Revegetation Test Plot Program
Final Monitoring Report

PERMANENTE QUARRY
CUPERTINO, SANTA CLARA COUNTY, CALIFORNIA

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ENVIRONMENTAL CONSULTANTS

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1.0 INTRODUCTION

The purpose of this report is to summarize the results of monitoring visits and maintenance activities in Year 5 (2013) and the overall Revegetation Test Plot Program at the Permanente Quarry (Quarry) in Cupertino, Santa Clara County, California (Figure 1). The data collected over the past five years is being analyzed to evaluate the efficacy of different revegetation (i.e. seeding, soil amendment) treatments in meeting revegetation performance criteria set forth in the Permanente Quarry Revegetation Plan (WRA 2011a). The Revegetation Plan was prepared in support of the updated Reclamation Plan for the Quarry (Santa Clara County 2012). Year 5 test plot results and analysis are presented in this report. Year 5 results are also compared to Years 1, 2, 3, and 4 (WRA 2009, 2011b, 2012a, 2012b) test plot results to examine potential trends in revegetation efforts. Final test plot program results will inform a final revegetation plan for the Quarry.

1.1 Revegetation Performance Standards

Performance standards have been developed for the Permanente Quarry Revegetation Plan based on a study of reference sites in the vicinity of the Quarry conducted by WRA and preliminary test plot results from Years 1 and 2. A final revegetation plan will incorporate final results from this five-year revegetation monitoring program. Performance standards represent anticipated conditions five years after final installation of revegetation seeds and plantings. Revegetation of the Reclamation Plan Area (RPA) is intended to create approximately 40 percent coverage of native tree and shrub habitat interspersed among grasses within five years of final revegetation. Planting areas on south-facing benches of the RPA are anticipated to be dominated by shrubs, while planting areas on north- and east-facing benches are anticipated to eventually be dominated by trees and shrubs (WRA 2011a)

Reference site data were used to create a science-based and achievable set of performance standards (Table 1). Native species richness targets have been chosen to reflect data collected from the reference sites and preliminary test plot results. These densities and percent cover values reflect the expected growth of trees and shrubs in the first five years of the revegetation areas.

Reference data values for percent cover and density of trees and shrubs describe mature woody communities that have not seen significant disturbance in decades. While the target plant communities of the revegetation areas should eventually blend with these mature communities, they cannot be expected to achieve similar characteristics over only five years of growth. Instead, shrub and tree planting areas are designed to mimic pioneering plant communities that will continue to develop and dominate the benches and slopes over several decades through tree growth and natural regeneration.

Table 1. Proposed Five-Year Performance Standards for RPA Project Area Revegetation								
	Oak Woodland (north- and northeast-facing benches)		Pine Woodland (east-facing benches)		Hydroseed Areas* shrub/grassland mix		Riparian Areas	
	Woody Plants	Herbs	Woody Plants	Herbs	Woody Plants	Herbs	Woody Plants	Herbs
Richness *(avg. native species per plot)***	5	3	4	3	3*	3*	4	3
Density *(avg. native individuals per acre)*	470	-	345	-	-	-	470	-
Canopy Cover	40%		40%		40%*		40%	

* Performance standards for hydroseed areas may need to be adjusted to reflect feasible five-year results of the species mix ultimately selected based on the final test plot program results and early revegetation efforts during the reclamation period. In particular, the balance between shrub and herbaceous species cover may vary.
** Richness standards are based on plot sizes used in reference data collection and described in this Plan: 10m-radius plots for trees, 5m-radius plots for shrubs, and 1m-radius plots for herbs/grasses.

1.2 Test Plot Design and Installation

The *Revegetation Test Plot Program As-Built Report* (WRA 2010) provides details on the test plot program design and installation, which is summarized here. Test plots were installed in the fall of 2008, including 13 plots (plots 1-12 and 16) at a flat site within the Yeager Yard and 3 plots (plots 13, 14, and 15) on a slope in the East Materials Storage Area (EMSA) (Figures 2 and 3). Each plot was demarcated with straw bales and further divided into four quadrants using straw wattles. Installation included various "soil treatments" (i.e. application of multiple combinations and depths of quarry materials and compost) to test potential materials to use for soil and vegetation establishment on top of bare graded overburden rock. The components of these soil treatments are listed in Table 2.

Each plot soil treatment was then seeded using one of four different herbaceous seed mixes in each of the quadrants (labeled by colors: red, yellow, blue, and green), and all quadrants were also seeded with a shrub mix. Following seeding, straw mulch and a hydroslurry consisting of fertilizers and a tackifier were applied to all of the plots. At the EMSA site only, mycorrhizal inoculants were included in the hydroslurry.

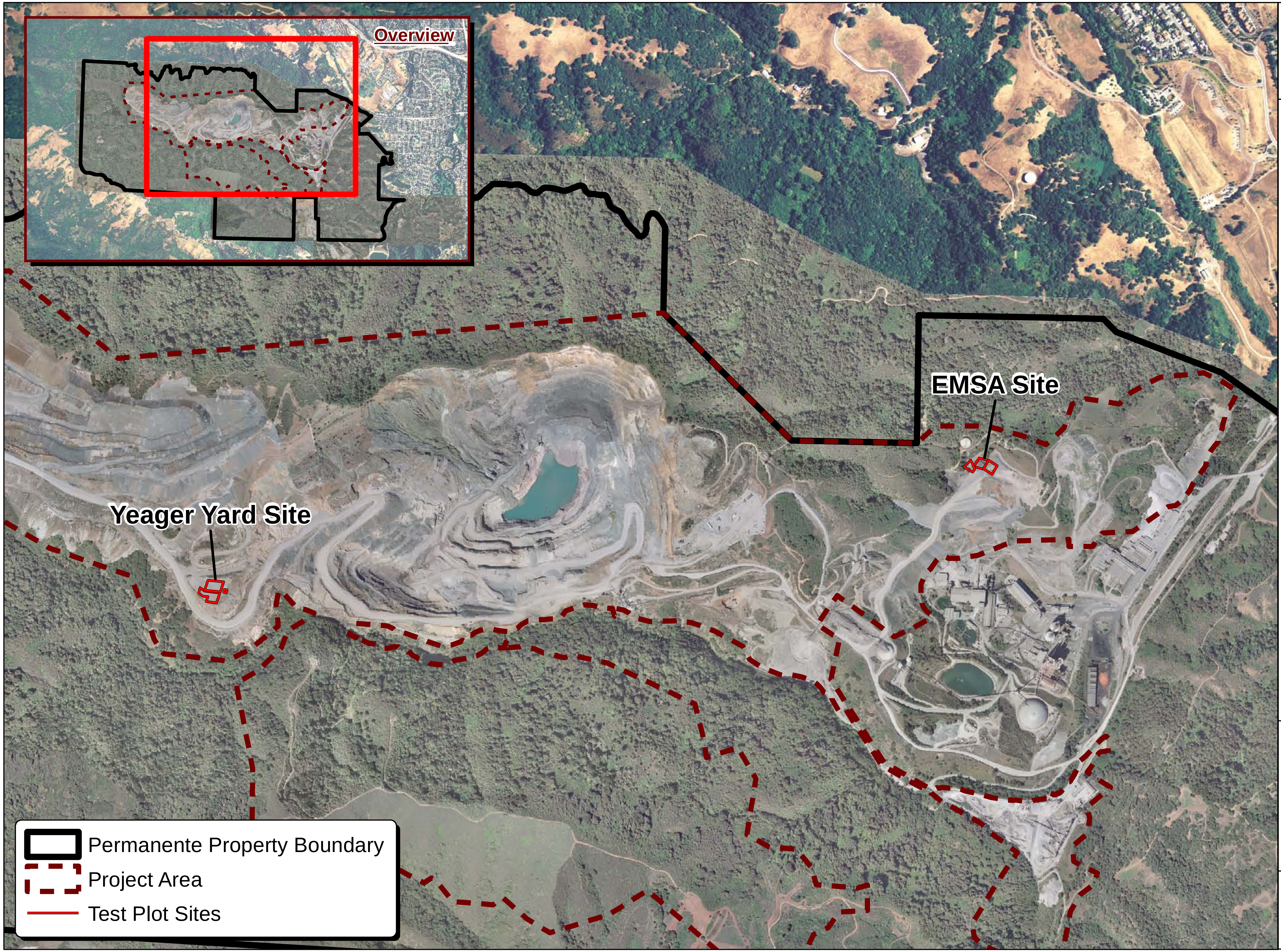
Containerized native shrubs and trees were installed in the deepest soil treatments (Plots 11, 12, and 16) by Central Coast Wilds, a division of Ecological Concerns, Inc., in November 2009. Nine species were tested, as shown in Table 6, with eight individuals of each species planted in both plots 11 and 12, and three of each in plot 16. Plantings were laid out by WRA at a minimum spacing of 3 feet, and the final installation was mapped by species to assist future monitoring efforts. In each plot, an equal number of each species was installed per quadrant, and each quadrant's plantings were tested with various plant care treatments. DriWater gel pacs, a biodegradable silica-based product that is buried next to the plants and slowly releases water into the soil, were installed next to all plants in the green quadrants. In the yellow quadrants, plantings were mulched (with approximately 1-foot radius circle of 2-inch deep wood chip mulch). Plantings in the blue quadrants were installed with both DriWater and mulch, and plantings in the red quadrants were installed without DriWater or mulch.

1.3 Variations from Test Plot Design and Specifications

The test plots were built according to the Test Plot Program specifications developed by Lehigh Permanente (2008) with the following exceptions:

- Due to space limitations, the dimensions of plot 15 are approximately 40' x 100' x 100' x 100' rather than a 100' square.
- Compost in plot 10 was not blended with overburden rock into a 24" mixture per the specifications. As a result, this plot is testing the placement of 6" of compost on top of overburden rock with no mixing.
- The Lehigh Permanente native erosion control mix was accidentally applied to the blue quadrant of plot 14. Plot 14 also did not receive a shrub seed mix treatment. The amount of Seed Mix #4 designated for plot 14 was instead applied evenly to plots 13 and 15 by the contractor (a study design change not approved by WRA).
- Seed Mix #3 was not applied to plot 16 as it was not included in the delivery from the seed company.

It should also be noted that conditions are significantly different between the Yeager Yard and EMSA test plots. Differences include plot size, slope, and aspect (the EMSA planting area is a north-facing slope while Yeager Yard is flat and completely exposed), which may impact soil moisture and suitability for various species, including weeds. Mycorrhizal inoculants were applied to EMSA plots but not to Yeager Yard plots. In addition, deer browse, deer bedding, and rodent burrows have also been observed at significant levels in Yeager Yard test plots, but wildlife use does not appear to be significant at EMSA test plots.



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Lehigh Permanente Quarry, Santa Clara County, California

Figure 1.

