FINAL REPORT

for the

University of California, Berkeley
Richmond Field Station Remediation and Restoration Project
Habitat Restoration Progress Report 2003 – 2007




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1.0 Introduction

The purpose of this report is to summarize habitat restoration and invasive non-native plant control activities undertaken between 2003 and 2007 in Western Stege Marsh and the adjacent coastal terrace prairie habitat, both located on the University of California, Berkeley's (UC Berkeley) Richmond Field Station (RFS). Habitat restoration work began following completion ofremoval of environmental contaminants from eastern section of the marsh system in 2004. The removal of contaminants provided an opportunity to enhance the native plant community diversity of the site, including the revegetation of the marsh, ecotone and upland areas. Grassland restoration was also undertaken within a 4-acre area, with a primary focus on protecting locally rare species through the control of Harding grass (*Phalaris aquatica*).

The restoration and invasive non-native plant control actions were primarily undertaken by the Watershed Project (formerly the Aquatic Outreach Institute) with the support of UC Berkeley staff and community volunteers. The majority of the funding was provided through a contractual agreement with UC Berkeley, with additional philanthropic and grant funding acquired by the Watershed Project.

The report includes a summary of the original project goals and objectives and an analysis of the project's successes and failures for the reporting period 2004-2007, as well as guidance for future restoration activities at the Richmond Field Station (RFS).

1.1 Marsh Restoration Project Goals and Objectives

Restoration goals and objectives were set forth in the Biological Assessment [Blasland, Bouck and Lee (BBL), 2003]. They include separate goals and objectives for marsh vegetation, invasive species control, and revegetation, as described below.

1.1.1 Marsh Vegetation Goals and Objectives

Marsh restoration goals were set forth in the Richmond Field Station Remediation Project Biological Assessment Report (BBL, 2003). They include the following:

- **Enhance Marsh Habitat** by removing invasive/exotics plant species from the coastal scrub habitat. This enhancement goal includes the establishment of native coastal scrub to reduce colonization and competition from invasive plant species, as well as removal of pampas grass (*Cortaderia jubata*), fennel (*Foeniculum vulgare*) and Harding grass (*Phalaris aquatica*) in recently graded areas.

- **Develop Marsh/Upland Ecotone,** from high marsh habitat to upland habitat to improve California Clapper Rail (*Rallus longirostris obsoletus*) habitat and to create upland refugia for the species. This enhancement goal includes establishing native vegetation cover and structure in the upland areas to provide suitable refugia for the California Clapper Rail and other marsh birds from predators during high tide events.

Photo 1.1 California Clapper Rail in Stege Marsh

Additionally, compliance with the US Fish and Wildlife Service's (USFWS) Biological Opinion (BO) to the Army Corps of Engineers Nationwide Permit for the project (Army Corps of Engineers, 2004) requires the following vegetation performance measures and cover by the end of the 5-year monitoring period:

- **2.2[1] acres of pacific cordgrass** *(Spartina foliosa)* with a vegetative cover of 85%.
- **1.5[2] acres of pickleweed** *(Salicornica virginica)* with a vegetative cover of 85%.

Interim performance standards were established to help ensure that the project met these overall project goals. These annual performance standards that were described in the Western Stege Marsh Restoration Project Monitoring Plan (BBL, 2004a) are provided in Table 1.1 below.

Table 1.1. Project Standards for Marsh Vegetation, Richmond Field Station Western Stege Marsh Remediation and Restoration Project, Richmond California
(Source: BBL, 2004a).

Project Standard	Field Indicator/Measure
Percentage cover of native vegetation (excluding tidal mudflats)	Year 2: Greater or equal to 20% Year 3: Greater or equal to 40% Year 4: Greater or equal to 60% Year 5: Greater or equal to 80%
Total Acreage of Pacific Cordgrass	**Target Acreage: 2.6 acres** Year 1: Greater or equal to 15% of target acreage (0.4 acre) Year 2: Greater or equal to 30% of target acreage (0.8 acre) Year 3: Greater or equal to 50% of target acreage (1.3 acres) Year 4: Greater or equal to 65% of target acreage (1.7 acres) Year 5: Greater or equal to 85% of target acreage (2.2 acres)
Total Acreage of Pickleweed	**Target Acreage: 1.7 acres** Year 1: Greater or equal to 15% of target acreage (0.3 acre) Year 2: Greater or equal to 30% of target acreage (0.5 acre) Year 3: Greater or equal to 50% of target acreage (0.9 acre) Year 4: Greater or equal to 65% of target acreage (1.1 acres) Year 5: Greater or equal to 85% of target acreage (1.5 acres)
Vigor of Planted Stock	Greater or equal to 80% of vegetation plots assessed as "Good" or "Excellent"

1.1.2 Invasive Non-Native Plant Species Goals and Objectives

Invasive non-native plant species management goals for the marsh restoration area were set forth in the Invasive /Exotic Species Management Program (Blasland, Bouck and Lee, 2004b). The focus of the invasive non-native plant control program is to reduce establishment and cover of priority invasive non-native plant species that may impact marsh and upland habitats used by California Clapper Rail.

[1] The total target acreage for Pacific cordgrass is 2.6 acres
[2] The total target acreage for pickleweed is 1.7 acres

The Invasive/Exotic Species Management Program outlines the following 4 objectives:

- **Actively monitor and control priority invasive non-native vegetation** within the project area to promote high quality marsh and upland habitat for California Clapper Rail;

- **Enhance and increase ecotonal and upland refugia habitat for California Clapper Rail;**

- **Engage and educate students and community volunteers** in the invasive/exotic vegetation management program; and

- **Institute an education program with RFS maintenance staff** to increase awareness and control patches of priority invasive non-native vegetation adjacent to the project area.

Additionally, the USFWS BO requires that UC Berkeley continue to monitor and manage the hybrid smooth grass (*Spartina alterniflora*) infestations located on the outboard side of Western Stege Marsh in partnership with the Invasive Spartina Project (ISP). Additionally the BO states that perennial pepperweed (*Lepidium latifolium*) must also be controlled to reduce impacts on California clapper rail habitat.

The highest priority invasive non-native plant species for initially identified for control in this project included the following species:

- Perennial pepperweed,
- Smooth cordgrass,
- Pampas grass, jubata grass,
- Fennel, and
- Harding grass.

In addition, several invasive plants that typically colonize unvegetated and newly planted areas were also targeted during the course of the project (e.g, Himalayan blackberry *(Rubus discolor),* yellow star thistle *(Centaurea solstitialis),* Russian thistle *(Salsola soda),* five-hook bassia *(Bassia hyssopifolia),* stinky tarweed (*Dittrichia graveolens*), and other species). These species were detected and controlled during the course of the project between 2004 and 2007.

1.1.3 Revegetation Goals and Objectives

Revegetation goals and objectives were set forth in the Western Stege Marsh and Ecotone Revegetation Plan (Aquatic Outreach Institute, 2004a) and the Western Stege Marsh Upland Revegetation Plan (Aquatic Outreach Institute, 2004b). They include:

- **Establish vegetative dominance in each habitat** type (e.g. high marsh) to remain similar to that which existed prior to remediation activities;

- **Increase native vegetation richness and cover;**

- **Promote species diversity and advance the establishment of a viable seed bank** while maintaining an opportunity for natural vegetative recruitment within the regraded marsh habitat;

- **Establish healthy sustainable native vegetation cover** for wildlife habitat; and

- **Increase native vegetation cover to reduce colonization of invasive non-native plant species.**

Specific planting palettes and revegetation strategies for the marsh, ecotone and upland habitat areas are identified within these Plans. Dominant aggressively growing species, including annual pickleweed (*Salicornia europea*) and some prolific native species, like dodder (*Cuscata salina var. major*), salt grass (*Distichlis spicata*) and spearscale (*Atriplex triangularis*) were eliminated from the marsh revegetation plan in anticipation of natural colonization. The focus instead was on 11 less common or less aggressively colonizing species, such as Pacific cordgrass (*Spartina foliosa*), marsh heliotrope (*Heliotropium curasssavicum*) and alkali-heath (*Frankenia salina*).

BBL: biologists initially recommended that Pacific cordgrass should be allowed to naturally colonize within the marsh. This approach was modified during the winter of 2004-5 in accordance with recommendations provided by the Invasive Spartina Project (Grijalva, 2005). Instead, Pacific cordgrass divisions were collected from approved local sources and planted within the marsh.

The Watershed Project's restoration and invasive plant control activities within the marsh were guided by the goals and objectives stated above. Sections 3.1 and 4.0 outline species planted, control treatments and adaptive management actions undertaken, and an assessment of whether the goals and objectives were achieved.

1.2 Grassland Restoration Goals and Objectives

The second phase of the RFS Remediation and Restoration Project completed in 2003 required the unavoidable paving of a portion of historic grassland to create asphalt mixing pads for contaminated sediments removed from the marsh. Portions of the areas under the pads and in the surrounding construction zone had been identified as sensitive upland natural communities. In order to mitigate for the loss of these natural communities, the Richmond Field Station Remediation Project, Initial Study, California Environmental Quality Act (URS, 2003a) stipulated two mitigation measures: Bio-4, seed collection and plant salvage, and Bio-5, enhancement or restoration of other designated areas of equal or greater area for unavoidable losses. Project environmental consultants calculated the loss of sensitive habitat during Phase 2 to be equal to 45,066 ft^2 (1.03 acre area).

In 2003 grassland restoration goals and objectives were developed collaboratively by Jepson Herbarium and other UC Berkeley staff and faculty, and the Watershed Project staff, and other local restoration experts. It was decided that the most valuable area for mitigation restoration was the open areas in the western part of the RFS where nineteen acres had been designated in the 1990s by Chancellor Tien to be maintained as native prairie grasslands and seasonal wetlands. Two portions of the grassland corridor were identified as preferred, priority locations to complete invasive weed abatement and native plant enhancement to mitigate for the loss of grassland habitat due to the construction of the asphalt pads (see Figure 2.3a):

Area 1: A one-acre portion of the field in the southwestern corner of the RFS uplands west of the EPA Region 9 laboratory containing a variety of native grasses and flowering plants. The majority of the field west of the EPA laboratory area is degraded by invasive non-native plants and deposited fill and debris. Area 1 was relatively better preserved than the remainder of the field.

Area 2: A three acre portion of the field located east of Building 280 in the larger field north of the EPA Lab. Area 2 is considered prime grassland habitat and has been partially restored, but still contains about 20-25% non-native species.

Jepson Herbarium and other UC Berkeley staff initially identified two restoration and monitoring priorities for the grassland habitat:

- **Map the range and distribution of the locally rare plant species** found within the project area; and
- **Remove unused research equipment and debris from the grassland habitats.**

In 2003-4, the Watershed Project, in partnership with UC Berkeley's Environmental Sciences Teaching Program (ESTP) mobilized more than 100 volunteers to complete these priorities. Following initial grassland monitoring activities the following two goals were established for the project.

- **Control pioneer patches and isolated individuals of Harding grass (*Phalaris aquatica)*** within and adjacent to habitat supporting the highest native species richness.

- **Determine the most effective techniques for controlling Harding grass.** In 2003, the literature provided limited information on effective control strategies and most local practitioners had limited success with long-term control. Section 4.1.4 describes the control treatments and the efficacy of each treatment.

To comply with the CEQA mitigation plan, approximately 4 acres of grasslands containing approximately 1 acre of non-native species (25 %), were actively restored through the removal of weeds throughout the four acres and by replanting plots in the most disturbed portions of the two areas.

1.3 Community Stewardship Goals

The restoration of the Western Stege Marsh and associated upland grassland habitat provided an opportunity for the Watershed Project (previously the Aquatic Outreach Institute) to expand student learning opportunities at the Richmond Field Station (RFS) through active natural resource management, service-learning activities, and guided curriculum-based programs. The community stewardship goals of these programs were to:

- **Strengthen relationships** between and among university educators and interns with students in the neighboring under-served Richmond community, the campus;

- **Build greater community awareness** for the bayshore's natural environment;

- **Develop an on-site community stewardship program** for interested UC Berkeley students, employees and community participants to help protect and restore the natural habitats within the RFS; and

- **Engage volunteers** in meaningful restoration actions and build support for UC Berkeley's habitat enhancement goals.

A key adjunct to the restoration program was the expansion of the existing RFS nursery facility to support increased propagation of local native vegetation necessary for the marsh and grassland habitat enhancement efforts. Plant propagation, similar to the restoration and invasive plant control work would be accomplished through curriculum-based and service learning programs for youth, community volunteers and UC Berkeley students.

To achieve these goals, the Watershed Project was tasked with providing coordination and leadership for both the nursery operations and associated environmental education programs under University guidance, direction and funding support. Additionally, the Watershed Project was tasked to develop sustainable partnerships with University programs such as the UC Berkeley Environmental Sciences Teaching Program (ESTP), and local youth development programs.

2.0 Restoration Site Preparation Activities

Remediation activities to remove contaminated sediments in Western Stege Marsh were completed in three phases from 2002 to 2004. Remediation required significant excavation of contaminated materials, followed by the importation and grading of clean fill materials to achieve the final marsh and upland topography. Erosion control included the installation of jute netting and the application of sterile rice straw. All of these actions were completed by UC Berkeley and its construction contractors.

2.1 Establishment of Study Plots

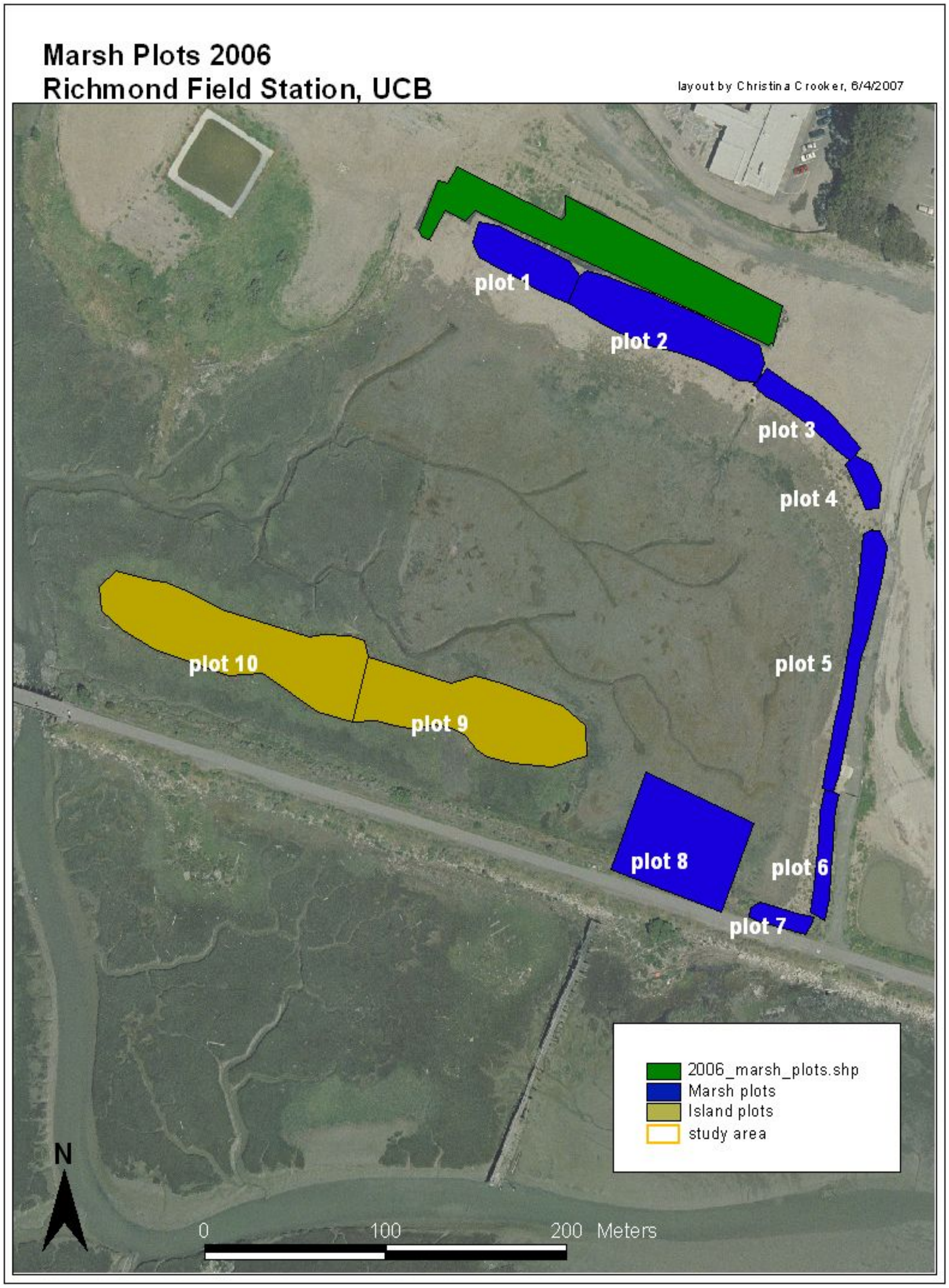
For restoration purposes, the marsh was initially divided into 8 ecotone plots spanning the high marsh [above 5 feet National Geodetic Vertical Datum 29 (NGVD29)] to upland ((10 – 30' above high tide line), and 2 island (upland) plots in 2003 (see Figure 2.1a). Restoration activities also took place in the tidally-influenced marsh below these study plots, encompassing an area of 1.223 acres. In 2006, 3 additional upland plots (from east to west: 12-14) were added. These plots had been covered with weed block fabric by the Watershed Project for approximately one year to help suppress weed colonization and establishment and reduce the viability of the seed bank. In September 2006, the weed fabric was removed.

Table 2.1 summarizes the size of each ecotone, island, and upland plot.

Table 2.1- Ecotone and Island/ Upland Plot Sizes

Plot Number	Meters (sq)	Acres
Plot 1 (Ecotone Plot)	366.134	0.090
Plot 2 (Ecotone Plot)	765.933	0.189
Plot 3 (Ecotone Plot)	242.143	0.060
Plot 4 (Ecotone Plot)	96.407	0.024
Plot 5 (Ecotone Plot)	397.033	0.098
Plot 6 (Ecotone Plot)	169.704	0.042
Plot 7 (Ecotone Plot)	94.872	0.023
Plot 8 (Ecotone Plot)	1025.012	0.253
Subtotal Ecotone Plot Area	**3157.238**	**0.779**
Plot 9 (Island Plot)	1463.113	0.361
Plot 10 (Island Plot)	1253.490	0.310
Plots 12-14 (Upland Plots)	1521.454	0.375
Subtotal Upland Plot Area	**1438.057**	**1.046**
Plot 1a (PHAQ Treatment Plot)	297.303	0.073
Plot 1b (PHAQ Treatment Plot)	161.232	0.040
Plot 2 (PHAQ Treatment Plot)	161.269	0.040
Plot 3 (PHAQ Treatment Plot)	22.463	0.006
Plot 4a (PHAQ Treatment Plot)	208.004	0.051
Plot 4b (PHAQ Treatment Plot)	264.643	0.065
Plot Connie(PHAQ Treatment Plot)	231.907	0.057
Plot Claire(PHAQ Treatment Plot)	309.746	0.077
Subtotal PHAQ Treatment Plot	**1656.567**	**0.409**
TOTAL AREA (Study Plots)	**9051.862**	**2.234**

Figure 2.1a: Ecotone and Upland/Island Plots (2006)


Marsh Plots 2006
Richmond Field Station, UCB
layout by Christina Crooker, 6/4/2007
plot 1
plot 2
plot 3
plot 4
plot 5
plot 6
plot 7
plot 8
plot 9
plot 10
2006_marsh_plots.shp
Marsh plots
Island plots
study area
N
0
100
200 Meters

2.2 Import of Fill Material and Plot Preparation

The origin of the fill material varied between plots. Below the groundwater table, granular (sand) fill material was imported from the Presidio or San Francisco; a San Francisco Pacific Gas and Electric source; and/or a private San Francisco source (URS 2003b, URS 2004).

Fill material above the groundwater table included the following:

- Fill for Plots 4-6 (Phase 1, 2002) was imported from the Port of Oakland, a site adjacent to Golden Gate Park and the Jean Hargrove Music Library on the UC Berkeley campus;

- Fill for Plots 1-3 (Phase 2, 2003) included clean overburden material previously located on the site and imported material from the Stanley Hall construction site on the UC Berkeley campus; and

- Plots 8-10 were created around 1959 with fill brought in during the construction of the rail spur that is now the East Bay Regional Park District's Bay Trail.

- The area directly north of Plot 3 was used as a staging area for Bay mud fill from Martinez.

- Plots 12-14 (revegetation initiated in 2006) - following the removal of the weed fabric the soil was tilled and amended due to the high level of compaction, poor microbial content, and high clay content. The fill material was similar to that found in plots 1-3, where survivorship of plantings had been poor in areas where the soil had been compacted. Prior to tilling, the area was watered and sterile rice straw was distributed approx. 6 inches deep across the entire area (in a checkerboard pattern. - segments of straw approximately 2-feet wide and 2-feet long). During tilling, it became apparent that the straw application needed to be reduced for effective mixing. As a result, less straw was placed in the western half of the plots. With less mulch to suppress weeds, this area was more susceptible to weed colonization. Future tilling should include the application of a 3-4 inch mulch layer following tilling and prior to planting.

  A tractor with a roto-tiller attachment was used to break up the soil and mix in the straw. The ground surface was extremely difficult to penetrate, requiring approximately 10 passes up and down one small strip of soil to till the soil under 2-4 inches. Larger equipment should be used in the future to ensure that the rice straw penetration is at least 8-10 inches.

