

2020

## Exhibit B



# CITY OF CANNON BEACH FOREDUNE MANAGEMENT PLAN

Photo Credit: Google Earth

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# EXECUTIVE SUMMARY

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This is an updated version of the City of Cannon Beach's previously adopted Foredune Management Plan. Revisions provide consistency with Statewide Planning Goal 18. The City of Cannon Beach's Foredune Management Plan has historically focused on Management Unit Areas; this updated Plan eliminates subarea dune management, and instead provides best practices for preventative dune maintenance, remedial grading, guidelines for maintaining access, and emergency grading options.

Over the past few decades sand has accumulated north of Haystack Rock causing substantial accretion of the dunes west of Midtown and the north end of town. Although the shoreline fronting these portions of Cannon Beach has experienced sand accretion over the past decades, other portions of the management area have been shown to be susceptible to episodic wave-induced erosion and flooding. Specifically, Tolovana North and South have experienced minor erosion. As a generalization, within city limits, areas north of Haystack Rock have experienced sand accretion, and areas south of Haystack Rock have experienced erosion between 1997 and 2016.

This plan and its implementation do not constitute a guarantee or assurance that erosion, flooding, tsunamis, and sand inundation will not impact property owners or the City. Damages related to ocean wave erosion, flooding, tsunamis, and sand accumulation is borne by the property owners and is an inherent risk of having property located in a changing environment adjacent to the Pacific Ocean

The revisions reflect best practices management for potential dune grading, while including factors affecting the stability of the shoreline and includes sand management directions for the City's foredune areas. Other documents that have been prepared to address the requirements in Statewide Planning Goal 18: Beaches and Dunes (Implementation Requirement 7), the Cannon Beach Comprehensive Plan and City of Cannon Beach Municipal Code (Chapter 17.42) include a Background Report and an Implementing Ordinance which formally outlines the procedures for carrying out prescribed management practices. Together, these materials constitute an overall plan for management of the foredune area fronting Cannon Beach.

Extensive public engagement efforts were carried out to incorporate public input to develop this updated Foredune Management Plan. Review and comment on a draft of this document will be requested from representatives of the Oregon Department of Land Conservation and Development and the Oregon Parks and Recreation Department. The technical background report which informed this plan was prepared by Jonathan Allan, Laura Gabel, and Fletcher O'Brien of the Oregon Department of Geology and Mineral Industries (DOGAMI) in 2018.

Updates to the Plan include allowing limited dune grading; grading is allowed to address sand inundation of structures, maintaining public access and limited emergency situations. Grading is no longer permitted to maintain views.

## **INTRODUCTION**

Over time, Cannon Beach's beach is susceptible to erosion. Erosion events like those documented in the background report will likely occur occasionally, in between more regular periods of accretion. The grading directions in this plan will not increase the risk of erosion, or of flooding resulting from erosion.

In between major erosion events, which in most parts of town may occur every several decades, large volumes of sand accumulate in Cannon Beach's foredunes. Windblown sand reaches through the foredune and inundates private properties and public streets.

This Foredune Management Plan allows for the building up eroded foredunes and removing sand inundation. This plan is focused on measures to protect the health and safety of the community by providing foredune grading measures that complement the erosion and flood hazard mitigation benefits provided by the foredunes.

## **GRADING GOALS & OBJECTIVES**

### **Overall Objective**

The overall objective is to maintain and stabilize the existing foredunes and encourage sand deposition on the seaward portion of the foredunes with the goal to at least maintain existing foredune widths. When necessary, moving sand seaward of the foredunes makes sand available for along-shore transport to promote better sand distribution.

### **Goals**

The overall goals to be balanced by the foredune management plan are:

1. To ensure the dunes sustain an adequate sand volume in order to withstand the erosional effects of extreme weather and to minimize any potential for wave overtopping and inundation (flooding) of backshore;
2. To strengthen weak points in the dune system by repairing areas subject to localized blowouts from wind or waves in order to prevent the dune buffer from weakening and potentially being breached during a storm;
3. To maintain valuable habitat for a wide range of plants and animals, such as shellfish, including razor clams, and in some cases rare species; and
4. To maintain the integrity and natural beauty of the dunes, while providing for the necessary functions of public access, facilities and utilities.

## FOREDUNE CONFIGURATION

Foredunes lowered by grading must maintain a minimum elevation of the FEMA BFE+4 feet to comply with Statewide Planning Goal 18. Foredune width is measured seaward from the Statutory Vegetation Line. Foredune width must not decrease with grading activity.

The City of Cannon Beach wants to add an additional height requirement to protect the community from the effects of climate change. The National Ocean and Atmospheric Administration (NOAA) has created sea level rise (SLR) scenarios beginning in the year 2000 and projecting as far out as 2100. For communities in Clatsop County estimates are based on data gathered from the tide gate in Astoria. The table to the left summarizes the estimated rise in sea level starting in the year 2000 according to the Extreme scenario which predicts for the highest level of sea level rise. Based on these projections, the City elected to add a one-foot safety factor to the state defined foredune height of the current BFE + 4 feet.

Year	Projected Rise in Sea Level in Feet
2020	0.39
2040	1.41
2060	3.28
2080	5.84
2100	9.19

**Table 1: Projected sea level rise for Cannon Beach under an "Extreme" scenario from NOAA. <sup>1</sup>**

The City of Cannon Beach will ensure that grading does not negatively impact wildlife, including razor clams. Evidence suggests that razor clams can have a survival rate of 100% for burial up to 12 cm (4.7 in) and a 70% survival rate when the burial depth on the beach is doubled to 24 cm (9.5 in).<sup>2</sup> Any proposal for a grading project with a burial depth on the beach of more than 12 cm will not be approved by the City. The City encourages sand to stay within the foredune.

Sand that is graded from the foredune crest to the fore-slope must be placed at a gradient not exceeding 25-33%.<sup>3</sup> Alternatively, sand may be graded back toward the statutory vegetation

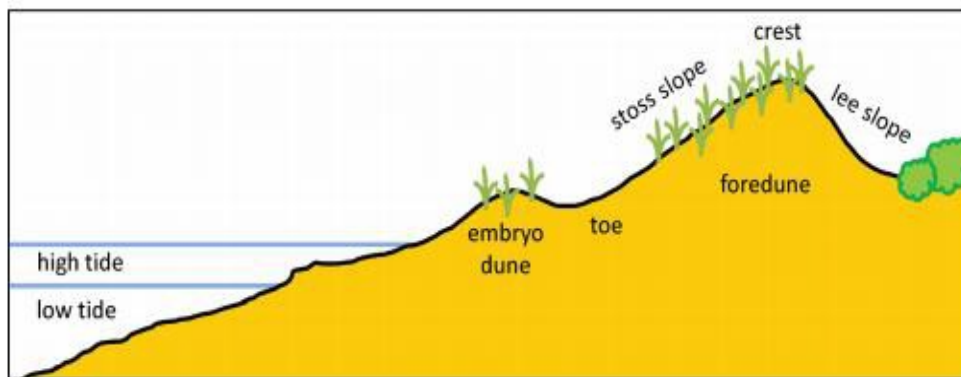


Figure 1: Diagram of a coastal dune system. Figure from US Army Corps of

line to fill areas of interdunal trough. This grading should minimize impacts to vegetation by minimizing transport distances and fill relatively small areas higher, rather than filling

<sup>1</sup> NOAA Office for Coastal Management. (2015). Sea Level Rise Viewer.

<sup>2</sup> Vavrinec, J., Kohn, N.P., Hall, K.D., Romano, B.A. (2007). *Effects of Burial by the Disposal of Dredged Materials from the Columbia River on Pacific Razor Clams (Siliqua patula)* (Report PNNL-16350).

