bKzn
15

San Francisco – Oakland Bay Bridge
East Span Seismic Safety Project

EXPERIMENTAL EELGRASS TRANSPLANT PLAN FOR EMERYVILLE FLATS, SAN FRANCISCO BAY

Investigations for On-Site Eelgrass Mitigation

June 12, 2002

EA 012000
04-SF-80 KP 12.2/KP 14.3
04-ALA-80 KP 0.0/KP 2.1

San Francisco – Oakland Bay Bridge
East Span Seismic Safety Project

EXPERIMENTAL EELGRASS TRANSPLANT PLAN FOR EMERYVILLE FLATS, SAN FRANCISCO BAY
Investigations for On-Site Eelgrass Mitigation

June 12, 2002

Prepared by

Keith W. Merkel
Merkel & Associates, Inc.

Reviewed by

Michael W. Davis for
Parsons Brinckerhoff Quade & Douglas, Inc.

Approved by

June 10, 2002

for Steven Hulsebus
Caltrans District 4

Table of Contents

Figures

Tables

INTRODUCTION

The California Department of Transportation (Caltrans) is replacing the East Span of the San Francisco-Oakland Bay Bridge (SFOBB) to provide seismic safety to this lifeline facility. Construction of the new bridge across the edges of an intertidal and subtidal sandflat will impact eelgrass habitat found on the Emeryville Flats in Oakland (Figure 1). To mitigate these impacts, Caltrans is conducting an On-site Eelgrass Restoration Program. This experimental transplant study plan is the first in that program.

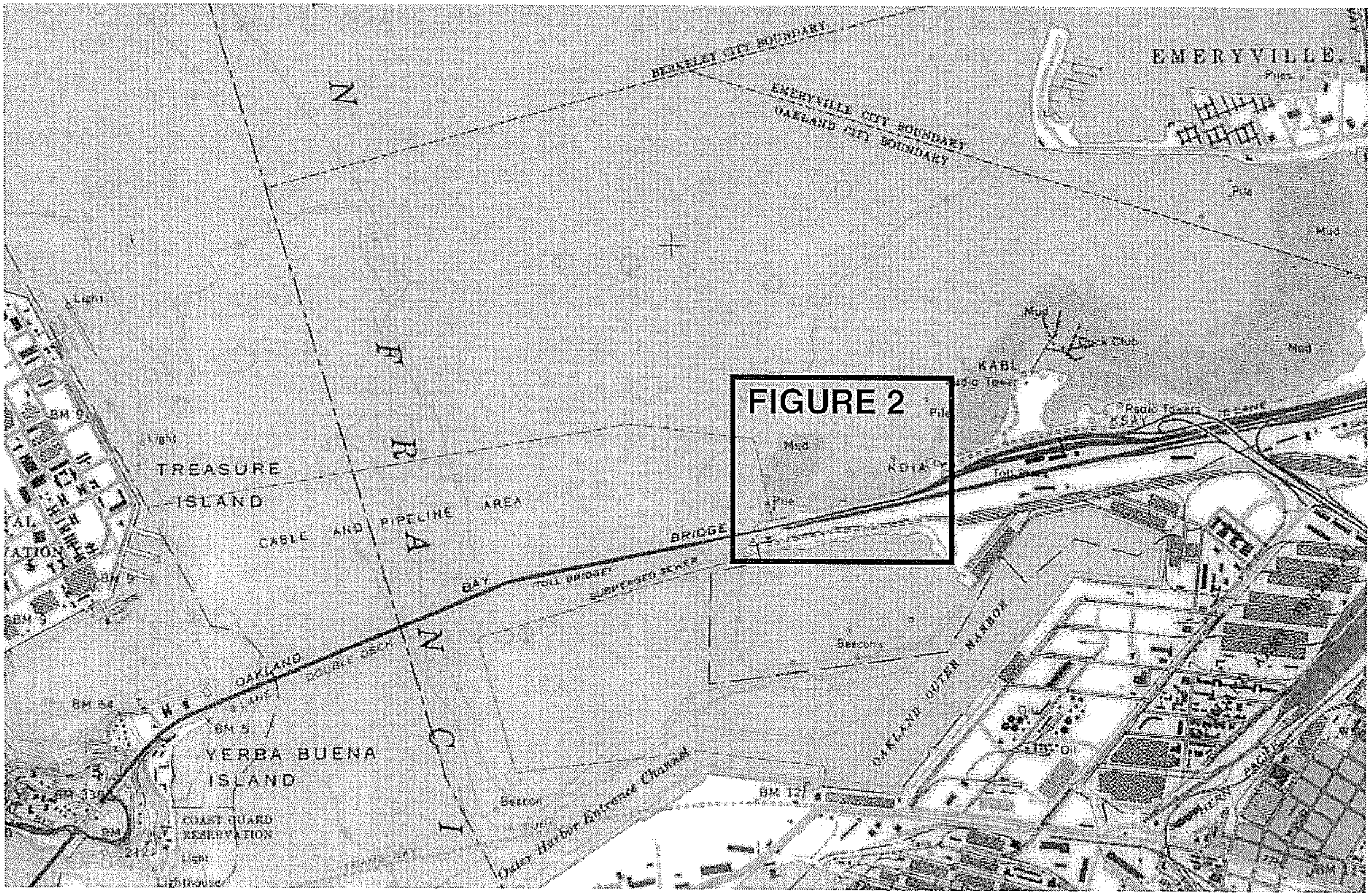
TRANSPLANT REQUIREMENTS

Permits for the project require Caltrans to harvest (salvage) and transplant approximately 0.55 acres (2,227 square meters) of eelgrass from within the footprint of the barge access channel that will be dredged at the Oakland Touchdown area to facilitate construction in shallow water areas. Eelgrass would be transplanted to areas of the Emeryville Flats located north and east of the barge access channel.

It is recognized that such transplants may not result in prolonged enhancement of eelgrass within this area. Eelgrass beds at this site may expand and contract considerably as a result of environmental fluctuations. The capacity of the Emeryville Flats to support eelgrass is dictated by available habitat and environmental stressors rather than an availability of parent plant material. However, an experimental transplant program may provide further understanding of eelgrass resources and restoration within San Francisco Bay. It will also provide Caltrans with site-specific information to design and implement restoration of the barge access channel and off-site eelgrass mitigation at the East Shore State Park (Central Bay mitigation sites). Caltrans proposes to focus its requirements for the 0.55 acre (2,227 square meter) transplant to answer specific questions related to the future restoration, monitoring, and management of eelgrass. While these questions are principally related to on and off-site mitigation requirements for the East Span Project, they also contribute directly to the sparse body of information available on San Francisco Bay eelgrass beds in general.

