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Technical Memorandum

From: Grace A. McCarley Holder, Geologist

To: Sapphos Environmental INC.

Date: October 4, 2013

Subject: Preliminary Results of Plant Establishment in the Straw Bale Demonstration Dust Control Project

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Introduction

The District is currently testing a potential new dust control measure that uses straw bales and native plants. The straw bales act as roughness elements to stabilize an active source area and also as shelter for newly planted native shrubs. In the conceptual design of the measure, dust control will be transferred from the bales, as they degrade over time, to the plants as they mature and grow. The beauty of the conceptual design of the project is that immediate control of an active dust source area is achieved with the placement of the straw bales and that full dust control effectiveness is maintained throughout establishment and growth of the native shrubs. Additionally, the potential new control measure can be implemented with minimal impacts to existing natural resources and if placed in the right environment can ultimately be self-sustaining.

In order to determine if the conceptual design of the proposed new dust control measure will work within the design parameters, the District is conducting a small-scale test of the straw bale measure. The 50 meter by 100 meter (1.2 acre) test site for the project (Straw Bale Demonstration Project) is located in the northern portion of the Keeler Dunes on an active sand sheet. If successful, the new dust control measure could be used on a large scale within the dunes as well as on other active dust sources in the area, such as those on the bed of Owens Lake. In particular, this new control measure has applicability in the transition from Shallow Flooding to Managed Vegetation or to a Managed Vegetation-Shallow Flooding control combination (termed “Hybrid”).

The Straw Bale Demonstration Project has two main components being tested and monitored:

1) control effectiveness (reduction in the sand motion and surface winds across the site) and
2) establishment of selected native shrubs.

The purpose of this technical memorandum is to present the results, as of September 13, 2013, on the establishment of the native shrubs planted on the test site on May 30, 2013. An interim report on the control effectiveness or the effect of the straw bale array on the wind speed and sand motion across the test site is being prepared by Dr. Jack Gillies of the Desert Research Institute (DRI) in a separate technical report (Gillies, 2013).

Overview of Straw Bale Demonstration Test

The Straw Bale Demonstration Project site was instrumented with sand catchers, Sensits and meteorological equipment in April 2013. Placement of the 504 straw bales on the site occurred on two dates, May 23 (336 bales) and June 12 (168 bales). Several weeks of pre-bale monitoring was conducted on the test site prior to bale placement in order to measure the pre-control magnitude and the spatial variability of the sand motion and wind data across the site.

A critical component of the Straw Bale test is the establishment of native shrubs on the site. As such, the District contracted with Ms. Katie Quinlan of the Bristlecone Chapter of the California Native Plant Society in the spring of 2012 for propagation of shrubs in anticipation of the test beginning in the fall of 2012[1]. Five species of locally adapted native shrubs were planted and propagated at the White Mountain Research Station (WMRS) facility in Bishop, CA operated cooperatively by the Bristlecone Chapter of the California Native Plant Society, Bureau of Land Management (BLM), and the U.S. Forest Service. The five species (listed below) chosen for planting on the test site are found naturally within the Owens Lake area and were considered to have a high likelihood of success.

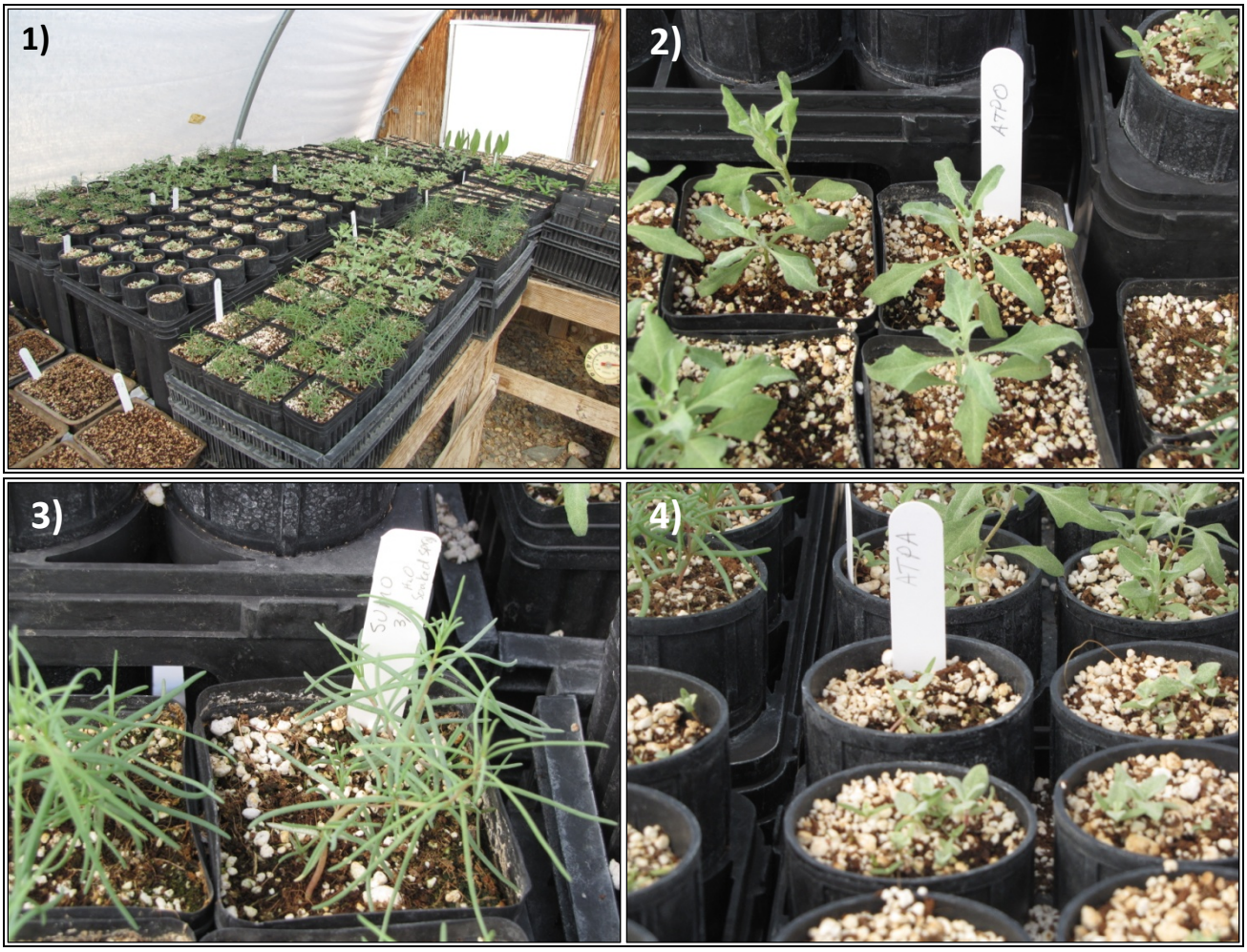
Atriplex polycarpa (ATPO) – cattle saltbush, cattle spinach
Atriplex parryi (ATPA) – Parry's saltbush
Atriplex confertifolia (ATCO) - shadscale
Sarcobatus vermiculatus (SAVE) - greasewood
Suaeda moquinii (SUMO)[2] – Mojave seablite, bush seepweed