Test Plot Location Map

Date: January 2011
Map by: Michael Rochelle
Image Date: April 2007

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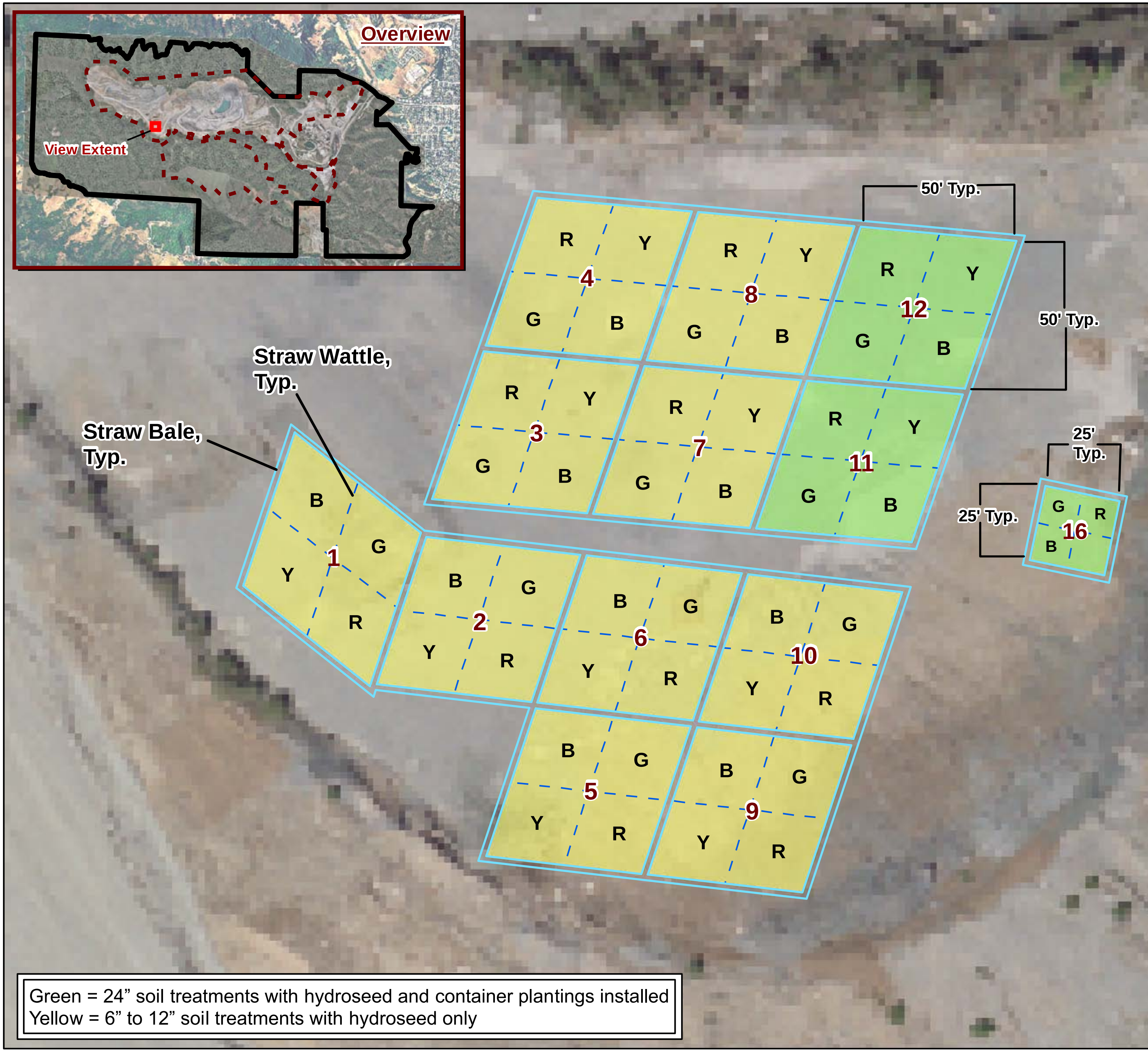

WRA ENVIRONMENTAL CONSULTANTS

Lehigh Permanente Quarry, Santa Clara County, California

Figure 2.

Test Plot Layout at Yeager Yard Site

N
W E
S

0 25 50 Feet

Date: January 2011
Map by: Michael Rochelle
Image Date: April 2007

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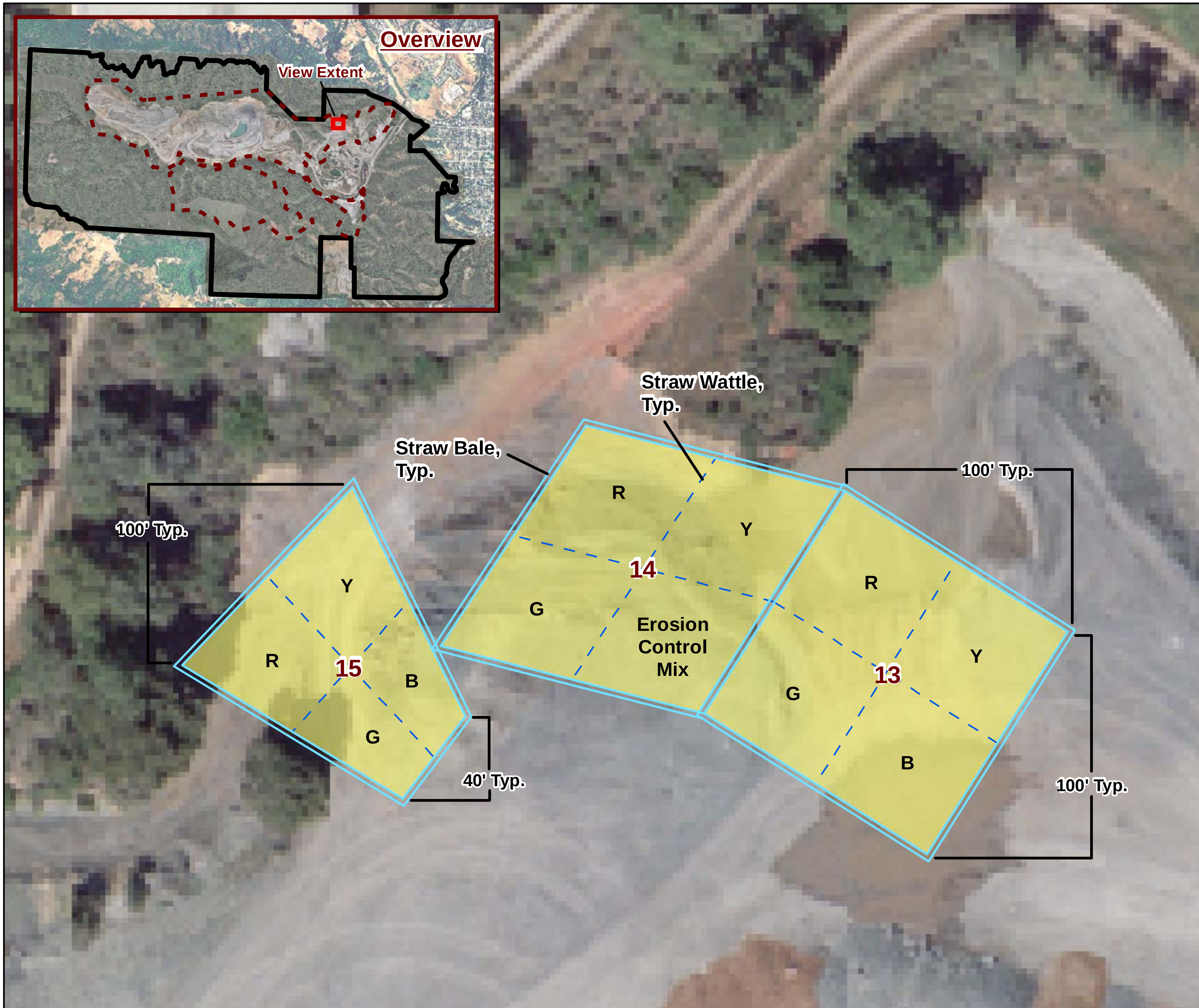

Green = 24” soil treatments with hydroseed and container plantings installed
Yellow = 6” to 12” soil treatments with hydroseed only

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Lehigh Permanente Quarry, Santa Clara County, California

Figure 3.

Test Plot Layout at EMSA Site

Date: January 2011
Map by: Michael Rochelle
Image Date: April 2007

Path: L:\Acad 2000 Files\16000\16143\gis\arcmap\2010 Report\Test Plot Report January 2011\Figure3_EMSA_Site.mxd

1.4 Maintenance

Maintenance at the Permanente test plots has included weeding and DriWater gel pac replacement. In summer 2009, bare rock areas adjacent to the test plots were scraped to remove weeds, predominantly the invasive species stinkwort (*Dittrichia graveolens*), summer mustard (*Hirschfeldia incana*), yellow star thistle (*Centaurea solstitialis*), and foxtail brome (*Bromus madritensis* ssp. *rubens*). In June 2010, black mustard (*Brassica nigra*) and yellow star thistle were removed from all Yeager Yard plots (plots 1-12 and 16) using hand picks and soil knives. Dense populations in Plots 12 and 16 were not completely removed. Plots 13-15 at the EMSA were notably infested by black mustard in and around the test plots in 2011.

In November 2011, all plots at both the Yeager Yard and EMSA sites were weeded by hand, and plant materials were bagged and removed from the sites. The primary plants removed from the Yeager Yard plots were stinkwort, black mustard, yellow star thistle, fennel (*Foeniculum vulgare*), and Italian thistle (*Carduus pycnocephalus*). The Yeager Yard plots were once again invaded by stinkwort at the time of 2011 maintenance activities. However in the EMSA plots, black mustard was the predominant weed observed and subsequently removed in 2011 (other weeds existed and were removed from the EMSA site, but to a much lesser extent) (Laslett, pers. comm., 2011).

No weeding was performed in 2012 or 2013. By the time of monitoring in June 2012 and June 2013, most weeds had already set seed for the year, and WRA biologists determined that weeding would not be a useful effort at this time given the potential for disturbing the test plot and potentially introducing new weeds through personnel access. Weeds were less prevalent across test plots in 2013 with the exception of Italian thistle at the Yeager Yard site and summer mustard at the EMSA site. These weeds should be the target of weed treatment efforts across the test plots in the future. Foxtail brome and rattail fescue (*Vulpia myuros*) were the most prevalent weeds observed in monitoring quadrats, but it is unlikely that these herbaceous, annual grasses, which are naturalized in grasslands throughout the region and produce prolific amounts of seed, could be controlled effectively.

Only a few individuals of stinkwort were observed in a single plot, and yellow star thistle was not as prevalent as in past monitoring visits, showing that treatment for these two species has been effective. These two species should continue to be treated if observed during future weed management visits.

DriWater gel pacs were replenished for all live plantings with DriWater tubes in June and September 2010. Gel pacs were only replaced for surviving plantings, including those that were severely stressed but still had some live bark or any slightly green leaves (including 43 plantings in June and 4 in September). Empty tubes next to dead plantings were removed in September 2010. Gel pacs were not replenished in 2011, 2012, or 2013.