Because not all of the eelgrass to be transplanted would be necessary for conducting the restoration investigation, a residual transplant effort will be undertaken after all study plots are established to ensure that not less than 0.55 acres (2,227 sq. m) of eelgrass is transplanted. The residual transplant will be performed at either Albany Beach or Brickyard Cove, which are two of the Central Bay sites being considered for mitigation. Caltrans will use a bareroot transplant technique with eelgrass harvested from the barge access channel. The final site selection for this residual transplant will be made after field data collection for the Central Bay mitigation sites is completed. The final site will be selected in consultation with the interagency review group for the East Span Project. Monitoring of this residual planting effort will be relatively limited since the most significant effort will be focused on monitoring of the study plots. Monitoring of the residual planting area will be included in the annual side-scan survey conducted at the Emeryville Shoal. These surveys will be discontinued if the transplanted eelgrass does not persist.

Figure 1. Project locator map



RESEARCH GOALS

Caltrans has identified several study goals described below:

Study Goal 1: Determine the relative initial survival of bare root and sediment plug planting units.

For this test, Caltrans will perform trials to test the initial establishment success of sediment plugs against a standard bare root planting unit. The purpose of this investigation is to determine if one type of transplant unit performs better than others at the Emeryville Flats. Trials were previously undertaken by Merkel & Associates to transplant sediment plug units to Bayfarm Island and the Alameda shoreline in association with experimental, common garden transplants conducted to assist in the design of the Middle Harbor Enhancement Area eelgrass restoration program. However, due to the highly sandy nature of the sediment plugs collected, the integrity of the unit was always lost before the plugs could be planted and the study never took place. Zimmerman *et al.* (1991) has demonstrated that sediment plugs can be successfully transplanted through experimental reciprocal transplants between Point Molate and Keil Cove. Zimmerman has even suggested that such techniques may be necessary to perform some restoration efforts in San Francisco Bay.

Study Goal 2: Determine the influence of turion (shoot) count on establishment of bare root planting units.

This test is similar to an investigation conducted in southern California by Merkel (1990). Within the southern California studies, Merkel determined that an optimal bare root transplant unit included 8-12 turions. However, the morphology of most Southern California eelgrass is substantially different from that of eelgrass found in San Francisco Bay and other northern bays and estuaries where a wide-leafed and thick rhizomed material typifies the eelgrass beds. Given these morphological differences and some of the physiological differences known to exist, it is reasonable to question whether the same optimal planting unit size for southern California transplants is optimal in San Francisco Bay. This question is particularly relevant since the general paucity of eelgrass in San Francisco Bay naturally limits the availability of material for conducting large-scale transplants.

Study Goal 3: Determine the effects of leaf trimming prior to transplanting units.

In preparation of the eelgrass restoration plan for the Port of Oakland's Middle Harbor Enhancement Area, independent reviewers at Battelle Marine Sciences questioned the logic of trimming leaves of eelgrass units prior to their planting. The concern raised by Battelle was that leaf trimming eliminated significant quantities of photosynthetic tissue causing plants to suffer added light limitation during initial establishment. Battelle Marine Sciences explained that eelgrass leaves are damaged by harvesting, bundling, transporting, and replanting the eelgrass. This damage causes flooding of the lacunae (air chambers) in the leaves. The lacunae keep eelgrass upright when it is submerged. When leaves are damaged, they usually fall down on the bottom and are silted over in a manner that retards photosynthesis while still adding to the respiratory demand of the leaf biomass. The process of transplanting bare root units also removes most of the root material, resulting in the need to generate new roots to feed plant growth. It is possible that leaf trimming benefits eelgrass transplants in the same way that pruning above ground biomass of a terrestrial plant benefits these plants when roots are damaged. In less formal investigations, Merkel (personal observation) has noted that eelgrass transplant units that are moved with leaves intact generally die back to the sediment level before recovering while eelgrass trimmed before transplant tends not to lose its leaves. These observations have been made both through anecdotal observations and within environments that are typically not as light-limiting as San Francisco Bay. However, transplant shock and damage of transplanted material were also noted to be significant factors resulting in eelgrass loss during the 1985 Richmond Training Wall transplant conducted by the Army Corps of Engineers (Fredette et al. 1988). For these reasons, it is worth exploring the potential of leaving the full leaf biomass intact on transplant units to determine if any advantage may exist under the light-limited circumstances found at the Emeryville Flats.

Study Goal 4: Determine if material from different donor sites results in differential unit establishment and survival.

Phillips and Wyllie-Echeverria have suggested that multiple populations of eelgrass exist in San Francisco Bay (Phillips 1990). Wyllie-Echeverria and Rutten (1989) have further identified the wide and fragmented distribution of small beds of eelgrass within San Francisco Bay. Because there are different ecotypes found within disjunct portions of San Francisco Bay, there may be differences in the transplant performance of donor material from different locations. Given that differences in performance likely occur, it is appropriate to determine if more robust strains exist and should be considered for use in restoration efforts.

Study Goal 5: Determine if eelgrass restoration can be enhanced by construction of an elevated sand plateau using either imported coarse-grained sand or by recontouring site-native sand bottom.

Eelgrass on the Emeryville Flats is limited to an extremely narrow depth range of less than one meter. Success of the proposed on-site restoration of the barge access channel will depend both upon restoring the appropriate depths using sediments that will support eelgrass but not erode away. Imported coarse-grained sand may prove suitable for such restoration, but this has not been demonstrated in San Francisco Bay. Similarly, there is a question as to whether imported sand is even required to accomplish the restoration. It is possible that native sands may be adequate to create a suitable site that is stable in wave environment of the Emeryville Flats. To test these issues, Caltrans proposes that small pilot sites, which are too deep to support eelgrass in their present conditions, be filled to create mini-plateaus at elevations that fall within the range necessary to support eelgrass. Such fills have proven extremely successful at creating suitable eelgrass restoration sites in other areas (Merkel 1991, Merkel & Associates 1998, and Merkel & Hoffman 1993). Half of these would be constructed using imported coarse-grained sand while the other half would use native sand dredged from the nearby bottom. Sites would be planted with bare root units and sediment plugs and would be monitored for transplant unit growth and survival as well as natural recruitment and physical processes of erosion and sedimentation.

Study Goal 6: Determine how eelgrass transplants perform within light-limited environments.

