Technical Memorandum

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To: Wendie Kellington, Kellington Law Group

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

Date: May 27, 2021

Subject: Supplement to the March 2021 Pine Beach Revetment Technical Memorandum

1. Introduction

Pine Beach subdivision and George Shand Tracts (Ocean Boulevard Properties) - together we refer to them as the "Subject Properties - are located on the Oregon coast about 2 miles south of Rockaway Beach in the northwest part of Oregon (Figure 1). These landowners along the oceanfront have been losing portions of their property from coastal erosion, and experience coastal flooding during high tides combined with high wave run-up as was the case with the King Tides on February 8-12, 2020. During this event, the maximum stillwater level reached the ocean front 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' structures, land, and infrastructure without the proposed revetment.

WEST Consultants, Inc. (WEST) was contracted by Kellington Law Group 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.

Recently, the Department of Land Conservation and Development (DLCD) sent a letter to Tillamook County about the proposed protective structure on the Subject Properties. The letter identified some concerns related to WEST's March 2021 technical memorandum and are identified as: (1) alternative evaluations; (2) assessment of potential impacts; and (3) references. This technical memorandum documents the responses to these concerns.

Figure 1. Location map

2. Alternatives

Various alternatives were considered for the site, but not documented in the March 2021 technical memorandum. It is important to state the objective and constraints for the proposed structure. The proposed revetment is required to reduce the risk of damage to life, property, and the natural environment from beach erosion and coastal flooding resulting from large waves occurring during high tides. The proposed structure is entirely contained within the existing backyards of the oceanfront properties, and it cannot adversely impact beach access. The project constraints limit the available measures that can be constructed at the site. The alternatives considered are summarized in Table 1.

Table 1. Summary of Alternatives

Alternative	Description	Discussion
1	Do Nothing	Does not meet the project objectives
2	Rock Revetment	Rock revetment was selected because it meets the project objectives within the defined constraints, it is flexible and will accommodate settlement. It is easy to maintain and modify, resistant to damage by debris, absorbs and dissipate wave energy in lieu of reflecting it, and results in less wave runup and overtopping than a vertical wall structure.
3	GeoTube Revetment	GeoTube is a proprietary product manufactured by TenCate. The geotextile tubes that can be filled with sand and/or gravel material. They allow for some differential settling, but a rock apron would be required to prevent undermining of the structure. Designs were provided by TenCate, and preliminary plan sheets were prepared. This alternative was not selected because of concerns with impacts to the northern beach access trail and a lack of construction contractors experienced with the product in Oregon.
4	Gabion Revetment	Gabions are wire or geo-textile baskets that are filled with cobbles. This alternative was not selected because of concerns with durability of baskets over the project life.
5	Retaining Wall	Construction of a timber or concrete wall would meet the objective of reducing erosion associated with coastal flooding risks. However, wall structures can increase beach erosion at the toe of the structure, increase wave runup, and reflect waves away from the structure (USACE, 2011). Deep foundations for the structure would also be required. Due to these factors this alternative eliminated from further consideration.
6	Dynamic\Cobble Revetment	A dynamic revetement is a structure that is composed of gravels and cobbles that can adjust the beach profile according to the involved wave conditions, resulting in reduced wave reflection and increased wave dissipation. These structures require a large volume of gravels\cobbles and space. Also, it would require material to be allowed to move within the active beach. This type of structure cannot be constructed because of the project area constraints and was eliminated from further consideration.
7	Bio-engineering (Drift)	Bio-engineering is the use of living plant materials to provide some engineering function. The only potential viable option is to implement driftwood, which does not qualify as a true bio-engineering option. This option would require some form of anchor (rock ballast or mechanical anchors) to ensure the wood does not float and be transported by the ocean. This alternative was not selected because of concerns with undermining and potential impacts to the northern beach access.
8	"Breakwater" Ocean Barrier	Breakwaters are built offshore to protect a part of the shoreline. This option was not considered due to its extreme unlikelihood of success, cost, time it would take to get permitting approval if any, and the fact that it is not located on the subject properties.

3. Potential Impacts

The proposed revetment will be located within the Rockaway Beach littoral cell. This littoral cell extends from Cape Falcon on the north to Cape Madreas on the south, a distance of about 20 miles. This littoral cell has three subregions: (1) Nehalem, which is the area north of the Nehalem Bay jetties; (2) Rockaway, which is the area between Nehalem Bay and Tillamook Bay; and (3) Bayocean, which is the area south of the Tillamook Bay jetties. The proposed project would be located in the Rockaway subregion (between Nehalem Bay and Tillamook Bay).

Approximately 5.6% (5,930 ft of 106,200 ft) of the entire Rockaway Beach littoral cell has some riprap or concrete wall revetment. Figure 2 shows where revetments are located within the Rockaway subregion (the area between Nehalem Bay and Tillamook Bay). This does not count the four jetties in the cell. The proposed 880-foot-long riprap revetment for the Subject Properties will increase the total revetment length in the entire Rockaway Beach littoral cell to 6,810 feet, an increase of 0.8%. When considering the Rockaway subregion, the proposed revetment will increase the percentage already comprised of rock/wall revetments from 18.6% to 21.4% (a 2.8% increase), again not counting the jetties.