Three hundred and twenty eight plants (328) were started in April 2012 from a combination of seed and stem cuttings. Seed used for the project was collected by District staff in the fall of 2011 from plants in the Owens Lake area. Literature research indicated that *S. vermiculatus* and *A. confertifolia* are difficult to propagate from seed such that stem cuttings of these two species were collected and placed in a cutting box for root development and cultivation. The other three species (*A. parryi, A. polycarpa, and S.moquinii)* were propagated from seed. Approximately one-third of the shrubs started in April 2012

[1] Note: The test was originally planned to begin in September of 2012. However, due to a delay in getting the funding for the test, the test did not begin until April of 2013, approximately 7 months behind schedule. The plants started in April 2012 were ready to plant in the fall of 2012 but had to be kept in pots over the winter. A combination of unusually cold weather in December and January, heavy herbivory, and lack of success of the cuttings reduced the number of plants from 328 to 143 over the winter. Two plants were in poor condition in May 2013 and were not planted leaving 141 total plants placed in the ground on May 30, 2013.

[2] Note: According to the current Jepson Manual of plant identification, the classification for this species has changed. The current species name is *Suaeda nigra* instead of *Suaeda moquinii.* For the purposes of this report and project the former name of *Suaeda moquinii* will continue to be used to avoid confusion.

were from cuttings and two-thirds from seed. Photos 1-6 provide pictures of the seedlings and stem cuttings of the native plants propagated for the Straw Bale Demonstration Test in April 2012.



Photos 1-4: Native plant seedlings in April 2012. Photo 1 (upper left) – overview of seedlings in the greenhouse at WMRS. Photo 2 (upper right) – ATPO seedlings. Photo 3 (lower left) – SUMO seedlings. Photo 4 (lower right) – ATPA seedlings.

Photo 5: Placement of SAVE cuttings into prepared perlite bed in the cutting box.

Photo 6: View of SAVE and ATCO cuttings in the cutting box on April 15, 2012.

Table 1 provides the number of planted individuals of each species and the method of propagation used. Notice that of the 328 plants originally propagated in April 2012 only 141 (or 43%) were actually placed in the ground in May 2013. This was due to a combination of a high rate of herbivory over the winter, extremely cold weather in December 2011 and January 2012 and poor success of the rooting and establishment of the stem cuttings (see footnote [1]).

Table 1. Native shrubs planted on the Straw Bale Demonstration Project site in May 2013.

Species – Scientific Name	Abbreviation	Common Name	Number of Plants started in April 2012	Propagation Method	Number of Shrubs Planted in May 2013
Atriplex confertifolia	ATCO	Shadscale saltbush	49	Cuttings	23
Atriplex parryi	ATPA	Parry's saltbush	59	Seed	46
Atriplex polycarpa	ATPO	Cattle spinach, Cattle saltbush	90	Seed	54
Sarcobatus vermiculatus	SAVE	Greasewood	64	Cuttings	12
Suaeda moquinii[2]	SUMO	Mojave seablite, bush seepweed	66	Seed	6
		TOTAL	**328**		**141**

Planting and Watering

Planting of the native shrubs on the test site was conducted on May 30, 2013 in association with the first shipment of bales. The shrubs were planted in a block of 47 bales located on the southeastern portion of the test site. Three shrubs were planted along the northern side of each bale. In between the plants, two watering tubes were installed to facilitate the delivery of water directly to the root zone area (Photos 7 and 8). Figure 1 provides a map of the test site and the block of bales where the native shrubs were planted.

Photo 7: Plants and watering tubes ready for placement in the ground, May 30, 2013.

Photo 8: Picture of the newly planted shrubs along the edge of a straw bale, May 30, 2013.