Understanding eelgrass growth and survival in stressed environments is critical to determining how eelgrass is likely to perform under the proposed eelgrass restoration program. Many studies have demonstrated that light is generally the limiting factor for eelgrass growth along the lower margin of eelgrass beds. Because photosynthesis reaches a saturation level, the duration of light is more important than the intensity of light above the photo-saturation level. Because of this phenomenon, eelgrass often recruits at depth during the summer months and dies back during the winter months when days are shorter and light levels are lower. This results in a patchy distribution of eelgrass within areas that are chronically in a state of flux. To understand the relationship of light to eelgrass sustainability at Emeryville Flats, Caltrans proposes a summer season transplant into deeper fringe environments. Light levels will be monitored in native dense eelgrass beds as well as the marginal transplant areas. Merkel and Associates anticipates that as the year progresses, the hours of photosynthetic saturation will decline at both sites, resulting in the ultimate die-off of the deeper transplants and the sustained presence of the shallower eelgrass. By examining the difference between light levels experienced at these two sites, one may determine the lower threshold for light required to support eelgrass throughout the year. The importance of this information is that light levels and duration are important to eelgrass presence, while depth is not. For the potential Central Bay mitigation sites at the East Shore State Park, where local reference areas may be less available than at the Emeryville Flats, it would be inappropriate to rely only on the depth range to indicate suitability for eelgrass restoration. It will be necessary to determine what light environments are sustainable at the potential mitigation sites and relate these environments to the physiological tolerance of eelgrass within local beds.

Study Goal 7: Determine the rates of seedling recruitment, plant mortality, and expansion rates of native eelgrass beds on the Emeryville Flats.

The dynamic nature of eelgrass beds within many areas of San Francisco Bay is indicative of the highly stressed environment of the Bay (Thompson *et al.* 1998, Fredette *et al.* 1988, and Wyllie-Echeverria and Rutten 1989). This dynamism is readily seen in reviewing the changes in the eelgrass distribution on the Emeryville Flats between the October 1999, 2000, and 2001 surveys (Merkel & Associates 2001). This instability is cause for concern when contemplating restoration of eelgrass as mitigation. However, it also suggests that a restoration program that is most reliant upon natural seedling recruitment and less reliant on transplantation of plant materials may be the best method for implementing such restoration. Understanding the rate of seedling recruitment, plant expansion and extinction may provide considerable insight into what should be expected for a restoration project.

EXPERIMENTAL DESIGN

Site and Plot Layout

All transplants are to occur within and adjacent to the eelgrass beds found on the Emeryville Flats north and east of the SFOBB Oakland Touchdown area. Four geographically separated study areas (A through D) are to be located on the Emeryville Flats. Initially, these study areas will be distributed as illustrated in Figure 2. Figure 2 also shows the composite eelgrass map that identifies the highest eelgrass densities detected during the 1999-2001 October field surveys. Final study area selection will occur during additional field reviews.

Within each study area, eight study plots (1 through 8) will be situated within and around existing eelgrass as illustrated in the conceptual layout (Figure 3). Each of the eight study plots within a study area will provide opportunities to investigate various questions outlined under the research goals. The four separate study areas will provide replication. An individual study plot will consist of a 5x5 square meter plot partitioned into quarters to support four differing combinations of treatments and controls (Figure 4). The location of a treatments and controls within the plot will be assigned randomly.

The plots will be partitioned with 3/8-inch nylon rope anchored against the bottom. Where treatment plantings are conducted in a quarter plot, a 5x5 array of 25 planting units will be used (Figure 5). The planting units will be 1.5 feet (0.5 meters) on center. For bare controls (BC) and eelgrass controls (EC) the quarter plot will be situated over bare ground or will be established to include existing eelgrass.

Study Summaries

Sediment Plug vs. Bare Root (Study 1)

The study design will include a single test of planting unit survival and early growth of sediment plugs and bare root transplants. These will be tested alongside a bare control and an eelgrass control which would account for normal vegetation die-back as well as local seedling recruitment. This plot layout is reflected by Figure 5.

Caltrans will conduct monitoring at intervals of 4, 8, 12, 24, and 48 weeks after planting. At each monitoring interval, the number of live planting units will be counted and a random sampling of 10 units in each treatment will be measured from each study plot. The eelgrass control will be monitored to determine expansion or contraction of the basal area using measurements taken between stakes situated within and outside the existing beds. Four distinct boundary change measures will be taken and averaged to provide change estimates within a single plot. The bare control will be searched for seedling recruitment and the number of new plants emerging in these controls will be noted by a total plant count.

Data will allow the direct comparison of the performance of sediment plug and bare root planting units relative to unit mortality and basal spread over the first year of planting.