2.3 Test Treatments in Grassland Plots

Grassland plots were established (see Table 2.1) in order to test efficacy of various Harding grass control methods. The treatments for each plot were as follows:

- Plot 1a: Hand Removal and Mulch (with 3-6 inches of sterile rice straw)

- Plot 1b: Herbicide Treatment (1.5 % glyphosate)

- Plot 2: Herbicide Treatment (1.5% glyphosate) and Mulch (with 3-6 inches of sterile rice straw)

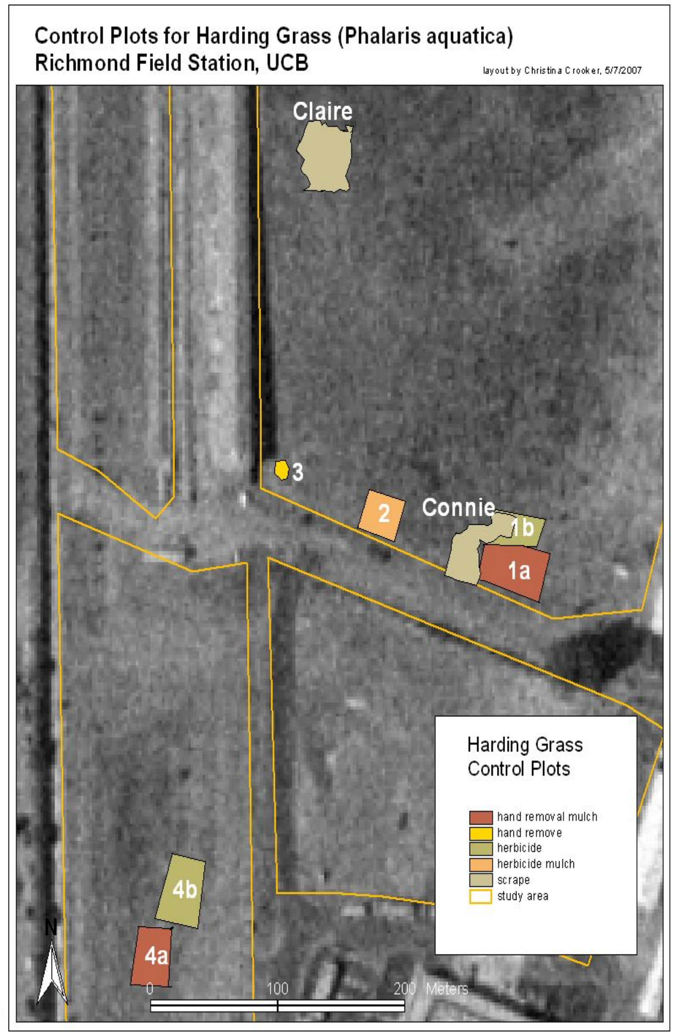
- Plot 3: Hand Removal

- Plot 4a: Hand Removal and Mulch (with 3-6 inches of sterile rice straw)

- Plot 4b: Herbicide Treatment (1.5 % glyphosate)

Figure 2.3a: Four–acre Restoration Project Location

Figure 2.3b: Grassland Treatment Plots



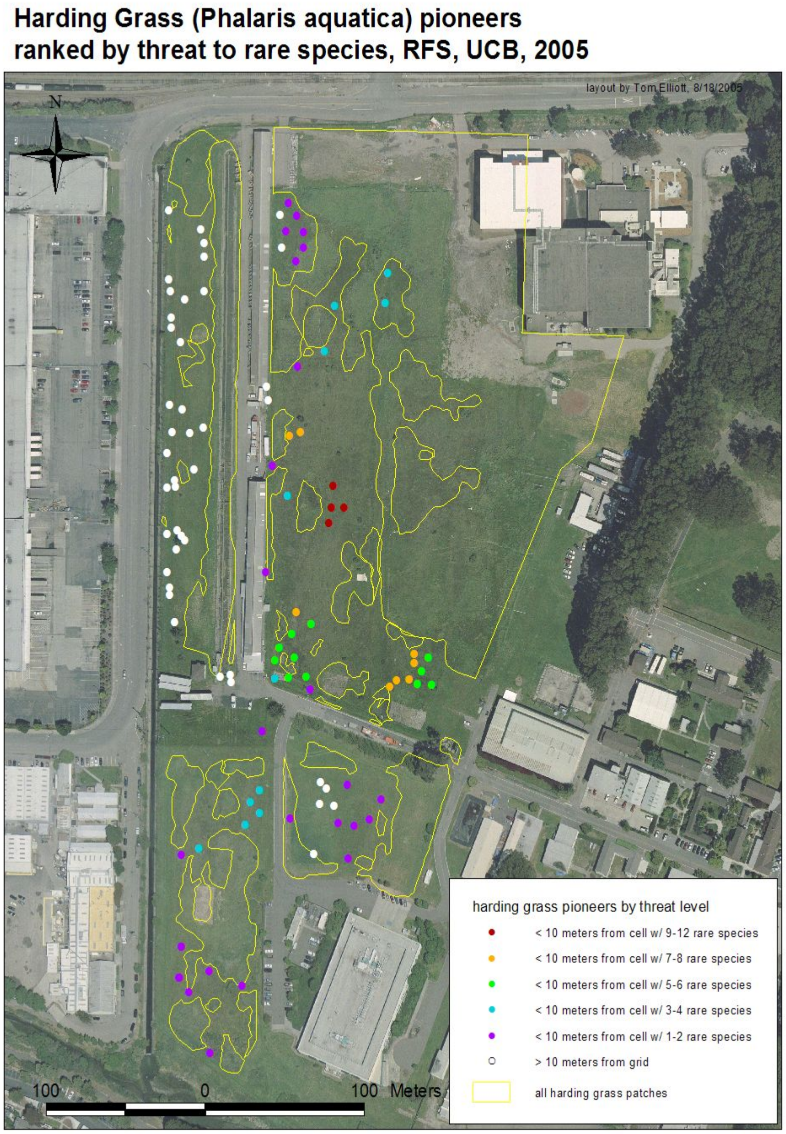


Figure 2.3c – Pioneer Patches of Harding Grass ranked By Threat to Rare Species. [Note this figure, and several others were used to help prioritize control activities in 4-acre plot].

3.0 Revegetation Strategies

Active revegetation is a critical component of the restoration of Western Stege Marsh, its associated upland, and coastal terrace prairie restoration projects. Plant palettes for both marsh and coastal terrace prairie habitat types were carefully selected after consulting historic species palette, local wetland restoration projects, early botanical records, and some herbarium records. Additionally, the Watershed Project staff met with Jepson Herbarium staff and other local restoration experts to evaluate both planting palettes and propagule collection sources. With this information, the Watershed Project provided BBL Inc. with draft revegetation strategies for the low marsh, ecotone, upland and grassland habitats. The following sections provide a detailed summary of the revegetation strategies and outcomes.

3.1 Marsh and Upland Revegetation

The marsh revegetation strategy focused on establishing greater biological diversity and healthy stands of Pacific cordgrass within the marsh. Dominant aggressive species, including both annual and perennial pickleweed (*Salicornia europea and S. virginica* respectively) and some prolific native species, like dodder (*Cuscata salina var. major*), salt grass (*Distichlis spicata*) and spearscale (*Atriplex triangularis*) were eliminated from the revegetation plan in anticipation of natural colonization. By eliminating or limiting the presence of these species in the revegetation plan, and implementing the approved vegetation monitoring program to assess for their establishment, the focus was on establishing and expanding populations of the less common species selected for revegetation.

Critical to this strategy was the understanding that if vegetation monitoring data indicated that the desired species (as identified within the requirements of the USFWS Biological Opinion and other regulatory documents) were not colonizing at rates equal to, or above the established performance measures, the revegetation strategy will be adaptively managed to meet the performance criteria.

3.2.1 Targeted Species for Revegetation

3.2.1.1 Marsh and Ecotone Plantings. Based on the revegetation strategy cited above, only sparse plantings limited to locally rare plant species, and clustered planting of Pacific cordgrass were proposed for the low and mid marsh habitat, with the goal of achieving the restoration performance measures and increasing vegetation richness.

The distribution and planting plan for these marsh species was dictated by each species' tolerance to salt, tolerance of tidal inundation, and ability to compete. Each of the marsh species proposed for revegetation was evaluated to determine the optimal tidal zone for planting with the goal of mimicking natural vegetative tidal distribution. This was carefully considered during project planning phase in 2003-2004 so as to maximize planting survivorship.

Table 3.2.1.1a identifies all of the low, middle and high marsh species originally selected for revegetation. The table also includes the optimal tidal zone, anticipated area for each tidal zone and proposed number of plants.

Following remediation, the marsh and ecotone were divided into plots for the purpose of restoration planning, tracking survivorship and weed management. These plots are illustrated earlier in Figure 2.1a. The marsh was not mapped as separate plots, but for ease in planning the marsh areas below each upland plot were referenced by the same plot number. The marsh revegetation goals identified in Table 3.2.1.1a were adjusted to each specific plot and are illustrated in Table 3.2.1.1b. Table 3.2.1.1b was used to establish propagule collection and planting goals.

The following guidelines were followed when installing plantings:

- Plants were to be installed at a density that would both successfully promote the establishment of a diverse seed bank (without inhibiting native vegetation recruitment), and limit available habitat for early colonizing invasive non-native plant species. An average 3-foot on center planting distance was used as a guide for marsh plant installation.

- Plantings were to mimic the natural elevational range and optimal growth habitat for each species. Plant installations occurred between 2.5 and 6 ft. NGVD29 elevation.

Propagation ratios for each species were developed to mimic natural species assemblages to the greatest degree feasible. Species assemblage data was based on field observations, reference books, and past project and expert recommendations. Reproductive strategies were also considered when developing the propagation goals. For example, many salt marsh species expand primarily through clonal growth. Seeds dispersed by these species typically have very low germination rates. In anticipation of low seed recruitment, several clonal species were propagated in larger quantities in order to promote their establishment throughout the site.

Lastly, it was determined that less common species would be propagated at slightly inflated ratios in anticipation of potential for increased competition and mortality rates.

Table 3.2.11c compares the total number of plants propagated by species to the original propagation goals. As illustrated, there were fewer plants propagated than originally proposed. This was due to the rapid establishment of annual pickleweed, perennial pickleweed, and salt grass; the high survivorship of the plantings; and the rapid growth of many plantings (for example salty Susan *(Jaumea carnosa)* plantings exhibited greater than 1-foot of new growth during the first planting season, and many plantings are now greater than 3-feet in width. Field experiments also revealed that marsh gum plant *(Grindelia stricta augutifolia)* and Western marsh rosemary *(Limonium californicum)* also readily established by seed, therefore reducing the need for propagation and planting. Appendix 1 summarizes all of the species propagated for the Western Stege Marsh and RFS grassland projects.

Table 3.2.1.1a Original Marsh Species Proposed For Revegetation At Western Stege Marsh

Species Proposed for Revegetation (Scientific Name)	Species Proposed for Revegetation (Common Name)	Marsh Zone	NGVD Elevation	Area Range in Restored Marsh (sq.ft.)	% Relative Cover for Proposed Revegetation	Preliminary #s of plants proposed for planting on 3 ft. centers (2005)
Castilleja ambigua	Johnny-nip	High Marsh	5-6ft	20,800	5	116 (seeding)
Distichlis spicata	Salt grass	Middle Marsh	3-4ft	19,600	10	218
Frankenia salina	Alkali-heath	High Marsh	3-4ft	19,600	15	327
Grindelia stricta augutifolia	Marsh gum plant	High Marsh	5-6ft	20,800	20	462
Heliotropium currassavicum	Marsh heliotrope	High Marsh	5-6ft	20,800	10	231
Jaumea carnosa	Salty susan	Middle Marsh	3-4ft	19,600	15	327
Lasthenia glabrata	Marsh goldfields	High Marsh	5-6ft	20,800	5	116
Limonium californicum	Western marsh	High Marsh	5-6ft	20,800	10	231
Spartina foliosa	Pacific cordgrass	Low Marsh	2.5-3	37,100	100	4122
Spergularia macrotheca	Perennial sand spurrey	High Marsh	5-6ft	20,800	10	231
Spergularia marina	Sand spurrey	High Marsh	5-6ft	20,800	5	116
Triglochin concinna	Arrow grass	Middle Marsh	3-4ft	19,600	5	109
Triglochin maritima	Giant arrow grass	Middle Marsh	3-4ft	19,600	10	218
TOTAL PLANTS						**6822**

Note: It was anticipated that the dominant species of the middle to high marsh will be *Salicornia virginica* which will establish on its own, and the numbers of plants targeted for revegetation were developed based upon this.

Area of tidal habitat by contour:

2.5 – 3 Contour (37,100 Sq. Feet)

3 - 4 Contour (19,600 Sq. Feet)

4 - 5 Contour (19,000 Sq. Feet)

5 - 6 Contour (20,800 Sq. Feet)

TABLE 3.2.1.1b. Adjusted Marsh Planting Goals Based Upon Delineation of Restoration Plots (est. 2005)

Marsh Species	Number of Marsh Plants Planned Per Restoration Plot						Total
	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	
Grindelia stricta augustifolia	110	268	66	37	49	46	576
Frankenia salina	100	231	76	54	104	69	633
Triglochin concinna	5	12	4	3	5	3	32
Triglochin marina	95	221	72	51	99	65	604
Limonium californicum	86	198	65	46	89	59	543
Heliotropium currassavicum	78	180	59	42	81	53	492
Distichlis spicata	7	17	5	5	10	5	49
Jaumea carnosa	92	203	64	58	119	64	600
TOTAL PLANTS	**572**	**1329**	**410**	**296**	**556**	**365**	**3529**

Table 3.2.1.1c. Comparison of Original Propagation Goals and Actual Propagation Numbers

Marsh Species	Original Propagation Goals as Developed in 2005	Actual Numbers of Plants Propagated
Grindelia stricta augustifolia	576	428
Frankenia salina	633	537
Triglochin concinna	32	32
Triglochin marina	604	578
Limonium californicum	543	512
Heliotropium currassavicum	492	276
Distichlis spicata	49	53
Jaumea carnosa	600	512
Total Plants	**3529**	**2928**

3.2.1.2 Pacific Cordgrass Plantings. Pacific cordgrass was the first species to be planted in the marsh immediately following regrading with clean imported bay mud fill in 2003. The source of the cordgrass was the remediation area designated M3. Plants were removed prior to excavation of the underlying sediments. Sediment was washed from the roots and the plants were kept in salt water-filled tubs until the backfill had been graded to the desired elevation. The initial survivorship was low, probably due to the extended time the plants spent in tubs. Cordgrass was eliminated from the planting palette in 2004 in anticipation of natural colonization, as it is known to successfully establish in Bay Area wetlands without active planting However, following conversation with the Invasive Spartina Project (ISP) (Tetratech 2007) regarding non-native cordgrass infestations and hybridization issues, it was determined that Pacific cordgrass should be planted at the site. Divisions were taken from approved sites where no known invasive or hybrid cordgrass infestations are located. This decision was based upon the following:

Photo 3.2.1 Spartina planting Dec. 2003

- Pacific cordgrass readily hybridizes with non-native cordgrass, resulting in hybrid cordgrass plants that compete with, and are difficult to distinguish from native Pacific cordgrass (and therefore difficult to control).

- The hybrid plants can produce seeds that readily colonize newly restored area; and

- The hybrid plants can produce 3-10 times the pollen load of the native Pacific cordgrass, potentially "swamping" native cordgrass plants with hybrid pollen, increasing the possibility that the native Pacific cordgrass will produce mostly hybrid seeds.

In 2005 the Watershed Project staff, in coordination with UC Berkeley established a planting goal of 4,000 divisions, with an anticipated survivorship of 80% (Ward, pers. comm.. 2004). Western Stege Marsh was initially identified as an ideal collection site. However due to concerns over possible recontamination within the marsh (i.e., Pacific cordgrass growing in un-remediated areas of the marsh could have soil contaminants attached to roots, and washing each division would be prohibitively time consuming), the Watershed Project worked directly with the ISP to identify alternative collection locations. Requirements for selecting an alternative site included:

- Absence of S. alterniflora and any hybrids
- Absence of California Clapper Rail
- Approval from property owner
- Safe access

The marsh directly adjacent to Goodman's Lumber (775 Redwood Highway, Mill Valley, Marin County) was selected as the collection site. Table 3.2.1.2 lists the number of divisions collected and the specific collection locations. See Section 4.1.3 for further discussion.

Table 3.2.1.2. Pacific Cordgrass Collection Sites for Revegetation

Date of Division Collection	Location of Division Collection	Number of Divisions	Planting Date
December 2003	Western Stege Marsh	2000	January, 2004
December 2005	Marsh south of Goodman's Lumber	1,200	December 2005
January 2006	Marsh south of Goodman's Lumber	2,375	January 2006
Total Number of Divisions Planted		**5,575**	

3.2.1.3 Marsh Upland. The species selected for the ecotone and upland areas of the marsh were chosen by referencing the native species observed on the RFS with species observed in adjacent upland and ecotone areas as well as other local native grasslands and upland scrub plant communities. Information from reference sites was used to develop a general list of upland native species to guide propagule collection (seed and cuttings). The upland and ecotone areas were divided into 3 planting regions for the purpose of developing planting palettes. These regions were:

- Upland Habitat (Plots 9,10)
- Fill Material North of Bay Trail (Plots 7 and 8)
- North Ecotone and Upland (Plots 1-6 & 12-14)

Table 3.2.1.3a, 3.2.1.3b, and 3.2.1.3c identify the proposed species for revegetation within each of those regions respectively. It is important to note, that the proposed propagation goals were adjusted slightly based upon limited propagule availability, propagation success, survivorship and natural recruitment within the restoration site. Appendix 1 includes the final number of each species propagated and planted over the 3-year restoration period.

Mostly scrub species and sub-shrubs and grasses were selected for upland and ecotone areas. Trees larger than toyon (*Heteromeles arbutifolia*), such as California wax myrtle *(Myrica californica*) and coast live oak (*Quercus agrifolia*) were excluded from the planting plan so as not to introduce possible perching habitat for species that could prey on California Clapper Rails. The few toyons were planted above the marsh along the northern edge of the upland habitat.

The planting design sought to establish patches of grassland and scrub habitat connected to the marsh ecotone. A clustered planting pattern of 3 to 7 individuals was used to mimic natural habitat patchiness observed at reference sites. Some individual species were randomly distributed within the planting areas.

Planting densities were developed to generally mimic the density and dominance patterns observed in the reference native plant communities. Densities of target plant species were modified to fit field conditions (e.g. soil types present in the planting area), field observations of conditions at nearby plant assemblages, and past project experience with installation of similar species. In general, shrub and sub-shrub species were planted on 4-foot centers, while grasses and forbs were planted on 2-foot centers.

Table 3.2.1.3a Upland Island Species Proposed for Revegetation -Plots 9 & 10

Scientific Name	Common Name	Estimated Planting Density as % of total # planted	Preliminary #s proposed for planting on 4 ft. centers
Achillea millefolium	Yarrow	5	54
Anaphalis margaritacea	Pearly Everlasting	3	33
Artemisia californica	California sagebrush	10	109
Aster chilensis	California Aster	7	76
Baccharis pilularis	Coyote bush	15	163
Bromus carinatus ssp. maritimus	California Brome, Seaside Brome	3	33
Ceanothus thyrsiflorus	Coast Blue Blossom, Calif. Lilac	3	33
Elymus glaucus ssp. glaucus	Blue wild rye, Western Wild Rye	3	33
Eriogonum latifolium	Coast buckwheat	5	54
Eriophyllum staechadifolium	Lizard-tail, Seaside wooly sunflower	10	109
Eschscholzia californica	California poppy	Seed	
Festuca rubra	Red fescue	5	54
Fragaria chiloensis	Beach or Dune Strawberry	3	33
Grindelia stricta	Gumweed	2	22
Hordeum brachyantherum	Meadow barley	5	54
Leymus triticoides	Valley Wild-rye	3	33
Lotus scoparius	Deer Weed, California Broom	7	76
Lupinus arboreus	Yellow Bush Lupine, Tree Lupine	Seed	
Mimulus aurantiacus	Sticky or Bush Monkey Flower	3	33
Nassella pulchra	Purple Needlegrass	5	54
Solidago californica	California Goldenrod	3	33
TOTAL		**100**	**1035**

Table 3.2.1.3b Upland Scrub Species Proposed for Revegetation of Slope Below Bay Trail, plots 7 & 8.

Scientific Name	Common Name	Estimated Planting Density as % of total # planted	Preliminary #s of plants proposed for planting on 4 ft. centers
Aster chilensis	California Aster	8	54
Baccharis pilularis	Coyote brush	25	163
Nassella pulchra	Purple Needlegrass	8	54
Eriogonum latifolium	Coast buckwheat	8	54
Eriophyllum staechadifolium	Lizard-tail, Seaside wooly sunflower	25	163
Grindelia stricta	Gumweed	3	22
Lotus scoparius	Deer Weed, California Broom	11	76
Lupinus arboreus	Yellow Bush Lupine, Tree Lupine	seed	
Mimulus aurantiacus	Sticky or Bush Monkey Flower	8	54
Solidago californica	California Goldenrod	3	22
TOTAL		**99**	**662**

Table 3.2.1.3c Species Proposed for Revegetation of the Northern Ecotone and Upland Area, plots 1-6 & 12-14.

Scientific Name	Common Name	Estimated Planting Density as % of total # planted	Preliminary #s of plants proposed for planting on 4 ft. centers
Aster chilensis	California Aster	7	170
Baccharis pilularis	Coyote brush	14	340
Bromus carinatus ssp. maritimus	California Brome, Seaside Brome	1	34
Elymus glaucus ssp. glaucus	Blue wild rye, Western Wild Rye	4	102
Eriogonum latifolium	Coast buckwheat	7	170
Eriophyllum staechadifolium	Lizard-tail, Seaside wooly sunflower	9	238
Eschscholzia californica	California poppy	seed	
Festuca rubra	Red fescue	4	102
Fragaria chiloensis	Beach or Dune Strawberry	4	102
Gnaphalium ramosissimum	fragrant cudweed	seed	
Grindelia stricta	Gumweed	1	34
Hordeum brachyantherum	Meadow barley	4	102
Leymus triticoides	Valley Wild-rye	3	68
Lotus scoparius	Deer Weed, California Broom	7	170
Lupinus arboreus	Yellow Bush Lupine, Tree Lupine	seed	
Marah fabaceus	Man-root, Wild Cucumber	seed	
Mimulus aurantiacus	Sticky or Bush Monkey Flower	7	170
Nassella pulchra	Purple needlegrass	4	102
Phacelia californica	California coast phacelia	3	68
Phacelia distance	wild heliotrope	seed	
Rhamnus californica	California coffeeberry	8	204
Satureja douglasii	Yerba Buena	4	102
Scrophularia californica	California Figwort	7	170
Solidago californica	California Goldenrod	3	68
TOTAL		**100**	**2516**

3.2.2 Propagule Collection

Neither the Western Stege Marsh nor the coastal terrace prairie restoration sites supported all of the species proposed for revegetation. Therefore additional collection sites were selected based upon the following criteria:

- Sites were on public land and had ecologically similar habitats to the restoration site (e.g., similar soils, wave exposure, disturbance patterns, nutrient inputs, etc.);
- Collection sites were within the local watershed, or were located within a natural dispersal distance;
- Sites were in proximity to the restoration site.

After evaluating all of the potential collection locations, five sites were selected within a 10-mile radius of the Western Stege Marsh restoration project. These sites included:

- Bay Trail;
- El Cerrito Natural Area;
- Miller Knox Regional Shoreline;
- Point Molate; and
- Point Pinole.

Collection permits were received from East Bay Regional Parks and other landowners prior to collecting plant material. Table 3.2.2 identifies the propagation collection sites that were selected for each species that had limited propagule availability on the RFS. Propagule collection was performed by the Watershed Project staff and contractors with support from UC Berkeley and community volunteers. Marsh species propagule collection began during summer 2003, and continued through fall 2006. No more than 10% of the propagules were taken from any one population or individual plant during the fruiting season[3]. Seeds were collected from each species throughout its ripening season in order to include a diverse range of flowering times in the collection pool. For some species such as creeping wildrye (*Leymus triticoides*), divisions were extracted using flat-bladed shovels. Seeds were collected by hand, dried, then stored in paper envelopes or grocery bags.

[3] A higher percentage of plant material was harvested in areas that were to be disturbed or remediated, and for sites where the future disturbance would result in the loss of the vegetation.