2.0 METHODS

Year 5 revegetation test plot monitoring was conducted by WRA on June 6, 2013. Monitoring methodology is described in the following sections.

2.1 Seed Monitoring

Monitors divided each plot quadrant into nine equal sections; each plot quadrant was numbered consistently from one through nine. A random list of numbers between one and nine was generated prior to the site visit, and this list was utilized to select two of the nine sections for sampling in each consecutive quadrant. One 0.25-square-meter quadrat was randomly dropped in each of the two selected sections to sample vegetation data. As a result, approximately 0.9 percent of each plot and quadrant was sampled, with a lower sampling intensity in the larger (100-foot x 100-foot) plots, and higher intensity in the 25-foot x 25-foot plot (plot number 16).

WRA identified all plants present in each sampling quadrat to the species level when possible. In each sampling quadrat, monitors estimated absolute percent cover of each species, and an overall percent cover of vegetation, bare ground, and thatch/litter (thatch is defined as dead grasses, while litter is defined as dead leaves and stems from non-grasses). Monitors also walked through each plot quadrant and noted any additional species present that were not observed within the sampling quadrats.

Monitoring was scheduled for June, assuming it would be the height of the growing season and a time when the most species, including both annual grasses and perennial shrubs, were readily identifiable. Plant cover and distribution should also be most representative during the height of the growing season when plants have achieved their maximum growth and cover for the year. Although the 2012 – 2013 rainfall season was drier than average and most plants accordingly senesced and desiccated earlier than during a typical rainfall year, almost all plants were still readily identifiable during the June monitoring visit. All future monitoring visits should be performed during the window of May to June to observe plants when they are most identifiable and capture representative conditions at the height of the growing season.

2.2 Container Plant Monitoring

Container plants were originally installed in plots 11, 12, and 16 in a grid pattern with each species mapped during final plant layout. Each planting was located using the map, counted for survival, and assessed for health during the June and September 2010 monitoring visits. Container plantings were revisited in November 2011, June 2012, and June 2013 and counted for survival.

3.0 RESULTS AND DISCUSSION

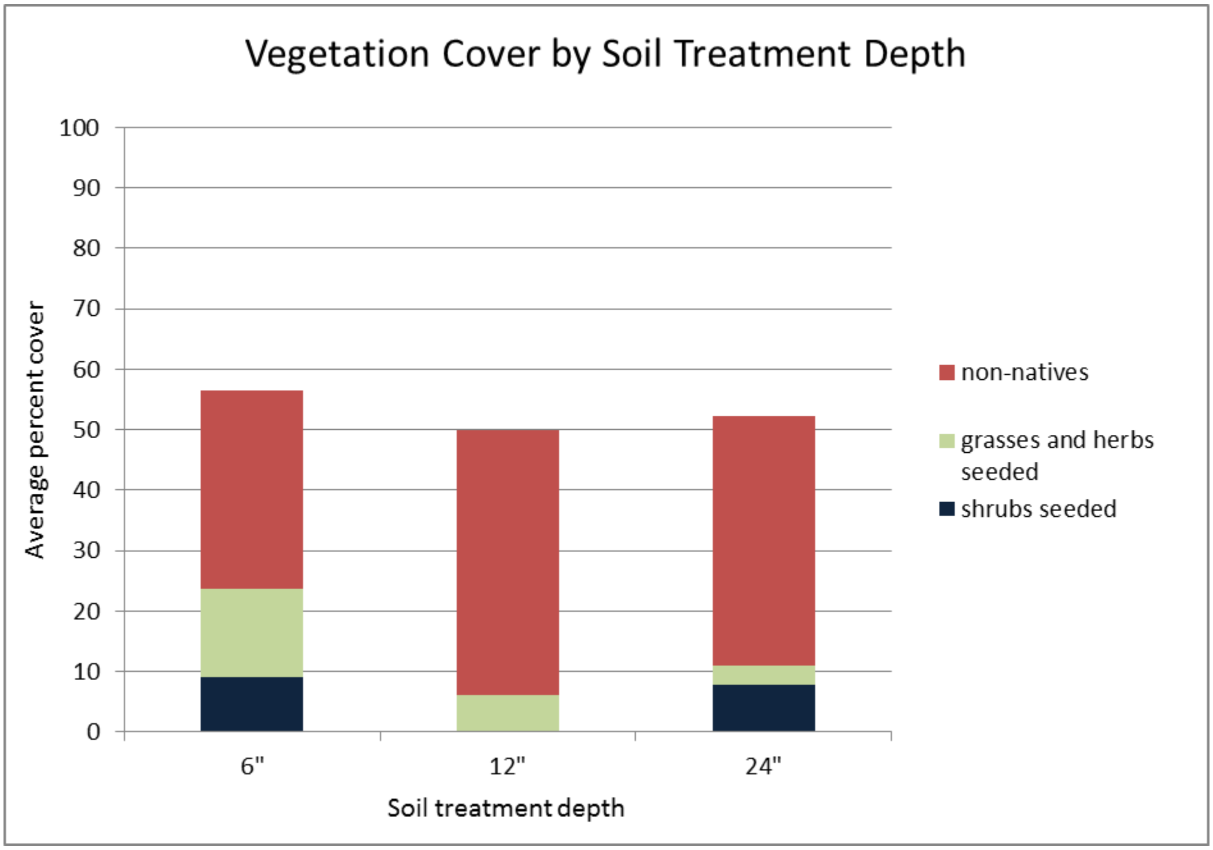
3.1 Seeds and Soil Treatments

Data collected during the June 6, 2013, monitoring visit for vegetation cover across the various soil treatments is summarized in Tables 2-5 and graphs in Figures 4 and 5. Table 2 shows the average vegetation cover, performance of the native seed mixes, cover of non-native species, and thatch/litter in each plot. Table 3 summarizes plot data taken in terms of the metrics proposed in the Revegetation Plan for monitoring future Quarry reclamation efforts (total cover, stem density, and species richness) in the RPA. Table 4 is a summary of the performance of individual species in the seed mixes. Table 5 summarizes cover of non-native species observed in the plots.

Table 2. Summary of vegetation cover based on soil treatment in Year 5.
(Sorted by total cover of native shrubs)

PLOT #	Soil treatment depth	SOIL COMPONENTS (%)				AVERAGE PERCENT COVER (%)				
		Overburden Rock	Compost	Pit 1 Fine Greenstone	Rock Plant Fines	Seeded species (incl. shrubs)	Native shrubs	Non-native species	Thatch/ litter	Bare ground
13	6"	75	25			49	33	20	29	13
15	6"		25	75		46	27	22	25	4
16	24”	37.5	25	37.5		19	14	37	18	17
14	6"	35	25		40	56	11	19	32	3
1	6”	100				20	7	7	3	79
12	24”	25	25	25	25	8	5	54	18	6
5	6”		25	75		11	5	33	36	7
11	24”		25	75		6	4	33	31	6
6	6”	33	25	25	17	8	3	47	35	3
3	6”	50	50			10	3	41	22	16
2	6”	75	25			27	2	37	33	9
4	6”	35	25		40	7	2	35	21	41
8	12”	37.5	25	37.5		9	0	46	31	7
9	12”	25	25	25	25	6	0	49	30	15
7	12”	75	25			4	0	37	34	6
10	6"		100			2	0	70	15	3