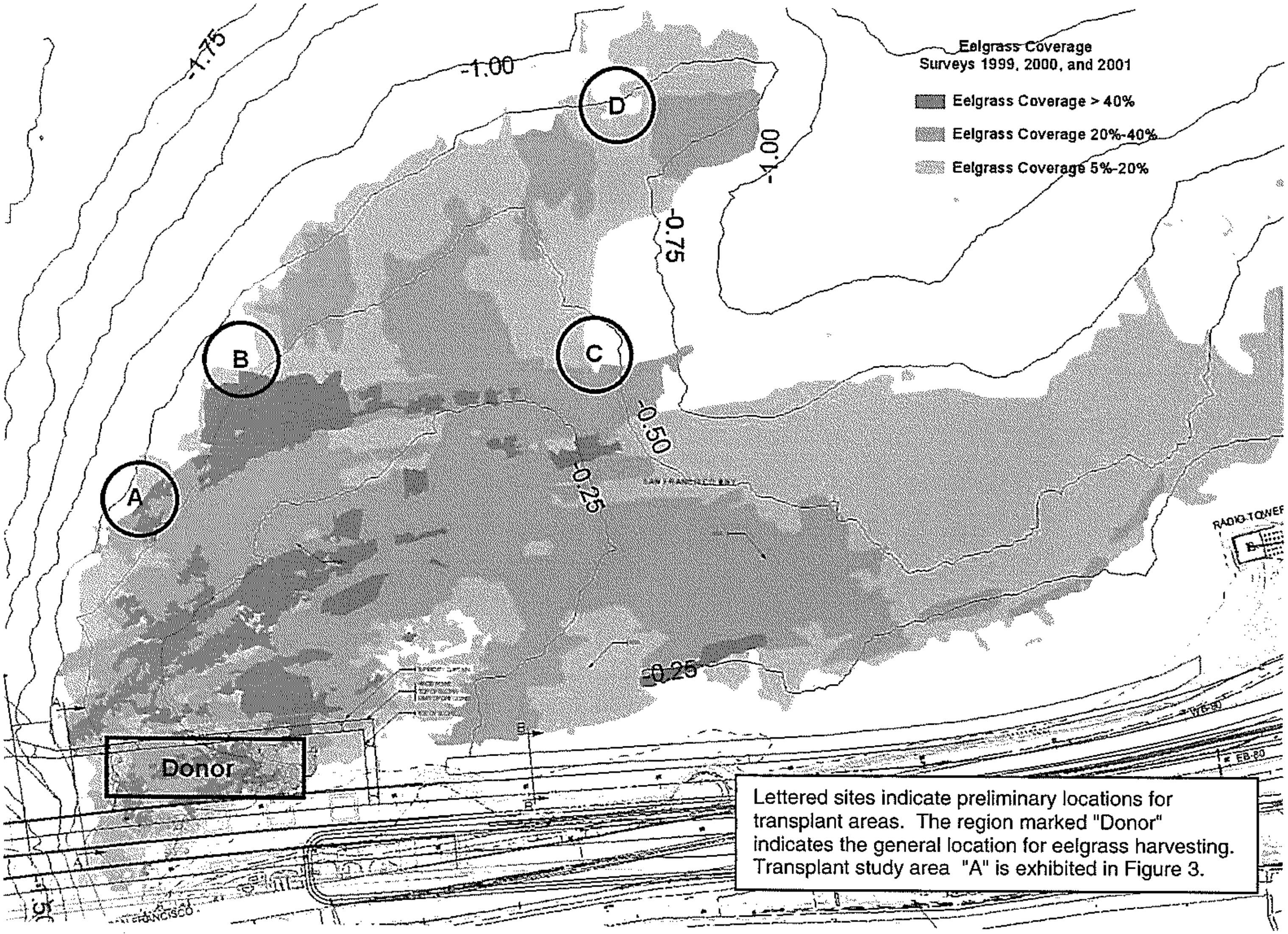


Figure 2. Conceptual locations for Emeryville Flats eelgrass study areas. Bathymetric contours are presented in meters MLLW.

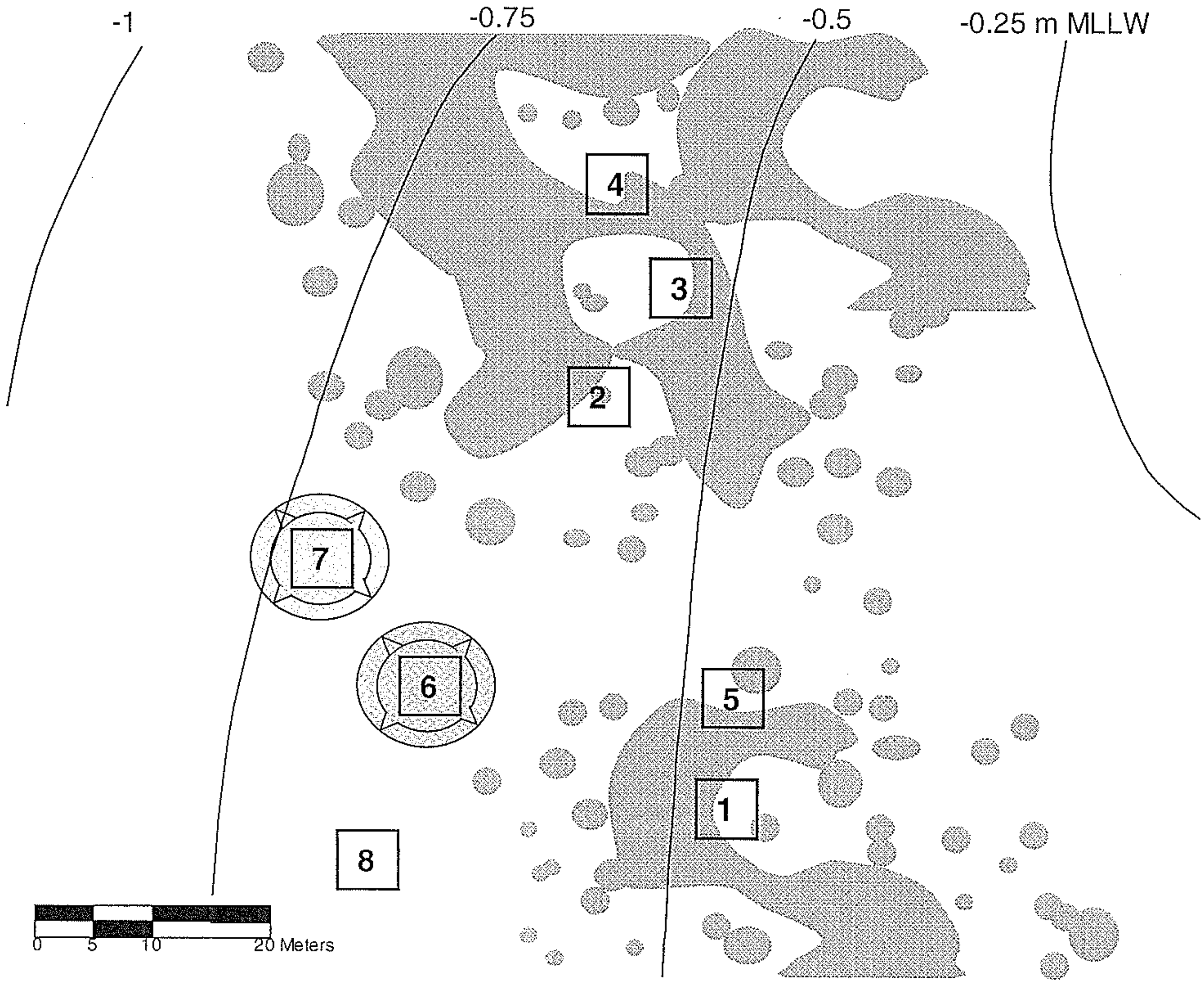


Figure 3. Schematic plot layout for study area "A" at Emeryville Flats transplant area.