Table 3.2.2 Propagule Collection Sites for RFS Restoration Projects

Species	Common Name	Collection Sites
Achillea millefolium	Yarrow	ECNA, M/K
Artemisia californica	Sagebrush	BT
Artemisia douglasiana	Mugwort	BT
Aster chilensis	California aster	RFSG
Baccharis pilularis	Coyote bush	BT
Brodiaea elegans	Harvest brodiaea	RFSG
Bromus carinatus	California brome	RFSG
Calandrinia ciliata	Red maids	RFSG
Calystegia occidentalis ssp. occidentalis	Morning glory	RFSG
Calystegia subacaulis ssp. subacaulis	Morning glory	RFSG
Camissonia ovata	Sun cups	RFSG
Cardamine californica	Milk maids	RFSG
Carex densa	Carex	RFSG
Carex subbractiata	Carex	RFSG
Castilleja ambigua	Johnny-nip	PP,
Castilleja exserta ssp. exserta	Purple owl's clover	RFSG
Centuculus mininus	Chaffweed	RFSG
Chlorogalum pomeridianum	Soap plant	RFSG
Cicendia quadrangularis		RFSG
Danthonia californica var. californica	California oatgrass	RFSG
Eleocharis macrostachya	Spikerush	RFSG
Elymus multisetus	Big squirreltail	RFSG
Elymus trachycaulus ssp. trachycaulus	Slender wheatgrass	RFSG
Eriogonum latifolium	Coast buckwheat	BT
Eriphyllum staechadifolium	Lizard tail	BT
Eryngium armatum	Coyote thistle	RFSG
Festuca rubra	Red fescue	PM
Grindelia hirsutula var. hirsutula	Hairy gumplant	RFSG
Grindelia stricta var. augustifolia	Marsh gumplant	BT
Heliotropium curassavicum	Heliotrope	PP, BT
Hordeum brachyantherum	Meadow barley	RFSG
Jaumea carnosa	Salty susan	PP
Juncus bufonius var. bufonius	Toad rush	RFSG
Juncus bufonius var. congestus		RFSG
Juncus occidentalis var. occidentalis		RFSG
Juncus patens		RFSG
Juncus phaeocephalus var. paniculatus		RFSG
Koeleria macrantha	Junegrass	PM
Leymus triticoides		PP, PM
Limonium californicum	Sea lavender	RFSM, PP
Lotus purshianus		RFSG
Lupinus arboreus	Yellow bush lupine	RFSM
Lupinus nanus	Sky lupine	RFSG
Madia sativa	Tarweed	RFSG

Melica californica	California melic	PM
Mimulus aurantiacus	Sticky monkey-flower	BT
Nassella pulchra	Purple needlegrass	RFSG
Plantago erecta	California plantain	RFSG
Ranunculus californicus	California buttercup	RFSG
Ribes sanguineum	Red-flowering currant	ECNA
Rumex salicifolius var. salicifolius		RFSG
Scrophularia californica	Bee plant	BT
Sisyrinchium bellum	Blue-eyed grass	RFSG
Spiranthes romanzoffiana		RFSG
Stachys ajugoides var. ajugoides	Hedgenettle	RFSG
Trifolium willdenovii	Tomcat clover	RFSG
Trifolium wormskioldii		RFSG
Triglochin concinna	Arrowgrass	PP, RFSM
Triteleia hyacinthina	White brodiaea	RFSG
Triteleia laxa	Ithuriel's spear	RFSG
Viola adunca	Western blue violet	RFSG
Wyethia angustifolia	Mule's ears	RFSG

Legend	
Bay Trail	BT
Richmond Field Station Grassland	RFSG
Richmond Field Station Marsh	RFSM
Miller Knox Regional Park	M/K
PM	Point Molate
PP	Point Pinole
ECNA	El Cerrito Natural Area

3.2.3 Revegetation Techniques and Timing

Revegetation was phased over a 3-year period. As described earlier, phase 1 of the Pacific cordgrass division plantings was initiated in 2003. The remainder of the planting within the larger marsh, upland and coastal terrace prairie was phased over three years from 2004 to 2007, with the largest number of plantings occurring in late 2005 and early 2006. Planting typically began in late November and continued through mid March (for marsh species). The November through March timeframe was selected as the optimal time to install plants because winter rainfalls helped establish upland plantings as well as reduce bay salinity levels from the marsh and ecotone soil. Although halophytic (salt-loving) vegetation native to marshes are adapted to living in saltwater conditions, high salt concentrations can be harmful, especially to young, newly-established plants. Planting when salinity levels were at their lowest provided the young plants with an opportunity to gradually acclimatize to the bay's increasing salt conditions.

The 2005-6 plantings in the tidal marsh areas were done in two distinct batches, the first half in early January, and the second in mid March. The purpose of planting in two phases was to help ensure that plants were installed at the optimum elevation to help maximize survival. Elevational lines were marked with pin flags around the marsh at different recorded high tides. These tidal elevations were then compared to elevations of naturally established populations of target native marsh plants within the restoration site. Using these observations, planting zones for each species were determined. This method was chosen over using the elevational survey markers established by BBL, as the markers did not appear to accurately correlate to the observed tidal elevations or anticipated planting zones. Table 3.2.3 presents the tide elevations used for identifying marsh planting locations:

Table 3.2.3. Optimal Planting Elevations presented by Species

Species	Target Tidal Elevation (based upon observed tides)
Distichlis spicata	5.7- 5.9
Frankenia salina	5.9 -6.8'
Grindelia stricta	just above 6.8' tide line
Heliotrope curassavicum	just above the 5.9'
Jaumea carnosa	5.9 -6.8'
Limonium californicum	just below 6.8'
Triglochin maritima	5.9 -6.8'

In addition to the planted tidal marsh plants, natural recruitment was observed for a number of species during the first 2 years. Pickleweed established naturally throughout much of the marsh and sand-spurry (*Spergularia marina*) also established naturally, and is now ubiquitous throughout most the marsh. In 2006 a single plant of alkali heath also established naturally, and preliminary 2007 monitoring data indicates that more seedlings are present.

Marsh gum plant established both from planting nursery stock and through direct seeding. Other species that were direct seeded included: Western marsh rosemary, which established very successfully from direct seeding in 2005, and Johny nip, which had limited establishment following direct seeding in 2004 and 2005.

The following guidelines were used for planting the Pacific cordgrass divisions:

- Each division had 5-6 stems
- Divisions were planted within 48 hours of collection[4];
- Some soil remained on the stems during storage;
- Divisions were planted in clusters of 6-7 divisions on 1-foot centers; and
- Divisions were planted along elevational contours based upon optimal establishment[5].

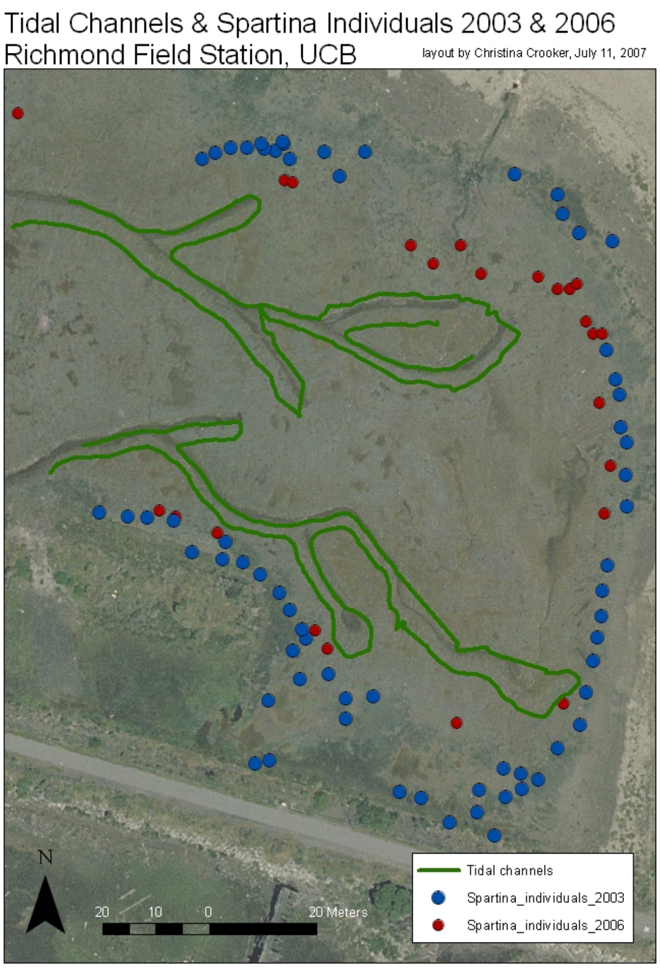
For upland species, plantings were installed by staff and trained volunteers. Plants were typically placed in planting plots prior to volunteer workdays to ensure that species were located in the correct areas. Volunteers used hand picks, trowels and shovels to dig planting holes. Planting holes were tailored to the pot size of the transplant and were approximately 2-3 inches deeper and wider than the pot. Slow release fertilizer tablets were placed in the planting holes to aid establishment. The same methods were used for plots 12-14 with the addition of placing a small amount (several tablespoons) of soil from the coastal terrace prairie into each hole. The soil was dug up from underneath native grasses (mostly California oat grass (*Danthonia californica*), with the goal of inoculating soil with native species of mycorrhizae.

[4] Storage of 48 hours or less was undertaken in 2006, however the divisions collected in 2003-4 were stored in 5-gallon buckets for up to 3 weeks following excavation as the marsh footprint was not ready for planting until January 2004. It is likely that this deviation from the planting guidelines resulted a higher than anticipated mortality rate for these plantings.

[5] Prior to planting the 2006 divisions, the survivorship of the 2003 divisions was noted and 2006 plantings occurred along the contour (plus or minus 1-foot) of the surviving 2003 plantings.

Photo 3.2.3 Volunteers planting marsh upland Dec. 2006

Figure 3.2.3 illustrates the distribution of Spartina in spring 2007 from the 2003-4 and 2005-6 planting activities. **FIGURE 3.2.3.**



3.2.4 Survivorship Monitoring

Following planting, survivorship monitoring was performed to determine whether or not revegetation strategies or other management actions needed to be changed. Following each planting season a random selection of plants were either tagged with pin flags or mapped for future monitoring. These plantings constituted approximately 10 percent of the original plantings. Four to six months following planting, staff monitored the survivorship and general health of the flagged sub-sample. Tables 3.2.4a and 3.2.4b are examples of data gathered for the marsh plantings in 2006 and the upland plantings in 2007.

A number of trends were observed in 2004-5. Marsh species survivorship was very high, with some species including marsh gumplant, salty Susan and alkali heath having 100% survivorship. Marsh heliotrope had varied survivorship depending upon the location of the plantings. Plants installed in lower depressions and tidal pools yielded a higher level of survivorship. Conversely, those planted in 2007 in low areas did not survive. Arrowgrass plantings were initially heavily impacted by herbivory: more than 75 percent were eaten almost to the ground- possibly by the Canada geese. However, monitoring in 2006 indicated that plants had survived and had established within the marsh, flowering in 2006.

Several marsh restoration project managers from around the Bay Area were consulted regarding the most effective way to harden off seedlings prior to planting within the marsh and ecotone habitats. Some indicated that marsh plantings should be pre-treated with salt water in the nursery environment (Ward, pers. comm., 2005). Their experience indicated that if tidal marsh seedlings were not pre-treated with salt water in the nursery they would likely be subjected to osmotic shock following planting. The Watershed Project staff initiated a salt watering test, with very low salt concentrations, on a small subset of the plants in the nursery setting (i.e. a treatment that was well below the salt concentration level found in marsh waters). Preliminary results indicated plants watered with salt water exhibited a noticeable loss of vigor; and a high percentage of these plants died.

The proponents of salt watering stated while initial loss of vigor in the nursery setting may occur, salt water treatment can increase plant survivorship once the treated plants are planted into a marsh, therefore the net effect of the treatment is positive, even if some die back or mortality occurs in the nursery.

With this in mind, the Watershed Project treated half of the tidal marsh plant nursery stock with salt solutions, and half without salt solutions, in order to compare the outcomes of plants watered with and without salt water. Plants were treated with salt water at a concentration of 3 ppm, a level well below that of the Bay (the salinity level of San Francisco Bay in the winter is approximately 25 ppm). The initial plan was to increase the level of salinity every two weeks by 5 ppm until the salinity level reached 25 ppm. However, the treated plants showed evident signs of distress and mortality at 3 ppm, so salinity concentrations were not increased any further.

Initial results from the 2005-6 salt watering experiment indicate that salt watering done in the nursery to harden off marsh plants may not be necessary and in fact may do more harm than good. Salt marsh plants watered with even low concentrations of salt had high rates of dieback in the nursery (i.e., approximately 33% or greater). Of those plants that survived the salt water treatment, survivorship rates indicated no advantage over salt marsh plants that had never been hardened off with salt water at all. Only one species that received the salt water treatment, salty Susan, appeared to be slightly more vigorous months after planting, although overall survivorship rates did not change between salt water treated and untreated plants.

In upland habitat Plots 1-3, survivorship was patchy and spatial in nature (i.e. die off was not species-specific but rather was restricted to certain areas within the plots). The lowest survivorship was observed in Plot 3. Sticky monkey and coffeeberry had the highest mortality rates. It was originally thought that a combination of high salinity concentrations from the bay mud storage and poor nutrient capacity resulted in the observed mortality of these two species. However, when UC Berkeley and Watershed Project staff tested salinity levels, salinity concentrations were not high (Note: testing occurred following a number of large rain events and may have affected salinity readings). In 2005-6, dead plant material was replaced and monitored in Plot 3. High mortality was again observed and a more thorough soil analysis was conducted by Tetratech. The findings indicated that the soil contained average nutrients. It is assumed that the high die off in this plot was due to poor soil structure and lack of organic matter. (Note: Because marsh soils tend to become a "hardpan" when dry, it was postulated that it may be prohibitively difficult for plant root establishment. As a result, areas that form a hardpan layer at the surface do not support much vegetation, and plants that do survive seem stunted initially).

Photo 3.2.4

An alternative soil treatment was employed in Plots 12-14 in 2006-7, with the goal of increasing survivorship for future plantings in the upland area. Staff members researched several alternative methods for improving this hardpan soil before planting. The selected method involved roto-tilling rice straw into the soil, with an additional application of rice straw on the surface to act as a weed barrier. Additionally, fertilizer and/or soil inoculated with mychorrhizae were added to each planting hole. AgSafe 12-8-8 or 20-10-5 tablets that release nutrients on a time-released basis were used as fertilizer (as opposed to broadcast distribution of fertilizer across the entire site) within each planting hole. Fertilizing the entire area was presumed likely be counter productive as it would encourage more annual, non-native plants that favor high levels of nutrients. The efficacy of placing native soil in each planting hole may be difficult to determine, but should be further evaluated as time permits.

This change in treatment approach yielded a higher survivorship for upland plantings, however sticky monkey flower still had high mortality, perhaps as a function of slow water percolation due to the high clay content in the soils. Overall, the survivorship in the upland habitat went from less than 50 percent recorded in 2004-5 to approximately 80 percent in 2007. Of the 80 percent that survived, approximately 40 percent exhibited healthy new growth, the remaining appeared stressed and will be monitored again in 2008.

Mortality was also high in Plot 6 due to dense infestations of brass buttons *(Cotula coronopifolia),* and kikuyu grass *(Pennesetum clandestinum)* and poor soil conditions. Hand and mechanical weeding was inefficient in controlling these species and UC Berkeley and East Bay Regional Parks District authorized herbicide treatment as a control mechanism. The entire plot was treated with Aquamaster in February 2006, killing the majority of the weed infestation. Herbicide spot treatments followed, and the area was replanted and yielded higher survivorship by 2007.

Initial results from the 2007 vegetation monitoring indicate that marsh, island, and ecotonal/upland plantings continue to thrive, with pickleweed, Pacific cordgrass, saltgrass, and salty Susan the most common dominant species of the low marsh. Shrub and tree species on the islands continue to increase in height and canopy cover, as evidenced by new growth and reproduction (i.e. presence of flowers, fruit).

Upland habitat areas had the highest plant diversity, and most interesting patterns of plant survivorship and die-off. Plants with little or no die off by 2007 from original planted material include: California sage, mugwort, coast buckwheat, marsh gumplant, rushes, creeping wildrye, and lupines *(Lupinus* spp.). Plants with complete, or very high mortality rates include California brome, Coyote thistle, and cow parsnip *(Heracleum lanatum).* Refer to Table 3.2.4b for more information on 2007 vegetation monitoring results.

A comprehensive assessment of pickleweed and Pacific cordgrass establishment was conducted in October 2007, intended to assess the progress of the site restoration towards stated acreage and density goals for these species established in the Biological Opinion. While the results are still preliminary, it appears that pickleweed has met and exceeded the stated acreage and density goals, with approximately 2.23 acres of pickle weed established at the marsh, at an average density of 80 percent. Pacific cordgrass continued to increase in aerial extent and density, with increases in plants radiating out from the original planting locations. Despite the overall increase in the extent of Pacific cordgrass at the site, overall acreage is 0.37, less than the target acreage of 1.3.

Table 3.2.4a Results of the 2006 Tidal Marsh and Upland Plant Survivorship Monitoring

Winter 2005-2006 Season
Monitoring Date:7/18/06

Plot No.	Species	Planting Survivorship				Health*					
		# of Plants Assessed	# Alive	% Alive	Dead	G	%G	F	%F	P	%P
1	Heliotropium curassavicum	15	13	87%	2	10	77%	2	15%	1	8%
1	Jaumea carnosa	4	4	100%	0	4	100%	0	0%	0	0%
1	Triglochin maritima	30	10	33%	20	5	50%	5	50%	0	0%
2	Grindelia stricta	4	4	100%	0	4	100%	0	0%	0	0%
2	Lasthenia glabrata	6	2	33%	4	0	0%	2	100%	0	0%
2	Triglochin maritima	20	15	75%	5	9	60%	1	7%	5	33%
3	Frankenia salina	6	6	100%	0	6	100%	0	0%	0	0%
3	Grindelia stricta	6	6	100%	0	6	100%	0	0%	0	0%
3	Heliotropium curassavicum	3	3	100%	0	2	67%	1	33%	0	0%
3	Jaumea carnosa	4	4	100%	0	2	50%	2	50%	0	0%
3	Limonium californicum	10	10	100%	0	10	100%	0	0%	0	0%
3	Triglochin maritima	76	43	57%	33	18	42%	14	33%	11	26%
4	Heliotropium curassavicum	3	1	33%	2	0	0%	0	0%	1	100%
4	Lasthenia glabrata	4	1	25%	3	0	0%	1	100%	0	0%
4	Triglochin maritima	75	46	61%	29	5	11%	16	35%	25	54%
5	Frankenia salina	8	8	100%	0	8	100%	0	0%	0	0%
5	Grindelia stricta	8	8	100%	0	6	75%	1	13%	1	13%
5	Heliotropium curassavicum	3	0	0%	3	0	0%	0	0%	0	0%
5	Jaumea carnosa	8	8	100%	0	8	100%	0	0%	0	0%
5	Limonium californicum	6	6	100%	0	6	100%	0	0%	0	0%
5	Triglochin maritima	79	23	29%	56	9	39%	8	35%	6	26%
6	Triglochin maritima	18	12	67%	6	4	33%	4	33%	4	33%

Health Assessment:
G = Good Health
F = Fair Health
P = Poor Health

Table 3.2.4b Results of the 2007 Tidal Marsh and Upland Plant Survivorship Monitoring

Date of Monitoring: 8/1/2007

Species Monitored	Healthy	% healthy	stressed	% stressed	Dead	% dead
Achillea millefolium	3	21%	9	64%	2	14%
Artemisia californica	13	65%	5	25%	2	10%
Artemisia douglasiana	2	40%	3	60%	0	0%
Aster chilensis	12	52%	10	43%	1	4%
Baccharis pilularis	38	76%	10	20%	2	4%
Bromus carinatus	3	38%	0	0%	5	63%
Carex densa	0	0%	8	89%	1	11%
Carex subbractiata	7	30%	14	61%	2	9%
Danthonia californica	0	0%	3	100%	0	0%
Eryngium armatum	0	0%	0	0%	2	100%
Eriogonum latifolium	11	92%	1	8%	0	0%
Eriophyllum staechadifolium	15	43%	17	49%	3	9%
Grindelia hirsutula	10	71%	3	21%	1	7%
Grindelia stricta	16	80%	4	20%	0	0%
Heracleum lanatum	0	0%	0	0%	2	100%
Hordeum brachyantherum	5	83%	0	0%	1	17%
Juncus occidentalis	0	0%	5	63%	3	38%
Juncus patens	1	14%	6	86%	0	0%
Juncus phaeocephalus	0	0%	11	65%	6	35%
Leymus triticoides	11	79%	3	21%	0	0%
Lupinus arboreus	1	100%	0	0%	0	0%
Lupinus propinquis	6	100%	0	0%	0	0%
Melica califonica	0	0%	7	70%	3	30%
Mimulus aurantiacus	4	8%	32	63%	15	29%
Nassella pulchra	4	36%	3	27%	4	36%
Scrophularia californica	1	7%	10	71%	3	21%
Wyethia angustifolia	2	40%	1	20%	2	40%

3.3 Grassland Revegetation

Coastal terrace prairie (grassland) revegetation focused on replacing grassland habitat that was lost as a part of the remediation staging facilities. Grassland propagation collection began in spring 2003, and continued throughout 2007. Revegetation was proposed for approximately one acre of habitat within a four acre area of the coastal terrace prairie. Propagation goals for the coastal terrace prairie areas were developed using URS's inventory data (2003), and coastal terrace prairie inventory and monitoring data gathered by interns and staff at the Watershed Project in 2003.

Increasing biological diversity, with a focus on locally rare species was paramount to the development of the goals. Table 3.3 below lists all of the species considered for revegetation and the anticipated propagation numbers. This list was adapted each season in response to observations of naturally establishing species, survivorship data and local micro-hydrology. Additionally, species not found during an inventory of coastal terrace species conducted in 2003 were removed from the propagation list at the request of Barbara Ertter, Jepson Herbarium (Ertter, pers. comm., 2005).