Retrieved from Pacific Northwest National Laboratory

[https://www.pnnl.gov/main/publications/external/technical\\_reports/PNNL-16350.pdf](https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-16350.pdf)

<sup>3</sup> Oregon Department of Land Conservation and Development (1989). *Dune Management Planning: A Guide to Preparing a Dune Management Plan as Provided for in Statewide Planning Goal 18 (Beaches and Dunes)*.

large areas lower. The plan also encourages grading to mimic natural deposition patterns and avoid obvious signs of man-made grading, such as excessive flat areas or evenly spaced plantings of vegetation.

## **PREVIOUSLY PERMITTED GRADING**

The City of Cannon Beach has historically permitted three forms of foredune grading: foredune grading for views, maintenance grading and remedial grading. Where previous plans allowed large volumes to be moved over a multi-year grading plan to allow grading for views, this plan provides guidelines for limited, one-year, preservation grading plans, to be approved under the Cannon Beach Planning Commission's Conditional Use Permit and remedial grading permits to be issued under the City's development permit process. With this Foredune Management Plan Update, the City of Cannon Beach no longer permits grading for views.

The City's previous foredune management plan addressed four management units based on the management unit boundaries specified in the 1997 plan.<sup>4</sup> These boundaries separated areas with distinct foredune, development, and recreation conditions. The previous foredune management plan anticipated unique plans within the historic downtown and presidential management units to achieve the flood and erosion prevention, access, and recreational objectives in each area. The policies of the previous plan were implemented through the Comprehensive Plan and City Zoning Ordinance and any projects outside of these areas required amendments to the Comprehensive Plan, along with management area plans specific to the management units.

FEMA Flood Insurance Rate Maps (FIRM) for Cannon Beach were updated in 2010 and again in 2018. In 2018 Oregon DOGAMI published "Beach and Shoreline Dynamics in the Cannon Beach Littoral Cell; Implications for Dune Management".<sup>5</sup> Base Flood Elevations (BFEs) along with the DOGAMI report provided the basis for this plan. The most up to date BFE should be used in implementing the policies from this plan.

## **TYPES OF GRADING & PERMITTING PROCESS**

Grading in Cannon Beach may only be performed under a permit issued through the Community Development Department. All grading projects also require permits from the Oregon Parks and Recreation Department (OPRD). Grading is divided into three types, each with its own permitting process: Remedial, Preservation, and Emergency/Access.

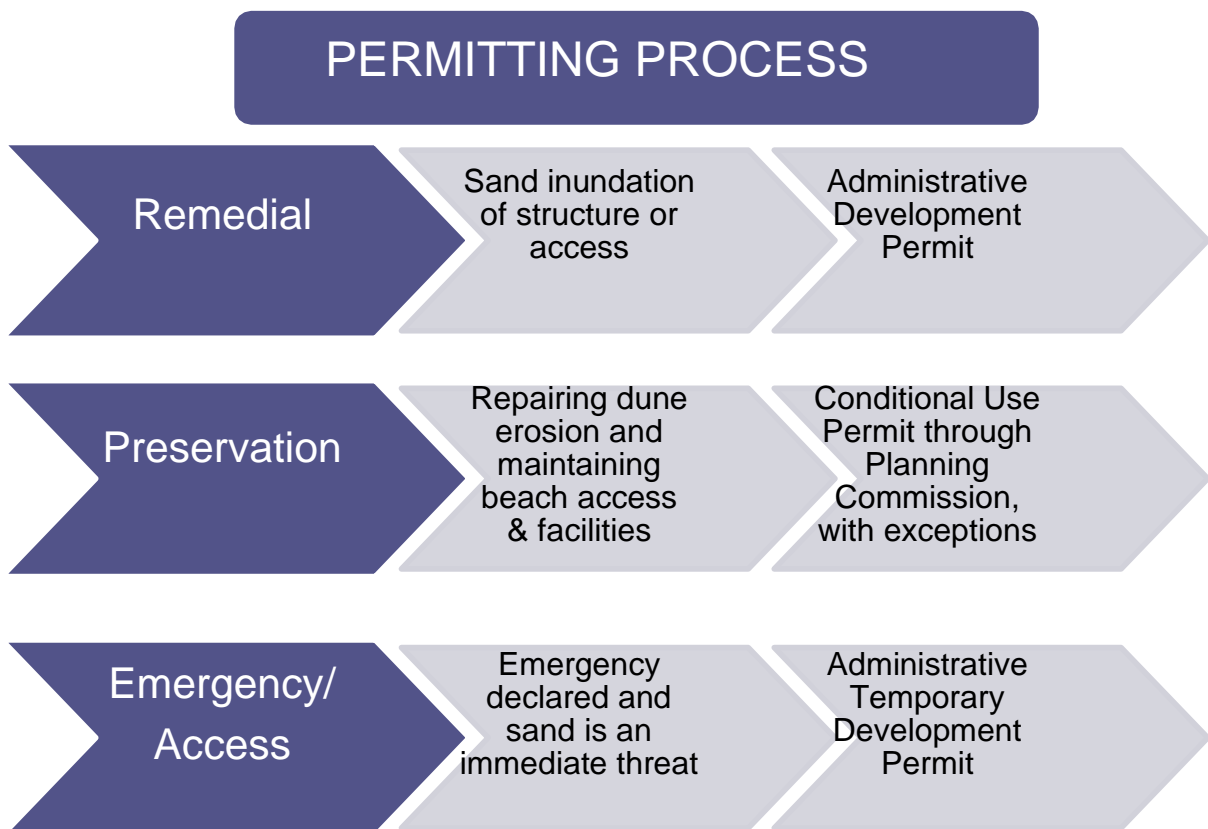
All grading in Cannon Beach must comply with and be permitted under this newly adopted plan and associated ordinances. No "vested," or "grandfathered" permits are allowed.

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<sup>4</sup>Rosenfeld, C. L. (1997). *Cannon Beach: An Integrated Approach to Sand Management*. And Ordinance 01-02, 13. *Presidential Streets Sand Management Strategy*.

<sup>5</sup>State of Oregon, Oregon Department of Geology and Mineral Industries. 2018. Special Paper 49. *Beach and Shoreline Dynamics in the Cannon Beach Littoral Cell; Implications for Dune Management*. By Jonathan C. Allan, Laura L. Gabel, and Fletcher O'Brien.





## REMEDIAL GRADING

“Remedial grading” refers to the clearing of sand necessary to maintain the function of a structure and includes the removal of sand that has built up against exterior walls, doors, or windows and that blocks access to a residential or commercial structure, or any public facility, utility or infrastructure. In this regard, directions for remedial grading around residential or commercial structures are as follows:

1. Rear yard sand may be removed to the level of the top sill of the foundation within 35 feet of the structure. From the 10-foot line, the graded area shall slope upward to the elevation of the fronting foredune. This slope shall not exceed 50%.
2. Side yard sand that is landward of the structure may be removed to the top of the sill of the foundations, provided grading in this area does not create a slope in excess of 50% with adjacent properties.
3. Where the front yard is seaward of the structure, sand may be removed to the level of the top sill of the foundation within 35 feet of the structure. From the 10-foot line, the graded area shall slope upward of the elevation of the fronting foredune. This slope shall not exceed 50%.

4. Grading shall not lower the front yard below the level of adjacent streets or roads, except to clear sidewalks or driveways.<sup>6</sup>

Areas graded more than three feet in height shall be immediately replanted. All graded sand must remain within the management area. Graded sand should be used to fill low dune areas within individual management units. Graded sand may also be used to nourish identified areas as needed. The height of the foredune shall not be lowered.