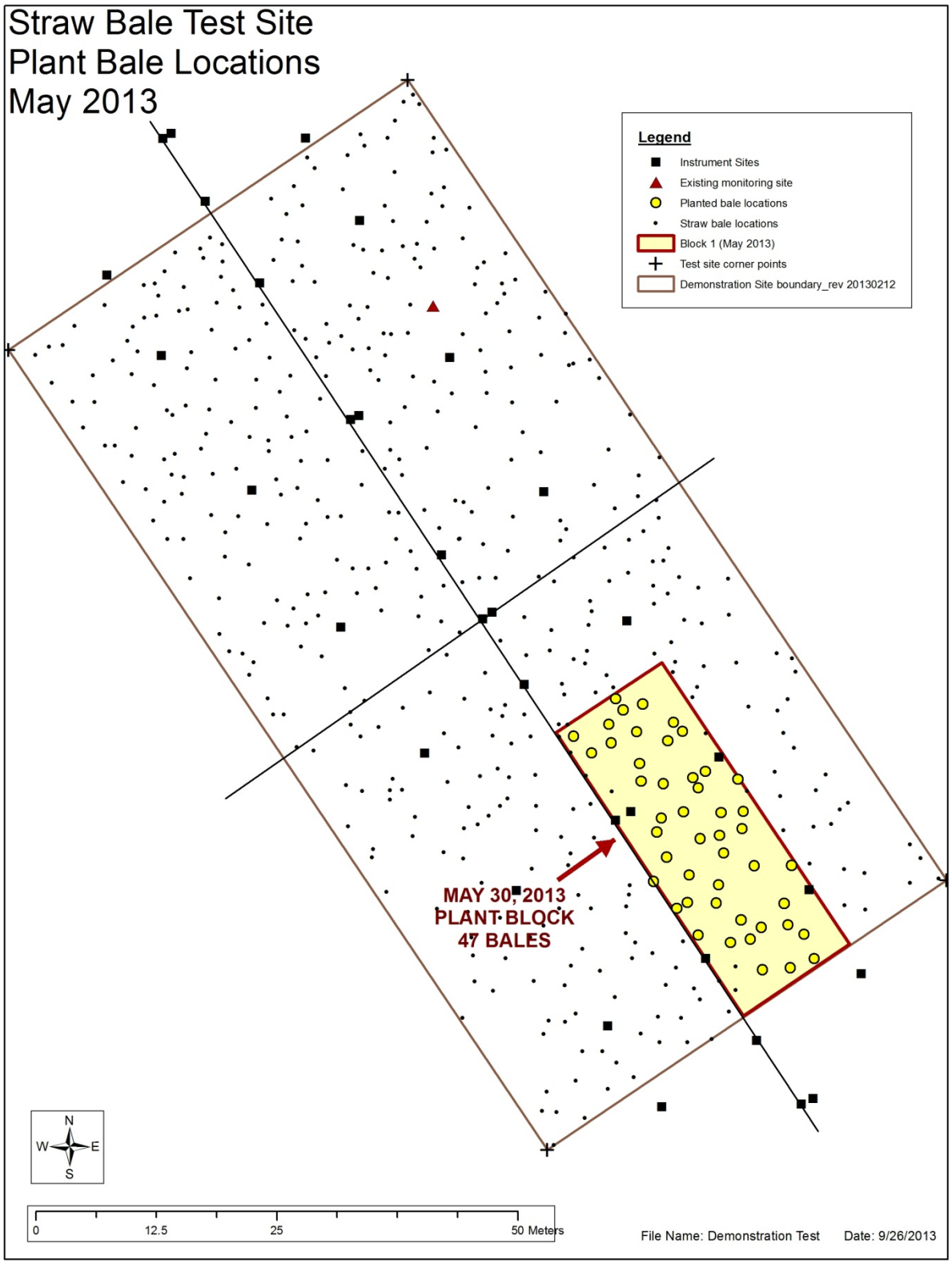


Figure 1. Map showing the location of the block of bales (highlighted in yellow) for the May 2013 planting of native shrubs on the Straw Bale Test Project.

Minimal preparation of the soil was conducted prior to planting of the shrubs. Due to the dry conditions of the sand sheet in the test area, the ground underneath and along the northern side of the selected bales was watered with approximately 5.4 gallons of water the day before (May 29, 2013) placement of the plants in the ground. Three teams of two people worked for approximately 2-3 hours in planting the shrubs and installing the watering tubes. The plants and watering tubes were placed in a trench approximately 18-20"long and 6-8" wide dug using a small hand shovel. The trench was backfilled with the borrowed sand and tamped around the plants and watering tubes. Care was taken by each team to remove each plant from the pot and in placing each plant in the ground in order to maintain the integrity of the soil around the roots. However this was particularly difficult for the ATPA which tended to fall apart when removed from their pots.

Following planting, each planted bale location was watered with approximately 5.4 gallons of water applied mostly through the watering tubes directly to the root zone of the plants. Due to the harsh conditions during June and July 2013, the newly planted shrubs were given supplemental water to assist in establishment. During the first month following planting, supplemental water was provided seven times with an average of 4 days between watering events. The watering frequency was reduced to an average of every 7-8 days during July through mid-September. Then in mid-September, the irrigation schedule was further reduced to approximately every two weeks. The District is planning on continuing to reduce the frequency of irrigation first to once every three weeks and then four weeks until the end of the growing season. During all of the supplemental watering events following planting on May 30, 2013, an average of 3.0 gallons of water was provided to each planted bale. A summary of the water use and irrigation schedule is provided in Table 2.

A portable watering system is used to provide water to the plants on the test site. The system consists of a 250 gallon plastic tank and small pump mounted on an ATV trailer. The water is transported from the tank to the planted bales through a 1-inch fire hose (Photo 9). The water tank is filled with water at the District's Keeler field office/yard. Fertilizer was applied once to the plants on the test site. The application was conducted on July 3, 2013 and consisted of approximately 1 teaspoon of slow release fertilizer pellets (Osmocote Smart-release Plant Food 14-14-14) added to each watering tube.

