ROCKAWAY - NEDONNA BEACH

Technical Report on the Foredune Management Study

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line of defense to absorb most of the wave energy. dunes are the last zone of defense in absorbing the energy of storm waves that overtop the berm. Although dunes erode during severe storms, they are often substantial enough to afford complete protection to the land behind them. Even when breached by waves of a severe storm, dunes may gradually rebuild naturally to provide protection during future storms. Continuing encroachment on the sea with manmade development has often taken place without proper regard for the protection provided by dunes. Large dune areas have been leveled to make way for real estate developments, or have been lowered to permit easy access to the beach. Where there is inadequate dune or similar protection against storm waves, the storm waters may wash over low lying land, moving or destroying everything in their path.

"Gently sloping shores, whether beaches or wetlands, are natural defenses against erosion. The slopes of the foredune form a first line of defense, dissipating the energy of breaking waves. The berm prevents normal high water from reaching the backshore. Dunes and their vegetation offer protection against storm-driven high water and also provide a reservoir of sand for rebuilding the beach. Wise management of shore areas should include protection of these natural defenses where they exist.

"Although erosion is essentially caused by natural shoreline processes, its rate of seveity can be intensifed by human activity. The shoreline and the water are highly valued for recreational activities, but heavy use and development may accelerate erosion. Those who build 'permanent' homes and recreation facilities often ignore the fact that the shoreline is being constantly built up and worn away again. They may also fail to take into account the periodic and unpredictable effects of storms." (Corps of Engineers, 1975)

In Europe where some dune areas have been intensively managed for years, foredunes, referred to as barrier dunes, are given prime consideration because of their protective nature.

"On sandy coasts, the ridges of sand dunes are often the natural protective structures against flooding the low-lying land, the villages or towns during storm tides. The strength and resistance of these barrier dunes, which are found just landward of the beach, is to be estimated in consideration of the extent and the height of the dunes as well as of the width, the height and the stability of the beach. As in many cases on the beach in consequence of altering sea and wave conditions and different littoral drift, the disposition for erosion or aggradation varies, dunes and beaches have to be observed constantly. The beginning of a considerable erosion of the dunes has to be seen in connection with the development of the beach. A systematic research of the reasons and the further development has to be done. The research has to include the total dune-beach-profile." (Erchinger, 1974)

In West Germany annual erosion of foredune foreslopes is repaired each season. Erchinger also speaks to repair of eroded foredune foreslopes in the Netherlands on the Isle of Tuxel by use of bulldozers followed by replanting of stabilizing vegetation.

Grading the foredune for ocean viewing was the impetus to cause this study to take place. but the ultimate benefit can be strengthening the protective nature of the foredune through informed management.

Two concepts that are critical to foredune management emerge from the national and international literature:

1. Sand in the nearshore, beach and foredune is part of a dynamic, constantly changing system. Whether in the offshore bar, nearshore slope, beach, beach berm, or foredune, sand is critical to the stability of the shoreline.

2. Typically the foredune is above the level of high tides and most waves. The foredune is composed of sand in storage; sand that is available to protect inland areas from severe storm surges and storm waves.

Maintenance and enhancement of the foredune and natural beach-dune processes is critical because of the protective function of this dynamic system against ocean flooding and erosion. If the foredune is damaged or the dynamic system disrupted, the potential for flood damage to beachfront development is increased. The beach and foredune respond to ocean flooding in a predictible way:

"The natural beach exists in a state of dynamic tension, continually shifting in response to waves, winds, and tide and continually adjusting back to equilibrium. Long-term stability is gained by holding the slope or profile intact through balancing the sand reserves held in various storage elements - dune, berm, offshore bar, and so forth. Each component of the beach profile is capable of receiving, storing, and giving sand, depending on which of several constantly changing forces is dominant at the moment. Stability is fostered by maintaining the storage capacity of each of the components at the highest level.

"When storm waves carve away a beach, they are taking

> sand out of storage. In the optimum natural state there is enough sand storage capacity in the berm or dune to replace the sand lost from the beach to storms. Consequently, the effects are usually temporary, with the dune or berm gradually building up again." (Clark, 1977, pp. 320-323)

Clark also explains the role of dunes in this protective function:

> "As the dune is attacked by storm waves, eroded material is carried out and deposited offshore, where it alters the underwater configuration of the beach. Accumulating sand decreases the offshore beach slope (makes it more nearly horizontal), thereby presenting a broader bottom surface to storm wave action. This surface absorbs or dissipates through friction an increasingly large amount of destructive wave energy that would otherwise be focused on the shoreline behind the barrier.
>
> "The capacity of the dune for absorbing and moderating wave energy is not dependent on any ability to completely prevent breaching or flooding. Even in the process of being inundated and destroyed, as many are by hurricanes, the dune moderates back beach storm damage. This effect is less pronounced for low dunes, but nevertheless persists. Since storm resistance increases with dune height, however, all human uses of the barrier that devegetate, erode, or lower the dune expose the shoreline behind the barrier to increased storm damage." (Clark, 1977, p. 67)

The effectiveness of unaltered dunes in providing protection from flooding is a principal reason for the prohibition of building on undeveloped foredunes subject to ocean flooding or erosion. Foredunes in the study area have been altered, but their flood protection capability has not been completely compromised. Several areas have eroded or are eroding without imminent threat of damage to existing homes. Nonetheless, it is likely that some areas will experience erosion that, if unchecked, will damage or destroy structures. (North Nedonna Beach experienced this kind of heavy erosion in 1970-71 and 1978-79.)

This section on coastal processes summarizes regional information relevant to the study area. It is the purpose of this section to provide relatively non-technical information useful for understanding site-specific information presented in the following sections.

Offshore Processes

The offshore processes and features described here are tides, waves, offshore bars, and nearshore currents.

Tides are an important shoreline altering process when combined with storm surges, large waves, and rip-current embayments. Episodes of beach and foredune erosion occur in periods of high tide particularly when combined with storm surges and large waves. Figure 2 illustrates the tidal elevations on the Oregon Coast. The lowest estimated tide that can occur is 3.5 feet below mean lower low water. The highest tide predicted by tide tables is 10.3 feet above mean lower low water. The highest tide projected to occur, the sum of the highest predicted tide and the highest recorded storm surge, is 14.5 feet above mean lower low water.

Waves provide the energy for beach and nearshore sand movement and for erosion of the beach and foredune. Waves are generated by winds and reflect seasonal variations in weather patterns.

The nearest published wind information is for Tillamook. Figure 3 shows wind roses for the typical winter and summer months of January and July. In January, the major wind directions are from the south and southeast, but there are significant winds from the east. In July, the majority of winds are from the northwest, but there are notable winds from the north and west.

In general, waves approach the Oregon Coast from the southwest in the winter and from the northwest in the summer. Wave period and breaker height vary seasonally; in both cases they are higher in the winter and lower in the summer.

Wind speed, wind duration and the extent of ocean exposed to the wind influence wave height and frequency. The wind direction influences wave direction. Waves can be generated by both local and distant storms. Wave conditions have been studied by O'Brien (1951) on the Columbia River lightship and studied on offshore oil drilling rigs by Rogers (1966) and by Watts and Faulkner (1968). Offshore wave heights of up to 58 feet were reported and one exceptional wave was reported as 95 feet high. According to Komar and others (1976b): "The measurements of both Rogers and Watts and Faulkner do not represent average wave conditions during the severe storms, but exceptional waves produced by the chance constructive summation of several large waves." On the shoreline, the constructive summation of two or more waves can produce what is called a freak wave or sneaker.

In 1971, a seismic recording system was installed at the Marine Science Center at Newport. Komar and others (1976b) present a summary description of the system and its

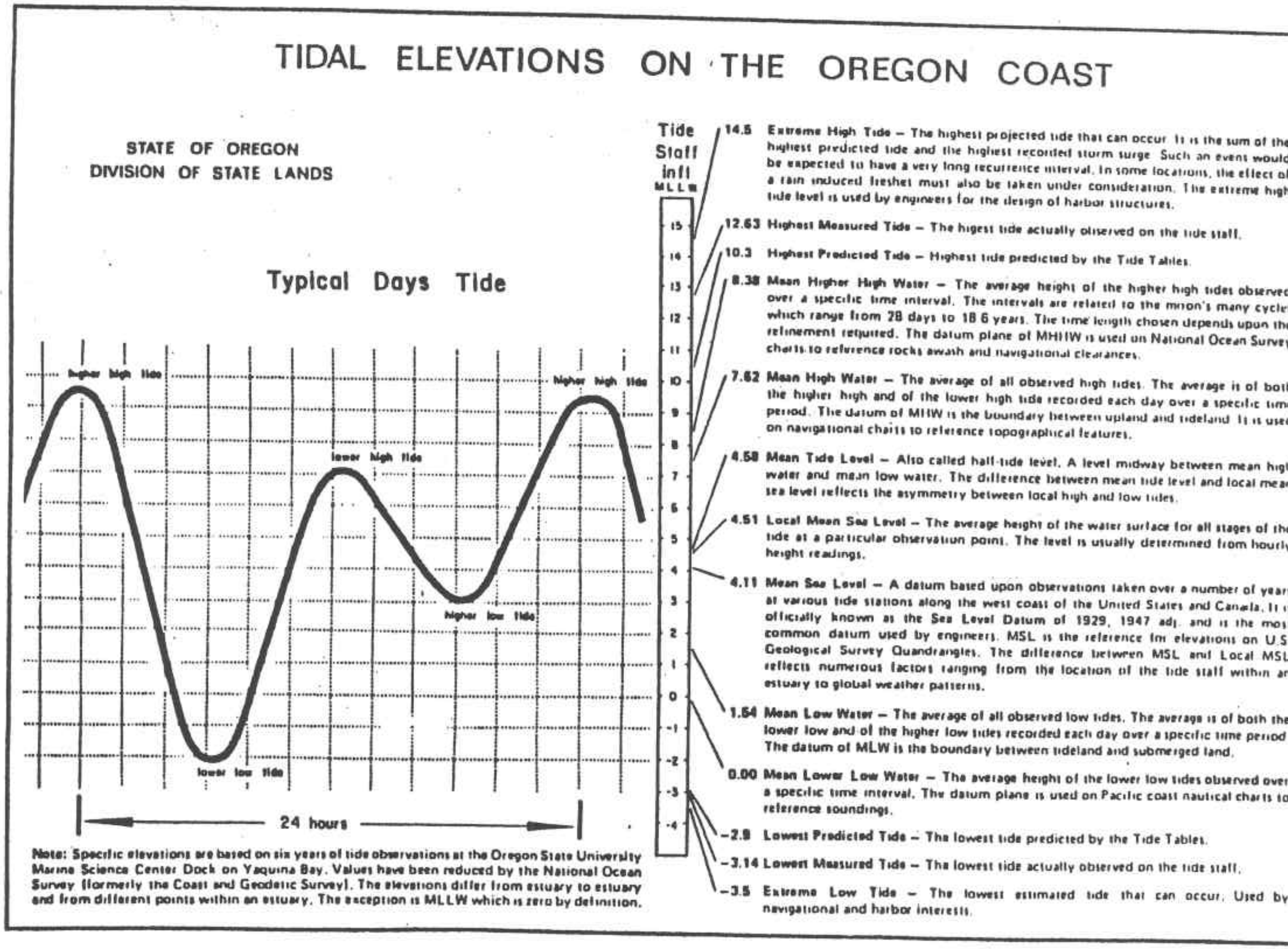

Figure 2. Tidal elevations as measured in Yaquina Bay (from Hamilton, 1973).

Figure 3. January and July wind roses for selected sites. This plate was provi
by the Portland District, U.S. Army Corps of engineers.

limitations and provide an analysis of recorded measurements from November 1971 through June 1975. Figure 4 illustrates significant wave breaker heights from July 1972 through June 1973. This figure includes large storm waves produced in December 1972 that resulted in significant erosion on the shoreline. The maximum wave breaker height measured was 7 meters (23 feet). Average height of the larger breaking waves was estimated by Komar (1979) as about 15 feet. He also noted that heights of 23 feet are truly exceptional and that similarly high breakers were recorded in December 1972, October 1977 and February 1978 which were periods of severe shoreline erosion. Similar extreme wave heights were recorded more frequently for storms during the 1981 to 1984 El Nino episode. The evidence gives support to the somewhat obvious observation that large waves, especially on high tides, are largely responsible for shoreline erosion. Another reasonable conclusion is that moderate-sized breakers, days or weeks before a series of large breakers, can set up conditions for severe erosion. (Note the November breaker heights on Figure 4.) The first storm removes sand from the beach and enlarges rip-current embayments, allowing subsequent high tides and large breakers to come closer to the backshore and foredune before breaking and losing energy.

The seasonal variation in wave conditions produces changes in the nearshore zone and beach (Figure 5). High and frequent waves in winter months erode sand from the beach and deposit the sand in offshore bars. In the summer months, the sand in the offshore bars is moved back on to the beach. Because this sand movement is controlled by wave conditions, this cycle is not strictly seasonal. Low waves during the winter will move sand onshore.

Littoral currents are caused by waves that generally approach the Rockaway/Nedonna shoreline from the northwest in the summer months and from the southwest in the winter months. Waves push sand up the beach and the retreating water takes sand off the beach. The result is net movement of sand to the south in summer and to the north in winter. Aerial photos, field evidence, and previous studies (Komar and others, 1976a and Lizarraga-Arciniega and Komar, 1975) indicate that this shoreline has both north and south littoral transport but that the long-term sum of the transport (net drift) is zero or near zero.

Field evidence also indicates that there has been an apparent short-term net northerly drift in the recent past (at least in 1983 and 1984). The primary evidence of this is shoreline erosion north of Cape Meares, north of the Tillamook North Jetty, and north of the Nehalem North Jetty. This evidence is not conclusive, but increased sand on the beach at Neahkahnie, north of the study area, strongly supports a short-term net northerly drift. Recent rehabilitation of the Nehalem jetties and recent extension of

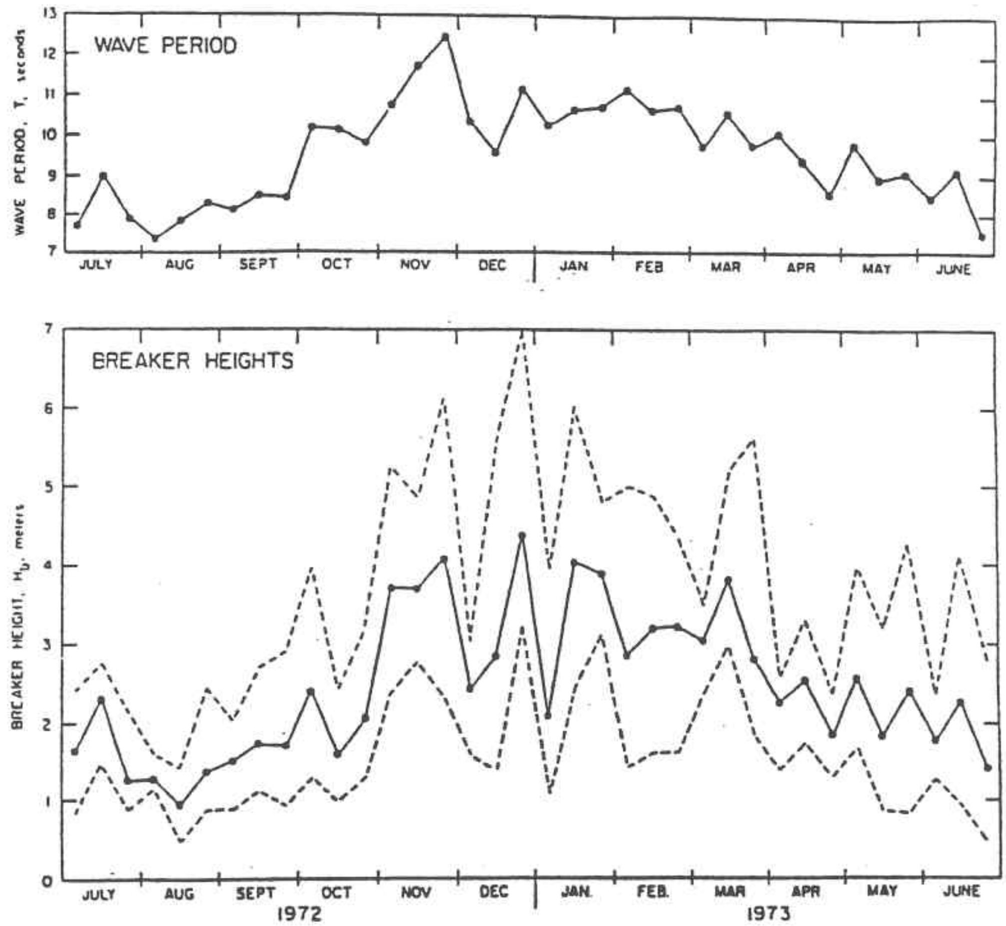

Figure 4 . Significant wave breaker heights and periods measured at Newport during July 1972 through June 1973. Each datum point gives the average for one-third month. The dashed lines give the maximum and minimum breaker heights during those one-third month intervals. Note the arrival of large storm waves during the last part of December 1972. (From Komar, 1979).