	Sediment Plug Bare Root		Planting Unit Turion Count				Long / Short Leaves		Donor Site Differences		Raised Bottom Planting Areas Angel Is. Sand		Native Sand		Light Limited Growth/Survival	
	1		2		3		4		5		6		7		8	
A	EC	BC	BR8	EC	BC	BR8	EC	BC	BRBI	BRBF	ER	BC	ER	BC	ER	BC
	BR8	SP	BR10	BR6	BR20	BR16	BRS	BRL	BRKC	BREF	BR8	SP	BR8	SP	BR8	SP
B	BR8	EC	BR12	EC	BC	BR2	BRL	EC	BREF	BRBF	BR8	ER	BR8	ER	BR8	ER
	BC	SP	BR16	BR4	BR4	BR10	BC	BRS	BRKC	BRBI	SP	BC	BC	SP	BC	SP
C	EC	BR8	EC	BR20	BC	BR20	EC	BRS	BRBI	BREF	SP	BR10	ER	BR8	ER	BR8
	BC	SP	BR2	BR6	BR8	BR12	BC	BRL	BRKC	BRBF	BC	ER	BC	SP	BC	SP
D	BC	SP	BR4	BR16	BC	BR6	BC	BRL	BRKC	BREF	BC	SP	BC	SP	BC	SP
	BR8	EC	BR12	EC	BR10	BR2	BRS	EC	BRBF	BRBI	BR8	ER	BR8	ER	BR8	ER

BC - Bare Control --- No planting, plot is monitored for natural recruitment
EC - Eelgrass Control --- Naturally occurring eelgrass within plots is monitored for expansion/decline
SP - Sediment Plugs --- Sediment plugs of eelgrass, 15 cm dia. x 15 cm deep salvaged and moved intact
BR# - Bare Root Units (# turions) --- Bare root units, cut 15 cm leaves w/variable turion counts
BRS/L - Bare Root Units (short or long) --- Eight turion bare root units, cut 15 cm and uncut leaves
BRxx - Bare Root Units (Keil Cove, Brooks Is., Bay Farm, Emeryville Flats) --- Eight turion bare root units from different sites
ER - Erosion/Sed. Monitoring --- Center and edge erosion stakes and sediment cones on sites

Figure 4. Emeryville Flats experimental transplant schematic plot design.

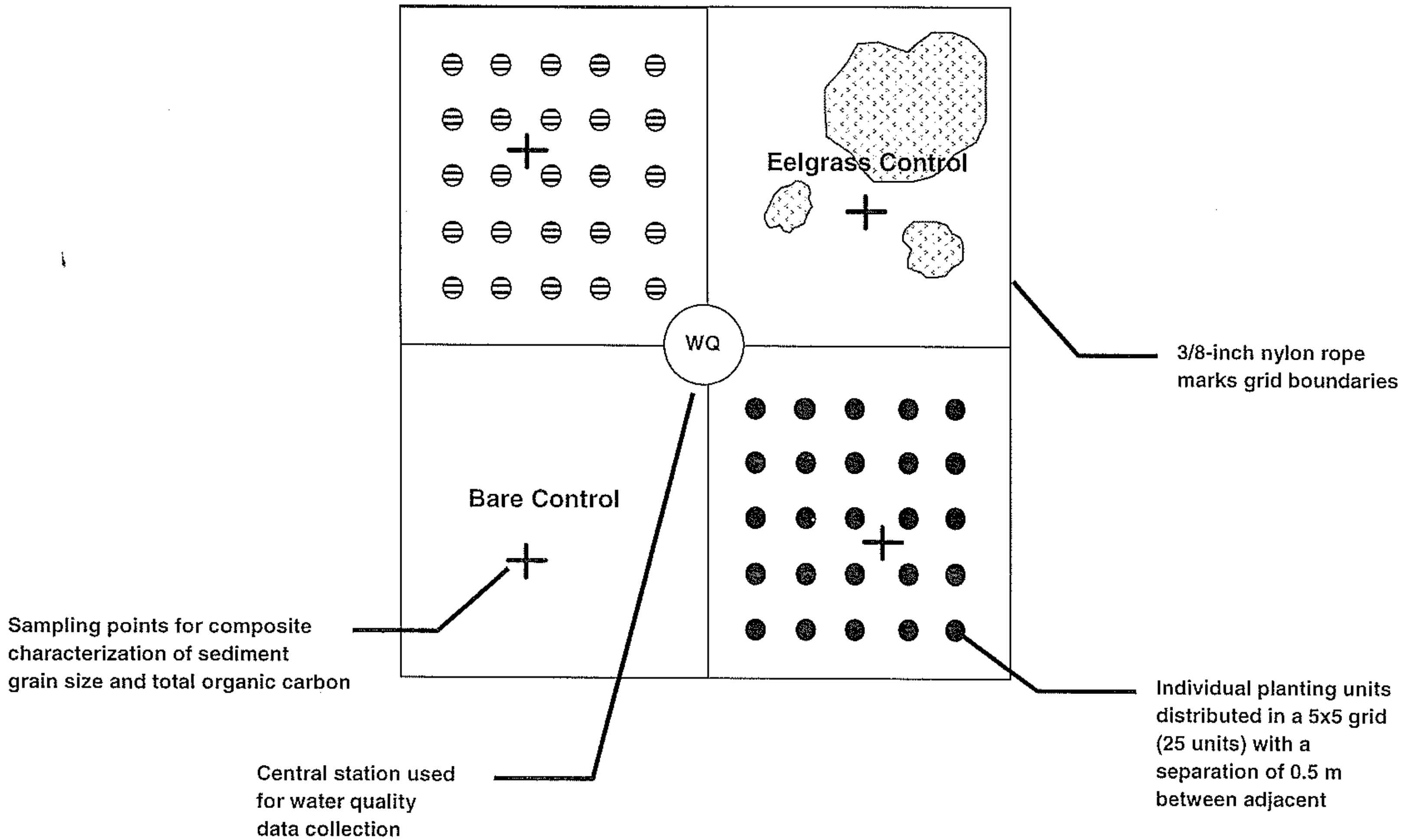


Figure 5. Detail of individual study plot.

Planting Unit Turion Count (Study 2)

This study will test bare root eelgrass transplant units, varying in turion counts, against each other to determine their relative rates of survival and establishment. The study is designed to explore early establishment periods and not long-term growth response. Planting units will be tested at 2, 4, 6, 8, 10, 12, 16, and 20 turions/unit. Also an eelgrass control and bare control will be used to evaluate natural environmental effects within the study areas. Caltrans proposes three replicates at each planting unit size.

Monitoring will be conducted at 2, 4, 8, and 12 weeks following planting. At each monitoring interval, the number of live planting units will be counted and a random sampling of 10 units in each treatment will be measured from each study plot. The eelgrass control will be monitored to determine expansion or contraction of the basal area using measurements taken between stakes situated within and outside the existing beds. Four distinct boundary change measures will be taken and averaged to provide change estimates within a single plot. The bare control will be searched for seedling recruitment and the number of new plants emerging in these controls will be noted by a total plant count.

Long and Short Leaves (Study 3)

In this study, eelgrass would be planted using a standard cut leaf approach versus leaving the leaves on transplant units at their full length. This study would include four replicate plots of 25 units each of both a trimmed planting unit (15 cm leaves) and uncut planting units.

Like the planting unit size study, this investigation is designed to assess differences in early performance of planting units rather than long-term performance. After a few months, normal growth and erosion of leaves would tend to equalize planting units that were installed with longer rather than shorter leaves.