There are two inlets with coastal jetties that have had a significant influence on the sediment longshore transport and beach geomorphology (DOGAMI, 2014) within the Rockaway Beach littoral cell: (1) Tillamook Bay, which is about 5 miles north of Cape Madreas (north jetty was constructed in 1914 while the south jetty was constructed in 1974); and (2) Nehalem Bay, which is about 6 miles north of Tillamook Bay (south jetty was constructed in 1916 while the north jetty was constructed in 1918). A historic perspective on the changes to the shoreline as a result of these jetties taken from in *Evaluation of Erosion Hazard Zones for the Dune-Backed Beaches of Tillamook County, Oregon* (DOGAMI, 2014) is as follows:

> "*Construction of Tillamook's north jetty was completed in October 1917. During the construction phase, changes in the inlet channel and the adjacent shorelines soon became evident (Figure 2-22). North of the jetty, sand began to accumulate 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 about 1 km (0.62 mi). However, by 1920 the rate of sand accumulation on the north side of the jetty had slowed dramatically, so that the position of the shoreline was much the same as it is today*". Note: Figure 2-22 is shown in Figure 3)."

The pronounced accretion is also noted in the geologic inspection of the Pine Beach Development completed by Paul D. See and Associates, Inc. for Handforth Larson & Barrett, Inc in 1994 where it is stated that the shoreline had accreted westerly at least 1,000 feet since at least 1939. The proposed revetment is necessary because the long period of prograding has reversed and the shoreline has seen a steady reduction to the point that the subject properties are significantly threatened.

For the WEST March 2021 technical memorandum, the top of shoreline (identified using vegetation) near the subject properties was determined for the various years available from Google Earth for the period between 1994 and 2019. Additional resources on changes in the shoreline were obtained and are discussed in the following paragraphs.

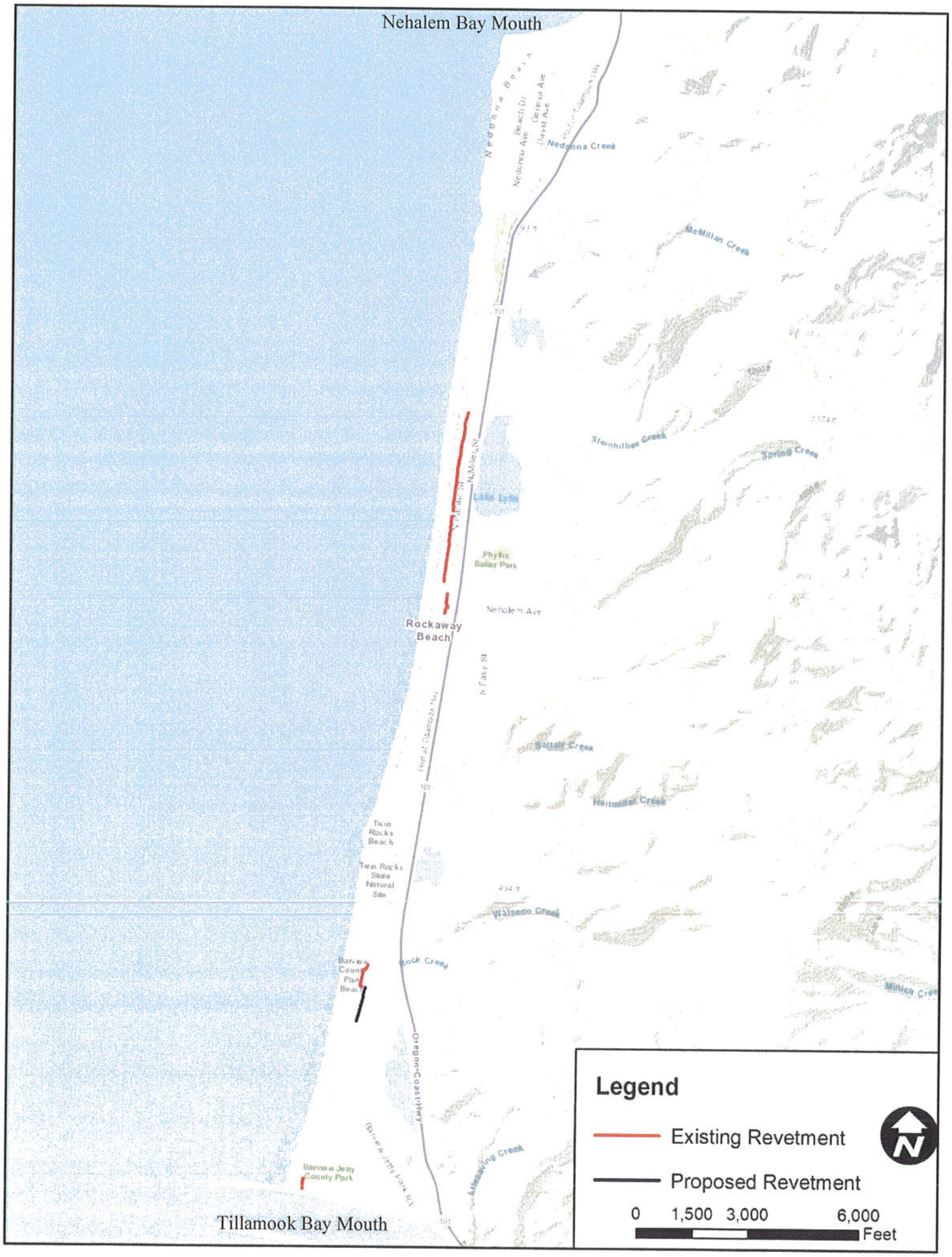

Figure 2. Existing and proposed revetment with Rockaway Beach subregion of the littoral cell (the area between Nehalem Bay and Tillamook Bay)