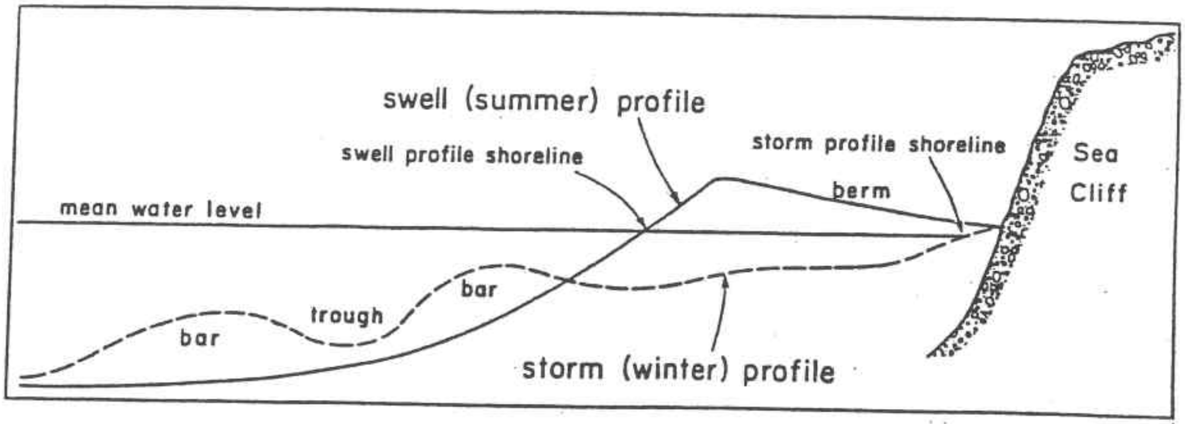

Figure 5. Schematic illustration of the beach profiles produced by storms versus gentle swell waves. On the Oregon coast these profile changes are approximately seasonal due to our storms occurring principally during the winter months. (From Komar, 1979).

the south jetty at Tillamook Bay could explain some of the recent erosion but does not explain the accretion at Neahkahnie.

Rehabilitation of the Nehalem jetties has caused accretion adjacent to the jetties. Typically, the sand supply loss related to jetties is made up by nearby shoreline erosion (Komar and others, 1976a). The accretion at Nehalem jetty has not caused any notable backshore or foredune erosion in the study area, but comparison of 1978 and 1984 aerial photos does indicate a reduction in beach width to the south near Crescent Lake Outlet.

At Tillamook Bay, the extension of the south jetty was followed by adjacent accretion. There has also been substantial erosion north of the north jetty and moderate erosion south of the accretion area. The erosion north of the jetty could be related to blockage of northerly sand movement around the newly extended south jetty in the winter. However, some experts, including Komar (personal communication) believe that there is very little or no sand transport around jetties.

We concur with Komar's theory that there is a net northerly littoral movement of sand associated with El Nino which caused changes in the number of large waves from the southwest (Komar, personal communication). He is investigating the shoreline alterations of the 1982-1983 El Nino. Komar argues that recent accretion at the south jetties of Tillamook and Nehalem Bays and at Neahkahnie (observed by the study team) is evidence of net northerly drift caused by El Nino. He also believes that since their construction the Tillamook and Nehalem jetties and outflow from the bays has blocked longshore transport, and the extension of the south jetty did not cause the erosion to the north. Aerial photography indicates that the erosion north of the Tillamook jetties occurred between 1982 and 1985, which corresponds to the El Nino. It is our conclusion that the erosion was caused by the short term net northerly sand movement associated with the El Nino and that there is little or no sand transport around the jetties.

Rip currents develop along the shoreline of the study area and the embayments (cusps) that form are often related to local shoreline erosion (Figure 6). Rip current channels and embayments were observed on aerial photos and in field investigations. The locations were transferred to the Technical Report Map to allow identification of any patterns of rip current reoccurrence. This evidence indicates that in some locations rip currents can be somewhat stationary. Typically, rip currents reoccur more often adjacent to stationary shoreline features such as jetties and the deltas at the mouths of creeks. In other areas, the rip currents do not follow an identifiable pattern.

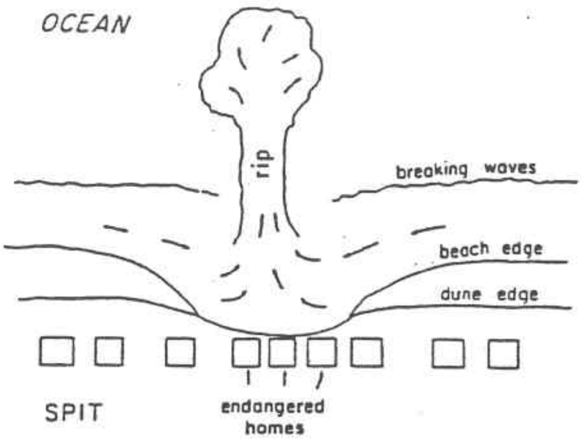

Figure 6. A rip current flowing outward across the beach hollowing out an embayment into the beach and eventually into the foredunes causing property losses. (From Komar, 1979).

Before the rehabilitation of the Nehalem jetties, rip current embayments were common along the northern portion of the Nedonna Beach area. In 1977 and 1978, two rip currents reduced the width of the beach and thereby contributed to foredune erosion that threatened several homes located on the backslope of the foredune. Emergency riprap was placed to protect the homes threatened by erosion (see Technical Report Map). North of Rock Creek, a rip current appears to have contributed to recent foredune erosion that was still evident in 1985 as a large erosion escarpment. In the mid-1960's, an embayment slightly north of Saltair Creek appears to have contributed to shoreline erosion that extended almost to the 1939 shoreline. Slightly north of Spring Lake Outlet an embayment possibly contributed to foredune erosion in the winter of 1982-83. Other specific erosion episodes could probably be related to rip current formed embayments but the aerial photo coverage of the study area is available for a limited number of years (Table 1).

A tsunami is a wave or set of waves produced by a submarine earthquake or volcanic eruption. The term "tidal wave" is sometimes inappropriately used in reference to tsunami. In recent history, the most common source of tsunami waves on the Oregon Coast is the Alaska area. The most recent tsunami events affecting the Oregon Coast occurred in 1964 and 1968 (Schatz and others, 1974 and Wilson and Torum, 1968). Figure 7 illustrates maximum wave heights at several locations on the Oregon Coast including Nehalem and Tillamook Bays for the 1964 tsunami. The largest wave at

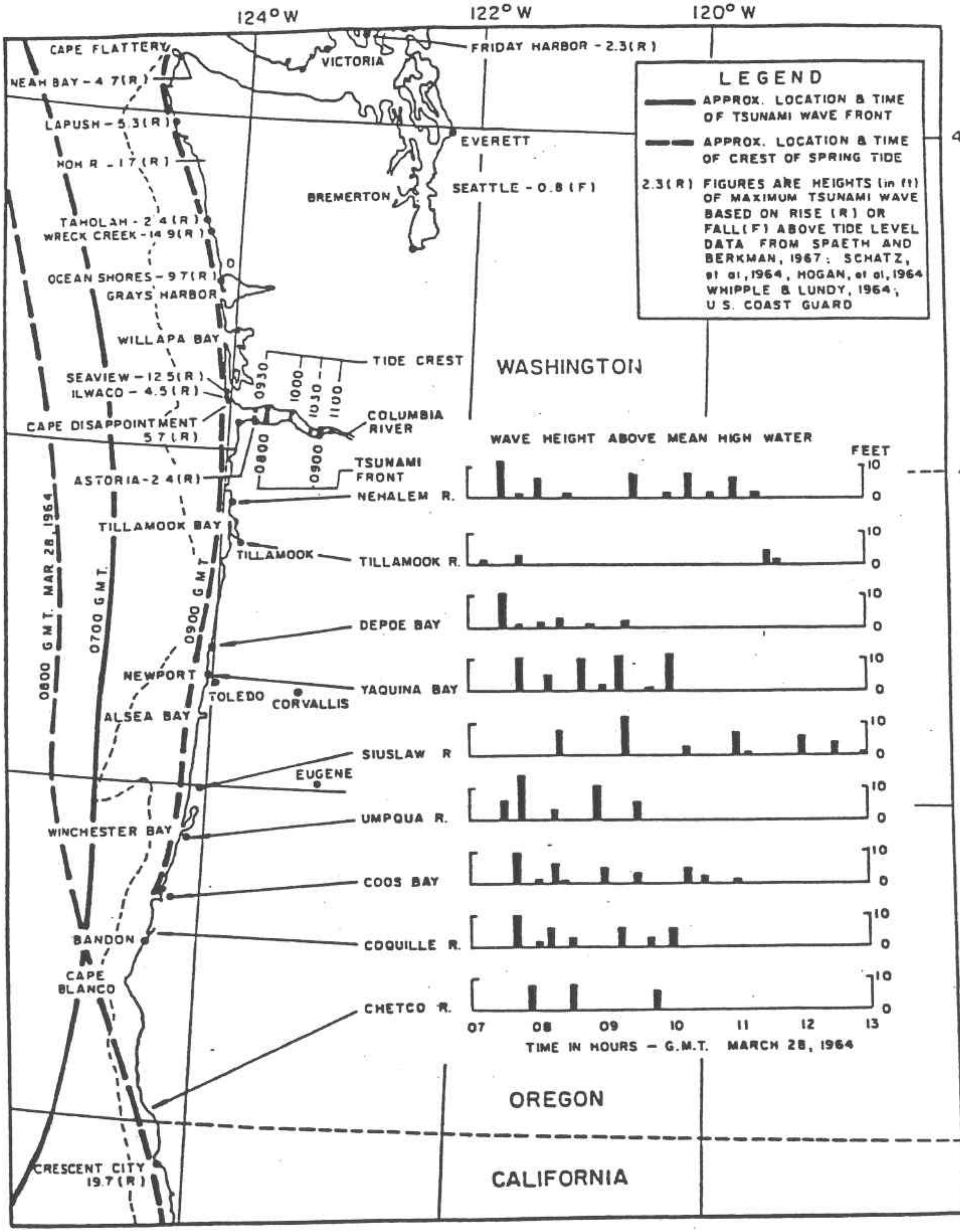

Figure 7. Maximum heights of tsunami waves recorded at tide stations or by observations along the Washington-Oregon coast (from Wilson and Torum, 1968).

Nehalem Bay was about 12 feet in height. The low wave heights at the Tillamook River are indicative of the loss of wave energy as the tsunami passed through the broad and shallow bay.

There is solid evidence of a slow, world-wide rise in sea level. A change in sea level could have substantial consequence on shoreline erosion and the long-term safety of the study area. Evidence accumulated by Hicks (1972) suggests that there was a rise in sea level of about 1.5 mm (0.06 inch) per year in the 34 years of records analyzed. However, these records indicate that the Oregon Coast may be rising at about the same rate as the rise in sea level (Figure 8). Records at Astoria, Crescent City in California and Friday Harbor in Washington show no apparent sea-level changes (Hicks, 1972). Alaska is rising faster than the rise in sea level.

There is presently a controversy regarding an increase in the rate of world-wide sea level rise. Hicks (1978) has updated his previous data, but he only reports on the average rise. Gornitz and others (1982) proposes that there is an increase in the rate of sea level rise related to the Greenhouse Effect. Barnett (1984) disagrees with Gornitz. This controversy promises to continue. If the rate of sea level rise is increasing and continues then Oregon's shoreline will be affected at some time in the future. Because the sea level rise will be initially very slow and very small, there will be sufficient time to re-evaluate foredune grading practices and to react to the growing threat to low-lying coastal areas.

SAND SUPPLY

Information on the nearshore ocean bottom can be used in some cases to indicate trends in the sand supply. For instance, offshore sand bars move inland to the beach in the summer and a reduction in the size of the bar can be an indication of a diminishing sand supply. Information on nearshore bathymetry (water depth) of the study area is limited to navigation charts produced by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Survey (NDAA) and its predecessors, the U.S. Coastal Survey (USCS) and the U.S. Coast and Geodetic Survey (USC & GS). The 1982 NDAA chart shows water depths at the time of sounding at the Nehalem Bay outlet in 1982. South of the Nehalem bar area, the depths are from 1956 surveys.

The 1982 chart indicates the location and depth of sand bars. At the mouth of Nehalem River, the bar extends about 2,100 feet beyond the jetties and appears to influence the configuration of the offshore area for about one mile north and south. The shallow depths at the Nehalem bar (1 to 8 feet, MLLW datum) indicate that some sand may have been

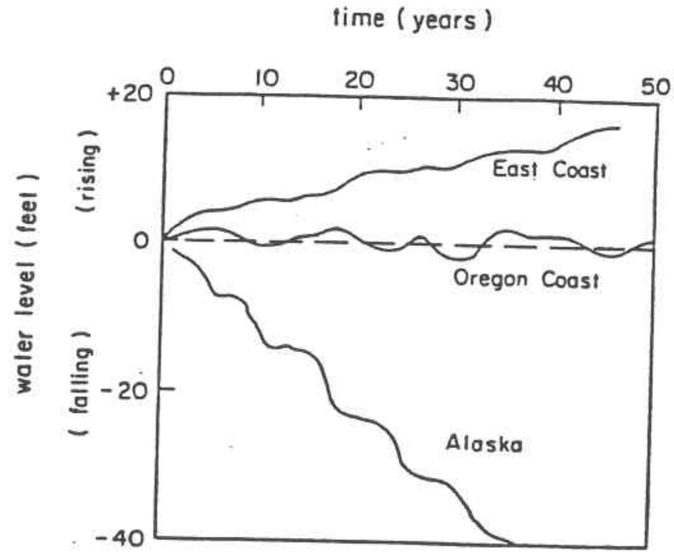

Figure 8. Schematic of water level changes on the Oregon coast as compared to the East coast and the coast of Alaska, based on the data of Hicks (1972). (From Komar, 1977).

able to bypass the jetties and the mouth before the rehabilitation of the jetties that was completed in the Fall of 1982. Increased scouring of the bar after jetty rehabiliation may have eliminated sand bypass.