Because the value of later monitoring would decline, Caltrans proposes that monitoring be conducted at 2, 4, 8, and 12 weeks following planting. At each monitoring interval, the number of live planting units will be counted and a random sampling of 10 units in each treatment will be measured from each study plot. The eelgrass control will be monitored to determine expansion or contraction of the basal area using measurements taken between stakes situated within and outside the existing beds. Four distinct boundary change measures will be taken and averaged to provide change estimates within a single plot. The bare control will be searched for seedling recruitment and the number of new plants emerging in these controls will be noted by a total plant count.

Effects of Donor Beds (Study 4)

The principal donor site for eelgrass transplant materials is the footprint of the barge access channel at the Oakland Touchdown area (Figure 2). In addition, for evaluation of donor sites as a factor in dictating success or failure of a transplant, Caltrans proposes to harvest a small amount of material from three off-site locations. These include Keil Cove on the Tiburon Peninsula (a sandy clear-water site), Brooks Island (a mud bottom, turbid environment), and Bayfarm Island Shoals (a sand bottom turbid environment) (Figure 6). As with the on-site harvesting, collection from these sites will require issuance of a letter of authorization by the California Department of Fish & Game.

In this study, material from each of the donor sites will be planted in four replicates of 25 bare root units each. Units would be prepared using a standard of eight turions for each of the sites and would be cut to 15 cm (6 inches).

Monitoring will be conducted at intervals of 4, 8, 12, 24, and 48 weeks after planting. At each monitoring interval, the number of live planting units will be counted and a random sampling of 10 units in each treatment will be measured from each study plot.

Created Plateaus as a Suitable Eelgrass Restoration Site (Study 5)

This study will use imported and site native sands to create hummocks on the bottom. The hummocks will raise the bottom to a depth adequate for providing the necessary light to support eelgrass at the Emeryville Flats. Caltrans contemplates using 4 hummocks each with coarse-grained imported sand and native. The total yardage for creating the necessary hummocks is estimated to be approximately 800 cubic yards (600 cubic meters) of clean sediment.

The study design will include a single test of planting unit survival and early growth of sediment plugs and bare root transplants. These will be tested alongside a bare control. The fourth quarter of each plot would be reserved for investigations of erosion and sedimentation.

Monitoring is to be conducted at intervals of 4, 8, 12, 24, and 48 weeks after planting. At each monitoring interval, the number of live planting units will be counted and a random sampling of 10 units in each treatment will be measured from each study plot. The bare control will be searched for seedling recruitment and the number of new plants emerging in these controls will be noted by a total plant count. Erosion and sedimentation will be monitored using sediment stakes and sediment collection cones.

Light-Limited Environments (Study 6)

The study design will include a single test of planting unit survival and early growth of sediment plugs and bare root transplants along the deeper fringe of eelgrass habitat. These will be tested alongside a bare control. Light monitoring in this study is to be paired with light monitoring within sites located within denser eelgrass beds. The relative.rate of growth or decline between bare root transplants and sediment plugs will be noted as well as the performance of these transplants relative to native eelgrass and transplanted eelgrass within higher light environments.

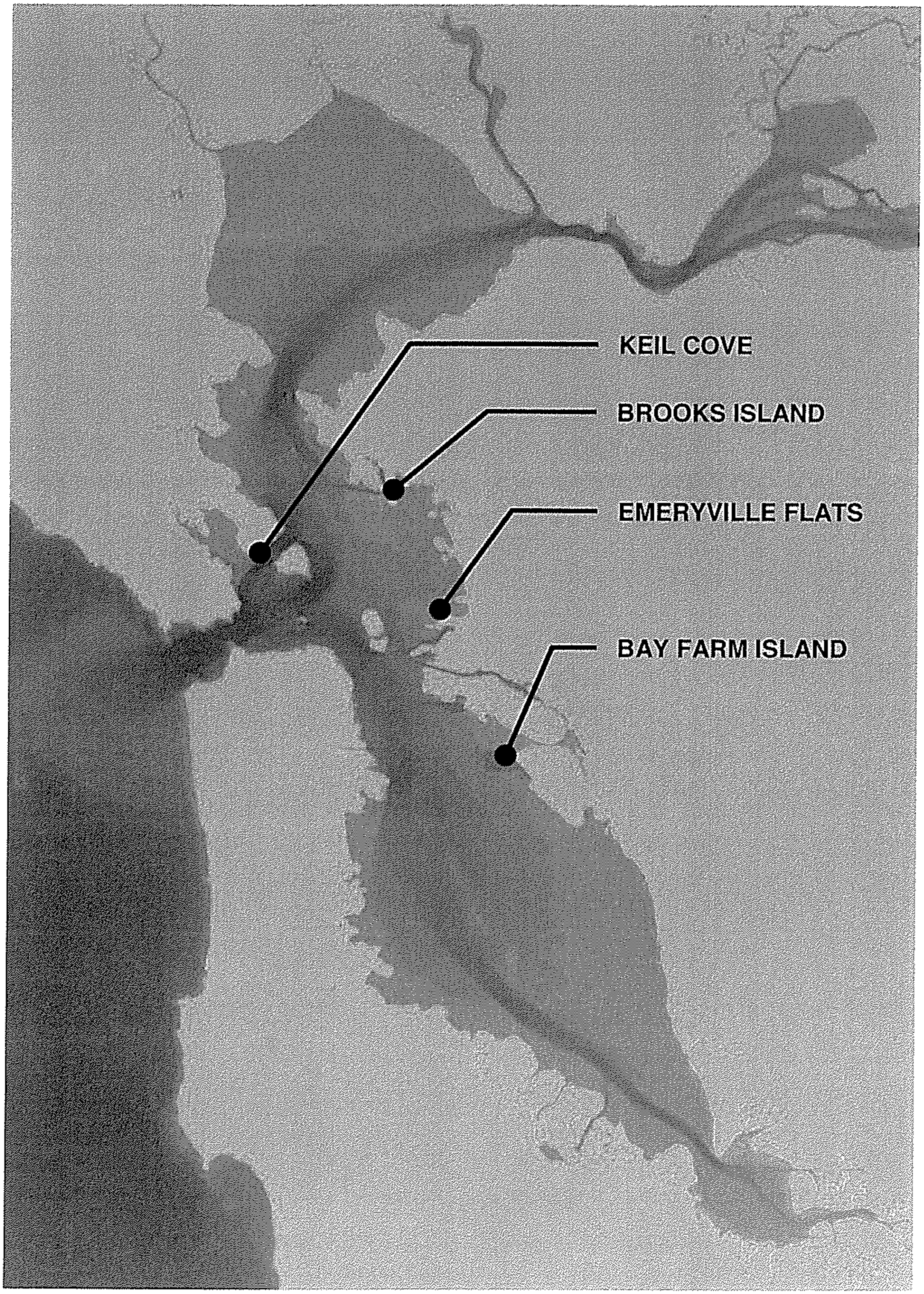


Figure 6. Location of off-site eelgrass donor sites.

