

# Appendix 3. Research and Restoration

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## Introduction

In the appendix, an overview is presented of the activities undertaken by the Land Retirement Team and Endangered Species Recovery Program (ESRP) during the course of the Land Retirement Demonstration Project 1998-2004. Topics are presented as follows.

Baseline Surveys of the Tranquillity and Atwell Island Property were conducted prior installing the Habitat Restoration Studies (HRS) plots.

An established monitoring regime was carried out each year on both the Tranquillity and Atwell Island Habitat Restoration Studies.

ESRP undertook restoration of portions of the Tranquillity property, and conducted a large number of restoration trials.

A native plant nursery was established on the Tranquillity property. Seed collecting sites were located throughout the westside of the San Joaquin Valley, and seed was collected for use in the nursery and in restoration efforts. These activities, as well as a brief overview of the seed processing facility are presented in this appendix.

Biotic monitoring at Atwell Island was conducted by ESRP from 1998 until October 2002. Since that time, Bureau of Land Management (BLM) has taken over responsibility for all management and research activities at Atwell Island. Activities specific to BLM will be presented by that agency in a separate report.

## Baseline Surveys

### *Tranquillity Site*

**Biotic Survey** A baseline biotic survey of the Tranquillity property was conducted on December 2, 1998. The survey protocol entailed driving the perimeter roads around each quarter section, with periodic foot surveys onto the first 15-30 m (50-100 feet) of each field. A preliminary species list was compiled, and areas that merited additional surveys were identified. A follow-up field survey was conducted on December 7 and 14, 1998, during which time, the previously identified high-priority areas were more intensively surveyed.

Outcomes from the baseline survey included (1) a preliminary catalog of all noted plant species and animals (identified visually or by sign) was compiled; and (2) areas which potentially might support species of interest were identified. Subsequent site work (e.g., tilling and contouring) was structured to avoid these areas. A report of the baseline survey was submitted to the Land Retirement Team (see Selmon 1999).

In 2002, ESRP conducted a baseline survey of the “North Avenue Property” (formerly, the Bell Property), an approximately 162 ha (400 ac) parcel that was purchased by the Land Retirement Team in May of that year. The property was surveyed in its entirety (May-June 2002). Monitoring was conducted for vegetation, invertebrates, birds, mammals, amphibians, and reptiles. Outcomes from this survey included a catalog of species noted on the site, and a survey report (included in Uptain et al. 2004).

**Physical Impacts Monitoring** Monitoring of physical conditions at the Tranquillity site was designed to address the potential for selenium contamination of the local biota. Soil monitoring was aimed at detecting changes in levels of soil selenium, boron, and salinity that might result from land retirement over the 5-year life of the Demonstration Project. The initial surveys conducted in September and October of 1999 established baseline values for soil chemistry including salinity, selenium, boron, nitrate, ph and major anions, cations, and nutrients.

Soil sampling methodologies were as follows. A rectangular sampling grid was established and land surface soil sampling was conducted at 124 locations. Soils were collected from a depth of 0 to 30.5 cm (0 to 1 foot) at each corner of the HRS plot using a shovel. In addition, sampling of soils from 0 to 30.5 cm (0 to 1 foot), 60.9 to 91.4 cm (2 to 3 feet), and 121.9 to 152.4 cm (4 to 5 feet) was performed in the center of each plot, and from an additional six locations per plot, using a 10.1 cm (4 in) inside diameter split barrel core sampler driven to a depth of 152.4 cm (5 feet).

Groundwater monitoring was instituted in July of 1998 to detect the subsurface level of water and test the hypothesis that the water level would decline in the absence of surface watering (i.e. the irrigation of crops). Monitoring entailed collecting samples from 27 wells and sumps on the Tranquillity site.

### ***Atwell Island Site***

**Biotic Survey** An initial baseline survey of the Atwell Island property was conducted in April and May 2000 (see Uptain et al. 2001 for a complete report of this survey). The property was divided into three large areas; the delineations were based primarily on land-use history. Surveys were conducted for vegetation, birds, small mammals, invertebrates, contaminants (selenium), and, peripherally, herptiles. Vegetation monitoring methodology consisted of a series of walkover surveys, in which all observed species were identified and recorded. Avian

monitoring methodology utilized visual encounter surveys. In these surveys, researchers walked transects across designated field. Recorded data included all avian species that were heard or observed, as well as any observed mammals or reptiles. Small mammals were surveyed by nighttime trapping (Sherman traps). Invertebrates were surveyed using pitfall traps. Selenium monitoring followed the same general methodologies as were used at the Tranquillity project site.

**Physical Impacts Monitoring** As with the monitoring of physical impacts at the Tranquillity site, data were collected at the Atwell Island site to determine the potential negative effects of selenium and other naturally occurring elements on the site's biota. Baseline soil monitoring was initiated in 2002 and comprised 432 samples. Three soil samples were taken from near the center of each of the 48 approximately 0.8 ha (2 ac) research plots. One composite sample consisting of four sub-samples was collected from a depth of 0.0 to 30.5 cm (0 to 12 in); three of the four sub-samples were taken from within a two-meter radius of the center; while the remaining sub-sample was taken from the center. Additionally, one sample each from 30.5 to 76 cm (12 to 30 in) and 76 to 152 cm (30 to 60 in) was taken. Two field replicate samples were taken from each quarter section. Samples were analyzed for selenium, sulfate, chloride, electrical conductivity, and moisture. Surface samples were analyzed for boron, magnesium, potassium, sodium, carbonate and nitrate. Protocols and procedures taken to ensure quality of data in soil collection and analysis are outlined in the Quality Assurance Project Plan (QAPP) for the LRDP (CH2M Hill 1999).

In the fall of 1999, Reclamation installed 17 monitoring wells to measure groundwater levels and sample for water quality. Baseline surface and groundwater monitoring was conducted in January 2002.

## Annual Monitoring Activities

### Tranquillity HRS

#### *Biotic Surveys*

Each year, 32 surveys were conducted of the biota on the Tranquillity site. The majority of surveys were specific to the HRS plots (Table A3-1); however, a number of site-wide surveys were also conducted (Table A3-2). The effort required to conduct these surveys was quite variable, with some (e.g., the vegetation contaminants monitoring) generally requiring only a couple of person-days to complete. Others, such as the small mammal trapping, required up to 20 person-days (e.g., five biologists for 4 days).

