

Lower Colorado River Multi-Species Conservation Program



Balancing Resource Use and Conservation

Seeding *Salix Gooddingii* with
Lassenite Pozzolan Soil

Amendment: 2012 Annual Report



March 2013

Lower Colorado River Multi-Species Conservation Program Steering Committee Members

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Bureau of Reclamation
U.S. Fish and Wildlife Service
National Park Service
Bureau of Land Management
Bureau of Indian Affairs
Western Area Power Administration

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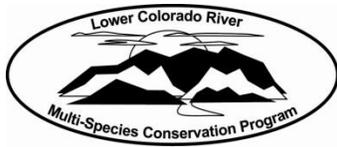
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Ducks Unlimited
Lower Colorado River RC&D Area, Inc.
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Lower Colorado River Multi-Species Conservation Program

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Amendment: 2012 Annual Report

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Lower Colorado River
Multi-Species Conservation Program
Bureau of Reclamation
Lower Colorado Region
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March 2013

TABLE OF CONTENTS

TABLE OF CONTENTS.....	I
LIST OF TABLES.....	II
LIST OF FIGURES	II
LIST OF APPENDICES.....	III
1.0 INTRODUCTION	1
2.0 METHODS	3
2.1 Task 1: Project Management.....	3
2.2 Task 2: Preparation of Experimental Design and Study Plan	3
2.3 Task 3: Seed Collection and Preparation	6
2.4 Task 4: Site Preparation	7
2.5 Task 8: Reporting	9
3.0 RESULTS	11
3.1 Task 3: Seed Collection and Preparation	11
3.2 Task 4b: Perimeter Pole Planting.....	12
4.0 DISCUSSION	13
5.0 RECOMMENDATIONS.....	14
6.0 ACKNOWLEDGEMENTS.....	15
7.0 REFERENCES	16

LIST OF TABLES

Table 1. Project task and sub-task status for project base year, February 14, 2012 through February 13, 2013.	4
Table 2. Locations, Universal Transverse Mercator (UTM) coordinates (Zone 11 North, NAD 1983) and weight of Goodding’s willow seed collected during 2012.....	6
Table 3. Goodding’s willow seed viability testing results.....	12

LIST OF FIGURES

Figure 1. Transplanted Fremont cottonwood seedlings in PVC deep pots, March 16, 2012. ..	8
Figure 2. Fremont cottonwood deep pot nursery prior to outplanting at Beal Lake Conservation Site, June, 2012.....	8
Figure 3. Fremont cottonwood deep pot being prepared for planting (left) and GSA staff measuring recently planted cottonwood height (right).	9

LIST OF APPENDICES

Appendix A. 2012 Goodding's Willow Seed Collection Locations

1.0 INTRODUCTION

Sandy soils at Lower Colorado River (LCR) Multi-species Conservation Program (MSCP) habitat creation sites have limited establishment of native riparian tree seedlings and precluded maintenance of elevated soil moisture as desired for avian habitat. Through Project R12PX30002, Seeding *Salix gooddingii* with Lassenite Pozzolan Soil Amendment, the Bureau of Reclamation (Reclamation) seeks to determine the effectiveness of the aforementioned soil amendment in enhancing Goodding's willow (*Salix gooddingii*) seedling establishment, improving irrigation distribution, and maintaining soil moisture between irrigation events. Eight project tasks are included, as follows:

A. Task 1: Project Management

- a. *Sub-task 1a: Yearly Kick-off Meeting*
- b. *Sub-task 1b: Obtain Permits*
- c. *Sub-task 1c: Project planning and coordination*

B. Task 2: Preparation of Experimental Design and Study Plan

- a. *Task 2a: Prepare and submit experimental design to Reclamation*
- b. *Task 2b: Finalize experimental design and study plan*

C. Task 3: Seed Collection and Preparation

- a. *Sub-task 3a: Seed Collection*
- b. *Sub-task 3b: Seed Treatment and Storage*
- c. *Sub-task 3c: Seed Preparation*

D. Task 4: Site Preparation

- a. *Sub-task 4a: Weed Management and Salt Leaching*
- b. *Sub-task 4b: Perimeter Pole Planting*
- c. *Sub-task 4c: Lassenite Incorporation*
- d. *Sub-task 4d: Placement of Irrigation Control Berms and Furrows*
- e. *Sub-task 4e: Infiltration and Soil Salinity Testing*
- f. *Sub-task 4f: Purchase, Calibration, and Installation of Instruments*

E. Task 5: Seeding

- a. *Sub-task 5a: Hydroseeding*

F. Task 6: Monitoring

- a. *Sub-task 6a: Irrigation Monitoring*
- b. *Sub-task 6b: Weed Management*

- c. *Sub-task 6c: Vegetation Monitoring*
- d. *Sub-task 6d: Soil Moisture Data Collection*

G. *Task 7: Data Management*

- a. *Sub-task 7a: Data Management*

H. *Task 8: Reporting*

- a. *Sub-task 8a: Monthly Reports*
- b. *Sub-task 8b: Draft Annual Reports*
- c. *Sub-task 8c: Final Annual Reports*

Base-year (February 14, 2012 through February 13, 2013) project activities included components of Task 1 through Task 4 and Task 8. Work completed on these tasks during this project year is detailed in the following sections.