Monitoring will be conducted at intervals of 4, 8, 12, 24, and 48 weeks after planting. At each monitoring interval, the number of live planting units will be counted and a random sampling of 10 units in each treatment will be measured from each study plot. The bare control will be searched for seedling recruitment and the number of new plants emerging in these controls will be noted by a total plant count. Light conditions will be monitored over a week period at one of the stations and within one of the higher light stations.

Natural Eelgrass Dynamics (Study 7)

A discrete study layout is not proposed to address this study purpose. The 6 prior studies outline the use of numerous bare controls and eelgrass controls occurring under different circumstances within the Emeryville Flats. The results of the monitoring at each of these control plots along with the annual eelgrass survey data (Merkel & Associates (2001) and new surveys) is anticipated to provide greater insight into the dynamics of eelgrass within these marginal eelgrass habitats found within San Francisco Bay.

IMPLEMENTATION

AUTHORIZATIONS REQUIRED

Implementation of the experimental transplant program will require a number of authorizations from various agencies and landowners. These are identified below.

California Department of Fish & Game

The California Department of Fish & Game would need to authorize the harvest and transplant of eelgrass at all experimental sites. The authorization would include the following:

1. Collection, by SCUBA divers, of approximately 1,000 turions from each of three eelgrass beds found at Keil Cove, Brooks Island and Bay Farm Island. Turions are to be collected as bare root units salvaging no more than 5% from any portion of the donor beds.

2. Collection of eelgrass, by any means, from within the dredging footprint of the Oakland Touchdown for the SFOBB. Eelgrass salvage is to include sediment plug and bare root material and is anticipated to include the removal of 9,600 eelgrass turions for experimental bare root planting units, 400 sediment plugs, and 15,800 turions for bare root plantings to complete the required 0.55 acre eelgrass transplant.

Bay Conservation and Development Commission
U.S. Army Corps of Engineers
Regional Water Quality Control Board

Approvals from the ACOE, BCDC and RWQCB are required for the placement of eight small sand plateaus onto which eelgrass is to be planted in study plots. The best mechanism for permitting the placement of experimental study site fills has not yet been determined and will be worked out with the individual regulatory agencies. The authorizations would include the following:

1. The placement of approximately 800 cubic yards (600 cubic meters) of clean sand fill to create eight raised hummocks for the purpose of conducting experimental transplants of eelgrass in support of habitat mitigation efforts for the SFOBB.

2. Sand fill shall be placed using either mechanical methods or hydraulic pumping and shall be placed within the confines of a surface to bottom silt curtain to control turbidity during placement.

East Bay Regional Park District
Port of Oakland

The final location of harvest and transplant receiver sites may occur on lands administered by either the Port of Oakland or the East Bay Regional Park District and, if so, would require authorization by the appropriate property owner. These authorizations may be granted either through a right-of-entry permit or other approval process yet to be determined.

CONSTRUCTION OF PLANTING PLATEAUS

The only project element involving placement of fill within the Bay is the construction of the eight test plot plateaus onto which eelgrass will be transplanted. While the cumulative size of these features is extremely small, the construction work could generate turbidity and affect adjacent eelgrass beds unless measures are implemented to protect these resources. Additionally, placement must be done in a manner that does not result in artificially steep slopes or undulating bottom conditions that will weather differently than would a larger restoration site or native condition. This section describes the design measures to address these concerns.

Sand Plateau Placement

Caltrans will create the test plot plateaus using approximately 800 cubic yards (600 cubic meters) of sand. This will include imported Angel Island coarse-grained sand with a median grain size of approximately 0.024 inches (0.6 mm) and site native sand from the Emeryville Shoals. For each plot, the material will be placed and spread hydraulically. This will be accomplished by pumping sand through a diffuser located on a tender boat that is used to deposit a smooth hummock of sand approximately 1.6 feet

(0.5 m) deep in areas of the shoal that are presently too deep to support eelgrass. This elevation lift would raise the hummocks into the required photic zone essential to meet the light requirements of eelgrass. It is anticipated that approximately 100 cubic yards (77 cubic meters) of material will be used for each plateau. The hummocks will occupy a basal diameter of approximately 60 feet (18 m) each and will rise gently to a crest diameter of approximately 33 feet (10 m). Site native sediment will be extracted either from areas within the barge access channel at the Oakland Touchdown or from areas adjacent and down-drift of the locations where plateaus will be constructed. By using material from the area immediately adjacent to the test plots, erosion of the native sand hummocks is expected to re-establish the native grades.

After placement of the sand, additional smoothing of the sites will be accomplished by dragging the plateaus with an I-beam or by minor sand-gun sculpting of the surface to fill depressions and remove smaller mounds. Keith Merkel and associates have used these practices to manipulate the bathymetry and prepare other similar sites for eelgrass restoration.

Adjacent Resource Impact Control

Turbidity control measures will be implemented to protect the existing eelgrass beds. Turbidity control will be accomplished by using a full containment silt curtain that extends from the surface of the Bay to the Bay floor surrounding each constructed plateau. The boom will be constructed in a ring with an exterior diameter of approximately 82 feet (25 meters). The construction of the plateaus will be monitored to ensure compliance with the same water quality criteria established by the Regional Water Quality Control Board and required for dredging associated with the bridge construction.

To further ensure protection of adjacent eelgrass beds during the construction of test plots, the most proximate eelgrass to each of the plots will be marked with buoys during plot construction and the areas will be avoided while maneuvering vessels for material placement and silt curtain deployment.

The field leader for Merkel & Associates will be responsible for ensuring full compliance with the resource protection measures during the construction of the study plots.

SCHEDULE

The overall schedule for completion of the experimental transplant efforts is estimated to extend over approximately 18 months, however, the schedule for initiating pilot transplant studies is very short. The timeframe for completion of the transplant efforts is dictated both by the overall bridge construction schedule, which includes dredging the Oakland Touchdown access channel in 2003, as well as growing season constraints on completing successful transplant efforts. The preliminary schedule for completing transplants and subsequent monitoring is outlined in Table 1. The primary goal for this pilot transplant study is to establish planting units as early in the 2002 growing season as possible. It is believed that this can be accomplished by August 1. While it would be preferable to conduct transplants earlier, permitting for transplants involving placement of fill to create hummocks is anticipated to take 45 to 60 days and would result in the principal delay in the study efforts.