**Table A3-1. Annual monitoring activities on the Habitat Restoration Study plots (Tranquillity site), 1999-2003, with the number of times each survey was conducted per year.**

Survey	Repetitions
Avian Nesting Survey	1
Avian Survey	4 <sup>A</sup>
Fall Shrub Monitoring	1 <sup>B</sup>
Invertebrate Pitfall Survey	1
Invertebrate Sweep Survey	1
Photographic Stations Survey	4
Reptile and Amphibian Coverboard Survey	1
Reptile and Amphibian Transect Survey	1
Small Mammal Pitfall surveys	1
Small Mammal Trapping	4 <sup>C</sup>
Spring Vegetation Monitoring	1

A. Only conducted 3 times in 1999.

B. Only conducted in 2002.

C. Only conducted once in 1999 and 3 times in 2000.

It should be noted that all monitoring activities outlined here were accompanied by a significant body of data-related activities. Examples are data entry, data proofing, voucher preparation and cataloging, photo archiving, etc.

**Table A3-2. Annual site-wide monitoring activities at the Tranquillity site, 1999-2003, with the number of times each survey was conducted per year.**

Survey	Repetitions
Invertebrate Contaminants Monitoring	1
Small mammal Contaminants Monitoring	1
Spotlighting Survey	4
Track Station Survey	4
Vegetation Contaminants Monitoring	1
Winter Raptor Survey	1

### ***Physical Impacts Monitoring***

Soil monitoring followed the methodologies outlined, re-sampling of all deep borings and a partial sampling of shallow sites where selenium concentrations were found to be highest in 1999 were conducted in November 2002. The Quality Assurance Project Plan for the LRDP describes the protocols and procedures taken to ensure quality of data in soil collection and analysis (CH2M Hill 1999).

Weather data have been collected by the California Irrigation Management System (CIMIS) weather station #105 located approximately 2.5 km (1.5 mi) west of the Tranquillity site and are summarized in the final reports for each year. Data collected and summarized included precipitation, temperature, wind, and relative humidity.

Irrigation regimes were reported on an annual basis beginning in 1999. Amount of water (in acre-feet) and methods and dates of application are reported. In addition to groundwater level monitoring, groundwater quality testing occurred on a quarterly basis during the first year of monitoring (October 1999; February, May, and July 2000), and annually thereafter. Unfiltered groundwater samples were analyzed for major ions, trace elements, isotopes, electrical conductivity, pH, temperature, and turbidity.

## **Atwell Island HRS**

### ***Biotic Monitoring***

The same suite of surveys that were conducted on the Tranquillity site served as the model for the surveys undertaken at the Atwell Island HRS (Table A3-3). As with monitoring at the Tranquillity HRS, the effort required to conduct these surveys was quite variable, and spanned approximately the same range of person-days as did the surveys at Tranquillity. Likewise, monitoring at Atwell Island was accompanied by the same body of associated tasks (e.g., data entry and proofing).

**Table A3-3. Annual monitoring activities on the Habitat Restoration Study plots (Atwell Island site) 2001-02, with the number of times each survey was conducted per year.**

Survey	Repetitions
Avian Nesting Survey	1
Avian Survey	4 <sup>A</sup>
Fall Shrub Monitoring	1 <sup>B</sup>
Invertebrate Pitfall Survey	1
Invertebrate Sweep Survey	1
Photographic Stations Survey	4
Reptile and Amphibian Coverboard Survey	1
Reptile and Amphibian Transect Survey	1
Small Mammal Pitfall surveys	1
Small Mammal Trapping	4 <sup>C</sup>
Spring Vegetation Monitoring	1

A. Only conducted 3 times in 2001.

B. Only conducted in 2002.

C. Only conducted once in 1999 and 3 times in 2000.

### ***Physical Impacts Monitoring***

Soil monitoring followed the methodologies outlined. All deep borings and the shallow sites with the highest selenium concentrations (in 1999) were re-sampled in November 2002.

Weather data were collected from the CIMIS station #21 located approximately 29 km (18 mi) west of the project site. Data collected included hourly precipitation, wind, and relative humidity.

In the fall of 1999, Reclamation installed 17 monitoring wells to measure groundwater levels and sample for water quality. Baseline surface and groundwater monitoring was conducted in January 2002; subsequent monitoring was conducted on a quarterly basis. To evaluate the influence of irrigation on groundwater levels, the amount (in acre-feet) of irrigation water applied, application method, and date were recorded throughout the course of the project

## **Restoration and Site Management — Tranquillity**

During the course of the Demonstration Project, ESRP has conducted a variety of restoration trials and has undertaken restoration of portions of the Tranquillity property. Additionally, various management strategies have been utilized on portions of the property. These activities are briefly summarized in this section, and are presented in the following order: (1) restoration research (includes both the HRS and ancillary trials); (2) restoration; and (3) site management.

In contrast to the other sections of this Appendix, which are organized by calendar year, activities in this section are organized by growing season. This approach was taken because it better represents the order in which activities were undertaken. For example, trial installation would typically be scheduled for the latter portions of a particular calendar year (e.g., October to December); however, due to various limitations, some of the same year's trials might not be installed until January or February of the following calendar year. Nevertheless, treatment applications (e.g., herbicide applications) and monitoring for all the aforementioned trials would occur during the same period (generally, spring). By presenting the trials in this manner, it allows the reader to distinguish between those trials that were installed in the latter part of one growing season (e.g., January in the 2001-02 growing season) from those trials that were installed in the following fall (e.g., November of the 2002-03 growing season).

### **1998-99 Growing Season**

In the fall of 1998, a cover crop of barley was planted on approximately 493 ha (1,220 ac) of the Tranquillity property. This planting was done in the hopes of establishing relatively homogenous conditions on the areas on which the HRS plots were to be sited.

## **1999-00 Growing Season**

### ***HRS Plot Installation***

Treatments were applied to the HRS plots. Seed of 13 native species was imprinted across the 10 “seeded” plots in March 2000. Native seedlings were also transplanted onto these experimental plots in March and April 2000.

Transplanted seedlings were closely grouped in “shrub islands.”

Microtopographic contours (berms) were created on the ten “bermed” plots. The 240, approximately 12 m (39.4 foot) long berms were installed on each plot.

### ***Imprinting Trial***

To investigate the restoration techniques proposed for the HRS, a small-scale imprinting and berming trial was undertaken. Berms were constructed using various approaches, and the imprinter was pulled over the plot. Those techniques which appeared to be best suited for conditions at the Tranquillity site were adopted for the HRS.