2.0 METHODS

Work for the project to date includes components of Task 1 through Task 4 and Task 8. Tasks 5 through 7 will be initiated in February 2013. The status of project tasks is provided in Table 1, and detail is provided below.

2.1 Task 1: Project Management

During 2012, GSA staff attended conference calls with the Reclamation Contracting Office Representative (COR) to discuss project activities and the study design. These discussions were used to guide development of the draft experimental design (Task 2).

Special Use Permits (SUPs) were obtained from the US Fish and Wildlife Service for Havasu National Wildlife Refuge (NWR), Bill Williams River NWR, and Cibola NWR during Month 1 to allow for site preparation at Havasu NWR (Task 4) and seed collection at each refuge (Task 3). SUPs for Havasu NWR and Bill Williams River NWR have been renewed for project Year 2. Because no additional seed collection is currently planned for Cibola NWR during Year 2, the permit was not renewed for this refuge.

Project planning and coordination has included phone and email conversations with the GSA project team and the Reclamation COR. Additional project management work included establishment of a payment schedule and submittal of invoices. To date, no obstacles have been encountered for Task 1.

2.2 Task 2: Preparation of Experimental Design and Study Plan

Task 2 was comprised of development and submittal of the experimental design and study plan for 2013 and 2014. A draft study plan was submitted to Reclamation on October 8, 2012. Reclamation comments were received and addressed in the revised study plan submitted on November 9, 2012. An additional phone conference was held on January 3, 2013 to discuss experimental design issues with the Reclamation biostatistician, and additional design revisions were requested. A revised study plan incorporating the final experimental study design will be submitted to Reclamation by March, 2013 (GSA 2013).

Table 1. Project task and sub-task status for project base year, February 14, 2012 through February 13, 2013.

Task/Sub-Task	Project Month											
	1	2	3	4	5	6	7	8	9	10	11	12
	Feb 14- Mar 13	Mar 14- Apr 13	Apr 14- May 13	May 14- Jun 13	Jun 14- Jul 13	Jul 14- Aug 13	Aug 14- Sep 13	Sep 14- Oct 13	Oct 14- Nov 13	Nov 14- Dec 13	Dec 14- Jan 13	Jan 14- Feb 13
	Status ¹											
1: Project Management	O	O	O	O	O	O	O	O	O	O	O	O
1a: Yearly Kick-off Meeting	C	--	--		--				--			
1b: Obtain Permits	O	C	--		--				--			--
1c: Project Planning and Coordination	O	O	O--	O	O--	O--	O--	O	O--	O--	O	O
2: Preparation of Experimental Design and Study Plan	O	O	O--	O	O--	O--	O--	C	----	--C	O ⁴	C
2a: Prepare and Submit Experimental Design to Reclamation	O	O	O	O	O	C	--	--	--	--	⁴	O
2b: Finalize Experimental Design	--		--		--		O	O	C	O ⁴ O	O	O
3: Seed Collection and Preparation	O	O	O	O	O	O	O	O	O	O	O	O
3a: Seed Collection	O	O	O	C ²	--				--			
3b: Seed Treatment and Storage	--	O	O	O	O	O	O	O	O	O	O	O
4: Site Preparation	O	O	O	O	O--	O--	O--	O	O--	O--	O--	O
4a: Weed Management and Salt Leaching	--		--		--				--			
4b: Perimeter Pole Planting	O	O	O	O	O	C ³	--		--			
8: Reporting	O	O	O	O	O	O	O	O	O	O	O	O
8a: Monthly Reports	O	O	O	O	O	O	O--	O	O--	O--	O--	O
8b: Draft Annual Report	--	--	--	--	--	O	O	O	O	O	O	O

Task/Sub-Task	Project Month											
	1	2	3	4	5	6	7	8	9	10	11	12
	Feb 14- Mar 13	Mar 14- Apr 13	Apr 14- May 13	May 14- Jun 13	Jun 14- Jul 13	Jul 14- Aug 13	Aug 14- Sep 13	Sep 14- Oct 13	Oct 14- Nov 13	Nov 14- Dec 13	Dec 14- Jan 13	Jan 14- Feb 13
8c: Final Annual Report	--		--		--				O	O	O	O

¹Status indicates no work (--), ongoing (O), or completed (C). ²Seed collection is completed pending germination testing and study plan finalization.