Figure 4. Soil Treatment Summary Graphs



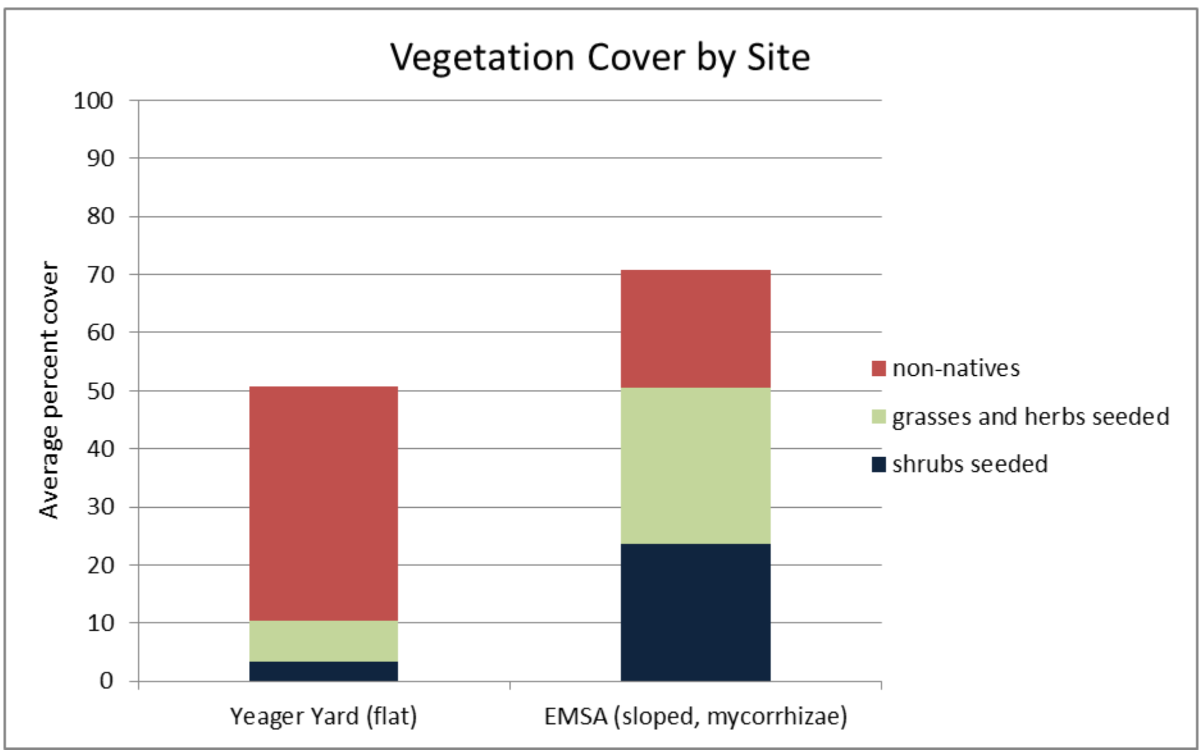


Figure 4 (cont.). Soil Treatment Summary Graphs

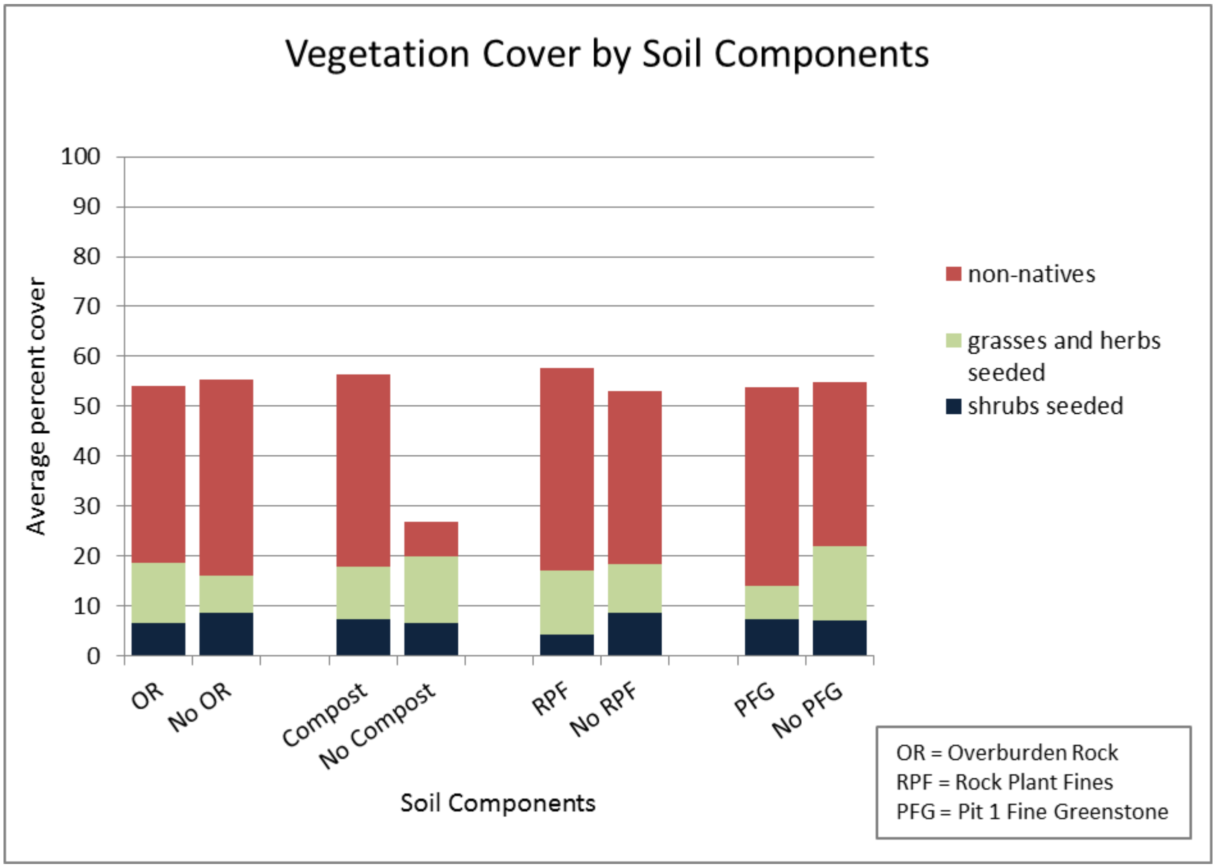


Table 3. Summary of test plots in Year 5 based on proposed monitoring metrics in the Revegetation Plan (Sorted by stem density per acre).

PLOT #	Soil treatment depth	SOIL COMPONENTS (%)				PROPOSED RECLAMATION MONITORING METRICS (Revegetation Plan [WRA 2011a])		
		Overburden Rock	Compost	Pit 1 Fine Greenstone	Rock Plant Fines	Total live vegetative cover (%) in June 2013	Native species richness (species/ 2 m^2)[1] in June 2013	Stem density (shrubs per acre) [2] in June 2013
1	6	100	-	-	-	10.6	21	72,845
2	6	75	25	-	-	66.1	19	12,141
3	6	50	50	-	-	50.5	15	6,070
4	6	35	25	-	40	38.0	16	54,634
5	6	-	25	75	-	60.2	15	32,376
6	6	33	25	25	17	63.0	15	2,023
7	12	75	25	-	-	50.5	11	8,094
8	12	37.5	25	37.5	-	59.9	15	18,211
9	12	25	25	25	25	63.3	11	ND
10	6	-	100	-	-	78.6	11	16,188
11	24	-	25	75	-	66.1	16	12,141
12	24	25	25	25	25	72.4	14	ND
13	6	75	25	-	-	66.1	20	16,188
14	6	35	25	-	40	69.3	18	2,023
15	6	-	25	75	-	63.0	13	26,305
16	24	37.5	25	37.5	-	56.8	11	20,235

[1] Species richness values are not directly comparable to the proposed performance criteria in the Revegetation Plan, as the sampling plot size is different, although only slightly different for herbaceous species. Richness values in Table 3 are the total number of native species observed in all sampling quadrats per plot, in an area totaling 2 m^2. Performance criteria monitoring currently proposed in the Revegetation Plan would obtain richness values for trees in a 10 meter-radius plot, shrubs in a 5 meter-radius plot, and herbs in a 1 meter-radius plot (3.1 m^2).

[2] ND = Not Detected. Shrubs may have been in the plot, but did not show up in the eight randomly placed quadrats.

Figure 5. Stem Density and Species Richness Graphs Year 5

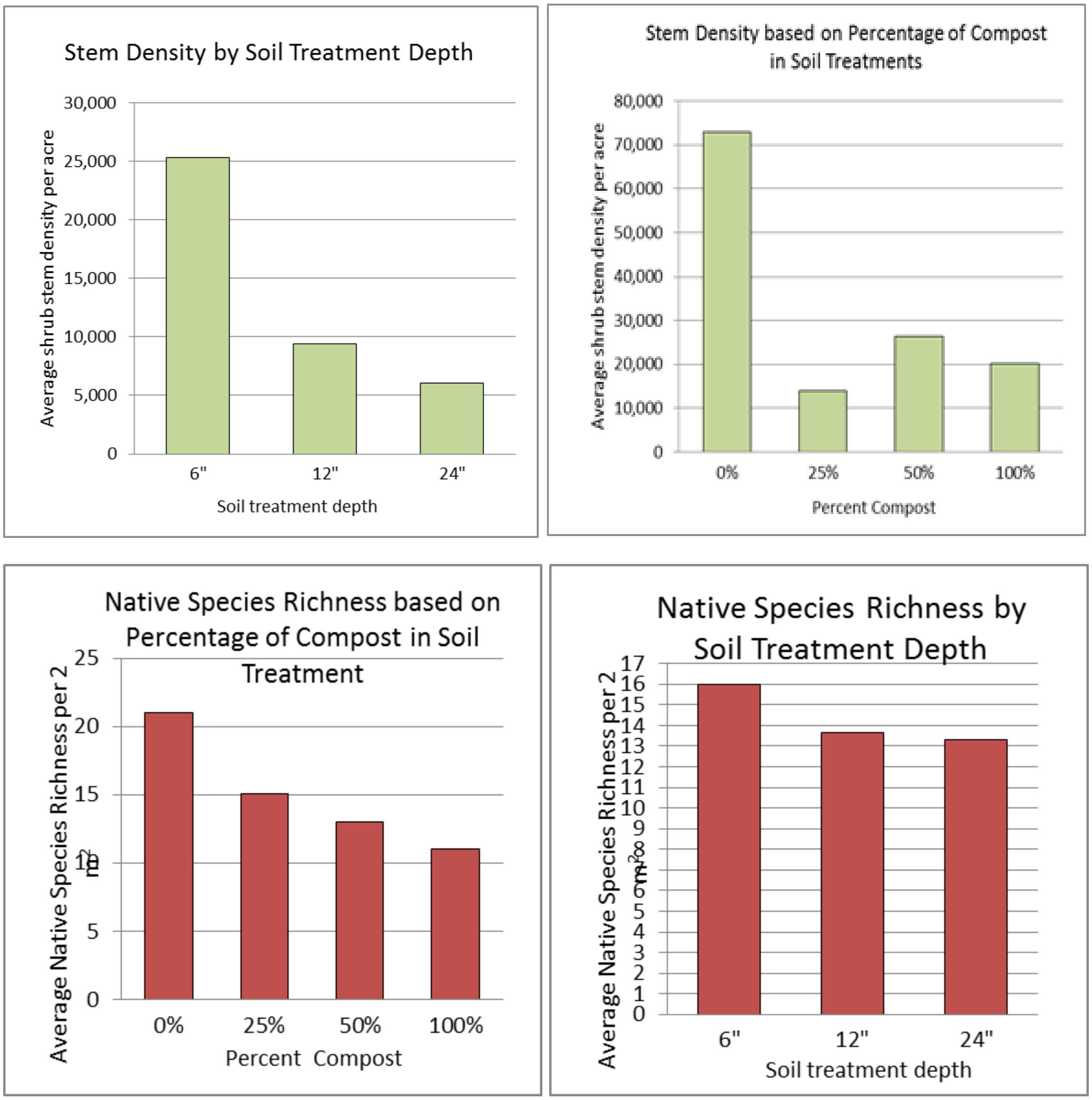


Table 4. Seed Performance in Test Plots – Year 5.
Seed mixes: #1 green (G); #2 red (R); #3 yellow (Y); #4 blue (B); shrub (S) [applied to all plots]; erosion (E) [in place of blue mix in plot 14]

SCIENTIFIC NAME	COMMON NAME	Seed mixes containing species	Presence in quadrants where seeded (%)	Average cover where seeded (%)
Vulpia microstachys	small fescue	GRYBE	60.3	6.7
Achillea millefolium	yarrow	GYB	34.8	2.1
Sisyrinchium bellum	blue-eyed grass	B	33.3	0.2
Nassella pulchra	purple needlegrass	G	31.3	0.2
Eriogonum fasciculatum	California buckwheat	S	30.2	4.2
Elymus glaucus	blue wildrye	GRYBE	25.4	0.9
Artemisia californica	California sagebrush	S	23.8	2.6
Lotus purshianus	Spanish lotus	GYB	21.7	0.4
Leymus triticoides	creeping wildrye	B	13.3	0.0
Heterotheca grandiflora	telegraph weed	G	12.5	0.1
Salvia mellifera	black sage	S	11.1	0.7
Artemisia douglasiana	California mugwort	S	9.5	0.2
Lotus scoparius	deerweed	GY	6.5	0.0
Bromus carinatus	California brome	GRYBE	4.8	0.1
Plantago erecta	foothill plantain	GBE	3.1	0.0
Adenostoma fasciculatum	blue wildrye	S	1.6	0.0
Baccharis pilularis	coyote brush	S	1.6	0.1
Mimulus aurantiacus	sticky monkeyflower	S	1.6	0.0
Ceanothus cuneatus	buckbrush	S	0.0	0.0
Clarkia purpurea ssp. *quadrivulnera*	purple clarkia	GY	0.0	0.0
Eriodictyon californicum	yerba Santa	S	0.0	0.0
Eriogonum nudum	naked buckwheat	B	0.0	0.0
Eriophyllum confertiflorum	golden yarrow	B	0.0	0.0
Festuca occidentalis	western fescue	B	0.0	0.0
Festuca rubra	red fescue	E	0.0	0.0
Heteromeles arbutifolia	toyon	S	0.0	0.0
Lupinus nanus	sky lupine	GYE	0.0	0.0
Melica californica	California melic grass	B	0.0	0.0
Oenothera hookeri	evening primrose	GY	0.0	0.0
Poa secunda	one-sided bluegrass	B	0.0	0.0
Scrophularia californica	bee plant	B	0.0	0.0
Trifolium willdenovii	tomcat clover	RE	0.0	0.0

