.9 magnitude in DOGAMI's methodology. More distant earthquake source zones can also generate tsunamis.

7.0 Climate Change

According to most of the recent scientific studies, the Earth's climate is changing as the result of human activities, which are altering the chemical composition of the atmosphere through the buildup of greenhouse gases, primarily carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons (EPA, 1998). Although there are uncertainties about exactly how the Earth's climate will respond to enhanced concentrations of greenhouse gases, scientific observations indicate that detectable changes are underway (EPA, 1998; Church and White, 2006). Global sea-level rise, caused by melting polar ice caps and ocean thermal expansion, could lead to flooding of low-lying coastal property, loss of coastal wetlands, erosion of beaches and bluffs, and saltwater contamination of drinking water. Global climate change and the resultant sea-level rise will likely impact the subject site through accelerated coastal erosion and more frequent and severe flooding. It can also lead to increased rainfall, which can result in an increase in landslide occurrence.

8.0 Conclusions and Recommendations

The main engineering geologic concerns at the site are:

1. The bluff slope west of the site is undergoing continuous erosion, sloughing, and landsliding, which can fail back 5 to 15 feet or more at a time. Undercutting by ocean waves causes retreat of the toe of the slope, resulting in instability and failures along the upper slope. The western portion of the subject site lies in the mapped low-risk coastal erosion hazard zone.

2. Fill, soft/loose, disturbed, and organic-rich soils at least approximately 2 feet deep or more are present at the site and will need to be removed from footing and slab areas prior to construction.

3. There is an inherent regional risk of earthquakes along the Oregon Coast, which could cause harm and damage structures. The site lies outside the mapped tsunami inundation hazard zone. However, a tsunami impacting the Lincoln City area could cause harm, loss of life, and damage to structures. These risks must be accepted by the owner, future owners, developers, and residents of the site.

The following recommendations should be adhered to during design and construction:

8.1 General Recommendations

1. HGSA will need to review a complete plan set for any proposed construction on the lot. The plans will need to incorporate the recommendations provided herein.

   Additional recommendations or modifications of the recommendations included herein may be needed depending on the proposed design(s).

2. Carefully control and maintain all stormwater drainage systems at the site. Plan sets should incorporate proper drainage and erosion control, as discussed in Sections 8.4, 8.5, 8.8, 8.9, 8.10, and 8.11 below.

3. Lincoln City may require a topographic survey performed by a licensed land surveyor to identify the bluff edge and determine the bluff setback's exact location. This would require access to the other properties northwest of the subject property. Lincoln City may also require an infiltration test for on-site infiltration of stormwater.

Provided that all recommendations herein are adhered to, no adverse effects are anticipated on adjacent properties.

8.2 Site Preparation and Foundation Setbacks

It is anticipated that excavations at the site can be completed using conventional earth-moving equipment. Unsuitable organic-rich, soft, and fill soils should be completely removed from all building areas (refer to Section 8.3 below). We anticipate that non-organic, stiff soils will be encountered at depths of approximately 2 feet. However, depths may vary.

Any tree stumps, including the root systems, should be removed from beneath footing, slab and pavement areas, and the resulting holes backfilled with compacted non-organic structural backfill placed in lifts not exceeding 8 inches and compacted to a dry density of at least 95 percent of the Modified Proctor maximum dry density (ASTM D1557).

Wet weather grading is not generally recommended. If wet weather grading is unavoidable due to construction schedules, or if wet soil conditions are encountered, stabilization of the subgrade soils with aggregate may become necessary. The use of clean, well-graded 1 inch minus crushed rock fill (containing less than 5 percent material passing the No. 200 sieve) is recommended. The thickness of the applied granular fill should be sufficient to stabilize the subgrade soils.

Based on the average annual erosion rate of the bluff west of the site, a 60-year expected life of the structure, plus the 5 feet psychological setback, we recommend that foundations be setback a minimum of 41 feet east of the upper bluff edge. The western property boundary of the site is located approximately 100 east of the upper bluff edge; therefore, no additional geologic hazard setback from the bluff edge is required at this time. We have determined this oceanfront setback based on an average annual erosion rate of 0.6 ft/yr for 60 years and have added Lincoln City's required additional 5 feet.

Please note, the Oregon Coast is a dynamic and energetic environment. Most of the coastline is currently eroding and will continue to erode in the future. Most structures built near ocean bluffs will eventually be undermined by erosion and landsliding. The setback recommendations presented in this report are based on past average erosion rates as determined from aerial photography, and past and current geologic conditions and processes. These setbacks are intended to protect the structure(s) from bluff recession for 60 years. Geologic conditions and the rates of geologic processes can change in the future. Setbacks greater than our recommended minimum setbacks would provide the proposed structure with greater anticipated life and lower risk from some geologic hazards.

8.3 Soil Bearing Capacities for Shallow Foundations

Individual and/or continuous spread footings should bear in undisturbed, native, non-organic, medium-stiff/dense soils or properly engineered and compacted granular fill placed on these soils. All footing areas should be stripped of all organic and loose/soft soils and existing fills.

Footings bearing in undisturbed, native, non-organic, firm soils or properly compacted structural fill placed on these soils may be designed for the following:

ALLOWABLE SOIL BEARING CAPACITIES	
Allowable Dead Plus Live Load Bearing Capacity [a]	1,500 psf
Passive Resistance	200 psf/ft embedment depth
Lateral Sliding Coefficient	0.30
[a] Allowable bearing capacity may be increased by one-third for short term wind or seismic loads.	

