Pacific City

Foredune Management Plan:

MANAGEMENT STRATEGY

prepared for

cific City Beachfront Homeowners Association
Box 601
Pacific City, OR 97135

by

Shoreland Solutions
P.O. Box 1046
Newport, OR 97365

July 1998

DRAFT

Preface

This document outlines a strategy for management of the foredune area fronting the rural community of Pacific City in Tillamook County, Oregon. The proposed strategy takes the form of recommendations on the types of sand management practices applicable within this area.

This document is one in a set of documents that together constitute the Pacific City Foredune Management Plan. Other documents in this set are: the Background Report, which reviews the factors affecting the stability of shoreline in the management area; the Monitoring Program, which describes the types of information to be collected and analyzed in order to evaluate the success of the manager strategy; the Maintenance Program, which describes activities needed to ensure the succ management strategy; and the Implementing Ordinance, which is the formal mechanism prescribed sand management practices. This set of documents is intended to addr of Statewide Planning Goal 18: Beaches and Dunes - Implementation Requirement (4)(C) (2) of the Tillamook County Land Use Ordinance regarding foredune grading.

This document was prepared by Shoreland Solutions at the request of the Pacific City Beachfront Homeowners Association.

Pacific City

Foredune Management Plan:

MANAGEMENT STRATEGY

Table of Contents

Pacific City

Foredune Management Plan:

MANAGEMENT STRATEGY

Overview

The Pacific City foredune management area extends from Nestucca Spit State Park on the south to Cape Kiwanda State Park on the north (Figure 1). It encompasses the foredune area fronting the rural community of Pacific City in Tillamook County, Oregon. Its landward boundary is specifically defined as the seaward (western) wall-supporting foundation of existing structures and a direct line between the foundations where there is no structure.

At least since the late 1960's the shoreline along much of this area has exhibited a net seaward migration due to sand accumulation. Sand accumulation since the early 1980's has been dramatic. This increase in beach and dune sand volume has enhanced ocean flood/erosion protection potential. However, it has also presented problems for local residents and visitors alike, as the accumulating sand and the accompanying growth in height and width of the foredune area has led to the inundation of oceanfront homes, the reduction of ocean views, and the restriction of beach access.

While much of the shoreline fronting Pacific City has experienced net accretion over the last 30 years, at least two episodes of erosion have occurred during this time. During one such episode in the the late 1970's Nestucca Spit was breached. Extensive foredune retreat occurred elsewhere along the Pacific City shoreline at this time and, as a result, as much as 2500 feet of riprap was placed above the shoreline along the central portion of the management area.

Following from the above, the overall objectives of the proposed foredune management strategy in order of priority are:

- To maintain or enhance ocean flood/erosion protective functions of the natural foredune area;

- To minimize inundation brought about by excessive accumulation of wind-blown sand and correspondingly maintain or enhance ocean views; and

- To maintain or enhance access to recreational uses associated with the open sand beach.

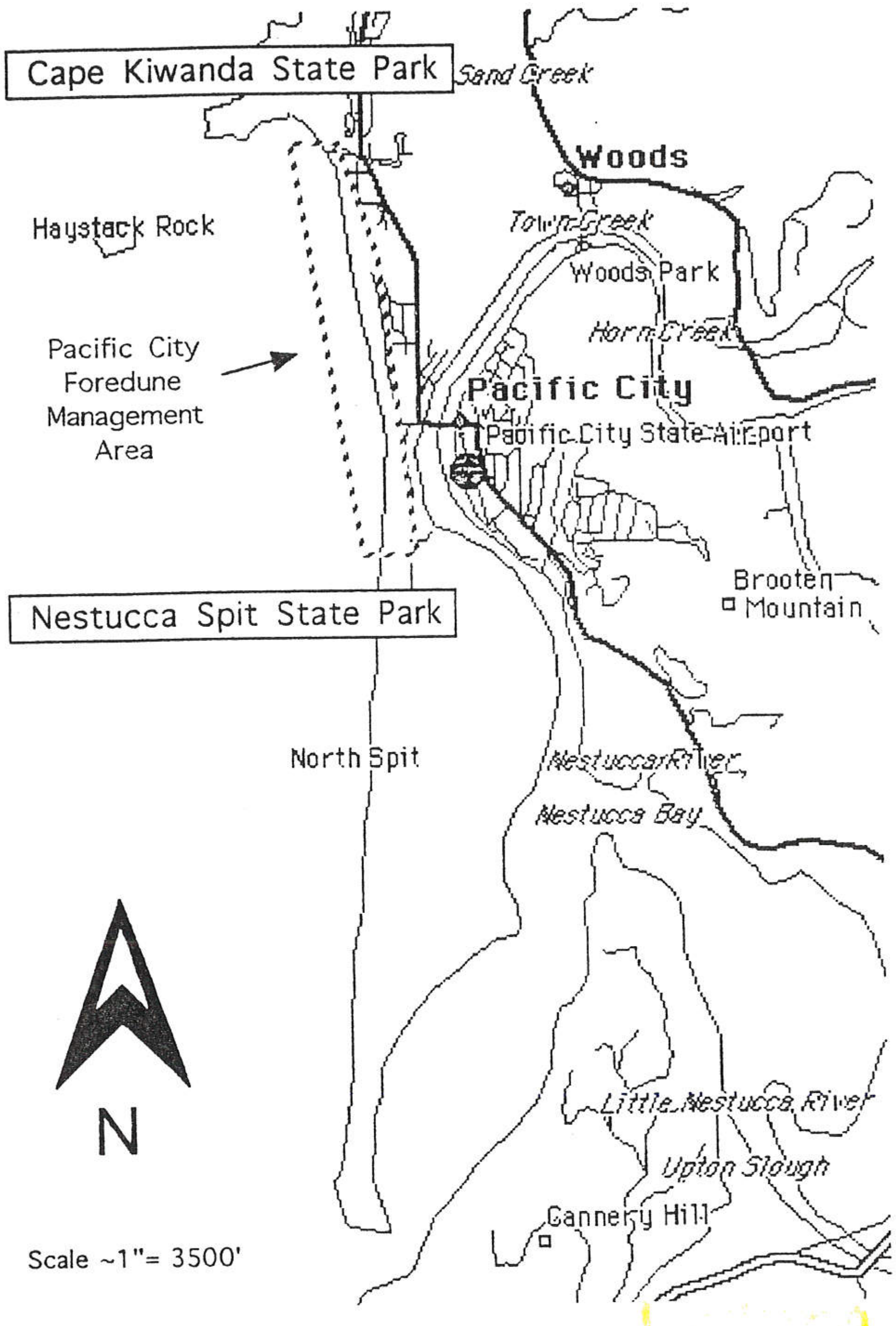


Figure 1. The Pacific City Foredune Management Area

The recognition of individual *management units* within the overall management area constitutes the framework of the proposed foredune management strategy (Figure 2 and Attachment A: for additional information see the Background Report). Individual management units are distinguished by the combination of physical and social settings that exist within each area. For each management unit the relative priority of the management objectives identified above is established on the same basis. The result is that different types of management practices are prescribed for different management units.

Initially, prescribed management practices will focus on areawide foredune grading and vegetative stabilization (Table 1). Under the proposed strategy foredune grading, specifically *view grading*, may be conducted in areas where the elevation of the foredune exceeds the 'V-zone 100 year plus 4 foot' elevation. Grading down to the 'V-zone 100 year plus 4 foot' elevation is allowed in these areas. As a basis for further defining the extent of grading in these areas, a *design foredune configuration* has been identified - a foredune area with sufficient height and width to withstand storm wave attack (Figure 3: for additional information see the Background Report). Under the proposed strategy it is envisioned that view grading will be conducted within smaller *subareas* within the individual management units. Priority will be given to the transfer of sand from high areas behind the foredune crest to low areas elsewhere along the crest and foreslope. Only after low areas within the subareas have been filled, will 'excess' sand (i.e. that which exists above and beyond prescribed foredune elevations and widths) be transferred seaward of the lower foreslope/ beachface so as to allow a combination of wave and wind-driven sediment transport to redistribute it.

Table 1. Type and Timing of Prescribed Management Practices

	PHASE I Years 0 - 2	PHASE II Years 3 - 5
Foredune Grading	•	•
Vegetative Stabilization	•	•
Access Management	•	•
Monitoring	•	•
Maintenance	•	•

Remedial grading is another type of foredune grading called for within the foredune management strategy. Remedial grading is defined as the limited transfer or removal of sand which has, or is soon to be, piled up against exterior walls, windows, doors, or decks and thus interferes or is about to interfere with access to or with the safe use or occupancy of existing structures. Unlike view grading which is carried out an areawide basis, it is envisioned that remedial grading will be conducted by individual property owners on an as needed basis. Although it is an activity that would occur outside of the

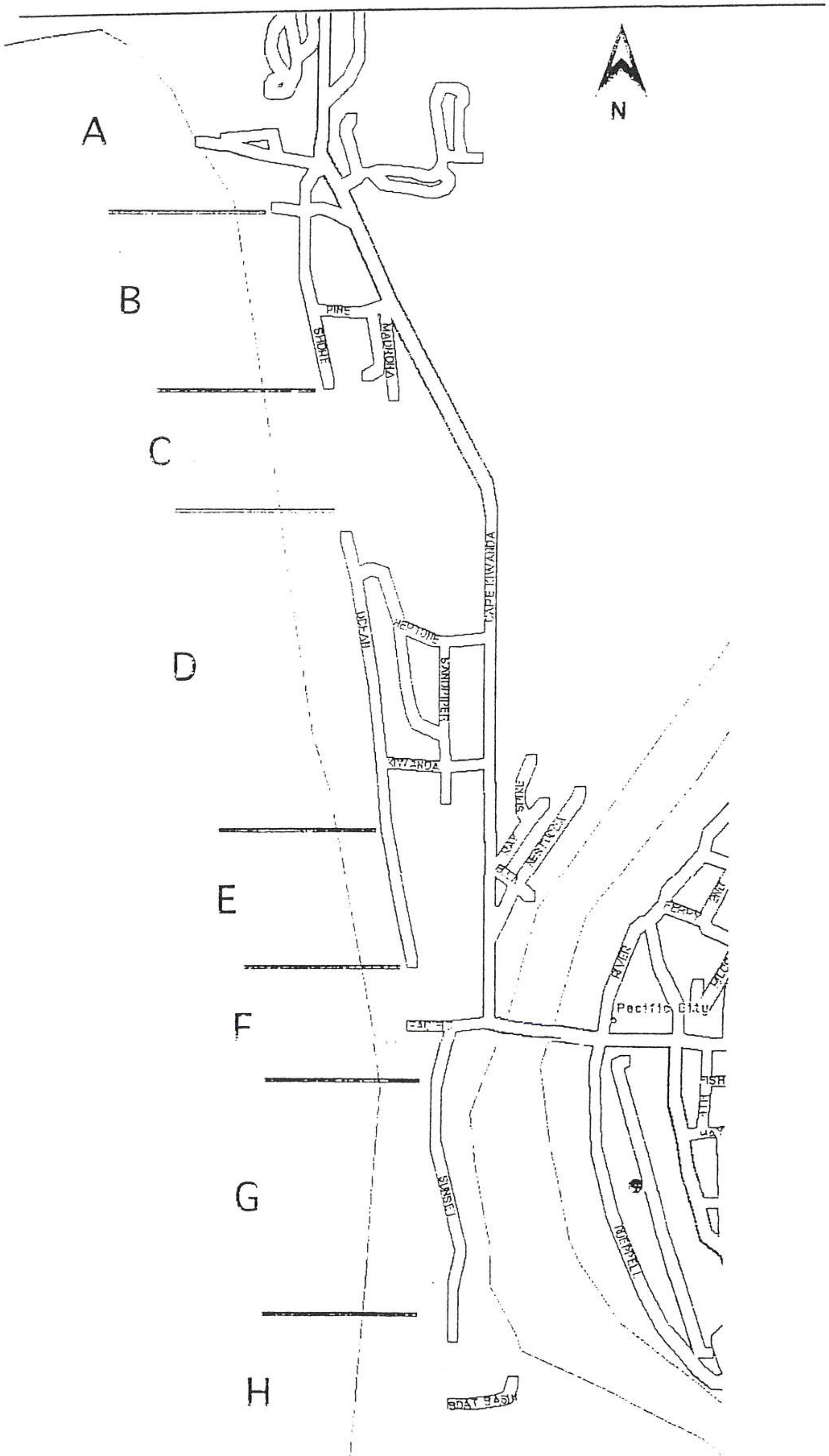


Figure 2. Pacific City Foredune Management Units (see also Appendix A).

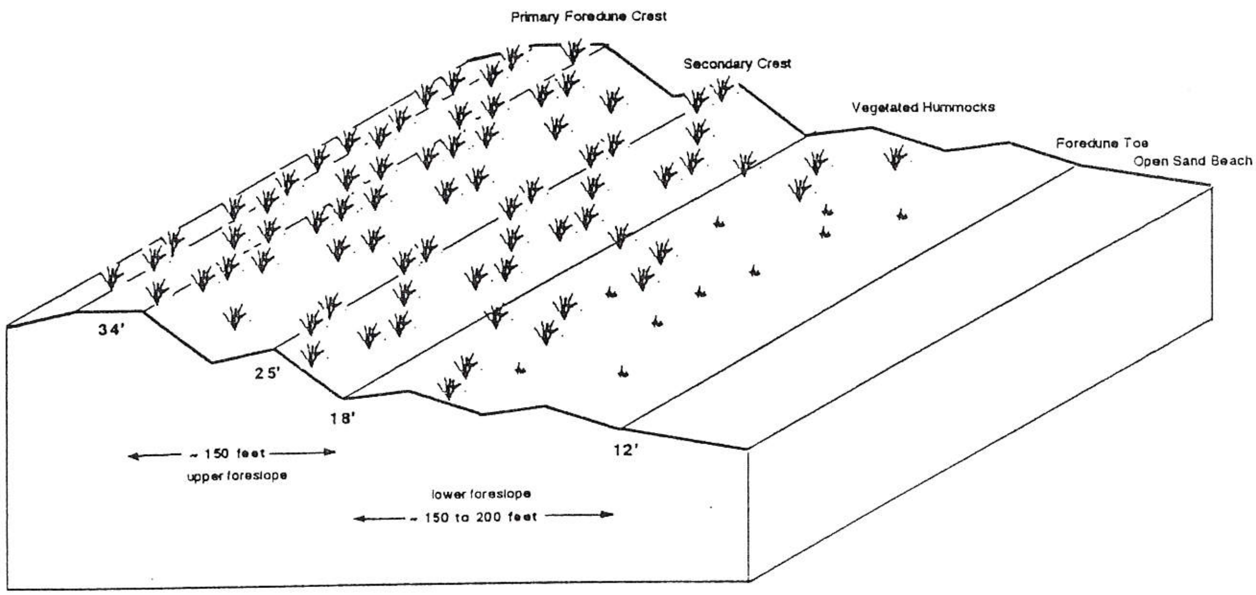


Figure 3. The Pacific City Design Foredune.

identified foredune management area, the proposed foredune management strategy also calls for the *grading of vacant lots*.

Typically, vegetative stabilization will be conducted in association with view grading. Primary grasses are to be planted in the graded areas along and directly landward of the foredune crest so as to stabilize these open sand areas and thereby reduce the potential for sand inundation. Primary grasses are also to be planted along the upper and lower foreslope. It is envisioned that the ability to capture and hold sand in these areas will encourage growth in foredune width as opposed to height, and thereby maintain flood/erosion protection potential as well as reduce the potential for sand inundation. The central portion of the management area is one location where less extensive planting is likely. Here, dwellings are fronted by riprap and lie in relatively close proximity to the shoreline. Other locations where planting is likely to be limited are in the vicinity of the Dory Boat Ramp and the Turnaround. Recreational use is particularly heavy in these areas.

Access management is another management practice prescribed throughout the management area under the proposed foredune management strategy. Access management is needed to address potential conflicts between vegetative stabilization and recreational use. It may involve, for example, placing informational and/or educational signs at identified points along the foredune to direct residents and visitors away from recently planted areas.

Although much of the first two years of foredune management efforts will focus on areawide foredune grading and vegetative stabilization, the proposed strategy also calls for areawide monitoring and maintenance during this time. Monitoring will typically involve biannual visual inspections and elevation surveys in 'active' management areas (i.e. those areas where areawide foredune grading and vegetative stabilization have been conducted). Maintenance measures may include remedial grading, noted above, as well as foreslope shaping and repair planting. In the years following initiation of prescribed management practices, monitoring and maintenance are likely to be the focus of foredune management efforts. Recommended project monitoring and maintenance measures are detailed in the Monitoring Program and Maintenance Program documents respectively.

The proposed foredune management strategies for each of the identified management units is given below. It includes a more detailed description of the setting, objectives, and prescribed management practices associated with each of the management units. Before proceeding, it should be noted that the exact specifications pertaining to foredune grading and vegetative stabilization within management units will be developed in the context of subarea plans. In this way the needs of individual property owners can be provided for in a manner consistent with the management unit strategies.

Management Unit Strategies

Management Unit A

Setting. This management unit extends from the southern boundary of Cape Kiwanda State Park to the southern boundary of Alder Street (the line between Tax Lots 2000 and 2100).

This segment of shoreline is characterized by relatively minor shoreline change over over the period 1967 to 1997. Specifically, portions of the foredune area have increased in width by as much as 65 feet and in height by as much as 15 feet during this time (Table 2; Figure 4). This area has also experienced episodic erosion. As much as 50 to 100 feet of foredune retreat has occurred on at least two occasions over the last 30 years.

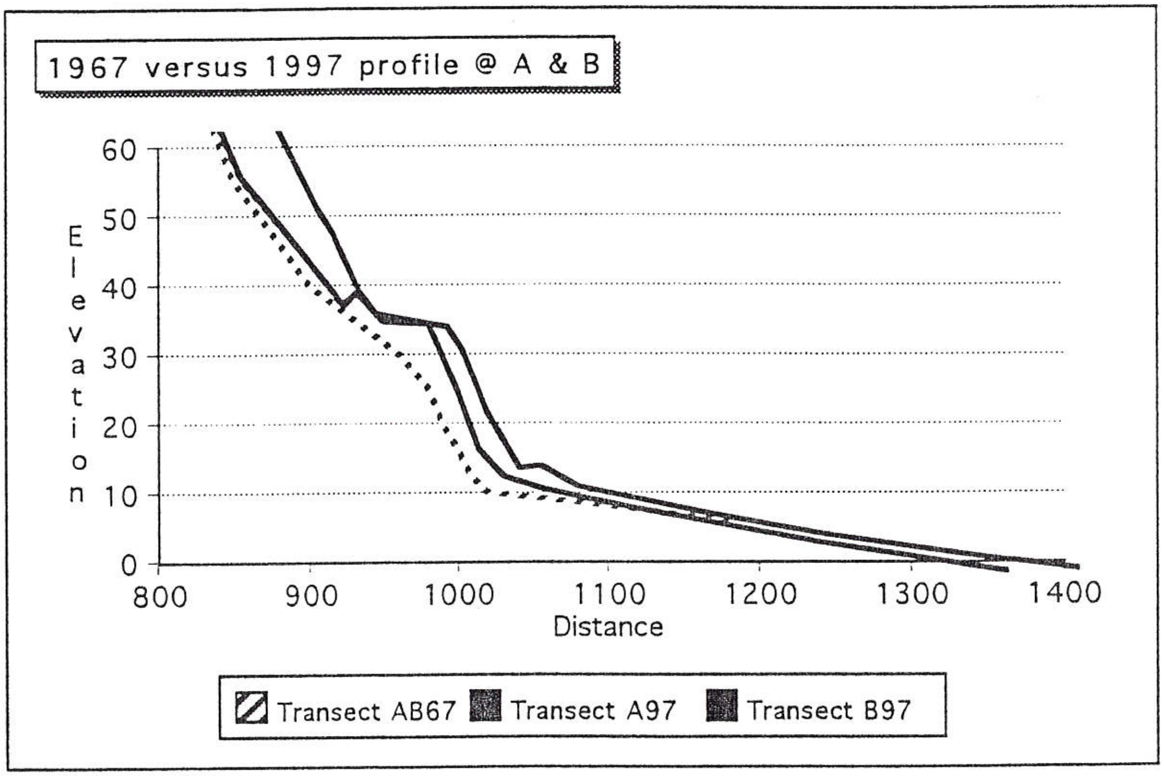


Figure 4. Cross-section Showing Profile Change over the Period 1967 to 1997 in Management Unit A.

Currently, foredune morphology varies somewhat along this segment of shoreline. The northern and central portions are characterized by a relatively low, narrow, graded profile. The southern portion is

Table 2. Setting, Objectives, and Management Practices for **Management Unit A** (Cape Kiwanda State Park to Alder Stree

Setting

- **Minimal Shoreline Change**

1967 versus	1997	
@ 10' contour	0' to +5'	elevation
	+35' to 65'	width
@ 20' contour	+10 to 15 '	elevation
	+15' to 35'	width
25' to 30'	35' to 45'	elevation
	of primary foredune crest	

- **Episodic Erosion** 50' to 100'

- **mixed** morphology (north/south) - **low/high, wide/narrow, graded/accreted**
  - crest elevation 35' to 45'
  - toe elevation 13' to 15'
  - foreslope width 50' to 150'

- **Poorly to Moderately vegetated**
  crest and backslope
  10 to 60% cover
  foreslope
  open sand to 30% patchy cover

- **C1- commercial**
  dwelling elevation low ~32'
  dwelling location ~100' from OPRD Vegetation Line

- **Heavy Recreational Use with Vehicular and Pedestrian Access**

- **Sand Inundation**, extensive **Riprap**

Objectives

- Maintain Flood/Erosion Protection
- **Minimize Sand Inundation and Enhance Ocean Views**
- **Maintain or Enhance Access**

Management Practices

- **View Grading** (south only)

	elevation	location
Foundation	*34'*	@ 0'
Primary Crest	*34'*	@ 100'
Secondary Crest	25'	@ 200'
Toe of Foreslope	12'	@ 400'

- Remedial Grading Parking L

- **Vegetative Stabilization** (north only

Backslope	60 to 90% cover
Primary Crest	60 to 90% cover
Secondary Crest	30 to 60% cover
Upper Foreslope	30 to 60% cover
Lower Foreslope	10 to 30% cover

- **Access Management**
  Dory Boat Ramp/County Parking Lot
  Alder Street

- **Monitoring and Maintenance**

characterized by a relatively high, wide, accreted profile. The foredune crest along this segment of shoreline ranges from about 35 to 45 feet NGVD in elevation. The elevation of the foredune toe ranges from about 13 to 15 feet NGVD. The width of the foreslope ranges from about 50 to 150 feet. The foredune area is poorly to moderately vegetated, with vegetation cover on the crest and backslope ranging from about 10 to 60 % and on the foreslope from open sand to about 30%. Vegetation is mostly European Beachgrass, although American Dunegrass and Sea Rocket are scattered throughout the open sand that exists along the toe of the foreslope. Secondary species (e.g. Shore Pine and Purple Beach Pea) exist along the backslope in the northern portion of this segment of shoreline.

Zoning along this segment of shoreline is C1- Neighborhood Commercial. The northern portion, adjacent to Cape Kiwanda State Park, is currently vacant. The central portion is occupied by the Dory Boat Ramp and associated County Parking Lot. A commercial structure, the Pelican Brew Pub, exists along the southern portion of this segment of shoreline. At about 32 feet NGVD the finished floor elevation of this structure is relatively low compared to the existing 'V-zone 100 year plus 4 foot' elevation and it is located about 100 feet landward of the OPRD 1969 Statutory Vegetation Line. The Dory Boat Ramp and County Parking Lot is a designated public pedestrian-vehicular beach access. Correspondingly, this segment of shoreline experiences heavy recreational use. Riprap exists at the top of the beach along the northern portion of this management unit. Drifting sand has been identified as a problem along the central and southern portions of this segment of shoreline.

Management Objectives (with relative priority in bold)

- To maintain or enhance ocean flood/erosion protective functions of the natural foredune area;

- **To minimize inundation brought about by excessive accumulation of wind-blown sand and correspondingly maintain or enhance ocean views; and**

- **To maintain or enhance access to recreational uses associated with the open sand beach.**

Recommendations. Prescribed management practices for this management unit are outlined in Table 2, illustrated in Figure 5, and summarized below.

- **Sand Removal** - The removal of sand from the foredune management area is prohibited under the proposed foredune management strategy.

- **Foredune Grading** - View grading down to the 'V-zone 100 year plus 4 foot' elevation may occur in the southern portion of this management unit. Ideally, a primary foredune crest will be established at an elevation at or above the 'V-zone 100 year plus 4 foot' elevation and at a distance at least 100 feet seaward from the western foundation of oceanfront structures. At an elevation of approximately

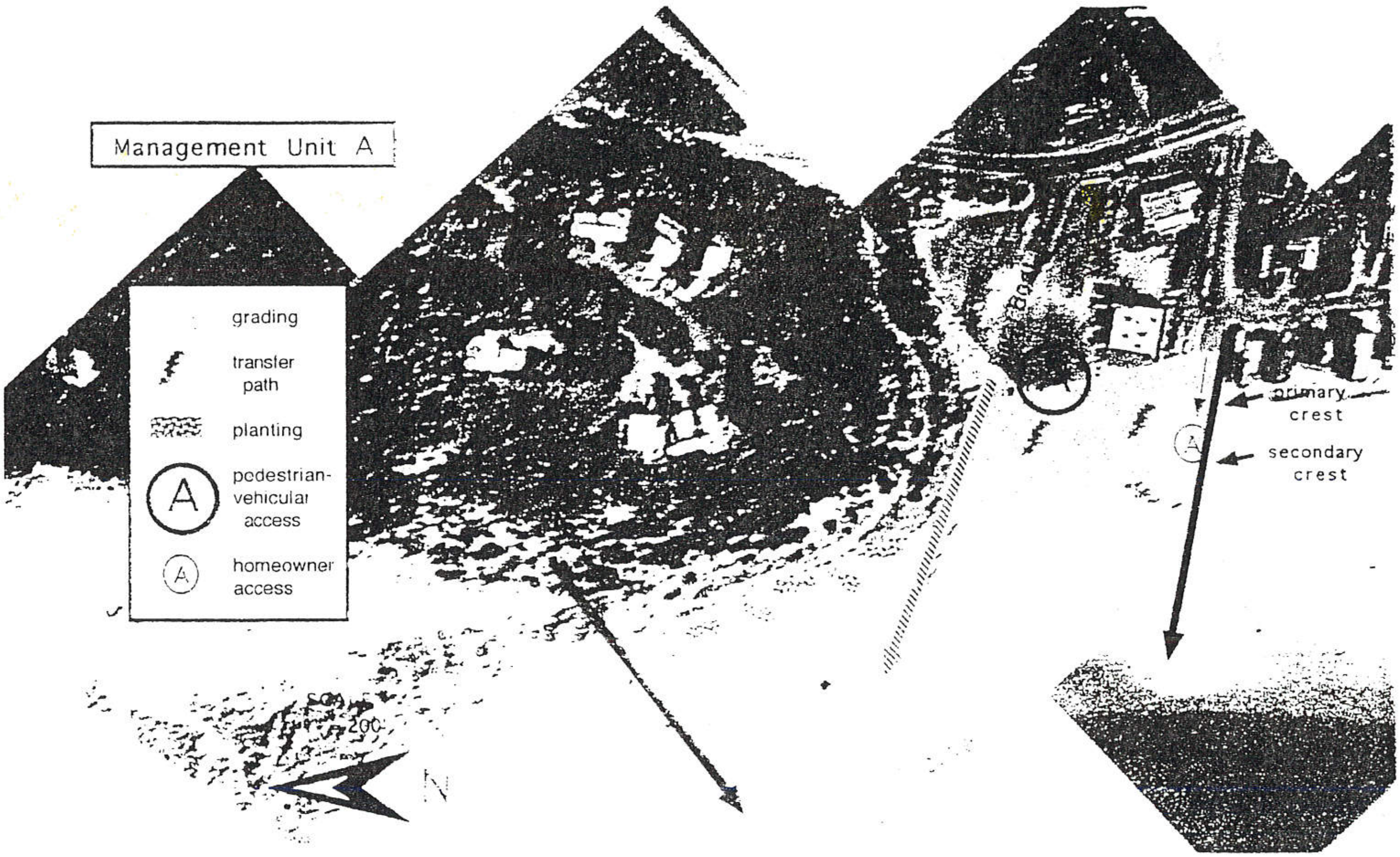


Figure 5. Plan Map Showing Proposed Management Practices for Management Unit A

25 feet NGVD, an irregular secondary foredune crest will be located approximately 100 feet seaward from the primary foredune crest. The lower foreslope will extend out a distance about 200 feet seaward from the secondary foredune crest and down to an elevation of about 12 feet NGVD.

Must maintain BFE +4

Graded sand is to be transferred seaward from high areas behind the foredune crest to low areas elsewhere along the crest and foreslope. After low areas have been filled consideration may be given to the transfer of excess sand seaward of the lower foreslope/ beachface so as to allow a combination of wave and wind-driven sediment transport to redistribute it. In this regard, consideration should be given to the transfer of excess sand to the toe of the sand slope along the northern portion of this management unit.

Although allowed, it is unlikely that view grading will occur elsewhere in this management unit.

The need to maintain the Dory Boat Ramp and County Parking lot suggest that remedial grading will be the principal management practice conducted in the central portion of this management unit. As such, it should be allowed on an as needed basis.

• **Vegetative Stabilization** - Heavy recreational use precludes the existence of a dense vegetation cover in this management unit, however limited planting of stand-stilling grasses is recommended under the proposed management strategy. Planting should occur immediately following view grading. Planting should be carried out so as to mimic natural vegetation patterns as much as possible. Specific planting recommendations for this management unit are as follows:

Full Blown FG

Along the upper foreslope in the northern portion of this management unit plant primary grasses (e.g. 80% European Beachgrass and 20% American Dunegrass) at high densities (e.g. hill spacing of 12" with 5 culms per hill) to achieve greater than 60% cover down to an elevation of about 25 feet NGVD.

Along the lower foreslope in the northern portion of this management unit plant primary grasses (e.g. 80% European Beachgrass and 20% American Dunegrass) at high densities (e.g. hill spacing of 12" with 5 culms per hill) to achieve as much as 60% cover over the area from about 25 feet to 18 feet NGVD in elevation and plant primary grasses (e.g. 80% European Beachgrass and 20% American Dunegrass) at moderate densities (e.g. hill spacing of 18" with 3 culms per hill) to achieve as much as 30% cover over the area from about 18 feet to 14 feet NGVD in elevation. Vegetation planted below an elevation of about 16 feet NGVD is best viewed as sacrificial, in that it may well be lost during winter storms and as a result need to be replanted on a regular basis.

In all cases, planting should be carried out during rainy months (November through April) before and/or after winter storms, when temperatures are between 32 and 60 degrees F and the sand is wet at a 3 inch depth. Preferably immediately after planting, fertilize with ammonium sulfate fertilizer (N-P-K:21-0-0) at a rate of ~200 - 400 pounds per acre, with follow up fertilization again in the subsequent late fall or early spring rainy period (after SCS, 1991).

Although allowed, it is unlikely that vegetative stabilization will occur elsewhere in this management unit.

• **Access Management** - To a great extent access management in this area is already addressed by existing Oregon Park and Recreation Department (OPRD) regulations:

Cape Kiwanda south along the beach to ~700 feet north of the Dory Boat Ramp - Vehicles are allowed to use this area only for the purpose of boat launching;

The Dory Boat Ramp north along the beach to ~700 feet north of the Dory Boat Ramp - Vehicles are allowed to park in this area for the purpose of boat launching; and

The Dory Boat Ramp south along the beach to ~450 feet south of the Dory Boat Ramp - Vehicles are allowed all year.

Access management will also be addressed by conducting remedial grading and other types of activities associated with maintenance of the Dory Boat Ramp and County Parking Lot. Additional access management measures may be warranted in the northern and southern portions of this management unit. Specifically, informational signs could be placed along the toe of the foreslope in the northern portion of this management unit and along the beach access at Alder Street. The purpose of these signs would be to identify sensitive foredune areas and direct recreational users away from them. Consideration may also be given to implementation of more formal access management measures, such as post and rope fencing of identified access trails, wooden walkover structures, and temporary access restriction using fencing in particularly sensitive foredune areas.

• **Monitoring and Maintenance** - Recommended monitoring and maintenance measures are detailed in the Monitoring Program and Maintenance Program documents respectively.

Management Unit B

Setting. This management unit extends from the southern boundary of Alder Street (the line between Tax Lots 2000 and 2100) to one lot north of Tamarack Street (the line between Tax Lots 300 and 400).

This segment of shoreline is characterized by a net accumulation of sand over the period 1967 to 1997. Specifically, portions of the foredune area have increased in width by as much as 255 feet and in height by as much as 25 feet during this time (Table 3; Figure 6a and 6b). This area has also experienced episodic erosion. As much as 50 to 150 feet of foredune retreat has occurred on at least two occasions over the last 30 years.

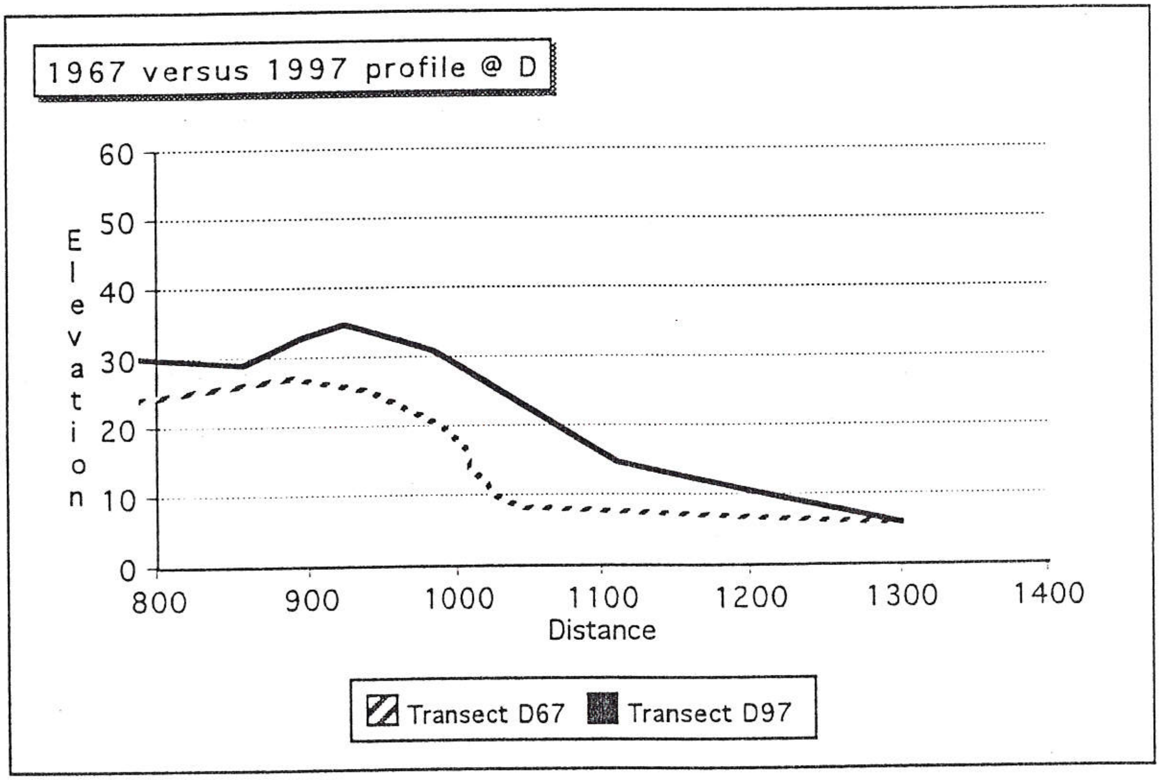


Figure 6a. Cross-section Showing Profile Change over the Period 1967 to 1997 in Management Unit B.

Currently, foredune morphology along this segment of shoreline is characterized by a relatively low, wide, graded profile ('Type B' morphology). The foredune crest along this segment of shoreline ranges from about 35 to 40 feet NGVD in elevation. The elevation of the foredune toe is around 16 feet NGVD. Th width of the foreslope is around 190 feet. The foredune area is poorly vegetated, with vegetation cover

Table 3. Setting, Objectives, and Management Practices for **Management Unit B** **(Alder Street to Tamarack Street)**

Setting

- **Net Accretion**

1967 versus 1997

@ 10' contour	+15' to 25'	elevation
	+ 195' to 255'	width
@ 20' contour	+10' to 15'	elevation
	+ 80' to 130'	width
25' to 30'	35' to 40'	elevation

of primary foredune crest

- **Episodic Erosion** 50' to 150'

- **'Type B'** morphology
  low, wide, graded profile
  crest elevation 35' to 40'
  toe elevation 15' to 16'
  foreslope width 185' to 190'

- **Poorly vegetated**
  crest and backslope
  open sand to 10 to 30% patchy cover
  foreslope
  open sand/gravel to 10% patchy cover

- **R2- residential**
  dwelling elevation low 28' to 31'
  dwelling location ~50' to 140' from OPRD Vegetation Line

- **Heavy to Moderate Recreational Use with Uncontrolled Access**

- **Sand Inundation**, limited **Riprap**

Objectives

- Maintain Flood/Erosion Protection
- **Minimize Sand Inundation and Enhance Ocean Views**
- Maintain or Enhance Access

Management Practices

- **View Grading**

	elevation	location
Foundation	*34'*	@ 0'
Primary Crest	*34'*	@ 50'
Secondary Crest	25'	@ 150'
Toe of Foreslope	12'	@ 350'

- Remedial Grading 30' seaw

- **Vegetative Stabilization**

Backslope	60 to 90% cover
Primary Crest	60 to 90% cover'
Secondary Crest	60 to 90% cover
Upper Foreslope	30 to 60% cover
Lower Foreslope	10 to 30% cover

- **Access Management**
  Alder Street
  Pine Street
  Tamarack Street

- **Monitoring and Maintenance**

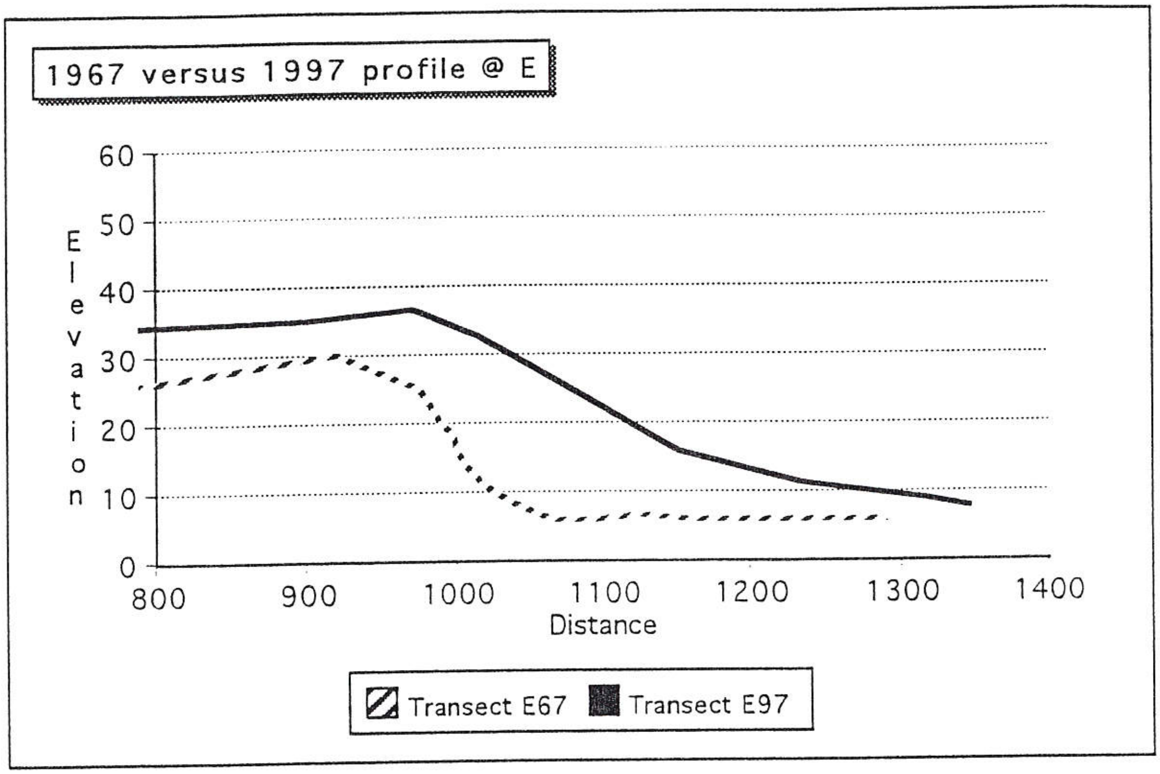


Figure 6b. Cross-section Showing Profile Change over the Period 1967 to 1997 in Management Unit B.

on the crest and backslope ranging from open sand to about 30 % and on the foreslope from open sand to about 10%. Vegetation cover consists mostly of patches, or 'hummocks', of European Beachgrass. American Dunegrass, Sea Rocket, and Yellow Sand Verbena are among other species that exist locally. Transverse open-sand dunes are evident along the crest and backslope. Gravel deflation surfaces are evident on the foreslope. Both of these features are indicative of active wind-driven sediment transport within this management unit.

Zoning along this segment of shoreline is R2- Medium Density Urban Residential. Correspondingly, the area is occupied by single family residential dwellings. With finished/garage floor elevations ranging from about 28 to 31 feet NGVD, dwellings are relatively low compared to the existing 'V-zone 100 year plus 4 foot' elevation. Dwellings are located at distances as close as 50 feet and as far as 140 feet landward of the OPRD 1969 Statutory Vegetation Line. Because of its proximity to The Dory Boat Ramp and County Parking Lot this segment of shoreline experiences relatively heavy to moderate recreational use. Also, homeowner access to the beach is uncontrolled along this segment of shoreline. Riprap exists along the top of the beach at the southern end of this management unit. Drifting sand has been identified as a problem all along this segment of shoreline.

Management Objectives (with relative priority in bold)

- To maintain or enhance ocean flood/erosion protective functions of the natural foredune area;

- **To minimize inundation brought about by excessive accumulation of wind-blown sand and correspondingly maintain or enhance ocean views; and**

- To maintain or enhance access to recreational uses associated with the open sand beach.

Recommendations. Prescribed management practices for this management unit are outlined in Table 3, illustrated in Figure 7, and summarized below.

- **Sand Removal** - The removal of sand from the foredune management area is prohibited under the proposed foredune management strategy.

- **Foredune Grading** - View grading down to the 'V-zone 100 year plus 4 foot' elevation may occur along the entire length of this management unit. Ideally, a primary foredune crest will be established at an elevation at or above the 'V-zone 100 year plus 4 foot' elevation and at a distance at least 50 feet seaward from the western foundation of oceanfront dwellings. At an elevation of approximately 25 feet NGVD, an irregular secondary foredune crest will be located approximately 100 feet seaward from the primary foredune crest. The lower foreslope will extend out a distance about 200 feet seaward from the secondary foredune crest and down to an elevation of about 12 feet NGVD.

  Graded sand is to be transferred seaward from high areas behind the foredune crest to low areas elsewhere along the crest and foreslope. After low areas have been filled consideration may be given to the transfer of excess sand seaward of the lower foreslope/ beachface so as to allow a combination of wave and wind-driven sediment transport to redistribute it.

  Remedial grading should be allowed on an as needed basis. It may be fairly extensive in scope and regular in frequency following initial grading and planting. However, it is anticipated that the scope and frequency of remedial grading in this area will decrease over time.

- **Vegetative Stabilization** - The planting of stand-stilling grasses immediately following view grading is recommended in this management unit under the proposed strategy. It is envisioned that the capture of sand in the foreslope of this foredune area -essentially encouraging outward as opposed to upward growth of the foredune- will not only minimize the potential for inundation and in turn maintain ocean views, but will also maintain flood/erosion protection potential.

  Planting should be carried out so as to mimic natural vegetation patterns as much as possible. Specific planting recommendations for this management unit are as follows:

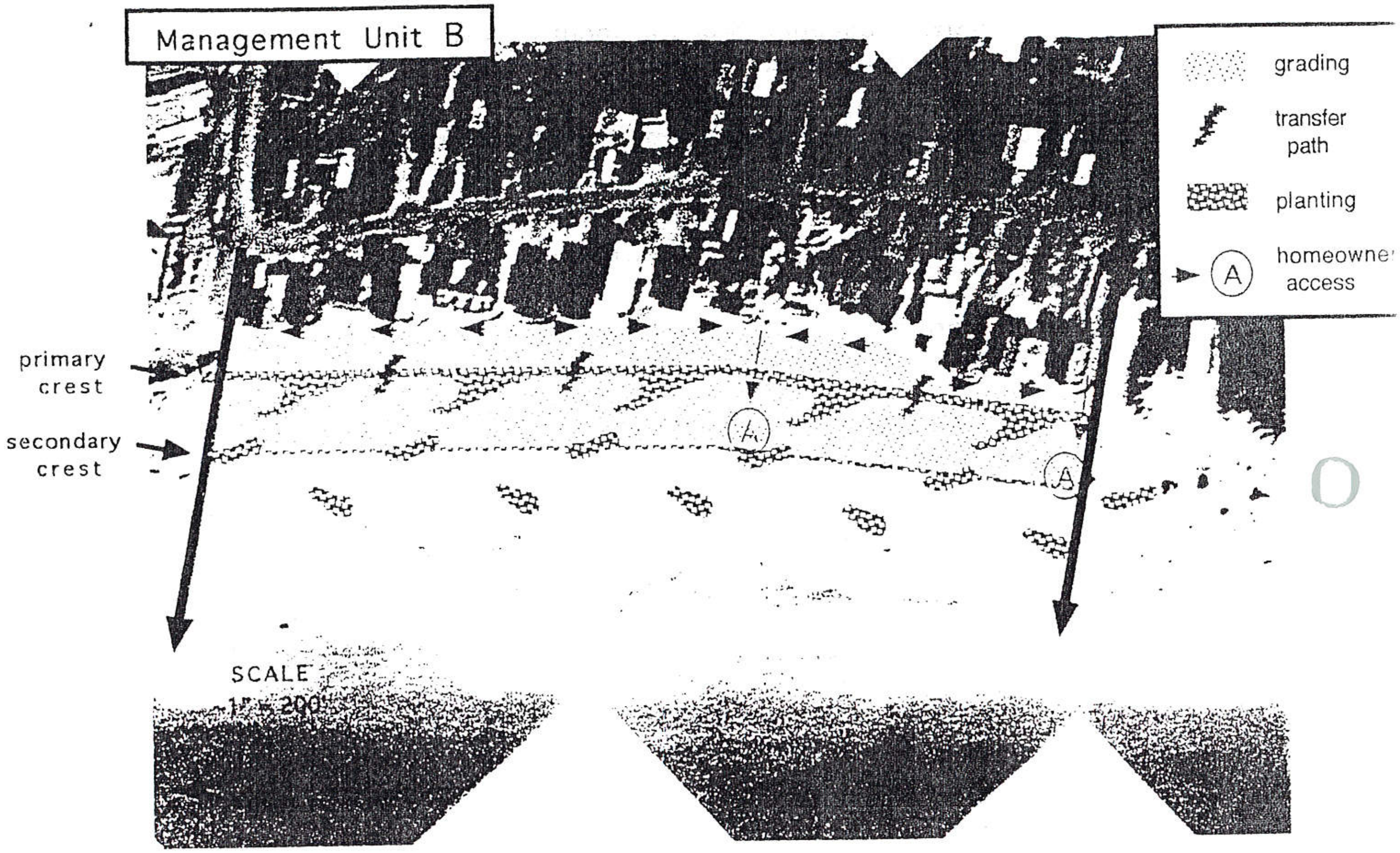


Figure 7. Plan Map Showing Proposed Management Practices for Management Unit B.

