Appendix D
Draft Carpinteria Dune Restoration Plan

Draft Dune Conceptual Restoration Plan for the Carpinteria Living Shoreline

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1) INTRODUCTION

BACKGROUND

This restoration plan describes steps for creating naturally functioning dunes as part of a larger shoreline management project that includes beach nourishment, sand retention, and elimination of the winter berm. The goal of these changes in management is to increase coastal resilience in the City of Carpinteria. This plan is based on the project alternative developed by Moffatt and Nichol and presented in the City of Carpinteria, sea level rise vulnerability assessment and adaptation project (Moffatt and Nichol 2021a) and in the Memorandum: Carpinteria Living Shoreline Concept and Analysis (Moffatt and Nichol 2021b). The Carpinteria shoreline was divided into four reaches (shoreline segments) based on beach, dune and infrastructure features (Fig. 1) in the constraints analysis by Moffatt and Nichol (2021a). The City waterfront (Reach 2) was selected for the most detailed analysis and design. The proposed project footprint with the greatest proposed changes (Reach 2) extends along the city's shoreline from Ash Avenue to Linden Avenue (Fig. 2). The area does not currently support vegetated dunes and is fronted by a beach of moderate width. Current shoreline management in Reach 2 includes mechanically grooming of the intertidal beach and grading on the upper shore at least twice per year to construct, maintain if needed, and then to remove a winter sand berm intended to protect inland infrastructure from erosion and flooding.

Several design alternatives were developed for the project area along Reach 2 and these were evaluated using modeling (e.g. XBeach, Moffatt and Nichol 2021b). The modeling approach included evaluation of the site under current conditions with the winter berm, with beach nourishment (sand imported to the site) and with different dune configurations. These were modeled with combinations of extreme storms and sea level rise. The modeling results for these alternatives are included in the Memorandum: Carpinteria Living Shoreline Concept and Analysis (Moffatt and Nichol 2021b). One alternative was selected for further design and it is described below.

One of the primary goals in increasing resiliency at the site is to establish vegetated dunes capable of trapping blowing sand in the area that is currently upper beach. Healthy dunes can provide buffer inland areas during storms, particularly when combined with a newly nourished wider sandy beach. In optimum situations, dunes have some capacity for self-repair after disturbance and can adjust to rising sea levels, especially where room exists for landward migration. Nourishment and sand retention are included in the proposed actions for Reach 2 and would increase accommodation space there. In Carpinteria, the best accommodation space and best opportunities for long-term coastal resilience are in Reach 3.

INTERTIDAL BEACH, COASTAL STRAND AND DUNE HABITATS

The existing conditions in the project area are summarized in the constraints analysis report by Moffatt and Nichol (2021a). The surf zone and the beach in all four reaches (and in Reach 3, the dunes) are part of a dynamic system that shares the same sand resources. The sections of dunes with native plants at Carpinteria State Beach (Reach 3) provides an appropriate example for developing goals and actions in Reach 2 including elevation profiles and vegetation characteristics. Southern foredune habitats occur in areas with sufficient sediment supply (usually a sandy beach), sufficient wind to blow sand, and the presence of vegetation adapted to growing in dunes. Dunes will only occur where there is sufficient room landward of the beach that is not regularly eroded by storm waves. In California, the native plant species that are well-adapted to this harsh environment include red sand verbena (*Abronia maritima*), beach bur (*Ambrosia chamissonis*) and beach saltbush (*Atriplex leucophylla*). These species build dunes through cycles of burial by blowing sand followed by stem growth above the sand surface. This process leads to increases in dune elevation and increased sand storage on the upper shore. In low disturbance areas in southern California, native dune vegetation may achieve total cover of 10- 50%. Plants adapted to growing in more stable dunes (including beach evening primrose and coastal California poppy) can be added to restored dunes after primary dune forms and vegetation are established.