### ***Native Species, Cover Crop, and Mycorrhiza Trial***

Another, small-scale trial was installed in which a variety of native species were interplanted with potential cover crop species. A second component of this trial involved the use of mycorrhizal inoculum, which was incorporated into a portion of the test plots.

### ***Site Management***

The barley in the buffers surrounding the HRS plots (~ 243 ha; 600 ac) was thrashed, and the area was surface disked. Barley was reseeded where necessary.

## **2000-01 Growing Season**

### ***Imprinting vs. Drilling of Native Species Trial***

The Imprinting vs. Drilling of Native Seeds trial was designed to investigate planting methods that require a minimal amount of ground preparation. Tillage breaks down the soil structure and can bring weed seeds to the soil surface. It was hoped that less soil disturbance would decrease weed density and promote the establishment of mycorrhizal networks in the soil, both of which tend to favor native plants (cf. St. John 1995). Comparisons were made between two seeding methods, imprinting and drilling.

Plots were ca. 0.6 ha (1.5 ac) in size; treatments were replicated three times. A mixture containing seed of nine native species was imprinted. Data (percent cover and species composition) were collected from eight quadrats (35 x 70 cm) per plot. Installation of the experiment was undertaken in the fall of 2000; vegetation sampling was conducted the following spring (14-15 May 2001).

### ***Imprinting vs. Drilling of Cover Crops Trial***

This trial was designed to (1) investigate appropriate techniques for establishing cover crops, and (2) to examine the utility of planting native species in combination with a cover crop (i.e., a “nurse species”). The impetus for this trial

came from the understanding that it will no doubt be necessary to undertake large-scale restoration in phases. Cover crops will most likely be an important tool in the implementation of restoration, particularly if the cover crops can be planted with minimal soil preparation.

Plots were ca. 0.6 ha (1.5 ac) in size; each treatment was replicated three times. Two seed “mixtures” were used: (1) barley and (2) barley in combination with three native grasses. Data (percent cover and species composition) were collected from eight quadrats (35 x 70 cm) per plot. Installation of the experiment was undertaken in the fall of 2000; vegetation sampling was conducted the following spring (14-15 May 2001).

### **Section 23 Restoration**

Restoration of approximately 64.8 ha (160 ac) was undertaken in December 2000. Berms were constructed in a more or less random configuration. Both linear and curved berms were constructed; berms were oriented in either a north/south or an east/west direction. A mixture containing seed of 17 native species was imprinted at a rate of 9 pounds per acre of native seed and 14 pounds per acre of wheat bran used to keep variably sized native seeds in suspension).

One hundred “shrub islands” were planted on the western and northern edges of the restoration area. Forty-three seedlings were transplanted at each island: 20 of *Allenrolfea occidentalis*, 11 of *Atriplex polycarpa*, and 12 of *Sporobolus airoides*. For each island, an additional 5 seedlings of *A. occidentalis* and 2 seedlings of *S. airoides* were planted on an adjacent berm. In total, 2,500 seedlings of *A. occidentalis*, 1,100 seedlings of *A. polycarpa*, and 1,400 seedlings of *S. airoides* were transplanted. Vegetation monitoring was conducted in the May 2001 and again in February 2002.

### **Site Management**

**HRS Buffer Maintenance** The barley in the buffers surrounding the HRS plots (~ 243 ha; 600 ac) was thrashed, and the area was surface disked. Barley was reseeded where necessary.

**Hedgerow Seeding** Vegetation on field borders may harbor pests; therefore, these areas are usually disked or sprayed with herbicide. Hedgerows planted with native species are a positive alternative to these management practices. Hedgerows can be maintained with minimal management, can provide important habitat for birds and other wildlife, and may tend to favor beneficial insects.

In December 2000, an approximately 3 m (10 foot) wide hedgerow was imprinted with seed of 11 native species. Low berms were constructed along the edges of the seeded area to allow for flood irrigation. In January 2001, seedlings of *Atriplex lentiformis*, *Leymus triticoides*, *Nassella pulchra* and *Sporobolus airoides* were planted along one berm at approximately 0.6 m (2 feet) on center.

**Marsh Area Seeding** During the initial years of the Demonstration Project, a seasonal wetland would form annually on lands adjacent to the Tranquillity project site. The wetland was created by agricultural runoff, and occasionally this water also inundated approximately 3.2 ha (8 ac) of LRDP land. During periods of inundation, these areas supported large numbers of herons and other water birds. To enrich this habitat, a mixture containing seed of 14 native species was imprinted onto the LRDP portion. Species were selected that were typical for both mesic and upland habitats.

#### ***Ditch Bank Seeding***

Ditches are a common feature of the agricultural landscape and are often managed with herbicides and blading to prevent the accumulation of weedy species. Native plants can potentially prevent weedy species from overtaking ditches while providing excellent cover for wildlife. In December 2000, a ditch was created on the northern and western boundary of the Section 23 Restoration area. Seedlings of *Leymus triticoides* and *Nassella pulchra* were planted along the ditch banks. In January 2001, a mixture of 13 native species has hand-seeded along the ditch.

### **2001-02 Growing Season**

#### ***Atriplex spinifera Planting***

In this trial, an evaluation was made of the success of *Atriplex spinifera* (spiny saltbush) when planted in various groupings. *Atriplex spinifera* is an important component of the Central Valley's native habitats. This species was also of interest because of its ability to become established in habitats dominated by red brome (*Bromus madritensis*).

*Atriplex spinifera* transplants were grown-out from cuttings taken from shrubs on Section 10. A local nursery with extensive experience working with California native plants (Intermountain Nursery, Auberry, California; Ray LeClerge, owner) was contracted to undertake the propagation and grow-out. Plants were maintained in approximately gallon-sized peat pots until transplanting, and were watered as deemed appropriate (approximately bi-weekly) while in the nursery. Two treatment effects were investigated: (1) planting density and (2) plant spacing. Shrubs were transplanted in groups (shrub islands) of four different configurations. All plants were watered at the time of transplanting. Additional watering occurred weekly until the site received soil-soaking rains (late December 2001). The condition of each plant was monitored in April, July, and December 2002, May 2003, and January 2004.

#### ***Berm and Mycorrhiza Trial***

The Berm and Mycorrhiza Trial was developed to investigate methods of enhancing topography and of facilitating recovery of the soil's mycorrhizal communities. Two factors were considered: (1) berm "architecture" (i.e., the manner by which berms were constructed); and (2) mycorrhizal inoculation. Two methods of berm construction were compared. The first method ("dressed" berms) approximated that used to construct berms in the HRS trial; in the second

method (“rough” berms), berms were constructed using just the border maker and were not compacted. Commercially purchased mycorrhizal was applied to half the plots.

