THESIS APPROVAL

The abstract and thesis of Charles M. Clough for the Master of Science in Geology presented April 22, 2005, and accepted by the thesis committee and the department.

COMMITTEE APPROVALS: ____________________________________

Curt Peterson, Chair

____

Georg Grathoff

____

Frederick Thrall

____

Trevor Smith
Representative of the Office of Graduate Studies

DEPARTMENTAL APPROVAL: ____________________________________

Michael Cummings, Chair
Department of Geology

ABSTRACT

An abstract of the thesis of Charles M. Clough for the Master of Science in Geology presented April 22, 2005.

Title: Geologic Model and Geotechnical Properties of Stratified Paleodune Deposits, Central Oregon Coast, Oregon.

Recent examinations of surficial deposits on the Central Oregon Coastal Plain have identified the remnants of a Pleistocene dune sheet (Newport Dune Sheet) that covers the preserved marine terraces. Mapping of the dune sheet (150 ground-truthing sites) shows that the dune deposits mantle more than 90% of the coastal plain. Detailed soil profiles (1-30 m depth) show that the paleodune deposits consist of interbedded dune sand, paleosols (Bg or Bw accumulation horizons), deflation surfaces, and iron-oxide (Ortstein) layers. Two dominant paleosol facies types consist of 1) flat lying, semi-continuous, Bg-accumulation horizons associated with groundwater level deflation surfaces, and 2) curvilinear, discontinuous Bw accumulation horizons associated with stabilized upland dune forms. Investigation of the cement mineralogy using XRD and SEM analytical methods show that the deposits are composed of weakly cemented minerals (vermiculite, gibbsite, allophane, imogolite, and ferrihydrite) resulting from sediment mineral weathering products, loess infiltration, and groundwater precipitation within the paleodune strata.

The field and laboratory methods used in this study to characterize the geotechnical and hydrological properties included ground penetrating radar (GPR), pressuremeter, direct shear testing, flexible wall permeability, and triaxial compression testing. The dune facies consisted of clean (<5% fines), fine uniform sand with an average hydraulic conductivity of $1.49x10^{-3}$ cm/s. The paleosol facies consisted of silty (>40% fines) fine sand to sandy silt with a hydraulic conductivity ranging from $6.21x10^{-4}$ cm/s to $1.63x10^{-6}$ cm/s. Results from soil strength tests showed that the calculated cohesion values taken from direct shear, triaxial, and PMT testing ranged from 0 to 64.2 kPa and the angle of internal friction taken from direct shear and triaxial testing ranged from 18 to 43 degrees. The measured shear strengths of the paleodune strata are lower than values expected to support observed semi-stable slopes of 50°-70°. Laboratory testing underestimated temporary cemented sand shear strength, however, the measured internal angles of friction should provide conservative values for long-term slope stability analysis. The results of the geologic framework and geotechnical characterization will provide a basis to aid engineers, geologists, and developmental planners in appropriate design and effective construction for “sustainable development” on the paleodune deposits.

GEOLOGIC MODEL AND GEOTECHNICAL PROPERTIES OF STRATIFIED PALEODUNE DEPOSITS, CENTRAL OREGON COAST, OREGON

by

CHARLES M. CLOUGH

A thesis submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE
in
GEOLOGY

Portland State University
2005

Dedication

For Suzan, Lauryn and Jonathon.

Acknowledgments

My entire secondary education has been completed with the support of my wife, Suzan. Her patience and support has been the catalyst for my ability to reach this goal. This thesis is a culmination of work completed in conjunction with many researchers and supporters. I would like to thank Dr. Curt Peterson for his patience, guidance, expertise in coastal processes, and his leadership in this research project. Dr. Georg Grathoff provided the knowledge and data for the paleodune cement mineralogy. Dr. Trevor Smith provided his knowledge in geotechnical testing and spent time in the field to conduct pressuremeter testing and data analysis on selected paleodune deposits. I would like to thank the following people: Renee Summers for help in the field and providing direct shear data; Rodger Hart and Susan Waycaster for help with field mapping; and Melissa Schweitzer for providing GIS maps of the field sites.

I would especially like to thank Dr. Rick Thrall for his support of my masters degree and helping me to establish my professional career as a consulting geologist. Dr. Thrall initiated my quest for this degree and arranged for the time and financial support to allow completion of my course work and thesis. I am very grateful to GeoDesign, Inc., of Tigard, Oregon, for providing funding for my tuition. In addition, the use of the geotechnical laboratory equipment and facility at GeoDesign amounted to over $17,000 in test results for use in this thesis.

Support for the research presented here was facilitated by the NOAA Office of Sea Grant and Extramural Programs, U.S. Department of Commerce, under grant number NA76RG0476, project R/SD-04.

Table of Contents

List of Tables

Number *Page*

List of Figures

Number *Page*

Introduction

The Oregon coastal plain (Figure 1) contains 505 km of ocean-facing coastline, of which 314 km, or 62%, contain some form of active or stabilized sand dune (Reckendorf, 1998).

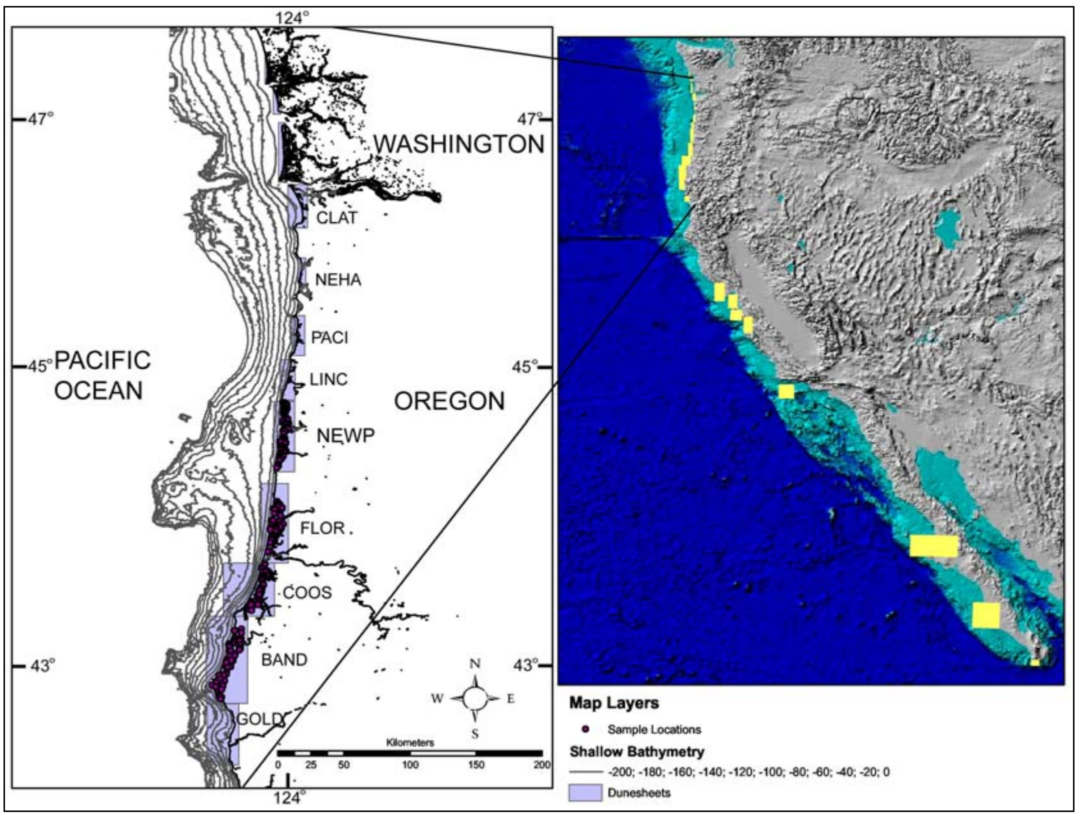


Figure 1: Regional map on right shows the west coast of the United States and locations of mapped dune sheets (shaded boxes). The map on the left shows the mapped dune sheets in Oregon. This study focuses on the Newport Dune Sheet (NEWP) located on the Central Oregon Coast.

Commercial and residential development is primarily confined to the portion of the coastal plain that contains some form of sand dune cover. The prehistoric dune (paleodune) deposits contain interbedded soils, sand layers, iron oxide layers, and deflation plain gray clay layers that are characterized by unique geotechnical and hydrological properties (Figure 2). In this thesis, the term “geotechnical” is defined as the application of the principles of engineering and geology to solve engineering problems.

Figure 2: Paleodune deposits at Ona Beach State Park.

Previous geological studies (Schlicker, et al., 1973 and Snavely, et al., 1976) have shown the Oregon Central coastal plain to be covered by undifferentiated marine terrace deposits including dunes, beach sand and lenses of pebble and cobbles. Maps from these studies do not fully show the extent of the ancient sand dunes and their inter-stratification of sand and buried soil horizons. A fundamental question to be addressed is “Do the paleodune deposits require special geotechnical consideration for site planning, development, and construction?” In order to answer this question, several objectives are addressed as follows: 1) Identification and mapping of paleodune deposits, 2) Formation of a geologic model to explain the variability of strata cementation, 3) Characterization of general geotechnical properties of the deposits, and 4) Identification of geologic hazards associated with the deposits.

Planning for sustainable development is a key issue facing coastal communities along the Central Coastal plain. The Oregon coastal planners require a "framework of geologic and geotechnical understanding" in order to promote sustainable development.

Figure 3: The Capes Development at the headwall scarp of a dune slide in the Netarts dune sheet. (Peterson et al., 2002).

"Sustainable development," is defined in this study as a means to manage and protect coastal resources for long-term use by coastal communities. Efficient development requires a thorough understanding of the geologic and geotechnical parameters that effect development (Figure 3). Presently there is an incomplete understanding of the paleodune deposits, especially among practicing engineers and geologists, that appears to result in slope, drainage, settlement, and erosional type failures associated with site grading and development. The failures appear largely related to misinterpreting field reconnaissance and exploration data and a lack of appreciation of the complex structure and variability of the dunal deposits. Further, seismic issues consisting of the mechanics of shaking and the response of the dune deposits to seismic events are becoming a significant consideration for future developments on the coastal plain. The purpose of this study is to establish a geological model of the stratified dunal deposits to further develop that understanding and aid in sustainable development and resource planning.

Recent reports by Beckstrand (2001), and Peterson et al. (2002) point to the emplacement of large dune sheets that occupied the present coastline and the inner-continental shelf during the late Pleistocene. It is hypothesized that the paleodune deposits present along the Central Oregon Coast are remnants of widespread dune sheets that formed during late-Pleistocene episodes of marine regression (low stand sea levels). Some of these paleodune sheets extend 3-6 km inland from the present coastline. The dune deposits mantle the terraces of the coastal plain, which account for about 90% of the coastal residential, commercial, and public development. In June 2002, Dr. Curt Peterson, Dr. Trevor Smith, Dr. Georg Grathoff (Portland State University), and Dr. John Baham (Oregon State University) initiated a study to investigate the geohydrology, groundwater geochemistry and geotechnical properties of the paleodunal deposits. The two studies were funded by Oregon Sea Grant (Peterson et al., 2005).

In this thesis I present a detailed database of the shallow subsurface stratigraphic development of the paleodune deposits for the Newport dune strata on the Central Oregon Coast, (Figure 1). Representative sites were investigated in detail to develop geotechnical models of the Pleistocene dune strata, in the Newport and Florence regions. (Figure 1 and Figure 4).

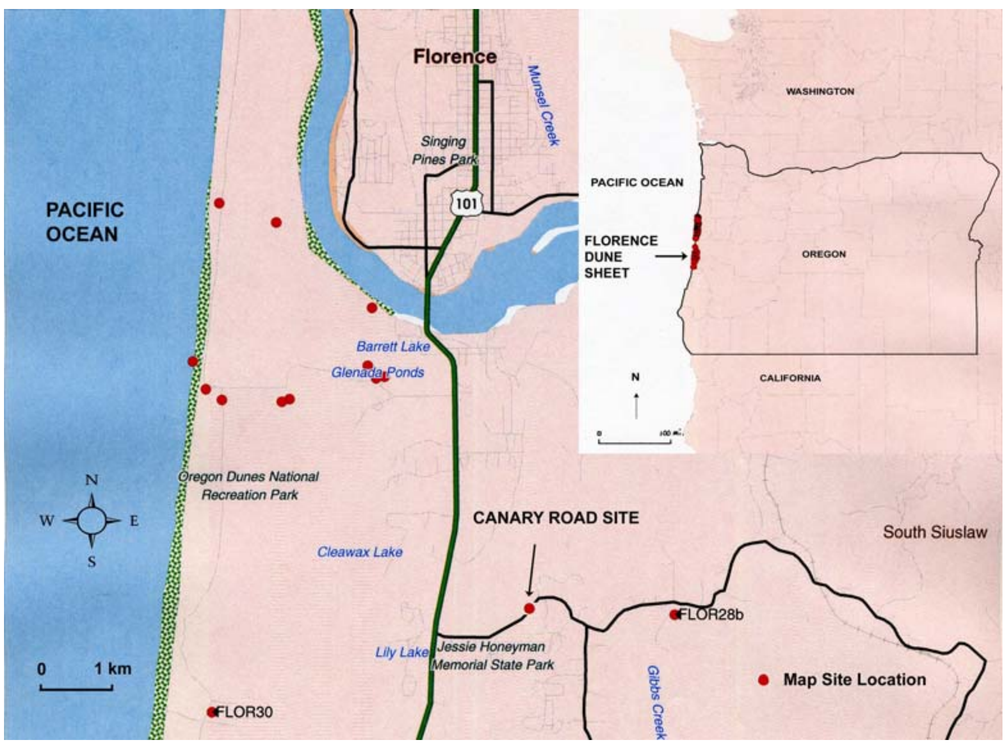


Figure 4: Florence Area Map showing location of Canary Road geotechnical site and mapped dune profile sites.

The dune stratigraphic profiles are compared to dune radiocarbon and luminescence dates to form a geologic model of diagenetic alteration and cementation. The variously cemented dune strata are measured for geotechnical properties of density, permeability, and shear strength, among others. The geotechnical hazards of poor drainage, weak shear strength, settlement, and over-steepened slopes are related to sites of recent failures. The most visible and obvious hazards are slope failures, thus, slope stability is the main focus of this study. Several field procedures and laboratory test methods are provided for performing geotechnical site investigations in paleodune deposits along the Oregon Coast. Estimates of seismic response is beyond the scope of this study, but is a major hazard effecting development and should be pursued in future research.

Background

Study Area

The study site for this thesis is centered in the Central Oregon Coastal Plain, which contains the informally named Newport dune sheet. The Newport dune sheet is bounded by Cape Foulweather on the north, Cape Perpetua on the south, the Coast Range to the east and the Pacific Ocean to the west. The Florence dune sheet is bounded by Heceta Head on the north, the Umpqua River on the south, the Coast Range to the east and the Pacific Ocean to the west. The Newport and Florence dune sheets are remnants of a large complex of dunes that covered the coastal plain and ramped up onto the foothills of the Coast Range. The dune sheets are believed to have extended westward of the current coastal headlands and were possibly contiguous on the continental shelf during low sea level stands (Peterson et al, 2002). Along the Coast Range uplands the paleodune deposits mantle the Pleistocene terrace deposits that overlie the Tertiary age marine sedimentary deposits and locally, basalts, as exposed in the resistant headlands.

Modern Climate

The central coastal climate is presently characterized by wet, stormy winters and dry, mild summers. Temperatures typically range from 11°C to 15° C during the summers and from 7°C to 9°C during the winter months. Precipitation primarily occurs from November to March with an annual average of 177 cm recorded from 1971 to 2000. The average temperature and precipitation measurements for the Central Oregon Coast is shown in Table 1. The modern wind direction along the coastline shifts with the seasons, with winter wind directed from the southwest and summer wind directed from the northwest.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average precip. (cm)	26.04	22.07	19.66	12.37	9.35	6.91	2.64	2.59	6.07	13.00	27.10	28.91	176.71
Extreme 24 hr precip. (cm)	9.25	8.28	7.80	6.32	5.28	8.36	3.68	4.11	6.40	8.38	12.67	9.91	12.67
Temp. 1971-2000 (°C)	7.2	8.0	8.5	9.4	11.3	13.1	14.4	14.6	14.0	11.7	9.2	7.3	10.7

Table 1 : Historical precipitation and temperature records for the Central Oregon Coast.

Paleoclimate Data

Worldwide climate fluctuations coincided with several glacial advance and retreat episodes during the late Pleistocene (120 to 10 thousand years before present-ka). The glacial fluctuations are represented by eustatic sea level curves (Figure 5) that show the relative elevation of sea level during periods of glacial advance and retreat (Pirazzoli, 1993). The sea level curves show that the sea levels ranged from 30 m to 125 m below present.

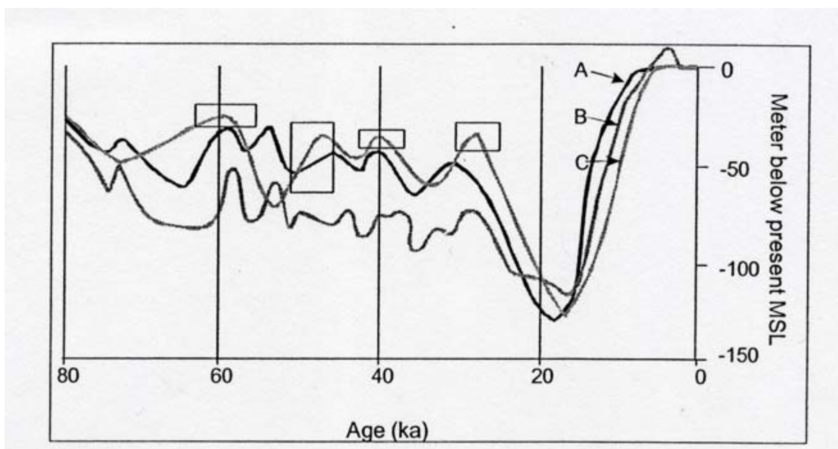


Figure 5: Eustatic sea level curves (worldwide) with respect to elevation for last 80 ka years BP. Line A is from Chappell and Shackleton (1986), line B is from Shackleton (1987), and line C is from Bloom and Yonekura (1985). Boxed areas are probable error ranges for age and height for line C. Modified from Pirazzoli (1993).

Paleoclimate data is provided from core records of pollen collected at Little Lake, located east of Florence in the Oregon Coast Range (Grigg and Whitlock, 1997; Worona and Whitlock, 1995). The lake records extend back to about 40,000 RCYBP. This Late-Pleistocene record covers the time-period of the majority of late-Pleistocene dune deposits (Beckstrand, 2001). The pollen data indicates vegetation changes that imply regional climate change and wide-scale fire events. During the late-Glacial

Transition from approximately 16 ka to 11 ka, the pollen data indicates several fluctuations in climate from cool and dry to warm and wet conditions associated with fire events. A regional change to a warmer, drier climate (Table 2) is indicated by a vegetation change at Little Lake approximately 11 ka. The climate conditions and the lower relative sea level that occurred during most of the latest Pleistocene would have been optimal for sand mobilization on the exposed continental shelf. Paleoclimate records for the San Francisco Bay area, located approximately 900 km to the south, indicate that during the last glacial maximum (21 ka to 17 ka) the Bay area was a broad forested valley and the shoreline was approximately 30 km west of the present California coastline (Helley et al., 1979).

Paleoclimate data has also been provided from foraminiferal species assemblages and oxygen isotope data collected from marine sediments. The marine deposits on the continental shelf/slope record marine water upwelling and downwelling currents that provide evidence for wind patterns along the Pacific Coastline during the LGM (Ortiz et al., 1997). Modeling based on microfossil records during the late Pleistocene (22ka to 10ka) indicate a stronger southerly onshore wind flow.

AGE (Years BP)	Oregon Coast Range (Little Lake)	Paleoclimate and Conditions
0	Douglas fir, w. hemlock, and w. red cedar forests	INTER-GLACIAL PERIOD - Warmer and dryer; Sea level rising
5,000	Douglas fir, w. hemlock, cedar, and alder forests	
10,000	Douglas fir, alder, and w. red cedar forests	
	Pine, fir, and hemlock forests	LATE GLACIAL TRANSITION - Warm and wet; Sea level rising
	Douglas fir, alder, and hemlock forests	
15,000	Spruce, fir, and hemlock forests	
20,000	Parkland forests of Engelmann spruce, lodge pole pine, and mountain hemlock	GLACIAL MAXIMUM PERIOD - Cool and dry; Sea level at low point (90 to 125 meters below present)
25,000		
30,000	W. white pine, fir, and w. hemlock forests	INTER-GLACIAL PERIOD - Warmer and dryer; Sea level fluctuations (30 to 70 meters below present)
35,000		
40,000		
	(Modified from Worona and Whitlock, 1995)	**(Taken from Pirazzoli, 1983)**

Table 2: Vegetation history of Oregon Coast Range compared with paleoclimate and relative sea level conditions. Modified from Worona and Whitlock, (1995) and Pirazzoli (1993).

Local Geology

The geology and origin of the Oregon coastal plain has been studied by many geologists that include Beaulieu and Hughs (1975), Schlicker, et al. (1973), and Snavely, et al. (1976). During the late Cretaceous and early Tertiary periods, a majority of western Oregon was covered by shallow seas that deposited sediments shed from the western edge of the continental margin. A subduction zone was present trending northeast to southwest across what is now north-central Oregon. By the early Eocene, the subduction zone migrated slowly to the west followed by formation of the Siletz River Volcanics which consists of a thick sequence of basalt flows, pillow basalts, breccia, interbedded tuffs, siltstone, and volcaniclastic sandstone. During the late Eocene to middle Oligocene, the subduction zone had migrated near its present location and the Siletz River Volcanics were overlain by thick formations of marine sandstone and siltstone (Tyee, Flournoy, Yamhill, Yaquina). During the middle Miocene, uplift of the Coast Range began, accompanied by deposition of the Nye Mudstone and Astoria Formation and eruption of basalt flows (Depoe Bay Basalt and Cape Foulweather Basalt). Wave cut platforms were created on the Tertiary bedrock along the coastal plain during the Pleistocene due to rise and fall of sea level during episodes of continental glaciation and deglaciation. Multiple elevated platforms were formed due to net tectonic uplift of the coastal plain (Komar, 1997). The wave cut platforms are covered by Quaternary terrace deposits consisting of a mix of gravel lag deposits, beach sand, fluvial sand and gravel deposits, and layers of silt and fine sand. The terrace deposits are mantled by beach and eolian (dune) sand deposits.

Origins of coastal dunes

Two models, based on eustatic sea-level, have been used to explain the origin of the dune deposits. One model theorizes that marine transgressions (high-stand model) force sand onshore. The sand is subsequently transported by onshore winds and formed into dune deposits (Figure 6).

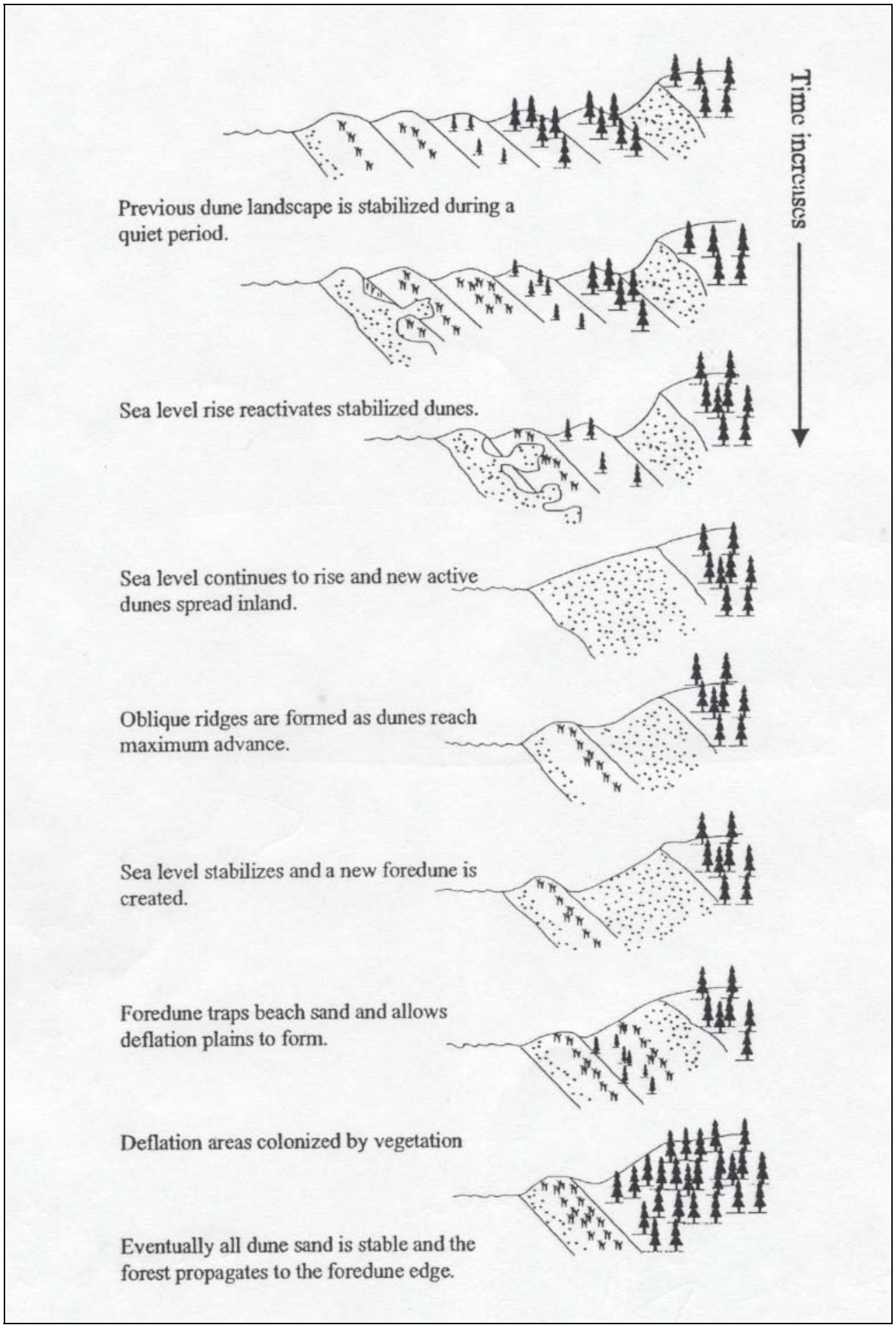


Figure 6: Schematic illustration of the high-stand emplacement model, from Beckstrand (2001).

A second model, outlined by Beckstrand (2001), theorizes that during low-stand sea levels (glacial periods), the inner continental shelf was subaerially exposed by lowered sea level of approximately 40 to 120 meters below present sea level. During the low-stands, onshore winds transported eolian dunes over receptive lowlands (Cooper, 1958). The paleodune sheets locally mantled the marine terraces and ramped-up against a topographic barrier, the Coast Range foothills (Figure 7).

Both models apply to the Newport dune sheet. The thick Pleistocene dunes developed during marine low-stand conditions. By comparison, the thin Holocene dune caps at the tops of the modern sea cliffs were formed after the Holocene marine transgression.

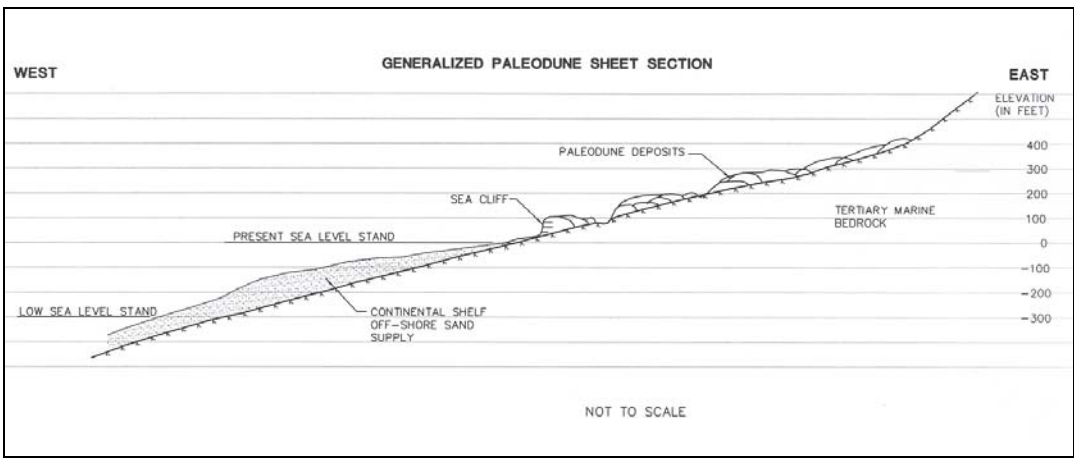


Figure 7: Generalized section of low stand emplacement model, modified from Beckstrand (2001).

The Pleistocene sand dunes were transitory by nature, being episodically forested and remobilized. The episodic stabilization caused by climate and vegetation change resulted in numerous stacked deflation plain deposits and buried forest soils (Alton et al., 1996), as shown in Figure 2. In addition, fluvial and lacustrine processes coincided with dune forming processes that further complicated the geologic setting and resulted in the remnant dune sheet geomorphology that exits today.

Previous work

The origin of sand dunes along the Oregon coastal plain has been studied by many geologists and soil scientists that include Cooper (1958), Reckendorf (1975, 1985, 1998), Komar (1997), Beaulieu and Hughes (1975), Schlicker, et al. (1973), and Snavely, et al. (1976). They have reported the presence of sand dune deposits overlying the Quaternary terrace deposits that form a majority of the coastal plain. However, the dune and underlying beach or alluvium deposits are not differentiated in the published geology or environmental geology maps. Published geotechnical properties (Table 3) that characterize the stabilized dune and undifferentiated marine terrace deposits, as taken from the available literature, is limited (Schlicker et al., 1973 and Hampton, 1963). Available published data on paleodune deposits included index testing (soil classification, grain size, and plasticity), strength testing (internal friction angle and cohesion), and geohydrology (porosity and permeability). However, the data did not clearly identify or characterize the paleodune deposits due to the limited number of samples used for analysis.

	Stabilized dune sand	Quaternary Marine Terrace	Well 18/12w-26B1	Well 18/12w-26B3	Well 18/12w-14R1	Test hole 18/12w-23Q1
Depth (m)	-	-	3.66	1.83	1.68	6.10
Soil classification	SM	ML	SP	SP	SP	SP
Angle of internal friction	32 - 37	15 - 25	-	-	-	-
Cohesion (tsf)	0	0.29 - 0.5	-	-	-	-
Plasticity Index	0	0 - 4	-	-	-	-
Mean grain size, D50 (mm)	0.09 - 0.37	0.013 - 0.09	0.225	0.260	0.250	0.210
Porosity (%)	-	-	39.2	38.8	39.5	36.5
Permeability (cm/s)	5.6E-3 - 1.7E-2	1.6E-2 - 0.17	1.27E-02	2.83E-02	2.83E-02	1.93E-02
Reference	**(Schlicker et al., 1973)**		**(Hampton, 1963)**			

Table 3: Published geotechnical parameters of dune sheet and marine terrace deposits by the Oregon Department of Geology and Mineral Resources (DOGAMI) and the United States Geological Survey (USGS).

Surficial soil data, from the Natural Resources Conservation Service (NRCS) Soil Survey, that characterize soils developed on the dune deposits are shown in Table 4 and Table 5 from Lane and Lincoln Counties, respectively (Patching, 1987 and Shipman, 1997). However, the soil survey data typically reflects the top 1.5 m of the soil profile and the geotechnical parameters were developed using variable and largely undetermined sampling and testing methods.

	Bandon 7B	Bullards 21B-G	Ferrelo 21 B-G	Waldport 132E
Depth (m)	1.5	1.5	1.5	1.5
Soil classification	SM	SM	SM	SM
Plasticity Index	NP	NP	NP	NP
Mean grain size, D50 (mm)	0.11	0.28	0.17	0.15
Permeability (10^{-3}cm/s)	1.41 - 1.67	1.41 - 1.67	1.41 - 1.67	14.1 - 70.6
Reference	**(Patching, 1987)**			

Table 4: Geotechnical data of surficial soils from Lane County soil survey.

	Bandon 3C-E	Nelscott 42C-E	Netarts 47C-E	Waldport 63E	Yaquina 67A
Depth (m)	1.5	1.5	1.5	1.5	1.5
Soil classification	SM	SM	SM	SM	SM
Plasticity Index	NP	NP	NP	NP	NP
Mean grain size, D50 (mm)	0.11	0.07 - 0.2	0.19 - 0.29	0.2	0.2 - 0.25
Permeability (10^{-3}cm/s)	1.41 - 1.67	1.41 - 1.67	1.67 - 14.1	14.1 - 70.6	1.67 - 14.1
Reference	**(Shipman, 1997)**				

Table 5: Geotechnical data of surficial soils from Lincoln County soil survey.

The distributions of marine terrace deposits in the Newport dune sheet are shown in Figure 8. The distribution of dune soils, spodisols, for the Newport dune sheet are shown in Figure 9. These published maps of potential dune sheet extent were ground-truthed for discrimination of dune sheet and shoreface deposits in this study.

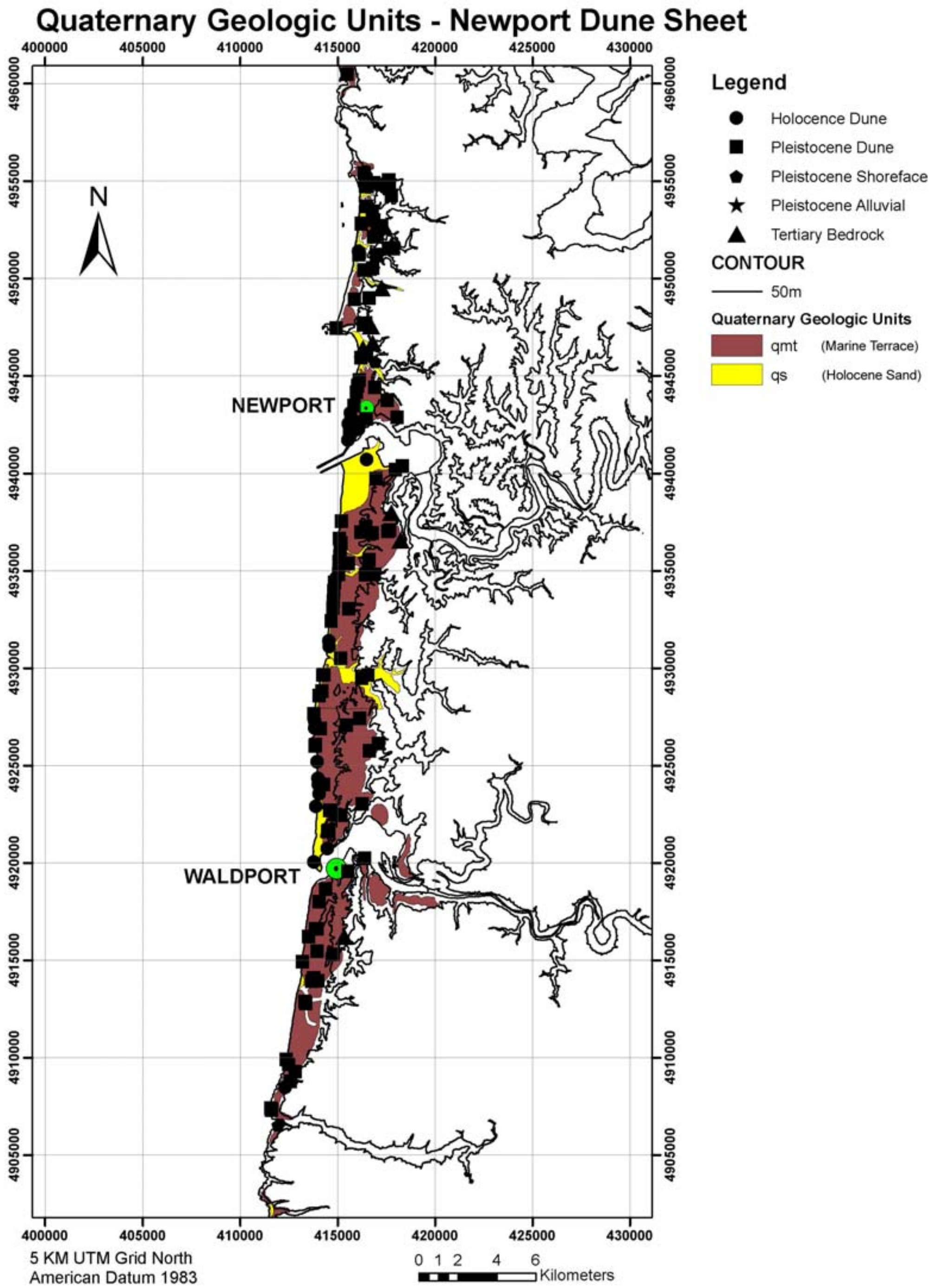


Figure 8: Map of Quaternary geologic units previously mapped in the Newport dune sheet with locations of mapped dune deposits (This Study). Redrafted from Schlicker et al. (1973) and Snavely et al. (1976).

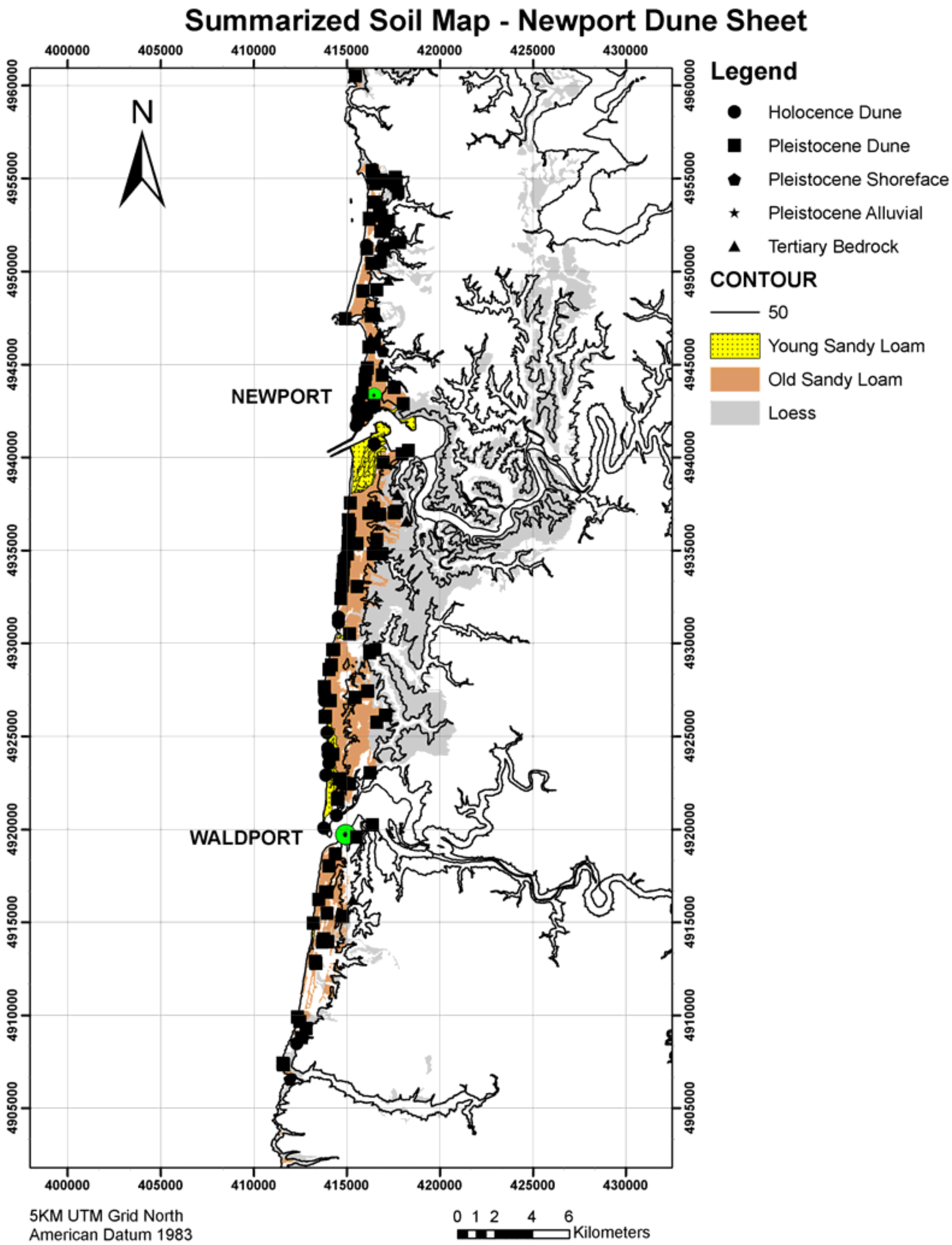


Figure 9: Summarized soil survey map of Newport dune sheet with locations of mapped dune deposits (This Study). Redrafted from Shipman (1997).

Methodology

This Methodology section outlines the geologic and geotechnical techniques used to establish the distribution and selected engineering properties of paleodune deposits located on the Central Oregon Coast. The methods used for this study are divided into geologic research, field mapping, site investigation, and laboratory testing. Geologic research and field mapping were conducted to establish a spatial and stratigraphic distribution of paleodune deposits that mantle the terrace deposits on the coastal plain. Geotechnical field and laboratory methods and tests were completed to broadly classify the typical soils that compose the paleodune deposits. The field procedures and test methods used to characterize the Newport Dune Sheet are summarized in a flow chart (Figure 10). These tests and methods assign general engineering properties to a range of Pleistocene dune strata in the Newport dune sheet.

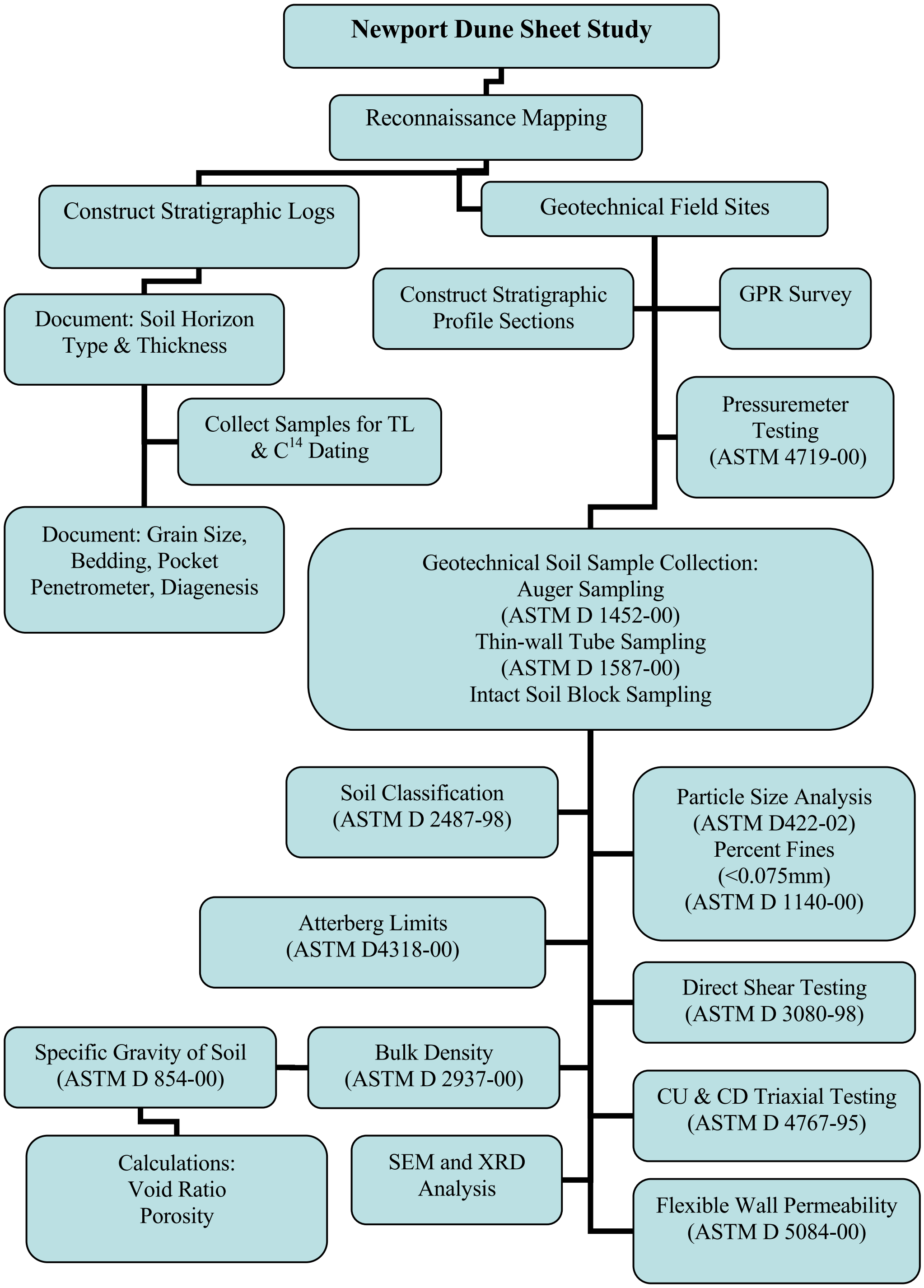


Figure 10: Field procedures and laboratory test methods used to characterize paleodune deposits of the Newport Dune Sheet.

Field mapping was accomplished by integrating several reconnaissance survey methods. These included, 1) walking out sea cliff exposures, 2) driving along west-east transect, and 3) field checking proxy maps of dune sheet back edges. Topographic maps (USGS 1:24,000 scale), modified environmental geologic maps (Figure 8) and modified NCRS soils maps (Figure 9) were used to identify potential exposures of paleodune deposits in sea cliffs, road cuts and stream valleys of uplifted marine terraces. Paleodune geomorphologic features were identified in topographic maps that included impounded ponds or diverted streams and a change in contour expression from broad rounded lowland contours (marine terraces) to steep, sharp upland contours (Tertiary marine bedrock). Geologic and geotechnical site locations that were examined in the field were located using a global position satellite (GPS) system (Peterson et al., 2005). Groundtruthing of terrace surface deposits was conducted to establish the landward extent of paleodune strata. These strata were identified as dune sand, paleosols, cemented hardpans, and peats. Groundtruthing was completed by driving or walking public roads, right of ways, forest land, and beaches to locate paleodune exposures (Figure 11). Some private property was accessed after owner permission was granted.

Figure 11: Road cut profile (Pinecrest site) along Highway 101 approximately 2 km north of Waldport. Center of picture is a 5m tall survey rod for scale.

Paleodune deposits were identified based on stratigraphic position, grain size, and the presence of dune morphology such as foresets, truncated bedding (deflation surface), and buried soils. Surficial geomorphic features that characterize paleodune deposits were used to target potential dune topography during the reconnaissance mapping (Cooper, 1958; Schlicker et al., 1973; Ritter, 1986;). Surface features included :

- Rolling topography
- Linear ridges bounded by steep valleys
- Impounded streams or lakes and ponds (barrage ponds)

- High groundwater areas, broad shallow wetlands (deflation plains)
- Thick, modern soil cover often with mature forest
- Exposures show alternating layers of fine sand varying from tan to red-brown (dune sand) with layers of silty sand to sandy silt varying from grey to brown (paleosol/deflation plain)
- Paleodune strata (uniformly graded fine sand, hardpan layers, paleosols, deflation plains, and peats).

Stratigraphic profiles were constructed to represent the paleodune deposit at each groundtruthing site. Profile exposure lengths ranged from 10's of meters in road cuts to hundreds of meters in sea cliffs. Measured profiles show the vertical sequence and thickness of the paleodune strata. Stratigraphic profiles were measured using a 10 meter or 100 meter tape. Long profiles (greater than 10 meters) were measured using a hand-held clinometer to record slope angles for calculation of vertical and horizontal distance. Some sea-cliff exposures were too hazardous to climb and slope measurements were estimated using a known height of an object or person in digital photo mosaics taken at ground level.

The compiled site locality maps (Figures 27, 28, and 29; located in the Results Section) demonstrate the distribution of measured profiles of paleodune deposits. The groundtruthing site profiles were used to construct transects trending landward (west to east) from the sea cliff to the coastal uplands. Several of the groundtruthing sites were selected for radiocarbon (samples collected by Rodger Hart) and thermoluminescence dating (samples collected by Errol Stock, Griffith University, Australia and analyzed by David Price, Wollongong University, Australia. Samples of wood for radiocarbon dating were collected from road cuts and sea cliff exposures. Sand was collected for thermoluminescence dating from hand auger borings (Peterson et al., 2002). The degree of modern topsoil formation was used as an indicator of relative age of the underlying deposit, i.e. Holocene (0 to 10,000 years BP) or Pleistocene (10,000 to 100,000 years BP). Relative age of the dune deposits was used to map the extent of young (uncemented) Holocene dune deposits and old (variably cemented) Pleistocene dune deposits. Soil formation parameters include: 1) overall profile thickness; 2) iron oxide accumulation i.e., soil color (Bw horizon) (chroma and hue) based on the Munsell color chart; 3) zone of clay accumulation (Bt horizon); and 4) presence of gibbsite mineral precipitates (Beckstrand, 2001). Mineral precipitates are common within the paleodune deposits and include red iron oxide staining (Figure 12) or cemented hardpans (ortstein), black iron oxide and/or humate nodules, allophane wood replacement, and white gibbsite nodules (Grathoff et al., 2003). Red iron oxide staining or cemented hardpan layers are the most apparent forms of the mineral precipitates in the paleodune sand deposits of the central Oregon Coast.

Figure 12: Photo of iron oxide cemented layer above tan fine sand.

The pocket penetrometer was used in the field to establish relative surficial soil strength characteristics of selected soil horizons (Figure 13). A fresh, smooth surface was cut into the outcrop and the penetrometer was pushed into the soil until the tip penetrated 6.4 mm or a maximum reading was reached. Several readings were collected to determine a representative penetration reading for a test location. The pocket penetrometer is designed to record the unconfined compressive strength of cohesive soils (silt and clay) in units ranging from 0.25 to 4.5 kg/cm^2 . This device was not intended to replace laboratory testing, but to determine relative cementation of soil horizons for establishing soil development and selecting soil horizons for laboratory testing. It should be noted that the penetrometer is relatively ineffective in granular and cemented materials and results from this test should be interpreted as relative penetration for comparing different soil units.

Figure 13: Photo of a pocket penetrometer.

Soil profile logs were constructed from mapped exposures that included road cuts, sea cliffs, slope cuts, trenches, and hand augers. The information collected included exposure type, unit age based on relative age and stratigraphic position, unit parent material, soil horizon designations, horizon thickness, predominant grain size, bedding structure, maximum Munsell color, soil formation structure, and diagenesis.

The relative geologic age designation of mapped surficial units consisted of Tertiary (T), Pleistocene (P), or Holocene (H). The parent materials were classified into one of the following: dune(D), loess(L), colluvium(U), peat(P), alluvial/fluvial(V), lagoon/estuary(N), beach shoreface(S), and basal conglomerate(M). The soil horizon designations were adapted from Birkeland (1984) and included the following: organic (A), leached (E), accumulation (B), Fe+3 accumulation (Bw), incipient clay accumulation (Btj), clay accumulation (Bt), Fe+2 reduced gleyed layer (Bg), parent material (C), and oxidized parent material (Cox). The horizon thickness was measured to an accuracy of 1 cm using a tape measure, however some profiles did not have direct access (i.e. steep cliffs) and measurements were estimated with an accuracy of 0.25 meters using a suspended tape measure or scaled digital photographs. The horizon grain size was classified as silt (0.002-0.075 mm), sand (0.075-4.75 mm), gravel (4.75-75 mm), or cobbles (75-300 mm) as based on the Unified Soil Classification System (USCS-ASTM-2487-98). Sand sizes ranged from coarse to very fine grained. Bedding structures, such as cross beds, planar beds, and laminations were recorded. The maximum Munsell color for selected horizons was recorded based on a moist field condition. Pocket penetrometer measurements were collected for relative soil strength comparisons. Soil formation structure included loose, very weak blocky, weak blocky, strong blocky, and columnar/prismatic (modified from Birkeland, 1984). Finally, inter-stratal groundwater diagenesis of horizons included Fe-ortstein (hard pan layer), Fe-humate, allophone, and gibbsite were recorded where observed in the stratigraphic section.

The geotechnical study was separated into two parts that included a field component and a laboratory component for each geotechnical field site. The sites were selected to provide a range of conditions associated with Pleistocene dune deposits found on the Central Oregon Coast. The field component of the site investigations included measured sections, detailed logs, and pocket penetrometer measurements of variably cemented dune strata on road cuts and sea cliff exposures. Subsurface information was collected using hand auger borings or excavated test pits. A slope cut exposure profile, subsurface boring log or test pit log was constructed for each geotechnical site using standard engineering geology classification. Visual field logging methods included estimated density, color, soil type based on main constituent and descriptors, moisture content, texture, and structure. These logs were formatted using a field logging sheet (Appendix B) based on American Society for Testing and Materials (ASTM) procedures (modified slightly by consulting practice methods) and terminology for ease of use by engineers and planners.

Field Sampling and In-situ Testing Methods

The variably cemented dune deposits proved to be difficult to sample without disturbing the sample integrity. Several different sampling strategies were incorporated into the field sampling program to reduce sample disturbance. The paleodune deposits were observed to be discontinuous and change orientations within the subsurface. Ground Penetrating Radar (GPR) was used to create subsurface profiles and to extend borehole and outcrop profiles. Pressuremeter testing was performed at selected sample sites to compare insitu field strength and laboratory measured sample strength.

Field Sampling

Hand auger borings were performed to collect samples at targeted depths using a 3-inch diameter aluminum sand auger. Typical boring depths ranged from 2 to 10 meters below ground surface. Hand auger borings generally extended down to refusal based on penetration resistance or boring collapse below ground water level. Individual paleodune layers were logged based on visual methods. Soil samples were collected vertically downhole or horizontally back into the outcrop exposure by one of several methods including auger grab (disturbed) samples, brass ring samples, Shelby tube samples, and excavated block samples. As indicated, all samples sustain variable levels of disturbance depending on the sampling method.

Disturbed samples were collected by hand or from hand auger cuttings (ASTM D 1452-00). The disturbed samples were placed in sealed plastic bags to retain moisture. Tests conducted on disturbed samples included moisture content, grain size, Atterberg limits, and specific gravity. Brass ring samples (Dames and Moore rings) were collected from hand auger borings and outcrop exposures using an AMS core soil sampler (Figure 14). The AMS sampler consists of a 6 pound hand slide hammer, one-meter extension rods, and a drive head that holds six 2-inch diameter by 1-inch tall brass rings. The drive head was driven (at the sample interval) with the slide hammer. The drive head was either pulled or dug out by shovel. The ring samples were carefully removed from the drive head and placed in a plastic liner and sealed in a tube for transport. Tests conducted on ring samples included moisture content, unit weight and direct shear.

Figure 14: Photo showing soil sampling using a driven or pushed Shelby tube (on left in outcrop) and an AMS core sampler that holds six Dames and Moore brass rings (on the right).

Shelby tube samples were collected from outcrop exposures using two methods. The first method involved driving the tube into the sample interval with a cushioned hammer (ASTM D 1587-00). This method resulted in relatively undisturbed samples. Some disturbance was suspected from driving the Shelby tubes into the weakly cemented sand deposits. This potential disturbance is addressed in the Results section.

The second method involved trimming an "undisturbed" block sample into a Shelby tube. Material was carefully removed with a hand trowel and knife to allow a Shelby tube to slide down around the sample with minimal force. The tube ends were trimmed flush and the ends were capped for transport. The steel Shelby tubes were split lengthwise using a Dremel tool and cutting blade to reduce the friction (sand lock) of the sandy soil during extrusion of the specimen. This is the preferred method to obtain, transport, and store “undisturbed” paleodune soil samples. The quotes indicate that no sample is completely “undisturbed” during or after removal from the sample site.

A third sampling method involved collecting large (50x50x50cm) block samples (Figure 15). The block samples were collected from outcrop exposures using several straight-edge shovels and hand trowels to excavate an intact soil block from a sample interval. The block was trimmed (30x30x30cm) in the field and wrapped in plastic sheeting, padded, and placed in a cardboard box for transport. The blocks were trimmed into cylinders in the laboratory for unit weight, hydraulic conductivity, and triaxial testing. A few block samples were collected only at the Pinecrest site due to the difficulty in handling, transport, and storage of large block samples required for trimming test specimens in the laboratory. Several of the large block samples fractured along internal planes of weakness during removal from the outcrop.

Figure 15: Photo of block sample collection at the Pinecrest site.

Field Exploration and Testing Methods

Ground Penetrating Radar

An Ecopulse 100A ground penetrating radar (GPR) system was used by Harry Jol (University of Wisconsin at Eau Claire) with a 100 MHz antenna and a 300 volt transmitter to profile the sand dune strata (Figure 16).

Figure 16: Photo showing GPR equipment with the 100 MHz antenna attached.

A step spacing of 0.5m was used to increase reflection density. A common mid-point (CMP) test was performed at each locality to establish velocity to depth relations (Jol, Smith & Meyers, 1996). GPR profiles were collected parallel to the outcrop at the Yachats site (Figure 17) to compare the GPR reflections to the outcrop measured profile strata that included paleosols, hardpans, dune cross-beds, deflation surfaces, and discontinuities (Figure 18). GPR profiles were also collected orthogonal to the outcrop face to extend the orientations of various strata back into the slope.

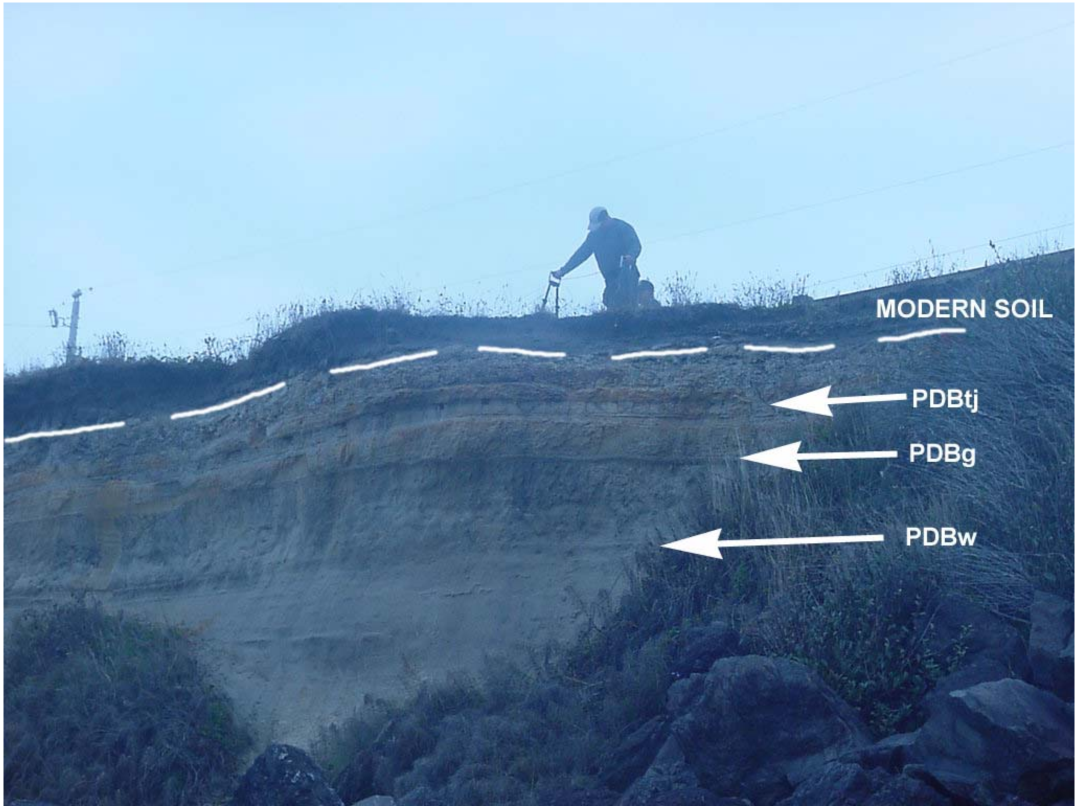


Figure 17: Photo showing GPR survey running parallel to the sea cliff (Yachats) to compare the stratigraphic log to the GPR reflections. Arrows point to major soil horizons.

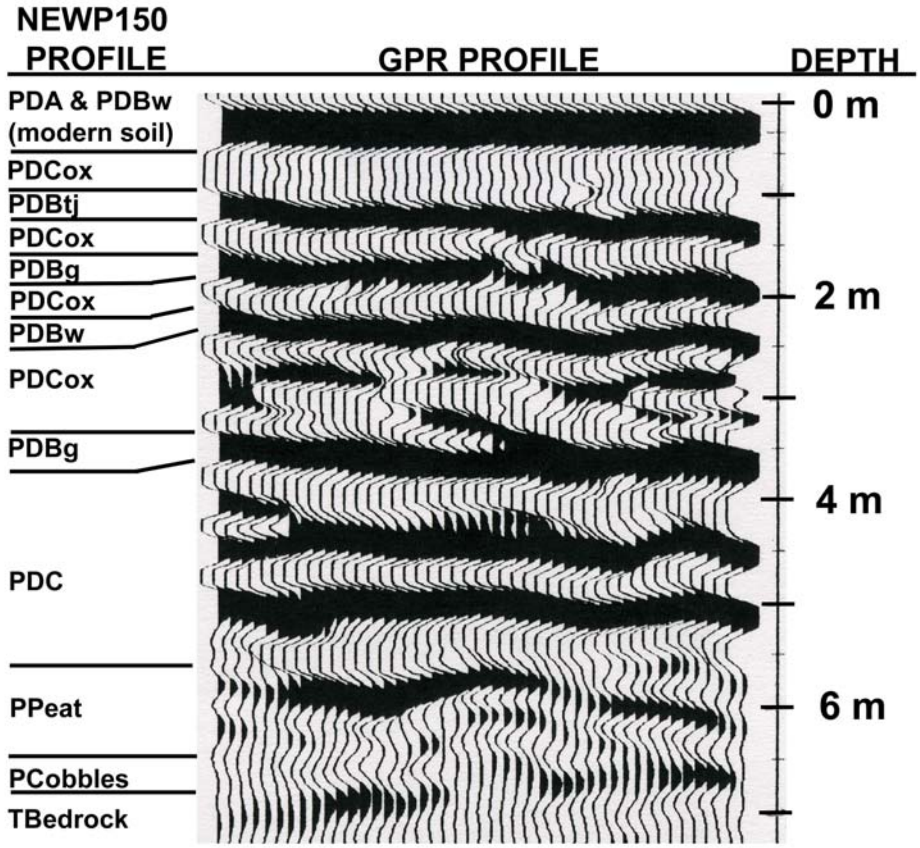


Figure 18: Comparison of the measured profile section at Yachats (NEWP150) with the GPR reflection profile. The top 4 meters show a good correlation.

ASTM D 4719-87

Standard Test Method for Pressuremeter Testing in Soils

Prebored pressuremeter testing was done at selected intervals on boring locations (Figure 20). The PMT test locations were chosen based on the results of the field site investigations and laboratory testing to compare the in-situ soil strength to the laboratory measured soil strength. The Pressuremeter test is an in-situ stress-strain test performed with a cylindrical probe that expands radially within a prepared cavity, generally a bore hole. The cylindrical probe is then expanded in equal volume increments while measuring the change and pressure within the probe (Figure 22). The test was performed to ASTM D 4719-87 standard test method for pressuremeter testing in soils. The test measures soil stiffness and strength and reports the PMT Modulus (Eo) and Limit Pressure (P_L). The 32 mm EX-size diameter probe (Figure 22) was used in hand augered boreholes. Both Texam, manufactured by Roctest of New York (Figure 19), and Portland State University Pressuremeter (PuP) were used as control units. The PuP unit is a small capacity (maximum of 300 cc) portable unit for difficult access sites.

Figure 19: Photo of Texam pressuremeter control unit in use at the Ona 1A site located on the top of Ona Beach sea cliff.

Figure 20: Photo of pressuremeter test location at Pinecrest road cut.

Figure 21: Photo of PuP pressuremeter control box and pressure gauges.

Figure 22: Photo of fully expanded EX pressuremeter membrane.

Geotechnical Laboratory Tests

Testing was conducted in general accordance to ASTM standard test methods and performed in the field or in geotechnical soils laboratories located at GeoDesign, Inc. and at PSU Civil and Environmental Engineering Department (Portland, Oregon). The following is a list of laboratory tests performed to characterize paleodune geotechnical soil parameters.

Soil Classification

ASTM D 2487-98

Standard practice for classification of soils for engineering purposes (unified soil classification system).

The USCS was used to supplement the visual descriptions prepared in accordance with the field logging methods. The soil classification is based on laboratory test results that include particle-size analysis (ASTM D 422), liquid limit, and plasticity index (ASTM D 4318). The procedure assigns an appropriate group name and symbol to foundation soil samples based on laboratory testing. The Unified Soil Classification System (USCS) is a standard method to describe and correlate behavior of soils with similar engineering properties.

Index Tests

ASTM D 4318-00

Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils

This method was used to determine the plasticity index of the paleodune deposits for the purpose of USCS soil classification. Few samples required this test due to the sandy nature of the soils.

ASTM D 2937-00

Standard Test Method for Density of Soil in Place by the Drive-Cylinder Method

This method was used to determine the in place density of paleodune samples. Thin-wall sample tubes were pushed or driven with a cushioned hammer to the target depth, removed, and sealed for transport to the laboratory. The tube ends were cut square with a pipe cutter and the ends of the sample trimmed flush. The volume of sample was determined by measuring the sample dimensions in the tube using a caliper capable of reading to 0.025mm. The moist weight of the sample was recorded before drying. The moisture content of the sample was determined and the dry density calculated by dividing the weight of dry soil by the volume of soil.

ASTM D 422-63(2002)

Standard Test Method for Particle-Size Analysis of Soils

This method was used to determine the grain size distribution of the paleodune deposits. A hydrometer analysis was run on samples containing more than 10 percent fines (silt or clay) based on visual determination. Due to potential cementation effects, particle size may be variable based on the amount of aggregated grain breakdown imposed during the test. Further, allophane has a tendency to flocculate in the hydrometer, resulting in test results potentially biased toward the larger particle sizes.

ASTM D 854-92

Standard Test Method for Specific Gravity of Soils

This method was used to determine the specific gravity of the paleodune deposits. Test Method D was used for moist samples. The soil samples were placed in a 250mL or 500mL calibrated volumetric flask, partially filled with distilled water and gently boiled for a minimum of 2 hours. The sample plus water was allowed to cool and the flask was filled to the calibration mark and weighed. The specific gravity (G) was calculated using the formula:

$G_T = M_o / (M_o + (M_a - M_b))$

Where: M_o = Mass of oven dry soil

M_a = Mass of flask filled with water

M_b = Mass of flask filled with water plus soil

T = Temperature of flask contents at determination of M_b

The sample porosity, void ratio, and degree of saturation was calculated for each geotechnical sample based on index test results for sample moisture content, dry bulk density, and soil specific gravity. Each parameter was determined from the following formulas:

Porosity (n) is defined as the proportion of the volume of space between soil particles to the total volume of the space occupied by the sample. In terms of easily measured parameters were:

$n = 1-((\gamma_d)/G_s*\gamma_w)$

Where: γ_d = dry density; G_s = specific gravity; and γ_w = unit weight of water.

Void ratio (e) is defined as the proportion of the volume of space between soil particles and the volume occupied by the solid particles.

$e = (G_s*G_w)/ \gamma_d)-1$

<u>Degree of saturation</u> (S) is defined as the proportion of total volume that contains water.

$S = (w * G_s)/ e$

Where: γ_d = dry density of soil; G_s = soil specific gravity; γ_w = unit weight of water; and w = percent water content of the soil.

Soil Strength Tests

ASTM D 3080-90

Standard Test Method for Direct Shear Test of Soils Under Consolidated Drained Conditions

This test method was used to determine the consolidated drained shear strength of undisturbed paleodune samples. In general, three direct shear tests were conducted on brass ring (61mm diameter) samples at different confining stresses to generate a Mohr strength envelope. The resulting strength envelope indicates shear strength as defined by the angle of internal friction (phi) and cohesion intercept (c). The majority of the direct shear testing was performed by Renee Summers (civil engineering, Portland State University) for her Masters project.

ASTM D 4767-95

Standard Test Method for Consolidated Undrained Triaxial Compression Test for Cohesive Soils.

This test method was used to determine the stress-strain relationship of undisturbed paleodune samples collected and prepared in accordance to procedures outlined in the previous section. Samples were saturated to a minimum “B” pore pressure parameter of 0.95. The samples were saturated with de-aired water by means of a back-pressure method. Air within the sample is dissolved into the water by application of incremental changes of the sample confining pressure and the internal sample head pressures. The B coefficient is determined by the change in pore-water pressure in the sample divided by the change in confining pressure. Once saturated, the samples were consolidated in two stages to an effective stress matching the median effective stress of the triaxial test for the representative sample location. In general, three triaxial strength tests were completed on 73mm diameter samples at different effective stresses to generate a Mohr strength envelope. Triaxial strength tests were conducted using drained and undrained methods. Under undrained conditions, the sample volume is held constant and the change in excess pore water pressure is monitored during loading. Under drained conditions, excess pore water pressure is held at zero and the change in sample volume is monitored during loading. In either case, drained strength parameters are determined.

Triaxial testing was conducted using a GeoComp Products Lab System. The GeoComp system is a computer-controlled, fully automated soil testing system produced by the GeoComp Corporation of Boxborough, Massachusetts (Figure 23). The system consists of a load frame, two automated flow pumps that control the cell and sample pressures, and a computer for data acquisition.

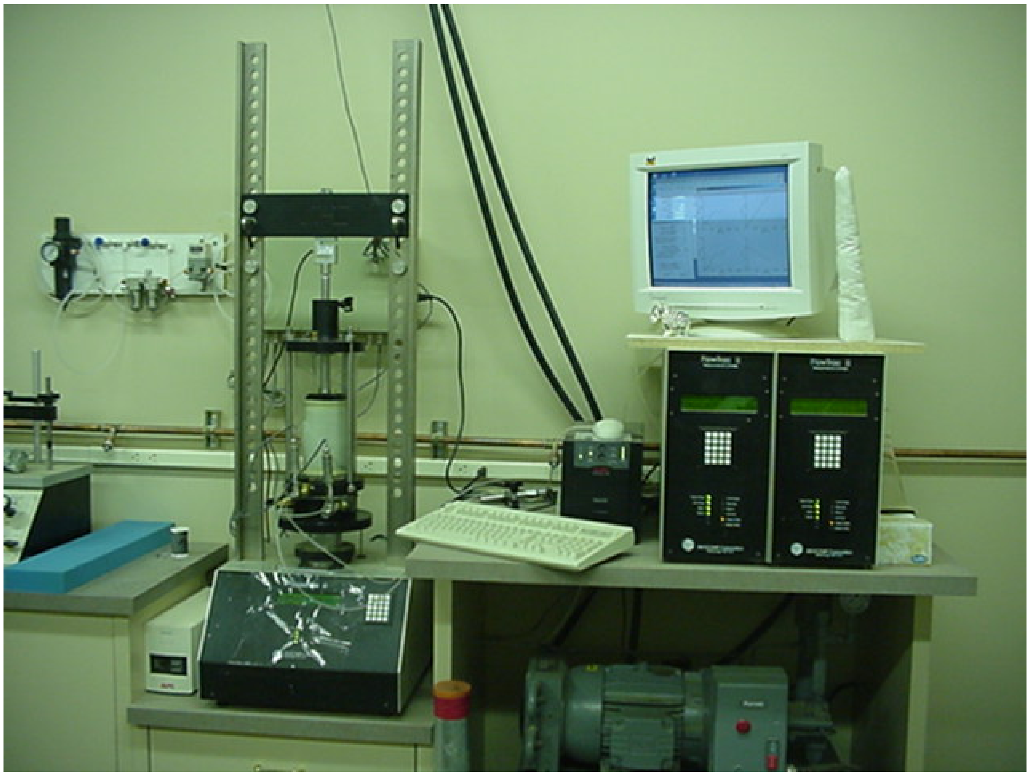


Figure 23: Triaxial and flex-wall permeability test equipment.

Permeability Tests

ASTM D 5084-00

Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter.