Along the backslope plant primary grasses (e.g. 80% European Beachgrass and 20% American Dunegrass) at moderate densities (e.g. hill spacing of 18" with 3 culms per hill) to achieve greater than 60% cover.

Along the primary crest plant primary grasses (e.g. 80% European Beachgrass and 20% American Dunegrass) at high densities (e.g. hill spacing of 12" with 5 culms per hill) to achieve greater than 60% cover down to an elevation of about 25 feet NGVD.

Along the secondary crest and foreslope plant primary grasses (e.g. 80% European Beachgrass and 20% American Dunegrass) at high densities (e.g. hill spacing of 12" with 5 culms per hill) to achieve as much as 60% cover over the area from about 25 feet to 18 feet NGVD in elevation and plant primary grasses (e.g. 80% European Beachgrass and 20% American Dunegrass) at moderate densities (e.g. hill spacing of 18" with 3 culms per hill) to achieve as much as 30% cover over the area from about 18 feet to 14 feet NGVD in elevation. Vegetation planted below an elevation of about 16 feet NGVD is best viewed as sacrificial, in that it may well be lost during winter storms and as a result need to be replanted on a regular basis.

In all cases, planting should be carried out during rainy months (November through April) before and/or after winter storms, when temperatures are between 32 and 60 degrees F and the sand is wet at a 3 inch depth. Preferably immediately after planting, fertilize with ammonium sulfate fertilizer (N-P-K:21-0-0) at a rate of ~200 - 400 pounds per acre, with follow up fertilization again in the subsequent late fall or early spring rainy period (after SCS, 1991).

- **Access Management** - Access management measures warranted in this area include the posting of signs identifying sensitive foredune areas and directing not only recreational users, but homeowners away from these areas. In this regard it is recommended that, in addition to the beach access at Alder Street, homeowner access paths be established in the vicinity of Pine Street and Tamarack Streets.

- **Monitoring and Maintenance** - Recommended monitoring and maintenance measures are detailed in the Monitoring Program and Maintenance Program documents respectively.

Management Unit C

Setting. This management unit extends from one lot north of Tamarack Street (the line between Tax Lots 300 and 400) to the northern boundary line of the Kiwanda Shores Subdivision (the northern boundary of Tax Lot 7300).

This segment of shoreline is characterized by a net accumulation of sand over the period 1967 to 1997. Specifically, portions of the foredune area have increased in width by as much as 305 feet and in height by as much as 40 feet during this time (Table 4; Figure 8a and 8b). This area has also experienced episodic erosion. As much as 50 to 150 feet of foredune retreat has occurred on at least two occasions over the last 30 years.

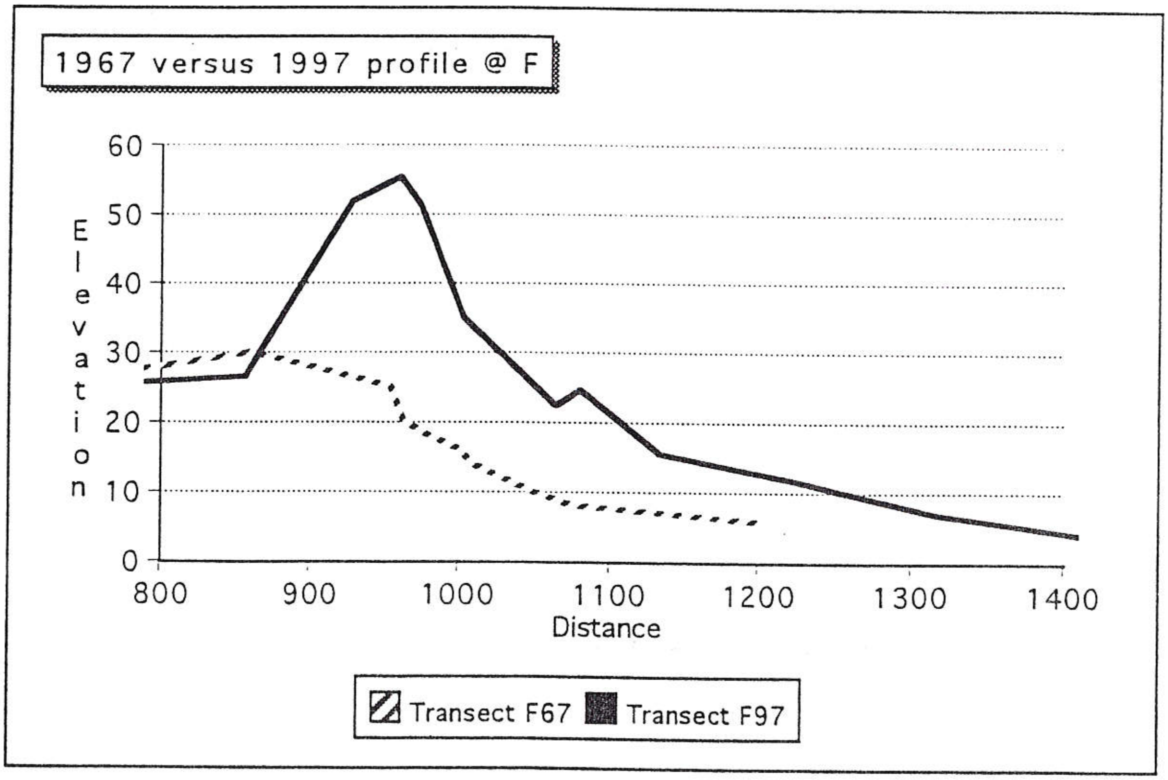


Figure 8a. Cross-section Showing Profile Change over the Period 1967 to 1997 in Management Unit C.

Currently, foredune morphology along this segment of shoreline is characterized by a relatively high, narrow, accreted profile ('Type C' morphology). The foredune crest along this segment of shoreline, which is an amalgam of hummocks, ranges from about 55 to 60 feet NGVD in elevation. The elevation of the foredune toe is about 15 to 17 feet NGVD. The width of the hummocky foreslope is about 160 feet.

Table 4. Setting, Objectives, and Management Practices for **Management Unit C** (**Tamarack Street to Kiwanda Shores Nc**

Setting

- **Net Accretion**

1967 versus 1997

@ 10' contour	+15' to 30 '	elevation
	+ 210' to 305'	width
@ 20' contour	+35' to 40 '	elevation
	+ 145' to 160'	width
30'	55' to 60'	elevation

of primary foredune crest

- **Episodic Erosion** 50' to 150'

- **'Type C'** morphology
  high, narrow, accreted profile
  crest elevation 55' to 60'
  toe elevation 15' to 17'
  foreslope width 160'

- **Well vegetated**
  crest and backslope
  60 to 90% cover
  foreslope
  10 to 60% cover, hummocky

- **R2- residential**
  dwelling elevation **moderate** 33' to 34'
  dwelling location ~60' to 70+' from OPRD Vegetation Line

- **Moderate Recreational Use with Controlled Access**

- limited **Riprap**

Objectives

- **Maintain Flood/Erosion Protection**
- Minimize Sand Inundation and Enhance Ocean Views
- **Maintain or Enhance Access**

Management Practices

- **View Grading**

  ELIGIBLE,
  BUT NOT ENVISIONED
  AT THIS TIME

- **Vegetative Stabilization**

Upper Foreslope	30 to 60% cove
Lower Foreslope	10 to 30% cove

- **Access Management**
  Wooden Walkways across the Foredun
- **Monitoring and Maintenance**

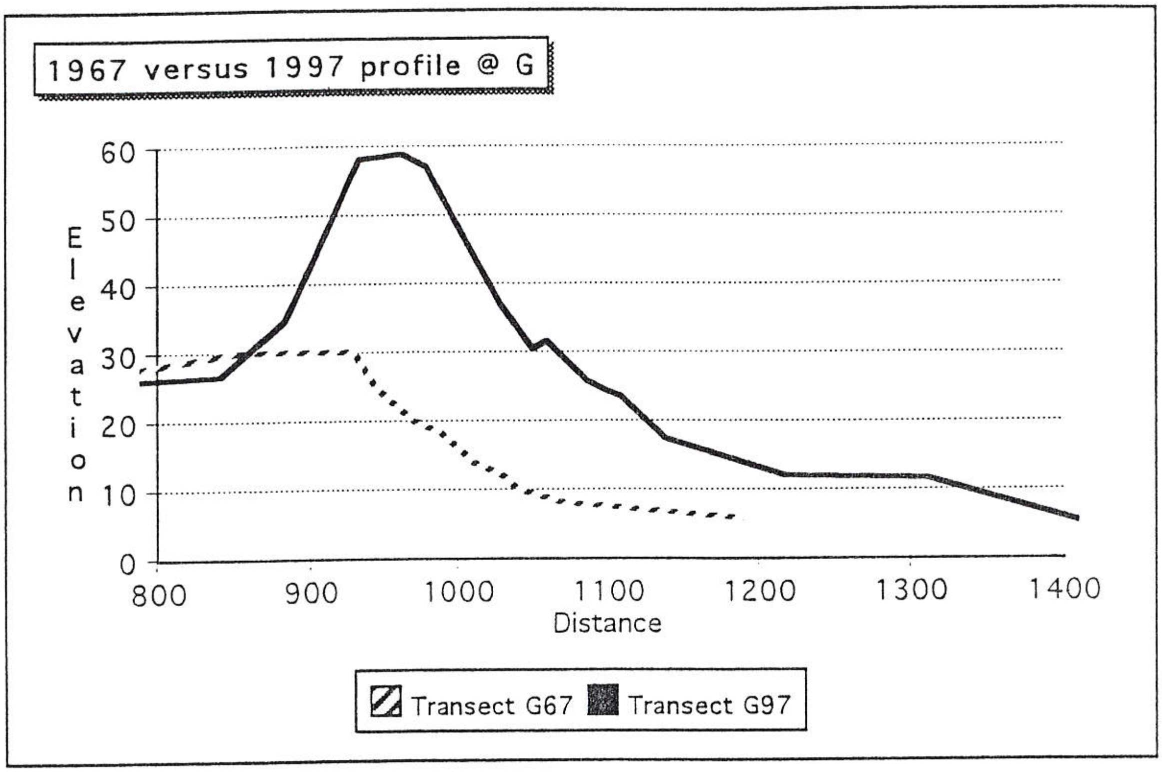


Figure 8b. Cross-section Showing Profile Change over the Period 1967 to 1997 in Management Unit C.

The foredune area is well vegetated, with vegetation cover on the crest and backslope ranging from about 60 to 90% and on the foreslope from as little as 10% in lower portions and as much as 60% in upper portions. Vegetation cover along the steeper-sloping, narrower primary crest is mostly European Beachgrass (80-90%) with minor amounts of American Dunegrass (10-20%). Vegetation cover along the gentler-sloping, wider secondary crest consists of patches of American Dunegrass and Yellow Sand Verbena, as well as European Beachgrass. Recent accumulations of sand along portions of the crest are indicative of active wind-driven sediment transport within this management unit.

Zoning along this segment of shoreline, which fronts Shore Pine Village, is R2- Medium Density Urban Residential. The only directly oceanfront dwelling in this management unit is located more than 60 feet landward of the OPRD 1969 Statutory Vegetation Line. At around 34 feet NGVD, the finished/garage floor elevation of this dwelling is about that of the existing 'V-zone 100 year plus 4 foot' elevation. Recreational use along this segment of shoreline is moderate compared to other portions of the management area. Also, homeowner access to the beach is controlled along this segment of shoreline - A wooden walkway delineates access to the beach from Shore Pine Village. Riprap exists along the top of the beach at the northern end of this management unit. Drifting sand has not been identified as a problem along this segment of shoreline.

Management Objectives (with relative priority in bold)

- **To maintain or enhance ocean flood/erosion protective functions of the natural foredune area;**

- To minimize inundation brought about by excessive accumulation of wind-blown sand and correspondingly maintain or enhance ocean views; and

- **To maintain or enhance access to recreational uses associated with the open sand beach.**

Recommendations. Prescribed management practices for this management unit are outlined in Table 4, illustrated in Figure 9, and summarized below.

- **Sand Removal** - The removal of sand from the foredune management area is prohibited under the proposed foredune management strategy.

- **Foredune Grading** - View grading down to the 'V-zone 100 year plus 4 foot' elevation may occur along the entire length of this management unit. However, under the proposed strategy it is not envisioned that such grading will occur.

  Remedial grading may be warranted at the northern end of this management unit and should be allowed in this area on an as needed basis.

- **Vegetative Stabilization** - The planting of stand-stilling grasses so as to encourage outward as opposed to upward growth of the foredune is the primary management measure envisioned for this management unit. Planting should be carried out so as to mimic natural vegetation patterns as much as possible. Specific planting recommendations for this management unit are as follows:

  Along the secondary crest and foreslope plant primary grasses (e.g. 80% European Beachgrass and 20% American Dunegrass) at high densities (e.g. hill spacing of 12" with 5 culms per hill) to achieve as much as 60% cover over the area from about 25 feet to 18 feet NGVD in elevation and plant primary grasses (e.g. 80% European Beachgrass and 20% American Dunegrass) at moderate densities (e.g. hill spacing of 18" with 3 culms per hill) to achieve as much as 30% cover over the area from about 18 feet to 14 feet NGVD in elevation. Vegetation planted below an elevation of about 16 feet NGVD is best viewed as sacrificial, in that it may well be lost during winter storms and as a result need to be replanted on a regular basis.

  In all cases, planting should be carried out during rainy months (November through April) before and/or after winter storms, when temperatures are between 32 and 60 degrees F and

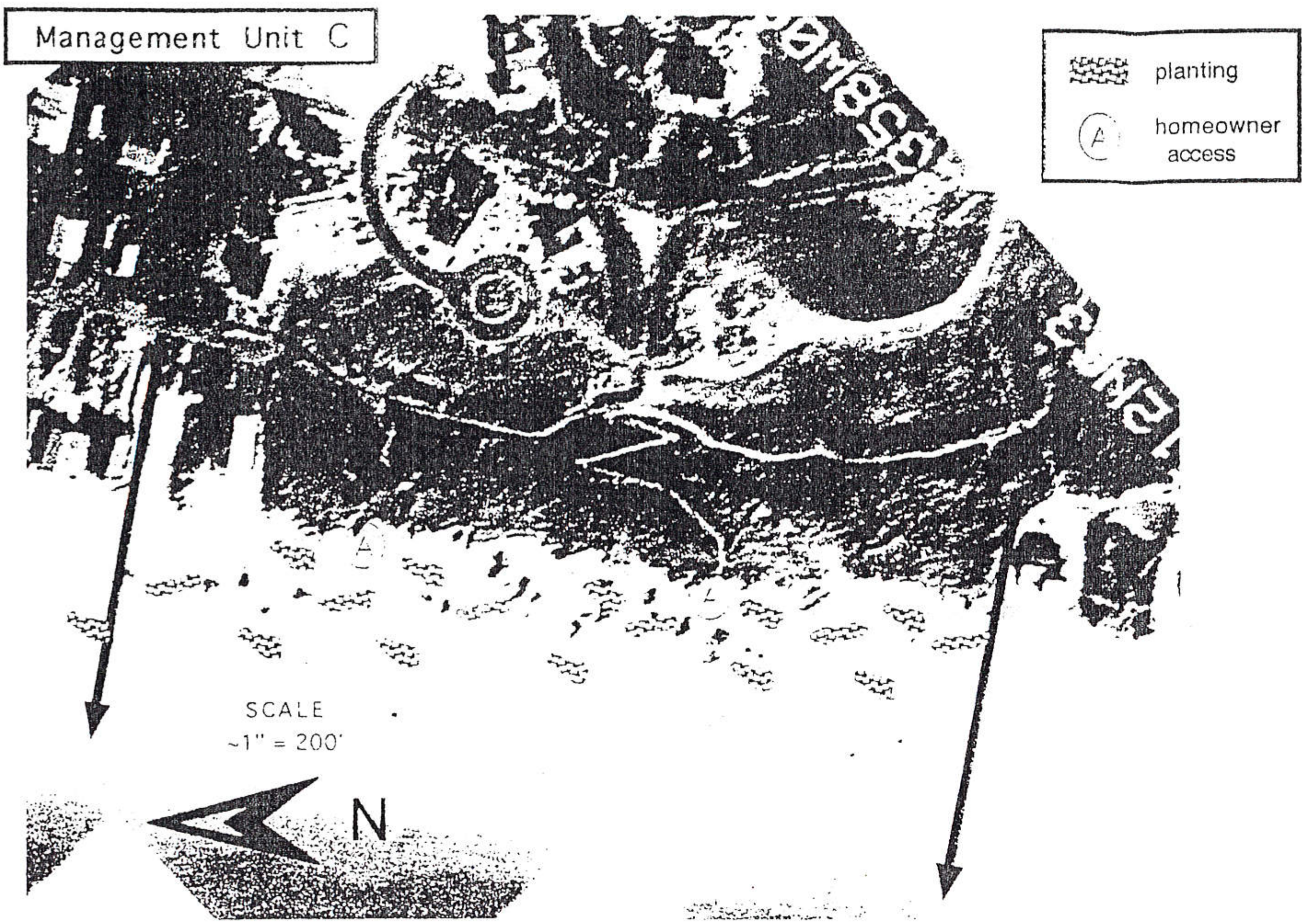


Figure 9. Plan Map Showing Proposed Management Practices for Management Unit C.

the sand is wet at a 3 inch depth. Preferably immediately after planting, fertilize with ammonium sulfate fertilizer (N-P-K:21-0-0) at a rate of ~200 - 400 pounds per acre, with follow up fertilization again in the subsequent late fall or early spring rainy period (after SCS, 1991).

• **Access Management** - Access management measures warranted in this area may include the posting of signs identifying sensitive foredune areas and directing not only recreational users, but homeowners away from these areas. Consideration may also be given to establishing a second wooden walkway/homeowner access between the northern and central portions of the management unit.

• **Monitoring and Maintenance** - Recommended monitoring and maintenance measures are detailed in the Monitoring Program and Maintenance Program documents respectively.

Management Unit D

Setting. This management unit extends from the northern boundary line of the Kiwanda Shores Subdivision (the northern boundary of Tax Lot 7300) to just south of the boundary between the First and Fourth additions of the Kiwanda Shores Subdivision (the line between Tax Lots 8100 and 8200).

This segment of shoreline is characterized by a net accumulation of sand over the period 1967 to 1997. Specifically, portions of the foredune area have increased in width by as much as 270 feet and in height by as much as 25 feet during this time (Table 5; Figure 10a,10b, and 10c). This area has also experienced episodic erosion. As much as 50 to 150 feet of foredune retreat has occurred on at least two occasions over the last 30 years.

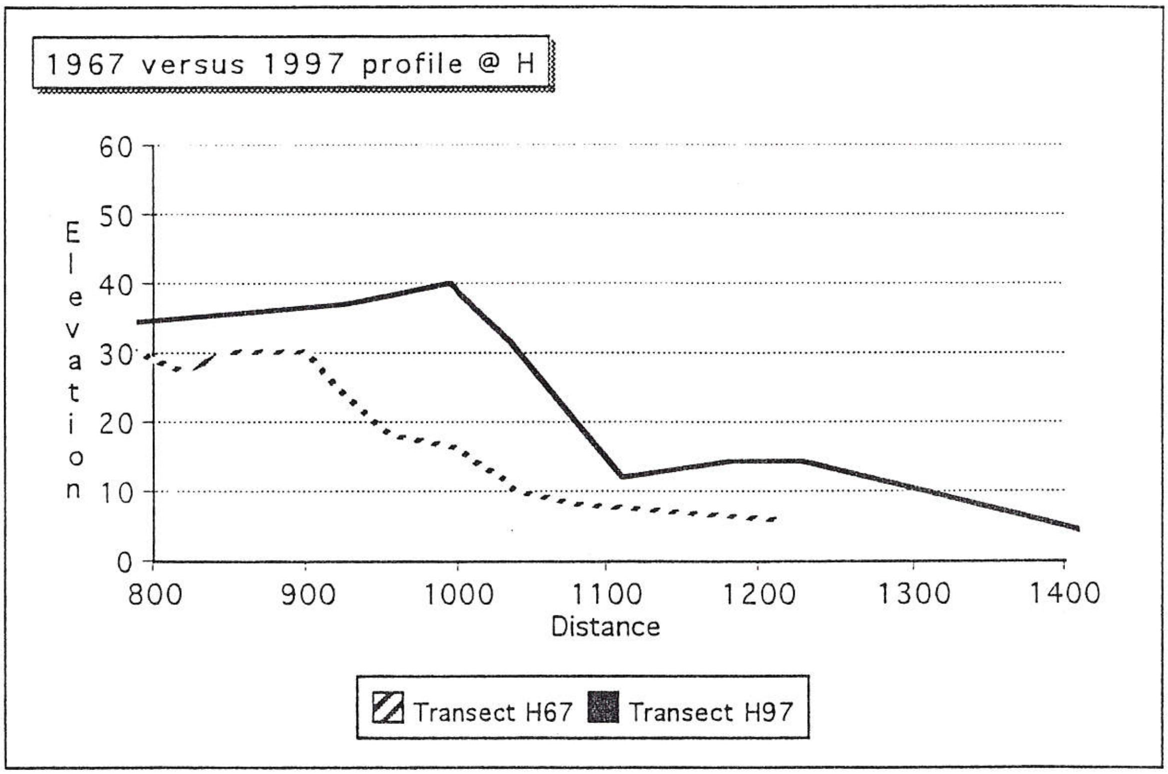


Figure 10a.
Cross-section Showing Profile Change over the Period 1967 to 1997 in Management Unit D.

Currently, foredune morphology along this segment of shoreline is characterized by a relatively high, narrow, graded profile ('Type A' morphology). The foredune crest along this segment of shoreline ranges from about 40 to 50 feet NGVD in elevation. The elevation of the foredune toe ranges from about 10 to

Table 5. Setting, Objectives, and Management Practices for **Management Unit D** **(North to South Kiwanda Shores)**

Setting

- **Net Accretion**

1967 versus 1997		
@ 10' contour	+15' to 25 '	elevation
	+135' to 270'	width
@ 20' contour	+20' to 25 '	elevation
	+125' to 145'	width
30'	40' to 50'	elevation
	of primary foredune crest	

- **Episodic Erosion** 50' to 150'

- **'Type A'** morphology
  high, narrow, graded profile
  crest elevation 40' to 50'
  toe elevation 10' to 20'
  foreslope width 85' to 160'

- **Poorly vegetated**
  crest and backslope
  open sand/gravel to 30% patchy cover
  foreslope
  open sand/gravel to 30% patchy cover

- **R2- residential**
  dwelling elevation **low** 30' to 35'
  dwelling location ~50' to 70' from OPRD Vegetation Line

- **Moderate Recreational Use with Uncontrolled Access**

- **Sand Inundation**, extensive **Riprap**

Objectives

- Maintain Flood/Erosion Protection
- **Minimize Sand Inundation and Enhance Ocean Views**
- Maintain or Enhance Access

Management Practices

- **View Grading**

	elevation	location
Foundation	34'	@ 0'
Primary Crest	34'	@ 50'
Secondary Crest	25'	@ 75'
Toe of Foreslope	12'	@ 200'

- Remedial Grading 30' seaw[illegible]

- **Vegetative Stabilization**

Backslope	open sand
Primary Crest	open sand
Secondary Crest	60 to 90% cover
Upper Foreslope	30 to 60% cover
Lower Foreslope	10 to 30% cover

- **Access Management**
  Sea Swallow Drive/Ocean Drive
  Kiwanda Drive/Ocean Drive

- **Monitoring and Maintenance**

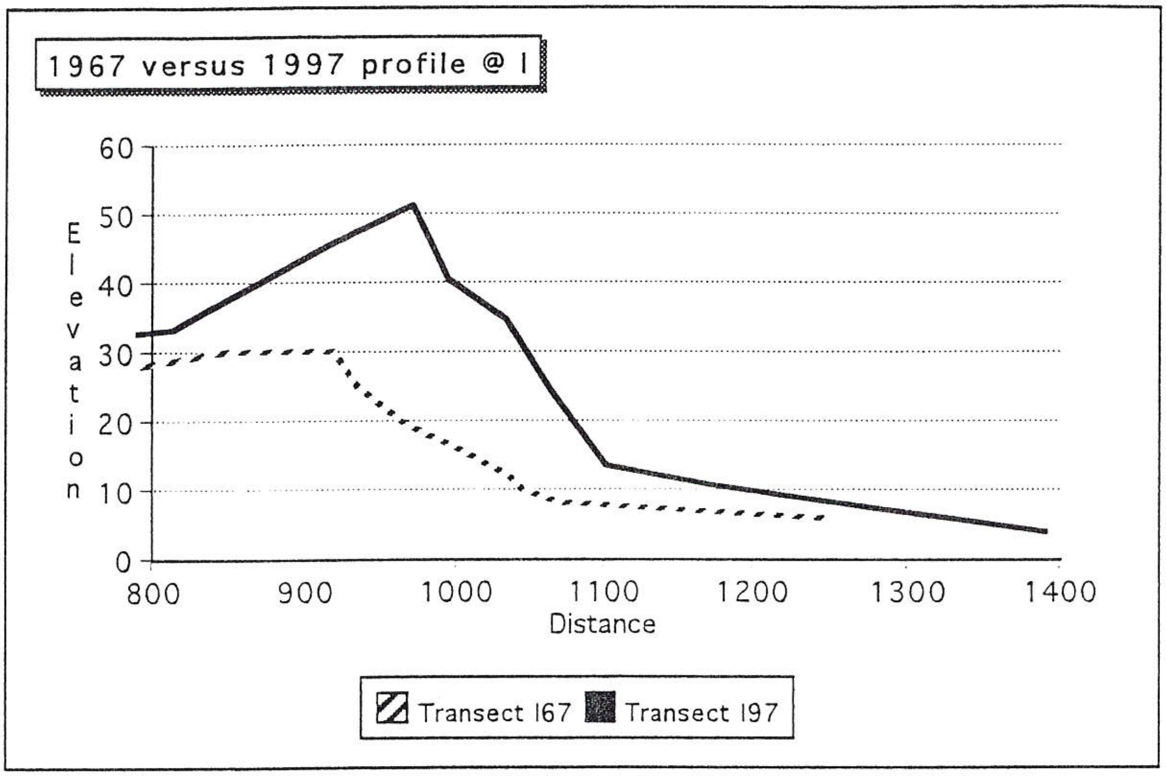


Figure 10b.
Cross-section Showing Profile Change over the Period 1967 to 1997 in Management Unit D.

20 feet NGVD. The width of the hummocky foreslope ranges from about 85 to 160 feet. The foredune area is poorly vegetated, with vegetation cover on the backslope, crest, and foreslope ranging from open sand and gravel to about 30%. Vegetation consists mostly of scattered patches of European Beachgrass, American Dunegrass, and Yellow Sand Verbena. Transverse open-sand dunes are evident along the crest and backslope. Gravel deflation surfaces are evident on the foreslope. Both of these features are indicative of active wind-driven sediment transport within this management unit.

Zoning along this segment of shoreline is R2- Medium Density Urban Residential. Correspondingly, most of the area is occupied by single family residential dwellings. With finished/garage floor elevations ranging from about 30 to 35 feet NGVD, dwellings are relatively low compared to the existing 'V-zone 100 year plus 4 foot' elevation. Dwellings are located at distances about 50 to 70 feet landward of the OPRD 1969 Statutory Vegetation Line. Several lots within this management unit are vacant. Well vegetated hummocks typically occupy these areas. Recreational use along this segment of shoreline is moderate compared to other portions of the management area. Also, homeowner access to the beach is uncontrolled along this segment of shoreline. Riprap is extensive in this management unit. It exists at the

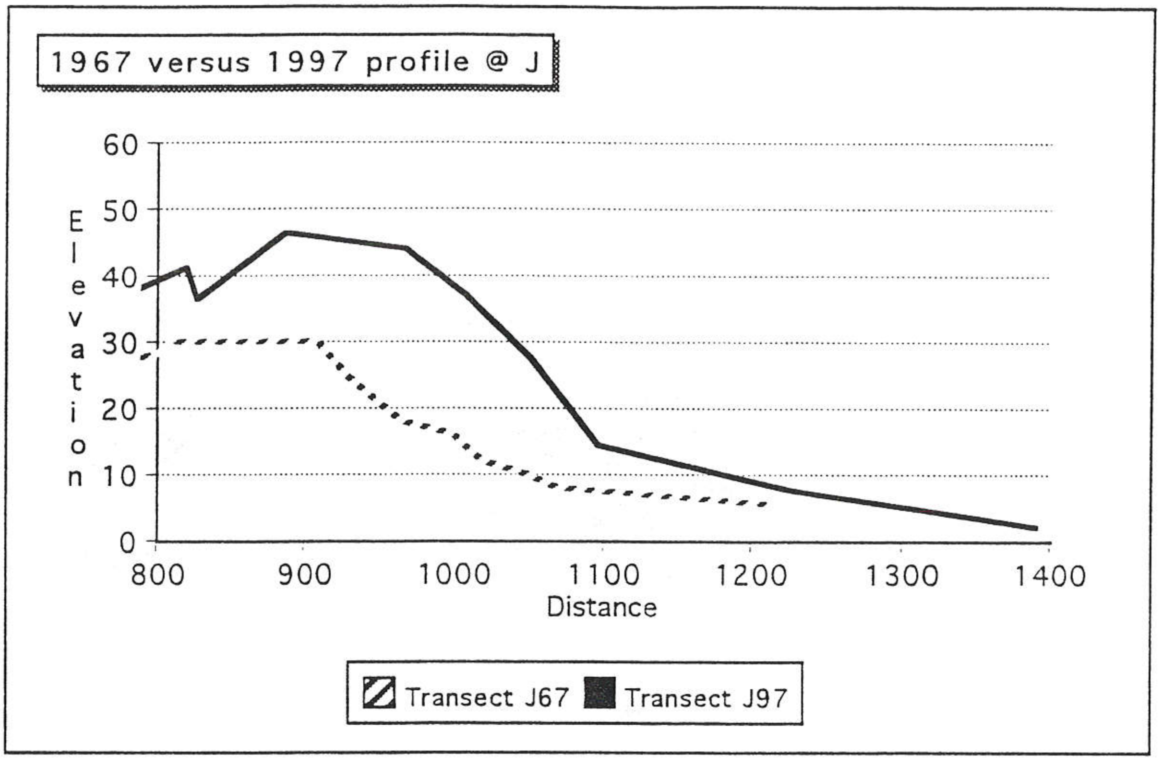


Figure 10c.
Cross-section Showing Profile Change over the Period 1967 to 1997 in Management Unit D.

top of the beach along almost the entire area. Drifting sand has been identified as a problem all along this segment of shoreline.

Management Objectives (with relative priority in bold)

- To maintain or enhance ocean flood/erosion protective functions of the natural foredune area;

- **To minimize inundation brought about by excessive accumulation of wind-blown sand and correspondingly maintain or enhance ocean views; and**

- To maintain or enhance access to recreational uses associated with the open sand beach.

Recommendations. Prescribed management practices for this management unit are outlined in Table 5, illustrated in Figure 11, and summarized below.

- **Sand Removal** - The removal of sand from the foredune management area is prohibited under

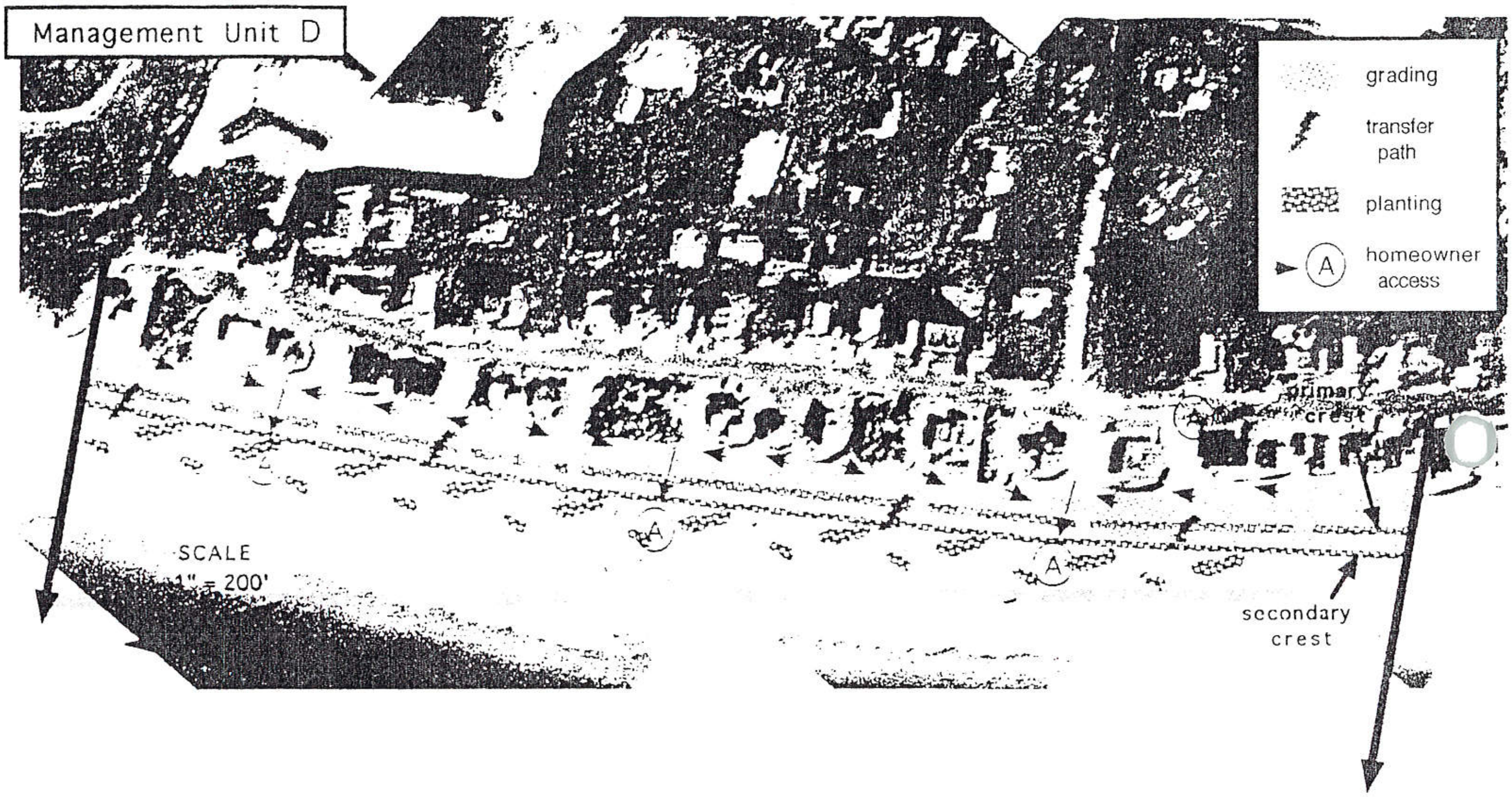


Figure 11. Plan Map Showing Proposed Management Practices for Management Unit D.

the proposed foredune management strategy.

• **Foredune Grading** - View grading down to the 'V-zone 100 year plus 4 foot' elevation may occur along the entire length of this management unit. Ideally, a primary foredune crest will be established at an elevation at or above the 'V-zone 100 year plus 4 foot' elevation and at a distance at least 50 feet seaward from the western foundation of oceanfront dwellings. At an elevation of approximately 25 feet NGVD, an irregular secondary foredune crest will be located approximately 25 feet seaward from the primary foredune crest. The lower foreslope will extend out a distance about 125 feet seaward from the secondary foredune crest and down to an elevation of about 12 feet NGVD.

View grading to these specifications will result in a foredune configuration that approximates the design minimum. This is deemed acceptable because of the existence of riprap along this segment of shoreline, which affords an increased level of flood/erosion protection, and the proximity of the dwellings to the shoreline, which limits the ability to encourage outward as opposed to upward growth of the foredune.

Graded sand is to be transferred seaward from high areas behind the foredune crest to low areas elsewhere along the crest and foreslope. In this regard, it is recommended that the grading of vacant lots be conducted in conjunction with view grading. This will facilitate more even growth of the foredune area and in turn reduce potential for sand inundation. After low areas have been filled consideration may be given to the transfer of excess sand seaward of the lower foreslope/ beachface so as to allow a combination of wave and wind-driven sediment transport to redistribute it.

Because limited vegetative stabilization is also part of the proposed strategy for this management unit (see below), it is envisioned that remedial grading will frequently be warranted. Remedial grading should be allowed on an as needed basis.

• **Vegetative Stabilization** - It was noted above that the proximity of the dwellings to the shoreline limits the ability to encourage outward as opposed to upward growth of the foredune. Efforts to use vegetation to establish a wide foredune in this area are likely to be thwarted by high wave runup and erosion during winter storms: Planting the entire foredune in this area is likely to result in primarily upward growth of the foredune. Therefore, in order to maintain ocean views it is recommended that the upper portion of the foredune area in this management unit remain as mostly open sand. (As noted above, this means that foredune grading may be needed on a regular basis).

An effort should be made to establish stand-stilling grasses along the lower portion of the foredune area in the management unit. Any sand that can be captured and held in this area will enhance flood/erosion protection potential as well as reduce the potential for sand inundation. Planting should occur immediately following view grading. Planting should be carried out so as to mimic natural vegetation patterns as much as possible. Specific planting recommendations for this management unit are as follows:

Along the secondary crest and foreslope plant primary grasses (e.g. 80% European Beachgrass and 20% American Dunegrass) at high densities (e.g. hill spacing of 12" with 5 culms per hill) to achieve as much as 60% cover over the area from about 25 feet to 18 feet NGVD in elevation and plant primary grasses (e.g. 80% European Beachgrass and 20% American Dunegrass) at moderate densities (e.g. hill spacing of 18" with 3 culms per hill) to achieve as much as 30% cover over the area from about 18 feet to14 feet NGVD in elevation. Vegetation planted below an elevation of about 16 feet NGVD is best viewed as sacrificial, in that it may well be lost during winter storms and as a result need to be replanted on a regular basis.

In all cases, planting should be carried out during rainy months (November through April) before and/or after winter storms, when temperatures are between 32 and 60 degrees F and the sand is wet at a 3 inch depth. Preferably immediately after planting, fertilize with ammonium sulfate fertilizer (N-P-K:21-0-0) at a rate of ~200 - 400 pounds per acre, with follow up fertilization again in the subsequent late fall or early spring rainy period (after SCS, 1991).

• **Access Management** - Access management measures warranted in this area include the posting of signs identifying sensitive foredune areas and directing not only recreational users, but homeowners away from these areas. In this regard it is recommended that homeowner access paths be established in the vicinity of the intersections between Sea Swallow/Ocean Drives and Kiwanda/Ocean Drives. Consideration may also be given to establishing a third homeowner access path between these two locations.

• **Monitoring and Maintenance** - Recommended monitoring and maintenance measures are detailed in the Monitoring Program and Maintenance Program documents respectively.

Management Unit E

Setting. This management unit extends from just south of the boundary between the First and Fourth additions of the Kiwanda Shores Subdivision (the line between Tax Lots 8100 and 8200) to just north of the Turnaround (the line between Tax Lots 9200 and 9300).

This segment of shoreline is characterized by a net accumulation of sand over the period 1967 to 1997. Specifically, portions of the foredune area have increased in width by as much as 140 feet and in height by as much as 25 feet during this time (Table 6; Figure 12). This area has also experienced episodic erosion. As much as 50 to 150 feet of foredune retreat has occurred on at least two occasions over the last 30 years.

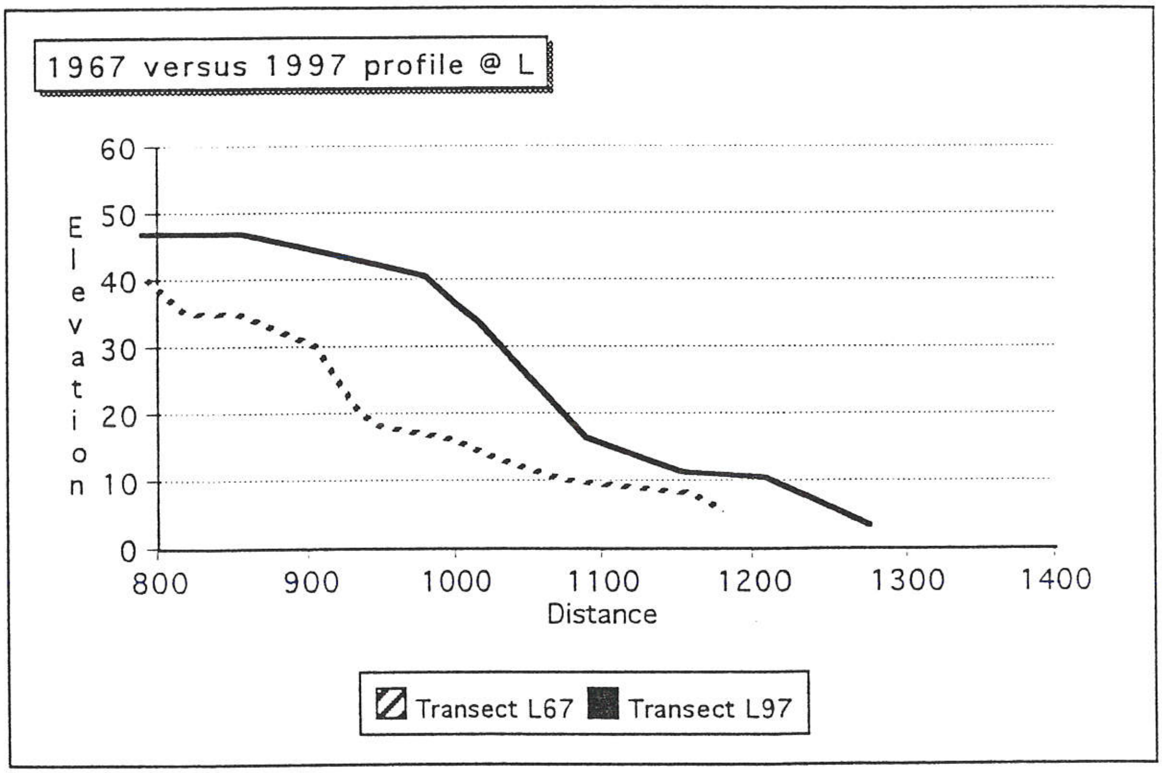


Figure 12.
Cross-section Showing Profile Change over the Period 1967 to 1997 in Management Unit E.

Currently, foredune morphology along this segment of shoreline is characterized by a relatively high, narrow, graded profile ('Type A' morphology). The foredune crest along this segment of shoreline ranges from about 40 to 50 feet NGVD in elevation. The elevation of the foredune toe is about 18 feet NGVD.

The width of the hummocky foreslope ranges from about 85 to 110 feet. The foredune area is poorly vegetated, with vegetation cover on the backslope, crest, and foreslope ranging from open sand and gravel to about 30%. Vegetation consists mostly of scattered patches of European Beachgrass, American Dunegrass, and Yellow Sand Verbena. Transverse open-sand dunes are evident along the crest and backslope. Gravel deflation surfaces are evident on the foreslope. Both of these features are indicative of active wind-driven sediment transport within this management unit.

Zoning along this segment of shoreline is R2- Medium Density Urban Residential. Correspondingly, most of the area is occupied by single family residential dwellings. With finished/garage floor elevations ranging from about 30 to 43 feet NGVD, dwellings are relatively high compared to the existing 'V-zone 100 year plus 4 foot' elevation. Dwellings are located at distances about 50 to 70 feet landward of the OPRD 1969 Statutory Vegetation Line. Recreational use along this segment of shoreline is moderate compared to other portions of the management area. Also, homeowner access to the beach is uncontrolled along this segment of shoreline. Riprap is extensive in this management unit. It exists at the top of the beach along almost the entire area. Drifting sand has been identified as a problem all along this segment of shoreline.

Management Objectives (with relative priority in bold)

- To maintain or enhance ocean flood/erosion protective functions of the natural foredune area;

- **To minimize inundation brought about by excessive accumulation of wind-blown sand and correspondingly maintain or enhance ocean views; and**

- To maintain or enhance access to recreational uses associated with the open sand beach.

Recommendations. Prescribed management practices for this management unit are outlined in Table 6, illustrated in Figure 13, and summarized below.

- **Sand Removal** - The removal of sand from the foredune management area is prohibited under the proposed foredune management strategy.

- **Foredune Grading** - View grading down to the 'V-zone 100 year plus 4 foot' elevation may occur along the entire length of this management unit. Ideally, a primary foredune crest will be established at an elevation at or above the 'V-zone 100 year plus 4 foot' elevation and at a distance at least 50 feet seaward from the western foundation of oceanfront dwellings. At an elevation of approximately 25 feet NGVD, an irregular secondary foredune crest will be located approximately 25 feet seaward from the primary foredune crest. The lower foreslope will extend out a distance about 125 feet seaward from the secondary foredune crest and down to an elevation of about 12 feet NGVD.