Plot size was approximately 0.2 ha (0.5 ac); each treatment was replicated five times. Each plot contained seven berms; berms were evenly-spaced on approximately 9.1 m (30 feet) centers and were oriented east to west. A seed mixture of thirteen native species was imprinted. Installation of the trial began in mid-February 2002. Because of the late seeding date and the low rainfall, the plots were irrigated twice during the course of the experiment (March 21 and April 20, 2002). Data (percent cover and species composition) were collected from 15 quadrats (35 x 70 cm) per plot. Vegetation monitoring was conducted in mid-May 2002 (May 6, 11-12, 14, 17-20).

### ***Succession Trial***

The Succession Trial was developed to examine differences in the dispersal and establishment of three different seed mixtures: (1) barley; (2) barley with native grasses; and, (3) the native seed mixture that had been used on the HRS plots. Two factors were examined — the ability of native grasses to become established when imprinted over an existing barley crop; and, the relative abilities of barley and imprinted native grasses to spread beyond the confines of the area in which they had been seeded.

The trial was installed on an approximately 32.4 ha (80 ac) area of the Tranquillity property. Fifteen plots (five replicates of three treatments) were delineated. Plot width for the barley monoculture was approximately 36.6 m (120 feet); plot width for the other two treatments was ca. 18.3 m (60 feet). Barley had previously been planted as a cover crop in this area in the fall of 2000, and had been thrashed and harrowed in 2001. This planting had provided sufficient seed such that the plots assigned to the barley monoculture did not require replanting. Plots assigned to the other two treatments were disked and imprinted with the appropriate seed mixture. Trial installation took place during February 13-15, 2002.

Because of the low rainfall that year and the relatively late seeding date, vegetation establishment was not sufficient to warrant monitoring of this trial. Although systematic sampling of the Succession Trial was never conducted, the trial area received periodic visits during the following growing season, during which time general observations were recorded.

### ***Suitability Trial***

The Suitability Trial was developed to evaluate the performance (i.e., establishment and growth) of various native species under field conditions at the Tranquillity Demonstration Site. Forty-three species were initially considered for inclusion in the trial. These species represented species that had previously been used in restoration activities in California. The species were ranked based on

18 criteria (see, Uptain et al. 2004, p. 136). Six species (five perennial grasses and one sub-woody perennial), were selected for inclusion in the trial.

Each species was planted (imprinted) in a single, approximately 0.13 ha (0.33 ac) plot (12' x 1200'). This approach was adopted because of difficulties associated with seeding small plots with an imprinter. Although this experimental design promoted a more equitable seeding of the plots, this approach limited the analysis options as there were no true replicates (i.e., pseudoreplication, sensu Hurlbert 1984). Hence, rather than being treated as a rigorous experiment, this trial should be interpreted more as a structured step in identifying suitable species for inclusion in restoration efforts in the study area.

Imprinting was undertaken on March 15, 2002. The plots were sprinkler irrigated twice during the course of the experiment (March and April 2002). Vegetation sampling was conducted during June 16-18, 2002. Plots were divided into 40 equal-length (ca. 9.2 m; 30 feet) segments; vegetation data were collected from one randomly located quadrat (35 x 70 cm) within each segment.

#### ***Suaeda moquinii* Salvage Trial**

The *Suaeda moquinii* Salvage was an attempt to relocate a number of native perennials from an area that was undergoing development. The source population was located alongside State Route 180 in adjacent to the Kerman Ecological Reserve. This portion of the highway was being widened, and numerous native plants were threatened with removal.

Salvage activities were limited to a single species, *Suaeda moquinii* (bush seepweed). This species was selected because there were hundreds of individuals available and many were small enough (15 cm to 30.5 cm; 6-12 inches in height) to be transplanted with relative ease. Although many individuals of *Atriplex polycarpa* were also present, most were large and would have been problematic to transplant.

A portion of the Native Plant Nursery was prepared for transplanting by removing all weeds and working the soil. Transplanting took place on April 18, 2002. The soils at the donor site were hard clay and very dry. These conditions proved problematic, as the soil would crack when a shovel was put into the ground and fall away from the plant, leaving broken bare roots. Care was taken to dig around the plants in an attempt to remove them with an intact root ball, but this was generally not possible. The root ball was wrapped in a burlap sheet cut to size and then kept moist until transplanted. A few plants were also taken bare root.

One hundred forty individuals were transplanted. Plants were moved by truck to the nursery and were planted, with each individual given approximately 3.8 liters (1 gallon) of water. The following day, the transplants were flood irrigated to provide deep moisture to the plants.

### ***Manning Avenue Restoration***

Restoration (i.e., contouring and imprinting) of an approximately 32.4 ha (80 ac) parcel located south of Manning Avenue was undertaken late January and early February 2002. Seeding of this area was also used to refine calibration of the imprinter. Imprinting was undertaken when the ground was wet. The soils on the property are heavy clay, and imprinting under these conditions had pronounced negative effects. The soil was compacted to where it was not possible to push a shovel into the ground. As would be expected under these conditions, germination of both native and introduced species was very limited.

### ***Site Management***

**HRS Buffer Maintenance** The barley in the buffers surrounding the HRS plots (~ 243 ha; 600 ac) was thrashed, and the area was surface disked. Barley was reseeded where necessary.

**Marsh Mix Planting** Following the initial seeding of the “Marsh Mix Area,” the area was mistakenly disked by the farmer that had been contracted to conduct site maintenance. The area (~ 3.9 ha; 9.6 ac) was re-seeded in January 2002 with a mixture of 14 native species.

### **2002-03 Growing Season**

#### ***Section 23 Restoration Trial***

As noted, rainfall during the first three years of the project was below average. In contrast, winter rainfall for the 2002-03 growing season was predicted to be fairly high (i.e., mild El Niño conditions were predicted). In anticipation of these wetter conditions, an experiment—the Section 23 Restoration Trial—was developed in which various species could be evaluated during an above-average rainfall year. In this experiment, two species mixtures were compared. The first mixture, the “traditional mix” was composed of a subset (9 of 13) of the species that were imprinted on the HRS Plots. The second mixture, the “experimental mix” incorporated various species that had been used to some success in other restoration trials at Tranquillity, augmented by a few species that had demonstrated restoration potential elsewhere in California.