This test method was used to determine the hydraulic conductivity of paleodune samples. Samples were saturated as in the triaxial test. Once saturated, the samples were consolidated in two stages to an effective stress matching the median effective stress of the triaxial test for the representative sample location. Water is then forced through the sample under a constant gradient. Hydraulic conductivity (K) is calculated from a constant rate of flow at a constant gradient (i) through the sample by the formulas:

$i = \Delta h / L$

$K = (\Delta Q * L) / (A * \Delta h * \Delta t)$

Where: ΔQ = average of inflow and outflow for time Δt

L = sample length

A = sample cross-sectional area

Δh = average head loss across sample

Δt = time interval of measurement

Flexible wall permeability testing was also carried out using the GeoComp system (Figure 20).

Clay Mineralogy

X-ray diffraction (XRD) analysis was performed on selected geotechnical samples to determine the nature of the cementing material in the paleodune sands. Sample preparation consisted of a wash using distilled water and a #270 (53µm) sieve and collection of all wash liquid. The supernatant liquid was mixed with 90 mL of dispersant (sodium metahexaphosphate) and allowed to settle the oversize (>2µm) fraction under the influence of gravity using Stokes Law. The remaining suspended size fraction was collected and placed in a centrifuge to settle and concentrate the desired size fraction (<2µm). Sample analysis was completed by Catrina M. Johnson. The analysis was conducted using a Philips theta-theta X-pert, Cu K-alpha, and Peltier cooled energy dispersive detector.

The paleodune deposits were successfully sampled and characterized by the methods outlined in this section. Non-cohesive materials are difficult to maintain in an undisturbed condition when removed from the field. During laboratory testing, some samples had to be abandoned due to suspected disturbance or desiccated conditions.

Samples that contained some fines (<0.075mm), or were lightly cemented, were less prone to disturbance.

Results

The results of this study are intended to characterize the geologic framework and geotechnical properties of Pleistocene dune deposits that are located in the paleodune sheets of the central Oregon coast. This Results section is organized into: 1) field work consisting of geologic field mapping; 2) geotechnical study sites and field observations; 3) geotechnical testing consisting of sample collection and laboratory testing; and 4) in situ field testing using the pressuremeter. The mapping and most of the field sampling was performed in the Newport Dune Sheet.

Field Mapping

The Pleistocene dune strata cover marine terrace shoreface deposits of the coastal plain and Tertiary bedrock that form wave-cut platforms at the base of the Coast Range foothills. The Pleistocene dunes are typically overlain by topsoil horizons. The coastal plain is locally developed with residences, multistory buildings, and roads that are built on the paleodune deposits (Figures 24, 25 and 26). Significant future development is planned or underway.

Figure 24: Road cut heading east from Highway 101 through paleodune deposits. The area on both sides of the road is zoned for residential development. The dip in the road (shown by arrows) is an interdunal stream running north to south.

Figure 25: House foundation excavation situated on a paleodune deposit located on top of a sea cliff at Ona Beach.

Figure 26: House situated on paleodune deposit located in residential area of Newport, Oregon.

The Newport Paleodune Sheet deposits extend from the beach and foredune deposits east to the coast range foothills. The north and south features bounding the Newport dune sheet are arbitrarily defined at the two major headlands, Cape Foulweather and Cape Perpetua. Mapping the dune sheet has produced 151 site profiles that show wide-spread coverage of paleodune deposits and their eastern limit along the coast range foothills. Site profile data is located in Appendix A. Radiocarbon (RC) and thermoluminescence (TL) dating performed on paleodune deposits at selected sites indicate that the dunes are mostly Pleistocene age. Dating results will be discussed later in the Results section.

The Newport dune sheet covers approximately 55 kilometers (km) along the central Oregon coastline and extends inland from the beach up to 3.5 km. From the

151 mapped sites, 16 locations (10.6%) did not contain paleodune deposits. The elevation of the paleodune sheet ranged from less than 5 meters (sea cliff sites) to 131 meters (NEWP23). The mapped eastern limit of the paleodune sheet corresponds with the western margin of the Coast Range foothills and is shown on Figure 27, Figure 28, and Figure 29 at a scale of 1:125,000. Based on the mapped eastern limit of the paleodune deposits, the average width of the paleodune sheet was measured to be 2.0 km.

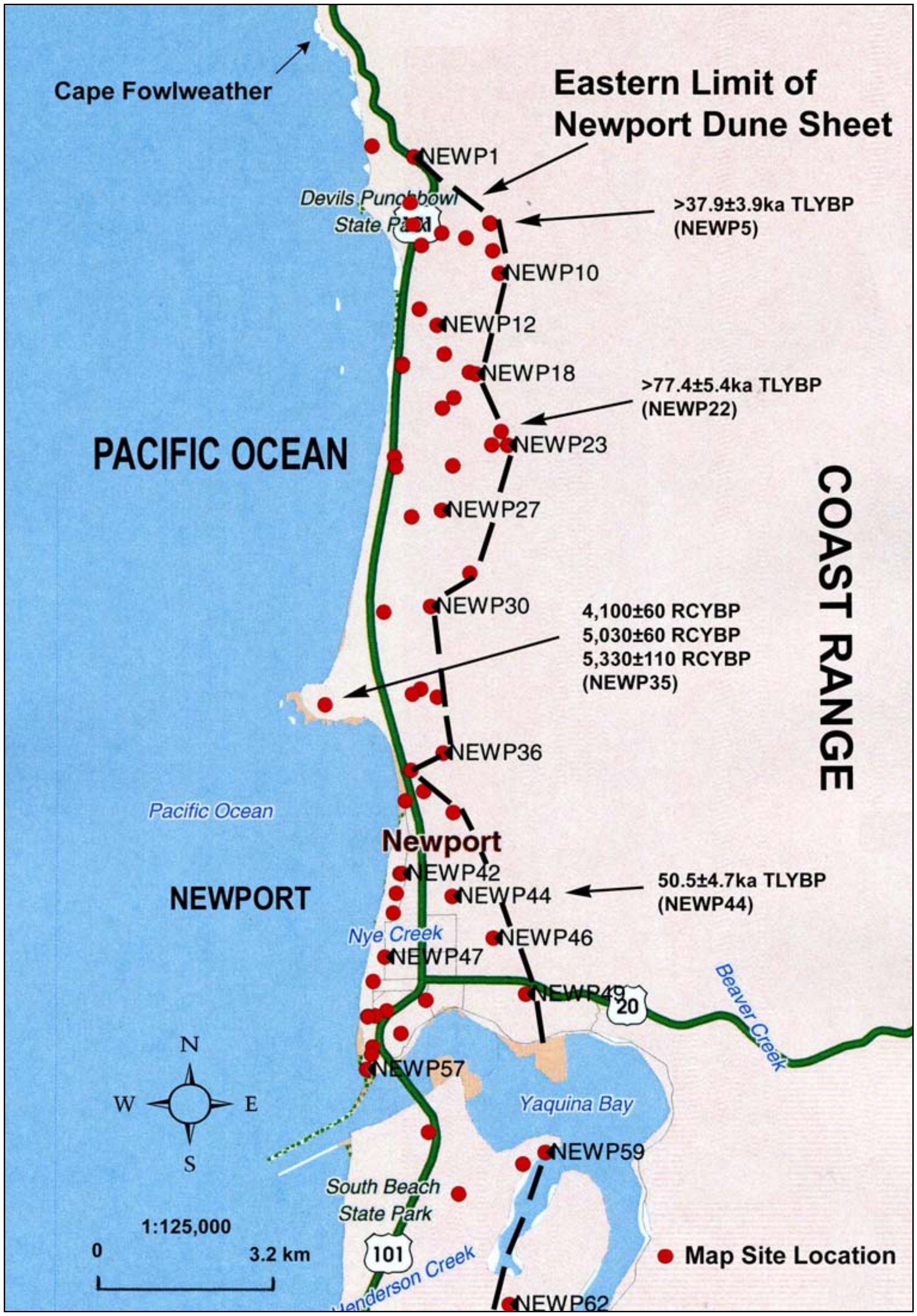


Figure 27: Northern portion of dune sheet showing map sites NEWP1 to NEWP62.

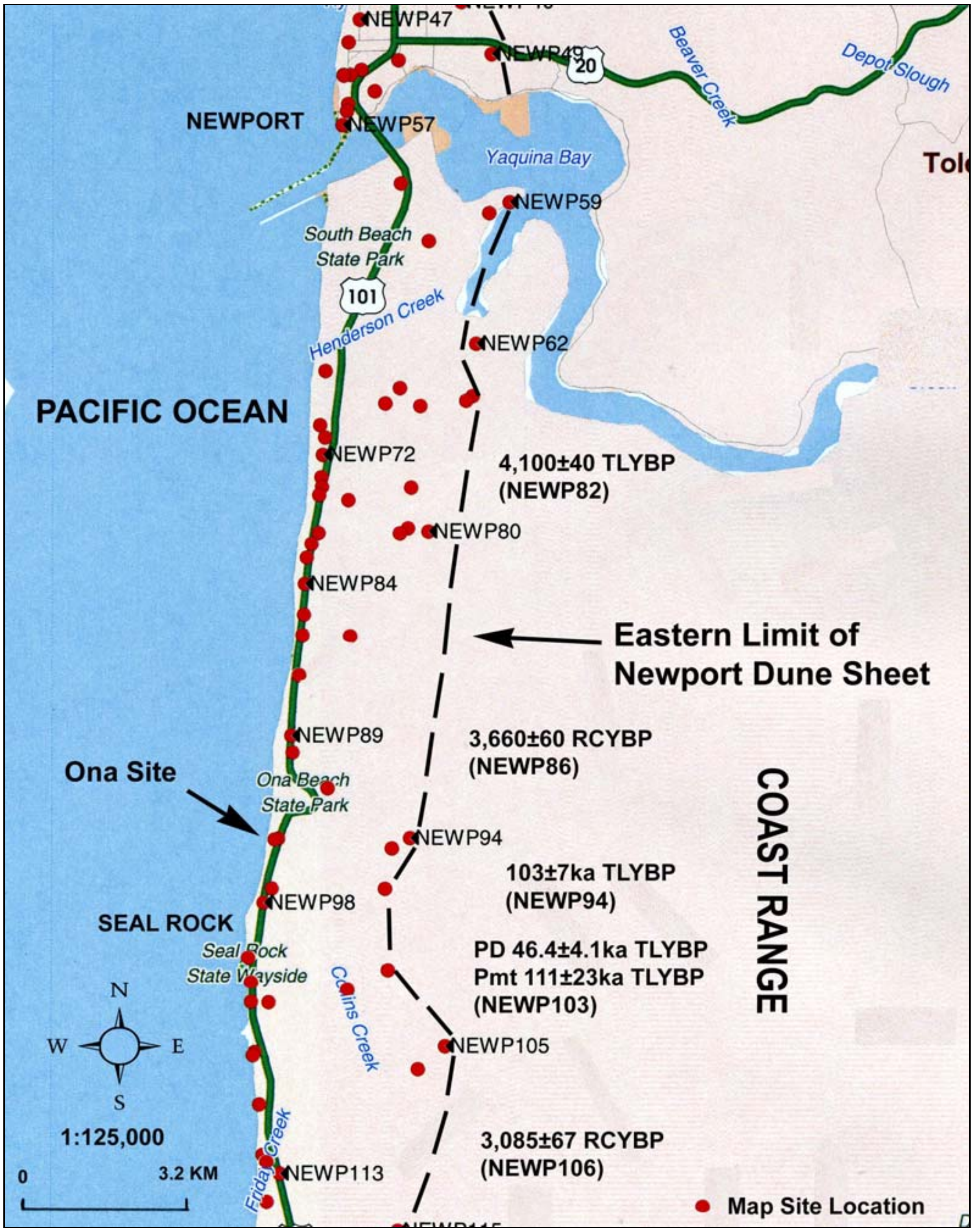


Figure 28: Central portion of dune sheet showing map sites NEWP47 TO NEWP113.

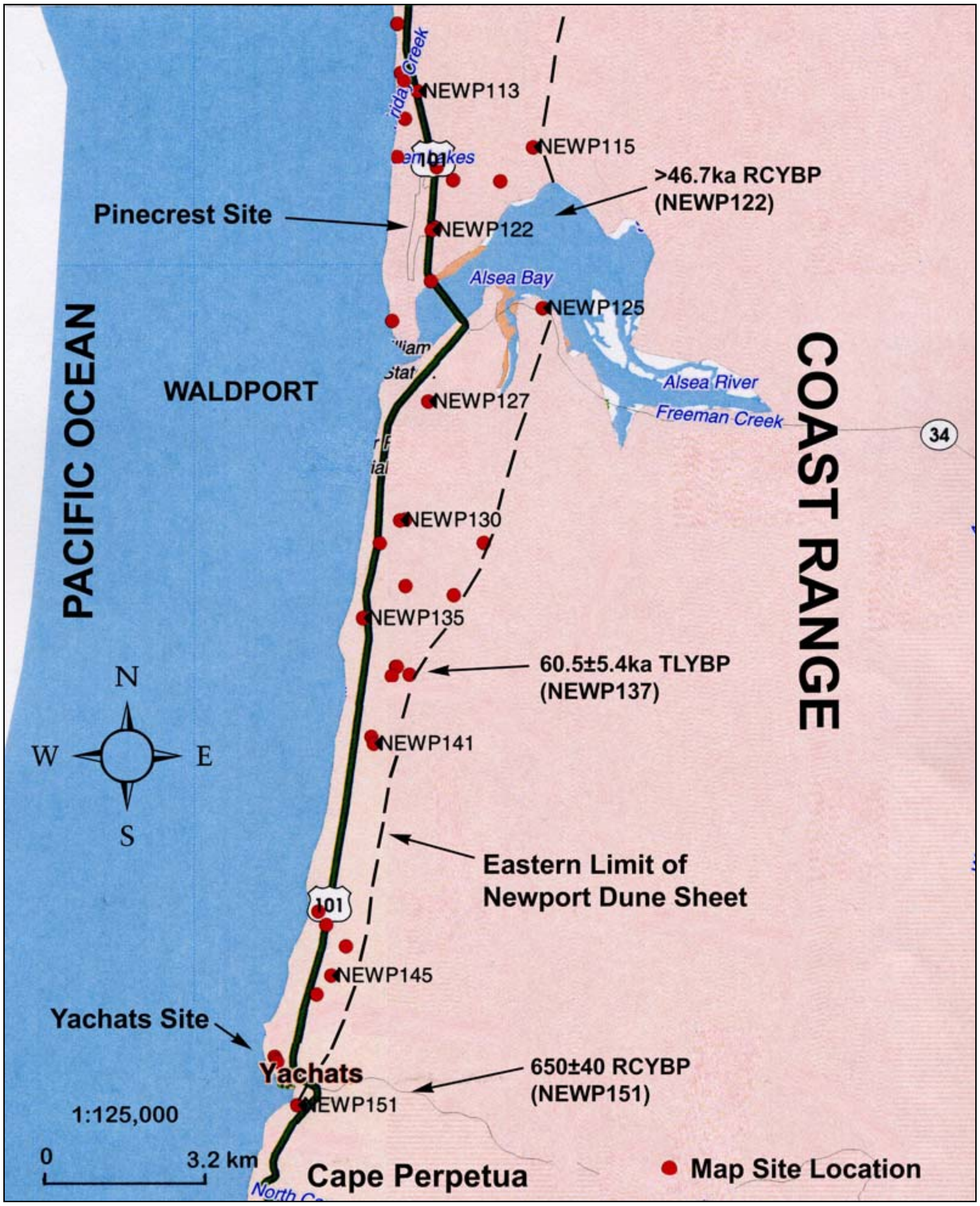


Figure 29: Southern portion of dune sheet showing map sites NEWP113 to NEWP151.

USDA soil taxonomy was used for measuring topsoil profiles in an attempt to match the mapped paleodune deposits with the regional soil survey maps (Shipman, 1997) (Figure 9). However, soil survey profiles only extend a maximum of 5 feet below ground surface (bgs) and focus on soil taxonomy related to agriculture applications. In plan view the taxonomy may be used to discriminate between paleodune and marine terrace deposits, however no such classification is made with depth. Soil color (chroma & hue), soil texture, soil structure, position, and thickness are used to determine the relative age of the paleodune deposit profiles.

Figure 30: Photo of logging road cut outcrop using a tape measure.

Paleodune strata profile logs were created for 151 mapped sites within the Newport Paleodune Sheet (Appendix A). In general, the mapped profiles consisted of one or more type of unit that included Holocene dune deposits, Pleistocene dune deposits, marine terrace deposits, and Tertiary bedrock units. A summary of thicknesses for the total profile, Holocene dune deposits, Pleistocene dune deposits, and underlying units from the mapped sites is shown on Table 6.

	Total Profile	Holocene Dune Deposits	Pleistocene Dune Deposits	Underlying Units	
				Marine Terrace Deposits	Tertiary bedrock
Total Dune Sheet	thickness (cm)	thickness (cm)	thickness (cm)	thickness (cm)	thickness (cm)
AVERAGE	496.1	221.2	305.3	168.2	295.3
MEDIAN	305.0	125.0	265.0	131.0	174.0
MODE	100	400	300	100	25
MAX	3120	1897	1330	660	2039
MIN	25	10	10	5	10
OCCURRENCES (n)	151	38	131	51	44
North Section NEWP1-NEWP57					
AVERAGE	439.0	398.4	267.7	192.8	339.0
MEDIAN	290.0	270.0	220.0	100.0	85.0
MODE	300	400	300	100	25
MAX	3120	1897	708	660	2039
MIN	25	17	50	20	10
OCCURRENCES (n)	57	10	46	15	14
Middle Section NEWP58-NEWP113					
AVERAGE	633.0	154.7	348.9	176.3	328.7
MEDIAN	514.0	100.5	300.0	166.0	254.0
MODE	150	35	150	11	674
MAX	1790	590	1330	396	804
MIN	25	15	30	5	10
OCCURRENCES (n)	56	18	51	27	21
South Section NEWP114-NEWP151					
AVERAGE	380.0	158.4	290.9	102.6	179.4
MEDIAN	312.5	96.0	270.0	101.0	42.0
MODE	150	#N/A	315	150	25
MAX	1157	400	930	150	1000
MIN	35	10	10	40	25
OCCURRENCES (n)	38	10	34	9	9

Table 6: Summary of mapped profile thicknesses of Holocene and Pleistocene dune deposits and underlying units. The number of occurrences (n) indicates how many

of each deposit type was recorded in the profile logs. The data includes outcrop and hand auger profile logs.

The average observed profile thickness for the Newport Dune Sheet is 4.96 meters. The measured thickness of most sites was limited by the exposure in road cuts, slope cuts, and sea cliffs (Figure 30). The average observed Holocene dune deposit thickness is 2.21 meters and the average observed Pleistocene dune deposit thickness is 3.05 meters. The observed marine terrace deposit thickness averages 1.68 meters. The middle section of the Newport Dune Sheet contains the thickest observed profile exposures (6.33 meters). A better measure of dune sheet thickness is taken from the sea cliff exposures. The average dune sheet thickness observed in sea cliff profiles from the northern, central, and southern sections of the field area are 17.5m, 10.0m, and 6.0m, respectively (Table 7). The road cut exposures represent the intermediate and eastern portions of the dune sheet (Figure 31). The average dune sheet thickness for road cut profiles from the northern, central, and southern sections of the field area are 3.0m, 3.0m, and 2.9m, respectively (Table 7). Marine terrace deposits and/or bedrock exposures were generally not observed underlying the paleodune deposits in road cut exposures. Road cut exposures are considered to represent minimum dune sheet thicknesses due to the entire deposit (stratigraphic section) was generally not exposed.

	Exposures	
	Sea Cliff thickness (cm)	Road Cut thickness (cm)
Total Dune Sheet		
AVERAGE	1000.0	296.6
MEDIAN	865.0	270.0
MODE	1370	200
MAX	3120	850
MIN	272	25
OCCURRENCES (n)	45	83
Northern Section NEWP1-NEWP57		
AVERAGE	1745.3	297.8
MEDIAN	1661.0	300.0
MODE	#N/A	300
MAX	3120	700
MIN	275	25
OCCURRENCES (n)	6	40
Central Section NEWP58-NEWP113		
AVERAGE	997.9	303.9
MEDIAN	956.5	235.0
MODE	1370	150
MAX	1790	850
MIN	272	50
OCCURRENCES (n)	28	22
Southern Section NEWP114-NEWP151		
AVERAGE	598.7	286.7
MEDIAN	525.0	265.0
MODE	#N/A	100
MAX	1157	731
MIN	365	35
OCCURRENCES (n)	11	21

Table 7: Summary of measured sea cliff and road cut profile thicknesses. The number of occurrences (n) indicates how many of each exposure type was recorded in the profile logs.

The profile logs used the following soil horizon classification scheme to categorize each paleodune layer (Peterson et al., 2005 and Birkeland, 1984):

- (A-horizon) organic accumulation zone (modern topsoil);
- (Btj) clay accumulation or incipient accumulation zone (paleosol if buried);
- (Bw) iron oxide, Fe+3, accumulation zone (hard pan or iron pan);
- (Bg) gleyed horizon (Figure 32), reduced iron (deflation plain);
- (C or Cox) parent material or oxidized parent material.

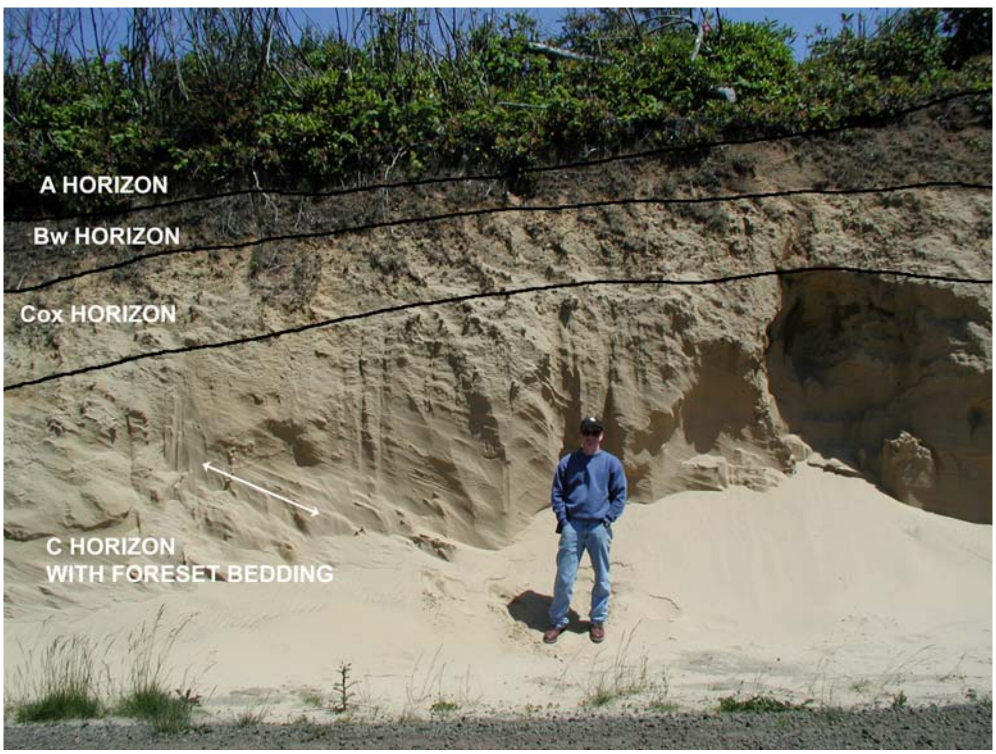


Figure 31: Paleodune profile located 1.5 km east of Seal Rock at approximate elevation of 40 meters above MSL. The road outcrop contained a thin topsoil horizon formed on a Pleistocene dune deposit that was probably stripped off during logging activities. Dune sand contained well-developed foreset bedding dipping 20^{o} to 30^{o} to the south.

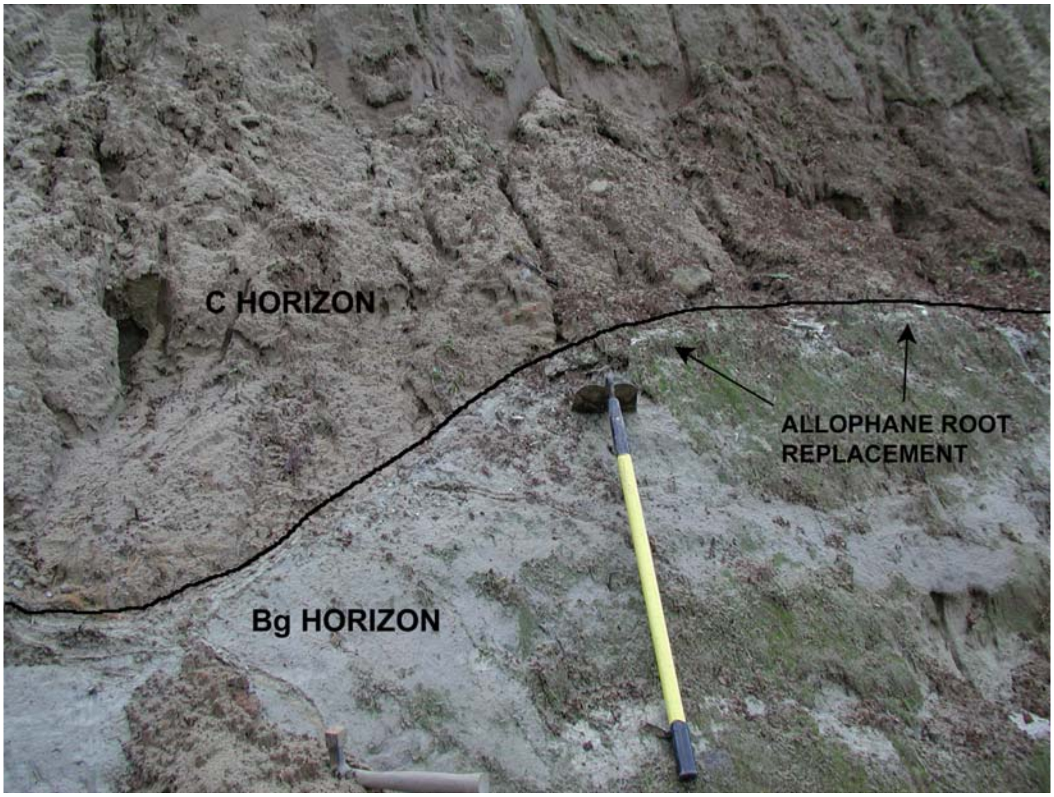


Figure 32: Photo of contact between a deflation plain/paleosol (Bg horizon) and overlying dune sand (C horizon) located at Canary Road, Florence. The thin light colored layer is allophone root replacement.

A summary of mapped paleodune profiles is shown in Table 8. The average total thickness of the paleodune sand facies (PDC and PDCox) was calculated to be 1.35 meters. The middle section of the Newport Dune Sheet contained the greatest number of sand units (83) and the largest average thickness (1.44 meters) of sand units.

	Pleistocene Dune Deposits			
Total Dune Sheet	PDC, PDCox thickness (cm)	PDBw thickness (cm)	PDBtj thickness (cm)	PDBg thickness (cm)
AVERAGE	134.7	49.5	44.7	23.1
MEDIAN	100.0	40.0	36.5	17.0
MODE	100	50	30	10
MAX	1000	200	200	110
MIN	2	2	5	2
OCCURRENCES (n)	199	151	46	113
PERCENTAGE OF TOTAL UNITS	39	30	9	22
North Section NEWP1-NEWP57				
AVERAGE	139.8	55.5	60.8	24.0
MEDIAN	100.0	50.0	50.0	20.0
MODE	100	50	50	10
MAX	350	200	200	80
MIN	10	10	20	5
OCCURRENCES (n)	53	54	23	26
Middle Section NEWP58-NEWP113				
AVERAGE	143.5	52.3	32.6	23.7
MEDIAN	100.0	40.0	30.0	20.0
MODE	60	20	30	20
MAX	1000	200	60	110
MIN	2	5	15	5
OCCURRENCES (n)	83	57	14	58
South Section NEWP114-NEWP151				
AVERAGE	114.3	38.6	22.2	20.8
MEDIAN	80.0	30.0	15.0	15.0
MODE	100	50	15	10
MAX	450	166	50	100
MIN	10	2	5	2
OCCURRENCES (n)	63	40	9	29

Table 8: Summary of Pleistocene dune horizon thicknesses. The number of occurrences (n) indicates how many of each horizon type was recorded in the profile logs.

The most frequently occurring deposit type mapped within the Newport Dune Sheet was the PDC/PDCox unit (39%) followed by the PDBw unit (30%) and the

PDBg unit (22%). The PDBtj unit occurred the least often (9%). The terrace deposits consist of beach sand and gravel layers, fluvial and lacustrine deposits, estuary and bog deposits (peat), and other preexisting soil surfaces. These deposits were differentiated from overlying paleodune sheet deposits on the basis of distinctive texture and structure criteria. Paleodune deposits are recognized in the field on the basis of :

1. tan to red-brown, well-sorted (uniformly graded) fine sand;
2. large-scale foreset beds, cross-bedding, thin horizontal beds;
3. subaerial features that include paleosol interbeds consisting of gray to brown silty sand or sandy silt with carbonized organics, truncated root casts, and peat horizons.

Foreset beds are not abundant in the irregular parabolic dunes located in the foot hills or in the flat-lying dune sand layers interbedded with the deflation plain layers. Foreset bedding is locally developed in the thicker paleodune sequences and are generally preserved near the top of the section. The presence of deflation plain strata indicates removal or truncation of preexisting dune sand morphologic structures. The subaerial features including paleosols and deflation surfaces are common in the temperate coastal dune deposits of the Pacific Northwest (Peterson et al., 2002).

Paleodune deposits were locally observed in contact with underlying Tertiary bedrock units consisting of marine sedimentary rocks and volcanic and volcaniclastic rocks. Preexisting topography covered by paleodune deposits include marine wave-cut terraces (Ona Beach-Figure 33), sea-stacks (Seal Rocks), incised stream valleys (Beverly Beach), and ancient landslide debris (Johnson Creek Landslide).

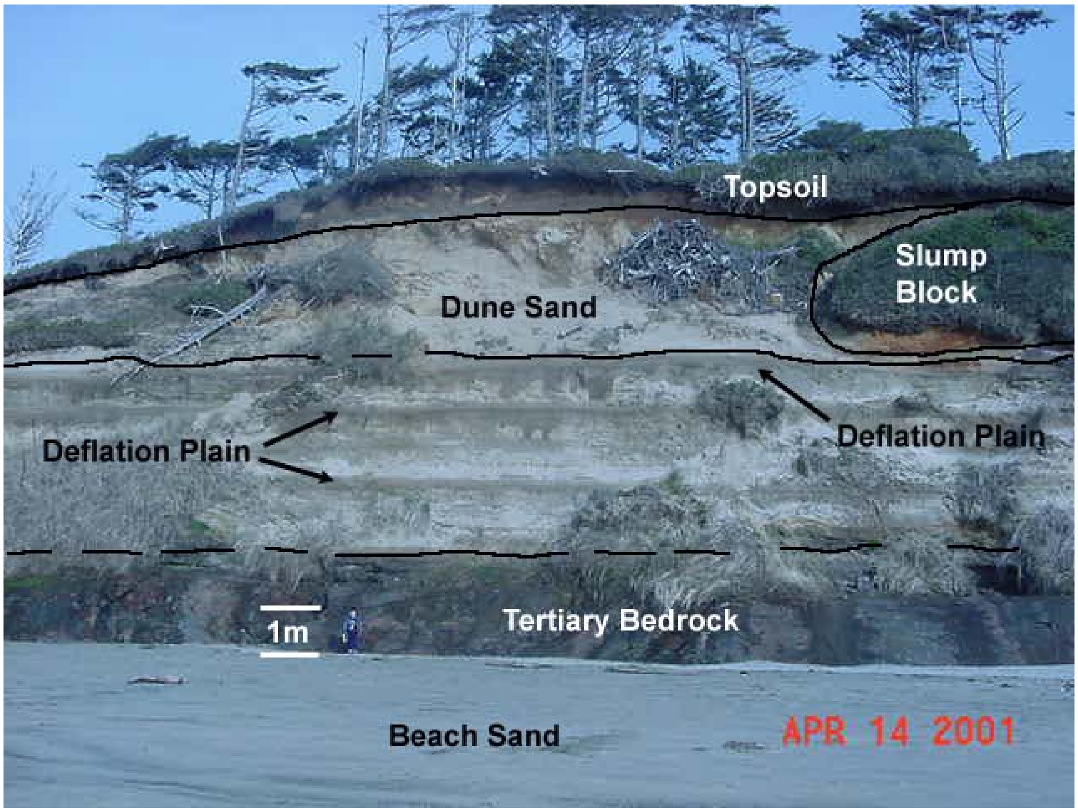


Figure 33: Ona Beach sea cliff exposure showing interbedded dune sand layers with deflation plain layers (PDBtj and PDBg) overlying Tertiary Bedrock and covered by a well-established modern topsoil. Dune sand unit at top of section shows dune morphology with concave surface.

Paleodune deposits observed during this study are described in terms of two general facies consisting of clean sand dune strata (dune facies) and paleosol or deflation plain strata (paleosol facies). The term facies is used in this study to describe a discrete set of strata that depicts the lateral and vertical change in lithology as a result of contemporaneous soil formation, sand deposition and/or erosion due to migration of dune deposits, fluctuating groundwater conditions, and change in vegetative cover.

Based on field observations, the dune facies consists of a uniform, subangular to subround fine sand that varies in color, bedding structure, thickness, relative density, and incipient cementation. Color of the deposits varies from tan, brown, green-gray, orange-brown, and red-brown. The orange and red color is an indicator of the presence of iron oxide precipitates. The precipitates occur as hard concretions, layers (commonly called hard pans, ortsteins, or iron pans), bands or zones, within the paleodune sand. Observed paleodune bedding structures consist of a collection of horizontal to dipping planar laminations, shallow to steeply dipping foresets, truncated surfaces, and massive bedding (Figure 34).

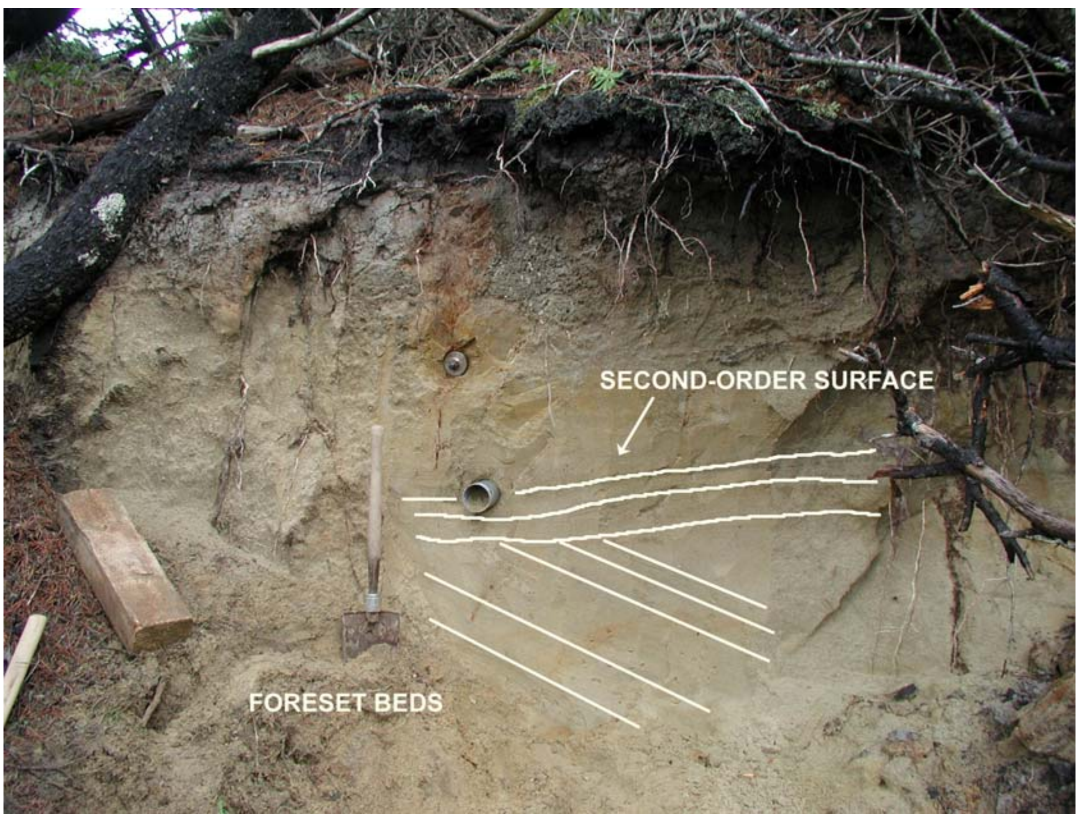


Figure 34: Photo of paleodune sand structure with foreset beds truncated by overlying horizontal sand bedding.

The paleodune deposits observed on the Oregon coastal plain exhibit classic dune stratification and contain first-order and second-order bounding surfaces (Boggs, 1987). First-order surfaces consist of flat-lying bedding that truncate underlying paleodune strata. These surfaces were observed as sharp contacts (generally <5cm wide) between the different dune strata and/or between dune strata and paleosol strata.

Second-order surfaces consist of an angular contact between first-order surfaces and underlying paleodune strata. These surfaces were often observed as a sharp truncation of foreset bedding by overlying strata (Figure 34). The dune surfaces are readily discriminated from low angle, continuous beach laminae.

Soil Horizon Dating

Selected samples were collected from representative paleodune horizons for thermoluminescence (TL) and radiocarbon (C14) dating (Peterson et al., 2005). The results of sample dating is shown on Tables 9 and 10 and also located on Figures 27, 28, and 29.

Dune Sheet/ Sample Site	Exposure Type	Dune Sheet Strata/Setting	Depth (m)	Age TLYBP (ka)
NEWP5	Road Cut	E. Pleist. Dune	3.5	>37.9±3.9
NEWP22	Road Cut	E. Pleist. Dune	4.3	>77.4±5.4
NEWP44	Road Cut	E. Pleist. Dune	3.0	50.5±4.7
NEWP82	Sea Cliff	Base Holo. Dune	2.5	4.1±0.4
NEWP93	Sea Cliff	Base Pleist. Dune	12.7	62.6±4.1
NEWP94	Road Cut	E. Pleist. Dune	2.5	103±7
NEWP103	Sea Cliff	Top Pleist. Dune	2.5	46.4±4.1
NEWP103	Sea Cliff	Beach Backshore	7.5	111±23
NEWP137	Road Cut	E. Pleist. Dune	4.3	60.5±5.4

Table 9: Results of thermoluminescence dating for the Newport Dune Sheet (Peterson et al., 2005).

Sample Site	Exposure Type	Strata/Setting	Depth (m)	Material Rad/AMS	Conventional C14 ±1s. YBP
NEWP35	NA	Dune Ramp Top	NA	Charcoal	4100±60
NEWP35	NA	Dune Ramp	NA	Charcoal	5030±60
NEWP35	NA	Dune Ramp	NA	Charcoal	5330±110
NEWP86	Sea Cliff	Dune Ramp Base	0.5	Wood (-25.3)	3420±60
NEWP106	Sea Cliff	Dune Ramp Base	1.5	Charred AMS (-24.5)	2930±40
NEWP122	Road Cut	Pleist. Dune	5.8	Wood	>46,690
NEWP151	Sea Cliff	Holo. Dune	0.8	Charred AMS (-28.4)	650±40

Table 10: Results of radiocarbon dating for the Newport Dune Sheet (Peterson et al., 2005).

Geotechnical Observations

Slope stability is a major consideration in our assessment of geotechnical issues and is a major focus of this study. Examples of various observed slope failures are shown on Figures 35, 36, 37, and 38.

Figure 35: Wedge block slide on sea cliff located north of Seal Rock.

Figure 36: Sea cliff failure in Yachats located a few meters from a city street. Block failure occurred during a winter storm event in 2004. The failure may have been the result of ocean wave undercutting the sea cliff.

Groundwater seepage from paleodune cut slopes and sea cliffs was a common occurrence along the central Oregon coastal plain. Slow groundwater seepage was often observed near the base of cut slopes and above the contact between a dune sand layer and an underlying paleosol layer. A majority of the slope failures contained zones of seepage (Figures 37 and 38) .

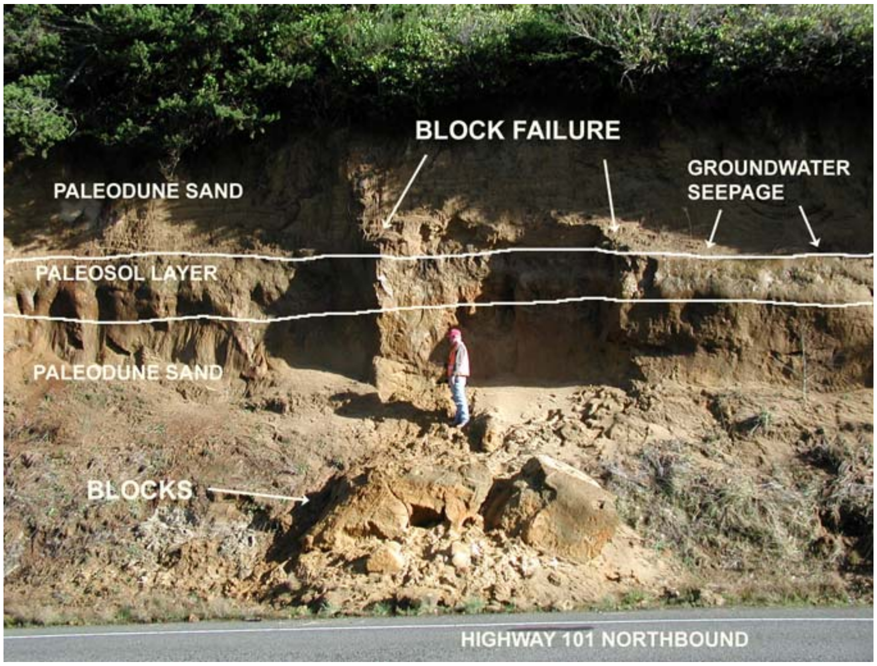


Figure 37: Small block failure (2m high x 3m wide x 2m deep) on road cut at the Pinecrest site during winter of 2004. Groundwater seepage observed along contact between paleosol layer and upper paleodune sand.

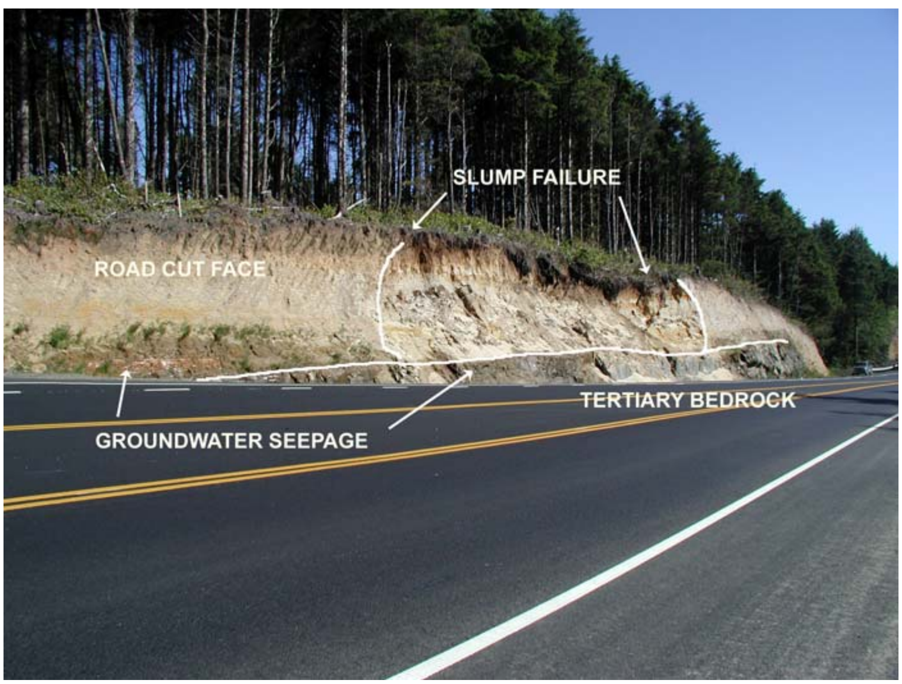


Figure 38: A roadcut failure along Highway 101 just south of the Newport Airport. Groundwater seepage at contact between paleodune deposits and underlying bedrock.

The relative strength of selected paleodune horizons was performed to try to assess the relationship between relative strengths of the soils. Strength surveys were performed during mapping using a pocket penetrometer. The results of the penetrometer data is shown in Table 11. The penetrometer was designed to determine the unconfined compressive strength of soft to medium stiff cohesive soils. The pocket penetrometer is not typically used in sandy soils, however, in this case the pocket penetrometer was used in this study as a standard to compare relative strengths of selected units. Thus, the actual measurement may not represent inherent material properties. The results can be used for purposes of general comparison.

The penetrometer values ranged from 0.5 to greater than 4.5 kg/m^2. The penetrometer values for the Pleistocene dune deposits averaged 3.4 kg/m^2 (C and Cox horizons), 3.7 kg/m^2 (Bw horizons), 4.0 kg/m^2 (Btj horizons), and 2.5 kg/m^2 (Bg horizons). The holocene dune sand deposits averaged 1.3 kg/m^2.

Total Paleodune Sheet	Holocene Dune Deposits	Pleistocene Paleodune Deposits			
	HDC, HDCox	PDC, PDCox	PDBw	PDBtj	PDBg
	Pocket Pen. (kg/m^2)	Pocket Pen. (kg/m^2)	Pocket Pen. (kg/m^2)	Pocket Pen. (kg/m^2)	Pocket Pen. (kg/m^2)
AVERAGE	1.3	3.4	3.7	4.0	2.5
MEDIAN	1.0	3.5	4.0	4.0	2.5
MODE	0.5	3	4	4.5	2.5
MAX	2.75	4.5	4.5	4.5	4
MIN	0.5	1.75	2	3	0.5
OCCURRENCES (n)	30	66	74	28	29
Section NEWP1-NEWP57					
AVERAGE	1.6	3.8	3.8	4.0	3.5
MEDIAN	1.5	3.9	4.0	4.3	3.5
MODE	1.5	4.5	3.5	4.5	#N/A
MAX	2.75	4.5	4.5	4.5	4
MIN	0.5	2.75	3	3	3
OCCURRENCES (n)	12	8	13	8	2
Section NEWP57-NEWP113					
AVERAGE	1.3	3.4	3.8	4.0	2.5
MEDIAN	1.0	3.5	4.0	4.0	2.5
MODE	0.5	3	4	4	3.5
MAX	2.5	4.5	4.5	4.5	4
MIN	0.5	1.75	2	3.5	1
OCCURRENCES (n)	13	43	44	11	19
Section NEWP114-NEWP151					
AVERAGE	0.6	3.2	3.2	4.0	2.3
MEDIAN	0.5	3.3	3.3	4.0	2.5
MODE	0.5	3.25	4	4.5	2.5
MAX	1	4.5	4	4.5	4
MIN	0.5	2	2	3	0.5
OCCURRENCES (n)	5	15	17	9	8

Table 11: Summary of pocket penetrometer data. . The number of occurrences (n) indicates how many pocket penetrometer readings of each horizon type was recorded in the profile logs.

Geotechnical Study Sites

Geotechnical study sites were chosen based on a exposure of representative paleodune layers, location as a road cut or sea cliff, and presence of a potential slope stability problem. Three geotechnical field study sites were specifically selected for analysis based on the following criteria: 1) a good exposure representing typical paleodune strata; and 2) a location that represents typical development concerns such as road construction, residential development, and sea cliff stability. The three study sites chosen include a small subdivision at Pinecrest, a high sea cliff site at Ona Beach, and a tall road cut that has partially failed on Canary Road located south of Florence (note that the Canary Road site is outside of the study area).

Pinecrest Site

The Pinecrest site (NEWP122) is a partially developed subdivision located along the crest of a Pleistocene dune ridge (Figure 39). The site has been mostly cleared of trees, vegetation, and some topsoil for development of 8 to 10 single family residential lots (a very typical coastal development). A paved street runs north from an older subdivision along the ridge crest and ends at the north end of the dune ridge. The slopes along the ridge are moderate to steep (10 to 30 degrees). The east side of the site contains a steep slope down to a small drainage that flows into a pond located on the north end of the site. The west side of the site slopes down to a 10 to 12 meter high road cut along the northbound lane of Highway 101. A site profile transect was constructed trending east to west from the subdivision street to the highway (Figure 39). The hand auger borings, 2 GPR survey lines, and a road cut slope log were completed along the transect to define subsurface stratigraphy.

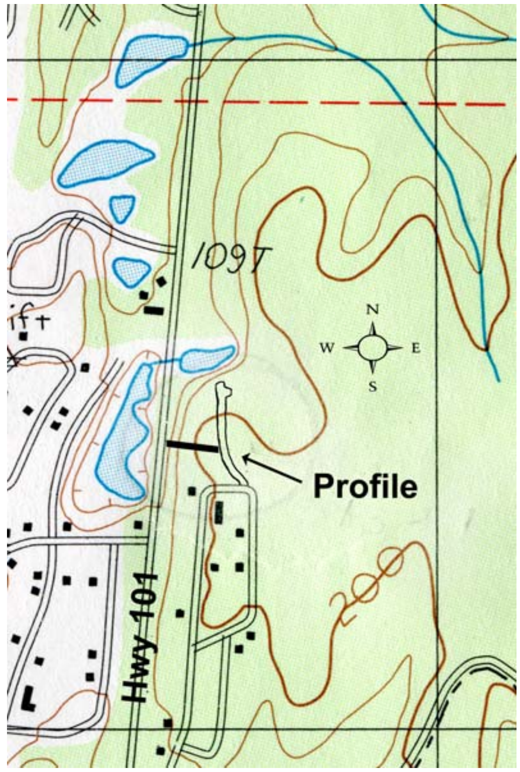


Figure 39: Site map of Pinecrest showing location of the measured slope profile transect (modified from USGS, 1984 Waldport Quad.).

Two hand auger borings (Pine-1 and Pine-2) were completed near the top of the dune ridge and penetrated down to 6 meters below ground surface (bgs) where the bore hole collapsed due to groundwater infiltration. The groundwater level was measured at 5.5 m bgs. The boring logs are located in Appendix B. Two pressuremeter (PMT) tests were performed in boring Pine-1 at 2.4 m and boring Pine-2 at 1.7 m bgs. The results of the PMT tests are discussed later in the Results section. The road cut slope ranges from 30^o (areas of past slope failure) to near vertical. Four distinct paleodune layers are exposed in the cut (Figure 40). A log of the road cut profile that includes the soil horizon terminology (mapping data) and the geotechnical soil descriptions is described in Table 12.

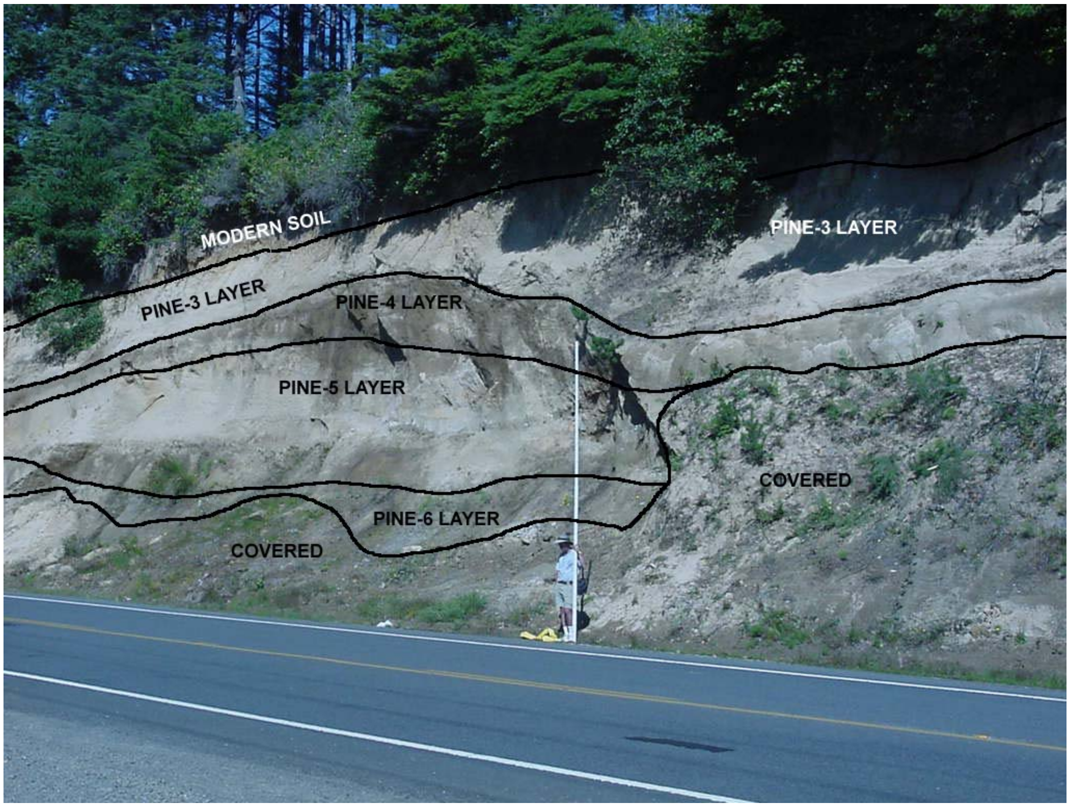


Figure 40: Pinecrest site showing road cut along Highway 101 and interpreted paleodune stratigraphy with geotechnical sample layer names. Pine-3 layer is a dune sand (PDC) containing foreset bedding, Pine-4 is a truncated paleosol (PDBtj horizon), Pine-5 is a dune sand(PDCox and PDC), and Pine-6 is a paleosol/deflation plain (PDBg horizon) that contains a discontinuous peat layer. Upper paleodune strata is dipping out of the road cut face approximately 20 to 30 degrees.

Soil samples were collected from selected layers (Pine-2 through Pine-6) to characterize the geotechnical soil parameters that comprise the paleodune deposits at Pinecrest. Geotechnical test results are discussed later in the Results section.

DEPTH (CM)	UNIT NAME (Geotech Layer)	DESCRIPTION (Soil Horizon Description)
0-15	PDA	(Modern topsoil with organic horizon)
15-53	PDBtj	Brown, moist, fine silty SAND/sandy SILT with trace fine organics and roots; blocky structure (Modern topsoil B horizon with trace clay accumulation)
53-97	PDBw	Brown to red-brown, moist, fine SAND with trace to some silt; blocky structure. Uniformly graded. (Modern topsoil B horizon with Fe^{3+} accumulation)
97-247	PDCox (Pine-3)	Red-brown to tan, moist, fine SAND; uniformly graded, weak to moderately cemented, contains shallow dipping (SW) foreset beds. (Paleodune sand with cross bedding)
247-269	PDBtj (Pine-4)	Brown, moist to wet, fine sandy SILT/silty SAND; low plasticity to non-plastic, weak to moderately cemented, blocky structure, contains trace charcoal and gibbsite concretions. (Paleosol, truncated B horizon)
269-279	PDBw (Pine-4)	Brown to red-brown, moist, fine SAND with trace to some silt; blocky structure, uniformly graded. (Paleosol B horizon with Fe^{3+} accumulation)
279-579	PDCox and PDC (Pine-5)	Red-brown to tan, moist to wet, fine SAND; uniformly graded, weakly cemented to uncemented, some cross bedding. (Paleodune sand with cross bedding)
579-601	PDP (Pine-6)	Black to gray-brown, wet, sandy SILT with trace clay and some fine organics and wood fragments; moderately plastic, contains some thin sand lenses. (Paleosol, truncated peat horizon)
601-701	PDBg (Pine-6)	Light gray, wet, sandy SILT with trace clay and fine organics; moderately plastic, contains some thin sand lenses. (Paleosol, Bg horizon)
701-731 (End of profile)	PDCox	Red-brown, wet, fine SAND; uniformly graded, weak to moderately cemented. (Paleodune sand)

Table 12: Profile log of the Pinecrest road cut with geotechnical soil description and interpreted soil horizon.

Ground penetrating radar (GPR) was used at the Pinecrest site (Figure 41) to demonstrate the complex geomorphic features of the paleodune surfaces. The GPR profile (Figure 41) shows strong reflection layers that were interpreted to be paleosols. Outcrop observations indicate that the paleodune deposits contain multiple buried surfaces that are not laterally continuous or horizontal for great distances (Figure 42). Generally, borehole data does not provide sufficient information to trace thin (<10cm thick) subsurface features with a high degree of accuracy unless the borehole and sample interval spacing is close. Subsurface information was supplemented using GPR to "extend" borehole data and outcrop observations to trace out common paleosol horizons and construct an interpreted subsurface profile (Figure 43). The low permeability of the silt-rich paleosols causes these layers to redirect groundwater flow, as shown by seepage at dune sand/paleosol contacts exposed in cuts.

Figure 41: GPR profile line (facing east) at Pinecrest site using a 100 MHz antenna.

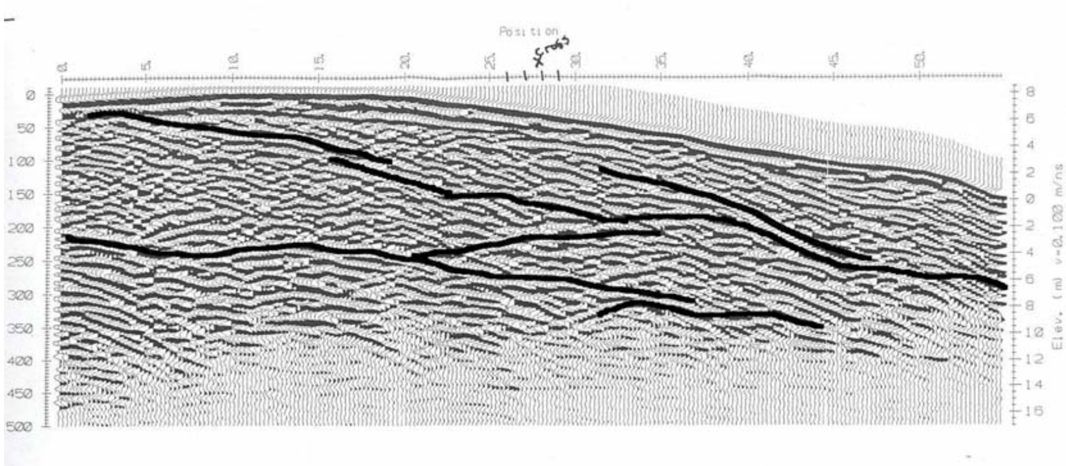


Figure 42: Interpreted GPR profile (east to west) of Pinecrest site showing interpreted strong subsurface reflections (darkened lines are interpreted as paleosols). Exaggerated vertical scale.

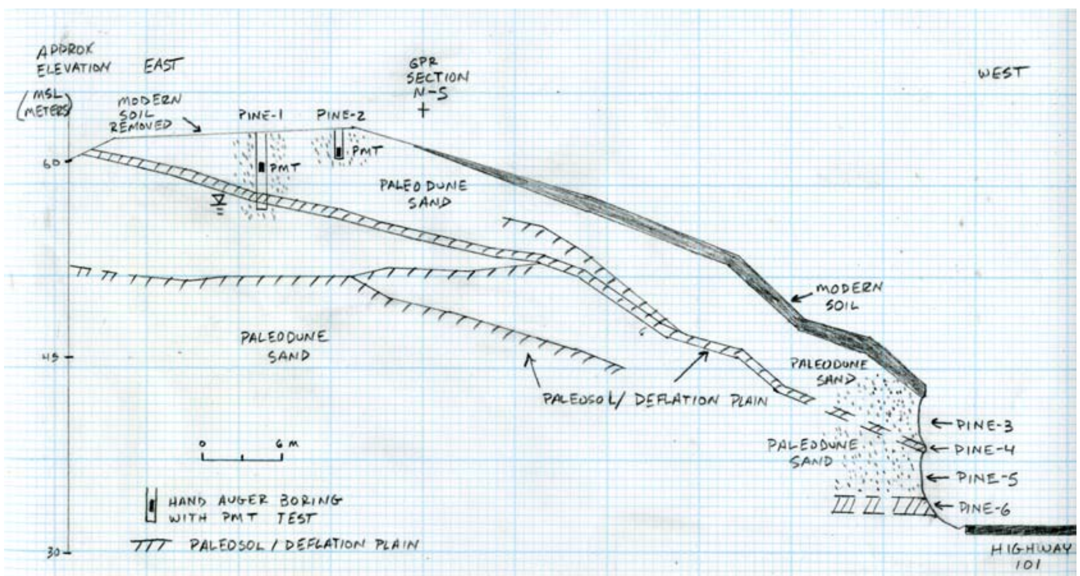


Figure 43: Compiled east to west subsurface transect profile of the Pinecrest site using hand auger boring data, GPR data, and road outcrop observations.

Ona Beach Site

The Ona Beach site (NEWP93) is a tall (13.9 meter) sea cliff located 2 km north of Seal Rock (Figure 44). The site represents a typical sea cliff section that contains a thick (12.9 m) paleodune section, overlying a thin (0.9 m) marine terrace deposit, that overlies Tertiary sandstone bedrock (wave-cut platform). The top of the sea cliff contains single family residences.

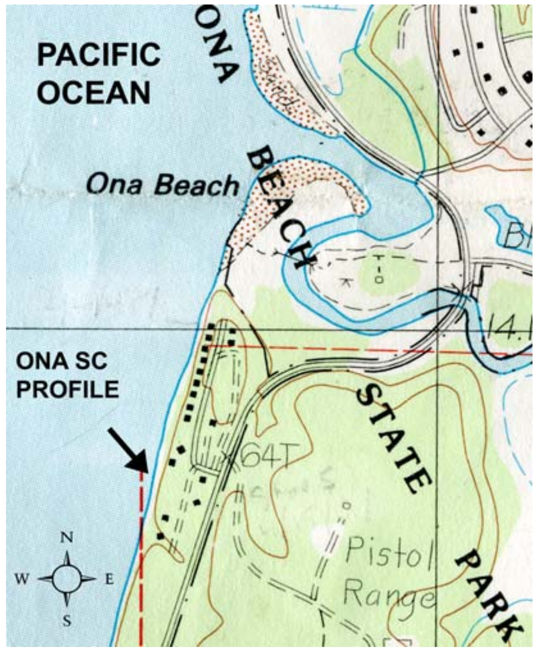


Figure 44: Site map of Ona Beach showing location of sea cliff profile.

The paleodune strata is traceable along the sea cliff for approximately 500 meters (Figure 66-located in Discussion Section). In general, the paleodune strata consists of weak to moderately cemented dune sand layers with interbedded thin, gray, sandy silt deflation layers (Figure 45). The deflation layers typically form ridges more resistant to erosion than the adjacent dune sand layers. The uppermost sand layers and Bw paleosols form concave and convex strata. The lowermost strata, including Bg horizons, are flat lying and semi-continuous in the sea cliff exposure.

Slow groundwater seepage was observed along the contacts between the dune sand layers and the underlying deflation layers. Small slump blocks (< 10 m^3) are common along the base of the sea cliff and often form a vegetated talus slope. Observations made during repeat visits to the site indicate that the talus material is removed from the beach during winter storm events.

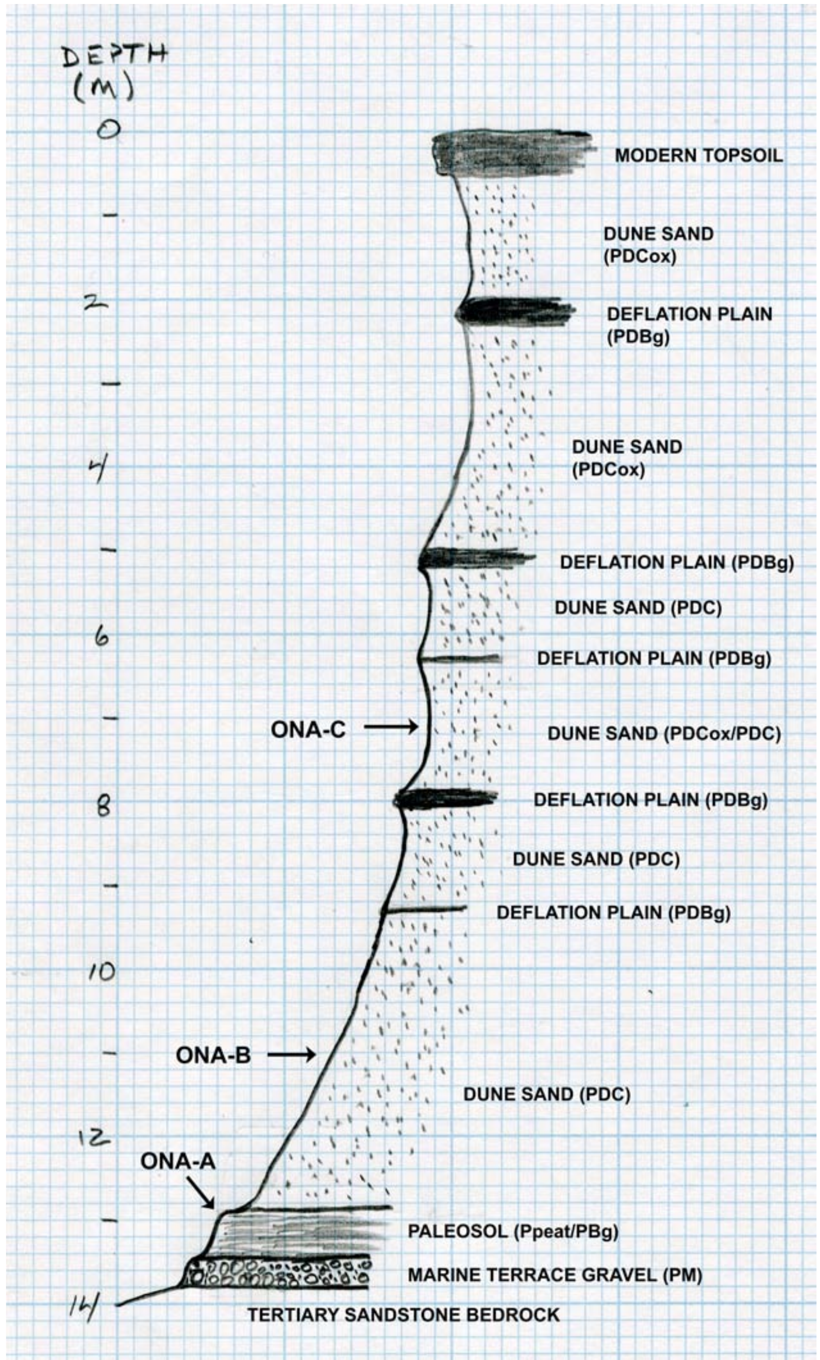


Figure 45: Stratigraphic profile of Ona sea cliff site (NEWP93).

Soil samples were collected from selected layers (Ona-A, Ona-B, and Ona-C) to characterize the geotechnical soil parameters that comprise the paleodune deposits at Ona Beach. Geotechnical test results are discussed later in the Results section.

Canary Road Cut Site

The Canary Road Site is located in the Florence Dune Sheet approximately 8 km south of Florence, Oregon. This site was selected to study the geotechnical soil properties of a road cut failure in paleodune deposits (Figure 46). Further, is was included to form a potential basis for comparison between the Newport and Florence Dune Sheets. Based on conversations with local residents, the county road was widened during the Summer of 1999 and the slope was constructed at approximately a 57 degree (0.5 horizontal to 1 vertical) angle. The slope failure occurred during the Winter of 1999/2000. The failure surface angle measurements ranged from 32 to 36 degrees (Figure 47). Groundwater seepage was observed near mid-slope above a paleosol layer where a majority of the failure had initiated.

Figure 46: Large road cut failure along Canary Road south of Florence. Slope was cut at 57^o to widen the road shoulders.

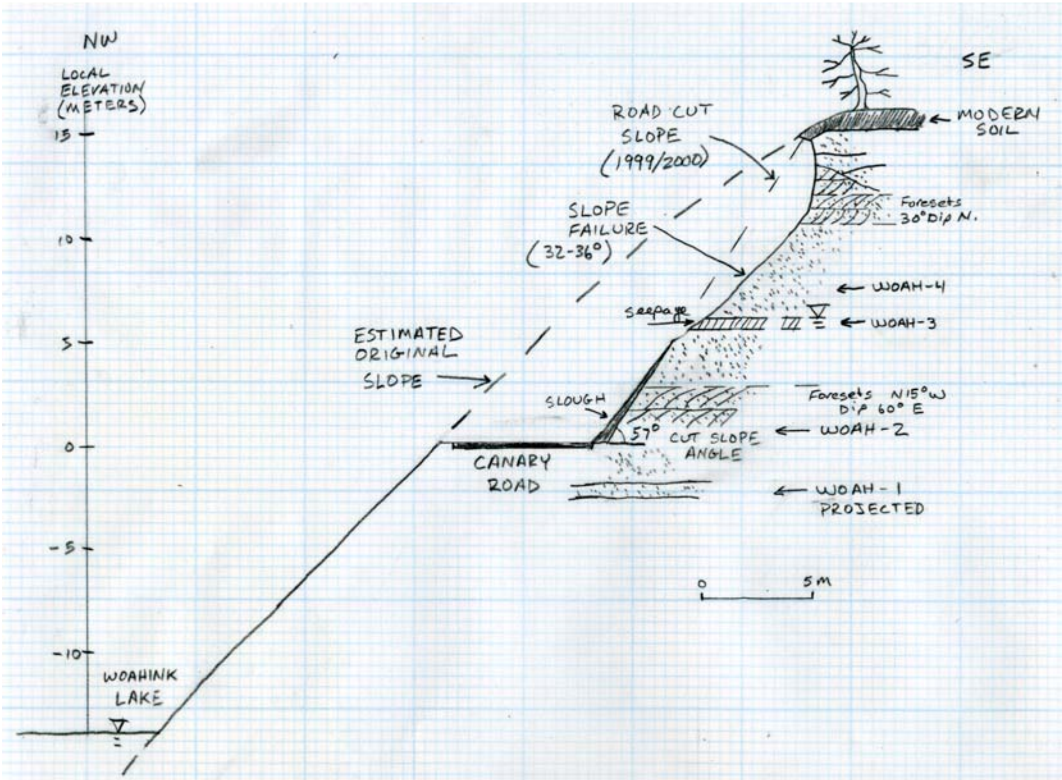


Figure 47: Interpreted dune profile and measured section showing slope originally extended down to interdunal stream cut (Woahink Lake). Four paleodune soils were sampled for geotechnical testing as shown.

Geotechnical Testing

Geotechnical testing was conducted on representative paleodune layers at the three selected sites (Pinecrest, Ona Beach, and Canary Road). Geotechnical sample testing and in situ field testing was conducted in a cooperative effort with Renee Summers and Dr. Trevor Smith (Portland State University Civil and Environmental Engineering Department) and GeoDesign, Inc. (a local geotechnical consultant). Ms. Summers' work reported in this thesis consisted of direct shear testing and constant head permeability testing of samples. GeoDesign provided the use of their laboratory and specialized testing apparatus.

Sample Collection

Disturbed and relatively undisturbed samples were collected to perform soil classification and laboratory testing. All samples were sealed in plastic bags or metal tubes to prevent moisture loss and damage during transport. Undisturbed samples of paleodune deposits are difficult to collect due to their brittle nature. Slight disturbance of the sample during removal from the outcrop or borehole can destroy inherent cementation or in-place density. Disturbed samples were recognized by the formation of cracks in the sample or expansion (bulging) of the sample during collection. Disturbance was also recognized by the presence of loose material that disaggregated during extraction, transport, or storage.

Collection of shear strength and permeability samples was completed using hand methods. Hand driving Shelby tubes or brass ring samples (ASTM) was the fastest method of sample recovery, but it resulted in a high occurrence of disturbed samples. Hand-carved block and tube samples resulted in a lower frequency of disturbed samples. Transportation and storage of block samples can become a logistical problem due to the sample size required for triaxial strength testing. Block samples require more laboratory sample preparation time and are more prone to moisture loss. All samples are likely to have a reduced stress states relative to the in situ field conditions due to removal of confining pressures that existed in the outcrops.