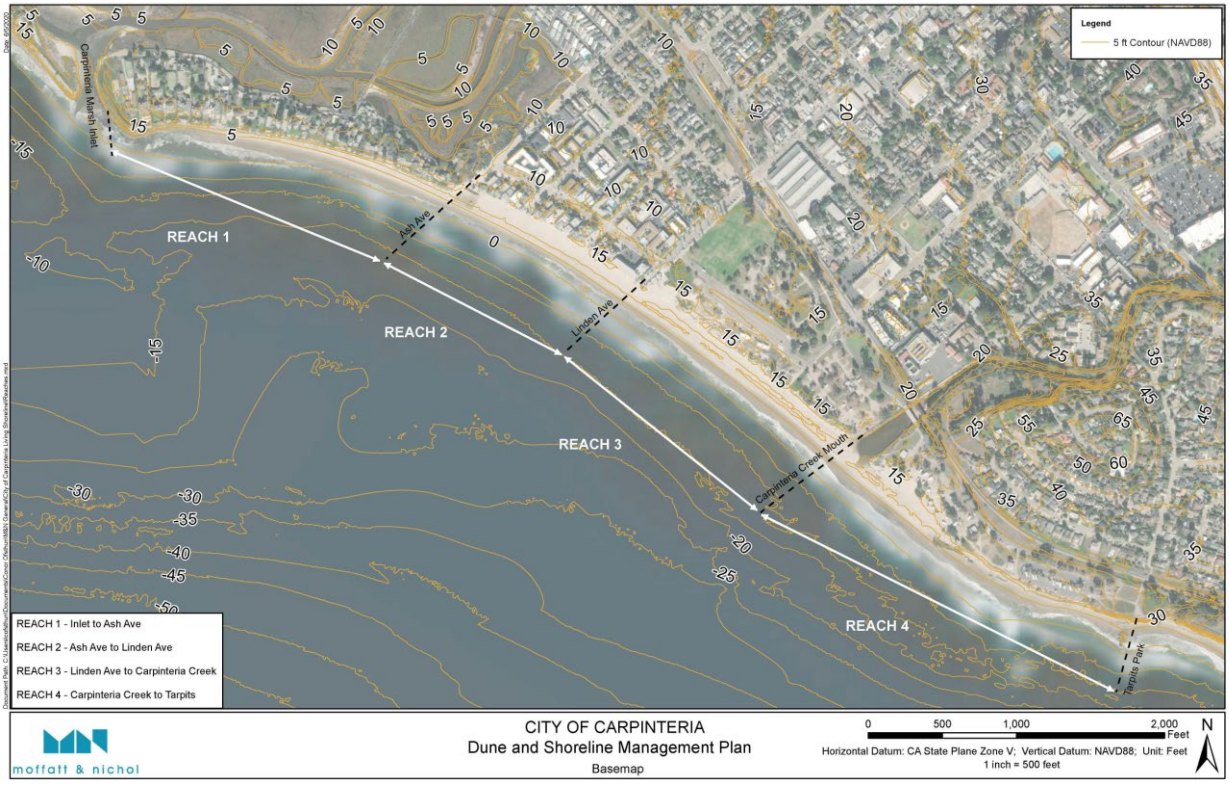

Figure 1. Carpinteria living shoreline study area as shown in Fig 2.1 of Moffatt and Nichol 2021a. The study area was divided into four reaches based on shoreline conditions. This

draft plan focuses on actions in Reach 2, but includes suggested for less extensive improvements in Reaches 3 and 4.

2) PROJECT DESCRIPTION

PROJECT COMPONENTS

The actions proposed for the chosen project alternative in Reach 2 are intended to increase the resilience of the area to coastal erosion and flooding driven by storms, swells and sea level rise, and would also provide ample beach access, recreation space and habitat (Moffatt and Nichol 2021b). This alternative relies on three components: 1) beach nourishment to widen the shore, increase sediment volume and to create more space for coastal dynamics (accommodation space), 2) installation of a sand retention structure to increase the life span of sand put in place in the nourishment component, and 3) the establishment of vegetated dunes on the backshore (Fig. 2). The dunes will be constructed then vegetated with plant species native to California coastal dunes.