  View grading to these specifications will result in a foredune configuration that approximates the

Table 6. Setting, Objectives, and Management Practices for **Management Unit E** (South Kiwanda Shores to the Turnaround)

Setting

- **Net Accretion**

1967 versus 1997		
@ 10' contour	+ 10'	elevation
	+130'	width
@ 20' contour	+ 25 '	elevation
	+ 140'	width
40'	40' to 50' of primary foredune crest	elevation

- **Episodic Erosion** 50' to 150'
- **'Type A'** morphology
  high, narrow, graded profile
  crest elevation 40' to 50'
  toe elevation 17' to 19'
  foreslope width 85' to 110'
- **Poorly vegetated**
  crest and backslope
  open sand/gravel to 30% patchy cover
  foreslope
  open sand/gravel to 30% patchy cover
- **R2- residential**
  dwelling elevation **high** 30' to 43'
  dwelling location ~50' to 70' from OPRD Vegetation Line
- **Moderate Recreational Use with Uncontrolled Access**
- **Sand Inundation**, extensive **Riprap**

Objectives

- Maintain Flood/Erosion Protection
- **Minimize Sand Inundation and Enhance Ocean Views**
- Maintain or Enhance Access

Management Practices

- **View Grading**

	elevation	location
Foundation	*34'*	@ 0'
Primary Crest	*34'*	@ 50'
Secondary Crest	25'	@ 75'
Toe of Foreslope	12'	@ 200'

- Remedial Grading 30' seaward

- **Vegetative Stabilization**

Backslope	open sand
Primary Crest	open sand
Secondary Crest	60 to 90% cover
Upper Foreslope	30 to 60% cover
Lower Foreslope	10 to 30% cover

- **Access Management**
  Central Portion of Management Unit
- **Monitoring and Maintenance**

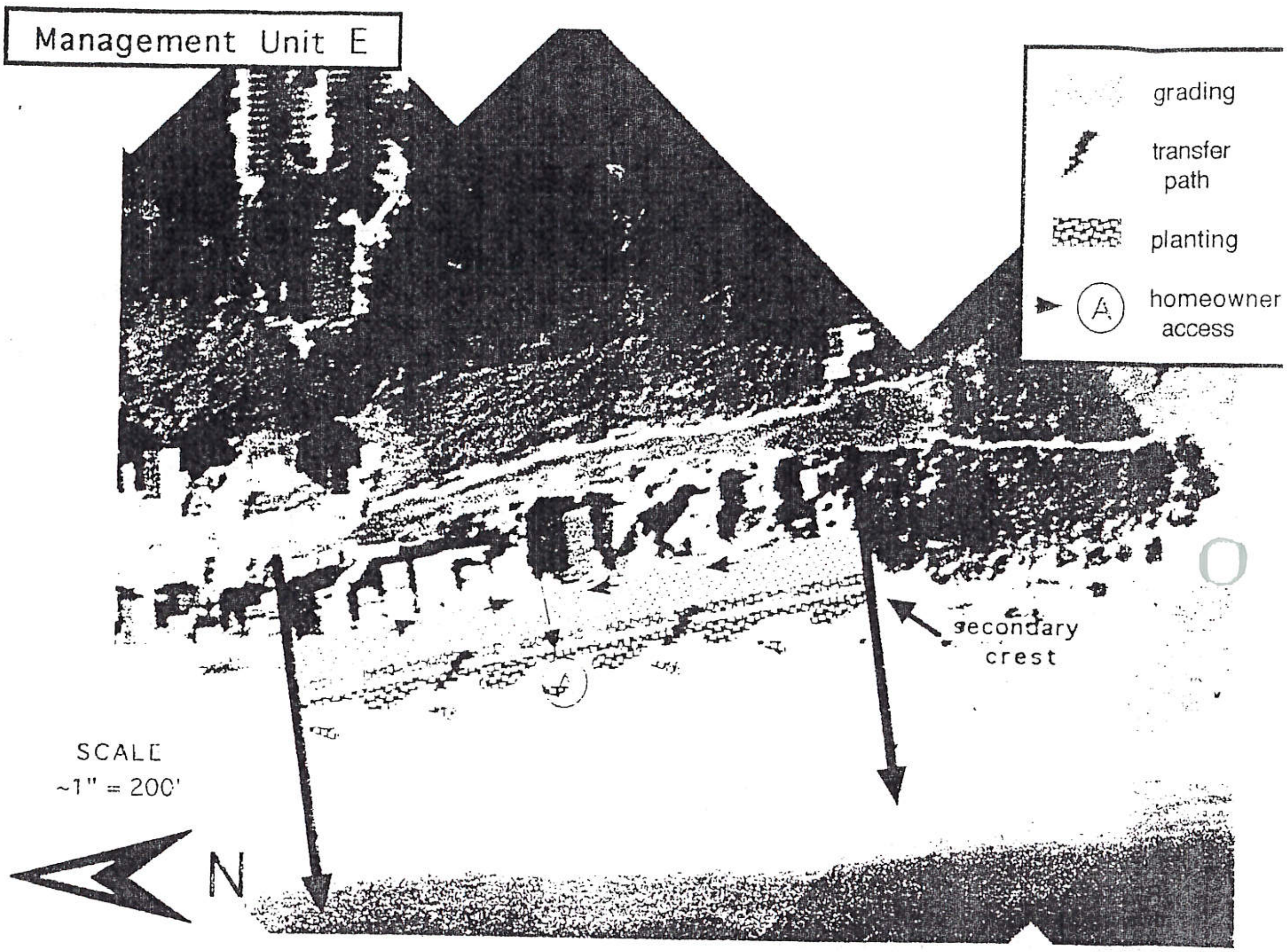


Figure 13. Plan Map Showing Proposed Management Practices for Management Unit E.

design minimum. This is deemed acceptable because of the existence of riprap along this segment of shoreline, which affords an increased level of flood/erosion protection, and the proximity of the dwellings to the shoreline, which limits the ability to encourage outward as opposed to upward growth of the foredune.

Graded sand is to be transferred seaward from high areas behind the foredune crest to low areas elsewhere along the crest and foreslope. After low areas have been filled consideration may be given to the transfer of excess sand seaward of the lower foreslope/ beachface so as to allow a combination of wave and wind-driven sediment transport to redistribute it.

Because limited vegetative stabilization is also part of the proposed strategy for this management unit (see below), it is envisioned that remedial grading will frequently be warranted. Remedial grading should be allowed on an as needed basis.

• **Vegetative Stabilization** - It was noted above that the proximity of the dwellings to the shoreline limits the ability to encourage outward as opposed to upward growth of the foredune. Efforts to use vegetation to establish a wide foredune in this area are likely to be thwarted by high wave runup and erosion during winter storms: Planting the entire foredune in this area is likely to result in primarily upward growth of the foredune. Therefore, in order to maintain ocean views it is recommended that the upper portion of the foredune area in this management unit remain as mostly open sand. (As noted above, this means that foredune grading may be needed on a regular basis).

An effort should be made to establish stand-stilling grasses along the lower portion of the foredune area in the management unit. Any sand that can be captured and held in this area will enhance flood/erosion protection potential as well as reduce the potential for sand inundation. Planting should occur immediately following view grading. Planting should be carried out so as to mimic natural vegetation patterns as much as possible. Specific planting recommendations for this management unit are as follows:

> **Along the secondary crest and foreslope** plant primary grasses (e.g. 80% European Beachgrass and 20% American Dunegrass) at high densities (e.g. hill spacing of 12" with 5 culms per hill) to achieve as much as 60% cover over the area from about 25 feet to 18 feet NGVD in elevation and plant primary grasses (e.g. 80% European Beachgrass and 20% American Dunegrass) at moderate densities (e.g. hill spacing of 18" with 3 culms per hill) to achieve as much as 30% cover over the area from about 18 feet to 14 feet NGVD in elevation. Vegetation planted below an elevation of about 16 feet NGVD is best viewed as sacrificial, in that it may well be lost during winter storms and as a result need to be replanted on a regular basis.
>
> In all cases, planting should be carried out during rainy months (November through April) before and/or after winter storms, when temperatures are between 32 and 60 degrees F and the sand is wet at a 3 inch depth. Preferably immediately after planting, fertilize with ammonium sulfate fertilizer (N-P-K:21-0-0) at a rate of ~200 - 400 pounds per acre, with follow up fertilization again in the subsequent late fall or early spring rainy period (after SCS, 1991).

• **Access Management** - Access management measures warranted in this area include the posting of signs identifying sensitive foredune areas and directing not only recreational users, but homeowners away from these areas. In this regard it is recommended that a homeowner access path be established in the central portion of this management unit.

• **Monitoring and Maintenance** - Recommended monitoring and maintenance measures are detailed in the Monitoring Program and Maintenance Program documents respectively.

Management Unit F

Setting. This management unit extends from just north of the Turnaround (the line between Tax Lots 9200 and 9300) to just south of the Turnaround (the line between Tax Lots 1300 and 1400).

This segment of shoreline is characterized by relatively minor shoreline change over the period 1967 to 1997. Specifically, the foredune area has increased in width by at most 55 feet and in height by at most 10 feet during this time (Table 7; Figure 14). This area has also experienced episodic erosion. As much as 50 to 150 feet of foredune retreat has occurred on at least two occasions over the last 30 years.

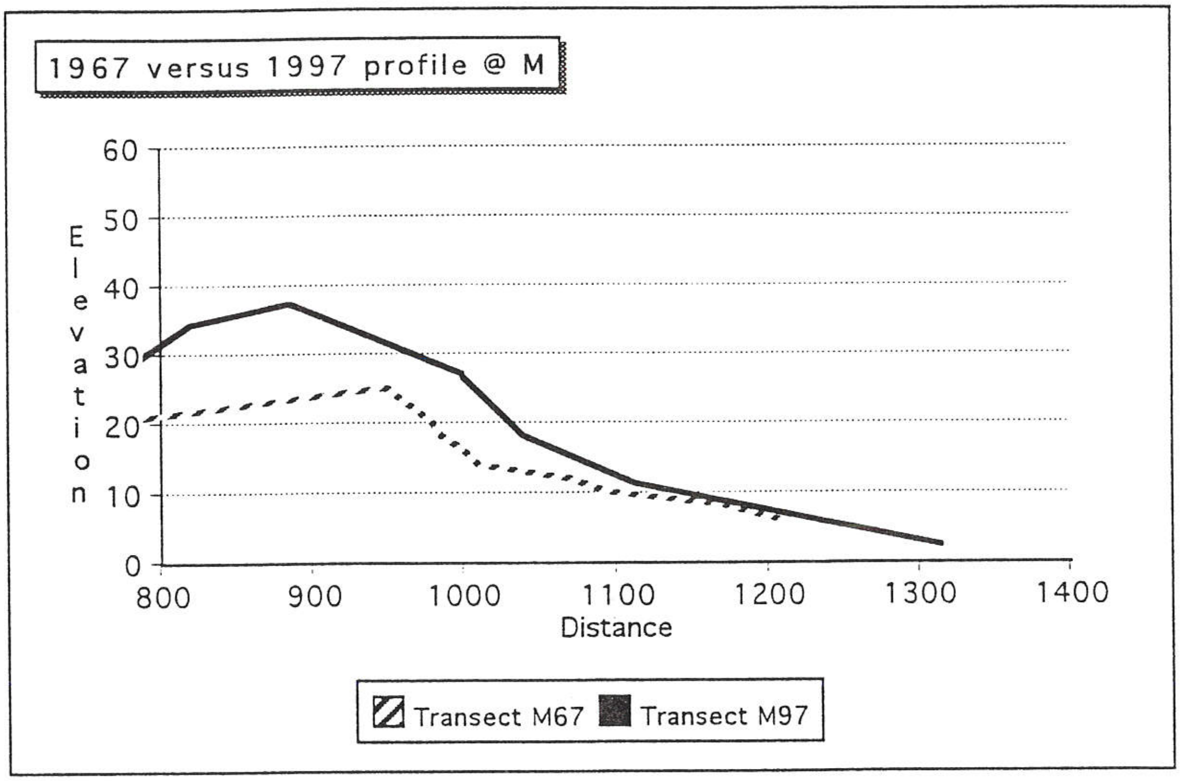


Figure 14.
Cross-section Showing Profile Change over the Period 1967 to 1997 in Management Unit F.

Currently, foredune morphology along the central portion of this segment of shoreline is characterized by a relatively low, wide, graded profile ('Type B' morphology). The foredune crest is about 40 feet NGVD in elevation. The elevation of the foredune toe is about 18 feet NGVD. The width of the foreslope is about 150 feet. The foredune area is poorly vegetated, with vegetation cover on the backslope, crest, and

Table 7. Setting, Objectives, and Management Practices for **Management Unit F** **(Turnaround)**

Setting

- **Minimal Shoreline Change**

1967 versus 1997		
@ 10' contour	0'	elevation
	+ 10'	width
@ 20' contour	+ 10'	elevation
	+ 55'	width
25'	40'	elevation
	of primary foredune crest	

- **Episodic Erosion** 50' to 150'
- **'Type B'** morphology
  - **low, wide, graded profile**
  - crest elevation 40'
  - toe elevation 18'
  - foreslope width 155'
- **Poorly vegetated**
  - crest and backslope
    - open sand to 60 to 90 % cover
  - foreslope
    - open sand to 10 to 60% cover
- **C1- commercial**
  - dwelling elevation **mixed** 27' to 45'
  - dwelling location ~140' to 290' from OPRD Vegetation Line
- **Heavy Recreational Use with Vehicular and Pedestrian Access**
- **Sand Inundation**

Objectives

- Maintain Flood/Erosion Protection
- Minimize Sand Inundation and Enhance Ocean Views
- **Maintain or Enhance Access**

Management Practices

- **View Grading**

	elevation	location
Turnaround	34'	@ 0'
Primary Crest	34'	@100-150'
Secondary Crest	25'	@175-200'
Toe of Foreslope	12'	@ 300-350'

- **Remedial Grading** Parking Lot
- **Vegetative Stabilization** (north/south)

Backslope	60 to 90% cover
Primary Crest	60 to 90% cover
Secondary Crest	60 to 90% cover
Upper Foreslope	30 to 60% cover
Lower Foreslope	10 to 30% cover

- **Access Management**
  - Turnaround
- **Monitoring and Maintenance**

foreslope ranging from open sand to about 10 %. In contrast, the foredune area in the northern and southern portions of this segment of shoreline is higher and well vegetated. Vegetation cover approaches 90% along the crest and decreases from about 60 to about 10% from the upper to lower hummocky foreslope. Vegetation is mostly European Beachgrass. Patches of American Dunegrass and Yellow Sand Verbena exist locally.

Zoning along this segment of shoreline is C1- Neighborhood Commercial. The central portion is occupied by The Turnaround and associated County Parking Lot. The northern and southern portions are currently vacant. The finished floor elevation of structures in the foredune area range from about 27 to 45 feet NGVD and are located from about 140 to 290 feet landward of the OPRD 1969 Statutory Vegetation Line. The Turnaround is a designated public pedestrian-vehicular beach access. Correspondingly, this segment of shoreline experiences heavy recreational use. Drifting sand has been identified as a problem along the central portion of this segment of shoreline.

Management Objectives (with relative priority in bold)

- To maintain or enhance ocean flood/erosion protective functions of the natural foredune area;

- To minimize inundation brought about by excessive accumulation of wind-blown sand and correspondingly maintain or enhance ocean views; and

- **To maintain or enhance access to recreational uses associated with the open sand beach.**

Recommendations. Prescribed management practices for this management unit are outlined in Table 7, illustrated in Figure 15, and summarized below.

- **Sand Removal** - The removal of sand from the foredune management area is prohibited under the proposed foredune management strategy.

- **Foredune Grading** - View grading down to the 'V-zone 100 year plus 4 foot' elevation may occur along the length of this management unit. However, it is likely to occur only in the central portion of this management unit in association with remedial grading needed to maintain public access at the Turnaround. Ideally, a primary foredune crest will be established at an elevation at or above the 'V-zone 100 year plus 4 foot' elevation and at a distance at least 100 feet seaward from the western foundation of oceanfront structures. At an elevation of approximately 25 feet NGVD, an irregular secondary foredune crest will be located as much as 100 feet seaward from the primary foredune crest. The lower foreslope will extend out a distance about 100 to 150 feet seaward from the secondary foredune crest and down to an elevation of about 12 feet NGVD.

  Graded sand is to be transferred seaward from high areas behind the foredune crest to low areas

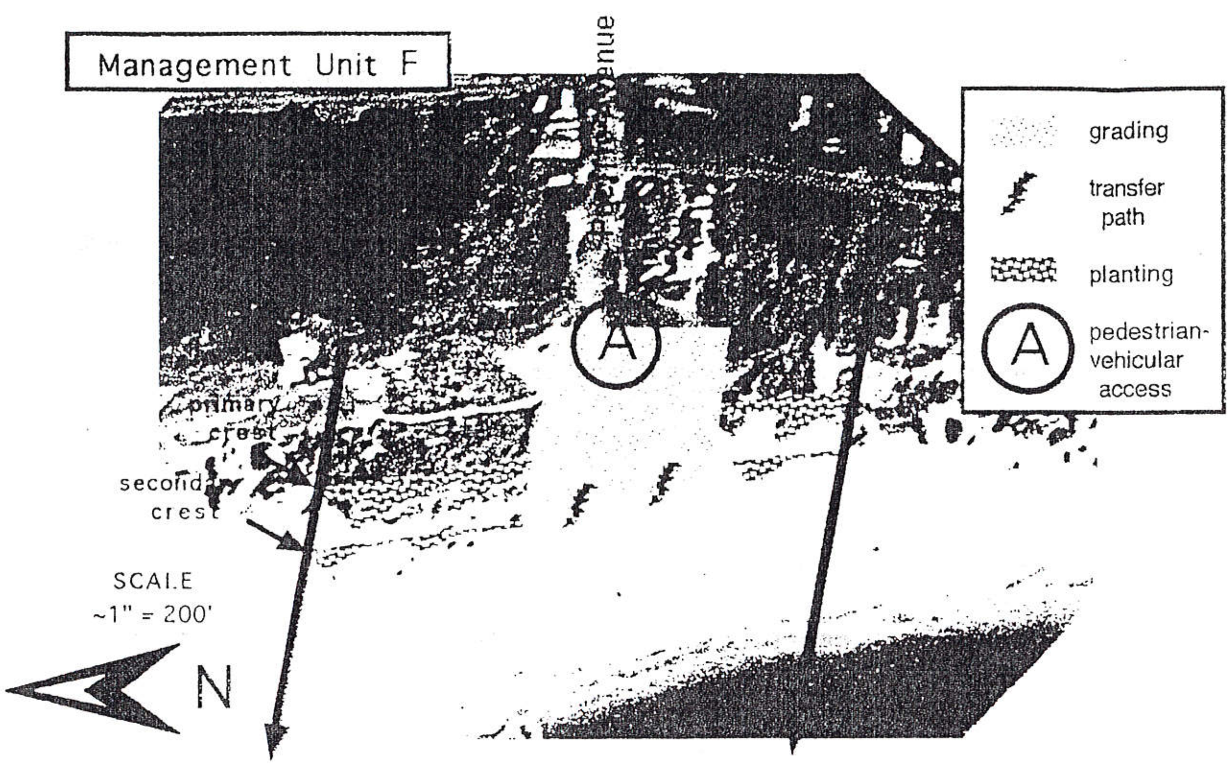


Figure 15. Plan Map Showing Proposed Management Practices for Management Unit F.

elsewhere along the crest and foreslope. After low areas have been filled consideration may be given to the transfer of excess sand seaward of the lower foreslope/ beachface so as to allow a combination of wave and wind-driven sediment transport to redistribute it.

The need to maintain the Turnaround and County Parking lot suggest that remedial grading will be the principal management practice conducted in the central portion of this management unit. As such, it should be allowed on an as needed basis.

• **Vegetative Stabilization** - Heavy recreational use precludes the existence of a dense vegetation cover. Therefore, vegetative stabilization is not required in the central portion of this management unit. Limited planting of stand-stilling grasses elsewhere, however, is recommended under the proposed management strategy. Planting should be carried out so as to mimic natural vegetation patterns as much as possible. Specific planting recommendations for this management unit are as follows:

> **Along the lower foreslope** in the northern and southern portions of this management unit plant primary grasses (e.g. 80% European Beachgrass and 20% American Dunegrass) at high densities (e.g. hill spacing of 12" with 5 culms per hill) to achieve as much as 60% cover over the area from about 25 feet to 18 feet NGVD in elevation and plant primary grasses (e.g. 80% European Beachgrass and 20% American Dunegrass) at moderate densities (e.g. hill spacing of 18" with 3 culms per hill) to achieve as much as 30% cover over the area from about 18 feet to 14 feet NGVD in elevation. Vegetation planted below an elevation of about 16 feet NGVD is best viewed as sacrificial, in that it may well be lost during winter storms and as a result need to be replanted on a regular basis.
>
> In all cases, planting should be carried out during rainy months (November through Aprii) before and/or after winter storms, when temperatures are between 32 and 60 degrees F and the sand is wet at a 3 inch depth. Preferably immediately after planting, fertilize with ammonium sulfate fertilizer (N-P-K:21-0-0) at a rate of ~200 - 400 pounds per acre, with follow up fertilization again in the subsequent late fall or early spring rainy period (after SCS, 1991).

• **Access Management** - To some extent access management in this area is addressed by existing Oregon Park and Recreation Department (OPRD) regulations:

> **The Turnaround (Pacific Avenue) south along the beach to the tip of Nestucca Spit** - Vehicles are allowed all year.

Access management will also be addressed by conducting remedial grading and other types of activities associated with maintenance of the Turnaround and County Parking Lot. Informational signs could be placed along the toe of the foreslope in the northern and southern portions of this management unit. The purpose of these signs would be to identify sensitive foredune areas and direct recreational users away from them. Consideration may also be given to implementation of more formal access management measures, such as post and rope fencing of identified access trails or wooden walkover structures.

· **Monitoring and Maintenance** - Recommended monitoring and maintenance measures are detailed in the Monitoring Program and Maintenance Program documents respectively.

Management Unit G

Setting. This management unit extends from just south of the Turnaround (the line between Tax Lots 1300 and 1400) to just north of Rueppel's Subdivision (the line between Tax Lots 2501 and 2502).

This segment of shoreline is characterized by relatively minor shoreline change over the period 1967 to 1997. Specifically, while some portions of the foredune area have increased in width by as much as 75 feet and in height by as much as 15 feet, other portions of the foredune area have actually decreased in width and not changed in height during this time (Table 8; Figure 16). This area has also experienced episodic erosion. As much as 50 to 150 feet of foredune retreat has occurred on at least two occasions over the last 30 years.

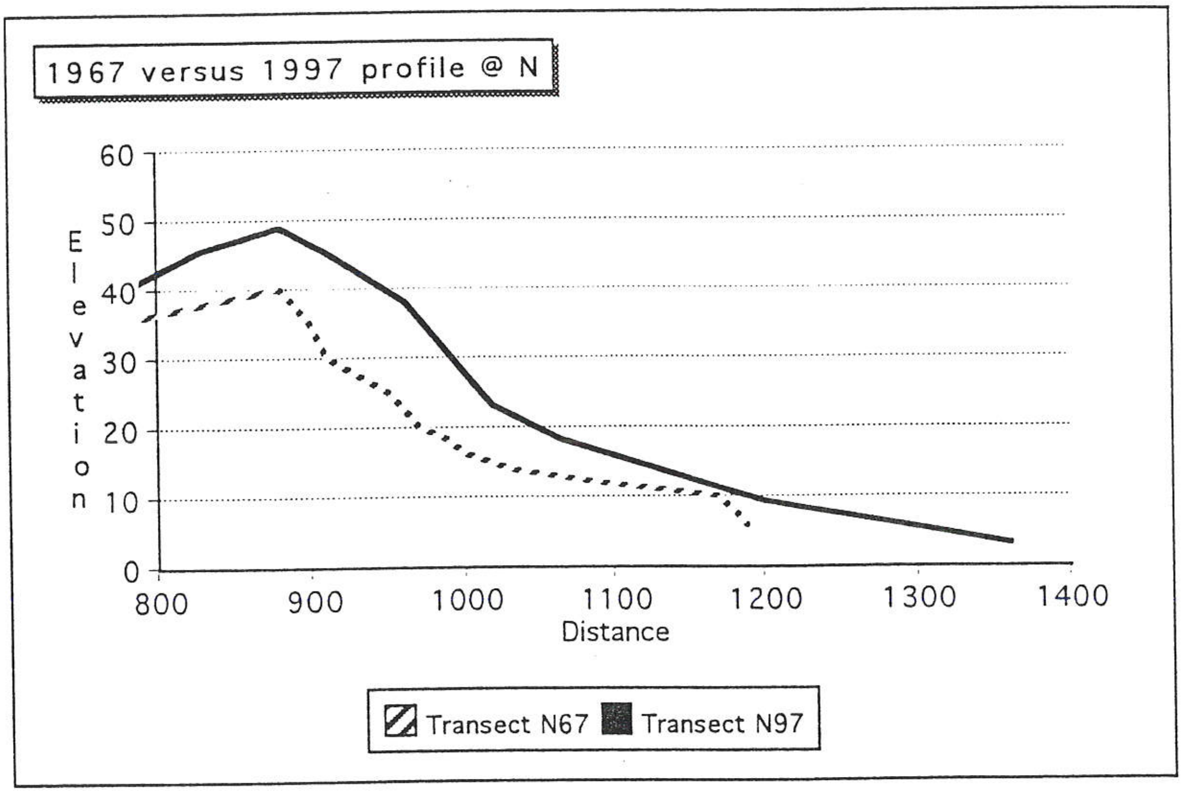


Figure 16.
Cross-section Showing Profile Change over the Period 1967 to 1997 in Management Unit G.

Currently, foredune morphology along this segment of shoreline is characterized by a relatively high, wide, accreted profile ('Type D' morphology). The foredune crest along this segment of shoreline, which is an amalgam of hummocks, ranges from about 30 to 50 feet NGVD in elevation. The elevation of the

Table 8. Setting, Objectives, and Management Practices for **Management Unit G** **(the Turnaround to Rueppel's Subdivision)**

Setting

- **Minimal Shoreline Change**

1967 versus 1997		
@ 10' contour	0 '	elevation
	- 10' to + 20'	width
@ 20' contour	+10 to +15'	elevation
	+ 70' to 75'	width
30' to 40'	30' to 50' of primary foredune crest	elevation

- **Episodic Erosion** 50' to 150'

- **'Type D'** morphology
  high, wide, accreted profile
  crest elevation 30' to 50'
  toe elevation 11' to 18'
  foreslope width 155' to 225'

- **Well vegetated**
  crest and backslope
  60 to 90% cover
  foreslope
  10 to 60% cover, hummocky

- **R2- residential**
  dwelling elevation **high** 33' to 48'
  dwelling location ~120' to 220' from OPRD Vegetation Line

- **Moderate Recreational Use with Uncontrolled Access**

- **Sand Inundation**, limited **Riprap**

Objectives

- **Maintain Flood/Erosion Protection**

- **Minimize Sand Inundation and Enhance Ocean Views**

- Maintain or Enhance Access

Management Practices

- **View Grading**

	elevation	location
Foundation	*34'*	@ 0'
Primary Crest	*34'*	@50-125'
Secondary Crest	25'	@150-225'
Toe of Foreslope	12'	@350-425'

- Remedial Grading 30' seaward

- **Vegetative Stabilization**

Backslope	60 to 90% cover
Primary Crest	60 to 90% cover
Secondary Crest	60 to 90% cover
Upper Foreslope	30 to 60% cover
Lower Foreslope	10 to 30% cover

- **Access Management**
  Central Portion of Management Unit

- **Monitoring and Maintenance**

foredune toe ranges from about 11 to 18 feet NGVD. The width of the hummocky foreslope ranges from about 150 to 250 feet. The foredune area is well vegetated, with vegetation cover on the crest and backslope ranging from about 60 to 90% and on the foreslope from as little as 10% in lower portions and as much as 60% in upper portions. Vegetation cover along the primary crest is mostly European Beachgrass (80-90%) with minor amounts of American Dunegrass (10-20%). Vegetation cover along the secondary crest and foreslope consists of patches of American Dunegrass and Yellow Sand Verbena, as well as European Beachgrass. Transverse open-sand dunes evident along portions of the crest and backslope are indicative of active wind-driven sediment transport within this management unit.

Zoning along this segment of shoreline is R2- Medium Density Urban Residential. Correspondingly, most of the area is occupied by single family residential dwellings. With finished/garage floor elevations ranging from about 33 to 48 feet NGVD, dwellings are relatively high compared to the existing 'V-zone 100 year plus 4 foot' elevation. Dwellings are located at distances about 120 to 220 feet landward of the OPRD 1969 Statutory Vegetation Line. Several lots within this management unit are vacant. Well vegetated hummocks typically occupy these areas. Recreational use along this segment of shoreline is moderate compared to other portions of the management area. Also, homeowner access to the beach is uncontrolled along this segment of shoreline. Riprap exists locally in this management unit. Having actually resulted in the burial of a dwelling, drifting sand has been identified as a problem along this segment of shoreline.

Management Objectives (with relative priority in bold)

- **To maintain or enhance ocean flood/erosion protective functions of the natural foredune area;**

- **To minimize inundation brought about by excessive accumulation of wind-blown sand and correspondingly maintain or enhance ocean views; and**

- To maintain or enhance access to recreational uses associated with the open sand beach.

Recommendations. Prescribed management practices for this management unit are outlined in Table 8, illustrated in Figure 17, and summarized below.

- **Sand Removal** - The removal of sand from the foredune management area is prohibited under the proposed foredune management strategy.

- **Foredune Grading** - View grading down to the 'V-zone 100 year plus 4 foot' elevation may occur along the entire length of this management unit. Ideally, a primary foredune crest will be established at an elevation at or above the 'V-zone 100 year plus 4 foot' elevation and at a distance at least 50 and as much as 125 feet seaward from the western foundation of oceanfront dwellings. At an elevation of

Management Unit G

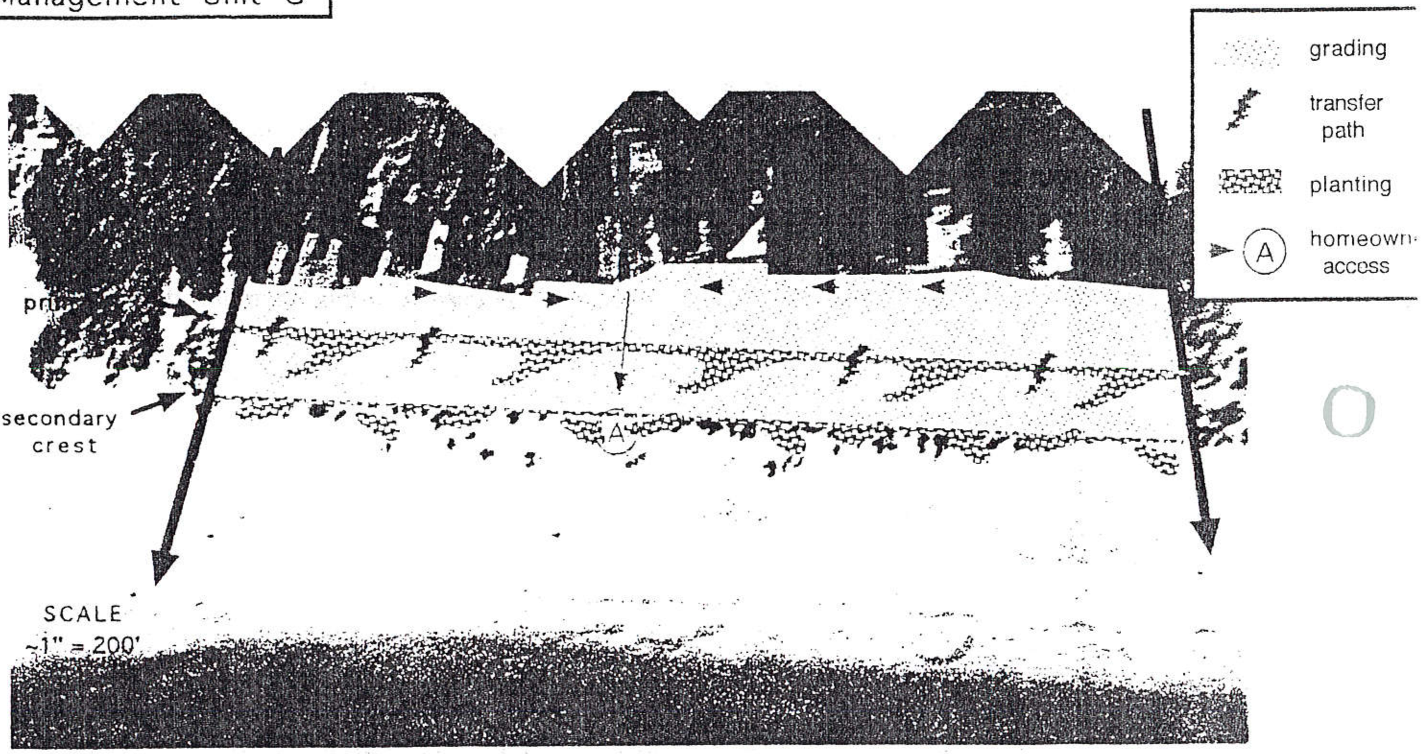


Figure 17. Plan Map Showing Proposed Management Practices for Management Unit G.

approximately 25 feet NGVD, an irregular secondary foredune crest will be located approximately 100 feet seaward from the primary foredune crest. The lower foreslope will extend out a distance about 200 feet seaward from the secondary foredune crest and down to an elevation of about 12 feet NGVD.

Graded sand is to be transferred seaward from high areas behind the foredune crest to low areas elsewhere along the crest and foreslope. In this regard, it is recommended that the grading of vacant lots be conducted in conjunction with view grading. This will facilitate more even growth of the foredune area and in turn reduce potential for sand inundation. After low areas have been filled consideration may be given to the transfer of excess sand seaward of the lower foreslope/ beachface so as to allow a combination of wave and wind-driven sediment transport to redistribute it.

Remedial grading should be allowed on an as needed basis. It may be fairly extensive in scope and regular in frequency following initial grading and planting. However, it is anticipated that the scope and frequency of remedial grading in this area will decrease over time.

· **Vegetative Stabilization** - The planting of stand-stilling grasses immediately following view grading is recommended in this management unit under the proposed strategy. It is envisioned that the capture of sand in the foreslope of this foredune area -essentially encouraging outward as opposed to upward growth of the foredune- will not only minimize the potential for inundation and in turn maintain ocean views, but will also enhance flood/erosion protection potential.

Planting should be carried out so as to mimic natural vegetation patterns as much as possible. Specific planting recommendations for this management unit are as follows:

Along the backslope plant primary grasses (e.g. 80% European Beachgrass and 20% American Dunegrass) at moderate densities (e.g. hill spacing of 18" with 3 culms per hill) to achieve greater than 60% cover.

Along the primary crest plant primary grasses (e.g. 80% European Beachgrass and 20% American Dunegrass) at high densities (e.g. hill spacing of 12" with 5 culms per hill) to achieve greater than 60% cover down to an elevation of about 25 feet NGVD.

Along the secondary crest and foreslope plant primary grasses (e.g. 80% European Beachgrass and 20% American Dunegrass) at high densities (e.g. hill spacing of 12" with 5 culms per hill) to achieve as much as 60% cover over the area from about 25 feet to 18 feet NGVD in elevation and plant primary grasses (e.g. 80% European Beachgrass and 20% American Dunegrass) at moderate densities (e.g. hill spacing of 18" with 3 culms per hill) to achieve as much as 30% cover over the area from about 18 feet to 14 feet NGVD in elevation. Vegetation planted below an elevation of about 16 feet NGVD is best viewed as sacrificial, in that it may well be lost during winter storms and as a result need to be replanted on a regular basis.

In all cases, planting should be carried out during rainy months (November through April) before and/or after winter storms, when temperatures are between 32 and 60 degrees F and the sand is wet at a 3 inch depth. Preferably immediately after planting, fertilize with ammonium sulfate fertilizer (N-P-K :21-0-0) at a rate of ~200 -400 pounds per acre, with follow up fertilization again in the subsequent late fall or early spring rainy period (after SCS, 1991).

• **Access Management** - Access management measures warranted in this area include the posting of signs identifying sensitive foredune areas and directing not only recreational users, but homeowners away from these areas. In this regard, it is recommended that a homeowner access path be established in the central portion of this management unit.

• **Monitoring and Maintenance** - Recommended monitoring and maintenance measures are detailed in the Monitoring Program and Maintenance Program documents respectively.

Management Unit H

Setting. This management unit extends from just north of Rueppel's Subdivision (the line between Tax Lots 2501 and 2502) to the northern boundary of Nestucca Spit State Park.

This segment of shoreline is characterized by relatively minor shoreline change over the period 1967 to 1997. Specifically, while some portions of the foredune area have increased in width by as much as 110 feet and in height by as much as 10 feet, other portions of the foredune area have actually decreased in width and not changed in height during this time (Table 9; Figure 18a, 18b, 18c, and 18d). This area has also experienced episodic erosion. As much as 50 to 150 feet of foredune retreat has occurred on at least two occasions over the last 30 years.

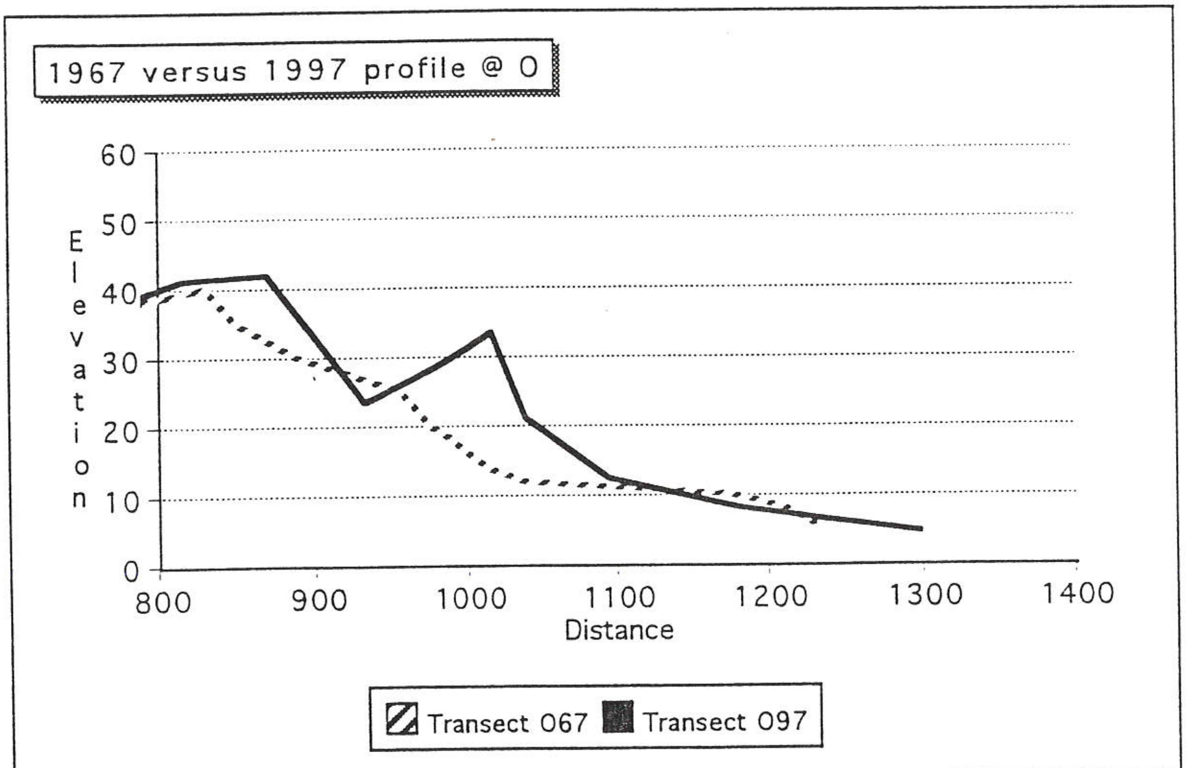


Figure 18a.
Cross-section Showing Profile Change over the Period 1967 to 1997 in Management Unit H.

Currently, foredune morphology along this segment of shoreline is characterized by a relatively low, wide, accreted profile ('Type D' morphology). The foredune crest along this segment of shoreline, which is an amalgam of hummocks, ranges from about 25 to 40 feet NGVD in elevation. The elevation of the

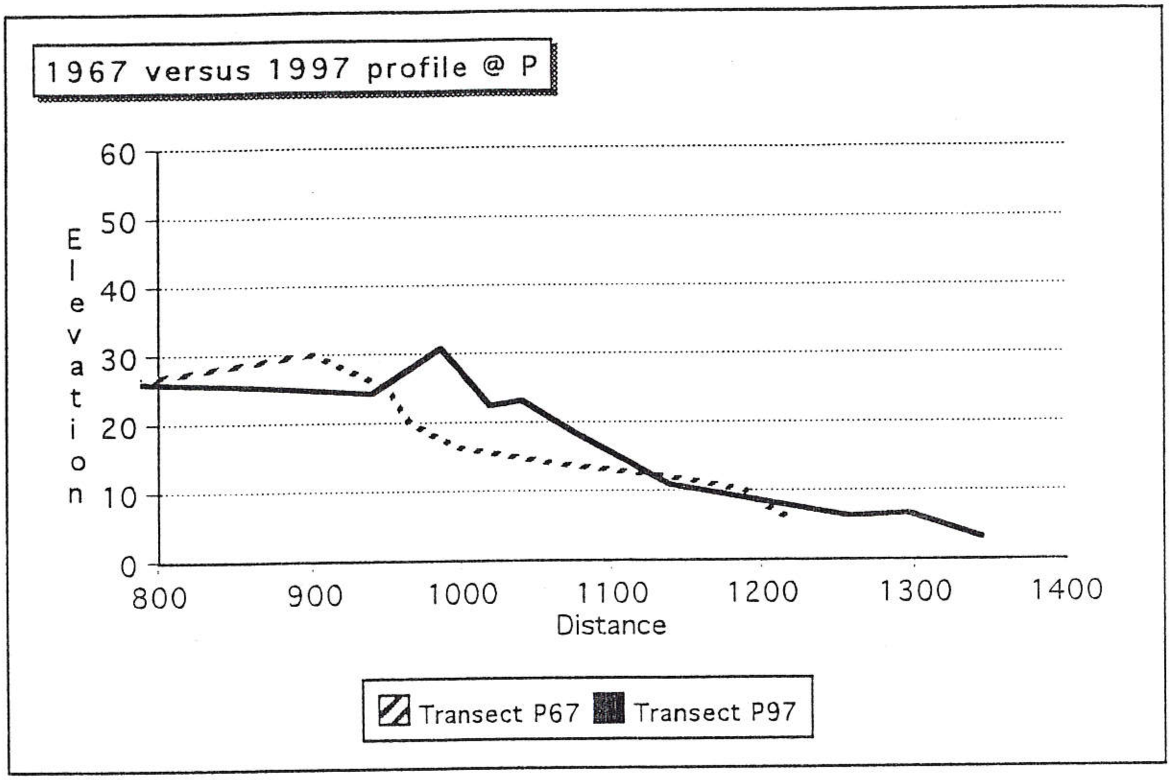
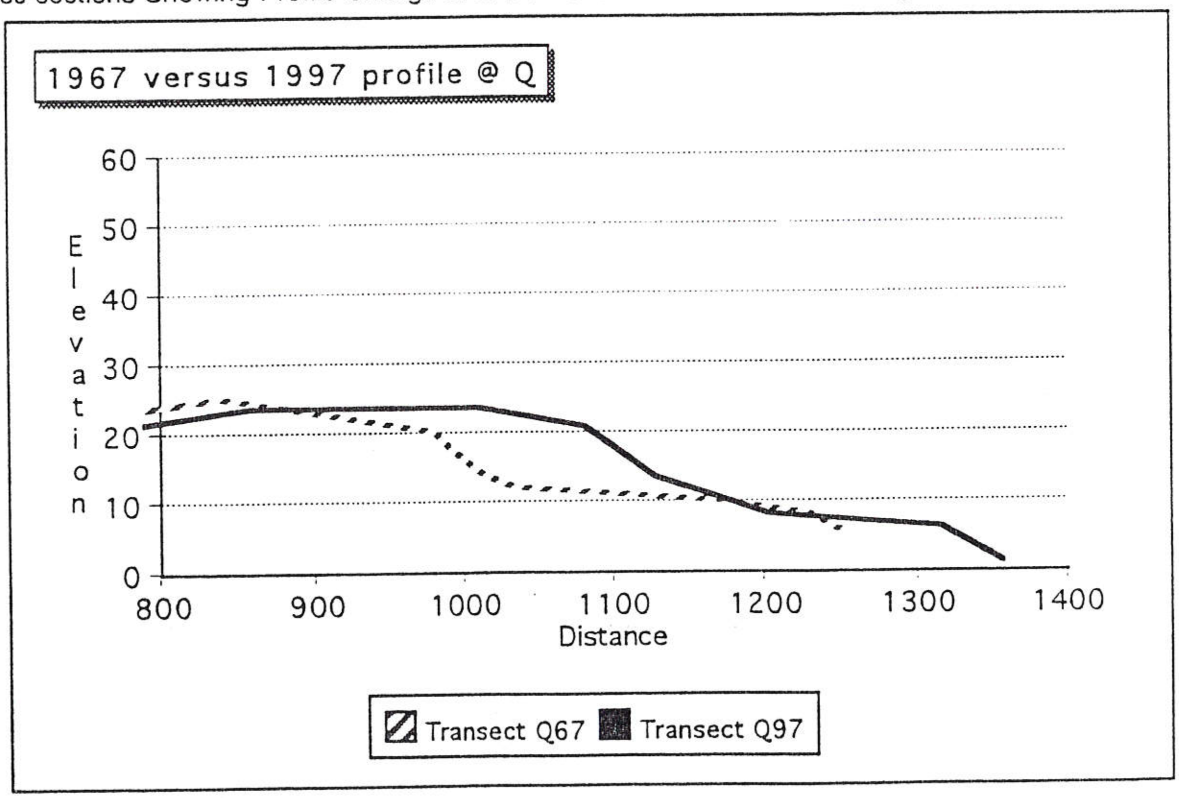


Figure 18b and 18c.
Cross-sections Showing Profile Change over the Period 1967 to 1997 in Management Unit H.



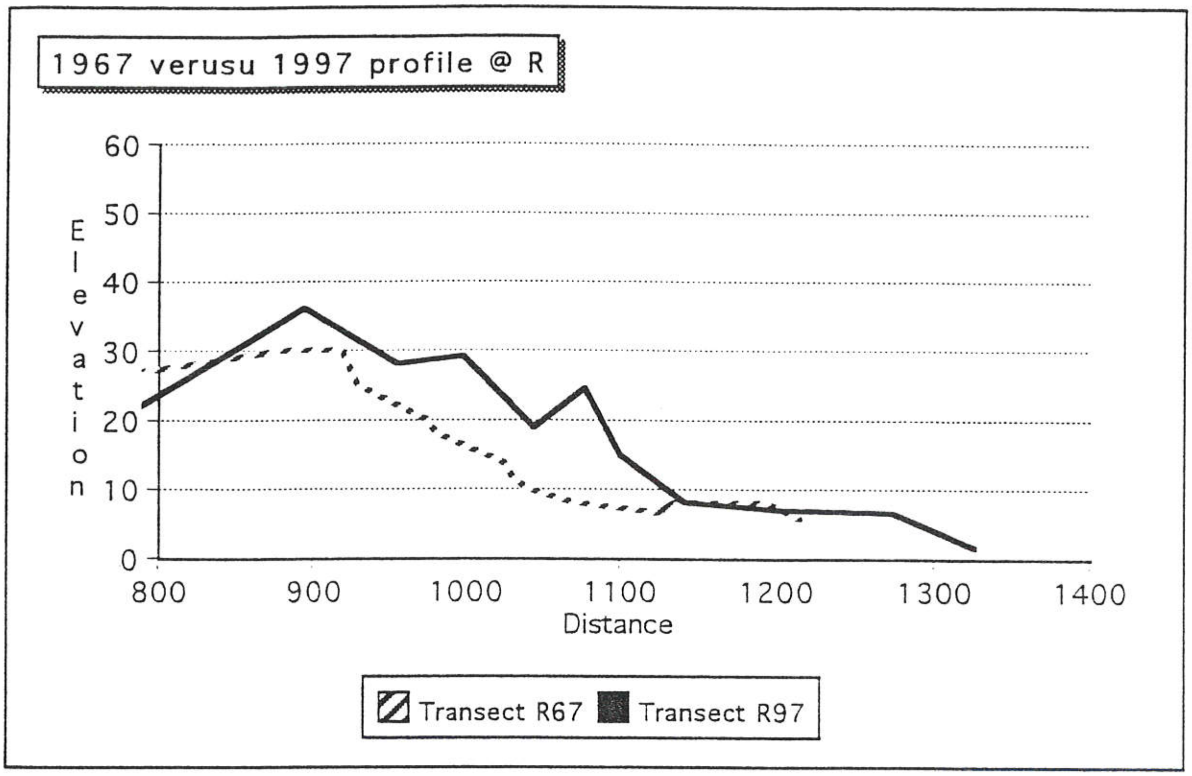


Figure 18d.
Cross-section Showing Profile Change over the Period 1967 to 1997 in Management Unit H.

foredune toe ranges from about 8 to 13 feet NGVD. The width of the hummocky foreslope ranges from about 120 to 235 feet. Vegetation cover is variable along this segment of shoreline. Portions of the foredune area are well vegetated, with vegetation cover on the crest and backslope ranging from about 60 to 90% and on the foreslope from as little as 10% in lower portions to as much as 60% in upper portions. Other portions of the foredune area are poorly vegetated, with vegetation cover on the crest and backslope ranging from open sand to about 60 % and on the foreslope from open sand to about 30%. Vegetation cover along the primary crest is mostly European Beachgrass (80-90%) with minor amounts of American Dunegrass (10-20%). Vegetation cover along the secondary crest and foreslope consists of patches of American Dunegrass and Yellow Sand Verbena, as well as European Beachgrass. Transverse open-sand dunes evident along portions of the foreslope are indicative of active wind-driven sediment transport within this management unit.