Table 1. Schedule for completion of experimental eelgrass transplants

Task	Start	End
Prepare draft experimental transplant plan	Apr. 12, 2002	May 5, 2002
Agency TAC review	May 8, 2002	May 28, 2002
Final experimental transplant plan	May 29, 2002	Jun. 3, 2002
Permitting and approvals	Jun. 4, 2002	Jul. 31,2002
Mobilization for transplant studies	Jul. 20, 2002	Jul. 31, 2002
Site preparation and pilot transplanting	Aug. 1, 2002	Aug. 15, 2002
Post-planting initial report	Aug. 16, 2002	Aug. 25, 2002
2-week monitoring for studies 2 and 3	Aug. 15, 2002	Aug. 20, 2002
4-week monitoring for studies 1-6	Aug. 25, 2002	Sep. 5, 2002
8-week monitoring for studies 1-6	Oct. 3, 2002	Oct. 13, 2002
12-week monitoring for studies 1-6	Nov. 10, 2002	Nov. 20, 2002
First interim data report	Nov. 21, 2002	Dec. 11, 2002
24-week monitoring for studies 1, 4-6	Feb. 12, 2003	Feb. 22, 2003
Second interim data report	Feb. 23, 2003	Mar. 10, 2002
48-week monitoring for studies 1, 4-6	Jul. 30, 2003	Aug. 8, 2003
Third and final data report	Aug. 9, 2003	Aug. 24, 2003
Draft study report	Aug. 9, 2003	Sep.15, 2003
Agency TAC review of draft study report	Sep.16, 2003	Oct. 1, 2003
Final study report	Oct. 2, 2003	Oct. 17, 2003

Reporting Program

The reporting program contemplated to accompany the pilot experimental transplant efforts includes the following reports:

1. Final experimental transplant plan – This plan will be the finalized version of the present document and would include consideration of comments offered by the Agency TAC and Caltrans reviewers.

2. Post-planting initial report – This document will be a short post-transplant summary of the activities conducted in the initiation of the transplant program. It would identify any areas where deviations from the plan occurred. This report is not proposed to be subject to an Agency TAC draft review process.

3. First interim data report – This document will be a data summary report that will include tabular data summaries for monitoring data collected during the 2, 4, 8 and 12-week monitoring efforts. This report is proposed as a data transfer tool

and will not include data analyses or interpretation. This report is not proposed to be subject to an Agency TAC draft review process.

4. Second interim data report – This document will be a data summary report that will include tabular data summaries for monitoring data collected during the 24 week monitoring efforts. The report will provide data in a cumulative format that includes data collected during prior monitoring intervals. This report is proposed as a data transfer tool and will not include data analyses or interpretation. This report is not proposed to be subject to an Agency TAC draft review process.

5. Third and final data report – This document will be a data summary report that will include tabular data summaries for monitoring data collected during the 48 week monitoring efforts. The report will provide data in a cumulative format that includes data collected during prior monitoring intervals. This report is proposed as a data transfer tool and will not include data analyses or interpretation. This report is not proposed to be subject to an Agency TAC draft review process.

6. Draft study report – A draft report will be prepared in the format of a technical study document. It will include sections on Background, Study Area and Design, Methods, Results, and Discussion. This document will be sent out in draft form to the Agency TAC for review and comment prior to finalization.

7. Final study report – A final study report will be prepared following Agency TAC review and comment on the draft report.

REFERENCES

Fredette, T., M. Fonseca, W.J. Kenworthy, and S. Wyllie-Echeverria. 1988. An Investigation of Eelgrass (*Zostera marina*) Transplanting Feasibility in San Francisco Bay, California. Internal Working Document EL-88-2, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Merkel & Associates, Inc. 1998. Analysis of Eelgrass and Shallow Water Habitat Restoration Programs along the North American Pacific Coast: Lessons Learned and Applicability to Oakland Middle Harbor Enhancement Area Design. Prepared for Middle Harbor Habitat Technical Advisory Committee and the Port of Oakland. August 1998.

Merkel & Associates, Inc. 1999. Middle Harbor Habitat Design, Governing Design and Engineering Criteria for Target Habitat Elements. Prepared for: Winzler & Kelly and the U.S. Army Corps of Engineers. November 1999. (data originally gathered for the Port of Oakland and the Middle Harbor Habitat Technical Advisory Committee).

Merkel & Associates, Inc. 2001. Eelgrass Habitat Surveys (October 1999, 2000, and 2001): San Francisco-Oakland Bay Bridge East Span Seismic Safety Project.

Prepared for Parsons Brinkerhoff Quade & Douglas and the California Department of Transportation. Caltrans Contract 04A0148. November 2001

Merkel, K.W. 1990. Growth and Survival of Transplanted Eelgrass: The Importance of Planting Unit Size and Spacing. In: Proceedings of the California Eelgrass Symposium (K.W. Merkel and R.S. Hoffman, eds.). Sweetwater River Press, National City, CA.

Merkel, K.W. 1991. The Use of Seagrasses in the Enhancement, Creation and Restoration of Marine Habitats along the California Coast: Lessons Learned from Fifteen Years of Transplants. Technical Advisory Panel, Marine Board - National Research Council: Committee on the Role of Technology in Marine Habitat Protection and Enhancement. Washington D.C.

Merkel, K.W. and R.S. Hoffman. 1993. The Use of Dredged Materials in the Restoration of Eelgrass Meadows: A Southern California Perspective. In: M.S. Landin et al., ed., Proceedings of a Regional Workshop: Beneficial Uses of Dredged Materials in the Western U.S. U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi.

Phillips, R.C. 1990. General Ecology of Eelgrass with Special Emphasis on Restoration and Management. In: Proceedings of the California Eelgrass Symposium (K.W. Merkel and R.S. Hoffman, eds.). Sweetwater River Press, National City, CA.

Thompson, T., K.W. Merkel and J. Nakayama. 1997. Use of Acoustic Survey Techniques to Map Seagrasses in Highly Turbid Environments, California. Society of Wetland Scientist. Bozman, Montana.

Wyllie-Echeverria, S. and P. Rutten. 1989. Inventory of Eelgrass (*Zostera marina* L.) in San Francisco/San Pablo Bay. NMFS/NOAA Administrative Report SWR-89-05. Terminal Island, CA. October 1989.

Zimmerman, R.C., J.L. Reguzzoni, S. Wyllie-Echeverria, M. Josselyn, and R.S. Alberte. 1991. Assessment of Environmental Suitability for Growth of Zostera marina, L. (Eelgrass) in San Francisco Bay. Aquatic Bot. 39:353-366.