Fire-resistant species are the preferred stabilizing vegetation within twenty-five feet of existing dwellings or structures. Fire-resistant vegetation shall only be planted when the foreslope and crest of the dune are adequately stabilized to prevent significant accumulation of windblown sand.

Remedial Grading Development Permits are issued administratively through the Cannon Beach Community Development Department.

## **PRESERVATION GRADING**

Grading or sand movement may be allowed in active dune areas only if the area is committed to development, meeting the requirements of Comprehensive Plan Foredune Management Policy and achieve a balance of these four objectives:

1. To ensure the dunes sustain an adequate sand volume in order to withstand the erosional effects of extreme weather and to minimize any potential for wave overtopping and inundation (flooding) of backshore;
2. To strengthen weak points in the dune system by repairing areas subject to localized blowouts from wind or waves in order to prevent the dune buffer from weakening and potentially being breached during a storm;
3. To maintain valuable habitat for a wide range of plants and animals, such as shellfish, including razor clams, and in some cases rare species; and
4. To maintain the integrity and natural beauty of the dunes, while providing for the necessary functions of public access, facilities and utilities.

Preservation grading in Cannon Beach may only be performed under an approved Conditional Use Permit, issued by the Community Development Department, through the provisions of Chapter 17.42 of the Cannon Beach Municipal Code. Preservation Grading does not include grading necessary for the repair, maintenance or installation of stormwater outfalls or facilities, including infiltration and water quality systems.

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<sup>6</sup>Oregon Department of Land Conservation and Development (1989). *Dune Management Planning: A Guide to Preparing a Dune Management Plan as Provided for in Statewide Planning Goal 18 (Beaches and Dunes)*.

This plan provides the general guidelines and conceptual approach to foredune grading and management in Cannon Beach. It does not provide specific designs for specific areas within the planning area, nor does it consist of a permit for actual grading projects.

Designs shall consider the existing and proposed foredune configurations nearby. Adjoining projects shall be designed to complement each other in terms of erosion and flood protection, public access, and resource integrity.

All preservation grading projects require permits from OPRD and a Conditional Use Permit (CUP) from the City of Cannon Beach approved by the City's Planning Commission. Written permission from all property owners must be obtained by any permit applicant seeking to grade on private property. Dune management activities generally will not be funded by the City. This means that property owners must pay for a range of activities associated with dune grading, including: the creation of permitted area plans, obtaining permits for individual grading projects, hiring consultants to design grading projects, and monitoring grading projects. Property owners desiring to grade may consider a variety of options to collectively finance grading activities including development of a taxing district or local improvement district.

Organized parties may begin implementing this plan immediately after it is adopted, but it may take time for the landowners and others who want to carry out the grading project to organize themselves in a way that provides for collective decision-making and financing for applying for permits, paying for grading, and managing the grading contractors and consultants.

Preservation Grading Plan Conditional Use Permits must meet the Cannon Beach Planning Commission's Standards and Conditions of Approval.

## **EMERGENCY MEASURES & ACCESS MANAGEMENT**

During times of extreme weather events sand may be dramatically shifted due to winds, tides or wave effects causing sand inundation. In these instances, when structures, facilities, utilities, public Rights of Way, or infrastructure is inundated or access compromised, homeowners and public officials may need to perform emergency measures under a 'temporary' development permit and "emergency" OPRD permit. The City reserves the right to declare emergency events and grant temporary development permits to allow the City to move sand from City facilities, structures, utilities and infrastructures to protect the public welfare. After the emergency situation is mitigated, the public or private entity should complete the development permit process with the Community Development Department.

All other grading should be done under an approved Administrative Development Permit or Conditional Use Permit, issued by the Community Development Department, through the provisions of Chapter 17.42 of the Cannon Beach Municipal Code.

## **IMPLEMENTATION & BEST PRACTICES**

### **METHODS OF SAND REMOVAL**

There is one method of sand removal proposed in Cannon Beach. This method is commonly used in Oregon and other coastal areas. It involves using a bulldozer to move dune sand seaward and placing the sand along the seaward face of the dune. Once the sand is placed in this location the wind moves the sand within the littoral cell. This activity may occur in November through March.

### **TIMING OF SAND REMOVAL**

The 2018 Background report suggests that the best time for preservation grading to occur is late spring/mid-summer and that there are challenges associated with the activity regardless of which time of year it occurs. The City of Cannon Beach collected public comment and the Planning Commission considered when is the best time of year to carry out this activity. After considering multiple factors, such as wind and wave patterns with the tourist season, the City determined preservation grading may occur in November through March.

Due to the nature of remedial and emergency/access grading, more flexibility is provided for methods and timing of sand removal.

### **VEGETATION PLANTING AFTER GRADING**

Areas disturbed by grading or other sand removal shall be revegetated immediately after the activity. Appropriate signage should be placed to discourage beach users from entering and disturbing planted areas while the plants are getting established.

A first planting in the area shall consist of beach grass. There are three species of these grasses.<sup>7</sup> European beach grass (*Ammophillia arenaria*) currently dominates the dunes throughout Cannon Beach; the City is interested in exploring alternatives.

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<sup>7</sup> There are three types of grass that are discussed in this plan. *Ammophillia arenaria* is European beach grass and is currently found in Cannon Beach. *Elymus mollis* is a dune grass that is native to Oregon. *Ammophila breviligulata* is a non-native American dune grass introduced from the Eastern U.S.

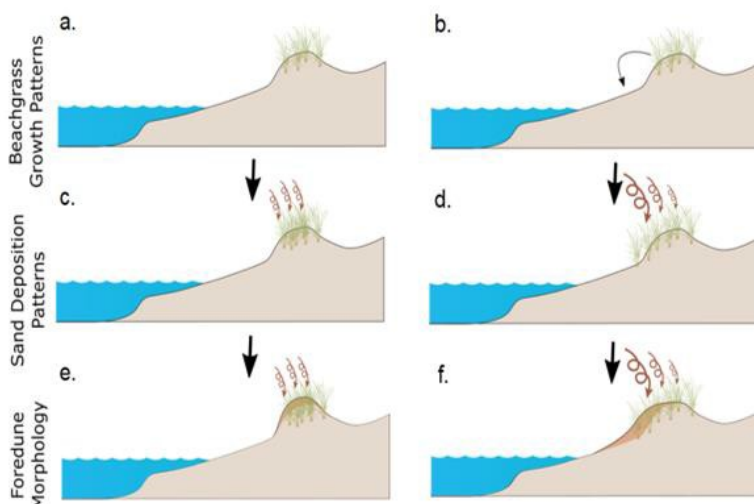
## How do the two beachgrass species create different dune shapes?

### European beachgrass

Dense, vertical growth form  
Taller, narrower foredunes

### American beachgrass

Less dense, horizontal growth form  
Shorter, wider foredunes



Biel, Hacker, Ruggiero 2019 *Journal of Geophysical Research*

European beach grass traps sand and forms tall and narrow dunes, whereas, native American dune grass (*Elymus mollis*) and American beach grass creates shorter and wider dunes.<sup>8</sup> These grasses could be used together to stabilize foredunes post-grading. It is important that European beach grass be planted closer to buildings. Applicants may propose planting plans that utilize American dune grass towards the front of the dunes. These plans should be prepared by a professional who will consider the importance of protecting existing infrastructure.

Secondary planting in the backslope to make the vegetation more fire resistant may include Salal, Evergreen Huckleberry, Purple Beach Pea, Seashore Lupine, and Tree Lupine. Secondary species should be planted directly in the beach grass. For additional information regarding vegetation maintenance refer to Carlson, et al., 1991.<sup>9</sup> No state listed noxious weeds may be used to revegetate foredunes.