Zoning along this segment of shoreline is R2- Medium Density Urban Residential. Correspondingly, most of the area is occupied by single family residential dwellings. With finished/garage floor elevations ranging from about 22 to 40 feet NGVD, dwellings are relatively low compared to the existing 'V-zone 100 year

Table 9. Setting, Objectives, and Management Practices for **Management Unit H** (North Rueppel's Subdivision to State Park)

Setting

- **Minimal Shoreline Change**

1967 versus 1997		
@ 10' contour	0' to +10 '	elevation
	- 15' to 95'	width
@ 20' contour	+ 5' to 10 '	elevation
	+ 70' to 110'	width
25' to 40'	25' to 40'	elevation
	of primary foredune crest	

- **Episodic Erosion** 50' to 150'

- **'Type D'** morphology
  - **low, wide, accreted profile**
  - crest elevation 25' to 40'
  - toe elevation 8' to 13'
  - foreslope width 120' to 235'

- **Well to poorly vegetated**
  - crest and backslope
    - open sand to 90% cover
  - foreslope
    - open sand to 30% cover, hummocky

- **R2- residential**
  - dwelling elevation **low** 22' to 40'
  - dwelling location ~80' to 150' from OPRD Vegetation Line

- **Moderate Recreational Use with Uncontrolled Access**

- **Sand Inundation**, limited **Riprap**

Objectives

- **Maintain Flood/Erosion Protection**
- **Minimize Sand Inundation and Enhance Ocean Views**
- Maintain or Enhance Access

Management Practices

- **View Grading**

	elevation	location
Foundation	*34'*	@ 0'
Primary Crest	*34'*	@50-200'
Secondary Crest	25'	@150-300'
Toe of Foreslope	12'	@350-500'

- Remedial Grading 30' seaward

- **Vegetative Stabilization**

Backslope	60 to 90% cover
Primary Crest	60 to 90% cover
Secondary Crest	60 to 90% cover
Upper Foreslope	30 to 60% cover
Lower Foreslope	10 to 30% cover

- **Access Management**
  Northern, Central, and Southern Portions of the Management Unit

- **Monitoring and Maintenance**

plus 4 foot' elevation. Dwellings are located at distances about 80 to 150 feet landward of the OPRD 1969 Statutory Vegetation Line. Several lots within this management unit are vacant. Well vegetated hummocks typically occupy these areas. Recreational use along this segment of shoreline is moderate compared to other portions of the management area. Also, homeowner access to the beach is uncontrolled along this segment of shoreline. Riprap exists locally in this management unit. Drifting sand has been identified as a problem along this segment of shoreline.

Management Objectives (with relative priority in bold)

- **To maintain or enhance ocean flood/erosion protective functions of the natural foredune area;**

- **To minimize inundation brought about by excessive accumulation of wind-blown sand and correspondingly maintain or enhance ocean views; and**

- To maintain or enhance access to recreational uses associated with the open sand beach.

Recommendations. Prescribed management practices for this management unit are outlined in Table 9, illustrated in Figure 19, and summarized below.

- **Sand Removal** - The removal of sand from the foredune management area is prohibited under the proposed foredune management strategy.

- **Foredune Grading** - View grading down to the 'V-zone 100 year plus 4 foot' elevation may occur along the entire length of this management unit. Ideally, a primary foredune crest will be established at an elevation at or above the 'V-zone 100 year plus 4 foot' elevation and at a distance at least 50 and as much as 200 feet seaward from the western foundation of oceanfront dwellings. At an elevation of approximately 25 feet NGVD, an irregular secondary foredune crest will be located approximately 100 feet seaward from the primary foredune crest. The lower foreslope will extend out a distance about 200 feet seaward from the secondary foredune crest and down to an elevation of about 12 feet NGVD.

  Graded sand is to be transferred seaward from high areas behind the foredune crest to low areas elsewhere along the crest and foreslope. In this regard, it is recommended that the grading of vacant lots be conducted in conjunction with view grading. This will facilitate more even growth of the foredune area and in turn reduce potential for sand inundation. After low areas have been filled consideration may be given to the transfer of excess sand seaward of the lower foreslope/ beachface so as to allow a combination of wave and wind-driven sediment transport to redistribute it.

  Remedial grading should be allowed on an as needed basis. It may be fairly extensive in scope and regular in frequency following initial grading and planting. However, it is anticipated that the scope and frequency of remedial grading in this area will decrease over time.

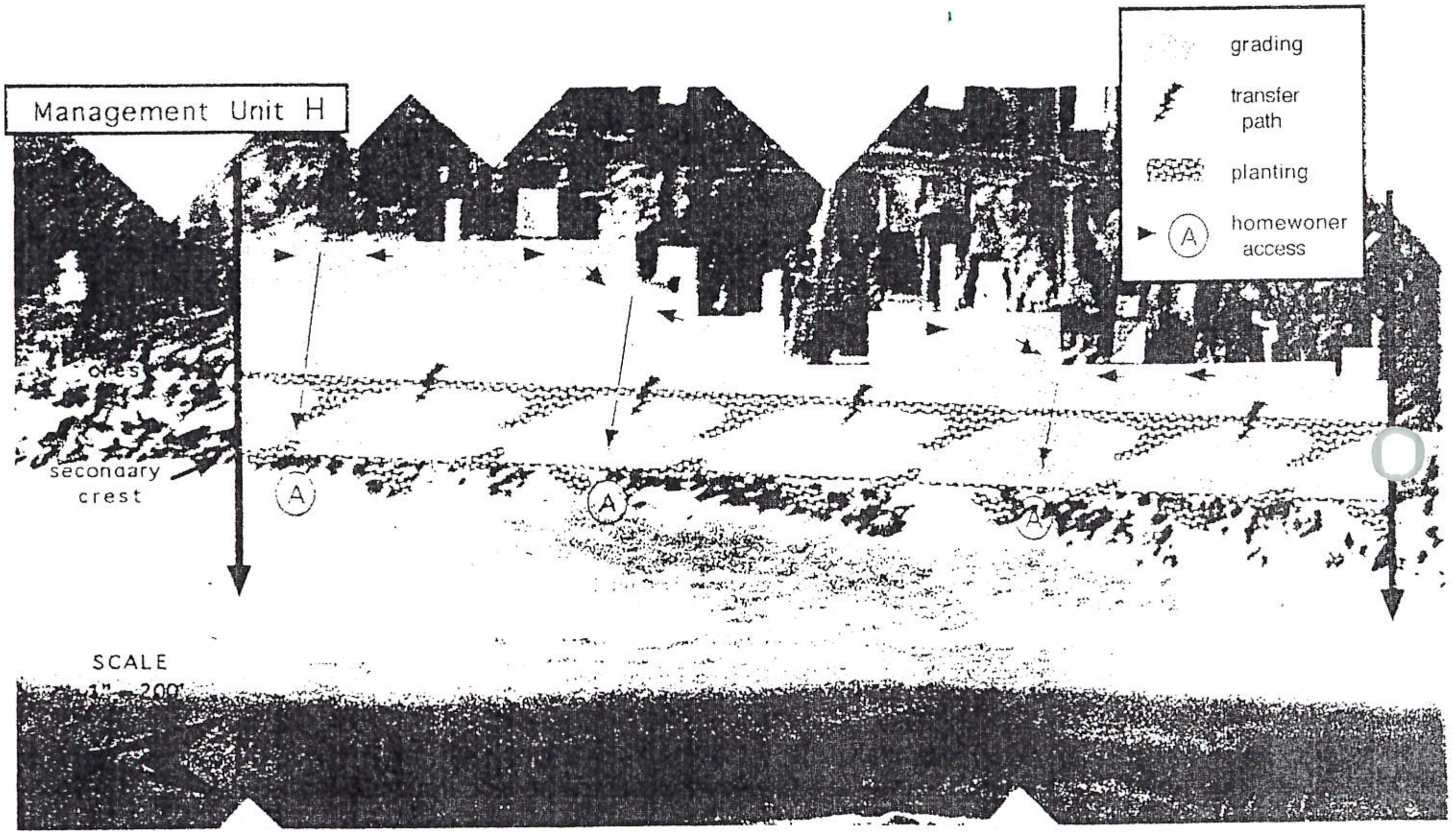


Figure 19. Plan Map Showing Proposed Management Practices for Management Unit H.

• **Vegetative Stabilization** - The planting of stand-stilling grasses immediately following view grading is recommended in this management unit under the proposed strategy. It is envisioned that the capture of sand in the foreslope of this foredune area -essentially encouraging outward as opposed to upward growth of the foredune- will not only minimize the potential for inundation and in turn maintain ocean views, but will also enhance flood/erosion protection potential.

Planting should be carried out so as to mimic natural vegetation patterns as much as possible. Specific planting recommendations for this management unit are as follows:

> **Along the backslope** plant primary grasses (e.g. 80% European Beachgrass and 20% American Dunegrass) at moderate densities (e.g. hill spacing of 18" with 3 culms per hill) to achieve greater than 60% cover.
>
> **Along the primary crest** plant primary grasses (e.g. 80% European Beachgrass and 20% American Dunegrass) at high densities (e.g. hill spacing of 12" with 5 culms per hill) to achieve greater than 60% cover down to an elevation of about 25 feet NGVD.
>
> **Along the secondary crest and foreslope** plant primary grasses (e.g. 80% European Beachgrass and 20% American Dunegrass) at high densities (e.g. hill spacing of 12" with 5 culms per hill) to achieve as much as 60% cover over the area from about 25 feet to 18 feet NGVD in elevation and plant primary grasses (e.g. 80% European Beachgrass and 20% American Dunegrass) at moderate densities (e.g. hill spacing of 18" with 3 culms per hill) to achieve as much as 30% cover over the area from about 18 feet to 14 feet NGVD in elevation. Vegetation planted below an elevation of about 16 feet NGVD is best viewed as sacrificial, in that it may well be lost during winter storms and as a result need to be replanted on a regular basis.
>
> In all cases, planting should be carried out during rainy months (November through April) before and/or after winter storms, when temperatures are between 32 and 60 degrees F and the sand is wet at a 3 inch depth. Preferably immediately after planting, fertilize with ammonium sulfate fertilizer (N-P-K:21-0-0) at a rate of ~200 - 400 pounds per acre, with follow up fertilization again in the subsequent late fall or early spring rainy period (after SCS, 1991).

• **Access Management** - Access management measures warranted in this area include the posting of signs identifying sensitive foredune areas and directing not only recreational users, but homeowners away from these areas. In this regard, it is recommended that homeowner access paths be established at two or three locations within this management unit.

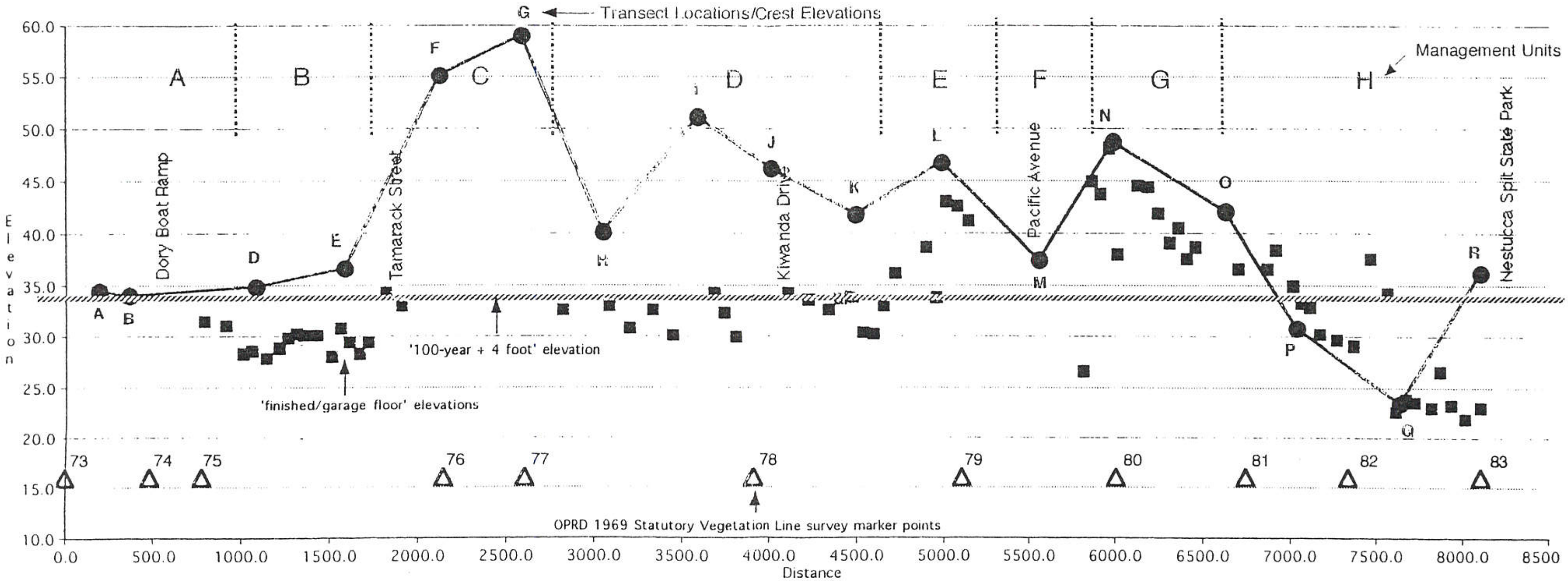
• **Monitoring and Maintenance** - Recommended monitoring and maintenance measures are detailed in the Monitoring Program and Maintenance Program documents respectively.

Limitations

The set of recommendations that constitute the proposed foredune management strategy are based on a consideration of past conditions and conditions as they exist at the time of this writing. They should be considered to be subject to revision upon review of additional or more detailed information. They may also need to be modified should events occur which alter existing conditions (e.g. ocean erosion). Finally, Shoreland Solutions is excluded from responsibility for any adverse effects that result from actions taken by other parties that are based on the observations, interpretations, and recommendations contained in this document.

Reference

SCS, 1991. Carlson, J., Reckendorf, F., and Ternyik, W. Stabilizing Coastal Sand Dunes in the Pacific Northwest. USDA Soil Conservation Service (SCS) Handbook 687, August 1991. 53p.


Transect Locations/Crest Elevations
Management Units
A
B
C
D
E
F
G
H
Dory Boat Ramp
Tamarack Street
Kiwanda Drive
Pacific Avenue
Nestucca Spit State Park
'100-year + 4 foot' elevation
'finished/garage floor' elevations
OPRD 1969 Statutory Vegetation Line survey marker points
Elevation
Distance

Appendix A:

Management Units, Transect Locations, and Key Characteristics along the Pacific City shoreline.

This figures shows:

- Location of Management Units along the Pacific City shoreline (blue letters);
- Location of Transect Locations along the Pacific City shoreline (green letters);
- Elevation of the primary foredune crest along the Pacific City shoreline (green line);
- The '100-year + 4 foot' elevation (dashed red line);
- Finished/garage floor elevations along the Pacific City shoreline (black boxes); and
- Location of the OPRD 1969 Statutory Vegetation Line survey marker points (numbered triangles)

North is to the left. Elevations and distances are in feet. Elevations are referenced to the NGVD.

List of Tables and Figures

Pacific City

Foredune Management Plan:

BACKGROUND REPORT

prepared for

Pacific City Beachfront Homeowners Association
P.O. Box 601
Pacific City, OR 97135

by

Shoreland Solutions
P.O. Box 1046
Newport, OR 97365

March 1998

Preface

This document reviews factors affecting shoreline stability within the foredune area fronting the rural community of Pacific City, Tillamook County, Oregon. It is one in a set of documents that together constitute the Pacific City Foredune Management Plan. Other documents in this set are: the Management Strategy, which outlines recommendations on the types of sand management measures to be conducted within the identified management area; the Monitoring Program, which describes the types of information to be collected and analyzed in order to evaluate the success of the management strategy; the Maintenance Program, which describes activities needed to ensure the success of the management strategy; and the Implementing Ordinance, which is the formal mechanism for carrying out prescribed management measures. This set of documents is intended to address the requirements of Statewide Planning Goal 18: Beaches and Dunes - Implementation Requirement 7 and Section 3.085 (4)(C) (2) of the Tillamook County Land Use Ordinance pertaining to foredune grading.

This document was prepared by Shoreland Solutions at the request of the Pacific City Beachfront Homeowners Association.

Pacific City
Foredune Management Plan:
BACKGROUND REPORT

Table of Contents

Pacific City
Foredune Management Plan:
BACKGROUND REPORT

List of Tables and Figures

Pacific City

Foredune Management Plan:

BACKGROUND REPORT

Introduction

Statewide Planning Goal 18: Beaches and Dunes - Implementation Requirement 7 outlines the elements of a foredune management plan (LCDC, 1995). According to Implementation Requirement 7, such a plan must be "based on a consideration of factors affecting the stability of the shoreline to be managed", where factors affecting shoreline stability include "sources of sand, ocean flooding, and patterns of accretion and erosion, and effects of beachfront protective structures and jetties". This document addresses these requirements. Through the identification of a design foredune configuration for and individual management units within the overall management area, it also provides a framework for the development of a foredune management strategy for the shoreline fronting Pacific City.

The general area under consideration is identified as the Nestucca Littoral Cell - an approximately 9 mile long stretch of beach and dunes bounded by Cascade Head on the south and Cape Kiwanda on the north (Figure 1). The northern portion of the Nestucca Littoral Cell is the area within which active management is to occur and is thus of particular interest. This segment of shoreline extends from the Nestucca River Inlet on the south to Cape Kiwanda on the north. It encompasses portions of Nestucca Spit State Park, the rural community of Pacific City, and Cape Kiwanda State Park.

Factors affecting the stability of dune-backed shorelines are illustrated in Figure 2. In this figure a distinction is made between long term *trends* and short term *events*. Long term trends include processes and responses related to relative sea level rise, earthquake-induced tsunami, and sand supply. They occur over relatively long time scales and affect relatively large areas. Short term events encompass processes and responses that are more limited in duration and extent. Wave attack and human activities are included in this category. These and other distinctions illustrated in Figure 2 provide the conceptual framework for the following consideration of factors affecting stability of the Pacific City shoreline.

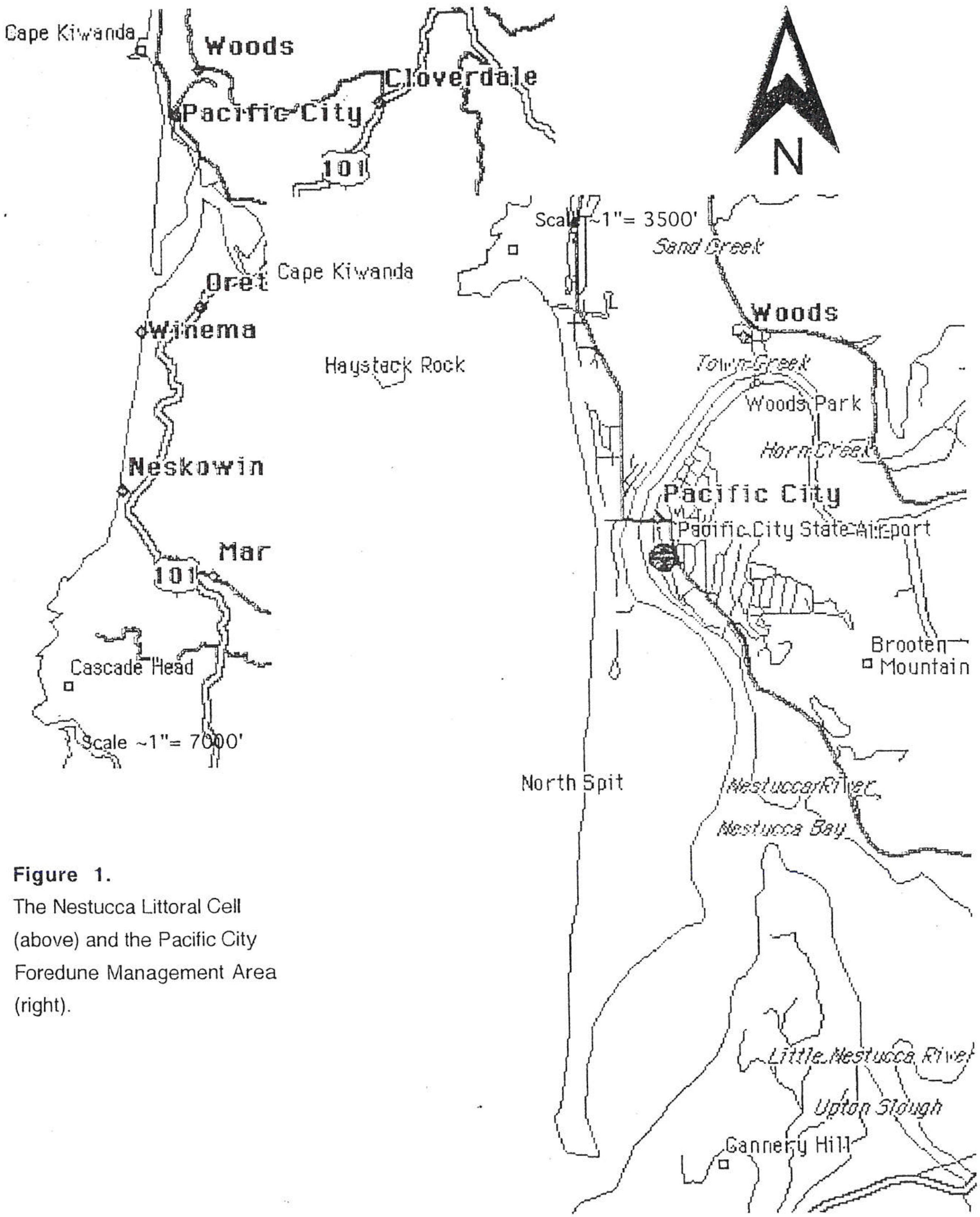


Figure 1.
The Nestucca Littoral Cell (above) and the Pacific City Foredune Management Area (right).

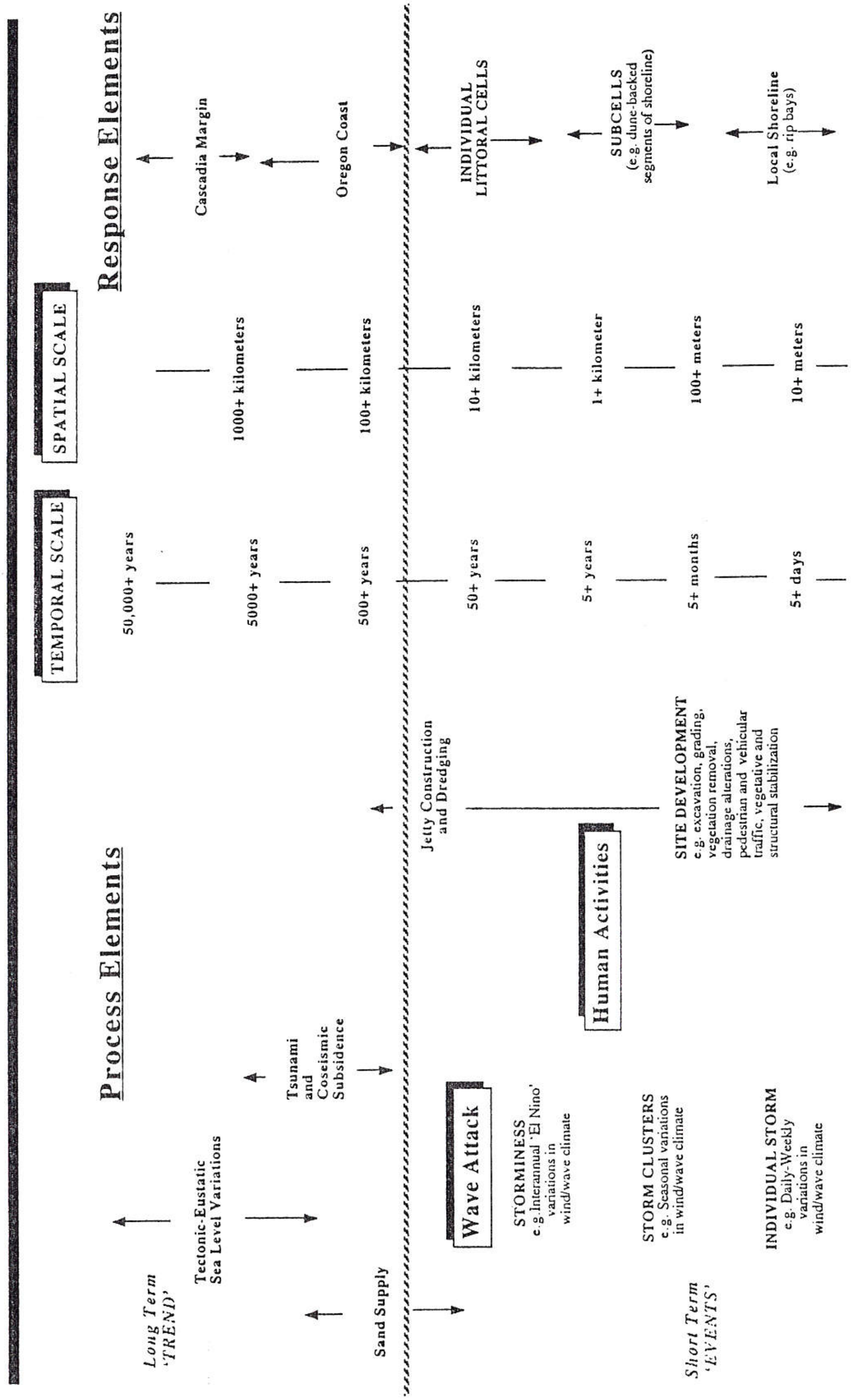


Figure 2. FACTORS AFFECTING SHORELINE STABILITY along dune-backed shorelines

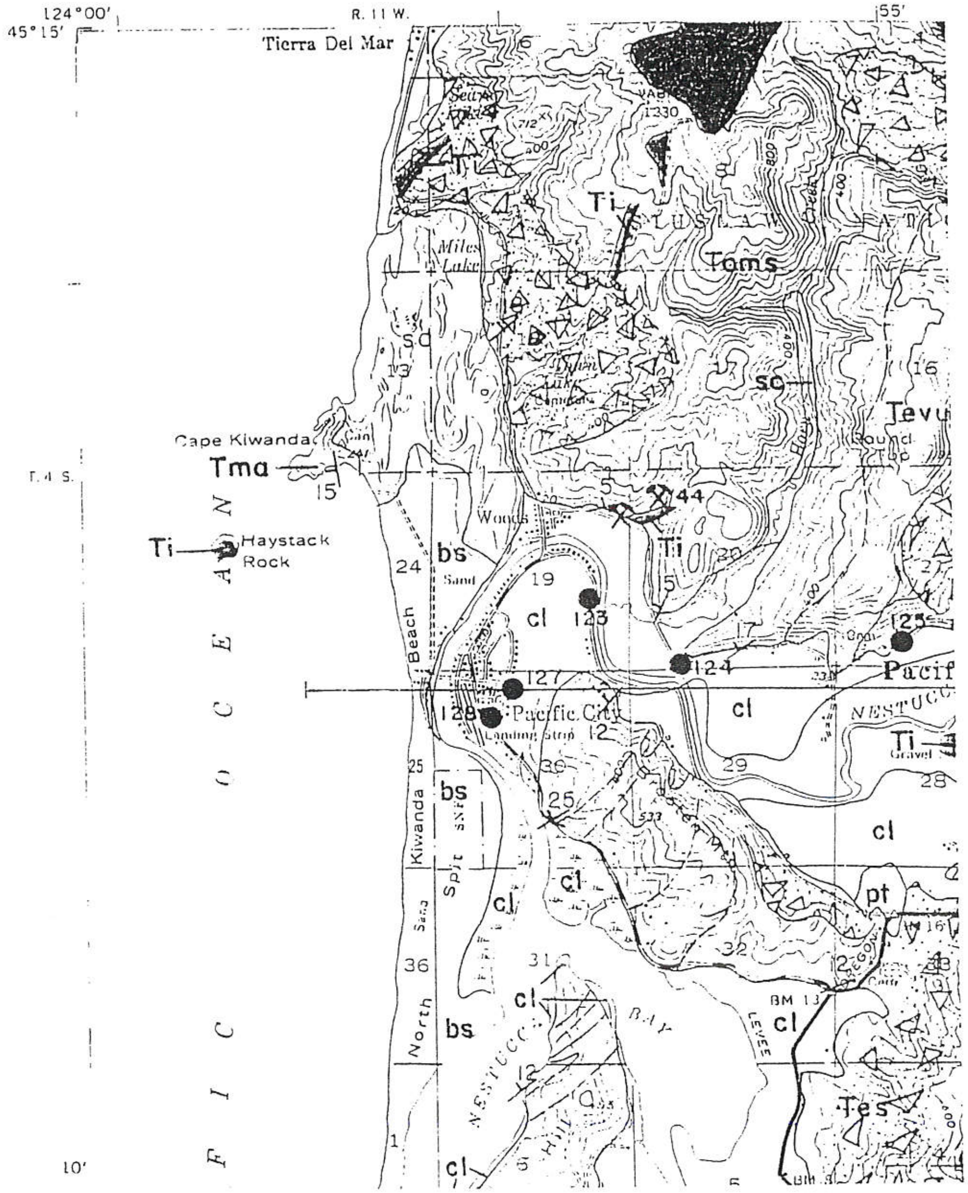


Figure 3. Geologic map of the Pacific City area (DOGAMI, 1972).

Long Term Trends

Regional Geology and Geologic Setting. Descriptions of the principal geologic units in the Pacific City area are given below after DOGAMI (1972). The distribution of these units is shown in Figure 3.

Eocene Sedimentary Rocks (Tes) - This unit consists of thin-bedded tuffaceous siltstone and massive siltstone. Carbonaceous, volcanic ash, and fine-grained sandstone interbeds occur locally.

Eocene Volcanic Rocks (Tevu) - This unit consists of dark grey to black, porphyritic basalt, dark grey basaltic breccia, and basaltic lapilli tuff. Tuffaceous claystone interbeds occur locally.

Oligocene-Miocene Sedimentary Rocks (Toms) - In the Pacific City area this unit consists of massive beds of medium-grained to coarse-grained, basaltic sandstone, basaltic conglomerate, sandy tuff, and sandy silt.

Tertiary Intrusive Rocks (Ti) - This unit represents dikes and sills composed of medium to dark grey, fine to medium-grained, granophyric gabbros and granophyric diorites.

Astoria Formation (Tma)- At Cape Kiwanda this unit consists of dark grey to buff, massive beds of medium to fine-grained, arkosic sandstone and siltstone. Concretions occur locally. Basaltic pebbles are common high in the section.

Surficial Deposits (sd, bs, cl) - These units include the present day sand which makes up the beaches and dunes, and the mud on tidal flats.

The geologic setting of the Oregon coast is that of a convergent margin, where the oceanic Juan de Fuca Plate plunges below the continental North American Plate at the Cascadia Subduction Zone (Figure 4). The geologic units in the Pacific City area are the result of deposition, erosion, and tectonic deformation that has occurred along this convergent margin over the last sixty million years.

According to Orr et al. (1992) the basalt platform that makes up the core of the coast range was formed when a chain of volcanic seamounts or a series of mid-ocean ridges atop the underriding plate collided with and were swept up by the overriding plate during the late Paleocene and early Eocene (50-60 m.y.a.). During the middle and late Eocene (40-50 m.y.a.) sands, silts, muds, and volcanic debris were deposited atop the basalt platform in a newly developed basin (Tes). Initiated as flows erupted under water on a shallow shelf, basalts were deposited towards the end of this interval (Tevu).

Deposition continued along the convergent margin during the Oligocene (40-25 m.y.a.). Uplift, tilting, and rotation of the coast range also continued during this time. Towards the end of the Oligocene igneous intrusions occurred in the coast range, land areas emerged, and a period of erosion commenced in all but the central and northern portions of the margin. Deposition in what was now a series of small, shrinking basins continued into the Miocene (25-5 m.y.a.). It was was during this interval that basaltic sandstone and conglomerates (Toms) and in turn arkosic sandstone and siltstones (Tma) were formed in the Pacific City area. The middle Miocene (15 m.y.a.) also saw the deposition of invasive basalts (Ti),

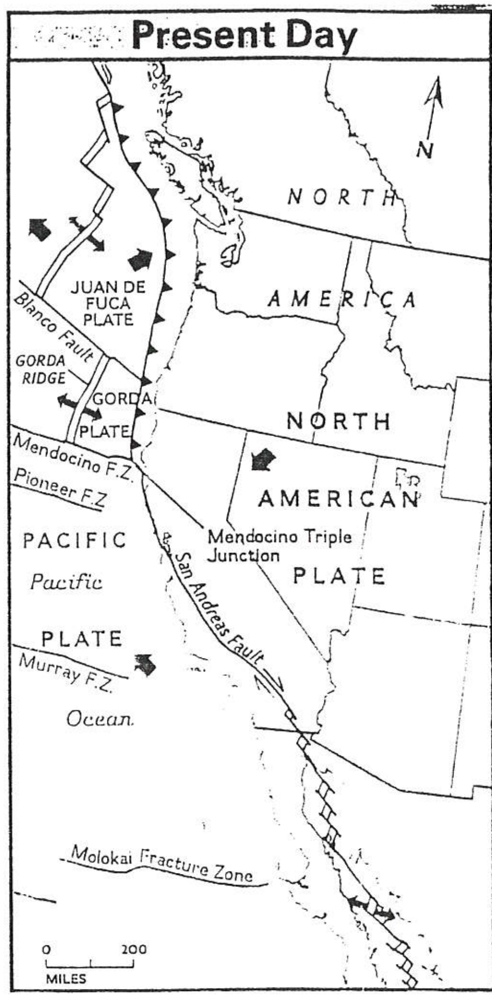


Figure 4. The geologic setting of the Oregon coast (National Geographic Society, 1995).

which include the basalts off Cape Kiwanda and which exhibit compositional affinities to the Columbia River lavas. Continued uplift of the coast range and shrinking of the basin resulted in an extended period of erosion that culminated in the formation of the river valleys and prominent peaks of the existing coast range. Erosion continued during the Pliocene (5-2 m.y.a.) when much of the area was above sea level and the coastline lay in approximately its present location.

During the early Quaternary (2 m.y.a. to present) a thin veneer of sediments was deposited on the seaward-dipping wedge of sediments that had accreted onto the leading edge of the North American Plate. These Pleistocene (~1 m.y.a.) marine terraces of beach and dune origin have emerged at a rate of about 1 inch per 100 years. Terracing is complex, reflecting both the eastward tilting of the coast range as well as the rise and fall of sea level during the Pleistocene. Coupled with the formation of modern beach and dune deposits, uplift and erosion of these terrace deposits continues at present.

Relative Sea Level Rise. Recent scientific evidence suggests that tectonic activity along the convergent margin is cyclic (Madin, 1992). During one part of the tectonic cycle, an extended period of gradual aseismic uplift of the coastal margin occurs in response to the accumulation of strain within the subduction zone. Gradual variations in mean water level, and hence shoreline position, accompany this part of the tectonic cycle. Superimposed upon these tectonically-induced variations in shoreline position are variations in global eustatic sea level due to the alternating growth and melting of glaciers. What is of particular interest are the net changes in mean water level, or relative sea level rise.

In this regard, Komar (1992) has plotted elevation changes and their relationship to sea level rise as a basis for estimating rates of relative sea level rise along the length of the Oregon coast. From Komar's work it can be inferred that the mean water level along the Pacific City shoreline is increasing at a rate that is currently on order of 4 to 8 inches per century (Table 1). If rates of relative sea level rise increase as envisioned under scenarios of global warming in response to the greenhouse effect (SCOR, 1991; Komar, 1998), then a rate of 20 to 30 inches per century is not an unreasonable estimate for the projected rate of increase in the mean water level along the Pacific City shoreline.

Earthquake-Induced Tsunami. The other part of the tectonic cycle is characterized by a major seismic event which occurs as the strain that has accumulated within the subduction zone is suddenly and dramatically released. Recently, a great deal of attention has been given to these Cascadia Subduction Zone earthquake events. Summarizing the work of a number of investigators, DOGAMI(1995) suggest that the Oregon coast coast could experience a M8-9 earthquake in the near future. Specifically, they report that there is a 10-20% chance that such a great earthquake event could occur in the next 50 years. This estimate is based on analyses which suggest that the average return interval for such an event is on the order of every 400 ± 200 years and that the last event occurred approximately 300 years ago.

Damage from such an event would not only include that resulting from ground shaking, but also that resulting from earthquake-induced liquefaction, landsliding, subsidence, and tsunami. Madin (1992) has outlined a scenario for such an event. At the onset, severe ground shaking occurs for several minutes. During this time, amplification and liquefaction effects occur in areas of unconsolidated, saturated sediment. Massive ancient landslides are reactivated. Rapid, coast-wide subsidence on the order of 2 to 6 feet also occurs in association with the subduction zone earthquake. Although flooding associated with subsidence would occur immediately in some low-lying areas, the effects of subsidence are more likely to be manifest over the long term as increased flooding and coastal erosion during storms. This scenario is further complicated by the likely occurrence of locally generated tsunami arriving at the coast within a half hour after initial ground shaking. The shorelines of bays, estuaries, and low lying sand barriers would experience immediate flooding and erosion.

DOGAMI (1995) has conducted numerical simulations of tsunami waves generated in response to

Table 1. Summary of Water Level Parameters for the Pacific City shoreline*

Relative Sea Level Rise		
50 years	2 - 4 inches	10 - 15 inches
100 years	4 - 8 inches	20 - 30 inches
	@ current rate	@ accelerated rate
	(after Komar, 1992)	(after SCOR, 1991: Komar, 1998)

Earthquake-induced Tsunami		
Low 14 - 18 feet	Middle 16 - 28 feet	High 20 - 38 feet
	(after DOGAMI, 1995)	

Mean Sea Level(MSL)		
10 year	8.4 feet	7.3 feet
50 year	9.5 feet	7.7 feet
100 year	10.0 feet	7.8 feet
	(from FEMA, 1990)	(from Komar et al., 1997)

Wave Height(H_s)		
10 year	23.9 feet	24.7 feet
50 year	25.9 feet	25.6 - 26.9 feet
100 year	26.9 feet	26.7 - 28.2 feet
500 year	27.5 feet	(from Ruggiero et al., 1996; Tillotson and Komar, 1997; Komar et al., 1997)
	(from FEMA, 1989)	

Wave Runup(R_t)	
10 year	11.2 - 11.6 feet
50 year	12.1 - 12.7 feet
100 year	12.6 - 13.4 feet

(from Ruggiero et al., 1996; Tillotson and Komar, 1997; Komar et al., 1997)

Total Water Level(MSL + R_t)		Total	Storm
5 year		18.5 feet	16.3 feet
10 year	10.0 - 26.5 feet	18.9 feet	17.0 feet
50 year	11.5 - 32.5 feet	19.8 - 20.4 feet	18.6 feet
100 year	12.0 - 35.0 feet	20.4 - 21.2 feet	19.3 feet
500 year	14.0 - 40.0 feet	(from Ruggiero et al., 1996; Tillotson and Komar, 1997; Komar et al., 1997)	
	(from FEMA, 1990)		

FEMA 100 year 'V-zone' elevation = 30 feet

* all elevations are referenced to the N.G.V.D.

Cascadia Subduction Zone earthquake events. For the Nestucca Littoral Cell they project locally generated tsunami elevations that range from 14 to 18 feet NGVD under the low end scenario and 20 to 38 feet NGVD under the high end scenario (Table 1). Elevations of 16 to 28 feet NGVD are given as mid-range estimates. With respect to a tsunami resulting from a Cascadia Subduction Zone earthquake, waves should be expected to arrive within 5 to 40 minutes after the initial earthquake and to continue to arrive at intervals over a period of several hours. It is possible that these waves may be as high as 50 feet. An earthquake should be taken as a signal to quickly seek high ground.

Tsunamis generated by earthquakes which have occurred elsewhere have also been shown to affect water levels along the Oregon coast (e.g. April 1, 1946 and March 27, 1964 Alaskan earthquakes). Elevations of such far-source tsunamis are projected to be well below those noted above in association with near-source tsunamis.

Sand Supply. Another first order control on shoreline stability is sand supply. Sand supply is typically considered in the context of the sediment budget. This concept involves viewing a given segment of shoreline in terms of the positive or negative transfers of sediment that occur within it (Figure 5). The resultant balance of the sediment budget is determined by comparing the volume of sediment gained from sources (positive transfers, or *credits*) to the volume lost to sinks (negative transfers, or *debits*). A negative balance means that more sand is leaving than is arriving and, that as a result, that segment of shoreline is eroding. Conversely, a positive balance means that more sand is arriving than is leaving so that the segment of shoreline is accreting. An analysis of the sediment budget of the Nestucca Littoral Cell is beyond the scope of this work. However, some general comments can be made regarding credits, debits, and the budget balance (Table 2).

The Nestucca and Little Nestucca Rivers, as well as numerous creeks including Neskowin Creek, are probably the major contributors of sediment to the Nestucca Littoral Cell. This suggestion is supported by the nature of these drainages, which experience heavy rainfall (80 to 120 inches/year) and have steep slopes (commonly in excess of 25-50%) composed of weakly consolidated materials (Tertiary sedimentary and volcanic rocks). As a result of episodic wave-induced erosion, the dunes may also be considered an important sediment source. Contributions from wave-driven longshore transport (into the area from around headlands) or onshore transport (into the area from the inner shelf) are probably minimal. The same is true for wind-driven transport.

With respect to sediment sinks there is evidence for losses due to wind-driven transport. Specifically, wind-blown sand moves directly inland to form dunes that are out of reach of storm wave attack as well as up and over Cape Kiwanda (Cooper, 1958). The extent to which losses from wave-driven longshore transport are important is unknown. Because they are bounded by large headlands which extend to deep enough water to prevent sand from being transported around them, many of the littoral cells along the

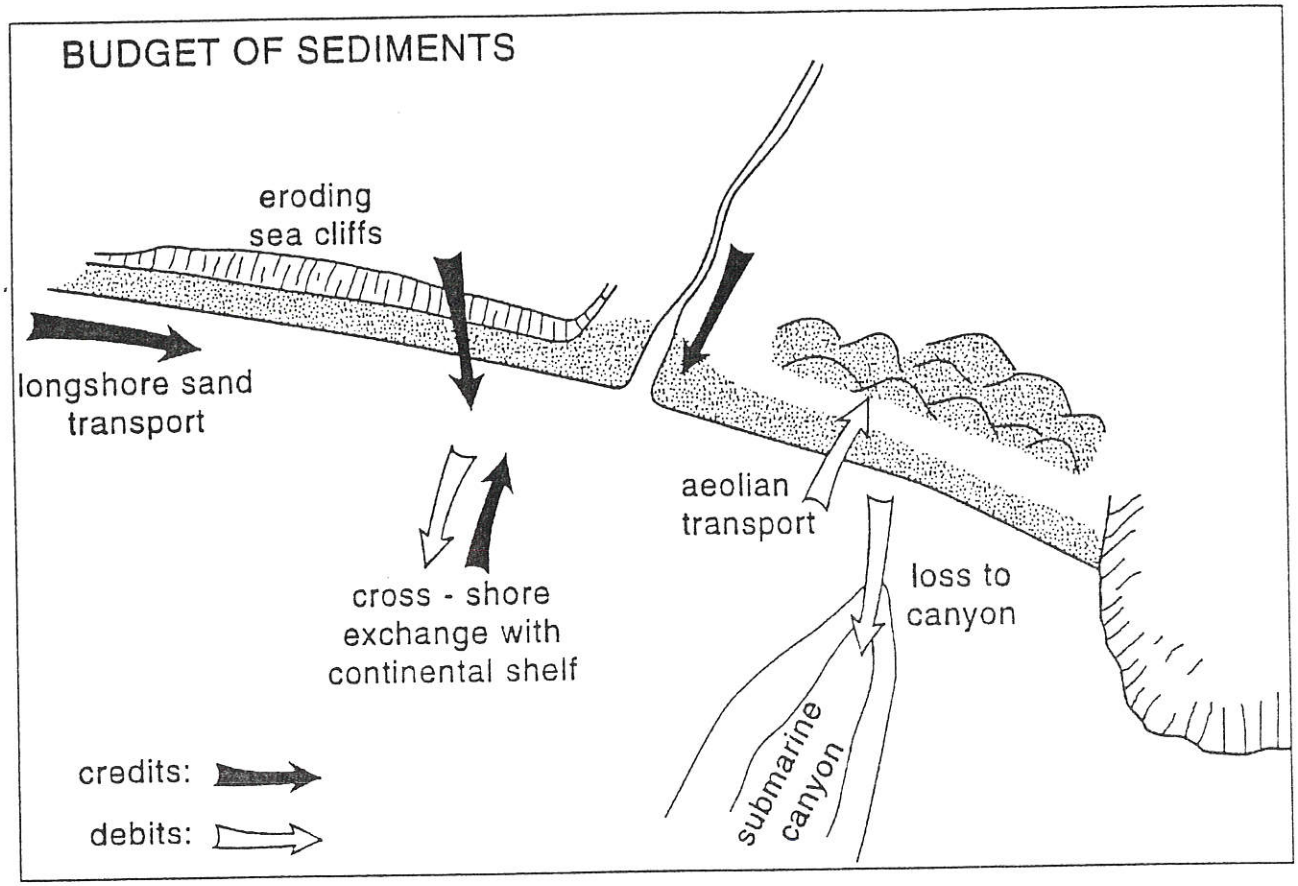


Figure 5. Illustration of the components of a typical sediment budget (Komar,1996).

Table 2. The Nestucca Littoral Cell Sediment Budget

Credits	Debits	Balance
Rivers and Creeks	**Dune accretion**	**Roughly**
Dune erosion	**Longshore Transport**	**Balanced**
Longshore Transport	**Cross-shore Transport**	
Cross-shore Transport	Sand mining	

Bold text indicates probable primary sources and sinks.

