

ABA Consultants

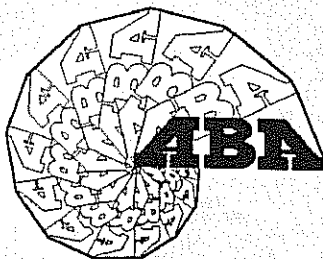
P.O. Box 1151 Capitola, California 95010 (408) 479-0277

Environmental Research, Assessment and Planning

Biological Assessment and Restoration Plan
Sand Dune Reconstruction
at
Moss Landing Marine Laboratories

Prepared for

William Nighswonger
Office of the Chancellor
California State University



1 April 1992

AI

Biological Assessment and Restoration Plan:**SAND DUNE RECONSTRUCTION AT MOSS LANDING MARINE LABORATORIES**

Prepared for William Nighswonger

Office of the Chancellor, California State University

1 April 1992

Contents

1. Summary.....	1
2. Introduction.....	1
3. Purpose of the Report.....	1
4. Background.....	2
4.1 Moss Landing Marine Laboratories' Parcels	2
4.2 Relation to Local and Regional Plans.....	2
4.3 Development Plans of Adjacent Properties	5
5. History of the Parcel.....	7
5.1 Natural History.....	7
5.2 Human Influence.....	8
5.3 Moss Landing Marine Laboratories.....	9
5.4 Demolition of Marine Laboratories	9
5.5 Sand Berm & Shoreline Protection	10
6. Present Environment	11
6.1 Physical Setting	11
6.2 Biological Setting	12
6.2.1 Survey Methods.....	12
6.2.2 Flora.....	13
6.2.3 Fauna.....	15
6.2.4 Endangered Species.....	18
7. Restoration.....	19
7.1 Goals of Restoration.....	20
7.2 Reconstruction	20
7.3 Dune Stabilization.....	22
7.4 Revegetation.....	24
7.5 Volunteers	28
7.6 Eradication of Exotic Plants	28
7.7 Endangered Species	29
7.8 Education and Access	30
8. Monitoring Program.....	31
8.1 Assessment of Recovery Success.....	31
8.2 Methods.....	31
8.3 Evaluation.....	33
9. References	33
10. Experts Consulted	34

Figures and Tables

Figure 1: Regional map showing location of Moss Landing restoration site, and the locations of State Parks restoration sites at Asilomar and Marina.....	3
Figure 2: Map of Moss Landing showing pertinent parcels and the restoration site.....	4
Figure 3: Topographic map of restoration site as of July 1991.....	6
Figure 4: Cross section of dune showing dune configuration and vegetation types associated with dune zones.	14
Figure 5: Topographic map of site showing proposed restoration contours.	22
Table 1. Species found on the sand dunes immediately south and adjacent to the MLML restoration site.....	16
Table 2. Species to be used in revegetating the dune reconstruction site with their appropriate propagation method, (self) indicates species that establish themselves.	26

1. SUMMARY

This report describes the sand dune restoration project on the site of the old Moss Landing Marine Laboratories which were damaged in the Loma Prieta earthquake and demolished leaving a vacant sand lot. A natural dune formation will be constructed on the site using wind blown dune sand from on and off site. The design of dune formation and the plant species used in revegetation are based on the natural model of dune habitats and communities found on the relatively undisturbed dunes to the south of the project site. Fore, mid, and back dune communities will be restored with native vegetation which will provide habitat and protection for native wildlife and therefore aid in its restoration. Reconstructing a natural dune formation and revegetation with native plants are the most important components of the restoration project. The recommended revegetation methods are the most successful methods used in other local and regional sand dune restoration projects, primarily done by State Parks. The revegetation process will be monitored to insure that restoration goals are met and to remediate the project as needed.

2. INTRODUCTION

The Loma Prieta earthquake in October 1989 severely damaged the Moss Landing Marine Laboratories (MLML). Subsequently, the buildings and seawall were demolished in February 1991 leaving an open lot adjacent to the beach. A protective berm was constructed as an interim measure until a sand dune reconstruction plan could be developed. This report provides a plan for the reconstruction and restoration of sand dunes on the site.

Sand dunes are fragile habitat with specialized vegetation adapted to unique conditions. Sand dune habitat is a diminishing resource along the California Coast primarily the result of destruction by human developments. As a result a number of dune species are now threatened and/or endangered. There are few opportunities to reconstruct sand dunes, as shoreline developments are rarely removed from dune habitats. The demolition and relocation of MLML provides a unique opportunity to reconstruct important natural habitat and restore coastal communities of special biological significance.

The sand dune reconstruction project is being undertaken by California State University (CSU) with funding from the Federal Emergency Management Agency (FEMA) and support from the State of California Office of Emergency Services (OES).

3. PURPOSE OF THE REPORT

The purpose of this report is to determine the feasibility of restoring a sand dune on the vacant parcels; to ascertain if there are any endangered or threatened species that can be disturbed by reconstruction efforts; to provide a restoration and implementation plan to return the parcel to as natural a state as possible; to protect the sand dune habitat from human induced disturbance; and to describe a monitoring program to document the restoration's progress. The report is being prepared as requested by the Monterey County Planning Department and the California Coastal Commission.

4. BACKGROUND

4.1 MOSS LANDING MARINE LABORATORIES' PARCELS

The proposed reconstruction site is a roughly rectangular area of 2.1 acres in the central Monterey Bay region (Figure 1), and includes parcel numbers 133-232-7 and 133-232-8 in Monterey County records (Figure 2). The site is bordered by ocean and beach to the west, the temporary shore facility for MLML to the north, a road (the only emergency access to the island in Moss Landing) and the Old Salinas River channel to the east, and sand dunes to the south.

The site is currently owned by the California State University (CSU). In addition, CSU owns the sand dunes south of the site and a driveway ending in a public access parking lot for a total of approximately 8 acres within the Moss Landing Beach and dune system. CSU intends to restore the site to natural sand dune habitat and to shift ownership of the entire 8 acres to the California Department of Parks and Recreation.

4.2 RELATION TO LOCAL AND REGIONAL PLANS

The management of coastal resources such as sand dunes is addressed in local plans and in coastal regulations resulting from the Coastal Act 1972. Coastal planning gives sand dune preservation, protection, and enhancement the highest priority. The North Monterey County Land Use Plan states: "The highest priority is placed upon the preservation and protection of natural resources including sensitive habitat areas i.e., dunes, ...". Sand dunes are identified as Areas of Special Biological Significance by the State Water Resources Control Board. The plan's policy section states "The environmentally sensitive habitats ... shall be protected, maintained, and where possible, enhanced and restored." The North County Area Plan identifies the vegetation communities on sand dunes as "unique coastal strand" and sets policies "To retain the viability of threatened or limited vegetative communities,... to promote the area's scenic qualities to preserve rare, endangered and endemic plants for scientific study." "The conservation of North County's remaining tracts of native vegetation shall be given high priority." The Monterey County Coastal Implementation Plan (MCCIP) regulations (part 1) for resource conservation districts state, "The purpose of this chapter is to provide a district to protect, preserve, enhance and restore sensitive resources areas in the Coastal Zone including ... dunes." This plan also delineates the principal uses of resource conservation areas to include "Restoration and management programs for fish, wildlife, or other physical resources." The MCCIP regulations for development in the North County Land Use Plan Area presents standards for environmentally sensitive habitat such as dunes: "The intent of this section is to provide development standards which will allow for the protection, maintenance, and where possible, enhancement and restoration of North County environmentally sensitive habitats. [These habitats] are unique, limited and fragile resources of Statewide significance."

The County plans also outline uses that are appropriate for dune habitat which are primarily low intensity recreational and educational uses with an emphasis on providing the public's right to shoreline access. The North County Land Use Plan addresses these issues as follows: "The beaches of the coast north of the Salinas River, including the Salinas River State Beach and Zumdotski

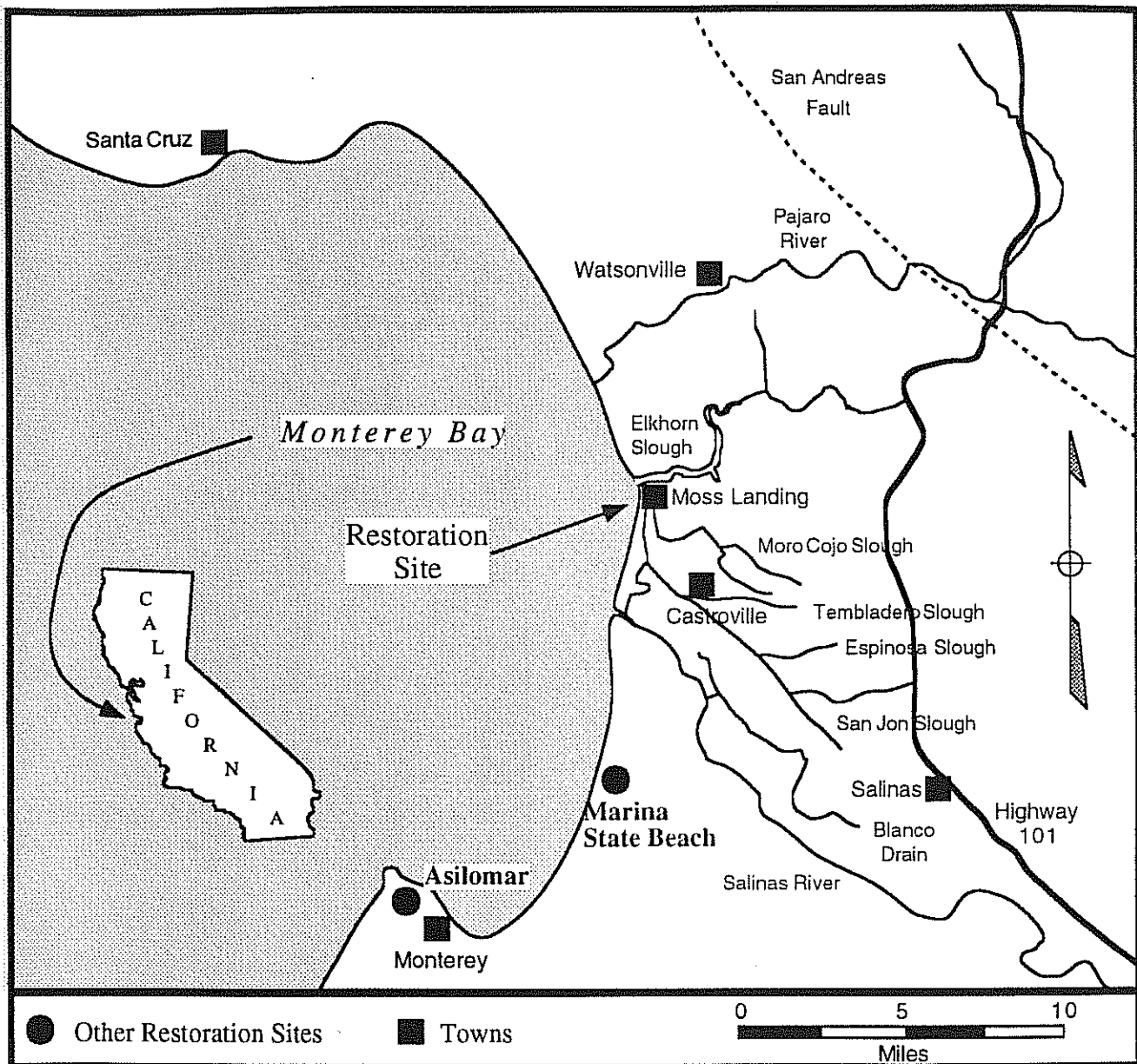


Figure 1: Map showing location of Moss Landing restoration site on Monterey Bay, and the locations of State Parks restoration sites at Marina and Asilomar State Beaches.