South of Nehalem Bay the chart depicts longshore sand bars 1000 to 1700 feet from the shoreline as far south as the area offshore from Lake Lytle. From there to the edge of the chart at Twin Rocks there are no sand bars mapped. It is not known whether the offshore bar was not present or had moved inland beyond the survey area. The latter is more likely because the bar is closer to the shoreline on the south.

Seven historic charts of the bathymetry off of the northern portion of the study area were examined at the Oregon Historical Society in Portland. These charts provide limited information on the longshore bar. The 1916 chart shows a bar about 2150 feet from the high tide line at that time. The bar extended only about 1 mile south of the south jetty at Nehalem Bay. The minimum depth to the bar was 6 feet below mean lower low water. The charts published in 1920, 1922 and 1924 show the same bathymetry on the bar. The 1931 chart indicates a bar about 1600 to 2000 feet from the shoreline at a minimum depth of 12 feet (MLLW datum). The 1933 and 1938 charts show the same bathymetry as the 1931 chart.

It is not possible to make conclusions on offshore sand supply from this limited information.

The major factors of the littoral sediment budget are listed in Table 2. Littoral transport into the study area is apparently blocked by Cape Meares headland on the south and by Neahkahnie headland on the north. Cape Meares is a headland with a precipitous shoreline that extends over 200 feet west of the sandy shoreline in the study area. The offshore depth is shown as rapidly dropping off to 18 feet on the U.S. Geologic Survey topographic map. Neahkahnie headland has a precipitous shoreline that extends over 5000 feet west of the sandy shoreline. The jetties and channels at Tillamook and Nehalem Bays apparently also block littoral drift. Blocked littoral currents create a pocket beach with a fixed sand budget. River and stream transport from upland areas appears to be negligible or very small (Kulm and Byrne, 1966). The streams do return wind-transported sand to the beach and nearshore system. Some new sand does come from the Astoria Formation sandstone on the north side of Cape Meares headland but does not contribute sand to the study area because of the apparent blockage at the Tillamook Bay jetties. Onshore transport occurs seasonally.

The amount of sand permanently lost to offshore transport is not known. Wind does transport some of the sand inland to the foredune. As the foredune continues to receive

Table 2: The Budget of Littoral Sediments
(Adapted from Komar, 1979)

Credit	Debit	Balance
Longshore Transport into Area	Longshore Transport Out of Area	Beach Deposition or Erosion
River Transport	Wind Transport Out	
Shoreline Erosion	Offshore Transport	
Onshore Transport	Deposition in Submarine Canyons	
Hydrogenous Transport	Solution and Abrasion	
Wind Transport onto Beach	Mining	
Beach Nourishment		

sand deposits from the beach, there is a net temporary loss to the system. There is periodic ocean wave erosion on the frontal area of the foredune, but there is slow net accretion. The amount lost to solution and abrasion is not known, but it is probably very small. The amount of sand removed in the past by mining is not known at this time, but it is probably negligible.

The slow accretion of the central Rockaway shoreline over the last 47 or more years indicates that there are no large supply increases or losses. Our conclusion is that the shoreline segment between the Tillamook and Nehalem jetties has had a roughly balanced sand budget. There are no known sources of new sand. A small amount of sand may be added to the system by streams that do not flow through the lakes (i.e. Watseco Creek and Rock Creek). There may be a net loss or gain from offshore or onshore transportation, but further detailed study of the offshore sand system changes over time is needed.

Inland sand losses are more apparent. Accretion after the construction of the jetties removed a substantial volume of sand from the system. Slow accretion and foredune growth, since at least 1939, has removed a much smaller amount of sand from the active sand budget.

It is evident that much more information is needed on the sand budget in the study area. The necessary information must be obtained through research that is beyond the scope of this investigation. More research is needed on all aspects of the littoral sediment budget. Even a qualitative evaluation on this shoreline is limited by a lack of information on the shoreline and nearshore previous to the placement of jetties at Tillamook Bay and the Nehalem River.

The following is presented as a summary of the best available information as applied to and in evidence in the study area:

1. The condition of the study area shoreline before construction of the jetties at Tillamook and Nehalem Bays is not well known. It is assumed that there was a broad beach on the Rockaway shoreline that was backed on the east side by a well vegetated barrier dune ridge, the remnants of which are still present. A U.S. Coast Survey chart dated 1868 does show the mouth of the Nehalem River. The original manuscript can be seen at the Oregon Historical Society in Portland. The mouth of the Nehalem was a wide, shoaled area near where the mouth is now. The Nedonna area was mostly a shallow ocean and beach area that time.

2. When the south jetty was completed at Nehalem Bay in 1915 and the north jetty was completed at Tillamook Bay in 1912 there was accretion in the low-lying embayments adjacent to the jetties. The source of the sand needed to fill these embayments presumably was provided by littoral transport and onshore transport. After completion of the north jetty at Tillamook in 1917, the embayment created between the jetty and the pre-jetty shoreline to the north began filling with sand. For further information on this process see the section of the report on jetties. The sand for this filling was presumably transported by littoral current from areas to the north and transported on shore by winds and waves. Some of the sand probably came from the offshore bar and the delta at the mouth of the bay. The completion of the jetties at Nehalem Bay also created an embayment in the Nedonna Beach area. This area was largely part of the deltaic shallows at the mouth of the river before filling began. Filling of the embayment occurred rapidly in the period from 1915 to 1920 (Corps of Engineers, 1980, p. 1-2). The sand to fill the embayment came from the river delta, the longshore bar and littoral transport from the beach between the Nehalem and Tillamook jetties.

3. After the accretion associated with the jetty construction a new equilibrium condition might have been briefly established that was subsequently disturbed by the rapid deterioration of the Nehalem jetties. Jetty deterioration at Nehalem Bay resulted in shoreline

erosion for an unknown distance south of the jetty. The shoreline configuration in 1939 indicates that erosion extended at least 2000 feet south of the south jetty. The eroded sand was probably transported to the offshore bar and trasported south by littoral transport.

4. The introduction of European beach grass in the 1930's modified the shoreline character and possibly altered the beach width and profile. The beach grass created a foredune ridge where previously there had been a broad backshore area.

5. Since the introduction of European beach grass there has been slow episodic accretion in all of the foredune management units, but there has not been a consistent pattern of accretion near the creek mouths.

Beach Processes

Figure 9 illustrates typical features of a sand beach and the names of the features. The offshore bar is not illustrated.

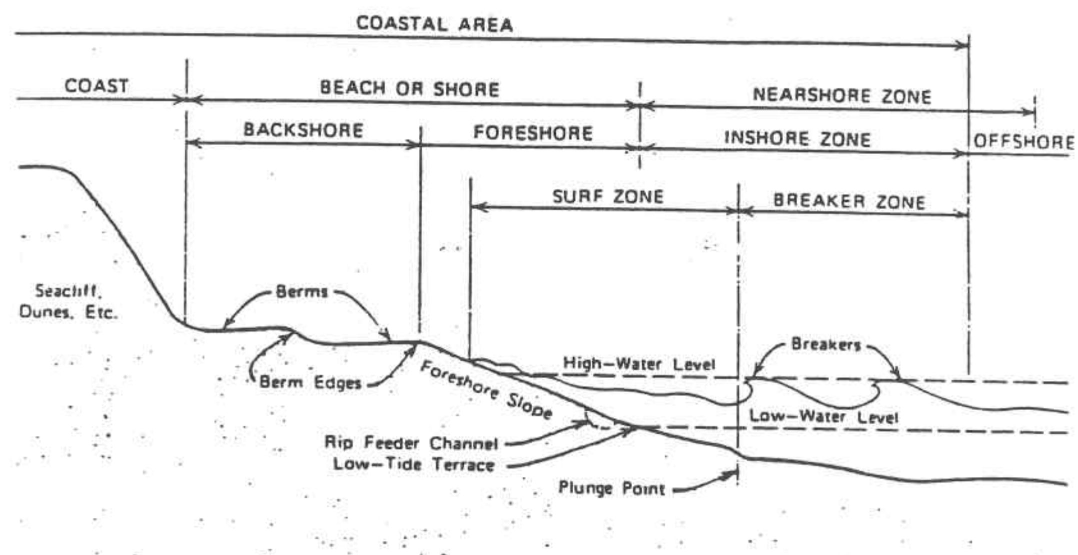

Figure 9. Features of a typical sand beach. (From U. S. Army Corps of Engineers, 1971).

> "The natural beachfront exists in a state of dynamic tension, continually shifting in response to waves, winds, and tide and continually adjusting back to equilibrium." (Clark, 1977, p. 320).

The components of the typical sand shoreline store sand to defend against wave attack. Figure 10 shows sand removed from beach and foredune storage moves to the nearshore and is stored there as nearshore accretion and offshore bars. With the return of gentle swells, the stored sand is then moved back on to the beach.

The energy used to move sand off the beach and out of the foredune reduces the energy of the attacking waves. The offshore bar also provides protection from wave attack:

> "Where the land meets the ocean, nature has provided the waves. The first defense against the waves is the sloping nearshore bottom which dissipates the energy or weakens the force of the deepwater waves. Yet some waves continue toward the shore with force and energy still at tremendous levels until they near the beach. There they break, and unleash most of their destructive energy. This process of breaking often builds in front of the beach another defense in the form of an offshore bar which helps to trip following waves. The broken waves reform to break again and may do this several times more before finally rushing up the foreshore of the beach. At the top of wave uprush a ridge of sand is formed and serves as a defense against uprush of following waves. Beyond this ridge, or crest of the berm, lies the flat beach berm which is reached only by higher storm waves." (Corps of Engineers, 1971, p. 7).

If sand is removed from this dynamic system, then there will be an adjustment to the shoreline toward a new equilibrium. This adjustment would be through shoreline erosion, foredune erosion, and/or reduction in the volume of offshore sand.

Winds blowing across the beach move sand in a series of hops and bounds. This method of particle movement by wind or water is known as saltation. The typical northwest and southwest winds carry sand from the foreshore to the backshore and from the backshore on to the foredune. Sand that is blown into the creeks can be carried back into the ocean. Eolian (wind) transportation of sand is an important part of the natural repair of foredunes eroded by storm waves.

During periods without storm waves and particularly during the summer, the sand in bars is moved inland by relatively gentle waves and swells on to the beach where it develops a wider beach and a berm (see Figures 5 and 10). The widened beach renews protection for the foredune and upland from wave action and provides a wider area for wind

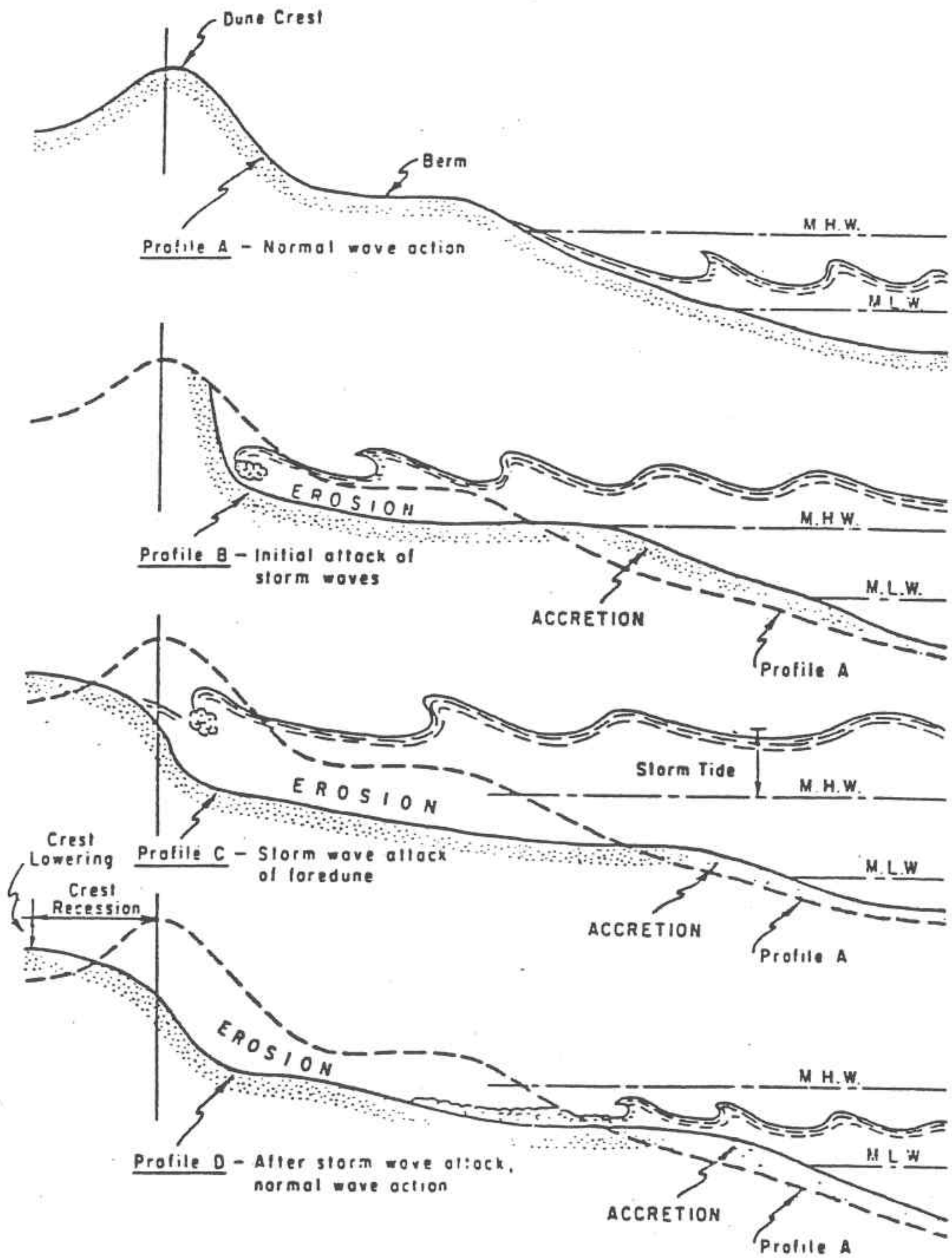

Figure 10. Schematic diagram showing shoreline changes and sand movement under storm wave attack. (From U.S. Army Corps of Engineers, 1973).

transportation of sand.

Substantial deposits of logs were found south of Spring Lake/Watseco Creek Outlet, at Spring Lake Outlet and slightly south of Crescent Lake Outlet. Old aerial photos indicate that driftwood deposits have been common features at the creek outlets and near the jetties over at least the last 47 years. The photos also indicate logs behind the foredune after major storm events. Drift logs are often exposed in eroded portions of foredunes.

Aerial photos taken April 28, 1939, after a large storm in January, show driftwood in almost all the creek outlets, where it was wedged into the narrow landward part of the outlet areas. The 1939 photos also show that the largest concentrations of drift logs are near the mouth of Nehalem and Tillamook Bays, the drift logs are mostly on low lying land accreted as a result of jetty construction, and a large number of drift logs had been tossed or floated over the then low foredunes. Aerial photos taken in 1964 show a substantial volume of driftwood near Crescent Lake outlet on both the north and south. Photos taken in 1966 show the logs near Crescent Lake outlet and another large driftwood deposit in an area slightly north of Saltair Creek. Some of these logs were apparently tossed inland onto Highway 101 in a storm in December 1967.