Laboratory Testing

The apparent weakly cemented samples were difficult to prepare for testing. Permeability and triaxial compression samples require careful preparation for testing to ensure accurate density and strength results. Several samples were disturbed during collection, transportation, and sample preparation. Disturbed samples were recognized by loose material, cracks or breaks in the sample, and shrinkage due to dehydration. Long-term storage of sand samples in Shelby tubes can result in “sand lock” of the material in the tube due to friction during extrusion. Samples with the appearance of disturbance were not tested or test results were noted as a “disturbed sample.” Damage to samples resulted in incomplete data for some of the sample locations.

Geotechnical laboratory testing of paleodune strata was conducted to document material properties. Laboratory tests include moisture content, density, plasticity index, grain size distribution, specific gravity, void ratio, porosity, degree of saturation, coefficient of permeability, and shear strength. Test results are summarized for each geotechnical site and are located in Appendix D. Published values of typical test results for uniform sand are shown in Table 13.

	Loose, uniform sand	**Dense, uniform sand**
Percent Moisture	32.0	19.0
Dry density (g/cu cm)	1.43	1.75
Dry density (pcf)	89.3	109.2
Wet density (g/cu cm)	1.89	2.09
Wet density (pcf)	118.0	130.5
Void ratio (*e*)	0.85	0.51
Porosity (n)	0.46	0.34

Table 13: Typical geotechnical parameters of loose and dense sand, modified from Terzaghi and Peck (1967).

Grain Size Analysis

The paleodune strata were separated into dune facies or paleosol facies depending on the percent passing #200 (0.075mm) sieve. A summary of the paleodune deposits separated by dune facies and paleosol facies is located in Table 14.

Paleodune Sand Layers - DUNE FACIES		
Sample Site	Field Description	Percent passing #200 (0.075mm)
Woah-2	Tan, fine sand (PDC horizon)	0.1
Woah-4	Red-brown fine sand (PDC horizon)	0.2
Ona-1A&1B	Tan to red-brown fine sand (PDCox horizon)	0.3
Ona-B	Tan, fine sand (PDC horizon)	0.1
Ona-C	Tan, fine sand (PDC horizon)	0.4
Pine-2	Red-brown fine sand (PDCox horizon)	3.1
Pine-3	Tan, fine sand (PDC horizon)	0.7
Pine-5	Light brown fine sand (PDC horizon)	0.5
	AVERAGE	0.68

Paleosol/deflation Plain Layers - PALEOSOL FACIES		
Sample Site	Field Description	Percent passing #200 (0.075mm)
Woah-1	Gray, silty fine sand (PDBg horizon)	43
Woah-3	Gray, silty fine sand (PDBg horizon)	43.4
Pine-4	Orange-brown, silty fine sand (PDBtj horizon)	49
Pine-6	Light gray, sandy silt (PDBg horizon)	52.8
	AVERAGE	47.1

Table 14: A summary of the percent fines (material finer than 0.075mm) of geotechnical samples.

Grain size analysis was conducted on permeability samples of representative strata from each geotechnical site. The grain size plots (Figure 48 and Figure 49) show a delineation between the paleodune sand strata and the paleosol/deflation plain strata.

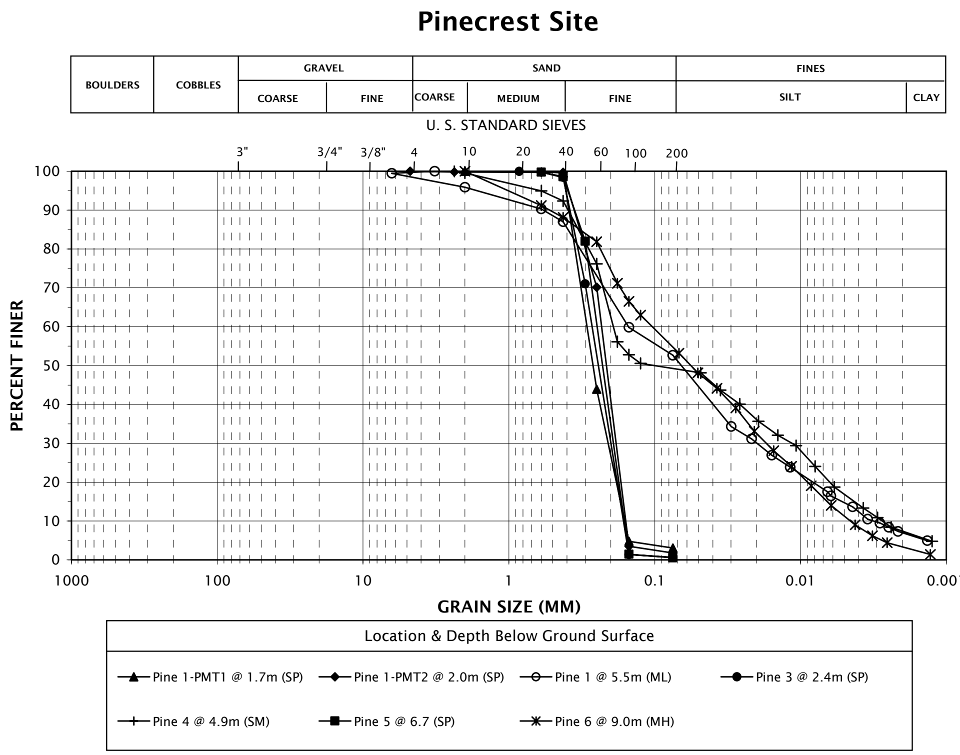


Figure 48: Grain size distribution from Pinecrest site showing difference in grain size between dune sand facies (Pine-1, Pine-3, and Pine-5) and the paleosol/deflation plain facies (Pine-1 @ 5.5m, Pine-4, and Pine-6).

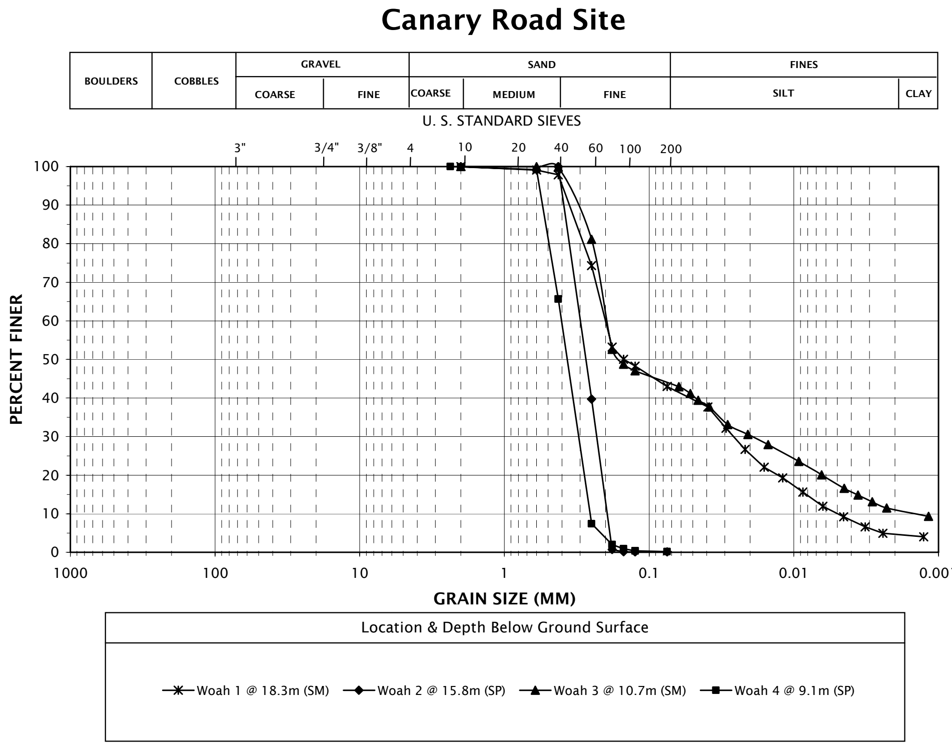


Figure 49: Grain size distribution from Canary Road site showing difference in grain size between dune sand facies (Woah-2 and Woah-4) and the paleosol/deflation plain facies (Woah-1 and Woah-3).

The dune facies are shown to consist of fine, uniform (well-sorted) sand. The sand contains a very low percentage (<5%) of the total material passing the #200 sieve (0.075mm) as based on a washed analysis. The average fines content (passing 0.075mm sieve) of the dune facies tested in this study is 0.68 percent.

The moderate to strongly cemented clasts that are present in the paleodune sand strata observed in the field often misrepresent the actual gradation. Several sand samples that contained abundant iron-oxide cement, noted by strong red-brown soil color, did not break down with firm finger pressure during sample washing. After oven drying the large clasts typically separated into individual fine sand particles during sieving. The clasts, however, may determine the overall geotechnical behavior of the deposit.

The paleosol/deflation plain stratum are shown to consist of silty fine sand to fine sandy silt. The paleosol strata contained more than 40 percent of the total material passing the #200 sieve (0.075) as based on a washed analysis. The average fines content of the paleosol/deflation plain strata tested in this study is 47.1 percent. The paleosol strata located at the Pinecrest site contained a low percentage (<15%) of medium to coarse sand-sized particles. Close examination of the particles revealed that the coarse material generally consisted of aggradations of strongly cemented fine dune sand grains in an iron-oxide cement and clay matrix and that the particle size distribution is dependent on the amount of mechanical work put into sample preparation (See Mineralogy later in Results). Standard methods were used for the purpose of this study, however, other methods may need to be developed to adequately define the geotechnical behavior of the deposits.

Densities

The measured dry densities of the paleodune deposits are highly variable. The paleodune sand densities ranged from 1.47 g/cu. cm to 1.74 g/cu. cm with an average density of 1.60 g/cu. cm and a standard deviation of 0.11 g/cu. cm. The paleosol densities ranged from 1.08 g/cu. cm to 1.82 g/cu. cm with an average density of 1.47 g/cu. cm and a standard deviation of 0.36 g/cu. cm. Typical values (Table 15) of dry densities of uniform fine sand ranged from 1.43 g/cu. cm (loose) to 1.75 g/cu. cm (dense).

Paleodune Sand Layers - DUNE FACIES		
Sample Site	Field Description	Dry density (g/cu. cm)
Woah-2	Tan, fine sand (PDC horizon)	1.74
Woah-4	Red-brown fine sand (PDC horizon)	1.74
Ona-1A&1B	Tan to red-brown fine sand (PDCox horizon)	1.47
Ona-B	Tan, fine sand (PDC horizon)	1.60
Ona-C	Tan, fine sand (PDC horizon)	1.63
Pine-2	Red-brown fine sand (PDCox horizon)	1.49
Pine-3	Tan, fine sand (PDC horizon)	1.47
Pine-5	Light brown fine sand (PDC horizon)	1.62
	AVERAGE	1.60

Paleosol/deflation Plain Layers - PALEOSOL FACIES		
Sample Site	Field Description	Dry density (g/cu. cm)
Woah-1	Gray, silty fine sand (PDBg horizon)	1.73
Woah-3	Gray, silty fine sand (PDBg horizon)	1.82
Pine-4	Orange-brown, silty fine sand (PDBtj horizon)	1.08
Pine-6	Light gray, sandy silt (PDBg horizon)	1.24
	AVERAGE	1.47

Table 15: Dry density results of geotechnical samples.

Index Tests

Plasticity index was determined on 3 of the 4 paleosol facies samples and ranged from 7% to 44% (Table 16). In general, the paleosol deposits are characterized as having low plasticity to non-plastic behavior.

Paleosol/deflation Plain Layers - PALEOSOL FACIES				
Sample Site	Field Description	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)
Woah-1	Gray, silty fine sand (SM)	32	25	7
Woah-3	Gray, silty fine sand (SM)	NP	NP	NP
Pine-4	Orange-brown, silty fine sand (SM)	58	40	18
Pine-6	Light gray, sandy silt (MH)	94	50	44

Table 16: Summary of plasticity index testing.

Dry density tests and specific gravity tests were performed on the samples in order to calculate void ratio, porosity, and degree of saturation. The results are shown on Table 17. Specific gravity results ranged from 2.63 to 2.69.

Paleodune Sand Layers - DUNE FACIES						
Sample Site	Field Description	Sample Moisture (%)	Dry density (g/cu. cm)	In-situ Void ratio (*e*)	Porosity (n)	Degree of Saturation (%)
Woah-2	Tan, fine sand (SP)	10.3	1.74	0.53	0.35	52
Woah-4	Red-brown fine sand (SP)	12.6	1.74	0.55	0.35	61
Ona-1A	Tan to red-brown fine sand (SP)	14.0	1.47	0.80	0.44	46
Ona-B	Tan, fine sand (SP)	9.3	1.60	0.65	0.39	38
Ona-C	Tan, fine sand (SP)	17.6	1.63	0.64	0.39	72
Pine-2	Red-brown fine sand (SP)	14.9	1.49	0.79	0.44	50
Pine-3	Tan, fine sand (SP)	17.0	1.47	0.83	0.45	56
Pine-5	Light brown fine sand (SP)	15.2	1.62	0.67	0.40	62
Paleosol/deflation Plain Layers - PALEOSOL FACIES						
Sample Site	Field Description	Sample Moisture (%)	Dry density (g/cu. cm)	In-situ Void ratio (*e*)	Porosity (n)	Degree of Saturation (%)
Woah-1	Gray, silty fine sand (SM)	20.3	1.73	0.55	0.36	99
Woah-3	Gray, silty fine sand (SM)	22.2	1.82	0.41	0.29	100
Pine-4	Orange-brown, silty fine sand (SM)	47.8	1.08	1.47	0.59	86
Pine-6	Light gray, sandy silt (MH)	38.2	1.24	1.16	0.53	88

Table 17: Summary of index tests for selected geotechnical samples.

The results of index test on selected samples indicated the paleodune sand layers are partially saturated ranging from 38 to 72 percent. The paleosol layers were highly saturated ranging from 86 to 100 percent. It should be noted that moisture may have been lost during transport and storage of the samples before testing. Moisture content is highly dependent on the timing of sample collection and testing and also the season the samples are collected.

Permeability Testing

Typical range of hydraulic conductivity values for sand and loess from Terzaghi and Peck (1967) are listed in Table 18. These values can be used to compare to test results from this study.

Typical Values	
Hydraulic Conductivity	**(cm/s)**
Dune sand	0.1 to 0.3
loess	10^{-3}
Very fine uniform sand	6.4×10^{-3} to 10^{-4}
Degree of Permeability	**(cm/s)**
High	>0.1
Medium	0.1 to 10^{-3}
Low	10^{-3} to 10^{-5}
Very Low	10^{-5} to 10^{-7}
Impermeable	$>10^{-7}$

Table 18: Typical values of hydraulic conductivity for fine sand and silt. Range of relative permeability values for general classification, modified from Terzaghi and Peck (1967).

Initial constant head (ASTM D2434) permeability tests were conducted by Renee Summers and Trevor Smith (PSU unpublished data) to determine a general range of conductivity (k) values for the paleodune strata. The permeability results ranged from 4.4×10^{-3} cm/s to 7.0×10^{-7} cm/s which is lower than the typical conductivity value of 10^{-3} cm/s recommended for the constant head procedure. The results of hydraulic conductivity testing is shown in Table 19.

Flex-wall permeability tests conducted on the geotechnical site samples were performed using constant gradients ranging units from 5 to 20 at an effective stress of 17 kPa to 34 kPa. The constant head test might give lower hydraulic conductivity, when fines are present, due to a lower degree of saturation.

Paleodune Sand Layers - DUNE FACIES		
Sample Site	Field Description	Hydraulic conductivity (cm/s)
Woah-2	Tan, fine sand (PDC horizon)	6.3×10^{-4}
Woah-4	Red-brown fine sand (PDC horizon)	5.5×10^{-4}
Ona-1A	Tan to red-brown fine sand (PDCox horizon)	3.8×10^{-3}
Ona-B	Tan, fine sand (PDC horizon)	4.4×10^{-4}
Ona-C	Tan, fine sand (PDC horizon)	5.5×10^{-4}
Pine-2[(1)]	Red-brown fine sand (PDCox horizon)	4.4×10^{-3}
Pine-3	Tan, fine sand (PDC horizon)	6.4×10^{-4}
Pine-5	Light brown fine sand (PDC horizon)	9.4×10^{-4}
(1) indicates constant head test	**AVERAGE**	1.5×10^{-3}

Paleosol/deflation Plain Layers - PALEOSOL FACIES		
Sample Site	Field Description	Hydraulic conductivity (cm/s)
Woah-1	Gray, silty fine sand (PDBg horizon)	1.6×10^{-6}
Woah-3	Gray, silty fine sand (PDBg horizon)	1.3×10^{-5}
Pine-4	Orange-brown, silty fine sand (PDBtj horizon)	*6.2×10^{-4}*
Pine-6	Light gray, sandy silt (PDBg horizon)	2.0×10^{-5}
Italics indicates suspect value	**AVERAGE**	1.6×10^{-4}

Table 19: Hydraulic conductivity results for geotechnical samples. Values in italics indicate a suspect result, possibly due to sample disturbance.

Direct Shear Testing

Direct shear testing was conducted on selected paleodune samples by Renee Summers and Dr. Trevor Smith (Portland State University, Civil and Environmental Engineering Department). The typical range of the angle of internal friction (phi) for a uniform fine sand is 27 to 37 degrees. In addition, sand is generally considered to have no cohesion. The direct shear results for the dune sand, shown in Table 20, have phi angles ranging from 20 to 43 degrees and cohesion values ranging from 0 to 64.3 kPa. The test results for Ona-C and Pine-5 have anomalously low phi angles (20 degrees) and higher cohesion values (64.3 kPa and 27.2 kPa, respectively). The anomalous results are likely due to sample disturbance.

Paleodune Sand Layers - DUNE FACIES			
Sample Site	Field Description	Direct Shear ϕ'_p (degrees)	Direct Shear c' psf (kPa)
Woah-2	Tan, fine sand (PDC horizon)	43	0
Woah-4	Red-brown fine sand (PDC horizon)	37	124 (5.9)
Ona-1A&1B	Tan to red-brown fine sand (PDCox horizon)	40	236 (11.3)
Ona-B	Tan, fine sand (PDC horizon)	35	384 (18.4)
Ona-C	Tan, fine sand (PDC horizon)	*20*	*1343 (64.3)*
Pine-2	Red-brown fine sand (PDCox horizon)	42.6	270 (12.9)
Pine-3	Tan, fine sand (PDC horizon)	42	335 (16.0)
Pine-5	Light brown fine sand (PDC horizon)	*20.5*	*568 (27.2)*

Italics indicates suspect value

Paleosol/deflation Plain Layers - PALEOSOL FACIES			
Sample Site	Field Description	Direct Shear ϕ'_p (degrees)	Direct Shear c' psf (kPa)
Woah-1	Gray, silty fine sand (PDBg horizon)	37	248 (11.9)
Woah-3	Gray, silty fine sand (PDBg horizon)	36	519 (24.8)
Pine-4	Orange-brown, silty fine sand (PDBtj horizon)	36	568 (27.2)
Pine-6	Light gray, sandy silt (PDBg horizon)	No value	No value

1 kPa = 20.8854 psf

"p" indicates peak value

Table 20: Direct Shear results of geotechnical samples.

Triaxial Testing

Consolidated drained (CD) and consolidated undrained (CU) triaxial compression tests were conducted on the paleodune deposit samples. The dune facies samples were tested under CD conditions and the paleosol facies samples were tested under CU conditions. Two exceptions are that samples from Pine-5 was tested under CU conditions and samples from Pine-6 was tested under CD conditions. General testing convention is to test fine-grained (cohesive) samples under undrained conditions such that the sample volume is held constant and the change in excess pore water pressure is monitored during loading. Granular (non-cohesive) samples are typically tested under drained conditions such that excess pore water pressure is held at zero and the change in sample volume is monitored during loading.

Triaxial strength plots of representative paleodune layers were constructed for each of the geotechnical sites (Pinecrest, Ona Beach, and Canary Road) and are located in Table 21 and in Appendix E. Units of pounds per square foot (psf) were used for the triaxial tests for comparison with the direct shear results produced by Renee Summers and Dr. Trevor Smith (Portland State University, Civil and Environmental Engineering Department). The plots document the drained shear strength parameters for the major paleodune layers found covering the coastal plain. The plotted Mohr's circles are based on residual shear strengths as are typically interpreted for general geotechnical engineering applications.

Paleodune Sand Layers - DUNE FACIES					
Sample Site	Field Description	Triax ϕ'_r (degrees)	Triax ϕ'_p (degrees)	Triax c'_r psf (kPa)	Triax c'_p psf (kPa)
Woah-2	Tan, fine sand (PDC horizon)	29	25	55 (2.6)	217 (10.4)
Woah-4	Red-brown fine sand (PDC horizon)	29.6	29.3	84 (4.0)	525 (25.1)
Ona-1A	Tan to red-brown fine sand (PDCox horizon)	-	-	-	-
Ona-B	Tan, fine sand (PDC horizon)	30	32	0	108 (5.2)
Ona-C	Tan, fine sand (PDC horizon)	33	38	0	0
Pine-2	Red-brown fine sand (PDCox horizon)	-	-	-	-
Pine-3	Tan, fine sand (PDC horizon)	-	-	-	-
Pine-5	Light brown fine sand (PDC horizon)	*18*	*21*	*178 (8.5)*	*0*
"-" NOT TESTED	**AVERAGE**	27.9	29.1	60.8 (2.9)	245.0 (11.7)
Paleosol/deflation Plain Layers - PALEOSOL FACIES					
Sample Site	Field Description	Triax ϕ'_r (degrees)	Triax ϕ'_p (degrees)	Triax c'_r psf (kPa)	Triax c'_p psf (kPa)
Woah-1	Gray, silty fine sand (PDBg horizon)	28.6	29.4	181 (8.7)	383 (18.3)
Woah-3	Gray, silty fine sand (PDBg horizon)	25.4	27	1207 (57.8)	1016 (48.6)
Pine-4	Orange-brown, silty fine sand (PDBtj horizon)	36.5	36.1	0	0
Pine-6	Light gray, sandy silt (PDBg horizon)	32.7	34.5	0	0
	AVERAGE	30.8	31.8	347.0 (16.6)	349.8 (16.7)

Table 21: Summary of triaxial testing for geotechnical samples. Note: 1 kPa = 20.8854 psf.

Consolidated Drained Tests

Consolidated drained triaxial test result plots (Appendix E) indicate that the dune facies samples exhibited dilation during shearing at low strain levels. The stress-strain plot (Figure 50) shows a peak in the deviator stress at low strain followed by a drop in stress as strain is increased. The peak strength indicates that the soil particles are densely packed and must overcome a peak shear stress prior to moving past adjacent particles. Dense soils often have brittle behavior during triaxial shear resulting in a well-developed shear plane as shown in Figure 51. The residual strength is defined as the ultimate shear strength of the soil where no increase in deviator stress or volume occurs with an increase in axial strain (Lambe and Whitman, 1969).

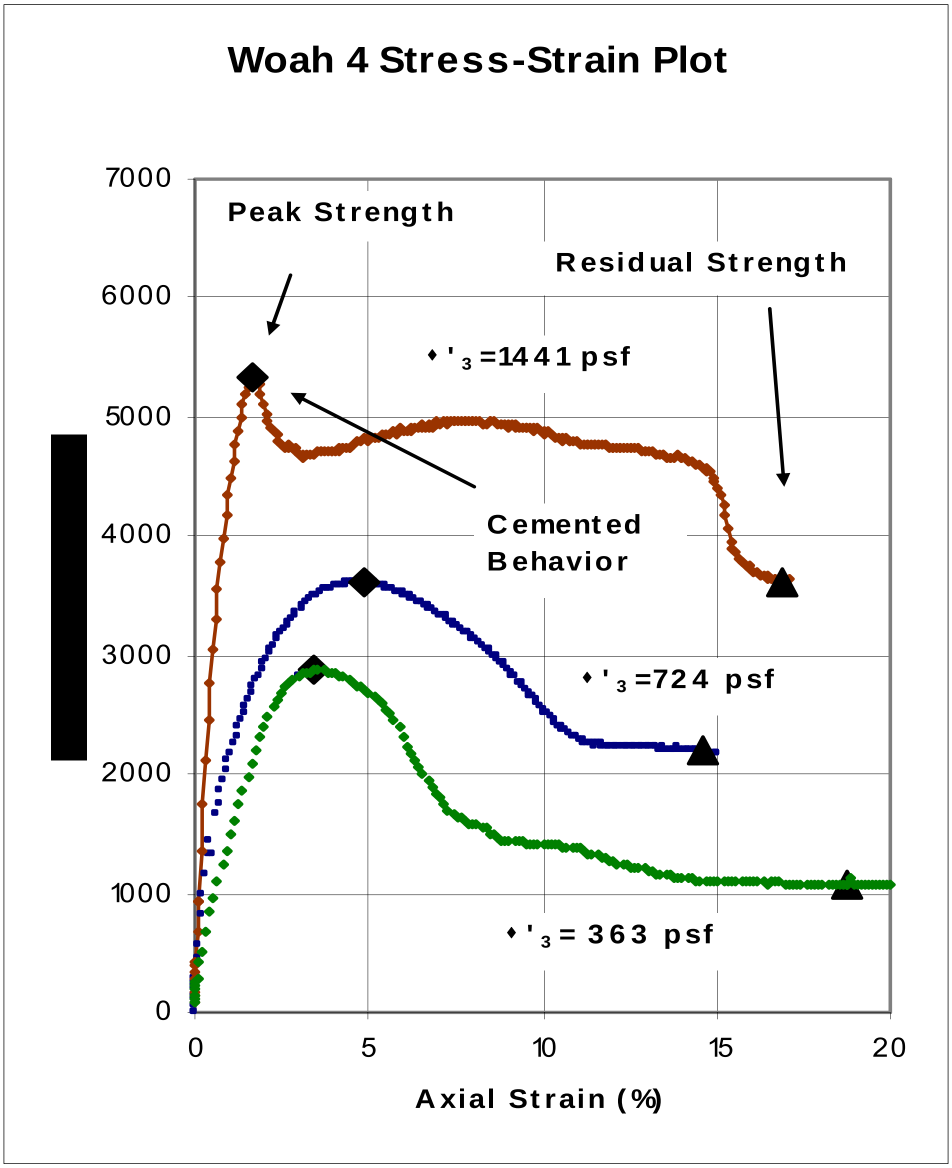


Figure 50: An example showing the stress-strain plot for a consolidated drained (CD) triaxial test for Woah-4. A higher peak strength followed by a low residual strength is indicative of dense or cemented material. Note: 1 kPa = 20.8854 psf.

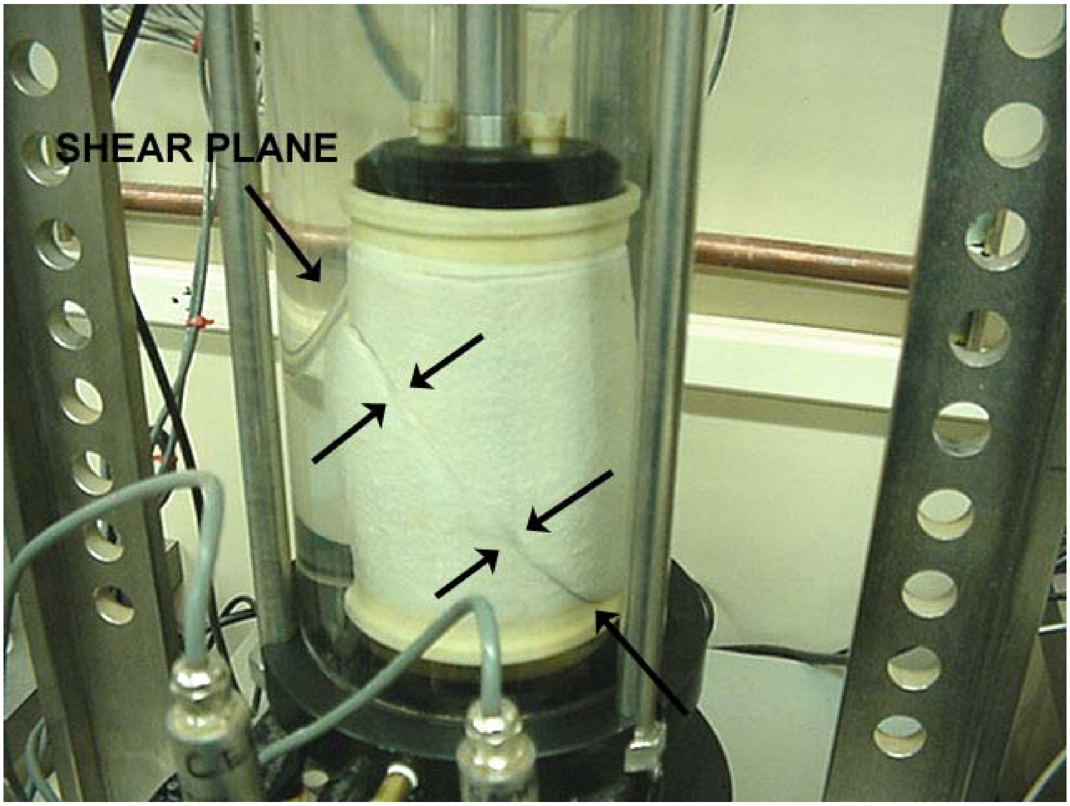


Figure 51: Sheared paleodune sand sample showing well-developed shear plane indicating brittle failure.

The volumetric strain plot (Figure 52) shows a small peak followed by a drop in volumetric strain to negative values. Negative volumetric strain is indicative of an increase in sample volume as the soil particles move away from each other during shearing as a result of an initial dense packing (Lambe and Whitman, 1969).

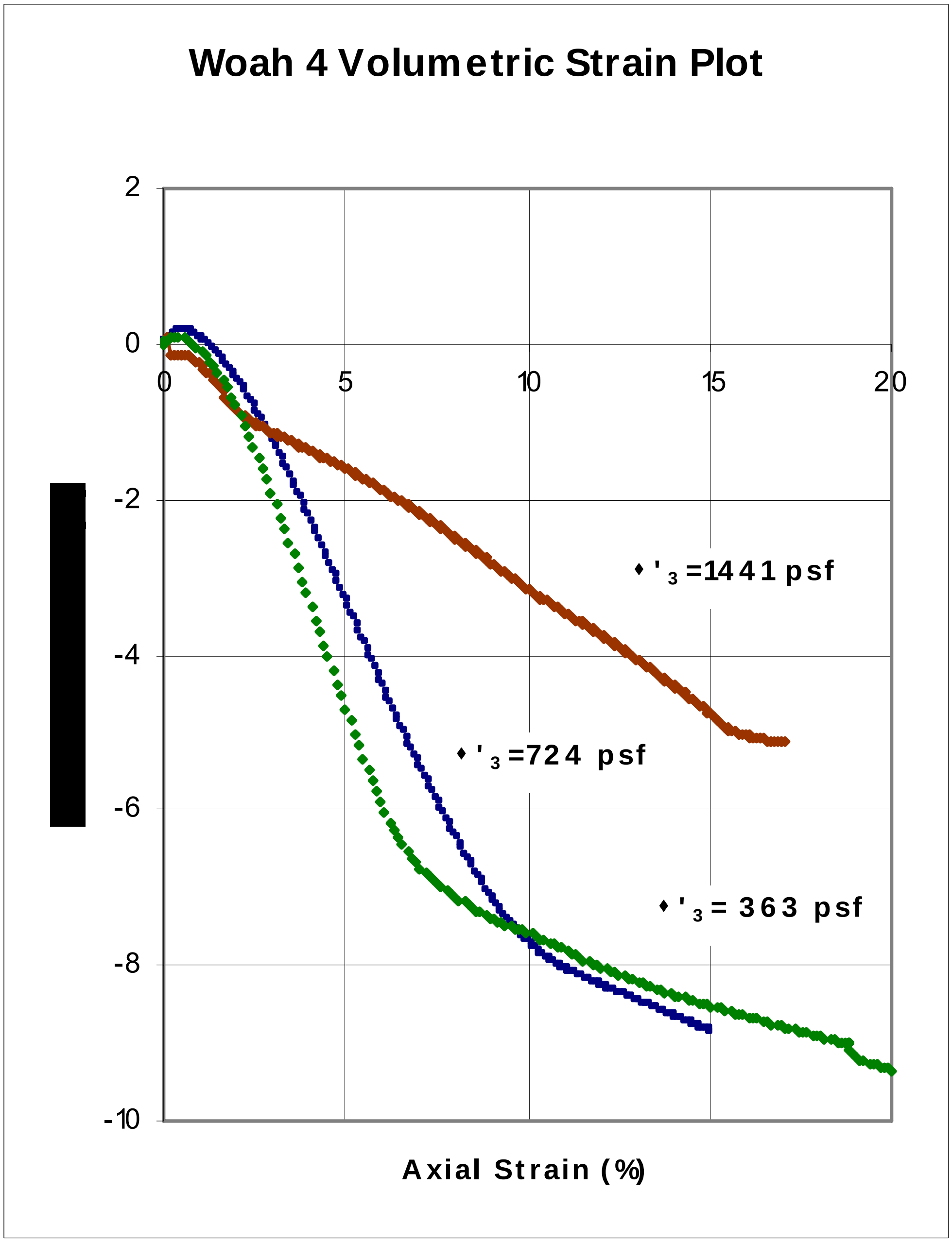


Figure 52: An example showing the volumetric strain plot for a consolidated drained (CD) triaxial test for Woah-4. Note: 1 kPa = 20.8854 psf.

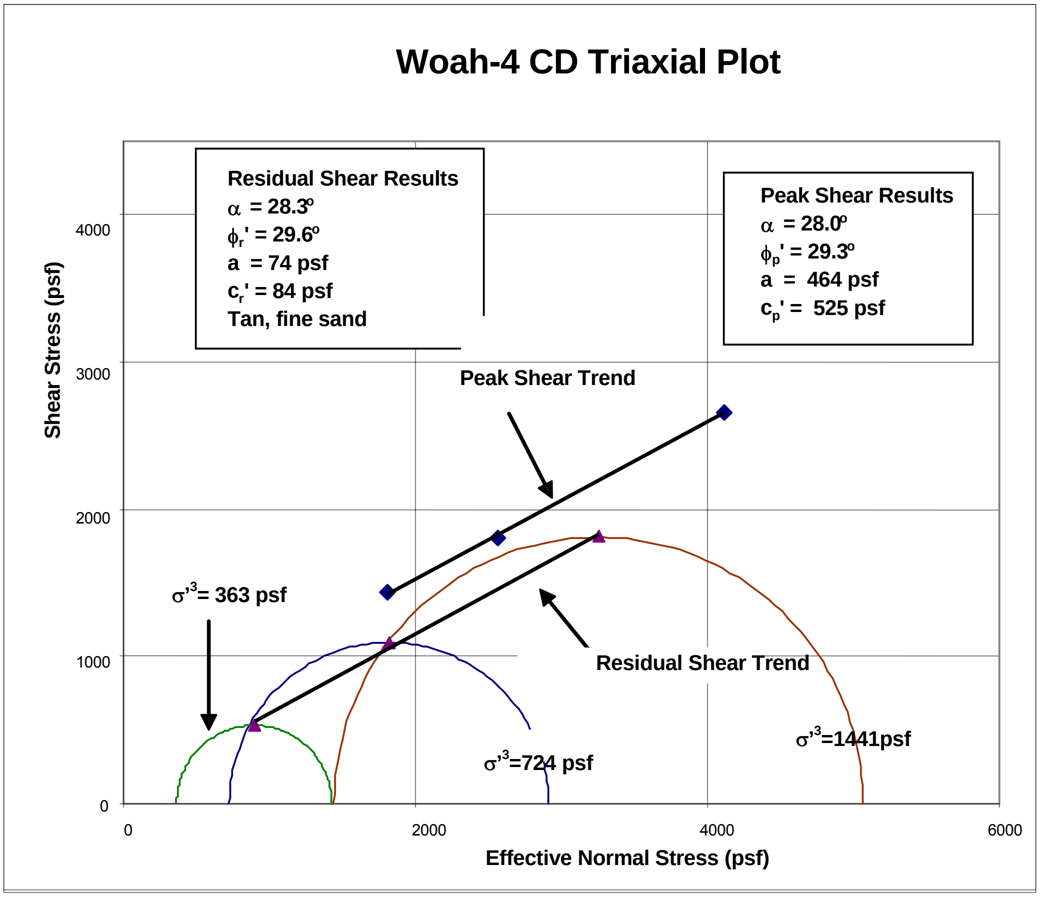


Figure 53: An example plot showing Mohr's circles for a consolidated drained (CD) triaxial test for Woah-4. The residual shear trend is the peak of the Mohr's circles (plotted) based on the residual shear stress. The "α" parameter is the slope of the peaks of each circle which is then corrected to "ϕ'_r" to get the angle of internal friction. The "a" parameter is the shear stress axis intercept of the αline. The parameter "a" is corrected to "c'_r" which is the residual shear trend. The "ϕ'_r" parameter is the slope of tangent to the Mohr's circles which is the effective angle of internal friction. The "c'_r" parameter is the shear stress axis intercept of the tangent to the Mohr's circles (strength envelope). The peak shear trend is the peak of the Mohr's circles (not plotted) based on the peak shear stress. Note: 1 kPa = 20.8854 psf.

Consolidated Undrained Tests

Consolidated undrained triaxial test result plots (Appendix E) indicate that the dune facies samples exhibited dilation due to fracturing of the sample during shearing at low strain levels. The change in pore water pressure plot (Figure 55) shows a peak within one percent axial strain followed by a rapid drop in pore water pressure as strain is increased. The measure of dilation is a result of the expansion of cracks within the sample as the unfractured and partially fractured materials reposition themselves during shearing (Yamamuro, 2005, personal communication). The peak strength indicates that the soil particles are densely packed or cemented and must overcome a peak shear stress prior to moving past adjacent particles or cemented blocks. Evidence for brittle behavior during triaxial shear is shown by a well-formed fracture plane that was observed in many of the test samples (Figure 51).

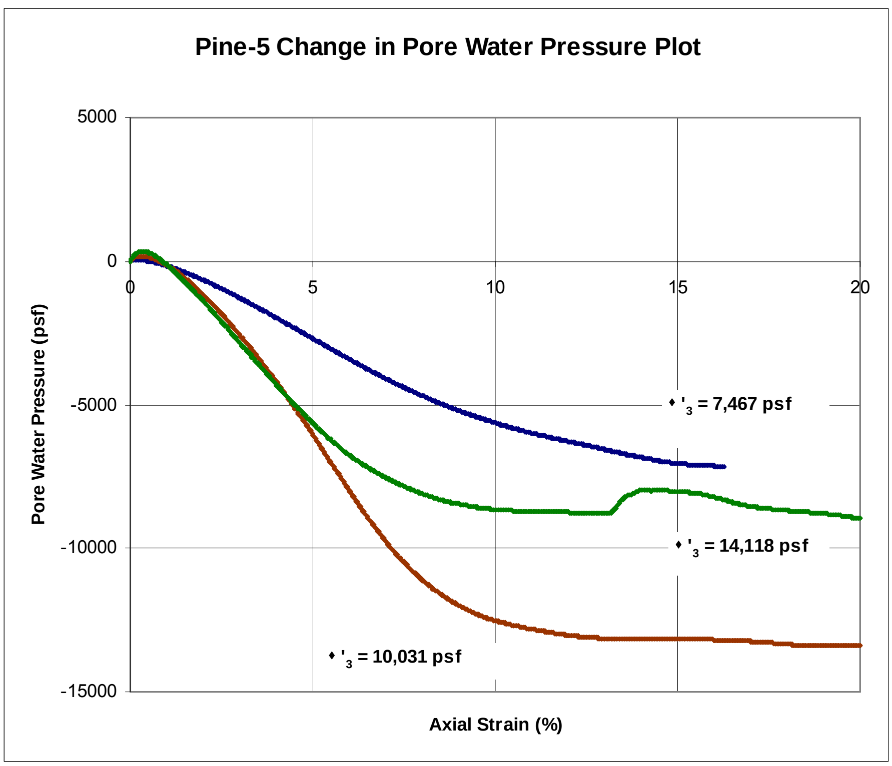


Figure 54: Plot of the change in pore water pressure during shearing of the triaxial sample. Negative pore water pressure indicates dilation of the sample during shearing. Note: 1 kPa = 20.8854 psf.

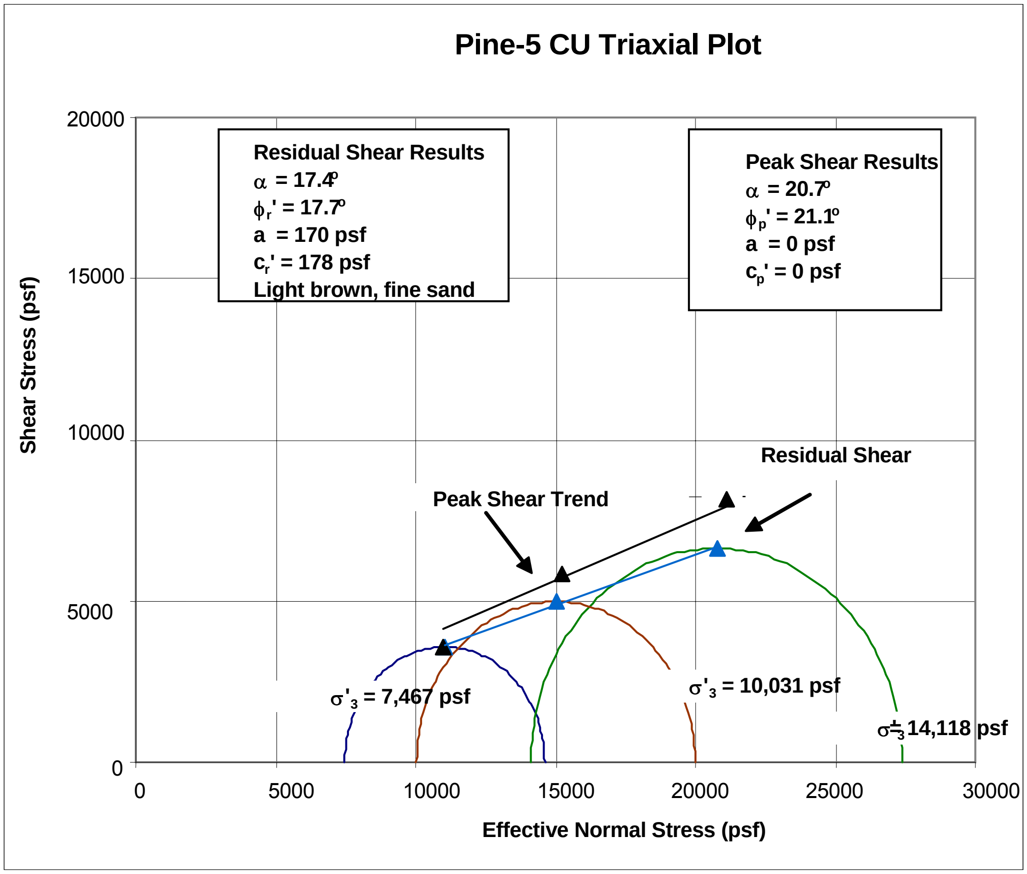


Figure 55: Example of consolidated undrained (CU) triaxial test. See Figure 53 for explanation. Note: 1 kPa = 20.8854 psf.

The peak stress of the upper two curves shown on Figure 56 coincides with the maximum slope of the pore water pressure curves shown on Figure 54. The fact that the rate of dilation continues after shear stress drops and that the "residual strength" appears to increase relative to the peak strength as the confining pressure increases, indicates that the sample is exhibiting a "fracturing behavior" and is most likely cemented (Yamamuro, 2005, personal communication). The slope of the residual strength trend (Figure 55) represents the friction angle between the sliding cemented blocks at the applied low levels of normal stress and confining pressures. An increase in effective stress and confining pressures on test samples will most likely overcome the affects of weak cementation resulting in a residual strength of the sand particles and not the cemented blocks.

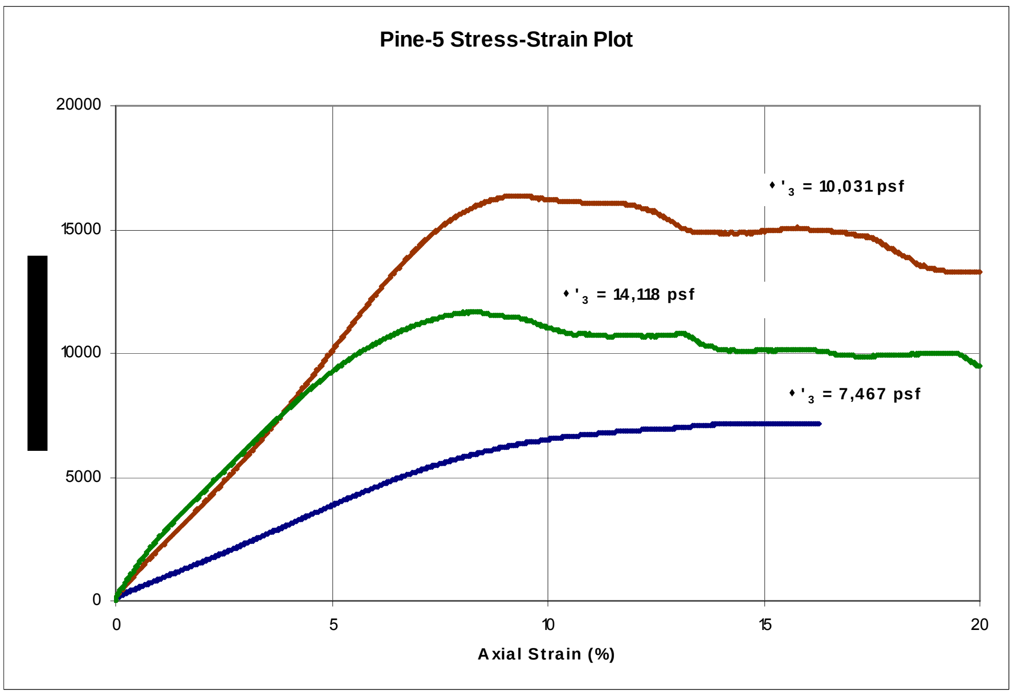


Figure 56: An example showing the stress-strain plot for a consolidated undrained (CU) triaxial test for Pine-5. A higher peak strength followed by a low residual strength is indicative of dense or cemented material. Note: 1 kPa = 20.8854 psf.

Typical triaxial strength envelopes are comprised of three tests at different effective stresses. However, a few envelopes have only one or two tests due to lack of “undisturbed” sample material (Table 22). A significant number of the samples tested are not included due to errors in the testing. Typical test errors included loss of data from power failures, program errors, operator errors, and sample shear strengths greater than the apparatus load cell.

Paleodune Sand Layers - DUNE FACIES			
Sample Site	Field Description	Test	Number of strength tests
Woah-2	Tan, fine sand (SP)	CD	3
Woah-4	Red-brown fine sand (SP)	CD	3
Ona-1A	Tan to red-brown fine sand (SP)	CD	1
Ona-B	Tan, fine sand (SP)	CD	2
Ona-C	Tan, fine sand (SP)	CD	3
Pine-2	Red-brown fine sand (SP)	NA	—
Pine-3	Tan, fine sand (SP)	NA	—
Pine-5	Light brown fine sand (SP)	CU	3
Paleosol/deflation Plain Layers - PALEOSOL FACIES			
Sample Site	Field Description	Test	Number of strength tests
Woah-1	Gray, silty fine sand (SM)	CU	2
Woah-3	Gray, silty fine sand (SM)	CU	3
Pine-4	Orange-brown, silty fine sand (SM)	CU	3
Pine-6	Light gray, sandy silt (MH)	CD	2

Table 22: Table showing geotechnical sample site and test type and number of completed triaxial strength test. For test method “CD” is consolidated drained, “CU” is consolidated undrained, and “NA” is no test attempt.

Triaxial Test Samples

Pinecrest Site

Consolidated undrained triaxial tests were conducted on Pine-4 and Pine-5 samples. Consolidated drained triaxial tests were conducted on Pine-6 samples. The results of the triaxial tests are shown in Table 18 and Appendix E. Only two tests were completed for Pine-6 due to sample disturbance during sample preparation. Interpretation of test results are located in the Discussion section. The measured values for the residual angle of internal friction ranged from 17 to 37 degrees and the cohesion values ranged from 0 to 8.5 kPa (Table 23). The measured values for the peak angle of internal friction ranged from 21 to 37 degrees with no cohesion (Table 23).

	Pine – 4			**Pine – 5**			**Pine - 6**		
Field Description	Hwy 101 roadcut; Orange-brown, silty fine SAND; FeO staining			Hwy 101 roadcut; Light brown, fine SAND			Hwy 101 roadcut; Light gray to olive-brown, sandy SILT with some clay		
Triaxial Compression Test Method	Consolidated Undrained			Consolidated Undrained			Consolidated Drained		
Residual Soil Shear Strength	**σ'_3 psf (kPa)**	**σ'_1-σ'_3 psf (kPa)**	**Δu_r psf (kPa)**	**σ'_3 psf (kPa)**	**σ'_1-σ'_3 psf (kPa)**	**Δu_r psf (kPa)**	**σ'_3 psf (kPa)**	**σ'_1-σ'_3 psf (kPa)**	**$\Delta\varepsilon_{vol}$ (%)**
	936 (44.8)	3625 (137.6)	1079 (51.7)	7467 (357.5)	7141 (341.9)	-7107 (-340.3)	721 (34.5)	2109 (101.0)	-0.16
	1019 (48.8)	4372 (209.3)	422 (20.2)	10031 (480.3)	9957 (476.7)	-8877 (-425.0)	1441 (69.0)	4335 (207.6)	1.34
	1055 (50.5)	4576 (219.1)	-314 (-15.0)	14118 (676.0)	13271 (635.4)	-13397 (-641.5)	-	-	-
Angle of internal friction (ϕ'_r) Cohesion psf (kPa)	36.5° 0			17.7° 178 (8.5)			32.7° 0		
Peak Soil Shear Strength	**σ'_3 psf (kPa)**	**σ'_1-σ'_3 psf (kPa)**	**Δu psf (kPa)**	**σ'_3 psf (kPa)**	**σ'_1-σ'_3 psf (kPa)**	**Δu psf (kPa)**	**σ'_3 psf (kPa)**	**σ'_1-σ'_3 psf (kPa)**	**$\Delta\varepsilon_{vol}$ (%)**
	857 (41.0)	3639 (174.2)	1158 (55.4)	7390 (353.8)	7175 (343.5)	-7030 (-336.6)	717 (34.3)	2409 (115.3)	-0.14
	958 (45.9)	4644 (222.4)	-217 (-10.4)	9412 (450.6)	11659 (558.2)	-8258 (-395.4)	1438 (68.9)	5082 (243.3)	-1.55
	1019 (48.8)	4372 (209.3)	422 (20.2)	12904 (617.8)	16368 (783.7)	-12182 (-583.3)	-	-	-
Angle of internal friction (ϕ'_p) Cohesion (psf)	37.2° 0			21.1° 0			34.5° 0		
Indicates suspect or estimated value "-" Indicates no value Subscript "r" = residual; "p" = peak									

Table 23: Summary of triaxial results for Pinecrest site. Note: 1 kPa = 20.8854 psf.

Ona Site

Consolidated drained triaxial tests were conducted on Ona-1A, Ona-B, and Ona-C. Triaxial test results are shown on Table 24. Only two tests were completed for Ona-B due to sample disturbance during sample preparation. One test was completed for Ona-1A due to poor sample recover in the field. Interpretation of test results are located in the Discussion section. The measured values for the residual angle of internal friction ranged from 30 to 33 degrees with no cohesion. The measured values for the peak angle of internal friction ranged from 32 to 38 degrees and the cohesion values ranged from 0 to 5.2 kPa (Table 24).

SITE LOCATION	Ona-1A			Ona-B			Ona-C		
Field Description	Tan to red-brown, fine SAND; house foundation-PMT1			Beach sea cliff; Dense, tan fine SAND			Beach sea cliff; Dense, tan fine SAND		
Exploration Method	Hand auger			Grab sample			Grab sample		
Triaxial Compression Test Method	Consolidated Drained			Consolidated Drained			Consolidated Drained		
Residual Soil Shear Strength	**σ'_3 psf (kPa)**	**σ'_1-σ'_3 psf (kPa)**	**$\Delta\varepsilon_{vol}$ (%)**	**σ'_3 psf (kPa)**	**σ'_1-σ'_3 psf (kPa)**	**$\Delta\varepsilon_{vol}$ (%)**	**σ'_3 psf (kPa)**	**σ'_1-σ'_3 psf (kPa)**	**$\Delta\varepsilon_{vol}$ (%)**
	722 (34.60	2289 (109.6)	-4.6	721 (34.5)	1630 (78.0)	-5.9	350 (16.8)	802 (38.4)	-6.2
	-	-	-	1455 (69.7)	3388 (162.2)	-6.4	721 (34.5)	2421 (115.9)	-5.2
	-	-	-	-	-	-	1441 (69.0)	4496 (215.3)	-5.2
Angle of internal friction (ϕ'_r)	-			30°			33.2°		
Cohesion psf (kPa)	-			0			0		
Peak Soil Shear Strength	**σ'_3 psf (kPa)**	**σ'_1-σ'_3 psf (kPa)**	**$\Delta\varepsilon_{vol}$ (%)**	**σ'_3 psf (kPa)**	**σ'_1-σ'_3 psf (kPa)**	**$\Delta\varepsilon_{vol}$ (%)**	**σ'_3 psf (kPa)**	**σ'_1-σ'_3 psf (kPa)**	**$\Delta\varepsilon_{vol}$ (%)**
	731 (35.0)	2889 (138.3)	-0.3	753 (36.1)	2565 (122.8)	-1.8	353 (16.9)	1178 (56.4)	-3.4
	-	-	-	1437 (68.8)	4432 (212.2)	-2.1	729 (34.9)	4601 (220.3)	-1.2
	-	-	-	-	-	-	1445 (69.2)	6833 (327.4)	-0.8
Angle of internal friction (ϕ'_p)	-			32°			38.4°		
Cohesion psf (kPa)	-			108 (5.2)			0		

Indicates suspect or estimated value
"-" Indicates no value
Subscript "r" = residual; "p" = peak

Table 24: Summary of triaxial test results for Ona site. Note: 1 kPa = 20.8854 psf.

Canary Road Site

Consolidated undrained triaxial tests were conducted on Woah-1 and Woah-3 samples. Consolidated drained triaxial tests were conducted on Woah-2 and Woah-4 samples. The results of the triaxial tests are shown on Table 25. Only two tests were completed for Woah-1 due to disturbance during sample preparation. Interpretation of test results are located in the Discussion section. The measured values for the residual angle of internal friction ranged from 25 to 30 degrees and the cohesion values ranged from 2.6 to 57.8 kPa. The measured values for the peak angle of internal friction ranged from 27 to 31 degrees and the cohesion values ranged from 10.4 to 48.6 kPa (Table 25). The results of stress-strain and volumetric strain plots from test sites Woah-2 and Woah-4 indicate strong sample dilation during shearing. The results of stress-strain and change in pore water pressure plots from test site Woah-3 also indicate strong sample dilation during shearing.

SITE LOCATION	Woah-1			Woah-2			Woah-3			Woah-4		
Field Description	Canary Road roadcut; Gray, silty fine SAND			Canary Road roadcut; Tan, fine SAND			Canary Road roadcut; Gray, silty fine SAND			Canary Road roadcut; Red-brown, fine SAND		
Triaxial Compression Test Method	Consolidated Undrained			Consolidated Drained			Consolidated Undrained			Consolidated Drained		
Residual Soil Shear Strength	**σ'_3 psf (kPa)**	**σ'_1-σ'_3 psf (kPa)**	**Δu_r psf (kPa)**	**σ'_3 psf (kPa)**	**σ'_1-σ'_3 psf (kPa)**	**$\Delta\varepsilon_{vol}$ (%)**	**σ'_3 psf (kPa)**	**σ'_1-σ'_3 psf (kPa)**	**Δu_r psf (kPa)**	**σ'_3 psf (kPa)**	**σ'_1-σ'_3 psf (kPa)**	**$\Delta\varepsilon_{vol}$ (%)**
	2945 (141.0)	7790 (373.0)	1053 (50.4)	357 (17.1)	998 (47.8)	-8.4	2053 (93.8)	7577 (362.8)	-973 (-46.6)	363 (17.4)	1063 (50.9)	-9.0
	5894 (282.2)	14889 (712.9)	-3878 (-185.7)	724 (34.7)	1771 (84.8)	-8.4	2882 (138.0)	8807 (421.7)	-2522 (-120.8)	724 (34.7)	2189 (104.8)	-8.8
	-	-	-	1441 (69.0)	3369 (161.3)	-5.2	3530 (169.0)	10082 (482.7)	-2811 (-134.6)	1441 (69.0)	3624 (173.5)	-5.1
Angle of internal friction (ϕ'_r)	28.6			28.8			25.4			29.6		
Cohesion psf (kPa)	181 (8.7)			55 (2.6)			1207 (57.8)			84 (4.0)		
Peak Soil Shear Strength	**σ'_3 psf (kPa)**	**σ'_1-σ'_3 psf (kPa)**	**Δu psf (kPa)**	**σ'_3 psf (kPa)**	**σ'_1-σ'_3 psf (kPa)**	**$\Delta\varepsilon_{vol}$ (%)**	**σ'_3 psf (kPa)**	**σ'_1-σ'_3 psf (kPa)**	**Δu psf (kPa)**	**σ'_3 psf (kPa)**	**σ'_1-σ'_3 psf (kPa)**	**$\Delta\varepsilon_{vol}$ (%)**
	2862 (137.0)	8038 (384.9)	1137 (54.4)	401 (19.2)	1651 (79.1)	-2.7	2053 (98.3)	7577 (362.8)	-973 (-46.6)	370 (17.7)	2884 (138.1)	-2.6
	5849 (280.1)	14907 (713.8)	-3833 (-183.5)	754 (36.1)	3200 (153.2)	-2.4	2882 (138.0)	8807 (421.7)	-2522 (-120.8)	755 (36.1)	3608 (172.8)	-3.1
	-	-	-	1449 (69.4)	4338 (207.7)	-2.1	3511 (168.1)	10351 (495.6)	-2791 (-133.6)	1458 (69.8)	5326 (255.0)	-0.7
Angle of internal friction (ϕ'_p)	29.4			30.7			27			29.3		
Cohesion psf (kPa)	383 (18.3)			217 (10.4)			1016 (48.6)			525 (25.1)		

Indicates suspect or estimated value Subscript "r" = residual; "p" = peak

"-" Indicates no value

Table 25: Summary of triaxial results for the Canary Road site. Note: 1 kPa = 20.8854 psf.

Cement Mineralogy

The results of field observations and laboratory strength testing led to closer inspection of the cement agent within the paleodune deposits. The analysis of the cement mineralogy was conducted by Dr. Georg Grathoff and Catrina Johnson (Portland State University, Geology Department). A scanning electron microscope (SEM) was used to identify the cement morphology around the individual sand grains (Figures 57, 58, and 59). The SEM analysis showed portions of the paleodune sand samples to contain aggregations of cemented grains (Figure 57). The observed cement morphology consisted of cement bridges between grains, pore space filling, and sand grain surface coating (Figure 58). The sand grain coating contained abundant desiccation cracks indicative of dehydration of the cement minerals (Figures 58 and 59).

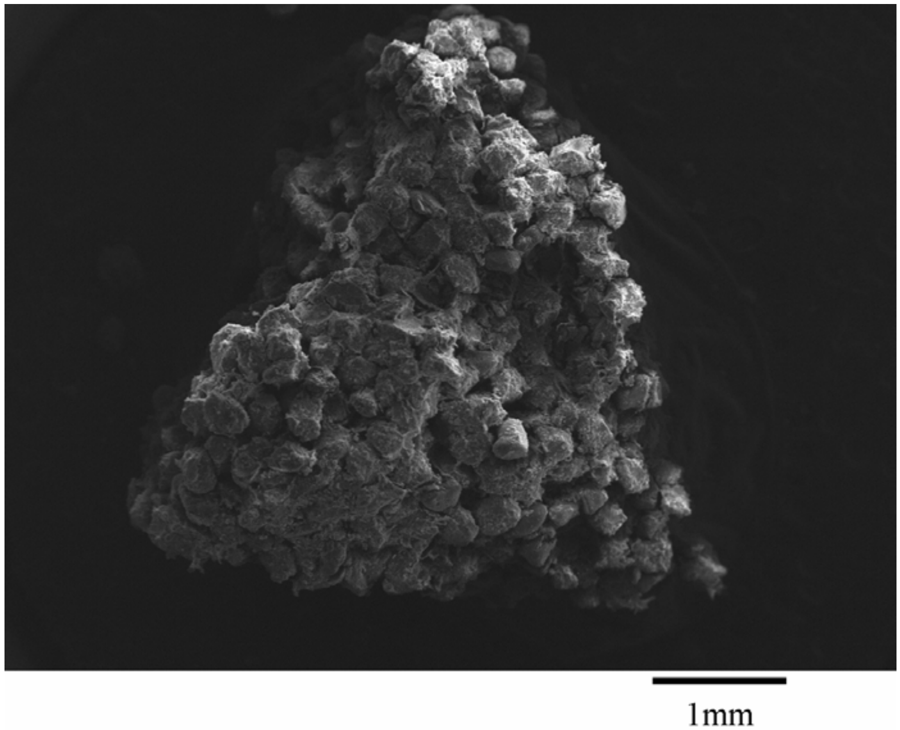


Figure 57: SEM photo of cemented sand grains.

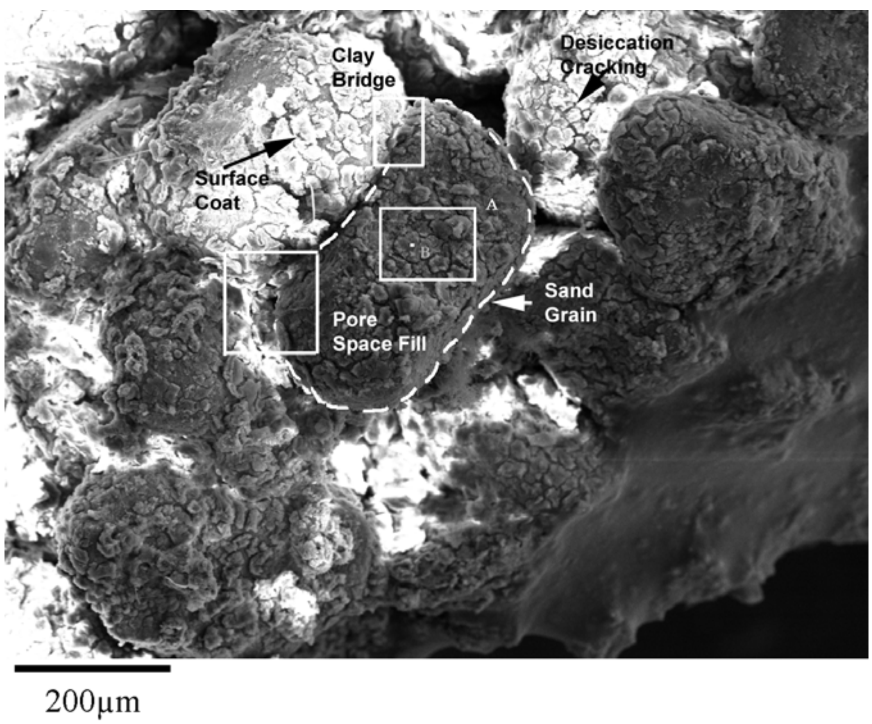


Figure 58: SEM photo of clay cement morphology collected from Pinecrest site.

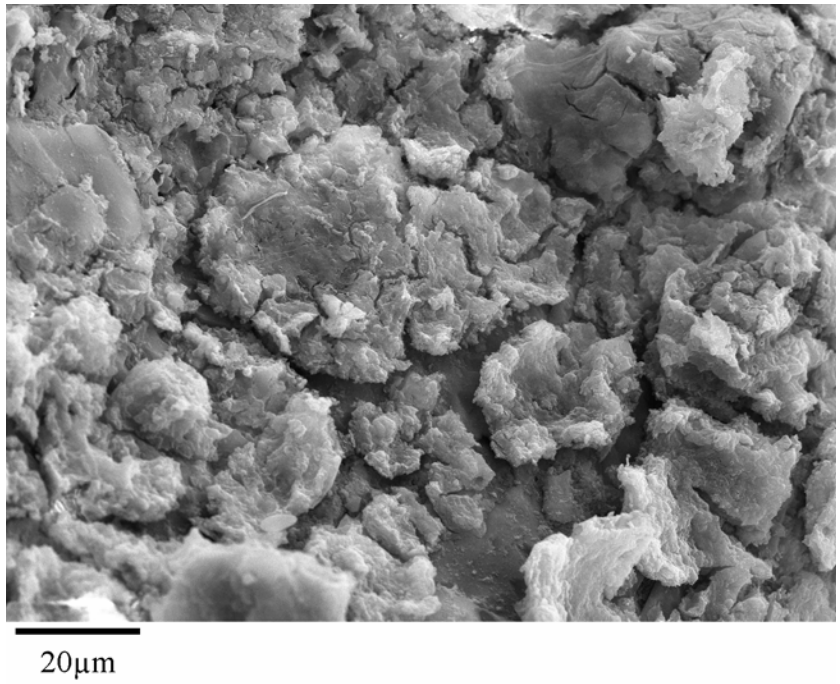
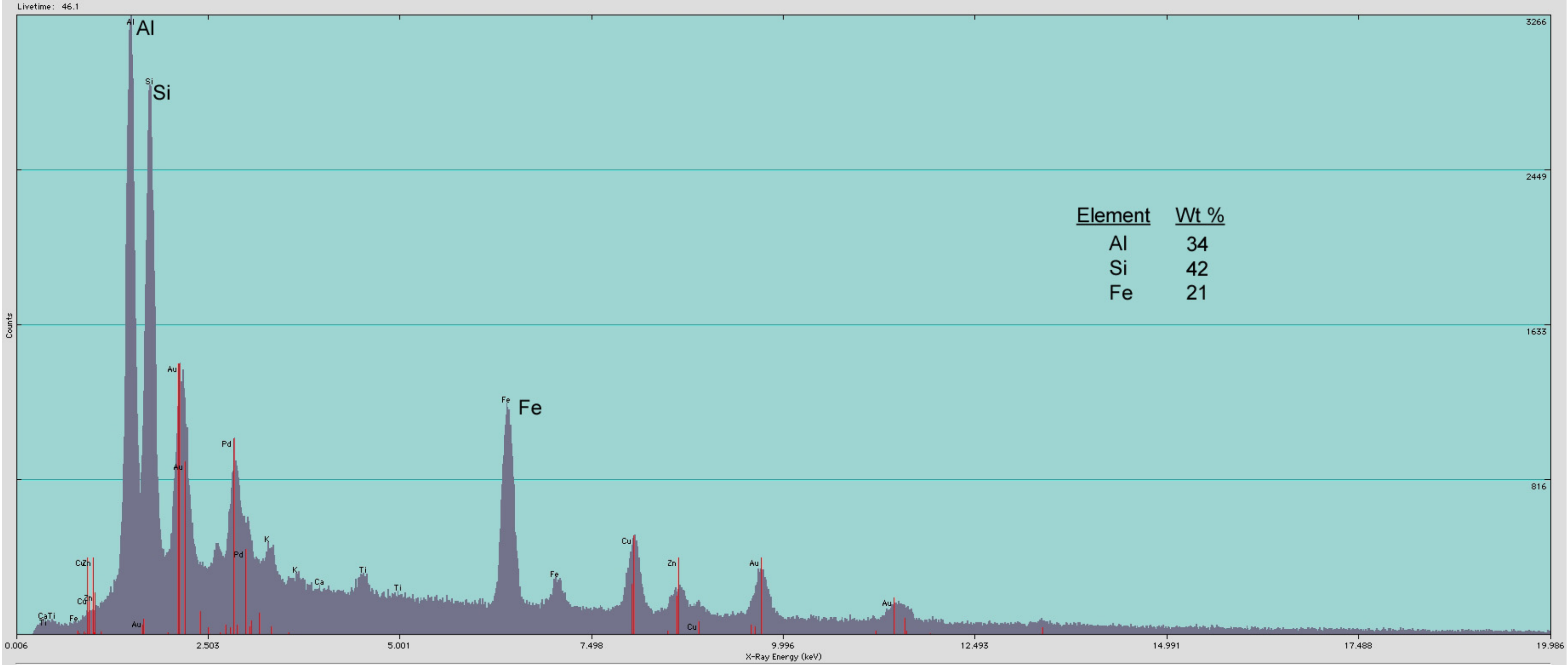


Figure 59: Enlarged SEM photo of clay cement material coating and desiccation cracks (Box A of Figure 58).

Analysis of the cement using Energy Dispersive X-ray (EDX) detected the major elements of the cement coating on selected paleodune sand samples (Figure 60). The main elements identified in the cement for the Pinecrest sample consisted of Al, Si, and Fe. X-ray diffraction (XRD) techniques (Figure 61) identified the majority of the cements to contain the minerals gibbsite, vermiculite, allophane, imogolite, and ferrihydrite. The cement morphology consisted of crystalline and amorphous phases, however hematite was the only crystalline phase identified (Johnson, 2003). The majority of the cement minerals were poorly crystalline to amorphous.

Realtime: 122.6
Livetime: 46.1



Quantitative Results - Manual Bulk Analysis (Standardless) - Spectrum4
Acquired 10-Mar-2003, 25.0 KeV @10 eV/channel

Element	Weight %	Std. Dev.	MDL	Atomic %	k-Ratio	Intensities
Al	34.15	1.08	0.86	39.47	0.1921	29843.5
Si	42.01	1.10	1.22	46.64	0.1568	26092.4
K ?	1.64	0.53	2.09	1.31	0.0109	1580.0
Ca ?	0.22	0.09	4.82	0.17	0.0016	228.1
Ti ?	1.41	0.47	1.99	0.92	0.0114	1290.3
Fe	20.58	0.98	0.58	11.49	0.1844	14391.0
Total	100.00					

? These elements are statistically insignificant.
Element determined by stoichiometry.

Figure 60: EDX spectra of clay cement from a Pinecrest sample.

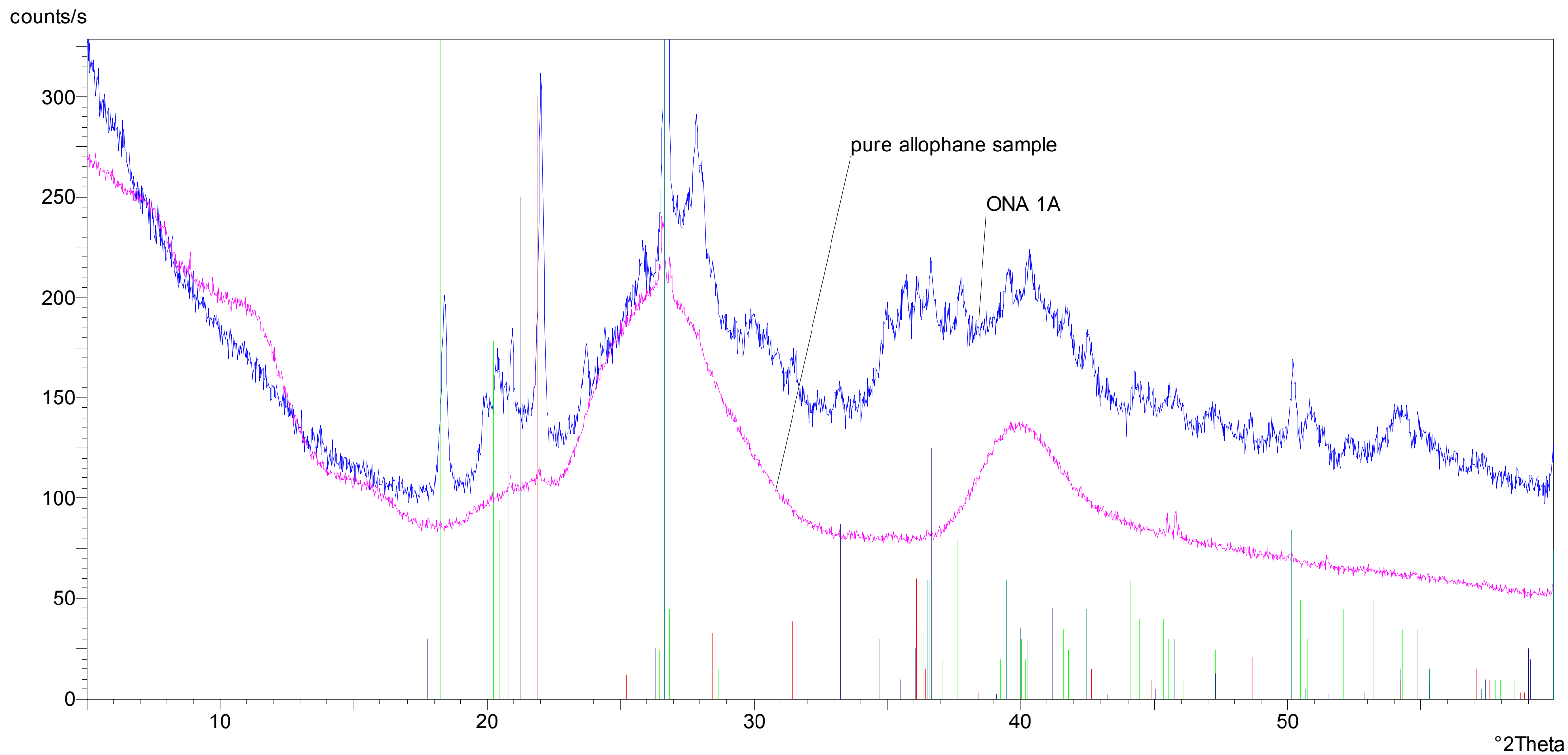


Figure 61: X-ray diffraction pattern of the less than 2 micrometer size fraction of the ONA 1A sample (blue) overlain with a pure sample of allophane (pink). The lines below are lines from the other identified phases in the ONA 1A sample: gibbsite, quartz, cristobalite, and goethite. The comparison with the allophane sample shows that the ONA 1A sample contains a high concentration of allophane. The presence of the other minerals such as quartz may originate from detrital grains, rather than from secondary cement.