³Perimeter planting is complete pending success of deep potted plants and volunteer vegetation. ⁴Sub-tasks re-opened due to additional revision requests.

2.3 Task 3: Seed Collection and Preparation

Seed collection and treatment was implemented per previously-documented protocols (GSA 2007), with modifications in the drying process to allow efficient up-scaling of seed collection and processing capacity. During March 2012, Goodding’s willow seed collection was initiated at Bill Williams River NWR; in April, seed collection was conducted at Cibola NWR; in May, seed was collected from a remnant tree along the Colorado River levee road at Palo Verde Ecological Reserve (PVER); and, in June, seed was collected from Havasu NWR and Bureau of Land Management (BLM) property adjacent to Cibola NWR. Seed has been collected exclusively from remnant (not planted for MSCP habitat creation) Goodding’s willow trees. Global Positioning System (GPS) coordinates and seed amounts have been recorded from all source trees, and are provided in Table 2. Maps showing locations of all source trees are provided in Appendix A.

Table 2. Locations, Universal Transverse Mercator (UTM) coordinates (Zone 11 North, NAD 1983) and dry weight of Goodding’s willow seed collected during 2012.

Collection Site	Tree ID	Date Collected	UTM E	UTM N	Weight (g)
Bill Williams River National Wildlife Refuge	bwr-salgoo-2	3/14/2012	771879	3796328	108
	bwr-salgoo-3		771941	3796163	25
	bwr-salgoo-4		772504	3795826	11
	bwr-salgoo-5		771973	3796115	17
	bwr-salgoo-6		771968	3796133	17
Cibola National Wildlife Refuge	cnwr-salgoo-1	4/2/2012	717240	3686420	632
	cnwr-salgoo-2		717148	3686635	701
	cnwr-salgoo-3		717197	3687071	811
	cnwr-salgoo-4	4/16/2012	717277	3686905	735
Havasu National Wildlife Refuge	hnwr-salgoo-1	6/9/2012	729981	3849398	421
	hnwr-salgoo-2		730294	3849391	557
Mineral Wash (Bill Williams River National Wildlife Refuge)	mw-salgoo-1	3/17/2012	775781	3794344	19
	mw-salgoo-2		775714	3794367	14
	mw-salgoo-3		775652	3794380	23
	mw-salgoo-4		775348	3794501	19
	mw-salgoo-5		775355	3794498	20
	mw-salgoo-7	4/3/2012	775279	3794491	175
	mw-salgoo-13	4/5/2012	775886	3794332	158
	mw-salgoo-14		776188	3794441	611
	mw-salgoo-15		776210	3794439	723
	mw-salgoo-16		776082	3794381	306
	mw-salgoo-17		775285	3794575	177
	mw-salgoo-18		775327	3794558	1256
	Palo Verde Ecological Reserve (PVER)	pver-salgoo-3	5/25/2012	730455	3733621
Bureau of Land Management	wc-salgoo-1	4/16/2012	716381	3681295	1140

All collected seed was transported to Tucson, Arizona in either paper bags or cardboard boxes. Upon arrival in Tucson, seed was placed in cardboard drying boxes vented with window screen. A fan was used to force air through the screen. After a minimum of three days of drying, seed was removed from drying boxes, transferred to freezer bags, and placed in freezers for storage.

To confirm the success of revised seed processing methods, preliminary germination trials were completed in early May 2012 for seed from 25 trees located within the Bill Williams River NWR and Cibola NWR. Additional trials were conducted in late September 2012 for seed from four additional trees at Havasu NWR, PVER, and *wc-salgoo-1*. Seeds were counted manually and placed on moist paper towels in petri dishes. They were then incubated in the dark at 25 degrees Celsius for four to six days. Emergent seedlings were counted, and divided by the total number of seeds to determine percent germination.

2.4 Task 4: Site Preparation

Task 4 activities to date are comprised primarily of *sub-task 4b: Perimeter pole planting*. GSA anticipated planting Fremont cottonwood (*Populus fremontii*) poles around the perimeter of both fields during spring of 2012. However, due to the later than expected contract award date, pole collection was not allowed at MSCP project sites until after the 2012 growing season. As an alternative to pole planting, GSA, in conjunction with the COR, determined that planting of Fremont cottonwood “deep pots” would be an acceptable alternative. Deep pots provide an alternate approach for planting phreatophytic trees which allows for placement of the tree roots directly into the groundwater, therefore eliminating the need for irrigation during establishment (Dreesen 2010).