The alternative development and analysis process focused on protecting the vulnerable residences and public infrastructure in Reach 2, however enhancement of degraded dunes in Reach 3 and dune restoration of a small segment of living shoreline in Reach 4 are suggested to increase resilience in these stretches and improve habitat values.

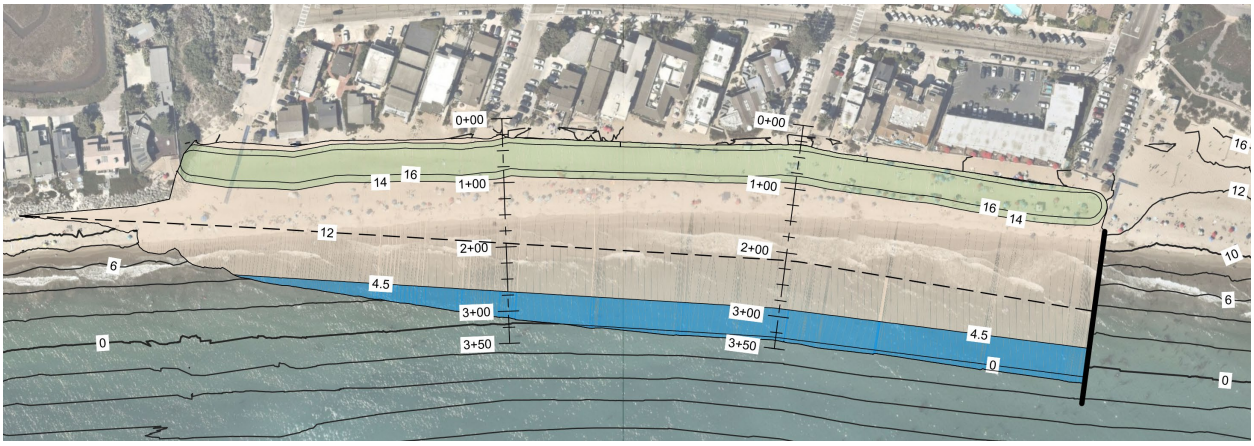

Fig. 2. Carpinteria living shoreline components as shown in Moffatt and Nichol 2021b, Fig. 5). This view shows proposed beach nourishment, sand retention structure and constructed dune between Ash Avenue and Linden Avenue.

BEACH NOURISHMENT

The proposed project would place about 500,000 cubic yards of imported sand (beach nourishment) in Reach 2 (Fig. 2). The addition of sand would create a wider beach that could buffer the new dunes and inland structures from wave attack and preserve recreational space. The imported sand texture should match the texture of sand currently on the site in order to support dune-building processes (the size of the sand grains in the imported sand would be generally the same as sand currently at the site). The Moffatt and

Nichol (2021b) analysis shows plan and profile views of the beach at the time of sediment placement and after equilibrating under winter storm wave action. The initial width of the nourished beach is predicted to narrow under the influence of storm waves and this change is reflected in the design. The beach would still be considerably wider after nourishment and it would contain much greater sand volume than in current conditions.

SAND RETENTION STRUCTURE

The second project component would be the installation of a sand retention structure (groin) at the Linden Avenue end of Reach 2 (Fig. 2). The proposed structure would likely consist of a low-crested sheet pile wall installed from the intertidal zone to the shallow surf zone (Moffatt and Nichol 2021b). The structure would be designed to help maintain the wider beach after nourishment. The dimensions and placement of the structure would be matched to the beach nourishment component of the project with the intention of allowing sand to bypass the structure, thus avoiding downcoast sand loss and beach erosion impacts.