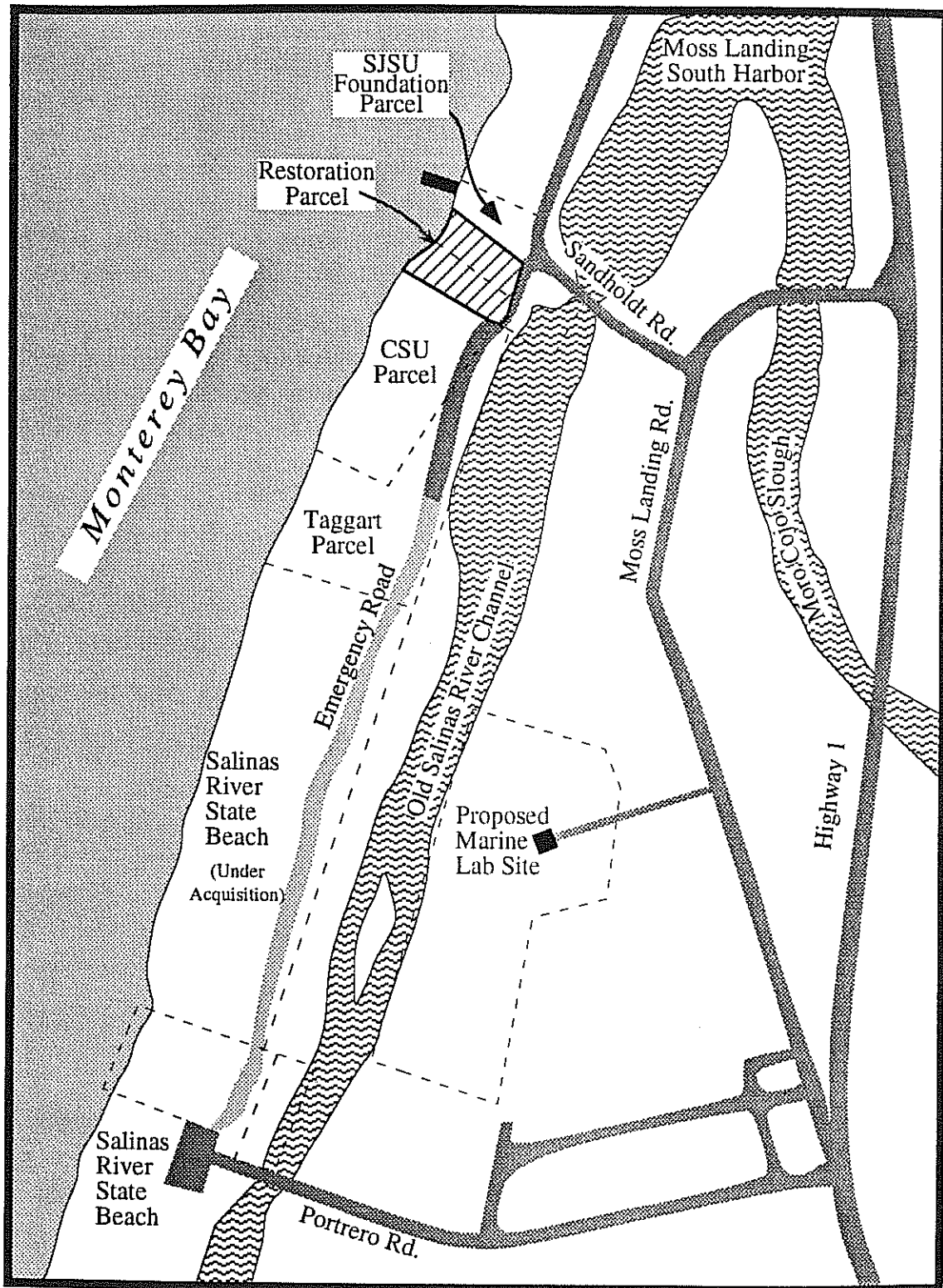


Figure 2: Map of Moss Landing vicinity showing pertinent parcels and restoration site.

State beach, are designated for Scenic and Natural Resource Recreation." The plan continues in the policy section, "The Moss Landing Community contains a variety of sandy beaches, dunes, estuaries and wetland habitats... In the spirit of the Coastal Act, public access to these areas shall be provided. However, conservation of the sensitive natural resources of the coastline is an even higher priority." Moss Landing Marine Laboratories has provided public access via a parking lot and dune boardwalk behind the dunes and next to the restoration site. This access is listed as a major beach access site in the NCLUP (pp123) for long-term public use. The Monterey County Coastal Implementation Plan identifies the principle uses for sensitive resource areas to include, "Resource dependent educational and scientific research and low intensity day use recreation...".

The California Department of Parks and Recreation's regional goals include extending the Salinas River State Beach system northward to Moss Landing. The parks department is currently in the process of acquiring the land just north of the current state beach boundaries (and south of the restoration site). Once the current acquisition is complete there will be only one parcel between the Salinas River State Beach boundaries and CSU's shoreline properties. The proximity of CSU's property to Salinas River State Beach, its location midway between Moss Landing State Beach and Salinas State Beach, and the already developed public access to CSU's property (Figures 1 & 2) makes the transfer of the property to state beach a natural extension of park jurisdiction. The draft letter of intent to extend Salinas River State Beach is currently in review within the park system and strongly supports adding the CSU parcels including the restoration site (Roth, pers. comm.).

4.3 DEVELOPMENT PLANS OF ADJACENT PROPERTIES

There are currently no plans for additional development to the west or south of the site.

The property to the north is owned by San Jose State Foundation and is used by MLML and the California Department of Fish and Game (CDFG), and has been used as a temporary shore facility since the earthquake. The shore facility consists of trailers, storage sheds, and a seawater system and aquarium area (Figure 3). Some of the activity on this parcel will be moved to the new MLML once it is rebuilt. MLML is considering the site as a support facility for an offshore seawater intake, and as a research staging area.

There are two small parcels immediately east of the site across the road. The parcels are part of CSU's acreage that will be transferred to state parks and there are no plans to develop the property. There are two small buildings on the east side (parcel # 133-233-1) which are used by MLML as field labs. MLML plans to continue to maintain and use the buildings after the property is transferred to State Parks. The buildings and their use are not in conflict with the sand dune restoration. The remaining parts of these parcels are salt marsh and tidal mudflat (Figure 3).

The dune complex immediately to the south is also CSU property and will be transferred to State Parks ownership in the near future. South of the CSU land are two privately owned parcels. State Parks is currently in the process of acquiring the one adjacent to and north of the Salinas River State Beach. Because of current coastal zone regulations it is highly unlikely that the remaining private

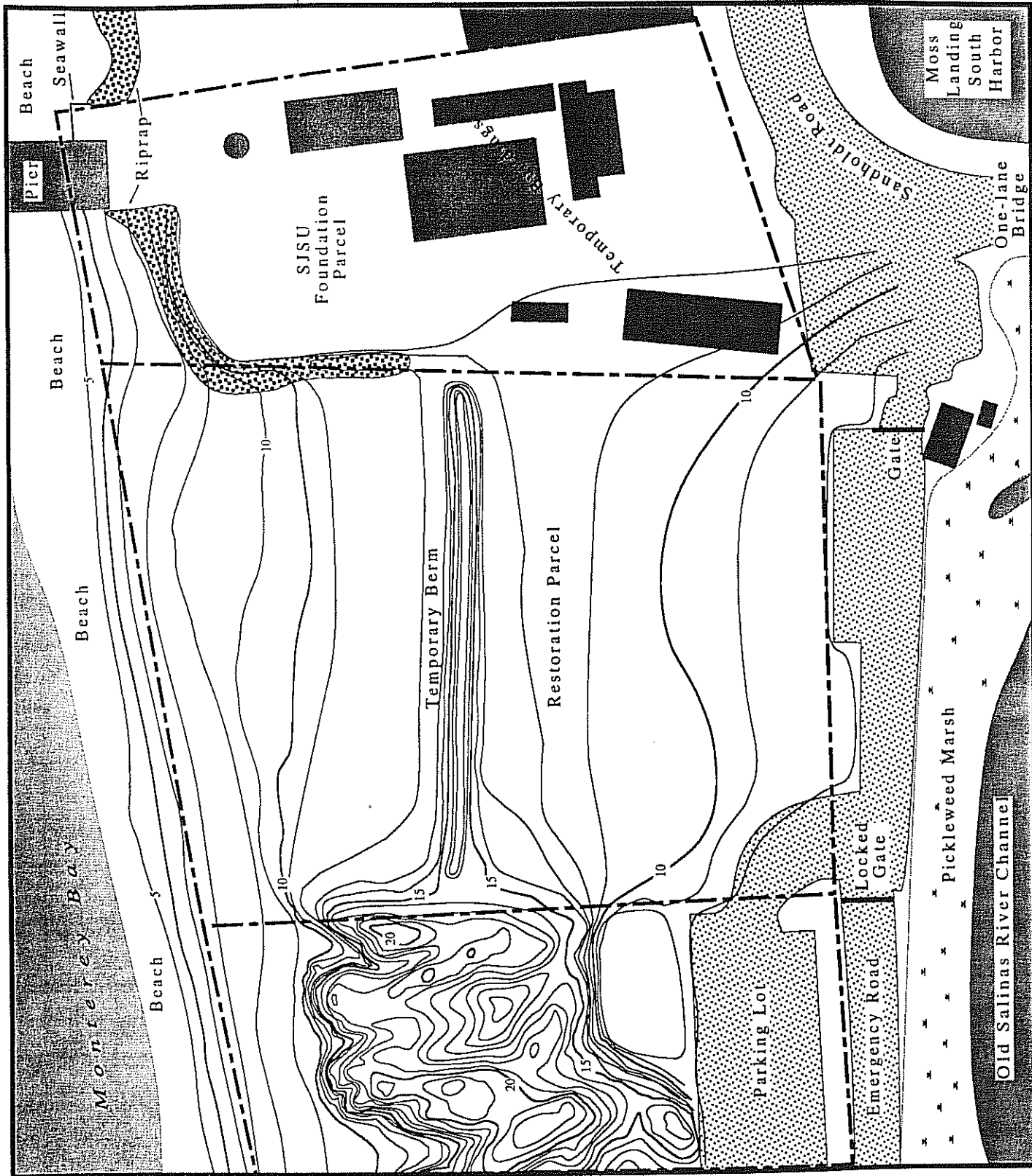


Figure 3:

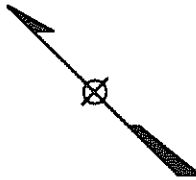
Moss Landing Marine Labs

Dune Restoration

Contours as of
July 1991

Contour Interval = 1 foot

Contours from MSL



parcel will be developed. State Parks is interested in acquiring the parcel which would result in a continuous strip of protected coastline from Moss Landing south to the Salinas River.

While it is unlikely that there will be any development of the Old Salinas River Channel, there has been local discussion about expanding Moss Landing Harbor into the area. As the channel is rare wetland habitat, it is more likely that this will become a dedicated wildlife conservation area. The North Monterey County Local Coastal Plan mandates the development of a wetland management plan for the Old Salinas River. This plan has not been produced. Restored and well maintained dune habitats will protect the integrity of habitats on the shoreline, wetlands, and river channel.