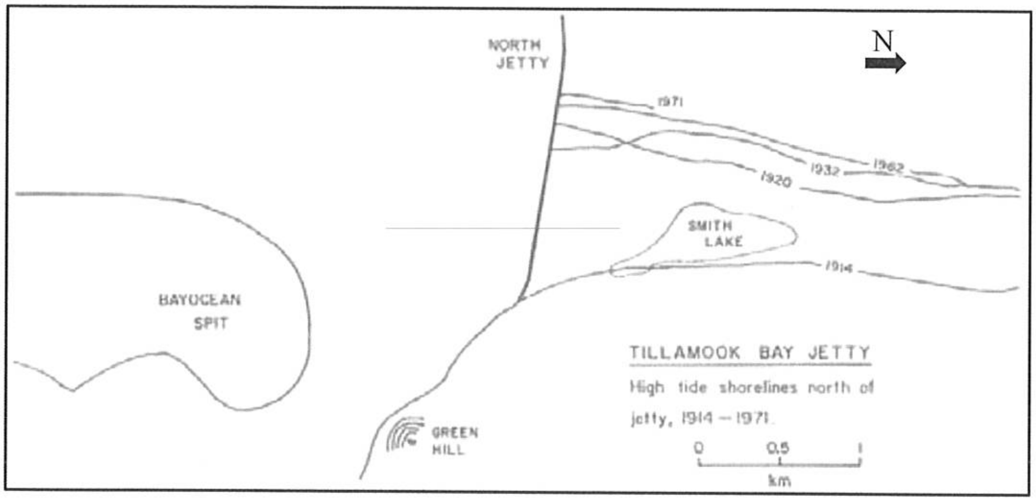

Figure 3. Shoreline positions north of Tillamook Bay north jetty (DOGAMI, 2014)

As indicated in *National Assessment of Shoreline Change: Historical Change Along the Pacific Northwest* (USGS, 2012), the entire Rockaway littoral cell experienced erosion acute from the mid-1990s with pronounced erosion occurring during the winter 1997-8 (El Nino event) and winter 1998-9 (La Nina event). This document provides information related to long- (1880s through 2002) and short- (1960s through 2002) shoreline change rates for the various littoral cells along the Pacific North coast. This reference indicates that the long-term shoreline change rate for the Rockaway littoral cell is about 1 ± 1 foot/year of accretion, while the short-term shoreline change is 2 ± 0.3 foot/year of accretion. This reference also includes a figure that shows the short- and long-term shoreline change rates within littoral cells. The long-term shoreline change rate at the Subject Properties is about +6.6 feet/year, while the short-term shoreline change rate is about -5.0 feet/year.

Evaluation of Erosion Hazard Zones for the Dune-Backed Beaches of Tillamook County, Oregon (DOGAMI, 2014) documents an evaluation to define future projections of shoreline for six hazard levels that considers sea level rise and total water levels. Figure 4 shows the erosion hazard zones (from higher to lower hazard) at the proposed revetment site. This figure shows that without protection, erosion will eventually overtake not only the subject properties, but much of the community of Watseco. The revetment structure is necessary to reduce the coastal erosion risk for these properties. Note that the "rip rap" scenarios are hatched on the figure because rip rap is expected to protect the protected properties from erosion that would otherwise occur.

It should be noted that the Rockaway subregion (the area between Nehalem Bay and Tillamook Bay) is experiencing unique erosion compared to other areas of Tillamook County. This is evident in Figure 3-11 (see Figure 5) from Coastal Flood Hazard Study, Tillamook County, Oregon (DOGAMI, 2015).

