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Technical Memorandum

April 26, 2022 Project# 230210.040

To: Lisa Cornutt
Oregon Department of Transportation
3500 NW Stewart Parkway, Roseburg OR 97470
From: Wende Wilber, Chris Bame, Molly McCormick
RE: Final Technical Memorandum #2 Inventory

INTRODUCTION

The purpose of the South Coast Slide Study project is to develop a plan for transportation resiliency along US 101, between the City of Port Orford and the City of Brookings. Study landslides and road failures, shown in Table 1 and Figure 1 along this segment have been an ongoing problem for decades. These events result in full or partial closures of travel lanes and require days or even weeks of maintenance work to be able to fully reopen to passenger car and heavy vehicle travel. As a result, these landslide and road movement incidents have a significant cost to Oregon Department of Transportation (ODOT), disrupt the local and regional economies, strain emergency services, and reduce the mobility of communities to reach critical services.

Sustainable, technically feasible, and cost-effective solutions and management strategies will be identified as part of this project to stop, avoid, and/or reduce the recurrence of thirteen priority landslides and improve the adaptability/recoverability of the system before, during and after a landslide. ODOT and the communities directly and indirectly impacted by landslides will work together to enhance the common base of information about the corridor and regional transportation network, document and communicate the opportunities and challenges, and consider new ways of working together to mitigate impacts.

This memo consolidates and summarizes the existing knowledge base related to the historic occurrence of slides and roadway closures, and existing practices for mitigating the occurrence and consequence of landslides. This memo also summarizes data that may help inform the development of further mitigation strategies.

The study area is along the southern Oregon coast, within Curry County, and extending into northern California to capture transportation corridors. The study area is divided by the coastal mountain range into the coastal area to the west and the valley to the east. US 101 is the only thoroughfare serving north-south travel west of the mountains. Connections between the coastal area and the valley are sparse, with the only highway connections being OR 42, OR 42S, and I-5/US 199, more than 100 miles apart. A

majority of the study area is forested or farmed, although land is more developed along US 101 in the cities along the coast. The study area land use is shown in Figure 2.

Table 1 Study Landslides

ID Number	Common Name	Unstable Slopes Inventory Record ID	Mile Point	Length (feet)
1	Retz Creek South Slide	SL009-0304-72BB1	304.72	950
2	Coal Point Slide	SL009-0305-53BB1	305.53	634
3	North Brush Creek Hump	SL009-0306-12LN1	306.12	422
4	Brush Creek Slide	Not in database	310.24	60
5	Arizona North Slide (part of Arizona Slide Complex)	SL009-0312-00BB1	312.00	1,478
6	Arizona Inn Slide (part of Arizona Slide Complex)	SL009-0312-27BB1	312.39	1,267
7	Christmas Tree Slide (aka Frankport North)	Not in database	314.10	310
8	Sisters Rock Sink	SL009-0314-32BB1	314.32	317
9	Frankport Slide (aka Frankport South)	SL009-0314-79BB1	314.79	422
10	Woodroof Creek Slide (aka Horneblenzer Slide, Skull Ridge Slide, Squire Slide)	SL009-0315-93BB1	315.93	317
11	Eighty Acres Slide	SL009-0332-55RS1	332.55	264
12	Burnt Hill Slide	SL009-0343-55BB1	342.55	634
13	Hooskanaden Slide	SL009-0343-63BB1	343.63	1,267

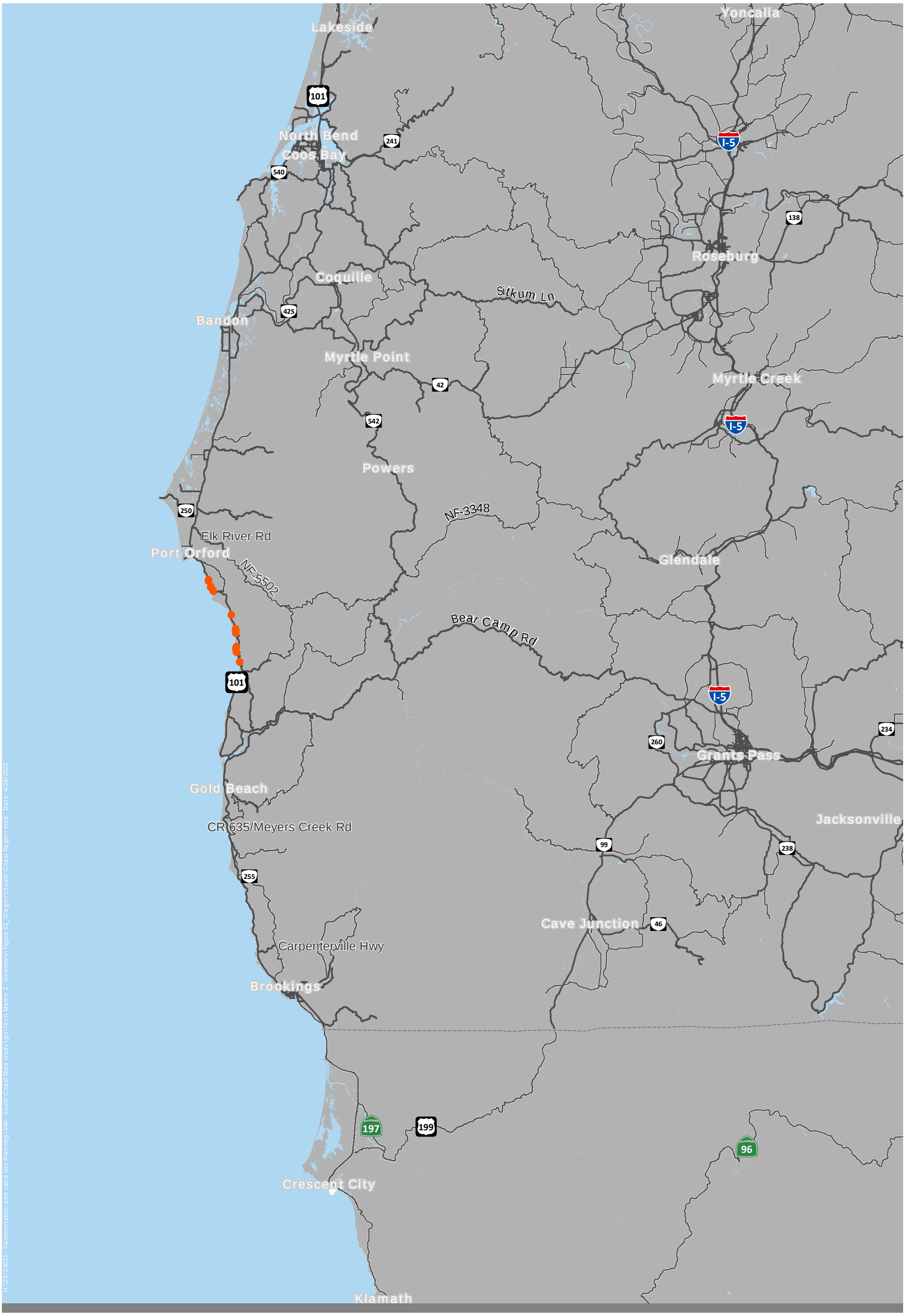

Figure 1

Landslides

Oregon's South Coast Region

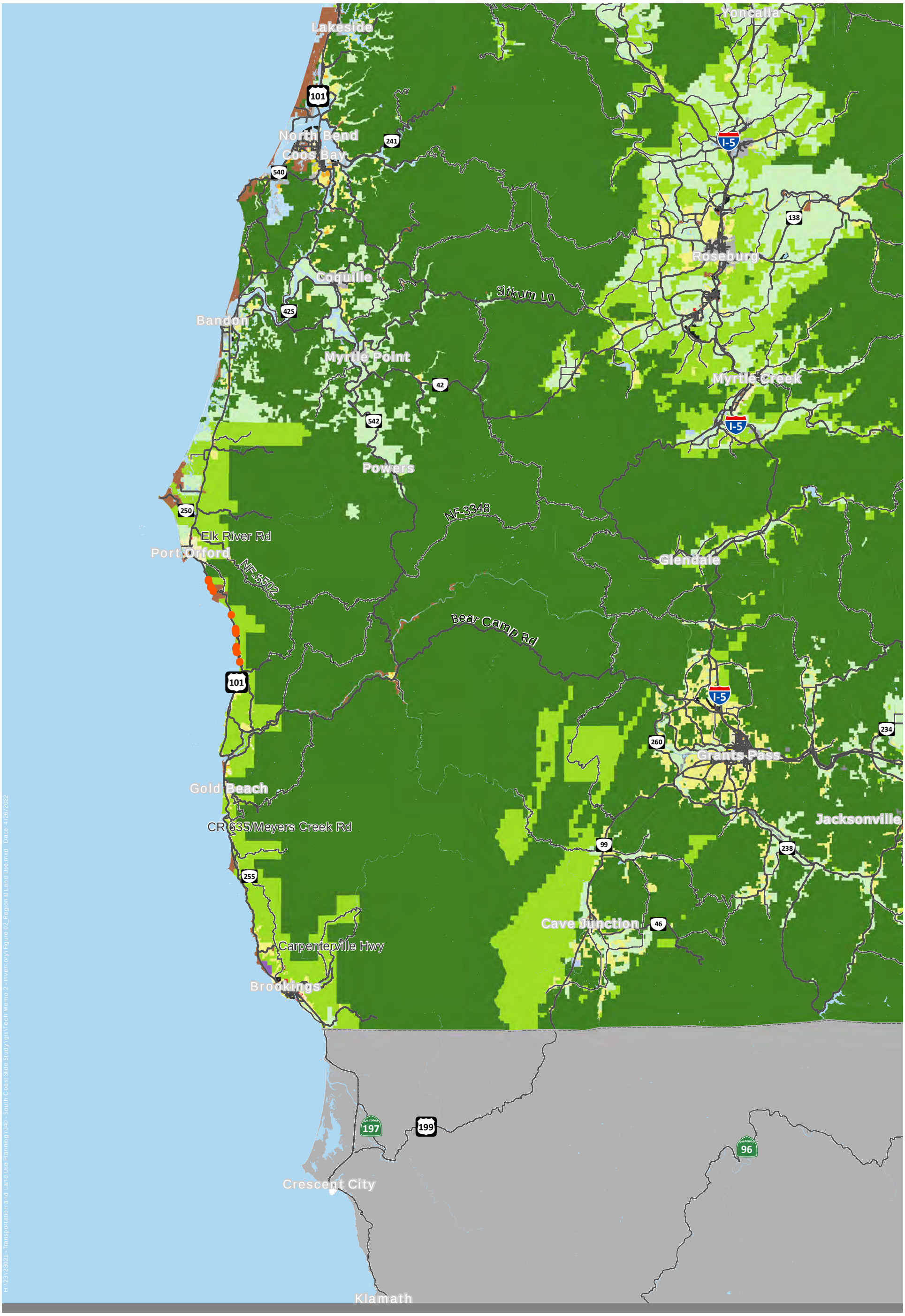

Figure 2

Regional Land Use

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STUDY AREA CONTEXT

This section provides on overview of the study area. The information serves as a foundation for understanding the high-level context of US 101 and adjacent areas. Subsequent sections provide further details for each highlighted slide area.

Roadway and Traffic Conditions

US 101 is the only major roadway that connects many of Oregon's coastal communities. It serves the critical function of connecting people to work and services and for moving goods. This section describes the existing roadway and traffic characteristics, primarily focused on US 101 and Carpenterville Highway. Information presented is based on available data for state-owned facilities. The Geographic Information System (GIS) data was obtained from ODOT.

FUNCTIONAL CLASSIFICATION

A roadways functional classification defines its role in the transportation system and reflects desired operational and design characteristics such as right-of-way requirements, pavement widths, pedestrian and bicycle features, and driveway (access) spacing standards. Figure 3 illustrates the federal functional classification designation of the area roadways. The following provides a description of each functional classification per FHWA Highway Functional Classification Concepts, Criteria and Procedures, 2013 Edition.

- Interstate: Interstates are the highest classification of Arterials and were designed and constructed with mobility and long-distance travel in mind.
- Other Freeways & Expressways: The roads in this classification have directional travel lanes are usually separated by some type of physical barrier, and their access and egress points are limited to on- and off-ramp locations or a very limited number of at-grade intersections. Like Interstates, these roadways are designed and constructed to maximize their mobility function, and abutting land uses are not directly served by them.
- Other Principal Arterial: These roadways serve major centers of metropolitan areas, provide a high degree of mobility and can also provide mobility through rural areas. Unlike their access-controlled counterparts, abutting land uses can be served directly.
- Minor Arterial: Minor Arterials provide service for trips of moderate length, serve geographic areas that are smaller than their higher Arterial counterparts and offer connectivity to the higher Arterial system. In an urban context, they

interconnect and augment the higher Arterial system, provide intra-community continuity and may carry local bus routes.

- Major and Minor Collector: Collectors serve a critical role in the roadway network by gathering traffic from Local Roads and funneling them to the Arterial network. Major Collector routes are longer in length; have lower connecting driveway densities; have higher speed limits; are spaced at greater intervals; have higher annual average traffic volumes; and may have more travel lanes than their Minor Collector counterparts.
- Local: Locally classified roads account for the largest percentage of all roadways in terms of mileage. They are not intended for use in long distance travel, except at the origin or destination end of the trip, due to their provision of direct access to abutting land. Bus routes generally do not run on Local Roads. They are often designed to discourage through traffic. As public roads, they should be accessible for public use throughout the year.

FREIGHT ROUTES

The Oregon Highway Plan (OHP) identifies all interstate highways and certain Statewide, Regional, and District Highways as freight routes. These routes are intended to facilitate efficient and reliable interstate, intrastate, and regional truck movement through a designated freight route system. There are no OHP designated freight routes in the study area. The closest OHP freight routes are OR 42 to the north and I-5/US 199 to the east.

NATIONAL HIGHWAY SYSTEM

The National Highway System (NHS) is a network of highways, including interstate highways, that serve strategic economic, defense, and transportation facilities, such as airports, ports, rail or truck terminals, railway stations, and pipeline terminals. US 101 is designated as an NHS route, as well as OR 42 to the north and I-5 /US 199 to the east.

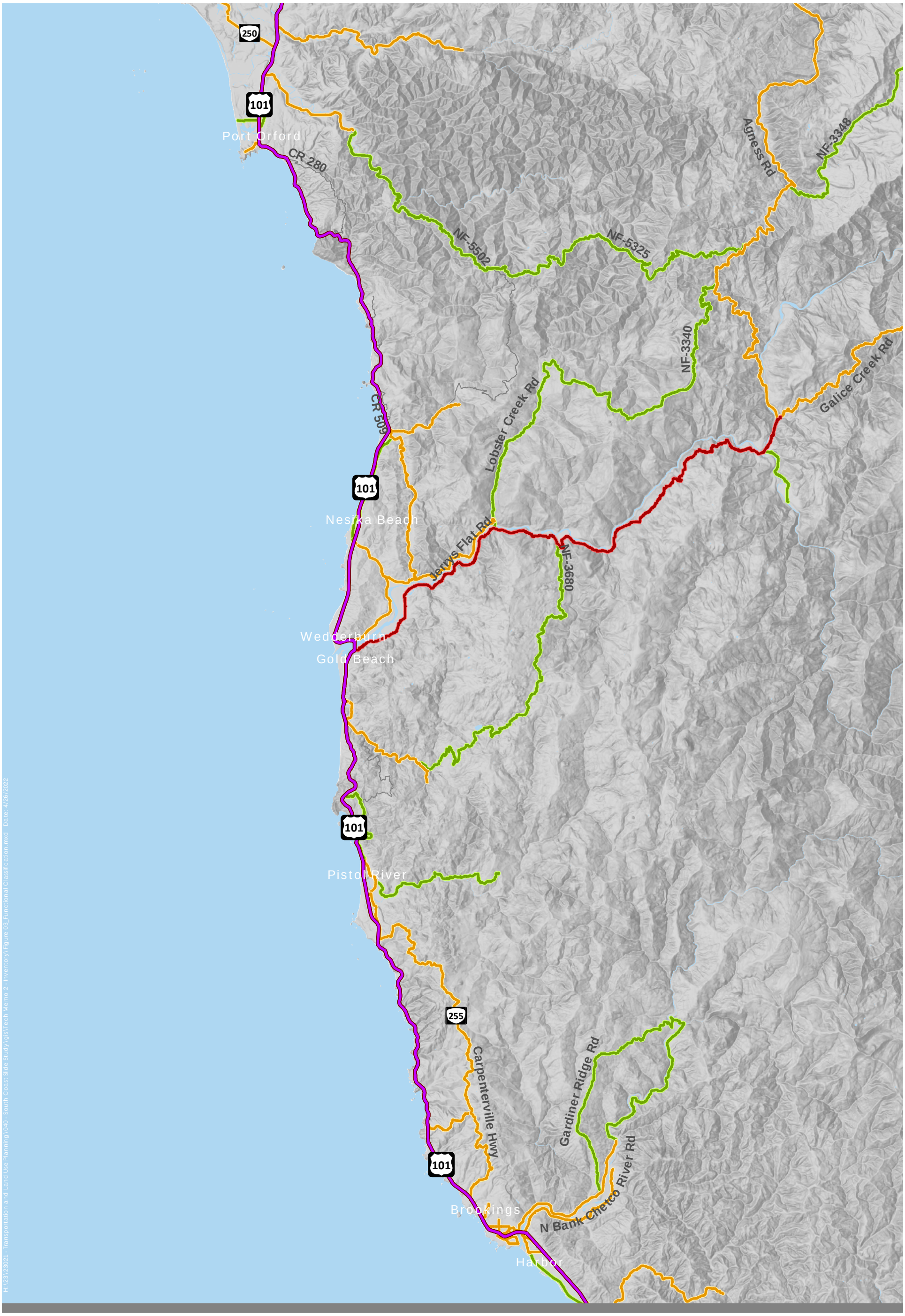


Figure 3

Functional Classificiation

NUMBER AND WIDTH OF TRAVEL LANES

The number of travel lanes along US 101 and Carpenterville Highway are shown in Figure 4. In general, US 101 has two to four lanes within the study area, and Carpenterville Highway has two lanes. Travel lane widths on US 101 are typically 12 feet. For Carpenterville Highway, travel lane widths vary between 9 and 12 feet.

POSTED SPEED LIMITS

Speed limits generally correspond with the functional classification of the roadway. Roadways with higher functional classifications (e.g. interstates and arterials) typically have higher speeds than roadways with lower classifications (e.g. collectors and locals). Based on the available data from TransGIS, US 101 and Carpenterville Highway have posted speed limits of 55 MPH in the study area, with the following exceptions in Table 2.

Table 2: US 101 and Carpenterville Highway Posted Speed Limits Lower than 55 MPH

Roadway	Begin Milepoint	End Milepoint	Posted Speed Limit	Notes
US 101	299.78	301.75	30/45	Within Port Orford City UGB
	327.25	330.05	30/40	Within Gold Beach UGB
	355.27	359.50	25/35/45	Within Brookings UGB
Carpenterville Highway	361.91	362.27	40	Within Brookings UGB

PAVEMENT CONDITION

Pavement condition information along ODOT facilities was obtained from the ODOT TransGIS database and is shown in Figure 5. ODOT conducts surveys to determine the extent of pavement conditions in rut fatigue, patch, no load, raveling, and overall condition. Overall pavement condition rating categories include very good, good, fair, poor, and very poor. Both US 101 and Carpenterville Highway are reported with pavement conditions varying from good to poor.

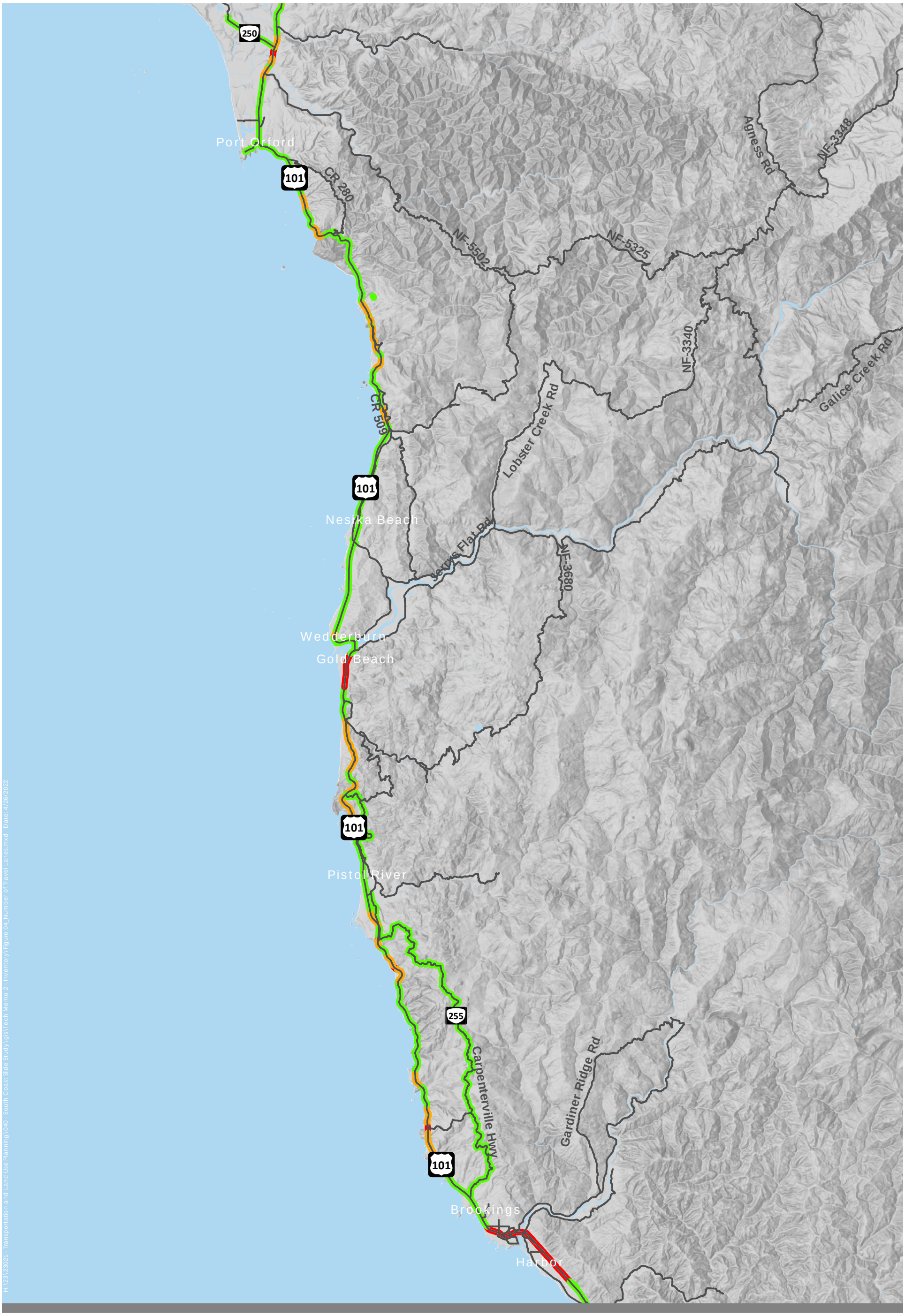


Figure 4

Number of Travel lanes

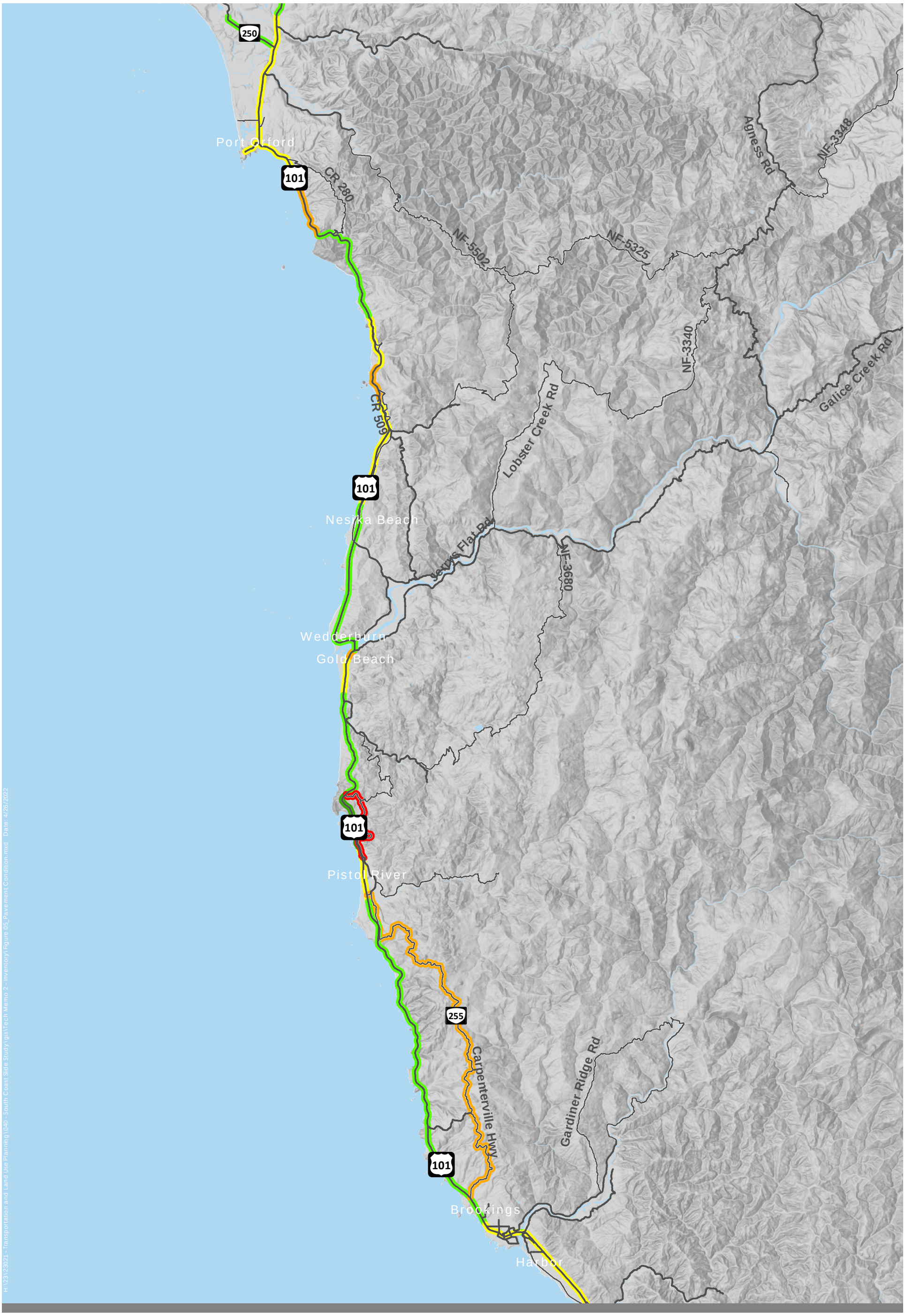


Figure 5

Pavement Condition

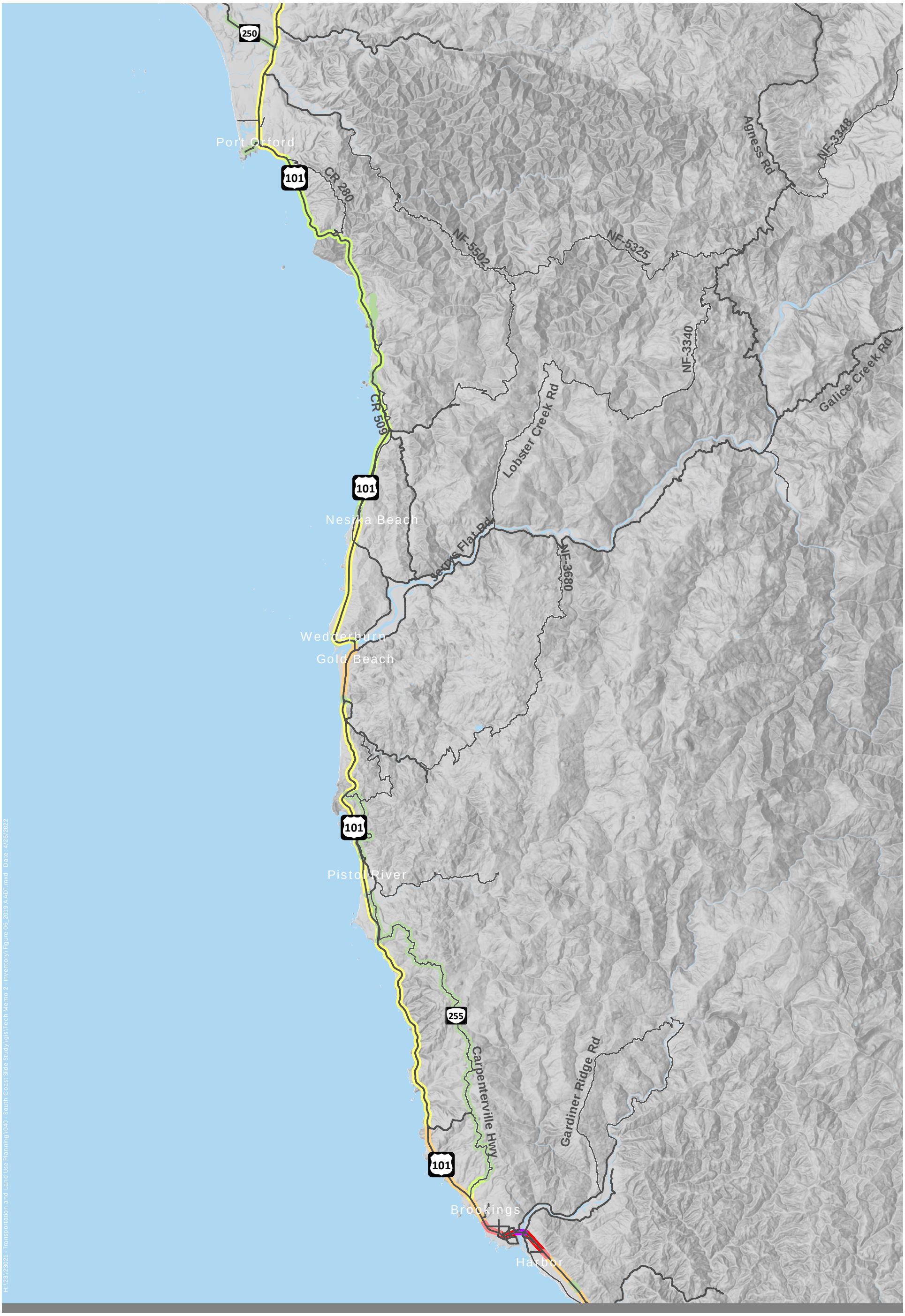
EXISTING AVERAGE ANNUAL DAILY TRAFFIC (AADT)

ODOT provides existing bi-directional Average Annual Daily Traffic (AADT) volume ranges through the ODOT TransGIS database, which are updated annually. Data used to determine the AADT ranges include 48-hour road tube counts (where applicable), automatic traffic recorders (ATRs), and manual classification counts. ODOT's count program for the highway system is conducted on a three-year cycle with one third of the lane miles counted each year. Growth factors are applied for years when a specific segment is not counted. Due to COVID-19, ODOT conducted minimal new counts in 2020 and generally maintained the same highway system AADT values and ranges shown within the online database. As shown in Figure 6, US 101 between Port Orford and Brookings ranges from approximately 1,000 to 10,000 daily trips. The highest AADTs of 5,000-10,000 occur between the Rogue River and Gold Beach and between the southern end of Carpenterville Highway to north of Brookings.

In addition to the bi-directional AADT for all vehicles, ODOT provides a truck AADT for state facilities. As shown in Figure 7, US 101 serves a truck AADT up to 3,000. Similar to overall AADT, the highest truck AADTs of 1,500 to 2,000 occur between the Rogue River and Gold Beach and between the southern end of Carpenterville Highway to north of Brookings. Carpenterville Highway, also shown in Figures 6 and 7, has up to 1,000 daily trips, including up to 500 trucks.

FORECASTED FUTURE AVERAGE ANNUAL DAILY TRAFFIC (AADT)

When ODOT annually updates the AADTs for state-owned facilities, forecasted 20-year horizon AADTs are also estimated. For the study section of US 101, the future AADTs are similar to the reported 2020 AADTs. Figure 8 shows the forecasted 20-year horizon AADTs for state- owned facilities. The two sections of US 101 that moved up to a new AADT range are between Port Orford and Nesika Beach and around Brookings (up to over 20,000 daily trips on certain segments). Carpenterville Highway is forecast to continue to experience an AADT below 1,000 within the 20-year horizon.



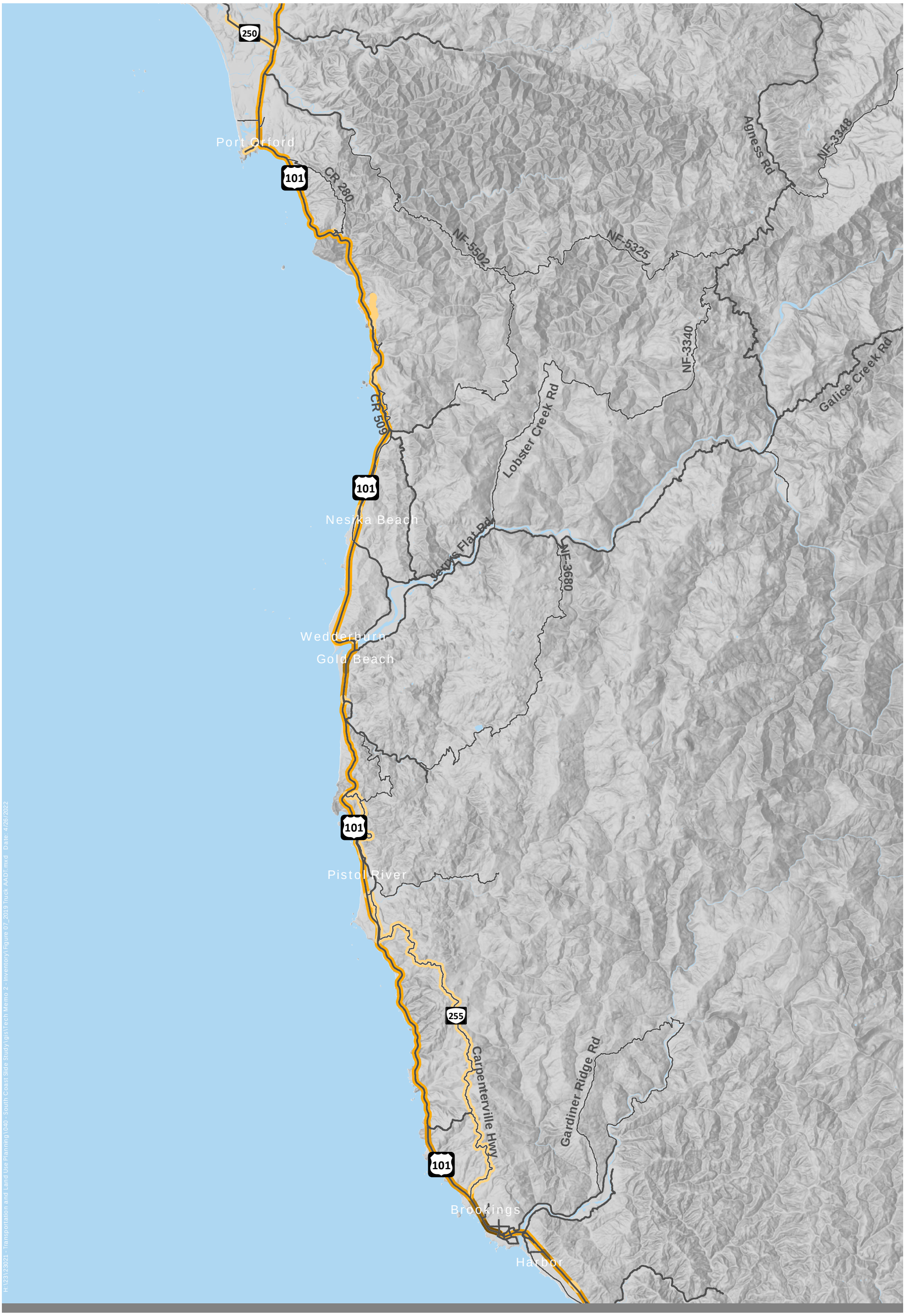
Average Annual Daily Traffic

- 0 - 1,000
- 1,001 - 2,500
- 2,501 - 5,000
- 5,001 - 10,000
- 10,001 - 15,000
- 15,001 - 20,000
- 20,000+

0 4 Miles

Figure 6

2019 Average Annual Daily Traffic (AADT)



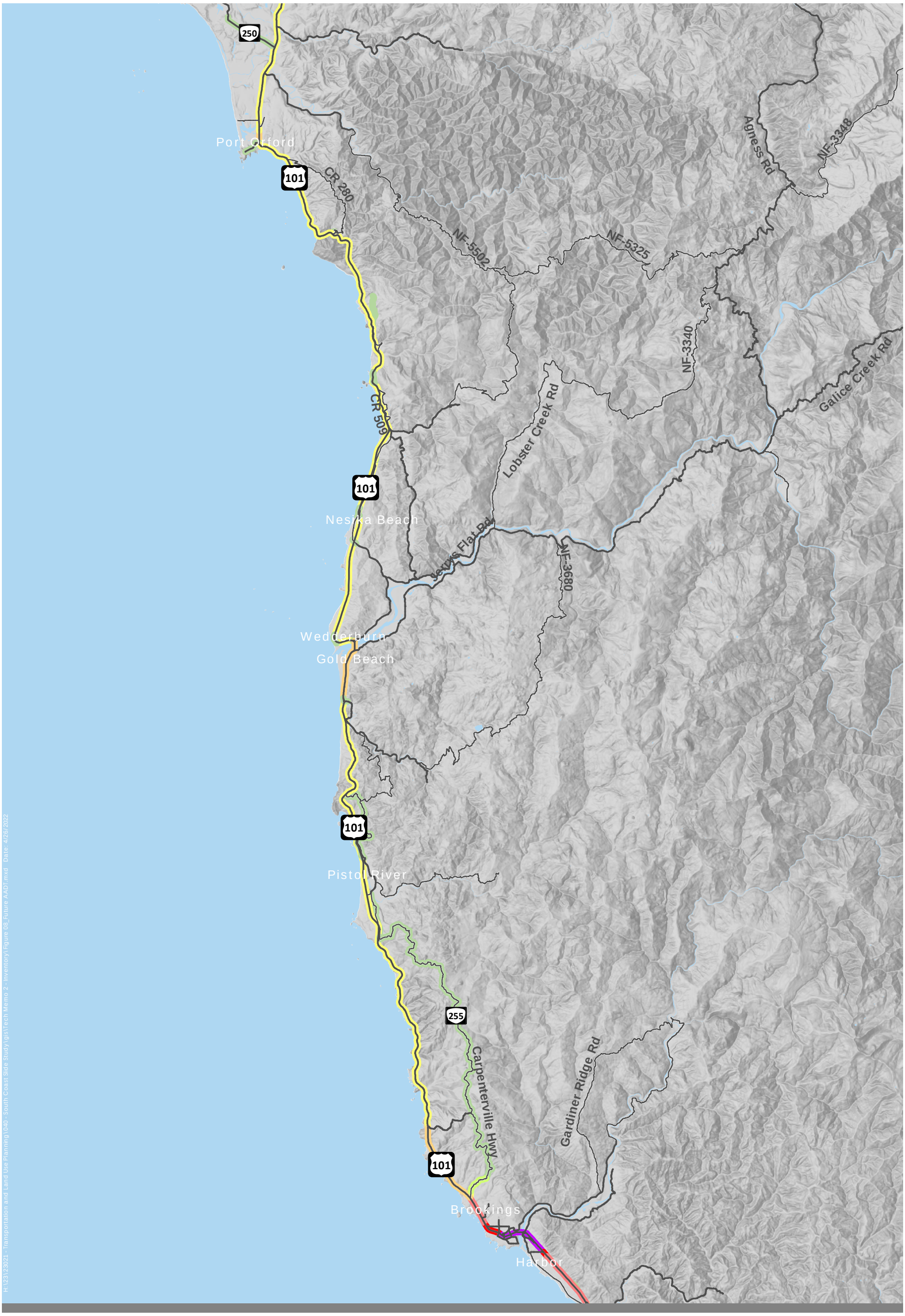
Truck Average Annual Daily Traffic

- 0 - 499
- 500 - 999
- 1,000 - 1,499
- 1,500 - 1,999
- 2,000 - 2,999
- 3,000+

0 4 Miles

Figure 7

2019 Truck Average Annual Daily Traffic (AADT)



Future Average Annual Daily Traffic

- 0 - 1,000
- 1,001 - 2,500
- 2,501 - 5,000
- 5,001 - 10,000
- 10,001 - 15,000
- 15,001 - 20,000
- 20,000+

0 4 Miles

Figure 8

Forecasted 20-Year Horizon Future Average Annual Daily Traffic (AADT)

TRANSIT

Curry County is served by the Coastal Express bus route, which travels from south of Brookings to North Bend. There are 3 Coastal Express buses per day, with no service on Sundays. The Coastal Express travels along US 101, through all of the study slide locations. Brookings is also served by Oregon Point, Oregon's intercity bus service. The Oregon Point bus connects Brookings to Crescent City, Grants Pass, Medford, and Klamath Falls. Brookings is served once per day by the Oregon Point bus, with no service on Sundays. The Oregon Point route does not pass through any of the study slide locations. The transit routes are shown in Figure 9.

Other transportation options in the region include dial-a-ride services in Curry County, local transit routes in the Coos Bay immediate area, and the Retired Senior Volunteer Program (RSVP), which provides local transportation by volunteers.

CRASH DATA

Crash records were obtained from ODOT for the five-year period from January 1, 2015 through December 31, 2019. Figure 10 illustrates the location and severity of the crashes within Curry County. Table 3 summarizes the crashes that occurred along US 101 and Carpenterville Highway.

Based on the data, a total of 414 crashes occurred along US 101 within Curry County, of which six resulted in a fatality, 205 resulted in injuries, and 203 resulted in property-damage-only. Of the six crashes resulting in fatalities, three were fixed object crashes, one was an angle crash, one involved a pedestrian, and one was labeled "non-collision" for an overturned vehicle. Three of the crashes resulting in fatalities occurred at night.

Based on the data, a total of 19 crashes occurred along Carpenterville Highway, of which one resulted in a fatality, nine resulted in injuries, and nine resulted in property-damage-only. The crash that resulted in a fatality occurred at night and involved a car that overturned due to excessive speed.

Table 3: Reported Crash Summary within Curry County (2015-2019)

Roadway	Collison Type					Fatality	Injury	PDO	Total Crashes
	Angle/ Turning	Fixed Object	Rear-end	Side-swipe	Other				
US 101	105	140	70	25	74	6	205	203	414
Carpenter-ville Road	1	13	0	1	4	1	9	9	19

Fatal: Includes fatal and incapacitating injuries
Injury: Includes non-incapacitating injuries and possible injuries/complaint of pain
PDO: Property Damage Only

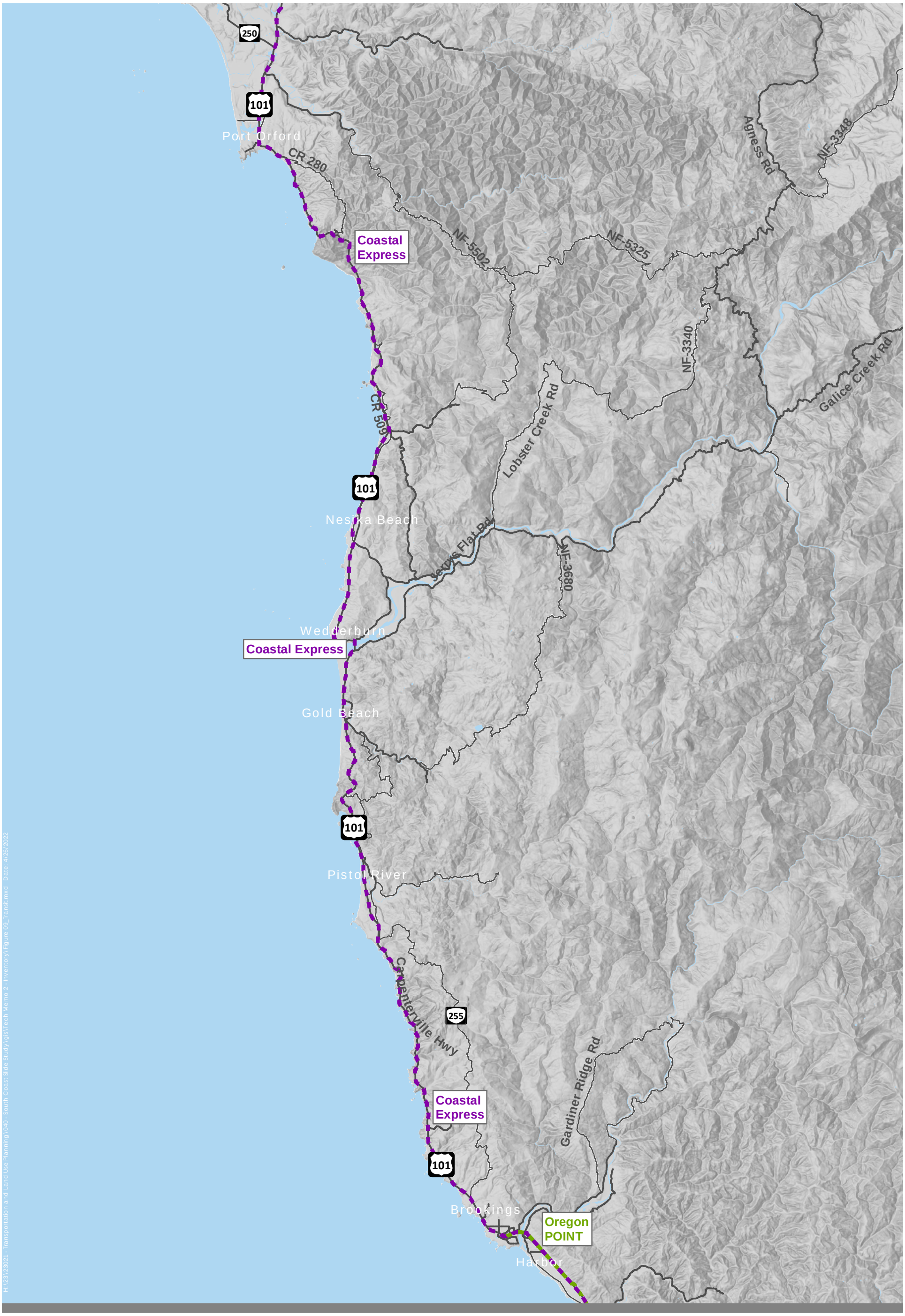


Figure 9

Transit Routes

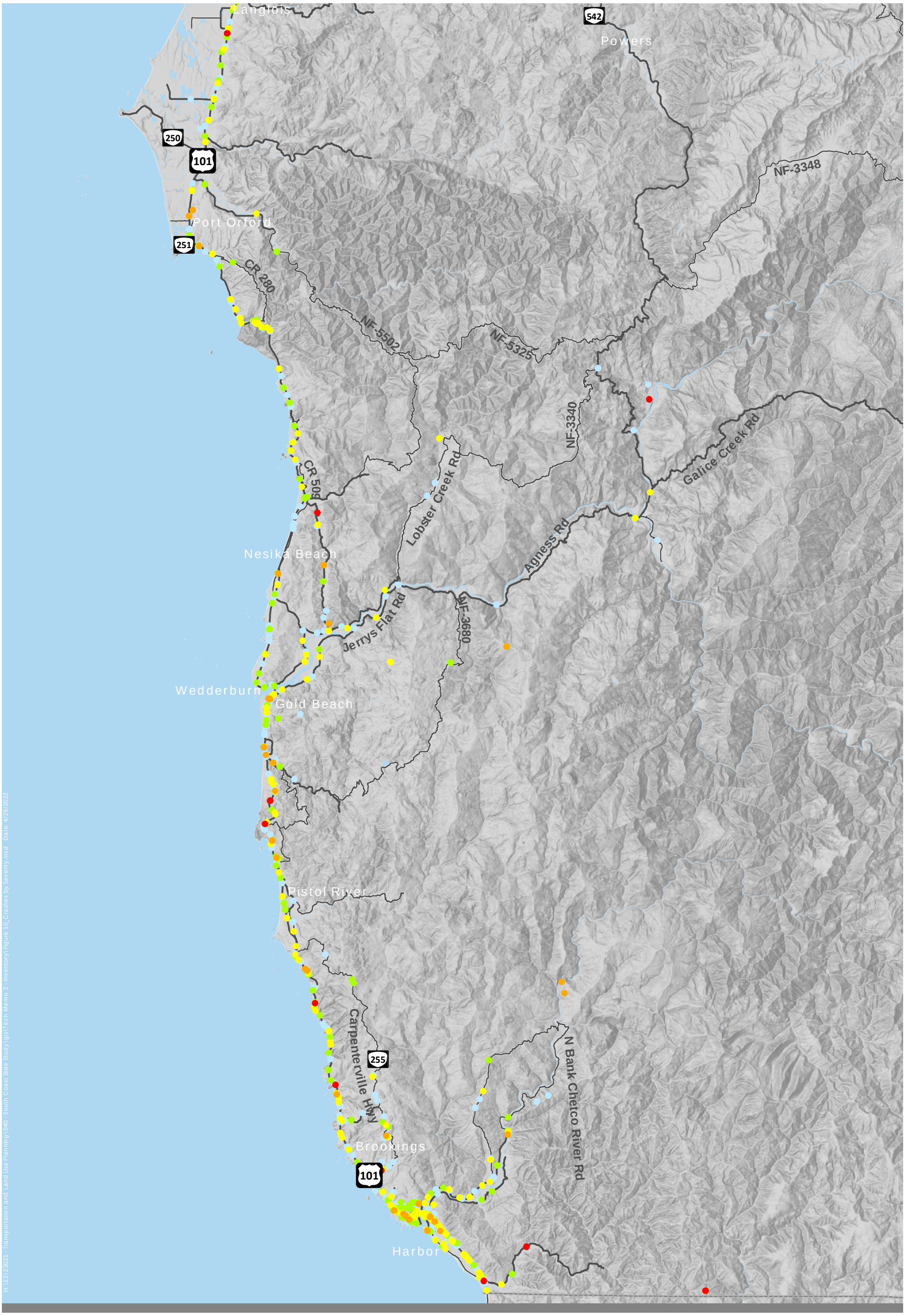


Figure 10

Reported Crashes by Severity from 2015 to 2019

Socio-Economic Context

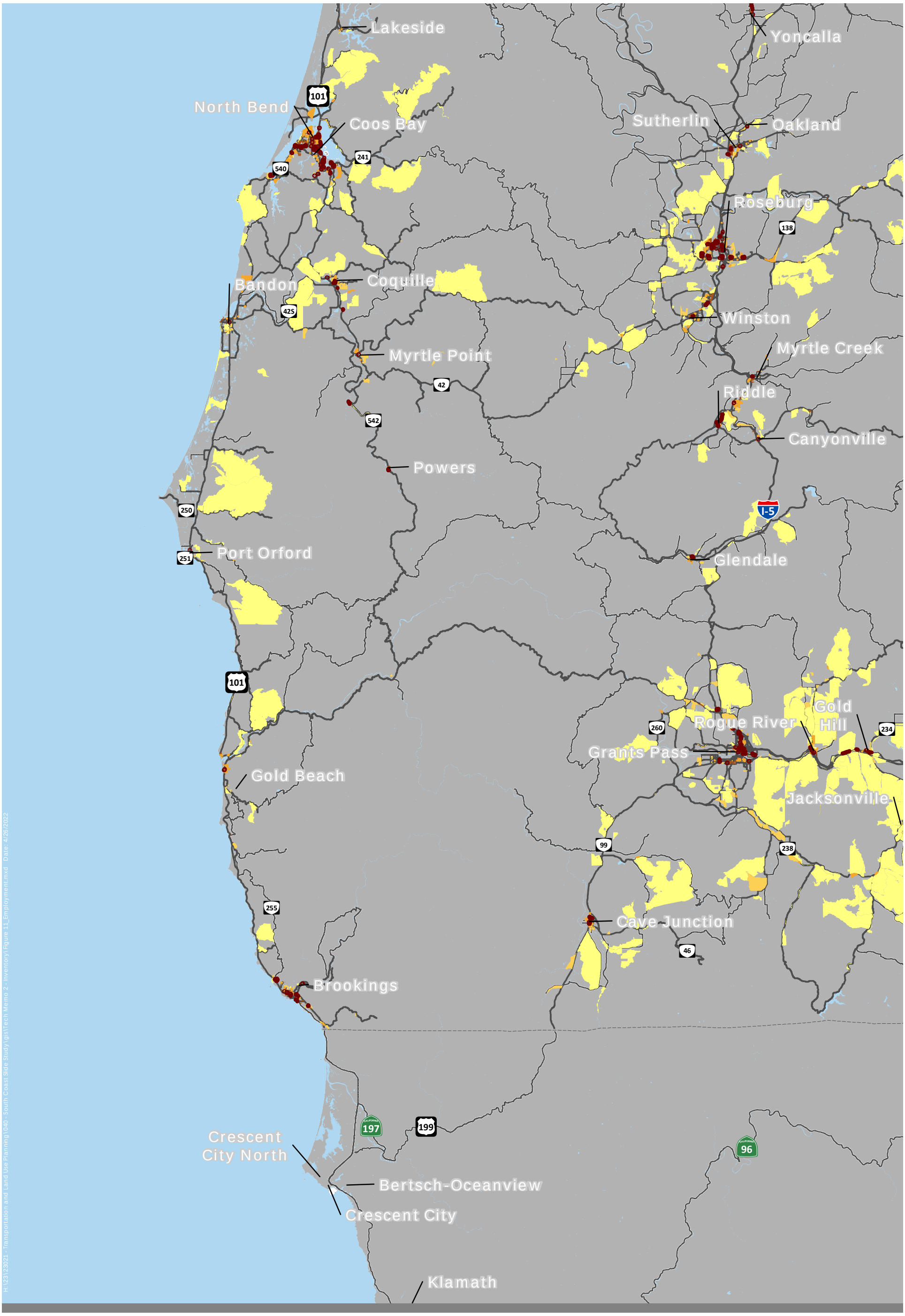
This section provides an overview of the socioeconomic characteristics of the study area and each community to help inform the slide impacts. Landslides along US 101 have historically impacted access to jobs and critical services, tourism, and freight movement. In general, the longer US 101 remains fully closed, the greater the impacts to the communities and traveling public.

Approximately 23,000 people live in Curry County, many of whom live along US 101. The major job centers in the study area are shown in Figure 11. The highest employment densities are found in Brookings, Coos Bay, Roseburg, and Grants Pass. Gold Beach, Port Orford, and Bandon also have a significant number of jobs; however, they are much smaller compared to the neighboring regional centers. The number of jobs in each of these areas is summarized in Table 4. Several neighboring regional centers including Medford, Ashland, Roseburg, and Grants Pass are included in Table 4 for reference. Approximately 20 percent of the jobs along the southern Oregon coast are located at decentralized locations outside of Census Designated Places. These jobs are shown in Figure 11 but are not included in Table 4.

Table 4: Number of Jobs by Job Center

Census Designated Place	Jobs
Medford	31,372
Ashland	6,505
Coos Bay / North Bend	6,125
Roseburg	3,510
Grants Pass	3,138
Brookings / Harbor	763
Coquille	372
Bandon	236
Gold Beach	172
Port Orford	130

It is worth noting that tourism is an important economic sector for Oregon's coastal communities and the surrounding area. A 2019 Travel Oregon study estimated that $134.5 million dollars were spent by visitors in Curry County in 2018.



0 30 Miles

Employment Density (jobs/sq. mi.)

- 0 - 40
- 41 - 220
- 221 - 780
- 781 - 3,300
- 3,300+

Figure 11

Employment Density

BROOKINGS

Brookings is at the southern end of the study area, six miles north of the California border. According to 2020 US Census data, there are 6,744 people living in Brookings. Brookings is the largest city in Curry County, with 29 percent of the Curry County population (23,446) living in Brookings. The US Census 2019 Longitudinal Employer-Household Dynamics (LEHD) Origin-Destination Employment Statistics (LODES) data reports 594 jobs within Brookings, with a job density of about 143 per square mile. The American Community Survey 2016-2020 was used to understand some additional population characteristics. Compared to the state, Brookings has a greater portion of the population over 65 years old (31% in Brookings, 18% in Oregon) and a smaller portion of the population employed (41% in Brookings, 51% in Oregon). Population growth in Brookings is expected to be minimal over the next 50 years, with an average annual population growth rate of 0.4 percent in the Brookings Urban Growth Boundary between 2018 and 2068 (Portland State University, Population Research Center).