5. HISTORY OF THE PARCEL

5.1 NATURAL HISTORY

Monterey Bay beaches have resulted from the remarkably dynamic Pleistocene climatic fluctuations. Continental-wide ice sheets advanced and retreated four times, with associated sea level changes of hundreds of feet; tremendous changes in weather from cold, dry, and windy to wet enough to produced 900 foot deep lakes in what is now desert California. During the last million plus years these forces built a huge dune system between the southeast shore of the bay and the Salinas River, now mainly covered by Fort Ord and Seaside - the pre-Flandrian sheet. The shoreward face of these dunes eroded and the sands were superposed on the pre-Flandrian formation into high, active Flandrian dunes which are slowly retreating due to heavy winter surf and a gradual sea level rise. Pre-Flandrian and Flandrian dune cliffs also face the northern part of the bay. The very recent dunes bounding the floodplains of the Pajaro, and Salinas Rivers and Elkhorn Slough are formed of fluvial sediment from those drainages (Cooper, 1967). The historic coastal route of the Salinas River was parallel to shore, just behind these recent dunes, to its mouth a mile north of the north Moss Landing jetty. During heavy rain years the river breached the dunes at the site or nearby. There are no breachings in recorded history, and since 1908 the river was permanently diverted to its present mouth about 5 miles south and the Old Salinas River Channel became a drainage for only local runoff (Gordon 1979).

Climate has also strongly influenced the vegetation covering dunes. The dynamic Pleistocene weather caused great floral migrations, north, south and elevational, extinctions, speciations, isolation of relict or retreating populations. Much of todays vegetation is derived from a northern flora (Arcto-Tertiary) established under cold ice age conditions, and a southern flora (Madrone-Tertiary) from the south (Munz and Keck, 1959). Dune vegetation growing under the often harsh cold, dry, windy Pleistocene climates would have been marginally effective at stabilizing sands. In the last few thousand years the local climate has been moderate, gradually becoming drier, resulting in contemporaneous gradual changes in natural flora and fauna.

Before European colonization, Coastal Central California was inhabited with an impressive population of large animals, many of which used dune habitats to greater or lesser degree. There are anecdotal accounts of large numbers of grizzly bears roaming the beaches scavenging carrion of

stranded whales. California condors certainly fed off the same carrion (the Pajaro River takes its name from that bird). Elk may still be found along the beaches of northern California. Certainly Indian use of this coast is well documented through middens which they left behind in dunes. Wolves and pronghorn antelope were present as were legendarily huge populations of waterfowl, all of which undoubtedly made at least occasional use of dune habitats. Mountain lions, bobcats, deer and coyotes, still (or again) reasonably abundant, do not occur frequently or at all in the local dunes, but likely made more use of dune habitats in pre-Columbian times, although all four species use the larger pre-Flandrian dune systems. Many species of marine mammals abounded on the seaward side of the dunes. Sea otters haul out in dunes in Alaska and may well have done so here. Seals still use local beaches for resting and pupping. Sea lions and especially elephant seals, again abundant after near extirpation, may have made more or less use of Monterey Bay sands for hauling out, breeding and pupping. In the last 200 years abrupt and dramatic changes have taken place due to the European colonization. These changes are permanent, species are extinct, population proportions have been enormously distorted, habitats have been used up. Even those few species whose populations are at approximately pristine levels cannot return to pristine conditions, as interactions with other species, migration or travel routes, habitats for feeding, breeding and other activities no longer exist.

5.2 HUMAN INFLUENCE

The area has been influenced by humans since Native Americans used the area as early as 7,000 years ago. There are a large number of Indian middens, village remains, burials, and other archaeological sites around the Old Salinas River Channel and the mouth of Elkhorn Slough. Local excavations have shown the Indians often lived on low hillsides adjacent to the wetland areas and their diet included a large amount of marine species, especially shellfish (Gordon 1979, Breschini 1991). However, the impacts of such use to the local dunes were minimal. The Native American presence and impacts largely disappeared after European settlement.

Europeans, mostly Spanish-Mexicans, first established settlements in Monterey Bay about 1770. In the late 1800's shoreline whaling began in Monterey Bay. This industry was established throughout the bay including several whaling stations and canneries in Moss Landing. These early whaling stations failed as the number of coastal whales decreased. A second whaling era, utilizing mechanized whale capture and processing factories, flourished in the 1920's, killing almost all the humpback and other larger whales in the coastal region. One factory was located in Moss Landing just north of the restoration site, but closed in 1926 when whales became scarce (Gordon 1979).

In the 1870s the Moss Landing area was developed into a harbor and port for agricultural products. The activity increased the local population and small houses were built on the dunes. At least two small homes were located in the general area of the restoration site, and Cypress trees were planted next to the homes.

The restoration site was subjected to breaches by the Salinas River and low parts of the dunes where undoubtedly cut open by heavy surf. In 1909-1910 the river breached the dunes to its present

location 5 miles south of the restoration site. The river mouth has since been maintained at this location by diking. The southern relocation of the river mouth has greatly reduced the degradation of the Moss Landing dunes, and the beach and dunes have broadened somewhat as a result (Gordon 1979).

In 1946 the Army Corps of Engineers breached the dunes north of the restoration site and built jetties creating a permanent harbor opening. In the same era, large industrial plants were located on the landward side of the harbor: both the Kaiser Refractories (now National Refractories) established in 1942 and the Pacific Gas and Electric plant established in 1952, use seawater in the operation and have discharges offshore and into the air. Effects of the industry on the sand dune community are unknown, but some acid rain may effect the dune vegetation.

A sardine cannery was built on the restoration site in the late 1930's or early 1940's and was used as a warehouse in the late 1950's. The Beaudette Foundation acquired the cannery building in their early 1960s and converted the building into a marine laboratory. The marine laboratory was transferred to the California State University system in 1966, becoming its first and only field research facility.

5.3 MOSS LANDING MARINE LABORATORIES

Moss Landing Marine Laboratories, a marine educational and research facility, has been located on the site for the last 25 years. The labs began in the original cannery warehouse. The cannery building reached from shore to wetland and was two stories high. In 1983, the labs were expanded and doubled in size to over 35,000 square feet, covering approximately 2.1 shoreline acres with buildings. The buildings had a significant visual impact on the coast and could be observed from the state beach, the central antique shop area, the harbor, and offshore. The expanded labs had a high seawater tower that could be seen from a long distance away.

5.4 DEMOLITION OF MARINE LABORATORIES

During the Loma Prieta Earthquake, the MLML buildings suffered severe damage as the result of liquefaction and movement of the underlying sand. The location of the lab buildings relatively close to the steep walls of the Monterey Submarine Canyon, as well as over an old river channel, resulted in more extensive damage compared to other buildings in the Moss Landing area. FEMA determined MLML could not be rebuilt on the original site because of high earthquake risk and its location within the 100 year floodplain. It was therefore necessary to reconstruct the lab at a different location.

The labs buildings were demolished in February 1991 and all the debris larger than 5 inches was removed. The seawall which protected the labs was also removed. A riprap revetment was installed along the adjacent San Jose State University Foundation property to provide temporary protection from wave damage. The restoration site was extensively disturbed during the demolition process and the remaining sand was moved by bulldozers, leaving a vacant sand lot without any vegetation. The site is now a low area at the northern edge of a more extensive natural dune complex. The low

sand is 1-2 feet higher at the south end than the north. The rise was created by bulldozers moving sand from the road area and by the natural drift of sand from the southern dunes.

The driveway, parking lot and boardwalk over the dunes were not removed during demolition. The public has continued to have access to the beach through the parking area. The access was created as a result of a mandate in the North County Land Use Plan when the labs buildings were expanded. The boardwalk is in need of repair, and sand from the dunes has begun to encroach on the parking lot.

5.5 SAND BERM & SHORELINE PROTECTION

There was considerable local concern from marine labs staff, the Moss Landing Harbor District, Monterey County Flood Control, and the State Coastal Commission that ocean waves and high tides might breach the site and damage adjacent property, wetlands, emergency access road, and harbor. As a result, FEMA and OES supported the construction of a protective sand berm across the site to reduce the threat of such ocean breaching. The sand berm was intended as an interim solution until a sand dune reconstruction plan (this document) could be prepared. The berm is only a first phase in the full restoration project.

The berm construction was completed during the first days of March 1991. It was located approximately 40 feet inland from the pre-existing lab seawall, and is 45 feet wide at the base, 13 feet across the top, over 15 feet above MSL, and is about 270 feet long from the north to south (Figure 3). The rock rip rap protecting the northern property extends underneath the northern end of the berm.

The berm was built using over 3,500 cubic yards of sand donated from Monterey County's sand stockpile located directly across the harbor from the site. The material was analyzed for grain size and consisted of 25% fine silty sand, 25% fine grained sand, 40% medium grained sand, and 10 % coarse grained sand. The harbor district contracted chemical analysis of the material (by Toxscan, Inc.), and found it to be essentially clean of chemical contamination. While more than adequate as basement material, the berm material is too coarse and silty to be used as surface dune sand and needs to be covered by surface dune sands.

The berm construction was made possible as the result of donations to the construction of the berm by several agencies. Monterey County Flood Control contributed the sand, loaders, dump trucks, and operators. The Moss Landing Harbor District provided chemical analysis, a dump truck and driver, and refreshments for the workers. CSU, with support from OES and FEMA, provided additional trucks and a construction crew to shape the berm. The Gabilan Conservation Camp crew supervised by the California Dept. of Forestry donated time to stabilize the sand berm. This high degree of cooperation between diverse agencies and institutions is unprecedented in the Moss Landing area.

Drift fencing was installed around the new berm to capture wind blown sand and to discourage pedestrians from walking through the area. In addition, signs identifying the restoration project were placed around the project. To further stabilize the barrier sand and to capture additional wind

blown sand, the barrier and adjacent flat sand areas were straw plugged with long stem straw in early July 1991. Handfuls of the straw were pushed into the sand by hand leaving about half the straw plug above ground (about 1 foot high). The entire barrier was plugged with plugs approximately 2-3 feet apart. Straw plugging stabilizes dune sand for up to three years, and has an additional benefit of trapping local seeds and additional sand.

The berm is not as large as the adjacent dunes. A more natural dune formation requires approximately 5 to 7 thousand cubic yards of additional sand. The acquisition of this additional sand is part of the restoration plan.

6. PRESENT ENVIRONMENT

6.1 PHYSICAL SETTING

The dunes are constantly under the influence of winds and especially waves. During heavy storms, such as those in 1982-83, waves are known to erode and cut back the fore dunes. It was necessary to build a seawall to protect the expanded MLML from wave erosion. Waves can be as large as 20 feet and have cut into the fore dunes over 10 feet. This formidable force is an important consideration in the restoration project.

The major source of sand for the beach and dunes is from local rivers, especially the Salinas and Pajaro. The natural flows in these rivers have been grossly modified by damming, diverting, and ditching tributaries and the main river. The main river courses have been straightened, diked, and channelized. Wetlands associated with rivers were ditched and drained for reclamation for farming, grazing, and other human activities (Gordon 1979, Lydon 1985). In addition to grossly modifying the surface flow and storage of water, the subsurface water resources have been radically altered by wells. Salt water intrusion is now common in the first and second major aquifers around the mouths of both rivers and around Elkhorn Slough (Johnson 1983).

The changes in water flow have reduced the input of sands from rivers. As a result, beaches are receding in most parts of Monterey Bay. Sand dunes are also eroding from the shore at rates as high as a meter per year. Even the size of the sediment fans on the continental shelf around the Salinas River has decreased in this century.

Sand movement to the Moss Landing beaches comes from both the north and south with a significant fraction captured behind the north jetty and much of the material eventually flowing into the submarine canyon. The submarine canyon brings deep water closest to shore at Moss Landing. In fact the most shoreward arm of the canyon is directly in front of the Moss Landing pier and adjacent to the old marine lab site. This steep offshore topography permits the development of only relatively narrow beaches at the canyon head. In addition, the submarine canyon diverts wave energy away from its head creating an area of relatively small waves at the canyon head. The low wave energy and reduced erosion of the back dunes after the Salinas River was diverted probably account for the lack of significant net erosion of the dune system since at least 1930.