The Section 23 restoration trial occupied an area of approximately 28.3 ha (70 ac). This area had received some weed control and was the largest contiguous block of “unassigned” land remaining on the Tranquillity site. Plots were ca. 3.0 ha (7.5 ac) in size; a complete randomized block design was applied, with treatments replicated four times. Micro-topographic contours (berms) were installed in all plots. Berms were aligned east to west and were the full length of the plot. Berm spacing was 9.2 m (30 feet), such that part of a flat and half of a berm would be imprinted in a single pass and with a final pass through the middle of a flat, there would be no overlap in seeding. In this manner, the berms were also compacted slightly. Berms were constructed on December 11, 2002. Imprinting was scheduled to follow immediately thereafter; however, rainfall

during this period precluded the use of heavy equipment throughout December and imprinting was postponed until January 28-31, 2003.

### ***Pre-Irrigation Trial***

In this trial, the utility of pre-irrigating lands prior to imprinting was investigated. Pre-irrigation is a common weed-control practice in agriculture (Lanini et al. 2003), and is a recommended approach in hedgerow installation (Earnshaw 2004). Hence, it appeared that this technique might also have some utility in the ecological restoration of retired agricultural lands.

Pre-irrigation entails irrigating the land before the start of the growing season (i.e., the initiation of winter rainfall in late fall-early winter) to promote germination of the ‘winter weeds.’ The weeds are then removed, either chemically, by tillage, or by burning, and the crop is seeded. In this manner, the seeded species hopefully have a competitive advantage over any additional weeds that germinate later in the growing season.

The area designated for the trial had been dominated by a variety of weeds during the preceding year, and the area had been disked for weed control during the winter of 2001-02. Plots were ca. 0.2 ha (0.5 ac) in size; a complete random block design was applied with treatments replicated four times. A single treatment factor (pre-irrigation) was evaluated.

Site preparation was initiated on September 3, 2002. The soil was disked and trenches were installed for flood irrigation. To account for the effects of site preparation on vegetation establishment, the control plots received the same preparation as the treatment plots (i.e., trenches were also dug in the control plots but these were not flooded). The pre-irrigated plots were sprinkler-irrigated (cf. Lee & Dyer 1997) from September 7-9. After the winter weeds had germinated, all plots (treatment and control) were disked (October 14, 2002).

Following disking, a mixture containing seed of eight native species was imprinted in all plots (19 November 2004). Data were collected from 12 quadrats (35 x 70 cm) per plot. Vegetation monitoring was conducted on April 29, 2003.

### ***Growth Form and Herbicide Trial***

The Growth-form and Herbicide trial was developed to examine how specific seed mixtures, in combination with specific herbicides could produce good ground cover, lower competition from weeds, and ultimately affect long-term planting success. Three seed and herbicide “treatments” were applied: (1) the “Grasses Treatment,” a mixture of native grasses with an application of broadleaf herbicide (Weedar 64); (2) the “Forb Treatment,” a mixture of native forbs with an application of a grass-specific herbicide (Sethoxydim); and (3) the “Late-Season Treatment,” a mixture of late-germinating perennial species with an early application of a broad-scale herbicide (Glyphosate).

Plots were ca. 0.2 ha (0.5 ac) in size; a complete randomized block design was applied, with each treatment and a control (i.e., no treatment) replicated four times. The plots were seeded on November 20, 2002. The Forb and Late-Season Treatments were imprinted. Originally, it was intended that the Grass treatment would also be imprinted; however, the long awns on some of the seeds did not feed properly through the imprinter hopper. Therefore, for this treatment the seed was first broadcast over the plot, and was then worked into the soil by a pass with an empty imprinter. Herbicide for the Grass Treatment was applied on the last week of February; herbicides for the other two treatments were applied in the middle of March.

Vegetation monitoring of the Grass and Forb treatments and the control plots was conducted during May 2003. Monitoring of the Late-Season plots was timed to coincide with the plants having attained their maximum growth for the season. Monitoring of these plots occurred on November 8, 2003. Data were collected from twelve quadrats (35 x 70 cm) per plot, for the Grass, Forb and Control plots. The Late-Season plots received a higher-density of sampling, with 24 quadrats (100 cm x 150 cm) per plot.

### **Section 10 Burn and Mowing Trial**

Section 10 on the Tranquillity site is an area dominated by *Bromus madritensis* (red brome), with a characteristically heavy layer of thatch. Prescribed fire is a common management tool that also possesses utility in restoration strategies, and has been demonstrated to be effective in grass-dominated habitats (Pollak and Kan 1998; Wilson and Stubbendieck 2000).

The Section 10 Burn and Mowing Trial was developed to take advantage an accidental fire that burned a large portion of Section 10 in June 2002. The timing of the accidental burn was not optimal in terms of controlling the winter-germinating grasses. Nevertheless, it was a good opportunity to evaluate the restoration potential of some seemingly fire-adapted native species. Mowing, another common management tool was incorporated in the trial as a second treatment factor.

Shortly after the fire, the burned area was mapped using a global positioning system receiver in June. Four “blocks” were designated within the burned area; these blocks were delineated in such a manner as to “standardize” the burn intensity of the areas selected for the study plots. Plots were ca. 0.2 ha (0.5 ac) in size; a complete randomized block design was applied, with treatments replicated four times. A mixture containing seed of seven native species was imprinted. In order to subject the control plots to the same level of disturbance as the treated plots, an empty imprinter was run over the control plots.

Data were collected from 12 quadrats (35 x 70 cm) per plot. Imprinting occurred on November 22, 2002. The “mowing” plots were mown a single time (March 28, 2003). Although it was anticipated that the plots might need to be mowed multiple times, weed growth under that year’s extremely dry conditions

was not sufficient to warrant additional mowing. Vegetation monitoring was conducted on May 5, 2003.

### ***Mowing Trial***

The Mowing Trial was developed to test whether various mowing regimes could facilitate the establishment of native species by reducing weed competition. The trial was originally intended to be situated on the North Avenue Property; however, repeated incidences of trespass grazing on that property necessitated that the trial be relocated on Section 23.

Two treatment factors, seeding and mowing, were incorporated into the design. Restoration (imprinting, berming, and transplanting) had been attempted on Section 23 in 2000; however, the entire area had been trespass grazed in the summer following restoration, and few plants survived the grazing. Hence, unseeded plots were incorporated into the study design as it was hoped that mowing might help “release” the seed in the seed bank that remained from these restoration activities.