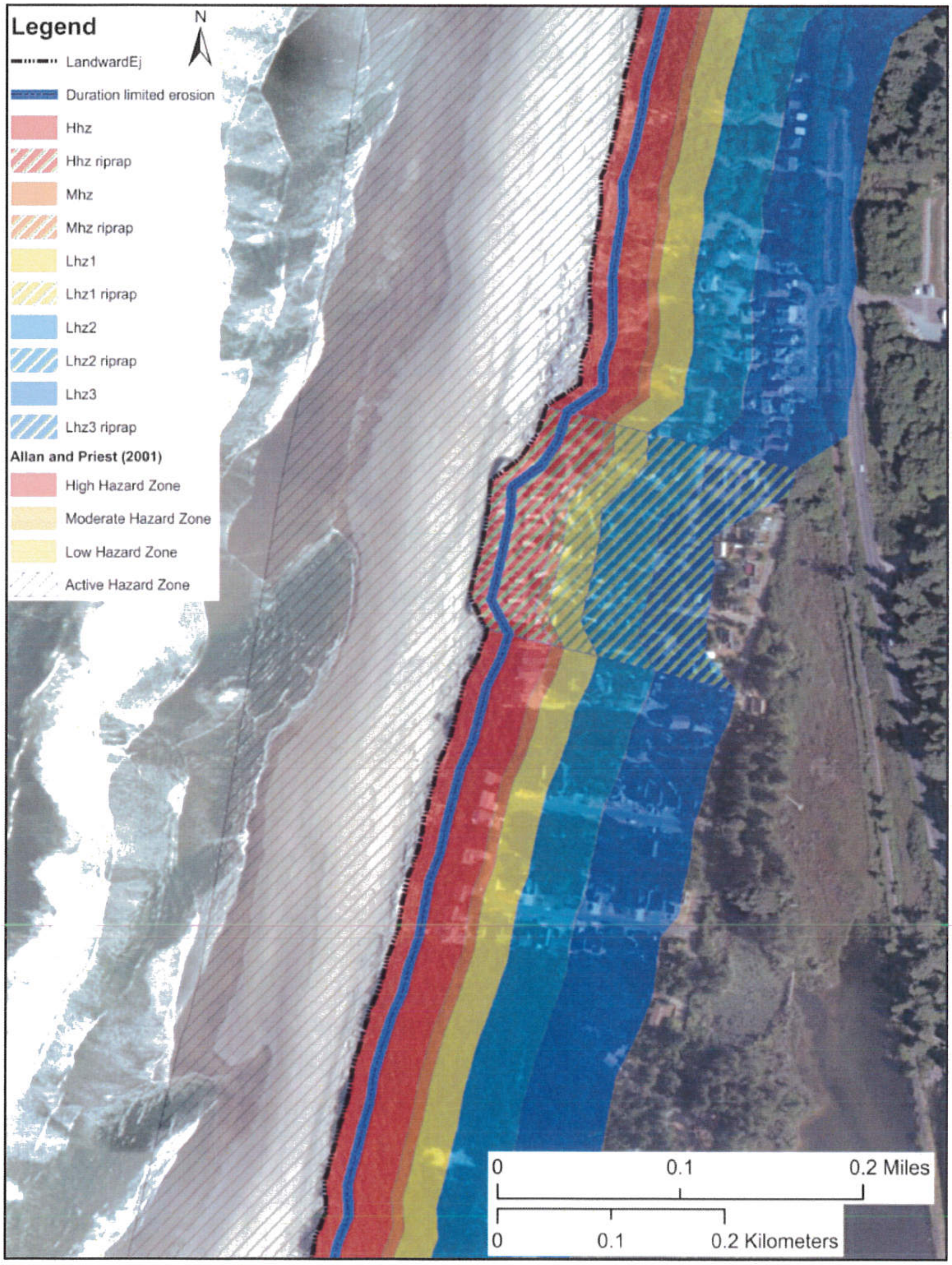

Figure 4. Future dune edge at proposed revetment site (DOGAMI, 2014)

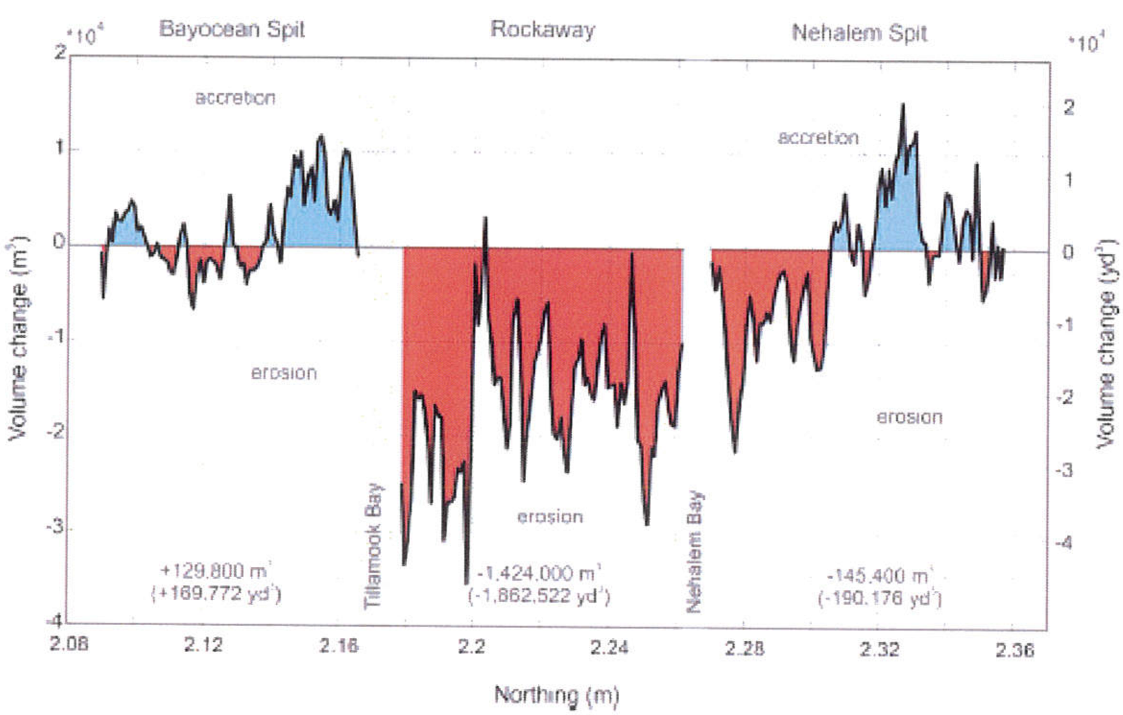

Figure 5. Net beach sediment volume changes along Rockaway littoral cell between 1997-2002 (DOGAMI, 2015)

Another source of useful information related to shoreline changes is ongoing beach monitoring data available from the Northwest Association of Networked Ocean Observing Systems (NANOOS) website (NANOOS, 2021) for the period between 1997 and 2021. Figure 6 shows the monitoring locations within the Rockaway Beach littoral cell. Rockaway2 is the closest monitoring location to the project site, and it is located about 1,400 feet south of the Pine Beach Development. Figure 7 shows the three types of graphs available for each location: (1) beach profiles for selected days, ± 1 standard deviation (σ) profiles to capture the 68% of natural variability, and maximum/minimum based on all available survey data; (2) contour change plots (heights of 3, 4, 5, and 6 meters); and (3) shoreline change trend determined at the 6-meter contour elevation. A review of these plots for Rockaway2 indicate: (1) the natural variability in the bed ranges from ±1.4 feet at an elevation of 6 feet to ±2 feet at an elevation of 16 feet, (2) variability is most pronounced at elevation 10 feet and decreases up to elevation 16 feet with no variability existing at elevation 20 feet; and (3) the 20 feet contour shoreline change rate is about -1.18 ± 0.07 feet per year (-0.36 ± 0.02 m/yr).