Pressuremeter Testing

The problems encountered with undisturbed sampling and testing of paleodune strata led to in situ testing of representative sample sites. The pressuremeter (PMT) was used to perform companion strength testing at geotechnical sample sites. A summary of pressuremeter tests is shown on Table 26. Plots of individual PMT tests are located in Appendix F. Pressuremeter tests were performed typically in easy access locations in the key strata identified in each study site. To permit the maximum number of tests to be conducted on occasionally steep dune faces, all tests were conducted in hand augered boreholes.

SITE	Location	Test Reference	Field Description	PL* (kPa)	Eo (kPa)	Eo/PL* ratio	Test Quality (*** = max)	Interpreted Shear Behavior	Interpreted material properties	COMMENTS
Ona	Ona-1A @ 1.7m bgs	#3	Tan to red-brown fine sand	2188	23413	10.7	***	Drained conditions	Φ'r range from 36° to 40°	Good fit to Eo/PL* guidance
	Ona-1A @ 2.9m bgs	#4	Tan to red-brown fine sand	2375	22504	9.5	***	Drained conditions	Φ'r range from 36° to 40°	Good fit to Eo/PL* guidance
	Ona-A	PMT1	Black to brown silty sand/sandy silt	168	2442	14.6	**	Partially drained conditions (cemented)	unclear	Poor fit to Eo/PL* due to weak cementation breakdown
	Ona-B	PMT2	Tan fine sand	656	12784	19.5	***	Drained conditions (2)	Φ'r range from 30° to 33°	Poor fit to Eo/PL* due to weak cementation
	Ona-C	PMT3	Tan fine sand	1053	23078	21.9	**	Cemented full range		Poor fit to Eo/PL* due to weak cementation breakdown
Pinecrest	Pine-2 @ 1.7m bgs	#5 in PMT1	Red-brown fine sand	1853	24227	13.1	***	Drained conditions (2)	Φ'r range from 34° to 38°	Poor fit to Eo/PL* due to weak cementation
	Pine-2 @ 2.5m bgs	#6 in PMT1	Red-brown fine sand	2135	23605	11.1	***	Drained conditions	Φ'r range from 36° to 42°	Good fit to Eo/PL* guidance
	Pine-5 PDBw	PMT3	Orange-brown silty fine sand	1288	20780	16.1	***	Partially drained conditions (cemented)		Poor fit to Eo/PL* due to weak cementation
	Pine-5 PDC	PMT2	Light brown fine sand	397	4740	11.9	***	Drained conditions	Φ'r range from 28° to 30°	Good fit to Eo/PL* guidance
	Pine-6	PMT1	Light gray sandy silt	263	3639	13.8	***	Undrained conditions	Su(PL*) = 35 (kPa)	Good fit to Eo/PL*, no creep

Canary Road (Woahink)	Woah-1	#3	Gray to brown silty fine sand	2384	35000	14.7	***	Drained conditions (2)	Φ'r range from 35° to 39°	Poor fit to Eo/PL* due to weak cementation breakdown
	Woah-3	#4	Gray silty fine sand	783	9049	11.6	***	Partially drained conditions (cemented)	Su(PL*) = 90 (kPa)	Poor fit to Eo/PL* due to weak cementation breakdown
Yachats	Peel site	#7	Red-brown fine sand	2475	19583	7.9	***	Drained conditions (2)	Φ'r range from 36° to 44°	Good fit to Eo/PL* guidance

NOTES: PL* stands

1) For sandy materials: 7<Eo/PL*<12; For clayey materials: Eo/PL*>12;

2) Typical sand Eo/PL* <12; however cementation and/or overconsolidation will raise sand Eo/PL* ratio.

3) All phi should be considered as phi residual (Φ'r), i.e. constant volume, not peak.

4) Φ'r is the residual angle of internal friction for granular materials; $Su_{(PL*)}$ is the undrained shear strength for cohesive materials.

Table 26: Summary of pressuremeter test results for key layers at the geotechnical study sites. PL* stands for limit pressure and Eo stands for initial load modulus.

The PMT test results provide a limit pressure (PI*) and an initial load modulus (Eo) (Figure 62). The limit pressure is the maximum pressure, observed or calculated, at soil failure. This is defined as the pressure at a point where the cavity volume, expanded by the membrane, is double the initial borehole size. The initial load modulus is the calculated slope of the linear elastic strain portion of the pressuremeter curve. Unload and reload in cycles are often incorporated in PMT testing to gain insight into the soil behavior under increased stress levels. The ratio of Eo/P_L* can be used to compare specific PMT tests to average values for sand and clay (Briaud, 1986; Baguelin et. al., 1978).

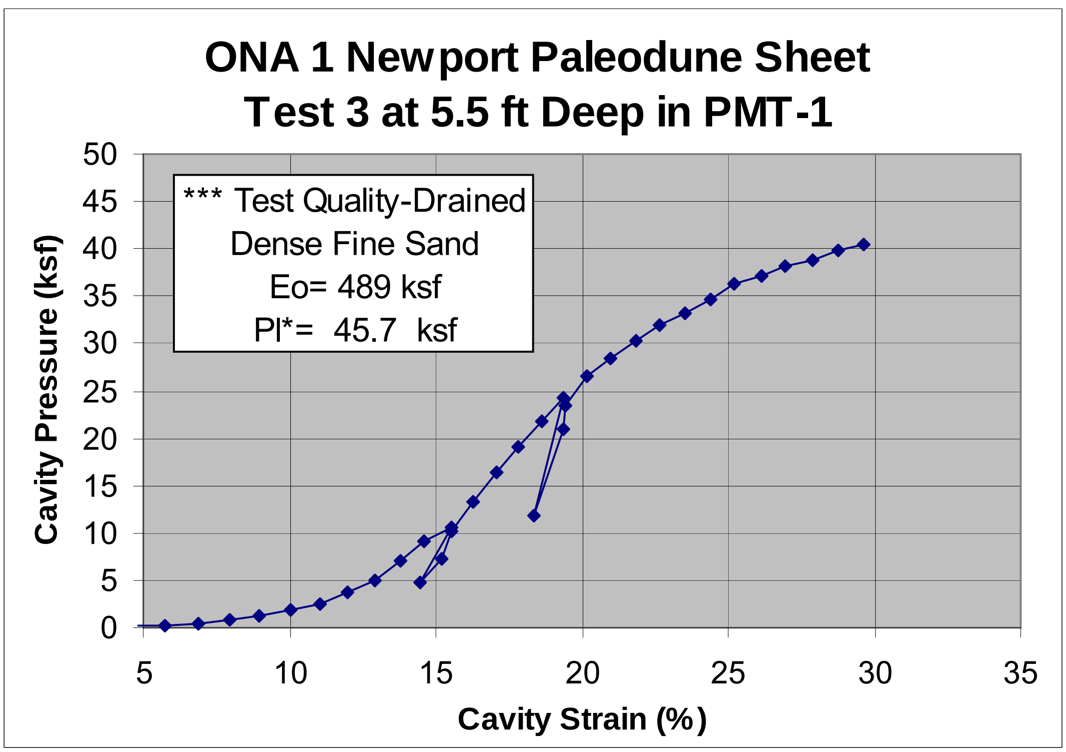


Figure 62: Example of a pressuremeter test conducted at Ona-1A. The two dips in curve are unload and reload cycles.

Borehole Data

Geotechnical drilling data was obtained from the Oregon Department of Transportation (ODOT) to supplement and expand the characterization of the paleodune deposits to other dune sheets. A total of 33 boring logs were reviewed from 14 geotechnical investigation sites located along the coastal plain of Oregon (Peterson et al., 2005). Summary of the boring logs are located in Appendix G. The paleodune soil horizons were interpreted from the boring log descriptions which reported the material type, depth, and standard penetration test (SPT) results (blow counts). The borehole data was differentiated by Holocene and Pleistocene dune deposits based on the soil log description and reported paleodune stratigraphy in nearby sites (Table 27). The Holocene dune deposits ranged in thickness from 2 to 14 meters and had an average thickness of 5 meters. The Pleistocene dune deposits ranged in thickness from 1 to 15 meters and had an average thickness of 5 meters.

ODOT BOREHOLE DATA	Holocene Dune	Pleistocene Dune
Number of Dune Type	17	20
Minimum Thickness (m)	2	1
Maximum Thickness (m)	14	15
Mean Thickness (m)	5	5
1 Std.Dev.	±3	±4

Table 27: Geotechnical borehole data from ODOT showing thickness of Holocene and Pleistocene dune deposits.

Standard penetration test blow counts (N) of individual paleodune soil horizons were identified from the boring logs (Table 28). The range in blow counts for the

Holocene dune deposits (HDC) ranged from 2 to 26 blows per foot (N) with an average N-value of 9. The range in blow counts for the Pleistocene dune sand (PDC) ranged from 8 to 100 blows per foot (N) with an average N-value of 44. The range in blow counts for the Pleistocene paleosol deposits (PDBg and PDBtj) ranged from 0 to 24 blows per foot (N) with an average N-value of 11. The range in blow counts for the Pleistocene dune sand (PDBw and PDCox) ranged from 69 to 100 blows per foot (N) with an average N-value of 84.

Description/Statistics	Holocene dune sand	Pleistocene dune sand	Pleistocene dune paleosol with loess	Pleistocene dune sand; cemented with iron oxide	Tertiary bedrock
USCS	SP	SP	SM	SP	
Soil Horizon	HDC	PDC	PDBg, PDBtj	PDBw, PDCox	T
Number of Tests	62	64	38	4	10
Minimum (N)	2	8	0	69	34
Maximum (N)	26	100	24	100	100
Mean (N)	9	44	11	84	81
1Std.Dev. (N)	±5	±28	±6	±16	±31
note: SPT (N) values greater than 100 blows per 12 inches are rounded to N=100 for statistical calculations.					

Table 28: Geotechnical borehole data from ODOT showing blow counts (N) for individual paleodune soil horizons.

Discussion

Sustainable development on the Central Oregon Coastal plain requires a thorough understanding foundation soils, cut slope stabilities, and subsurface drainage. The bedrock geology is well-established through work by Vokes et al. (1949), Baldwin (1956), Baldwin (1961), and Snavely (1976). DOGAMI Bulletin 81 (Schlicker et al., 1973) was the first comprehensive work to outline the geologic hazards and engineering geology issues for the coastal plain of Lincoln County, Oregon. In the previous literature, the authors show that the coastal plain is covered by Pleistocene surficial deposits. These deposits were combined together into a generic unit called "marine terrace deposits." The terrace deposits were not well-defined in terms of depositional environment, lithology, stratigraphy, thickness, or engineering properties. This study demonstrates that development on the coastal plain is generally built on the Pleistocene surficial deposits and not on the underlying bedrock or shoreface beach deposits. The results of this thesis show that the coastal plain is covered by a remnant Pleistocene dune sheet that extends from the beach to the Coast Range foothills and that the dune sheet is a separate unit from the marine terrace deposits. These Pleistocene dune strata vary in their geotechnical and geohydrologic properties. The generalized geotechnical characterizations of these dune strata are the focus of this project.

The setting of the Central Oregon coastal plain had a much different geomorphic appearance during the late Pleistocene (100 ka to 10 ka) than at present. The offshore continental shelf of Central Oregon is broad, flat, and wide, based on compiled geologic mapping by Peterson et al., (1986). Relative sea level curves indicate the mean sea level (MSL) fluctuated between 25 and 125 meters below current MSL as shown on Figure 63. The coast line of Central Oregon would have been 7 to 45 km west of the present shoreline, respectively (Figure 64). Low-stand sea level would have exposed a broad, flat shelf containing an abundant source of sand and silt for eolian transport and formation of a dune sheet during most of the late-Pleistocene.

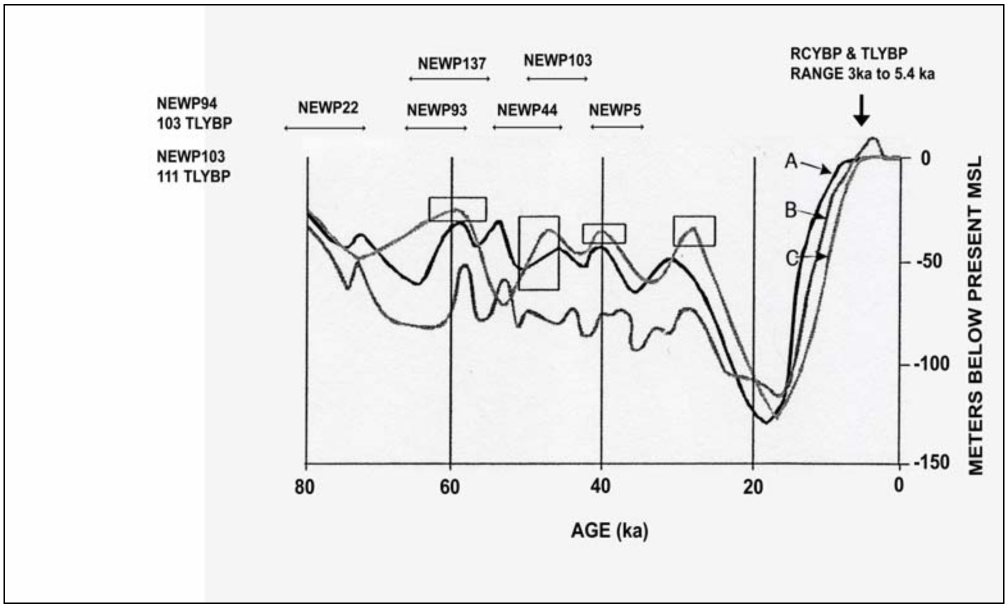


Figure 63: Eustatic sea level curves with respect to elevation for last 80 ka years BP. Line A is from Chappell and Shackleton (1986), line B is from Shackleton (1987), and line C is from Bloom and Yonekura (1985). Boxed areas are probable error ranges for age and height for line C. The C^{14} and TL dates have been added with their respective error bars (double arrow). Modified from Pirazzoli (1983).

The evidence for a large, preexisting dune sheet is found on the Central Coast of Oregon within the coastal plain, which includes the Newport Dune Sheet. Mapping of paleodune deposits for this thesis has shown that a remnant dune sheet mantles a majority of the coastal plain in the Newport area. The geographic boundaries of the Newport Dune sheet are the Pacific Ocean to the west, the Coast Range to the east, Cape Foulweather to the north, and Cape Perpetua to the south.

The maximum inland extent of the dune sheet is approximately 3 km east of the present shoreline (Figures 27,28, and 29). The dune sheet laps up onto the Coast Range foothills which act as physical and climatological barriers. The Coast Range receives a great deal of precipitation (~200 cm/yr) as western storm tracks come off the Pacific Ocean, dropping moisture as they cross over the Coast Range mountains. The combination of high precipitation, associated dense vegetation cover, and higher elevation of the foothills created a barrier to westerly dune sheet migration. At the end of the last glacial period (beginning 17 ka) the rise in sea level resulted in a transgression across the continental shelf and sea cliff erosion back to present coastline (Figure 64).

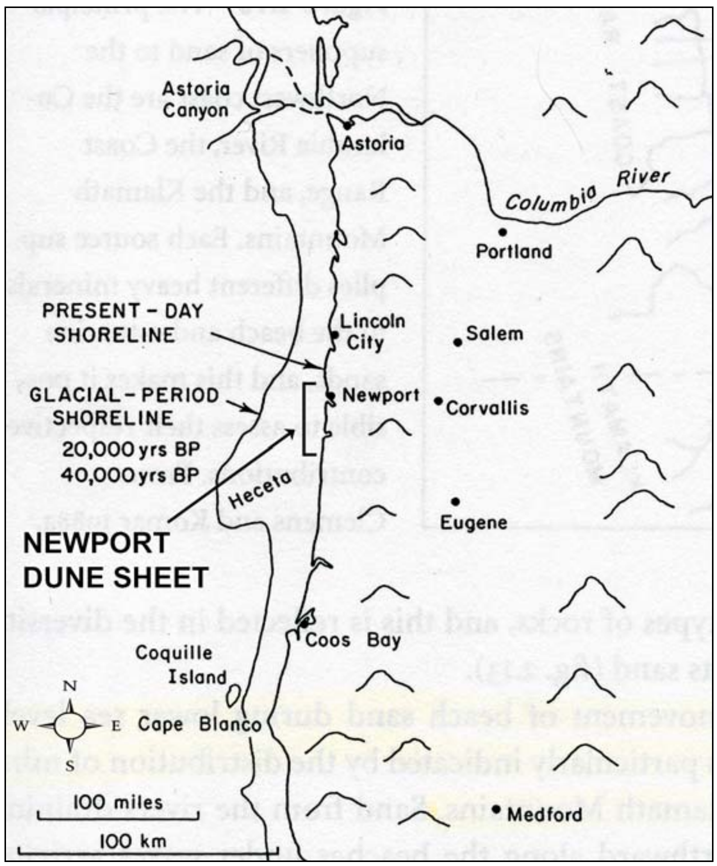


Figure 64: Figure showing location of Newport Dune Sheet relative to exposed continental shelf during low-stand sea level (20 ka). Modified from Komar (1997).

The widest area of the remnant Newport Dune Sheet corresponds to a stretch of terraced coastline between remnant basaltic headlands at Cape Foulweather and Cape

Perpetua. The dune sheet is characterized by a series of transects, one transect running north to south, and 4 transects running west to east. The transects cross mapped paleodune profiles that show lateral and vertical sequences of lithologies that correspond to distinct depositional or erosional conditions (facies) that occurred during the episodic deposition of a dune sheet.

Paleodune Stratigraphy and Geomorphology

The paleodune deposits contain two general facies consisting of sand dune strata (dune facies) and paleosol strata (paleosol facies). The dune facies is depicted as a tan to red-brown, fine, uniformly-graded (well-sorted), subangular to subrounded sand containing less than 5% fines (C and Cox horizons). The dune facies contains eolian dune cross-bedding, massive to laminated bedding, and/or truncated strata. The dune facies bedding average 1.35 meters in thickness, but is found in zones up to 10 meters thick.

The paleosol facies is depicted as a brown to light gray sandy silt to silty fine sand containing more than 40% fines and commonly contains trace carbonized organics and wood fragments. These paleosols are roughly divided into two categories based on soil accumulation horizons (ie. oxidative Bw/Btj horizons and reductive Bg horizons). Some paleosols have preserved organic layers and peat. The paleosol facies varies from Bg flat-lying planar beds, traceable to more than 100 meters laterally, to concave and convex Bw/Btj horizons that are discontinuous (Figure 65).

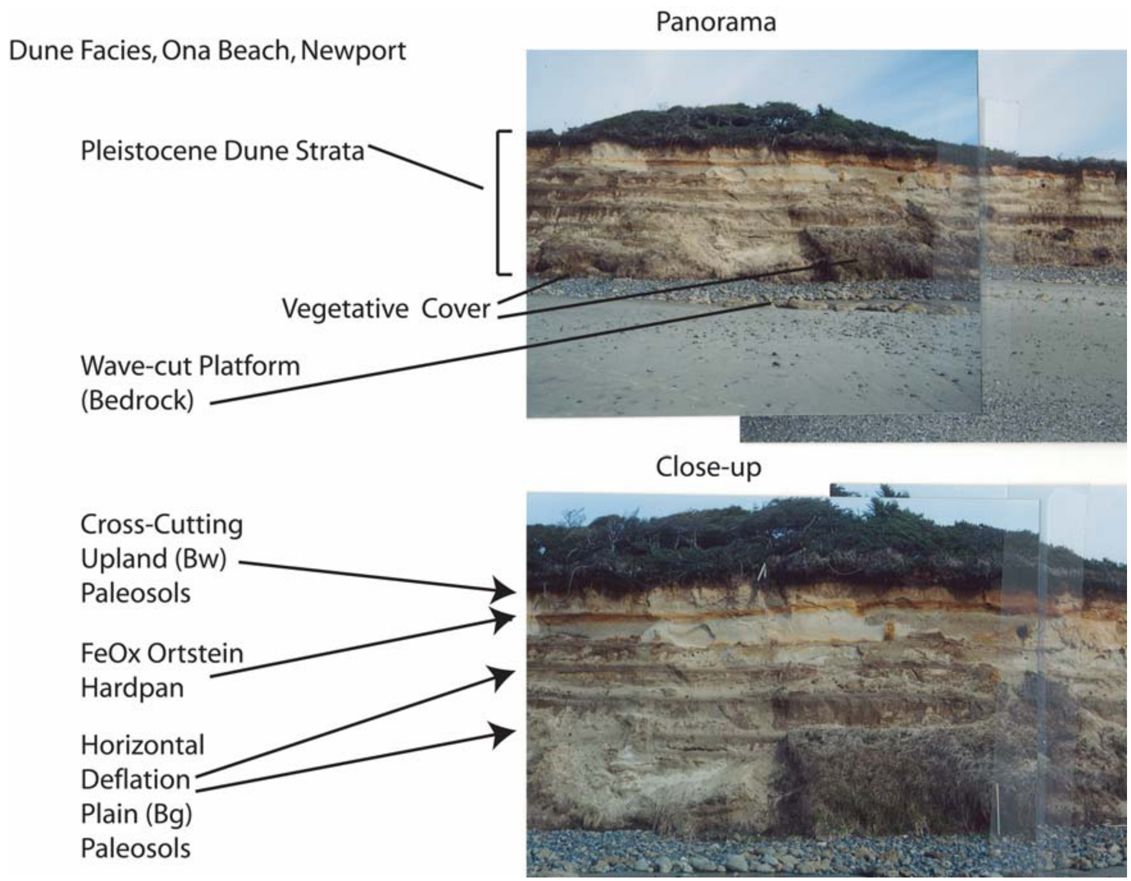


Figure 65: Annotated photos of Ona Beach sea cliff showing deflation plain (Bg horizons) underlying thicker dune sand layers (top) containing a hard pan.

The sea cliff exposures provided the best stratigraphic view of the Newport Dune Sheet. The north-south transect (Figure 67) runs parallel to the beach and shows relative thicknesses of paleodune deposits that form the sea cliffs. Paleodune coverage is continuous from Cape Foulweather south to Cape Perpetua. The paleodune deposits have the greatest thickness near the middle of the dune sheet and progressively thin towards the north and south headland boundaries. Often the paleodune deposits were in contact with the marine terrace deposits (beach sand, cobble gravel, and peat horizons) and the wave-cut Tertiary bedrock.

Early results of the sea cliff exposure mapping demonstrated two different morphostratigraphic relations in the Newport Dune Sheet. Specifically, the higher elevation (> 10m MSL) dune paleosols were oxidative (Bw) and frequently inclined, cross-cut, and discontinuous. By comparison, the lower elevation paleosols (< 10m MSL) were reductive (Bg) and were generally horizontal and continuous out 10s to 100s of meters. (Figure 66).

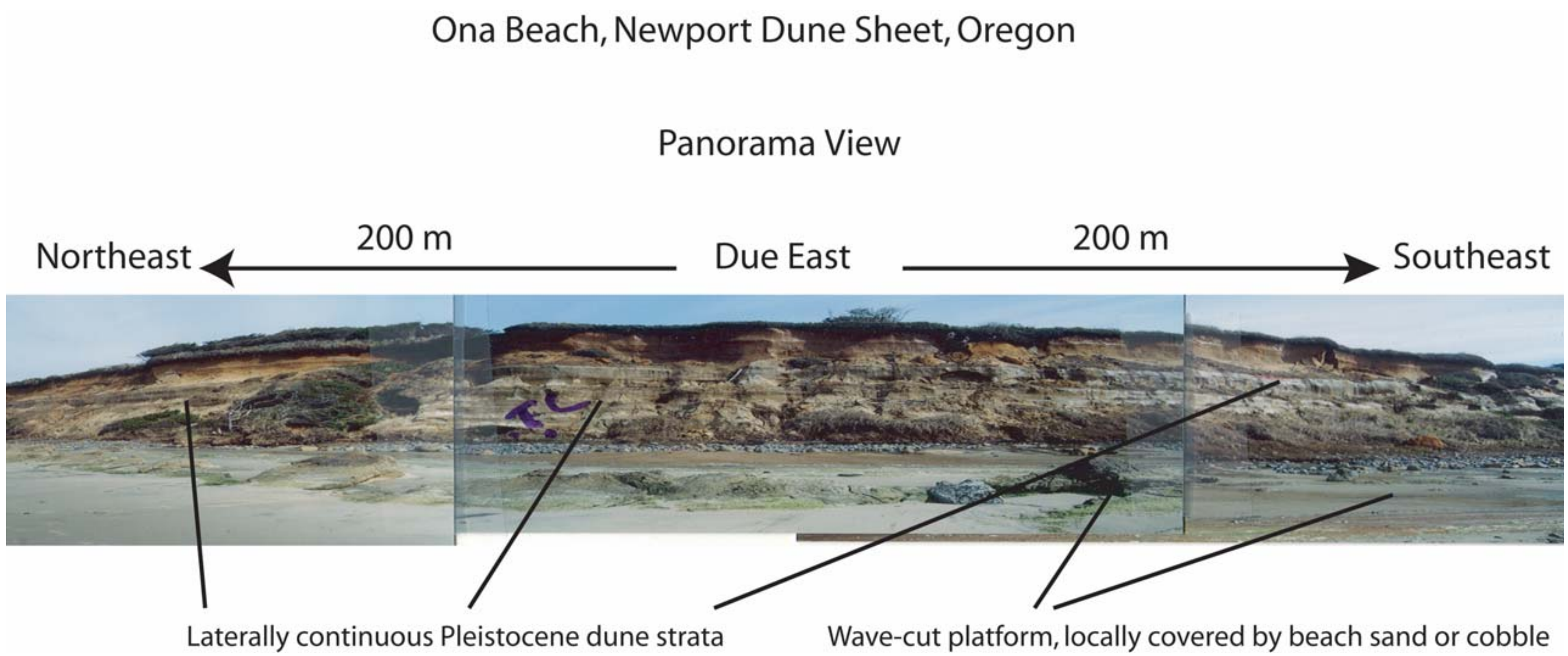


Figure 66: Panorama view of Ona Beach sea cliff showing lateral extent of paleodune strata.

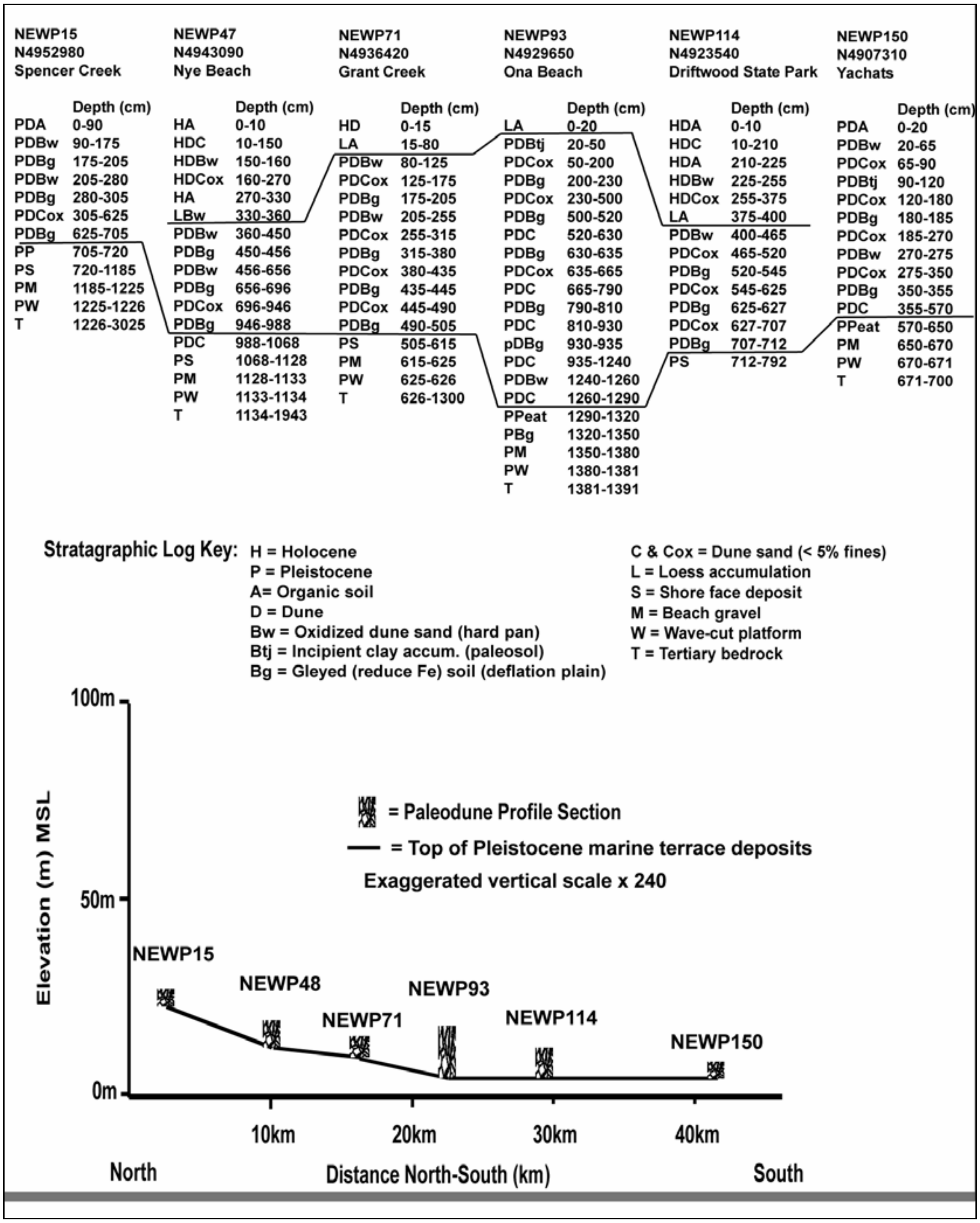


Figure 67: North to south transect across the Newport Dune Sheet running parallel to the sea cliffs.

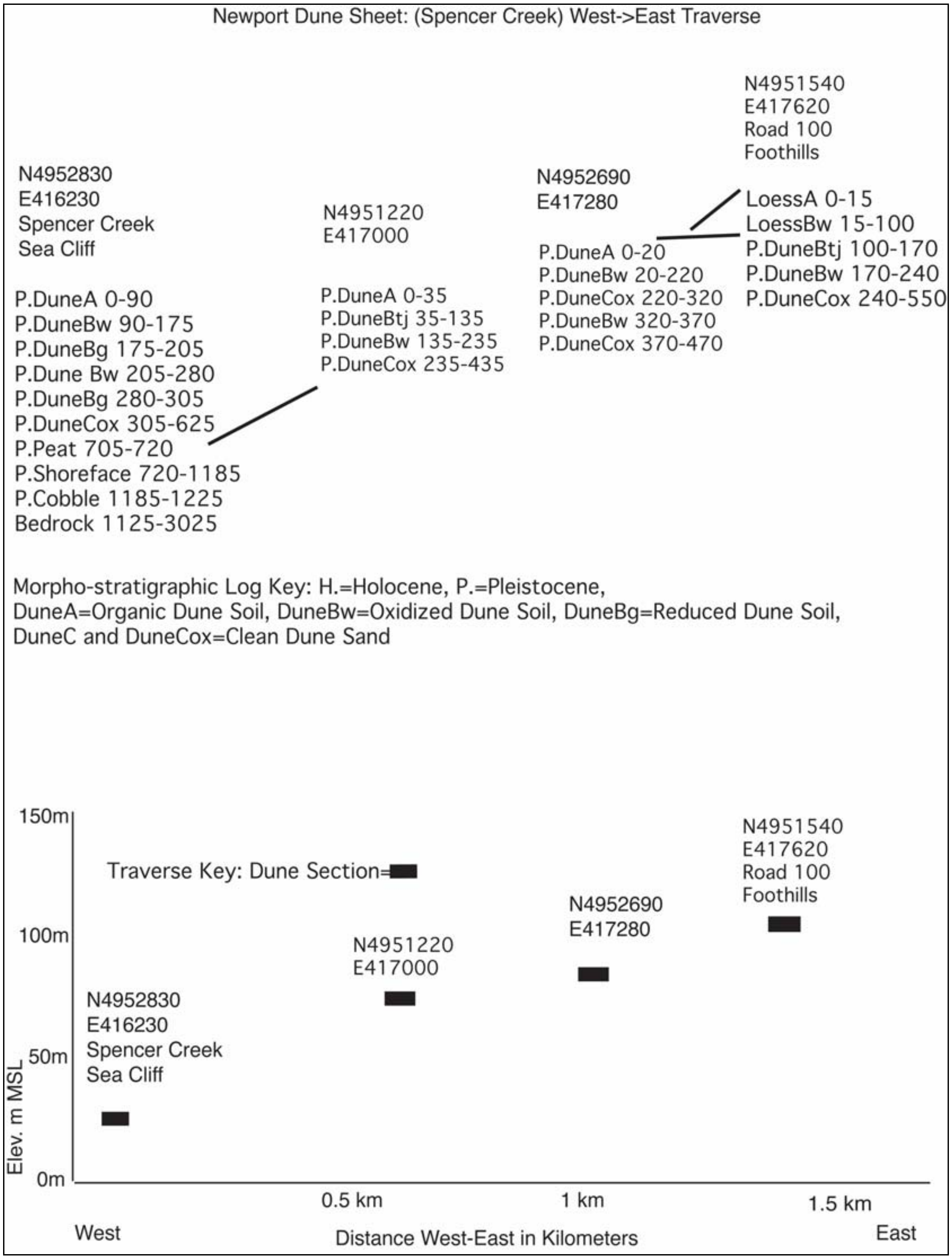


Figure 68: East to west traverse across the Newport Dune Sheet at Spencer Creek site.

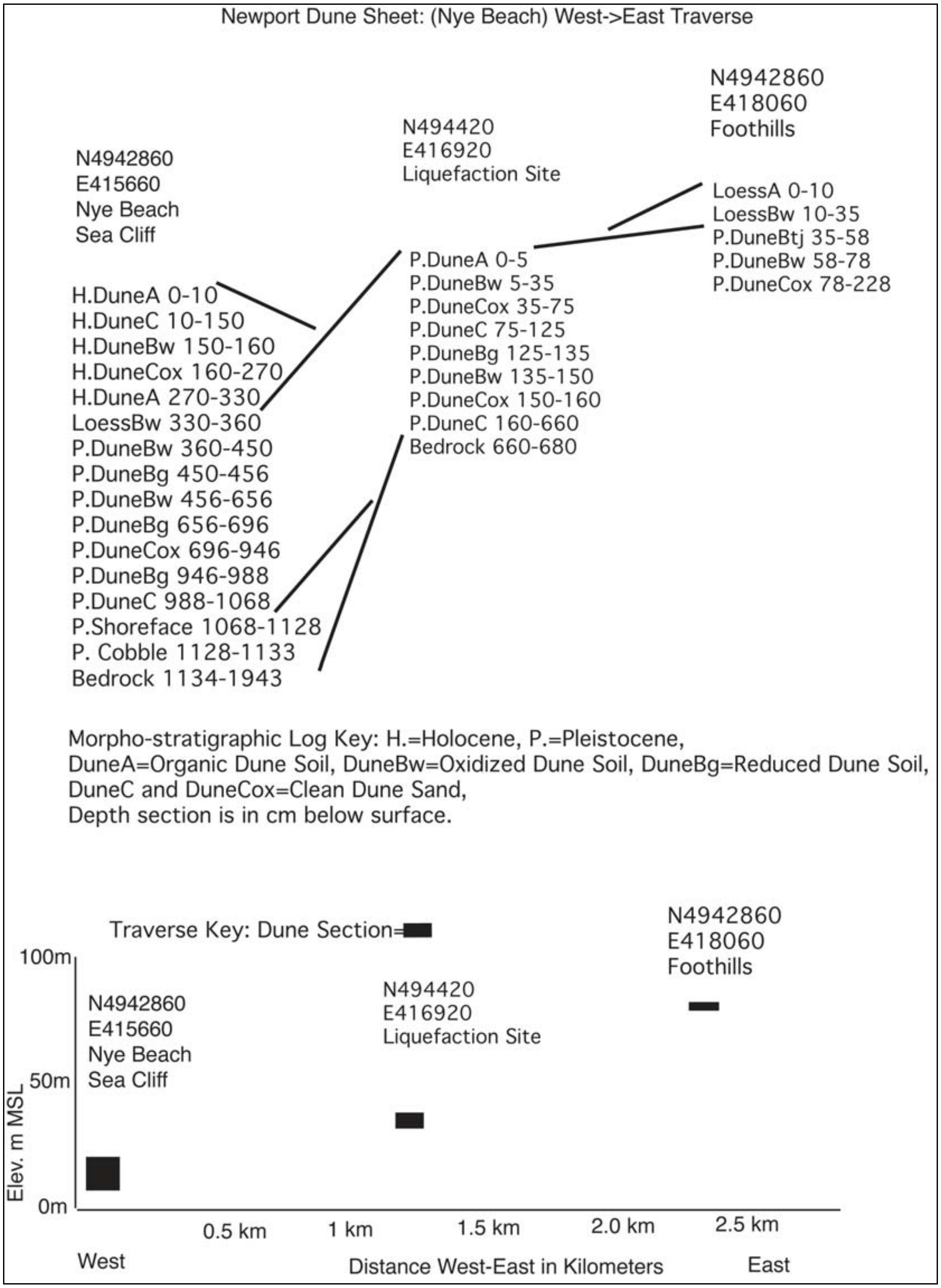


Figure 69: East to west traverse across the Newport Dune Sheet at Nye Beach site.

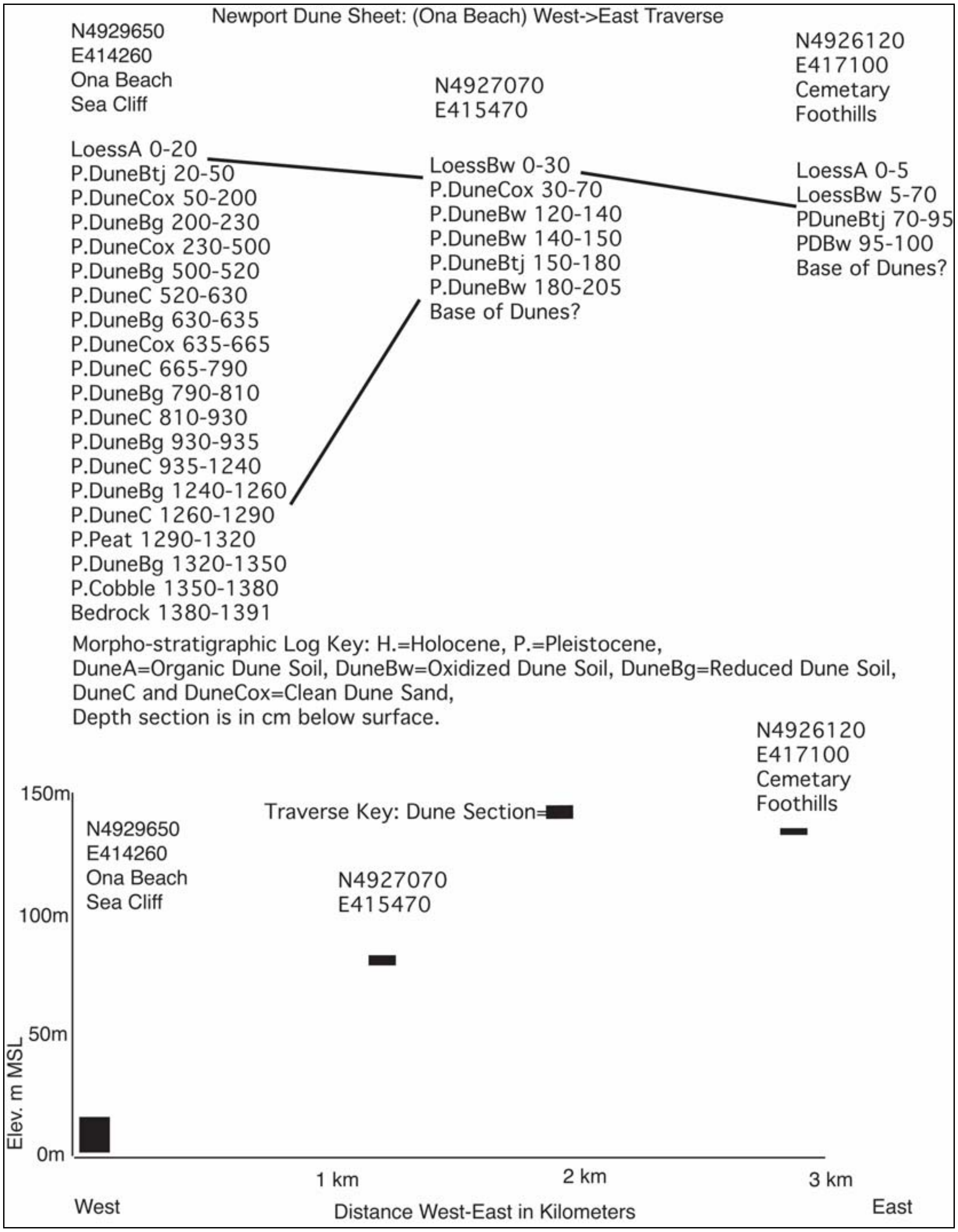


Figure 70: East to west traverse across the Newport Dune Sheet at Ona Beach site.

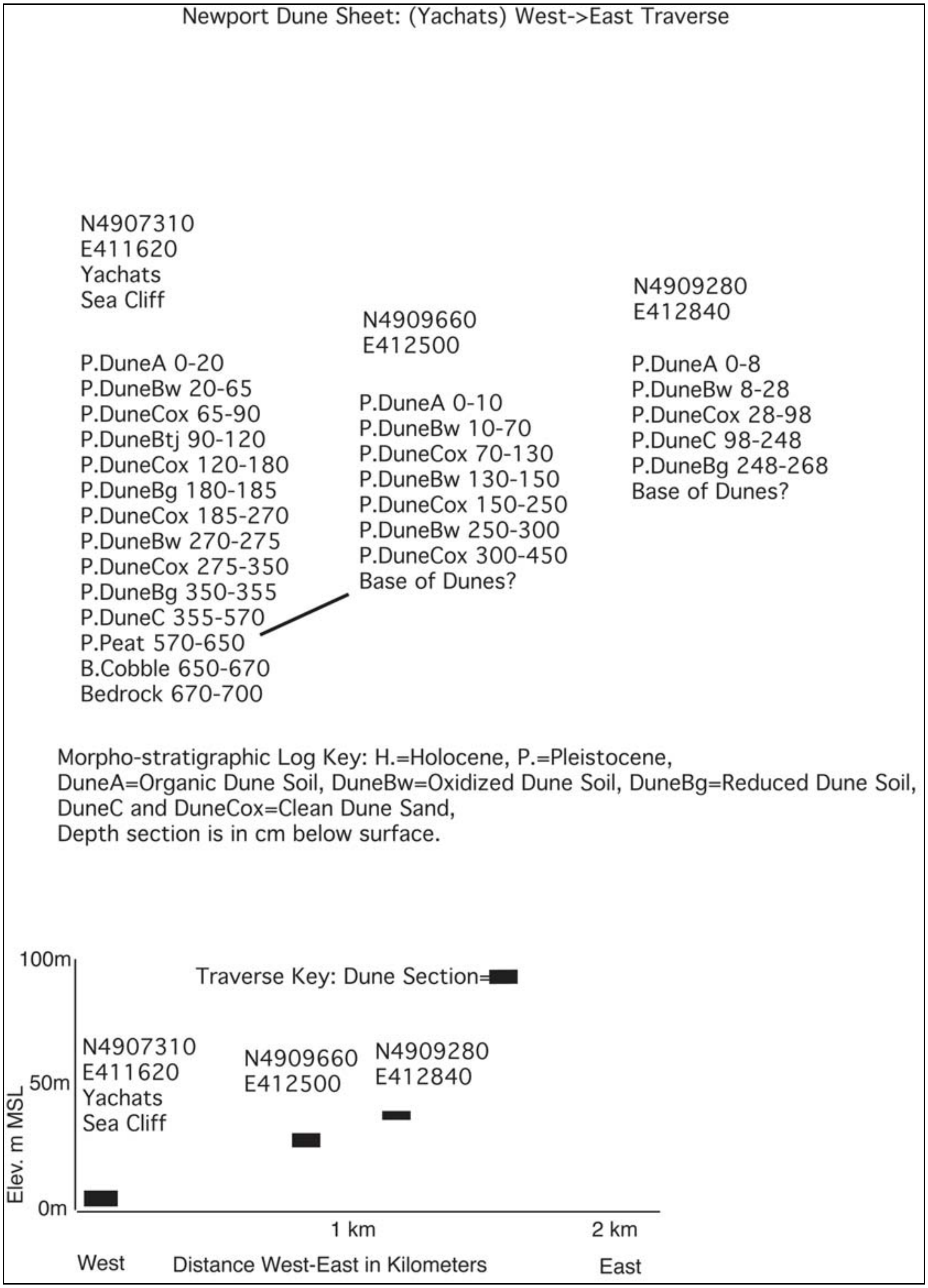


Figure 71: East to west traverse across the Newport Dune Sheet at Yachats site.

The west to east transects (Figures 68-71) show the paleodune deposits climbing in elevation to the east, but also thinning until the deposits pinch-cut with bedrock or bedrock regolith. A majority of the paleodune profiles mapped east of the sea cliffs (road cuts) do not show the base of the paleodune deposits so they are considered to represent minimum dune sheet thicknesses.

The sea cliff exposures typically contain flat-lying paleosols that are interbedded with dense dune sand near the lower portions of the profiles (Figure 72). This strata sequence is interpreted to be the result of formation of paleosols in deflation plains that are controlled by groundwater table during dune sheet mobilization. The strata type changes with an increase in elevation to yield dune facies with discontinuous, and concave or convex bedding. The implications of variable geotechnical behavior between relatively uniform interbedded deposits and discontinuous concave or convex bedding is obvious. Understanding the complex geomorphology of the paleodune deposits as well as the geotechnical behavior of the soil units will help to properly characterize a site for development.

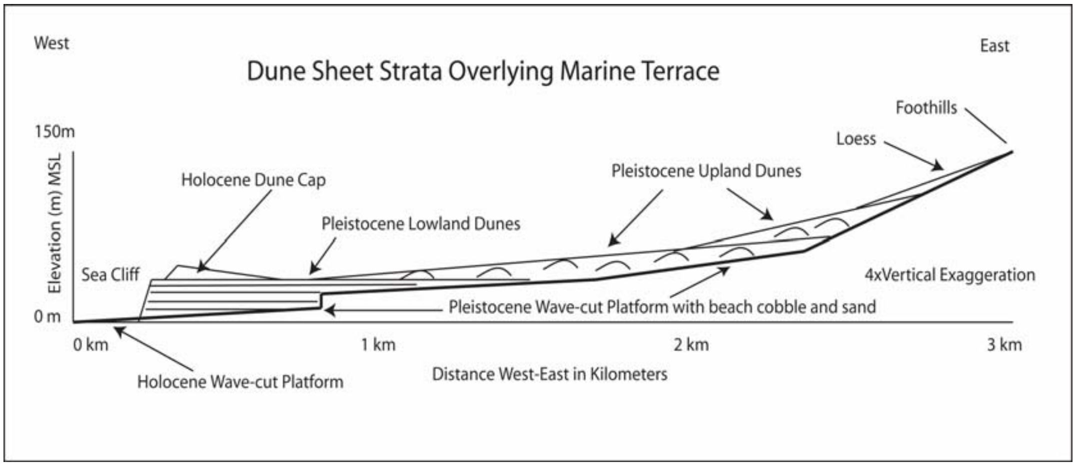


Figure 72: Generalized profile of the Newport Dune Sheet stratigraphy showing a transition of horizontal, flat-lying deflation plain sequences at the sea cliff to discontinuous, concave and convex upland dune sequences.

Changing climate and vegetation have likely influenced the formation of the deflation plains along the Central Oregon Coastal Plain. During much of the latest Pleistocene (last 40 ka), the Oregon Coast was drier and more sparsely vegetated than at present (Worona and Whitlock, 1995). These conditions permitted sand plains to migrate across the exposed continental shelf. Deflation plains are the result of the lateral migration of dune sand and the stripping of sand down to the local groundwater surface. (Kocurek, 1992) The proximity of the groundwater to the surface promotes vegetation growth and stabilized soil formation. Carbonized organics, root casts, and peat are often associated with deflation plain deposits indicating past vegetation. Deflation plains generally conform to the top of the groundwater surface and are flat-lying. The process of weathering and influx of silt and clay fines on to the deflation plain due to eolian processes (loess) incorporate fine particles into the uniform sand deposits. Over time soil formation creates silty (Bg) horizons that are nearly horizontal and fairly continuous. Conditions that are favorable for sand mobilization (strong wind, dry climate, and available sand supply) will both erode preexisting dunes and bury preexisting landforms. If sand supply is low, wind is high, and groundwater is low, then the dune sheet will deflate, resulting in a high occurrence of truncated dune and deflation plain surfaces.

The dune facies found above the deflation plains are interpreted to be an influx of dune sand that covered the previous deposits. Over time the buried deflation plain soil will consolidate due to overburden pressure and become a low permeable layer. Locally, groundwater will perch within the dune sand overlying the previous deflation plain paleosols. Subsequent wind erosion of the overlying dune will form a new deflation plain at the higher groundwater elevation. This creates a vertical succession of interbedded dune sand and paleosol/deflation plain layers. The flat-lying deflation plains reflect paleo-groundwater surfaces. The implications of the existence of zones within the paleodune strata that concentrate groundwater are important for both slope stability and drainage issues.

As previously noted, the flat lying Bg paleosols (deflation plain strata) grade up section and with distance into upland dune strata dominated by discontinuous Bw and Btj horizons. The higher elevations of the upland dunes place the episodically stabilized dune surfaces well above groundwater surfaces. These dune surfaces are well-drained, seasonally oxidative, and are susceptible to blow-outs. Filling of the blow-out truncations leads to the discontinuous nature of the inclined dune form (Bw) paleosols. As the dune sheet aggrades vertically, in ramps against the foothills, the corresponding sand strata are increasingly interbedded with the irregular, discontinuous, inclined Bw horizons.

The Pleistocene dune deposits were locally capped by Holocene dune deposits that had formed ramps from the late-Holocene beach platforms to the tops of the sea cliffs. The Holocene dunes were differentiated from the older deposits based on stratigraphic position, degree of soil formation, lack of cementation, and relative strength. The Holocene dunes mantled the older deposits and typically exhibited thin, poorly developed soil profiles compare to the Pleistocene dune soils (Figure 73). The Holocene dune deposits generally lacked cementation and exhibited low strength when tested with a pocket penetrometer. Exceptions to this general rule occur at the base of the Holocene dune caps where oxidative groundwater precipitated iron-oxide in Ortstein layers. Penetrometer readings for the Holocene sand layers averaged 1.3 kg/m^2 where the Pleistocene sand layers averaged 3.4 kg/m^2. Recall that pocket Penetrometer readings are used to compare relative cementation values.

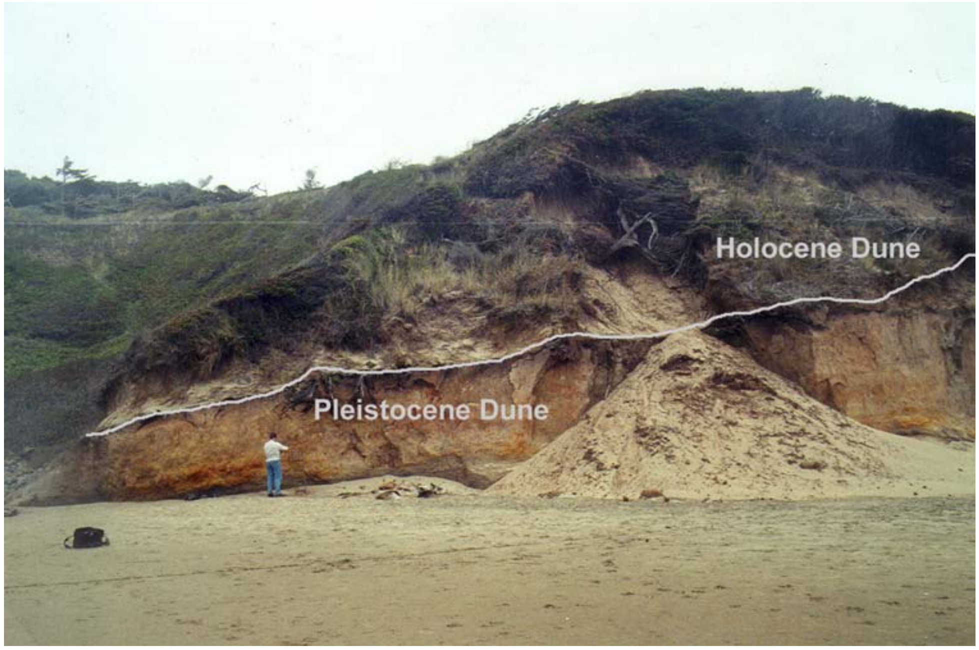


Figure 73: Photo of Holocene dune paleosol with a Bw horizon overlying a Cox horizon.

Groundwater Model and Cemented Deposits

The interaction of vegetation, weathering, and soil formation all influence redox conditions in the shallow groundwater. The redox conditions control the precipitation of dissolutions of some cements. Specifically, oxygenated groundwater (high-redox) precipitates goethite and other iron oxides in shallow dune strata. (Figure 74). The precipitation and concentration of the reddish iron oxides results in Ortstein layers. In contrast, deeper groundwater flows below the influence of the shallow oxidative zone. At these depths microsoil respiration of dissolved organics lowers the oxygen content of the groundwater. The low redox state of the deeper groundwater converts Fe^{+++} to Fe^{++}, thereby destabilizing and dissolving the amount of iron oxide cements (Baham, personal communication, 2005). Sand strata leached of cement are observed at the base of many Pleistocene dune sections as illustrated on the model (Figure 74).

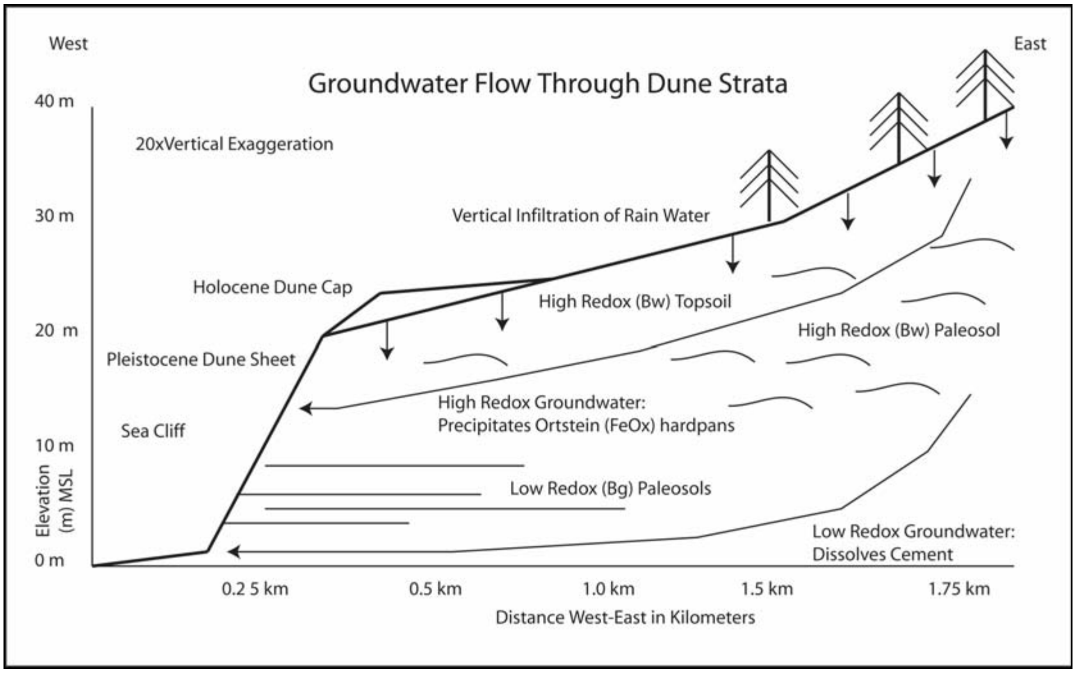


Figure 74: Illustration of groundwater flow model showing possible high and low redox conditions throughout the paleodune strata.

Surface water and groundwater can easily penetrate and flow through permeable dune sand. Weathering and soil formation processes leach chemicals and minerals from the dune sand. The parent mineralogy of the dune sand found on the Central Oregon Coast (Beckstrand, 2001; Peterson et al., 1991) in turn creates hydrous oxides of aluminum and iron silicate clay minerals. The clay minerals form both crystalline and amorphous Fe, Al, and Si products that act as cementing agents in the paleodune deposits (Figure 57 and Figure 58). The clay minerals identified using X-ray diffraction (XRD) techniques include gibbsite, vermiculite, allophane, imogolite, and ferrihydrite. A scanning electron microscope (SEM) was used to identify the amorphous phases (allophane, imogolite, and ferrihydrite) coating and cementing the sand grains in the B and C horizons of the paleodune deposits (Grathoff et al., 2003).

Geotechnical Parameters

The geologic model, outlined above, demonstrates the formation and structure of the deposits of the Newport Dune Sheet. A common observation is that the sea cliffs and road cuts are primarily composed of weakly cemented dune sand. The typical range of angle of repose for a uniform, fine sand is 27-37°. General visual observations made of existing road cut and sea cliff slope angles indicate that slopes are apparently temporarily stable at angles greater than 40°, and locally 45 to 80 degrees. These higher slope angles are apparently temporarily stabilized by cementing of paleosols (Figure 75) and/or iron oxide layers. In contrast, leaching of some sand layers could produce weaker strata. This result implies that the strength of the materials at the base of the slope is gradually reduced. Over time this may result in significant reduction in the stability of the slope.

Undisturbed and bulk soil samples were collected of representative paleodune layers to determine laboratory soil index and strength parameters. Index parameters included USCS classification, grain size, dry density, plasticity index, specific gravity, void ratio, porosity, degree of saturation, and permeability.

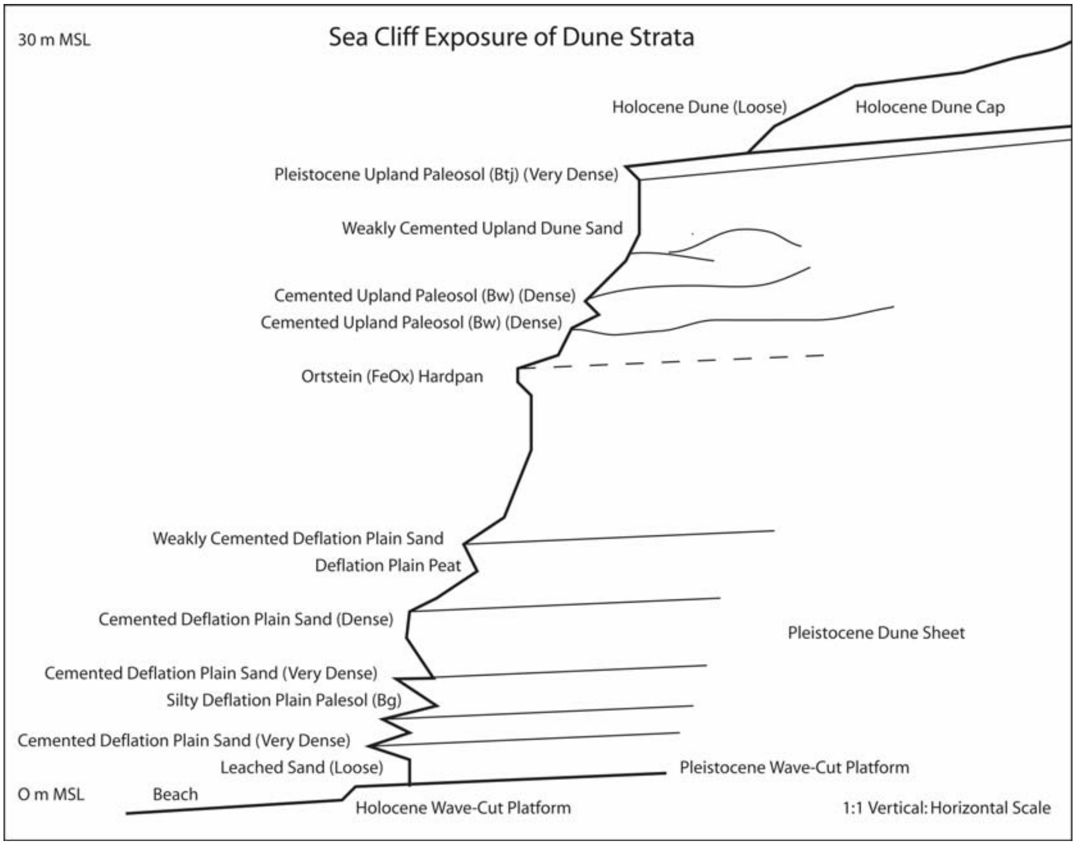


Figure 75: Sea cliff model of paleodune strata.

Grain size analysis indicated a clear distinction between the amount of fines (<0.075mm) in the dune facies samples (0.7% average) and the paleosol facies. The dune strata facies samples consisted of a fine, uniformly-graded (well-sorted) sand. The paleodune facies samples consisted of a well-graded (poorly-sorted) fine silty sand/sandy silt. Several of the samples that contained heavy Fe-staining and cementation contained cemented clasts of fine sand that did not break down during the wash process. However, the clasts completely disaggregated into individual sand particles after oven drying and sieving, indicating their cohesion resulted from unstable cement.

The USCS classification (ASTM D2488) was performed only on the laboratory tested samples. In general, the dune facies samples classified as a poorly graded sand (SP) and the paleosol facies samples classified as a silty sand (SM). One paleosol sample classified as an elastic silt (MH). Based on observation, the paleodune deposits are more variable (ie. grain dissaggradation) than what the USCS classification system determines or allows. Further, the USCS system may not adequately reflect the actual behavior of the materials.

Permeability testing was conducted on undisturbed paleodune samples and is summarized in the Results section. The test results indicate the paleodune deposits have lower permeability values than expected for dune sand (see Results Section). Low permeability values are caused either by tight packing of particles or filling of the pore space between particles with gels or cement-type materials (ie. loess).

Direct shear and Triaxial strength tests were performed on twelve sets of samples collected from the geotechnical investigation sites. The sample layers selected included eight dune facies layers and four paleosol facies layers. The strength test results are summarized in Table 29.

Paleodune Sand Layers - DUNE FACIES

Sample Site	Field Description	Direct Shear ϕ'_p (degrees)	Direct Shear c' psf (kPa)	Triax ϕ'_r (degrees)	Triax ϕ'_p (degrees)	Triax c'_r psf (kPa)	Triax c'_p psf (kPa)
Woah-2	Tan, fine sand (SP)	*43*	0	28.8	30.7	55 (2.6)	217 (10.4)
Woah-4	Red-brown fine sand (SP)	*37*	124 (5.9)	29.6	29.3	84 (4.0)	525 (25.1)
Ona-1A	Tan to red-brown fine sand (SP)	*40*	236 (11.3)	-	-	-	-
Ona-B	Tan, fine sand (SP)	*35*	384 (18.4)	30	32	0	108 (5.2)
Ona-C	Tan, fine sand (SP)	*20*	*1343 (64.3)*	33	38	0	0
Pine-2	Red-brown fine sand (SP)	*42.6*	270 (12.9)	-	-	-	-
Pine-3	Tan, fine sand (SP)	*42*	335 (16.0)	-	-	-	-
Pine-5	Light brown fine sand (SP)	*20.5*	*568 (27.2)*	18	21	*178 (8.5)*	*0*

Paleosol/deflation Plain Layers - PALEOSOL FACIES

Sample Site	Field Description	Direct Shear ϕ'_p (degrees)	Direct Shear c' psf (kPa)	Triax ϕ'_r (degrees)	Triax ϕ'_p (degrees)	Triax c'_r psf (kPa)	Triax c'_p psf (kPa)
Woah-1	Gray, silty fine sand (SM)	37	248 (11.9)	28.6	29.4	181 (8.7)	383 (18.3)
Woah-3	Gray, silty fine sand (SM)	36	519 (24.8)	25.4	27	1207 (57.8)	1016 (48.6)
Pine-4	Orange-brown, silty fine sand (SM)	36	568 (27.2)	36.5	36.1	0	0
Pine-6	Light gray, sandy silt (MH)	-	-	32.7	34.5	0	0

Table 29: Comparison of direct shear and triaxial strength testing of geotechnical samples. Note: 1 kPa = 20.8854 psf.

Generalized plots, modeled after Budhu (2000), are summarized in Figure 76. These plots show typical behavior of different soil types to shearing force. Loose sands and normally consolidated and lightly over-consolidated clays (Type I soils) show a gradual increase in shear stress, with increase in shear strain, until no change is recorded (ultimate or residual strength, Figure 76a). Type I soils will compress (positive volume change), until a critical void ratio is reached (Figure 76b). Dense sands and heavily over-consolidated clays (Type II soils) show a rapid increase in shear stress to a peak value (peak stress) at low strain, followed by a decrease in shear stress, until no change in stress with increasing strain is measured (ultimate or residual strength). Type II soils will initially compress, and then expand (negative volume change), until a critical void ratio is reached (Figure 76b).

The direct shear angle of internal friction (phi) ranged from 20° to 43° for the dune facies and ranged from 36° to 37° for the Paleosol facies. The cohesion (c) ranged from 0 to 1,343 psf for the dune facies and ranged from 248 psf to 568 psf for the paleosol facies. The direct shear tests behaved as dense soils, based on the spikes recorded on the stress-strain plots (Summers, 2005). A portion of the peak may be related to cementation.

Work published by Clough (1981) on consolidated drained (CD) triaxial testing and Saxena and Lastrico (1978) on consolidated undrained (CU) triaxial testing, indicate that cemented behavior can be determined from specific test results. CD triaxial testing by Clough (1981) and CU triaxial testing by Saxena and Lastrico

(1978) on cemented sands indicate that cemented behavior can be recognized in test results as follows:

- Peak strength increases with degree of cementation
- The strain at peak strength decreases with the degree of cementation
- Volume increase during shear is concentrated over a smaller strain range
- Failure mode for weakly cemented sand is brittle at low confining pressures
- Cemented sands with a significant percent fines (<0.075mm) content were stronger than samples with a small proportion of fines

Cemented behavior can be recognized in CU triaxial testing based on the following behavior (Saxena and Lastrico, 1978):

- Pore water peaks within 1% strain and then decreases
- Cementation creates an “apparent” high density behavior
- Higher strengths can occur at lower confining pressures compared to same samples at higher confining pressures

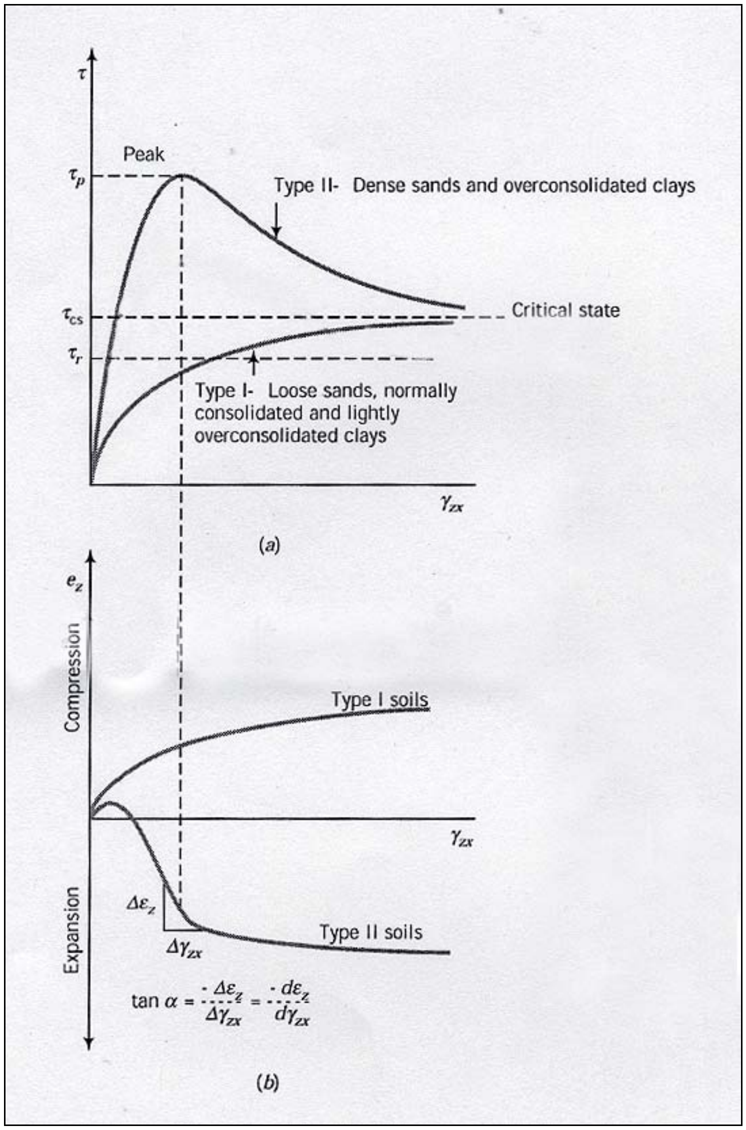


Figure 76: Generalized stress/strain plot (a) and volumetric strain plot (b) for different soil types. Modified from Budhu (2000).

The paleodune samples were run in CU and CD conditions at low confining stress in an effort to detect the above effects. Consolidated drained triaxial test result plots indicate that the dune facies samples exhibited dilation during shearing at low strain levels. The stress-strain plots show a peak in the deviator stress at low strain followed by a drop in stress as strain is increased (See Results section). The peak strength indicates that the soil particles are either densely packed and/or cemented and must overcome a peak shear stress prior to moving past one another. Negative volumetric strain is indicative of an increase in sample volume as the soil particles move away from each other during shearing as a result of an initial dense packing (Lambe and Whitman, 1969).

The paleodune samples tested in triaxial conditions in most cases exhibit unusually high negative pore water pressure (CU testing), or negative volume strain (CD testing) as a result of sample dilation. The occurrence of sample dilation during triaxial shearing is interpreted to be a result of the effects of weak cementation of the particles. During shearing of the sample, the material deforms elastically at low strain until the stress levels exceed the strength of the weak cement holding the particles together (as shown in Figure 51). At this point (peak strength) one or more fractures form within the sample and dilation occurs as the cracks move past each other and fractures expand as strain increases (Yamamuro, personal communication, 2005). Examples of similar exaggerated behavior is found in the literature for dense or potentially cemented sands (Clough et al., 1981; Saxena and Lastrico, 1978).