To provide deep pots for this project, GSA obtained 220 approximately 8-inch tall seedlings from Greenheart Farms (Arroyo Grande, CA) in March 2012. These trees were propagated from seed collected previously on the LCR. Seedlings were transplanted to 2 and 3-inch diameter, 30 to 40-inch long PVC pipes at a nursery in Lake Havasu City, Arizona on March 16-17, 2012 (Figure 1). Each PVC pipe contained a mix of purchased potting soil and sand obtained from the project site. Trees grew rapidly, and by early July 2012, trees average approximately 3 ft in height (Figure 2), and roots were emerging from the bottom of the PVC tubes.



Figure 1. Transplanted Fremont cottonwood seedlings in PVC deep pots, March 16, 2012.



Figure 2. Fremont cottonwood deep pot nursery prior to outplanting at Beal Lake Conservation Site, June, 2012.

Trees which had extensive rooting out the bottom of the PVC tubes were planted along the southeast, southwest, and northwest borders of both fields on July 17th and 18th, 2012. Planting holes were dug to 4 feet below ground surface using a gas-powered soil auger. Additional augering was completed via a hand auger until saturated soils (groundwater) was encountered. Trees were removed from the PVC tubes, and the root mass was inserted in the

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holes. Soil was backfilled around the root mass, and the backfill soil was wetted with water from the adjacent Beal Lake ditch. Stem height above the soil was measured and recorded to allow follow-up documentation of success of this transplanting method (Figure 3). Tree spacing was approximately ten feet along the field edges, with tree placement alternating on the lower and upper edge of the outer field berms. A total of 179 trees were planted.

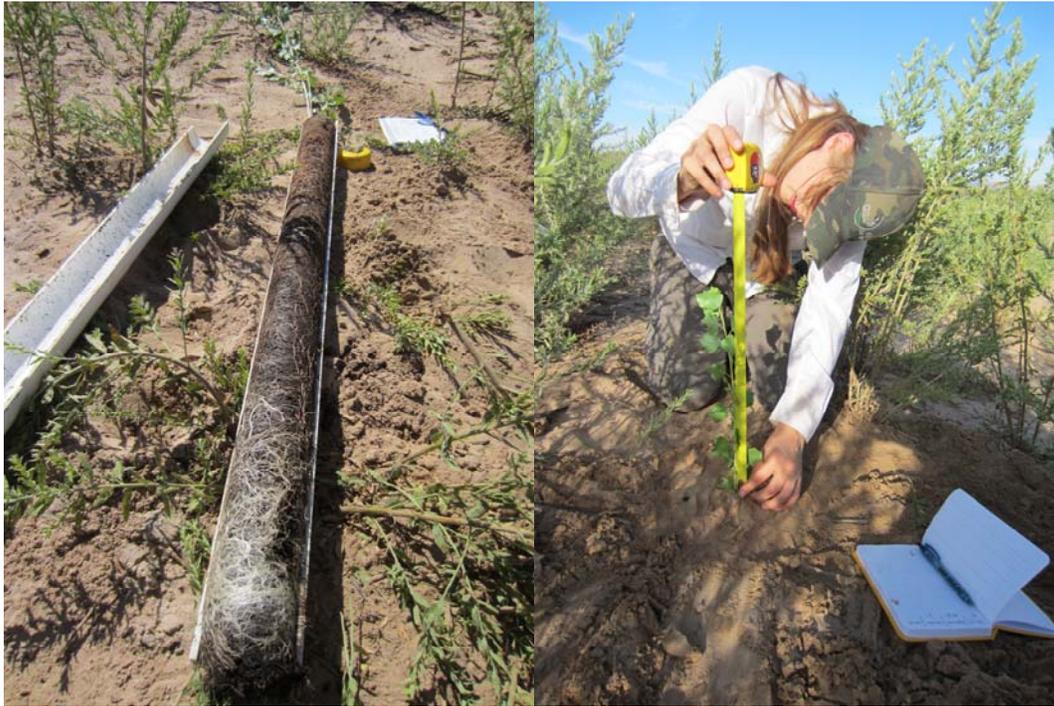


Figure 3. Fremont cottonwood deep pot being prepared for planting (left) and GSA staff measuring recently planted cottonwood height (right).

In fall 2012, contractor we sought for assistance with field preparation and weed management as part of subtask 4a. GSA contacted numerous local contractors and all farmers in the vicinity of Beal Lake. A local excavation company was retained, and field clearing will begin in February. Irrigation to leach soil salts was initiated in January 2013.