Table 5. Non-Native Species in Test Plots – Year 5			
SCIENTIFIC NAME	COMMON NAME	INVASIVE STATUS[1]	AVERAGE PERCENT COVER (ALL PLOTS)[2]
Bromus madritensis	foxtail brome	moderate	6.6
Vulpia myuros	rattail fescue	moderate	6.0
Bromus hordeaceus	soft chess	limited	5.3
Medicago polymorpha	bur clover	limited	5.0
Carduus pycnocephalus	Italian thistle	moderate	4.3
Bromus diandrus	ripgut brome	moderate	3.9
Lolium multiflorum	rye grass	moderate	1.3
Melilotus indicus	annual yellow sweetclover	--	1.0
Avena sp.	wild oats	moderate	0.8
Hirschfeldia incana	short podded mustard	moderate	0.6
Trifolium hirtum	rose clover	moderate	0.5
Centaurea solstitialis	yellow star thistle	high	0.3
Lactuca serriola	prickly lettuce	--	0.2
Dittrichia graveolens	stinkwort	moderate (ALERT)	0
Pseudognaphalium sp.	cudweed	--	0
Hordeum murinum	foxtail barley	moderate	0
Bromus tectorum	cheatgrass	high	0
Trifolium glomeratum	clustered clover	--	0
Cirsium vulgare	bull thistle	moderate	0
Foeniculum vulgare	fennel	high	0
Hypochaeris sp.	cat's ear	limited - moderate	0
Petrorhagia sp.	pink grass	--	0
Phalaris minor	little seed canary grass	--	0
Picris echioides	bristly ox-tongue	limited	0
Polygonum arenastrum	prostrate knotweed	--	0
Polypogon monspeliensis	rabbitsfoot grass	limited	0
Sonchus asper	spiny sow thistle	--	0
Sonchus oleraceus	common sow thistle	--	0
Taeniatherum caput-medusae	medusahead grass	high	0
Taraxacum sp.	dandelion	--	0

[1] Invasive status as listed in Cal-IPC 2014. High = Species with severe ecological impacts on physical processes, plant and animal communities, and vegetation structure. Moderate = Species with substantial and apparent—but generally not severe—ecological impacts on physical processes, plant and animal communities, and vegetation structure. Limited = Invasive species but with ecological impacts that are minor on a statewide level or there was not enough information to justify a higher score; may be locally persistent and problematic.

[2] Species with zero percent cover were observed as present in the plots but did not appear within sampling quadrats.

In Year 1, the non-vegetative cover in the test plots was predominantly bare rock or straw mulch. In Year 2, non-vegetative cover was predominantly bare ground and thatch from the previous year's annual grasses. In Years 3, 4, and 5 the non-vegetative cover in plots was predominantly thatch from the previous growing season's annual grasses, indicating that plant cover has increased over time.

It should be noted that while mugwort (*Artemisia douglasiana*) was included in the shrub seed mix, it is not counted as shrub cover in this analysis, as it is a perennial herb that does not provide the same structure and habitat values of the shrubs targeted for establishment in reclamation areas. It should also be noted that the summary results shown in Figure 4 and Tables 4 and 5 include combined results for EMSA and Yeager Yard test plots, although conditions at the two sites varied greatly. However, evaluating only plots 1-12, which provide the most uniform set of conditions, does not affect averages shown in Figure 4 by more than a few percentage points and does not change the overall results discussed here.

Similar to the previous four years, shrub cover was low throughout the test plots in Year 5, with 7.25 percent average cover across all plots. However, shrub cover has been expanding across plots by about 1.5 percent on average over the years: shrub cover was less than 1 percent on average across plots in Year 1, 2.4 percent in Year 2, 4.2 percent in Year 3, and 5.5 percent in Year 4. In addition, several plots had notably higher percentages of shrub cover in Year 4 with Plots 11, 13, 5, and 16 supporting 11 to 19 percent cover of shrubs. In Year 5, Plots 6, 8, 9, and 10 had increased shrub cover ranging from 11-33 percent. Low, but expanding shrub cover is to be expected as it takes several years for the slow-growing shrubs to become well-established.

Shrubs were also generally considerably larger in the EMSA than at Yeager Yard, possibly due to the north-facing aspect, the mycorrhizal inoculant, or the significantly lower amounts of deer browse observed during monitoring (WRA 2011b). In Years 2 through 5, shrub size was significantly more robust and shrub quantities were far greater at plot edges adjacent to the straw bales that form the border of the plots. The straw bales clearly provide favorable conditions for the shrubs, but the reason they do so is not apparent. It could be related to increased soil moisture (the straw bale may act as a slow-release water reservoir), protection from wind, protection from herbivory, or increased nutrients that slowly leach out of the decomposing bales. See Appendix B for further analysis of shrub growth along straw bales in the test plots.

Despite the low total cover of shrubs in the preliminary revegetation stages, many plots supported high densities of shrub seedlings, particularly plots with less grass and non-native species cover. In Year 2, plots with the shallowest (6”) soil treatments supported greater cover of shrubs. In years 3 and 4, Plot 16, the plot with the deepest (24”) soil treatment, supported the greatest cover of shrubs (see photographs in Appendix A). Plot 16 exhibited 19 percent cover of shrubs in Year 4, increasing from 13 percent in the previous year. In Year 5, Plot 16 decreased from 19 to 14 percent cover. In contrast to the Year 4 data, Figures 4 and 5 from Year 5, show that plots with the shallowest (6”) soil treatments and no compost supported greater cover and density of shrubs.

The data from Years 2 to 4 show that for shrubs to become established in the test plots, shallower soils, with no or minimal compost amendments, favor hardier native species over highly competitive non-native annual grasses. Shallower soils hold less moisture which could favor shrub establishment over grasses, the latter of which require more water for sustained growth. Although it appears that, once established, shrubs seem to be growing and expanding more vigorously in plots with deeper soils, Year 5 data shows a change in this trend. In contrast to previous years, 2013 data suggests that the plots with shallower soil and no compost have greater native species richness and higher average percent cover for shrubs. This supports the concept that plots without compost and harsher soils deter the germination and establishment of non-native species

Similarly, Plot 1 contains the least productive soils (100 percent overburden rock with no soil amendments), but it had the highest shrub density of all the plots in Years 3, 4, and 5. Improved shrub germination and initial growth is most likely due to less competition from native herbaceous species and non-natives in the shallower soils with less nutrient and moisture-rich conditions. However, although native shrub stem densities are highest in Plot 1, shrubs in this plot are often smaller and less robust than shrubs growing in other plots. Although shallow soils favor shrub germination and give shrubs a more competitive edge in the test plots, the deeper soils in some plots have favored more robust shrub growth (and therefore expansion of cover of individual shrubs), comparatively.

Small fescue (*Vulpia microstachys*), a native annual grass species, and California buckwheat (*Eriogonum fasciculatum*), a native shrub, exhibited the highest presence in plots where they were seeded, indicating that these two species have been able to most readily establish from seed. California buckwheat has exhibited the highest cover of shrub species over the past five years of monitoring, closely followed by California sagebrush (*Artemisia californica*). Although black sage (*Salvia mellifera*) and coyote brush (*Baccharis pilularis*) averaged only 0.7 and 0.1 percent cover, respectively, in quadrats in Year 5, these shrubs have consistently exhibited strong cover at the edge of plots next to straw bales and straw wattles (see photos in Appendix A). Again, straw bales and wattles seem to provide conditions which have favored shrub establishment and growth in the test plots.

Small fescue has consistently exhibited the highest cover in plots across monitoring years as it produces large amounts of seed and is able to readily colonize bare soils in the test plots. Blue wildrye (*Elymus glaucus*), a native perennial grass species, also performed very well in Years 2 through 5, and it exhibited a higher cover than most seeded species in most plots. Higher cover of small fescue, blue wildrye, and highly competitive non-native grasses (e.g. rattail fescue and foxtail brome) in plots has correlated with lower shrub cover in those plots. It is well documented that grass species are able to outcompete and preclude the establishment of shrub species in certain conditions.

The fourteen native species listed at the bottom of Table 4 were not observed in Year 5, and the majority of these species also did not appear to germinate or survive in plots in Years 2 through 5. Some of these species may require additional pre-treatments to mimic natural conditions that stimulate germination. For some others, such as one-sided bluegrass (*Poa secunda*), there is no clear reason for the lack of germination, as they are known to perform well in similar conditions. There may have been issues with the seed source or age, local site conditions, or yearly climate variability which prevented germination. Chamise (*Adenostoma fasciculatum*) did not germinate at all in any of the monitoring years, but it is suited to the rocky conditions in the reclamation areas and is present in adjacent vegetated areas at Permanente Quarry. This species requires fire to germinate, and after seeding efforts were complete, the seed supplier informed WRA that no fire-mimicking treatment was applied to the seed prior to application in the test plots. However the supplier did note that they had experience with the seed germinating after several years of sitting idle in natural conditions after seeding. After five years of monitoring with no observation of chamise in the test plots, it appears unlikely that this species will germinate from the seed that was supplied.

In Year 5, overall native species richness increased significantly in plots 1, 2, 3, 4, 6, 11, 13, and 15. In plots 5, 7, 8, 9, 10, and 11, overall species richness decreased by an average of 3 percent while plots 15 and 16 saw no increase from Year 4 to Year 5. Additionally, richness increased by an average of 4 percent per plot from Year 4 richness values. In Years 4 and 5, plots were monitored at the height of the growing season when nearly all species growing in plots were readily identifiable and exhibiting their maximum growth and cover for the year. Comparing Years 4 and 5, richness also increased in eight plots, decreased in six plots, and remained the same in two plots. Species richness increased by an average of 6 percent across plots. Monitoring in Years 4 and 5 was performed at the same general time during the height of the growing season and therefore offers a more accurate comparison. Year 5 data show that native species richness has been increasing across plots from previous years and is on average 15 species per 2 square meters, which exceeds the richness value performance criteria for larger plot sizes listed in Table 1 above.

Although sampling plot sizes for the performance criteria listed in the Revegetation Plan are not directly comparable to the sampling plot sizes for the test plots (see footnote in Table 3 above), shrub and tree richness numbers appear to be lower than what might be necessary to meet the woody richness criterion listed in Table 1 above. As of Year 5, shrub richness is greatest in Plot 15, at 7.7, and lowest in Plot 10, at 0.6. Shrub richness averages 3.4 shrubs across all plots. Additionally, only one native tree species, grey pine (*Pinus sabiniana*), remained growing in the plots where planted. Although native species richness is high and meets the general richness criteria in all plots, woody species richness may need to increase to meet the performance criteria listed in Table 1. Increasing woody species diversity should be the focus of the final revegetation treatments selected for the Final Revegetation Plan.