Photo 9. Water tank and fire hose system used to provide water to the plants on the test site.

Plant Survivorship

Following planting of the shrubs on the test site, the health of the plants was monitored regularly. During each monitoring event the vigor or overall health of each plant is assessed based on a qualitative ranking scale that ranges from 0-4: Excellent (4), Good (3), Fair (2), Poor (1), and Dead (0). The vigor rankings are based on factors such as number of leaves, leaf color, leaf size, presence of new growth, etc. Photographs were taken of the plants at each bale just after planting (5/30/2013), mid-summer (7/17/2013) and at the end of September (9/30/2013).[3] Tables 3 through 5 provide a summary of the plant vigor and mortality/survivorship data from May 30, 2013 to September 13, 2013.

As of September 13, 2013, the overall survivorship rate was at 72% for the 141 shrubs planted on May 30, 2013. Thirty-nine individual plants have died over the first 15 weeks of the test. The total number of plant deaths is primarily dominated by one species. Over two-thirds of the total number of plant deaths (27 out of 39 total dead) has occurred in the ATPA population. This accounts for over 50% of the 46 original ATPA planted on the test site.

Perhaps just as important as or perhaps even more important than focusing on the number of plants that have died is to look at the vigor of the surviving 102 plants on the test site. As of September 13, 2013, 66% of the living plants are doing well with a vigor rating of Good or Excellent while only 34% are in the Fair and Poor categories (Table 3).

[3] Note: Subsequent plant monitoring will include photos of the plants in the spring when they break dormancy (March or April), at peak plant biomass (July), and at the end of the season (November). Additional photos were taken during the initial plant establishment in order to document the plant establishment and growth.

Table 2. Summary of the water schedule and use on the Demonstration Test site as of September 13, 2013.

Date	Total gallons	Gallons per Bale	Water per plant	Notes
5/29/2013	255	5.4	N/A	pre-planting watering
5/30/2013	255	5.4	1.8	initial plant watering
6/03/2013	120	2.6	0.9	
6/06/2013	120	2.6	0.9	
6/10/2013	100	2.1	0.7	
6/14/2013	220	4.7	1.6	
6/20/2013	120	2.6	0.9	
6/25/2013	120	2.6	0.9	
6/28/2013	120	2.6	0.9	
7/03/2013	125	2.7	0.9	start watering once per week
7/15/2013	125	2.7	0.9	
7/22/2013	120	2.6	0.9	
8/01/2013	130	2.8	0.9	
8/06/2013	140	3.0	1.0	
8/15/2013	140	3.0	1.0	
8/22/2013	140	3.0	1.0	
8/30/2013	140	3.0	1.0	
9/06/2013	140	3.0	1.0	
9/13/2013	140	3.0	1.0	start watering every 2-4 wks
9/30/13				planned irrigation event
10/21/13				planned irrigation event
11/18/13				planned irrigation event
Total	**2,770**	**58.9**	**17.8**	
Average	**145.8**	**3.1**	**1.0**	

Table 3. Summary of plant vigor data from 5/30/2013 to 9/13/2013. Vigor results are given as the total number of plants within each vigor classification ranking. (ND = no data)

Date	Plant Vigor				
	Dead	Poor	Fair	Good	Excellent
5/30/2013	0	0	13	127	1
6/03/2013	2	2	ND	ND	ND
6/05/2013	4	3	19	112	3
6/10/2013	4	5	20	109	3
6/14/2013	3	3	27	88	19
6/20/2013	3	3	29	88	18
6/25/2013	4	3	28	88	18
6/28/2013	8	4	24	87	18
7/03/2013	9	3	16	92	21
7/15/2013	13	11	31	79	7
7/22/2013	18	6	31	79	7
8/01/2013	23	7	20	64	19
8/06/2013	23	21	23	55	19
8/15/2013	28	17	25	49	22
8/22/2013	32	18	20	47	24
8/30/2013	35	17	20	46	23
9/06/2013	38	19	15	45	24
9/13/2013	39	19	16	41	26

Table 4. Summary of plant mortality from 5/30/13 to 9/13/13.

Date	Number of Dead Plants by Species					Total # Dead	Overall % dead	Total # living	Overall % alive
	ATCO	ATPA	ATPO	SAVE	SUMO				
5/30/2013	0	0	0	0	0	0	0	141	100
6/03/2013	0	1	1	0	0	2	1	139	99
6/06/2013	0	3	1	0	0	4	3	137	97
6/10/2013	0	3	1	0	0	4	3	137	97
6/14/2013	0	2	1	0	0	3	2	138	98
6/20/2013	0	2	1	0	0	3	2	138	98
6/25/2013	0	3	1	0	0	4	3	137	97
6/28/2013	1	6	1	0	0	8	6	133	94
7/03/2013	1	7	1	0	0	9	6	132	94
7/15/2013	1	11	1	0	0	13	9	128	91
7/22/2013	1	14	2	0	1	18	13	123	87
8/01/2013	1	17	3	0	2	23	16	118	84
8/06/2013	1	17	3	0	2	23	16	118	84
8/15/2013	1	21	3	0	3	28	20	113	80
8/22/2013	1	24	3	0	4	32	23	109	77
8/30/2013	2	26	3	0	4	35	25	106	75
9/06/2013	2	27	3	1	5	38	27	103	73
9/13/2013	2	27	3	2	5	39	28	102	72

Table 5. Summary of the plant survivorship given as percentage of original number of shrubs planted for each species from 5/30/13 to 9/13/13.