To date, the primary obstacle for this task was restriction on collection of poles from MSCP sites or wildlife refuges due to seasonal timing. This obstacle was overcome by utilizing deep pots.

2.5 Task 8: Reporting

To date, reporting has consisted of preparation of monthly project reports this 2012 Annual Report. Monthly project updates are being delivered to Reclamation within two weeks of the

end of the project month (i.e. the 27th). To date, no obstacles have been encountered in this task.

3.0 RESULTS

Project results to date are limited to those associated with Task 3 and Subtask 4b. Seed collection and preparation results are provided in Section 3.1. Preliminary results of perimeter pole planting for establishment of a wind break are provided in Section 3.2.

3.1 Task 3: Seed Collection and Preparation

Locations of all trees from which mature Goodding's willow seed was collected are presented in Table 2, and maps of all collection locations are presented in Appendix A. Results of germination testing are summarized in Table 3. Germination rates ranged from 34% to 100%, and averaged 72% for all trees. It is anticipated that enough seed has been collected for Option Year 1 hydroseeding, and no seed collection is anticipated for 2013. Work for Task 3 will be limited to weight calibrations and additional germination testing to determine pure live seed (PLS) rates for Option Year 1. Pre-seeding germination trials will be repeated for a minimum of 20% of seed prior to hydroseeding. If germination testing reveals a notable decrease in seed viability, incubation testing will be completed on 100% of seed.

Table 3. Goodding's willow seed germination testing results.

Site	Tree ID	Date Collected	Date Frozen	Germination Trial Data		
				Total Seeds	Seeds Germinated	Viability
Bill Williams River National Wildlife Refuge (BWNWR)	bwr-salgoo-2	3/14/2012	3/21/2012	57	57	100%
	bwr-salgoo-3	3/14/2012	3/21/2012	55	20	36%
	bwr-salgoo-4	3/14/2012	3/18/2012	55	33	60%
	bwr-salgoo-5	3/14/2012	3/21/2012	50	30	60%
	bwr-salgoo-6	3/14/2012	3/21/2012	60	59	98%
Cibola National Wildlife Refuge (CNWR)	cnwr-salgoo-1	4/2/2012	4/12/2012	55	27	49%
		4/17/2012	4/23/2012	55	43	78%
	cnwr-salgoo-2	4/2/2012	4/9/2012	55	42	76%
		4/17/2012	4/23/2012	50	47	94%
	cnwr-salgoo-3	4/16/2012	4/23/2012	55	50	91%
cnwr-salgoo-4	4/16/2012	4/23/2012	55	44	80%	
Havasu National Wildlife Refuge (HNWR)	hnwr-salgoo-1	6/9/2012	6/18/2012	50	40	80%
	hnwr-salgoo-2	6/9/2012	6/18/2012	50	38	76%
Mineral Wash (BWNWR)	mw-salgoo-1	4/2/2012	4/12/2012	50	42	84%
	mw-salgoo-1	3/17/2012	3/21/2012	55	53	96%
	mw-salgoo-2	3/17/2012	3/23/2012	60	39	65%
	mw-salgoo-3	3/17/2012	3/23/2012	60	53	88%
	mw-salgoo-4	3/17/2012	3/23/2012	55	43	78%
	mw-salgoo-5	3/17/2012	3/23/2012	35	19	54%
	mw-salgoo-7	4/5/2012	4/12/2012	40	35	88%
	mw-salgoo-13	4/5/2012	4/12/2012	55	49	89%
	mw-salgoo-14	4/5/2012	4/12/2012	55	36	66%
	mw-salgoo-15	4/5/2012	4/12/2012	55	26	47%
	mw-salgoo-16	4/5/2012	4/12/2012	55	30	55%
	mw-salgoo-17	4/5/2012	4/12/2012	55	43	78%
mw-salgoo-18	4/5/2012	4/12/2012	55	31	56%	
Palo Verde Ecological Reserve (PVER)	pver-salgoo-3	5/25/2012	6/4/2012	50	24	48%
Walter's Camp	wc-salgoo-1	5/26/2012	6/4/2012	50	17	34%

3.2 Task 4b: Perimeter Pole Planting

Preliminary observations indicate that extensive herbivory impacted deep-potted Fremont cottonwoods and might result in mortality of trees. Additionally, a small portion of trees appear to have succumbed to moisture stress, as evident by desiccated leaves and branches. The success of deep potted trees will be determined in early 2013, once leaves have fully emerged on local cottonwood trees.