Table 3.3: Species Considered for Revegetation of Coastal Terrace Prairie Habitat

Scientific Name	Common Name	Estimated Planting Percentage (note * = <1)	Preliminary #s of plants proposed for planting on 2 ft. centers
Achillea millefolium	Yarrow	1	136
Allium dichlamydeum	Coast Red Onion	1	136
Anaphalis margaritacea	Pearly Everlasting	1	136
Aster chilensis	California Aster	2	272
Astragalus gambellianus	Milkvetch, Dwarf Loco Weed	*	
Brodiaea elegans	Harvest Brodiaea	*	
Bromus carinatus ssp. Carinatus	California Brome, Mountain Brome	5	681
Calandrinia ciliata	Red Maids	seed	
Castilleja densiflora	Owl's Clover	seed	
Castilleja sp.?	Indian Paintbrush	2	272
Chlorogalum pomeridianum var. divaricatum	Soap Plant	2	272
Claytonia perfoliata	Miner's Lettuce	seed	
Danthonia californica var. California	California Oatgrass	7	953
Deschampsia cespitosa ssp. holciformis	Tufted hairgrass	2	272
Dichelostemma capitatum	Blue Dicks, Wild Hyacinth	1	136
Dichondra donelliana	Dichondra	*	

Table 3.3 Continued

Scientific Name	Common Name	Estimated Planting Density	Preliminary #s of plants proposed for planting on 2 ft. centers
Elymus glaucus	wild rye	5	681
Eriogonum latifolium	Coast buckwheat	3	408
Eschscholzia californica var. maritime	California coastal poppy	seed	
Festuca rubra	Red fescue	5	681
Fragaria chiloensis	Wild Strawberry	5	681
Hordeum brachyantherum	Meadow barley	5	681
Iris douglasiana	Douglas Iris	2	272
Koeleria macrantha	June Grass	3	408
Lasthenia californica	Goldfields	seed	
Layia platyglossa	Tidy Tips	seed	
Leymus triticoides	Valley Wild-rye	2	272
Lomatium caruifolium	Lomatium	*	
Lomatium dasycarpum	Wooly Parsnip	*	
Lupinus bicolor	Miniature Lupine, Annual Lupine	seed	
Lupinus nanus	Sky Lupine	seed	
Lupinus variicolor	Varicolored Lupine, Varied Lupine	5	681
Melica californica	California Melica	5	681
Monardella villosa	Western Pennyroyal	*	
Nassella lepida	Foothill Needlegrass	5	681
Nassella pulchra	Purple Needlegrass	5	681
Navarretia squarrosa	Skunkweed	seed	
Perideridia kelloggii	Yampah	*	
Phacelia californica	California coast phacelia	*	
Phalaris californica	California Canary Grass	*	
Plantago erecta	drarf plantain	seed	
Pteridium aquilinum var. pubescens	Western Bracken, Bracken Fern	*	
Ranunculus californicus	California Buttercup	2	272
Sanicula arctopoides	Footsteps-of-Spring	*	
Sanicula bipinnatifida	Purple Sanicle	*	
Satureja douglasii	Yerba Buena	3	408
Sidalcea malvaeflora	Checkerbloom, Wild Hollyhock	2	272
Sisyrinchium bellum	Blue-Eyed Grass	2	272
Trifolium willdenovii	Tomcat Clover	seed	
Trifolium wormskioldii	Cow Clover, Coast Clover	*	
Triphysaria pusilla	Owl's Clover, Dwarf Owl's Clover	seed	
Triteleia laxa	Ithuriel's spear	2	272
Viola adunca	Blue or Western Dog violet	*	
Wyethia angustifolia	Narrow-leaf mule's ears	seed	
TOTAL		**100**	**11570**

3.3.1 Propagule Collection

Refer to discussion under 3.2.2 regarding collection techniques. As stated above, all propagules for this component of the restoration project were collected locally from within the RFS.

Seeds were collected from each species throughout its ripening season in order to include a diverse range of flowering times in the collection pool. Seeds were collected by hand, dried, then stored in paper envelopes or grocery bags.

3.3.2 Revegetation Techniques and Timing

Grassland planting was phased over 3 years, with the largest number of plantings occurring in 2005-6. Grassland planting typically began in January and extended through February. However, planting in Plot 1A had to be delayed until March due to the water inundation following the hand removal of Harding grass. Plots "Claire" and "Connie" were also planted late in the season due to water inundation following scraping.

In 2005, a large number of wetland-loving species were added to the grassland revegetation strategy in response to the large increase in standing water within the Plots. These species included *Juncus occidentalis, J. phaeocephalus, J. patens*, and coyote thistle. Additional plants were installed on 1 to 3 foot centers, depending upon the size and species of the planting stock. The same guiding principles for planting depth were used as described earlier in section 3.2.4. See Appendix 1 for the total number of these species that were planted into the grassland plots.

3.3.3 Survivorship Monitoring

Less emphasis was placed on monitoring survivorship in the coastal terrace prairie plots than in the marsh plots due to the regulatory requirements associated with the marsh, the time-intensive nature of grassland species monitoring and limited project resources. While several belt and line transects were monitored to evaluate survivorship and species composition, the majority of the monitoring was completed using ocular estimates.

The following is a summary of general trends observed. Prior to controlling weeds in the coastal terrace prairie treatment plots, cover of invasive non-native plants was estimated using ocular estimates. Plots 1a, 1b, and 4b all supported greater than 70 percent absolute cover of Harding grass and an additional 15 percent cover of other invasive non-native plants such as teasel *(Dipsacus fullonium.*), cut-leafed plantain *(Plantago coronopus)* and annual grasses. Plots 2, 3 and 4a supported approximately 60 percent cover of Harding grass.

Following treatments and 2 years of revegetation, Plots 1-3 had an average of 48 percent native cover and 25 percent non-native cover, with the remaining areas supporting either mulch or bare soil. Within the 48 percent of native cover, high survivorship (greater than 60 percent) was recorded for all of the planted rushes *(Juncus* spp.) and sedges *(Carex* spp.), aster, yarrow, blue wildrye, California oatgrass, buttercup, blue-eyed grass and purple needle grass. Poor survivorship was recorded for mule's ears and California brome.

Planting in Plots 4a and b was limited due to the heavy establishment of Italian wildrye *(Lolium multiflorum)* and ripgut brome *(Bromus diandrus);* the overall survivorship of planting was poor (less than 30%). Site conditions were also poor due to compacted substrate and fragments of cement and other debris. These plots were abandoned in 2006 and replaced with Plots "Claire" and "Connie" which presented greater opportunity for successful restoration, as determined by spring 2006 mapping. Revegetation of these plots began in 2006-7, and survivorship monitoring will need to occur in 2008 to determine how species perform.

Natural colonization of native plant species was high in both Plots "Claire" and "Connie." Species included rushes, coyote thistle and sedges.

4.0 Invasive Plant Control

Invasive plant control actions were prioritized as directed by the Invasive/Exotic Species Management Program (BBL Inc., 2004b) and based on the California Invasive Plant Council (CalIPC) ranking system which characterizes the level of invasiveness. In addition, site-specific characteristics, such as the size of the invasive population, rate of spread; presence within a sensitive or preferred habitat, and proximity to sensitive or endangered species habitat were considered when determining invasive species control priorities for the project area Table 4.0 identifies priority invasive species that were controlled as part of the restoration project.

4.1 Summary of Invasive Plant Control Work

Prior to development of an integrated Invasive Species Management Program, UC Berkeley staff directed the Watershed Project to initiate control of several targeted priority species. The following section summarizes invasive plant control activities undertaken during this time (2003 and early 2004).

4.1.1 Preliminary Invasive Non-Native Plant Control Efforts

In 2003, the Watershed Project in partnership with the UC Berkeley Environmental Sciences program initiated an invasive non-native plant species early detection program. The targeted species included perennial pepperweed (*Lepidium latifolium*), pampas grass (*Cortaderia jubata)*, five-hook bassia (*Bassia hyssopifolia*), yellow star thistle (*Centaurea solstitialis*), sweet fennel (*Foeniculum vulgare*) and smooth cordgrass. Staff and UC Berkeley and Merritt College students surveyed the marsh weekly recording infestation locations and removing infestations where feasible.

Pampas grass has been growing along the Bay trail and within the marsh ecotone and upland habitats for several decades. Mature plants were greater than 6-8 feet in diameter. Initial 2003 monitoring indicated that more than 145 mature plants were growing either within or on the windward side of the project area. In 2003 and 2004, approximately 120 mature plants were cut to the ground with chainsaws, with root balls grubbed out for more than 5o percent. Resprouts were controlled manually on a quarterly basis.

Between 2003 and 2004, 112 yellow star thistle individuals were located and removed from upland areas within the marsh and the area adjacent to 46th Ave. along Zeneca's property line.

In July, 2003, staff and volunteers from the Watershed Project actively controlled a newly detected invasive non-native plant species, five hook bassia, which had colonized the marsh ecotone at densities over 50% cover. This species had been introduced with imported fill materials from Martinez during the first phase of the remediation efforts. Control efforts included brush-cutting dense stands of bassia on the soil stock pile to prevent seed set, as well as hand removing dense stands and pioneering individuals from the mid and high marsh habitats. Removal efforts required approximately 400 hours of hand labor. Bassia plants were removed off site in green waste containers or composted until removed. The imported soils were monitored, and newly establishing plant seedlings were detected and removed.

Three isolated patches of perennial pepperweed were also detected and removed by hand, which included grubbing out root material to a depth of 6-inches. The infestation locations were then subsequently monitored to detect any subsequent perennial pepperweed infestations. Perennial pepperweed was also detected growing adjacent to the project site, on Zeneca's lands. The Watershed Project also completed removal on Zeneca property during the spring of 2004 to prevent reinfestation.

Dense stands of sweet fennel had established in the rocky fill material along the Bay trail on EBRPD's land, on the "bulb area" of the project site, and on the marsh upland islands. Due to fennel's deep roots and the nature and composition of the rocky fill soils along the Bay trail, digging out the roots was not a viable option, as it could result in slope instability. The Watershed Project staff and UC Berkeley students removed the seed heads and most of the above ground portions in fall 2003 to prevent further spread. In 2004 staff developed a partnership with EBRPD to control this species on their adjacent land. The integrated pest management (IPM) coordinator authorized an herbicide application of glyphosate during spring 2004, controlling 90 percent of the infestation. The remaining infestation was controlled manually through seed head reduction by UC Berkeley interns.

By 2004, BBL in partnership with the Watershed Project developed an integrated Invasive/Exotic Species Management Plan. This document became the guiding strategy following its adoption by UC Berkeley.

4.1.2 Targeted Invasive Non-Native Plant Control Efforts (2004-7)

The following section summarizes the techniques that were developed and implemented for controlling invasive plants at the project site from 2004 to present. The summary of control activities for the majority of the project are presented in tabular form. Refer to Table 4.0 for a species list and control time period and Table 4.1a for a summary of control techniques undertaken for top priority invasive non-native species. Monthly work efforts focused on detecting and removing those species targeted for control. Actual invasive plant treatment and removal hours for each year of control are presented below in Table 4.1b.

The percent weed cover increased in the marsh upland revegetation plots in 2007, and is likely to increase again in 2008. Staff hours were not sufficient to achieve adequate control in spring and summer 2007 for several reasons. The reduction in the volunteer program meant that staff and contractors were needed to out-plant in order to achieve restoration goals, a task usually shared by volunteers. Also as a consequence of the program cut back, two key staff members left. Towards the end of the fiscal year, continued funding levels were uncertain, so additional staff to control invasive non-native plants were not available.

While the Invasive/Exotic Species Management Program did not include control strategies for priority infestations in the coastal terrace prairie habitats, the same guiding principles were used to control these species. Section 4.1.2 outlines specific control treatments for targeted invasive non-native species infesting the grassland restoration project.

Table 4.0 Invasive Non-Native Plants Controlled during Marsh and Upland Restoration

Scientific Name	Common Name	Marsh	Island	Grassland	Preferred Control Period (Quarter)
Acacia sp.	Acacia, green wattle	X	X		Q3, Q4
Avena fatua	Wild oat	X	X		Q1
*Bassia hyssopifolia**	Bassia, five hook bassia*	X			Q1, Q2, Q3
Beta vulgaris	Beet	X			Q2
Brassica raphanistrum	Wild mustard	X	X		Q2
Briza maxima	Rattlesnake grass	X	X		Q1
Bromus diandrus	Ripgut brome	X	X		Q3
*Centaurea solstitialis**	Yellow star thistle*		X	X	Q2, Q3
Cirsium vulgare	Bull thistle	X			Q2
Conuim maculatum	Poison hemlock			X	Q2, Q3
Conyza sp.	Horseweed	X			Q2
*Cortaderia jubata**	Pampas grass, jubata grass*		X	X	Q2, Q3
Cotula coronopifolia	Brass buttons	X			Q2, Q3, Q4
*Dipsacus fullonium**	Teasel*	X		X	Q2, Q3
*Dittrichia graveolens**	Stinky tarweed*	X			Q3,Q4
Epilobuim sp.	Fireweed	X			Q2, Q3
*Foeniculum vulgare**	Fennel*	X	X	X	Q2, Q3
Gnaphalium sp.	Cudweed	X			Q2, Q3
Hordeum murinum	Hare barley	X			Q2
*Lepidium latifolium**	Perennial pepperweed*	X	X	X	Q1, Q2
Lolium multiflorum	Italian ryegrass	X	X		Q2
*Lotus corniculatus**	Birdfoot trefoil*	X			Q2, Q3
*Lythrum tribracteatum**	Loosestrife*	X		X	Q2, Q3
Medicago polymorpha	Burclover	X			Q2, Q3
Melilotus sp.*	Sweet clover*	X			Q2, Q3
*Phalaris aquatica**	Harding grass*	X	X	X	Q2, Q3
Picris echioides	Bristly oxe-tongue	X		X	Q2, Q3
Plantago coronopifolia	Cut-leaved plantain	X		X	Q2
Plantago lanceolata	Plantain	X		X	Q2
Polygonum arenastrum	Common knotweed	X			Q2
Raphanus sativus	Wild radish	X	X		Q2, Q3
Rubus discolor	Himalayan blackberry		X	X	Q2, Q3
Rumex crispus	Curly dock	X		X	Q2, Q3
*Salsola soda**	Russian thistle*	X			Q2, Q3, Q4
Sonchus asper	Sow thistle			X	Q2
*Spartina alterniflora**	Smooth cordgrass*	X			Q3,Q4
*Tragopogon porrifolius**	Salsify*			X	Q2, Q3

Notes: * indicates top priority invasive plant species

Q1= Jan-Mar
Q2= Apr-Jun
Q3= Jul-Sept
Q4= Oct-Dec

Est. Hours of invasive plants control per Quarter:

2006: Q1=55 hours Q2= 378 hours, Q3=210.5 hours, Q4=55 hours
2007= Q1 40 hours Q2= 247 hours, Q3=218.5 hours

Table 4.1a Summary of Control Techniques Utilized for Selected Priority Invasive Plant Species

Scientific Name	Common Name	Preferred Control Period (Quarter)	Control Techniques & Estimated Cover Reduction Following Control Implementation
Bassia hyssopifolia	Bassia, Five Hook Bassia	Q1, Q2, Q3	**Technique:** Hand pulling was the most effective control technique for discreet populations. Hand removal was accomplished most easily following rainfall when soil is loose. Plants were typically pulled as soon as they are large enough to grasp and before they bolt or are able to produce seed. Pieces of root remaining in the soil did not sprout again if the plant was removed to include material below the crown. Plants were readily destroyed by hand hoeing, either by cutting off the tops, or by stirring the surface soil to expose seedlings to drying by the sun. Large infestations were reduced by weed whipping or brushcutting prior to bolting. The plants were cut as low to the ground as feasible. Follow up on resprouting individuals was required for approximately 20 percent of the plants cut mechanically. **Cover Reduction:** Following the completion of the remediation efforts, the cover of five-hooked bassia was estimated at 85 percent in the upland staging area and approximately 10 percent throughout the high marsh. Control actions have reduced that to less than 1 percent.
Centaurea solstitialis	Yellow Star Thistle	Q2, Q3	**Technique:** Most of the initial control actions involved spot-controlling new individuals or colonies. At RFS, the population was sufficiently small that diligent monitoring and rapid control of both the site and adjacent properties enabled staff to effectively manage this species. Plants were hand-pulled before they bolted or are able to produce seed. Pieces of root remaining in the soil will not sprout again if below the crown. Plants were readily destroyed when small by hand hoeing, or by stirring the surface soil to expose seedlings to drying by the sun. **Cover Reduction:** In 2003 and 2004 approximately 112 individuals were removed. In 2005-6 this dropped to less than 25 and in 2007 less than 10 individuals were identified and removed.
Cortaderia jubata	Pampas Grass, Jubata Grass	Q2, Q3	**Technique:** Staff and volunteers typically pulled or hand grubbed pampas grass seedlings. This method was highly effective if seedlings are less than one-year old. For larger plants, however, a pulaski, mattock, or shovel were the safest and most effective tools for removing established clumps. To prevent resprouting, staff removed the entire crown and top 3-4 inches of the rootball. Removed plants were left lying on the soil surface to decompose (note: it is important to expose roots upwards to prevent re-establishment). A large chainsaw or brushcutter was used by trained staff and contractors to remove the sharp blades and expose the base of the plant, allowing for better access for removing the crown and for making disposal of the detached plant more manageable. **Cover Reduction:** In 2003-4 approximately 120 mature plants were identified and removed. Additionally, the Watershed Project staff in partnership with EBRPD removed approximately 26 plants from the Bay Trail corridor. In 2005-6, 3 seedlings were removed and in 2007 less than 6 seedlings were removed.

Cotula coronopifolia	Brass Buttons	Q2,Q3,Q4	**<u>Treatment:</u>** Brass buttons were first controlled in 2004-5. This species is located on the outboard side of the marsh and on Zeneca property. The first colonizing location within the restoration site was located in Plots 6 and 7. This very dense infestation covered approximately 24 square feet and was grubbed out by hand. Small root fragments of up to 0.25 cm in diameter were removed to reduce resprouting. This same infestation doubled in size in 2005-6, and was treated with glyphosate. Approximately 90 percent of the infestation was controlled. Resprouts were treated successfully by hand in 2006, and the infestation was minimized in 2007. Additional smaller infestations colonized Plots 2 and 3 in 2006. Only 50 percent of these incipient patches were successfully treated. In 2007 the distribution remained the same, however less than 50 percent of the emerging plants were controlled due to limited resources from the Watershed Project. This area will require more aggressive control work in the future and infestations should be mapped. Due to the ability of this species to regenerate from residual root stock, chemical control methods may be required to eliminate populations. **<u>Cover Status:</u>** In 2004-5 there was one 25 square foot patch. This patch was successfully reduced to less than 5 square-feet, however requires additional re-treatment. In 2006-7 this species began colonizing Plots 1-2, and resprouts were observed in approximately 50% of the treated areas. Additional treatments will be required in 2008 to reduce the spread of this species into adjacent marsh habitat.

Dipsacus fullonium	Teasel	Q2,Q3	**Technique:** Hand pulling was the most effective control technique for discreet populations. Hand removal was accomplished most easily following rainfall when soil is loose. Plants were typically pulled as soon as they are large enough to grasp and before they bolt or are able to produce seed. If the basal rosette of the plants were greater than 6-8 inches, then hand picks and pick maddocks were used to either grub out the plant of cut it directly below the crown. Large infestations were also reduced by weed whipping or brushcutting prior to bolting. The plants were cut as low to the ground as feasible. Follow up on resprouting individuals was required for approximately 30 percent of the plants cut mechanically. **Cover Reduction:** An ocular estimate of the teasel cover within the 4-acre coastal terrace prairie site was done in 2004. At that time it was estimated that approximately 20 percent of the grassland was dominated by teasel and that the teasel was expanding into the drier areas of the grassland. Control actions have reduced the teasel cover to less than 5 percent.
Dittrichia graveolens	Stinky tarweed	Q3,Q4	This plant was not present prior to the remediation project and was first detected in 2006. Several isolated individuals were observed colonizing the high marsh and ecotone habitats. These plants could have been introduced from adjacent properties or through propagules carried with the tide. Treatment of this species was not considered a high priority following its initial detection as its level of invasiveness is not really documented in the literature. Peter Baye provided information to the Watershed Project staff in fall 2006 about the potential threat posed by this species, and control became a priority. Diligent efforts were made to pull most of it while in flower. This plant continues to persist, however, due to the delay in recognizing the threat, and set seed in the high marsh and ecotones areas near Plots 12-14 and below Plots 1-3. A small amount (5 – 6 stems) was pulled from plots 6 & 7 in 2007, and it was also observed on the access road above that area. **Technique:** Hand pulling was the most effective control technique for removing discreet populations. Hand removal was accomplished most easily following rainfall when soil is loose or when the plants were small. Plants were typically pulled as soon as they are large enough to grasp and before they flower or are able to produce seed. Plants were also readily destroyed when removed while still small. This was accomplished by hand hoeing, either by cutting off the tops, or by stirring the surface soil to expose seedlings to drying by the sun. **Cover Status:** 2006 records indicate that less than 10 individuals were removed from the high marsh and ecotone habitats. However in 2007, more than 300 plants have been observed, with approximately 25 percent setting seed due to the reduction in invasive non-native plant control hours by the Watershed Project. Diligent monitoring and rapid removal will be paramount in 2008.

Foeniculum vulgare	Fennel	Q2, Q3	**Technique:** Staff and volunteers typically performed manual methods of control. This treatment was very effective when infestations are sparse and locally restricted. Digging out individual plants by hand was the most effective control, but it was labor-intensive, particularly in rocky soils. Cutting, mowing, and chopping established vegetative growth temporarily reduced the height of fennel plants within a stand and prevented seed set. This method however, was typically ineffective as a method of permanent removal. In areas where fennel stands were well established along and adjacent to the Bay Trail Corridor, herbicide treatment was required for successful control. EBRPD treated approximately 400-feet of established fennel on the rocky slopes above plots 7 and 8. This successfully killed approximately 85 percent of the plants. Staff and volunteers from the Watershed cut back resprouts within the treatment area in 2006 and 2007. Re-treatment is required in 2008 to continue to reduce the cover and infestation size. Small seedlings have occasionally established within the upland areas, but have been removed prior to establishment. Future management efforts should focus on preventing or reducing soil disturbance, which favors spread, **Cover Reduction:** The stand of fennel on the lower slopes of the Bay Trail had an estimated cover of 65 percent in 2004. In 2007 the cover is less than 10 percent.
Lepidium latifolium	Perennial Pepperweed	Q1	**Treatment:** Perennial pepperweed was first controlled in 2003-4. Two large stands were cut back mechanically, and root pieces were removed by hand. The third smaller stand was cut back manually and root fragments of up to 0.5 cm in diameter were removed to reduce resprouting. Each infestation required a minimum of 6 additional control treatments. The Watershed Project staff and volunteers also hand removed colonizing pepperweed from the outboard side of the marsh near the Bay Trail and Meeker Slough. This area will require more aggressive control work in the future and infestations should be mapped. Due to the ability of pepperweed to regenerate from residual root stock, chemical control methods may be required to eliminate populations. **Cover Reduction:** The initial infestation size of the 3 patches was estimated at approximately 35 square feet. In 2007, resprouts were observed in only one infestation located below the Bay Trail near Plot 8. The estimated coverage was less than 3 square feet. An additional treatment in 2007 will be required to reduce spread.
Lotus corniculatus	Birdfoot trefoil	Q2, Q3	This plant was not observed in 2003 prior to the completion of the remediation project. It was first detected in 2004, growing on the northern upland area. Only isolated individuals were observed colonizing this area. These plants were likely introduced from adjacent properties or through propagules carried with the tide. This plant was not initially considered an invasive threat, as it was anticipated that it would be outcompeted by establishing native subshrubs and shrubs. However, in areas where the soil compaction was high and revegetation survivorship low, this species has persisted and expanded. This plant continues to persist and dominate Plots 2 and 3, and in 2007 set seed in the ecotone and upland areas in Plots 1-3. **Technique:** Hand pulling was the most effective control technique for removing discreet populations. Hand

			removal was accomplished most easily following rainfall when soil is loose or when the plants were small. Plants were typically pulled as soon as they are large enough to grasp and before they flower or are able to produce seed. Plants were also readily destroyed by hand hoeing, either by cutting off the tops, or by stirring the surface soil to expose seedlings to drying by the sun. Control of this species has become problematic, and will likely require a more aggressive contractor-based approach in 2008. **Cover Status:** 2004 records indicate that less than very few isolated individuals were observed and removed. In 2005-6 a high number of plants (filling approximately 16 large garbage bags) were observed colonizing Plots 1-3 and approximately 90 percent were removed in 2005-6. However in 2007, with fewer work hours available from the Watershed Project, this species dominated Plots 2 and 3, with approximately 60 percent setting seed. Diligent monitoring and rapid removal will be paramount in 2008. Lotus was also found in the grassland; at least 16 bags were removed in 2007.
Lythrum tribracteatum	loosestrife	Q2, Q3	Small infestations of loosestrife were observed colonizing the ecotone and upland habitat in 2005. Staff did not prioritize control of this species, as there was limited information regarding the level of invasiveness. In 2006 however, the cover of this species increased significantly below Plots 1-3 and 12-14. It also occurs in the scraped grassland plots. **Technique:** Hand pulling was the most effective control technique for very small and discreet populations. Hand removal was accomplished most easily when the plants were small. Plants were typically pulled as soon as they are large enough to grasp and before they were able to produce seed. Plants were also readily destroyed by hand hoeing, either by cutting off the tops, or by stirring the surface soil to expose seedlings to drying by the sun. Large infestations were reduced by weed whipping or brushcutting prior to seed set However, this presented a problem as the not all plants developed seed at a consistent time. Given the dense cover in 2006, a more aggressive control treatment was piloted. All plants were weed-whipped and then an industrial sized shop vacuum was used to remove all of the remaining vegetation and seed material from the site. It was estimated that approximately 90 percent of the plant material was removed during this effort. The plants were cut as low to the ground as feasible. Follow up on resprouting individuals was required for approximately 20 percent of the plants cut mechanically. The use of the shop vacuum was labor intensive, however preliminary monitoring indicating that the loosestrife cover was reduced. In 2007 however, the control of this species was minimal as the Watershed Project reduced its services during the peak control period. **Cover Reduction:** Following the completion of the remediation efforts, the cover of loosestrife was estimated at less than one percent in the ecotone and upland habitat. Control actions have been inconsistent and the cover has increased to greater than 5 percent, with the largest infestations on the northern side of the marsh.