COASTAL DUNES

The third component of the project would be the creation of dunes on the backshore along Reach 2 (shown in profile view in Fig. 3) and enhancing or restoring dunes in parts of Reaches 3 and 4. Dune establishment in Reach 2 would involve placement of sand, seeding with native plant seeds, and installation of sand fencing to stabilize the site in the short term, and installation of symbolic perimeter fencing to reduce disturbance from vehicles and foot traffic. The dunes would be located in the area where the City's winter sand berm is currently constructed (Fig. 3). The dunes should be constructed with sand that has grain size characteristics equivalent to natural sand at the site. The focus of the project would be on dune creation along Reach 2. Coastal resilience at downcoast sites could be increased using similar methods: removal of non-native invasive species (e.g., ice plant and Myoporum) and revegetation with native dune species along Reach 3, and restoration of a small segment of dunes in Reach 4.

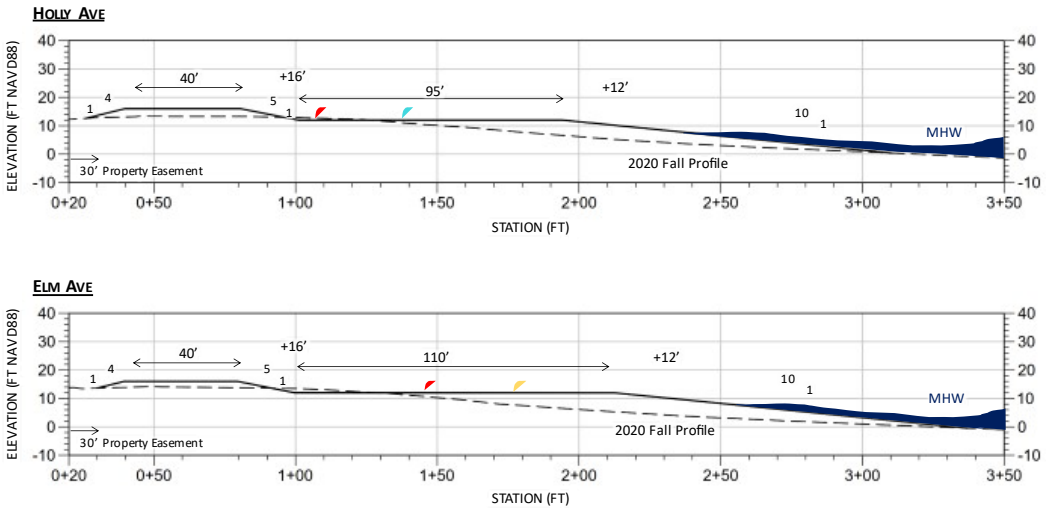

Fig. 3. Profile views of proposed project at Holly Avenue and at Elm Avenue (solid lines show the proposed condition with beach nourishment and dune construction (Fig. in Moffatt and Nichol 2021b). The dashed lines show the existing profiles at these sites in Fall 2020. The ocean is shown at the right side of the panels. Elevations are given relative to NAVD88 datum (y-axis). The constructed dunes are shown as flat-topped mounds at the left in each panel. The dune crest elevations are at 16 feet and the dune crests are 40 feet wide.

3) IMPLEMENTATION GUIDANCE

GENERAL

A detailed implementation plan will need to be developed as the project for Reach 2 undergoes further development and refinement. That plan will need to refine the general techniques and approaches outlined below. The implementation plan will also need to include quantifiable success criteria linked to project goals, an adaptive management plan, and more detailed cost estimates.

PERIMETER FENCING

The project should stablish defined boundaries at the project site using symbolic fencing. (Fig. 4). Dune plants do not survive or thrive in areas with routine trampling or driving. The project should use post and rope fencing to minimize view impacts.

Fig. 4. Carpinteria Living Shoreline project site. The pink line shows the configuration of four dune areas in Reach 2 separated by beach access paths and also the locations for installation of symbolic fencing. The access paths are set at an angle (North to south or NNW to SSE) so that they do not line up with the angle of strong winds at the site (often from the west). Installation of sand fencing on the seaward sides of the dune areas during the first year of the project would reduce sand movement across the site and might improve early plant establishment.