4.0 DISCUSSION

To assist in the determination of the effectiveness of the Lassenite pozzolan soil amendment in enhancing seedling establishment of Goodding's willow and maintaining soil moisture between irrigation events, during project Year One, GSA:

- Prepared and submitted an experimental design and study plan.
- Submitted monthly project status reports.
- Collected sufficient Goodding's willow seed for hydroseeding of eight acres in spring 2013.
- Grew and planted 179 Fremont cottonwood deep pots to establish a windbreak around the study site in preparation for hydroseeding.
- Began preparations for field clearing, construction, and maintenance.

Results to date are limited to seed collection and treatment efficiency and effectiveness, and the success of deep pot tree propagation and outplanting. It is anticipated that sufficient seed was collected for the 8-acre project site with approximately 140 personnel hours, including mobilization time. Seed drying and processing required approximately 60 personnel hours. Revised seed collection and processing methods have resulted in increased efficiency compared to previous projects.

Preparation and installation of Fremont cottonwood deep pots required approximately 200 personnel hours. This includes labor for nursery construction and maintenance, planting of trees, and recording initial tree heights. Because this method requires little to no irrigation post-planting and allows for year-round planting, it might have specific applications along the LCR. However, preliminary results indicate the need for protection of small trees from herbivory.

Additional work on Tasks 1, 2, and 4, and initiation of Tasks 5-7 will commence starting in February 2013. For the 2013 annual report, GSA anticipates presentation of soil moisture abundance, irrigation distribution, and Goodding's willow seeding success at BLCA as related to Lassenite pozzolan soil amendment rates.

5.0 RECOMMENDATIONS

Abundant seed is available from remnant and planted trees at various locations along the LCR. While collection from remnant trees along the LCR requires additional travel time and cost compared to collection from one location, it promotes maintenance and establishment of genetic diversity at MSCP habitat creation sites.

Deep potting methods have been demonstrated as an effective option for planting of phreatophytic trees for other projects. Although success rates have not yet been quantified, it is apparent that mortality was extensive during the 2012 growing season, due primarily to herbivory. Thus, the use of tree cages to protect small stems is recommended for this method on the LCR. In lieu of additional pole planting to establish a windbreak, it is recommended that existing arrowweed (*Pluchea sericea*) and other native vegetation around the perimeter of both fields be utilized. Success of this vegetation indicates that it is receptive to current site conditions. Additionally, because this vegetation has been present for at least one growing season, its structure is more likely to provide an effective windbreak than newly-established poles.

6.0 ACKNOWLEDGEMENTS

We thank the Lower Colorado River Multi-Species Conservation Program and the Bureau of Reclamation Lower Colorado Regional office for its funding and guidance for this project.

Additionally, we thank the Fish and Wildlife Service management and staff at Havasu NWR for their assistance and access to Beal Lake Restoration Site.

7.0 REFERENCES

Dreesen, D.R. and Fenchel, G.A. 2010. Deep-planting techniques to establish riparian vegetation in arid and semi-arid regions. *Native Plants Journal* 11:15-18, 20-22.

GeoSystems Analysis, Inc. 2007. Feasibility Study Using Native Seeds in Restoration, California-Arizona-Nevada (Bureau of Reclamation Contract No. 06CR308057) – 2006 Annual Report. Prepared for Bureau of Reclamation, Lower Colorado Region, February 1, 2007.

GeoSystems Analysis, Inc. 2013. Seeding *Salix gooddingii* with Lassenite Pozzolan Soil Amendment (Bureau of Reclamation Contract No. R12PX30002) – Project Study Plan. Prepared for Bureau of Reclamation, Lower Colorado Region. In Preparation.

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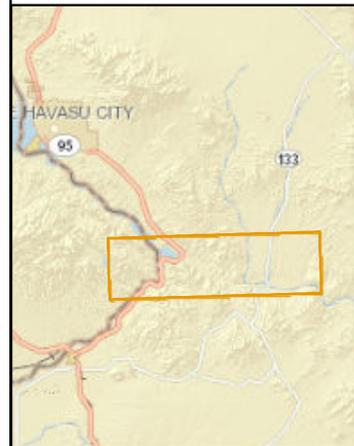
Appendix A



**March/April 2012 Seed Collection Locations:
Bill Williams River National Wildlife Refuge**

Legend

- Species Collected**
- ★ Populus fremontii
 - ✱ Salix exigua
 - ⊗ Salix goodingii
 - ▭ USFWS Refuge Boundary