Brookings' economy is supported by lumber, fishing, and the lily bulb farms located between Brookings and Smith River, California. These stable industries allow Brookings to be less dependent on tourism than many of Oregon's coastal cities[1]. However, the Brookings Economic Profile also reports that tourism is increasing in Brookings, with Transient Occupancy Tax receipts increasing by 8 percent from 2018 to 2019.

Brookings is served by medical centers within Brookings including Curry Medical Center, Sutter Coast Health Center, and the VA Clinic. Additionally, regional medical centers are in Gold Beach and Crescent City. Cal-Ore Life Flight provides ground and air transportation in medical emergencies.

GOLD BEACH

Gold Beach is located at the outflow of the Rogue River into the Pacific Ocean, along US 101 approximately in the middle of the study area. US Census 2020 data shows a population of 2,341 people living in Gold Beach. The LEHD LODES data reports 176 jobs within Gold Beach, with a job density of about 64 per square mile. Population growth in The American Community Survey 2016-2020 was used to understand some additional population characteristics. Compared to the state, Brookings has a greater portion of the population over 65 years old (24% in Gold Beach, 18% in Oregon) and a smaller portion of the population employed (40% in Gold Beach, 51% in Oregon).Gold Beach is expected to be minimal over the next 50 years, with an average annual population growth rate of 0.7 percent in the Gold Beach Urban Growth Boundary between 2018 and 2068 (Portland State University, Population Research Center).

[1] https://www.brookings.or.us/89/City-History-Demographics

The economy of Gold Beach has been supported by commercial fishing, then by timber, and to a lesser extent by sport fishing[2].

Gold Beach is served by Curry General Hospital. Additionally, regional medical centers are in Coos Bay, Brookings, and Crescent City. Cal-Ore Life Flight provides ground and air transportation in medical emergencies.

PORT ORFORD

Port Orford is located along US 101, at the northern end of the study area, the oldest town on the Oregon Coast, and the most westerly town in the continental United States. According to 2020 US Census data, there are 1,146 people living in Port Orford. The American Community Survey 2016-2020 was used to understand some additional population characteristics. Compared to the state, Brookings has a greater portion of the population over 65 years old (38% in Port Orford, 18% in Oregon) and a smaller portion of the population employed (36% in Port Orford, 51% in Oregon). The LEHD LODES data reports 132 jobs within Port Orford, with a job density of about 83 per square mile. Population growth in Port Orford is expected to be minimal over the next 50 years, with an average annual population growth rate of 0.6 percent in the Port Orford Urban Growth Boundary between 2018 and 2068 (Portland State University, Population Research Center).

Port Orford continues to be a working fishing port and also is also an active art community and tourist destination (especially in the summer). The Port of Port Orford is home to nearly 30 commercial fishing boats, which together catch about $5 million of product annually[3].

There is not a medical center within Port Orford. However, regional medical centers are in Coos Bay, Gold Beach, and Coquille. Cal-Ore Life Flight provides ground and air transportation in medical emergencies.

LANDSLIDES AND IMPACTS TO TRAVEL

The Slide Inventory Technical Memorandum, prepared by Shannon & Wilson is included in Attachment A. It provides a more detailed history of each slide including slide characteristics, movements and historic mitigation actions.

For the purpose of identifying impacts to travel and potential roadway mitigation measures, the slides have been grouped by three primary "slide areas" based upon the

[2] https://www.goldbeachoregon.gov/about
[3] https://portorford.org/about-port-orford/

location of regional destinations and availability of alternative routes around the slide, as shown in Figure 12. Based on input from ODOT staff representing planning, geotechnical, and maintenance groups two types of routes were identified to for use during a landslide roadway closure (For full meeting notes, see Attachment B).

- Detour routes. These are ODOT or other publicly-owned and maintained roads suitable for the general public and freight use with no restrictions. Detour routes are approved by ODOT and documented in the Oregon Coast Highway 9 US 101 Emergency Detour Contingency Manual. According to the ODOT Mobility Procedure Manual, detour routes must serve all vehicles that normally use the route they are serving as a detour for. If some vehicles that use the route cannot be served by the detour route, a secondary route must be designated for these vehicles. In some instances, a roadway may also be a viable detour route if temporary restrictions for operational and safety reason are instituted, for example pilot cars.
- Restricted access routes. These routes generally do not meet operational and safety standards for the general public or heavy vehicles. Their intended use is restricted to ODOT maintenance and emergency vehicles during major events to provide critical services. These routes are not recommended by ODOT to the travelling public. These routes typically have some portions that are not paved and may have topographical and sharp curve challenges.

The historic occurrences, detour and restricted access routes, and impacts of slides at each of the slide areas (as shown in Figure 12) are summarized in Table 5 and elaborated upon in this section. For all slides, I-5, OR 42/OR 42S, and US 199 are the identified detour routes.

Table 5: Summary of Historic Occurrences by Landslide Area

Slide Area	Historic Occurrences	Length of Full Closure	Detour Routes	Restricted Access Routes	Most Impacted Communities
Humbug Mt.	- Full road closure in 1993, 2012 - Lane closures in 2006, 2011, 2012 - Roadway damage in 1980's, 1981, 2012	1993: 2 weeks 2012: 2 weeks	- I-5 - OR 42/OR 42S - US 199	- Elk River Rd/ NF 5502/ Euchre Creek Rd	- Gold Beach - Brookings - Crescent City
Eighty Acres	- Lane closures in 2012 - Roadway damage in 2006	-	- I-5 - OR 42/OR 42S - US 199	None	- Gold Beach - Crescent City
Hooskanaden	- Full road closures in 1977, 1995, 2005, 2006, 2019	Ranging from 2 days to 3 weeks	- Carpenterville Rd - I-5 - OR 42/OR 42S - US 199	None	- Gold Beach - Crescent City

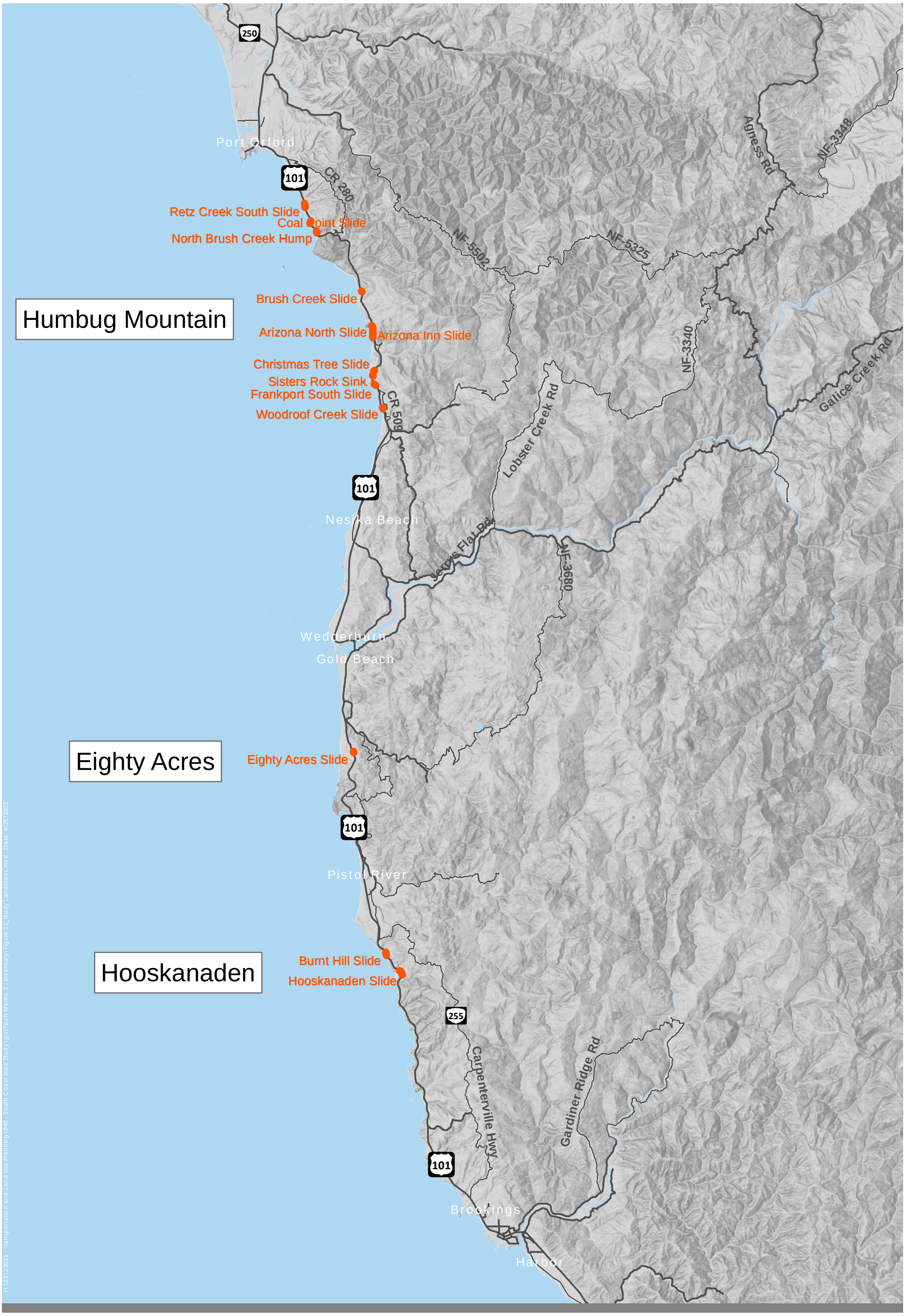


Figure 12

Landslides

Study Landslides

Preliminary mitigations measures were discussed during the interviews with ODOT staff and identified during the field visit. These measures and others will be further explored in future phases of the project.

- Focus on how to make the routes more truck friendly.
    - For example, trucks often ran out of gas when using Carpenterville Highway during the 2019 Hooskanaden landslide US 101 closure.
    - For the 2019 Hooskanaden landslide, establishing weight masters at each end of the detour route was very successful.
- Finding locations to stockpile gravel along US 101to facilitate repairs.
- Finding locations for limited widenings or pullouts without exacerbating landside conditions.
- Carpenterville Highway improvements could include adding rock/gravel to the established pullouts.
- Improved detour signage along Carpenterville Highway.
- Formalized traffic control plans, such as the Hoosdanaden example, for all the study landslide locations.
- Early notification to freight and fuel providers to minimize disruptions in the supply chain to local communities.
    - For example, it is difficult to get fuel to Brookings for some landslide locations because fuel trucks are restricted on US 199 for environmental reasons. With early notification, sending smaller freight/fuel trucks may be option.
- Add coordination and communication with the Forest Services as part of the plan, for areas where this may be beneficial.

Humbug Mountain Slide Area

There are 10 study landslides near Humbug Mountain between Ophir and Port Orford, as shown in Figure 13, although there are many other landslides that are not part of this study. Table 6 summarizes landslide events that impacted travel. The most significant roadway closures occurred in 1993 when the Arizona Inn Slide closed US 101 for over a week. In 2012, the Brush Creek Slide closed US 101 for one day and closed the northbound lanes for 10 days. Other slides have periodically resulted in lane closures along US 101.

Table 6: Summary of Historic Occurrences for the Humbug Mountain Slide Area

Slide Name	Slope Type	Documented Travel Impacts
Retz Cr South Slide	Landslide	**1980's**: Slide movement affecting 300 ft of US 101 2006: Slide movement closing southbound lanes 2011: Slide movement closing outside southbound lane Per ODOT comment, closing the outside southbound lane has been common for the location for decades. Normally occurs every other year for a few weeks and up to a few months.
Coal Point Slide	Landslide	**1980's**: Significant slide movement 2006: Slide movement closing outside southbound lane (applied gravel 2x/day to keep open) Ultimately repaved 2012: Slide movement resulting in repaving
North Brush Cr Hump	Landslide	2006: Hump closing outside northbound lane
Brush Creek Slide	Landslide	-
Arizona North Slide (part of Arizona Slide Complex*)	Landslide	-
Arizona Inn Slide (part of Arizona Slide Complex*)	Landslide	1981: Slide movement requiring material to be imported to maintain roadway alignment 1993: Slide movement at a rate too great to maintain the roadway, requiring closure for about 2 weeks
Christmas Tree Slide (aka Frankport North)	Landslide	-
Sisters Rock Sink	Fill Failure	-
Frankport Slide (aka Frankport South)	Landslide	-
Woodroof Creek Slide (aka Horneblenzer Slide, Skull Ridge Slide, Squire Slide)	Fill Failure	2012: Slide movement resulting in closure of southbound lanes and inside northbound lane. The same slide movement occurred in 2006 and 2016, although lane closures were not noted for those occurrences.

Figure 13

Evaluated Restricted Access and Detour Routes:
Humbug Mountain Area

DETOUR AND RESTRICTED ACCESS ROUTE ALTERNATIVES

Along this section of US 101, there are few alternative travel routes. A partial or full closure could potentially disrupt:

- The commute for an estimated 1,000 who live and work on opposite sides of the slides at Humbug Mountain (Based on US Census Longitudinal Origin Destination Employment (LODEs) data).
- Tourists travelling to Gold Beach or Brookings from outside of southern Oregon. Compared to the other slide locations, the impact to tourism is expected to be most pronounced due to slides around Humbug Mountain compared to slides at the other study locations.
- An estimated 2,400 to 5,000 daily trips
- An estimated 560 to 1,000 freight trips per day
- The Coastal Express transit route (3 buses in each direction per day)
- Emergency Services

Elk River Rd / FS 5502 / Euchre Creek Rd was identified as a viable restricted access route. This route bypasses all study landslides around Humbug Mountain. The route follows a combination of paved county roads, paved local roads, and Forest Service gravel roads. It should be noted that although these roadways are outside of the study landslide locations, they are likely to be impacted by the same storm events that would result in US 101 landslides closing the highway and may not be viable during these events.

- The route is approximately 34 miles long and takes about 2 hours to drive at an average travel speed of 15 mph.
- There is significant elevation change along the route. Vehicle restrictions would likely be needed, although the route may be viable for passenger cars, small freight, and emergency vehicles.
- This route could be further improved by providing destination signage to US 101, adding curve warning signage, and paving the northern most five miles of the route that are currently gravel. The gravel northern portion of the route is extremely steep, based on field observations, so paving the roadway would improve traction and comfortability of the road.

Other routes considered but eliminated as restricted access routes include:

- Arizona Ranch Rd: This route bypasses the South Retz Creek, Coal Point, and North Brush Creek Hump slide complexes, but is a less accessible route than the Elk River Rd route.
    - The entire route is gravel, narrow, and extremely steep, based on field observations.
    - The route would not be traversable by vehicles other than passenger cars

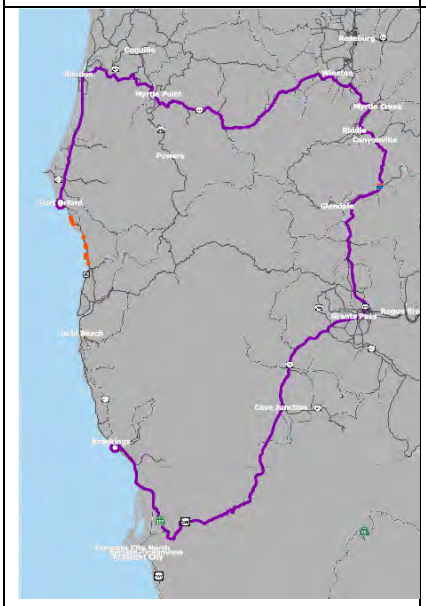
- CR 509: This route bypasses the Woodruff Creek slide. The route is paved; however, the road is gated at the northern end with an access to a private residence.
    - The route does not reconnect with US 101 at the north end, so it does not provide an alternative route to US 101.
- CR 595 / Agness Rd / Through Powers / SR 542 / SR 42: This route bypasses all landslides around Humbug Mountain. The route follows a combination of paved county roads, paved local roads, and Forest Service gravel roads.
    - The route travels through Powers before accessing OR 542 and then OR 42 before reconnecting with US 101.
    - The route was not reviewed during the field review due to being much longer than the evaluated Elk River Rd restricted access route.
    - Additionally, ODOT staff noted that OR 542 is challenging to keep open during the winter.

In addition to routes that by-pass US 101 east-west routes connecting US 101 to Grants Pass and I-5 across the Coastal Mountain Range were considered but eliminated as detour or restricted routes.

- The 2002 Port Orford TSP identifies a potential project as providing an improved east-west connection between the coast and I-5. ODOT previously conducted a study in 1974 that identified a preferred alignment, however the report concluded that the economic benefits did not warrant the construction costs.
- Bear Camp Rd is the primary east-west route across the Coastal Mountain Range; however, it is closed in the winter months due to snow coverage, which is likely when slides would impact US 101. Additionally, portions of Bear Camp Rd have a gravel surface and there are blind curves without frequent turnouts along the route.

Detour traffic is expected to be served by I-5, OR 42/OR 42S, and US 199. Estimated travel time are shown in Exhibit 1. Travel along the coast, for example between Port Orford and Gold Beach, is expected to be the most impacted with travel times increasing by up to 5 hours. Travel time impacts may be less for trips along US 101 that are able to reroute prior to reaching the landslide, for example trips between Coos Bay and Crescent City would only have travel time increased by about 2 hours. Trips between I-5 and the study area may have travel time increased by about 1 hour if they need to detour around the slides in the Hooskanaden area.

Exhibit 1: Detour Routes for Humbug Mountain Slides

Port Orford to Brookings	Port Orford to Gold Beach	Gold Beach to Brookings
US 101 Travel Time: 1 hr	US 101 Travel Time: 0.5 hrs	US 101 Travel Time: 0.5 hrs
Detour Travel Time: 5 hrs	Detour Travel Time: 5.5 hrs	Detour Travel Time: N/A
Travel Time Impact: 4 hrs	Travel Time Impact: 5 hrs	Travel Time Impact: None
		

Eighty Acres Slide Area

The Eighty Acres slide, as shown in Figure 14, presents a unique situation where no restricted access routes are available around the slide. Table 7 summarizes landslide events that impacted travel. The Eighty Acres slide has a long history of closing the southbound lanes on US 101, however it has not historically resulted in a complete road closure and has had a relatively small impact on the community.

Table 7: Summary of Historic Occurrences for the Eighty Acres Slide Area

Slide Name	Slope Type	Historic Occurrences	Documented Travel Impacts
Eighty Acres Slide	Landslide	2006: Slide movement requiring repaving 2012: Slide movement closing the outside southbound lane from January 2012 to July 2012 Per ODOT comment, closure of the outside southbound lane was common for a week up to months every few years for decades. This occurrence interval was reduced after the addition of a French drain to the northbound ditch line.	-

DETOUR AND RESTRICTED ACCESS ROUTE ALTERNATIVES

A partial or full closure could potentially disrupt:

- The commute for an estimated 1,000 who live and work on opposite sides of the slides at Eighty Acres (Based on US Census Longitudinal Origin Destination Employment (LODEs) data).
- Tourists travelling to Brookings from outside of southern Oregon or travelling from Brookings or northern California to other destinations in the study area. Compared to the other slide locations, the impact to tourism is expected to be less due to slides around Eighty Acres compared to slides at the other study locations.
- An estimated 3,900 to 4,400 daily trips
- An estimated 810 to 930 freight trips per day
- The Coastal Express transit route (3 buses in each direction per day)
- Emergency Services

One restricted access route was evaluated to by-pass US 101:

CR 636 / Meyers Creek Rd: This is the only route that potentially bypasses the Eighty Acres slide, however, the route is not accessible at either the north or south end. The access at the northern end has significant vegetation and is no longer clearly marked. The access at the southern end is blocked by a closed gate. This route is not a viable restricted access route. It Detour traffic is expected to be served by I-5, OR 42, and US 199. Estimated travel time impacts for several general origins and destinations are shown Exhibit 2. Travel along the coast, for example between Gold Beach and Brookings, is expected to be the most impacted with travel times increasing by up to 5 hours. Travel time impacts may be less for trips along US 101 that are able to reroute prior to reaching the landslide, for example trips between Coos Bay and Crescent City would only have travel time increased by about 2 hours. Trips between I-5 and the study area may have travel time increased by about 1 hour if they need to detour around the Eighty Acres slide.

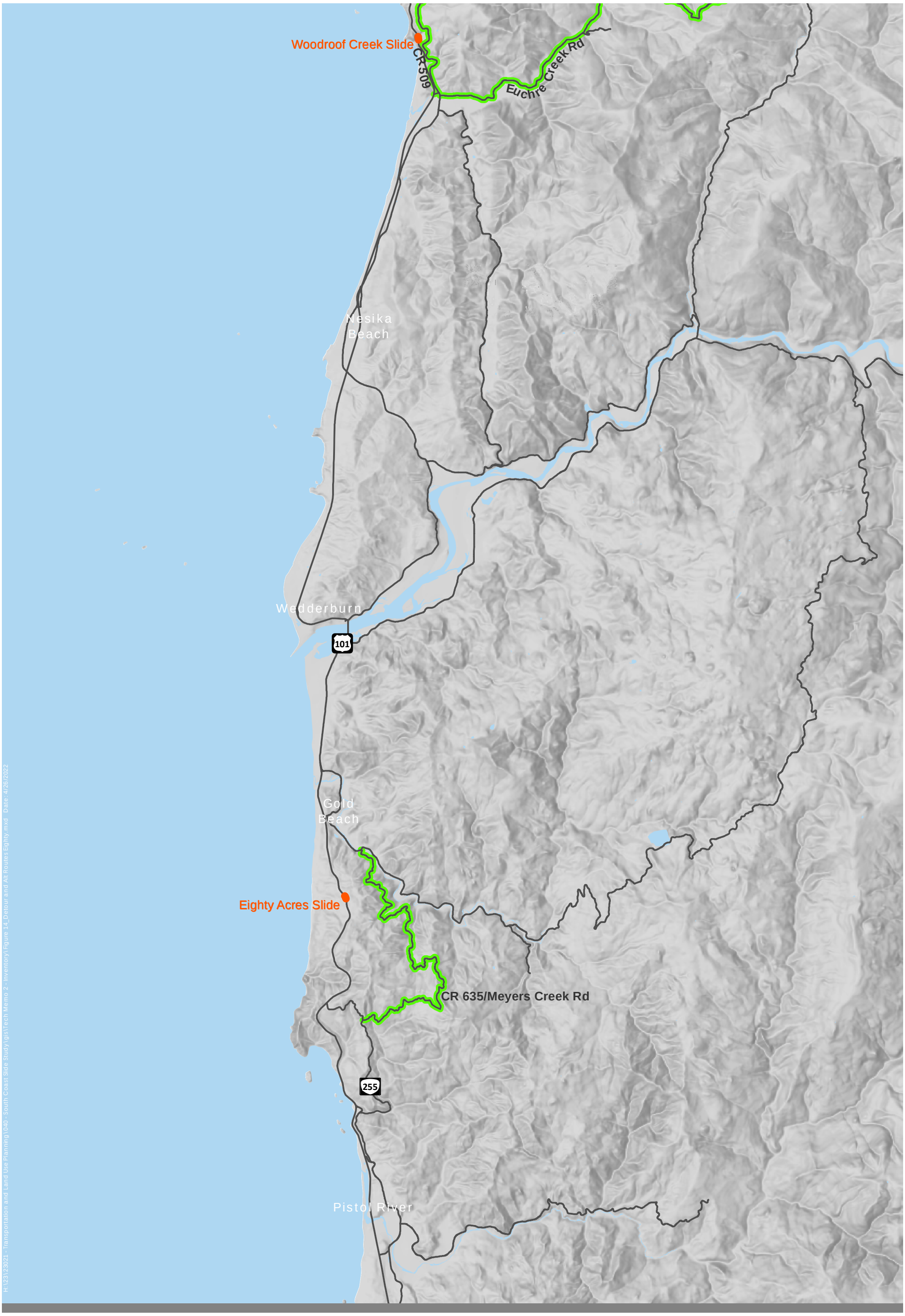
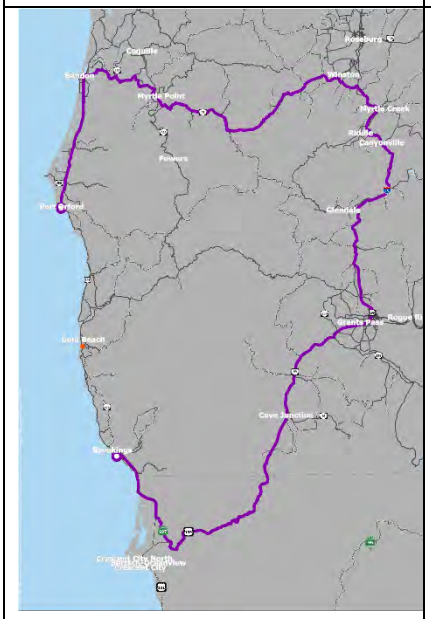
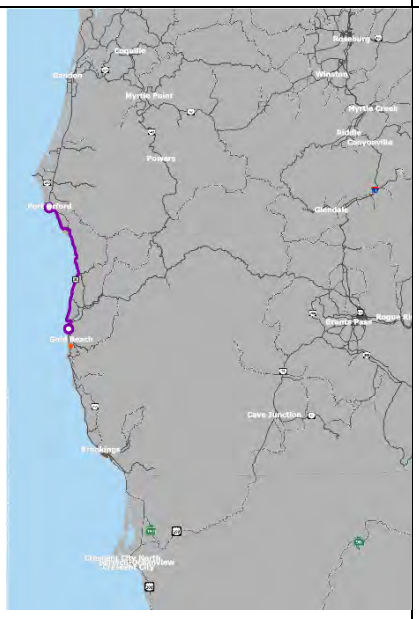
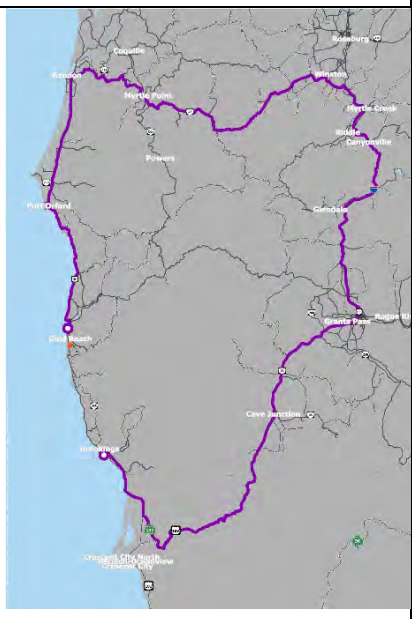


Figure 14

Evaluated Restricted Access and Detour Routes:
Eighty Acres Area

Exhibit 2: Travel Time Impacts of Detour Routes - Eighty Acres Area

Port Orford to Brookings	Port Orford to Gold Beach	Gold Beach to Brookings
US 101 Travel Time: 1 hr	US 101 Travel Time: 0.5 hrs	US 101 Travel Time: 0.5 hrs
Detour Travel Time: 5 hrs	Detour Travel Time: N/A	Detour Travel Time: 5.5 hrs
Travel Time Impact: 4 hrs	Travel Time Impact: None	Travel Time Impact: 5 hrs
		

Hooskanaden Slide Area

There are two landslides north of Brookings around the Hooskanaden Slide, as shown in Figure 15. Table 8 summarizes landslide events that impacted travel. The Hooskanaden Slide has resulted in full road closures in 1977, 1995, and most recently in 2019. Additionally, the Burnt Hill Slide resulted in a full road closure in 2005. Carpenterville Hwy provides a viable detour route, with restrictions, for most vehicles around these slide locations.

Table 8: Summary of Historic Occurrences for the Hooskanaden Slide Area

Slide Name	Slope Type	Documented Travel Impacts
Burnt Hill Slide	Landslide	2005: Slide movement resulting in full closure for 2-3 days and partial closures for one month
Hooskanaden Slide	Landslide	1977: Slide movement resulting in full closure for 3 weeks 1995: Slide movement resulting in full closure for 9 days 2006: Slide movement resulting in full closure for a short period of time 2019: Slide movement resulting in full closure for multiple weeks

DETOUR AND RESTRICTED ACCESS ROUTE ALTERNATIVES

A partial or full closure could potentially disrupt:

- The commute for an estimated 1,000 who live and work on opposite sides of the slides at Hooskanaden (Based on US Census Longitudinal Origin Destination Employment (LODEs) data).
- Tourists travelling to or from Brookings or northern California. Compared to the other slide locations, the impact to tourism is expected to be less due to slides around Hooskanaden compared to slides at the other study locations.
- An estimated 3,600 to 5,400 daily trips
- An estimated 750 to 1,100 freight trips per day
- The Coastal Express transit route (3 buses in each direction per day)
- Emergency Services

Figure 15

Evaluated Restricted Access and Detour Routes:
Hooskanaden Area

Carpenterville Highway is the only route that by-passes the slides evaluated to by-pass slides near Hooskanaden and has been used as detour route in the past. No restricted access routes are present.

- The route is about 19 miles in length with a posted speed limit of 55 mph. The route takes approximately 40 minutes to drive, compared to the about 20 minutes along US 101.
- Curve warning signage was recently installed along the route. Although there are many tight turns along the roadway, there are also numerous locations along the roadway where slower traffic could use pullouts.
- This route has oversize restrictions for loads that are overweight, over width, or long. Historically, pilot cars have been used to allow larger freight to navigate the corridor.

It should be noted that although Carpenterville Highway is outside of the study landslide locations, it is likely to be impacted by the same storm events that would result in US 101 landslides closing the highway and may not be viable during these events. There are reportedly approximately 100 landslide locations that could potentially impact Carpenterville Highway and limit engineering solutions to widen roads and address sharp curves. The route could be improved by adding destination signage to US 101 (either permanent or temporary), installing guardrail in spot locations, and lengthening pullouts in existing widened areas.

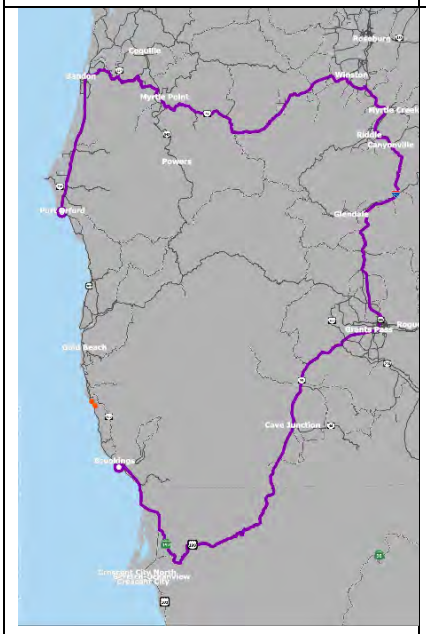
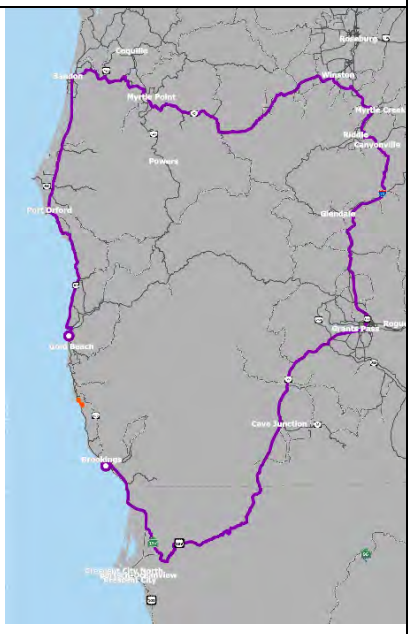
ODOT has developed a traffic control plan for the use of Carpenterville Hwy as a detour to US 101. Although the traffic control plan was specifically written for the closure of US 101 related to the Hooskanaden Slide, the close proximity of the Burnt Hill Slide would also allow the same traffic control plan to be used, if US 101 was closed due to that slide. The traffic control plan has been effectively implemented during past closures of US 101, most recently in 2019. The traffic control plan outlines:

- Initial road closure procedures.
- Where soft and hard closures should be located in relation to the Hooskanaden Slide.
- A trucking advisory message with the restrictions for using Carpenterville Hwy
- Message board signs to alert motorists to the closure of US 101 throughout the state.

Detour traffic is expected to be served primarily by I-5, SR 42, and US 199. Estimated travel time impacts for several general origins and destinations are shown in shown in Exhibit 3. Travel along the coast, for example between Gold Beach and Brookings, is expected to be the most impacted with travel times increasing by up to 5 hours. Travel time impacts may be less for trips along US 101 that are able to reroute prior to reaching the landslide, for example trips between Coos Bay and Crescent City would only have travel time increased by about 2 hours. Trips between I-5 and the study area may have

travel time increased by about 1 hour if they need to detour around the slides in the Hooskanaden area.

Exhibit 3: Travel Time Impacts of Detour Routes - Hooskanaden Area

Port Orford to Brookings	Port Orford to Gold Beach	Gold Beach to Brookings
US 101 Travel Time: 1 hr	US 101 Travel Time: 0.5 hrs	US 101 Travel Time: 0.5 hrs
Detour Travel Time: 5 hrs	Detour Travel Time: N/A	Detour Travel Time: 5.5 hrs
Travel Time Impact: 4 hrs	Travel Time Impact: None	Travel Time Impact: 5 hrs
		

REFERENCES AND PREVIOUS STUDIES

Relevant studies and reports that have been previously completed were reviewed and summarized in Table 9. A full list of resources shared by ODOT for review through this study is provided in Attachment D.

Table 9 Summary of Relevant Studies

Study	Agency	Date	Key Points
US 101 Hooskanaden Sink/Slide Traffic Control Plan (See Attachment C)	ODOT	Undated	• Description of three phases for handling traffic and freight during a landslide event that closes US 101, including initial road closure, reinforce/complete local traffic control setup, and evaluate plan • Graphics to support traffic control activities • US 101 closure alert strategy for the state variable message sign (VMS) network
Hooskanaden Slide Mitigation Options	ODOT	April 2019	• Presents three mitigation options and cost estimates for each • Construction of a suspension bridge - $302 Million • Reconstruction of Carpenterville Hwy - $440 Million • Hooskanaden slide mitigation - $281 Million
ODOT Detour Routes for US 101 (Draft Oregon Coast Highway 9 US 101 Emergency Detour Contingency Manual)	ODOT	Undated	• Scanned document provided by ODOT • Identification of detour routes along US 101, including definition of signing locations and oversize restrictions • Carpenterville Hwy is the only detour route that navigates around a study landslide location
City of Port Orford TSP	City of Port Orford	September 2002	• Summary of transportation services • Identification of high level alternatives for landslide effect mitigation • Review of US 101 alternative routes • Summary of East-West connection alternative
Last Chance Grade (Project in northern California)	CalTrans	Ongoing	• Similar project that provides ideas for project priorities, data to explore, and potential alternatives

ATTACHMENT A: SLIDE INVENTORY TECHNICAL MEMORANDUM

SHANNON & WILSON

MEMORANDUM

DATE: April 1, 2022

PROJECT: South Coast Slide Study

PROJ. #: 106381-006

SUBJECT: Technical Memorandum #2 – Slide 1 Retz Creek South (MP 304.63 to 304.81)

INTRODUCTION

Shannon & Wilson, Inc. (Shannon & Wilson) collected and reviewed all provided existing data for the Retz Creek South slide including:

- Previous Geology and Geotechnical Reports;
- ODOT provided electronic and hard copy files;
- Maps and publications from the U.S. Geological Survey (USGS) and Oregon Department of Geology and Mineral Industries (DOGAMI);
- Light Detection and Ranging (LiDAR) data;
- As-constructed plans for previous slide repairs or mitigation projects;
- ODOT maintenance records and as-constructed plans including slide stabilization and paving records;
- Historical precipitation data from the nearest available gauge station; and
- Interferometric Synthetic Aperture Radar (InSAR) ground movement data.

Our review of existing data included interviews with ODOT geotechnical engineers and roadway maintenance personnel. This memo includes a general summary of our key findings from the data collection and analysis, site plans showing the locations of existing subsurface explorations and preliminary landslide boundaries based on our review of existing data including LiDAR and InSAR data, and a list of references/reports.

KEY FINDINGS

Slide History

- **1920's:** Original US 101 highway construction.
- **1953:** US 101 embankment construction "Rocky Point – Brush Creek Section". Three-lane roadway section constructed slightly west from 1920s alignment. Retz Creek channel elevation increased 13 feet vertically (i.e. groundwater level increased). Filled in historic

Retz Creek channel to Elevation 75 feet to force water to invert of new reinforced concrete box culvert.

- **Early 1980s:** Significant slide movement of Retz Creek North, approximately 300 feet of US 101 affected.
- **June 1983:** US 101 realigned 20 to 25 feet east of 1953 alignment to mitigate slide damage at Retz Creek North. Box culvert extended 40 feet on easterly side to accommodate realignment.
- **March 1996 to October 1997:** Borings DH7210-01 to DH7210-04 drilled with installation of inclinometer and piezometer in each.
- **October 2005 to August 2006:** Borings 13776-01 to 13776-04 drilled with installation of inclinometer and piezometer in each.
- **January 2006 to March 2006:** Slide movement at Retz Creek Slide Complex and furthest west southbound lane closed at least some of this time based on photos taken January 19th and March 22nd, 2006.
- **September 2006:** Repaved US 101.
- **October 2008 to November 2009:** Retz Creek Slide Complex – North Slide Subsurface Investigation performed.
- **Early 2011:** Slide movement resulting in closure of furthest west US 101 southbound lane.
- **2012-2013:** Retz Creek North Slide stone buttress and stone column mitigation constructed.

Slide Geometry

The Retz Creek Slide is broken into two units, north and south. Retz Creek North extends directly south of the reinforced concrete box culvert (conveying Retz Creek beneath the highway embankment) and extends for an additional 1,075 feet southward along US 101. Retz Creek South begins 500 feet south of the Retz Creek North slide and extends for an additional 800 feet southward along US101 (about 950 feet along the coastline). The entire complex extends approximately 2,400 feet south of the Retz Creek box culvert along US 101 (ODOT, 2011).

Slide movement affecting US 101 has generally manifested itself in the form of southbound lane pavement distress, however a scarp has been observed in 2019 in the unpaved roadway (old highway) just east of US 101. Retz Creek North inclinometers have encountered slide planes between 15 to 60 feet below ground surface (bgs), however have also encountered deeper seated movement between 76 and 110 feet bgs. Inclinometers installed in the northbound lane did not observe movement at Retz Creek North during the monitoring

period (late 2008 to at least late 2011). The US 101 Kobernik Slide Complex Repair Unit 2 Report (ODOT, 2011), published December 2011, suggests failure planes penetrate from the head scarps within the roadway, through the embankment fill, and into the underlying sheared Mudstone and Sandstone of the Rocky Point Formation (as indicated by inclinometer data). The slide planes are noted to daylight, by observation of shear plane and gouge material, along the upper 3 to 10 feet of the steeply eroded coastal bluff to the beach. The north trending drainage of Retz Creek and its south fork is suspected to be a graben, with the blocks to the west slowly moving towards the west along the deeper-seated slide plane encountered between 76 and 110 feet bgs. The 2011 report did not include further analysis of the deeper-seated slide plane (ODOT, 2011).

Retz Creek South inclinometers have encountered two slide planes, between 13 feet to 89 feet bgs. Inclinometers installed in the US 101 northbound lane at Retz Creek South observed movement during the monitoring period, and data indicates the slide extends east of US 101. The slide may toe out below sea level as indicated by ODOT.

Exhibit 1: Aerial photo looking east at US101 within the Retz Creek South slide limits. The photo shows recent re-pavement of US 101. Photo taken February 10, 2006.

Slide Mechanics

Slide movement is likely attributed to high groundwater (including potential artesian conditions encountered in boring 13776-03), and erosion of the toe due to wave energy. Field observations of the project area indicate that slide movement in the upper decomposed, weathered and sheared zones of the Rocky Point Formation has been occurring in this area before the existing highway alignment was constructed, however depending on the geometry of failure plane, additional embankment fill could have induced additional driving forces (ODOT, 2011).

Groundwater

Groundwater has been encountered between 11 and 44 feet bgs at Retz Creek South, with one boring (13776-03) encountering artesian pressure with a head equivalent to 18 feet above roadway grade (no artesian flow noted on boring log, VWT picked up a pressure head equal to 18 feet above roadway grade). Groundwater was encountered between 30 and 34 feet below roadway grade at Retz Creek North (ODOT, 2011).

Existing Slide Mitigation

A 1,075-foot-long buttress, comprised of Stone Embankment Material (SEM) was constructed within the Retz Creek North Slide limits, to a depth of 28 to 32 feet (ODOT, 2012). Beneath the buttress, ODOT installed closely spaced 5-foot diameter stone columns to depths between 15 and 40 feet below the base of the buttress to intersect the slide plane.

Excavation of the existing US 101 embankment and replacement with lightweight fill was conceptually considered at Retz Creek South, however no mitigation has been documented at this slide area.

Precipitation Data

Typically, the groundwater level at the site is a function of the amount and intensity of precipitation that occurs within the drainage basin, amongst other factors. We have gathered precipitation data from nearby weather stations, including from precipitation monitoring instruments installed in the late 1990's at the Arizona Inn Slide location. For the Retz Creek South site, the closest precipitation gauge is USC00356784 in Port Orford, 3.5 miles NW of the project site.

PRELIMINARY LANDSLIDE BOUNDARIES

Preliminary landslide boundaries were generated using a combination of existing information, observations made during the recent site reconnaissance performed by Shannon & Wilson, and LiDAR and InSAR data analysis. The preliminary boundaries, including DOGAMI landslide boundaries from SLIDO 4.2, are shown on the Site and Exploration Plans attached to this memo.

During the recent site reconnaissance, landslide areas and features were mapped and compared to existing data. Shannon & Wilson then worked with SkyGeo to create an interactive map viewer which combined landslide inventory mapping and LiDAR data from DOGAMI, with InSAR data generated by SkyGeo. The InSAR data provided consisted of L-Band satellite data collected from March 19, 2016 to May 24, 2020. A desktop analysis of the available information and data was performed, and preliminary landslide boundaries were created and imported into the SkyGeo map viewer. Shannon & Wilson then held a meeting with SkyGeo to review the preliminary landslide boundaries and analysis methods.

REFERENCES

Boring Logs with VWP and Inclinometer Data: 13776-01, 13776-02, 13776-03, 13776-04, DH7210-01, DH7210-02, and DH7210-04

ODOT, 2011, Geotechnical Engineering and Engineering Geology Report, Retz Creek Slide Complex – North Slide, US101: Kobernik Slide Complex Repair Unit 2, Oregon Coast Highway (Hwy 9, MP 304.35 – 304.62) Curry County, dated December 2011

ODOT, 2012, Contract Plans for FFO-US101: Kobernik Slide Complex Repair Unit 2, dated March 2012

Oregon Department of Geology and Mineral Industries (DOGAMI), 2017, Statewide Landslide Information Database for Oregon, Release 4.2 (SLIDO 4.2): Available: https://gis.dogami.oregon.gov/maps/slido/.

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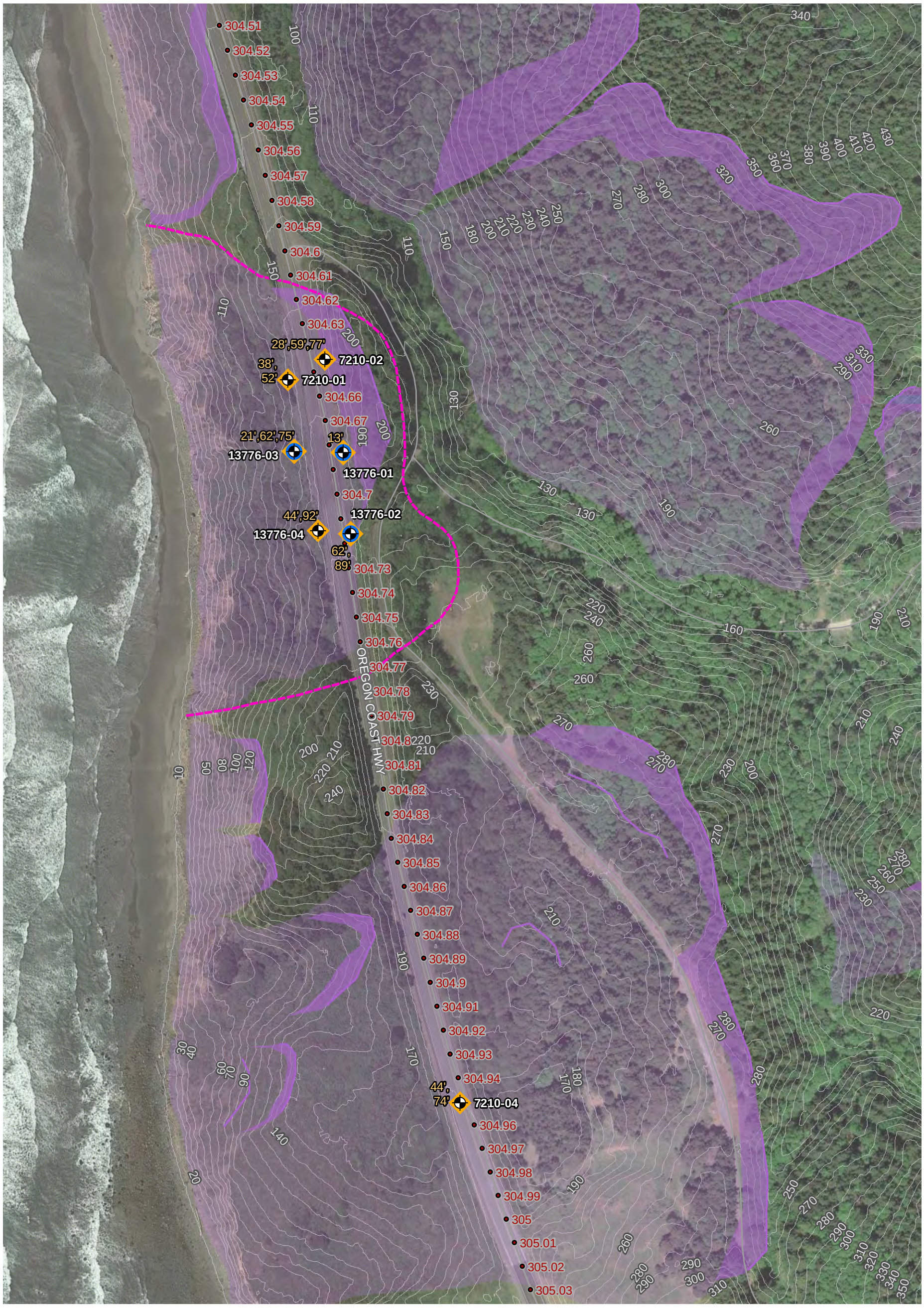

LEGEND

13' Approximate Location of Boring with Inclinometer and Shear Plane Depth

13' Approximate Location of Boring with Inclinometer, Shear Plane Depth, and Piezometer

Interpreted Slide Extents

Mapped Slide Scarp

Mapped Slide Scarp

Mapped Landslide Deposits

0 100 200 400

Scale in Feet

NOTES

1. Aerial imagery obtained through Google Maps Satellite.
2. Mapped slide features from SLIDO-4.2, obtained through DOGAMI.
3. Contours created from 2009 LiDAR data obtained through DOGAMI.

South Coast Landslide Study
Curry County, Oregon

SITE AND EXPLORATION PLAN
RETZ CREEK SOUTH

April 2022 106381

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. 1

FIG. 1

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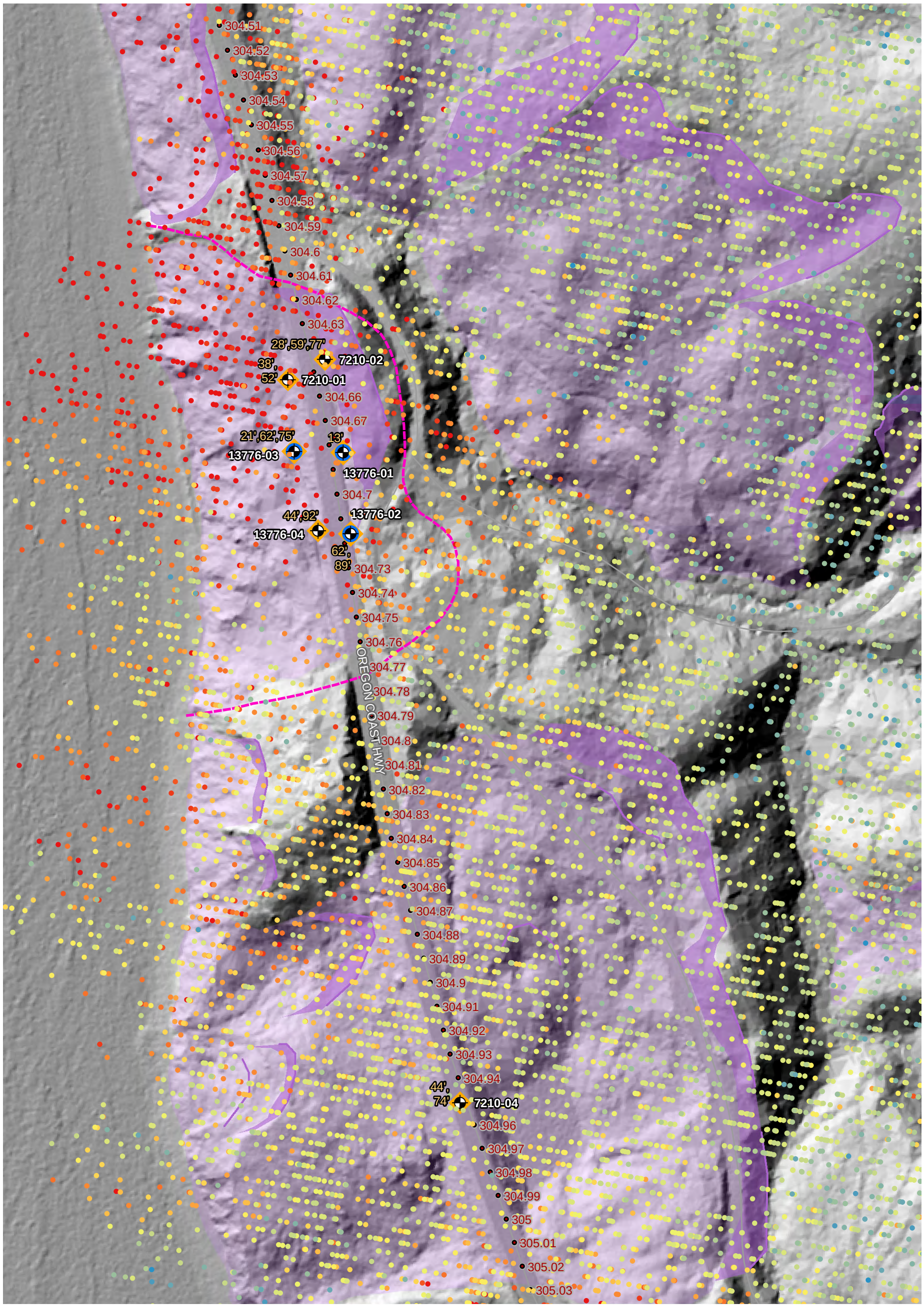

LEGEND

13' Approximate Location of Boring with Inclinometer and Shear Plane Depth

13' Approximate Location of Boring with Inclinometer, Shear Plane Depth, and Piezometer

Interpreted Slide Extents

Mapped Slide Scarp

Mapped Slide Scarp

Mapped Landslide Deposits

Displacement L-Band (mm/year)

- <-40
- -40 to -36
- -36 to -32
- -32 to -28
- -28 to -24
- -24 to -20
- -20 to -16
- -16 to -12
- -12 to -8
- -8 to -4
- -4 to 4
- 4 to 8
- 8 to 12
- 12 to 16
- 16 to 20
- 20 to 24
- 24 to 28
- 28 to 32

0 100 200 400

Scale in Feet

NOTES

1. Hillshade created from 2009 LiDAR data obtained through DOGAMI.
2. Mapped slide features from SLIDO-4.2, obtained through DOGAMI.
3. Displacement rate points from InSAR data downloaded from SkyGeo on December 3, 2021. Only points with quality of 0.3 or higher are shown.

South Coast Landslide Study
Curry County, Oregon

SITE AND EXPLORATION PLAN
RETZ CREEK SOUTH

April 2022 106381

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GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. 2

FIG. 2

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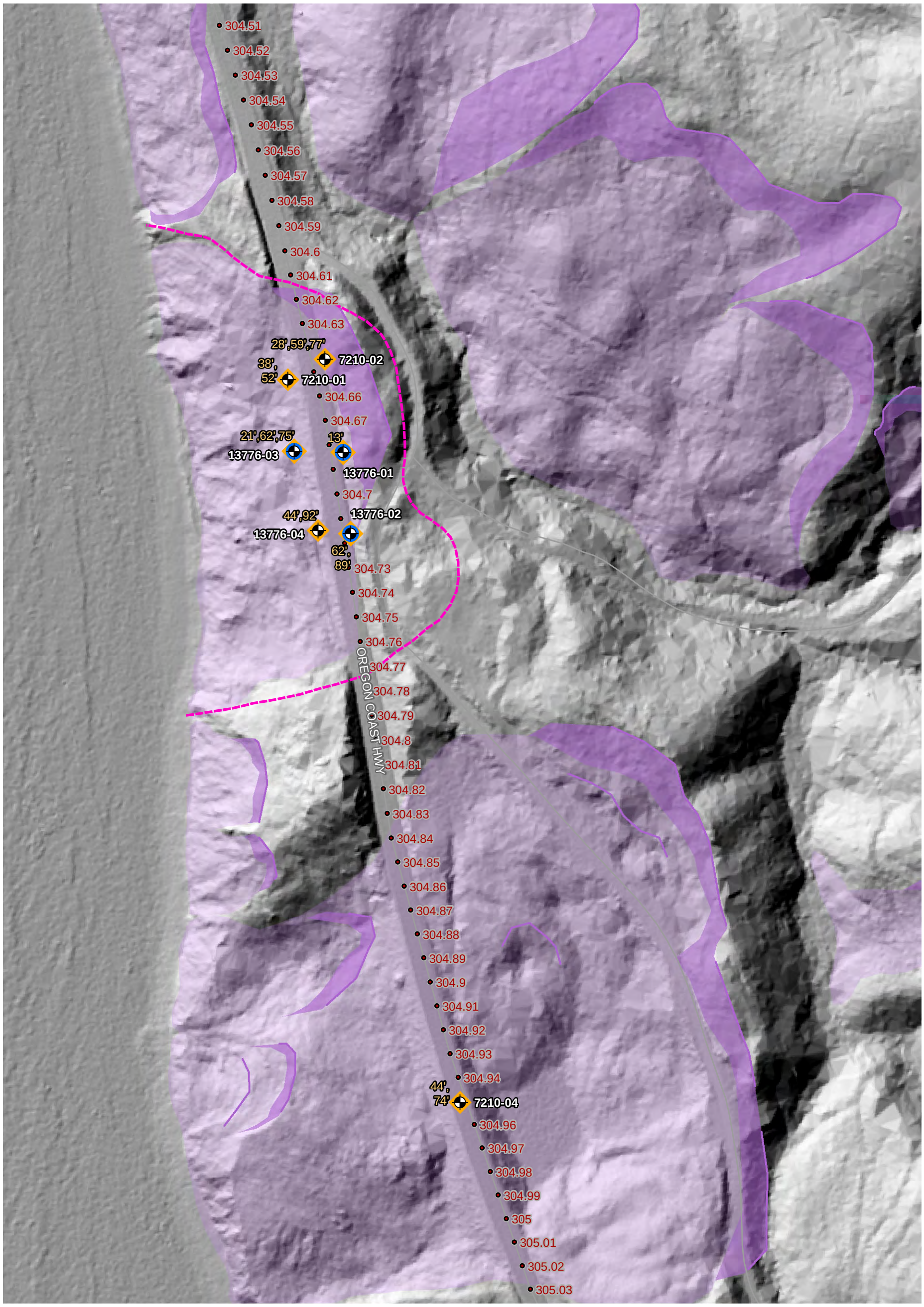

LEGEND

- 13' — Approximate Location of Boring with Inclinometer and Shear Plane Depth
- 13' — Approximate Location of Boring with Inclinometer, Shear Plane Depth, and Piezometer
- Interpreted Slide Extents
- Mapped Slide Scarp
- Mapped Slide Scarp
- Mapped Landslide Deposits

0 100 200 400

Scale in Feet

NOTES

1. Hillshade created from 2009 LiDAR data obtained through DOGAMI.
2. Mapped slide features from SLIDO-4.2, obtained through DOGAMI.