Previous work published in the literature, has typically tested sand under drained conditions with no measure or attention paid to pore water pressure. However, with the capabilities of the GeoComp apparatus a detailed record of the change in pore pressure and volumetric strain can be recorded. In drained testing, typically, the samples are not back-pressure saturated in drained compression. The pore space is open to the atmosphere and volume changes are not measured. For this study, the samples are back-pressure saturated and the GeoComp computer ‘micro-stepping pumps’ maintain zero pore pressure by precisely pumping water into and out of the sample. Similarly with undrained testing, high negative pore pressures can be generated by the ‘micro-stepping pumps’ allowing exactly no volume change in real time during the test. It appears, therefore that in this study the ability to precisely control the conditions within the pore space of the sample has illuminated behaviors which were previously difficult to detect in all but the most sophisticated and properly operated equipment.

The next question would be what is generating those extreme pressures or volume changes. Typical dense sand does not respond with negative pressures of the magnitude noted above. Therefore it must be some other phenomenon, possibly light cementation which was heretofore undetectable by older testing methods and apparatus. The hydraulic conductivity results of the paleodune samples tested in this study also supports the presence of weak cementation. The overall conductivity levels observed in the samples tested were lower than expected for a typical eolian sand deposit (Tables 18 and 19). The results of XRD, EDX, and SEM analysis has shown that the paleodune sand grains contain cementation consisting of poorly crystalline to amorphous minerals of gibbsite, vermiculite, allophane, imogolite, and ferrihydrite. These minerals act as a weak cement to bond particles and also reduce the permeability of the deposits by coating the particles and filling pore space in the sand matrix. Ortstein layers (iron oxide hard pans) are known for having very low permeability characteristics. Further research and significant additional testing, along with more sophisticated sampling methods would be required to confirm these suspicions.

Issues not considered but needing further work:

- The stability of the paleodune deposits is important for providing sustainable development on the Central Oregon Coastal plain. The majority of the observed slope failures are classified as slumps, block topples, or wedge failures. Slope failures were observed in road cut and sea cliff exposures, however detailing the total number and areal extent of slope failures in paleodune deposits on the coastal plain was beyond the scope of this thesis project. At some point, the failure(s) should be mapped relative to the improvement(s) that may be affected.

- A risk matrix related to development on the dunes such as: shallow versus deep foundations for major structures; steep versus shallow cuts for grading. This may be further developed by suggesting type, spacing, and depth of explorations for various developments.

- Further interpretive information regarding paleodune structure, for instance, sand materials seem to be loose on the lee side of the dune and dense on the windward side. Is the relative size (thickness) of the dune strata relative to slope stability hazards?

- Further investigate the response to seismic shaking relative to the presence of cement content within the soil structure. This would be accomplished by specialized sampling and testing using a cyclic triaxial apparatus.

Conclusions

Paleodune deposits are unique geotechnical materials in that the method of formation does not fall into the typical soil formation process that is commonly understood from a geotechnical standpoint. Typical soil formation processes involve weathering of in-place bedrock (residual soil) or soil formation from colluvial or alluvial processes. The formational history of paleodune deposits most likely can be defined as a series of alternating deposition and erosion sequences. The paleodune deposits appear to be formed as a result of optimal climactic conditions (cool and dry) and geographic location (broad continental shelf) with an abundant sand supply. These conditions are not unique to the Central Oregon Coast and therefore paleodune deposits are likely widespread at least on the West Coast region and on other continents having similar geography, climate, and sand supply. The implications are that most significant developments occur in coastal areas within a few kilometers of the existing shoreline as indicated in this study.

The Central Oregon Coastal Plain is covered by paleodune deposits that comprise the Newport Dune Sheet. The Newport Dune Sheet is a remnant of a large dune sheet that existed on the continental shelf during the late Pleistocene. It is postulated that during low-stand sea level the Newport Dune Sheet probably spread along the coastline to the north and south and combined with adjacent dune sheets. The paleodune deposits were previously mapped as Pleistocene marine terrace deposits. (Schlicker et al, 1973). This study changes the previous conception of the coastal plain based on the following major findings regarding:

- The need for practitioners in the private and public sector to understand the complexity of the dune sheet system and to properly and safely construct within the dune sheet area.

- The presence of a significant percentage of weak cements within the soil matrix of the paleodune deposits add to the variability and significantly affect the behavior of the deposits for slope stability and foundation design.

- From groundtruth mapping, the paleodune deposits are shown to have continuous coverage over the Central Oregon Coast Plain from Cape Foulweather (northern boundary) to Cape Perpetua (southern boundary), and from the ocean sea cliffs east to the Coast Range foothills. The average thickness of the Pleistocene dune deposits (approximately 5 to 10 meters) extends beyond the maximum construction depths in many sites.

- The Pleistocene dune strata was observed to have a brittle nature likely caused by a combination of consolidation over time, dense packing of sand grains, and varying cementation.

- The paleodune deposits consist of interbedded dune sand facies and paleosol facies. The paleosol facies can be separated into upland (Bw horizon) facies and flat-lying deflation plain (Bg horizon) facies.

- Direct shear and triaxial testing of paleodune samples report the angle of internal friction (phi) ranging from 20 to 35 degrees and generally having low cohesion.

- The Newport Dune Sheet are observed to contain slope angles observed to range from 50 to 70 degrees. These slope angles are up to twice the expected angle of repose estimated from laboratory testing indicating a certain amount of cohesion with the deposits. The cohesion may be caused by the cementation products observed during sample analysis.

- The measured phi angles represent largely conservative parameters for use in slope stability models.

The unique combination of materials tested, particularly the potential cementation effect, with the precise triaxial testing apparatus, may have revealed unique extremes relative to volumetric change and generation of negative pore pressure.

References

Alton, C., Cowburn, S., Jones, J., Knoepp, C., Peterson, C.D., Polidoro, B., and Stock, E., 1996. Origin of a Coastal Dune Complex: Source Mineralogy and Paleosol Development, From the Central Oregon Coast, GSA Cordilleran Meeting, Programs with Abstracts, 28:42.

Baguelin, F., Jezequel, J.F., and Shields, D.H., 1978. *The Pressuremeter and Foundation Engineering*, Trans Tech Publications, France, 614 p.

Baldwin, Ewart M., 1956. Geologic Map of the Lower Suislaw River Area, Oregon, USA. Washington, DC: US Geological Survey, Map OM-186.

Baldwin, Ewart M., 1961. Geologic Map of the Lower Umpqua River Area, Oregon, USA. Washington, DC: US Geological Survey, Map OM-204.

Baldwin E.M., J.D. Beaulieu, L. Ramp, J. Gray, V.C. Newton, and R.S. Mason, 1973. Geology and Mineral Resources of Coos County, Oregon. Oregon Department of Geology and Mineral Industries, Bulletin 80, 82 p. with maps.

Beaulieu J.D., and P.W. Hughes, 1975. Environmental geology of western Coos and Douglas Counties, Oregon. State of Oregon Department of Geology and Mineral Industries, Bulletin 90, 148 p. with maps.

Beckstrand, D.L., 2001. Origin of the Coos Bay and Florence Dune Sheets, South Central Coast, Oregon. Unpublished M.S. thesis, Portland State University, Portland, Oregon, 192 p.

Birkeland, P.W., 1984. *Soils and Geomorphology*. New York: Oxford University Press, 372 p.

Briaud, Jean-Louis, 1986. Pressuremeter and Foundation Design, Proceedings of the ASCE Specialty Conference on “Use of In Situ Tests in Geotechnical Engineering”.

Boggs, Jr., Sam, 1987. *Principles of Sedimentology and Stratigraphy*. Columbus, Ohio: Merrill Publishing Co., 784 p.

Clough, G. Wayne, Sitar, Nicholas, Bachus, Robert, and Rad, Nader Shafii, 1981. Cemented Sands Under Static Loading. Journal of the Geotechnical Engineering Division, pp. 799-817.

Cooper, W. S., 1958, Coastal sand dunes of Oregon and Washington, Geological Society of America. Memoir 72: New York, Geological Society of America, 169 p.

Grathoff, Georg H., Baham, John., Peterson, Curt D., Johnson, Catrina M., 2003. Authigenic AL, FE, SI Minerals of Varying Crystallinity in Dunal Soils Near Newport, Oregon, USA. The Clay Mineral Society, joint meeting, Abstract.

Grathoff, Georg H., Peterson, Curt D., Beckstrand, Darren L., 2003. Coastal Dune Soils in Oregon, USA, Forming Allophane and Gibbsite. Proceedings of the 12th International Clay Conference, pp. 197-204.

Grigg, Laurie D. and Whitlock, Cathy, 1997. Late-Glacial Vegetation and Climate Change in Western Oregon. Quarternary Research, No. 49, pp. 287-298.

Hampton, E.R., 1963, Ground Water in the Coastal Dune Area Near Florence, Oregon: United States Geological Survey, 1539-K.

Hart R.A., and C.D., Peterson, 2002. Alternation of dune and forest landscapes: evidence from paleosols in marine terrace deposits, Lincoln County, Oregon. Geological Society of America, 98th Annual Meeting, Cordillera Section, Abstracts with Programs, 34:A7.

Helley, E.J., Lajoie, K.R., Spangle, W.E., and Blair, M.L., 1979. Flatland Deposits of the San Francisco Bay Region, California-their geology and engineering properties, and their importance to comprehensive planning. US Geological Survey Professional Paper 943.

Hofgren, J. C., Burkett, S. P., Peterson, C. D., Origin of Pleistocene dunal gray layers: deflation wetland deposition versus upland pedogenic weathering, Lincoln City Dune Sheet, Oregon. Geological Society of America, Cordillera Meeting Abstracts, in press.

http://www.ocs.orst.edu/allzone/allzone1.html, 2002.

Johnson, Catrina M., 2003. Iron Mineralogy in the Newport Dune Sheet, Oregon Coast. Unpublished senior thesis, Portland State University.

Jol, Harry M., Smith, Derald G., and Meyers, Richard A., 1996. Digital Ground Penetrating Radar (GPR): A New Geophysical Tool for Coastal Barrier Research Examples from the Atlantic, Gulf, and Pacific Coasts, USA. Journal of Coastal Research, Vol. 12, No. 4, pp. 960-968.

Kocurek, G., Townsley, M., Yeh, E., Kavholm, K., and Sweet, M.L., 1992. Dune and Dune-Field Development on Padre Island, Texas, with Implications for Interdune Deposition and Water-Table-Controlled Accumulation. Journal of Sedimentary Petrology, Vol. 62, No. 4, pp. 622-635.

Komar, Paul D., 1997. *The Pacific Northwest Coast*, Durham, North Carolina: Duke University Press, 195 p.

Lambe, T. William and Whitman, Robert V., 1969. *Soil Mechanics*. New York: John Wiley & Sons, Inc., 553 p.

Minor, Rick, 1991, Yaquina Head: A Middle Archaic Settlement on the North-Central Oregon Coast. Bureau of Land Management, cultural resource manual No. 6. Natural Resource Conservation Service, 1997, Soil Survey of Lincoln County Area, Oregon.

Orr, E., Orr, W. and Baldwin, E., 1992, *Geology of Oregon*. Dubuque, Iowa: Kendall Hunt Publishing, 254 pp.

Ortiz, J., Mix, A., Hostetler, S., and Kashgarian, M., 1997. The California Current of the last glacial maximum; reconstruction at 42 degrees N based on multiple proxies. Paleoceanography, v. 12, no. 2, p. 191-205.

Patching, W.R., 1987. Soil Survey of Lane County Area, Oregon. Natural Resources Conservation Service, US Department of Agriculture, 369 p., 153 map sheets.

Peterson, C.D., Gleeson, G., and Wetzel, N., 1987. Stratigraphic Development, Mineral Sources, and Preservation of Marine Placers from Pleistocene Terraces in Southern Oregon. Sedimentary Geology, 53:203-229.

Peterson C.D., M.E., Darienzo, D.J. Pettit, P. Jackson, and C. Rosenfeld, 1991. Littoral Cell Development in the Convergent Cascadia Margin of the Pacific Northwest, USA. In. R. Osborne (ed) From Shoreline to the Abyss, Contributions in Marine Geology in Honor of F.P. Shepard, SEPM Special Publication, 46:17-34.

Peterson, C.D., Jol, H.M., Woxell, L.K., Vanderburgh, S., Phipps, J.B., Percy, D., Reckendorf, F., Gelfenbaum, G.R., 2001. Late Holocene Shoreface Retreat Scarps from Ground Penetrating Rader Profiles, Columbia River Littoral Cell, Washington-Oregon, USA. USGS OpenFile Report. In Press.

Peterson, C.D., Baham, J., Beckstrand, D., Clough, C., Cloyd, C., Erlandson, J., Grathoff, G., Hart, R., Jol, H., Percy, D., Reckendorf, F., Rosenfeld, C., Smith, T., Phyllis Steeves, P., Stock, E., 2002. Field Guide to the Pleistocene and Holocene Dunal Landscapes of the Central Oregon Coast: Newport to Florence, Oregon. Geological Society of America, Field Trips Guide, Cordillera Meeting, Corvallis, Oregon, USA, 13 p.

Peterson, C.D., Stock, E., and C., Cloyd, 2002. Further constraints on age dating of late-Pleistocene and Holocene coastal dunes and spodosol chronosequences from the Central Oregon coast based on reconnaissance thermoluminescence dating. Geological Society of America, 98th Annual Meeting, Cordillera Section, Abstracts with Programs, 34:A7.

Peterson, C.D., 2005. Morphostratigraphy and Dating of Coastal Dune Sheets in Washington, Oregon, Northern California, and San Miguel Island, United States, and Baja California Sur, Mexico: West Coast Dune Database. Oregon Sea Grant Report. (In press.)

Pirazzoli, P.A., 1993. Global Sea-Level Changes and Their Measurement, Global and Planetary Change, v.8, pp. 135-148.

Reckendorf F.F., 1975. Beaches and Dunes of the Oregon Coast. US Department of Agriculture, Oregon Department of Soil Conservation Service, and Oregon Coastal Conservation and Development Commission, 161 p.

Reckendorf, Frank, et al. 1985. Stabilization of Sand Dunes in Oregon. In Douglas Helms and Susan L. Flader [eds.] The History of Soil and Water Conservation: A Symposium. Agr. History Society, Davis, California, USA.

Reckendorf, Frank, 1998, Geologic Hazards of Development on Sand Dunes along the Oregon Coast. Environmental, Groundwater and Engineering Geology, Applications from Oregon, edited by Scott Burns, Belmont, California: Star Publishing Company, pp. 429-438.

Ritter, Dale F., 1986. *Process Geomorphology*, Dubuque, Iowa: Wm. C. Brown Publishers, 579 p.

Schlicker, Hebert G., Deacon, R.J. Olcott, G.Wm. and Beaulieu J.D., 1973. Environmental Geology of Lincoln County Oregon. Oregon Department of Geology and Mineral Industries, Bulletin 81.

Saxena, Surendra K., Lastrico, Roberto M., 1978. Static Properties of Lightly Cemented Sand. Journal of the Geotechnical Engineering Division, pp. 1449-1463.

Shipman J.A., 1997. Soil Survey of Lincoln County, Oregon. Natural Resources Conservation Service, US Department of Agriculture, 256 p. 50 map sheets.

Smith, Trevor, 2005. (PSU civil engineering, unpublished data.)

Snavely, Jr., Parke D., MacLeod, Norman S., Wagner, Holly C., and Rau, Weldon W., 1976. Geologic Map of the Yaquina and Toledo Quadrangles, Lincoln County, Oregon, USA. Washington, DC: US Geological Survey, Map I-867.

Snavely, Jr., Parke D., MacLeod, Norman S., Wagner, Holly C., and Rau, Weldon W., 1976. Geologic Map of the Waldport and Tidewater Quadrangles, Lincoln, Lane, and Benton Counties, Oregon, USA, Map I-866.

Summers, Renee, 2005. (PSU Civil and Environmental Engineering Department, unpublished Masters project data).

Terzaghi, K., and Peck, R., 1967. *Soil Mechanics in Engineering Practice*. New York: John Wiley & Sons, Inc.

Vokes, H.E., Norbisrath, H., and Snavely, P.D., Jr., 1949, Geology of the Newport-Waldport area, Lincoln County, Oregon: U.S. Geological Survey Oil and Gas Investigation, Preliminary Map 88.

Worona, M.A., and Whitlock, C., 1995, Late Quaternary vegetation and climate history near Little Lake, Central Coast Range, Oregon. GSA Bulletin, v. 107, no. 7, p. 867-876.

Yamamuro, Jerry A., 2005, personal communication, Department of Civil, Construction and Environmental Engineering, Oregon State University, Corvallis, Oregon.

Appendix A: Dune Sheet Mapping Profile Logs

Newport Dune Sheet, Oregon

UTM Sector and Datum (xx/yr), Northing, Easting, Estimated Error (EPE +-m), DEM Altitude (Alt m MSL).

Exposure Type: Active (AC), Trench (TR), Auger (AU), Road Cut (RC), Creek Cut (CC), Sea Cliff (SC), Slope (SL).

Units: Age: Tertiary (T), Pleistocene (P), Holocene (H), Wave-cut Platform (W); Parent Material; Soil Horizon

Parent Material: Eolian Dune (D), Loess (L), Colluvium (U), Peat (P), Alluvial/Fluvial (V), Lagoonal/Estuary (N),
Beach Shoreface (S), Basal Conglomerate (M).
Note: Loess (L) is designated where it overlies bedrock, colluvium, or pre-existing Bw/Bt horizons.

Soil Horizon: Organic (A), Leached (E), Accumulation (B), Fe+3 Accumulation (Bw),
Incipient Clay Accumulation (Btj), Clay Accumulation (Bt), Humate Accumulation (Bh),
Calcrete (Bk), Silcrete (Bq), Reduced Glade Layer (Bg), Subsoil Calcrete (K),
Dune Parent (C), Oxidized Parent (Cox).

Subsurface depth (cm); Dominant Grain Size: Silt, Sand, Pebbles, Cobbles (default is sand)
Sand sizes (Coarse U/L, Medium U/L, Fine U/L,VeryFine U/L)

Bedding: Cross Beds (XB,dipxx), Planar Beds (PB), Fluidization (FL), Heavy Mineral Laminae (HM)

Munsel Maximum Color (field condition: moist)

Penetrometer: (P. kg/square cm) unconfined compressive strength.

Structure: loose, very weak blocky, weak blocky, strong blocky, columnar/prismatic.

Diagenesis: Fe-ortstein, Fe-humate, allophane, gibbsite, calcrete, silcrete

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP1	10N/1983	4956110	416450	10	101	6/24/2000	SL

Site Notes: Loess and coluvium over basalt. At least one paleosol is preserved within the loess cap.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
LBw	0-100	Silt					
PU	100-300						
TBtj	300-350						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP2	10N/1983	4956290	415790	7	17	6/24/2000	SL

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PU	0-100						
PUBw	100-200			10YR4/8			
PM	200-220						
PW	220-221						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP3	10N/1983	4955400	416380	8	34	6/24/2000	AU

Site Notes: Easternmost limit of Pliestoncene dune sheet, top is truncated by loess colluvium.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
LBw	0-40	Silt					
PUBw	40-60						
PDBw	50-100	FU					

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure

NEWP4	10N/1983	4955050	417630	4	112	6/26/2000	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDC	0-300		XBdipNE				

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP5	10N/1983	4955040	417640	4	114	6/29/2000	RC

Site Notes: Pleistocene dunes, abundant gibbsite, locally truncated by mass wasting.

TL Sample (039N) taken at depth of 3.5 m in Quarry north facing side wall.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
UBw	0-50		Disturbed				
LBw	50-100	Silt	Truncated		2	Very Weak B.	
PDBtj	100-150				4.5	Stong Blocky	
PDBw	150-180	FU			4.5	Weak Blocky	gibbsite
PDCox	180-380		XBdipNE				gibbsite

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP6	10N/1983	4955020	416420	10	37	6/24/2000	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
LA	0-10	Silt					
LBw	10-50	Silt			2.5	Very Weak B.	
PDBtj	50-110	FL		7.5YR4/4	4.5	Weak Blocky	
PDBg	50-130						
PDBw	130-180						
PDBg	180-200						
PDC	200-300						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP7	10N/1983	4954900	416870	5	75	6/26/2000	RC

Site Notes: Eastern edge of dune cover.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA	0-10						
PDBtj	10-100			10YR5/8			
PDBw	100-150						
PDCox	150-200						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP8	10N/1983	4954820	417250	8	72	6/26/2000	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDBtj	0-75						
PDBw	75-85						
PDCox	85-150						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP13	10N/1983	4954710	416550	9	47	6/26/2000	RC

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDBw	0-50			7.5YR6/8 w7.5YR4/6	4.5	Weak Blocky	

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP9	10N/1983	4954610	417670	7	116	6/26/2000	RC

Site Notes: Eastern edge of dune cover overlying pebbly sand.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDC	0-100		XBdipNE				
PV	100-200						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP10	10N/1983	4954250	417770	7	105	6/26/2000	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA	0-17				1		
PDBtj	17-52			10YR5/8	4	Weak Blocky	
PDBW	52-117						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP11	10N/1983	4953700	416510	10	25	6/25/2000	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA	0-20						
PDBtj	20-60			7.5YR4/3		Very Weak B.	
PDBw	60-90					Very Weak B.	
PDCox	90-290						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP12	10N/1983	4953440	416780	8	33	6/25/2000	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA							
PDBw				10YR5/8			
PDCox							
PDBw				10YR3/4			
PDCox							

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP10	10N/1983	4954250	417770	7	105	6/26/2000	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA	0-17				1		
PDBtj	17-52			10YR5/8	3.5	Very Weak B.	rare charcoal
PDBW	52-117						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP14	10N/1983	4952980	416890	4	42	6/24/2000	SL
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis

PDBtj	0-100			7.5YR5/8	4.5	Stong Blocky	
PDBw	100-200			7.5YR5/8			
PDCox	200-300						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP15	N10/83	4952830	416230	19	37	5/8/2000	SC

Site Notes: This site is 500 m south of beach access at Beverly Beach State Park, ie., south of Spencer Creek.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA	0-90						
PDBw	90-175	FU		10YR5/8	4	Weak Blocky	Fe-ortstein
PDBg	175-205					Very Weak B.	
PDBw	205-280	FU			3.5	Very Weak B.	allophane
PDBg	280-305			2.5Y6/1		Very Weak B.	
PDCox	305-625	FU		10YR6/3			
PDBg	625-705						
PP	705-720						
PS	720-1185	MU-Pebbles			4		
PM	1185-1225	Cobbles					
PW	1225-1226						
T	1226-3025						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP16	10N/1983	4952800	416230	5	39	6/24/2000	RC

Site Notes: Site is just south of Beverly Beach Road exit, at corner of Beverly Drive and Beverly Lane.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA	0-25						
PDBw	25-45			10YR5/8			
PDCox	45-145						
PDBtj	145-165			2.5YR4/6			Fe-ortstein
PDBw	165-195						
PDCox	195-295						
PDBg	295-305						
PDCox	305-325						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP17	10N/1983	4952690	417280	9	80	6/24/2000	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA	0-20						
PDBw	20-220			7.5YR5/6			
PDCox	220-320						
PDBw	320-370			7.5YR5/6			
PDCox	370-470						
T		Mudstone					

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP18	10N/1983	4952660	417380	4	99	6/24/2000	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
U	0-100						
T							

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP19	10N/1983	4952290	417030	4	76	6/24/2000	RC

Site Notes: Eastern limit of Pleistocene dune sand.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA	0-10						
PDBtj	10-110	VFL		7.5YR4/6			
PDBw	110-260	FU					

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP20	10N/1983	4952130	416850	4	39	6/24/2000	SL
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
LA	0-15	Silt					
LBw	15-75	Silt					
PDBtj	75-115	FL		7.5YR4/6			
PDBw	115-215	FU					
PDCox	215-265						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP21	10N/1983	4951750	417770	5	158	6/24/2000	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
T		Mudstone					

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP22	10N/1983	4951540	417620	8	110	6/29/2000	RC

Site Notes: Near top of Road 100 (TL Sample 540N taken at depth of 4.3 m).

Units	Depth cm	Thickness cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure
LA	0-15	15	Silt				
LBw	15-100	85	Silt				
PDBtj	100-170	70	VFL	Shear Failure			Columnar
PDBw	170-240	70	FU				Weak Blocky
PDCox	240-550	310	FU	XBdipNE			Very Weak B.

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP23	10N/1983	4951530	417870	10	141	6/25/2000	RC

Site Notes: Site is about 100 m west of eastern limit dune sheet.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA	0-20						

PDBtj	20-220			7.5YR4/4			
PDCox	220-520						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP24	N10/83	4951370	416090	18	32	5/7/2000	SC

Site Notes: This section is located 0.5 km south of Wade Creek, and continues upsection to HW101 road.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
HDA	0-20						
HD	20-210					Very Weak B.	
PDBw	210-310	FU		10YR5/8	4	Stong Blocky	allophane.
PDCox	310-410					Very Weak B.	Fe-ortstein
PDBg	410-430						
PDCox	430-780	FU	XBdipNE	10YR4/3	4.5		allophane
PDBg	780-830						
PS	830-1040	ML-pebbles			4		
PM	1040-1070	Cobbles					
PW	1070-1071						
T	1071-3120						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP25	10N/1983	4951220	417000	9	72	6/24/2000	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA	0-35						
PDBtj	35-135			7.5YR5/6			
PDBw	135-235						
PDCox	235-435						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP26	10N/1983	4951210	416110	6	33	6/24/2000	RC

Site Notes: Site is 10 m east of HW101 at 100 Rd intersection.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA	0-10						
PDBw	10-30			10YR5/6			
PDCox	30-130						
PDBg	130-150						
PDCox	150-200						
PDBw	200-230						
PS	230-330						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP27	10N/1983	4950520	416820	4	75	6/25/2000	RC

Site Notes: Site is at easternmost limit of dune cover and includes regolith Btj under thin dune deposits.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
U	0-50						

PDBtj	50-100						
PDBw	100-120						
TBtj	120-220		Truncated				
T	220-270						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP28	10N/1983	4950420	416350	7	37	6/25/2000	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA	0-5						
PDBtj	5-35			7.5YR5/6	3.5	Very Weak B.	
PDBw	35-65				3	Very Weak B.	
PDCox	65-85				2.75	Very Weak B.	
PDBw	85-100			7.5YR4/6			

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP29	10N/1983	4949520	417250	5	106	6/25/2000	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
TBtj	0-150						
T	150-300						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP30	10N/1983	4949000	416630	5	76	6/26/2000	RC

Site Notes: Easternmost edge of dune cover.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDBtj	0-30		Truncated	5YR4/6	3	Very Weak B.	
PDBw	30-100					Very Weak B.	

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP31	10N/1983	4948920	415890	8	36	6/25/2000	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA	0-5						
PDBtj	5-35			7.5YR5/6			
PDBw	35-85						
PDCox	85-185						
PDBw	185-215			7.5YR6/6			
PDCox	215-415						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP32	10N/1983	4947690	416460	6	74	6/28/2000	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDBtj	0-50			5YR4/4	4.5	Strong Blocky	
PDBw	50-70				3.5	Weak Blocky	
PDBg	70-87				3	Very Weak B.	
PDCox	87-147						

PDBg	147-172						
PDCox	172-222						
PMBw	222-242						Fe-orstein
T	242-342						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP33	10N/83	4947610	416330	5	60	6/25/2000	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDBtj	0-50			7.5YR5/6			
PDBw	50-100						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP34	10N/1983	4947560	416720	7	89	6/25/2000	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
UBtj	0-50						
T							

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP35	N10/83	4947460	414940	8	62	7/11/2002	RC

Site Notes: This site is in the saddle of Yaquina Head, located about 30 m east of the Visitors Center parking lot. Colluvium from ridge (now quarried) covered the thin dune deposit, preserving it from deflation.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
Fill	0-30						
LBw	30-80						
UBw	80-110						
UC	110-150						
PDBw	150-200	FU and cobble					
PDCox	200-500	FU					
T	500-700	Basalt					

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP36	10N/1983	4946680	416800	7	54	6/28/2000	SL

Site Notes: No dune sand east of Agate Beach golf course. Golf course developed on PS deposits (1 m thick).

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
TA	0-30						
TBtj	30-130						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP37	10N/1983	4946410	416290	7	28	6/28/2000	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PMBtj	0-100						
T	100-150						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP38	10N/1983	4946080	416490	7	31	6/28/2000	RC

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA	0-10						
PDBtj	10-100			7.5YR5/6			
PDBw	100-160						
PDCox	160-210						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP39	N10/83	4945930	416200	6	18	3/9/2003	RC

Site Notes: This PD site is at the northernmost extent of the Holocene dunes.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDBw	0-45						
PDCox	45-200	FU					

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP40	10N/1983	4945740	416950	5	31	6/28/2000	RC

Site Notes: Shoreface deposits above wave cut platform, cut into Pleistocene alluvium/lagoonal deposits.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PSBtj	0-50						
PSCox	50-300						
PM	300-350						
PW	350-360						
PV	360-660						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP41	N10/83	4944790	416100	6	25	3/9/2003	RC

Site Notes: Site is adjacent to a slope contact with Pleistocene dunes (deflation surface?) immediately to the east.
The Holocene dunes (mid-Holocene Fe-Ox stained) do not contain deflation Bg or other paleosols at this site.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
HDA	0-10						
HDBW	10-35				1.5	Very Weak B.	
HDCox	35-400	FU					Fe-ortstein

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP42	N10/83	4944790	416130	6	27	3/9/2003	RC

Site Notes: Pleistocene dunes (multiple deflation Bg paleosols) directly east of Holocene dunes.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA	0-10						
PDBw	10-60				4.5	Strong Blocky	
PDCox	60-100	FU					Fe-ortstein
PDBg	100-110						
PDCox	110-220	FU					
PDBg	220-230						Fe-ortstein
PDCox	230-350						
PDBg	350-370						
PDCox	370-500						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP43	N10/83	4944480	416040	8	35	3/9/2003	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA	0-30						
PDBW	30-60				3.5	Weak Blocky	
PDCox	60-200						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP44	10N/1983	4944420	416920	8	37	6/28/2000	RC

Site Notes: Liquefaction Site east hills of Newport. Clastic dikes 25, 30 and 40 cm wide.
TL Sample (416N) taken at 3.0 m depth.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA	0-5						
PDBw	5-35	VFL		7.5YR4/3			
PDCox	35-75	FU					
PDC	75-125	FU					
PDBg	1215-135						
PDBw	135-150		Fluidization				
PDCox	150-160		Fluidization				
PDC	160-460		XBdipNW				

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP45	N10/83	4944170	415990	9	33	3/9/2003	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA	0-50	VFL					
PDBw	50-100				3.5	Weak Blocky	
PDCox	100-200	FU					

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP46	10N/1983	4943750	417560	5	88	6/30/2000	SL

Site Notes: Newport Middle School, east parking-lot bank cut, tree seedlings, grass, and netted stabilization.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDBtj	0-46	FVU		7.5YR4/6			
PDBw	46-66	FU					
PDCox	66-266	FU					

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP47	N10/83	4943470	415850	6	16	3/9/2003	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDCox	0-300				4	Strong Blocky	

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP48	N10/83	4943090	415660	14	19	5/26/2000	SC

Site Notes: Nye Beach, Newport. Section taken about 100 m north of beach access trail from Davis Park.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
HA	0-10					Loose	
HDC	10-150	FU-ML			0.5	Loose	
HDBw	150-160			5YR5/8			
HDCox	160-270			10YR5/6	1		
HA	270-330						
LBw	330-360	Silt				Very Weak B.	
PDBw	360-450	FL	Planar	10YR5/8	3.5	Weak Blocky	
PDBg	450-456	FL					
PDBw	456-656		XBdipE			Very Weak B.	allophane
PDBg	656-696		Planar				
PDCox	696-946	FU-ML	XBdipE	10YR5/6			allophane
PDBg	946-988						
PDC	988-1068		Planar		4.5		
PS	1068-1128		Ripples				
PM	1128-1133	Cobbles					
PW	1133-1134						
T	1134-1943						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP49	10N/1983	4942860	418060	11	73	6/30/2000	RC

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
LA	0-10	Silt					
LBw	10-35	Silt			2	Very Weak B.	
PDBtj	35-58	FVU		7.5YR5/6	4.5	Strong Blocky	
PDBw	58-78	FU				Very Weak B.	
PDCox	78-228						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP50a	N10/83	4942780	416490	6	39	3/9/2003	RC

Site Notes: This is a cut bank slope on Hatfield Street, south of community center.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
Disturbed	0-10						
PDCox	10-200						
PDBw	200-230						
PDCox	230-300						
PDBw	300-310						
PDCox	310-400						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP50b	N10/83	4942620	415870	9	38	3/9/2003	RC

Site Notes: This site is located at the eastern edge of the Holocene dunes, at the intersection of 7th, Fall Sts.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis

PDBw	0-50				4	Strong Blocky	
PDCox	50-300				3		

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP51	N10/83	4942540	415570	25	25	9/1/2001	SC

Site Notes: Site is south of the Shilo Inn café (sampled at 1887 cm depth).

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
HA	0-15					Loose	
HD	5-137					Loose	
HDBw	137-187	FU		10YR3/6		Very Weak B.	
HDCox	187-1847		XB	10YR5/6	0.5	Loose	
LA	1847-1877	Silt			1	Very Weak B.	
LBw	1877-1897	Silt			2.25	Very Weak B.	
PDBw	1897-1922			10YR5/8	4	Weak Blocky	
PDBg	1922-1947				3	Very Weak B.	
PDBw	1947-2002	FU				Very Weak B.	allophane
PDBg	2002-2012						
PDBw	2012-2062				4		
PDBg	2062-2072						
PDCox	2072-2272	FU	Truncated		3.5		allophane
PM	2272-1368	Cobbles					
PW	1368-1369						
T	1369-1379						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP52	10N/1983	4942540	415690	5	36	6/28/2000	SL
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
HAD	0-2						
HDCox	2-17						
PDBw	17-52			7.5YR4/6			
PDCox	52-202						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP53	10N/1983	4942530	415570	5	17	6/28/2000	SC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
HDA	0-5			10YR6/4			
HCox	5-155			2.5YR6/6			
PDA	155-185						
PDBtj	185-105			5YR3/4			
PBw	105-135						
PBg	135-145						

PBw	145-155
PCox	155-255
PBg	255-275

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP54	N10/83	4942260	416090	6	35	3/8/2003	RC

Site Notes: This site is on the NW edge of the Holocene dunes that rimmed the northern bay mouth.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
HDA	0-10						
HDBw	10-40					Weak Blocky	
HDCox	40-400						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP55	N10/83	4942050	415640	4	26	3/8/2003	AU

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDBw	0-50				3.5	Weak Blocky	

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP56	N10/83	4941930	415620	10	25	3/8/2003	AU

Site Notes: This site is on the north side of the Light House park near the play ground.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
HDA	0-5						
HDBw	5-15				1	Very Weak B.	
HDCox	15-100	FU				Loose	
PDBw	100-120				3.75	Weak Blocky	
PDCox	120-230	FU					

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP57	N10/83	4941700	415540	10	18	6/22/2000	SC

Site Notes: This site is located below the parking lot at Yaquina Point State Park, just north of the old lighthouse.
About 4 m of Holocene dunes, with multiple A horizons and weak Bw horizons overlie the Pleistocene dunes.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
HDA	0-10	FU			0	Loose	
HDC	10-60	FU		10YR6/2	0.5	Loose	
HDA	60-80				1.5	Loose	
HDBw	80-100			5YR5/8	1.5	Very Weak B.	
HDCox	100-200	FU			2	Loose	
HDBg	200-220				2.75		Fe-ortstein
HDC	220-260	FU		2.5Y5/4	2.5	Loose	
HDBw	260-285			2.5YR5/6	2.25		
HDC	285-395	FU		2.5Y6/6	2.5		
LA	395-465	Silt			2.75	Very Weak B.	
LBg	465-520	Silty Sand	Truncated		3	Weak Blocky	

PDBw	520-640	FU		10YR5/8	4	Weak Blocky	
PDBg	640-655				3.5		
PDCox	655-675			10YR5/8	3.5		
PDBg	675-680			2.5Y6/1	4	Very Weak B.	
PDCox	680-690						
PDBg	690-700						
PDCox	700-730						
PM	730-735	ML					
PW	735-736	Cobbles					
T	736-1155						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP58	10N/1983	4940700	416510	5	13	6/30/2000	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
HDA	0-3						
HDBw	3-8				1		
HDCox	8-75						
HDC	75-275	200	FU	XBdipSE			

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP59	10N/1983	4940360	418340	7	9	6/24/2000	RC
Site Notes: Site is at edge of King Slough.							
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
LA	0-20	Silt				Loose	
LBw	20-40	Silt		7.5YR5/6		Loose	
PDCox	40-240	FU				Very Weak B.	
PDBw	240-290						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP60	10N/1983	4940180	417990	10	37	6/27/2000	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
LA	0-30	Silt				Loose	
LBw	30-100	Silt		7.5YR5/8		Loose	
PDBw	100-130	FU				Very Weak B.	
PDCox	130-230	ML					
PDCox	230-430		XBdipE				Fe-Humate

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP61	10N/1983	4939720	416970	7	44	6/27/2000	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
LBtj	0-40	Silt		7.5YR4/4			
PDBw	40-60	FU					
PDCox	6-260	FU					

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure

NEWP62	10N/1983	4937970	417750	11	64	6/27/2000	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
T		Mudstone					

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP63	N10/83	4937540	415210	13	20	12/18/2000	SC

Site Notes: This site is the scarp face of a small slope failure just south of Henderson Creek.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
HD	0-35					Loose	
LA	35-70	Silt				Very Weak B.	
LBg	70-100	Silty Sand				Very Weak B.	
PDBw	100-120			6.5YR4/6	4	Weak Blocky	Fe-ortstein
PDCox	120-240		XBdipE			Very Weak B.	
PDBg	240-250					Very Weak B.	
PDCox	250-270				3.75		
PDBg	270-300					Very Weak B.	
PDCox	300-360	ML	XBdipE	10YR6/8	4		allophane
PDBg	360-370	FL	Truncated	2.5Y6/1	2.5	Very Weak B.	
PDC	370-400						
PS	400-695	MU			4.5		
PM	695-795	Cobbles					
PW	795-796						
T	796-1600						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP64	10N/1983	4937240	416460	11	50	6/25/2000	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA	0-10			7.5YR4/6			
PDBtj	10-70				4		
PDBw	70-140						
PDCox	140-180	ML					

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	
NEWP65	10N/1983	4937090	417680	4	99	6/27/2000	

Site Notes: Site is at eastern limit of Pleistocene dune sheet.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA	0-30						
PDBw	30-73			7.5YR7/6			
PDCox	73-103	FU					

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP66	10N/1983	4937010	417570	6	99	6/27/2000	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
LA	0-17	Silt				Very Weak B.	
PDBtj	17-60	VFL		7.5YR4/4	4	Weak	

						Blocky	
PDBw	60-183	123	FU		4.5	Strong Blocky	

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP67	10N/1983	4936980	416210	4	40	6/27/2000	RC

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDCox	0-100		XB				
PDC	100-150						gibbsite

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP68	10N/1983	4936930	416800	8	63	6/27/2000	RC

Site Notes: Site is at north end of Newport Airport runway.

Sample 926N is a quartz-shard rich lense (not ash) in Bg layer (25-45 cm depth).

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDBw	0-25						
PDBg	25-45						
PDCox	45-150						Fe-ortstein

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP69	N10/83	4936630	415110	19	12	12/8/2000	SC

Site Notes: This site is 70 m south of Grant Creek.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
LA	0-30						
LBg	30-45	Silt		2.5Y6/1		Very Weak B.	
PDBw	45-65	FU		10YR5/8	4	Weak Blocky	
PDBg	65-125		Truncated			Very Weak B.	
PDCox	125-185	FU	XBdipE				
PDBg	185-200					Very Weak B.	
PDCox	200-390	FU		10YR6/3	4	Very Weak B.	
PM	390-400	Cobbles	Truncated				
PW	400-401						
T	401-1075						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP70	10N/1983	4936550	418230	7	122		RC

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
TBtj	0-100						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP71	N10/83	4936420	415190	15	15	12/16/2000	SC

Site Notes: This site is located about 250 m south of Grant Creek, beside a rip-rap installation.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
HD	0-15	FU				Loose	
LA	15-80	Silt				Very Weak B.	

PDBw	80-125	FU	Truncated	10YR5/8	4	Weak Blocky	allophane
PDCox	125-175			2.5Y6/1			
PDBg	175-205		Truncated			Very Weak B.	
PDBw	205-255						Fe-ortstein
PDCox	255-315						allophane
PDBg	315-380				3.5		
PDCox	380-435			10YR6/3			
PDBg	435-445						
PDCox	445-490	FL					Fe-ortstein
PDBg	490-505						
PS	505-615	ML					Fe-ortstein
PM	615-625	Cobbles					
PW	625-626						
T	626-1300						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP72	N10/83	4936130	415150	18	17	12/8/2000	SC

Site Notes: This site is located 0.5 km north of Moore Creek. The base of the section contains a peat.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
LA	0-34	Silt				Very Weak B.	
LBg	34-60	VFL				Very Weak B.	
PDBw	60-100	FU	Truncated	10YR5/8	4	Strong Blocky	allophane
PDCox	100-200					Very Weak B.	
PDBg	200-310			2.5Y6/1		Very Weak B.	
PDCox	310-560	FU		10YR6/1	4		
PDBg	560-580						
PS	580-755	MU	Ripple XB		4.5		
PP	755-811						
PM	811-816	Cobbles					
PW	816-817						
T	817-1416						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP73	N10/83	4935750	415120	18	16	12/8/2000	SC

Site Notes: This site is just south of Moore Creek. The wave-cut platform (PW) has a step (reoccupied?).

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
LA	0-25					Very Weak B.	
LBg	25-45				1	Very Weak B.	
PDBw	45-85	FU		7.5YR5/8 w7.5YR4/6	4	Weak Blocky	
PDCox	85-165	FU			4	Very Weak B.	
PDBg	165-185			2.5Y6/1		Very Weak B.	
PDCox	185-491	FU			3.5		
PDBg	491-501					Very Weak B.	
PDCox	501-750	FU			4.25		

PM	750-760						
PW	760-761						
T	761-1370						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP74	N10/83	4935590	415130	17	12	12/8/2000	SC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA	0-20						
PDBW	20-40			7.5YR4/6	4	Weak Blocky	
PDCox	40-160	FU			3	Very Weak B.	
PDBg	160-165			2.5Y6/1		Very Weak B.	
PDCox	165-295	FU		10YR6/3	3.5		
PDBg	295-355					Very Weak B.	
PS	355-635	ML			4.5		Fe-ortstein
PW	635-636						
T	636-1135						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP75	N10/83	4935560	416630	8	59	6/11/2002	TR/AU

Site Notes: This site is on the eastern margin of the Ferris Nursery in the Lint Soil Series.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
LA	0-40	Silt		10YR3/2	0.5	Very Weak B.	
LBw	40-84	Silt		10YR3/3	2	Weak Blocky	
PDBw	84-103	FU		10YR4/3	4	Strong Blocky	
PDC	103-105	FU			4		Fe-ortstein

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP76	N10/83	4935450	415080	18	11	12/8/2000	SC

Site Notes: This site is located 700 m north of Theil Creek, local cliff slumping.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA	0-35		Truncated			Very Weak B.	
PDBw	35-55	FU		7.5YR4/6	4	Weak Blocky	
PDCox	55-165		PB			Very Weak B.	Fe-ortstein
PDBg	165-195	FL				Very Weak B.	
PDCox	195-355	ML	PB	10YR6/3	3.5		Fe-ortstein
PS	355-495	MU			4		
PM	495-510	Cobbles					
PW	510-511						
T	511-1010						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP77	10N/1983	4935360	415570	11	38	6/25/2000	RC

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA	0-15			10YR3/1	0.5	Very Weak B.	
PDBtj	15-45			10YR4/6	4	Weak Blocky	
PDBw	45-85			10YR4/4	3	Very Weak B.	
PDBg	85-100			10YR5/1	3.5		
PDC	100-200			10YR6/4	4		

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP78	10N/1983	4934870	416570	6	18	6/25/2000	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA	0-10						
PDBw	10-50			10YR5/6		Weak Blocky	
PDCox	50-150			10YR4/6		Very Weak B.	

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP79	N10/83	4934810	415060	16	13	12/8/2000	SC

Site Notes: This site is located just south of Theil Creek beach access trail.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA	0-5						
PDBw	5-50				4	Very Weak B.	
PDC	50-235	FU			3	Very Weak B.	
PDBw	235-250				2.25	Very Weak B.	
PDBg	250-272				3.5	Very Weak B.	
PDBw	272-342			7.5YR4/6	4.5	Weak Blocky	
PDC	342-382		XBdipE		3.5		allophane
PDBg	382-402	FL		2.5Y6/1	1.25		Fe-ortstein
PDC	402-497	FU		10YR6/3	3		allophane
PDBg	497-502	FL			2.5		
PS	502-612	ML		7.5YR4/6	4.5		Fe-ortstein
PM	612-637	Cobbles					
PW	637-638						
T	638-957						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP80	10N/1983	4934810	416910	6	13	6/25/2000	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
LA	0-10	Silt				Very Weak B.	
LBw	10-75	Silt				Very Weak B.	
PDBtj	75-110					Weak Blocky	
PDCox	110-410	FU					

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP81	10N/1983	4934790	416430	10	26	6/25/2000	RC

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
LA	0-13	Silt				Very Weak B.	
LBw	13-50	Silt				Very Weak B.	
PDBtj	50-68			10YR4/3	4	Weak Blocky	
PDBw	68-138	FU		10YR5/8	3	Very Weak B.	
PDCox	138-538			10YR7/8	4.5		

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP82	N10/83	4934630	414940	17	15	6/24/2002	SC

Site Notes: This site is located near Thiel Creek (TL sample taken at about 2.5 m depth).

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
HDA	0-15				0.5	Loose	
HD	15-115	FU			0.5	Loose	
HA	115-135				1	Loose	
HDBw	135-190			2.5YR5/6	1.5	Loose	
HDCox	190-325				2	Loose	Fe-ortstein
LA	325-380	Silt			1.5	Very Weak B.	
LBg	380-395	FL			3	Very Weak B.	
PDBw	395-485	FU		7.5YR4/6	4	Weak Blocky	allophane
PDBg	485-505			2.5Y6/1	3	Very Weak B.	
PDCox	505-575	FU	XBdipNE		3.25		
PDBg	575-640	FL					
PS	640-960	ML			4.5		
PM	960-965	Cobbles					
PW	965-966						
T	966-1345						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP83	N10/83	4934400	414860	19	12	12/7/2000	SC

Site Notes: This site is south of Thiel Creek.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
HD	0-55						
LA	55-77	Silty			2		
LBg	77-137	FL	Convolute		3	Very Weak B.	
PDBw	137-212			7.5YR4/6	4	Weak Blocky	allophane
PDBg	212-230			2.5Y6/1		Very Weak B.	
PDCox	230-380	FU	XBdipNE	10YR6/3	3.25		allophane
PS	380-600	FU-ML	Wave-ripples		3.5		Fe-ortstein
PM	600-610	Cobbles					
PW	610-611						
T	611-865						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP84	N10/83	4933950	414820	16	11	12/4/2000	SC

Site Notes: This site is opposite the 116th St.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
HDA	0-5					Loose	
HDC	5-30	FL				Loose	
LA	30-45					Very Weak B.	
LBg	45-55	FL				Very Weak B.	
PDBw	55-90			5YR5/8	4	Weak Blocky	allophane
PDBg	90-110	FL				Very Weak B.	
PDCox	110-222	FU	Planar		3		allophane
PDBg	222-227	FL			1.25	Very Weak B.	Fe-ortstein
PDCox	227-427	FU		2.5Y6/1	3.5		
PS	427-532	MU	Wave-ripples		4.5		Fe-ortstein
PM	532-537	Cobbles					
PW	537-538						
T	538-712						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP85	N10/83	4933430	414800	13	13	12/6/2000	SC

Site Notes: This site is located 750 m north of Lost Creek.

	Depth (m)	Photos					
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
HDA	0-10					Loose	
HDC	10-86					Loose	
LA	86-131	Silt				Very Weak B.	
LBg	131-161		Truncated		2.5	Very Weak B.	
PDBw	161-256			5YR5/8	4	Stong Blocky	Fe-humates
PDBg	256-291	FL		2.5Y6/1			gibbsite
PDCox	291-461	FU		10YR6/3	4		gibbsite
PDBg	461-486					Very Weak B.	allophane
PS	486-696	ML			4.5		Fe-ortstein
PM	696-706	Cobbles					
PW	706-707						
T	707-956						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP86	N10/83	4933080	414770	14	10	12/5/2000	SC

Site Notes: This site is located 440 m north of Lost Creek State Park.

RC sample taken from soil in sea cliff near this site, equivalent to 0.5 m depth in loess enriched soil horizon.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
LA	0-42						
LBg	42-77						
PDBw	77-107	ML		5YR5/8	4	Weak Blocky	allophane

PDCox	107-202	ML			3.5	Very Weak B.	allophane
PDBg	202-214	FL		2.5Y6/1	2.5		
PS	214-369	MU	XB ripples		4.5		Fe-ortstein
PM	369-474	Cobbles					
PW	474-475						
T	475-649						
Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP87	10N/1983	4933050	415570	11	47		SL
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA	0-10			10YR3/2	1		
PDBtj	10-30			10YR5/6	3.75		
Cox	30-100			10YR7/8	4.5		
C	100-250			10YR7/8			
Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP88	N10/83	4932410	414690	15	10	12/5/2000	SC
Site Notes: This site is located 300 m south of Lost Creek.							
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
HDA	0-5					Loose	
HDC	5-17	FL				Loose	
LA	17-51	Silt			2	Very Weak B.	
LBg	51-69				2.75	Very Weak B.	
PDBw	69-91			5YR5/8	4	Weak Blocky	Fe-ortstein
PDBg	91-103	FL				Very Weak B.	
PDBw	103-133				4.5		
PDCox	133-285	FU	Planar		2.5		allophane
PDBg	285-300	FL			3.5	Very Weak B.	
PS	300-455	ML		2.5Y5/3	4.5		gibbsite.
PM	455-465	Cobbles					Fe-ortstein
PW	465-466						
T	466-680						
Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP89	N10/83	4931390	414560	10	12	4/14/2002	SC
Site Notes: This site is about 1 km north of Beaver Creek.							
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
HDA	0-10						
HD	10-180	FL	XBdipNE		0	Loose	
LA	180-205				1	Very Weak B.	
LBg	205-230		Truncated		2	Very Weak B.	
PDBw	230-265			7.5YR4/6	3.5	Weak Blocky	allophane
PDCox	265-325				3		
PDBg	325-330				3.5	Very Weak B.	

PDCox	330-400	FL			3		
PDBg	400-420				4	Very Weak B.	Fe-humates
PS	420-632	ML	Planar		4.5		gibbsite
PM	632-637	Cobbles					
PW	637-638						
T	638-877						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP90	N10/83	4931110	414580	11	7	12/4/2000	SC

Site Notes: This site is located 800 m north of Beaver Creek, Holocene foredune seaward of wetland.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
HDA	0-12						
HDCox	12-132			10YR8/2	0	Loose	
HDA	132-137			2.5Y6/2	0.5	Loose	
HDCox	137-212			10YR5/8	0.5	Loose	
HDA	212-217				0.5	Loose	
HDBw	217-262				1.5	Very Weak B.	
HDCox	262-272				1.5	Loose	

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP91	10N/1983	4930500	415170	5	12	6/24/2000	RC

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDBw	0-50						
PDC	50-550						
T	550-850						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP92	N10/83	4929660	414320	21	16	12/24/2001	SC

Site Notes: Site is located 400 m south of Ona Beach State Campround beach access trail.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
LA	0-10	Silt				Very Weak B.	
LBw	10-60	Silt					
LBg	60-75	FU	Truncated			Very Weak B.	
PDBw	75-90			7.5YR4/6	4	Weak Blocky	Fe-ortstein
PDCox	90-270	FU			3	Very Weak B.	allophane
PDBg	270-280				1.25	Very Weak B.	
PDCox	280-370						
PDBg	370-390						allophane
PDCox	390-485	FL			2.5		
PDBg	485-510				1		allophane
PDCox	510-650						
PDBg	650-665						
PDCox	665-755	FU					
PDBg	755-765						

PS	765-920	ML			4.5		
PP	920-1060						
PM	1060-1070	Cobble					
PW	1070-1071						
T	1071-1166						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP93	N10/83	4929650	414260	10	20	7/9/2001	SC
Site Notes: Site is 10-30 m south of north Ona Beach section. Compare to NEWP92 (TL sample at 1270 cm).							
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
LA	0-20	Silt					
PDBtj	20-50			7.5YR5/8			
PDCox	50-200	FU		10YR8/8			
PDBg	200-230			2.5Y7/3			
PDCox	230-500						allophane
PDBg	500-520						Fe-ortstein
PDC	520-630						
PDBg	630-635						
PDCox	635-665						
PDC	665-790						
PDBg	790-810						allophane
PDC	810-930						
PDBg	930-935						
PDC	935-1240						Fe-ortstein
PDBw	1240-1260						
PDC	1260-1290						
PP	1290-1320						
PDBg	1320-1350						
PM	1350-1380						
PW	1380-1381						
T	1381-1391						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP94	10N/1983	4929640	416550	10	23	5/11/2002	RC
Site Notes: Site is on west side of N. Beaver Creek Rd (TL Sample taken at 2.5 m depth).							
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
LA	0-10	Silt			1	Very Weak B.	
LBw	10-60	Silt		10YR5/3	2.25	Very Weak B.	
PDBt	50-90	FVL		10YR5/5	4.5	Stong Blocky	
PDBw	90-120	FU			4.5	Weak Blocky	
PDCox	120-180	FU			3.5		gibbsite
PDBw	180-240				4.5	Strong Blocky	
PDCox	240-490		XBdipNE	10YR6/3	4		gibbsite

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP95	10N/1983	4929470	416240	6	13	6/24/2000	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
LA	0-10	Silt		10YR4/3			
LBw	10-70	Silt			2.75	Very Weak B.	
PDBt	70-110			10YR5/4	3.75	Strong Blocky	
PDBw	110-170	FU	XB	10YR6/4	4.5	Strong Blocky	gibbsite
PDC	170-245			10YR8/2	4.5		
PDCox	245-345			10YR6/6	4.5		

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP96	N10/83	4928820	414200	21	11	12/10/2000	SC

Site Notes: Sea cliff exposure near Deer Creek. Site is located 50 m north of Parkikng Lot on HW101.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
LA	0-25	Silt			2.6	Very Weak B.	
PDBw	25-200	Silty Sand				Very Weak B.	
PDBw	200-250	FU		7.5YR4/6	4	Weak Blocky	
PDBg	250-135	FL				Very Weak B.	
PDCox	135-255	FU			2		
PDBg	255-275	FL					
PDC0x	275-370	FU			2.25		
PDBg	370-385	FL					
PS	385-635	ML/Pebbles			4.5		Fe-ortstein
PM	635-655	Cobbles					
PW	655-656						
T	656-800						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Exposure	Date
NEWP97	10N/1983	4928790	416120	9	74	RC	6/24/2000

Site Notes: Eastern edge of dune cover.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
LA	0-7			10YR3/2			
LBw	7-75	Silt		10YR4/3	3.5	Very Weak B.	
UBtj	75-105			10YR4/6	3.75	Weak Blocky	
UCox	105-205	FU		10YR5/6			

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP98	N10/83	4928580	414060	10	10	3/4/2001	SC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
LA	0-50				2.5	Very Weak B.	
LBg	50-75	FL		5Y4/1	2.5	Very Weak B.	
PDBw	75-160				4	Weak Blocky	Fe-ortstein

PDBg	160-210	FL				Very Weak B.	
PDC	210-300	FU					
PDBw	300-310				4.5	Very Weak B.	Fe-ortstein
PDCox	310-510	FU			2		
PP	510-540	FL			1.25		
PS	540-590	FU			4.5		
PM	590-610	Cobbles					
PW	610-611						
T	611-820						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP99	N10/83	4927650	413800	18	12	12/20/2000	SC

Site Notes: Site is in sea cliff located 300 m north of Seal Rocks State Park.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
HDA	0-25	Shells				Loose	
PDA	25-55				2.5	Very Weak B.	
PDBw	55-80				4	Weak Blocky	allophane
PDBg	80-95		Truncated	2.5Y6/1		Very Weak B.	
PDBw	95-245				4	Weak Blocky	
PDCox	245-305				3		
PDBg	305-315					Very Weak B.	
PDCox	315-445		PB				
PDA	445-470						
PDS	470-720		XB ripples				
PP	720-775						
PM	775-785						
PW	785-786						
T	786-900						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP100	10N/1983	4927410	416150	5	97	6/25/2000	SL
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDBw	0-9			10YR5/4	2	Very Weak B.	
PDBg	9-22			10YR5/1	2		
PDBw	22-32			10YR5/8			
PDCox	32-132						

Site Notes: Seal Rock midden site.

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP101	10N/1983	4927260	413830	4	17	6/19/2000	SC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
HDA	0-5	Shell					
HDC	5-105	ML					
HDA	105-125	ML					

LBw	125-140	Silt				Very Weak B.	
PDBtj	140-170		Truncated		4	Weak Blocky	
PDCox	170-1170	FU					
PM	1170-1270						
PW	1270-1370						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP102	10N/1983	4927070	415470	4	78	6/24/2002	RC/AU

Site Notes: This site is near the eastern limit of dunes. Loess deposits (0-30 cm contain three layers).

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
LBw	0-30	Silt		10YR6/4	2.5	Very Weak B.	
PDCox	30-70	FVL			1.75	Very Weak B.	
PDBw	120-140	Silt			3	Very Weak B.	
PDBw	140-150	FVL			2.25	Very Weak B.	
PDBtj	150-180	FU			3.5	Weak Blocky	
PDBw	180-205	FU			4	Weak Blocky	
TBtj	205-210						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP103	N10/83	4926910	413830	17	12	1/6/2001	SC

Site Notes: This section is located about half a kilometer south of Seal Rocks State Park.

TL Samples (SER1 at 7.5 m depth=beach backshore and SER2 at top of Pleistocene dune section at 2.5 m depth).

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
HDA	0-20	FL Shell			1	Loose	
HDC	20-130					Loose	
LA	130-190				2.5		
LBg	190-205	FL	Truncated		2	Very Weak B.	
PDBw	205-265			7.5YR4/6	4	Weak Blocky	Fe-ortstein
PDCox	265-335	FU			3.5	Very Weak B.	
PDBg	335-350	Silt			2	Very Weak B.	
PDCox	350-440	FU			4		Fe-ortstein
PDBg	440-470				2		
PS	470-680	ML and H.M.			4.5		
PM	680-740	Cobbles					
PW	740-741						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP104	10N/1983	4926900	414130	4	39	6/19/2000	RC

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDBw	0-200			7.5YR3/3	3.25		
PDCox	200-400						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure

NEWP105	10N/1983	4926120	417100		132	6/23/2000	RC

Site Notes: Easternmost limit of Pleistocene dune sheet, near cemetery on ridge.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
LA	0-5						
LBw	5-70	Silt			2	Very Weak B.	
PDBtj	70-95	FVU		7.5YR5/6	4.5	Stong Blocky	
PDBw	95-100	FU				Weak Blocky	

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP106	N10/83	4926060	413880	10	9	6/24/2002	SC/CC

Site Notes: Recessed sea clif at small creek valley. Sand/reworked loess (wash) drapes the creek valley wall. RC sample in sandy loess (150 cm depth).

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
HDC	0-35	FU	Truncated		0	Loose	
LBw	35-125	Silt		10YR4/4	2	Very Weak B.	
LBw	125-175	Silt		7.5YR5/4	2.5	Very Weak B.	
PDA	175-205	VFL		10YR3/2	1.75	Very Weak B.	
PDC	205-305	FU			3.75		

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP107	N10/83	4926010	413850	12	8	12/10/2000	SC

Site Notes: This section is located just north of Quail Street, south of Seal Rocks.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
HDA	0-20	FU				Loose	
HDC	20-50				2.5	Very Weak B.	
HDA	50-60					Very Weak B.	
LBg	60-80					Very Weak B.	Fe-ortstein
PDBw	80-165			7.5YR4/6	4	Weak Blocky	Fe-humate
PDCox	165-265				3	Very Weak B.	allophane
PDBg	265-290	FL			4	Very Weak B.	
PDCox	290-385						
PDBg	385-390						
PDCox	390-475	FU					
PDBg	475-485						
PS	485-595	ML			4.5		
PM	595-610	Cobbles					
PW	610-611						
T	611-630						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP108	10N/1983	4925740	416640	5	148	6/23/2000	RC

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis

LA	0-20	Silt					
LBw	20-40	Silt				1.5	Very Weak B.
PDBtj	40-55			10YR5/3		3.5	Weak Blocky
PDBw	55-60	FU		10YR6/4		2	
PDC	60-125					3	

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP109	N10/83	4925180	413950	20	13	12/17/2000	SC

Dune Sheet: This section is located about 1.5 km north of Driftwood State Park.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis //Other
HD	0-190					Loose	
LA	190-205	Silt				Very Weak B.	
LBw	205-275	Silt			2	Very Weak B.	
PDBw	275-325	FU			4	Weak Blocky	
PDA	325-380				2.5	Very Weak B.	
PDBw	380-530	FU		7.5YR4/6	4.5	Weak Blocky	Fe-ortstein
PDBg	530-550	FL				Very Weak B.	
PS	550-800	ML					

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP110	N10/83	4924330	414000	5	20	8/16/2002	SC

Site Notes: This site is located about just north of Driftwood Park Access. Groundwater seeps at the base of the Holocene.

FeOx stains modern beach sands in front of the sea cliff.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
HDA	0-5					Loose	
HDC	5-100	FU				Loose	
HDBw	100-120				2.25	Weak Blocky	
HDCox	120-500		XBdipN			Very Weak B.	Fe-ortstein
PDBw	500-570		Truncated		3.75	Weak Blocky	
PDC	570-1270	FU	PB			Weak Blocky	
PDBw	1270-1320						
PDC	1320-1470						Fe-ortstein

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP111	N10/83	4924210	414060	16	21	12/17/2000	SC

Site Notes: This section is located just north of Driftwood State Park (compare to previous section NEWP110).

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
HD	0-500					Loose	
HDA	500-515					Very Weak B.	

HDCox	515-590	FU		10YR6/2	2.5	Very Weak B.	
PDA	590-615					Very Weak B.	
PDBw	615-765				4	Weak Blocky	Fe-ortstein
PDCox	765-1065	FU					
PDBw	1065-1115				4.5	Weak Blocky	
PDCox	1115-1565	FU			3.5		
PDBg	1565-1590	FL			1.25		
PDC	1590-1650	FU					
PS	1650-1790	ML			4		

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP112	10N/1983	4924020	414030	10	12	6//00	SC

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
HDA	0-5						
HDBw	5-15						
HDCox	15-115						
PDBtj	115-155						
PDBw	155-191						
PDCox	191-253						
PDC	253-278						
PDBg	278-288						
PDC	288-338						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP113	10N/1983	4924010	414290	7	12	6//00	RC

Site Notes: Eastern pinchout of Holocene sand cover.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
HDBw	0-10						
PDBw	10-50			10YR5/6			

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP114	N10/83	4923540	414060	12	11	12/17/2000	SC

Site Notes: This section is just south of Bucley Creek or about 500 m south of Driftwood State Park.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
HDA	0-10					Loose	
HDC	10-210	FU				Loose	
HDA	210-225					Loose	
HDBw	225-255			2.5YR6/6 w2.5YR5/6		Very Weak B.	Fe-ortstein
HDCox	255-375	FU				Very Weak B.	
LA	375-400	Silt			2.5	Very Weak B.	
PDBw	400-465	FVL		7.5YR5/8 w7.5YR4/6	4	Weak Blocky	
PDCox	465-520				3		
PDBg	520-545	FL			2.5	Very Weak B.	

PDCox	545-625		XBdipS				
PDBg	625-627	FL					
PDCox	627-707	FL			3		allophane
PDBg	707-712						
PS	712-792				4.5		

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP115	10N/1983	4923020	416270	7	104	6/23/2000	SL
Site Notes: Easternmost limit of dune sand (patches 0-30 cm in thickness).							
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDBw	0-30					Very Weak B.	
TBtj	30-90					Strong Blocky	

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP116	N10/83	4922890	4139000	18	11	12//00	SC
Site Notes: This site is just north of the north beach access from Bay Shore, i.e. due west of Hidden Valley Lake.							
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
HDA	0-5					Loose	
HDC	5-215	FU			0.5	Loose	
PDA	215-240				2.5	Very Weak B.	
PDBw	240-265	FU			4	Weak Blocky	
PDBg	265-270	FL				Very Weak B.	
PDC	270-305	FU			2		allophane
PDBg	305-330	FL			1.25		
PDC	330-530	FU			2.5		

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP117	10N/1983	4922700	414600	13	25	6/23/2000	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
LA	0-6	Silt					
LBw	6-56	Silt		10YR6/6	2	Very Weak B.	
PDBw	56-86	FU			3.75	Weak Blocky	
PDCox	86-224						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP118	10N/1983	4922470	414880	9	54	6/23/2000	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA	0-11						
PDBw	11-98			7.5YR5/6			
PDC	98-228						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP119	10N/1983	4922440	41570	6	77	6/23/2000	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis

LA	0-5	Silt					
LBw	5-50	Silty Sand				Very Weak B.	
LBw	50-105	Silty Sand		10YR6/4	2.5	Very Weak B.	
PDCox	105-205	200	FU				

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP120	N10/83	4921660	414550	8	59	9/2/2001	TR

Site Notes: Trenches dug by developer for residential development, NW Pine Crest Way.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
Fill	0-26						
PDE	26-30				3.75	Weak Blocky	
PDBtj	30-45		Truncated	7.5YR 5/6	4.5	Strong Blocky	
PDBw	45-120			7.5YR 5/4	4		
PDCox	120-150						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP121	N10/83	4921650	414560	5	62	9/2/2001	TR

Site Notes: Section taken at south end of Pine Crest development (compare to NEWP120).

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
Fill	0-30						
PDA	30-35						
PDBtj	35-45			7.5YR 5/6	4.5	Strong Blocky	
PDBw	45-65			7.5YR 6/4	3	Very Weak B.	
PDCox	65-130			10YR 7/6	2.5		

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP122	10N/1983	4921610	414500	19	43	6//00	RC

Site Notes: Site in slump headwall on US101, north of Alsea Bay wayside (RC Sample taken in PP at 5.8m).

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA	0-15						
PDBtj	15-53			10YR3/6	4	Weak Blocky	
PDBw	53-97					Very Weak B.	
PDCox	97-247		XB		4.5		
PDBtj	247-269			10YR5/6	3	Very Weak B.	
PDBw	269-279					Very Weak B.	
PDCox	279-579		XB		4.5		
PP	579-601						
PDBg	601-701			1Gley6/104	0.5		
PDCox	701-731						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP123	10N/1983	4920730	414470	7	25	6/23/2000	BC

Site Notes: North end of Alsea Bay bridge (wayside-turnout access).

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis

HDA	0-3						
HDBw	3-27						
HDCox	27-227						
PDBw	227-277			7.5YR6/8			
PDCox	277-477						
PDBw	577-597						Fe-ortstein
PDCox	497-797						
PDBg	797-807						
PDC	807-907						
PDBw	907-957			10YR7/8			
PDC	957-1157						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP124	N10/83	4920050	413790	18	10	12/26/2000	SC

Site Notes: This site is the foredune at Bay Shore spit, north of Waldport.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
HDC	0-400	FL		10YR6/2	0.5	Loose	

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date
NEWP125	10N/1983	4920230	416400	6	10	6/22/2000

Site Notes: Easternmost limit of dune sand above bedrock terrace.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA	0-5						
PDBw	5-55				2.25		
PDCox	55-155						
T	155-1155						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP126	10N/1983	4919560	415540	3	44	6/22/2000	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
A	0-15						
PDBw	15-65			10YR4/4			
PDCox	65-270			10YR6/4			

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP127	10N/1983	4918650	414400	6	45	6/22/2000	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA	0-5						
PDBw	5-80			10YR4/7			
PDCox	80-240						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP128	10N/1983	4918010	414060	10	22	6/20/2000	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA	0-20						

PDBw	20-45						
PDCox	45-95						Fe-ortstein
PDBw	95-115						
PDCox	115-265						
Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP129	10N/1983	4916620	413970	10	25	6/20/2000	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDCox	0-100			10YR6/4			
PDC	100-190						
PDBg	190-195				2.5		
PDC	195-215						
PDBg	215-257						
PDC	257-557		XBdipE	10YR6/6			
Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP130	10N/1983	4916610	413880	10	22	6/20/2000	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA	0-10						
PDBtj	10-60				4.25		
PDC	60-410		XBdipE				
Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP131	10N/1983	4916220	413520	6	13	6/21/2000	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA	0-5						
PDBw	5-35			10YR7/3	2.25	cohesive	
PDCox	35-85			10YR7/6			
PDBg	85-95						
PDCox	95-145						
PDBg	145-155						
PDC	155-355						
Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP132	10N/1983	4916200	415330	24	25	6/27/2000	RC
Easternmost extent of Pleistocene sand cover.							
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDCox	0-10						
T							
Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP133	10N/1983	4915470	413960	10	36	6/20/2000	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA	0-10						
PDBw	10-80			10YR6/6	2.5	Very Weak B.	

DCox	80-180		XBdipE				
PDBg	180-190						
PDC	190-290		XBdipE				

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP134	10N/1983	4915300	414800	10	67	6/22/2000	RC

Site Notes: Eastermost limit of dune sheet in area.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDBw	0-50						
TBtj	50-100				4.5	Strong Blocky	

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP135	10N/1983	4914930	413210	6	10	6/21/2000	SL

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
HDA	0-2						
HDCox	2-72						
PDA	72-79						
PDBw	79-114			7.5YR5/3	3.75	Weak Blocky	
PDCox	114-159				3.25	Very Weak B.	

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP136	10N/1983	4914090	413770	7	15	6/21/2000	RC

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA	0-5						
PDBw	5-35			7.5YR5/4	3		
PDBg	35-50						
PDC	50-335						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP137	N10/1983	4914090	413790	8	20	5/12/2002	RC

Site Notes: Reynolds Creek area (TLSample 088N at 4.3 m depth).

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
LA	0-10	Silt					
PDBw	10-35	VFL			3	Very Weak B.	
PDBg	35-50	VFL			4	Very Weak B.	
PDCox	50-500	FU			3.25		

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP138	10N/1983	4913950	414010	5	20	6/27/2000	RC

Site Notes: Topsoil Btj horizon developed on silt colluvium above beach deposits above wavecut platform.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
LA	0-5	Silt			1	Very Weak B.	
LBw	5-45	Silt			2	Very Weak B.	
PSBtj	45-65			7.5YR7/8	4	Strong Blocky	

PSBw	65-95				3.5	Weak Blocky	
PSCox	95-195	CL	Beach laminae		3		
PM	195-145	Cobbles					
PW	145-155						
T	155-200	Mudstone					

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP139	10N/1983	4913930	413700	13	20	6/21/2000	RC

Site Notes: Site is at eastern limit of Pleistocene dune sheet.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA	0-5						
PDBw	5-55	FU					
T	55-97						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP140	N10/83	4912890	413330	20	10	6/12/2000	SC

Site Notes: This section is located 200 m south of Tillicum State Park walkway to the beach.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
HDA	0-5					Loose	
HDC	5-30	FL			0.5	Loose	
PDA	30-60					Loose	
PDBw	60-110	FU		10YR5/8	4	Weak Blocky	
PDBg	110-155			2.5Y6/1	3	Very Weak B.	
PDCox	155-270	FU			3.5		allophane
PDBg	270-280					Very Weak B.	
PDCox	280-335			10YR6/3	3.5		allophane
PDBg	335-385						
PDC	385-445	FU					

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP141	10N/1983	4912770	413370	7	13	6/21/2000	RC

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA	0-5						
PDBw	5-25				2		
PDCox	25-55						
PDBw	55-65						
PDBg	65-80						
PDBw	80-120						
PDBg	120-135				1.5		
T	135-160						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP142	10N/1983	4909890	412370	25	10	6/18/2000	SC

Site Notes: Sites is north of Yachats.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
HDA	0-5					Loose	
HDC	5-35					Loose	
HDA	35-65					Loose	
PDBtj	65-80		Truncated		4	Weak Blocky	
PDBw	80-95		Truncated			Very Weak B.	
PDCox	95-135	ML					
PDBg	135-155						
PDBw	155-180		Truncated			Very Weak B.	
PDCox	180-220						
PDBg	220-230						
PDCox	230-250						
PDBg	250-265		Truncated				
PDBw	265-285					Weak Blocky	Fe-ortstein
PDBg	285-305						
PDCox	305-345						
PDBw	345-365					Very Weak B.	