Year 5 native species richness is consistent with Years 2, 3, and 4 in that it is still highest in plots with 6-inch soil treatments and no compost added. These soil conditions seem to be the best for the establishment of native plants, especially shrubs, over non-native species. In Year 4, Plot 1, with the shallowest soils and highest proportion of overburden rock (100%), exhibited the highest density of native shrubs, the highest species richness, and the lowest cover of exotic species in Year 4. Although Plot 1 also had the lowest percentage of vegetative cover, the harsher soils clearly favor shrub establishment and native cover, which are two of the performance criteria for revegetation efforts in the RPA. The data from Year 5 shows that although Plot 1 still maintains the highest species richness and lowest percent cover of exotic species, Plot 13 now has the highest density of native shrubs. A possible explanation for this is that, over time, shrubs might more readily establish themselves in soils that contain higher amounts of compost.

In Year 1, non-native species averaged between 2 and 12 percent cover in the test plots, and the unexpected germination of straw mulch (sterile wheat [*Triticum aestivum*]) provided a significant portion of that cover. In Year 2, non-native species increased due largely to invasion by non-native grasses (predominantly Italian rye [*Lolium multiflorum*]) and summer mustard. Non-native cover was lowest in Plot 1 (7 percent) and highest in Plot 12 (53 percent, dominated by Italian rye and annual yellow sweetclover [*Melilotus indicus*]). The highly invasive yellow star thistle was present in small quantities and was removed from the EMSA after the June monitoring was conducted. This species will be a target for control in future reclamation efforts.

In Year 3, non-native cover decreased in 11 plots, increased in five plots, and decreased by an average of 7 percent across all plots. This change in non-native cover was partially based on the use of ratios of cover of native annual grasses to non-native annual grasses, which served as a best estimate of annual grass cover in light of identification issues at the time of monitoring. In Year 4, non-native species cover increased from Year 3, but decreased by an average of 6 percent across plots from Year 2. Once again, comparing Years 2 and 4, which were both monitored at the height of the growing season, yields a more accurate analysis of change than comparing Years 3 and 4, as described above. In Year 5, non-native cover increased in 15 plots and decreased in one. Overall, the non-native cover increased by an average of 83 percent across all plots. This increase is likely a function of the establishment of the non-native, invasive plant species that disperse large quantities of seed.

In Year 2, summer mustard invaded all plots, but particularly the EMSA plots. In Year 2, summer mustard was removed from the Yeager Yard site and the treatment seemed to have reduced the prevalence of plants there. In Year 3, summer mustard was observed in most plots and was still very abundant at the EMSA site. Summer mustard was also present at higher densities in the eastern portion of the Yeager Yard site, in plots 5, 9, 10, and 16, but was only present in 54 percent (7 of 13) of Yeager Yard plots. Treatment of summer mustard in Year 2 seems to have reduced the prevalence of summer mustard in Year 3, but the species was still germinating at high levels in untreated areas. In Year 4 summer mustard was still prevalent at the EMSA site and was also observed in 100 percent (13 of 13) Yeager Yard plots, where it is spreading. In Year 4, Italian thistle was also a prevalent invasive weed and was observed in all test plots, with a more significant infestation noted at the Yeager Yard plots. In Year 5, summer mustard was present in all plots except Plot 1. Italian thistle was also abundant in all Plots.

3.2 Container Plants

Tables 6 through 8 present a summary of container plant survival based on species, plant care, treatment, and soil treatment, respectively. All but seven container plantings had died by the time of the September 2010 monitoring visit, and only four plants survived through the 2011 Year 3 monitoring visit. The surviving plantings were four relatively healthy grey pines. By the time of the June 2012 Year 4 monitoring visit, three grey pine saplings remained. By Year 5, all but one grey pine had died. As a result of the low survivorship numbers, little valuable data on long term container plant survival can be obtained from the Years 2 through 5 monitoring results. However, monitoring conducted during this period can provide some information on potential species hardiness and the effectiveness of plant care treatments during the establishment period, as discussed below.

Mulch significantly improved plant survival in the first seven months compared to plantings without mulch. DriWater irrigation did not have a clearly beneficial impact on plant survival, and in June 2010 the plantings with no DriWater or mulch survived at a higher rate than those with DriWater. Plantings with both mulch and DriWater had the highest survival rate in June, so it is possible that the mulch improved the effectiveness of DriWater by preventing loss of the additional soil moisture. The effectiveness of DriWater irrigation could have been improved by installing the tubes at a more horizontal angle, to allow moisture coming from the base of the tube to reach areas closer to the soil surface for the smaller plant container sizes. In addition, more tubes could have been used for each plant, and Gel Pacs could have been replaced more frequently. The 90-day product performed as advertised, with moisture or leftover gel found at the base of all the tubes when they were checked in September 2010, three months after replenishment. The installation design in the test plots was selected to mimic the more conservative plant care treatments that would likely be necessary on a large scale revegetation effort.

Multiple factors appeared to contribute to the poor survivorship rates of the container plantings. Container sizes selected were mostly small treebands, selected due to the expected high volume and cost of planting the reclamation areas. However, many specimens were also very small for their container sizes, so they may not have obtained a deep and well-established root system in the nurseries. Some of the smallest plants had become buried in mulch, particularly the scrub oak (*Quercus berberidifolia*) and blue oak (*Quercus douglasii*) seedlings. Coast live oak (*Quercus agrifolia*) was installed in larger “treepots”, and although plantings showed a relatively high survival rate in June, all died by September 2010.

Table 6. Tree and Shrub Container Plant Survival by Species								
SCIENTIFIC NAME	COMMON NAME	CONTAINER SIZE	TOTAL					
			Planted	Alive	Alive	Alive	Alive	Alive
			Nov. 2009	June 2010	Sept. 2010	Nov. 2011	June 2012	June 2013
Pinus sabiniana	grey pine	TB	19	18 (95%)	6 (32%)	4 (21%)	3 (16%)	1
Quercus agrifolia	coast live oak	TP	19	14 (74%)	0	0	0	0
Cercocarpus betuloides	mountain mahogany	TB	19	13 (68%)	1 (5%)	0	0	0
Heteromeles arbutifolia	toyon	1G	19	8 (42%)	0	0	0	0
Arbutus menziesii	Pacific madrone	DP	19	6 (32%)	0	0	0	0
Quercus berberidifolia	scrub oak	TB	19	6 (32%)	0	0	0	0
Ribes californicum	hillside gooseberry	TB	19	6 (32%)	0	0	0	0
Quercus douglasii	blue oak	LT6 (2-LT4)	19	5 (26%)	0	0	0	0
Frangula californica	coffeeberry	TB	19	4 (21%)	0	0	0	0
		TOTAL	171	80 (47%)	7 (4%)	4 (2%)	3 (1.7%)	0%

Table 7. Tree and Shrub Container Plant Survival by Plant Care Treatment						
PLANT CARE TREATMENT	PLANTED NOV. 2009	ALIVE JUNE 2010	ALIVE SEPT. 2010	ALIVE NOV. 2011	ALIVE JUNE 2012	ALIVE JUNE 2013
Mulch and DriWater	36	24 (67%)	2 (6%)	1 (3%)	1 (3%)	0
Mulch only	45	23 (51%)	2 (4%)	1 (2%)	1 (2%)	0
DriWater only	45	13 (29%)	2 (4%)	1 (2%)	0 (0%)	0
No treatment	45	20 (44%)	1 (2%)	1 (2%)	1 (2%)	0

Table 8. Tree and Shrub Container Plant Survival by Soil Treatment							
PLOT	SOIL TREATMENT	PLANTED NOV. 2009	ALIVE JUNE 2010	ALIVE SEPT. 2010	ALIVE NOV. 2011	ALIVE JUNE 2010	ALIVE JUNE 2013
Plot 11	75% Pit 1 fine greenstone, 25% compost	72	30 (42%)	4 (6%)	3 (4%)	2 (2%)	0
Plot 12	25% overburden rock, 25% compost, 25% Pit 1 fine greenstone, 25% Rock Plant fines	72	38 (53%)	2 (3%)	0 (0%)	0 (0%)	0 0
Plot 16	37.5% overburden rock, 37.5% Pit 1 fine greenstone, 25% compost	27	12 (44%)	1 (4%)	1 (4%)	1(4%)	0

Another factor impacting the plantings was wildlife (WRA 2011b). Evidence of extensive deer impacts was observed throughout the Yeager Yard test plots, and deer bedded in the denser grasses of the deeper plots. The tops of most toyon (*Heteromeles arbutifolia*) and coffeeberry (*Frangula californica*) had been chewed off by deer. Evidence of mouse activity was also significant in plots 11 and 12. In June 2010, the main stems of most of the hillside gooseberry (*Ribes californicum*) and many blue oak and mountain mahogany (*Cercocarpus betuloides*) had bark chewed off or were completely chewed through. Mice had also tunneled around many plantings and DriWater tubes by this time, and in September 2010 approximately half of the DriWater tubes had large holes chewed out of them. Mice, one live and one dead, were found inside the tubes in September; it was not clear if they had consumed some of the DriWater gel or just used the empty tubes for shelter.

Finally, the planting medium of the test plots consisted of a combination of quarry materials and compost, rather than soil. The test plot soil treatments were found to be difficult to plant in, and once soils dried out in the summer after planting, the surface layer was hard. Finer materials like the Pit 1 Fine Greenstone and Rock Plant Fines are likely to have created this dense texture, whereas larger-textured overburden rock and moisture-retaining compost help to allow air and water movement.

4.0 CONCLUSION AND RECOMMENDATIONS

4.1 Seeds and Soil Treatments

Year 5 test plot monitoring indicates that native shrubs and herbaceous species can be established by seed on all of the various combinations of compost and quarry materials tested. The target composition of reclaimed areas in the Revegetation Plan is a dominant canopy of shrubs and trees (WRA 2011a). Grasses and herbaceous species are also desirable for early establishment to aid in erosion control, compete with non-native plants, and increase native diversity. However, test plot results in Years 1, 2, 3, 4, and 5 have shown that establishing a dense cover of grasses may impede germination or survival of shrubs, the target community to be created over the longer term over much of the quarry. While Plot 1, with bare overburden rock, has the lowest total vegetative cover, it also has high cover of native shrubs and the highest density of shrubs of all plots, possibly due to the lack of competition from grasses and non-native species (see photograph in Appendix A). Other plots with the highest cover of shrubs initially included the shallowest (6 inches) soil treatments (Year 2) and EMSA plots (which had less deer browsing, north-facing slopes, and mycorrhizal inoculant treatments). In Years 3, 4, and 5, however, plots with the deepest (24 inches) soil treatments showed the highest cover of shrubs, indicating that once shrubs have been established, deeper soils may provide better growing conditions.