South Coast Landslide Study
Curry County, Oregon

SITE AND EXPLORATION PLAN
RETZ CREEK SOUTH

April 2022 106381

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. 3

FIG. 3

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MEMORANDUM

DATE: April 1, 2022

PROJECT: South Coast Slide Study

PROJ. #: 106381-006

SUBJECT: Technical Memorandum #2 – Slide 2 Coal Point (MP 305.47 to 305.59)

INTRODUCTION

Shannon & Wilson, Inc. (Shannon & Wilson) collected and reviewed all provided existing data for the Coal Point slide including:

- Previous Geology and Geotechnical Reports;
- ODOT provided electronic and hard copy files;
- Maps and publications from the U.S. Geological Survey (USGS) and Oregon Department of Geology and Mineral Industries (DOGAMI);
- Light Detection and Ranging (LiDAR) data;
- As-constructed plans for previous slide repairs or mitigation projects;
- ODOT maintenance records and as-constructed plans including slide stabilization and paving records;
- Historical precipitation data from the nearest available gauge station; and
- Interferometric Synthetic Aperture Radar (InSAR) ground movement data.

Our review of existing data included interviews with ODOT geotechnical engineers and roadway maintenance personnel. This memo includes a general summary of our key findings from the data collection and analysis, site plans showing the locations of existing subsurface explorations and preliminary landslide boundaries based on our review of existing data including LiDAR and InSAR data, and a list of references/reports.

KEY FINDINGS

Slide History

- **1920's:** Original US 101 highway construction.
- **1953:** US 101 embankment construction "Rocky Point – Brush Creek Section", realigning US 101 west from the existing highway.

- **Early 1980s:** Likely significant slide movement of Coal Point, prompting drilling of borings 1-83 and 2-83 in 1983 and subsequent installation of inclinometers and piezometers.
- **April 1996:** Borehole 96-01 drilled with installation of inclinometer and piezometer.
- **January 2006:** Slide movement inferred from pavement distress in photos, resulted in repaving of US 101 and closure of furthest west southbound lane.
- **December 2006:** High flow from 24-inch storm drain routed into T-drain approximately 100 feet downslope from roadway resulted in debris flow, eroding a 100-foot-wide by 10-foot-deep by 200-foot-long area. Resulted in connecting a line and piping water flow down slope to sea terrace.
- **February 2009 to March 2009:** Borings 15278CP-01 through 15278CP-04 drilled with installation of inclinometer and piezometer in each.
- **April 2012:** Slide movement inferred from photos, resulted in repaving of US 101.
- **June 2014:** Preliminary Engineering Geology Report (PEGR) for US 101: Coal Point Slide recommends a minimum of two additional boreholes upslope and downslope of roadway.
- **October 2014:** Project Charter for Coal Point Slide Repair outlines proposed mitigation strategy at Coal Point Slide to go into construction for summer 2017.
- **January 2015:** Borings 18896CP-05 and 18896CP-06 drilled with installation of inclinometer and piezometer in each.

Slide Geometry

The June 2014 PEGR described the slide as 400 feet in width at the US 101 roadway prism, and 800 feet wide at the coastline (ODOT, 2014a). The horizontal length of the slide is estimated to be approximately 1,500 to 1,600 feet, reaching up to at least 1,000 feet upslope of US 101 (towards the east, and upslope of the old US 101).

DOGAMI's SLIDO shows several mapped scarps in the area, indicating the slide discussed in the June 2014 PEGR may be part of a larger slide complex. The PEGR states the possibility for the slide limits to extend out of the mapped slide deposits and into the Poverty Ridge beach terrace deposits (ODOT, 2014a), likely referring to the scarps outlined in SLIDO east of the major head scarp.

Slide planes have been observed in all completed borings (except 18896CP-06), from depths of approximately 28 feet to 83 feet below ground surface. Slide planes generally persist through contacts between the Residual Soil and Sandstone of the Rocky Point Formation. However, a deeper failure plane has been observed within the sheared Sandstone of the

Rocky Point Formation encountered in borings 15278CP-01, 02, 04, and 05. A 1986 interoffice memo states movement is observed at the base of the fill (noted at approximately 8 to 20 feet below roadway grade), in addition to deeper planes that are likely too expensive to mitigate (OSHD, 1986). October 2014 project charter summarizes the slide plane depth is about 35 feet below ground surface (bgs) on the north end, 80 to 90 feet bgs in the center, and 60 feet bgs on the south end (ODOT, 2014b).

Exhibit 1: Aerial photo looking northeast at US 101 within the Coal Point slide limits. The photo shows recent re-pavement of US101 due to slide activity. Photo taken February 10, 2006.

Slide Mechanics

Slide movement is likely attributed to elevated groundwater during high precipitation events, as well as erosion of the toe due to wave energy. DOGAMI has the slide aged at least 150 years, and therefore it can be inferred that movement in the slide zone has been occurring prior to construction of US 101.

Groundwater

Groundwater has been encountered between 9 and 32 feet bgs in the upper piezometers, and between 33 and 80 feet below the ground surface in the deeper piezometers installed in borings 15278CP-01, 03, 04, 05 and 06. Boring 96-01 showed a range of groundwater levels within the inclinometer tube ranging from 21 feet to 108.5 feet bgs (ODOT 2014a).

Existing Slide Mitigation

The Project Charter for Coal Point Slide Repair (ODOT, 2014b) proposed a shear key buttress where there is adequate room to stage traffic on the north end (250 feet long) and drilled stone columns on the middle and south end (300 feet long) where the depth of the slide plane and geometric constraints prevent extensive rerouting of traffic. The charter outlined a final Geotechnical Report submittal of Fall 2016, and a bid date of April 2017. We understand the project was ultimately dropped before a Geotechnical Report was prepared because the estimated mitigation cost exceeded the project budget. However we do understand two boreholes were drilled in 2015 per recommendation of the June 2014 PEGR.

Precipitation Data

Typically, the groundwater level at the site is a function of the amount and intensity of precipitation that occurs within the drainage basin, amongst other factors. We have gathered precipitation data from nearby weather stations, including from precipitation monitoring instruments installed in the late 1990's at the Arizona Inn Slide location. For the Coal Point site, the closest precipitation gauge is USC00356784 in Port Orford, 4.5 miles NW of the project site.

PRELIMINARY LANDSLIDE BOUNDARIES

Preliminary landslide boundaries were generated using a combination of existing information, observations made during the recent site reconnaissance performed by Shannon & Wilson, and LiDAR and InSAR data analysis. The preliminary boundaries, including DOGAMI landslide boundaries from SLIDO 4.2, are shown on the Site and Exploration Plans attached to this memo. Although the LiDAR and InSAR data analysis indicates the slide extends approximately 1,270 feet along US 101, our site reconnaissance and discussions with ODOT personnel indicate slide movements at roadway grade have only been problematic along the southern 500 feet of this slide area.

During the recent site reconnaissance, landslide areas and features were mapped and compared to existing data. Shannon & Wilson then worked with SkyGeo to create an interactive map viewer which combined landslide inventory mapping and LiDAR data from DOGAMI, with InSAR data generated by SkyGeo. The InSAR data provided consisted of L-Band satellite data collected from March 19, 2016 to May 24, 2020. A desktop analysis of the available information and data was performed, and preliminary landslide boundaries were created and imported into the SkyGeo map viewer. Shannon & Wilson then held a meeting with SkyGeo to review the preliminary landslide boundaries and analysis methods.

The Coal Point landslide is located within and adjacent to larger mapped landslide areas according to DOGAMI (2017). InSAR data indicates significant surface displacement outside of the Coal Point slide boundaries which may be associated with a larger or separate landslide.

REFERENCES

Boring Logs with VWP and Inclinometer Data: 1-83, 2-83, 96-01, 15278CP-01 through 15278CP-04, 18896CP-05, and 18896CP-06

OSHD, 1986, Interoffice Memo, Slide Monitoring along Coast Highway – Highway #9, Oregon State Highway Division, dated April 9, 1986

ODOT, 2006, Site Visit Memo detailing T-Drain erosion and subsequent drainage recommendations, dated December 1, 2006

ODOT, 2014a, Preliminary Engineering Geology Report, US 101: Coal Point Slide, Oregon Coast Highway (No. 9) M.P. 305.4, Curry County, Oregon, dated June 2014

ODOT, 2014b, Project Charter KN18896 – US101: Coal Point Slide Repair, dated October 13, 2014

Oregon Department of Geology and Mineral Industries (DOGAMI), 2017, Statewide Landslide Information Database for Oregon, Release 4.2 (SLIDO 4.2): Available: https://gis.dogami.oregon.gov/maps/slido/.

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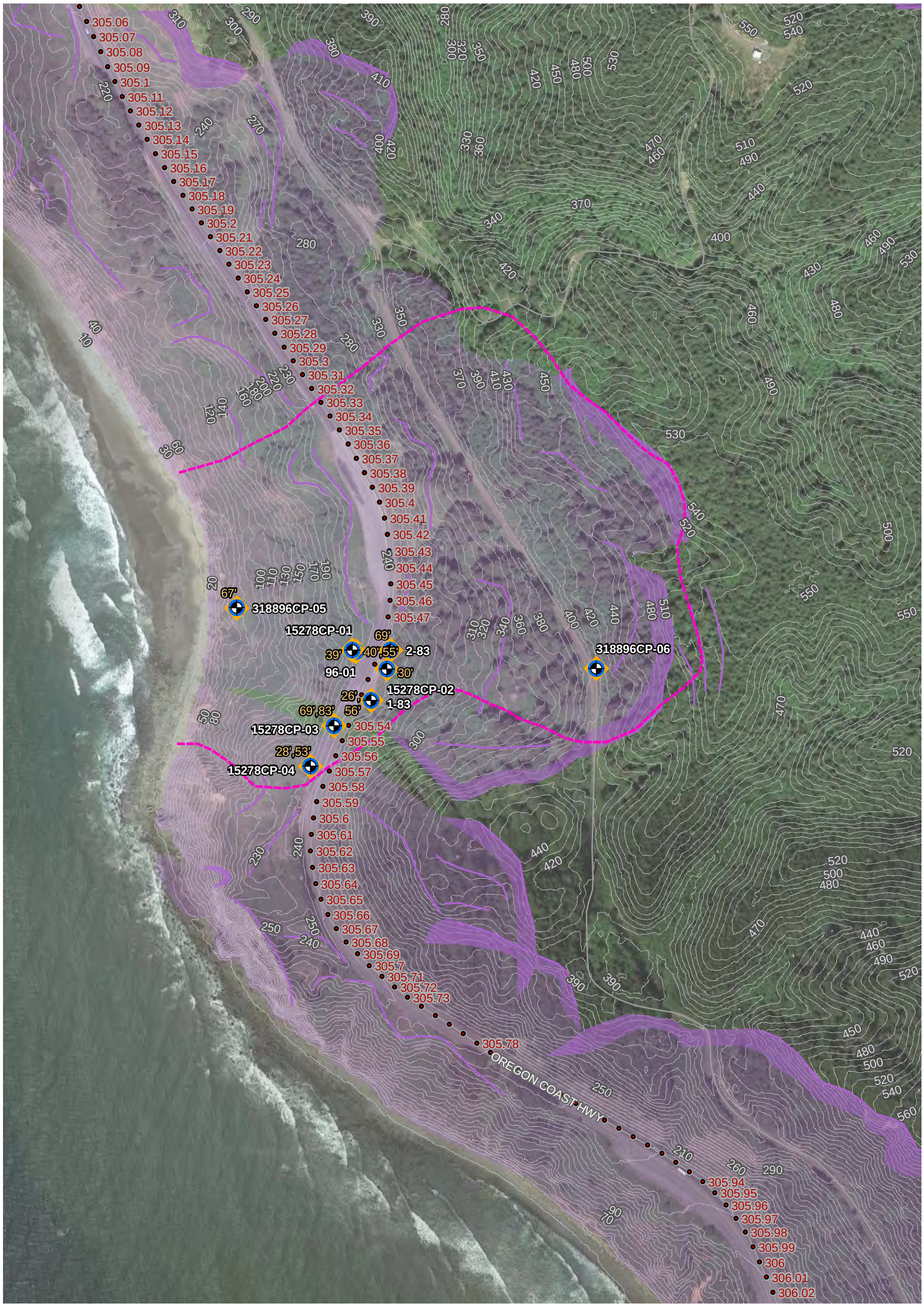

LEGEND

13' Approximate Location of Boring with Inclinometer, Shear Plane Depth, and Piezometer

Interpreted Slide Extents

Mapped Slide Scarp

Mapped Slide Scarp

Mapped Landslide Deposits

0 150 300 600

Scale in Feet

NOTES

1. Aerial imagery obtained through Google Maps Satellite.
2. Mapped slide features from SLIDO-4.2, obtained through DOGAMI.
3. Contours created from 2009 LiDAR data obtained through DOGAMI.

South Coast Landslide Study
Curry County, Oregon

SITE AND EXPLORATION PLAN
COAL POINT

April 2022 106381

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. 1

FIG. 1

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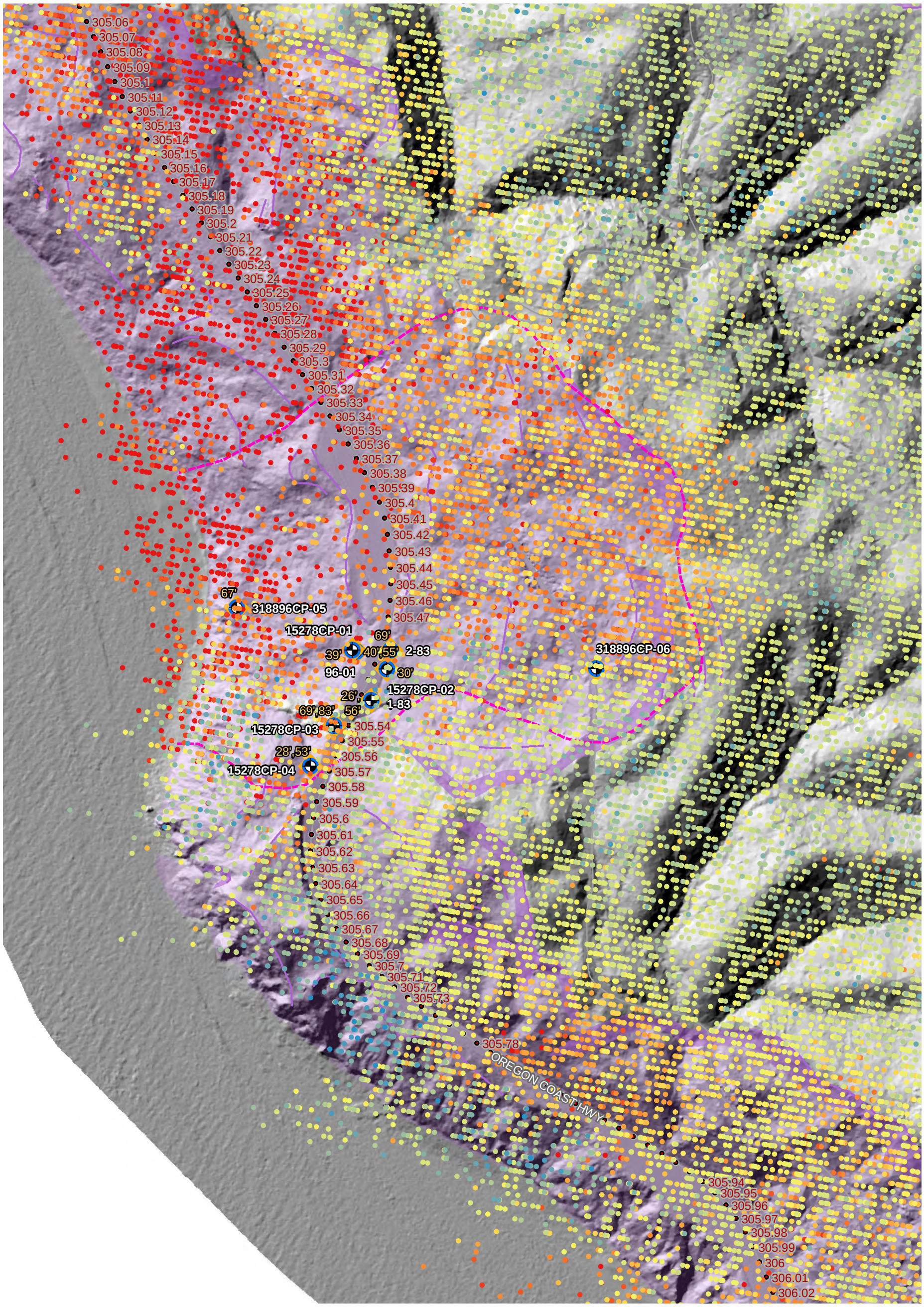

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Scale in Feet

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2. Mapped slide features from SLIDO-4.2, obtained through DOGAMI.
3. Displacement rate points from InSAR data downloaded from SkyGeo on December 3, 2021. Only points with quality of 0.3 or higher are shown.

Displacement L-Band (mm/year)				
<-40	-36 to -32	-20 to -16	-4 to 4	16 to 20
-40 to -36	-32 to -28	-16 to -12	4 to 8	20 to 24
	-28 to -24	-12 to -8	8 to 12	24 to 28
	-24 to -20	-8 to -4	12 to 16	28 to 32

South Coast Landslide Study
Curry County, Oregon

SITE AND EXPLORATION PLAN
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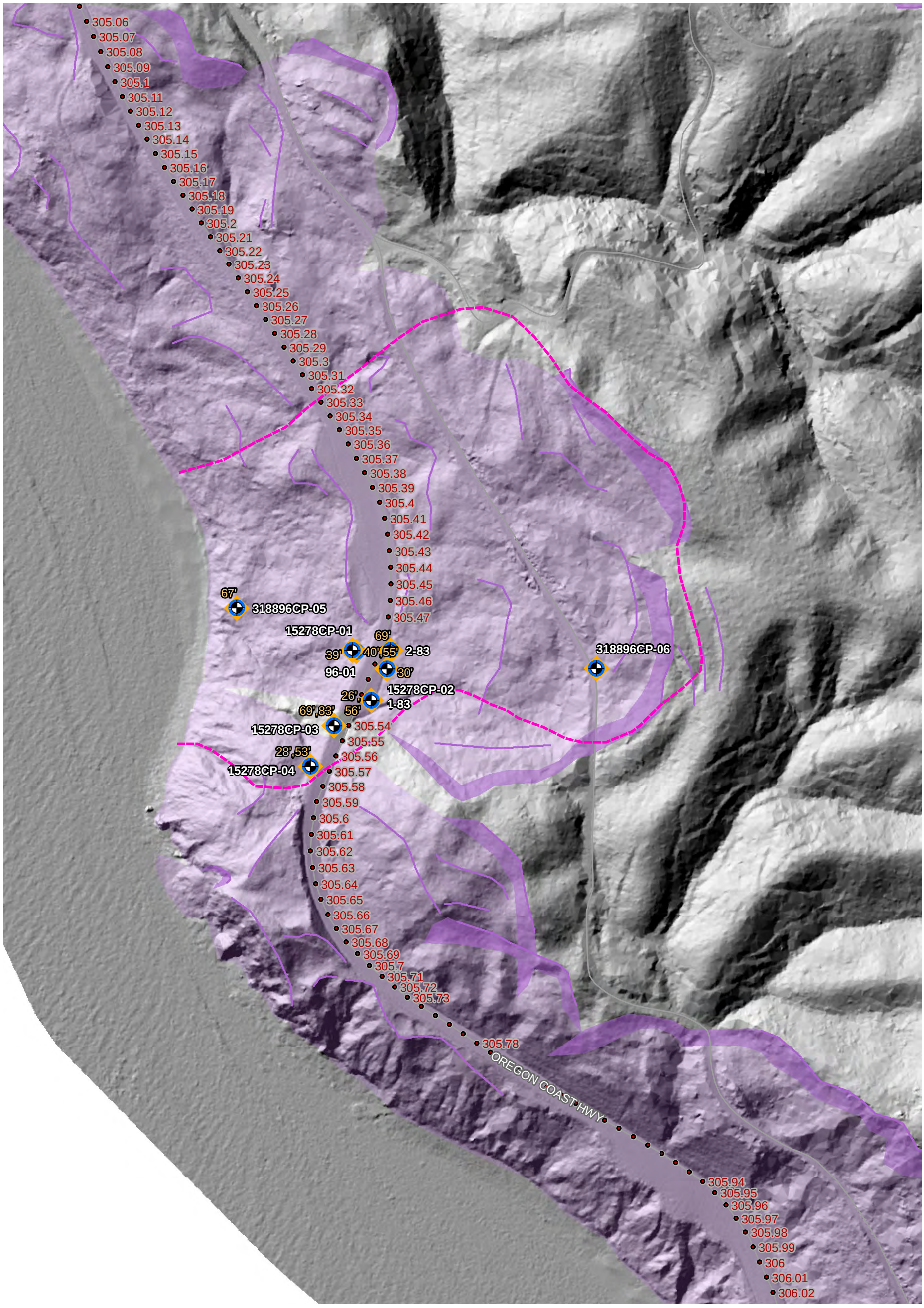
FIG. 2

FIG. 2

Filename: T:\Projects\PDX\106000s\106381_ODOT R3 South C\Avmxd\SitePlan2Coal_10.7.mxd Date: 3/24/2022 Login: AEH



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Interpreted Slide Extents

Mapped Slide Scarp

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Mapped Landslide Deposits

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Scale in Feet

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2. Mapped slide features from SLIDO-4.2, obtained through DOGAMI.

South Coast Landslide Study
Curry County, Oregon

SITE AND EXPLORATION PLAN
COAL POINT

April 2022 106381

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. 3

FIG. 3

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MEMORANDUM

DATE: April 1, 2022

PROJECT: South Coast Slide Study

PROJ. #: 106381-006

SUBJECT: Technical Memorandum #2 – Slide 3 North Brush Creek Hump (MP 306.08 to 306.16)

INTRODUCTION

Shannon & Wilson, Inc. (Shannon & Wilson) collected and reviewed all provided existing data for the North Brush Creek Hump slide including:

- Previous Geology and Geotechnical Reports;
- ODOT provided electronic and hard copy files;
- Maps and publications from the U.S. Geological Survey (USGS) and Oregon Department of Geology and Mineral Industries (DOGAMI);
- Light Detection and Ranging (LiDAR) data;
- As-constructed plans for previous slide repairs or mitigation projects;
- ODOT maintenance records and as-constructed plans including slide stabilization and paving records;
- Historical precipitation data from the nearest available gauge station; and
- Interferometric Synthetic Aperture Radar (InSAR) ground movement data.

Our review of existing data included interviews with ODOT geotechnical engineers and roadway maintenance personnel. This memo includes a general summary of our key findings from the data collection and analysis, site plans showing the locations of existing subsurface explorations and preliminary landslide boundaries based on our review of existing data including LiDAR and InSAR data, and a list of references/reports.

KEY FINDINGS

Slide History

- **1920's:** Original US 101 highway construction.
- **1953:** US 101 embankment construction "Rocky Point – Brush Creek Section", realigning US 101 west from the existing highway.
- **July 1989:** Site inspection resulted in observation of highway "humping".

- **March 1995 to April 1995:** Borings DH3892-01 to DH3892-06 were drilled for the Brush Creek Bridge.
- **May 1997:** Braclin and Yeager Excavating cut upslope of roadway, near Brush Creek Bridge, to a 1.5H:1V slope. Newly cut slope failed after 4 inches of rainfall fell over Memorial Day weekend.
- **Late 1990's:** Excavated the slope associated with the May 1997 failure along slide plane to 2H:1V and placed a 2-meter-thick rock blanket below slide plane (can be seen from google earth).
- **January 2003:** Boring HH-01 drilled with installation of inclinometer and piezometer.
- **March 2006:** Hump in furthest east northbound lane of US 101 resulted in lane closure (based on photos).
- **2011:** Slide mitigation consisting of shear key buttress constructed. Tension cracks and scarps observed upslope of buttress after construction, indicating the slide extends to at least the old US 101 roadway. Slope movement observed downslope of US 101, possibility of future encroachment on roadway.

Slide Geometry

A variety of documents discuss several shallow instabilities along the west facing cut slope just north of the Brush Creek Bridge. In the 1995 Geology Report of Foundation Exploration for Brush Creek Bridge (ODOT, 1995b), the author refers to a slope failure located approximately 0.3 miles north of the site (near the existing shear key buttress). This slide was 500 feet long, with the head scarp approximately 100 feet above US 101 and was "stabilized" with a buttress constructed by the maintenance crew.

In 1996, the cut slope north of Brush Creek Bridge was excavated to a 1H:1V slope but experienced stability problems and sloughing near the top. The cut slope was re-graded in early 1997 to a 1.5H:1V slope, leaving a 30-foot-long by 40-foot-wide bench at the base of the slope. In May 1997, the 1.5H:1V cut slope experienced two minor slides after 4 inches of rainfall fell. The area of sliding was entirely above the bench. Cracks appeared at the top of the cut and bulging was observed lower down on the cut. The northern slide was about 100 feet wide and 160 feet long. It had a 6- to 10-foot-high head scarp and toe bulge, with a slide plane up to 15 to 20 feet deep, confined to a fractured mudstone layer. The southern slide was about 80 feet wide and 60 feet long, with a head scarp generally less than 2 feet high. This slide was also confined to the highly fractured mudstone unit (ODOT, 1998).

The 2003 boring HH-01 drilled to 40 feet below roadway grade showed potential shear planes at 15 feet and 30 feet below roadway grade.

DOGAMI's SLIDO shows the mapped head scarp of a larger slide complex approximately 500 feet upslope from US 101, and about 100 to 200 feet upslope from the old US 101 highway. This head scarp persists about 1,500 feet running parallel alongside US 101.

Exhibit 1: Photo looking north at pavement distress within the North Brush Creek Slide limits. Photo taken March 22, 2006.

Slide Mechanics

Failure mechanisms for the shallower slides are likely attributed to poor rock quality within the cut slope. The two major rock types, extremely fractured Gray Wacke Sandstone and very friable Mudstone, with the minor presence of Shale, occur in alternating layers with an average strike and dip of N20E, 58W. A large fault zone (up to 15 meters wide) trending northwest to southeast dips steeply to the southwest. The Memorial Day 1997 slide originated within this fault zone. The 1995 Brush Creek Bridge GER states the same rock types and orientations observed at the Brush Creek Bridge are present at the cut slope north of the site, based on rock outcroppings (ODOT, 1995b).

July 1989 site inspection notes state the primary failure mode of a slide causing highway bulging within the area is due to orientation of bedding planes in the bedrock of the hillside upslope from US 101, measuring a strike and dip of N45E, 50NW (ODOT, 1989). The memo states bedding planes daylight as a ridge about 150 feet upslope from the highway. Notches exist at the ridgetop, collecting rainfall, which subsequently flows through the bedding planes.

The March 1998 ODOT interoffice memo regarding the 1997 cut slope failure stated the primary failure mechanism was intense rainfall saturated the fine-grained mudstone material on the steep slope, increasing the pore-water pressure, and causing failure (ODOT, 1998).

Groundwater

Water in the form of springs was observed at the base of 1997 slide's toe bulge, and springs have been observed along the roadside at the base of the cut slope in wetter months (ODOT, 1998). Surficial springs have been noted to dry up in the dryer months. September 2011 photos during shear key buttress excavation, an excavation approximately 15 to 20 feet below roadway grade, indicated a dry excavation with no signs of dewatering techniques. However, boring HH-01 observed groundwater within the upper 1.5 feet of the borehole in January 2003.

The June 29, 1995 ODOT Brush Creek Bridge interoffice memo states groundwater was not encountered in any of the Brush Creek Bridge geotechnical explorations and that groundwater is likely flowing along sandstone bedding planes (ODOT, 1995a). However, the published Brush Creek Bridge geology report states groundwater was observed around elevation 15 feet (26 to 50 feet below ground surface) measured by two stand-pipe piezometers (ODOT, 1995b).

Existing Slide Mitigation

Prior to 2011, slope cutting, rock blankets, and buttresses have been constructed over the years to mitigate the shallow cut slope failures. Dewatering methods were not recommended for the shallow slide mitigation due to the extreme weathering of the subsurface materials and limited budget during projects.

A 600-foot-long Stone Embankment Material (SEM) shear key buttress was constructed in 2011 by ODOT district maintenance. Based on design plans, the buttress was designed to extend approximately 30 to 80 vertical feet upslope with a finished grade of 1.5H:1V, a 0- to 10-foot thickness at the top, and keyed approximately 15 to 20 feet below roadway grade

with a base width of 25 feet (ODOT, 2010). However due to ground cracking observed during construction, available as-constructed plans indicate an approximate 250-foot length of the buttress was extended an additional 40 feet upslope (ODOT, 2011). Based on site photos, cracking and scarps have been observed upslope of the buttress after construction. No subsurface explorations were performed specifically for the mitigation and no stability calculations were documented.

Precipitation Data

Typically, the groundwater level at the site is a function of the amount and intensity of precipitation that occurs within the drainage basin, amongst other factors. We have gathered precipitation data from nearby weather stations, including from precipitation monitoring instruments installed in the late 1990's at the Arizona Inn Slide location. For the North Brush Creek Hump site, the closest precipitation gauge is USC00356784 in Port Orford, 5.1 miles NW of the project site.

PRELIMINARY LANDSLIDE BOUNDARIES

Preliminary landslide boundaries were generated using a combination of existing information, observations made during the recent site reconnaissance performed by Shannon & Wilson, and LiDAR and InSAR data analysis. The preliminary boundaries, including DOGAMI landslide boundaries from SLIDO 4.2, are shown on the Site and Exploration Plans attached to this memo.

During the recent site reconnaissance, landslide areas and features were mapped and compared to existing data. Shannon & Wilson then worked with SkyGeo to create an interactive map viewer which combined landslide inventory mapping and LiDAR data from DOGAMI, with InSAR data generated by SkyGeo. The InSAR data provided consisted of L-Band satellite data collected from March 19, 2016 to May 24, 2020. A desktop analysis of the available information and data was performed, and preliminary landslide boundaries were created and imported into the SkyGeo map viewer. Shannon & Wilson then held a meeting with SkyGeo to review the preliminary landslide boundaries and analysis methods.

The North Brush Creek landslide is located within and adjacent to larger mapped landslide areas according to DOGAMI (2017). InSAR data indicates significant surface displacement outside of the North Brush Creek slide boundaries which may be associated with a larger or separate landslide.

REFERENCES

Boring Logs with VWP and Inclinometer Data: DH3892-01 through DH3892-06 and HH-01

ODOT, 1989, Site Inspection Notes, dated July 1989

ODOT, 1995a, Geology Report on Foundation Exploration, Brush Creek Bridge, No. 7785, Oregon Coast Highway, #9, (U.S. 101) M.P. 306.20 – 306.50, Curry County, dated June 29, 1995

ODOT, 1995b, Geology Report of Foundation Exploration, Brush Creek Bridge, Oregon Coast Highway (U.S. 101), Curry County, dated November 9, 1995

ODOT, 1997, Brush Creek Bridge Supplemental Report, Geology of the Northern Cut-Slope, dated October 10, 1997

ODOT, 1998, Geotechnical Recommendation, Brush Creek Cutslope Failure, Sta. 8+380 (Metric), Brush Crk. Bridge Oregon Coast Hwy #9, dated March 4, 1998

ODOT, 2010, Revised Contract Plans, US101: Kobernik Slide Complex, Unit 1, Oregon Coast Highway, Curry County, August 2010

ODOT, 2011, Typical Section Revision Due to 19 JUL 11 Ground Cracking, US 101: Kobernik Slide Complex Unit 1, North Brush Creek Hump, annotated by Pete Castro, July 2011.

Oregon Department of Geology and Mineral Industries (DOGAMI), 2017, Statewide Landslide Information Database for Oregon, Release 4.2 (SLIDO 4.2): Available: https://gis.dogami.oregon.gov/maps/slido/.

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LEGEND

- Approximate Location of Boring
- 13' Approximate Location of Boring with Inclinometer and Shear Plane Depth
- Approximate Location of Boring with Piezometer
- Interpreted Slide Extents
- Mapped Slide Scarp
- Mapped Slide Scarp
- Mapped Landslide Deposits

0 100 200 400

Scale in Feet

NOTES

1. Aerial imagery obtained through Google Maps Satellite.
2. Mapped slide features from SLIDO-4.2, obtained through DOGAMI.
3. Contours created from 2009 LiDAR data obtained through DOGAMI.

South Coast Landslide Study
Curry County, Oregon

SITE AND EXPLORATION PLAN
NORTH BRUSH CREEK HUMP

April 2022 106381

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. 1

FIG. 1

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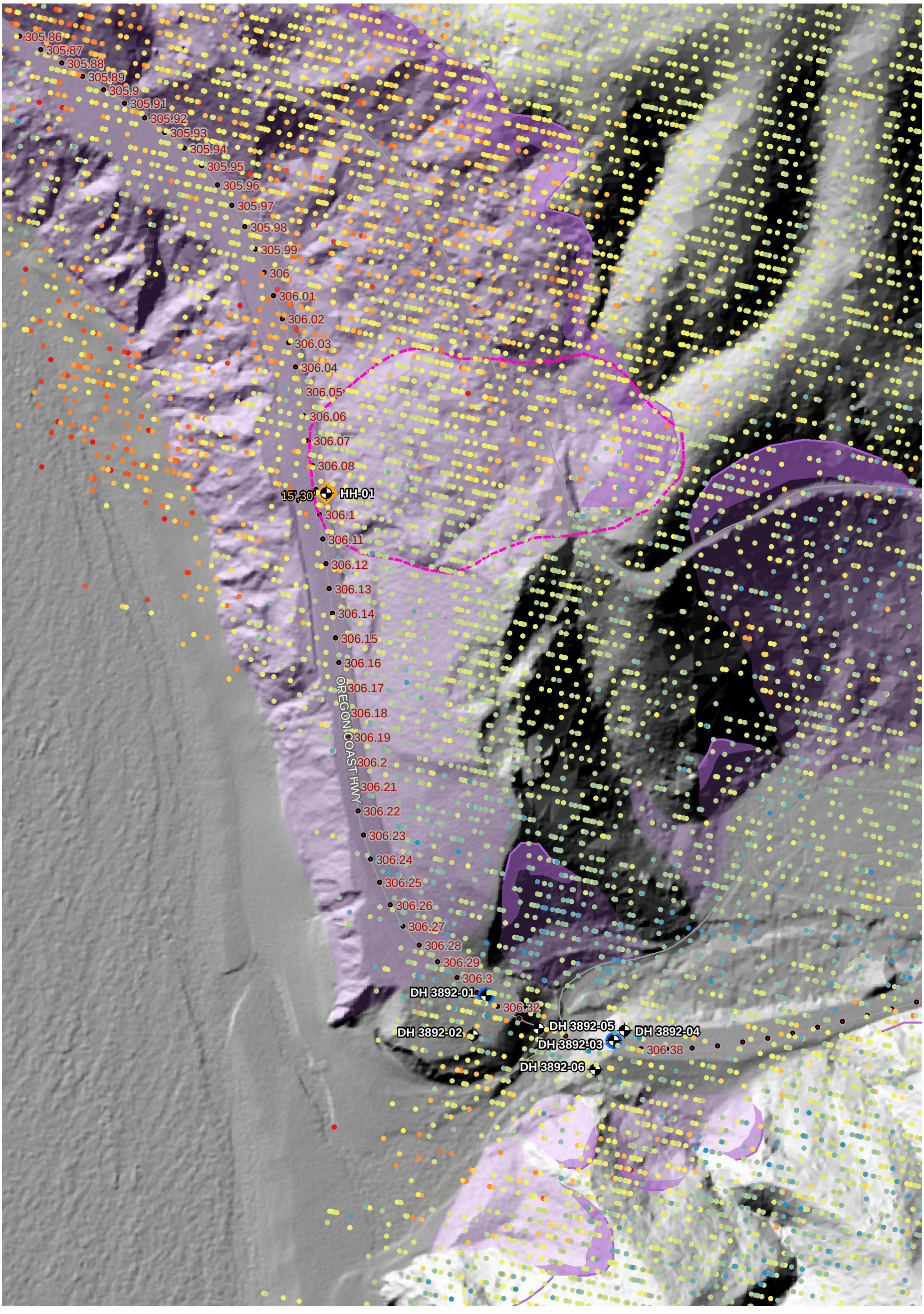

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Displacement L-Band (mm/year)

<-40	-36 to -32	-20 to -16	-4 to 4	16 to 20
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Scale in Feet

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South Coast Landslide Study
Curry County, Oregon

SITE AND EXPLORATION PLAN
NORTH BRUSH CREEK HUMP

April 2022 106381

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. 2

FIG. 2

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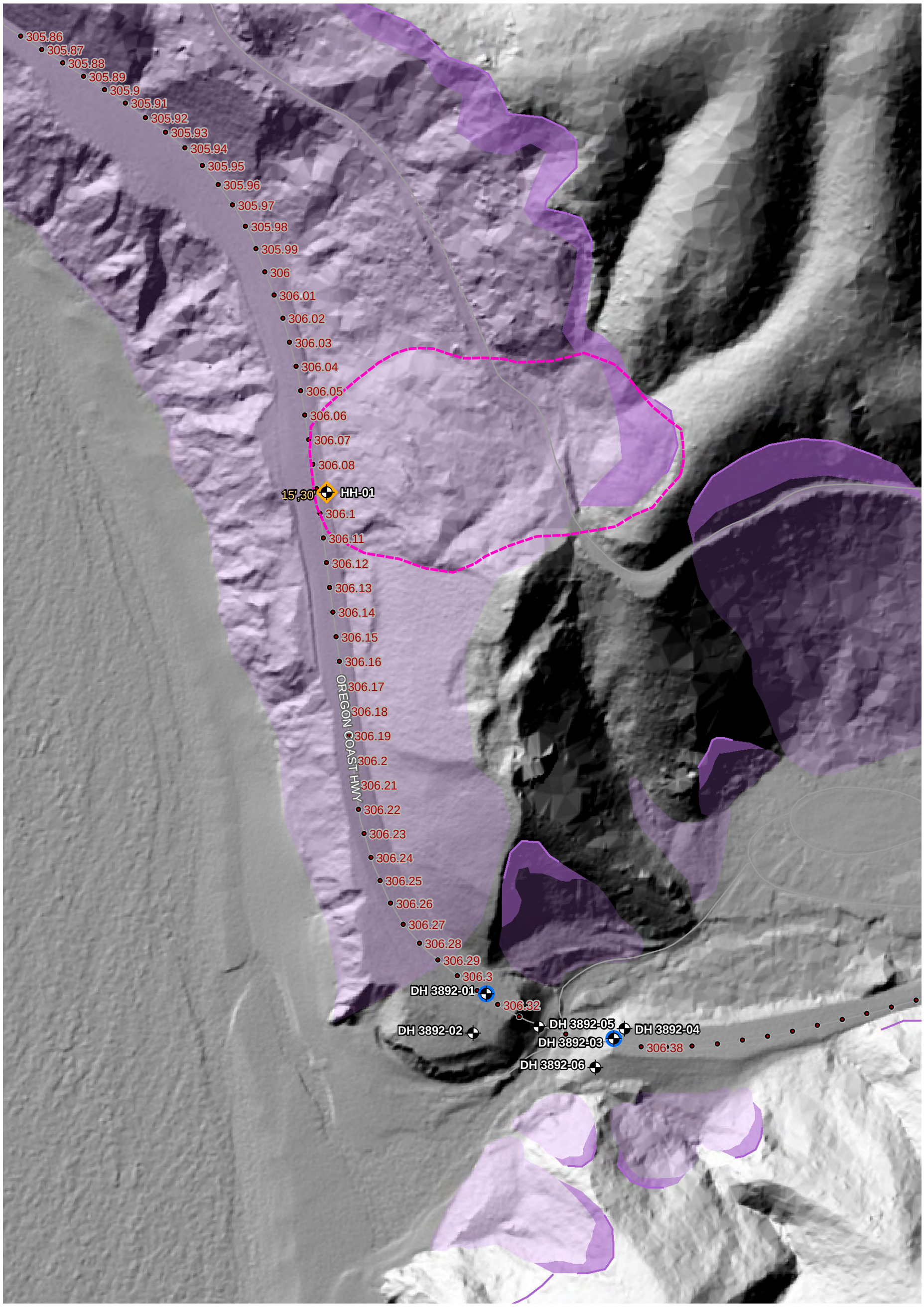

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0 100 200 400
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South Coast Landslide Study
Curry County, Oregon

SITE AND EXPLORATION PLAN
NORTH BRUSH CREEK HUMP

April 2022 106381

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. 3

FIG. 3

SHANNON & WILSON

MEMORANDUM

DATE: April 1, 2022

PROJECT: South Coast Slide Study

PROJ. #: 106381-006

SUBJECT: Technical Memorandum #2 – Slide 4 Brush Creek (MP 310.24)

INTRODUCTION

Shannon & Wilson, Inc. (Shannon & Wilson) collected and reviewed all provided existing data for the Brush Creek slide including:

- Previous Geology and Geotechnical Reports;
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KEY FINDINGS

Slide History

- **1920's:** Original US 101 highway construction.
- **1953:** Current alignment US 101 construction "Rocky Point – Brush Creek Section", realigning US 101 westward of original alignment.

- **January 2003:** Rockfall event from south end of rock cut slope along US 101 northbound producing 60 yards of material on northbound lane of US 101.
- **September 2004:** Borings 9086-01 and 9086-02 drilled upslope from US 101 at crest of rock cut slope along US 101 northbound.
- **January 12, 2006:** Head scarp observed (from photos) above coastal bluff indicating movement towards ocean.
- **Summer 2011:** Slope protection mat installed along rock cut upslope of US 101 northbound.
- **March 29, 2012:** Large rockfall/slide event upslope of US 101 northbound resulting in 200 to 300 cubic yards of material blocking roadway, primarily northbound lanes. Entire US 101 closed for less than one day, US 101 northbound closed for about 10 days. Although this is along the same section of US 101 affected by the Brush Creek slide, it is not connected to or related to the slide.
- **April 5, 2012:** Head scarp observed (from photos) above coastal bluff indicating movement towards ocean.

Slide Background

The US 101 alignment in the slide area is in a through cut (i.e. cut slopes of both sides of roadway). The rock cut upslope of US 101 northbound is responsible for producing multiple road closures from rockfall events. The cut has generally been raveling since its construction in the 1950/60s, and in summer 2011 a slope protection mat was installed along the most active portion of the cut slope. A large rockfall event occurred in late March 2012, blocking primarily the northbound (furthest east) lanes (ODOT, 2012).

The Brush Creek slide is not related to the rockfall, but rather the slide that has been observed to begin from the head scarp originating in the US 101 southbound lane, daylighting somewhere on the coastal bluff towards the ocean. Separate, additional slide movement was observed directly south on January 12, 2006 based on a Site Visit Memo by Rick Kobernik (ODOT, 2006). This movement is not associated with the Brush Creek Slide.

Slide Geometry

The observed scarp along the roadway may be a secondary scarp of the larger slide complex mapped by DOGAMI, that extends approximately 350 feet upslope from the roadway. This slide is mapped approximately 200 feet wide by 800 feet long, from head scarp to the toe at the coast. The slide stemming from the secondary scarp within the roadway would only be approximately 50 to 100 feet wide. It is not documented where this slide would toe out, nor the depth to failure plane.

Groundwater

Groundwater was not documented in the two borings drilled from the crest of the cut slope above US 101 northbound, however a picture shows wet pavement in the vicinity of the slide, at the base of the cut slope, while the surrounding pavement is dry. This is indicative of locally high groundwater in the slide area potentially related to a culvert that passes under US 101 just north of the slide area.

A phone conversation with Jerry Gregory was documented regarding rockfall along the cut slope above US 101 northbound. He mentioned most of the rockfall is from the center of the slope, and generally heavy rain events produce failure.

Existing Slide Mitigation

Periodic repaving of the scarp along US 101 southbound has been observed in photos and google earth, however no additional mitigation measures have been documented.

Periodic rock scaling has been performed on the rock cut slope above US 101 northbound. In summer 2011, rockfall protection was constructed on the rock cut slope consisting of a slope protection mat.

Precipitation Data

Typically, the groundwater level at the site is a function of the amount and intensity of precipitation that occurs within the drainage basin, amongst other factors. We have gathered precipitation data from nearby weather stations, including from precipitation monitoring instruments installed in the late 1990's at the Arizona Inn Slide location. For the Brush Creek slide site, the closest precipitation gauge is USC00356784 in Port Orford, 8.3 miles NW of the project site.

PRELIMINARY LANDSLIDE BOUNDARIES

Preliminary landslide boundaries were generated using a combination of existing information, observations made during the recent site reconnaissance performed by Shannon & Wilson, and LiDAR and InSAR data analysis. The preliminary boundaries, including DOGAMI landslide boundaries from SLIDO 4.2, are shown on the Site and Exploration Plans attached to this memo.

During the recent site reconnaissance, landslide areas and features were mapped and compared to existing data. Shannon & Wilson then worked with SkyGeo to create an

interactive map viewer which combined landslide inventory mapping and LiDAR data from DOGAMI, with InSAR data generated by SkyGeo. The InSAR data provided consisted of L-Band satellite data collected from March 19, 2016 to May 24, 2020, and ascending and descending C-Band satellite data collected from May 23, 2015 to December 31, 2021. A desktop analysis of the available information and data was performed, and preliminary landslide boundaries were created and imported into the SkyGeo map viewer. Shannon & Wilson then held a meeting with SkyGeo to review the preliminary landslide boundaries and analysis methods.

REFERENCES

Boring Logs: 9086-01 and 9086-02

ODOT, 2004, Geologic Project Narrative, Brush Creek Rock Fall, Oregon Coast Highway (Hwy. 9, M.P. 310.1) Coos County, dated December 1, 2004

ODOT, 2006, Site Visit Memo, Brush Cr. Rock Fall Sink, Hwy 101, MP 310.1, Curry County, ODOT, dated January 13, 2006

ODOT, 2009, Contract Plans, US101: Kobernik Slide Complex, Unit 1, Oregon Coast Highway, Curry County, October 2009

ODOT, 2012, Event History Report documenting March 2012 rockfall event at Brush Creek, dated March 29, 2012

Oregon Department of Geology and Mineral Industries (DOGAMI), 2017, Statewide Landslide Information Database for Oregon, Release 4.2 (SLIDO 4.2): Available: https://gis.dogami.oregon.gov/maps/slido/.

Filename: T:\Projects\PDX\106000s\106381_ODOT R3 South C\Avmxd\SitePlan4Brush_10.7.mxd Date: 3/24/2022 Login: AEH

LEGEND

- Approximate Location of Boring
- Interpreted Slide Extents
- Mapped Slide Scarp
- Mapped Slide Scarp
- Mapped Landslide Deposits

0 100 200 400

Scale in Feet

NOTES

1. Aerial imagery obtained through Google Maps Satellite.
2. Mapped slide features from SLIDO-4.2, obtained through DOGAMI.
3. Contours created from 2009 LiDAR data obtained through DOGAMI.

South Coast Landslide Study
Curry County, Oregon

SITE AND EXPLORATION PLAN
BRUSH CREEK

April 2022 106381

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GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. 1

FIG. 1

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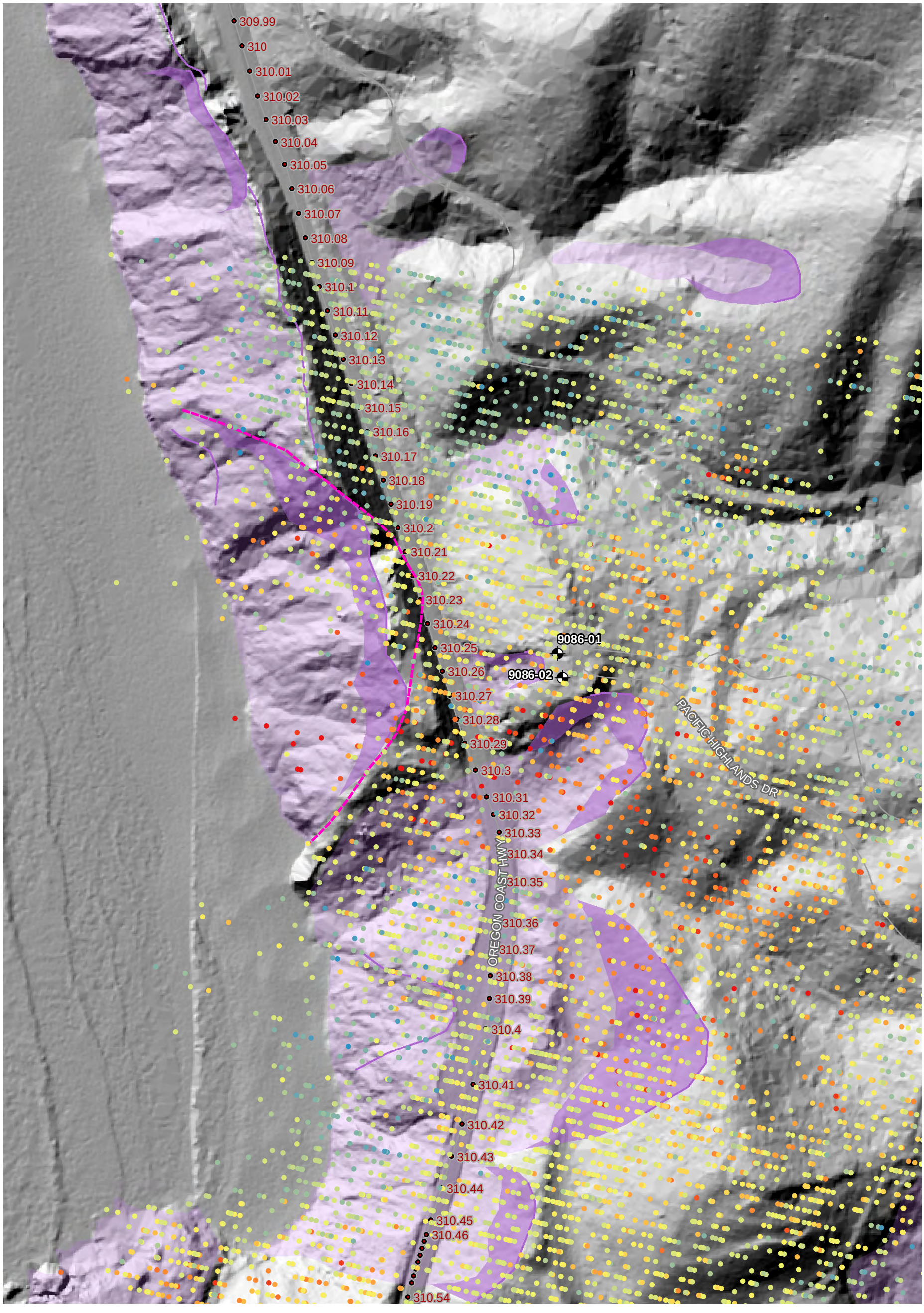

LEGEND

- Approximate Location of Boring
- Interpreted Slide Extents
- Mapped Slide Scarp
- Mapped Slide Scarp
- Mapped Landslide Deposits

Displacement L-Band (mm/year)

<-40	-36 to -32	-20 to -16	-4 to 4	16 to 20
-40 to -36	-32 to -28	-16 to -12	4 to 8	20 to 24
	-28 to -24	-12 to -8	8 to 12	24 to 28
	-24 to -20	-8 to -4	12 to 16	28 to 32

0 100 200 400

Scale in Feet

NOTES

1. Hillshade created from 2009 LiDAR data obtained through DOGAMI.
2. Mapped slide features from SLIDO-4.2, obtained through DOGAMI.
3. Displacement rate points from InSAR data downloaded from SkyGeo on December 3, 2021. Only points with quality of 0.3 or higher are shown.