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP143	10N/1983	4909660	412500	11	26	6/21/2000	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA	0-10						
PDBw	10-70			7.5YR6/6	2.75		
PDCox	70-130						
PDC	130-450						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP144	10N/1983	4909280	412840	4	31	6/21/2000	RC
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA	0-8						
PDB	8-28			10YR7/6	4.5		
PDCox	28-98						
PDC	98-248						
PDBg	248-268						Fe-ortstein

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP145	10N/1983	4908780	412580	9	34	6/21/2000	SL
Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA	0-5						
PBw	5-50		3.75				
PDCox	50-105						
PDBtj	105-110						
PM	110-150						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP146	N10/83	4908460	412320	22	22	9/12/2000	SC

Site Notes: This site is located 900 m south of Vingie Creek, north of Yachats (RC Sample from 100 cm depth).
Holocene dunes are now being truncated (post-HDA RC sample date 1.0ka) indicating net littoral sand loss.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
HU	0-100				0	Loose	
HDA	100-120						
PDA	120-140						
PDBg	140-160					Very Weak B.	
PDBw	160-326			10YR4/6	4	Weak Blocky	allophane
PDBg	326-391				3	Very Weak B.	
PDCox	391-421					Very Weak B.	
Cover							

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP147	10N/1983	4907870	412130	10	31	6/23/2000	RC

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PUBw	50						
PUC	50						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP148	10N/1983	4907400	411580	5	12	6/20/2000	SC

Site Notes: Pleistocene dunes above reoccupied wave-cut platform (N. Yachats) multiple truncated Bw, Bg layers.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
HDA	0-2						
HDBw	2-10						
PDBtj	10-25			10YR6/6	3.25		
PD	25-325						
PM	325-475						
T	475-525						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP149	N10/83	4907350	411600	4	12	9/2/2001	SC

Site Notes: This section is located 15 m north of park bench at turnout on Sea Cliff in Yachats.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDBw	0-15			7.5YR 7/8	3.25	Weak Blocky	
PDCox	15-80	FU		10YR 6/1	2.5	Very Weak B.	
PDBg	80-90					Very Weak B.	Fe-ortstein
PDCox	90-155						
PDBw	155-165					Weak Blocky	
PDCox	165-270						allophane
PDBw	270-280					Very Weak B.	
PDCox	280-320						

PDBw	320-322					Very Weak B.	
PDCox	322-340						
PDC	340-580	ML			3.25		gibbsite
PP	580-600						
PSBtj	600-640						
PS	640-680	MU			4.5		
PM	680-710	Cobbles					
PW	710-711						
T	711-751						

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP150	N10/83	4907310	411620	7	12	9/2/2001	SC

Site Notes: This site is located 30 m south of the bench at the park.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
PDA	0-20				2.5	Very Weak B.	
PDBw	20-65			5YR 5/1	3.5	Weak Blocky	
PDCox	65-90	FU		10YR 6/6	3	Very Weak B.	
PDBtj	90-120				3.75	Weak Blocky	
PDCox	120-180				3.25		
PDBg	180-185					Very Weak B.	
PDCox	185-270						allophane
PDBw	270-275		Truncated			Very Weak B.	
PDCox	275-350						
PDBg	350-355		Truncated			Very Weak B.	
PDC	355-570						Fe-ortstein
PP	570-650						
PM	650-670	Cobbles	Truncated				
PW	670-671						
T	671-700	Basalt					

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP151	N10/83	4906560	411960	5	10	6/25/2002	SC

Site Notes: This site is located on the south side of the Yachats River mouth, just east of the beach access stair way. RC sample from base of Holocene dune 0.8 m.

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
HDA	0-25	Shells		2.5Y2.5/1	0.25	Loose	
HDC	25-29	FU Shells		2.5Y7/4	0.5	Loose	
HDA	29-55				1	Loose	
HDC	55-58	FU Shells		2.5Y7/3	0	Loose	
HDA	58-70			5Y3/1	0.25	Very Weak B.	
Fire Pit	70-80	Shells		10YR6/6	1.5		
LBw	80-120	Silt		10YR3/4	2	Weak Blocky	
PUBw	120-125	Pebbles		10YR5/6	3.5	Strong	

						Blocky	
PSBw	125-160	MU		10YR7/8	4.5	Strong Blocky	
PM	160-200	Cobbles			4.5		
PW	200-201						
T	201-500	Basalt					

Dune Sheet	Zone/NAD	UTM-N	UTM-E	EPE (m)	Alt (m)	Date	Exposure
NEWP152	N10/83	4888720	410460	17	21	2020	SC

Site Notes: This site is 500 m north of Hobbit trail at Heceta Head.

RC Sample from base of Holocene dunes (HDA1070 cm).

Units	Depth cm	Grain Size	Bedding	Color	P.kg/cm^2	Structure	Diagenesis
HDA	0-15						
HDC	15-1065		XB			Loose	
HDA	1065-1085					Loose	
HDC	1085-1385					Loose	
PDA	1385-1440					Loose	
PDBw	1440-1680	FU			4	Strong Blocky	
PDBg	1680-1780					Very Weak B.	

Appendix B: Geotechnical Hand Auger Boring Logs

SOIL DESCRIPTION FORMAT

(1) Consistency,	(10) structure,
(2) color,	(11) cementation,
(3) grain size,	(12) reaction to HCL,
(4) classification name [secondary PRIMARY additional];	(13) odor,
(5) moisture,	(14) groundwater seepage,
(6) plasticity of fines,	(15) caving,
(7) gradation,	(16) (unit name and/or origin)
(8) angularity,	(17) (till zone/topsoil and root zone).
(9) shape,	For Rock and Intermediate Materials, see pages 3 and 4.

Note: Bolded items are the minimum required elements for a soil description. Examples are on back of sheet.

1. CONSISTENCY - COARSE-GRAINED

Term	SPT (140-lb. hammer)[1]	D & M Sampler (140-lb. hammer)[1]	D & M Sampler (300-lb. hammer)[1]	Field Test (using ½-inch rebar)
Very loose	0 - 4	0 - 11	0 - 4	Easily penetrated when pushed by hand
Loose	4 - 10	11 - 26	4 - 10	Easily penetrated several inches when pushed by hand
Medium dense	10 - 30	26 - 74	10 - 30	Easily to moderately penetrated when driven by 5-pound hammer
Dense	30 - 50	74 - 120	30 - 47	Penetrated 1-foot with difficulty when driven by 5-pound hammer
Very dense	>50	>120	>47	Penetrated only few inches when driven by 5-pound hammer

1. CONSISTENCY - FINE-GRAINED

Term	SPT (140-lb. hammer)[1]	D & M Sampler (140-lb. hammer)[1]	D & M Sampler (300-lb. hammer)[1]	Pocket Pen.[2]	Torvane[3]	Field Test
Very soft	<2	<3	<2	<0.25	<0.13	Easily penetrated several inches by fist
Soft	2 - 4	3 - 6	2 - 5	0.25 - 0.5	0.13 - 0.25	Easily penetrated several inches by thumb
Medium stiff	4 - 8	6 - 12	5 - 9	0.50 - 1.0	0.25 - 0.5	Can be penetrated several inches by thumb with moderate effort
Stiff	8 - 15	12 - 25	9 - 19	1.0 - 2.0	0.5 - 1.0	Readily indented by thumb but penetrated only with great effort
Very stiff	15 - 30	25 - 65	19 - 31	2.0 - 4.0	1.0 -2.0	Readily indented by thumbnail
Hard	>30	>65	>31	>4.0	>2.0	Difficult to indent by thumbnail

[1] Standard penetration resistance (SPT blow count); Dames & Moore (D & M) sampler, number of blows/ft for last 12" and 30" drop.
[2] Unconfined compressive strength with pocket penetrometer; in tons per square foot (tsf).
[3] Undrained shear strength with torvane (tsf).

2. COLOR

Use common colors. For combinations use hyphens. To describe tint use modifiers: pale, light, dark. For color variations use "mottles". If something is speckled, not mottled, you may add that information at the end of the soil description. Mottles and speckles mean two different things. Soil color charts may be required by client. Examples: red-brown; brown-gray SILT with orange mottles; or dark brown.

4. CLASSIFICATION NAME*

	Name and Modifier Terms	Constituent Percentage	Constituent Type
Coarse-grained	GRAVEL, SAND, COBBLES, BOULDERS	>50%	PRIMARY
	sandy, gravelly, cobbley, bouldery	30 - 50%	secondary
	silty, clayey**	15 - 50%	
	some (gravel, sand, cobbles, boulders)	15 - 30%	additional
	some (silt, clay)**	5 - 15%	
	trace (gravel, sand, cobbles, boulders)		
	trace (silt, clay)**	<5%	
Fine-grained	CLAY, SILT**	>50%	PRIMARY
	silty, clayey**	30 - 50%	secondary
	sandy, gravelly		
	some (sand, gravel, cobbles, boulders)	15 - 30%	additional
	some (silt, clay)**		
	trace (sand, gravel, cobbles, boulders)	5 - 15%	
	trace (silt, clay)**		
Organic	PEAT	50 - 100%	PRIMARY
	organic (soil name)	15 - 50%	secondary
	(soil name) with some organics	5 - 15%	additional

* For grain sizes see: 3. Grain Size.
** For describing fine-grained soil dry strength, dilatancy, toughness, and plasticity testing are performed to determine silt and/or clay constituent percentage (see Describing Fine-Grained Soil page 2). Confirmation requires laboratory testing (Atterberg Limits and hydrometer).

3. GRAIN SIZE

Description		Sieve*	Observed Size
boulders		-	>12"
cobbles		-	3" - 12"
gravel	coarse	¾" - 3"	¾" - 3"
	fine	#4 - ¾"	0.19" - ¾"
sand	coarse	#10 - #4	0.079" - 0.19"
	medium	#40 - #10	0.017" - 0.079"
	fine	#200 - #40	00029" - 0.017"
fines		<#200	<0.0029"

* Use of #200 field sieve encouraged.

5. MOISTURE

Term	Field Test
dry	very low moisture, dry to touch
moist	damp, without visible moisture
wet	visible free water, usually saturated

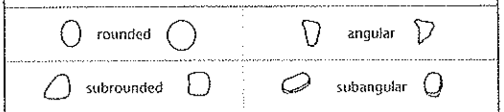
6. PLASTICITY OF FINES

Term	Field Test
nonplastic	Dry specimen ball falls apart easily. Cannot be rolled into thread at any moisture.
low plasticity	Dry specimen ball easily crushed with fingers. Can be rolled into 1/8" thread with some difficulty.
medium plasticity	Difficult to crush dry specimen ball. Easily rolled into 1/8" thread.
high plasticity	Cannot crush dry specimen with fingers. Easily rolled and re-rolled into 1/8" thread.

7. GRADATION - COARSE-GRAINED

TERM	OBSERVATION
well graded	Full range and even distribution of grain sizes
poorly graded	Narrow range of grain sizes present
uniformly graded	Consists of predominantly one grain size
gap graded	Within the range of grain sizes present, one or more sizes are missing

8. ANGULARITY



9. SHAPE

TERM	OBSERVATION
flat	particles with width/thickness ratio >3
elongated	particles with length/width ratio >3
flat and elongated	particles meet criteria for both flat and elongated

10. STRUCTURE

TERM	OBSERVATION
stratified	alternating layers >1 cm thick, describe variation
laminated	alternating layers <1 cm thick, describe variation
fissured	contains shears and partings along planes of weakness
slickensides	partings appear glossy or striated
blocky	breaks into lumps, crumbly
lensed	contains pockets of different soils, describe variation
homogenous	same color and appearance throughout

11. CEMENTATION

TERM	FIELD TEST
weak	breaks under light finger pressure
moderate	breaks under hard finger pressure
strong	will not break with finger pressure

12. REACTION TO HCL (HYDROCHLORIC ACID)

TERM	FIELD TEST
none	no visible reaction
weak	bubbles form slowly
strong	vigorous reaction

13. ODOR

Describe odor as organic; or potential non-organic*
*Needs further investigation

14. GROUNDWATER SEEPAGE

Describe occurrence (soil horizon, fissures) and rate: slow (<1 gpm); moderate (1 - 3 gpm); rapid (>3 gpm)

15. CAVING

Describe occurrence (depths, soils) and amount			
Test Pits	minor (<1 ft³)	moderate (1-3 ft³)	severe (>3 ft³)
Borings	minor (<1 linear ft)	moderate (1-3 linear ft)	severe (>3 linear ft)

16. (UNIT NAME/ORIGIN)

Name of stratigraphic unit (e.g. Willamette Silt), formation name (e.g. Cowlitz Formation) or origin of deposit (Alluvium, Colluvium, Residual, Loess, fill, etc.).

17. (TILL ZONE/TOPSOIL AND ROOT ZONE)

Describe the thicknesses of tillzone, topsoil, and/or root zone layers.

DESCRIBING FINE-GRAINED SOIL

NAME	FIELD TEST			
	DRY STRENGTH (A BELOW)	DILATANCY REACTION (B BELOW)	TOUGHNESS OF THREAD (C BELOW)	PLASTICITY (PAGE 1 ITEM 5)
SILT	none, low	rapid	low	nonplastic, low
SILT with some clay	low, medium	rapid, slow	low, medium	low
clayey SILT	medium	slow	medium	low, medium
silty CLAY	medium, high	slow, none	medium, high	medium
CLAY with some silt	high	none	high	high
CLAY	very high	none	high	high
organic SILT	low, medium	slow	low, medium	nonplastic, low
organic CLAY	medium to very high	none	medium, high	medium, high

A. DRY STRENGTH

TERM	OBSERVATION
none	Dry specimen crumbles into powder with mere pressure of handling.
low	Dry specimen crumbles into powder with some finger pressure.
medium	Dry specimen breaks into pieces or crumbles with considerable finger pressure.
high	Dry specimen can not be broken with finger pressure. Will break into pieces between thumb and a hard surface.
very high	Dry specimen can not be broken between thumb and a hard surface.

B. DILATANCY REACTION

TERM	OBSERVATION
none	No visible change in the specimen.
slow	Water appears slowly on surface of specimen during shaking and doesn't disappear or disappears slowly upon squeezing.
rapid	Water appears quickly on the surface of the specimen during shaking and disappears quickly upon squeezing.

C. TOUGHNESS OF THREAD

TERM	OBSERVATION
low	Only slight hand pressure is required to roll the thread near the plastic limit. The thread and lump are weak and soft.
medium	Medium pressure is required to roll the thread to near the plastic limit. The thread and lump have medium stiffness.
high	Considerable hand pressure is required to roll the thread to near the plastic limit. The thread and lump have very high stiffness.

Examples: Stiff, brown SILT (Willamette Silt); or Loose, brown, fine, silty SAND; poorly graded, subrounded, weak cementation, no reaction to HCL (Alluvium); or Very dense, brown, silty GRAVEL with some sand; wet, nonplastic, angular (Colluvium).

Field log should also include: interpreted contacts (based on samples, cuttings, drilling rate/changes), drillers comments (hardness, changes, lost circulation, etc.), interpreted unit descriptions (interbedded, gradational changes, etc.), and water level observations.

DEPTH FEET	MATERIAL DESCRIPTION	ELEV DEPTH	TESTING	SAMPLE	▲ BLOW COUNT ● MOISTURE CONTENT % RQD% CORE REC% (0 50 100)	INSTALLATION AND COMMENTS
0.0	Medium dense, brown, fine, silty SAND; moist, uniformly graded, some small roots.					
2.5	Medium dense, light brown, fine SAND with trace to some silt; moist, uniformly graded.	2.5				
	Dense, orange-brown, fine SAND with red-brown mottles; moist, uniformly graded, moderately cemented with Fe-oxide (Paleodune sand). becomes light orange-brown with trace silt and weakly cemented with Fe-oxide at 6 feet	4.1				
5.0			SIEV			@t 5.5 feet PMTÉ 5.5 P200 = 3.1%
7.5			SIEV			PMT at 8 feet P200 ~ 1.8%
10.0	Medium dense, tan, fine SAND; moist, uniformly graded (Paleodune sand).	10.0				
12.5						
15.0						
	Medium dense, dark gray-brown to light gray, fine, silty SAND; moist to wet, uniformly graded (Paleosol/deflation plain).	16.5	SIEV			P200 = 16.1%
17.5	Medium dense to dense, red-brown, fine SAND with trace silt; wet, uniformly graded (Paleodune sand).	18.0	SIEV			P200 = 4.9%
20.0	Boring terminated due to collapse at groundwater surface.	20.0				
22.5						
25.0						
27.5						
30.0						

7/13/02

DRILLED BY: LOGGED BY: CMC COMPLETED: 7/13/02

BORING METHOD: hand auger (see report text) BORING BIT DIAMETER: 3-inch

GEODESIGN INC 15575 SW Sequoia Parkway - Suite 100 Portland, Oregon 97224 Off 503.968.8787 Fax 503.968.3068	PINECREST DEVELOPMENT	BORING HA-1	
	FEBRUARY 2005	PINECREST DEVELOPMENT WALDPORT, OR	FIGURE A-4

BORING LOG PINECRESTDEV.GPJ GEODESIGN.GDT PRINT DATE: 2/9/05

DEPTH FEET	MATERIAL DESCRIPTION	ELEV. DEPTH	TESTING	INSTALLATION AND COMMENTS
0	Medium dense, dark brown, fine SAND with some silt; moist, uniformly graded, some fine organics (upper portion of topsoil removed during grading).			
	Medium dense to dense, orange-brown, fine SAND; moist, uniformly graded.	3.9		
5	Medium dense, dark brown to brown, fine SAND with trace silt and fine organics; moist, uniformly graded (weak Paleosol/deflation plain).	5.1	SIEV	PMT1 at 5.5' P200 = 1.9% PP = 9.5 tsf
	Medium dense to dense, light orange-brown to tan, fine SAND; moist, uniformly graded(Paleodune sand).	5.2	PP	
10			PP	PMT2 at 9.5' PP = 4.34 tsf
			PP	PP = 2.4 tsf
15				
20	Medium dense, brown, silty, fine SAND; moist, uniformly graded (Paleosol?).	19.5		
	Dense, red-brown, fine SAND with trace to some silt; moist, uniformly graded, moderately cemented with Fe-oxide (iron pan).	20.5		
25	Medium dense to dense, light brown, fine SAND; moist, uniformly graded (Paleodune sand).	22.5		
30				
35	Boring terminated at 33.5 feet below ground surface.	33.5		
40				

Graphic Log | Sample | ▲ BLOW COUNT ● MOISTURE CONTENT % RQD% CORE REC% (0 – 50 – 100)

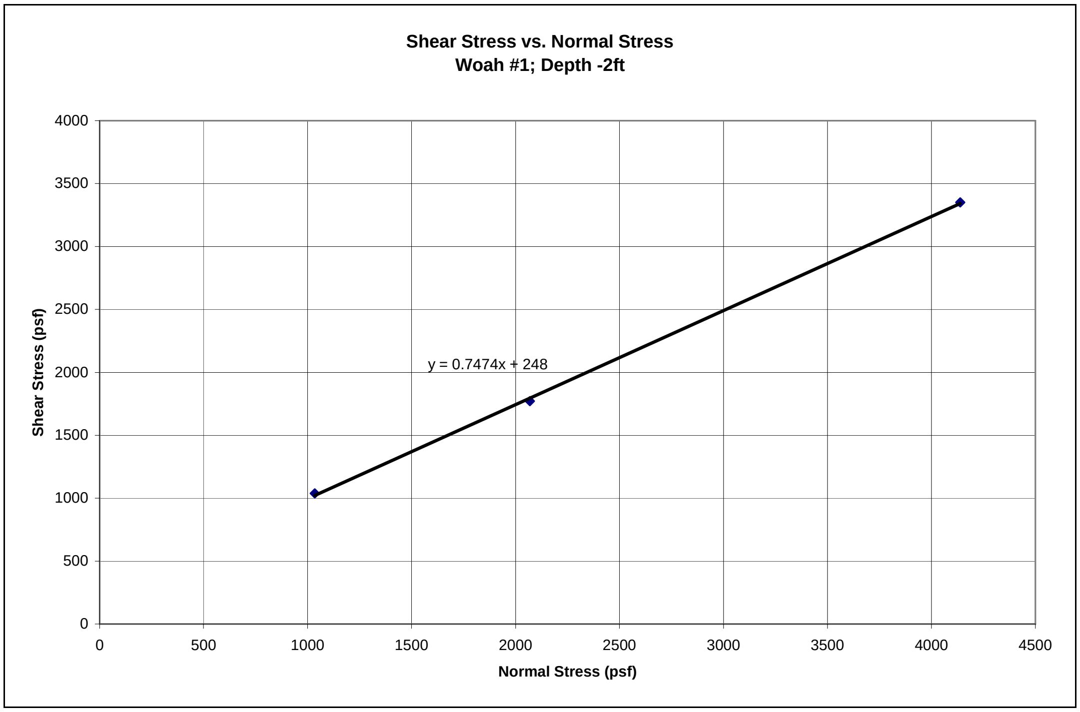
DRILLED BY: LOGGED BY: CMC COMPLETED: 3/09/05

BORING METHOD: hand-auger (see report text) BORING BIT DIAMETER: 3-inch

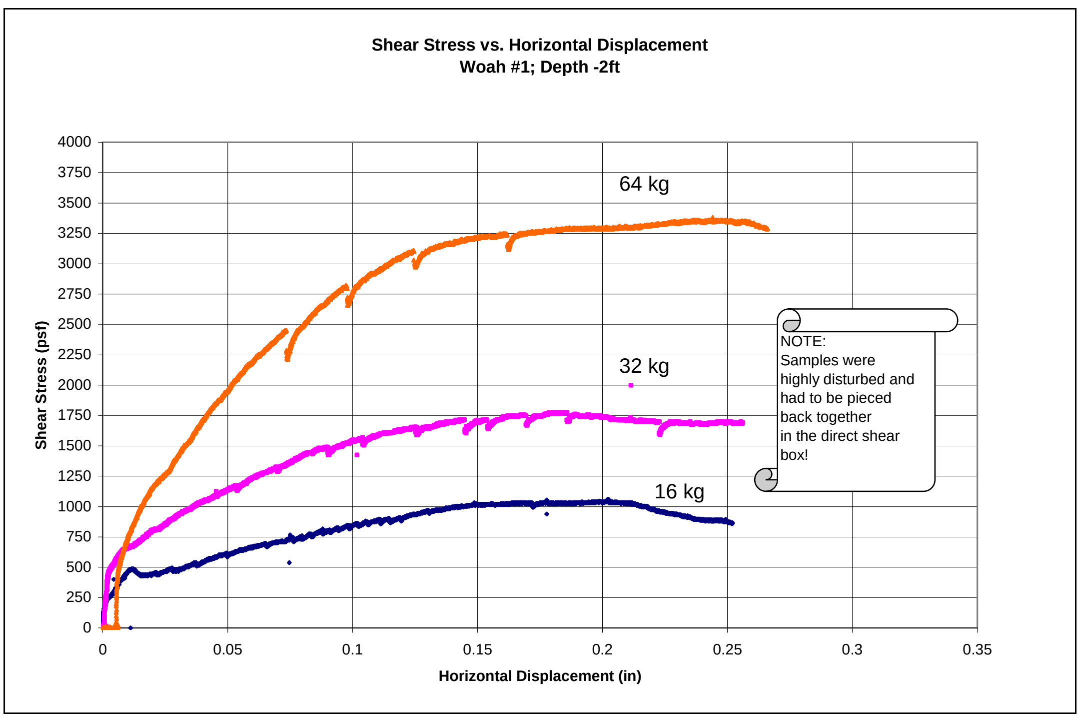
GEODESIGN INC	ONA HOUSE	BORING HA-2	
	FEBRUARY 2005	DAN MACABES HOUSE SEAL ROCK, OR	FIGURE A-5

BORING LOG ONAHOUSE.GPJ GEODESIGN.GDT PRINT DATE: 2/9/05

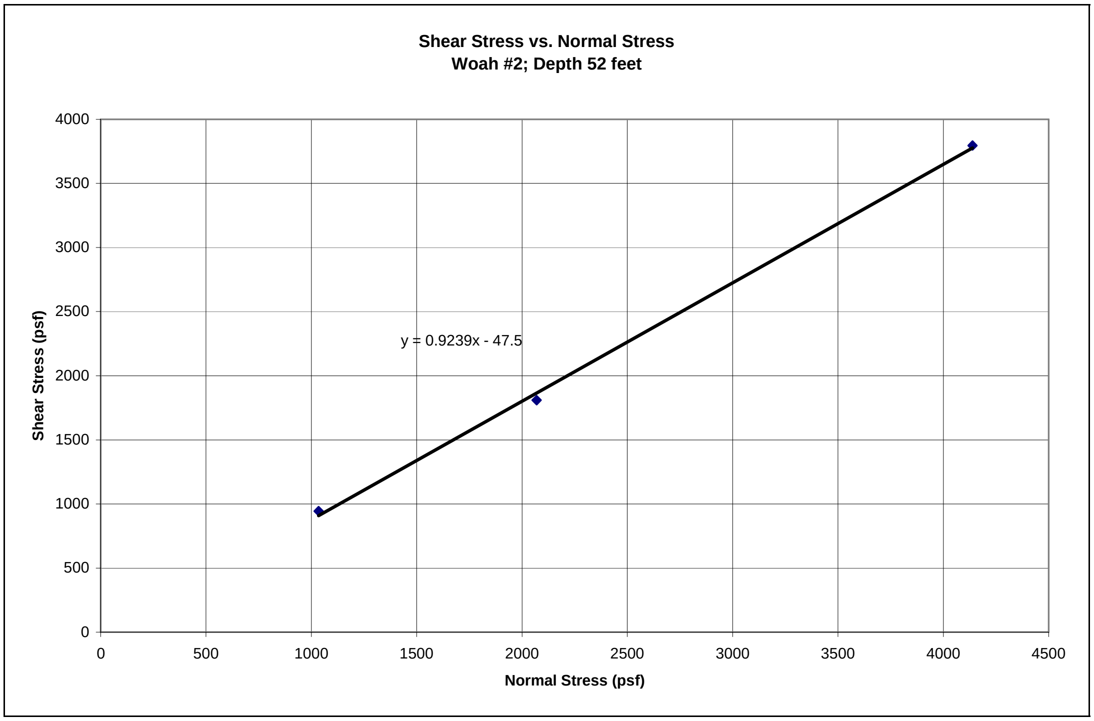
Appendix C: Direct Shear Data From Renee Summers, Civil Engineering, PSU

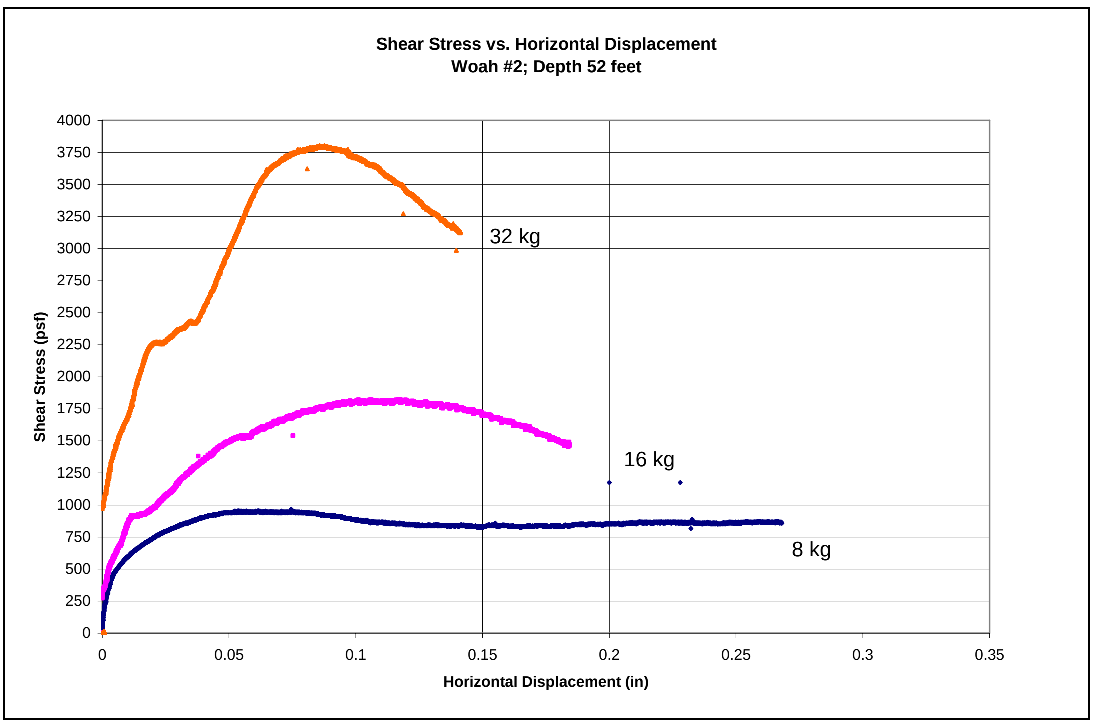


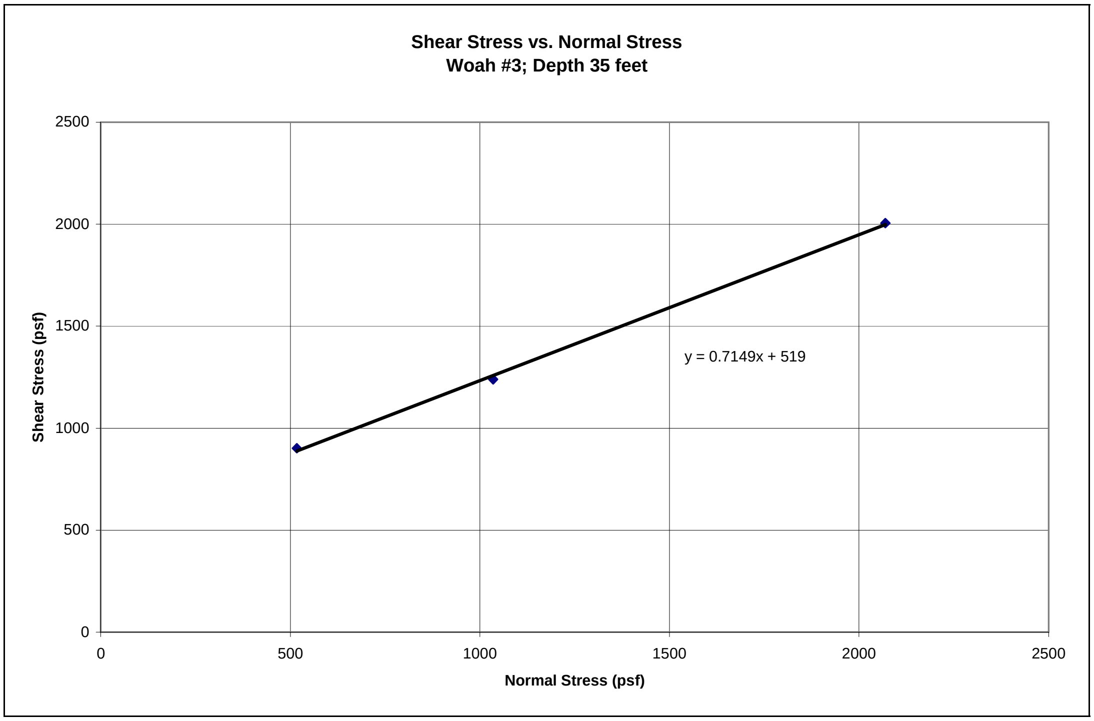
Shear Stress vs. Normal Stress
Woah #1; Depth -2ft
4000
3500
3000
2500
2000
1500
1000
500
0
Shear Stress (psf)
y = 0.7474x + 248
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Normal Stress (psf)

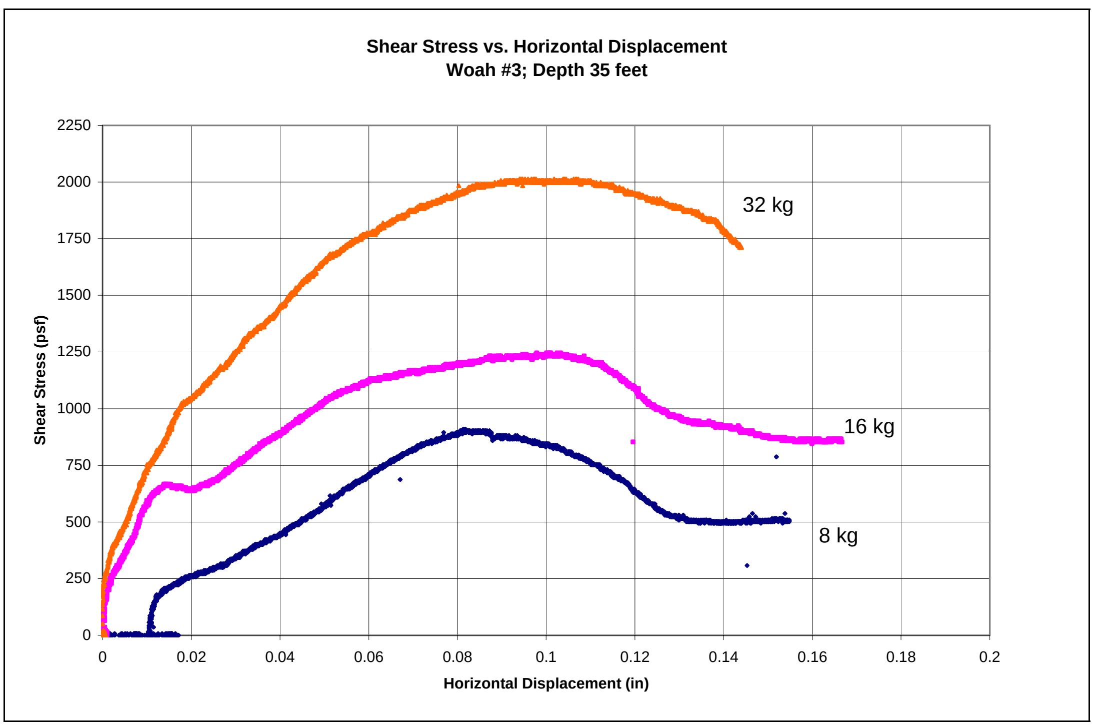


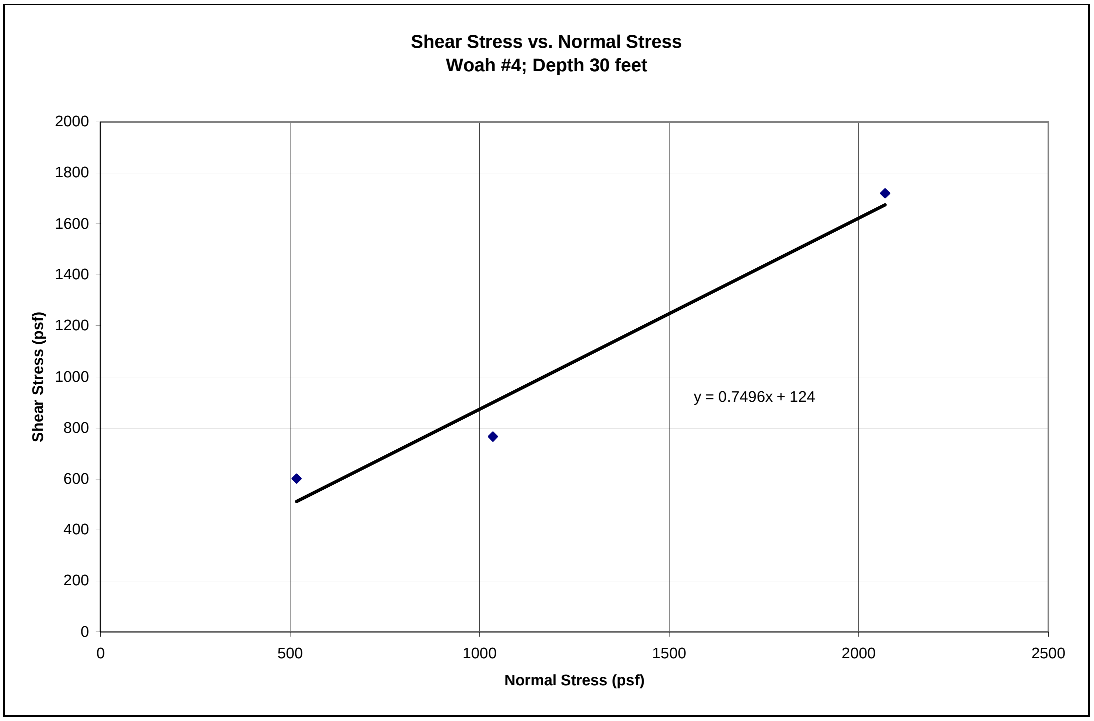
Shear Stress vs. Horizontal Displacement
Woah #1; Depth -2ft
4000
3750
3500
3250
3000
2750
2500
2250
2000
1750
1500
1250
1000
750
500
250
0
Shear Stress (psf)
64 kg
32 kg
16 kg
NOTE:
Samples were
highly disturbed and
had to be pieced
back together
in the direct shear
box!
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
Horizontal Displacement (in)

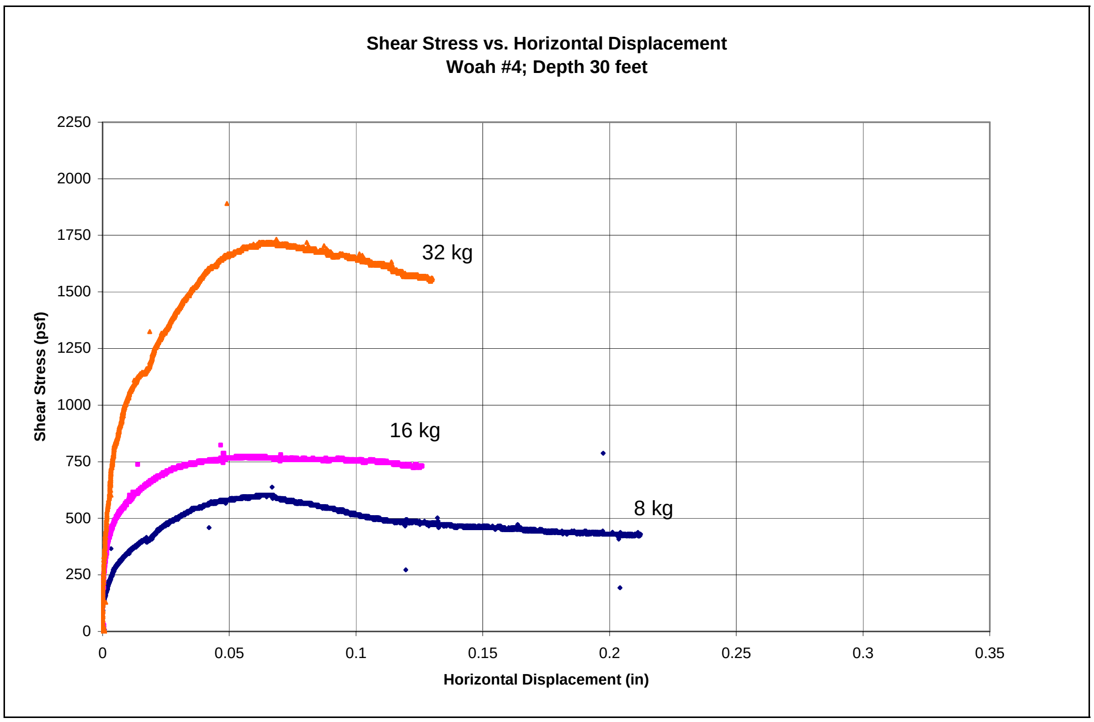

Shear Stress vs. Normal Stress
Woah #2; Depth 52 feet
y = 0.9239x - 47.5
Shear Stress (psf)
Normal Stress (psf)
0
500
1000
1500
2000
2500
3000
3500
4000
4500

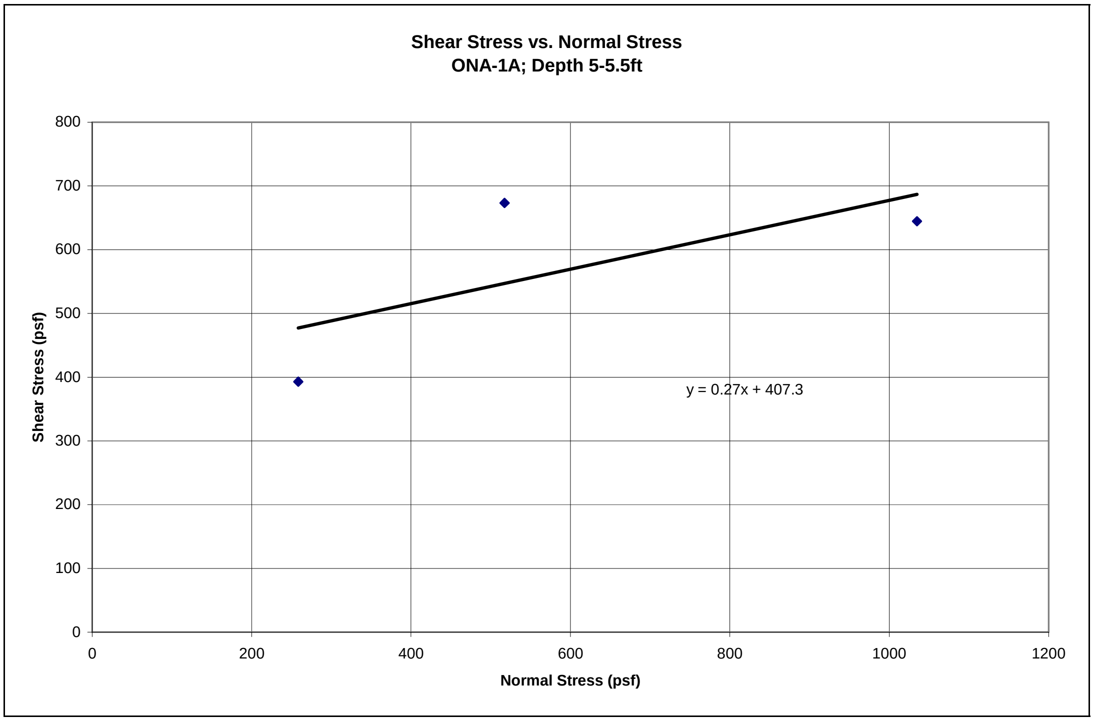

Shear Stress vs. Horizontal Displacement
Woah #2; Depth 52 feet
32 kg
16 kg
8 kg
Shear Stress (psf)
Horizontal Displacement (in)
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
3000
3250
3500
3750
4000
0.05
0.1
0.15
0.2
0.25
0.3
0.35

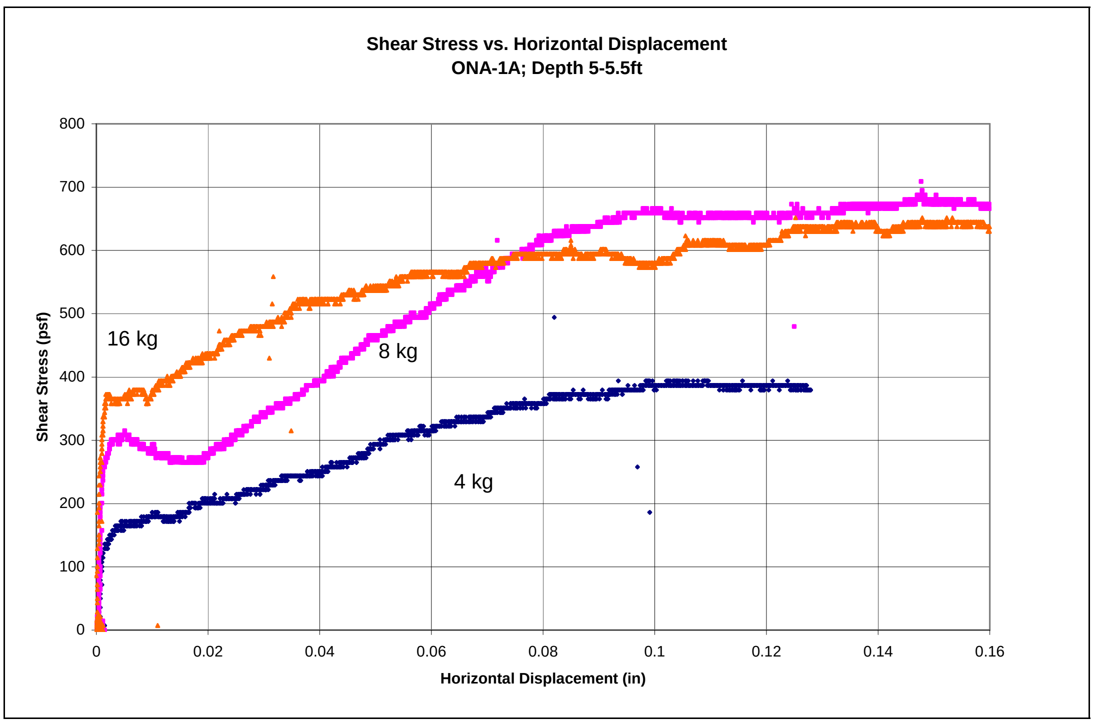

Shear Stress vs. Normal Stress
Woah #3; Depth 35 feet
Shear Stress (psf)
Normal Stress (psf)
y = 0.7149x + 519
2500
2000
1500
1000
500
0
0
500
1000
1500
2000
2500

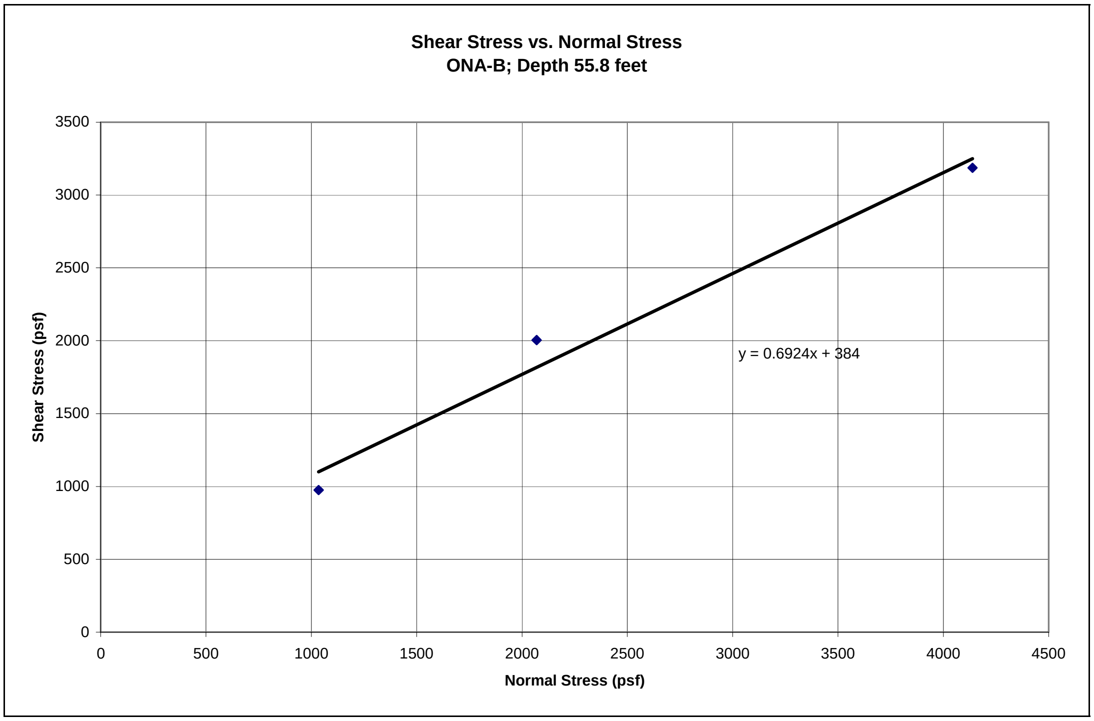

Shear Stress vs. Horizontal Displacement
Woah #3; Depth 35 feet
Shear Stress (psf)
Horizontal Displacement (in)
32 kg
16 kg
8 kg
2250
2000
1750
1500
1250
1000
750
500
250
0
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2

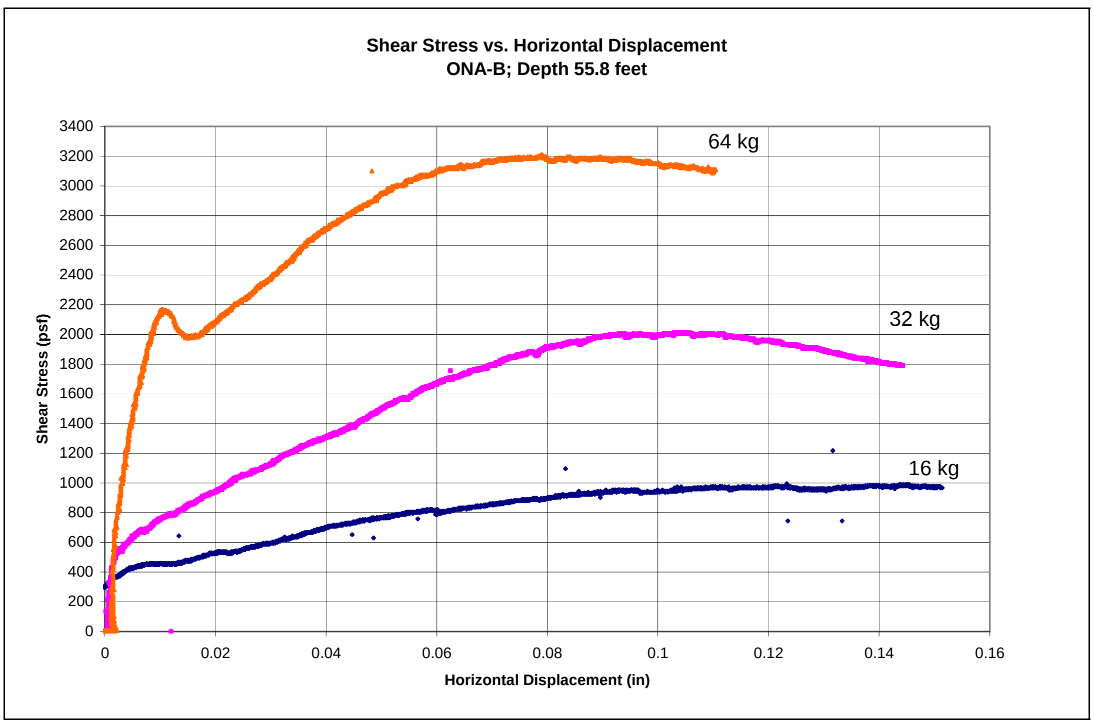

Shear Stress vs. Normal Stress
Woah #4; Depth 30 feet
y = 0.7496x + 124
Shear Stress (psf)
Normal Stress (psf)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
0
500
1000
1500
2000
2500


Shear Stress vs. Horizontal Displacement
Woah #4; Depth 30 feet
32 kg
16 kg
8 kg
Shear Stress (psf)
Horizontal Displacement (in)
0
250
500
750
1000
1250
1500
1750
2000
2250
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35


Shear Stress vs. Normal Stress
ONA-1A; Depth 5-5.5ft
Shear Stress (psf)
Normal Stress (psf)
y = 0.27x + 407.3
800
700
600
500
400
300
200
100
0
0
200
400
600
800
1000
1200

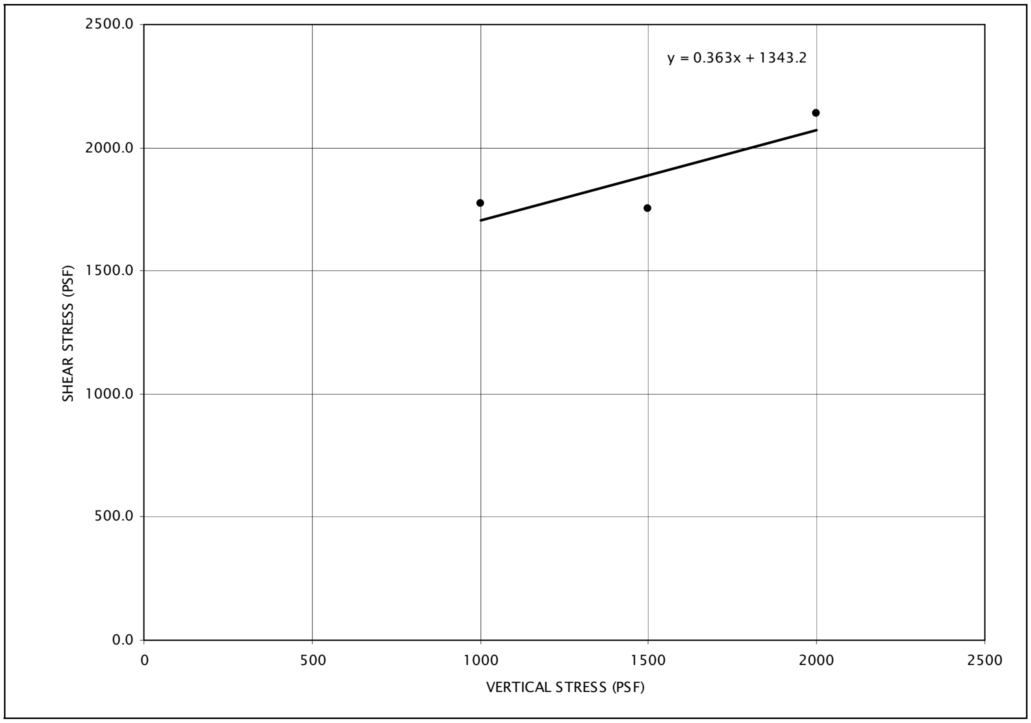

Shear Stress vs. Horizontal Displacement
ONA-1A; Depth 5-5.5ft
Shear Stress (psf)
Horizontal Displacement (in)
16 kg
8 kg
4 kg
800
700
600
500
400
300
200
100
0
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16

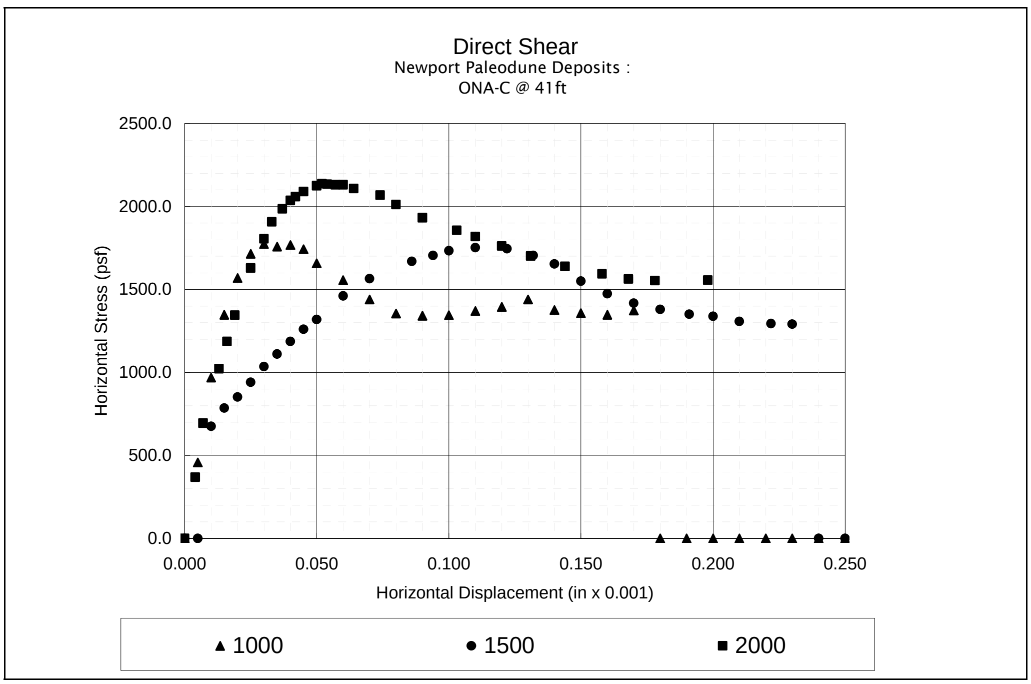

Shear Stress vs. Normal Stress
ONA-B; Depth 55.8 feet
Shear Stress (psf)
Normal Stress (psf)
y = 0.6924x + 384
0
500
1000
1500
2000
2500
3000
3500
4000
4500

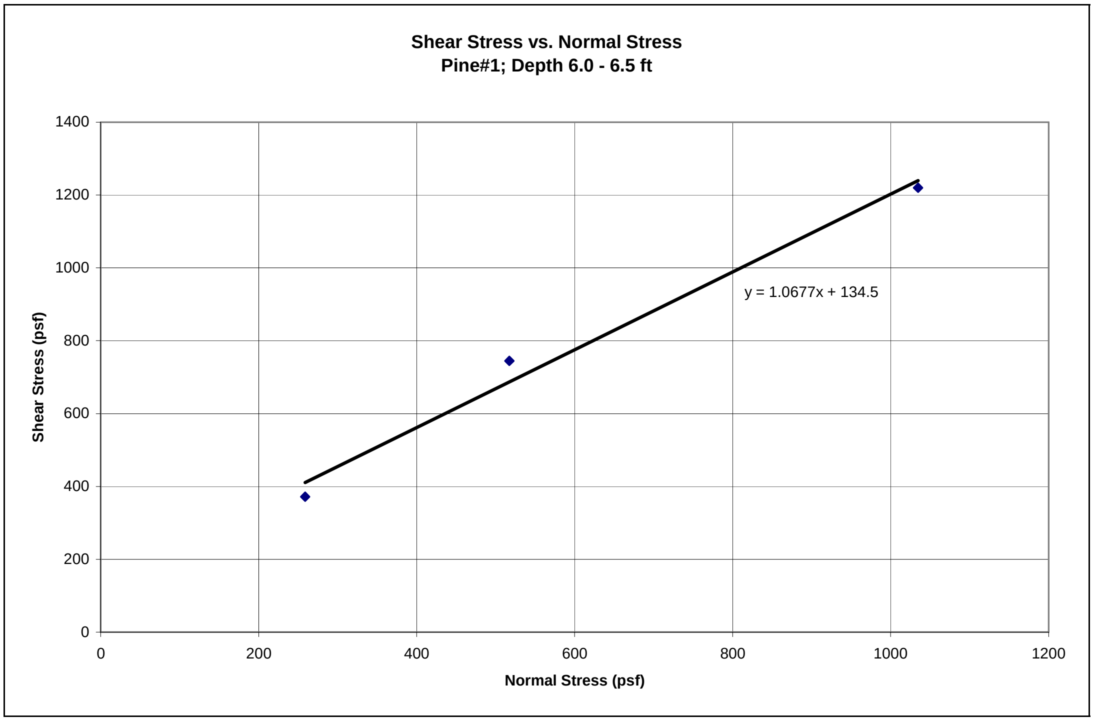

Shear Stress vs. Horizontal Displacement
ONA-B; Depth 55.8 feet
Shear Stress (psf)
Horizontal Displacement (in)
64 kg
32 kg
16 kg
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
3200
3400
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16

Shear Stress vs. Normal Stress

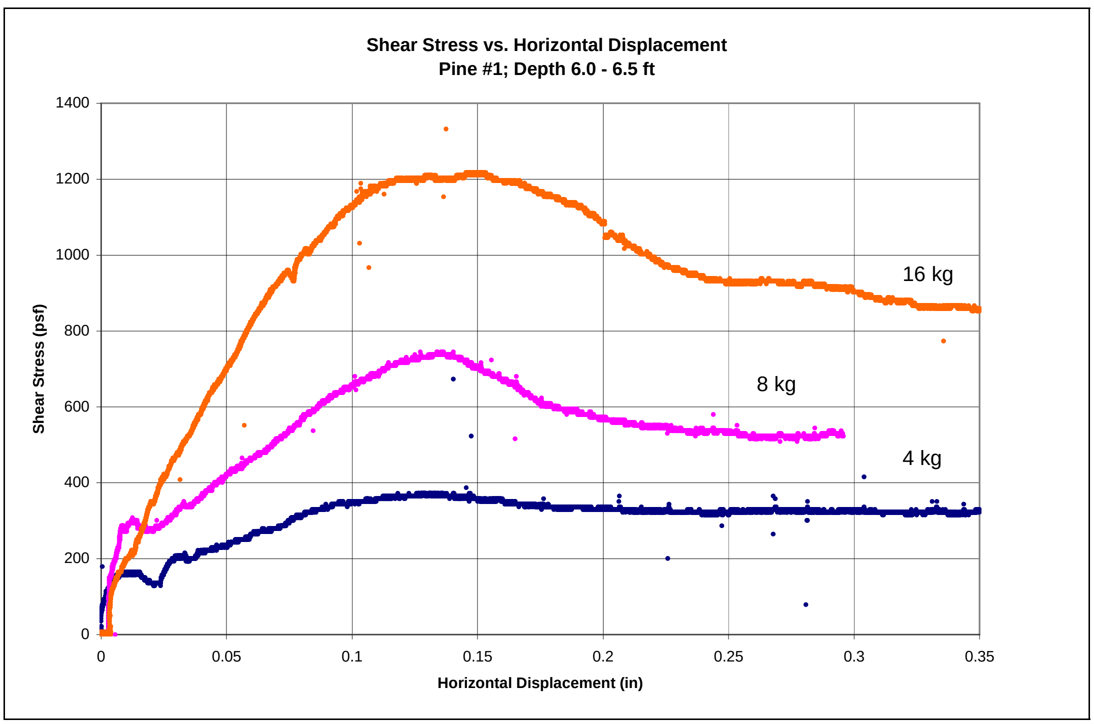
Ona-C at Depth 41 feet



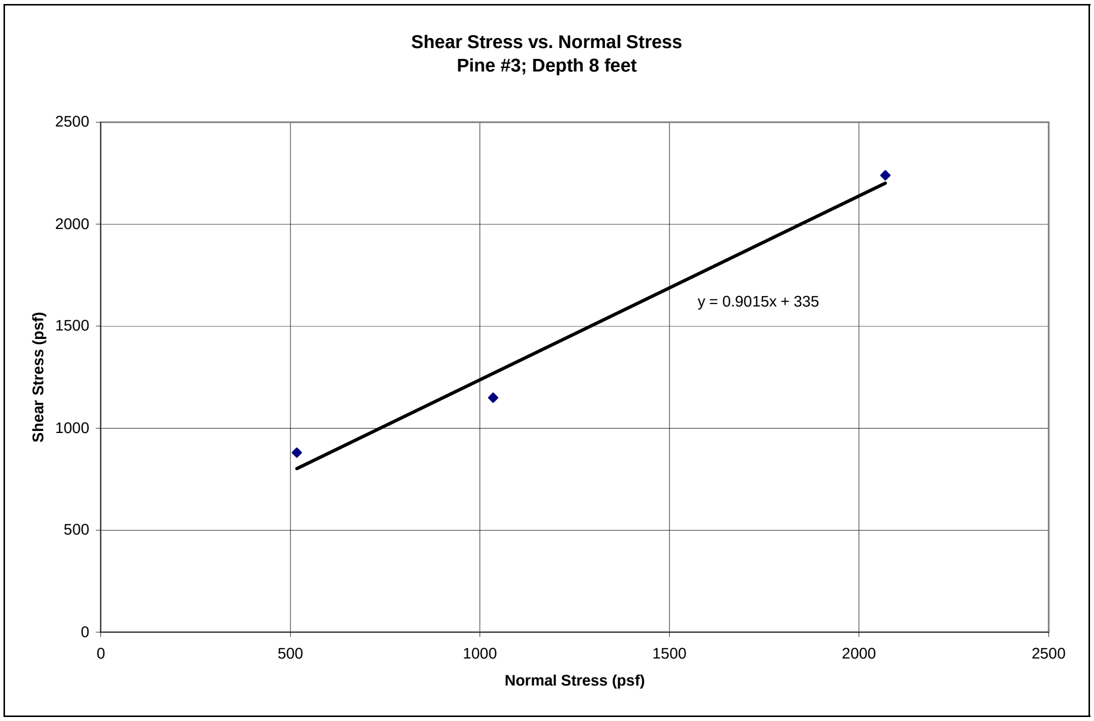


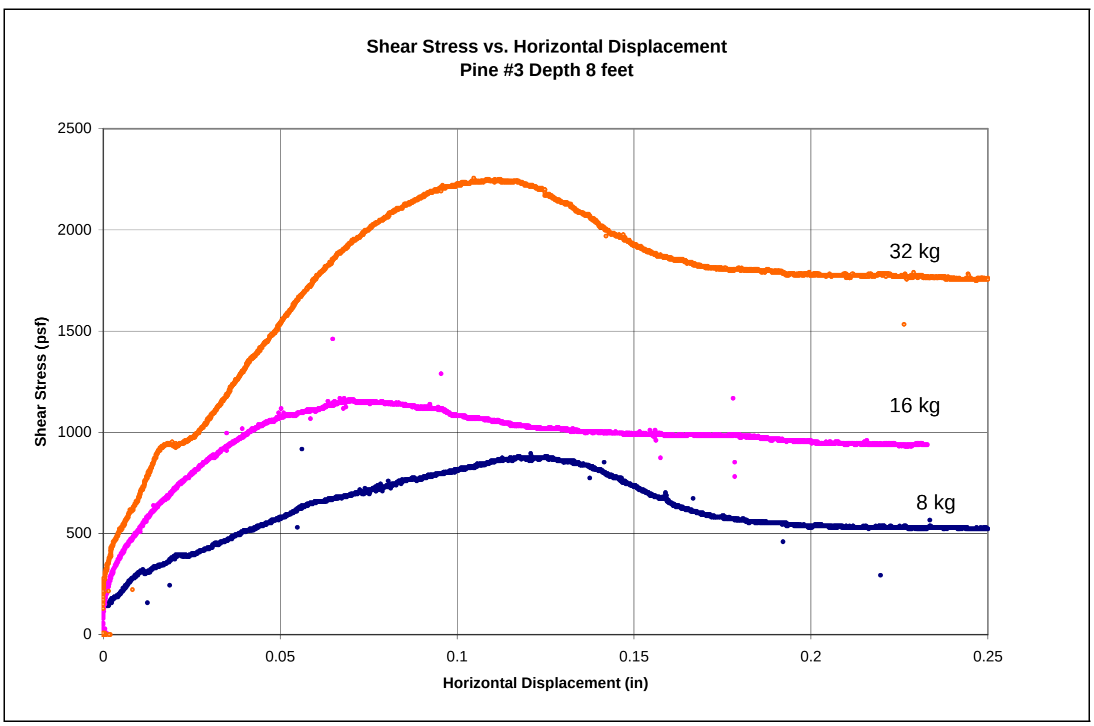


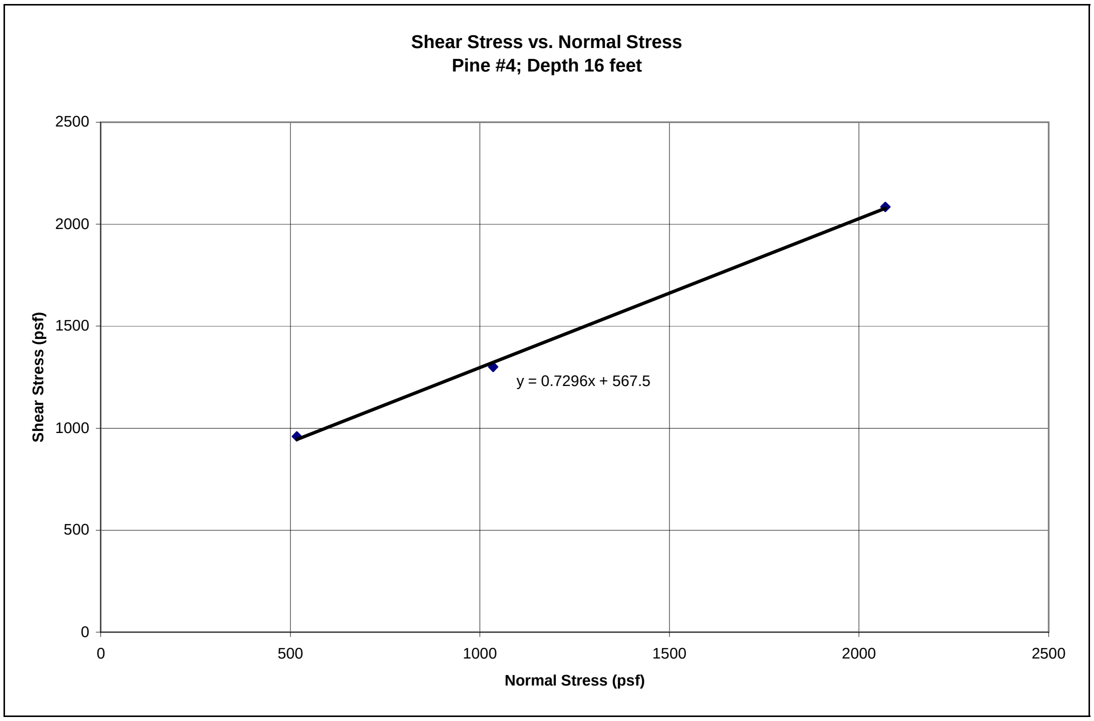
Shear Stress vs. Normal Stress
Pine#1; Depth 6.0 - 6.5 ft
Shear Stress (psf)
Normal Stress (psf)
y = 1.0677x + 134.5
0
200
400
600
800
1000
1200
1400
0
200
400
600
800
1000
1200