Date	% Survivorship by species				
	ATCO	ATPA	ATPO	SAVE	SUMO
5/30/2013	100.0	100.0	100.0	100.0	100.0
6/03/2013	100.0	97.8	98.1	100.0	100.0
6/06/2013	100.0	93.5	98.1	100.0	100.0
6/10/2013	100.0	93.5	98.1	100.0	100.0
6/14/2013	100.0	95.7	98.1	100.0	100.0
6/20/2013	100.0	95.7	98.1	100.0	100.0
6/25/2013	100.0	93.5	98.1	100.0	100.0
6/28/2013	95.7	87.0	98.1	100.0	100.0
7/03/2013	95.7	84.8	98.1	100.0	100.0
7/15/2013	95.7	76.1	98.1	100.0	100.0
7/22/2013	95.7	69.6	96.3	100.0	83.3
8/01/2013	95.7	63.0	94.4	100.0	66.7
8/06/2013	95.7	63.0	94.4	100.0	66.7
8/15/2013	95.7	54.3	94.4	100.0	50.0
8/22/2013	95.7	47.8	94.4	100.0	33.3
8/30/2013	91.3	43.5	94.4	100.0	33.3
9/06/2013	91.3	41.3	94.4	91.7	16.7
9/13/2013	91.3	41.3	94.4	83.3	16.7

The cause for the high death rate for the ATPA is uncertain but is thought to be related to the long flexible ("leggy") plant stems and poor root development. Instead of having a stiff upright stem structure, the ATPA plants placed on the test site in May 30, 2013 were short in height and had long leggy stems (Photos 10 and 11). Observations made during plant monitoring events note that the APTA stems were buried and burned by the hot sand moving within the project. District staff uncovered the affected plants on several occasions from the sand that covered them but generally the damage was already done. Another contributing factor to the high mortality of the ATPA is thought to be the root development structure. While being planted on the test site, the soil of many of the ATPA "fell apart" when the plant was removed from the pot for placement into the prepared trench. This did not occur with the other plant species and is thought to have occurred due to the root distribution of the ATPA. Instead of having roots distributed throughout the soil column in the pot, roots were concentrated at the top near the surface and at the base of the pot with very few roots in-between creating poor soil-root integrity.

In addition to the high mortality rate for the ATPA, the SUMO population has also experienced high mortality with the death of 5 of the 6 original plants. However, unlike the ATPA which started to die within the first few days of being planted, all of the SUMO deaths have occurred since July 22, 2013 (Table 4). The main cause of the SUMO deaths is thought to be from browsing from small mammals that have started to utilize the test site. Similarly, browsing impact has been observed on the SAVE plants (although not as severe as the SUMO). Wire protective cages were constructed and placed around all plants at bales containing either SUMO or SAVE in mid- September 2013.

The most successful species, through 9/13/13, are the ATPO and ATCO. Both species have survivorship rates over 90% (see Table 5). The SAVE population also has a high survivorship rate of over 80%. Both SAVE deaths have occurred in September 2013 and, as mentioned above, are thought to be related to browsing activities from small rodents.

Figures 2 through 4 show plots of the plant monitoring data through September 13, 2013. The overall survivorship of the plants on the test site is 72% as of September 13, 2013. The weighted average vigor ranking for all of the plants on the test site has declined from 2.9 on May 30, 2013 to 1.97 on September 13, 2013 (Figure 4).

To illustrate the change over the first four months of the project, photo sequences of the plants at three different bales are presented in Photos 12-14. The photos were taken on three dates; at the time of planting (5/30/2013), mid-summer (7/17/2013), and at the end of September (9/30/13). The photos taken at bale numbers 5, 8 and 47 (see Photos 12- 14) illustrate the overall growth and Good to Excellent vigor rating of the ATPO and ATCO plants over the course of the summer. An example of one of the wire protective structures installed to protect the SAVE and SUMO plants is visible in Photo 12C.

Photos 10 and 11. Photos showing the long leggy stems of the ATPA on May 30, 2013. Photo 10 (left) shows the contrast in plant structure between the ATPA (in the tray near the cardboard box) and the rest of the plants. Photo 11 (right) shows a close up of an ATPA in its pot prior to planting. Notice the long leggy stems draped over the edge of the pot.