Fire-resistant species are the preferred stabilizing vegetation within twenty-five feet of existing dwellings or structures, but fire-resistant vegetation shall only be planted when the fore-slope and crest of the dune are adequately stabilized to prevent significant accumulation of windblown sand.

<sup>8</sup>Zarnetske, et al (2012). Biophysical feedback mediates effects of invasive grasses on coastal dune shape. *Ecology* 93(6), 1439-1450.

<sup>9</sup>Carlson, J., Reckendorf, F., and Temyik, W. 1991. Stabilizing Coastal Sand Dunes in the Pacific Northwest. USDA Soil Conservation Service SCS Handbook 687, August 1991. 53p.

## VEGETATION PLANTING SPECIFICATIONS

European beach grass<sup>10</sup> currently dominates the dunes in Cannon Beach. This grass has been shown to build tall and narrow dunes.<sup>11</sup> The City desires an alternative dune shape. A lower and wider dune provides storm protection. Research demonstrates that the two types of American beach grass/dune grass create shorter and wider dunes than European beach grass. These grasses also have a lower rate of sand capture than European beach grass.

The American dune grass that is native to Oregon (*Elymus mollis*) has demonstrated a lower transplant survival rate than European beach grass and dies back in the winter. Therefore, because projects aim for a survival rate of approximately 98%<sup>12</sup> European beach grass and American dune grass should be co-planted, with European beach grass closer to existing infrastructure and structures.

As planting methods are proven to be successful at meeting the objectives and goals of this plan the successful methods will be incorporated into the permitting process.

Revegetation shall cover the entire area subject to grading. In the event that sand fences are installed, a 35-foot-wide unvegetated buffer located directly west of the fence is permitted to allow the area to fill with sand. Stabilizing vegetation shall be planted once the area has filled in.

### Planting Stock

For initial dune stabilization, *Elymus mollis* and *Ammophillia arenaria* shall be the bulk of the grass used for the replanting. The applicant will be required to ensure the quality of the planting stock. The location of each species shall be detailed on a planting plan that is submitted to the City.

### Preparation and Storage

The plants shall be thoroughly cleaned by shaking sand and silt from the roots. Dead stalk and trash shall be removed from the culms by stripping. The underground stems shall be broken back so that one or two nodes remain. The grass culms shall be sorted and tied into bundles that weigh approximately ten pounds; tops shall be cut back so that the overall length of the planting stalk measures approximately 20 inches.

The planting stock shall be planted within eight hours of removal from the nursery or heeling-in beds. The heeling-in beds shall be a well-drained damp trench with roots (nodes) covered to a depth of at least eight inches. Stock shall be held in the heeling-in beds for a period not to exceed 14 days. The supply of stock at the planting site must be kept in a cool shady place or otherwise protected against damage from excessive drying. Cold storage at 34°F-38°F for periods of up to two months is also acceptable.

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<sup>10</sup> There are three types of grass that are discussed in this plan. *Ammophillia arenaria* is European beach grass and is currently found in Cannon Beach. *Elymus mollis* is a dune grass that is native to Oregon. *Ammophila breviligulata* is a non-native American dune grass introduced from the Eastern U.S.

<sup>11</sup> Zarnetske, et al (2012). Biophysical feedback mediates effects of invasive grasses on coastal dune shape. *Ecology* 93(6), 1439-1450.

<sup>12</sup> Carlson, J., Reckendorf, F., and Temyik, W. 1991. Stabilizing Coastal Sand Dunes in the Pacific Northwest. USDA Soil Conservation Service SCS Handbook 687, August 1991. 53p.

The planting stock shall be handled and transported by any method that does not damage the planting stock or area.

### **Planting<sup>13</sup>**

1. The grass shall be planted in hills with an average of 3 live culms (stems) per hill. 3 live culms shall be present on at least 90% of the hills. This means there will be approximately 3,004 plants per 1,000 square feet and 130,680 plants per acre.
2. The grass shall be planted to a depth of 12 inches, with sand compacted to exclude air from the roots (nodes). The top of the plant shall be upright and extend approximately eight inches above the ground.
3. No planting shall be done on any area until the moisture is within 3 inches of the ground surface. Nor shall any planting be done when the temperature exceeds 60°F or when freezing conditions prevail.
4. Plants shall be kept in water immediately prior to planting to maintain root moisture and proper temperature. Plants shall be watered after planting.
5. Cannon Beach prefers to reduce the use of chemical fertilizers in the dunes. If fertilizer is used, organic fertilizers are preferred. State guidelines for fertilizing beach or dune grass is as follows: Planted areas may be fertilized with organic coarse particle ammonium sulfate commercial fertilizer (21-0-0), applied at a rate of 200 lbs. /acre (one pound of available nitrogen per 1,000 ft<sup>2</sup>). Fertilizer may be applied when the wind is calm and the rain is steady; irrigation may be substituted for rain. Application of fertilizer depends on timing of planting, the above factors, and how long it has been since the grass was planted. Compost and biochar are available alternatives.
6. Any area with pre-existing beach grass graded more than 3 feet deep or any area with less than 50% cover shall also be replanted.

### **Vegetation Maintenance**

Maintenance is required on beach grass for about the first two years; after that only periodic maintenance is required. If a large blow-out develops, the most effective maintenance procedure is to replant with the appropriate grass and then spread brush on the steep edges. Re-fertilizing any weak areas can bring back sufficient cover if the plant root systems have not been uncovered. Based on performance during the first two years, planted areas shall be given an annual application of organic 200 lbs/acre of 21-0-0 fertilizer or be supplemented with compost and/or biochar.

### **Transplanting Beach Grass as Clumps**

Transplanted clumps of healthy beach grass salvaged from foredune areas that are lowered for grading may also be used instead of the planting stalks listed above. This process involves removing large clumps of beach grass from areas that are to be graded. The clumps are “heeled-in” on site in moist, protected areas while the grading occurs. When the graded area is ready to plant, the large clumps are divided into 6”-8” clumps and transplanted to a depth of approximately a foot. Planted clumps shall be spaced 12 inches apart. No published specifications regarding this process were found. Prior to implementing this method, a qualified

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<sup>13</sup> Oregon Department of Land Conservation and Development (1989). *Dune Management Planning: A Guide to Preparing a Dune Management Plan as Provided for in Statewide Planning Goal 18 (Beaches and Dunes)*.

landscaper shall be retained to refine the process, prepare more detailed specifications, and supervise its implementation.

### **Secondary Stabilization**

The areas where this plan allows for dune grading that are backed by lawns or Ocean Avenue do not require vegetation for secondary stabilization of the dunes. However, if this configuration were to ever change, then the types of vegetation listed below would be appropriate choices.

Plantings of secondary stabilizing vegetation which is more fire resistant is appropriate in well vegetated areas between the foredune crest and homes but not on the foredune crest or foreslope. Detailed guidelines for planting secondary vegetation can be found in the Soil Conservation Service's publication Stabilizing Coastal Sand Dunes in the Pacific Northwest. Below is a sample of possible species:

- Salal (*Gaultheria shallon*)
- Evergreen Huckleberry (*Vaccinium ovatum*)
- Purple Beach Pea (*Lathyrus japonicas*)
- Seashore Lupine (*Lupinus littoralis*)
- Tree Lupine (*Lupinus arboreas*)

Other species may be considered. Preference is given to native vegetation. A list of native plants for foredune areas can be found in the appendix.