Natural deposits of well interlocked drift logs that sometimes accumulate at the mouth of streams have a positive value in protecting against ocean erosion. The accumulation acts as an extension of the foredune in reducing the velocity and impact of breaking waves in large storm/high tide events. In an undeveloped area, these are qualities worthy of protection. Single or poorly interlocked drift logs are more likely to be destructive when driven by waves.

In developed areas the accumulations of drift logs at the mouth of streams can have negative values, particularly if they are not interlocked. Fresh and marine flood waters drain from areas east of the logs at a slower rate than through a clear channel. Outflow past the logs can cause local scouring of stream banks and nearby foredunes. Inadequately interlocked driftwood at the creeks can be moved by storm waves and freak waves to inland areas, damaging houses and blocking the highway and railroad.

In some instances massive accumulation of drift logs at creek mouths can trap eolian sand, particularly in low creek flow periods. With renewed rainfall and streamflow the creek can be forced to migrate to the north or south around the mass of logs and sand. As a result, the backshore and foredune can be eroded and the beach berm removed several tens or hundreds of feet from the normal stream route across the beach. The rerouted stream channel on the beach and the reduced beach elevation can result in increased local erosion of the foredune by ocean waves on high tides.

Driftwood removal has been occurring where accumulations build up at the stream outlets, except at Spring Lake Outlet. Removal in other beach and foredune areas is occurring but currently appears to be only at a low level. A higher level of removal is not presently feasible because of the sparse distribution of driftwood, except in the Watseco Creek area.

There are presently no massive accumulations of well interlocked driftwood at the base of the foredune in the study area, but there is a large poorly interlocked accumulation near Watseco Creek in a former creek channel. The following narrative is provided in anticipation of future accumulations and in regard to the accumulation near Watseco Creek.

Driftwood deposits on the backshore can either be a benefit or destructive force to the foredune. Massive driftwood deposits that interlock provide excellent wave protection by breaking up wave energy before it reaches the foredune. They also collect wind-blown sand and can be the start of new foredunes or can aid in the repair of erosion damaged foredune areas. Backshore deposits known to the study team on other beaches are sometimes 50 to 100 feet wide and a mile long. They tend to create a false security for oceanfront proterty owners.

At Kla-he-nee Shores, north of Florence, Oregon, during the El Nino waves of winter 1982-83, the entire driftwood mass floated off the beach in less than three days. Wave erosion was severe and emergency riprap was permitted on 2,200 feet of oceanfront. This same area had been stable for twenty years due to the wave protection afforded by the driftwood deposit. The same protection was afforded the sand bluffs north of Siletz Bay from the bay to the Inn at Spanish Head until beach logging was allowed in 1976. Severe wave erosion followed the log removal, again resulting in emergency riprap installation. It is not known whether or not logs driven by waves contributed to the erosion.

The partial removal of wood from interlocked deposits can loosen the mass. Loose drift logs can act as battering rams, increasing erosion of the foredune and increasing inland structural damage. Drift logs that occur in massive and interlocked accumulations in backshore areas need to be evaluated before any removal is allowed.

Driftwood should not be removed when it accumulates in an eroded portion of a foredune because it aids the natural repair of the foredune.

The accumulation of drift logs near Watseco Creek are not well interlocked and could be pushed or floated further inland, or northerly, where they could block Watseco Creek. As a result, the channel of Watseco Creek could move to the south and possibly endanger existing development. However, some of the logs are now occupying a gap in the foredune and will probably increase the rate of repair of the foredune. The logs at Watseco Creek could also be washed out and transported to other shoreline or stream mouth areas. It is our opinion that the logs in the former foredune area should remain to aid in the rebuilding of the foredune.

Foredune Processes

> "Previous to the introduction of European beachgrass in Oregon in the late 1800's, the active foredune on most shorelines was absent or was a relatively low, discontinuous ridge composed mostly of remote to closely spaced mounds. After European beachgrass colonized the foredune, the increased deposition of sand elevated the ridge first as isolated hummocks that coalesced and resulted in a relatively continuous ridge." (Soil Conservation Service, 1975)

Foredunes are classified by the Soil Conservation Service (SCS, 1975) as active foredunes, conditionally stable foredunes and inland foredunes. The foredunes at the back of the beach in the study area are active. They are subject to wind erosion and sand deposition, wave overtopping and wave erosion. Figure 11 is a generalized cross section of a foredune and its parts.

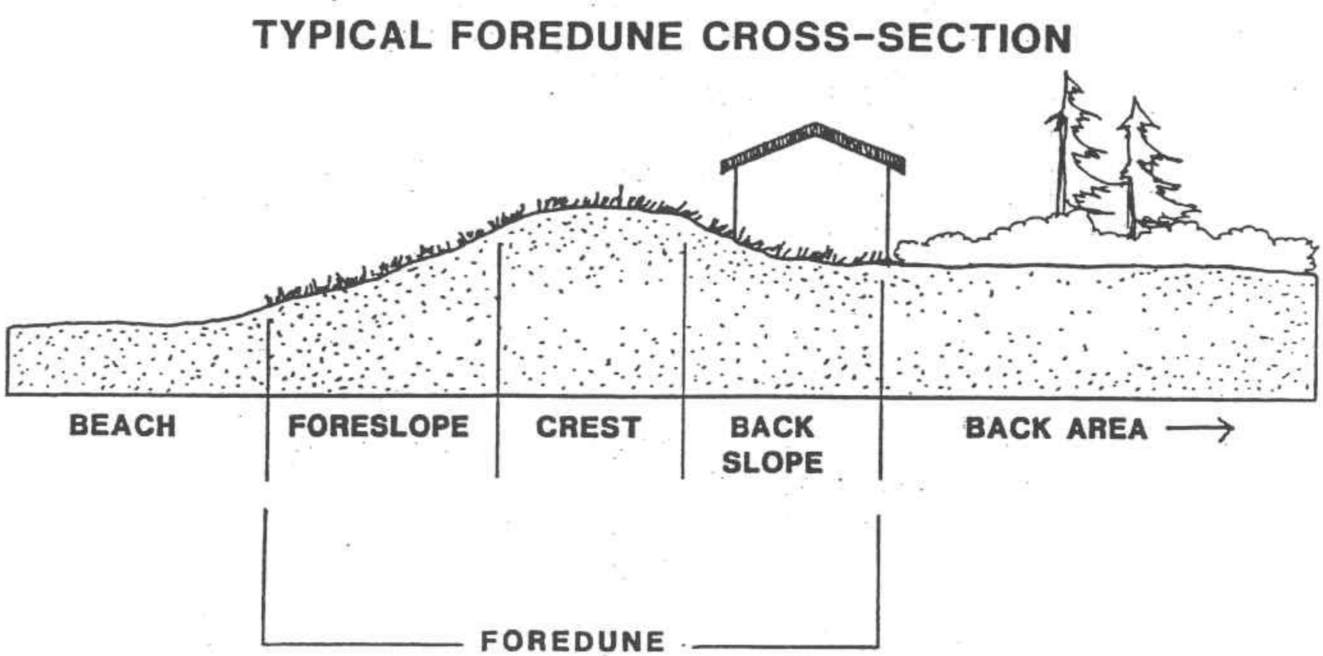

Figure 11. Typical foredune cross section and classification of features.

Foredunes on the Oregon Coast are primarily vegetated with European beachgrass (Ammophila arenaria). It was first introduced for sand stabilization in the late 1900's (Crook, 1972). It spread rapidly and became naturalized on the coastal sand areas. Because it prefers sites of continuous sand deposition, it has colonized sites near the beach where there is a good supply of wind transported sand. Prior to the introduction of European beachgrass, there was no native plant which could tolerate wave attack and thick deposition of sand, and therefore, there was no foredune (Soil Conservation Service, 1975).

Apparently, the native beachgrasses such as American beachgrass or sea lyme grass (Elymus mollis) were the previous pioneer species on dune sand. These native grasses now occur on the foredune, on the backslope, and locally on the crest where salt spray and sand deposition is restricted.

Other plants survive on the foredune where salt spray and sand deposition is not excessive for their survival. These secondary species include beach pea or maritime pea (Lathyrus japonicus), wild strawberry (Fragaria chiloensis), and seashore lupine (Lupinus littoralis). "Later successional species may include such woody shrubs as salal (Gaultheria shallon), or kinnickinnick (Arctostaphylos uva ursi) and an occasional shore pine (Pinus contorta)." (Crook, 1979).

To a limited extent, the foredune is capable of acting like a dike against ocean flooding and is capable of dissipating wave energy through erosion of the stored sand. However, ocean flooding is still a hazard where the foredune is low in elevation and thin enough to be breached by erosion.

On a shoreline like that in the study area, where there are numerous creeks that create breaches in the foredune, the ocean flood protection is not as good as where there are no breaches in the foredune. These breaches allow velocity flooding (ocean flooding with waves) to extend further inland, and high seas are more likely to inundate low elevation areas.

The foredune and the European beachgrass on the foredune reduce the sand transporting capacity of wind. This results in deposition of sand on the foredune instead of on inland areas. The beachgrass and other foredune vegetation also reduces the capacity of wind to transport sand off of the foredune. The protective capability of the beach-foredune system is enhanced by retaining sand in the foredune.

> "Dunes are the final protection line against the sea, and are also a savings bank for the storage of sand against a stormy day.
>
> "And stormy days do come. Strong winds blow high waves

before them. These waves are so huge that the nearshore slope weakens them only slightly. The thrust of the wind and the waves toward the shore raises the elevation of the sea and large waves pass over an offshore bar without breaking. If the storm occurs at high tide, the storm surge and the tide superelevate the waves and some of them may break high on the beach or even at the base of the dunes. After a storm or stormy season, the natural defenses are again reformed by normal wave and wind action." (Corps of Engineers, 1971, p. 7)

Snapshots dating from the early 1900's (Walker, 1983) indicate that there was little or no active foredune formation at that time in the central portion of the study area. It is reasonable to assume that without European beachgrass and with repeated wave erosion, the only "foredunes" were isolated hummocks that developed on the accreted lands adjacent to the jetties and on backshore portions of the beach.

The central shoreline appears in old photos as a broad, gently sloping beach leading inland to a relatively well vegetated stable dune ridge. This dune is classified as a younger stabilized dune by the Soil Conservation Service (1975). Remnants of this stable dune remain in the study area to the east of the 1939 shoreline mapped from aerial photographs in this report (Technical Report Map). Remnants of the old dune are generally absent near the creek outlets. The highest elevations on this dune are in the Lake Lytle area, where it reaches 43 feet (MLLW datum). The mature vegetation and height of the old dune indicates that much of the shoreline had been stable for at least 50 years.

The process that resulted in this stable dune is not known and is worthy of future research. The available evidence (current landforms, old photos, and the vegetation on the stable dune) suggests that this former "foredune" developed further inland from the average high tide line than the present foredune, that there was a wider beach, and that the rate of dune growth was slower than the foredune formed be European beachgrass.

The date of the introduction of European beachgrass in the Nedonna/Rockaway area was not determined during this investigation. Some residents and publications identify the 1930's as the probable time. Aerial photos from 1939 indicate that beachgrass was present at that time, but it was not possible to determine whether the grass was European beachgrass or native grasses. It was assumed that the grass was European beachgrass because of the development of a dune ridge at the back of the beach which is not characteristic of native grasses. The aerial photos were taken 3 or 4 months after a severe storm. This early predecessor of today's active foredune had been severely eroded, breached and overtopped by storm waves.

The foredune continued to increase in height and width after the introduction of European beachgrass. The foredune growth has been episodic because of both local and wide-spread wave erosion. Repeated episodes of erosion in some locations has produced one or more remnant foredune ridges east of the present foredune. These remnant ridges are evidence of the episodic nature of accretion on this shoreline following the introduction of European beachgrass. Repeated ocean and stream erosion has resulted in poor foredune development near stream outlets throughout the history of active foredune development.

Variations in ocean erosion, wind deposition, and grading has resulted in a complex and somewhat irregular active foredune. The foredune is illustrated on the Technical Report Map. The foredunes in the unstable creek outlet areas are treated separately.

The foreslope is the seaward side of the foredune. Most foreslopes in the study area show evidence of past erosion. Erosion in the past two or three years has left a nearly vertical foreslope in some locations. After erosion of the foreslope, wind transported sand, driftwood and European beachgrass combine to repair the damage to the foredune. At first the repaired foreslope has an uneven surface and an uneven distribution of beachgrass. With more sand deposition the foreslope can eventually develop a relatively even slope and coverage of beachgrass. It can take two to five years or more, for the foreslope repair to occur. Further erosion can take place before repair can be completed.

The foredune crest is the top of the foredune. The shape, width and height of the crest, like the foreslope, is dependent mostly on the past erosion history or the amount of grading. Wave erosion can extend in to the crest or, in extreme cases, all the way through the crest. Wind transported sand and European beachgrass repair the erosion damage over several years, similar to the natural repair of foreslope damage. As a result, the crest varies in the study area from very thin, low and irregular to broad, high and relatively smooth.

The backslope is inland of the crest. It is relatively smooth and evenly sloped where there are lowlands inland from the foredune, such as in the Nedonna Beach area. In other areas backed by an older, stable foredune, such as the Lake Lytle oceanfront area, continuous accretion and episodic erosion has resulted in a condition where there is almost no backslope. What backslope exists merges in a short distance in to the back area.

The back area referred to in this study refers to the conditionally stable and stable sand areas inland from the foredune backslope. In the Nedonna Beach, Saltair Creek, and Watseco Creek areas the back area is low lying land. In Nedonna Beach the low-lying back area appears to have been a deflection plain. A deflection plain develops in some locations immediately inland from the foredune. It forms from wind erosion that removes sand down to the level of the summer water table. The area is no longer an active deflation plain; wind erosion is not occurring apparently because of the residential development. In the rest of the study area, the back area is composed of remnants of older foredunes and stable dune ridges.

The protective capability of the foredune is primarily a function of its bulk (height and width). The height is protection from flooding and its overall bulk is protection from erosion. European beachgrass is integral to the protective ability of the foredune. The beachgrass helps to build a high foredune and the roots bind the sand, thereby increasing resistance to wind and wave erosion. A gently sloping foreslope is also protective in that the energy of wave runup can be dissipated with a minimum amount of erosion.

At this time there is no known optimum dune bulk. In developed areas the optimum height is logically that elevation necessary to adequately protect inland areas from probable levels of ocean flooding. In regards to width, the wider the better because in a wide foredune there is more sand in storage available to be eroded. In regard to the slope of the foreslope, the general rule is--the flatter the better, but European beachgrass traps sand and builds up so rapidly that maintaining a low slope is unrealistic. A foreslope of 1:4 to 1:3 (25% to 33%) is reasonably realistic and is the range of managed foredune foreslopes in Europe.

Flooding

Two types of flooding occur in the Rockaway/Nedonna area -- fresh water and ocean flooding. Fresh-water flooding is not a direct subject of this study, but driftwood and sand blocked stream outlets can aggravate inland flooding. Ocean flooding occurs when high tides combine with large storm surges and/or large waves. Historic ocean flooding has not been as extensive as the flooding projected for the 100-year flood (U.S. Department of Housing and Urban Development, 1978).

A comprehensive documentation of past ocean flooding in the study area, as well as the rest of the Oregon Coast, was compiled by Stembridge (1975) using newspaper accountsas an indication of what happened. It was not possible or necessary within the limitations of the Rockaway/Nedonna study to review newspaper reports specific to the study area. The information from Stembridge has been examined for specific information on the study area. This information was combined with information provided by Schlicker and others (1972), information from the tabloid "Memories of Rockaway, Oregon" compiled by Rosemary Walker (1983), and from information provided by residents. Table 3 provides the information compiled from these sources.