In summary, although beaches and sand dunes are receding in much of Monterey Bay, the narrow beaches and dunes at Moss Landing have been relatively stable for over 50 years. This situation changed after the Loma Prieta earthquake.

The earthquake caused significant local subsidence of coastal areas in Moss Landing and up the Elkhorn Slough. Surveys of established bench marks show a drop of 6 inches on the east side of the one lane bridge and one foot at the west end of the bridge at the property line of the parcel owned by San Jose State University Foundation (Figure 3). These elevations were compared to a marker at Highway One, which also may have been lowered by the earthquake. There have been no surveys of larger areas to test for larger subsidence patterns. Clearly, the seaward areas of Moss Landing in front of the pier subsided. The lowering increases from east to west, and was greatest at the seawall of the old marine lab and directly in front of the pier. Here the land surface is at least 1.5 feet lower than the reference marker at Highway One.

As a result, the erosion of the beach at the pier has been severe since the earthquake. Old industrial structures which have been buried in the beach for decades were exposed with the first winter storms after the quake. The 1989-90 winter was remarkably mild. The 1990-91 winter was almost as mild. The first 10-20 year storm will cause major erosion around the pier. The present dune restoration plan addresses this likely erosion and attempts to provide as much shoreline protection as possible. There are distinct physical limitations to this protection, largely related to the lower elevations caused by the earthquake, the narrow dune system at Moss Landing, and the ending of the dune at the commercial developments to the north of the restoration site. These are important physical limitations to natural dune development and restoration.

The general impacts of the earthquake on local topography were significant beyond the old marine lab site and the pier. The natural marshes in the Old Salinas River subsided at least 6 inches and the upper marsh vegetation has already changed because of increased tidal inundation. The natural marshes in Bennett Slough subsided an unknown amount, but the physical evidence of subsidence was obvious. There was major cracking of marsh deposits around the old mouth of the Salinas River and the deposits in wet tidal creeks were uplifted in response to larger areas of vegetated marsh sinking. The most biological significant subsidence occurred along the main channel of Elkhorn Slough. Extensive vegetated salt marshes flank this channel along its entire length, which extends some 7 miles inland. These marshes are several inches to 1/2 foot lower after the earthquake. The daily rise of the tide covers more marsh than at any time in recorded history. Although as yet unexplored, this tidal inundation will cause major changes in the Elkhorn Slough marshes which were already eroding and degrading at record rates before the earthquake (Oliver et al. in review).

6.2 BIOLOGICAL SETTING

6.2.1 Survey Methods

A survey of plants on the dunes just south of the restoration site was performed in May 1991 during the flowering period, with a follow up visit in early September when many species had completed

their annual cycle. Since the surveys were during the dry season, fungi were not observed. In addition, we examined dune survey data and slides collected by MLML from 1972 to 1988. The MLML data were collected in a similar manner over the same dune area on a nearly annual basis as part of classwork (Caillett, 1972-1988). In this report we present a comprehensive list showing the species that were present and identified in MLML surveys and our more recent surveys (Table 1).

The survey was done by walking the entire area and visually observing all plants. Because the area is small and covered by a well defined community of plants, more sophisticated survey methods were unnecessary. Most of the plants were readily identified visually in the field. Any plant not recognized in the field was collected as a voucher specimen and identified in the laboratory.

The sand berm area on the restoration site was surveyed in the same fashion in July 1991, before non-natives were weeded, with a follow-up survey in September 1991.

6.2.2 Flora

The dune area is part of an integrated system of intertidal, beach, dune and wetland habitat. Each habitat is closely associated to the other and wildlife such as birds, mammals and insects travel regularly and easily from one type the other. The plant communities tend to overlap at the transition zones between them. As a result, wetland species such as pickleweed can be found in a dune transect but should not be considered as a revegetation species for the restoration site.

The plant community adjacent to the restoration site is entirely coastal sand dune, also referred to as coastal strand, with at least 32 plant species present. No listed endangered or threatened plant species were found in the survey, but Monterey Indian Paint Brush is considered a species of special concern by the California Native Plant Society's rare and endangered plant inventory.

Sand dune communities are zonal, with different species from the fore dune (beach side) to the back dune (roadside), but the sequences may vary between sites. Differences between plant communities in the fore and back dune are caused by physical factors. Fore dunes are nearly continually windswept and subjected to abrasive sands, surf, and salt spray. Back dunes are protected and develop good soil. As a result, there are usually more plant species, including woody varieties, wildlife, and plant cover (vertical and horizontal) on back dunes. Fore dune species may occur on the back dune especially in disturbed areas. The zonation is distinct in larger dune systems such as the Salinas River State Beach dunes. The dominant plant species on the fore dunes of the study site are sea rocket, salt bush, silky beach pea, beach bur, beach primrose, dune grasses, and ice plant. The back dune dominants are bush lupine, sand verbena, golden yarrow, mock heather, ice plant, wild mustards and annual grasses (Figure 4) (Table 1).

Exotic or introduced species are of major concern in the Monterey Bay coastal dune system. They alter and damage the dune habitat influencing virtually all dune plant processes including succession, productivity, diversity, and stability (Moss 1987). They can out-compete native plants probably by colonizing disturbed habitat and inhibiting reestablishment of the native species.

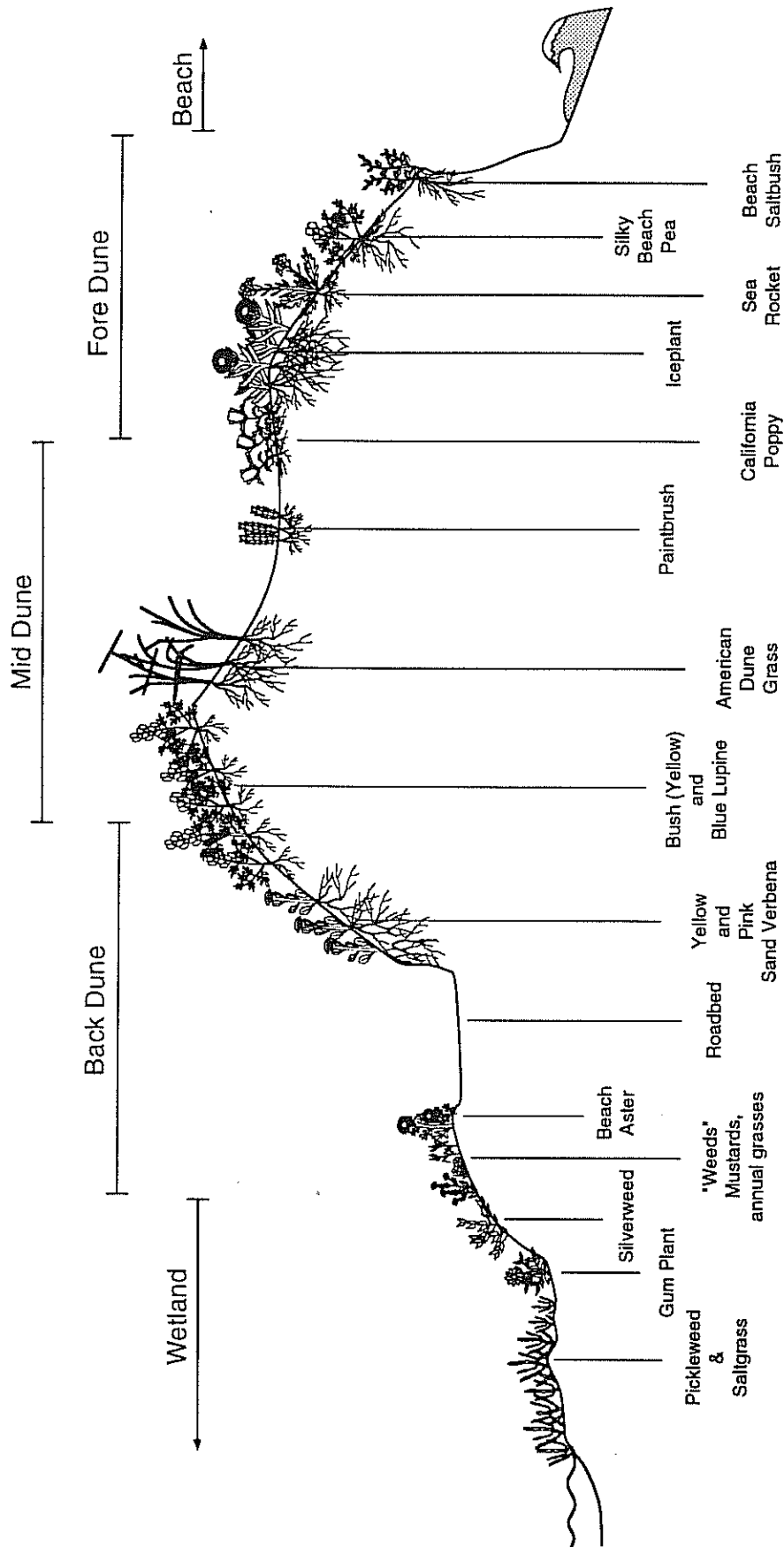


Figure 4: Cross section of dune showing dune configuration and vegetation types associated with dune zones. Shown are both endemics and exotics, some of which (ice plant specifically) will be eradicated as part of restoration.

Aggressively invasive exotics found on the adjacent dunes include ice plant, or hottentot fig, Holland dune grass, annual grasses (e.g. ripgut, rye, foxtail), and wild mustards, including wild radish. These problem species require aggressive control measures. New Zealand spinach and sea rocket are also exotics but without the same negative value.

Ice plant is one of the most invasive exotic species in the local dune system. By July 1991, ice plant seedlings were already colonizing the sand berm. It forms extensive mats that spread rapidly and crowd out native plants, and may impede recolonization of native plants with alleopathic chemicals. It has displaced several state endangered plant species including Menzies' wallflower, Tidestrom's lupine, and coast gila throughout the state. Ice plant is unsuitable habitat for most wildlife species including native insect populations which are consumed by other wildlife. Legless lizards, which eat insects, do not occur in ice plant, and are only found with native plants. In addition, ice plant may increase erosion and sand loss in the dune structure because it is not as effective as native plants at trapping wind blown sand; it even dies when buried by moving sands. A decrease in size of the sand dunes at Asilomar was blamed on ice plant (Moss, 1987).

As a result of the detrimental effects of exotic species, many dune enhancement projects including those at Sunset State Beach, Asilomar State Beach, and Marina State Beach include aggressive removal of exotic species (Gray 1985a & 1985b, Moss 1987). The non-native sea rocket species (*C. maritima*) is an early colonizer which has replaced the native species (*C. edentulata*) and its removal is not necessarily recommended.

The sand berm restoration site has been colonized by local plants both from wind blown seed and by seeds already in the sand berm soil. The colonizing species include beach primrose, sea rocket, beach bur, fat hen, ice plant, salt grass, and New Zealand spinach. The sand berm has been weeded of all ice plant seedlings in July and December 1991. There was an average of 2.3 ice plant seedlings per square meter in the July weeding, but only several dozen plants in December. Otherwise few non-native pest species sprouted. Rapid and early colonization indicates that the base material is essentially free of non-dune species and good habitat for establishing dune plants. The colonizers have helped to capture wind blown sand on the new dune.