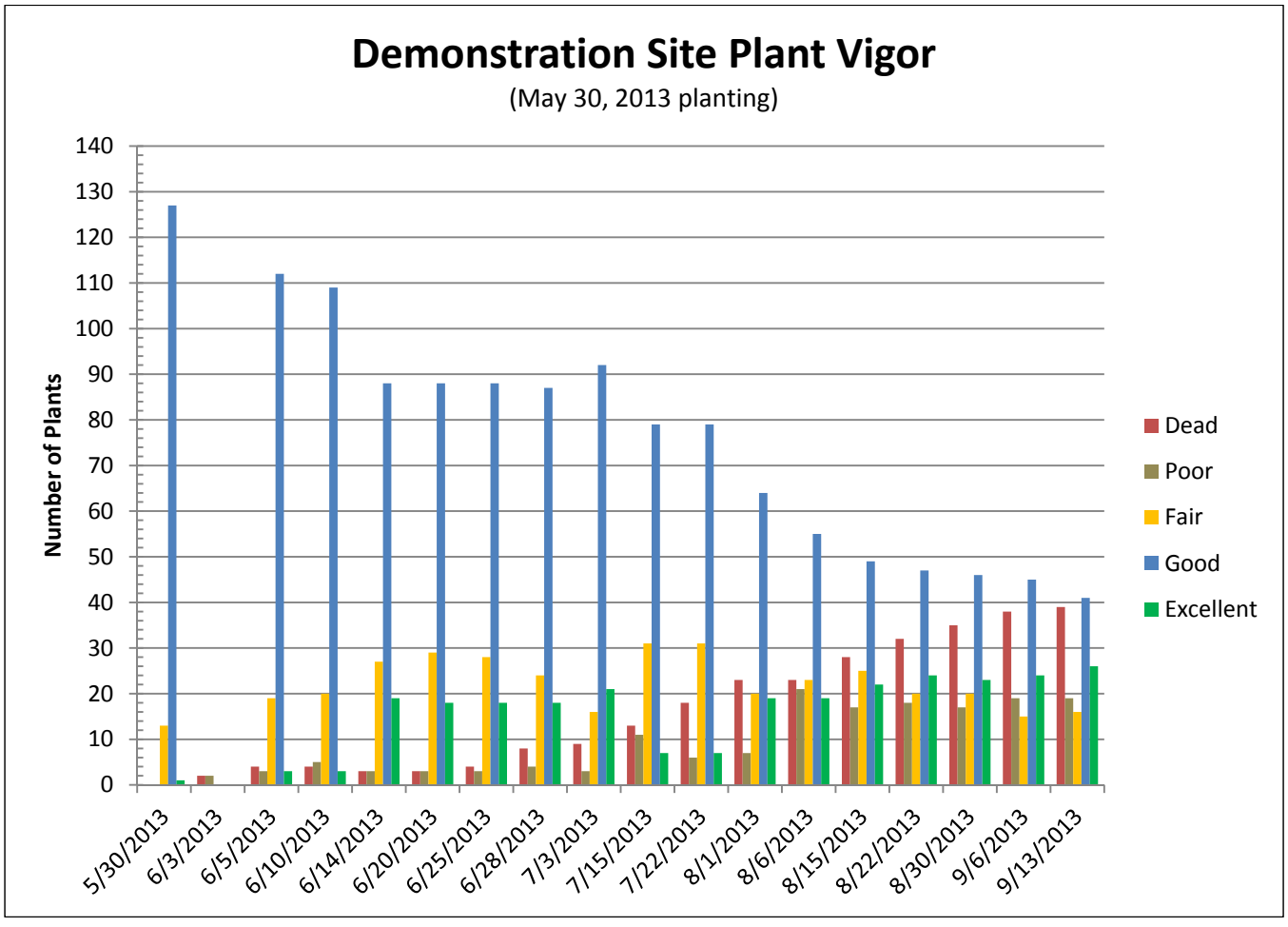


Figure 2. Plot showing the number of plants in each vigor ranking category through 9/13/2013.

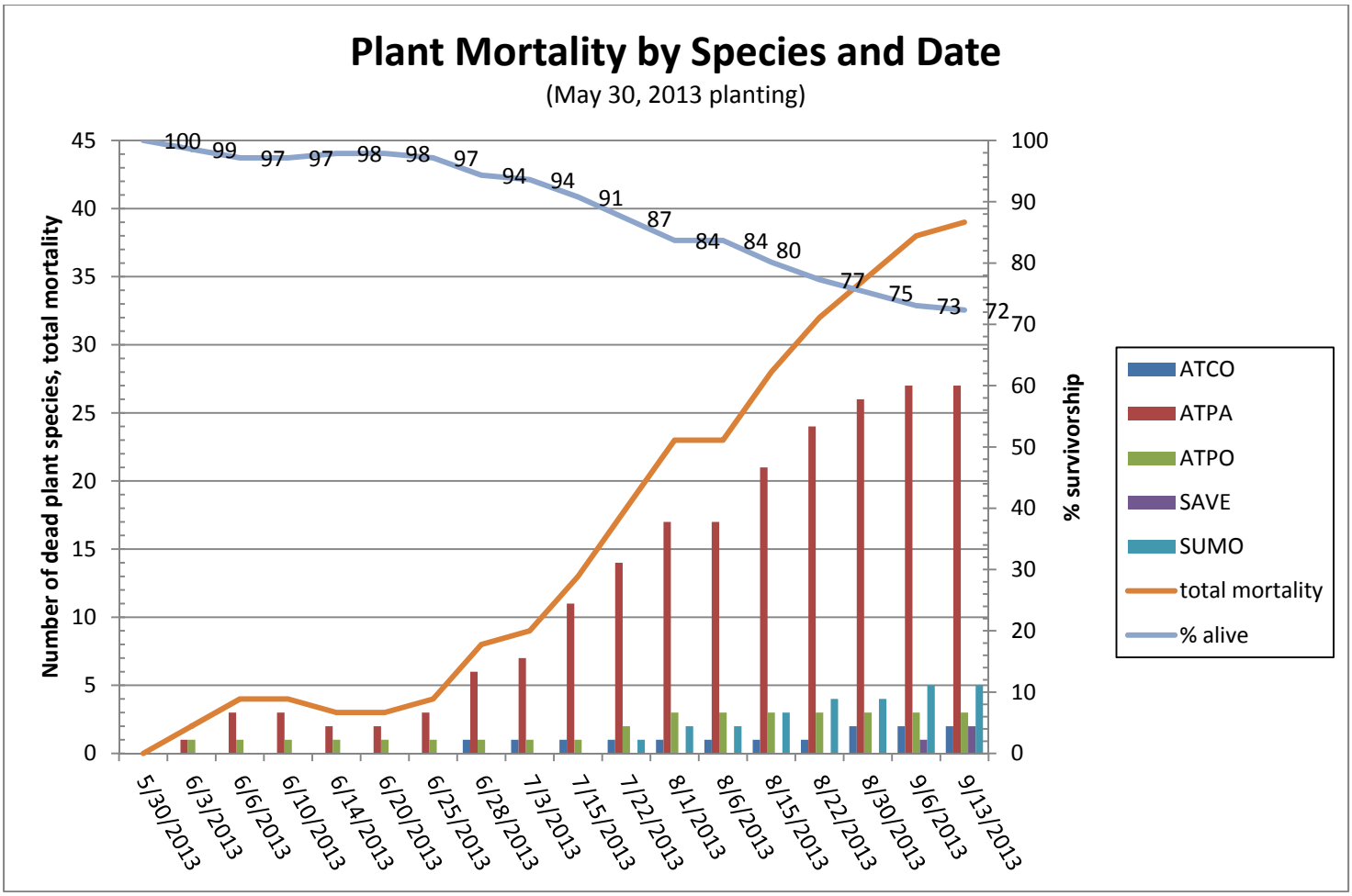


Figure 3. Plot showing the number of dead plants and total mortality (left axis) and percent survivorship (right axis) through September 13, 2013. The colored bars show the number of dead plants from each of the five species of native shrubs planted on the test site.