The U.S. Department of Housing and Urban Development (1978) and Federal Emergency Management Agency (1982) have conducted studies and prepared maps of coastal flooding for use in establishing flood hazard designations and flood insurance rates. This is the only mapping of coastal flooding for the study area. The regulatory flood is the 100-year frequency flood, a hypothetical flood with a statistical recurrence interval of once every 100 years (1% chance of occurrence in any year). The flood maps (reproduced on the Technical Report Map) show several classifications of flooding. Of primary interest in this study is the velocity flood area (area subject to wave action) and the base flood (100 year flood) elevations. In inland areas, the base flood elevations or depth of flood waters is illustrated as well as the extent of areas prone to flooding. Flooding extends inland beyond the limit of the map. See the flood maps for more information.

The flood mapping is based on numerous hydrologic and hydraulic factors. Consideration was given to tides, storm surge, wave action, swell, offshore water depth, effective beach slope, and other factors (Department of Housing & Urban Development, 1978). Future changes in offshore depth and changes on the beach and foredune following the mapping were not considered (Green, personal communication, 1985). In fact, it is those variations in offshore and onshore conditions that result in the differences in base flood elevation from one shoreline reach

<u>Table 3. Damaging Events Affecting the Rockaway/Nedonna Area</u>

Feb. 1911	Breakers and drift logs over railroad.
Jan. 1914	No description.
Dec. 1931	Local flooding and logs tossed on Hwy. 101.
Oct. 1934	Local flooding and logs tossed on Hwy. 101.
Dec. 1935	Local flooding and logs tossed on Hwy. 101.
Jan. 1939	Local flooding and wave tossed log damage to houses at Twin Rocks and Manhattan Beach. Recurrence interval of 75 years.
Dec. 1940	No description.

Oct. 1941	No description.
Nov. 1948	Local flooding and logs tossed inland.
Jan. 1953	Local flooding and logs tossed inland. Shoreline erosion at Nedonna Beach.
Apr. 1958	Local flooding and logs tossed inland.
Jan. 1960	Local flooding and logs tossed inland.
Feb. 1960	Local flooding and logs tossed inland.
Oct. 1960	Freak wave damaging houses at Saltair Creek and tossing logs across Hwy. 101.
Spring 1962	Shoreline erosion at Rock Creek
Dec. 1967	Local flooding and logs tossed over foredune at Nedonna Beach, and Manhattan Beach; logs tossed on Highway 101 at Rock Creek and Saltair Creek.
Dec. 1972	Shoreline erosion.
Dec. 1974	Logs tossed inland.
Feb. 1976	Logs tossed inland. Recurrence interval of 10-15 years.
Oct. 1977	Shoreline erosion.
Feb. 1978	Shoreline erosion.
Winter 82/83	Shoreline erosion.

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to another shown on the Technical Report Map.

> "On the open coast, effective beach slope and storm wave breaking height may vary dramatically in a relatively short distance along the shoreline. Therefore, two adjacent reaches may have 100-year flood elevations that differ by more than 1 foot." (Department of Housing and Urban Development, 1978)

The accuracy of the ocean flood hazard mapping is dependent on how much change occurs over time. In the study area, there have been changes in foredune width and height and beach width and slope since the flood studies. Further changes will occur through shoreline erosion, recovery from the recent El Nino, and possibly from natural changes in the offshore water depths (including seasonal changes).

The Technical Report Map illustration of flood zones was reproduced from HUD and FEMA flood insurance rate maps. The original maps are at a scale of 1 inch = 1000 feet and 1 inch = 600 feet. The information was transferred as accurately as possible to our working map scale of 1 inch = 100 feet.

The regulatory flood insurance mapping supercedes natural and man-made changes in the elevation and configuration of the land. This leaves a potentially significant discrepancy between the regulatory flood and the real factors controlling shoreline flooding. This is one of the reasons why foredune grading, allowable under Goal 18 of the Statewide Planning Goals and Guildlines, is limited to an elevation of 4 feet above the base flood elevation. The extra 4 feet is necessary to accommodate the constantly changing nature of the shoreline and the inflexible nature of flood plain regulation.

Shoreline Erosion and Accretion

There is very little documentation of shoreline erosion in the study area. The Oregon Department of Transportation has a file on the 1977-78 erosion at Nedonna Beach. Schlicker and others (1972) noted erosion near Watseco Creek in 1971-72. A publication by Terich and Komar (1974) on the erosion at Bayocean Spit included a diagram that implied that erosion occurred in the study area as a result of the construction of the north jetty at Tillamook Bay. Erosion of much of the foredune in the southern half of the study area was noted in a study of the beaches and dunes of Oregon (Soil Conservation Service, 1975). Further information on shoreline erosion has been obtained by field investigation, aerial photo interpretation, and information supplied by residents and County Planning Department staff.

The lack of published documentation is apparently the result of the small amount of structural damage in the study area that has been caused directly by erosion. There has been severe local erosion, primarily near the stream outlets and near the jetties. Erosion by rip currents preceding storm surges and large waves has increased flood damage in some locations. Examples of erosion events are presented but do not represent all of the erosion that has occurred in the recent past.

It appears that foredune erosion in the study area is similar to erosion events on other portions of the Oregon Coast. In the following quote Komar (1979) discusses the erosion that took place on the Siletz spit in the 1950's, early 1960's and in the winters of 1972-1973, 1975-1976, and 1977-1978.

> "In each instance foredune erosion did not occur over the entire length of the spit. Instead, it was limited to two or three zones, each some 200 feet of spit

deposit sand at the base of the escarpment and promote repair of the foredune foreslope.

The current practice of uncontrolled foredune grading now occurring in the Nedonna Beach and other sections is causing minor wind erosion because of the exposure of sand unprotected by beachgrass. Due to the shallow depths and direction of the present grading cuts (east-west), most wind-blown sand deposits are small and occur on the easterly portions of the same lot. The beachgrass in the newly graded areas generally recovers quickly because the excavations are major wind erosion problems.

Creek Outlet Processes and Features

> "Coastal locations adjacent to stream mouths are dynamic environments. Waves and wave-induced currents interact with tidal currents and stream flow to produce a complicated pattern of water flow and sediment movement. The landforms which characterize these environments are constantly changing. Cycles of deposition and erosion related to the sediment budget of the streams and fluctuations in the location of the stream channel are superimposed on the cycle of changes on the beach caused by waves. The timing of these cycles and the amount of shoreline accretion and erosion are difficult to predict; this complicates planning for human use of these environments." (Nordstrom, 1986)

Shoreline processes at creek outlets are not well documented. No published information specific to creek mouths was found in our research. This section of the report presents information on shoreline processes analyzed in respect to the observed features at creek outlets in the study area. In addition to our own observations we were fortunate in having the input of Dr. Karl Nordstrom of Rutgers University. Dr. Nordstrom provided an as yet unpublished discussion paper on his research on the small stream mouths in the study area (Nordstrom, 1986).

Figure 12 illustrates the typical features found at creek mouths in the study area. The northern and southern limits of the area of creek influence were determined from the inland curvature of the shoreline. Because the shoreline at the creek areas has changed more radically over time than the foredune areas (see Figures 16, 17, 18, and 19), the area of creek influence was determined from historical shorelines, as well as the present shoreline. Former shorelines were mapped from historic aerial photos dating back to 1939. In some cases the shoreline is further inland than in 1939, but in most cases the shoreline is further seaward than in 1939. In the latter situation the area between the former shoreline and the present shoreline is an area of irregular foredunes, dune hummocks, active wind erosion, and driftwood length. This localization of dune erosion was governed by the positions of rip currents as ...

"In summary, erosion of foredune areas can be very rapid, removing some 100 feet of property in two or three weeks. The erosion is mainly centered in the lee of rip currents which hollow out embayments into the beach. Maximum erosion occurs under large storm waves, and is also aided by the high water levels of spring tides. Following erosion the foredunes may be re-established by beach sand washing and blowing into the eroded zone; drift logs aid in dune reformation by trapping the wind-blown sand." (Komar, 1979)

There is also little information on shoreline accretion in the study area. Accretion on the shoreline south of the Nehalem jetties was briefly acknowledged by the Corps of Engineers (1980). There are several reports that refer to the accretion north of the Tillamook jetties (Lizarraga-Arciniega and Komar, 1975; Komar and others, 1976a; and Komar, 1979). Cooper (1958) identified the study area as progradational and noted widening of the beach possibly as a result of construction of the north jetty at Tillamook Bay. Dicken (1961) notes progradation at several points in the study area determined from comparison of aerial photographs taken in 1939 and 1960. Stembridge (1975) maps the shoreline as prograding and notes that the least accretion was 30 feet between 1939 and his investigation.

The shoreline and accretion in the study area that has been documented in this investigation is illustrated on the Technical Report Map and described in the descriptions of each of the management units and stream areas in the study area. The accretion since 1939 in the study area could be attributed to: 1) lowering of sea level, 2) increased sand supply, 3) construction of jetties, or 4) introduction of European beachgrass. The ultimate cause of shoreline accretion in the study area is not known, but it is probably because of the introduction of the jetties and the introduction of European beachgrass.

Snapshots of this shoreline early in this century and the condition of the younger stable dune east of the active foredune suggest that shoreline accretion was not occurring as rapidly prior to the introduction of European beachgrass.

Wind Erosion and Deposition

Wind erosion does not have a severe impact at this time. Minor scouring of poorly vegetated foredune areas is occurring in all management units. This tends to perpetuate uneven foredune growth, but it does not present a direct threat to inland properties. Wavecut escarpments in the foredune are experiencing wind erosion, but this tends to deposit sand at the base of the escarpment and promote repair of the foredune foreslope.

The current practice of uncontrolled foredune grading now occurring in the Nedonna Beach and other sections is causing minor wind erosion because of the exposure of sand unprotected by beachgrass. Due to the shallow depths and direction of the present grading cuts (east-west), most wind-blown sand deposits are small and occur on the easterly portions of the same lot. The beachgrass in the newly graded areas generally recovers quickly because the excavations are major wind erosion problems.

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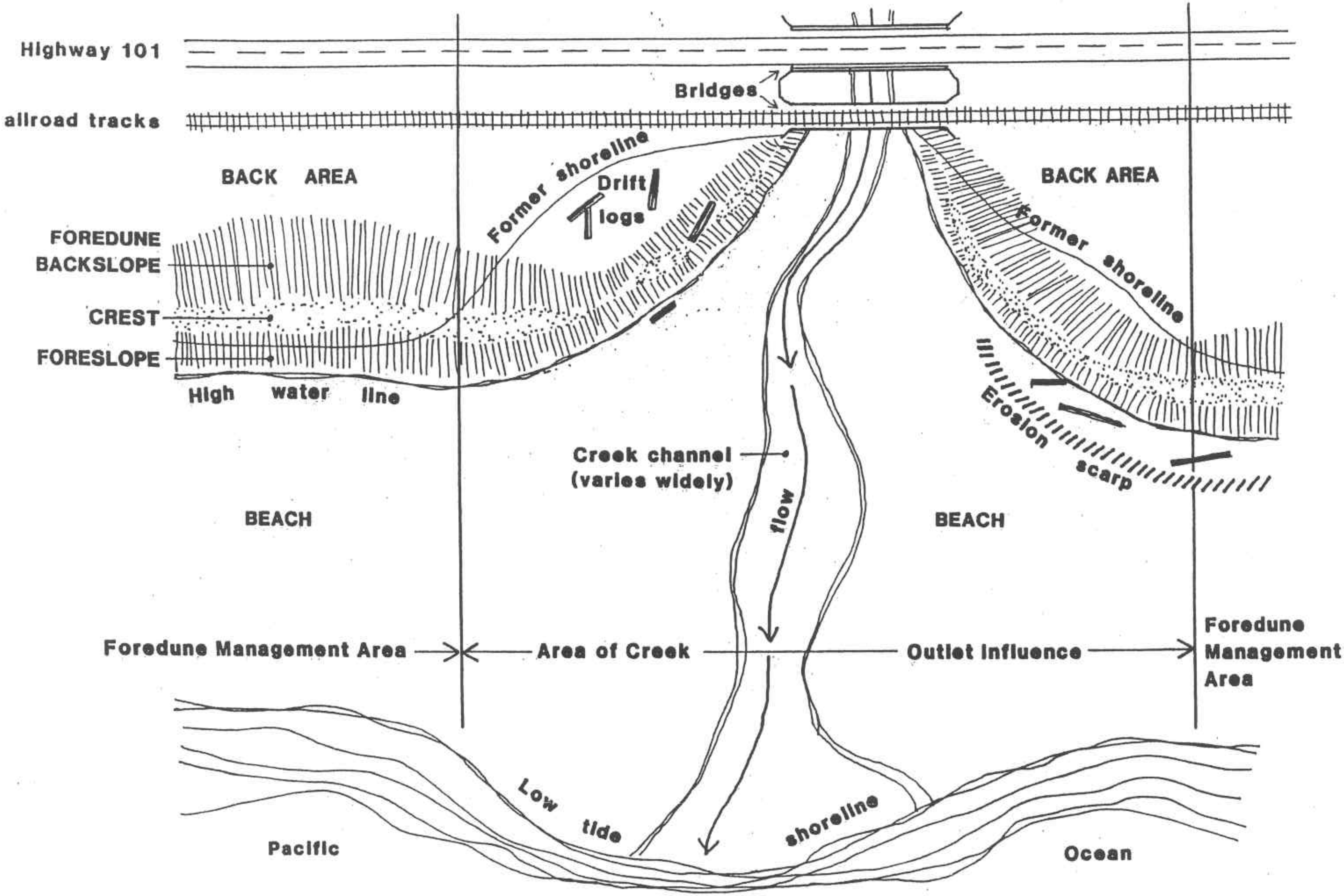
The present shoreline near the creeks is backed by a low, thin, poorly developed foredune or no foredune at all. The presence of emerging foredune ridges and hummocks near creek outlets appears to be related to a recent history of shoreline accretion, and shorelines recently subject to erosion have little or no developing foredune.

Observations made during this study (April 1985 to February 1986) indicates that wind and wave deposition of sand in the creek outlet areas occurs during periods of calm seas and low creek flow. Erosion occurs during periods of storm waves and high stream runoff, and typically leaves a beach escarpment or berm of a few inches to several feet in height on the beach. In some cases the erosion extended to the vegetated shoreline, in to the poorly developed foredune or to previously placed revetment. The erosion appears to be caused both by ocean waves, and stream flow.

Review of historic aerial photos indicates that the creeks migrate within the area of creek influence.

> "This may be caused either by deflection of the flow due to obstacles in the path of the stream (e.g. driftwood) or by the process of natural stream meandering, whereby a stream flowing through granular sediments lengthens its course and reduces its gradient by developing a sinuous channel. (Figure 13). The term stream deflection is used here to describe stream changes by both of these mechanisms."