We recommend an elevated floor and crawlspace design. For conventional light-frame construction*, our recommended minimum widths and embedment depths for continuous footings are as follows:

MINIMUM FOOTING WIDTHS & EMBEDMENT DEPTHS			
Number of Stories	One	Two	Three
Minimum Footing Width	12 inches	15 inches	23 inches
Minimum Exterior Footing Embedment Depth [a]	18 inches	18 inches	24 inches
Minimum Interior Footing Embedment Depth [b]	6 inches	6 inches	6 inches
[a] If foundations will be placed along or immediately adjacent to slopes steeper than 3H:1V, foundation embedments will need to be a minimum of 24 inches, or as approved by a representative of our firm. [b] Interior footings should be embedded a minimum of 6 inches below the lowest adjacent finished grade, or as otherwise recommended by our firm. In general, interior footings placed on sloping or benched ground should be embedded or set back in such a manner as to provide a minimum horizontal distance between the foundation component and the face of the slope of one foot per every foot of elevation change.			

*Please contact us for additional recommendations if brick veneer, hollow concrete masonry, or solid concrete or masonry wall construction is incorporated in the design of the house.

Isolated footings should meet Section R403.1.7 of the 2021 Oregon Residential Specialty Code (ORSC) requirements.

Deck footings should meet or exceed the minimum sizes set forth in Table R507.3.1 of 2021 ORSC.

8.4 Slabs-On-Ground

All areas beneath slabs for driveways and garages should be excavated a minimum of 6 inches into native, non-organic, firm soils. The exposed subgrade in the slab excavation should be cut smooth, without loose or disturbed soil and rock remaining in the excavation.

SLABS-ON-GROUND	
Minimum thickness of 3/4 inch minus crushed rock beneath slabs	6 inches
Compaction Requirements	Minimum of 95% ASTM D1557, compacted in 8-inch lifts maximum

The slab excavation should then be backfilled with a minimum of 6 inches of ¾ inch minus, clean, free-draining, crushed rock placed in 8-inch lifts maximum, which are compacted to a minimum of 95 percent of the Modified Proctor (ASTM D1557). Reinforcing of the slab is recommended, and the slab should be fully waterproofed in accordance with structural design considerations. Slab thickness and reinforcing should be determined in accordance with structural considerations. An underslab drainage system is recommended for all below grade slabs, as per the architect's recommendations. Where floor coverings are planned, slabs should also be underlain by a suitable moisture barrier.

8.5 Retaining Walls

Due to the gently sloping nature of the site, we do not anticipate the need for free-standing retaining walls. If design recommendations for free-standing retaining walls are desired, please contact us.

8.6 Seismic Requirements

The structure and all structural elements should be designed to meet current Oregon Residential Specialty Code (ORSC) seismic requirements. Based on our knowledge of subsurface conditions at the site, and our analysis using the guidelines recommended in the ORSC, the structure should be designed to meet the following seismic parameters:

SEISMIC DESIGN PARAMETERS	
Site Class	D
Seismic Design Category	D_2
Mapped Spectral Response Acceleration for Short Periods	S_S = 1.344 g
Site Coefficients	F_a = 1.200 F_v = 1.700
Design Spectral Response Acceleration at Short Periods	S_{DS} = 1.075 g

8.7 Structural Fills

Structural fills should consist of imported, crushed granular material, free of organics and deleterious materials, and contain no particles greater than 1 inch in diameter so that nuclear methods (ASTM D2922 & ASTM D3017) can be easily used for field density and moisture testing. Structural fill should be placed in lifts not exceeding 8 inches and compacted to a minimum of 95% of the maximum dry density as determined by ASTM D1557. All areas to receive fill should be stripped of all soft soils, organic soils, organic debris, existing fill, and disturbed soils.

STRUCTURAL FILL	
Compaction Requirements	Minimum of 95% ASTM D1557 maximum dry density, compacted in 8-inch lifts maximum, at or near the optimum moisture content.

Proper test frequency and earthwork documentation usually require daily observation during stripping, rough grading, and placement of structural fill. Field density testing should generally conform to ASTM D2922 and D3017, or D1556. To minimize the number of field and laboratory tests, fill materials should be from a single source and of a consistent character. Structural fill should be approved and periodically observed by HGSA and tested by a qualified testing firm. Test results will need to be reviewed and approved by HGSA. We recommend that at least three density tests be performed for every 18 inches or every 200 cubic yards of fill placed, whichever requires more testing. Because testing is performed on an on-call basis, we recommend that the earthwork contractor schedule the testing. Relatively more testing is typically necessary on smaller projects.

8.8 Groundwater

Groundwater may be encountered in excavations. If groundwater is encountered, unwatering of the excavation is required and should be the contractor's responsibility. This can typically be accomplished by pumping from one or more sumps, or daylighting excavations to drain.

8.9 Erosion Control

Vegetation should be removed only as necessary, and exposed areas should be replanted following construction. Disturbed ground surfaces exposed during the wet season (November 1 through April 30) should be temporarily planted with grasses, or protected with erosion control blankets or hydromulch.

Temporary sediment fences should be installed downslope of any disturbed areas of the site until permanent vegetation cover can be established.

Exposed sloping areas steeper than 3 horizontal to 1 vertical (3H:1V) should be protected with a straw erosion control blanket (North American Green S150 or equivalent) to provide erosion protection until permanent vegetation can be established. Erosion control blankets should be installed as per the manufacturer's recommendations.

8.10 Cut and Fill Slopes

We do not anticipate any temporary or permanent cut slopes related to the proposed development.

However, temporary unsupported cut and fill slopes less than 9 feet in height should be sloped no steeper than 1 horizontal to 1 vertical (1H:1V). If temporary slopes greater than 9 feet high are desired, or if water seepage is encountered in cuts, HGSA should be contacted to provide additional recommendations. Temporary cuts in excess of 4 feet high and steeper than 1H:1V will likely require appropriate shoring to provide for worker safety, per OSHA regulations. Temporary cuts should be protected from inclement weather by covering them with plastic sheeting to help prevent erosion and/or failure.