Year 2 test plot results verified assumptions made in development of the Revegetation Plan, such as that shallower soils without compost are suitable for establishing drought-tolerant native shrubs, and deeper soils and compost result in higher cover of grass and non-native species. However, Years 3, 4, and 5 monitoring results suggest that once shrubs have been established in the plots, deeper soils (Plot 16) possibly provide more nutrients and a better substrate for native shrubs to grow and compete with other species. Similar to monitoring results from previous years, Year 5 monitoring results show that shrubs performed well in plots with both 6-inch and 24-inch soil depths with a slightly greater average percent cover in the plots with 6-inch deep soils.

The Revegetation Plan currently specifies slopes to be prepared with a 6-inch blend of 50 percent native topsoil and 25 percent overburden rock. This blend could be ideal for the initial establishment of native shrubs and exclusion of exotic species (as shown by Plot 1 results), and final test plot results from Year 5 will show if this is the ideal blend for continued shrub survival or if deeper soils with more compost, rock plant fines, or fine greenstones will better promote more long-term shrub establishment.

As suggested following Year 1 and 2 monitoring, small fescue performs well as a rapidly-established erosion control species. However, it and other highly competitive species, both native and non-native, may outcompete and prevent the establishment of shrubs and other desirable native species. Since shrub cover is the dominant community targeted in the Revegetation Plan for the RPA at Permanente Quarry, small fescue may be an undesirable seed mix component for promoting long-term shrub diversity, at least in such high numbers in the seed mix. However, small fescue does appear to be a good species for erosion control as it will rapidly colonize disturbed soils. Other native grasses, including blue wild rye and California brome (*Bromus carinatus*) have also performed well in many plots over the first four years of monitoring, particularly on the north-facing slopes of the EMSA. These grasses should be included in reclamation efforts to provide erosion control, but not at densities that would prevent desired shrub seed germination.

The recommended seed mix for reclamation as described in the Revegetation Plan (WRA 2011a) was developed based on results from Year 1 test plot monitoring, and no additional changes were recommended after initial years of monitoring. However, establishing a greater diversity of shrubs per plot to meet woody species richness performance criteria should be considered after woody richness results have consistently been low over the five Years of monitoring. Chamise would still be a highly desirable species to add to the seed mix, but only if a fire-replicating seed treatment is found to improve germination rates. However, this species may be able to establish in reclaimed areas naturally due to its abundance in adjacent vegetated areas.

The Permanente Quarry erosion control mix currently used, which was tested in one quadrant of Plot 14, is also included in the Revegetation Plan as a potential preliminary step in reclamation.

As observed in the test plots in Years 1 and 2, the high density of grass seed results in rapid establishment of native cover. Native shrub cover increased significantly in Plot 14 in Years 3, 4, and 5 as shrubs became more established and were able to compete with grasses and forbs. Although native cover decreased overall in Years 3, 4, and 5 compared to Year 2, the cover of native shrub species has increased significantly following initial establishment in Years 1 and 2. As mentioned above, shrubs growing in all of three of the EMSA plots, including Plot 14, are very robust and healthy compared with shrubs in the Yeager Yard. It appears that after initial establishment of erosion control grass species, both shrubs and non-native herbs (e.g. summer mustard) have been able to establish. Native shrub cover continued to increase again in Year 5. This continued increase suggests that the performance criteria of the long term Revegetation Plan are being met and that the erosion control mix in Plot 14 was successful at establishing initial dense native cover for the purpose of erosion control leading to an eventual native-shrub dominated community.

While the erosion control seed mix is still recommended for temporarily disturbed areas where erosion control is needed, the revegetation seed mix described in the Revegetation Plan is recommended for larger reclamation areas because it includes a lower density of grasses per acre.

The majority of test plots are meeting all three performance criteria set forth in the Revegetation Plan (Table 3). Although the species richness numbers are not directly comparable (see Table 3 footnote), they indicate that test plot conditions should meet the species richness revegetation performance criteria for overall native cover. However, woody native richness is low in most plots, and the majority of plots would not meet woody richness performance criteria listed in Table 1 above and the Revegetation Plan.

After five years of monitoring, shallower soils and lower amounts of compost seem to provide ideal conditions for establishing native species, especially shrubs, which can better compete with non-native plants in these growing conditions. In addition, it has become evident after five years of monitoring that the straw bales at the edges of the test plots are supporting robust and sustained shrub growth and survival. Therefore, WRA recommends randomly scattering straw bales throughout reclamation areas to similarly promote successful shrub growth and survival as part of the Final Revegetation Plan.

Years 3, 4, and 5 data show that once shrubs are established, however, they seem to prefer the growing conditions provided by deeper soils (Plot 16). High levels of compost in soils seem to still be preventing shrub establishment in Year 5.

4.2 Container Plants

Container plantings were largely a failure, possibly due to the dry and exposed conditions of the Yeager Yard and lack of natural topsoil combined with heavy damage from mice and deer. On the larger scale of Quarry reclamation, wildlife impacts should not have such a significant impact, but protective cages around toyon and coffeeberry may be necessary as these were observed to be most susceptible to deer browse, both in the test plots and at many other restoration sites monitored by WRA. The majority of container plantings are proposed for benches on north and east facing slopes that will supply more moisture and likely benefit container plant establishment. Furthermore, given the noted success and large growth of shrubs adjacent to straw bales, using scattered straw bales adjacent to some container plantings may provide enhanced survival rates.

Mulching around container plantings may be the most feasible protective treatment to improve survival rates. The test plots do confirm that grey pine, which is a dominant component of the

Revegetation Plan, is a hardy tree species that may have the best chance of survival of the species selected. The Revegetation Plan also suggests acorn planting for oak plantings. WRA recommends this method of establishing oaks because it can result in better-established trees that are naturally selected for the local conditions.

Larger container sizes may also be desirable for reclamation efforts, but the plantings should still be installed as young (generally 1-2 year old) plants in narrow, deep containers, and they should be hardened off prior to installation. The emphasis in growing trees and shrubs for the Quarry should be to obtain plants with deep root systems that are not dependent on protective nursery conditions.

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APPENDIX A

MONITORING PHOTOGRAPHS

Above: Year 5 shrub cover in Plot 16, yellow quadrant.

Below: Year 5 shrub cover in Plot 16, blue quadrant

Photographs taken June 6, 2013.

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Above: In Year 5, shrubs exhibit robust growth when adjacent to straw bales which may provide additional moisture, shade, or wind protection.

Below: Robust shrub cover adjacent to straw bales also depicted here.

Photographs taken June 6, 2013.

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Above: Shrubs are more robust and developed at the EMSA site compared to the Yeager Yard site.

Below: Another example of the robust shrub growth at the EMSA site. At the EMSA site, robust shrubs are found throughout the Plot and not just along the wattles and hay bales.

Photographs taken June 6, 2013.

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Above: In Year 4, Plot 1 with 6" soils composed of 100 percent overburden rock exhibits the lowest total vegetation cover, but also the lowest cover of exotics, and the highest density of shrub stems per acre.

Below: In Year 5, Plot 1 vegetation cover and shrub growth had not shown much improvement since Year 4.

Above Photograph taken June 8, 2012.
Below Photograph taken June 6, 2013.

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APPENDIX B

SHRUB DENSITY COMPARISON BETWEEN STRAW BALES AND CENTER-PLOTS

1.0 INTRODUCTION

As part of the design of the Revegetation Test Plot Program (WRA 2010), straw bales were used to delineate the outer boundary of each plot. WRA, Inc. (WRA) biologists observed that shrub growth, particularly that of coyote brush (*Baccharis pilularis*), appeared denser and more robust in close proximity to the straw bales. Though this effect was unintended, WRA decided to take advantage of the situation and sample shrub vegetation along the straw bales. The purpose of this smaller study was to determine whether the placement of straw bales is a useful treatment for future revegetation needs at the Permanente Quarry (Quarry).

2.0 METHODS

On September 10, 2013, WRA biologists used 0.5 square-meter quadrats to sample stem density of shrubs along the straw bales. Each quadrat was randomly placed along the edges of the straw bales, and the number of stems of each woody species was counted within the quadrats. A total of eight sample points were used for each plot. In the Yeager Yard area of the Quarry, which has 13 plots, 104 sample points were used. In the East Materials Storage Area (EMSA) part of the Quarry, which has three plots, 24 sample points were used.

The shrub density, measured as the average number of stems per acre, along the straw bales was compared with the shrub density of the overall plot, which was determined from the annual vegetation monitoring. Comparisons were made between the Yeager Yard plots, the East Material Storage Area (EMSA) plots, and all plots combined.

Although cover was not measured directly, a qualitative observation was made to compare cover along the straw bales and the center-plot vegetative cover.

It should be noted that while mugwort (*Artemisia douglasiana*) was included in the shrub seed mix, it is not included in shrub cover in this analysis. It is a perennial herb that does not provide the same structure and habitat values of the shrubs targeted for establishment in reclamation areas.

3.0 RESULTS

Yeager Yard

The stem density measured 11,363 stems per acre over the 104 straw bale quadrats with a range of 0 to 16 per quadrat. The stem density measured 18,056 stems per acre over the 104 center-plot quadrats with a range of 0 to 14 per quadrat. Stem density along the straw bales was approximately 37 percent lower than in the center-plot quadrats.

Although overall stem density over was lower along the straw bales, the stem density of coyote brush and black sage (*Salvia mellifera*) increased; the stem density of California sagebrush (*Artemisia californica*), California buckwheat (*Eriogonum fasciculatum*), and sticky monkeyflower (*Mimulus aurantiacus*) decreased; and the stem density of the remaining species was unchanged with zero stems per acre.

Shrub cover along the straw bales was greater than shrub cover in the center of the plots. Generally, the shrubs along the straw bales were larger and had denser foliage, covering much more area per plant than those in the center of the plots.

The sampling results in the Yeager Yard are summarized in Table 1 and Figure 1.

Table 1. Summary of Stem-Density Sampling Efforts in the Yeager Yard Plots.