South Coast Landslide Study
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SITE AND EXPLORATION PLAN
BRUSH CREEK

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FIG. 2

FIG. 2

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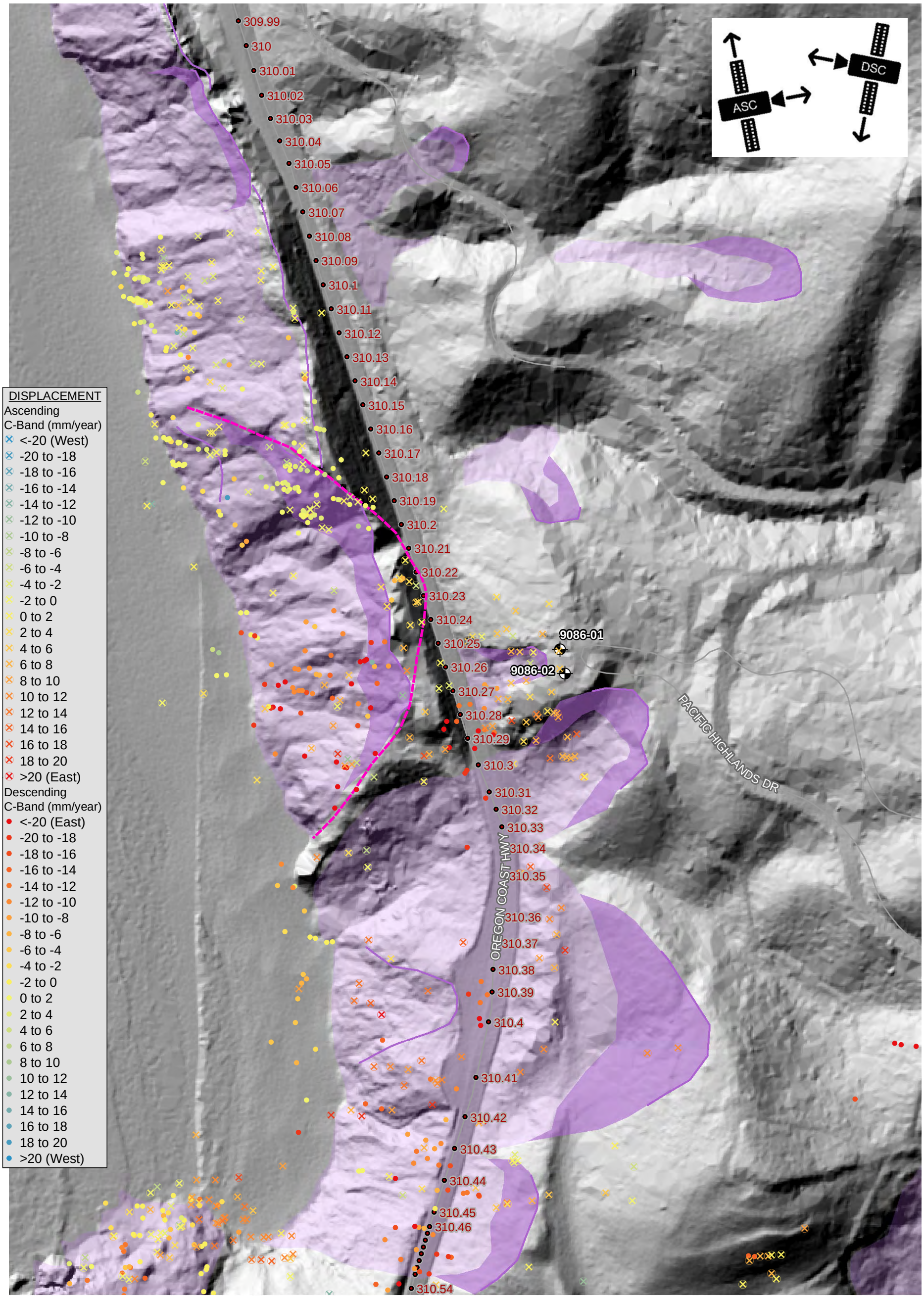

LEGEND

Approximate Location of Boring

Interpreted Slide Extents

Mapped Slide Scarp

Mapped Slide Scarp

Mapped Landslide Deposits

0 100 200 400

Scale in Feet

NOTES

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SITE AND EXPLORATION PLAN
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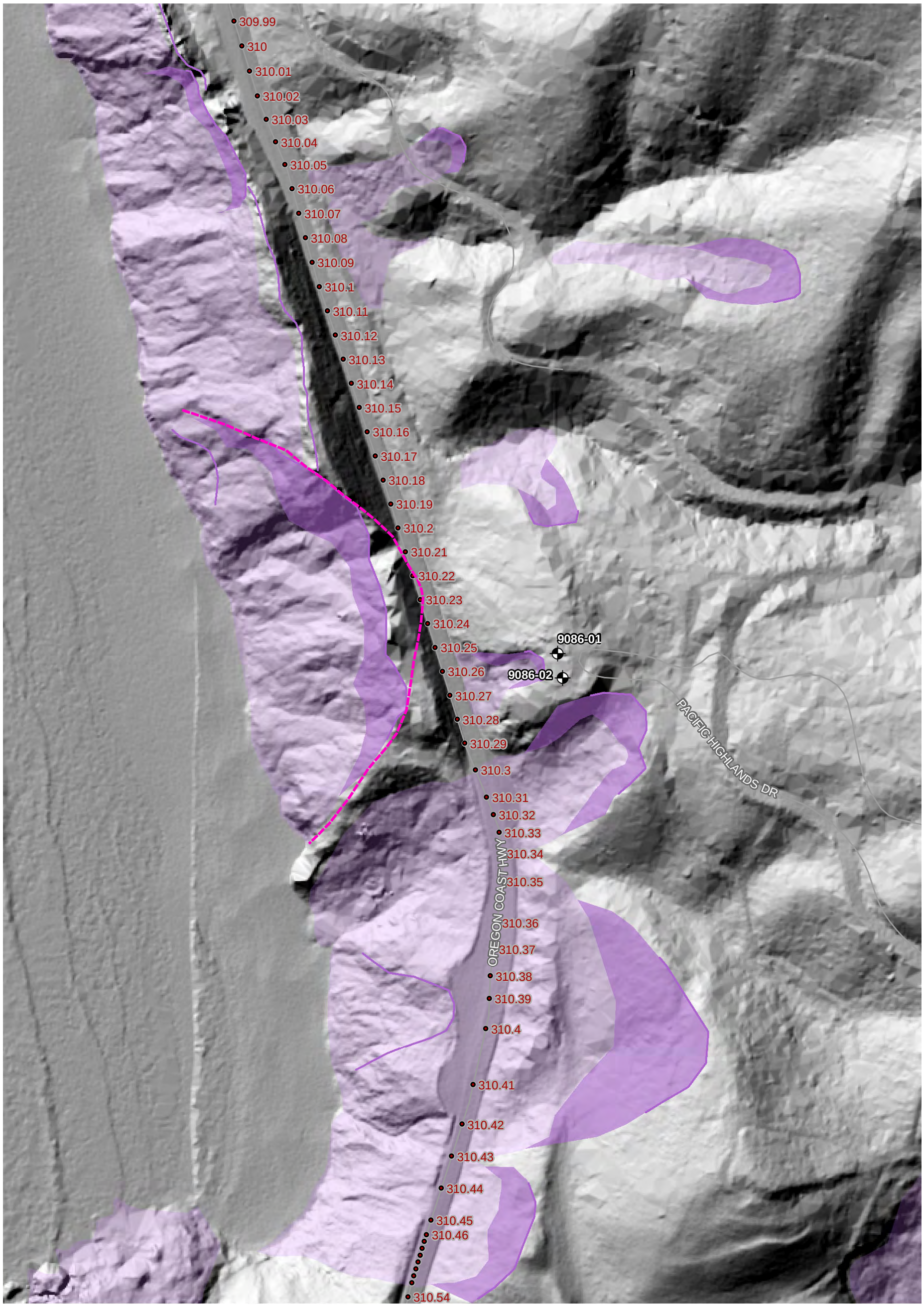
FIG. 3

FIG. 3

Filename: T:\Projects\PDX\106000s\106381_ODOT R3 South C\Avmxd\SitePlan4Brush_10.7.mxd Date: 3/24/2022 Login: AEH



LEGEND

- Approximate Location of Boring
- Interpreted Slide Extents
- Mapped Slide Scarp
- Mapped Slide Scarp
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Scale in Feet

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South Coast Landslide Study
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SITE AND EXPLORATION PLAN
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FIG. 4

FIG. 4

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MEMORANDUM

DATE: April 1, 2022

PROJECT: South Coast Slide Study

PROJ. #: 106381-006

SUBJECT: Technical Memorandum #2 – Slide 5 Arizona North (MP 311.86 to 312.14)

INTRODUCTION

Shannon & Wilson, Inc. (Shannon & Wilson) collected and reviewed all provided existing data for the Arizona North slide including:

- Previous Geology and Geotechnical Reports;
- ODOT provided electronic and hard copy files;
- Maps and publications from the U.S. Geological Survey (USGS) and Oregon Department of Geology and Mineral Industries (DOGAMI);
- Light Detection and Ranging (LiDAR) data;
- As-constructed plans for previous slide repairs or mitigation projects;
- ODOT maintenance records and as-constructed plans including slide stabilization and paving records;
- Historical precipitation data from the nearest available gauge station; and
- Interferometric Synthetic Aperture Radar (InSAR) ground movement data.

Our review of existing data included interviews with ODOT geotechnical engineers and roadway maintenance personnel. This memo includes a general summary of our key findings from the data collection and analysis, site plans showing the locations of existing subsurface explorations and preliminary landslide boundaries based on our review of existing data including LiDAR and InSAR data, and a list of references/reports.

KEY FINDINGS

Slide History

- **1930's:** Original US 101 construction, located 50 to 100 feet upslope (east) of current alignment.
- **1954:** US 101 realigned to present day alignment in slide area.

- **Winter 1996-1997:** Approximately 5 feet of movement observed in one day, prompting immediate installation of 14 horizontal drains, 200 to 330 feet in length each.
- **1996 - 1998:** Borings 96-01, 9617-01, 9617-02, 9226-03, 9226-03P, and 9226-04 through 9226-10 drilled with installation of inclinometers and piezometers.
- **June 2000:** Horizontal drains installed downslope of US 101 southbound.
- **February 2020:** Horizontal drain cleaning work performed by ODOT in 2020 indicates an average 34 percent of the total horizontal drain lengths are still functioning.
- **May 2020:** 315-foot-long stabilization (using soil nails and reinforced shotcrete) constructed downslope of US 101 southbound by GSI.
- **Summer 2021:** Borings AZ21-01, AZ21-02, AZ21-03, AZ21-04, and AZ21-06 drilled with installation of inclinometers and piezometers. Arizona North Slide and Arizona Inn Slide grouped into the "Arizona Landslide Complex".

Slide Background

Slide movement has been observed since the initial highway construction and has occurred fairly regularly every wet season. Average vertical and horizontal movement can vary between 0.5- and 1-foot (several times a year) and range up to 5 feet in a day (winter of 1996-1997).

Slide Geometry

Arizona North Slide is approximately 900 feet wide by 950 feet long, from the beach area to the head scarp in the US 101 roadway. Vertical relief from the head scarp to the beach is approximately 360 feet. An ancient, potentially active portion of the Arizona North Slide and Arizona Inn Landslide Complex is interpreted to continue upslope of US 101 approximately 1,500 to 2,000 feet (ODOT, 1999).

There are two different movement regimes noted at the Arizona North Slide based on inclinometer data, site reconnaissance, and subsurface explorations. Shallow erosional slides approximately 15 to 50 feet below ground surface (bgs) occur near the toe of the complex within the Slide Debris material unit as indicated from inclinometer data (extremely soft and mixed graphite schist, with material ranging from clay to gravel sized graphite schist fragments).

Deeper seated slides approximately 110 to 180 feet deep were also observed based on inclinometer data, site reconnaissance, and subsurface explorations. Historically, the shallower slides exhibited a faster rate of movement. The slide movement at the 15- to 50-foot level rapidly sheared some of the inclinometer casings and prevented long term

readings at depth. It was ODOT's 1999 interpretation that if movement is occurring at the deeper plane, it is very slow and most likely due to the larger ancient slide complex (ODOT, 1999). ODOT's 2022 investigation was able to capture a rate of displacement through inclinometer monitoring along the deeper slide plane, however (ODOT, 2022).

ODOT produced a Draft Engineering Geology Report (EGR) to summarize the results of their subsurface exploration and instrumentation monitoring performed in the summer of 2021. Their report interpreted the results of the subsurface exploration program, InSAR data, field mapping, and monitoring program within the Arizona Landslide Complex. Exhibit 1 displays interpreted landslide features from within the Arizona Landslide Complex based on their investigation.

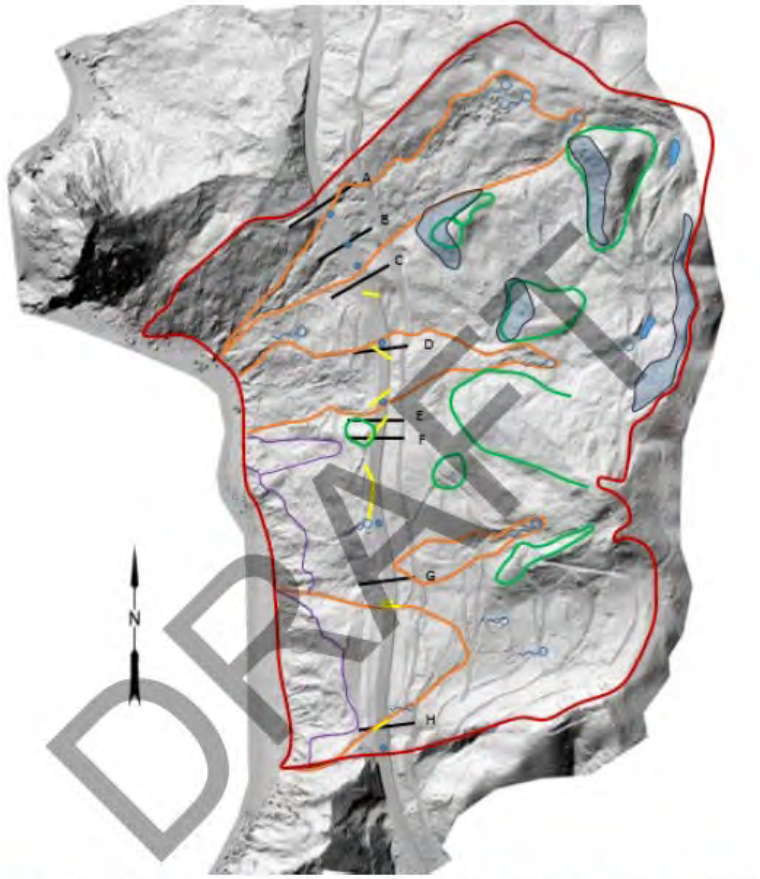

Figure 15: Hillshade Map with Landslide Features. This image shows the results of desktop evaluation and field reconnaissance. The 2021 bare-earth hillshade serves as the base map. Landslide limits are marked in red. Areas demonstrating higher rates of movement based on LiDAR imagery and features mapped in the field are shown in orange. These orange features coincide with areas of intermittent and perennial springs or seeps – shown with spring symbol. Mapped pavement cracks are shown in yellow. Areas mapped as blocks that may be static or entrained in the landslide are shown in green. Several more prominent scarps are highlighted with dark blue. Ponded water is mapped in light blue. Erosional features at the toe of the landslide are shown in purple. Culverts are shown in blue donuts. Black lettered lines coincide with sectors shown in C-Band Profile Displacement Rate Map – Figure 14.

Exhibit 1: Figure from ODOT's 2022 EGR presenting their slide interpretations based off their 2021 subsurface investigation.

Slide Mechanics

The slide toe has been noted at the beach, and therefore it is constantly being eroded by the wave action. Immediately north and south of the slide, more resistant blocks of rock have been incorporated in the softer, mélange, therefore preventing significant erosion and limiting the slide boundaries to the north and south (ODOT, 1999). ODOT's 2021 subsurface explorations revealed resistant rock blocks within the mélange. The blocks encountered within the Arizona North slide (northern section of the Arizona Landslide Complex) appear entrained within the landslide material, rotating with the landslide movement. Blocks encountered near the middle of the slide complex (directly south of the Arizona North slide) appear to be resisting landslide movement, and influencing the slide geometry and mechanics (ODOT, 2022).

Historically the southerly 400 feet of the Arizona North slide has moved at a faster rate than the rest of the slide. InSAR data presented in ODOT's 2022 report also shows a higher rate of ground displacement and increased pavement cracking within the southern half of the slide (ODOT, 2022). Highway shoulder heave has been observed due to slide movements above the highway, as well (ODOT, 1999).

Back calculation analyses were made to determine residual shear strengths between 32 and 35 degrees for the shallow slide plane. Correlations of plasticity indexes and residual friction angles indicated residual strengths between 18 and 22 degrees, with direct shear testing revealing a residual friction angle near 21 degrees. The difference between back calculated, correlated, and tested strengths may be due to the gravel sized particles that exist in the actual material but were removed as part of the testing (ODOT, 1999).

Because of the relatively high strength values obtained, and observations of faster movement on the south side of the slide (in conjunction with surficial water observations), the primary failure mechanism was interpreted to be high piezometric pressures within the upper 33 to 50 feet, substantiated by the reduced rates of movement in the southerly half of the Arizona North Slide since the 1997 horizontal drains were installed (ODOT, 1999). ODOT's 2022 report correlates an increase in slide movement (as inferred from InSAR data) with elevated groundwater and surface water generally related to seasonal rainfall (ODOT, 2022). However, not all InSAR data points show this trend, potentially indicating other triggering mechanisms are at work.

Groundwater

Several highly saturated areas and springs were observed in the southerly half of the slide mass and have been observed to flow year-round (ODOT, 1999). Comparisons with

groundwater instrumentation installed at deeper depths within the slide boundaries indicate that the groundwater associated with an upper sliding surface appears to be confined to within and above the slide zone. Groundwater levels appear to rise between 3 to 5 feet during wetter months. It is interpreted that the springs and seeps found at the surface are a reflection of this perched groundwater zone as it daylights at the ground surface. High piezometric levels were not encountered in the deeper slide plane (ODOT, 1999). Based on maximum groundwater elevations measured during ODOT's 2021 subsurface explorations, groundwater flow direction in both the shallow and deep zones is generally west toward the Pacific Ocean. Potentiometric groundwater contours generally match with the topographic contours, indicating a lack of artesian potential (ODOT, 2022).

Existing Slide Mitigation

In immediate response to the Winter 1996-1997 movement, fourteen horizontal drains, each 200 to 330 feet in length were installed. Although surface failures have destroyed several of the water collector systems, the yearly movement has decreased since the installation of the drains (ODOT, 1999).

ODOT recommended installing a series of horizontal drains in 1999, to achieve a drawdown of at least 8 to 13 feet (2.5 to 4 meters) in the upper slide zone. ODOT also recommended installing horizontal drains into the deeper slide zone. In June 2000, horizontal drains were installed downslope of US 101 (ODOT, 2000). An annotated plan sheet by ODOT, detailing the results of a May 23, 2017 site visit, notes that some of the drain pads and horizontal drains were damaged due to slide activity (ODOT, 2017).

In 2020, GSI constructed a 315-foot-long stabilization (consisting of soil nails and shotcrete facing) downslope of US 101 southbound in the more active southerly portion of the slide. The slope height was up to 17 feet in height, and the soil nail lengths were between 28 and 58 feet long. 20-foot-long horizontal drains were installed, spaced 10-feet on-center, and a French drain was installed at the toe of the excavated slope (GSI, 2020).

Horizontal drain cleaning work performed by ODOT in 2020 indicates an average 34 percent of the total horizontal drain lengths are still functioning. ODOT's 2022 report anticipates a gradual decrease in horizontal drain groundwater production due to damage from landslide movement and mineralization (ODOT, 2022).

Precipitation Data

Typically, the groundwater level at the site is a function of the amount and intensity of precipitation that occurs within the drainage basin, amongst other factors. We have

gathered precipitation data from nearby weather stations, including from precipitation monitoring instruments installed in the late 1990's at the Arizona Inn Slide location. For the Arizona North slide site, the closest precipitation gauge is USC00356784 in Port Orford, 9.8 miles NW of the project site.

PRELIMINARY LANDSLIDE BOUNDARIES

Preliminary landslide boundaries were generated using a combination of existing information, observations made during the recent site reconnaissance performed by Shannon & Wilson, and LiDAR and InSAR data analysis. The preliminary boundaries for Arizona North and Arizona Inn slides, including DOGAMI landslide boundaries from SLIDO 4.2, are shown on the Site and Exploration Plans attached to this memo.

During the recent site reconnaissance, landslide areas and features were mapped and compared to existing data. Shannon & Wilson then worked with SkyGeo to create an interactive map viewer which combined landslide inventory mapping and LiDAR data from DOGAMI, with InSAR data generated by SkyGeo. The InSAR data provided consisted of L-Band satellite data collected from March 19, 2016 to May 24, 2020, and ascending and descending C-Band satellite data collected from May 23, 2015 to December 31, 2021. A desktop analysis of the available information and data was performed, and preliminary landslide boundaries were created and imported into the SkyGeo map viewer. Shannon & Wilson then held a meeting with SkyGeo to review the preliminary landslide boundaries and analysis methods.

REFERENCES

Boring Logs with VWP and Inclinometer Data: 96-01, 9617-01, 9617-02, 9226-03 through 9226-09, AZ21-02, and AZ21-03.

GSI, 2020, As-Constructed Soil Stabilization Plans, HWY 101 MP 312.1 (North Arizona), Geostabilization International, dated May 7, 2020

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ODOT, 2017, North Arizona Slide Horizontal Drain Pad Locations, Hwy 101, MP 312.1 SB, annotated by Pete Castro of ODOT, dated June 7, 2017

ODOT, 2022, Draft Engineering Geology Report, US101: Arizona Landslide Complex Mitigation Assessment, MP 312, dated January 2022

Oregon Department of Geology and Mineral Industries (DOGAMI), 2017, Statewide Landslide Information Database for Oregon, Release 4.2 (SLIDO 4.2): Available: https://gis.dogami.oregon.gov/maps/slido/.

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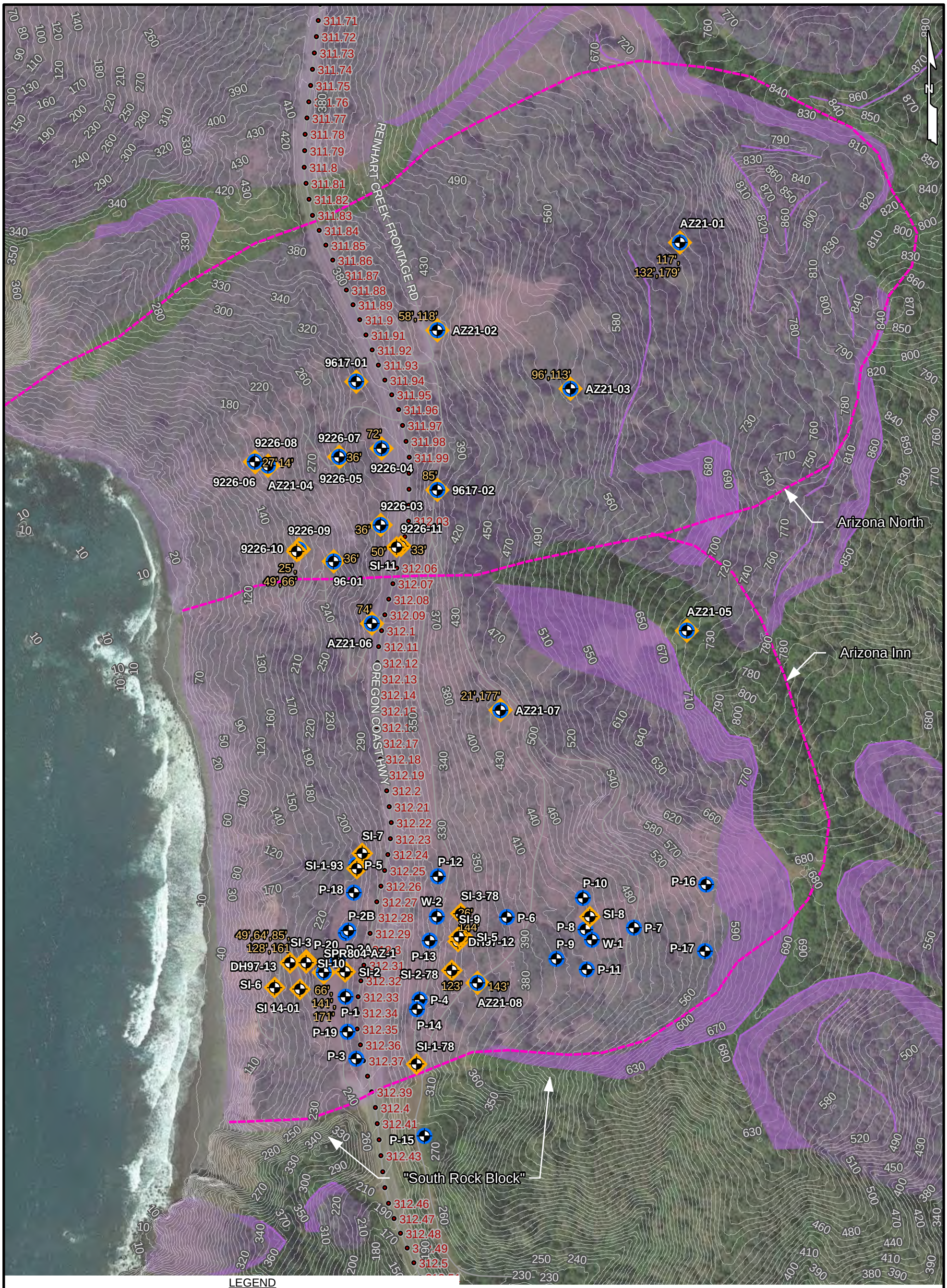

LEGEND

- Approximate Location of Boring with Inclinometer and Shear Plane Depth (13')
- Approximate Location of Boring with Piezometer
- Approximate Location of Boring with Inclinometer, Shear Plane Depth, and Piezometer (13')
- Interpreted Slide Extents
- Mapped Slide Scarp
- Mapped Slide Scarp
- Mapped Landslide Deposits

0 150 300 600

Scale in Feet

NOTES

1. Aerial imagery obtained through Google Maps Satellite.
2. Mapped slide features from SLIDO-4.2, obtained through DOGAMI.
3. Contours created from 2009 LiDAR data obtained through DOGAMI.

South Coast Landslide Study
Curry County, Oregon

SITE AND EXPLORATION PLAN
ARIZONA INN COMPLEX

April 2022 106381

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. 1

FIG. 1

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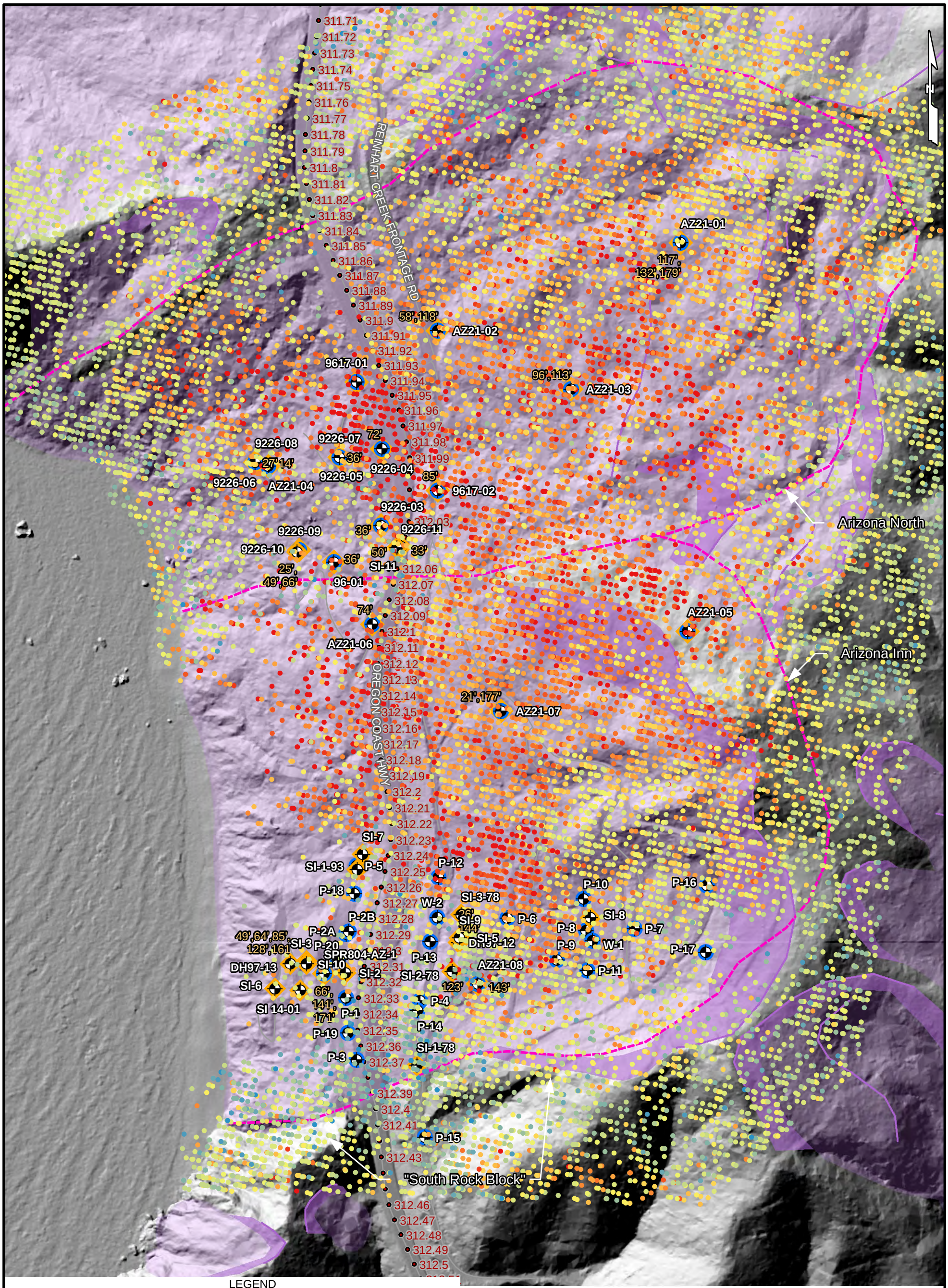

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Displacement L-Band (mm/year)

<-40	-36 to -32	-20 to -16	-4 to 4	16 to 20
-40 to -36	-32 to -28	-16 to -12	4 to 8	20 to 24
	-28 to -24	-12 to -8	8 to 12	24 to 28
	-24 to -20	-8 to -4	12 to 16	28 to 32

0 150 300 600

Scale in Feet

NOTES

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South Coast Landslide Study
Curry County, Oregon

SITE AND EXPLORATION PLAN
ARIZONA INN COMPLEX

April 2022 106381

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FIG. 2

FIG. 2

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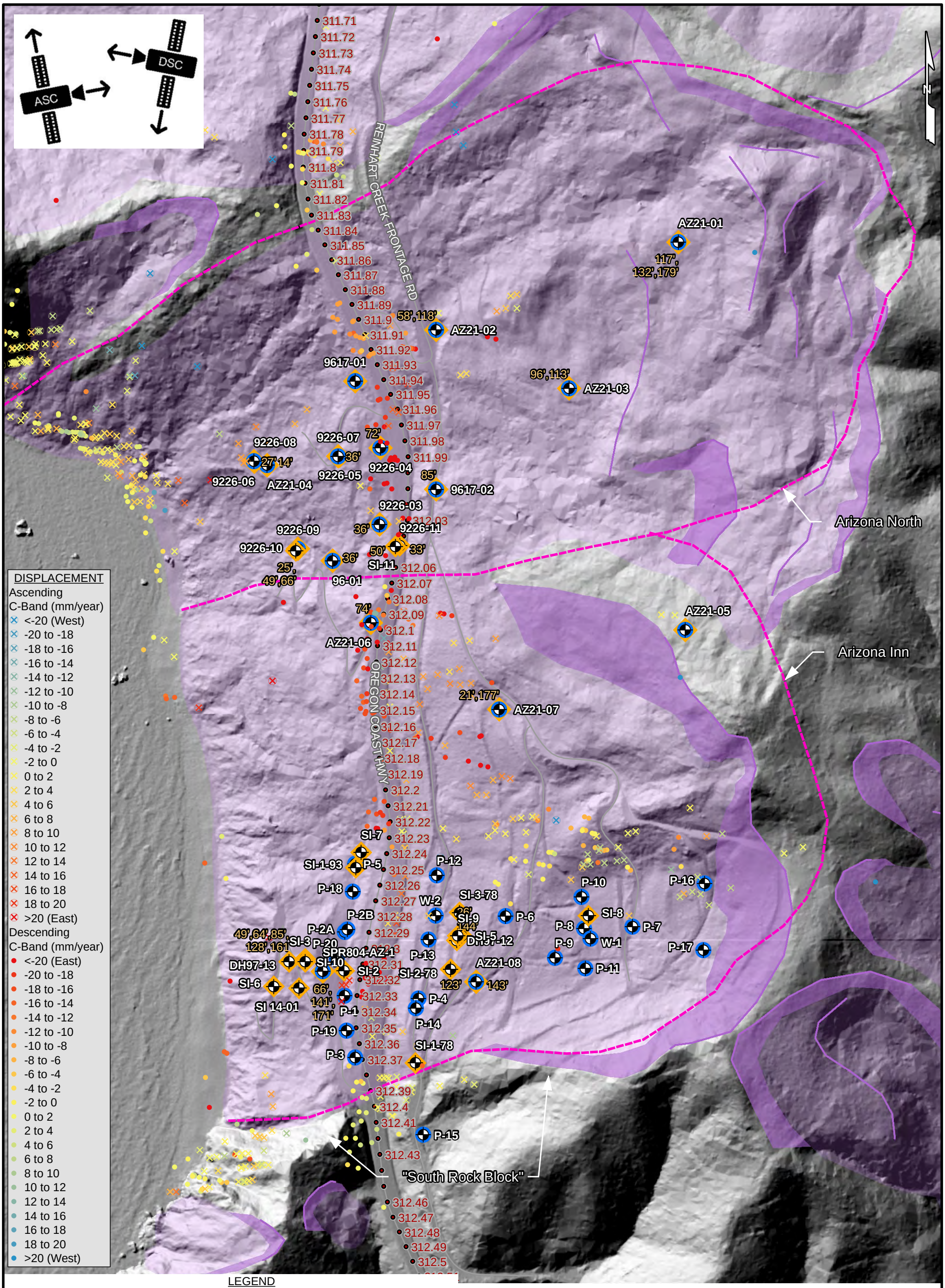

DISPLACEMENT

Ascending C-Band (mm/year)

- <-20 (West)
- -20 to -18
- -18 to -16
- -16 to -14
- -14 to -12
- -12 to -10
- -10 to -8
- -8 to -6
- -6 to -4
- -4 to -2
- -2 to 0
- 0 to 2
- 2 to 4
- 4 to 6
- 6 to 8
- 8 to 10
- 10 to 12
- 12 to 14
- 14 to 16
- 16 to 18
- 18 to 20
- >20 (East)

Descending C-Band (mm/year)

- <-20 (East)
- -20 to -18
- -18 to -16
- -16 to -14
- -14 to -12
- -12 to -10
- -10 to -8
- -8 to -6
- -6 to -4
- -4 to -2
- -2 to 0
- 0 to 2
- 2 to 4
- 4 to 6
- 6 to 8
- 8 to 10
- 10 to 12
- 12 to 14
- 14 to 16
- 16 to 18
- 18 to 20
- >20 (West)

LEGEND

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South Coast Landslide Study
Curry County, Oregon

SITE AND EXPLORATION PLAN
ARIZONA INN COMPLEX

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FIG. 3

FIG. 3

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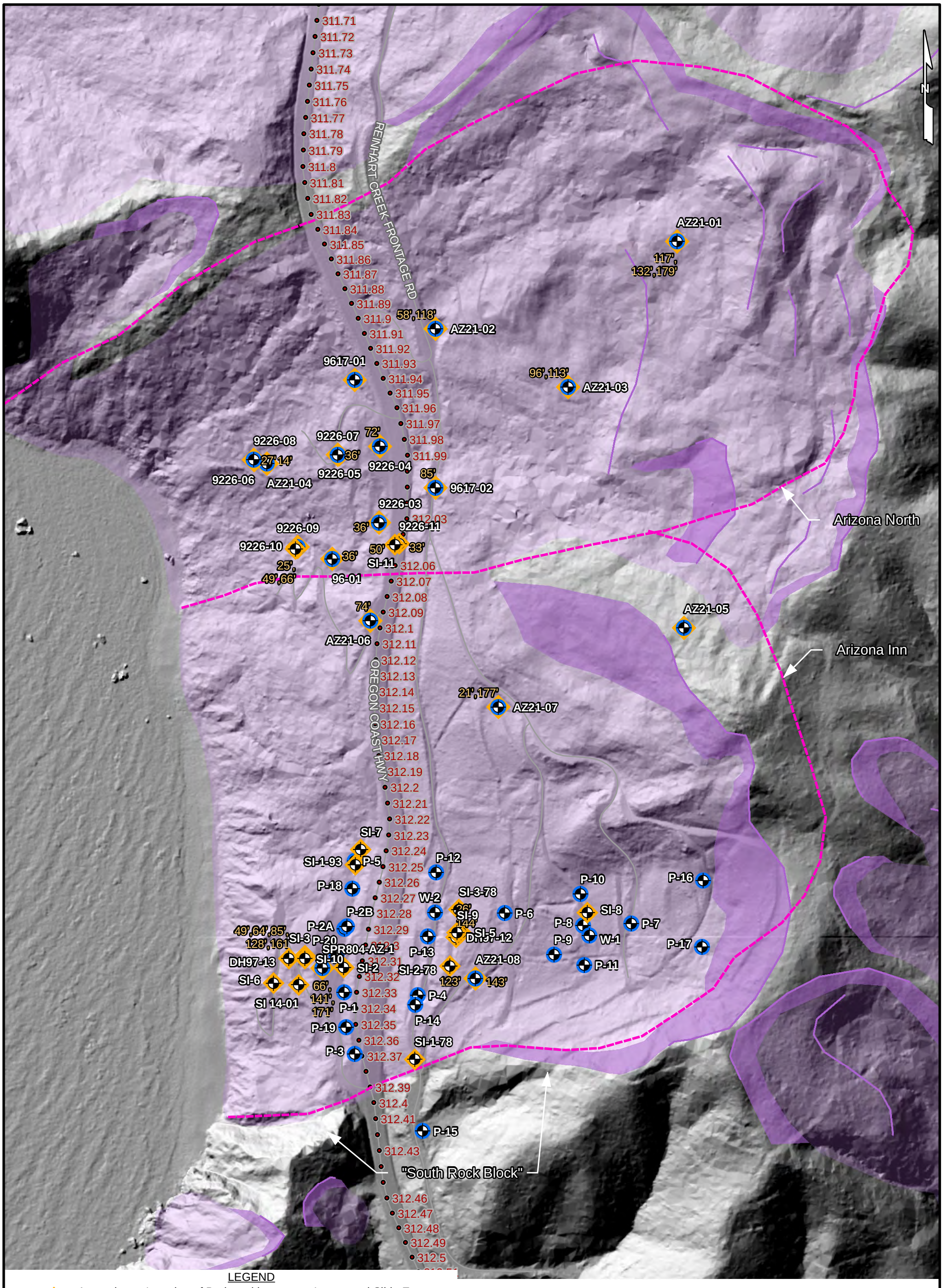

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South Coast Landslide Study
Curry County, Oregon

SITE AND EXPLORATION PLAN
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FIG. 4

FIG. 4

SHANNON & WILSON

MEMORANDUM

DATE: April 1, 2022

PROJECT: South Coast Slide Study

PROJ. #: 106381-006

SUBJECT: Technical Memorandum #2 – Slide 6 Arizona Inn (MP 312.15 to 312.39)

INTRODUCTION

Shannon & Wilson, Inc. (Shannon & Wilson) collected and reviewed all provided existing data for the Arizona Inn slide including:

- Previous Geology and Geotechnical Reports;
- ODOT provided electronic and hard copy files;
- Maps and publications from the U.S. Geological Survey (USGS) and Oregon Department of Geology and Mineral Industries (DOGAMI);
- Light Detection and Ranging (LiDAR) data;
- As-constructed plans for previous slide repairs or mitigation projects;
- ODOT maintenance records and as-constructed plans including slide stabilization and paving records;
- Historical precipitation data from the nearest available gauge station; and
- Interferometric Synthetic Aperture Radar (InSAR) ground movement data.

Our review of existing data included interviews with ODOT geotechnical engineers and roadway maintenance personnel. This memo includes a general summary of our key findings from the data collection and analysis, site plans showing the locations of existing subsurface explorations and preliminary landslide boundaries based on our review of existing data including LiDAR and InSAR data, and a list of references/reports.

KEY FINDINGS

Slide History

- **1930's:** Original US 101 construction, located 50 to 100 feet upslope (east) of current alignment.
- **1938:** First documentation of slide movement. Size and boundaries similar to 1993 movement, with a recorded displacement of 25 feet both horizontally and vertically. Five shafts and a 40-foot-long tunnel were excavated to evaluate subsurface conditions.

- **1954:** Slide movements occur with similar geometry and displacement to 1938 event. Approximately 500,000 cubic yards of slide debris was removed from the upper portion of slide mass and placed near the toe of the slide between present day US 101 alignment and ocean. 53 horizontal drains were installed on the bench above present day alignment, ranging from 10 to 159 feet in length, with flows described as dry to full.
- **1954:** US 101 realigned to present day alignment in slide area.
- **1958:** 20 percent of material placed near the toe of the slide in 1954 is noted as having been eroded, slide movement continuing.
- **1978:** Slide movement observed and three inclinometers (1-78 through 3-78) installed to depths of 130 feet each, recording movement at depths of 72, 122, and 80 feet.
- **December 1981:** Slide movements occur, displacement on the order of 1938 and 1954 events. Roadway alignment maintained by importing material during period of movement.
- **Summer 1982:** Slide surface grading, ditch culvert installation, and vegetation clearing.
- **March 21, 1993:** Increased slide movements observed by Port Orford Maintenance Crew. Slide movement increased in magnitude and on March 23, the rate of movement was so great the road could not be maintained and highway was closed for about 2 weeks. By the end of movement, north edge of slide moved 20 feet horizontally and vertically at US 101, and southerly edge moved 10 feet horizontally and 5 feet vertically at US 101. Slide movement observed after seven days of average 2.25 inches of rain measured per day. On March 23, 7.33 inches of rainfall fell (measured by Elk Creek Fish Hatchery).
- **April 8, 1993:** Roadway re-opened
- **1993-1997:** A total of 30 borings drilled with installation of inclinometers and piezometers.
- **July 1995:** Horizontal drains installed upslope of US 101.
- **March 1996:** 17.5-foot inside diameter **d**rainage shaft and associated horizontal drains installed downslope of US 101.
- **2002:** Cleaned horizontal drains, increasing total flow from 16 GPM to 50 GPM.
- **2005:** Horizontal drain cleaning (upslope and downslope)
- **October 2014:** Boring 14-01 drilled with installation of inclinometer and piezometer.
- **February 2017:** Oregon State University (OSU) completed one geotechnical boring (SPR804-AZ-1) with installation of one micro-electromechanical systems (MEMS) array.
- **January 19, 2019:** 0.5 inches of movement observed in one day by OSU MEMS array as measured at the ground surface (primary shear plane depth is approximately 140 feet below ground surface).

- **February 2020:** Horizontal drain cleaning work performed by ODOT in 2020 indicates an average 34 percent of the total horizontal drain lengths are still functioning.
- **Summer 2021:** Borings AZ21-05, AZ21-06, AZ21-07, and AZ21-08 drilled with installation of inclinometers and piezometers. Arizona North Slide and Arizona Inn Slide grouped into the "Arizona Landslide Complex".

Slide Geometry

The slide is approximately 700 feet wide and 1,900 feet in length from head scarp to the beach. The toe of the landslide appears to be at the beach or within the surf zone where active erosion is occurring at the toe of the slide. Slopes are at approximately 19.5 degrees over 700 feet of relief. The upper portion of the landslide contains a graben, with prominent head scarps and a retrogressive smaller scarp near the ridge crest. Another prominent set of ground cracks extend across the slide mass 200 to 300 feet upslope of US 101. Portions of the upper head scarps have failed as earth flows, displaying intermittent spring activity (Peterson et al, 1998).

A prominent fault-like, planar face is oriented at N61E, 60N on the north side of South Rock block (an isolated, 800-foot-wide block floating in the mélange) between US 101 and the coast. This face is likely projected through the subsurface, as it was consistently encountered in boreholes, and has been interpreted to form the southern boundary of the slide. (Peterson et al, 1998).

A northern-bounding lateral scarp of the active slide mass lies at a transition in material types, particularly in the upper portion of the slide. North of the lateral scarp, large, exposed rock blocks between tens to hundreds of feet wide, include metamorphics and conglomerate (where the landslide material is generally highly sheared rocky point formation, i.e. mudstone and sandstone) (Peterson et al, 1998).

A single shear plane in the upper slide mass above US 101, at 150 to 160 feet below ground surface (bgs), was observed from the explorations following the 1993 slide event. The shear plane inclination was observed to be 12 degrees. In the lower slide mass, below US 101, the failure surface steepens to about 19 degrees, and multiple shear planes are present. A significant series of ground cracks marks the reflection of the steeper sloping slide portion. Depth of the primary shear movements range from 140 to 170 feet in the lower slide mass. Near the slide toe, the primary shear planes extend down to mean sea level. Uncertainty exists with respect to the ultimate location of slide toe, which extends at least into the surf zone. Reconnaissance in 1994 revealed elevated wave cut terraces, minor spring activity, and clayey mélange materials underlying thin beach sand deposits, supporting

interpretation of a passive wedge being uplifted at the beach and are consistent with stability analyses of the slide mass (Squier, 1995).

Exhibit 1: Photo looking south along US101 after the 1993 slide event.

ODOT produced a Draft Engineering Geology Report (EGR) to summarize the results of their subsurface exploration and instrumentation monitoring performed in the summer of 2021. Their report interpreted the results of the subsurface exploration program, InSAR data, field mapping, and monitoring program within the Arizona Landslide Complex. Exhibit 2 displays interpreted landslide features from within the Arizona Landslide Complex based on their investigation.

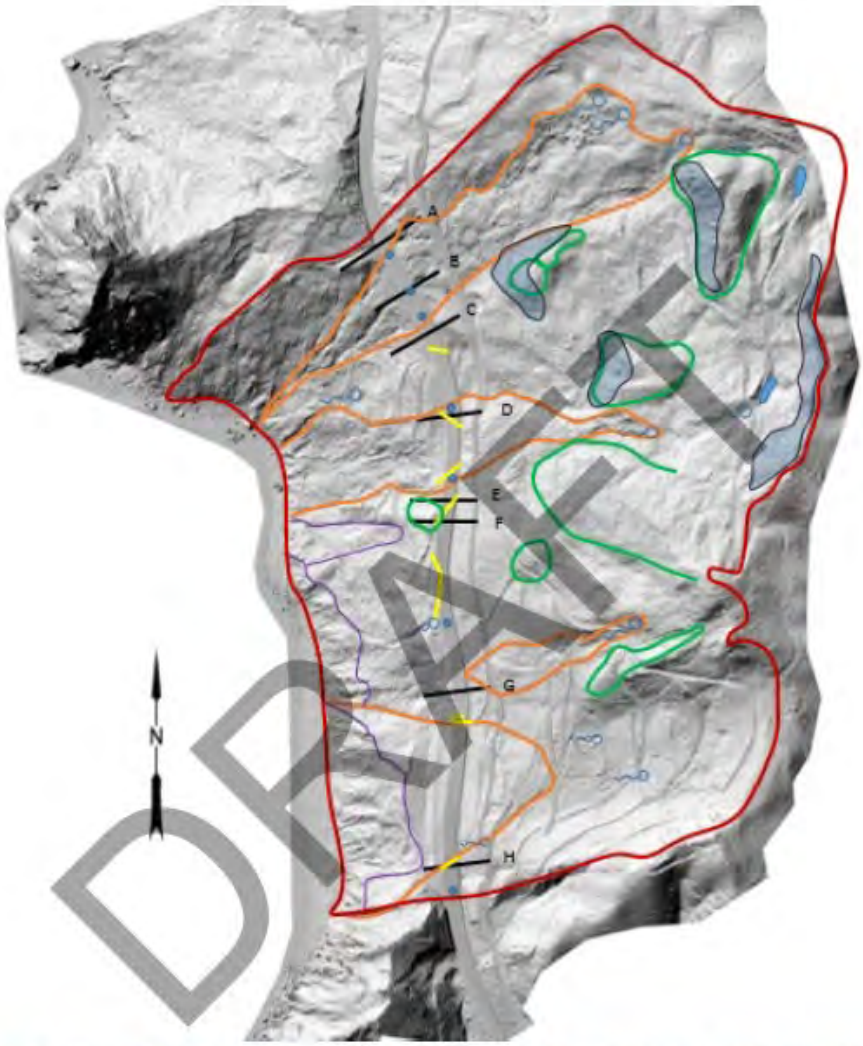

Figure 15: Hillshade Map with Landslide Features. This image shows the results of desktop evaluation and field reconnaissance. The 2021 bare-earth hillshade serves as the base map. Landslide limits are marked in red. Areas demonstrating higher rates of movement based on LiDAR imagery and features mapped in the field are shown in orange. These orange features coincide with areas of intermittent and perennial springs or seeps – shown with spring symbol. Mapped pavement cracks are shown in yellow. Areas mapped as blocks that may be static or entrained in the landslide are shown in green. Several more prominent scarps are highlighted with dark blue. Ponded water is mapped in light blue. Erosional features at the toe of the landslide are shown in purple. Culverts are shown in blue donuts. Black lettered lines coincide with sectors shown in C-Band Profile Displacement Rate Map – Figure 14.

Exhibit 2: Figure from ODOT's 2022 EGR presenting their slide interpretations based off their 2021 subsurface investigation.

ODOT encountered two slide planes within their Arizona Inn Slide (now the southern portion of the Arizona Landslide Complex) borings. A shallow failure of erosional nature was encountered at approximately 21-feet and deeper-seated surfaces were encountered at 143-feet and 177-feet below ground surface (bgs). No movement was observed in Boring AZ21-05, however InSAR data showed movement near the boring location. ODOT attributed the disagreement in data to the Sandstone/Siltstone encountered in AZ21-05

moving as a block within the slide (in reference to Block and Matrix Mélange geology). In previous investigations, the area between the Arizona Inn Slide and Arizona North Slide was generally believed to be resistant to slide movement. An additional block of Sandstone/Siltstone was believed to be encountered within AZ21-06, which ODOT interpreted to be responsible for limiting the depth of slide (i.e. force the slide to daylight above the block) (ODOT, 2022).

Slide Mechanics

A regionally significant shear zone about 2 miles in width encompasses the landslide area and extends well offshore. The landslide mass is generally comprised of a mélange of sheared sandstone and mudstone of the Rocky Point Formation, a block-in-matrix rock type with a mylonitic structural fabric (Peterson et al, 1998).

Table 2: Selected Modes of Failure Analyzed

Mode Failure: Name and File	Failure Surface Description
Shallow Short Failure Computer File Arizona 1	Located from mid-slope, beneath highway, to a toe in ocean bluff, failure at highest inclinometer shear zone.
Intermediate Short Failure Computer File Arizona 2	Located from mid-slope, beneath highway, to a toe in bluff near beach level, failure at mid inclinometer shear zone.
Deep Short Failure Computer File Arizona 3	Located from mid-slope, beneath highway, to a passive toe at beach, failure along primary landslide failure plane.
Deep Long Failure Computer File Arizona 4	Primary deep failure plane for entire landslide.

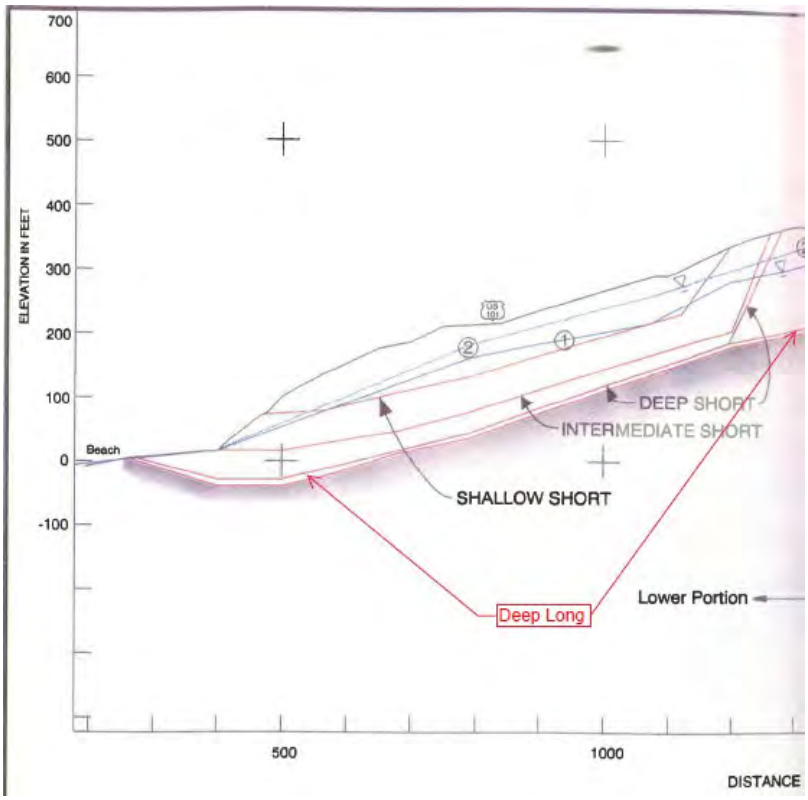

Exhibit 3: (Squier, 1994a) presents the four failure modes observed and analyzed in the Arizona Inn slide mass.

The landslide mass is comprised of extensively sheared sandstone and mudstones that form a fine-grained mélange. Slickensided surfaces are ubiquitous throughout the landslide materials and within the underlying rock mass. Consequently, without inclinometer data to define them, shear zones are were indistinguishable from the overall extensively sheared rock mass. The planar bounding surface of South Rock is a key geologic and hydrologic component of the slide. Within the slide mass, angular rock fragments from cobbles to gravels exist, with the occasional boulder. Larger rock fragments exist near the north and south end of the slide. Laboratory analyses of sheared materials corresponded with back calculated stability analyses on the order of 25 to 28 degrees (Peterson et al, 1998).

Irregularly shaped zones of moderately permeable materials surrounded by low permeability materials result in artesian pressures within permeable zones (Squier, 1994a). Faulting near the South Rock block appears to provide a source of ascending groundwater, distinct from precipitation. Other deep sources also contribute to a year-round supply of confined groundwater into the upper portion of the slide. Accelerated movements occur when combined water sources produce critical hydrostatic pressures within the landslide mass (Squier, 1994a). Permeable zones are generally associated with failure surfaces of slide and lateral boundaries, formed by large rock blocks.

ODOT's 2022 report correlates an increase in slide movement (as inferred from InSAR) with elevated groundwater and surface water generally related to seasonal rainfall (ODOT, 2022). However, not all InSAR data points show this trend, potentially indicating other triggering mechanisms are at work.

Groundwater

Significant fluctuations in groundwater levels were observed in response to rainfall. The shallow piezometer in P16 shows piezometric responses to high rainfall periods on the order of 50 feet. The upper piezometer in P17 and mid-level piezometers in both graben borings (P16 and P17) showed significant response to rainfall on the order of 10 to 20 feet (Squier, 1995). Low piezometric response was observed in the mid to lower landslide areas near US 101 over the wet winter months, agreeing with observations of poor hydraulic interconnection. The test horizontal drain program showed piezometric drawdowns up to 70 feet in nearby piezometers (Squier, 1995).

Spring activity was observed nearly up to the ridge top at elevation 700 feet, and outside the landslide to nearly 800 feet elevation (Peterson et al, 1998). The amount of drawdown observed in the piezometers from well W-1 test was related to the direction and vertical distance from the inferred south rock ridge bounding structure and not to the radial distance from the pumping well. Well W-1 communicated at nearly 100 percent hydraulic efficiency with borings that encountered the project boundary of the South Rock block (borings P-11 and P-9). In contrast, the hydraulic efficiency at the closest observation well (P-8) only saw 28 percent efficiency. Efficiency, as used herein, is defined as observed drawdown in piezometer relative to drawdown in pumping well. Boring P-11 and W-1 were both hydraulically connected, as mentioned, and both produced sulfurous, poor quality water (including a spring near elevation 75 feet by the southern slide border). The northern planar boundary of South Rock Block has been identified as a primary preferred flow path for this deeply circulating sulfurous water system. Available data suggests the artesian head in this area fluctuates only slightly on a year-round basis. The location of the sulfurous spring at elevation 75 feet also suggests a relationship to the structural boundary of the South Rock block. Well W-2 demonstrated very low permeability of the mid-section of the landslide and was not able to maintain a 2gpm flow rate. Therefore, the central portion (horizontally referenced) of the landslide is presently inferred to form a hydraulic barrier, restricting seepage from the upper portion of the landslide, where higher piezometric pressures, including confined, artesian pressures exist (Squier, 1995).

Two groundwater regimes are present. Shallow groundwater receives recharge from rainfall; and deeper pressurized groundwater invades the slide mass year-round from

distant sources in the mélange, particularly along the South Rock Block boundary. High hydrostatic pressures are extensive in the upper portion of the slide, likely due to the hydraulic barrier at mid-slope and to the sulfurous water that ascends into the slide mass along flow paths near the planar boundary of south rock ridge. Isolated, cellular aquifers in situ in the upper slide mass probably exhibit high (locally flowing artesian) head year-round and are most likely related to this deeply circulated groundwater recharge (Squier, 1995).

Based on maximum groundwater elevations measured during ODOT's 2021 subsurface explorations, groundwater flow direction in both the shallow and deep zones is generally west toward the Pacific Ocean (ODOT, 2022).

Existing Slide Mitigation

In an attempt to stabilize the 1954 slide, approximately 500,000 cubic yards of slide debris was removed from the upper portion of slide mass and placed by conveyor near the toe of the slide between present day US 101 alignment and the ocean. 53 horizontal drains were installed on the bench above the present-day alignment, ranging from 10 to 159 feet in length, with flows described as dry to full. By 1958, approximately 20 percent of the relocated material had been eroded by the ocean (ODOT, 1993).

Squier Associates initially recommended two remediation schemes, horizontal drains drilled via the surface or a shaft, or a drainage tunnel with radial drains. After their Phase II horizontal drain test resulted in a significant reduction in landslide creep rate and magnitude during the 1994 to 1995 winter, Squier recommended a full-scale hybrid horizontal drain remediation scheme as the drainage tunnel was more expensive. Radial horizontal drains (200 to 500 feet in length) were installed from a drainage shaft downslope of US 101 to reduce risk of damage to the long surface drains due to erosion of the coastal bluffs from wave energy. Long surface horizontal drains (250 to 700 feet in length) were installed above US 101. The shaft was installed to 205.5 feet bgs, 40 feet beyond the deepest shear plane. The shaft started from the surface with a 20-foot-deep reinforced concrete collar. The remainder of the shaft diameter was lined with welded wire fabric reinforced shotcrete, in conjunction with lattice girder support.

Horizontal drain cleaning work performed by ODOT in 2020 indicates an average 34 percent of the total horizontal drain lengths are still functioning. ODOT's 2022 report anticipates a gradual decrease in horizontal drain groundwater production due to damage from landslide movement and mineralization (ODOT, 2022).

Precipitation Data

Typically, the groundwater level at the site is a function of the amount and intensity of precipitation that occurs within the drainage basin, amongst other factors. We have gathered precipitation data from nearby weather stations, including from precipitation monitoring instruments installed in the late 1990's at the Arizona Inn Slide location. For the Arizona Inn slide site, the closest precipitation gauge is USC00356784 in Port Orford, 10.1 miles NW of the project site.

PRELIMINARY LANDSLIDE BOUNDARIES

Preliminary landslide boundaries were generated using a combination of existing information, observations made during the recent site reconnaissance performed by Shannon & Wilson, and LiDAR and InSAR data analysis. The preliminary boundaries for Arizona Inn and Arizona North slides, including DOGAMI landslide boundaries from SLIDO 4.2, are shown on the Site and Exploration Plans attached to this memo.