> "Streams may be forced to flow alongshore, parallel to the shoreline trend, as a result of natural berm buildup, (Figure 13B). This process is defined as stream diversion. Diversion of stream flow may occur in both alongshore directions (north or south) as a result



GENERALIZED CREEK MOUTH AREA OF INFLUENCE FOR THE ROCKAWAY-NEDONNA BEACH AREA

Figure 12

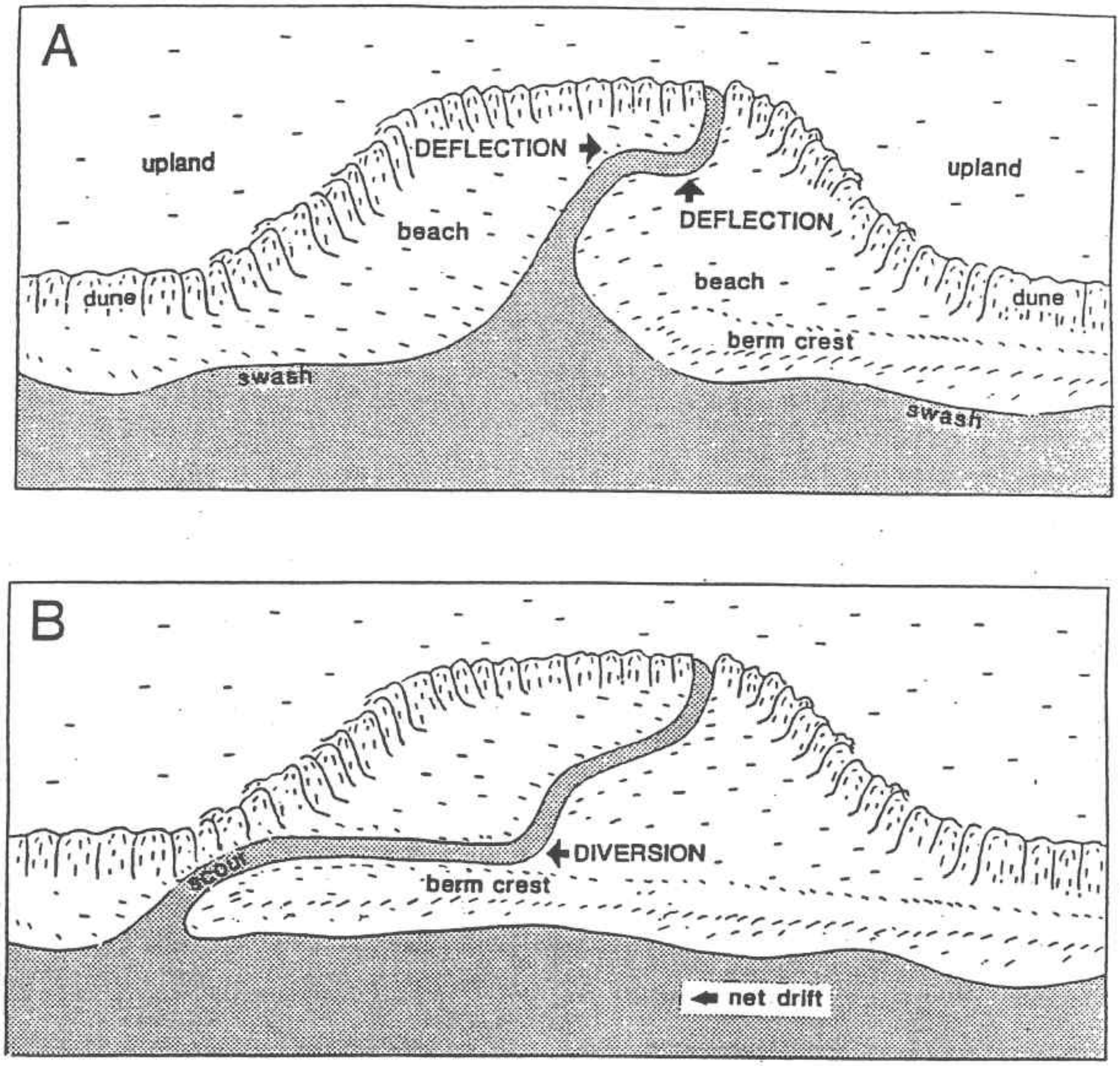


Figure 13. Mechanisms for widening of embayment by deflection and diversion of the stream.

> of reversals in the direction of longshore drift. Stream diversion has been greatest at Watseco Creek, where the beach berm is widest as a result of accretion caused by the north jetty at Tillamook Bay."

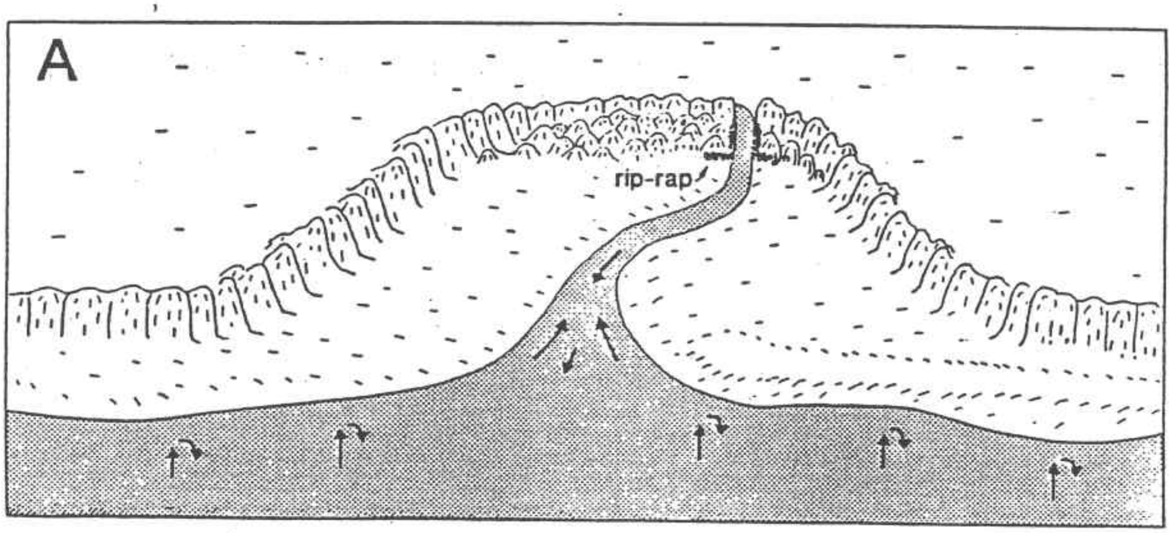
The streams are both directly and indirectly responsible for the formation of the stream mouth embyments. They erode the shoreline directly as a result of diversion and deflection, and by flowing across the beach they create a low area compared to adjacent beach areas. As a result, the streams create embayments that are subject to enhanced ocean wave and current action as compared to adjacent area.

The effect of waves and currents at the embayments are illustrated in figure 14. At high water levels waves break at an angle to the shoreline trend causing lateral basal sapping (erosion). Some wave energy is dissipated on breaking. Some energy is reflected seaward, where it interacts with incoming waves. Basal sapping and reflected waves remove sand from the embayments, counteracting movement of sand into the embayment.

Sand is moved into the embayments by winds and gentle waves, replenishing sand lost to stream and wave erosion. Some sand is blown to the backshore and foredune. The embayments are natural traps for drift logs, and the logs help trap wind blown sand. Logs can also block stream flow where the embayment is narrow.

Shoreline stabilization structures in the stream areas alter the embayment. Rip rap structures can protect inland areas from erosion, but they also reflect wave energy and cause increased scour locally. Training walls alongside the streams reduce meander by moving the stream mouth further seaward, but they can also increase erosion locally in the embayment or increase erosion locally in the embayment or increase the length of shoreline influenced by the stream outlet. Training walls can be extended too far seaward where they are subject to higher wave energy and block sand movement.

Stream outlets in the Rockaway area appear to be similar in physical processes to larger shoreline embayments at unprotected river mouths. The impacts of the natural processes and the impacts of alterations are similar but smaller in scale at the creek mouths. Episodic shoreline erosion is greater than at adjacent locations. The hazard of ocean flooding is greater than non-creek areas because the creek is a breach in the foredune, and the foredune that is present is low and irregular. Shorline protection structures can provide protection to inland areas but can also adversely impact the embayment and adjacent shoreline areas. Shoreline areas of stream influence should be special management zones.



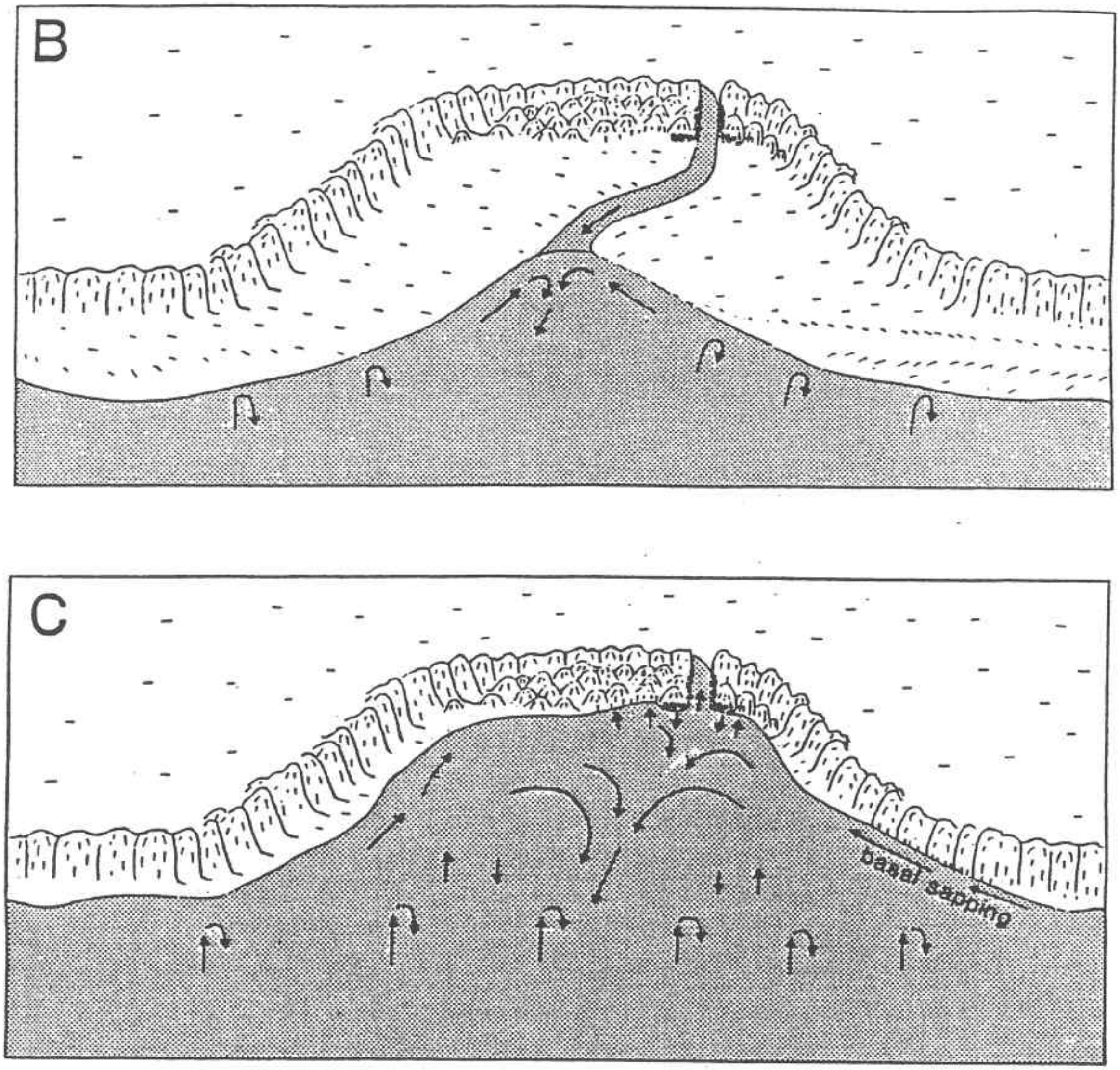


Figure 14. Effect of waves and currents on stream embayments at different stages of the tide.

Jetties

The Nehalem Bay jetties on the north and the Tillamook Bay jetties on the south have had a profound effect on beaches and dunes in the study area. The south jetty at Nehalem Bay was completed in 1915. The north jetty was completed in 1918 (Corps of Engineers, 1980). The north jetty at Tillamook Bay was completed in 1917 (Komar, 1976a). Jetties are placed to stabilize a river mouth at a particular location as it enters the ocean. Without jetties, river mouths tend to migrate in response to littoral movement of sand and offshore sandbars, as well as in response to river flow, and river sediment load, and changes in channel location in the estuary.

Extensive studies of the effect of jetties on shorelines along the Oregon Coast have been done by Dr. Paul Komar of Oregon State University: Komar describes the process as follows:

> "It is seen that where two jetties are constructed, there is beach sand accumulation both to the north and south, immediately adjacent to the jetties. This deposition and shoreline advance occurs because an embayment is formed between the newly constructed jetty and the pre-jetty shoreline. Before jetty construction, the shoreline curved inward toward the inlet and was in equilibrium with both the ocean waves and with the currents coming in and out of the inlet. Jetty construction eliminated the inlet currents acting on that curved portion of shoreline, leaving only the waves. The waves broke at angles to the curved shoreline and so moved sand into the embayment until it completely filled with sand (Figure 15). Once the embayment filled and there was a smooth and nearly straight shoreline parallel to the dominant waves, then a zero net littoral drift once again prevailed. (Komar, 1979, pp. 25-26)

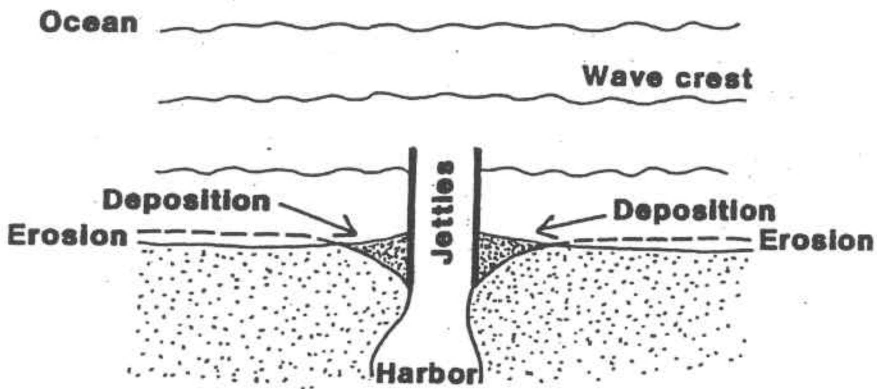


Figure 15. Sand accumulation in embayments created by jetties.

In fact, Nedonna Beach is such a filled embayment. Prior to construction of the Nehalem jetties the Nedonna Beach area was part of the river mouth and curved shoreline re-entrant.

> "The sand that fills the shoreline embayments produced by jetty construction must come from somewhere, and most of it comes from shoreline erosion at greater distances from the jetties. Thus a symmetrical pattern of erosion and deposition results with beach sand accumulation immediately adjacent to the jetties, both to the north and south, and with erosion at greater distances from the jetties."

> "The amount of shoreline retreat produced by jetty construction in areas, such as the Oregon coast where there is a zero net littoral drift, is a function of the size of the embayment to be filled adjacent to the jetty

and the length of beach over which erosion occurs to supply the sand."

"The shoreline affected by the Tillamook and Nehalem jetties appear to be at or near equilibrium. However, Bayocean Spit experienced dramatic erosion following jetty construction and up to 1952 when the spit was breached. Now that the embayment at the jetty has filled it is reasonable to conclude that little, if any, jetty-induced erosion will occur. Komar further notes that once this equilibrium is established jetties can subsequently be extended without producing additional major shoreline readjustments and erosion."

