Comment/Answer

- *"Site conditions and environmental factors that impact development are beyond the County's control. At what point does the County's responsibility to protect private properties developed in coastal high hazard areas end?"*
- The existing residential development on the Subject Properties was never in a mapped "coastal high hazard area."
- The Subject Properties became subject to ocean undercutting/wave overtopping due to the unusual effect of too closely placed man-made jetties influenced by successive El Nino and El Nina events causing unexpected erosion in the Rockaway subregion that reversed the 70+-year period of prograding that had been occurring when residential development was approved on the Subject Properties.
- County obligations under Goal 7: "Protect people and property from natural hazards." Goal 18: "Reduce the hazard to human life and property from natural or man-induced actions associated with [coastal beach and dune] areas."

KELLINGTON LAW GROUP, PC

Comment/Answer

- *"Goal 18 recognizes importance of natural function of the beach. Actions should not contribute to loss of a natural resource. Rip rap always contribute to loss of natural function of the beach"*
- The proposed BPS will not contribute to loss of the beach. The BPS will not be sited on the beach; it will be sited entirely in the Applicants' backyards which are still vegetated.
- Proposed BPS is "Type II" in Weggel's classification system = structure w/minimal impacts on coastal processes within littoral cell system.
- There are types of BPS that cause harm, but the proposed BPS is not one of them – it has been carefully designed and per the well-known classification system, the proposal has minimal impact.

KELLINGTON LAW GROUP, PC

Comment/Answer

- *"Goal 18 protects public access to the beach and citizen rights to enjoy the beach. Construction of a BPS will restrict access to the beach."*
- As explained throughout the record, the BPS will not restrict access to *or along* the beach any more than is already occurring.
- Shorewood RV Resort's BPS restricts access along the beach during high tides.
- Proposed BPS will be located further inland than Shorewood RV Resort's BPS.
- High tides already restrict N-S access along the beach in front of Subject Properties (water comes right up to homes). BPS will not further restrict N-S access.

KELLINGTON LAW GROUP, PC

Comment/Answer

- *"The beach is the natural resource and protecting the resource is greater than the right to protect private property from erosion and ocean flooding."*
- Goal 18 places two overarching goal obligations on the County: (1) To conserve, protect, where appropriate develop, and where appropriate restore the resources and benefits of coastal beach and dune areas; and (2) To reduce the hazard to human life and property from natural or man-induced actions associated with these areas.
- The acknowledged planning program for the Subject Properties is under Goal 18's "appropriate development" prong.
- County is obligated under Goal 18 to protect human life and property from the hazards of coastal erosion and flooding.

KELLINGTON LAW GROUP, PC

Comment/Answer

- *"Concern of negative impacts to neighboring properties if BPS is constructed. Shorewood RV Park and other properties in the County were identified to support these concerns."*
- BPS will have no negative impacts to adjacent properties.
- Property to north is entitled to BPS (built before 1977), hence not part of this application. And can get BPS anytime they want it without going through a Goal exception process.
- Shorewood RV Park BPS does not harm neighboring properties. Erosion on adjacent properties caused by same forces that are eroding the Subject properties.

KELLINGTON LAW GROUP, PC

Comment/Answer

- *"Lack of demonstration and justification to grant exception through Reasons criteria."*
- The Applicants have thoroughly demonstrated that the proposal complies with the requirements for a Goal 18-specific "reasons necessary" standard under OAR 660-004-0022(11) and the requirements for a "catch-all" reasons exception under OAR 660-004-0020(1).
- Respectfully, it appears likely that many commentors have not read the Applicants' submittals.

KELLINGTON LAW GROUP, PC

Comment/Answer

- *"Blanket exceptions should not be granted. The taking of one exception does not alone constitute or satisfy criteria for granting additional exceptions."*
- This is no "blanket exception." Authoritative papers encourage property owners to work together as here to avoid the "sawtooth effect."
- Subject Properties' existing exceptions not sole basis for granting the requested exceptions, but factor into "reasons why" calculus of why the requested exception should be approved.
- Existing exceptions are only directly used in the Applicants' requested ALTERNATIVE decision that the existing exceptions already allow residential development on the eroding dune and so are an exception to the prohibition in Goal 18, Implementation Measure 2, that residential development be prohibited on an eroding dune.

KELLINGTON LAW GROUP, PC

Comment/Answer

- *"This decision is precedent setting, as DOGAMI projections indicate conditions are going to get worse, what obligation will the County be under in the future should this exception request be approved?"*
- DOGAMI and other professional projections indicate only Rockaway littoral subregion is experiencing significant continued erosion.
- 90% of all properties in Rockaway subregion are already entitled to BPS, so will not require a Goal 18 exception when they need BPS.
- Other 10% are mostly large tracts in public ownership or large tracts with no development that would require a BPS.
- Neskowin is also experiencing significant erosion but they also already have a Goal 18 exception that allows the BPS.
- Other Goal 18 exceptions requests will have to be evaluated on a case-by-case basis.
- No reasonable basis to conclude this is precedent setting because no other known part of the County or the state has the unique circumstances that are causing severe erosion here.

KELLINGTON
LAW GROUP, PC

Thank you

- Questions?

KELLINGTON
LAW GROUP, PC

Allison Hinderer

From: Sarah Mitchell <sm@klgpc.com>
Sent: Tuesday, July 27, 2021 4:18 PM
To: Sarah Absher; Allison Hinderer
Cc: Wendie Kellington; Bill and Lynda Cogdall (jwcogdall@gmail.com); Bill and Lynda Cogdall (lcogdall@aol.com); Brett Butcher (brett@passion4people.org); Dave and Frieda Farr (dfarrwestproperties@gmail.com); David Dowling; David Hayes (tdavidh1 @comcast.net); Don and Barbara Roberts (donrobertsemail@gmail.com); Don and Barbara Roberts (robertsfm6@gmail.com); evandanno@hotmail.com; heather.vonseggern@img.education; Jeff and Terry Klein (jeffklein@wvmeat.com); Jon Creedon (jcc@pacifier.com); kemball@easystreet.net; meganberglaw@aol.com; Michael Munch (michaelmunch@comcast.net); Mike and Chris Rogers (mjr2153@aol.com); Mike Ellis (mikeellispdx@gmail.com); Rachael Holland (rachael@pacificopportunities.com); teriklein59@aol.com
Subject: EXTERNAL: 851-21-000086-PLNG & 851-21-000086-PLNG-01 Pine Beach BOCC Hearing Packet - Additional Evidence
Attachments: Exh 4 - Tillamook-HNA-Final-Report - Buildable Lands Inventory BLI.pdf; Exh 5 - Tax Statements 2020-21.pdf

Importance: High

Hi Sarah and Allison,

Please include the attached exhibits in the record of 851-21-000086-PLNG /851-21-000086-PLNG-01 and in the Board of Commissioners' packet for the July 28, 2021 hearing on these matters. Would you please confirm your receipt? Thank you.

Best,
Sarah

KELLINGTON LAW GROUP

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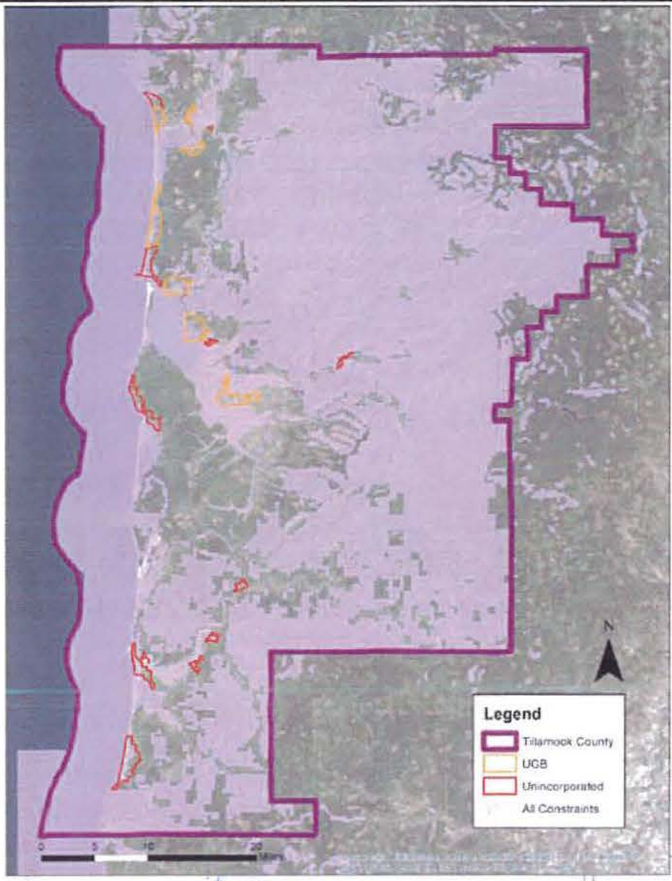
Tillamook County

Housing Needs Analysis



Tillamook County

Netarts

Pacific City - Woods

Neskowin

December 27, 2019

ACKNOWLEDGEMENTS

This work is made possible through input provided by County staff and the Tillamook County Housing Commission. We specifically recognize and appreciate the time and attention dedicated to this work by the following participants.

Tillamook County

David Yamamoto (Tillamook County Commission Chair)

Bill Baertlein, (Tillamook County Commission Vice Chair, Liaison to County Housing Commission)

Mary Faith Bell (Tillamook County Commissioner)

Sarah Absher (Tillamook County Community Development Director)

Jake Davis (Tillamook County, Housing Coordinator)

Tillamook County Housing Commission

Cami Aufdermauer (at-Large)

Sarah Beaubien (Major Employer)

Tim Borman (at-Large)

Mis Carlson-Swanson (Non-Profit)

Kari Fleisher (at-Large)

Ed Gallagher (at-Large)

Kris Lachenmeier (Major Employer)

Barbara McLaughlin (North County)

Gale Ousele (South County)

Erin Skaar (Non-Profit)

Mayor Suzanne Weber (City of Tillamook)

John Southgate, Strategic Partner, Project Coordinator

Interviews and Work sessions

During the course of this assignment, FCS GROUP collected information gleaned from the following property owners, business owners, developers, and local planning commissions. We sincerely thank these individuals and collective bodies for sharing their time and attention.

- Todd Bouchard, developer/local resident
- Julie Garver, Director, Innovative Housing, Inc. (nonprofit housing developer)
- Thomas Kemper, nonprofit housing developer
- Jeff Schons and Mary Jones, Pacific City property owners/developers/business owners
- Paul Wyntergreen, City of Tillamook, City Manager
- Manzanita City Planning Commission
- Bay City Planning Commission

Project Consultants

FCS GROUP

Todd Chase, AICP, LEED AP, Principal/Project Manager

Timothy Wood, Project Consultant/Economist

Zech Hazel, Analyst

Cascadia Partners

Alex Steinberger, Partner

Alex Joyce, Managing Partner

Victor Tran, Associate

TABLE OF CONTENTS

Section I. INTRODUCTION

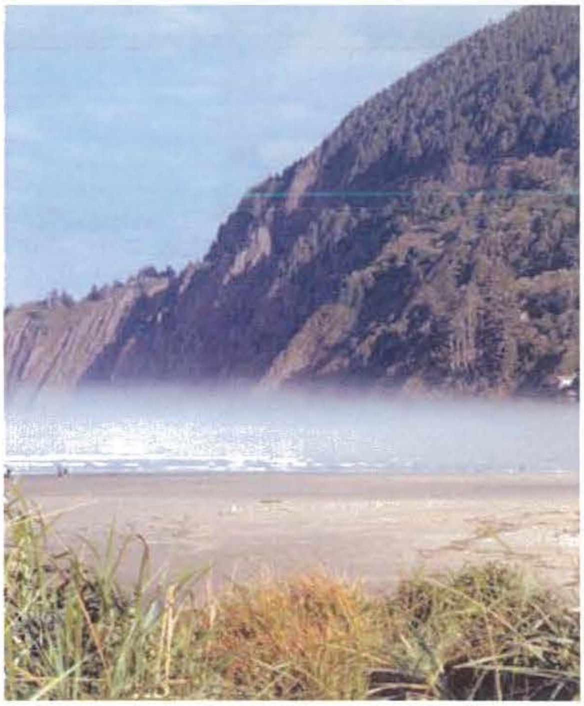
Tillamook County is widely known for its dramatic coastline, misty beaches and award winning dairy and seafood products. Tillamook County is located along the breathtaking northern Oregon Coast within 50 miles from the Portland and Salem metro regions.

Like many coastal communities, portions of Tillamook County are experiencing strong housing demand by part-time seasonal residents, especially in coastal "resort" communities. Over the past decade, new housing production has not nearly kept pace with the demand generated by permanent residents and seasonal home owners. With the majority of its housing, now controlled by part-time residents, vacancy rates have plunged to near zero and rents/prices have increased to record levels. This has led to a severe housing affordability challenge that is exacerbated by: environmental flood zone and agricultural land use constraints; limited vacant land area with adequate water, sewer and roadway infrastructure; and a growing service economy with limited family wage job opportunities.

These challenges continue to mount as employers struggle to fill job positions since workers are faced with very limited housing choices.

The Tillamook Housing Needs Analysis (HNA) is being conducted to ensure that the County can plan for coordinated housing growth in line with community preferences and market forces. The HNA includes the following:

- A determination of 20-year housing needs based upon long-term growth forecast of demand by permanent and seasonal population increases.
- An analysis of buildable vacant, part-vacant and re-developable land inventory (BLI) for land that's planned to accommodate housing.
- Identification of new housing goals, objectives, and policy actions that address housing opportunities.



Section II. MARKET TRENDS AND FORECASTS

This section of the HNA includes a forecast of housing needed to accommodate expected year round and seasonal population growth for Tillamook County. The housing needs forecast represents a 20-year projection from the base year (2019) through year 2039. These technical findings are also consistent with the State of Oregon requirements for determining housing needs per Oregon land use planning Goals 10 and 14, OAR Chapter 660, Division 8, and applicable provision of ORS 197.295 to 197.314 and 197.475 to 197.490, except where noted.

II.A. METHODOLOGY

The methodology for forecasting housing needs for Tillamook County considers a mix of demographic and socio-economic trends, housing market characteristics and long-range population growth projections. Population is a primary determinate for household formations—which in-turn drives housing need. Given the significance of coastal tourism and visitation, the demand for second homes and short-term rentals is also an important determinate in understanding future housing needs.

County-wide population, households, income and housing characteristics are described in this section using available data provided by reliable sources, such as the U.S. Census Bureau (Census and American Community Survey), the U.S. Department of Housing and Urban Development (HUD), Oregon Department of Housing and Community Services, Portland State University (PSU) and Tillamook County's Planning and Community Development department. Where trends and forecasts are provided by an identified data source, FCS GROUP has included extrapolations or interpolations of the data to arrive at a base year (2019 estimate) and forecast year (2039 projection).

The housing need forecast translates population growth into households and households into housing need by dwelling type, tenancy (owner vs. renter) and affordability level.

II.B. DEMOGRAPHICS AND SOCIO-ECONOMICS

Population

Since the year 2000, Tillamook County's permanent year-round population (including local cities) increased 8.6%, from 24,262 residents in 2000 to 26,348 in 2019. Population within Tillamook County is projected to increase to 29,284 over the next 20 years (0.5% avg. annual growth rate).

As population increases, the demand for all types of housing will increase. This HNA supports long-range planning focused on expanding the local housing inventory to accommodate baseline population growth.

Population Growth Forecast in AGR Tillamook County, Oregon, 2019-2039
Source: Portland State University Population Research Center

0.50%
Tillamook County

1.05%
Oregon

The long-range population forecast prepared by PSU's Population Research Center (PRC) expects 2,936 additional people to be added to Tillamook County by year 2039. This equates to an annual average growth rate (AGR) of 0.5%. Baseline population growth forecasts for Tillamook County and its incorporated areas is shown below in **Exhibit 2.1**.

Exhibit 2.1 Population Growth Forecast

	Estimate 2019	Forecast 2039	Proj. Change 20 Years	Proj. AGR (2019-2039)
Oregon	4,209,177	4,954,640	745,463	0.8%
Tillamook County	26,348	29,284	2,936	0.5%
Bay City	1,448	1,796	348	1.1%
Garibaldi	802	875	73	0.4%
Manzanita	910	1,209	299	1.4%
Nehalem	1,272	1,642	370	1.3%
Rockaway Beach	1,590	1,862	272	0.8%
Tillamook	5,643	6,439	796	0.7%
Wheeler	415	486	72	0.8%
Unincorporated	14,261	14,971	710	0.2%

Source: Portland State Population Research Center, 2017 estimate; 2017-2040 forecast, interpolated by FCS GROUP. Compiled by FCS Group. AGR = average annual growth rate.

*Populations are based on Urban Growth Boundary

Tillamook County has a relatively older population in comparison to the Oregon average. In Tillamook County, nearly 24% of the population is 65 or older, compared to 16% for Oregon as a whole. The median age of residents in Tillamook County was 48 in 2017, compared with the State average of 39.2.

Median Age, Tillamook County, Oregon, 2017
Source: U.S. Census Bureau, 2013-2017 American Community Survey, compiled by FCS Group

48.0
Tillamook County

39.2
Oregon

Tillamook County's average household size is 2.41 people per occupied household, which is slightly less than the statewide average of 2.5.

Average Number of People per Unit, Tillamook County, Oregon, 2017
Source: U.S. Census Bureau, 2013-2017 American Community Survey, compiled by FCS Group

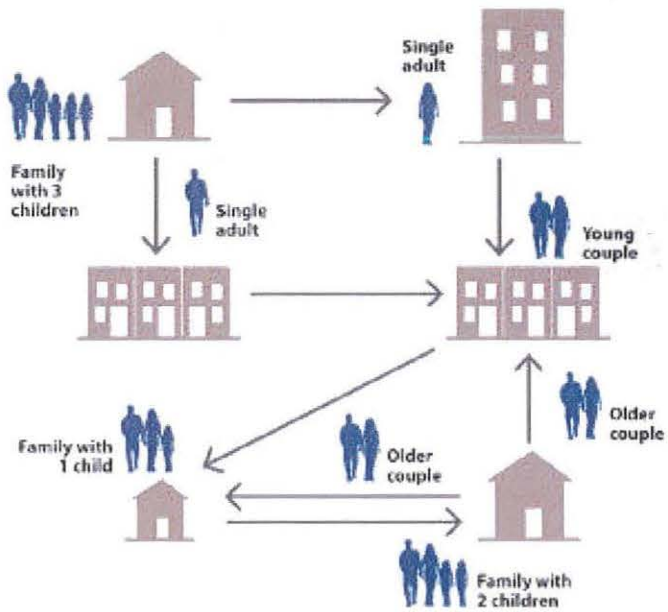
2.41	2.5
Tillamook County	Oregon

Factors Affecting Housing Demand

There is a clear linkage between demographic characteristics and housing choice. As shown in the figure below, housing needs change over a person's lifetime. Other factors that influence housing include:

- Homeownership rates increase as income rises.
- Single family detached homes are the preferred housing choice as income rises.
- Renters usually have lower incomes than owners and are much more likely to choose multifamily housing options (such as apartments or plexes) over single-family housing.
- Very low-income households (those earning less than 50% of the median family income) are most at-risk for becoming homeless if their economic situation worsens.
- The housing available to households earning between 50% and 120% of the median family income is crucial to middle-income residents, and is often referred to "missing middle" housing stock or "workforce housing."
- Seasonal housing demand by part time residents will continue to occur primarily in coastal communities that provide access to recreational areas and services.

Housing Life Cycle



FCS GROUP

Key definitions:

"Households" consist of all people that occupy a housing unit.

"Family" is a group two or more people (one of whom is the householder) related by birth, marriage, or adoption and residing together.

The relationship between demographic changes and housing needs can be used to forecast future housing needs. Three main demographic changes affecting housing in Tillamook County include:

Generational Cohorts

As people age, their housing requirements change with time. **Exhibit 2.2** summarizes the current (2017) distribution of major generational cohorts of people living in Tillamook County.

Greatest/Silent Generation (those born before 1925 to 1945)

This includes retirees better than age 74, who were raised during the Great Depression, Word War I or World War II. This cohort currently accounted for 9% of the county's population in 2017. As they reach their 80s some move into assisted living facilities with convenient health care services and transit access. Meanwhile, others will leave the county to be closer to family or medical services.

Baby Boom Generation (those born 1946 to 1964)

Baby boomers (currently age 55 to 74) accounted for 32% of Tillamook County residents in 2017. The boomer population segment has been growing more rapidly than the other cohorts over the past 10 years and many are now entering their retirement years. Boomers usually prefer to "age in place" but may downsize or move in with family members, sometimes opting to reside in accessory dwellings off the main house.

Generation X (born early 1965 to 1980)

Gen X (currently includes people between age 39 to 54) accounted for 17% of Tillamook County residents in 2017. GenX households often include families with children, and many prefer to live in single family detached dwellings at various price points.

Millennials (born early 1980s to early 2000s)

Millennials (currently in their twenties or thirties) accounted for 21% of Tillamook County residents in 2017. Younger millennials tend to rent as they establish their careers and/or payback student loans. Working millennials often become first-time homebuyers, opting to purchase smaller single-family detached homes or townhomes.

Generation Z (born mid-2000s or later)

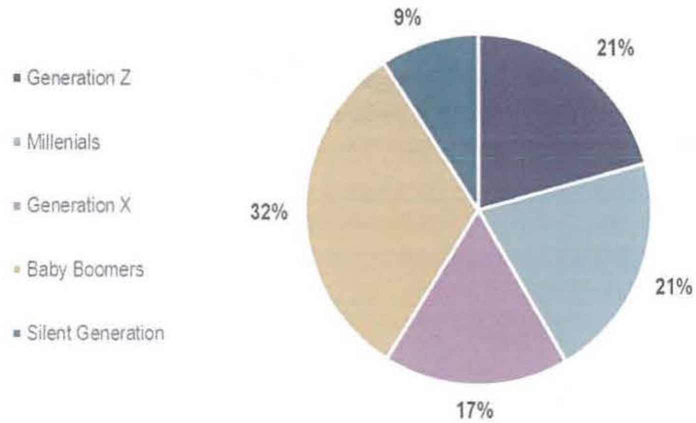
GenZ includes residents age 19 or less, which accounted for 21% of Tillamook County residents in 2017. This segment mostly includes children living with Gen Xers or Millennials.

Families with Children living at home

This category includes a subset of Baby Boomers, Gen Xers and millennials. Taken as a whole, this category constitutes a significant proportion of Tillamook County's population; and is expected to increase moderately over the next two decades. Families prefer to live in a variety of housing types (detached homes or townhomes/plexes) at price points commensurate with their family income.

Exhibit 2.2

Population Share by Generational Cohort, Tillamook County, 2013-2017



Income Characteristics

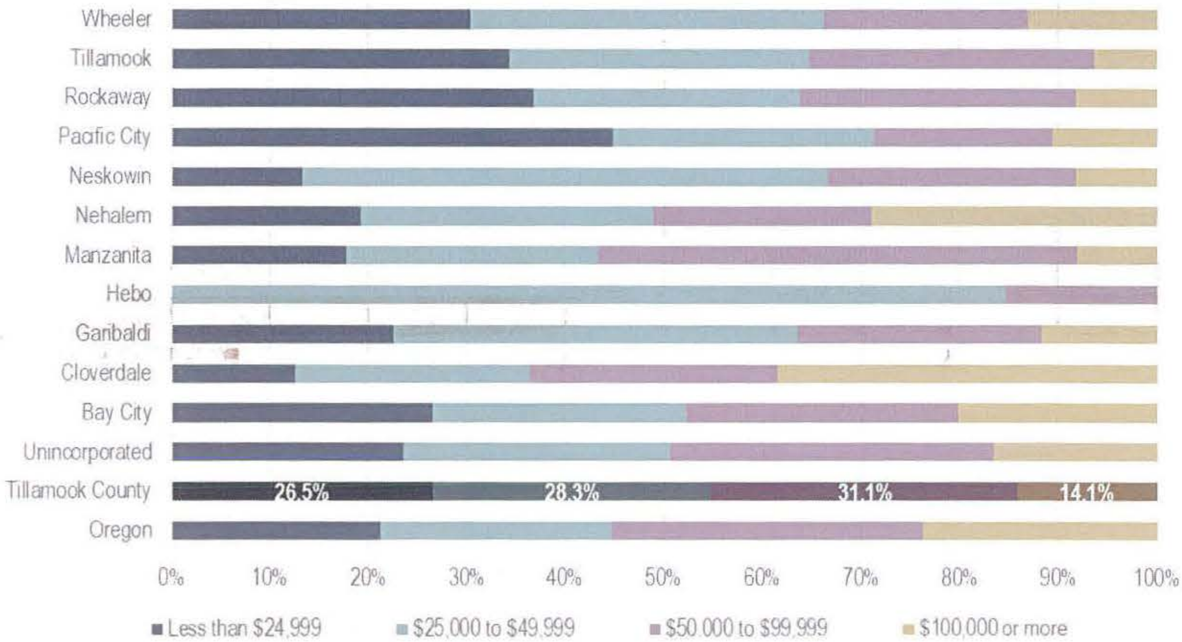
The median household income in Tillamook County ($45,061) is well below incomes observed statewide in Oregon ($56,119).

As shown in **Exhibit 2.3**, Tillamook County in comparison with Oregon, has a higher share of low-income residents (earning less than $30,000), and a lower share of middle- and upper-income residents (those earning more than $50,000). Countywide incomes vary significantly between communities, with Hebo, Pacific City, Rockaway and City of Tillamook residents having relatively lower incomes compared with Manzanita and Nehalem.

It should be noted that this analysis focuses on local cities and Census Defined Places, since those are the communities for which comparative data are available. There are additional small communities in Tillamook county, such as Oceanside, Netarts and Beaver, which do not have readily available statistics. While such small communities are vital, they are referenced here within the unincorporated county area.

Exhibit 2.3

Household Income, Tillamook County, Other Comparison Cities, Oregon, 2017



Source: U.S. Census Bureau, 2013-2017 American Community Survey (Table B19001), compiled by FCS Group

II.C. EXISTING HOUSING CHARACTERISTICS

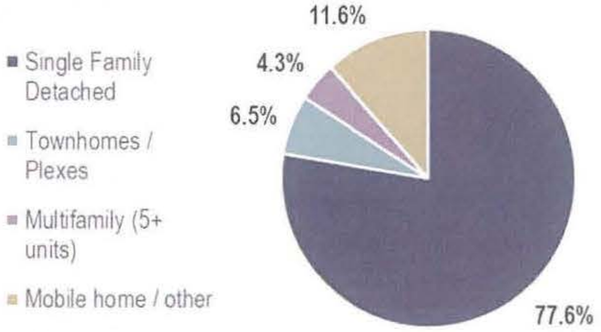
An analysis of historical development trends and local housing market dynamics provides insight regarding how the housing market functions. Findings indicate that changes in demographic and socio-economic patterns over the next two decades will result in a shift in housing demand from what is now predominantly single-family detached housing to wider mix of housing types.

Housing Inventory and tenancy

The existing housing stock in Tillamook County is dominated by single family detached (low density development) which accounts for just over three-fourths of the inventory. This is well above the state average of 63.7%. Mobile homes/other housing types comprise the remaining 11.6% of the inventory. Townhomes/plexes (medium density development) accounts for 6.5% of the inventory. Multifamily apartments and condos (with more than 5 units per structure) currently comprise only 4.3% of the inventory (see **Exhibit 2.4**).

Exhibit 2.4

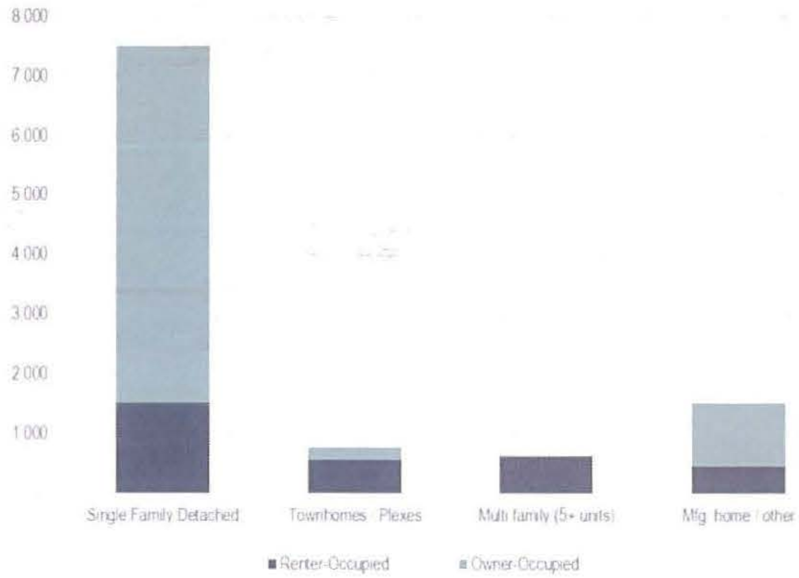
Households by Housing Type, Tillamook County, 2017



The overall housing tenancy in Tillamook County mirrors the Oregon statewide average, with 69% of the permanent residents owning their homes, and the remaining 31% renting. As shown in **Exhibit 2.5**, most homeowners reside in single family detached homes or mobile homes (including manufactured housing). Renters occupy all types of housing, and constitute the majority of demand for townhomes/plexes and multifamily apartments.

Exhibit 2.5

Tenancy by Type of Housing, Tillamook County, 2017

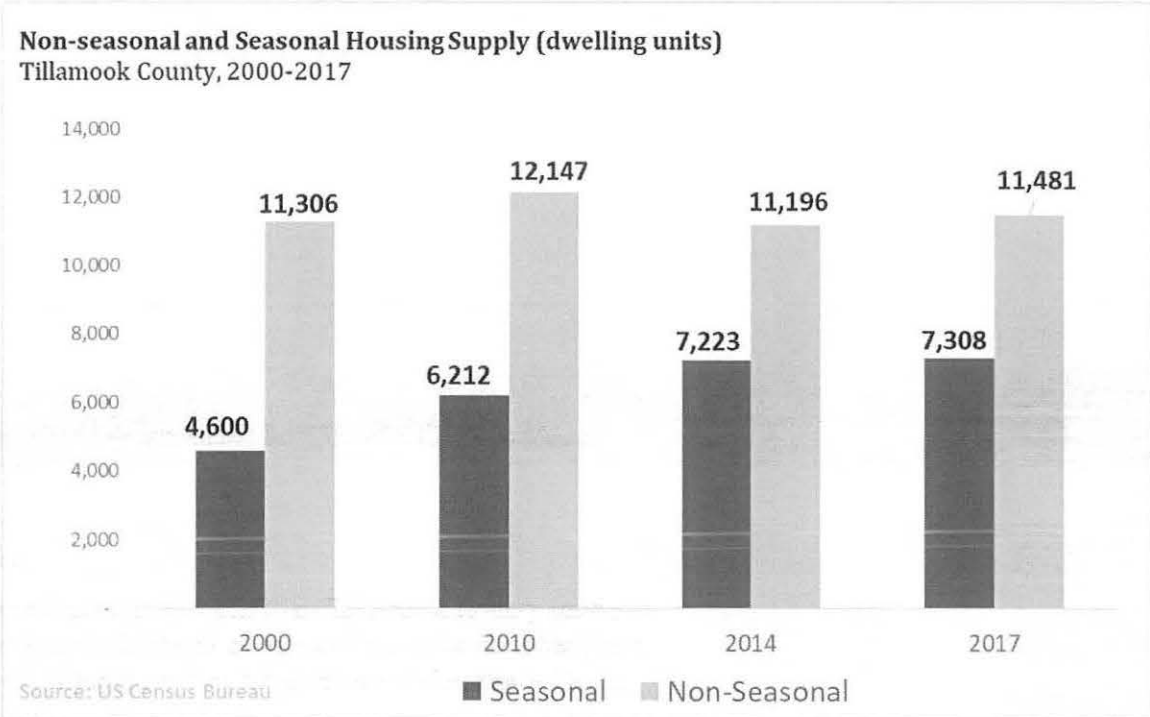


Seasonal Housing Inventory and Vacancy Rates

The prior housing study that was prepared for Tillamook County, *Creating a Healthy Housing Market for Tillamook County*, March 2017 (by CZB), noted that the housing market in Tillamook County has two distinct parts. There is a ***coastal market*** with strong demand from upper-income households, investors, second home buyers and retirees. And there is an ***interior market*** concentrated largely around Tillamook and other inland communities, such as Bay City. This market has a relatively older and less expensive housing inventory, which is more attainable to local residents. The demand for both seasonal housing and year-round non-seasonal demand is rising, as indicated in **Exhibit 2.6**.

Of Tillamook County's 18,789 total housing units, 44%, were classified as having "seasonal ownership" in 2017, up from 38% in 2010, according to the U.S. Census American Community Survey.

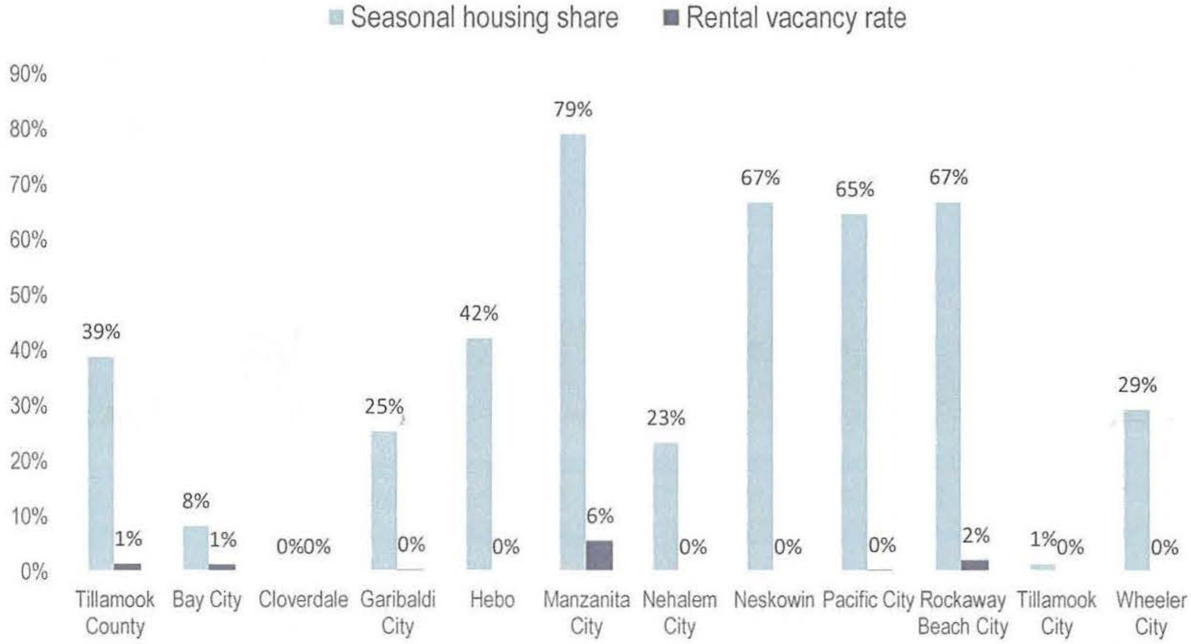
Exhibit 2.6



The seasonal housing inventory varies significantly by location, with the City of Tillamook, Bay City and Cloverdale having the lowest rates of seasonal homeownership and coastal resort areas such as Rockaway Beach and Manzanita having the highest levels at 74% and 87%, respectively.

As shown below in **Exhibit 2.7,** the vacancy rates for non-seasonal (year round rental housing) is well below 1% in all areas and near zero in Cloverdale, Gribaldi, Hebo, Nehalem, Neskowin and Wheeler. In comparison, the statewide average housing vacancy rate was 9.3% in 2017.

Exhibit 2.7 Vacancy Rates by Housing Type



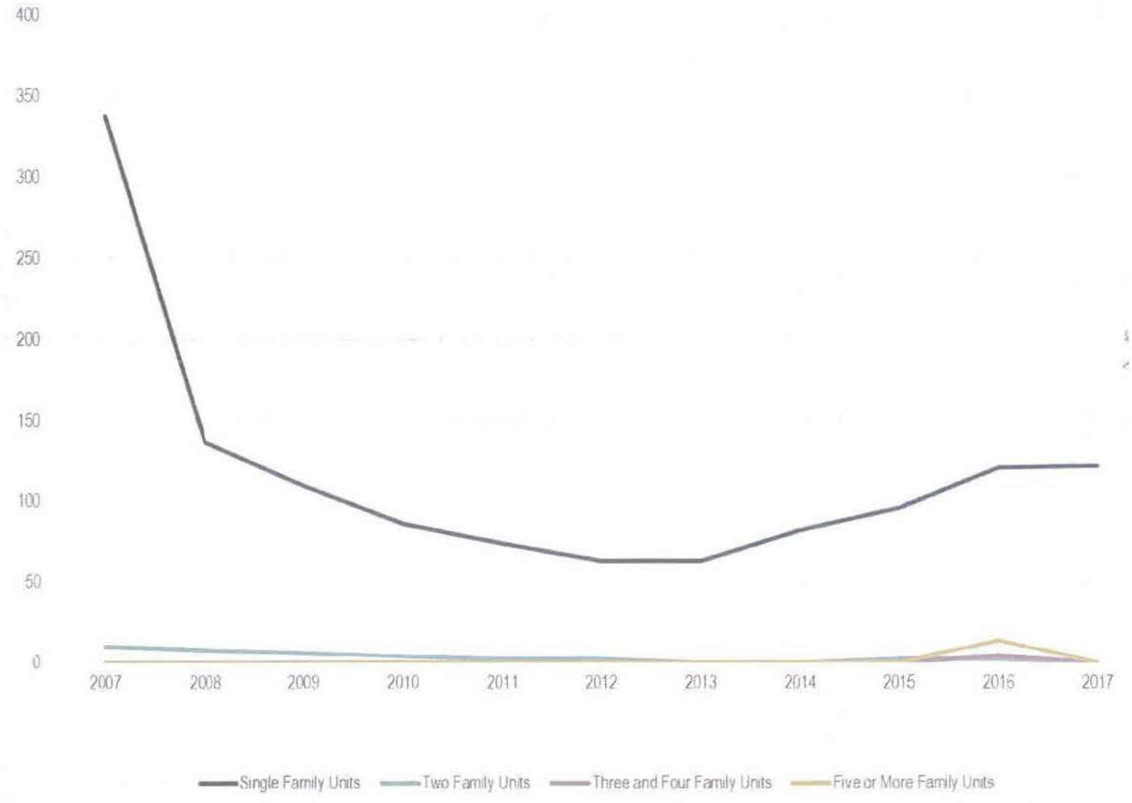
Housing Construction Permitting Activity

During the past decade new housing construction in Tillamook County has been dominated by single family housing. Despite falling sharply following the recession, the county has issued an average of 117 single family permits annually for new construction since 2007. Issuance of new permits has picked up since its low of 2013 (**Exhibit 2.8**).

Housing production has not nearly kept up with the pace of demand. Between 2007 and 2017, about 120 new dwellings were added throughout Tillamook County annually with the vast majority as second homes. Most new housing construction has occurred in coastal "resort" towns, such as Manzanita, Neskowin, Pacific City and Rockaway Beach, where 66%-80% of the total housing stock is now owned by part-time residents. During this same time frame, it is estimated that about 80-90 existing dwelling units were converted to seasonal units or short-term vacation rentals each year. As such, the permanent year-round housing inventory in Tillamook County has been decreasing at a time when nearly 60 households were moving into the county each year.

Exhibit 2.8

Building Permits Issued, Tillamook, 2007-2017



Source: HUD Government Website, SOCDS Building Permits Database 2007-2017

Housing Affordability

The median home price in Tillamook County was approximately $323,000 (2019, 1st Q), which is slightly below the median home price in Oregon as a whole. As shown in **Exhibit 2.9**, year-over-year, home prices in Tillamook County increased by 12.2% from $288,000 in 2018 to $323,000 in 2019.

Median Home Sales Price, Tillamook County, Oregon, January 2018 to 2019

$323,000	**$346,100**
Tillamook County	Oregon

In general, home values declined following the Great Recession (2009 to 2014), then began a steady ascent. In Tillamook County, it is estimated that median home prices have increased by over 40%

between 2014 and 2019. During this same time frame, median household income levels in Tillamook County increased only 21%; thereby creating a major housing affordability challenge.

Based on active home listings and average sales over the past two years in Tillamook County, there is less than a three month supply of homes priced under $300,000; and only a four to five month inventory of homes priced $300,000 to $500,000. For comparison, a healthy housing market is considered to have a six month housing inventory.

Exhibit 2.9

Homes Sales and Inventory, Tillamook County

Sales Price Level	Recent Sales (past 2 years)	Avg. Sales Per Month (past 2 years)	Current Listings	Remaining Inventory (months)
Sales Price Level				
Less than $100,000	175	7.3	4	0.5
$100,000 to $199,999	384	16.0	27	1.7
$200,000 to $299,999	556	23.2	61	2.6
$300,000 to $399,999	421	17.5	70	4.0
$400,000 to $499,999	270	11.3	57	5.1
$500,000 or more	298	12.4	124	10.0
Total	2,104	88		

Source: Zillow.com; analysis by FCS 9/3/19.

Median Home Price Sales Trends in Select Markets

	Aug-18	Aug-19	Change %
Tillamook County	$288,000	$323,000	12.2%
Bay City	$213,000	$244,000	14.6%
Nehalem	$372,000	$415,000	11.6%
Neskowin	$425,000	$457,000	7.5%
Pacific City	$292,000	$323,000	10.6%
Rockaway Beach	$255,000	$294,000	15.3%
Tillamook City	$251,000	$283,000	12.7%

Source: Zillow.com; analysis by FCS Group 1/24/18.

Median rents are also slightly lower in Tillamook County compared with the Oregon statewide average. However, in many communities within Tillamook County, rents are now on par with or have surpassed the statewide average (**Exhibit 2.10**).

Exhibit 2.10

Median Gross Rent, Tillamook, Tillamook County, Oregon, Other Comparison Cities, 2013-2017

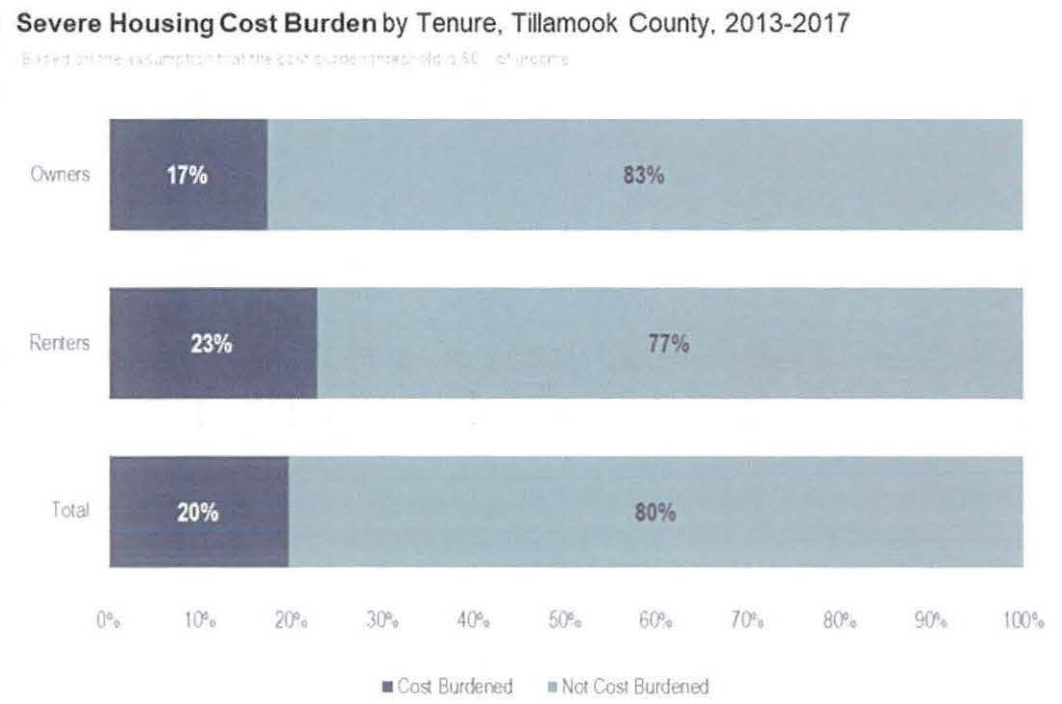
Source: U.S. Census Bureau 2013-2017 American Community Survey 5-Year Estimates, Table B25064

Housing Cost Burdens

According to the U.S. Housing and Urban Development (HUD) standards, households are considered "cost burdened" if they pay over 30% of their income on housing. Households are "severely cost burdened" if they pay over 50% of their income on housing.

Despite relatively low housing costs, the fact that there limited numbers of family wage jobs makes finding attainably priced housing difficult for many residents. Approximately 23% of the renters and 17% of the owners in Tillamook County are severely cost burdened (see **Exhibit 2.11**).

Exhibit 2.11



Severe rent burdens vary widely between local areas. For example, Wheeler faces severe rent burden rates of just 10%, while 30% of Bay City renters are severely rent burdened (see **Exhibit 2.12**).

Exhibit 2.13 further illustrates the link between lower incomes and housing cost burdens. Over 80% of households earning less than $20,000 were cost burdened in Tillamook County. In fact, almost 60% of households earning less than $50,000 are paying more than 30% of their income in housing costs.

Exhibit 2.12

Severe Rent Cost Burden, Tillamook County, Oregon, Other Comparison Cities, 2013-2017

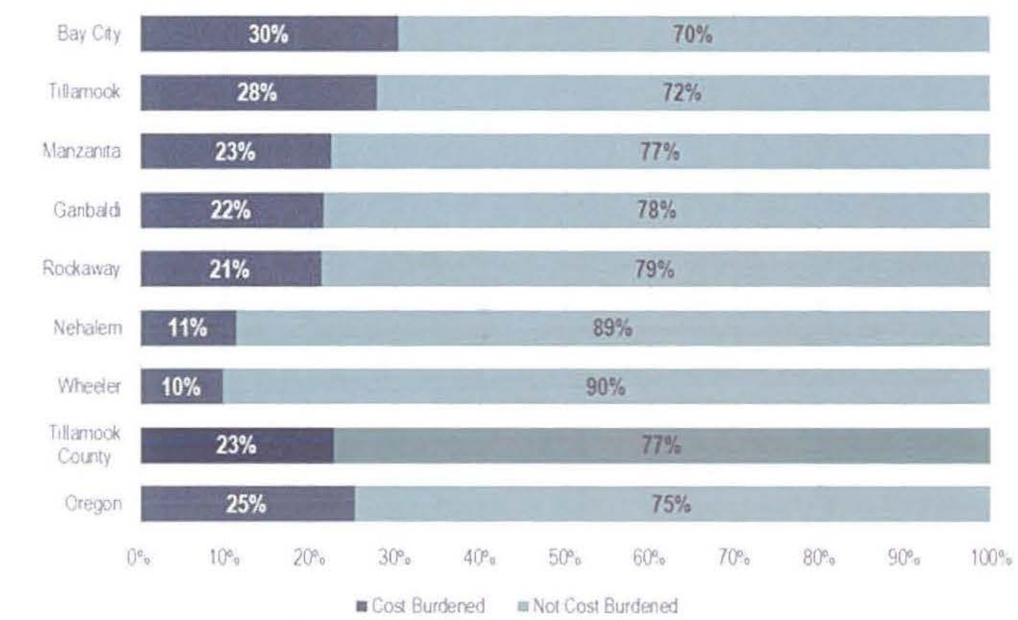
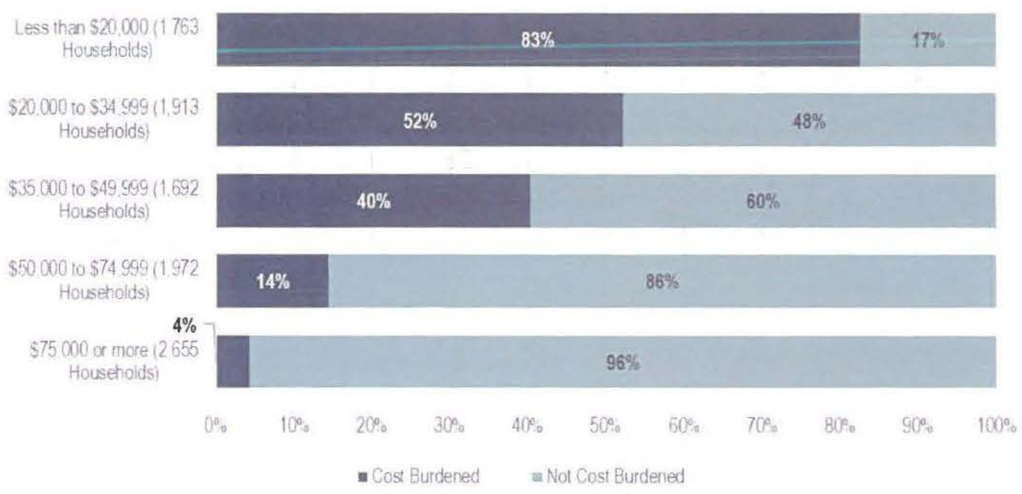


Exhibit 2.13

Housing Cost Burden by Income, Tillamook County, 2013-2017



Workforce Housing Demand

Representatives from local businesses, school districts, hospitals and emergency service sectors (e.g., police and fire districts) have voiced concern over the lack of attainable housing for their employees. Many workers now travel very long distances to jobs in Tillamook County. According to U.S. Census stats, **almost one in four workers in Tillamook County commute greater than 50 miles each way (100 miles per day); which is double the statewide average**. Nearly one in three local workers now reside outside Tillamook County.

Note: These findings are based on U.S. Census On-the-Map Longintudinal Employer-Household Dynamics (LEHD) data which are based on tabulated and modeled administrative employer suvey data, which are subject to error. The Quarterly Workforce Indicators (QWI), LEHD Origin-Destination Employment Statistics (LODES), Job-to-Job Flows (J2J), and Post-Secondary Employment Outcomes (PSEO) are available online for public use.

Because the estimates are not derived from a probability-based sample, no sampling error measures are applicable. While no direct measurement of these joint effects has been obtained, precautionary steps are taken in all phases of collection and processing to minimize the impact of nonsampling errors.

As indicated in **Exhibit 2.14**, FCS GROUP has documented market gaps in Tillamook County's available housing inventory. Conversion of homes to seasonal and vacation rentals, low vacancy rates, and inadequate housing construction levels result in market gaps that can only be corrected by supply additions. Based on relatively low market capture rates, as of year 2017, there is a housing gap of approximately 406 units for housing units needed for moderate income households at 50% to 120% of the area median family income (MFI) level.

In addition, there is also a significant market gap for government assisted housing available to households earning less than 50% of the MFI level. This analysis indicates that the market gap for rental housing at this price point equates to over 600 dwellings. In light of inadequate levels of state and federal housing grants, we have assumed a 33% market capture rate or approximately 200 units of low income housing demand is needed at this time.

Exhibit 2.14 Existing Housing Market Gaps, Tillamook County

Current Housing Market Gap for Housing at 50% to 120% MFI or higher, Tillamook County

		Total Dwelling Units	Rental Units	Owner Units
Existing Workers in Tillamook County	9,476			
Long Distance commuters (over 100 miles per day)	2,030			
Market Demand Sensitivity Analysis				
Low Capture Rate	15%	305	152	152
Midpoint Capture Rate	**20%**	406	203	203
High Capture Rate	25%	508	254	254

Based on U.S. Census Bureau, On-The-Map data for Tillamook County, 2017.

Current Market gap for Housing at less than 50% MFI, Tillamook County

Affordable Monthly Rent Costs *	Current # of Renter-Occupied Households	Estimated Available Rental Units at this rent level	Housing (Gap) or Surplus	Capture Rate for Analysis	Housing Needed (units)
Less than $500	1,139	528	(611)	33%	202

Source: U.S. Census Bureau, American Community Survey, 2017. * Assumes 30% of income towards rent.

This analysis conservatively assumes that the level of near-term pent up market demand could support development of over 400 units of rental housing, with about half needed for households in the 50% to 120% of the MFI level for Tillamook County.

II.D. FUTURE HOUSING NEEDS

The methodology includes three housing forecast scenarios which were reviewed and discussed by the Housing Committee. They include:

Scenario A Baseline Forecast

Scenario B Baseline + Workforce Housing Forecast

Scenario C Policy Scenario as modified version of Scenario 2

Scenario D Midpoint of low and high growth forecasts

Scenario A: Baseline Housing Demand Forecast

The future (20 year) housing forecast for Tillamook County takes into account the population and socioeconomic and housing characteristics described earlier.

The baseline forecast applies the long term population forecast by Portland State University, and assumes that current household size, group quarters demand, vacancy rates and seasonal housing rates remain constant. With the baseline forecast, Tillamook County is projected to add 2,936 people which will require 2,305 new dwellings over the next 20 years. If the future housing demand is distributed within Tillamook County based on the current housing mix, the 20-year housing demand in the unincorporated areas would equate to 510 dwellings, and the various incorporated area UGBs would need to accommodate the remaining 1,795 housing unit (see **Exhibit 2.15**).

Exhibit 2.15 Scenario A Baseline Forecast

Baseline Housing Demand Forecast, Tillamook County, 2019-2039

	Net New Population[1]	Group Quarters Share	Group Quarters Pop. [2]	Avg. HH Size[2]	Occupied Dwellings[2]	Seasonal & Vacancy Rate[2]	Seasonal & Vacant Dwellings	Total Dwelling Need (excl. group quarters)
Unincorporated areas	**707**	2.6%	18.4	2.41	**286**	**44.0%**	**225**	**510**
Tillamook UGB	796	0.88%	7.0	2.47	**319**	8.5%	30	**349**
Nehalem UGB	370	0.00%	-	3.43	**108**	25.0%	36	**144**
Bay City UGB	348	0.00%	-	3.43	**101**	14.6%	17	**119**
Manzanita UGB	299	0.00%	-	3.43	**87**	86.6%	562	**649**
Rockaway Beach UGB	272	0.00%	-	2.27	**120**	73.7%	336	**456**
Garibaldi UGB	73	0.75%	0.5	2.62	**28**	31.8%	13	**41**
Wheeler UGB	72	1.45%	1.0	2.62	**27**	29.4%	11	**38**
Total	**2,936**	**0.9%**	**27**		**1,076**	**53.3%**	**1,229**	**2,305**

Notes: [1] population forecast from PSU Population Research Center, interpolated by FCS GROUP; [2] based on 2017 ACS. Numbers may not add due to rounding.

Scenario B: Baseline + Workforce Housing Forecast

This scenario includes the baseline housing forecast based on future growth along with a capture of a portion of the current market gap for workforce housing.

As discussed earlier in this report, there is a demonstrated "market gap" for workforce housing in Tillamook County. In this scenario, it is assumed that the overall housing demand over the next 20 years equates to the baseline demand described in Scenario A plus an additional 400 units of pent up demand for rental housing. This would include approximately 200 units of moderate income rental housing attainable to households earning 50% to 120% of the MFI; and another 200 units for households earning less than 50% of the MFI level.

This forecast scenario assumes that the majority of the housing production would occur in communities that can provide water and sanitary sewer service, with capacity that can be increased as needed to accommodate new housing development. As shown in **Exhibit 2.16**, the housing forecast under Scenario B equates to 2,730 dwelling units over 20 years.

Exhibit 2.16 Baseline + Workforce Housing Forecast Scenario B

	Demand Dist. (Scenario A)	Demand Dist. (Scenario B)	Pent Up Rental Workforce Housing Need (units)	Baseline Housing Need (Scenario A)	Total Housing Need (Scenario B)
Tillamook UGB	15%	25%	106	349	455
Nehalem UGB	6%	5%	21	144	165
Bay City UGB	5%	5%	21	119	140
Manzanita UGB	28%	10%	43	649	691
Rockaway Beach UGB	20%	10%	43	456	499
Garibaldi UGB	2%	5%	21	41	62
Wheeler UGB	2%	5%	21	38	59
Subtotal UGBs	78%	65%	276	1,795	2,071
Unincorporated areas	**22%**	**35%**	**149**	**510**	**659**
Total Dwelling Units	100%	100%	**425**	**2,305**	**2,730**

Scenario C: Coordinated Policy Forecast

This scenario assumes that same level of overall Countywide housing demand as with Scenario B, but takes into account the fact that many of the coastal communities may have achieved market prices for land and housing that is out of reach for most residents. Small cities and resort communities in Tillamook County may not be capable of accommodating all of the potential market demand. Limiting factors may include inadequate infrastructure (particularly sewer) and environmental risks associated with developing housing in floodways, floodplains and tsunami hazard areas.

As shown in **Exhibit 2.17**, with this scenario it is assumed that the share of housing demand that will be accommodated within incorporated cities is 59% of total demand, down from about three quarters of total demand in the prior scenarios. Hence, the level of demand that would need to be addressed within unincorporated portions of Tillamook County would increase to 41% of the Countywide housing demand, compared with 22% to 24% in Scenarios A and B.

Exhibit 2.17 Housing Market Share by Scenario

	Demand Dist. (Scenario A)	Demand Dist. (Scenario B)	Demand Dist. (Scenario C)	Total Housing Need (Scenario C)
Tillamook UGB	15%	17%	30%	819
Nehalem UGB	6%	6%	5%	137
Bay City UGB	5%	5%	5%	137
Manzanita UGB	28%	25%	5%	137
Rockaway Beach UGB	20%	18%	10%	273
Garibaldi UGB	2%	2%	2%	55
Wheeler UGB	2%	2%	2%	55
Subtotal UGBs	**78%**	**76%**	**59%**	**1,611**
Unincorporated areas	**22%**	**24%**	**41%**	**1,119**
Total Dwelling Units	100%	100%	100%	**2,730**

Comparison of Housing Forecast Scenarios

These findings indicate that the future housing market in Tillamook County is expected to remain strong, barring natural disasters or global or national economic downturns. Population increases due largely to second home investors will likely account for just over half of the future housing demand. In order for housing prices and rents to be attainable to households at 120% or less of the local median income level for the County ($45,060), for sale housing would need to be priced at $299,000 or less and rentals priced at $1,352 or less (per month for 2 bedroom unit). For additional analysis of housing affordability levels, please refer to **Appendix A.**

Exhibit 2.18 provides a comparison of the housing demand within local areas for each of the three forecast scenarios. The findings indicate a low and high range of housing needs along with a mid-point demand forecast, which is referred to as Scenario D.

Exhibit 2.18

Tillamook County 20-year Housing Forecast Scenarios (dwelling units)

	Scenario A	Scenario B	Scenario C
Tillamook UGB	349	455	819
Nehalem UGB	144	165	137
Bay City UGB	119	140	137
Manzanita UGB	649	691	137
Rockaway Beach UGB	456	499	273
Garibaldi UGB	41	62	55
Wheeler UGB	38	59	55
Subtotal UGBs	**1,795**	**2,071**	**1,611**
Unincorporated areas	**510**	**659**	**1,119**
Total Dwelling Units	**2,305**	**2,730**	**2,730**

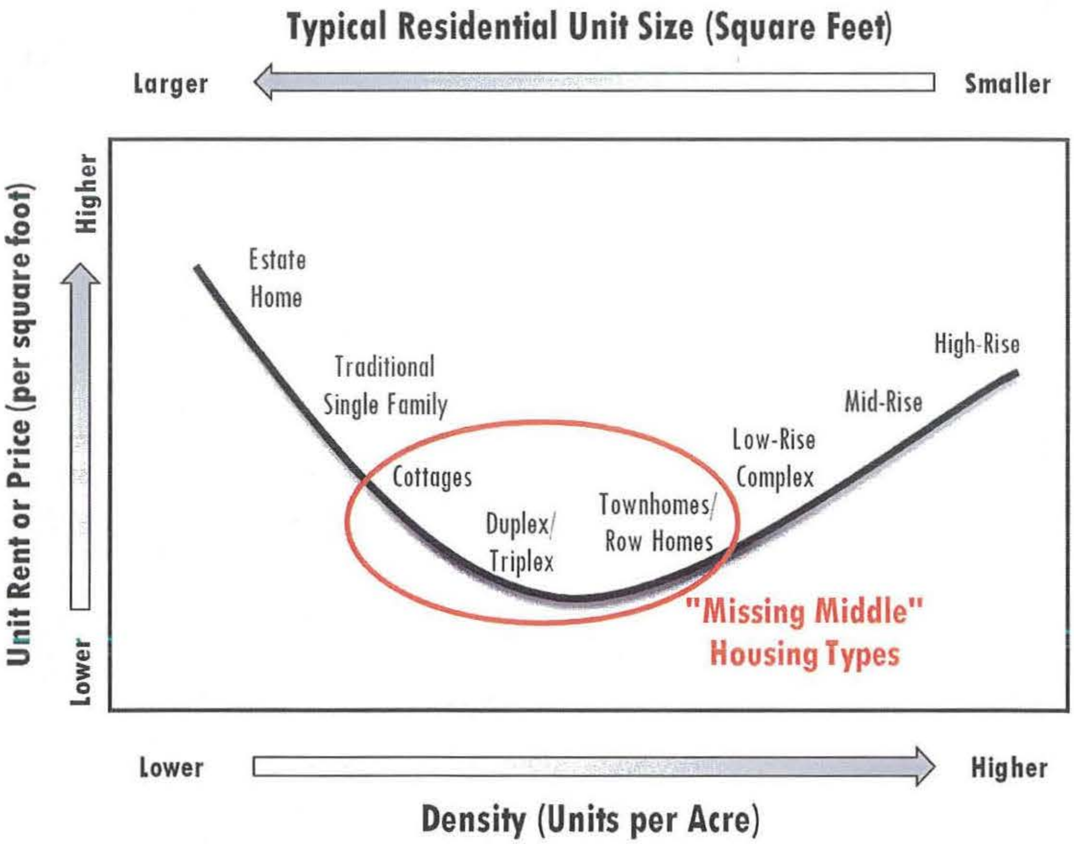
	Low	High	Midpoint (Scenario D)
Tillamook UGB	349	819	584
Nehalem UGB	137	165	151
Bay City UGB	137	140	138
Manzanita UGB	137	691	414
Rockaway Beach UGB	273	499	386
Garibaldi UGB	55	62	58
Wheeler UGB	55	59	57
Subtotal UGBs	**1,141**	**2,435**	**1,788**
Unincorporated areas	510	1,119	815
Total Dwelling Units	**1,651**	**3,554**	**2,603**

Source: prior exhibits.

Projected Needs by Housing Type

In light of the current housing affordability challenges, the future demand for attainably priced housing within Tillamook County will need to increase measurably in the future. This would require development of affordable "missing middle" housing types, such as market rate and government assisted plexes, townhomes and apartments as well as cottage homes, manufactured homes and accessory dwelling units (ADUs). As shown in **Exhibit 2.19**, these housing types can be delivered at a lower cost and rent level per square foot than other housing types.

Exhibit 2.19

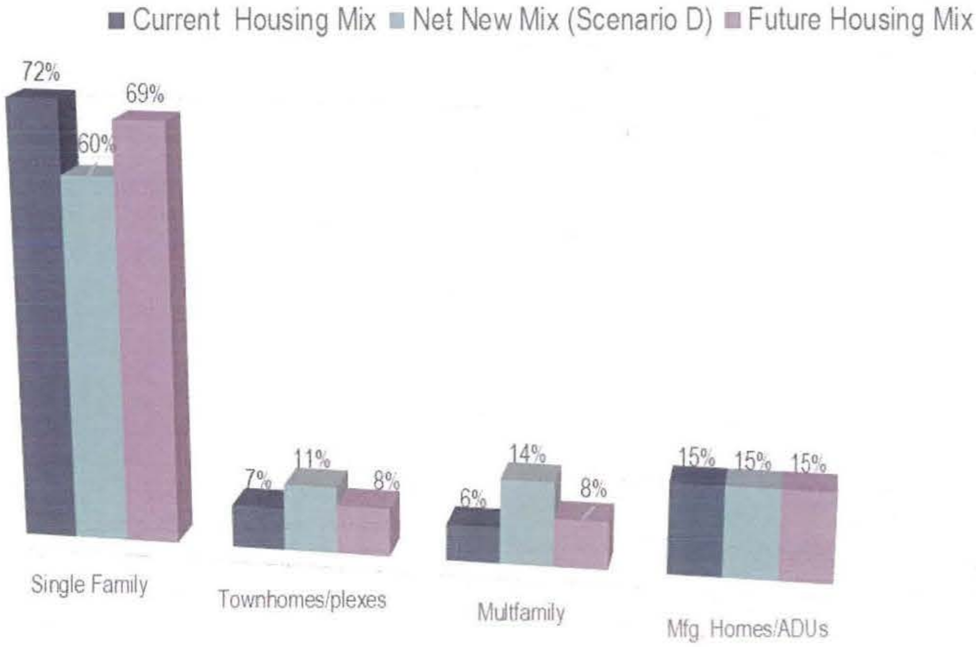


The forecasted housing mix that addresses future demand will likely consist of: 1,562 single-family detached homes (including cottage homes), 286 townhomes/duplexes/ADUs, 364 multifamily housing units and 390 manufactured housing units (see **Exhibit 2.20**). There will also be some "group quarters" housing demand for about 30 additional residents that will require shared living arrangements (such as congregate care or interim housing).

The graph below juxtaposes the housing mix in Tillamook County today compared with the projected mix of units to be added in the next twenty years and the overall housing mix observed in the county after twenty years. As shown in **Exhibit 2.21**, the Policy Scenario D would increase the overall share of multifamily, townhomes, and plexes in comparison to the current mix. The share of single family detached housing would decline and the share of manufactured housing would remain relatively constant.

Exhibit 2.20

Tillamook County Housing Need: Current and Future dwelling units



Source: U.S. Census Bureau 2013-2017 American Community Survey (Table B25032), and Scenario D forecast

At midpoint of the forecast scenarios (Scenario D), the net new housing need is expected to consist of: 1,796 owner-occupied dwellings and 807 renter-occupied dwellings. As shown in **Exhibit 2.21**, the types of housing that is most suited to meet qualifying income levels for home ownership vary by family income level. The owner and rental housing forecast that's suited to meet qualifying income levels is shown below

Exhibit 2.21 Current and Future Housing Mix, Scenario D

	Current Housing Mix	Net New Housing Mix (Policy Scenario C)	Future Housing Mix
Single Family	72%	60%	69%
Townhomes/Plexes	7%	11%	8%
Multi family	6%	14%	8%
Mfg. home / other	15%	15%	15%
Total	100%	100%	100%

	Current Housing Mix	Net New Housing Mix (Policy Scenario C)	Future Housing Mix
Single Family	7,501	1,562	9,063
Townhomes/Plexes	781	286	1,067
Multi family	641	364	1,005
Mfg. home / other	1,531	390	1,921
Total	**10,454**	**2,603**	**13,057**

Source: prior exhibits.

As we consider the demand for housing by affordability level, the vast majority of housing demand needs will be from households at 120% or below of the Median Family Income level for Tillamook County (see **Exhibit 2.22**).

For additional analysis regarding housing affordability price points for owner occupied and renter occupied housing please refer to **Appendix A**.

Exhibit 2.22 Forecasted Housing Demand by Affordability (Scenario D)

Approximate Attainable Home Price*	Owner-Occupied	Renter-Occupied	Total	Dist. %	Attainable Housing Products
Upper (120% or more of MFI)	790	166	956	36.7%	Standard Homes, Townhomes, Condos
Upper Middle (80% to 120% of MFI)	647	135	782	30.0%	Small Homes, Townhomes, Apartments
Lower Middle (50% to 80% of MFI)	269	163	433	16.6%	ADUs, Townhomes, Mfgd. Homes,
Low (30% to 50% of MFI)	90	190	279	10.7%	Govt. Assisted Apts. & Plexes
Very Low (less than 30% of MFI)	0	153	153	5.9%	Govt. Assisted Apts.
Total	1,796	807	2,603	100.0%	

*Assumes 30% of income is used for rental or mortgage payments. Derived from Appendix A.

Projected Residential Land Needs

Using the mid-points of the housing demand forecasts, the buildable land that will be needed to accommodate planned housing production is shown in **Exhibit 2.23. At the midpoint of the growth forecast scenarios (Scenario D), the overall amount of residential land that will be needed within all of Tillamook County over the next 20 years equates to just over 1,340 buildable acres of land area.**

It should be noted that actual gross land needs could be much higher given the limited availability of sewer infrastructure capacity with in Tillamook County.

The forecast of residential land that is needed within each local community and incorporated cities is provided below by general land use type (low, medium and high density) for discussion and policy planning purposes.

Exhibit 2.23

Tillamook County 20-year Housing Land Need Forecast at Midpoint

		Housing Mix*				Land Need (Buildable acres)				
	Total Housing Need (Midpoint)	Very Low Density (single family homes)	Low Density (single family and mfg. homes)	Medium Density (townhomes, plexes)	Higher Density (apartments	Very Low Density	Low Density	Medium Density	Higher Density	Total Land Need (buildable acres)
Tillamook UGB	584	-	292	124	169	-	97	21	14	132
Nehalem UGB	151	-	75	32	44	-	25	5	4	34
Bay City UGB	138	-	69	29	40	-	23	5	3	31
Manzanita UGB	414	-	207	88	120	-	69	15	10	94
Rockaway Beach UGB	386	-	193	82	112	-	64	14	9	87
Garibaldi UGB	58	-	29	12	17	-	10	2	1	13
Wheeler UGB	57	-	28	12	17	-	9	2	1	13
Subtotal UGBs	**1,788**	**-**	**894**	**378**	**518**	**-**	**298**	**63**	**43**	**404**
Unincorporated areas**	**815**	**407**	326	81	-	**815**	109	14	-	**937**
Total	**2,603**	**407**	**1,220**	**460**	**518**	**815**	**407**	**77**	**43**	**1,341**

*Assumes mix and density as follows:

	City/Town Housing Mix	Unincorp. Area Mix**	Dwellings per acre (avg.)
Very Low Density*	0%	50%	0.5
Low Density	50%	40%	3
Medium Density	21%	10%	6
Higher Density	29%	0%	12
Total	**100%**	**100%**	

Source: compiled by FCS GROUP based on midpoint of housing forecast scenarios and expected market demand.

Section III. Buildable Land Inventory

This section includes a summary of the residential buildable land inventory (BLI) in Tillamook County. The focus of this 2019 BLI analysis is on the following geographic areas:

- Tillamook County, unincorporated areas outside existing urban growth boundaries (UGBs)
- Tillamook UGB
- Manzanita UGB
- Bay City UGB

In addition to these locations, this report cites findings from prior adopted plans and BLI studies to ascertain buildable lands in the following locations:

- Garibaldi UGB
- Nehalem UGB
- Rockaway Beach UGB
- Wheeler UGB

METHODOLOGY

As part of Tillamook County's Housing Needs Analysis process, an estimate of buildable lands was completed to assess the supply of available land for housing development in unicorporated areas as well as three cities that opted to update their land inventories at this time. The Buildable Lands Inventory (BLI) was completed in accordance with OAR 660-008-0005 (2) and guidance provided by the Department of Land Conservation and Development (DLCD).[1]

[1] While Oregon state regulations pertaining to BLI methods apply only to UGBs of incorporated areas, the same methodology was applied to unincorporated portions of Tillamook County with one exception which was reviewed by the Housing Committee: the removal of 100-year flood zones from the vacant land inventory for unincorporated areas only. The BLIs for incorporated areas assume land within 100-year flood zones is considered to be unconstrained and buildable.

The objective of the residential BLI is to determine the amount of developable land available for future residential housing development. The steps taken to perform this analysis are as follows:

1. Create a unified environmental constraints layer. These are areas where land is unsuitable for development due to natural hazards
2. Generate the residential land base by identifying all taxlots that are zoned to allow residential development (either permitted outright or as a conditional use)
3. Subtract all environmentally constrained land from the residential land base
4. Classify land by development category (vacant, partially vacant, or redevelopable)
5. Calculate total net buildable acres by netting out land needed for public facilities such as roads and utility infrastructure and factoring a redevelopment rate for parcels deemed redevelopable

Please refer to the separate Tillamook County Residential Buildable Land Inventory reports by Cascadia Partners for additional details regarding the methodology used for each location.

ALL AREAS OF THE COUNTY

An estimate of the total buildable land for residential development is provided in **Exhibit 3.1**. The results indicate that overall there is over 3,700 acres of buildable residential land area throughout the county, with the vast majority located in unincorporated areas.

It should be noted that the term density is used to reflect the average number of housing units per buildable acre on a particular site. Density is a relative term that generally reflects the type of housing that a land use zone is planned to accommodate. Based on local construction trends and market activity in Tillamook County, the density and housing types generally fall into the following categories:

- Very Low Density: 1 dwelling per 2 acres on average. Rural development typically relies on septic systems and connections to local water systems.
- Low Density: average of 3 dwellings per acre. Typically single family detached housing or mobile homes.
- Medium Density: 6-9 dwellings per acre. May include duplexes, townhomes and small lot cottage homes.
- High Density: typically 9-18 dwellings per acre. Includes townhomes and apartments.

TILLAMOOK COUNTY (UNINCORPORATED AREAS)

Based on the BLI finding for the unincorporated portions of Tillamook County shown in **Exhibit 3.2 and Map 3.1**, approximately 2,135 acres of land are available in the residential buildable lands inventory. Not surprisingly, as most of unincorporated Tillamook County is rural, most of the land available falls under low density residential zoning (roughly 54%). Medium density residential and high density residential make up 34% and 10% of the residential buildable lands inventory respectively. Only 2% of the residential land base is comprised of land zoned as commercial / mixed-use.

Vacant land represents by far the largest opportunity for development, comprising more than 95% of the land available in the buildable lands inventory. While less partially vacant and redevelopable land is available, the location of specific parcels are important as they may represent geographies where development is highly desired (i.e., areas close to commercial cores) or where infrastructure (water and sewer) is available.

Exhibit 3.1: Summary of Residential Buildable Lands Inventory, Unicorp. Tillamook County (acres)

	Relative Zoned Housing Density Class				
Location (BLI Source)	**Very Low**	**Low**	**Medium**	**High**	**Total**
County Commercial (Cascadia 2019)	30		25		54
County Residential Zones (Cascadia 2019)	1,710	286	11	11	2,017
Manzanita UGB (Cascadia 2019)		52	69	6	127
Neahkahnie (Cascadia 2019)		13	25	76	114
Nehalem (2018)		207	95	43	345
Nehalem (COG 2007)		36	94	19	149
Neskowin (Cascadia 2019)	235	158	2	0	395
Netarts (Cascadia 2019)		59	56	18	133
Oceanside (Cascadia 2019)		82	1		82
Pacific City (Cascadia 2019)	30	49	34	83	196
Tillamook UGB (Cascadia 2019)	-	-	17	45	62
Wheeler (COG 2007)		61	18		79
Total	**2,004**	**1,001**	**446**	**302**	**3,753**

Source: various Tillamook County and local area Buildable Land Inventory studies, as noted.

Exhibit 3.2: Residential Buildable Lands Inventory, Unincorporated Tillamook County, 2019

Housing Category	Vacant	Partially Vacant	Redevelopable	Total Buildable
Very low density Residential	1,097	27	21	1,145
Medium Density Residential	694	29	4	727
High Density Residential	205	8	1	214
Commercial / Mixed-use	45	2	1	48
Total:	**2,042**	**66**	**27**	**2,135**

Source: Tillamook County Buildable Land Inventory by Cascadia Partners et al., September 2019.

Incorporated Cities

In addition to the 2019 BLI studies by Cascadia Partners and FCS GROUP, other communities in Tillamook County have completed residential buildable land inventories (BLIs) within the last 15 years. The objective of the residential BLI is to determine the amount of developable land available for future residential housing development within the UGB. BLI highlights include the following

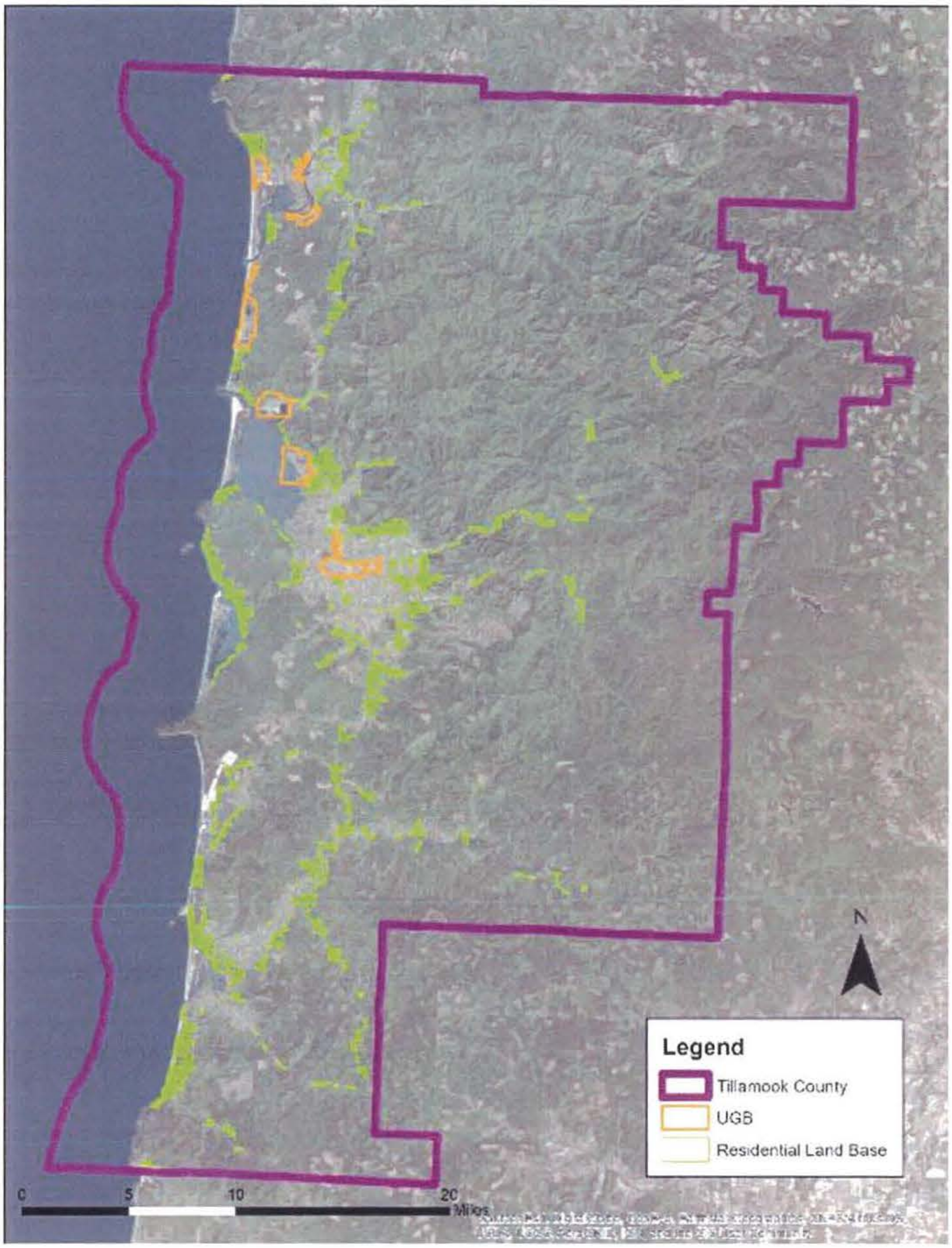
- **Tillamook:** draft findings by FCS GROUP/Cascadia Partners indicate that there is a current need for additional low- and medium-density zoned land area within the Tillamook UGB that ranges from approximately 48 to 76 acres of net buildable land area.
- **Nehalem:** according to the City of Nehalem, no residential land shortages were identified for the planning horizon (2007-2027) with an overall residential buildable land **surplus of 121.4 acres**. The City is in the process of approving a new buildable land inventory which indicates a **supply of 377.15 acres of residential land**. That BLI work is still in process.
- **Wheeler:** according to the City, no residential land shortages were identified for the planning horizon (2007-2027) with an overall residential buildable land **surplus of 66.7 acres**.
- **Rockaway Beach:** according to the City of Rockaway Beach, no residential land shortages were identified for the planning horizon (2007-2027) with an overall residential buildable land **surplus of 57 acres**.
- **Bay City:** Buildable Land Inventory is in process; however Housing Needs Analysis appears to be outdated.

- **Manzanita:** FCS/Cascadia identified a total land inventory of 122 net acres (residential zones) plus 4 acres of mixed use zoning (BLI adopted by City in Sept. 2019). This level of supply appears to be adequate for meeting the 20 year demand identified earlier in this report (94 acres at midpoint of low and high forecast scenarios).

These findings indicate the City of Tillamook may be able to justify a UGB expansion or a Comprehensive Plan amendment and with changes in zoning to allow for more housing. However, it is unlikely that other cities can do so in the near future.

In light of the significant level of housing demand outside the incorporated cities and their urban growth boundaries, and the desire to encourage more development in those locations, several local and state policy actions are identified in the next Section of this report for additional consideration.

Map 3.1 Residential Land Base, Unincorporated Tillamook County



FCS GROUP

Section IV. Action Plan

Policy Recommendations

This section summarizes relevant federal and state housing policies and identifies a set of Action Plan recommendations.

RECENT POLICIES

Several recent policy changes have occurred at the federal, state and regional level that may affect the future housing supply and demand in Tillamook County.

Federal Policies

Tax Cuts and Jobs Act

Passed in 2017, the Tax Cuts and Jobs Act initiates large scale federal tax reform. The reform made changes in many ways but most notable was the shift in the federal corporate tax rate, decreasing from 35% to 21%. The new tax cuts also lower most individual income tax rates, including the top marginal rate from 39.6 percent to 37 percent. The lower tax rates potentially affect Tillamook County and its municipalities because it makes tax free municipal bonds and affordable housing tax credits less attractive to investors because the relative advantage of lowering taxable income by investing in tax exempt bonds would decrease in most cases. However, with the adoption of measure 102 (see below), Oregon voters have expressed the need for investing in affordable housing bonds, and these state measures should mitigate the impact of this federal act.

Low Income Housing Tax Credits

The Low Income Housing Tax Credits program is a series of tax incentives administered by the IRS to encourage developers to construct affordable housing. Currently the program accounts for the largest source of new affordable housing in the U.S. In securing these credits, developers agree to rent out housing at an affordable level, often below market price (this is referred to as a use restriction). State agencies distribute credits to developers based on a state designed application process. These credits come in two forms, 9% (this raises about 70% of total cost) and 4% (this raises about 30% of the total cost), where 4% tax credits are often complimented with support from state bonds. In Oregon and in Tillamook County's case, Measure 102 (see below) should enable more funding of housing tax credit bonds and strengthen the effect of these tax credits on a for affordable housing development in Tillamook County.

Oregon Policies

Oregon's Statewide Housing Plan: "Breaking New Ground"

Oregon's 2018 Statewide Housing Plan is a long-term plan designed to increase housing in Oregon. The plan was researched and developed by Oregon Housing Community Services (OHCS) and its implementation will rely on OHCS in conjunction with local governments and private businesses. OHCS is Oregon's housing finance agency and as such the organization issues grants and loans to help facilitate home ownership in the state. OHCS regards housing in Oregon as a statewide crisis. Housing production has failed to keep up with Oregon's population growth therefore demand has outpaced supply, pushing up home prices. From 2000 to 2015, an additional 155,156 housing units would need to have been built throughout Oregon to keep up with demand.[2]

The Statewide Housing Plan calls for over 85,000 new units to be constructed for households earning below 30% of Median Family Income (MFI). The plan is outlined in six priorities and each promotes increased housing supply. Priorities include an increase housing supply that: (1) improves racial equity; (2) combats homelessness; (3) increases housing stability for families; (4) makes rent affordable; (5) proliferates homeownership; and (6) empowers rural communities. With this in mind, OHCS will triple the existing pipeline of affordable rental housing — up to 25,000 homes in the development pipeline by 2023.

The plan proposes increased access to housing through partnerships with community organizations, loans with low interest rates, better access to OHCS resources, funding grants for housing projects, improved technology, and streamlined processes with a foundation of collaboration. Implementation seems to rely on each area's ability to utilize and engage with OHCS as the plan clarifies goals and does not specify implementation policies.

Senate Bill 1533

Enacted by the 2016 Oregon Legislature, this bill aims to promote affordable housing development through local regulations and a new source of funding: the Affordable Housing Construction Excise Tax (CET). The bill allows municipalities to adopt regulations that impose conditions on development for new multifamily structures (20 units or more per project), including: requirements for the inclusions of some affordable housing; or the option of paying an in-lieu fee (construction excise tax) not to exceed $1 per square foot of floor area for residential, and $0.50 per square foot for nonresidential structures (with a maximum cap of $25,000 per building or structure). For new

[2] Up for Growth, "Housing Underproduction in the U.S.: Economic, Fiscal and Environmental Impacts of Enabling Transit-Oriented Smart Growth to Address America's Housing Affordability Challenge," Up For Growth National Coalition, 2018, 9.

affordable housing projects, this legislation supports special incentives including: full or partial exemption of ad valorem property taxes, SDC waivers or reductions and other incentives.

Tillamook County voters soundly defeated a local CET ballot measure in 2017, and there is little appetite to pursue another CET at this time.

Measure 102: Passed by Oregon voters in November 2018

Measure 102 is intended to empower the collaborative partnerships described in Oregon's Statewide Housing Plan. Measure 102 amends the state's constitution to allow cities and counties to issue bonds for the construction of affordable housing construction without retaining 100% public ownership of the property. The goal is to allow local governments to pursue private public partnerships to better facilitate demand for housing.

KEY FINDINGS AND POLICY RECOMMENDATIONS

Based on the 20-year population growth forecasts for Tillamook County (forecasted increase of 2,936 year-round residents) and seasonal housing and demographic characteristics, **the recommended housing needs for Tillamook County requires 2,305 to 2,603 net new dwelling units.** The Tillamook County Housing Needs Analysis supports a variety of housing is needed over the next 20 years, including approximately 1,692 owner-occupied dwellings and 911 renter-occupied dwellings.

Recommended Actions

Market factors combined with limiting state and local land use policies have led to unprecedented housing challenges facing Tillamook County today. Addressing these challenges will require a coordinated effort by local and state government officials.

Vacancy rates for long-term rental units are now near zero in most communities in Tillamook County. While there is a strong and stable level of near term and long term demand for new housing construction throughout Tillamook County, there are very few local builders/developers that are focused on constructing the missing middle housing types needed for the workforce. To attract private investment and development of new workforce housing, a mix of local, state and federal policies, incentives and actions need to occur.

Local Policies and Actions

Challenge: Relatively high land and development costs in coastal areas hamper financial viability of developing attainable workforce housing for permanent residents. As a result, Tillamook County has an existing deficit for "missing middle" housing.

Tillamook County is tied for the second highest rate of economically distressed households in Oregon. Cities including Tillamook and Bay City have the highest share of severe rent burdened households at 28% and 30% of households, respectively.

To help encourage or incentivize construction of missing middle housing priced at 120% or below of the median family income levels, the County should continue to pursue state OHCS housing investment grants and work with local cities to consider the following policies:

Short-term Actions (1-2 years)

- ✓ Identify public-owned properties (excluding park/open space areas) that could be developed for a mix of housing types.
- ✓ Work with cities and sewer districts to update SDCs so that they are lower for smaller housing units than larger homes. Encourage SDC deferrals so that payments can be deferred for a period of time after building permit issuance for developments that contain deed restricted housing units.
- ✓ Consider a tax abatement program, such as the multiple-unit limited tax exemption program to promote development of affordable housing.
- ✓ Embark on a program that encourages Accessory Dwelling Units (ADUs) and "Cottage Homes" and "Tiny Home Communities" as an allowed use or conditional use within low density zones.
- ✓ Allow "lot size averaging" so that the site of individual lots in a short-plat development can vary from the zoned minimum or maximum density, in a manner that the overall development still meets average lot size requirements.
- ✓ Encouraging upper-level redevelopment and conversions in downtown Tillamook and other locations through financial assistance programs, such as use of urban renewal funds as loans.
- ✓ Tillamook County and its eligible local communities should leverage CDBG funds, state grants and bonds to help communities expand water, sewer and transportation infrastructure within areas planned for workforce housing through establishment of local improvement districts or reimbursement district programs.

Long-term Actions (2-5 years)

Challenge: locations with available sewer capacity are limited to areas such as the city of Tillamook.

- ✓ Support Tillamook UGB expansion and potential rezoning efforts that result in additional housing development opportunities. The current Tillamook UGB contains 98 acres of buildable residential land inventory, yet residential land needs are forecasted to be up to 175 acres. In light of this finding the City and County should identify ways to increase low and medium density housing development opportunities through a UGB expansion
- ✓ Work local sewer and water districts to document their current and planned capacity levels to address future housing needs and inform the county wide housing strategy.

Challenge: Tillamook County like many rural locations has a short supply of qualified residential construction workers and specialty contractors. This results in higher housing prices as construction workers and crews must be obtained from the Willamette Valley region and temporarily housed.

- ✓ Facilitate development of trade related certification programs for people interested in residential construction and trades offered by Tillamook Bay Community College and Tillamook High School in partnership with home builders and general contractors.

State Policies and Potential Actions[3]

Challenge: Oregon planning requirements for urban areas hamstring local cities and counties ability to create coordinated and creative housing strategies.

- ✓ Engage DLCD and Oregon Legislature to draft new planning guidelines for rural counties (e.g., population under 50,000) to adopt a coordinated county-wide Housing Needs Strategy. This would enable jurisdictions to prepare housing strategies that meet PSU's baseline forecasts countywide and allows for a localized allocation of housing and population (among cities and rural centers). This regional HNA approach would be intended to reflect unique market conditions and development opportunities and constraints in order to optimize the provision of more attainable housing.
- ✓ Engage DLCD and Oregon Legislature to include new state rules that allow rural development centers (outside UGBs) to rezone land for housing as long as there are adequate public facilities.

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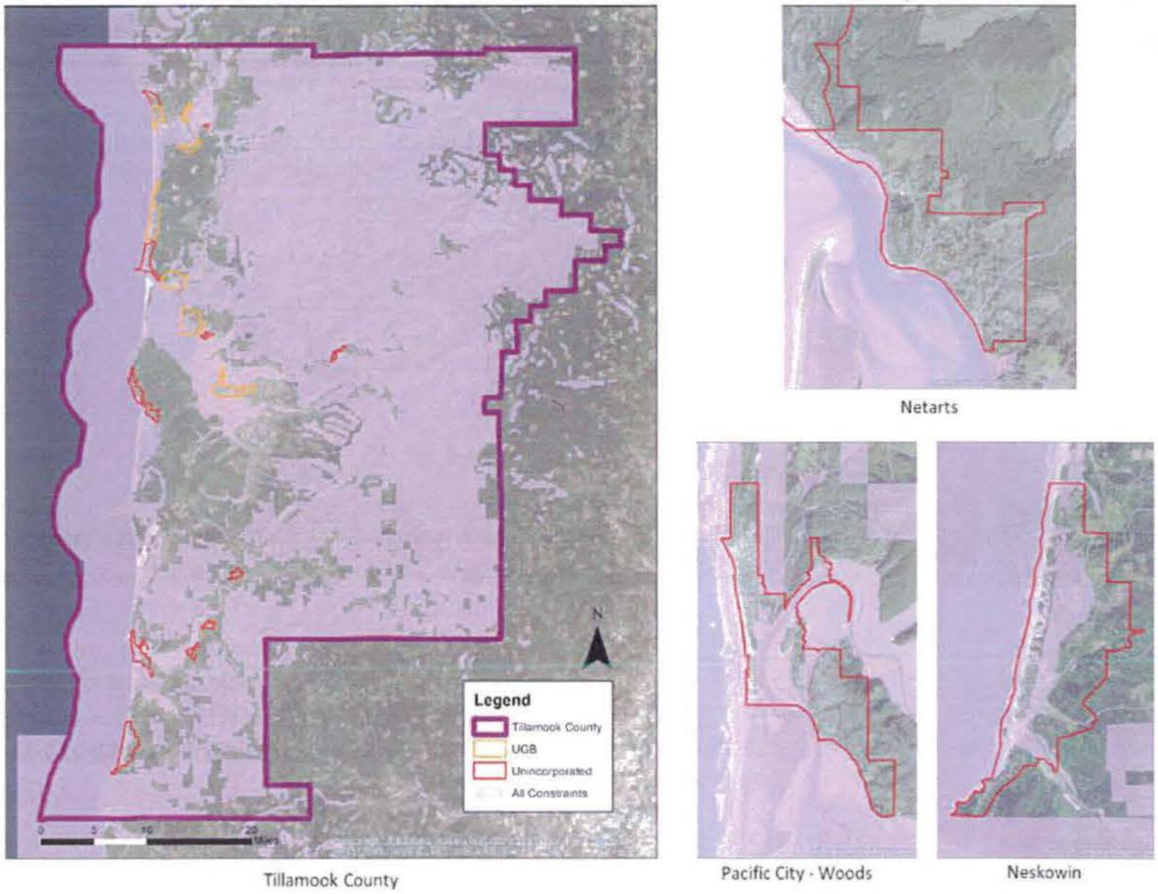
[3] Input received from DLCD staff regarding current interpretation of state rules applying to local HNAs and Economic Opportunity Analysis (EOA) compliance is provided in Appendix B.

Challenge: Tillamook County has a large share of vacant lands in areas that are subject to frequent flooding and agricultural use restrictions. This restricts the amount of development that is likely to occur in rural residential zones (see **Map 3.2**).

- ✓ The County should pursue Oregon Legislature initiated amendments to the Oregon Administrative Rules to allow property owners to transfer future development rights (TDRs) from environmentally sensitive areas (such as vacant land within floodplains and tsunami hazard zones) and agricultural areas onto receiving areas that are located in communities that can provide adequate public facilities, such as roads, sewer and water services.

Map 3.2 Constrained Land Areas



APPENDIX A. HOUSING ATTAINABILITY ANALYSIS

Appendix A. Housing Attainability Analysis for Tillamook County

Median Family Income Level (2017)*	$45,061	
Market Segment by Income Level	**Lower-end**	**Upper-End**
High (120% or more of MFI)		120%
Upper Middle (80% to 120% of MFI)	80%	120%
Lower Middle (50% to 80% of MFI)	50%	80%
Low (30% to 50%)	30%	50%
Very Low (less than 30% of MFI)	30%	
Qualifying Income Level	**Lower-end**	**Upper-End**
High (120% or more of MFI)	$54,073	or more
Upper Middle (80% to 120% of MFI)	$36,049	$54,073
Lower Middle (50% to 80% of MFI)	$22,531	$36,049
Low (30% to 50%)	$13,518	$22,531
Very Low (less than 30% of MFI)	$13,518	or less
Available Annual Housing Payment (@30% of income level)	**Lower-end**	**Upper-End**
High (120% or more of MFI)	$16,222	or more
Upper Middle (80% to 120% of MFI)	$10,815	$16,222
Lower Middle (50% to 80% of MFI)	$6,759	$10,815
Low (30% to 50%)	$4,055	$6,759
Very Low (less than 30% of MFI)	$4,055	or less
Available Monthly Rent or Payment (@30% of income level)	**Lower-end**	**Upper-End**
High (120% or more of MFI)	$1,352	or more
Upper Middle (80% to 120% of MFI)	$901	$1,352
Lower Middle (50% to 80% of MFI)	$563	$901
Low (30% to 50%)	$338	$563
Very Low (less than 30% of MFI)	$338	or less
Approximate Attainable Home Price**	**Lower-end**	**Upper-End**
High (120% or more of MFI)	$299,000	or more
Upper Middle (80% to 120% of MFI)	$199,000	$299,000
Lower Middle (50% to 80% of MFI)	$104,000	$166,000
Low (30% to 50%)	$62,000	$104,000
Very Low (less than 30% of MFI)	$62,000	or less

* based on U.S. Census American Community Survey 2013-17.
** High and upper middle income levels assume 20% down payment on 30-year fixed mortgage at 5% interest.
** Lower middle and low income levels assume 0% down payment on 30-year fixed mortgage at 5% interest.
Source: Housing and Urban Development guidelines, and U.S. Census data, analysis by FCS Group

Tillamook County Owner-Occupied Housing Needs, 20-year Forecast*

Family Income Level	Upper Range of Qualifying Income	Upper Range of Home Price*	Attainable Housing Products	Estimated Distribution of Owner-Occupied Units	Projected Owner-Occupied Units Needed
Upper (120% or more of MFI)	Greater than $54,073	Greater than $299,000	Standard Homes	44%	790
Upper Middle (80% to 120% of MFI)	$54,073	$299,000	Small Homes, Townhomes	36%	647
Lower Middle (50% to 80% of MFI)	$36,049	$166,000	Mfgd. Homes, Plexes	15%	269
Low (30% to 50% of MFI)	$22,531	$104,000	Govt. Assisted	5%	90
Very Low (less than 30% of MFI)	$13,518			0%	0
Total Dwelling Units				**100%**	**1,796**

**Assumes 30% of income is used for mortgage payment, with 5% interest, 30-year term with 20% downpayment for upper middle and high income levels, and 5% downpayment for lower income levels.*

Tillamook County Renter-Occupied Housing Needs, 20-year Forecast*

Family Income Level	Upper Range of Qualifying Income	Upper Range of Monthly Rent*	Attainable Housing Products	Estimated Distribution of Units	Projected Renter-Occupied Units Needed
Upper (120% or more of MFI)	Greater than $54,073	Greater than $1,551	Standard Homes, Townhomes, Condos	21%	166
Upper Middle (80% to 120% of MFI)	$54,073	$1,551	Small Homes, Townhomes, Apartments	17%	135
Lower Middle (50% to 80% of MFI)	$36,049	$1,034	ADUs, Townhomes, Mfgd. Homes, Plexes, Apts.	20%	163
Low (30% to 50% of MFI)	$22,531	$646	Govt. Assisted Apts.	23%	190
Very Low (less than 30% of MFI)	$13,518	$388	Govt. Assisted Apts.	19%	153
Total Dwelling Units				**100%**	**807**

**Assumes 30% of income is used for rental payments.*

APPENDIX B. DLCD STAFF INPUT

From: "Phipps, Lisa" <lisa.phipps@state.or.us>
Date: Monday, December 16, 2019 at 10:40 AM
To: Paul Wyntergreen <pwyntergreen@tillamookor.gov>
Subject: FW: HNAs and EOAs

HI, Paul,
Here are the answers to the questions regarding the life span of a document and HNA approach. I met with Kevin Young in Salem to address these questions:

1) Do EOAs have a lifespan? The City of Tillamook had an EOA completed around 2013 and are now looking at updating their HNA, etc. Is it possible that a review of the EOA could show that it is still relevant (or mostly still relevant)? Would a letter just accompany that review showing it is still relevant? Or regardless, do they need to go through a full-blown process?

In 2013 it should have projected a 20-year need for employment lands. Since then, best practice would be to track what has developed since that time so they have a current understanding of their inventory of employment lands. There's no requirement for periodic updates of EOAs at this time, but what often drives a local gov. to do that is running short on land supply. The most recently adopted EOA remains valid until it is replaced by an updated EOA. There's no expiration date, but if they run out of land it becomes pretty irrelevant.

2) The City of Tillamook is currently having a BLI completed. I held a Planning Commission 101 workshop for the city before Thanksgiving and one of the questions that came up was whether it was acceptable to do a regional HNA? I know that 10-13 years ago, three of the cities and Tillamook County did a regional BLI and HNA with each community getting a HNA that was unique to them as well. So there was this broad overview of the area and its needs and then the community-specific HNAs were completed. Are you comfortable with this approach? Also, the commission asked about Safe Harbor and what pitfalls there might be in moving in that direction.

I think a regional HNA makes sense, as we discussed. I would not encourage use of the safe harbor methods from Div. 24. Reportedly, those have not worked that well. They created quite a bit of confusion with the recent Dallas HNA.[4]

Paul, I talked to Kevin about several different ways to approach the HNA. The first was to do an HNA just for the city, but one that included a regional overview given the City's place as the County seat and home of most of the industry. He thought that made good sense but wanted to make sure that in terms of any decisions that might come out of the HNA with this approach, that it was related to the city limits only – but that the overview could provide good context.
The second was that the City partner with the county (and other cities), to do a broader and more global HNA – however, in order for it to be of value for the City (in terms of UGBs, etc.) it would also need to include an HNA specific to the City of Tillamook (and the other cities).

Does that make sense? I did ask, that as you get closer, if we could hold a workshop for Tillamook and he said yes...if you want one!
Thanks!
Lis

Lisa M. Phipps
North Coast Regional Representative | Ocean/Coastal Services Division
Cell: 503-812-5448 | Main: 503-842-8222 ext 4004
lisa.phipps@state.or.us | www.oregon.gov/LCD

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[4] Note by T. Chase, FCS GROUP with respect to Safe Harbors. **"Safe harbor"** means an optional course of action that a local government may use to satisfy a requirement of Goal 14 (urbanization) based on projected population, and residential zoned density levels; and if the city needs to expand their urban growth boundary, a safe harbor analysis lends protections from appeals on certain elements which can cost time and money. A safe harbor approach per OAR 660-024-0040(1)-(8) is not the only way or necessarily the preferred way to comply with the requirements of a housing needs analysis. It was employed for the city of Dallas (along with other approaches) as an alternative way of looking at residential land need scenarios for the 20-year forecast. The Dallas City Council successfully adopted their HNA in December 2019 without appeal.

From: Paul Wyntergreen [mailto:pwyntergreen@tillamookor.gov]
Sent: Monday, December 16, 2019 2:11 PM
To: Phipps, Lisa <lphipps@dlcd.state.or.us>
Cc: Debbi Reeves <dreeves@tillamookor.gov>
Subject: Re: HNAs and EOAs

Thank you Lisa; this is very helpful and yes let's schedule up a workshop for February or March.

It is wonderful to see that a regional approach is a possibility. I am still a bit confused by your last couple of paragraphs; I understand that the City and the County (with other cities) would each do an HNA, but it is unclear as to whether the project demand could be allocated. Since High-premium cities at the beach will probably not produce sufficient approachable housing at rent levels that its service workers could afford, but places like Tillamook City could, is it allowable to assign additional growth allocation to certain cities if agreement is reached between communities?

Paul Wyntergreen
City Manager
City of Tillamook
210 Laurel Avenue
Tillamook, OR 97141

From: "Phipps, Lisa" <lisa.phipps@state.or.us>
Date: Friday, December 20, 2019 at 1:29 PM
To: Paul Wyntergreen <pwyntergreen@tillamookor.gov>
Cc: Debbi Reeves <dreeves@tillamookor.gov>
Subject: RE: HNAs and EOAs

Hi, Paul,
That is a great question with a good philosophical foundation. But, I am not sure that the laws have caught up with the realities of what regions like ours face. I will reach out again with the nuance described below, but my initial reaction, that while the regional approach will give people a better understanding of the how and why, the growth will still be confined to the PSU estimate for each city.

But, I will follow up.

Thanks, Lisa

Lisa M. Phipps
North Coast Regional Representative | Ocean/Coastal Services Division
Cell: 503-812-5448 | Main: 503-842-8222 ext 4004
lisa.phipps@state.or.us | www.oregon.gov/LCD

Tax Statements 2020-21

Account #	Map #	Tax 2020-21
399441	1N1007DD00114	$8,969.35
399444	1N1007DD00115	$5,075.78
399447	1N1007DD00116	$5,456.46
399450	1N1007DD00117	$2,329.53
399453	1N1007DD00118	$5,566.80
399456	1N1007DD00119	$2,329.53
399459	1N1007DD00120	$5,249.30
399462	1N1007DD00121	$5,451.05
399465	1N1007DD00122	$5,181.77
399468	1N1007DD00123	$7,609.27
62425	1N1007DA03000	$5,787.17
62611	1N1007DA03100	$5,419.97
355715	1N1007DA03104	$5,261.53
62719	1N1007DA03203	$2,647.78
322822	1N1007DA03204	$2,647.78
	TOTAL:	**$74,983.07**

*2020-21 county tax statements do not include taxes for Twin Rocks Sanitary District or Watseco-Barview Water District because those payments are made directly to the districts by the property owners.

REAL PROPERTY TAX STATEMENT
JULY 1, 2020 TO JUNE 30, 2021
TILLAMOOK COUNTY, OREGON
201 LAUREL AVE
TILLAMOOK, OREGON 97141
(503) 842-3400

ACCOUNT NO
399441

PROPERTY DESCRIPTION

CODE:	5624
MAP:	1N1007DD00114
ACRES:	0.36
SITUS:	17300 PINE BEACH WAY COUNTY
LEGAL:	PINE BEACH REPLAT UNIT 1 LOT-11

COGDALL, JOHN WILLIAM IV & LYNDA
39455 NW MURTAUGH RD
NORTH PLAINS OR 97133

VALUES:	LAST YEAR	THIS YEAR
REAL MARKET (RMV)		
LAND	366,590	336,830
STRUCTURES	1,169,580	1,238,690
TOTAL RMV	1,536,170	1,575,520
TOTAL ASSESSED VALUE	932,130	960,090
EXEMPTIONS		
NET TAXABLE:	932,130	960,090
TOTAL PROPERTY TAX:	8,718.29	8,969.35

TAX BY DISTRICT

SCHOOL 56	4,320.60
NW REGIONAL ESD	147.66
TILLAMOOK BAY CC	253.08
EDUCATION TOTAL:	4,721.34
TILLAMOOK COUNTY	1,486.79
COUNTY LIBRARY	624.06
SOLID WASTE	12.00
GARIBALDI RFD	462.09
TWIN ROCKS SANITARY DISTRICT	0.00
WATS-BARVIEW WD	0.00
PORT OF GARIBALDI	251.54
4H-EXTENSION SD	66.25
EMCD-911	180.78
TILLA TRANSPORTATION	192.02
TILLA SOIL & WATER CONS	57.61
GENERAL GOVT TOTAL:	3,333.14
COUNTY LIBRARY	46.47
TILLA CNTY BONDS AFTER 2001	250.68
SCHOOL 56 BONDS AFTER 2001	502.22
TILLA BAY CC BONDS AFTER 2001	115.50
BONDS - OTHER TOTAL:	914.87

Payments Online: www.co.tillamook.or.us
Payments by Phone: 1-844-784-9680

2020 - 2021 TAX (Before Discount) 8,969.35

PAYMENT OPTIONS

Date Due	3% Option	2% Option	Trimester
11/16/20	8,700.27	5,859.98	2,989.79
02/16/21			2,989.78
05/17/21		2,989.78	2,989.78
Total	8,700.27	8,849.76	8,969.35

TOTAL DUE (After Discount and Pre-payments) 8,700.27

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2020 - 2021 PROPERTY TAXES

ACCOUNT NO. 399441

TILLAMOOK COUNTY TAX COLLECTOR
201 LAUREL AVE
TILLAMOOK, OREGON 97141

PAYMENT OPTIONS	Discount	Date Due	Amount
Full Payment Enclosed	3%	11/16/20	8,700.27
or 2/3 Payment Enclosed	2%	11/16/20	5,859.98
or 1/3 Payment Enclosed	0%	11/16/20	2,989.79

FORWARDING SERVICE REQUESTED

☐ Mailing address change on back DISCOUNT IS LOST & INTEREST APPLIES AFTER DUE DATE

$ Enter Payment Amount

COGDALL, JOHN WILLIAM IV & LYNDA
39455 NW MURTAUGH RD
NORTH PLAINS OR 97133

MAKE PAYMENT TO:

TILLAMOOK COUNTY TAX COLLECTOR

-008776-870027

291000039944100002989790000585998000087002 74

REAL PROPERTY TAX STATEMENT
JULY 1, 2020 TO JUNE 30, 2021
TILLAMOOK COUNTY, OREGON
201 LAUREL AVE
TILLAMOOK, OREGON 97141
(503) 842-3400

ACCOUNT NO
399444

PROPERTY DESCRIPTION

CODE: 5624
MAP: 1N1007DD00115
ACRES: 0.27
SITUS: 17320 PINE BEACH WAY COUNTY
LEGAL: PINE BEACH REPLAT UNIT 1 LOT-12

ROGERS, MICHAEL J &
ROGERS, CHRISTINE M
17231 NW DAIRY CREED RD
NORTH PLAINS OR 97133

VALUES:	LAST YEAR	THIS YEAR
REAL MARKET (RMV)		
LAND	366,590	336,830
STRUCTURES	303,230	321,130
TOTAL RMV	669,820	657,960
TOTAL ASSESSED VALUE	526,960	542,760
EXEMPTIONS		
NET TAXABLE:	526,960	542,760
TOTAL PROPERTY TAX:	4,933.93	5,075.78

TAX BY DISTRICT

SCHOOL 56	2,442.53
NW REGIONAL ESD	83.48
TILLAMOOK BAY CC	143.07
EDUCATION TOTAL:	2,669.08
TILLAMOOK COUNTY	840.52
COUNTY LIBRARY	352.79
SOLID WASTE	12.00
GARIBALDI RFD	261.23
TWIN ROCKS SANITARY DISTRICT	0.00
WATS-BARVIEW WD	0.00
PORT OF GARIBALDI	142.20
4H-EXTENSION SD	37.45
EMCD-911	102.20
TILLA TRANSPORTATION	108.55
TILLA SOIL & WATER CONS	32.57
GENERAL GOVT TOTAL:	1,889.51
COUNTY LIBRARY	26.27
TILLA CNTY BONDS AFTER 2001	141.71
SCHOOL 56 BONDS AFTER 2001	283.92
TILLA BAY CC BONDS AFTER 2001	65.29
BONDS - OTHER TOTAL:	517.19

Payments Online: www.co.tillamook.or.us
Payments by Phone: 1-844-784-9680

2020 - 2021 TAX (Before Discount) 5,075.78

PAYMENT OPTIONS

Date Due	3% Option	2% Option	Trimester
11/16/20	4,923.51	3,316.17	1,691.93
02/16/21			1,691.93
05/17/21		1,691.93	1,691.92
Total	4,923.51	5,008.10	5,075.78

TOTAL DUE (After Discount and Pre-payments) 4,923.51

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2020 - 2021 PROPERTY TAXES

ACCOUNT NO. 399444

TILLAMOOK COUNTY TAX COLLECTOR
201 LAUREL AVE
TILLAMOOK, OREGON 97141

PAYMENT OPTIONS	Discount	Date Due	Amount
Full Payment Enclosed	3%	11/16/20	4,923.51
or 2/3 Payment Enclosed	2%	11/16/20	3,316.17
or 1/3 Payment Enclosed	0%	11/16/20	1,691.93

FORWARDING SERVICE REQUESTED

☐ Mailing address change on back

DISCOUNT IS LOST & INTEREST APPLIES AFTER DUE DATE

$ Enter Payment Amount

ROGERS, MICHAEL J &
ROGERS, CHRISTINE M
17231 NW DAIRY CREED RD
NORTH PLAINS OR 97133

MAKE PAYMENT TO:

TILLAMOOK COUNTY TAX COLLECTOR

-008807-492351

291000039944400001691930000331617000049235 17

REAL PROPERTY TAX STATEMENT
JULY 1, 2020 TO JUNE 30, 2021
TILLAMOOK COUNTY, OREGON
201 LAUREL AVE
TILLAMOOK, OREGON 97141
(503) 842-3400

ACCOUNT NO
399447

PROPERTY DESCRIPTION

CODE:	5624
MAP:	1N1007DD00116
ACRES:	0.21
SITUS:	17340 PINE BEACH WAY COUNTY
LEGAL:	PINE BEACH REPLAT UNIT 1 LOT-13

FARR, DAVID L & FRIEDA F
17340 PINE BEACH WAY
ROCKAWAY BEACH OR 97136

VALUES:	LAST YEAR	THIS YEAR
REAL MARKET (RMV)		
LAND	364,400	334,830
STRUCTURES	471,550	499,240
TOTAL RMV	835,950	834,070
TOTAL ASSESSED VALUE	593,000	610,790
EXEMPTIONS	26,435	27,228
NET TAXABLE:	566,565	583,562
TOTAL PROPERTY TAX:	5,303.83	5,456.46

TAX BY DISTRICT

SCHOOL 56	2,626.15
NW REGIONAL ESD	89.75
TILLAMOOK BAY CC	153.83
EDUCATION TOTAL:	2,869.73
TILLAMOOK COUNTY	903.71
COUNTY LIBRARY	379.32
SOLID WASTE	12.00
GARIBALDI RFD	280.87
TWIN ROCKS SANITARY DISTRICT	0.00
WATS-BARVIEW WD	0.00
PORT OF GARIBALDI	152.89
4H-EXTENSION SD	40.27
EMCD-911	109.88
TILLA TRANSPORTATION	116.71
TILLA SOIL & WATER CONS	35.01
GENERAL GOVT TOTAL:	2,030.66
COUNTY LIBRARY	28.24
TILLA CNTY BONDS AFTER 2001	152.37
SCHOOL 56 BONDS AFTER 2001	305.26
TILLA BAY CC BONDS AFTER 2001	70.20
BONDS - OTHER TOTAL:	556.07

TAX STATEMENT INFORMATION WAS SENT TO:
WFR Wells Fargo Real Estate Tax Services, LLC

Payments Online: www.co.tillamook.or.us
Payments by Phone: 1-844-784-9680

2020 - 2021 TAX (Before Discount) 5,456.46

PAYMENT OPTIONS

Date Due	3% Option	2% Option	Trimester
11/16/20	5,292.77	3,564.89	1,818.82
02/16/21			1,818.82
05/17/21		1,818.82	1,818.82
Total	5,292.77	5,383.71	5,456.46

TOTAL DUE (After Discount and Pre-payments) 5,292.77

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2020 - 2021 PROPERTY TAXES

ACCOUNT NO. 399447

TILLAMOOK COUNTY TAX COLLECTOR
201 LAUREL AVE
TILLAMOOK, OREGON 97141

PAYMENT OPTIONS	Discount	Date Due	Amount
Full Payment Enclosed	3%	11/16/20	5,292.77
or 2/3 Payment Enclosed	2%	11/16/20	3,564.89
or 1/3 Payment Enclosed	0%	11/16/20	1,818.82

FORWARDING SERVICE REQUESTED

☐ Mailing address change on back

DISCOUNT IS LOST & INTEREST APPLIES AFTER DUE DATE

$ Enter Payment Amount

FARR, DAVID L & FRIEDA F
17340 PINE BEACH WAY
ROCKAWAY BEACH OR 97136

MAKE PAYMENT TO:

TILLAMOOK COUNTY TAX COLLECTOR

-004543-529277

291000039944700001818820000356489000052927770

REAL PROPERTY TAX STATEMENT
JULY 1, 2020 TO JUNE 30, 2021
TILLAMOOK COUNTY, OREGON
201 LAUREL AVE
TILLAMOOK, OREGON 97141
(503) 842-3400

ACCOUNT NO
399450

PROPERTY DESCRIPTION

CODE: 5624
MAP: 1N1007DD00117
ACRES: 0.21

LEGAL: PINE BEACH REPLAT UNIT 1 LOT-14

CREEDON, JONATHAN C
7501 SE 17TH ST
VANCOUVER WA 98664

VALUES:	LAST YEAR	THIS YEAR
REAL MARKET (RMV)		
LAND	346,120	316,730
STRUCTURES	0	0
TOTAL RMV	346,120	316,730
TOTAL ASSESSED VALUE	242,420	249,690
EXEMPTIONS		
NET TAXABLE:	242,420	249,690
TOTAL PROPERTY TAX:	2,264.25	2,329.53

TAX BY DISTRICT

SCHOOL 56	1,123.65
NW REGIONAL ESD	38.40
TILLAMOOK BAY CC	65.82
EDUCATION TOTAL:	1,227.87
TILLAMOOK COUNTY	386.67
COUNTY LIBRARY	162.30
GARIBALDI RFD	120.18
TWIN ROCKS SANITARY DISTRICT	0.00
WATS-BARVIEW WD	0.00
PORT OF GARIBALDI	65.42
4H-EXTENSION SD	17.23
EMCD-911	47.02
TILLA TRANSPORTATION	49.94
TILLA SOIL & WATER CONS	14.98
GENERAL GOVT TOTAL:	863.74
COUNTY LIBRARY	12.08
TILLA CNTY BONDS AFTER 2001	65.19
SCHOOL 56 BONDS AFTER 2001	130.61
TILLA BAY CC BONDS AFTER 2001	30.04
BONDS - OTHER TOTAL:	237.92

Payments Online: www.co.tillamook.or.us
Payments by Phone: 1-844-784-9680

2020 - 2021 TAX (Before Discount) 2,329.53

PAYMENT OPTIONS

Date Due	3% Option	2% Option	Trimester
11/16/20	2,259.64	1,521.96	776.51
02/16/21			776.51
05/17/21		776.51	776.51
Total	2,259.64	2,298.47	2,329.53

TOTAL DUE (After Discount and Pre-payments) 2,259.64

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PLEASE RETURN THIS PORTION WITH YOUR PAYMENT
2020 - 2021 PROPERTY TAXES

ACCOUNT NO. 399450

TILLAMOOK COUNTY TAX COLLECTOR
201 LAUREL AVE
TILLAMOOK, OREGON 97141

PAYMENT OPTIONS	Discount	Date Due	Amount
Full Payment Enclosed	3%	11/16/20	2,259.64
or 2/3 Payment Enclosed	2%	11/16/20	1,521.96
or 1/3 Payment Enclosed	0%	11/16/20	776.51

FORWARDING SERVICE REQUESTED

☐ Mailing address change on back

DISCOUNT IS LOST & INTEREST APPLIES AFTER DUE DATE

$ Enter Payment Amount

CREEDON, JONATHAN C
7501 SE 17TH ST
VANCOUVER WA 98664

MAKE PAYMENT TO:

TILLAMOOK COUNTY TAX COLLECTOR

-020934-225964

29100003994500000077651000015219600002259647

REAL PROPERTY TAX STATEMENT
JULY 1, 2020 TO JUNE 30, 2021
TILLAMOOK COUNTY, OREGON
201 LAUREL AVE
TILLAMOOK, OREGON 97141
(503) 842-3400

ACCOUNT NO
399453

PROPERTY DESCRIPTION

CODE:	5624
MAP:	1N1007DD00118
ACRES:	0.21
SITUS:	17380 PINE BEACH WAY COUNTY
LEGAL:	PINE BEACH REPLAT UNIT 1 LOT-15

ROBERTS, DONALD W 1/2 TRUSTEE &
ROBERTS, BARBARA A TRUSTEE &
503 RHODODENDRON DR
VANCOUVER WA 98661

VALUES:	LAST YEAR	THIS YEAR
REAL MARKET (RMV)		
LAND	364,400	334,830
STRUCTURES	354,970	375,470
TOTAL RMV	719,370	710,300
TOTAL ASSESSED VALUE	578,050	595,390
EXEMPTIONS		
NET TAXABLE:	578,050	595,390
TOTAL PROPERTY TAX:	5,411.10	5,566.80

TAX BY DISTRICT

SCHOOL 56	2,679.37
NW REGIONAL ESD	91.57
TILLAMOOK BAY CC	156.94
EDUCATION TOTAL:	2,927.88
TILLAMOOK COUNTY	922.02
COUNTY LIBRARY	387.00
SOLID WASTE	12.00
GARIBALDI RFD	286.56
TWIN ROCKS SANITARY DISTRICT	0.00
WATS-BARVIEW WD	0.00
PORT OF GARIBALDI	155.99
4H-EXTENSION SD	41.08
EMCD-911	112.11
TILLA TRANSPORTATION	119.08
TILLA SOIL & WATER CONS	35.72
GENERAL GOVT TOTAL:	2,071.56
COUNTY LIBRARY	28.82
TILLA CNTY BONDS AFTER 2001	155.46
SCHOOL 56 BONDS AFTER 2001	311.45
TILLA BAY CC BONDS AFTER 2001	71.63
BONDS - OTHER TOTAL:	567.36

Payments Online: www.co.tillamook.or.us
Payments by Phone: 1-844-784-9680

2020 - 2021 TAX (Before Discount) 5,566.80

PAYMENT OPTIONS

Date Due	3% Option	2% Option	Trimester
11/16/20	5,399.80	3,636.98	1,855.60
02/16/21			1,855.60
05/17/21		1,855.60	1,855.60
Total	5,399.80	5,492.58	5,566.80

TOTAL DUE (After Discount and Pre-payments) 5,399.80

↑ Tear Here PLEASE RETURN THIS PORTION WITH YOUR PAYMENT Tear Here ↑

2020 - 2021 PROPERTY TAXES

ACCOUNT NO. 399453

TILLAMOOK COUNTY TAX COLLECTOR
201 LAUREL AVE
TILLAMOOK, OREGON 97141

PAYMENT OPTIONS	Discount	Date Due	Amount
Full Payment Enclosed	3%	11/16/20	5,399.80
or 2/3 Payment Enclosed	2%	11/16/20	3,636.98
or 1/3 Payment Enclosed	0%	11/16/20	1,855.60

FORWARDING SERVICE REQUESTED

☐ Mailing address change on back

DISCOUNT IS LOST & INTEREST APPLIES AFTER DUE DATE

$ Enter Payment Amount

ROBERTS, DONALD W 1/2 TRUSTEE &
ROBERTS, BARBARA A TRUSTEE &
503 RHODODENDRON DR
VANCOUVER WA 98661

MAKE PAYMENT TO:

TILLAMOOK COUNTY TAX COLLECTOR

-020870-539980

29100003994530000185560000036369800005399800

REAL PROPERTY TAX STATEMENT
JULY 1, 2020 TO JUNE 30, 2021
TILLAMOOK COUNTY, OREGON
201 LAUREL AVE
TILLAMOOK, OREGON 97141
(503) 842-3400

ACCOUNT NO
399456

PROPERTY DESCRIPTION

CODE: 5624
MAP: 1N1007DD00119
ACRES: 0.21

LEGAL: PINE BEACH REPLAT UNIT 1 LOT-16

MUNCH, MICHAEL T TRUSTEE
5012 DOGWOOD DR
LAKE OSWEGO OR 97035

VALUES:	LAST YEAR	THIS YEAR
REAL MARKET (RMV)		
LAND	346,120	316,730
STRUCTURES	0	0
TOTAL RMV	346,120	316,730
TOTAL ASSESSED VALUE	242,420	249,690
EXEMPTIONS		
NET TAXABLE:	242,420	249,690
TOTAL PROPERTY TAX:	2,264.25	2,329.53

TAX BY DISTRICT

SCHOOL 56	1,123.65
NW REGIONAL ESD	38.40
TILLAMOOK BAY CC	65.82
EDUCATION TOTAL:	1,227.87
TILLAMOOK COUNTY	386.67
COUNTY LIBRARY	162.30
GARIBALDI RFD	120.18
TWIN ROCKS SANITARY DISTRICT	0.00
WATS-BARVIEW WD	0.00
PORT OF GARIBALDI	65.42
4H-EXTENSION SD	17.23
EMCD-911	47.02
TILLA TRANSPORTATION	49.94
TILLA SOIL & WATER CONS	14.98
GENERAL GOVT TOTAL:	863.74
COUNTY LIBRARY	12.08
TILLA CNTY BONDS AFTER 2001	65.19
SCHOOL 56 BONDS AFTER 2001	130.61
TILLA BAY CC BONDS AFTER 2001	30.04
BONDS - OTHER TOTAL:	237.92

Payments Online: www.co.tillamook.or.us
Payments by Phone: 1-844-784-9680

2020 - 2021 TAX (Before Discount) 2,329.53

PAYMENT OPTIONS

Date Due	3% Option	2% Option	Trimester
11/16/20	2,259.64	1,521.96	776.51
02/16/21			776.51
05/17/21		776.51	776.51
Total	2,259.64	2,298.47	2,329.53

TOTAL DUE (After Discount and Pre-payments) 2,259.64

Tear Here — PLEASE RETURN THIS PORTION WITH YOUR PAYMENT — Tear Here

2020 - 2021 PROPERTY TAXES

ACCOUNT NO. 399456

TILLAMOOK COUNTY TAX COLLECTOR
201 LAUREL AVE
TILLAMOOK, OREGON 97141

PAYMENT OPTIONS	Discount	Date Due	Amount
Full Payment Enclosed	3%	11/16/20	2,259.64
or 2/3 Payment Enclosed	2%	11/16/20	1,521.96
or 1/3 Payment Enclosed	0%	11/16/20	776.51

FORWARDING SERVICE REQUESTED

☐ Mailing address change on back

DISCOUNT IS LOST & INTEREST APPLIES AFTER DUE DATE

$ Enter Payment Amount

MUNCH, MICHAEL T TRUSTEE
5012 DOGWOOD DR
LAKE OSWEGO OR 97035

MAKE PAYMENT TO:

TILLAMOOK COUNTY TAX COLLECTOR

-002930-225964

29100003994560000077651000015219600002259644

REAL PROPERTY TAX STATEMENT
JULY 1, 2020 TO JUNE 30, 2021
TILLAMOOK COUNTY, OREGON
201 LAUREL AVE
TILLAMOOK, OREGON 97141
(503) 842-3400

ACCOUNT NO
399459

PROPERTY DESCRIPTION

CODE:	5624
MAP:	1N1007DD00120
ACRES:	0.21
SITUS:	17420 PINE BEACH WAY COUNTY
LEGAL:	PINE BEACH REPLAT UNIT 1 LOT-17

17420 PINE BEACH WAY LLC
%MICHAEL T MUNCH
5012 DOGWOOD DR
LAKE OSWEGO OR 97035

VALUES:	LAST YEAR	THIS YEAR
REAL MARKET (RMV)		
LAND	364,400	334,830
STRUCTURES	350,220	370,290
TOTAL RMV	714,620	705,120
TOTAL ASSESSED VALUE	545,010	561,360
EXEMPTIONS		
NET TAXABLE:	545,010	561,360
TOTAL PROPERTY TAX:	5,102.49	5,249.30

TAX BY DISTRICT

SCHOOL 56	2,526.23
NW REGIONAL ESD	86.34
TILLAMOOK BAY CC	147.97
EDUCATION TOTAL:	2,760.54
TILLAMOOK COUNTY	869.32
COUNTY LIBRARY	364.88
SOLID WASTE	12.00
GARIBALDI RFD	270.18
TWIN ROCKS SANITARY DISTRICT	0.00
WATS-BARVIEW WD	0.00
PORT OF GARIBALDI	147.08
4H-EXTENSION SD	38.73
EMCD-911	105.70
TILLA TRANSPORTATION	112.27
TILLA SOIL & WATER CONS	33.68
GENERAL GOVT TOTAL:	1,953.84
COUNTY LIBRARY	27.17
TILLA CNTY BONDS AFTER 2001	146.57
SCHOOL 56 BONDS AFTER 2001	293.65
TILLA BAY CC BONDS AFTER 2001	67.53
BONDS - OTHER TOTAL:	534.92

Payments Online: www.co.tillamook.or.us
Payments by Phone: 1-844-784-9680

2020 - 2021 TAX (Before Discount) 5,249.30

PAYMENT OPTIONS

Date Due	3% Option	2% Option	Trimester
11/16/20	5,091.82	3,429.54	1,749.77
02/16/21			1,749.77
05/17/21		1,749.77	1,749.76
Total	5,091.82	5,179.31	5,249.30

TOTAL DUE (After Discount and Pre-payments) 5,091.82

↑ Tear Here — PLEASE RETURN THIS PORTION WITH YOUR PAYMENT — Tear Here ↑

2020 - 2021 PROPERTY TAXES

ACCOUNT NO. 399459

TILLAMOOK COUNTY TAX COLLECTOR
201 LAUREL AVE
TILLAMOOK, OREGON 97141

PAYMENT OPTIONS	Discount	Date Due	Amount
Full Payment Enclosed	3%	11/16/20	5,091.82
or 2/3 Payment Enclosed	2%	11/16/20	3,429.54
or 1/3 Payment Enclosed	0%	11/16/20	1,749.77

FORWARDING SERVICE REQUESTED

☐ Mailing address change on back

DISCOUNT IS LOST & INTEREST APPLIES AFTER DUE DATE

$ Enter Payment Amount

17420 PINE BEACH WAY LLC
%MICHAEL T MUNCH
5012 DOGWOOD DR
LAKE OSWEGO OR 97035

MAKE PAYMENT TO:

TILLAMOOK COUNTY TAX COLLECTOR

-002859-509182

29100003994590000174977000034295400005091828

REAL PROPERTY TAX STATEMENT
JULY 1, 2020 TO JUNE 30, 2021
TILLAMOOK COUNTY, OREGON
201 LAUREL AVE
TILLAMOOK, OREGON 97141
(503) 842-3400

ACCOUNT NO
399462

PROPERTY DESCRIPTION

CODE:	5624
MAP:	1N1007DD00121
ACRES:	0.20
SITUS:	17440 PINE BEACH WAY COUNTY
LEGAL:	PINE BEACH REPLAT UNIT 1 LOT-18

KLEIN, JEFFREY S & TERRY
12230 SW RIVERVIEW LN
WILSONVILLE OR 97070

VALUES:	LAST YEAR	THIS YEAR
REAL MARKET (RMV)		
LAND	364,400	334,830
STRUCTURES	326,640	345,810
TOTAL RMV	691,040	680,640
TOTAL ASSESSED VALUE	566,000	582,980
EXEMPTIONS		
NET TAXABLE:	566,000	582,980
TOTAL PROPERTY TAX:	5,298.56	5,451.05

TAX BY DISTRICT

SCHOOL 56	2,623.53
NW REGIONAL ESD	89.66
TILLAMOOK BAY CC	153.67
EDUCATION TOTAL:	2,866.86
TILLAMOOK COUNTY	902.80
COUNTY LIBRARY	378.94
SOLID WASTE	12.00
GARIBALDI RFD	280.59
TWIN ROCKS SANITARY DISTRICT	0.00
WATS-BARVIEW WD	0.00
PORT OF GARIBALDI	152.74
4H-EXTENSION SD	40.23
EMCD-911	109.78
TILLA TRANSPORTATION	116.60
TILLA SOIL & WATER CONS	34.98
GENERAL GOVT TOTAL:	2,028.66
COUNTY LIBRARY	28.22
TILLA CNTY BONDS AFTER 2001	152.22
SCHOOL 56 BONDS AFTER 2001	304.96
TILLA BAY CC BONDS AFTER 2001	70.13
BONDS - OTHER TOTAL:	555.53

Payments Online: www.co.tillamook.or.us
Payments by Phone: 1-844-784-9680

2020 - 2021 TAX (Before Discount) 5,451.05

PAYMENT OPTIONS

Date Due	3% Option	2% Option	Trimester
11/16/20	5,287.52	3,561.35	1,817.02
02/16/21			1,817.02
05/17/21		1,817.02	1,817.01
Total	5,287.52	5,378.37	5,451.05

TOTAL DUE (After Discount and Pre-payments) 5,287.52

↑ Tear Here — PLEASE RETURN THIS PORTION WITH YOUR PAYMENT — Tear Here ↑

2020 - 2021 PROPERTY TAXES

ACCOUNT NO. 399462

TILLAMOOK COUNTY TAX COLLECTOR
201 LAUREL AVE
TILLAMOOK, OREGON 97141

PAYMENT OPTIONS	Discount	Date Due	Amount
Full Payment Enclosed	3%	11/16/20	5,287.52
or 2/3 Payment Enclosed	2%	11/16/20	3,561.35
or 1/3 Payment Enclosed	0%	11/16/20	1,817.02

FORWARDING SERVICE REQUESTED

☐ Mailing address change on back

DISCOUNT IS LOST & INTEREST APPLIES AFTER DUE DATE

$ Enter Payment Amount

KLEIN, JEFFREY S & TERRY
12230 SW RIVERVIEW LN
WILSONVILLE OR 97070

MAKE PAYMENT TO:

TILLAMOOK COUNTY TAX COLLECTOR

-003822-528752

29100003994620000181702000035613500005287521

REAL PROPERTY TAX STATEMENT
JULY 1, 2020 TO JUNE 30, 2021
TILLAMOOK COUNTY, OREGON
201 LAUREL AVE
TILLAMOOK, OREGON 97141
(503) 842-3400

ACCOUNT NO
399465

PROPERTY DESCRIPTION

CODE:	5624
MAP:	1N1007DD00122
ACRES:	0.24
SITUS:	17460 PINE BEACH WAY COUNTY
LEGAL:	PINE BEACH REPLAT UNIT 1 LOT-19

HOLLAND, GLENNA M TRUSTEE &
HOLLAND, RACHAEL M TRUSTEE
3136 NE 45TH AVE
PORTLAND OR 97213

VALUES:	LAST YEAR	THIS YEAR
REAL MARKET (RMV)		
LAND	366,590	336,830
STRUCTURES	343,370	362,100
TOTAL RMV	709,960	698,930
TOTAL ASSESSED VALUE	537,990	554,120
EXEMPTIONS		
NET TAXABLE:	537,990	554,120
TOTAL PROPERTY TAX:	5,036.91	5,181.77

TAX BY DISTRICT

SCHOOL 56	2,493.65
NW REGIONAL ESD	85.22
TILLAMOOK BAY CC	146.07
EDUCATION TOTAL:	2,724.94
TILLAMOOK COUNTY	858.11
COUNTY LIBRARY	360.18
SOLID WASTE	12.00
GARIBALDI RFD	266.70
TWIN ROCKS SANITARY DISTRICT	0.00
WATS-BARVIEW WD	0.00
PORT OF GARIBALDI	145.18
4H-EXTENSION SD	38.23
EMCD-911	104.34
TILLA TRANSPORTATION	110.82
TILLA SOIL & WATER CONS	33.25
GENERAL GOVT TOTAL:	1,928.81
COUNTY LIBRARY	26.82
TILLA CNTY BONDS AFTER 2001	144.68
SCHOOL 56 BONDS AFTER 2001	289.86
TILLA BAY CC BONDS AFTER 2001	66.66
BONDS - OTHER TOTAL:	528.02

Payments Online: www.co.tillamook.or.us
Payments by Phone: 1-844-784-9680

2020 - 2021 TAX (Before Discount) 5,181.77

PAYMENT OPTIONS

Date Due	3% Option	2% Option	Trimester
11/16/20	5,026.32	3,385.42	1,727.26
02/16/21			1,727.26
05/17/21		1,727.26	1,727.25
Total	5,026.32	5,112.68	5,181.77

TOTAL DUE (After Discount and Pre-payments) 5,026.32

↑ Tear Here PLEASE RETURN THIS PORTION WITH YOUR PAYMENT Tear Here ↑

2020 - 2021 PROPERTY TAXES

ACCOUNT NO. 399465

TILLAMOOK COUNTY TAX COLLECTOR
201 LAUREL AVE
TILLAMOOK, OREGON 97141

PAYMENT OPTIONS	Discount	Date Due	Amount
Full Payment Enclosed	3%	11/16/20	5,026.32
or 2/3 Payment Enclosed	2%	11/16/20	3,385.42
or 1/3 Payment Enclosed	0%	11/16/20	1,727.26

FORWARDING SERVICE REQUESTED

☐ Mailing address change on back

DISCOUNT IS LOST & INTEREST APPLIES AFTER DUE DATE

$ Enter Payment Amount

HOLLAND, GLENNA M TRUSTEE &
HOLLAND, RACHAEL M TRUSTEE
3136 NE 45TH AVE
PORTLAND OR 97213

MAKE PAYMENT TO:

TILLAMOOK COUNTY TAX COLLECTOR

-015970-502632

291000039946500001727260000338542000005026328

REAL PROPERTY TAX STATEMENT
JULY 1, 2020 TO JUNE 30, 2021
TILLAMOOK COUNTY, OREGON
201 LAUREL AVE
TILLAMOOK, OREGON 97141
(503) 842-3400

ACCOUNT NO
399468

PROPERTY DESCRIPTION

CODE:	5624
MAP:	1N1007DD00123
ACRES:	0.33
SITUS:	17480 PINE BEACH WAY ROCKAWAY BEACH
LEGAL:	PINE BEACH REPLAT UNIT 1 LOT-20

ELLIS, MICHAEL LEON TRUSTEE
2614 Q ST
VANCOUVER WA 98663

VALUES:	LAST YEAR	THIS YEAR
REAL MARKET (RMV)		
LAND	366,090	336,330
STRUCTURES	758,590	802,560
TOTAL RMV	1,124,680	1,138,890
TOTAL ASSESSED VALUE	790,600	814,310
EXEMPTIONS		
NET TAXABLE:	790,600	814,310
TOTAL PROPERTY TAX:	7,396.36	7,609.27

TAX BY DISTRICT

SCHOOL 56	3,664.56
NW REGIONAL ESD	125.24
TILLAMOOK BAY CC	214.65
EDUCATION TOTAL:	4,004.45
TILLAMOOK COUNTY	1,261.04
COUNTY LIBRARY	529.30
SOLID WASTE	12.00
GARIBALDI RFD	391.93
TWIN ROCKS SANITARY DISTRICT	0.00
WATS-BARVIEW WD	0.00
PORT OF GARIBALDI	213.35
4H-EXTENSION SD	56.19
EMCD-911	153.33
TILLA TRANSPORTATION	162.86
TILLA SOIL & WATER CONS	48.86
GENERAL GOVT TOTAL:	2,828.86
COUNTY LIBRARY	39.41
TILLA CNTY BONDS AFTER 2001	212.62
SCHOOL 56 BONDS AFTER 2001	425.97
TILLA BAY CC BONDS AFTER 2001	97.96
BONDS - OTHER TOTAL:	775.96

Payments Online: www.co.tillamook.or.us
Payments by Phone: 1-844-784-9680

2020 - 2021 TAX (Before Discount) 7,609.27

PAYMENT OPTIONS

Date Due	3% Option	2% Option	Trimester
11/16/20	7,380.99	4,971.39	2,536.43
02/16/21			2,536.42
05/17/21		2,536.42	2,536.42
Total	7,380.99	7,507.81	7,609.27

TOTAL DUE (After Discount and Pre-payments) 7,380.99

↑ Tear Here — PLEASE RETURN THIS PORTION WITH YOUR PAYMENT — Tear Here ↑

2020 - 2021 PROPERTY TAXES

ACCOUNT NO. 399468

TILLAMOOK COUNTY TAX COLLECTOR
201 LAUREL AVE
TILLAMOOK, OREGON 97141

PAYMENT OPTIONS	Discount	Date Due	Amount
Full Payment Enclosed	3%	11/16/20	7,380.99
or 2/3 Payment Enclosed	2%	11/16/20	4,971.39
or 1/3 Payment Enclosed	0%	11/16/20	2,536.43

FORWARDING SERVICE REQUESTED

☐ Mailing address change on back

DISCOUNT IS LOST & INTEREST APPLIES AFTER DUE DATE

$ Enter Payment Amount

ELLIS, MICHAEL LEON TRUSTEE
2614 Q ST
VANCOUVER WA 98663

MAKE PAYMENT TO:

TILLAMOOK COUNTY TAX COLLECTOR

-020912-738099

29100003994680000253643000049713900007380991

REAL PROPERTY TAX STATEMENT
JULY 1, 2020 TO JUNE 30, 2021
TILLAMOOK COUNTY, OREGON
201 LAUREL AVE
TILLAMOOK, OREGON 97141
(503) 842-3400

ACCOUNT NO
62425

PROPERTY DESCRIPTION

CODE:	5624
MAP:	1N1007DA03000
ACRES:	0.67
SITUS:	17560 OCEAN BLVD COUNTY

DOWLING, DAVID A & ANGELA M
19690 WILDWOOD DR
WEST LINN OR 97068

VALUES:	LAST YEAR	THIS YEAR
REAL MARKET (RMV)		
LAND	368,780	338,830
STRUCTURES	327,820	351,300
TOTAL RMV	696,600	690,130
TOTAL ASSESSED VALUE	600,990	619,010
EXEMPTIONS		
NET TAXABLE:	600,990	619,010
TOTAL PROPERTY TAX:	5,625.38	5,787.17

TAX BY DISTRICT

SCHOOL 56	2,785.67
NW REGIONAL ESD	95.20
TILLAMOOK BAY CC	163.17
EDUCATION TOTAL:	3,044.04
TILLAMOOK COUNTY	958.60
COUNTY LIBRARY	402.36
SOLID WASTE	12.00
GARIBALDI RFD	297.93
TWIN ROCKS SANITARY DISTRICT	0.00
WATS-BARVIEW WD	0.00
PORT OF GARIBALDI	162.18
4H-EXTENSION SD	42.71
EMCD-911	116.56
TILLA TRANSPORTATION	123.80
TILLA SOIL & WATER CONS	37.14
GENERAL GOVT TOTAL:	2,153.28
COUNTY LIBRARY	29.96
TILLA CNTY BONDS AFTER 2001	161.62
SCHOOL 56 BONDS AFTER 2001	323.80
TILLA BAY CC BONDS AFTER 2001	74.47
BONDS - OTHER TOTAL:	589.85

Payments Online: www.co.tillamook.or.us
Payments by Phone: 1-844-784-9680

2020 - 2021 TAX (Before Discount) 5,787.17

PAYMENT OPTIONS

Date Due	3% Option	2% Option	Trimester
11/16/20	5,613.55	3,780.95	1,929.06
02/16/21			1,929.06
05/17/21		1,929.06	1,929.05
Total	5,613.55	5,710.01	5,787.17

TOTAL DUE (After Discount and Pre-payments) 5,613.55

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2020 - 2021 PROPERTY TAXES

ACCOUNT NO. 62425

TILLAMOOK COUNTY TAX COLLECTOR
201 LAUREL AVE
TILLAMOOK, OREGON 97141

PAYMENT OPTIONS	Discount	Date Due	Amount
Full Payment Enclosed	3%	11/16/20	5,613.55
or 2/3 Payment Enclosed	2%	11/16/20	3,780.95
or 1/3 Payment Enclosed	0%	11/16/20	1,929.06

FORWARDING SERVICE REQUESTED

☐ Mailing address change on back

DISCOUNT IS LOST & INTEREST APPLIES AFTER DUE DATE

$ Enter Payment Amount

DOWLING, DAVID A & ANGELA M
19690 WILDWOOD DR
WEST LINN OR 97068

MAKE PAYMENT TO:

TILLAMOOK COUNTY TAX COLLECTOR

-003645-561355

291000006242500001929060000378095000056135558

REAL PROPERTY TAX STATEMENT
JULY 1, 2020 TO JUNE 30, 2021
TILLAMOOK COUNTY, OREGON
201 LAUREL AVE
TILLAMOOK, OREGON 97141
(503) 842-3400

ACCOUNT NO
62611

PROPERTY DESCRIPTION

CODE:	5624
MAP:	1N1007DA03100
ACRES:	0.22
SITUS:	17490 OCEAN BLVD COUNTY

DANNO, EVAN F TRUSTEE
144 HIGHLAND RIDGE RD
KALISPELL MT 59901

VALUES:	LAST YEAR	THIS YEAR
REAL MARKET (RMV)		
LAND	364,400	334,830
STRUCTURES	343,880	363,480
TOTAL RMV	708,280	698,310
TOTAL ASSESSED VALUE	562,770	579,650
EXEMPTIONS		
NET TAXABLE:	562,770	579,650
TOTAL PROPERTY TAX:	5,268.40	5,419.97

TAX BY DISTRICT

SCHOOL 56	2,608.54
NW REGIONAL ESD	89.15
TILLAMOOK BAY CC	152.80
EDUCATION TOTAL:	2,850.49
TILLAMOOK COUNTY	897.64
COUNTY LIBRARY	376.77
SOLID WASTE	12.00
GARIBALDI RFD	278.99
TWIN ROCKS SANITARY DISTRICT	0.00
WATS-BARVIEW WD	0.00
PORT OF GARIBALDI	151.87
4H-EXTENSION SD	40.00
EMCD-911	109.15
TILLA TRANSPORTATION	115.93
TILLA SOIL & WATER CONS	34.78
GENERAL GOVT TOTAL:	2,017.13
COUNTY LIBRARY	28.06
TILLA CNTY BONDS AFTER 2001	151.35
SCHOOL 56 BONDS AFTER 2001	303.21
TILLA BAY CC BONDS AFTER 2001	69.73
BONDS - OTHER TOTAL:	552.35

Payments Online: www.co.tillamook.or.us
Payments by Phone: 1-844-784-9680

2020 - 2021 TAX (Before Discount) 5,419.97

PAYMENT OPTIONS

Date Due	3% Option	2% Option	Trimester
11/16/20	5,257.37	3,541.04	1,806.66
02/16/21			1,806.66
05/17/21		1,806.66	1,806.65
Total	5,257.37	5,347.70	5,419.97

TOTAL DUE (After Discount and Pre-payments) 5,257.37

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2020 - 2021 PROPERTY TAXES

ACCOUNT NO. 62611

TILLAMOOK COUNTY TAX COLLECTOR
201 LAUREL AVE
TILLAMOOK, OREGON 97141

PAYMENT OPTIONS	Discount	Date Due	Amount
Full Payment Enclosed	3%	11/16/20	5,257.37
or 2/3 Payment Enclosed	2%	11/16/20	3,541.04
or 1/3 Payment Enclosed	0%	11/16/20	1,806.66

FORWARDING SERVICE REQUESTED

☐ Mailing address change on back

DISCOUNT IS LOST & INTEREST APPLIES AFTER DUE DATE

$ Enter Payment Amount

DANNO, EVAN F TRUSTEE
144 HIGHLAND RIDGE RD
KALISPELL MT 59901

MAKE PAYMENT TO:

TILLAMOOK COUNTY TAX COLLECTOR

-000343-525737

29100000626110000180666000035410400005257379

REAL PROPERTY TAX STATEMENT
JULY 1, 2020 TO JUNE 30, 2021
TILLAMOOK COUNTY, OREGON
201 LAUREL AVE
TILLAMOOK, OREGON 97141
(503) 842-3400

ACCOUNT NO
355715

PROPERTY DESCRIPTION

CODE:	5624
MAP:	1N1007DA03104
ACRES:	0.17
SITUS:	17488 OCEAN BLVD COUNTY

LOCKWOOD, MARY ANN CO-TRUSTEE &
KEMBALL, T. MARK CO-TRUSTEE
2355 SW SCENIC DR
PORTLAND OR 97225

VALUES:	LAST YEAR	THIS YEAR
REAL MARKET (RMV)		
LAND	364,400	334,830
STRUCTURES	284,490	301,390
TOTAL RMV	648,890	636,220
TOTAL ASSESSED VALUE	546,290	562,670
EXEMPTIONS		
NET TAXABLE:	546,290	562,670
TOTAL PROPERTY TAX:	5,114.45	5,261.53

TAX BY DISTRICT

SCHOOL 56	2,532.13
NW REGIONAL ESD	86.54
TILLAMOOK BAY CC	148.32
EDUCATION TOTAL:	2,766.99
TILLAMOOK COUNTY	871.35
COUNTY LIBRARY	365.74
SOLID WASTE	12.00
GARIBALDI RFD	270.81
TWIN ROCKS SANITARY DISTRICT	0.00
WATS-BARVIEW WD	0.00
PORT OF GARIBALDI	147.42
4H-EXTENSION SD	38.82
EMCD-911	105.95
TILLA TRANSPORTATION	112.53
TILLA SOIL & WATER CONS	33.76
GENERAL GOVT TOTAL:	1,958.38
COUNTY LIBRARY	27.23
TILLA CNTY BONDS AFTER 2001	146.91
SCHOOL 56 BONDS AFTER 2001	294.33
TILLA BAY CC BONDS AFTER 2001	67.69
BONDS - OTHER TOTAL:	536.16

Payments Online: www.co.tillamook.or.us
Payments by Phone: 1-844-784-9680

2020 - 2021 TAX (Before Discount) 5,261.53

PAYMENT OPTIONS

Date Due	3% Option	2% Option	Trimester
11/16/20	5,103.68	3,437.54	1,753.85
02/16/21			1,753.84
05/17/21		1,753.84	1,753.84
Total	5,103.68	5,191.38	5,261.53

TOTAL DUE (After Discount and Pre-payments) 5,103.68

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2020 - 2021 PROPERTY TAXES

ACCOUNT NO. 355715

TILLAMOOK COUNTY TAX COLLECTOR
201 LAUREL AVE
TILLAMOOK, OREGON 97141

PAYMENT OPTIONS	Discount	Date Due	Amount
Full Payment Enclosed	3%	11/16/20	5,103.68
or 2/3 Payment Enclosed	2%	11/16/20	3,437.54
or 1/3 Payment Enclosed	0%	11/16/20	1,753.85

FORWARDING SERVICE REQUESTED

☐ Mailing address change on back

DISCOUNT IS LOST & INTEREST APPLIES AFTER DUE DATE

$ Enter Payment Amount

LOCKWOOD, MARY ANN CO-TRUSTEE &
KEMBALL, T. MARK CO-TRUSTEE
2355 SW SCENIC DR
PORTLAND OR 97225

MAKE PAYMENT TO:

TILLAMOOK COUNTY TAX COLLECTOR

-017297-510368

29100003557150000175385000034375400005103685

REAL PROPERTY TAX STATEMENT
JULY 1, 2020 TO JUNE 30, 2021
TILLAMOOK COUNTY, OREGON
201 LAUREL AVE
TILLAMOOK, OREGON 97141
(503) 842-3400

ACCOUNT NO
62719

PROPERTY DESCRIPTION

CODE: 5624
MAP: 1N1007DA03203
ACRES: 0.15

BERG, MEGAN
1734 W YAMPA ST
COLORADO SPRINGS CO 80904

VALUES:	LAST YEAR	THIS YEAR
REAL MARKET (RMV)		
LAND	341,740	312,720
STRUCTURES	0	0
TOTAL RMV	341,740	312,720
TOTAL ASSESSED VALUE	275,540	283,800
EXEMPTIONS		
NET TAXABLE:	275,540	283,800
TOTAL PROPERTY TAX:	2,573.60	2,647.78

TAX BY DISTRICT

SCHOOL 56	1,277.16
NW REGIONAL ESD	43.65
TILLAMOOK BAY CC	74.81
EDUCATION TOTAL:	1,395.62
TILLAMOOK COUNTY	439.49
COUNTY LIBRARY	184.47
GARIBALDI RFD	136.59
TWIN ROCKS SANITARY DISTRICT	0.00
WATS-BARVIEW WD	0.00
PORT OF GARIBALDI	74.36
4H-EXTENSION SD	19.58
EMCD-911	53.44
TILLA TRANSPORTATION	56.76
TILLA SOIL & WATER CONS	17.03
GENERAL GOVT TOTAL:	981.72
COUNTY LIBRARY	13.74
TILLA CNTY BONDS AFTER 2001	74.10
SCHOOL 56 BONDS AFTER 2001	148.46
TILLA BAY CC BONDS AFTER 2001	34.14
BONDS - OTHER TOTAL:	270.44

TAX STATEMENT INFORMATION WAS SENT TO:
FTC First Tech Credit Union

Payments Online: www.co.tillamook.or.us
Payments by Phone: 1-844-784-9680

2020 - 2021 TAX (Before Discount) 2,647.78

PAYMENT OPTIONS

Date Due	3% Option	2% Option	Trimester
11/16/20	2,568.35	1,729.89	882.60
02/16/21			882.59
05/17/21		882.59	882.59
Total	2,568.35	2,612.48	2,647.78

TOTAL DUE (After Discount and Pre-payments) 2,568.35

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2020 - 2021 PROPERTY TAXES

ACCOUNT NO. 62719

TILLAMOOK COUNTY TAX COLLECTOR
201 LAUREL AVE
TILLAMOOK, OREGON 97141

PAYMENT OPTIONS	Discount	Date Due	Amount
Full Payment Enclosed	3%	11/16/20	2,568.35
or 2/3 Payment Enclosed	2%	11/16/20	1,729.89
or 1/3 Payment Enclosed	0%	11/16/20	882.60

FORWARDING SERVICE REQUESTED

$ Enter Payment Amount

☐ Mailing address change on back

DISCOUNT IS LOST & INTEREST APPLIES AFTER DUE DATE

BERG, MEGAN
1734 W YAMPA ST
COLORADO SPRINGS CO 80904

MAKE PAYMENT TO:

TILLAMOOK COUNTY TAX COLLECTOR

-000873-256835

2910000062719000008826000001729890000256835б

REAL PROPERTY TAX STATEMENT
JULY 1, 2020 TO JUNE 30, 2021
TILLAMOOK COUNTY, OREGON
201 LAUREL AVE
TILLAMOOK, OREGON 97141
(503) 842-3400

ACCOUNT NO 322822

PROPERTY DESCRIPTION

CODE:	5624
MAP:	1N1007DA03204
ACRES:	0.12

VON SEGGERN, HEATHER STECK
337 SOMERSET AVE
SARASOTA FL 34243

VALUES:	LAST YEAR	THIS YEAR
REAL MARKET (RMV)		
LAND	341,740	312,720
STRUCTURES	0	0
TOTAL RMV	341,740	312,720
TOTAL ASSESSED VALUE	275,540	283,800
EXEMPTIONS		
NET TAXABLE:	275,540	283,800
TOTAL PROPERTY TAX:	2,573.60	2,647.78

TAX BY DISTRICT

SCHOOL 56	1,277.16
NW REGIONAL ESD	43.65
TILLAMOOK BAY CC	74.81
EDUCATION TOTAL:	1,395.62
TILLAMOOK COUNTY	439.49
COUNTY LIBRARY	184.47
GARIBALDI RFD	136.59
TWIN ROCKS SANITARY DISTRICT	0.00
WATS-BARVIEW WD	0.00
PORT OF GARIBALDI	74.36
4H-EXTENSION SD	19.58
EMCD-911	53.44
TILLA TRANSPORTATION	56.76
TILLA SOIL & WATER CONS	17.03
GENERAL GOVT TOTAL:	981.72
COUNTY LIBRARY	13.74
TILLA CNTY BONDS AFTER 2001	74.10
SCHOOL 56 BONDS AFTER 2001	148.46
TILLA BAY CC BONDS AFTER 2001	34.14
BONDS - OTHER TOTAL:	270.44

Payments Online: www.co.tillamook.or.us
Payments by Phone: 1-844-784-9680

2020 - 2021 TAX (Before Discount) 2,647.78

PAYMENT OPTIONS

Date Due	3% Option	2% Option	Trimester
11/16/20	2,568.35	1,729.89	882.60
02/16/21			882.59
05/17/21		882.59	882.59
Total	2,568.35	2,612.48	2,647.78

TOTAL DUE (After Discount and Pre-payments) 2,568.35

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2020 - 2021 PROPERTY TAXES

ACCOUNT NO. 322822

TILLAMOOK COUNTY TAX COLLECTOR
201 LAUREL AVE
TILLAMOOK, OREGON 97141

PAYMENT OPTIONS	Discount	Date Due	Amount
Full Payment Enclosed	3%	11/16/20	2,568.35
or 2/3 Payment Enclosed	2%	11/16/20	1,729.89
or 1/3 Payment Enclosed	0%	11/16/20	882.60

FORWARDING SERVICE REQUESTED

☐ Mailing address change on back

DISCOUNT IS LOST & INTEREST APPLIES AFTER DUE DATE

$ Enter Payment Amount

VON SEGGERN, HEATHER STECK
337 SOMERSET AVE
SARASOTA FL 34243

MAKE PAYMENT TO:

TILLAMOOK COUNTY TAX COLLECTOR

-000218-256835

2910000322822000008826000017298900002568354

Allison Hinderer

From:	Sarah Mitchell <sm@klgpc.com>
Sent:	Tuesday, July 27, 2021 4:20 PM
To:	Sarah Absher; Allison Hinderer
Cc:	Wendie Kellington; Bill and Lynda Cogdall (jwcogdall@gmail.com); Bill and Lynda Cogdall (lcogdall@aol.com); Brett Butcher (brett@passion4people.org); Dave and Frieda Farr (dfarrwestproperties@gmail.com); David Dowling; David Hayes (tdavidh1 @comcast.net); Don and Barbara Roberts (donrobertsemail@gmail.com); Don and Barbara Roberts (robertsfm6@gmail.com); evandanno@hotmail.com; heather.vonseggern@img.education; Jeff and Terry Klein (jeffklein@wvmeat.com); Jon Creedon (jcc@pacifier.com); kemball@easystreet.net; meganberglaw@aol.com; Michael Munch (michaelmunch@comcast.net); Mike and Chris Rogers (mjr2153@aol.com); Mike Ellis (mikeellispdx@gmail.com); Rachael Holland (rachael@pacificopportunities.com); teriklein59@aol.com
Subject:	EXTERNAL: 851-21-000086-PLNG & 851-21-000086-PLNG-01 Pine Beach BOCC Hearing Packet - Additional Evidence
Attachments:	Exh 6 - West Consultants Fourth Supp Technical Memo 7.27.2021.pdf
Importance:	High

[**NOTICE:** This message originated outside of Tillamook County -- **DO NOT CLICK** on **links** or open **attachments** unless you are sure the content is safe.]

Hi Sarah and Allison,

Please include the additional attached exhibit in the record of 851-21-000086-PLNG /851-21-000086-PLNG-01 and in the Board of Commissioners' packet for the July 28, 2021 hearing on these matters. Would you please confirm your receipt? Thank you.

Best,
Sarah

KELLINGTON LAW GROUP

Sarah C. Mitchell | Associate Attorney
P.O. Box 159
Lake Oswego, OR 97034
(503) 636-0069 office
(503) 636-0102 fax
sm@klgpc.com
www.wkellington.com

Technical Memorandum

WEST Consultants, Inc.
2601 25th St. SE
Suite 450
Salem, OR 97302-1286
(503) 485 5490
(503) 485-5491 Fax
www.westconsultants.com

REGISTERED PROFESSIONAL ENGINEER
67050PE
OREGON
JULY 9, 2001
CHRIS D. BAHNER
EXPIRATION DATE: 12/31/21

To: Wendie Kellington, Kellington Law Group

From: Chris Bahner, P.E., D. WRE

Date: July 27, 2021

Subject: Fourth Supplemental Technical Memorandum

1. Introduction

This memorandum summarizes the changes to the dune classifications at the location of a proposed shoreline protection revetment for the oceanfront properties of the Pine Beach subdivision and all but one of the oceanfront lots in the George Shand Tracts (Ocean Boulevard Properties), together referred to as the "Subject Properties", in response to comments made at the July 15, 2021 Planning Commission hearing that the dune classifications of the Subject Properties have not changed. This is the fourth supplement to the design technical memorandum completed by WEST in March 2021 (WEST, 2021a).

The Subject Properties are located on the Oregon coast about 2 miles south of Rockaway Beach along the northwest coast of Oregon (Figure 1). These oceanfront landowners have been losing portions of their property due to coastal erosion and are experiencing coastal flooding as a result of high tides and wave run-up. Most recently, coastal flooding occurred during the King Tides in January of 2021, as well as in February of 2020. During these events, the maximum stillwater level reached the oceanfront homes, and went past the southernmost home for a distance of about 45 feet. There is a high level of risk for future damage to the Subject Properties' land, structures, and infrastructure without the proposed revetment. It is not accurate to state, as some commentors have, that the Subject Properties are not subject to wave overtopping or undercutting. They are subject to both.

WEST Consultants, Inc. (WEST) was contracted by Kellington Law Group to study and if appropriate to develop a rock riprap revetment design, which if constructed, is expected to prevent further erosion of the landowners' properties and to reduce the risk of coastal flooding. The revetment structure design and information required by Tillamook County was documented in a technical memorandum completed by WEST in March 2021 (WEST, 2021a). WEST also completed a three supplemental technical memorandum: (1) in May 2021 (WEST, 2021b); (2) in June 2021 (WEST, 2021c); and (3) on 21 July 2021 (WEST, 2021d).

Figure 1. Location map

2. Dune Classifications

The extents of beaches and dunes geomorphic classification and mapping was originally undertaken between 1972 and 1975 by the U.S. Department of Agriculture Soil Conservation Service and published in *Beaches and Dunes of the Oregon Coast* (USDA, 1975). Figure 2 shows the USDA 1975 beaches and dunes geomorphic classification at the proposed site. This figure shows that the oceanfront properties were located in the "younger stabilized dunes" with some inclusions of "open dune sand conditionally stable".

Changes to the beaches and dunes geomorphic characterization was noted in the dune hazard report of the Pine Beach Development completed by Handforth Larson & Barrett, Inc in 1994. This report indicates that coastal vegetation had grown within the area classified as "open dune sand conditionally stable" which tended to show that there was little to no ocean overtopping or undercutting, there were no "active foredunes" at the site, and development would be located on an area classified as "younger stabilized dune" which was not expected to be in danger of ocean flooding.

Figure 2. Beach and dune geomorphic mapping classifications at Subject Project (USDA, 1975)

Due to changes in coastal morphology from the significant erosion along the coastline, the Department of Geology and Mineral Industries (DOGAMI) completed a study in 2020 (DOGAMI, 2020). The 2020 DOGAMI study's updated dune classifications are consistent with the county plan's process for updated dune classifications where greater accuracy and detail are needed, given the dramatic changes that have occurred to the Tillamook coastline in the 45 years since USDA first mapped the county's dunes. Figure 3 shows the beaches and dunes geomorphic classification at the proposed site defined by the DOGAMI 2020 study. This figure shows that the residential development and residentially developable areas on the Subject Properties is near the interface of the "active foredune" and "recently stabilized foredune". Figure 4 shows the nomenclature used by the Oregon Department of Land Conservation and Development's (DLCD's) for beaches and dunes, and it shows that "recently stabilized foredune" is classified as "foredune, conditionally stable", which is subject to ocean undercutting and wave overtopping. The proposed beachfront protective structure (BPS) will be located within the "active foredune" classification area.

The following items summarizes the changes to the beaches and dunes classifications at the Subject Properties:

- Younger stabilized dune, with some inclusions of open dune sand conditionally stable defined from the USDA 1975 original classification. The area where residential development was established or authorized was not subject to ocean flooding (overtopping/undercutting).
- Coastal vegetation had filled in portions of property that were open dune sand conditionally stable (i.e. the Pine Beach subdivision's "common area") where no residential development was contemplated, and there was no active foredune on the Subject Properties. The residential development was on younger stabilized dune which was not expected to be subject to ocean flooding, as documented in the 1994 dune hazard report of the Pine Beach Development (Handforth Larson & Barrett, Inc, 1994).
- DOGAMI 2020 coastal morphology study indicates residential development on the Subject Properties – both existing and authorized – is now on a recently stabilized foredune, which DLCD refers to as a "conditionally stable foredune" that is now subject to ocean undercutting and wave overtopping. The proposed BPS in on an active foredune.

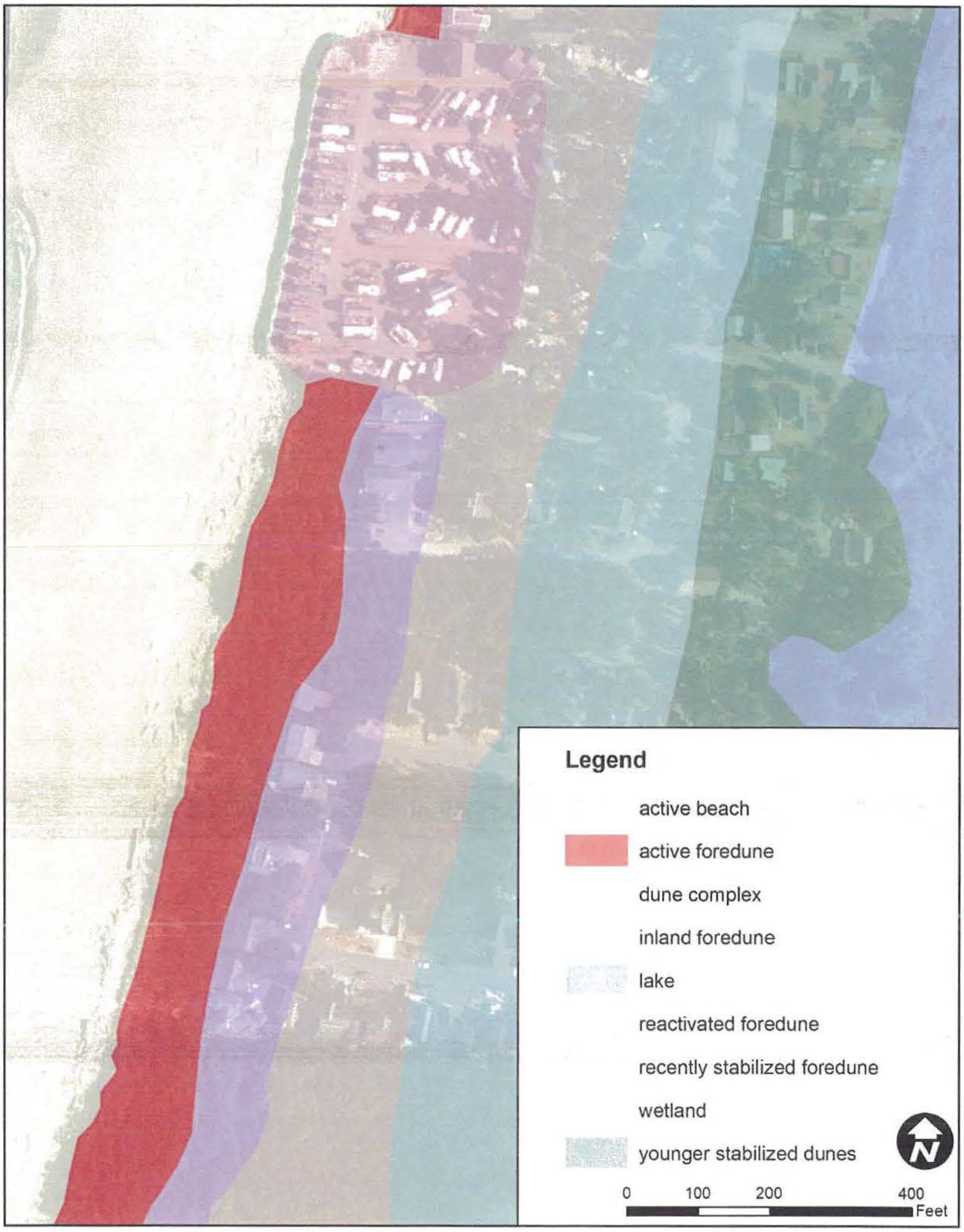

Figure 3. Beach and dune geomorphic mapping classifications at Subject Project (DOGAMI, 2020)

Associated Dune Category	Inventory Classification	DLCD Classification	Mapping Unit
Active Beach and Foredune	beach	Beach	B
	active foredune	Foredune, Active	FDA
	active dune hummocks	Hummocks, Active	H
Recently Stabilized Dunes	recently stabilized foredune	Foredune, Conditionally Stable	FD
	inland foredune		IFD
	dune complex	Dune Complex	DC
	younger stabilized dunes	Dune, Younger Stabilized	DS
Older Stabilized Dunes	older stabilized dunes	Dune, Older Stabilized	ODS
Inland Dunes	open dune sand	Dune, Active/Dune, Parabolic	OS
	open dune sand conditionally stable	Dune, Conditional Stable	OSC
	active inland dune	Dune, Active	AID

Figure 4. Beach and dune overlay zone nomenclature (after USDA, 1975) (DOGAMI, 2020)

3. Conclusion

When mapped by USDA in 1975, the Subject Properties were on a "younger stabilized dune" with some inclusions of "open dune sand conditionally stable" and were not subject to ocean flooding (overtopping and undercutting). The dune hazard report performed in 1994 for the Pine Beach Subdivision found that since the properties were mapped in 1975, coastal vegetation had grown within the area classified as "open dune sand conditionally stable" which tended to show that ocean erosion was not occurring. That report noted that there were no "active foredunes" at the Subject Properties, and that residential development would be located on area classified as "younger stabilized dune". Further changes in the subject area are described in DOGAMI's 2020 report, which follows the county plan's Beaches and Dunes Element process for updated dune classification and now describes the area in which residential development exists or is contemplated as a conditionally stable foredune and the area in which the BPS is proposed as an active foredune. There is no dispute that the conditionally stable foredune is now subject to ocean undercutting and wave overtopping. Accordingly, the coastal morphology of the dunes upon which the Subject Properties are located have changed since they were originally mapped in 1975. The county's plan for beaches and dunes describes that the County will consult with the USDA SCS Soils Survey for coastal Tillamook County and will perform field inspections using criteria described in 1975 USDA report and in *A System of Classifying and Identifying Oregon's Beaches and Dunes*' (Oregon Coastal Zone Management Association, Inc, 1979). Notwithstanding that old County dune classifications of the area on which the Subject Properties are sited may not have been updated since 1975, the fact is that the dunes and their classifications have changed, and the dune classification should be adopted for the site since there are changes and classification system is consistent with the county's process for dune classification.

4. References

Handforth Larson & Barrett, Inc, 1994 (June). *Dune Hazard Report and Modified Dune Hazard Report, Tax Lot 100, 101 & 102, 1N 10 7DD, Pine Beach Replat, Watseco, Oregon*, prepared for Mr. Dave Farr and Mr. Don Nessmeier

Oregon Coastal Zone Management Association, Inc., 1979. *A System of Classifying and Identifying Oregon's Coastal Beaches and Dunes*, by Christianna Stachelrodt Crook, Research Associate, OCZMA, Beaches and Dunes Study Team

State of Oregon Department of Geology and Mineral Industries, 2020. *Temporal and Spatial Changes in Coastal Morphology, Tillamook County, Oregon,* prepared by Jonathan C. Allan

U.S. Department of Agriculture Soil Conservation Service [USDA], 1975, *Beaches and Dunes of the Oregon Coast*: USDA Soil Conservation Service, 158 p

WEST, 2021a (March). *Technical Memorandum, Subject: Pine Beach Revetment Design*

WEST, 2021b (May). *Technical Memorandum, Subject: Supplement to the March 2021 Pine Beach Revetment Technical Memorandum*

WEST, 2021c (June). *Technical Memorandum, Subject: Second Supplement Memorandum*

WEST, 2021d (July 21). *Technical Memorandum, Subject: Third Supplement Memorandum*

Allison Hinderer

From:	REED Meg * DLCD <Meg.REED@dlcd.oregon.gov>
Sent:	Tuesday, July 27, 2021 3:52 PM
To:	Sarah Absher; Allison Hinderer; Public Comments
Cc:	SNOW Patty * DLCD; PHIPPS Lisa * DLCD; Shipsey Steven; WADE Heather * DLCD
Subject:	EXTERNAL: DLCD Written Comments on 851-21-000086-PLNG-01 and 851-21-000086-PLNG
Attachments:	DLCDletter_7.27.21_851-21-000086-plng-01-goalexceptionrequest.pdf

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Hi Sarah,

Please find attached DLCD's letter regarding the hearing on applications 851-21-000086-PLNG-01 and 851-21-000086-PLNG with the Tillamook Board of County Commissioners tomorrow.

Also, I would like to sign up to give public comment virtually at the hearing tomorrow.

Thank you,
Meg

DLCD

Meg Reed
Coastal Shores Specialist | Oregon Coastal Management Program
Pronouns: She/her
Oregon Department of Land Conservation and Development
Cell: 541-514-0091 | Main: 503-373-0050
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My email address has changed. Please update your records to reflect my new email address: meg.reed@dlcd.oregon.gov. Note that your Outlook Cache may need to be cleared.

Oregon
Kate Brown, Governor

Department of Land Conservation and Development
Oregon Coastal Management Program
810 SW Alder Street, Suite B
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July 27, 2021

Mary Faith Bell, Chair
Tillamook County
Board of County Commissioners
201 Laurel Avenue
Tillamook, OR 97141

Re: 851-21-000086-PLNG-01: Goal Exception Request
851-21-000086-PLNG: Floodplain Development Permit Request

Dear Chair Bell and Tillamook County Commissioners,

Thank you for the opportunity to provide written testimony for the goal exception request, #851-21-000086-PLNG-01, and for the floodplain development permit request, #851-21-000086-PLNG. These requests are seeking approval of an exception to Statewide Planning Goal 18, Implementation Requirement 5, to place a beachfront protective structure along the westerly lots of the Pine Beach Subdivision and five oceanfront lots to the north located within the Barview/Twin Rocks/Watseco Unincorporated Community Boundary. Please enter this letter into the record of the hearing on the subject requests.

This testimony will focus on the following topics: beachfront protective structure limitation of Goal 18 policy; reasons exception pathway to seek a goal exception; comments by the Tillamook County Planning Commission; and proposed beachfront protective structure design.

Date Limitation of Beachfront Protective Structures

The above referenced properties (15 tax lots) are seeking a pathway to place a beachfront protective structure (BPS) along the oceanfront to mitigate ocean flooding and erosion. Goal 18, Implementation Requirement (IR) 5 states:

> *Permits for beachfront protective structures shall be issued only where development existed on January 1, 1977. Local comprehensive plans shall identify areas where development existed on January 1, 1977. For the purposes of this requirement and Implementation Requirement 7 'development' means houses, commercial and industrial buildings, and vacant subdivision lots which are physically improved through construction of streets and provision of utilities to the lot and includes areas where an exception to (2) above has been approved.*

After much research, County planning staff have determined that the five lots that are part of the George Shand Tracts subdivision, Tax Lots 3000, 3100, 3104, 3203 and 3204 of Section 7DA in Township 1 North, Range 10 West of the Willamette Meridian, Tillamook County, Oregon, do meet the definition of development under Goal 18, IR 5, and thus do **not** need an exception to the goal for the placement of a BPS.

On the other hand, the County has concluded that the ten tax lots that are part of the Pine Beach Replat Unit #1 do not meet the definition of development because they were developed after 1977. These are Tax Lots 114 through 123, of Section 7DD in Township 1 North, Range 10 West of the Willamette Meridian, Tillamook County, Oregon. The County's determination was made based upon the following information:

- Utilizing the 1977 aerial imagery from the Army Corps of Engineers, the County determined that qualifying development (residential, commercial, or industrial buildings) was not present on any of these tax lots.
- Although the original plat "Pine Beach" was recorded in 1932 containing 121 lots, the County has found that the entire plat, with the exception of Second Street between Pacific Highway and Ocean Boulevard and the separate ownerships along Second Street, was vacated in 1941. The Pine Beach Replat was then subsequently approved in 1994. Thus, on January 1, 1977, there was no eligible development on the oceanfront parcels at this site and it was not part of a statutory subdivision. Additionally, the replat in 1994 was processed by the County as a new subdivision and the resulting lots are in a significantly different configuration than the Pine Beach subdivision plat of 1932. This resulted in a new subdivision.

Based on the County staff determinations for the above referenced parcels, the George Shand Tracts parcels meet the definition of development under Goal 18, IR 5 and therefore do not need a goal exception for the placement of a BPS, while the Pine Beach Replat Unit #1 parcels do not meet the definition of development under Goal 18, IR 5 and therefore do need a goal exception to the 1977 development date limitation of Goal 18 for the placement of a BPS, in addition to any local criteria.

It is unclear from the Planning Commission recommendation to the Board of County Commissioners whether the Planning Commissioners decided that all or part of this area needs a goal exception. Tillamook County must make the threshold determination of eligibility for BPS very clear for each of the tax lots under this goal exception request. State law authorizes a county to take a goal exception for uses not allowed by the goal or to allow a use authorized by a statewide planning goal that cannot comply with the approval standards for that type of use. If an area was developed on January 1, 1977, then a county need not, and cannot lawfully, take an exception to Goal 18, IR 5. Previous case law has affirmed that a goal exception cannot be taken for a use that the goal allows. *DLCD v. Yamhill County*, 183 Or App 556, 53 P3d 462 (2002). That makes sense, because the statutory definition of an "exception" is that the amendment to the comprehensive plan does "not comply with some or all goal regulations applicable to the subject property." ORS 197.732(1)(b)(B). *See also* OAR 660-004-0022 (use not allowed by the goal); OAR 660-004-0020(2)(b) (areas that do not require an exception). Thus, the initial determination before the County is whether the applications are for properties that were not developed on January 1, 1977.

<u>Reasons Exception Pathway</u>

The applicants suggest multiple pathways for approving their goal exception request. The Planning Commission determined that there is only one avenue for these applicants, which is a general "reasons" exception and that the applicants only need an exception to Goal 18 IR 5, not IR 2. The department agrees.

Part II of Statewide Planning Goal 2 provides a process a local government can follow when taking an "exception" to one of the land use goals, when unique circumstances justify that the state policy should not apply. The rules governing exceptions are provided in OAR chapter 660, division 4. There are several goals and goal provisions to which a specific pathway is outlined, but for those where no other specific pathway exists or fits, a general "reasons" exception applies.

The department agrees with the Planning Commission that a general "reasons" exception to Goal 18 is necessary for the lots that are not eligible for BPS under Goal 18 and that the proper administrative rule provisions are those of OAR 660-004-0022(1) and OAR 660-004-0020.

The homes that exist in the application area were built in conformance with the other provisions of Goal 18, specifically Goal 18, IR 2. The houses were **not** built in an active foredune or in a dune area subject to ocean flooding at the time of development, which means they did not need an exception to Goal 18, IR2. The other goal exceptions (to Goals 3, 4, 11, and 14) that allow for the Barview/Twin Rocks/Watseco community to be residentially developed, do not specify the exact location of development on each parcel in this unincorporated community. Additional zoning requirements dictate those limits, and in the case of these ocean-fronting parcels, Tillamook County applied the Beach & Dune Overlay Zone of their Land Use Ordinance. The houses were built in the eastern portions of their respective parcels to comply with the prohibition areas of Goal 18 for residential development. The department understands the applicants to argue that the exceptions to Goals 3, 4, 11, and 14 allowed the development to be placed, and because those homes are now in a foredune subject to ocean flooding, they automatically have or should be allowed by right to have an exception to Goal 18, IR2. However, the rules provide that an "exception to one goal or goal requirement does not ensure compliance with any other applicable goals or goal requirements for the proposed uses at the exception site." OAR 660-004-0010(3). The notion of an implied or precautionary exception, as the applicants suggest, is not supported by law. Furthermore, an exception to exclude certain lands from the requirements of Goals 3, 4, 11, and 14 does not exempt the County from the requirements of any other goals, including Goal 18, for which the County has not taken an exception. OAR 660-004-0010(3). A goal exception is an affirmative act that is incorporated into a comprehensive plan. Tillamook County has identified and adopted specific exception areas for Goal 18, IR 2 in the County's Comprehensive Plan (Part 6 of the Beaches and Dunes Element). The lands in the application are not part of an existing goal exception under Goal 18 and are not reflected in the Tillamook County Comprehensive Plan. Nor do these homes need a retroactive exception to Goal 18, IR 2, as the applicants suggest.

The question at hand is not whether these properties need an exception to exist where they are, but whether they can install a beachfront protective structure to protect the existing development. The applicants are seeking an exception to the date-based limitation on the placement of beachfront protective structures for Goal 18 because they were developed after January 1, 1977. Therefore, only a general "reasons" exception to Goal 18, IR 5 is needed in this case (OAR 660-004-0022(1)).

Recent LUBA decisions, subsequent to this application, also provide additional guidance on the matter:

- Coos County: https://www.oregon.gov/luba/Docs/Opinions/2021/05-21/20002.pdf
- City of Coos Bay: https://www.oregon.gov/luba/Docs/Opinions/2021/05-21/20012.pdf

In brief, these LUBA decisions note that taking a reasons exception is a high bar and the applicant and jurisdiction must follow the reasons exception process closely and carefully to demonstrate the need.

The department agrees with the County Staff Report, dated May 27, 2021, page 5, which states: "staff also finds that an exception to one goal or goal requirement (ex. Goals 11 and 14) does not ensure compliance with any other applicable goals or goal requirements, in this case for the proposed construction of the beachfront protective structure. Staff finds the Applicants must meet the burden of proof to satisfy the applicable exception criteria without the sole basis of argument that other exceptions have already been taken".

<u>OAR 660-004-0022 Reasons Necessary to Justify an Exception Under Goal 2, Part II(c)</u>
As mentioned above, the provisions of OAR 660-004-0022 specify the pathway for the applicants for the ineligible properties. Specifically, OAR 660-004-0022(1) provides:

(1) For uses not specifically provided for in this division, or in OAR 660-011-0060, 660-012-0070, 660-014-0030 or 660-014-0040, the reasons shall justify why the state policy embodied in the applicable goals should not apply. Such reasons include but are not limited to the following:
(a) There is a demonstrated need for the proposed use or activity, based on one or more of the requirements of Goals 3 to 19; and either
(A) A resource upon which the proposed use or activity is dependent can be reasonably obtained only at the proposed exception site and the use or activity requires a location near the resource. An exception based on this paragraph must include an analysis of the market area to be served by the proposed use or activity. That analysis must demonstrate that the proposed exception site is the only one within that market area at which the resource depended upon can reasonably be obtained; or
(B) The proposed use or activity has special features or qualities that necessitate its location on or near the proposed exception site.

An application that does not satisfy these provisions fails and may not be approved.

<u>OAR 660-004-0020 Goal 2, Part II(c), Exception Requirements</u>
If the provisions of OAR 660-004-0022(1) are found to be satisfied, the review may then turn to the provisions of OAR 660-004-0020. In addition to the above, there are four tests to be addressed when taking an exception, which are set forth in Statewide Planning Goal 2, Part II and more specifically in OAR 660-004-0020(2)(a) – (d). Those criteria are:
1) *Reasons that justify why the state policy embodied in the applicable goal should not apply;*
2) *Areas which do not require a new exception cannot reasonably accommodate the use;*

3) *The long-term environmental, economic, social and energy consequences resulting from the use of the proposed site with measures designed to reduce adverse impacts are not significantly more adverse than would typically result from the same proposal being located in areas requiring a goal exception other than the proposed site; and*
4) *The proposed uses are compatible with other adjacent uses or will be so rendered through measures designed to reduce adverse impacts.*

It is imperative that the County focus on these standards when evaluating the exception application for the lots deemed ineligible within the Barview/Twin Rocks/Watseco Unincorporated Community Boundary. As already stated, the other exception pathways the applicants argue for are not relevant in this case and those arguments cannot be the basis for an exception decision.

Findings Made by the Tillamook County Planning Commission

A staff memo dated July 21, 2021, summarizes the findings made by the Tillamook County Planning Commission to recommend approval of these requests. Of particular concern to the department is the following statement:

"It is not right to deny a property owner the same opportunities to protect their property that others are afforded due to grandfathered rights that allow them to take action for protection of their property. (Properties where 'development' existed on January 1, 1977.)"

This finding cannot be used to justify a goal exception. Goal 18, IR 5 is a 'grandfather clause' to allow development already in existence at the time the policy was adopted to use shoreline armoring, while new development must account for shoreline erosion through non-structural approaches. As seen in previous case law, "the purpose of a 'grandfather clause' is to prevent hardship to individuals who have existing uses. A 'grandfather clause' is enacted to preserve rights, not to grant additional rights." *Spaght v. Dept. of Transportation*, 29 Or App 681, 686, 564 P2d 1092 (1977) (citation omitted).

Here, the Planning Commission seems to assert that the Goal 18, IR 5 grandfather clause for developed properties should grant the same rights to other properties that were not developed. That interpretation is contrary to the purpose of Goal 18, IR 5, which is in part to preserve the rights to protect a developed property with a BPS, while providing that future development occur in a manner that does not rely on BPS in order to afford the natural functions of the beach and dunes to continue. To construe otherwise is to defeat a primary purpose of Goal 18. In addition, "the exceptions process is not to be used to indicate that a jurisdiction disagrees with a goal." OAR 660-004-0000(2). Therefore, not agreeing with the policy does not authorize the County to use that disagreement as a basis for a valid goal exception decision.

During the Planning Commission's deliberation at the July 15^{th} hearing of these applications, there was discussion of the County's obligations, particularly under Goal 7, to protect these properties from ocean flooding and erosion. Goal 7 obligates jurisdictions to plan for natural hazards by adopting inventories, policies and implementing measures in their comprehensive plans to reduce risk to people and property from natural hazards. The Goal does not obligate the County to protect life and property indefinitely once development has occurred, but to consider natural hazards in the course of planning. The County is not compelled by the Goal 7 requirements to grant the exception, nor would the County be out of compliance with Goal 7 in the absence of the exception. What the applicants are seeking is an exception to allow them to place a beachfront protective structure to mitigate the impacts of coastal erosion and flooding. The proposed BPS is their preferred solution, which the regulations currently prohibit. It could be argued that the risk to persons and property could be addressed or even eliminated in other ways – such as removal or relocation of the houses and infrastructure.

Proposed Beachfront Protective Structure

The applicants put forth a specific design for a beachfront protective structure, referenced throughout the applications. The department has some concerns about the design as proposed.

BPS are not the ultimate solution to eliminate coastal hazard risks. The applicants claim that the proposed beachfront protection will solve all threats to the properties from coastal flooding and erosion and not incur further harm to either the beach or surrounding properties. It is important to note that erosion will continue to occur in this location and the impacts of climate change will continue to exacerbate those conditions. Beachfront protective structures can provide a level of protection for development from erosion and flooding but will need to be continually maintained and may fail over time. Additionally, the structures themselves will continue to impact the beach in this area by withholding sediment and fixing the shoreline in place, as has been seen in other beach systems. While one structure may not affect the system very much, the cumulative effects of armoring along the entirety of this system will have an impact over time, limiting north/south beach access as sea levels continue to rise. Beachfront protective structures do not conserve nor protect the beach and dune environment, they protect development from the impacts of coastal erosion.

The applicants have identified that nearly 90% of the Rockaway Subregion of the Rockaway littoral cell is eligible for BPS. While many of those homeowners may choose to armor their properties over the coming years and decades, many of those lots are not yet armored and those permitting decisions have not yet been made. Much of this sublittoral cell, and particularly the area of the subject properties, is not currently armored. If the County decides to approve this exception request and application for a BPS, the County is committing to a high level of shoreline armoring in this sublittoral cell. As has been observed in other beach systems, particularly in Lincoln Beach in Lincoln County, the proliferation of shoreline armoring has been detrimental to the natural functioning of the beach system. By approving additional armoring, the County is committing to a preference for private development protection over protection of the beach and dune resource.

Additionally, applicants claim that because the BPS will initially be erected on private property and buried with sand and vegetation that the structure will remain that way indefinitely and never become exposed. If this is the case, then they are assuming that sand nourishment, dune augmentation, and vegetation methods will work to mitigate the hazards, in which case they do not need a structure or a goal exception. However, if these non-structural methods are not sufficient, as the applicants argue elsewhere, then it is important to evaluate the structure assuming it will become exposed and located on the ocean shore and public beach. Assuming conditions remain similar to what the area has experienced over the past two decades, the beach will continue to narrow over time resulting in increased wave energy directed on the structure. Once located on the ocean shore and within the jurisdiction of Oregon Parks and Recreation Department (OPRD), the BPS will be an unpermitted structure that will have to seek a permit through OPRD. The Ocean Shore is defined as "the land lying between extreme low tide of the Pacific Ocean and the statutory vegetation line as described by ORS 390.770 or the line of established upland shore vegetation, whichever is farther inland."

The applicants argue that sand will build up over the revetment during summer months. However, this is an eroding coastline experiencing a net loss of sand; any sand placed on structures gets eroded quickly. El Nino conditions can cause hotspot erosion in the southern ends of littoral cells and accretion in the northern ends of littoral cells. Accretion of sand over beachfront protective structures in other parts of the Rockaway beach littoral cell does not guarantee the same will happen at the site of the proposed beachfront protection structure. Supplemental sand placement and re-vegetation will likely be needed here. Taking sand from the public beach, if that is proposed, will need to be permitted by OPRD. Applicants have also cited that the current vegetation is dying due to saltwater inundation from flooding. Any vegetation that is planted or replanted in this area will need to be tolerant of the saltwater flooding, and continually be maintained. The maintenance for this structure as proposed, especially with these additional requirements (buried in sand and vegetated), is perpetual and may not be possible over the long term.

The applicants do include an analysis of potential impacts from this proposed structure in regards to north/south beach access. However, these calculations are for present water level and wave conditions only and do not consider various sea level rise scenarios in the coming decades. As the shoreline continues to naturally erode back towards the BPS, the beach will most likely steepen in addition to the BPS itself presenting a steeper slope, which will result in different wave runup conditions. These processes could set up a feedback in which the wave runup continues to increase, resulting in more attack on the BPS and causing less 'safe hours' to walk past the structure in the north/south direction.

Independent of the decision regarding the Goal Exception request, if the Board approves the structure, DLCD supports the Planning Commission's recommendation to add conditions of approval to the permit, particularly to ensure applicants have the responsibility to maintain their structure in perpetuity and should the structure be uncovered, that the property owners obtain any new permits from the County and OPRD. Many BPS built along the Oregon coast are initially buried with sand and planted with beach grass or other vegetation. However, almost none of them retain that state for very long and it can become very difficult for homeowners to keep up with that level of maintenance because of costs and lack of sand supply, especially in highly erosive environments.

Conclusion

To summarize, DLCD recommends that the County make a clear determination on the eligibility status of each of the 15 tax lots under the application and only evaluate a goal exception for those areas that need a goal exception to Goal 18, IR 5. As previously stated, a goal exception cannot be taken for a use already allowed by the goal. Additionally, the pathway of review for this application is a general "reasons" exception as provided in OAR 660-004-0020 and OAR 660-004-0022(1). Only the criteria for this pathway should be evaluated for a goal exception decision. The County cannot use a disagreement with the grandfather clause of Goal 18, IR 5 as the basis for granting a goal exception. Lastly, the department recommends that the County carefully review the proposed BPS and attach specific conditions of approval to the permit, if approved, to ensure the structure is built as designed and maintained in perpetuity by the owners.

DLCD wants and supports a better outcome for oceanfront development and infrastructure. We do not want to see homes falling into the ocean, but we also do not want to see a proliferation of armoring in all cases because it is a short-sighted solution that impacts the public beach. There are alternative outcomes to pursue, ones that require envisioning a coastal future that looks different from the coastline of the past. One that is more mindful of the hazards that are present in this environment and that will continue to get worse with climate change.

Thank you for this opportunity to comment. Please enter this letter into the record of these proceedings. If you have any questions, please contact Meg Reed, Coastal Shores Specialist, at (541) 514-0091 or meg.reed@state.or.us.

Sincerely,

Patty Snow, Coastal Program Manager
Oregon Coastal Management Program
Department of Land Conservation and Development

cc: Meg Reed, Oregon Department of Land Conservation and Development
Lisa Phipps, Oregon Department of Land Conservation and Development
Heather Wade, Oregon Department of Land Conservation and Development
Steven Shipsey, Oregon Department of Justice
Jay Sennewald, Oregon Parks and Recreation Department

Allison Hinderer

From: Sarah Mitchell <sm@klgpc.com>
Sent: Tuesday, July 27, 2021 2:23 PM
To: Sarah Absher; Allison Hinderer
Cc: Wendie Kellington; Bill and Lynda Cogdall (jwcogdall@gmail.com); Bill and Lynda Cogdall (lcogdall@aol.com); Brett Butcher (brett@passion4people.org); Dave and Frieda Farr (dfarrwestproperties@gmail.com); David Dowling; David Hayes (tdavidh1 @comcast.net); Don and Barbara Roberts (donrobertsemail@gmail.com); Don and Barbara Roberts (robertsfm6@gmail.com); evandanno@hotmail.com; heather.vonseggern@img.education; Jeff and Terry Klein (jeffklein@wvmeat.com); Jon Creedon (jcc@pacifier.com); kemball@easystreet.net; meganberglaw@aol.com; Michael Munch (michaelmunch@comcast.net); Mike and Chris Rogers (mjr2153@aol.com); Mike Ellis (mikeellispdx@gmail.com); Rachael Holland (rachael@pacificopportunities.com); teriklein59@aol.com
Subject: EXTERNAL: RE: 851-21-000086-PLNG & 851-21-000086-PLNG-01 Pine Beach BOCC Hearing Packet - Additional Evidence (Part 6 of 6)
Attachments: Exh 3 - DOGAMI O-20-04 Report.pdf

Importance: High

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Please include the attached in the record of 851-21-000086-PLNG /851-21-000086-PLNG-01 and in the Board of Commissioners' packet for the July 28, 2021 hearing. This is part 6 of 6.

As I mentioned below, we will also be submitting additional items later this afternoon for inclusion in the record and the BOCC packet, so would you please keep an eye out for those as well? Thank you very much.

Best,
Sarah

KELLINGTON LAW GROUP

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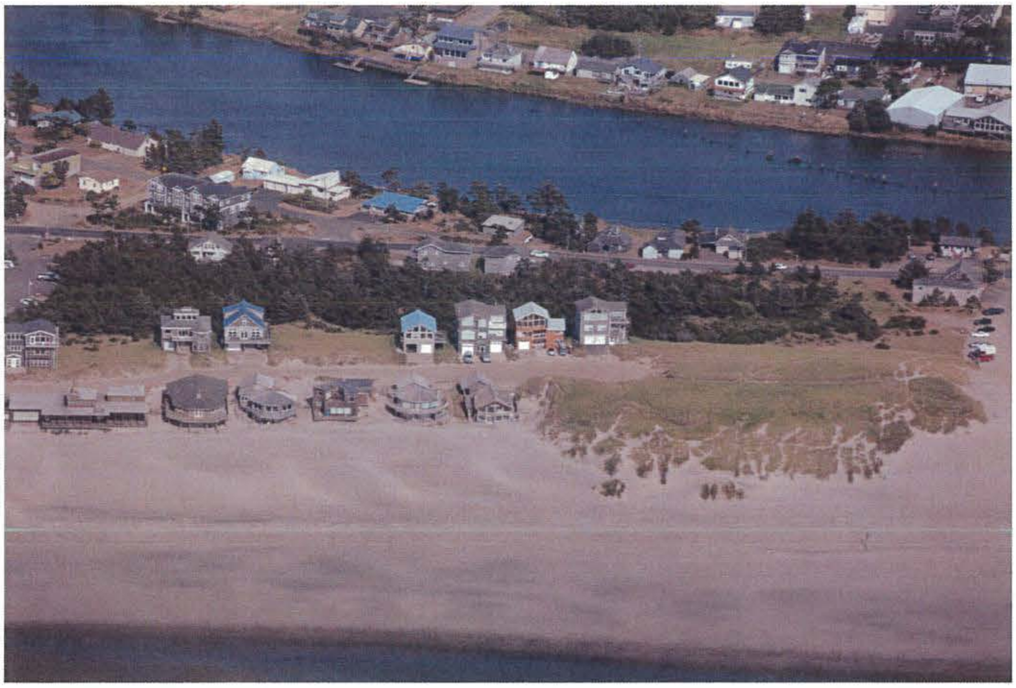
State of Oregon
Oregon Department of Geology and Mineral Industries
Brad Avy, State Geologist

OPEN-FILE REPORT O-20-04

TEMPORAL AND SPATIAL CHANGES IN COASTAL MORPHOLOGY, TILLAMOOK COUNTY, OREGON

by Jonathan C. Allan[1]



2020

[1]Oregon Department of Geology and Mineral Industries, Coastal Field Office, P.O. Box 1033, Newport, OR 97365

DISCLAIMER

Cover photograph: Contemporary and historical dune development at Pacific City, Tillamook County. Photo taken by E. Harris, August 12, 2011.

WHAT'S IN THIS REPORT?

New lidar based mapping along the Tillamook County coast provides updated spatial extents of beaches and dunes that may be subject to existing and future storm-induced wave erosion, runup, overtopping, and coastal flooding. Side-by-side maps of the spatial extent of beaches and dunes in 1975 and now show changes that have taken place. These data will help communities implement Oregon Statewide Planning Goal 18: Beaches and Dunes.

Oregon Department of Geology and Mineral Industries Open-File Report O-20-04
Published in conformance with ORS 516.030

For additional information:
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Portland, OR 97232
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https://www.oregongeology.org
https://oregon.gov/DOGAMI/

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GEOGRAPHIC INFORMATION SYSTEM (GIS) DATA

See the digital publication folder for files.
Geodatabase is Esri® version 10.1 format. Metadata is embedded in the geodatabase and is also provided as a separate .xml format file.

tillamook_dune_geodb.gdb:

Feature dataset: dune_polygons

feature classes:

BeachesandDunes_orcoast_original (polygon)
BeachesandDunes_revised_tillamook_2020 (polygon)

Beaches & Dunes 2020.lyr – layer file providing symbology for the feature class *BeachesandDunes_revised_tillamook_2020*

ABSTRACT

The objective of this study was to produce updated information on the spatial extent of beaches and dunes in Tillamook County that may be subject to existing and future storm-induced wave erosion, runup, overtopping, and coastal flooding. These data are of importance to the Department of Land Conservation and Development and the seven coastal counties of Oregon in order to implement Statewide Planning Goal 18: Beaches and Dunes.

Oregon Statewide Planning Goal 18 requires local jurisdictions adopt a beach and dune overlay zone in their comprehensive plan, which may be used to manage development on or near beaches and dunes. Regional mapping of the coastal geomorphology of the Oregon coast to define the extent of its beaches and dunes was originally undertaken between 1972 and 1975 by the U.S. Department of Agriculture Soil Conservation Service (USDA, 1975). However, in the intervening 45 years, much has changed on the coast. Of particular importance has been the proliferation of European beach grasses that have helped stabilize many coastal dune systems, while many areas of the Tillamook County coastline have experienced significant erosion, especially since the late 1970s. In addition, new technologies such as lidar are now providing unprecedented levels of detail, enabling scientists to more accurately map the spatial extents of both the contemporary and historical foredune systems. These three factors combined necessitate that the USDA (1975) overlay zone be updated to reflect contemporary conditions. As a result of the updated mapping, our analyses indicate the following broad-scale changes:

- Overall, areas defined as open sand (OS) have decreased by about ~67% since the 1970s, from 2,335 acres to 767 acres. Most of this change can be directly attributed to anthropogenic effects, particularly the introduction of European beach grass (*Ammophila arenaria*) as well as stabilization from shore pine (*Pinus contorta*) and other native plant species.
- Areas subject to existing coastal hazards, which include active foredunes (FDA) and, new in 2020, reactivated foredunes (FDR), indicate an overall slight increase in their spatial extent. However, within discrete sections of the littoral cells, some areas have experienced significant loss of active foredunes, including the Rockaway Beach area, followed by Nestucca Spit and Nehalem Spit.
- Areas classified as recently stabilized foredune (FD) have seen a significant expansion (~45% increase) in spatial coverage, increasing from ~287 acres in the 1970s to ~522 acres in 2020. Consistent with the changes seen on active foredunes, the increase in stabilized foredunes can be attributed to the proliferation of dune grasses and other native trees and shrubs.

1.0 INTRODUCTION

The Oregon Department of Land Conservation and Development (DLCD) and Tillamook County Department of Community Development commissioned the Oregon Department of Geology and Mineral Industries (DOGAMI) to undertake detailed mapping of beach and dune features in Tillamook County. The purpose for such mapping is to produce updated information on the extent of the contemporary beach and foredune system that may be subject to future storm-induced erosion, runup, overtopping, and coastal flooding. These data are of importance to DLCD and the county in order to improve implementation of Statewide Planning Goal 18: Beaches and Dunes (https://www.oregon.gov/lcd/OP/Pages/Goal-18.aspx). Specifically, Oregon Statewide Planning Goal 18 requires that local jurisdictions adopt a beach and dune overlay zone in their comprehensive plan, which may be used to manage development on or near such features.

Regional mapping of the beaches and dunes of the Oregon coast was originally undertaken between 1972 and 1975 by the U.S. Department of Agriculture Soil Conservation Service (U.S. Department of Agriculture Soil Conservation Service [USDA], 1975). However, much has changed along the Oregon coast over the past 45 years, so the original maps are both inaccurate and importantly lack sufficient resolution to support current land use planning efforts. Some of the largest changes to have taken place along the coast include:

- The rapid expansion of European beach grass (*Ammophila arenaria*), which has helped to stabilize many dune systems;
- Encroachment of human development into foredune areas;
- Dune management activities such as foredune grading and planting;
- Changes in beach and dune morphology due to either coastal erosion or accretion;
- Construction of coastal engineering used to mitigate erosion hazards; and,
- Shoreline changes at the mouths of estuaries controlled by jetties.

Accordingly, the purpose of this project is to produce modern maps of beach and dune features along the Tillamook County coastline, defined in a geographical information system (GIS) and informed by historical and contemporary aerial photographs, airborne lidar, coastal erosion and FEMA flood modeling (Allan and others, 2015), and recent coastal change analyses and monitoring undertaken along the beaches of the county (Allan and Priest, 2001; Allan and Hart, 2007, 2008; Allan and others, 2009; Allan and Harris, 2012). Although the geospatial data used today to define the various mapping units are much improved, the original USDA (1975) nomenclature consisting of 12 core mapping units is retained, and in some cases is modified or refined. Finally, it is recognized that the six other Oregon coastal counties face similar challenges with beach and dune overlays that are presently outdated. Accordingly, the mapping and accompanying report undertaken for Tillamook County may be used as a framework for similar mapping of beaches and dunes in these coastal counties.

2.0 COASTAL GEOLOGY AND GEOMORPHOLOGY

Tillamook County is located on the northwest Oregon coast, between latitudes 45° 45′ 49.49″ N (Cape Falcon) and 45° 3′ 54.88″ N (Cascade Head), and longitudes 124° 1′ 15.57″ W and 123° 17′ 59.88″ W (**Figure 1**). The terrain varies from low-elevation sandy beaches and dunes on the coast to elevations over 1,000 m (e.g., Rogers Peak reaches 3,706 ft [1,130 m]) farther inland. The coastal strip is approximately 65 miles (104 km) in length and varies in its geomorphology from broad, low-sloping sandy beaches backed by dunes, to beaches backed by engineered structures, cobble and boulder beaches adjacent to the headlands, and cliff shorelines (Allan and others, 2015). In these areas sand entrained by wind is carried up into the dunes where the sand becomes trapped by plants (primarily beach grass). Where vegetation is absent or sparsely present, the dunes are able to drift in response to the prevailing wind direction. In some areas, the drifting dune sand can become a nuisance as the sand accumulates in and around coastal properties, while in other areas the migrating dune may engulf buildings, contributing to their eventual destruction (Komar, 1997).

The formation of dunes is dependent on three simple requirements:

- A sufficient supply of sediment;
- A prevailing wind. Wind speed is especially important as strong winds entrain and mobilize sediments across the beach and carry sand up into the developing dunes. Wind direction is also important as it governs the types of dunes that could develop; and,
- Obstacles to trap the sand such as woody debris, vegetation, and micro-topography.

Where sediment supply is sufficient, dunes provide effective coastal protection and at a significantly lower cost when compared with coastal engineering structures (Woodhouse, 1978). Along the Tillamook County shoreline, the bulk of the coastline is dominated by barrier spits, backed by dunes of varying ages. In recent decades, however, parts of the coast have experienced significant coastal erosion, requiring the construction of coastal engineering in order to mitigate the erosion hazards (e.g., Neskowin, Pacific City, and Rockaway Beach).

Prominent headlands formed of resistant basalt (e.g., Cascade Head, Cape Meares, Cape Lookout, and Neahkahnie Mountain) provide natural barriers to alongshore sediment transport (Komar, 1997), effectively dividing the Tillamook County coastline into four littoral cells (**Figure 1**). These are:

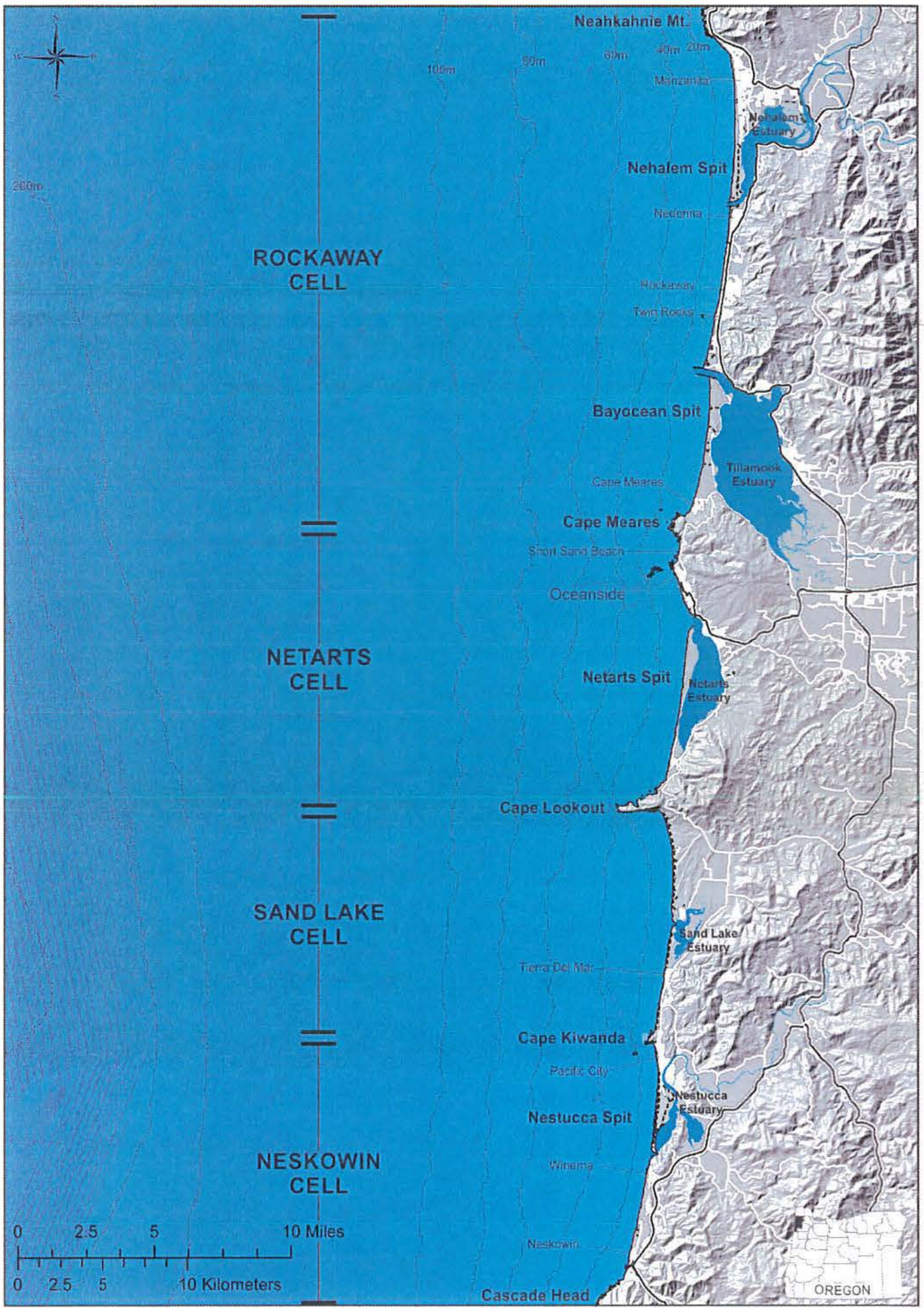
- Neskowin (~ 8.9 miles [14.3 km]), extends from Cascade Head to Cape Kiwanda;
- Sand Lake (~ 8.2 miles [13.2 km]), extends from Cape Kiwanda north to Cape Lookout;
- Netarts (~ 9.9 miles [15.9 km]), extends from Cape Lookout to Cape Meares; and,
- Rockaway (~ 17.5 miles [28.2 km]), extends from Cape Meares to Neahkahnie Mountain in the north.

Each of these cells is further divided into a series of subcells due to the presence of five estuaries (from south to north: Nestucca, Sand Lake, Netarts, Tillamook, Nehalem), two of which (Tillamook and Nehalem) are stabilized by prominent jetties (**Figure 1**). The county also is characterized by several major rivers (Nestucca, Nehalem, Miami, Tillamook, Trask, Kilchis, and Wilson Rivers) that terminate in the estuaries. Due to their generally low flows and the terrain they are eroding, these rivers carry little beach sediment out to the open coast but instead deposit most of their sediment in the estuaries (Clemens and Komar, 1988). Hence, the beaches of Tillamook County receive very little sediment along the coast today other than from erosion of the backshore.

2.1 Local Geology

The predominant geologic unit along coastal Tillamook County consists of latest Holocene beach sand present along the full length of the coastline (Cooper, 1958). Interspersed between the sand are invasive basalt bodies of the Miocene Columbia River basalt, such as Neahkahnie Mountain at the northern end of the county coastline, and flows of Columbia River Basalt that form the prominent headlands such as at Cape Meares and Cape Lookout (Schlicker and others 1972; Wells and others, 1994, 1995; Smith and Roe, 2015). These latter rocks are described as fine grained. In all cases, rockfalls and landslides in these latter units are actively providing new material (gravel and cobbles) to the beaches, albeit at relatively slow rates. These failures contribute to the formation of extensive cobble and boulder berms, which accumulate along their northern/southern flanks, where beaches have merged up against the headlands (Allan and others, 2006).

Figure 1. Location map of the Tillamook County coastline, including key place names.



South of Cape Lookout and north of the Sand Lake estuary, part of the beach is backed by bluffs, which have an average height of 24 m (Allan and Harris, 2012) and consist of medium-grained sandstone and interbedded siltstone of the Astoria Formation. Adjacent to the bluffs, sand dune sheets have accreted and ramped up against the marine terraces, before spilling over and inundating large areas in landward of the bluffs. Astoria Formation sandstone and siltstone also characterize the geology of Cape Kiwanda, adjacent to Pacific City. Eocene-Oligocene basaltic sandstone of the Alsea Formation is also prominent along a small section of the coast adjacent to Porter Point, located just south of the Nestucca estuary mouth. These sediments are massive basaltic sandstone that is predominantly fine to medium grained (Schlicker and others, 1972; Wells and others, 1994, 1995; Smith and Roe, 2015).

The contemporary beach and dune system characteristic of Tillamook County is, in geologic terms, young, having begun to form around 5,000–7,000 years ago, as the rate of post-glacial sea level rise slowed as it approached its current level (Komar, 1997). At this stage the prominent headlands would have begun to interrupt sediment transport, leading to the formation of barrier spits and beaches within the headland-bounded littoral cells.

Much of the beach sand present on the beaches of Oregon consists of grains of quartz and feldspar. The beaches also contain small amounts of heavier minerals (e.g., garnet, hypersthene, augite, and hornblende), which can be traced to various sediment sources along the Pacific Northwest coast (Clemens and Komar, 1988). Concentrations of augite, a product of erosion of the volcanic rocks present throughout the county, are especially abundant along the Tillamook County coast. This suggests that at the time, rivers and streams were carrying these sediments out to the coast where they mixed with other sediments. It is possible that concentrations of augite likely increased during the past 150 years as human settlement accelerated, leading to increased deforestation (Peterson and others, 1984; Komar and others, 2004), which correspondingly contributed to increased sediment loads in the various rivers. However, although some of these sediments reached the open coast, the bulk of the sediments are retained in the estuaries due to generally low discharge levels characteristic of the rivers (Komar and others, 2004).

Prior to the 1940s, many of the barrier spits were devoid of significant vegetation. With the introduction of European beach grass (*Ammophila arenaria*) in the early 1900s and its subsequent proliferation along the Oregon coast, the dunes and barrier spits eventually stabilized. The product today is an extensive foredune system, which consists of large "stable" dunes containing significant volumes of sand. Accompanying the stabilization of the dunes, humans have settled on them, building in the most desirable locations, typically on the most seaward foredune.

3.0 METHODOLOGY

An initial meeting was held with DLCD staff to discuss the overall study approach. This included evaluating the existing Beach and Dune Overlay Zone in a geographical information system (GIS), developed by DLCD from the original 1975 mapping. These data were used to establish the baseline on which the updated GIS layer was developed. **Table 1** identifies the key beach and dune classifications that are used in the revised mapping, including their accompanying DLCD classification where applicable, and derived originally from USDA (1975). In addition, we define six new classifications in **Table 1**, including:

- Artificial Active Foredune (AFDA) – An artificial foredune constructed from geotextile sand bags and planted with dune grass. This category is unique to Cape Lookout State Park where such a structure was constructed;
- Reactivated foredune (FDR) – In several areas the existing foredune has been:

1. completely removed such that coastal processes are presently eroding into the previously stabilized foredune (FD); and,
2. extreme total water levels are expected to inundate portions of the backshore (e.g., FD or DS) landward of the active foredune (FDA). The latter results are based on the work of Allan and others (2015).

- Coastal Landslides (LD) – Derived from coastal landslide mapping undertaken by Allan and Priest (2001), as well as more recent landslide failures observed and documented by the author;
- Fluvial and Estuarine Deposits (FED) – Defined from geologic mapping undertaken by Wells and others (1994) and compiled in the Oregon Geologic Database Compilation (OGDC-6; Smith and Roe, 2015). The OGDC is a digital geologic map and database covering the entire state and depicting the best available geologic mapping in any location;
- Coastal Lakes (LK) from e.g., ; and,
- Wetland (WL) – These data stem from the National Wetlands Inventory (https://www.fws.gov/wetlands/) compiled by the U.S. Fish and Wildlife Service (USFWS).

These latter classifications simply help to better define additional geographic and geologic features evident along the Tillamook County coastline but not explicitly addressed by USDA (1975). Definitions of the original mapping nomenclature are described by USDA (1975) and are not repeated here.

Table 1. Beach and dune overlay zone nomenclature (after USDA, 1975).

Associated Dune Category	Inventory Classification	DLCD Classification	Mapping Unit
Active Beach and Foredune	beach	Beach	B
	active foredune	Foredune, Active	FDA
	active dune hummocks	Hummocks, Active	H
Recently Stabilized Dunes	recently stabilized foredune	Foredune, Conditionally Stable	FD
	inland foredune		IFD
	dune complex	Dune Complex	DC
	younger stabilized dunes	Dune, Younger Stabilized	DS
Older Stabilized Dunes	older stabilized dunes	Dune, Older Stabilized	ODS
Inland Dunes	open dune sand	Dune, Active/Dune, Parabolic	OS
	open dune sand conditionally stable	Dune, Conditional Stable	OSC
	active inland dune	Dune, Active	AID
Interdune Forms	wet interdune	Interdune	W
	wet deflation plain	Deflation Plain	WDP
	wet mountain front		WMF
Estuary	wet surge plain		WSP
	wet flood plain		WFP
Other	coastal terrace		CT
	New:		
	artificial active foredune		AFDA
	reactivated foredune (subject to erosion/flooding)		FDR
	coastal landslide		LD
	fluvial and estuarine deposits		FED
	lake		LK
	wetland		WL

3.1 Previous Coastal Hazard Studies

Because the foundation of the Beach and Dune Overlay Zone reflects those areas subject to active coastal change (either erosion or accretion), and/or may be impacted by storm wave runup, overtopping, and flooding, the revised mapping undertaken here was strongly guided by existing information available from a number of recent coastal investigations. These include coastal erosion hazard studies (Allan and Priest, 2001; Stimely and Allan, 2014), beach and shoreline monitoring efforts undertaken along the Tillamook County coastline (Allan and Hart, 2007, 2008) and continuing (e.g., http://nvs.nanoos.org/BeachMapping), analyses of lidar data (Allan and Harris, 2012), and recently completed geomorphic, erosion analyses, coastal flood modeling, and mapping (Allan and others, 2015).

3.2 Lidar

Beach and dune morphology was mapped for this study largely from light radar (lidar) data collected by DOGAMI in 2009. Lidar is a remote sensing technique consisting of x, y, and z values of land topography that are derived using a laser ranging system and geo-located using an onboard Real-Time Kinematic Differential Global Positioning System (RTK-DGPS). The lidar data have a vertical accuracy of ~0.1 m (0.3 ft), while the horizontal accuracy is ~1 m (3 ft). Because lidar collected by DOGAMI consisted of multiple laser returns, processing of these data enabled the production of bare-earth rasters of the ground surface; i.e., the vegetation was able to be stripped off, leaving just the ground elevation.

Analyses of these data were previously undertaken by Allan and Harris (2012) in order to define various beach, dune, and bluff morphological characteristics (e.g., tidal-datum based shorelines, cross-sections, and a variety of geomorphic features including the beach-dune toe, foredune toe, dune crest, dune heal, bluff toe, and bluff crest). These data were subsequently refined and updated by Allan and others (2015). Additional information concerning post-2009 beach and shoreline changes were determined from lidar collected in 2016 on behalf of the USGS, from recent observations of beach profile and shoreline changes measured using RTK-DGPS by DOGAMI staff (e.g., http://nvs.nanoos.org/BeachMapping), and from modern aerial images of the coastline.

3.3 Aerial Imagery

Although lidar is the foundation on which the geomorphic mapping is based, valuable geomorphic information may also be gleaned from analyses of repeat aerial photographic imagery of the coast collected over the last century.

The earliest compilation of aerial photographs of Oregon coast was undertaken in 1939 by the U.S. Army Corps of Engineers. Unfortunately, the images are simply stereo (pairs) images that have never been rubber-sheeted or ortho-rectified. Orthorectification is an approach used to process imagery in order to account for optical distortions (e.g., tilt or relief) with the goal of yielding an image that is planimetrically correct that is fixed to a geospatial coordinate system, enabling the data to be viewed and analyzed in GIS.

In order to rubber-sheet the images, the 1939 aerial photographs were added to ArcGIS and processed using the Georeferencing suite of tools. This is accomplished by identifying common ground control points (e.g., road junctions, bridges, buildings, rock outcrops) that can be identified in the 1939 images and in contemporary (1994, 2000, 2004, 2009, 2014, 2016) orthorectified images (or lidar) collected for the State of Oregon. Using this approach, twenty-six 1939 photos were able to be georeferenced for Tillamook County, enabling comparisons to be made against modern images of the coastline and from lidar. These data were extremely useful for understanding early historical changes in the morphology of the barrier spits, including the proliferation of dune grasses on the dunes and their subsequent stabilization of the dunes.

Imagery acquired by the Oregon Department of Transportation (ODOT) in 1967 (Ruggiero and others, 2013) was also examined. These aerial photographs extend along the entire coast of Oregon and reflect a collection of 1,611 photographs along roughly 50 to 60 flight paths for the open ocean beaches (no bays). The photographs were taken at 1:6,000 scale, such that 1 inch on the photograph is 500 ft (152 m) on the ground. The images were originally processed and orthorectified for DOGAMI by the Washington Department of Ecology using Leica Photogrammetry Suite, controlled by a digital elevation model developed from 2002 lidar data.

3.4 Wet Interdunes

The USDA (1975) beach and dune mapping identified many areas among the dunes as either *Wet Deflation Plain*, *Wet Mountain Front*, or *Wet Interdune*. These sites reflect areas characterized by high water tables such that the areas are either underwater or are seasonally covered in water. In the large majority of cases, these classifications are analogous to areas delineated as "wetland." To that end, the USFWS National Wetland Inventory[1] was downloaded for Oregon and examined in a GIS. Identified wetlands were added to the revised beach and dune overlay.

3.5 Estuary Shoreline and Storm Flood Water Level

The USDA (1975) beach and dune mapping include two additional geospatial attributes defined as the *Wet Surge Plain* and *Wet Flood Plain*. The *Wet Surge Plain* was defined by USDA (1975) as the area between the lowest and highest tides within an estuary and delineated as the drift line; no additional explanation is provided as to how the drift line was identified, such as from aerial imagery or early National Ocean Service (NOS) topographic "T" Sheets. The *Wet Flood Plain* is essentially that area that can be reasonably expected to be inundated under a flood condition. Again, no specific information is provided that describes how it was mapped.

For the purposes of the revised mapping, a more refined approach involved adopting a tidal datum-based shoreline and then extrapolating the defined tidal shorelines from lidar. For the *Wet Surge Plain*, we used an elevation of 7.9 ft (2.4 m, relative to NAVD88), which equates to the Mean Higher High Water (MHHW) tidal datum defined for the Garibaldi tide gauge station by NOAA NOS. The NOS defines MHHW as "the average of the higher high water height of each tidal day observed over the National Tidal Datum Epoch"[2] and is a reasonable approximation for the *Wet Surge Plain*. For the *Wet Flood Plain*, we used an elevation of 11.5 ft (3.5 m, relative to NAVD88), which equates to the highest observed tidal elevation at the same gauge. This latter elevation reflects a storm flood, whereby the elevated water levels are a function of the combined effects of high tide, plus a storm surge component, plus riverine flooding. In both cases, contours for the predefined elevations were extracted from 2009 DOGAMI lidar data.

In a number of areas, changes in the configuration of the estuary have occurred since the lidar data were collected in 2009, necessitating a need to adjust the boundary of the *Wet Surge Plain*. This was achieved by using recently collected digital ortho imagery (e.g., 2016) to evaluate any spatial changes that may have ensued in the estuary shoreline between 2009 and 2016.

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1 https://www.fws.gov/wetlands/Data/State-Downloads.html
2 https://tidesandcurrents.noaa.gov/datum_options.html

4.0 RESULTS

The primary results associated with this latest mapping effort is contained in an Esri geodatabase "tillamook_dune_geodb.gdb". The feature dataset file "BeachesandDunes_revised_tillamook_2020" contains the updated geospatial information and includes the following key attributes: "Codes", "Feature", "Feature_2", "Notes", "Coastal_hazard", and "Cell". This contrasts with the original geospatial overlay, which only included information specific to the codes and feature class. In the updated overlay, 'Codes' and 'Features' are identical to information included in the original mapping. "Feature_2" includes secondary information relating to the feature class (e.g., younger/older deposits, wet (due to ocean flooding) etc.). The "Notes" attribute includes additional information about the respective feature (e.g., pre or post-jetty foredunes) or source information (e.g., landslide data from Allan and Priest (2001) or from field observations). The "Coastal_hazard" attribute includes specific hazard information unique to that feature, including whether it is subject to current wave erosion, runup, overwash and inundation processes, or may be impacted in the near future. Finally, the "Cell" attribute categorizes the geomorphic units by littoral cell or subcell.

Here we will briefly describe and summarize some of the key changes that have taken place along the Tillamook County ocean shore. The approach taken is to focus initially on broad scale changes that can be observed in the landscape, followed by a series of brief qualitative descriptions of changes identified within each littoral cell identified in **Figure 1**.

4.1 Countywide Beach and Dune Changes

Figure 2 presents pie charts depicting changes in the coastal geomorphology of Tillamook County from the 1970s to the present. Data inputs used to generate the pie charts are derived from the change in surface area of the respective geomorphic unit over time; note that USDA (1975) defined "Beach" for only Nehalem and Bayocean Spit and ignored the other areas. The overall focus of **Figure 2** is a subset of the suite of USDA classifications identified in **Table 1**, with emphasis on those geomorphic units closest to the beach and as such directly dependent on coastal and aeolian processes for their formation and evolution. These units include the active foredune (FDA), reactivated foredune (FDR, new in 2020), recently stabilized foredune (FD), dune complexes (DC), hummocks (H), and areas characterized as having open sand (OS). The reason for focusing on these specific units is that they are of greatest significance under Goal 18. The values listed for each pie in **Figure 2** reflect the acreage associated with the six units used here, while the proportions of each pie graphic are based on the sum of the combined acreage of the six units. Thus, Figure 2's significance is less about the actual proportions (which may be of interest), and more about the degree of change that has taken place from one time period to the next. **Table 2** includes cell specific information of the actual change in acreage over the time period for each unit, and expressed as a summary total for the entire county; results shown in Table 2 reflect a smaller subset of the suite of units defined in **Table 1**.

As can be seen in **Figure 2** (left), a significant portion of the county coastline in the 1970s was classified as open sand (totaling ~2,335 acres [9.5 km^2]), while the amount of active and stabilized foredune were ~685 and 287 acres respectively. Hummocky terrain and dune complex (essentially a complex mix of different units) made up comparably smaller portions of the county coastline. As a result of anthropogenic effects associated with dune planting (especially *Ammophila arenaria*) and the proliferation of shore pine (*Pinus contorta*) and other coastal shrubs and trees since the 1970s, there has been a significant decrease in the amount of open sand present throughout the county. Overall, **Figure 2** (right) indicates the open sand class has decreased by 67% to ~767 acres in 2020. The bulk of this reflects a shift toward these areas now being reclassified as younger stabilized dunes (DS). Of interest, although the total area of active foredune (FDA) remains essentially unchanged for the entire county (Figure 2), changes within individual subcells indicate some loss (Table 2). For example, Rockaway Beach is characterized by the largest decrease in active foredunes (−61 acres), followed by Nestucca Spit and Nehalem Spit. Losses in the Rockaway Beach area are compounded by the fact that previously stabilized dune areas are now being actively eroded into reactivated foredune (FDR), or are subject to wave runup, overtopping, and inundation during extreme storms. Conversely, the proliferation of beach grass (and other anthropogenic effects) throughout the county has resulted in an expansion in recently stabilized foredune (FD), which have seen an increase of ~82%. Similarly, the expansion of dune hummocks (H) and dune complex (DC) throughout the county can be attributed to anthropogenic effects associated with jetty construction (e.g., Bayocean Spit tip) or rehabilitation (e.g., both sides of Nehalem Bay mouth), which resulted in rapid seaward progradation of the shoreline, limiting foredune development in those areas, until such time as the rate of advance slowed and approached equilibrium. In other areas, hummock terrain can be linked with spit breaching such as on Nestucca Spit and mid-way along Bayocean Spit.

Figure 2. Pie charts depicting Tillamook County countywide changes over time for select coastal geomorphic units. Values shown for each pie reflect the acreage of that unit. Note: totals for the 1970s (3,588 acres) and for 2020 (2,656 acres) differ by ~930 acres.

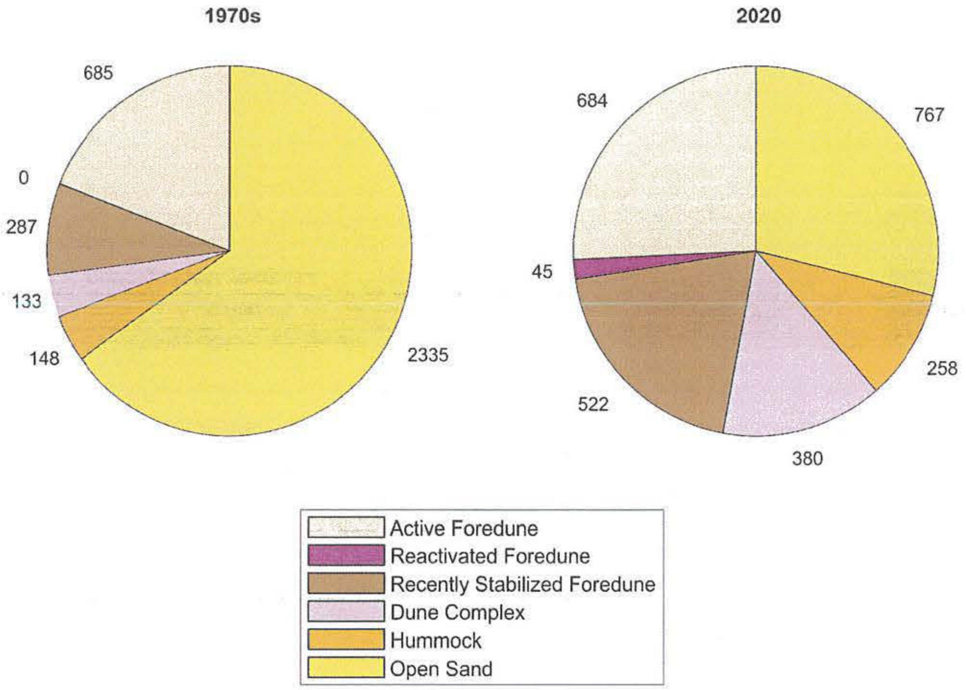


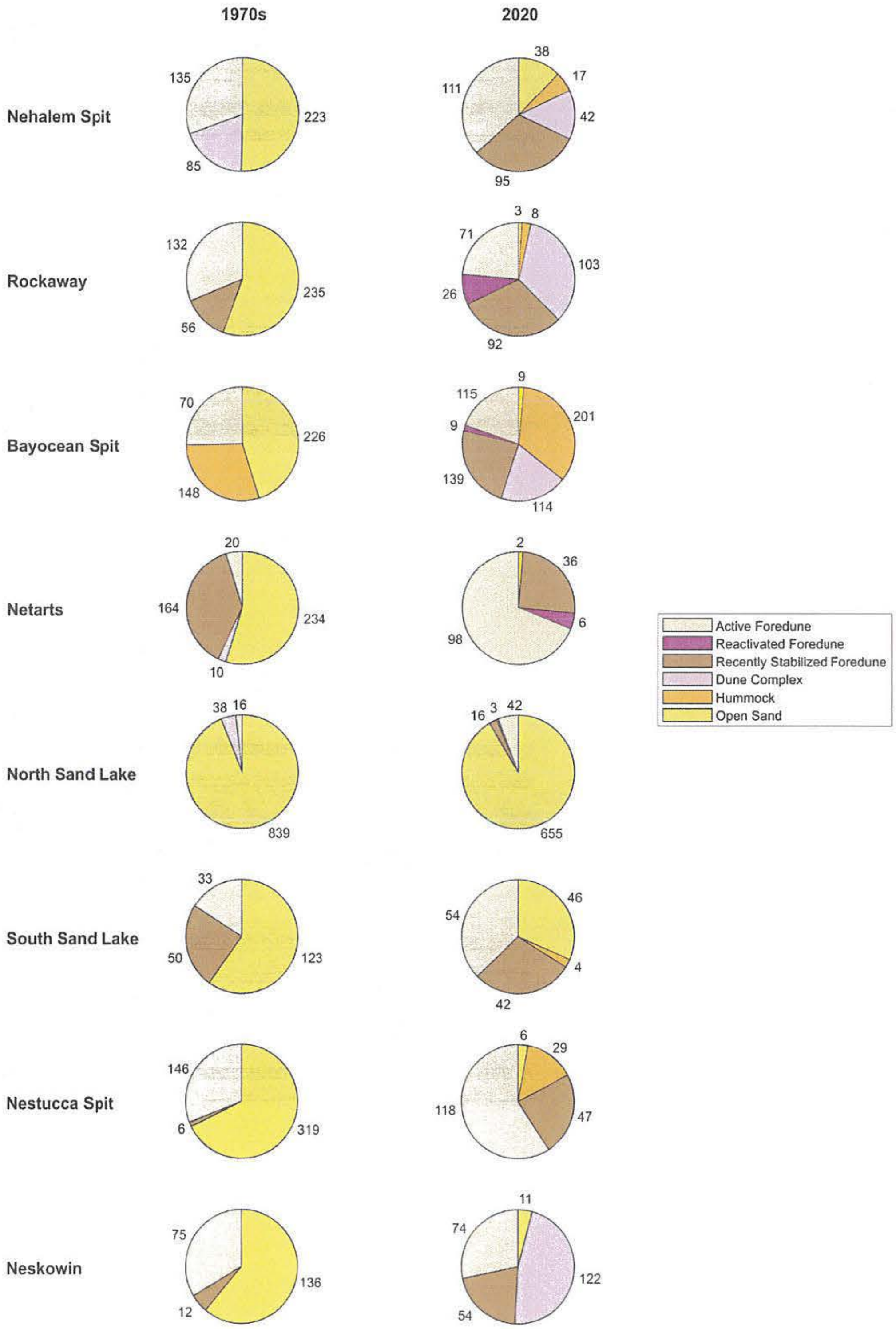
Table 2. Change in acreage of various coastal geomorphic units identified in Tillamook County from the 1970s to 2020.

Code	Description	Nehalem Spit	Rockaway	Bayocean Spit	Netarts Spit	North Sand Lake	South Sand Lake	Nestucca Spit	Neskowin	Total
B	Beach	161.1	367.7	214.0	370.0	253.7	280.2	199.6	268.3	2,114.6
FDA	Active Foredune	−24.3	−61.1	−11.6	77.8	26.1	21.1	−27.3	−1.1	−0.4
FDR	Reactivated Foredune	0	26.4	9.1	6.4	3.3	0	0	0	45.2
FD	Recently Stabilized Foredune	95.4	35.8	139.1	−127.5	16.2	−7.8	40.9	42.5	234.6
DC	Dune Complex	−42.2	102.7	113.5	−9.9	−38.1	0	0	121.7	247.6
H	Hummocks	17.1	8.1	52.5	0	0	3.5	28.5	0	109.6
DS	Younger Stabilized Dunes	275.3	625.2	−141.7	126.4	237.7	-20.9	−18.2	1.4	1,085.0
OS	Open Sand	−185.5	−232.3	−217.6	−232.7	−183.7	−77.4	−313.1	−125.6	−1,567.9
W	Interdune	−193.8	0	3.8	−54.1	−521.9	0	0	0	−766.0
WDF	Wet Deflation Plain	0	−73.2	−48.1	38.5	0	18.0	−179.3	0	−244.3
WMF	Wet Mountain Front	−29.6	−129.3	0	−59.3	−195.7	−82.0	−69.9	−147.9	−713.7
WL	Wetland	123.2	339.7	164.1	157.7	690.3	93.9	219.8	272.7	2,061.4

4.2 Nehalem Spit

Figure 3 presents summary pie charts of the same six geomorphic units identified in Figure 2, but now broken down according to each subcell; values provided are the actual unit acres, while summary changes are provided in Table 2. Figure 4 presents a map showing the complete suite of geomorphic units based on the original mapping (left) compared with present-day conditions (right). Overall, the area designated as active foredune has decreased by 18% (~24 acres) since the 1970s. Much of this change reflects improvements in base map accuracy due to the use of lidar data, coupled with improved geomorphic designation of the primary frontal dune and modeling of the erosion, wave runup, and inundation extents (Allan and others 2015). The jetties at the mouth of Nehalem Bay were originally constructed between 1916 and 1918 and later rehabilitated in the early 1980s (Lizarraga-Arciniega and Komar, 1975). Following construction of the jetties, Nehalem Spit advanced seaward. However, the shoreline did not straighten and tended to recurve landward near the jetties; the latter is evident in the curvilinear nature of the dunes near the spit tip (Figure 4). The reason for this was because the jetties were constructed low and quite porous, allowing sand to migrate across the jetty and into the estuary.

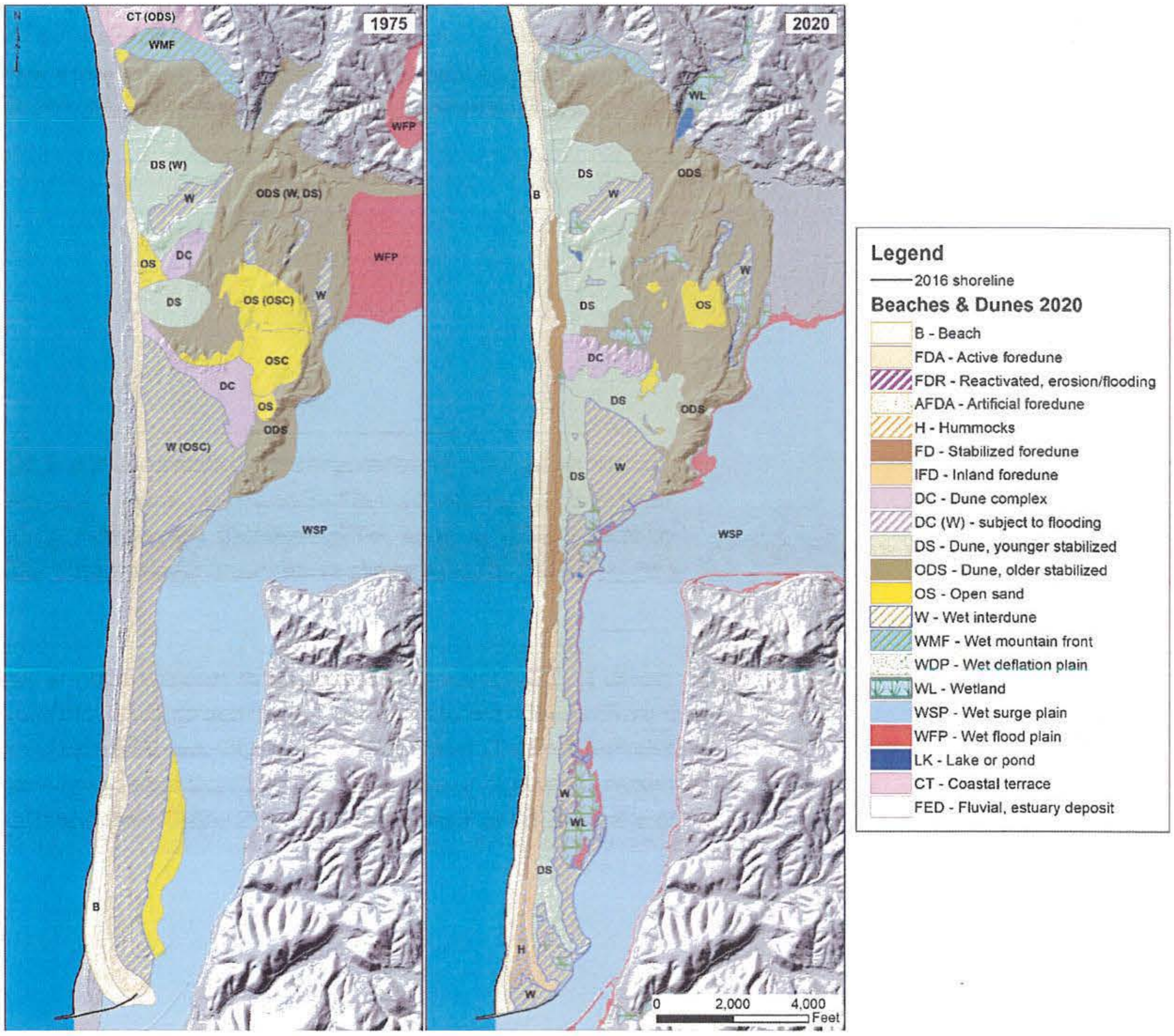
Figure 3. Pie charts depicting coastal geomorphic unit changes defined for each Tillamook County subcell. Values shown for each pie reflect acres of land, drawn from Table 2. Pie proportions are a function of the combined value of the six units presented in the figure, and their sums are not necessarily the same from 1970 to 2020.



With rehabilitation of the jetties in the 1980s, the beach stabilized and advanced seaward, leading to the formation of an entirely new active foredune system, while resulting in stabilization of the previously active foredune. Hence, evident from both Figure 3 and 4 is the appearance of the stabilized foredune designation (FD), which is now present along two thirds of the spit. Lidar mapping has also helped refine the number of foredunes present on the spit, which now reflect at least four sequences of development, with the most landward extent (DS) probably reflecting the pre-jetty position of the beach and dune.

Other notable features along Nehalem Spit include the reduction in areas designated as open dune sand (OS), and the presence of hummock terrain near the estuary mouth and between the present-day active foredune and an inland foredune. Refinements in both the wet surge plain and wet flood plain better characterize those areas impacted by daily tides as well as high water events.

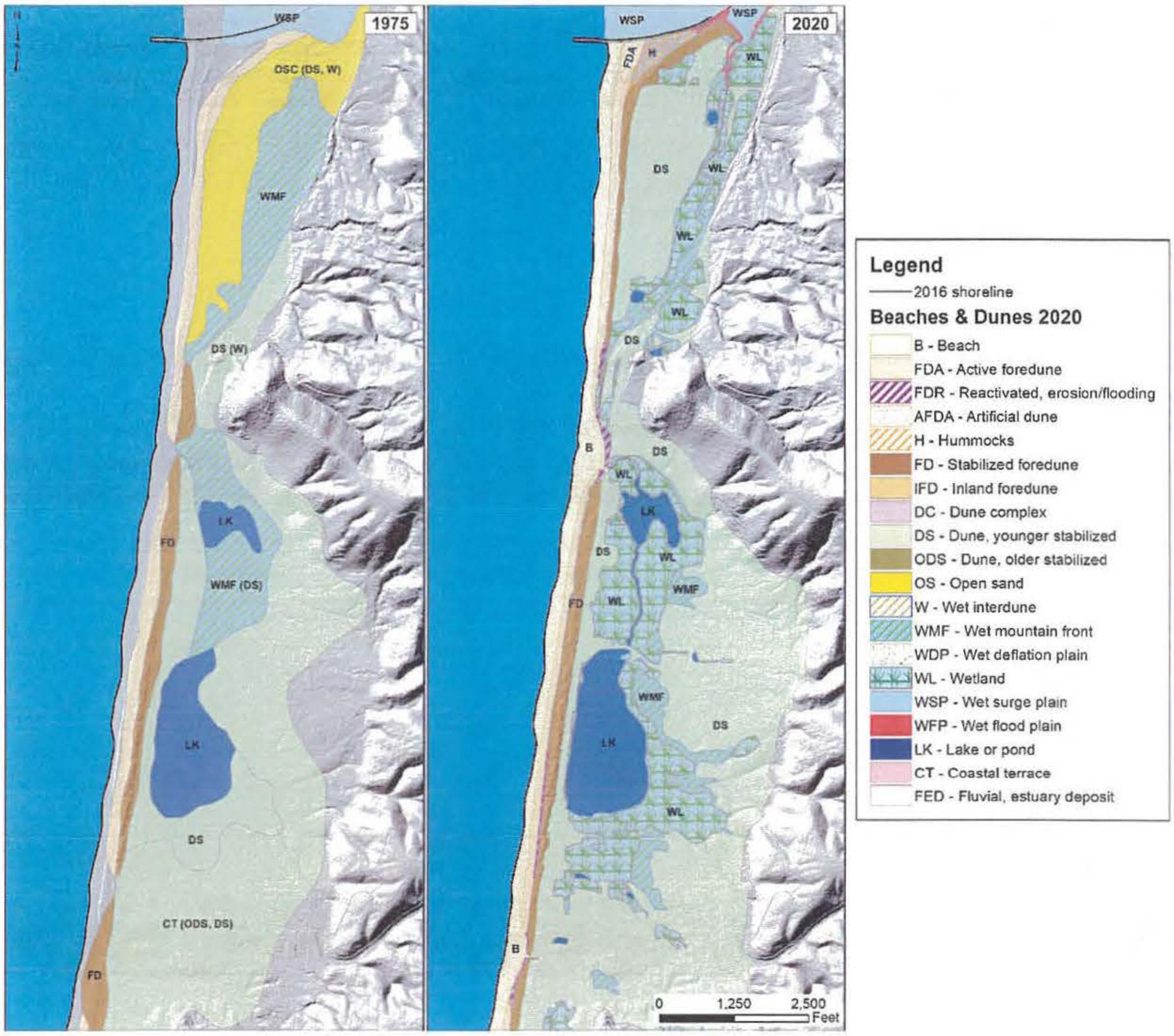
Figure 4. Beach and dune geomorphic mapping classifications for Nehalem Spit. (*left*) original USDA (1975), (*right*) updated version.



4.3 Rockaway Beach

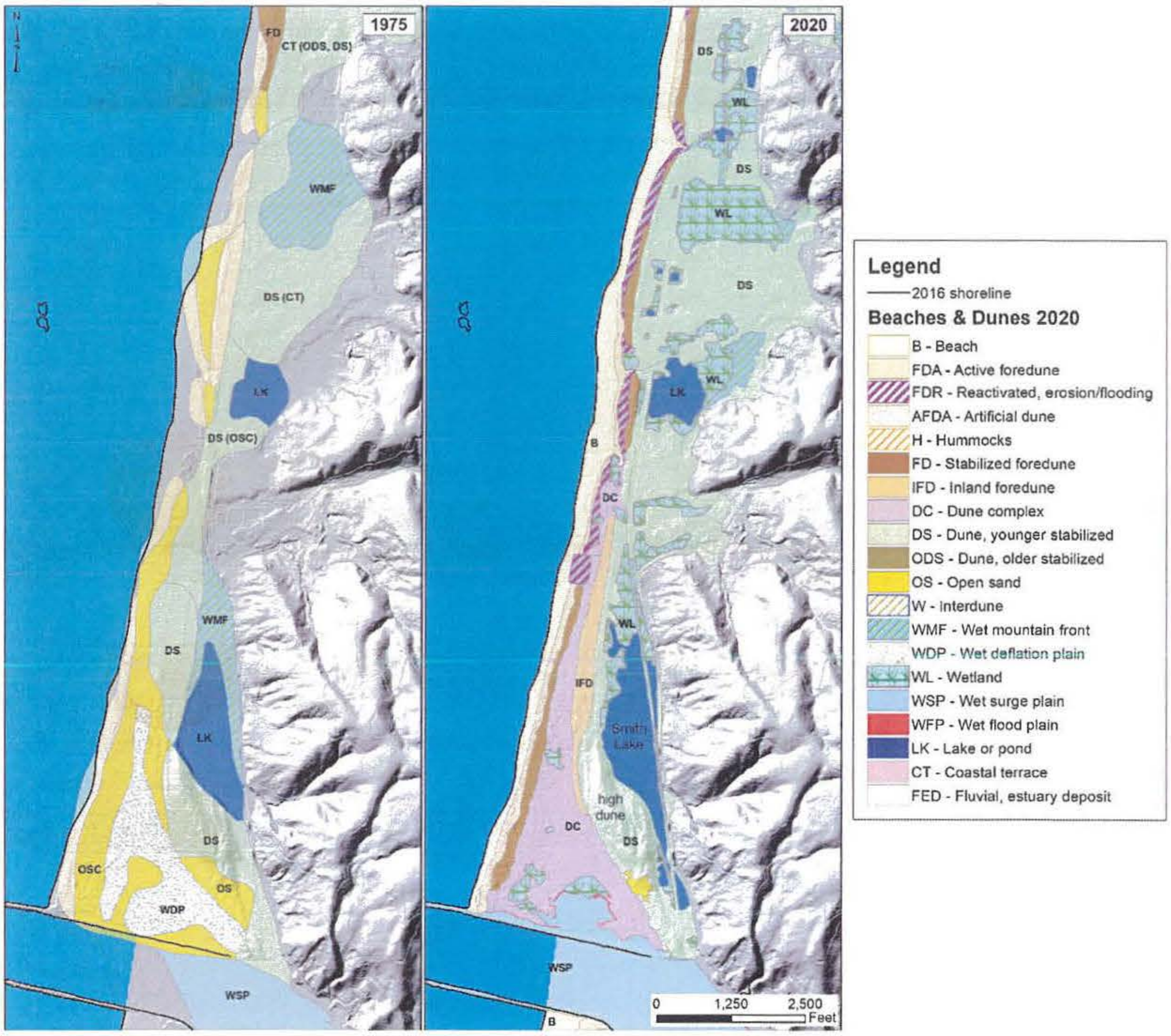
Figure 5 and Figure 6 present maps showing the suite of coastal geomorphic units based on the original mapping (left) compared with present-day conditions (right) for the Rockaway Beach and the Twin Rocks areas. Beginning with Rockaway, the most obvious changes have occurred in the north adjacent to the mouth of Nehalem Bay where previous areas of open sand (Figure 5, left) have since been stabilized (Figure 5, right). As noted in section 4.2 for Nehalem Spit, these changes reflect improvements to the jetty undertaken in the early 1980s, which caused the shoreline to build seaward. As can be seen in Figure 4 and Figure 5, associated with this advance was stabilization of the previous foredune and the formation of a new active foredune seaward of it. In fact, our analyses reveal a more contiguous foredune system today compared with the 1970s. Of interest also is the inclusion of a new geomorphic unit (FDR) that reflects erosion into the former stabilized foredune. This new class is especially prevalent along the Rockaway Beach and Twin Rocks shoreline and is reflective of the fact that this area has been undergoing significant erosion since at least 1997. The erosion is especially acute at Manhattan Beach wayside near the north central area of Figure 5, such that it has all but eliminated portions of the previous active foredune. To the south, development has encroached onto the dune, and much of the Rockaway Beach area today is now engineered (i.e., riprap) as a result of erosion effects that have occurred since 1997 (Allan and Hart, 2008; Allan and others, 2009). Other notable changes include the proliferation of wetland-designated areas throughout the area, which are found concentrated in areas defined previously as wet mountain front or wet interdunes (i.e., areas subject to high water tables and periodic standing water).

Figure 5. Beach and dune geomorphic mapping classifications for Rockaway Beach. (*left*) original USDA (1975), (*right*) updated version.



Between Twin Rocks and the mouth of Tillamook Bay, areas designated as open sand have now been virtually eliminated, the exception being a small designated area of high dune by Smith Lake, near Barview (Figure 6). Erosion hazards have also increased along most of the shore to the point where it is now considered to be chronic, such that the previous active foredune has been eliminated in a number of areas (FDR). As a result, erosion is continuing and is now cutting landward into older dune features that formed both prior to and immediately following jetty construction (completed in 1917) at the mouth of Tillamook Bay. Finally, a large area defined previously as a wet deflation plain (Figure 6, left) has been redefined as dune complex (Figure 6, right) since this feature can be attributed entirely to coastal nearshore processes that resulted in rapid beach and shoreline advance following construction of the north Tillamook jetty (Komar, 1997), as opposed to wind-dominated processes.

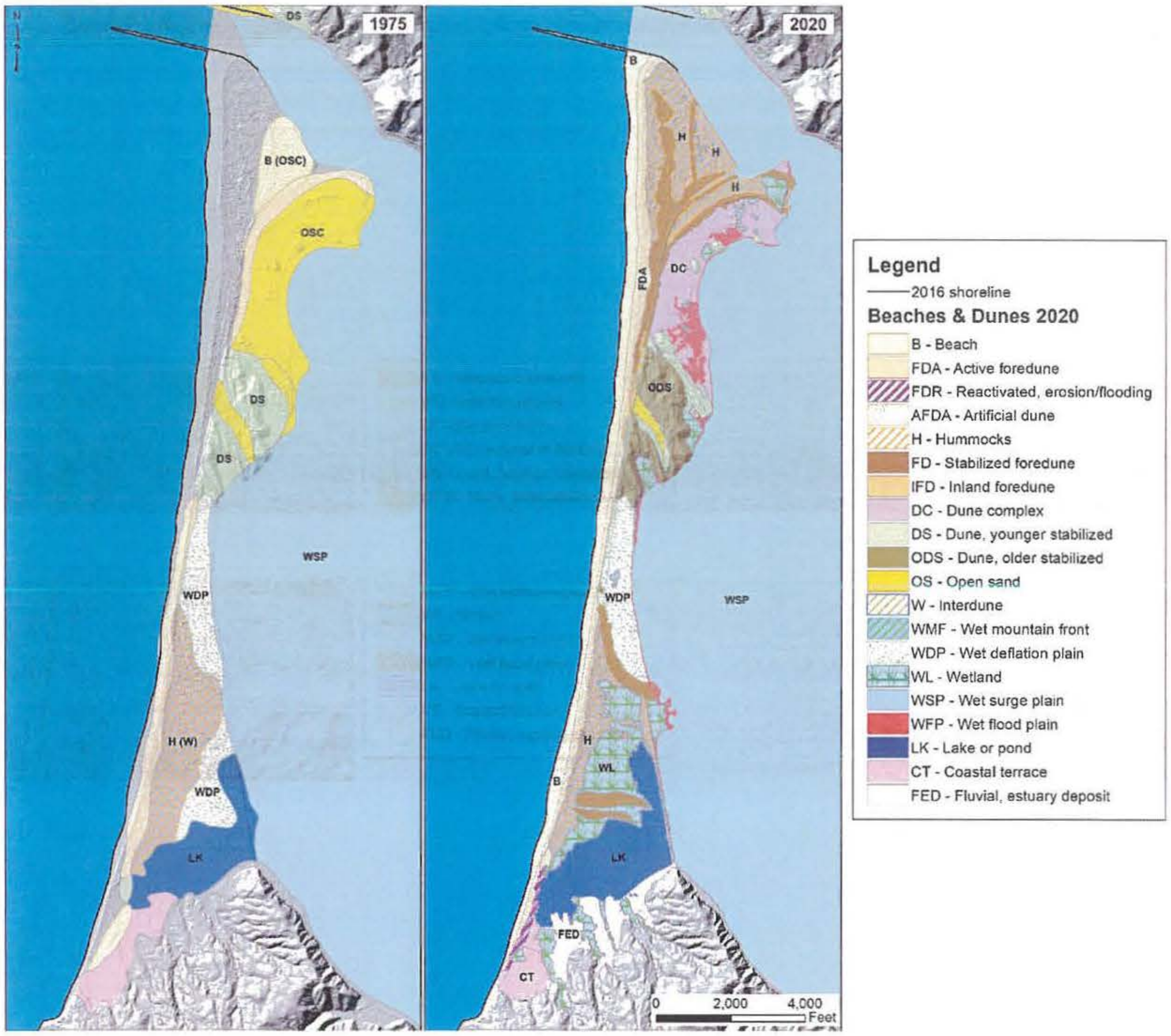
Figure 6. Beach and dune geomorphic mapping classifications for Twin Rocks. (*left*) original USDA (1975), (*right*) updated version.



4.4 Bayocean Spit

Figure 7 shows changes in the suite of coastal geomorphic units based on the original mapping (left) compared with present-day conditions (right) for Bayocean Spit. Several interesting features are apparent from the updated mapping. For context, the original mapping would have occurred prior to completion of the south Tillamook Jetty, which was finished in 1974. Hence, along the spit tip one can see evidence of varying stages of foredune development that occurred as the jetty was being built, with the shoreline transitioning from a curvilinear shape at the tip, to a more linear feature as sand aggraded against the jetty as it was being built. As can be seen from Figure 7, there is evidence of at least two stabilized foredunes (FD) that run parallel to the existing active foredune (FDA). Between these dunes is an area of hummock terrain, indicative of the rapid pace in which the shoreline advanced, followed by a period of slower growth, enabling the foredune to begin developing.

Figure 7. Beach and dune geomorphic mapping classifications for Bayocean Spit. (*left*) original USDA (1975), (*right*) updated version.



Immediately south of the pre-jetty spit tip is a large area of open sand conditional (OSC, **Figure 7**, *left*) that has since been stabilized by dune grasses, shore pine, and other coastal shrubs. This section has been redefined as a dune complex because it is still evolving toward a stabilized younger dune state. A section of parabolic dunes in the north central portion of the spit previously classified as younger stabilized dune (DS) has been redefined as older stabilized dune (ODS); the original distinction between the two units is largely based on soil development. However, this section is almost certainly much older than originally identified by the USDA (1975) with extensive forest and soil development (evident in early 1939 photos of the area) and observed by Cooper (1958), such that calling it a younger stabilized dune (DS) would be inconsistent with other ODS designations used by the USDA (1975) elsewhere. Moreover, (Cooper, 1958) speculated on the longevity of these dune features noting that they have almost certainly been around for a long time given the size of the dune features and their persistence in having survived any potential shifts in the location of the estuary mouth, which likely has remained in the north. Evident also in **Figure 7** (left), is that at the time of mapping USDA (1975) did not identify an active foredune in front of the older dunes, suggesting that this site was probably experiencing intense erosion, essentially truncating the dunes.

The erosion of Bayocean Spit is especially well documented, culminating with the spit breaching in the late 1940s (Komar, 1997; Allan and Priest, 2001). The cause of the erosion was entirely due to construction of the north Tillamook jetty (completed in October 1917), which interrupted the natural supply of sediment. During the construction phase, changes in the inlet channel and the adjacent shorelines soon became evident. North of Tillamook Bay, sand accumulated rapidly and the shoreline advanced seaward at a rate almost equal to the speed at which the jetty was being constructed (Komar 1997). Between 1914 and 1927, the coastline just north of the jetty advanced seaward some 975 m (3,200 ft). However, by 1920 the rate of sand accumulation on the north side of the jetty had slowed, so that the position of the shoreline was much the same as it is today. In the south, the shoreline near Cape Meares retreated some 200 m (650 ft). The erosion was particularly severe between 1927 and 1953, with the mean shoreline retreating at a rate of ~ 2.4 to 3 m/yr (~8 to 10 ft/yr), culminating with the cutting away of a 1,220 m (4,000 ft) section of the spit on November 13, 1952, breaching the spit. The geomorphic evidence of the breach is clear in our updated geomorphic mapping (**Figure 7**, *right*). As can be seen in the south-central portion of the spit, curved stabilized foredunes (FD) are evident in the landscape, while the bulk of the area between the relict foredunes is characterized by hummock terrain and/or wetlands. In the far south, adjacent to Cape Meares, portions of this area are subject to wave overtopping and inundation of the backshore (FDR), while much of the terrain above the community is characterized by active landsliding.

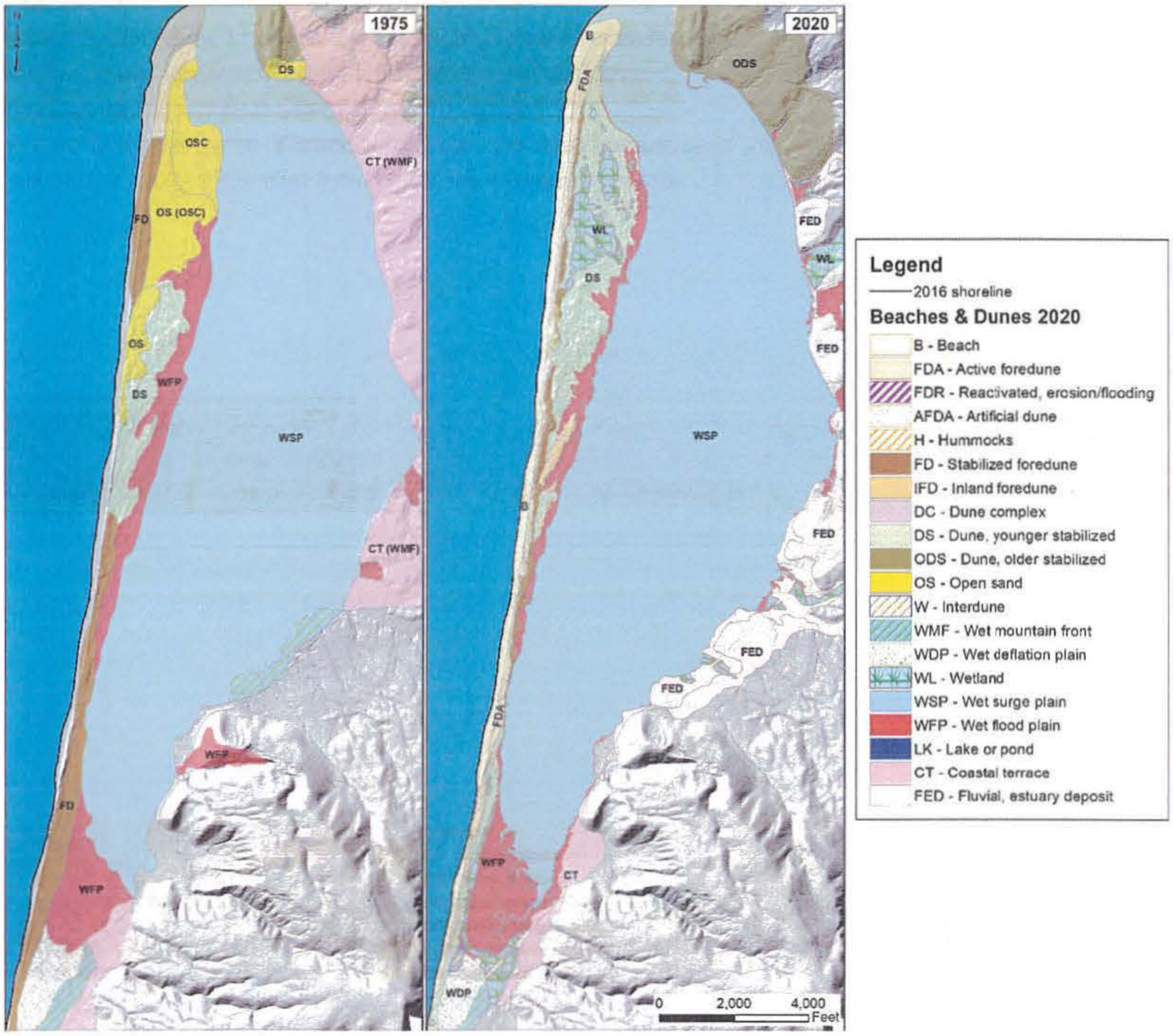
Finally, it is worth noting that the degree of the post-jetty changes identified in **Figure 7** (right) is indicative of the speed at which the entire spit adjusted and eventually stabilized. This process began to occur almost immediately after construction on the south Tillamook Bay jetty started. As a result, conditions today now reflect an extensive active foredune system that effectively developed over a very short period. Ongoing beach monitoring by the author indicates that the southern half of the spit is largely stable (neither eroding nor accreting), while the northern half of the spit is presently accreting at rates of ~0.6 to ~1 m (2-3 ft) per year[3].

[3] http://nvs.nanoos.org/BeachMapping?action=oiw:beach_mapping_point:bay06:plots:trends (after Allan and Hart, 2008)

4.5 Netarts Spit

Updated mapping of the beaches and dunes along Netarts Spit is presented in **Figure 8**. Consistent with other areas, the most notable change reflects the stabilization of open sand areas and their conversion to younger stabilized dunes. This change reflects a decrease in the total acreage of open sand areas by 232.7 acres (**Table 2** and **Figure 3**). Apparent also are changes in the large areas defined as stabilized foredune (FD), evident in **Figure 8** (left), much of which has been redefined as active foredune (FDA, **Figure 8** [right]). While we don't disagree with the original interpretation, it is puzzling that the USDA (1975) did not map any active foredune along the spit other than a small area near the spit tip. Finally, it is worth mentioning that prior to the 1980s, Netarts Spit may have been stable. However, since the 1980s the spit has experienced some of the fastest rates of erosion in the county, which has continued to the present (Komar, 1986, 1998; Allan and others, 2006). The culmination of the erosion occurred at the south end of the cell at Cape Lookout State Park, where Oregon State Parks constructed an artificial foredune to mitigate the erosion.

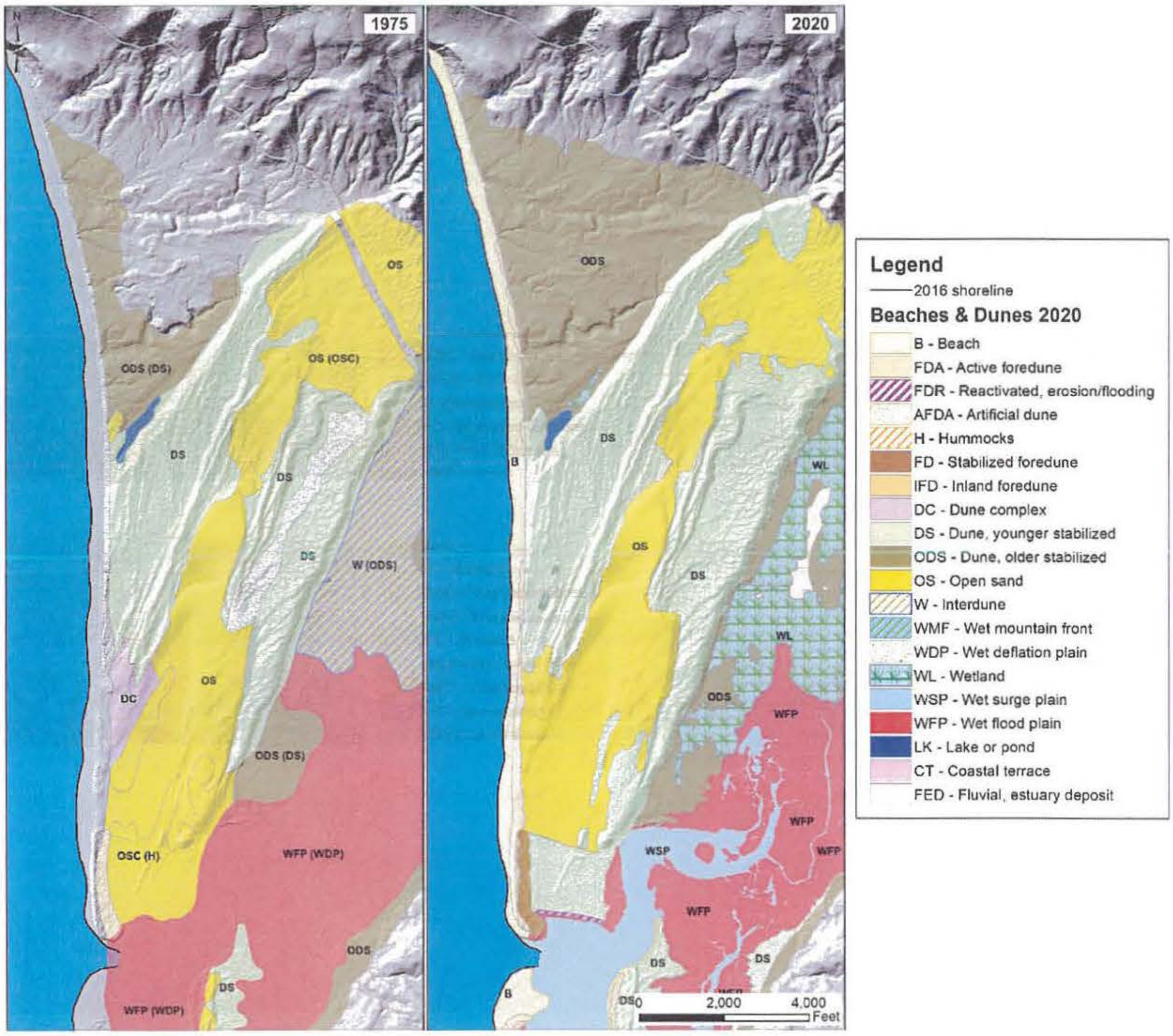
Figure 8. Beach and dune geomorphic mapping classifications for Netarts Spit. (*left*) original USDA (1975), (*right*) updated version.



4.6 Northern Sand Lake

Updated mapping of the beaches and dunes along the northern half of the Sand Lake littoral cell is presented in **Figure 9**. The main refinements to the latest mapping include designations of the active foredune (where applicable), improvements to the wet flood zone and wet surge plain, and updates to the extent of open sand in the area. Of the four littoral cells in Tillamook County, the Sand Lake cell has the largest area of open sand remaining, the bulk of which is located in the northern half of the cell (**Figure 9**). However, since the 1970s, open sand in this area has decreased by about 22%, from a high of 839 acres to ~655 acres today (**Table 2** and **Figure 3**). Much of this reflects the stabilization of areas in the south, adjacent to the estuary, and to a lesser extent in the northeast. A small area in the south adjacent to the estuary has been mapped as reactivated foredune (FDR) and is presently being eroded into by ocean waves from the southwest. Areas of older stabilized dunes (ODS) in the north have expanded significantly based on the mapping of Wells and others (1994).

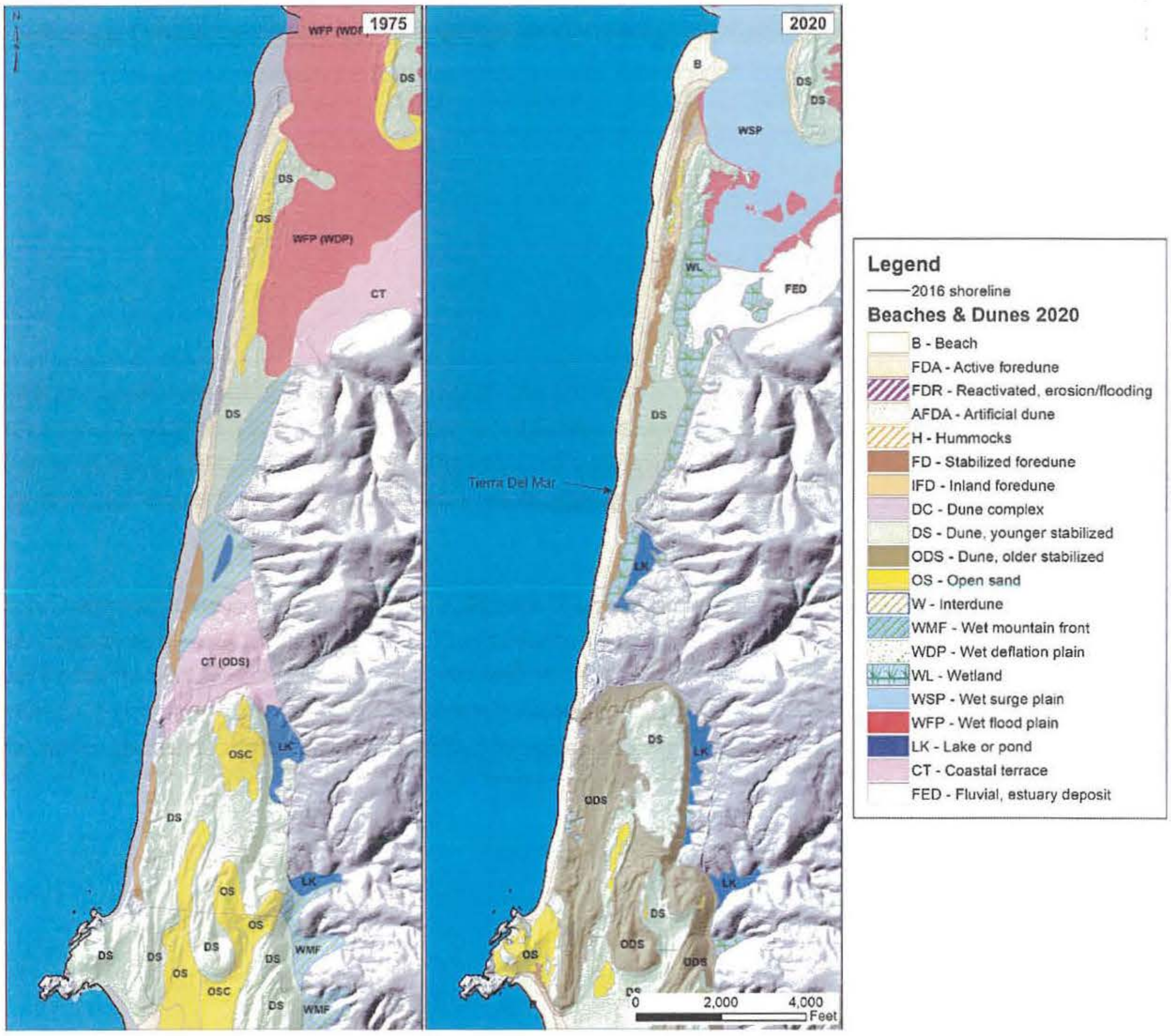
Figure 9. Beach and dune geomorphic mapping classifications for northern Sand Lake. (*left*) original USDA (1975), (*right*) updated version.



4.7 South Sand Lake

Figure 10 shows changes in the suite of coastal geomorphic units based on the original mapping (left) compared with present-day conditions (right) for the southern half of the Sand Lake littoral cell. Our updated mapping indicates that areas designated as open sand (OS) have been reduced by ~63% since the 1970s (Figure 3). The bulk of these changes occurred north of Tierra De Mar out on the spit, and in the south, just north of Pacific City. Stabilized foredunes (FD) have contracted slightly, while active foredunes have expanded by ~64%. Other notable changes include the inclusion of fluvial/estuarine deposits (mapped by Wells and others [1994]) located adjacent to the estuary, and the reclassification of areas designated as younger stabilized dunes (DS) to older stabilized dunes (ODS) based on an evaluation of 1939 aerial photos of the area. Finally, refinements to the wet surge plain and wet flood plain indicate more realistic tidal effects, along with flood potential (Figure 10).

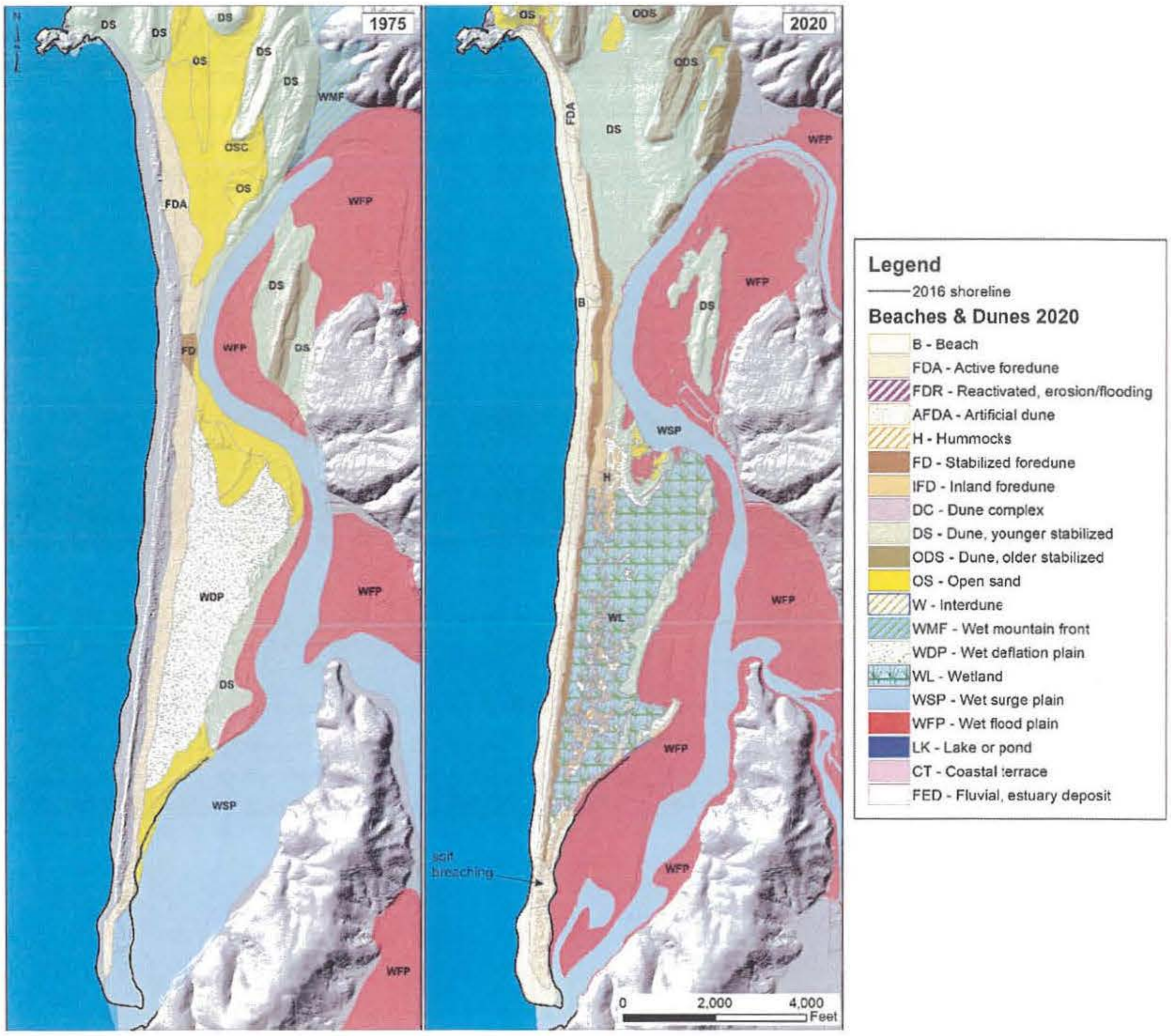
Figure 10. Beach and dune geomorphic mapping classifications for southern Sand Lake. (*left*) original USDA (1975), (*right*) updated version.



4.8 Nestucca Spit

Updated mapping of the beaches and dunes along Nestucca Spit is presented in **Figure 11**. As can be seen from the figure, the largest change since the 1970s is the dramatic reduction in areas defined as having open sand, the bulk of which was concentrated in the north, near Cape Kiwanda. Thus, while the area of open sand has contracted, the updated mapping indicates that much of this has been converted to younger stabilized dunes (DS). Refinements to the active foredune area indicate that it has contracted by about 29%, while stabilized foredunes (FD) have expanded substantially. Near the spit tip, evidence of spit breaching that took place in 1978 remains evident in the landscape today. Finally, the large area defined as wet deflation plain has been re-designated as a mixture of wetland (WL, USFWS National Wetland Inventory), hummock terrain, and wet deflation plain.

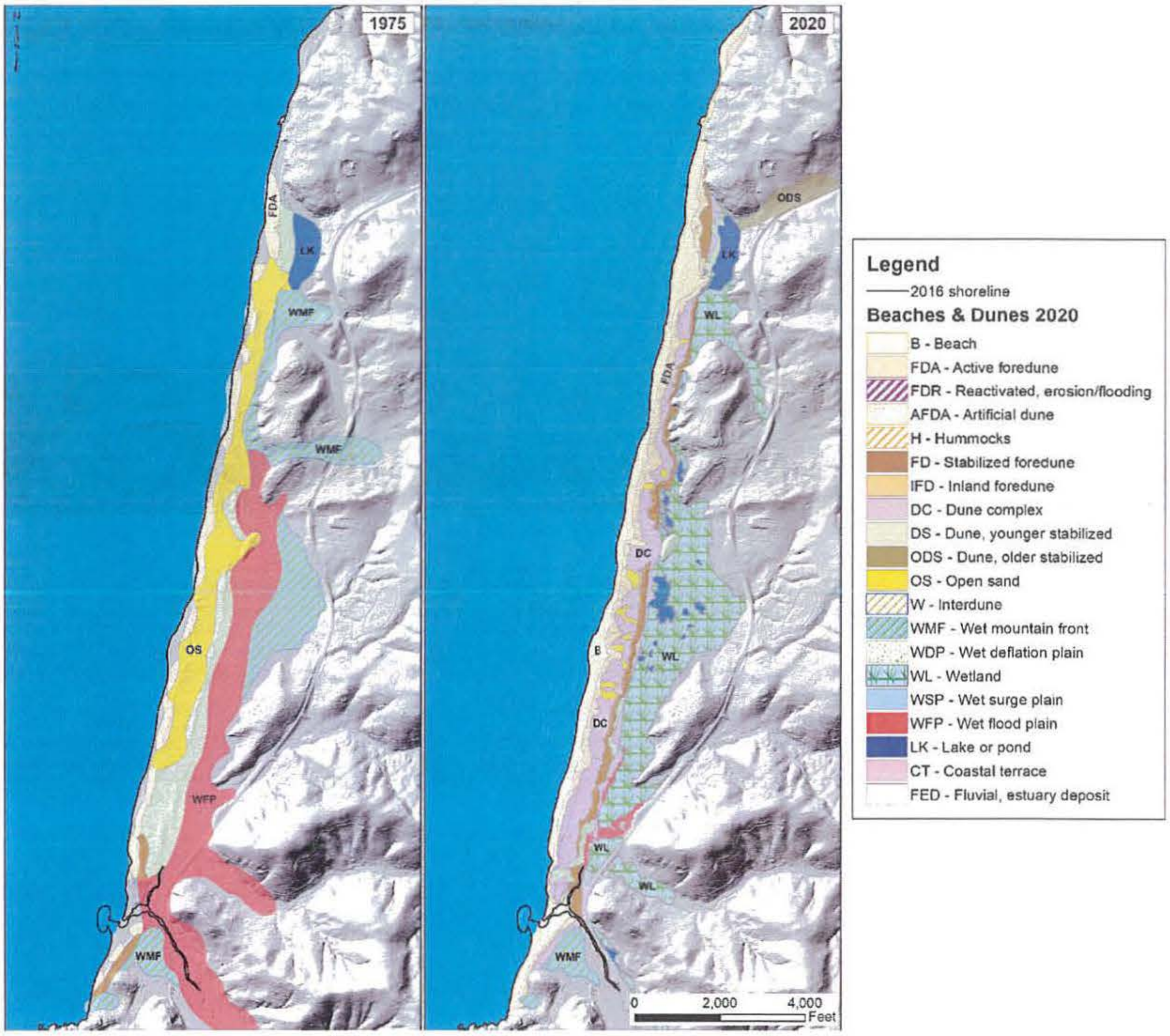
Figure 11. Beach and dune geomorphic mapping classifications for Nestucca Spit and Pacific City. (*left*) original USDA (1975), (*right*) updated version.



4.9 Neskowin

Figure 12 shows changes in the suite of coastal geomorphic units based on the original mapping (left) compared with present-day conditions (right) for the Neskowin area. Consistent with other areas in Tillamook County, the largest change reflects the overall decrease (98%) in areas characterized as open sand. The remaining pockets of open sand are largely confined to areas where dune blowouts have occurred, due to aeolian and/or wave runup-inundation processes. Consistent with the decrease in open sand areas has been a shift toward stabilized foredunes, which are now spread along the length of the Neskowin shoreline. Because the area landward of the foredune exhibits a complex history with many factors contributing to its overall development, it is designated dune complex (DC). Finally, with refinements in the wet flood plain toward using a tidal datum-based shoreline, the wet flood plain in 2020 is significantly smaller when compared with the area mapped in the 1970s.

Figure 12. Beach and dune geomorphic mapping classifications for Neskowin. (*left*) original USDA (1975), (*right*) updated version.



5.0 CONCLUSION

The objective of this pilot beach and dune mapping study has been to produce updated information on the spatial extent of the beach and foredune system in Tillamook County that may be subject to existing and future storm-induced wave erosion, runup, overtopping, and coastal flooding. These data are of importance to DLCD and the coastal counties of Oregon in order to improve implementation of Statewide Planning Goal 18: Beaches and Dunes. Specifically, Oregon Statewide Planning Goal 18 requires that local jurisdictions adopt a beach and dune overlay zone in their comprehensive plan, which may be used to manage development on or near such features. Regional mapping of the original beaches and dunes overlay zone of the Oregon coast was undertaken between 1972 and 1975 by the U.S. Department of Agriculture Soil Conservation Service (USDA, 1975). However, much has changed on the Oregon coast, requiring that the USDA (1975) overlay zone be updated to reflect current conditions. As noted throughout this report, some of the largest changes to have taken place along the coast include:

- The rapid expansion of European beach grass (*A. arenaria*), which has helped to stabilize many dune systems;
- Encroachment of human development into foredune areas;
- Dune management activities such as foredune grading and planting;
- Changes in beach and dune morphology due to either coastal erosion or accretion;
- Construction of coastal engineering used to mitigate erosion hazards; and,
- Shoreline changes at the mouths of estuaries controlled by jetties.

Although the updated beaches and dune overlay zone maintains the core classification structure developed originally by the USDA (1975), it does include several new classes that address changes in the coastal geomorphology of Tillamook County. Importantly, the geospatial attributes associated with the GIS are now much refined, so that they account for comments and notes made by the author and include specific references to their susceptibility to coastal hazards.

Analyses presented here clearly demonstrate the transformation of the coast over the past 45 years. Of particular note has been the overall reduction in areas defined as open sand (OS), which has decreased by ~67% since the 1970s. Most of this change can be directly attributed to anthropogenic effects, particularly the introduction of European beach grass (*Ammophila arenaria*) as well as stabilization from shore Pine (*Pinus contorta*) and other native plant species. Although the bulk of this transformation can be attributed to a shift toward younger stabilized dunes (DS), the expansion of areas defined as active foredune (FDA) and stabilized foredunes (FD) is a testament to the role humans have played in driving these changes.

6.0 ACKNOWLEDGMENTS

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Allison Hinderer

From: Sarah Mitchell <sm@klgpc.com>
Sent: Tuesday, July 27, 2021 2:21 PM
To: Sarah Absher; Allison Hinderer
Cc: Wendie Kellington; Bill and Lynda Cogdall (jwcogdall@gmail.com); Bill and Lynda Cogdall (lcogdall@aol.com); Brett Butcher (brett@passion4people.org); Dave and Frieda Farr (dfarrwestproperties@gmail.com); David Dowling; David Hayes (tdavidh1 @comcast.net); Don and Barbara Roberts (donrobertsemail@gmail.com); Don and Barbara Roberts (robertsfm6@gmail.com); evandanno@hotmail.com; heather.vonseggern@img.education; Jeff and Terry Klein (jeffklein@wvmeat.com); Jon Creedon (jcc@pacifier.com); kemball@easystreet.net; meganberglaw@aol.com; Michael Munch (michaelmunch@comcast.net); Mike and Chris Rogers (mjr2153@aol.com); Mike Ellis (mikeellispdx@gmail.com); Rachael Holland (rachael@pacificopportunities.com); teriklein59@aol.com
Subject: EXTERNAL: RE: 851-21-000086-PLNG & 851-21-000086-PLNG-01 Pine Beach BOCC Hearing Packet - Additional Evidence (Part 5 of 6)
Attachments: Exh 2 - DOGAMI SP-47 Report_Part4.pdf

Importance: High

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Please include the attached in the record of 851-21-000086-PLNG /851-21-000086-PLNG-01 and in the Board of Commissioners' packet for the July 28, 2021 hearing. This is part 5 of 6.

From: Sarah Mitchell
Sent: Tuesday, July 27, 2021 2:20 PM
To: sabsher@co.tillamook.or.us; Allison Hinderer <ahindere@co.tillamook.or.us>
Cc: Wendie Kellington <wk@klgpc.com>; Bill and Lynda Cogdall (jwcogdall@gmail.com) <jwcogdall@gmail.com>; Bill and Lynda Cogdall (lcogdall@aol.com) <lcogdall@aol.com>; Brett Butcher (brett@passion4people.org) <brett@passion4people.org>; Dave and Frieda Farr (dfarrwestproperties@gmail.com) <dfarrwestproperties@gmail.com>; David Dowling <ddowling521@gmail.com>; David Hayes (tdavidh1@comcast.net) <tdavidh1@comcast.net>; Don and Barbara Roberts (donrobertsemail@gmail.com) <donrobertsemail@gmail.com>; Don and Barbara Roberts (robertsfm6@gmail.com) <robertsfm6@gmail.com>; evandanno@hotmail.com; heather.vonseggern@img.education; Jeff and Terry Klein (jeffklein@wvmeat.com) <jeffklein@wvmeat.com>; Jon Creedon (jcc@pacifier.com) <jcc@pacifier.com>; kemball@easystreet.net; meganberglaw@aol.com; Michael Munch (michaelmunch@comcast.net) <michaelmunch@comcast.net>; Mike and Chris Rogers (mjr2153@aol.com) <mjr2153@aol.com>; Mike Ellis (mikeellispdx@gmail.com) <mikeellispdx@gmail.com>; Rachael Holland (rachael@pacificopportunities.com) <rachael@pacificopportunities.com>; teriklein59@aol.com
Subject: RE: 851-21-000086-PLNG & 851-21-000086-PLNG-01 Pine Beach BOCC Hearing Packet - Additional Evidence (Part 4 of 6)
Importance: High

Please include the attached in the record of 851-21-000086-PLNG /851-21-000086-PLNG-01 and in the Board of Commissioners' packet for the July 28, 2021 hearing. This is part 4 of 6.

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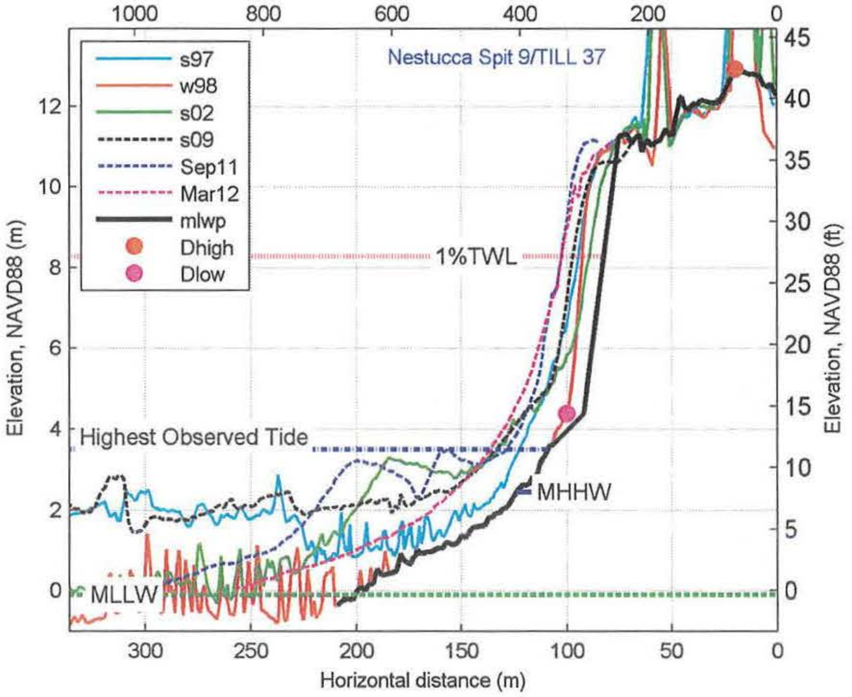

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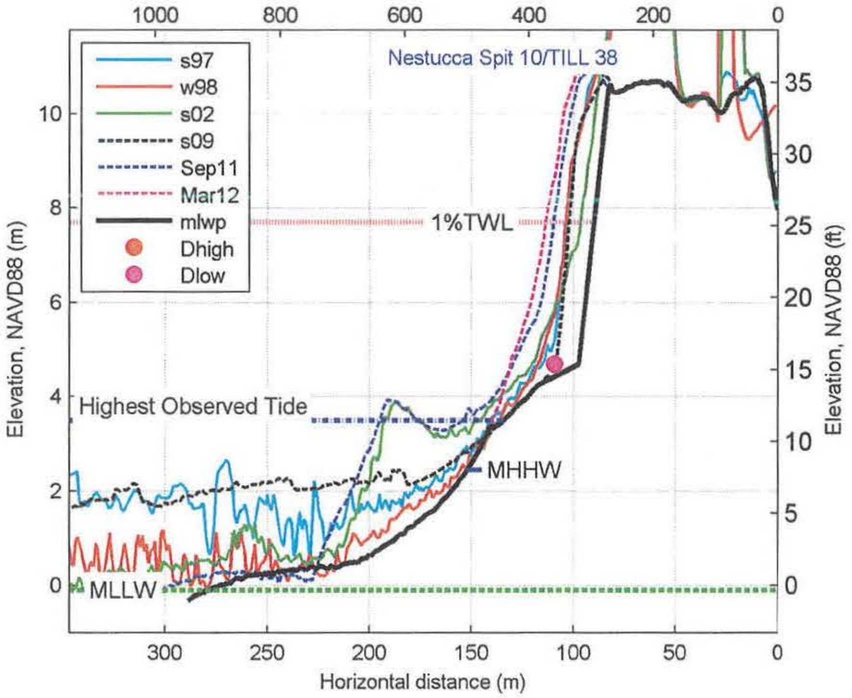

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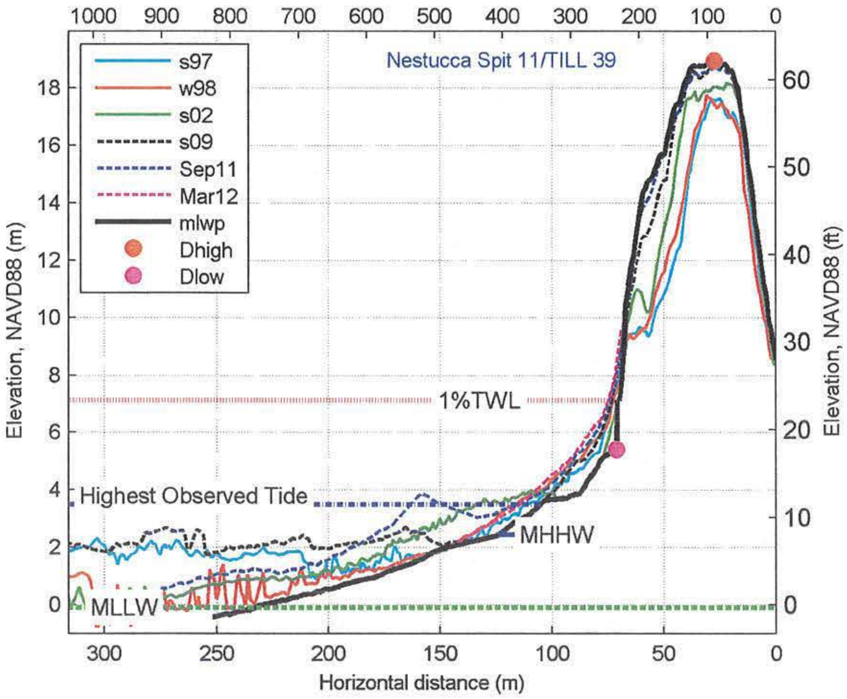

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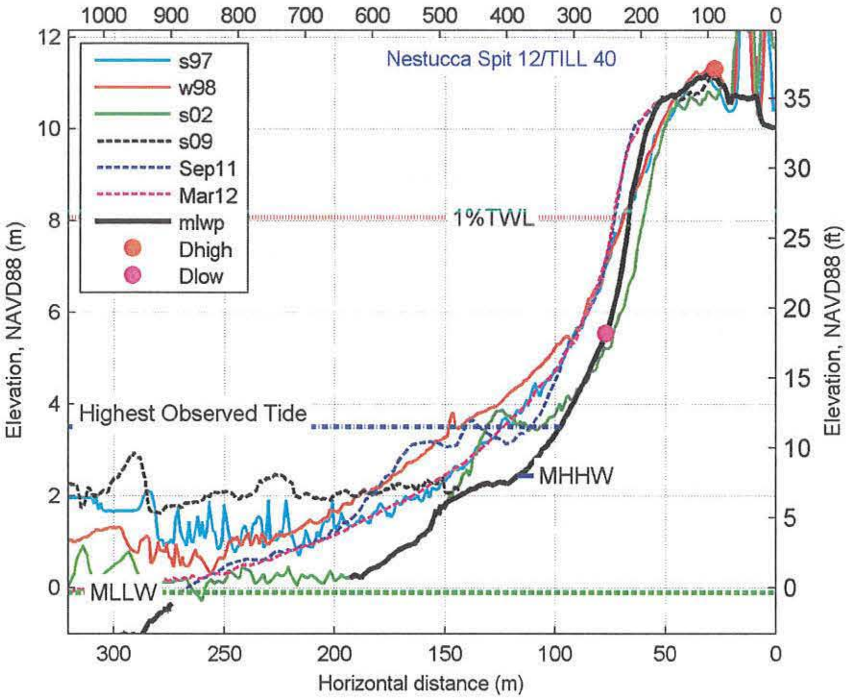

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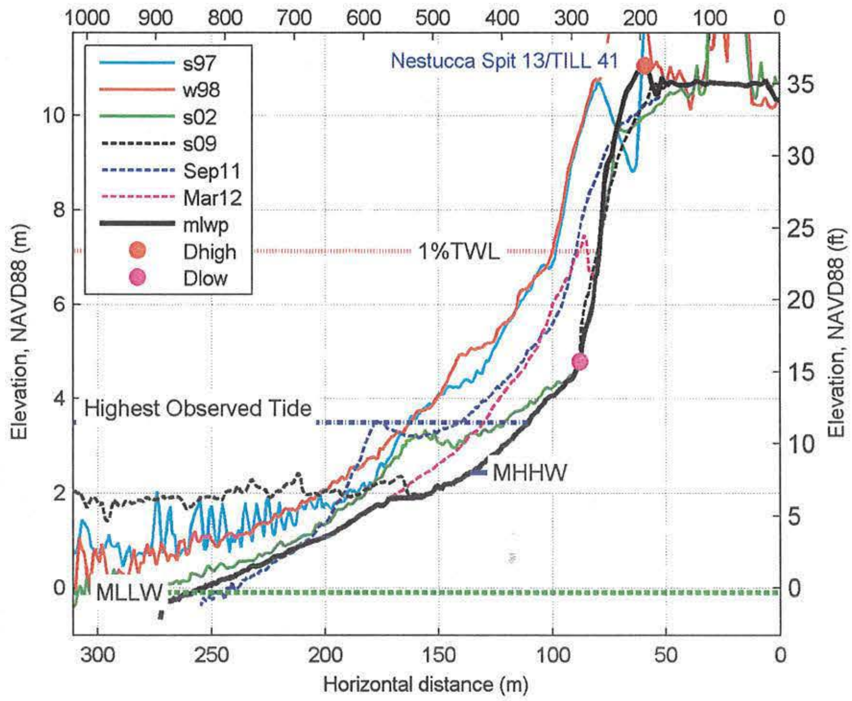

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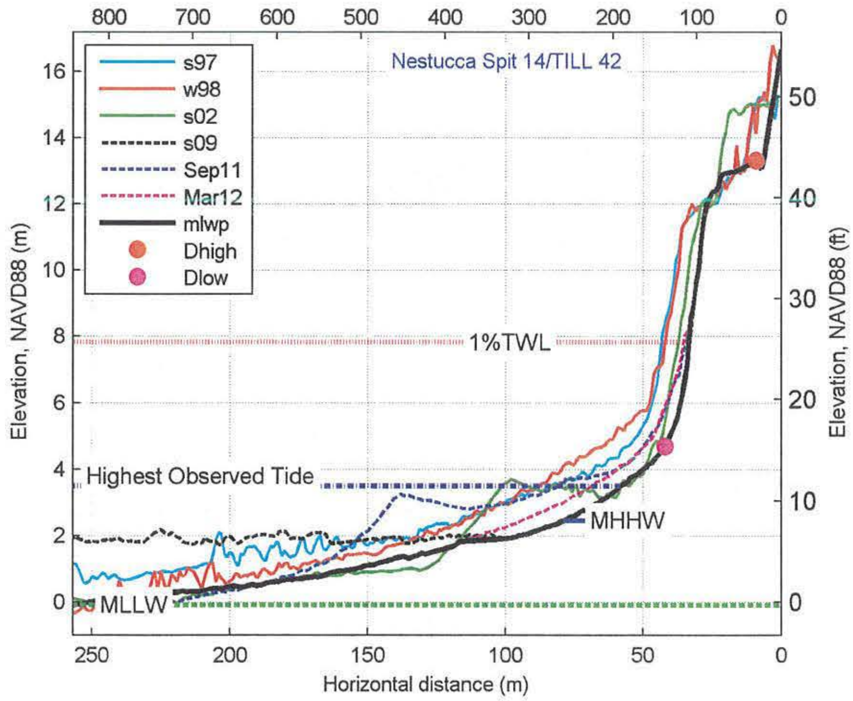

11.4.3 Sand Lake

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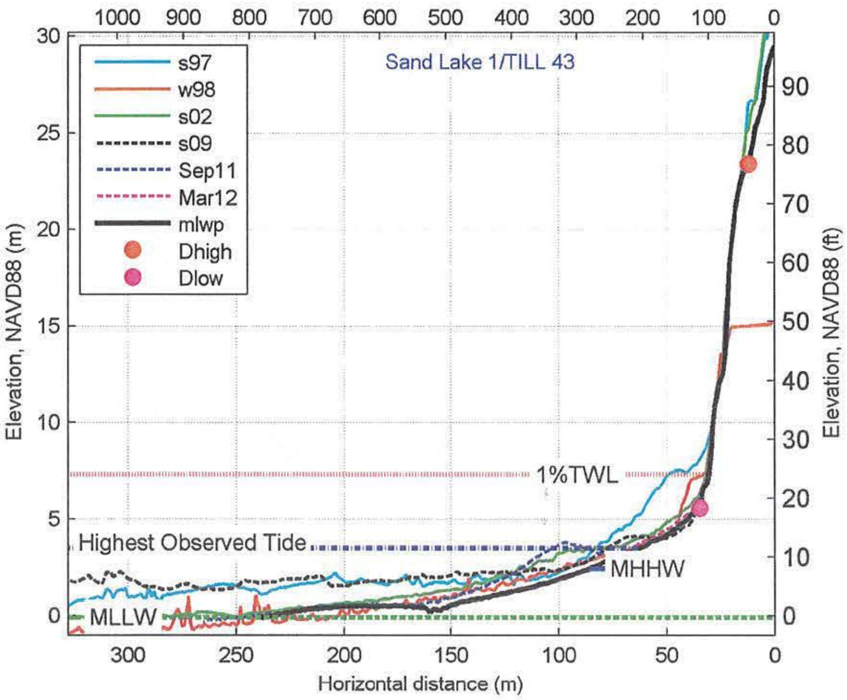

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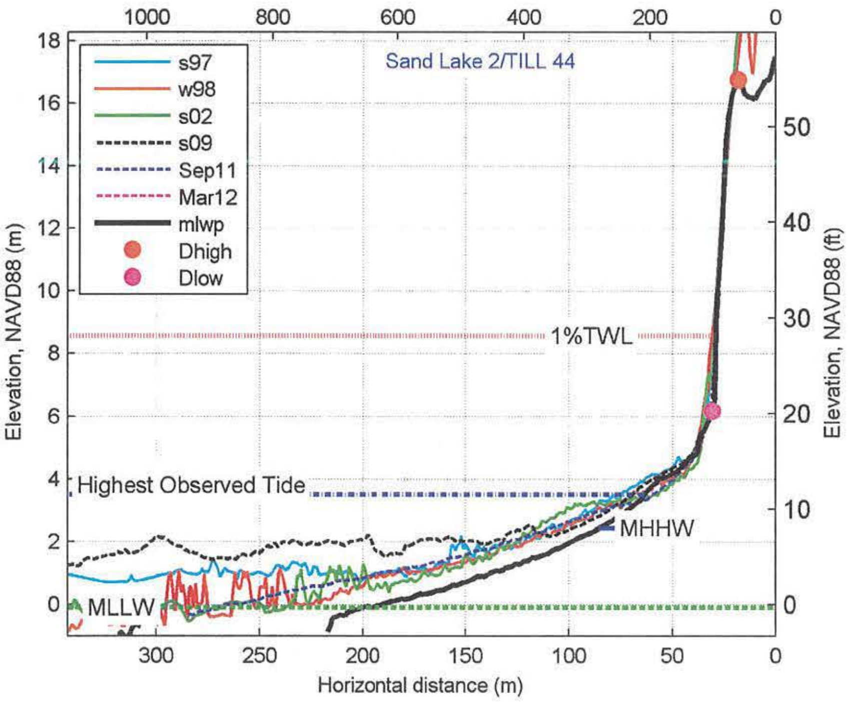

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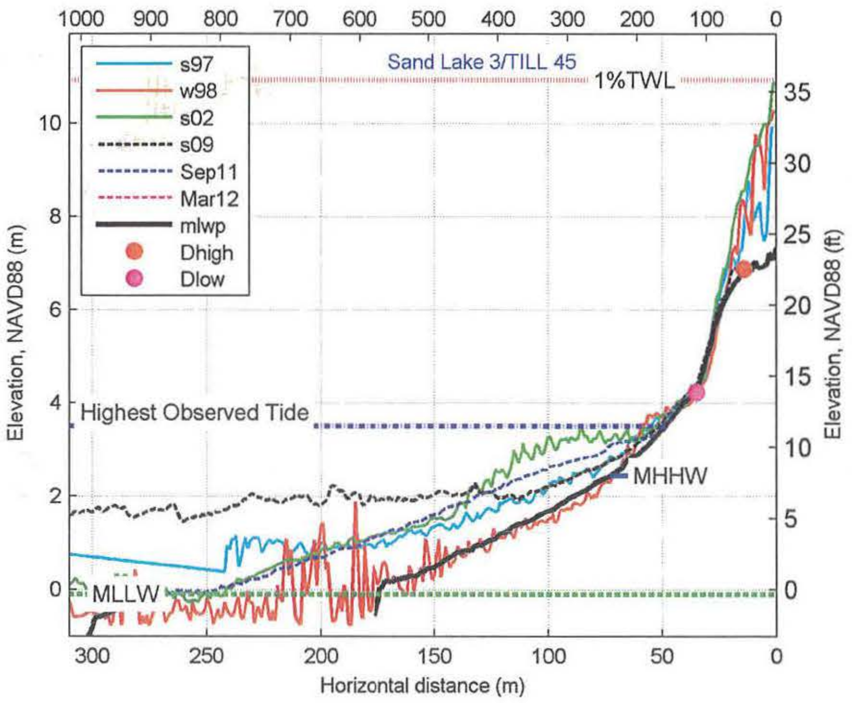

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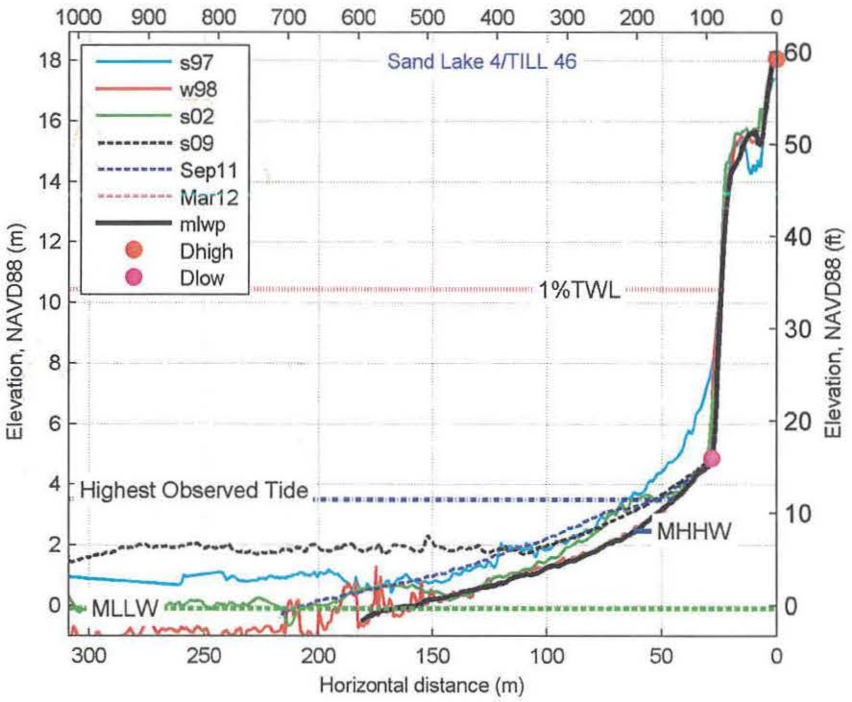

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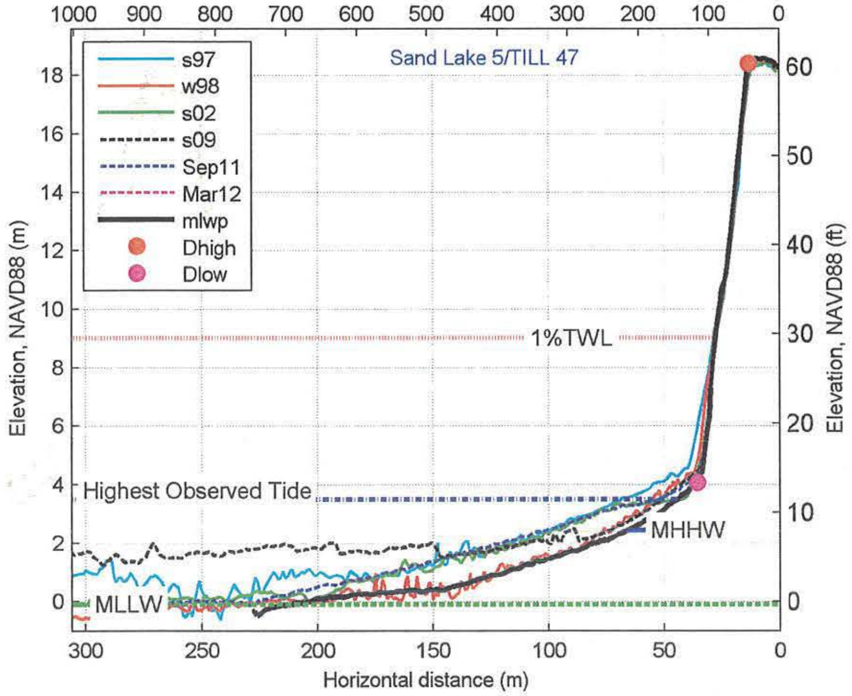

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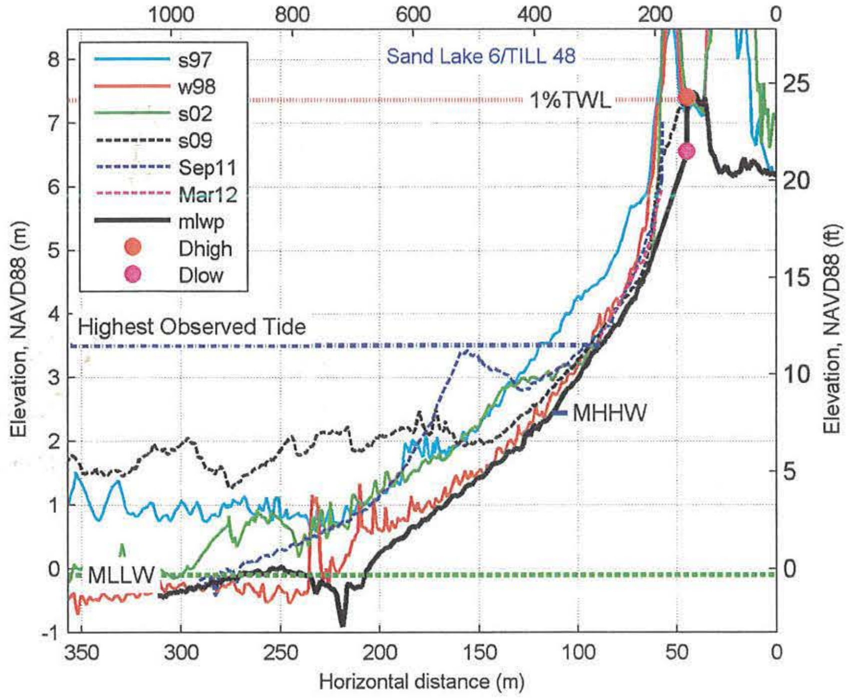

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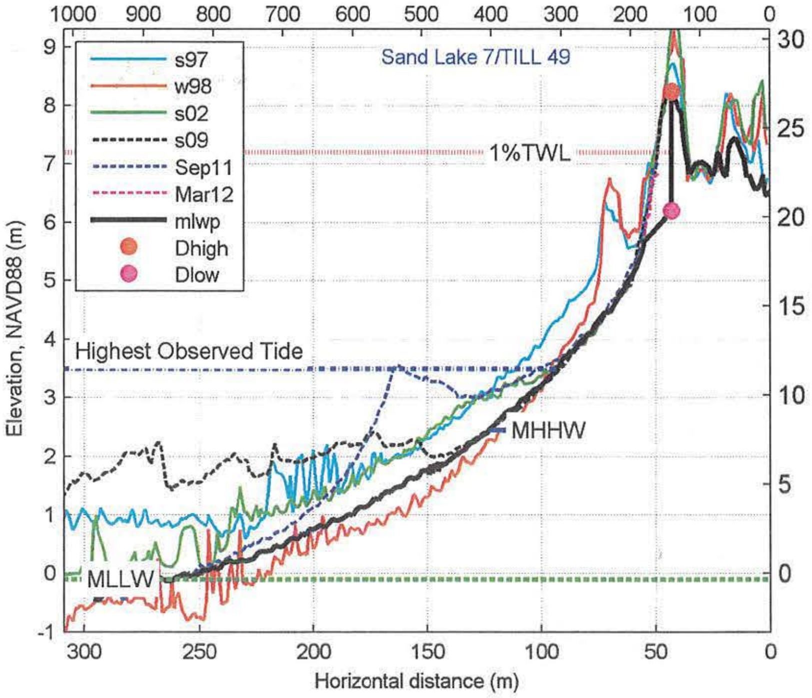

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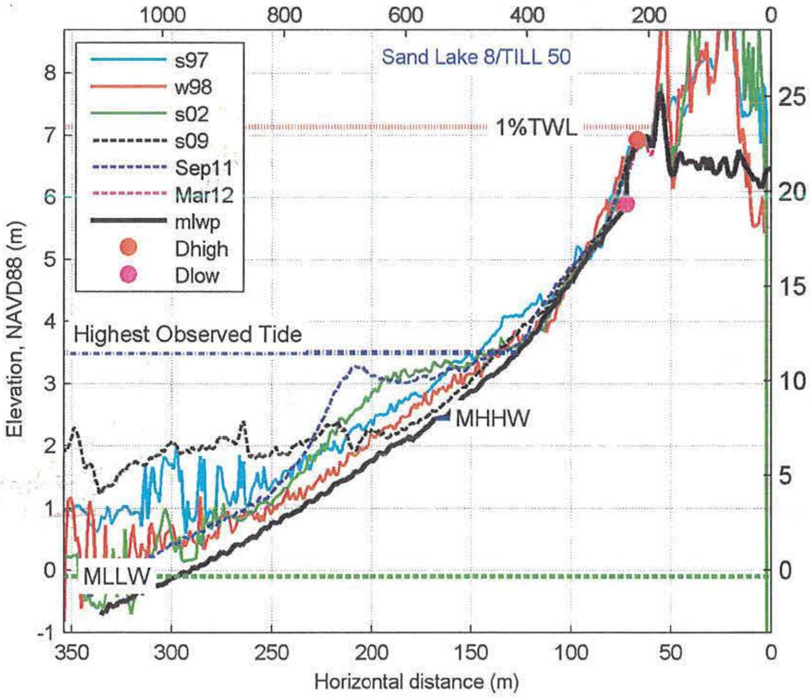
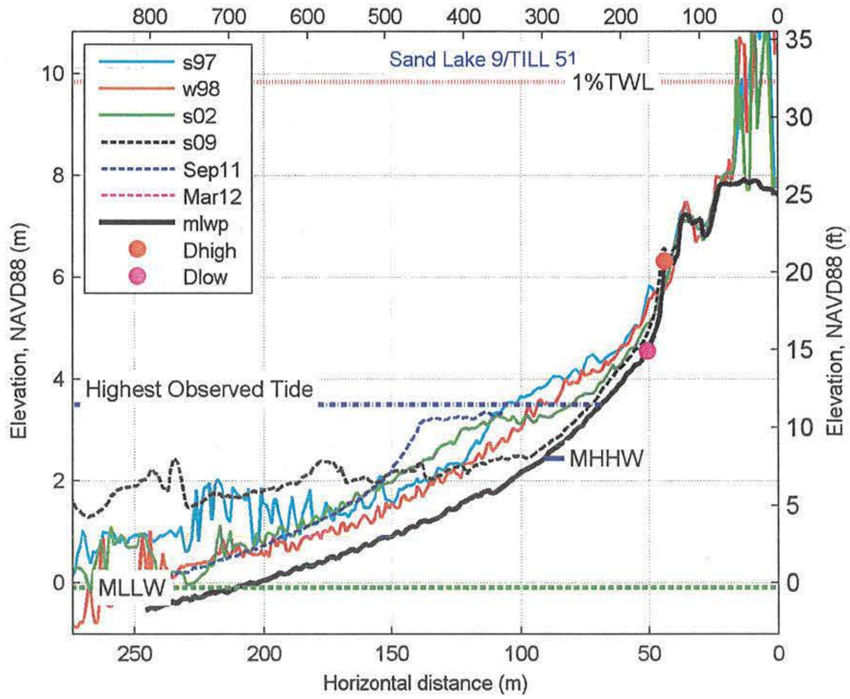


fm_slk 9



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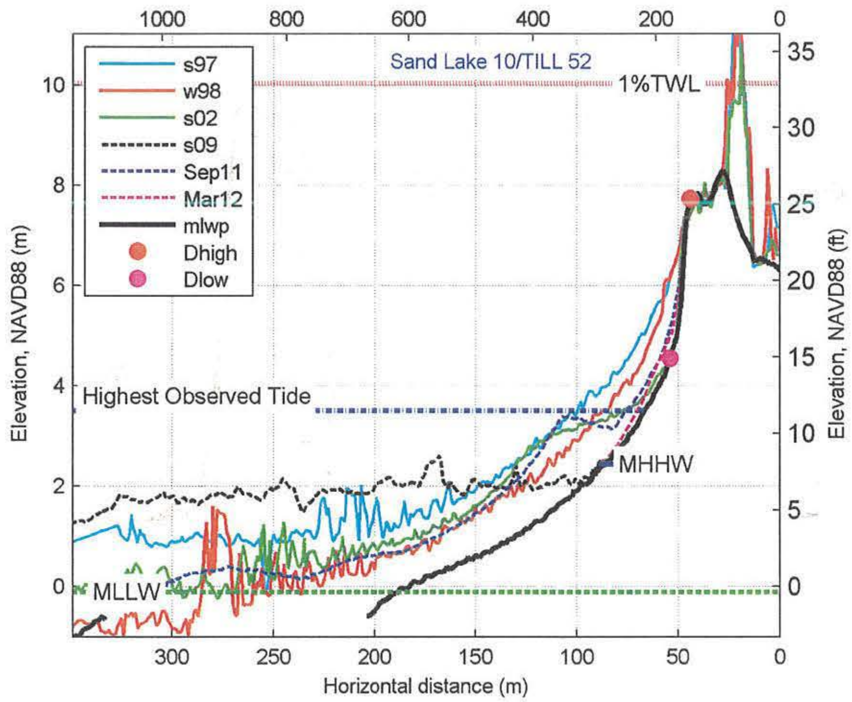

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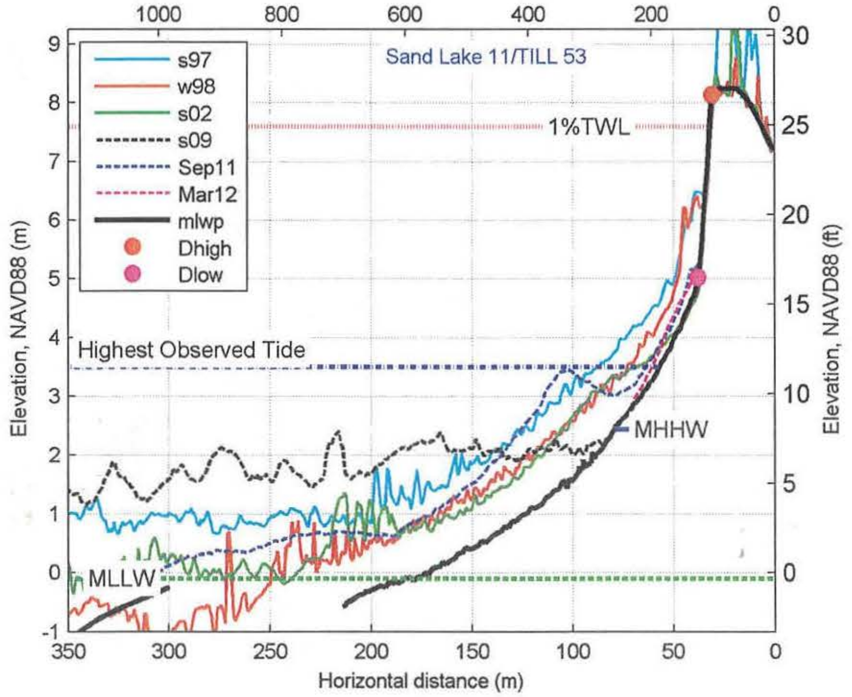

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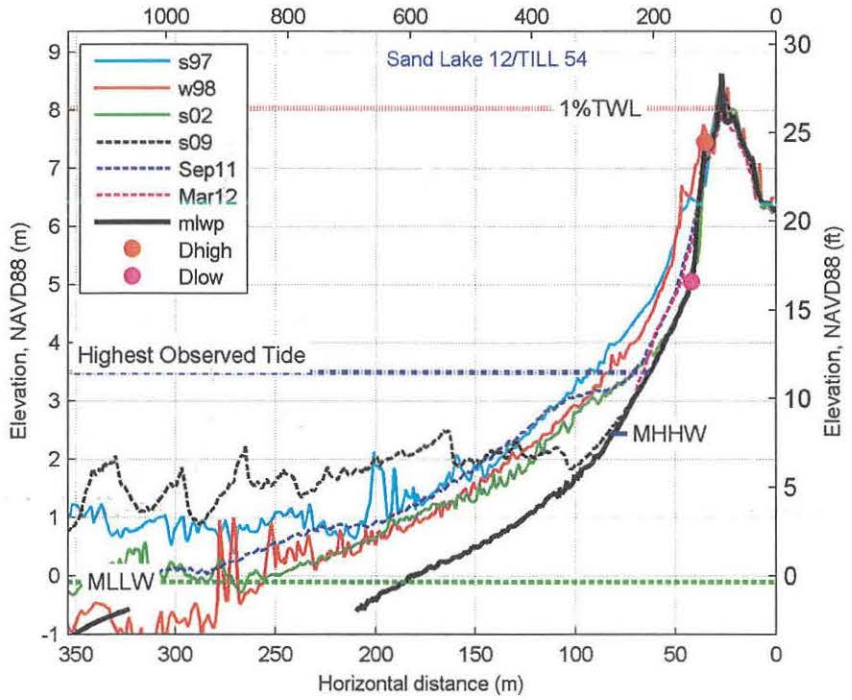

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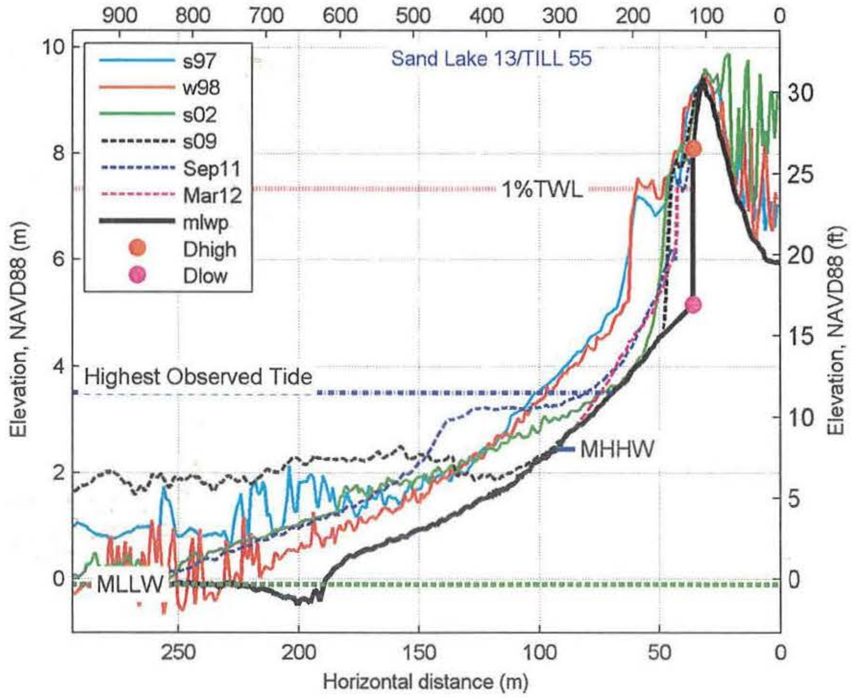

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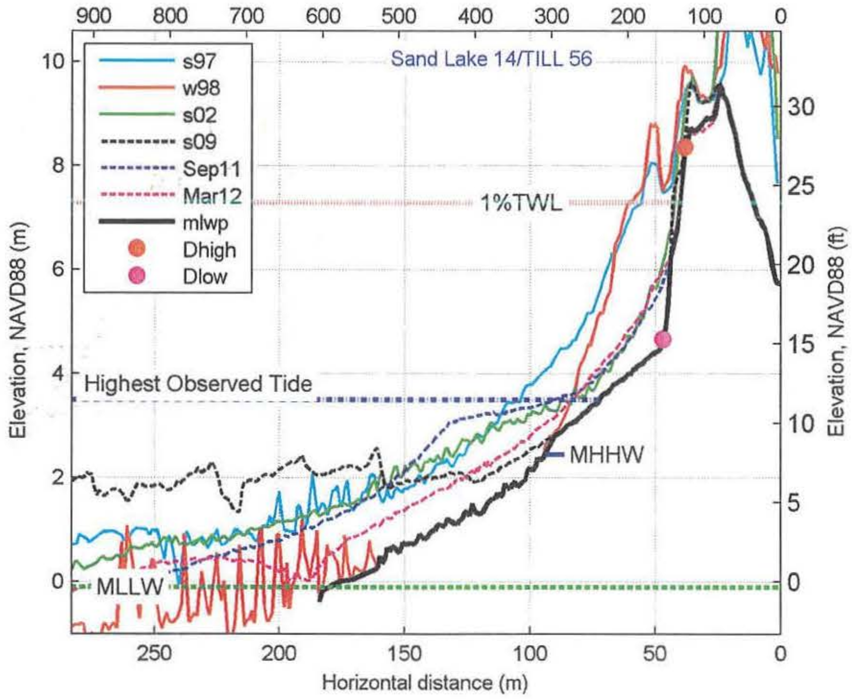

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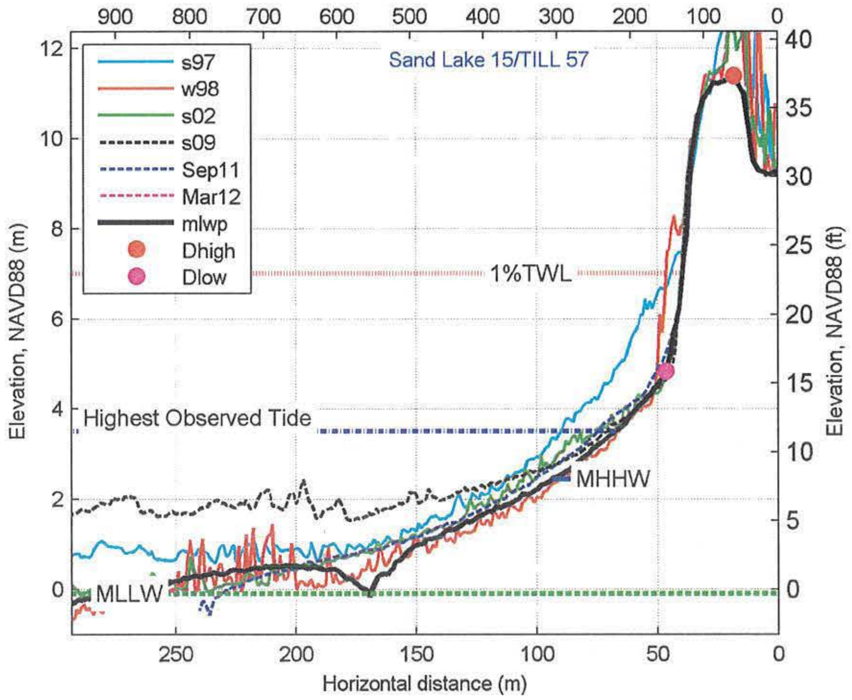

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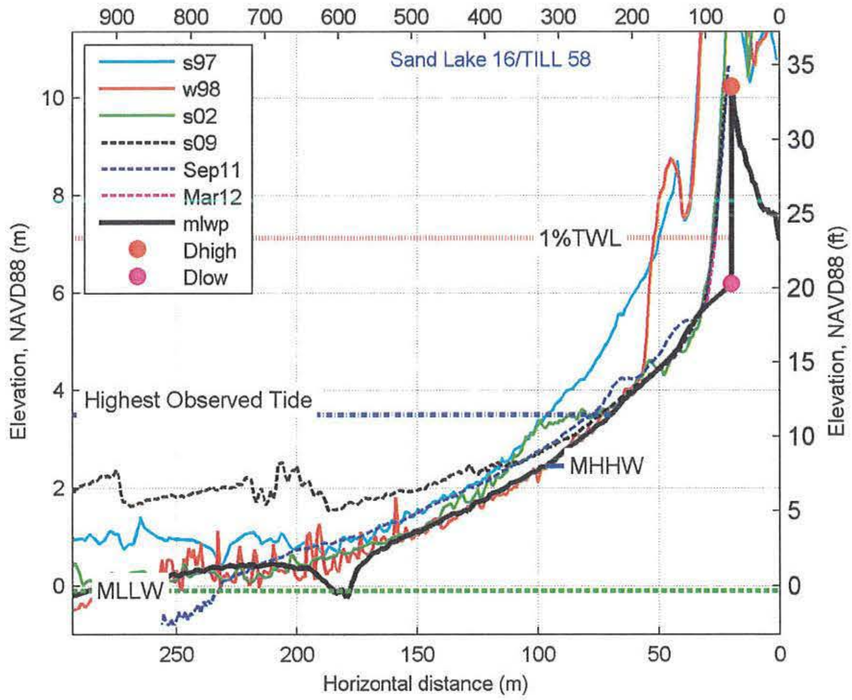

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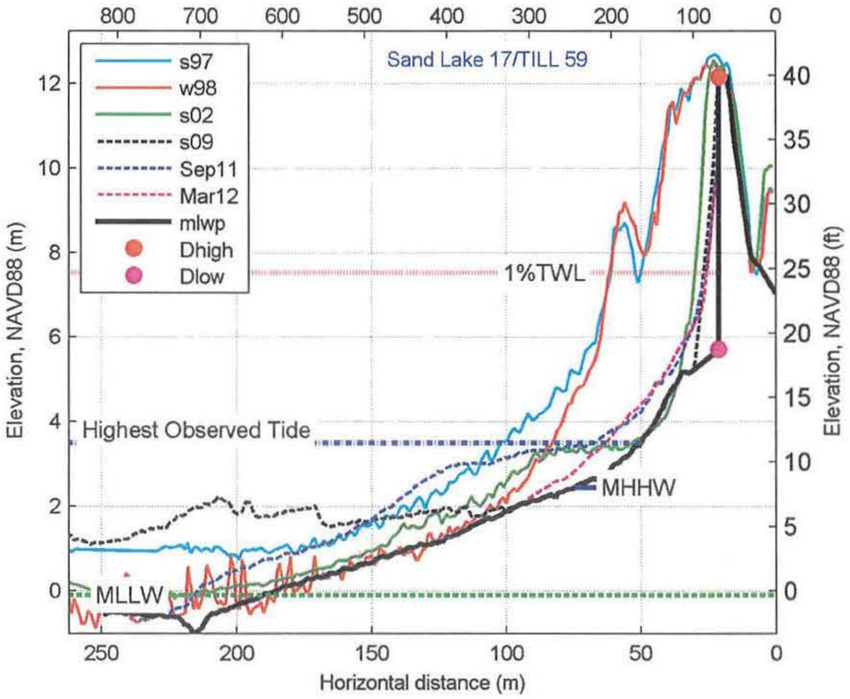

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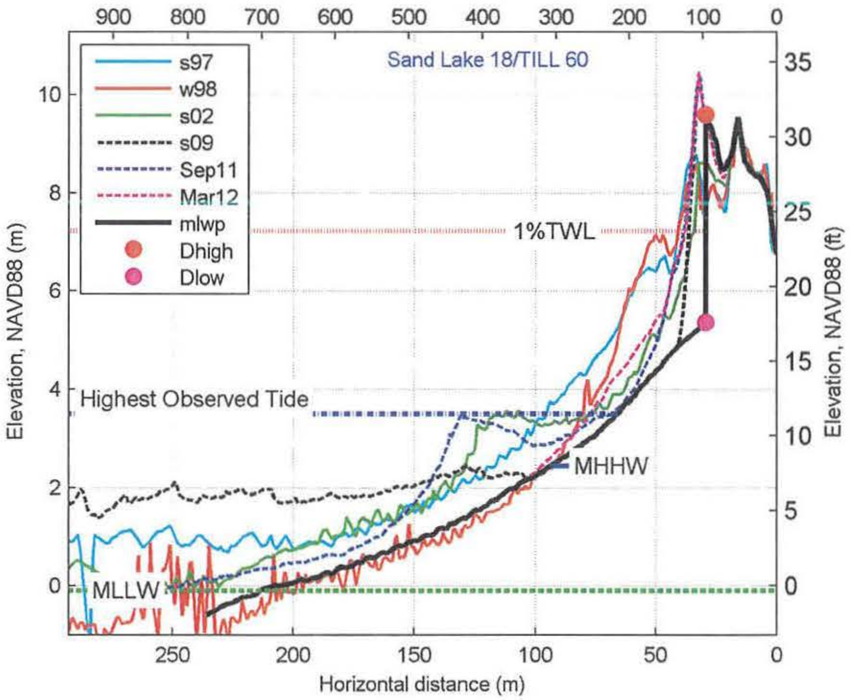

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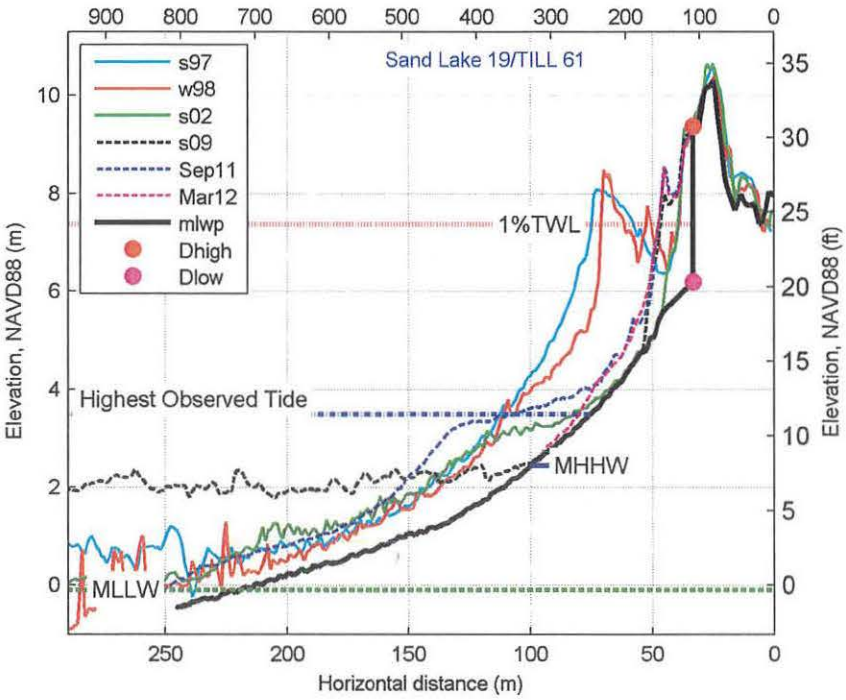

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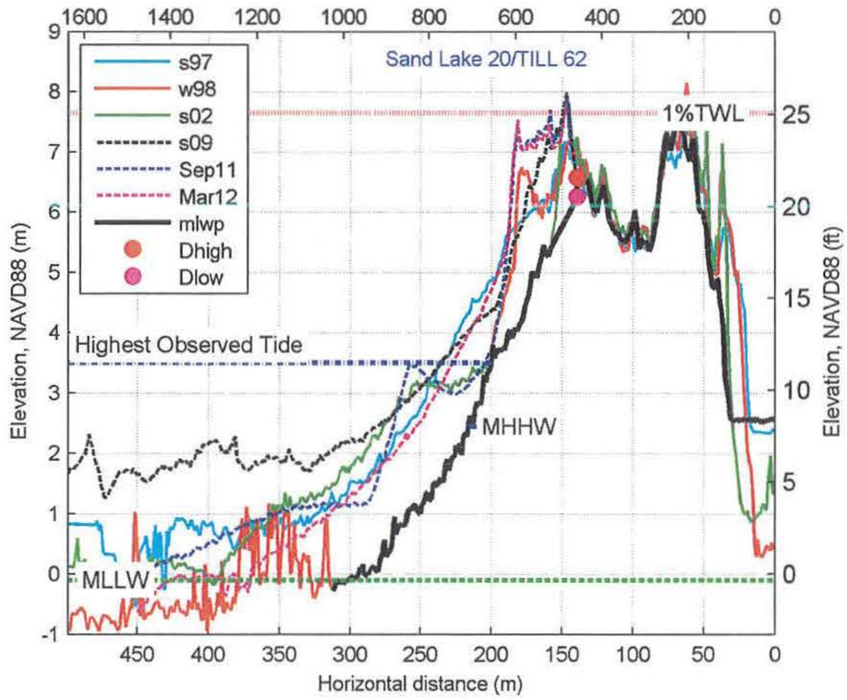

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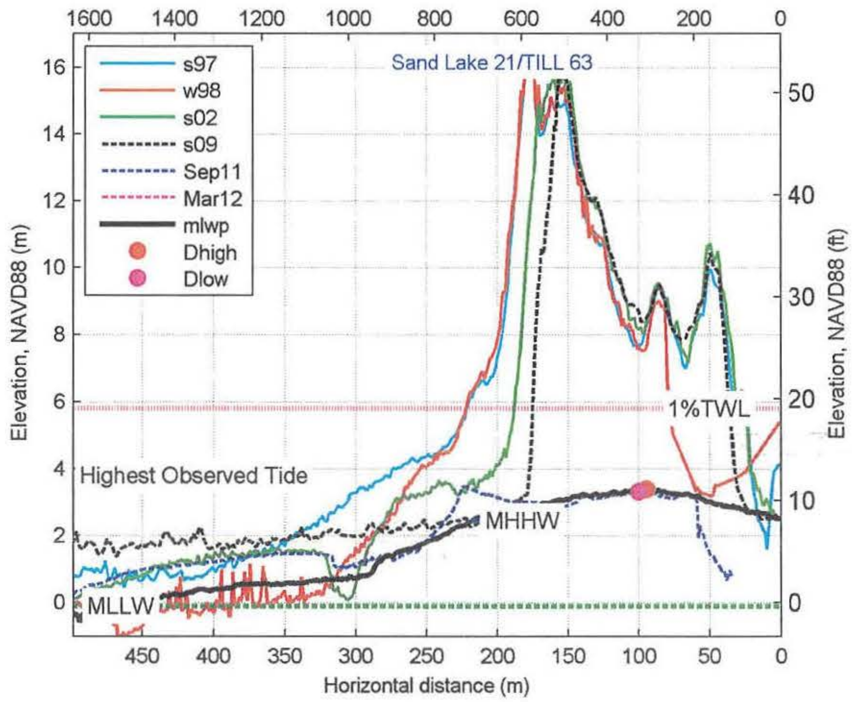

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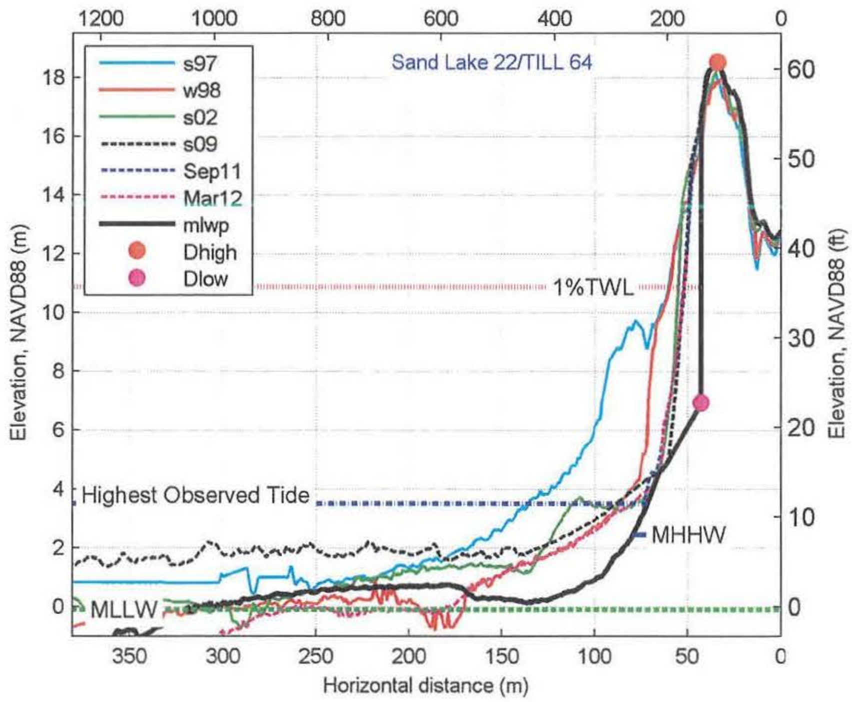
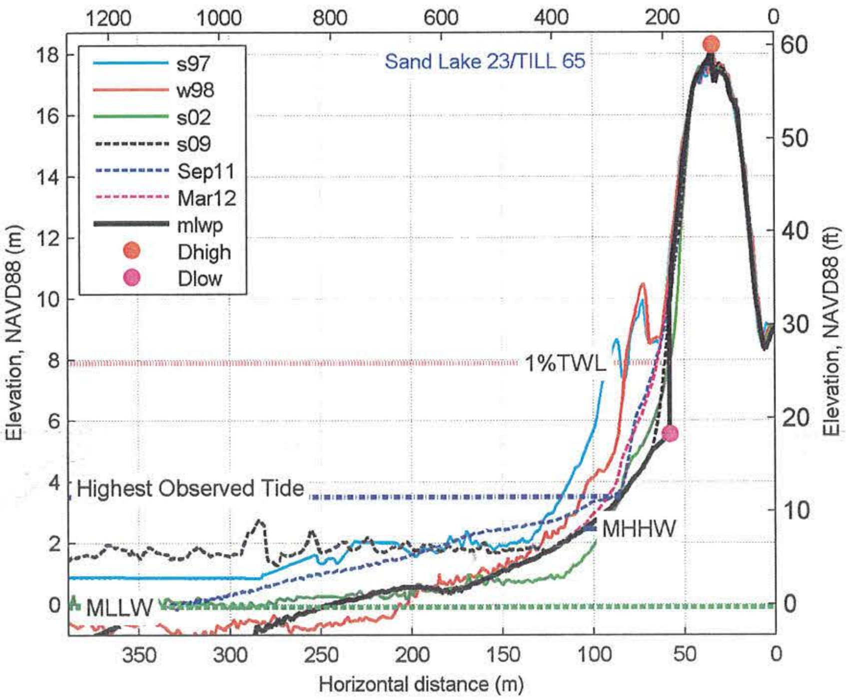


fm_slk 23



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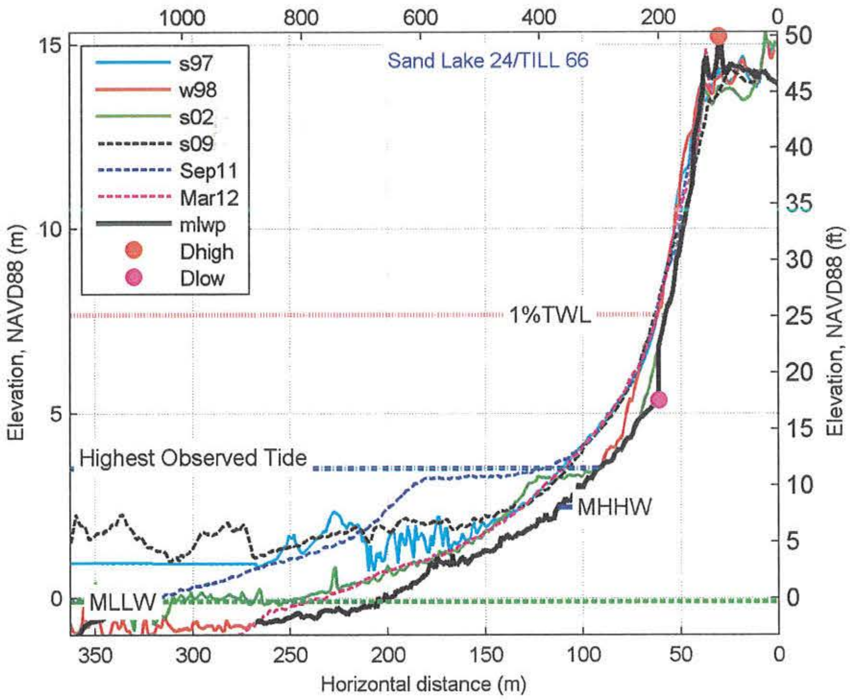
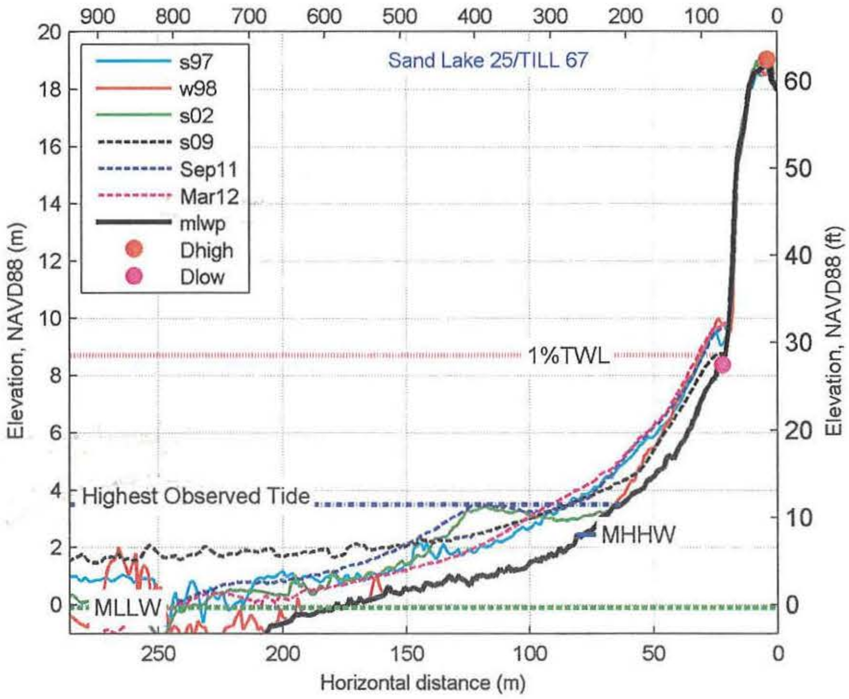


fm_slk 25



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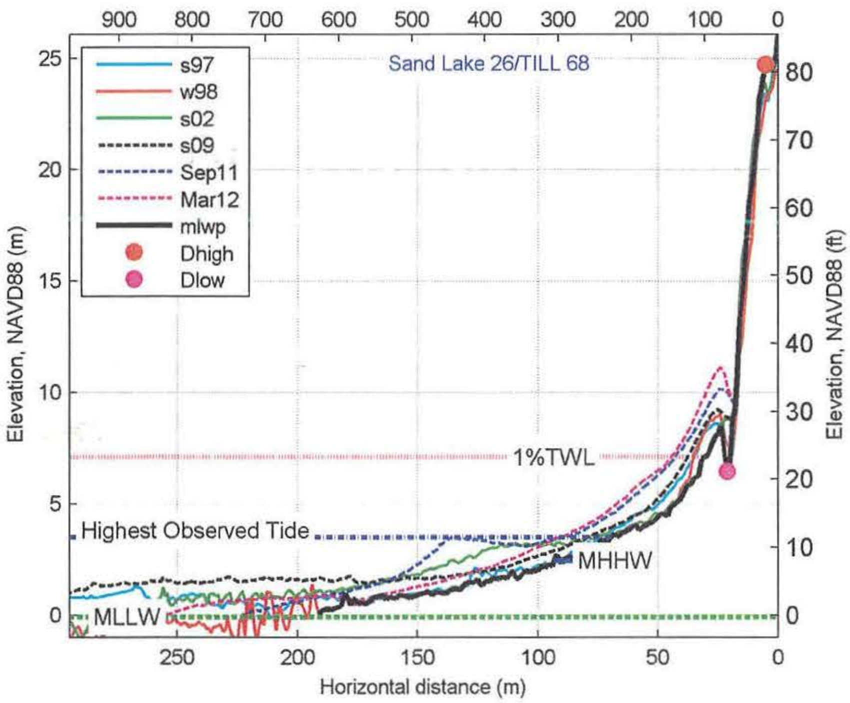

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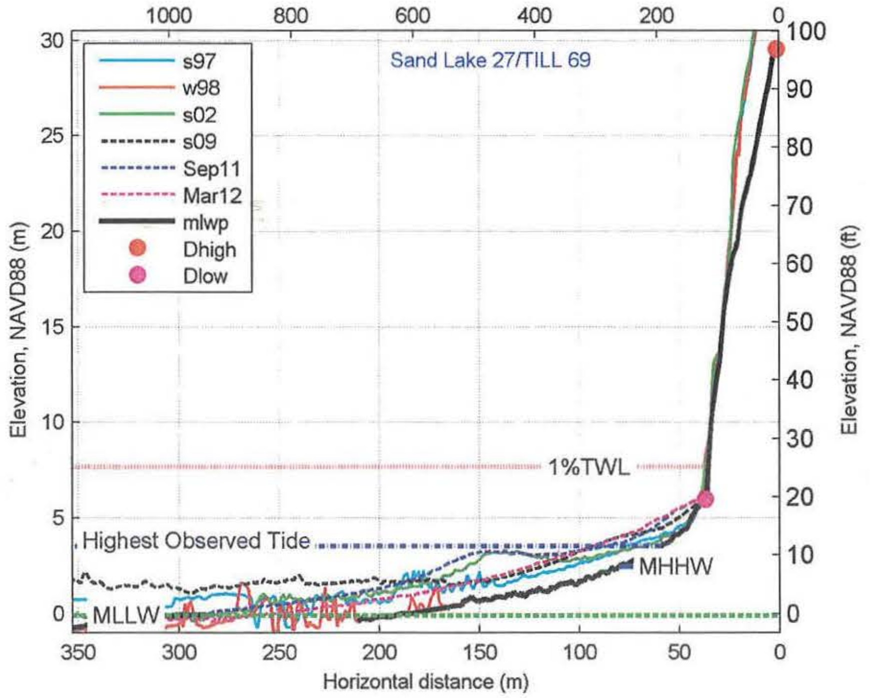

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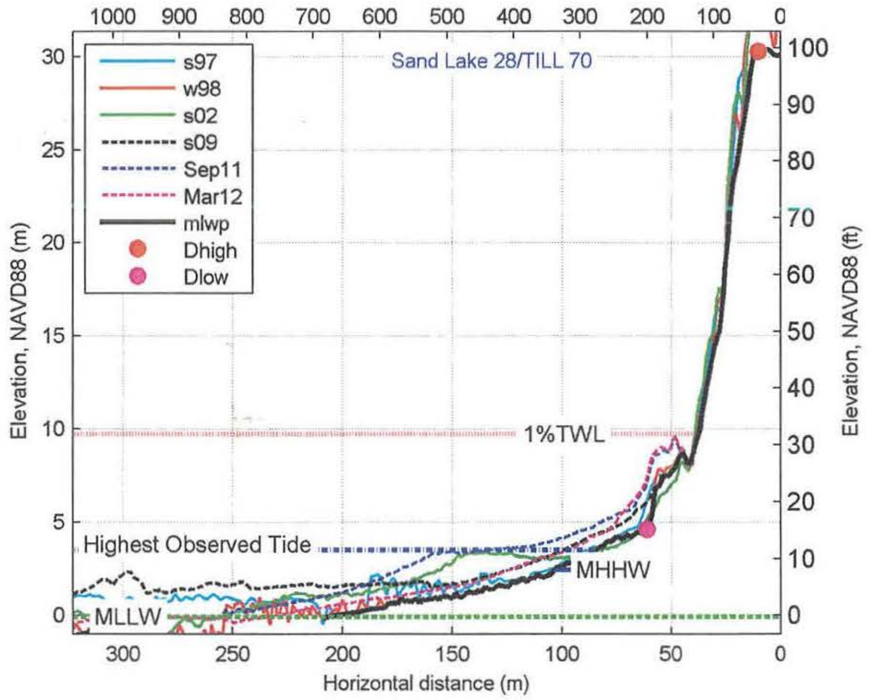

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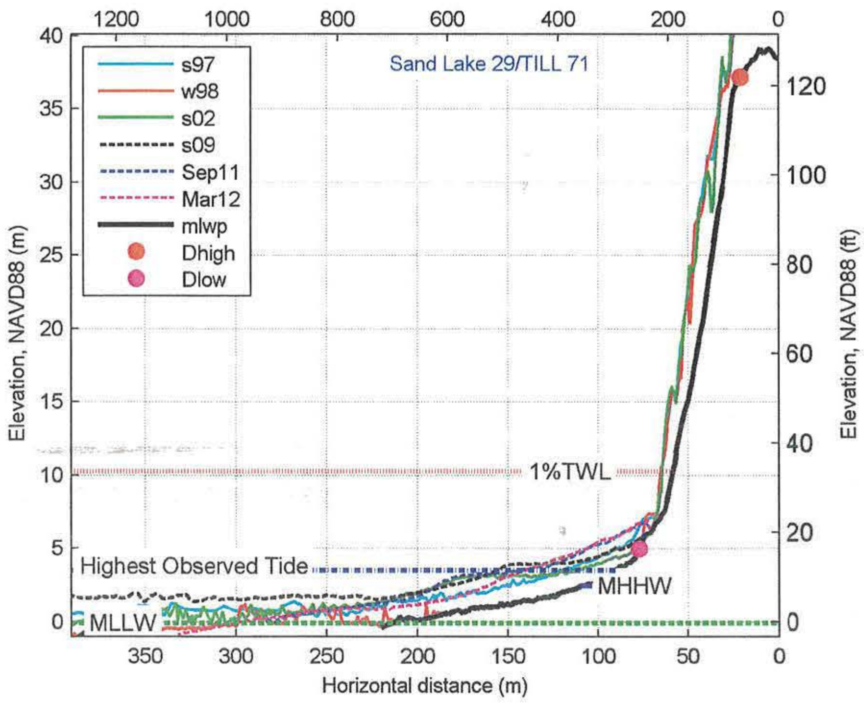

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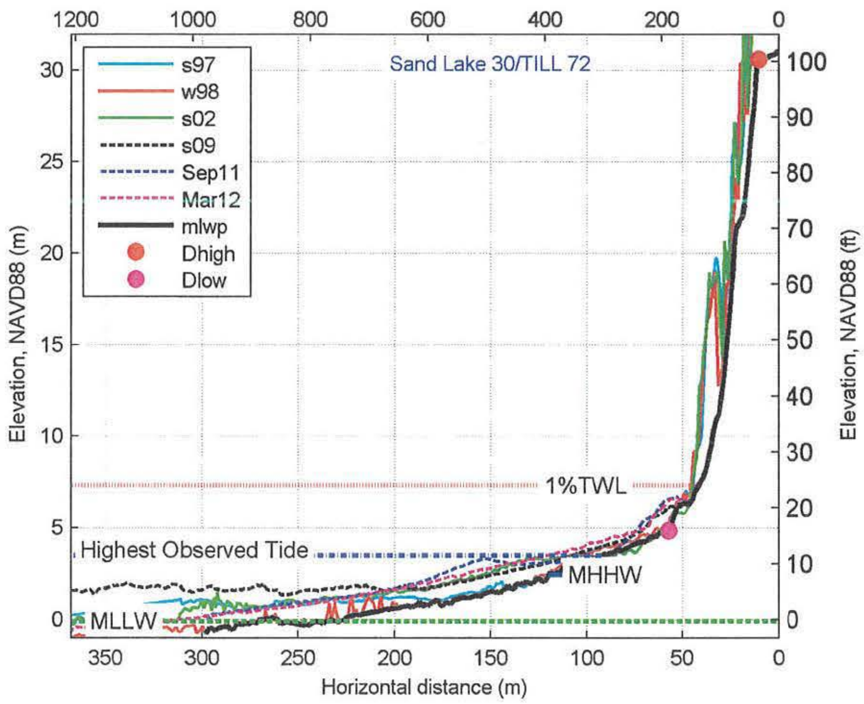

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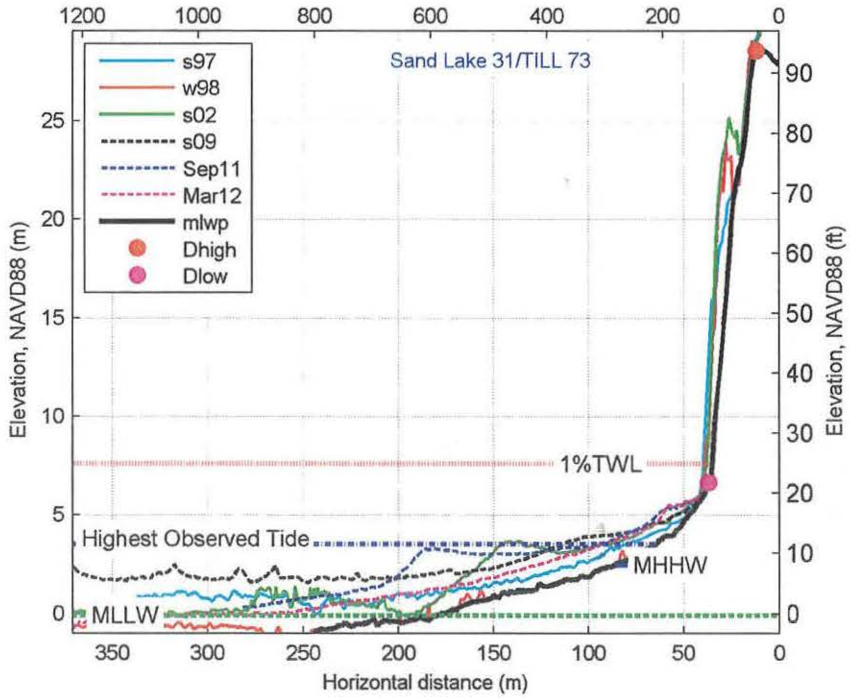

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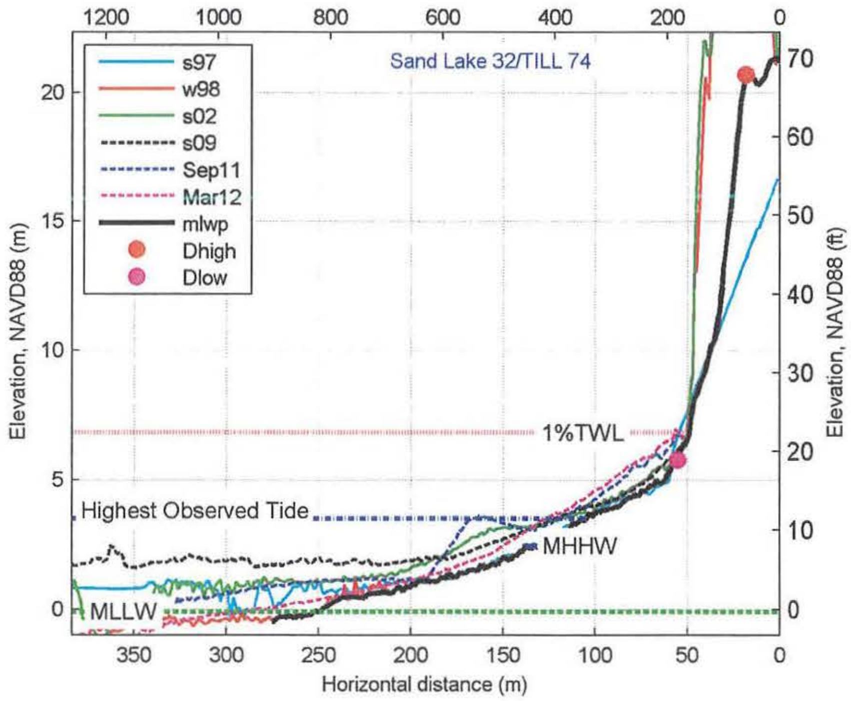
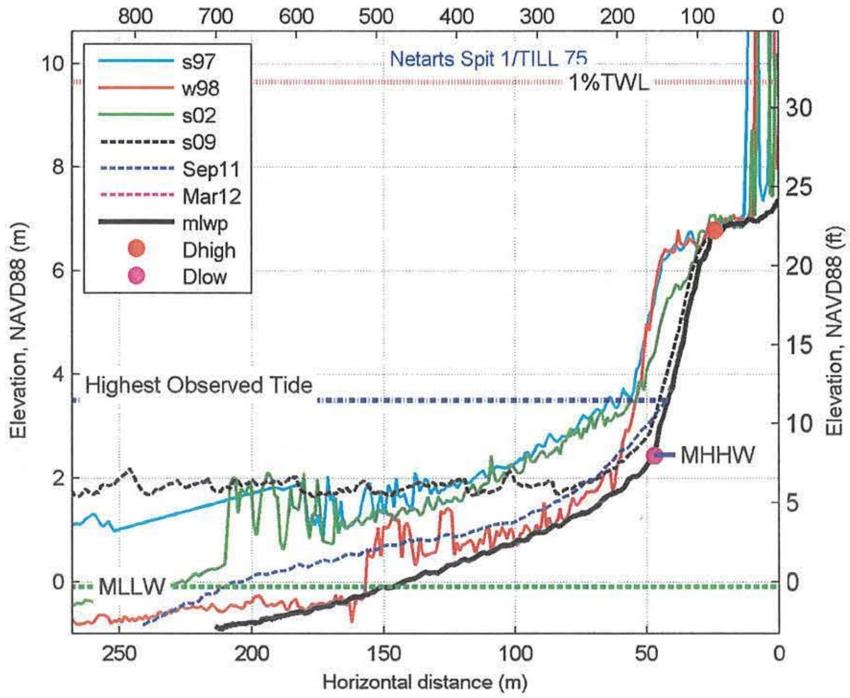


11.4.4 Netarts Spit

fm_netarts 1



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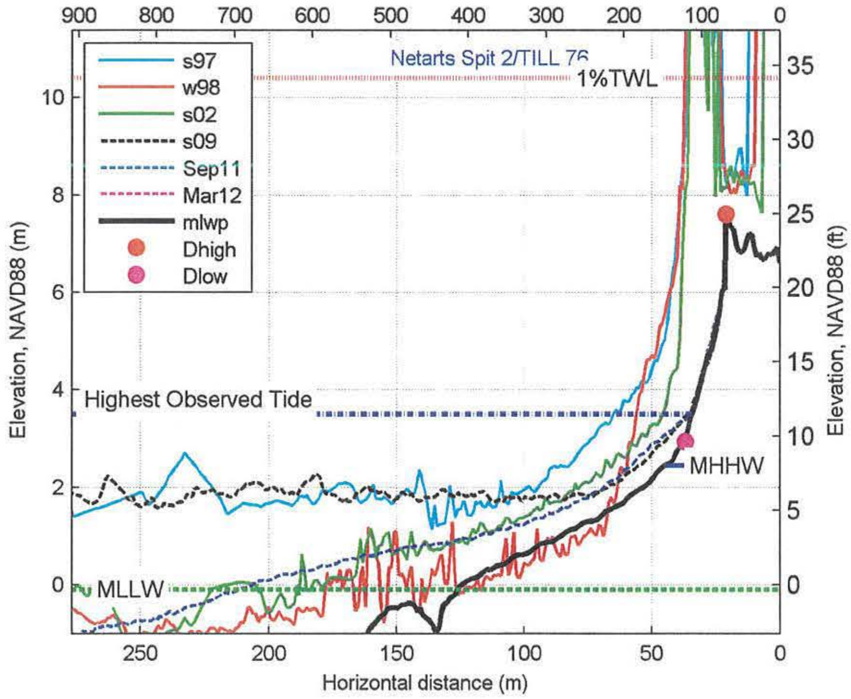
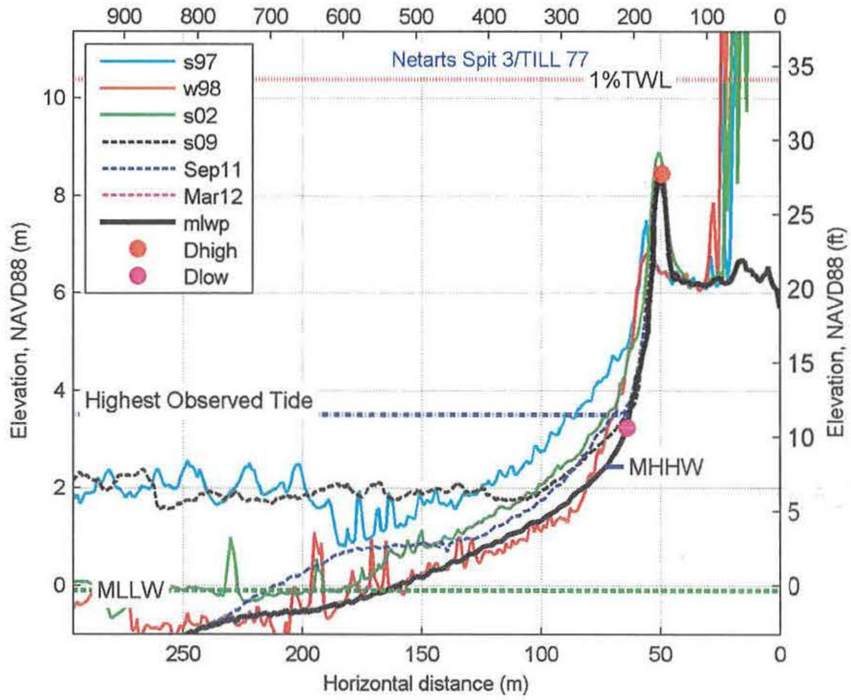


fm_netarts 3



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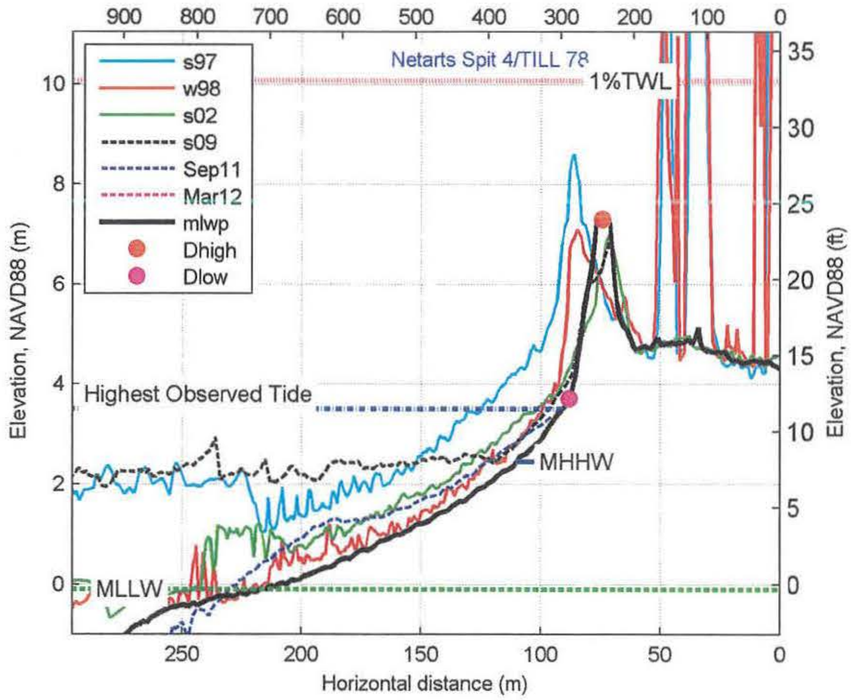

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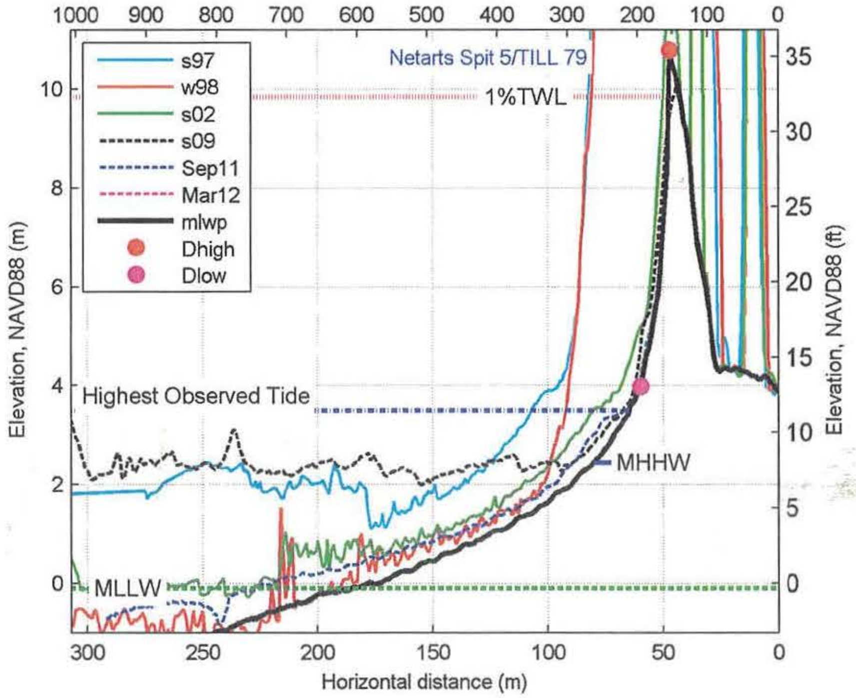
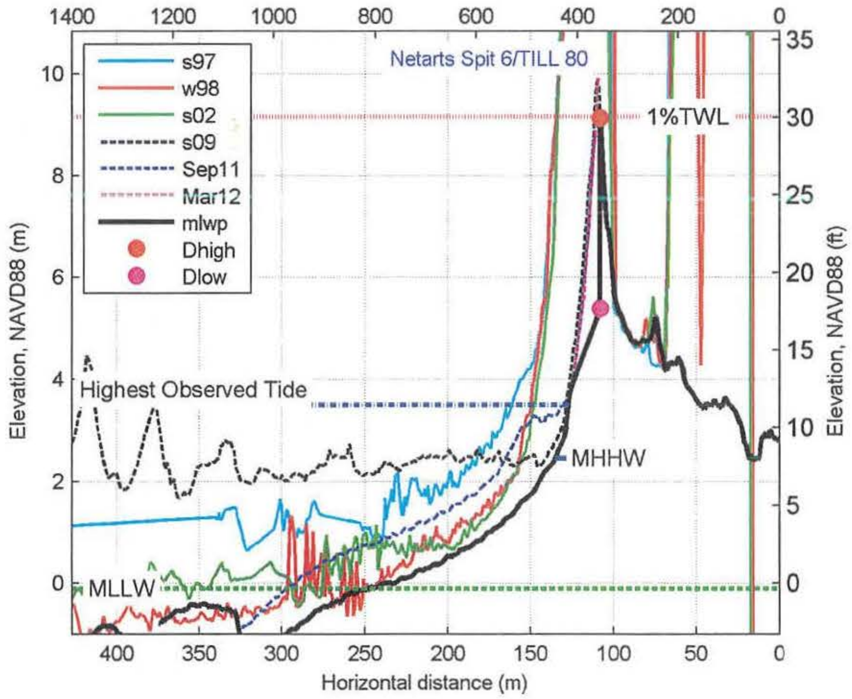
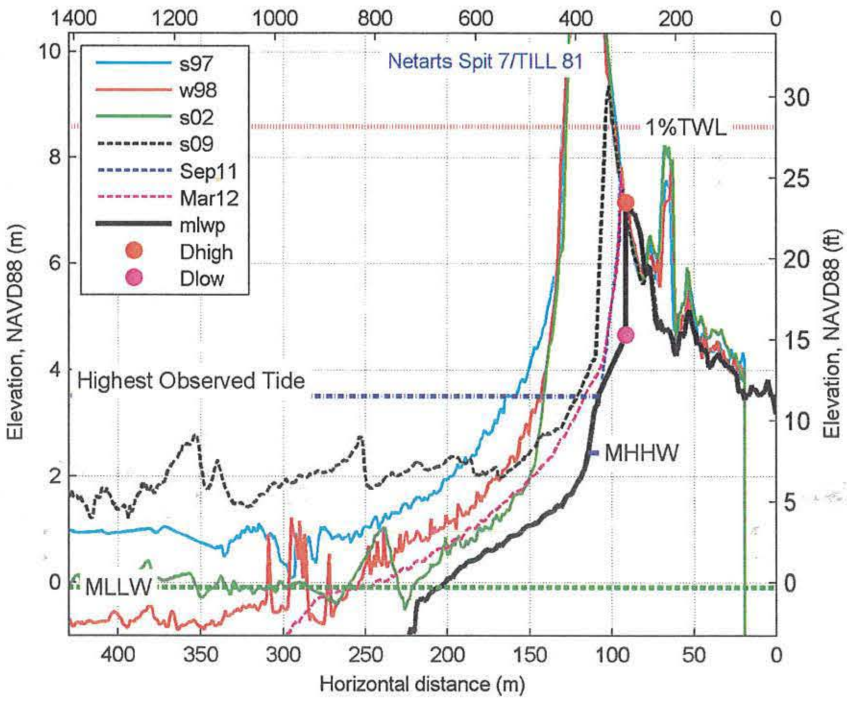


fm_netarts 6



fm_netarts 7



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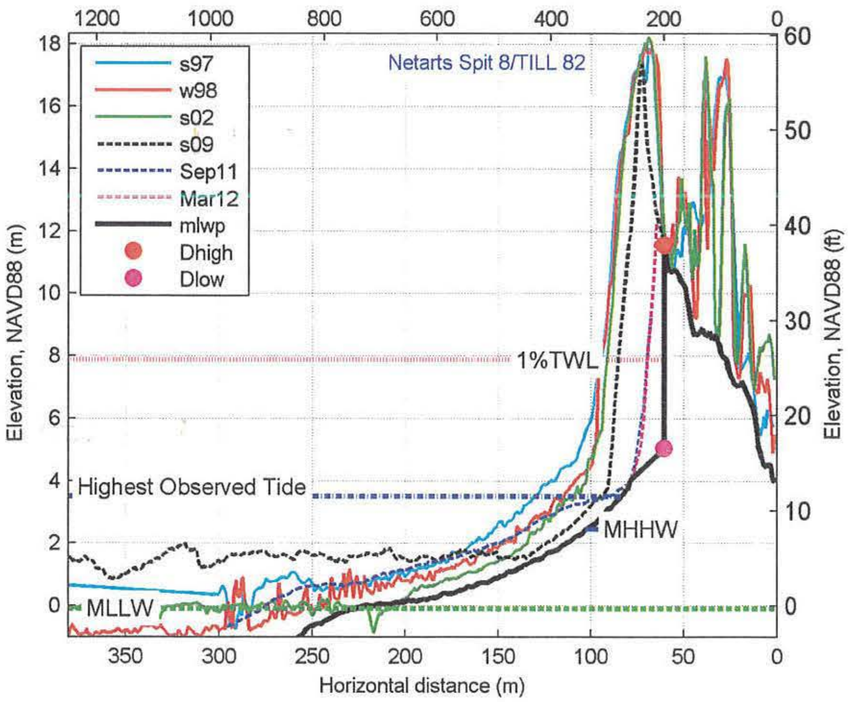

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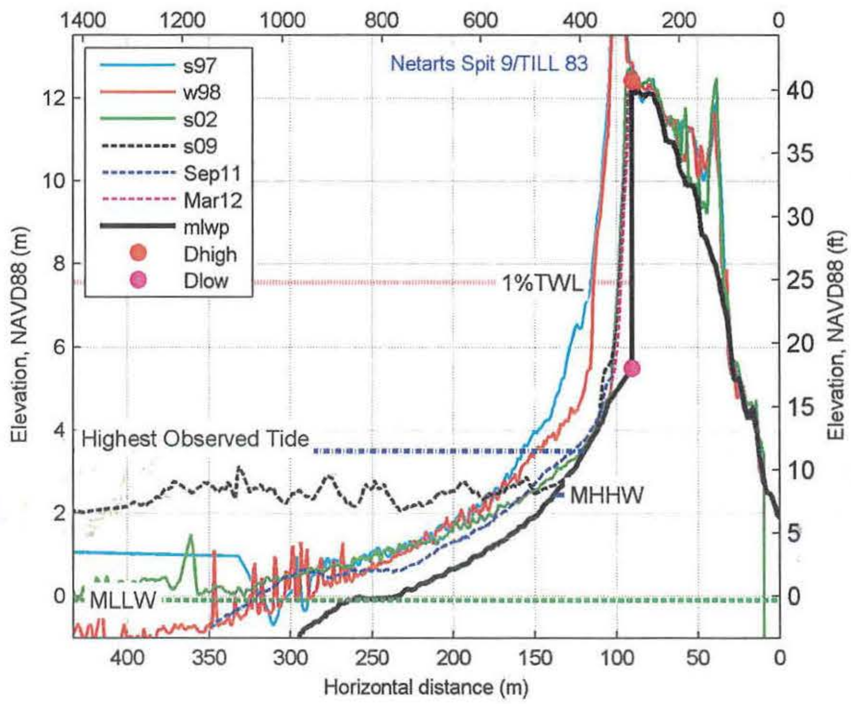

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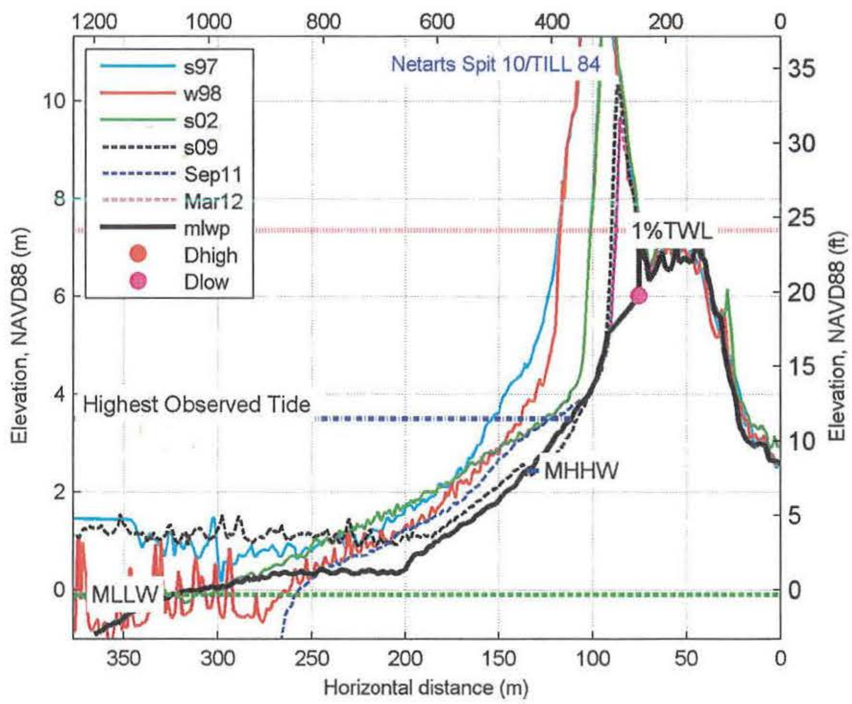

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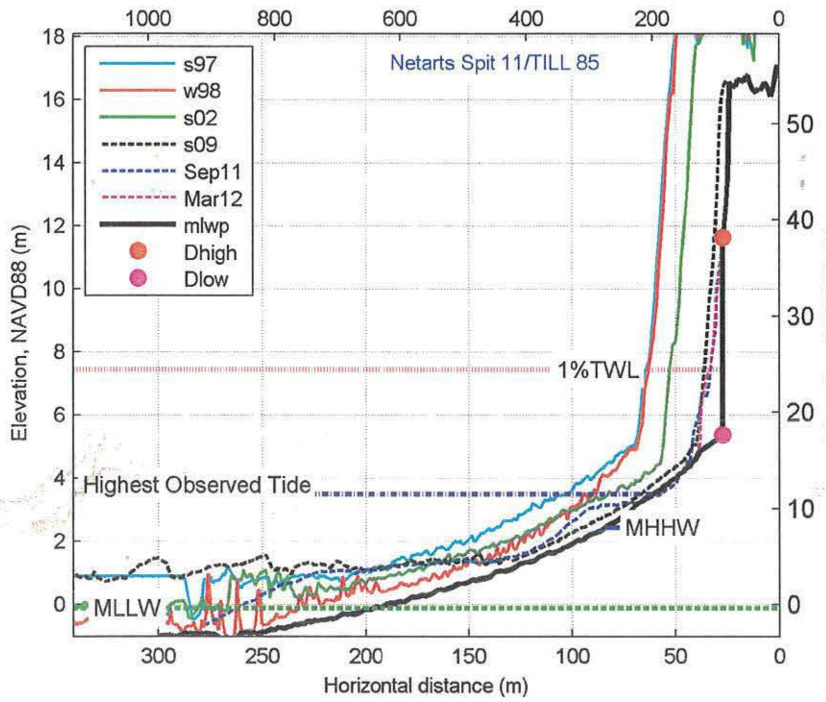

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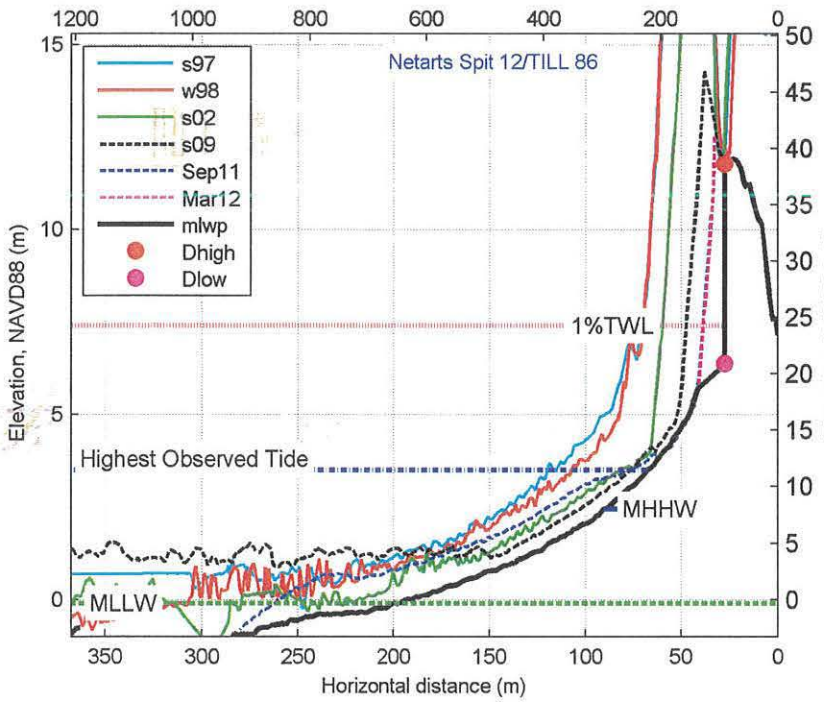

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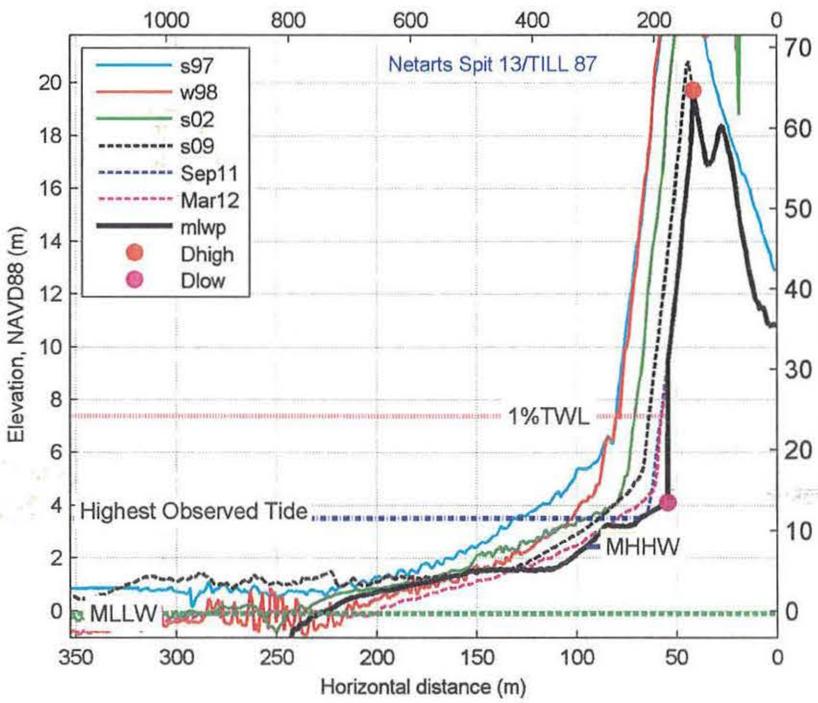

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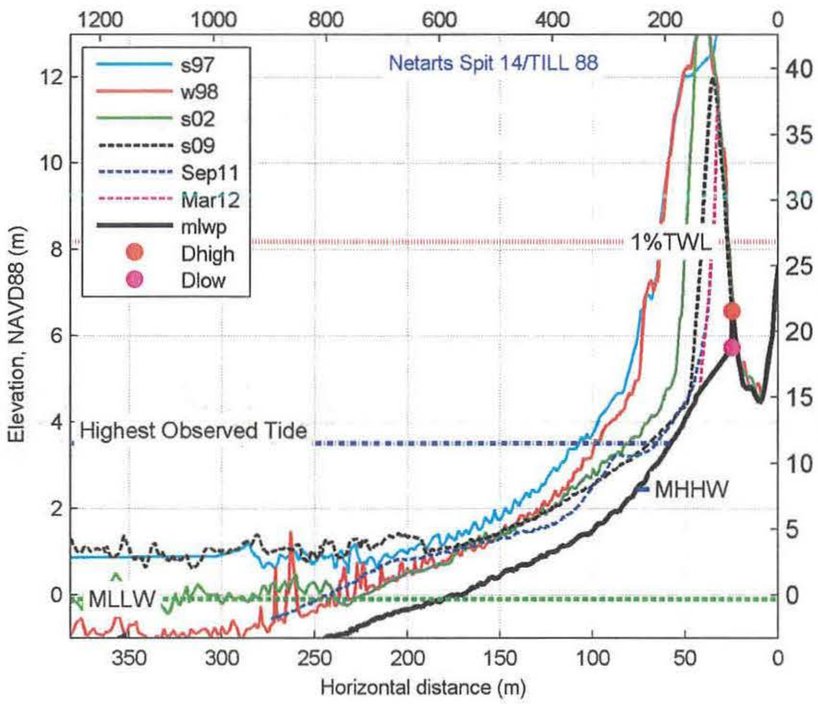

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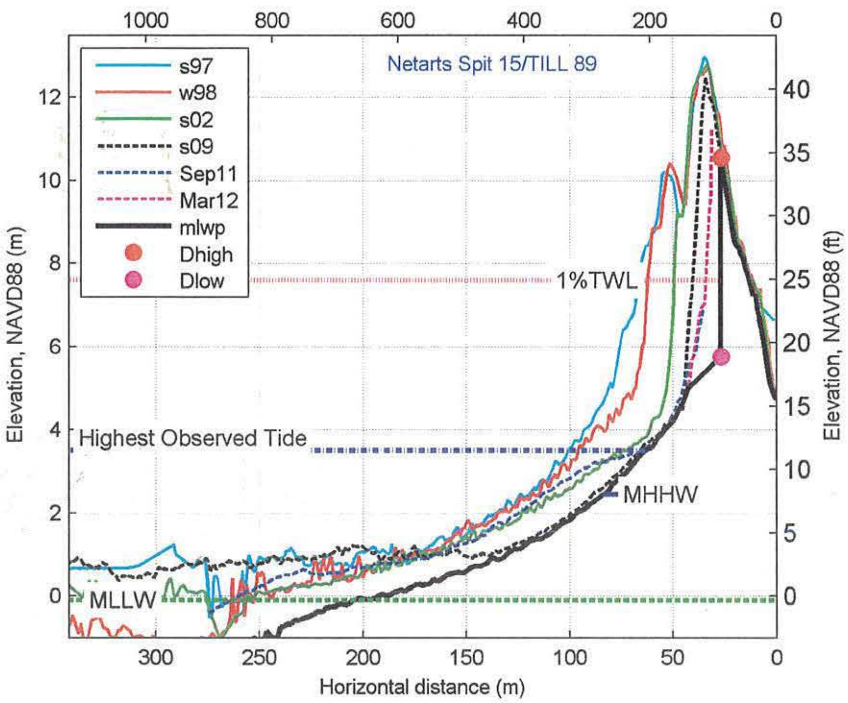
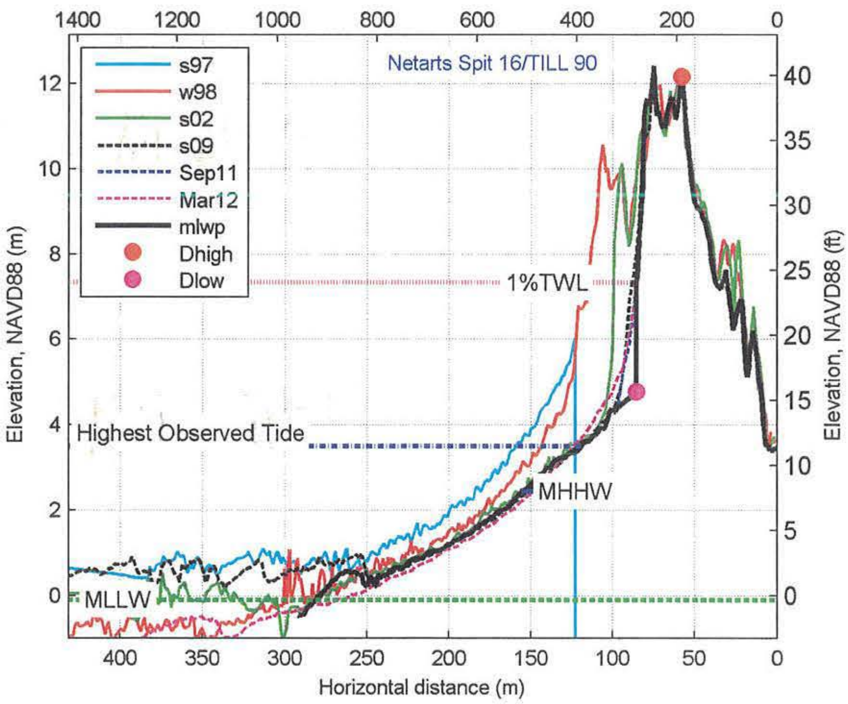


fm_netarts 16



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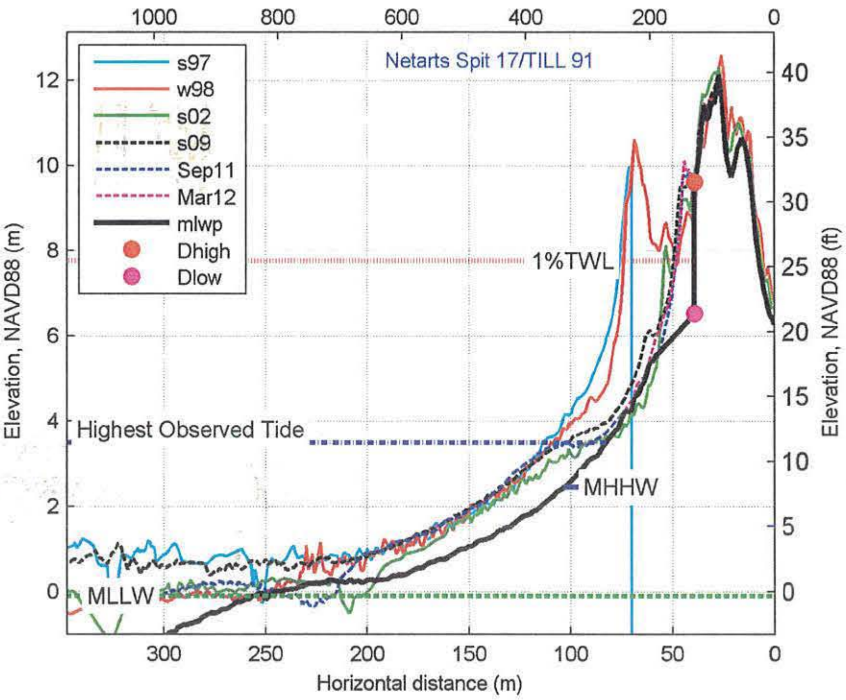

**fm_netarts
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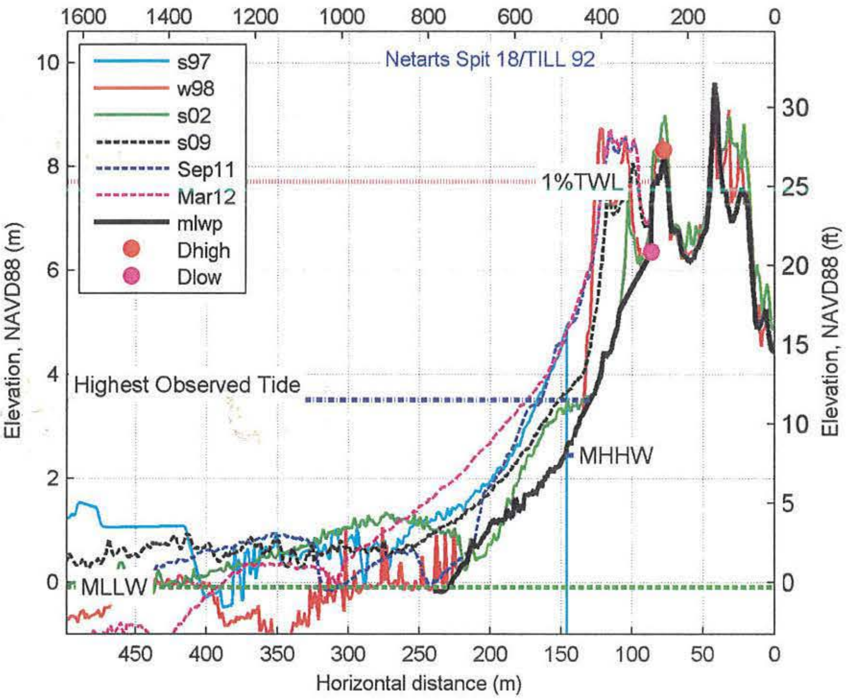
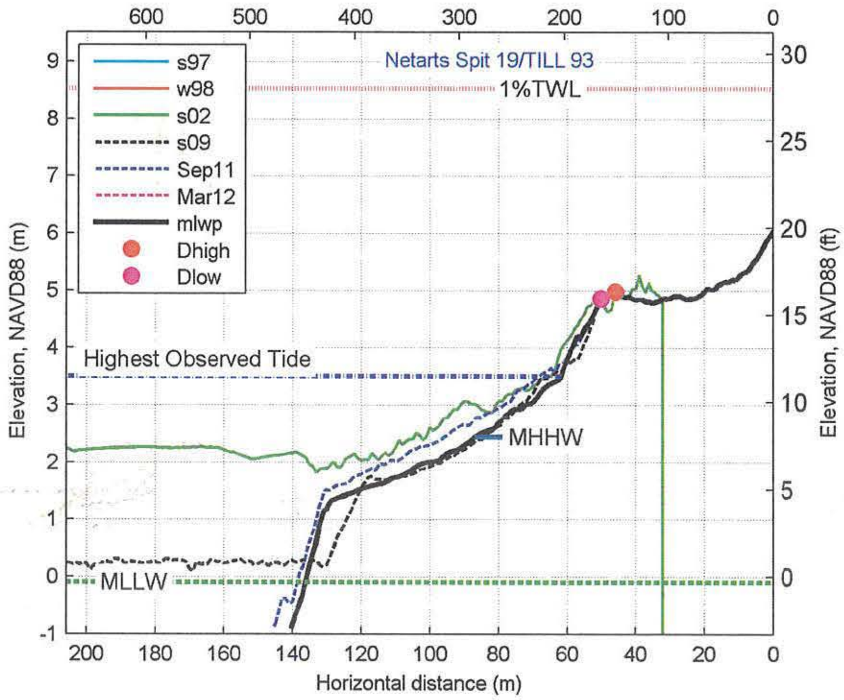
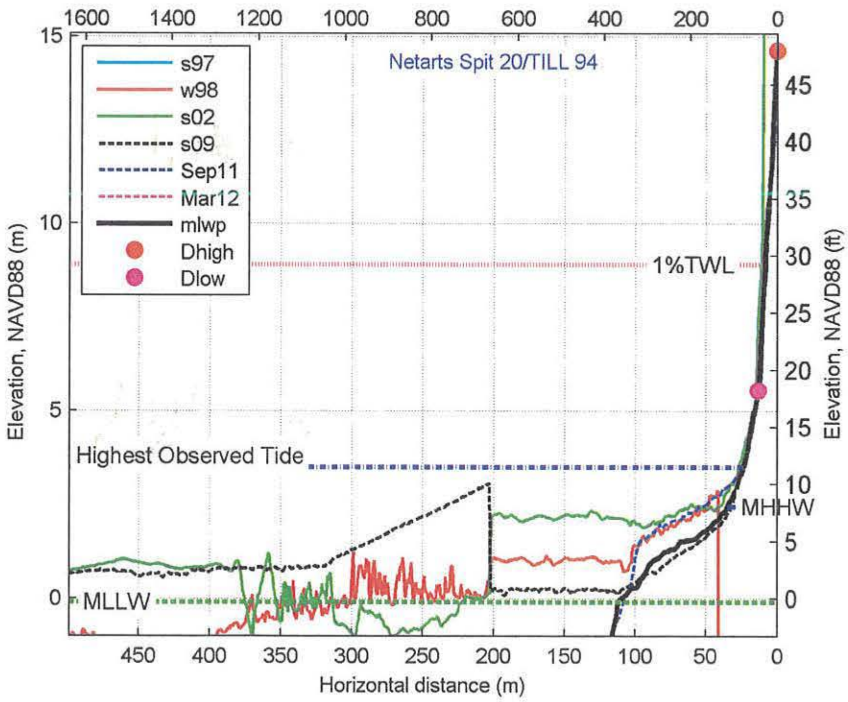


fm_netarts 19



fm_netarts 20



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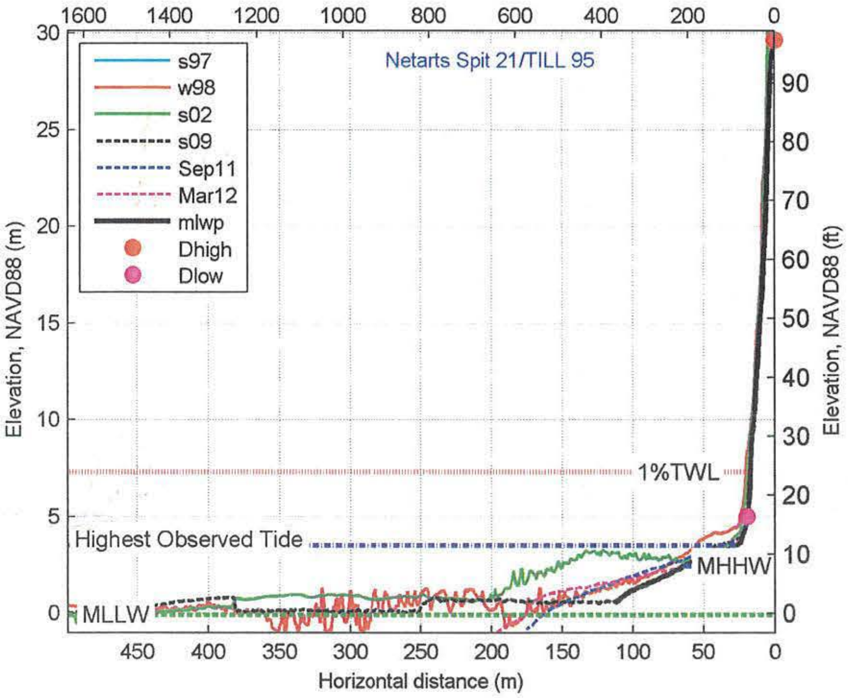

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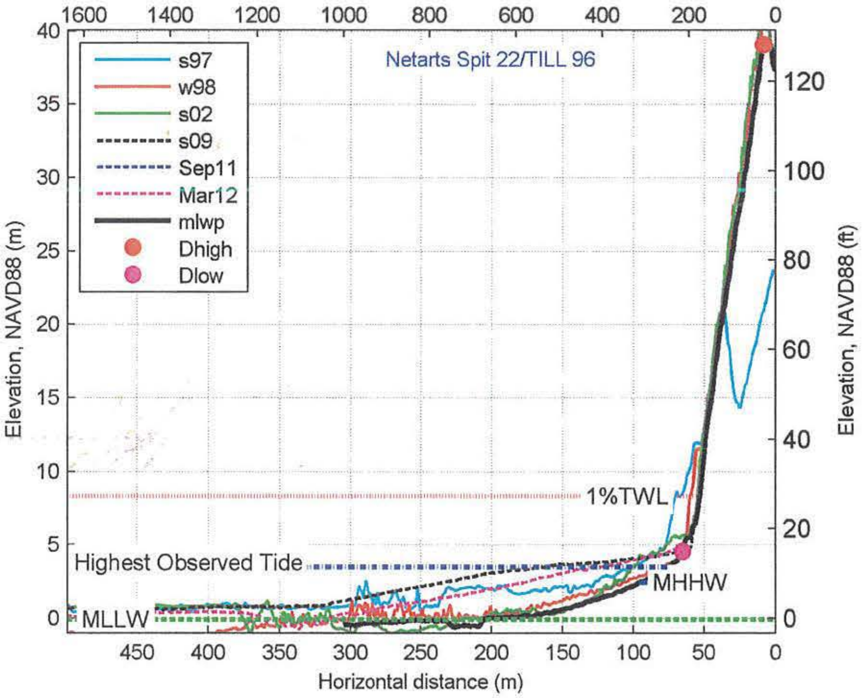

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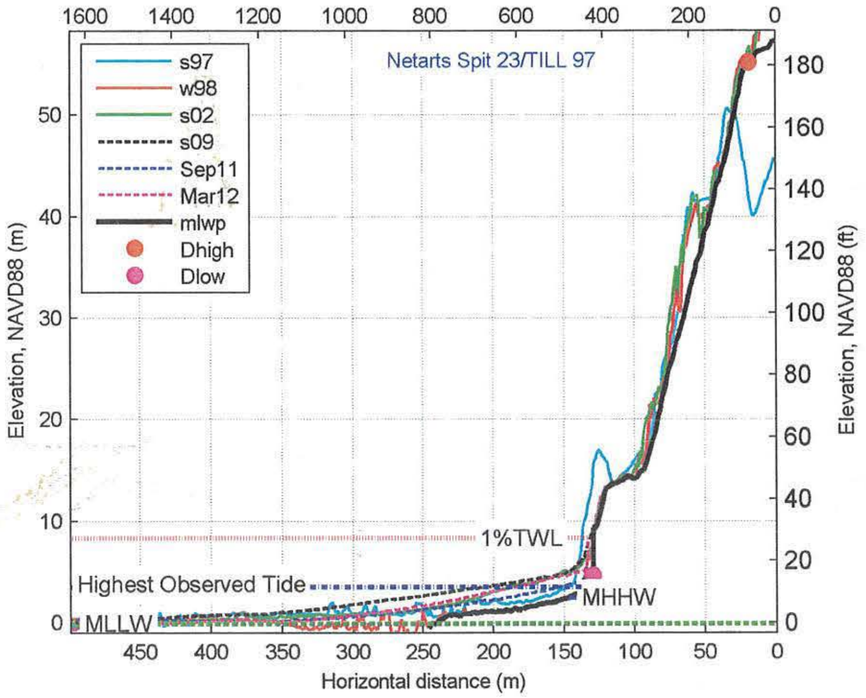

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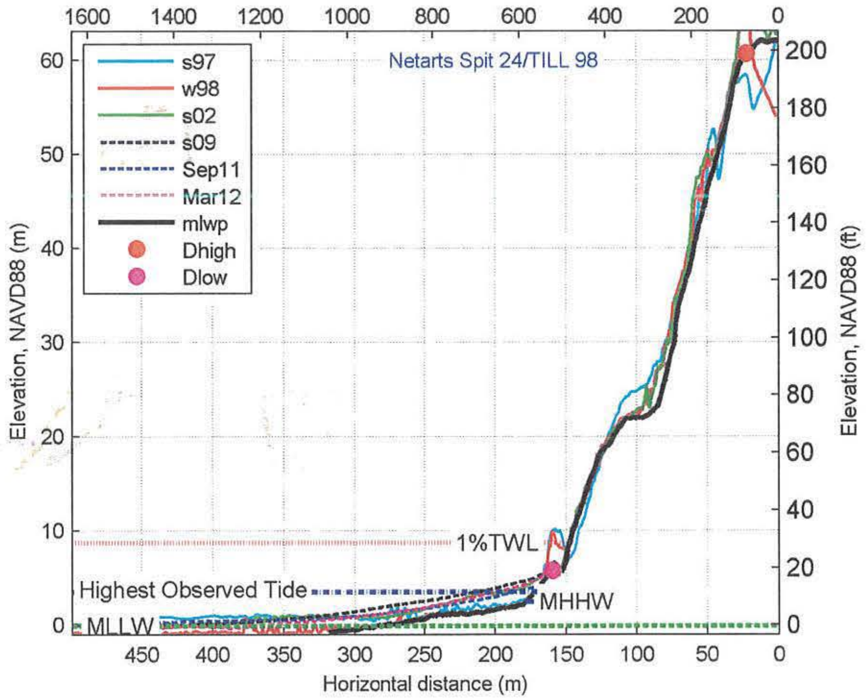

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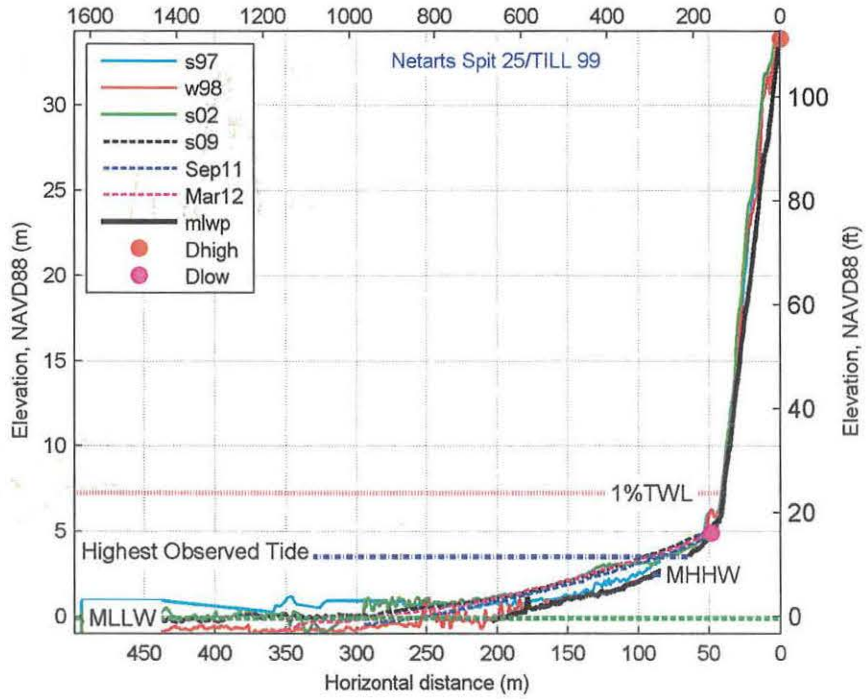

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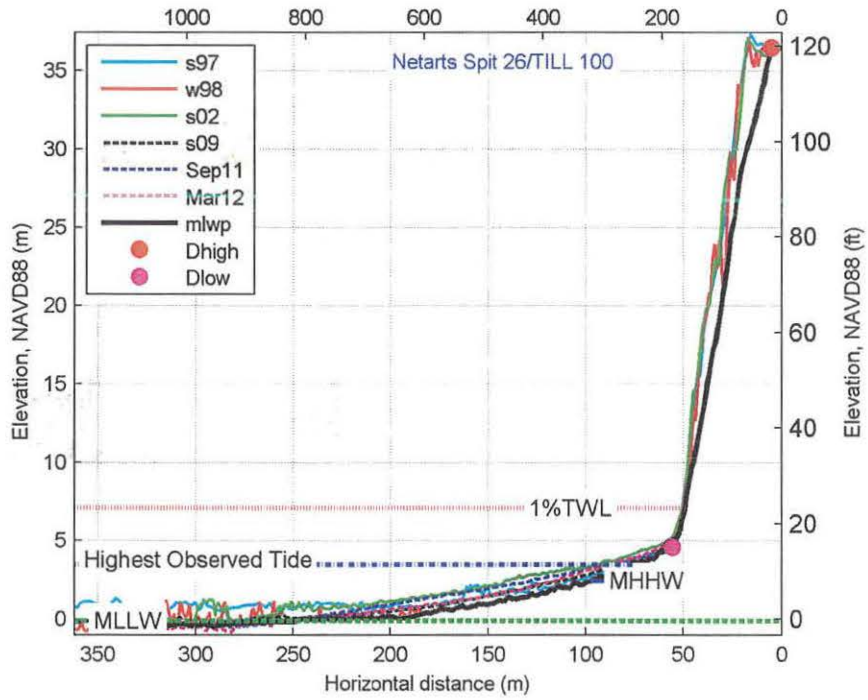
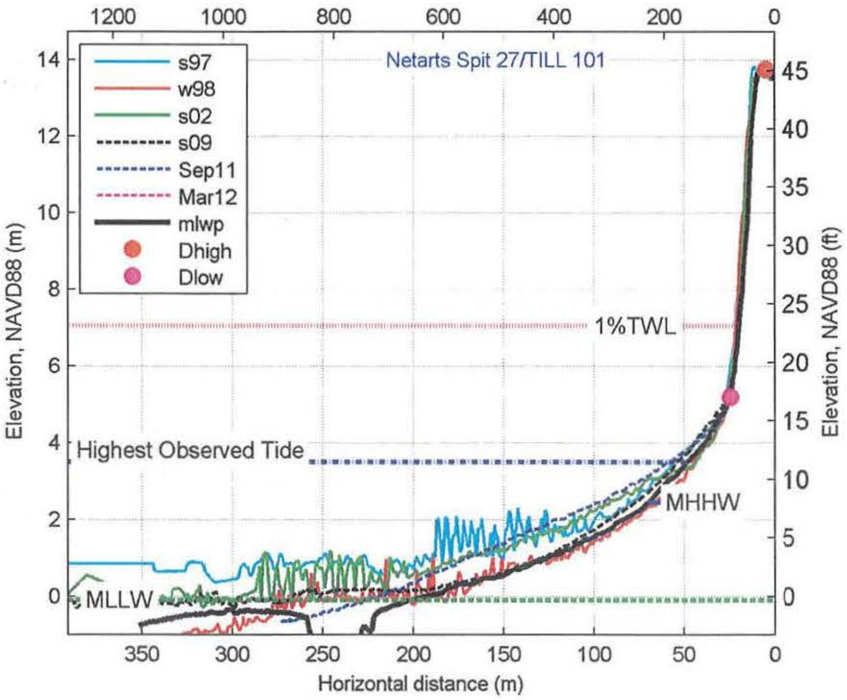
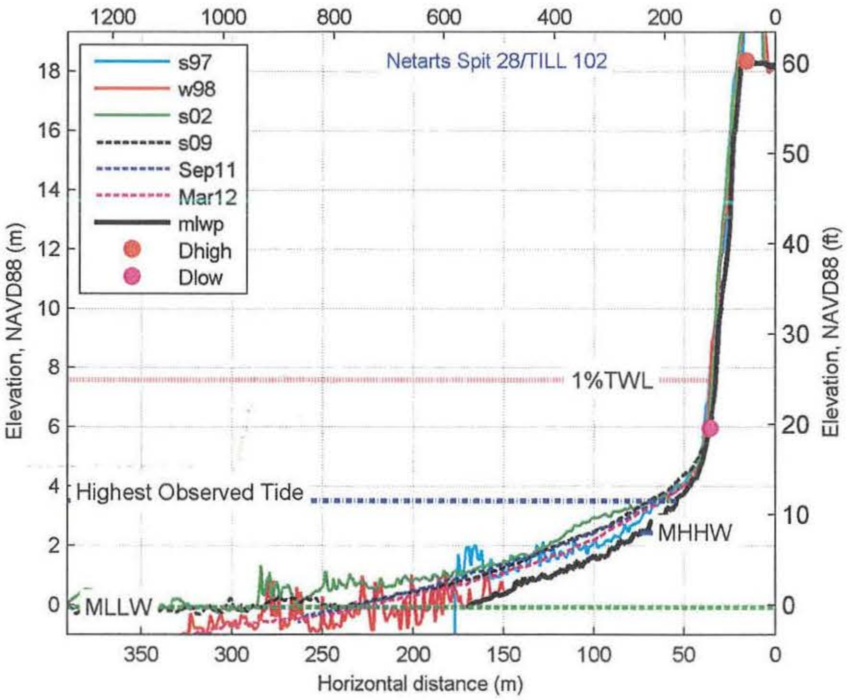


fm_netarts 27



fm_netarts 28



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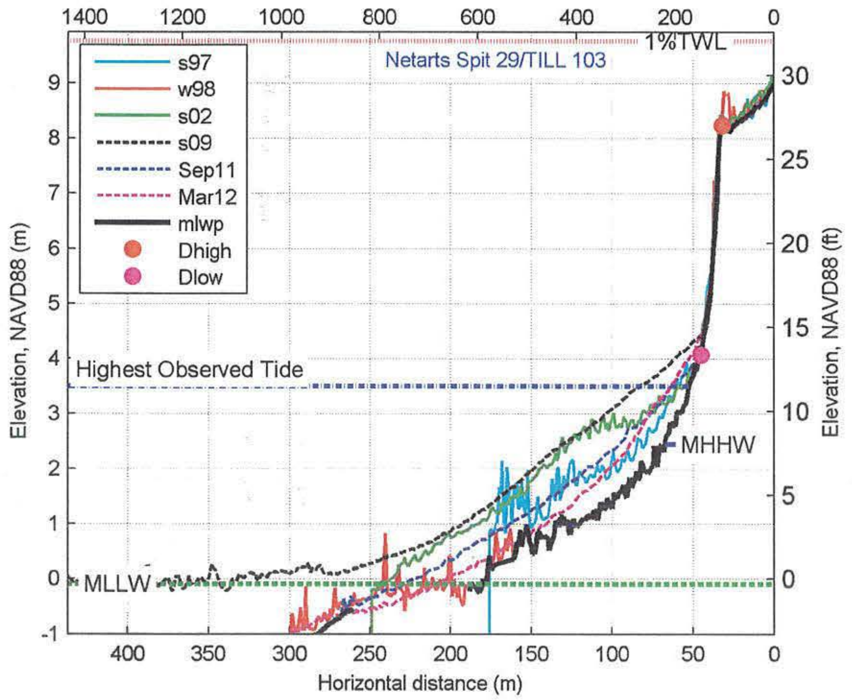
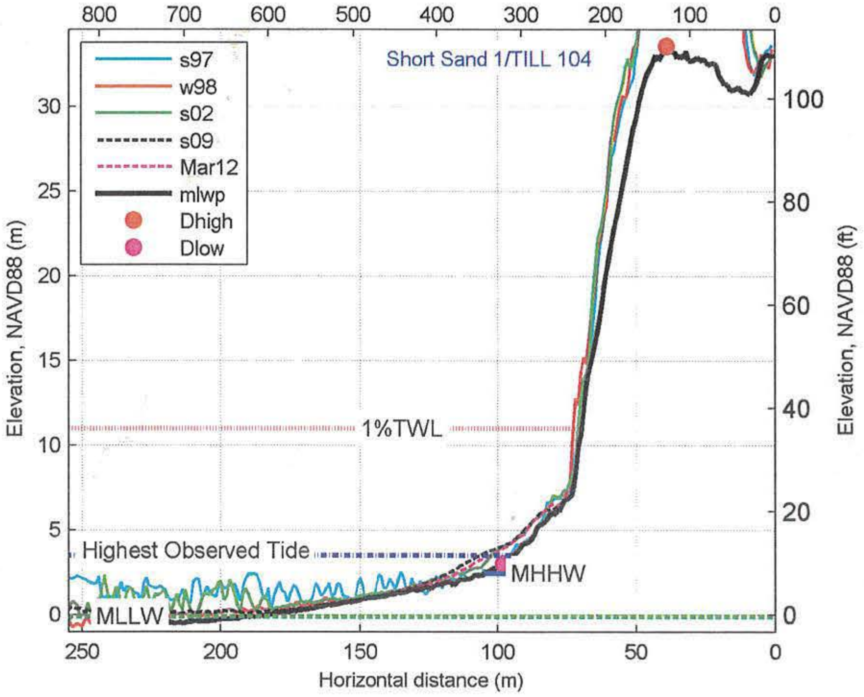


11.4.5 Short Sand Beach

fm_ss 1



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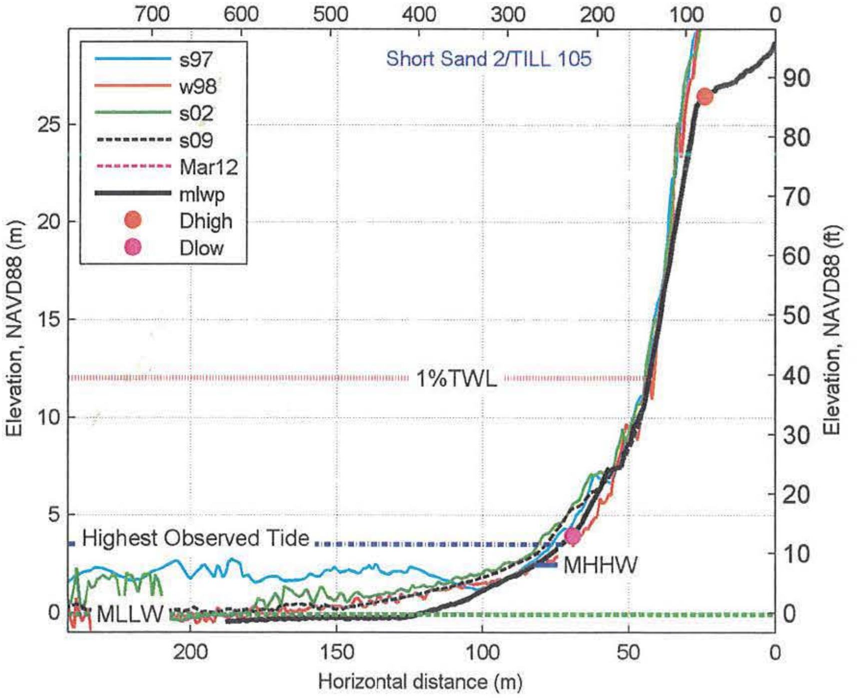
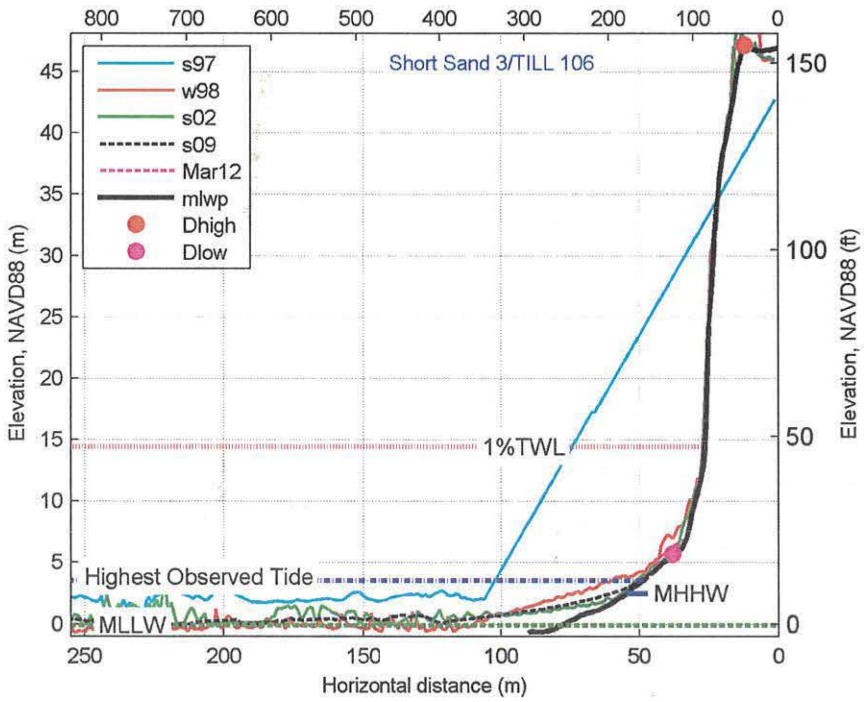
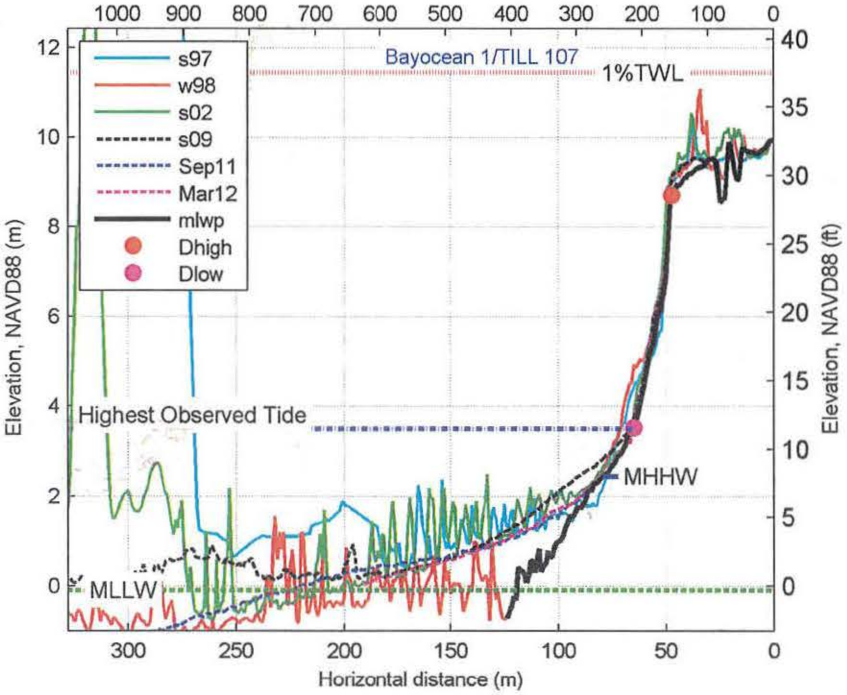


fm_ss 3

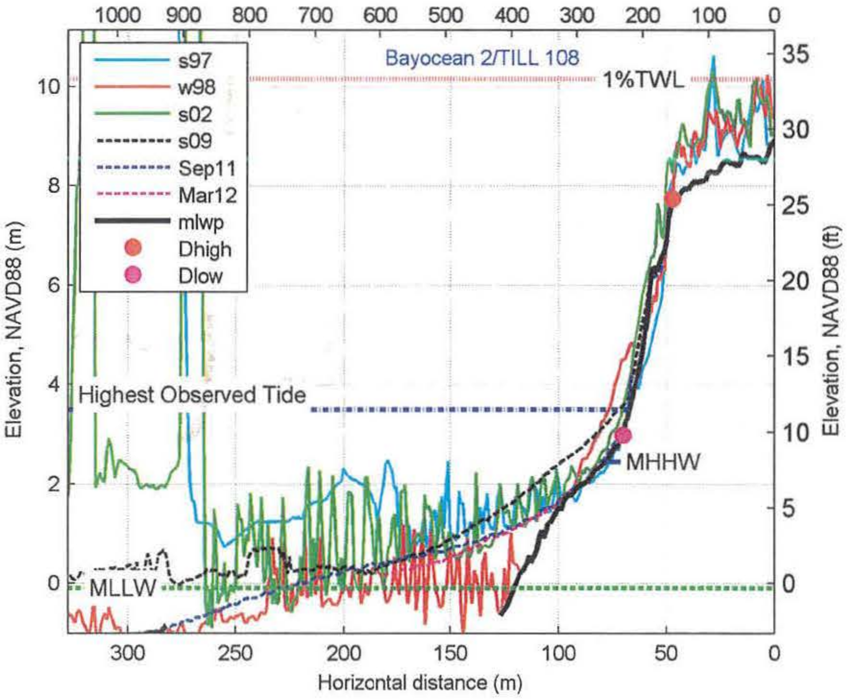

800
700
600
500
400
300
200
100
0
Short Sand 3/TILL 106
s97
w98
s02
s09
Mar12
mlwp
Dhigh
Dlow
45
40
35
30
25
20
15
10
5
0
Elevation, NAVD88 (m)
150
100
50
0
Elevation, NAVD88 (ft)
1%TWL
Highest Observed Tide
MHHW
MLLW
250
200
150
100
50
0
Horizontal distance (m)

11.4.6 Bayocean Spit

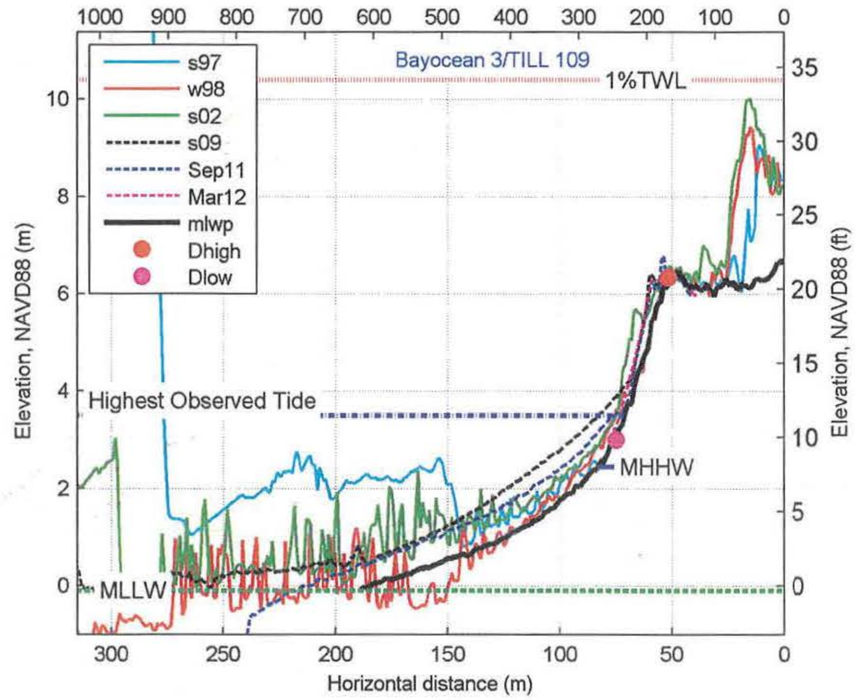
fm_bay 1



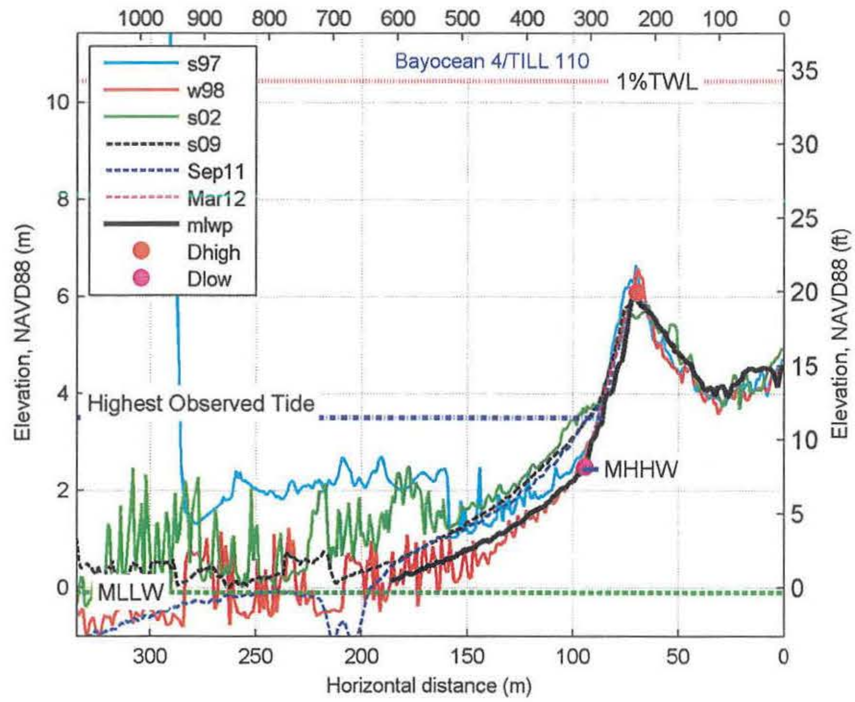
fm_bay 2



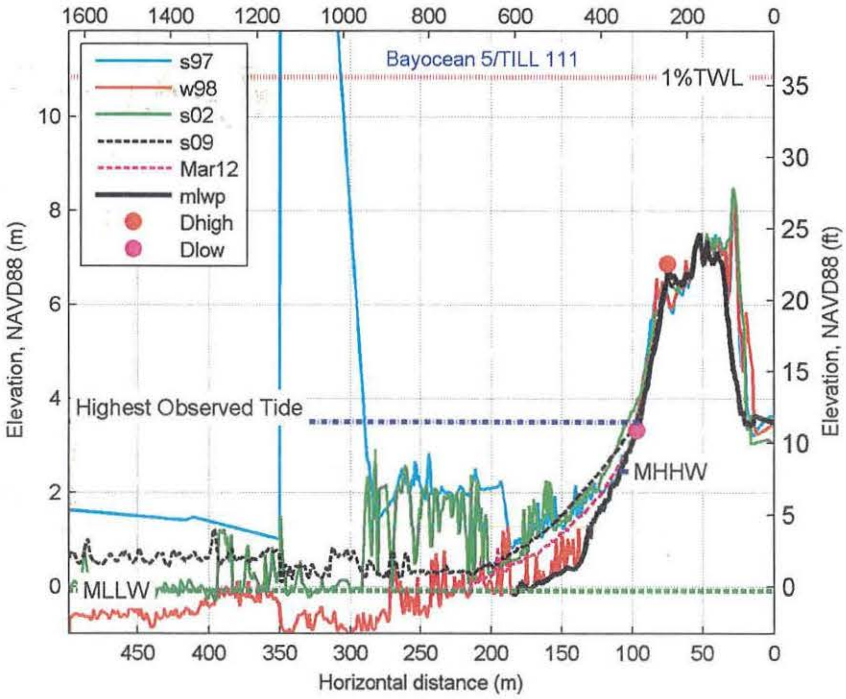
fm_bay 3



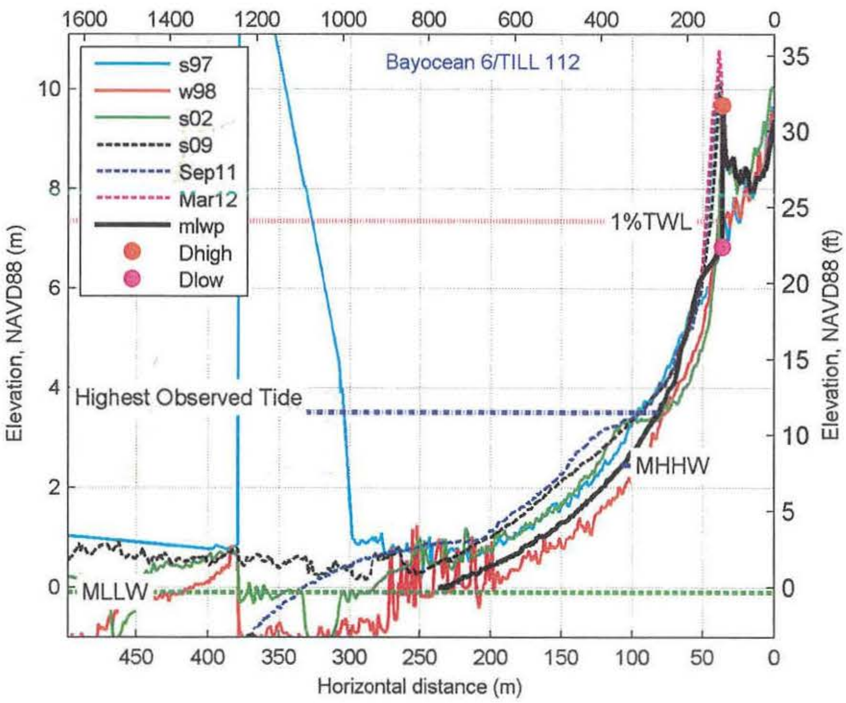
fm_bay 4



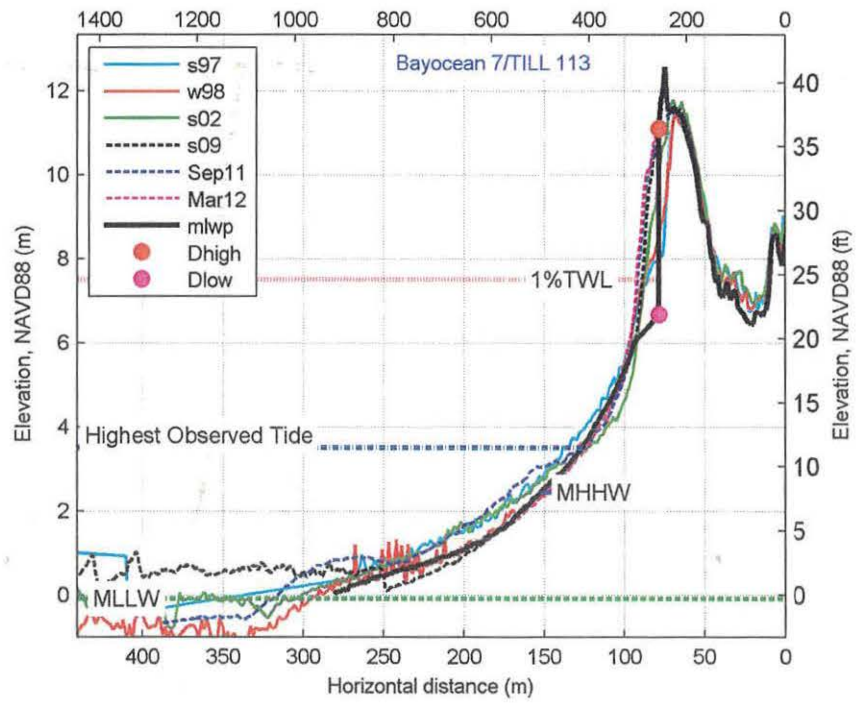
fm_bay 5



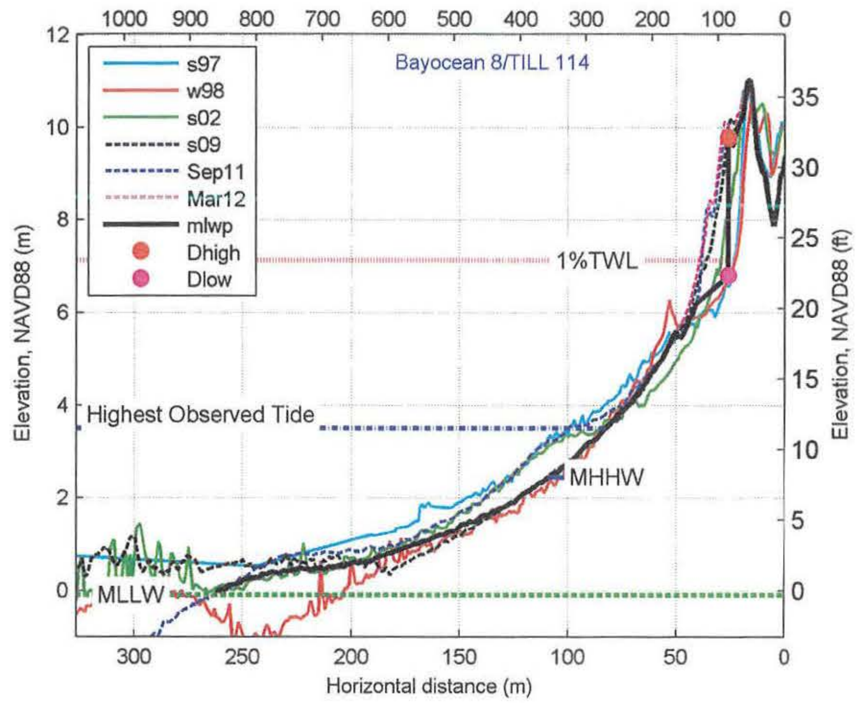
fm_bay 6



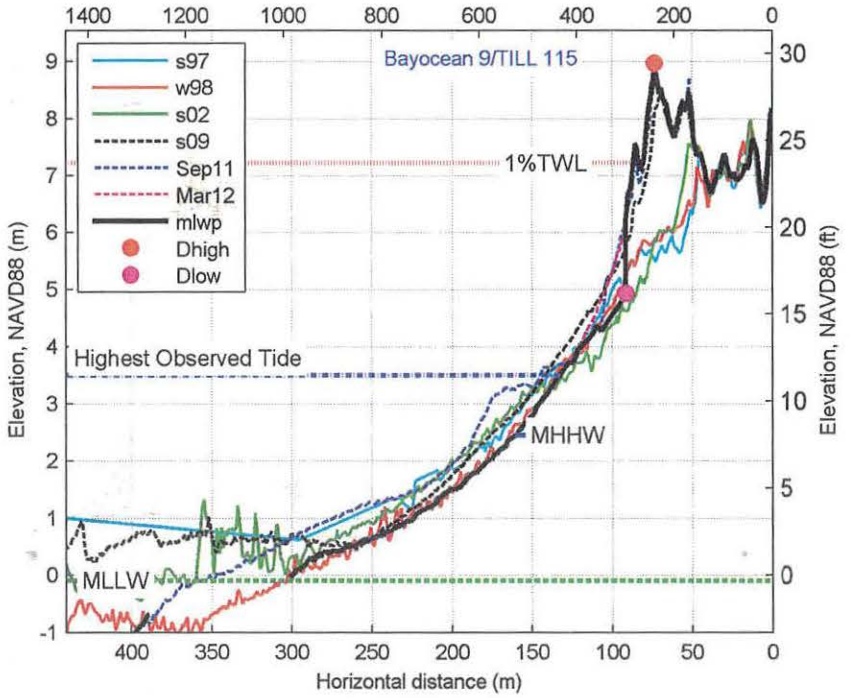
fm_bay 7



fm_bay 8



fm_bay 9



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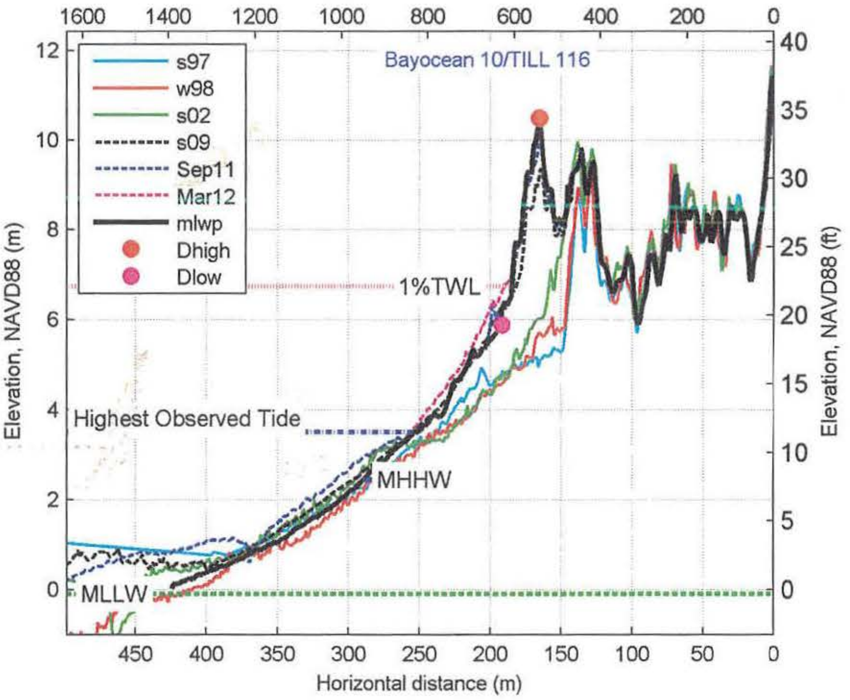
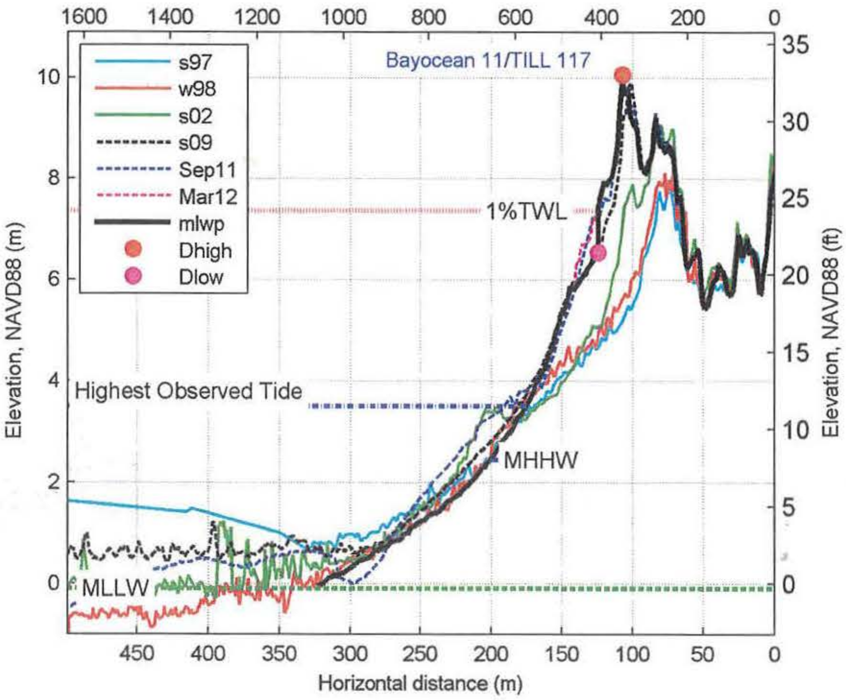


fm_bay 11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1200
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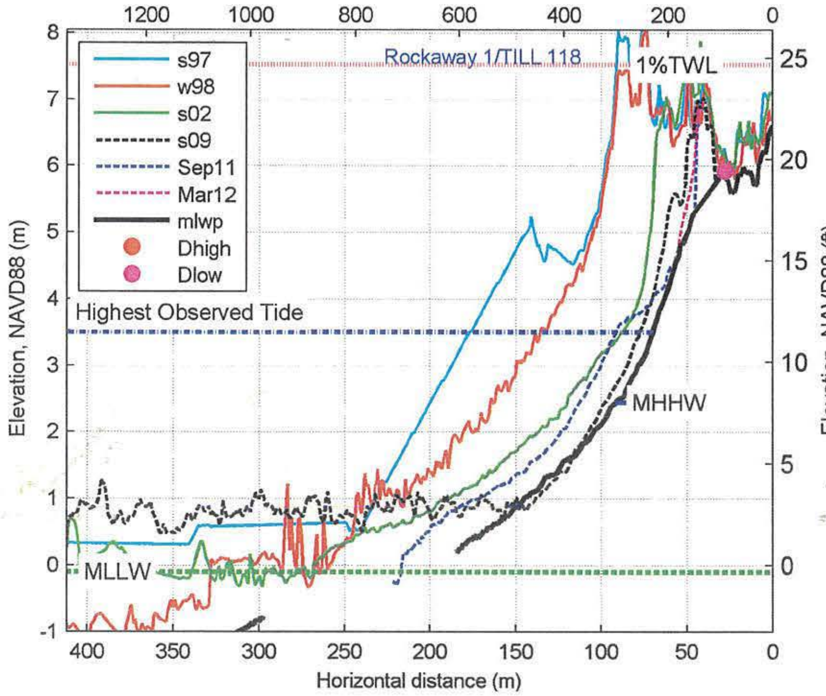
800
600
400
200
0
Bayocean 11/TILL 117
s97
w98
s02
s09
Sep11
Mar12
mlwp
Dhigh
Dlow
1%TWL
Highest Observed Tide
MHHW
MLLW
Elevation, NAVD88 (m)
Elevation, NAVD88 (ft)
Horizontal distance (m)
450
400
350
300
250
200
150
100
50
0

11.4.7 Rockaway

fm_rck 1



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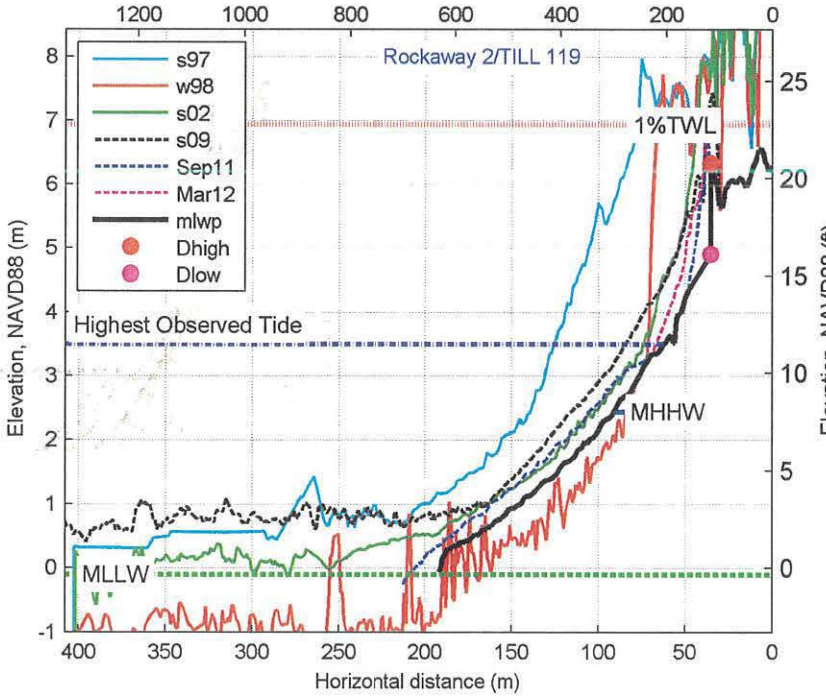

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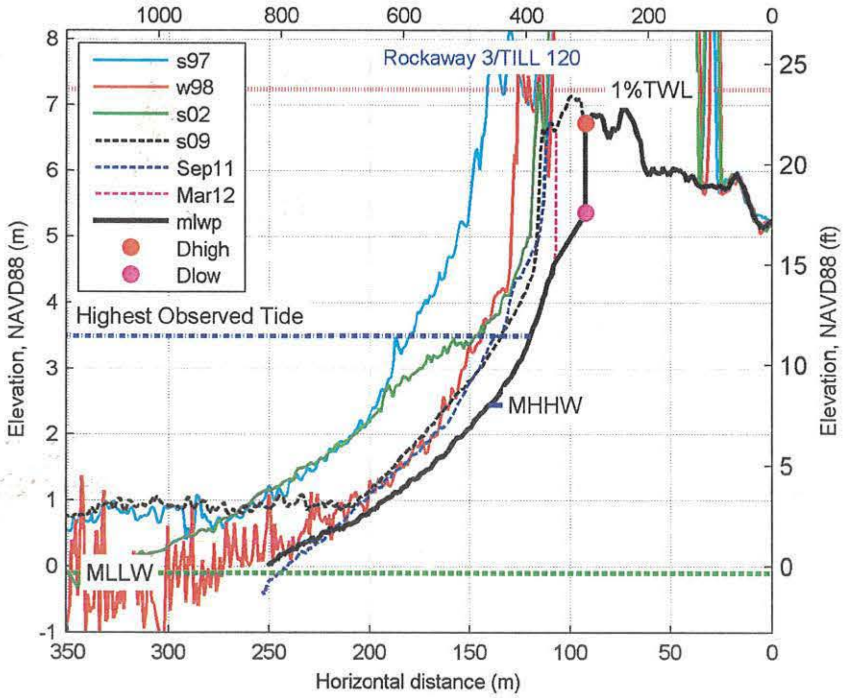

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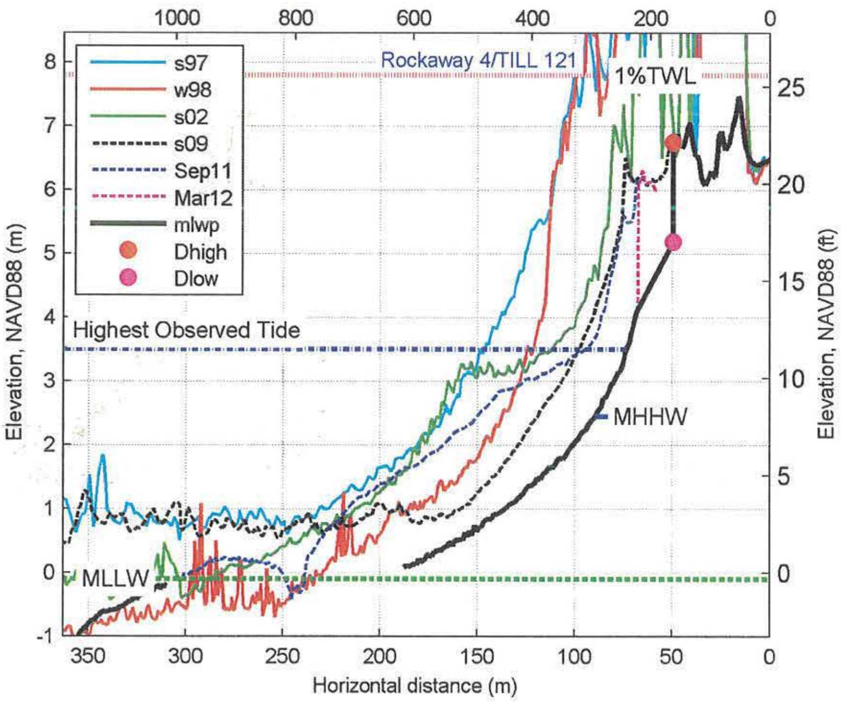

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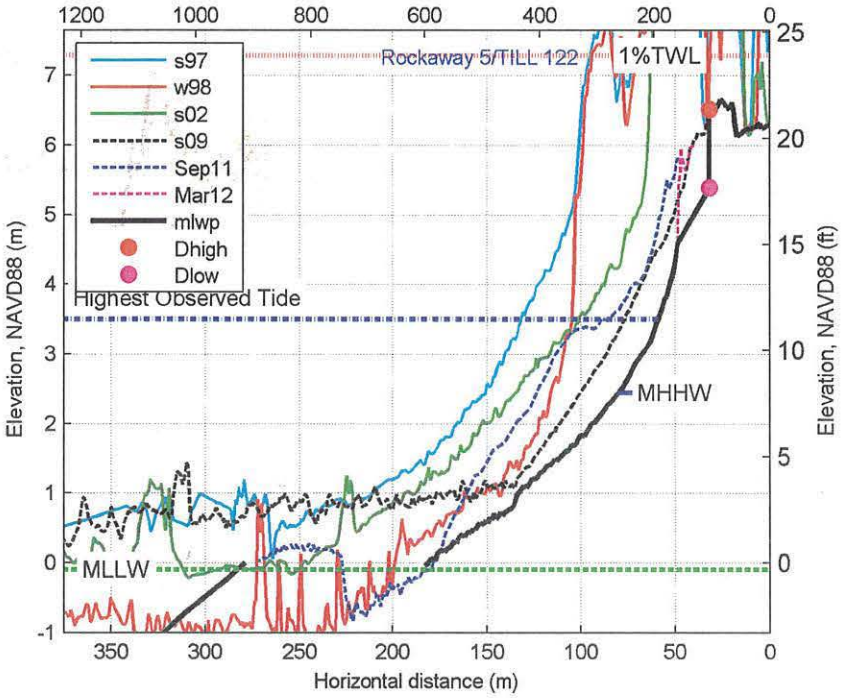

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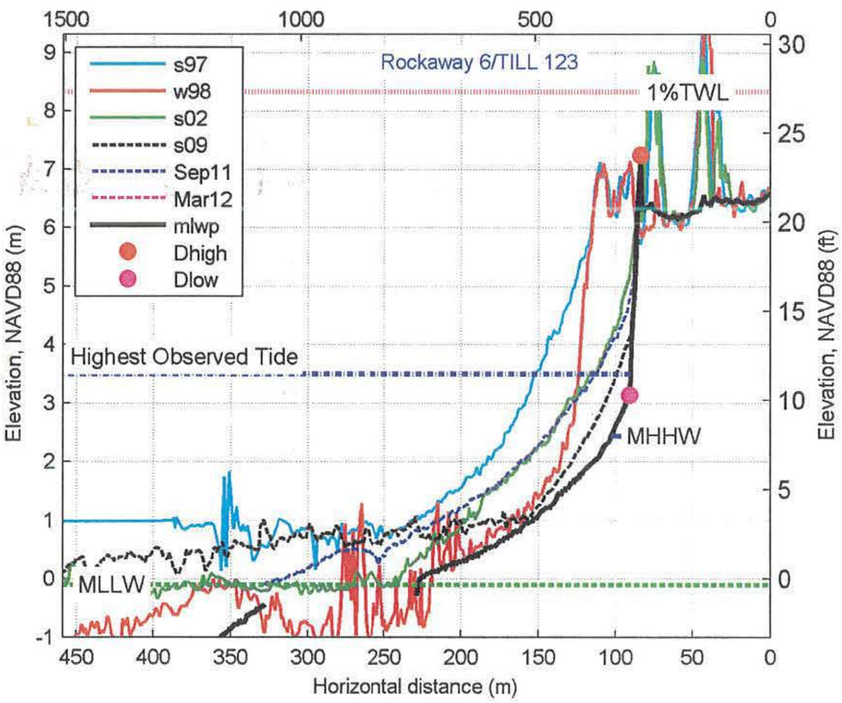

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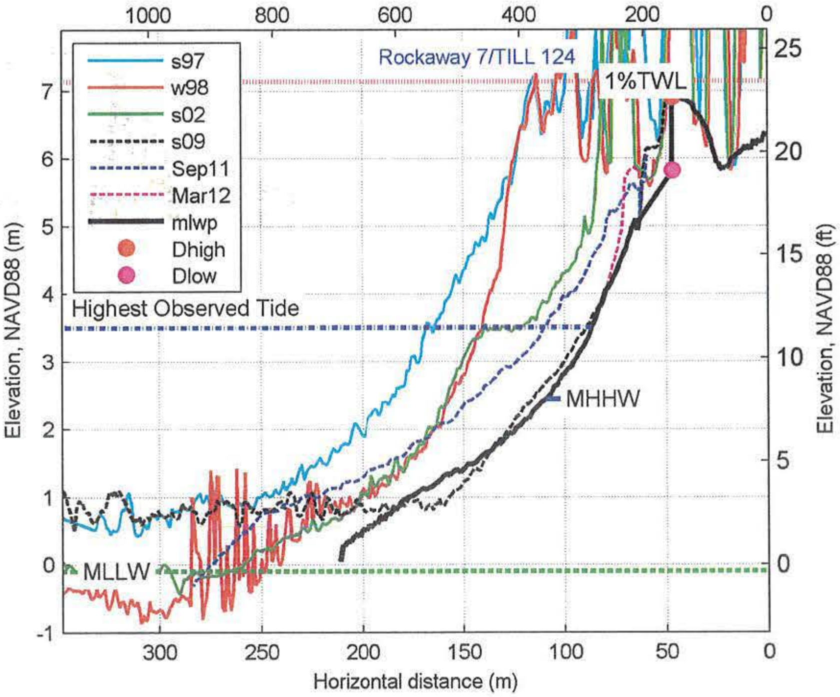

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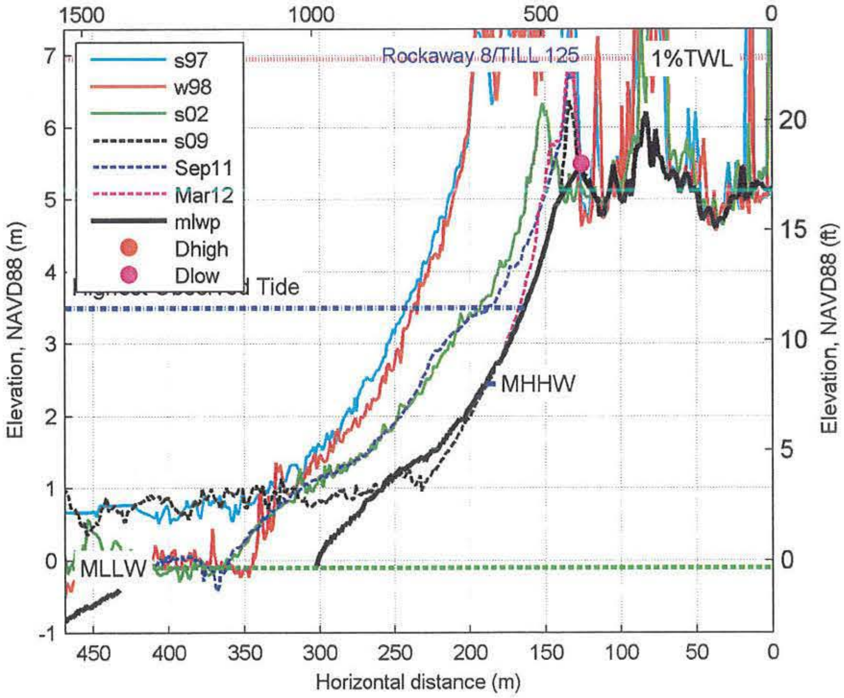

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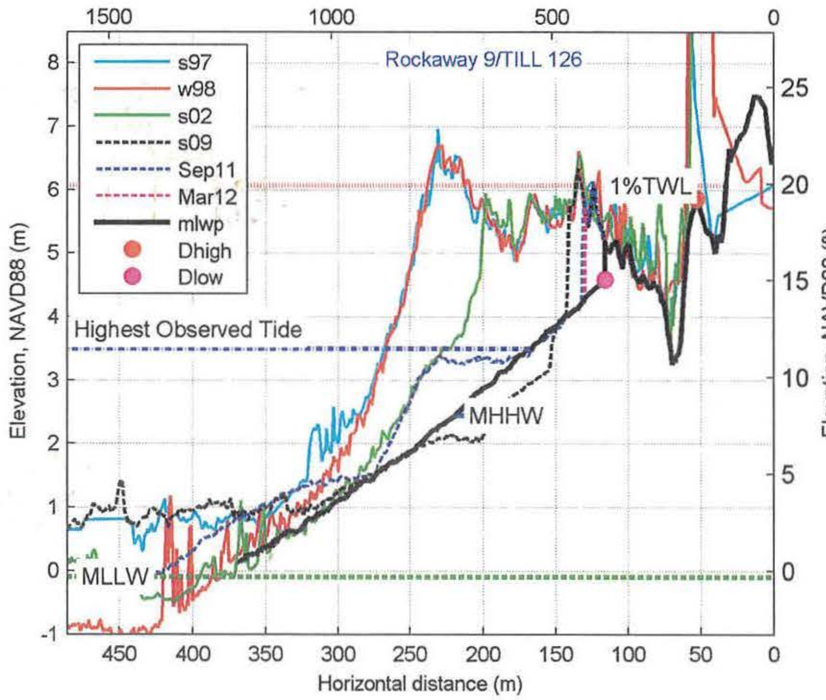

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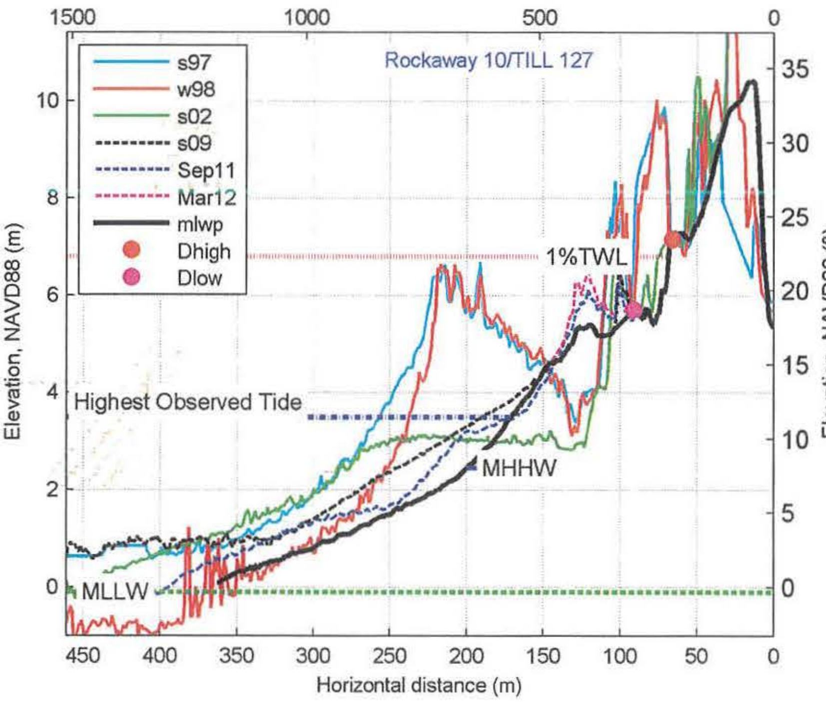

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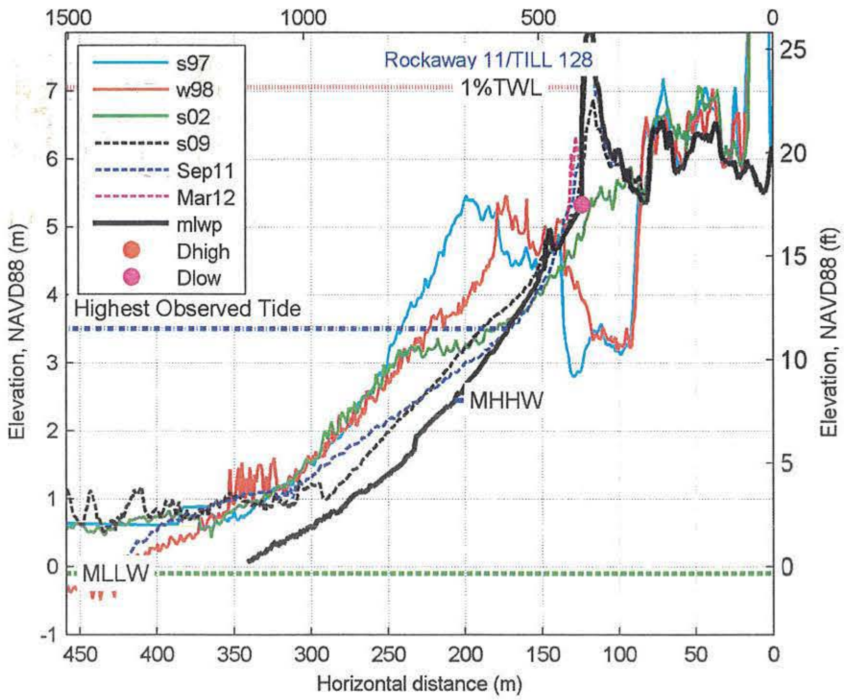

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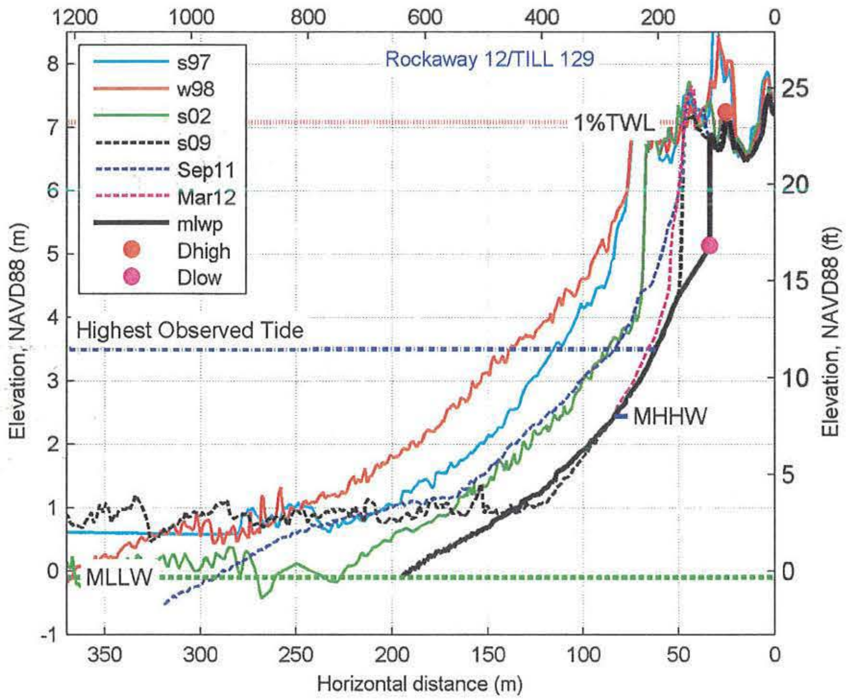

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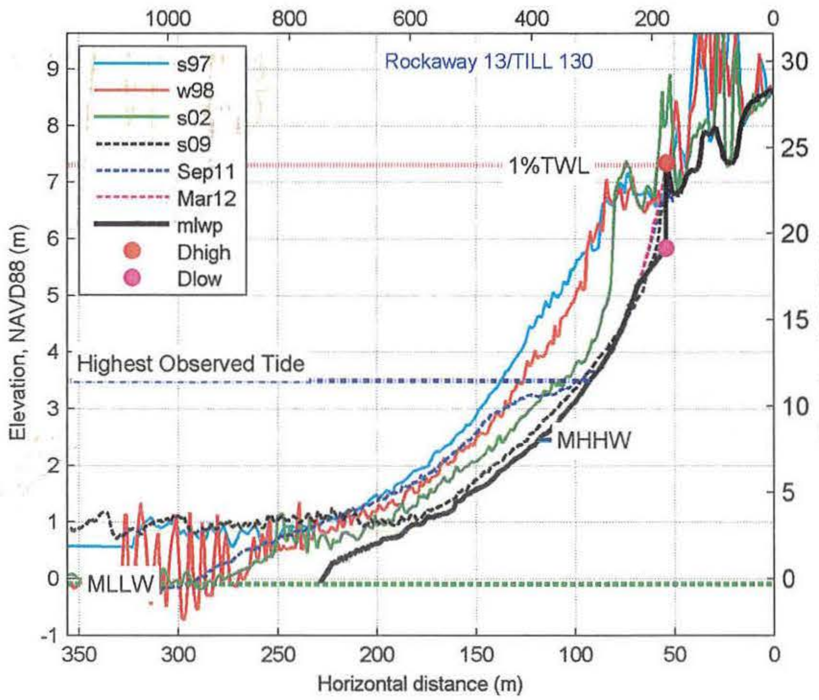

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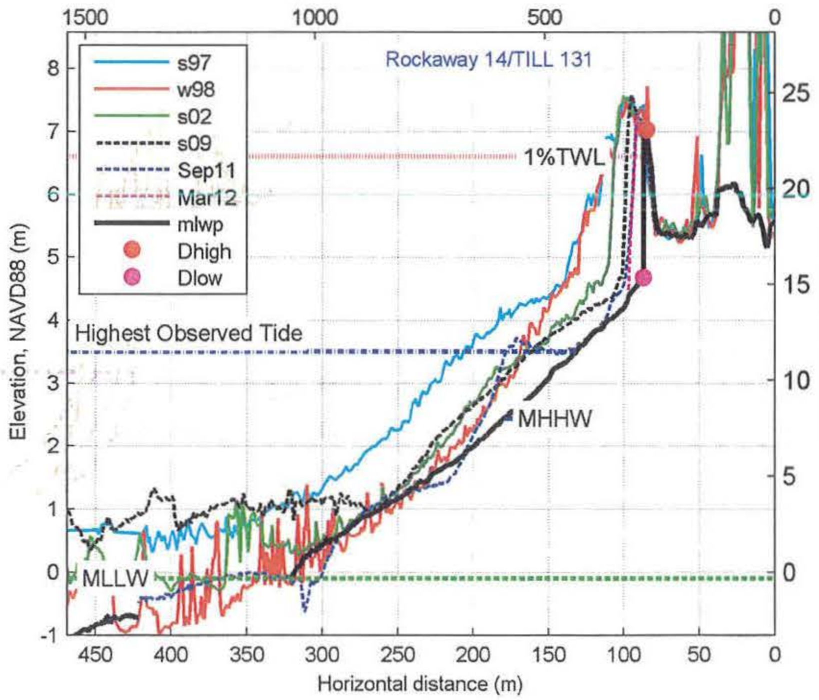

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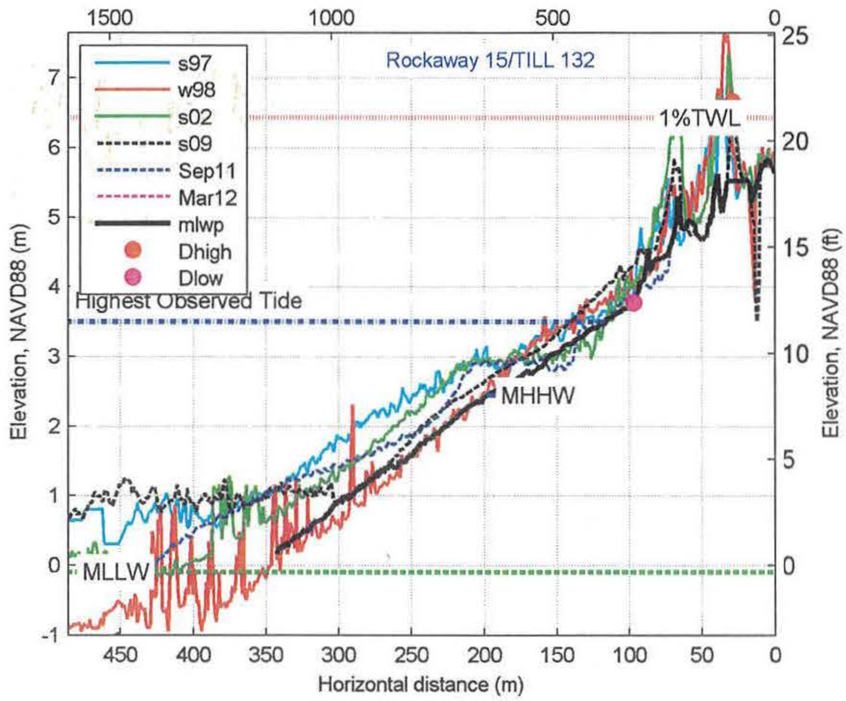

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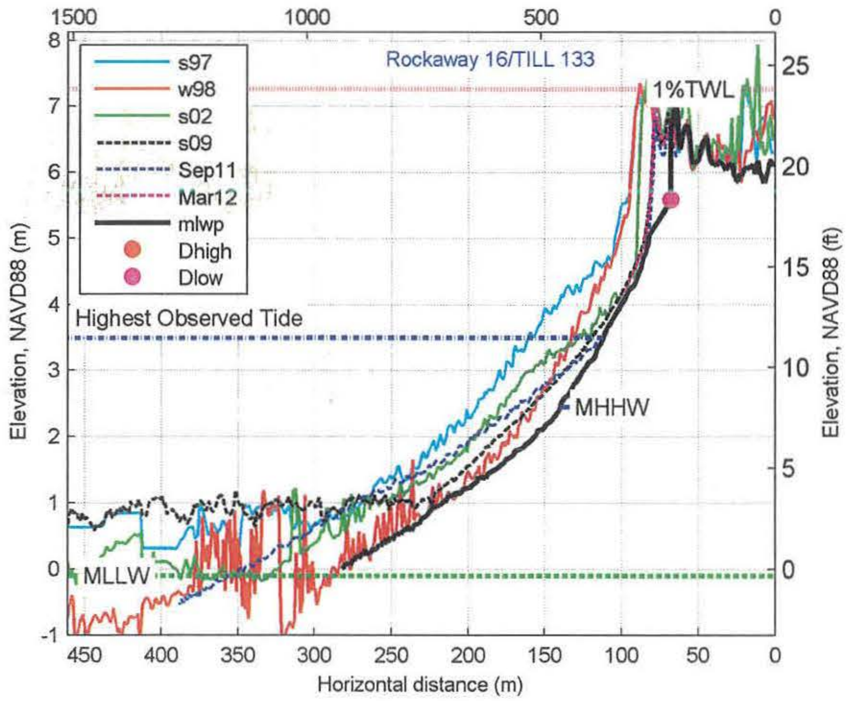

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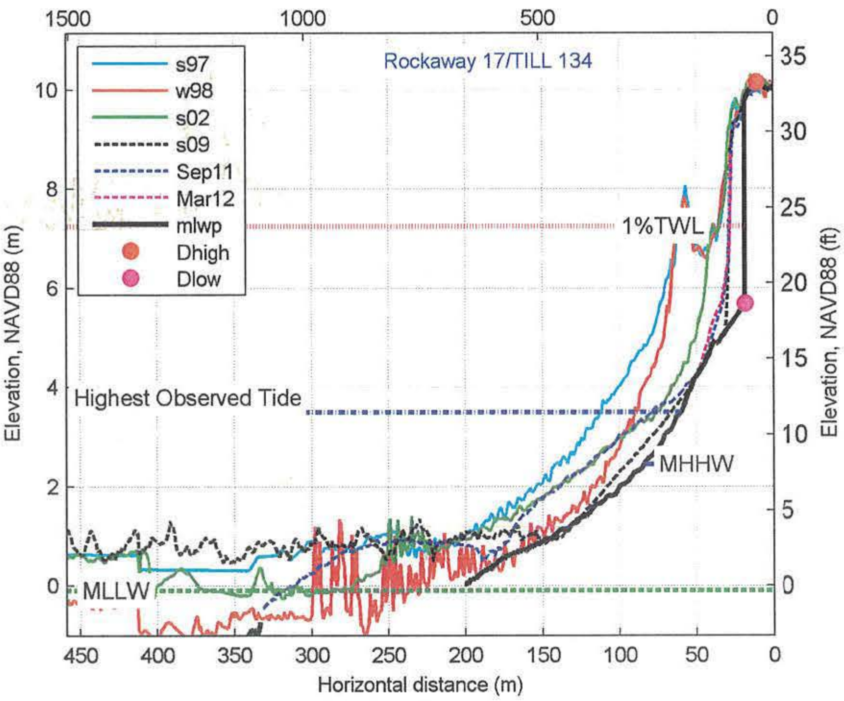

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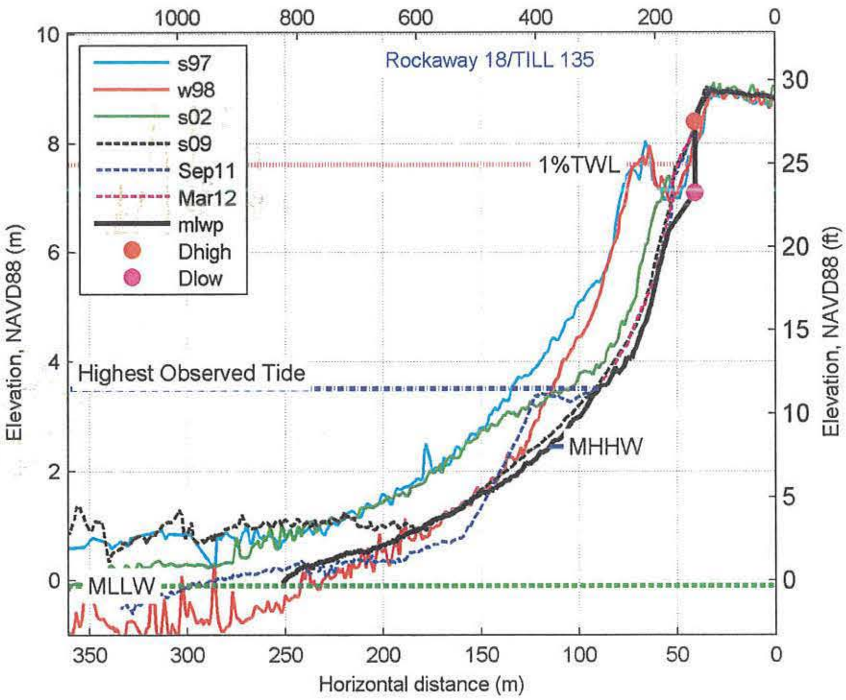

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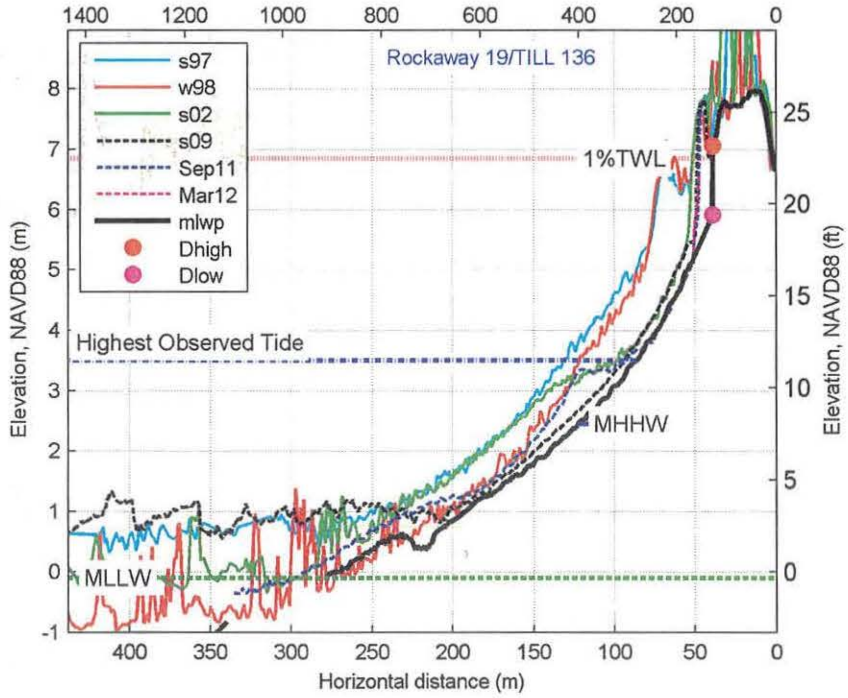

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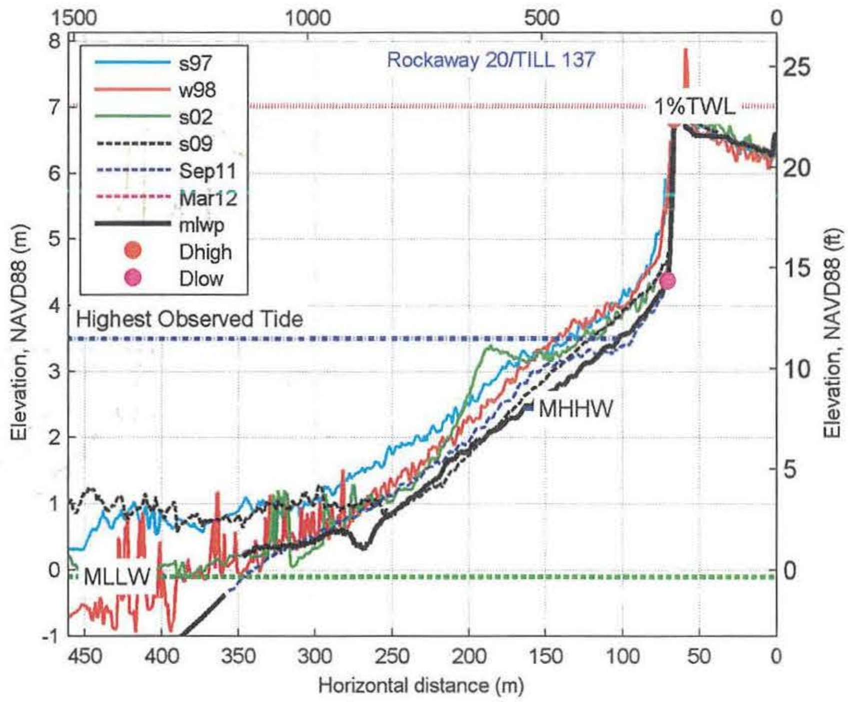

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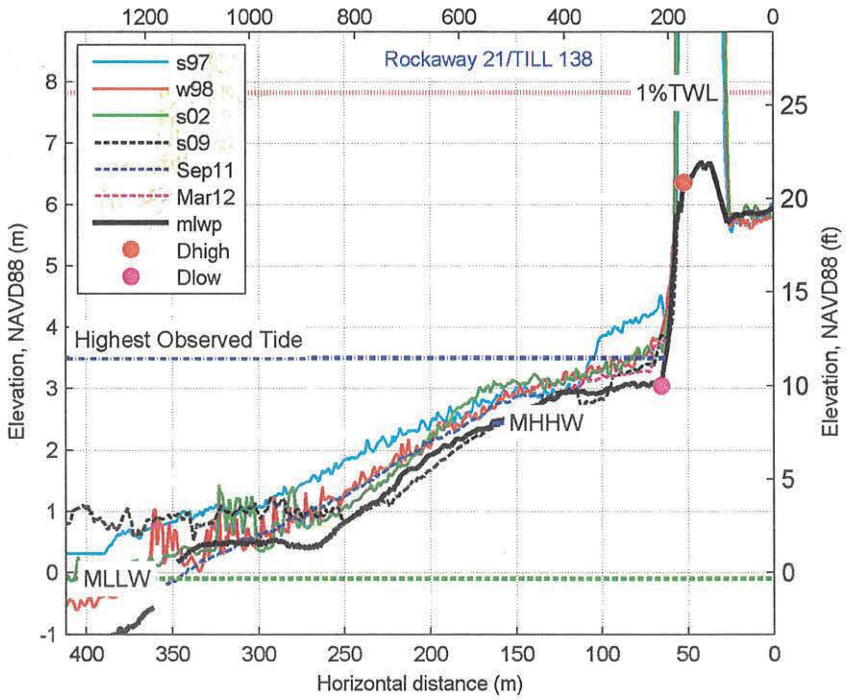

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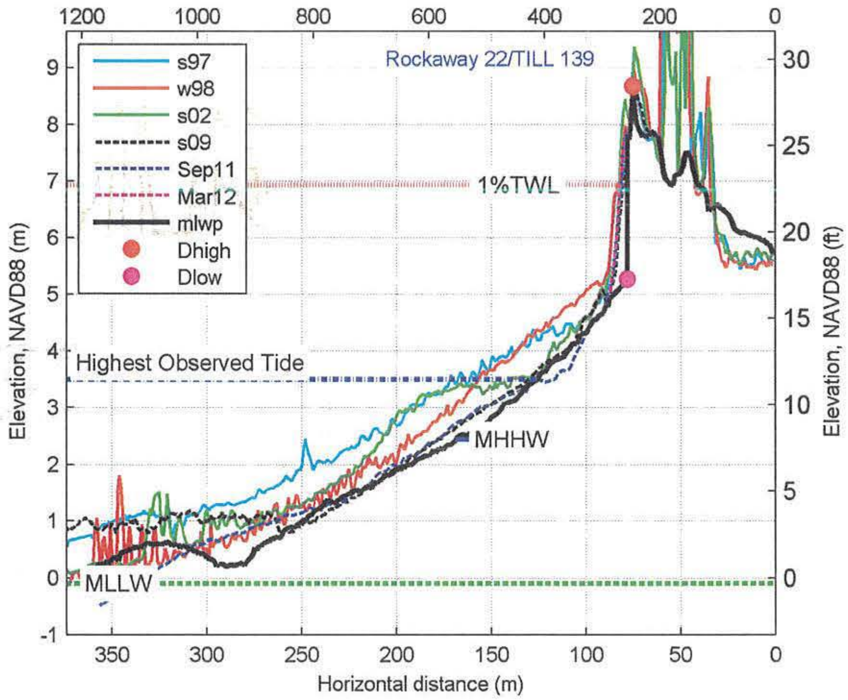

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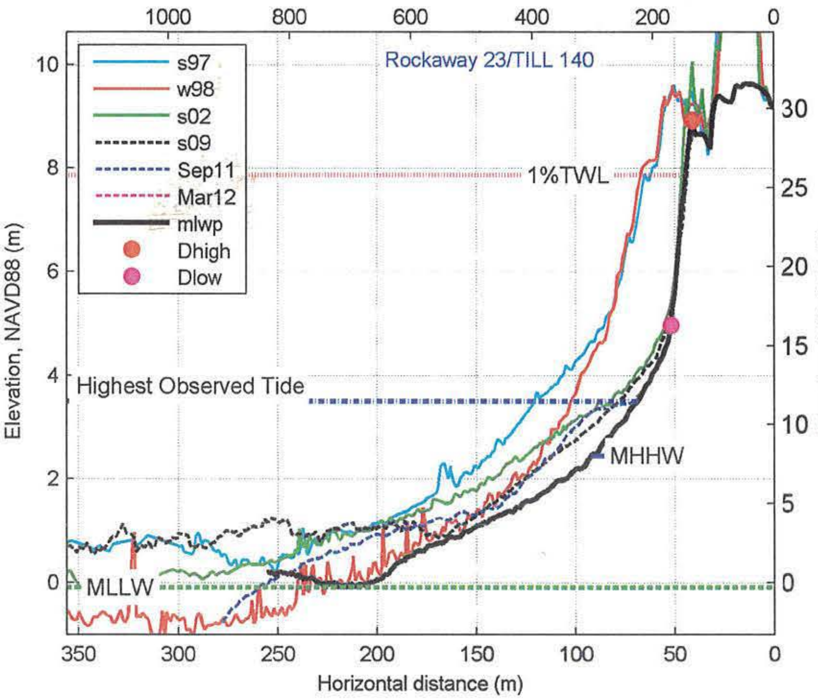

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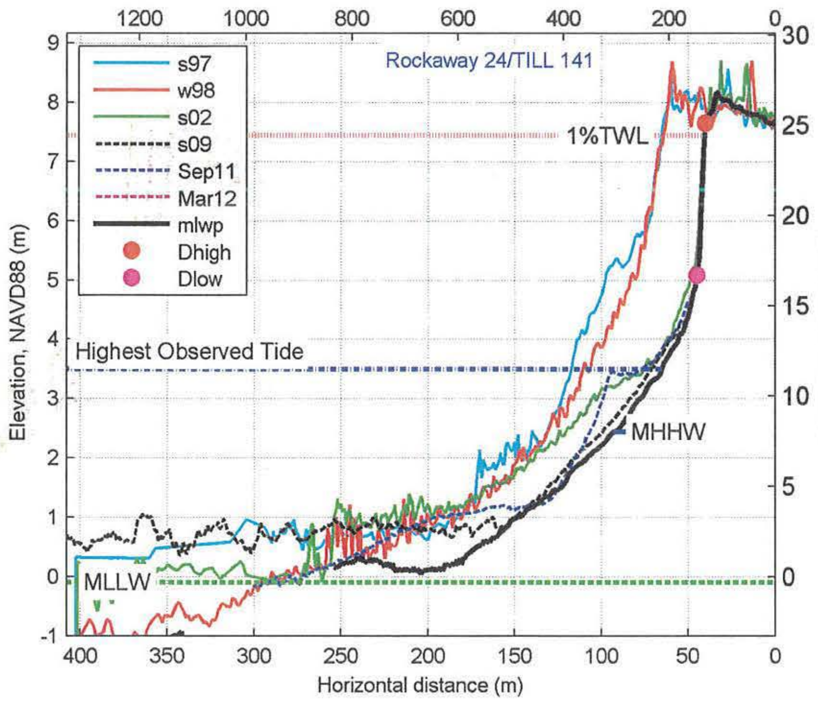

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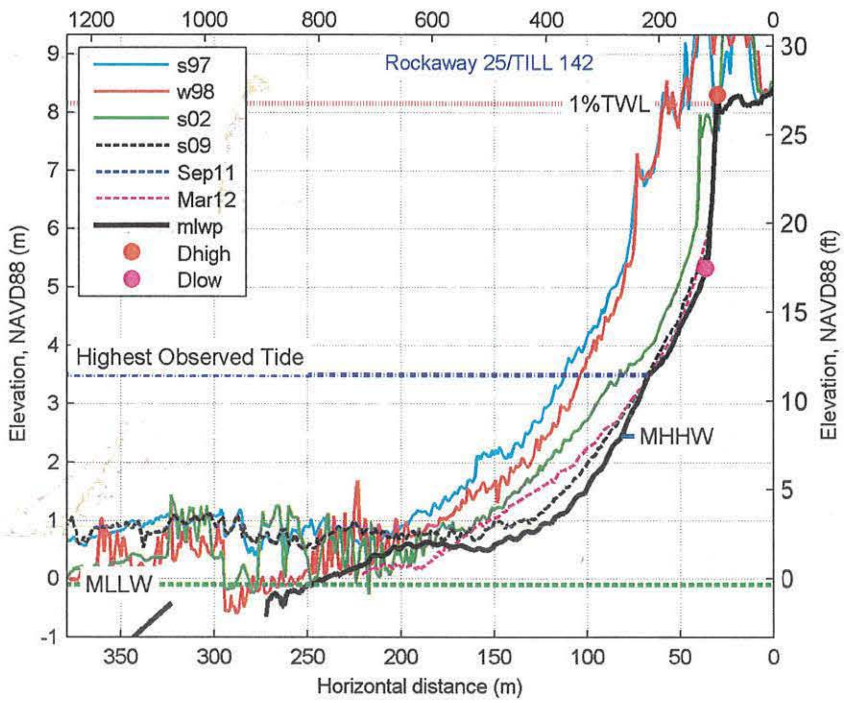

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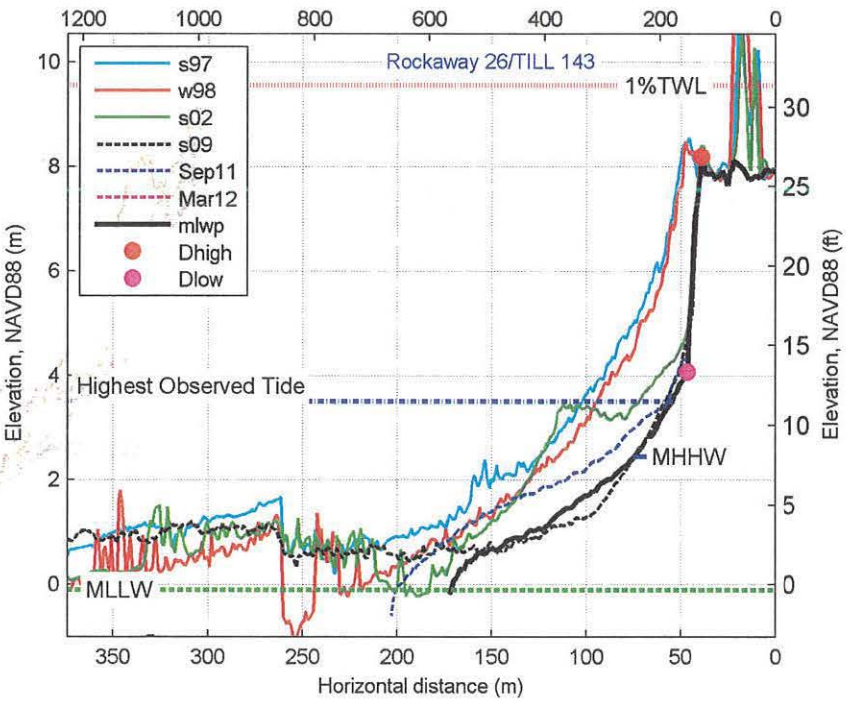

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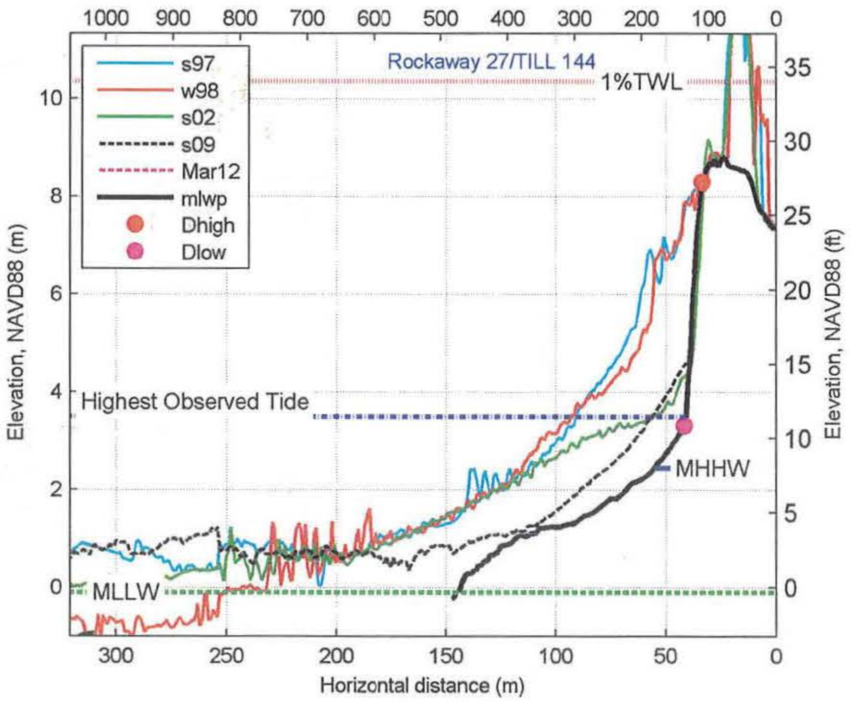

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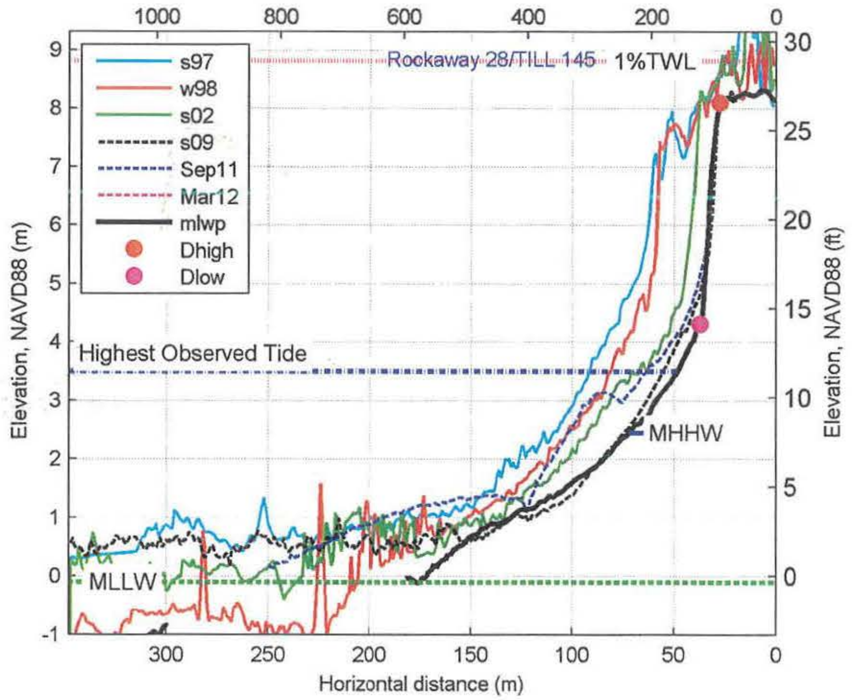

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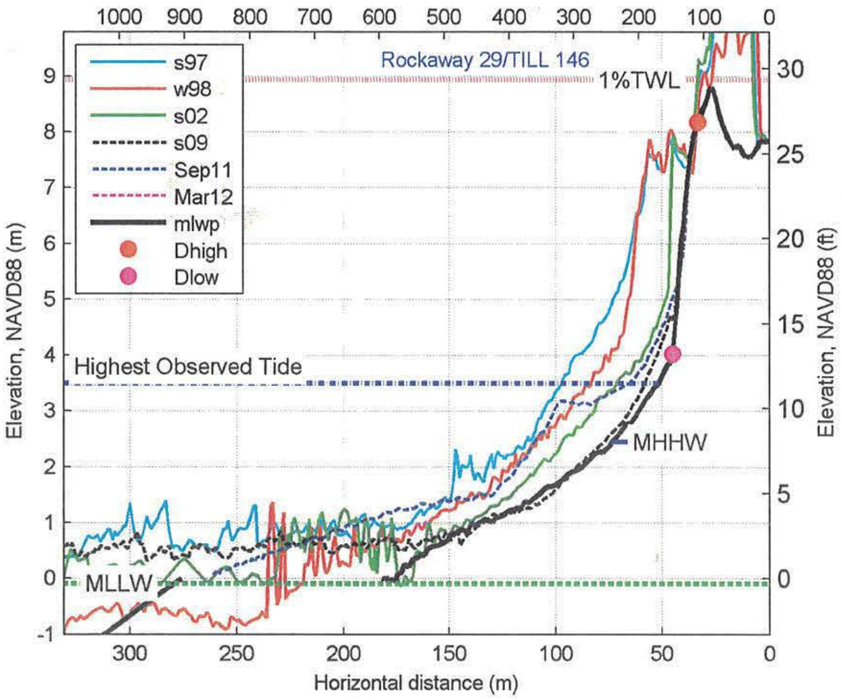

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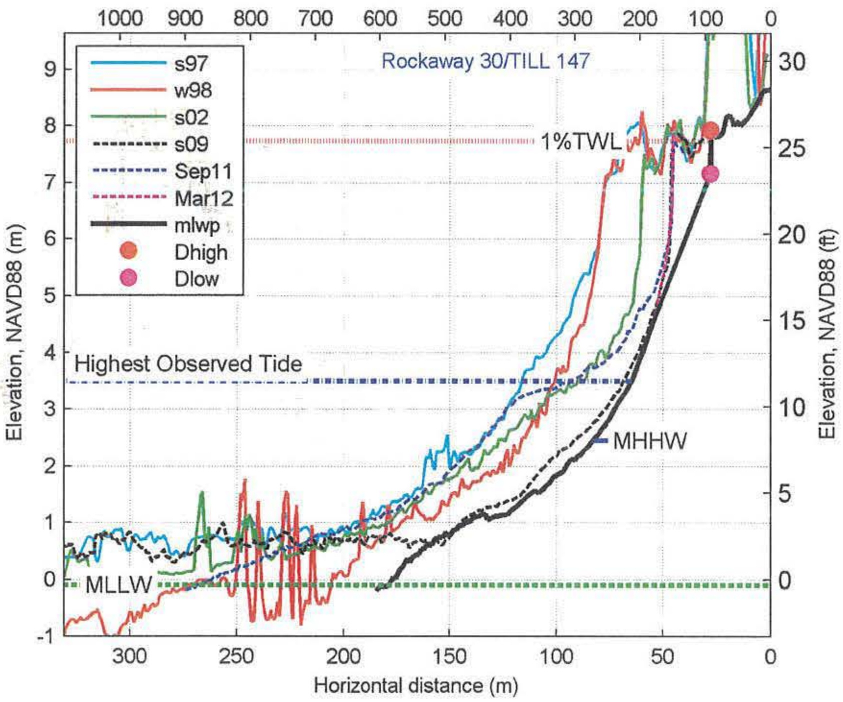

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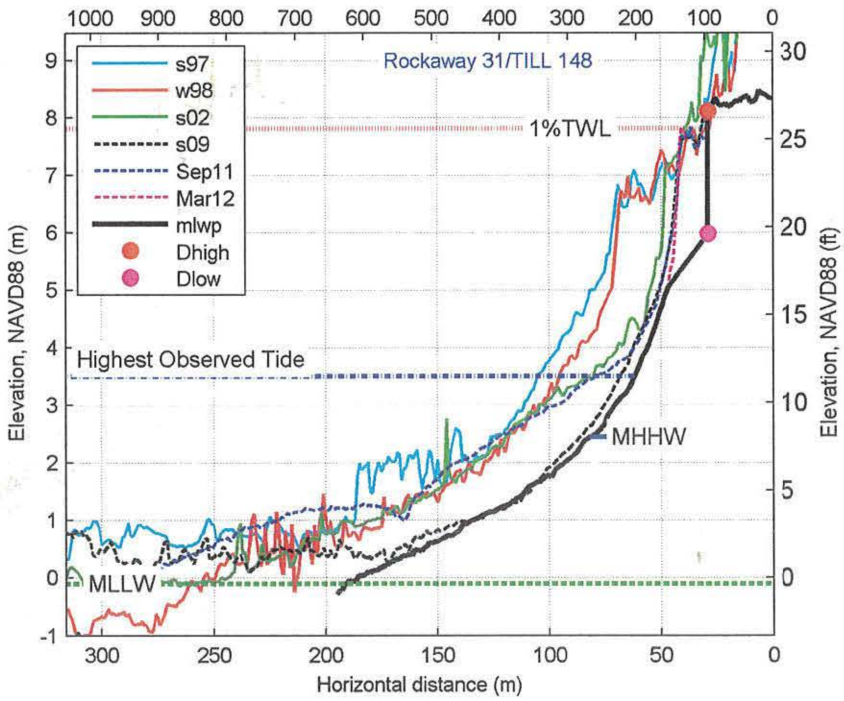

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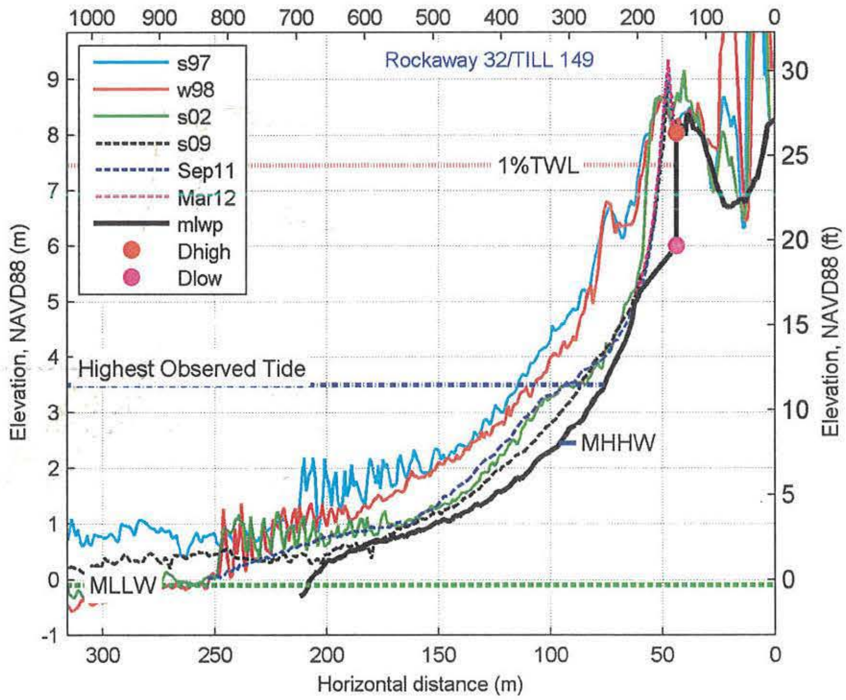

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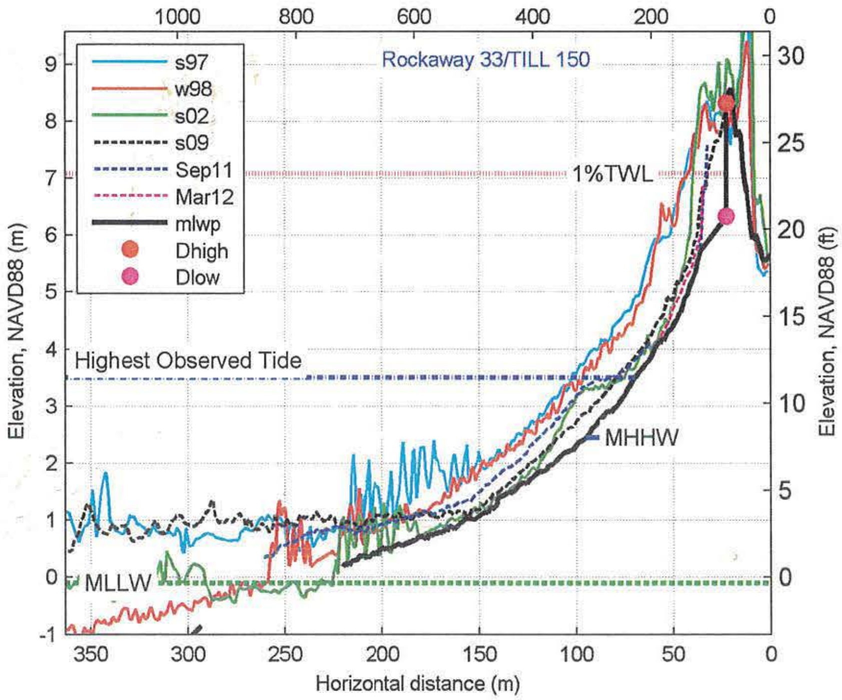

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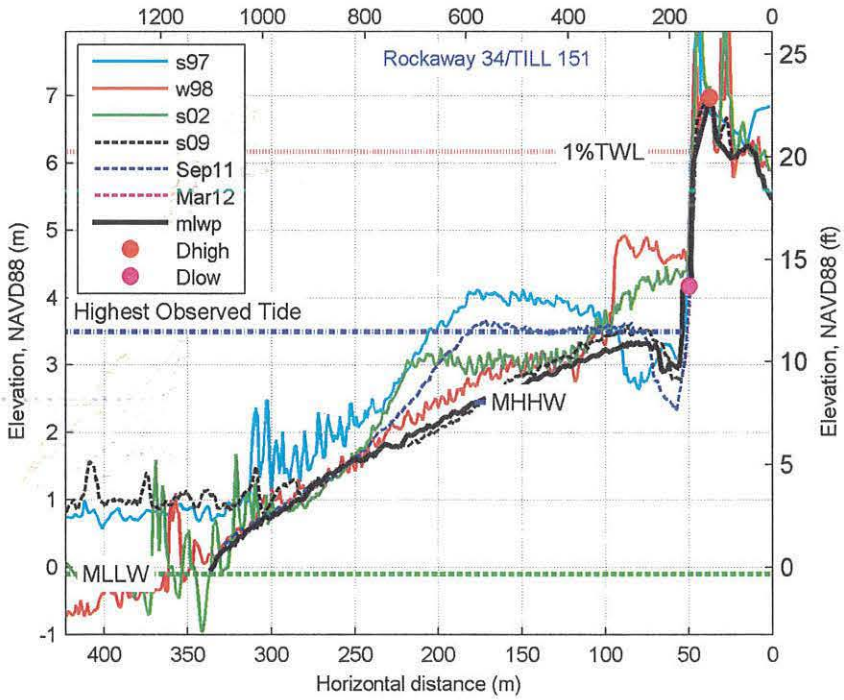

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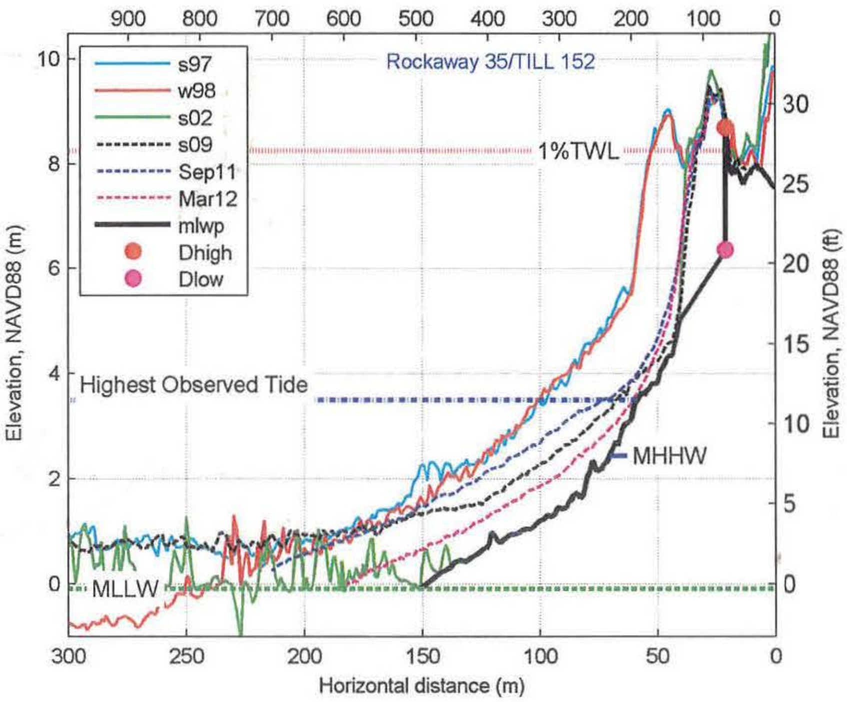

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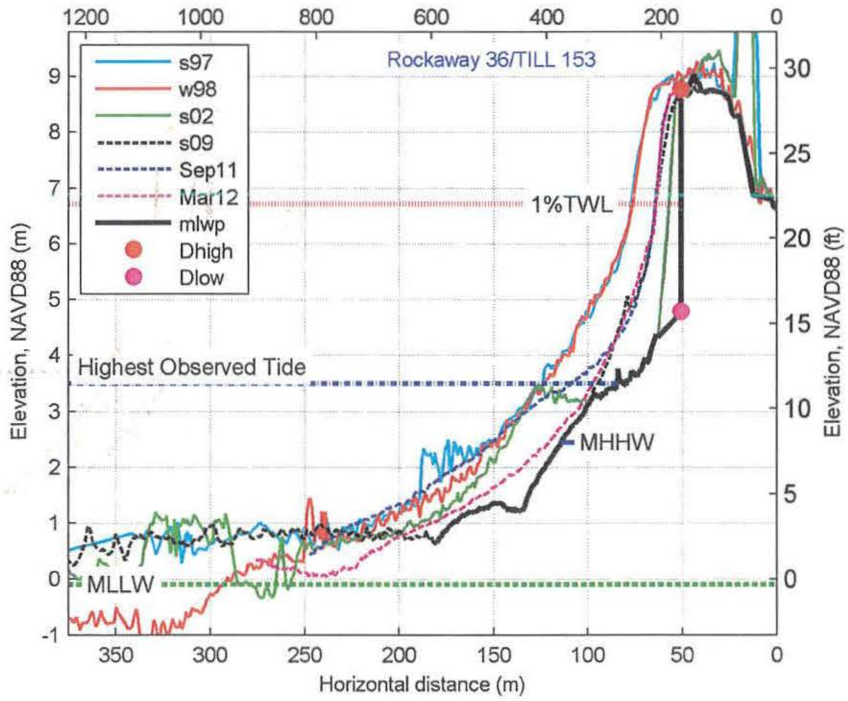

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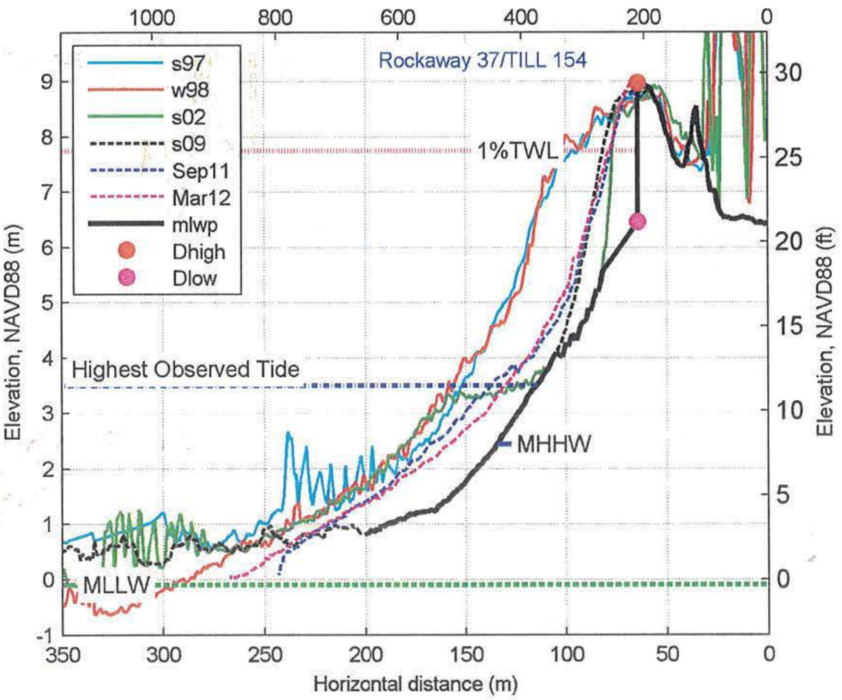

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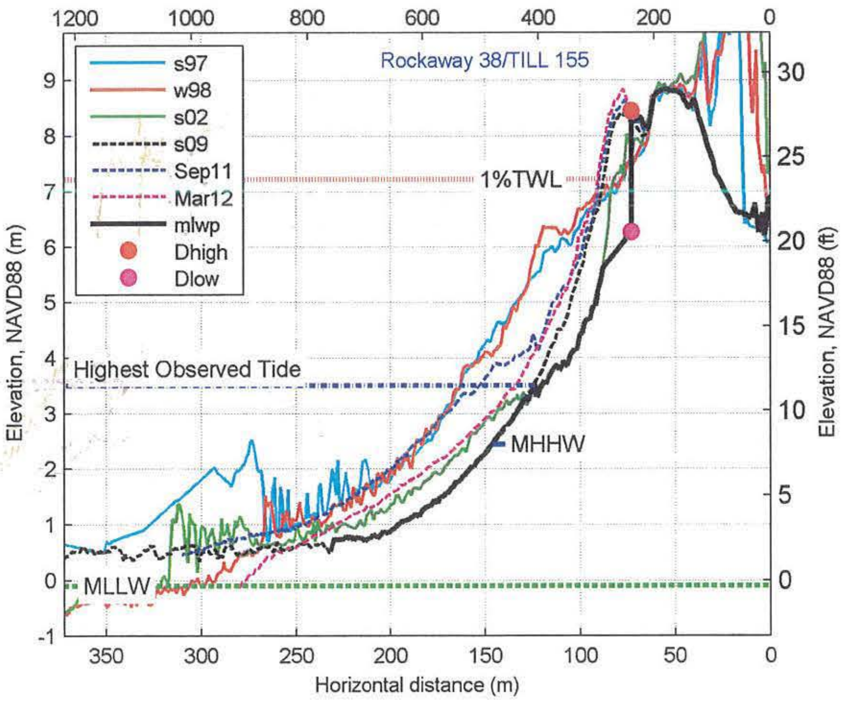

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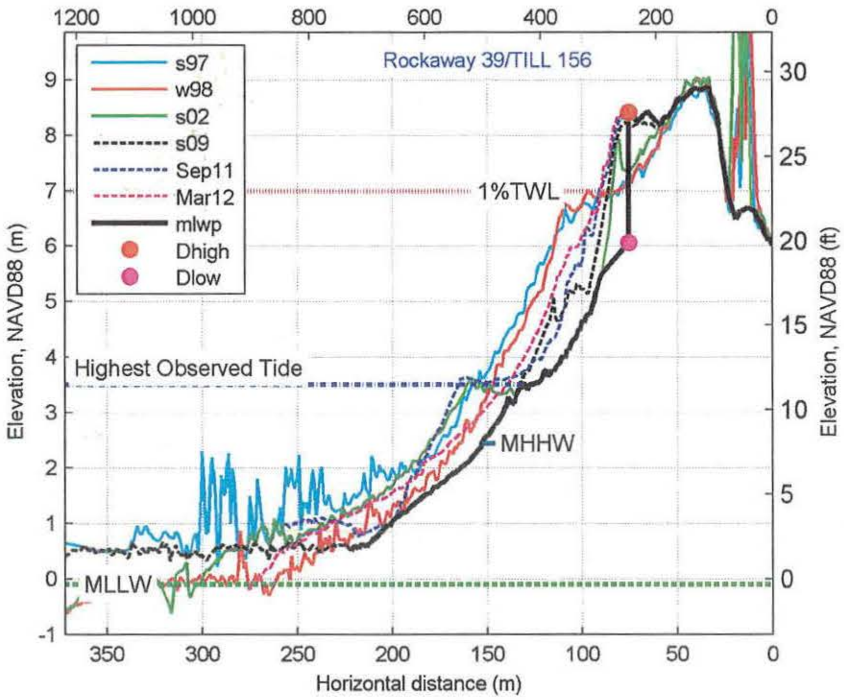

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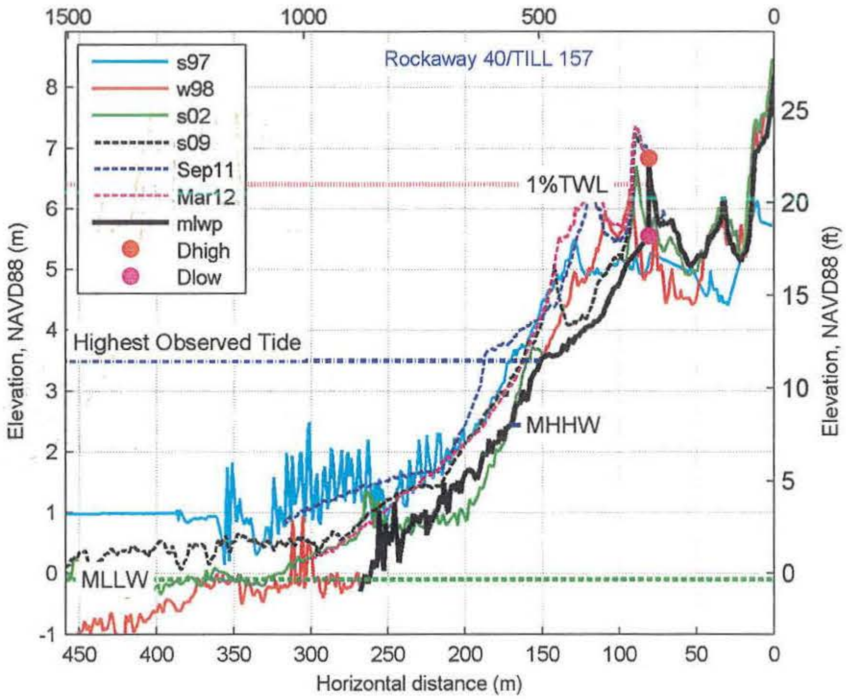
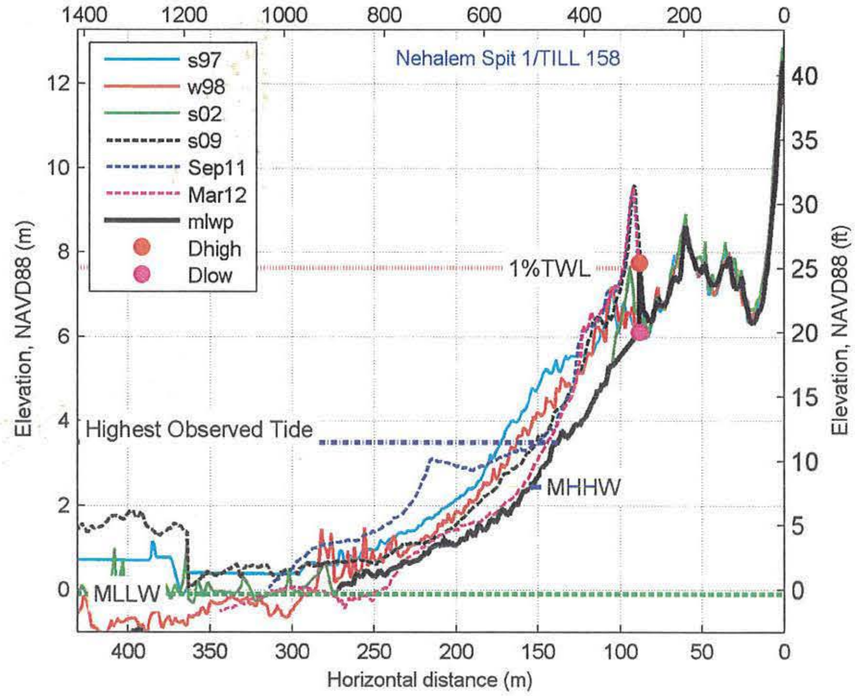


11.4.8 Nehalem Spit

fm_neh 1



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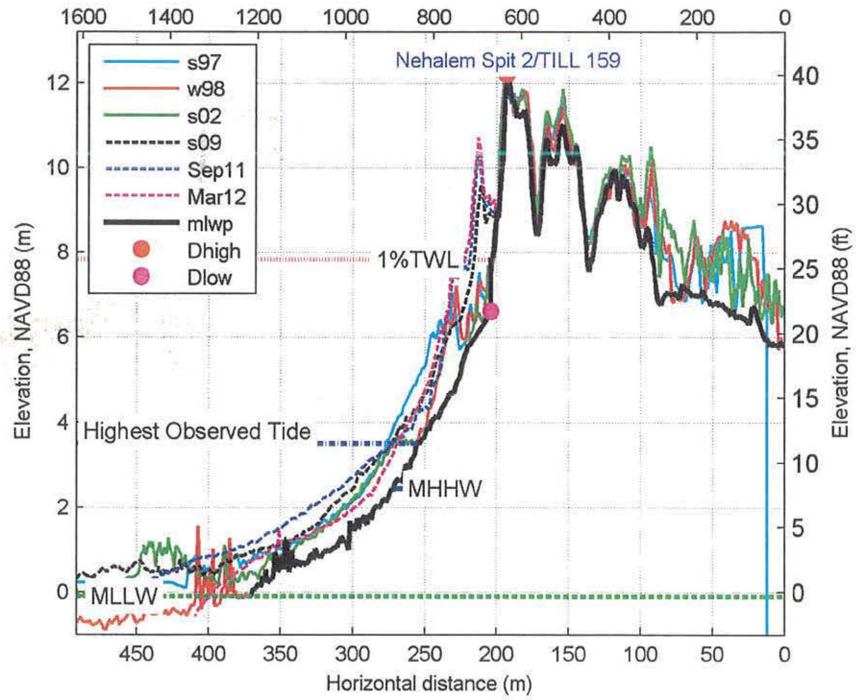

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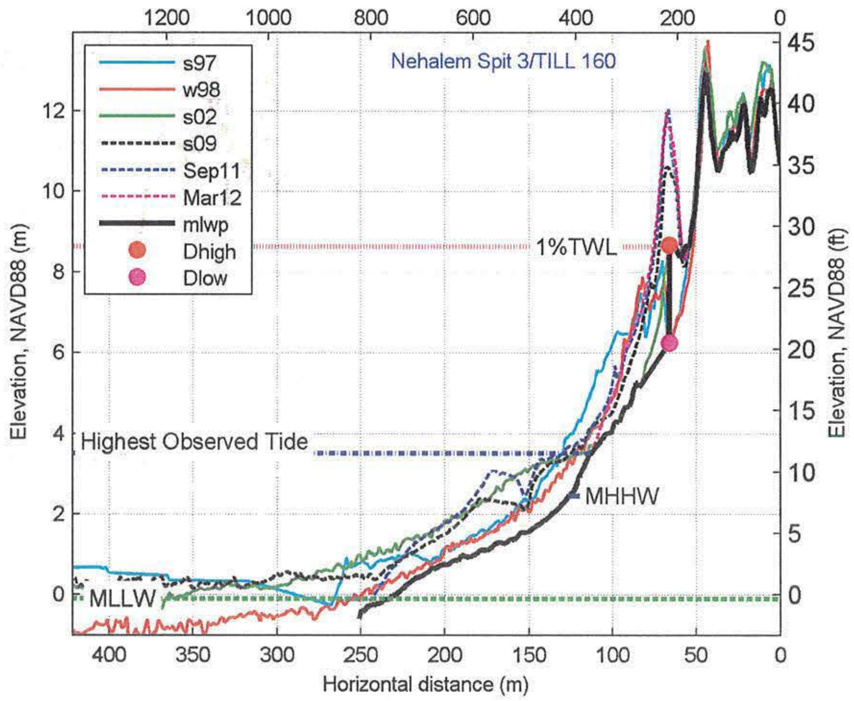

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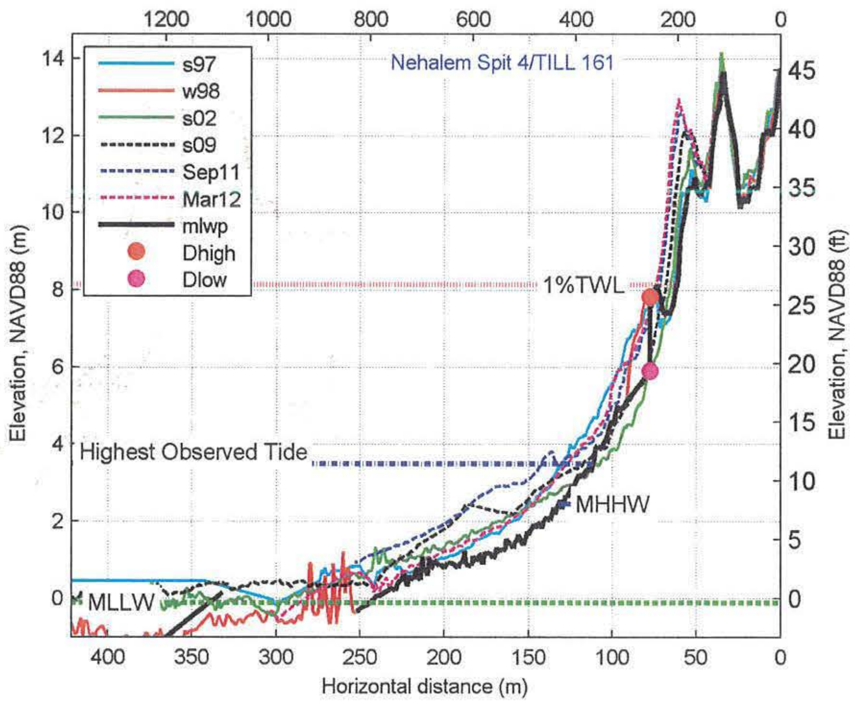

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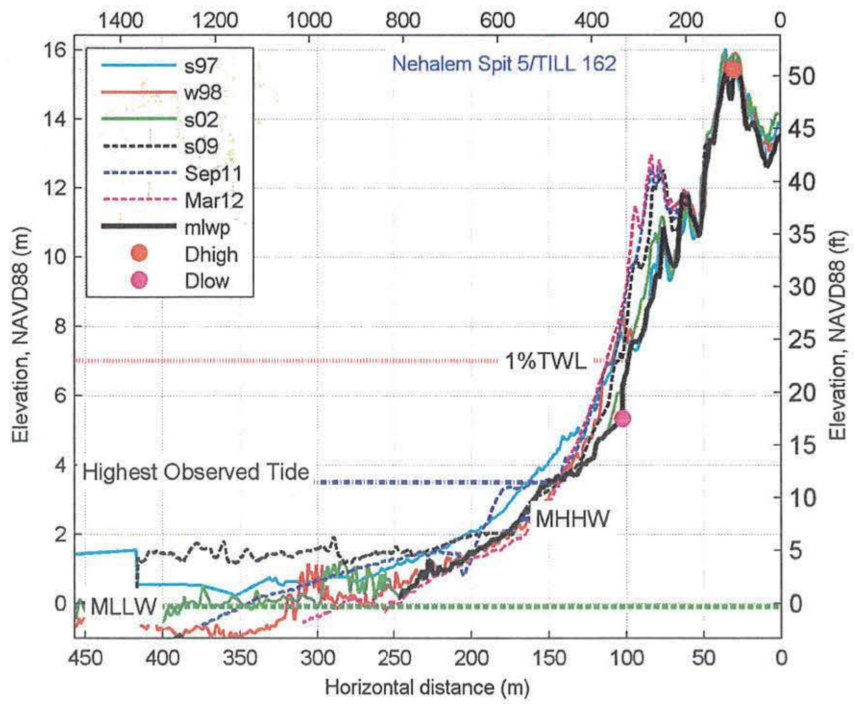

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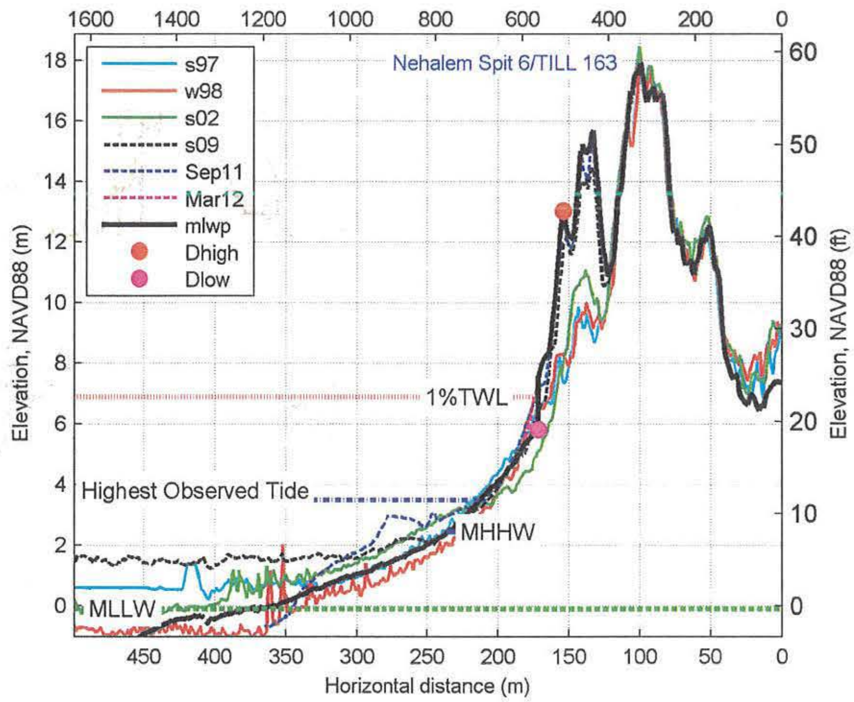
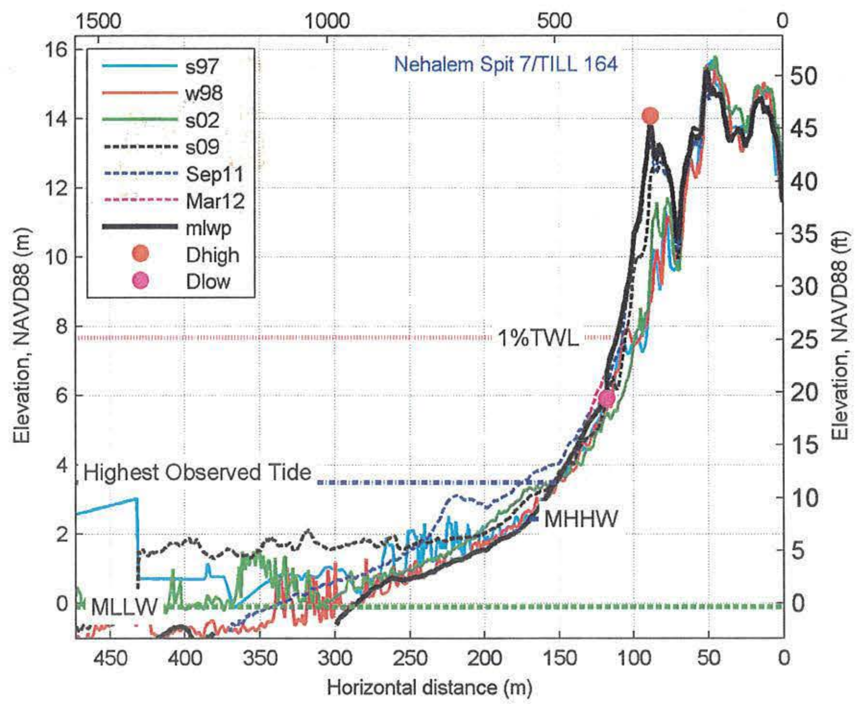


fm_neh 7



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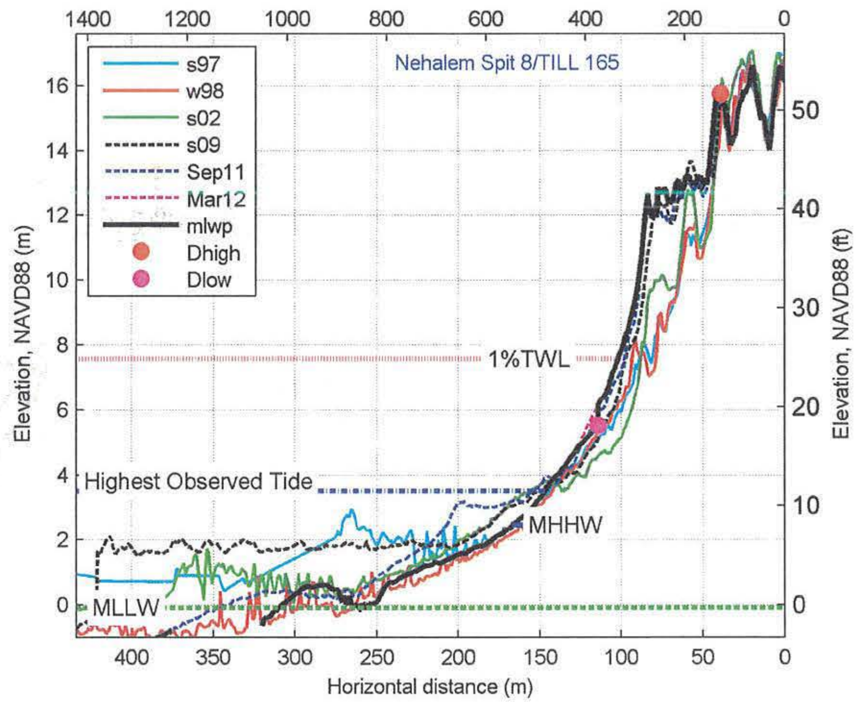
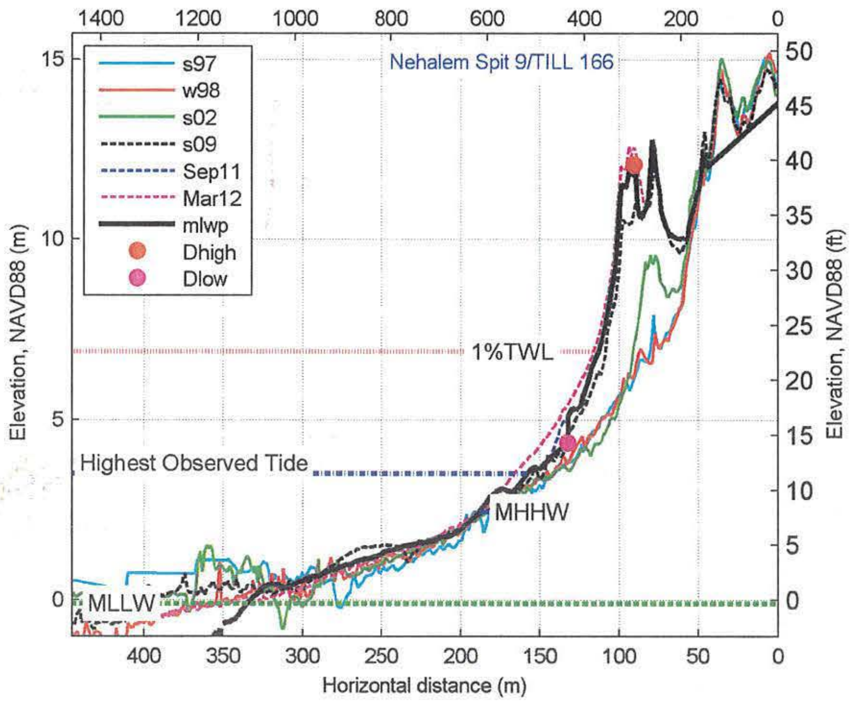


fm_neh 9



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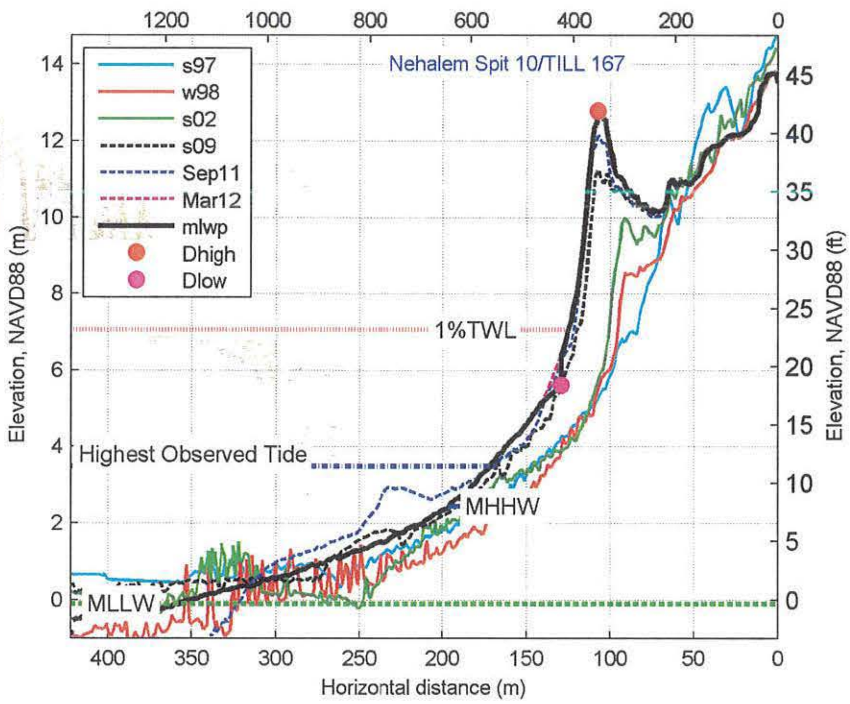

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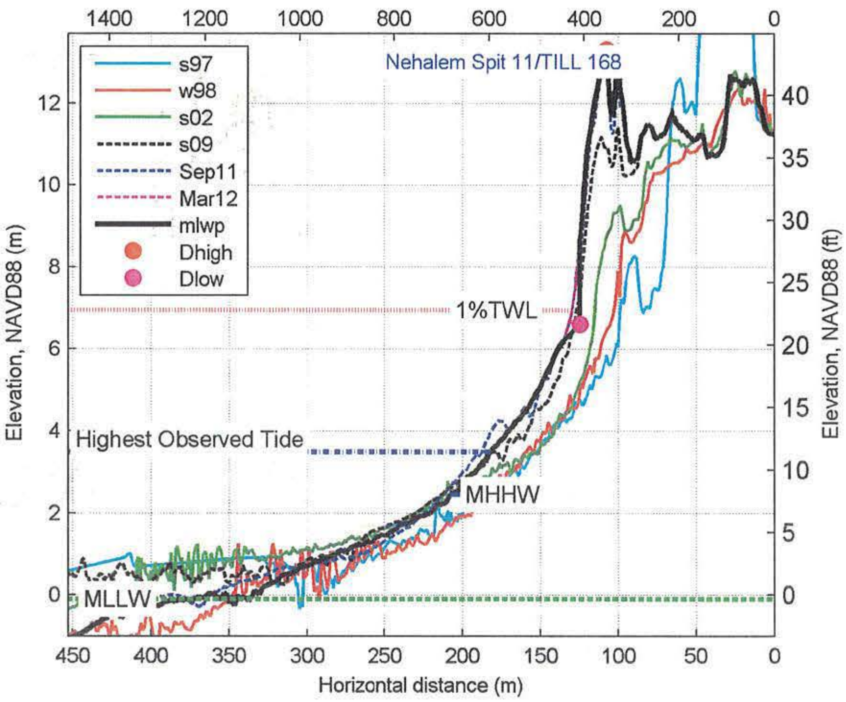

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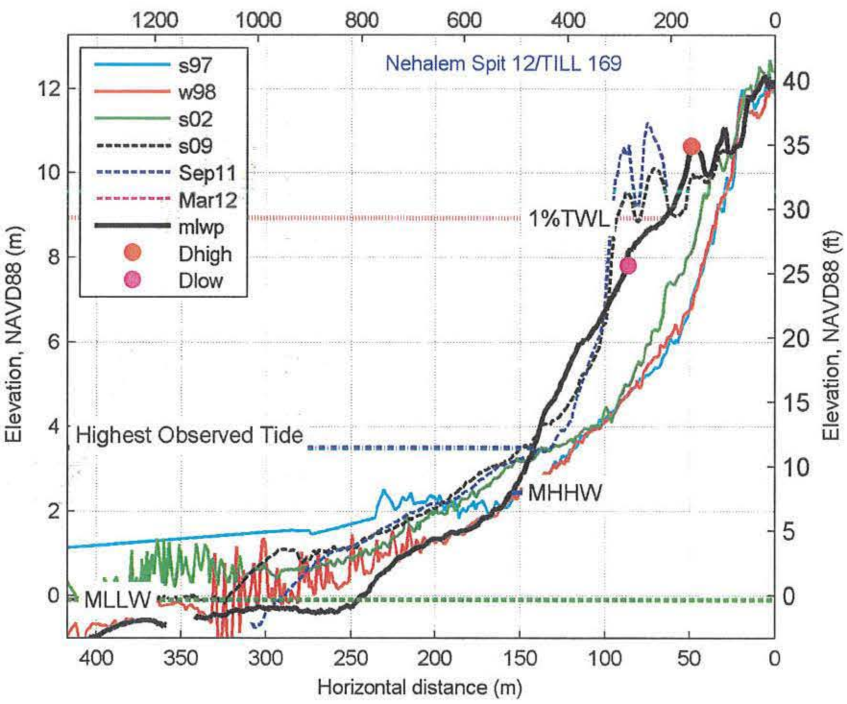

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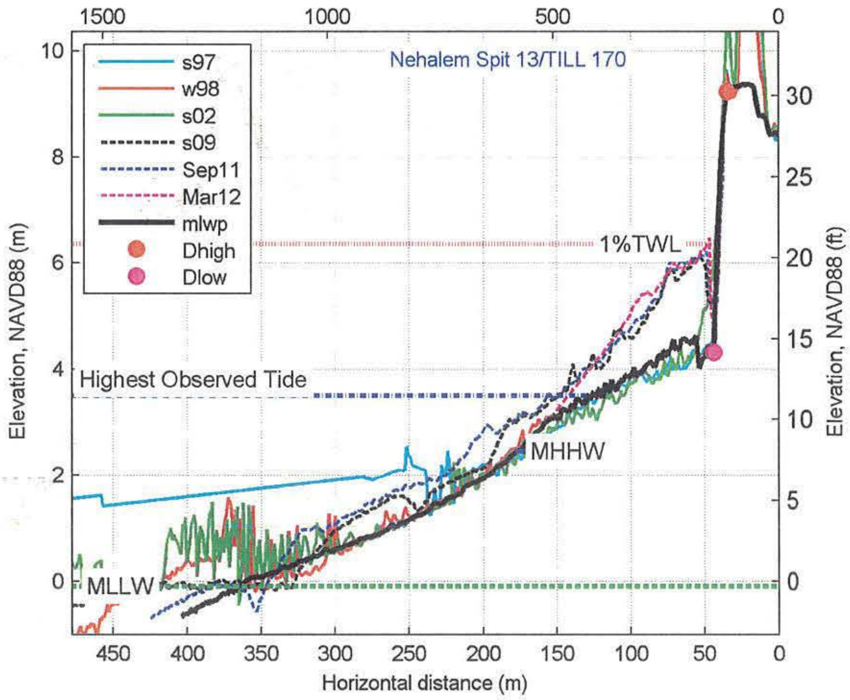

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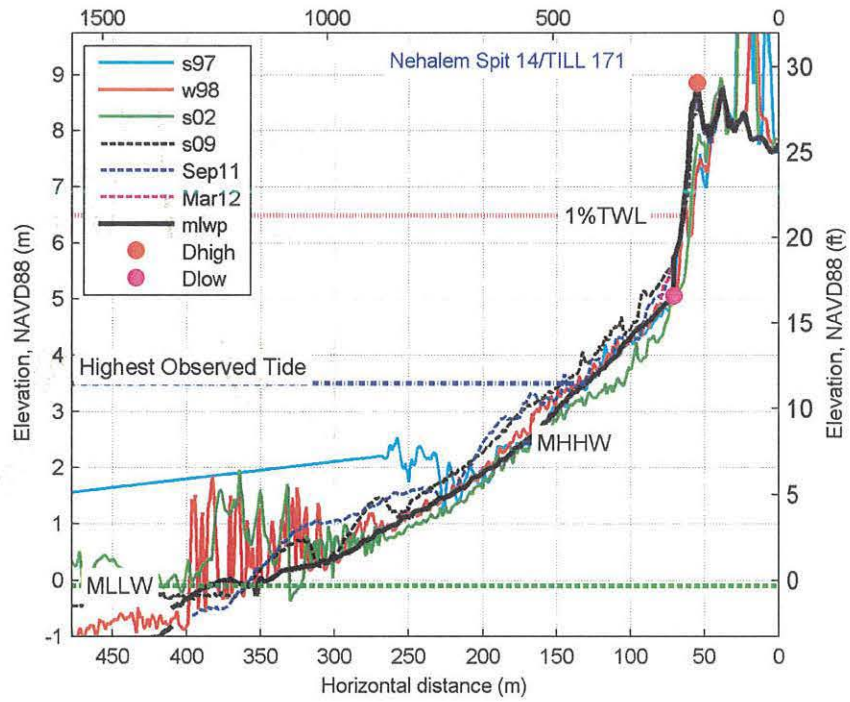

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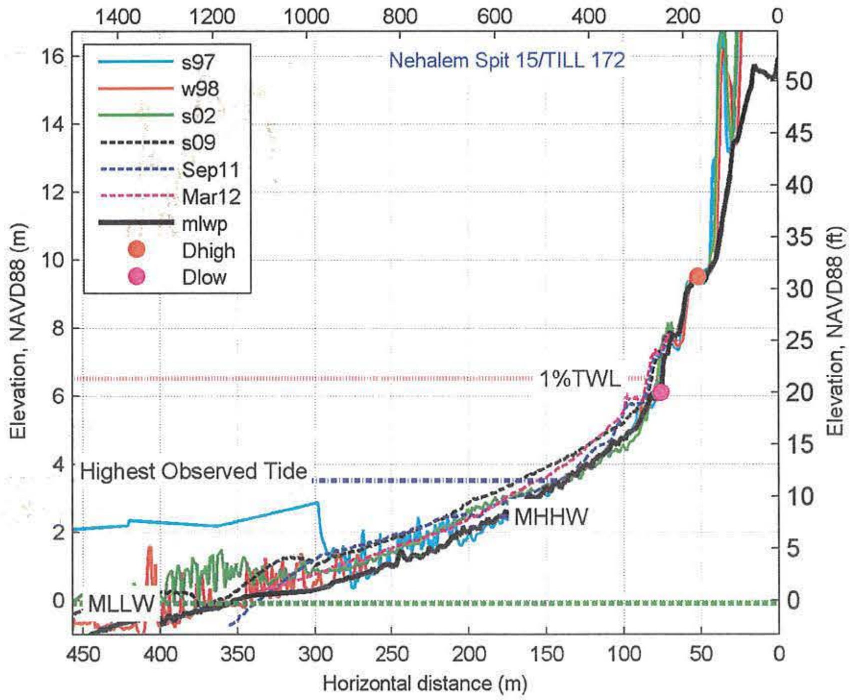

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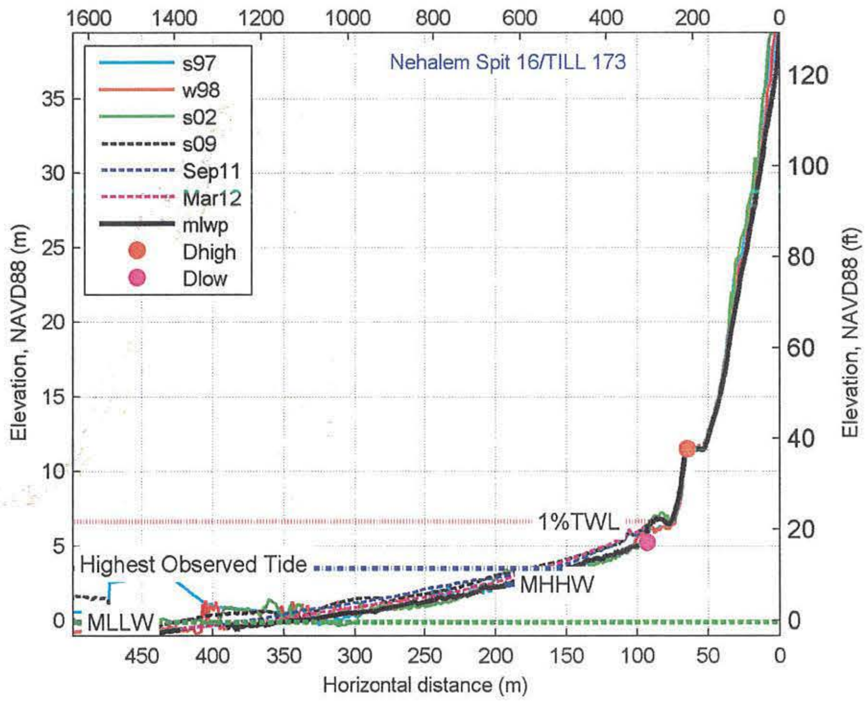

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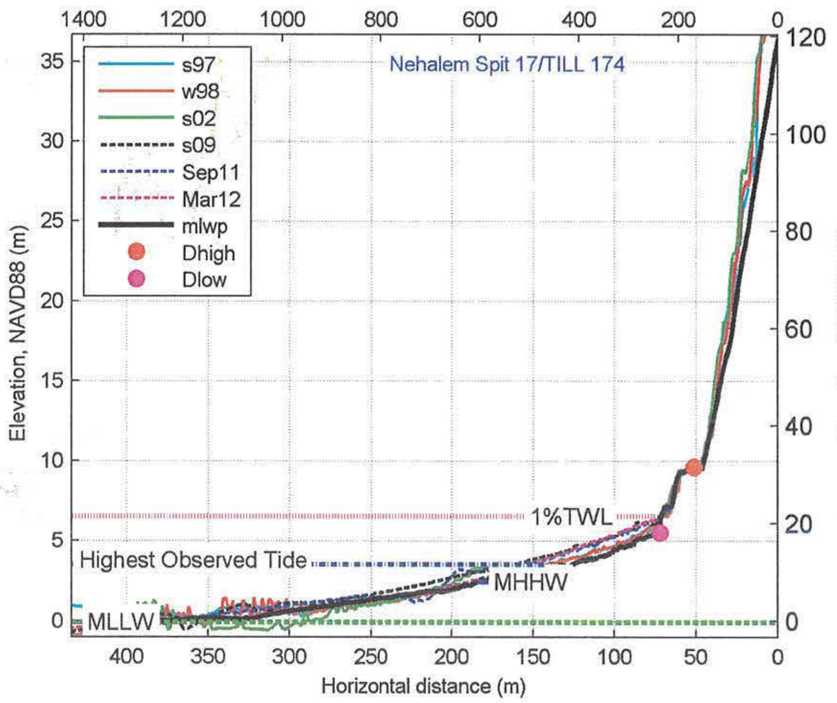

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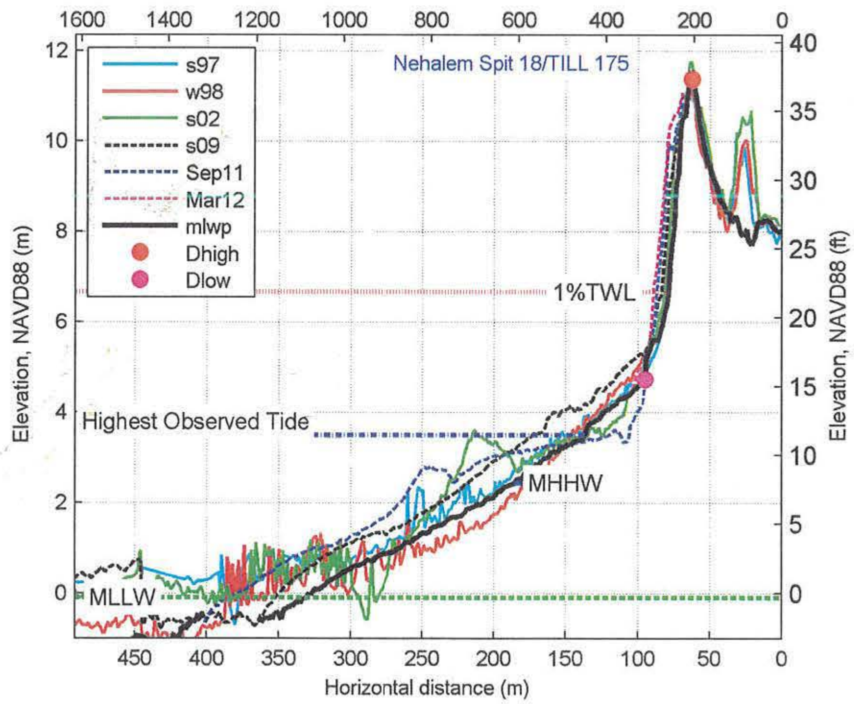

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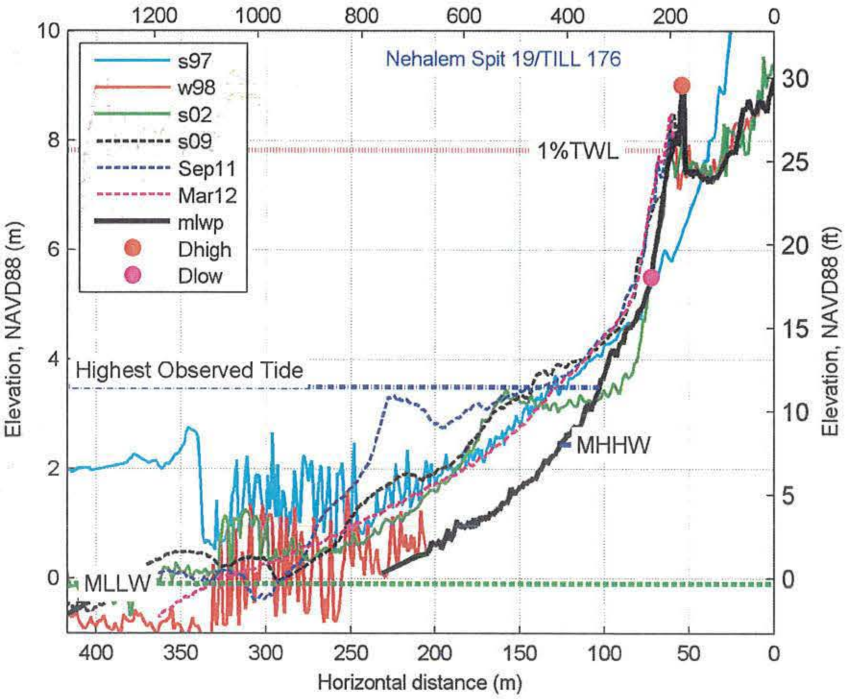

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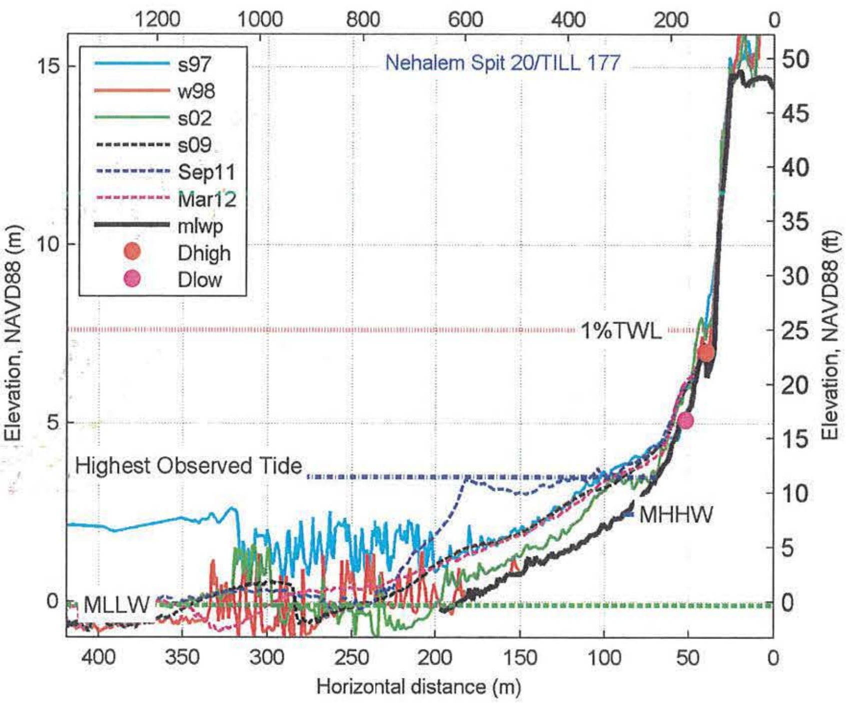
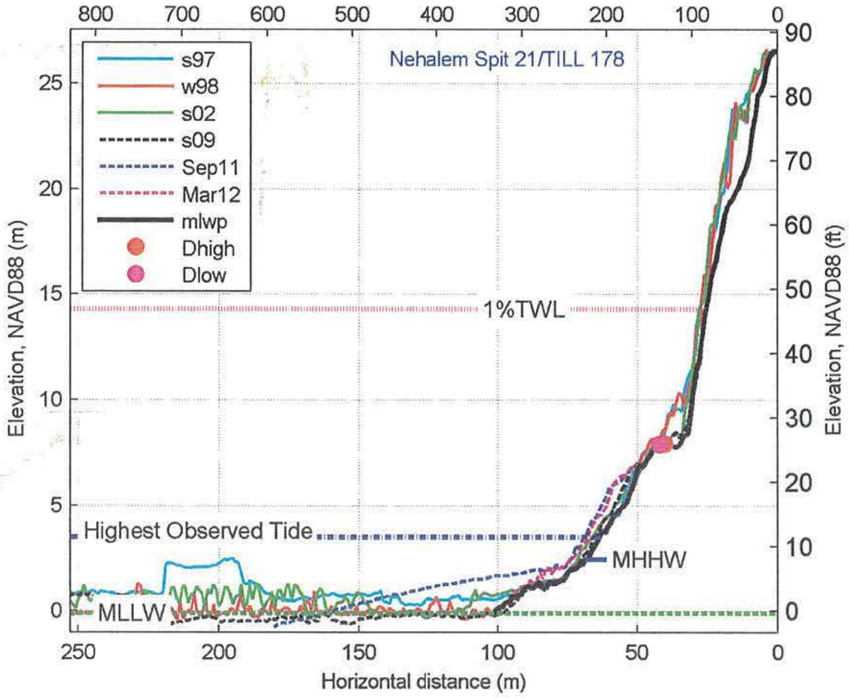


fm_neh 21


Nehalem Spit 21/TILL 178
s97
w98
s02
s09
Sep11
Mar12
mlwp
Dhigh
Dlow
1%TWL
Highest Observed Tide
MHHW
MLLW
Elevation, NAVD88 (m)
Elevation, NAVD88 (ft)
Horizontal distance (m)
800 700 600 500 400 300 200 100 0
250 200 150 100 50 0
0 5 10 15 20 25
0 10 20 30 40 50 60 70 80 90

11.5 Appendix D: Supplemental Transect Overtopping Table

Profiles	Transect	Dist_3 (≥0.91 m)	Dist_2 (>0.61 <0.91 m)	Dist_1 (≤0.31 m)	$hV2 > 5.7$ m3/s2 (m)	Comment
Neskowin	TILL 2_3524					Mapped to D_{high}
	TILL 2_3521					Mapped to splashdown distance
	TILL 2_3517					Mapped to splashdown distance
	TILL 3_3514					Mapped to D_{high}
	TILL 3_3508					Mapped to D_{high}
	TILL 3_3506					Mapped to D_{high}
	TILL 3_3504					Mapped to D_{high}
	TILL 3_3502			24.98	47.03	Mapped overtopping
Netarts	TILL 79_2035	6.08	45.44	96.74	151.89	Mapped overtopping
	TILL 79_2033					Forced transition from overtopping at TILL 79_2035 to meet the PFD
	TILL 135_857					Mapped to D_{high}
	TILL 135_856					Mapped to D_{high}
	TILL 147_783					Mapped to D_{high}
	TILL 147_778					Mapped to D_{high}

Allison Hinderer

From: Sarah Mitchell <sm@klgpc.com>
Sent: Tuesday, July 27, 2021 2:20 PM
To: Sarah Absher; Allison Hinderer
Cc: Wendie Kellington; Bill and Lynda Cogdall (jwcogdall@gmail.com); Bill and Lynda Cogdall (lcogdall@aol.com); Brett Butcher (brett@passion4people.org); Dave and Frieda Farr (dfarrwestproperties@gmail.com); David Dowling; David Hayes (tdavidh1 @comcast.net); Don and Barbara Roberts (donrobertsemail@gmail.com); Don and Barbara Roberts (robertsfm6@gmail.com); evandanno@hotmail.com; heather.vonseggern@img.education; Jeff and Terry Klein (jeffklein@wvmeat.com); Jon Creedon (jcc@pacifier.com); kemball@easystreet.net; meganberglaw@aol.com; Michael Munch (michaelmunch@comcast.net); Mike and Chris Rogers (mjr2153@aol.com); Mike Ellis (mikeellispdx@gmail.com); Rachael Holland (rachael@pacificopportunities.com); teriklein59@aol.com
Subject: EXTERNAL: RE: 851-21-000086-PLNG & 851-21-000086-PLNG-01 Pine Beach BOCC Hearing Packet - Additional Evidence (Part 4 of 6)
Attachments: Exh 2 - DOGAMI SP-47 Report_Part3.pdf

Importance: High

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Please include the attached in the record of 851-21-000086-PLNG /851-21-000086-PLNG-01 and in the Board of Commissioners' packet for the July 28, 2021 hearing. This is part 4 of 6.

From: Sarah Mitchell
Sent: Tuesday, July 27, 2021 2:19 PM
To: sabsher@co.tillamook.or.us; Allison Hinderer <ahindere@co.tillamook.or.us>
Cc: Wendie Kellington <wk@klgpc.com>; Bill and Lynda Cogdall (jwcogdall@gmail.com) <jwcogdall@gmail.com>; Bill and Lynda Cogdall (lcogdall@aol.com) <lcogdall@aol.com>; Brett Butcher (brett@passion4people.org) <brett@passion4people.org>; Dave and Frieda Farr (dfarrwestproperties@gmail.com) <dfarrwestproperties@gmail.com>; David Dowling <ddowling521@gmail.com>; David Hayes (tdavidh1@comcast.net) <tdavidh1@comcast.net>; Don and Barbara Roberts (donrobertsemail@gmail.com) <donrobertsemail@gmail.com>; Don and Barbara Roberts (robertsfm6@gmail.com) <robertsfm6@gmail.com>; evandanno@hotmail.com; heather.vonseggern@img.education; Jeff and Terry Klein (jeffklein@wvmeat.com) <jeffklein@wvmeat.com>; Jon Creedon (jcc@pacifier.com) <jcc@pacifier.com>; kemball@easystreet.net; meganberglaw@aol.com; Michael Munch (michaelmunch@comcast.net) <michaelmunch@comcast.net>; Mike and Chris Rogers (mjr2153@aol.com) <mjr2153@aol.com>; Mike Ellis (mikeellispdx@gmail.com) <mikeellispdx@gmail.com>; Rachael Holland (rachael@pacificopportunities.com) <rachael@pacificopportunities.com>; teriklein59@aol.com
Subject: RE: 851-21-000086-PLNG & 851-21-000086-PLNG-01 Pine Beach BOCC Hearing Packet - Additional Evidence (Part 3 of 6)

Please include the attached in the record of 851-21-000086-PLNG /851-21-000086-PLNG-01 and in the Board of Commissioners' packet for the July 28, 2021 hearing. This is part 3 of 6.

From: Sarah Mitchell
Sent: Tuesday, July 27, 2021 2:17 PM

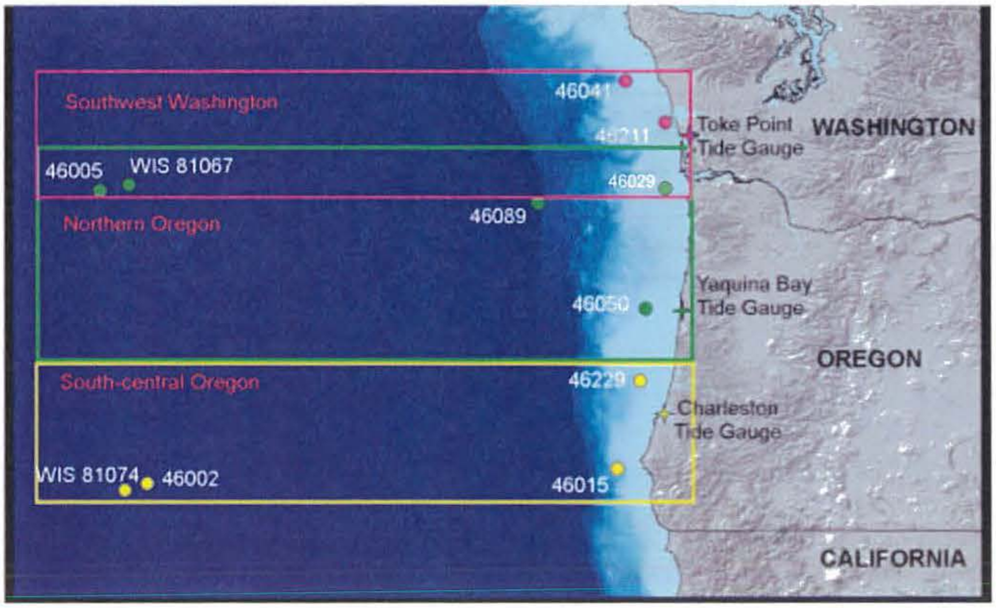


Figure 5-2. Map showing the regional divisions from which synthesized wave climates have been developed.

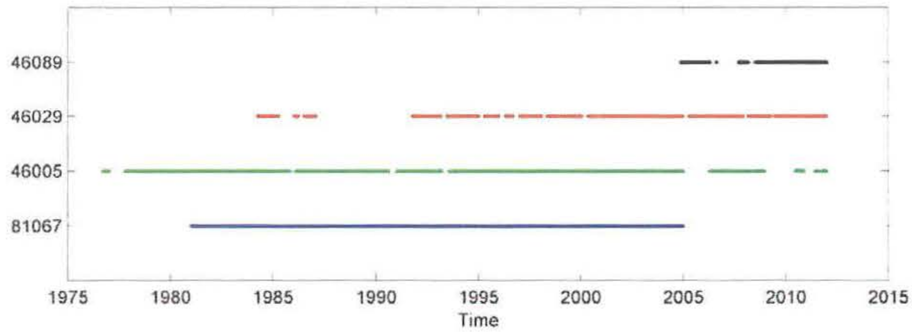


Figure 5-3. Available wave data sets timeline (after Harris, 2011).

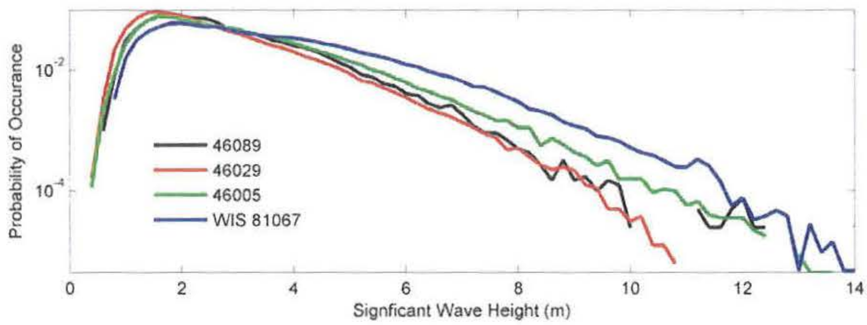


Figure 5-4. Differences in the empirical probability distribution functions of the on shore and off shore buoys.

To transform the 46005 and 46029 waves to the shelf edge, we created wave period bins (0–6, 6–8, 8–10, 10–12, 12–14, 14–16, 16–21, and 21–30 s) to evaluate if there has been a wave period dependent difference in wave heights observed at Washington 46005 and Columbia River 46029 compared with the Tillamook buoy. (Note that the NDBC wave buoys only relatively coarsely resolve long-period waves. Between 21 and 30 s only a wave period of 25 s is populated in the data set. There are no 30-s waves in the time series. Of the waves with periods between 16 s and 20 s, over 80 percent are at approximately 16 s. Only a relatively few waves in the record have recorded periods of 17, 18, and 19 s. This coarse resolution in the raw data determined our choice of period bin widths.) For our comparisons, the time stamps associated with waves measured at either 46005 or 46029 were adjusted based on the group celerity (for the appropriate wave period bin) and travel time it takes the wave energy to propagate to the wave gauge locations. For example, for waves in the period range 10–12 s the group celerity is about 8.3 m/s, and therefore it takes 13 hours for the energy to propagate from 46005 to the Tillamook buoy (**Figure 5-5**).

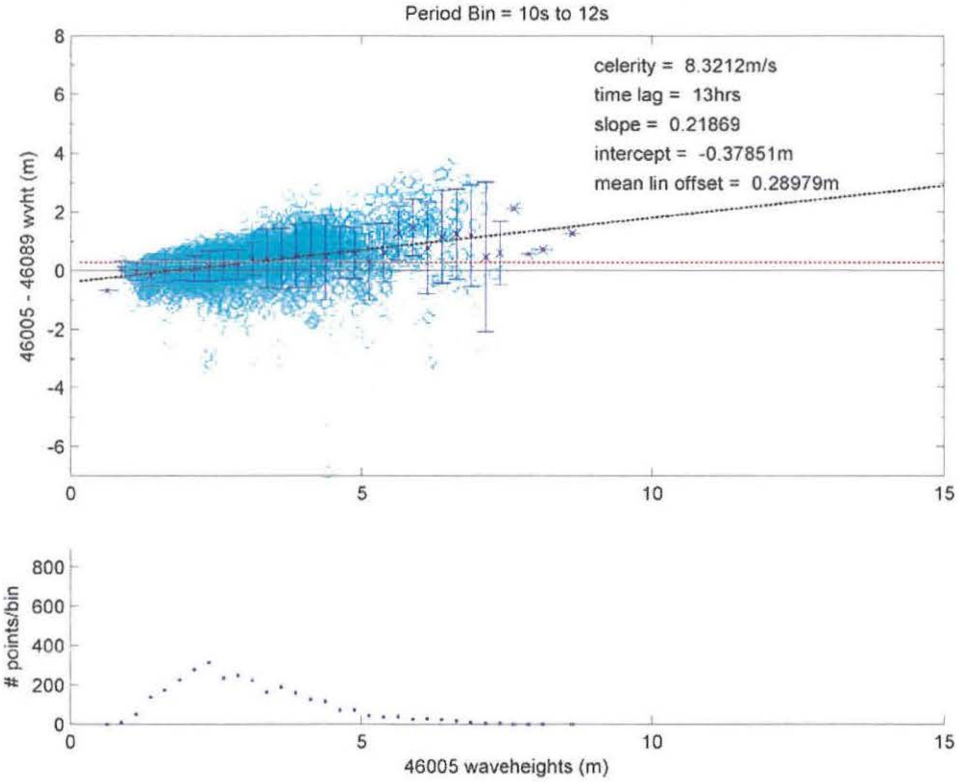


Figure 5-5. Example development of transformation parameters between the Washington buoy (#46005) and the Tillamook (#46089) buoy for period range 10 s to 12 s. In the top panel the dashed black line is the linear regression and the dashed red line is the constant offset. Blue error bars represent the standard deviation of the wave height differences in each period bin (Harris, 2011).

After correcting for the time of wave energy propagation, the differences in wave heights between the two buoys, for each wave period bin, were examined in two ways as illustrated in **Figure 5-5**:

1. A best fit linear regression through the wave height differences was computed for each wave period bin; and
2. A constant offset was computed for the wave height differences for each period bin.

Upon examination of the empirical probability density functions (PDF) of the buoys' raw time series (using only the years where overlap between the buoys being compared occurred) and after applying both transformation methods (**Figure 5-6**), it was determined that the constant offset method did a superior job of matching the PDFs, particularly for the high wave heights. Therefore, a constant offset adjustment dependent on the wave period was applied to the wave heights from the Washington 46005 and Columbia River 46029 buoys. Because the WIS hindcast data used in this study were also located well beyond the boundary of the SWAN model (basically at the location of 46005), the same series of steps comparing WIS wave heights to the Tillamook buoy was carried out, with a new set of constant offsets having been calculated and applied.

After applying the wave height offsets to the necessary buoys, gaps in the time series of Tillamook 46089 were filled in respectively with the Columbia River and Washington buoys. Where there were still gaps following this procedure, we filled in the time series with the corrected WIS data. Because wave transformations (particularly refraction) computed by SWAN are significantly dependent on wave direction, when this information was missing in the buoy records it was replaced with WIS data for the same date in the time series (but the wave height and period remained buoy observations where applicable).

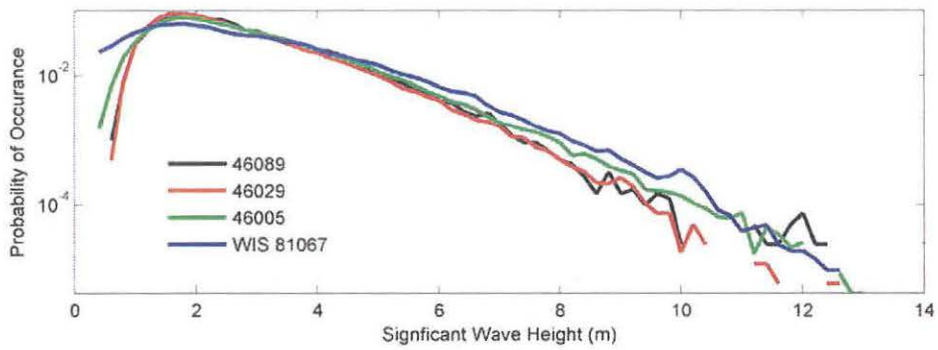


Figure 5-6. Adjusted probability density functions (corrected using the constant offset approach) for buoy 46005 (green line), buoy 46029 (red line), and WIS station 81067 (blue line) as compared to the raw probability density function for buoy 46089 (black line).

The final synthesized wave time series developed for Tillamook County extends from June 1980 through December 31, 2011, and consists of approximately ~31 years of data (measurements including at least wave height and periods) (**Figure 5-7**). Forty-two percent of the synthesized wave climate is from NDBC 46050, 36% from NDBC 4605, 15% from NDBC 46089, and ~7% from WIS station 81067. As can be seen from **Figure 5-7A**, the wave climate offshore from the northern Oregon coast is episodically characterized by large wave events (> 8 m [26 ft]), with some storms having generated deepwater extreme waves on the order of 14.5 m (48 ft). The average wave height offshore from Tillamook County is 2.6 m (8.5 ft), while the average peak spectral wave period is 10.9 s, although periods of 20–25 s are not uncommon (**Figure 5-7B**).

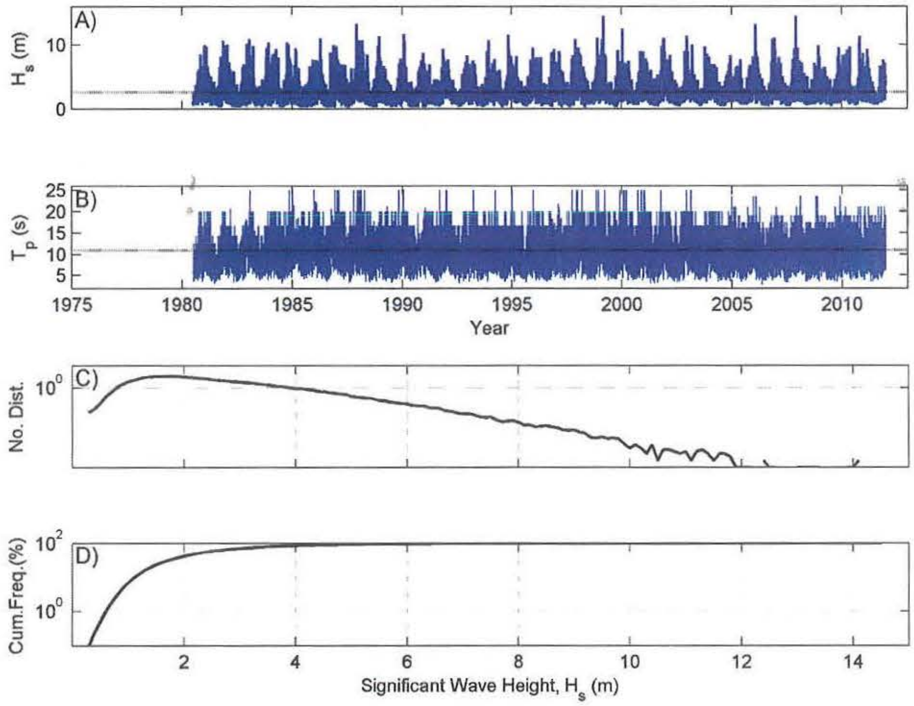


Figure 5-7. Synthesized wave climate developed for Tillamook County. A) Significant wave height with mean wave height denoted (dashed line), B) Peak spectral wave period with mean period denoted (dashed line), C) Probability distribution of wave heights plotted on a semi-log scale, and D) Significant wave height cumulative frequency curve plotted on a semi-log scale.

The PNW wave climate is characterized by a distinct seasonal cycle that can be seen in **Figure 5-8** by the variability in wave heights and peak periods between summer and winter. (The groupings evident in the peak periods (**Figure 5-7B**) are directly from the data and are a product of the data processing methods used by the NDBC to establish the wave frequencies and hence periods. It is for this reason that we chose coarse wave period bins for long-period waves [i.e., > 16 s].) Monthly mean significant wave heights are typically highest in December and January (**Figure 5-8**), although large wave events (>12 m [39.4 ft]) have occurred in all of the winter months except October. The highest significant wave height observed in the wave climate record is 14.5 m (48 ft). In general, the smallest waves occur during late spring and in summer, with wave heights typically averaging ~1.5 m during the peak of the summer (July/August). These findings are consistent with other studies that have examined the PNW wave climate (Tillotson and Komar, 1997; Allan and Komar, 2006; Ruggiero and others, 2010b). **Figure 5-7C** shows a probability density function determined for the complete time series, while **Figure 5-7D** is a cumulative frequency curve. The latter indicates that for 50% of the time waves are typically less than 2.2 m (7.2 ft), and less than 4.4 m (14.4 ft) for 90% of the time. Wave heights exceed 6.9 m (22.6 ft) for 1% of the time. However, although rare in occurrence it is these large wave events that typically produce the most significant erosion and flooding along the Oregon coast.

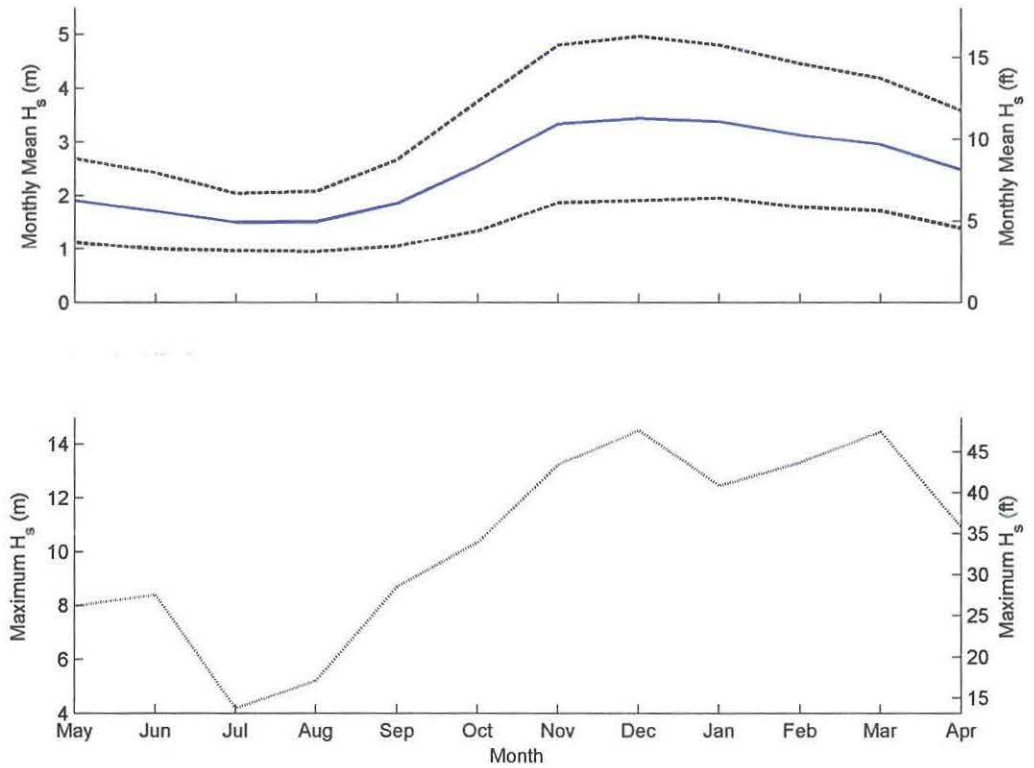


Figure 5-8. Seasonal variability in the deepwater wave climate offshore from the northern Oregon coast. (Top) The monthly average wave height (blue line) and standard deviation (dashed line); (Bottom) The maximum monthly significant wave height.

Finally, **Figure 5-9** provides a wave rose of the significant wave height versus direction developed for the northern Oregon coast. In general, the summer is characterized by waves arriving from the northwest, while winter waves typically arrive from the west or southwest (Komar, 1997). This pattern is shown in **Figure 5-9**, which is based on separate analyses of the summer and winter directional data developed from the synthesized time series. As can be seen in **Figure 5-9**, summer months are characterized by waves arriving from mainly the west-northwest (~48%) to northwesterly quadrant (~42%), with few waves out of the southwest. The bulk of these reflect waves with amplitudes that are predominantly less than 3 m (9.8 ft). In contrast, the winter months are dominated by much larger wave heights out of the west (~23%) and to a lesser extent the northwest (~5.8%), while waves from the southwest account for ~21% of the waves.

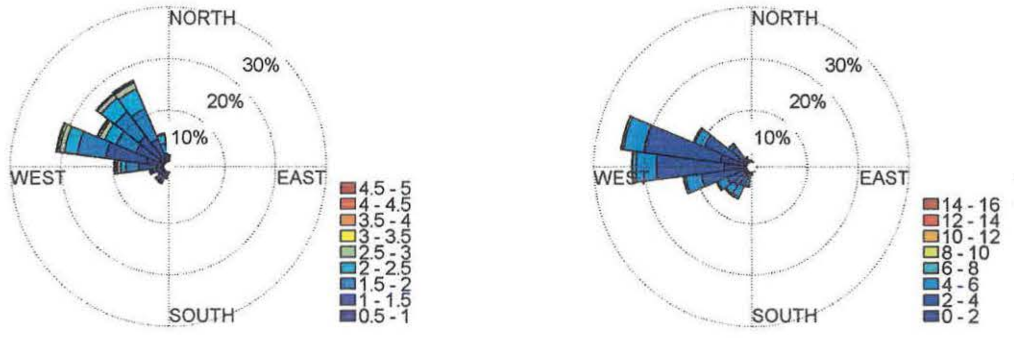


Figure 5-9. (Left) Predominant wave directions for the summer months (June-August), and (Right) winter (December-February). Colored scales indicate the significant wave height in meters.

5.2 Comparison of GROW versus Measured Waves

This section presents a more detailed analysis of GROW Fine Northeast Pacific wave hindcast data compared with measured waves obtained from selected wave buoys offshore from the Oregon coast. The objective here is to better define the degree of congruence between these two contrasting data sets in order to assess their relative strengths and weaknesses. The approach used here is similar to the tide analyses presented in Section 4, using empirical probability density functions (PDFs) to assess the shapes of the distributions. For the purposes of this analysis, PDF plots were derived for the GROW station (#18023) and for NDBC wave buoys 46089, located 66 km (41 mi) northwest of 18023 (**Figure 4-1**), and 46005 (not shown on map), located 540 km (335 mi) west of the Columbia River mouth.

The first plot (**Figure 5-10**) presents a series of significant wave height empirical PDFs for all measured data from NDBC buoys 46005 and 46089 as well as the GROW hindcast data from site 18023. Data from the stations span the following time frames: NDBC 46005 from 1976 through 2010; NDBC 46089 from 2004 through 2010; GROW 18023 from 1980 through 2009. Based on these PDFs, it is immediately apparent that the GROW data contain a larger number of smaller wave heights (in the 2-3 m range) than those measured by the buoys.

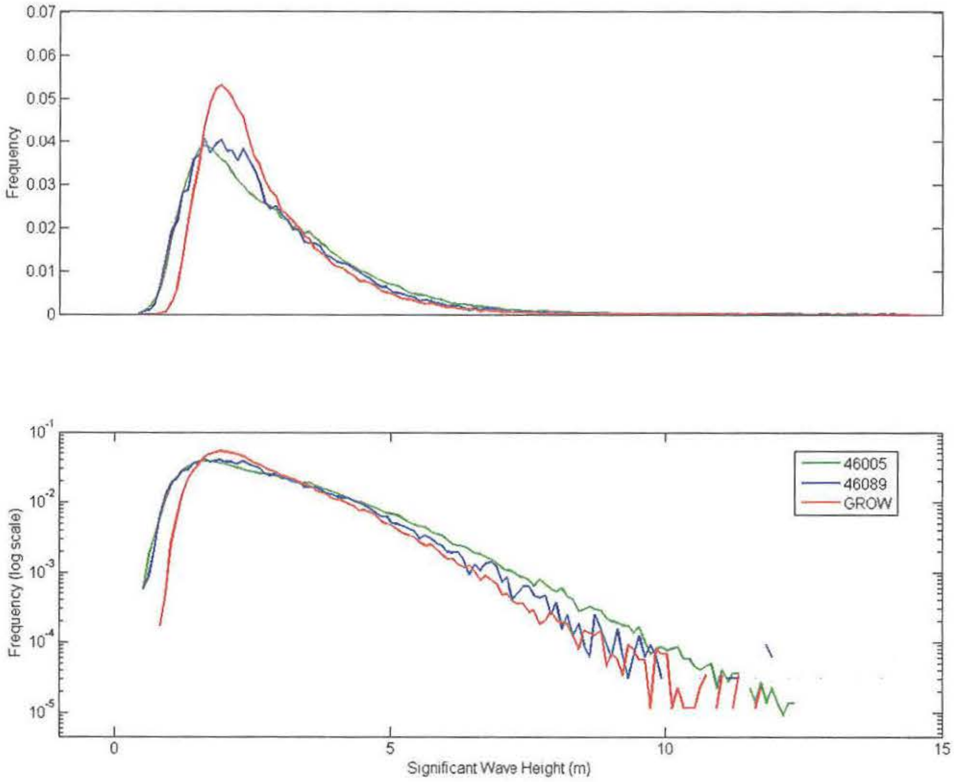


Figure 5-10. Probability density function (PDF) plots of significant wave heights plotted on a normal (top) and log (bottom) scale. Plots include all existing data from these stations.

Additionally, examination of the log-scale plot (bottom of **Figure 5-10**) indicates that the GROW hindcast at 18023 tends to underestimate the more extreme wave heights (waves >7 m), which are the most important for inundation and erosion vulnerability studies. **Table 5-1** lists general statistics of the various data sets where the maximum wave height modeled by GROW is shown to be nearly 3 m lower than that measured by the 46089 buoy. In contrast, GROW indicates on average slightly higher peak periods when compared with the NDBC stations. While differences between NDBC 46005 and NDBC 46089 may simply reflect buoy locations relative to the tracks of the storms, differences between 46089 and GROW 18023 are almost certainly entirely due to the ability of the numerical model to hindcast the waves. Because NDBC station 46089 spans a much shorter measurement period compared with 46005 and the GROW site, the results from the full PDFs may be construed to be misleading. To better assess this potential bias, we again performed analyses of the truncated time series, which revealed nearly identical results to those presented in **Figure 5-10**. Summary statistics for the truncated time series are included in **Table 5-1**. **Figure 5-11** shows a PDF of the peak periods for 46005, 46089, and GROW for the time period 2004–2009. This last plot clearly indicates that GROW is tending to overestimate the higher peak periods when compared with the measured data.

Table 5-1. General statistics of the NDBC buoy and GROW data sets based on the complete time series of data and on truncated time series. Note: *H* denotes the significant wave height and *T* is the wave period.

	46005	46089	GROW
Data availability	1976–present	2004–present	1980–2009
Mean *H*	2.8 m	2.7 m	2.6 m
Max *H*	13.6 m	14.5 m	11.7 m
Min *H*	0.2 m	0.4 m	0.72 m
H standard dev.	1.4 m	1.3 m	1.1 m
Mean *T*	10.8 s	11.1 s	12.6 s
Data availability	2004–2009	2004–2009	2004–2009
Mean *H*	2.8 m	2.6 m	2.6 m
Max *H*	12.7 m	14.5 m	11.7 m
Min *H*	0.5 m	0.4 m	0.9 m
H standard dev.	1.4 m	1.3 m	1.1
Mean *T*	10.6 s	11.1 s	12.7 s

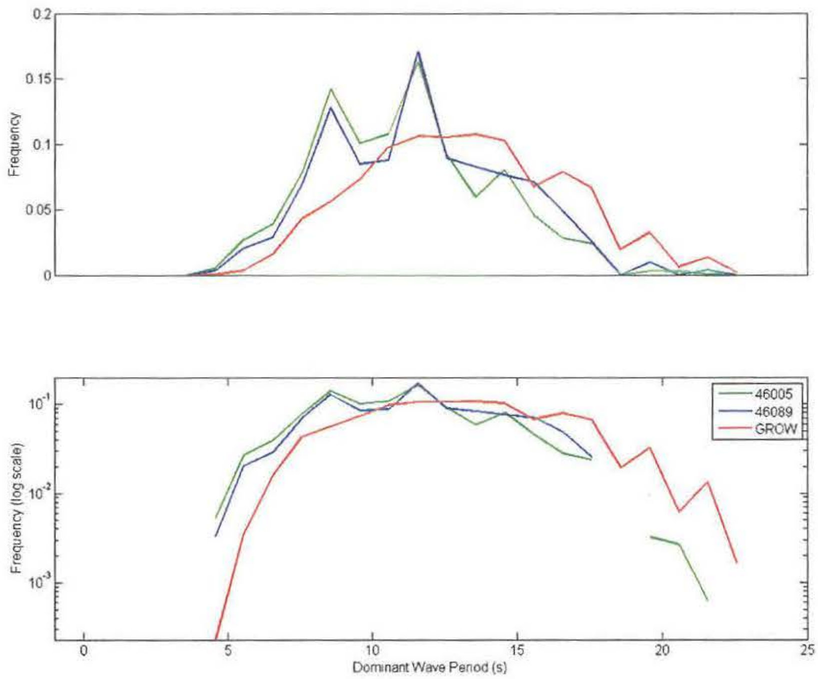


Figure 5-11. Probability density function (PDF) plots of peak wave periods from 2004 through 2009 on a normal (top) and log (bottom) plot.

After examination of PDFs of the various data sets, additional analyses were carried out for selected individual storms in order to better assess how well GROW is performing. The approach adopted was to select the five largest storms measured by the NDBC 46089. The storm events were selected by using a 3-day filter to ensure the selection of independent storm events. Once the peak of the storm was identified, the data (±2 days) were plotted with the GROW data. **Figure 5-12** presents results from two of the five selected storms. In general, our results indicate that while the timing of the events seems to be accurately determined by the GROW model, the magnitude is often lower than that measured by the wave gauges. This result may be due to the GROW approach of only estimating model results every 3 hours as opposed to NDBC's hourly buoy measurements. As a result, sampling at 3 hourly intervals has the potential to miss the peak of the storms. In fairness to GROW, the 3 hourly sampling probably reflects the fact that modeling waves on an hourly basis is dependent on having temporally and spatially suitable meteorological information, which remains a challenge for large-scale regional models.

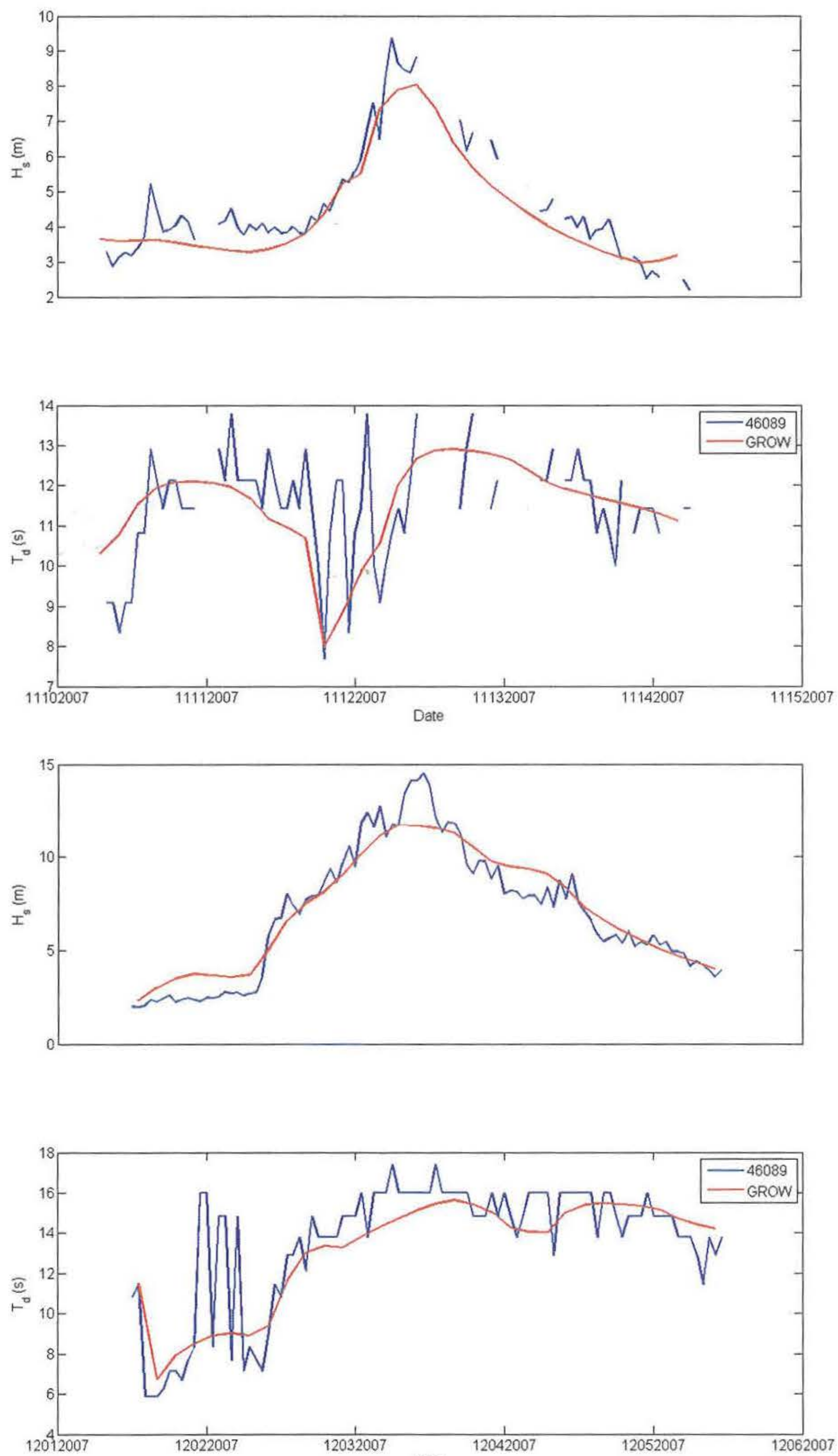


Figure 5-12. Two examples of storms where measured and modeled waves are compared. Top) Storm on November 12, 2007, and Bottom) Major storm event on December 3, 2007.

Finally, we also compared 2% exceedance extreme runup values estimated using the Stockdon and others (2006) approach and waves from the buoys and the GROW station. These results are presented in **Figure 5-13** and were calculated using a representative beach slope (tan β) of 0.04, which is typical for Oregon beaches. Only data from 2004 through 2009 were included in these calculations to provide a standard time frame for the comparison. Results indicate that, just as with the significant wave height PDFs, the extreme runup levels (>2.5 m [8.2 ft]) are underestimated by the GROW model, while the highest calculated runup differs by about 0.4 m (1.3 ft). Although the difference in the calculated runup between GROW and our measured time series is not as large as expected, the shape of the PDF plot would potentially reduce the number of storms available for defining the 100-year wave runup and total water level, as well as in overtopping, inundation, and erosion analyses as required for FEMA detailed coastal studies. From these findings we have concluded that all subsequent modeling of waves should be based, as much as possible, on the measured wave time series as opposed to using GROW hindcast data.

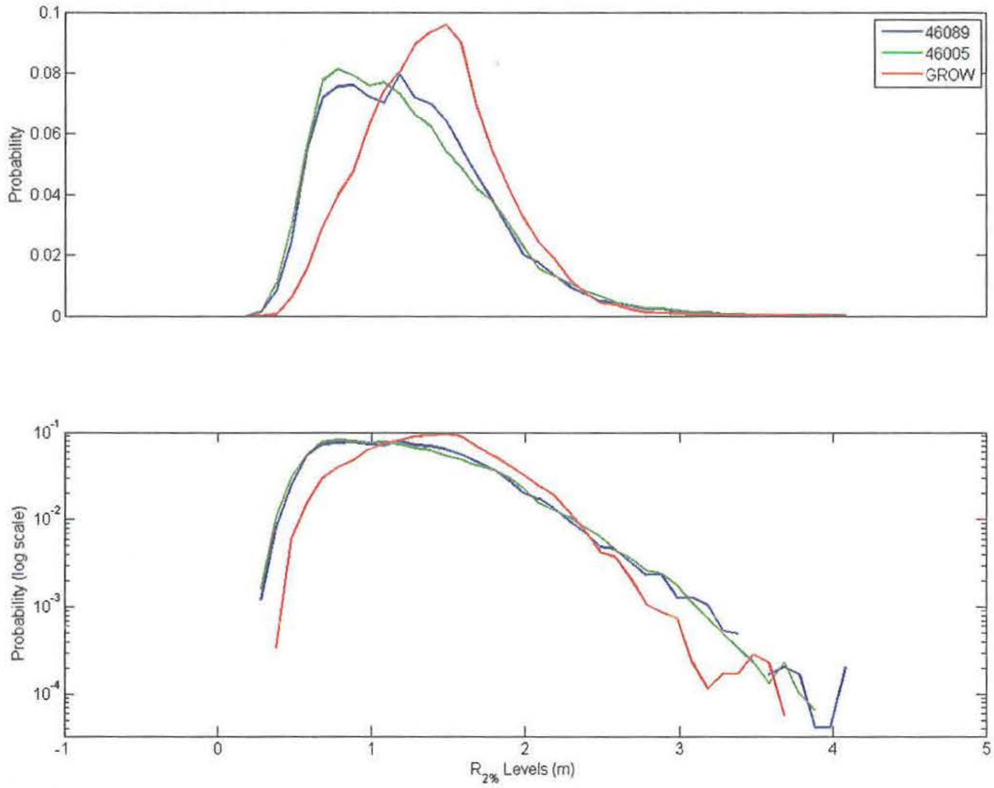


Figure 5-13. Probability density function (PDF) plots of 2 percent extreme runup elevations ($R_{2\%}$) for NDBC 46005, 46089, and GROW hindcast results. An average beach slope of 0.04 was used for runup calculations. The bottom plot is the same as the top, but with the y-axis having been plotted using with a logarithmic scale in order to emphasize the higher wave runup characteristics.

5.3 SWAN Model Development and Parameter Settings

We used the historical bathymetry assembled by the National Geological Data Center (NGDC) (described in Section 3.4) and created a model grid that covers a large portion of the northern Oregon coast (**Figure 5-1**).

SWAN (Simulating WAves Nearshore) version 40.81, a third-generation wave model developed at the Technical University of Delft in the Netherlands (Booij and others, 1999; Ris and others, 1999), was used in this study. The model solves the spectral action balance equation using finite differences for a spectral or parametric input (as in our case) specified along the boundaries. For the Tillamook County study, the cross-shore and alongshore resolution of the model grid used is 100*100 m. The total grid area is 72 km by 139 km in length, which yields 716*1,390 computational nodes. The SWAN runs were executed in stationary mode and included physics that account for shoaling, refraction, and breaking, while model settings varying from the default values are discussed in more detail below.

The north, south, and west boundaries of the model were specified using grid coordinates and forced using a parameterized JONSWAP spectrum. The functions for spectral peakedness parameters γ and *nn* in the JONSWAP directional spectra are given as:

$$\gamma = \begin{cases} 3.3\ if\ Tp < 11s \\ 0.5Tp - 1.5\ if\ Tp \geq 11s \end{cases}$$

$$nn = \begin{cases} 4\ if\ Tp < 11s \\ 2.5Tp - 20\ if\ Tp \geq 11s \end{cases} \quad (5.1)$$

Thus, the directional distribution is generated by multiplying the standard JONSWAP frequency spectrum by $cos^{nn}(\theta - \theta_{peak})$ (Smith and others, 2001). Wind wave spectra are broad (low γ and *nn* values) while swell typically have narrow distributions (high γ and *nn* values). The values used in the SWAN wave modeling were based on the input peak periods which ranged $4.055 \leq \gamma \leq 11.03$ and $7.775 \leq nn \leq 42.65$. To ensure that the wave directional spread is sufficiently resolved by the model, we specified directional bins giving a 4-degree directional resolution. The spectrum was discretized in frequency space with 29 bins from 0.032 to 1 Hz. Wind was not included in the SWAN simulations and therefore no energy growth due to wind or quadruplet wave-wave interactions occur in the simulations. Triad interactions, diffraction, and wave setup also were not activated in the model. We used the Janssen frictional dissipation option, which has a default friction coefficient of 0.067 m^2/s^3. No model calibration was performed in this study, although several numerical experiments were implemented to test various assumptions in the wave modeling (e.g., not to use winds).

5.3.1 Wind effects

The decision not to model the effect of winds on wave growth over the continental shelf in our original Coos County study (Allan and others, 2012) was based on two observations:

- To develop our combined wave time series described previously, we performed a "statistical" wave transformation between buoy 46002 and the buoys at the edge of the continental shelf and found that, in general, the wave heights during storm events decreased even with hundreds of kilometers of additional fetch. Without understanding the details of this phenomenon (e.g., white capping versus wind wave growth) and with no data for calibration we felt that attempting to model wind growth would add to the uncertainty of our input wave conditions.
- We also have previous experience with SWAN wave modeling in the region (U.S. Pacific Northwest) in which sensitivity runs including wind were performed with only minor impact on results (Ruggiero and others, 2010a).

To test the validity of the assumptions made in our Coos County study, several wave modeling experiments were performed in order to specifically examine the role of additional wind wave development over the shelf. The basic question that was addressed is: How much do wind fields result in wave growth between the location of the GROW stations that were purchased (an off-shelf location roughly equivalent to the offshore extent of the Tillamook (46089) buoy shown in **Figure 4-1**) and the inner shelf. The latter was defined as the 100 m (300 ft) isobath. To address this question, hindcast waves were modeled for the months of January and February (i.e., peak of the winter season) and for two representative years (2006 and 2010). The wave modeling was accomplished by running a regional Eastern North Pacific (ENP) model and a 3 arc-min grid for the Oregon coast, with the outer boundary coinciding with the Tillamook buoy station (**Figure 5-14**). The model runs were forced by analyzed Global Forecast System winds with a temporal resolution of 6 hours and a spatial resolution of 1 arc-degree. A similar run was undertaken without winds over the same 3 arc-min grid, just propagating the boundary conditions. Hindcast wave data were obtained from selected points across the shelf at contour depths of 500, 400, 300, 200, and 100 m along a cross-shore transects from the offshore GROW station (A and B in **Figure 5-14**).

Results from the model runs (with and without winds) are presented in **Figure 5-15** and **Figure 5-16**. Modeled and measured waves for two NDBC buoys (46089 and 46029) are included for comparative purposes (**Figure 5-17** and **Figure 5-18**). In general, our experiments indicated that although the addition of wind sometimes changed the timing of the large wave events, producing at times a relatively large percentage error for part of the "wave hydrograph," the peaks of the wave events showed very little difference between cases where wind was included or excluded (**Figure 5-15** and **Figure 5-16**). Furthermore, in the majority of cases, the differences in the derived wave heights between model runs including (excluding) wind (no wind) were on the whole minor. This finding was also observed in the derived peak wave periods, which appear to be virtually identical in all the plots. Of greater concern in these model tests are the occasional large differences between the modeled runs (irrespective of whether wind/no wind is applied) and the actual measurements derived from NDBC wave buoys (**Figure 5-17** and **Figure 5-18**), as well as the GROW data derived for station 18023. These latter findings will be explored in more detail later in this section.

These experiments support our decision to not include wind growth in our model runs, and therefore quadruplet wave-wave interactions were also not incorporated in the simulations. Further, wave setup is not included in the simulations because we extract the transformed wave parameters at the 20-m depth contour and use the Stockdon and others (2006) empirical model to compute wave runup (which incorporates setup) along the coast.

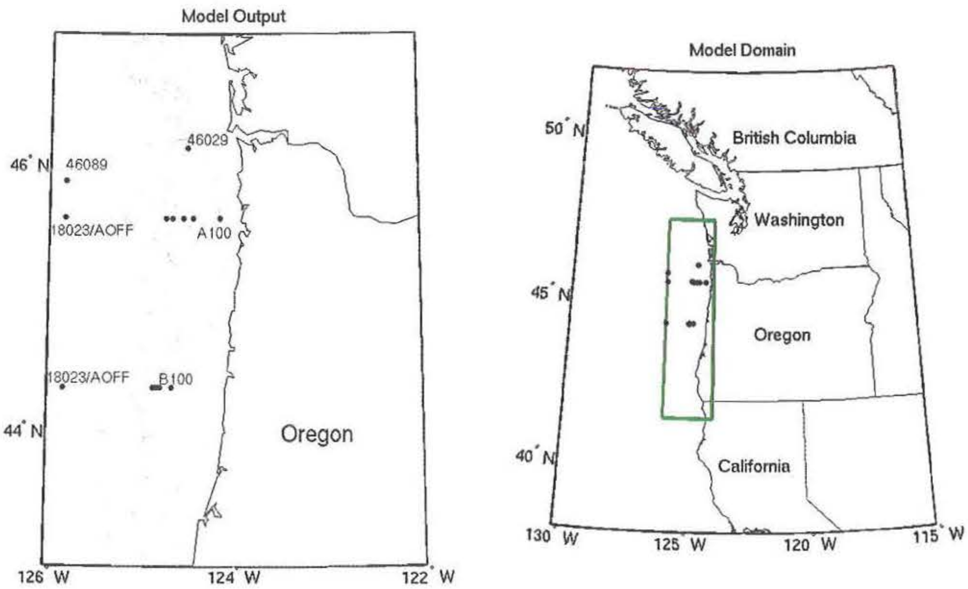


Figure 5-14. Left) Map showing the locations of the northern Oregon coast buoys, and transect lines (A and B), and Right) model domain.

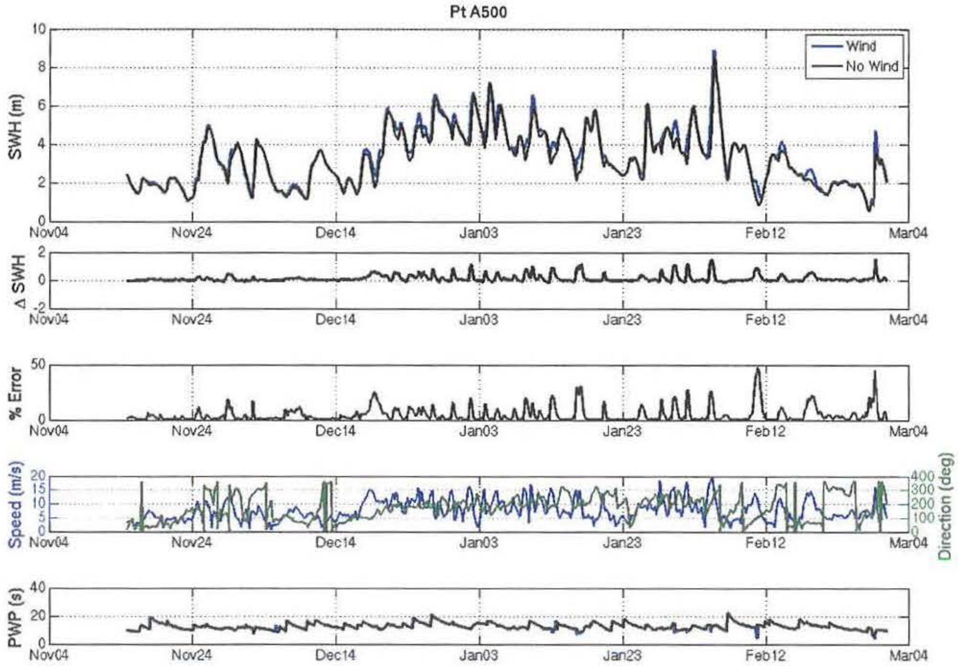


Figure 5-15. Model-model comparison at 500-m depth on transect A for the 2006 simulation.

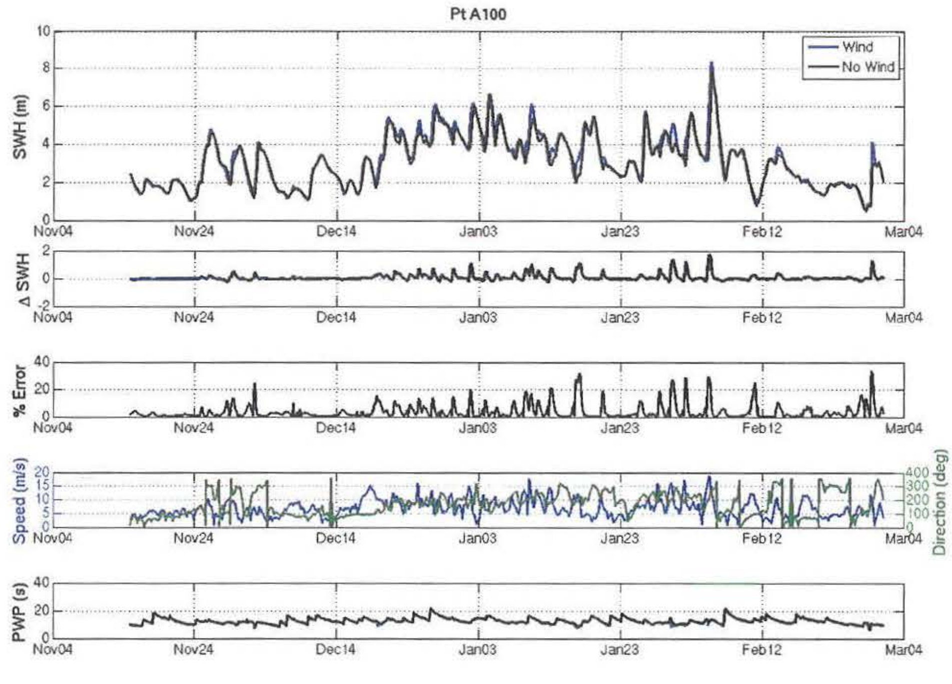


Figure 5-16. Model-model comparison at 100-m depth on transect A for the 2006 simulation.

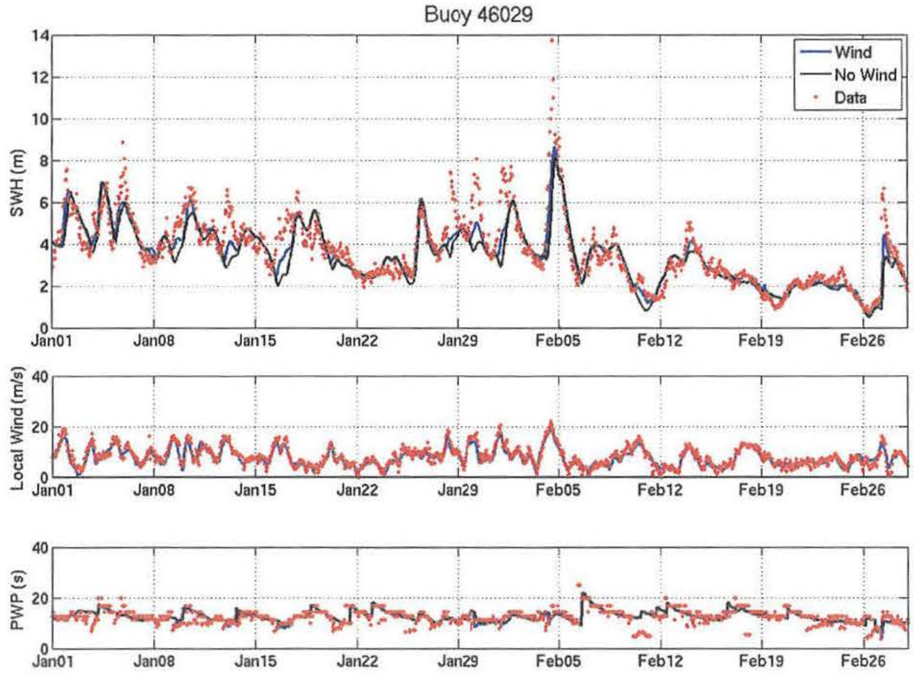


Figure 5-17. Model data comparison at NDBC buoy #46029 for the 2006 simulations.

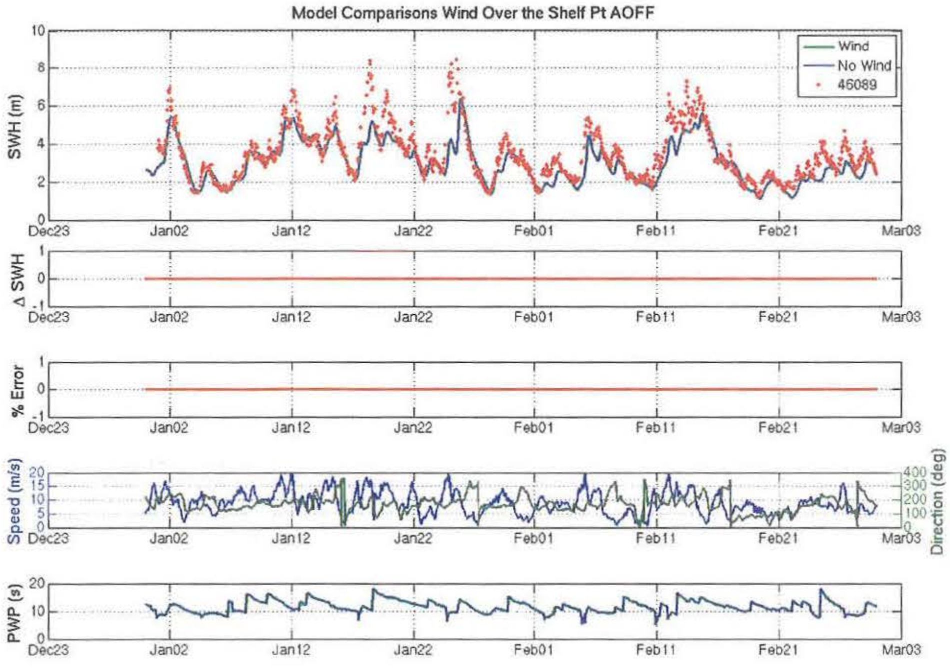
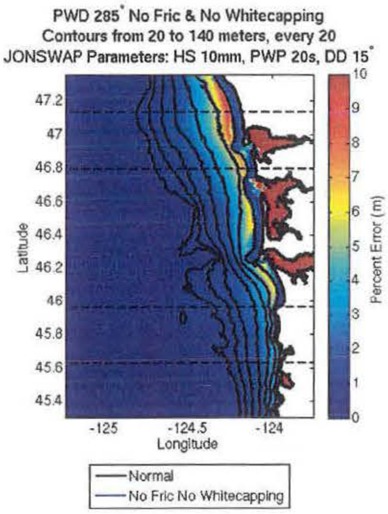


Figure 5-18. Model data comparison at Station Aoff (GROW station location) versus NDBC buoy #46089 for the 2010 simulations.

5.3.2 Frictional and Whitecapping Dissipation of the Wave Energies

Additional testing was undertaken to explore the effect of not including friction and whitecapping. **Figure 5-19** and **Figure 5-20** provide two test case conditions associated with a significant wave height of 10 m and peak period of 20 s, with the waves approaching from a direction of 285 degrees (NW), while the second case is for a significant wave height of 14 m, peak period of 14 s, with the waves approaching from a direction of 270 degrees (W). **Figure 5-19** indicates that for this particular condition, the modeled results are relatively similar until immediately prior to wave breaking, where significant differences arise. However, as the significant wave height increases (**Figure 5-20**) the effect of excluding bottom friction and whitecapping becomes considerably larger. The exclusion of these processes results in an overestimation of wave heights prior to breaking. Therefore, we have chosen to include frictional dissipation and dissipation due to whitecapping in our modeling.



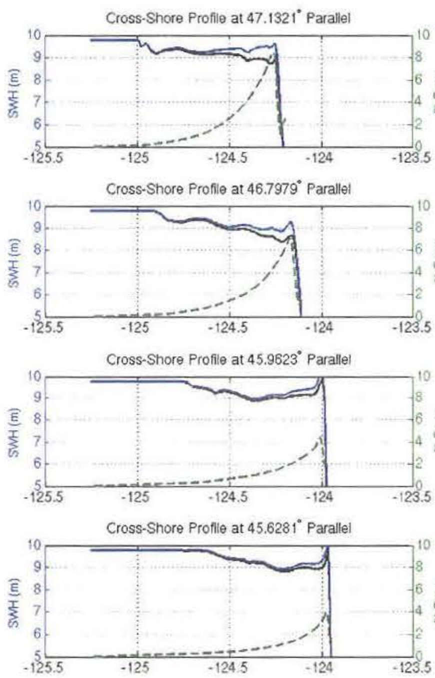


Figure 5-19. The impact of ignoring bottom frictional dissipation and dissipation due to whitecapping for a 10-m significant wave height with a peak period of 20 s approaching from a direction of 285 degrees.

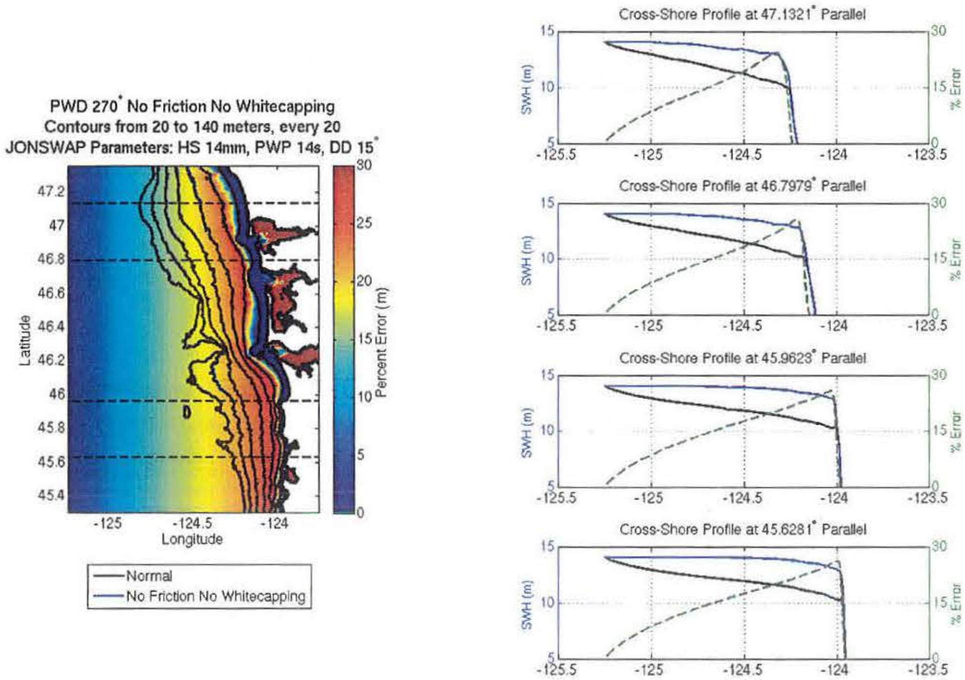


Figure 5-20. The impact of ignoring bottom frictional dissipation and dissipation due to whitecapping for a 14-m significant wave height with a peak period of 14 s approaching from a direction of 270 degrees.

5.3.3 Lookup table development

Having demonstrated that winds have little impact in terms of additional wave development across the continental shelf of Oregon, our next goal was to develop an efficient methodology that could be used to minimize the total number of SWAN runs needed to perform the actual wave modeling and transformations, while ensuring that we resolve the influence of varying parameters on the wave transformations. To do this, we discretized the significant wave height (H_s), peak period (T_p), wave direction (D_p), and water level (WL) time series.

For the direction bins (D_p), the bin widths were made approximately proportional to the probability distribution function of the GROW time series (and the synthesized wave climate time series). In application of this approach in our Clatsop County study, 11 directional bins were created that have approximately an equal probability of occurrence (**Figure 5-21**). As defined, the bin edges are: D_p = [170, 225, 240, 251, 260, 268, 277, 288, 304, 331, 370] and were subsequently refined in SWAN to D_p = [170, 225, 240, 250, 260, 270, 280, 290, 305, 330, 370], resulting in 11 direction cases for our SWAN runs. At the bin edges, linear interpolation is used to derive the wave parameters. Using initial sensitivity runs undertaken as part of our Clatsop County study, we have determined that these bin widths are more than adequate. **Figure 5-22** shows the result of interpolating over a 20-degree bin spacing.

For the purposes of the Tillamook County work, we further refined our original approach to include an additional two directional bins. This was accomplished by refining the spread of the bins to better reflect the observed conditions offshore Tillamook and Lincoln Counties. The final bin edges are defined as: D_p = [175, 205, 225, 240, 250, 260, 270, 280, 290, 300, 315, 335, 365].

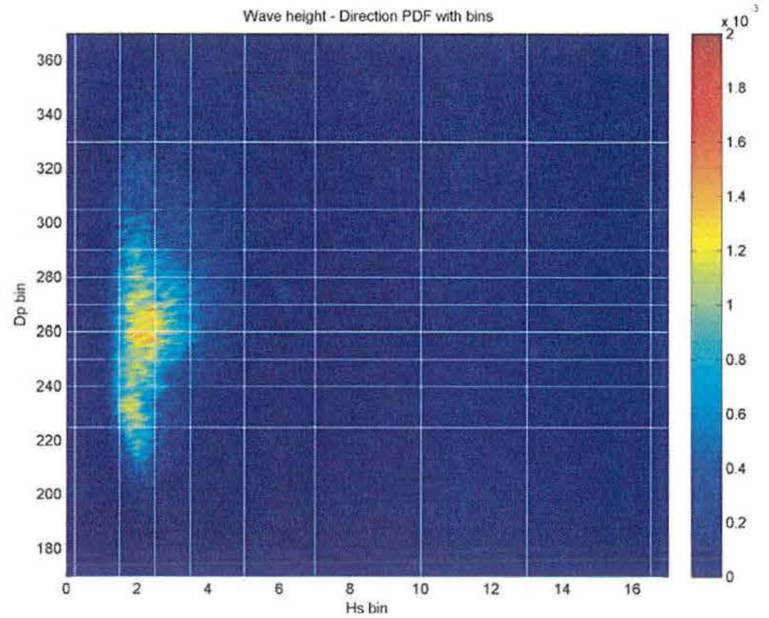


Figure 5-21. Joint probability of wave height and dominant direction derived from the GROW time series. Overlaid in white are the wave height and direction bins for use in the wave modeling on the Clatsop coast.

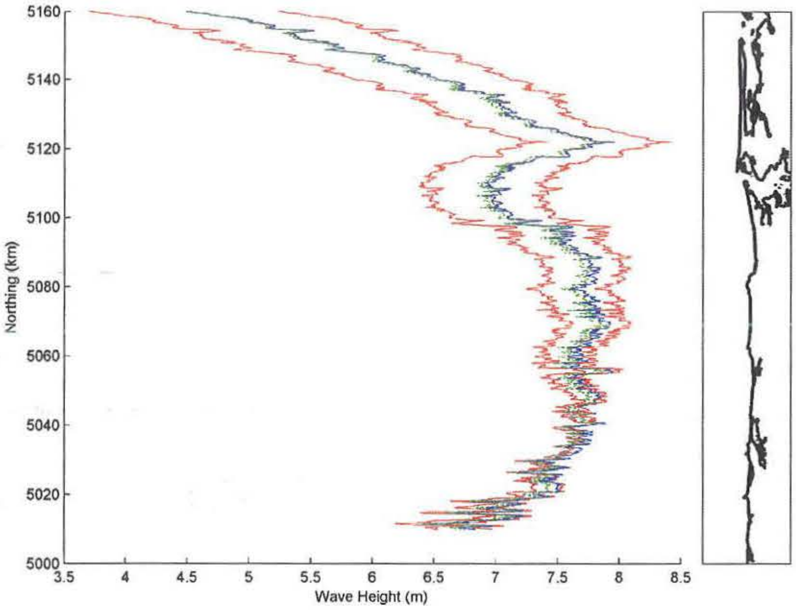


Figure 5-22. SWAN wave modeling and calculated alongshore wave variability using the look-up table approach. The left red line represents the alongshore variable wave height at the 20-m depth contour for an incident angle of 240 degrees (H_s = 10, T_p = 15 s) and the right red line is for an angle of 260 degrees. The blue line is the wave height for an angle of 250 degrees as modeled in SWAN, while the green line represents the linearly interpolated wave heights using the look-up table. Note that this is a preliminary SWAN model run, meant for testing the interpolation scheme, and the lateral boundary conditions are not dealt with in the same manner as in our production SWAN runs.

For the significant wave heights bins, we identified the following deepwater significant wave heights for inclusion in SWAN: H_s = [0.25, 1.5, 2.5, 3.5, 5, 7, 10, 13, 16.5], which gives us nine cases. From our sensitivity tests, we found that a bin width of 3 m for large waves is sufficient for resolving the linearly interpolated wave conditions (**Figure 5-23**). In the case of the deepwater peak periods, our analyses identified the following period bins for inclusion in SWAN: T_p = [2, 4, 6, 9, 11, 13, 15, 17, 20, 23, 26], which provides a total of 11 additional cases. From our sensitivity tests, we found that the linear interpolation approach for wave period is not quite as good as for direction and wave height. Because wave period affects breaking, shoaling, and whitecapping, there is significant variability in the wave transformations as a function of wave period. For our sensitivity run of H_s = 10 m, and D_p = 260 degrees, **Figure 5-24** illustrates the impact of linear interpolation. However, for the most part in our parameter space we will have interpolation errors only around 10%. In this particular example the maximum error is only approximately 4 percent.

Figure 5-25 presents the joint probability of wave height and peak period from the GROW time series. The white dots represent bin centers, from a much smaller mesh, in which this combination of H_s and T_p does not exist in the GROW time series. The red line represents the theoretical wave steepness limit below which waves are nonphysical. We can use this information to reduce the overall matrix of model runs.

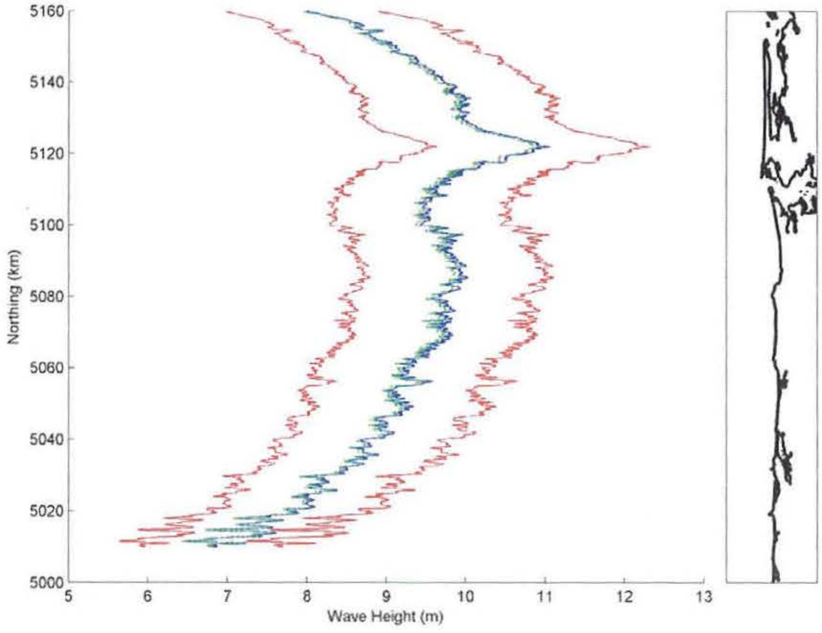


Figure 5-23. SWAN wave modeling and calculated alongshore wave variability using the look-up table approach for an 11-m and 15-m wave. In this example the red lines are the alongshore varying wave height for an 11-m and 15-m incident wave height in 20 m. The blue line is the modeled transformed 13-m wave height, while the green represents a linear interpolation between the 11- and 15-m results.

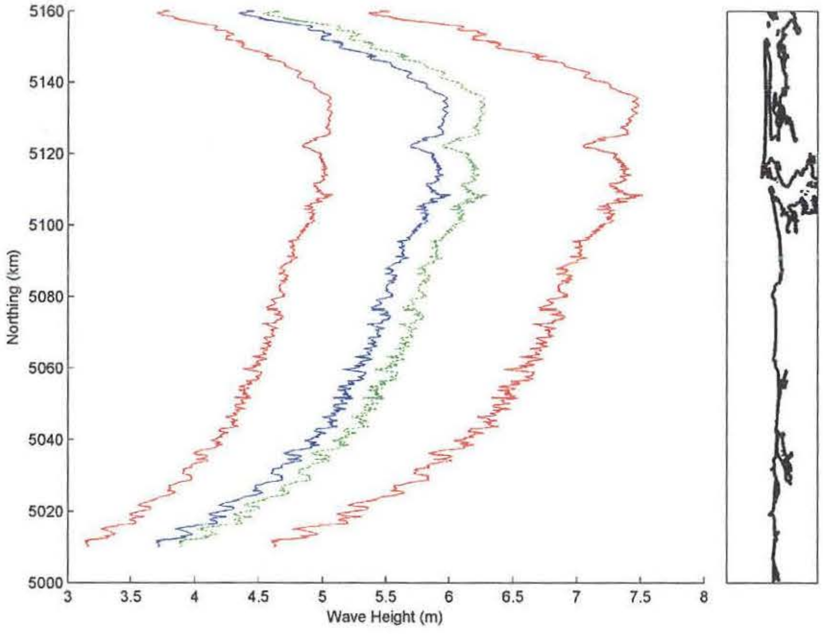


Figure 5-24. SWAN wave modeling and calculated alongshore wave variability using the look-up table approach for a 10-m wave. In this example the red lines are the alongshore varying wave height for a 10-m wave arriving from 260 degrees for 20 s and 24 s. The blue line is the modeled wave height for 22 s, and the green line represents a linear interpolation.

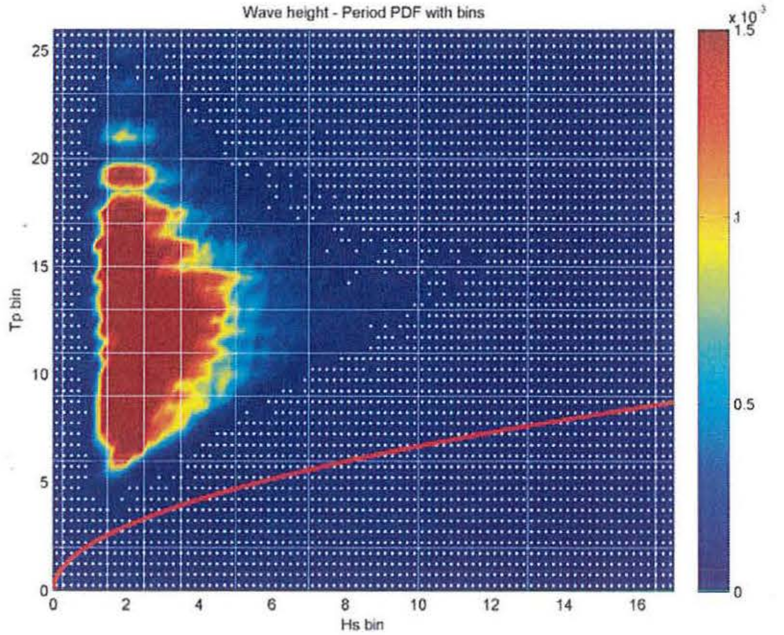


Figure 5-25. Joint probability of wave height and peak period from the GROW time series. The white dots represent bin centers, from a much smaller mesh, in which this combination of Hs and Tp does not exist in the GROW time series. The red line represents the theoretical wave steepness limit below which waves are nonphysical.

Figure 5-26 is the joint probability of peak period and dominant wave height shown here for completeness. Finally, we illustrate our bin choice on the individual parameter PDFs in Figure 5-27 (buoy data).

In summary, the lookup tables were generated using all wave parameter cases and two contrasting water levels. Our sensitivity tests indicated that varying water levels have a negligible impact on the model and linearly transformed waves. The following matrix of SWAN runs is considered for lookup table development for transforming waves offshore from Tillamook County:

D_p = [175, 205, 225, 240, 250, 260, 270, 280, 290, 300, 315, 335, 365] — 13 cases
H_s = [0.25, 1.5, 2.5, 3.5, 5, 7, 10, 13, 16.5] — 9 cases
T_p = [2, 4, 6, 9, 11, 13, 15, 17, 20, 23, 26] — 11 cases
WL = [-1.5, 4.5] — 2 cases

In total, this equates to 2,574 model cases that can be used for linearly interpolating the waves from a time series of data. However, Figure 5-25 indicates that several H_s–T_p combinations are physically not realistic. Multiplying these bins by the D_p and WL bins means that we can eliminate 390 bins for a new total of only 2,184 model runs.

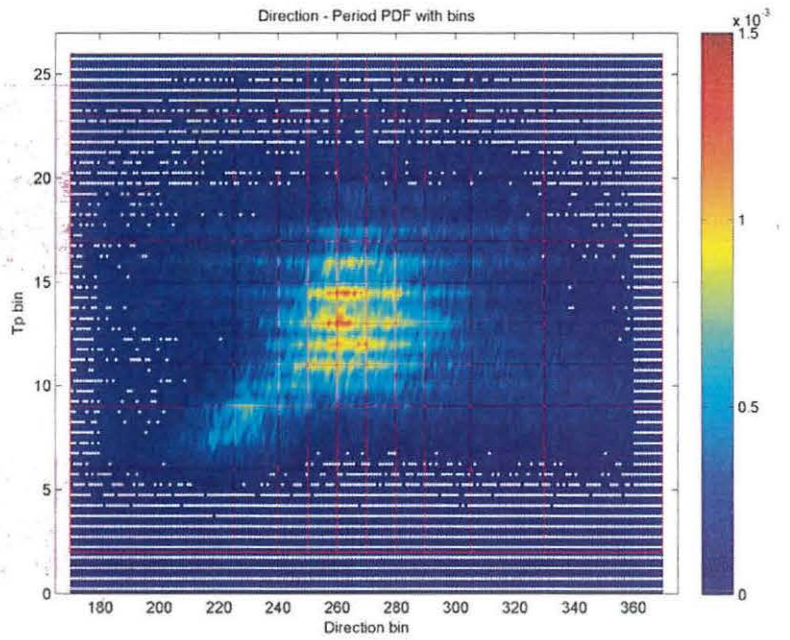


Figure 5-26. Joint probability of dominant direction and peak period from the GROW time series. The white dots represent bin centers, from a much smaller mesh, in which this combination of D_p and T_p does not exist in the GROW time series. The red lines depict the boundaries of the binning.

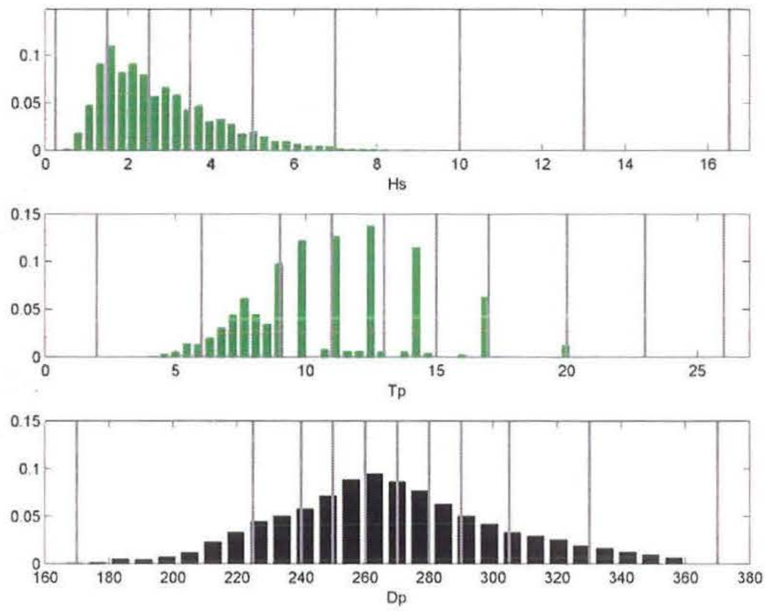


Figure 5-27. Individual parameter probability density function plots and bin edges using the combined buoy wave time series.

5.4 Summary of SWAN Results

Significant alongshore variability is apparent in many of the conditions examined with SWAN (**Figure 5-28**). Differences on the order of 3 m in significant wave height along the 20-m isobaths are not uncommon in Tillamook County. To calculate the wave runup along the County's shoreline, we subsequently extracted the wave characteristics along the 20-m contour, or the seawardmost location where the wave breaking parameter equaled 0.4, throughout the model domain (**Figure 5-28**, right panel). Because all of the parametric runup models used in this study rely on information on the deepwater equivalent wave height and peak periods as inputs, we then computed the linear wave theory shoaling coefficient and back shoaled our transformed waves to deep water. These transformed deepwater equivalent waves were then used to calculate the wave runup and generate the TWL conditions used in the subsequent extreme value analysis.

To confirm that our approach of interpolating wave transformations using lookup tables yields acceptable results, we ran several additional SWAN runs that were not part of our original matrix. These additional runs extended across a range of conditions, including extreme events capable of forcing high water levels at the coast. We then compared the results from using the lookup tables to these additional direct SWAN computations at the 20-m contour location. **Figure 5-29**, **Figure 5-30**, and **Figure 5-31** show a sample of these results for wave heights, peak periods, and directions, respectively, for a SWAN run driven with an offshore boundary condition of H_s = 11.5, T_p = 18.5, D_p = 320, and a water level of 4.5 m NAVD88. In all cases, the percentage error between the lookup table and direct computation is low, averaging well less than 5 percent. In only a few locations, near model boundaries or inlets, are the errors significant. None of the transects analyzed in detail for extreme flooding later in this report are near those problem locations.

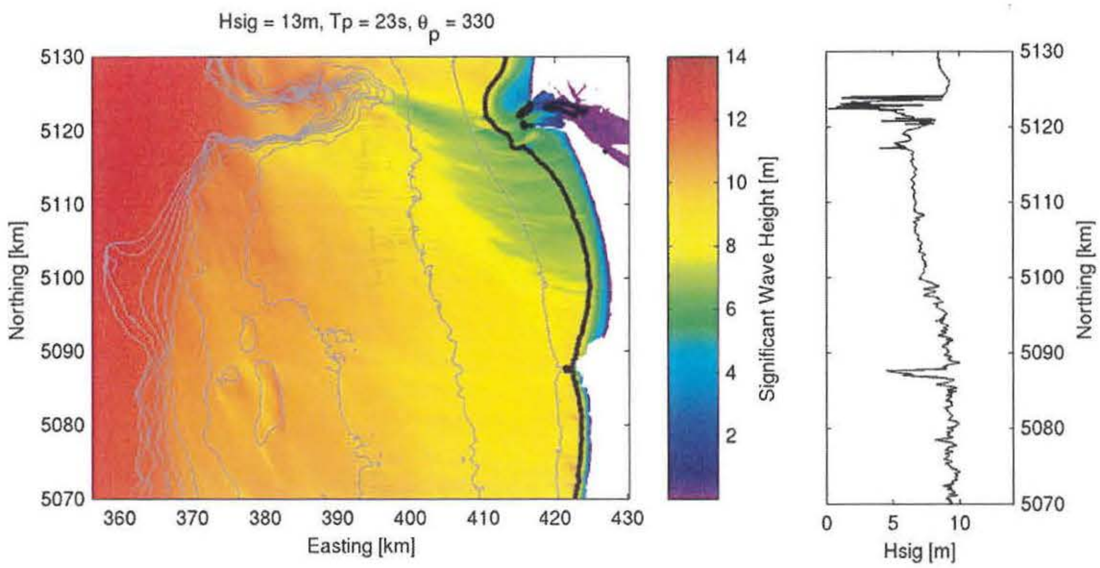


Figure 5-28. Example SWAN simulation, for an offshore significant wave height 13 m, peak wave period 23 s, and peak wave direction of 330°. Left) Significant wave height in the modeling domain is shown in colors. Dissipation processes result in reduced wave height. Contour lines are drawn from 50 to 500 m every 50 m in grey and every 20 m in black. Right) Modeled significant wave height extracted at 20-m water depth.

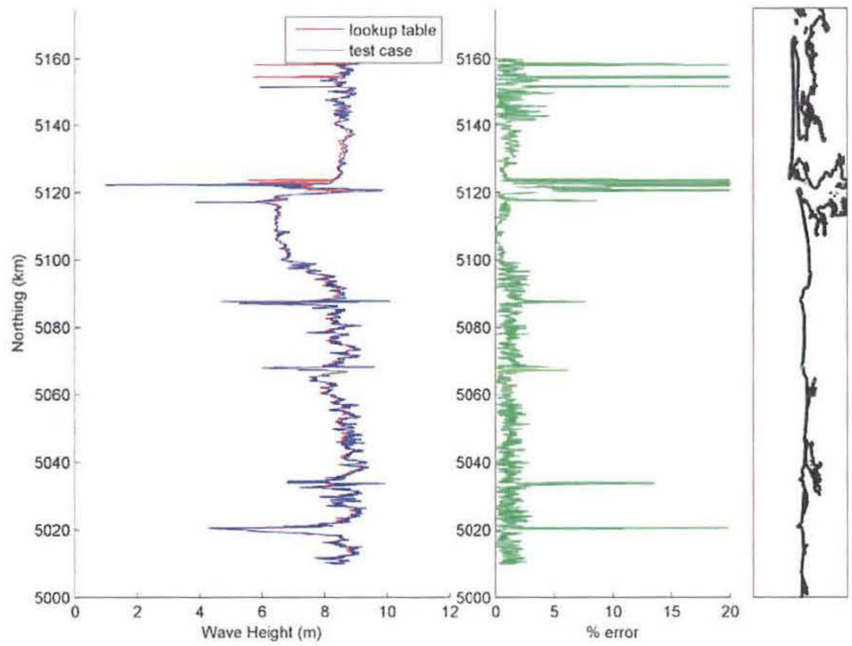


Figure 5-29. Comparison of alongshore varying wave height at the 20-m contour extracted from the lookup tables (red line) and from a direct SWAN computation (blue line) with an offshore boundary condition characterized as H_s = 11.5, T_p = 18.5, D_p = 320, and a water level of 4.5 m NAVD88.

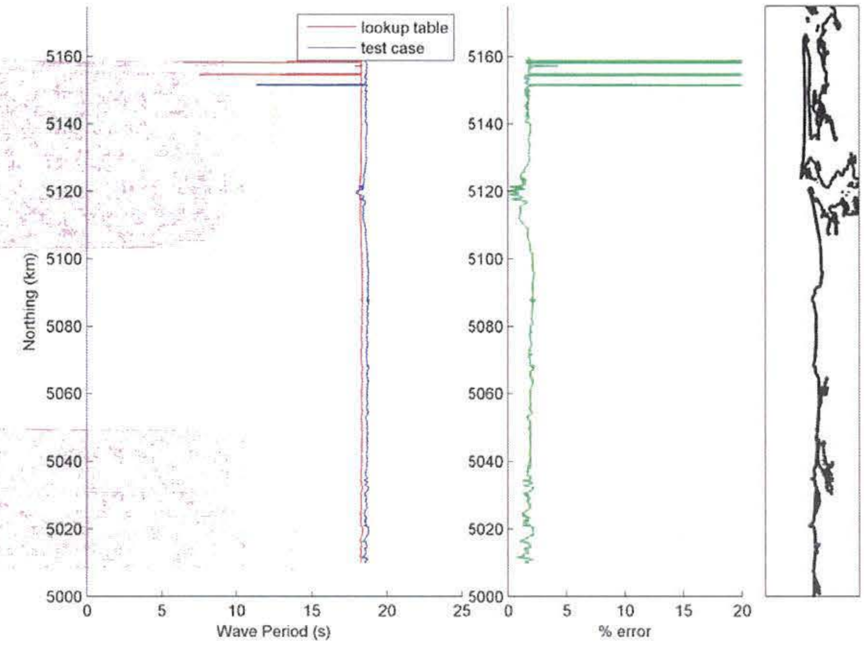


Figure 5-30. Comparison of alongshore varying wave period at the 20-m contour extracted from the lookup tables (red line) and from a direct SWAN computation (blue line) with an offshore boundary condition characterized as H_s = 11.5, T_p = 18.5, D_p = 320, and a water level of 4.5 m NAVD88.

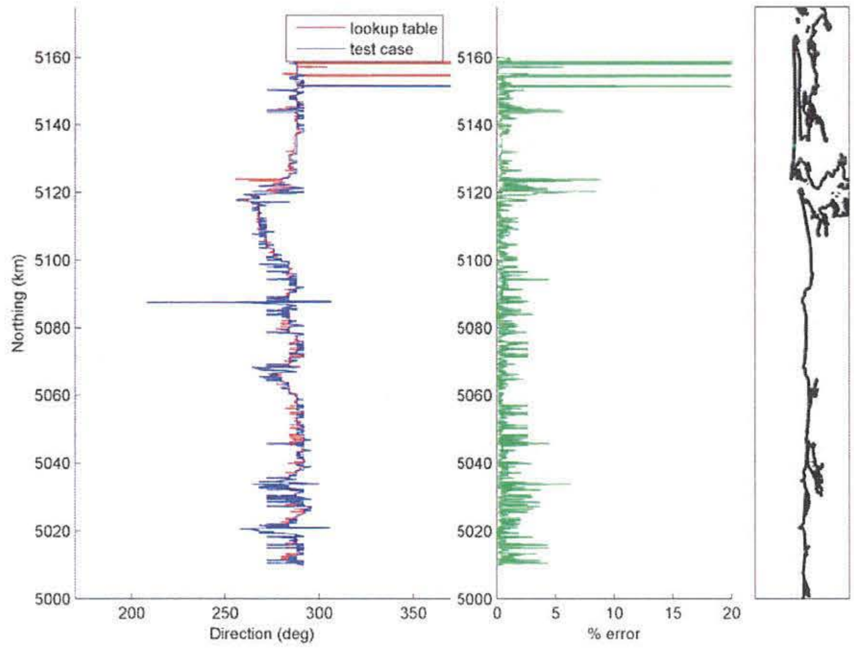


Figure 5-31. Comparison of alongshore varying wave direction at the 20-m contour extracted from the lookup tables (red line) and from a direct SWAN computation (blue line) with an offshore boundary condition characterized as H_s = 11.5, T_p = 18.5, D_p = 320, and a water level of 4.5 m NAVD88.

6.0 WAVE RUNUP AND OVERTOPPING

Wave runup is the culmination of the wave breaking process whereby the swash of the wave above the still water level is able to run up the beach face, where it may encounter a dune, structure, or bluff, potentially resulting in the erosion or in overtopping and flooding of adjacent land (**Figure 6-1**). Runup, *R*, or wave setup plus swash, is generally defined as the time-varying location of the intersection between the ocean and the beach and, as summarized, is a function of several key parameters. These include the deepwater wave height (H_o or H_s), peak spectral wave period (T_p) and the wave length (L_o) (specifically the wave steepness, H_o/L_o), and through a surf similarity parameter called the Iribarren number,

$$\xi_o = \frac{\beta}{\sqrt{H_o/L_o}},$$

which accounts for the slope (β) of a beach or an engineering structure, as well as the steepness of the wave.

The total runup, *R*, produced by waves includes three main components:

- wave setup, $\overline{\eta}$;
- a dynamic component to the still water level, $\widehat{\eta}$; and
- incident wave swash, S_{inc}

$$R = \overline{\eta} + \widehat{\eta} + S_{inc} \quad (6.1)$$

Along the Pacific Northwest Coast of Oregon and Washington, the dynamic component of still water level, $\widehat{\eta}$, has been demonstrated to be a major component of the total wave runup due to relatively high contributions from infragravity energy (Ruggiero and others, 2004). This process occurs due to a transfer of energy from the incident wind-generated waves to the longer-period infragravity wave energy, the division being placed at ~20-s periods. On the dissipative beaches of the Oregon coast, it is the infragravity energy that increases swash runup levels during major storms that is ultimately responsible for erosion and overwash events. The combination of these processes produces "sneaker waves," yielding the most extreme swash runup levels.

A variety of models have been proposed for calculating wave runup on beaches (Ruggiero and others, 2001; Hedges and Mase, 2004; Northwest Hydraulic Consultants, 2005; Stockdon and others, 2006). Here we explore two approaches available for runup calculations along Tillamook County, Oregon. These included the runup model developed by Stockdon and others (2006) and the direct integration method (DIM) described in NHC (2005).

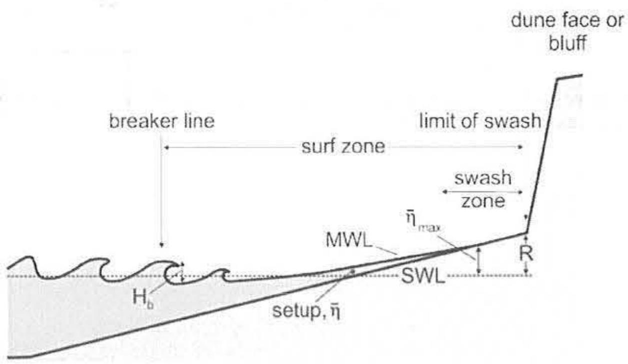


Figure 6-1. Conceptual model showing the components of wave runup associated with incident waves (modified from Hedges and Mase, 2004).

6.1 Runup Models for Beaches

6.1.1 Stockdon Runup Model

For sandy beaches, Stockdon and others (2006) developed an empirical model based on analyses of 10 experimental runup data sets obtained from a wide variety of beach and wave conditions, including data from Oregon (Ruggiero and others, 2004), and by separately parameterizing the individual runup processes: setup and swash. Stockdon and others (2006) proposed the following general relationship for the elevation of the 2% exceedance elevation of swash maxima, R_2, for any data run:

$$R_2 = 1.1[\overline{\eta} + \frac{S}{2}] \qquad (6.2)$$

where:

$$S = \sqrt{(S_{inc})^2 + (\widehat{\eta})^2} \qquad (6.3)$$

and:

$$\overline{\eta}, S_{inc}, \widehat{\eta} = f(H_o, T_o, \beta_f)$$

where β_f is the slope of the beach face, and S reflects both the dynamic, $\overline{\eta}$, and incident swash, S_{inc}, components. The 1.1 coefficient value was determined because the swash level assumes a slightly non-Gaussian distribution. The final parameterized runup equation is:

$$R_{2\%} = 1.1\left(0.35 \tan\beta\,(H_o L_o)^{\frac{1}{2}} + \frac{[H_o L_o(0.563 \tan\beta^2 + 0.004)]^{\frac{1}{2}}}{2}\right) \qquad (6.4)$$

which may be applied to natural sandy beaches over a wide range of morphodynamic conditions. In developing equation 6.4, Stockdon and others (2006) defined the slope of the beach as the average slope over a region ±2σ around the wave setup, $\overline{\eta}$, where σ is the standard deviation of the continuous water level record, η(t). Simply put, the setup reflects the height of the mean-water level (MWL) excursion above the SWL, such that the slope is determined to span the region around this MWL. For Tillamook County, the slope of the beach was determined by fitting a linear regression through those data points spanning the region located between 2 and 4 m.

Combining equation 6.4 with the measured water level at tide gauges produces the total water level (TWL) at the shore, important for determining the erosion or flood risk potential. Given that equation 6.4 has been derived from quantitative runup measurements spanning a range of beach slopes (beach slopes ranged from 0.01 to 0.11 and Iribarren numbers [ξ] ranged from 0.1 [fully dissipative conditions] to ~2.2 [reflective conditions], Table 1 of Stockdon and others [2006]), the model is valid for the range of slopes and conditions observed along the Tillamook County coastline and elsewhere on the Oregon coast.