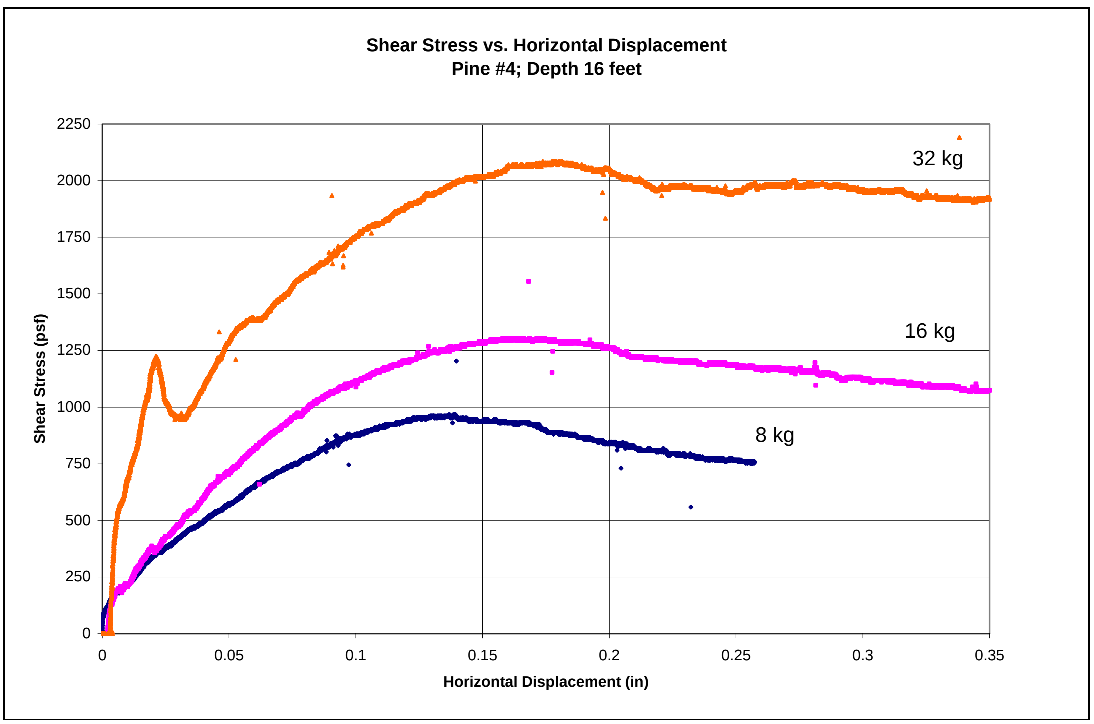


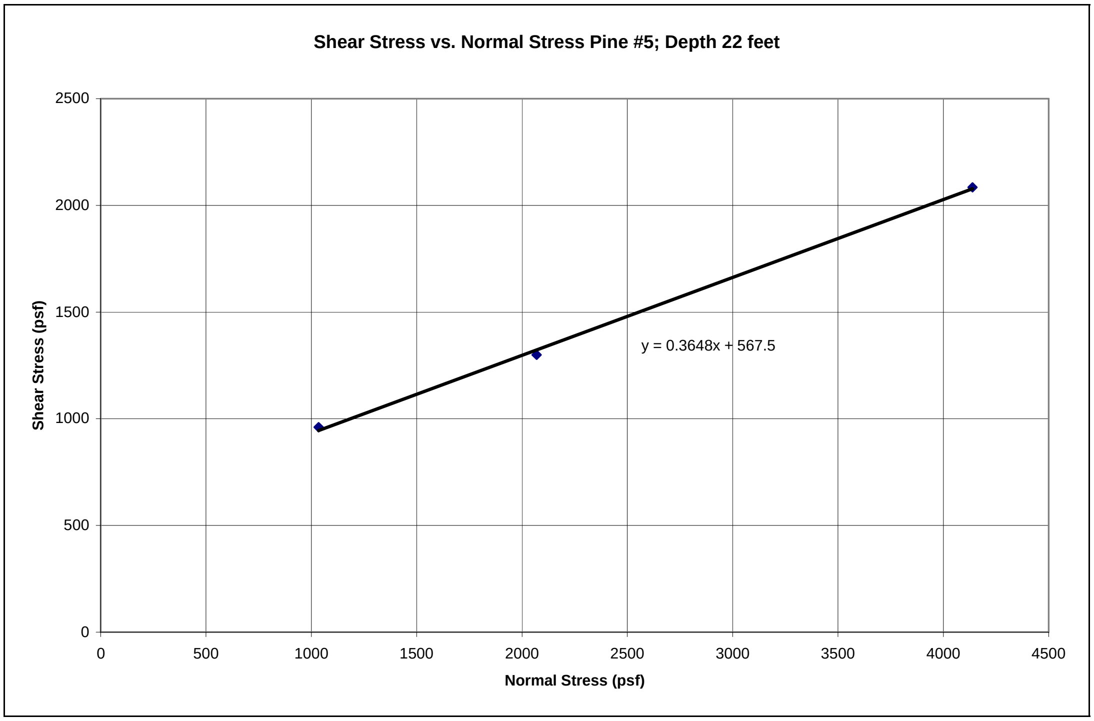
Shear Stress vs. Horizontal Displacement
Pine #1; Depth 6.0 - 6.5 ft
Shear Stress (psf)
Horizontal Displacement (in)
16 kg
8 kg
4 kg
0
200
400
600
800
1000
1200
1400
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35

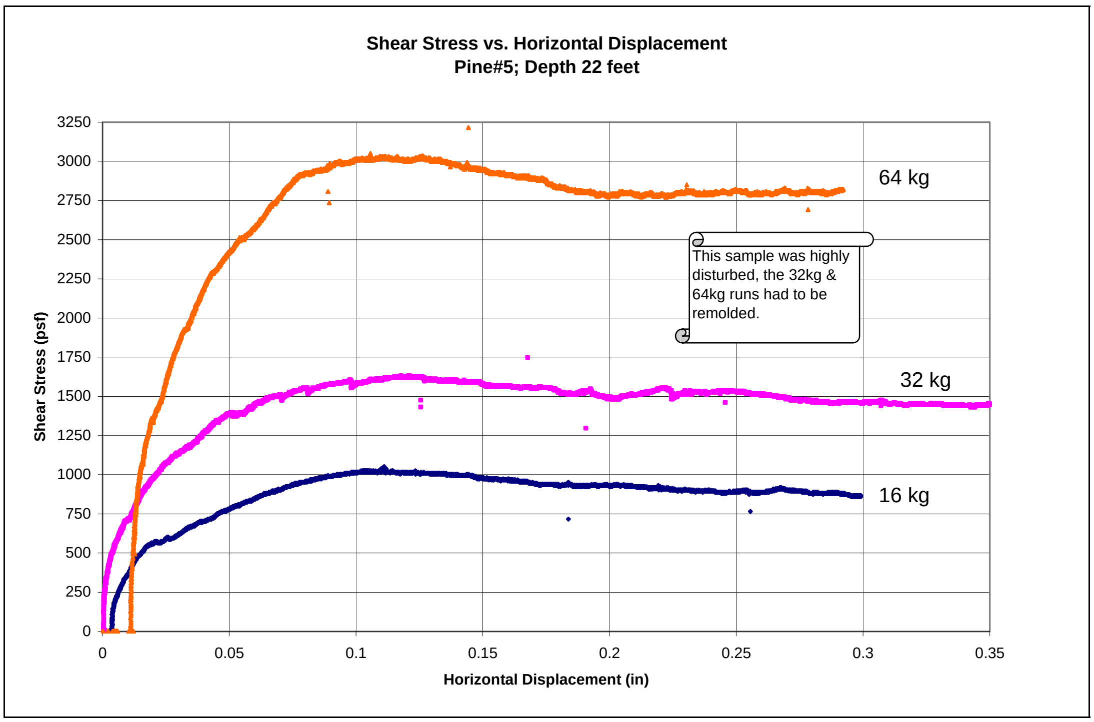

Shear Stress vs. Normal Stress
Pine #3; Depth 8 feet
Shear Stress (psf)
2500
2000
1500
1000
500
0
y = 0.9015x + 335
0
500
1000
1500
2000
2500
Normal Stress (psf)


Shear Stress vs. Horizontal Displacement
Pine #3 Depth 8 feet
Shear Stress (psf)
2500
2000
1500
1000
500
0
32 kg
16 kg
8 kg
0
0.05
0.1
0.15
0.2
0.25
Horizontal Displacement (in)

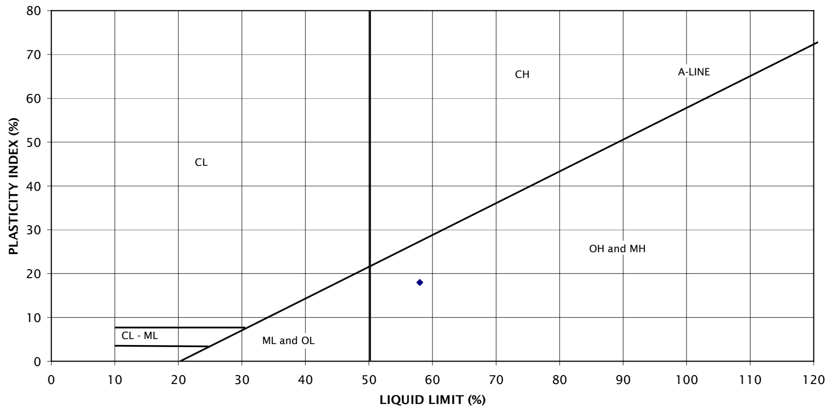

Shear Stress vs. Normal Stress
Pine #4; Depth 16 feet
Shear Stress (psf)
Normal Stress (psf)
y = 0.7296x + 567.5
0
500
1000
1500
2000
2500


Shear Stress vs. Horizontal Displacement
Pine #4; Depth 16 feet
Shear Stress (psf)
Horizontal Displacement (in)
32 kg
16 kg
8 kg
0
250
500
750
1000
1250
1500
1750
2000
2250
0.05
0.1
0.15
0.2
0.25
0.3
0.35

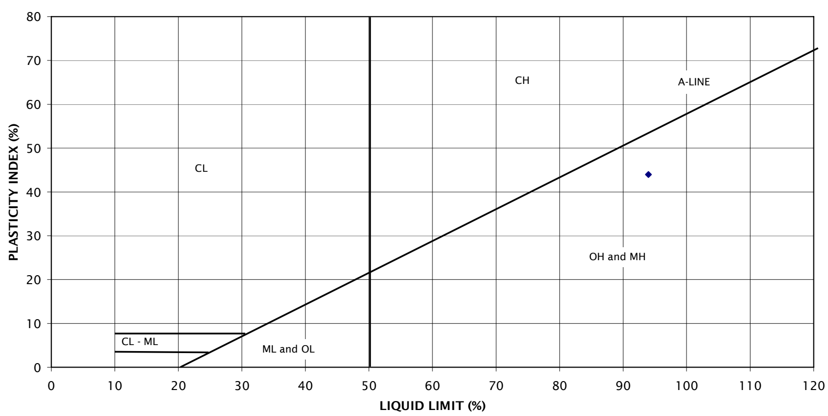

Shear Stress vs. Normal Stress Pine #5; Depth 22 feet
Shear Stress (psf)
Normal Stress (psf)
y = 0.3648x + 567.5
0
500
1000
1500
2000
2500
3000
3500
4000
4500


Shear Stress vs. Horizontal Displacement
Pine#5; Depth 22 feet
Shear Stress (psf)
Horizontal Displacement (in)
64 kg
32 kg
16 kg
This sample was highly disturbed, the 32kg & 64kg runs had to be remolded.
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35

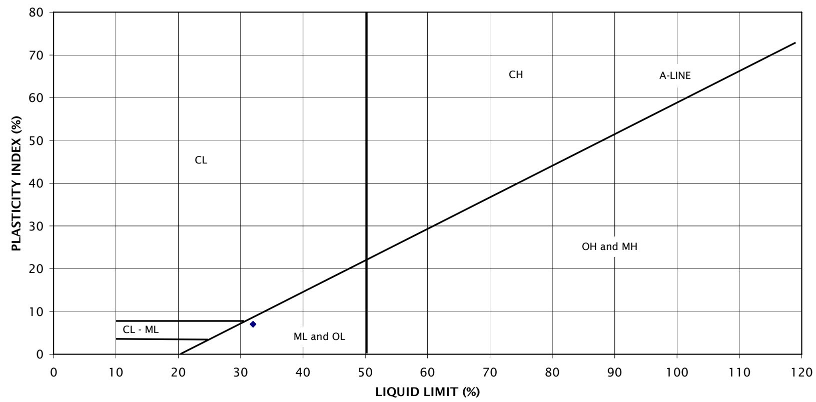
Appendix D: Laboratory Test Summaries for Geotechnical Samples



KEY	EXPLORATION NUMBER	SAMPLE DEPTH (FEET)	MOISTURE CONTENT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	SOIL DESCRIPTION
◆	Pine 4	0	52	58	18	Red-brown silt with trace fine sand



KEY	EXPLORATION NUMBER	SAMPLE DEPTH (FEET)	MOISTURE CONTENT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	SOIL DESCRIPTION
◆	Pine 6	0	93	94	44	Olive gray clay with some organics



KEY	EXPLORATION NUMBER	SAMPLE DEPTH (FEET)	MOISTURE CONTENT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	SOIL DESCRIPTION
◆	Woah-1	40	28	32	7	Gray sandy SILT with some clay

SITE LOCATION	Pine 1/Pine 2	Pine 3	Pine 4	Pine 5	Pine 6
Field Description	House Site, PMT 1; Red-brown, fine SAND	Hwy 101 roadcut; Tan, fine SAND; foreset beds	Hwy 101 roadcut; Orange-brown, silty fine SAND; FeO staining	Hwy 101 roadcut; Light brown, fine SAND	Hwy 101 roadcut; Light gray to olive-brown, sandy SILT with some clay
Exploration Method	Hand auger	Grab Sample	Grab Sample	Grab Sample	Grab Sample
Depth below ground surface (ft)	5.75	8	16	22	29.5
USCS Group Name	Poorly graded sand	Poorly graded sand	Silty sand	Poorly graded sand	Elastic silt with sand
USCS Group Symbol	SP	SP	SM	SP	MH
Percent Moisture[1]	14.9	17.0	47.8	15.2	38.2
Wet density (pcf)[1]	107.0	107.6	99.3	116.4	106.9
Dry density (pcf)[1]	93.2	92.0	67.4	101.0	77.4
Plasticity Index	Nonplastic	Nonplastic	18.0	Nonplastic	44.0
Percent passing #200 (0.075mm)	3.1	0.7	49.0	0.5	52.8
Specific gravity	2.68	2.683	2.656	2.692	2.650
In-situ Void ratio (e)[1]	0.79	0.83	1.47	0.67	1.16
Porosity (n)[1]	0.44	0.45	0.59	0.40	0.54
Degree of saturation[1]	50.1	56.4	86.1	62.2	88.3
Permeability (cm/s)	4.40E-03 [3]	6.36E-04	6.21E-04	9.36E-04	2.03E-05

Triaxial Compression Test Method							Consolidated Undrained			Consolidated Undrained			Consolidated Drained		
Ultimate Soil Shear Strength	σ'_3 (psf)	$\sigma'_1-\sigma'_3$ (psf)	Δu_{ult} (psf)	σ'_3 (psf)	$\sigma'_1-\sigma'_3$ (psf)	Δu_{ult} (psf)	σ'_3 (psf)	$\sigma'_1-\sigma'_3$ (psf)	Δu_{ult} (psf)	σ'_3 (psf)	$\sigma'_1-\sigma'_3$ (psf)	Δu_{ult} (psf)	σ'_3 (psf)	$\sigma'_1-\sigma'_3$ (psf)	$\Delta \varepsilon_{vol}$ (%)
	-	-	-	-	-	-	936	3625	1079	7467	7141	-7107	721	2109	-0.159
	-	-	-	-	-	-	1019	4372	422	10031	9957	-8877	1441	4335	1.34
	-	-	-	-	-	-	1055	4576	-314	14118	13271	-13397	-	-	-
Angle of internal friction (ϕ'_r)[2]	-			-			36.5			17.7			32.7		
Cohesion (psf)	-			-			0			178			0		
Peak Soil Shear Strength	σ'_3 (psf)	$\sigma'_1-\sigma'_3$ (psf)	Δu (psf)	σ'_3 (psf)	$\sigma'_1-\sigma'_3$ (psf)	Δu (psf)	σ'_3 (psf)	$\sigma'_1-\sigma'_3$ (psf)	Δu (psf)	σ'_3 (psf)	$\sigma'_1-\sigma'_3$ (psf)	Δu (psf)	σ'_3 (psf)	$\sigma'_1-\sigma'_3$ (psf)	$\Delta \varepsilon_{vol}$ (%)
	-	-	-	-	-	-	857	3639	1158	7390	7175	-7030	717	2409	-0.14
	-	-	-	-	-	-	958	4644	-217	9412	11659	-8258	1438	5082	-1.55
	-	-	-	-	-	-	1019	4372	422	12904	16368	-12182	-	-	-
Angle of internal friction (ϕ'_p)[2]	-			-			37.2			21.1			34.5		
Cohesion (psf)	-			-			0			0			0		

	Pine 1/Pine 2	Pine 3	Pine 4	Pine 5	Pine 6
Maximum Soil Shear Strength[3]	Direct Shear Test	Direct Shear Test	Direct Shear Test	Direct Shear Test	Direct Shear Test
Angle of internal friction (ϕ'_p)	42.6	42	36.1	***20.5***	NA
Cohesion (psf)	270	335	568	***568***	NA
Max. Cementation Shear Strength[3]	Direct Shear Test	Direct Shear Test	Direct Shear Test	Direct Shear Test	Direct Shear Test
Angle of internal friction (ϕ')	1.9	23	30	NA	NA
Cohesion (psf)	211	106	0	NA	NA
				Disturbed Sample	

Indicates suspect value 1) Average value from triax and perm testing 3) From Summers (2005)

"-" Indicates no value 2) Subscript "r" = residual; "p" = peak

SITE LOCATION	Ona-1A/1B			Ona-A			Ona-B			Ona-C		
Field Description	Tan to red-brown, fine SAND; house foundation-PMT1			Beach sea cliff; Dense, black to brown silty fine SAND;			Beach sea cliff; Dense, tan fine SAND;			Beach sea cliff; Dense, tan fine SAND;		
Exploration Method	Hand auger			Grab sample			Grab sample			Grab sample		
Depth below ground surface (ft)	5.5			62			55.8			41		
USCS Group Name	Poorly graded SAND			-			Poorly graded SAND			Poorly graded SAND		
USCS Group Symbol	SP			-			SP			SP		
Percent Moisture[1]	14.0			44.1			9.3			17.6		
Wet density (pcf)[1]	104.5			99.3			109.5			119.2		
Dry density (pcf)[1]	91.8			68.7			100.1			101.7		
Plasticity Index	Nonplastic			-			Nonplastic			Nonplastic		
Percent passing #200 (0.075mm)	1.9			-			0.1			0.4		
Specific gravity	2.629			-			2.644			2.674		
In-situ Void ratio (e)[1]	0.80			-			0.65			0.64		
Porosity (n)[1]	0.44			-			0.39			0.39		
Degree of saturation[1]	46.1			-			38.3			72.2		
Permeability (cm/s)	3.77E-03			-			4.41E-04			5.54E-04		
Triaxial Compression Test Method	Consolidated Drained						Consolidated Drained			Consolidated Drained		
Ultimate Soil Shear Strength	σ'_3 (psf)	σ'_1-σ'_3 (psf)	$\Delta\varepsilon_{vol}$ (%)	σ'_3 (psf)	σ'_1-σ'_3 (psf)	Δu_{ult} (psf)	σ'_3 (psf)	σ'_1-σ'_3 (psf)	$\Delta\varepsilon_{vol}$ (%)	σ'_3 (psf)	σ'_1-σ'_3 (psf)	$\Delta\varepsilon_{vol}$ (%)
"-" Indicates no value	722	2289	-4.6	-	-	-	721	1630	-5.9	350	802	-6.2
	-	-	-	-	-	-	1455	3388	-6.4	721	2421	-5.2
	-	-	-	-	-	-	-	-	-	1441	4496	-5.2
Angle of internal friction (ϕ'_r)[2]	-			-			30			33.2		
Cohesion (psf)	-			-			0			0		
Peak Soil Shear Strength	σ'_3 (psf)	σ'_1-σ'_3 (psf)	$\Delta\varepsilon_{vol}$ (%)	σ'_3 (psf)	σ'_1-σ'_3 (psf)	Δu (psf)	σ'_3 (psf)	σ'_1-σ'_3 (psf)	$\Delta\varepsilon_{vol}$ (%)	σ'_3 (psf)	σ'_1-σ'_3 (psf)	$\Delta\varepsilon_{vol}$ (%)
"-" Indicates no value	731	2889	-0.3	-	-	-	753	2565	-1.8	353	1178	-3.4
	-	-	-	-	-	-	1437	4432	-2.1	729	4601	-1.2
	-	-	-	-	-	-	-	-	-	1445	6833	-0.8
Angle of internal friction (ϕ'_p)[2]	-			-			32			38.4		
Cohesion (psf)	-			-			108			0		
Maximum Soil Shear Strength[3]	Direct Shear Test			Direct Shear Test			Direct Shear Test			Direct Shear Test		
Angle of internal friction (ϕ'_p)	40			NA			35			20		
Cohesion (psf)	236			NA			384			1343		
Max. Cementation Shear Strength[3]	Direct Shear Test			Direct Shear Test			Direct Shear Test			Direct Shear Test		
Angle of internal friction (ϕ')	NA			NA			NA			NA		
Cohesion (psf)	NA			NA			NA			NA		

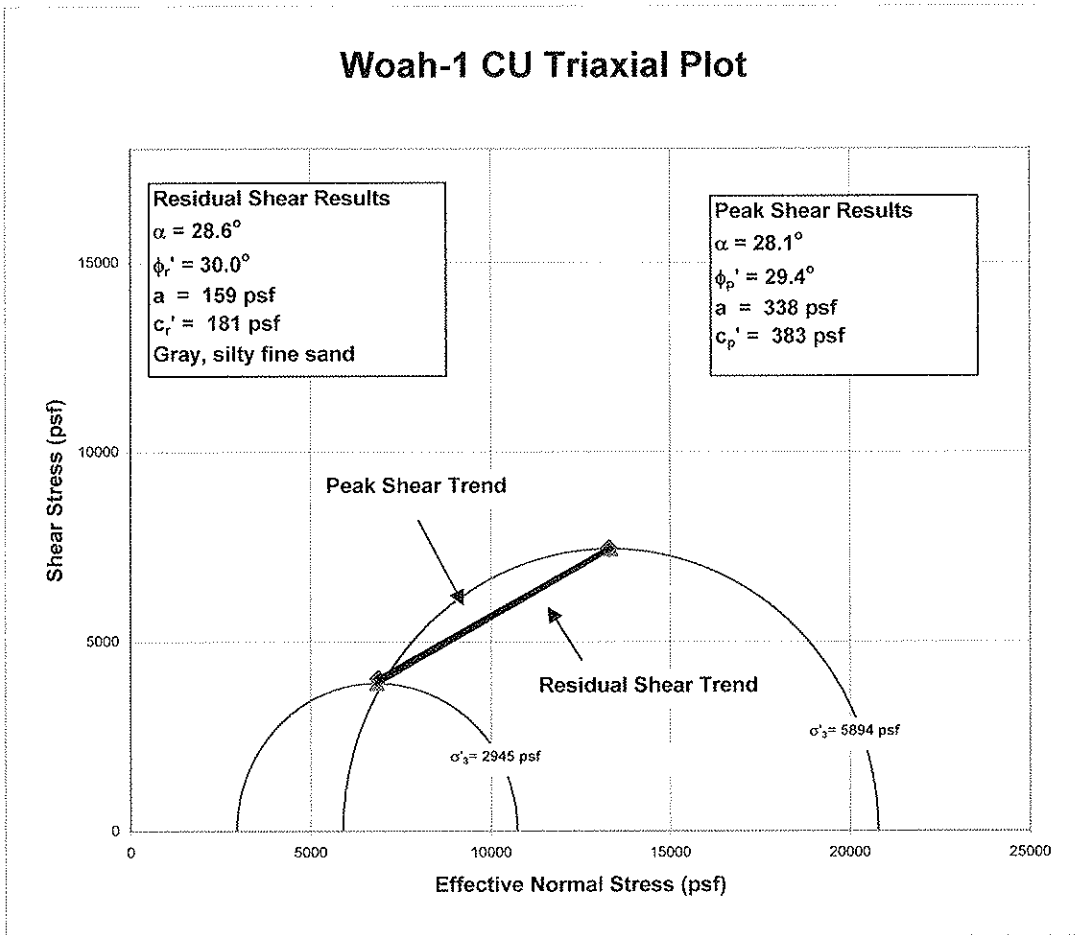
Indicates suspect value 1) Average value from triax and perm testing 2) Subscript "r" = residual; "p" = peak 3) From Summers (2005)

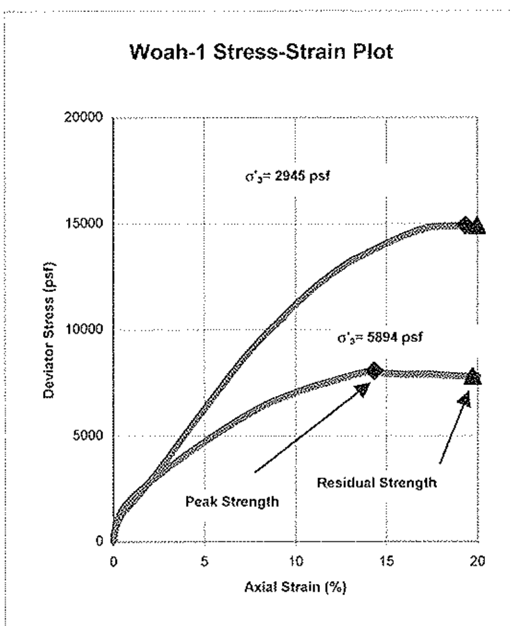
SITE LOCATION	Woah-1			Woah-2			Woah-3			Woah-4		
Field Description	Canary Road roadcut; Gray, silty fine SAND			Canary Road roadcut; Tan, fine SAND			Canary Road roadcut; Gray, silty fine SAND			Canary Road roadcut; Red-brown, fine SAND		
Exploration Method	Grab Sample			Grab Sample			Grab Sample			Grab Sample		
Depth below ground surface (ft)	60			52			35			30		
USCS Group Name	Silty SAND			Poorly graded SAND			Silty SAND			Poorly graded SAND		
USCS Group Symbol	SM			SP			SM			SP		
Percent Moisture[1]	20.3			10.3			22.2			12.6		
Wet density (pcf)[1]	129.8			120.0			134.5			122.0		
Dry density (pcf)[1]	107.9			108.8			113.9			108.4		
Plasticity Index	7.0			Nonplastic			Nonplastic			Nonplastic		
Percent passing #200 (0.075mm)	43.0			0.1			43.4			0.2		
Specific gravity	2.680			2.668			2.569			2.683		
In-situ Void ratio (*e*)[1]	0.55			0.53			0.41			0.55		
Porosity (n)[1]	0.36			0.35			0.29			0.35		
Degree of saturation[1]	98.6			51.6			***120.1***			61.4		
Permeability (cm/s)	1.63E-06			6.28E-04			1.25E-05			5.53E-04		
Triaxial Compression Test Method	Consolidated Undrained			Consolidated Drained			Consolidated Undrained			Consolidated Drained		
Ultimate Soil Shear Strength	σ'_3 (psf)	$\sigma'_1-\sigma'_3$ (psf)	Δu_{ult} (psf)	σ'_3 (psf)	$\sigma'_1-\sigma'_3$ (psf)	$\Delta\varepsilon_{vol}$ (%)	σ'_3 (psf)	$\sigma'_1-\sigma'_3$ (psf)	Δu_{ult} (psf)	σ'_3 (psf)	$\sigma'_1-\sigma'_3$ (psf)	$\Delta\varepsilon_{vol}$ (%)
"-" Indicates no value	2945	7790	1053	357	998	-8.4	2053	7577	-973	363	1063	-9.0
	5894	14889	-3878	724	1771	-8.4	2882	8807	-2522	724	2189	-8.8
	-	-	-	1441	3369	-5.2	3530	10082	-2811	1441	3624	-5.1
Angle of internal friction (ϕ'_r)[2]	28.6			28.8			25.4			29.6		
Cohesion (psf)	181			55			1207			84		
Peak Soil Shear Strength	σ'_3 (psf)	$\sigma'_1-\sigma'_3$ (psf)	Δu (psf)	σ'_3 (psf)	$\sigma'_1-\sigma'_3$ (psf)	$\Delta\varepsilon_{vol}$ (%)	σ'_3 (psf)	$\sigma'_1-\sigma'_3$ (psf)	Δu (psf)	σ'_3 (psf)	$\sigma'_1-\sigma'_3$ (psf)	$\Delta\varepsilon_{vol}$ (%)
"-" Indicates no value	2862	8038	1137	401	1651	-2.7	2053	7577	-973	370	2884	-2.6
	5849	14907	-3833	754	3200	-2.4	2882	8807	-2522	755	3608	-3.1
	-	-	-	1449	4338	-2.1	3511	10351	-2791	1458	5326	-0.7
Angle of internal friction (ϕ'_p)[2]	29.4			30.7			27			29.3		
Cohesion (psf)	383			217			1016			525		

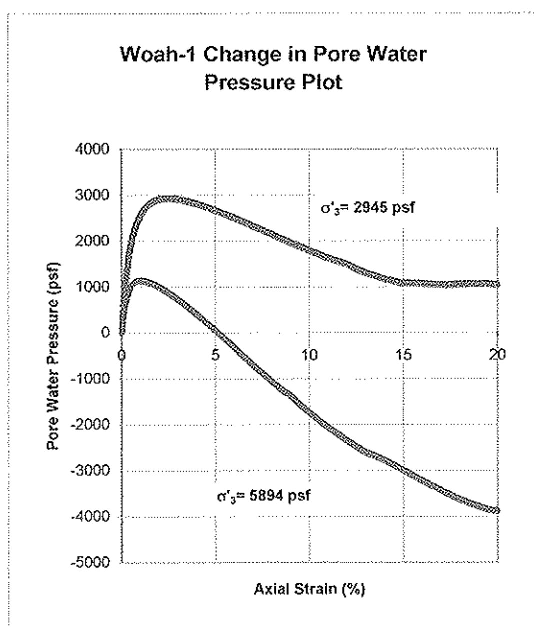
	Woah-1	Woah-2	Woah-3	Woah-4
Maximum Soil Shear Strength[3]	Direct Shear Test	Direct Shear Test	Direct Shear Test	Direct Shear Test
Angle of internal friction (ϕ'_p)	37	43	36	37
Cohesion (psf)	248	0	519	124
Max. Cementation Shear Strength[3]	Direct Shear Test	Direct Shear Test	Direct Shear Test	Direct Shear Test
Angle of internal friction (ϕ')	6.7	31	28	27
Cohesion (psf)	338	0	20	165

Indicates suspect value 1) Average value from triax and perm testi 2) Subscript "r" = residual; "p" = peak 3) From Summers (2005)

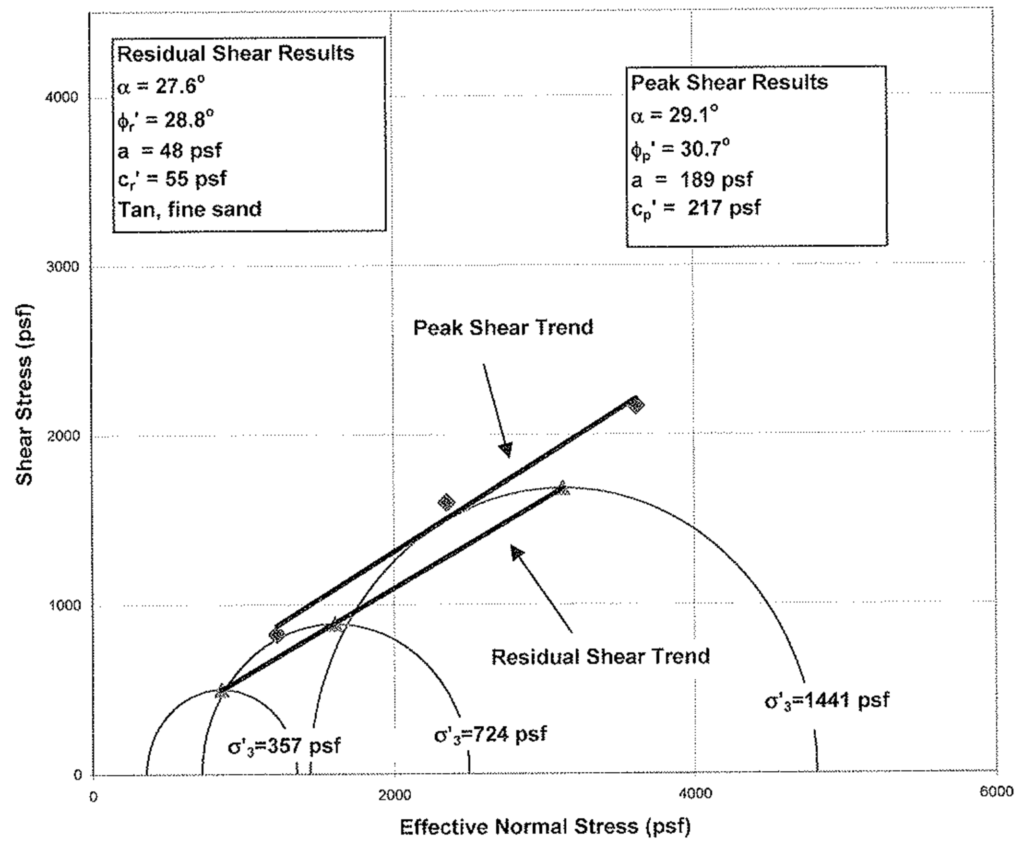
Appendix E: Triaxial Test Results


Woah-1 CU Triaxial Plot
Residual Shear Results
α = 28.6°
φr' = 30.0°
a = 159 psf
cr' = 181 psf
Gray, silty fine sand
Peak Shear Results
α = 28.1°
φp' = 29.4°
a = 338 psf
cp' = 383 psf
Peak Shear Trend
Residual Shear Trend
σ'3= 2945 psf
σ'3= 5894 psf
Shear Stress (psf)
Effective Normal Stress (psf)
0
5000
10000
15000
20000
25000

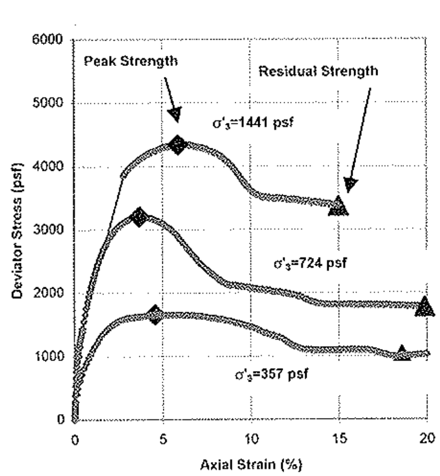

Woah-1 Stress-Strain Plot
σ'3= 2945 psf
σ'3= 5894 psf
Peak Strength
Residual Strength
Deviator Stress (psf)
Axial Strain (%)
0
5000
10000
15000
20000
5
10
15
20


Woah-1 Change in Pore Water Pressure Plot
σ'3= 2945 psf
σ'3= 5894 psf
Pore Water Pressure (psf)
Axial Strain (%)
4000
3000
2000
1000
0
-1000
-2000
-3000
-4000
-5000
5
10
15
20

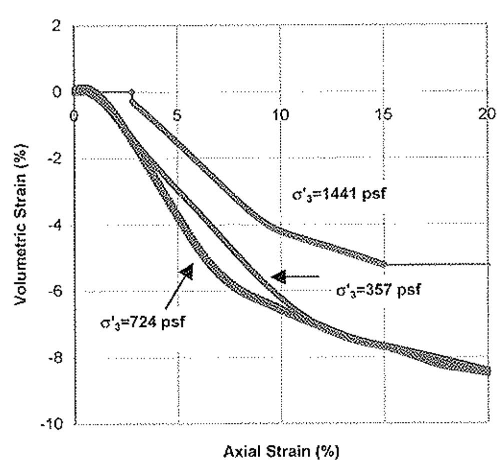
Woah-2 CD Triaxial Plot



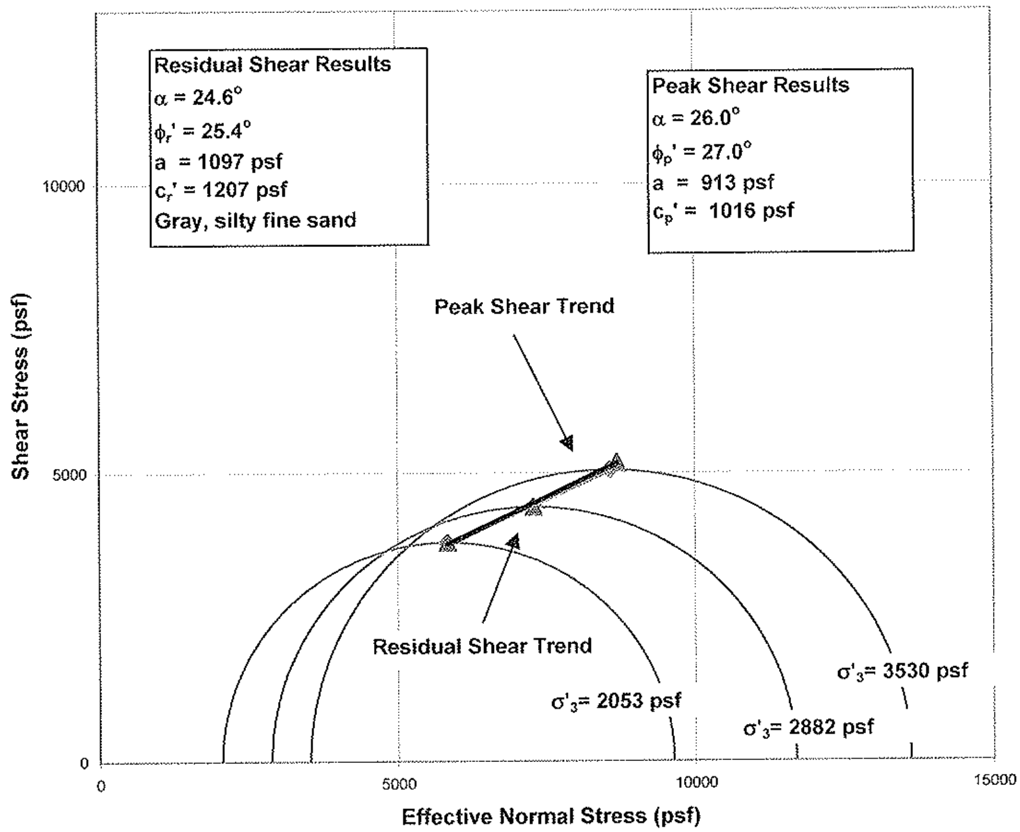
Woah-2 Stress-Strain Plot



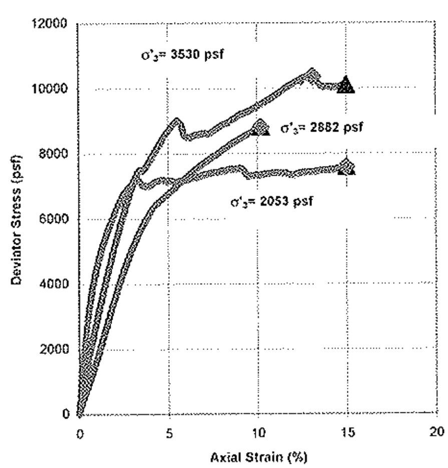
Woah-2 Volumetric Strain Plot



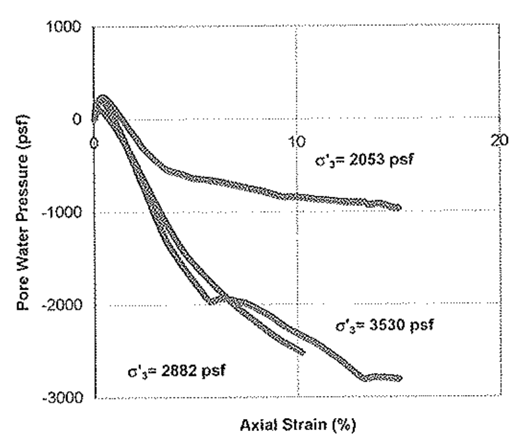
Woah-3 CU Triaxial Plot

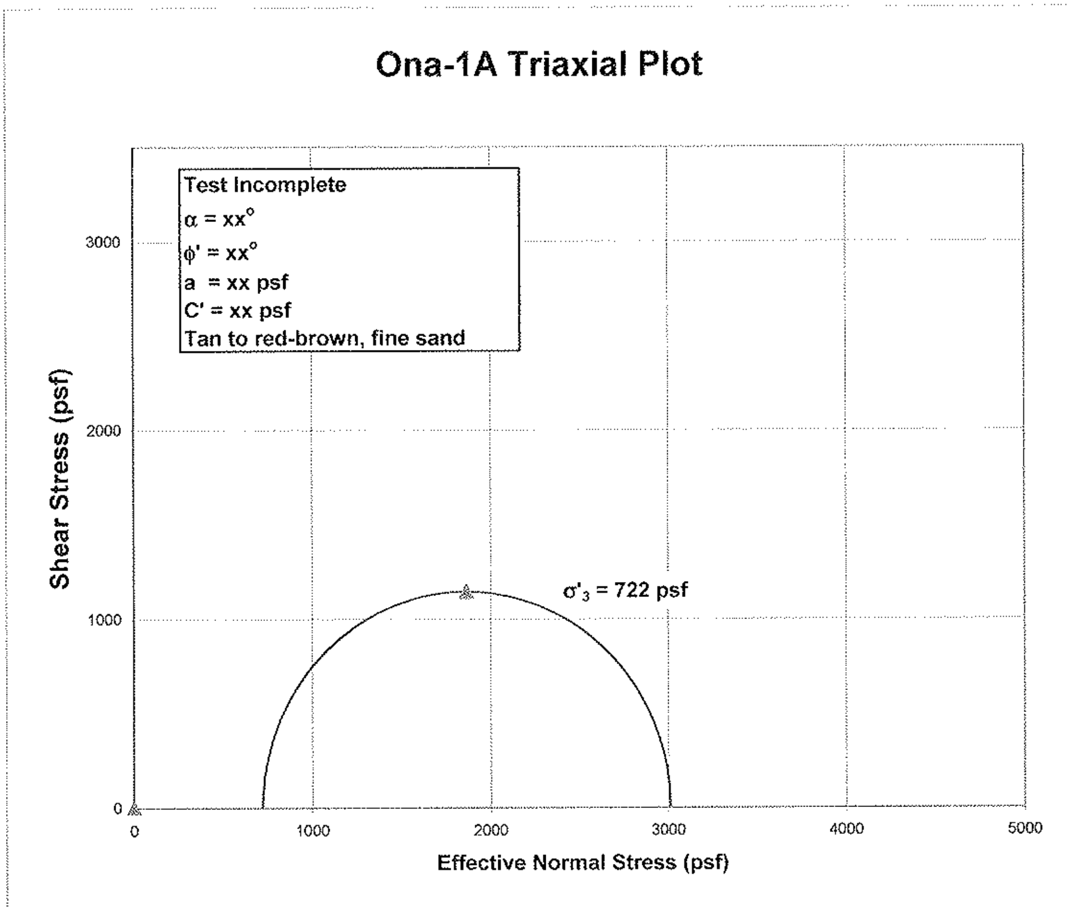


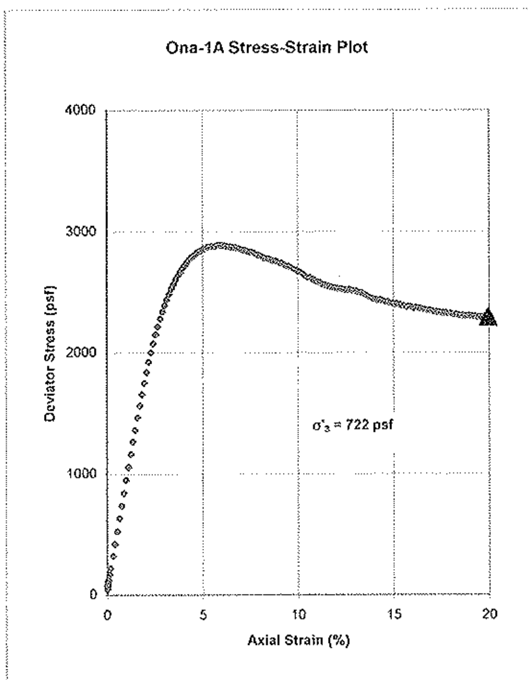
Woah-3 Stress-Strain Plot

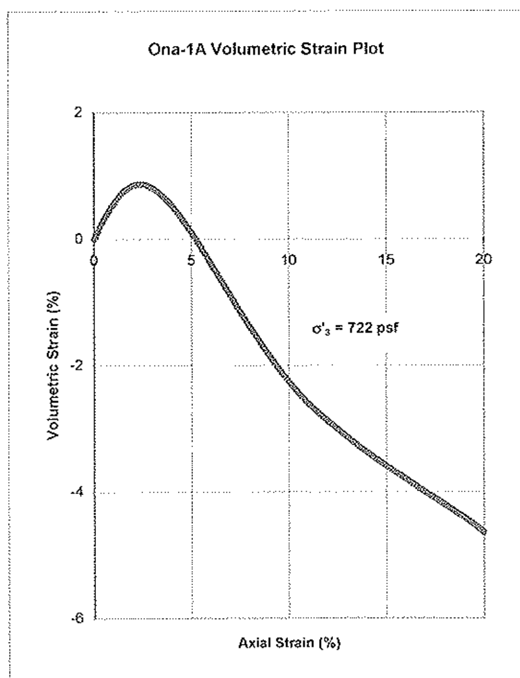


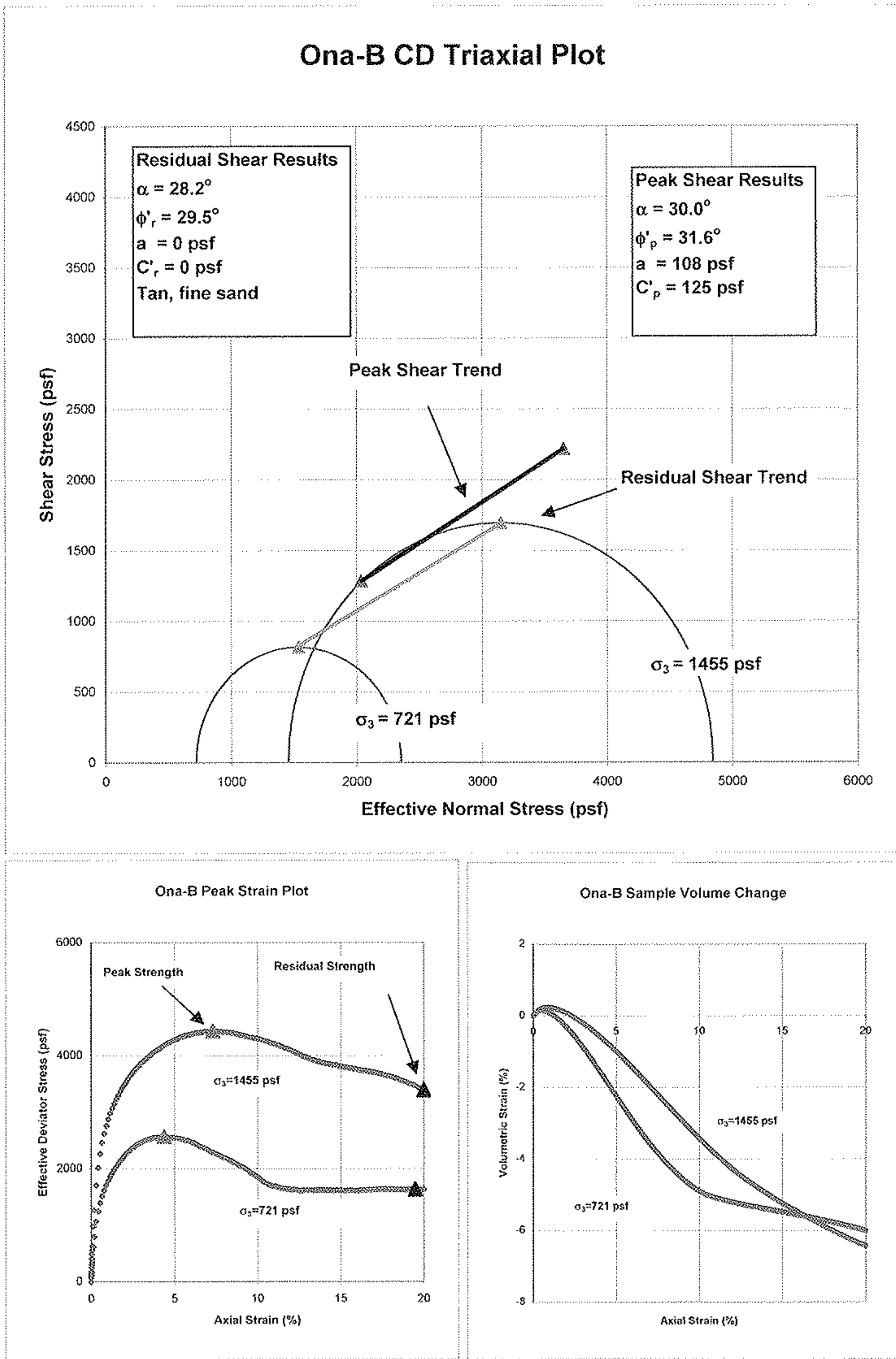
Woah-3 Change in Pore Water Pressure Plot

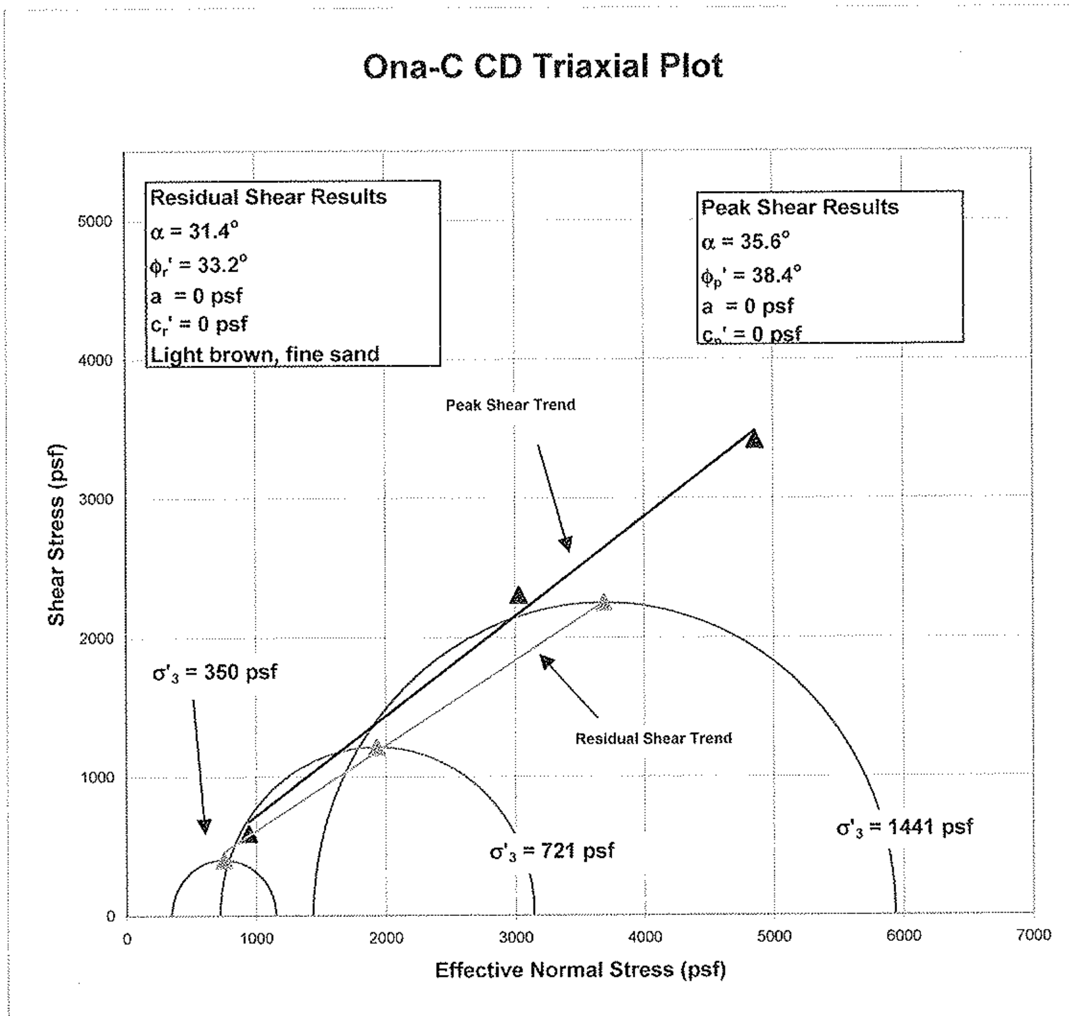



Ona-1A Triaxial Plot
Test Incomplete
α = xx°
φ' = xx°
a = xx psf
C' = xx psf
Tan to red-brown, fine sand
σ'3 = 722 psf
Shear Stress (psf)
Effective Normal Stress (psf)
0
1000
2000
3000
4000
5000

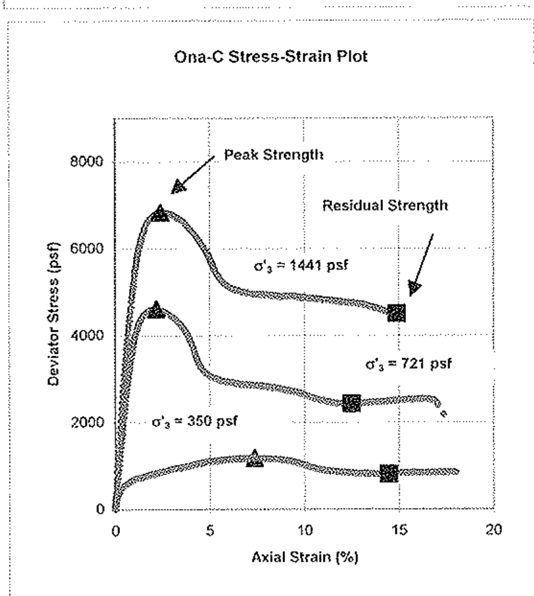

Ona-1A Stress-Strain Plot
Deviator Stress (psf)
Axial Strain (%)
σ'3 = 722 psf
0
1000
2000
3000
4000
5
10
15
20


Ona-1A Volumetric Strain Plot
Volumetric Strain (%)
Axial Strain (%)
σ'3 = 722 psf
2
0
-2
-4
-6
5
10
15
20

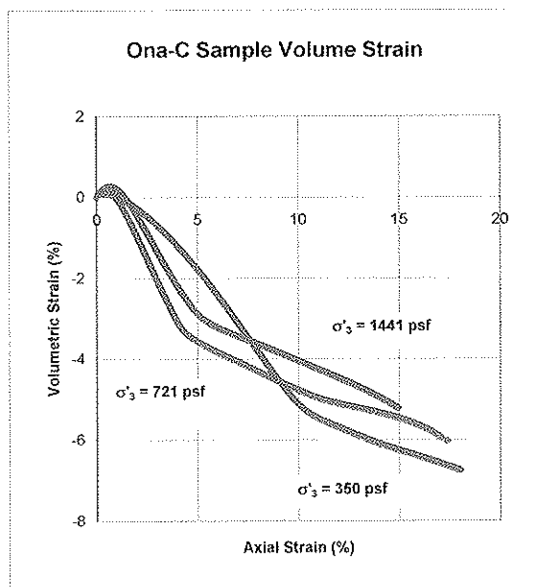

Ona-B CD Triaxial Plot
Residual Shear Results
α = 28.2°
φ'r = 29.5°
a = 0 psf
C'r = 0 psf
Tan, fine sand
Peak Shear Results
α = 30.0°
φ'p = 31.6°
a = 108 psf
C'p = 125 psf
Peak Shear Trend
Residual Shear Trend
σ3 = 1455 psf
σ3 = 721 psf
Shear Stress (psf)
Effective Normal Stress (psf)
Ona-B Peak Strain Plot
Peak Strength
Residual Strength
σ3=1455 psf
σ3=721 psf
Effective Deviator Stress (psf)
Axial Strain (%)
Ona-B Sample Volume Change
σ3=1455 psf
σ3=721 psf
Volumetric Strain (%)
Axial Strain (%)



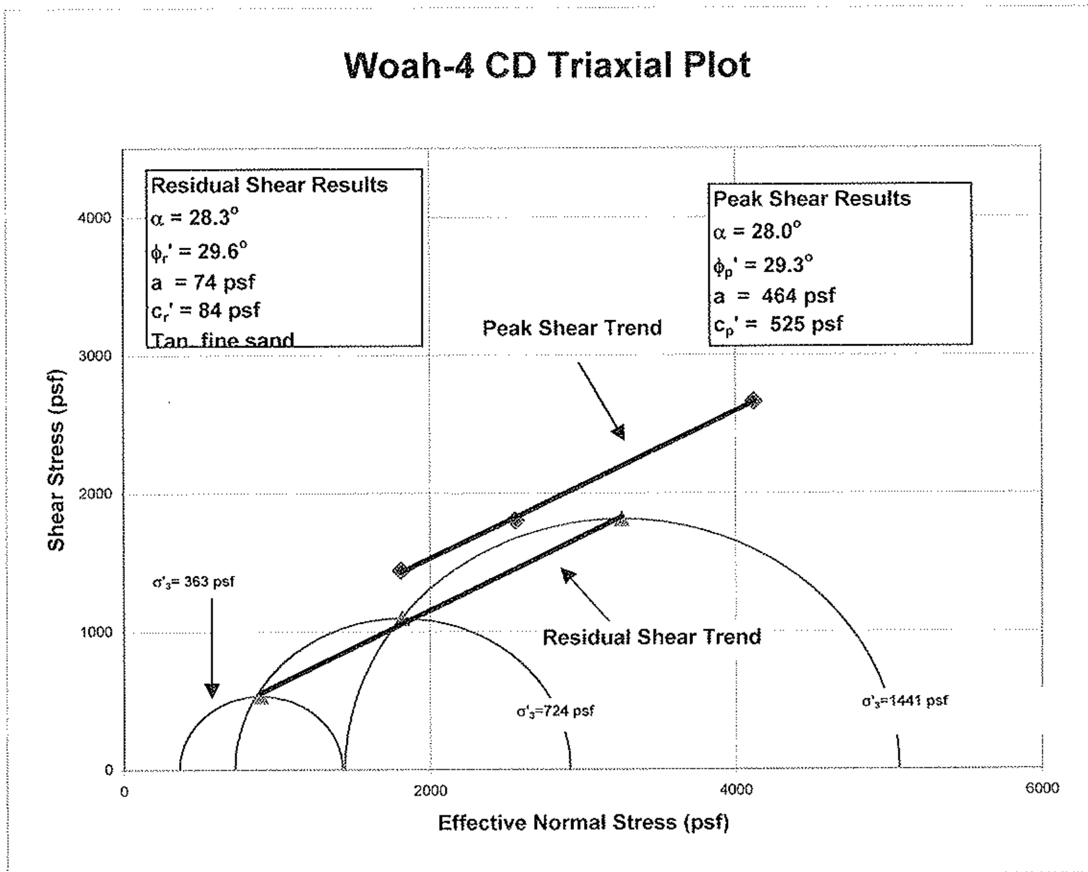
Ona-C CD Triaxial Plot
Residual Shear Results
α = 31.4°
φr' = 33.2°
a = 0 psf
cr' = 0 psf
Light brown, fine sand
Peak Shear Results
α = 35.6°
φp' = 38.4°
a = 0 psf
cp' = 0 psf
Peak Shear Trend
Residual Shear Trend
σ'3 = 350 psf
σ'3 = 721 psf
σ'3 = 1441 psf
Shear Stress (psf)
Effective Normal Stress (psf)

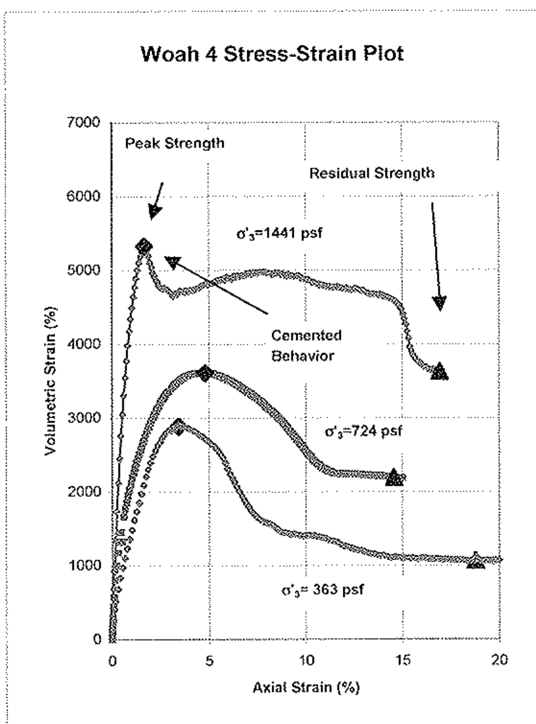


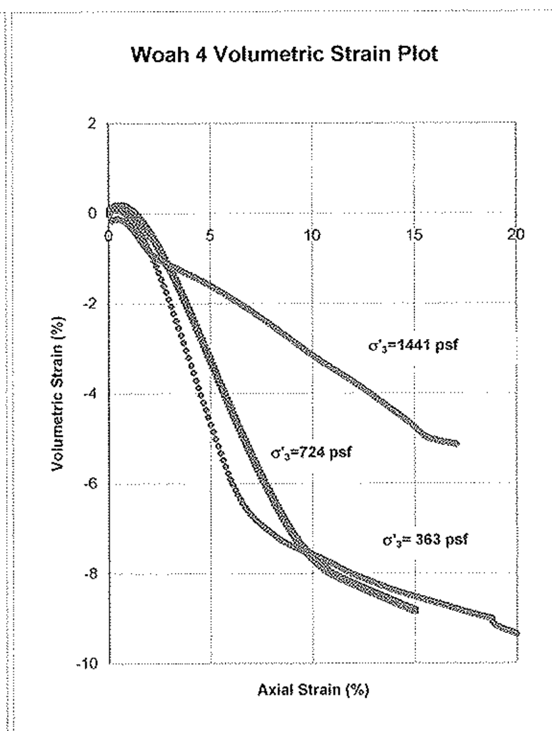
Ona-C Stress-Strain Plot
Peak Strength
Residual Strength
σ'3 = 1441 psf
σ'3 = 721 psf
σ'3 = 350 psf
Deviator Stress (psf)
Axial Strain (%)



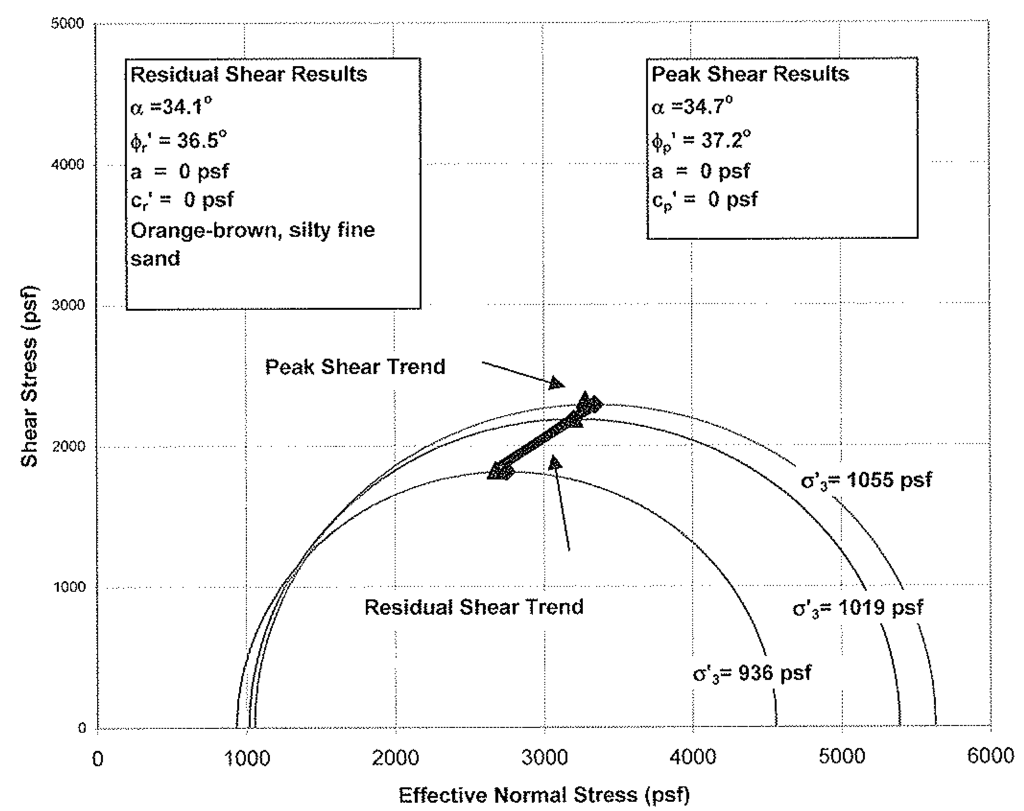
Ona-C Sample Volume Strain
σ'3 = 1441 psf
σ'3 = 721 psf
σ'3 = 350 psf
Volumetric Strain (%)
Axial Strain (%)


Woah-4 CD Triaxial Plot
Residual Shear Results
α = 28.3°
φr' = 29.6°
a = 74 psf
cr' = 84 psf
Tan, fine sand
Peak Shear Results
α = 28.0°
φp' = 29.3°
a = 464 psf
cp' = 525 psf
Peak Shear Trend
Residual Shear Trend
σ'3= 363 psf
σ'3=724 psf
σ'3=1441 psf
Shear Stress (psf)
Effective Normal Stress (psf)
0
1000
2000
3000
4000
6000

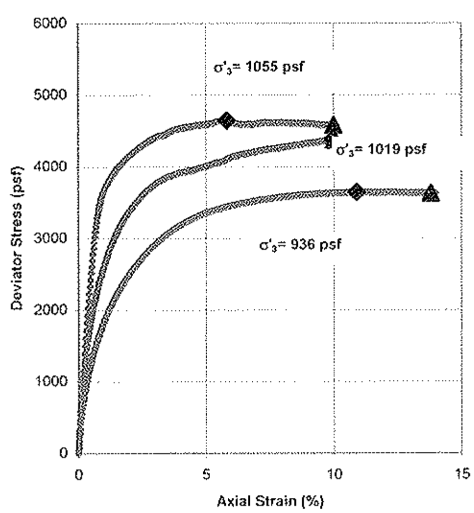

Woah 4 Stress-Strain Plot
Peak Strength
Residual Strength
σ'3=1441 psf
Cemented Behavior
σ'3=724 psf
σ'3= 363 psf
Volumetric Strain (%)
Axial Strain (%)
0
1000
2000
3000
4000
5000
6000
7000
5
10
15
20


Woah 4 Volumetric Strain Plot
σ'3=1441 psf
σ'3=724 psf
σ'3= 363 psf
Volumetric Strain (%)
Axial Strain (%)
2
0
-2
-4
-6
-8
-10
5
10
15
20

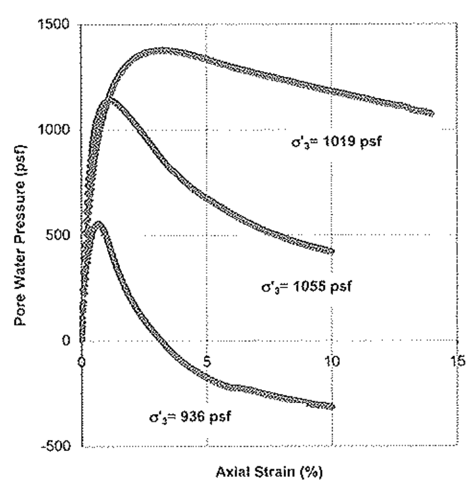
Pine-4 CU Triaxial Plot

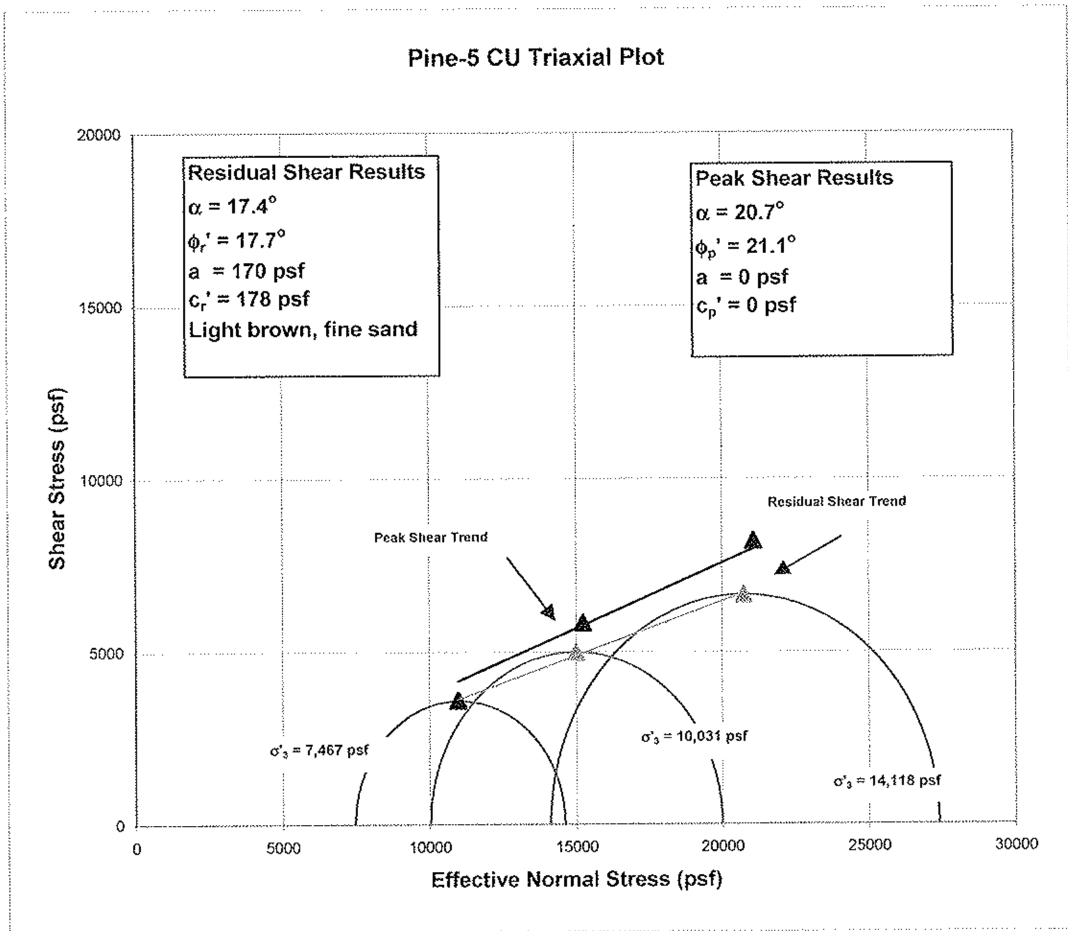


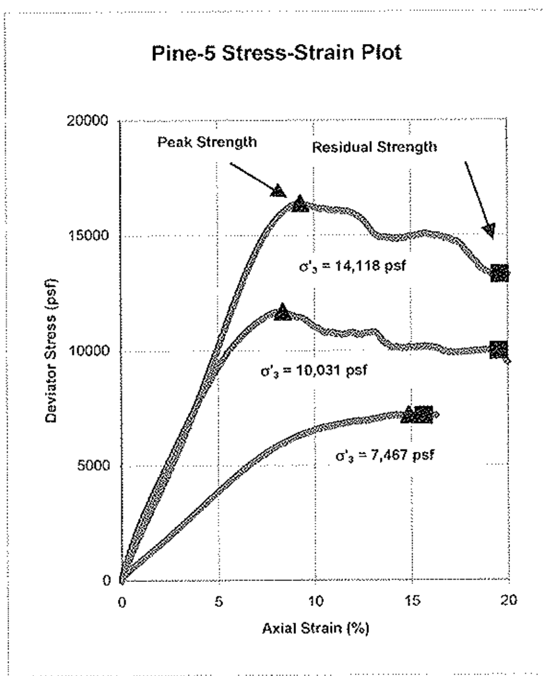
Pine-4 Stress-Strain Plot

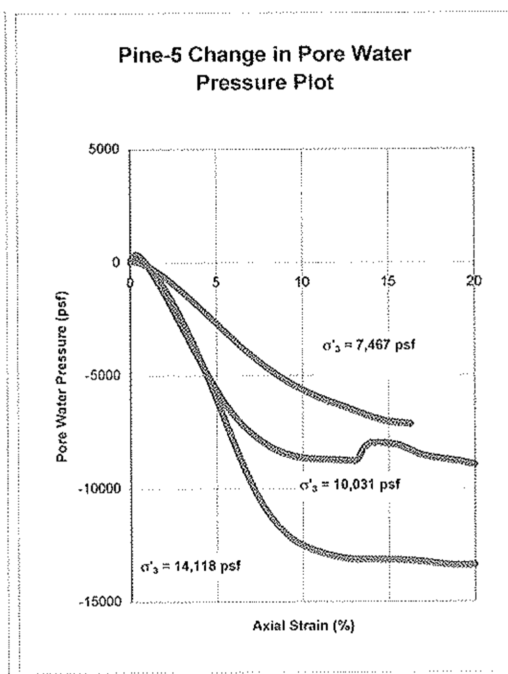


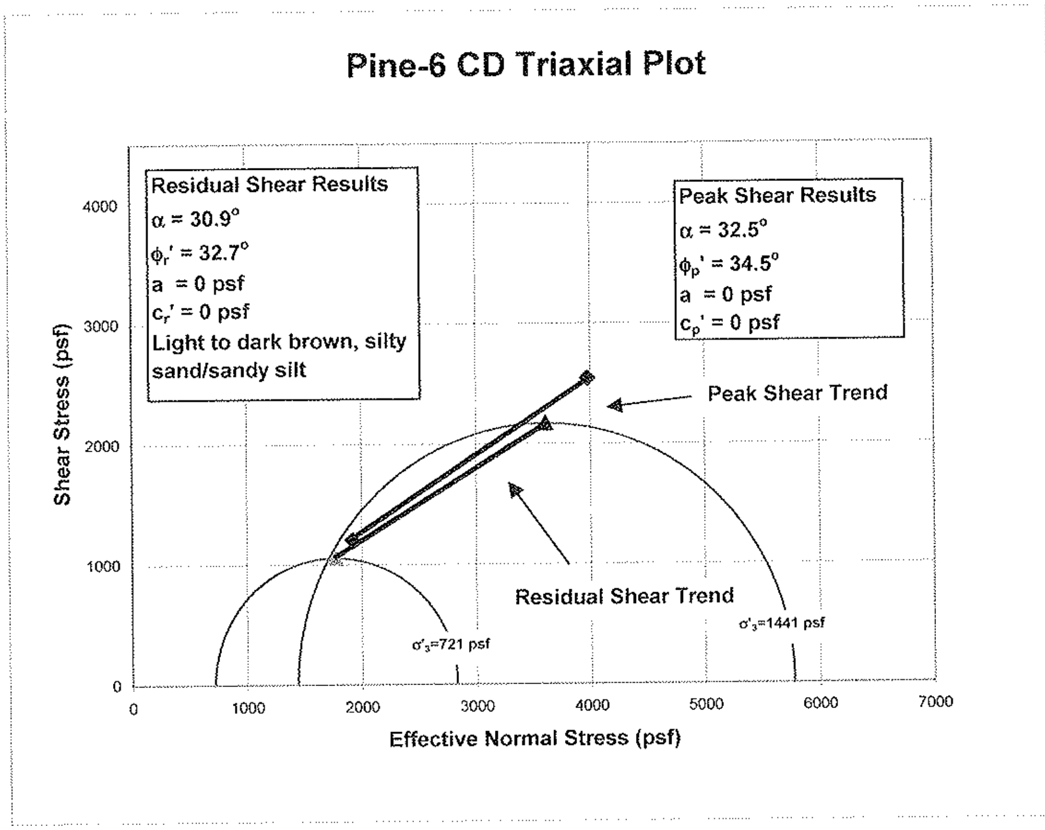
Pine 4 Change in Pore Water Pressure Plot