Permanent unsupported cut and fill slopes shall be constructed no steeper than 2 horizontal to 1 vertical (2H:1V).

8.11 Drainage

Surface water should be diverted from building foundations and walls to approved disposal points by grading the ground surface to slope away a minimum of 2 percent for 6 feet towards a suitable gravity outlet to prevent ponding near the structures. Permanent subsurface drainage of the building perimeter is recommended to prevent extreme seasonal variation in moisture content of subgrade materials and subjection of foundations and slabs to hydrostatic pressures.

Footing drains should be installed adjacent to the perimeter footings and sloped a minimum of 2.0 percent to a gravity outlet. A suitable perimeter footing drain system would consist of 4-inch diameter, perforated pipe (typical) embedded adjacent to the bottom of footings and backfilled with approved drain rock. The type of pipe to be utilized may depend on building agency requirements and should be verified prior to construction. HGSA also recommends lining the drainage trench excavation with a geotextile filter such as Mirafi® 140N or equivalent, to increase the life of the drainage system. The perimeter drain excavation should be constructed in a manner that prevents undermining of foundation or slab components or any disturbance to supporting soils.

In addition to the perimeter foundation drain system, drainage of any crawlspace areas is required. Each crawlspace should be graded to a low point for installation of a drain that is tied into the perimeter footing drain and tightlined to an approved disposal point.

All roof drains should be collected and tightlined in a separate system independent of the footing drains, or an approved backflow prevention device shall be used. All roof and footing drains should be discharged to an approved disposal point. If water will be discharged to the ground surface, we recommend that energy dissipaters, such as splash blocks or a rock apron, be utilized at all pipe outfall locations. Water collected on the site should not be concentrated and discharged to adjacent properties.

8.12 Plan Review and Site Observations

We should be provided the opportunity to review all site development, foundation, drainage, and grading plans prior to construction to assure conformance with the intent of our recommendations (Appendix B). The plans, details, and specifications should clearly show that the above recommendations have been implemented into the design.

A representative of HGSA should observe foundation setbacks and site foundation excavations prior to placing structural fill, forming and pouring concrete (Appendix B). Please provide us with at least five (5) days' notice prior to any needed site observations. There will be additional costs for these services.

9.0 Limitations

The Oregon Coast is a dynamic environment with inherent, unavoidable risks to development. Landsliding, erosion, tsunamis, storms, earthquakes, and other natural events can cause severe impacts to structures built within this environment and can be detrimental to the health and welfare of those who choose to place themselves within this environment. The client is warned that, although this report is intended to identify the geologic hazards causing these risks, the scientific and engineering communities' knowledge and understanding of geologic hazards processes is not complete. This report pertains to the subject site only and is not applicable to adjacent sites, nor is it valid for types of development other than that to which it refers. Geologic conditions, including materials, processes, and rates, can change with time, and therefore a review of the site and/or this report may be necessary as time passes to assure its accuracy and adequacy.

The hand augered boring logs and related information depict generalized subsurface conditions only at these specific locations, and at the particular time the subsurface exploration was completed. Soil and groundwater conditions at other locations may differ from the conditions at these locations.

Our investigation was based on engineering geological reconnaissance and a limited review of published information. The data presented in this report are believed to be representative of the site. The conclusions herein are professional opinions derived in accordance with current standards of professional practice, budget, and time constraints. No warranty is expressed or implied. Site-specific performance of this site during a seismic event has not been evaluated. If you would like us to do so, please contact us. This report may only be copied in its entirety.

10.0 Disclosure

H.G. Schlicker & Associates, Inc. and the undersigned Certified Engineering Geologist have no financial interest in the subject site, the project, or the Client's organization.

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It has been our pleasure to serve you. If you have any questions concerning this report or the site, please contact us.