"The filled embayment areas to either side of inlet jetties are depandent upon the presence of the jetties. If the jetties are allowed to degrade than there may be some erosion of filled areas. Prior to rehabilitation in 1980-81, the Nehalem jetties deteriorated to the point that they were covered with water at high tide. The shoreline at this time curved back inward into the inlet but not as much as prior to jetty construction meaning that without rehabilitation further erosion might have been expected." (Komar, 1979, pp. 26-28).

Reconstruction of the Nehalem jetties was completed in the fall of 1982. The rehabilitated jetties have, in concert with the 1982-83 El Nino, resulted in substantial accretion of the beach at the south jetty. Approximately 200 feet of beach widening occurred in some locations from October 1978 to January 1984.

The jetties were rehabilitated to standards superior to the original construction according to Tom Clapper and Harold Herndon of the U.S. Army Corps of Engineers (personal communications, 1986). The large, outer armoring stores were carefully placed rather than randomly end-dumped and a core of smaller store was placed. The jetties have an economic life expectancy of 50 years, but maintenance will be required in 15 to 20 years (1997 to 2002).

Because there is no absolute assurance of maintenance of the jetties or of the projected life expectancy, it is recommended that no new development be allowed on lands at the north end of Nedonna Beach between the existing foredune and the jetty. The condition of the jetties should be monitored. Newly accreted lands adjacent to the south jetty should not be developed because of the possibility of future erosion and flooding as the jetties deteriorate.

FOREDUNE MANAGEMENT UNIT DESCRIPTIONS AND RECOMMENDATIONS

The shoreline of the study area has been divided into foUR foredune management units (See the Technical Report Map).

From the north to south, the units are:

1) Nedonna Beach - extending from the south jetty at Nehalem Bay to Crescent Lake outlet,

2) Lake Lytle Oceanfront - extending from Crescent Lake outlet to Rock Creek,

3) Rockaway Beach - extending from Rock Creek to Saltair Creek, and

4) Rockaway South/Twin Rocks Beach - extending from Saltair Creek to Spring Lake Outlet/Watseco Creek.

The shoreline was divided into these four landscape/management units based on an analysis of the physical characteristics of the components of the shoreline (beach, foredune and upland area). This analysis confirmed our initial impression. Each shoreline between the creek mouths in the study area has relatively consistent landscape characteristics. They are definable physiographic landscape units appropriate in scale for the purpose of management.

The physical processes and characteristics at the creek that breach the foredune have resulted in a shoreline that curves inland compared to the rest of the shoreline, and the foredune is poorly established or nearly non-existent near the creeks.

The following is a description of the foredune management units and recomendation for foredune management. Descriptions and recommendations for creek outlet areas follow the section on foredune management units.

Nedonna Beach Management Unit

General

This management unit extends from the recently rehabilitated south jetty at Nehalem Bay to the area of influence of the stream outlet of Crescent Lake, a shoreline distance of about 5900 feet. (See the Techncial Report Map.)

The north end of Nedonna Beach is similar to stream outlet areas in having a foredune that curves inland, but this area is not treated separately as are the creek outlets. This is because experience at other jetties indicates that the area will develop a new foredune roughly perpendicular to the jetty and west of and connected to the existing foredune as a result of rehabilitation of the Nehalem jetties. Treatment of this area as a foredune is desirable at this time to promote inland protection from ocean flooding and erosion. If the jetty is allowed to deteriorate, then the area would need to be managed like the more unstable stream outlet areas.

This foredune unit begins on the north on land that accreted to the shoreline after the construction of the Nehalem jetties. The south jetty was completed in 1915 (Corps of Engineers, 1980). The westerly extension of shoreline adjacent to some jetties on the Oregon Coast has been discussed in this report by Lizarraga-Arciniega and Komar (1975) and summarized by Komar and others (1976a) and Komar (1979). The initial accretion occurred rapidly following jetty construction in 1915 until about 1920, but deterioration of the jetties reversed the trend to one of shoreline erosion. Erosion has occurred in this area but cycles of erosion and foredune repair has resulted in a slowly accreting shoreline. Recent rehabilitation of the Nehalem jetties has resulted in increased accretion near the jetties that will probably continue for several years and will probably result in a new foredune west of the present foredune. The rate of new foredune development can be increased by proper placement of sand fencing and/or planting with European beachgrass.

Presently, the foredune on the north end of the management unit ranges from about 150 feet to 250 feet in width. The crest ranges from about 19 feet to 25.5 feet in elevation (MLLW datum). The foredune is lowest and thinnest at the Tillamook County parking lot, apparently because of vehicle and foot traffic over the dune and removal of sand to keep the parking lot clear.

The middle portion of the Nedonna Beach area from about Park Street to the Manhattan Beach Wayside has been subjected to less ocean erosion and more wind-blown sand deposition compared to the northern portion. As a result, the foredune is locally over 300 feet in width and up to 32 feet in height (MLLW). There are also remnants of a slightly older foredune about 70 feet east of the present foredune. This slow accretion does not mean that the area is free from future ocean erosion. In 1977-78, this beach was subjected to substantial erosion of the foredune.

In the southern portion of Nedonna Beach (Manhattan Beach Wayside Area), the foredune is 22 to 28 feet in elevation. The height decreases toward Crescent Lake outlet on the south. Adjacent to the Manhattan Beach State Wayside the present foredune is backed on the east by an older, stable dune that is less than 26 feet in elevation.

Vegetation

The vegetation line has been moving seaward on the foreslope of this accreting beach. The dominant species is European beachgrass which is in a vigorous state of growth because of wind-blown (eolian) sand deposition. There is less than 5% sea lyme-grass. It is showing the same vigorous growth but it is currently providing no competition for the European beachgrass. American sea rocket grows sparingly at the winter high tide line. The foreslope is the westward slope of a very irregular foredune. Vegetation coverage is only 10% to 50%. Large voids in the vegetative cover cause hummocking and allow wind scour. West of the active foredune crest is what appears to be a newly forming foredune with hummocks occupied primarily by European beachgrass.

The crest of the current active foredune is shown on the Technical Report Map. The dominant species (80% to 90% average coverage) is European beachgrass in a vigorous state of growth because of continuing wind-blown sand deposition from the beach. Sea lyme-grass in small patches is scattered throughout the crest area. In the central portion of this management area the sea lyme-grass (a successional dune species) appears to be left over from the early foredune that formed after the initial construction of the south jetty at the mouth of the Nehalem River. Beach pea, another successional species, is present in the southern two-thirds of this management unit. Again, this is an indication of a foredune backslope species that is still surviving on a new foredune crest after erosion of the former foredune crest. The result is a mix of initial (or pioneer) and secondary species. In addition, there is a scattering of large headed sedge, indicating the lessening sand supply caused by the formation of the new foredune out front.

Grading (excavating) of the foredune crest has occurred in this area. There is no evidence of substantial adverse impacts to the vegetative cover as a result of the alteration. This is apparently because grading has not totally removed the roots of the beachgrass, and the grass has recovered.

On the backslope of the Nedonna Beach foredune, vigorous stands of European beachgrass dominate. The upper half of this backslope is locally either European beachgrass or lyme-grass with evidence of a supply of fresh beach sand from eolian transportation. Again, this stand is complemented by large areas of beach pea. Vegetation coverage is generally 100%. Graded areas have vigorous stands of European beachgrass from recovery from old roots. The beachgrass is of varying height and density, depending on the time of year of grading. The grass has not recovered after grading in two locations. Since they are both on the north end, it is possible that they were poorly vegetated wead spots before grading. However, herbicides may have been used. The lower two-thirds of the backslope in the Manhatten Beach Wayside area is a mix of old lyme-grass stands and scattered pockets of successional species associated with dune areas cut off from the beach sand supply.

Flooding

The base flood elevation for the 100-year flood in this management unit is 22 feet (MLLW datum). The foredune is over 32 feet in elevation at its highest. At the County parking lot at the north end of Nedonna Beach the foredune is about 18 to 19 feet in elevation at its lowest. Northeast of the parking lot the foredune curves inland and drops in elevation. The lowest foredune elevations are on the north and south ends of this management unit. Grading has reduced some portions of the foredune in elevation below the 22 foot base flood level.

Erosion

This area accreted rapidly after the construction of the jetties and apparently by 1938 had developed a low foredune. A very severe storm in January 1939 eroded an unknown width of the west side of the foredune and breached and overtopped the foredune locally. In January 1953, there was shoreline erosion at Nedonna Beach but the extent is unknown. In the winter of 1977-78, a rip current embayment possibly related to a lack of an offshore bar resulted in erosion on the northern end of Nedonna Beach. The shoreline recession appears to have been about 100 feet. This erosion threatened many homes and emergency riprap was placed to reduce further erosion. The riprap is illustrated on the Technical Report Map, but it is now almost completely under sand that has healed the washout of the foredune. There was widespread shoreline erosion at the same time in Nedonna Beach south of the rip current (see the 1970 and 1977 shorelines on the Technical Report Map), but the overall erosion did not exceed 10 to 20 feet. The entire shoreline has had minor erosion (in the tens of feet), but overall there has been slow net accretion since 1939 on the shoreline.

Accretion

After construction of the south jetty at Nehalem Bay in 1915, there was rapid accretion in the northern portion of this unit. There are no records of the amount of accretion, but 1939 aerial photos indicate 1,200 feet or more of accretion occurred. According to the U.S. Army Corps of Engineers (1980), the shoreline "built out rapidly until about 1920, then began receding..." From 1915 to 1920 that is 240 feet per year or more. The shoreline recession was caused by the deterioration of the Nehalem jetties. Rehabilitation of the jetties was completed in the fall of 1982. Accretion is now occurring near the south jetty. Aerial photography indicates that there has been beach accretion of 150 feet or more from 1978 to 1984, but the accretion might be partially a result of the net northerly littoral drift produced by the recent El Nino.

The northern portion of this management unit has had net accretion of up to 100 feet from 1939 to 1984 (an average of about 2.2 feet per year). From 1939 to 1964, the shoreline had accretion of up to about 100 feet. The extent of intervening erosion during that time is not known. From 1964 to 1970 there was up to 80 feet of accretion. From 1970 to 1984 there was erosion caused shoreline retreat of up to 80 feet.

The central and southern portion of this unit had net accretion of up to about 120 feet from 1939 to 1964. From 1964 to 1970 there was a maximum of about 40 feet of accretion. From 1970 to 1984 the shoreline remained somewhat stable with local erosion and accretion of a few feet. For the peiod from 1939 to 1984 there was average accretion of about 3.6 feet per year.

Present and Future Foredune Stability

The foredune at Nedonna Beach has generally demonstrated net accretion, but there have been episodes of severe erosion. The shoreline can be expected to be at least equally unstable for a similar or larger period into the future. From the completion of the south jetty in 1915 until about 1920 there was rapid accretion in the Nedonna Beach area. The accretion was followed by an unknown total amount of erosion resulting from the deterioration of the jetties. The Corps of Engineers estimates an average of 5 feet per year. The aerial photos of 1939 are the earliest, accurate information available on the shoreline in Nedonna Beach. From 1939 to the present there has been slow accretion of the shoreline and growth of the foredune interrupted by episodes of erosion.

There are documented erosion events in 1953 and 1977-78. These erosion events indicate that shoreline and foredune erosion can be anticipated to be as great as 100 feet to 150 feet and to possibly breach the foredune locally. Erosion that has breached or nearly breached the foredune has been generally limited to 1000 feet or less of shoreline where a rip current embayment effectively concentrated the foredune erosion. In 1977-78 the foredune erosion was concentrated on about 2000 feet of shoreline by two rip current embayments. Widespread shoreline erosion has occurred, but it has not been as damaging as the rip current related erosion.

Eroded areas of the foredune have been naturally repaired by wind and wave transported sand and then continued to slowly accrete.

An increase in the rate of foredune accretion is expected to occur for several years following the rehabilitation of the Nehalem jetties. The rate of accretion will be greatest near the south jetty and smallest on the south end of the Nedonna Beach Management Unit. There is no precedent on which to estimate the rate or total extent of accretion. A new foredune will probably develop to the west of the present foredune from the south jetty to about Riley Street. The rate of foredune development could be increased by sand fences and beachgrass planting. This new foredune will decrease the potential for ocean flood or erosion damage to existing development in the northern Nedonna Beach area until the Nehalem jetties deteriorate. If the jetties deteriorate, the new foredune will be eroded and the shoreline might return to the equilibrium condition prior to jetty rehabilitation.

South of Riley Street there may be a short term increase in the rate of accretion as a result of jetty repair, punctuated by episodes of erosion. This will then be followed by a return to the previous condition of slow net accretion with periodic erosion.

The south end of this management unit could experience short term shoreline retreat if this area is a source of sand for the new foredune near the jetty. There is no evidence of substantial shoreline erosion in this area following jetty construction, and there is a long shoreline area available to supply sand for the accretion. To minimize the amount of sand needed in the accretion area before an equilibrium condition is reached, it would be beneficial to promote Depending on the amount of foreslope erosion, foredune development in the accretion area by planting European beachgrass or possibly by using sand fencing. This would minimize the amount of sand blown inland behind the new foredune and effectively taken out of the sand supply-sand storage system.

Portions of the Nedonna Beach Management Unit have foredune crest heights in excess of that legally required to allow grading. The required elevation is 26 feet (MLLW datum) as stipulated in Goal 18. There are also areas on the foredune crest that are below this minimum level. Sand excavated from crest areas above 26 feet elevation should be first used to fill in crest areas that are below the minimum height, thereby increasing the protective capability of the foredune in the event of a flood with a recurrence interval equal to or in excess of the regulatory 100-year flood. Foredune management in this area should also promote widening of the foredune to increase protection from ocean erosion. Widening of the foredune increases the amount of sand in storage in the foredune. The amount of widening that is practical is limited by existing development on the backslope of the foredune and by the easterly limit of the beach. Because there is no way to know how far westerly the foredune can be extended, it would be best to use excess sand from the foredune crest to build up low and eroded segments of the foreslope and not use excess sand to extend the foredune westerly until the other priority fill areas are satisfied. Sand filling north of about Riley Street can occur where a new foredune is actively developing west of the existing foredune.

Lake Lytle Oceanfront Management Unit

General

This section of shoreline is between the creek influence areas at Crescent Lake outlet and Rock Creek, a distance of about 6,800 feet. This is the longest, uninterrupted stretch of shoreline in the study area. Aerial photos from 1939 show substantial development along the shoreline. The photos also indicate damage to many structures in the storm of January 1939. The damaged homes had been built west of the older, stable dune that is east of Pacific Street. The Technical Report Map shows the shoreline after the storm but does not indicate the damage to inland areas from flooding and wave tossed logs. Since 1939 the shoreline has been slowly accreting, but there have been periods of erosion alternating with accretion. Apparently because of the alternating accretion and erosion, the foredune is poorly developed. The average foredune crest elevation is about 24 feet (MLLW datum). The low and high points are approximately 18 feet and 28 feet in elevation on the active foredune crest. The base flood elevation ranges from 25 feet on the north, 26 feet and 27 feet in the middle of the unit, to 23 feet on the south end. Only a small area at the south end of the management unit exceeds the minimum elevation for grading. This unit is not suitable for dune grading. Dune management would increase the flood protection ability of the foredune.

Vegetation

The dominant species on the foreslope is European beachgrass with about 30% to 50% coverage. The beachgrass is in a state of vigorous growth due to deposition of sand from the beach. Because of the sparse grass cover, hummocks and wind scour troughs exist now and tend to perpetuate an unstable foredune with low-lying weak spots. With minor surface grading, beachgrass planting of unvegetated areas, and a fertilizer maintenance program, this foreslope area could provide increased protection to inland development, though erosion will continue to occur periodically.