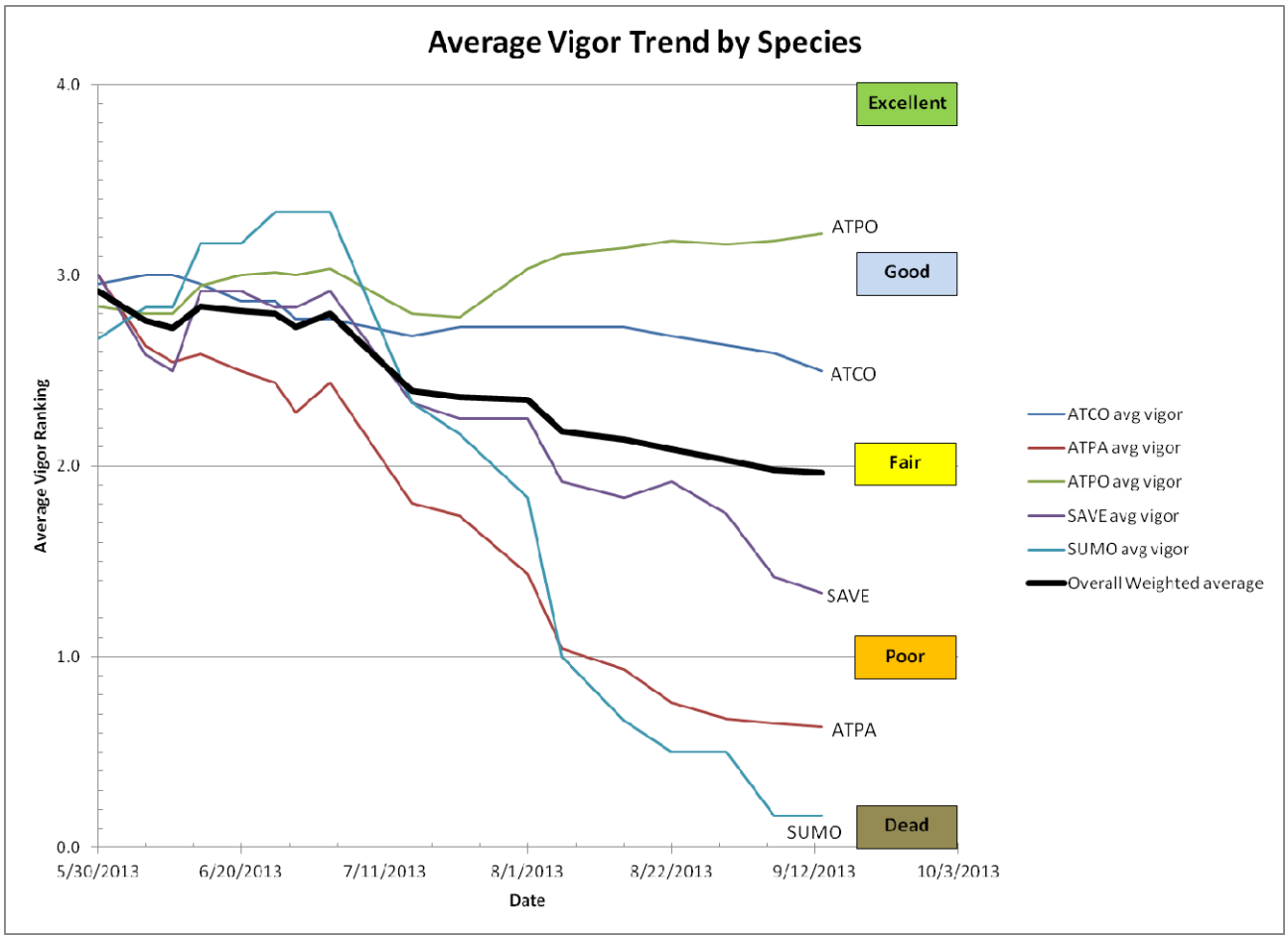


Figure 4. Plot of the average vigor ranking for each plant species from May 30, 2013 through September 13, 2013. An overall weighted average trend line is also provided. The ATPO and ATCO plants continue to have an overall high vigor ranking well above the weighted average line. ATPA and SUMO vigor has declined during the first 15 weeks of the test into an overall ranking of Poor.