During the recent site reconnaissance, landslide areas and features were mapped and compared to existing data. Shannon & Wilson then worked with SkyGeo to create an interactive map viewer which combined landslide inventory mapping and LiDAR data from DOGAMI, with InSAR data generated by SkyGeo. The InSAR data provided consisted of L-Band satellite data collected from March 19, 2016 to May 24, 2020, and ascending and descending C-Band satellite data collected from May 23, 2015 to December 31, 2021. A desktop analysis of the available information and data was performed, and preliminary landslide boundaries were created and imported into the SkyGeo map viewer. Shannon & Wilson then held a meeting with SkyGeo to review the preliminary landslide boundaries and analysis methods.

REFERENCES

Boring Logs with VWP and Inclinometer Data: 1-78 through 3-78, P1-93, P10-93 through P20-93, SI1-93 through SI6-93, SI11-94, W1-94, W2-94, DH97-12, DH97-13, SPR804-AZ-1, SI14-01, AZ21-05, AZ21-07, and AZ21-08.

ODOT, 1993, Geotechnical Reconnaissance Report, Arizona Inn Landslide, Oregon Coast Highway #9 Curry County C008-1901 #07070, dated October 1993

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Squier, 1994a, Phase I Arizona Inn Landslide Geotechnical Investigation, Curry County, Oregon, prepared by Squier Associates, dated November 9, 1994

Squier, 1994b, Arizona Inn Landslide Technical Design Memorandum, Remedial Design Schemes, Curry County, Oregon, prepared by Squier Associates, dated December 2, 1994

Squier, 1995, Phase II Arizona Inn Landslide Geotechnical Investigation, Curry County, Oregon, prepared by Squier Associates, dated May 5, 1995

ODOT, 1996, As-Constructed Plans for Arizona Inn Slide Correction, Phase 1 Sec., Oregon Coast Highway, Curry County, dated October 30, 1996

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ODOT, 1999, Geotechnical Report, Arizona North Slide Repair, Oregon Coast Highway (#9), MP 312 Curry County, dated April 1999

ODOT, 2022, Draft Engineering Geology Report, US101: Arizona Landslide Complex Mitigation Assessment, MP 312, dated January 2022

Oregon Department of Geology and Mineral Industries (DOGAMI), 2017, Statewide Landslide Information Database for Oregon, Release 4.2 (SLIDO 4.2): Available: https://gis.dogami.oregon.gov/maps/slido/.

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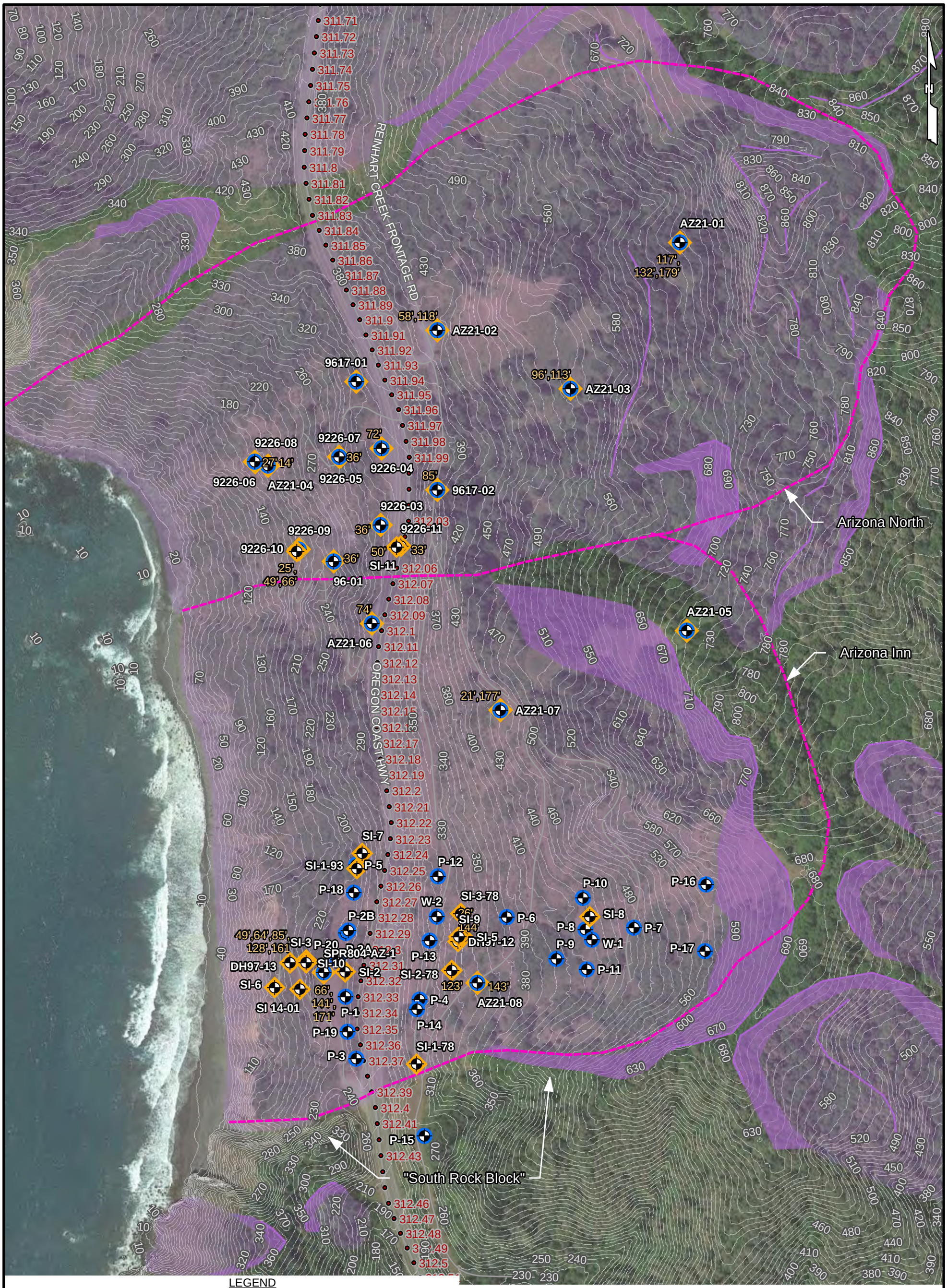

LEGEND

- Approximate Location of Boring with Inclinometer and Shear Plane Depth (13')
- Approximate Location of Boring with Piezometer
- Approximate Location of Boring with Inclinometer, Shear Plane Depth, and Piezometer (13')
- Interpreted Slide Extents
- Mapped Slide Scarp
- Mapped Slide Scarp
- Mapped Landslide Deposits

0 150 300 600

Scale in Feet

NOTES

1. Aerial imagery obtained through Google Maps Satellite.
2. Mapped slide features from SLIDO-4.2, obtained through DOGAMI.
3. Contours created from 2009 LiDAR data obtained through DOGAMI.

South Coast Landslide Study
Curry County, Oregon

SITE AND EXPLORATION PLAN
ARIZONA INN COMPLEX

April 2022 106381

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. 1

FIG. 1

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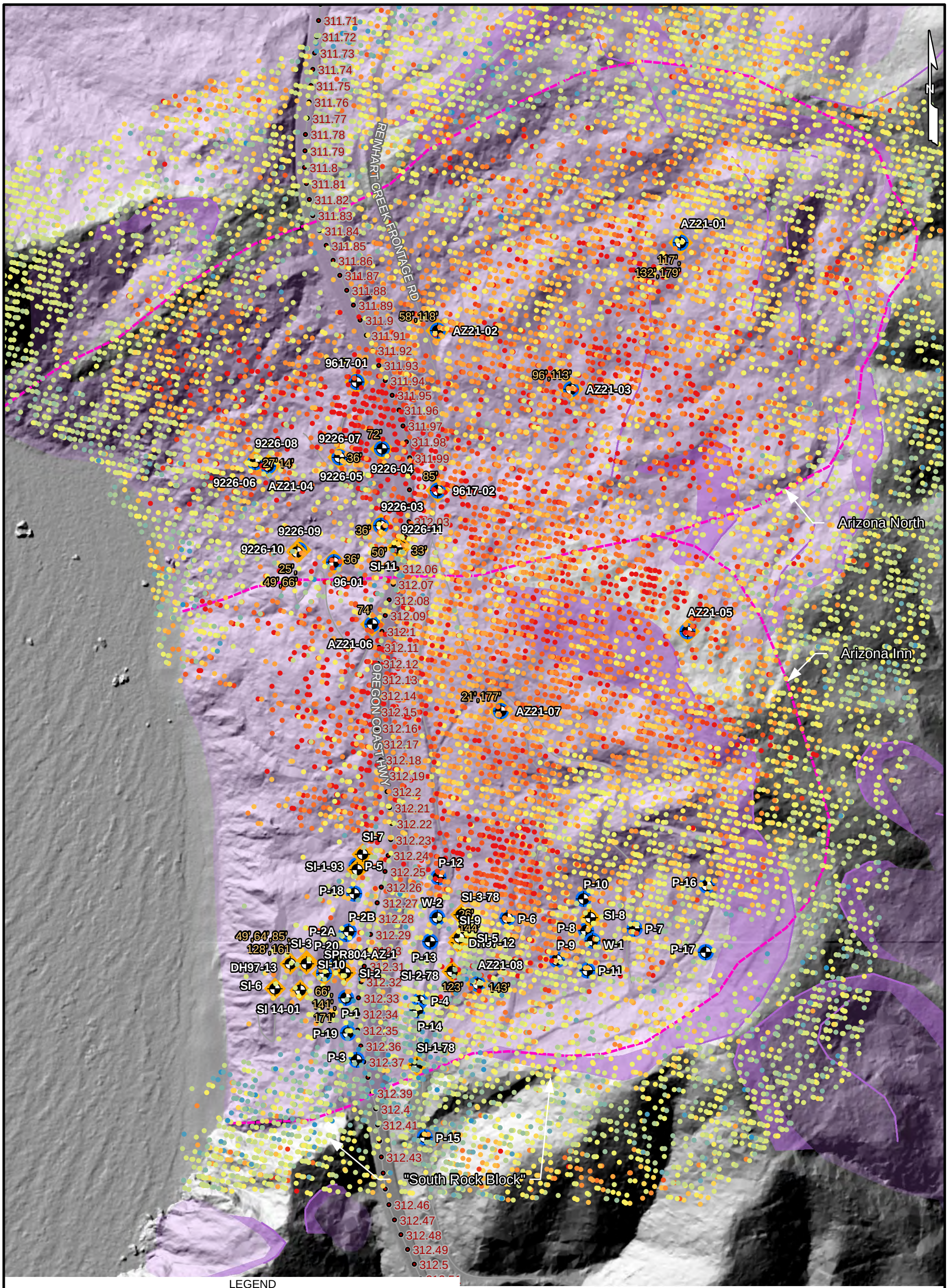

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- Approximate Location of Boring with Inclinometer, Shear Plane Depth, and Piezometer (13')
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- Mapped Slide Scarp
- Mapped Landslide Deposits

Displacement L-Band (mm/year)

<-40	-36 to -32	-20 to -16	-4 to 4	16 to 20
-40 to -36	-32 to -28	-16 to -12	4 to 8	20 to 24
	-28 to -24	-12 to -8	8 to 12	24 to 28
	-24 to -20	-8 to -4	12 to 16	28 to 32

0 150 300 600

Scale in Feet

NOTES

1. Hillshade created from 2009 LiDAR data obtained through DOGAMI.
2. Mapped slide features from SLIDO-4.2, obtained through DOGAMI.
3. Displacement rate points from InSAR data downloaded from SkyGeo on December 3, 2021. Only points with quality of 0.3 or higher are shown.

South Coast Landslide Study
Curry County, Oregon

SITE AND EXPLORATION PLAN
ARIZONA INN COMPLEX

April 2022 106381

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FIG. 2

FIG. 2

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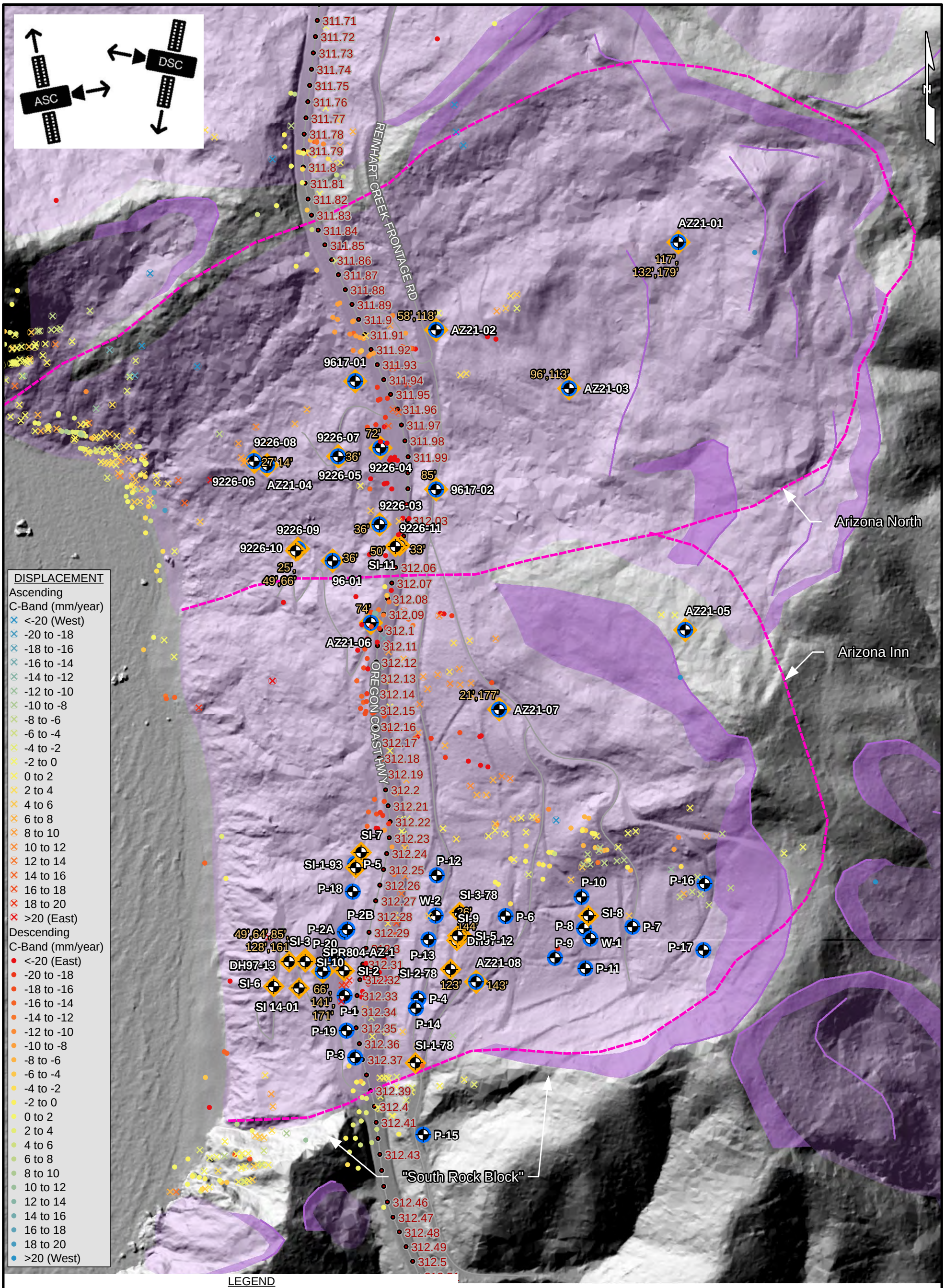

DISPLACEMENT

Ascending C-Band (mm/year)

- <-20 (West)
- -20 to -18
- -18 to -16
- -16 to -14
- -14 to -12
- -12 to -10
- -10 to -8
- -8 to -6
- -6 to -4
- -4 to -2
- -2 to 0
- 0 to 2
- 2 to 4
- 4 to 6
- 6 to 8
- 8 to 10
- 10 to 12
- 12 to 14
- 14 to 16
- 16 to 18
- 18 to 20
- >20 (East)

Descending C-Band (mm/year)

- <-20 (East)
- -20 to -18
- -18 to -16
- -16 to -14
- -14 to -12
- -12 to -10
- -10 to -8
- -8 to -6
- -6 to -4
- -4 to -2
- -2 to 0
- 0 to 2
- 2 to 4
- 4 to 6
- 6 to 8
- 8 to 10
- 10 to 12
- 12 to 14
- 14 to 16
- 16 to 18
- 18 to 20
- >20 (West)

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- Mapped Landslide Deposits

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Scale in Feet

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1. Hillshade created from 2009 LiDAR data obtained through DOGAMI.
2. Mapped slide features from SLIDO-4.2, obtained through DOGAMI.
3. Displacement rate points from InSAR data downloaded from SkyGeo on March 14, 2022. Only points with quality of 0.3 or higher are shown.

South Coast Landslide Study
Curry County, Oregon

SITE AND EXPLORATION PLAN
ARIZONA INN COMPLEX

April 2022 106381

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FIG. 3

FIG. 3

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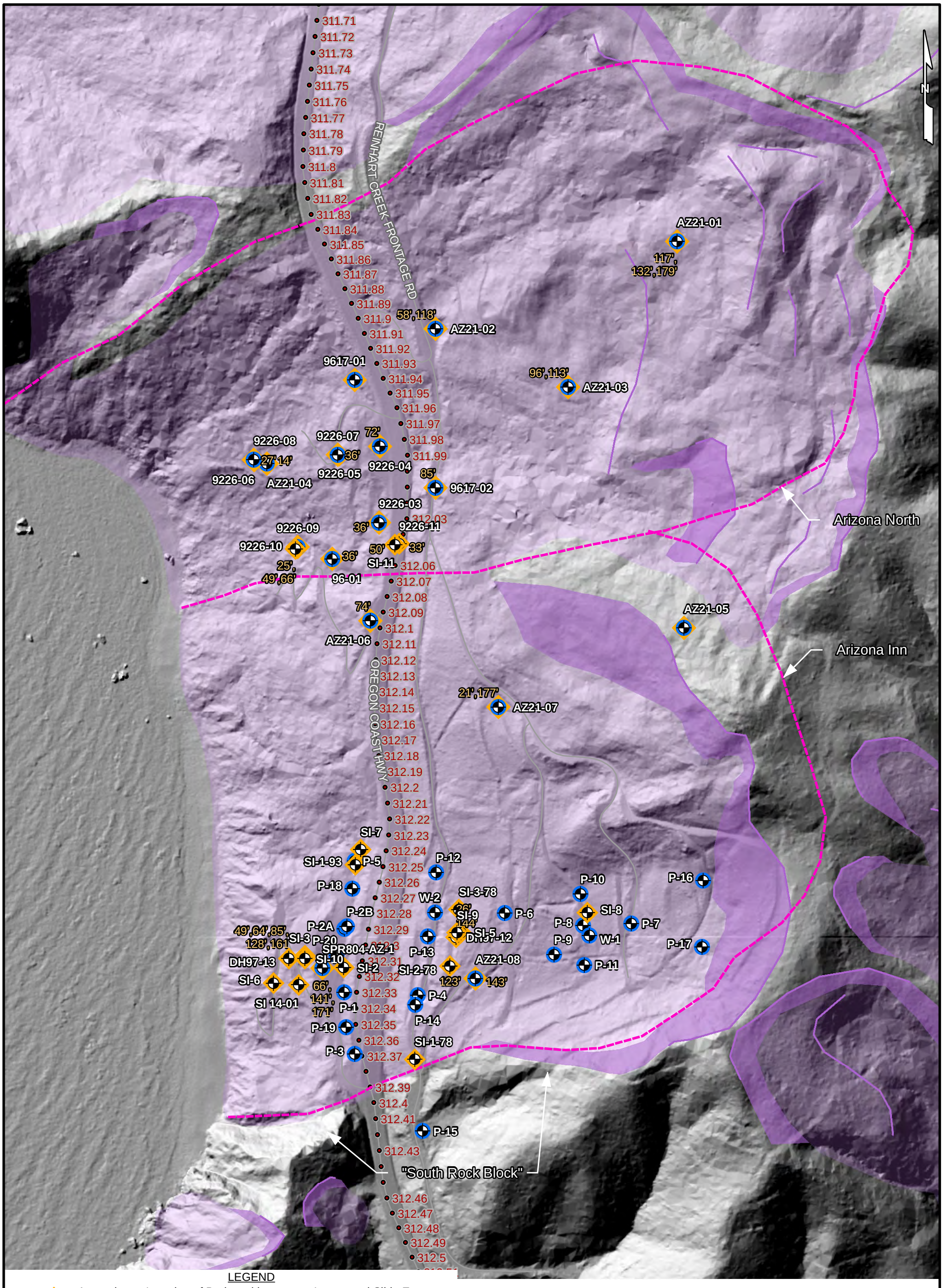

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South Coast Landslide Study
Curry County, Oregon

SITE AND EXPLORATION PLAN
ARIZONA INN COMPLEX

April 2022 106381

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FIG. 4

FIG. 4

SHANNON & WILSON

MEMORANDUM

DATE: April 1, 2022

PROJECT: South Coast Slide Study

PROJ. #: 106381-006

SUBJECT: Technical Memorandum #2 – Slide 7 Christmas Tree (Frankport North) (MP 314.10)

INTRODUCTION

Shannon & Wilson, Inc. (Shannon & Wilson) collected and reviewed all provided existing data for the Christmas Tree (Frankport North) slide including:

- Previous Geology and Geotechnical Reports;
- ODOT provided electronic and hard copy files;
- Maps and publications from the U.S. Geological Survey (USGS) and Oregon Department of Geology and Mineral Industries (DOGAMI);
- Light Detection and Ranging (LiDAR) data;
- As-constructed plans for previous slide repairs or mitigation projects;
- ODOT maintenance records and as-constructed plans including slide stabilization and paving records;
- Historical precipitation data from the nearest available gauge station; and
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Our review of existing data included interviews with ODOT geotechnical engineers and roadway maintenance personnel. This memo includes a general summary of our key findings from the data collection and analysis, site plans showing the locations of existing subsurface explorations and preliminary landslide boundaries based on our review of existing data including LiDAR and InSAR data, and a list of references/reports.

KEY FINDINGS

Slide History

- **1920's:** Original US 101 highway construction.
- **1956:** US 101 construction "Frankport – Greggs Creek Unit Section". Two-lane roadway section constructed slightly east from 1920s alignment.

- **May 1984:** During relocation of US 101 eastward, a small slide occurred upslope of US 101 just south of Christmas Tree slide (same slide as identified in Sisters Rock Sink memo).
- **June 1984:** Geophysical profiles (seismic refraction traverses) conducted nearby May 1984 slide to determine depth of overburden.
- **July 1984:** Landslide Stabilization Report published for the small slide upslope of US 101 immediately south of the Christmas Tree Slide. Recommended a rock buttress with French drains upslope as a mitigation alternative.
- **May 1996:** Borings DH 96-01 and DH 96-02 drilled with installation of inclinometer in each.
- **January 2006:** Slide movement observed (inferred from photo date) near driveway of residential property along north lateral scarp of slide, downslope of US 101.

Slide Geometry

The Christmas Tree (Frankport North) slide extends from the head scarp along the southbound shoulder of US 101 (appears to be progressing into southbound lane based on photos), down towards the coast 800 to 1,200 feet west and downslope of US 101. DOGAMI mapped the slide approximately 350 feet wide along US 101, expanding to about 1,000 feet at the toe of the slide near the coast. A 1996 site plan shows what appears to be slide limits stemming from the same head scarp as mapped in DOGAMI, but with a narrower approximate 150-foot-wide toe near the coast. Based off the two inclinometers installed from the southbound shoulder, slide planes were encountered approximately 18 to 20 feet below roadway grade.

A slide upslope from US 101, directly south of the Christmas Tree slide (same slide as identified in Sisters Rock Sink memo) occurred in May 1984 (OSHD, 1984). The slide was about 300 feet long by 200 feet wide, with the head scarp near elevation 300 feet and the toe daylighting in the 1984 cut slope east of US 101. Geophysical profiles indicate overburden ranges from 6 to 10 feet thick, overlying schist bedrock dipping easterly into the cut slope. The failure plane was interpreted as the contact between overburden and schist bedrock (OSHD, 1984).

Exhibit 1: Photo looking northeast at the head scarp of the Frankport North slide. Photo taken March 22, 2006.

Slide Mechanics

Slide movement is likely attributed to low strength, predominately decomposed, and highly sheared Otter Point Formation, coupled with high groundwater after heavy precipitation events (surficial water observed in site photos).

The May 1984 slide mass is interpreted to be a translational failure, "a graben (active wedge) located at the head of the slide pushing on a sliding (translational) block about 6 to 10 feet thick. Resistance to this mode of sliding consists of a component of shear strength along the soft clay seam failure plane (possibly derived from ash)." The backcalculated residual friction angle was 13 degrees (OSHD, 1984).

Groundwater

Groundwater was encountered during drilling (mud rotary/HQ) at 5.9 feet and 16.7 feet below ground surface (bgs) in boring 96-01. No groundwater was documented during the drilling of boring 96-02, which was terminated at a depth of 55 feet bgs. Both borings were

drilled in May 1996 using mud rotary and HQ coring techniques. No piezometer installations were noted. Surficial water was observed in project photos.

A small pond was observed near the crest of the 1984 slide, indicating surficial water is present near the site (OSHD, 1984).

Existing Slide Mitigation

The May 1984 slide preferred mitigation solution was a rock toe buttress with a French drain system upslope of the buttress. The rock toe buttress was proposed to be excavated 3 feet below the schist bedrock, and constructed with clean, hard, angular well-graded rock. The French drains were proposed to be 2-feet wide and excavated down to schist bedrock (OSHD, 1984). Construction of this mitigation was not documented.

No existing mitigations have been documented for the Christmas Tree slide.

Precipitation Data

Typically, the groundwater level at the site is a function of the amount and intensity of precipitation that occurs within the drainage basin, amongst other factors. We have gathered precipitation data from nearby weather stations, including from precipitation monitoring instruments installed in the late 1990's at the Arizona Inn Slide location. For the Christmas Tree slide site, the closest precipitation gauge is USC00356784 in Port Orford, 11.5 miles NW of the project site.

PRELIMINARY LANDSLIDE BOUNDARIES

Preliminary landslide boundaries were generated using a combination of existing information, observations made during the recent site reconnaissance performed by Shannon & Wilson, and LiDAR and InSAR data analysis. The preliminary boundaries, including DOGAMI landslide boundaries from SLIDO 4.2, are shown on the Site and Exploration Plans attached to this memo.

During the recent site reconnaissance, landslide areas and features were mapped and compared to existing data. Shannon & Wilson then worked with SkyGeo to create an interactive map viewer which combined landslide inventory mapping and LiDAR data from DOGAMI, with InSAR data generated by SkyGeo. The InSAR data provided consisted of L-Band satellite data collected from March 19, 2016 to May 24, 2020, and ascending and descending C-Band satellite data collected from May 23, 2015 to December 31, 2021. A desktop analysis of the available information and data was performed, and preliminary

landslide boundaries were created and imported into the SkyGeo map viewer. Shannon & Wilson then held a meeting with SkyGeo to review the preliminary landslide boundaries and analysis methods.

REFERENCES

Boring Logs with Inclinometer Data: 96-01 and 96-02

OSHD, 1984, Landslide Stabilization Report, State HWY. 1, MP 314.12 to MP 314.36, Frankport, Oregon, dated July 6, 1984.

Oregon Department of Geology and Mineral Industries (DOGAMI), 2017, Statewide Landslide Information Database for Oregon, Release 4.2 (SLIDO 4.2): Available: https://gis.dogami.oregon.gov/maps/slido/.

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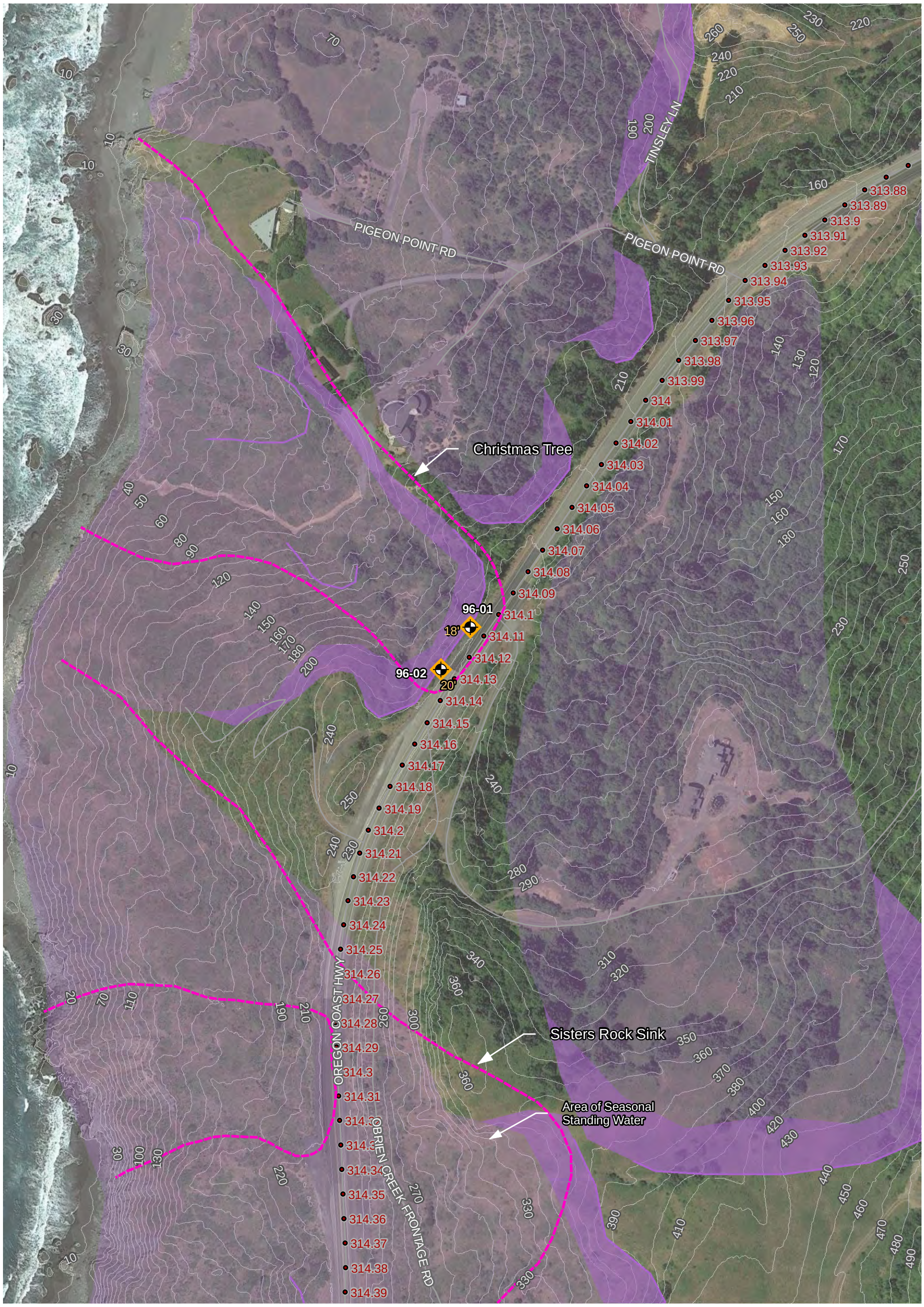


LEGEND

13' Approximate Location of Boring with Inclinometer and Shear Plane Depth

Interpreted Slide Extents

Mapped Slide Scarp

Mapped Slide Scarp

Mapped Landslide Deposits

0 100 200 400

Scale in Feet

NOTES

1. Aerial imagery obtained through Google Maps Satellite.
2. Mapped slide features from SLIDO-4.2, obtained through DOGAMI.
3. Contours created from 2009 LiDAR data obtained through DOGAMI.

South Coast Landslide Study
Curry County, Oregon

SITE AND EXPLORATION PLAN
CHRISTMAS TREE
(FRANKPORT NORTH)

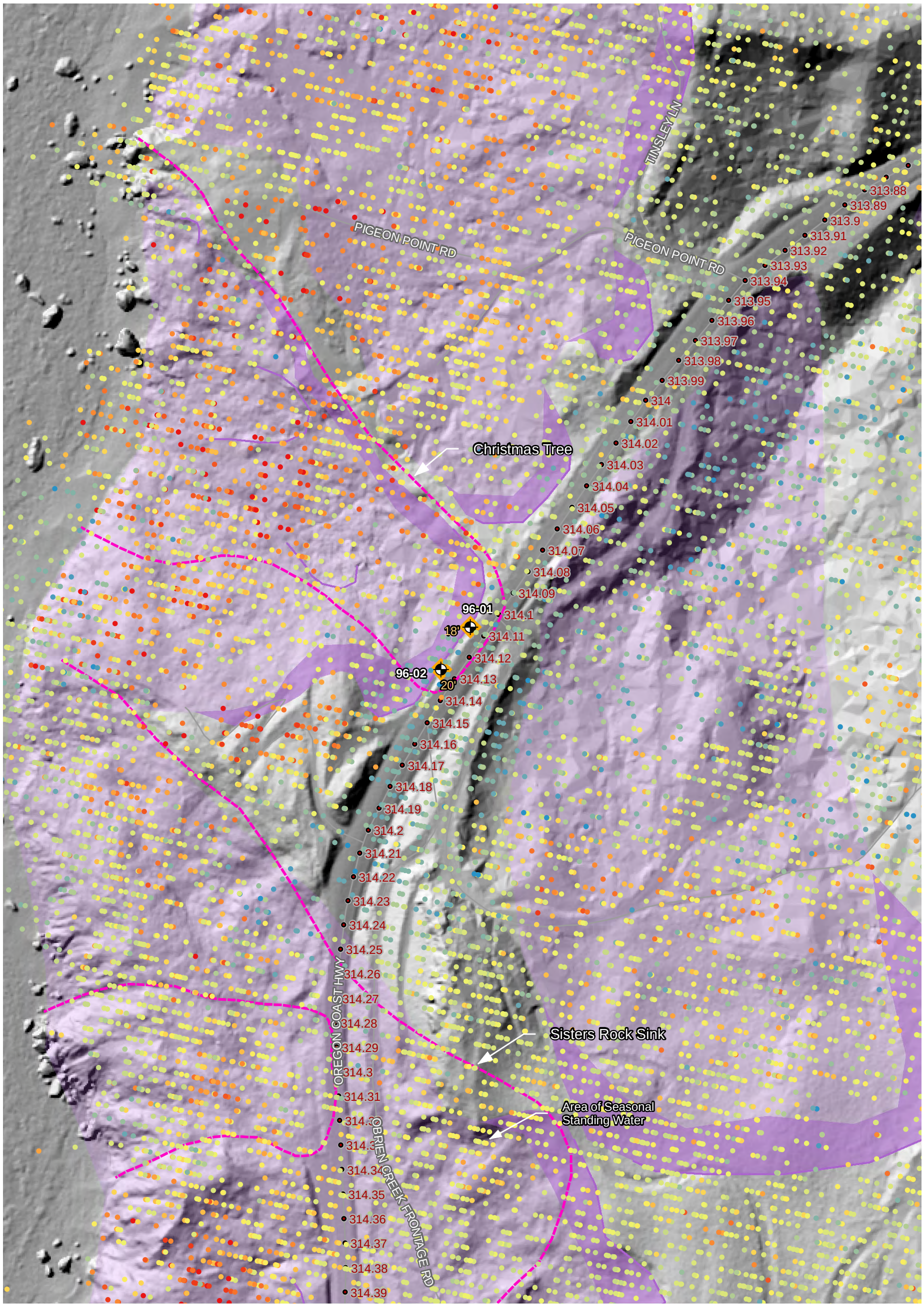
April 2022 106381

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. 1

FIG. 1

Filename: T:\Projects\PDX\106000s\106381_ODOT R3 South C\Avmxd\SitePlan7FrankportN_10.7.mxd Date: 3/31/2022 Login: AEH



LEGEND

13' Approximate Location of Boring with Inclinometer and Shear Plane Depth

Interpreted Slide Extents

Mapped Slide Scarp

Mapped Slide Scarp

Mapped Landslide Deposits

Displacement L-Band (mm/year)

- <-40
- -40 to -36
- -36 to -32
- -32 to -28
- -28 to -24
- -24 to -20
- -20 to -16
- -16 to -12
- -12 to -8
- -8 to -4
- -4 to 4
- 4 to 8
- 8 to 12
- 12 to 16
- 16 to 20
- 20 to 24
- 24 to 28
- 28 to 32

0 100 200 400

Scale in Feet

NOTES

1. Hillshade created from 2009 LiDAR data obtained through DOGAMI.
2. Mapped slide features from SLIDO-4.2, obtained through DOGAMI.
3. Displacement rate points from InSAR data downloaded from SkyGeo on December 3, 2021. Only points with quality of 0.3 or higher are shown.

South Coast Landslide Study
Curry County, Oregon

SITE AND EXPLORATION PLAN
CHRISTMAS TREE
(FRANKPORT NORTH)

April 2022 106381

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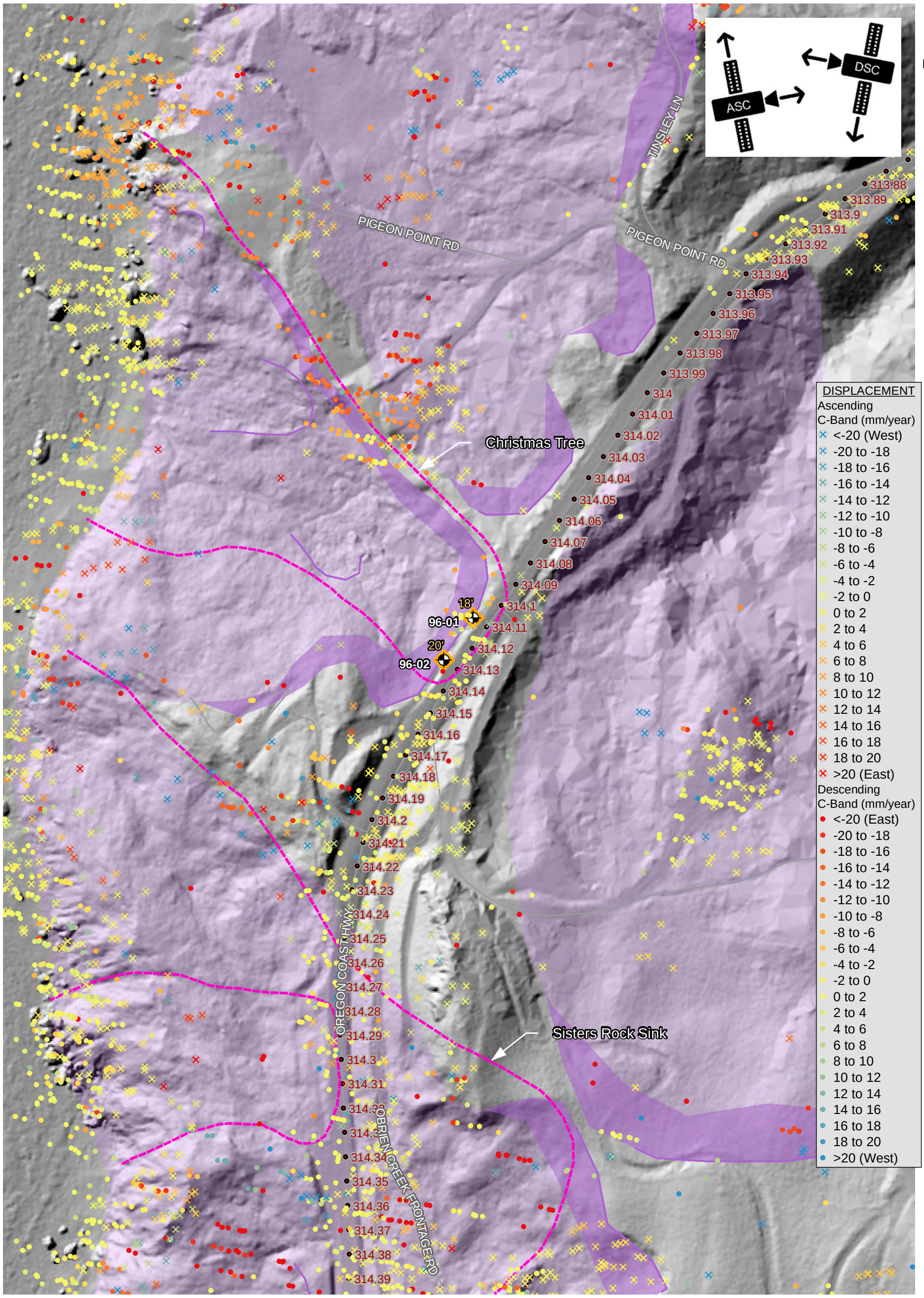
FIG. 2

FIG. 2

Filename: T:\Projects\PDX\106000s\106381_ODOT R3 South C\Avmxd\SitePlan7FrankportN_C_10.7.mxd Date: 3/31/2022 Login: AEH



LEGEND

13' Approximate Location of Boring with Inclinometer and Shear Plane Depth

Interpreted Slide Extents

Mapped Slide Scarp

Mapped Slide Scarp

Mapped Landslide Deposits

0 100 200 400

Scale in Feet

NOTES

1. Hillshade created from 2009 LiDAR data obtained through DOGAMI.
2. Mapped slide features from SLIDO-4.2, obtained through DOGAMI.
3. Displacement rate points from InSAR data downloaded from SkyGeo on March 14, 2022. Only points with quality of 0.3 or higher are shown.

South Coast Landslide Study
Curry County, Oregon

SITE AND EXPLORATION PLAN
CHRISTMAS TREE
(FRANKPORT NORTH)

April 2022 106381

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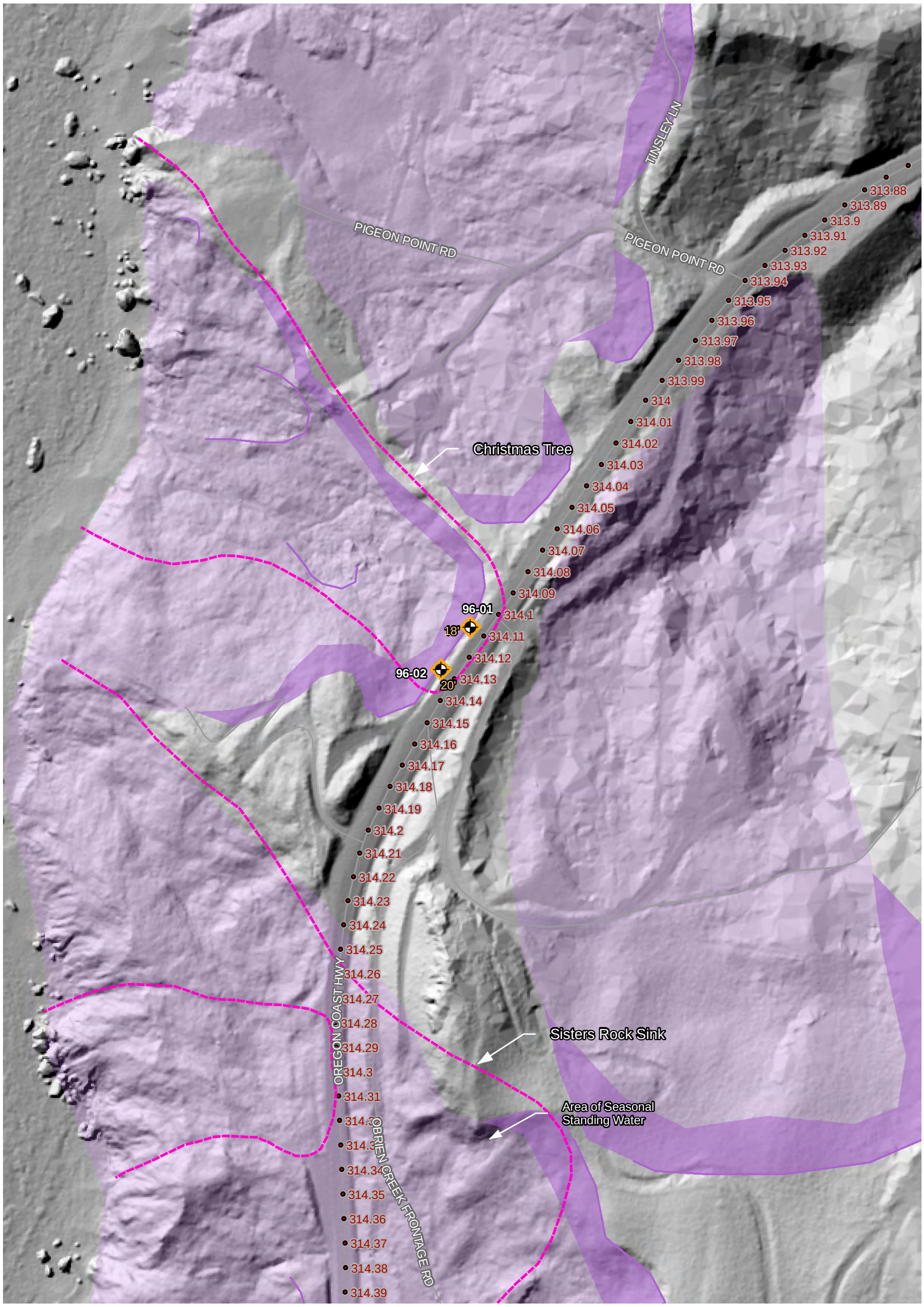
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. 3

FIG. 3

Filename: T:\Projects\PDX\106000s\106381_ODOT R3 South C\Avmxd\SitePlan7FrankportN_10.7.mxd Date: 3/31/2022 Login: AEH



LEGEND

13' Approximate Location of Boring with Inclinometer and Shear Plane Depth

Interpreted Slide Extents

Mapped Slide Scarp

Mapped Slide Scarp

Mapped Landslide Deposits

0 100 200 400

Scale in Feet

NOTES

1. Hillshade created from 2009 LiDAR data obtained through DOGAMI.
2. Mapped slide features from SLIDO-4.2, obtained through DOGAMI.

South Coast Landslide Study
Curry County, Oregon

SITE AND EXPLORATION PLAN
CHRISTMAS TREE
(FRANKPORT NORTH)

April 2022 106381

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. 4

FIG. 4

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MEMORANDUM

DATE: April 2, 2022

PROJECT: South Coast Slide Study

PROJ. #: 106381-006

SUBJECT: Technical Memorandum #2 – Slide 8 Sisters Rock Sink (MP 314.29 to 314.35)

INTRODUCTION

Shannon & Wilson, Inc. (Shannon & Wilson) collected and reviewed all provided existing data for the Sisters Rock Sink slide including:

- Previous Geology and Geotechnical Reports;
- ODOT provided electronic and hard copy files;
- Maps and publications from the U.S. Geological Survey (USGS) and Oregon Department of Geology and Mineral Industries (DOGAMI);
- Light Detection and Ranging (LiDAR) data;
- As-constructed plans for previous slide repairs or mitigation projects;
- ODOT maintenance records and as-constructed plans including slide stabilization and paving records;
- Historical precipitation data from the nearest available gauge station; and
- Interferometric Synthetic Aperture Radar (InSAR) ground movement data.

Our review of existing data included interviews with ODOT geotechnical engineers and roadway maintenance personnel. This memo includes a general summary of our key findings from the data collection and analysis, site plans showing the locations of existing subsurface explorations and preliminary landslide boundaries based on our review of existing data including LiDAR and InSAR data, and a list of references/reports.

KEY FINDINGS

Slide History

- **1920's:** Original US 101 highway construction.
- **1956:** US 101 construction "Frankport – Greggs Creek Unit Section". Two-lane roadway section constructed slightly west from 1920s alignment.

- **May 1984:** During relocation of US 101 eastward, a small slide occurred upslope of US 101 just north of Sisters Rock Sink (same slide as identified in Christmas Tree slide memo).
- **June 1984:** Geophysical profiles (seismic refraction traverses) conducted nearby May 1984 slide to determine depth of overburden.
- **July 1984:** Landslide Stabilization Report published for the small slide upslope of US 101 north of the Sisters Rock Sink. Recommended a rock buttress with French drains upslope as a mitigation alternative.
- **October 1990:** Notes indicate movement was observed at the slide area, with a "possible extension to the north".
- **June 1996:** Boring 96-01 drilled with installation of inclinometer and piezometer.

Slide Geometry

The Sisters Rock Sink extends from the head scarp along the southbound lane of US 101. It is unclear how far downslope below US 101 the slide extends, and whether it dips into the native material, but historic slide toes are observed approximately 1,000 feet downslope of US 101 near the coast. ODOT has stated the slide width is approximately 320 feet along US 101. Based off the single inclinometer installed at the project site, the slide plane was encountered 25 feet below roadway grade (assuming the borehole was drilled from the roadway), at the fill to native soil interface. Site notes from 1990 describe the small sliver fill overloading the low strength soils at the site (ODOT, 1990).

A slide upslope from US 101, directly north of the Sisters Rock Sink (same slide as identified in Christmas Tree slide memo) occurred in May 1984 (OSHD, 1984). The slide was about 300 feet long by 200 feet wide, with the head scarp near elevation 300 feet and the toe daylighting in the 1984 cut slope east of US 101. Geophysical profiles indicate the overburden ranges from 6 to 10 feet thick, overlying schist bedrock dipping easterly into the cut slope. The failure plane was interpreted as the contact between overburden and schist bedrock (OSHD, 1984).

Exhibit 1: Photo looking northeast along US101 at the ground movement within the Sisters Rock Sink area. Photo taken March 16, 2007.

Slide Mechanics

Notes describing a site visit indicate the slope instability has been attributed to loading of a weak failure plane (described as medium plasticity silty CLAY / clayey SILT), potentially coupled with shallow and/or perched groundwater within the slide zone (ODOT, 1990).

The May 1984 slide mass is interpreted to be a translational failure, "a graben (active wedge) located at the head of the slide pushing on a sliding (translational) block about 6 to 10 feet thick. Resistance to this mode of sliding consists of a component of shear strength along the soft clay seam failure plane (possibly derived from ash)." The backcalculated residual friction angle was 13 degrees (OSHD, 1984).

Groundwater

Groundwater was encountered between 9.6 feet and about 25 feet below roadway grade. It generally appears average static groundwater is 25 feet below ground surface. A 24-inch CMP exists beneath US 101 in the slide area, potentially increasing groundwater levels.

A small pond was observed near the crest of the 1984 slide, indicating surficial water is present near the site (OSHD, 1984).

Existing Slide Mitigation

A 1997 figure indicates ODOT proposed to excavate and replace a portion of the existing embankment fill with lightweight wood fiber fill, however this mitigation was never constructed. No other mitigations have been documented for this slide.

The May 1984 slide preferred mitigation solution was a rock toe buttress with a French drain system upslope of the buttress. The rock toe buttress was proposed to be excavated 3 feet below the schist bedrock, and constructed with clean, hard, angular well-graded rock. The French drains were proposed to be 2-feet wide and excavated down to schist bedrock (OSHD, 1984). Construction of this mitigation was not documented.

Precipitation Data

Typically, the groundwater level at the site is a function of the amount and intensity of precipitation that occurs within the drainage basin, amongst other factors. We have gathered precipitation data from nearby weather stations, including from precipitation monitoring instruments installed in the late 1990's at the Arizona Inn Slide location. For the Sisters Rock slide site, the closest precipitation gauge is USC00356784 in Port Orford, 11.9 miles NW of the project site.

PRELIMINARY LANDSLIDE BOUNDARIES

Preliminary landslide boundaries were generated using a combination of existing information, observations made during the recent site reconnaissance performed by Shannon & Wilson, and LiDAR and InSAR data analysis. The preliminary boundaries, including DOGAMI landslide boundaries from SLIDO 4.2, are shown on the Site and Exploration Plans attached to this memo.

During the recent site reconnaissance, landslide areas and features were mapped and compared to existing data. Shannon & Wilson then worked with SkyGeo to create an

interactive map viewer which combined landslide inventory mapping and LiDAR data from DOGAMI, with InSAR data generated by SkyGeo. The InSAR data provided consisted of L-Band satellite data collected from March 19, 2016 to May 24, 2020, and ascending and descending C-Band satellite data collected from May 23, 2015 to December 31, 2021. A desktop analysis of the available information and data was performed, and preliminary landslide boundaries were created and imported into the SkyGeo map viewer. Shannon & Wilson then held a meeting with SkyGeo to review the preliminary landslide boundaries and analysis methods.

The Sisters Rock Sink landslide is located within and adjacent to larger mapped landslide areas according to DOGAMI (2017). InSAR data indicates significant surface displacement outside of the Sisters Rock Sink slide boundaries which may be associated with a larger or separate landslide.

REFERENCES

Boring Logs with Inclinometer and Piezometer Data: 96-01

OSHD, 1984, Landslide Stabilization Report, State HWY. 1, MP 314.12 to MP 314.36, Frankport, Oregon, dated July 6, 1984.

ODOT, 1990, Hwy 9, M.P. 314.33, Notes

Oregon Department of Geology and Mineral Industries (DOGAMI), 2017, Statewide Landslide Information Database for Oregon, Release 4.2 (SLIDO 4.2): Available: https://gis.dogami.oregon.gov/maps/slido/.

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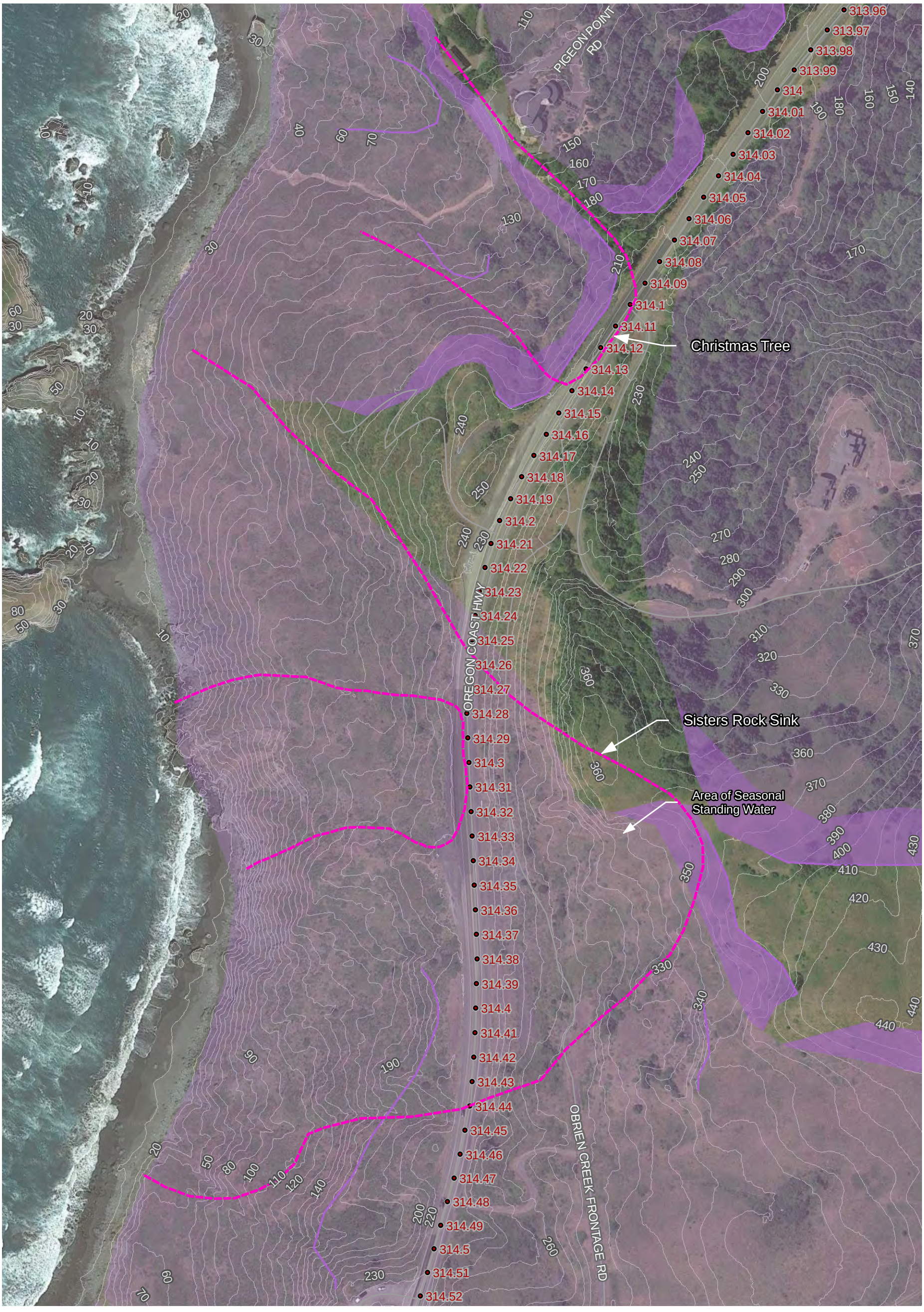


LEGEND

- Interpreted Slide Extents
- Mapped Slide Scarp
- Mapped Slide Scarp
- Mapped Landslide Deposits

0 100 200 400

Scale in Feet

NOTES

1. Aerial imagery obtained through Google Maps Satellite.
2. Mapped slide features from SLIDO-4.2, obtained through DOGAMI.
3. Contours created from 2009 LiDAR data obtained through DOGAMI.