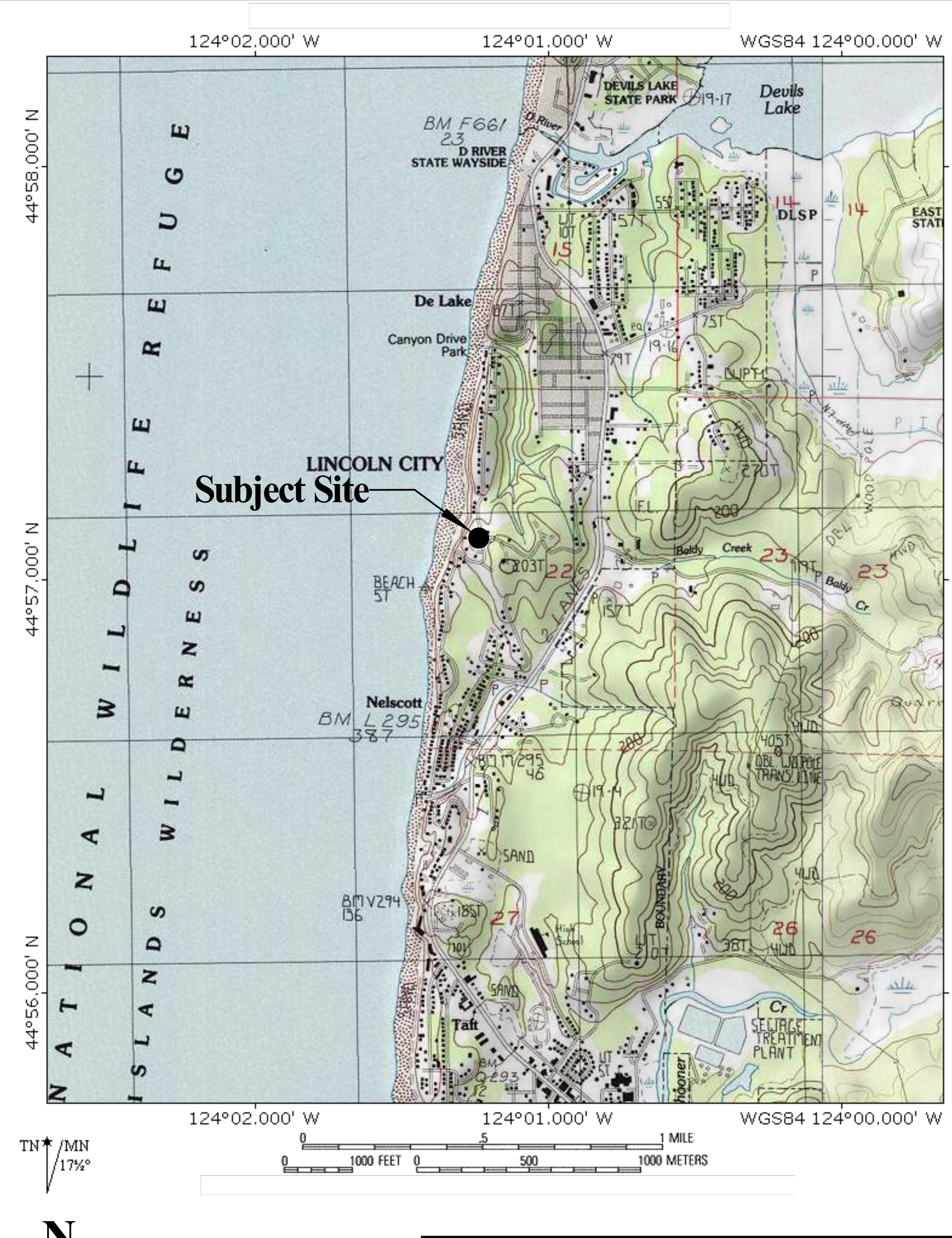
Respectfully submitted,

H.G. SCHLICKER AND ASSOCIATES, INC.

EXPIRES: 10/31/2022

J. Douglas Gless, MSc, RG, CEG, LHG
President/Principal Engineering Geologist

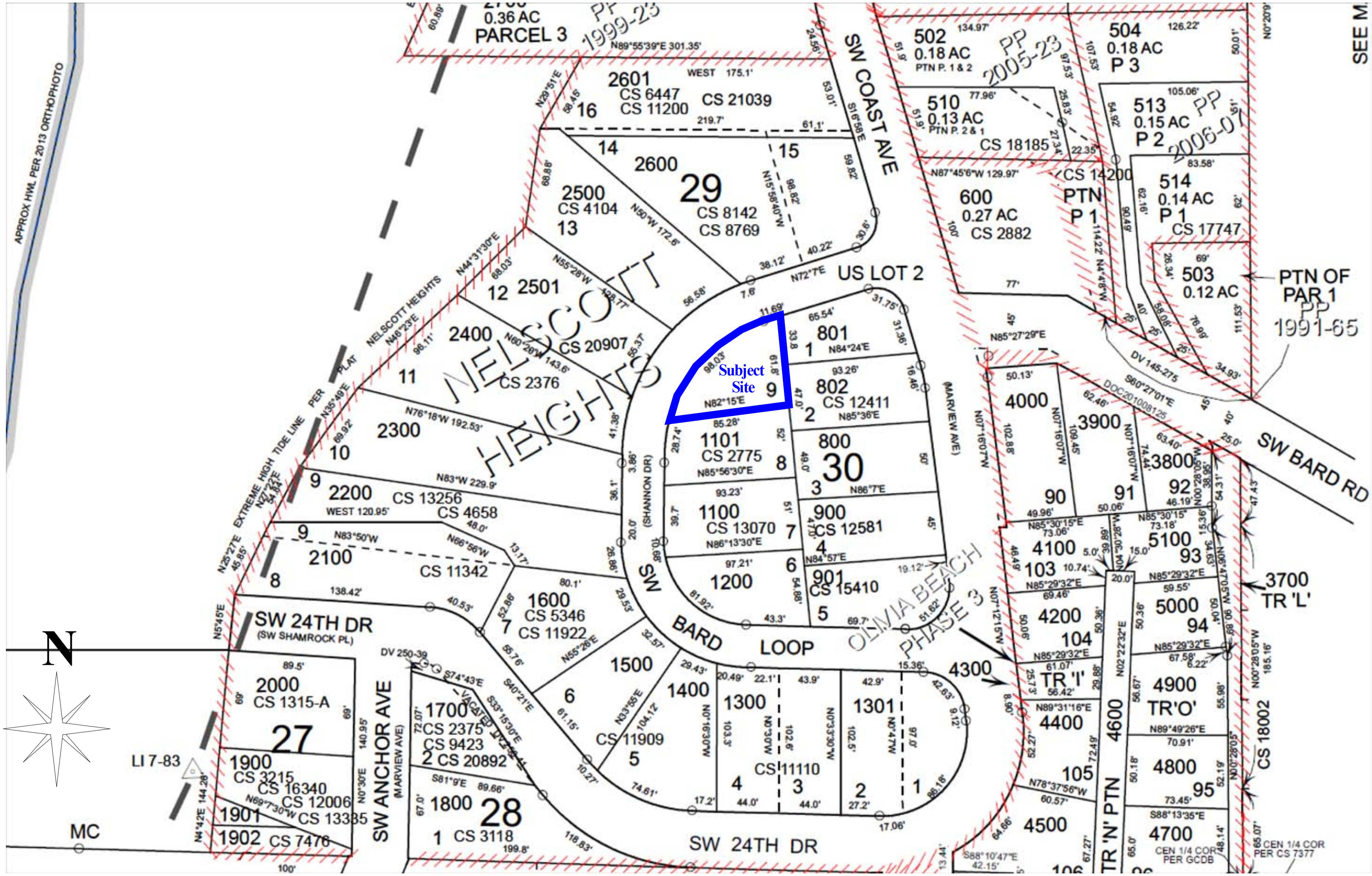
JDG:mgb



Date: 07/07/2022	**Project #Y224627**	Prepared by: MGB
Scale: 1" = 2,000'		Approved by: JDG