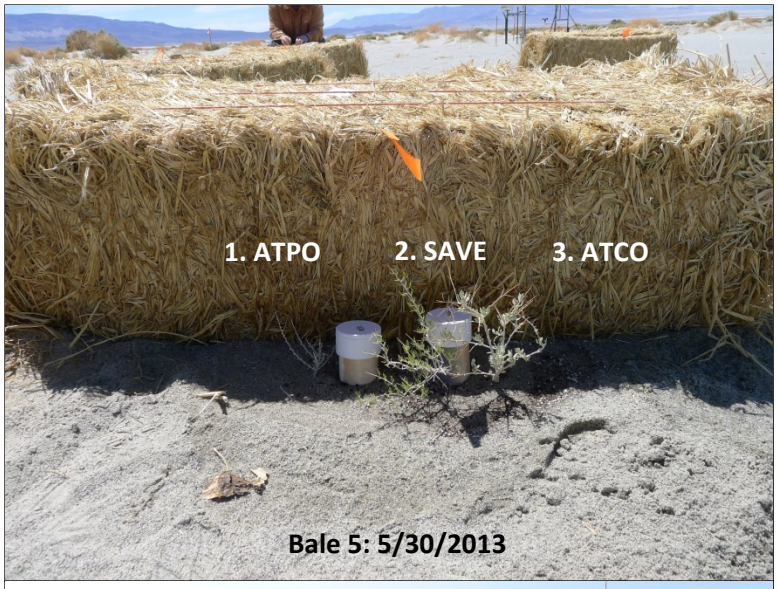


Photo 12: Monitoring photos taken of the plants at Bale number 5 showing the plants from three dates from May to September 2013. The plants are numbered 1, 2, and 3 sequentially from left to right. On September 30, 2013 (bottom photo) the vigor rankings were Plant 1 (ATPO) = Excellent, Plant 2 (SAVE) = Good, and Plant 3 (ATCO) = Good

A) May 30, 2013: date of planting

B) July 17, 2013:

C) September 30, 2013: Notice the wire protective structure placed around the plants to prevent browsing impacts on the SAVE.

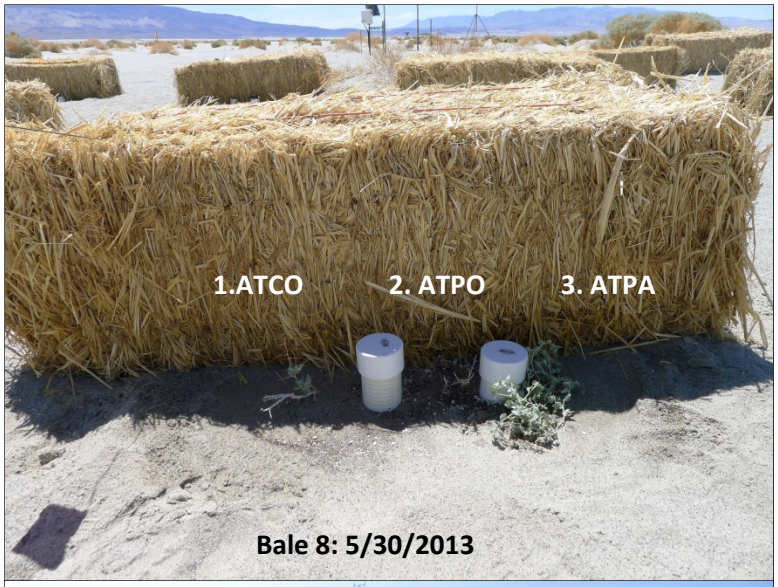


Photo 13: Monitoring photos taken of the plants at Bale number 8 showing the plants from three dates from May to September 2013. The plants are numbered 1, 2, and 3 sequentially from left to right. On September 30, 2013 (bottom photo) the vigor rankings were Plant 1 (ATCO) = Excellent, Plant 2 (ATPO) = Excellent, and Plant 3 (ATPA) = Dead

A) May 30, 2013: Notice the leggy structure of the ATPA on the right.

B) July 17, 2013

C) September 30, 2013: Notice the Excellent vigor of the ATCO and ATPO and that the ATPA is now Dead.

Photo 14: Monitoring photos taken of the plants at Bale number 47 showing the plants from three dates from May to September 2013. The plants are numbered 1, 2, and 3 sequentially from left to right. On September 30, 2013 (bottom photo) the vigor rankings for all three ATPO plants was Excellent.

A) May 30, 2013

B) July 17, 2013

C) September 30, 2013: Notice the continued growth of the ATPO from May to September.

Summary

Most desert restoration projects consider a survivorship rate of 50% or higher to be successful (Abella and Newton, 2009). So far this success level has been achieved on the Straw Bale Demonstration project within the first 2 ½ months of the project. Due to the time of planting, right before the extended hot period at the peak of summer season, District staff made extra effort to provide water and conditions suitable for plant success. This level of effort is not sustainable for the proposed large scale dust control project which has a foot print of approximately 200 acres.

The optimum time for planting in desert vegetation projects is in the fall season right before the plants go dormant for the winter. A second set of approximately 500 native plants were started from seed in April 2013 for planting on the test site in October 2013. This second planting will provide valuable information on plant survivorship as designed for the full scale project.

Two main issues of concern that were identified in the first set of plants on the bale project include browsing impacts and plant/root structure. In order to address these issues for the next set of plants being planted on the test site at the end of October 2013, the District is going to place protection structures around the plants at each bale that has a SUMO or SAVE when the plants are placed in the ground and is also having the new ATPA plants pruned to promote an upright stem structure. The District plans to continue monitoring the health of the existing plants on the test site as well as begin monitoring the health and establishment of the new plants schedule for placement in the ground in October.

References

Abella, S. R.and A.C. Newton. 2009. A systematic review of species performance and treatment effectiveness for revegetation in the Mojave Desert, USA. In *Arid Environments and Wind Erosion*, eds. A. Fernandez-Bernal & M. A. De La Rosa. Hauppauge, NY: Nova Science Publishers, 45-74.

Gillies, J. 2013. Using Roughness (Solid Elements and Plants) to Control Sand Movement and Dust Emissions: Keeler Dunes Dust Demonstration Project, Interim Report. Prepared by the Desert Research Institute for the Great Basin Unified Air Pollution Control District, September 26, 2013.