SAND FENCING

Sand fencing is an effective technique for stabilizing areas with high levels of blowing sand and for building dune volume in the short-term. It is not a permanent solution. Sand fencing can be effectively used alongside of re-vegetation techniques to delineate restoration areas, slow sand movement, build topography and create areas suitable for plant establishment. Sand fencing can also limit the amount of nuisance sand blowing into streets and residences backing the beach and dunes.

REVEGETATION

The dunes should be vegetated with California native plants. Native dune plants are the most sustainable long-term choice for building coastal dunes in California without

irrigation. There are situations in which some form of sand stabilization may help in the establishment phase (sand fencing, crimped straw mulch on the sand surface). California native dune plants also benefit greatly from protection from vehicles driving on the beach (e.g., beach grooming, lifeguards) and trampling by residents or beach goers accessing the beach. Directing foot and any kind of vehicle traffic around vegetated dunes will be an important part of the project.

Beach access will be maintained in all phases of the project, but the paths from parking areas should be delineated with post and rope fencing to focus access and minimize trampling. Boardwalks are expensive, but they are effective for providing good public access and keeping beach goers on trails. Other options include the use of rubber or plastic matting in areas with high levels of foot traffic above the annual reach of tides.

STREET END PARKING LOT MAINTENANCE

Removal of sand deposited on roads, sidewalks and parking areas should be viewed as an opportunity for the beneficial re-use of the sediment. Clean sand removed from paved areas should be moved to designated areas seaward of vegetated dunes for beach enhancement and dune restoration.

RE-VEGETATION STRATEGIES

In sand dune areas, the most effective strategy for re-introducing native species is to seed the areas in the late fall and to let the seeds germinate with winter rains. Timing is very important. Irrigation is not usually effective. The Project should use seeds from the local area and the seed at rates (pounds per acre) recommended by S & S Seeds. The revegetation areas would be prepared by using a rock rake to roughen up the sand surface (leave deep grooves). Seeds/fruits can then be scattered by hand and buried by raking again with rock rakes.

Most dune plant seeds remain viable for many years but the germination rates of native dune plant seeds will be low in any given year. The recommended seeding rates account for the low germination rates in any single year. If year-one performance is poor because of very low rainfall (less than 6 inches), consider re-seeding in the second year. It will be crucial to prevent grading, grooming, driving and trampling in seeded areas. These same approaches could be used in Reach 3 after non-native plants are removed and in Reach4.

1) Dune forming plants: common name, species and seeding rate (pounds per acre).

Red sand verbena	*Abronia maritima*	10
Beach bur	*Ambrosia chamissonis*	6
Beach saltbush	*Atriplex leucophylla*	8

2) Other plants: common name and species. These plants establish better in areas of stable sand (e.g. the inland edge of site especially after Year One).

California poppy (coastal) *Eschscholzia californica*

Beach evening primrose *Camisoniopsis cheiranthifolia*

INVASIVE NON-NATIVE SPECIES CONTROL

In order to establish appropriate vegetation cover with native plants in the project area, non-native plants will need to be controlled to some extent (the source of the sand used to create the dunes may or may not come with a non-native seed bank). Non-native plants on dunes can be removed by hand or with hand tools. Where the weeds are sparse and when they are growing close to mature native plants, hand removal is recommended. Hand-pulled weeds can be left on site upside down or disposed of off-site. Sea rocket (*Cakile maritima*) should be removed annually by hand-pulling large plants in April and May before seeds fall from the plants. Other non-native plants that must be controlled and could occur along Reach 2 include non-native annual grasses (e.g. ripgut brome, *Bromus diandrus*), ice plant (*Carpobrotus edulis*), sweet clovers (*Melilotus* species), Russian tumbleweed (Salsola kali), New Zealand Spinach (*Tetragonia tetragonioides*). Any weeds that have viable seeds should be disposed of off-site.