Melilotus sp.	Sweet clover	Q2, Q3	This plant was not observed in 2003 prior to the completion of the remediation project. It was first detected in 2004, growing on the eastern upland area. Approximately 35 isolated individuals were observed colonizing this area. These plants were likely introduced from adjacent properties or through propagules carried with the tide. This plant continues to persist and due to the reduction of control activities by the Watershed Project in 2007, was allowed to set seed in the high marsh, ecotone and upland areas in Plots 1-7. **Technique:** Hand pulling was the most effective control technique for removing discreet populations. Hand removal was accomplished most easily following rainfall when soil is loose or when the plants were small. Plants were typically pulled as soon as they are large enough to grasp and before they flower or are able to produce seed. Plants were also readily destroyed when removed while still small. This was accomplished by hand hoeing, either by cutting off the tops, or by stirring the surface soil to expose seedlings to drying by the sun. **Cover Status:** 2004 records indicate that less than 35 individuals were observed and removed. More than 75 plants were observed and removed in 2005-6. However in 2007, the population expanded greatly, and staff hours were insufficient to control it. More than 200 plants have been observed, with approximately 50 percent setting seed. Diligent monitoring and rapid removal will be paramount in 2008.
Phalaris aquatica	Harding Grass	Q2, Q3	Harding grass produces an abundant seedbank and can also spread and regenerate from small rhizomes and rot fragments. Dense stands of Harding grass persist adjacent to the marsh restoration area, on the "bulb" and within and surrounding the entire coastal terrace prairie habitat. **Technique:** A series of test plots were established in the coastal terrace prairie restoration site. Refer to Section 4.1.4 and Table 4.1c for a summary of treatment techniques and results. The small number of seedlings found in the marsh revegetation plots were removed by hand.
Rubus discolor	Himalayan Blackberry	Q3	**Technique:** Himalayan blackberry was intermixed with the pampas grass and sweet fennel growing in Plots 9 and 10 and along the Bay Trail corridor. All of the treatments performed by the Watershed Project were either hand or mechanical. Rootstocks were removed by digging; this was the preferred method to control for seedling and new infestations of Himalayan blackberry. Continued monitoring was critical as root pieces that remain in the soil often resprouted and required additional treatment. Mechanical removal was utilized for the dense stands that existed on Plots 9 and 10. Vines and canes were cut with hedgetrimmers, loppers, clippers, shovels, or occasionally pulled using a weed wrench. Effective control required several cuttings before reserve food supply of the root system was exhausted. The optimal treatment time was when the plants begin to flower. At this stage the reserve food supply in the roots is nearly exhausted, and new seeds have not yet been produced. **Cover Reduction:** In 2003 the Himalayan blackberry cover in Plots 9 and 10 was more than 55 percent. It was approximately 20 percent above Plot 8 and approximately 35 percent on the slopes below the Bay Trail. Treatment focused primarily in Plots 8-10, with the current vegetative

			cover in Plot 8 at approximately 5 percent and less than 10 percent in Plots 9 and 10.
Salsola soda	Russian thistle	Q2, Q3, Q3	This plant was not present within the project area prior to the remediation project and was first detected in 2004. Several isolated individuals were observed colonizing the mid and high marsh habitats. These plants could have been introduced from adjacent properties or through propagules carried with the tide. This plant continues to persist and set seed in the high marsh and ecotones areas near Plots 12-14 and below Plots 1-3. Additionally, a large infestation of this plant is growing on the outboard side of the marsh west of the Bay Trail and near the "bulb" area which is currently not managed for weed control, and it occurs along the fence between UC and the Zeneca properties. **Technique:** Hand pulling was the most effective control technique for removing discreet populations. Hand removal was accomplished most easily following rainfall when soil is loose or when the plants were small. Plants were typically pulled as soon as they are large enough to grasp and before they flower or are able to produce seed. Plants were also readily destroyed when removed while still small. This was accomplished by hand hoeing, either by cutting off the tops, or by stirring the surface soil to expose seedlings to drying by the sun. **Cover Status:** 2005 records indicate that less than 65 individuals were removed from the mid and high marsh habitats. This remained consistent in 2006, however in 2007, more than 150 plants have been observed, with approximately 25 percent setting seed. Over 10 bags were pulled in spring and summer 2007. Diligent monitoring and rapid removal will be paramount in 2008.
Spartina alterniflora	Smooth Cordgrass	Q3,Q4	Two populations of *Spartina alterniflora* were observed west of the Bay trail in 2003 and were genetically tested by the Invasive Spartina Project (ISP) for verification. The following control strategy was developed by ISP, UC Berkeley, BBL and the Watershed Project. Treatment types and treatment success is discussed separately in Section 4.1.3. .

Tragopogpn porrifolius	Salsify	Q2, Q3	Until spring 2006, this plant was occasionally observed in very small numbers and in very isolated areas within the larger coastal terrace prairie habitat. During April and May 2006, this species emerged throughout the grassland, and was hand removed by hired contractors and interns. The reason for the exponential increase in population size is unclear and could be related to environmental conditions. Future study is required. **<u>Technique:</u>** Hand pulling was the most effective control technique for removing discreet populations. Hand removal was accomplished most easily following rainfall when soil is loose or when the plants were small. Plants were typically pulled as soon as they are large enough to grasp and before they flower or are able to produce seed. Plants were also readily destroyed when removed while still small. This was accomplished by using hand picks to loosen the roots and then the seedlings were bagged and composted. **<u>Cover Status:</u>** 2003-5 records indicate that this species persisted in small isolated infestations, and was not considered to be of concern. However in 2006, more than 27 full-sized garbage bags of this species were filled by staff , contractors and volunteers. Extensive weeding activities also occurred in 2007,. Diligent monitoring and rapid removal will be paramount in 2008.
	All Lower Ranking Invasive Non-Native Species	Q1,Q2,Q3,Q4	For all other secondary infestations, rapid detection and control is recommended as resources permit. The primary species that were addressed in 2004-7 were bur clover, bristly ox tongue, horseweed, Italian wildlrye, common knotweed, sow thistle and wild radish. The project areas were patrolled regularly (on average of weekly) to detect new invasive plant species and infestations that could be problematic. In most cases, hand pulling (especially for new seedlings and young plants) was the optimal method of control. For larger and more extensive infestations, the Weed Worker's Handbook and CalIPC staff were contacted for information on appropriate control techniques. A combination of hand pulling, mechanical control (weed eating, brushcutting), spot treatment with herbicide, and mulching or covering with weed fabric were all used as a part of a broader IPM strategy.

Table 4.1b Summary of Invasive Control Efforts (Hours)

Treatment Year	**Staff and Volunteer Hours Per Quarter**	**Subtotal Hours**
2004	Q1= hours not tracked Q2= *138 hours Q3=305 hours Q4= hours not tracked	443
2005	Q1= 70 hours Q2= 125 hours Q3=**172.5 hours Q4= 136 hours	503.5
2006	Q1= 55 hours Q2= 378 hours Q3=210.5 hours Q4= 55 hours	698.5
2007 (Est)	Q1= **40 hours Q2= **247 hours Q3=218.5 Hours Q4= Xx hours	505.5 (3 quarters)
TOTAL Hours Expended on Invasive Plant Control (2004-2007) Numbers based upon work performed summaries, and are not necessarily a true total of invasive control hours. ** reporting of hours was incomplete on work performed data sheets. It is recommended that future records be maintained to include both volunteer and staff hours.		

Special attention was given to two particularly problematic species, Harding grass, and smooth cordgrass. Harding grass was the predominant invasive infesting the coastal terrace prairie restoration areas, while smooth cordgrass was a high priority for low marsh areas. Smooth cordgrass control was specifically required within the USFWS Biological Opinion. Control efforts for these two species are described below in Sections 4.1.3 Smooth Cordgrass Control and 4.1.4 Harding Grass Control below.

4.1.3. Smooth Cordgrass Monitoring and Control

As discussed in Section 3.2.1.2 above, priority was given to the detection and control of smooth cordgrass, a species that readily hybridizes with the native Pacific cordgrass. Following installation of native Pacific cordgrass at the site in 2003 and again in 2006, a comprehensive program of detection and control of smooth cordgrass was implemented.

Above-ground portions of smooth cordgrass were cut back and covered with a weed fabric on the outboard side of the marsh to reduce the plants ability to photosynthesize. The infestations were first cut back with weed whips and then covered with geo-textile fabric in the spring. An excess of at least 1-meter of geo-textile extended beyond the boundary of the infestation perimeter. The geo-textile was then firmly anchored into the mudflat using stakes at least 12-inches long. Bi-weekly monitoring was implemented. Seedling detection and genetic testing was implemented on a periodic basis to ensure that no hybrid seedlings or invasive plants established onsite. For plants less than 0.5 meters in diameter, hand pulling was implemented as the simplest control method. Each infestation site was marked and photographed. For covered infestations, it was anticipated that the patches would die within four months, however, the tidal influence impacted the integrity of the geo-textile on a regular basis, therefore limiting the efficacy of the treatment. The fabric was removed within 1-year of installation and alternative treatments were implemented in coordination with the ISP.


Photo 4.1.3 Covering Spartina Sept. 2003

Alternative treatments included weed-whipping the infestation prior to flowering to prevent pollen and seed development; cutting back the flowering heads prior to reproduction; removing isolated individuals by hand using shovels, hand picks and other equipment; and herbicide application. The Watershed Project staff and volunteers performed all but the later control treatment on a regular basis following monitoring activities. Herbicide treatment was performed by the ISP and EBRPD.

In addition, ongoing monitoring of the entire marsh was conducted to detect any suspicious cordgrass seedlings and/or suspected new infestations of smooth cordgrass. Suspect seedlings were collected, and sent to a lab for genetic testing to determine if they were hybrids or not. Confirmed hybrids were either hand-removed or sprayed with herbicide. Table 4.1c summarizes the monitoring and treatment actions performed by the Watershed Project staff and interns in coordination with UC Berkeley, ISP and EBRPD.

In summary, the smooth cordgrass monitoring and control program that was implemented at the Western Stege Marsh from 2004 to 2007 was considered "highly effective" for control of small, satellite infestations of smooth cordgrass (Grijalva, pers. comm. 2006). Future detection and control efforts will focus on continuing regular (quarterly) monitoring of the marsh, collection of any suspect seedlings, genetic testing to determine if they are hybrids, and if so, application of control treatments.

Table 4.1c Summary of Invasive Smooth Cordgrass Monitoring and Control Efforts (2003-2007)

Date	Activity
Sep-03	Install Tarp over clones
Oct-03 to Dec-03	Monthly Monitoring and Maintenance of Tarp
Dec-03 to Feb-04	Monthly Monitoring and Maintenance of Tarp, Monitoring of Adjacent Marsh
Mar-04	Detection of satellite clone area adjancet to tarped area. Control of new infestation.
Mar- 04 to Jun 04	Monthly Monitoring and Maintenance of Tarp, Monitoring of Adjacent Marsh
Jun-04	Removed tarp for inspection, most plants dead, a few still green.
Jul-04 to Dec-04	Monthly Monitoring and Maintenance of Tarp, Monitoring of Adjacent Marsh. Inspected Tarp, all plants dead
Dec-04	Remove Tarp. Genetic Testing of possible new infestations
Jan-05	Confirmation of hybrids in marsh- control of new hybrid colonies south and west of tarped area.
Apr-05	Monthly Monitoring, Detection of some sprouts in previously tarped area
Apr-05 to Jul-05	Monthly Monitoring
Aug-05	Detection of new infestation by pier, plants in flower. ISP coordinate removal of 18 sq. feet of plants and herbicide application (glyphosate)

Aug-05 to Nov-05	43 seedling removed
Jun-06	Removed seedlings (# unknown)
Jul-06 to Aug-07	Monthly Monitoring, Annual Inventory
September 06	ISP treats the hybrid spartina population on the outboard side of the marsh (on both east and west side of the dock) with Imazypr.
May 2007	Observed 2 large colonies of potential hybrid cordgrass. ISP took samples for genetic analysis. These did prove to be hybrids, and were sprayed in Oct. 2007.
Oct-07	37 seedlings mapped and removed by May and Associates; approximately 7 suspected hybrid seedlings were collected for genetic testing.

4.1.4 Harding Grass Control

One of the primary biological threats to the health of the RFS coastal terrace prairie habitats is the spread of a perennial non-native grass – Harding grass (*Phalaris aquatica*). This highly invasive grass thrives in wet meadow and coastal grassland habitats, changing both the vegetation composition and hydrology of the areas that it invades. The Watershed Project in collaboration with UC Berkeley has initiated a pilot community-based approach to controlling this species.

In 2005 the Watershed Project staff mapped the entire Harding grass distribution and density using a Global Positioning System (GPS) unit. Figure 4.1.1a presents the distribution of Harding grass in the upland portion of the RFS in the project site. Funds from the San Francisco Foundation enabled staff to re-map the distribution and density, create GIS database attributes, and perform several spatial analyses for this species. The GIS analysis has played, and will continue to play, a pivotal role in determining which pioneer patches and which edges of Harding grass should be controlled as the restoration program is expanded.

Figure 4.1.1b illustrates an overlay of the locally rare plant species and the distribution and density of Harding grass. From this analysis, the Watershed Project in coordination with UC Berkeley staff could understand which Harding grass patches poses the greatest threat to the areas of greatest sensitivity and which patches should be immediately treated (e.g. lower density), and which should be prioritized for mowing or large-scale scraping. Figure 4.1.1b also provides a valuable tool for communicating priorities to volunteers who are investing their time to improve the health of the grassland.

Control efforts were initiated in 2004 to test and evaluate a number of control techniques (e.g. hand removal, mulching, scraping, etc.) within small restoration plots. Figure 4.1.1c illustrates the locations of the pilot restoration plots. The methods and results of the various test treatments is presented below in Section 4.1.4.1.

Figure 4.1.1d illustrates the change in distribution and density for Harding grass between 2005 and 2007. A number of pioneer patches of Harding grass no longer persist or have reduced density and size due to restoration efforts. Several of the eastern patch edges have been slightly reduced due to ongoing mowing practices Figures 4.1.1d and 4.1.1e illustrate analyses that help staff and volunteers understand and evaluate the overall effects of the current restoration work. Figure 4.1.1d depicts the changes in Harding grass distribution and density overlain with the restoration plot location. Overall Harding grass density and distribution has been reduced within the restoration plots. Low density patches still exist and will require continued control until the species is eradicated within these areas. Figure 4.1.1e indicates how the targeted native plants species (e.g. specific to the 43 species monitored) richness has changed in response to the control of Harding grass within the plots. Species richness was measured by the number of different native taxa per 10 meter x 10 meter cell. Again, the overall change is positive indicating that richness has increased within the plots – a primary goal of the pilot restoration project.

The combination of plot treatments and the control of isolated infestations within the 4-acre project areas have resulted in the removal of approximately 1.3 acres of Harding grass. Monitoring has indicated that resprouts and seedling germination is still present in some treatment areas, totaling approximately 0.4 acres. The estimated average cover of Harding grass within this combined area is less than 20% and will require spot herbicide and grubbing treatments in the future.

Figure 4.1.1a

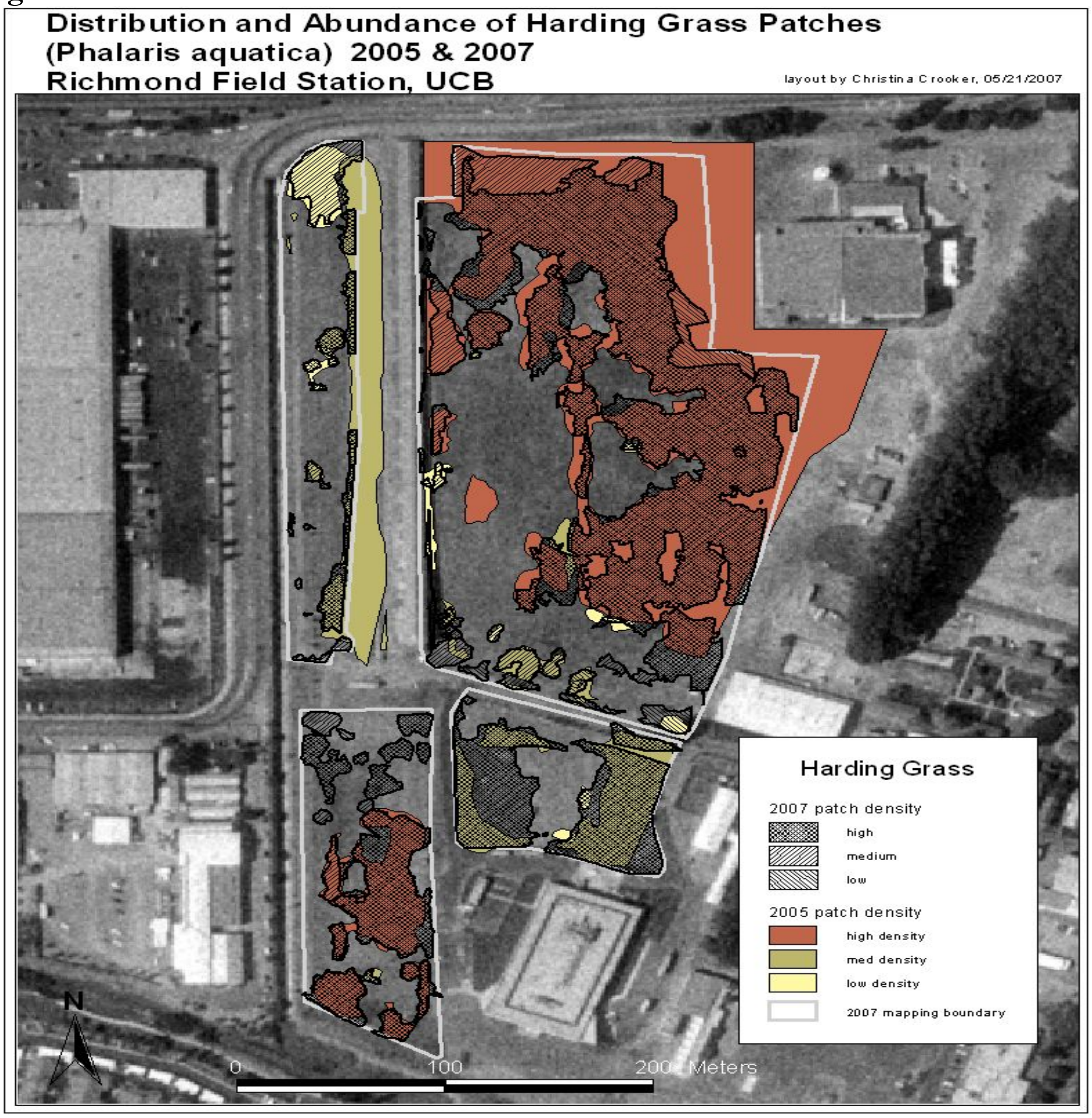
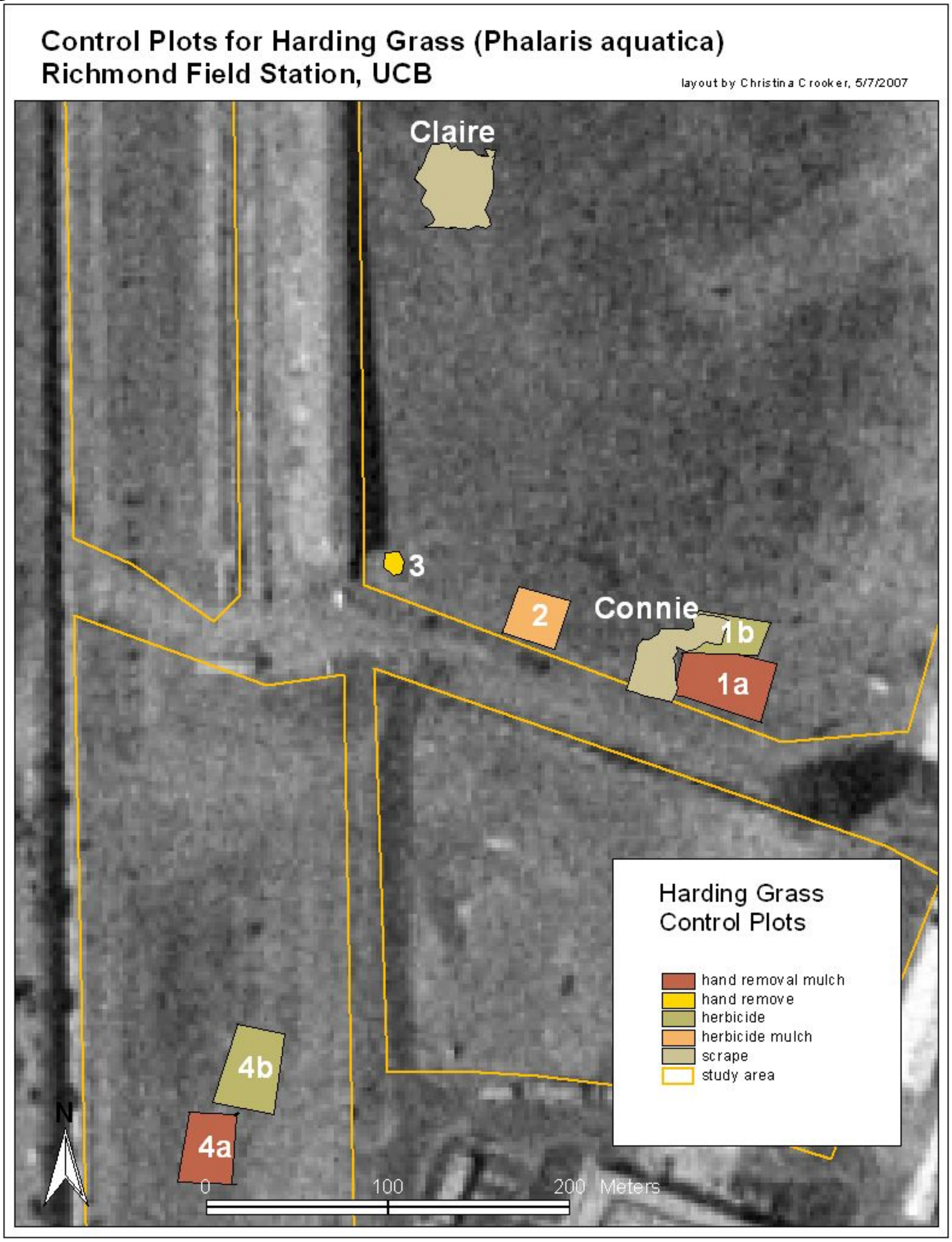