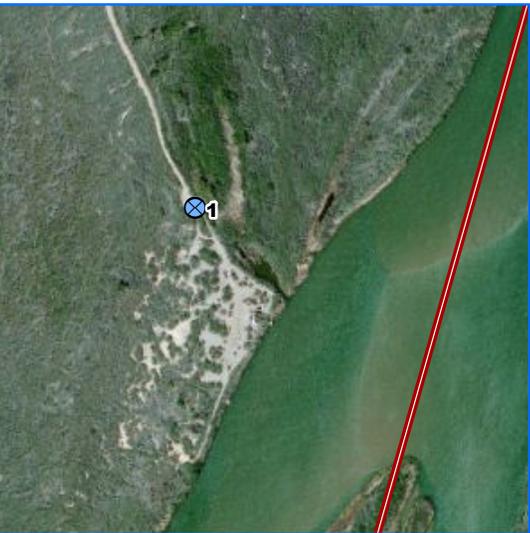
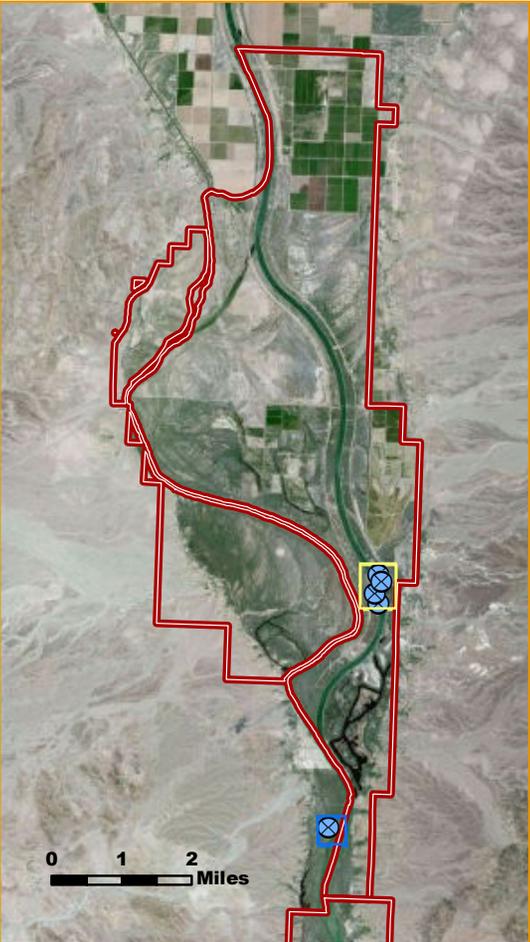
Map projection = UTM NAD 1983,
Zone 12N, meters
Map created by Chad McKenna,
GeoSystems Analysis, Inc.
on July 9, 2012.

Background imagery:
Bing Basemap served
via ESRI online

Refuge boundary:
USFWS Cadastral
Geodatabase

Seed collection locations:
Sub-meter field GPS locations
GeoSystems Analysis

**March/April 2012 Seed
Collection Locations:
Cibola National Wildlife Refuge**

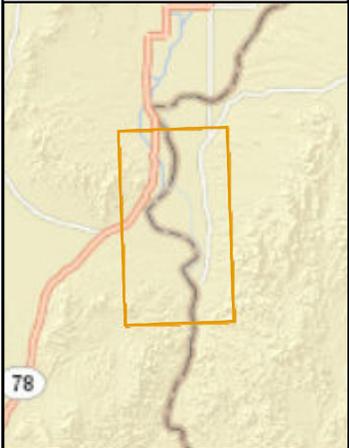


Legend

Species Collected

- ★ Populus fremontii
- ✱ Salix exigua
- ⊗ Salix goodingii

USFWS Refuge Boundary



Map projection = UTM NAD 1983,
Zone 12N, meters
Map created by Chad McKenna,
GeoSystems Analysis, Inc.
on July 9, 2012.

Background imagery:
Bing Basemap served
via ESRI online

Refuge boundary:
USFWS Cadastral
Geodatabase

Seed collection locations:
Sub-meter field GPS locations
GeoSystems Analysis



**March/April 2012 Seed Collection Locations:
Havasu National Wildlife Refuge**



Legend

Species Collected

- ★ Populus fremontii
- ✱ Salix exigua
- ⊗ Salix gooddingii

▭ USFWS Refuge Boundary



Map projection = UTM NAD 1983,
Zone 12N, meters
Map created by Chad McKenna,
GeoSystems Analysis, Inc.
on July 9, 2012.

Background imagery:
Bing Basemap served
via ESRI online

Refuge boundary:
USFWS Cadastral
Geodatabase

Seed collection locations:
Sub-meter field GPS locations
GeoSystems Analysis



**March/April 2012 Seed Collection Locations:
Palo Verde Ecological Reserve**



Legend

Species Collected

- ★ Populus fremontii
- ✱ Salix exigua
- ⊗ Salix gooddingii

▭ USFWS Refuge Boundary



Map projection = UTM NAD 1983,
Zone 12N, meters
Map created by Chad McKenna,
GeoSystems Analysis, Inc.
on July 9, 2012.