Dune restoration efforts in Reach 3 would include initial intensive efforts to remove non-native vegetation such as iceplant and ngaio tree (*Myoporum laetum*). Follow up efforts would be needed, especially to eliminate iceplant seedlings and resprouting ngaio trees. No work would be performed within Carpinteria State Beach without participation and approval of California State Parks.

MONITORING AND PERFORMANCE CRITERIA

Performance criteria for the living shoreline project should be directly tied to both topographic and vegetation goals. These specific goals should be developed in future stages of planning and based on modeling results and the assessment of one or more reference sites. Monitoring the site and assessing whether those criteria have been met will help assure that the resilience-building and ecosystem-related benefits of the project are realized. Performance criteria should focus on measuring appropriate physical and biological ecosystem attributes which respond to coastal processes. The monitoring information will be used to assess whether the project is functioning in the short-term and how it might be expected to be self-sustaining in the long-term. Any performance criteria used should be quantitative and measurable. Monitoring and performance criteria would be focused on Reach 2 in areas under City control, but would also generally apply to Carpinteria State Beach should those project elements proceed.

The ecosystem monitoring strategy for the project should be closely tied to the performance criteria. The specific goals of ecosystem monitoring include: 1) quantitatively assessing progress towards achieving performance criteria during the initial implementation phase, 2) quantitatively documenting achievement of performance criteria at the end of implementation, and 3) informing the adaptive management process during implementation.

Monitoring Protocols

Ecosystem monitoring should occur pre-project and then annually between May 1 and June 30 for at least five years. All monitoring shall be conducted by ecologists familiar with the native and non-native plant species.

Vegetation monitoring will characterize the cover and diversity of native and non-native plants. The monitoring protocols will use at least twelve shore-normal transects extending from the back beach. The transects will consist of lines perpendicular to shore with an established inland endpoint and a fixed compass orientation. The inland endpoints will be located in a stratified-random manner along the shore. During monitoring, fiberglass measuring tapes will be placed on the lines with the zero meter end at the inland endpoint. Data will be collected along the line using a 1 x 1 meter quadrat placed every two meters along the tape. In each quadrat, the cover of each living plant species present will be estimated to the nearest percent. A similar methodology should be carried out at least one reference site.

The data from the project site and reference site(s) will be summarized to allow assessment of project success. Percent cover of vegetation will be calculated (including zero values) for each species on each transect. Overall cover will be calculated by averaging the means for each transect for each species, total natives, total annual non-natives, and total perennial non-natives. Native species richness will be calculated for each transect by totaling the number of different native species observed. Overall average species richness will be calculated by averaging the total for each transect. The project will have achieved its vegetation goals when it is similar to the reference site(s).

The final design for Reach 2 will include a target dune crest elevation. Topographic monitoring will be used to assure this target is met and assess overall changes in sand surface elevation at the site. Topographic monitoring will occur along the same transects used for vegetation monitoring. At a minimum, elevations will be taken every meter along each transect. Elevations may be captured with an auto-level or total station and tied to a benchmark of known elevation, or with a GPS accurate to +/- 5 cm in elevation. Better measurements could be gathered using an RTK GPS to get continuous data along each transect Changes in topography will be estimated by comparing the elevations along the profile during annual monitoring to the profile of that transect as measured pre-project (and also to the most recent year). The change for each of the transects will be averaged at each site to get estimates of change in profile cross section which will allow for estimation of volume changes. This data will be used to assess whether the dunes are increasing in volume (accreting) or decreasing in volume (eroding), and will be important in locating problem areas (erosion hotspots).