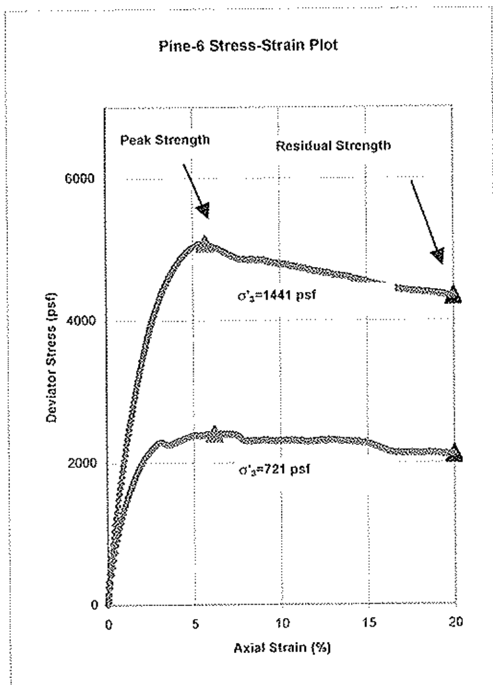

Pine-5 CU Triaxial Plot
Residual Shear Results
α = 17.4°
φr' = 17.7°
a = 170 psf
cr' = 178 psf
Light brown, fine sand
Peak Shear Results
α = 20.7°
φp' = 21.1°
a = 0 psf
cp' = 0 psf
Residual Shear Trend
Peak Shear Trend
σ'3 = 7,467 psf
σ'3 = 10,031 psf
σ'3 = 14,118 psf
Shear Stress (psf)
Effective Normal Stress (psf)
20000
15000
10000
5000
0
0
5000
10000
15000
20000
25000
30000


Pine-5 Stress-Strain Plot
Peak Strength
Residual Strength
σ'3 = 14,118 psf
σ'3 = 10,031 psf
σ'3 = 7,467 psf
Deviator Stress (psf)
Axial Strain (%)
20000
15000
10000
5000
0
0
5
10
15
20

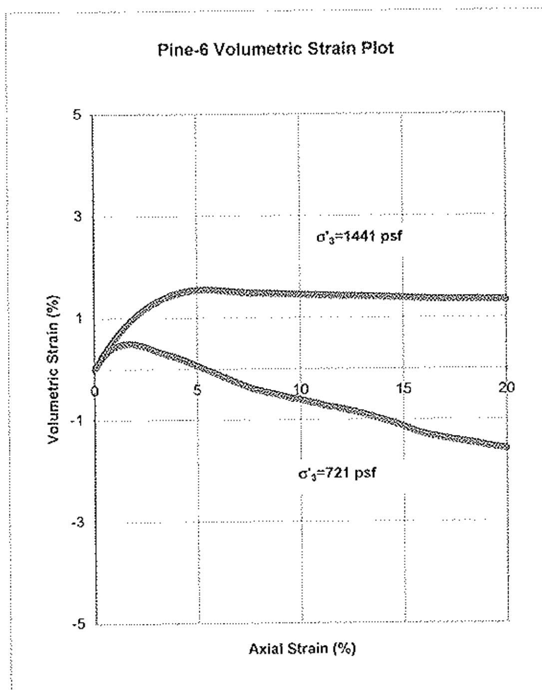

Pine-5 Change in Pore Water Pressure Plot
σ'3 = 7,467 psf
σ'3 = 10,031 psf
σ'3 = 14,118 psf
Pore Water Pressure (psf)
Axial Strain (%)
5000
0
-5000
-10000
-15000
5
10
15
20



Pine-6 CD Triaxial Plot
Residual Shear Results
α = 30.9°
φr' = 32.7°
a = 0 psf
cr' = 0 psf
Light to dark brown, silty sand/sandy silt
Peak Shear Results
α = 32.5°
φp' = 34.5°
a = 0 psf
cp' = 0 psf
Peak Shear Trend
Residual Shear Trend
σ'3=721 psf
σ'3=1441 psf
Shear Stress (psf)
Effective Normal Stress (psf)

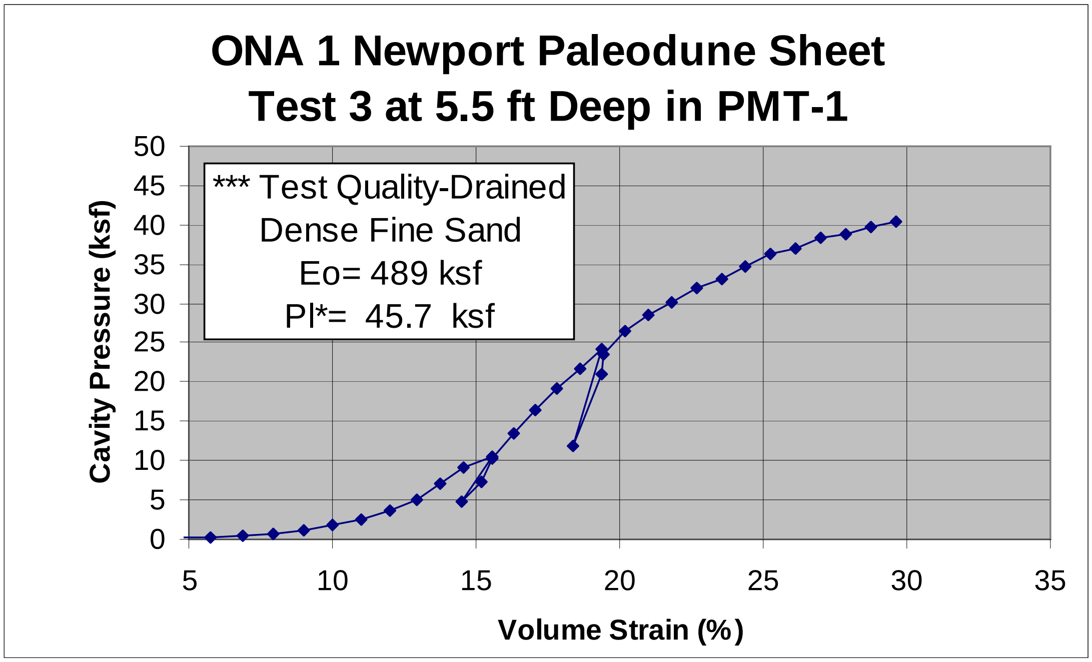


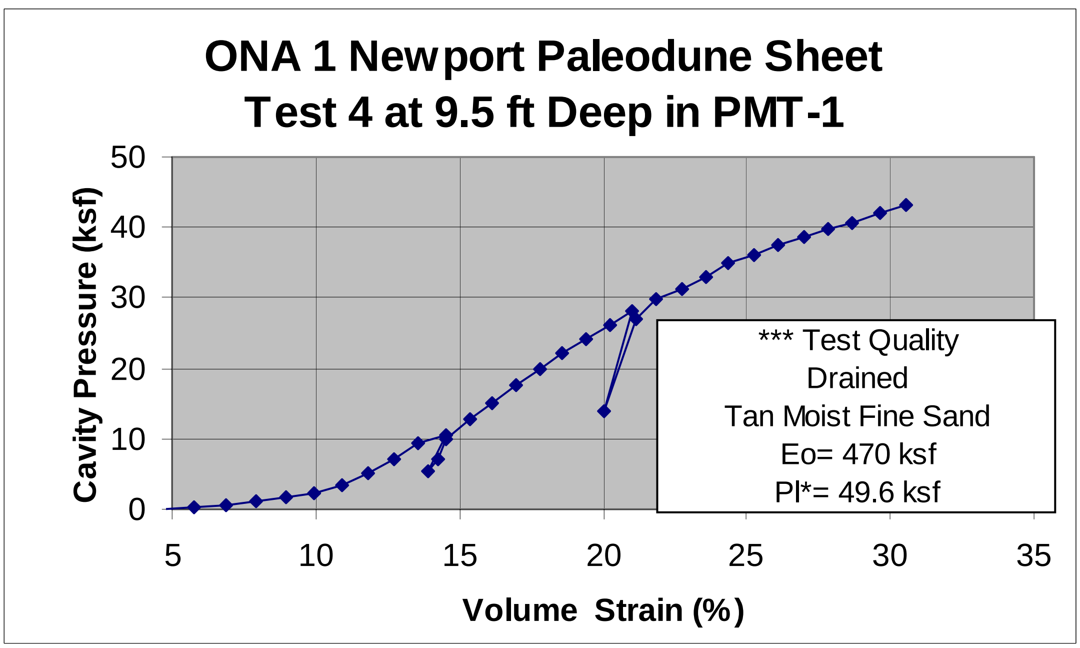
Pine-6 Stress-Strain Plot
Peak Strength
Residual Strength
σ'3=1441 psf
σ'3=721 psf
Deviator Stress (psf)
Axial Strain (%)

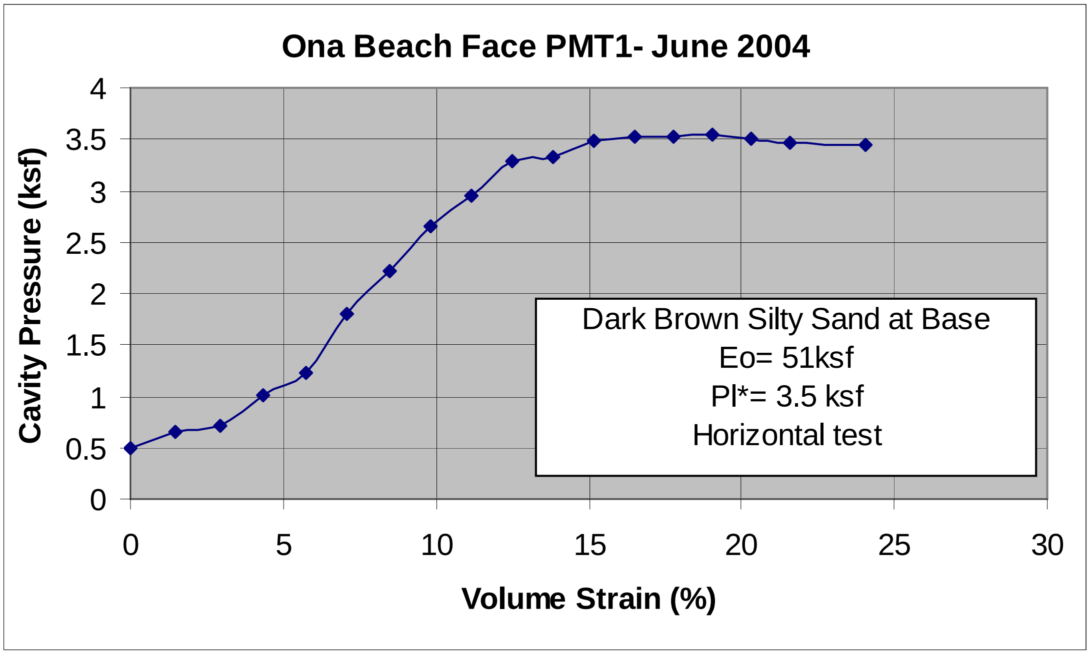


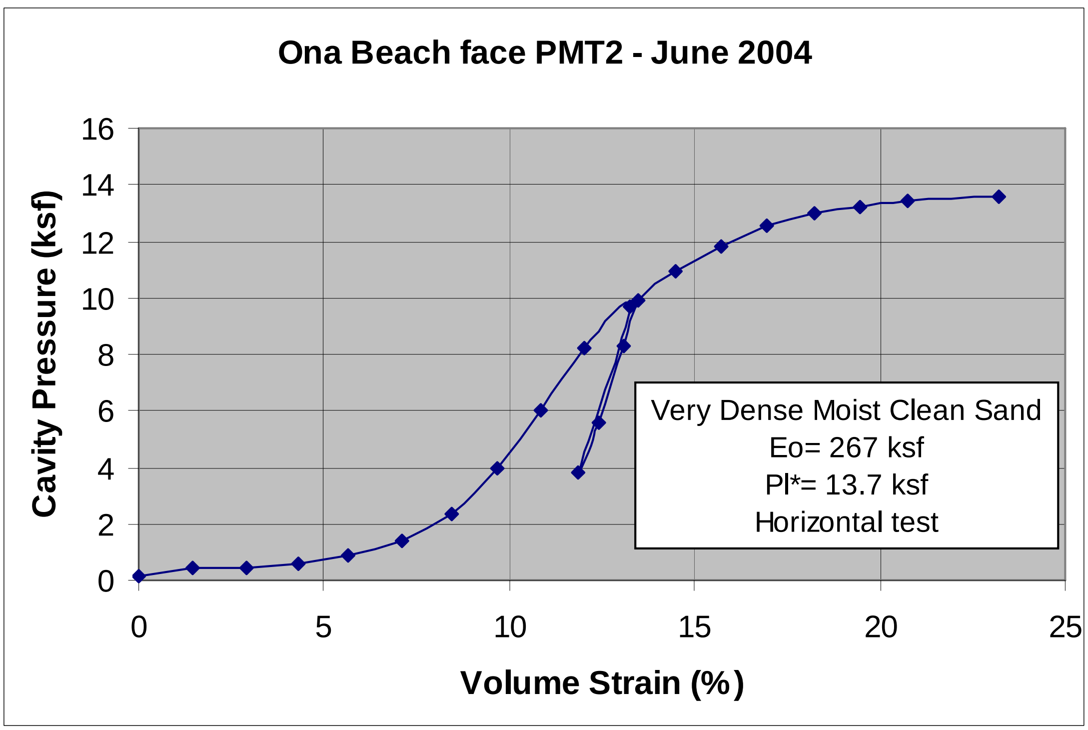
Pine-6 Volumetric Strain Plot
σ'3=1441 psf
σ'3=721 psf
Volumetric Strain (%)
Axial Strain (%)

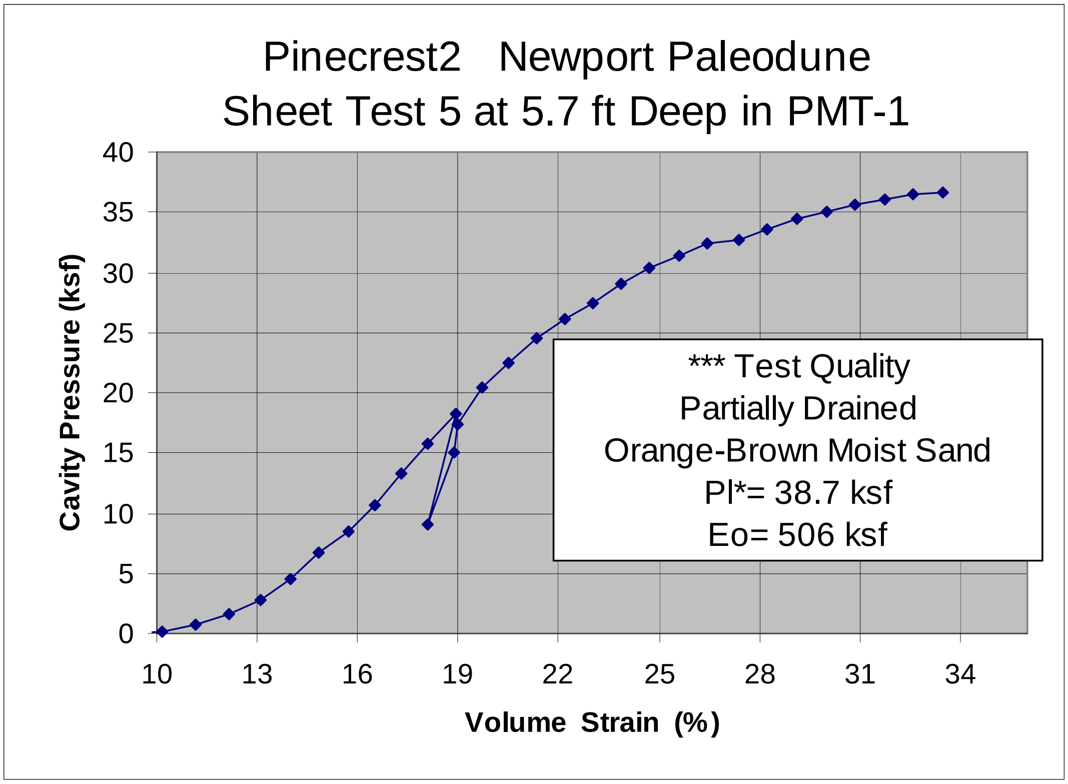
Appendix F: Pressuremeter Test Results

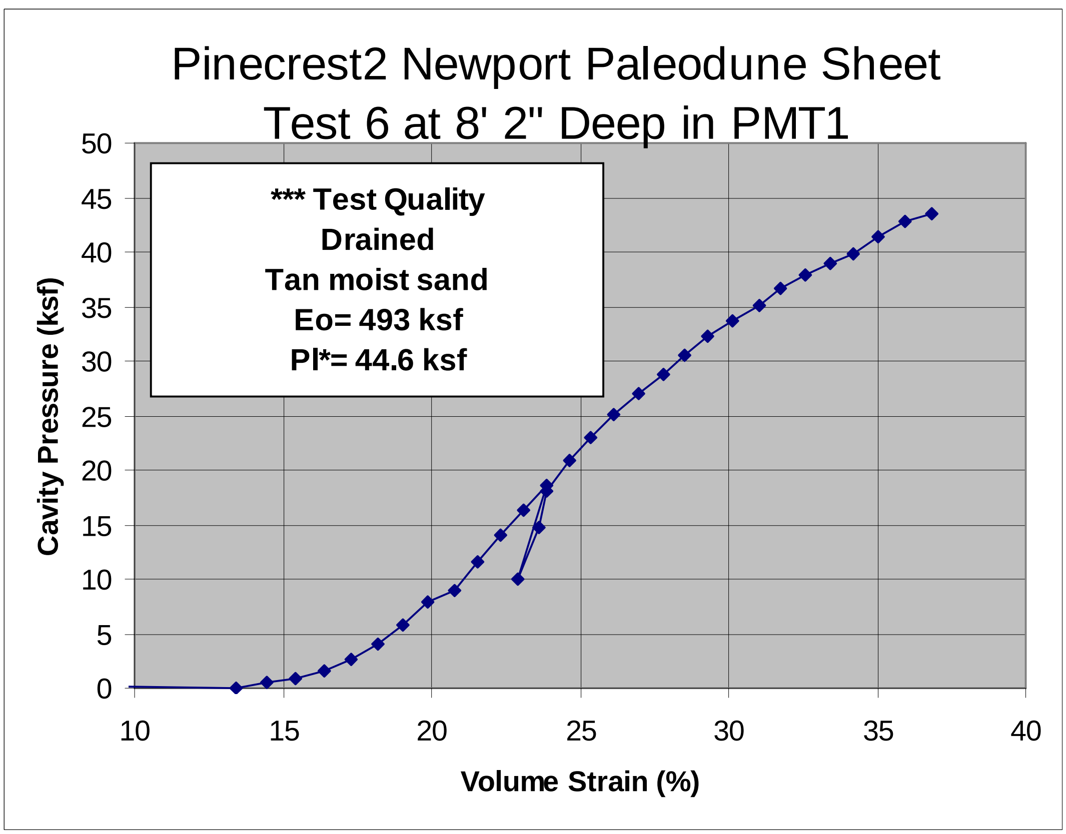

ONA 1 Newport Paleodune Sheet
Test 3 at 5.5 ft Deep in PMT-1
*** Test Quality-Drained
Dense Fine Sand
Eo= 489 ksf
Pl*= 45.7 ksf
Cavity Pressure (ksf)
0
5
10
15
20
25
30
35
40
45
50
5
10
15
20
25
30
35
Volume Strain (%)

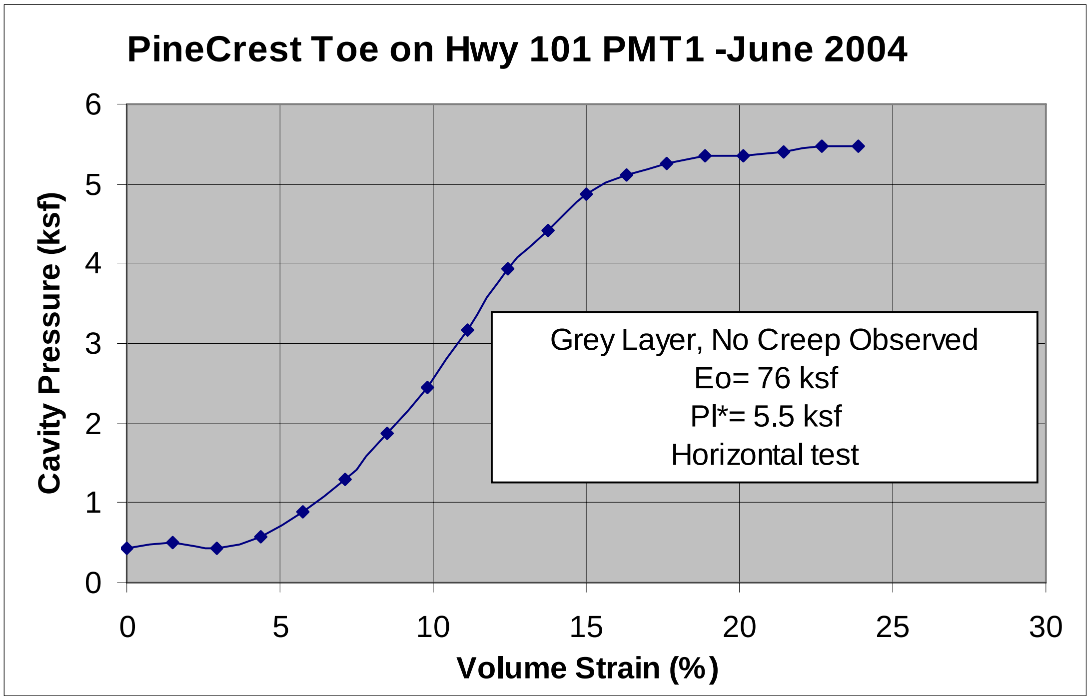

ONA 1 Newport Paleodune Sheet
Test 4 at 9.5 ft Deep in PMT-1
*** Test Quality
Drained
Tan Moist Fine Sand
Eo= 470 ksf
Pl*= 49.6 ksf
Cavity Pressure (ksf)
0
10
20
30
40
50
5
10
15
20
25
30
35
Volume Strain (%)

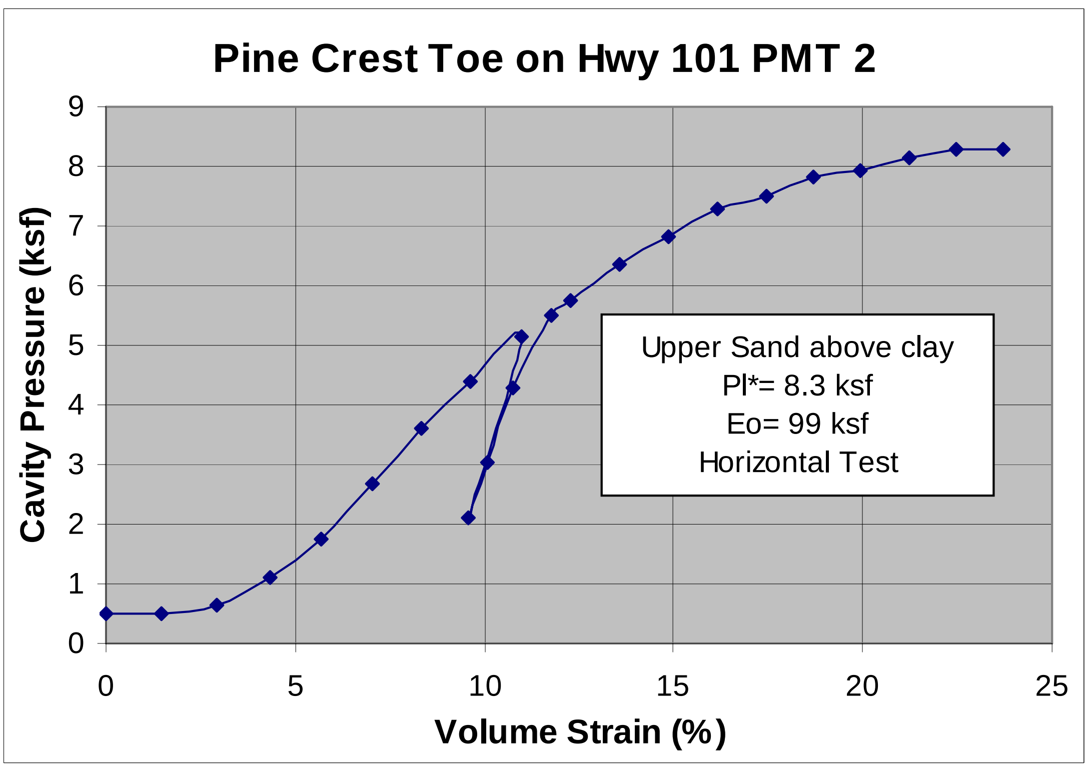

Ona Beach Face PMT1- June 2004
Cavity Pressure (ksf)
Volume Strain (%)
Dark Brown Silty Sand at Base
Eo= 51ksf
Pl*= 3.5 ksf
Horizontal test

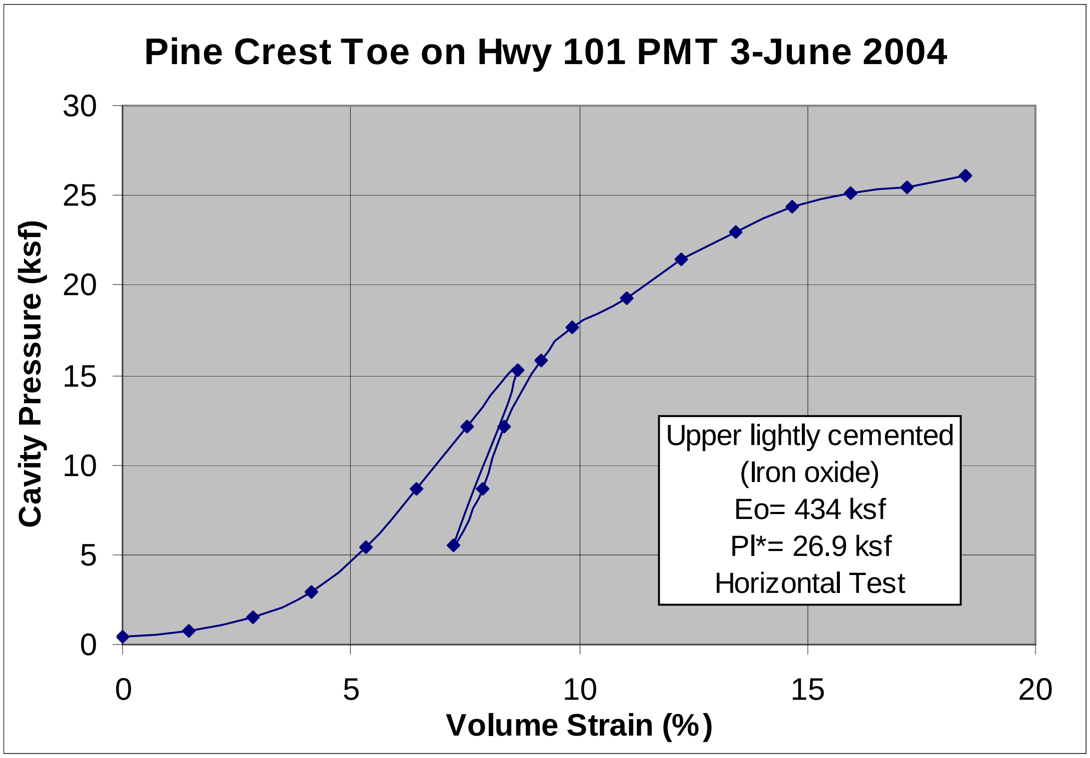

Ona Beach face PMT2 - June 2004
Cavity Pressure (ksf)
Volume Strain (%)
Very Dense Moist Clean Sand
Eo= 267 ksf
Pl*= 13.7 ksf
Horizontal test

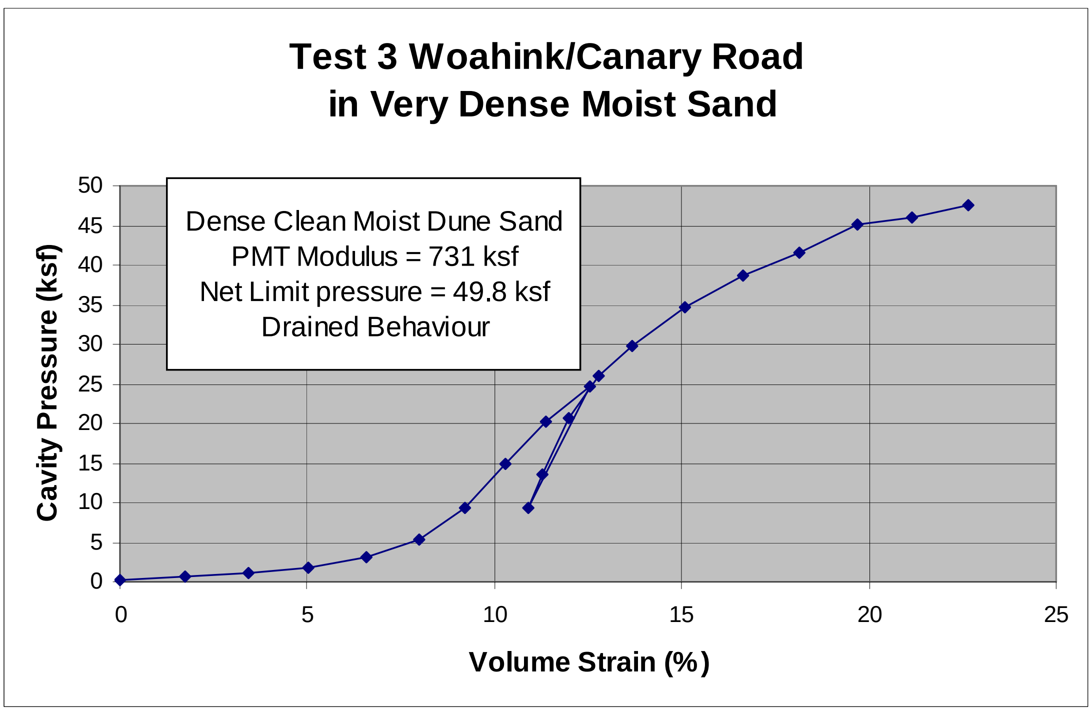

Pinecrest2 Newport Paleodune
Sheet Test 5 at 5.7 ft Deep in PMT-1
Cavity Pressure (ksf)
Volume Strain (%)
0
5
10
15
20
25
30
35
40
10
13
16
19
22
25
28
31
34
*** Test Quality
Partially Drained
Orange-Brown Moist Sand
Pl*= 38.7 ksf
Eo= 506 ksf

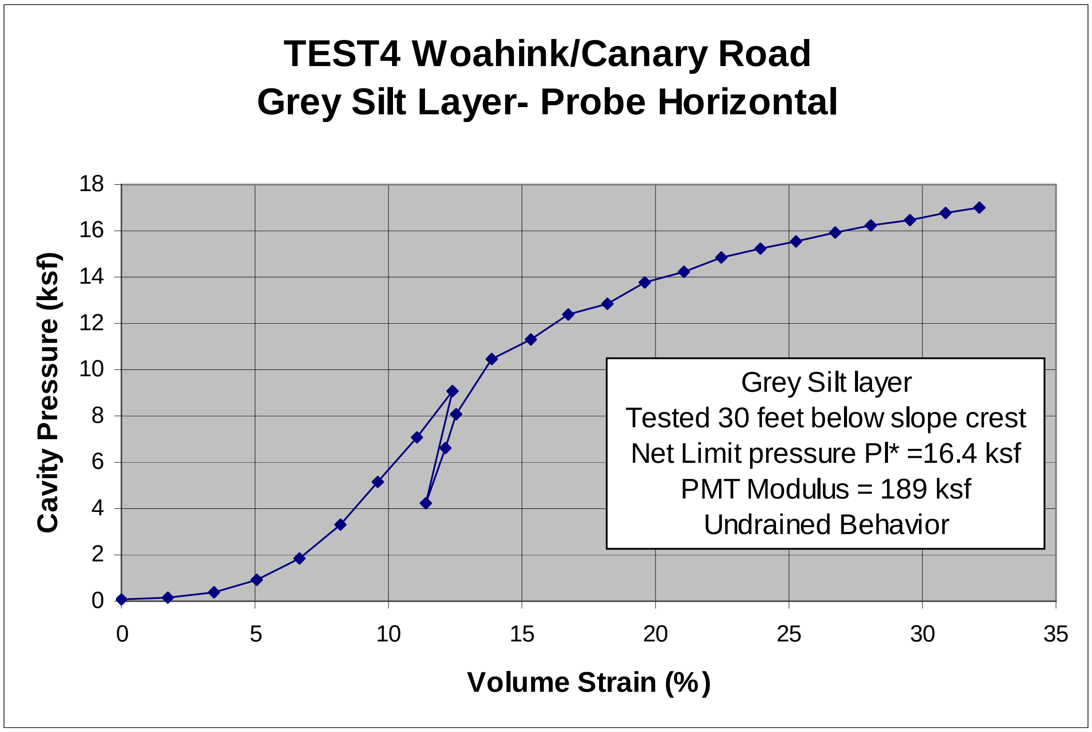

Pinecrest2 Newport Paleodune Sheet
Test 6 at 8' 2" Deep in PMT1
Cavity Pressure (ksf)
Volume Strain (%)
0
5
10
15
20
25
30
35
40
45
50
10
15
20
25
30
35
40
*** Test Quality
Drained
Tan moist sand
Eo= 493 ksf
Pl*= 44.6 ksf


PineCrest Toe on Hwy 101 PMT1 -June 2004
Cavity Pressure (ksf)
Volume Strain (%)
Grey Layer, No Creep Observed
Eo= 76 ksf
Pl*= 5.5 ksf
Horizontal test
0
1
2
3
4
5
6
0
5
10
15
20
25
30


Pine Crest Toe on Hwy 101 PMT 2
Cavity Pressure (ksf)
Volume Strain (%)
Upper Sand above clay
Pl*= 8.3 ksf
Eo= 99 ksf
Horizontal Test
0
1
2
3
4
5
6
7
8
9
0
5
10
15
20
25


Pine Crest Toe on Hwy 101 PMT 3-June 2004
Cavity Pressure (ksf)
Volume Strain (%)
0
5
10
15
20
25
30
0
5
10
15
20
Upper lightly cemented
(Iron oxide)
Eo= 434 ksf
Pl*= 26.9 ksf
Horizontal Test


Test 3 Woahink/Canary Road
in Very Dense Moist Sand
Cavity Pressure (ksf)
Volume Strain (%)
0
5
10
15
20
25
30
35
40
45
50
0
5
10
15
20
25
Dense Clean Moist Dune Sand
PMT Modulus = 731 ksf
Net Limit pressure = 49.8 ksf
Drained Behaviour


TEST4 Woahink/Canary Road
Grey Silt Layer- Probe Horizontal
Cavity Pressure (ksf)
Volume Strain (%)
Grey Silt layer
Tested 30 feet below slope crest
Net Limit pressure Pl* =16.4 ksf
PMT Modulus = 189 ksf
Undrained Behavior
0
2
4
6
8
10
12
14
16
18
0
5
10
15
20
25
30
35

Appendix G: ODOT Borehole Logs

Compilation of Geotech Data from Drill Holes in Oregon Coastal Dune Sheets

Drill Hole position as reported by HW101 Mile Post, distance in ODOT decimal miles.
UTM coordinates estimated from USGS 1:24,000 Map Series.
Elevation of colar (in decimal feet or meters) above mean sea level (NGVD1927 orWGS83).
Depth below drilling surface in decimal feet or meters below colar.
Soil Type: Unified Soil Clasification: Sand (S), Gravel (G) Silty Fines (M),
Clay (C), Organics (0), >90% Organics (PT)
Grading: Well Graded (W) Poorly Graded (P): Fine-grained >50 liquid limit (H) < 50 liquid limit (L).
Moisture: Wet/Dry, Moist, Percent Natural (%)
Unit Age: Holocene (H), Pleistocene (P), Tertiary Shale, Siltstone, of Sandstone, Modern Fill (Fill)
Unit Facies: Dune (D), Paleosol (Ps), Iron Oxide (Fe), Wetland (Peat), Loess (L), Lacustrine (Pond)
Beach/Shelf Shoreface (S), Lagoon/Estuary Mud (Bay), Alluvial, Colluvial, Other (*named)

Project	HW 101 MP	Date		Burns and Thommen (1988)		
Alder Creek	2.3	1988				
Drill Hole	UTM-N	UTM-E	Elevation			
1-87	5114200	428100	~15 (ft)			
Sample	Depth (ft)	Size/ Grading	Moisture % natural	Structure	Unit Age /Facies	Resistance /12"
N1	5				Fill	2
N2	10	S/P			H/D	5
N3	15	S/P			H/S	30
N4	20	S/P			H/S	42
N5	25	S/P			H/S	58

Project	HW 101 MP	Date		Reference: Kleutsch (1992)		
West Lake	12.1-16.3	1992				
Drill Hole	UTM-N	UTM-E	Elevation			
DH1-91	5102100	429400	19.8 (ft)			
Sample	Depth (ft)	Soil/ Grading	Moisture % natural	Structure	Unit Age /Facies	Resistance /6"
N1	5-6.5	Peat	68	Non-Plastic	H/P	1-1-1
N2	9-10.5	S/P	40	Non-Plastic	H/D	1-3-3
N3	10.5-12	S/P	36	Loose	H/D	2-5-5
N4	12-13.5	S/P	38	Medium Dense	H/D	4-7-9
N5	15-16.5	S/P	29	Medium Dense	H/D	4-6-12
N6	17-18.5	S/P	26	Dense	H/S	6-13-18
N7	20-21.5	S/P	29	Dense	H/S	3-10-18
N8	22-23.5	S/P	30	Dense	H/S	10-16-32
N9	25-26.5	G-S/P	19	Very Dense	H/S	7-19-34
N10	27-28.5	S/P	26	Dense	H/S	6-22-25
N11	30-31.5	S/P	27	Dense	H/S	9-18-21
N12	32-33.5	S/P	34	Medium Dense	H/S	5-10-10
N13	35-36.5	S/P	32	Dense	H/S	8-13-15
N14	37-38.5	S/P	31	Dense	H/S	9-12-13

N15	38.5-40	S/P	26	Dense	H/S	10-18-25
N16	42-43.5	S/P	27	Dense	H/S	7-14-18
N17	45-46.5	S/P	22	Very Dense	H/S	13-24-30
N18	47-48.5	S/P	21	Dense	H/S	8-12-28
N19	50-51.5	S/P	36	Dense	H/S	6-14-23
N21	65-65.5				Shale	50/5"Refusal
Project	HW 101 MP	Date		Reference: Kleutsch (1992)		
West Lake	12.1-16.3	1992				
Drill Hole	UTM-N	UTM-E	Elevation			
DH2-91	5105600	429200	14.6 (ft)			
Sample	Depth	Soil/	Moisture	Structure	Unit Age	Resistance
	(ft)	Grading	% natural		/Facies	/6"
N1	5-6.5	S/P	30		H/D	2-2-2
N2	10-11.5	S/P	27	Dense	H/D	5-7-9
N3	15-16.5	S/P	29	Medium Dense	H/S	6-10-14
N4	20-21.5	SM	28	Dense	H/S	8-12-19
N5	25-26.5	SM	31	Dense	H/S	6-10-15
N6	30-31.5	SM	34	Medium Dense	H/S	6-9-13
N7	35-36.5	S/P	35	Dense	H/S	7-12-18
N8	40-41.5	S/P	31	Dense	H/S	8-13-18
N9	45-46.5	SM	30	Medium Dense	H/S	4-4-8
N10	50-51.5	S/P	30	Dense	H/S	12-20-29
N11	55-56.5	Peat	94	Medium Stiff	H/Peat	2-2-3
N12	66-66.5	CH	41	Medium Stiff	H/Bay	2-3-4
N13	75-76.5	CH	39	Stiff	H/Bay	4-4-6
N14	85-86.5	CH	41	Stiff	H/Bay	3-4-6
N15	95-96.5	COH	57	Medium Stiff	H/Bay	2-2-3
N16	105-106.5	CH	64	Stiff	H/Bay	5-6-7
N17	115-116.5	PT	44	Loose	H/Bay	4-9
N18	125-126				Shale	12-50/6"
Project	HW 101 MP	Date		Reference: Kleutsch (1992)		
West Lake	12.1-16.3	1992				
Drill Hole	UTM-N	UTM-E	Elevation			
DH3-91	5105100	428900	37.6 (ft)			
Sample	Depth	Soil/	Moisture	Structure	Unit Age	Resistance
	(ft)	Grading	% natural		/Facies	/6"
N1	5-6.5	PT	39	Very Loose	H/Peat	2-1-1
N2	10-11.5	PT	32	Loose	H/Peat	1-2-3
N3	15-16.5	S/P	23	Dense	H/D	4-5-7
N4	20-21.5	S/P	29	Dense	H/D	3-5-7
N5	25-26.5	S/P	27	Dense	H/S	6-10-12
N6	30-31.5	S/P	23	Dense	H/S	10-18-18
N7	35-36.5	S/P	25	Dense	H/S	11-15-20
N8	40-41.5	S/P	21	Dense	H/S	17-24-26
N9	45-46.5	S/P	27	Dense	H/S	12-20-25
N10	50-51.5	S/P	25	Dense	H/S	12-20-24

N11	60-61.5	S/P	30	Dense	H/S	10-13-21
N12	70-70.8				Shale	50/4"Refusal

Project	HW 101 MP	Date		Reference: Interdepartmental Correspondence (1969)		
Neacoxi Ck		1992				
Drill Hole	UTM-N	UTM-E	Elevation			
1	5100600	428800	~15 (ft)			
Sample	Depth (ft)	Soil/ Grading	Moisture % natural	Structure	Unit Age /Facies	Resistance /12"
N1	10	S/P			H/S	24
N3	20	S/P			H/S	30
N4	25	S/P			H/S	48
N5	30	S/P			H/S	48

Project	HW 101 MP	Date		Reference: Joint Geology/Geotechnical Report (1991)		
Neahkahnie	41.5-43.7	1992				
Drill Hole	UTM-N	UTM-E	Elevation			
6-92	5063300	427800	107 (ft)			
Sample	Depth (ft)	Soil/ Grading	Moisture % natural	Structure	Unit Age /Facies	Resistance /6"
N1	4-5.5	S/P		Very Loose	H/D	1-1-1
N2	9-10.5	S/P		Very Loose	H/D	2-2-2
N3	14-15.5	S/P		Loose	H/D	2-3-4
N4	19-20.5	S/P		Loose	H/D	2-3-3
N5	24-25.5	S/P		Loose	H/D	3-3-6
N6	29-30.5	S/P		Loose	H/D	2-3-6
N7	44-45.5	S/P	Wet	Loose	H/D	2-3-5

Project	HW 101 MP	Date		Reference: Joint Geology/Geotechnical Report (1991)		
Neahkahnie	41.5-43.7	1992				
Drill Hole	UTM-N	UTM-E	Elevation			
7-92	5063100	427800	109.3 (ft)			
Sample	Depth (ft)	Soil/ Grading	Moisture % natural	Structure	Unit Age /Facies	Resistance /6"
N1	5-6.5	S/P		Loose	H/D	2-2-3
N2	10-11.5	S/P		Loose	H/D	2-3-3
N3	15-16.5	S/P		Loose	H/D	1-2-3
N4	20-21.5	S/P		Medium Dense	H/D	5-5-7

Project	HW 101 MP	Date		Reference: Joint Geology/Geotechnical Report (1991)		
Neahkahnie	41.5-43.7	1992				
Drill Hole	UTM-N	UTM-E	Elevation			
10-92	5063200	428200	71.6 (ft)			
Sample	Depth (ft)	Soil/ Grading	Moisture % natural	Structure	Unit Age /Facies	Resistance /6"
N1	6.5-8	S/P	28	Loose	H/D	2-3-5
N2	11.5-13	S/P	23	Medium Dense	H/D	6-7-10
N3	16.5-18	S/P	24	Medium Dense	H/D	5-9-12

N4	21.5-23	ML	35	Medium Stiff	Regolith	5-3-3
Project	HW 101 MP	Date		Reference: Joint Geology/Geotechnical Report (1991)		
Neahkahnie	41.5-43.7	1992				
Drill Hole	UTM-N	UTM-E	Elevation			
11-92	5063200	428100	77.6 (ft)			
Sample	Depth (ft)	Soil/ Grading	Moisture % natural	Structure	Unit Age /Facies	Resistance /6"
N1	6-7.5	S/P	26		H/D	3-2-1
N2	11-12.5	S/P	23		H/D	1-1-1
N3	16-17.5	C	54	Soft	Regolith	1-1-1
N4	26-27.5	CL	56	Medium Plasticity	Regolith	4-6-8
Project	HW 101 MP	Date		Reference: Stephens (1999)		
Neahkahnie	41.5-43.7	1999				
Drill Hole	UTM-N	UTM-E	Elevation			
B-01-99	5063000	427900	326 (ft)			
Sample	Depth (ft)	Soil/ Grading	Moisture % natural	Structure	Unit Age /Facies	Resistance /6"
N1	2.5-4	S/P		Medium Dense	Fill	7-13-15
N2	5-6.5	S/P			H/D	5-6-5
N3	7.5-9	S/P	Wet	Loose	H/D	5-8-9
N4	10-11.5	S/P		Loose	H/D	3-3-3
N5	12.5-14	S/P			H/D	2-2-3
N6	15-16.5	S/P			H/D	2-2-3
N7	17.5-19	S/P-SM			H/D	2-2-3
N8	20-21.5	S/P-SM		Loose	H/D	2-3-4
N9	22.5-24	S/P			H/D	2-3-4
N10	25-26.5	S/P		Loose	H/D	5-7-8
N11	27.5-29	S/P-SM			H/D	3-5-8
N13	32-33.5	S/P-SM		Loose	H/D	3-3-5
N14	34-35.5	CL			Regolith	4-4-6
N17	38.7-40.2	CL-M		Stiff	Siltstone	12-18-22
Project	HW 101 MP	Date		Reference: Rodzinski (1973)		
Spanish Head		1973				
Drill Hole	UTM-N	UTM-E	Elevation			
73-1	4976100	419200	40 (ft)			
Sample	Depth (ft)	Soil/ Grading	Moisture % natural	Structure	Unit Age /Facies	Resistance /6"
N1	5-7.0				P/D	8-11-14
N2	10-12.0				P/D	9-11-13
N3	15-17.0				P/D	10-13-18
N4	20-22.0				P/D	12-13-16
Project	HW 101 MP	Date		Reference: Rodzinski (1973)		
Spanish Head		1973				
Drill Hole	UTM-N	UTM-E	Elevation			

73-2	4976100	419200	27 (ft)			
Sample	Depth (ft)	Soil/ Grading	Moisture % natural	Structure	Unit Age /Facies	Resistance /6"
N1	5-7.0				P/D	8-12-16
N2	10-12.0				P/D	9-12-14
N3	15-17.0				P/D	12-15-18
N4	20-22.0				P/D	10-15-20
N5	25-27.0				P/D	11-16-19
N6	30-32.0				P/D	9-10-14

Project	HW 101 MP	Date		Reference: Carmel Knoll (1985)		
Carmel Knoll	135	1985				
Drill Hole	UTM-N	UTM-E	Elevation			
1-85	4951700	416200	~60 (ft)			
Sample	Depth (ft)	Soil/ Grading	Moisture % natural	Structure	Unit Age /Facies	Resistance /12"
N1	10-11.0				H/D	7
N2	13-14.0				H/D	5
N3	16-17.0				P/D	21
N4	22-23.0				Siltstone	34

Project	HW 101 MP	Date		Reference: Howard, Needles, Tammen and Bergendoff (1986)		
Alsea Bridge		1986				
Drill Hole	UTM-N	UTM-E	Elevation			
B-113	4920700	414600	92 (ft)			
Sample	Depth (ft)	Soil/ Grading	Moisture % natural	Structure	Unit Age /Facies	Resistance /6"
N1	5	S/P		Very Dense	P/D	14-20-34
N2	10	S/P		Very Dense	P/D	14-28-44
N3	15	S/P		Very Dense	P/D	19-38-51
N4	20	S/P		Very Dense	P/D	24-60/5.5
N5	25	S/P	Moist	Very Dense	P/D	22-39-60/4
N6	30				Siltstone	60/5

Project	HW 101 MP	Date		Reference: Howard, Needles, Tammen and Bergendoff (1986)		
Alsea Bridge		1986				
Drill Hole	UTM-N	UTM-E	Elevation			
B-112	4920600	414600	85.9 (ft)			
Sample	Depth (ft)	Soil/ Grading	Moisture % natural	Structure	Unit Age /Facies	Resistance /6"
N1	5	S/P		Dense	P/D	10-13-18
N2	10	S/P	Moist	Very Dense	P/D	12-15-35
N3	15	S/P		Very Dense	P/DFe	18-31-41
N4	20	S/P		Very Dense	P/D	10-20-38
N5	25	S/P		Very Dense	P/DFe	24-56-60/3
N6	30	SCG		Very Dense	Regolith	19-26-22
N7	35	C		Very Stiff	Regolith	6-6-7
N8	40				Siltstone	60/4

Project	HW 101 MP	Date		Reference: Howard, Needles, Tammen and Bergendoff (1986)		
Alsea Bridge		1986				
Drill Hole	UTM-N	UTM-E	Elevation			
B-111	4920600	414600	87.9 (ft)			
Sample	Depth (ft)	Soil/ Grading	Moisture % natural	Structure	Unit Age /Facies	Resistance /6"
N1	5	S/P		Medium Dense	P/D	2-7-16
N2	10	S/P		Very Dense	P/D	14-26-36
N3	15	S/P		Very Dense	P/D	21-42-95
N4	20	S/P		Very Dense	P/D	25-48-60/5"
N5	25	S/P		Very Dense	P/D	25-48-60/5"
N6	30	S/P		Very Dense	P/DFe	35-60/4"
N7	35	S/P		Very Dense	P/D	38-60/4"
N8	40	S/P		Very Dense	P/D	26-42-44
N9	45	S/P		Very Dense	P/DFe	16-38-60/5"
N10	50	S/P		Very Dense	P/D	56-60/2"
N11	55				Siltstone	56-60/2"
N12	60				Siltstone	58-60/3"

Project	HW 101 MP	Date		Reference: Howard, Needles, Tammen and Bergendoff (1986)		
Alsea Bridge		1986				
Drill Hole	UTM-N	UTM-E	Elevation			
B-114	4920500	414600	14.2 (ft)			
Sample	Depth (ft)	Soil/ Grading	Moisture % natural	Structure	Unit Age /Facies	Resistance /6"
N1	5	S/P		Loose	Fill	2-3-3
N2	10	S/P		Very Dense	P/D	9-22-33
N3	15				Siltstone	60/3

Project	HW 101 MP	Date		Reference: Bolander (1987)		
Sutton Creek		1987				
Drill Hole	UTM-N	UTM-E	Elevation			
87-1	4878200	412200	44.9 (ft)			
Sample	Depth (ft)	Soil/ Grading	Moisture % natural	Structure	Unit Age /Facies	Resistance /6"
N1	0-2	S	Moist	Medium Dense	Fill	3-7-6-6
N2	5.5-7.5	S		Medium Dense	H/D	8-8-10-10
N3	10.5-12.5	S/P	Wet	Medium Dense	H/D	8-12-14-12
N4	15.5-17.5	SO	Wet	Loose	H/DPond	2-2-4-5
N5	20.5-22.5	S/P		Medium Dense	P/D	4-8-13-20
N6	25.5-27.5	S/P		Very Dense	P/D	17-28-42
N7	30.7-32.7	S/P		Very Dense	P/DPs	21-33-25-22
N8	35.5-37.5	S/P		Dense	P/D	5-14-11-25
N9	40.5-42.5	S/P		Dense	P/D	2-10-20-31
N10	50.5-51.7	S/P		Very Dense	P/D	26-43
N11	60.5-61	S/P		Very Dense	P/D	43
N12	70.5-72.5	SMO		Medium Stiff	P/Bay	23-18-11-9

N13	80.5-82.5	S/P		Loose	Collapse	2-3-3-4
N14	90.5-91.5	S/P		Very Dense	P/Bay	19-40
N15	100-101	S/P		Very Dense	P/Bay	9-26-40

Project	HW 101 MP	Date		Reference: Narkiewicz (1995)		
Clear Lake	218-219	1995				
Drill Hole	UTM-N	UTM-E	Elevation			
95-1	483200	404300	79 (ft)			
Sample	Depth (ft)	Soil/ Grading	Moisture % natural	Structure	Unit Age /Facies	Resistance /6"
N1	5			Loose	H/D	3-4-4
N2	10			Loose	H/D	3-3-4
N3	15			Loose	H/D	2-2-2
N4	20			Damp	H/D	1-1-1
N5	25			Wet	P/D	4-12-50/6

Project	HW 101 MP	Date		Reference: Kobernick (1999)		
Wildwood	220.6	1999				
Drill Hole	UTM-N	UTM-E	Elevation			
9087-07	4829200	404700	67.5 (m)			
Sample	Depth (ft)	Soil/ Grading	Moisture % natural	Structure	Unit Age /Facies	Resistance /6"
N1	1.4-1.8	SM	61	Very Loose	P/DL*	1-1-2
N2	2.9-3.4	C		Medium Stiff	P/DPsL*	1-1-1
N3	4.2-4.9	M		Medium Stiff	P/DL*	2-1-4
N4	5.9-6.4	M		Medium Stiff	P/DL*	3-4-4
N5	7.5-7.9	M		Medium Stiff	P/DL*	2-2-4
N6	9.0-9.4	M	59	Medium Stiff	P/DL*	2-2-3
N7	10.5-11.0	M		Medium Stiff	P/DL*	3-4-7
N8	12-12.5	M		Stiff	P/DL*	4-6-6
N9	13.5-14	M	51	Very Stiff	P/DL*	5-10-13
N10	15.1-15.5	M		Very Stiff	P/DL*	6-6-7

*Loess in Colluvium

Project	HW 101 MP	Date		Reference: Kobernick (1999)		
Wildwood	220.6	1999				
Drill Hole	UTM-N	UTM-E	Elevation			
9087-11	4829100	404700	55.6 (m)			
Sample	Depth (ft)	Soil/ Grading	Moisture % natural	Structure	Unit Age /Facies	Resistance /6"
N1	0-1.2	M			Fill	1-3-3
N2	2.0-2.4	S/P			H/D	1-1-3
N3	2.7-3.2	S/P	Moist	Loose	H/D	1-2-2
N4	4.2-4.7	S/P	Wet	Loose	H/D	1-2-2
N5	5.8-6.2	S/P			H/D	2-3-9
N6	7.3-7.8	S/P		Loose	H/D	5-1-1
N7	9.1-9.6	M		Very Stiff	P/D/PsL	3-8-11
N8	10.6-11.1	M		Very Stiff	P/D/PsL	5-7-10

N9	12.1-12.6	M		Very Stiff	P/D/PsL	5-10-12
N10	13.7-14.2				Mudstone	16-17-19

Project	HW 101 MP	Date		Reference: Bellin (1988)		
Tenmile	223.2	1988				
Drill Hole	UTM-N	UTM-E	Elevation			
1	4825300	403800	~25 (ft)			
Sample	Depth (ft)	Soil/ Grading	Moisture % natural	Structure	Unit Age /Facies	Resistance /6"
N1	0-2	SG			Fill	7-4-3-3
N2	4-6	S	46		H/D	1-1-1-1
N3	9-11	S			H/D	1-1-1-1
N4	14-16	S			H/D	3-4-6-11
N5	19-21	S	49.5		H/D	6-10-6-11
N6	24-26				Siltstone	16-28-30-33

Project	HW 101 MP	Date		Reference: Bellin (1988)		
Tenmile	223.2	1988				
Drill Hole	UTM-N	UTM-E	Elevation			
2	4825300	403800	~ 25 (ft)			
Sample	Depth (ft)	Soil/ Grading	Moisture % natural	Structure	Unit Age /Facies	Resistance /6"
N1	0-2	SG			Fill	4-5-6-5
N2	2-4	SM	57.3		H/D	1-1-1-2
N3	9-11	S	14.6		H/D	2-5-5-6
N4	14-16	S			H/D	1-1-1-1
N5	19-21	S			H/D	2-4-4-7
N6	24-26	S			H/D	6-10-10-11
N7	29-31	S			H/D	1-2-2-3
N8	34-36	S			H/D	3-3-4-8

Project	HW 101 MP	Date		Reference: Turner (1994)		
Bullards	259.5	1994				
Drill Hole	UTM-N	UTM-E	Elevation			
94-1	4778100	386500	9 (ft)			
Sample	Depth (ft)	Soil/ Grading	Moisture % natural	Structure	Unit Age /Facies	Resistance /6"
N1	5-7	S/P	Wet	Medium Dense	H/D	10-8-5-3
N2	11-13	S/P	Wet	Medium Dense	H/D	5-7-8-8
N3	15-17	S/P		Medium Dense	P/D	3-7-12-12
N4	20-22	S/P		Medium Dense	P/D	10-11-17-26
N5	25-27	S/P		Dense	P/D	0-15-17-20
N6	30-32	S/P		Very Dense	P/D	16-22-28-36
N7	35-37	S/P		Very Dense	P/D	17-24-27-31

Project	HW 101 MP	Date		Reference: Bounds (2000)
Nesika	320-328	2000		
Drill Hole	UTM-N	UTM-E	Elevation	

10817-01	4705800	38400	37.1 (m)			
Sample	Depth (m)	Soil/ Grading	Moisture % natural	Structure	Unit Age /Facies	Resistance /6"
N1	0.7-1.2	S/P	12.4	Dense	Fill	14-17-21
N8	6.9-7.3	SM	Damp	Medium Dense	P/D/PsL	6-7-8
N9	7.6-8.1	SM	18.8	Loose	P/D/PsL	6-5-4
N10	8.4-8.8	SM		Medium Dense	P/D/PsL	8-10-10
N11	9.1-9.6	SM	27.9	Loose	P/D/PsL	3-3-5
N12	9.9-10.4	SM		Loose	P/D/PsL	1-2-5
N13	10.7-11.2	SM	29.8	Very Loose	P/D/PsL	1-1-2
N14	11.4-11.9	PT		Very Loose	P/Peat	1-4-4
N15	12.2-12.6	CL	42.6	Soft	P/PsL	0-0-0

Project	HW 101 MP	Date		Reference: Bounds (2000)		
Nesika	320-328	2000				
Drill Hole	UTM-N	UTM-E	Elevation			
10817-02	4705800	38400	36.3 (m)			
Sample	Depth (m)	Soil/ Grading	Moisture % natural	Structure	Unit Age /Facies	Resistance /6"
N3	2.3-2.7	S/P	11.5	Medium Dense	Fill	6-9-10
N9	6.9-7.3	S/P	9.7	Dense	P/D	12-16-17
N10	7.6-8.1	SM		Medium Dense	P/DPsL	3-5-6
N11	8.3-8.8	S/P	14.6	Medium Dense	P/D	8-9-10
N12	9.1-9.6	S/P		Medium Dense	P/D	7-12-12
N13	9.9-10.4	S/P	24.4	Medium Dense	P/D	8-12-13
N14	10.7-11.1	ML	Moist	Stiff	P/D/PsL	3-6-9
N15	11.4-11.9	S/P	27.5 Wet	Dense	P/D	7-14-19
N16	12.1-12.6	S/P		Very Dense	P/D	17-50

Project	HW 101 MP	Date		Reference: Bounds (2000)		
Nesika	320-328	2000				
Drill Hole	UTM-N	UTM-E	Elevation			
10817-03	4705400	383900	40.3 (m)			
Sample	Depth (m)	Soil/ Grading	Moisture % natural	Structure	Unit Age /Facies	Resistance /6"
N2	1.5-2.0	S/P		Very Loose	Fill	3-2-2
N6	4.6-5.0	S/P	18.3	Medium Dense	P/D	5-8-5
N7	5.3-5.8	ML	41.3	Very Soft	P/DPsL	0-0-0
N8	7.5-7.9	S/P		Medium Dense	P/D	1-10-13
N9	8.4-8.8	S/P	26.1	Medium Dense	P/D	7-13-13
N10	9.1-9.6	S/P		Very Dense	P/DFe	8-29-40

Project	HW 101 MP	Date		Reference: Bounds (2000)		
Nesika	320-328	2000				
Drill Hole	UTM-N	UTM-E	Elevation			
10817-04	4705400	383900	40.3 (m)			
Sample	Depth (m)	Soil/ Grading	Moisture % natural	Structure	Unit Age /Facies	Resistance /6"

N3	2.3-2.7	SM	24.8	Loose	Fill	3-4-3
N8	6.9-7.3	SM		Medium Stiff	P/DPsL	3-2-2
N9	7.6-8.1	S/P	29.1 Wet	Dense	P/D	3-14-21
N10	8.4-8.8	S/P		Dense	P/D	9-17-25
N11	9.1-9.6	S/P	26.6	Medium Dense	P/D	13-11-12

Project	HW 101 MP	Date		Reference: Bounds (2000)		
Nesika	320-328	2000				
Drill Hole	UTM-N	UTM-E	Elevation			
10817-05	4705800	38400	36.9 (m)			
Sample	Depth (m)	Soil/ Grading	Moisture % natural	Structure	Unit Age /Facies	Resistance /6"
N2	1.5-2.0	S/P	10.8	Medium Dense	Fill	10-13-12
N5	3.8-4.3	SM		Medium Dense	P/DPsL	4-5-6
N6	4.6-5.0	SM	12.8	Medium Dense	P/DPsL	7-8-11
N7	5.3-5.8	S/P		Medium Dense	P/D	8-12-14
N8	6.1-6.5	S/P	11.6	Medium Dense	P/D	7-11-12
N9	6.9-7.3	S/P		Loose	P/D	4-5-4
N10	7.6-8.1	SM	19.2	Loose	P/DPsL	3-4-4
N11	8.3-8.8	S/P		Medium Dense	P/D	7-11-11
N12	9.1-9.6	S/P	19.9	Loose	P/D	4-4-4
N13	9.9-10.4	SM		Loose	P/DPsL	1-2-3
N14	10.6-11.1	SM	41	Loose	P/DPsL	2-3-6
N15	11.4-11.8	SM		Medium Dense	P/DPsL	3-8-6
N16	12.2-12.6	ML	49.4	Soft	P/Wetland	2-2-3

Project	HW 101 MP	Date		Reference: Bounds (2000)		
Nesika	320-328	2000				
Drill Hole	UTM-N	UTM-E	Elevation			
10817-06	4705800	38400	34.9 (m)			
Sample	Depth (m)	Soil/ Grading	Moisture % natural	Structure	Unit Age /Facies	Resistance /6"
N2	1.5-2.0	S/P	14.5	Medium Dense	Fill	9-11-13
N8	6.1-6.5	SM	13.1	Medium Dense	P/DPsL	7-12-12

Project	HW 101 MP	Date		Reference: Bounds (2000)		
Nesika	320-328	2000				
Drill Hole	UTM-N	UTM-E	Elevation			
10817-07	4705800	38400	(m)			
Sample	Depth (m)	Soil/ Grading	Moisture % natural	Structure	Unit Age /Facies	Resistance /6"
N2	1.5-2.0	S/P	7.6	Medium Dense	Fill	7-11-11
N10	7.6-8.1	SM	26.8	Loose	P/DPsL	2-4-4
N11	8.4-8.8	S/P		Medium Dense	P/D	9-13-12
N12	9.1-9.6	SM	25.1	Medium Dense	P/DPsL	4-8-7
N13	9.9-10.4	S/P		Medium Dense	P/D	6-8-10
N14	10.7-11.1	SM	26.5	Medium Dense	P/DPsL	5-6-9
N15	11.4-11.9	S/P		Medium Dense	P/D	6-11-19

N16	12.2-12.6	S/P	27.4	Medium Dense	P/D	7-9-16

Project	HW 101 MP	Date		Reference: Bounds (2000)		
Nesika	320-328	2000				
Drill Hole	UTM-N	UTM-E	Elevation			
10817-08	4704900	383800	38.6 (m)			
Sample	Depth (m)	Soil/ Grading	Moisture % natural	Structure	Unit Age /Facies	Resistance /6"
N2	1.5-2.0	SM	12.5	Medium Dense	Fill	6-9-8
N4	3-3.5	S/P	8	Medium Dense	P/D	8-15-17
N5	3.8-4.3	S/P		Medium Dense	P/D	7-11-14
N6	4.6-5	S/P	14.7	Medium Dense	P/D	7-11-13
N7	5.3-5.8	SM		Medium Dense	P/DPsL	6-9-10
N8	6.1-6.5	S/P	14.5	Medium Dense	P/D	6-11-11
N9	6.9-7.3	SM		Loose	P/DPsL	2-3-4
N10	7.6-8.1	SM	29	Loose	P/DPsL	2-4-5
N11	8.4-8.8	SM		Medium Dense	P/DPsL	4-8-8
N12	9.1-9.6	SM	39.8	Medium Dense	P/DPsL	3-4-7

Project	HW 101 MP	Date		Reference: Bounds (2000)		
Nesika	320-328	2000				
Drill Hole	UTM-N	UTM-E	Elevation			
10817-10	4704900	383800	38.7 (m)			
Sample	Depth (m)	Soil/ Grading	Moisture % natural	Structure	Unit Age /Facies	Resistance /6"
N2	1.5-2.0	SM	15.7	Medium Dense	Fill	6-8-12
N8	6.1-6.5	SM	16.6	Medium Dense	P/DPsL	7-9-12
N9	6.9-7.3	SM		Medium Dense	P/DPsL	3-4-6
N10	8.2-8.7	SM		Loose	P/DPsL	3-3-6
N11	9.1-9.6	SM	30.9	Loose	P/DPsL	3-4-3

Summary of SPT Statistics for Dune and Associated Terrace Deposits of the Oregon Coast

Unit Age: Holocene (H), Pleistocene (P), Tertiary Shale, Siltstone
Unit Facies: Dune (D), Paleosol (Ps), Iron Oxide (Fe), Wetland (Peat), Loess (L)
Beach/Shelf Shoreface (S), Lagoon/Estuary Mud
(Bay)
Soil Type: Unified Soil Clasification: Sand (S), Gravel (G) Silty
Fines (M),
Clay (C), Organics (0), >90% Organics (PT)
Grading: Poorly Graded
(P)

Unit/Facies Description	Holocene Dune	Holocene Shoreface	Holocene Bay/Pond	Holocene Peat	Pleistocene Dune	Pleistocene Dune Paleosol with Loess	Pleistocene Dune Hardpan Fe-stain	Tertiary Bedrock
Unit Abbrev.	H/D	H/S	H/Bay	H/Peat	P/D	P/DPsL	P/DFe	Siltstone
Material	(S/P)	(S/P)	(M,C,O)	(PT)	(S/P)	(SM)	(S-Fe)	/Shale
Statistics								
Number Tests	62	35	7	4	64	38	4	10
Minimum (N)	2	20	5	2	8	0	69	34
Maximum (N)	26	58	13	5	100	24	100	100
Mean (N)	9	37	9	3	44	11	84	81
1Std.Dev. (N)	±5	±11	±3	±2	±28	±6	±16	±31

note: SPT N values greater than 100 blows per 12 inches are rounded to N=100 for statistical calculations.

REFERENCE:

Bellin, G.H., 1988. Tenmile Creek Bridge, Oregon Coast (Lakeside Frontage Rd) Coos County, Br 949B, Foundation Rpt, ODOT.

Bolanbder, P, 1987. Foundation Rpt, Sutton Creek Bridge, Oregon Coast Hwy, Sutton Lake to Florence Section, Lane Cty, Bridge 1494A, ODOT.

Bounds, J.D., 2000. Nesika Beach, Rogue River, Curry County, Oregon, Engineering Geology Report, ODOT.

Burns, R.W. and Thommen, G.R., 1988. Foundation Report, Powers Slough, Alder Creek, Bridge Fort Stevens #104. Structural Design Section, ODOT.

Carmel Knoll, 1985. Carmel Knoll, Oregon Coastal Highway MP 135, ODOT.

Geotechnical Rpt, 1991. Neahkanie Mountain-Manzanita Junction, Oregon Coast Highway #9, Tillamook County CO29-1408, ODOT.

Howard, Needles, Tammen & Bergendoff, 1986. Preliminary Found. Rpt. for Proposed Alsea Bay Bridge, CH2MHILL Prepared for Geo/Hydro Section, ODOT.

Interdepartmental Correspondence, 1969. Neacoxi Creek Bridge, Del Ray Beach Road, Bridge 9894. ODOT.

Kleutsch, B., 1992. Camp Rilea Road-Dellmoor Loop Road, Oregon Coast Hwy MP12.1-16.3 Clatsop Cty. C004140, #00534, Geotechnical Svcs Unit, ODOT.

Kobernick, R.M., 1999. County Line Slide, Geology Report, Oregon Coast Highway, MP 220.4, Douglas County. Geohydro Services Section, ODOT.

Narkiewicz, S., 1995. Summary of Hydrological Investigation, Clear Lake (Reedsport) Oregon Coast Highway #9 MP218.1-219.1, ODOT.

Rodzinski, 1973. Inn at Spanish Head, Lincoln City, Oregon. ODOT.

Stephens, R.L., 1999. Neahkahnie Creek Culvert No.1 Project MP43.27 Tillamook County, Kleinfelder Inc. ODOT.

Turner, D., 1994. Coquille River, Bullards Bridge #07020 NW Corner Operations Building, Oreogn Coast Highway, Coos County, Geotechnical Report, ODOT.

NOTE: ODOT refers to the Oregon Department of Transportation, Salem, Oregon.