Oregon coast are considered to be closed systems in terms of longshore sediment transport (Komar, 1992; Shoreland Solutions 1994b). Cape Kiwanda, however, only extends seaward about 2000 feet. Thus it is likely that some sediment does move out of the area around this 'leaky' headland. Losses out of the area are also attributable to wave-driven cross-shore transport. Komar (1978) describes a breach of Nestucca Spit that resulted in the deposition of sand in Nestucca Bay. The extent to which sand moves out of the area into Nestucca Bay through the inlet or offshore to the outer shelf is unknown. The extent to which removal of sand from the area by humans has affected the sediment budget, although probably minimal, is also unknown .

In terms of the balance of the Nestucca Littoral Cell sediment budget an analysis of historical shoreline change conducted as part of this work suggests that the Pacific City shoreline is like other dune-backed shorelines along the Oregon in that it erodes episodically only to eventually recover (Komar, 1992; Shoreland Solutions 1994b). Thus, the budget of the Nestucca Littoral Cell can be viewed as roughly balanced.

Short Term Events

Wind. Wind plays an important role in controlling shoreline stability. Sand deposited on beaches is exposed at low tides, dries quickly, is caught by wind, and is carried inland to form dunes. Thus, as facilitator in the transfer of sediment from beach to dune, wind-driven sediment transport is the direct cause of sand accumulation in the foredune area. Together with vegetation, wind controls dune form. As a wave generator, and thus facilitator in the transfer of sediment from dune to beach, wind indirectly completes the sediment exchange loop that governs shoreline stability.

The regional wind/wave climate of the Oregon coast exhibits a marked seasonal bimodality (Figure 6: Komar, 1976; Hunter et al., 1983; Wiedemann, 1984; Peterson et al., 1992). In summer, regional atmospheric circulation is dominated by the North Pacific High. This summer atmospheric circulation pattern brings fair weather and north-north westerly winds. The dry summer northerlies and northwesterlies are of moderate velocity, commonly reaching speeds of 20 to 30 miles per hour hour (Hunter et al., 1983). Land-sea breeze effects contribute to these winds, which tend to reach peak velocities in the afternoons (Wiedemann, 1984). In winter, regional atmospheric circulation is dominated by the Aleutian Low, a series of low pressure centers that pass over the North Pacific. This atmospheric circulation pattern is responsible for the frontal storms that move over the coast in winter at intervals of several days to a week or two bringing heavy rains and strong south to southwesterly winds. The wet winter southerlies and southwesterlies are of high velocity, commonly reaching speeds of 30 to 50 miles per hour and occasionally attaining hurricane force (Hunter et al., 1983).

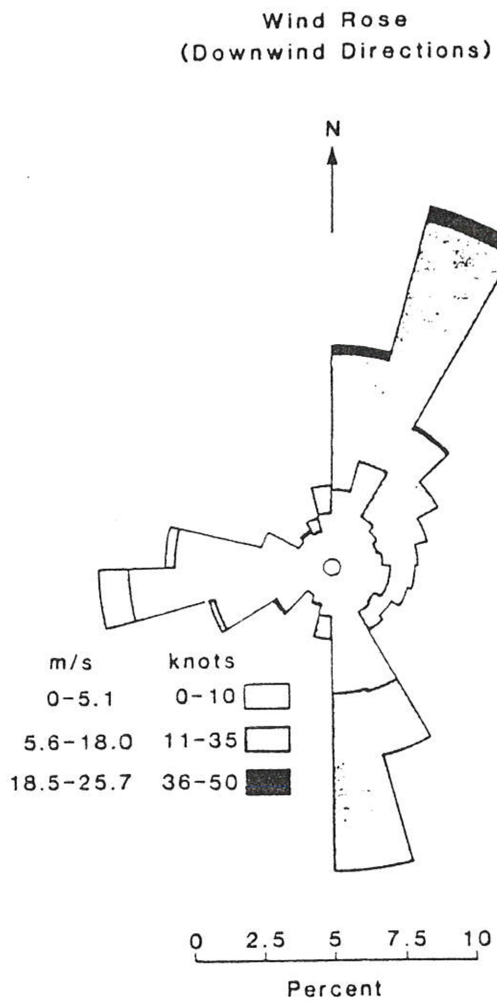


Figure 6. Wind Rose for Newport, Oregon (Hunter et al., 1983).

Wiedemann, (1984) suggested that in Washington and Oregon, both the northerly winds of summer and the southerly winds of winter are important in the dune-forming process. However, for localities north of Heceta Head, Wiedemann suggested that it is the southwest winds of winter that are the primary control on dune form. Hunter et al. (1983), in their study of storm controlled oblique dunes of the central Oregon coast, also suggested that it is the strong, south-southwesterly winter storm winds that are largely responsible for larger dune form, orientation, and migration. They suggested that with the exception of small transverse dunes in unvegetated areas, which tend to be controlled largely by the northerly summer winds, the moderate north-northwesterly summer winds act largely as modifiers of dune form but not dune trend. These interpretations are consistent with those of Cooper (1958) who, with respect to the Pacific

City shoreline, suggested that "the middle sector is by far the most active. It lies broadside to the winter winds, and much of the sand carried into the deflation area by the summer wind is later deflected north-eastward." DOGAMI (1972) also suggested that "the free sand areas south of Manzanita supply sand for active slip faces to the northeast during the winter storms."

Calculations carried out in the development of the Manzanita Foredune Management Plan background report support these suggestions (Shoreland Solutions 1994a). Specifically, wind-driven sediment transport rates were calculated for a range of wind speeds. The results of this analysis suggest that the southwesterly winds (with modal speeds in the range of 30 to 50 miles per hour) have sediment transport rates that are on the order of 2.5 to 5 times greater than those of the northwesterly winds (with modal speeds in the range of 20 to 30 miles per hour hour). Further, the results of entrainment threshold calculations suggest that although moisture content is likely to have a significant impact on sediment transport by increasing the entrainment threshold, wind speeds associated with the southwesterly winds of winter are sufficient to overcome these attenuating effects. (*Entrainment threshold refers to the minimum wind speed at which sediment grains begin to move across the open sand surface.*) Thus, in terms of sediment transport capabilities southwesterly winds make up for in intensity what they may lack in frequency.

Finally in regards to the potential implications of wind-driven sediment transport, the calculations of Sherman and Nordstrom (1994) are interesting to note. They suggest that sand accumulation rates during a typical storm are on the order of 1 cubic foot per hour and that dunes may migrate as much as 10 feet during a single period of intense winds.

Wave Attack: Regional Overview. Along dune-backed shorelines processes of wave attack, namely wave *overtopping* and *undercutting,* are the primary control on shoreline stability. In terms of wave overtopping (i.e. flooding), it is the magnitude of an extreme runup event that is of particular interest. Tides, storm surges, barometric pressure effects, temperature effects, and baroclinic currents all affect mean water level. Superimposed upon these longer term elevations in mean water level are short-term variations associated with the passage of waves. Extreme water surface elevations achieved during storms, and expressed at the shoreline as wave runup, result from the simultaneous occurrence of individual maxima within this range of forcing events.

In terms of wave undercutting (i.e. erosion) it is not only the magnitude of runup but its frequency of occurrence that is of interest. As noted above, the regional wind/wave climate of the Oregon coast exhibits a marked seasonal bimodality (Komar, 1976; Komar,1979; Komar, 1992; Peterson et al., 1992). Over the calm summer months, when waves are low, sand moves onshore where it is stored in the subaerial beach and dune (Figure 7). During the stormy winter months high winter waves coupled with high water levels move sand offshore, storing it in subaqueous bars.

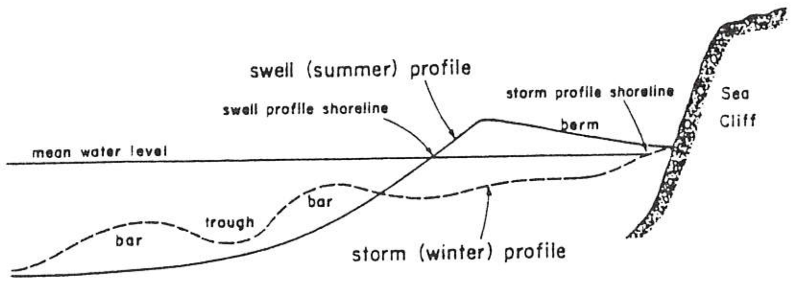


Figure 7. The general pattern of seasonal change in the beach profile (Komar, 1976).

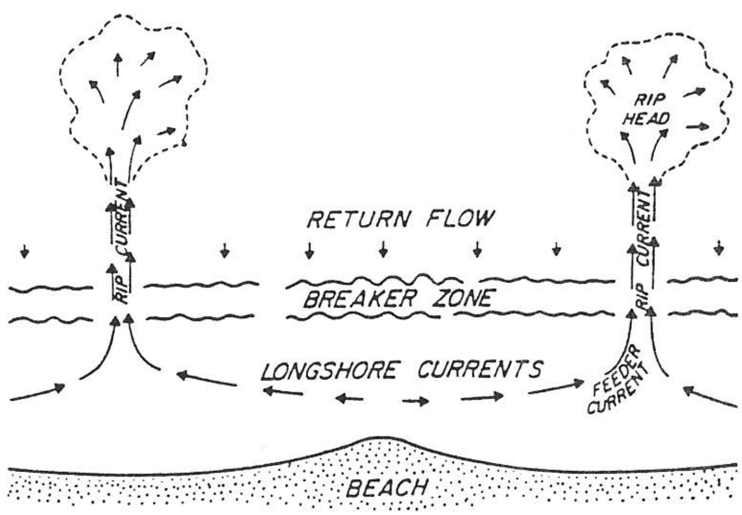


Figure 8. Horizontal 'rip' cell circulation (Komar, 1992).

During winter storms, erosion may be accentuated locally by rip currents (Komar, 1979; Komar et al., 1989; Komar, 1992). Rip currents are wave-generated, seaward-flowing currents that develop as part of a larger pattern of horizontal cell circulation (Figure 8). Rips act as the locus of storm wave attack, eroding crescent-shaped embayments and moving sand offshore. Runup within rip embayments may be as great as 5 feet above the average total runup height and is thus comparable to seasonal variations in terms of magnitude. Rip currents are an important factor affecting shoreline stability within Oregon coast littoral cells.

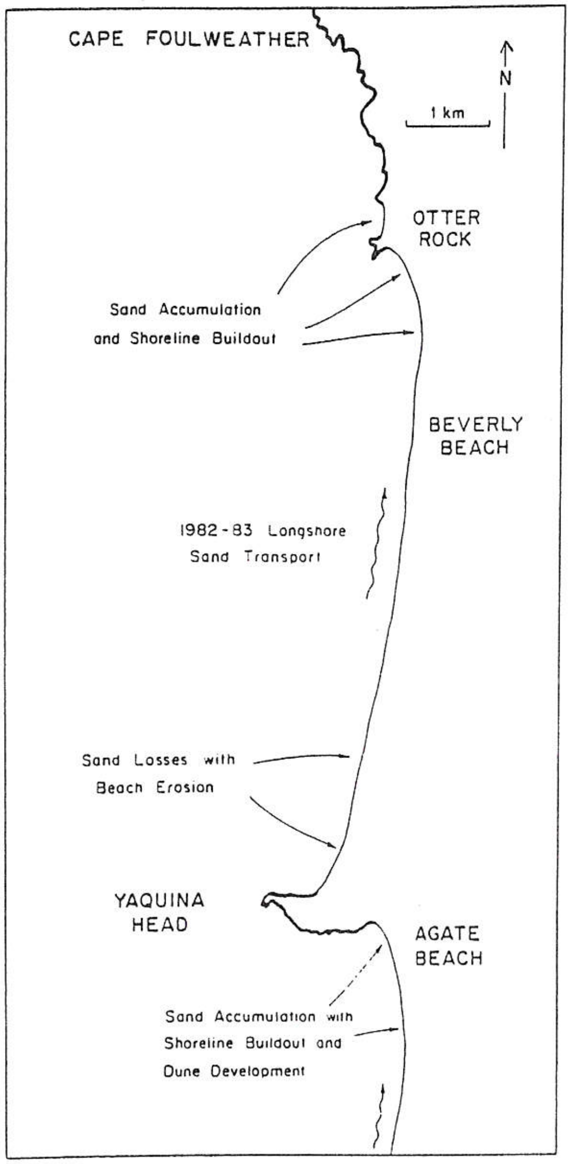


Figure 9. The pattern of erosion and accretion observed in the Beverly Beach Littoral Cell during the 1982-1983 El Nino (Komar, 1986).

Because winds and waves tend to arrive from the southwest during the winter and from the northwest during the summer, Oregon coast littoral cells generally exhibit a seasonal reversal in the direction of longshore as well as cross-shore transport (Komar, 1992). Specifically, net transport is offshore and to the north in winter: onshore and to the south during the summer. Interannual, El Nino events have been shown to exaggerate the characteristic seasonal pattern of erosion and accretion (Komar, 1986; Komar

1992; Komar et al., 1989; Peterson et al., 1992; Marra, 1993). Significant short term variation in shoreline position has been associated with the 1982-83 El Nino event for example. Due to the southward displacement of winter storm tracks, waves approached the coast from a more southwesterly direction than normal. An increased frequency of large storms, and in turn more frequent high waves also occurred during this event - wave heights in the Coquille-Newport area exceeded the average wave height by 2 standard deviations on 22 days. Anomalously high values of mean sea level, values as much as 2 feet above the average, were also reported during this event. In many Oregon coast littoral cells the response to these conditions appears to have been a short-term net displacement of sand from the southern to the northern ends of littoral cells. More precisely, the southern ends of littoral cells experienced major erosion during and in the years immediately following an El Nino (Figure 9). At the northern ends of littoral cells, accretion occurred in conjunction with and over the years following an El Nino. Thus, interannual variations in the wind/wave climate are an important factor affecting shoreline stability within Oregon coast littoral cells.

Wave Attack: Water Levels. Water level parameters for the Nestucca Littoral Cell are summarized in Table 1. FEMA's (1990) projections of extreme still water level (MSL) elevations range from 8.4 to 10.0 feet NGVD for return intervals ranging from 10 to 100 years respectively. Projected extreme still water level elevations given in Komar et al. (1997) range from 7.3 to 7.8 feet NGVD for return intervals ranging from 10 to 100 years respectively. Note that the FEMA projections are slightly higher than those given in Komar et al. - 10.0 feet versus 7.8 feet NGVD respectively for the projected 100 year extreme still water level for example. This is probably because FEMA's projections of extreme still water level are based on models developed for the East and Gulf coast where storm surge contributes more to extreme still water levels than it does along the Oregon coast (Ruggiero et al., 1996).

Projected extreme significant wave heights (H_s) from FEMA (1989) show good agreement with those given in Ruggiero et al. (1996), Tillotson and Komar (1997), and Komar et al. (1997). Projected 10 year significant wave heights range from 23.9 to 24.7 feet NGVD; 50 year significant wave heights from 25.6 to 26.9 feet NGVD; and 100 year significant wave heights from 26.7 to 28.2 feet NGVD. Applying the empirical relationship for the 2% exceedence elevation given in Ruggiero et al. (1996), extreme runup elevations (R_t) for the significant wave heights given above range from 11.2 to 11.6 feet NGVD for the 10 year event; 12.1 to 12.7 feet NGVD for the 50 year event; and 12.6 to 13.4 feet NGVD for the 100 year event.

FEMA's (1990) projections of the total water level, the sum of the extreme still water level and extreme wave runup (MSL + R_t), show a broad range across a range of return intervals. For example, FEMA's projected 100 year total water levels for reaches within the Nestucca Littoral Cell range from as low as 12.0 feet to as high as 35.0 feet NGVD. This wide range in values is probably attributable, at least in part, to the strong dependence on beach slope within the models used by FEMA to predict wave runup - even a relatively narrow range in beach slopes would be expected to result in a relatively wide range in projected values of extreme runup and hence total water levels. Projected total water levels obtained from Ruggiero et al. (1996), Tillotson and Komar (1997), and Komar et al. (1997) range from 19.8 to 20.4 feet NGVD for the 50 year event and from 20.4 to 21.2 feet NGVD for the 100 year event.

Ruggiero et al. (1996), Tillotson and Komar (1997), and Komar et al. (1997) also identify projected 'storm' total water levels. Whereas the total water levels given above result from simple summing and thus assume that both extreme still water levels and waves occur at the same time, the storm totals are based on an analysis of the probabilities of combined extremes in individual storms. The storm analysis results in lower projected extreme total water levels than that obtained by simple summing. For example, the 100 year storm total water level of 19.3 feet NGVD is about 1 to 2 feet less than that projected by simple summing. Ruggiero et al. (1996) provide evidence to support the suggestion that although the simple summing approach may be appropriate in settings like the East and Gulf coasts, the storm analysis approach is probably the preferred approach in the case of the Oregon coast. In this regard it is interesting to note that the total water levels projected by the Army Corps of Engineers numerical model SBEACH for the Manzanita shoreline, which range from ~16 to 19 feet NGVD for the 50 year event and from ~17 to 20 feet NGVD for the 100 year event (McDougal et al., 1995), compare most favorably with the storm totals.

Flood Insurance Rate Maps (FIRMs) describe the forecasted 100-year ocean base-flood in terms of a zone of velocity flooding, or *V-zone*. The FIRMs for the Pacific City area indicate that along the entire length of the Pacific City shoreline the V-zone elevation is 30 feet NGVD (FIRM, 1978). Goal 18 IR#7 requires that the minimum height for flood protection be 4 feet above the 100 year flood elevation, or 34 feet NGVD. Thus, irrespective of the values and considerations pertaining to extreme water levels given above, for management purposes the minimum elevation that the foredune along the Pacific City shoreline can be graded down to is 34 feet NGVD.

Wave Attack: Existing Morphology. Beach and dune profile parameters for the Pacific City shoreline are summarized in Table 3. This information was obtained from 17 beach and dune profiles measured at approximately 500 foot intervals along the length of the Pacific City Shoreline during September of 1997. A map showing the approximate location of these profiles is give in Appendix A. Individual profiles normalized in the cross-shore to the location of the OPRD 1969 Statutory Vegetation Line are plotted in Figure 10. Conditions at the time of beach profiling were documented using a V8 video camera. A series of frame-grabbed video images showing key morphologic features found along the Pacific City shoreline is given in Appendix B.

Along the Pacific City shoreline profile form and character is highly variable. The elevation of the primary foredune crest ranges from 23.5 to 59.0 feet NGVD, a difference of over 35 feet. Where present,

Table 3. Summary of Pacific City Beach and Dune Profile Parameters

<u>Primary Foredune Crest</u>

Elevation	range 23.5 - 59.0 feet	mean 41.1 ± 9.2 feet
Width	range 150 - 550 feet	

<u>Secondary Crest</u>

Elevation	range ~24 - 34 feet	

<u>Foredune Toe</u>(beach/dune junction)

Elevation	range 7.9 - 19.2 feet	mean 14.4 ± 2.9 feet

<u>Foreslope</u>

Elevation	range 7.9 - 59.0 feet
Width (primary crest to toe)	range 115.7 - 284.5 feet
(primary crest to secondary crest)	range 21.5 - 168.6 feet

<u>Profile Envelope</u> (difference between width of *horn* and *bay* profiles)

@ + 5 foot contour	250 feet		
@ + 10 foot contour	240 feet		
@ + 14.5 foot contour		(toe)	170 feet
@ + 15 foot contour	110 feet		
@ + 20 foot contour	100 feet		
@ + 24.5 foot contour		(crest)	70 feet

* all elevations are referenced to NGVD

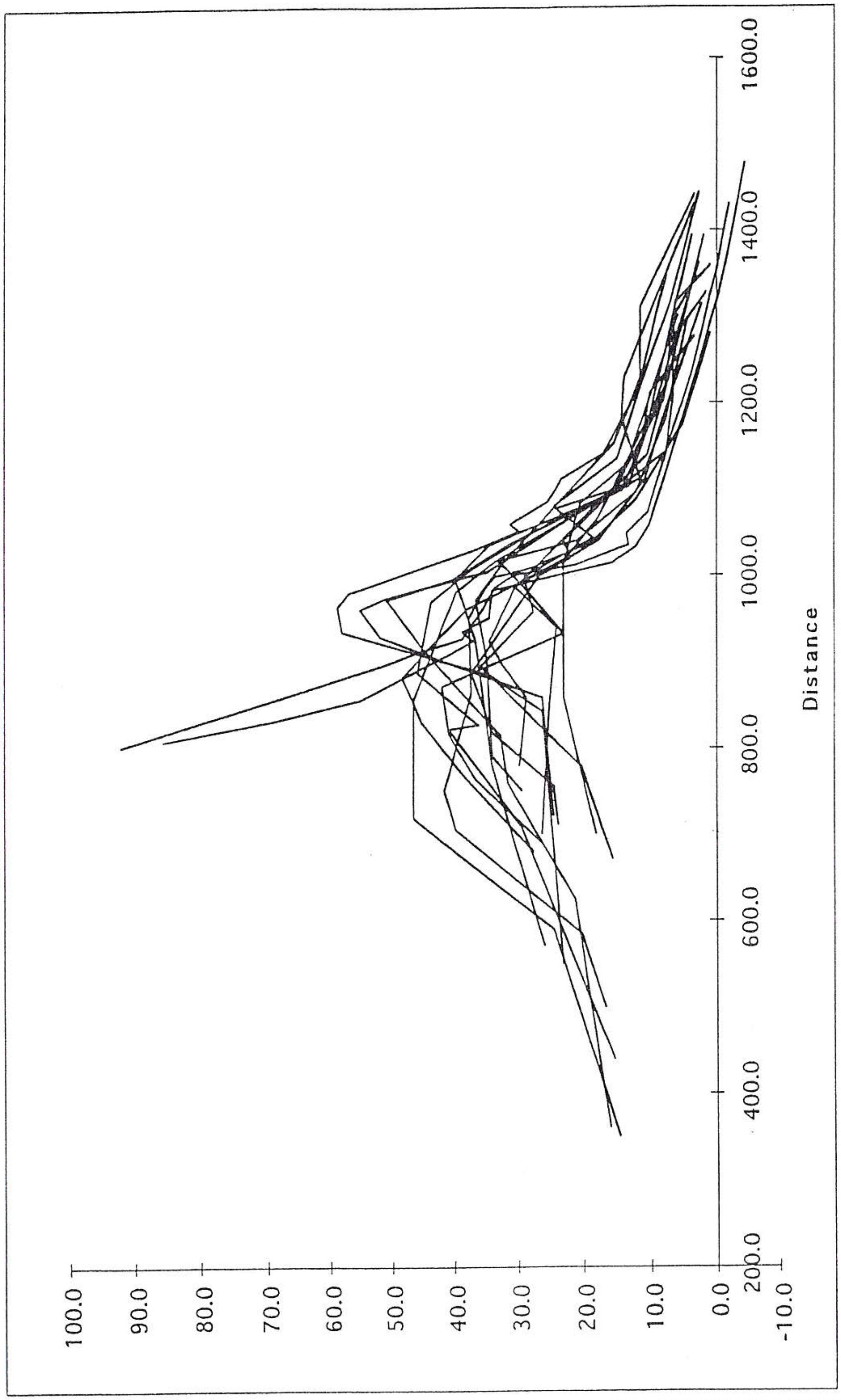


Figure 10. Plot of Pacific City beach and dune profiles normalized in the cross-shore to the location of the OPRD 1969 Statutory Vegetation Line. Elevations and distances are in feet. Elevations are referenced to NGVD. The 1000 foot mark represents the location of the OPRD 1969 Statutory Vegetation Line.

secondary crests range in elevation from ~24 to 34 feet NGVD. The elevation of the foredune toe (a.k.a. the beach/dune junction) ranges from 7.9 to 19.2 feet NGVD. The mean elevation of the foredune toe is 14.4 feet NGVD with a standard deviation of ± 2.9 feet. The width of the primary foredune crest - from the toe of the backslope to the beginning of the upper foreslope - ranges from ~150 to 550 feet. The width of the foreslope - from primary crest to toe- ranges from ~115 to 285 feet. Thus, the foreslope varies by as much as 170 feet in width along the Pacific City shoreline.

Differences in foredune width are also readily apparent when the profile envelope at specific contour intervals is examined. For example, the location of the the +5 foot NGVD contour varies by as much as 250 feet; the location of the the +14.5 foot NGVD contour by as much as 170 feet; and the location of the the +24.5 foot NGVD contour by as much as 100 feet. These differences are used to establish the form of the idealized end member profiles illustrated in Figure 11. They form the basis for a more detailed description of existing beach and dune characteristics.

The *horn* profile (a.k.a. accreted or swell profile) is characterized by:

- **Open Sand Beach**, which occupies the area from lower low water up to an elevation of ~12.5 feet NGVD. Beach face slopes vary alongshore, generally steepening to the south. They are typically on the order of 0.02 to 0.04 ($\tan_b$). However they may be accentuated locally to a value of 0.07 ($\tan_b$) by the presence of a *berm* which occurs at elevations ranging from ~6 to 12 feet NGVD.

  Although this area is dominated by wave-driven sediment transport, it is the sediment deposited in this area that is carried inland by wind to form dunes.

- **Transition Zone**, which occupies the area ranging in elevation from ~12.5 to 17.5 feet NGVD. Characteristic features of this area are the wrack line and the *foredune toe*, the latter of which is typically identified as the the first distinct change in foreshore slope. This area is predominantly open sand beach. Small transverse dunes occur locally. American Searocket *(Cakile edentula)* is scattered throughout this area, as are occasional clumps of mostly American dunegrass *(Elymus mollis)*.

  This area marks the transition from open sand beach to vegetated foredune. It also marks the transition from areas dominated by wave-driven sediment transport to those dominated by wind-driven sediment transport. It is the immediate sink of wind-blown sand carried inland from the open sand beach. It represents a source area for sand carried inland to the crestal portions of the foredune. Although dominated by wind-driven sediment transport during the summer, during the winter much of the sand that has accumulated in this area is removed by wave forces in the form of high runup.

- **Lower Foreslope**, which occupies the area ranging in elevation from ~17.5 to 24.5 feet NGVD. This area is characterized by gentler slopes than the upper foreslope. Open sand is predominant. However, American Searocket and clumps of American dunegrass are scattered throughout lower portions of this area. Vegetation cover increases in the upper portions of this area. Typically on the

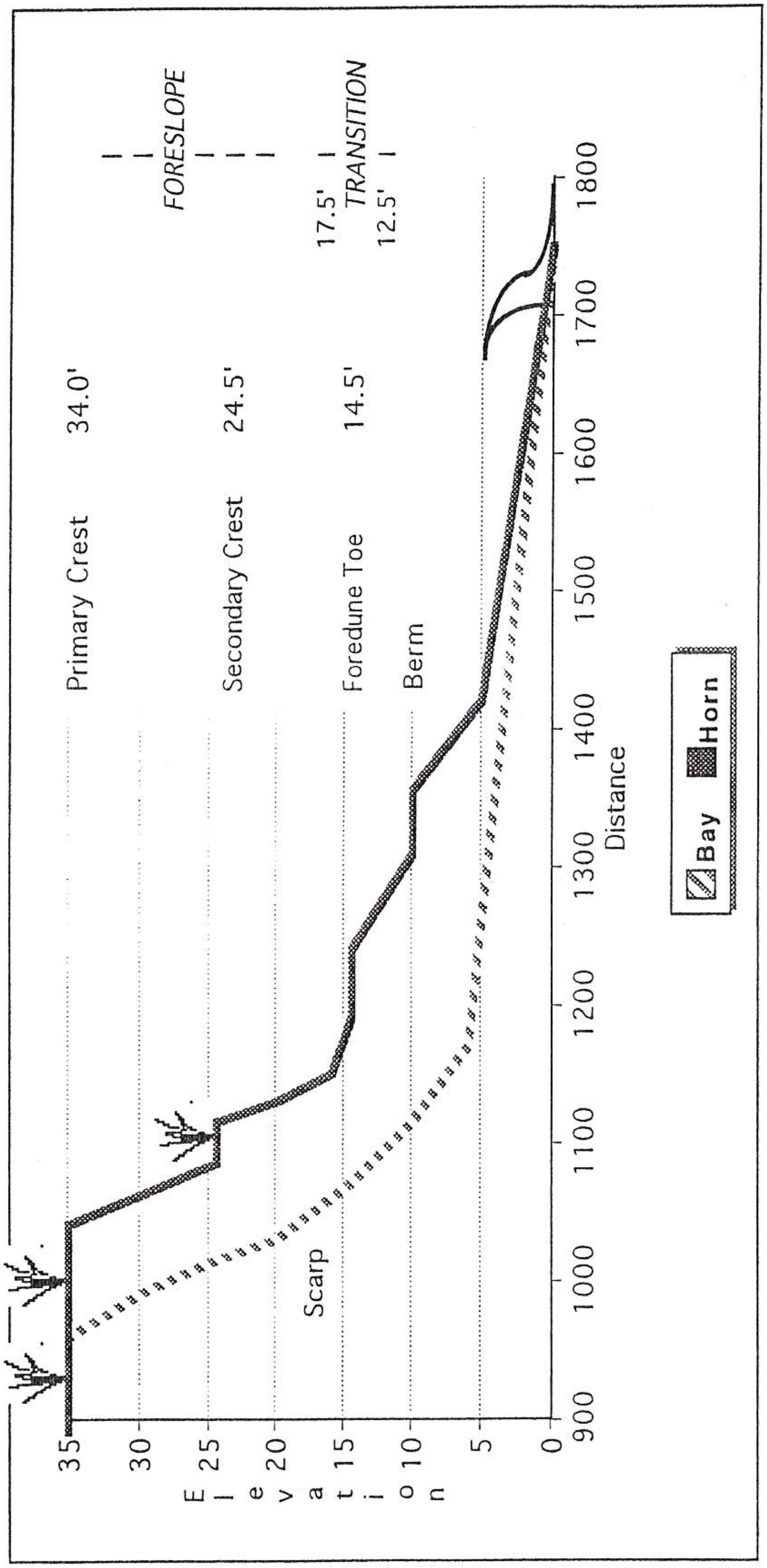


Figure 11. Idealized end member profiles for the Pacific City shoreline. Elevations and distances are in feet. Terms shown in figure are described in the text.

Although the foredune crest is generally oriented parallel to the shoreline, close inspection reveals that, like the foreslope, it too is an irregular feature composed of an amalgam of hummocks. Also, there is a tendency for the amalgamated as well as isolated hummocks that make up the crest and foreslope to be oriented in a manner that facilitates both northwesterly and southwesterly sediment transport. Specifically, they tend to be lined-up along both northwest-southeast and northeast-southwest axes. The former is the dominant orientation. It appears that sediment blown up the open spaces by northwest winds in the summer is made available for transport by southwest winds in the winter.

The *bay* profile (a.k.a. eroded or storm profile) is characterized by:

- **Open Sand Beach, Transition Zone, and Lower Foreshore** which occupies the area from lower low water up to an elevation of ~24.5 feet NGVD. Beach face slopes are typically on the order of 0.01 to 0.03 (tan_b). Deposits of driftwood and debris are prevalent along the toe of the foreslope.

- **Upper Foreslope and Primary Foredune Crest**, which occupies the area above ~24.5 NGVD in elevation. As a result of wave undercutting the *scarped* foreslope is steep and narrow (e.g. near vertical slopes and a width of 25 feet).

Wave Attack: Historical Shoreline Change. A chronology of shoreline change in the Pacific City area over the period 1939 to the present is outlined in Table 4.

One of the earliest descriptions of the Pacific City shoreline is that of Cooper (1958). He described the management area as part of a northeast-southwest trending parabola complex associated with Cape Kiwanda and the Nestucca Spit (Figure 13). At the time of Cooper's work the shoreline was characterized as predominantly open sand with transverse dunes and isolated American dunegrass hummocks. Development of a foredune started around the early 1950's with the introduction of European beachgrass into the area (Reckendorf, 1993). By 1967 there was a well developed vegetated foredune that had been graded at the north and south ends of the management area to accommodate new residential and commercial development.

An analysis of aerial photographs conducted by H.G. Schlicker and Associates (1990) suggests that during the period 1939-1967 the Pacific City shoreline experienced from 60 to as much as 130 feet of net accretion. Analysis of the 1967 ODOT 'beach zone' aerial photographs conducted as part of this work also suggests that the extent of accretion was variable. Table 5 summarizes 1967 beach and dune profile parameters along the same transects as those measured during September 1997. Individual profiles, normalized in the cross-shore to the location of the OPRD 1969 Statutory Vegetation Line, are plotted in Figure 14. Like the 1997 profiles, the 1967 profiles show considerable longshore variation in form. The elevation of the primary foredune crest varied from ~25 to 40 feet NGVD. With respect to foredune width,

Table 4. Chronology of Shoreline Change in the Vicinity of Pacific City

<u>1939 - 1967</u>

- **Introduction of European Beach Grass**
- **Net Accretion**
- Foredune grading associated with the siting of new development and maintenance of existing development in response to sand accumulation

<u>1967 - 1978</u>

<u>Early 70's (1972-73 El Nino Event)</u>

- **Net Erosion**
- Armoring north of the Dory Boat Ramp and at other locations along the central portion of the management area
- Foredune grading associated with the siting of new development and maintenance of existing development in response to sand accumulation

<u>Late 70's (1977-78 El Nino Event)</u>

- **Net Erosion** - highly localized
- **Breach of Nestucca Spit**
- **Extensive armoring of the central portion of the management area**
- Foredune grading associated with the siting of new development and maintenance of existing development in response to sand accumulation

<u>1978 -present</u>

<u>Early 80's (1982-83 El Nino Event)</u>

- **Net Accretion** - with localized erosion
- Foredune grading associated with the siting of new development and maintenance of existing development in response to sand accumulation

<u>Mid- 80's - present</u>

- **Net Accretion** - with localized erosion
- **Sand Inundation leading to burial of house south of Pacific Avenue**
- Foredune grading associated with the maintenance of existing development in response to sand accumulation

order of 10-20%, vegetation cover consists of large hummocks of European Beachgrass *(Ammophila arenaria)*, small clumps of American dunegrass, and low mounds of Yellow Sand Verbena *(Abronia latifolia)*.

• **Upper Foreslope**, which occupies the area ranging in elevation from ~24.5 to 34.5 feet NGVD. Characterized by steeper slopes than the lower foreslope, this area consists of an amalgam of large hummocks of European Beachgrass that form a *secondary foredune crest* seaward of the the primary crest. Vegetation cover is in the range of 30-60%. Although these characteristics may be viewed as typical, the upper foreslope is highly variable. The width of the upper foreslope - from the peak of the *primary foredune crest* to the the peak of the secondary crest varies by as much as 150 feet. As a result, some areas are characterized by a series of well vegetated (30-60% cover) secondary foredune crests, while others exhibit none and are poorly vegetated (10-30% cover). Yet others consist primarily of deflation surfaces, characterized by open sand and gravel.

• **Primary Foredune Crest**, which generally occupies areas above 34.5 feet NGVD in elevation. The peak of the primary foredune crest commonly reaches an elevation of 40 to 50 feet NGVD and is over 200 feet in width. In some areas however, the primary foredune crest approaches 60 feet NGVD in elevation and is under 200 feet in width. In others, the primary foredune crest is less than 30 feet NGVD in elevation and is over 400 feet in width. The elevation of the toe of the backslope is typically on the order of 24 to 26 feet NGVD.

In Figure 12 foredune crest elevations at the September 1997 profile locations are plotted along the length of the Pacific City shoreline. In this figure, foredune crest elevations can be seen to reach their peak in the northern portion of the management area (55 to 60 feet NGVD). Although highly variable (35 to 50 feet NGVD), they generally decrease gradually in elevation towards the southern portions of the management area, where they are particularly low (25 to 30 feet NGVD). The foredune crest is also relatively low along the northern-most portion of the management area (35 feet NGVD).

Along some segments of shoreline the foredune crest is very well vegetated (60-90% cover). Vegetation cover is dominated by European Beachgrass. However, American dunegrass commonly occurs within European Beachgrass stands, where it reaches as much as 20% of the vegetation cover. American dunegrass also occurs in patches in open sand areas between European Beachgrass stands. Secondary species that occur within and behind the foredune crest include Yellow Sand Verbena, Purple Beach Pea *(Lathyrus japonicus)*, Seashore Lupine *(Lupinus littoralis)*, Seashore Bluegrass *(Poa macanthra)*, Large-Headed Sedge *(Carex macrocephala)*, Coast Strawberry *(Fragaria chiloensis)*, Western Bracken Fern *(Pteridium aquilinum)*, and Shore Pine *(Pinus contorta)*.

In contrast to the characteristics of vegetation cover described above, large segments of the foredune crest along the Pacific City shoreline consist of a broad expanse of predominantly open sand. Evidence of recent sand accumulation in these areas takes the form of transverse dunes, whose active slip faces trend northwest-southeast, northeast-southwest, and north-south. Deflation surfaces, consisting of open sand and gravel, also occur sporadically throughout portions of these altered foredune crests. Where present, vegetation cover is typically very poor (<10%).

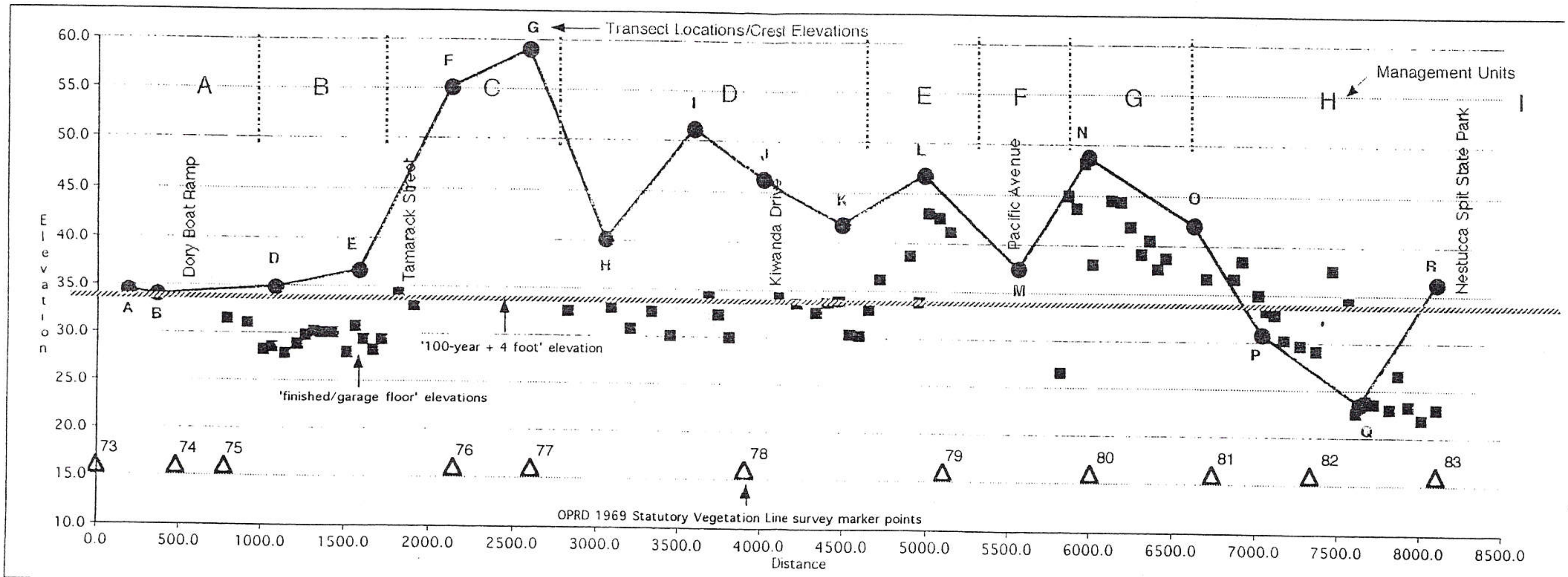


Figure 12. Longshore variation in the elevation of the primary foredune crest along the Pacific City shoreline. The '100-year + 4 foot' elevation, 'finished/garage floor' elevations, the location of the OPRD 1969 Statutory Vegetation Line survey marker points, key streets, and management unit designations are also shown in this Figure. North is to the left. Elevations and distances are in feet. Elevations are referenced to the NGVD

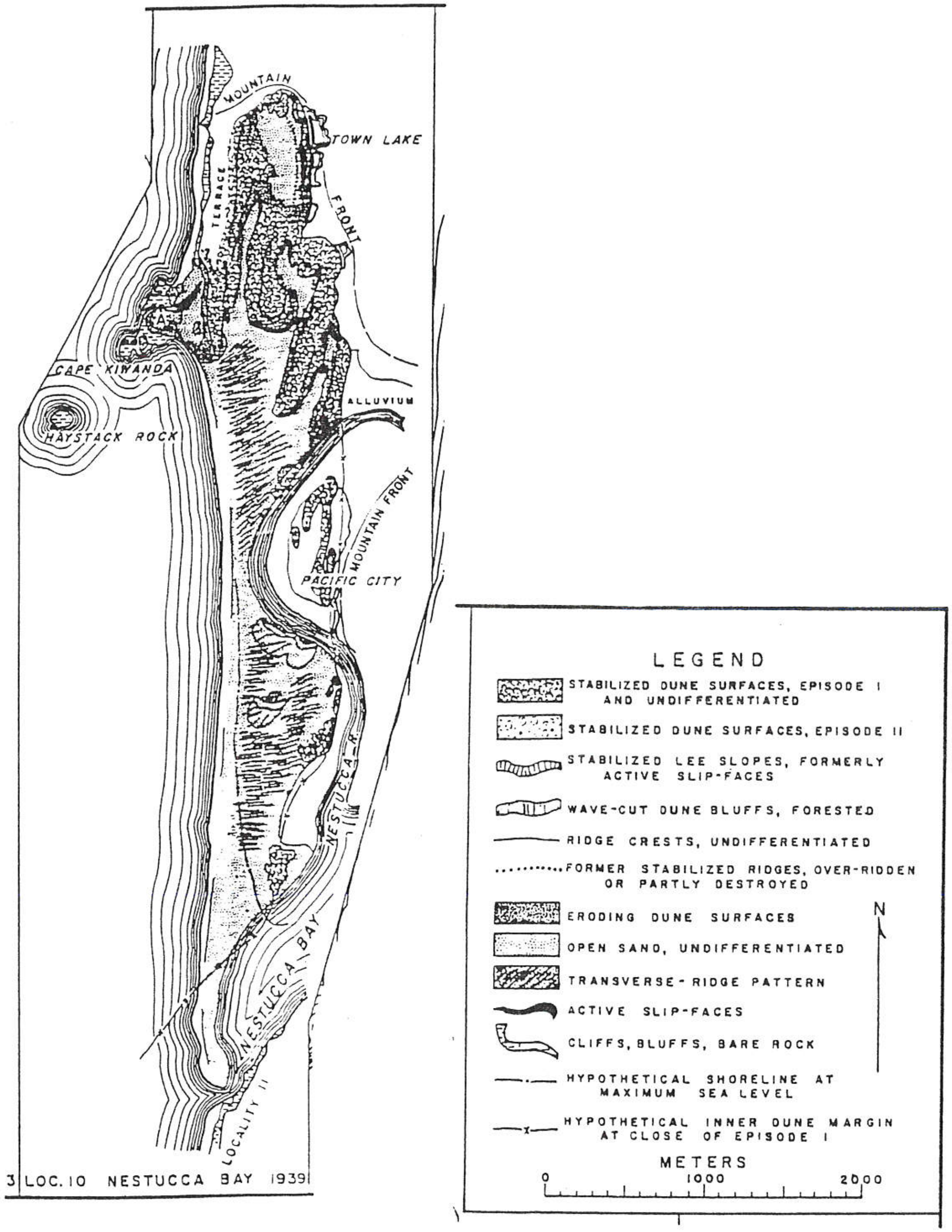


Figure 13. Plan sketch of surficial deposits in the vicinity of Cape Kiwanda (Cooper, 1958).

Table 5. Summary of 1967 Beach and Dune Profile Parameters

Primary Foredune Crest

Elevation range ~**25.0 - 40.0 feet**

Profile Envelope(difference between width of *horn* and *bay* profile)

@ + 5 foot contour	220 feet
@ + 10 foot contour	165 feet
@ + 14 foot contour	60 feet
@ + 20 foot contour	55 feet
@ + 25 foot contour	135 feet

* all elevations are referenced to NGVD

the location of the the +~5 foot NGVD contour varied by as much as 220 feet; the location of the +14 foot NGVD contour by as much as 60 feet; and the location of the +25 foot NGVD contour by as much as 135 feet.

At least two episodes of erosion occurred over the period 1967 to 1978, both in conjunction with El Nino events (Appendix C). The first, in the early 1970's is reported by H.G. Schlicker and Associates (1990) to have resulted in 50 to as much as 100 feet of erosion. About this time riprap was placed along the shoreline north of the Dory Boat Ramp and at several locations along the shoreline in the central portion of the management area.

Also about this time, a coastwide dunes inventory was conducted by the SCS (1975: Figure 15). In their handbook 'Beaches and Dunes' of the Oregon Coast', they identify Active Foredune (FDA), Recently Stabilized Foredune (FD), Open Dune Sand (OS), Open Dune Sand Conditionally Stable (OSC), and Younger Stabilized Dune (DS) as dune forms along the Pacific City shoreline. It is important to note that the terms 'active' and 'stable' apply to wind-driven sediment transport. Thus, Figure 15 represents the extent to which the Pacific City shoreline had been stabilized by vegetation cover at the time of mapping.