### **Conditions**

1. Secondary stabilization shall only be done when initial stabilizing vegetation is well established.
2. Secondary plantings shall be conducted directly in existing stands of beach grass. Beach grass shall not be destroyed or removed prior, during, or after planting, so that it can continue to stabilize the area as secondary plants are establishing themselves. Succession should occur without destruction since beach grass tends to thin out and die where it is cut off from sand accretion.

### **Access Management for Plantings**

Plants used for stabilization are vulnerable to trampling. It may be difficult to completely restrict pedestrian traffic in planted areas. Access management shall emphasize resident and visitor education and encourage voluntary avoidance of planted areas. Informational signs should identify sensitive foredune areas and direct recreational users away from these areas. Smaller signs encouraging pedestrians to stay out of planted areas should be placed around the boundary of planted areas



## **MAINTENANCE**

Maintenance may include:

- additional plantings, to supplement stabilization;
- grading or sand removal to maintain public access routes where accretion has continued to occur, and
- fore-slope shaping, as needed.

Maintenance activities to be carried out will generally consist of regular repair planting.

Monitoring and maintenance of dune and vegetation management projects are the responsibility of and are required of the applicant as a condition of permit approval.

## **MONITORING**

### **Project Monitoring**

Monitoring is required for all dune grading or sand removal projects. Monitoring shall include inspections, photographic documentation, and profile surveys. At a minimum, profiles shall be measured prior to grading, after grading has occurred, and after the graded areas have been subjected to a winter season. Affected areas shall be inspected at least annually for a period of five years after a grading or sand removal project is completed. A brief assessment of whether the intended outcomes of grading were accomplished and sustained shall be made after the winter season measurement and after the five-year inspection. These shall include a comparison of the foredune design profile described in this plan, the permitted foredune design profile, and the foredune profile after the winter season. An independent reviewer shall review monitoring reports that are submitted to the City.

### **Plan Monitoring**

Robust enforcement of the policies from this plan is critical for correct implementation. As the permitting and regulatory authority, the City shall maintain and monitor the effectiveness of this plan. Five years after adopting this plan, the City shall complete a preliminary evaluation of the extent to which the plan objectives have been achieved (existing profile elevations/volumes versus design profile elevations/volumes, percent vegetation cover and degree of foredune stabilization, effect on plants and wildlife (including shellfish, razor clams, and rare species), extent of access to public facilities, etc. Ten years after adopting this plan, the City shall update the evaluation, complete a review and update of the background report, and revise the Foredune Management Plan as necessary.

## **LIMITATIONS**

This Foredune Management Plan is based on a consideration of past and present conditions. Although grading for views was permitted in the past, with this Plan grading for views in the City of Cannon Beach is prohibited. If new information on site conditions is developed or events occur which alter existing conditions, a full revision of this Foredune Management Plan and accompanying Zoning Ordinances and Comprehensive Plan amendments will be required.

## **APPENDIX:**

# **OREGON STATEWIDE PLANNING GOAL 18: BEACHES AND DUNES**

## **Oregon's Statewide Planning Goals & Guidelines**

### **GOAL 18: BEACHES AND DUNES**

**OAR 660-015-0010(3)**

**To conserve, protect, where appropriate develop, and where appropriate restore the resources and benefits of coastal beach and dune areas; and**

**To reduce the hazard to human life and property from natural or man-induced actions associated with these areas.**

Coastal comprehensive plans and implementing actions shall provide for diverse and appropriate use of beach and dune areas consistent with their ecological, recreational, aesthetic, water resource, and economic values, and consistent with the natural limitations of beaches, dunes, and dune vegetation for development.

#### **INVENTORY REQUIREMENTS**

Inventories shall be conducted to provide information necessary for identifying and designating beach and dune uses and policies. Inventories shall describe the stability, movement, groundwater resource, hazards and values of the beach and dune areas in sufficient detail to establish a sound basis for planning and management. For beach and dune areas adjacent to coastal waters, inventories shall also address the inventory requirements of the Coastal Shorelands Goal.

#### **COMPREHENSIVE PLAN REQUIREMENTS**

Based upon the inventory, comprehensive plans for coastal areas shall:

1. Identify beach and dune areas; and
2. Establish policies and uses for these areas consistent with the provisions of this goal.

#### **IDENTIFICATION OF BEACHES AND DUNES**

Coastal areas subject to this goal shall include beaches, active dune forms, recently stabilized dune forms, older stabilized dune forms and interdune forms.

#### **USES**

Uses shall be based on the capabilities and limitations of beach and dune areas to sustain different levels of use or development, and the need to protect areas of critical environmental concern, areas having scenic, scientific, or biological importance, and significant wildlife habitat as identified through application of Goals 5 and 17.

#### **IMPLEMENTATION REQUIREMENTS**

1. Local governments and state and federal agencies shall base decisions on plans, ordinances and land use actions in beach and dune areas, other than older stabilized dunes, on specific findings that shall include at least:
  - (a) The type of use proposed and the adverse effects it might have on the site and adjacent areas;
  - (b) Temporary and permanent stabilization programs and the planned



maintenance of new and existing vegetation;

(c) Methods for protecting the surrounding area from any adverse effects of the development; and

(d) Hazards to life, public and private property, and the natural environment which may be caused by the proposed use.

2. Local governments and state and federal agencies shall prohibit residential developments and commercial and industrial buildings on beaches, active foredunes, on other foredunes which are conditionally stable and that are subject to ocean undercutting or wave overtopping, and on interdune areas (deflation plains) that are subject to ocean flooding. Other development in these areas shall be permitted only if the findings required in (1) above are presented and it is demonstrated that the proposed development:

(a) Is adequately protected from any geologic hazards, wind erosion, undercutting, ocean flooding and storm waves; or is of minimal value; and

(b) Is designed to minimize adverse environmental effects.

3. Local governments and state and federal agencies shall regulate actions in beach and dune areas to minimize the resulting erosion. Such actions include, but are not limited to, the destruction of desirable vegetation (including inadvertent destruction by moisture loss or root damage), the exposure of stable and conditionally stable areas to erosion, and construction of shore structures which modify current or wave patterns leading to beach erosion.

4. Local, state and federal plans, implementing actions and permit reviews shall protect the groundwater

from drawdown which would lead to loss of stabilizing vegetation, loss of water quality, or intrusion of salt water into water supplies. Building permits for single family dwellings are exempt from this requirement if appropriate findings are provided in the comprehensive plan or at the time of subdivision approval.

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

(a) visual impacts are minimized;

(b) necessary access to the beach is maintained;

(c) negative impacts on adjacent property are minimized; and

(d) long-term or recurring costs to the public are avoided.

6. Foredunes shall be breached only to replenish sand supply in interdune areas, or on a temporary basis in an emergency (e.g., fire control, cleaning up oil spills, draining farm lands, and alleviating flood hazards), and only if the breaching and restoration after breaching is consistent with sound principles of conservation.

7. Grading or sand movement necessary to maintain views or to prevent sand inundation may be allowed for structures in foredune areas only if



the area is committed to development or is within an acknowledged urban growth boundary and only as part of an overall plan for managing foredune grading. A foredune grading plan shall include the following elements based on consideration of factors affecting the stability of the shoreline to be managed including sources of sand, ocean flooding, and patterns of accretion and erosion (including wind erosion), and effects of beachfront protective structures and jetties. The plan shall:

- (a) Cover an entire beach and foredune area subject to an accretion problem, including adjacent areas potentially affected by changes in flooding, erosion, or accretion as a result of dune grading;
- (b) Specify minimum dune height and width requirements to be maintained for protection from flooding and erosion. The minimum height for flood protection is 4 feet above the 100 year flood elevation;
- (c) Identify and set priorities for low and narrow dune areas which need to be built up;
- (d) Prescribe standards for redistribution of sand and temporary and permanent stabilization measures including the timing of these activities; and
- (e) Prohibit removal of sand from the beach-foredune system.