Plots were ca. 0.2 ha (0.5 ac) in size; a complete randomized block design was applied, with treatments replicated four times. A mixture containing seed of five native species was imprinted. To subject the non-seeded plots to the same level of disturbance as the seeded plots, an empty imprinter was run over the non-seeded plots. The plots were imprinted on November 13, 2002. The “mowing” plots were mown a single time (March 28, 2003); as with the Section 10 Burn Trial, weed growth was not sufficient to warrant additional mowing. Vegetation monitoring was conducted on 1 May and 6 May 2003. Data (percent cover and species composition) were collected from 12 quadrats (35 x 70 cm) per plot.

### ***North Avenue Property Restoration***

Restoration efforts were undertaken on an approximately 32.4 ha (80 ac) area at the northern end of the North Avenue Property. Restoration included micro-topographic contouring (berming) and imprinting of native seed (13 species). Berm installation took place from December 5-7, 2002; imprinting was conducted from December 8-10, 2002.

Prior to creating the berms, any large tumbling saltbushes (*Atriplex argentea* and *A. rosea*) were shredded to ground level. Berms were spaced on 6.1 m (20 feet) centers and were oriented east to west. The berms were installed in a serpentine manner to produce a more natural look and to maximize micro-habitat heterogeneity. The areas between the berms (the “flats”) were not disked, as the soils were generally slightly moist and friable, allowing a good imprint without soil preparation. In some areas, the thatch of Mediterranean grasses was so thick that it prevented a solid imprint from forming; however, we felt that the benefits of imprinting into undisturbed soil outweighed the negatives associated with establishing vegetation in the thatched areas.

### ***Manning Avenue Restoration***

As described previously, the attempted restoration of the Manning Avenue Property during the 2001-02 growing season met with little success due to the soil compaction that resulted from imprinting on wet soils. Another attempt was made to restore (berming and seeding) this area during the 2002-03 growing season. At this time, the soil was still sufficiently hard-packed and required the area to be disked. Following disking, a series of low, serpentine berms were installed on approximately 9.1 m (30 feet) centers. Disking and berming took place during October 12-14, 2002.

A mixture of 12 native species was imprinted. Imprinting was originally scheduled for the first week of November; however rainfall at that time precluded imprinting until late in the month (November 24-30, 2002).

### ***Site Management***

**HRS Buffer Maintenance** The barley in the buffers surrounding the HRS plots (~ 243 ha; 600 ac) was thrashed, and the area was surface disked. Barley was reseeded where necessary.

**Hedgerows** Approximately 3 miles of hedgerow were installed during the 2002-03 growing season. Hedgerows were situated along the roads that parallel the HRS study blocks. A number of different mixtures of native seed were used (see Uptain et al. 2004), to investigate the potential of various species for their applicability in restoration. Seed was both imprinted and spread by hand. The hedgerows were watered (flood irrigation) at selected times during the growing season.

### **2003-04 Growing Season**

#### ***Seed Augmentation and Planting Method Trial***

The Seed Augmentation and Planting Method Trial, and the Herbicide and Charcoal Treatment Trial represent a collaborative effort involving Reclamation (Reclamation; Technical Service Center, Denver; and Land Retirement Program, Fresno), the Endangered Species Recovery Program, Dr. Joe DiTomaso (University of California, Davis; UCD), and the Lockeford Plant Materials Center (USDA-NRCS; Lockeford).

The Seed Augmentation and Planting Method Trial (5.6 ha; installed November 19-25, 2003) is a replicated, [3x4x4] factorial study evaluating effects of three factors on establishment success of eight native grass, forb and shrub species. Treatment factors were (a) mechanical soil surface (seedbed) manipulation, (b) cover crop use, and (c) chemical rhizosphere augmentation. Mechanical surface treatments addressed drilled seeding across variable depths and row spacing of deep-furrow seed placement (furrow depth: 1 cm [control standard], 10 cm, and 20 cm; row spacing: 30 cm [control standard] and 45 cm). Deep-furrow seed placement is designed to increase precipitation capture and retention, creating seed germination micro-sites exhibiting lower salinity and

increased protection from environmental extremes. Second-level treatment involved use of a dryland barley “nurse crop” seeded at typical agronomic rates ( $68 \text{ kg ha}^{-1}$ ) in alternate rows (60 cm and 90 cm spacing) with seeded natives to evaluate effects on weed suppression and further buffering of climatic extremes. Third-level rhizosphere augmentation involved combinations of treatments for sodium reduction using banded application of HydraHume™ at  $112 \text{ kg ha}^{-1}$ ; banded phosphorous fertilizer (0-45-0 super treble  $\text{PO}_4$  at  $45 \text{ kg ha}^{-1}$ ); and polymerized, clay-based seed coating (2:1 seed weight ratio). Influence of pre-treatment soil parameters will also be analyzed, including surface and subsurface texture, pH, sodium adsorption ratio (SAR), electrical conductivity ( $\text{EC}_e$ ), and major nutrients.

Plant counts for native and weed species, utilizing ten  $1,500 \text{ cm}^2$  (30 cm row spacing) or  $2,300 \text{ cm}^2$  (45 cm row spacing) within-row quadrats per row, were conducted during the first growing season (April 26-30, 2004) for cool-season species to provide estimates of species germination, emergence, and survival (stand success). Because of extreme drought conditions after this date, emergence of warm-season species was insufficient to warrant data collection in 2004.

#### ***Planting Techniques Trial and Water Use Trial***

These two trials were carried out by CSU, Fresno, Masters Student Emily Magill. The Planting Techniques Trial is a field-based experiment that was developed to investigate the relative performance of three planting techniques (drilling, imprinting, and broadcasting). Four species of native plants—*Atriplex polycarpa*, *Hemizonia pungens*, *Phacelia ciliata*, and *Suaeda moquinii*—were planted as monocultures. The study required 60 plots; plot size was approximately 3.7 m by 7.6 m (12 feet by 25 feet). Each treatment (i.e., species-planting combination) was replicated 5 times. Monitoring included measurements of soil moisture, soil electrical conductivity, percent cover, photosynthetic rates, and plant height.

The second trial, the Water Use Trial, was a greenhouse-based experiment that investigated how different watering regimes affected the germination and growth of native versus invasive species. Native species were represented by a subset of the species used in the Planting Techniques Trial (*Atriplex polycarpa* and *Phacelia ciliata*). Invasive species were represented by a single species, *Bromus madritensis* (red brome). Data collected in this trial included percent cover, photosynthetic rate, biomass (above- and below-ground), and water stress. This trial was initiated in the 2003-04 growing season and was continued into the 2004-05 growing season.