Following a brief period of rapid sand accumulation, a major episode of erosion occurred along the Pacific City shoreline during the late 1970's. This erosion episode is well documented by Komar (1978). He

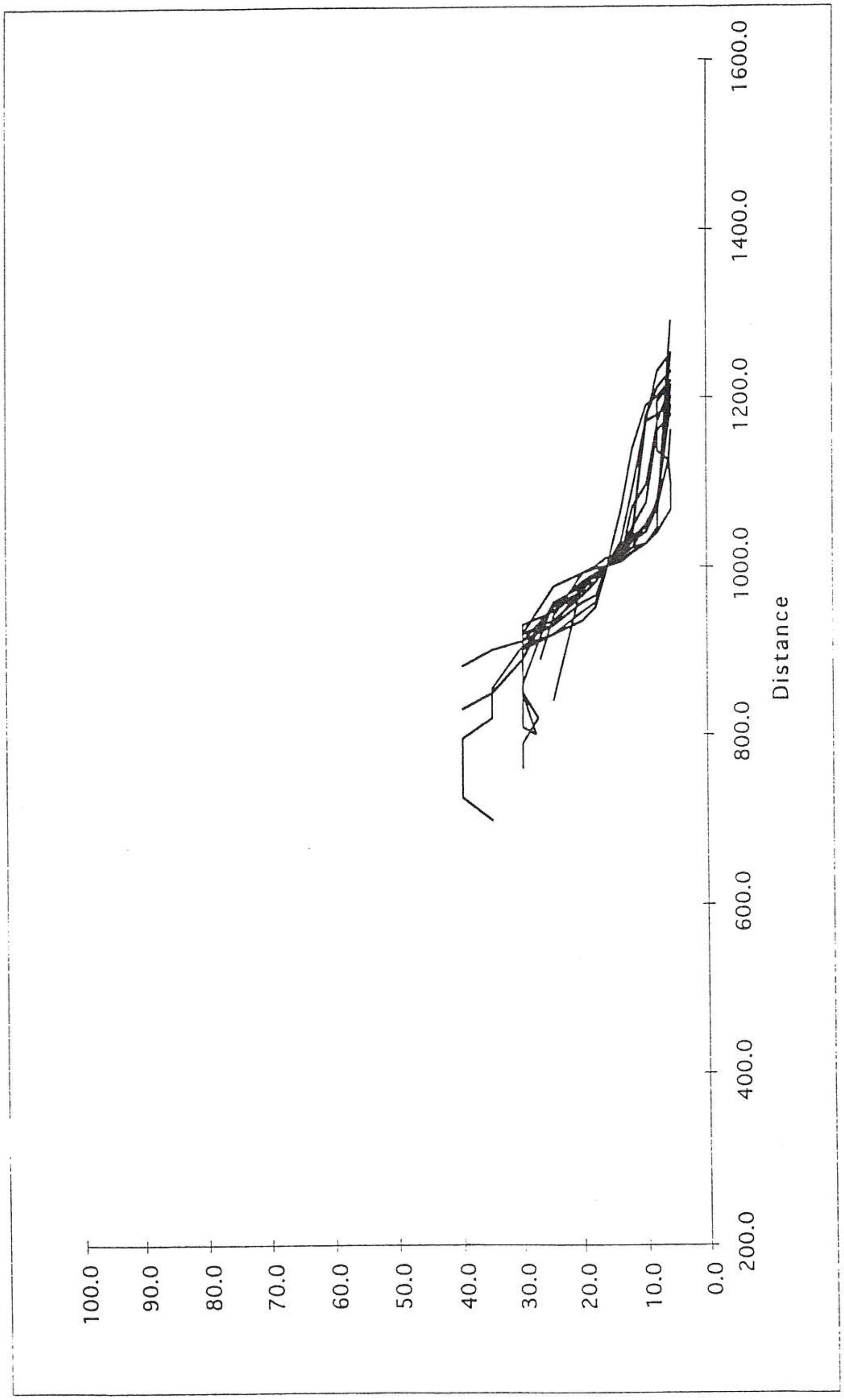


Figure 14. Plot of Pacific City 1967 beach and dune profiles

Elevations and distances are in feet. Elevations are referenced to NGVD.

The 1000 foot mark represents the location of the OPRD 1969 Statutory Vegetation Line.

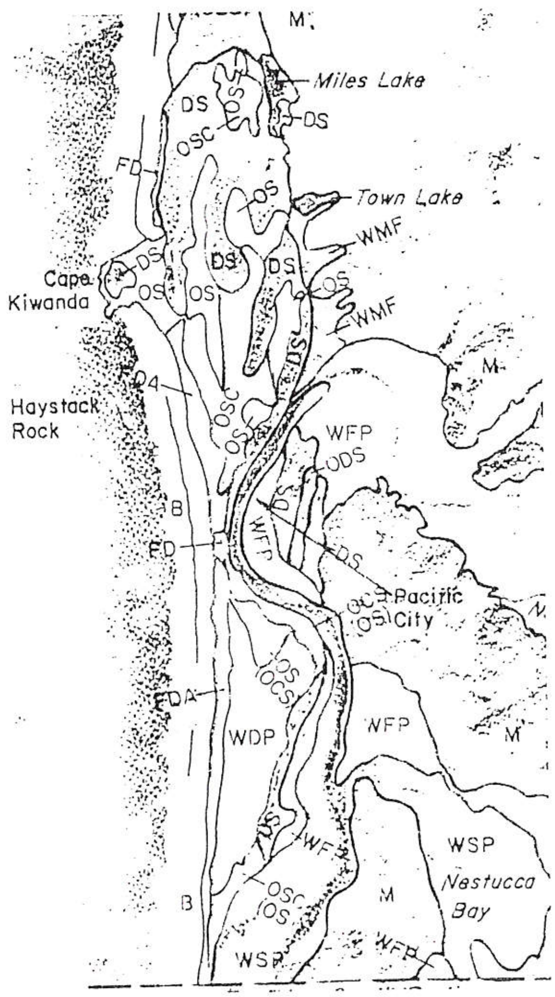


Figure 15. Plan map of dune forms along the Pacific City shoreline (SCS, 1975).

reports that at least four major storms took place during the winter of 1977-1978, the last of these in early February. The combination of large waves and high tides that occurred during the February 1978 storm were such that the Nestucca Spit was overwashed and breached - the only such natural event recorded along the Oregon coast (Figure 16). At its inception the breach measured over 400 feet in longshore extent. At its culmination the breach cut a gap through the spit that was as much as 1000 feet wide. Komar observed that although erosion occurred along the entire length of the Pacific City shoreline during the winter of 1977-1978, it tended to be highly localized. A review of the 1978 ODOT 'beach zone' aerial photographs confirm Komar's observation. The aerial photographs show that foredune retreat on the order of 50 to 100 feet occurred at several different locations along the Pacific City

Figure 16. The overwashing and breaching of Nestucca Spit during the [illegible]
(from Komar 1992)

shoreline. Because homes were threatened, as much as 2500 feet of shoreline in the central portion of the management area was riprapped at this time (Figure 17a).

By 1981 erosion ceased and an episode of sand accumulation commenced (Figure 17b). Interrupted only by minor episodes of localized erosion, most notably during the 1982-1983 El Nino event, this period of net accretion has continued to the present. That sand accumulation has been rapid is evident from Figures 17a and 17b. Further evidence for rapid sand accumulation is the 1984 ODOT 'Beach Zone' aerial photographs, which show the complete burial of the extensive riprap placed along the Pacific City shoreline in 1978. Noting the burial of a dwelling in the southern portion of the management area, DLCD (1989) reports that excessive sand accumulation was a problem for homeowners since at least 1984 . As a result, foredune grading for maintenance purposes has been carried out on a regular basis by individual homeowners at least since then. Recent efforts to address problems associated with excessive sand accumulation on an areawide basis are considered further below in the context of human activities. Apparently the net displacement of sand from the southern to the northern end of Nestucca Littoral Cell has persisted well beyond the 1982-83 El Nino.

Comparisons between individual 1967 and 1997 beach and dune profiles is given in Appendix C and summarized in Table 6. These comparisons confirm that the foredune in the Pacific City area has grown considerably, both in terms of height and width, over the last 30 years. For example, foredune elevations at the location of the 1967 16 foot NGVD contour now reach 39.5 feet NGVD at some locations- an increase of 23.5 feet in height. Comparable changes have occurred in terms of foredune width. Specifically, the location of the +10 foot NGVD contour moved west by as much as 310 feet; the location of the the +15 foot NGVD contour by as much as 225 feet; and the location of the the +20 foot NGVD contour by as much as 160 feet at some locations. The changes noted above are most prominent along the northern portions of the Pacific City shoreline north of Pacific Avenue. Changes in beach and dune profiles in the area south of Pacific Avenue have been less dramatic. In this area the elevation of the primary crest tends to show little or no change since 1967. Foredune width has generally increased throughout this area. However, along one transect in this area the location of the +10 foot NGVD contour has actually moved east by ~25 feet.

Before moving on to a consideration of projected shoreline change, it should be noted that the existing literature and aerial photographs suggest that horizontal 'rip' cell circulation is an important element of Pacific City beach and surfzone dynamics. In the aerial photographs rip current channels and the shoreline rhythms (i.e horn and bay profiles) that accompany them area readily apparent (Figure 18). The width of the rip channels is typically on the order of 250, 400, and 1200 feet. Correspondingly the longshore spacing of the shoreline rhythms is commonly on the order of 400, 800, 1200, and 2400 feet. These observations and the fact that the maximum variation in the apparent foredune toe observed alongshore at a given time in the aerial photographs (~150 feet) appears to be greater than the maximum

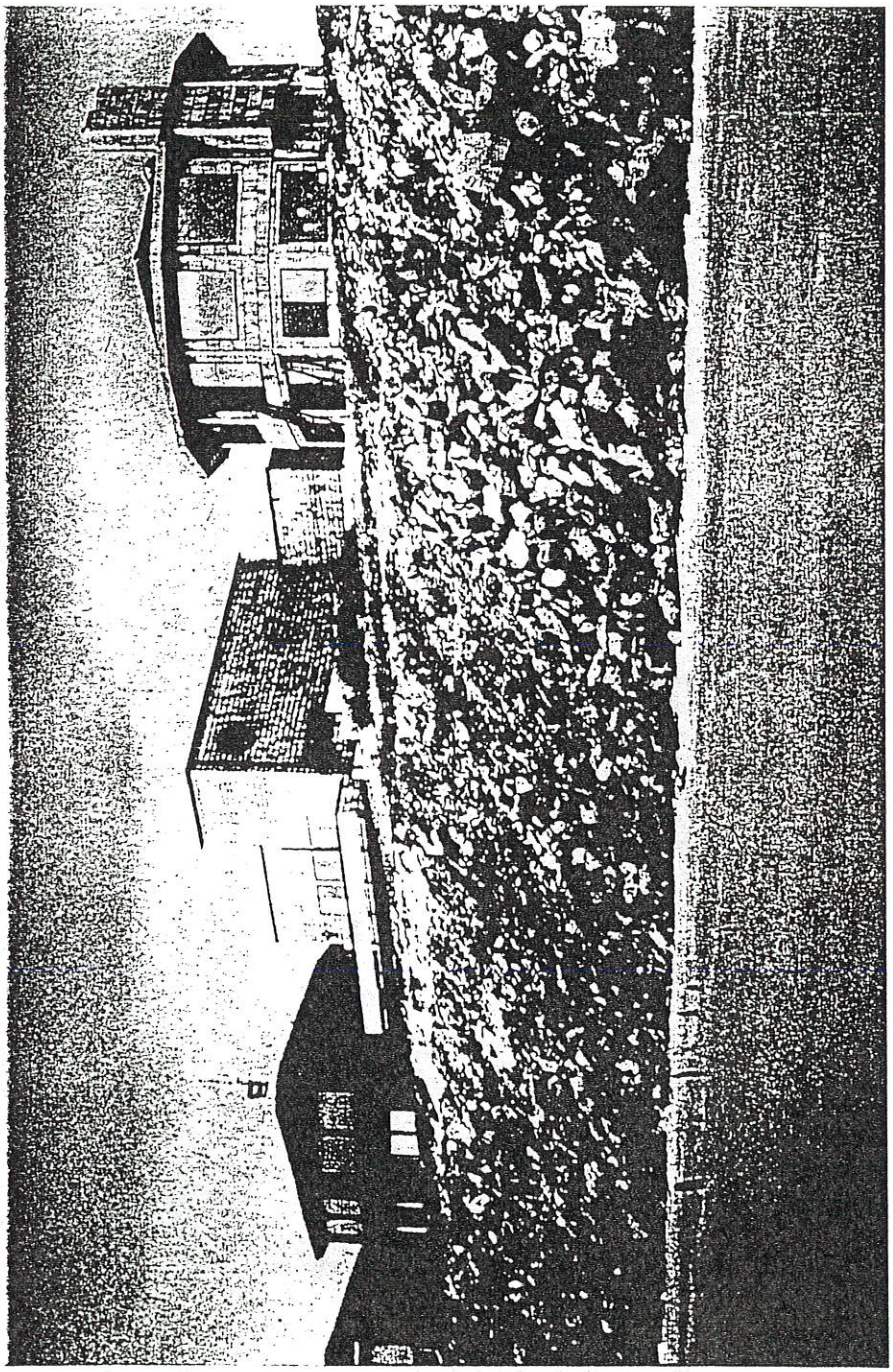


Figure 17. Riprap and recovery of Pacific City Shoreline: (a) March 1978 (courtesy of Paul Komar)

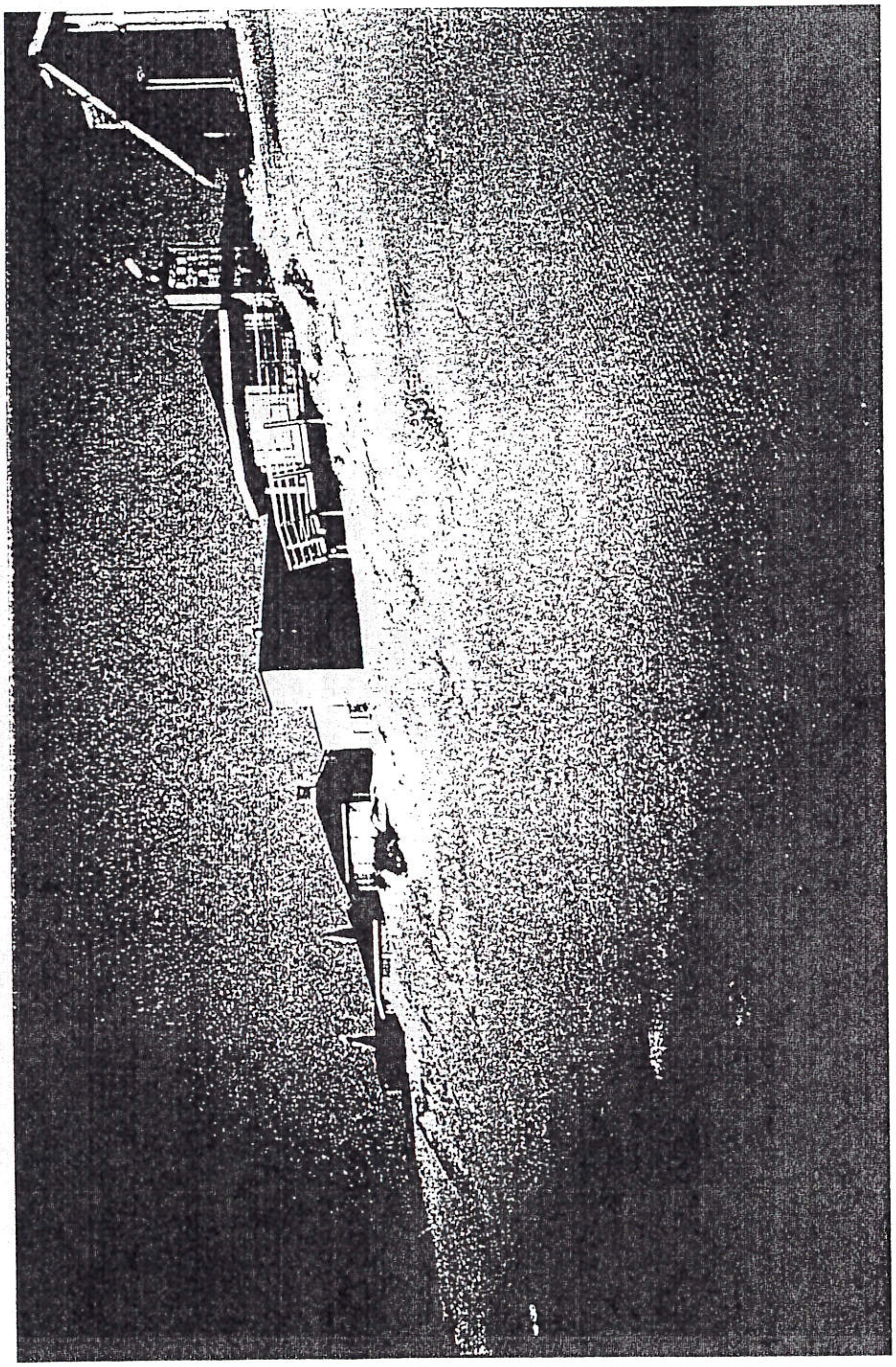


Figure 17. Riprap and recovery of Pacific City Shoreline: (b) May 1981 (courtesy of Paul Komar)

Table 6. Summary of Historical Profile Variation 1967-1997

Elevation Change @ 16 foot contour	
range +7.3 to +23.5	
Elevation Change @ 16 foot contour	
@ + 10 foot contour	-25 to +310 feet
@ + 15 foot contour	+100 to +225 feet
@ + 20 foot contour	+55 to +160 feet

* all elevations are referenced to NGVD

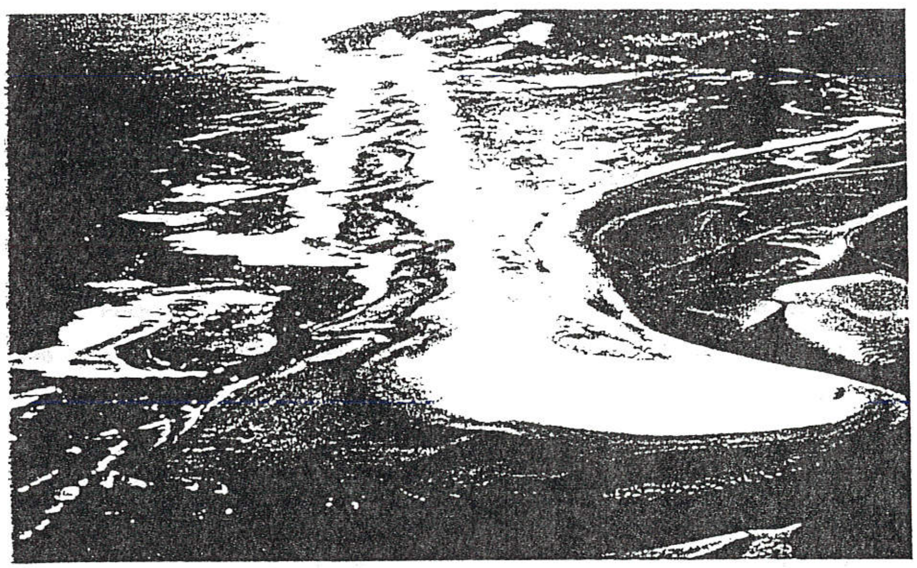


Figure 18. Aerial view of the Pacific City shoreline at low tide showing rip current channels and the shoreline rhythms that accompany them (from Komar, 1992).

variation in the apparent foredune toe observed at any one location over time in the aerial photographs (~110 feet) support this suggestion.

Wave Attack: Projected Foredune Retreat. The results of a series of analyses that were conducted to assess the potential landward extent of foredune retreat during extreme storm events are summarized in Table 7 and illustrated in Figure 19.

Following from the work of Komar et al. (1997), along dune-backed shorelines the potential landward extent of foredune retreat, or the '**Dune Hazard Zone** (DHZ)', can be expressed as:

$$DHZ = [(S_{dune} + D) + (L_R \times T_p) + (L_r \times T_p)]$$

(Formula 1)

where S_{dune} = the total horizontal extent of ocean undercutting projected to occur during a design storm event or cluster of storm events (feet);

D = the dune topographic stability factor (feet);

L_R = the average annual rate that the shoreline is projected to migrate landward due to sediment budget considerations (feet/year);

L_r = the average annual rate that the shoreline is projected to migrate landward due to relative sea level rise (feet/year); and

T_p = the anticipated years of protection or planning period (years).

S_{dune} is determined through application of a simple geometric model that translates the existing beach/dune form landward in response to elevated storm water levels. Key components of the geometric model are the total water level, the elevation of the beach/dune junction, and the beach slope. Here, a range of storm water level values were used. They include values of 16.3, 18.6, 19.3, and 23.2 feet NGVD for the 5 year, 50 year, 100 year, and 100 year + 20% storm water levels respectively. The basis of these values was considered earlier in the context of extreme water levels. Values for the elevation of the beach/dune junction were taken as 14.4 feet and 11.5 feet NGVD. The former value represents the mean elevation of the foredune toe measured from the 1997 beach and dune profiles. The latter value represents the mean elevation of the foredune toe minus one standard deviation. It is used to represent a rip bay scenario. A value of 0.030 ($\tan_b$) was taken as the beach slope. This value falls in the mid-range of the range of measured beach slopes along the Pacific City shoreline and is typical of winter beach slopes along the Oregon coast.

The dune topographic stability factor, D, is taken as a horizontal to vertical ratio of 1.5:1. This corresponds approximately to a slope of 33 degrees, a typical value for the stable angle of repose in loose sand. Thus, the distance for D is determined by multiplying the difference in elevation between the toe and crest of the foredune by 1.5. Depending on the projected inland relocation of the toe, the difference in elevation between the toe and crest ranged from ~10 to 36 feet.

Table 7. Summary of Pacific City Foredune Retreat Projections

Geometric Model	
5 year storm	86.6
(rip bay)	(194.6)
50 year storm	174.9
(rip bay)	(284.9)
100 year storm	206.1
100 year storm + 20%	367.5
FEMA Model	
Area above 100 year still water level = 540 square feet	42.3
Area above 100 year still water level = 1000 square feet	105.0
Numerical Simulation (SBEACH)	
100 year storm @ +5 foot elevation contour	35 to 90
Maximum Observed Profile Variation	
@ +5 foot elevation contour	250
@ +14.5 foot elevation contour	170
@ +16 foot elevation contour	110

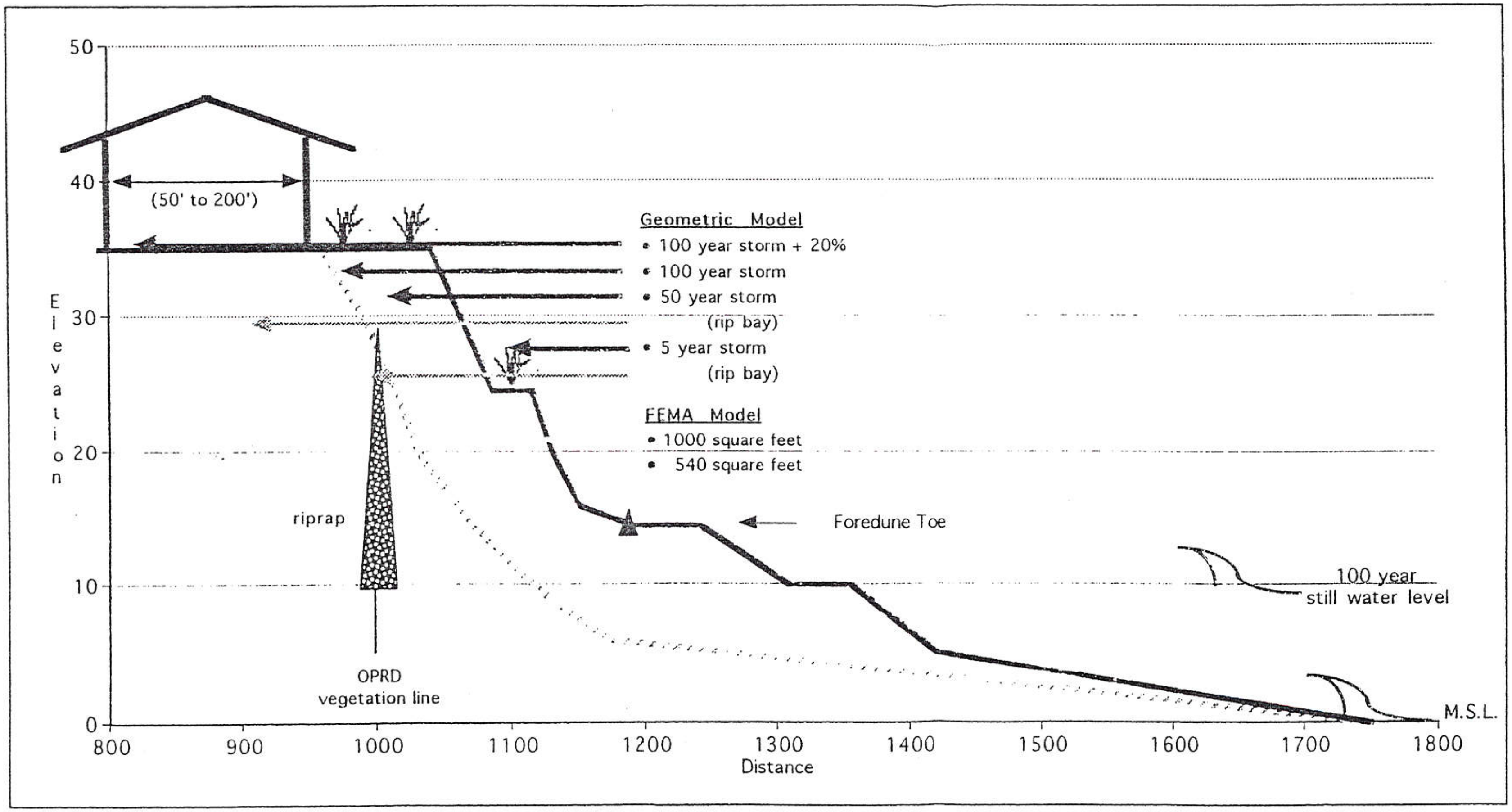


Figure 19. Schematic illustration of potential foredune retreat.

Note: the arrows indicate the landward extent of foredune retreat predicted under the different scenarios discussed in the text, the 50' to 200' and arrow shown inside the dwelling represents the range of existing dwelling locations relative to the location of the 1969 OPRD statutory vegetation line; and the illustration shows to scale the riprap that exists along the central portion of the Pacific City shoreline

With respect to the average annual rate that the shoreline is projected to migrate landward due to sediment budget considerations (L_R), it is inferred that the Pacific City shoreline -like many dune-backed shorelines along the Oregon coast (Shoreland Solutions, 1994b; Komar et al., 1997)- exhibits relative long term stability. As a result, the term $L_R \times T_p$ is set equal to zero and thus excluded from the analysis.

Estimates of the rate of relative sea level rise were considered earlier in the context of long term trends of shoreline change. The range of values used here include $L_r \times T_p = 3$ inches, 6 inches, and 12.5 inches. These values correspond to the amount of increase in the still water level due to relative sea level rise at its current rate over a 50 year period, at its current rate over a 100 year period, and at an accelerated rate over a 50 year period respectively. Here, these values were added to the value of the total storm water level used to calculate S_{dune}.

The results of the analysis using Formula 1 and the geometric model yielded values for the potential inland extent of foredune retreat along the Pacific City shoreline ranging from as little as 86.6 feet as much as 591.3 feet landward of the foredune toe. Projected values given in Table 7 correspond to the following specific sets of assumptions:

- **Scenario #1.** The **5 year storm water level** combined with relative sea level rise at its current rate over a 50 year period, the mean elevation for the beach/dune junction, a beach slope of 0.030, and a foredune elevation of 24.5 feet. Under this scenario **the total projected landward extent of foredune retreat is equal to 86.6 feet.** The rip bay value under this scenario is 194.6 feet.

- **Scenario #2.** The **50 year storm water level** combined with relative sea level rise at its current rate over a 50 year period, the mean elevation for the beach/dune junction, a beach slope of 0.030, and a foredune elevation of 32.2 feet. Under this scenario **the total projected landward extent of foredune retreat is equal to 174.9 feet.** The rip bay value under this scenario is 284.9 feet.

- **Scenario #3.** The **100 year storm water level** combined with relative sea level rise at its current rate over a 100 year period, the mean elevation for the beach/dune junction, a beach slope of 0.030, and a foredune elevation of 32.2 feet. Under this scenario **the total projected landward extent of foredune retreat is equal to 206.1 feet.**

- **Scenario #4.** The **100 year storm water level + 20%** combined with relative sea level rise at an accelerated rate over a 50 year period, the mean elevation for the beach/dune junction, a beach slope of 0.030, and a foredune elevation of 41.4 feet. Under this scenario **the total projected landward extent of foredune retreat is equal to 367.5 feet.**

An important point to note about using the geometric model to determine S_{dune} is that the geometric model is not time dependent. In other words, the geometric model assumes that the extreme storm event is of unlimited duration. Recent work involving process-based models to explore this issue suggests that although much of the storm-induced profile change occurs rapidly, time periods as long as one month are needed to develop the fully eroded profile predicted by the geometric model (William G. McDougal, personal communication). This, together with the fact that long term trends (i.e. relative sea level rise) are accounted for in the analysis, suggests that the projections of the landward extent of foredune retreat obtained through the application of Formula 1 and the geometric model should probably be viewed as an indication of the potential maximum.

This said, it is interesting to note that the landward extent of foredune retreat observed during the February 1978 erosion episode that included the breaching of Nestucca Spit is comparable to that projected by Formula 1 and the geometric model. The February 1978 storm is calculated to be about a 10 year event. The projected extent of landward foredune retreat for such an event is about 90 feet using the mean elevation for the foredune toe and 185 feet using the mean elevation of the foredune toe minus one standard deviation (i.e. a rip bay). It may seem surprising that such a relatively high frequency storm event could result in such intense erosion. However, when the fact that the storm during which Nestucca Spit was breached was at least the fourth in a succession of storm events that occurred that winter is considered, it is not so surprising. That is, the extreme wave conditions existed for a time period that was indeed long enough for the fully eroded profile to develop. This suggests that, at least for relatively high frequency storm events, the potential role of storm clusters needs to be taken into account when assessing the validity of the projections of the landward extent of foredune retreat obtained through the application of Formula 1 and the geometric model. In support of this suggestion is the observation that the maximum amount of variation in the location of the foredune toe observed along the 1997 Pacific City shoreline (and encompassed in the idealized end member profiles) corresponds almost exactly with the extent of ocean undercutting (S_{dune}) predicted by the geometric model for the 5 year storm event (170 feet versus 167.9 feet respectively).

FEMA, in its determinations of wave elevations and V-zone mapping, uses a variation of the geometric model as a means of assessing whether or not the foredune will be removed during extreme storm events (FEMA, 1989a). The FEMA model expresses the potential landward extent of ocean undercutting in terms of the cross-sectional area of the foredune that exists above the 100-year still water level, or *the frontal dune reservoir.* A cross-sectional area of 540 square feet is the typical value used in their analyses. However, a recent memorandum by FEMA recommends that in the context of site development a more conservative cross-sectional area of 1000 square feet be used (FEMA, 1994).

Here, both the 540 and 1000 square foot frontal dune reservoirs were determined using the ideal horn profile. Although a value 7.8 feet NGVD for the 100-year still water level is given by Komar et al. (1997), the more conservative FEMA (1990) estimate of 10 feet NGVD for the 100-year still water level was used here. Adding a distance attributable to the dune topographic stability factor, D, to the values calculated using the FEMA model results in values of 42.3 and 105.0 feet from the foredune toe as the projected landward extent of foredune retreat along the Pacific City shoreline associated with the 540 and 1000 square foot frontal dune reservoirs respectively.

These values are appreciably lower than those predicted by the geometric model. Considering that the FEMA model was formulated for conditions which differ considerably from those found along the Oregon coast (e.g. high waves, dissipative beaches and runup, rip currents), the projections of the landward extent of foredune retreat obtained through the application of the FEMA model should probably be viewed as an indication of the potential minimum. This statement is also applicable to the use of process-based models along the Oregon coast (Komar et al, 1995; Komar et al, 1997). For example, in the development of the Manzanita Foredune Management Plan one such process-based model, the U.S. Army Corps of Engineers SBEACH model, was used to evaluate beach response during extreme storm conditions (McDougal et al., 1995). This analysis yielded landward retreat distances of the +5 foot contour ranging from 35 to 90 feet (Table 7.) These values are considerably lower than the maximum amount of variation in the location of the +5 foot contour observed along the 1997 Pacific City shoreline-250 feet. This difference is not surprising considering the inclusion of time dependency in the process-based models as well as the differences in the conditions under which these models were formulated.

Before moving on to a consideration of human factors, the potential affect that inlet dynamics can have on shoreline stability is briefly noted. Here, the conclusion is that the Nestucca River inlet undoubtedly plays a role in controlling shoreline stability with the Nestucca Littoral Cell. However, over the short term its effects are mostly local in nature. They are principally related to inlet migration, and are confined to the segment of shoreline in the vicinity of the spit tip.

Human Activities. The introduction of European beachgrass into the Pacific City area was noted earlier in the context of historical shoreline change. Its spread has had a dramatic effect on the Pacific City shoreline as well as the entire Oregon coast. Prior to the introduction of European Beachgrass, areas of open mostly unvegetated sand existed along the shoreline. These areas were associated with large expanses of active dunes that in some areas extended considerable distances inland. The vegetated foredunes that today characterize much of the Oregon coast formed as European beachgrass stabilized major portions of these active dune areas.

Residential and commercial development accompanied the spread of European beachgrass along the Oregon coast. Aerial photographs reveal that by 1967 residential and commercial development existed at both the north and south ends of the Pacific City shoreline. By 1984 development existed along almost the entire length of the Pacific City shoreline. Tillamook County landuse zoning for the area reflects this (Figure 20). Specifically, the area north of the Dory Boat Ramp to Cape Kiwanda State Park and the area directly west of Pacific Avenue (a.k.a. the Turnaround) are zoned C-1 Neighborhood Commercial. The remainder, and what is the bulk of the Pacific City shoreline, is zoned R-2 Medium Density Urban

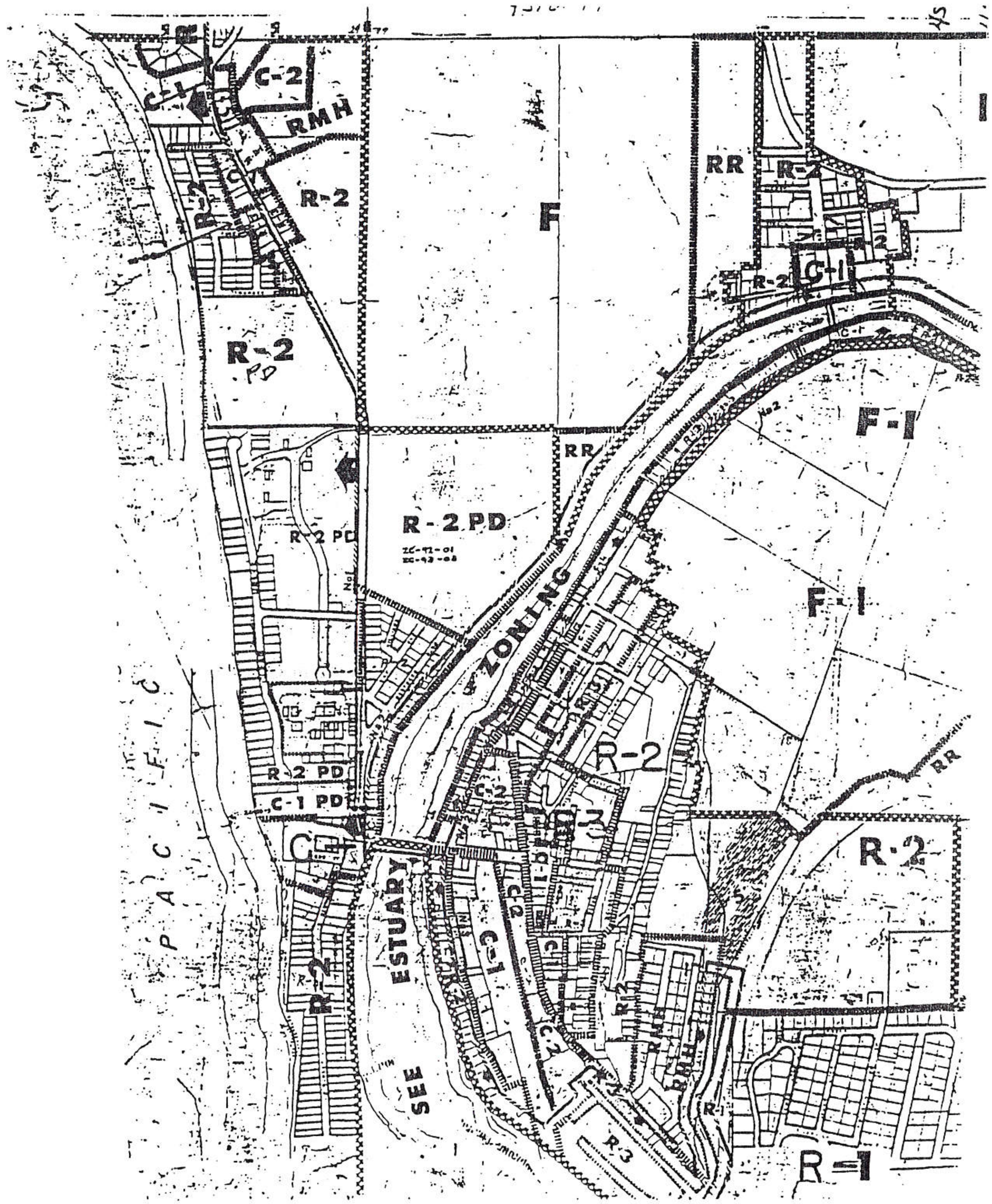


Figure 20. Map of Tillamook County landuse zoning along the Pacific City shoreline.

Residential. In this regard, Figure 12 shows that 'finished/garage floor' elevations vary considerably alongshore, ranging from as low as 21.9 feet to as high as 48.2 feet. Figure 12 also shows a general tendency for finished/garage floor elevations at the southernmost portion of the management area to be the lowest, and for finished/garage floor elevations adjacent and to the north of this area be the highest. Finished/garage floor elevations further north of these areas are less variable. The cross-shore location of dwellings also vary considerably alongshore. The 1984 ODOT 'beach zone' aerial photographs reveal that dwellings 'westernmost foundations' are located as close as 50 feet and as far as 200 feet east of the OPRD 1969 Statutory Vegetation Line. In general, westernmost foundations along the north and central portions of the Pacific City shoreline are located closer (seaward) to the OPRD 1969 Statutory Vegetation Line, and westernmost foundations along the southern portion of the Pacific City shoreline are located farther (landward) from the OPRD 1969 Statutory Vegetation Line.

Activities associated with commercial and residential uses have had an impact on the Pacific City shoreline. Excavation and grading that has occurred in the context of site development per se has acted to remove stabilizing vegetation as well as lower and broaden the foredune area. Dwellings have also had the effect of trapping in the foredune area, sand that would in the past have blown through the foredune area to be deposited further inland. Grading subsequent to site development has also affected shoreline stability. To address what is an ongoing problem associated with excess sand accumulation, grading has been carried out on a regular basis by individual oceanfront homeowners since at least 1984, and probably much earlier. Most recently (1994-1996), the Pacific City Beachfront Homeowners Association has carried out grading and planting on an areawide basis to address this problem. Unfortunately these actions have not been particularly successful. Without an overall plan for managing foredune grading pursuant to Statewide Planning Goal 18: Beaches and Dunes (Implementation Requirement 7) and Section 3.085 (4)(C) (2) of the Tillamook County Land Use Ordinance the ability of oceanfront property owners to address problems associated with sand accumulation remains limited.

Another activity associated with commercial and residential uses that has had an impact on the Pacific City shoreline is armoring. As noted earlier in the context of historical shoreline change, riprap has been placed along along the foredune toe north of the Dory Boat Ramp and along as much as ~2500 feet of the foredune toe in the central portion of the management area. The 1978 ODOT 'beach zone' aerial photograph suggests that riprap also exists sporadically elsewhere along the shoreline. A key issue in this regard is the extent to which this riprap can be expected to fix the position of the shoreline.

A review of OPRD permits suggest that the riprap placed along the central portion of the Pacific City shoreline consists of 2 to 3 foot diameter armor units placed as much as 8 feet below and extending to 15 feet above the excavated foredune toe. At the toe, the riprap covers an area as much as 22 feet in width. The location of the riprap relative to mean sea level is not clear from the permits. Also, the composition of the armor units is not stated in the permits. Photographs of the riprap, Figure 17a among others, suggest that the riprap does not conform completely to the specifications outlined in the OPRD permits. The photographs suggest that the riprap consists of armor units (probably angular basalt clasts) that range widely in size (from about 3/4 inch to 3 feet in diameter with most being about 1 foot in diameter). Also the riprap appears to be more 'dumped' than 'placed' in nature.

To assess the stability of the riprap a simple analysis was preformed using a modified form of the Hudson equation, the standard method used in revetment design for determining armor stone weight as a function of water depth at the structure toe (SPM, 1984; Kraus and McDougal, 1992). That is,

$$\mathbf{W} = 16\,\mathbf{d}^{3}$$

(Formula 2)

where **W** is the weight of the armor stone in pounds and **d** is the water depth at the revetment toe in feet. Assuming angular quarry stones are placed at a slope of 1.5:1 (horizontal:vertical), and setting the water depth at the toe of the structure equal to the difference between 50-year and 100-year total storm water levels (18.6 feet and 19.3 feet N.G.V.D. respectively) and the toe of the structure (14.5 feet N.G.V.D.), then armor stones with a weight of about 1100 and 1800 pounds would be stable for the 50-year and 100-year events respectively. Correspondingly, assuming that the density of basalt is 165 pounds per cubic foot, then stones just under 2 feet in diameter are projected to be mobile during the 50-year event and stones just over 2 feet in diameter are projected to be mobile during the 100-year event.

The results of this analysis alone suggest that although the riprap may resist moderate wave attack, it should be expected to suffer damage during extreme wave attack. The need for repair following extreme wave attack should be anticipated. Considering the fact that the riprap appears to be mixed sizes placed at a slope of 1:1 raises greater concerns about the potential for damage during extreme wave attack and the subsequent need for repair. These concerns are further heightened when the inability to accurately identify the water depth at the toe of the structure is contemplated. That water depth greatly affects the stability of a riprap structure is illustrated by noting that, whereas an armor stone with the weight of about 1000 pounds is stable for the 50 year event when the water depth at the toe of the structure is 4 feet, a stone weight of about 5500 pounds is required for stability during the 50 year event when the water depth at the toe of the structure is 7 feet. Further, the riprap along the central portion of the Pacific City shoreline is discontinuous. These gaps represent spots that weaken the overall stability of the riprap. This said, the presence of riprap along the central portions of the shoreline undoubtedly enhances the erosion and flood protection in the area beyond that which would otherwise exist without it. However, without more detailed information about the nature of the riprap and more detailed analyses, the extent to which the riprap can be expected to maintain its integrity during major storm events and in turn preclude foredune retreat can not be precisely quantified.

Recreational use, specifically pedestrian and vehicular traffic may also impact shoreline stability. Beachgrass and other species of foredune vegetation are particularly vulnerable to trampling. As a result, heavy and continuous pedestrian or vehicular traffic acts to reduce and/or eliminate existing vegetation cover. Correspondingly, these activities are likely to hinder efforts to establish vegetation in open sand areas. Along the Pacific City shoreline pedestrian and vehicular traffic is concentrated in the vicinity of the Dory Boat Ramp and the Turnaround. County parking lots exists at both locations. The Dory Boat Ramp also has public restrooms. That foot traffic is heavy along the beach and foredune in these areas is readily apparent. That vegetation cover is minimal in these areas is to be expected. Pedestrian traffic occurs elsewhere along the Pacific City shoreline, however to a lesser extent. In this regard, beach access is uncontrolled along the length of the Pacific City shoreline. Perhaps the only exception is the wooden walkway associated with Shorepine Village.

Vehicular traffic is also concentrated in the vicinity of the Dory Boat Ramp and the Turnaround. At the former location vehicles use the Dory Boat Ramp and park along the shoreline north of the boat ramp. The latter location is used mostly as a means of accessing the beach. Specific regulations regarding vehicular access and use along the Pacific City shoreline are as follows (personal communication, Steve Williams, North Coast Landuse Coordinator, OPRD):

- Cape Kiwanda south along the beach to ~700 feet north of the Dory Boat Ramp- Vehicles are allowed to use this area only for the purpose of boat launching.

- The Dory Boat Ramp north along the beach to ~700 feet north of the Dory Boat Ramp- Vehicles are allowed to park in this area for the purpose of boat launching.

- The Dory Boat Ramp south along the beach to ~450 feet south of the Dory Boat Ramp- Vehicles are allowed all year.

- ~450 feet south of the Dory Boat Ramp south along the beach to the Turnaround (Pacific Avenue) - Vehicles are prohibited.

- The Turnaround (Pacific Avenue) south along the beach to the tip of Nestucca Spit - Vehicles are allowed all year.

Conclusions

Summary of Factors Affecting Shoreline Stability. As required by Statewide Planning Goal 18 Implementation Requirement 7 and Section 3.085 (4)(C) (2) of the Tillamook County Land Use Ordinance, the effects of a range of factors upon the stability of the shoreline have been considered as a basis for establishing a foredune management plan for the area extending from the Nestucca River Inlet on the south to Cape Kiwanda on the north. Key observations are summarized below.

• Along the Pacific City shoreline relative sea level is currently rising at a rate of about 4 to 8 inches per century. If sea level rises as envisioned under scenarios of global warming in response to the greenhouse effect rates increase to as much as 20 to 30 inches per century.

• Every 400 years, on average, the Pacific Northwest experiences a catastrophic subduction zone earthquake. These sudden and dramatic seismic events are expected to produce damage resulting from ground shaking, earthquake-induced liquefaction, landsliding, subsidence, and tsunami. Projected locally generated tsunami elevations for the Nestucca Littoral Cell range from as low as 14 to 18 feet to as high as 20 to 38 feet NGVD.

• In terms of Nestucca Littoral Cell sand supply, sources include the Nestucca and Little Nestucca Rivers as well as episodic wave-induced dune erosion. Sinks include losses due to wind-driven transport of sand inland to dunes as well as wave-driven longshore and cross-shore sediment transport. Eroding episodically only to eventually recover, the sediment budget of the Nestucca Littoral Cell is probably roughly balanced over the long term.

• Winds in the Pacific City area exhibit a marked seasonal bimodality. The wet winter southerlies and southwesterlies, winds which reach speeds in excess of 50 miles per hour, are the primary control on dune form. The dry summer northerly and northwesterly winds act as modifiers of dune form.

• In terms of the potential for wave overtopping, FEMA's estimate for the 100 year still water level is 10.0 feet NGVD; the 100 year significant wave height is 26.9 feet NGVD; and the 100 year total water level is from 12.0 to 35.0 feet NGVD. More recent estimates are 7.8 feet NGVD, 26.7 to 28.2 feet NGVD, and 19.3 feet NGVD for the 100 year still water level, the 100 year significant wave height, and the 100 year total storm water level respectively. The Flood Insurance Rate Map for the Pacific City area indicates that the 100 year V-zone elevation is 30 feet NGVD along the entire length of the Pacific City shoreline. Following from Goal 18 IR#7, the minimum height for flood protection in the management area is 4 feet above the 100 year V-zone elevation, or 34 feet NGVD.

• Existing beach and dune characteristics vary considerably along the Pacific City shoreline. The elevation of the primary foredune crest generally ranges from about 35 to 50 feet NGVD. It reaches a high of about 60 feet NGVD in the north central portion of the management area and a low of about 24 feet NGVD in southernmost portion of the management area. The mean elevation of the foredune toe is 14.4 feet ± 2.9 feet. Ranging from about 155 to 285 feet, the width of the foreslope varies by as much as 170 feet along the Pacific City shoreline. Along some segments of shoreline the foredune is well vegetated, the vegetation cover consisting mostly of European Beachgrass. Elsewhere the foredune is poorly vegetated, consisting mostly of open sand and gravel.

In terms of ideal end member profiles, the *horn* profile is characterized by an open sand beach and berm backed by a relatively wide and gently-sloping foreslope. Vegetated hummocks occupy lower portions of the foreslope and a densely vegetated secondary crest upper portions of the foreslope. In contrast, the *bay* profile is characterized by a relatively narrow and steeply-sloping foreslope with sparse vegetation cover.

• With the introduction of European beachgrass into the Pacific City area around the early 1950's, the shoreline changed from predominantly open sand with transverse dunes and isolated American dunegrass hummocks to a well developed vegetated foredune over the period 1939 to 1967 . The Pacific City shoreline experienced from 60 to as much as 130 feet of net accretion over this period.