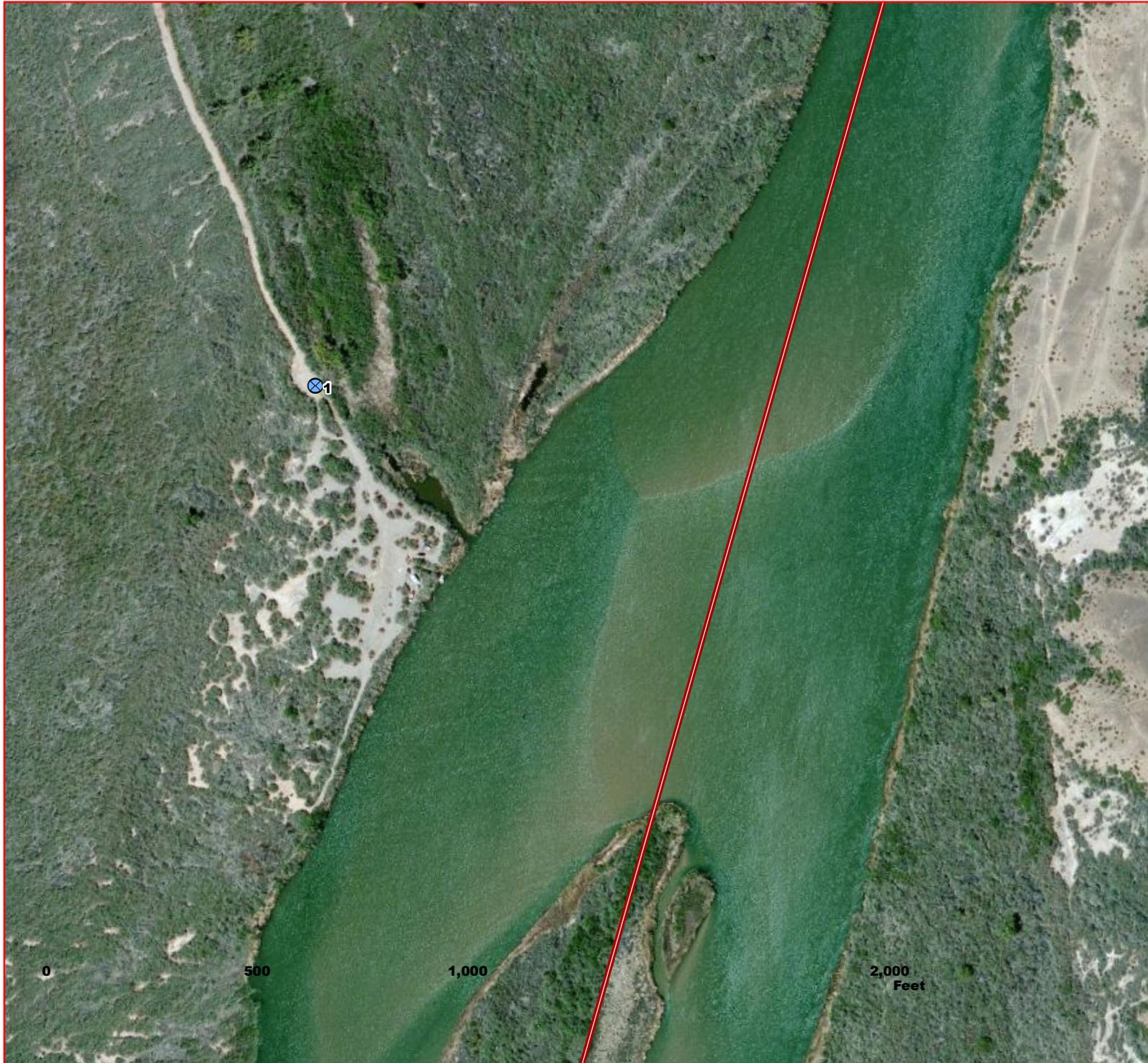
Background imagery:
Bing Basemap served
via ESRI online

Refuge boundary:
USFWS Cadastral
Geodatabase

Seed collection locations:
Sub-meter field GPS locations
GeoSystems Analysis



**March/April 2012 Seed Collection Locations:
Walter's Camp**



Legend

Species Collected

- ★ Populus fremontii
- ✱ Salix exigua
- ⊗ Salix gooddingii

□ USFWS Refuge Boundary



Map projection = UTM NAD 1983,
Zone 12N, meters
Map created by Chad McKenna,
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Seed collection locations:
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