Location Map
Tax Lot 1000, Map 07-11-22BD
Lincoln City, Oregon

H.G. Schlicker & Associates, Inc. — **Figure 1**



Date: 07/07/2022	**Project #Y224627**	Prepared by: MGB
Scale: 1" = 100'		Approved by: JDG

Plat Map

Tax Lot 1000, Map 07-11-22BD

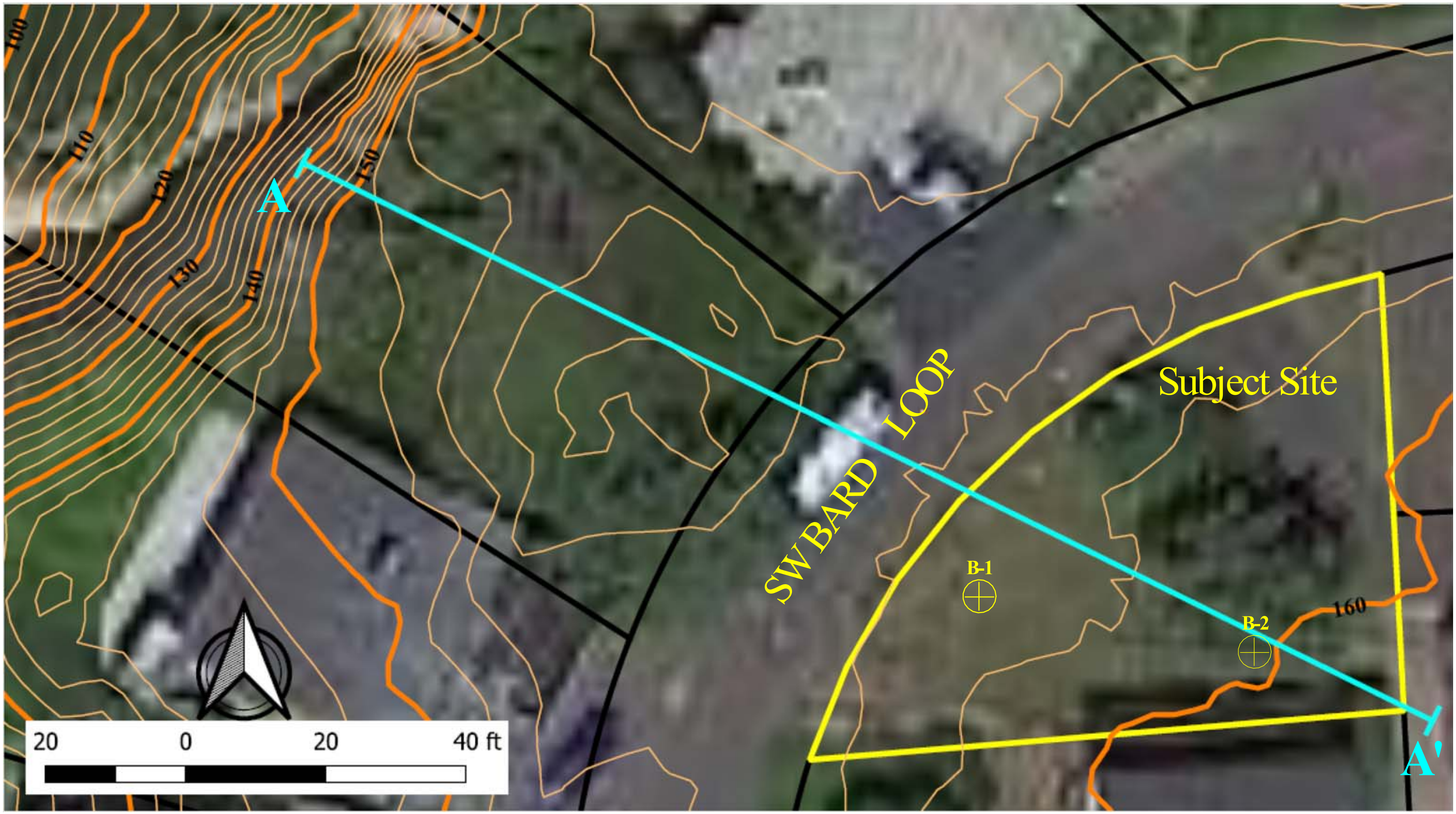
Lincoln City, Oregon

H.G. Schlicker & Associates, Inc.

Figure 2

Modified from the Lincoln County assessor's plat 07-11-22, Lincoln City

All locations and dimensions are approximate.