At least two episodes of net erosion occurred over the period 1967 to 1978. One in the early 1970's resulted in about 50 to as much as 100 feet of foredune retreat. One in the late 1970's resulted in the overwashing and breaching of the Nestucca Spit, as well as foredune retreat elsewhere along the Pacific City shoreline. Erosion over this period was such that by 1978 as much as 2500 feet of riprap was placed above the shoreline in the central portion of the management area. Both of these erosion episodes appear to have occurred in conjunction with El Nino events. This suggests that interannual variations in the wind/wave climate are an important factor affecting shoreline stability within the Nestucca Littoral Cell.

By 1981 erosion ceased and an episode of net accretion commenced. This period of net accretion has continued to the present. Rapid sand accumulation, which has resulted in the burial of a dwelling in the southern portion of the management area, continues to be a problem. Net accretion over the period 1967 to 1997 has been such that foredune elevations at the location of the 1967 16 foot NGVD contour have increased as much as 23.5 feet. Correspondingly, the location of the +15 foot NGVD contour has moved west by as much as 225 feet. These changes are most prominent along the northern portions of the Pacific City shoreline north of Pacific Avenue. Changes in beach and dune profiles in the area south of Pacific Avenue have been less dramatic.

• Like the 1997 profiles, the 1967 profiles show considerable longshore variation in form. The maximum variation in the apparent foredune toe observed from location to location at a given time is about 150 feet. The maximum variation in the apparent foredune toe observed at any one location over time is about 110 feet. This, along with other evidence, suggests that horizontal 'rip' cell circulation is an important factor affecting Pacific City shoreline stability.

• A series of analyses were conducted to assess the potential landward extent of foredune retreat during extreme storm events. The results suggest that the total projected landward extent of foredune retreat during the 50 year storm is about 175 feet. When the potential for enhanced erosion associated with rip currents is taken into account, this value may be as high as 285 feet. This value is higher than the total projected landward extent of foredune retreat during the 100 year storm, which the analyses suggest may be as high as 205 feet. The the total projected landward extent of foredune retreat during the 100 year + 20% storm may be as high as 370 feet.

• Human activities have dramatically altered the Pacific City shoreline. In addition to the planting of European Beachgrass, activities associated with site development have acted to remove stabilizing vegetation as well as lower and broaden the foredune area. In regards to existing dwellings, 'finished/garage floor' elevations range from as low as 21.9 feet to as high as 48.2 feet. There is a general tendency for finished/garage floor elevations at the southernmost portion of the management area to be the lowest, and for finished/garage floor elevations adjacent and to the north of this area be the highest. Also in this regard, 'westernmost foundations' are located as close as 50 feet and as far as 200 feet east of the OPRD 1969 Statutory Vegetation Line. In general, westernmost foundations along the north and central portions of the Pacific City shoreline are located closer (seaward) to the OPRD 1969 Statutory Vegetation Line, and westernmost foundations along the southern portion of the Pacific City shoreline are located farther (landward) from the OPRD 1969 Statutory Vegetation Line.

Besides excavation and grading associated with site development, grading subsequent to site development has been carried out on a regular basis to address the ongoing problem associated with excess sand accumulation. Extensive armoring of the Pacific City has also occurred subsequent to site development. Although the presence of riprap will undoubtedly enhance erosion and flood protection potential, analyses conducted as part of this work raise doubts about the ability of the riprap to maintain its integrity during major storm events and in turn preclude future foredune retreat.

Recreational use, in the form of pedestrian and vehicular traffic, is concentrated in the vicinity of the Dory Boat Ramp and the Turnaround. Beachgrass and other stabilizing vegetation is unlikely to become established in these areas. Uncontrolled beach access exists along the length of the Pacific City shoreline. At some of these locations heavy foot traffic is likely to hinder efforts to establish vegetation.

Pacific City Foredune Management Units. Based on the preceding discussion the Pacific City shoreline is divided into eleven geographic areas, or *management units* (Appendix E). Individual management units are distinguished by the combination of physical and social settings that exist within each area. The characteristics of individual management units are summarized in Table 8 and described briefly below.

- **Management Unit A** extends from the southern boundary of Cape Kiwanda State Park to the southern boundary of Alder Street (the line between Tax Lots 2000 and 2100). The Dory Boat Ramp and the shoreline fronting the County Parking Lot and Pelican Brew Pub is encompassed within this management unit. It is zoned C1-commercial, is a designated pedestrian-vehicular beach access and, as a result, experiences heavy recreational use. Riprap exists along the top of the beach north of the Dory Boat Ramp. Other than the foredune fronting the Pelican Brew Pub, the foredune in this area is relatively low and narrow. It is also poorly vegetated.

- **Management Unit B** extends from the southern boundary of Alder Street (the line between Tax Lots 2000 and 2100) to one lot north of Tamarack Street (the line between Tax Lots 300 and 400). This R2-Medium Density Urban Residential zoned area is occupied by single family residential dwellings. These dwellings are relatively low in finished/garage floor elevation and are mostly located relatively far from the OPRD 1969 Statutory Vegetation Line. Uncontrolled pedestrian access exists all along this segment of shoreline, which experiences a moderate level of recreational use. Riprap exists along the top of the beach at the south end of this management unit. The foredune in this area is relatively low and wide. It is also poorly vegetated. Sand inundation is a concern in this area.

Table 8. Pacific City Foredune Management Units*

Management Unit		Physical Setting	Social Setting
A	**crest elevation**	**34.0-43.8**	**C1-commercial**
	toe elevation	12.5-13.5	**Heavy recreational use**
	foreslope width	48.0-187.4	Pedestrian-vehicular access
		poorly vegetated	partially Riprapped
	dwelling elevation		**31.5**
	dwelling location		~110-190
B	**crest elevation**	**34.8-36.7**	**R2-residential**
	toe elevation	14.5-15.7	Recreational use/access
	foreslope width	183.2-187.4	**Sand Inundation**
		poorly vegetated	limited Riprap
	dwelling elevation		**28.0-31.1**
	dwelling location		~50-140
C	**crest elevation**	**55.2-59.0**	**R2-residential**
	toe elevation	15.3-17.2	Recreational use/access
	foreslope width	159.1-160.5	
		well vegetated	limited Riprap
	dwelling elevation		**33.0-34.3**
	dwelling location		~60-70+
D	**crest elevation**	**40.1-51.1**	**R2-residential**
	toe elevation	11.8-19.2	Recreational use/access
	foreslope width	84.8-130.0	**Sand Inundation**
		poorly vegetated	**extensive Riprap**
	dwelling elevation		**30.0-34.3**
	dwelling location		~50-70

* All distances are in feet and elevations in feet NGVD

Table 8. Pacific City Foredune Management Units* (continued)

Management Unit		Physical Setting	Social Setting
E	**crest elevation**	**41.8-46.8**	**R2-residential**
	toe elevation	16.6-19.2	Recreational use/access
	foreslope width	84.8-110.1	**Sand Inundation**
		poorly vegetated	**extensive Riprap**
	dwelling elevation		**30.3-43.0**
	dwelling location		~50-70
F	**crest elevation**	**37.5**	**C1-commercial**
	toe elevation	17.9	**Heavy recreational use**
	foreslope width	152.9	Pedestrian-vehicular access
		poorly vegetated	
	dwelling elevation		**26.6-45.0**
	dwelling location		~140-290
G	**crest elevation**	**30.9-48.7**	**R2-residential**
	toe elevation	10.7-18.1	Recreational use/access
	foreslope width	152.7-224.2	**Sand Inundation**
		well vegetated	limited Riprap
	dwelling elevation		**32.9-48.2**
	dwelling location		~120-220
H	**crest elevation**	**23.5-36.3**	**R2-residential**
	toe elevation	7.9-13.3	Recreational use/access
	foreslope width	117.9-234.6	**Sand Inundation**
		poorly vegetated	limited Riprap
	dwelling elevation		**21.9-37.6**
	dwelling location		~80-150

* All elevations are in feet NGVD

• **Management Unit C** extends from one lot north of Tamarack Street (the line between Tax Lots 300 and 400) to the northern boundary line of the Kiwanda Shores Subdivision (the northern boundary of Tax Lot 7300). The shoreline fronting Shore Pine Village is encompassed within this management unit. This management unit is zoned R2-Medium Density Urban Residential. Other than those at its north end, single family residential dwellings in this area are located landward of the foredune. Pedestrian access is controlled along this segment of shoreline, which experiences a moderate level of recreational use. Riprap exists along the top of the beach at the north end of this management unit. The foredune in this area is relatively high and narrow. It is also well vegetated.

• **Management Unit D** extends from the northern boundary line of the Kiwanda Shores Subdivision (the northern boundary of Tax Lot 7300) to just south of the boundary between the First and Fourth additions of the Kiwanda Shores Subdivision (the line between Tax Lots 8100 and 8200). This R2-Medium Density Urban Residential zoned area is occupied by single family residential dwellings. These dwellings are relatively low in finished/garage floor elevation and are located relatively close to the OPRD 1969 Statutory Vegetation Line. Uncontrolled pedestrian access exists all along this segment of shoreline, which experiences a moderate level of recreational use. Riprap exists along almost the entire top of the beach in this management unit. The foredune in this area is relatively high and narrow. It is also poorly vegetated. Sand inundation is a concern in this area.

• **Management Unit E** extends from just south of the boundary between the First and Fourth additions of the Kiwanda Shores Subdivision (the line between Tax Lots 8100 and 8200) to just north of the Turnaround (the line between Tax Lots 9200 and 9300). This R2-Medium Density Urban Residential zoned area is occupied by single family residential dwellings. These dwellings are relatively high in finished/garage floor elevation and are located relatively close to the OPRD 1969 Statutory Vegetation Line. Uncontrolled pedestrian access exists all along this segment of shoreline, which experiences a moderate level of recreational use. Riprap exists along almost the entire top of the beach in this management unit. The foredune in this area is relatively high and narrow. It is also poorly vegetated. Sand inundation is a concern in this area.

• **Management Unit F** extends from just north of the Turnaround (the line between Tax Lots 9200 and 9300) to just south of the Turnaround (the line between Tax Lots 1300 and 1400). The Turnaround and associated County Parking Lot are encompassed within this management unit. It is zoned C1-commercial, is a designated pedestrian-vehicular beach access and, as a result, experiences heavy recreational use. Structures in this area vary considerably in terms of finished/garage floor elevation and location relative to the OPRD 1969 Statutory Vegetation Line. For the most part the foredune in this area is relatively low and wide. It is also poorly vegetated.

• **Management Unit G** extends from just south of the Turnaround (the line between Tax Lots 1300 and 1400) to just north of Rueppel's Subdivision (the line between Tax Lots 2501 and 2502). This R2-Medium Density Urban Residential zoned area is occupied by single family residential dwellings. These dwellings are relatively high in finished/garage floor elevation and are located relatively far from the OPRD 1969 Statutory Vegetation Line. Uncontrolled pedestrian access exists all along this segment of shoreline, which experiences a moderate level of recreational use. The foredune in this area is relatively high and wide. It is also well vegetated. Sand inundation is a concern in this area.

- **Management Unit H** extends from just north of Rueppel's Subdivision (the line between Tax Lots 2501 and 2502) to the northern boundary of Nestucca Spit State Park. This R2-Medium Density Urban Residential zoned area is occupied by single family residential dwellings. These dwellings are relatively low in finished/garage floor elevation and are located relatively far from the OPRD 1969 Statutory Vegetation Line. Uncontrolled pedestrian access exists all along this segment of shoreline, which experiences a moderate level of recreational use. The foredune in this area is relatively low and wide. It is also poorly vegetated. Sand inundation is a concern in this area.

- **Management Unit I** extends from the northern boundary of Nestucca Spit State Park to the end of Nestucca Spit. This RM-Recreation Management zoned area encompasses Nestucca Spit State Park. Correspondingly, there is no development along this segment of shoreline. Pedestrian access exists at designated areas along this segment of shoreline, which experiences a moderate level of recreational use. The foredune in this area is relatively high and wide. It is also well vegetated.

The Pacific City Design Foredune. Based on the preceding discussion an idealized *design foredune* is identified for the Pacific City Foredune Management Area (Figure 21). Described in terms of specified elevations associated with morphologic features, as well as the distribution of vegetation cover, the design foredune establishes the "minimum dune height and width requirements to be maintained for protection from flooding and erosion" under Statewide Planning Goal 18 Implementation Requirement 7 (b). Characteristics of the design foredune are outlined in Table 9 and summarized below.

At an elevation of 34 feet NGVD, the **primary foredune crest** is ideally located a distance at least 50 feet seaward of the western foundation of oceanfront dwellings. This elevation corresponds to the maximum projected '100 year plus 4 foot' elevation. An irregular **secondary foredune crest**, located 150 feet from the western foundation of oceanfront dwellings, is 25 feet NGVD in elevation. This elevation is on the order of 20% above the projected 100 year total water elevations of Ruggiero et al. (1996), Tillotson and Komar (1997) and Komar et al. (1997). **Vegetated hummocks**, extend seaward of the secondary foredune crest down to 18 feet NGVD in elevation. The 150 foot width of the relatively steeply-dipping **upper foreslope**, which is defined as the area between the seaward edge of the primary foredune crest and the seaward edge of vegetated hummocks, exceeds by over 10% the maximum extent of foredune retreat observed to have occurred at this range of elevations since 1967. Seaward of the vegetated hummocks lies the **foredune toe**, which occupies elevations between 14.5 and 12.0 feet NGVD. This 150 to 200 foot wide area constitutes the relatively gently-dipping **lower foreslope**. The combined 350 to 400 foot ideal width of the design foredune approaches or exceeds the maximum extent of foredune retreat projected under not only the 50 year rip bay/storm scenario, but under the 100 year + 20% storm scenario as well. It also exceeds, by about 40% the, the maximum extent of foredune retreat observed to have occurred at elevations above 5 feet above NGVD since 1967. In areas where the ideal foredune width is unachievable (e.g. due to an existing deficit of sand) or

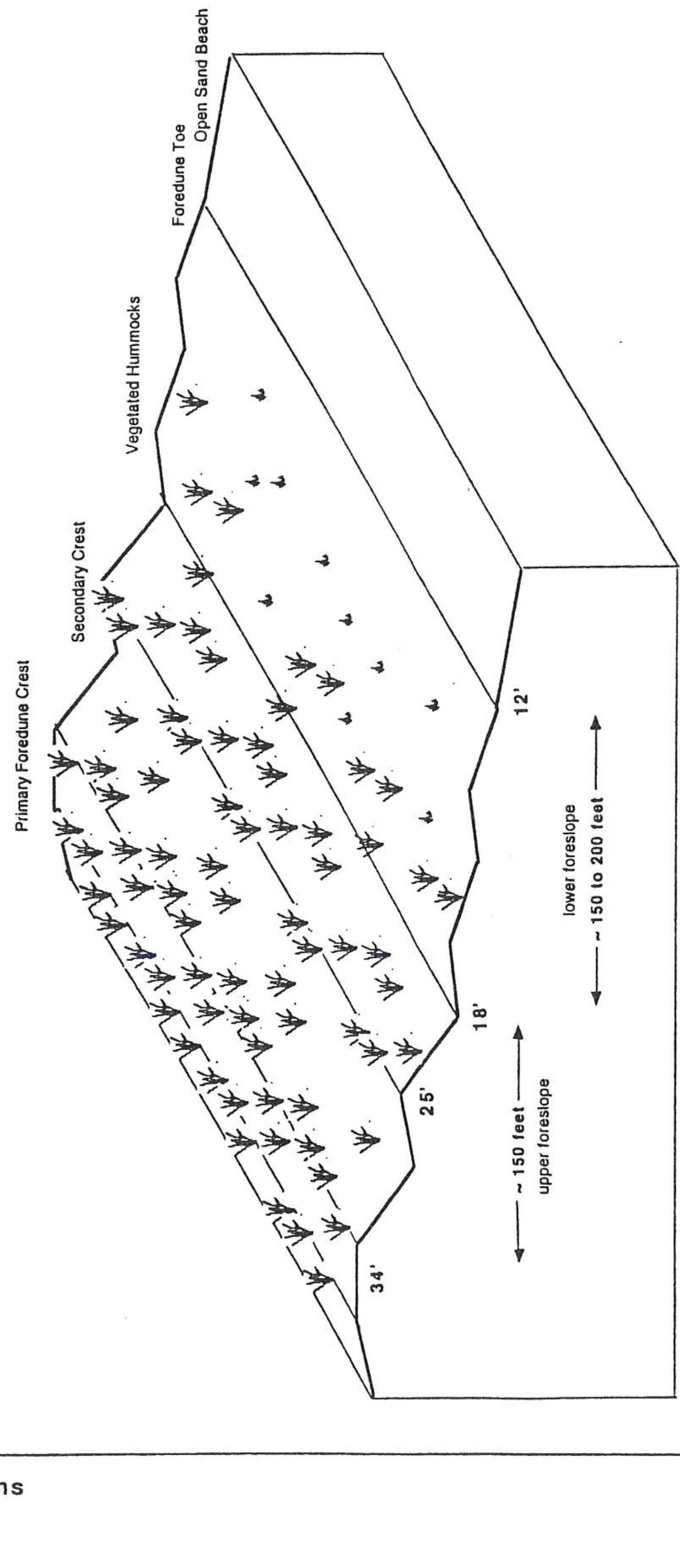


Figure 21. The Pacific City Design Foredune.

Table 9. Dimensions of the Pacific City Design Foredune

Feature	Elevation	Distance	Foreslope
Primary Foredune Crest	34.0 feet	0 to 50 feet	150 feet upper foreslope
Secondary Crest	25.0 feet	150 feet	
Vegetated Hummock	18.0 feet	200 feet	lower foreslope 150 to 200 feet
Foredune Toe	14.5 feet to 12.0 feet	350 to 400 feet	
Berm	10.0 feet to 8.0 feet	500+ feet	

* All elevations are in feet NGVD

arguably not wholly warranted (e.g. due to the existence or riprap) 175 feet is identified as the absolute minimum design foredune width. This minimum foredune width corresponds to the maximum extent of foredune retreat projected under the 50 year storm scenario. It also corresponds closely to the maximum amount of observed variation in the location of the foredune toe. Further it exceeds the extent of foredune retreat projected under the FEMA 1000 square foot frontal dune reservoir scenario by about 40%. Seaward of the foredune toe lies the open sand beach and berm.

Patterns of vegetation on the design foredune are intended to mimic those which occur naturally. Along the primary foredune crest, primary grasses (80% European Beachgrass and 20% American Dunegrass) are evenly spread across a well vegetated area (i.e. 60 to 90% cover). Within the upper foreslope primary grasses are irregularly spread, and correspondingly, the areas is moderately to well vegetated (i.e. 30 to 90% cover). Along the lower foreslope, primary grasses decreases in regularity and density in the seaward direction (i.e. from 30% cover at elevation 18.0 feet NGVD to 10% cover at elevation 14.5 feet NGVD.)

Limitations

The observations, interpretations, and recommendations contained in this document are based on a consideration of past conditions and conditions as they exist at the time of this writing. They should be considered to be subject to revision upon review of additional and/or more detailed information. They may also need to be modified should events occur which alter existing conditions. Finally, Shoreland Solutions is excluded from responsibility for any adverse effects that result from actions taken by other parties that are based on the observations, interpretations, and recommendations contained in this document.

Sources of Information

• CERC (Coastal Engineering Research Center), 1984. Shore Protection Manual Department of the Army. United States Army Corps of Engineers, Waterways Experiment Station, Vicksburg MI; V1.

• Cooper, W.S., 1958. Coastal Sand Dunes of Oregon and Washington. Geological Society of America Memoir 72.

• DLCD, 1989. Dune Management Assessment: An Assessment of the Feasibility of Foredune Management and View Grading for Five Communities along the Oregon Coast. Oregon Department of Land Conservation and Development. July 1989.

• DOGAMI, 1972. Oregon Department of Geology and Mineral Industries. Bulletin 74: Environmental Geology of the Coastal Region of Tillamook and Clatsop Counties, Oregon. Schlicker, H.G., Deacon R.J., Olcott, G.W., AND Beaulieu, J.D. 164p.

• DOGAMI, 1995. Oregon Department of Geology and Mineral Industries. Explanation of Mapping Methods and Use of the Tsunami Hazard Maps of the Oregon Coast: Nestucca Bay Quadrangle. Open File Report O-95-67. George Priest.

• FEMA, 1989a. Federal Emergency Management Agency. Basis of Assessment Procedures for Dune Erosion in Coastal Flood Insurance Studies. Dewberry and Davis. 68p. January, 1989.

• FEMA, 1989b. Federal Emergency Management Agency. Coastal Flood Insurance Study for Manzanita (Unincorporated Area) Tillamook County, Oregon. CH2MHill. 50p. September, 1989.

• FEMA, 1990. Federal Emergency Management Agency. Flood Insurance Study for Tillamook County, Oregon (Unincorporated Areas). CH2MHill. 74p.

• FEMA (Federal Emergency Management Agency), 1994. Memorandum: Dune Grading and Compliance with National Flood Insurance Program Requirements, from Charles L. Steele, Director Mitigation Division, FEMA Region X, Bothell, WA. April 14, 1994.

• FIRM, 1978. Flood Insurance Rate Map Community Panel #'s 410 196 0305A and 410 196 0315A. August 1978. U.S. Department of Housing and Urban Development.

• H.G. Schlicker and Associates, 1990. Proposed Cape Kiwanda Condominiums Dune Hazard Study. Report to William F. Brenner, Super One Inc. Project #90-602, H.G. Schlicker and Associates, Inc., August 1, 1990.

• Hunter, Ralph E., Richmond, B.M., and Alpha, T.R., 1983. Storm-controlled Oblique Dunes of the Oregon Coast. G.S.A. Bulletin, V.94:1450-1465.

• Komar, P.D., 1978. Wave Conditions on the Oregon Coast During the Winter of 1977-78 and the Resulting Erosion of Nestucca Spit. Journal of the American Shore and Beach Preservation Association. 46(1);3-8.

• Komar, P.D., 1992. Ocean Processes and Hazards Along the Oregon Coast. Oregon Geology. 54(1): 3-19.

• Komar, P.D., Carpenter, D., and McDougal, W.G., 1995. The Application of Beach and Dune Erosion Models to the High-Energy Oregon Coast. Unpublished Report to the Oregon Department of Land Conservation and Development. December, 1995.

• Komar, P.D., 1996. The Budget of Littoral Sediments: Concepts and Applications. Journal of the American Shore and Beach Preservation Association. 64(3);18-26.

• Komar, P.D., Ruggiero, P., McDougal, W.M., and Marra, J.J., 1997. Coastal Erosion Processes and the Assessment of Setback Distances: Application to the Oregon Coast. Unpublished Report to the Oregon Department of Land Conservation and Development. February, 1997.

• Komar, P.D., 1998. BEACH PROCESSES AND SEDIMENTATION. 2nd Edition. Prentice-Hall Inc. 544p.

• Kraus, N.C. and McDougal, W.G., 1992. Shore Protection and Engineering with Special Reference to the Oregon Coast. In Good J.W. and Ridlington S.S. ed. COASTAL NATURAL HAZARDS: SCIENCE, ENGINEERING, AND PUBLIC POLICY, Oregon Sea Grant, ORESU-B-92-001, 79-101.

• LCDC, 1995. Land Conservation and Development Commission. Oregon's Statewide Planning Goals and Guidelines. 1995 Edition.

• Madin, I., 1992. Seismic Hazards on the Oregon Coast. In COASTAL NATURAL HAZARDS: SCIENCE, ENGINEERING, AND PUBLIC POLICY, Good J.W. and Ridlington S.S. ed., Oregon Sea Grant, ORESU-B-92-001:3-27.

• Marra, J. J., 1993. Sand Management Planning in Oregon. In Proceedings of the Eighth Symposium on

Coastal and Ocean Management, July 1993. New Orleans, LA .

• McDougal, W.G., Ruggiero, P., and Carpenter, D.G., 1995. Manzanita Foredune Management Plan: Beach and Dune Responses to Storms. Appendix In MANZANITA FOREDUNE MANAGEMENT PLAN: STRATEGY, Shoreland Solutions, Unpublished Report to the Manzanita/Neahkahnie Dunes Management Association. March, 1995. 53p.

• Nordstrom, K.F., Psuty, N., and Carter, W. 1990. COASTAL DUNES:FORM AND PROCESS. John Wiley & Sons Ltd., 392p.

• Orr, E.L., Orr, W.N., and Baldwin, E.M., 1992. GEOLOGY OF OREGON 4th ed. Kendall/Hunt Publishing Co., 254p.

• Peterson, Curt D., Hansen, M., Briggs, G., Yeager, R., Saul, I.A., Jackson, P.L., Rosenfeld, C.R., White, G., Booth, B., Zhang, H., Assail, D., Terich, T., 1992. Regional Sediment Dynamics and Shoreline Instability in Littoral Cells of the Pacific Northwest. CZM 309 Program: Final Project Report.

• Reckendorf, F., 1993. Pacific City Critical Area Treatment, Tillamook County, Oregon. Special Report, Soil Conservation Service, WNTC, Portland, OR, January 1993.

• Ruggiero, P., Komar, P.D., McDougal, W.M., and Beach R.A., 1996. Extreme Water Levels, Wave Runup, and Coastal Erosion. Proceedings of the 25th International Conference on Coastal Engineering:2793-2805.

• SCOR, 1991. Scientific Committee on Ocean Research Working Group 89. The Response of Beaches to Sea-Level Changes: A Review of Predictive Models. Journal of Coastal Research 7(3):895-921.

• SCS, 1975. Beaches and Dunes of the Oregon Coast. U.S.D.A. Soil Conservation Service and Oregon Coastal Conservation and Development Commission. March, 1975. 141p.

• Sherman, D.J. and Nordstrom, K.F., 1994. Hazards of Wind-blown Sand and Coastal Sand Drifts: A Review. In COASTAL HAZARDS: PERCEPTION, SUSCEPTIBILITY, AND MITIGATION, Finkl, C.W. jr. ed, Journal of Coastal Research Special Issue No. 12: 263-275.

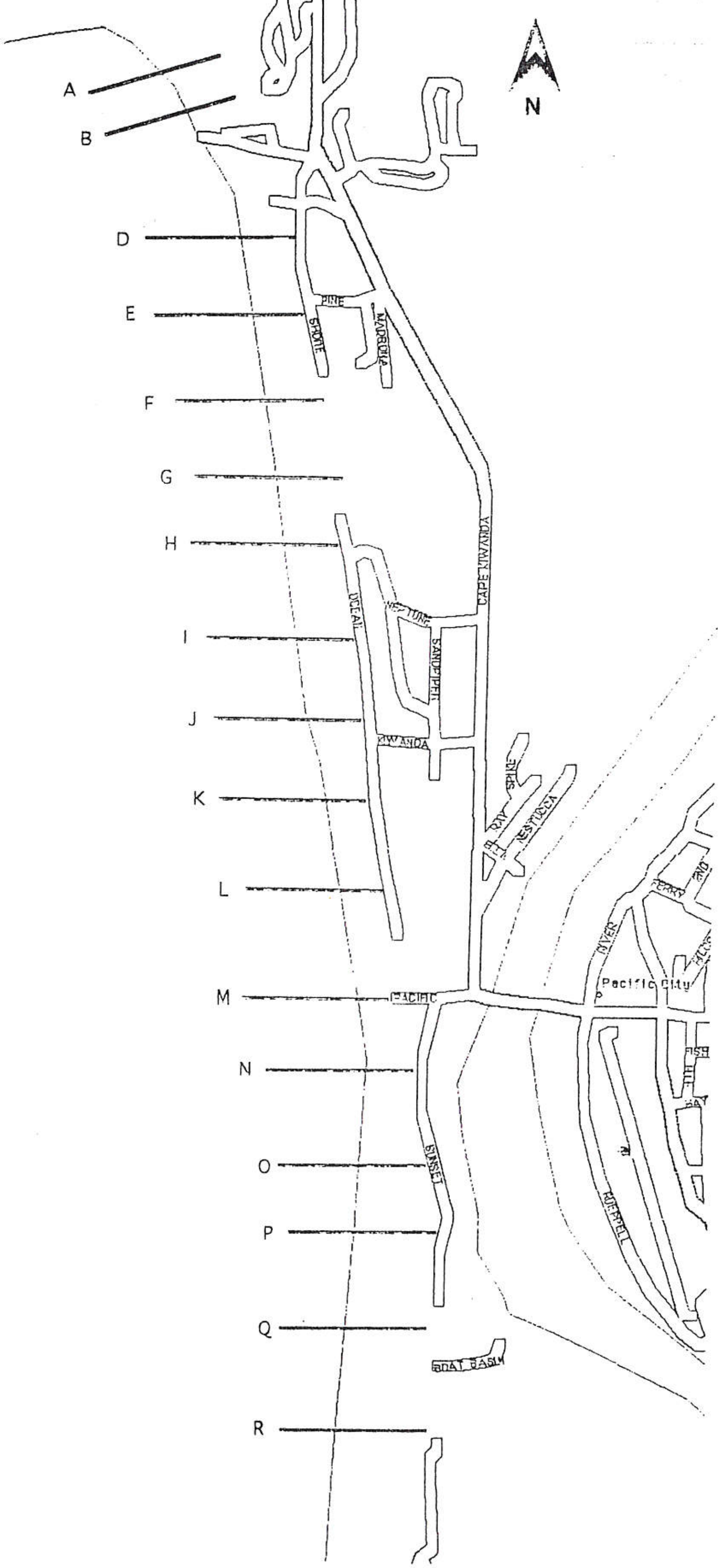
• Shoreland Solutions, 1994a. Manzanita Foredune Management Plan: Background Report. Unpublished Report to the Manzanita/Neahkahnie Dunes Management Association. October, 1994. 32p.

• Shoreland Solutions, 1994b. Appraisal of Chronic Hazard Alleviation Techniques with special reference to the Oregon Coast. Unpublished Report to the Oregon Department of Land Conservation and Development for the Oregon Coastal Zone Management Association. December, 1994. 121p.

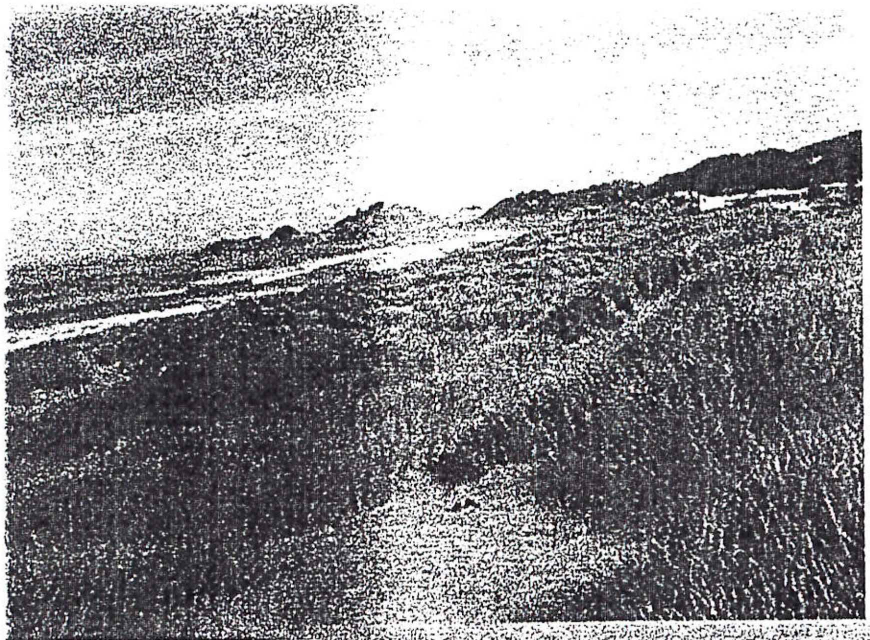
• Tillotson, K. and Komar, P.D., 1997. The wave climate of the Pacific Northwest (Oregon and Washington): A comparison of data sources. Journal of Coastal Research V13:2, 440-452.

• Wiedemann, Alfred M. 1984. The Ecology of Pacific Northwest Coastal Sand Dunes: A Community Profile. FWS/OBS-84/04.

Appendix A: Map showing the location of September 1997 beach and dune profiles.

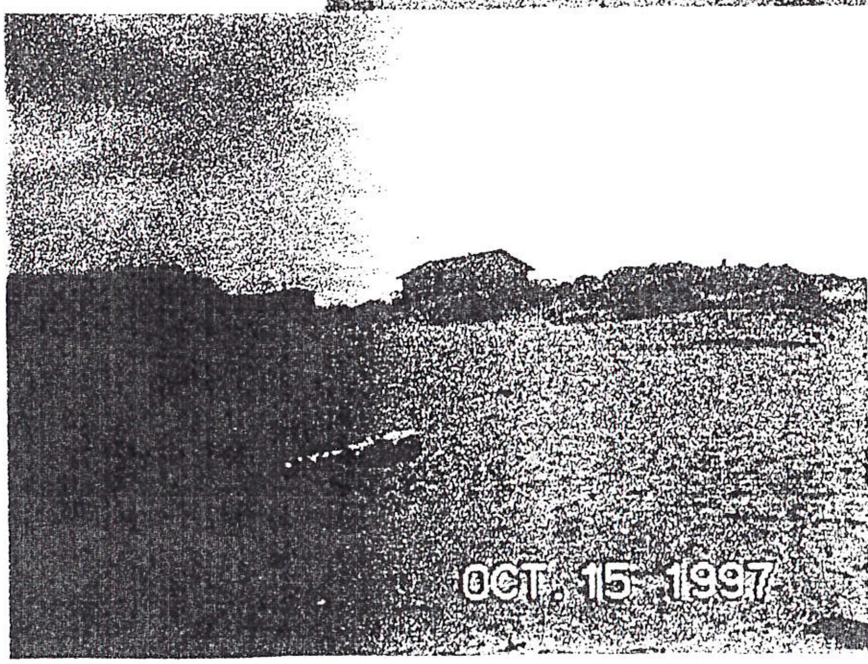


Appendix B: Frame-grabbed video images of morphologic features.



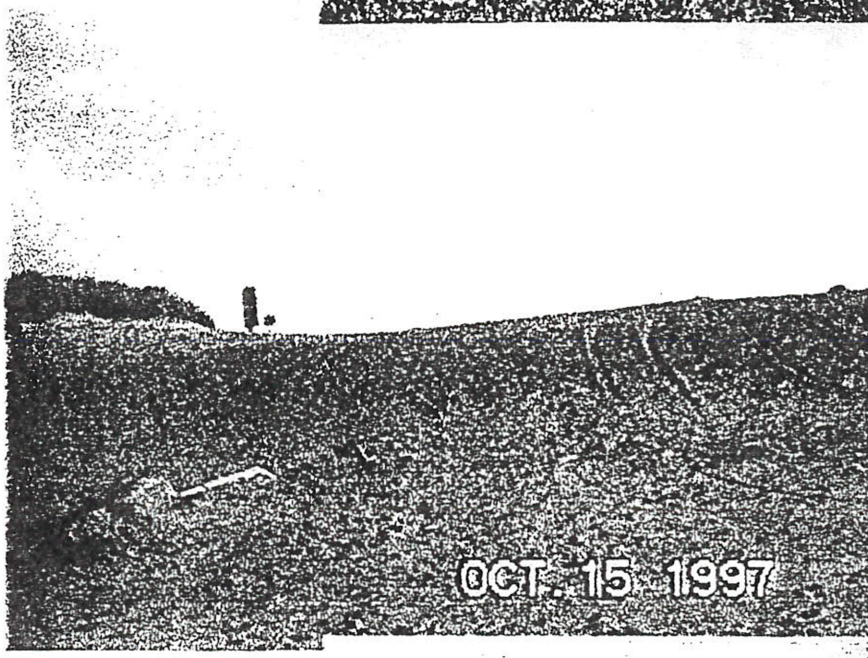
<- Plate 1.
Vegetated Foredune Crest in Nestucca Spit State Park looking north towards Cape Kiwanda

Plate 2. ->
Beach and Foreslope in Nestucca Spit State Park



<-Plate 3.
Gap in Foredune north of Nestucca Spit State Park

Plate 4. ->
Vegetated Foredune
south of The Turnaround
looking South

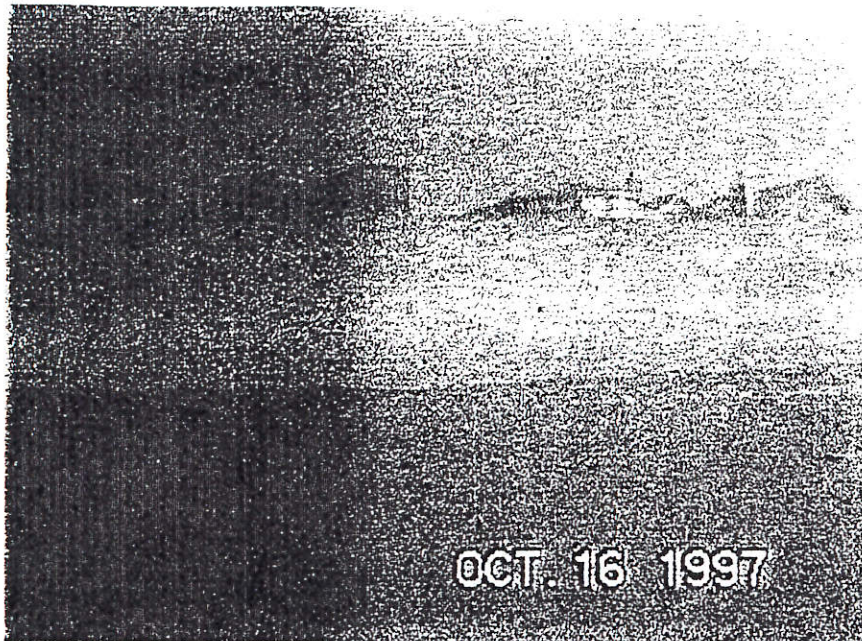


<-**Plate 5.**
The Turnaround

Note lack of vegetation
along with heavy pedestrian
and vehicular traffic

Plate 6. ->
Foreslope north of
The Turnaround

Note relative lack
of vegetation



<- Plate 7.
Foreslope north of The Turnaround

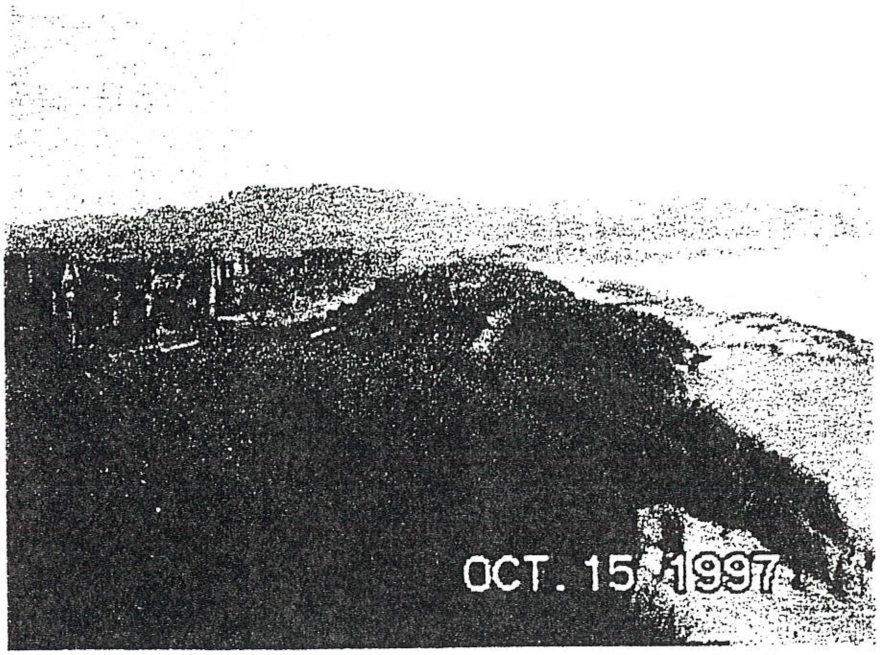
Note relative lack of vegetation and inland extent of runup

Plate 8. ->
Foreslope north of The Turnaround

Note relative lack of vegetation and inland extent of runup

<- Plate 9.
Foredune Crest north of The Turnaround

Note lack of vegetation Although not clearly evident in this image, this area is occupied by transverse dunes with north-dipping slip faces



<- Plate 10.
Foredune Crest fronting Shore Pine Village looking south towards Kiwanda Shores

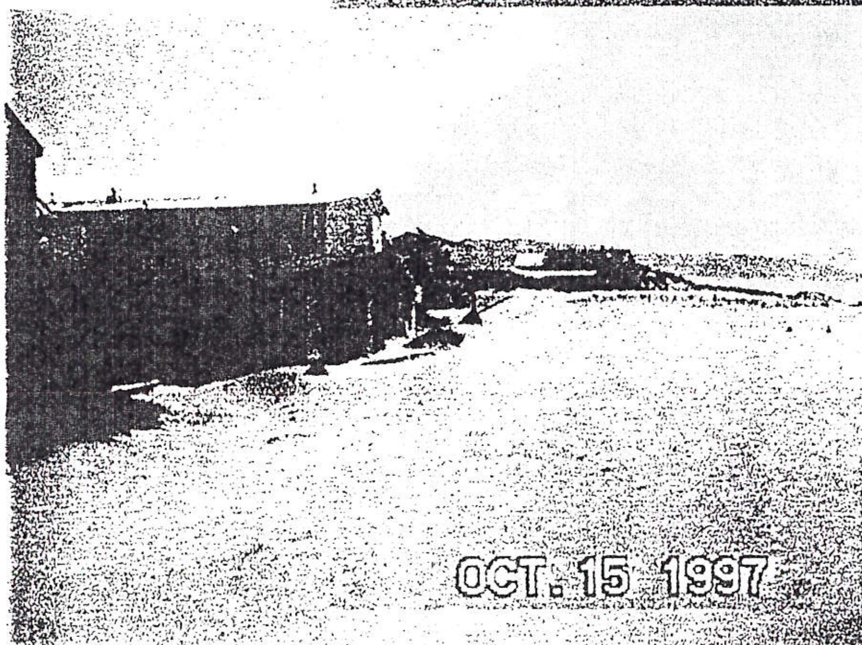
Note how dwelling are roughly in line with the foredune crest in the foreground and how the foredune crest at Kiwanda shores is 'pushed' further west than the crest in the foreground

Also note vegetation cover

Plate 11. ->
Active accumulation of wind-blown sand at the crest of the foredune shown in the above image

Note the primary foredune crest approaches 60 feet NGVD in elevation at this location

Plate 12. ->
Accreted Foreslope
fronting
Shorepine Village



<- **Plate 13.**
Foredune Crest
south of
Dory Boat Ramp

Note lack of vegetation
and active slip faces of
transverse dunes

Plate 14. ->
Foreslope south of
Dory Boat Ramp

Note relative lack
of vegetation

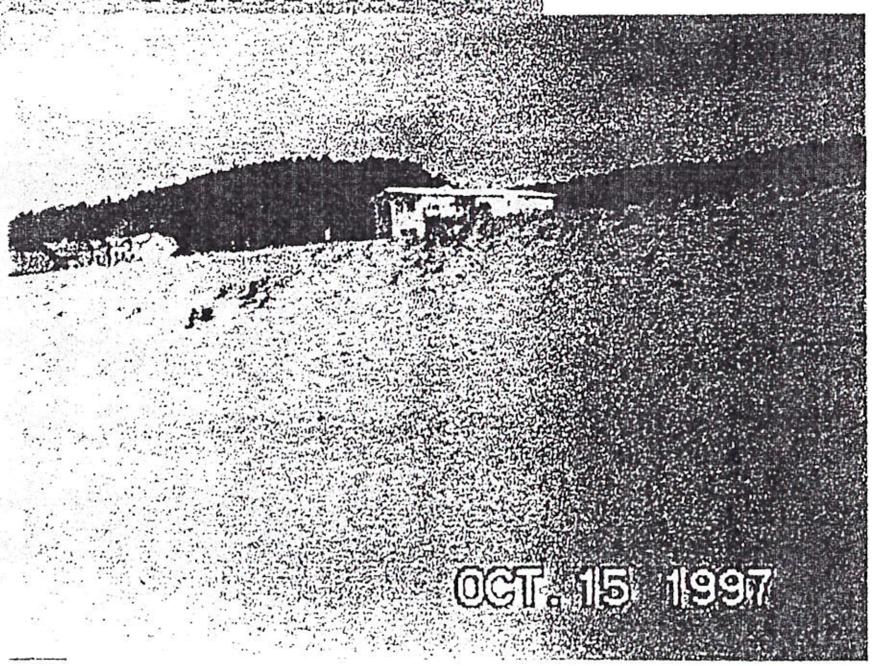
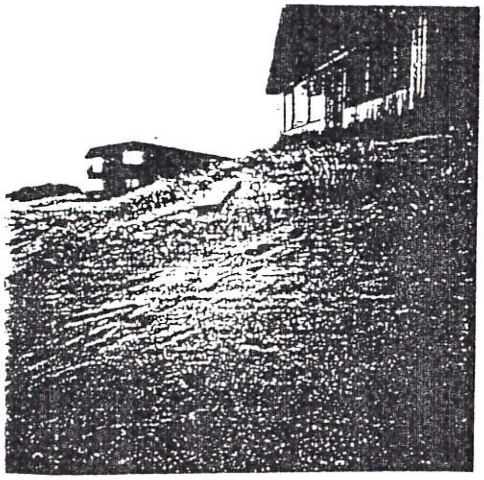


Plate 15. ->
Foreslope south of
Dory Boat Ramp

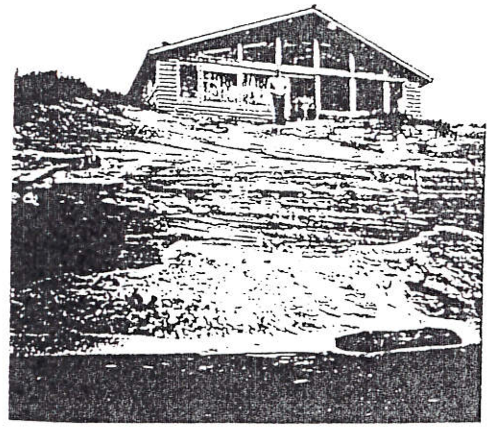
Note gravel covered
'deflation' surface

<- **Plate 18.**
Mix of Vegetation
within the
Pacific City Foredune Area

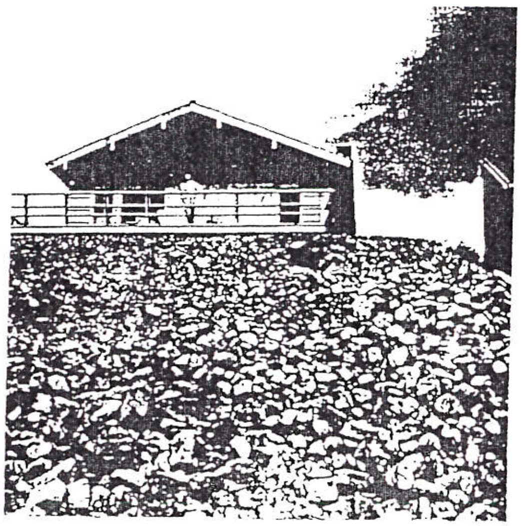
Appendix C: Photographs of shoreline change at one location through the 1970's.