Figure 4.1.1b

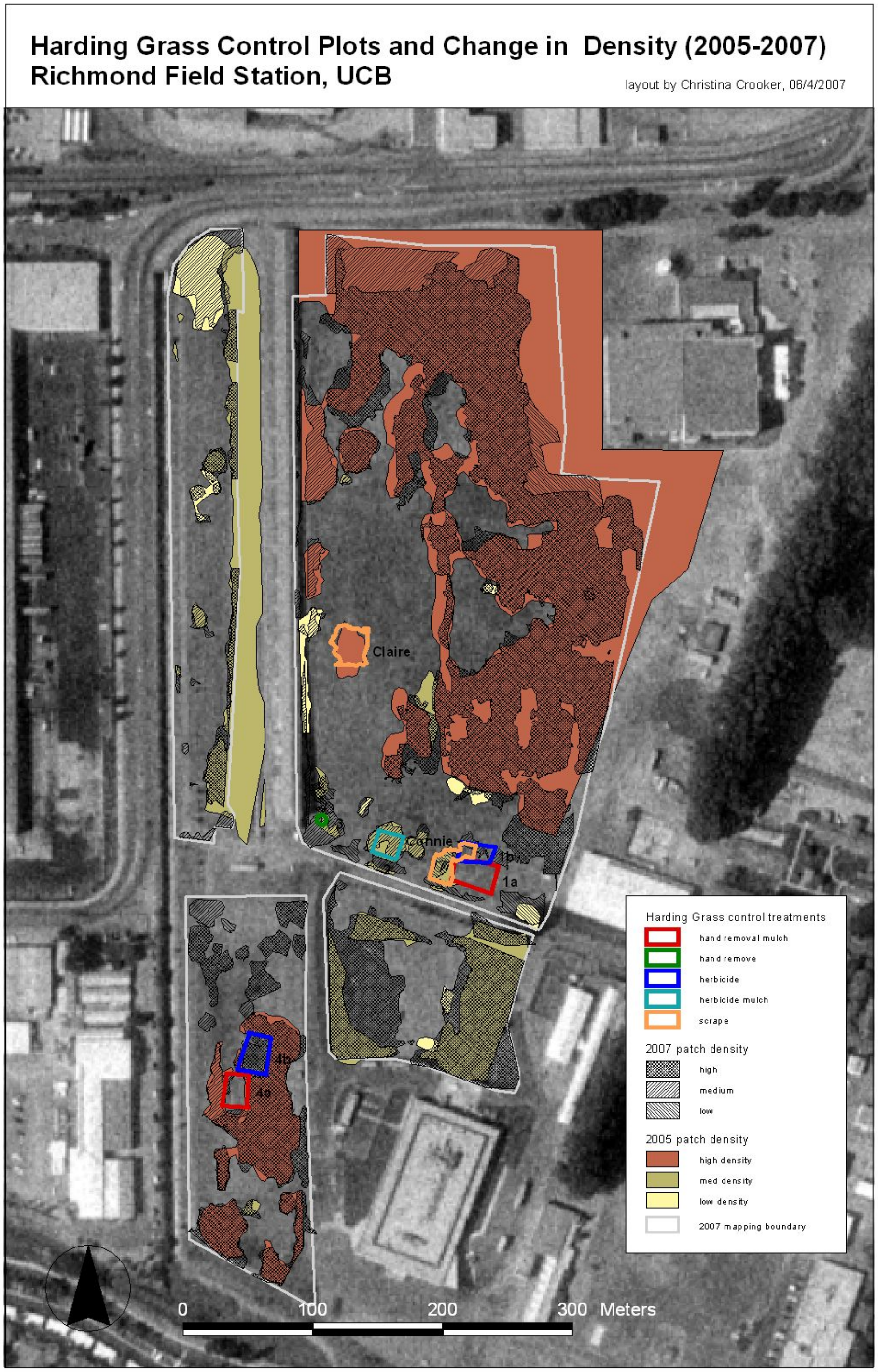
California Native Plant Society (CNPS) Rare Taxa
2006 Species Richness & 2007 Harding Grass Density
Richmond Field Station, UCB
layout by Christina Crooker, 05/21/2007
species richness
1
2
3
4
2007 patch density
high
medium
low
0
100
200
300 Meters

Figure 4.1.1c



Control Plots for Harding Grass (Phalaris aquatica)
Richmond Field Station, UCB
layout by Christina Crooker, 5/7/2007
Claire
3
2
Connie
1b
1a
4b
4a
N
0
100
200 Meters
Harding Grass Control Plots
hand removal mulch
hand remove
herbicide
herbicide mulch
scrape
study area

Figure 4.1.1d



Harding Grass Control Plots and Change in Density (2005-2007)
Richmond Field Station, UCB
layout by Christina Crooker, 06/4/2007
Claire
Connie
1b
1a
4b
4a
Harding Grass control treatments
hand removal mulch
hand remove
herbicide
herbicide mulch
scrape
2007 patch density
high
medium
low
2005 patch density
high density
med density
low density
2007 mapping boundary
0
100
200
300 Meters

Figure 4.1.1e

Harding Grass Control Plots, Change in Native Species
Richness and 2007 Harding Grass Density
Richmond Field Station, UCB
layout by Christina Crooker, 06/4/2007
Claire
3
Connie
2
1b
1a
4b
4a
Harding Grass control treatments
hand removal mulch
hand remove
herbicide
herbicide mulch
scrape
2007 patch density
high
medium
low
2007 mapping boundary
change in species richness
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
0
100
200
300 Meters

4.1.4.1 Summary of Experimental Control Results for Harding Grass

This section summarizes the results of a Harding grass test study performed within the coastal terrace prairie. This study was undertaken to investigate the efficacy of several possible treatments for this problematic species. Six control methods were tested and are described in Table 4.1.1.1, below.

1. Hand Removal
2. Mechanical scraping
3. Herbicide
4. Straw mulch and sheet mulch
5. Mowing & brushcutting
6. Hydro-mechanical obliteration

Several methods were also combined to test the efficacy of a multi-pronged control approach. These combined treatments are also described in the following section.

In summary, the most effective control seemed to be tied to dropping the soil level (thereby decreasing the distance to groundwater, and increasing soil wetness). Increasing soil wetness seemed to favor establishment of water-loving plants, and discourage establishment of Harding grass. Conversely, it is speculated that the reason Harding grass has not invaded some of the drier prairie areas is due to the increased distance from groundwater. It appears that Harding grass is most competitive within a limited soil moisture threshold. The groundwater monitoring study undertaken in 2006-7 (described in Section 5.4) was established as a means to confirm this hypothesis and identify this threshold. So far data has been limited due to the low rainfall recorded last year.

A combination of control techniques was found to be most effective. For small infestations, hand-removal, followed by spot application of herbicides on resprouts was determined to be the most effective technique. For large infestations, mechanical scraping, followed by long term monitoring and spot application of mulch and appropriate herbicides was found to be the most effective technique.

Table 4.1.1.1 Summary of Harding Grass Test Plot Study

Treatment	Plot Location	Summary of Treatment Methods	Results
Hand Removal	Plots 1A, 3, 4A	In the summer of 2004, all Harding grass plants, and associated biomass, including rootstock, were hand-removed from each plot. This treatment left each plot completely bare, and in some cases reduced the soil level of the plot. Because the cover of Harding grass was greater than 70 percent, other species present in the plots also had to be removed. The removal of Harding grass significantly lowered the ground level by several inches (4" or greater) in Plot 1A and 3. The resulting effect was that several of these plots turned into shallow ponds that persisted throughout the rainy season and more than a month beyond. Following removal, Plots 1A and 4 were covered with straw mulch, planted with native plants at an approximate density 2.5' centers, and weeded for all targeted non-native species identified in Table 4.0. Planting palettes are described in Section 3.3.	Results of hand removal across the three plots varied significantly. Following treatment, Plots 1A and 3 supported an increase in native species, and reduced numbers of Harding grass. Plot 4, however, supported mostly non-native grass species following treatment, and continued to have a high level of Harding grass infestation. This was attributed to the poor condition of the soils in Plot 4, including the presence of rubble, cement and other debris. Additionally, the surrounding area was dominated with annual non-native grasses, unlike the habitat surrounding Plots 1A and 3, which was primarily fresh water meadow and upland prairie.
Mechanical Scraping	Claire and Connie	Because hand-removal proved to be too prohibitively labor-intensive, mechanical scraping was investigated. In November 2006, another test plot was established to test mechanical scraping. The entire plot was scraped using heavy equipment prior to the first rains to minimize soil impaction. The plot location was determined by using the GIS analysis previously described, with the goal of removing a pioneer patch of Harding grass that was expanding into an area of high species richness. A 300 sq m. patch of Harding grass was selected as a high-priority for removal due to its proximity to a species-rich, seasonally wet, native habitat. Furthermore, this patch of Harding grass was visibly higher in elevation by 4-6" compared to the immediately adjacent, native habitat, suggesting that Harding grass had artificially built up the soil level. A mini-excavator was used to scrape approximately the top 6" of the plot until the soil level matched that of the adjacent native area. Following this treatment, native plants were installed. The plot was left uncovered (i.e. was not mulched) to enable native seedlings to emerge. Post-treatment monitoring in Spring 2007, identifying a number of naturally colonizing wetland species (see section 3.3).	Based on the initial recolonization of native seedlings, this remains a very promising technique, particularly for patches of Harding grass that were part of the mosaic of seasonally wet areas. It appears that Harding grass may have altered the low-lying coastal grassland not only by reducing habitat for native grass species, but also by building up soil levels that further allow it to out-compete water-loving native species. By lowering the soil level, wet-loving native species began to re-emerge at the site. The results of this method should be further monitored over time to better understand the resiliency of the treated plot.
Herbicide, one application	Plots 1B, 2, 4B	Herbicide application plots were established to test the efficacy of one application of glyphosate (1.5% solution) on Harding grass, and compare herbicide treatment to hand-removal. These plots initially had greater than 70% cover of Harding grass. These three plots were mowed after the initial flush of spring growth, and sprayed with herbicide once the plants re-grew to approximately a foot tall, typically in June and July.	Within a month, treated Harding grass plants exhibited total dieback. Furthermore, some of the native *Danthonia californica* and *Juncus phaeocephalus* plants, originally intermixed in the Harding grass showed signs of resprouting by late summer, despite lack of rain. Despite these initially promising results, by the end of the following rainy season (spring 2006), much of the Harding grass had resprouted. One application of glyphosate herbicide (1.5%) applied to new spring growth did not effectively treat Harding grass in this grassland. These plants have large root systems, and it is likely that one treatment is not enough to treat all the belowground biomass. Recommend multiple treatments, or

Table 4.1.1.1 Summary of Harding Grass Test Plot Study

Treatment	Plot Location	Summary of Treatment Methods	Results
			herbicide in combination with other control techniques.
Straw mulch (3-8 inches)	Added to Plots 1a, 2, and 4a	Application of a thick layer (3-8 inches) of weed-free straw mulch on top of previously treated plots (hand or mechanical scraping, herbicide application plots).	While no formal data was collected, our experience clearly revealed that straw mulch was effective at suppressing weed seedlings from establishing once plots had been initially treated, if sufficient amounts of straw are used. Used alone, or with just mowing, straw mulch would not control Harding grass. It is critical to use certified weed free rice straw. Some providers sell "weed free" rice straw with abundant seeds heads that are not thought to be weeds, however this is unacceptable
Mowing and brushcutting	Leading edges of larger infestation and isolated patches	Beginning in 2003, the Watershed Project arranged to have several large areas of the grassland mowed yearly. In 2006, RFS maintenance began to mow the entire grassland once or several times per season, depending on need. The entire grassland affected by Harding grass should be mowed several times each season; mowing should be timed to prevent the development of viable seed. Plants should not, however, be mowed early in the season before they bolt- this may increase tillering. See Appendix 2 for proposed mowing guidelines.	Results are mixed. Anecdotally numerous practitioners have stated that this grassland had been regularly mowed up till the 90s until the practice was halted due to concern over the native plant populations, and that before the 90's the grassland had relatively little Harding grass (David Amme, pers. comm.. 2006). Ironically, the cessation of mowing appears to have contributed to the rapid increase of Harding grass over this last decade. The latest thinking on the matter is that in this setting, mowing may actually provide a competitive advantage to native prairie species over Harding grass (Amme, personal conversation). While no evidence supports the claim that mowing can impact Harding grass, it is nonetheless worth continuing. It is possible that more frequent mowing can be used as a tool to negatively impact Harding grass vigor.
Hydro-mechanical obliteration	Located adjacent to Plot 1b	Hydro-mechanical obliteration is a technique developed by Cameron Colson that uses jets of water vapor at extremely high pressure to cut and pulverize plant material. In the fall of 2006, this method was tested on several Harding grass plants. The plants were first cut to the ground, and then the jet of water vapor was aimed directly at the root ball for 5-10 seconds until it was thoroughly shredded.	This method is ineffective by itself, but may be paired with other techniques such as herbicide application or repeated treatment. Approximately 1 month after treatment, each treated plant had approximately 5-10 re-sprouts and this pilot treatment was deemed to be unsuccessful. Plants were able to re-sprout from root fragments as small as 2" long.

4.1.4.2 Summary of Harding Grass Seed Germination Experiment Following Covering

A second treatment experiment was undertaken in 2004. This involved selecting one area (approximately 15 feet x 20 feet) with 80-100 percent cover of Harding grass, mowing the Harding grass and then covering the plot with carpet for a minimum of 18 months. The carpet was staked into the soil and initially covered with weed-free rice straw) This was undertaken at the suggestion of several practitioners (Schwartz, pers. comm.) who had success covering weeds with carpet and layers of cardboard as a means of preventing photosynthesis, and ultimately resulting in mortality.

The plot was left fully covered for approximately 19 months. At that time a small section of the carpet was removed and soil samples (approximately 2 nursery propagation flats of material) were taken and placed in the greenhouse. These samples were then, and the carpet still remains on site as a physical barrier for containing the leading edge of the larger infestation south of the plot. Additionally, two samples were taken from each of the other Harding grass control plots. Appendix 3 outlines the methodology and results from 3 months of monitoring which species germinated from each plot. No Harding grass germinated from the "carpet" plot during the nursery experiment, indicating that this treatment may reduce the seed bank viability. It did not reduce the viability of several forbs, such as scarlet pimpernel. California oat grass was the only native grass that germinated from this area, and overall few species were noted in comparison to other plots.

5.0 Monitoring

Various monitoring activities were undertaken as a part of the restoration projects. Monitoring activities provided opportunities for integrating research and student projects into the long-term management and stewardship of the RFS ecological resources. Additional funding was also secured from the San Francisco Foundation's Bay Fund to repeat the grassland monitoring project. Below are summaries of several monitoring efforts and associated results.

5.1 Photomonitoring

Photopoints were established in Western Stege Marsh and the coastal terrace prairie treatment areas in 2005. Appendix 4 contains the descriptions and maps of the photomonitoring points and images taken during the past 3 years at selected points.

5.2 Special Status and Locally Rare Plant Monitoring

The Watershed Project in collaboration with UC Berkeley initiated a vegetation inventory and monitoring program in the Richmond Field Station's (RFS) native grassland habitats in 2003. The inventory and monitoring program had 4 primary components:

- Inventory all plant species (native and non-native) within the designated project area;
- Vegetation community mapping consistent with the California Native Plant Society (CNPS) protocols;
- Rare and targeted native plants species abundance and distribution monitoring within the designated project area; and
- Harding grass distribution and density monitoring.

The first 3 components were initiated in 2003, with the fourth initiated in 2006 with the procurement of additional funding (see Section 5.0 above). A protocol for the rare and targeted species monitoring was developed in collaboration with UC Berkeley and the Golden Gate National Recreation Area (GGNRA) in 2003, with peer review performed by UC Berkeley staff and faculty (James Bartolome, Ellen Simms and Barbara Ertter). The protocol is located in Appendix 5. A volunteer botanist oversaw the 2003 monitoring effort, with support from UC Berkeley students, the Watershed Project staff and volunteers. Data was recorded on field monitoring sheets and then digitized. Table 5.2a lists the known special status species as identified in Rare, Unusual and Significant Plants of Alameda and Contra Costa Counties, 7th Edition (Lake, 2004). Grassland species identified in this Table were included in the list of species recorded. Barbara Ertter and other UC professors added other species, bringing the total number of species to 43.

Table 5.2a : Locally Significant Plant Species in the Richmond Field Station Prairie

Based on Rare, Unusual and Significant Plants of Alameda and Contra Costa Counties, 7th edition, March 2004, by Dianne Lake

Species	*special status*	*rare at RFS*	*mapped in 2002*
Carex densa	*Ua2*	-	X
Carex subbracteata	*Ub*	-	X
Centuculus mininus	*Ua1*	X	X
Cicendia quadrangularis	*Ub*	X	X
Elymus trachycaulus	*Ub*	X	X
Elymus x hansenii	*Ua2*	X	X
Eryngium armatum	*Ua2*	-	X
Hordeum jubatum	*Ua2*	-	X
Juncus phaeocephalus var phaeocephalus	*Ub*	-	X
Rumex salicifolius var. salicifolius	*Ub*	X	X
Spiranthes romanzoffiana	*Ua1*	X	X
Stachys ajugoides var. ajugoides	*Ua2*	X	X

Ua A species given special status by state or federal agencies or by state level of CNPS. Protected by CEQA*

Ua1 Species known in 2 or less botanical regions in the counties

Ua1x Species believed to be extirpated

Ua2 Species currently known from 3 - 5 regions in the two counties, or meeting other important criteria
Ub A High- Priority Watch List: Species currently known from 6 - 9 regions in the two conunties, or meeting other important criteria
Uc A second priority watch list: species known from 10 or more regions in the two counties, but potentially threatened if certain conditions persist.

Attributes for the 43 native plant species were recorded in the database; the species are listed in Table 5.2b below. As noted above, these species were selected based upon their local rarity, limited abundance in the grassland, and association with wet meadow or wetland habitat. Plants were identified as "rare at the RFS" by Barbara Ertter of the Jepson Herbarium, in conjunction with Diane Lake's "Regionally Significant" categorization. See Appendix 5 for additional information. The grassland supports many other species however they were not included in this analysis. Table 5.2c identifies all of the additional species that were added to the flora list following the completion of the inventory. It also lists the voucher specimens that were collected and provided to the Jepson Herbarium per the request of Barbara Ertter.

The change in each of the 43 species' distribution and abundance was analyzed using GIS. The change in cover class designation (positive, negative or neutral) for each species was projected. For example, Figure 5.2a illustrates the change in distribution and abundance of *Ajuga*, hedge nettle. The red shading in each monitoring quadrat notes a positive change in cover class (therefore indicating an increase in the population size in that quadrat) and the blue shading indicates a decrease in the cover class designation. Overall, both the abundance and distribution of this species increased. A similar analysis was performed for each species, with varying results depending upon the species. Figure 5.2b depicts the same analysis for sun cups (*Camissonia ovata*). Layouts for all species are included on a CD that is a part of this report.

Figure 5.2c illustrates the overall native plant species richness and distribution for the grassland habitat, based upon the monitoring results from the individual 43 native plants species. The areas of greatest richness are located within the center of the main grassland (with some 10-meter x 10-meter plots supporting 13 targeted native plants) and in the western grassland habitat.

A GIS analysis was also performed for the 9 CNPS-listed locally rare plants species that are found in the grassland habitat. These species are listed in Figure 5.2d. The cumulative distribution and abundance of these species was analyzed and the results illustrated in Figure 5.2d. This layout provides a tool for understanding the areas of greatest locally-rare plant richness and a tool to focus habitat restoration efforts in areas of greatest sensitivity. The main grassland habitat supports the greatest richness of locally rare species. Figure 5.2e below identifies the locations of the Danthonia alliance releve plots identified within the prairie.

Appendix 6 includes the protocol for the GIS analysis and Appendix 7 includes the GIS metadata.