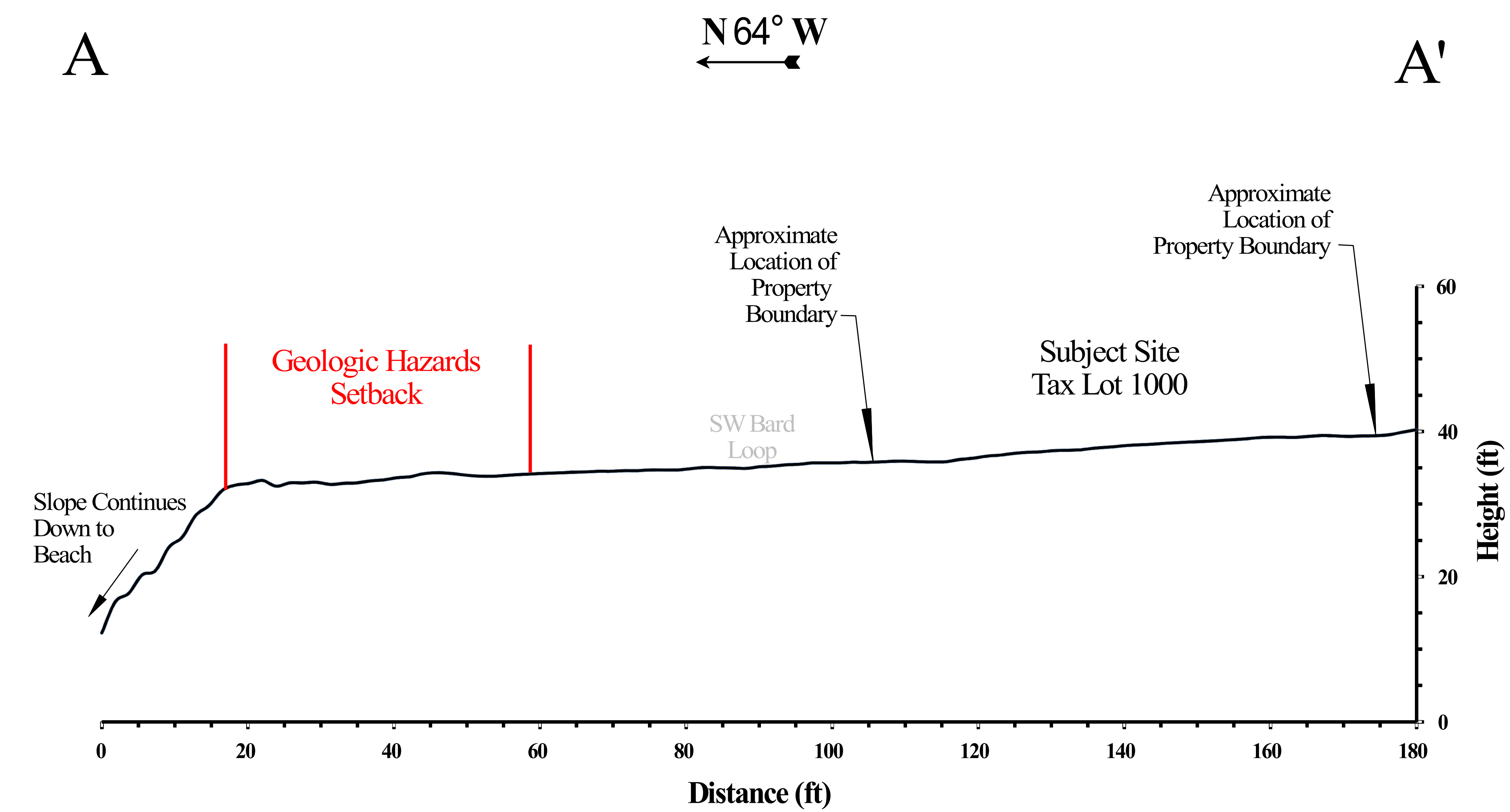


A — A' = Approximate trend of profile line

B-1 = Approximate location of hand augered boring

Imagery provided Google. Topographic data derived from West Coast 2016 el nino DEM provided by NOAA.
All locations and dimensions are approximate.

Date: 07/07/2022	**Project #Y224627**	Prepared by:MGB Approved by: JDG
Site Topographic Map Tax Lot 1000, Map 07-11-22BD Lincoln City, Oregon		
H.G. Schlicker & Associates, Inc.		**Figure 3**



Date: 07/07/2022 Scale: 1" = 20'	**Project #Y224627**	Prepared by: MGB Approved by: JDG
Slope Profile A-A' Tax Lot 1000, Map 7-11-22BD Lincoln City, Oregon		
H.G. Schlicker & Associates, Inc.		**Figure 4**

Slope profile derived from west coast 2016 el nino DEM provided NOAA.
All locations and dimensions are approximate.

Appendix A
– Site Photographs –


Photo 1 – Southwesterly view of the site along SW Bard Loop.


Photo 2 – Northerly view of the eastern portion of the site.

Photo 3 – Westerly view of the site along the southern property boundary.

Photo 4 – Close-up view of the soils encountered in boring B-1.

Photo 5 – Easterly view of the bluff slope, west of the subject site.

Photo 6 – Close-up view of the base of the bluff where water was emanating from over the exposed mudstone.