South Coast Landslide Study
Curry County, Oregon

SITE AND EXPLORATION PLAN
SISTERS ROCK SINK

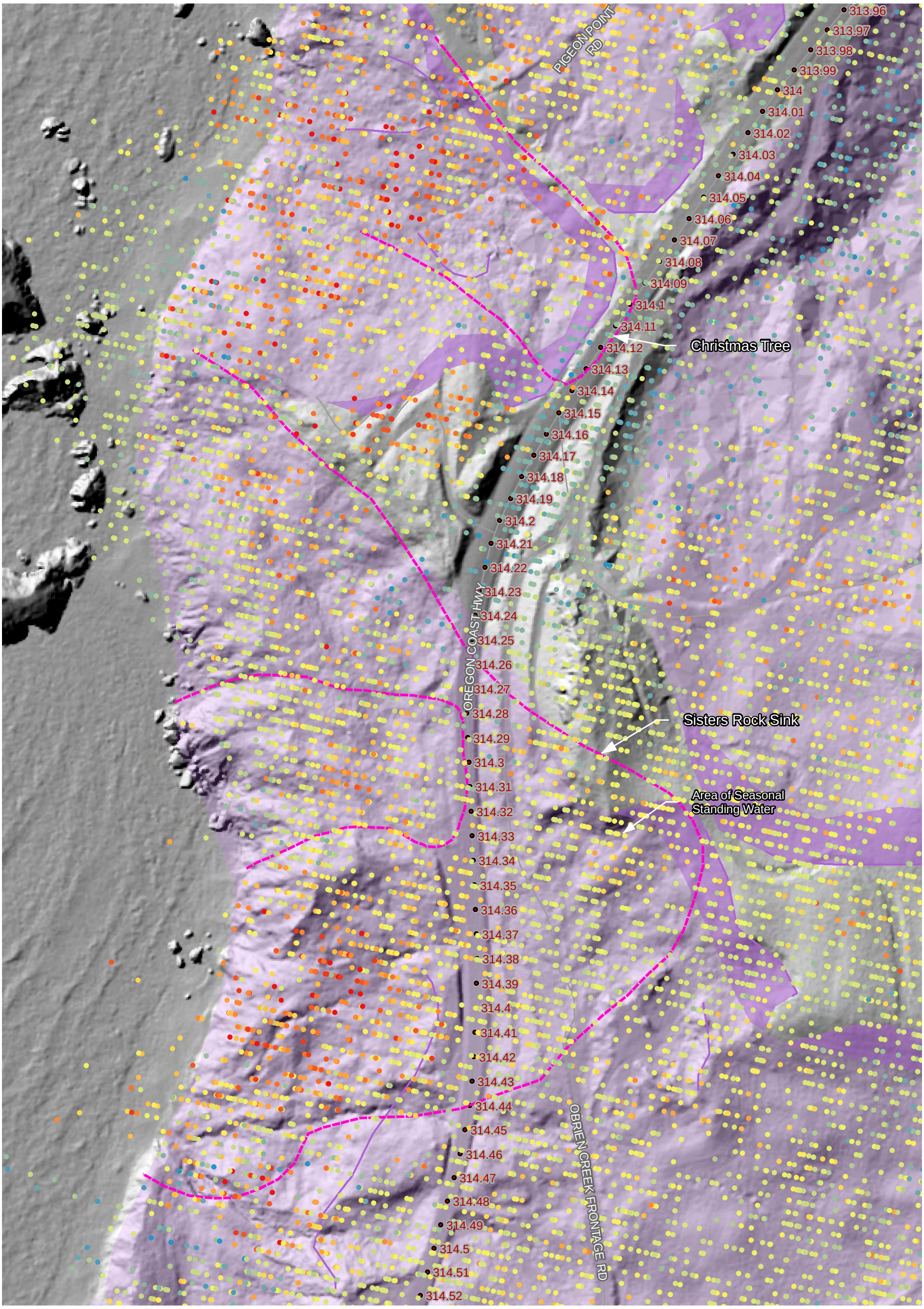
April 2022 106381

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. 1

FIG. 1

Filename: T:\Projects\PDX\106000s\106381_ODOT R3 South C\Avmxd\SitePlan8SistersRk_10.7.mxd Date: 3/25/2022 Login: AEH



LEGEND

- Interpreted Slide Extents
- Mapped Slide Scarp
- Mapped Slide Scarp
- Mapped Landslide Deposits

Displacement L-Band (mm/year)

<-40	-36 to -32	-20 to -16	-4 to 4	16 to 20
-40 to -36	-32 to -28	-16 to -12	4 to 8	20 to 24
	-28 to -24	-12 to -8	8 to 12	24 to 28
	-24 to -20	-8 to -4	12 to 16	28 to 32

0 100 200 400

Scale in Feet

NOTES

1. Hillshade created from 2009 LiDAR data obtained through DOGAMI.
2. Mapped slide features from SLIDO-4.2, obtained through DOGAMI.
3. Displacement rate points from InSAR data downloaded from SkyGeo on December 3, 2021. Only points with quality of 0.3 or higher are shown.

South Coast Landslide Study
Curry County, Oregon

SITE AND EXPLORATION PLAN
SISTERS ROCK SINK

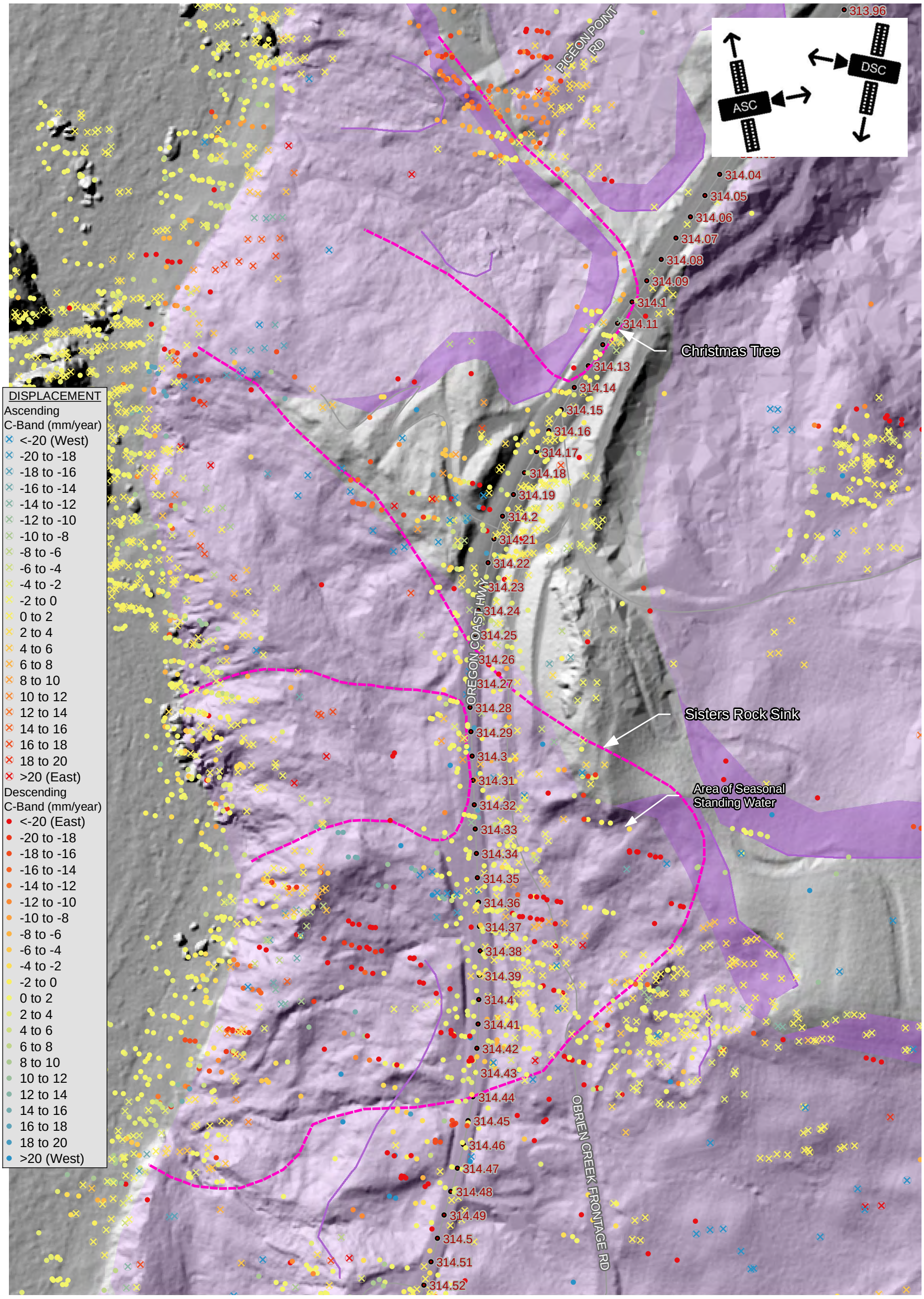
April 2022 106381

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. 2

FIG. 2

Filename: T:\Projects\PDX\106000s\106381_ODOT R3 South C\Avmxd\SitePlan8SistersRk_C_10.7.mxd Date: 3/25/2022 Login: AEH



LEGEND

- Interpreted Slide Extents
- Mapped Slide Scarp
- Mapped Slide Scarp
- Mapped Landslide Deposits

0 100 200 400

Scale in Feet

NOTES

1. Hillshade created from 2009 LiDAR data obtained through DOGAMI.
2. Mapped slide features from SLIDO-4.2, obtained through DOGAMI.
3. Displacement rate points from InSAR data downloaded from SkyGeo on March 14, 2022. Only points with quality of 0.3 or higher are shown.

South Coast Landslide Study
Curry County, Oregon

SITE AND EXPLORATION PLAN
SISTERS ROCK SINK

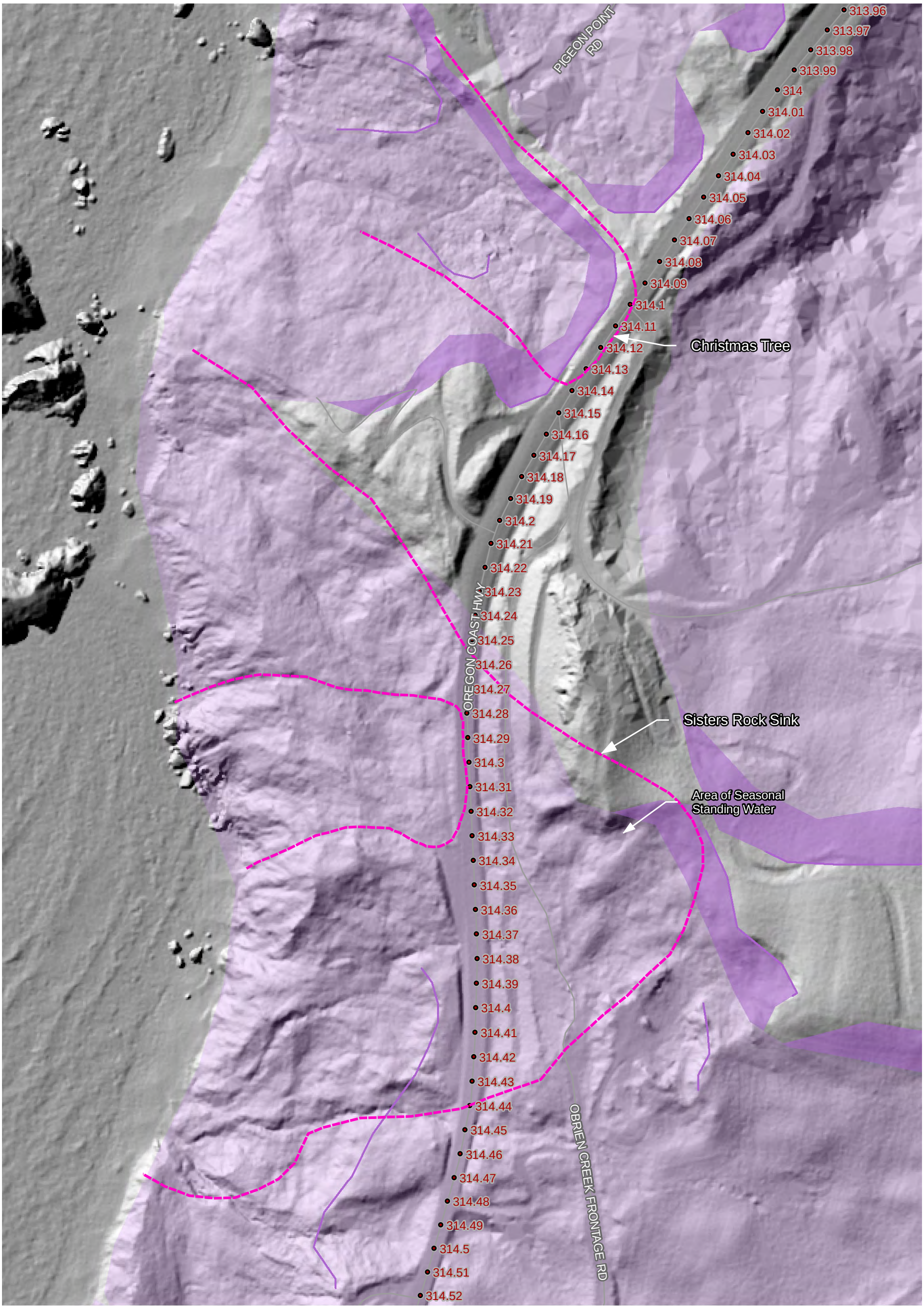
April 2022 106381

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. 3

FIG. 3

Filename: T:\Projects\PDX\106000s\106381_ODOT R3 South C\Avmxd\SitePlan8SistersRk_10.7.mxd Date: 3/25/2022 Login: AEH



LEGEND

- Interpreted Slide Extents
- Mapped Slide Scarp
- Mapped Slide Scarp
- Mapped Landslide Deposits

0 100 200 400

Scale in Feet

NOTES

1. Hillshade created from 2009 LiDAR data obtained through DOGAMI.
2. Mapped slide features from SLIDO-4.2, obtained through DOGAMI.

South Coast Landslide Study
Curry County, Oregon

SITE AND EXPLORATION PLAN
SISTERS ROCK SINK

April 2022 106381

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GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. 4

FIG. 4

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MEMORANDUM

DATE: April 1, 2022

PROJECT: South Coast Slide Study

PROJ. #: 106381-006

SUBJECT: Technical Memorandum #2 – Slide 9 Frankport South (MP 314.74 to 314.83)

INTRODUCTION

Shannon & Wilson, Inc. (Shannon & Wilson) collected and reviewed all provided existing data for the Frankport South slide including:

- Previous Geology and Geotechnical Reports;
- ODOT provided electronic and hard copy files;
- Maps and publications from the U.S. Geological Survey (USGS) and Oregon Department of Geology and Mineral Industries (DOGAMI);
- Light Detection and Ranging (LiDAR) data;
- As-constructed plans for previous slide repairs or mitigation projects;
- ODOT maintenance records and as-constructed plans including slide stabilization and paving records;
- Historical precipitation data from the nearest available gauge station; and
- Interferometric Synthetic Aperture Radar (InSAR) ground movement data.

Our review of existing data included interviews with ODOT geotechnical engineers and roadway maintenance personnel. This memo includes a general summary of our key findings from the data collection and analysis, site plans showing the locations of existing subsurface explorations and preliminary landslide boundaries based on our review of existing data including LiDAR and InSAR data, and a list of references/reports.

KEY FINDINGS

Slide History

- **1920's:** Original US 101 highway construction.
- **1956:** US 101 construction "Frankport – Greggs Creek Unit Section". Two-lane roadway section constructed slightly west from 1920s alignment.
- **1982:** Installed 24-inch CMP under US 101 within slide vicinity.

- **January 1983:** Soils and Geology Report detailing how the fill slope in the project area is having difficulty "catching" on the native ground surface.
- **May/June 1996:** Borings DH 96-01 and DH 96-02 drilled with installation of inclinometer and piezometer in each.

Slide Geometry

Based off DOGAMI mapping, the Frankport South Slide extends from the cut slope east and upslope of US 101, below US 101, and downslope to an unidentified toe. It is part of a large slide complex in the area, stretching up to 1,800 feet upslope from US 101 and extending down to the coast. Movement has been observed along the cut slope east of US 101 (scarps and cracking). ODOT has indicated the active section of Frankport South Slide stretches approximately 475 feet along US 101.

Two inclinometers were installed in 1996, picking up failure planes at 16 and 53 feet below ground surface. The 16-foot-deep shear zone observed in boring 96-01 could be indicative of an embankment fill type failure, as mentioned in the January 1983 Soils and Geology Report (OSHD, 1983). The 53-foot-deep shear zone could be from a larger, deeper seated slide. Based off the repaved area of US 101, the slide has affected approximately 200 feet of the roadway.

Exhibit 1: Photo looking north along US101, displaying pavement distress within the Frankport South slide limits. Photo taken March 22, 2006.

Slide Mechanics

Embankment fill placed on high plasticity soil could have overloaded an already weak failure plane. High static groundwater level is likely a contributor to the slope instability, coupled with perched water at times of heavy precipitation.

Groundwater

Groundwater was encountered in boring 96-02 between 7.4 feet and 24.7 feet below ground surface (bgs) in the deeper sensor, and between 17.3 and 25.1 feet bgs in the shallower sensor. Based off project photos, surficial water has been observed in the project vicinity.

Existing Slide Mitigation

Drainage measures have been implemented over the years as indicated by invoices for pipe installation in the project area from 1982. ODOT has indicated continuous repaving of the roadway every 1 to 3 years has been occurring, however no permanent mitigations have been documented.

Precipitation Data

Typically, the groundwater level at the site is a function of the amount and intensity of precipitation that occurs within the drainage basin, amongst other factors. We have gathered precipitation data from nearby weather stations, including from precipitation monitoring instruments installed in the late 1990's at the Arizona Inn Slide location. For the Frankport South slide site, the closest precipitation gauge is USC00356784 in Port Orford, 12.2 miles NW of the project site.

PRELIMINARY LANDSLIDE BOUNDARIES

Preliminary landslide boundaries were generated using a combination of existing information, observations made during the recent site reconnaissance performed by Shannon & Wilson, and LiDAR and InSAR data analysis. The preliminary boundaries, including DOGAMI landslide boundaries from SLIDO 4.2, are shown on the Site and Exploration Plans attached to this memo.

During the recent site reconnaissance, landslide areas and features were mapped and compared to existing data. Shannon & Wilson then worked with SkyGeo to create an interactive map viewer which combined landslide inventory mapping and LiDAR data from DOGAMI, with InSAR data generated by SkyGeo. The InSAR data provided consisted of L-Band satellite data collected from March 19, 2016 to May 24, 2020, and ascending and descending C-Band satellite data collected from May 23, 2015 to December 31, 2021. A desktop analysis of the available information and data was performed, and preliminary landslide boundaries were created and imported into the SkyGeo map viewer. Shannon & Wilson then held a meeting with SkyGeo to review the preliminary landslide boundaries and analysis methods.

The Frankport South landslide is located within and adjacent to larger mapped landslide areas according to DOGAMI (2017). InSAR data indicates significant surface displacement outside of the Frankport South slide boundaries which may be associated with a larger or separate landslide.

REFERENCES

Boring Logs with Inclinometer and Piezometer Data: 96-01 and 96-02

OSHD, 1983, Soils and Geology Report, Retz Creek and Frankport Creek Slides, M.P. 304.17 – 304.75; M.P. 314.25 – 314.85, Oregon Coast Highway, Curry County, dated January 12, 1983

Oregon Department of Geology and Mineral Industries (DOGAMI), 2017, Statewide Landslide Information Database for Oregon, Release 4.2 (SLIDO 4.2): Available: https://gis.dogami.oregon.gov/maps/slido/.

Filename: T:\Projects\PDX\106000s\106381_ODOT R3 South C\Avmxd\SitePlan9FrankportS_10.7.mxd Date: 3/24/2022 Login: AEH

LEGEND

13' Approximate Location of Boring with Inclinometer and Shear Plane Depth

13' Approximate Location of Boring with Inclinometer, Shear Plane Depth, and Piezometer

Interpreted Slide Extents

Mapped Slide Scarp

Mapped Slide Scarp

Mapped Landslide Deposits

0 150 300 600

Scale in Feet

NOTES

1. Aerial imagery obtained through Google Maps Satellite.
2. Mapped slide features from SLIDO-4.2, obtained through DOGAMI.
3. Contours created from 2009 LiDAR data obtained through DOGAMI.

South Coast Landslide Study
Curry County, Oregon

SITE AND EXPLORATION PLAN
FRANKPORT SOUTH

April 2022 106381

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. 1

FIG. 1

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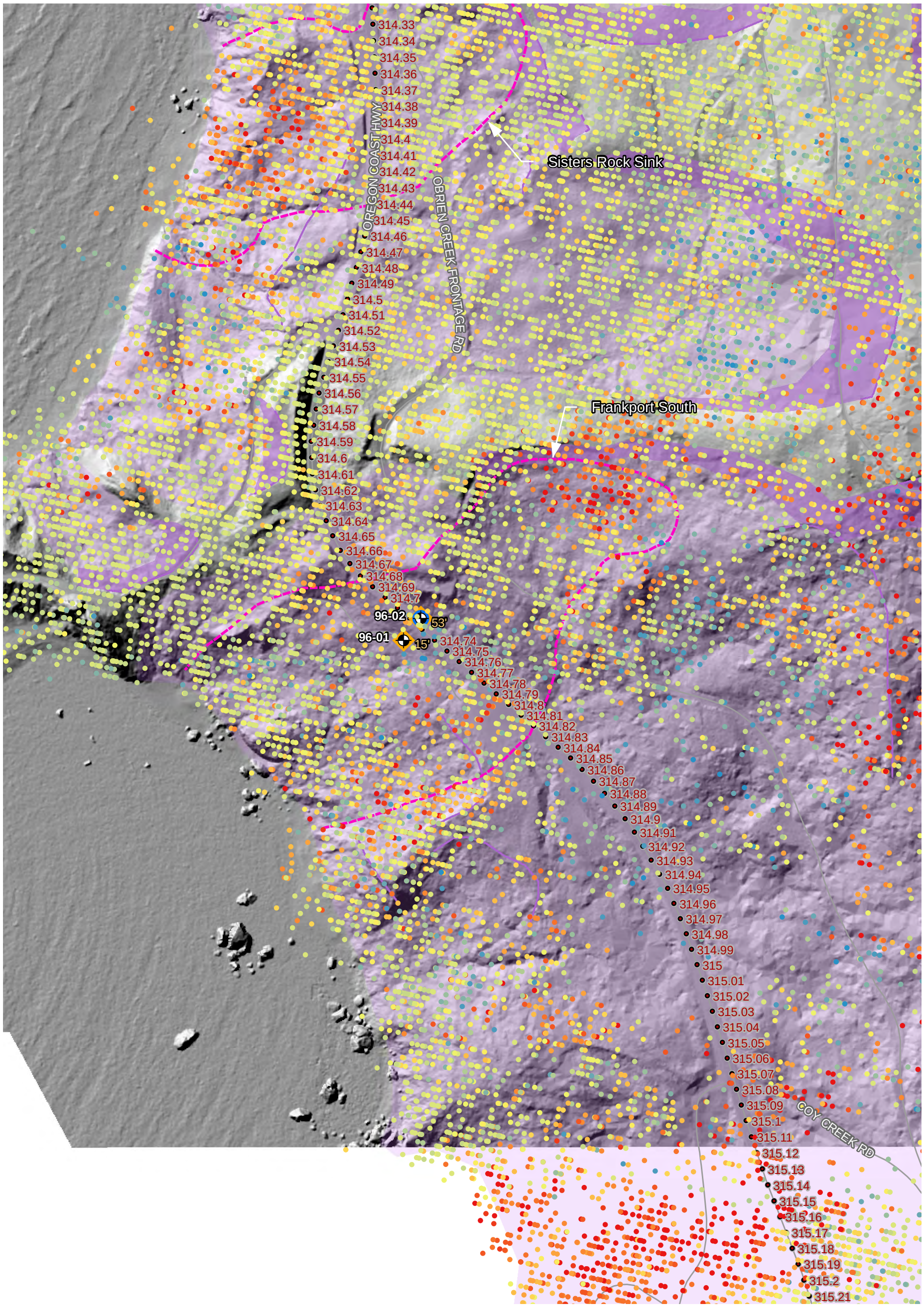

LEGEND

13' Approximate Location of Boring with Inclinometer and Shear Plane Depth

13' Approximate Location of Boring with Inclinometer, Shear Plane Depth, and Piezometer

Interpreted Slide Extents

Mapped Slide Scarp

Mapped Slide Scarp

Mapped Landslide Deposits

Displacement L-Band (mm/year)

- <-40
- -40 to -36
- -36 to -32
- -32 to -28
- -28 to -24
- -24 to -20
- -20 to -16
- -16 to -12
- -12 to -8
- -8 to -4
- -4 to 4
- 4 to 8
- 8 to 12
- 12 to 16
- 16 to 20
- 20 to 24
- 24 to 28
- 28 to 32

0 150 300 600

Scale in Feet

NOTES

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South Coast Landslide Study
Curry County, Oregon

SITE AND EXPLORATION PLAN
FRANKPORT SOUTH

April 2022 106381

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. 2

FIG. 2

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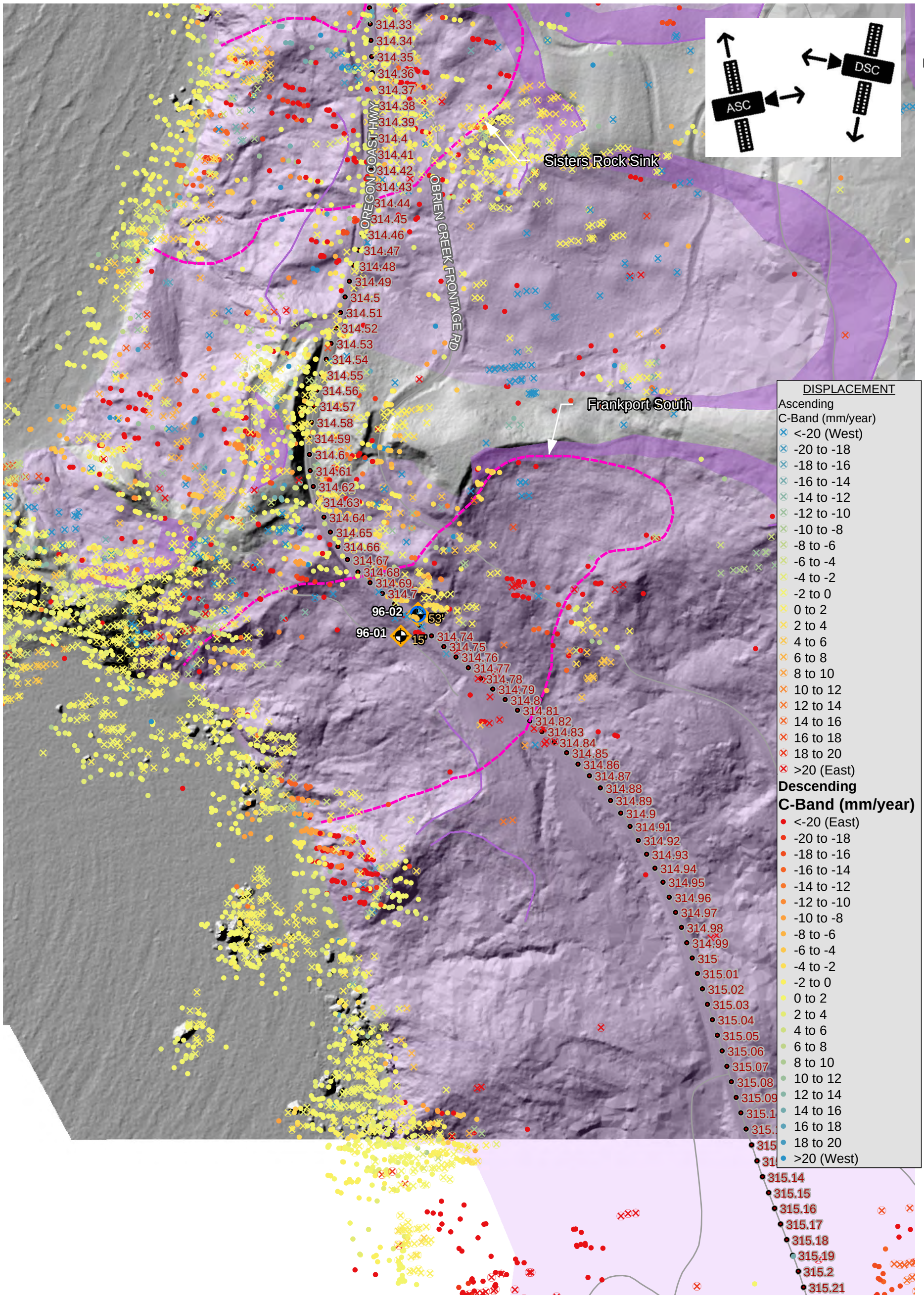

LEGEND

13' Approximate Location of Boring with Inclinometer and Shear Plane Depth

13' Approximate Location of Boring with Inclinometer, Shear Plane Depth, and Piezometer

Interpreted Slide Extents

Mapped Slide Scarp

Mapped Slide Scarp

Mapped Landslide Deposits

0 150 300 600

Scale in Feet

NOTES

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South Coast Landslide Study
Curry County, Oregon

SITE AND EXPLORATION PLAN
FRANKPORT SOUTH

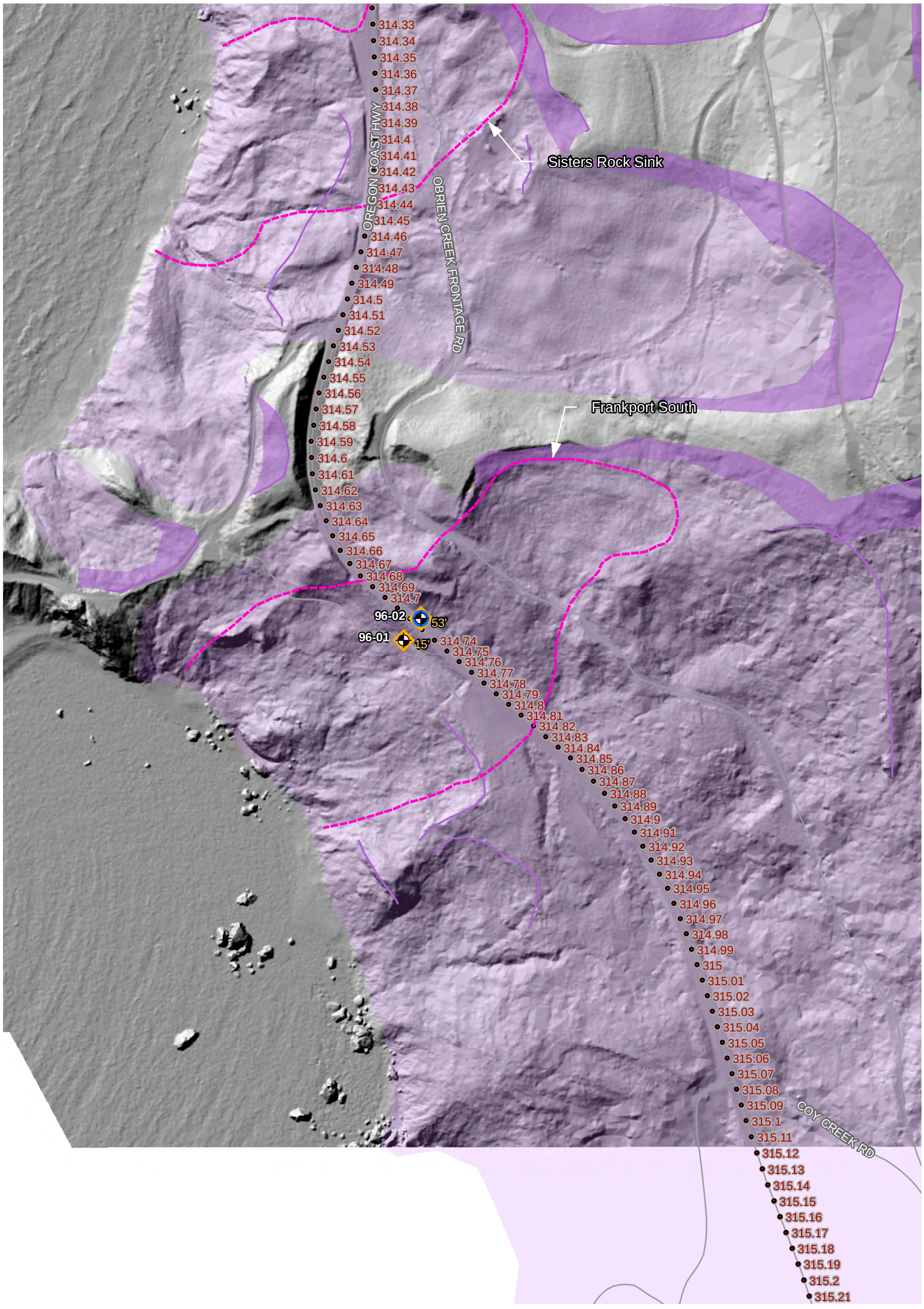
April 2022 106381

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. 3

FIG. 3

Filename: T:\Projects\PDX\106000s\106381_ODOT R3 South C\Avmxd\SitePlan9FrankportS_10.7.mxd Date: 3/24/2022 Login: AEH



LEGEND

13' Approximate Location of Boring with Inclinometer and Shear Plane Depth

13' Approximate Location of Boring with Inclinometer, Shear Plane Depth, and Piezometer

Interpreted Slide Extents

Mapped Slide Scarp

Mapped Slide Scarp

Mapped Landslide Deposits

0 150 300 600

Scale in Feet

NOTES

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South Coast Landslide Study
Curry County, Oregon

SITE AND EXPLORATION PLAN
FRANKPORT SOUTH

April 2022 106381

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. 4

FIG. 4

SHANNON & WILSON

MEMORANDUM

DATE: April 1, 2022

PROJECT: South Coast Slide Study

PROJ. #: 106381-006

SUBJECT: Technical Memorandum #2 – Slide 10 Woodroof Creek (MP 315.90 to 315.96)

INTRODUCTION

Shannon & Wilson, Inc. (Shannon & Wilson) collected and reviewed all provided existing data for the Woodroof Creek slide including:

- Previous Geology and Geotechnical Reports;
- ODOT provided electronic and hard copy files;
- Maps and publications from the U.S. Geological Survey (USGS) and Oregon Department of Geology and Mineral Industries (DOGAMI);
- Light Detection and Ranging (LiDAR) data;
- As-constructed plans for previous slide repairs or mitigation projects;
- ODOT maintenance records and as-constructed plans including slide stabilization and paving records;
- Historical precipitation data from the nearest available gauge station; and
- Interferometric Synthetic Aperture Radar (InSAR) ground movement data.

Our review of existing data included interviews with ODOT geotechnical engineers and roadway maintenance personnel. This memo includes a general summary of our key findings from the data collection and analysis, site plans showing the locations of existing subsurface explorations and preliminary landslide boundaries based on our review of existing data including LiDAR and InSAR data, and a list of references/reports.

KEY FINDINGS

Slide History

- **1950's:** Initial construction of US 101 in project area, including installation of 30-inch steel culvert to carry Woodroof Creek beneath US 101.
- **1956:** Slide occurred at Woodroof Creek the first winter after construction of the US 101 embankment, prompting installation of 17 horizontal drains. At that time, the slide was called the "Horneblenzer Slide".

- **1998:** Erosion around 30-inch cross culvert exposed 10-feet of pipe. Culvert invert observed to be rusted through and allowed water to escape and undermine material at toe of the embankment.
- **December 1998:** 270-foot-long scarp observed in southbound lane of US 101.
- **June 2003:** Embankment failure near the downstream end of the 30-inch cross culvert. Failure mechanism is continued undermining of embankment toe near cross culvert as observed in 1998.
- **2004 or 2005:** Existing culvert sliplined with HDPE pipe (no design or as-constructed drawings available).
- **2005 – 2006:** Large scale movement noted by ODOT
- **March 2012:** Large scale movement noted by ODOT resulting in closure of southbound and furthest west northbound lane of US 101 (based on photos)
- **2016:** Large scale movement noted by ODOT

Slide Geometry

The Woodroof Creek slide has also been referred to in previous documentation as the Horneblenzer Slide, Skull Ridge Slide, and Squier Slide.

A scarp approximately 270 feet long was observed near the southbound lane of US 101 in December 1998 (ODOT, 1998). The failure plane was inferred to daylight at the toe of the fill embankment, near the 30-inch culvert. Vertical distance from creek to centerline of highway is 104 feet, and horizontal distance from centerline of highway to edge of creek is 171 feet. Slope of the embankment is 1.5H:1V.

Exhibit 1: Photo looking north along US101 at the Woodroof Creek head scarp. Photo taken March 23, 2012.

Slide Mechanics

Slide movement is likely attributed to scour from Woodroof Creek at the embankment toe. Scour has resulted in local failures at the toe of the embankment, potentially reducing stability of a failure plane in the embankment that extends upslope towards US 101. Horizontal drain logs occasionally noted very easy to easy drilling within the embankment, and finished slope angle was noted to be 1.5H:1V.

Groundwater

Very wet soil was observed above, north, and south of the 30-inch culvert near the toe of the embankment in 1956 (Jenkins, 1956).

Existing Slide Mitigation

17 horizontal drains were installed within the embankment in 1956. No information regarding performance of the drains was documented.

In response to the 2003 embankment failure, ODOT recommended filling in the failed area around the culvert with angular stone embankment material (SEM) and extending/repairing the culvert so that the creek flows in isolation under the embankment and is deposited in a manner that limits erosion (ODOT, 2003b). A shear key into bedrock constructed of SEM was also proposed at the toe of the slope to replace the failed material in the 2003 event (ODOT, 2003a). We understand neither of these mitigation measures were constructed.

Precipitation Data

Typically, the groundwater level at the site is a function of the amount and intensity of precipitation that occurs within the drainage basin, amongst other factors. We have gathered precipitation data from nearby weather stations, including from precipitation monitoring instruments installed in the late 1990's at the Arizona Inn Slide location. For the Woodroof Creek slide site, the closest precipitation gauge is USC00353356 at the Gold Beach Ranger Station, 12.2 miles south of the project site.

PRELIMINARY LANDSLIDE BOUNDARIES

Preliminary landslide boundaries were generated using a combination of existing information, observations made during the recent site reconnaissance performed by Shannon & Wilson, and LiDAR and InSAR data analysis. The preliminary boundaries, including DOGAMI landslide boundaries from SLIDO 4.2, are shown on the Site and Exploration Plans attached to this memo.

During the recent site reconnaissance, landslide areas and features were mapped and compared to existing data. Shannon & Wilson then worked with SkyGeo to create an interactive map viewer which combined landslide inventory mapping and LiDAR data from DOGAMI, with InSAR data generated by SkyGeo. The InSAR data provided consisted of L-Band satellite data collected from March 19, 2016 to May 24, 2020, and ascending and descending C-Band satellite data collected from May 23, 2015 to December 31, 2021. A desktop analysis of the available information and data was performed, and preliminary landslide boundaries were created and imported into the SkyGeo map viewer. Shannon & Wilson then held a meeting with SkyGeo to review the preliminary landslide boundaries and analysis methods.

REFERENCES

Horizontal drain installation logs

Jenkins, J.C., 1956, Koblenzer Slide, Sta. 780, Frankport – Greggs Creek Section, Roseburg, Oregon, dated March 28, 1956

ODOT, 1998, Site Visit Memo for Sink Area, Oregon Coast MP 315.9, Curry County, dated December 24, 1998

ODOT, 2003a, ODOT Interoffice Memo, Site Investigation Culvert Erosion, Oregon Coast Hwy. No 9 MP 315.87, dated June 10, 2003

ODOT, 2003b, ODOT Interoffice Memo, Hwy 101, MP 315.87, Culvert Repair Site Visit and Recommendations, dated September 24, 2003

Oregon Department of Geology and Mineral Industries (DOGAMI), 2017, Statewide Landslide Information Database for Oregon, Release 4.2 (SLIDO 4.2): Available: https://gis.dogami.oregon.gov/maps/slido/.

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LEGEND

- Interpreted Slide Extents
- Mapped Slide Scarp
- Mapped Slide Scarp
- Mapped Landslide Deposits

0 100 200 400

Scale in Feet

NOTES

1. Aerial imagery obtained through Google Maps Satellite.
2. Mapped slide features from SLIDO-4.2, obtained through DOGAMI.
3. Contours created from 2009 LiDAR data obtained through DOGAMI.

South Coast Landslide Study
Curry County, Oregon

SITE AND EXPLORATION PLAN
WOODROOF CREEK

April 2022 106381

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. 1

FIG. 1

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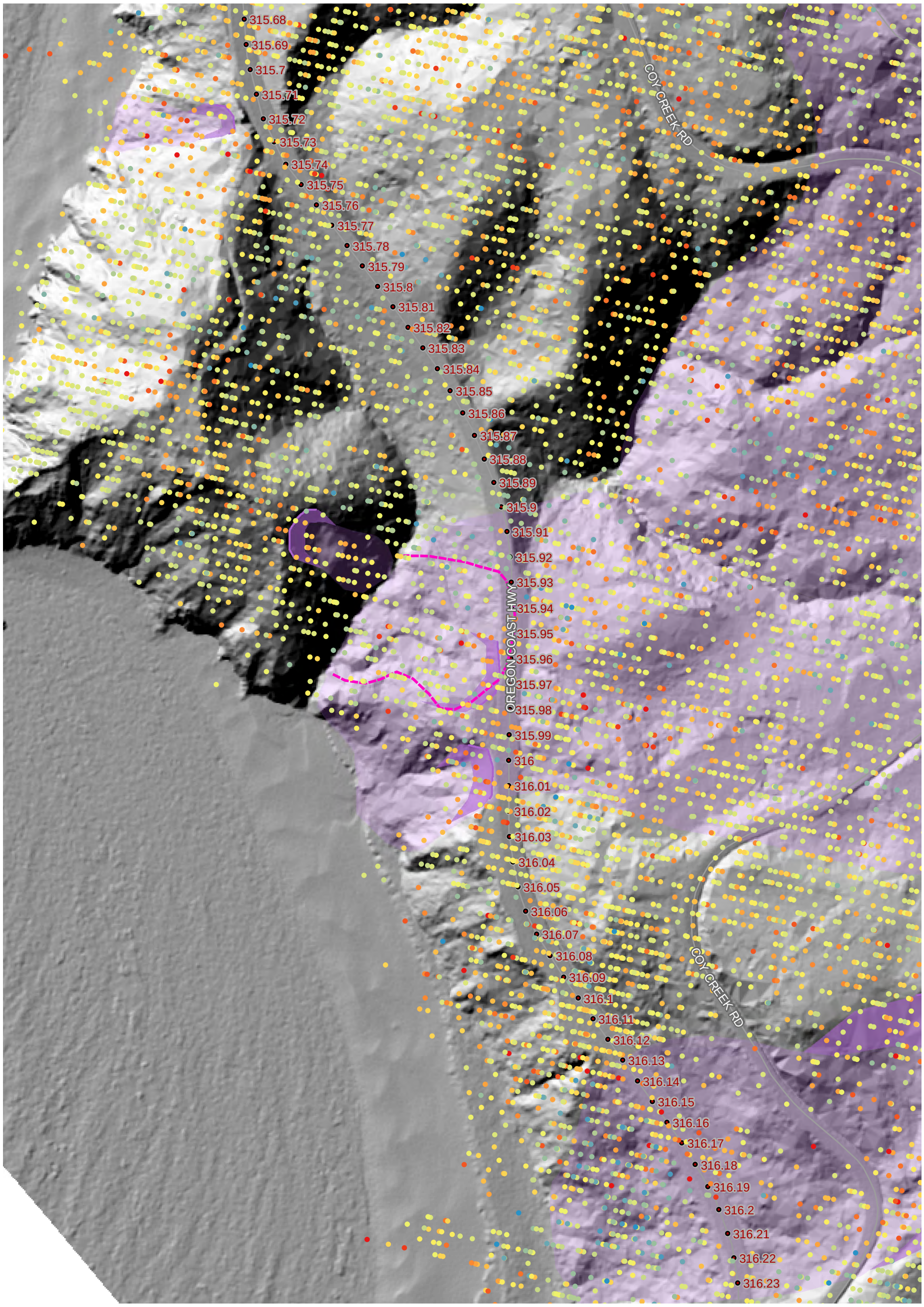

LEGEND

- Interpreted Slide Extents
- Mapped Slide Scarp
- Mapped Slide Scarp
- Mapped Landslide Deposits

Displacement L-Band (mm/year)				
<-40	-36 to -32	-20 to -16	-4 to 4	16 to 20
-40 to -36	-32 to -28	-16 to -12	4 to 8	20 to 24
	-28 to -24	-12 to -8	8 to 12	24 to 28
	-24 to -20	-8 to -4	12 to 16	28 to 32

0 100 200 400

Scale in Feet

NOTES

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South Coast Landslide Study
Curry County, Oregon

SITE AND EXPLORATION PLAN
WOODROOF CREEK

April 2022 106381

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FIG. 2

FIG. 2

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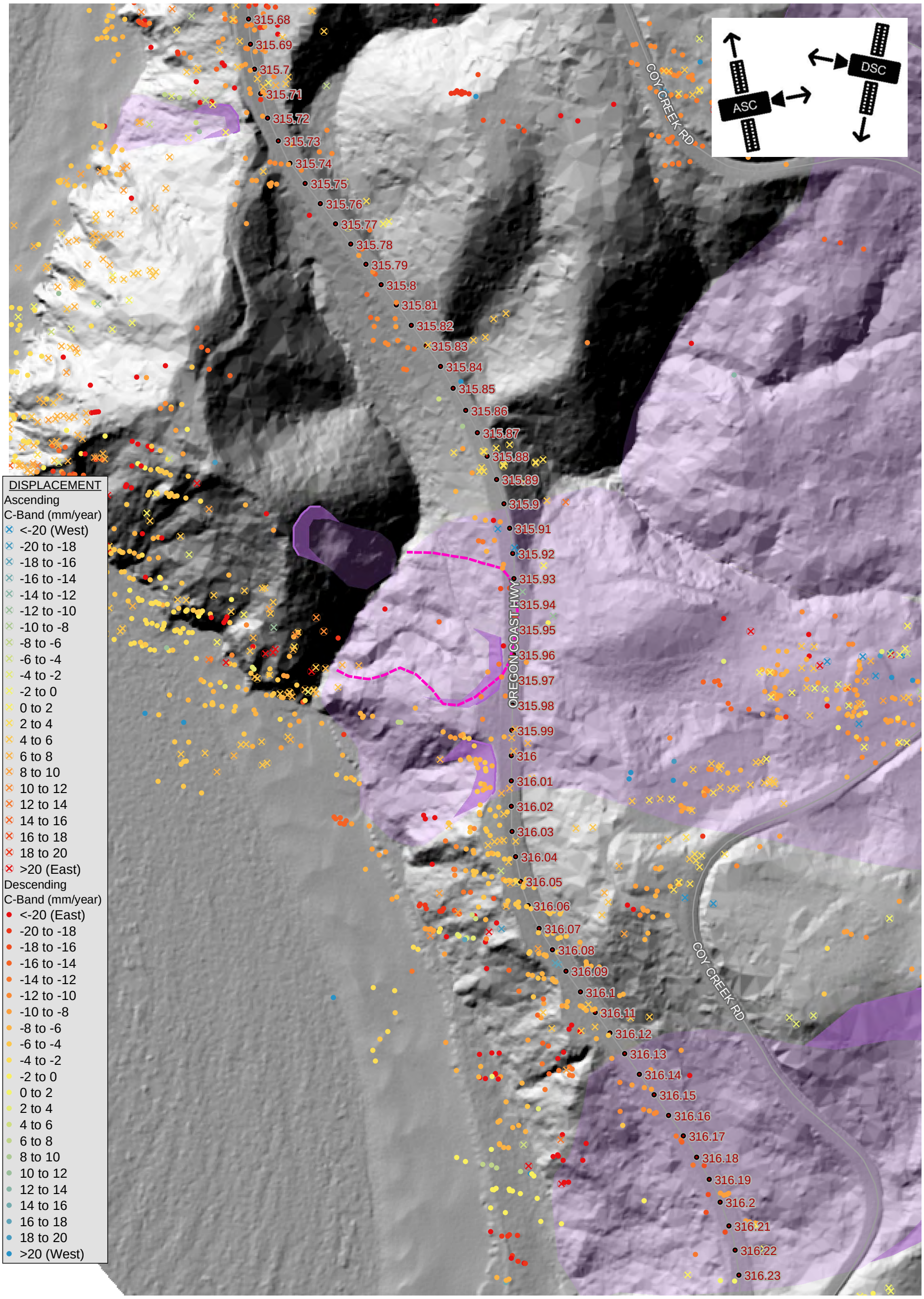

LEGEND

- Interpreted Slide Extents
- Mapped Slide Scarp
- Mapped Slide Scarp
- Mapped Landslide Deposits

0 100 200 400

Scale in Feet

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South Coast Landslide Study
Curry County, Oregon

SITE AND EXPLORATION PLAN
WOODROOF CREEK

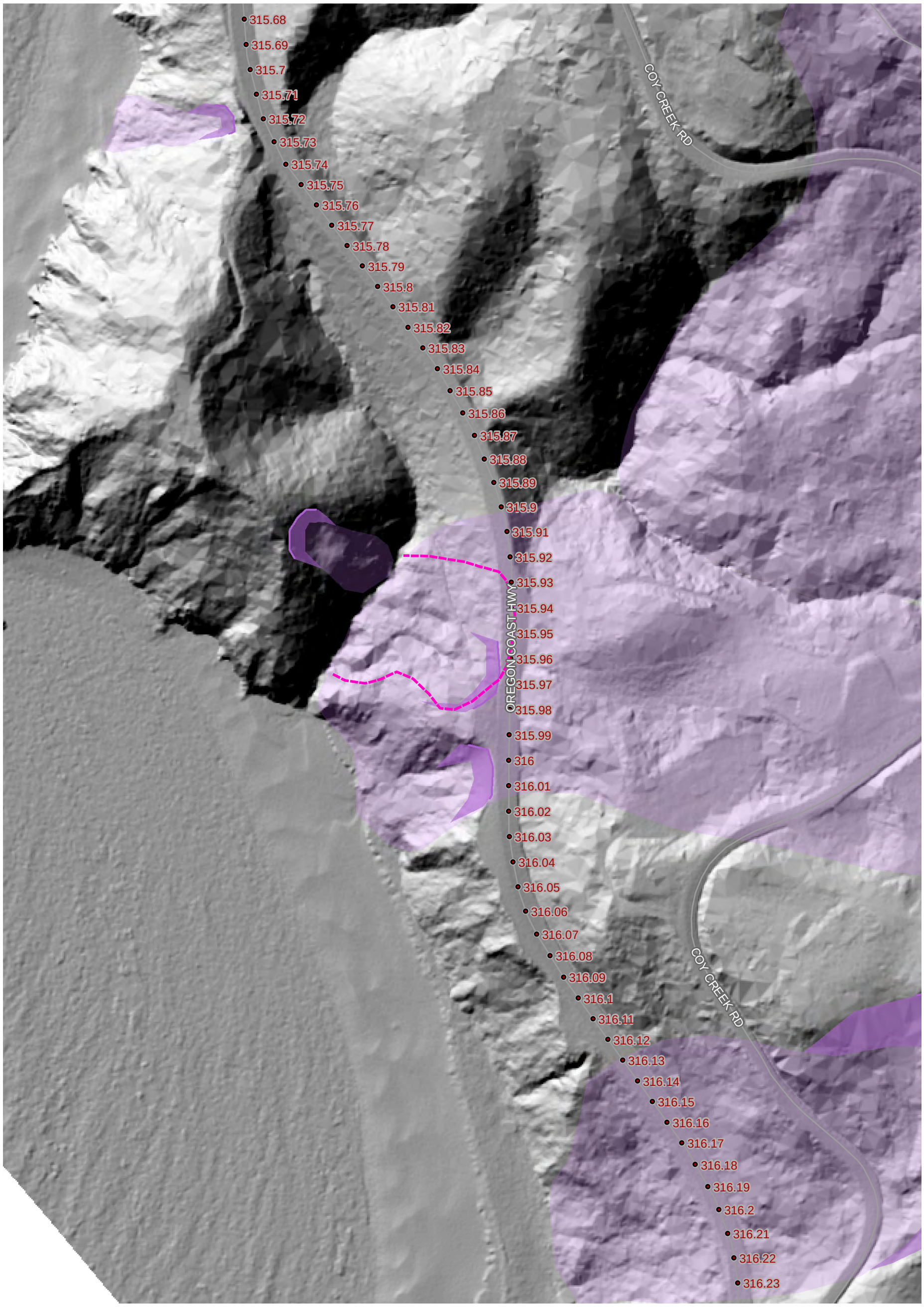
April 2022 106381

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. 3

FIG. 3

Filename: T:\Projects\PDX\106000s\106381_ODOT R3 South C\Avmxd\SitePlan10Woodroof_10.7.mxd Date: 3/24/2022 Login: AEH



LEGEND

- Interpreted Slide Extents
- Mapped Slide Scarp
- Mapped Slide Scarp
- Mapped Landslide Deposits

0 100 200 400

Scale in Feet

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South Coast Landslide Study
Curry County, Oregon

SITE AND EXPLORATION PLAN
WOODROOF CREEK

April 2022 106381

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. 4

FIG. 4

SHANNON & WILSON

MEMORANDUM

DATE: April 1, 2022

PROJECT: South Coast Slide Study

PROJ. #: 106381-006

SUBJECT: Technical Memorandum #2 – Slide 11 80 Acres (MP 332.52 to 332.57)

INTRODUCTION

Shannon & Wilson, Inc. (Shannon & Wilson) collected and reviewed all provided existing data for the 80 Acres slide including:

- Previous Geology and Geotechnical Reports;
- ODOT provided electronic and hard copy files;
- Maps and publications from the U.S. Geological Survey (USGS) and Oregon Department of Geology and Mineral Industries (DOGAMI);
- Light Detection and Ranging (LiDAR) data;
- As-constructed plans for previous slide repairs or mitigation projects;
- ODOT maintenance records and as-constructed plans including slide stabilization and paving records;
- Historical precipitation data from the nearest available gauge station; and
- Interferometric Synthetic Aperture Radar (InSAR) ground movement data.

Our review of existing data included interviews with ODOT geotechnical engineers and roadway maintenance personnel. This memo includes a general summary of our key findings from the data collection and analysis, site plans showing the locations of existing subsurface explorations and preliminary landslide boundaries based on our review of existing data including LiDAR and InSAR data, and a list of references/reports.

KEY FINDINGS

Slide History

- **1950's:** Construction of present-day US 101 alignment in slide area.
- **August – September 1995:** Borings 95-01, 95-02, and 95-03 drilled with installation of inclinometer in each and additional piezometer installed.

- **February 2006:** Slide movement observed (via photos) along US 101 southbound shoulder. Lead to repaving of US 101 during the summer of 2006.
- **Winter - Spring 2011:** Slide movement observed (via photos) along US 101 southbound shoulder.
- **Winter – Spring 2012:** Sustained movement observed (via photos) along US 101 southbound shoulder and upslope of roadway. Based on photos furthest west southbound lane closed from at least January 2012 through July 2012.
- **October 2011 – August 2012:** Borings 1753580ac-01 through 1753580ac-03 drilled.
- **2012 – 2013:** Stone blanket (i.e. shear key buttress) constructed upslope and north of slide area as observed from google earth (not related to 80 Acres slide directly).
- **May 2014 to April 2015:** DAP Plans created for shear key buttress and drainage mitigation. Mitigation was not constructed due to lack of funding.
- **Summer 2015:** French drain constructed along NB ditch line.