The Commission shall, by January 1, 1987, evaluate plans and actions which implement this requirement and determine whether or not they have interfered with maintaining the integrity of beach and dune areas and minimize flooding and erosion problems. If the Commission determines that these measures have interfered it shall initiate Goal amendment

proceedings to revise or repeal these requirements.

## **GUIDELINES FOR GOAL 18**

The requirements of the Beaches and Dunes Goal should be addressed with the same consideration applied to previously adopted goals and guidelines. The planning process described in the Land Use Planning Goal (Goal 2), including the exceptions provisions described in Goal 2, applies to beaches and dune areas and implementation of the Beaches and Dunes Goal.

Beaches and dunes, especially interdune areas (deflation plains) provide many unique or exceptional resources which should be addressed in the inventories and planning requirements of other goals, especially the Goals for Open Space, Scenic and Historic Areas and Natural Resources; and Recreational Needs. Habitat provided by these areas for coastal and migratory species is of special importance.

### **A. INVENTORIES**

Local government should begin the beach and dune inventory with a review of Beaches and Dunes of the Oregon Coast, USDA Soil Conservation Service and OCCDC, March 1975, and determine what additional information is necessary to identify and describe:

- 1. The geologic nature and stability of the beach and dune landforms;
- 2. Patterns of erosion, accretion, and migration;
- 3. Storm and ocean flood hazards;



4. Existing and projected use, development and economic activity on the beach and dune landforms; and
5. Areas of significant biological importance.

## **B. EXAMPLES OF MINIMAL DEVELOPMENT**

Examples of development activity which are of minimal value and suitable for development of conditionally stable dunes and deflation plains include beach and dune boardwalks, fences which do not affect sand erosion or migration, and temporary open-sided shelters.

## **C. EVALUATING BEACH AND DUNE PLANS AND ACTIONS**

Local government should adopt strict controls for carrying out the Implementation Requirements of this goal. The controls could include:

1. Requirement of a site investigation report financed by the developer;
2. Posting of performance bonds to assure that adverse effects can be corrected; and
3. Requirement of re-establishing vegetation within a specific time.

## **D. SAND BY-PASS**

In developing structures that might excessively reduce the sand supply or interrupt the longshore transport or littoral drift, the developer should investigate, and where possible, provide methods of sand by-pass.

## **E. PUBLIC ACCESS**

Where appropriate, local government should require new developments to dedicate easements for public access to public beaches,

dunes and associated waters. Access into or through dune areas, particularly conditionally stable dunes and dune complexes, should be controlled or designed to maintain the stability of the area, protect scenic values and avoid fire hazards.

## **F. DUNE STABILIZATION**

Dune stabilization programs should be allowed only when in conformance with the comprehensive plan, and only after assessment of their potential impact.

## **G. OFF-ROAD VEHICLES**

Appropriate levels of government should designate specific areas for the recreational use of off-road vehicles (ORVs). This use should be restricted to limit damage to natural resources and avoid conflict with other activities, including other recreational use.

## **H. FOREDUNE GRADING PLANS**

Plans which allow foredune grading should be based on clear consideration of the fragility and ever-changing nature of the foredune and its importance for protection from flooding and erosion. Foredune grading needs to be planned for on an area-wide basis because the geologic processes of flooding, erosion, sand movement, wind patterns, and littoral drift affect entire stretches of shoreline. Dune grading cannot be carried out effectively on a lot-by-lot basis because of these areawide processes and the off-site effects of changes to the dunes.

Plans should also address in detail the findings specified in Implementation Requirement (1) of this Goal with special emphasis placed on the following:

- Identification of appropriate measures for stabilization of graded areas and areas of deposition, including use of fire-resistant vegetation;
- Avoiding or minimizing grading or deposition which could adversely affect surrounding properties by changing wind, ocean erosion, or flooding patterns;
- Identifying appropriate sites for public and emergency access to the beach.

## **HISTORICAL MANAGEMENT UNIT STRATEGIES**

As noted above, although this plan allows for grading throughout the Cannon Beach city limits, the previous plan was based on four specific subareas, which are identified below. A map of these management units is on the following page.

### **Haystack Rock Management Unit**

This dynamic shoreline extends from the west end of Harrison Street south to Haystack Rock and has experienced both sand deposition and erosion. The management unit is zoned as Open Space (OS) and falls within the Oceanfront Overlay Zone. There is no development within these zones in the management area; however, development surrounds the management area to the east, and the beach is highly utilized. Current FEMA maps shall be consulted to determine appropriate elevations.

### **Presidential Management Unit**

Recently this area has experienced sand accretion. This management unit is zoned as Open Space (OS) and falls within the Oceanfront Overlay Zone. There is no development within these zones; however, residential development surrounds the management unit to the east and the beach is highly utilized in this area. Current FEMA maps shall be consulted when dune designs are created.

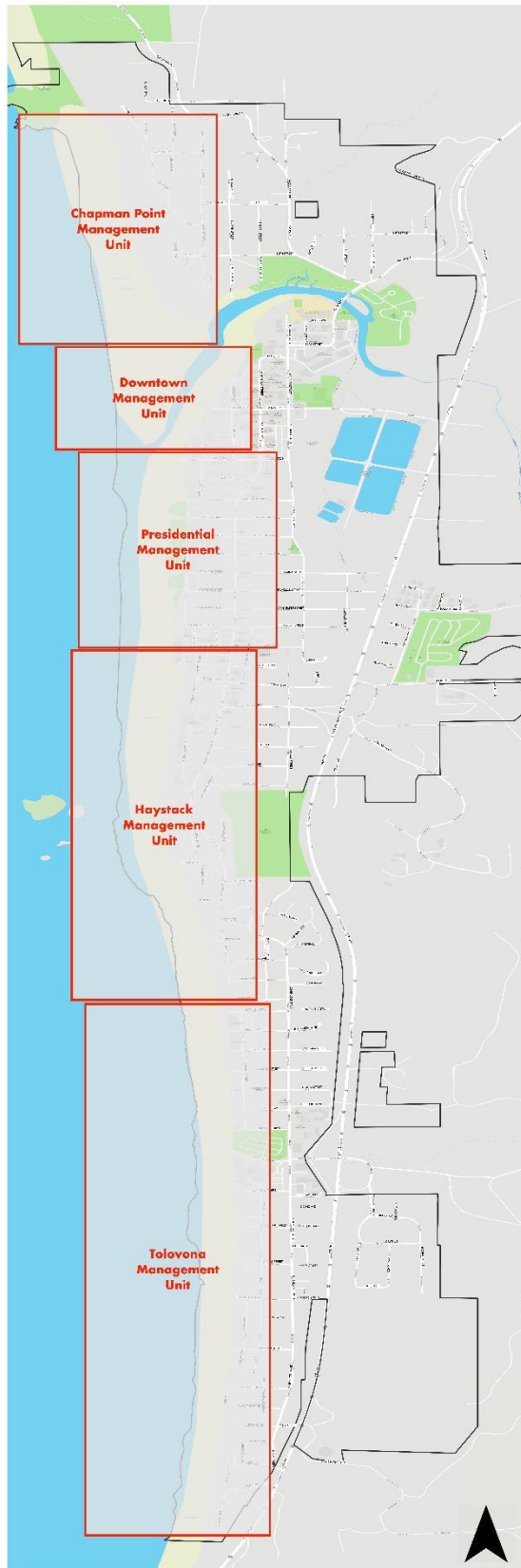
This subunit is located between the Haystack Management Unit and the Downtown Management Unit. The scope and timing of the sand management measures outlined above are intended to minimize adverse impacts to these adjacent areas. Monitoring and maintenance will help to ensure that impacts to adjacent properties are minimal.