The location and elevation of the dune crest (the high point along transect) will be measured on each transect. The location and height of the crest in Years 1 to 5 will be compared to pre-project conditions. For areas without existing dunes in the pre-project period, the location and elevation of the highest point along the transect should be recorded. The maximum elevation for each transect in the annual monitoring will be compared to pre-project conditions, design goals, and data from the previous year. This

will inform the understanding of dune dynamics at the site and help with prioritizing adaptive management actions.

Alternatively, elevation data for the whole site could be collected using a drone and Lidar imaging. This would allow more sophisticated analyses of erosion or accretion hotspots and dune crest elevations. There are increasing local and federal regulations of the flying of drones and they should be carefully assessed before committing to this strategy.

Photographic monitoring points will be established to support assessment of project success. The condition of the site and year-to-year changes can be documented by photographs. Locations of the points will be recorded using GPS. Each point will also have a compass bearing for the direction of the photo. Each photopoint should be re-visited at least annually at the time of vegetation monitoring.

PERFORMANCE CRITERIA

Objective measures of vegetation and topography should be used in assessing restoration success. Monitoring should be done in at least Years 1 through 5. Project monitoring should support the evaluation of success in meeting interim and final goals (Year 5). If any of the Year 1 to 4 goals are not being met, the implementation contractor should, in the annual report, either 1) explain why they still expect Year 5 goals to be met, or 2) trigger adaptive management actions. If any of the Year 5 quantitative goals are not met, the implementation contractor should continue work on the site and monitor project performance until the goals are met.

REPORTING

Monitoring reports will be prepared annually. The reports will include a summary of work to date, summaries of data collected during monitoring (presented in graphs and tables as appropriate), and a discussion of progress towards quantitative goals. The time series of each photo-monitoring sequence should be included as an appendix. Raw monitoring data should be included as Excel files.

ADAPTIVE MANAGEMENT

Adaptive management is a tool for achieving success where there is uncertainty as to what actions will be needed to accomplish specific goals. Ecological restoration is inherently uncertain. There are simply too many variables to control, especially in dynamic systems in a landscape being managed for multiple purposes, with high public visitation. Designing and implementing this project using an adaptive management approach will lead to better outcomes and help the project meet its goals.

The hallmark of the adaptive management approach is a reliance on data that are regularly analyzed and used to assess progress towards the achievement of goals. In the implementation phase of restoration, adaptive management has a clear role in assuring the goals and performance criteria are met by assessing progress (*i.e.*, data collection) and

tweaking techniques and designs as necessary to achieve the goals and performance criteria.

MAINTENANCE

The dunes will require maintenance in the long term. In particular: perimeter fencing will need repair and after a few years it will need to be replaced. Weeds should removed from the site annually to maintain optimum dune performance. Erosion hotspots can be modified with the installation of short segments of sand fencing.

REFERENCES

City of Carpinteria. 2019. City of Carpinteria, Sea level rise vulnerability assessment and adaptation project. Prepared by City of Carpinteria, Wood, Revell Coastal, California Coastal Commission and Caltrans.

Moffatt and Nichol 2021a. City of Carpinteria Dune and Shoreline Management Plan Constraints and Feasibility Report.

Moffatt and Nichol 2021b. Memorandum: Carpinteria Living Shoreline Concept and Analysis. 18 pp.

S and S Seeds. https://www.ssseeds.com/

APPENDIX 1. LIST OF PLANT SPECIES

Native dune plants	**Common name**	
Abronia maritima	Red sand verbena	coastal strand & foredune
Ambrosia chamissonis	Beach bur	coastal strand & foredune
Atriplex leucophylla	Beach saltbush	coastal strand & foredune
Distichlis spicata	Saltgrass	moist areas
Abronia umbellata	Pink sand verbena	stable dune
C*amissoniopsis cheiranthifolia*	Beach evening primrose	stable dune
Eschscholzia californica	California poppy (coastal)	stable dune
Non-native plants		
Ammophila arenaria	European beach grass	coastal strand & dune
Cakile maritima	Sea rocket	coastal strand & dune
Carpobrotus edulis	Ice plant	dune & other upland