The crest section of the Lake Lytle Oceanfront foredune system is in a state of natural recovery from past erosion. The dominant species is European beachgrass. The conditions here are similar to the foredune crest in the Nedonna Beach area. The crest area is uneven in height, and the vegetative cover is weak.

In this management unit, the backslope area is very short or indistinguishable from remnants of previous foredune crests. Vegetation consists mainly of old stands of European beachgrass with a mix of successional plants such as coast strawberry, seashore lupine, salal, and shore pine.

Flooding

The Technical Report Map shows the base flood elevations for portions of this management unit and the inland extent of the 100-year coastal flood with velocity (wave action). The map also shows areas that would experience shallow flooding (one foot deep on the average), areas above the 100-year flood level but below the 500-year flood level, and areas of minimal flooding. This information comes from the Firm Flood Insurance Rate Map (Federal Emergency Management Agency, 1982).

There is very little documentation of flooding in this unit. Schlicker and others (1972) noted damage to beachfront houses in the January 3, 1939 storm. That was a 75 year storm according to the Department of Housing and Urban Development (1978). They also mention damage in the December 1967 flood. In both cases the damage was attributed to wave transported drift logs.

Erosion

This area has had episodic minor erosion (tens of feet). The erosional escarpment of recent erosion (probably the winter of 1982-83) has healed in the central portion of the management unit and is almost healed on the north end. This erosion apparently effected the entire shoreline in this unit and resulted in about 5 to 20 feet of shoreline retreat. The condition of the foredune suggests that widespread but minor shoreline retreat might be common in this unit. The map in "Beaches and Dunes of the Oregon Coast" (Soil Conservation Service, 1975, sheet 1 of 3, Tillamook County) shows periodic undercutting along the foredune at the time of mapping (December, 1973). Frank Reckendorf, author of that study, states that "since I mapped an active foredune (FDA) being eroded, it would appear that there was a delicate balance at that time between erosion and accretion each year. Overall, the beach was accreting and the foredune was growing. However, significant wave breaker heights such as occurred between July, 1972 and June, 1973 were significantly eroding the beach and adjacent dunes during this time." (Personal Communication, 1986). Local erosion of the shoreline has also occurred where rip current embayments have reduced the width of the beach.

Accretion

In 1920, the shoreline in this unit was apparently near the present location of Pacific Street (Walker, 1983). By 1939 land had accreted west of Pacific Street and houses had been built on the new land. From 1920 to 1939 there may have been about 100 feet of accretion (over 5 feet per year). Aerial photographs indicate that many homes built on the new land experienced flood damage in the storm of January 1939. The newly formed foredune survived the storm but was severely eroded on the west side, and it was apparently overtopped throughout the unit. From 1939 to 1964 there was an average of 50 feet of accretion (2 feet per year). From 1964 to 1977, there was as average of about 30 feet of accretion (2.3 feet per year). The net affect of the erosion and accretion in this unit is a narrow foredune with relatively low relief. After erosion episodes, there is an erosional escarpment. The escarpment is buried by wind blown sand, and the shoreline continues to slowly accrete.

Present and Future Foredune Stability

This foredune management unit has had slow accretion interrupted by minor erosion and shoreline retreat since 1939 and possibly since 1920. From 1920 to 1939 the accretion rate may have been in excess of 5 feet per year. After 1939 the average accretion rate has been a little over 2 feet per year. There is no evidence that this trend will stop or reverse in the foreseeable future. Erosion events will occur in the future. Some will be local (about 200 to 1000 feet of shoreline) and widespread erosion will involve all or nearly all of the unit. Maximum shoreline retreat will generally be less than 30 feet. The unique coincidence of two erosion events in one year could almost double this rate of retreat. Eroded areas will repair naturally and then continue to slowly accrete.

Flooding and damage to structures has occurred here and will occur in the future. Eventhough this management unit is not suitable for foredune grading, management of the foredune could decrease the potential for future flooding and damage. The goal of the management would be to build up a higher foredune to reduce wave overtopping. This may not be desirable to many residents and businesses because of loss of views. Management is recommended to include minor grading to smooth the foreslope and crest of the foredune, selective planting of European beachgrass and fertilization of the beachgrass.

Rockaway Beach Management Unit

General

This management unit is almost 1100 feet in length; the shortest management unit in the study area. It extends from the area of influence of Rock Creek to the area of Saltair Creek. The foredune is relatively low and irregular because of episodic erosion and accretion, patchy vegetation, and wind erosion. The unit is subject to ocean flooding because of the low height of the foredune. There has been local shoreline erosion, mostly related to the occurrence of rip current embayments. Since 1939 there has been accretion of about 100 feet on the north end and about 350 feet on the south end. Foredune grading is not feasible in this unit because the foredune is too low, but management in the form of vegetation management and minor grading could increase flood protection for some developed inland areas. However, the amount of increased protection for existing development would be small.

Vegetation

In this unit, the entire length of the foredune foreslope area has experienced episodic accretion and repeated wave erosion. As a result, the vegetation line is very uneven with large gaps and wind scour troughs. This problem is magnified by some grading and by heavy foot traffic on the north portion of the unit. The present vegetation is scattered clumps of European beachgrass that occurs down to the winter high tide line.

As illustrated on the Technical Report Map, this foredune crest area lacks any consistent height or width. The present dominant plant species is beachgrass, growing in a series of hummocks. The condition of the grass varies in relation to the beach sand that has moved over the foredune.

Vegetation on the backslope in this area is sparse with old stands of European beachgrass scattered throughout on hummocks and remnants of older foredunes.

Flooding

The 100-year base flood elevation in this unit is 23 feet (MLLW datum). Grading would be allowable on the foredune only if it exceeded 27 feet in elevation. The highest foredune elevations are at the south end of this unit. The highest elevation is 23 feet. The lowest mapped foredune areas are on the north end of this management unit (around 17 to 18 feet in elevation).

The foredune and the immediate inland area has been flooded in the past and will flood again in the future. There are no specific reports of ocean flooding in this area, probably because the existing development is on a higher stable dune east of the present foredune. Dwellings and commercial structures are on or protected by land in excess of 22.5 feet in elevation.

Erosion

Aerial photos and vegetation indicates that an unknown but substantial amount of shoreline retreat has periodically occurred in this management unit. The erosion appears to have been related to rip current embayments and to unit-wide shoreline retreat. The north end of the unit appears to have been particularly prone to rip current embayment formation. The amount of shoreline retreat is not evident on the Technical Report Map because of limited aerial photo coverage. What is evident from the aerial photo mapping of shorelines is that from 1939 to 1966 there was less than 70 feet of shoreline accretion. What the shoreline mapping does not show is shoreline retreat in January 1953 and in the spring of 1962. From 1966 to 1970 there was little shoreline erosion, and there was up to 150 feet of accretion. From 1970 to 1984 there was little accretion, probably because of erosion in 1972, 1974, 1976, 1977, 1978, and the winter of 1982-83.

Accretion

This management unit has had slow accretion, but ocean erosion and wave overtopping has resulted in a very irregular rate of accretion. From 1939 to 1977 there was about 130 feet of accretion on the north end of the unit (about 3.4 feet per year). In the same period there was about 230 feet of accretion at the south end of the unit (about 6 feet per year). However, from 1939 to 1966 there was very little net accretion. There had probably been more accretion in the period from 1939 to 1966, but apparently extensive shoreline retreat occurred in 1962. From 1966 to 1970 there was very little erosion and the shoreline accreted rapidly. From 1970 to 1977 there was only a small net amount of accretion, probably because of shoreline retreat in the storms of December 1972, February 1976 and October 1977. There has been little change in the shoreline since 1977, probably because of shoreline erosion in February 1978 and in the El Nino period in 1982 and 1983.

Present and Future Foredune Stability

As in the other management units previously discussed in this report, there has been slow accretion in this foredune management unit area. However, the low and irregular foredune and the evidence of extensive shoreline retreat indicates that the present foredune is unstable and subject to ocean erosion and wave overtopping. The only stable landforms are east of the 1939 shoreline shown on the Technical Report Map.

Foredune grading is not feasible in this unit because of the low elevation of the foredune crest and because of the potential for future shoreline retreat. Management of the foredune by minor grading and increased beachgrass coverage would improve the ability of the foredune to protect inland areas from ocean flooding and erosion. However, there is the attendant danger of fostering new land development in low elevation areas west of existing development. Further, establishment of a higher and broader foredune is limited by a relatively short beach area available as a source of wind transported sand for a foredune. If foredune management is attempted in this area it should only occur if there is an effective restraint on land development west of the line of existing development.

Rockaway South/Twin Rocks Management Unit

General

This management unit extends from the area of influence of Saltair Creek to the area of influence of the combined Spring Lake Outlet and Watseco Creek, a shoreline distance of about 1800 feet. The highest elevation on the foredune is about 23 feet (MLLW datum). The lowest part of the foredune is about 16 feet in elevation. The 100-year base flood elevation is 24 feet on the north end and 19 feet on the south end (MLLW datum). The foredune is not high enough to allow foredune grading under Goal 18 provisions. Dwellings east of the foredune are only subject to minor ocean flooding under existing conditions in the event of an 100-year flood. This unit has had slow accretion since at least 1939. There have been periods of local and unit-wide erosion but natural repair of the foredune and accretion has followed the erosion events.

Vegetation

The vegetation in the foreslope area of the foredune is recovering from recent erosion. European beachgrass is the dominant species, but coverage is sparse. As a result of the sparse beachgrass coverage and natural foredune recovery from erosion, there is some minor wind erosion, sand deposition, and uneven development of the foredune.

The crest of the foredune is irregular because of the repeated episodes of erosion and the resultant wind erosion, sand deposition and uneven development of beachgrass cover. The dominant vegetation on the crest is European beachgrass.

This backslope area is one of the most stable of the management units. Species present, besides beachgrass, are the typical sucessional dune species. Surface grading in previous years appears to have caused no severe or persistent vegetative problems, probably because of the shallow depth of excavation.

Flooding

The base flood elevation is 24 feet in the northern portion of this unit and 19 feet on the south end. The foredune is only 16 to 23 feet in elevation and is subject to overtopping in a major flood. Existing structures are on an old and stable dune ridge about 250 to 400 feet east of the active foredune. The structures are generally at an elevation of 20 feet and many of the structures would be subject to flooding in a 100-year flood. Much of the flooding would be shallow in depth, but those structures subject to velocity flooding (wave action) could be damaged by the wave action and surf-swept drift logs.

Erosion

Overall this unit has accreted despite episodes of erosion. Erosion has been both unit-wide and local. Local erosion is typically related to the occurrence of rip current embayments in the nearshore that narrows the width of the beach. The Technical Report Map illustrates shorelines mapped from aerial photos, but photos are avilable for only a limited number of years.

The mapped shorelines indicate wide-spread erosion between 1970 and 1977 and between 1977 and the mapping for this study (1984). This unit-wide erosion probably occurred in December 1972, February 1976, October 1977, February 1978 and in the winter of 1982/1983. Previous episodes of wide-spread erosion undoubtably occurred but are impossible to document with the available information. Available information indicates that wide-spread erosion has resulted in shoreline retreat of 50 feet or less.

Rip current embayments have resulted in local shoreline erosion of about 500 feet in length and about 50 feet in depth in the period from 1966 to 1984.

Accretion

Overall there has been net accretion of the shoreline in this management unit since at least 1939. Aerial photos taken in April 1939 indicate that this area experienced accretion shortly after the completion of construction of the north jetty at Tillamook Bay in 1912, but the onset of accretion began at an unknown time. From 1939 to 1984 there was net accretion of as little as 200 feet on the north end of the unit and as much as 350 feet on the south end. This translates to an average net accretion rate from over 4.4 feet per year to almost 7.8 feet per year. From 1966 to 1970, apparently a period of little ocean erosion, there was an average rate of 20 feet of accretion per year. From 1970 to 1977, a period of time with many shoreline erosion events, there was no net accretion.

Present and Future Foredune Stability

The foredune is insufficent in height to allow grading. There has been accretion of the shoreline, but episodic local and unit-wide ocean erosion combined with wind erosion has resulted in a foredune that is low and irregular in elevation. Because there is no evidence of change in shoreline processes we believe that the past process of slow accretion will continue. It can also be assumed that unmanaged future foredune development will continue to produce a foredune that is low in elevation and irregular because of the ocean and wind erosion.

Vegetation management could produce a more stable foredune with increased protection for existing inland structures. However, management would necessarily include monitoring of the foredune condition, fertilization and periodic maintenance of the foredune vegetation.

Presently, because of the probability of velocity flooding behind the foredune, there should be no development of structures west of the existing line of dwellings along Breaker Avenue. Any development west of the existing line of dwellings would be subject to the hazards of velocity flooding, wave transported driftwood, wind erosion, wind-blown sand deposition, and shoreline retreat. Further development in this area should only be allowed if there is a plan for perpetual foredune management, demonstration of long-term stability of the managed foredune, and reasonable assurance of a future free from velocity flooding.

CREEK OUTLETS - DESCRIPTIONS AND RECOMMENDATIONS

Crescent Lake Outlet

General

This shoreline area is illustrated on Figure 16. Crescent Lake outlet has influenced about 1650 feet of the shoreline. Before the stream was constrained by a highway and railroad bridge the creek probably migrated over a shoreline area that extended further to the south. The drainage area of this creek includes Finney Creek, Steinhilber Creek, Lake Lytle, and Crescent Lake.

The foredune in the creek area of influence is narrow and low in elevation, typical of foredunes in the area of influence of creek outlets in the study area. As a result the area behind the foredune is prone to ocean flooding.

This creek outlet area also displays a trait characteristic of other outlets in the study area: erosion and accretion rates are greater and the area of influence is larger north of the outlet than to the south. Presumably this is because storm waves approach the shoreline and run up on the shoreline from the southwest. Waves generated by southwesterly winter storm winds are higher than northwestly summer waves, and winter tides are generally higher than summer tides. As a result the northern shorelines take the brunt of the energy in the waves and in wave run-up. Accretion of the shoreline north of the creek outlets occurs in the summer and in periods when winter storm driven waves do not coincide with high tides especially during winter months at low tide when a wide expanse is exposed to the southwesterly wind.

Vegetation

The foredune and the European beachgrass present is poorly established on the north side of this creek outlet area. The most northerly 340 feet of this unit has a very thin active dune area with an older stable dune immediately adjacent on the east. Further south on the north side there are foredune fragments up to about 19.5 feet in elevation (MLLW datum) and dune hummocks but the average dune height is less than 18 feet in elevation and the area is poorly vegetated. Just north of Crescent Lake Outlet there is an erosion escarpment that is partially protected by a revetment placed to protect the railroad tracks. The beachgrass is also sparse here.

South of Crescent Lake Outlet there is a low foredune that is very sparsely vegetated on the foreslope because of recent erosion. Part of the crest and all of the backslope area is well colonized by beachgrass indicative of recent stability,

FIGURE 16

but the foredune is generally thin and largely below 20 feet in elevation.

Flooding

The base flood elevation for the 100-year flood is 19 feet (MLLW datum). Low spots in the foredune and creek area (about 16 feet elevation on the north end and less than 16 feet on the south) allow flooding behind the foredune.

Erosion

The north side of Crescent Lake outlet has experienced substantial erosion and retreat of the shoreline. From 1939 to 1964 there was over 200 feet of erosion. From 1939 to 1977 there has been as much as 230 feet of shoreline retreat. There have been periods of shoreline accretion (1964 to 1979)