6.2.3 Fauna

By far, insects and spiders are the most abundant fauna living on the dunes. Over 300 insect species are known to live in local dune habitats and a large number of the species are herbivores. These insects are a primary food source for lizards that use the dunes. Several butterflies were observed in the study area and include painted and western ladies, cabbage butterflies, a monarch butterfly, small skippers, and buckeye butterflies. The latter use the dirt road behind the dunes as perching territory.

Several species of reptiles may be directly or indirectly associated with the site. Western fence lizards, alligator lizards, garter snakes, and gopher snakes are relatively common in north Monterey county and could occur in the back dunes or adjacent areas. However, two species are sand-dwellers and will ultimately benefit directly from restored dune habitat. The legless lizard is

Table 1. Species found on the sand dunes immediately south and adjacent to the MLML restoration site. Bolded names indicate species that have already begun to colonize the sand berm and open lot. Names with an asterisk are exotics, at least non-native to the area. (Scientific and common names used here are not necessarily the most current, but rather the most easily recognized.)

<u>COMMON NAME</u>	<u>SCIENTIFIC NAME</u>
American Dune Grass	<i>Elymus mollis</i>
Dune Bluegrass	<i>Poa douglasii</i>
Beach Aster	<i>Corethrogyne californica</i>
Beach Bur	<i>Ambrosia chamissonis</i>
Beach Morning Glory	<i>Convolvulus soldanella</i>
Beach Primrose	<i>Camissonia cheiranthifolia</i>
Beach Sagewort	<i>Artemisia pycnocephala</i>
Beach Saltbush	<i>Atriplex leucophylla</i>
Blue Beach Lupine	<i>Lupinus chamissonis</i>
California Poppy	<i>Eschscholzia californica</i>
California Sea-Blite	<i>Suaeda californica</i>
Coast Buckwheat	<i>Eriogonum latifolium</i>
Coastal Gum Plant	<i>Grindelia latifolia</i>
Farmer's Foxtail *	<i>Hordeum leporinum</i>
Fat Hen	<i>Atriplex patula</i>
Golden Yarrow or Lizard Tail	<i>Eriophyllum staechadifolium</i>
Hemlock*	<i>Conium Maculatum</i>
Holland Dune Grass *	<i>Ammophila arenaria</i>
Hottentot Fig (Ice Plant)*	<i>Carpobrotus edule</i>
Ice Plant (Sea Fig)*	<i>Carpobrotus chilense</i>
Malva Rose*	<i>Lavatera assurgentiflora</i>
Miner's Lettuce	<i>Montia perfoliata</i>
Mock Heather	<i>Haplopappus ericoides</i>
Monterey Indian Paint Brush	<i>Castilleja latifolia</i>
New Zealand Spinach*	<i>Tetragonia tetragoniodes</i>
Pickleweed	<i>Salicornia virginica</i>
Pink Sand Verbena	<i>Abronia umbellata</i>
Salt Grass	<i>Distichlis spicata</i>
Sea Rocket*	<i>Cakile maritima</i>
Silky Beach Pea	<i>Lathyrus littoralis</i>
Wild Mustards*	<i>Brassica</i> spp.
Wild Radish *	<i>Raphanus sativus</i>
Yellow Beach Lupine	<i>Lupinus arboreus</i>
Yellow Sand Verbena	<i>Abronia latifolia</i>

particularly interesting in that the ranges of both of the two subspecies (*Aniella p. pulchra* and *A. p. nigra*) occur in the dunes between Moss Landing and the Salinas River mouth. Consequently, individuals of intergrading population characteristics may be found. They are usually active at night and rely on insects for food (Stebbins, 1954). Therefore the lizards may be most often found beneath vegetation such as shrubs on which insects are abundant. The California horned lizard form of the coast horned lizard also requires insects, especially ants. This subspecies occurs at least as close as Marina State Beach (personal observation, Stebbins, 1954) and may become part of the fauna of the restoration site either through natural movement or through future translocation.

Several mammals use the dunes and or adjacent habitat: opossums, muskrats, cottontail and brush rabbits, jack rabbits, meadow voles and deer mice, pocket gophers, ground squirrels, red and gray foxes, weasels, skunks, raccoons, bats, shrews, and deer, include most of the species most likely to occur here and benefit from the project. Deer have not actually been observed using the restoration site area but are reported to use the dune complex south of Potrero Road. In addition, squirrels have a series of burrows in the roadside mounds south of the restoration area. Rabbits were observed feeding on the tender shoots of dune plants. While not observed, insectivorous small mammals, shrews and moles, undoubtedly use habitats adjacent to the dunes, and possibly the dunes.

Red foxes are a growing nuisance in North Monterey County since their illegal introduction several years ago. They may be observed in the dunes where they prey on small mammals and ground-nesting birds, which are seriously threatened by this introduction. Feral cats are another non-natural mammal which roam in the dune system and are a serious nuisance to wildlife restoration efforts. Norway rats and house mice from the nearby Moss Landing fish processing industry are threats to invade and disrupt natural flora and fauna through predation, herbivory, and direct competition. Restoration will discourage these two pests.

Many species of marine mammals use the waters adjacent to the restoration site. Several use the beach: harbor seals, California and Stellar sea lions, sea otters, and even occasionally northern fur seals. Almost always when individuals of these species are on this beach it is because they are sick, wounded or weakened and unable to behave normally.

A large number of bird species have been observed in the general area as residents, during seasonal migrations, or during daily movements. In fact nearly all west coast bird species can be observed traveling over the dune area or using the adjacent beach or wetlands. Gulls, for example, assemble by the thousands almost every late afternoon as they fly from down coast to Moss Landing where they turn and fly out to sea for the night. Many species, often in large numbers, make use of the Old Salinas River - phalaropes in seasonal pulses, and gulls and marbled godwits on a more frequent basis and sanderlings, willets and sand pipers. Birds making direct use of the dunes include killdeer, semipalmated plovers, western plovers, snowy plovers, and in the back dunes terrestrial species such as meadowlarks, white crowned sparrows, song sparrows, savannah sparrows, barn

swallows, and many raptors, e.g. marsh, red-tailed, red-shouldered, Cooper's hawks, and great horned and barn owls.

As the sand berm and adjacent area were highly modified during demolition and construction and are not natural habitat, there are relatively few animals using the site at present. Birds fly over the site and gulls occasionally roost on the backside of the berm. There may be some insects and spiders using the early plant colonizers. The site is marginal wildlife habitat in its present state.

6.2.4 Endangered Species

The California legless lizard, black subspecies *Anniella pulchra nigra*, a species of special concern, has been observed in the adjacent dunes by MLML students and faculty. The lizard buries itself in sand during the day emerging at night to eat insects. The legless lizard has not been found associated with exotic weed plants particularly ice plant, the removal of which would encourage an increase in legless lizards.

Smith's blue butterfly (*Euphilotes enoptes smithi*) does not currently occur at the site but is known to occur at the Salinas River mouth. This endangered butterfly could be encouraged by reestablishing host plants, seaside buckwheat (*Eriogonum parvifolium*) and coast buckwheat (*Eriogonum latifolium*). The butterfly is close enough to colonize the restoration area given time and host plant habitat (Lane, personal communication). The Globose Dune Beetle is a candidate species for the endangered species list. It has not been observed on the site but would also be a potential beneficiary of habitat enhancement and protection.

The snowy plover is a species of special concern on the state list, a sensitive species on the federal list, and is named on a petition to be considered as a threatened species. They have not been observed to nest north of the Potrero Road beach access due, at least in part, to human activity which includes dog harassment and horse trampling of their habitat. Dune restoration would not only produce additional habitat for these sensitive birds but, through the obvious efforts, could increase public awareness and support for protection of the birds. Since the species nests on the beach, it is very vulnerable to human nest disturbance and destruction, usually accidentally due to ignorance of nest presence.

Other listed threatened or endangered animals occur in the local area and include California brown pelican, California least tern, California clapper rail, Southern sea otter, peregrine falcon, brackish water snail (*Tryonia imitator*), and Santa Cruz long toed salamander. The site is probably rarely, if ever, actually used by these species. However, pelicans, terns and the peregrine falcon could use the dunes for roosting area and peregrines can hunt along both the dunes and wetlands. On the other hand, the pelicans, terns, rails, otters, and snails actually live, rest, feed and may even nest in the wetlands of the Salinas River Channel. Sand dunes protect the wetlands from wind and waves, provide an important habitat buffer for many wetland species, and increase the entire area of relatively natural habitats for wildlife conservation and public enjoyment.

While not a state or federally listed plant species, Monterey Indian paint brush is considered a species of special concern (List 4) in the California Native Plant Society's Inventory of Rare and

Endangered Plants. This species should be protected by minimizing human disturbance and enhanced by propagating from nearby plants and establishing them on the restoration area.

Threatened and endangered plant species have not been found in the local area. However, the site provides habitat consistent for the needs of Coast Wallflower (*Erysimum ammophilum*) (List 4) and Sand Gilia (*Gilia tenuiflora* var *arenaria*) (threatened). These species could be propagated at the restoration area pending approval of agencies and groups (California Native Plant Society, for example) qualified to judge such an effort. Since plants are not mobile their occurrence in nearby habitats would not signal their presence on the dunes. Nonetheless, endangered species in nearby habitats will also benefit from enhanced dune habitat. One example would be the possible use of the site as a refuge or propagation center from which endangered dune species could be outplanted to appropriate restoration sites. Menzies' Wallflower and Tidestrom's Lupine are possible examples.

The restoration site had already been heavily modified, and recently highly disturbed. The reconstruction and restoration efforts will not threaten any endangered or listed species. On the contrary, the restoration will provide more habitat for and further enhance populations of these important species.

7. RESTORATION

Coastal sand dunes (or coastal strand) have significant values as wildlife habitat, habitats for rare and endangered species, barriers to high waves and storms, low intensity human recreation, and of course great botanical importance. The Monterey Bay dunes complex provides habitat for endangered and other listed species for breeding, resting and feeding grounds of birds, mammals and reptiles, and for a wide array of invertebrates. In addition, sand dunes help to absorb the pounding of high waves and reduce overwash flooding during storms.

Coastal dune habitat in Monterey Bay is geographically limited and under threat of degradation or elimination by urban development, highway construction, sand mining, and recreational overuse. Fortunately, sand dunes are recognized by Federal, State, and County governments as areas of special biological importance and have been given high priority to protect, conserve, and restore (see Section 4.2 Relation to Local and Regional Plans). Major dune restoration projects have been initiated at Sunset Beach, Marina Beach, and Asilomar Beach; smaller planting projects have been done at all State park beaches where there are sand dunes. State parks have played a major role in educating the public about the fragile nature of dune communities and reducing disruptive human activities such as off road vehicle traffic.

There are few opportunities to restore sand dune habitat by actually removing human structures from the coastal zone. The demolition of the old marine labs buildings and facilities and their relocation off the dunes is therefore a unique opportunity to increase the total acreage of dunes and to restore the site to a healthy, natural ecological state.

The science of restoring natural habitat is poorly developed. All restoration projects are experiments which must be designed to meet regional resource goals while maximizing the local environmental

conditions. The local conditions include the natural setting as well as constraints from past, present, and future human activities and developments. The three major dune restoration projects which are ongoing in the Monterey Bay area have different designs and specific goals, yet each has been successful at enhancing and restoring a local dune habitat and community. There are many overlapping methods, techniques and goals as well. The most important common ground among these and other habitat restoration projects is the need to define the goals of the project and to establish a monitoring program to document the success in meeting the goals and to redirect the project if necessary. Sand dune communities require time to recolonize and may take decades to reach a natural state. Nevertheless, the first several years are critical in establishing the best habitat conditions, planting a desirable mix of native species, and removing and depressing exotic species.