Table 5.2b Coastal Terrace Prairie Species Assessed for Changes in Distribution and Abundance

Coastal Terrace Prairie Species	Specia l Status	Rare @ RFS	Mapped in 2003	Mapped in 2006	Notes
Aster chilensis	-	-	X	X	
Baccharis pilularis	-	-	X	X	
Brodiaea elegans	-	X	-		
Bromus carinatus	-	X	X	X	
Calystegia occidentalis ssp. Occidentalis	-	?	-	X	
Calystegia subacaulis ssp. Subacaulis	-	X	X	X	
Calandrinia ciliate	-	X	-	X	
Camissonia ovata	-	-	X	X	
Cardamine californica	-	X	X	X	
Carex densa	Ua2	-	X	X	
Carex subbracteata	Ub	-	X	X	
Chlorogalum pomeridianum	-	-	-	X	
Castilleja exserta ssp. Exserta	-	X	X	-	
Centuculus mininus	Ua1	X	X	-	
Cicendia quadrangularis	Ub	X	X	X	
Danthonia californica var. californica	-	-	-		too ubiquitous
Dienandra (Hemizonia) congesta ssp. luzulifolia	-	-	X		
Eleocharis macrostachya	-	-	-	X	
Elymus glaucus ssp. Glaucus	-	X	X		
Elymus trachycaulus	Ub	X		X	
Elymus x hansenii	Ua2	X	X		
Elymus multisetus	-	X	X	X	
Eryngium armatum	Ua2	-	X	X	
Festuca idahoensis	-	X	-	X	
Grindelia hirsutula var. hirsutula	-	-	X	X	
Hemizonia congesta			X	X	
Heteromeles arbutifolia	-	-	X	X	
Hordeum brachyantherum	-	-	X	X	
Hordeum jubatum	Ua2	-	X	X	
Juncus bufonius var. bufonius	-	X	X	X	
Juncus bufonius var. congestus	-	X	X	X	
Juncus occidentalis		-	-	X	Not mapped in 2003, too ubiquitous
Juncus patens	-	X	X	X	
Juncus phaeocephalus	-	-	X	X	
Lagophylla ramosissima (ssp. not identified)	-	-	-		
Lotus purshianus	-	X	X	X	
Lotus wrangelianus	-	X	X	X	
Lupinus albifrons	-	X	-		
Lupinus bicolor	-	X	X	X	
Lupinus formosus formosus	-	X	X		
Lupinus nanus				X	
Madia sativa	-	-	X	X	
Nassella pulchra	-	-	X	X	
Pentagramma triangularis	-	X	X	X	
Ranunculus californica	-	-	X	X	
Rumex salicifolius var. salicifolius	Ub	X	X	X	
Sisyrinchium bellum	-	-	X	X	
Spiranthes romanzoffiana	Ua1	X	X	-	
Stachys ajugoides var. ajugoides	Ua2	X	X	X	
Triteleia hyacinthine	-	X	X	X	
Triphysaria pusilla	-	X	X	X	
Wyethia angustifolia	-	-	X	X	

Table 5.2c Additions to RFS Flora

Observed and compiled by Lee Echols, Claire Beyer, Sharon Farrel and Watershed Project Interns - spring 2003
Nomenclature after Hickman et. al. 1993, special status per Lake,2004.

Family	Scientific Name	Common Name	Native *	Special Status	Mapped	Date Observed	Phenology	Comments	Voucher *
PTERIDACEAE	*Pentagramma triangularis* ssp. *triangularis*	goldback fern	*		Yes	3/17/2003	vegetative	Only several clumps found within study area	*
ASTERACEAE	*Hypochaeris radicata*	rough cat's ear				5/20/2003	flower		
	Senecio vulgaris	common groundsel				3/17/2003	flower		
BRASSICACEAE	*Cardamine oligosperma*		*			3/11/2003	fruit/flower		*
CARYOPHYLLACEAE	*Polycarpon tetraphyllum*	four-leaved allseed				5/20/2003	flower		*
FABACEAE	*Lupinus bicolor*	miniature lupine	*		Yes	3/25/2003	flower	Only observed in mowed areas of the field station; few plants observed	
	Lupinus formosus var. formosus	summer lupine	*		Yes	6/2/2003	flower		*
	Trifolium campestre	hop clover			Yes	3/25/2003	flower	Found in mowed area	*
	Trifolium hirtum	rose clover				3/25/2003	flower	Found In mowed area	*
	Vicia sativa ssp. nigra	common vetch				3/18/2003	flower/fruit		
POLYGONACEAE	*Polygonum arenastrum*	common knotweed				3/25/2003	flower	Found in cracks of pavement on Lark Dr.	

Table 5.2c Additions to RFS Flora

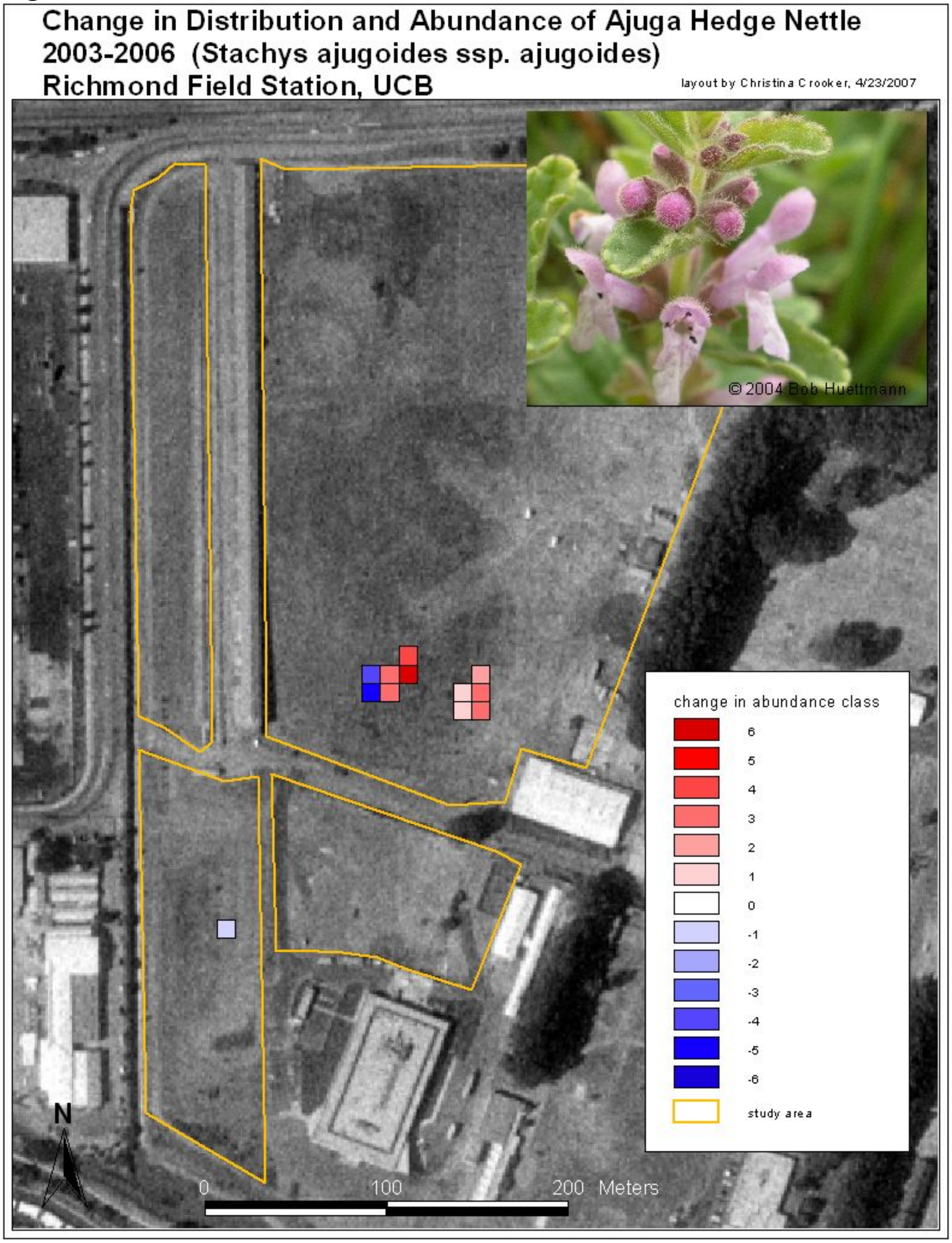
Observed and compiled by Lee Echols, Claire Beyer, Sharon Farrel and Watershed Project Interns - spring 2003
Nomenclature after Hickman et. al. 1993, special status per Lake,2004.

Family	Scientific Name	Common Name	Native *	Special Status	Mapped	Date Observed	Phenology	Comments	Voucher *
	Rumex salicifolius var. salicifolius	willow dock	*	W	Yes	5/5/2003	flower		*
PORTULACACEAE	*Centunculus minimus*	chaffweed	*	Ua1	Yes	4/13/2003		>100 plants observed in mowed field south of Lark outside of study area; found in scattered, moist, bare or mossy areas with *Cicendia quadrangularis* and *Juncus bufonius* var. *congestus;* all flowering specimens white flowers	*
PLANTAGINACEAE	*Plantago erecta*	California plantain	*			6/2/2003 4/7/2003	flower flower	Found east of the EPA building	
SCROPHULARIACEAE									

	Castilleja exserta ssp. exserta	purple owl's clover	*			5/20/2003	flower/fruit	Small population found in NE portion of study area North of Lark Dr. in marginal weedy area	
CYPERACEAE	*Eleocharis macrostachya*	spikerush	*			3/31/2003	flower	All plants observed with 2 stigmas/flower	*
JUNCACEAE	*Juncus bufonius* var. *bufonius*	toad rush	*		Yes	6/2/2003	flower	Possibly *J. bufonius* var. *halophyllus*; systematics for this species currently under review	*
	Juncus phaocephalus var. *phaocephalus*		*	w	Yes		flower	Sometimes occuring in close proximity to other plants that exhibit characteristics of *J. phaocephalus* var. *paniculatus*.	
ORCHIDACEAE	*Spiranthes romanzoffiana*	ladies' tresses	*	Ua1	Yes	7/8/2003	flower	Only one individual observed in main portion of study area North of Lark Dr.; plant previously reported from RFS by David Amme in 1993;	Photo documentation

								previously presumed extirpated from East Bay flora	
LILIACEAE	*Romulea rosea*					3/17/2003	flower		*
POACEAE	*Cynodon dactylon*	Bermuda grass				6/15/2003	flower	Found in mowed area	*
	Elymus hansenii		*	Ua2	Yes	5/20/2003	flower	One small clump observed in central portion of main study area North of Lark Dr.; hybrid resulting from cross between *E. glaucus* and *E. multisetus* or *E. glaucus* and *E. elymoides.*	*
	Gastridium ventricosum	nit grass				6/15/2003	flower		*
	Hordeum brachyantherum ssp. *brachyantherum*	meadow barley			Yes	5/5/2003	flower		*

Figure 5.2a



Abundance classes were ranked based upon number of individuals within one survey square of 10 meters squared as follows: Class 1, species not present; Class 2, 1-10 individuals; Class 3, 11-25; Class 4, 26-50: Class 5, 50 – 75; Class 6, 75 – 100; Class 7, 100+. Change in abundance class is the 2003 abundance class rank subtracted from the 2006 rank.

Figure 5.2b

Change in Distribution and Abundance of Sun Cups 2003-2006 (Camissonia ovata) Richmond Field Station, UCB

layout by Christina Crooker, 5/7/2007

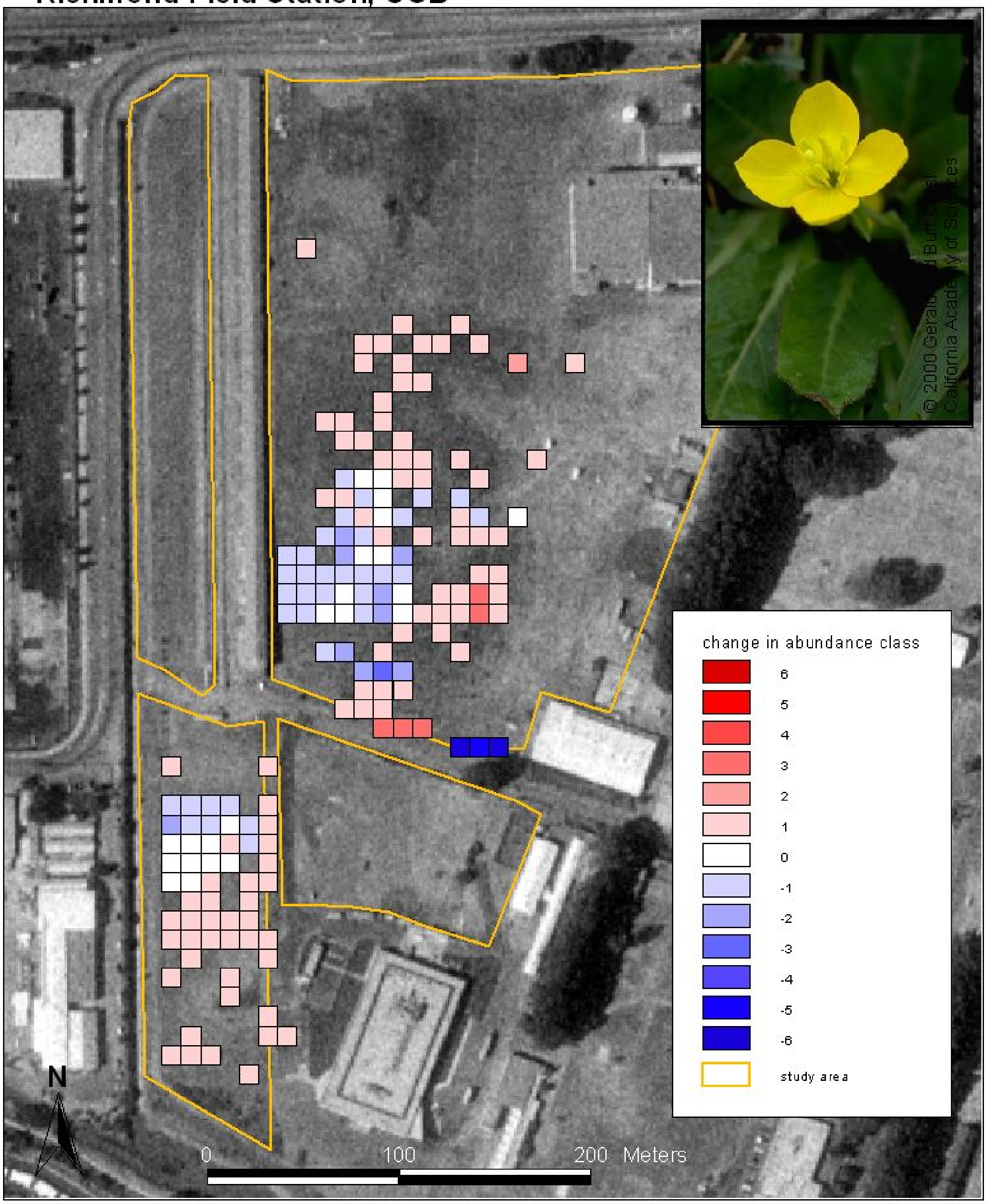
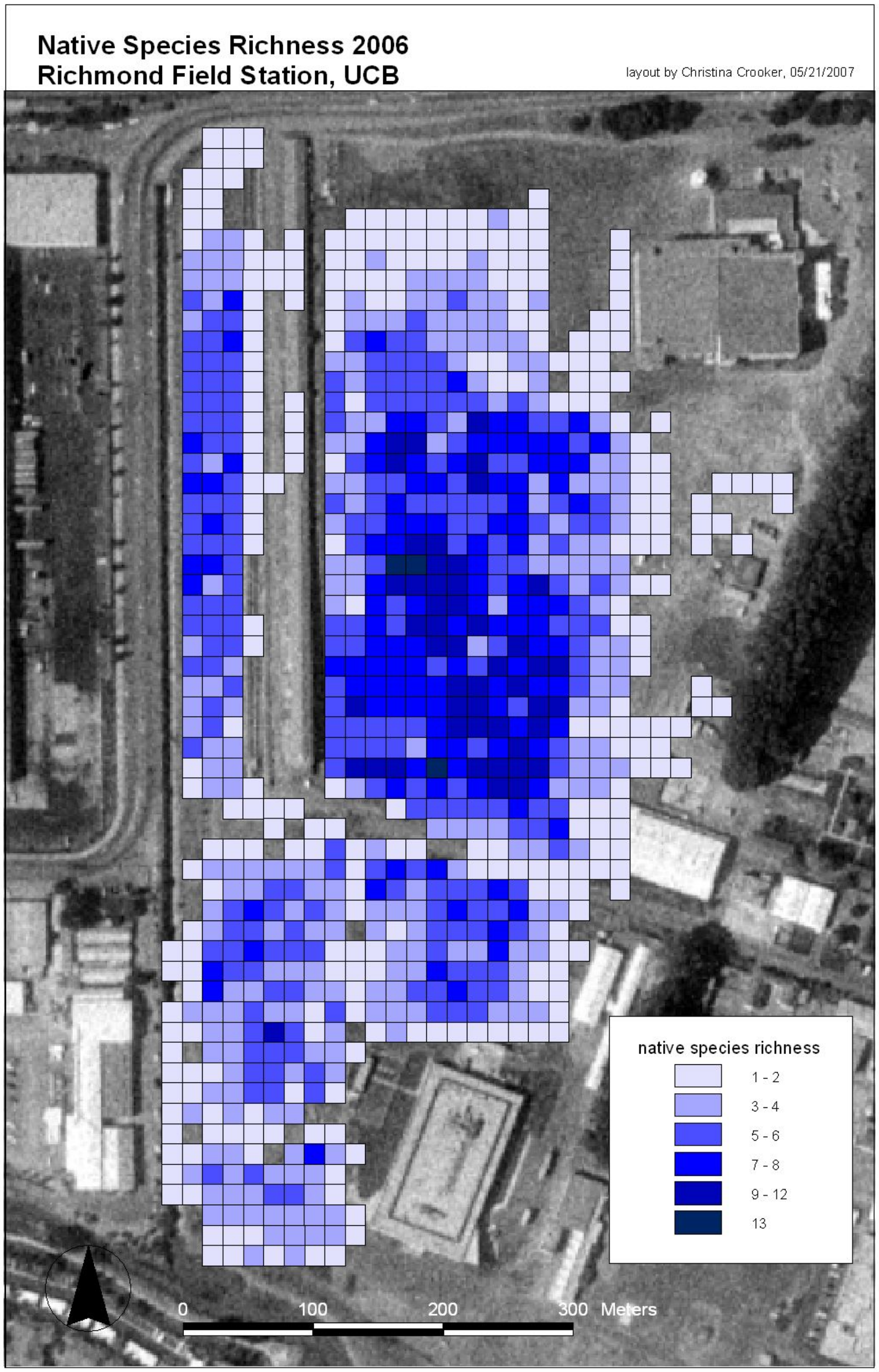


Figure 5.2c



Native species richness is defined by the number of different native species per 10 square meter survey square.

Figure 5.2d

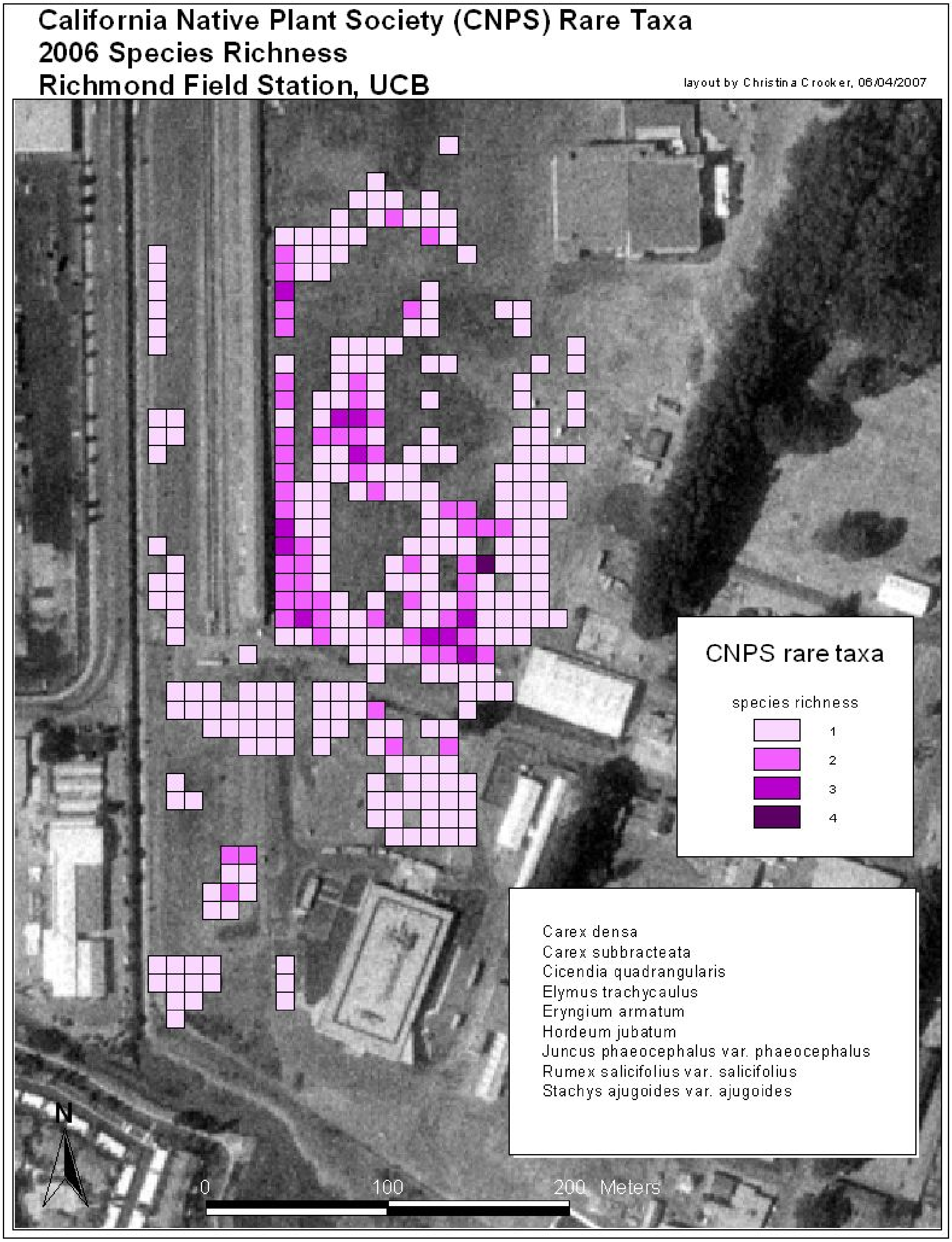
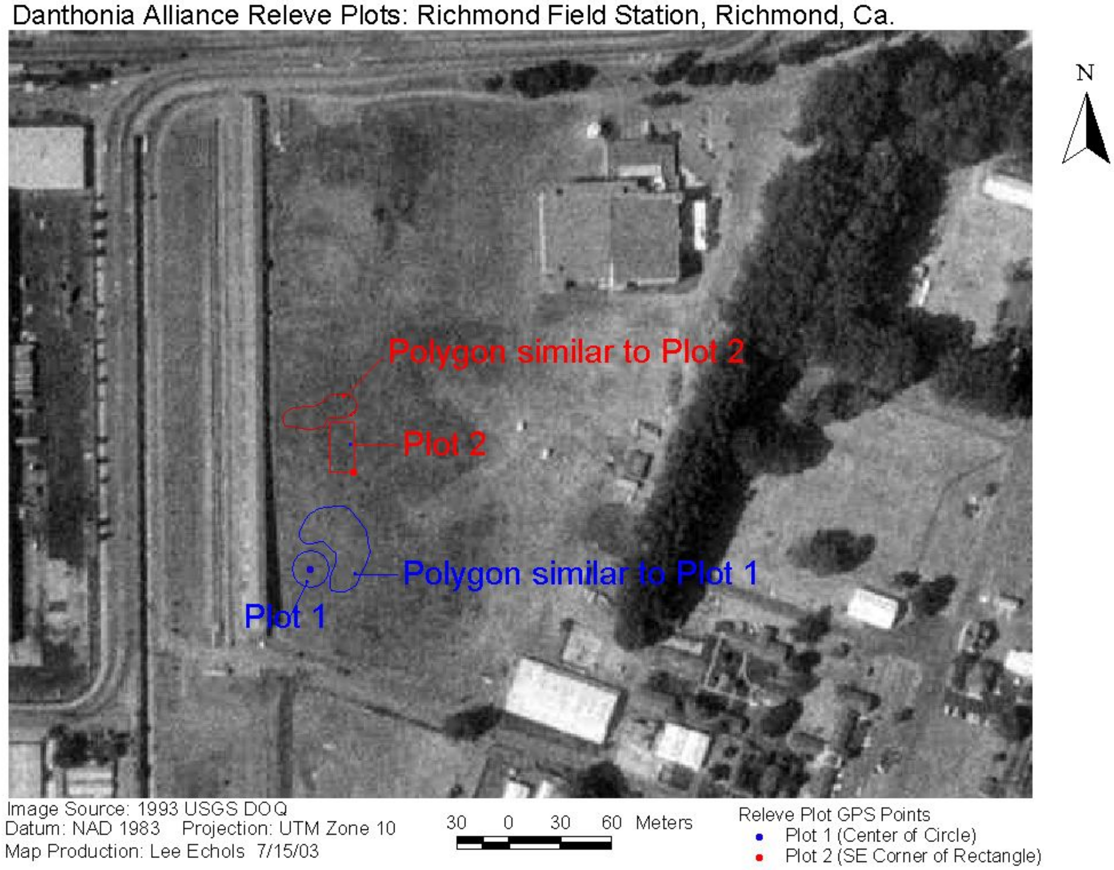

California Native Plant Society (CNPS) Rare Taxa
2006 Species Richness
Richmond Field Station, UCB
layout by Christina Crooker, 06/04/2007
CNPS rare taxa
species richness
1
2
3
4
Carex densa
Carex subbracteata
Cicendia quadrangularis
Elymus trachycaulus
Eryngium armatum
Hordeum jubatum
Juncus phaeocephalus var. phaeocephalus
Rumex salicifolius var. salicifolius
Stachys ajugoides var. ajugoides
N
0
100
200 Meters

Figure 5.2e



This photograph is of Plot 2 taken from the south.