### **2004-05 Growing Season**

#### ***Herbicide and Charcoal Treatment Trial***

Weed control remains the overriding limitation of restoration efforts on LRDP—retired (dewatered) lands. Chemical methods of weed control can be particularly problematic because most potential herbicide choices exhibit activity on non-target species (i.e., seeded species). Other integrated pest management (IPM)

strategies such as grazing, fire, and mechanical control are being evaluated, but have limited utility or windows of opportunity during seeded species establishment periods. Selective, pre-emerge herbicides with longer residual activity in conjunction with native seed / seedling safeners are needed to maximize this establishment window. The herbicide and Charcoal Treatment Trial was developed to determine if significant levels of control can be achieved using only natural precipitation to activate and move the herbicides into the root zone of the dominant weeds, with the activated charcoal serving as a protectant for the seeded natives. If one of the Experimental Use Permit (EUP) herbicides should prove more effective than other herbicide options, a special local permit may be pursued for its broader-scale use within the CVPIA-Land Retirement project, since 28,329-40,470 ha (70,000-100,000 acres) within the project may eventually be targeted for revegetation.

The experimental design incorporates a [6x3] factorial study (0.9 ha; installed December 13-16, 2004), in which four seeded native forb and shrub species were drilled without protectant safener (control) or precisely within an incorporated powder band or beneath an over-sprayed slurry band of activated charcoal (Gro-Safe<sup>®</sup>; Norit Americas; applied at 336 kg ha<sup>-1</sup>) to protect them from pre-emerge herbicides applied broadcast by ground rig. This weed management approach is commonly and successfully practiced in ryegrass and turfgrass industries, with possibilities for extension to drilled applications of native species. Six pre-emerge herbicide treatments (no herbicide [control], Landmark MP<sup>™</sup>, Telar DF<sup>™</sup>, Goal 2XL<sup>™</sup>, Broadrange<sup>™</sup>, and Cerano 5MEG<sup>™</sup> [the latter two of which are evaluated under an EUP]), compare potential control of a mixed composition of black mustard (*Brassica nigra*), London rocket (*Sisymbrium irio*), and the “tumbling saltbushes” (*Atriplex rosea* and *A. argentea*). Initial monitoring for seeded species emergence and survival will commence April 25, 2005.

It is anticipated that a similar study will be undertaken on the North Avenue Property in the 2005-06 growing season. This study will be situated in an area dominated by cool-season introduced grasses (*Hordeum murinum*, *Bromus madritensis*, *Avena* spp.), and will receive similar herbicide and activated charcoal treatments.

### ***Planting Techniques Trial – Year II***

This trial represents Emily Magill’s second year of Masters research. The same three planting methods that were compared in the initial Planting Techniques Trial were used here; however, two additional species—*Grindelia camporum* and *Lessingia glandulifera*—were incorporated. The study required 90 plots; plot size was approximately 3.7 m by 7.6 m (12 feet by 25 feet). Each treatment was replicated 5 times. Data collection will include those parameters as were described for the preceding year.

### ***Seed Delivery and Competition Trial***

This trial was situated on the northernmost portion of the North Avenue Property (ca. 16.2 ha; 40 ac). Restoration efforts had previously been applied to this area;

however, almost all of the native vegetation that was established from these efforts was situated on the berms (and adjacent trenches).

The Seed Delivery and Competition Trial was developed to compare two seed delivery methods (imprinting and broadcasting). An additional treatment factor, seed mixture, was incorporated into the trial. Two seed mixtures, the “Phacelia mixture” and the “Late-season Mixture” were compared. Seeding took place only on the “flats” (i.e., the portion between berms), as establishment of the previously seeded species was deemed sufficient on the berms to preclude re-seeding. Each flat was treated as an experimental plot. Treatments (i.e., the four seed delivery-seed mixture combinations) were assigned randomly in a complete randomized block design; each treatment was replicated eight times (32 plots total).

The “Phacelia mixture” (eight species) had a substantial component of *Phacelia ciliata* (great valley Phacelia), an early-germinating native forb that has shown promise in the Native Plant Nursery and in various restoration trials. It was hoped that *P. ciliata* would be able to successfully compete with the annual winter grasses that dominate much of the North Avenue Property. *Phacelia ciliata* possesses a spreading habit; as the species dies back during the summer months, the stems disarticulate creating open habitat. A number of the remaining species in this seed mixture were late-germinating perennials. It was hoped that these species would be able to become established in the (theoretical) open spaces formerly occupied by *P. ciliata*.

The “Late-Season Mixture” (seven species) was composed entirely of late-season species. The areas seeded with this mixture will be treated with herbicide in the early spring (i.e., before any of the seeded species are expected to germinate), to create suitable conditions for the establishment of the seeded species.

Originally, it was intended that seeding would occur shortly after the first rains. In this way, it was hoped that seeding would precede germination of the winter weeds. However, in the fall of 2004, the initial rains were followed by periodic rainy periods, such that during an approximately 6-week long period, the soil never dried sufficiently to allow seeding. Therefore, when conditions finally allowed seeding, the winter weeds (specifically, the non-native grasses) had developed sufficiently to allow them a distinct advantage over the seeded species. To control the weeds, seeding was preceded by working the soil with a hook-chisel. Seeding took place on November 22, 2004 (imprinting) and December 2-3 (broadcasting).

### **Native Release Trial**

The Native Release Trial was developed to examine the possibility of promoting germination of native seed in the seed bank by reducing competition from weeds. The trial was situated on a portion of the Tranquillity site that possessed a good-sized population of the native annual forb, *Malacothrix coulteri* (snakes head). This area served as a seed collecting site for snakes head during the 2002-03 growing season. However, during the next two growing seasons, the abundance

of the invasive grass *Bromus madritensis* increased dramatically. Concomitantly, *M. coulteri* decreased in abundance to the point that insufficient individuals did not allow harvesting.

It was hoped that by reducing *B. madritensis* through various weed-control methods, *M. coulteri* might once again proliferate in the area. Four treatments were applied: (1) flaming (i.e., burning existing vegetation with an agricultural flamer), (2) mowing, (3) spraying with Poast™, a grass-only herbicide, and (4) spraying with Roundup™, a broad-spectrum herbicide.

Plots dimensions were approximately 2 m by 3 m (6.7 feet by 9.8 feet). A complete randomized block design was applied, with treatments replicated eight times (40 plots total). Monitoring will be conducted during the spring of 2005.