7.1 GOALS OF RESTORATION

The overall goal of the restoration project is to reconstruct, repair, restore, and maintain the natural biological and physical dune system which had been present before being built on and eventually occupied by the MLML facilities prior to the Loma Prieta earthquake. The best model for the restoration is the natural historical habitats and communities which once occupied the site. Since the specific historical conditions are not documented, the next best model is the natural dune habitats and communities adjacent to the site. Therefore, we have made extensive qualitative surveys of the dunes between the Salinas and Pajaro Rivers to develop the best model for habitat restoration. This model is also influenced by surveys of all the dune systems within Monterey Bay, especially for restoring habitat of regionally endangered species and for overcoming problems with human use of the dunes.

More specific objectives of the project include:

1. To reconstruct on the site the natural dune configuration and size.
2. To stabilize the dune sands with vegetation, straw plugs and fencing where needed.
3. To restore the dune flora by revegetating with assemblages of native plant species indigenous to this dune system.
4. To enhance and protect habitat for endangered and other listed species including reintroduction where indicated.
5. To eradicate exotic nuisance plant species from the site and adjacent dunes.
6. To protect dunes from human disturbance and provide education by posting directional and informational signs.
7. To safeguard vegetation by maintaining accessways for foot traffic and using fences, signs and informal patrols to prevent intrusions into vulnerable habitat.
8. To implement a monitoring program to track progress towards achieving reconstruction and restoration goals and to evaluate trends.

7.2 RECONSTRUCTION

Sands on the reconstruction site will be contoured to create a naturally shaped dune topography continuous with the adjacent dunes. The proposed topography is presented in Figure 5. The reconstructed dunes will have an aerodynamic shape with slopes and contours consistent with the adjacent dune systems, or shapes that will readily form into good dune contours through natural processes, mainly wind. Generally, seaward slopes will not exceed 3:1, characteristic of natural adjacent dunes and readily allowing revegetation. The dune peaks may reach as high as but not exceed 20 feet (MSL), similar to adjacent dunes.

The sand berm will remain on the site and serve as base material in the reconstruction. The berm was engineered by Haro, Kasunich and Associates to provide shoreline protection and should be left in place with the shape and contour of the berm undisturbed. The berm material includes more fine and coarse sediment fractions than most of the adjacent natural dunes. Although this soil is excellent for growing dune plants, it will be covered by a more natural dune sand of the same size distribution as the adjacent dune complex. The surface sand over the berm will be modified to meet the more natural contours as shown in Figure 5. The early colonizers on the sand berm will be left in place and covered by the new surface sand which may kill them. Some early colonizers are weedy in nature and may be replaced during the revegetation program. The plant cover will help stabilize the berm and the surface sand covering. As more sand is trapped on the new dune we expect the layer of surface sand to be no less than two feet in the thinnest sections.

There is much less volume of sand on the site than in adjacent dunes. As a result, sand must be added to the site to reach the natural size and contours. A minimum of 5,000 cubic yards must be imported to the site. The sand needs to be clean of chemical contamination, free of plant seeds, and the proper grain size. There are several potential sources of imported sand.

1. Wind blown sand from the beach can be captured on the site by using drift fences, straw plugging and vegetation. Straw plugging of the sand berm and drift fencing have already captured as much as a foot of sand in local patches. This method is slow but effective and natural.
2. Sand can be bulldozed from the lower beach.
3. Sand in the Moss Landing Harbor channel entrance, between the jetties, is close to or identical to beach sand.
4. Sand can be purchased from local sand mining companies in the Monterey Bay area.
5. Some sand may be available from parking areas at Marina State Beach, Salinas River State Beach, and Jetty Road State Beach. This is not likely to be a large volume.
6. A small amount wind blown sand has encroached on the parking lot next to the reconstruction site (~50 cubic yards).
7. Sand City controls a large area of disturbed but usable sand

Figure 5:

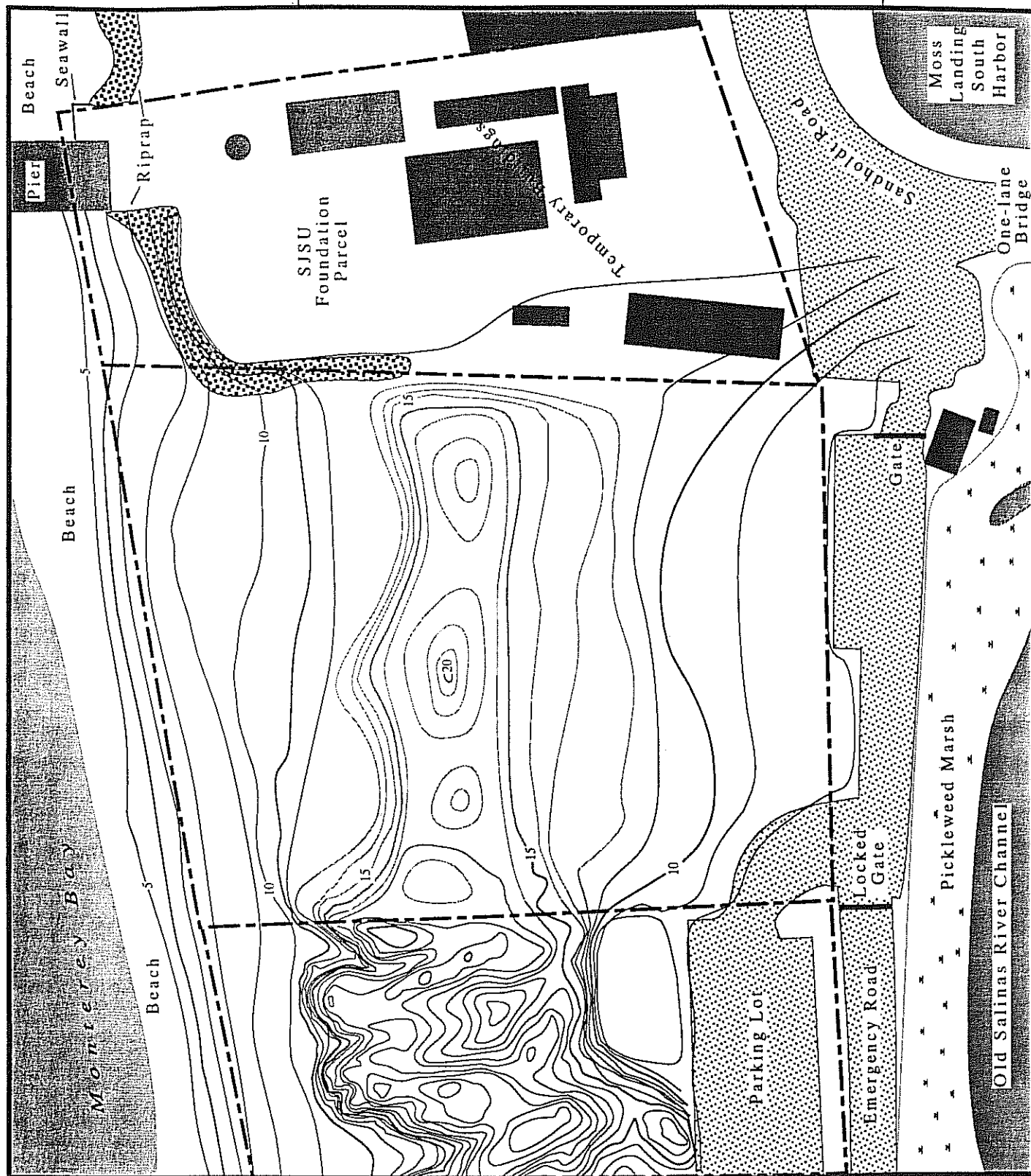
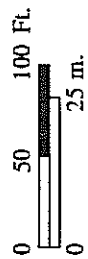
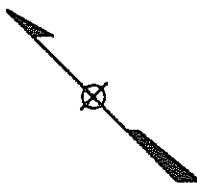
Moss Landing Marine Labs

Proposed Restoration
Topography

Contours as of July 1991

Contour Interval = 1 foot

Contours from MSL



While all the alternatives are viable, we recommend the following order of priority for sand sources: Alternative number one costs the least money, gains the best sand and from the most appropriate source, at an appropriate rate, and is non-disruptive.

Alternative number two is very attractive because it is the same as alternative one except faster. It is also more expensive. It could set an undesirable example of beach use and could cause difficulties with regulatory and conservation agencies. However, when the new MLML sea water collecting system is emplaced, excavated sand may be added to the dune then as an activity ancillary to a larger disruption. This would be relatively non-disruptive, except for a short period of time. Tidal and wave action would very quickly restore the excavated area to contours normal at that particular time. (The beach profile is very dynamic and therefore variable.)

Sand from alternative number three could be piped to the dune site and deposited there during maintenance dredging operations. Alternatives one, two and three all utilize local sand, and from the source from which sand normally accretes to the dune. Therefore those three sources require the least transportation and provide the best sand.

Alternative number four is expensive and removes unreplaceable sand from another fragile and important dune system. A small volume of sand could be purchased to supplement the primary source or sources.

Alternatives number five and six may also be supplemental, but will not provide enough volume to reconstruct the dune in the short term.

Alternatives number seven is possible if Sand City development proceeds. A large amount of sand would be excavated. It is good dune sand, wind deposited and relatively unaltered. Transportation costs would be considerable and the availability of the sand is uncertain.

If the major source of sand is by purchase, the project may need to be completed in phases to reduce the expense. For example, the minimum amount of sand could be purchased and surface sand then could build the rest of the dune over time (at least 5 years). Since most dune plants can outgrow natural sand deposition on the dunes, the phasing should not prevent revegetation. Faster growing species such as dune grass should be planted on the fore dune. The sand collection period will require multiple drift fences and repeated straw plugging of the site until a natural size is reached. The phasing method is not necessarily the best alternative and should be considered only if other options are unavailable, or as a supplement to other techniques.

Reconstruction and grading may be done by tractors and bulldozers. Trucks can bring imported sand via the road and dump on the roadside of the site. The heavy equipment can then shape the sand to meet the configuration in Figure 5 while minimizing disturbance to the berm. Sand from the adjacent parking lot can be moved by heavy equipment and spread over the top of the newly constructed dune.

Since this is a conservation project by government agencies, heavy equipment and operators may be available at a very low cost through the Army Reserve at Fort Ord, 375th Engineer Company. The work can also be completed by private contractors.

7.3 DUNE STABILIZATION

It is critical to stabilize dune sand as soon as possible. Local winds are strong and frequent, and will quickly blow sand and erode the new dune before new vegetation is established. Once plants are established, they will stabilize the dune sand. Several methods could be used to stabilize dune sands in preparation for revegetation: netting, excelsior blankets, straw, plugging in straw, spreading dead plant material, and hydromulching with a mixture of mulch and native plant seeds. Straw plugging, spreading dead plant material, fencing, and hydromulching have been used with the greatest success in past restoration projects in local state parks.

We recommend straw plugging as the primary stabilization method combined with fencing where needed. Plugging provides protection equivalent to more expensive methods. While plugging is labor intensive local volunteer groups and conservation camp are proven sources of effective labor. The entire site should be straw plugged. If areas begin to erode they may be more densely plugged with additional straw. Plugging must be done in conjunction with the revegetation which is the key to long-term dune stabilization. Fencing will help redirect foot traffic and act as a sand trap. Reducing or eliminating foot traffic will help prevent blowouts in sensitive areas, such as small valleys that are often seen as natural corridors by people, and allow stabilization of blowout sands being revegetated. Thus preventing instability is the most effective course and fences are best for that. This technique will be most useful for the revegetation areas in the dune system immediately adjacent to the south of the restored dune. Fences for directing foot traffic and sand accumulation will also be useful on the restored dune.

7.4 REVEGETATION

Revegetation will stabilize the reconstructed dune and provide habitat for wildlife. It will greatly increase the rate of dune recovery since the natural colonization process depends on the arrival and successful recruitment of seeds of native species and will be impeded by invasion by exotics. The dune will be revegetated by local native species as these can tolerate rapid sand accumulation, salt spray, sand abrasive, high winds, temperature changes, drought, and low soil nutrient.

Successful revegetation depends on adequate time and minimal human and natural disturbance (Dixon, pers. comm.; Moss, pers. comm.; Hylgaard 1980). The objective will be to establish a minimum of one plant every two square feet or approximately 22,000 plants per acre and a fully vegetated dune within 5 years.

Revegetation will be accomplished mainly by direct seeding. Seeds to be planted will have been collected from the dune system between Moss Landing and the Salinas River in order to ensure that no uncontrolled introductions of non-local plants are made. After the initial revegetation, plant sources away from the dune system may be used for propagation, but only where appropriate and

with the concurrence of specialists of each plant species. Seeds will be sprinkled by hand onto sand slightly surface-disturbed by raking or scuffing. Then more raking, scuffing or tamping after seed distribution will ensure good seed-soil contact. Seeding in conjunction with straw plugging will also ensure good soil-seed contact and protection from wind erosion. The sand will have been wetted by seasonal rains before seeding. To ensure maximum success seeding will be done only after the rainy season is well underway, after several storms and will ensure the likelihood that more or less normal precipitation will continue through the season. Plants will also be propagated by sprouting and growing in small containers, supercells, to provide seedlings or small plants. Outplanting seedlings obviously ensure a much greater proportion of successful plants per application. The balance in effort between direct seeding and planting seedlings lies in the likelihood of seed sprouting versus the cost in labor of growing seedlings. Each species has its own balance. Sand verbena is more effectively established by spreading seeds whereas mock heather should be planted as seedlings as well as directly seeded. Table 2 presents the names, preferred dune zone, and effective propagation method of species to be used in revegetation. Not all species will necessarily be planted. Some, e.g. beach bur, may establish themselves quite well with no propagation help. Others, e.g. blue grass, may require enough effort to produce viable revegetation material as to be of low priority relative to most of the other more readily propagated species. Still others are endangered or of special concern. They will be considered for propagation, but under the auspices of appropriate experts and agencies.

Light fertilizing with balanced, slow release pellets will be considered. Fertilizer may be used both on established but weak appearing plants, for example those that have been stressed by ice plant invasion, as well as on newly planted or sprouted plants. The application rate will be at about one half pound per 1000 square, a minimal level in order to give the plants slightly better odds at becoming established.

Some irrigation may be utilized, depending on the amount and distribution of rains. Large seedlings planted at the beginning of a normal to heavy and prolonged rainy season, with even distribution of rain over time, will survive the following dry season with no supplemental watering. This situation has not occurred locally for 8 years. Without adequate precipitation during the rainy season small outplants and seedlings from direct seeding could be severely stressed or killed during their first year. Consequently supplemental water may be necessary. We will monitor the soil moisture and irrigate on an as-needed basis. Although dune plants are drought-tolerant, adequate water, particularly when they are young, can increase their vigor and ultimately produce better vegetation. Also, with supplemental watering some species, particularly annuals, will flourish and may provide a very helpful seed source for continued revegetation. Irrigation will be used more to prevent failure than to enhance revegetation, i.e. to make restoration possible despite drought conditions.

Openings created by the eradication of exotic species, mainly ice plant, will also require revegetation. These areas will be stabilized by leaving the dead ice plant mat in place, an effective interim method. The openings will be revegetated by planting seedlings through the dead ice plant and its subcanopy litter—a difficult barrier to overcome by simple seeding. Also, ice plant has

Table 2. Species to be used in revegetating the dune reconstruction site, propagation method (self indicates self seeding), and zone to plant them in. Species with an asterisk* are of special concern.

COMMON NAME	PROPAGATION	ZONE
<u>SCIENTIFIC NAME</u>		
American Dune Grass <i>Elymus mollis</i>	outplant	fore
Beach-bur <i>Ambrosia chamissonis</i>	seed (self)	fore to back
Beach Aster <i>Corethrogyne californica</i>	seed	back
Beach Morning Glory <i>Convolvulus soldanella</i>	seed	mid
Beach Primrose <i>Camissonia cheiranthifolia</i>	seed	mid to back
Beach Sagewort <i>Artemisia pycnocephala</i>	seed, outplant	fore to back
Beach Saltbush <i>Atriplex leucophylla</i>	seed	fore
Blue Beach Lupine <i>Lupinus chamissonis</i>	seed, cutting	back
California Poppy <i>Eschscholzia californica</i>	seed	back
California Sea-Blite <i>Suaeda californica</i>	seed	back
Coastal Gum Plant <i>Grindelia latifolia</i>	seed	back
Coast Wallflower* <i>Erysium ammophilum</i>	outplant	back
Dune Bluegrass <i>Poa douglasii</i>	outplant	back
Lizard Tail <i>Eriophyllum staechadifolium</i>	seed	mid
Mock Heather <i>Haplopappus ericoides</i>	seed, outplant	mid to back

Monterey Indian Paint Brush*	seed, outplant	mid to back
<i>Castilleja latifolia</i>		
Pacific Sea Rocket	seed	fore
<i>Cakile edentula</i>		
Pink Sand Verbena	seed, cutting	mid to back
<i>Abronia umbellata</i>		
Sea Rocket	seed(self)	fore
<i>Cakile maritima</i>		
Seaside Buckwheat	seed, outplant	back
<i>Eriogonum parvifolium</i>		
Silky Beach Pea	seed, cutting	fore
<i>Lathyrus littoralis</i>		
Thrift	seed	mid to back
<i>Armeria maritima</i>		
Wild Buckwheat	seed, outplant	back
<i>Eriogonum latifolium</i>		
Yellow Bush Lupine	seed, outplant	back
<i>Lupinus arboreus</i>		
Yellow Sand Verbena	seed, cutting	fore to mid
<i>Abronia latifolia</i>		

overgrown but not killed many plants. By carefully killing the ice plant without harming the desired plants, these established plants can be the nuclei if not be the exclusive plants from which revegetation proceeds.

It will be important to plant the species in their natural zones along the dune complex: the fore dune, mid dune, and back dune. The fore dune is closest to the ocean and includes the seaward slope. The mid dune is between the fore and back dune and includes the small valleys and the peaks of the dune top. The backdune is the zone closest to the road and the back slope of the dunes. Each zone has different environmental conditions and is characterized by a distinct group of native plants (Figure 4).

Some plants are difficult to establish from seeds and will be transplanted from pots as seedlings or rooted cuttings. These species are listed in Table 2 as outplants. They will be grown in a greenhouse by a local nursery under contract. Care will be taken to insure that greenhouse reared plants are properly fertilized and watered since they will be transplanted into natural dune environments with low nutrients and water.

7.5 VOLUNTEERS

Much of the restoration program can be accomplished by volunteers. Volunteer projects can include straw plugging areas where needed, outplanting of potted species, collecting seeds, propagating seedlings and cuttings in a greenhouse, irrigating, fencing, posting signs, and even performing informal patrols. For example volunteers patrol and respond to calls to erect fences around snowy plover nests to protect against red fox depredation. However, volunteers are not completely free and require coordination. This coordination will be provided by consultants, state parks staff, and marine labs researchers and graduate students. The volunteers may come from the organizations involved in local conservation projects: Gabilian Conservation crews supervised by the California Department of Forestry, the Elkhorn Slough Interpretive Guides, the California Conservation Corps, State Park Volunteers, Pacific Grove Ecocorps, and various school groups from Monterey area and North County.

7.6 ERADICATION OF EXOTIC PLANTS

The establishment of native plants and wildlife will be aided and enhanced by the removal of exotic plants. Many of the exotic species are fast spreaders and their seeds are disbursed by wind and animals. Farmer's foxtail, ripgut brome, poison hemlock, mustards and radish are common and nuisance exotics. They are not currently threatening native dune plant assemblages, but control of them is important. Healthy restoration efforts may be adequate to deal with them. Ice plant and Holland dune grass are aggressive, pervasive and currently well established, occupying large areas. Their removal is important and must extend the full length of the CSU property to prevent future invasion of the restoration site.

The herbicide Round Up (active ingredient Glyphosate) has been used to kill ice plant over large areas in other local dune restoration projects, and is the method of choice here. The herbicide is

applied with a spray cannister and is readily administered specifically to subject species without harming any other plants. The spray can be well controlled by simply applying when strong winds are not blowing. It is applied at 2% with 1% surfactant, or activator, which enhances the herbicide's effectiveness. After the ice plant has died, it leaves a mat of dead vegetation over a layer of litter which still functions as a sand stabilizer. This dead vegetation mat can be cleared in small patches to mineral soil and seedlings may be planted. In many areas ice plant has surrounded but not yet killed plants such as verbena, paint brush, and sagewort. These native plants will not be sprayed and will spread over the dead ice plant when their competition and physical obstruction has been removed. Two patches of Holland dune grass are localized and within a healthy and expanding population of American dune grass. The exotic grasses can be eradicated by repeated applications of Round Up. The natives will fill in the small areas fairly rapidly. It should be noted that Round Up must be applied directly to foliage to be effective and does not persist long. The herbicide is quickly neutralized by soil. It has been sanctioned and used by the California Native Plant Society in their efforts to control pampas grass, and by the California State Parks in sand dune restoration projects.

7.7 ENDANGERED SPECIES

The best way to provide for endangered species is to restore the dune to as natural a state as possible. The revegetation and eradication programs are thus essential to wildlife as well as plants. By providing a refuge habitat, endangered species may be spared some of the stresses that may have contributed to their declining populations. Since habitat destruction is so often cited as the main threat to species in trouble, the provision of habitat here can be a step toward reversing declining numbers of certain species.

Snowy plovers will benefit from increased habitat. Instead of blowouts, loose sand and ice plant cover, natural habitat will provide resting and possibly even breeding areas. Additionally, natural habitat by definition is almost free of human activities. Plover activities will greatly benefit from by minimizing the disruptive influences of human intrusion. Not only will human presence and trampling be reduced but also other disturbances directly associated with people such as trampling by horses, and trampling and predatory behavior by dogs.

Removing the extensive cover of the exotic ice plant and replacing it with natives will help to provide more habitat for the California legless lizard. In addition, native plants will attract insect prey and therefore contribute a food source for the lizards.

Smith's blue butterfly may be attracted to the site by planting its native buckwheat host. The butterfly is known to occur just south of the area and could easily move northward to the Moss Landing site. Once the buckwheat has become well established (in about three years), it may be possible to introduce the butterfly directly into the local dune system. The California State Parks is already considering such a project with the U.S. Fish and Wildlife Service in the Asilomar area. We recommend that State Parks consider reintroducing the butterfly to this site if the butterfly does not return on its own.

The Monterey Indian Paint Brush is a species of concern. Its numbers can be preserved and enhanced by protecting the dune habitat, providing controlled public access, propagating the local plant, and transplanting it into the restoration site. Special attention will be given to the paint brush's establishment on the restoration site.

While not currently found in the adjacent dunes, the habitat is suitable for Coast Wallflower (*Erysium amophilum*) and Sand Gilia (*Gilia tenuiflora*). These species may have once occurred in the area and their introduction to the site should be seriously researched and considered. The plants can be propagated from local sources. In addition, the dune could eventually become a habitat for propagating other plants of concern. Great care must be taken in propagating species of concern and a number of agencies and groups and specialists must permit and collaborate with the effort. On the other hand researchers, restorationists and conservationists are willing to contribute their abilities to this project. For example, MLML graduate students conduct research on the ecology and plant biology of local dunes, and produce master's theses. The help of experts with concepts and specific plant biology and requirements will greatly enhance the project.