5.3 Wildlife Monitoring

Staff from the Watershed Project performed bird monitoring in the marsh during 2005 and 2006. This effort was in part funded through a grant from the San Francisco Foundation. Surveys were conducted two times during the last week of each month, one time at a high tide of 4-5 and another time at a low tide of 2-3. Observers counted the number and species of birds in the marsh, upland or overhead from 3 stations (one station located east of the marsh, one station located south of the marsh on the access road and the final observation station located on the bay trail west of the marsh). At least two monitors worked closely together, with one person recording the data and the others identifying, counting and observing behaviors of species in and around Stege Marsh. Behavior was also noted.

Table 5.3 is a summary of the monitoring data recorded. Appendix 8 includes the monitoring protocol.

Table 5.3. Stege Marsh Shorebird Census

SPECIES/ DATE	9/05	10/05	12/05	1/06	2/06	3/06	4/06	5/06	6/06	7/06	8/06	10/06	11/06	1/07	2/07	4/07	7/07
Pied-billed Grebe																	
Eared Grebe																	
Western Grebe																	
White Pelican																	
Double-crest. Cormorant										3							
Brandt's Cormorant																	
Great Blue Heron										1	1	1					1
Great Egret					1					3	1		1				1
Snowy Egret	3				1				2	2	1				1		1
B-C Night Heron																	
Black Brant																	
Canada Goose	16				11	4	14	7		14			11	3	6	14	1
Green-winged Teal			2											5			
Mallard		17	2	4	13	13			2				5		2		
Northern Pintail																	
Northern Shoveler																	
Gadwall																	
American Wigeon															2		
Eurasian Wigeon																	
Canvasback																	
Greater Scaup																	
Lesser Scaup																	
Surf Scoter																	

SPECIES/ DATE	9/05	10/05	12/05	1/06	2/06	3/06	4/06	5/06	6/06	7/06	8/06	10/06	11/06	1/07	2/07	4/07	7/07
White-winged Scoter																	
Common Goldeneye																	
Red-breasted Merganser																	
Bufflehead																	
Ruddy Duck																	
Clapper Rail																	
American Coot			11	38	17	4							8	9	16		
Black-bellied Plover	5	2			6									4			
Semipalmated Plover	2	61					3		2							7	10
Killdeer	18	121			275	90	4	13	13	52	20	6	9	30	2	40	43
American Avocet		1	11	40	6	11			8				3	30			9
Greater Yellowlegs																	
Willet	1	1			6	1				7			1				9
Whimbrel						29			1								2
Long-billed Curlew	2	1				1			1	2				1	2		
Marbled Godwit	2	2		8	51	22				6		2	1				
Ruddy Turnstone																	
Black Turnstone																	
Sanderling																	
Western Sandpiper	75	100					13			7			15	1,000		150	123
Least Sandpiper					132									10			
Dunlin																	
Dowitcher spp.																	
Common Snipe																	
Red Phalarope																	
Gull spp.	5	2	5	2		1	2	2	2	9		4	2	1	2	2	1
Forsters Tern																	
Caspian Tern							1									1	
Elegant Tern																	
Osprey										1							
Turkey Vulture	1					1						3	4	1			
Cooper's Hawk																	
Red-tailed Hawk															1		

SPECIES/ DATE	9/05	10/05	12/05	1/06	2/06	3/06	4/06	5/06	6/06	7/06	8/06	10/06	11/06	1/07	2/07	4/07	7/07
Northern Harrier																	
American Kestrel		1									1			1	1	1	
Anna's Humingbird																	
Red-winged black Bird								2		4							
House finch																	
Black Phoebe	1									2	1			3			1
American Crow					3		2					1	3	1	2		
Raven										5							
Barn Swallow							2		1								1
Swallow spp.									4	6						3	
CA Towhee									2								
Fox Sparrow																	
Song Sparrow		6															
White-crowned sparrow															2		
Golden-crowned sparrow				2													
Sparrow spp.					2												
Mourning Dove	1	1							1		1	1	2			1	
Meadowlark		1			2										1		
Wren spp.															1		
Blackbird														25			
Starling																	2

5.4 Groundwater and Distribution of Harding Grass

Harding grass has a significant negative impact on the ecological function and native prairie richness within the coastal terrace prairie. While its distribution comprises approximately 45 percent of the northern coastal terrace prairie habitat, it appears to be restricted to certain areas. Staff from the Watershed Project and other restoration practitioners speculated that the species' distribution was limited by soil moisture and possibly groundwater depth. This was further supported after Plot 1a was treated and the depth to groundwater decreased. Surface water was expressed for approximately 1-2 months following the cessation of rainfall.

Staff in partnership with UC Berkeley interns and Professor Barbara Allen-Diaz from the Department of Forestry and Resource Management Information developed an experimental design that placed transects of hollow stakes through out the coastal terrace prairie. John Welsh, an undergraduate student at UC Berkeley installed more than 20 hollow stakes in areas supporting dense stands of Harding grass and in areas with no colonization. Additionally, transects were also placed along the leading edges of discreet infestations to better understand the variance of groundwater depth with relationship to Harding grass establishment and early colonization. The study further aimed to examine the correlation between plant community types and water table fluctuation patterns. Weekly measurements of hollow stakes were taken to monitor the fluctuation pattern. The grassland was broken into four types of vegetation communities (annual non-native, wet native, Harding grass and dry native prairie).

A summary of the study findings is presented in Appendix 9. The preliminary data (taken in 2006-7) showed that other factors in addition to plant community type contribute to the water table fluctuation patterns. It appears that Harding grass recruitment is happening in the wetter areas of the grassland. In the wells in Harding grass infestations the water table was much higher than in the wells in dry native prairie habitat. Water table levels were comparable to the wells in the wet native areas in the wettest time of the season, however the Harding grass wells dried up more quickly than areas dominated by the wet native plant species.

This is confirmed by "designated plot 2" in which 2 of the Harding grass wells had a much higher water table level than the natives which were located in the adjacent dry native grassland areas. The dry native prairie areas appear to be much drier than any of the other community types possibly due to a higher elevation in those areas.

The study speculated that a possible mechanism for Harding grass invasion is recruitment into areas that would otherwise be dominated by wet natives and then drying out the area to the point where wet natives can no longer compete with it.

Data is being collected by UC Berkeley interns in 2007-8 to further refine the early project findings. If groundwater elevations can be used to predict areas of future invasion, this data set can be used concurrently with the locally rare species GIS data to prioritize infestations for future control. Additionally, gaining a better understanding of the effect of groundwater depth with relationship to Harding grass invasion will guide future control treatments and restoration goals.

5.5 Effects of Mowing on Invertebrate Richness

In 2007, Senay Yitberak, a UC Berkeley student conducted a study about the impact of mowing as a management strategy for Harding grass control on invertebrate populations. His study addressed the effects of Harding grass on herbivore communities. It also examined the direct effects of mowing Harding grass on herbivores.

The findings of his study are presented in Appendix 10. The study determined that herbivore abundances were highest in un-mowed native grass treatments. Grass stands dominated by Harding grass that underwent mowing had significantly lower insect abundances. Additionally, Harding grass stands that were unmowed also exhibited low insect abundance.

The results concluded that although mowing may be an effective tool to control invasive plant species in restored grasslands, care must be taken to consider the impacts on native insect communities.

5.6 Vegetation Monitoring – Plant Species Inventory Updates

In 2002-3 URS botanists conducted a series of botanical surveys throughout the RFS. The survey findings are published in the Richmond Field Station Remediation Project (URS, 2003). Staff and volunteers with the Watershed Project have continued to update the URS plant list, with the most recent list included in Appendix 11.

6.0 Continued Management Recommendations

The following section outlines recommendations for future management of both the restored marsh and coastal terrace prairie. The recommendations are made under the assumption that UC Berkeley will continue to assume the full leadership of the restoration project with the support of consultants, contractors and a small group of University students. It also assumes that the multi-aged model for stewardship, where students and local community members were fully integrated into all management actions will not continue to the same level as facilitated by the Watershed Project from 2003 – 2007.

Recommendations are based upon the current staffing model. Under this model, one contracted Restoration Coordinator manages the restoration program's daily operations, native plant nursery, record keeping, and contractor schedules. The Restoration Coordinator also recruits, trains, manages and evaluates volunteers. Additionally, the Restoration Coordinator maintains the working partnerships with the UCB staff, EBRPD, ISP, CNGA, CNPS, the Watershed Project and the UC Berkeley RFS Maintenance staff.

6.1 Invasive Non-Native Plant Control

Restoration and invasive non-native plant control actions should continue to be guided by the performance standards and directives as articulated in the Western Stege Marsh Restoration Project Monitoring Plan (BBL, 2004a). The primary focus should be controlling all targeted highly invasive seedlings and resprouts, and early colonizing weed species that impact the growth and vigor of plantings within the ecotone and upland plots.

This work should be accomplished through a combination of contractor and volunteer support. Table 7.1a identifies the targeted weeds and also outlines the anticipated control responsibilities for the 2007-2008 project calendar. This table should be modified for subsequent years by the Restoration Coordinator based upon site conditions and achievement (or not) of performance measures.

For 2007-2008, it is recommended that the Restoration Coordinator, with the support of the volunteer program, should be responsible for the following:

- Monitoring the distribution of targeted invasive non-native plants;
- Early detection, and control of pioneer species;
- Controlling weeds within at least a 2-foot buffer of plantings (except weeds that are identified for Contractor control); and
- Monitoring and controlling smooth cordgrass seedling and outboard infestations in coordination with ISP.

Only contractors should perform herbicide applications, flame seedling (if approved by UC Berkeley, and use chainsaws, unless otherwise authorized by UC Berkeley. The Restoration Coordinator should use the control methods outlined in Table 4.1a unless other viable methods are developed. If other volunteer-appropriate methods are implemented, the Restoration Coordinator should update Table 4.1a to record methods.

Smooth cordgrass control should continue using the same guidelines as previously stated in this report. All emerging seedlings should be mapped and removed from the marsh habitat. The outboard stands should be mapped and monitored on a bi-weekly basis to ensure that control measures are effective and that no plants flower and no new patches establish. All of the smooth cord grass control should continue to be recorded and document with the ISP. All monitoring and management actions should be documented on a quarterly basis

Table 7.1a Invasive Non-Native Plant Control Responsibilities

Scientific Name	Common Name	Marsh	Island	Grassland	Preferred Control Period (Quarter)
Acacia sp.	Acacia, green wattle	S	C		Q3, Q4
Avena fatua	Wild oat	AP	AP		Q1
Bassia hyssopifolia	Bassia, five hook bassia	S			Q1,Q2,Q3
Beta vulgaris	Beet	S			Q2
Brassica raphanistrum	Wild mustard	AP	AP		Q2
Briza maxima	Rattlesnake grass	AP	AP		Q1
Bromus diandrus	Ripgut brome	AP	AP		Q2
Centaurea solstitialis	Yellow star thistle		S	S	Q2, Q3
Cirsium vulgare	Bull thistle	S			Q2
Conuim maculatum	poison hemlock			S	Q2,Q3
Conyza sp.	Horseweed	AP			Q2
Cortaderia jubata	Pampas grass, jubata grass		S	S	Q2, Q3
Cotula coronopifolia	Brass buttons	C			Q2, Q3, q4
Dipsacus fullonium	Teasel	S		C	Q2,Q3
Dittrichia graveolens	Stinky tarweed	S			Q3,Q4
Epilobuim sp.	Fireweed	AP			Q2, Q3
Foeniculum vulgare	Fennel	S&EBRPD	S	S	Q2, Q3
Gnaphalium sp.	Cudweed	AP			Q2, Q3
Hordeum murinum	Hare barley	AP			Q2
Lepidium latifolium	Perennial pepperweed	C	C		Q1,Q2
Lolium multiflorum	Italian ryegrass	AP	AP		Q2
Lotus corniculatus	Lotus	C			Q2, Q3
Lythrum tribracteatum	Loosestrife	C		C	Q2,Q3
Medicago polymorpha	Burr clover	AP			Q2, Q3
Melilotus sp.	Sweet clover	S			Q2, Q3
Phalaris aquatica	Harding grass	S	S	C	Q2, Q3
Picris echioides	Bristly ox-tongue	AP		AP	Q2, Q3
Plantago coronopifolia	Cut-leaved plantain	AP		AP	Q2
Plantago lanceolata	Plantain	AP		AP	Q2
Polygonum arenastrum	Common knotweed	AP			Q2
Raphanus sativus	Wild radish	AP	AP		Q2,Q3
Rubus discolor	Himalayan blackberry		C	S	Q2,Q3
Rumex crispus	Curly dock	AP		AP	Q2, Q3
Salsola soda	Russian thistle	S			Q2,Q3,Q4
Sonchus asper	Sow thistle	AP		AP	Q2
Spartina alterniflora	Smooth cordgrass	S & ISP			Q3,Q4
Tragopogon porrifolius	Salsify			S	Q2, Q3

Table 7.1a Invasive Non-Native Plant Control Responsibilities

Scientific Name	Common Name	Marsh	Island	Grassland	Preferred Control Period (Quarter)
Notes:	Q1= Jan-Mar Q2= Apr-Jun Q3= Jul-Sept Q4= Oct-Dec				
Control Responsibility:	S=Stewardship/Restoration Coordinator C= Contractor AP= Control around plantings (stewardship/restoration coordinator) EBRPD= East Bay Regional Parks District coordinated by restoration coord. ISP= Invasive Spartina Project				

Recommendations for grassland restoration efforts are as follows. Control of Harding grass and teasel should remain the primary focus of the grassland restoration efforts. Contractor support for grassland restoration should include herbicide application of Harding grass re-sprouts and seedlings, and hand removal and herbicide spot-control of teasel, with support when feasible from the Restoration Coordinator and volunteers. Seedlings, resprouts and incipient patches within the 4-acre project area should remain the focus of the control activities. The Restoration Coordinator should work with the UC Berkeley maintenance staff to continue to strategically mow the dense stands of Harding grass to limit seed set and expansion, and to coordinate the timing of herbicide application with the Contractor. The mowing guidelines attached in Appendix 2 should be followed and amended as needed in coordination with the RFS Maintenance staff. The Restoration Coordinator should submit a written request annually through the UC Berkeley Environmental Programs staff to request and confirm mowing support. The Restoration Coordinator should also continue to lead 4-6 work days in the grassland restoration areas to control the loosestrife in the scraped plots and other targeted weeds as noted in Table 7.1a.

6.2 Revegetation

The 2007 marsh vegetation monitoring report (May & Associates Inc., March 2008) indicates that three of the four performance standards for revegetation of West Stege Marsh have been met or exceeded. The overall percent cover of native vegetation is 59%, exceeding the target of "greater than or equal to 40 percent cover". The acreage of pickleweed mapped in 2007 exceeds the target of 0.9 acre covered, and also exceeds the Year 5 project target of 1.5 acres. Additionally, the marsh and ecotone support both high species diversity and cover. Patches of salt grass, salty Susan, marsh lavender and other species are well distributed throughout the marsh system. A project target was also set for vigor of the planted stock in Year 3 of "80 percent of the quadrats with planted stock showing 'good' or 'excellent' vigor". There were 27 quadrats with planted stock in 2007, and 22, or 81%, of these were assessed as exhibiting good or excellent vigor.

However, the 2007 marsh vegetation monitoring data (May & Associates Inc., March 2008) also indicate that Pacific cordgrass cover does not meet the required performance standards of 1.3 acres for Year 3. The coverage of Pacific cordgrass in 2007 was 0.38 acres, 29% of the target. The combined coverage of pickleweed and cordgrass does exceed the combined target acreage. Additional Pacific cordgrass plantings may be required to help the project meet performance standards into the future. However, it is important to note that our observations seem to indicate that Pacific cordgrass is

establishing well in certain areas of the site, most likely linked to a specific elevation, tidal innundation, and moisture regime. It appears that Pacific cordgrass is not establishing well in other areas of the site that lack these characteristics, and it is very likely that this species may not thrive in these other locations during the 5-year performance period and beyond. In addition, while the cordgrass plantings exhibit excellent vigor, the rate of growth is much slower than was anticipated. Slow growth rates have been observed in other restored marsh systems in the Bay Area. Based upon both of the above factors, it is recommend that a more reasonable performance standard be considered for the Pacific cordgrass cover, that reflects the actual acreage of the site that falls within the elevational range, moisture regime, and tidal innundation where Pacific cordgrass is likely to thrive and persist over time.
Therefore, prior to initiating any additional planting, it is recommended that UC Berkeley engage in discussion with USFWS and RWQCB staff to re-evaluate and possibly reduce the current performance standards that are articulated in the Western Stege Marsh Restoration Project Monitoring Plan. Given that the marsh has excellent cover from a variety of native plant species, Western Stege Marsh may provide high quality habitat without dense stands of Pacific cordgrass.

If additional plantings are required to meet the modified performance standards, it is recommended that the same propagule source and collection methods that were previously used be followed again. Plantings should be installed within the same elevational range as the plantings that currently support highest vegetative cover and plant vigor. Within this elevational band, plantings should be placed more densely in areas where current cover is sparse or non-existent. It is anticipated that this would require an additional 4,000 – 6,000 divisions. It is likely, based on observed rates of spread from previous plantings, that a significant increase in Pacific cordgrass vegetation cover from new plantings would not likely be observed until the second or third growing season, therefore, performance standards for vegetative cover should be reduced, or this timeframe for performance extended to allow sufficient time for natural spread of the plantings.

In upland planting areas that were observed to be dominated by non-native plants or to have limited vegetative cover, additional in-plantings are recommended of fast growing rhizomatous plants and shrubs that have demonstrated high survivorship and/or recruitment. These species include: aster, yarrow, creeping wildrye, lizard tail, California sagebrush, gumplant, and lupine. In-fill will require approximately 1,500 seedlings and divisions. Upland area survivorship varied spatially and by species, with some areas supporting dense native cover, while others supported stunted and limited native cover (see Section 5). Selective in-filling of these fast growing rhizomatous species is recommended to help even out performance in the upland areas. In areas dominated by the invasive species bird's foot trefoil, we recommend that in-fill plantings be installed after control efforts are completed. Continued, effective control of persistent upland weeds, such as bird's foot trefoil, Russian thistle, and others will be vital. It is recommended that rhizomatous species be planted very densely in these areas to help reduce the potential for re-colonization by the trefoil. Approximately 20 percent of the planting palette should be shrubs and forbs in these areas.

Mulching should continue around all new plantings to preserve soil moisture content and help reduce weed establishment.

Control of invasive non-native species such as perennial pepperweed and smooth cordgrass should continue in Western Stege Marsh. A small infestation of pepperweed can be treated with herbicide, with follow up treatments as needed. The invasive smooth cordgrass that has been observed just outside the marsh should be mapped and monitored, and appropriate controls instituted in coordination with the Invasive Spartina Project and the East Bay Regional Park District. In addition, all cordgrass seedlings within the marsh should be removed. The consequence of allowing suspect seedlings to establish is extremely high, and genetic testing of each seedling is both costly and time consuming.

Natural recruitment has been observed within the grassland plots. Additionally, the vigor of the majority of the surviving plantings is high. Limited, if any additional plantings are recommended in the grassland habitat at this time. It is anticipated that the scraped plots located within the coastal terrace prairie will naturally colonize with both native and non-native plants. It is not recommended that any additional planting is required in these plots; however targeted weed species as described above and in Table 7.1a should be controlled.

6.3 Monitoring

It is recommended that the following monitoring programs continue under the leadership of the Restoration Coordinator.

- Photomonitoring both the marsh and prairie restoration sites annually, consistent with the methods included in Appendix 4.
- Revegetation survivorship monitoring for Plot 11 and marsh upland in-fill planting;
- Harding grass distribution monitoring within 4-acre restoration plot area (GIS support may need to be provided by consultant); and targeted weed infestation monitoring;
- Groundwater monitoring in coastal terrace prairie area (monitor piezometers) consistent with protocol outlined in Appendix 10.

It is also recommended that the locally-rare plant monitoring be continued in 2009. In addition to the protocol-based photomonitoring, it is recommended that the Restoration Coordinator photodocument all work activities (planting, weeding, intern projects, smooth cordgrass control, etc.) The resulting photos should be organized by activity and maintained throughout the duration of the project.

6.4 Record Keeping

All work should be recorded and summarized monthly using work performed data sheets. Cover classes of each targeted species should be assessed by the Restoration Coordinator during the spring prior to removal efforts. It is recommended that the Restoration Coordinator report all of the restoration project activities on a quarterly basis to UC Berkeley and each year prepare an addendum to this report. Findings should be integrated into the larger annual monitoring report prepared by UC Berkeley's consultants.

It is also recommended that the Restoration Coordinator organize all of the pertinent files from the Watershed Project for archiving purposes.

7.0 References

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BBL, 2004a, Western Stege Marsh Restoration Project Monitoring Plan, August

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Tetratech 2007, Year 2 Monitoring Report for the Western Stege Marsh Restoration Project, November 15, Appendix 4

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URS 2003b, Implementation Report Phase 1 Subunit 2A Meade Street Operable Unit University of California Richmond Field Station, September 4

URS 2004, Implementation Report Phase 2 Subunit 2A & 2B Meade Street Operable Unit University of California Richmond Field Station, December 3 .

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