### **Downtown Management Unit**

This dynamic shoreline has experienced sand deposition and erosion. The management unit is zoned as Open Space (OS) and falls within the Oceanfront Overlay Zone. There is no development within these zones in the management area; however, residential and commercial development surrounds the management to the east and the beach is highly utilized. Current FEMA maps shall be consulted to determine appropriate elevations.

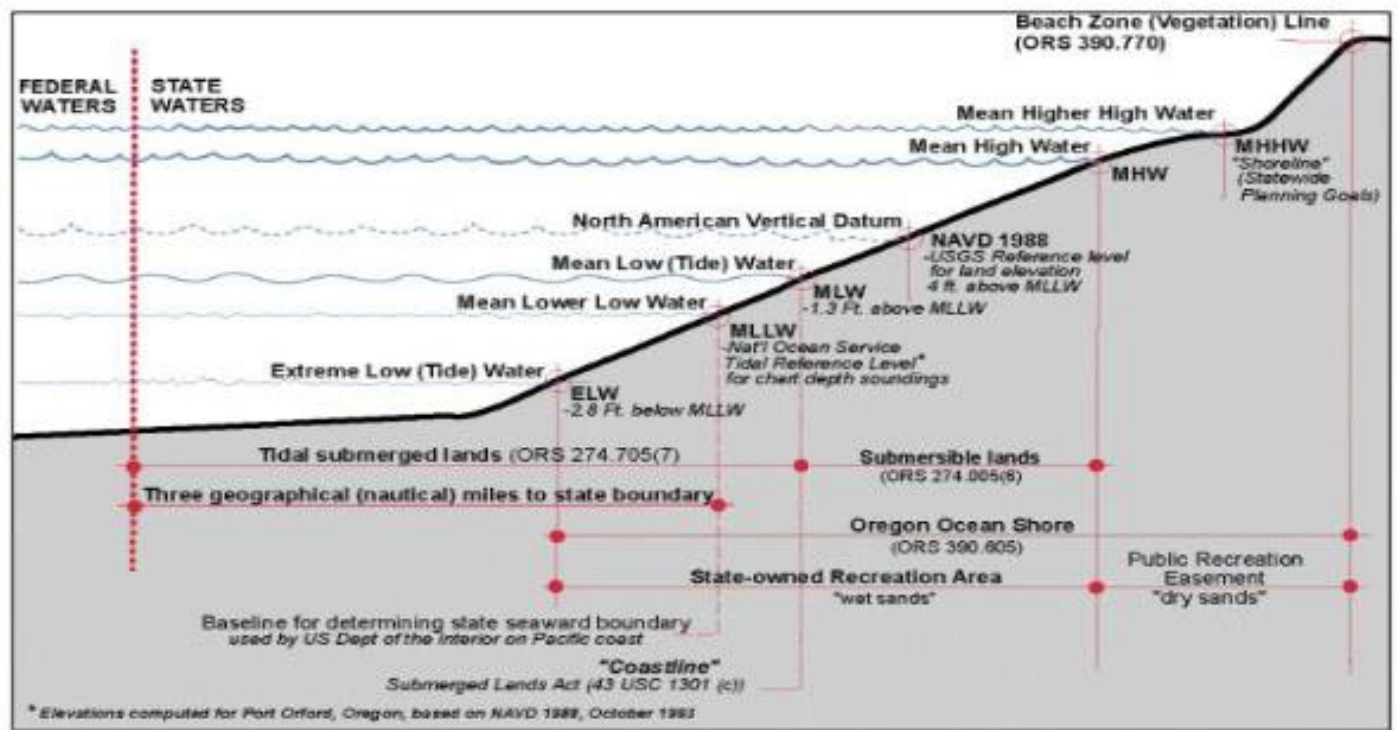
### **Chapman Point Management Unit**

This section of shoreline has experienced the highest amount of sand accretion within Cannon Beach. This management unit is zoned as Open Space (OS) and falls within the Oceanfront Overlay Zone. Current FEMA maps shall be consulted when dune grading projects are designed.



 **Cannon Beach**  
**Historic Foredune Management Units**





## Jurisdictional Beach Boundaries

## DEFINITIONS

**Back-passing or Bypassing** A Sand Bypass System is a permanent solution to sand erosion and littoral drift problems affecting river mouths and navigation channels worldwide. It is described as the artificial transport of littoral drift across tidal entrances to help prevent accretion, on the updrift side, control downdrift erosion and maintain navigation channels.<sup>14</sup>

**Base Flood Elevation (BFE)** FEMA defines BFEs as a the computed elevation to which floodwater is anticipated to rise during the base flood with wave effects included in coastal areas. The BFE is the minimum regulatory requirement for the elevation or floodproofing of structures. The relationship between the BFE and a structure's elevation determines the flood insurance premium.<sup>15</sup>

**Blowout** Blowout dunes are, “a saucer or trough shaped depression formed by wind erosion on a preexisting sand deposit.” Blowout dunes are composed of a depression (or basin) and depositional lobe, and depending on the internal depth of the depression an erosional wall will be present.<sup>16</sup>

Trough- or bowl shaped depressions in the seaward dune, so called blowouts, are common features in natural dunes and are essential to maintain dynamic species-rich dune ecosystems (see picture above). Blowout development is governed by the



Coastline near Heemskerk, the Netherlands. Terminology indicates the location of the intertidal zone, dry beach, fore dune, back dunes and a natural blowout (Arens et al., 2013) (photo: Rijkswaterstaat/Rens Jacobs, 2005)

hitherto unknown interaction between abiotic (e.g. aeolian sand transport and precipitation) and biotic factors (e.g. vegetation colonization).

**Breach** A barrier such as a dune or a dike can be breached due to the effect of waves acting on the barrier with forces that exceeds the barriers strength. Two types of breach mechanisms –or failure modes -may be of importance: Shear stress failures and/or Geotechnical failures<sup>17</sup>

<sup>14</sup> Boswood, P.K., Voisey, C.J., Victory, S.J., Robinson, D.A., Dyson, A.R. and Lawson, S.R. 2005. Beach Response to Tweed River Entrance Sand Bypassing Operations. Conference Australasian Coasts and Ports 2005, Adelaide, South Australia

<sup>15</sup> [https://www.fema.gov/media-library-data/1395338523968-084228a766df3f43be5b2179a8b47222/PFD+Fact+Sheet\\_FINAL.pdf](https://www.fema.gov/media-library-data/1395338523968-084228a766df3f43be5b2179a8b47222/PFD+Fact+Sheet_FINAL.pdf)

<sup>16</sup> Hesp, P., 2002. Foredunes and blowouts: initiation, geomorphology and dynamics. *Geomorphology*, 48: 245-269

<sup>17</sup> Mangor, K., Drønen, N. K., Kaergaard, K.H. and Kristensen, N.E. 2017. Shoreline management guidelines. DHI <https://www.dhigroup.com/marine-water/ebook-shoreline-management-guidelines>

**Overwash** When storm-induced waves exceed the height of the dune, sand is transported over the top of the dune and deposited inland. This process, known as overwash, causes a significant change in the landscape. During the overwash process, portions of the dune are often completely eroded, and sand is deposited inland in large layers called overwash fans. These fans can bury the first floors of homes, cover roads, fill ponds, and cover coastal vegetation.<sup>18</sup>

**Coastal Erosion** The loss or displacement of land, or the long-term removal of sediment and rocks along the coastline due to the action of waves, currents, tides, wind-driven water, waterborne ice, or other impacts of storms. The landward retreat of the shoreline can be measured and described over a temporal scale of tides, seasons, and other short-term cyclic processes. Coastal erosion may be caused by hydraulic action, abrasion, impact and corrosion by wind and water, and other forces, natural or unnatural.