### ***Native Mowing Trial***

The Native Mowing Trial, another small-plot trial, is situated in the same area as the Native Release Trial. This trial was developed to better evaluate the potential of mowing as a management strategy for promoting the continuance of native species in landscapes threatened by invasive species.

Treatments consisted of four mowing regimes (one to four mowings) and a control (no mowing). A complete randomized block design was applied, with treatments replicated eight times (40 plots total). Plots dimensions were approximately 2 m by 3 m (6.7 feet by 9.8 feet). Treatments will be applied during the 2004-05 growing season. Monitoring will be conducted during the spring of the following year (2006).

### ***Restoration Release Trial***

The Restoration Release Trial was another experiment that was developed to examine the possibility of promoting germination of native seed in the seed bank by reducing competition from weeds. This trial is situated on the Manning Avenue Property—an area that had previously undergone restoration efforts. It was hoped that by controlling the invasive species, some of the remaining imprinted seed might more readily germinate.

Four treatments were applied; with one exception, the treatments were the same as were used in the Native Release Trial. Treatments were (1) flaming (i.e., burning existing vegetation with an agricultural flamer), (2) mowing, (3) spraying with Roundup™, a broad-spectrum herbicide, and (4) spraying with BurnOut II™, a broad-spectrum herbicide.

Plots dimensions were approximately 2 m by 3 m (6.7 feet by 9.8 feet). A complete randomized block design was applied, with treatments replicated eight times (40 plots total). Monitoring will be conducted during the spring of 2005.

## Restoration and Site Management – Atwell Island

### 2000-01 Growing Season

#### **Site Management**

Barley was planted on the areas where the Habitat Restoration Study would be sited (ca. 243 ha; 600 ac), to provide a homogenous setting for the HRS plots. The barley was flood irrigated in Study Area 1, and was sprinkler irrigated in the other two Study Areas.

### 2001-02 Growing Season

#### **HRS Plot Installation**

Treatments were applied to the 48 HRS plots. Seed of the same 13 native species as was used for the Tranquillity HRS plots was imprinted across the 24 “seeded” plots in December 2001. In contrast to the Tranquillity HRS plots, no transplanting occurred on the Atwell Island plots. Microtopographic contours (berms) were created on the 24 “bermed” plots. Forty-nine approximately 12 m (39.4 foot) long berms were installed on each plot.

#### **Evaporation Basin Restoration**

The Evaporation Basin—an approximately 13.3 ha (33-acre) former evaporation basin located along the western edge of the Atwell Island LRDP property—was targeted for a partial restoration in late 2001. The evaporation basin was characterized by a flat expanse of highly alkaline, salt-encrusted soil, nearly devoid of vegetation; however, adjacent lands, which are managed by the BLM, support fair-sized populations of native alkali sink vegetation.

Restoration efforts occurred during November and December 2001. Only the outer edges of the evaporation basin were accessible, as rainfall at that time had created extremely wet and muddy conditions. Vegetation was introduced to the site by both seeding and transplanting. Areas to be seeded were prepared by loosening the soil with rakes. Native seed from adjacent properties was collected and then broadcast onto the raked seedbeds. Species planted in this manner were: *Allenrolfea occidentalis*, *Distichlis spicata*, *Frankenia salina*, *Heliotropium curassavicum*, and *Suaeda moquinii*. Two of these, *Distichlis spicata* and *Allenrolfea occidentalis*, also were introduced to the site through transplanting. Rhizomes of *D. spicata* that were growing along the perimeter and encroaching onto the salt flat were transplanted onto the restoration area. Plugs of *Allenrolfea occidentalis* were grown by the Southern California Edison Nursery (Auberry) from native seed collected from the Tranquillity area, and were transplanted directly onto the site.

#### **Site Management**

The barley in the buffers around the HRS plots (ca. 155.4 ha; 384 ac) was thrashed and worked into the soil by surface disking. Barley was reseeded in areas where the yield was poor.

## **Native Plant Nursery and Seed Collecting**

The LRDP Native Plant Nursery was established in the 2001-02 growing season to serve a variety of essential functions: (1) to augment available commercial sources of native seed; (2) to significantly amplify the number of San Joaquin Valley species that were available for use in local restoration activities; (3) to serve as a "laboratory", where the various species could be screened for their potential applicability in restoration settings; and (4) to provide a setting that was suited for outreach and volunteer-centered activities.

The nursery—and associated seed collecting and processing activities—have grown significantly throughout the course of the project. The original nursery occupied ca. 0.8 ha (2 ac), of which approximately 0.6 ha (1.5 ac) was planted. In the second year (2002-03 growing season), the nursery was relocated to a better site, and was expanded to approximately 1.6 ha (4 ac), with weed control measures applied to an additional 0.8 ha (2 ac) to prepare that area for future nursery expansion. During the third year (2003-04 growing season), the nursery expanded again. During this time ca. 0.2 ha (0.5 ac) of the area that was prepared during the previous year was put into production. Also, an additional 1.6 ha (4 ac) to the east of the nursery were established as a “mechanized nursery,” in which eight species were grown in single-species blocks (0.2 ha; 0.5 ac). In contrast to the “main” portion of the nursery, which was reliant on extensive hand labor, cultivation and harvesting in the mechanized nursery emphasized machine-based technologies (e.g., the tractor, sprayer, and mechanical seed harvester). For the current year (2004-05 growing season), the nursery has been slightly reduced in area. The main nursery has been reduced to ca. 1.6 ha (4 ac) and the mechanized nursery has been reduced by ca. 0.2 ha (0.5 ac).

Despite the slight reduction in nursery area for the current growing season, the number of species in cultivation has grown steadily. Eighteen species were cultivated during the first year. The number of species in cultivation rose steadily since that time, with 31 species in 2002-03, and 64 species in 2003-04. Planting of the 2004-05 nursery was ongoing at the time of this writing, but it is anticipated that about 80 species will be in cultivation.

Seed collecting activities have also grown dramatically during this period. In the first year of seed collection (2000-01) seeds were collected from just seven locations. In subsequent years, a significant amount of effort was expended on locating additional seed collecting sites. As a result, 45 local collecting sites (i.e., within 40 miles of the nursery) are now known. To accommodate the seed (i.e., dry, clean, and store) from the nursery and from additional seed collecting, an approximately 1,500 square foot facility was leased in 2003. Since that time, a variety of seed processing equipment has been purchased and/or constructed, and the building has been “outfitted” (e.g., dust-collecting equipment has been installed, shelving has been built, etc.).

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