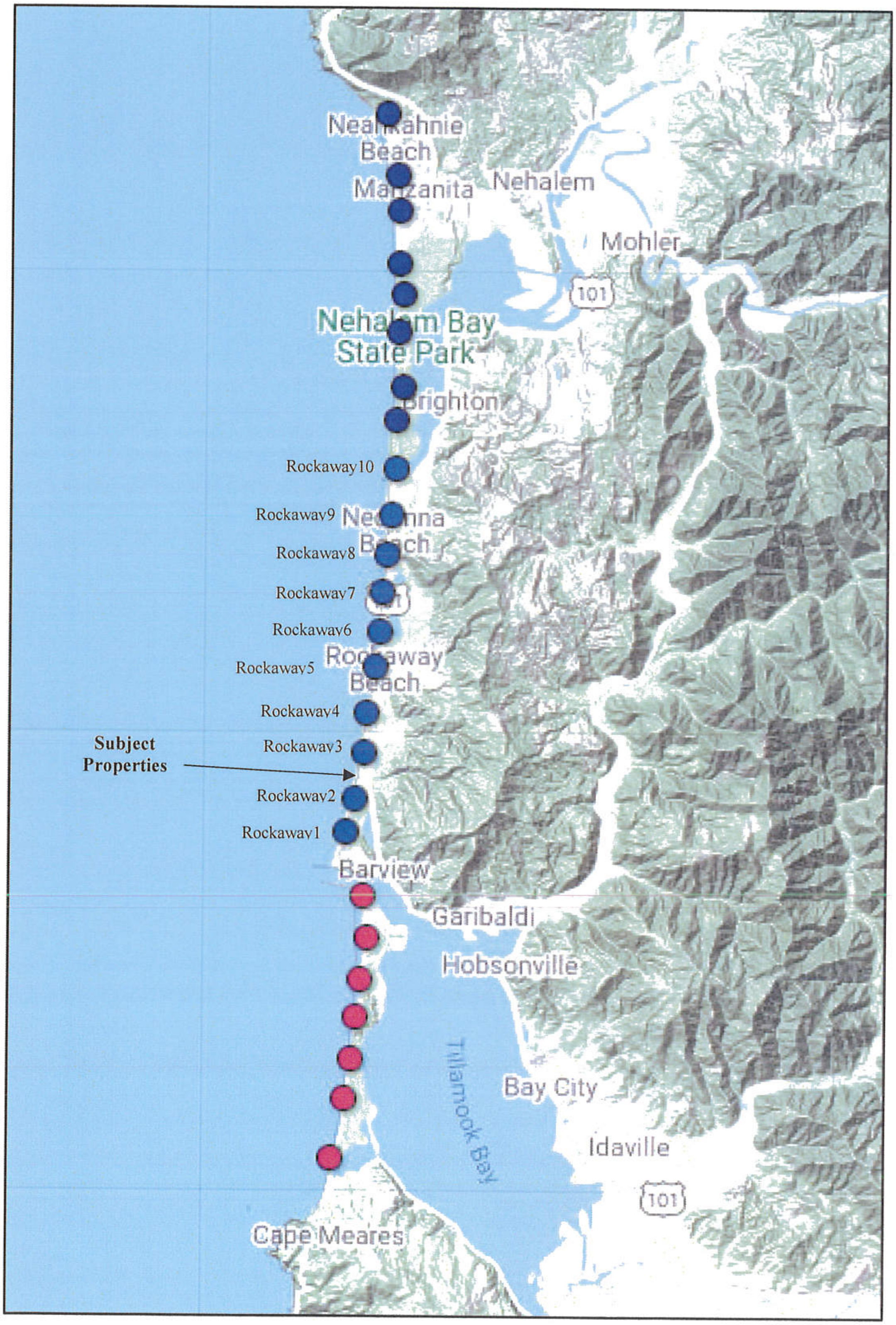

Figure 6. NANOOS monitoring locations in Rockaway littoral cell

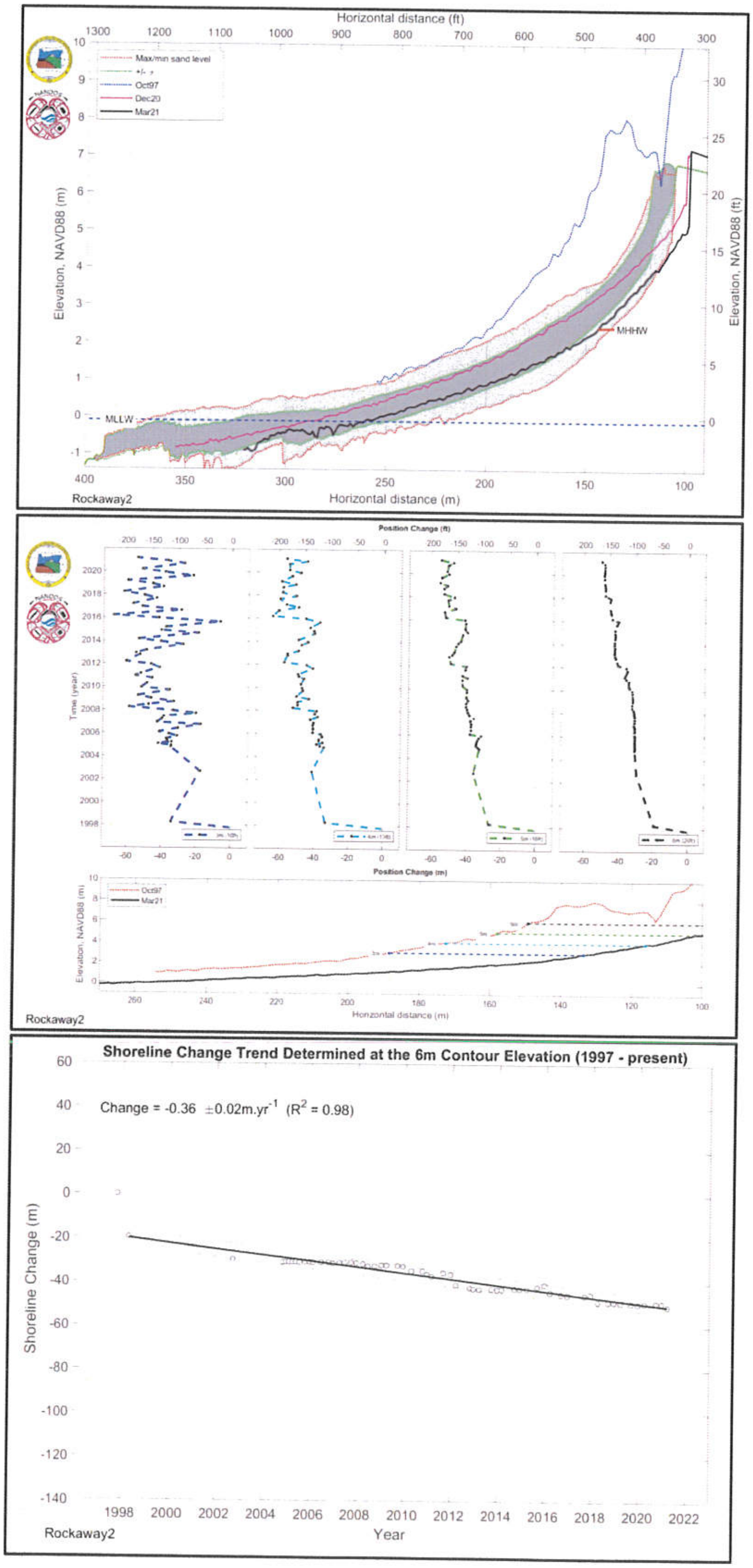

Figure 7. Available plots of NANOOS data

Table 2 provides the shoreline change trend determined at the 6-meter contour elevation for all locations within the Rockaway Beach littoral cell. This table indicates the following: (1) the shoreline at 6 meters has been eroding within the southern reach of the Rockaway subregion where the subject properties are situated (south of Rockaway6 site – see Figure 6), (2) the shoreline at 6 meters has been accreting within the northern end of Rockaway, Nehalem, and Bayocean subregions; (3) the maximum accretion has occurred at Bayocean6; (4) the maximum accretion within Rockaway subregion has occurred at the northern end (south of Nehalem Bay jetties); and (5) the maximum erosion has occurred at the Rockaway3 site (see Figure 6).

Table 3 provides information about the average beach slope, dune elevation, nearshore average slope, and nearshore average depth for the locations within the Rockaway subregion (the area between Nehalem Bay and Tillamook Bay). The average beach slope was extracted from the 2009 LiDAR. The dune elevation was extracted from the 2012 LiDAR data. The nearshore information was obtained from the available nearshore bathymetry data available from National Oceanic Atmospheric Administration (NOAA, 1957). Figure 8 shows the profile obtained from the NOAA data set. A review of data in Table 3 indicates the following: (1) the reach experiencing accretion has a flatter nearshore slope and lower average depth (indications of a wider surf zone and lower wave energy at the dune); (2) dune elevation ranges from about 18 to 36 feet, (3) average beach slope ranges from 0.0138 to 0.0649, (4) location that experience the largest dune erosion has the flattest slope (flat slope allows for more wave runoff and wave energy impacting the dune toe/this location is also at the outlet of Watseco Creek that can have an influence on the dune erosion), and (5) the average slope (see table notes) near theSubject Properties is comparable to other slopes within the Rockaway subregion (the area between Nehalem Bay and Tillamook Bay).