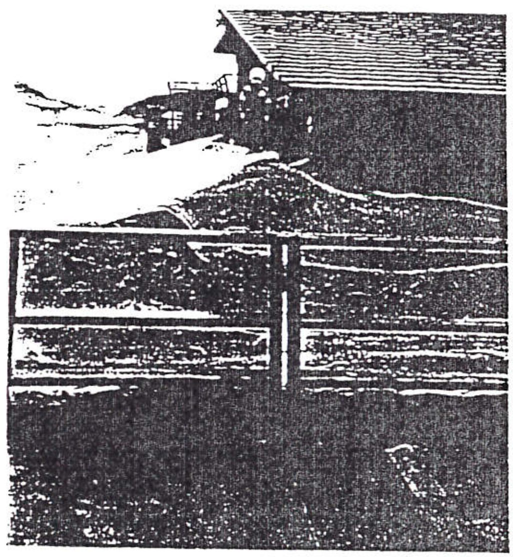
1970



1972



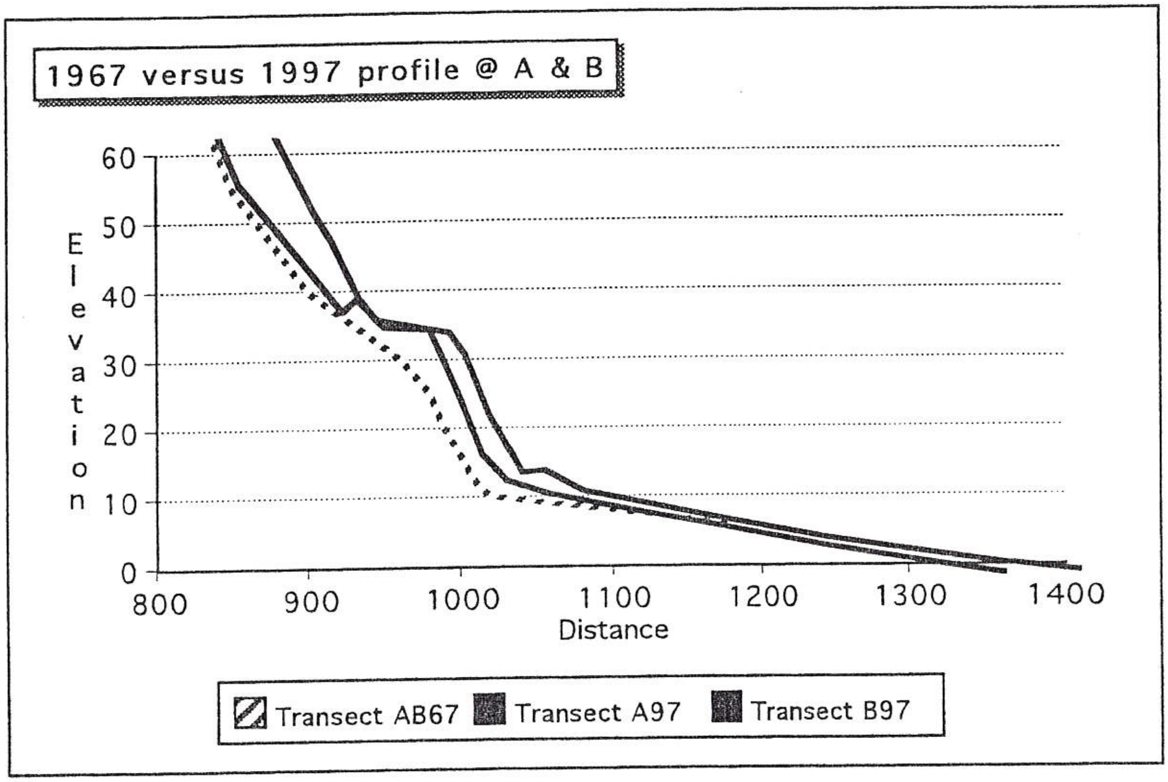
1975



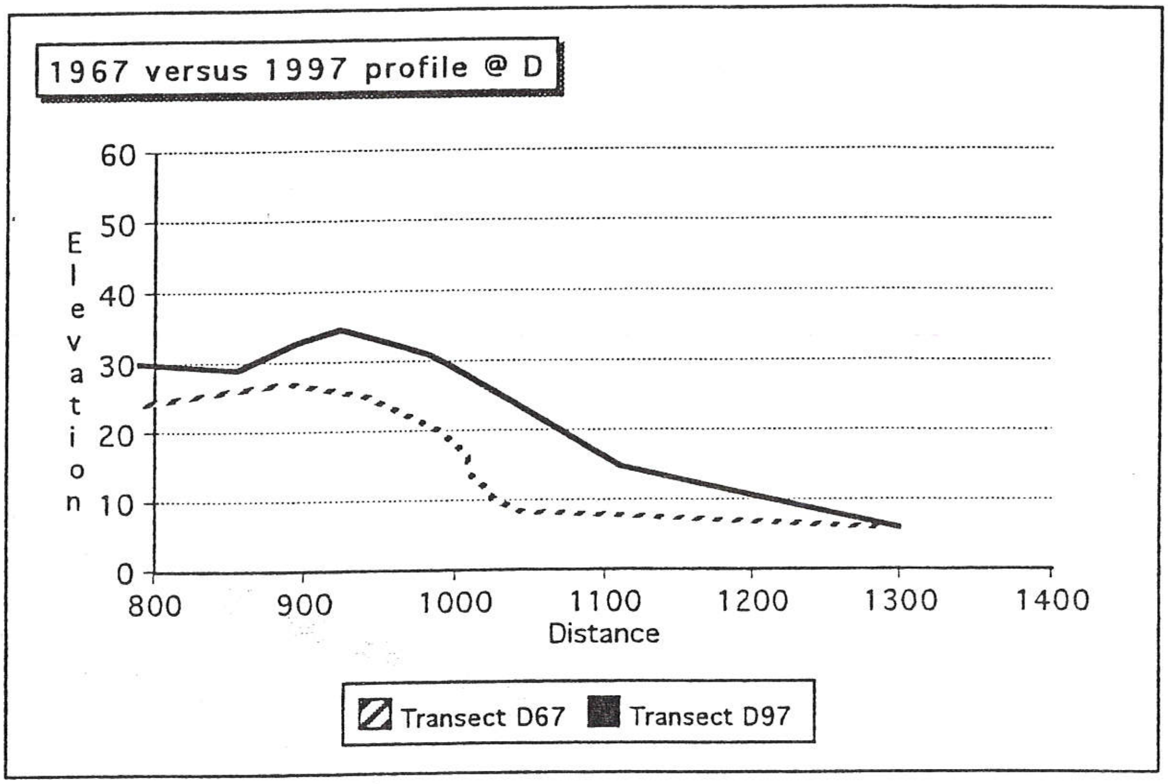
1976

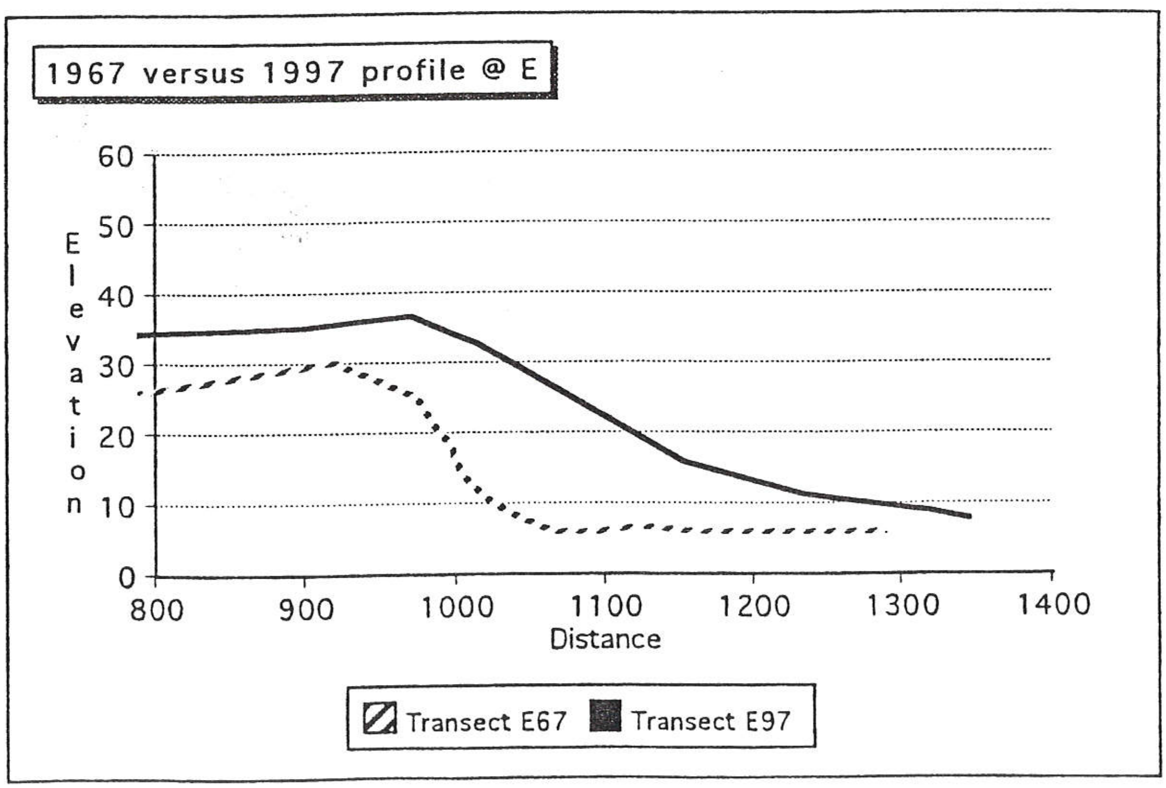
[illegible]

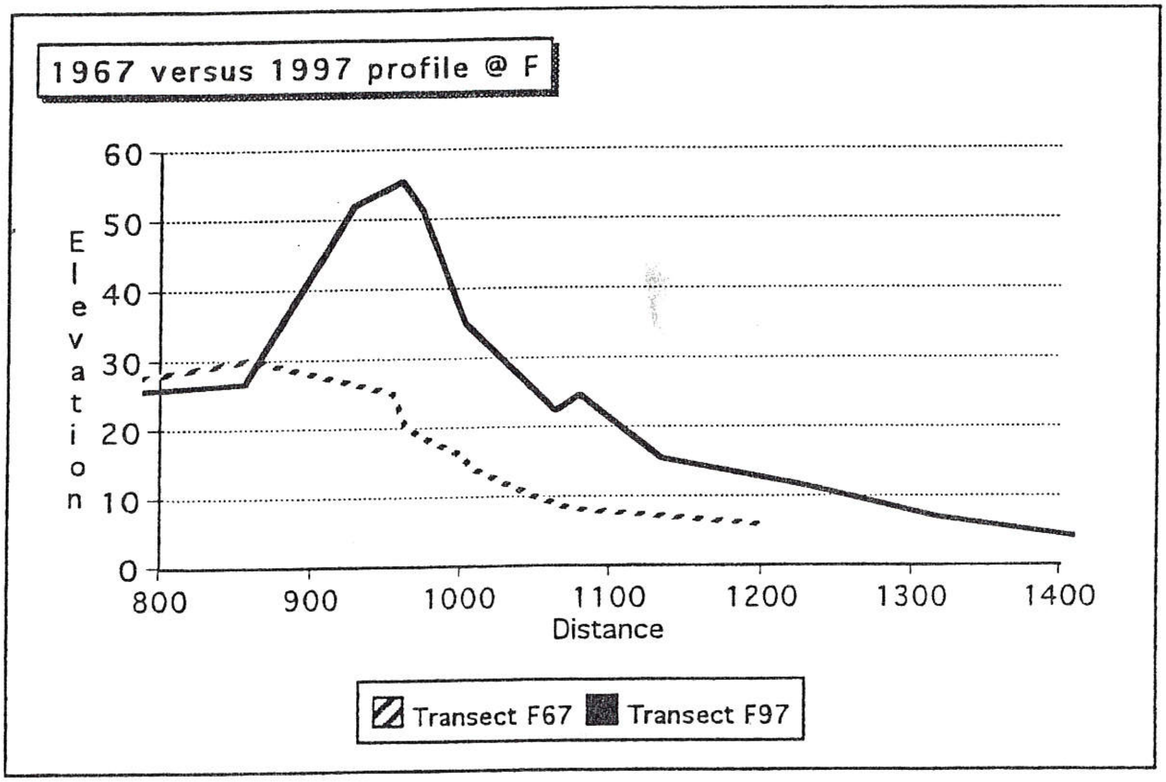
Appendix D: 1967 versus 1997 beach and dune profile pairs.

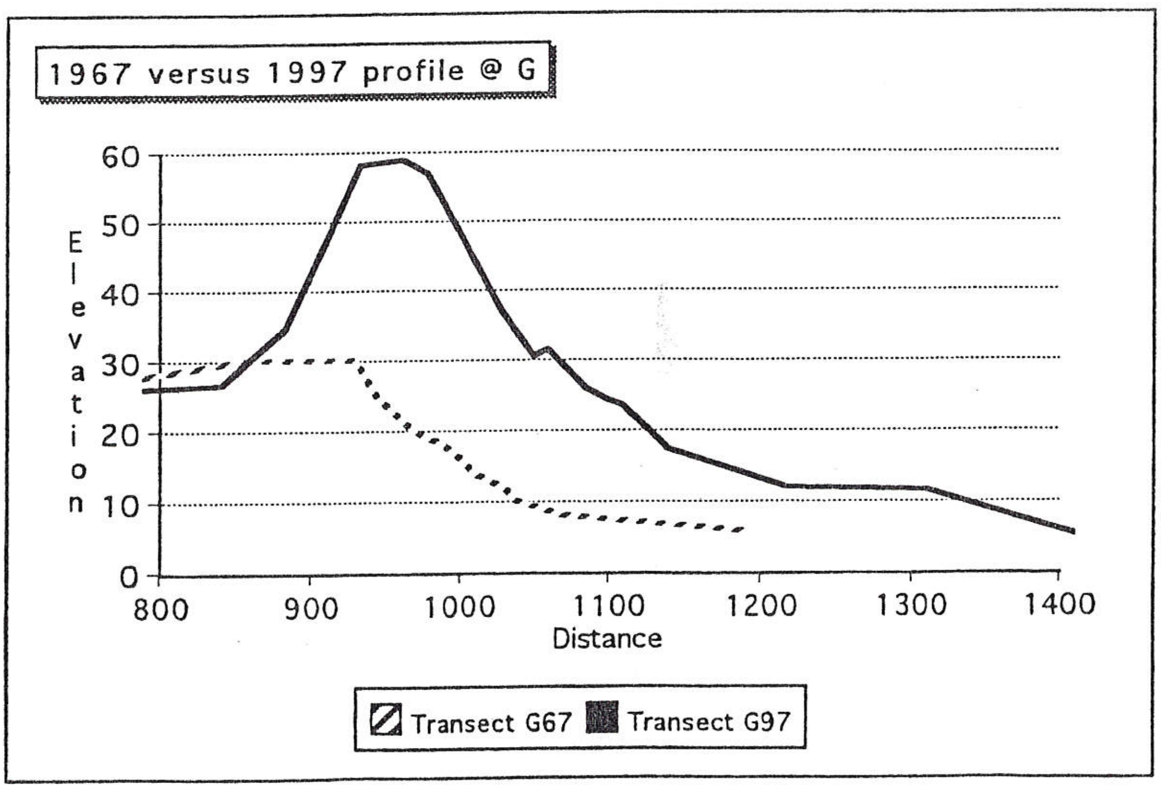


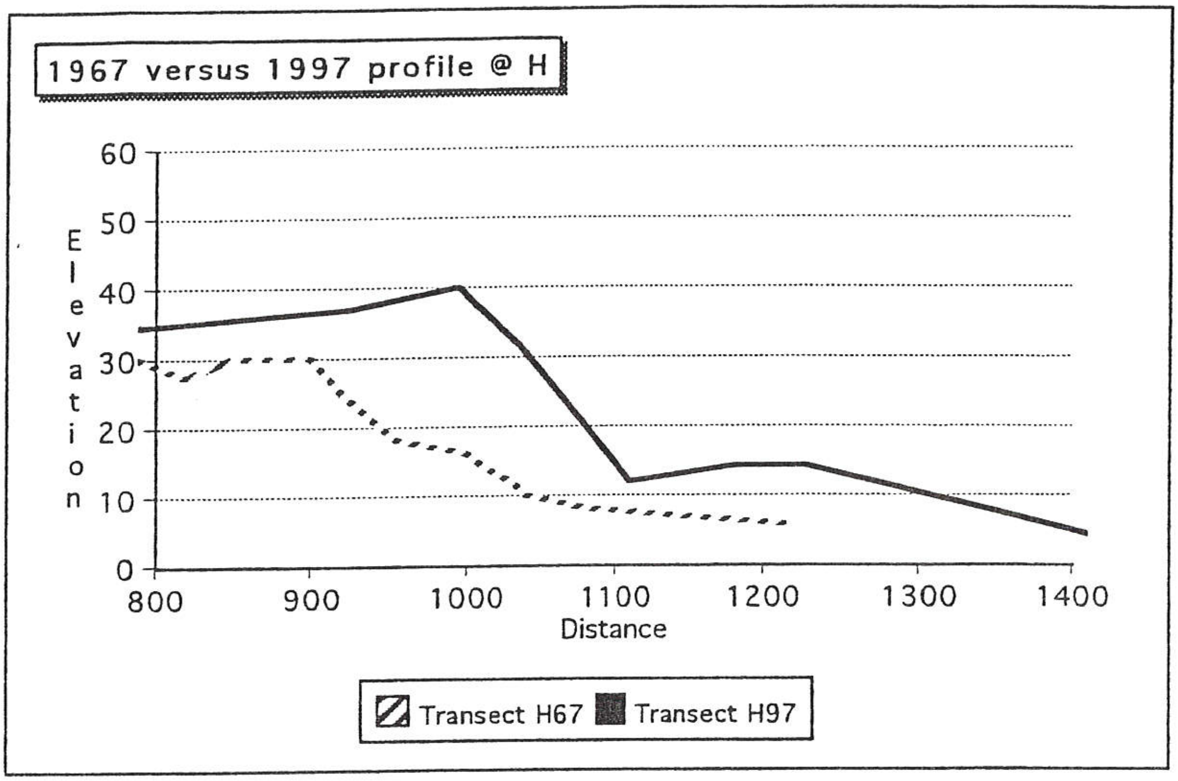
1967 versus 1997 profile @ A & B
Elevation
60
50
40
30
20
10
0
800
900
1000
1100
1200
1300
1400
Distance
Transect AB67
Transect A97
Transect B97

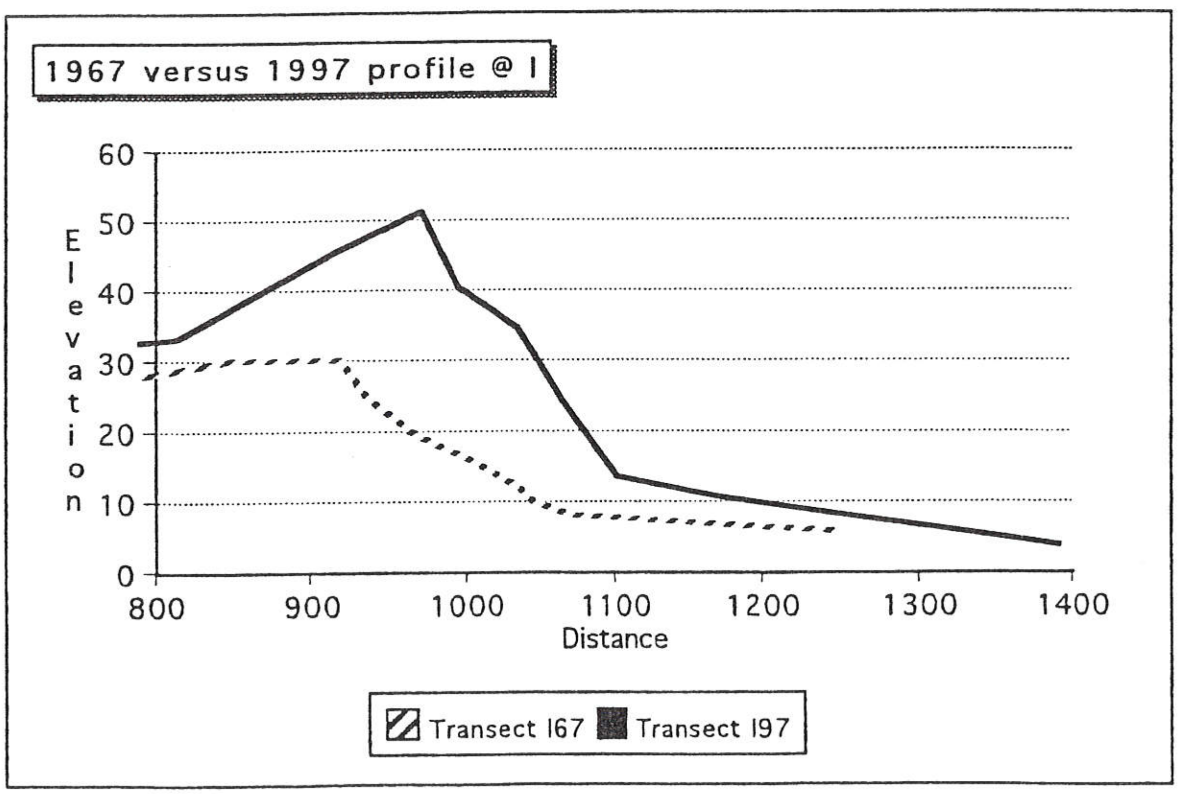

1967 versus 1997 profile @ D
Elevation
60
50
40
30
20
10
0
800
900
1000
1100
1200
1300
1400
Distance
Transect D67
Transect D97

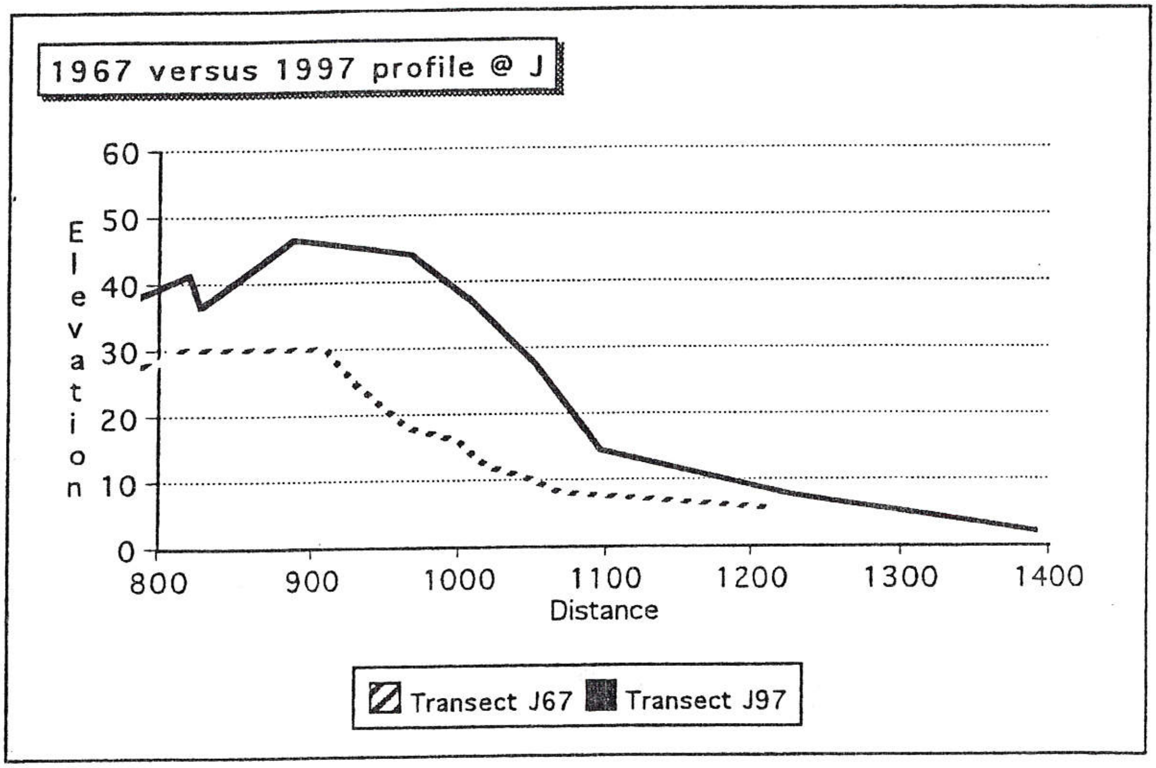

1967 versus 1997 profile @ E
Elevation
60
50
40
30
20
10
0
800
900
1000
1100
1200
1300
1400
Distance
Transect E67
Transect E97

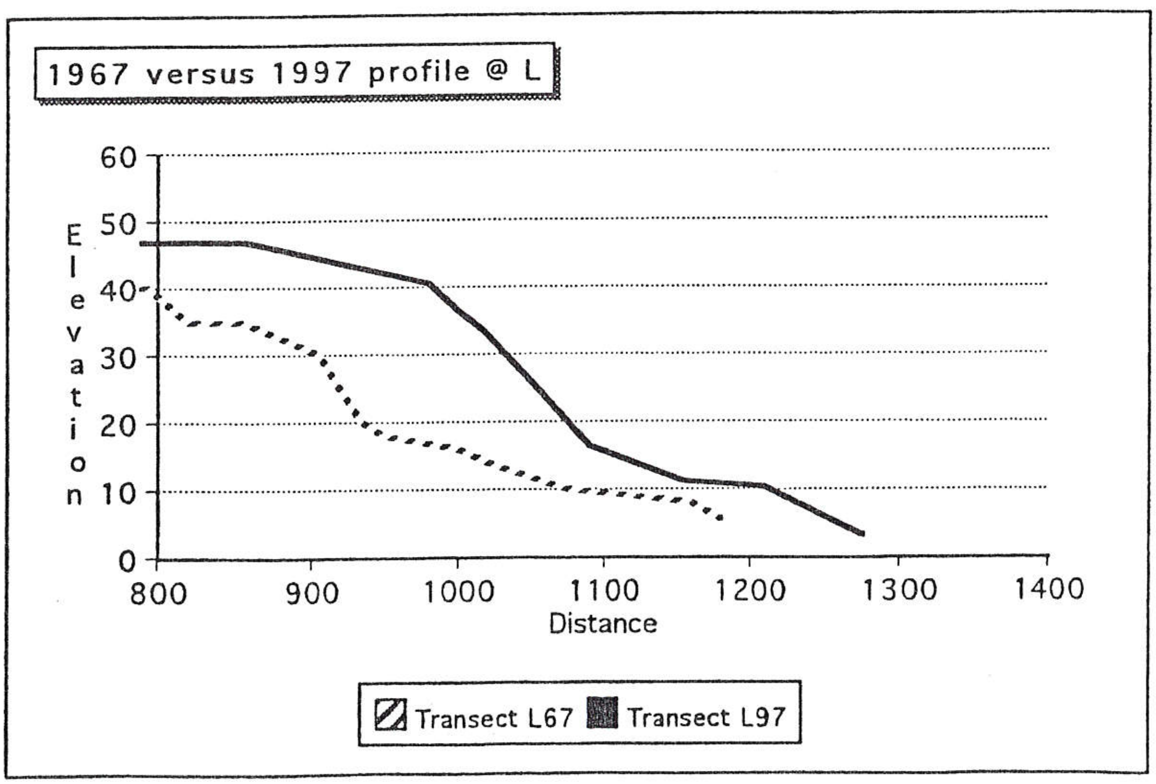

1967 versus 1997 profile @ F
Elevation
60
50
40
30
20
10
0
800
900
1000
1100
1200
1300
1400
Distance
Transect F67
Transect F97

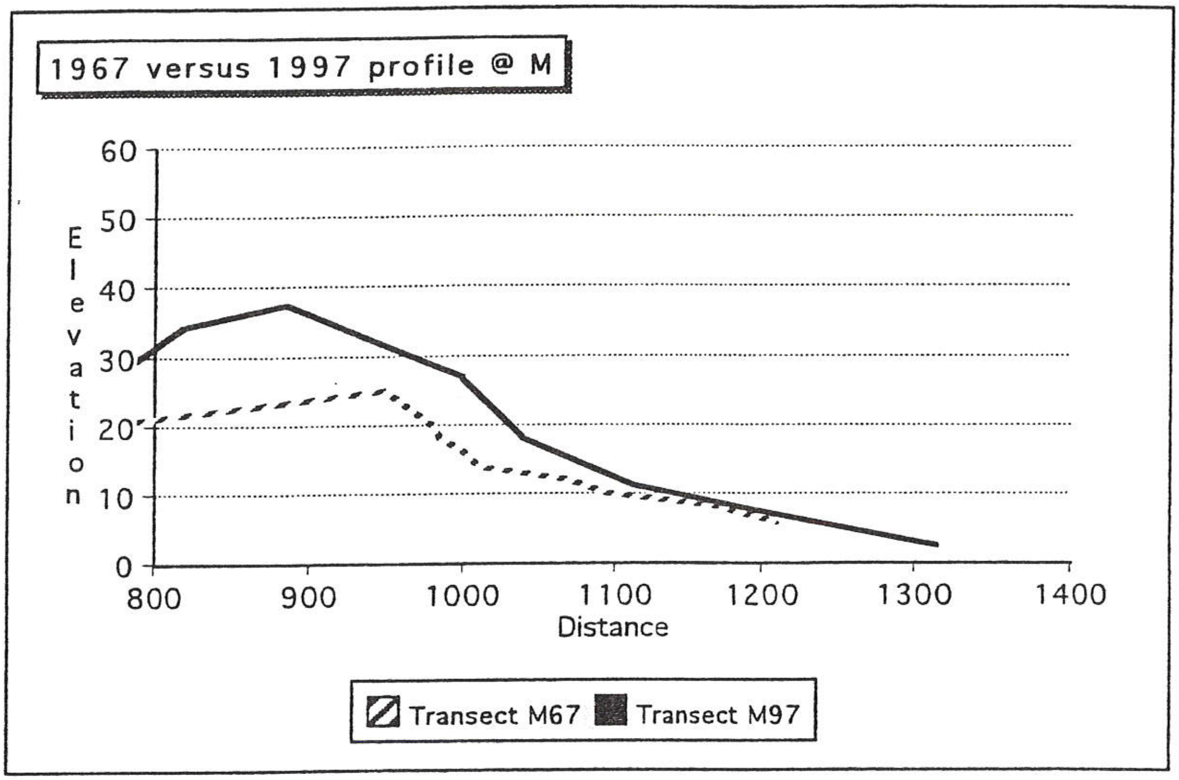

1967 versus 1997 profile @ G
Elevation
60
50
40
30
20
10
0
800
900
1000
1100
1200
1300
1400
Distance
Transect G67
Transect G97

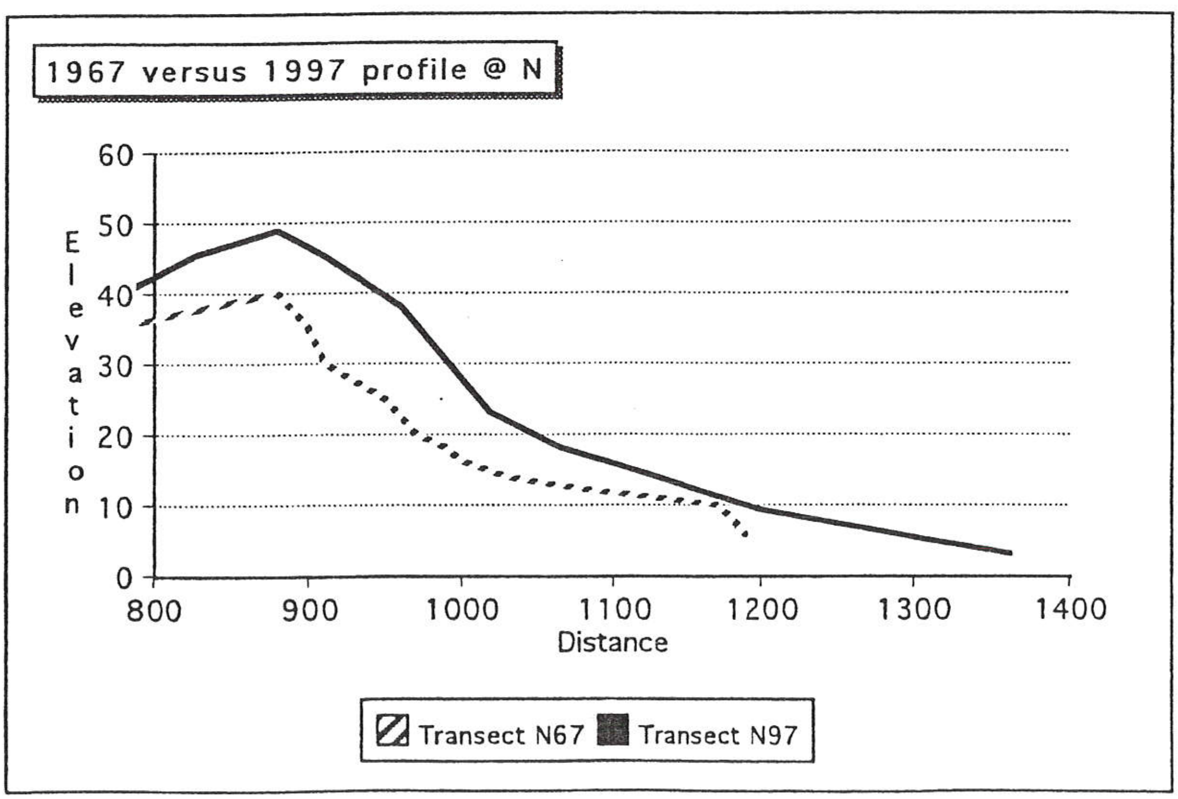

1967 versus 1997 profile @ H
60
50
40
30
20
10
0
Elevation
800
900
1000
1100
1200
1300
1400
Distance
Transect H67
Transect H97

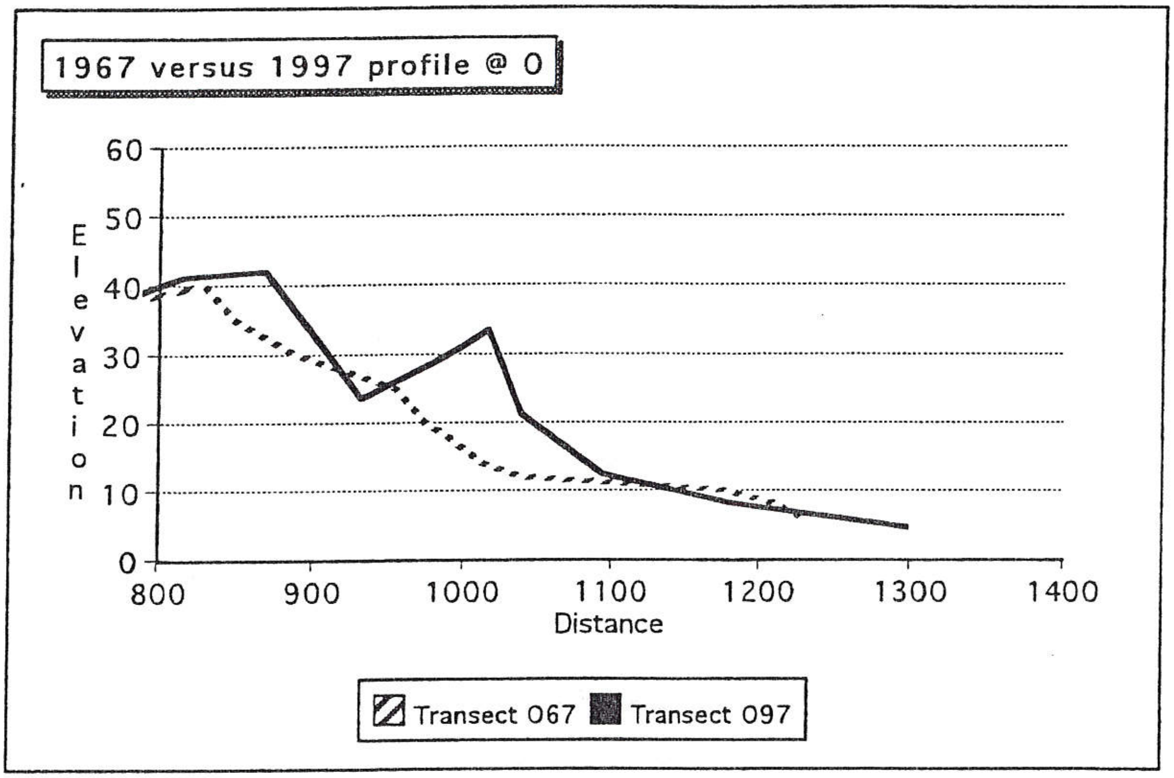

1967 versus 1997 profile @ I
60
50
40
30
20
10
0
Elevation
800
900
1000
1100
1200
1300
1400
Distance
Transect I67
Transect I97

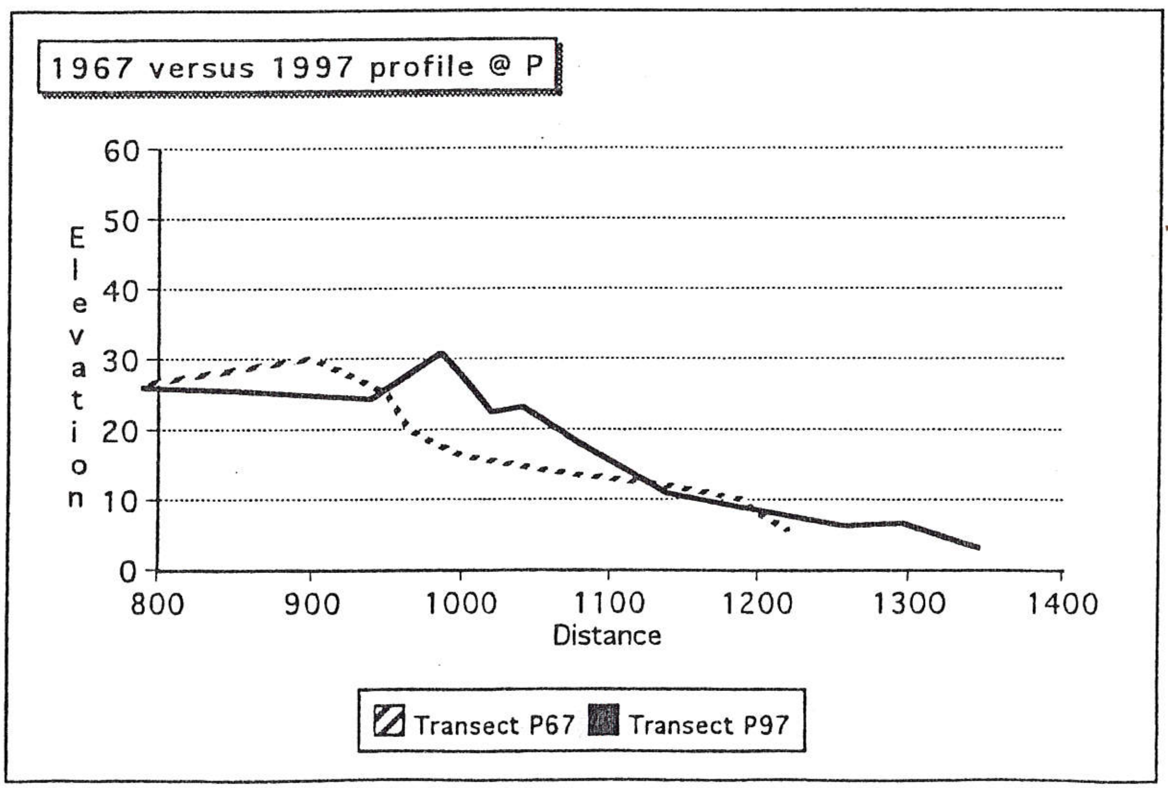

1967 versus 1997 profile @ J
60
50
40
30
20
10
0
Elevation
800
900
1000
1100
1200
1300
1400
Distance
Transect J67
Transect J97

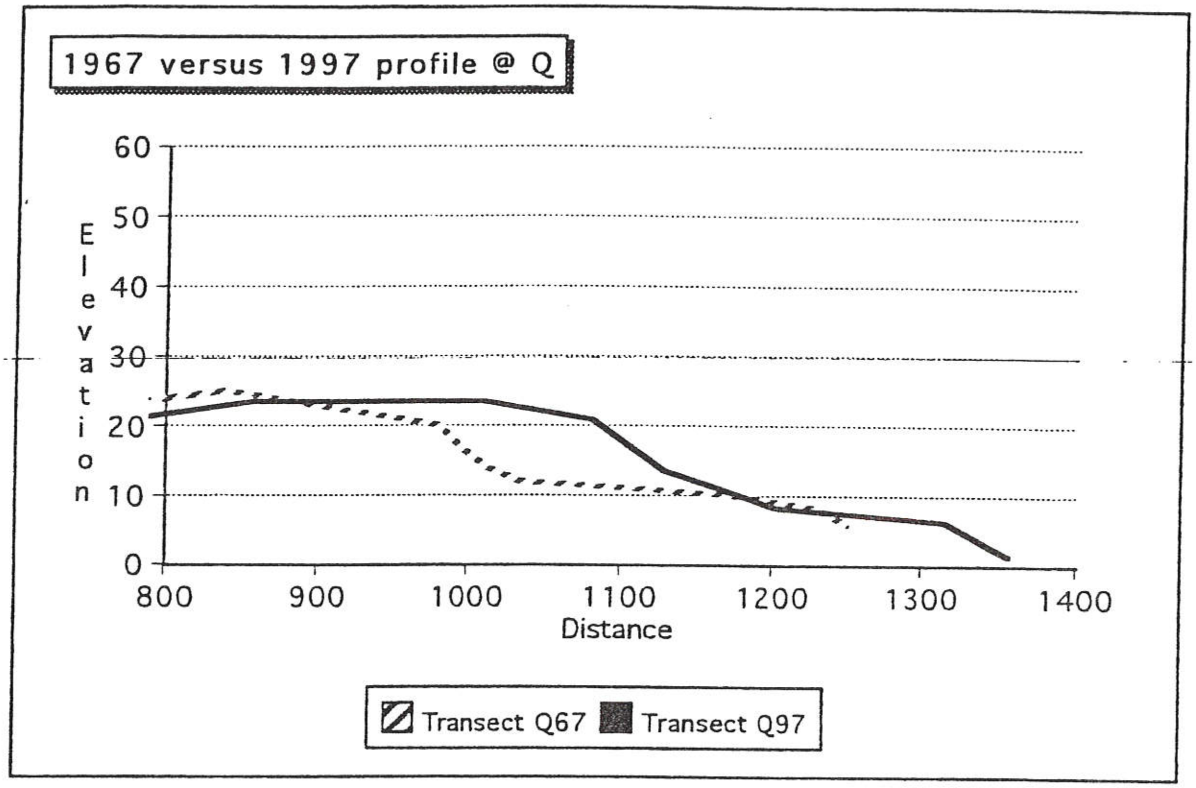

1967 versus 1997 profile @ L
60
50
40
30
20
10
0
Elevation
800
900
1000
1100
1200
1300
1400
Distance
Transect L67
Transect L97

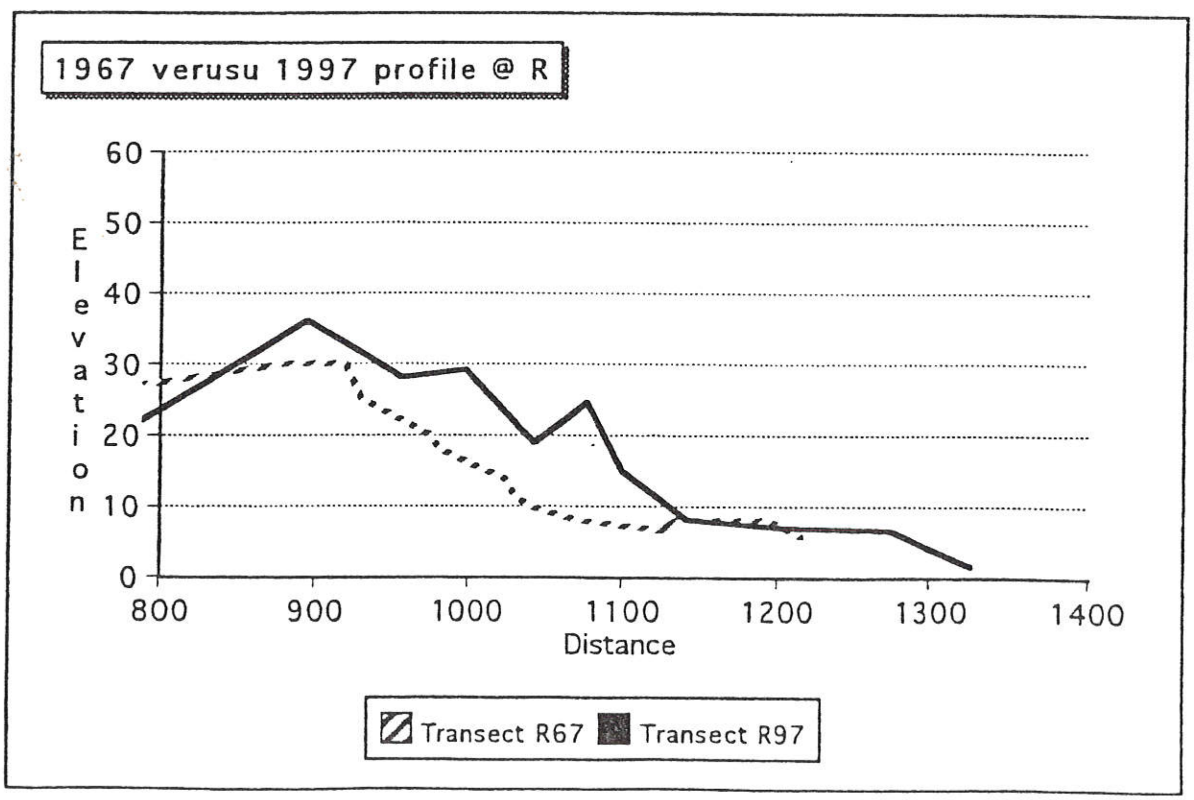

1967 versus 1997 profile @ M
Elevation
60
50
40
30
20
10
0
800
900
1000
1100
1200
1300
1400
Distance
Transect M67
Transect M97


1967 versus 1997 profile @ N
Elevation
60
50
40
30
20
10
0
800
900
1000
1100
1200
1300
1400
Distance
Transect N67
Transect N97


1967 versus 1997 profile @ O
60
50
40
30
20
10
0
Elevation
800
900
1000
1100
1200
1300
1400
Distance
Transect O67
Transect O97


1967 versus 1997 profile @ P
60
50
40
30
20
10
0
Elevation
800
900
1000
1100
1200
1300
1400
Distance
Transect P67
Transect P97


1967 versus 1997 profile @ Q
60
50
40
30
20
10
0
Elevation
800
900
1000
1100
1200
1300
1400
Distance
Transect Q67
Transect Q97


1967 verusu 1997 profile @ R
60
50
40
30
20
10
0
Elevation
800
900
1000
1100
1200
1300
1400
Distance
Transect R67
Transect R97

Appendix E: Map showing the Pacific City Foredune Management Units.