**Dune** The term 'dunes' generally indicates subaerial dunes. These dunes are ridges or mounds of loose, wind-blown sand (fine to medium) forming on the backshore and forming the coastal features at certain locations. Dunes are more or less vegetated. Dunes are active coastal form elements acting as a flexible sand reservoir. At coasts subject to structural coastal erosion they are moving backwards in parallel with shoreline retreat. Dunes act as a kind of flexible natural protection against erosion and flooding, see Dune erosion. If the vegetation is damaged by too much traffic or grazing etc. the integrity of the dunes may be endangered.

**Foredune Grading** The alteration of the foredune area through sand transfer or removal of sand by mechanical means.

**Foredune** A primary frontal dune (PFD) is defined by the National Flood Insurance Program (NFIP) as a continuous or nearly continuous mound or ridge of sand with relatively steep seaward and landward slopes immediately landward of and adjacent to the beach. PFDs are subject to erosion and may be vulnerable to overtopping or breaching from high water levels and waves during coastal storms<sup>19</sup>

**Fore-slope** shaping: Minor redistribution of sand in the crest and foreslope areas in order to maintain a regular, gently-sloping foredune.<sup>20</sup>

**Littoral Cell** A coastal compartment that contains a complete cycle of sedimentation including sources, transport paths, and sinks. The cell boundaries delineate the geographical area within which the budget of sediment is balanced, providing the framework for the quantitative analysis

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<sup>18</sup> <http://coastal.er.usgs.gov/hurricanes/coastal-change/overwash.php>

<sup>19</sup> [https://www.fema.gov/media-library-data/1395338523968-084228a766df3f43be5b2179a8b47222/PFD+Fact+Sheet\\_FINAL.pdf](https://www.fema.gov/media-library-data/1395338523968-084228a766df3f43be5b2179a8b47222/PFD+Fact+Sheet_FINAL.pdf)

<sup>20</sup> [https://ci.manzanita.or.us/\\_docs/ordinances/ord95-6foredune-management.pdf](https://ci.manzanita.or.us/_docs/ordinances/ord95-6foredune-management.pdf)

of coastal erosion and accretion.<sup>21</sup> The Cannon Beach Littoral Cell is from Falcon Cove to Chapman Point.<sup>22</sup>

**Preservation Grading** Grading or sand movement necessary to repair blow-outs, erosion or maintain public access or facilities, which may be allowed in active dune areas only if the area is committed to development and meeting the requirements of Comprehensive Plan Foredune Management Policy. Preservation Grading does not include grading necessary for the repair, maintenance or installation of stormwater outfalls or facilities, including infiltration and water quality systems.

**Remedial Grading** Clearing of sand necessary to maintain the accessibility and function of a structure or facility. It includes removal of sand that has built up against exterior walls, doors, or windows and that blocks access to a residential or commercial structure, or any public facility, utility, infrastructure or right-of-way.

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<sup>21</sup> Inman D.L. (2005) Littoral Cells. In: Schwartz M.L. (eds) Encyclopedia of Coastal Science. Encyclopedia of Earth Science Series. Springer, Dordrecht

<sup>22</sup> State of Oregon Department of Geology and Mineral Industries. (2018). *Beach and Shoreline Dynamics in the Cannon Beach Littoral Cell; Implications for Dune Management*. (Special Paper 18-49). By

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## NATIVE PLANTS FOR FOREDUNE AREAS

### North Oregon Coast—Dune Plants List

The following native plants are adapted to foredune areas. Those on the windward side are obligates in moving sand. This is a partial list of plants that grow in dunes on the Pacific Northwest coast.

Common Name	Scientific Name	Plant Windward	Plant General	Plant Leeward
Yellow Sand Verbena	Abronia latifolia: Nyctaginacea	√		
Yarrow	Achillea millefolium: Asteraceae		√	
Pearly Everlasting	Anaphalis margaritacea: Asteraceae		√	
Seawatch	Angelica lucida: Apiaceae			√
Beach Morningglory	Calystegia soldanella: Convolvulaceae	√		
Big-head Sedge	Carex macrocephala: Cyperaceae	√		
Sand Dune Sedge	Carex pansa: Cyperaceae			√
Edible Thistle	Cirsium edule: Asteraceae			√
Roemer's Fescue	Festuca roemerii: Poaceae			√
Beach Strawberry	Fragaria chiloensis: Rosaceae		√	
Beach Carrot, Beach Silvertop	Glehnia littoralis ssp. leiocarpa: Apiaceae	√		
Sea Purslane	Honckenya peploides: Brassicaceae	√		
Beach Pea	Lathyrus japonicus: Fabaceae	√		
Silky Beach Pea	Lathyrus littoralis: Fabaceae	√		
American Dunegrass	Leymus mollis: Poaceae		√	
Beach Lupine	Lupinus littoralis: Fabaceae	√		
Coast Bluegrass	Poa macrantha: Poaceae		√	
Black Knotweed	Polygonum paronychia: Polygonaceae			√
Dune Goldenrod	Solidago simplex ssp. spatulata: Asteraceae			√
Douglas Aster	Symphyotrichum subspicatum: Asteraceae			√
Beach Tansy, Dune Tansy	Tanacetum bipinnatum: Asteraceae	√		

## REFERENCES

- Carlson, J., Reckendorf, F., and Temyik, W. 1991. Stabilizing Coastal Sand Dunes in the Pacific Northwest. USDA Soil Conservation Service SCS Handbook 687. 53p.
- Commonwealth of Massachusetts, Office of Coastal Zone Management. (2017). *Interpreting Federal Emergency Management Agency Flood Maps and Studies in the Coastal Zone*.
- FEMA. (2010). *Flood Insurance Study 41007CV001A*.
- NOAA Office of Coastal Management. (2015). Sea Level Rise Viewer. Retrieved from <https://coast.noaa.gov/slr>
- Ordinance 01-02, 13. *Presidential Streets Sand Management Strategy*.
- State of Oregon Department of Geology and Mineral Industries. (2018). *Beach and Shoreline Dynamics in the Cannon Beach Littoral Cell; Implications for Dune Management*. (Special Paper 18-49). By Jonathan C. Allan, Laura L. Gabel, and Fletcher O'Brien.
- State of Oregon Department of Land Conservation and Development (1989). *Dune Management Planning: A Guide to Preparing a Dune Management Plan as Provided for in Statewide Planning Goal 18 (Beaches and Dunes)*.
- Rosenfeld, C. L. (1997). *Cannon Beach: An Integrated Approach to Sand Management*.
- United States Army Corps of Engineers. (2017). *Erosion of Coastal Foredunes: A Review on the Effect of Dune Vegetation* [PDF Version]. Retrieved from <http://njseagrant.org/wp-content/uploads/2016/05/ERDC-CHL-CHETN-I-94-DuneVeg.pdf>
- Vavrinec, J., Kohn, N.P., Hall, K.D., Romano, B.A. (2007). *Effects of Burial by the Disposal of Dredged Materials from the Columbia River on Pacific Razor Clams (Siliqua patula)* (Report PNNL-16350). Retrieved from Pacific Northwest National Laboratory [https://www.pnnl.gov/main/publications/external/technical\\_reports/PNNL-16350.pdf](https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-16350.pdf)
- Zarnetske, et al (2012). Biophysical feedback mediates effects of invasive grasses on coastal dune shape. *Ecology* 93(6), 1439-1450.