Weggel (Weggel, 1988) defined a classification system for coastal revetment structures that depends on their location on the beach and water depth at the toe. At one extreme (Type I), the structure is located landward of the limit of storm wave runup and has zero impact on coastal processes. At the other extreme (Type VI), the structure is located seaward of the normal breaker line and has a pronounced influence on the coastal processes. The proposed revetment will be located above the stillwater line and below the total water line (stillwater line plus wave runup). This structure would be a Type II structure in Weggel's classification system, indicating a structure with minimal impacts on the coastal processes within the littoral cell system.

A 12-year study completed at the Corps of Engineers Field Reach Facility, Duck, North Carolina that involved bi-week nearshore bathymetric data set surveyed (Basco and Ozger, 2001) indicated that the nearshore and beach profiles are dynamic, and the dynamic nature is reflected in the active sediment volume of the profile. This concept is evident in the NANOOS profile plots (Figure 7). The active sediment volume was computed for the Rockaway subregion (between Tillamook Bay and Nehalem Bay) using the NANOOS plots. The active sediment volume of about 3.2 million cy was estimated using the $\pm 1\sigma$ profiles. The potential loss of sediment contributing to the surf zone at the proposed revetment site was estimated using the geometric model approach documented and applied to erosion hazard zones for the dune-backed beaches of Tillamook County (DOGAMI, 2014). The DOGAMI study includes a GIS shapefile for the beach-dune junction. The elevation along this line ranges from 16 to 18 feet as determined from the 2012 LiDAR data. An elevation of 16 was considered for the loss volume calculations. The geometry model also includes the change in bed elevation for the eroded beach profile. This change was computed to be 1.8 feet from the NANOOS Rockaway2 data.