6.1.2 Direct integration method—beaches

The FEMA coastal flood mapping guidelines (NHC, 2005) for the U.S. West Coast presents an alternative method for calculating runup. According to NHC (2005), the direct integration method (DIM) approach allows for the wave and bathymetric characteristics to be taken into consideration; specifically, the spectral shape of the waves and the actual bathymetry can be represented. Here we review the parameterized set of runup equations that may be used to calculate runup on beaches. The equations are based on a parameterized JONSWAP spectra and uniform beach slopes.

Similar to equation 6.1, the runup of waves using DIM can be defined according to its three components: the wave setup, $\overline{\eta}$, a dynamic component, $\widehat{\eta}$, and the incident band swash, S_{inc}. Wave setup can be calculated using:

$$\overline{\eta} = 4.0\, F_H F_T F_{Gamma} F_{slope} \quad (6.5)$$

while the root mean square (rms) of the dynamic component, $\widehat{\eta}_{rms}$, may be estimated using:

$$\widehat{\eta}_{rms} = 2.7\, G_H G_T G_{Gamma} G_{slope} \quad (6.6)$$

where the units of $\overline{\eta}$ and $\widehat{\eta}_{rms}$ are in *feet* and the factors (F) are for the wave height (F_H and G_H), wave period (F_T and G_T), JONSWAP spectrum narrowness (F_{Gamma} and G_{Gamma}), and the nearshore slope (F_{slope} and G_{slope}). These factors are summarized as a series of simple equations in Table D.4.5-1 (NHC, 2005). For the purposes of defining an average slope, NHC recommended that the nearshore slope be based on the region between the runup limit and twice the wave breaking depth, h_b, where:

$$h_b = H_b / k \quad (6.7)$$

and

$$H_b = 0.39 g^{0.2} \left(T_p H_o^2\right)^{0.4} \quad (6.8)$$

where H_b is the breaker height calculated using equation 6.8 (Komar, 1998b), g is acceleration due to gravity (9.81 m/s), and for the purposes here k (breaker depth index) can be taken to be 0.78. Thus, one important distinction between the DIM and Stockdon methods for calculating runup is the method used to define the beach slope; the former accounts for a larger portion of the nearshore slope, while the latter is based on the slope calculated around the mid beach-face.

To derive the statistics of the oscillating wave setup and the incident swash components, the recommended approach is to base the calculations on the standard deviations (σ) of each component. The standard deviation of the incident wave oscillation (σ_2) on natural beaches may be calculated from:

$$\sigma_2 = 0.3 \xi_o H_o \quad (6.9)$$

Because the standard deviation of the wave setup fluctuations (σ_1) is proportional to equation 6.6, the total oscillating component of the dynamic portion of the wave runup can be derived from:

$$\widehat{\eta_T} = 2.0 \sqrt{\sigma_1^2 + \sigma_2^2} \quad (6.10)$$

Combining the results of equations 6.10 and 6.5 yields the 2% wave runup, and when combined with the tidal component results in the TWL.

6.1.3 Comparison between the Stockdon and DIM runup calculations

Fundamentally, the wave runup model proposed by Stockdon and others (2006) and the DIM method described in NHC (2005) are similar, because both models account for the three components of runup described in equation 6.1. Here we examine the runup results derived from both models based on a range of conditions characteristic of the Clatsop shore (**Figure 6-2** and **Figure 6-3**). We focus on our results from Clatsop, because this is where we first tested both approaches, before settling on one approach for calculating all subsequent runup for the Oregon coast.

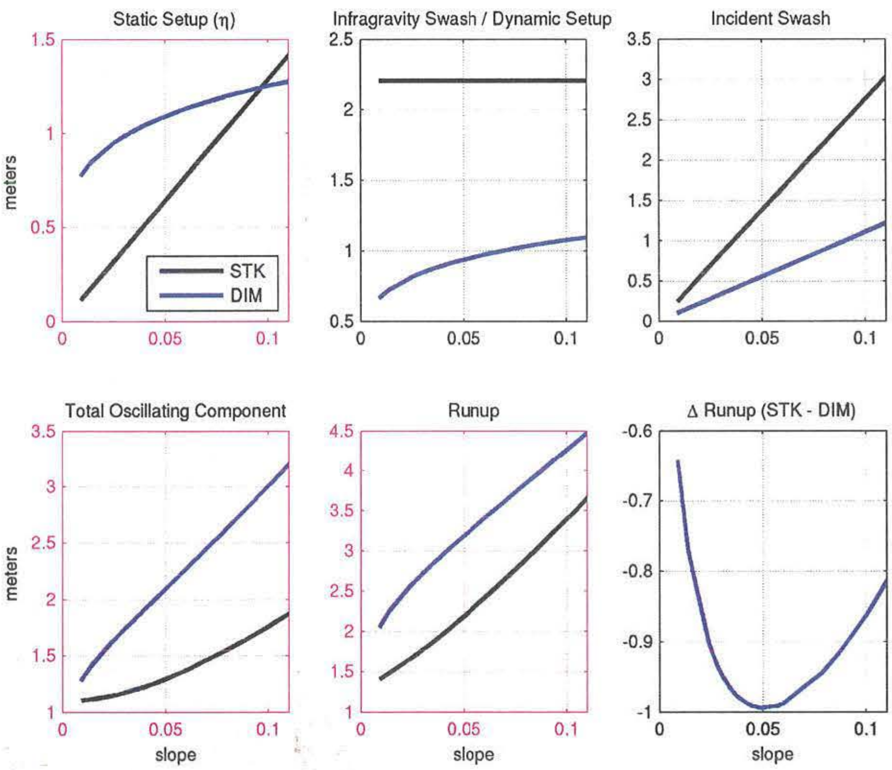


Figure 6-2. Calculated setup, swash and runup using the Stockdon and DIM runup equations. In this example, slope values are defined similarly for both methods, at a mid-beach elevation range of 2–4 m (6.6–13 ft). A 6-m (19.7 ft) significant wave height, 12-s peak wave period, and 270° wave direction were used to drive the models. Due to the semi-empirical nature of the equations, only the magnitudes of the subplots outlined in magenta are directly comparable (the two panels showing swash results are not directly comparable). The total oscillating component compares the results from equation 6.3 (S/2) with equation 6.10.

Figure 6-2 provides a comparison of the various calculated parameters (setup, infragravity swash, incident swash, total oscillating component, and runup) determined using the Stockdon and DIM approaches. In this example, we use the same slope defined for the mid-beach region in order to provide a direct comparison between DIM and Stockdon. Upper estimates have been truncated to tan β = 0.11, which reflects the slope limit on which Stockdon has been tested. In contrast, it is unclear the range of slope conditions on which DIM may be applied as there is no quantitative field testing of this particular formulation. As can be seen in **Figure 6-2**, although there are notable differences in the various parameterizations, the derived runup (bottom, middle plot) is similar. Nevertheless, as can be seen from the ΔR plot (bottom right), the DIM approach tends to estimate a slightly higher runup when compared to Stockdon, which in this example reaches a maximum of ~1 m (3.3 ft) for a beach slope of 0.04 to 0.05. Thus, overall, we can conclude that the two approaches are performing in a similar fashion when tested using the same slope.

Figure 6-3 presents a similar suite of comparisons under the same hydrodynamic conditions. Therefore the Stockdon and others (2006) results are identical to **Figure 6-2** in all panels. However, in this example we now account for the appropriate nearshore slope in the DIM runup calculations as defined above in Section 6.1.2. This was originally done by computing the DIM runup components for this hydrodynamic condition using the full nearshore slope at 85 transects spread along the Clatsop County coastline (Allan and others, 2014). The DIM values are, however, plotted against the foreshore beach slopes defined for all 85 transects in order to make the comparisons with Stockdon meaningful. As can be seen in **Figure 6-3**, application of the nearshore slope significantly changes the magnitudes of all the runup components and, in particular, reduces the calculated runup when compared to Stockdon for most foreshore slopes. In general, at lower slopes (tan $\beta < 0.05$) runup calculated by DIM is slightly higher than Stockdon, which reverses at steeper slopes (tan $\beta > 0.05$). This pattern is consistent with analyses performed by Allan and others (2012) in Coos County.

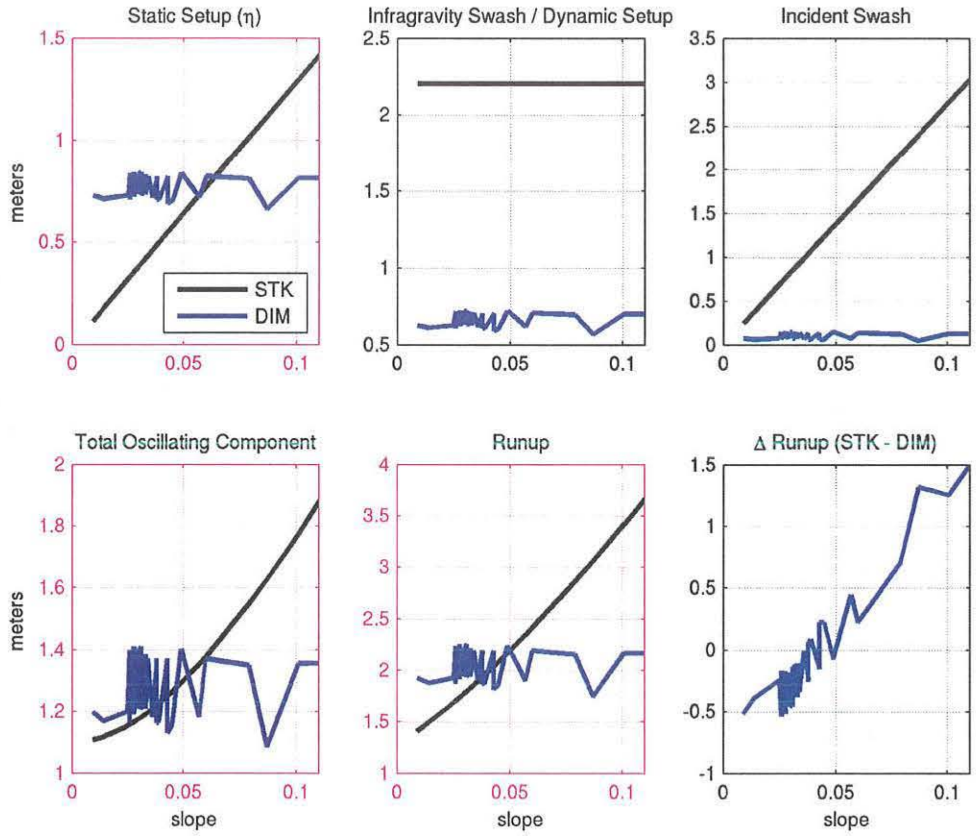


Figure 6-3. **Total water level calculations using the Stockdon (foreshore slope) and DIM runup equations (nearshore slope). A 6-m (19.7-ft) significant wave height, 12-s peak wave period, and 270° wave direction were used to drive the models. Due to the semi-empirical nature of these equations only the magnitudes of the subplots outlined in magenta are directly comparable. The results for DIM are sorted in ascending order as a function of foreshore beach slope.**

Most interesting in the comparisons shown in **Figure 6-3**, is that the DIM runup components actually do not vary as a function of the foreshore slope. The total runup **Figure 6-3**, bottom center) produced by DIM is relatively constant, oscillating between 1.7 and 2.3 m (5.6 and 7.5 ft). The oscillations are due primarily to the variability in the nearshore slopes, which are a function of wave height (equations 6.7 and 6.8). Because waves in the PNW are relatively large and upper shoreface slopes are relatively shallow, the DIM runup values are controlled by the nearshore slope with little influence from the upper beach. This lack of dependence on the foreshore is in contrast to field measurements made in Oregon (Ruggiero and others, 2004) in which runup is clearly a function of the foreshore slope. Because the Stockdon model has been extensively validated against measured runup data, including measurements on the Oregon coast (e.g., Ruggiero and others, 2001; Ruggiero and others, 2004) together with qualitative observations of runup during storms by DOGAMI staff at multiple sites along the coast, 1% extreme values of TWLs calculated for sandy beaches along the Tillamook County coast will be based primarily on the Stockdon and others (2006) model.

6.2 "Barrier" Runup Calculations

6.2.1 Introduction

According to NHC (2005) an alternate approach is recommended for use in calculating runup on steep barriers. By definition, *barriers include "steep dune features and coastal armoring structures such as revetments"* (NHC, 2005, p. D.45-10), although little guidance is offered in terms of the range of slopes to which this alternate approach would apply. Throughout this document we use the generic term *barrier* to define the range of morphological and engineering conditions where barrier runup calculations may apply. In general, runup on barriers depends not only on the height and steepness of the incident waves defined through the Iribarren number or breaker parameter ($\xi_{m-1,0}$) but also on the geometry (e.g., the slope of the barrier and/or if a berm is present), design characteristics of the structure, and its permeability.

The recommended approach for calculating runup on barriers is to use the TAW (Technical Advisory Committee for Water Retaining Structures) method, which provides a mechanism for calculating the runup, adjusted for various reduction factors that include the surface roughness, the influence of a berm (if present), and effects associated with the angle of wave approach (van der Meer, 2002; Northwest Hydraulic Consultants, 2005; Pullen and others, 2007). According to NHC (2005) the TAW method is useful as it includes a wide range of conditions for calculating the wave runup (e.g., both smooth and rough slopes) and because it agrees well with both small- and large-scale experiments.

Figure 6-4 is a conceptual model of the various components required to determine the extent of runup on barriers. Of importance is first determining the 2% dynamic water level ($DWL_{2\%}$) at the barrier, which includes the combined effects of the measured still water level (SWL), the wave setup ($\bar{\eta}$) and the dynamic portion ($\hat{\eta}$) of the runup (**Figure 6-4**), which is then used to establish the spectral significant wave height (H_{mo}) at the toe of the "barrier" (NHC, 2005).

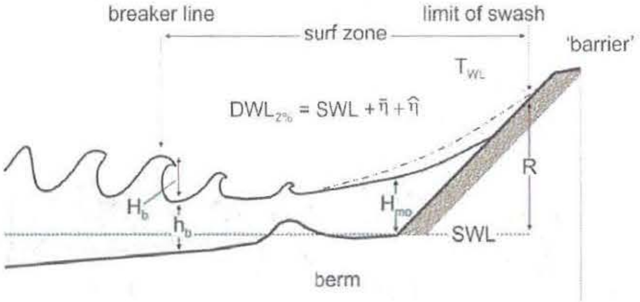


Figure 6-4. Wave runup on a beach backed by a structure or bluff (modified from NHC, 2005).

The general formula for calculating the 2% wave runup height on barriers is given in a non-dimensional form by equation 6.11:

$$\frac{R_{2\%}}{H_{mo}} = c_1 . \gamma_b . \gamma_f . \gamma_\beta . \xi_{m-1,0} \qquad (6.11)$$

with a maximum of:

$$\frac{R_{2\%}}{H_{mo}} = \gamma_f . \gamma_\beta \left(c_2 - \frac{c_3}{\sqrt{\xi_{m-1,0}}} \right)$$

where:

$R_{2\%}$ = wave runup height exceeded by 2% of the incoming waves

H_{mo} = spectral significant wave height at the structure toe

c_1, c_2, and c_3 = empirical coefficients with:

γ_b = influence factor for a berm (if present),

γ_f = influence factor for roughness element of slope,

γ_β = influence factor for oblique wave attack,

$\xi_{m-1,0}$ = breaker parameter

$$\left(\tan\beta / \left(\frac{H_{mo}}{L_{m-1,0}} \right)^{0.5} \right),$$

$\tan\beta$ = slope of the "barrier,"

$L_{m-1,0}$ = the deepwater wave length $\left(gT_{m-1,0}^2 / 2\pi \right)$, and

$T_{m-1,0}$ can be calculated from $T_p/1.1$, where T_p is the peak spectral wave period.

Substituting the empirical coefficients derived from wave tank experiments and incorporating a 5% upper exceedance limit into the general equations of 6.11 (van der Meer, 2002; Pullen and others, 2007), runup on barriers may be calculated by using:

$$R_{2\%} = H_{mo}(1.75 . \gamma_b . \gamma_f . \gamma_\beta . \xi_{m-1,0}), \quad \text{where } 0 < \gamma_b . \xi_{m-1,0} < 1.8 \qquad (6.12)$$

with a maximum of:

$$R_{2\%} = H_{mo} \left(1.0 . \gamma_f . \gamma_\beta \left(4.3 - \frac{1.6}{\sqrt{\xi_{m-1,0}}} \right) \right), where\ \gamma_b . \xi_{m-1,0} \geq 1.8$$

There are, however, notable differences between equation 6.12 originally described by van der Meer (2002) and Pullen and others (2007) from that presented in equation D.4.5-19 in the FEMA West Coast methodology (NHC, 2005). For example, equation D.4.5-19 in the NHC report contains a higher coefficient value (1.77), along with one additional reduction factor (porosity) for calculating runup when the breaker parameter is less than 1.8. Similarly, for conditions where the breaker parameter exceeds 1.8 and the maximum runup equation is used, equation D.4.5-19 in the NHC report contains two extra reduction factors (berm and porosity reduction factors) that are not included in the original solution, which potentially could have a very significant effect on the calculated runup. Based on these differences, we have used the original solution presented as equation 6.12 in van der Meer (2002) and Pullen and others (2007).

6.2.2 Specific procedure for calculating "barrier" runup

For those cases where the TAW method is used for determining runup on barriers (i.e., beaches backed by structures, cobble berms, and/or bluffs), we have followed the general approach laid out in section D.4.5.1.5.2 in NHC (2005), with the exception that we use Stockdon to define the $DWL_{2\%}$ (instead of DIM) at the structure toe, and TAW to calculate the incident swash on the barrier (i.e., equation 6-12). Because waves are depth limited at the barrier toe, H_{mo} may be estimated from $DWL_{2\%}$ using a breaker index of 0.78 (i.e., $H_{mo} = DWL_{2\%} * 0.78$). In performing these various derivations, $DWL_{2\%}$ was first determined using equation 6.13:

$$DWL_{2\%} = SWL + 1.1 * \left(\overline{\eta} + \frac{\widehat{\eta}}{2}\right) - D_{low} \qquad (6.13)$$

where:

SWL = measured tide

$\overline{\eta} = 0.35 * \tan\beta\sqrt{H_s * L}$ *Eqn. 10 in Stockdon and others (2006)*

$\widehat{\eta} = 0.06 * \sqrt{H_s * L}$ *Eqn. 12 in Stockdon and others (2006)*

D_{low} = the toe of the structure or bluff
$\tan\beta$ = the beach slope defined for the region between 2 and 4 m.

Having calculated $DWL_{2\%}$ and H_{mo}, the TAW runup calculation can be implemented. Equation 6.12 requires information on the slope of the barrier, used in the breaker parameter ($\xi_{m-1,0}$) calculation, which can be somewhat challenging to define. This is especially the case if the morphology of the barrier exhibits a composite morphology characterized by different slopes, such that errors in estimating the slope will translate to either significant underestimation or overestimation of the runup. According to van der Meer (2002) and Pullen and others (2007), because the runup process is influenced by the change in slope from the breaking point to the maximum wave runup, the characteristic slope should be specified for this same region. On the Oregon coast, the most common composite slope example is the case where a broad, dissipative sand beach fronts a structure or bluff that is perched relatively high on the back of the beach (structure toe > ~4-5 m). In this example, the wave runup is first influenced by the sandy beach slope and finally by the slope of the structure itself. To address this type of situation, we define a "local barrier slope" as the portion of the barrier that ranges from the calculated storm TWL (calculated initially using equation 6.4) down to a lower limit defined by the wave setup plus the SWL [i.e., $(1.1 * \overline{\eta}) + SWL$]). In a few cases, the TWL was found to exceed the barrier crest; in those cases we used the structure crest as the upper limit for defining the local slope. This process is repeated for every storm condition. Having determined the barrier slope, the TAW runup is calculated using equation 6.12 and reduced based on the appropriate site specific reduction factors.

Under certain conditions, we identified events that generated extreme runup that made little physical sense. For these (rare) cases, we calculated the TAW runup using an iterative approach based on procedures outlined in the Eurotop (2007) manual. Because the maximum wave runup is the desired outcome and is unknown when initially defining the slope, the process is iterative requiring two steps. First, the breaking limit is defined as $1.5H_{mo}$ *below* the SWL, while $1.5H_{mo}$ *above* the SWL defines the upper limit of the first slope estimate (**Figure 6-5**). Having determined the first slope estimate, the TAW runup is calculated using equation 6.12 and reduced based on the appropriate reduction factors. A second slope estimate is then performed based on the initial runup calculation, while a third iteration is not necessary based on our tests because this method converges quickly. The breaking limit is again defined as $1.5H_{mo}$ *below* the SWL, while $R_{2\%}$ *above* the SWL defines the upper limit, and the final barrier runup estimate is again calculated using equation 6.12 and reduced based on the appropriate reduction factors.

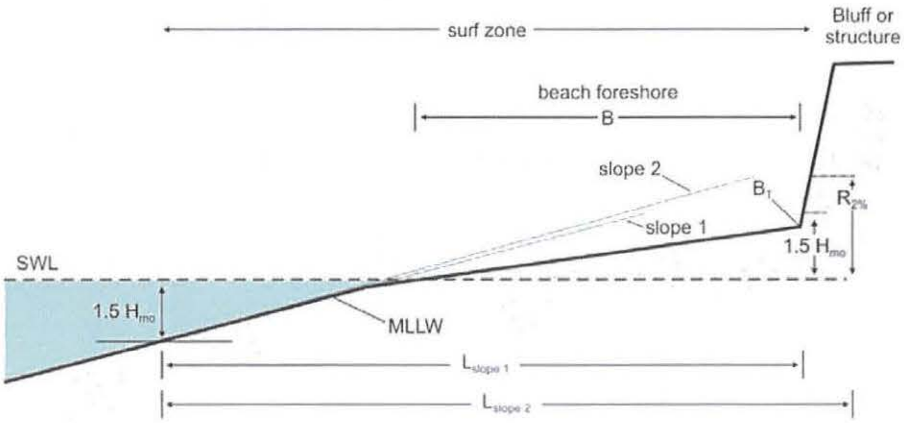


Figure 6-5. Determination of an average slope based on an iterative approach. The first estimate is initially based on $1.5H_{mo}$ ±SWL, while the second estimate is based on $1.5H_{mo}$ below the SWL and the calculated $R_{2\%}$ above the SWL that is based on the first slope estimate.

Finally, it is important to note that the runup estimates based on the "barrier" runup calculations is sensitive to the slope. Similar to our study in Coos and Clatsop counties, we identified several sites (primarily beaches backed by bluffs) along the Tillamook coast where the final TWLs calculated using TAW was unreasonably low. These few cases are entirely due to there being a very wide dissipative surf zone at these transect locations that results in very low slopes being defined. For these sites where the calculated TWL_s seemed unreasonably low (relative to the morphology of the beach and observations of storm wave runup along this shore and elsewhere), we have defaulted to the TWLs calculated using the Stockdon and others model.

6.2.3 "Barrier" runup reduction factors

Table 6-1 below presents information pertaining to the suite of parameters used to define wave runup (R) and ultimately the 1% TWLs along the Tillamook County coast. In the case of bluff roughness along the Tillamook shore, we used a value of 0.6 for those situations where a bluff face was highly vegetated. These bluffs are typically located at or near their stable angle of repose and are covered with Salal plants (*Gaultheria shallon*), forming a deep, nearly impenetrable thicket. The decision to use 0.6 was based on discussions with Dr. W. G. McDougal (Coastal Engineer, OSU, and Technical Coordinator of the North Pacific FEMA West Coast Guidelines, pers. comm., April 2010). At the Tillamook transects 26–28, 43–44, 46, 67–74, 94–96, and 104 (**Table 6-1**), the reduction factor was set to 1 due to the fact that these beaches were backed by a near-vertical bluff face that was essentially akin to a seawall situation. For those beaches backed by a significant riprap structure, we used a reduction factor of 0.55. In other cases, this was increased to 0.6 to 0.8, depending on whether the beach was backed by gravels/cobbles, a vegetated bluff face, or poor quality riprap. Wave direction (γ_β) reduction factors were determined based on the shoreline orientation at every transect site and the actual wave directions measured during each storm condition. The reduction factor was calculated using equation D.4.5-22 of NHC (2005, p. D.4.5-13). Finally, because none of the transects where structures are present contained a protective berm, no berm reduction factor was adopted for Tillamook County.

Table 6-1. Parameters used to define runup (*R*) and total water levels (TWLs) on beaches backed by dunes, structures, and bluffs.

Reach	Transect	DFIRM Transect	D_{HIGH} (m)	D_{LOW} (m)	Beach Slope (tan β)	Wave Dir. (Υ_θ)	Rough-ness (Υ_r)	Approach	Description
Salmon River	LINC 308	1	6.251	5.058	0.084	272.2	1.0	3	dune-backed cliff
Cascade Head	LINC 309	2	48.172	1.609	0.027	268.8	0.95	1	plunging cliff
	LINC 310	3	43.56	1.207	0.028	274.1	0.95	1	plunging cliff
	LINC 311	4	24.427	0.358	0.022	270.3	0.8	1	boulder beach backed by bluffs
	LINC 312	5	93.24	2.125	0.026	271.8	0.95	1	plunging cliff
	LINC 313	6	139.1	0	0.023	273.7	0.95	1	plunging cliff
Neskowin	TILL 1	7	47.278	0.764	0.025	294.5	0.55	1	sandy beach backed by riprap and high cliffs
	TILL 2	8	8.684	3.914	0.045	294	0.55	1	sand beach backed by riprap
	TILL 3	9	8.452	3.914	0.042	287.1	0.55	1	sand beach backed by riprap
	TILL 4	10	5.184	3.448	0.018	283.3	0.55	1	sand beach backed by riprap
	TILL 5	11	8.312	2.712	0.049	267.3	0.55	1	sand beach backed by riprap
	TILL 6	12	8.447	3.563	0.073	275.6	0.55	1	sand beach backed by riprap
	TILL 7	13	8.169	1.904	0.062	284.3	0.55	1	sand beach backed by riprap
	TILL 8	14	8.539	2.533	0.062	286.8	0.55	1	sand beach backed by riprap
	TILL 9	15	7.075	5.888	0.06	286.7	1.0	3	dune-backed
	TILL 10	16	8.897	6.235	0.054	285.1	1.0	3	dune-backed
	TILL 11	17	6.679	5.604	0.041	282.9	1.0	3	dune-backed
	TILL 12	18	8.374	5.521	0.044	281	1.0	3	dune-backed
	TILL 13	19	7.126	5.709	0.049	273.3	1.0	3	dune-backed
	TILL 14	20	8.118	5.086	0.099	282.3	0.55	1	sand beach backed by riprap
	TILL 15	21	7.587	4.642	0.069	272.4	0.55	1	sand beach backed by riprap
	TILL 16	22	6.767	6.014	0.052	277	1.0	3	dune-backed
	TILL 17	23	9.986	4.326	0.039	283.7	1.0	3	dune-backed
	TILL 18	24	8.387	5.512	0.074	284.4	1.0	3	dune-backed
	TILL 19	25	6.014	6.014	0.059	285.4	1.0	3	dune-backed
	TILL 20	26	7.648	7.066	0.098	284.5	1.0	3	dune-backed
	TILL 21	27	12.562	5.582	0.049	287.1	1.0	3	dune-backed
	TILL 22	28	6.241	4.489	0.034	283.2	1.0	3	dune-backed
	TILL 23	29	14.334	6.819	0.088	280.2	1.0	3	dune-backed
	TILL 24	30	7.792	7.185	0.06	278	1.0	3	dune-backed
	TILL 25	31	7.642	5.627	0.061	278.3	1.0	3	dune-backed
	TILL 26	**32**	**32.562**	**3.877**	**0.059**	**278.6**	**1.0**	**2**	**sandy beach backed by high cliffs**
	TILL 27	**33**	**28.194**	**4.519**	**0.088**	**281.5**	**1.0**	**2**	**sandy beach backed by high cliffs**
	TILL 28	**34**	**39.31**	**6.292**	**0.084**	**281.1**	**1.0**	**2**	**sandy beach backed by dunes and high cliffs**
Nestucca spit/ Pacific City	TILL 29	35	10.245	4.903	0.043	273.2	1.0	3	dune-backed
	TILL 30	36	14.485	5.083	0.048	273.8	1.0	3	dune-backed
	TILL 31	37	15.49	5.933	0.061	276.6	1.0	3	dune-backed
	TILL 32	38	14.358	5.413	0.093	277	1.0	3	dune-backed
	TILL 33	39	13.16	5.338	0.072	270.9	1.0	3	dune-backed
	TILL 34	40	15.877	6.611	0.086	271.1	1.0	3	dune-backed
	TILL 35	41	15.147	5.312	0.05	270	1.0	3	dune-backed
	TILL 36	42	17.709	5.908	0.051	268.7	1.0	3	dune-backed
	TILL 37	43	12.932	4.389	0.051	266.5	0.55	1	sand beach backed by riprap?
	TILL 38	44	11.283	4.69	0.053	264	0.55	1	sand beach backed by riprap?
	TILL 39	45	18.954	5.407	0.041	262.2	1.0	3	dune-backed
	TILL 40	46	11.314	5.539	0.057	261.1	0.55	3	sand beach backed by riprap?
	TILL 41	47	11.06	4.785	0.039	262.9	0.55	3	sand beach backed by riprap?
	TILL 42	48	13.304	4.681	0.043	262.8	0.6	1	sand beach backed by riprap and high bluffs

Reach	Transect	DFIRM Transect	D_{HIGH} (m)	D_{LOW} (m)	Beach Slope (tan β)	Wave Dir. (Υ_θ)	Rough-ness (Υ_r)	Approach	Description
Sand Lake/ Tierra Del Mar	**TILL 43**	**49**	**23.369**	**5.582**	**0.046**	**281.8**	**1.0**	**1**	**sandy beach backed by high cliffs**
	TILL 44	**50**	**16.741**	**6.162**	**0.075**	**281.3**	**1.0**	**1**	**sandy beach backed by high cliffs**
	TILL 45	51	6.868	4.232	0.042	280.2	0.6	1	sandy beach backed by cobbles - grades into bluff
	TILL 46	**52**	**18.071**	**4.865**	**0.055**	**280.8**	**1.0**	**1**	**sandy beach backed by high cliffs**
	TILL 47	53	18.396	4.063	0.045	279.7	0.55	1	sand beach backed by riprap
	TILL 48	54	7.412	6.555	0.048	279.8	1.0	3	dune-backed
	TILL 49	55	8.24	6.197	0.044	279.7	1.0	3	dune-backed
	TILL 50	56	6.931	5.891	0.041	290.1	1.0	3	dune-backed
	TILL 51	57	6.317	4.554	0.05	278.7	0.8	1	sand beach backed by riprap
	TILL 52	58	7.721	4.543	0.055	278.8	0.8	1	sand beach backed by riprap
	TILL 53	59	8.141	5.026	0.056	280.3	0.6	1	sand beach backed by riprap
	TILL 54	60	7.462	5.055	0.058	269.7	0.6	1	sand beach backed by riprap
	TILL 55	61	8.094	5.159	0.045	283.1	1.0	3	dune-backed
	TILL 56	62	8.357	4.652	0.046	278.7	0.55	1	sand beach backed by riprap
	TILL 57	63	11.383	4.823	0.04	284.8	0.55	3	sand beach backed by riprap
	TILL 58	64	10.224	6.18	0.042	278.7	1.0	3	dune-backed
	TILL 59	65	12.153	5.72	0.052	278.4	1.0	3	dune-backed
	TILL 60	66	9.595	5.355	0.041	278.4	1.0	3	dune-backed
	TILL 61	67	9.37	6.193	0.048	279.3	1.0	3	dune-backed
	TILL 62	68	6.573	6.26	0.052	279.1	1.0	3	dune-backed
	TILL 63	69	3.38	3.324	0.009	273.1	1.0	3	dune-backed
	TILL 64	70	18.524	6.915	0.111	270.7	1.0	3	dune-backed
	TILL 65	71	18.296	5.556	0.053	270.7	1.0	3	dune-backed
	TILL 66	72	15.211	5.34	0.049	271.5	1.0	3	dune-backed
	TILL 67	**73**	**19.042**	**8.385**	**0.069**	**272.4**	**1.0**	**3**	**sandy beach backed by high cliffs**
	TILL 68	**74**	**24.72**	**6.441**	**0.044**	**270.6**	**1.0**	**3**	**sandy beach backed by high cliffs**
	TILL 69	**75**	**29.519**	**5.96**	**0.051**	**268.7**	**1.0**	**3**	**sandy beach backed by high cliffs**
	TILL 70	**76**	**30.293**	**4.588**	**0.045**	**266.9**	**1.0**	**1**	**sandy beach backed by high cliffs**
	TILL 71	**77**	**37.153**	**4.979**	**0.055**	**263.4**	**1.0**	**1**	**sandy beach backed by high cliffs**
	TILL 72	**78**	**30.575**	**4.844**	**0.037**	**257.8**	**1.0**	**1**	**sandy beach backed by high cliffs**
	TILL 73	**79**	**28.571**	**6.625**	**0.048**	**256.8**	**1.0**	**3**	**sandy beach backed by high cliffs**
	TILL 74	**80**	**20.692**	**5.762**	**0.038**	**253.8**	**1.0**	**3**	**sandy beach backed by high cliffs**

Reach	Transect	DFIRM Transect	D_{HIGH} (m)	D_{LOW} (m)	Beach Slope (tan β)	Wave Dir. (Υ_θ)	Rough-ness (Υ_r)	Approach	Description
Netarts Spit/ Oceanside	TILL 75	81	6.775	2.43	0.029	276.8	0.6	1	sandy beach backed by low/high cliffs
	TILL 76	82	7.6	2.937	0.037	279.7	0.6	1	sandy beach backed by cobbles/boulders and low cliff
	TILL 77	83	8.447	3.235	0.047	285.7	0.6	1	sandy beach backed by dynamic revetment/artificial dune
	TILL 78	84	7.298	3.706	0.051	281.8	0.6	1	sandy beach backed by dynamic revetment/artificial dune
	TILL 79	85	10.798	3.976	0.043	284.6	0.6	1	dune-backed (+cobbles)
	TILL 80	86	9.131	5.381	0.082	285.4	1.0	3	dune-backed (+cobbles)
	TILL 81	87	7.159	4.661	0.067	285.8	1.0	3	dune-backed (+cobbles)
	TILL 82	88	11.562	5.04	0.056	283.3	1.0	3	dune-backed
	TILL 83	89	12.413	5.492	0.056	281.9	1.0	3	dune-backed
	TILL 84	90	7.322	6.012	0.046	271.7	1.0	3	dune-backed
	TILL 85	91	11.621	5.37	0.044	275.8	1.0	3	dune-backed
	TILL 86	92	11.763	6.361	0.047	276	1.0	3	dune-backed
	TILL 87	93	19.722	4.114	0.043	281.1	1.0	3	dune-backed
	TILL 88	94	6.567	5.72	0.057	271.2	1.0	3	dune-backed
	TILL 89	95	10.543	5.754	0.048	274	1.0	3	dune-backed
	TILL 90	96	12.156	4.768	0.046	278.7	1.0	3	dune-backed
	TILL 91	97	9.61	6.516	0.052	272.5	1.0	3	dune-backed
	TILL 92	98	8.324	6.36	0.05	284.5	1.0	3	dune-backed
	TILL 93	99	4.971	4.855	0.069	202.6	0.6	3	Cobble beach backed by low wall (estuary mouth)
	TILL 94	**100**	**14.619**	**5.554**	**0.074**	**223.7**	**1.0**	**2**	**sandy beach backed by high cliffs**
	TILL 95	**101**	**29.639**	**4.999**	**0.032**	**235.6**	**1.0**	**1**	**sandy beach backed by high cliffs**
	TILL 96	**102**	**39.082**	**4.536**	**0.055**	**236.2**	**1.0**	**2**	**sandy beach backed by high cliffs**
	TILL 97	103	55.206	4.631	0.065	241.7	1.0	3	sandy beach backed by dune and high cliffs
	TILL 98	104	60.658	5.832	0.073	250.3	1.0	3	sandy beach backed by dune and high cliffs
	TILL 99	105	33.925	4.907	0.044	254.1	0.6	3	sandy beach backed by high cliffs
	TILL 100	106	36.465	4.585	0.041	252.2	0.6	1	sandy beach backed by high cliffs
	TILL 101	107	13.733	5.191	0.045	248.4	0.7	3	sandy beach backed by poor riprap and low cliffs
	TILL 102	108	18.353	5.953	0.05	250	0.6	3	sandy beach backed by moderately high cliffs
	TILL 103	109	8.241	4.068	0.057	250.4	0.7	1	sandy beach backed by moderately high cliffs
Short Sand Beach	**TILL 104**	**110**	**33.582**	**3.026**	**0.056**	**277.7**	**1.0**	**1**	**sandy beach backed by gravels and high cliffs**
	TILL 105	111	26.461	3.932	0.075	277.9	0.8	1	sandy beach backed by gravels and high cliffs
	TILL 106	112	47.152	5.674	0.109	275.7	0.8	1	sandy beach backed by gravels and high cliffs

Reach	Transect	DFIRM Transect	D_{HIGH} (m)	D_{LOW} (m)	Beach Slope (tan β)	Wave Dir. (Υ_θ)	Rough-ness (Υ_r)	Approach	Description
Bayocean Spit	TILL 107	113	8.705	3.527	0.072	292	0.6	1	sandy beach backed by cobble/boulder and low cliffs
	TILL 108	114	7.74	2.981	0.05	286.2	0.6	1	sandy beach backed by cobble/boulder and low cliffs
	TILL 109	115	6.34	3	0.036	284.8	0.8	1	sandy beach backed by cobble/boulder berm
	TILL 110	116	6.081	2.495	0.026	280	0.8	1	sandy beach backed by cobble/boulder berm
	TILL 111	117	6.863	3.33	0.04	283.7	0.8	1	sandy beach backed by cobble/boulder berm
	TILL 112	118	9.667	6.824	0.041	279.7	1.0	3	dune-backed
	TILL 113	119	11.095	6.67	0.043	274.8	1.0	3	dune-backed
	TILL 114	120	9.781	6.804	0.04	276.6	1.0	3	dune-backed
	TILL 115	121	8.97	4.932	0.043	268.4	1.0	3	dune-backed
	TILL 116	122	10.49	5.889	0.04	265.4	1.0	3	dune-backed
	TILL 117	123	10.053	6.537	0.043	268.1	1.0	3	dune-backed
Rockaway	TILL 118	124	5.932	5.932	0.048	290.2	1.0	3	dune-backed
	TILL 119	125	6.332	4.905	0.043	285.6	1.0	3	dune-backed
	TILL 120	126	6.72	5.37	0.049	280.7	1.0	3	dune-backed
	TILL 121	127	6.749	5.178	0.058	282.2	1.0	3	dune-backed
	TILL 122	128	6.518	5.388	0.047	284.7	1.0	3	dune-backed
	TILL 123	129	7.242	3.13	0.029	286.4	0.55	1	sand beach backed by riprap
	TILL 124	130	6.905	5.82	0.05	285.9	1.0	3	dune-backed
	TILL 125	131	5.489	5.489	0.046	285.1	1.0	3	dune-backed
	TILL 126	132	5.858	4.586	0.02	286.4	1.0	3	dune-backed
	TILL 127	133	7.148	5.709	0.037	279.2	1.0	3	dune-backed
	TILL 128	134	7.976	5.327	0.038	279.6	1.0	3	dune-backed
	TILL 129	135	7.237	5.136	0.048	272.7	1.0	3	dune-backed
	TILL 130	136	7.344	5.839	0.046	274.4	1.0	3	dune-backed
	TILL 131	137	7.032	4.682	0.037	274.8	1.0	3	dune-backed
	TILL 132	138	5.486	3.77	0.038	290.9	0.8	3	sand beach backed by riprap
	TILL 133	139	7.133	5.593	0.038	276.7	1.0	3	dune-backed
	TILL 134	140	10.147	5.68	0.043	277.1	1.0	3	dune-backed
	TILL 135	141	8.387	7.085	0.052	276.2	1.0	3	dune-backed
	TILL 136	142	7.062	5.92	0.032	278.5	1.0	3	sand beach backed by low bluff
	TILL 137	143	6.827	4	0.034	279.7	0.55	1	sand beach backed by riprap
	TILL 138	144	6.359	3.045	0.013	274.8	0.55	1	sand beach backed by riprap
	TILL 139	145	8.67	5.263	0.034	268.9	1.0	3	dune-backed
	TILL 140	146	8.923	3.759	0.051	273.9	0.55	1	sand beach backed by riprap
	TILL 141	147	7.643	3.759	0.044	272.4	0.55	1	sand beach backed by riprap
	TILL 142	148	8.305	3.759	0.057	277.7	0.55	1	sand beach backed by riprap
	TILL 143	149	8.196	4.068	0.051	276	0.55	1	sand beach backed by riprap
	TILL 144	150	8.305	3.312	0.051	277.6	0.55	1	sand beach backed by riprap
	TILL 145	151	8.092	4.309	0.054	279.9	0.55	1	sand beach backed by riprap
	TILL 146	152	8.176	4.029	0.047	270.8	0.64	1	sand beach backed by riprap
	TILL 147	153	7.927	7.16	0.056	280.1	1.0	3	dune-backed
	TILL 148	154	8.101	5.982	0.052	281.5	1.0	3	dune-backed
	TILL 149	155	8.029	5.997	0.05	282	1.0	3	dune-backed
	TILL 150	156	8.315	6.325	0.045	283.3	1.0	3	dune-backed
	TILL 151	157	6.974	4.176	0.022	282.2	0.55	1	sand beach backed by riprap
	TILL 152	158	8.688	6.358	0.068	280.3	1.0	3	dune-backed
	TILL 153	159	8.773	4.786	0.037	279.4	1.0	3	dune-backed
	TILL 154	160	8.966	6.457	0.051	278.8	1.0	3	dune-backed
	TILL 155	161	8.448	6.267	0.042	278.2	1.0	3	dune-backed
	TILL 156	162	8.409	6.061	0.04	277.6	1.0	3	dune-backed
	TILL 157	163	6.833	5.548	0.031	277	1.0	3	dune-backed

Reach	Transect	DFIRM Transect	D_{HIGH} (m)	D_{LOW} (m)	Beach Slope (tan β)	Wave Dir. (Υ_θ)	Rough-ness (Υ_r)	Approach	Description
Nehalem Spit/ Manzanita	TILL 158	164	7.752	6.112	0.049	279.2	1.0	3	dune-backed
	TILL 159	165	12.218	6.616	0.053	279.7	1.0	3	dune-backed
	TILL 160	166	8.676	6.254	0.063	276.6	1.0	3	dune-backed
	TILL 161	167	7.828	5.901	0.056	273.6	1.0	3	dune-backed
	TILL 162	168	15.433	5.338	0.042	268.4	1.0	3	dune-backed
	TILL 163	169	13.023	5.823	0.043	263.4	1.0	3	dune-backed
	TILL 164	170	14.069	5.912	0.055	265.7	1.0	3	dune-backed
	TILL 165	170	15.75	5.514	0.051	268.4	1.0	3	dune-backed
	TILL 166	172	12.088	4.356	0.034	266.4	1.0	3	dune-backed
	TILL 167	173	12.772	5.616	0.039	266.2	1.0	3	dune-backed
	TILL 168	174	13.313	6.617	0.038	264.6	1.0	3	dune-backed
	TILL 169	175	10.635	7.807	0.075	267.9	1.0	3	dune-backed
	TILL 170	176	9.226	4.313	0.022	268.1	0.7	1	sand beach backed by riprap
	TILL 171	177	8.847	5.064	0.026	271.3	1.0	3	dune-backed
	TILL 172	178	9.502	6.107	0.03	267.6	1.0	3	dune-backed with road
	TILL 173	179	11.496	5.245	0.028	265	1.0	3	dune-backed with road
	TILL 174	180	9.609	5.516	0.027	261.3	1.0	3	dune-backed with road
	TILL 175	181	11.367	4.73	0.029	263	1.0	3	dune-backed
	TILL 176	182	9.012	5.504	0.048	258.9	0.7	3	sand beach backed by extensive cobble berm
	TILL 177	183	6.996	5.077	0.049	257.8	0.55	3	sand beach backed by extensive cobble berm and bluff
	TILL 178	184	7.921	7.894	0.169	227.4	0.55	1	sand beach backed by extensive cobble berm and bluff
Falcon Cove	CP 1	185	15.935	7.027	0.167	278	0.8	1	sand, cobble berm backed by high bluff

Notes:

D_{HIGH} denotes the crest of the dune, bluff, or structure;

D_{LOW} denotes the toe of the dune (i.e., E_j), bluff, or structure;

Beach slope reflects the calculated slope spanning the region between 2- and 4-m elevation;

Wave direction denotes the shoreline orientation used to calculate the wave reduction (Υ_θ) factor used in TAW runup calculations;

Roughness (Υ_r) defines the backshore roughness used in TAW runup calculations. Bold values indicate sites where the local slope goes to 1 due to the presence of a vertical bluff; and

Approach defines the final runup approach used to calculate the wave runup, where STK = Stockdon, Snsh/TAW = nearshore slope and TAW, and LocSlp/TAW = the local barrier slope and TAW.

6.3 Tillamook County Wave Runup and Total Water Level Calculations

The complete hourly combined time series is run through the lookup tables to derive alongshore varying transformed wave time series. Using the transformed wave conditions, and the measured alongshore varying beach and barrier slopes, initial TWL time series based on the Stockdon approach are developed at all transect locations. From these time series we identify the ~150 highest independent TWLs at each transect over the length of the record. Wave runup is then computed for each of these storm input conditions (about 5 events per year) at every profile site shown in **Figure 3-1**, **Figure 3-2**, and **Figure 3-3** using a combination of the Stockdon and others (2006) runup equation for dune-backed beaches (equation 6.4) and TAW (equation 6-12) for wave runup on a barrier. The specific approaches used in our calculations are defined above in **Table 6-1.** For both models, the calculated runup is combined with the SWL (measured tides) to develop the TWL conditions used to generate the 10, 50, and 100-year return level event as well as the 500-year return event. The input wave conditions from the SWAN modeling used in the various calculations were determined for each transect location by extending the shore-perpendicular transects from the backshore to where they intersected the 20-m contour, or the seaward most location of H_{mo}/depth = 0.4, whichever was farther offshore (but almost always shallower than 30 m). This ensured that only minor dissipation due to wave breaking influenced the model results. These intersections are where wave statistics from the SWAN output were extracted.

Having calculated the storm-induced TWLs, we used the generalized extreme value (GEV) family of distributions (specifically the peak over threshold (POT) approach) to estimate the 100-year and 500-year Total Water Levels for each of the beach profile sites. Specific information about the extreme value techniques used to estimate these TWLs is described in Section 4.6. **Figure 6-6** gives an example of the extreme value (GPD-Poisson) model for the TILL 6 profile site in which the 100-year event is calculated to be 11.6 m (38 ft) and the 500-year event is estimated to be 12.6 m (41 ft). The results for all of the profiles can be found in **Table 6-2.**

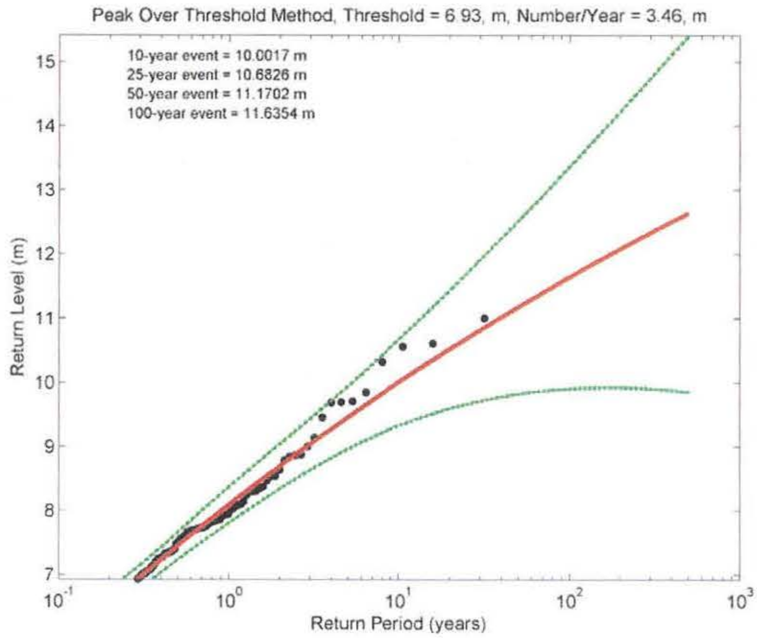


Figure 6-6. Example peak over threshold (POT) extreme value theory results for the Tillamook 6 transect site (with 95% confidence levels) located in the Neskowin littoral cell. Note that the y-axis vertical datum is relative to the NAVD88 vertical datum. Black dots reflect the discrete peak total water level events and the red line is the extreme value distribution fit to those data. Green dashed line reflects the 95% confidence boundary.

Table 6-2. 100-year (1%) and 500-year (0.2%) total water levels calculated for the Tillamook County transect sites.

Reach	Transect	DFIRM Transect	D_{HIGH} (m)	D_{LOW} (m)	100-year (m)	500-year (m)	Description
Salmon River	LINC 308	1	6.251	5.058	9.29	10.62	dune-backed cliff
Cascade Head	LINC 309	2	48.172	1.609	14.13	14.28	plunging cliff
	LINC 310	3	43.56	1.207	13.83	14.01	plunging cliff
	LINC 311	4	24.427	0.358	12.91	13.46	boulder beach backed by bluffs
	LINC 312	5	93.24	2.125	12.4	12.68	plunging cliff
	LINC 313	6	139.103	0	17.29	17.49	plunging cliff
Neskowin	TILL 1	7	47.278	0.764	9.97	10.04	sandy beach backed by riprap and high cliffs
	TILL 2	8	8.684	3.914	8.32	8.91	sand beach backed by riprap
	TILL 3	9	8.452	3.914	8.05	9.23	sand beach backed by riprap
	TILL 4	10	5.184	3.448	7.84	9.18	sand beach backed by riprap
	TILL 5	11	8.312	2.712	10.98	11.53	sand beach backed by riprap
	TILL 6	12	8.447	3.563	11.64	12.64	sand beach backed by riprap
	TILL 7	13	8.169	1.904	12.57	13.09	sand beach backed by riprap
	TILL 8	14	8.539	2.533	11.56	12.24	sand beach backed by riprap
	TILL 9	15	7.075	5.888	7.77	8.02	dune-backed
	TILL 10	16	8.897	6.235	7.79	8.27	dune-backed
	TILL 11	17	6.679	5.604	7.11	7.51	dune-backed
	TILL 12	18	8.374	5.521	7.22	7.60	dune-backed
	TILL 13	19	7.126	5.709	7.34	7.62	dune-backed
	TILL 14	20	8.118	5.086	11.24	12.59	sand beach backed by riprap
	TILL 15	21	7.587	4.642	9.13	9.41	sand beach backed by riprap
	TILL 16	22	6.767	6.014	7.47	7.73	dune-backed
	TILL 17	23	9.986	4.326	6.94	7.25	dune-backed
	TILL 18	24	8.387	5.512	8.66	9.25	dune-backed
	TILL 19	25	6.014	6.014	7.98	8.48	dune-backed
	TILL 20	26	7.648	7.066	10.08	10.68	dune-backed
	TILL 21	27	12.562	5.582	7.46	7.84	dune-backed
	TILL 22	28	6.241	4.489	6.77	7.07	dune-backed
	TILL 23	29	14.334	6.819	10.11	10.95	dune-backed
	TILL 24	30	7.792	7.185	7.95	8.16	dune-backed
	TILL 25	31	7.642	5.627	8.29	8.77	dune-backed
	TILL 26	32	32.562	3.877	9.35	10.11	sandy beach backed by high cliffs
	TILL 27	33	28.194	4.519	9.63	10.07	sandy beach backed by high cliffs
	TILL 28	34	39.310	6.292	8.76	9.08	sandy beach backed by dunes and high cliffs
Nestucca spit/ Pacific City	TILL 29	35	10.245	4.903	7.15	7.49	dune-backed
	TILL 30	36	14.485	5.083	7.31	7.66	dune-backed
	TILL 31	37	15.490	5.933	7.96	8.37	dune-backed
	TILL 32	38	14.358	5.413	9.76	10.32	dune-backed
	TILL 33	39	13.160	5.338	8.74	9.28	dune-backed
	TILL 34	40	15.877	6.611	9.45	10.03	dune-backed
	TILL 35	41	15.147	5.312	7.42	7.84	dune-backed
	TILL 36	42	17.709	5.908	7.58	8.01	dune-backed
	TILL 37	43	12.932	4.389	8.27	8.51	sand beach backed by riprap?
	TILL 38	44	11.283	4.690	7.68	8.12	sand beach backed by riprap?
	TILL 39	45	18.954	5.407	7.12	7.50	dune-backed
	TILL 40	46	11.314	5.539	8.06	8.66	sand beach backed by riprap?
	TILL 41	47	11.060	4.785	7.12	7.55	sand beach backed by riprap?
	TILL 42	48	13.304	4.681	7.81	8.67	sand beach backed by riprap and high bluffs

Reach	Transect	DFIRM Transect	D_{HIGH} (m)	D_{LOW} (m)	100-year (m)	500-year (m)	Description
Sand Lake/ Tierra Del Mar	TILL 43	49	23.369	5.582	7.30	7.67	sandy beach backed by high cliffs
	TILL 44	50	16.741	6.162	8.57	9.02	sandy beach backed by high cliffs
	TILL 45	51	6.868	4.232	10.93	12.05	sandy beach backed by cobbles - grades into bluff
	TILL 46	52	18.071	4.865	10.43	11.18	sandy beach backed by high cliffs
	TILL 47	53	18.396	4.063	9.01	10.64	sand beach backed by riprap
	TILL 48	54	7.412	6.555	7.36	7.71	dune-backed
	TILL 49	55	8.240	6.197	7.19	7.58	dune-backed
	TILL 50	56	6.931	5.891	7.13	7.46	dune-backed
	TILL 51	57	6.317	4.554	9.83	11.96	sand beach backed by riprap
	TILL 52	58	7.721	4.543	10.03	11.37	sand beach backed by riprap
	TILL 53	59	8.141	5.026	7.59	7.96	sand beach backed by riprap
	TILL 54	60	7.462	5.055	8.03	8.52	sand beach backed by riprap
	TILL 55	61	8.094	5.159	7.33	7.85	dune-backed
	TILL 56	62	8.357	4.652	7.29	7.68	sand beach backed by riprap
	TILL 57	63	11.383	4.823	7.00	7.36	sand beach backed by riprap
	TILL 58	64	10.224	6.180	7.11	7.51	dune-backed
	TILL 59	65	12.153	5.720	7.51	7.80	dune-backed
	TILL 60	66	9.595	5.355	7.22	7.63	dune-backed
	TILL 61	67	9.370	6.193	7.37	7.73	dune-backed
	TILL 62	68	6.573	6.260	7.64	8.09	dune-backed
	TILL 63	69	3.380	3.324	5.79	6.04	dune-backed
	TILL 64	70	18.524	6.915	10.87	11.59	dune-backed
	TILL 65	71	18.296	5.556	7.86	8.40	dune-backed
	TILL 66	72	15.211	5.340	7.66	8.14	dune-backed
	TILL 67	73	19.042	8.385	8.70	9.33	sandy beach backed by high cliffs
	TILL 68	74	24.720	6.441	7.08	7.40	sandy beach backed by high cliffs
	TILL 69	75	29.519	5.960	7.65	8.12	sandy beach backed by high cliffs
	TILL 70	76	30.293	4.588	9.71	10.22	sandy beach backed by high cliffs
	TILL 71	77	37.153	4.979	10.25	10.89	sandy beach backed by high cliffs
	TILL 72	78	30.575	4.844	7.30	7.95	sandy beach backed by high cliffs
	TILL 73	79	28.571	6.625	7.57	8.13	sandy beach backed by high cliffs
	TILL 74	80	20.692	5.762	6.82	7.17	sandy beach backed by high cliffs

Reach	Transect	DFIRM Transect	D_{HIGH} (m)	D_{LOW} (m)	100-year (m)	500-year (m)	Description
Netarts Spit/ Oceanside	TILL 75	81	6.775	2.430	9.63	9.99	sandy beach backed by low/high cliffs
	TILL 76	82	7.600	2.937	10.40	11.58	sandy beach backed by cobbles/boulders and low cliff
	TILL 77	83	8.447	3.235	10.38	11.11	sandy beach backed by dynamic revetment/artificial dune
	TILL 78	84	7.298	3.706	10.06	10.97	sandy beach backed by dynamic revetment/artificial dune
	TILL 79	85	10.798	3.976	9.84	11.42	dune-backed (+cobbles)
	TILL 80	86	9.131	5.381	9.15	9.59	dune-backed (+cobbles)
	TILL 81	87	7.159	4.661	8.58	9.13	dune-backed (+cobbles)
	TILL 82	88	11.562	5.040	7.87	8.34	dune-backed
	TILL 83	89	12.413	5.492	7.55	7.86	dune-backed
	TILL 84	90	7.322	6.012	7.34	7.77	dune-backed
	TILL 85	91	11.621	5.370	7.43	7.88	dune-backed
	TILL 86	92	11.763	6.361	7.40	7.83	dune-backed
	TILL 87	93	19.722	4.114	7.36	7.85	dune-backed
	TILL 88	94	6.567	5.720	8.17	8.84	dune-backed
	TILL 89	95	10.543	5.754	7.58	8.04	dune-backed
	TILL 90	96	12.156	4.768	7.33	7.63	dune-backed
	TILL 91	97	9.610	6.516	7.76	8.26	dune-backed
	TILL 92	98	8.324	6.360	7.70	8.20	dune-backed
	TILL 93	99	4.971	4.855	8.52	9.12	Cobble beach backed by low wall (estuary mouth)
	TILL 94	100	14.619	5.554	8.89	9.79	sandy beach backed by high cliffs
	TILL 95	101	29.639	4.999	7.30	8.08	sandy beach backed by high cliffs
	TILL 96	102	39.082	4.536	8.29	9.13	sandy beach backed by high cliffs
	TILL 97	103	55.206	4.631	8.30	8.80	sandy beach backed by dune and high cliffs
	TILL 98	104	60.658	5.832	8.71	9.15	sandy beach backed by dune and high cliffs
	TILL 99	105	33.925	4.907	7.21	7.56	sandy beach backed by high cliffs
	TILL 100	106	36.465	4.585	7.08	7.44	sandy beach backed by high cliffs
	TILL 101	107	13.733	5.191	7.05	7.36	sandy beach backed by poor riprap and low cliffs
	TILL 102	108	18.353	5.953	7.57	8.01	sandy beach backed by moderately high cliffs
	TILL 103	109	8.241	4.068	9.77	10.24	sandy beach backed by moderately high cliffs
Short Sand Beach	TILL 104	110	33.582	3.026	11.00	11.60	sandy beach backed by gravels and high cliffs
	TILL 105	111	26.461	3.932	11.99	12.89	sandy beach backed by gravels and high cliffs
	TILL 106	112	47.152	5.674	14.39	18.27	sandy beach backed by gravels and high cliffs

Reach	Transect	DFIRM Transect	D_{HIGH} (m)	D_{LOW} (m)	100-year (m)	500-year (m)	Description
Bayocean Spit	TILL 107	113	8.705	3.527	11.43	12.49	sandy beach backed by cobble/boulder and low cliffs
	TILL 108	114	7.740	2.981	10.15	10.57	sandy beach backed by cobble/boulder and low cliffs
	TILL 109	115	6.340	3.000	10.39	10.83	sandy beach backed by cobble/boulder berm
	TILL 110	116	6.081	2.495	10.44	10.69	sandy beach backed by cobble/boulder berm
	TILL 111	117	6.863	3.330	10.84	11.71	sandy beach backed by cobble/boulder berm
	TILL 112	118	9.667	6.824	7.34	7.76	dune-backed
	TILL 113	119	11.095	6.670	7.50	7.99	dune-backed
	TILL 114	120	9.781	6.804	7.12	7.50	dune-backed
	TILL 115	121	8.970	4.932	7.22	7.59	dune-backed
	TILL 116	122	10.490	5.889	6.74	6.97	dune-backed
	TILL 117	123	10.053	6.537	7.36	7.89	dune-backed
Rockaway	TILL 118	124	5.932	5.932	7.52	7.99	dune-backed
	TILL 119	125	6.332	4.905	6.93	7.19	dune-backed
	TILL 120	126	6.720	5.370	7.23	7.60	dune-backed
	TILL 121	127	6.749	5.178	7.79	8.18	dune-backed
	TILL 122	128	6.518	5.388	7.29	7.74	dune-backed
	TILL 123	129	7.242	3.130	8.32	8.52	sand beach backed by riprap
	TILL 124	130	6.905	5.820	7.13	7.44	dune-backed
	TILL 125	131	5.489	5.489	6.94	7.20	dune-backed
	TILL 126	132	5.858	4.586	6.06	6.28	dune-backed
	TILL 127	133	7.148	5.709	6.79	7.07	dune-backed
	TILL 128	134	7.976	5.327	7.05	7.42	dune-backed
	TILL 129	135	7.237	5.136	7.07	7.63	dune-backed
	TILL 130	136	7.344	5.839	7.30	7.78	dune-backed
	TILL 131	137	7.032	4.682	7.10	7.60	dune-backed
	TILL 132	138	5.486	3.770	7.34	7.81	sand beach backed by riprap
	TILL 133	139	7.133	5.593	7.26	7.70	dune-backed
	TILL 134	140	10.147	5.680	7.25	7.61	dune-backed
	TILL 135	141	8.387	7.085	7.60	7.89	dune-backed
	TILL 136	142	7.062	5.920	6.85	7.20	sand beach backed by low bluff
	TILL 137	143	6.827	4.000	7.44	8.20	sand beach backed by riprap
	TILL 138	144	6.359	3.045	7.82	8.27	sand beach backed by riprap
	TILL 139	145	8.670	5.263	6.93	7.25	dune-backed
	TILL 140	146	8.923	3.759	9.71	10.57	sand beach backed by riprap
	TILL 141	147	7.643	3.759	10.71	13.99	sand beach backed by riprap
	TILL 142	148	8.305	3.759	10.34	11.71	sand beach backed by riprap
	TILL 143	149	8.196	4.068	9.55	10.34	sand beach backed by riprap
	TILL 144	150	8.305	3.312	10.35	10.88	sand beach backed by riprap
	TILL 145	151	8.092	4.309	8.80	9.77	sand beach backed by riprap
	TILL 146	152	8.176	4.029	8.93	9.79	sand beach backed by riprap
	TILL 147	153	7.927	7.160	7.73	8.15	dune-backed
	TILL 148	154	8.101	5.982	7.80	8.27	dune-backed
	TILL 149	155	8.029	5.997	7.44	7.88	dune-backed
	TILL 150	156	8.315	6.325	7.08	7.37	dune-backed
	TILL 151	157	6.974	4.176	6.17	6.41	sand beach backed by riprap
	TILL 152	158	8.688	6.358	8.24	8.76	dune-backed
	TILL 153	159	8.773	4.786	6.71	7.03	dune-backed
	TILL 154	160	8.966	6.457	7.74	8.35	dune-backed
	TILL 155	161	8.448	6.267	7.21	7.69	dune-backed
	TILL 156	162	8.409	6.061	6.98	7.39	dune-backed
	TILL 157	163	6.833	5.548	6.39	6.67	dune-backed

Reach	Transect	DFIRM Transect	D_{HIGH} (m)	D_{LOW} (m)	100-year (m)	500-year (m)	Description
Nehalem Spit/ Manzanita	TILL 158	164	7.752	6.112	7.62	8.13	dune-backed
	TILL 159	165	12.218	6.616	7.83	8.33	dune-backed
	TILL 160	166	8.676	6.254	8.62	9.40	dune-backed
	TILL 161	167	7.828	5.901	8.13	8.73	dune-backed
	TILL 162	168	15.433	5.338	7.01	7.36	dune-backed
	TILL 163	169	13.023	5.823	6.89	7.17	dune-backed
	TILL 164	170	14.069	5.912	7.66	8.19	dune-backed
	TILL 165	170	15.750	5.514	7.57	8.05	dune-backed
	TILL 166	172	12.088	4.356	6.89	7.27	dune-backed
	TILL 167	173	12.772	5.616	7.05	7.49	dune-backed
	TILL 168	174	13.313	6.617	6.94	7.33	dune-backed
	TILL 169	175	10.635	7.807	8.93	9.58	dune-backed
	TILL 170	176	9.226	4.313	6.35	6.67	sand beach backed by riprap
	TILL 171	177	8.847	5.064	6.48	6.81	dune-backed
	TILL 172	178	9.502	6.107	6.51	6.78	dune-backed with road
	TILL 173	179	11.496	5.245	6.61	6.94	dune-backed with road
	TILL 174	180	9.609	5.516	6.54	6.86	dune-backed with road
	TILL 175	181	11.367	4.730	6.65	7.04	dune-backed
	TILL 176	182	9.012	5.504	7.81	8.51	sand beach backed by extensive cobble berm
	TILL 177	183	6.996	5.077	7.60	8.03	sand beach backed by extensive cobble berm and bluff
	TILL 178	184	7.921	7.894	14.26	15.29	sand beach backed by extensive cobble berm and bluff
Falcon Cove	CP 1	185	15.935	7.027	9.93	10.33	sand, cobble berm backed by high bluff

Notes:

100-year and 500-year total water level (TWL) values relative to NAVD88 vertical datum.

D_{HIGH} is the crest of the dune, bluff, or barrier determined for the eroded profile. *Red text denotes that the crest is overtopped.*

6.4 Overtopping Calculations

Overtopping of natural features such as foredunes, spits, and coastal engineering structures and barriers occurs when the wave runup superimposed on the tide exceeds the crest of the foredune or structure (**Figure 6-7**). Hazards associated with wave overtopping can be linked to a number of simple direct flow parameters including (Pullen and others, 2007):

- mean overtopping discharge, q;
- overtopping velocities over the crest and farther landward, V;
- landward extent of green water and splash overtopping $y_{G,\,outer}$; and
- overtopping flow depth, h at a distance y landward of the foredune crest or "barrier."

NHC (2005) notes that there are three physical types of wave overtopping:

1. *Green water or bore overtopping* occurs when waves break onto or over the foredune or barrier and the overtopping volume is relatively continuous;
2. *Splash overtopping* occurs when the waves break seaward of the foredune or barrier, or where the foredune or barrier is high relative to the wave height and overtopping consists of a stream of droplets. Splash overtopping can be a function of its momentum due to the runup swashing up the barrier and/or may be enhanced due to onshore direct winds; and,
3. *Spray overtopping* is generated by the effects of wind blowing droplets and spray that are derived from the wave crests.

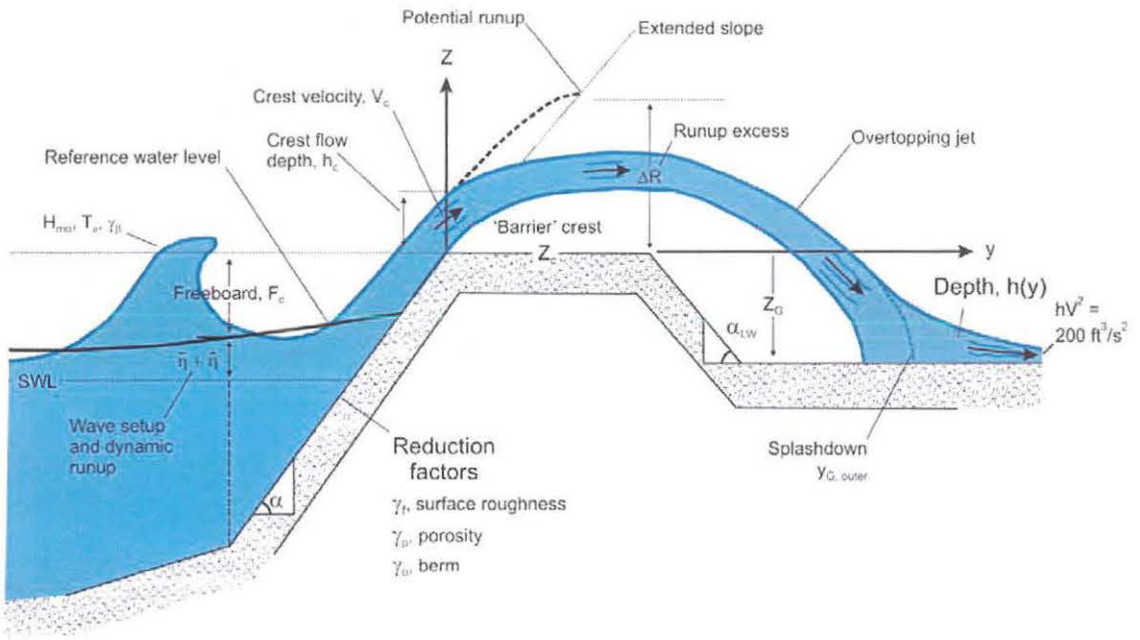


Figure 6-7. Nomenclature of overtopping parameters available for mapping base flood elevations (BFEs) and flood hazard zones (after NHC, 2005).

Mapping these respective flood inundation zones requires an estimate of the velocity, V, the overtopping discharge, q, of the water that is carried over the crest, the inland extent of green water and splash overtopping, and the envelope of the water surface that is defined by the water depth, h, landward of the barrier crest. According to NHC (2005) these hazard zones are ultimately defined from following two derivations:

- Base flood elevations (BFEs) are determined based on the water surface envelope landward of the barrier crest; and
- Hazard zones are determined based on the landward extent of green water and splash overtopping, and on the depth and flow velocity in any sheet flow areas beyond that, defined as $hV^2 = 5.7\ m^3/s^2$ or $200\ ft^3/s^2$.

A distinction can be made between whether green water (or bore) or splash overtopping predominates at a particular location that is dependent on the ratio of the calculated wave runup height relative to the barrier crest elevation, R/Z_c. When $1 < R/Z_c < 2$, splash overtopping dominates; when $R/Z_c > 2$, bore propagation occurs. In both cases, R and Z_c are relative to the 2% dynamic water level ($DWL_{2\%}$) at the barrier (Figure D.4.5-12 in NHC [2005, p. D.4.5-22]).

6.4.1 *Mean overtopping rate at the "barrier" crest*

Wave overtopping of dunes and barrier is a function of both hydraulic and barrier structure parameters whereby:

$$q = f(H_{mo}, T_p, \beta, F_c, DWL_{2\%}, geometry) \qquad (6.14)$$

where q is the overtopping discharge (expressed as cubic meters per second per meter, $m^3/s/m$ [$ft^3/s/ft$]), H_{mo} is the significant wave height at the toe of the structure, T_p is the peak period, β is the angle of wave attack, F_c is the freeboard, and $DWL_{2\%}$ is 2% dynamic water level at the toe of the structure (**Figure 6-7**).

Prior to calculating the mean overtopping rate at the barrier crest it is necessary to distinguish between four contrasting types of wave breaking situations that may impact a particular barrier or dune overtopping situation. There four conditions include *non-breaking* or *breaking* on a normally sloped barrier (where $0.067 < \tan\alpha < 0.67$), and *reflecting* or *impacting* on steeply sloping or vertical barriers (where $\tan\alpha \geq 0.67$). Of these, the breaking wave situation is the dominant condition in Tillamook County, where the waves have already broken across the surf zone and are reforming as bores prior to swashing up the beach face or barrier.

For beaches and normally sloping barriers (where $0.067 < \tan\alpha < 0.67$), a distinction can be made between situations where waves break directly on the barrier versus those conditions where the waves have not yet broken. These conditions can be determined using the surf similarity parameter (Iribarren number) defined here in terms of the beach or structure slope ($\tan\alpha$), and the wave steepness ($S_{op} = H_{mo}/L_o$):

$$\xi_{op} = \frac{\tan\alpha}{\sqrt{\frac{H_{mo}}{L_o}}} = \frac{\tan\alpha}{\sqrt{S_{op}}} \qquad (6.15)$$

Breaking on normally sloping surfaces generally occurs where the surf similarity number, $\xi_{op} \leq 1.8$, while non-breaking conditions occur when $\xi_{op} > 1.8$. As noted above, for the Tillamook County coastline the identified Iribarren numbers almost always fell below the 1.8 criteria, indicating that the incident waves are always broken prior to reaching the beach or the barrier face.

At the beach or barrier crest, the relative freeboard (F_c/H_{mo}), **Figure 6-7**, is a particularly important because changing these two parameters controls the volume of water that flows over the barrier crest. For example, increasing the wave height or period increases the overtopping discharge, as does reducing the beach or barrier crest height or raising the water level.

A variety of prediction methods are available for calculating the overtopping discharge and are almost entirely based on laboratory experiments using a range of structure slopes (slopes between 1:1 and 1:8, with occasional tests at slopes around 1:15 or lower). Factors that will serve to reduce the potential overtopping discharge include the barrier *surface roughness* (γ_f), the presence of a *berm* (γ_b), *wave approach directions* (γ_β), and the *porosity* of the barrier (γ_p) (**Figure 6-7**). In terms of porosity, increasing this variable effectively reduces the wave runup and overtopping discharge because more of the water is able to be taken up by the voids between the clasts and particles. As noted in NHC (2005), the effect of the *porosity* factor makes it convenient to distinguish between impermeable and permeable structures. Methods for determining the various reduction factors are described in Table D.4.5-3 in NHC (2005, p. D.4.5-13), with one difference whereby the approach recommended for determining the wave approach (γ_β) reduction factor for wave overtopping calculations is based on the following equation:

$$\gamma_\beta = \begin{Bmatrix} 1 - 0.0033|\beta|, (0 \le |\beta| \le 80°) \\ 1 - 0.0033|80|, (|\beta| \ge 80°) \end{Bmatrix} \qquad (6.16)$$

Table D.4.5-3 in NHC (2005, p. D.4.5-13) identifies four general categories of overtopping applications: overtopping on a normally sloping barrier (e.g., riprap structure), steep sloping or vertical barrier (e.g., seawall or bluff where some waves broken); steep sloping or vertical barrier (all waves broken); and shallow foreshore slopes subject to large Iribarren numbers.

For a normally sloping barrier, where $0.05 < \tan\alpha < 0.67$ and the Iribarren number (ξ_{op}) ≤ 1.8 (breaking wave condition), the following formulation can be used to determine the mean overtopping discharge (both dimensional [q] and non-dimensional [Q] forms) at the barrier crest:

$$q = Q\sqrt{\frac{gH_{mo}\tan\alpha}{S_{op}}} \text{ where:} \qquad (6.17)$$

$$Q = 0.06e^{-4.7F'} \text{, and}$$

$$F' = \frac{F_c}{H_{mo}} \frac{\sqrt{S_{op}}}{\tan\alpha} \frac{1}{\gamma_f\gamma_b\gamma_\beta\gamma_p}$$

For non-breaking conditions (Iribarren number (ξ_{op}) > 1.8):

$$q = Q\sqrt{gH_{mo}^3} \text{ where:} \qquad (6.18)$$

$$Q = 0.2e^{-2.3F'} \text{, and}$$

$$F' = \frac{F_c}{H_{mo}} \frac{1}{\gamma_f\gamma_\beta}$$

For steep sloping or vertical barrier, where $\tan\alpha > 0.67$ and $h_* \ge 0.3$ (reflecting conditions where

$$h_* = \frac{h}{H_{mo}}\left(\frac{2\pi h}{gT_m^2}\right)$$

and h is the water depth at the structure toe), the following formulation can be used:

$$q = Q\sqrt{gH_{mo}^3} \text{ where:} \qquad (6.19)$$

$$Q = 0.05e^{-2.78F_c/H_{mo}}$$

For impacting conditions ($h_* < 0.3$):

$$q = Q\sqrt{gh^3}\, h_*^2 \text{ where:} \qquad (6.20)$$

$$Q = 1.37 * 10^{-4}(F')^{-3.24} \text{, and}$$

$$F' = \frac{F_c}{H_{mo}} h_*$$

For steep sloping or vertical barrier (all waves are broken) where the structure toe < $DWL_{2\%}$ water level and where $(F_c/H_{mo})*h_* \le 0.03$:

$$q = Q\sqrt{gh^3}\, h_*^2 \text{ where:} \qquad (6.21)$$

$$Q = 0.27 * 10^{-4} e^{-3.24\,(F_c/H_{mo})h_*}$$

For steep sloping or vertical barrier (all waves are broken) where the structure toe > $DWL_{2\%}$ water level:

$$q = Q\sqrt{gh^3}\, h_*^2 \text{ where:} \qquad (6.22)$$

$$Q = 0.06e^{-4.7\,F_c S_{op}^{-0.17}}$$

We have implemented two additional overtopping calculations following discussions with Dr. W. G. McDougal, which may be applied to beaches subject to gently sloping ($\tan\beta < 0.4$), dissipative foreshores:

$$q = Q\sqrt{gh^3}h_*^2 \text{ where:} \quad (6.23)$$

$$Q = 0.21\sqrt{gH_{mo}^3}e^{-F\prime}\text{, and}$$

$$F' = \frac{F_c}{\gamma_f\gamma_\beta H_{mo}(0.33 + 0.022\xi_{op})}$$

and cases where there is negative freeboard. The latter occurs when the dynamic water level (DWL2%) is higher than the barrier crest, which produces a negative freeboard (i.e., $-F_c$). In this situation we apply the well-known weir type formula to define the volume of water that is overflowing the crest (Eurotop, 2007). The formulation used is:

$$q = Q_s + q_w \text{ where:} \quad (6.24)$$

$$Q_s = 0.4583(-F_C)\sqrt{-F_C g}\text{,}$$

$$Q_w = 0.21\sqrt{gH_{mo}^3}\text{, and}$$

$$q_w = Q_w\sqrt{gh^3}h_*^2$$

6.4.2 Overtopping limits and flood hazard zones landward of the "barrier" crest

Estimates of the landward limit of the splashdown distance associated with wave overtopping and the landward limit of the hazard zone require several calculation steps. These include:

1. The following three initial parameters are first calculated:
   a. excess potential runup: $\Delta R = R - Z_c$;
   b. crest flow rate, $V_c \cos\alpha$ (where $V_c = 1.1\sqrt{g\Delta R}$ for cases where splash overtopping, and $V_c = 1.8\sqrt{g\Delta R}$ for bore overtopping); and
   c. initial flow depth, h_c (where $h_c = 0.38\Delta R$).

2. The associated onshore wind component, *Wy*, is determined from available wind data. For the purposes of this study, we used *Wy* = 19.6 m/s (64.3 ft/s), which was determined from an analysis of winds (mean from a select number of storms) measured at the Cape Arago C-MAN station operated by the NDBC. In the absence of wind data, NHC (2005) recommends a wind speed of 13.4 m/s (44 ft/s).
3. The enhanced onshore water velocity component $(V_c \cos\alpha)'$ is then calculated using equation 6.25:

For vertical bluffs and seawalls;

$$(V_c \cos\alpha)' = 0.3 * W_y \quad (6.25)$$

All other cases:

$$(V_c \cos\alpha)' = V_c \cos\alpha + 0.3(W_y - V_c \cos\alpha)$$

4. The effective angle, α_{eff}, is calculated from:

$$\tan\alpha_{eff} = \frac{V_c \sin\alpha}{(V_c \cos\alpha)'}.$$

5. Having determined the above parameters, the outer limit of the splash region, $y_{G\ outer}$ is calculated using equation 6.26. Here we have used an algorithm developed by Dr. W. G. McDougal (Coastal Engineer, OSU and Technical Coordinator of the North Pacific FEMA West Coast Guidelines) of the form:

$$y_{G\ outer} = \frac{(V_c \cos\ \alpha)'}{g} * V_c \sin\ \alpha - mBackshore * (V_c \cos\ \alpha)' * \qquad (6.26)$$

$$1 + \sqrt{1 - \frac{2g * bBackshore}{(V_c \sin\ \alpha - mBackshore * (V_c \cos\ \alpha)'^2)}}$$

and

$$Z_G = bBackshore + (mBackshore * y_{G\ outer}) \qquad (6.27)$$

where *bBackshore* is the intercept for the backshore slope adjacent to the barrier crest and mBackshore is the slope of the backshore. equation 6.26 is ultimately based on Figure D.4.5-15 in NHC (2005, p. D.4.5-30).

6. The total energy, *E*, of the splashdown is calculated from $E = \Delta R\text{-}Z_G$.
7. Finally, the initial splashdown velocity, V_o (where $V_o = 1.1\sqrt{gE}$), and depth, h_o (where $h_o = 0.19E$) are calculated. In the case of green water or bore overtopping, the splashdown velocity, V_o, can be calculated from $V_o = 1.1\sqrt{g\Delta R}$, while the flow depth is determined as $h_o = 0.38E$.

Having determined the initial splashdown velocity, V_o, and flow depth, h_o, the landward extent of the overland flow is calculated using an approach modified from that originally proposed by Cox and Machemehl (1986). The version presented by NHC (2005) effectively calculates the flow depth, *h*, with distance, *y*, from the barrier crest, such that the flow depth decays asymptotically as y-distance increases away from the barrier crest, eventually approaching zero. The NHC (2005) equation is shown as equation 6.28:

$$h(y) = \left[\sqrt{h_o} - \frac{5(y - y_o)}{A\sqrt{gT^2}}\right]^2 \qquad (6.28)$$

where h_o is determined from step 7 above and for an initial approximation the nondimensional *A* parameter may be taken as unity. For sloping backshores, the *A* parameter in equation 6.28 can be modified such that $A_m = A(1 - 2 * \tan \alpha_{LW})$, and the value in parentheses is limited to the range 0.5 to 2. According to NHC (2005) if the maximum distance of splash or bore propagation calculated using equation 6.28 does not appear reasonable or match field observations, the *A* parameter can be adjusted in order to increase or decrease the landward wave propagation distance. In addition, for green water or bore propagation the *A* parameter value is taken initially to be 1.8.

For the purposes of this study we have adopted a modified version of equation 6.28 developed by Dr. W. G. McDougal of the form:

$$h(y) = \left[h_o^{1/2} - \frac{y - y_o}{2\alpha(\alpha+1)^{\frac{3}{2}}(1-2m)\, g^{0.5} T} \right]^2 \qquad (6.29)$$

where m is the slope of the backshore and α is a constant that can be varied in order to increase or decrease the landward wave propagation distance.

Finally, the landward limit of the hazard zone defined as $hV^2 = 5.7\ m^3/s^2$ (or 200 ft^3/s^2) is determined, whereby h is the water depth given by the modified Cox and Machemehl (1986) method (equation 6.29) and $V = V_o$ calculated from step 7 above.

6.4.3 Initial testing of the landward limit of wave overtopping

Our initial computations of the landward extent of wave overtopping using the steps outlined above yielded narrow hazard zones for our original coastal FIRM study in Coos County. To calibrate equation 6.29, we performed wave overtopping calculations and inundation for a site on the northern Oregon coast where there are field observations of wave overtopping: Cape Lookout State Park in Tillamook County (Allan and others, 2006; Allan and Komar, 2002a; Komar and others, 2003). The southern portion of Cape Lookout State Park is characterized by a wide, gently sloping, dissipative sand beach, backed by a moderately steep gravel berm and ultimately by a low foredune that has undergone significant erosion since the early 1980s (Komar and others, 2000).

On March 2-3, 1999, the crest of the cobble berm/dune at Cape Lookout State Park was overtopped during a major storm; the significant wave heights reached 14.1 m (46.3 ft), while the peak periods were 14.3 s measured by a deepwater NDBC wave buoy (Allan and Komar, 2002b). Wave overtopping of the dune and flooding extended ~70 m (230 ft) into the park (Dr. P. Komar, Emeritus Professor, College of Oceanic and Atmospheric Sciences, pers. comm., 2010), evidence for which included photos and field evidence including pockmarks at the bases of tree trunks located in the park. These pockmarks were caused by cobbles having been carried into the park from the beach by the overtopping waves, where the cobbles eventually slammed into the bases of the trees as ballistics. Because the average beach slopes at Cape Lookout State Park are analogous to those observed elsewhere along the Tillamook County coastline and because large wave events associated with extratropical storms affect significant stretches (100s to 1000 kilometers) of the coast at any single point in time, we believe these data provide a reasonable means in which to investigate a range of alpha (α) values that may be used to determine the landward extent of wave inundation in the park.

Using beach morphology data (slope ($\tan \beta$) = 0.089, barrier crest = 5.5 m [18 ft]) from Cape Lookout State Park and deepwater wave statistics from a nearby NDBC wave buoy (#46050), we experimented with a range of alpha values in order to replicate the landward extent of the inundation. As can be seen in **Figure 6-8**, in order to emulate the landward extent of flooding observed at Cape Lookout our analyses yielded an alpha of 0.58. Using alpha = 0.58, we in turn calculated the extent of the hazard zone where $h(y)$ = 200 ft^3/s^2, which was found to be ~34 m from the crest of the cobble berm/dune, consistent with damage to park facilities.

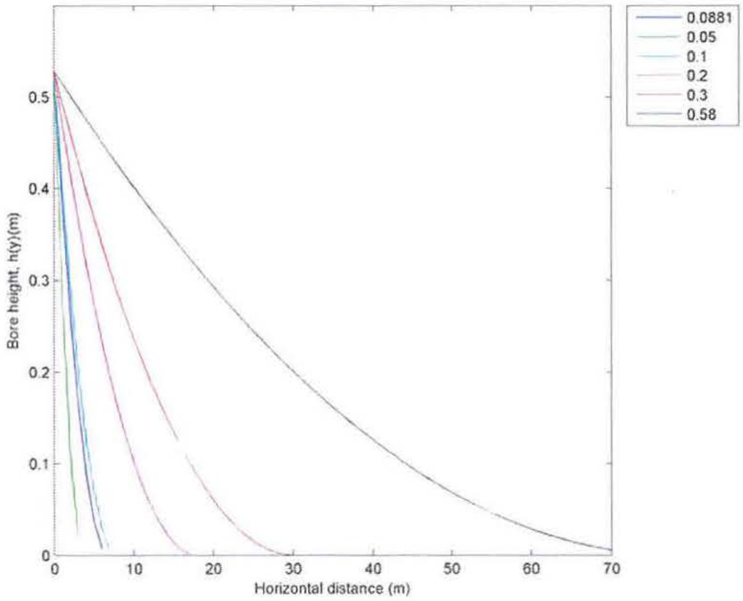


Figure 6-8. Calculations of bore height decay from wave overtopping at Cape Lookout State Park at the peak of the March 2-3, 1999, storm based on a range of alpha (α) values (shown in small box).

6.4.4 Wave overtopping and hazard zone limits calculated for Tillamook County

Table 6-3 presents the results of the calculated splashdown distances ($y_{G\,outer}$) and the landward extent of the flow (hV^2) where the flows approach 5.7 m^3/s^2 (or 200 ft^3/s^2). **Table 6-3** includes a more conservative splashdown distance, based on an enhanced wind velocity of 19.6 m/s (64.3 ft/s); this contrasts with the default wind speed of 13.4 m/s (44 ft/s) suggested by NHC (2005). This enhanced wind velocity was determined from an analysis of wind speeds measured by the Cape Arago C-MAN (http://www.ndbc.noaa.gov/station page.php?¬station=CARO3) station located adjacent to the mouth of Coos Bay (Allan and others 2012b). Essentially, Allan and others examined the wind speeds identified at Cape Arago for a range of storm events and identified a wide range of values, with a maximum mean wind speed of 19.6 m/s (64.3 ft/s). Because the measured wind speeds reflect a 2-min average such that higher wind speeds have been measured throughout the entire record (e.g., the maximum 2-minute average wind speed is 29.3 m/s [96 ft/s], while the maximum 5-s wind gust reached 38.1 m/s [125.0 ft/s]), we believe it is justified to use the more conservative enhanced wind velocity of 19.6 m/s (64.3 ft/s). Furthermore, comparisons by Allan and others (2012b) indicated that the relative difference between the value suggested by NHC (2005) and the enhanced wind used here differs by about 30%. As can be seen from the **Table 6-3**, the calculated splash-down distances ($y_{G\,outer}$) indicate splash distances that range from as little as 0.9 m (3 ft) to a maximum of 5.9 m (19.4 ft); the mean splash distance is 2.9 m (9.6 ft), while the standard deviation is 1.6 m (5.2 ft). Thus, adopting the reduced wind velocity would cause the zones to narrow by ~1.8 m for the highest splash distance and 0.3 m for the smallest. Overall, these differences are negligible given the tremendous uncertainties in calculating splash and overtopping (NHC, 2005).

Table 6-3. Splashdown and hazard zone limits calculated for Tillamook County detailed coastal sites. Values reported in the table reflect the maximum values derived from all the storm runup and overtopping calculations. Note: Dist_3, Dist_2, and Dist_1 reflect the landward extent at which the calculated bore height decreases from 0.9 m (3 ft), to 0.6 m (2 ft) and, finally, to 0.3 m (1 ft). In all cases, the hazard zones are ultimately defined relative to the location of the dune/structure crest.

Profiles	Transect	DFIRM Transect	Splashdown $y_{G\ outer}$ (m)	Bore Ht (m)	Dist_3 (≥0.91 m)	Dist_2 (>0.61 <0.91 m)	Dist_1 (≤0.31 m)	$hV^2 > 5.7m^3/s^2$ (m)
Salmon River	LINC 308	1	1.4	0.57			2.66	36.24
Neskowin	TILL 4	10	4.64	0.48			19.79	36.33
	TILL 5	11	6.54	0.50			21.97	39.86
	TILL 6	12	2.30	0.53			17.37	31.08
	TILL 7	13	7.69	0.82		14.24	39.89	64.60
	TILL 8	14	4.29	0.54			24.21	43.10
	TILL 9	15	1.29	0.15				
	TILL 11	17	0.33	0.04				
	TILL 13	19	1.15	0.05				
	TILL 14	20	2.73	0.55			26.58	47.15
	TILL 15	21	5.62	0.51			22.03	39.86
	TILL 16	22	1.59	0.16				
	TILL 18	24	3.74	0.29				
	TILL 19	25	2.55	0.42			14.05	26.84
	TILL 20	26	1.77	0.45			17.56	32.79
	TILL 22	28	1.30	0.11				
	TILL 24	30	0.77	0.04				
	TILL 25	31	0.69	0.08				
Sand Lake	TILL 45	51	1.00	0.68		7.52	47.53	80.16
	TILL 50	56	2.33	0.13				
	TILL 51	57	5.49	0.76		10.30	36.60	60.29
	TILL 52	58	4.71	0.51			18.23	32.88
	TILL 54	60	2.03	0.16				
	TILL 62	68	0.37	0.19				
	TILL 63	69	0.19	0.44			15.82	29.75
Netarts	TILL 75	81	2.24	0.52			30.63	54.94
	TILL 76	82	5	0.6			39.42	68.39
	TILL 77	83	10.79	1.33	27.1	51.41	83.07	123.33
	TILL 78	84	11.97	1.57	43.8	69.78	103.84	150.1
	TILL 80	86						
	TILL 81	87	1.1	0.24				
	TILL 88	94	4.53	0.48			20.98	38.47
	TILL 93	99	1.27	0.66		4.84	37.22	63.07
	TILL 103	109	3.78	0.37			7.02	14.21
Bayocean Spit	TILL 107	113	2.40	0.46			15.18	28.24
	TILL 108	114	1.51	0.44			14.67	27.56
	TILL 109	115	0.74	0.76		13.67	48.34	79.62
	TILL 110	116	2.21	0.81		18.46	53.68	87.21
	TILL 111	117	6.14	0.94	1.76	27.24	60.44	95.45

Profiles	Transect	DFIRM Transect	Splashdown $y_{G\,outer}$ (m)	Bore Ht (m)	Dist_3 (≥0.91 m)	Dist_2 (>0.61 <0.91 m)	Dist_1 (≤0.31 m)	$hV^2 >$ $5.7m^3/s^2$ (m)
Rockaway	TILL 118	124	1.83	0.33			2.95	6.84
	TILL 119	125	1.23	0.12				
	TILL 120	126	0.81	0.10				
	TILL 121	127	1.72	0.21				
	TILL 122	128	0.86	0.15				
	TILL 123	129	9.34	1.06	8.87	30.77	59.32	91.65
	TILL 124	130	0.22	0.05				
	TILL 125	131	1.99	0.31			0.56	2.10
	TILL 126	132	0.77	0.04				
	TILL 131	137	2.03	0.10				
	TILL 132	138	0.77	0.34			4.69	10.02
	TILL 137	143	0.58	0.02				
	TILL 138	144	1.55	0.27				
	TILL 140	146	1.71	0.15				
	TILL 141	147	2.84	0.52			24.25	43.49
	TILL 142	148	5.79	0.57			26.12	45.86
	TILL 143	149	6.12	0.49			18.26	33.29
	TILL 144	150	3.93	0.32			1.34	3.48
	TILL 145	151	1.58	0.12				
	TILL 146	152	0.92	0.14				