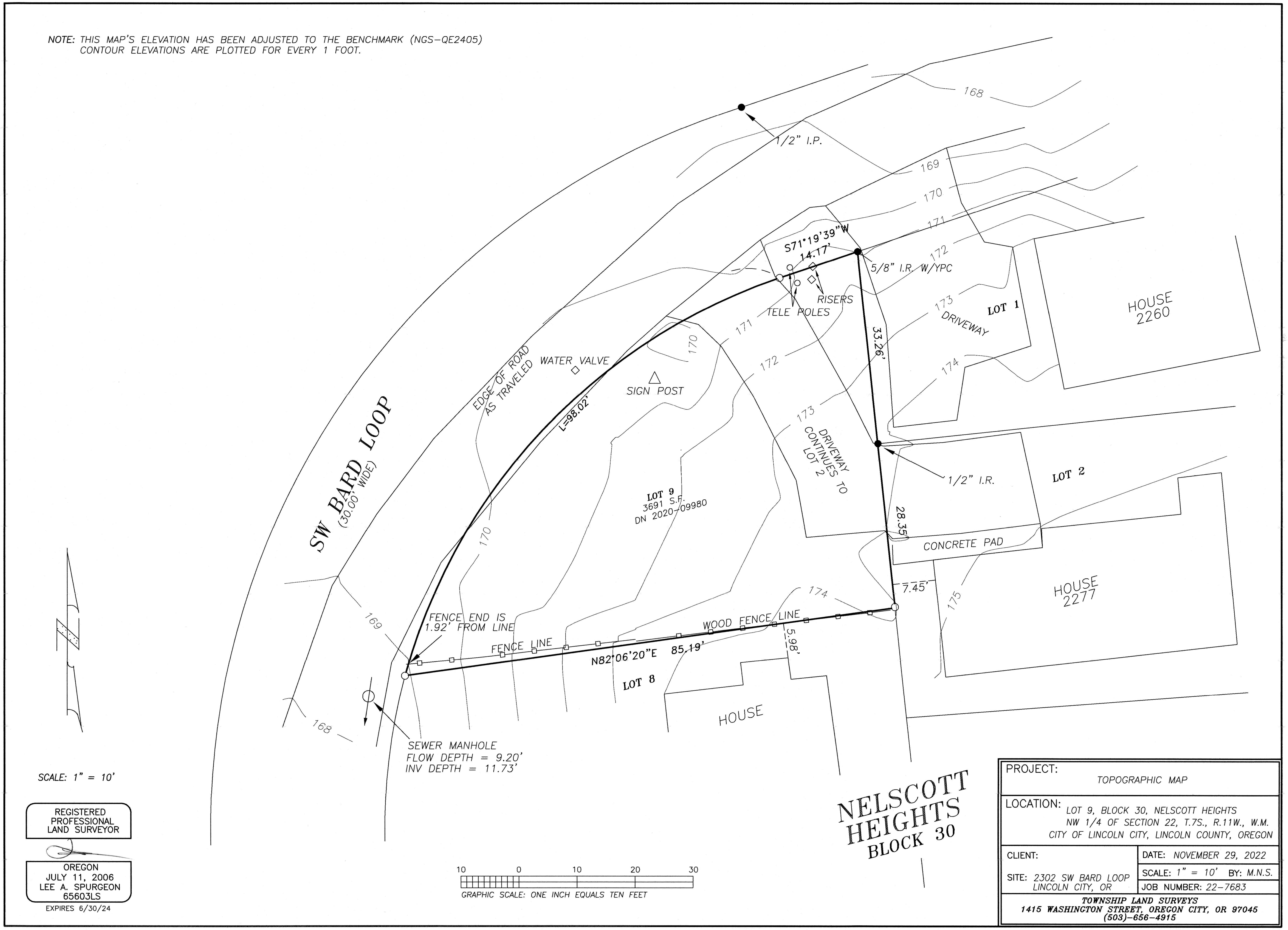
Appendix B
– Checklist of Recommended Plan Reviews and Site Observations –