Table 2. Summary of Shoreline Change Trend Determined at the 6m Contour Elevation (1997- present) (NANOOS, 2021)

Subregion	Location	Rate (ft/yr)	Uncertainty (ft/yr)	R^2
Nehalem	8	0.52	0.07	0.92
	7	0.52	0.07	0.94
	6	2.07	0.10	0.98
	5	2.00	0.13	0.97
	4	1.87	0.10	0.98
	3	2.13	0.16	0.98
	2	2.23	0.20	0.96
	1	2.17	0.26	0.93
Rockaway	10	2.49	0.43	0.77
	9	1.08	0.07	0.96
	8	0.36	0.07	0.82
	7	0.00	0.00	Riprap
	6	0.00	0.00	Riprap
	5	-0.26	0.13	0.41
	4	-1.21	0.13	0.96
	3	-3.90	0.59	0.97
	2	-1.18	0.07	0.98
	1	-0.43	0.20	0.42
Bayocean	7	2.40	0.10	1
	6	3.51	0.10	1
	5	2.23	0.07	0.99
	4	1.12	0.10	0.95
	3	1.05	0.13	0.9
	2	1.15	0.07	0.97
	1	0.03	0.03	0.21

Table 3. Additional Information for NANOOS Sites within the Rockaway Subregion

Subregion	Location	Rate (ft/yr)	Uncertainty (ft/yr)	R^2	Average Beach Slope	Dune Elevation (ft)	Nearshore	
							Average Slope	Average Depth
Rockaway	10	2.49	0.43	0.77	0.0446	23.0	-	18.3
	9	1.08	0.07	0.96	0.0649	29.4	0.00398	18.3
	8	0.36	0.07	0.82	0.0381	24.6	0.00388	19.1
	7	0.00	0.00	Riprap	0.0515	33.0	0.00375	19.3
	6	0.00	0.00	Riprap	0.0353	26.8	0.00375	19.3
	5	-0.26	0.13	0.41	0.0385	36.1	0.00400	20.6
	4	-1.21	0.13	0.96	0.0464	25.2	0.00433	20.6
	3	-3.90	0.59	0.97	0.0138	18.2	0.00422	19.1
	2	-1.18	0.07	0.98	0.0474	22.5	0.00450	19.8
	1	-0.43	0.20	0.42	0.0586	22.4	0.00440	19.2

Notes:

(1) For references, the average slope for the beach is 0.0492 at the Pine Beach Development, 0.0475 in front of the Shorewood RV park, and 0.0465 at about 900 feet north of the Shorewood RV park.

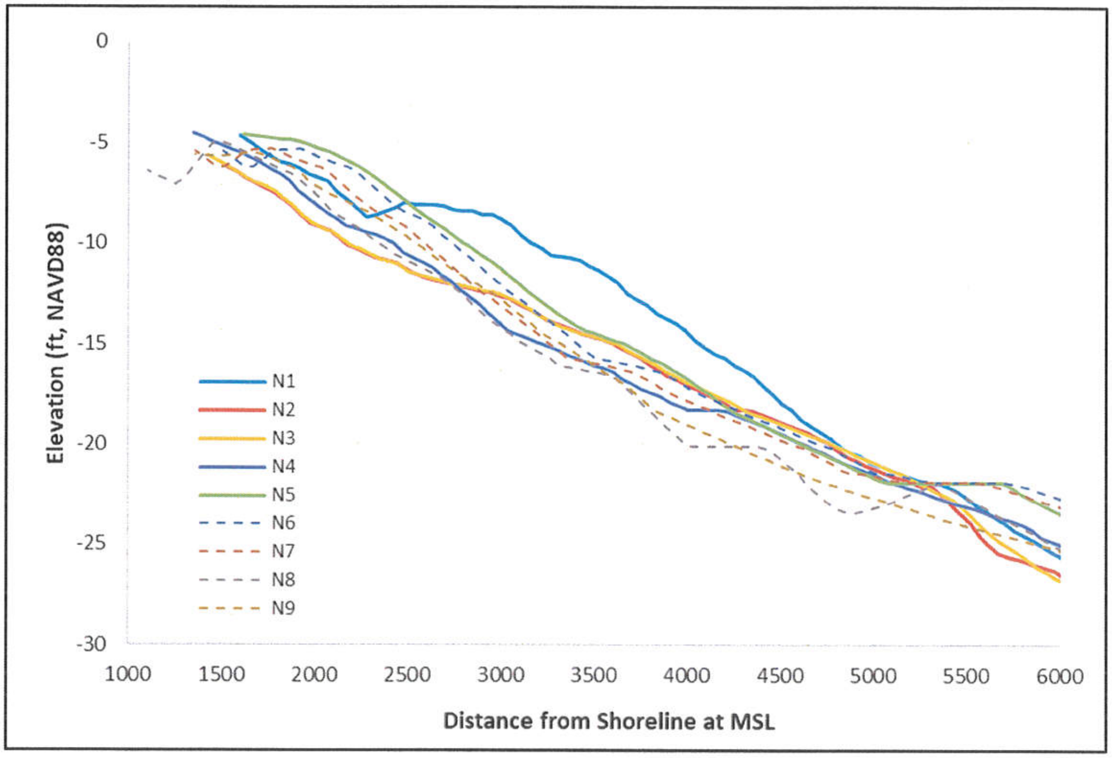

Figure 8. Nearshore profiles using NOAA data (NOAA, 1957)

The loss volume was estimated to be about 6,420 cy, which is about 0.2% of the active sediment volume within the Rockaway subregion (the area between Nehalem Bay and Tillamook Bay). The proposed revetment will have no distinguishable adverse impacts to the shoreline since it will be located above the 1% annual chance of exceedance still water line, and the amount of sediment loss from the proposed structure is small relative to the active sediment volume within the surf zone.

The proposed revetment structure will have no distinguishable adverse impacts to beach access or surrounding properties. The proposed revetment will include a ramp for the northern beach access and terminate north of the southern access. Both areas will be maintained by the property owners. As stated in the March 2021 technical memorandum, there will be no impacts to the surrounding properties (properties in the Rockaway Beach subregion) since it will not direct additional water to the surrounding property, increase wave heights/wave runup, or adversely impact the natural littoral drift of sediment along the coast. The northern and southern ends of the rock revetment will be angled into the bank to prevent flank erosion, and rocks will be placed to reduce the potential increases in velocities around the structure ends. Also, none of the other revetments in the Rockaway subregion show pronounced erosion of the ends of the revetment.

4. References in March 2021 Technical Memorandum

One of DLCD comments was that information cited in our references were dated and more up-to-date and publicly available publications for the applicable area should be consulted and included.

Table 4 provides the references cited in the March 2021 technical memorandum and comment about each reference. More up-to-date publications for the applicable area were considered in response to DLCD's comment, and they are documented in Section 6 of this memorandum.

5. Summary

The beach front landowners of the Subject Properties (Figure 1) have been losing portions of their property from coastal erosion and have experienced coastal flooding of their homes. As a result, WEST designed a rock revetment structure to prevent future erosion of their property and to reduce the risk of coastal flooding. The design was documented in a technical memorandum completed in March 2021. Recently, the DLCD sent a letter to Tillamook County that expressed concerns related to the March 2021 technical memorandum. As a result, this supplemental technical memorandum was prepared to respond to three concerns:

(1) Alternatives considered for the project are summarized in Table 1.

(2) A discussion of the references considered for the March 2021 technical memorandum is provided in Table 4, and additional references considered are summarized in Section 6 of this technical memorandum.

(3) Additional information related to the potential impacts to the coastal processes in the Rockaway littoral cell were investigated. This investigation involved additional information related to the changes in shoreline existing within the entire Rockaway littoral cell, the Rockaway subregion and at the proposed revetment. The potential loss of sediment from the proposed revetment will be small compared to the natural variability of sediment process that is occurring within the system. As a result, the proposed revetment will have no distinguishable impact on the surrounding properties.

Table 4. April 2019 Technical Memorandum References

Number	Reference	Comment
1	*AASHTO T 85 - Standard Method of Test for Specific Gravity and Absorption of Coarse Aggregate,* AASHTO, 2014 (January)	These references were used to define the durability index and percent absorption requirements of the rock. It is the latest reference on the subject matter.
2	*AASHTO T 210 - Method of Test for Aggregate Durability Index,* AASHTO, 2014 (January)	
3	*Site and Topography Survey for Pine Beach Ocean Front Owners,* Cook Surveying, 2019	Latest survey information of the site. The survey data was supplemented with LiDAR data from the Oregon Department of Geologic and Mineral Industries (DOGAMI, 2009 & 2012)
4	*Flood Insurance Study, Tillamook County Oregon Unincorporated Areas, Community Number 410196V000,* FEMA, 2002	This reference was used to define the coastal flooding risk for the site. The date of this reference is incorrect, and the most recent document, 28 September 2018, was actually used for the study.
5	*Beach Processes and Sedimentation,* Komar, 1976	A second edition of this textbook was released in 1998. This reference was used to compare the beach front slope to the beach grain size measured at the site and graph of this relationship developed from beaches on the west and east coast. A more recent relationship prepared by McFall (McFall, 2019) was also considered.
6	*CETN-III-1, Riprap Revetment Design,* ERDC, 1985	This reference was not actually referenced in the memorandum and should be removed from the document. Information from EM 1110-2-1100 (USACE, 2011) was used in sizing the rock at the site.
7	*EM 1110-2-1100, Coastal Engineering Manual, Part VI – Fundamentals of Design,* USACE 2011	This reference is one of the most comprehensive technical coastal engineering document available. The most recent version of the document was used for this study.
8	*National Assessment of Shoreline Change: Historical Shoreline Change along the Pacific Northwest Coast,* U.S. Geological Survey, 2012	This reference was used to support the erosion rates measured at the study site. It is also used as reference for this technical memorandum.

6. References

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State of Oregon Department of Geology and Mineral Industries, 2015. *Coastal Flood Hazard Study, Tillamook County, Oregon, Technical Report to the Oregon Department of Land Conservation and Development,* prepared by Laura L Stimely and Jonathan C. Allan

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

State of Oregon Department of Geology and Mineral Industries, 2020b. *Natural Hazard Risk Report for Tillamook County, Oregon, Including the Cities of bay City, Garibaldi, Manzanita, Nehalem, Rockaway Beach, Tillamook, and Wheeler and the Unincorporated Communities of Neskowin, Oceanside, Netarts, and Pacific City,* prepared by Matt C. Williams, Christina A. Appleby, John M. Bauer, and Jed T. Roberts

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