7.8 EDUCATION AND ACCESS

An important element in protecting the dune vegetation and the restoration site is public awareness and education. The site is a mandated public coastal access, so plans must be made to reduce inappropriate and destructive use. An informed public is more likely to use the area with less impact and vandalism. This reduced impact is essential if recovery is to be successful (Hylgaard, 1980).

Access should be directed to reduce pedestrian impact on the area. This can be achieved by repairing the existing boardwalk (damaged by the Loma Prieta earthquake), fencing, and placing signs. When in good repair, the existing boardwalk was successful and was well used by visitors. Existing signs should direct visitors to the boardwalk access, explain why staying on the boardwalk is necessary, and prohibit uses by horses and motor vehicles. The vegetation can be further protected by signs which identify the restoration project and its goals to preserve wildlife and how the public can help by staying off the dunes. It is important for signs to be informative and friendly. Fencing should protect new plants, prevent access to blow-outs and potential blow-out areas, and direct foot traffic.

The reconstruction site may need further safeguards such as fencing and signs. Drift fences on both sides of the sand berm have been effective in discouraging four wheel drive vehicles from driving up the berm. Fencing is low enough not to be too obtrusive and should be around the project site until the dune vegetation is well established. Restoration identification signs should be placed at appropriate locations around the site to discourage visitors from crossing fences. There should be one sign identifying the agencies that cooperated to reconstruct and restore the dune site.

Once the property is transferred to State Parks, staff should consider a low level interpretive program at the unit. The interpretive program could include volunteer guided walks, brochures, and panels. Information panels could address the fragile dune system, causes of dune damage, the restoration project, and opportunities for public cooperation. State Parks will be responsible for maintaining signs, fences, parking lot and boardwalk. The restoration site can also be linked to interpretive

educational walks and displays along the Old Salinas River and on the site of the new Moss Landing Marine Labs. These are being developed in conjunction with the new marine lab development and construction.

8. MONITORING PROGRAM

8.1 ASSESSMENT OF RECOVERY SUCCESS

Vegetation, and secondarily wildlife, are the accepted and trackable indicators of successfully reestablishing the natural habitat. The shape and stability of the dune is also indicative. Stability of sands in the restored dune and its vegetation patterns will be compared to the adjacent established dunes. It will also be compared to similar local State Park restoration projects. When the area compares favorably with healthy adjacent areas the project will be considered successful.

In accordance with California Coastal Commission policy, the monitoring program should continue for a minimum of 3 to 5 years. We propose that the consultant should monitor the project for the first year until the project is mostly stabilized and that State Parks staff should continue to monitor the project for two to four more years.

In accordance with current Monterey County and California Coastal Commission standards, the reconstruction and restoration should be monitored by a qualified sand dune scientist to insure the success of the project. If the monitoring program indicates that the project goals are not being met, then the monitoring program will provide data to help further guide restoration efforts on the site. All monitoring data should be collected using scientific methods so that it can be used to aid in designing future restoration programs.

8.2 METHODS

Dune stability will be assessed by walking and observing the entire area for blow outs and sand encroachment on the road behind the dune, and by visually estimating on-site sand quantity as compared to adjacent dunes. It is important to make comparisons with adjacent dunes since heavy storms can alter the entire face and volume of the dune system. Observations will need to be more frequent during the first months of the project until the vegetation begins to take hold and stabilize the sand. Aerial photographs will be obtained and inspected on an as-available basis. For example, State Parks acquires current photographs which are available for inspection. Various other options exist for acquisition or inspection of photographs: aerial photo series are taken by various groups at various times; flights can be directly chartered; chartered flights, especially by the marine labs, can be piggy-backed; even a local balloon photographer may be hired. The consultant will recommend any additional stabilization methods as needed.

The revegetated areas will be monitored qualitatively and quantitatively. Monitoring will take place 6 months after the project starts and annually thereafter. Qualitative analysis includes inspecting the vegetation for mortality, disease, herbivory and general health. The plants will be identified and categorized as native, exotic, or invasive exotic. Wildlife use of the project will be monitored. The

number and species of birds, mammals, and reptiles using the area will be noted during surveys and by volunteers assisting with the revegetation and its monitoring. Significant species such as plovers and red foxes will be particularly monitored, with more careful estimates of their abundance and more detailed observations on their use of the area noted. Where possible adjustments in restoration may be incorporated to enhance the opportunities for desirable species, and discourage (or eliminate) destructive ones.

Quantitative surveys of the vegetation will include density and per cent cover. Density will be estimated using a line intercept method. Permanent transects 30 meters long will be placed in the fore- mid- and back-dunes. At intervals of 1m, a meter stick will be extended at right angles to the transect on both sides and at 10cm intervals the point will be scored as bare or vegetated and by which species. Per cent cover will be measured by 1 or 0.25 square meter quadrats placed randomly (or haphazardly) in each of the 3 dune zones. The amount of plant cover within each quadrat area will be estimated as a percentage of the total area of the quadrat. The lengths of the transects and intervals may be altered in order to increase effectiveness of the technique; e.g. decreasing the length and increasing the number. And the number of quadrats will be adjusted by time and area to provide accurate numbers without unduly large sample sizes.

Goals will be as follows: Density should average at least one plant per 0.2 square meter (2 square feet). Initially the number may be significantly higher and decrease due to mortality of young plants. Per cent cover should be at least 10% at the end of the first year and increase to no less than 40%. By the end of the first year the percent density of invasive exotics, mainly ice plant and Holland dune grass, should be at or near 0. The percentage of all exotics should be well under 50% at the end of the first year and show a constant decline through the next 4 years. The only exotic expected to persist would be sea rocket, a colonizer on the lower fore-dune. Eventually even that species may be replaced by a native. No statistical analyses are recommended since a simple comparison of the few measurements will readily define differences or similarities between the condition of the restoration site and the goals. Goals are based on those set by Tom Moss at the Asilomar restoration project who graciously lent them to this effort. Since the Asilomar project is the current standard against which the success of other restoration project may be measured, meeting or exceeding those goals will indicate a successful restoration.

The consultant will monitor the success of the watering and fertilizing program on plant establishment and growth. This will require weekly observation during the initial months and monthly observation during the dry season (April to November). The consultant will look for signs that the watering is adequate yet not overdone, and will recommend watering and fertilizing adjustments.

The consultant will look for any potential human disturbance to the site that may be damaging to the recovery, such as four wheel drive vehicles, pedestrian traffic, or signage and fencing damage. Any damaged signs and fences should be replaced as quickly as possible. The consultant should recommend any further protective action needed.

8.3 EVALUATION

Annual reports will be prepared by the monitoring group by the Fall of each year following the annual sampling, and submitted to State Parks, the California Coastal Commission, Monterey County, and other concerned agencies. The reports will be in letter form and contain transect data, copies or photocopies of aerial photographs when available, and a short narrative description of the changes in the site and progress towards recovery. The reports will include assessment based on restoration goals. The reports will include further steps that should be taken to aid in the recovery if necessary. At the end of the first year, the consultant will provide a report summarizing the data and results, an evaluation of the effectiveness of the reconstruction and restoration effort, and recommendations for changes that might be incorporated into future restoration programs. State Parks will incorporate any recommendations into their monitoring program, and will provide the report in future years.

9. REFERENCES

- Abrams, L. Illustrated Flora of the Pacific States. 1923. Stanford University Press.
- Field Guide to the Birds of North America, 2nd ed., 1985. National Geographic Society, Washington, D.C.
- Cailliet, G. Marine Ecology Sand Dune Transects. 1972, 74, 75, 76,77, 78, 81, 84, 87, & 88. Moss Landing Marine Laboratories, Moss Landing, CA.
- Cooper, W.S. Coastal Dunes of California. 1967. The Geological Society of America Memoir 104, Boulder, CO.
- Emory, J. The Monterey Dunes:a relic on the edge. 1989. Pacific Discovery, 42:3, 23-31.
- Gordon, B.L. Monterey Bay Area: natural history and cultural imprints. 1977. Boxwood Press, Pacific Grove, CA.
- Gray, K.L. Draft - Marina State Beach Dune Revegetation Plan. 1985a. California Dept. of Parks and Recreation, Monterey District.
- Gray, K.L. Sunset State Beach Dune Revegetation Plan. 1985b. California Dept.of Parks and recreation, Pajaro District.
- Hylgaard, T. Recovery of Plant Communities on Coastal Sand Dunes Disturbed by Human Trampling, 1980. Biol. Conserv. 19:15-25.
- Monterey County Coastal Implementation Plan. Parts 1 & 2, 1988. Monterey County Planning Department, Salinas, CA.
- Moss, T.K. Asilomar State Beach Dunes Restoration Plan. 1987. California Dept. of Parks and Recreation, Monterey District.
- Munz, P.A. Shore Wildflowers of California, Oregon and Washington. 1964. Univ. of Calif. Press, Berkeley, CA.
- Munz, P.A. and D. Keck. A California Flora. 1959. Univ. of Calif. Press, Berkeley, CA.

- Niehaus, T.F. and C.L. Ripper. A Field Guide to Pacific State Wildflowers. 1976. The Peterson Field Guide Series, Houghton Mifflin Co., Boston, Mass.
- North County Area Plan: a part of the Monterey County general plan, 1985. Monterey County Planning Department, Salinas, CA.
- North County Land Use Plan: local coastal program, 1982. Monterey County Planning Department, Salinas, CA.
- Psuty, N.P. Dune/Beach Interaction. 1988. Journal of Coastal Research, CERF, summer special issue no. 3.
- Ranwell, D.S. Ecology of Salt marshes and Sand Dunes. 1975. Halsted Press, a division of John Wiley and Sons, Inc., New York.
- Shonman, D. Plant Inventory for the Monterey bay Aquarium Research Institute: planning documentation, 1988. Monterey Co.Planning Dept., parcel no. APN 133-232-02 and 03.
- Smith, H.M. and E.D. Brodie, Jr. A Guide to Field Identification : Reptiles of North America. 1982. Western Publishing, Wisconsin.
- Stebbins, R. C. Amphibians and Reptiles of Western North America. 1954. McGraw - Hill, New York.
- Williams, S.J., K. Dodd, and K.K. Gohn, Coasts in Crisis. 1990. U.S. Geological Survey Circular 1075.

10. EXPERTS CONSULTED:

- Dr. Greg Cailliet, ecologist and professor, Moss Landing Marine Laboratories
- David Dixon, Supervising Ranger, California Department of Parks and Recreation, North Sector, Monterey District
- Janie Figen, Monterey Dunes Coalition
- Dr. Mike Foster, botanist and professor, Moss Landing Marine Laboratories
- Kenneth Gray, Senior Ecologist, California Department of Parks and Recreation, Central Coast Region
- Patti Kriebert, owner, Sunset Coast Nursery, Watsonville
- John Lane, lepidopterist and naturalist, Santa Cruz City Museum of Natural History
- Dr. Michael Ledbetter, geologist and professor, Moss Landing Marine Laboratories
- Thomas Moss, Associate Resources Ecologist, Calif. Dept. of Parks and Recreation, Asilomar State Beach
- Dr. John Oliver, ecologist and professor, Moss Landing Marine Laboratories
- Victor Roth, regional land agent, Calif. Dept. of Parks and Recreation, Monterey Central Coast Region
- Ricky Warriner, biologist, Point Reyes Bird Observatory