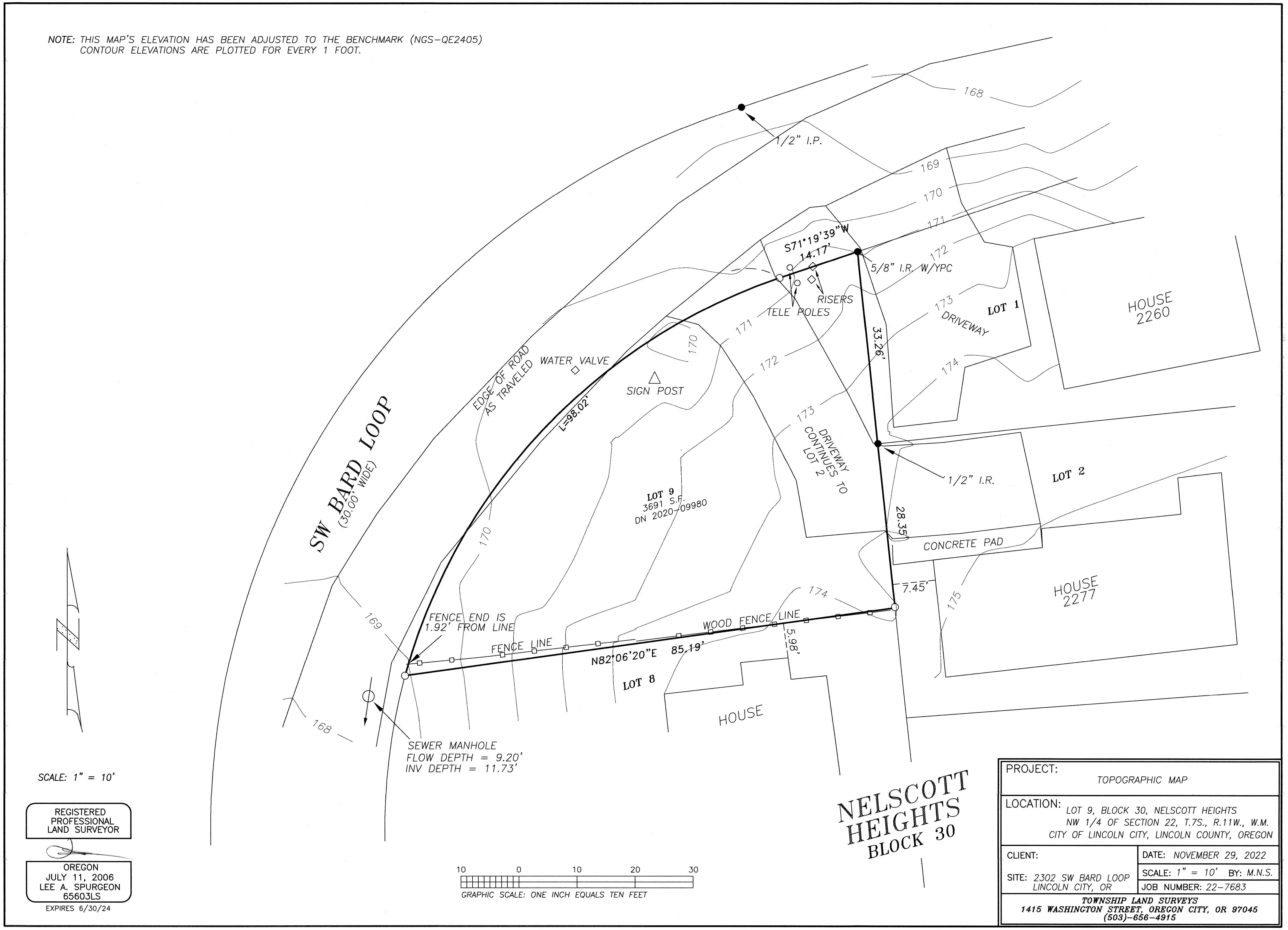
Project #Y224627

APPENDIX B
Checklist of Recommended Plan Reviews and Site Observations
To Be Completed by a Representative of H.G. Schlicker & Associates, Inc.

Item No.	Date Done	Procedure	Timing
1*		Review site development, foundation, drainage, grading, and erosion control plans.	Prior to permitting and construction.
2*		Observe foundation excavations.	Following excavation of foundations, and prior to placing fill, forming and pouring concrete. **
3*		Review Proctor (ASTM D1557) and field density test results for all fills placed at the site.	During construction.

* There will be additional charges for these services.
** Please provide us with at least 5 days' notice prior to all desired site observations.


NOTE: THIS MAP'S ELEVATION HAS BEEN ADJUSTED TO THE BENCHMARK (NGS-QE2405)
CONTOUR ELEVATIONS ARE PLOTTED FOR EVERY 1 FOOT.
1/2" I.P.
S71°19'39"W
14.17'
5/8" I.R. W/YPC
TELE POLES
RISERS
33.26'
DRIVEWAY
LOT 1
HOUSE 2260
EDGE OF ROAD AS TRAVELED
WATER VALVE
SIGN POST
L=98.02'
SW BARD LOOP
(30.00' WIDE)
DRIVEWAY CONTINUES TO LOT 2
1/2" I.R.
LOT 2
LOT 9
3691 S.F.
DN 2020-09980
28.35'
CONCRETE PAD
7.45'
HOUSE 2277
FENCE END IS 1.92' FROM LINE
FENCE LINE
WOOD FENCE LINE
N82°06'20"E 85.19'
5.98'
LOT 8
HOUSE
SEWER MANHOLE
FLOW DEPTH = 9.20'
INV DEPTH = 11.73'
SCALE: 1" = 10'
REGISTERED PROFESSIONAL LAND SURVEYOR
OREGON
JULY 11, 2006
LEE A. SPURGEON
65603LS
EXPIRES 6/30/24
10 0 10 20 30
GRAPHIC SCALE: ONE INCH EQUALS TEN FEET
NELSCOTT HEIGHTS BLOCK 30
PROJECT: TOPOGRAPHIC MAP
LOCATION: LOT 9, BLOCK 30, NELSCOTT HEIGHTS
NW 1/4 OF SECTION 22, T.7S., R.11W., W.M.
CITY OF LINCOLN CITY, LINCOLN COUNTY, OREGON
CLIENT:
DATE: NOVEMBER 29, 2022
SITE: 2302 SW BARD LOOP LINCOLN CITY, OR
SCALE: 1" = 10' BY: M.N.S.
JOB NUMBER: 22-7683
TOWNSHIP LAND SURVEYS
1415 WASHINGTON STREET, OREGON CITY, OR 97045
(503)-656-4915


NOTE: THIS MAP'S ELEVATION HAS BEEN ADJUSTED TO THE BENCHMARK (NGS-QE2405)
CONTOUR ELEVATIONS ARE PLOTTED FOR EVERY 1 FOOT.
1/2" I.P.
168
169
170
171
172
173
174
175
S71°19'39"W
14.17'
5/8" I.R. W/YPC
RISERS
TELE POLES
LOT 1
DRIVEWAY
HOUSE
2260
33.26'
SW BARD LOOP
(30.00' WIDE)
EDGE OF ROAD
AS TRAVELED
WATER VALVE
SIGN POST
L=98.02'
DRIVEWAY
CONTINUES TO
LOT 2
1/2" I.R.
LOT 2
LOT 9
3691 S.F.
DN 2020-09980
28.35'
CONCRETE PAD
HOUSE
2277
7.45'
FENCE END IS
1.92' FROM LINE
FENCE LINE
WOOD FENCE LINE
N82°06'20"E 85.19'
5.98'
LOT 8
HOUSE
SEWER MANHOLE
FLOW DEPTH = 9.20'
INV DEPTH = 11.73'
SCALE: 1" = 10'
REGISTERED
PROFESSIONAL
LAND SURVEYOR
OREGON
JULY 11, 2006
LEE A. SPURGEON
65603LS
EXPIRES 6/30/24
10 0 10 20 30
GRAPHIC SCALE: ONE INCH EQUALS TEN FEET
NELSCOTT
HEIGHTS
BLOCK 30
PROJECT: TOPOGRAPHIC MAP
LOCATION: LOT 9, BLOCK 30, NELSCOTT HEIGHTS
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