Slide Geometry

The 80 Acres Slide between MP 332.52 to 332.57 is approximately 500 feet wide, and about 650 feet long from the scarp mapped along the southbound shoulder of US 101 to the estimated toe of the slide downslope. A possible intermediate toe of the slide area was observed approximately 400 feet downslope from the scarp. The slide appears to be bounded by two drainages to the north and south. Slumping and additional ground cracking was observed upslope from US 101 as well. The depth to the slide plane in all inclinometers ranged from 25 to 36 feet below ground surface (ODOT, 2014a)

A larger slide complex mapped by DOGAMI in the vicinity of the 80 Acres slide extends about a ½-mile along US 101, and spans about ¾-miles from the head scarp to the coast. The mapped toe of the larger slide is approximately 2,200 feet downslope of US 101, and the head scarp is approximately 1,800 feet upslope of US 101.

Exhibit 1: Photo looking south along US101 at the Eighty Acres head scarp. Photo taken July 30, 2012

Slide Mechanics

The 80 Acres slide overlies the larger, dormant slide complex mapped by DOGAMI. A thrust fault obscured by landslide deposits is mapped running NW-SE through the project site. Additional N-S faults are mapped nearby and within the larger slide complex (ODOT, 2014a).

Movement of the 80 Acres slide has been attributed to heavy rainfall amounts in the winter, in combination with the creek flow into the head scarp area. The weak bedrock and sheared serpentinized fault material are also contributors to slope instability as well (ODOT, 2014a).

Prior to construction of the french drain along the US 101 northbound ditch line, we understand closures of the outside southbound lane due to slide movements were common for weeks or months every couple of years in the decades the preceded the drain installation.

Groundwater

Small springs and wetlands were observed within the 80 Acres slide area, and inactive larger slide area indicating elevated water levels. A nearly year-round spring and creek flow into the area above the head scarp of the 80 Acres slide by the southbound shoulder of US 101 (ODOT, 2014a). Groundwater was measured ranging from approximately ground surface to 20 feet below ground surface in the project geotechnical borings.

Existing Slide Mitigation

In the 2014 DAP plans, ODOT recommended the construction of a 500-foot-long shear key and buttress with stone embankment material, as well as construction of a 12-inch-diameter French drain (1 to 13 feet below ground surface) along the US 101 northbound shoulder (ODOT, 2014b). Based design plans, the French drain was constructed, however the shear key buttress was not constructed due to lack of funding (ODOT, 2015). The 2014 report recommended to analyze the effect any mitigation solution would have on the larger slide complex and stated the older slide could be partially reactivated if the drainage remains in the present state.

A stone blanket is observed from google earth on a cut slope directly upslope of US 101, approximately 900 feet north of the 80 Acres slide area. Based on google earth imagery, it was installed between 2012 and 2013.

Precipitation Data

Typically, the groundwater level at the site is a function of the amount and intensity of precipitation that occurs within the drainage basin, amongst other factors. We have gathered precipitation data from nearby weather stations, including from precipitation monitoring instruments installed in the late 1990's at the Arizona Inn Slide location. For the 80 Acres slide site, the closest precipitation gauge is USC00353356 at the Gold Beach Ranger Station, 3.1 miles north of the project site.

PRELIMINARY LANDSLIDE BOUNDARIES

Preliminary landslide boundaries were generated using a combination of existing information, observations made during the recent site reconnaissance performed by Shannon & Wilson, and LiDAR and InSAR data analysis. The preliminary boundaries, including DOGAMI landslide boundaries from SLIDO 4.2, are shown on the Site and Exploration Plans attached to this memo.

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REFERENCES

Boring Logs with Inclinometer and Piezometer Data: 95-01, 95-02, 95-03, 1753580ac-01, 1753580ac-02, and 1753580ac-03

ODOT, 2014a, Engineering Geology Report, 80 Acres Slide, Oregon Coast Highway No. 9 (US 101) M.P. 332.6, Curry County, Oregon, dated May 2014

ODOT, 2014b, DAP Plans Narrative US101: Slide Mitigation Oregon Coast Highway, ODOT, dated April 21, 2014

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Oregon Department of Geology and Mineral Industries (DOGAMI), 2017, Statewide Landslide Information Database for Oregon, Release 4.2 (SLIDO 4.2): Available: https://gis.dogami.oregon.gov/maps/slido/.

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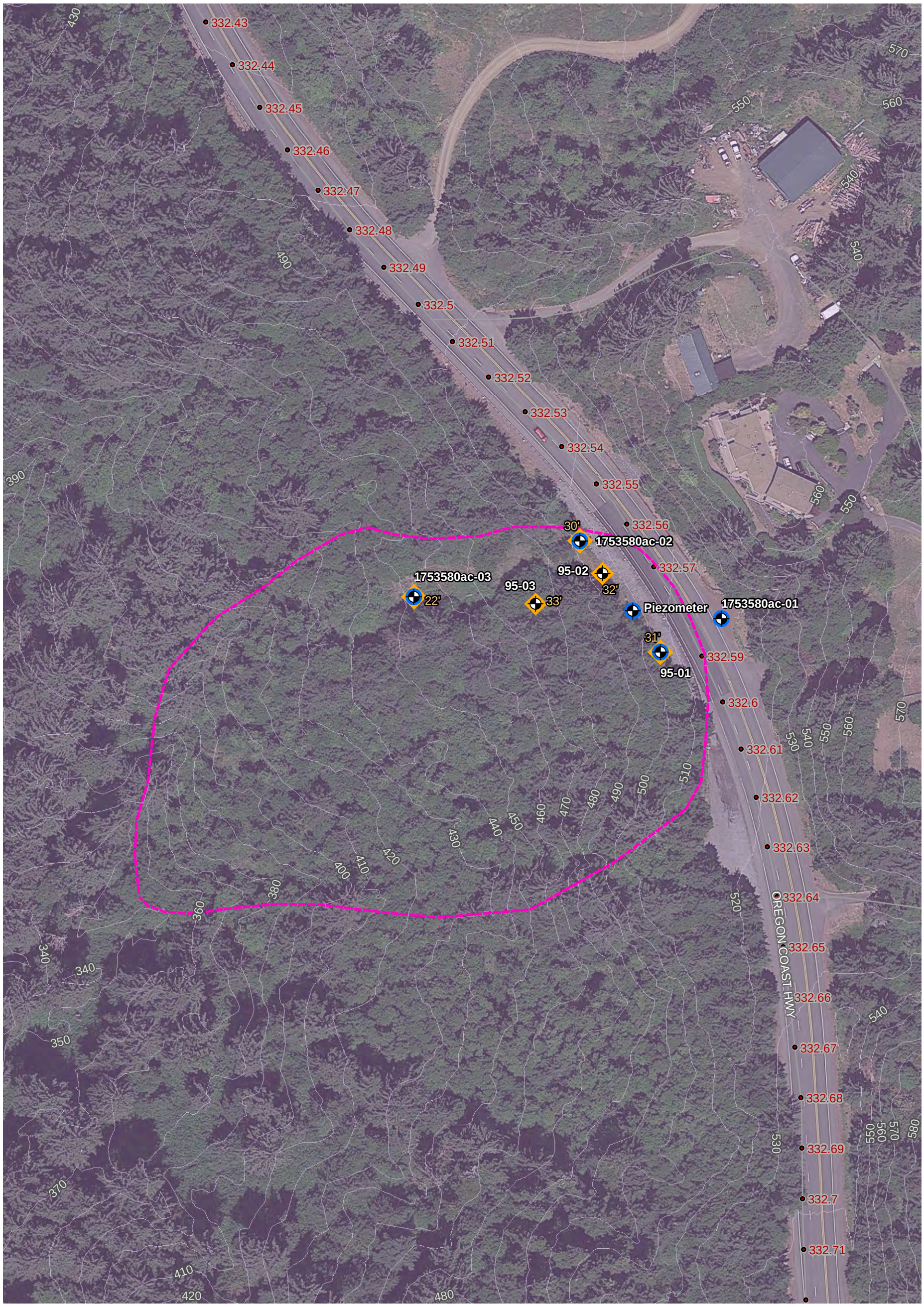

LEGEND

- 13' Approximate Location of Boring with Inclinometer and Shear Plane Depth
- Approximate Location of Boring with Piezometer
- 13' Approximate Location of Boring with Inclinometer, Shear Plane Depth, and Piezometer
- Interpreted Slide Extents
- Mapped Landslide Deposits

0 50 100 200

Scale in Feet

NOTES

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South Coast Landslide Study
Curry County, Oregon

SITE AND EXPLORATION PLAN
EIGHTY ACRES

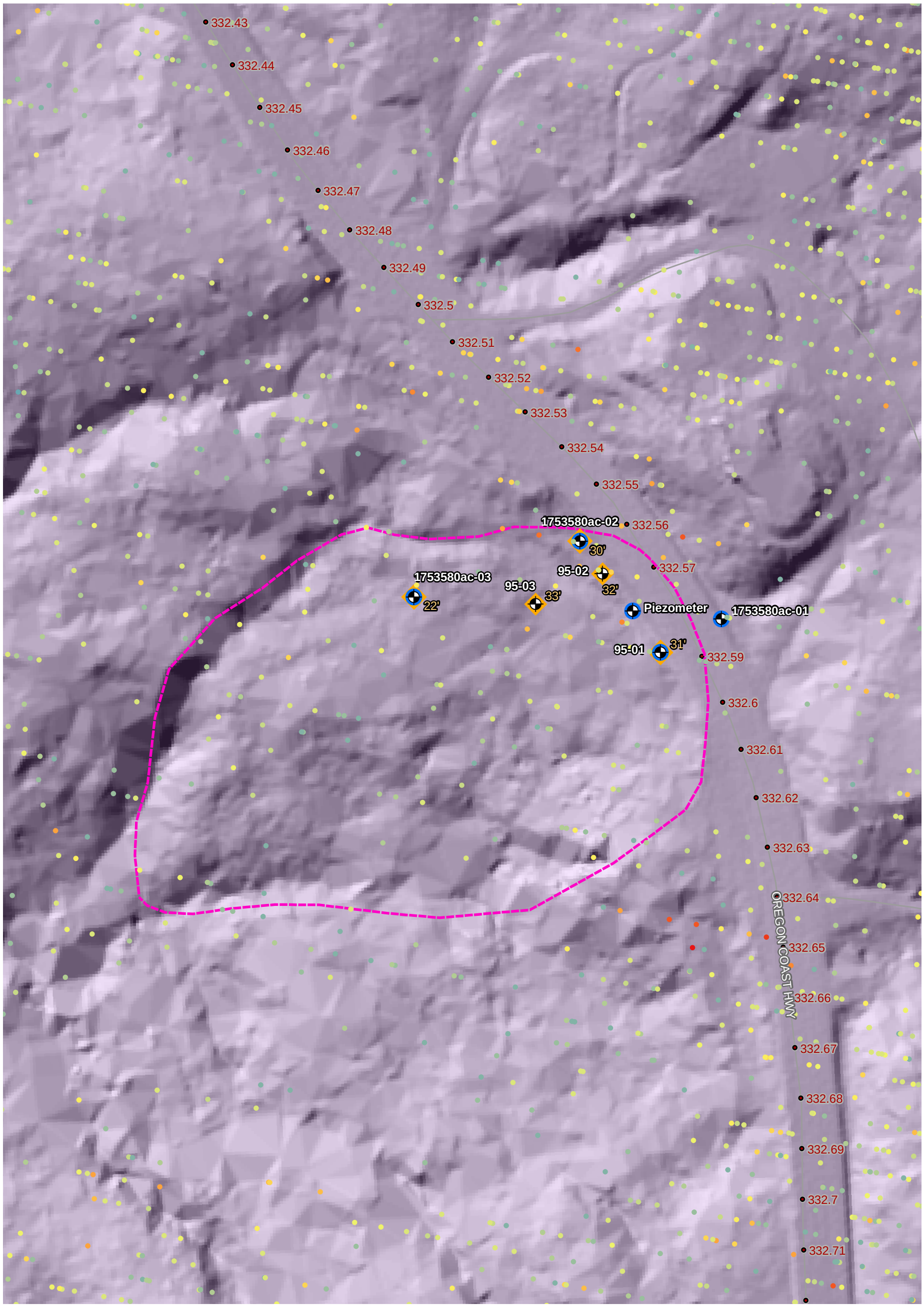
April 2022 106381

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. 1

FIG. 1

Filename: T:\Projects\PDX\106000s\106381_ODOT R3 South C\Avmxd\SitePlan11EightyAcres_10.7.mxd Date: 3/24/2022 Login: AEH



LEGEND

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Approximate Location of Boring with Piezometer

13' Approximate Location of Boring with Inclinometer, Shear Plane Depth, and Piezometer

Interpreted Slide Extents

Mapped Landslide Deposits

Displacement L-Band (mm/year)

- <-40
- -40 to -36
- -36 to -32
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- -24 to -20
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- 20 to 24
- 24 to 28
- 28 to 32

0 50 100 200

Scale in Feet

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South Coast Landslide Study
Curry County, Oregon

SITE AND EXPLORATION PLAN
EIGHTY ACRES

April 2022 106381

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. 2

FIG. 2

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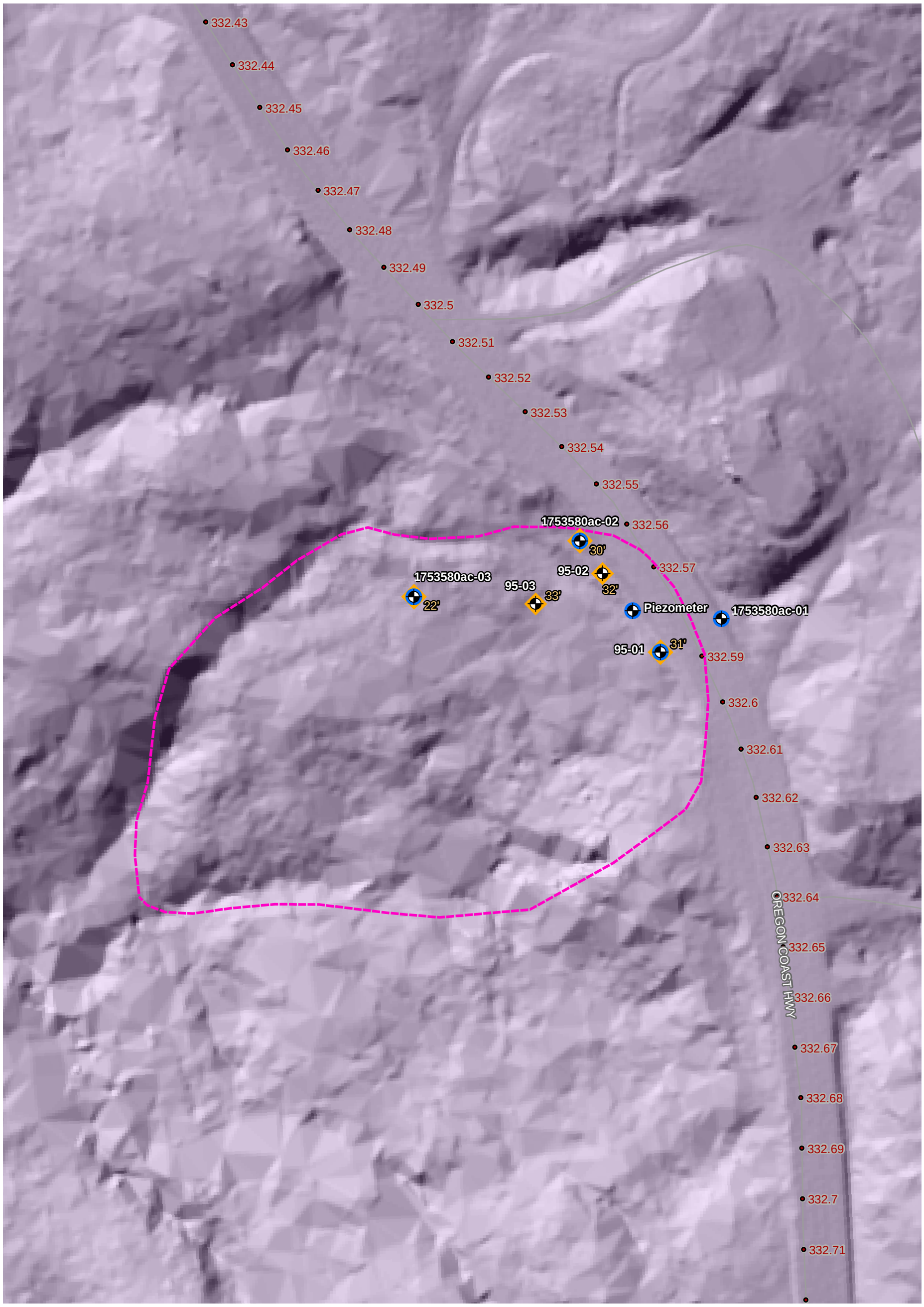


LEGEND

13' Approximate Location of Boring with Inclinometer and Shear Plane Depth

Approximate Location of Boring with Piezometer

13' Approximate Location of Boring with Inclinometer, Shear Plane Depth, and Piezometer

Interpreted Slide Extents

Mapped Landslide Deposits

0 50 100 200

Scale in Feet

NOTES

1. Hillshade created from 2009 LiDAR data obtained through DOGAMI.
2. Mapped slide features from SLIDO-4.2, obtained through DOGAMI.

South Coast Landslide Study
Curry County, Oregon

SITE AND EXPLORATION PLAN
EIGHTY ACRES

April 2022 106381

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. 3

FIG. 3

SHANNON & WILSON

MEMORANDUM

DATE: April 1, 2022

PROJECT: South Coast Slide Study

PROJ. #: 106381-006

SUBJECT: Technical Memorandum #2 – Slide 12 Burnt Hill (MP 342.49 to 342.61)

INTRODUCTION

Shannon & Wilson, Inc. (Shannon & Wilson) collected and reviewed all provided existing data for the Burnt Hill slide including:

- Previous Geology and Geotechnical Reports;
- ODOT provided electronic and hard copy files;
- Maps and publications from the U.S. Geological Survey (USGS) and Oregon Department of Geology and Mineral Industries (DOGAMI);
- Light Detection and Ranging (LiDAR) data;
- As-constructed plans for previous slide repairs or mitigation projects;
- ODOT maintenance records and as-constructed plans including slide stabilization and paving records;
- Historical precipitation data from the nearest available gauge station; and
- Interferometric Synthetic Aperture Radar (InSAR) ground movement data.

Our review of existing data included interviews with ODOT geotechnical engineers and roadway maintenance personnel. This memo includes a general summary of our key findings from the data collection and analysis, site plans showing the locations of existing subsurface explorations and preliminary landslide boundaries based on our review of existing data including LiDAR and InSAR data, and a list of references/reports.

KEY FINDINGS

Slide History

- **1950's:** Initial construction of US 101 in slide area
- **December 22, 2005:** Slide movement resulted in full highway closure for 2 to 3 days. Partial closures lasted up to one month.

Slide Background

According to ODOT Maintenance personnel, the Burnt Hill slide experiences slow, persistent movement every year but had not experienced a large-scale movement in memory. Large scale movement occurred on December 22, 2005. Movement progressed throughout the night and in the morning the two southbound US 101 lanes were impassible. The western edge of the roadway had dropped approximately 12-feet (ODOT, 2005).

Slide Geometry

The slide event occurring on December 22, 2005 was approximately 700 feet in length, from US 101 to the toe, 600 feet in width, and about 200 feet in vertical relief (from toe to scarp). There were indications of past movement above US 101, extending to the top of the hill side, but did not appear to exhibit any recent movement (ODOT, 2005).

Exhibit 1: Aerial photo looking north at US101 within the Burnt Hill slide limits. The photo shows recent re-pavement of US101 due to slide activity. Photo taken February 10, 2006.

Slide Mechanics

The entire slide area consists of many large slump blocks that have been moving slowly over the geologic history of the site. US 101 itself consists of 3 separate blocks with several more below the road extending down the slope to the beach (ODOT, 2005).

Perched groundwater and spring activity near the scarp of the slide is likely a primary contributor to slide instability.

Groundwater

In the December 22, 2005 site visit, large amounts of water flowing off of and out of the hillside into a roadside ditch on the east side of US 101 was observed. Several culverts and perforated pipes were located throughout the slide but their performance was poor (i.e. minimal water flow). The one pipe flowing water had the bottom completely corroded through. In the center of the slide area along US 101, water was found seeping underneath the road.

Existing Slide Mitigation

During the December 2005 event, two 40-foot sections of 18-inch pipe were placed in the US 101 northbound shoulder ditch with compacted gravel placed on the inlets to hold them in place and to force the water in the pipes.

ODOT recommended placing two 20-foot sections of 12-inch diameter pipe spanning both the north and south lateral head scarp cracks in the ditch line to slow water penetration directly into the slide mass. ODOT strongly recommended not to cut into the toe of the hillside to limit the possibility of the hillside above US 101 sliding (ODOT, 2005).

No permanent mitigations have been documented for the Burnt Hill slide.

Precipitation Data

Typically, the groundwater level at the site is a function of the amount and intensity of precipitation that occurs within the drainage basin, amongst other factors. We have gathered precipitation data from nearby weather stations, including from precipitation monitoring instruments installed in the late 1990's at the Arizona Inn Slide location. For the Burnt Hill slide site, the closest precipitation gauge is USC00353356 at the Gold Beach Ranger Station, 12 miles north of the project site.

PRELIMINARY LANDSLIDE BOUNDARIES

Preliminary landslide boundaries were generated using a combination of existing information, observations made during the recent site reconnaissance performed by Shannon & Wilson, and LiDAR and InSAR data analysis. The preliminary boundaries, including DOGAMI landslide boundaries from SLIDO 4.2, are shown on the Site and Exploration Plans attached to this memo.

During the recent site reconnaissance, landslide areas and features were mapped and compared to existing data. Shannon & Wilson then worked with SkyGeo to create an interactive map viewer which combined landslide inventory mapping and LiDAR data from DOGAMI, with InSAR data generated by SkyGeo. The InSAR data provided consisted of L-Band satellite data collected from March 19, 2016 to May 24, 2020, and ascending and descending C-Band satellite data collected from May 23, 2015 to December 31, 2021. A desktop analysis of the available information and data was performed, and preliminary landslide boundaries were created and imported into the SkyGeo map viewer. Shannon & Wilson then held a meeting with SkyGeo to review the preliminary landslide boundaries and analysis methods.

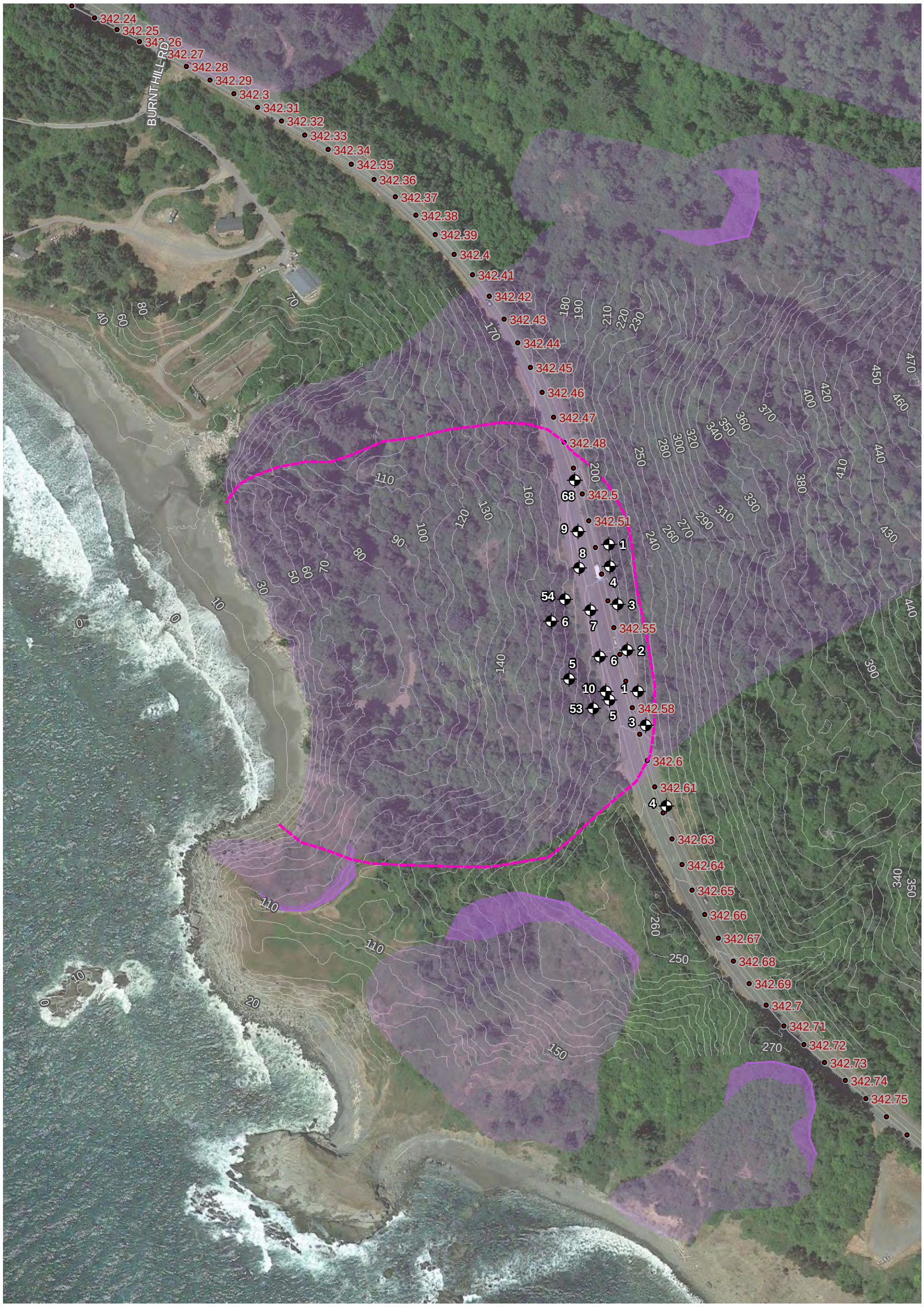
REFERENCES

Drill logs from original roadway construction

ODOT, 2005, Site Visit Memo, Burnt Hill Slide, Hwy 9 (US101), MP 342.7, Curry County, dated December 22 and 27, 2005

Oregon Department of Geology and Mineral Industries (DOGAMI), 2017, Statewide Landslide Information Database for Oregon, Release 4.2 (SLIDO 4.2): Available: https://gis.dogami.oregon.gov/maps/slido/.

Filename: T:\Projects\PDX\106000s\106381_ODOT R3 South C\Avmxd\SitePlan12Burnt_10.7.mxd Date: 3/25/2022 Login: AEH



LEGEND

- Approximate Location of Boring
- Interpreted Slide Extents
- Mapped Slide Scarp
- Mapped Slide Scarp
- Mapped Landslide Deposits

0 100 200 400

Scale in Feet

NOTES

1. Aerial imagery obtained through Google Maps Satellite.
2. Mapped slide features from SLIDO-4.2, obtained through DOGAMI.
3. Contours created from 2009 LiDAR data obtained through DOGAMI.

South Coast Landslide Study
Curry County, Oregon

SITE AND EXPLORATION PLAN
BURNT HILL

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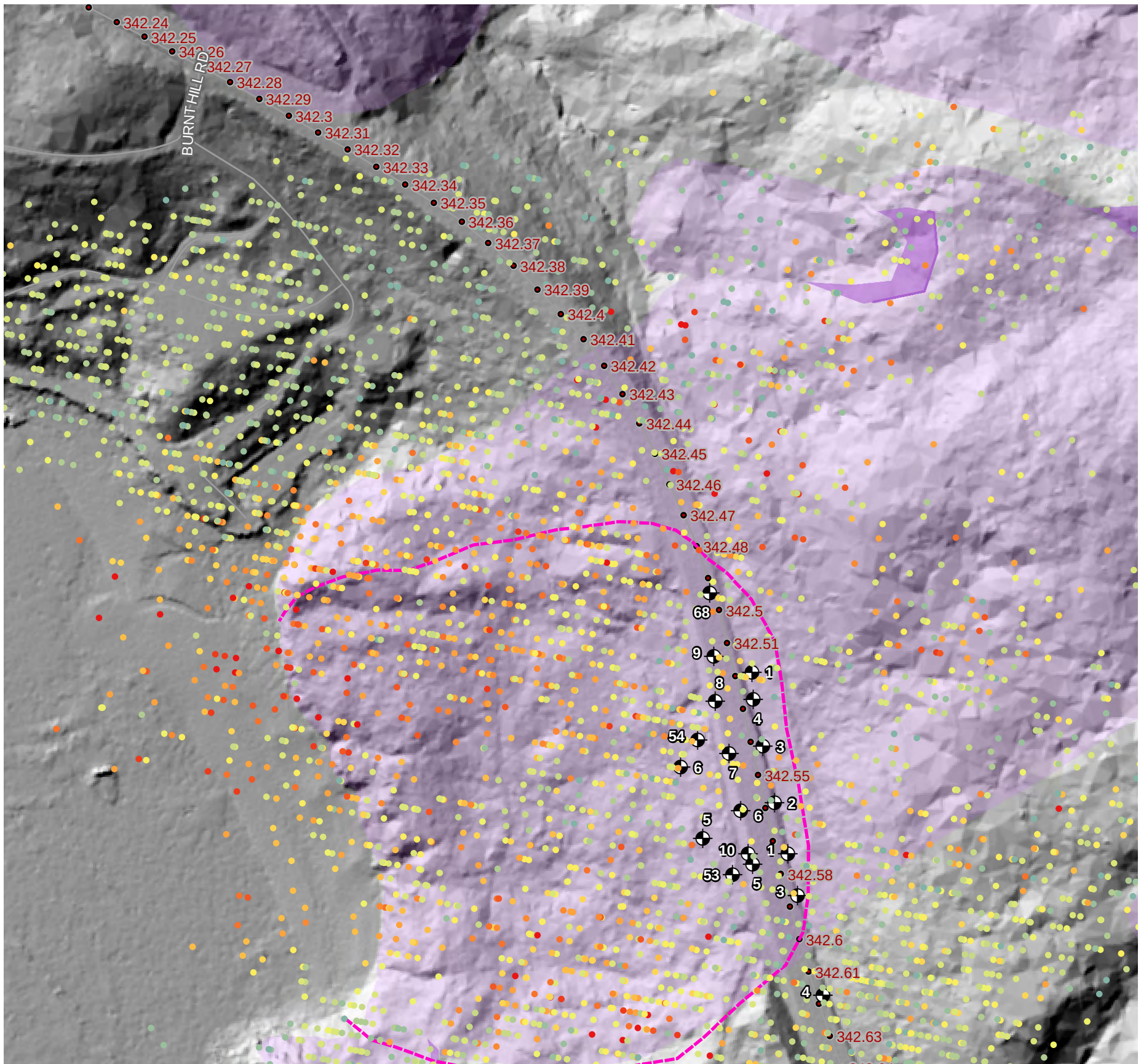
FIG. 1

FIG. 1

Filename: T:\Projects\PDX\106000s\106381_ODOT R3 South C\Avmxd\SitePlan12Burnt_10.7.mxd Date: 3/25/2022 Login: AEH



LEGEND

- Approximate Location of Boring
- Interpreted Slide Extents
- Mapped Slide Scarp
- Mapped Slide Scarp
- Mapped Landslide Deposits

Displacement L-Band (mm/year)

<-40	-36 to -32	-20 to -16	-4 to 4	16 to 20
-40 to -36	-32 to -28	-16 to -12	4 to 8	20 to 24
	-28 to -24	-12 to -8	8 to 12	24 to 28
	-24 to -20	-8 to -4	12 to 16	28 to 32

0 100 200 400

Scale in Feet

NOTES

1. Hillshade created from 2009 LiDAR data obtained through DOGAMI.
2. Mapped slide features from SLIDO-4.2, obtained through DOGAMI.
3. Displacement rate points from InSAR data downloaded from SkyGeo on December 3, 2021. Only points with quality of 0.3 or higher are shown.

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FIG. 2

FIG. 2

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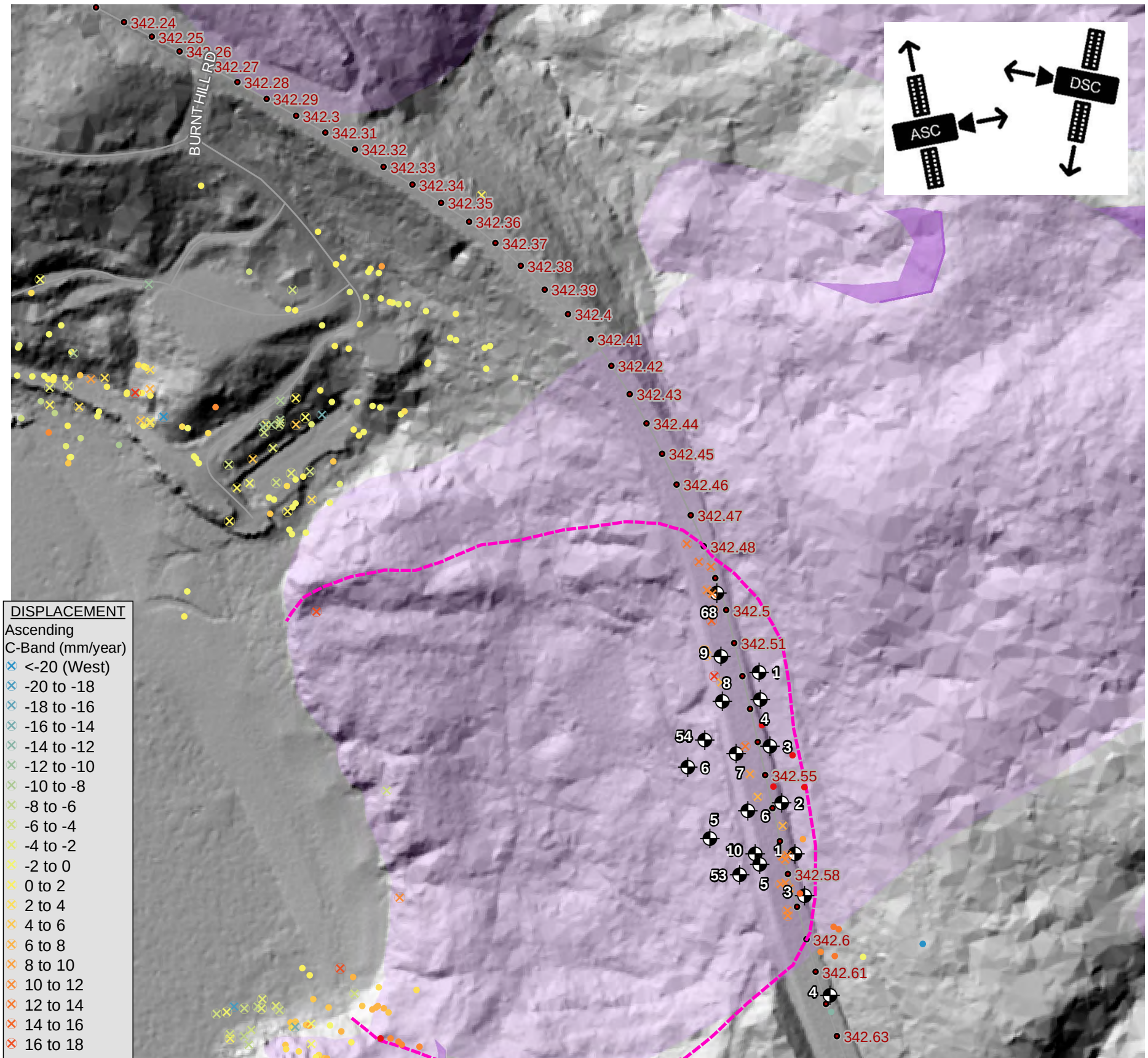

LEGEND

- Approximate Location of Boring
- Interpreted Slide Extents
- Mapped Slide Scarp
- Mapped Slide Scarp
- Mapped Landslide Deposits

0 100 200 400

Scale in Feet

NOTES

1. Hillshade created from 2009 LiDAR data obtained through DOGAMI.
2. Mapped slide features from SLIDO-4.2, obtained through DOGAMI.
3. Displacement rate points from InSAR data downloaded from SkyGeo on March 14, 2022. Only points with quality of 0.3 or higher are shown.

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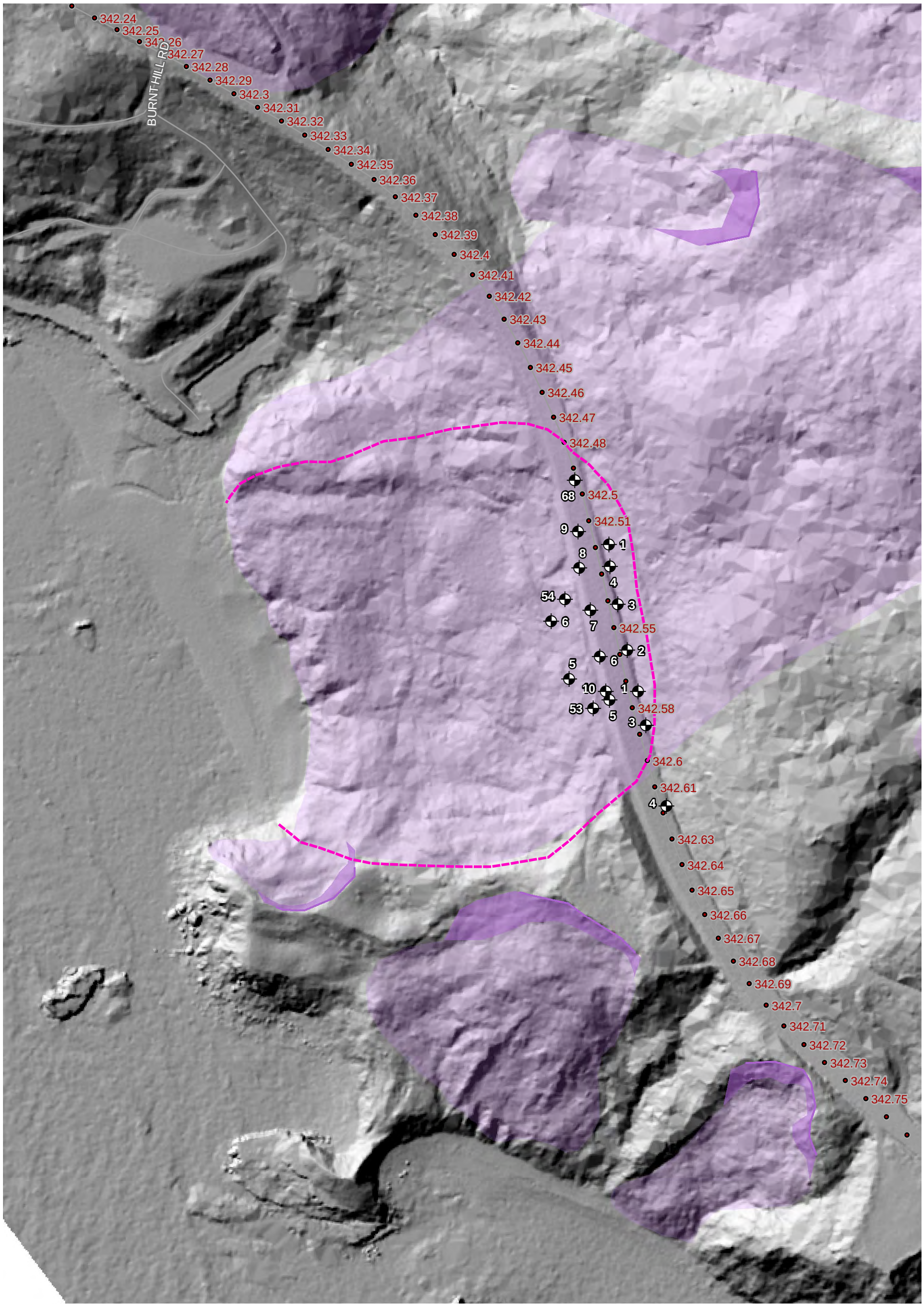
FIG. 3

FIG. 3

Filename: T:\Projects\PDX\106000s\106381_ODOT R3 South C\Avmxd\SitePlan12Burnt_10.7.mxd Date: 3/25/2022 Login: AEH



LEGEND

- Approximate Location of Boring
- Interpreted Slide Extents
- Mapped Slide Scarp
- Mapped Slide Scarp
- Mapped Landslide Deposits

0 100 200 400

Scale in Feet

NOTES

1. Hillshade created from 2009 LiDAR data obtained through DOGAMI.
2. Mapped slide features from SLIDO-4.2, obtained through DOGAMI.

South Coast Landslide Study
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SITE AND EXPLORATION PLAN
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FIG. 4

FIG. 4

SHANNON & WILSON

MEMORANDUM

DATE: April 1, 2022

PROJECT: South Coast Slide Study

PROJ. #: 106381-006

SUBJECT: Technical Memorandum #2 – Slide 13 Hooskanaden (MP 343.51 to 343.75)

INTRODUCTION

Shannon & Wilson, Inc. (Shannon & Wilson) collected and reviewed all provided existing data for the Hooskanaden slide including:

- Previous Geology and Geotechnical Reports;
- ODOT provided electronic and hard copy files;
- Maps and publications from the U.S. Geological Survey (USGS) and Oregon Department of Geology and Mineral Industries (DOGAMI);
- Light Detection and Ranging (LiDAR) data;
- As-constructed plans for previous slide repairs or mitigation projects;
- ODOT maintenance records and as-constructed plans including slide stabilization and paving records;
- Historical precipitation data from the nearest available gauge station; and
- Interferometric Synthetic Aperture Radar (InSAR) ground movement data.

Our review of existing data included interviews with ODOT geotechnical engineers and roadway maintenance personnel. This memo includes a general summary of our key findings from the data collection and analysis, site plans showing the locations of existing subsurface explorations and preliminary landslide boundaries based on our review of existing data including LiDAR and InSAR data, and a list of references/reports.

KEY FINDINGS

Slide History

- **1950's:** Initial construction of US 101 in slide area
- **1958:** First large-scale recorded slide movement, prompting drilling explorations. Slide place inferred to be greater than 114 feet below ground surface (bgs).

- **December 1977:** Large-scale slide movement severe enough to close the highway for about three weeks. Entire roadbed was replaced.
- **September 1978 – January 1979:** Four inclinometers installed, SI 1-78 to SI 4-79. Slide plane inferred to be greater than 150 feet in depth.
- **January 12, 1995:** Large-scale slide movement estimated to involve 40 million cubic yards of material. A 1,200-foot-long section of US 101 was displaced 60 feet laterally and 30 feet vertically downslope. US 101 closed for 9 days.
- **January 2006:** Movement of slide closed US 101 for a short period of time (based on photos), but not as long as 1977, 1995, and 2019 events.
- **December 1, 2017:** Oregon State University (OSU) completed one geotechnical boring (SPR808-H-1) with installation of one micro-electromechanical systems (MEMS) array. MEMS array damaged by the end of January 2019 due to slide movement.
- **February – March 2019:** Large-scale slide movement recorded affecting approximately 1,100 feet of US 101, requiring reconstruction of the roadway embankment. At US 101 grade along the south margin of the slide, lateral and vertical displacements up to 140 feet and 40 feet, respectively, were observed. US 101 closed for multiple weeks.
- **Spring 2019:** GSI constructed a 305-foot-long soil nail stabilization downslope of US 101 near the southern lateral scarp of the slide, with a maximum height of approximately 17 feet and a maximum nail embedment of approximately 58 feet.
- **Spring – Summer 2020:** Reconstructed roadway with a 6-foot-thick deep patch.

Slide Geometry

The active landslide mass is approximately 1,200 feet wide at the toe along the coast, and approximately 3,800 feet long from the shoreline to the head scarp. US 101 is approximately 2,100 feet downslope from the head scarp, and about 1,700 feet upslope from the toe. The head scarp is located approximately 2,000 feet downslope from Carpenterville Highway (ODOT, 2019).

Depth of the slide plane varies from 100 to 150 feet deep (ODOT, 1979). The overall basal movement of the slide is at approximately 20 degrees towards the beach, coinciding with the mean dip of the rock bedding units (OSHD, 1979). The OSU MEMS array detected a slide plane at approximately 105 feet bgs.

Exhibit 1: Aerial photo looking south at US101 within Hooskanaden Slide limits. Photo taken February 10, 2006

Slide Mechanics

Hooskanaden slide debris is derived from the Otter Point Formation, consisting of sheared sandstone, conglomerate, mudstone, interbedded sandstone and shale, with scattered blocks of resistant sandstone, chert, greenstones, and blueschist (Blocks-in-Matrix [BIM] structure). It is speculated that movement of the slide is occurring at or within the weaker sheared matrix materials of shale or siltstone, and several possible basal slide planes exist (ODOT, 2019).

Hooskanaden likely consists of several compartmentalized zones of movement, rather than a single mass failing along a single slide plane. The compartmentalized masses appear to conform to the regional BIM structure of the Otter Point Formation, as the pattern of surface deformation and slide features suggests that the individual compartment masses are moving along discrete failure arcs, controlled by percentage of internal BIMs and surfaces of weakness. Large BIMs interpreted to be present along the flanks of the landslide suggest that these are constraining the lateral limits of the movement. Movement within each

individual compartment of the slide appears to contribute to the overall movement of the slide mass as a whole by alternatively providing and removing passive resistance and increased driving force to the compartments above and below (ODOT, 2019).

The extent of the toe beyond the surf zone has not been resolved. The toe area of the slide debris is in almost constant flux, with debris being moved into the surf zone and removed by wave action. Increases of slide material in the toe area appear to be directly related with the combination of highwater wave energy and storm surges (i.e. raveling of sea cliff), creating a loss of some passive resistance to movement and acceleration of the movement within the area affecting US 101 (ODOT, 2019).

ODOT correlated rainfall totals to large-scale slide movement using the weather station KORBROOK40 located approximately 12.4 miles south-southwest of the slide, showing several days between January through March 2019 during which the rainfall approached or exceed 1-inch, with a maximum of 5 inches on February 24, 2019. These occurrences coincide with the large-scale movement of the slide. The ultimate conclusion is the primary controlling factor for large-scale slide movement at Hooskanaden has been the increase in groundwater levels due to heavy precipitation events (ODOT, 2019).

Groundwater

Groundwater was noted at depths ranging from 6 to 108 feet bgs during 1979 drilling explorations (ODOT, 1979). Two piezometers were installed during the OSU exploration, reading a pressure head equivalent to 180 feet of gravitational head (equating to artesian pressure at the upper piezometer, and a groundwater of 13 feet below ground surface at the lower piezometer.) Large ponds of water and high flow surficial runoff were observed in the upslope slide mass from project photos.

Existing Slide Mitigation

In spring 2019, GSI installed a 305-foot-long soil nail wall downslope of US 101 near the southern lateral scarp of the slide, with a maximum height of approximately 17 feet and a maximum nail embedment of approximately 58 feet (GSI, 2019). In 2020, ODOT reconstructed the roadway with a 6-foot-thick "Deep Patch" which consisted of placing approximately 15,000 cubic yards of stone embankment material with layers of subgrade geogrid reinforcement at 18-inch vertical spacing (ODOT, 2020). ODOT also excavated ditches and cleaned existing ditches upslope of US 101.

The 2019 memo (ODOT, 2019) discussed 5 possible mitigation strategies:

1) Wells could be productive within granular deposits, but not within the finer materials onsite (would require a larger number of well points due to decreased hydraulic conductivity). Well casings and pump riser lines would likely be sheared off by the slide movement before they could become effective.

2) Tieback anchors and walers was briefly considered to arrest slide movement but dismissed due to the extreme size of the slide mass.

3) A system of shear pins constructed along the uphill side of the alignment: 8-foot diameter drilled stone columns or reinforced concrete drilled shafts to depths of 120 feet below grade.

4) Protection of toe of slide by means of several armoring methods (i.e. seawall, breakwater, riprap).

5) Allow traffic along the coast to completely bypass the Hooskanaden Landslide and eliminate need to mitigate the slide movement (A suspension-type bridge over the toe area of the landslide or over the middle and narrower portion of the landslide, or an offshore pile-supported bridge beyond the toe of the landslide, or the improvement of Carpenterville Road upslope of the slide to handle increased traffic and act as a bypass). Each alternative possessed huge inherent negative issues that make them least desirable as means of mitigation for the landslide.

Precipitation Data

Typically, the groundwater level at the site is a function of the amount and intensity of precipitation that occurs within the drainage basin, amongst other factors. We have gathered precipitation data from nearby weather stations, including from precipitation monitoring instruments installed in the late 1990's at the Arizona Inn Slide location. For the Hooskanaden slide site, the closest precipitation gauge is USC00351058 at Brookings, 12.7 miles south of the project site.

PRELIMINARY LANDSLIDE BOUNDARIES

Preliminary landslide boundaries were generated using a combination of existing information, observations made during the recent site reconnaissance performed by Shannon & Wilson, and LiDAR and InSAR data analysis. The preliminary boundaries, including DOGAMI landslide boundaries from SLIDO 4.2, are shown on the Site and Exploration Plans attached to this memo.

During the recent site reconnaissance, landslide areas and features were mapped and compared to existing data. Shannon & Wilson then worked with SkyGeo to create an interactive map viewer which combined landslide inventory mapping and LiDAR data from DOGAMI, with InSAR data generated by SkyGeo. The InSAR data provided consisted of L-Band satellite data collected from March 19, 2016 to May 24, 2020. A desktop analysis of the available information and data was performed, and preliminary landslide boundaries were created and imported into the SkyGeo map viewer. Shannon & Wilson then held a meeting with SkyGeo to review the preliminary landslide boundaries and analysis methods.

REFERENCES

Drill Logs: SI-1-78, SI-2-78, SI-3-78, SI-4-79, and SPR808-H-1

OSHD, 1979, Progress Report – Slide Drilling, Hooskenaden Creek Slide, Oregon Coast Highway / Curry County, dated January 24, 1979

FHWA, 1995, Field Trip Report, dated January 26, 1995

GSI, 2019, As-Constructed Soil Stabilization Plans, Highway 101 – MP 343.9, Curry County, Oregon, GSI, dated March 22, 2019

ODOT, 2019, Hooskanaden Landslide Reconnaissance In Response to 2019 Episodic Movement, Oregon Coast Hwy (US101) (Hwy. 9, M.P. 343.5), Curry County, Oregon, dated December, 2019

ODOT, 2020, As-Constructed Plans for US101: Hooskanaden Slide Repair Project, Oregon Coast Highway, Curry County, dated August 6, 2020

Oregon Department of Geology and Mineral Industries (DOGAMI), 2017, Statewide Landslide Information Database for Oregon, Release 4.2 (SLIDO 4.2): Available: https://gis.dogami.oregon.gov/maps/slido/.

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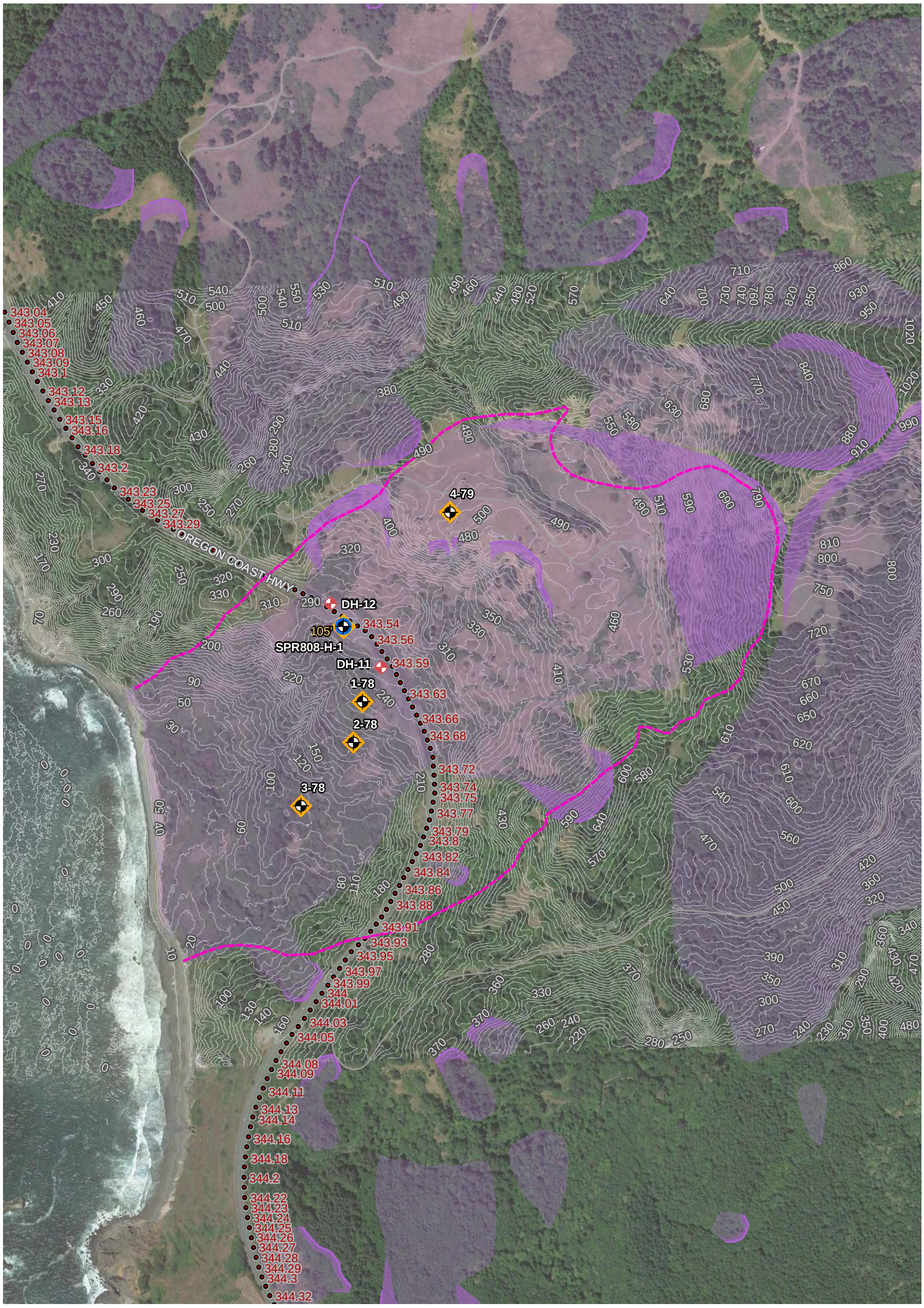

LEGEND

13' Approximate Location of Boring with Inclinometer and Shear Plane Depth

13' Approximate Location of Boring with Inclinometer, Shear Plane Depth, and Piezometer

Approximate Location of Boring (Missing Data)

Interpreted Slide Extents

Mapped Slide Scarp

Mapped Slide Scarp

Mapped Landslide Deposits

0 250 500 1,000

Scale in Feet

NOTES

1. Aerial imagery obtained through Google Maps Satellite.
2. Mapped slide features from SLIDO-4.2, obtained through DOGAMI.
3. Contours created from 2009 LiDAR data obtained through DOGAMI.