YEAGER	**Total Number of Stems**		**Average Number of Stems Per Plot**		**Average Stems Per Acre**	
	Center-Plot	**Straw Bales**	**Center-Plot**	**Straw Bales**	**Center-Plot**	**Straw Bales**
Adenostoma fasciculatum	0	0	0.00	0.00	0	0
Artemisia californica	62	21	4.77	1.62	9650	3269
Baccharis pilularis	2	14	0.15	1.08	311	2179
Ceanothus cuneatus	0	0	0.00	0.00	0	0
Eriodictyon californicum	0	0	0.00	0.00	0	0
Eriogonum fasciculatum	38	21	2.92	1.62	5915	3269
Eriophyllum confertiflorum	0	0	0.00	0.00	0	0
Heteromeles arbutifolia	0	0	0.00	0.00	0	0
Mimulus aurantiacus	3	1	0.23	0.08	467	156
Salvia mellifera	11	16	0.85	1.23	1712	2490
Total					18056	11363

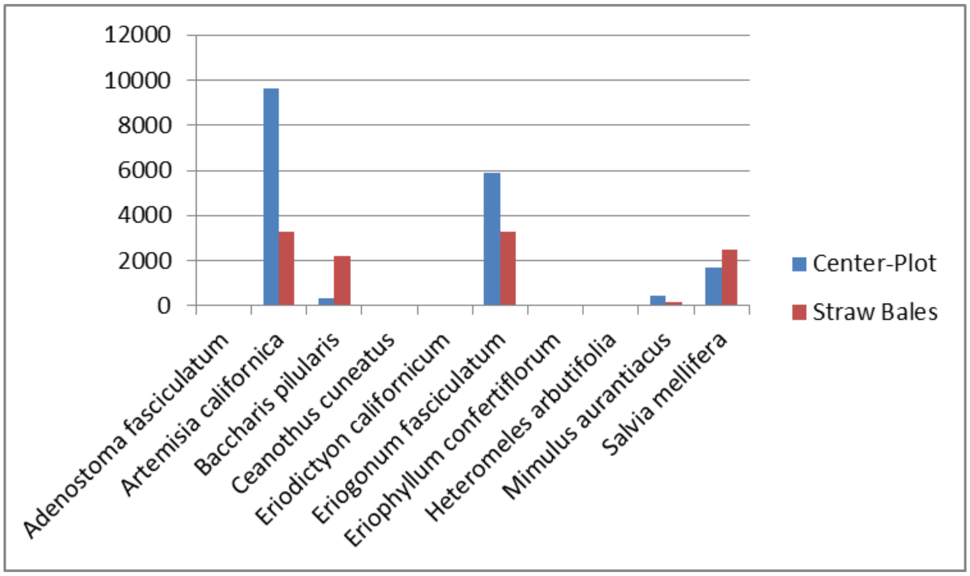

Figure 1. Bar graph depicting stem density sampling results by species in the Yeager Yard plots.

EMSA

The stem density measured 12,815 stems per acre over the 24 straw bale quadrats with a range of 0 to 9 per quadrat. The stem density measured 11,466 stems per acre over the 24 center-plot quadrats with a range of 0 to 8 per quadrat. Total shrub density was approximately 12 percent greater along the straw bales than it was in the center-plot quadrats.

Along the straw bales, the stem density of California buckwheat, coyote brush, and black sage increased; the stem density of California sagebrush decreased; and the stem density of the remaining species was unchanged at zero stems per acre.

Shrub cover along the straw bales did not appear to differ greatly from the cover in the center of the plot. Shrub size and foliage density was also similar between the two areas.

The sampling results in the EMSA are summarized in Table 2 and Figure 2.

Overall

The stem density measured 11,635 stems per acre over the 128 straw bale quadrats with a range of 0 to 16 per quadrat. The stem density measured 16,820 stems per acre over the 128 center-plot quadrats with a range of 0 to 14 per quadrat. Total shrub density was approximately 31 percent less along the straw bales than it was in the center-plot quadrats. The much smaller number of plots in the EMSA (three plots) than in the Yeager Yard (13 plots) results in the overall data being heavily influenced by the Yeager Yard data.

Along the straw bales, the stem density of coyote brush and black sage increased; the stem density of California sagebrush, California buckwheat, and sticky monkeyflower decreased; and the stem density of the remaining species was unchanged with zero stems per acre.

There was no overall trend in shrub cover, size, or density of foliage. As discussed in the previous two sections, the shrub cover, size, and foliage density in the Yeager Yard was greater along the straw bales than in the center-plot quadrats. In the EMSA, it was similar along the straw bales and in the center-plot quadrats.

The overall sampling results are summarized in Table 3 and Figure 3.

Table 2. Summary of Stem-Density Sampling Efforts in the EMSA Plots.

EMSA	Total Number of Stems		Average Number of Stems Per Plot		Average Stems Per Acre	
	Center-Plot	Straw Bales	Center-Plot	Straw Bales	Center-Plot	Straw Bales
Adenostoma fasciculatum	0	0	0.00	0.00	0	0
Artemisia californica	3	1	1.00	0.33	2023	674
Baccharis pilularis	0	1	0.00	0.33	0	674
Ceanothus cuneatus	0	0	0.00	0.00	0	0
Eriodictyon californicum	0	0	0.00	0.00	0	0
Eriogonum fasciculatum	14	16	4.67	5.33	9443	10792
Eriophyllum confertiflorum	0	0	0.00	0.00	0	0
Heteromeles arbutifolia	0	0	0.00	0.00	0	0
Mimulus aurantiacus	0	0	0.00	0.00	0	0
Salvia mellifera	0	1	0.00	0.33	0	674
Total					11466	12815

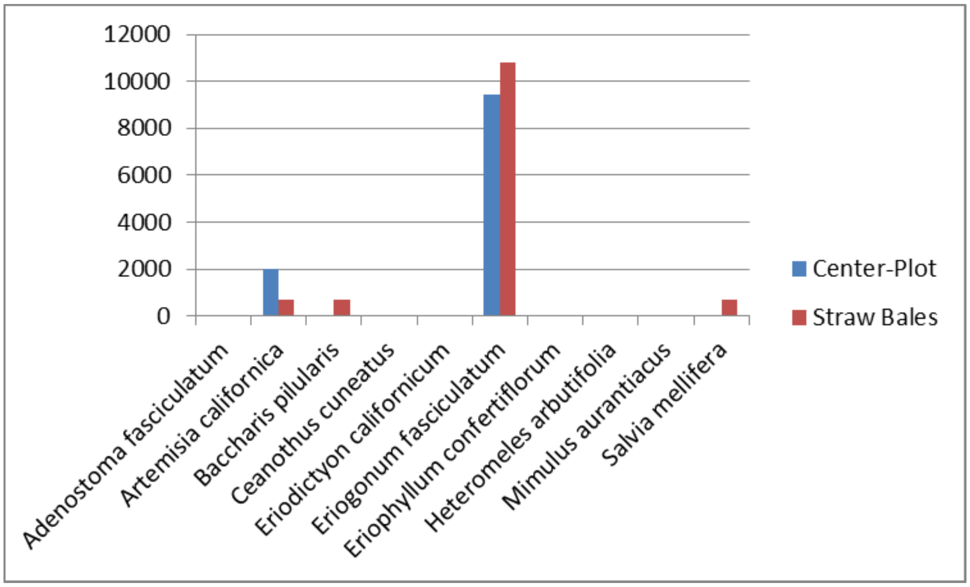

Figure 2. Bar graph depicting stem density sampling results by species in the EMSA plots.

Table 3. Summary of stem-density sampling efforts in all plots.

ALL PLOTS	**Total Number of Stems**		**Average Number of Stems Per Plot**		**Average Stems Per Acre**	
	Center-Plot	**Straw Bales**	**Center-Plot**	**Straw Bales**	**Center-Plot**	**Straw Bales**
Adenostoma fasciculatum	0	0	0.0	0.0	0	0
Artemisia californica	65	22	4.1	1.4	8220	2782
Baccharis pilularis	2	15	0.1	0.9	253	1897
Ceanothus cuneatus	0	0	0.0	0.0	0	0
Eriodictyon californicum	0	0	0.0	0.0	0	0
Eriogonum fasciculatum	52	37	3.3	2.3	6576	4679
Eriophyllum confertiflorum	0	0	0.0	0.0	0	0
Heteromeles arbutifolia	0	0	0.0	0.0	0	0
Mimulus aurantiacus	3	1	0.2	0.1	379	126
Salvia mellifera	11	17	0.7	1.1	1391	2150
Total					16820	11635

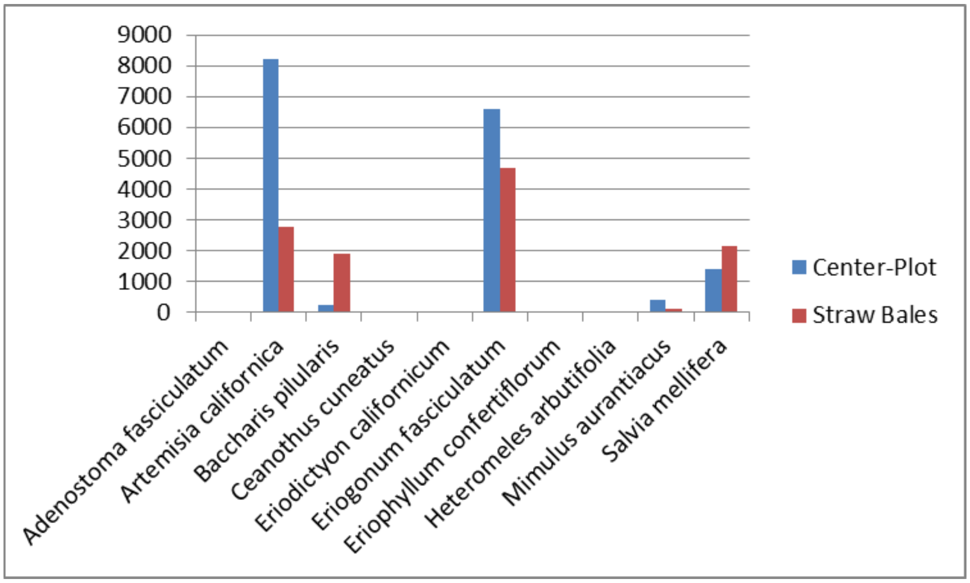

Figure 3. Bar graph depicting stem density sampling results by species in all plots.

4.0 CONCLUSION

Based on stem density and a qualitative, visual assessment of cover, it appears that the cooler, north-facing slopes in the EMSA lead to more favorable conditions for plant growth than the flat topography of Yeager Yard. Straw bales appear to have minimal influence on plant growth on north-facing slopes and may not be useful for revegetation in such conditions. However, the straw bales do appear to promote plant growth on flat sites which are hotter and receive more sunlight than north-facing slopes. The straw bales may provide thermal protection and increased moisture on harsher sites, and as such, could prove useful in revegetation efforts on flat ground or south-facing slopes.

For sites on north-facing slopes, California sagebrush and California buckwheat appear to be the best choices for revegetation efforts, regardless of the presence of straw bales. Coyote brush and black sage may also be good choices.

For harsher sites with straw bales, coyote brush appears to be the best choice. It is a fast-growing, tall, native shrub that provides cover, and its roots may provide protection from erosion by stabilizing the slopes it grows on. If coyote brush continues to respond to the presence of straw bales on other harsh sites, then the placement of straw bales could increase the likelihood of meeting performance criteria in such areas.

Many of the revegetation areas in the Quarry are steep, often at the angle of repose, and consist of loose substrate. Such conditions were not present at the Yeager Yard or the EMSA plots. Further experiments are recommended to see if the findings of this study can be applied to other situations in the Quarry.

5.0 REFERENCES

WRA, Inc. 2010. Revegetation Test Plot Program As-Built Report. Permanente Quarry, Cupertino, Santa Clara County, California. Prepared for Lehigh Southwest Cement Company. March.