South Coast Landslide Study
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SITE AND EXPLORATION PLAN
HOOSKANADEN

April 2022 106381

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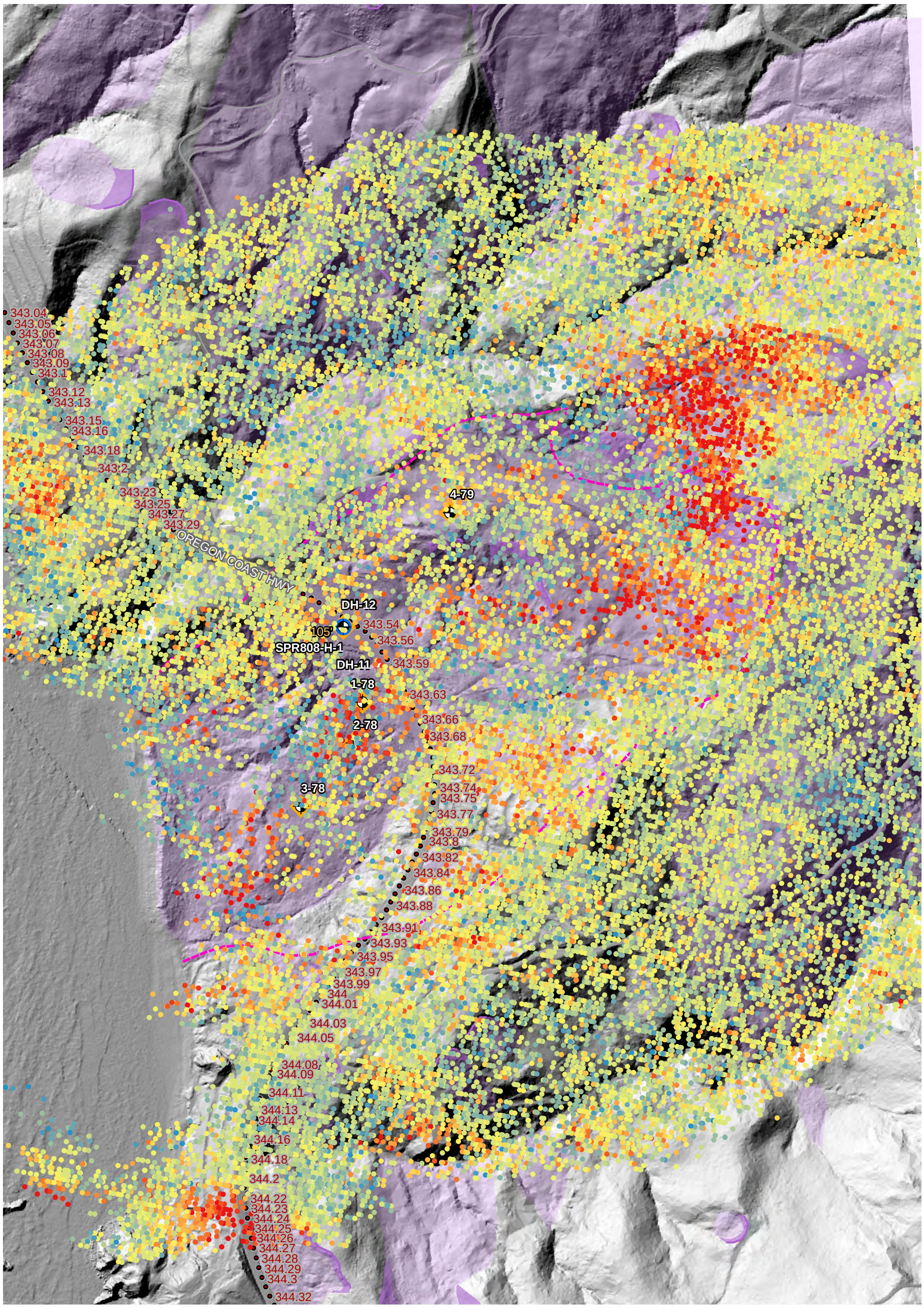
FIG. 1

FIG. 1

Filename: T:\Projects\PDX\106000s\106381_ODOT R3 South C\Avmxd\SitePlan13Hooskanaden_10.7.mxd Date: 3/24/2022 Login: AEH



LEGEND

13' Approximate Location of Boring with Inclinometer and Shear Plane Depth

13' Approximate Location of Boring with Inclinometer, Shear Plane Depth, and Piezometer

Approximate Location of Boring (Missing Data)

Interpreted Slide Extents

Mapped Slide Scarp

Mapped Slide Scarp

Mapped Landslide Deposits

Displacement L-Band (mm/year)

- <-40
- -40 to -36
- -36 to -32
- -32 to -28
- -28 to -24
- -24 to -20
- -20 to -16
- -16 to -12
- -12 to -8
- -8 to -4
- -4 to 4
- 4 to 8
- 8 to 12
- 12 to 16
- 16 to 20
- 20 to 24
- 24 to 28
- 28 to 32

0 250 500 1,000

Scale in Feet

NOTES

1. Hillshade created from 2009 LiDAR data obtained through DOGAMI.
2. Mapped slide features from SLIDO-4.2, obtained through DOGAMI.
3. Displacement rate points from InSAR data downloaded from SkyGeo on December 3, 2021. Only points with quality of 0.3 or higher are shown.

South Coast Landslide Study
Curry County, Oregon

SITE AND EXPLORATION PLAN
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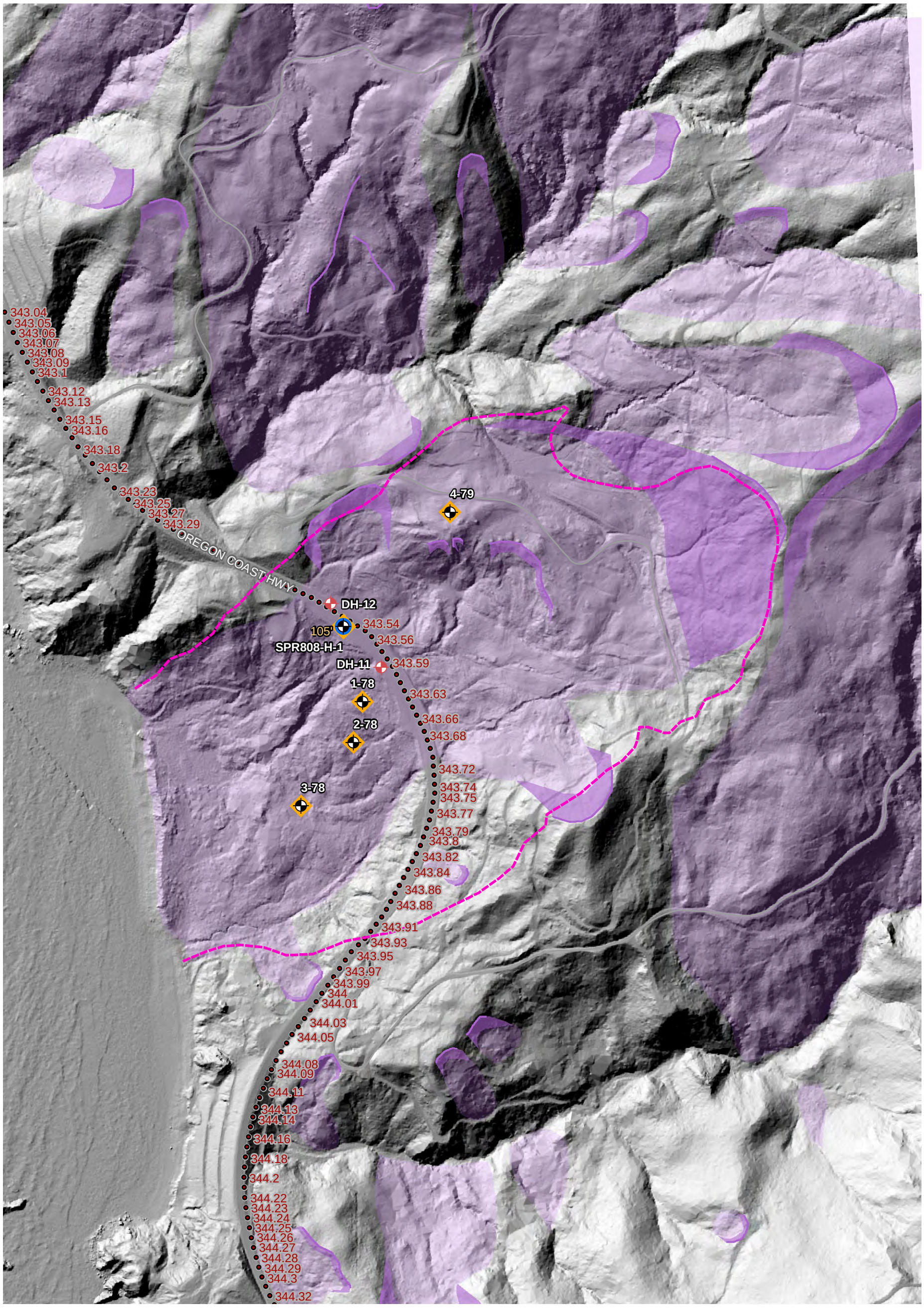
FIG. 2

FIG. 2

Filename: T:\Projects\PDX\106000s\106381_ODOT R3 South C\Avmxd\SitePlan13Hooskanaden_10.7.mxd Date: 3/24/2022 Login: AEH



LEGEND

13' Approximate Location of Boring with Inclinometer and Shear Plane Depth

13' Approximate Location of Boring with Inclinometer, Shear Plane Depth, and Piezometer

Approximate Location of Boring (Missing Data)

Interpreted Slide Extents

Mapped Slide Scarp

Mapped Slide Scarp

Mapped Landslide Deposits

0 250 500 1,000

Scale in Feet

NOTES

1. Hillshade created from 2009 LiDAR data obtained through DOGAMI.
2. Mapped slide features from SLIDO-4.2, obtained through DOGAMI.

South Coast Landslide Study
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SITE AND EXPLORATION PLAN
HOOSKANADEN

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FIG. 3

FIG. 3

ATTACHMENT B: MEETING NOTES

KITTELSON & ASSOCIATES
851 SW 6th Avenue, Suite 600
Portland, OR 97204
P 503.228.5230

MEETING SUMMARY

August 31, 2021

ODOT PA# B36373 Work Order #24
KAI Project# 23021-40

South Coast Slides Study Kick Off Meeting

Attendees

- Lisa Cornutt, ODOT Region 3 Project Manager
- Pete Castro, ODOT Region 3 Senior Geotechnical Engineer
- Wende Wilber, Kittelson
- Darren Hippenstiel, Kittelson
- Nicholas Polenske, Kittelson
- Christopher Bame, Kittelson
- Molly McCormick, Kittelson
- Jeff Whitman, Kittelson
- Eric Paslack, Shannon & Wilson
- Jessica Pickul, JLA Public Involvement

After introductions, the project team discussed the following topics.

1. Define Project Success from an ODOT Perspective
    - Strong communication among the internal ODOT team and the consultant team. Include Pete and Lisa on all communication.
    - A product that meets the needs of the internal ODOT stakeholders (geotechnical, maintenance, environmental, etc.). It should also meet the needs of the external stakeholders including impacted communities who want to be part of the solution. The report should be a communication tool to tell the story of the challenges and opportunities, trade-offs, costs, and benefits of mitigation solutions and detour routes. Closures are a big deal to the community. Provide more detail than saying the mitigation projects are "too big and too much money."
    - Consolidate information in one location and share the findings.
2. Identify Project Opportunities and Risks
    - A key challenge is the lack of feasible detour routes. Communicating this effectively will be critical. Suggest using figures that show topography and other constraints.
    - Cost of mitigation alternatives and improving detour routes will limit options.
    - Need to manage external communication form the onset and set expectations about what the scope of this project is.
    - Identifying detour routes/options to keep for commercial vehicles (fuel tanker/fish truck) moving.

3. Schedule
    - Smartsheet https://app.smartsheet.com/sheets/hm3HgmXMG4pVPJgVFxw4vH74wmPp55xhg2qrQw41?view=grid
    - Two Month Look Ahead
        - Purpose and Need Technical Memo – September 24
        - Site Visit #1 – Early Sept.
        - Site Visit #2 – October 10-15
4. Existing Data Collection
    - Status of Digitized Information
        - Geotech – Heritage files were digitized but district operations mitigation files (last 5 to 10 years) are not, nor are photographs.
        - Shannon & Wilson will plan on half day office visit.
    - ODOT will identify completed District operations plans for the landslide sites
    - Kittelson will request traffic/crash data and work with Lisa to identify any studies we might be missing.
        - The Kittelson two day site visit in scope will likely be used at a later date or tacked onto the week-long site visit for efficiency as there aren't any files we need to digitize.
        - Kittelson needs the Emergency Operations Manual (Lisa to ask Bob for a copy).
        - Lisa will ask District staff about existing detour route and traffic plans.
5. Confirmed Project Goals for Purpose and Need Memo
    - Develop a plan for transportation resiliency, defined as the ability of the transportation system to recover and regain functionality.
    - Provide common base of information about the corridor and regional transportation network and new ways of working together with communities to mitigate impacts.
    - Reduce slide occurrence
        - Prioritize slides by level of risk and identify high level, conceptual solutions, that are technically and fiscally feasible, to mitigate landslides and improve the recoverability of the system for each of the 13 slides to an acceptable level.
            - What is an acceptable level? 25 year occurrence - extend to 50 year interval. Relate mitigation to lower factor of safety - 1.1 to 1.0. range (a factor of safety 1.25 is not likely feasible during extreme events).
            - Consider what does the performance looks like. Is it slope creep or cracking asphalt that people can drive through versus a full closure?

    - There is a gravel stockpile site for the Hooskanaden slide to expedite response time. If it moves 10 feet, it can be graded and opened within 24/48 hours. There is a cost associated with stockpiling material and there is some loss as people help themselves to the gravel.
        - This project should identify potential stockpile sites. Pete will provide locations that have already been evaluated.
- Identify and assess high level, conceptual improvements related to safety and operations along U.S 101, Carpenterville Road, and previously identified detour routes that are technically and fiscally feasible, (i.e., removal of sight distance restrictions, widening of roadway, slow vehicle turnouts, etc.).
    - There may only be three detour routes.
        - For slides between MP 342 to 344, Carpenterville Road is a viable detour route.
        - For slides between MP 304 and 316, and near MP 332.5 there are no viable detour routes.
        - There are some detour routes identified in previous studies with limited access for overweight, wide/long loads.
    - Low cost mitigation is the goal strongly tied to factor of safety and performance. Gravel surface and restricted speed after slides are acceptable on US 101. The goal is to keep people moving with restrictions versus closures.
    - Cost/Benefit Analysis- SWIM. Compare the mitigation/detour cost to the economic and social benefits that the increase in roadway closure recurrence interval provides. ODOT will run the model.
    - Transportation management/control and communications plan
        - Consider local transit and/or vans.
            - Bus drivers report that don't feel comfortable driving through detours now. Would driver training or specialized drivers be viable?
    - Stakeholder Engagement
        - Reflect feedback in report – explain what we heard, how we responded, or why the feedback could not be incorporated.
        - Use photos to help tell story.

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MEETING SUMMARY

September 30, 2021

ODOT PA# B36373 Work Order #24
KAI Project# 23021-40

South Coast Slides Study Detour Route Meeting

Attendees

- Lisa Cornutt, ODOT Region 3 Project Manager
- Pete Castro, ODOT Region 3 Senior Geotechnical Engineer
- Angelita Delacruz, ODOT
- Sergio Mendoza, ODOT
- Darrin Neavoll, ODOT
- Mark Eeps, ODOT
- Glen Pederson, ODOT
- Robert Sechler, ODOT
- Jeremy Young, ODOT
- Wende Wilber, Kittelson
- Nicholas Polenske, Kittelson
- Christopher Bame, Kittelson
- Molly McCormick, Kittelson
- Eric Paslack, Shannon & Wilson

After introductions, the project team discussed the following topics.

1. Detour Route Discussion
    a. Where to focus on Site Visit – October 10-15
    b. Identify alternative transportation routes and areas for upgrades
        i. If route doesn't meet the ODOT Design Manual requirements, are there routes worth a spot analysis/improvement review to see what it would take to bring it up to standard.
        ii. Carpenterville Rd is defined as an appropriate detour route in the manual of US 101 Detour Routes, but in the SWIM analysis, Carpenterville was not acceptable and re-routed all the trips to I-5.
        iii. County Roads are all considered feasible
        iv. Does a routes inability to accommodate trucks/freight preclude it from being a detour route
    c. Identify and assess high level, conceptual improvements related to safety and operations along U.S 101, Carpenterville Road, and previously identified detour routes that are technically and fiscally feasible, (i.e., removal of sight distance restrictions, widening of roadway, slow vehicle turnouts, etc.).

2. Information Request
    a. Previous studies of US 101 and Carpenterville Road? Safety studies? Improvement plans/designs? ROW plans?
3. Schedule
    a. Smartsheet https://app.smartsheet.com/sheets/hm3HgmXMG4pVPJgVFxw4vH74wmPp55xhg2qrQw41?view=grid

Main Detour Routes

- Carpenterville Road
    - Is used as a detour with restrictions
    - This was outlined in ODOT's previous plan that identified what was done in the past and how viable this is in the future
    - As part of the project, review changes to operational detour plan, for example time of day plans.
    - Signage updated to MUTCD horizontal curvature standards
- I-5/US 199
    - Truck restrictions on US 199 in California requires switching out the freight trucks, from what is able to use US 101

Main Alternative Routes

- Elk River Road to Euchre Creek Road (Port Orford TSP)
    - Directly off of US101
    - Will explore this route specifically with ODOT staff
- Powers to Agness
    - Heavily used by log trucks
    - Likely don't need to specifically need to drive this whole detour route
    - Forest service is repaving the portion between Agness and Lobster Creek Campground
    - Review ORE 542 north of Powers which has had trouble staying open historically

General Comments

- Per ODOT Detour Contingency Plan
    - Detour Routes - Paved roadways that can accommodate highway traffic would be a detour route
        - Detour routes need to be able to handle freight
        - They do not necessarily need to have everything constructed to ODOT standard, but are signed to highlight normal substandard elements (curve warning signage, advanced warning signage, etc.)

        - These can also be used as the potential improvements to help identify detour routes
    - Alternative Routes - Alternate routing would be the more local alternative
        - Identifying the types of vehicles to use the route will be important
            - Review forest service as built plans
        - Identifying the overall length of route and travel time is also critical
        - Identify locations where additional traffic control may be needed
        - Do we actually provide this information to the traveling public or do we just identify "use alternate route"
        - We can use this information internally to EMS to help keep some of these routes that we wouldn't necessarily provide to the traveling public
        - Also no major freight logistics trucks using alternative routes, stick to detour routes
            - Identify additional traffic control to help accommodate larger vehicles if necessary (fuel/equipment)
- Needs to accommodate freight traffic and EMS to be able to access areas in need along the corridor
    - Identifying routes that can accommodate EMS also makes sense even if freight can't necessary can't get around
    - For both instances improvements should be identified if they make sense

Routes to NOT be Further Explored

- Bear Camp Road, east-west route
    - This route will be covered in snow and would be too difficult to maintain in winter months
- NF-3348
    - There is a gate directly off of OR42
    - Significant amount of hairpin turns
- Near Prehistoric Gardens, above Arizona slide a possibility, but not likely useable
    - If the Arizona slide goes, this will also take out this potential alternative route

Routes to Drive for Site Visit

- Coordinate with Jeremey Young, cc Lisa on coordination
- MP 303 to MP 307 near Humbug Mountain State Park, Forest Service 280 (alternative route)
- Elk River Road to Euchre Creek (alternative route)
- Meyers Creek to the road just south of 635, could go right around Eighty Acres
    - Likely not viable for a detour, but could be a good alternative route
- Carpenterville Road
    - ~100 unstable sites along this road

    - Brush Creek Canyon tightest curve used as the design standard for Carpenterville Road improvements
        - ODOT has scoping level estimates for improvements meeting this standard
        - Use this information to identify some of these sites
    - Identify wide spots that could be used for pull outs
- Only two turnarounds along US101 through this area (MP 308.4 & ???)
- MP 316 old county road (Coy Creek Rd / CR 509)
- CR 280/CR 277 near Humbug Mt State Park, south of Port Orford
- CR 645/CR 635 south of Gold Beach around Eighty Acres Slide. Gravel road.
- Previously we discussed identifying locations along US 101 near slides that could be used for material storage

Tasks

- Create a map of detour and alternative routes
    - Distinguish between detour and alternative routes
    - Identify additional travel time and travel distance for each route
    - Label MP numbers along US 101
    - Label slides
    - Clarify which routes will be examined in the field
- Review Forest Service and County as built plans to define the type of vehicles that can use the alternative routes

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MEETING SUMMARY

November 24, 2021

ODOT PA# B36373 Work Order #24
KAI Project# 23021-40

South Coast Slides Study Meeting with Local Transportation Maintenance Manager

Attendees

- Lisa Cornutt, ODOT Region 3 Project Manager
- Scott Mickeslon, ODOT Local Transportation Maintenance Manager
- Christopher Bame, Kittelson
- Molly McCormick, Kittelson

After introductions, the project team discussed the following topics.

1. There are a number of different scenarios for landslide impacts
    a. For all, have an alert program diagram in the Winter Operations handbook. It spells out where will put reader boards with a focus on I-5. Want to keep traffic on I-5 if 101 is closed or has just one lane open.
2. Have maintenance facilities at Gold Beach and Port Orford. About 12 detour signs at each location.
3. Full closures include flaggers, construction barrels, and a soft barrier (6-foot wide with chevrons on 4x6 panels). Does not include concrete barriers – would like to do this but not really feasible because need construction vehicles to come in.
4. Darren or Glen are the right staff to ask about funding
    a. Get a maintenance budget but there is a process for emergency funds
    b. It is a lot easier to get federal funding when declared an emergency
    c. Have a contingency for the district but doesn't fully cover US 101 since the budget is for the whole district
5. Have a good amount of stockpile. The issue is more for dump sites. Hard to move due to environmental requirements and lots of wetlands in the area
    a. Normally put that permit process on the contractor
6. Keep in mind that even Carpenterville Road is rough for a detour route

Landslide Response Procedures

When a landslide occurs, the response by ODOT and emergency staff will depend on the type of landslide, the impacts to US 101, and available detour routes. The primary landslide response scenarios that may occur include:

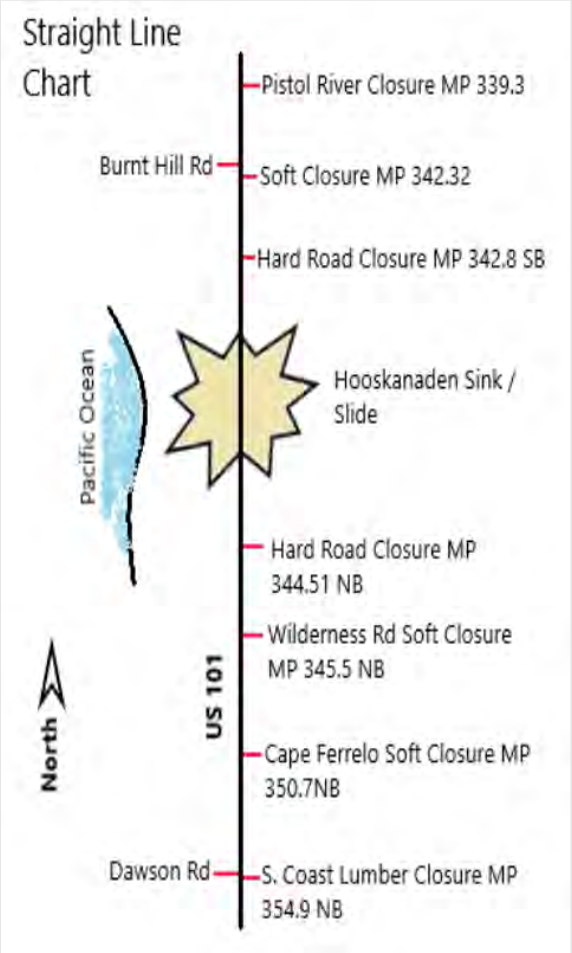
- No lanes closed
- One lane closed

- All lanes closed with viable detour route
- All lanes closed without viable detour route

For all landslides occurrences, the following steps are taken. The exact actions will vary based on the location and extent of the impact to US 101.

1. Receive notification of occurrence. This step is most often completed by a member of the public. ODOT does not have a system for continuously monitoring for landslides. Local community members are aware of the possibility of landslides and call in issues they see, from full landslide occurrences to minor pavement cracking. The Local Transportation Maintenance Manager receives this notification and then notifies ODOT dispatch, geotechnical, and public information groups.
2. Inform the traveling public. The public information officer handles information the public. ODOT's TripCheck system will show any closures. Local news stations will be notified.
3. Coordinate with ODOT geotechnical staff. ODOT staff work together to determine the type of occurrence and what should be done.
4. Dispatch ODOT response staff and any needed contractors. This effort will depend on the type of impact and needed traffic control. ODOT maintenance staff, contracted flaggers, and construction crews may be part of the response. For any lane or full closures, ODOT maintenance staff will be there 24/7 for liability reasons.
    a. For slow moving landslides, ODOT may be able to keep US 101 open by using a front loader and grader to add rock from established stockpiles along US 101. Equipment may be located at either maintenance facility (Gold Beach or Port Orford), but rebuilding can start from either end of a landslide regardless of which side the equipment is on.
5. Set up initial road closure, if needed. For one lane or all lane closures, this step includes flagging stations and detour route signage, including both mobile signs set up locally and variable message board alerts on the highway network. Dispatch will automatically make a request to impacted groups, such as:
    a. California Department of Transportation, who may need to set up VMS boards with highway closure alerts
    b. Motor Carrier, who may need to provide assistance with length restrictions on detour routes

6. Reinforce and complete local traffic control setup, if needed. ODOT currently only has one formalized traffic control plan for landslides in this area. See the US 101 Hooskanaden Sink/Slide Traffic Control Plan. An image from the plan is shown to the right.
    a. For more local detour routes, this may include ODOT staff handling pilot cars for trucking companies.
7. Watch and evaluate. Make sure that the staff and materials resources are appropriate. Watch the weather and the landslide to see if adjustments need to be made, especially for locations where trying to keep US 101 open.
8. Discuss finances and plan for repairing and reopening any closed lanes.



Ideas for Improvement

- Landslide preventative maintenance
    - Identify locations for soil nailing. It has proven to be very helpful for areas along the coast.
    - Unfortunately, most of the full fixes that would alleviate the landslide occurrences are not feasible due to cost.
- Focus on how to make the routes more truck friendly.
    - For example, trucks often ran out of gas when using Carpenterville Road during the 2019 Hooskanaden landslide US 101 closure.
    - For the 2019 Hooskanaden landslide, establishing weight masters at each end of the detour route was very successful.
- Finding locations to stockpile gravel along US 101to facilitate repairs.
- Finding locations for limited widenings or pullouts without exacerbating landside conditions.

- Carpenterville Road improvements could include adding rock/gravel to the established pullouts.
- Improved detour signage along Carpenterville Road.
- Formalized traffic control plans, such as the Hoosdanaden example, for all the study landslide locations.
- Early notification to freight and fuel providers to minimize disruptions in the supply chain to local communities.
    - For example, it is difficult to get fuel to Brookings for some landslide locations because fuel trucks are restricted on US 199 for environmental reasons. With early notification, sending smaller freight/fuel trucks may be option.
- Add coordination and communication with the Forest Services as part of the plan, for areas where this may be beneficial.

ATTACHMENT C: US 101 HOOSKANADEN SINK/SLIDE TRAFFIC CONTROL PLAN

US 101 Hooskanaden Sink / Slide

Traffic Control Plan

Phase 1 Initial Road Closure

A. Set initial road closure flagging stations at:
    a. Pistol River: US 101 & Carpenterville Hwy 255 MP 339.3
    b. South Coast Lumber: US 101 & Carpenterville Hwy 255 MP 354.9
B. Traffic control setup for flagging stations:
    a. Follow OTTCH for setup, and the following diagrams in this plan.
    b. Use **DETOUR** signs to direct traffic through the detour route and to direct traffic inside the closure back to the detour route, Gold Beach, or Brookings.
    c. Use extended queues for both flagging stations
C. Carpenterville Hwy 255 traffic control setup:
    a. Place **DETOUR HWY 101** with arrow signs at both ends of Carpenterville Hwy 255
D. VMS Boards
    a. Gold Beach US 101 MP 331.1 SB: "**DETOUR 10 MILE AHEAD,LENGTH LIMITS, TRIPCHECK CALL 511**"
    b. Harbor Scales US 101 MP 361.2 NB: "**DETOUR 6 MILES AHEAD, LENGTH LIMITS, TRIPCHECK CALL 511**"
    c. South Coast Lumber US 101 MP 355.2: "**ROAD CLOSED, DETOUR AHEAD**"
E. Dispatch will automatically make request:
    a. Contact California Dept. of Transportation to set up VMS boards at:
        i. US 101 & Hwy 199 Jct.: "**US 101 CLOSED, NORTH OF BROOKINGS, TRIPCHECK CALL 511**"
        ii. I-5 at Redding: "**US 101 CLOSED, SOUTH OF GOLD BEACH, TRIPCHECK CALL 511**"
    b. Contact Motor Carrier and request assistance for enforcement for Carpenterville Hwy length restrictions at flagging stations:
        i. Pistol River MP 339.3 (one person)
        ii. South Coast Lumber MP 354.9 (two people)
    c. Contact District TMM's and activate Level 1 & 2 US 101 Closure Alert Strategy Plan Pistol River to Brookings for VMS & HARs

Phase 2 Reinforce / Complete Local Traffic Control Setup

A. Set up detour over Carpenterville Hwy
    a. Place "**DETOUR HWY 101**" sign with arrows directing traffic North and South at:
        i. Boslee Butte Rd.
        ii. Cape Ferrelo
    b. Place "**LOCAL ACCESS ONLY**" sign at Cape Ferrelo & Carpenterville Hwy 255 Jct.
B. Set soft closures with type 3 barricade, "**ROAD CLOSED, TO THRU TRAFFIC, LOCAL ACCESS ONLY**" sign (OR11-4a (48"x30" Black on white)), barrels and "**DETOUR HWY 101**" with arrow directing side street traffic back to flagging station (Pistol River or Brookings / South Coast Lumber) at:
    a. US 101 & Cape Ferrelo MP 350.7 NB
    b. US 101 & Wilderness Rd MP 345.5 NB
    c. US 101 & Burnt Hill Rd MP 342.32 SB
C. Set manned hard closures with type 3 barricade, "**ROAD CLOSED**" sign, barrels and flagger at:
    a. US 101 MP 342.8 SB
    b. US 101 MP 344.35 NB

Phase 3 Evaluate Plan

A. Evaluate resources and the effectiveness of the plan.
B. Make necessary adjustments

Over-Dimensional Loads:

A. TMM or TMC will assist in coordinating loads traveling over Carpenterville Highway as needed.
    a. **Dedicated phone line for emergency coordination efforts: 541-247-0098**
    b. Phone will be forwarded to the Office Coordinator phone line. During the initial closure time this line may be forwarded to a designee to help manage coordination efforts until such time the local crew (ODOT South Coast Maintenance) can resume coordination efforts.
    c. While line is forwarded to external ODOT member (not on South Coast crew), the designee will work with the South Coast TMM / Coordinator in the coordination efforts to get over-dimensional loads over Carpenterville Hwy.
B. Consider hiring a pilot car company.
C. Over-dimensional loads can only be moved during "off peak" hours.

Carpenterville Hwy Restrictions (Trucking Advisory announcement February, 2019)

Oregon Department of Transportation | Trucking Advisory

Length Restrictions on Carpenterville Highway

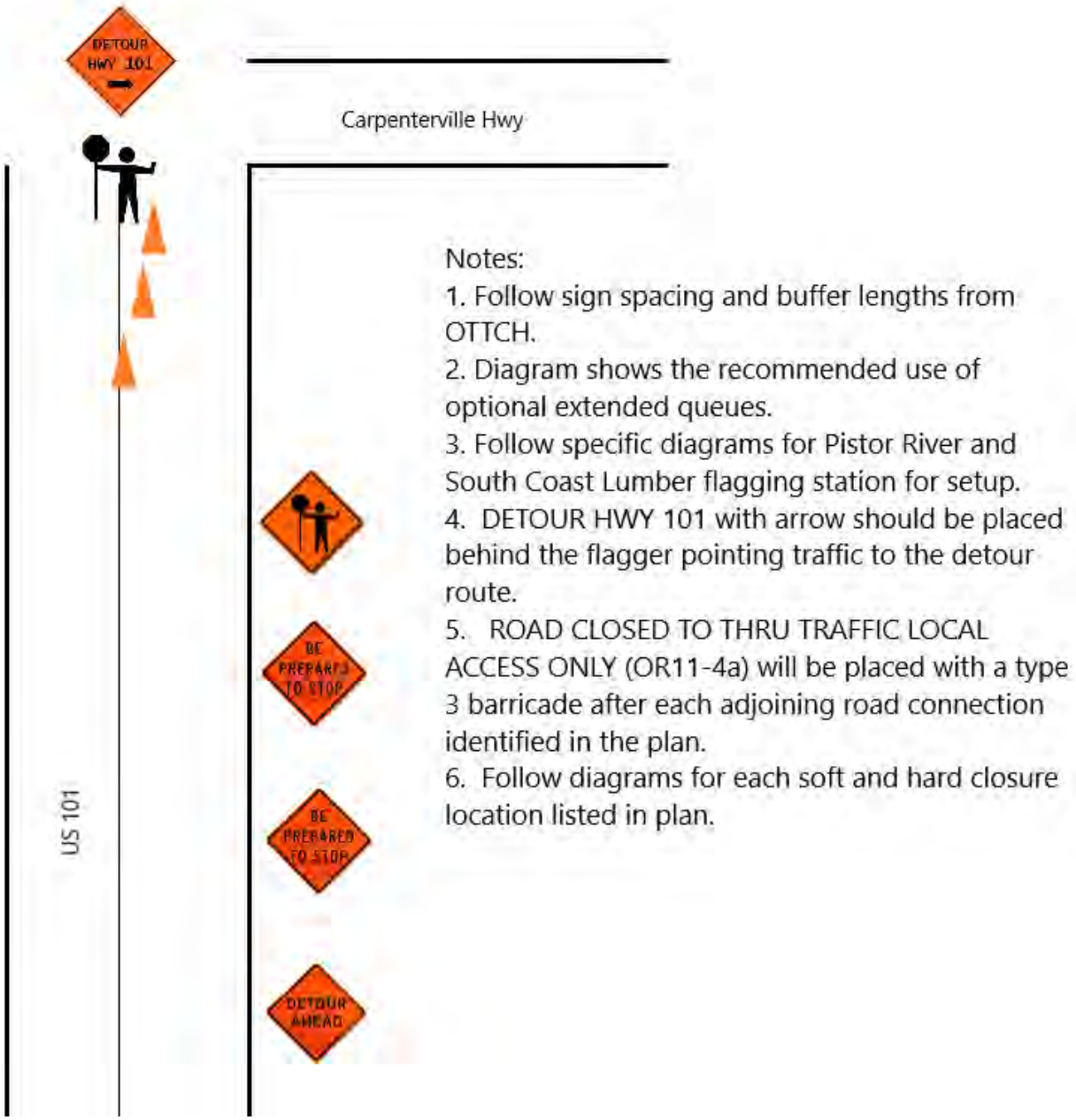
For more information: (503) 373-0000, option 1 for information about over-dimension loads; (503) 378-6699 for information about registration services

U.S. 101 is currently closed in both directions at MP 344, about 12 miles north of Brookings, due to a slide. Carpenterville Highway is a detour, but the Motor Carrier Transportation Division would like to remind commercial motor vehicle operators that the highway is limited to the following lengths:

- Truck Tractor and Semitrailer Combinations (fifth wheel hitch) - 60 feet overall length, 40 foot trailer length.
- Truck and Trailer Combinations (pintle hitch) - 65 feet overall length, 40 foot trailer length.
- Doubles Combinations - 65 feet overall length, 40 foot trailer length.
- Other length limits as shown on Group Map 1.

Carpenterville Highway is a narrow, two-lane highway, with sharp corners and limited site distance. For carriers hauling divisible loads, a permit is not available to exceed these length limits. Carriers exceeding the length limits on Carpenterville Highway should use other alternate routes.

Traffic Control Plan: Detour US 101 over Carpenterville Hwy 255



Notes:

1. Follow sign spacing and buffer lengths from OTTCH.
2. Diagram shows the recommended use of optional extended queues.
3. Follow specific diagrams for Pistor River and South Coast Lumber flagging station for setup.
4. DETOUR HWY 101 with arrow should be placed behind the flagger pointing traffic to the detour route.
5. ROAD CLOSED TO THRU TRAFFIC LOCAL ACCESS ONLY (OR11-4a) will be placed with a type 3 barricade after each adjoining road connection identified in the plan.
6. Follow diagrams for each soft and hard closure location listed in plan.

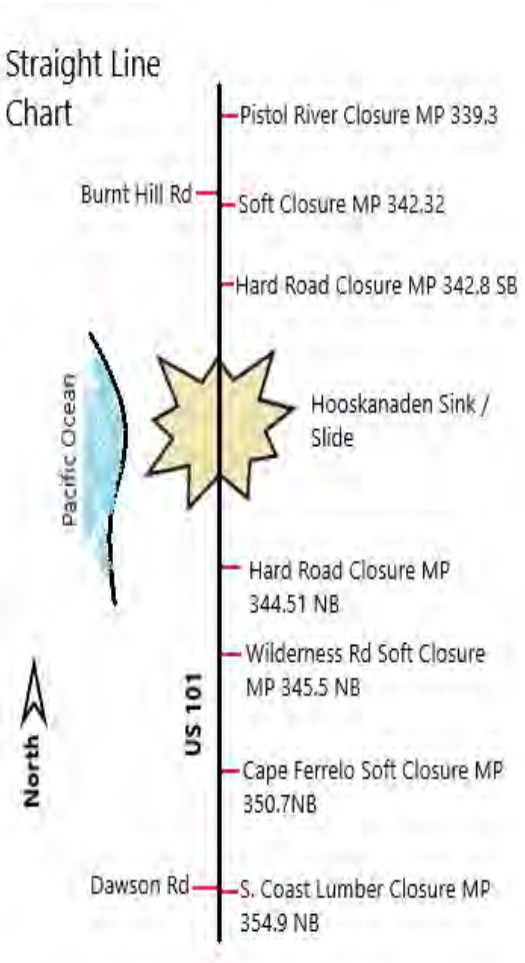
Locations north of Hooskanaden Slide / Sink

Top Right: Pistol River Flagging Station MP 339.3

Middle Right: **Soft Closure** Burnt Hill Rd MP 342.32 SB

Bottom Right: **Road Closed** MP 342.8 SB

Below: Straight Line Chart for traffic control location on US 101.



Locations south of Hooskanaden Slide

Top Right: **Road Closed** MP 344.51 near wide turn out.

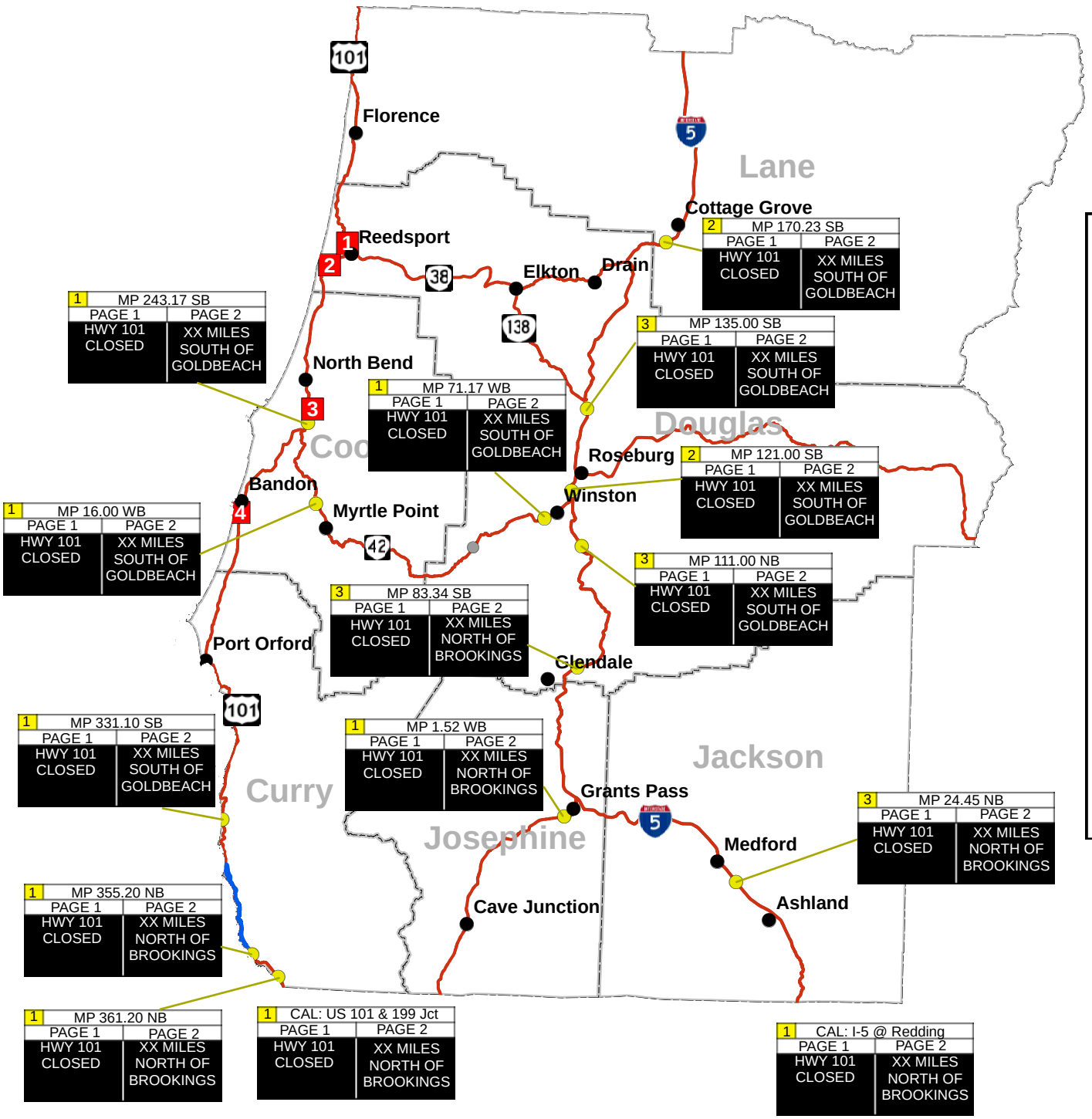
Middle Right: US 101 & Wilderness Rd **(Soft Closure).**

Bottom Right: US 101 & Cape Ferrelo **(Soft Closure).**

Below: Flagging station at South Coast Lumber near Brookings.

US 101 Closure Alert Strategy

US 101 Pistol River MP 339.3
-- Brookings MP 354.9



= US 101 Closure Area

? MP XX.XX	
Page 1	Page 2
HWY 101 CLOSED	XX MILES SOUTH OF XXXXX

= VMS Locations

1. Priority #1 - VMS in place or working towards setting up when closure is expected to cause delays.
2. Priority #2 - After Priority #1 boards in place, set up when delays / closures are expected to be longer than 3 hours.
3. Priority #3 - Set up when delays / closures expected to exceed 12 hours or more.

HARS Locations

(all will play "Hwy 101 closed XX miles south of XXXX; Use Alternate Route")

1. Hwy 101 MP 209.65 SB
2. Hwy 101 MP 215.30 SB
3. Hwy 101 MP 340.71 SB
4. Hwy 101 MP 275.86 SB

N

ODOT Region 3

Created By:
District 7 Operations
Dec. 27, 2019

ATTACHMENT D: SUMMARY OF RESOURCE DOCUMENTS

SUMMARY OF RESOURCE DOCUMENTS

ODOT provided a group of documents to be reviewed for the South Coast Slides Study. A short description of each document (titled as shared by ODOT) is provided below and relevant information has been included in the existing conditions summary.

Response Letter to Curry County (June 13, 2019)

- Response from OTC to local agencies regarding their letter about the adverse impacts of the Hooskanaden Slide
- Region 3 has identified three concepts for alternative solutions with preliminary costs. Stabilizing the slide area - $300M. Building a bridge that spans the slide - $350M. Improvements to Carpenterville Hwy - $440M.
- Impacts of the slide include:
    - Difficulty to travel to jobs, hospital appointments, and other critical locations
    - Limited truck traffic and commerce to and from the area
- OTC has asked Region 3 to determine if cost effective improvements can be made to Carpenterville Hwy to facilitate its use as a detour
- Look at other operational approaches that could reduce impacts to the community.
- Consider providing pilot vehicles to guide transit/critical shipments through a detour 3 or 4 times a day.
- Region 3 will review the Northern California project 'Last Chance Grade' to see what can be learned.

ACU-17-024 ODOTCoos (July 17)

- Land use permit application to locate the ODOT South Coast Maintenance Station and Seismic Resiliency Facility in Coos County
- The facility will serve as a recovery facility for the next Cascade earthquake and tsunami
- The facility will combine 3 existing facilities: Coquille Construction Office, Davis Slough Maintenance Station, Coos Bay Maintenance Station
- Site is located at OR 42 and US 101
- Current land is designated for Forest use
- As an outcome of the Oregon Resiliency Plan, Region 3 identified the need for a centrally located coastal facility to reopen roads and restore critical services throughout the region following a natural disaster
- Anticipated Cascade earthquake may isolate Coos County for up to 6 months
- Disasters may require hazmat spill cleanup, flood mitigation, road and bridge repair/replacement, and restoration of major utilities.
- Location is in a highland area that will not be subject to flooding
- Sufficient space is available to house other State agencies including the Oregon State Police
- Existing driveway between OR 42 and US 101 will be used to access property

Audrey McHugh-Britton OregonDOT Hooskanaden Slide

- Presentation by Audrey McHugh Britton at 2019 Symposium by the Sea. Study of the Hooskanaden Slide Using LiDAR Technology

- Presentation shares several different LiDAR methods that have been used over the past several years to study the slide area

City of Port Orford TSP September 2002

- Potential projects to consider include:
  - Improved east-west connection to I-5
  - Develop an alternative route to US 101
- Goals include:
  - Improve east/west corridor accesses
  - Identify alternative routes for use during natural disasters and/or emergencies
- Greyhound operates the only commercial bus service in the corridor and the only inter-city service to California.
- Paratransit services are available in Curry County.
- Curry County provides limited local fixed-route transit service.
- Cape Blanco State and Gold Beach airports serve Port Orford. Cape Blanco Airport was built for military defense and has a longer runway built for larger aircraft.
- 24-hour air ambulance service is available to residents who are part of the Mercy Flight program.
- The nearest commercial airports are in Crescent City and Coos Bay/North Bend.
- Develop an alternative route to US 101
  - Slides at Humbug Mountain, Arizona Beach, and Hooskanaden
  - Possible alternative routes include County and Forest Service roads, Elk River Rd, Euchre Creek Rd, Meyers Creek Rd, Pistol River Loop Rd, and Carpenterville Rd
  - Ophir Rd, North Bank Rogue River Rd, Edson Creek Rd, North Bank Rogue River Rd, and Squaw Valley Rd. Ophir Rd may be closed by the same slide that closes US 101 but could serve as an alternative during construction on US 101
  - Closure of US 101 results in economic impacts to Port Orford, Gold Beach, Brookings, and the County.
  - Agricultural products grown in Curry County are delayed in reaching markets
  - Products are delayed from reaching consumers in the County
  - Circuitous trips increase travel time, fuel consumption, and risk of a crash.
  - Tourist trips may not be made, impacting the tourism industry.
  - The needed reconstruction on several routes is identified
  - Carpenterville Rd was closed to trucks when passenger cars were rerouted to it due to safety issues of higher traffic volumes

    - Preferred alternative for Carpenterville Rd would be to restrict usage by time of day
- Improved East-West Connection Between the South Coast and I-5
    - ODOT studied 14 different alignments in 1974
    - Shasta Costa corridor was preferred alignment with a cost of $41-95M in 1974 dollars which far outweighed economic benefits.
    - Existing road should stay open year-round for emergency access
    - Still infeasible to construct a new corridor
    - Proposal to make the existing road a Forest Highway
    - Could also request ODOT to conduct a new study on the feasibility of an east-west connection

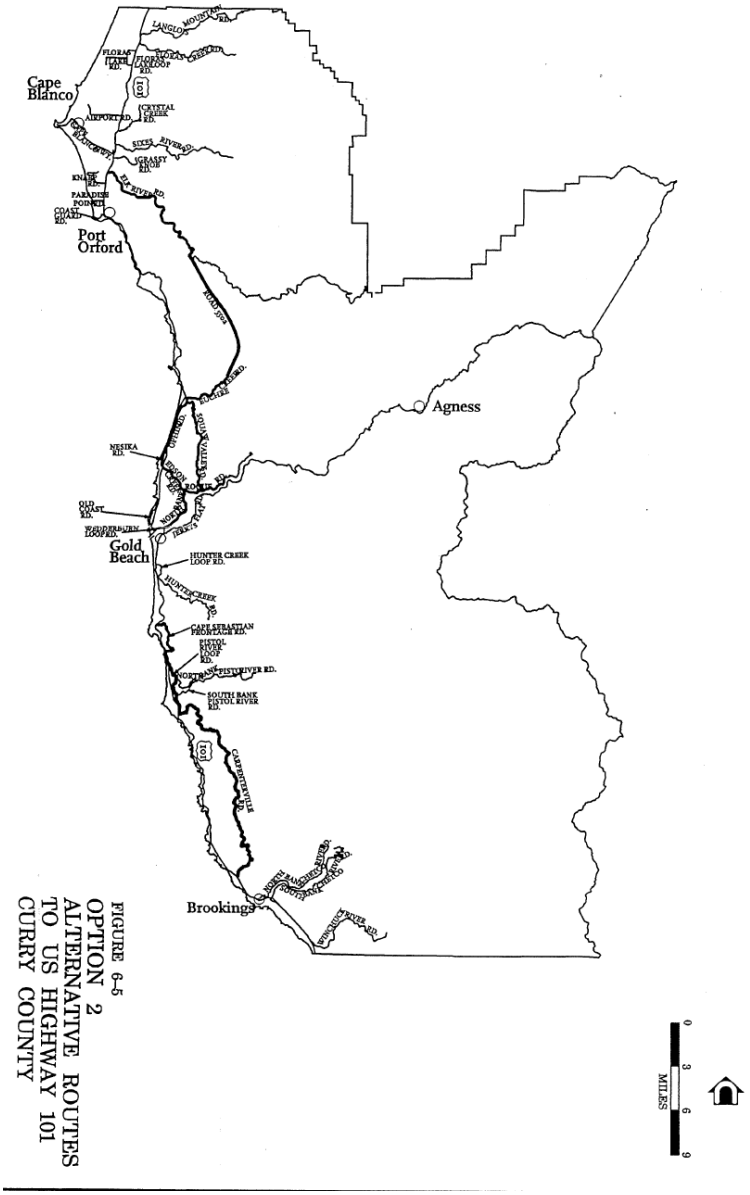


FIGURE 6-5
OPTION 2
ALTERNATIVE ROUTES
TO US HIGHWAY 101
CURRY COUNTY

-

Consent US 101 South Coast Slides Study Letter

- Amendment to 2018-2021 STIP to include the South Coast Slide Study
- Slides include: Hooskanaden, Slide Creek, Reinhart Creek, Arizona Inn.

- Study is to identify and evaluation solutions to reduce occurrence and impacts of slides.

Landslides in the Highway 1 Corridor: Geology and Slope Stability along the Big Sur Coast between Point Lobos and San Carporforo Creek, Monterey and San Luis Obispo Counties, California. 2001, Revised 6/1/2005

- Provide background information for the Coast Highway Management Plan
- Landslide maps
- Potential for landsliding depends on steepness of slopes, wave erosion, bedrock types and weathering characteristics, rainfall, geologic structure and faulting, and modification of slopes for roadway or other construction
- This is the result of a pilot study to examine the utility of landslide maps for planning within highway corridors and the needs of the Coast Highway Management Plan
- Documents the different types of rocks along California Coast
- Types of landslides

Draft City Port Orford Transportation System Plan. Sept 2002

- Excerpt from Port of Orford TSP regarding US 101 alternative routes

Hooskanaden News Clips

- Series of news stories about Hooskanaden and other slides
- Washout on Carpenterville Hwy north of Brookings
- Debris flow plugged a culvert under the road
- Hooskanaden slide also started moving although it did not close US 101
- There were also downed trees along Carpenterville Hwy, but those were cleared
- Rain was contributing factor in slide
- At the Hooskanaden slide a crack formed and they put gravel in the crack and used a pilot car to guide people through.

Last Chance Grade TMP. January 2016

- Attachment F: Transportation Management Plan
- Summary of geotechnical evaluation of 6 alternative alignments of US 101 to bypass the Last Chance Grade.
- Discusses the different alternatives and whether they are susceptible to the earth flow

News Clips. July 24, 2019

- Ambulances have been detouring to get patients to the nearest hospital
- Disrupted deliveries
- Suspended bus service between Brookings and Gold Beach and modified Coastal Express routes from North Bend/Coos Bay to turn around at Gold Beach
- Possible long term solutions presented by ODOT included an upgrade at Carpenterville Rd, mitigation of the slide, or construction of a suspension bridge. Costing between $300M and $440M.

ODOT-R3 Hooskanaden Update. July 2019

- Summary sheet for Hooskanaden Slide
- ODOT helped coordinate fuel deliveries by piloting large trucks through the detour on Carpenteville Rd

- After 13 days a single gravel lane was opened. About 2 months later 2 paved lanes were opened at 45 MPH speed limit.
- Small slides occur every 5-10 years. Major slides occur every 15-20 years.
- In small slides able to keep at least one lane of highway open.
- Brief overview of the possible solutions

Oregon notes

- This study should combine and update all the past studies and recommend new solutions that result in a strategic investment plan to prioritize improvements.
- Carpenterville re-route also experiences a lot of slides
- Plan for small, medium, and large slide events
- For large slides target mitigating community/economic impacts
- Research ODOT unstable slope data
- Identify movement rates
- Hard files in Roseburg
- Should quantify social and economic impacts at a high level to prioritize
- ODOT is the audience for the study, but will be shared with Southwest Area Commission, Gold Beach, Brookings
- NCHRP Hazard Mitigation / Resiliency Transportation Planning project

US101 Carpenterville Rd

- Map of Hazard Score along US 101.

US101 Hazard Score

- Same as above.

US101 Slides

- Spreadsheet of all the US 101 slides
- Includes MP, Lat/Long, Slope type, Hazard score, STIP score

WA Example

- Areas typically susceptible are steep hillsides and convergent topography

HOOSKANADEN SLIDE DOCUMENTS

Example Traffic Control Plan

- US 101 Hooskanaden Sink/Slide Traffic Control Plan
- Plan for road closure. Contact Motor Carrier for assistance with enforcement of length restrictions. Soft closures for local access permission. Hard closures at slide that are manned.
- Over dimensional loads can only be moved during off peak hours on Carpenterville, potentially with a pilot car.
- Restrictions on Carpenterville
- Truck tractor and semitrailer combinations (fifth wheel hitch): 60 ft overall, 40 ft trailer
- Truck tractor and semitrailer combinations (pintle hitch): 65 ft overall, 40 ft trailer
- Doubles combinations: 65 ft overall, 40 ft trailer

Includes temporary traffic control plans. Includes alert strategy for regional highways.

Carpenterville_LF-cost (002).xlsx

- Cost breakdown for projects along Carpenterville Hwy from 2019. Used the costs from OR42 as the representative costs. Costs are used to estimate what it would take to resolve the slides across Carpenterville Rd. $2,258 per foot is the cost estimate.

Potential fish passage issues on Carpenterville Highway Pistol River – Brookings

- 3 locations where fish passage may be an issue under Carpenterville Hwy. This information would be used for estimating costs for potential culvert replacements. The maps below were generated and included.

Carpenterville_FP_North.jpg and Carpenterville_FP_South.jpg and Potential_FP_Carpenterville_Detour.jpg

- Maps of Carpenterville Rd. that show streams and perhaps tributaries/runoff patterns?

Hooskanaden Narrative.pdf

Purpose of project is to provide detour route for US 101 between Brookings and Gold Beach. Without an acceptable detour route, commerce to the Brookings area ceases.

- Widen and straighten the roadway to allow 2 WB-67 trucks to pass each other in opposite directions at the same time at any point on the highway. Standard of 2 12' travel lanes and 2 6' shoulders is assumed. Minimum radius curve is 20 deg (286.48') based on curves in Humbug Canyon. Tangents will be constructed between all 20 deg curves to allow trucks to straighten out prior to entering next curve.
- 20 miles will have to be widened 16' or more to achieve the design standard. Multiple utility movements will be required. ROW acquisition will be required.

Linear Foot Estimate for Carpenterville Hwy Curve Realignment Sections

- Summarizes the cost estimates. $12.1M per miles, assuming 50% of the highway requires curve realignments the cost would be about $255M. Plus have the cost of remediating the slides along Carpenterville, which would be about $42.5M. Some of these may overlap with the curve realignments, but somewhere in the ballpark of $300M, which is comparable to the $277M bridge option.
- Includes a spreadsheet Carpenterville.xlsx which has the list and location of the slides along Carpenterville along with the number of lanes affected and hazard score.

SCOPING OR255 Carpenterville Highway Upgradess

- Cost estimate for widening Carpenterville Hwy, providing curve corrections, and repairing existing slides to enable a fully functional, unrestricted alternate route for traffic, including freight, in the event that US 101 is impassable.
- Cost estimate is $440M

SCOPING US101 Hooskanaden Slide Mitigation

Cost estimate for slide mitigation. Drainage improvements, slide plane shear strength improvements, toe protection with riprap, storage of embankment material. Total cost is $280M. Visual excerpt: