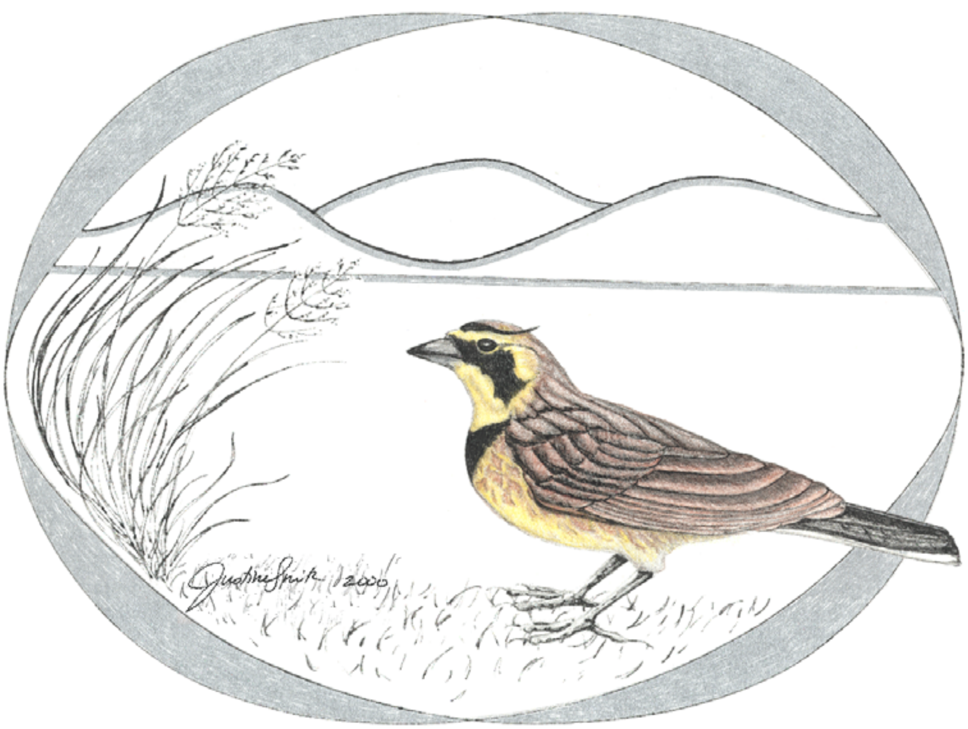
Land Retirement Demonstration Project
Year Two

2000 Annual Report



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Prepared for: Robert May (USBR), Bea Olsen (USFWS), and Tracy Rowland (BLM)
Interagency Land Retirement Team
1243 N Street
Fresno, CA 93721

List of Preparers:

Curt Uptain, Karen Dulik, Paul Brandy[1], Michelle Selmon[1], Patrick Kelly, Daniel Williams
California State University, Stanislaus
Endangered Species Recovery Program
1900 N. Gateway Blvd. #101
Fresno, CA 93727

and

Stephen Lee
USBR/Interagency Land Retirement Team
1243 N Street
Fresno, CA 93721

Joseph Brummer
USBR/Denver Technical Center
Denver, Colorado 80225-0007

[1] Current address: State of California /Department of Fish and Game 1234 East Shaw Avenue Fresno, CA 93710

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EXECUTIVE SUMMARY

Vast tracts of land on the west side of the San Joaquin Valley are characterized by a high groundwater level and high selenium content. The application of irrigation water to these lands results in an accumulation of poor quality drainwater. The elimination of drainwater is a chronic problem on these lands. One way to reduce the accumulation of drainwater and problems associated with its disposal is to retire the land from agricultural production. Land retirement comes with its own set of difficulties including acquisition of the lands, redistribution of the acquired water, and restoration of habitat to reduce the potential for agricultural weeds and pests, which would adversely impact neighboring farming interests.

The Central Valley Project Improvement Act (CVPIA) of 1992 includes provisions to implement land retirement. A multi-agency team consisting of representatives from the United States Bureau of Reclamation (USBR), the United States Fish and Wildlife Service (USFWS), and the United States Bureau of Land Management (BLM) has been assembled to accomplish the goals of the CVPIA Land Retirement Program. This program may purchase land, water, and other property interests from willing sellers who receive Central Valley Project allocations.

A 15,000 acre demonstration project has been designed to test various methods of habitat restoration and the effects of land retirement on drainwater reduction, groundwater levels, and the potential to decrease bio-available selenium and other toxic compounds prior to initiating land retirement on a greater scale. The focus of these studies is to determine appropriate means of habitat restoration, cost effective restoration methods, and the physical impacts of land retirement. The California State University Stanislaus Foundation’s Endangered Species Recovery Program (ESRP) was contracted by the USBR to lead the biological studies, whereas the physical impacts of land restoration are being examined by the USBR. Aside from the focused studies, land restoration is underway on the site located in Fresno County (Westlands Site) and in Tulare and Kings counties (Alpaugh Site). This report documents all aspects of the Demonstration Project from its inception in 1999 to January 2001. The report includes results of the Habitat Restoration Study, findings of the impacts of land retirement on physical properties (groundwater, soils, geology, etc), and restoration activities.

In 1999, a Habitat Restoration Study was implemented on 800 acres of the 1,646 acre Westlands Site. The study site was initially disced, groomed, and planted in a barley cover crop to reduce weeds and variations in residual fertilizers, pesticides and herbicides. The study consists of four treatments replicated five times in a randomized block design. The treatments included seeding and planting of native plant species, installation of microtopographic contouring, a combination of planting native plants and installing contours, and no treatment. Each 10-acre plot is located in the center of a 40-acre parcel; the remainder of each parcel is planted with a barley buffer to isolate the plots. Data collected includes plant cover , productivity, survivorship, invertebrate richness and abundance, reptile and amphibian richness and abundance, avian richness and abundance, and small mammal richness and abundance. Furthermore, data are being collected to examine winter raptor abundance, the presence of other wildlife species, and the bio-accumulation of contaminants throughout the site. The contaminant levels will be used to

investigate the effects of land restoration on the abundance, diversity, and health of wildlife. Data collected in 1999 reflect baseline conditions and were collected while the land was in barley production. Data collected in 2000 reflects conditions immediately after treatments were applied to the study plots and after some restoration on other lands on the Westlands Site had occurred.

Early results indicate that seeding by imprinting is a successful and cost-effective method of planting a variety of native plant species. Native plant species richness in 2000 was greater on plots where seeding occurred compared to those plots that were not seeded (richness = 4.00 and 4.40 on seeded plots vs. 0.80 and 1.00 on non-seeded plots). Likewise, native plant cover was greater on seeded plots than on non-seeded plots (3.00% and 3.20% vs. 0.6% and 0%). These results reflect the successful germination and survivorship of the seeded native plants. In contrast, productivity was greatest on the control plots where no treatments were applied, due largely to the persistence of barley. Micro-topographic contouring did not appear to affect the richness, cover, productivity or survivorship of native flora during this first season after planting. However, during subsequent years, once the annual species self-seed, the affects of micro-topographic contouring may become evident.

The survivorship of planted seedlings was generally poor. *Atriplex polycarpa* was the most successful; 34% survived the first growing season. Other seeding species persisted at much lower rates. Seedling failure can be attributed to lack of water once planted, small size of seedlings, a diversity of seedling quality and hardiness, and other factors. The planting of seedlings was much more time consuming, costly, and less effective than seeding. Additional trials will be conducted to determine methods to increase the survival rates of planted seedlings.

Richness and abundance of invertebrates varied little between treatments or between blocks. However, both richness and abundance increased by an order of magnitude from 1999. This was expected because of the change from an agricultural monoculture to a more diverse habitat. Only one amphibian was caught in the pitfall traps, but there are some anecdotal sightings of other species of reptiles and amphibians from the plots and surrounding area. Additional protocols to evaluate amphibian and reptile richness and abundance will be established in 2001 and will consist of visual encounter surveys and inspection of coverboards. Additional inspections of the pitfalls also will be instituted.

Avian species richness and abundance did not vary significantly between treatments, but did vary by block. There also were significant differences in richness and abundance between seasons. The seasonal activity patterns of birds, including winter migrations and spring nesting behaviors, adequately explains these findings. Avian abundance was greater on all plots in 2000 than it was in 1999, a supposed response to the change from the barley monoculture to a more diverse community.

Only two species of small mammals were captured during the 2000 small mammal censuses, although a third species (ornate shrews) were incidentally captured in the pitfall traps. While not conclusive, the abundance of small mammals is increasing on all plots, especially on those that were seeded with native plants and where contours were installed. While most of these data should be considered preliminary, it seems that as the habitat structurally develops, the diversity and abundance of wildlife species increases. This trend should continue until some equilibrium is reached.

A similar study was designed for the Alpaugh Site. Each plot will be 2 acres in size, located in the center of a 10-acre parcel. The buffer of each 10 acre parcel will be planted in barley to isolate the plots. The same 4 treatments that were used at the Westlands Site will be applied to 48 plots (12 replicates, 4 treatments) on 3 blocks. Data collection at Alpaugh will be the same as that collected at the Westlands Site, but the methods of collection will vary because of the constraints imposed by a smaller plot size. In December 2000, barley was planted on the study sites in Alpaugh. Some preliminary inventory data were collected in spring and summer 2000. Baseline data will be collected in 2001 and treatments will be applied in December 2001 and in early spring 2002. Accordingly, there is little to report in the way of findings at Alpaugh.

Some trials (ancillary restoration studies) using alternate planting methods, alternate native seed mixes, and alternate cover crop seed mixes were established in areas away from the Habitat Restoration Study site at Westlands. Although these trials have been implemented, no data collection has yet occurred. No such trials have been implemented at the Alpaugh Site and there are no current plans to do so. However, BLM may implement ancillary trials and conduct some small scale restoration studies.

Restoration implemented on the Westlands Site consisted of planting hedgerows, seeding and planting native plants on 160 acres, seeding ditch banks, and seeding an area that becomes intermittently inundated with a mix of marsh and upland species. Monitoring the success of these efforts will occur in 2001. Initial restoration efforts were begun on the Alpaugh Site by BLM, including planting of trees, seeding of a hedgerow, and seeding of safflower and barley. Some sheep grazing occurred on the site as a precursor to restoration that will begin in spring 2001.

Three different strata were sampled for contaminants at the Westlands Site: lands with a barley cover crop, idled lands, and experimental plots. Vegetation, invertebrates, and small mammals were collected and analyzed. Contaminant samples between 1999 and 2000 were similar and consisted of relatively low levels of selenium in vegetation. Black mustard (*Brassica nigra*) had the highest concentrations, but this would be expected because it is a known selenium accumulator. The selenium concentrations of invertebrates appear to be related to their feeding behavior. Crickets, a herbivorous group, had substantially lower selenium levels than isopods, a detritous-feeding group. In both 1999 and 2000, small mammals had lower concentrations of selenium in idled areas than in barley fields. This may indicate that the application of irrigation water increased the bio-availability of selenium. Similar results were found at the Alpaugh Site, except that the highest levels of selenium were found in an area that had been idled for at least 10 years. A tailwater pond that occurs on that site may be responsible for the elevated selenium levels.

The Westlands Site is underlain by flood basin deposits derived from floods on the San Joaquin and Kings Rivers. The flood basin deposits consist of moderately to densely compacted clays that range in thickness from 5 to 35 feet. The flood basin clays have low permeability and greatly impede the downward movement of applied irrigation water. The United States Department of Agriculture (USDA) soil types found at the site in order of abundance include the Tranquillity clay (80%), the Lillis clay (10%) and the Lethent silt loam (10%). Baseline soil chemistry data collected during 1999 indicate that the site soils are highly to moderately saline, and contain elevated concentrations of selenium and boron when compared to other soils in the San Joaquin Valley. Soil chemistry data collected during the first year of monitoring are adequate for establishing project baseline soil conditions. Groundwater monitoring data collected to date support the conceptual model of a declining shallow water table in response to land retirement. The average water level decline observed in ten onsite wells for the period between August 1999 and January 2001 is 3.75 feet. By comparison, the water level in a nearby offsite well monitoring the shallow groundwater system declined 1.26 feet during the same time period. The area of the site underlain by a shallow groundwater table within 7 feet of the land surface decreased from 600 acres (30% of the site) to 55 acres (3% of the site) during the time period from October 1999 to October 2000. Extreme vertical groundwater gradients measured at the site indicate perched water table conditions in the shallow groundwater system. Baseline groundwater quality data taken during 1999 indicate that the shallow groundwater is of extremely poor quality. The shallow groundwater underlying the site is a sodium sulfate type of water, is highly saline, and contains high concentrations of selenium and boron. Selenium concentrations observed in deep wells completed in the underlying Sierra Nevada deposits at the site are below the analytical detection limit for this study. Reducing geochemical conditions in the Sierran deposits may account for this observation. Isotopic (Tritium) data from the shallow monitor wells indicate that the shallow, perched groundwater consists of a mixture of water recharged before and after 1952. Tritium data from the deep wells completed in the Coastal Range deposits at the site indicate that the groundwater was recharged before 1952. Groundwater quality data collected during 1999 are adequate for establishing baseline project conditions.

In 2001 monitoring of the Habitat Restoration Study site at Westlands will continue and treatments will be applied to plots on the Alpaugh Site. Some changes will be made to sampling protocol to improve the ratio of effort expended to quantity and quality of data gathered. Additional monitoring will occur at Westlands to identify the successes and failures of the ancillary trial efforts and of larger scale restoration efforts. Additional restoration activities may also occur. The BLM will hire a restoration ecologist and begin to restore large tracts of land at the Alpaugh Site. Other land management options such as grazing and hunting may be explored.

ACKNOWLEDGEMENTS

The Land Retirement Demonstration Project has been implemented with considerable team effort. Bob May (USBR), Tracy Rowland (BLM), and Bea Olsen (USFWS) have the daunting role of Administration, Land acquisition, and Agency coordination. Without their dedication and hard work, none of this would have been possible. Stephen Lee (USBR) and Joseph

Brummer (USBR) collected, analyzed, and synthesized the physical impacts information. Larry Saslaw (BLM) has played a key role in planning, restoration and management of the Alpaugh Site. Tracey Rowland, Stephen Lee, and especially Bea Olsen, provided valuable input on various drafts of this manuscript.

Michelle Selmon deserves special recognition. Until January 2001, she was the Coordinator of the Land Retirement Demonstration Project for ESRP. She was responsible for establishing the study plots and cover crops, implementing the biological studies, and conducting the restoration and ancillary study trials at the Westlands Site. She also coordinated the initial research efforts at the Alpaugh Site. She conducted tours, gave presentations at scientific conferences, acted as a liaison with local farmers, and lead the survey monitoring efforts. This report is a result of her fine efforts and she deserves the bulk of the credit. ESRP field staff who also contributed an immense amount of effort to this project include: Howard Clark, Ellen Cypher, Adam Harpster, Kimberley Krietinger, Patrick Morrison, Darren Newman, Justine Smith, and Foung Vang. All of them have spent many grueling late nights, cold early morning, and hot buggy afternoon hours in the field. They have spent much time and effort organizing equipment and entering data. Finally, we are grateful to Dr. Hulbert (California State University, San Diego) for his help in study design considerations and statistical problem solving.

The Ryan Farming Company has been a tremendous asset to the project from the start. They have given us guidance on the farming aspects of the project and have been a great help. We would also like to thank Mr. Jones, our neighboring farmer, for his help in maintenance on the site. We would like to thank Southern California Edison, Westside Transplants and Intermountain Nursery for providing us with native seedlings. Finally we would like to thank the California Department of Fish and Game, Fresno West Golf and Country Club and Westlands Water District for allowing us to collect native seed in Fresno County. Additionally we would like to thank the Center for Natural Lands Management for permission to collect seed at the Thomas Payne Preserve for the Alpaugh Site.

I. INTRODUCTION

A. Background

Water diversions from northern California and the Sacramento-San Joaquin Delta to arid lands on the west side of the San Joaquin Valley (the Valley) of California have allowed for the conversion of millions of acres of grassland, saltbush scrub and marsh habitats to irrigated agriculture. A shallow underlying layer of clay, known as the Corcoran clay layer, in association with decades of irrigation has created shallow, contaminated water tables on the west side of the Valley (Figure 1). To prevent the water table from rising to the crop root zone and decreasing agricultural productivity, many fields have had tile-drains installed to collect the water once it has passed through the root zone. Drainwater collected in the tile-drains is disposed of in evaporation ponds.

Irrigation drainwater in evaporation ponds from west-side soils has produced serious effects in wildlife due to toxic levels of selenium and other contaminants (Ohlendorf et al. 1986, Ohlendorf 1989, Lemly 1994, Skorupa 1998). Cost-effective treatment technologies which remove these contaminants from drainwater to a level safe for wildlife have not yet been identified.

A report was prepared in 1990 by the San Joaquin Valley Drainage Program (SJVDP) which recommended various options for addressing drainage problems in the Valley (SJVDP 1990a). One recommended action was to selectively retire agricultural lands with drainage-problems. Land retirement will reduce the volume of drainwater produced on the west-side and simultaneously provide additional water supplies for other uses.

A multi-agency team consisting of representatives from the United States Bureau of Reclamation (USBR), United States Fish and Wildlife Service (USFWS), and the United States Bureau of Land Management (BLM) has been assembled to accomplish the goals of the Central Valley Project Improvement Act (CVPIA) Land Retirement Program. The CVPIA Land Retirement Program is a voluntary program whereby the United States Department of Interior (USDOI) may purchase land, water, and other property interests from willing sellers who receive Central Valley Project (CVP) water allocations. Condemnation of land by federal authorities is not a part of this program. However, willing sellers are numerous because of the low productivity and high cost of production on drainage impaired lands.

The broad goals of the Land Retirement Program are to:

- Reduce the volume of drainwater produced by retiring lands from irrigated agricultural production on the west side of the Valley,
- Acquire water for CVPIA purposes, and
- Enhance fish and wildlife resources.

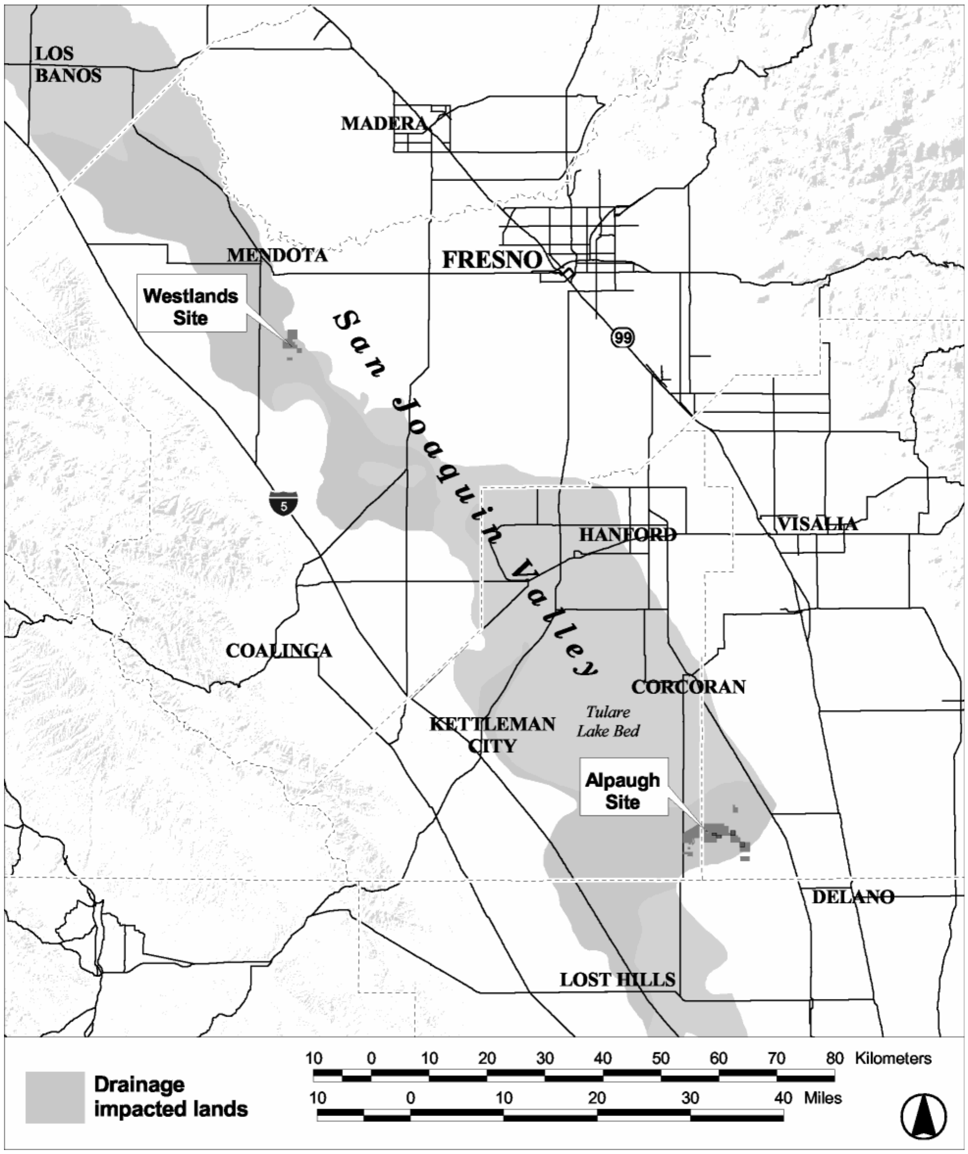

Figure 1. Drainage impacted lands in the San Joaquin Valley.

According to the Interim Land Retirement Program Guidelines, lands eligible for retirement under the program must receive CVP water, generally have shallow groundwater and high selenium levels (USDI 1997). The Interagency Land Retirement Team (LRT) accepts proposals from landowners wishing to sell their land and considers a number of criteria in selecting parcels for retirement, including:

- Poor drainage and low productivity,

- Potential for re-establishment of native upland community,
- Connectivity with other natural areas, and
- Availability of large blocks of land, or occurrence within a specified wildlife movement corridor (USFWS 1998).

Ceasing irrigation on lands with high selenium levels in the soil and groundwater should lead to a reduction in the overall volume of agricultural drainage water. This should decrease loading of salts and trace elements, including selenium, in the remaining drainwater. The effect should be decreased exposure of wildlife to toxic levels of those elements. Water acquired along with land purchases may be used in the restoration of Demonstration Project lands to upland wildlife habitat. It will be applied in a manner that will not contribute to deep percolation to the shallow groundwater underlying the project lands (USDI 1999). Water acquired in excess of the anticipated need may be sold or transferred to eligible landowners within the districts on an annual basis and used for irrigation on non-drainage impacted lands, or the water may be transferred to other CVPIA purposes.

B. Development of the Land Retirement Demonstration Project

During the comment period for the Land Retirement Program Draft Environmental Assessment (EA) concerns were raised about the magnitude of the project and the lack of knowledge about the potential positive and negative effects of retirement of agricultural land on a large scale (USDI 1999). The Land Retirement Demonstration Project (LRDP) was initiated to address concerns about the scope and degree of impacts of retirement on wildlife, drainage volume reduction, socio-economics, and overall cumulative effects of removal of land from irrigated agriculture.

Specifically, the goals of the Land Retirement Demonstration Project are to:

1. Provide site-specific scientific data to determine if land retirement is an effective way to reduce drainwater volume and provide habitat. Results will guide implementation of the larger Land Retirement Program;
2. Research cost-effective means of restoring self-sustaining communities of native upland plants and animals on LRDP lands that will be applicable to larger acreages;
3. Use adaptive management principles[1] (Holling 1978, Walters and Holling 1990) to maximize efficiency of the restoration research program;
4. Educate stakeholders about the Land Retirement Program;
5. Evaluate the need for continued use of acquired water on Demonstration Project lands. If

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1- Adaptive management is an approach to resource management that involves learning from the outcomes of management actions, and adjusting the management program accordingly based on the new knowledge. Monitoring is a way of providing feedback for decision-making in the adaptive management process.

not needed for habitat restoration or continued management of these lands, USDI may sell the water to another user within the water district or the water may be used for other CVPIA uses (USDI 1999).

The desired outcome for retired agricultural lands is drainage reduction and the reestablishment of self-sustaining upland communities such as California prairie, Valley Sink Scrub and Valley Saltbush Scrub (Holland 1986). Restored lands may require management but not additional restoration and would not be a source of invasive weedy species to neighboring agricultural fields. Because virtually no information is available on upland community restoration of retired agricultural land in the Valley, this Demonstration Project provides an opportunity to study the effects of various rehabilitation techniques prior to implementation on a larger scale.

The Demonstration Project will provide a way to assess impacts of land retirement on physical and biotic parameters and to test various habitat restoration and management strategies on a relatively small scale prior to implementation of land retirement on larger acreages. Results from monitoring and research on the Demonstration Project will be used to prepare environmental documentation for further land retirement, and guide restoration and management decisions for retired lands.

A resource monitoring plan was prepared by the California State University Stanislaus' Endangered Species Recovery Program (ESRP). That plan outlined habitat restoration research and protocols to monitor for potential contamination of wildlife resulting from the high selenium levels in shallow groundwater, soils, and surface accumulation of water (Selmon et al. 1999). The study design and methodologies described in that plan were implemented in 1999 and 2000 in this second annual report

C. Demonstration Project Site Locations and Descriptions

The Demonstration Project consists of project sites in two geographically and physiographically different drainage-impaired basins, in order to generate data representative of large scale land retirement. A western Fresno County site (Westlands Site) will consist of approximately 7,000 acres[2] and a site located in Kings and Tulare counties (Alpaugh Site) will be approximately 8,000 acres.

Monitoring of biota, soils, and surface and groundwater depth and quality will occur on the entire 15,000 acres of Demonstration Project lands as they are purchased. At the time of preparation of this second annual report, 4,292 acres have been acquired, and additional properties are in escrow and are planned to be purchased by fall 2001.

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[2] Imperial measurements are used throughout this report to remain consistent with established land measures. Metric units represented by accepted abbreviations are used for standardized biological protocols.

1. Westlands Site

The Demonstration Project was initiated on 1,646 acres in western Fresno County on the Westlands Site in fall 1998 (Figure 2). To date, no further land has been purchased, however the Westlands Site is expected to grow to approximately 7,000 acres. Much of the land had been in recent cultivation prior to purchase by the LRT. A cover crop was planted on approximately 1,200 acres of previously cultivated land for weed and erosion control. The remaining acreage had been idled for longer than 5 years, contained sufficient plant cover and was therefore left undisturbed. Nearby natural areas that will serve as reference sites and seed sources include Mendota State Wildlife Area, Alkali Sink State Ecological Reserve and Kerman State Ecological Reserve.

2. Alpaugh Site

As of March 2000, 2,646 acres of land had been purchased in Kings and Tulare counties in the Tulare Basin area near Alpaugh (Figure 3). To date, no further land has been purchased, but upcoming land acquisitions will increase this project site to approximately 8,000 acres. Much of the land that was purchased had been in recent cultivation, other portions were grazed, and some had been idle for up to 10 years. Surveys conducted by ESRP in 1998 indicated that several sensitive species inhabit or use some idled lands that have been purchased at this site (Uptain et al. 1998). Nearby natural areas that will serve as reference sites and seed sources include Kern National Wildlife Refuge, Pixley National Wildlife Refuge, Allensworth State Ecological Reserve, and the Payne Wildflower Preserve which is managed by the Center for Natural Lands Management.

D. Project Scope

A variety of restoration and management activities has been implemented on retired lands. Some of the land has been used for a Habitat Restoration Study and other restoration-related experimentation, some has undergone active restoration, and some has been used for wildlife-friendly farming and recreation. The following sections of this report describe the implementation of these activities and the results of monitoring the biotic and physical effects of land retirement. This report covers activities and information gathered from January 1999 to January 2001, except when noted.

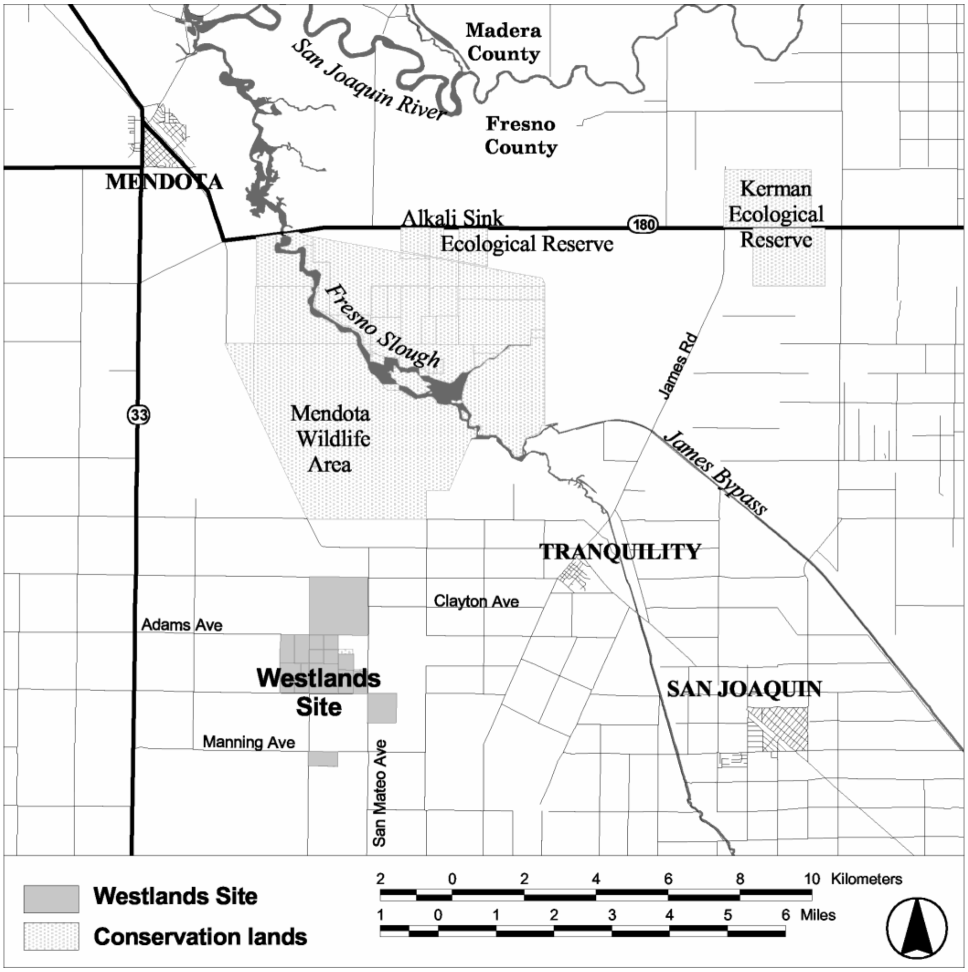

Figure 2. Westlands Land Retirement Demonstration Project Site and surrounding lands.

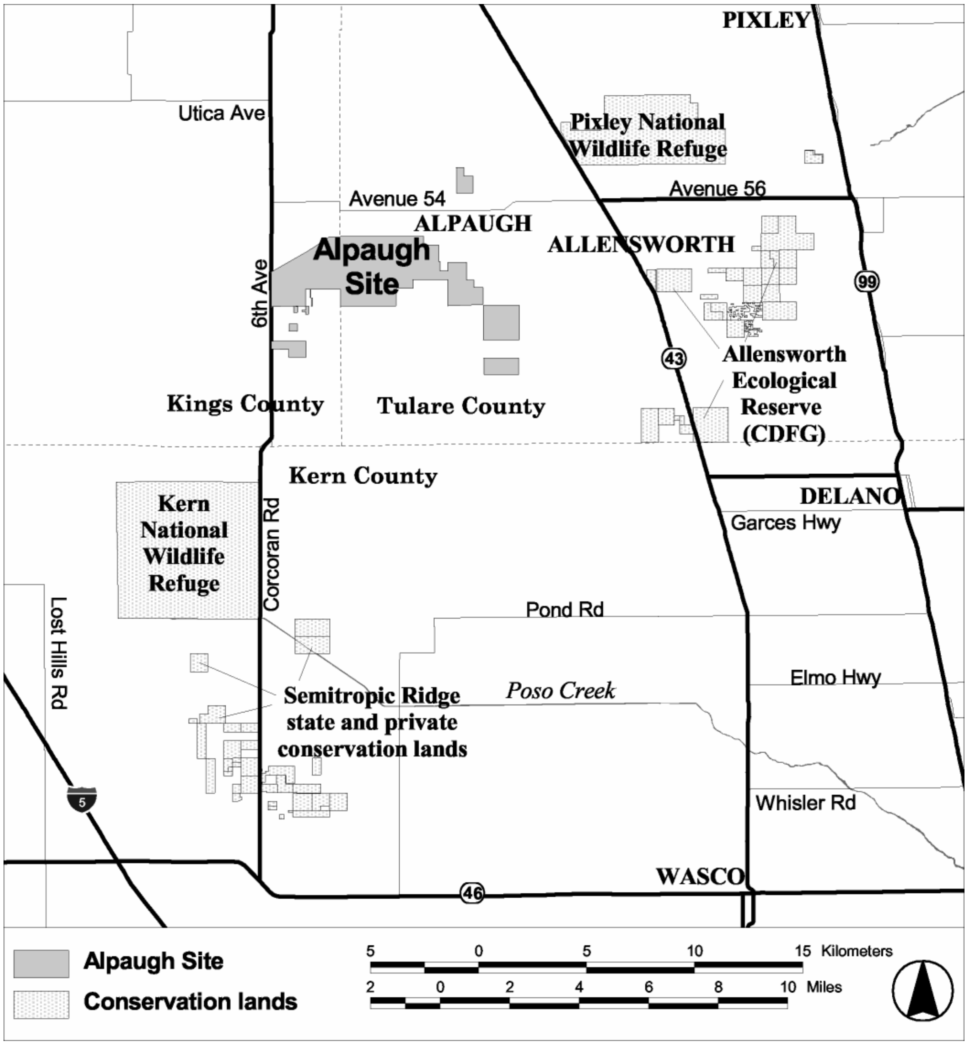

Figure 3. Alpaugh Land Retirement Demonstration Project Site and surrounding lands.

II. HABITAT RESTORATION STUDY (HRS)

A. Westlands Site

1. Study Design

An 800-acre Habitat Restoration Study (HRS) was established at the Westlands Site in 1999 to examine specific techniques of restoring natural habitat. Data will be collected for a minimum of 5 years and analyzed to assess differences between experimental treatments.

Specific objectives of the HRS are to:

- determine the efficacy of revegetation with native plants as a means to facilitate upland habitat restoration;
- determine the efficacy of microtopographic contouring as a means to facilitate upland habitat restoration; and
- examine the response of plants and wildlife to habitat changes.

The size of the HRS was a compromise between the amount of acreage that could be reasonably manipulated and monitored with a high degree of experimental rigor, and yet had potential to yield significant results in a relatively short amount of time (5 years or less). Twenty, 10-acre plots were established on 800 acres of the Westlands Site (Figure 4). Plots were arranged in a randomized block design to control variation caused by the heterogenous physical characteristics of the site. Four treatments were randomly assigned to plots within each block (Table 1). The four HRS experimental treatments were established in April of 1999. Plot corners were permanently marked with 3-foot sections of reinforcing bar (rebar). Pin flags were added to help locate plot corners. Plot corners were located with a Global Positioning System (GPS) receiver and data points were archived.

The 10-acre study plots were subjected to the prescribed treatment while the surrounding 30 acres functioned as a buffer region. A barley cover crop around the study area functioned as a homogenous buffer that prevented weeds from dominating regions between plots, decreases soil erosion, and reduces interactions between experimental treatments. During the first year of the Demonstration Project, all HRS experimental plots and the buffer regions were planted in barley. To grow a healthy cover crop the soil was turned and leveled. Soil was prepared until it was of uniform texture and barley was planted at approximately 170 pounds per acre.

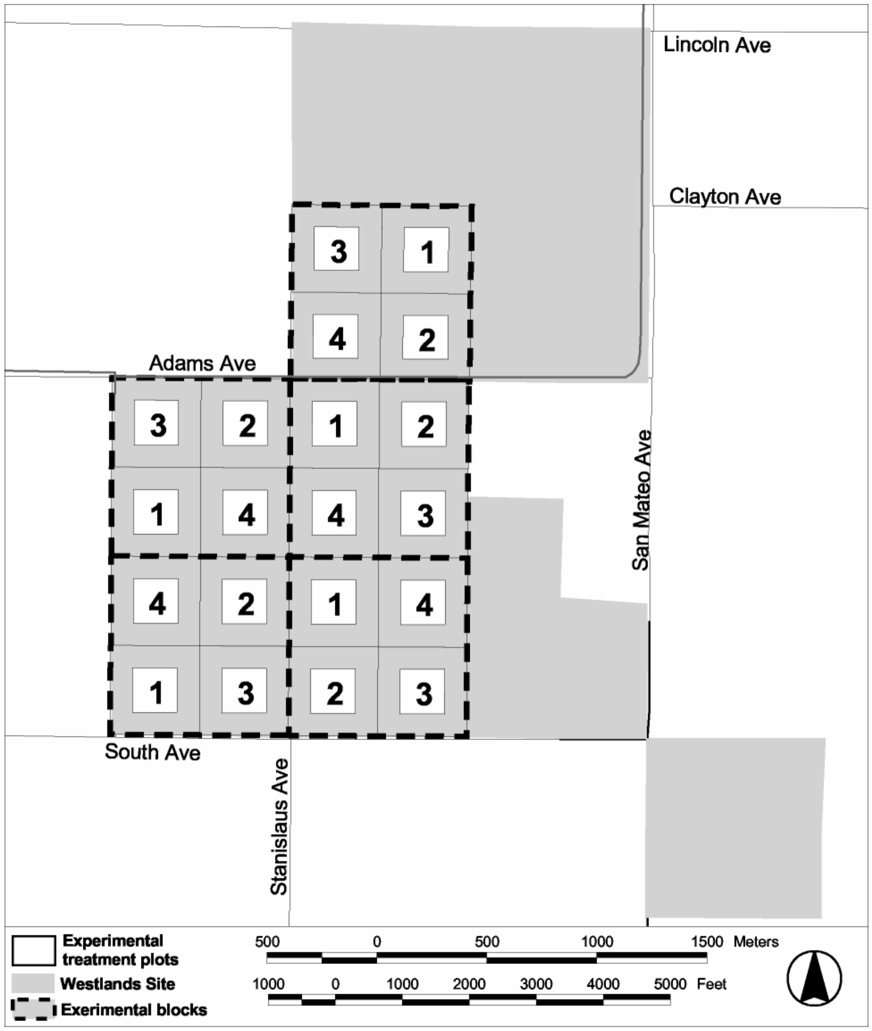

Figure 4. Treatments applied to Westlands HRS plots. Refer to Table 1 for treatment descriptions.

Table 1. HRS treatments and codes.* - C = contouring; R = reintroduction; N = no treatment.

Number	Code*	Description
1	CR	Microtopographic contouring (berms) with native plant reintroduction
2	CN	Microtopographic contouring (berms)
3	NR	Native plant reintroduction
4	NN	No treatment applied

Due to the effectiveness of the 1999 crop at controlling weeds and providing vegetative cover on retired lands, barley was again selected as the cover crop for 2000 and 2001. The seed is inexpensive ($0.10-$0.15 per pound) and can be planted without extensive ground preparation. Irrigation is necessary to inhibit weed growth and to obtain a profitable crop. The barley was irrigated with approximately 3 inches of water (an amount which will not contribute to deep percolation) for each of the past 2 years and will be watered again in spring 2001.

a. Microtopographic Contouring

Microtopographic contours (berms) were created to reintroduce minor vertical variation across the landscape. Such heterogeneity may create microhabitat suitable for plant germination and animal burrows. Berms were established on experimental plots in January 2000 (Figure 5) using a modified agricultural implement commonly used to create “checks” in flood-irrigated agricultural fields. Berms were approximately 12-18 in high. During a testing phase it was found that berms were compacted by the mechanical seeding device (imprinter). Accordingly, the berms in the plots that were seeded were initially about twice standard height. The resulting berms on all plots after seeding were consistent in height.

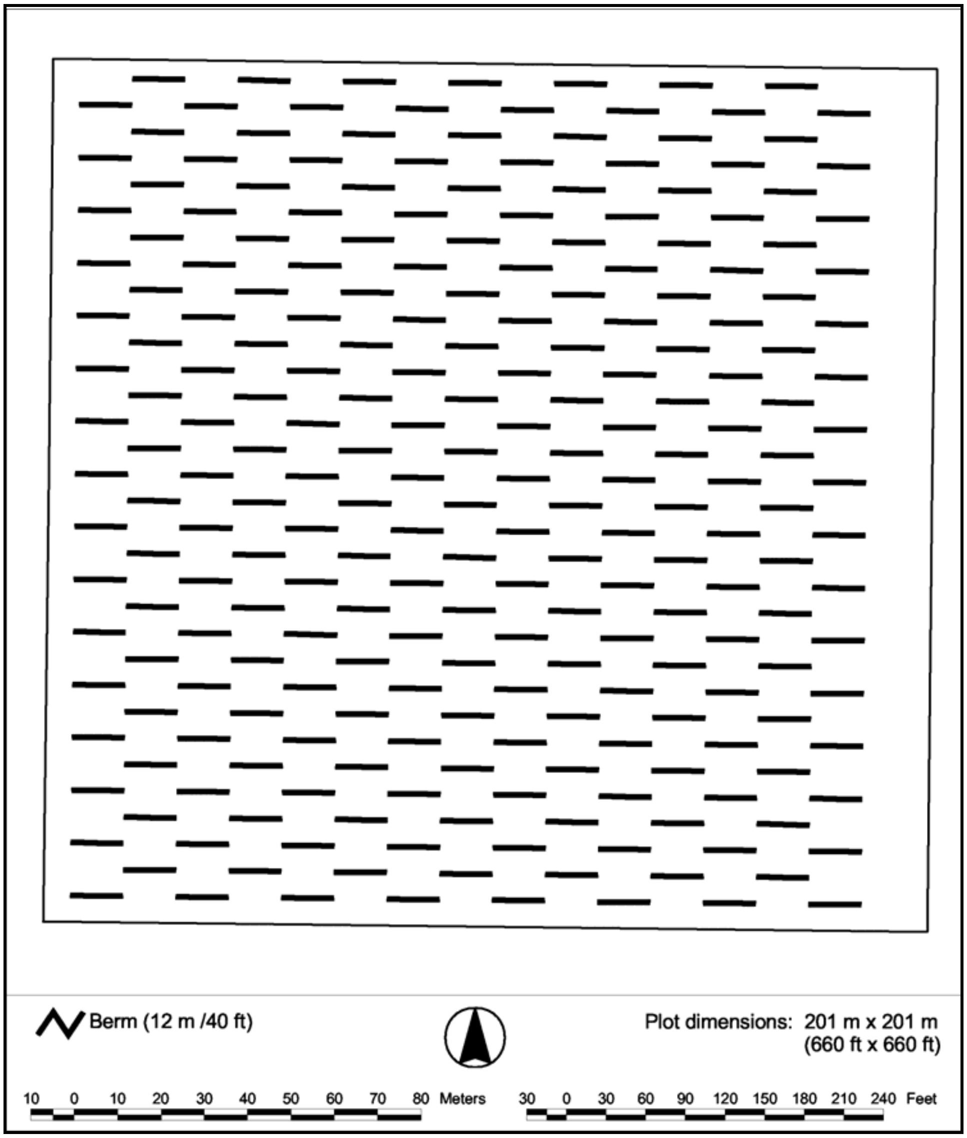

Figure 5. Representations of contours (berms) applied to plots at the Westlands Site.

b. Native Plants

i. Imprinting

Imprinting is an experimental seeding method that creates small impressions in the soil and deposits seed directly in the indentation (Dixon 1988). This method of seeding promotes seed-soil contact while protecting the seed from wind and predators. Native seed was imprinted evenly across the plots receiving the reintroduction prescription in March 2000. Plant species were selected based on species lists from nearby ecological reserves and known species composition of the desired plant communities (Table 2). Further information on rates of applications, costs and mix preparation can be found in Selmon et al (2000).

Table 2. Seed mix applied to the plots on the Westlands Site. Source information was provided by the seed vendor.

Scientific Name	Common Name	Source	Lbs/Ac
Allenrolfea occidentalis	iodine bush	unknown	2
Atriplex polycarpa	valley saltbush	Taft	2
Atriplex spinifera	spiny saltbush	Taft	1.5
Bromus carinatus	California brome	San Francisco Bay Area	3
Frankenia salina	alkali heath	San Diego County	0.5
Heliotropium curassavicum	heliotrope	Temecula	0.5
Hemizonia pungens	common spikeweed	unknown	0.1
Isocoma acradenia	goldenbush	Indio	1
Lasthenia californica	goldfields	Hemet	0.5
Leymus triticoides	creeping wild rye	Rio	2
Sporobolus airoides	alkali sacaton	unknown	1
Suaeda moquinii	bush seepweed	Lakeside	0.5
Vulpia microstachys	vulpia	San Bernadino	2

ii. Transplanting

Native plants were introduced onto the experimental plots via direct transplanting in March and April of 2000. Seedlings were grown from seed in local nurseries from commercial and local seed sources. Transplanted seedlings were closely grouped in “shrub islands” to promote a rapid establishment of a mycorrhizal network. Two types of shrub islands were created, one containing *Sporobolus airoides*, *Leymus triticoides* and *Allenrolfea occidentalis*, and another type with *Atriplex polycarpa* and *Isocoma acradenia*. Each plot was planted with a total of 25 islands, 13 were of the first island type and 12 were of the second island type.

Nursery stock generally needs ample rain or irrigation after planting for establishment in native soils. The study site rarely receives sufficient rainfall to support transplanted nursery stock, so supplemental water is necessary. DRiWATERÔ, a non-polymer time-release water product, was installed adjacent to seedlings when planting the shrub islands. Plants were also watered 2-3 times with a backpack sprayer within 2 weeks of planting to aid in establishment.

2. Biological Monitoring

Biological monitoring was conducted on the Westlands HRS plots in the year 2000. Surveys consisted of:

- annual vegetation surveys (composition and productivity)
- annual invertebrate surveys (sweep and pitfall)
- annual amphibian and reptile surveys
- quarterly avian surveys
- quarterly small mammal surveys

Other surveys were conducted on a site-wide basis, which are not directly applicable to the Westlands HRS plots. These surveys consisted of:

- quarterly spotlighting surveys
- quarterly track station surveys
- annual winter raptor survey
- annual contaminants monitoring (vegetation, invertebrates, and small mammals)

The HRS surveys are presented in the following section while the site-wide surveys are presented in the Site-Wide Activities section.

a. Vegetation Surveys

i. Methods

To analyze differences in vegetation between treatments and blocks, information was collected on species richness, survivorship, and productivity. Additionally, to examine differences between years, species richness was compared from 1999 and 2000. Vegetation changes were documented using two photo stations located on the south end of each plot.

Plant species richness and percent cover of individual species were determined for each experimental plot in April 1999 and April and May of 2000. Each experimental plot was divided into quarters and six quadrat sampling points were chosen at random within each quarter-plot, resulting in twenty-four quadrats per plot. Quadrats that overlapped shrub islands were repositioned so the plants in the islands were not included in the sample. Visual estimates of cover to the nearest 5% on 35 cm by 70 cm rectangular quadrats were made by qualified field personnel. Estimates were classified using the modified Daubenmire cover scale (Bonham 1989). Estimates of percent cover of individual species and percent total cover (all species combined) were recorded on datasheets in the field. Individual species were grouped into native and non-native categories for analysis. Richness and percent cover were compared with Kruskall-Wallis non-parametric ANOVA. Changes in overall richness between 1999 and 2000 was compared with a Mann-Whitney U test.

Shrub island survivorship was calculated per plot and across all plots. Survivorship was determined by counting the number of individuals alive in December 2000 as compared to those planted in spring of 2000. Survivorship was used to gauge success at planting seedlings rather than as a measure of treatment effects.

Productivity samples were collected from experimental plots in May 2000. Productivity was determined using the Comparative Yield Method (Haydock and Shaw 1975) with 35 cm by 70 cm rectangular quadrats. Productivity was determined on 24 quadrats by estimating the total dry weight of all vegetation contained within the quadrat frame. The Comparative Yield Method allows a framework for estimating biomass without clipping and weighing each sample. Productivity estimates were compared with Chi-square statistics from a contingency table.

Photos were taken on the experimental plots in September 1999 to document pre-treatment conditions. Photos also were taken in July, September, and December 2000 to document post-treatment conditions and to provide a permanent record of changes in vegetation structure and composition. Photographs were taken from two standard locations along the southern boundary of each plot (43 m from the 2 corners of each plot). A 35-mm and a digital photo were taken from each location facing north. Photographs are archived in a binder for easy review. Digital photos are archived on compact discs for future reference.

ii. Results

A total of 30 plant species were identified during the spring 2000 vegetation survey, including 10 species not found during the 1999 vegetation surveys. Eleven of the 30 species (36%) observed during the vegetation surveys were native, whereas in 1999 only 5 native species were observed. Six of the eleven native species recorded in 2000 were from the seed mix imprinted on the plots. Additionally, several species were observed on the plots, but were not recorded within quadrats (Table 3).

Table 3. Native plants observed on plots. Asterisks indicate that the species was observed in quadrats or imprinted.

Scientific Name	Common Name	In Quadrat	Imprinted
Allenrolfea occidentalis	iodinebush		*
Asclepias fasicularis	narrow-leaved milkweed		
Atriplex polycarpa	saltbush		*
Atriplex spinifera	saltbush		*
Bromus carinatus	California brome	*	*
Eremalche parryi parryi	Parry's Mallow		
Frankenia salina	alkali heath	*	*
Heliotropium curassavicum	heliotrope		*
Hemizonia pungens	common spikeweed		*
Isocoma acradenia	goldenbush	*	*
Lasthenia californica	goldfields	*	*
Leymus triticoides	creeping wild rye		*
Sporobolus airoides	alkali sacaton		*
Suaeda moquinii	bush seepweed	*	*
Vulpia microstachys	vulpia	*	*

The plots that were seeded with native plants had significantly (Kruskall-Wallis, $p < 0.02$) greater species richness than those plots that were not seeded (Table 4). No difference was discernable due to pre-treatment conditions (ie. no block effect). Additionally, non-native species richness did not differ by block or treatment (Table 4). In 2000, the species richness of natives and non-natives was significantly greater than 1999 (Mann-Whitney U: natives $p = 0.002$, non-natives $p = 0.001$).

Shrubs planted from seedlings had low survival throughout the site (0.3-24%). Survivorship of individual species was variable. *A. polycarpa* had the highest survivorship (34%) among the four species across all plots (Table 5). Thirty-one percent of gallon-sized *S. airoides* survived transplanting. Smaller seedlings of *S. airoides* were not as successful, with only 8% of plants surviving. The *A. occidentalis* seedlings had the lowest survival rate at 1% overall. Species survival in shrub islands on plots with berms was similar to those without berms.

Total cover in 1999 was significantly greater than in 2000 ($p < 0.01$), which was expected due to the barley cover crop (Table 4). Treatment 2 (see Table 1) was significantly greater ($p < 0.01$) than treatments 1, 3 and 4 in percent total cover in 2000. Total cover across blocks was highly variable ($p < 0.001$) with block 4 having the greatest cover and block 5 having the least.

Table 4. Vegetation species richness, percent cover of natives and percent total cover for treatments and blocks in 1999 and 2000 at the Westlands Site. (See Table 1 for definitions of treatments) ~ = measurement not made, ± = 1.96 standard deviations.

Treatments	7	1999	2000
1 (CR)	**Richness**	3.00 ± 1.00	4.00 ± 1.96
	% Cover Native	~	3.00 ± 4.00
	% Total Cover	41.30 ± 1.95	38.26 ± 1.97
2 (CN)	**Richness**	0.60 ± 0.89	0.80 ± 1.57
	% Cover Native	~	0.60 ± 0.40
	% Total Cover	52.30 ± 1.95	50.38 ± 2.44
3 (NR)	**Richness**	3.20 ± 2.05	4.40 ± 5.09
	% Cover Native	~	3.20 ± 0.90
	% Total Cover	38.0 ± 1.80	36.25 ± 1.88
4 (NN)	**Richness**	0	1.00 ± 1.38
	% Cover Native	~	0
	% Total Cover	35.60 ± 1.62	34.00 ± 1.64
Blocks			
1	**Richness**	1.25 ± 1.26	2.25 ± 3.70
	% Cover Native	~	1.25 ± 0.75
	% Total Cover	36.90 ± 1.67	34.87 ± 1.83
2	**Richness**	0	3.75 ± 5.39
	% Cover Native	~	2.50 ± 2.38
	% Total Cover	40.34 ± 1.93	37.78 ± 2.01
3	**Richness**	0	1.50 ± 3.39
	% Cover Native	~	1.25 ± 0.75
	% Total Cover	44.17 ± 2.37	41.90 ± 2.45
4	**Richness**	0	2.25 ± 2.94
	% Cover Native	~	1.25 ± 0.75
	% Total Cover	55.44 ± 2.15	52.99 ± 2.22
5	**Richness**	0	3.00 ± 6.19
	% Cover Native	~	2.25 ± 1.31
	% Total Cover	32.26 ± 2.47	31.07 ± 2.44

Table 5. Native seedling survivorship on Westlands study plots. Survival rates were determined by dividing the total number of seedlings planted by the number alive in December 2000.

Species	Number of Seedlings Planted	Mean Number Alive	Survival Rate
Allenrolfea occidentalis	1,820	1.9 ± 1.07	0.01 ± 0.01
Atriplex polycarpa	1,440	49.1 ± 10.39	0.34 ± 0.07
Sporobolus airoides	2,860	23.0 ± 8.89	0.08 ± 0.03
*Sporobolus airoides**	260	8.1 ± 1.81	0.31 ± 0.07
Isocoma acradenia	240	1.4 ± 0.64	0.06 ± 0.03

* = gallon size

Native cover in 2000 differed between treatments ($p < 0.05$) (Table 4). Plots that were imprinted with native seed (treatments 1 and 3) had greater native cover than those that were not imprinted (treatments 2 and 4); treatments 1 and 3 were similar to each other ($p = 0.60$) and treatments 2 and 4 were similar to each other ($p = 0.30$). There were no significant differences of percent native cover by block ($p = 0.84$).

Productivity varied among the treatments in 2000. Treatment 1 was significantly different (^{2} = 71.58 df = 24 $p < 0.001$) when compared to the other three treatments. Treatments 2, 3 and 4 were not significantly different from each other. Treatment 4, the control, had the highest estimated productivity at 3295 pounds per acre while treatment 1, contouring and native reintroduction, had the lowest estimated productivity at 1,840 pounds per acre. Productivity was not estimated in 1999.

In 2000, productivity varied significantly within the five blocks (^{2} = 75.6 df = 32, $p < 0.001$). The estimated productivity ranged from 1,560 pounds per acre in block 1 to 3,794 pounds per acre in block 2.

iii. Discussion

The entire HRS study site (plots and buffers) was planted in barley in 1999 and treatments were applied in early 2000. Many of the observed changes in species richness, total cover, native cover and productivity can be attributed to the change from a cultivated field to manipulated plots.

The higher species richness and native cover in treatments 1 and 3 is expected because of the introduction of native seed on those plots. This indicates that imprinting efforts were successful. The increase in species richness among some of the treatments and blocks from 1999 to 2000 was due to multiple factors. Block 1 had been idle for several years prior to the initiation of this study. Therefore, the higher species richness on block 1 in 1999 than in 2000 was due to a combination of two factors. First, native species persisted in the barley field in 1999, resulting in a relatively high species richness. Second, some natives on the plots were not sampled in the quadrats in 2000 due to sparse distributions and low numbers of individuals. As natives become more established, they should be better represented in our samples, so the difference of just a few individuals in the samples would not bias results.

Although there will not be more reintroduction of native plants to the HRS study plots, more individuals and species are expected to become established on the plots. Self-seeding of established species is expected and they should become more abundant. Due to the late timing of imprinting and lack of rain in the early spring, some native species did not germinate in 2000. However, native seeds can remain viable for several years in the soil if protected and often do not germinate for two or more years (Heady 1977). Additionally, several native species became established as volunteers throughout the HRS study site. For instance, *Asclepias fascicularis* (narrow-leaved milkweed) on Plot 10 demonstrates that some native species can recolonize naturally. A small source population of this species is currently growing outside the experimental plots on the NE portion of the Westlands Site.

Overall, survivorship of native seedlings was poor. Nursery stock was obtained from three different sources and varied in quality . The application of HRS treatments were delayed due to rain causing associated delays in planting the shrub islands. Plants remained in nursery containers longer than intended, resulting in seedlings being planted late in the season, in dry soil. The smaller seedlings became root-bound and stressed. The positioning of plants around DRiWATER™ tubes may have affected survivorship. Soil moisture created by the product was often just beyond the reach of plants' roots. Survivorship on plots 17 and 20 was substantially lower than other plots, possibly due to an infestation of the false chinch bug (*Nysius ericoe*). All plant species were heavily damaged by this infestation.

Survivorship of individual species was variable. Some species, especially larger seedlings, were healthier when planted which may explain some of the differences. Comparative survivorship of individual species is currently beyond the scope of this study. Research is being developed to determine requirements for germination and survival of *A. occidentalis* and other problematic native plant species.

Because of low survivorship of shrubs in spring 2000, some species were replanted in fall 2000 to create relatively homogeneous islands that could still be explored experimentally on the HRS plots. Planting and watering methods were also modified in an attempt to increase survivorship. The seedlings were planted in December 2000 and watered by hand at several day intervals for two weeks. Seedlings were replanted to create the following mix of species in each of the two types of shrub islands:

- 4 *A. occidentalis* (6 inches), 2 *S. airoides* (1 gallon) and, 8 *S. airoides* (6 inches);
- 8 *A. polycarpa* (4 inches) and 2 *I. acradenia* (replanted from seed).

Isocoma acradenia is a mycorrhizal species that may build a soil network in the shrub islands. This species appeared to germinate well from seed on experimental plots although seedlings did very poorly. As a result, *I. acradenia* was reintroduced to the islands by adding approximately 25 seeds in each location that formerly held a seedling.

b. Invertebrate Surveys

i. Methods

The year 2000 constituted the second invertebrate survey using the pitfalls. Five pitfall arrays on each plot, each consisting of four, 3 gallon buckets (8.75 inches high and 10.75 inches diameter) connected by 20 feet x 1 foot sections of galvanized steel flashing were established in April 1999 (Figure 6). The buckets were sunk in the soil so that the lip of the bucket was at ground level. The lid of the bucket was then situated slightly above the rim using wooden stakes. Pitfalls were opened the morning prior to the survey and remained open approximately 24 hours before being checked. Trap checks occurred for 4 consecutive days beginning just after sunrise in May of 1999 and June 2000. On the first morning of surveys in 1999 there were mortalities of small mammals in the pitfall traps. Early morning trap checks were instituted to release small mammals prior to counting invertebrates.

Values of richness and abundance information was generated from samples collected from the pitfalls. Richness is the number of invertebrate orders represented in each plot and mean abundance is the number of invertebrates caught per plot averaged across number of survey days. Abundance values were log-transformed and analyzed with ANOVA. Two invertebrate groups, Order Hemiptera and Order Thysanoptera, were excluded from the mean abundance estimates because their numbers were orders of magnitude greater than the other groups. By not excluding these groups, trends within all other invertebrate groups would not have been detectable. Richness and abundance values in 1999 were calculated differently than in 2000 (Selmon et al 2000). Values for 1999 were recalculated and are presented in a format consistent with 2000 data.

Species composition is the number of individuals in a group calculated as a percentage of the total number of individuals on a block or treatment. Species composition was derived for both blocks and treatments.Sweep surveys were initiated in August 2000 to sample winged invertebrates and those that live on vegetation. The surveys were conducted over a 3-day period with each plot being sampled once. A net was swept back and forth exactly 100 times through the top of the vegetation on two 50 m transects per plot. All insects captured in the net were transferred to ZiplocÔ bags and placed on ice until identified. Richness was calculated for sweep surveys in the same manner as for the pitfall surveys. Mean abundance and species composition were both excluded from the invertebrate sweep results due to the paucity of data.

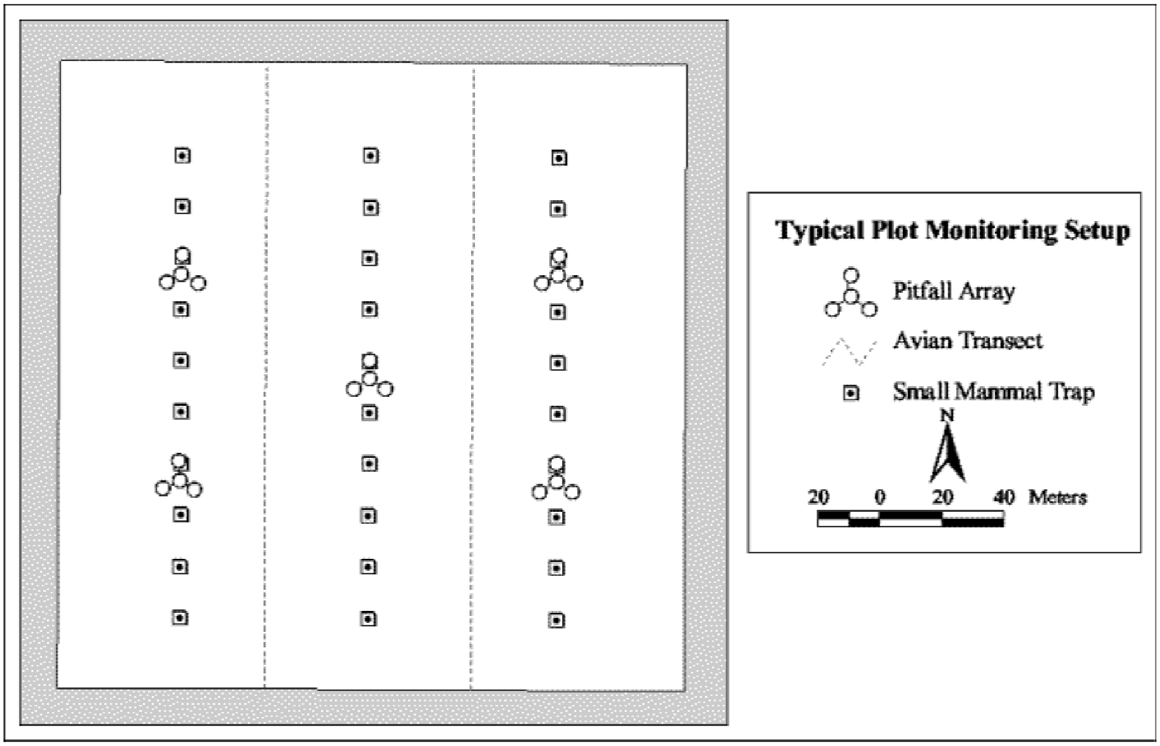

Figure 6. Pitfall array design and location and avian transect and small mammal trapping locations on a Westlands HRS plot.

ii. Results

Invertebrate richness in the pitfall arrays did not vary by treatment or block in 2000. The number of orders among treatments ranged from 11 to 12 and the number of orders among blocks ranged from 8 to 11 (Table 6). Invertebrate species richness did not appear to differ between years.

Mean abundance in pitfalls did not differ significantly within treatments in 2000; treatment 1 had the highest mean abundance averaging 3,157 individuals (Table 6). Mean abundance significantly increased within each treatment from 1999 to 2000. In 2000, block 2 had the highest mean abundance with an average of 3,606 individuals. Blocks 2 and 4 had a significantly higher mean abundance than blocks 1 and 3. Block 2 was also significantly higher in mean abundance than Block 5. All blocks significantly increased in mean abundance between 1999 and 2000.

Table 6. Invertebrate richness and abundance in 1999 and 2000 on the Westlands LRDP plots. ~ = survey not conducted ± = 1.96 standard errors.

		1999		2000	
		Pitfall	**Sweep**	**Pitfall**	**Sweep**
Treatment					
1	Richness	8.4 ± 0.2	~	7.8 ± 0.47	4.8 ± 1.02
	Abundance	355.8 ± 54.1	~	631.5 ± 117.40	179.0 ± 120.3
2	Richness	8.2 ± 0.5	~	8.3 ± 0.40	3.6 ± 0.93
	Abundance	258.5 ± 40.4	~	509.6 ± 101.60	110.5 ± 64.09
3	Richness	9.8 ± 0.33	~	9.1 ± 0.47	5.4 ± 0.40
	Abundance	372.9 ± 47.8	~	529.5 ± 100.5	249.2 ± 116.28
4	Richness	8.8 ± 0.48	~	8.0 ± 0.38	5.2 ± 0.37
	Abundance	265.9 ± 46.7	~	442.9 ± 73.6	171.0 ± 65.29
Block					
1	Richness	11.5 ± 0.25	~	9.8 ± 0.51	3.3 ± 1.03
	Abundance	478.8 ± 80.17	~	326.9 ± 21.55	90.3 ± 6.85
2	Richness	8.5 ± 0.25	~	8.3 ± 0.37	5.3 ± 0
	Abundance	250.1 ± 25.01	~	901.6 ± 155.9	240.0 ± 102.65
3	Richness	8.3 ± 0.24	~	7.8 ± 0.44	6.3 ± 0.48
	Abundance	411.3 ± 40.11	~	321.8 ± 34.41	80.0 ± 25.95
4	Richness	7.5 ± 0.25	~	7.3 ± 0.41	5.0 ± 0.41
	Abundance	199.0 ± 32.54	~	648.8 ± 94.83	423.9 ± 123.62
5	Richness	8.3 ± 0.43	~	8.3 ± 0.45	4.0 ± 1.08
	Abundance	227.2 ± 15.92	~	443.3 ± 53.19	53.0 ± 57.85

With the exception of thrips and false chinch bugs, Orthoptera, Isoptera, and Araneae were the most abundant groups within treatments and blocks in 2000 (Table 7). These three groups make up 68% of all invertebrates observed on the plots (thrips and chinch bugs were 191% more common than all other groups combined).

Richness in the sweep surveys varied little between blocks or treatments (Table 6). Specimens from nine different orders were collected (Table 7). The number of orders captured in the sweep samples ranged between seven and eight among treatments and between six and eight among blocks.

Table 7. Invertebrate species composition for pitfall arrays in 1999 and 2000 on the Westlands Site. + = present but less than 0.01.

Treatments				Group	Block				
1	2	**3**	**4**		**1**	**2**	**3**	**4**	**5**
Pitfall 1999									
0.10	0.08	0.08	0.08	**Araneae**	0.15	0.04	0.09	0.03	0.04
0.09	0.06	0.11	0.06	**Coleoptera**	0.11	0.03	0.10	0.04	0.04
0.06	0.03	0.05	0.04	**Dermaptera**	+	0.07	0.05	0.02	0.04
0.01	0.02	0.03	0.02	**Orthoptera**	0.02	0.01	+	0.03	0.02
+	+	0.01	+	**Hemiptera**	+	+	0.02	+	+
+	+	+	+	**Isopoda**	0.02	+	+	+	+
+	+	+	+	**Hymenoptera**	+	+	+	+	+
+	+	+	+	**Thysanura**	+	+	0	0	0
+	+	+	+	**Scorpiones**	+	0	0	0	0
+	+	+	+	**Unknown**	+	+	+	+	**+**
+	+	+	+	**Blattodea**	+	0	+	0	+
+	+	+	+	**Diptera**	+	+	0	+	+
+	+	+	+	**Lepidoptera**	0	+	+	0	+
+	0	+	0	**Opiliones**	+	+	0	0	0
0	+	+	0	**Homoptera**	0	+	+	0	0
Pitfall 2000									
0.15	0.04	0.08	0.05	**Orthoptera**	0.03	0.13	0.04	0.06	0.06
0.06	0.03	0.04	0.04	**Araneae**	0.03	0.04	0.03	0.05	0.02
0.03	0.02	0.03	+	**Hemiptera**	0.02	0.05	+	0.01	+
0.02	0.01	0.01	0.02	**Coleoptera**	+	0.02	+	0.02	0.01
0	0.04	0	+	**Diptera**	0	0	0	0.03	0.02
+	0.02	0.02	+	**Hymenoptera**	0.01	0.02	0.02	+	+
+	+	+	0.01	**Dermaptera**	+	+	+	0.01	+
+	+	+	0.02	**Unknown**	0	0.04	+	+	+
+	+	+	+	**Thysanura**	+	0	0	0	+
+	+	+	+	**Blattodea**	+	0	0	0	0
+	+	+	+	**Scorpiones**	+	+	0	+	0

iii. Discussion

No treatment effects were observed for richness, abundance or composition, however block effects were apparent. Because of their large numbers Orthoptera, Isoptera and Araneae likely had a significant impact on the observed block effects. The differences in richness, abundance, and composition between 1999 and 2000 within treatments and blocks were likely due to increase in diversity and plant cover on plots. In 1999 all plots were a monoculture of barley, whereas in 2000 treatments had been applied. Species composition of pitfall arrays and sweeps differed (see Table 7 and 8) because different vegetative structural elements were sampled. Pitfall arrays focused on ground dwelling invertebrates whereas sweep surveys sampled the upper canopy.

Table 8. Invertebrate species composition for sweep surveys in 2000 on the Westlands Site. + = present but less than 0.01.

Treatments				Group	Block				
1	**2**	**3**	**4**		**1**	**2**	**3**	**4**	**5**
0.13	0.11	0.33	0.17	**Hemiptera**	0.1	0.26	0.05	0.28	0.05
0.09	0.03	+	+	**Homoptera**	+	+	+	0.12	+
+	0	0	0.04	**Aphidae**	0	0	+	0.04	0
+	+	0.01	+	**Coleoptera**	+	+	+	0.01	+
0	0.01	0	0	**Hemiptera**	0	0	0	0.01	0
0.01	0	0	0	**Thysanura**	0	0	0.01	0	0
+	+	+	+	**Hymenoptera**	+	+	+	+	+
+	0	0	+	**Hemiptera**	0	0	+	+	0
+	+	+	+	**Araneae**	0	+	+	+	+
+	+	+	+	**Diptera**	+	+	+	0	+
+	0	0	+	**Araneae**	0	0	+	+	0
0	0	+	+	**Odonata**	+	0	+	+	0
+	0	0	0	**Beetle**	0	0	+	0	0
+	0	+	0	**Orthoptera**	0	+	0	+	0

c. Amphibian and Reptile Surveys

i. Methods

Invertebrate pitfall arrays also were used as reptile and amphibian pitfalls. Although no separate surveys were conducted all reptiles and amphibians captured during the invertebrate sampling efforts were tallied. Incidental reptile and amphibian observations made during other surveys were recorded.

ii. Results

No reptiles were observed during the pitfall surveys or incidentally during other surveys on the plots. One western toad (*Bufo boreas*) was captured in a pitfall on plot 6 adjacent to an irrigation ditch.

iii. Discussion

It is not surprising that amphibians (except the one toad) have not yet been observed on the plots because of the history of cultivation and the presence of the barley cover crop in 1999. Toads may be more common on the site than observed. Low numbers may have been a consequence of poor timing of the amphibian survey efforts. Reptiles and amphibians are expected to recolonize the plots from nearby habitat. Likely colonizers include western toad, side-blotched lizard (*Uta stansburiana*), western fence lizard (*Sceloporus occidentalis*), Gilbert's skink (*Eumeces gilberti)*, gopher snake (*Pituophis melanoleucus)*, and California king snake (*Lampropeltis getulus)*. Several of these species have been seen in the vicinity of the HRS study site.

d. Avian Surveys

i. Methods

Quarterly bird surveys (January, May, July and October in 2000) were conducted on the experimental plots. Plots were surveyed for 3 consecutive days each quarter. Observers were assigned daily to a random block and start times were synchronized.

Differences in species richness and relative abundance between treatments, blocks, and years were examined. Species richness is the number of species observed per plot per day. Relative abundance is the average number of birds seen per plot per day. Species composition was derived for both blocks and treatments. Species composition is the number of individuals of a species calculated as a percentage of the total number of individuals on a block or treatment. Block and treatment effects were examined with Kruskall-Wallis non-parametric ANOVA tests (a = 0.05).

Birds observed flying over the plots or adjacent to the plots were excluded from the analysis, but were included in the cumulative species list. Birds not identified to species were excluded from the species richness estimate and species composition, but included in relative abundance.

ii. Results

Species richness in 2000 ranged from 0.8 to 16.7, while the relative abundance ranged from 0.8 to 29.6 (Table 9). Richness and mean total abundance did not differ by treatment, but were significantly different by block in every season. However, the species richness combined across all treatments did not differ by block in 2000 (Kruskal-Wallis: df = 4, N = 240, p = 0.741). When all plots were combined, significant differences were found in abundance by season (Kruskal-Wallis: df = 3, N = 240, p > 0.001). Abundance estimates were higher in May and October than in January and July. However, when blocks were analyzed without the effect of season, no differences were detected (Kruskal-Wallis: df, N = 240, p = 0.331). That is, no block had either significantly lower or higher abundance estimates. Six species were observed in 2000 that were not recorded the previous year (Table 10, Table 11).

iii. Discussion

Bird abundance was significantly greater during the second year of this project. This may be due to changes in vegetation on the plots. Increased species diversity and structural heterogeneity lead to increased avian abundance so such a result would not be surprising.

Table 9. Avian richness and abundance in 1999 and 2000 on plots on the Westlands Site. ± = 1.96 standard errors.

		May 1999	July 1999	October 1999	January 2000	May 2000	July 2000	October 2000
Treatment								
1	**Richness**	0.9 ± 0.27	0.3 ± 0.16	1.6 ± 0.49	1.5 ± 3.69	9.9 ± 10.92	1.3 ± 3.1	6.5 ± 7.69
	Rel. Abund.	1.9 ± 0.91	0.5 ± 0.29	19.7 ± 7.24	5.3 ± 2.8	15.8 ± 2.56	1.8 ± 0.62	15.7 ± 2.57
2	**Richness**	1.1 ± 0.35	0.5 ± 0.17	1.5 ± 0.35	1.9 ± 3.74	8.9 ± 15.74	1.5 ± 2.76	7.5 ± 8.44
	Rel. Abund.	5.3 ± 1.88	0.6 ± 0.24	11.5 ± 3.74	3.3 ± 1.31	16.4 ± 4.84	1.7 ± 0.46	15.1 ± 1.99
3	**Richness**	0.7 ± 0.21	0.4 ± 0.16	1.3 ± 0.4	2.2 ± 3.79	8.0 ± 10.34	1.9 ± 3.01	6.5 ± 10.29
	Rel. Abund.	2.2 ± 0.92	0.6 ± 0.21	16.3 ± 7.65	3.4 ± 0.77	13.6 ± 2.3	2.3 ± 0.48	29.6 ± 12.5
4	**Richness**	1.3 ± 0.37	0.1 ± 0.13	1.3 ± 0.28	1.4 ± 3.54	8.5 ± 10.45	1.7 ± 3.01	6.9 ± 8.33
	Rel. Abund.	3.9 ± 1.97	0.1 ± 0.13	14.2 ± 6.76	2.3 ± 0.83	11.1 ± 1.99	1.7 ± 0.4	16.0 ± 4.02
Block								
1	**Richness**	1.7 ± 0.54	0.3 ± 0.13	1.9 ± 0.31	3.4 ± 4.38	3.3 ± 4.43	0.8 ± 2.38	10.0 ± 8.02
	Rel. Abund.	2.9 ± 1.08	0.5 ± 0.23	6.5 ± 1.36	6.3 ± 1.27	4.4 ± 1.08	0.9 ± 0.5	27.3 ± 5.11
2	**Richness**	1.3 ± 0.36	0.7 ± 0.22	2.5 ± 0.6	0.8 ± 2.38	16.7 ± 12.49	1.8 ± 3.43	6.8 ± 9.04
	Rel. Abund.	6.1 ± 2.53	0.6 ± 0.23	35.3 ± 10.39	0.8 ± 0.41	21.3 ± 2.20	2.1 ± 0.58	33.0 ± 15.12
3	**Richness**	1 ± 0.25	1 ± 0.08	0.25 ± 0.18	0.83 ± 1.84	7.42 ± 5.76	1.17 ± 2.18	5.67 ± 7.54
	Rel. Abund.	4.83 ± 2.29	0.17 ± 0.17	1 ± 0.83	0.92 ± 0.29	9.08 ± 1.38	1.17 ± 0.32	11.75 ± 1.81
4	**Richness**	0.67 ± 0.19	0.08 ± 0.08	1.5 ± 0.34	2.5 ± 3.69	5.83 ± 4.25	2.25 ± 3.03	6.58 ± 8.62
	Rel. Abund.	2.17 ± 0.82	0.42 ± 0.26	14.42 ± 6.23	7.67 ± 3.4	9.83 ± 1.47	2.92 ± 0.58	14.08 ± 2.05
5	**Richness**	0.42 ± 0.15	0.33 ± 0.19	1 ± 0.3	1.25 ± 2.66	11 ± 8.52	2.08 ± 2.83	5.25 ± 7.57
	Rel. Abund.	0.58 ± 0.23	0.67 ± 0.36	19.83 ± 7.91	2.17 ± 0.86	26.42 ± 4.83	2.33 ± 0.56	9.5 ± 2.54

Table 10. Species observed during avian surveys on the Westlands Site in 1999 and 2000.

	Treatments															
	January 2000				May 2000				July 2000				October2000			
Common name	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Red-winged blackbird	0	0	0	0	0.19	0.25	0.2	0.14	0.08	0.05	0.03	0.04	0	0	0.08	0
Western meadowlark	0.02	0.02	0.03	0.03	0.03	0.01	0.01	0.02	0.1	0.15	0.19	0.15	0.03	0.05	0.07	0.06
Savanna Sparrow	0	0.02	+	0	0	0	0	0	0	0	0	0	0.15	0.13	0.21	0.13
Brewer's blackbird	0.19	0	0	0	0.05	0.01	+	0.03	0	0	0	0	0	0	0.02	0
Long-billed Curlew	0.02	0.07	0.03	+	0	0	0	0	0	0	0	0	+	0	0	0
Song Sparrow	+	0.01	0.04	0.03	0	0	0	0	0	0	0.02	0	0	0.01	+	+
Sage Sparrow	0.09	+	+	0.03	0	0	0	0	0	0	0	0	0	0	0	0
American Kestrel	0.01	0.03	0.03	0.02	0	0	0	0	+	+	+	0	0	0	0	0
Mountain Plover	0	0.03	0.04	0	0	0	0	0	0	0	0	0	0	0	0	0
White-crowned Sparrow	+	0.01	+	0.04	0	0	0	0	0	0	0	0	0	0	0	0
White-tailed Kite	0	0	+	0	0	0	0	0	0	0	0	0.04	0.01	+	+	+
Barn Swallow	0	0	0	0	+	+	0	0	0	0.04	0	0	0	0	0	0
Northern Harrier	0	+	0.02	0	0	+	+	0	0	0	0	0	+	+	+	0.01
Horned Lark	0.02	0	+	0	+	0	0	0	0	0	0	0	+	+	+	+
Western kingbird	0	0	0	0	0	0	+	0	0	0	0.02	+	0	0	+	0
Short-eared Owl	+	0	0	0	+	0	0	0	0	0	0	0	+	0	0	+
Common Raven	0	0	0	0	0	+	+	0	+	0	+	0	0	0	0	0
American Crow	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0
Barn Owl	0	0	0	0	0	0	0	0	+	0	0	0	+	+	0	0
Cliff Swallow	0	0	0	0	+	0	0	0	0	0	+	0	0	0	0	0
House finch	0	0	0	0	0	0	0	0	0	0	+	0	0	+	0	0
Killdeer	0	0	0	+	0	+	+	0	0	0	0	+	0	0	+	0
Mallard	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0
Loggerhead shrike	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Red-tailed Hawk	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0
Ring-neck pheasant	0	0	0	0	+	+	0	+	0	0	0	0	0	0	0	0
Prairie Falcon	0	+	+	0	0	0	0	0	0	0	+	0	0	0	0	0

Table 10 (continued). Species observed during avian surveys on the Westlands Site in 1999 and 2000.

	Blocks																			
	January 2000					May 2000					July 2000					October 2000				
Common name	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
Red-winged blackbird	0	0	0	0	0	+	0.29	0.11	0.11	0.27	0	0.04	+	0.02	0.04	0	0.08	0	0	0
Western meadowlark	0.03	0.02	+	0.02	0.01	0.03	+	+	0.01	0.01	0.03	0.04	0.06	0.08	0.09	0.09	0.01	0.03	0.02	0.04
Savanna Sparrow	+	0	0	0.02	0	0	0	0	0	0	0	0	0	0	0	0.19	0.22	0.05	0.09	0.06
Brewer's blackbird	0	0	0	0.19	0	+	+	+	+	0.08	0	0	0	0	0	+	0.02	0	0	0
Long-billed Curlew	0.02	0	0	0.09	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+
Song Sparrow	0.09	0	0	+	0	0	0	0	0	0	0	+	0	0	0	0	0	0.02	0	0
Sage Sparrow	0.12	+	+	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
American Kestrel	+	0	0.01	0.03	0.04	0	0	0	0	0	+	0	0	+	0	0	0	0	0	0
Mountain Plover	0	0	0	0.03	0.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
White-crowned Sparrow	0.05	0	+	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
White-tailed Kite	0	+	0	0	0	0	0	0	0	0	0	+	0	+	+	0	+	+	+	+
Barn Swallow	0	0	0	0	0	0	0	+	0	+	0	+	0	0.01	0	0	0	0	0	0
Northern Harrier	+	+	+	0	0	0	0	0	+	0	0	0	0	0	0	+	+	+	+	+
Horned Lark	0.02	+	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	+	+	+
Western kingbird	0	0	0	0	0	+	0	0	0	0	0	0	0	0.01	0	0	0	+	0	0
Short-eared Owl	+	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	+	0	+
Common Raven]	0	0	0	0	0	0	0	0	+	0	0	+	0	0	0	0	0	0	0	0
American Crow	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0
Barn Owl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	+	+	0	+
Cliff Swallow	0	0	0	0	0	+	+	0	0	0	+	0	0	0	0	0	0	0	0	0
House finch	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	+	0
Killdeer	+	0	0	0	0	+	0	0	+	0	+	0	0	0	0	0	+	0	0	0
Mallard	0	0	0	0	0	+	+	+	0	0	0	0	0	0	0	0	0	0	0	0
Loggerhead shrike	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Red-tailed Hawk	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ring-neck pheasant	0	0	0	0	0	+	+	+	+	+	0	0	0	0	0	0	0	0	0	0
Prairie Falcon	0	0	+	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0

Table 10 (continued). Species observed during avian surveys on the Westlands Site in 1999 and 2000.

	Treatments											
	May 1999				July 1999				October 1999			
Common name	1	2	3	4	1	2	3	4	1	2	3	4
Red-winged blackbird	0.06	0.32	0.03	0.16	0	0	0	0	+	0.04	0.03	0
Western meadowlark	0.01	0.02	0.04	0.02	0.04	0.07	0.11	0	0.04	0.07	0.1	0.02
American Pipit	0	0	0	0	0	0	0	0	0.19	+	+	0.1
Brewer's blackbird	0.05	0.04	0.04	0.06	0	0	0	0	0.07	0	+	0
American Kestrel	0	0	0	0	0.11	0.07	0.04	0.04	0	0	+	+
Horned Lark	0.01	0	+	0.02	0	0	0.04	0	0.04	0.05	0.01	0.03
Sage Sparrow	0	0	0	0	0	0	0	0	+	0.03	0.09	+
Northern Harrier	0	0	0	0	0.07	0	0.04	0	+	+	+	+
Loggerhead shrike	0	0	0	0	0.04	0.07	0	0	0	0	0	0
Red-tailed Hawk	0	0	0	0	0	0	0.07	0	0	+	0	0
Killdeer	+	0.01	0	0.01	0	0.04	0	0	0	0	0	0
Savanna Sparrow	0	0.01	0.01	0.02	0	0	0	0	0	0	0	0
Mallard	0	0	0	0	0	0	0	0	0	+	0.04	0
Barn Swallow	0	+	0	0	0.04	0	0	0	0	0	0	0
White-tailed Kite	0	0	0	0	0	0.04	0	0	0	+	+	0
Cliff Swallow	0	0	0	0	0	0	0	0.04	0	0	0	0
Common Raven	0	0	0	0	0	0.04	0	0	0	0	0	0
House finch	0	0.01	0	0	0	0	0	0	0	0	0	0
Yellow-rumped Warbler	0	0	0	0	0	0	0	0	+	0	0	0
American Crow	0	0	+	+	0	0	0	0	0	0	0	0
Lark Sparrow	0	0	0	0	0	0	0	0	0	0	+	0
Long-billed Curlew	0	0	0	+	0	0	0	0	0	+	0	0
Northern Mockingbird	0	0	+	+	0	0	0	0	+	0	0	0
Western kingbird	0	0	0	+	0	0	0	0	0	0	0	0

Table 10 (continued). Species observed during avian surveys on the Westlands Site in 1999 and 2000.

	Blocks														
	May 1999					July 1999					October 1999				
Common name	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
Red-winged blackbird	0.03	0.18	0.24	0.11	0.01	0	0	0	0	0	0	0.07	0	0	0
Western meadowlark	0.06	+	+	0	+	0.15	0.04	0	0.04	0	0.04	0.15	+	0.03	0
American Pipit	0	0	0	0	0	0	0	0	0	0	+	0.24	0	+	0.05
Brewer's blackbird	0.03	0.16	0.01	0	0	0	0	0	0	0	0	+	0	0.07	0
American Kestrel	0	0	0	0	0	0	0.07	0	0	0.19	+	0	0	0	+
Horned Lark	+	0	+	0.01	0.02	0	0	0	0	0.04	0.03	0.03	+	+	0.06
Sage Sparrow	0	0	0	0	0	0	0	0	0	0	+	0	0	0.09	0.03
Northern Harrier	0	0	0	0	0	0	0.11	0	0	0	+	0	+	0	+
Loggerhead shrike	0	0	0	0	0	0	0	0	0.11	0	0	0	0	0	0
Red-tailed Hawk	0	0	0	0	0	0	0	0.07	0	0	0	+	0	0	0
Killdeer	+	0.02	0	+	0	0	0.04	0	0	0	0	0	0	0	0
Savanna Sparrow	0	0	0	0	0	0	0	0	0	0	0	0.05	0	0	0
Mallard	0.02	0	0.02	0	0	0	0	0	0	0	0	0	0	0	0
Barn Swallow	+	0	0	0	0	0	0	0	0	0.04	0	0	0	0	0
White-tailed Kite	0	0	0	0	0	0	0	0	0.04	0	0	0	0	+	0
Cliff Swallow	0	0	0	0	0	0	0.04	0	0	0	0	0	0	0	0
Common Raven	0	0	0	0	0	0	0.04	0	0	0	0	0	0	0	0
House finch	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Yellow-rumped Warbler	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0
American Crow	+	0	0	+	0	0	0	0	0	0	0	0	0	0	0
Lark Sparrow	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0
Long-billed Curlew	0	+	0	0	0	0	0	0	0	0	+	0	0	0	0
Northern Mockingbird	+	+	0	0	0	0	0	0	0	0	0	+	0	0	0
Western kingbird	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0

e. Small Mammal Surveys

i. Methods

Small mammal surveys were conducted for four nights each in May, August, and November 2000. The February small mammal census was cancelled due to seasonal rains making the site inaccessible. Thirty extended length Sherman traps were distributed 15 m apart along 3 150-m transects in each plot. Every trapping station contained one trap baited with millet seed and a wad of paper towel for insulation. Each of the surveys consisted of 2,400 total trap nights, with 600 trap nights per treatment or 480 trap nights per block.

Species richness and relative abundance to examine differences between treatments, blocks, seasons, and years. Species richness is the number of species observed per plot per day. Relative abundance is the average number of small mammals captured per plot per day. Differences in blocks and treatments were examined with Kruskall-Wallis ANOVA tests (= 0.05).

ii. Results

Two species of small mammals were captured on our small mammal trapping lines: deer mice *(Peromyscus maniculatus)* and house mice *(Mus musculus)* (Table 11). Shrews (*Sorex ornatus*) were captured in the pitfall arrays.

There were 646 small mammal captures during all three trapping surveys in 2000; 606 individuals and 40 recaptures. During the surveys in 2000 relative abundance of small mammals among treatments ranged from 0.7 to 6.45 (Table 11). Study blocks showed a larger range of abundance, from 0 to 9.81 (Table 11).

Only during the month of August did we find a significant difference in abundance between treatments (Kruskall-Wallis: $p = 0.007$). Treatments 1 and 3 (contouring and reintroduction of plants and reintroduction, respectively) had greater abundances than the other two treatments (Figure 7 and 8). There was a significant difference in abundance between study blocks in all three seasons (Kruskall-Wallis: $p < 0.01$). Small mammal abundance was greater in November 2000 than October 1999 and differed between both study treatments and blocks (Figure 7 and 8).

iii. Discussion

The significant difference between treatments in August 2000 may be the beginning of a trend of higher capture rates in treatments with introduced native plants. A similar, but non-significant pattern was observed in May and November 2000. This trend may be a function of increased plant diversity or higher seed abundance.

Although there was no change in the diversity of small mammals, ornate shrews were discovered to occupy the Westlands HRS Site in June 2000. A total of 18 shrews were captured in pitfalls after a rain during the 4 day invertebrate survey (Table 12). Seventy-two percent of the shrews captured were found in study blocks 2 and 3. Forty-four percent of the shrews captured were on treatment 1 while only 5% were caught on treatment four.

Table 11. Richness and relative abundance of small mammals on treatments and blocks in 1999 and 2000 on the Westlands Site. ± = 1.96 standard errors.

		1999	2000		
		November	**November**	**August**	**May**
Treatment					
1	**Richness**	2	1	2	2
	Rel. Abund.	0.2 ± 0.11	1.9 ± 0.08	6.5 ± 0.13	2.9 ± 0.09
2	**Richness**	1	1	2	2
	Rel. Abund.	0.2 ± 0.09	2.0 ± 0.12	2.8 ± 0.12	1.3 ± 0.05
3	**Richness**	1	1	1	2
	Rel. Abund.	0.6 ± 0.17	1.7 ± 0.1	4.35 ± 0.14	2.8 ± 0.07
4	**Richness**	2	1	2	2
	Rel. Abund.	0.5 ± 0.22	0.7 ± 0.04	2.0 ± 0.06	1.6 ± 0.05
Block					
1	**Richness**	1	1	1	1
	Rel. Abund.	0.1 ± 0.09	0.2 ± 0.02	0.2 ± 0.03	0 ± 0
2	**Richness**	2	1	2	2
	Rel. Abund.	0.4 ± 0.18	0.2 ± 0.02	0.5 ± 0.06	0.4 ± 0.05
3	**Richness**	1	1	2	2
	Rel. Abund.	0.1 ± 0.06	0.4 ± 0.05	1.2 ± 0.14	1.0 ± 0.11
4	**Richness**	1	1	2	1
	Rel. Abund.	0.2 ± 0.1	0.5 ± 0.06	0.6 ± 0.07	0.3 ± 0.04
5	**Richness**	1	1	2	1
	Rel. Abund.	0.9 ± 0.28	1.6 ± 0.18	1.4 ± 0.16	0.5 ± 0.06

Of the 18 shrews captured, two were alive and released while the 16 found dead were used for contaminants analysis. The relatively high abundance and widespread distribution of shrews on the HRS site was unexpected. These captures may indicate that shrews are more common in cultivated agricultural fields than had previously been thought.

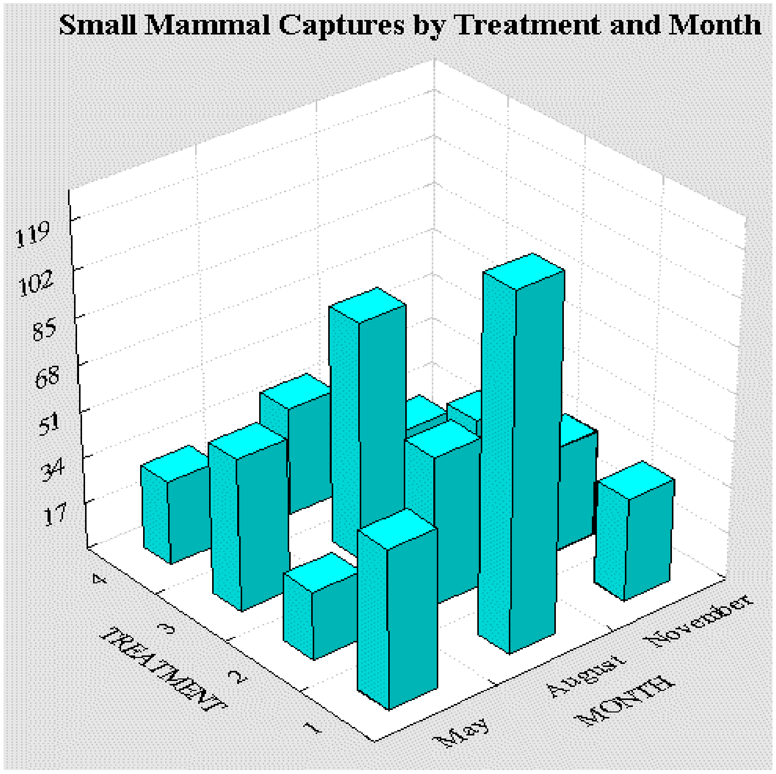

Figure 7. Small mammal captures by treatment on the Westlands Site.

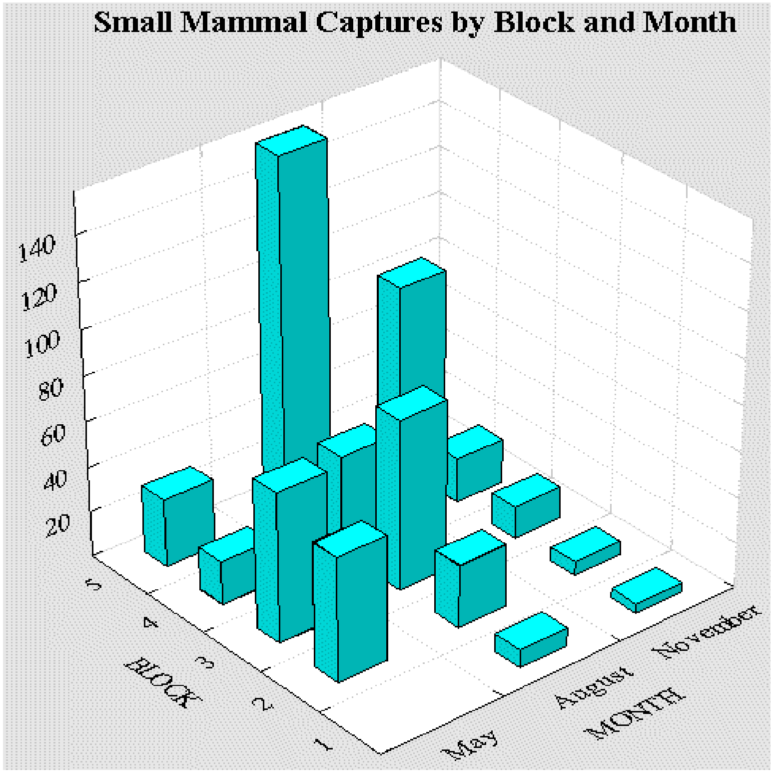

Figure 8. Small mammal captures by block on the Westlands Site.

Table 12. Locations of ornate shrew (*Sorex ornatus*) captures in June 2000 on the Westlands Site.

Treatment	Block	Sex			Total
		F	M	Unknown	
1	**2**	1	0	1	**2**
	3	2	1	0	**3**
	4	2	0	1	**3**
2	**1**	0	0	2	**2**
	2	1	1	0	**2**
	3	1	0	0	**1**
3	**2**	0	0	1	**1**
	3	1	2	0	**3**
4	**2**	0	1	0	**1**
Total		**8**	**5**	**5**	**18**

3. Conclusions

Preliminary restoration efforts appear to be promising. Seeding with the imprinter is particularly effective at establishing native plants. The increase in plant diversity may be leading to a greater use of restored plots by wildlife. Additionally, microtopographic contours seem to be contributing to this trend, particularly with respect to small mammal abundance.

Differences on plots in 1999 were measured prior to the application of the treatments. These differences are indicative of the high variation exhibited on the plots in 1999. There was also a high degree of variation on the plots in 2000. The effects of the treatments are expected to become more distinct with time. Much of the data exhibited block effects, which is also indicative of high variation among the plots.

Some of the results may be independent of the treatments that were applied and instead reflect other factors. For instance, the unexpected resprouting of barley on our study plots was problematic. This necessitated mowing of vegetation on the plots that were imprinted to reduce competition between native plants and barley. Accordingly, productivity on the mowed plots was significantly less than on the unmowed plots. An infestation of false chinchbugs was also a factor independent of the treatments. As a result of this infestation few plants remained alive in block 5. Because the infestation occurred in late June, after vegetation and invertebrate surveys were conducted in 2000, current results do not reflect the impact of the insects. However, detectable effects may be observed in subsequent sampling efforts.

4. Future Directions

Recommendations for several modifications to make the sampling efforts more robust are based upon this first year of post-treatment monitoring. These include increasing the number of surveys for invertebrates, increasing the level of surveys for reptiles and amphibians, conducting additional surveys for shrews, and comparing the plots to reference sites in native habitat.

The current protocols for sampling invertebrates does not allow for detection of seasonal variation of invertebrate abundance or for determining invertebrate community structure. A second sweep survey will be added in the spring. During the pitfall surveys invertebrates should be identified to family to increase the level of resolution of diversity. This level of detail would improve analysis of invertebrate data by trophic level and economic importance. This also would allow the determination of the relative health of the invertebrate community, overall ecosystem health, and potential impacts to neighboring farms.

Additional surveys will be added to increase the effort in locating reptiles and amphibians on the study plots. Two visual encounter transect surveys and four coverboard stations will be added on each plot (Heyer et al. 1994). The transects will be walked and the coverboards will be checked in June or July and December or January.

One or more reference sites should be established on native lands in the vicinity of the Westlands Site for comparison with the study plots. Comparisons of biotic and abiotic conditions would gauge progress in attaining the goal of establishing a natural community.

B. Alpaugh Site

1. Study Design

The Alpaugh HRS is a smaller scale, but similarly designed experiment that will provide biological and physical information relative to the implementation of land retirement in different regions of the Central Valley. The Alpaugh HRS is in its infancy. As of January 2001, the 3, 160-acre study blocks had been selected and the initial barley cover crop had been planted. Three 160-acre study blocks were selected on different soil types. Each block will contain 16 study plots, each 2-acre in size and located centrally in a 10-acre parcel (see Figure 1 in Appendix A). The plots will be randomly assigned one of the experimental treatments as on the Westlands Site (see Table 2). Treatments will be applied in winter 2001.

a. Microtopographic Contouring

Microtopographic contours will be installed similar to the Westlands Site. The berms will be of the same size and shape as the Westlands Site, but their numbers will be proportionately lower.

b. Native Plants

i. Imprinting

Imprinting will be conducted in the same manner as on the Westlands Site, however the seed mix may differ. The seed mix will include species that were most successful at the Westlands Site and may include other selected species common to natural areas in the Tulare Lake Basin.

ii. Transplanting

Because of the low survivorship and high costs associated with planting seedlings shrub islands will not be established on the Alpaugh plots.

2. Biological Monitoring

Biological monitoring will be initiated on the Alpaugh HRS plots in the year 2001. The first dataset will be considered baseline and will occur prior to the application of the treatments. Surveys will consist of:

- annual vegetation surveys (composition and cover)
- annual invertebrate surveys (sweep and pitfall)
- annual amphibian and reptile survey
- quarterly avian surveys
- quarterly small mammal surveys.

Other surveys will be conducted on a site wide basis and will not be directly applicable to the Alpaugh HRS plots. These surveys will consist of:

- quarterly spotlighting surveys
- quarterly track station surveys
- annual winter raptor survey
- annual contaminants monitoring (vegetation, invertebrates, and mammals).

The HRS survey methods are presented in the following section; no surveys have been conducted to date so there are no results or discussion. Some preliminary site-wide surveys have been conducted and those are presented in the Site-Wide Activities section.

a. Vegetation Surveys

To analyze the differences in vegetation between treatments, blocks and years, information on species richness, cover, and productivity will be collected. Each experimental plot will be divided into quarters and two quadrat sampling points will be chosen at random within each quarter-plot, resulting in eight quadrats per plot. Percent cover, richness, and species composition will be measured by using the modified Daubenmire cover scale (Bonham 1989) with 35 cm by 70 cm rectangular plots (quadrats).

Productivity will be estimated on each plot using eight randomly located quadrats. Samples will be collected in spring 2002 after treatments are applied and spring 2003. Above-ground vegetation in some quadrats will be clipped for verification of estimates (Bonham 1989). Samples will be sorted into native or non-native species categories and will be dried and weighed in the laboratory.

One photo station on each plot will document vegetation changes. A digital photograph and a 35-mm photograph will be taken from the southern point of the bird transect. Photographs will be archived on Compact Disk and in a binder.

b. Invertebrate Surveys

Two methods will be used to collect invertebrates: pitfall traps and aerial sweeps. One pitfall array will be established in the center of each plot. Each pitfall array will consist of four, 3-gallon buckets connected by 20-foot sections of galvanized steel flashing (Figure 9). The buckets will be sunk in the soil so that the rim of the bucket is at ground level and the lid of the bucket is then situated slightly above the rim using wooden stakes. Pitfalls will be opened the morning prior to the survey and will remain open approximately 24 hours before being checked. Trap checks will occur for 4 consecutive days beginning just after sunrise in May or June 2001. Small mammals will be counted and released from the pitfalls at the beginning of each survey day.

Aerial sweeps of vegetation to capture flying insects will be conducted at the same time as pitfall sampling. Another sweep will be conducted in April or May. Surveys will consist of walking a line 25 m long, sweeping vegetation with an insect net exactly 50 times. The transect will be randomly placed and the same transect will be walked in subsequent years. Insects from the sweeps will be transferred to a Ziploc™ bag and put on ice. Insects will be counted and identified to the level of family in the laboratory.

c. Amphibian and Reptile Surveys

Invertebrate pitfall arrays will also be used as reptile and amphibian pitfalls. All reptiles and amphibians captured during the invertebrate sampling efforts will be tallied. Incidental reptile and amphibian observations during other surveys will be recorded. Focused visual encounter transects and cover board surveys will be implemented in 2002 (Heyer et al. 1994).

d. Avian Surveys

Bird surveys will be conducted quarterly to estimate abundance and use of the research blocks. Surveys will occur quarterly starting in May 2001. One transect will be used per 2-acre plot (Figure 9) to estimate relative abundance and identify differences between experimental treatments (Dawson 1981, Ryder 1986).

Surveys will be conducted daily for 3 consecutive days beginning no later than 1 hour past sunrise. All species identified either visually or by vocalization that fall within plot boundaries will be recorded on standardized data sheets. Information collected will include the date and time of the survey, observer location for each sighting, species observed, bird activity at the time of observation, bird distance from the transect or point, and number of individuals of each species. Start and travel times will be standardized among observers so that equal time is spent on all plots. Avian species abundance will be expressed as the number of individuals observed per 90 m, the length of the transect.

e. Mammal Surveys

Small mammal relative abundance will be monitored on the four experimental treatments. Surveys will be conducted quarterly beginning in October 2001 for 4 consecutive nights.

One 100-m mammal trapping line will be established in each plot. The mammal trapping line will cut diagonally across each plot and will consist of 10 Sherman traps spaced 10 m apart (Jones et al. 1996). Traps will be baited with white proso millet seed and one dry paper towel will be placed in each for shredding material. Baiting of traps will begin approximately 1 hour before sunset and traps will be checked approximately 2 hours after sunset. All animals captured will be identified to species, sexed, weighed, ear-tagged or otherwise marked, and reproductive status determined.

III. ANCILLARY RESTORATION STUDIES

A. Westlands Site

Only a limited number of factors could be examined in the 800-acre HRS. To explore additional factors, two seeding method trials were initiated in the fall of 2000 and a berm size and orientation trial is scheduled to begin in fall 2001 (Figure 9).

1. Seeding Trials

Methods to introduce native seeds without the expensive ground preparation often required with traditional seed drills are highly desirable and are being explored in the current ancillary studies. Tillage brings weed seed to the soil surface and breaks down soil structure. Less soil disturbance should decrease weed density and promote the establishment of mycorrhizal networks in the soil, both of which tend to favor native plants (St. John 1995). Accordingly, these trials will be examined:

- imprinting and drilling of native seeds,
- imprinting and drilling of the barley cover crop, and
- imprinting and drilling of barley mixed with native grasses.

An imprinter was constructed in late 1999 and used to seed the HRS experimental plots and a non-experimental restoration area on the Westlands Site. The imprinter can be used without ground preparation given appropriate soil moisture, and can even be used directly over light vegetation. A Truax no-till seed drill was purchased in 2000 for use on the project site as an alternative for seeding native species on restored areas and grazing lands. The drill has traditionally been used for dryland farming in the Midwestern U.S., but has recently been used for seeding rangelands with native seeds (Anderson and Anderson 1996 and Magdoff and van Es 2000).

a. Imprinting and Drilling of Native Seeds

Six experimental plots approximately 1.5 acre in size were used to explore imprinting versus no-till drilling of native species. Three plots were imprinted and three plots were drilled with native seed (Figure 9, Table 13). Comparisons of cover, species diversity, and composition will be made by sampling quadrats as described in the methods for vegetation surveys on the Alpaugh HRS plots.

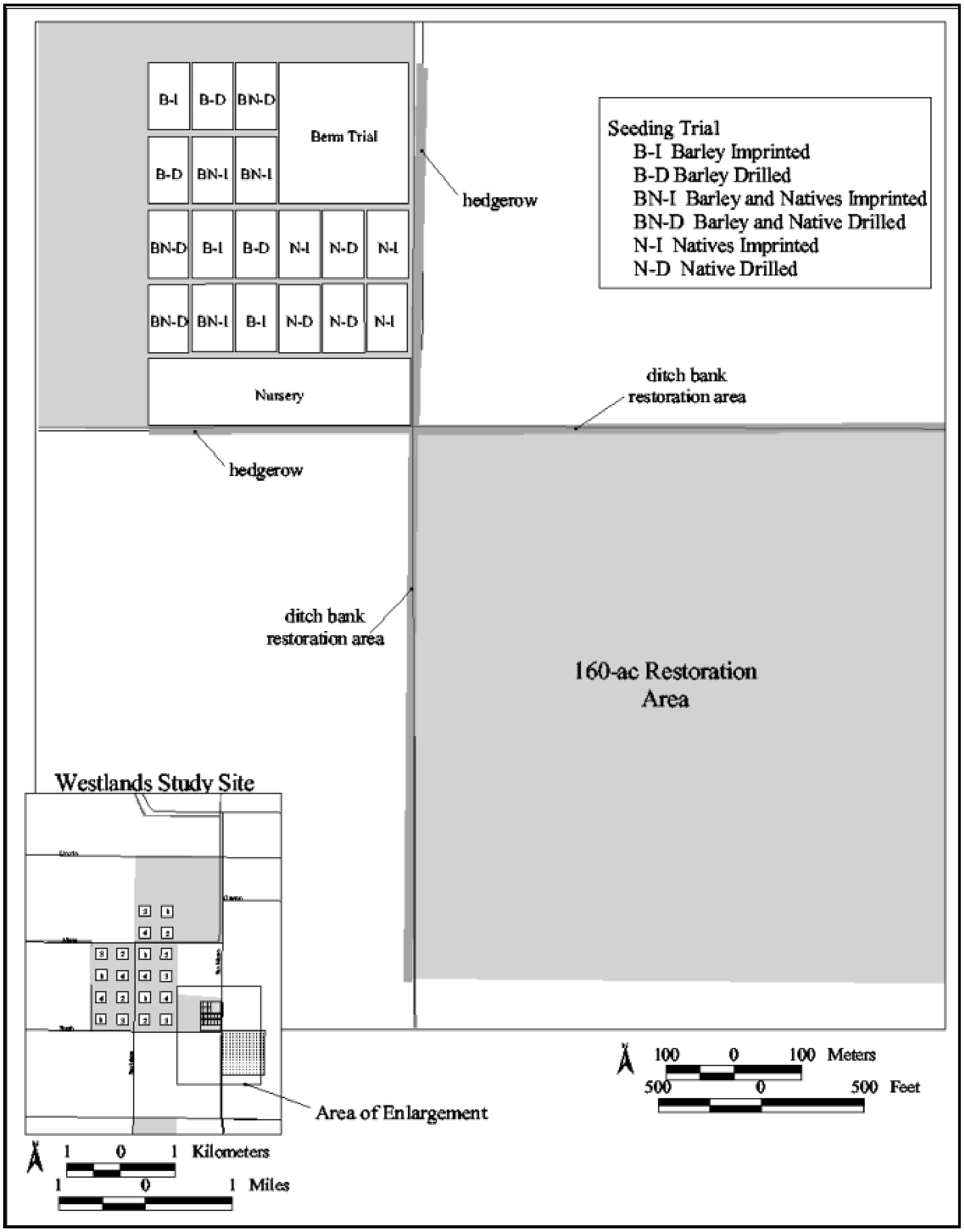

Figure 9. Location of seeding trial, berm trial, restoration areas and nursery on the Westlands Site.

Table 13. Native species composition of the Westlands seeding method trial. Source information provided by seed vendor.

Scientific Name	Common Name	Source	Lbs/Ac
Amsinckia menziesii	fiddleneck	San Bernardino County	1.2
Atriplex polycarpa	valley saltbush	Kern County	9.7
Hordeum depressum	low barley	Riverside	2.4
Isocoma acradenia	goldenbush	Riverside County	7.3
Lasthenia californica	goldfields	Riverside County	1.2
Leymus triticoides	creeping wild rye	Commercial-Rio	2.4
Sporobolus airoides	alkali sacaton	Commercial	2.4
Suaeda moquinii	bush seepweed	Riverside County	3.6
Vulpia microstachys	Nuttall's fescue	Fresno County	2.4

b. Imprinting and Drilling of Cover Crop

Cover crops probably will be a part of restoration on retired farmlands because reintroduction of native seeds is expensive and must be done in phases when large acreages are involved. Cover crops are an important restoration tool especially if they can be planted with minimal ground preparation and produce a viable crop to recoup planting costs or provide interim wildlife habitat. Cover crops are useful to deplete excess nutrients (e.g. nitrogen and phosphorous), residual pesticides, and other chemicals remaining from previous agricultural activities.

Twelve 1.5-acre plots were established to examine the relative effectiveness of imprinting and drilling barley and a mix of barley, *Bromus carinatus*, *Vulpia microstachys*, and *L. triticoides* (Figure 9, Table 14). Three replicates of four treatments were established:

- imprinted barley
- imprinted barley and native grasses
- drilled barley
- drilled barley and native grasses.

Monitoring will be conducted each spring beginning in May 2001. Cover, composition and diversity will be determined for each plot in a manner similar to the Alpaugh HRS.

Table 14. Cover crop seed mix for the Westlands Site seeding trial. Source information provided by seed vendor.

Scientific Name	Common Name	Source	Lbs/Ac
Hordeum vulgaris	barley	Commercial	120
Bromus carinatus	California brome	Commercial	5
Leymus triticoides	creeping wild rye	Commercial-Rio	5
Vulpia microstachys	Nuttall's fescue	Fresno County	10

c. Future Directions

Study design restrictions and logistical considerations on the HRS experimental plots prevented examining the effects of berm height and orientation on native seed germination. In fall of 2001 a research trial was initiated that will incorporate two berm heights and four orientations (see Figure 9 for trial location). A native seed mix will be imprinted over all the berms to prevent excessive weed establishment. Monitoring will consist of vegetation surveys and checks for small mammal burrows.

B. Alpaugh Site

No ancillary trials are currently planned by ESRP for the Alpaugh Site. However, trials to compare native seed germination on mounds and berms are being contemplated. Additional ancillary trials may be conducted by BLM in cooperation with ESRP.

IV. Site-wide Activities

A. Restoration

1. Westlands Site

a. 160-acre Restoration

Restoration of 160 acres of demonstration project lands was initiated in December 2000 (Figure 9). Berms were established on the restoration area in a fairly random pattern including both north/south and east/west orientations. Berms were not linear but curved. Gaps were always left between perpendicular berms to prevent ponding of water.

The LRDP imprinter was used to seed the area with native plants species (Table 15). Species that successfully germinated on the HRS plots were included in the seed mix for the restoration area. The seed mix was imprinted at a rate of 9 pounds per acre of native seed and 14 pounds per acre of wheatbran, which is used to keep variably sized native seeds in suspension. Preliminary germination tests indicate that *A. occidentalis* germinates better when the seed is sprinkled on the soil surface rather than buried (K. Dulik, pers. comm); so it was spread by hand after imprinting.

One hundred shrub islands were planted on the western and northern edges of the restoration area. Each island consists of 20 seedlings of *A. occidentalis*, 11 seedlings of *A. polycarpa*, and 12 seedlings of *S. airoides*. An additional 5 seedlings of *A. occidentalis* and 2 seedlings of *S. airoides* were planted on an adjacent berm. The final tally of seedlings planted was 2,500 seedlings of *A. occidentalis*, 1,100 seedlings of *A. polycarpa*, and 1,400 seedlings of *S. airoides.*

Monitoring of native species success will be determined on restoration areas as time and resources permit.

b. Hedgerow Seeding

Vegetation on field borders may harbor pests, therefore these areas are usually disced or sprayed with herbicide. Hedgerows planted with native species along field borders may be an alternative to discing or herbicide use. Hedgerows may be maintained with minimal management and may tend to favor beneficial insects (Clark and Rollins 1996). Hedgerows can also provide very important habitat for birds and other wildlife (Clark and Rollins 1996).

A 10-foot wide hedgerow was imprinted with native seed in December 2000 (Table 16). The hedgerow runs along the southern and eastern edge of the Ancillary Trial area (Figure 9). Berms were constructed along the edges of the hedgrow to allow the area to be flood irrigated. Seedlings of *Atriplex lentiformis*, *L. triticoides*, *Nassella pulchra* and *S. airoides* were planted along the berm adjacent to the hedgerow approximately 2 feet apart in January 2001.

Table 15. Native plants seeded on the Westlands 160-acre restoration area. Source information provided by seed vendor.

Scientific Name	Common Name	Source	Lbs/Ac
Allenrolfea occidentalis	iodine bush	Alameda County	0.6
Amsinckia menziesii	fiddleneck	San Bernardino County	0.3
Atriplex polycarpa	valley saltbush	Kern County	1.5
Dichelostemma capitatum	blue dick	San Diego County	0.2
Frankenia salina	alkali heath	San Diego County	0.6
Gilia tricolor	bird's eye gilia	Commercial	0.6
Grindelia camporum	gumplant	Yolo County	0.1
Gutierrezia californica	California matchweed	San Bernardino County	0.3
Heliotropium curassavicum	heliotrope	Riverside County	0.3
Hemizonia pungens	common spikeweed	Livermore Valley	0.3
Hordeum depressum	low barley	Riverside	0.5
Isocoma acradenia	goldenbush	Riverside County	0.6
Lasthenia californica	goldfields	Riverside County	0.5
Leymus triticoides	creeping wild rye	Commercial-Rio	1.3
Sporobolus airoides	alkali sacaton	Commercial	0.6
Suaeda moquinii	bush seepweed	Riverside County	0.9
Vulpia microstachys	Nuttall's fescue	Fresno County	0.5

c. Marsh Area Seeding

A seasonal wetland created by agricultural runoff water has partly formed for the past 2 years on lands not owned by the LRDP. The area supports large numbers of herons and other waterbirds when filled with water. Occasionally this water inundates approximately 8 acres of LRDP property. A mixture of native seed that is found in mesic conditions or upland habitats was imprinted (Table 17).

Table 16. Hedgerow seed mix for the Westlands Site. Source information provided by seed vendor.

Scientific Name	Common Name	Source	Lbs/Ac
Amsinckia menziesii	fiddleneck	San Bernardino	3.0
Atriplex lentiformis	quailbush	Taft	3.0
Atriplex polycarpa	valley saltbush	Fresno County	5.0
Dichelostemma capitatum	blue dick	Camp Pendelton	3.0
Eremocarpus setigerus	doveweed	Kern County	3.0
Frankenia salina	alkali heath	Southern CA	8.0
Helianthus annuus	sunflower	Ensenada	8.0
Heliotropium curassavicum	heliotrope	Temecula	3.0
Leymus triticoides	creeping wild rye	Fresno County	8.0
Sporobolus airoides	alkali sacaton	Unknown	3.0
Vulpia microstachys	Nutall's fescue	Fresno County	8.0

Table 17. Marsh area seed mix for the Westlands Site. Source information provided by seed vendor.

Scientific Name	Common Name	Source	Lbs/Ac
Atriplex polycarpa	valley saltbush	Fresno County	0.13
Dichelostemma capitatum	blue dick	Camp Pendelton	0.38
Eleocharis macrostachya	spikerush	Grass Valley	0.13
Frankenia salina	alkali heath	San Diego-Coastal	0.38
Heliotropium curassavicum	heliotrope	Temecula	0.38
Isocoma acradenia	goldenbush	Indio	0.25
Juncus balticus	Baltic rush	Unknown	0.25
Lasthenia californica	goldfields	Hemet	0.25
Leymus triticoides	creeping wild rye	Fresno County	1.13
Lupinus bicolor	miniature lupine	CA Valley/Carrizo	1.25
Mimulus guttatus	monkeyflower	Bakersfield	0.25
Poa secunda	bluegrass	W. Lower Central Valley	1.25
Sporobolus airoides	alkali sacaton	Unknown	0.50
Suaeda moquinii	bush seepweed	Lakeside	0.25

d. Ditch Bank Seeding and Planting

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 prevent weedy species from overtaking ditches while providing excellent cover for wildlife. Ditch banks were seeded with native species to demonstrate their value for wildlife without interfering with farming practices.

A ditch was created on the northern and western boundary of the 160-acre restoration area

(Figure 9). Seedlings of *L. triticoides* and *N. pulchra* were planted along the ditch banks in December 2000. The ditch was seeded by hand in January 2001 with a mix of species that would typically do well along an irrigation ditch (Table 18). A water outlet is located near the ditch, which will allow for easy watering of the plants.

Table 18. Ditch bank seed mix for the project Westlands Site. Source information provided by the seed vendor.

Scientific Name	Common Name	Source	Lbs/Ac
Amsinckia menziesii	fiddleneck	San Bernardino	12.5
Cressa truxillensis	alkali weed	Camp Pendelton	8.0
Eleocharis macrostachya	spikerush	Grass Valley	4.2
Frankenia salina	alkali heath	San Diego Cnty-Coast	8.0
Helianthus annuus	sunflower	Ensenada	8.0
Heliotropium curassavicum	heliotrope	Temecula	17.0
Hordeum depressum	low barley	Riverside	21.0
Leymus triticoides	creeping wild rye	Fresno County	21.0
Malvella leprosa	alkali -mallow	Unknown	8.0
Nassella pulchra	purple needlegrass	Central Valley	12.5
Poa secunda	bluegrass	West Lower Central Valley	42.0
Sporobolus airoides	alkali sacaton	Unknown	12.5
Vulpia microstachys	Nutall's fescue	Fresno County	21.0

e. Future Directions

i. Nursery

Native seed collected from local sources is preferable to commercially obtained seed to maintain local genotypes. The lack of extensive native plant populations and the cost of seed collection limit the amount of local seed that can be realistically obtained. Seed was collected from 18 plant species (Table 19) from seven available sites (Figure 10). The seed will be used for restoration mixes and propagation at an on-site nursery (Table 19). The seed will be grown to optimize germination and seed production.

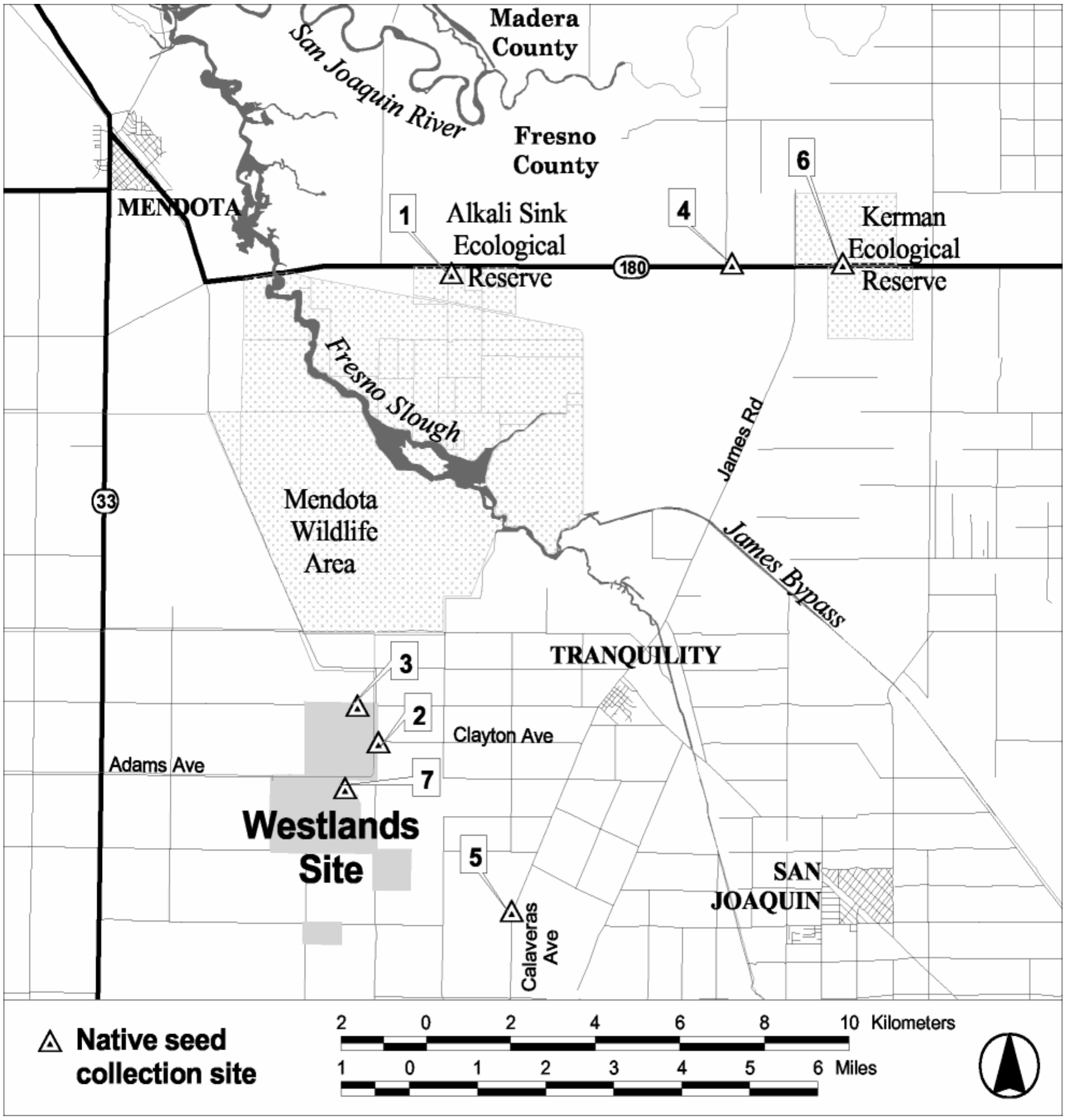

Figure 10. Native seed collection sites near the Westlands Site. Numbers correspond to Table 19.

Table 19. Locally collected native seed for restoration and propagation on the Westlands Site. Source codes correspond to Figure 10.

Scientific Name	Common Name	Source	Lbs
Allenrolfea occidentalis	iodine bush	2	13.00
Amsinckia menziesii	fiddleneck	4	0.04
Asclepias fasicularis	common milkweed	3	0.29
Asclepias fasicularis	common milkweed	5	1.00
Atriplex polycarpa	valley saltbush	6	3.00
Atriplex spinifera	spiny saltbush	3	4.00
Castilleja exserta	purple owl's clover	4	0.30
Dichelostemma capitatum	blue dick	6	0.05
Dichelostemma capitatum	blue dick	4	0.33
Helianthus annus	sunflower	5	1.10
Helianthus annus	sunflower	3	1.00
Hemizonia pungens	common spikeweed	6	13.00
Hemizonia pungens	common spikeweed	4	8.00
Isocoma acradenia	goldenbush	6	2.50
Lasthenia chrysantha	goldfields	4	0.31
Phacelia distans	phacelia	7	1.00
Spergularia macrotheca	spergularia	6	0.33
Spergularia marina	spergularia	4	0.06
Sporobolus airoides	alkali sacaton	1	0.06
Sporobolus airoides	alkali sacaton	6	0.13
Trichostema lanceolatum	vinegar weed	6	0.25
Trichostema lanceolatum	vinegar weed	6	0.27
Wislinzenia refracta	jackass clover	6	0.25
Wislizenia refracta	jackass clover	4	0.50

ii. Restoration

Currently there are approximately 80 acres of land on the Westlands Site planted with a cover crop of barley. In fall 2001, this area will be restored: 40 acres will be seeded over the harvested barley with the imprinter and 40 acres will be seeded over the harvested barley with the range drill.

No additional lands were retired at the Westlands Site in 2000. However, as additional lands become available and are purchased, they will be planted in cover crops, seeded with native species, or managed for weed control.

2. Alpaugh Site

The BLM has accepted responsibility of restoration and management of the Alpaugh Site, exclusive of the Habitat Restoration Study. All of the restoration activities that BLM conducted in 2000 was in preparation for the 2001 growing season. BLM conducted the following activities on the Alpaugh site in 2000 (Figure 11):

- Disked weeds along Road 40,
- Made repairs to the irrigation system in Sections 10 and 3,
- Disked and planted 60 acres of saflower and 20 acres of barley in Section 10, some of the lands were pre-irrigated,
- Approximately 150 native trees and shrubs were planted in a half-mile stretch along the east side of the Alpaugh Canal in Section 14, a drip line was installed and the trees were watered,
- A 500-foot long drip system was established along the north boundary of Section 14, east of the Alpaugh Canal, and 30 *Atriplex lentiformis* bushes were planted,
- Approximately 1 mile of the northern bank of an irrigation canal in Section 10 was raked and seeded with a hedgerow mix,
- Sheep were allowed to graze in Sections 10, 3, 14, and 23 to remove vegetation prior to disking and planting efforts.

The BLM also plans to hire several contractors to collect seed from nearby sources to be used in future restoration and research trials. A BLM restoration ecologist will coordinate these efforts at the Alpaugh Site.

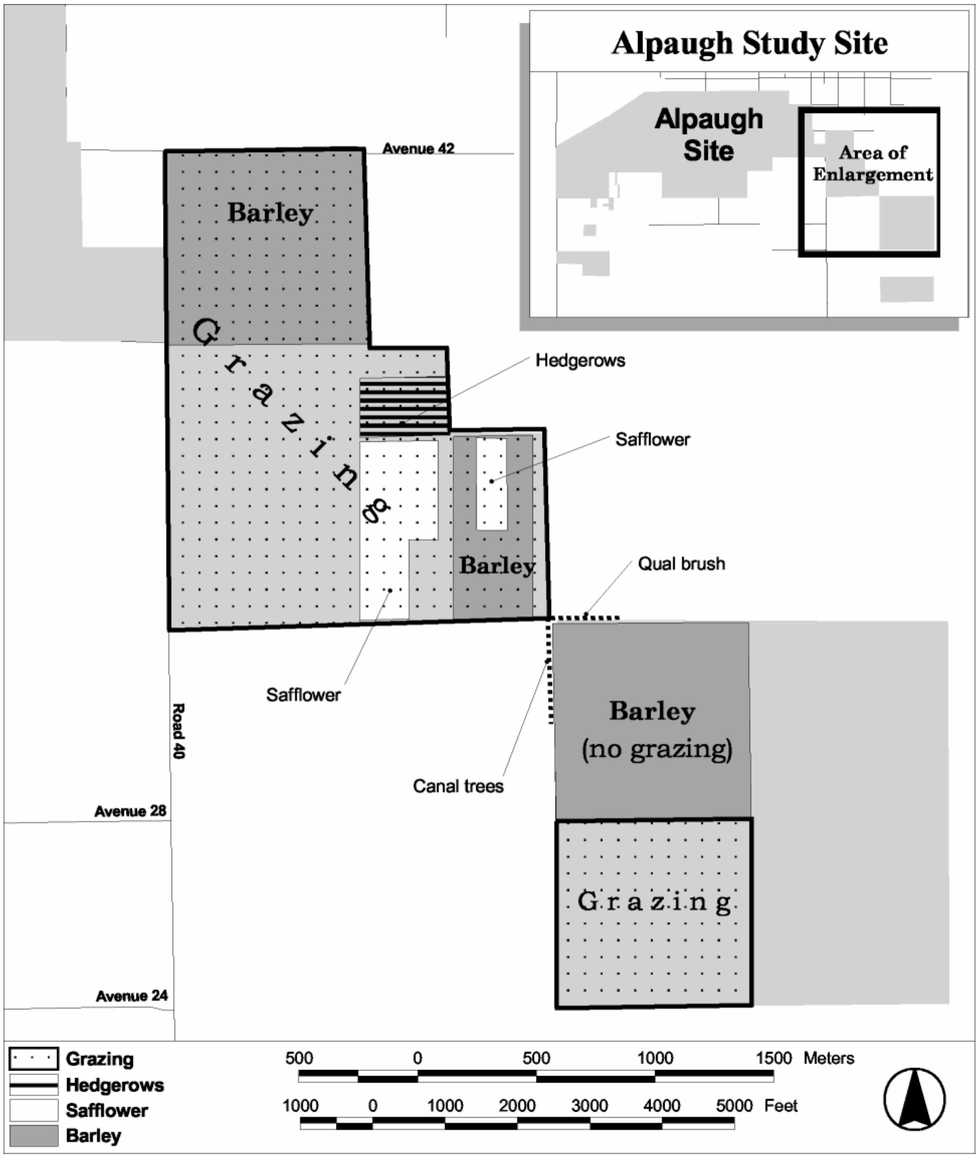

Figure 11. Locations of restortation activities conducted at the Alpaugh Site by BLM in 2000.

B. Biological Monitoring

1. Westlands Site

Site-wide monitoring activities that were conducted in 2000 in addition to the focused HRS included contaminants monitoring, spotlighting surveys, track station surveys, and winter raptor surveys.

a. Contaminants Monitoring

i. Methods

Three different strata were sampled for vegetation contaminants at the Westlands Site: lands with a barley cover crop, idled lands, and experimental plots. We selected a group of plants to sample that include selenium (Se) accumulators and potential food sources for wildlife. At least 5 g of plant material was collected from *Atriplex argentea*, *Avena fatua*, *Bromus madritensis* ssp. *rubens*, barley, *Brassica nigra*, *Heliotropium curassavicum*, and *Hordeum murinum*. A minimum of 5 g of seeds also were collected from *B. nigra* and barley. Volunteer sugar beets were also collected from experimental plots in block 2.

Five locations were sampled within each of the three different strata. Generally, the same areas were sampled for vegetation in 2000 that were sampled in 1999. However, the sparse distribution of some species resulted in variable collection locations from year to year. Samples were kept cold in an ice-chest while in the field and were frozen immediately upon return to the laboratory.

Invertebrates were collected from pitfall trap arrays on experimental plots. Several species were selected for sampling including beetles, crickets, isopods, and spiders.

Deer mice were collected from lands with a barley cover crop and idled lands. Mammal samples were not collected from experimental plots. At each sampling location, 30 Sherman small mammal traps were baited with white proso millet. We attempted to capture one animal at each location in a maximum of 4 nights of trapping. If a location didn't yield an animal, two animals were collected from one of the other locations to bring the sample size up to the required five animals per area. House mice were very uncommon and an adequate number of samples could not be collected. Additionally, 13 of the 18 ornate shrews were collected during the invertebrate pitfall surveys and were used as contaminat samples. Animals were transported back to the laboratory where they were euthanized and immediately frozen.

Contaminants samples were sent to Laboratory and Environmental Testing Inc (L.E.T.), Columbia, MO for analysis. Once received at the lab, samples are prepared by lyphilization (freeze-drying), homogenization, and digestion (Clark 1987). The selenium detection limit for plant and animal tissue is 0.2 ppm dry weight, as long as at least 0.5 g of a dry sample is available. However, 2 g dry weight is the minimum sample size requested by the laboratory.

L.E.T. quality control procedures include:

- using 5% blanks to assess contamination;
- duplicate analysis of 10% of the samples;
- analysis for recovery of spiked amounts in 10% of samples; and
- blind reference standards in 5% of samples with a minimum of one of each of the above (Ed Hinderberger, L.E.T., pers. comm.).

Results of contaminants analyses are reported below as the geometric mean (GM) and range of selenium (ppm or g/g) per group. No statistical comparisons have been made with the contaminants results to date because of the lack of long term data. Only preliminary apparent trends and observations are reported, herein. A more complete analysis will be included in subsequent reports.

ii. Results

All plant species had relatively low levels of Se present in 2000, ranging from less than detectable to as high as 3.9 ppm for one *H. curassavicum* sample from the uncultivated area. All other samples from all areas had Se levels below 2 ppm. *B. nigra* appeared to have slightly higher levels than other species in the cultivated area (Table 20). Vegetation contaminants monitoring results for the Westlands Site appear to be similar to 1999 results.

Isopods had the highest concentrations of selenium whereas crickets had the lowest (Table 21). Beetles and spiders contained similar levels of selenium. Invertebrate samples in 2000 had selenium levels similar to samples collected in 1999. Crickets had lower Se levels than isopods, which would be expected based on their feeding strategies.

Table 20. Vegetation contaminants monitoring results at Westlands (ppm)

	1999			2000		
	N	**GM**	**RANGE Se**	**N**	**GM**	**RANGE Se**
CULTIVATED						
Atriplex argentea	1		0.2	5		< 0.2-0.6
Avena fatua	~		~	5	0.33	0.2-0.4
Brassica nigra	1		0.3	4	1.01	0.3-1.7
Brassica nigra [seeds]	1		0.4	4	0.96	0.64-1.6
barley	5		< 0.2-0.4	5		< 0.2-0.6
barley [seeds]	5		< 0.2-0.3	5		< 0.2-0.4
sugar beets	~		~	5	0.58	< 0.2-1.0
EXPERIMENTAL						
Atriplex argentea	~		~	5		< 0.2-0.5
Avena fatua	~		~	5		< 0.2-0.5
Brassica nigra	~		~	4		< 0.2-0.9
Brassica nigra [seeds]	~		~	4	0.42	0.4-0.5
barley	~		~	5		< 0.2-0.5
barley [seeds]	~		~	5		< 0.2-0.4
UNCULTIVATED						
Atriplex argentea	3		< 0.2-0.5	5		< 0.2-0.2
Bromus madritensis	3		< 0.2	5		< 0.2-0.2
Brassica nigra	~		~	5		< 0.2-0.4
Brassica nigra [seeds]	~		~	5		< 0.2-0.6
Heliotropium curassavicum	1		< 0.2	3		< 0.2-3.9
Hordeum murinum	1		< 0.3	3		< 0.2-0.3

Table 21. Level of selenium (Se in ppm) in invertebrates at the Westlands Site. GM=geometric mean

	1999			2000		
	N	**GM Se**	**Range Se**	**N**	**GM Se**	**Range Se**
EXPERIMENTAL						
Beetles	2		< 1.0 - 1.2	5	1.27	0.6 - 2.7
Crickets	4	0.33	< 0.3 - 0.6	5	0.72	0.4 - 0.8
Isopods	3	4.03	1.0 - 5.6	5	3.23	2.2 - 4.5
Spiders	5	1.72	1.1 - 3.6	5	1.97	0.9 - 2.7

In 2000 both the body and liver of deermice had lower GM of selenium in uncultivated areas than in the cultivated areas (Table 22). A similar trend was seen in 1999.

Although there were few samples of house mice in 1999 and 2000, body and liver samples from cultivated areas appear to be higher in Se than samples from uncultivated areas (Table 22). Shrews had selenium levels similar to the house mice collected on cultivated areas in 2000.

iii. Discussion

These preliminary results provide encouraging evidence that land retirement can be implemented on drainage-impacted agricultural land without increasing selenium bioavailability to wildlife. Selenium availability may be proportional to the amount of irrigation water applied as well as other factors. Although the information available is not robust, lower Se levels were observed on idled lands than on cultivated and experimental areas. Over time Se levels may decrease on experimental lands due to limited irrigation.

Plant samples from all three strata had detectable levels of Se, indicating that some Se is being accumulated in plant tissues under all conditions on the Westlands Site. However, all levels are lower than those that are known to produce harmful effects in wildlife (USFWS 1998). Plants in the mustard family are known selenium accumulators (Banuelos and Meek 1990), so it is not surprising that the highest group GM was in the *B. nigra* samples. It appears that *H. curassavicum* may also be a Se accumulator due to the high level of Se observed.

Table 22. Level of selenium (Se in ppm) in vertebrates at Westlands Site. PEMA = deermice (*P. meniculatus),* MUMU = house mice (*M. musculus*), SOOR = ornate shrew (*S. ornatus*), GM = geometric mean, and ~ = no sample collected.

	1999			2000		
	N	**GM Se**	**Range Se**	**N**	**GM Se**	**Range Se**
UNCULTIVATED AREAS						
PEMA body	5	0.9	0.8-1.1	5	0.82	0.73-1.0
PEMA liver	5	3.4	2.9-4.4	5	2.67	1.6-3.9
MUMU body	2	0.8	0.7-1.0	~	~	~
MUMU liver	2	3.8	3.7-4.0	~	~	~
CULTIVATED AREAS						
PEMA body	5	1.1	1.0-1.5	5	1.42	0.95-1.7
PEMA liver	5	3.6	3.3-3.9	5	3.84	3.1-5.5
MUMU body	~	~	~	2	2.06	1.7-2.5
MUMU liver	~	~	~	2	6.08	4.4-8.4
EXPERIMENTAL AREAS						
SOOR body	~	~	~	13	2.51	2.0-4.8
SOOR liver	~	~	~	13	4.18	3.4-7.8

Invertebrates on retired lands are accumulating relatively low levels selenium. It is suspected that the levels of Se contained in the invertebrate samples from 1999 and 2000 are indicative of the cultivated condition that has been predominant on those lands for decades and should be considered background levels. Comparisons between 1999 and 2000 are not valid due to small sample sizes in 1999. Invertebrates were sampled late in the season in 1999 resulting in small sample sizes.

Levels of Se in small mammals on project lands in 2000 are similar to levels seen in 1999 samples and indicate that selenium is not rapidly bioaccumulating on retired lands. The high Se levels found in shrews are expected due to their insectivorous foraging habits (Ohlendorf and Santolo 1994). Deer mice may be eating a greater proportion of vegetative material relative to insect material compared to both shrews and house mice. Deer mice from the cultivated lands had higher levels of Se than those from the uncultivated areas, which is similar to the results found with the vegetation samples. Comparisons of Se levels among vegetation strata for house mice could not be made due to this species low occurrence rate. Shrews were incidentally captured on experimental lands and not in cultivated areas.

b. Spotlighting

i. Methods

Spotlighting surveys in 1999 were done on a bi-annual basis according to the Demonstration Project Resource Monitoring Plan (Selmon et al. 1999). Survey frequency was increased to four times per year in 2000 because of the low number of vertebrates encountered in 1999. Spotlighting surveys were conducted in March, June, September and November 2000. The route covers the entire extent of the current Demonstration Project lands at the Westlands Site (Figure 12). Two biologists using 1,000,000 candle-power spotlights drove the spotlighting route at approximately 15 mph for 3 consecutive nights for each survey. The survey route was reversed on the second night. Surveys began within an hour after sunset. All animals encountered were identified and the information recorded on standardized data sheets.

Spotlighting results are reported as percent frequency of occurrence and rate of occurrence. Percent frequency of occurrence is the number of nights during a survey an animal species was observed, and rate of occurrence is the number of individuals of a species observed per mile of the survey averaged over the number of survey nights.

Species richness and total abundance were tested for variation between seasons with an ANOVA. Abundance of individual species that were observed in every season were tested for significance with an ANOVA. Student’s t-tests were used to test between years in corresponding seasons. Results were considered significant below a = 0.05.

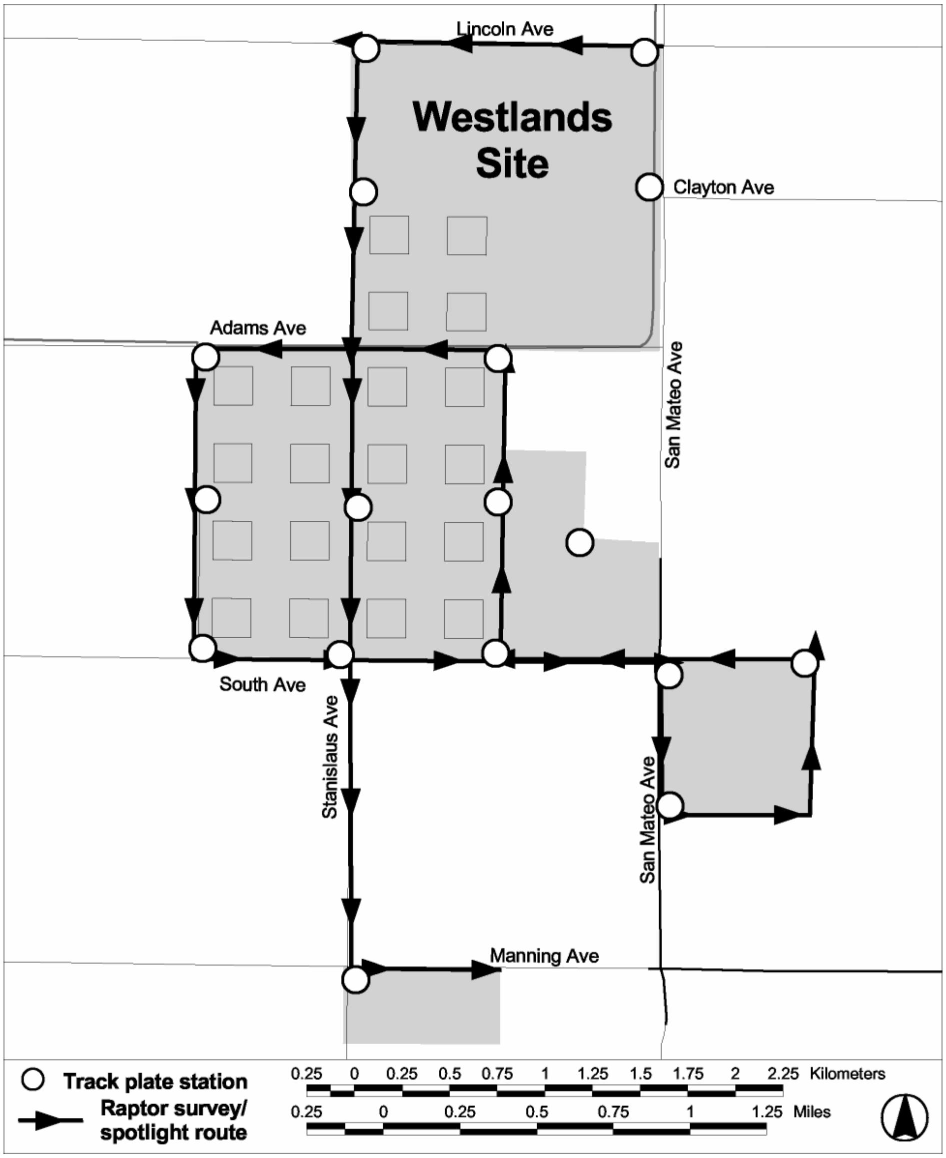

Figure 12. Spotlighting route, track station locations and winter raptor survey route on the Westlands Site.

ii. Results

In 2000, the number of species observed ranged from 5 to 8, with the mean total abundance ranging from 16 to 33 (Table 23). There was no significant difference in mean richness between the 4 different seasons in 2000. There was a significant difference in mean total abundance corresponding to the four seasons.

Abundances of barn owls (*Tyto alba*) and desert cottontails (*Sylvilagus audubonii*) in 2000 varied significantly between seasons while black-tailed jackrabbit (*Lepus californicus*) did not. Comparisons between September and December 1999 surveys did not show any significant differences in total abundance or richness. There were no significant differences in mean total abundance between September 1999 and 2000 or between December 1999 and November 2000.

Table 23. Mean species richness and abundance recorded during spotlighting surveys 1999 and 2000 at the Westlands Site.

	1999		2000			
	September	**December**	**March**	**June**	**September**	**November**
Richness	6.7 ± 3.79	5.7 ± 3.48	7.0 ± 1.00	8.0 ± 1.00	5.0 ± 2.00	6.3 ± 3.06
Total Abundance	20.0 ± 3.79	15.3 ± 3.48	21.0 ± 2.65	33.7 ± 8.62	14.3 ± 1.53	16.7 ± 6.03
Mean abundance:						
Tyto alba	13.0 ± 2.00	4.7 ± 1.45	0.0 ± 0.00	10.0 ± 3.06	5.3 ± 2.33	2.7 ± 0.88
Sylvilagus audubonii	0.7 ± 0.33	0.7 ± 0.33	4.7 ± 0.67	3.0 ± 1.00	0.7 ± 0.33	1.0 ± 0.58
Lepus californicus	1.0 ± 0.58	2.3 ± 1.86	2.7 ± 1.20	3.7 ± 0.67	1.3 ± 0.88	0.3 ± 0.33

The most commonly observed birds and mammals are presented in Table 24. Additionally, several interesting observations are worth mentioning. Western toads were routinely seen near sources of water and kangaroo rats (likely *Dipodomys heermanni*) on the northern edge of the LRDP land. Also, in June 2000 a California kingsnake (*Lampropeltis getulus californiae*) was observed along Adams Avenue. Occasionally, coyotes also were observed on the site.

Table 24. Most commonly observed birds and mammals seen each season during spotlighting at the Westlands Site.

Year	Month	Bird	Mammal
1999	**September**	Barn owl	Black-tailed Jackrabbit
	December	Red-tailed hawk	Black-tailed Jackrabbit
2000	**March**	Burrowing Owl	Desert cottontail
	June	Barn owl	Desert cottontail
	September	Barn owl	Black-tailed Jackrabbit
	November	Killdeer	Desert cottontail

iii. Discussion

Observed differences between quarterly surveys are likely due to seasonal activity patterns of individual species. Red-tailed hawks (*Buteo jamaicensis*) winter on the site whereas burrowing owls (*Athene cunicularia*) are only observed during the breeding season.

While the primary value of spotlighting surveys is to track relative abundance and richness as restoration proceeds, no differences were observed between 1999 and 2000. However, future data sets will add to the value of current information and will be an indicator of the success of restoration efforts.

c. Track Stations

i. Methods

Track station surveys were conducted in March, June, September and November 2000, concurrently with spotlighting surveys. Track plates were set at 17 locations on the Westlands Site (Figure 12). The 1-m^2 aluminum track plates were dusted with fire clay and baited with a can of cat food. They were checked for tracks each morning and rebaited and redusted as needed each evening.

Results are presented as percent frequency and rate of visitation. Percent frequency is calculated as the number of visits by each animal divided by the total number of monitoring nights X 100. Rate of visitation is calculated as the number of track stations visited by each animal divided by the total number of stations.

ii. Results

During every season, except March, in 2000 the most common (rate of visitation) and the most frequent (frequency of observation) tracks observed were of insects (Table 25). In March, tracks of mice were the most commonly and frequently observed. Mouse tracks were

Table 25. Results of track station surveys on the Westlands Site.

Group	1999 Total	%Freq.	Rate	2000 Total	%Freq.	Rate
March						
insects	~	~	~	4	33%	0.08
bird	~	~	~	3	33%	0.06
mouse	~	~	~	13	67%	0.25
June						
insects	~	~	~	50	100%	0.98
toad	~	~	~	9	100%	0.18
bird	~	~	~	6	67%	0.12
burrowing owl	~	~	~	1	33%	0.02
small mammal	~	~	~	2	33%	0.04
mouse	~	~	~	19	100%	0.37
crow	~	~	~	1	33%	0.02
ground squirrel	~	~	~	1	33%	0.02
kangaroo rat	~	~	~	1	33%	0.02
September						
toad	0	0	0	5	100%	0.10
insect	10	100%	0.20	16	100%	0.31
mouse	4	67%	0.08	13	100%	0.25
bird	0	0	0	1	33%	0.02
ground squirrel	0	0	0	3	67%	0.06
kangaroo rat	1	33%	0.02	2	67%	0.04
raven	0	0	0	1	33%	0.02
rabbit	3	67%	0.06	1	33%	0.02
coyote	1	33%	0.02	0	0	0
domestic dog	1	33%	0.02	0	0	0
vole	1	33%	0.01	0	0	0
December 1999 / November 2000						
toad	0	0	0	1	33%	0.02
insect	0	0	0	14	67%	0.27
domestic cat	0	0	0	1	33%	0.02
mouse	6	67%	0.12	12	100%	0.24
birds	0	0	0	10	100%	0.20
rabbit	2	33%	0.04	1	33%	0.02
domestic dog	1	33%	0.02	1	33%	0.02
ground squirrel	0	0	0	1	33%	0.02
hare	1	33%	0.02	0	0	0

also abundant during all other seasons and the frequency and rate varied little among seasons. Mice were observed on more track stations in 2000 than in 1999. Other visitors included kangaroo rats, voles and California ground squirrels.

iii. Discussion

The results show a trend of increasing diversity of types of tracks and total abundance of tracks. This may reflect an increase in the diversity and total abundance of wildlife on the Westlands Site.

The primary value of track station surveys is to monitor track diversity and total track abundance over time. Comparisons of 2000 to 1999 data were difficult because only two surveys were conducted during 1999. Furthermore, the 2000 data set was collected early in the restoration process; future data sets will add to the value of current information and will be an indicator of success of restoration efforts.

d. Winter Raptor Survey

i. Methods

The annual winter raptor survey was conducted in January 2001 for 3 consecutive mornings. Two observers drove the spotlighting survey route at 15 mph and recorded all observed raptors and loggerhead shrikes (*Lanius ladovicianus*). Raptor survey results are reported as percent frequency of occurrence and rate of occurrence.

ii. Results

Seven species of raptors were observed to be using the site during the annual winter raptor survey (Table 26). American kestrels (*Falco sparverius*), northern harriers (*Circus cyaneus*), and red-tailed hawks were the most commonly (highest observation rate) observed raptors during this survey. Northern harriers and white-tailed kites (*Elanus leucurus*) had higher observation rates in 2000 than 1999.

iii. Discussion

The primary value of winter raptor surveys is to track relative abundance and richness as restoration proceeds. The increases in relative abundance of some raptors between 1999 and 2000 may be related to restoration activities. Future data will add to the value of current information and will be an indicator of success of restoration efforts.

Table 26. Winter raptor survey results at the Westlands Site.

	1999			2000		
Scientific name	**Total**	**%Freq.**	**Rate**	**Total**	**%Freq.**	**Rate**
Falco sparverius	34	100%	0.97	29	100%	0.87
Circus cyaneus	19	100%	0.54	28	100%	0.84
Buteo jamaicensis	21	100%	0.60	21	100%	0.63
Elanus leucurus	5	67%	0.14	14	100%	0.42
Lanius ludovicianus	0	0	0	11	100%	0.33
Falco mexicanus	1	33%	0.03	1	33%	0.03
Buteo lagopus	3	100%	0.09	1	33%	0.03
Falco sp.	0	0	0	1	33%	0.03
Buteo sp.	5	100%	0.14	1	33%	0.03
Total	88			107		

2. Alpaugh Site

A pre-project inventory was conducted on the Alpaugh Site in 2000 to assess conditions prior to establishing the Habitat Restoration Study. Baseline monitoring will begin on study plots in spring 2001and treatment application will occur in fall 2001. Appendix A presents the methods, results and discussion of the pre-project inventory.

C. Management

The Demonstration Project provides an opportunity to explore alternative farming and grazing practices that may provide wildlife benefits. With appropriate management Demonstration Project lands may also provide recreational opportunities such as wildlife and wildflower viewing and hunting.

1. Westlands Site

a. Cover Crop

Cover crops can provide important sources of food and cover for wildlife, reduce the proliferation of weeds until restoration can occur, and may provide a harvestable crop and profit to be used in subsequent restoration. Currently, 80 acres of barley are planted on the Westlands Site to provide temporary wildlife habitat.

b. Grazing

Grazing could be used to manage retired lands on the Demonstration Project until restoration is initiated. Not all parcels will be restored at once, due to both financial and logistical constraints. In the interim, some lands may be leased for either wildlife-friendly farming demonstrations or for grazing. Grazing also may be an appropriate management tool on restored lands. There presently are no plans to manage the existing Westlands Site with grazing. However, grazing trials may be initiated on future land acquisitions.

c. Recreational Uses

Sixty acres of the Westlands Site have been planted in safflower since spring of 1999 by the California Department of Fish and Game. An annual Junior dove hunt is held on this parcel. In 2000, 45 hunters harvested 268 doves. Although there are no current plans to expand hunting opportunities on the existing Westlands Site, as land is acquired management for hunting will be considered. Similarly, as the site is enlarged, other recreational uses such as wildlife and wildflower viewing and environmental education will be expanded.

2. Alpaugh Site

a. Cover Crop

Limited cover crops have been planted on the Alpaugh Site. However, as lands are acquired cover crops may be used as an interim management tool.

b. Grazing

Grazing has been implemented at the Alpaugh Site in Sections 14 and 23 (T24S R23E). This grazing was preparatory to planting barley on some experimental areas and seeding of native plant species on approximately 320 acres. Experimental grazing management techniques that favor native plant species may be explored by the BLM on the Alpaugh Site.

c. Recreational Uses

In January 2001, safflower was planted in portions of Section 10 by BLM to provide game bird habitat. Some of the Alpaugh Site will be open to dove hunting in fall 2001. The BLM will be experimenting with seed mixes appropriate for pheasant habitat with the ultimate goal of providing pheasant hunting. As the Alpaugh Site is enlarged, other recreational opportunities such as wildlife and wildflower viewing and environmental education may become available.

V. PHYSICAL IMPACTS

A. Geology

The Westlands Site is located in the western San Joaquin Valley, an asymmetrical basin bounded by the Coast Ranges on the west, the Tehachapi Mountains on the south, the Sierra Nevada on the east and the delta of the San Joaquin and Sacramento Rivers on the north. The axis of the valley trough is closer to the Coast Ranges than to the Sierra Nevada. The basin is filled with alluvium overlying older Mesozoic and Cenozoic marine and continental sediments. The alluvial deposits underlying the central San Joaquin Valley were shed from the adjacent Coastal and the Sierra Nevada ranges and vary in thickness from 900 to 3,300 feet (Miller et al.1971). The Sierra Nevada consists mainly of granitic and metamorphic rocks of pre-Tertiary age while the Coast Ranges are composed primarily of folded and faulted beds of Cretaceous age marine shale and sandstone in the north and Cenozoic age sandstone and shale in the south (Prokopovich 1987). Bull (1964a), identified a series of alluvial fans derived from sediments from the coastal ranges that form the western margin of the San Joaquin Valley in the study area.

The Westlands Site is located in the trough of the San Joaquin valley in Western Fresno County. The geology of the site is represented schematically in the far right portion of Figure 13. The site is underlain directly by flood basin deposits derived from overbank deposition from the San Joaquin River and Fresno Slough. The flood basin deposits consist of fine textured, moderately to densely compacted clays that range in thickness from 5 to 35 feet (Belitz and Heimes 1990). The flood basin clays have low permeability and greatly impede the downward movement of water. On the northern part of the site (in Section 10), the flood basin deposits rest upon well sorted micaceous sand derived from the Sierra Nevada . The Sierran sands are highly permeable, reduced in oxidation state, and vary in thickness between 400 to 500 feet in the project vicinity. On the southern part of the site (in Sections 15 and 16), the flood basin deposits overlie sediments derived from the coastal ranges. The coastal range sediments inter-finger with Sierran sands in the project vicinity, and are oxidized and primarily fine grained. The Corcoran clay is a regionally extensive fine grained lake bed deposit that underlies the site at a depth of approximately 500 feet.

B. Soils

Soils in the Westlands Site consist of clays and loams which formed in alluvium derived from igneous and sedimentary rock. Individual soil mapping units in order of abundance in the project area include the Tranquillity clay, Lillis clay, and the Lethent silt loam. The Tranquillity mapping unit is the predominant soil type in the study area and covers approximately 80% of the site, while the Lillis and Lethent mapping units occur exclusively in Section 10 and cover the remainder of the site (Figure 14). The Tranquillity clay is a very deep, poorly to moderately drained saline-sodic soil found on low-lying alluvial fans and flood plains with slopes between 0 and 1%. The permeability of this soil is slow and the unit is suited to growing irrigated salt tolerant crops, or for wildlife habitat (USDA 1996). Runoff is low, and the hazard of water erosion is slight. The depth to the water table varies and is commonly highest during irrigation applications in the winter and early spring. These soils generally require intensive management to reduce salinity and maintain agricultural productivity. The United States Department of Agriculture (USDA) took soil samples from a test pit located in the NW 1/4 of Section 16 at the site in 1992. The samples were analyzed in the laboratory for particle size, chemistry and mineralogy. These soils consist predominantly of clay sized particles less than 0.002 mm in diameter. The USDA reported that the clay fraction from 6 samples taken from the test pit ranged from 48 to 52% of the total samples. Silt size particles (.002 - .05 mm in diameter) ranged from 36-37% of the total samples, and sand size particles made up from 11-16 % of the total samples (USDA 1992). Total selenium concentrations ranged from 0.5 to 1.1 ppm, and the Electrical Conductivity (EC) of soil water extracts ranged from 3.7 to 10.9 deciSiemens/meter (dS/m). These soils are highly plastic with Plasticity Indices ranging from 23-52%. The predominant clay mineral is Montmorillonite, which can take on water in the crystal lattice, resulting in high shrink, swell potential and development of deep cracks at the soil surface upon drying.

The Lillis clay mapping unit covers about 10 % of the study area in the eastern half of

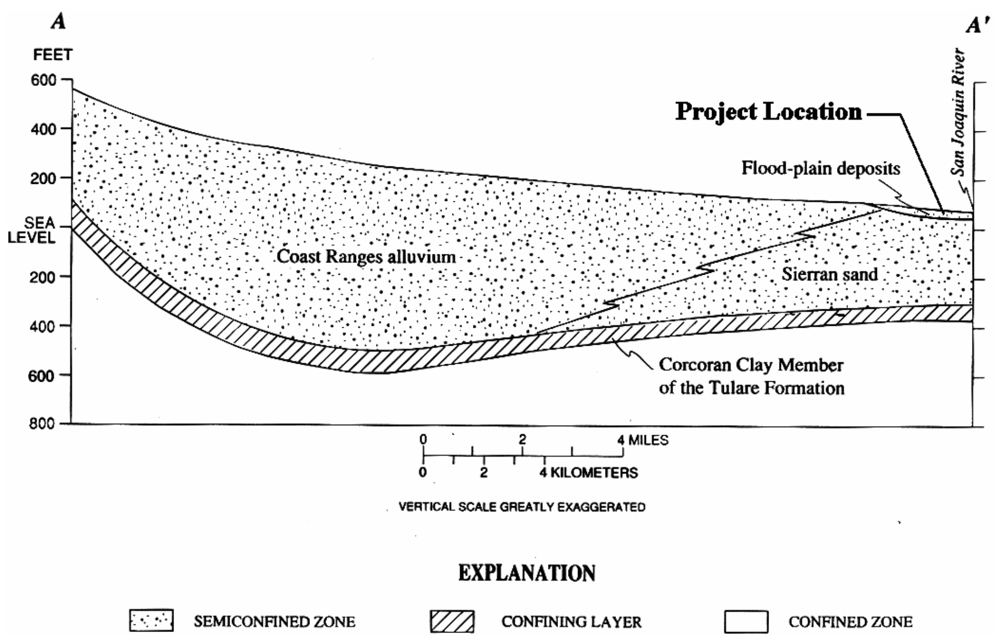

Figure 13. Generalized hydrogeologic cross section in the Land Retirement Demonstration Project vicinity. (Modified from Belitz and Heimes, 1990).

Section 10 (Figure 14). These soils are very deep, poorly drained, saline-sodic soils found typically on flood plains and basins. Permeability of the Lillis soil is extremely slow. The water infiltration rate is high when the soil is dry and the surface cracks are open. As the soil becomes wet and the cracks close, the infiltration rate greatly decreases. Surface water runoff is low and the hazard of water erosion is slight. The unit is used mainly for wildlife habitat and recreation. The USDA took soil samples from a test pit located in the SW 1/4 of Section 10 at the site in 1992. The samples were analyzed in the laboratory for particle size, chemistry and mineralogy. These soils consist predominantly of clay sized particles less than 0.002 mm in diameter. The USDA reported that the clay fraction from 9 samples taken from the test pit ranged from 59 to 66% of the total samples. Silt size particles (0.002 - 0 .05 mm in diameter) ranged from 29-36% of the total samples, and sand size particles made up from 2-7 % of the total samples (U.S.D.A., 1992). Total selenium concentrations ranged from 0.3 to 0.7 ppm, and the Electrical Conductivity (EC) of soil water extracts ranged from 9.6 to 38.6 deciSiemens/meter (dS/m). These soils are highly plastic with Plasticity Indices ranging from 33-61%. The predominant clay mineral is Montmorillonite, which can take on water in the crystal lattice, resulting in high shrink, swell potential.

The Lethent silt loam mapping unit covers about 10 % of the site in the north half of Section 10 (Figure 14). These soils are deep, moderately well drained, saline-sodic soil found on low lying alluvial fans and basin rims. Permeability of this soil is very slow, runoff is slow, and the hazard of water erosion is slight (USDA, 1996).

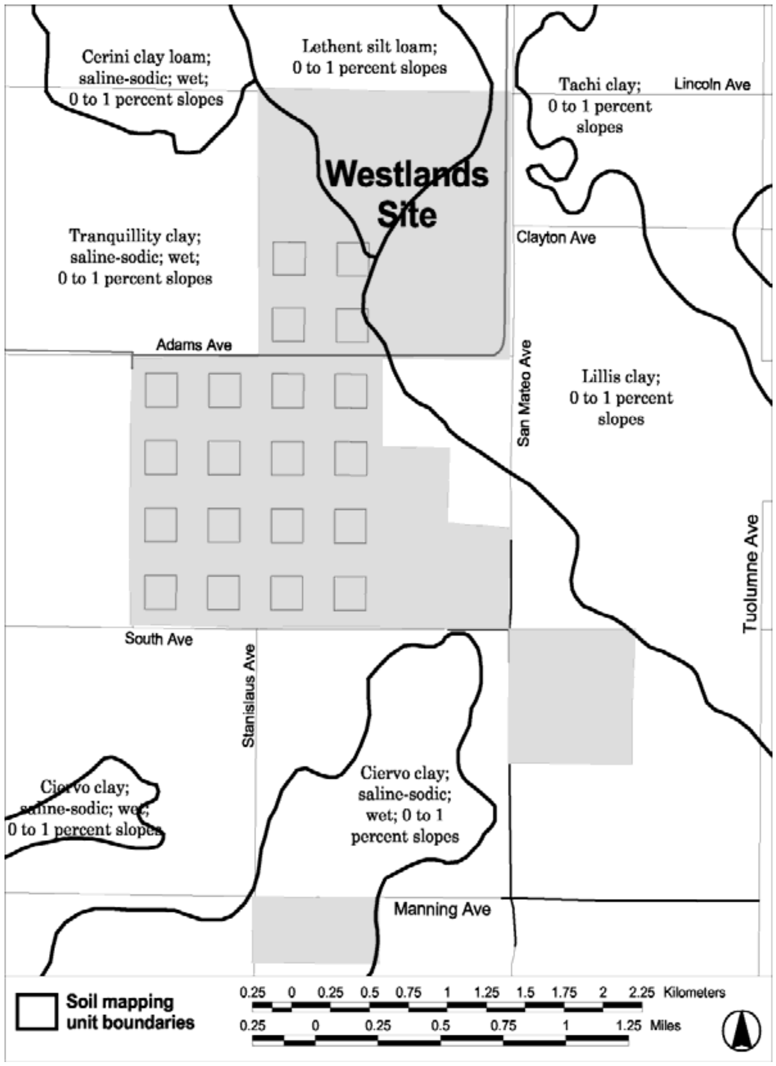

Figure 14. U.S. Department of Agriculture soil mapping units at the Westlands Site.

1. Sampling

The objective of the soil monitoring program for the first year of the demonstration project is to establish baseline soil chemistry for certain parameters of concern. The parameters of concern include salinity, selenium, and boron. The soil sampling was carried out by members of the Inter- Agency Land Retirement team during September and October, 1999. A rectangular sampling grid was chosen for long term monitoring of soil chemistry at the demonstration project site (Figure 15). Soil samples were taken at the land surface at 124 locations. Surface soil samples were taken at the corners of the 10 acre study plots from a depth of 0-1foot (0-30.48 cm) using a shovel. The samples were homogenized in the field at field moist conditions using a putty knife and stainless steel mixing bowls. The samples were collected at each site within a radius of about 1 m of the staked locations. The coordinates of the sample locations were recorded in the field with a Global Positioning System (GPS) receiver with an accuracy of 4 meters.

Discrete soil samples were taken at depths of 0-1 foot, (0-30.5 cm), 2-3 feet (60.9 - 91.4 cm), and 4-5 feet (121.9-152.4 cm) at the centers of the 10 acre experimental plots, in order to assess baseline soil chemistry with depth from the land surface (Figure 15). The depth samples were taken with a 10.1 cm inside diameter split barrel core sampler to a depth of 5 feet (152.4 cm). A continuous core was obtained at each site by pushing the core barrel with the hydraulic system of a Mobile Drill Model B-90 drill rig. Discrete depth samples were taken at a total of 26 locations at the site. The discrete depth samples were homogenized in the field at field moist conditions using a putty knife and stainless steel mixing bowls. The coordinates of the sample locations were recorded in the field with a GPS receiver with an accuracy of 4 meters.

2. Chemical Analyses

All soil samples were analyzed for total and water soluble selenium, sulfate, chloride, electrical conductivity, and moisture. In addition, all surface soil samples were analyzed for boron, magnesium, potassium, sodium, carbonate, and nitrate. The Quality Assurance Project Plan (QAPP) for the Land Retirement Demonstration Project describes in detail the analytical procedures and quality assurance measures taken to ensure soil data quality (CH2MHill 1999). The soils analyses were performed by the United States Geological Survey (USGS) analytical laboratory in Denver, Colorado.

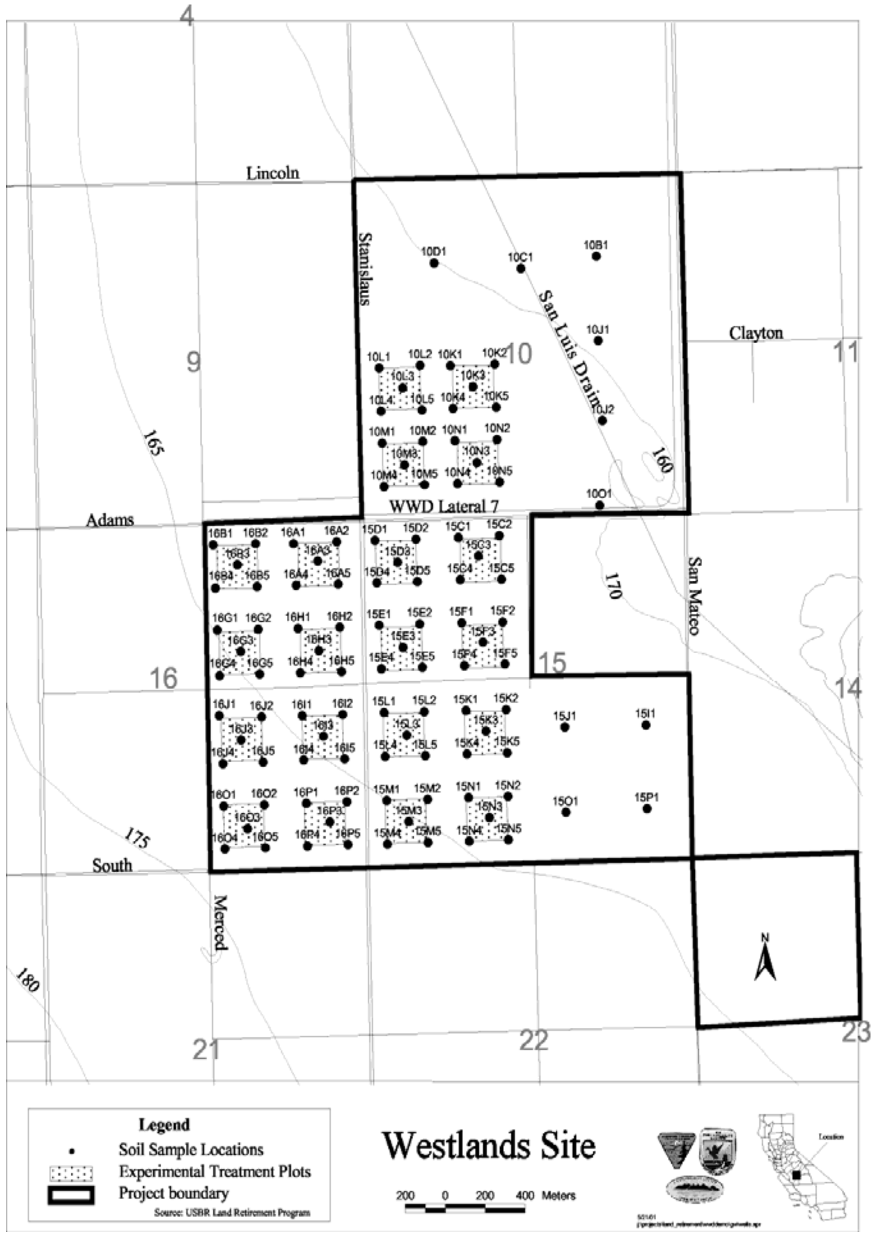

Figure 15. Soil sample locations on the Westlands Site.

The following analysis treats the collected soil samples as if they were randomly collected throughout the sample areas when in fact the sampling plan was laid out on a predetermined grid. It should be noted however that sampling crews did not avoid any areas and sampled at the predetermined grid locations. The grid covers all areas of the survey area and is considered to be close to a stratified random sample of the surveyed fields. In fact, 80 percent of the 0-1 foot samples collected are actually multi increment composite samples from within a one meter radius of the site. A total of 124 separate sites were sampled. At least 500 sample increments are included in these 124 samples. In addition, field replicate samples were collected at about 16 sites in order to determine micro variability of soil constituents. This evaluation will focus on selenium, soluble salts and boron. Both total selenium and soluble selenium content of the soil are evaluated.

3. Total Selenium Analysis

It appears that normal statistics can be used to describe the total selenium data. Geometric means were nearly identical to calculated normal means. It appears that the Lethent and Lillis soil series are a different population than the Tranquillity soil series, therefore the samples were separated on that basis (Table 27).

Table 27. Summary statistics for total selenium in soils.

Soil Series	Soil Depth (ft)	Mean Se (mg/kg)	95% Conf	CV%
Tranquillity	0-1	1.05	± 0.037	18.3
Lillis-Lethet	0-1	0.50	± 0.128	32.0

The variability within soil series populations was very low for total selenium. The coefficient of variation (CV) values of about 50 percent for total selenium is commonly found in section sized tracts of the same soil series or mapping unit in other areas of the west. Since some of the shallow samples were actually multi-increment composites taken from a sample site 2 m in diameter, the impact of micro variation may have been reduced somewhat in the 0-1 foot samples, however the deeper samples had similar CV values using discrete samples.

Variation with sample depth was also low (Tables 28 and 29). There is no statistical difference at the 95 percent confidence level between the mean value of the depth increment samples collected in the Tranquillity soils.

Table 28. Variation in selenium concentration with depth: Tranquillity soils.

Soil Depth (ft)	Mean Se (mg/kg)	95% Conf	CV %	N [(1)]
0-1	1.05	± 0.037	18.3	6
2-3	1.07	± 0.089	19.3	7
4-5	0.97	± 0.084	20.5	8

(1) Number of samples required to estimate the mean at the 95% confidence level and 15% accuracy

Table 29. Variation in selenium concentration with depth: Lillis/Lethent soils. nd= not determined , not enough data.

Soil Depth (ft)	Mean Se (mg/kg)	95% Conf	CV %	N
0-1	0.50	± 0.28	32	18
2-3	0.54	nd	nd	nd
4-5	0.55	nd	nd	nd

(1) Number of samples required to estimate the mean at the 95% confidence level and 15% accuracy

Since the 95 percent confidence intervals overlap, the selenium concentration changes are not significant at the 95 percent confidence levels.

The data was separated into 160 acre quarter sections for the 0-1 foot sampling depth. It would be possible that management and irrigation practices within a field size tract could result in different soil selenium concentrations. A comparison of quarter section surface Se data is presented in Table 30.

There appears to be a trend toward higher selenium values from northeast to southwest across Section 10. This trend is consistent with probable changes in parent material.

Table 30. Selenium concentrations: Tranquillity soil, 0-1 foot depth.

Field	Mean Se (mg/kg)	95% Conf	CV%	N [(1)]
SW10 [(2)]	0.88	± 0.052	13.4	4
NW15	1.14	± 0.113	21.9	9
SW15	1.08	± 0.059	12.0	3
NE16	1.08	± 0.045	9.5	2
SE16	1.03	± 0.080	17.6	6

(1) numbers of samples or sample increments needed to estimate the mean Se concentration of the field at the 95 % confidence level and be within 15 % of the mean.
(2) this field is significantly lower in Se than the other 4 fields.

Since the northeast corner of the area is closer to the old Kings River channel it is probable that granitic alluvium from basin soils makes up a greater proportion of the parent material. Sierra Nevada alluvium is generally very low in selenium. Lands in the southwest portion of the survey area are probably dominated by sedimentary alluvium from Coast Range deposits. The NE quarter of the SW quarter of Section 10 appears to be transitional, but is more like the Tranquillity population than the Lillis/Lethent population.

In terms of selenium concentration, the survey area would be considered moderately elevated when compared to typical western states soils. Data for comparison purposes are presented in Table 31.

Table 31. Comparison of total selenium concentrations in Demonstration Project soils to Western U.S. and San Joaquin Valley soils.

Mean Se western states soils	0.34 mg/kg
Geometric mean western states soils	0.23 mg/kg
Mean Se San Joaquin Valley soils	0.14 mg/kg
Mean Se survey area	1.05 mg/kg
Uncommonly high Se level western soils	1.4 mg/kg
Uncommonly high Se level San Joaquin Valley soils	0.92 mg/kg
Typical sediment toxicity threshold	4 mg/kg

Uncommonly high selenium concentrations in soils exceed 2 standard deviations above the mean value of a very large suite of soils sampled in the Western States (USGS data).

4. Soluble Element Analysis

The soluble element analysis was done on 1:5 soil extracts. One part soil was intermittently shaken in 5 parts water to extract soluble elements. The concentrations found in the extracts were multiplied by five in order to determine the dry weight concentration in mg/ kg soil. All data presented in this statistical analysis are based on mg/kg dry weight of soil. The focus of this analysis will be soluble selenium, boron and electrical conductivity of the 1:5 extract, which is a measure of soil salinity.

The 1:5 extract is also a measure of the residual gypsum present in the soil, therefore it can not be used as a direct measure of soil salinity at field moisture conditions. Soil saturation extract analysis would be needed to better determine soil salinity values for plant yield toxicity, and adaptability purposes . The 1:5 extract is useful for determining the soluble salts and gypsum present in the soil for baseline and trend analysis purposes. A saturation extract would also be useful for determining plant boron and selenium toxicity factors.

5. Salinity and Gypsum Content

Due primarily to the variation in soil gypsum content, the 1:5 soil conductivity values exhibit considerable variation (Tables 32 and 33). This variation was even apparent on 0-1 foot depth interval samples collected from the same site, but about 6 feet apart. A list of these samples is presented below: In order to determine the site value to use in the overall statistical evaluation, samples collected at the same site were averaged into one value.

Table 32. Soil electrical conductivity (EC) 1:5 data summary. id = insufficient data for meaningful determination, ds/m = decisiemens/meter.

Soil	Depth (ft)	Mean EC (ds/m)	95% Conf	CV%	N (1)
Lethent-Lillis	0-1	5.47	1.31	29.7	15
Tranquillity	0-1	3.48	0.34	49.8	43
Tranquillity	2-3	6.26	0.63	23.4	10
Lethent-Lillis	2-3	8.98	id	id	~
Tranquillity	4-5	7.43	0.75	25.6	12
Lethent-Lillis	4-5	11.39	id	id	~

(1) Number of samples needed to estimate mean at 95% confidence and 15% accuracy.

Table 33. Electrical conductivity (EC): Tranquillity soil summary, depth 0-1 foot. ds/m = decisiemens/meter.

Field	Mean EC (ds/m)	95% Conf	CV%	N (1)
SW10	4.9	0.83	38.4	26
NW15	3.99	0.50	28.4	14
SW15	3.56	0.43	26.3	12
NE16	2.48	0.59	54.0	50
SE16	2.29	0.82	79.4	108
ALL	3.49	0.34	49.8	43

(1) Number of samples needed to estimate mean at 95% confidence, and 15% accuracy.

6. Soluble Boron Content

The demonstration area is very high in soluble boron (Tables 34 and 35). Boron may be the most limiting soil constituent in terms of plant growth. Only boron tolerant plants should be considered for revegetation purposes. Much of the boron present at the site appears to be native boron from the soils. Much of the native boron has been leached from irrigated soils, however some of the fields that were only sporadically irrigated still contain extremely high boron concentrations. Boron concentrations tend to increase from southwest to northeast but exhibit considerable local random variability. Boron concentrations appear to increase with depth, especially in formerly irrigated fields.

Table 34. Soil boron data summary. id = insufficient data for meaningful determination.

Soil	Depth(ft)	Mean Se (mg/kg)	95% Conf	CV%	N (1)
Tranquillity	0-1	9.2	1.6	88	133
	2-3	25.6	6.3	59	60
	4-5	39.9	6.5	39.8	28
Lethent-Lillis	0-1	33.5	6.3	23.5	10
	2-3	41.5	id	id	id
	4-5	46.3	id	id	id

(1) Number of samples required to estimate the mean concentration at 95% confidence and 15% accuracy.

Table 35. Boron data summary Tranquillity soil, depth 0-1 foot.
ds/m = decisiemens/meter.

Field	Mean Se (mg/kg)	95% Conf	CV%	N (1)
SW10	18.35	5.07	63.1	68
NW15	9.21	2.14	53.2	49
SW15	9.52	2.50	58.5	59
NE16	4.55	1.31	64.1	71
SE16	3.41	0.59	37.2	24
ALL	9.24	1.59	88.0	133

(1) Number of samples required to estimate the mean concentration at 95% confidence and 15% accuracy.

7. Soluble Selenium Content

The demonstration area contains a significant concentration of soluble selenium. Soluble selenium concentrations tend to increase from southwest to northeast in the Tranquillity series, however as with total selenium, soluble selenium is significantly lower in the Lethent- Lillis soil series than in the Tranquillity series (Table 36). Soluble selenium concentrations range from about 1 percent to nearly 35 percent of the total selenium concentrations. Soluble selenium random variation within the 160 acre field size tracts appears to be high. Some of this variation is due to micro variation in pedon sized soil units (refer to RPD analysis of field replicate samples). It would be very expensive and time consuming to sample soils for soluble selenium based on 95 percent confidence level and 15 percent accuracy. A confidence level of 80 percent and a accuracy of 20 percent is a more realistic goal for the survey area. Soluble selenium is the most variable parameter of all the potentially toxic soil constituents. A statistical summary of soluble selenium concentration found in the survey area is presented in Table 37. All values are mg/kg dry soil.

Table 36. Soluble selenium data summary. id = insufficient data for meaningful determination.

Soil	Depth (ft)	Mean Se (mg/kg)	95% Conf	CV%	N [1]
Tranquillity	0-1	0.031	0.007	118	238
	2-3	0.087	0.037	104.5	188
	4-5	0.147	0.052	89.1	136
Lethent-Lillis	0-1	0.013	0.009	90.8	141
	2-3	0.032	id	id	id
	4-5	0.066	id	id	id

(1) Number of samples required to estimate the mean concentration at 95% confidence and 15% accuracy.

Table 37. Soluble selenium data summary Tranquillity soil series, depth 0-1 foot. ds/m = decisiemens/meter.

Field	Mean Se (mg/kg)	95% Conf	CV%	N [1]
SW10	0.048	0.021	98.7	166
NW15	0.051	0.025	110.1	207
SW15	0.021	0.009	95.0	154
NE16	0.018	0.002	29.7	16
SE16	0.014	0.003	48.6	41
ALL	0.031	0.007	118.0	238

(1) Number of samples required to estimate the mean concentration at 95% confidence and 15% accuracy.

8. Micro-variation Analysis

In order to determine micro-variation associated with the different elements, the soil samplers periodically re-sampled the same sites using the same sampling procedure. The samplers moved about 4 to 6 feet from the original site for the field replicate sample. The relative percent difference (RPD) between the two sample concentrations was evaluated to determine the micro variability in a pedon sized soil body. A summary of the data for the four major constituents of concern is presented in Table 38. About 16 replicate samples were evaluated for each constituent. The data presented in Table 38 indicates that the soluble constituents are quite variable. Total selenium is remarkably consistent at the Westlands Site compared to other areas of the west that have been evaluated for micro-variation.

Table 38. Micro-variation summary. RPD = relative percent difference.

	RPD Range	Mean RPD
Total soil selenium	0 - 40.7	5.8
Soluble soil selenium	0 - 156	30.8
Soluble soil boron	5.7 - 157.1	35.5
EC 1:5	0 - 86.7	28.5

9. Soluble Trace Element Analysis

A summary of data for elements of interest is presented in Table 39. All data are in mg/kg of dry soil units. For this analysis all the samples including the replicate samples were used to calculate the data. All depth increments were also included. This table is intended to give the reader some idea of the toxicity potential of the listed elements at the site and was derived from various published sources (Ayers and Westcot 1985, Gough et al 1979, National Academy of Sciences 1972). The toxicity thresholds are actually based on saturation extract concentrations of the respective elements. Although the mg/ kg values listed are roughly comparable to a saturation extract in terms of a dry weight basis, it should be noted that some elements will dissolve to a much greater extent in a 1:5 extract when compared to a 1:1 extract. A saturation extract on the fine textured soils in the vicinity of the Westlands Site would probably be close to a 1:1 extract.

Table 39. Soluble trace element summary. PT= plant toxicity, LP= Livestock poisoning.

Element	Mean (mg/kg)	Range (mg/kg)	CV	Toxicity Threshold (1)	Hazard
Boron	16.7	1.5-75	95.9	2	**PT**
Selenium	0.053	0.0005-0.45	144.9	0.05	**LP**

(1) For normal crops, sensitive plants or organisms can be damaged at lower concentrations

10. Toxicity Potential

Total soil selenium is moderately high at the site, however total Se concentrations are hard to relate to toxicity potential, although higher concentrations are more likely to be toxic. Since the Westlands Site is high in sulfate, the toxicity hazard should be reduced. Soluble selenium concentrations appear to be extremely variable and generally approach toxicity criteria. Saturation extract data, plant concentrations, and biota concentrations are more direct indicators of toxicity potential (see section ivb).

Boron is naturally elevated in the survey area soils. Irrigation over the years has leached boron from the soils, however, boron is still present in concentrations that are toxic to many plants. Native species adapted to the site were all very tolerant to boron. Any native plant selections for revegetation of this site should be selected for boron tolerance. Elevated Boron is probably the most limiting factor for plant selection, toxicity, and growth.

11. Soil Nutrient Status

The major nutrient elements and their average soil concentration in the demonstration area are tabulated in Table 40. These values are the average values of all soil samples collected.

Table 40. Soil nutrient status.

Soil Nutrient	Conc. (mg/kg)	Lbs/Ac-ft of Soil	Lbs/Ac-ft of Soil	Status
Nitrate	35.7	143	(32.3) as N	Adequate
Phosphorus	0.7	2.8	(6.4) as P_20_5	Low
Potassium	72	288	(347) as K_2O	Adequate
Sulfate	10581	42324	(13966) as S	Very High

(1) Assumes a bulk density of 1.47 g/cc.

C. Weather

Hourly precipitation, temperature, wind and relative humidity data are collected at the California Irrigation Management Information System (CIMIS) weather station # 105, which is located 1.5 miles west of the demonstration project site at the Westlands Water District (WWD) Tranquility Field Office. The CIMIS station is operated and maintained by the California Department of Water Resources (DWR), and can be used to guide crop irrigation scheduling and estimate consumptive water use for various crops. The weather at the site for calender year 2000 is best described as cool and dry. A total of 5.1 inches of rainfall was recorded at the CIMIS station, with most of the rainfall occurring between January and March . The maximum and minimum air temperatures recorded at the CIMIS station were 93 and 34 degrees F in August and December, respectively (Table 41).

Table 41. Estimated barley crop consumptive water use and monthly CIMIS weather data for calender year 2000. Eto = reference evapotranspiration; estimated evapotranspiration (ET) barley =consumptive use; Precip = measusred precipitation at the CIMIS Weather Station, barley COEF = barley crop coefficients.

					AIR TEMPERATURE		
Month	**ETo (in)**	**Barley Coef.**	**Estimated ET Barley (in)**	**PRECIP (in)**	**MAX (F)**	**MIN (F)**	**AVG (F)**
Jan-00	1.03	0.3	0.31	1.62	60	39	49
Feb-00	1.35	1.18	1.59	1.72	63	43	52
Mar-00	3.67	1.18	4.33	0.64	67	42	55
Apr-00	5.3	1.18	6.25	0	76	47	62
May-00	7.27	0.4	2.91	0	84	52	69
Jun-00	7.94	0.2	1.59	0	91	58	75
Jul-00	8.25	n/a	0.00	0	90	57	74
Aug-00	7.81	n/a	0.00	0	93	59	76
Sep-00	5.84	n/a	0.00	0	87	55	71
Oct-00	3.56	n/a	0.00	1.02	75	49	61
Nov-00	1.9	n/a	0.00	0	61	36	48
Dec-00	1.16	n/a	0.00	0.13	58	34	45
TOTAL	55.08		16.98	5.13			
				AVG	76	48	61

The consumptive water use of barley is estimated by calculating the evapotranspiration (ET) of barley. The consumptive water use is valuable in determining necessary application rates of irrigation water. A daily Reference Evapotranspiration (ETo) is calculated from the CIMIS weather data by the DWR. ETo is a term used to estimate the evapotranspiration rate of a reference crop expressed in either inches or millimeters. The reference crop used for the CIMIS program is grass, which is close clipped, actively growing, completely shading the soil, and well watered. ETo varies by location, time, and weather conditions. The main factors that influence ETo include incoming radiation (energy from the sun), outgoing radiation (sensible energy leaving the earth), the amount of moisture in the air, air temperature, and wind speed (DWR 2000). The ETo value can be used to estimate the consumptive water demand of an agricultural crop. ETo can be estimated quite accurately through the use of a "model" (a series of mathematical equations). The "model" that is used in CIMIS is a version of Penman's equation modified by Pruitt/Doorenbos (Proceedings of the International Round Table Conference on "Evapotranspiration", Budapest, Hungary 1977). It also employs a wind function developed at University of California, Davis. The version used in CIMIS uses hourly weather data to calculate daily ETo instead of daily weather data. Hourly averages of weather data are used in the "model" to calculate an hourly ETo value. The 24 hourly ETo values for the day (midnight to midnight) are summed to result in a daily ETo (DWR 2000). Hourly values of net radiation, air temperature, wind speed and vapor pressure are the inputs used to calculate ETo. Air temperature, wind speed, and vapor pressure are measured directly at each weather station. Hourly net radiation is estimated using a method developed by the University of California. This method uses solar radiation, vapor pressure, air temperature, and a calculated monthly cloud coefficient (DWR 2000).

D. Irrigation

A cover crop of sterile barley was planted at the site to provide weed and dust control. Approximately 4.9 inches of irrigation water was applied to 880 acres of barley at the site during 2000 (361 acre-feet applied over 880 acres). The water was applied using a hand moved sprinkler irrigation system in 12 hour sets during the time period from March 23 to April 26. The consumptive water use for the barley crop was estimated by multiplying the CIMIS reference evapotranspiration (ETo) data by published crop coefficients (Table 41). As shown in Figure 16 and Table 41 the estimated consumptive water demand of the barley crop (ET barley) exceeded the combined monthly precipitation and applied irrigation water during the irrigation period in March and April. It is therefore unlikely that any of the applied irrigation water contributed significantly toward deep percolation (recharge) to the shallow groundwater underlying the site during this time. Precipitation at the site exceeded consumptive crop demand in the months of January (+0.31 inches), February (+0.31 inches), October (+1.02 inches) and December (+0.13 inches) (Figure 16, Table 41). It is likely that due to dry soil conditions, the timing of the rainfall, and evapotranspiration of plants within the research plots that most of the moisture from precipitation was either evaporated or added to the soil moisture reservoir and thus did not contribute toward deep percolation (recharge) to the shallow groundwater. Continued declining groundwater level trends observed in the shallow monitor wells and sumps at the site during calender year 2000 support this inference.

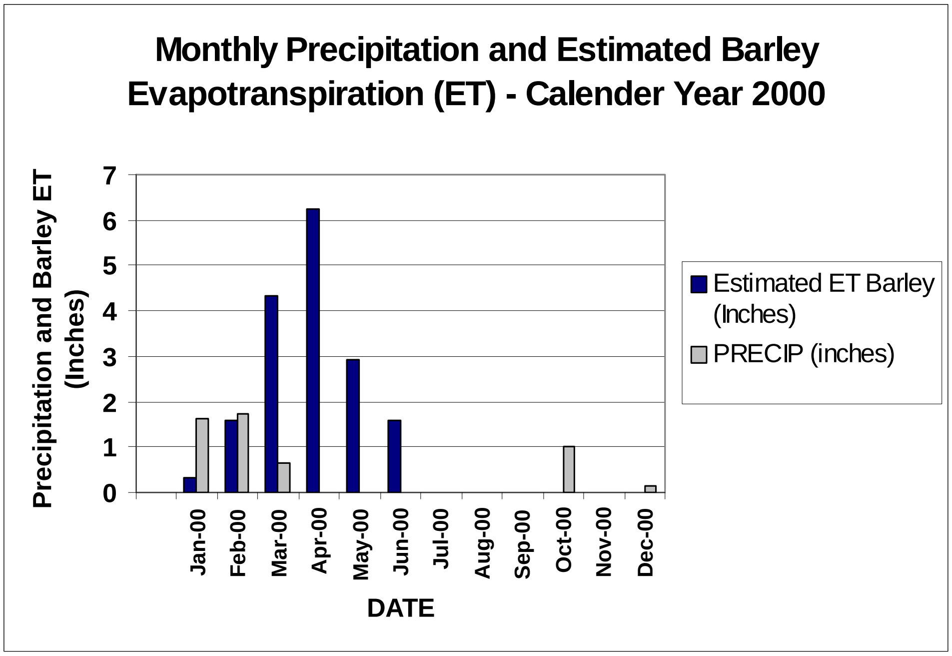

Figure 16. Monthly precipitation and estimated barley crop water use (ET) for calendar year 2000 at the Westlands Site.

E. Hydrology and Surface Water Monitoring

The natural drainage in the study area is to the east and northeast with ground surface elevations ranging from 169 feet above mean sea level (AMSL), in the southwest corner of the site to about 162 feet AMSL in the northeast portion of the site. The land surface in most of the study area has been laser leveled to facilitate irrigation of row crops. There are no perennial surface water bodies on the site. Shallow ephemeral surface water ponds may form on low lying portions of the study area due to localized sheet flow runoff during prolonged winter storm events. Surface water courses within the area consist principally of irrigation supply canals, and irrigation return flow ditches. Three irrigation tailwater ditches traverse the site on Sections 15 and 16. Tailwater is irrigation water that does not penetrate the soil, and runs off the irrigated cropland. Tailwater is usually collected in a surface water pond and recirculated into the irrigation system. Fresno Slough, which is located approximately 1 mile east of the study area, is the largest perennial surface water body in the vicinity of the project. Fresno Slough receives flood flow releases from the North Fork of the Kings River and serves as a storage reservoir for federal irrigation water from the Delta Mendota Canal. Fresno Slough also occasionally receives flood flows from Panoche Creek, which rises in the Coast Ranges to the west, and flows out onto the Panoche Fan during winter storm events. No surface water ponding was observed at the site that persisted more than 30 days during the calender year 2000, and thus no surface water samples were taken for chemical analysis.

F. Regional Groundwater System

The groundwater flow system on the west side of the San Joaquin Valley is strongly influenced by a fine textured, low permeability clay layer known as the Corcoran clay, member of the Tulare Formation. The Corcoran clay is a thick lake bed deposit that divides the groundwater flow system into an upper semi-confined aquifer and a lower confined aquifer. The Corcoran clay is present at a depth of approximately 500 feet beneath the site. The semi-confined aquifer underlying the west side of the San Joaquin groundwater basin consists of three distinct hydrogeologic units: Coast Ranges alluvium, Sierran Sand and flood basin deposits (Figure 13). These units all differ in texture, hydrologic properties and oxidation state. The flow system has undergone considerable change since the development of irrigated agriculture in the region. Under natural conditions recharge to the upper aquifer was primarily from infiltration of stream water from intermittent streams flowing from the Coast Ranges. According to Davis and Poland (1957) and Belitz and Heimes (1990), rainfall was an insignificant mechanism for recharging the aquifer system. Discharge from the aquifer system under natural conditions was primarily from evapotranspiration and to streams along the valley trough.

The following two paragraphs are excerpts from Belitz and Heimes (1990), and provide an excellent description of the history of groundwater development on the west side of the central San Joaquin Valley (SJV).

> "Agricultural activity in the area and the groundwater flow system response on the west side of the SJV began as early as the 1870s, but large-scale farming and irrigation did not occur until the First World War. Irrigation with groundwater expanded rapidly in the 1920s and steadily increased until World War II. After World War II, the price of commodities stimulated increased agricultural growth and by the early 1950s nearly one million acre-feet of water was being pumped from the aquifer system within WWD. Most of the water was pumped from beneath the Corcoran Clay member of the Tulare Formation. The increase in irrigated acreage and in pumpage significantly altered the groundwater flow system. Percolation of irrigation water past crop roots greatly exceeded infiltration of intermittent stream water and replaced the latter as the primary mechanism of recharge. Discharge of water through wells and evapotranspiration from crops replaced natural evapotranspiration as the primary mechanism of discharge. Postdevelopment recharge during 1961-77 was more than 40 times greater than the estimated predevelopment values for the Central Valley. Pumping of groundwater affected the hydraulic head and the direction of flow in the system. The most pronounced changes occurred in the lower confined zone. By 1952, the potentiometric surface of the confined zone was drawn down 100 to 200 feet from the presumed predevelopment altitude. Agricultural pumpage in excess of recharge continued for more than a decade after 1952 and led to further lowering of the potentiometric surface of the confined zone. By 1967, the potentiometric

surface had been lowered by hundreds of feet over much of the western valley. Pumping lifts exceeded 890 feet over parts of the area, and land subsidence of more than 2 feet occurred throughout the area, with local subsidence reaching as much as 28 feet."

As a result of land subsidence, increased pumping lifts, and water quality limitations, surface water was imported to the western valley in order to decrease pumpage. Beginning in 1967, surface water imported via the California Aqueduct began to replace groundwater as the primary source of irrigation supply in the area south of Mendota. The availability of surface water led to an increase in the total quantity of water applied, whereas the quantity of water removed from the system by wells decreased. The marked decrease in pumpage has allowed a recovery in hydraulic head. The rise in the potentiometric surface from 1967 to 1984 was nearly one-half the drawdown that occurred from predevelopment conditions to 1967. The potentiometric surface is defined as the level that water from the confined aquifer would rise to in a tightly cased well completed in the confined aquifer. Agricultural development also has affected the semiconfined zone. Increased rates of recharge resulting from percolation of irrigation water, combined with the rapid post-1967 decrease in pumpage, caused a rise in the altitude of the water table over much of the western valley (Belitz and Heimes 1990).

A regional tile-drain collector system, which was installed during 1980-81, also had appreciable effects on the groundwater flow system. This system underlies about 42,000 acres of land west and southwest of Mendota. During 1981-84, the drains collected an average of 6,900 acre-feet per year. By lowering water levels 1 to 3 feet in the drained area, the tile drain collector system was effective in decreasing the total area characterized by a water table within 5 feet of the land surface. Maps of depth to water table indicate that in April 1976 about 41 percent of the area later serviced by drains had a water table within 5 feet of the land surface. By April 1984, the size of this area had decreased to 6 percent of the drained area. In contrast, in an area of equivalent size, topographic relief, and geomorphic character, but not underlain by regional tile drains, the size of the area underlain by a water table within 5 feet of the land surface increased from 8 square miles in 1976 to 18 square miles in 1984 (Belitz and Heimes 1990). The subsurface drainage system in the vicinity of the Westlands Site was plugged in 1986 using a system of earthen and steel plugs and slide gate structures. The plugs were placed on a spacing of approximately one-quarter mile along the drain laterals, which are located generally upslope of the demonstration project. Groundwater monitoring conducted as part of the drainage system removal in the vicinity of the plugs indicated the plugs performed adequately in stopping the flow of subsurface drain water through the system (USBR 1986).

The semi-confined aquifer above the Corcoran clay is now nearly fully saturated in much of the western San Joaquin Valley. An area covering 228,000 acres in the demonstration project vicinity is underlain by a water table less than 5 feet from the land surface (DWR 1997). The concept of mitigating the drainage problem by retiring the land from irrigated agriculture is straightforward. The high water table results from an imbalance in the water budget as water is being applied at the land surface at a rate that exceeds the carrying capacity of the groundwater system, resulting in high groundwater levels in the absence of a subsurface drainage system. By greatly reducing irrigation by land retirement, the primary source of recharge to the shallow aquifer system is terminated, resulting in a declining water table beneath the site.

G. Conceptual Site Model - Groundwater

Depths to the water table in vicinity of the study area vary seasonally with the highest water levels generally corresponding to the irrigation season in the winter and spring, and the lowest water levels occurring in the summer and fall. The depth to the groundwater table beneath retired parcels of land is an important consideration. Direct evaporation of poor quality groundwater from a shallow water table could potentially result in increasing soil salinity and increasing concentrations of trace elements on or near the land surface. In general, the closer the water table is to the land surface, the higher the rate of direct evaporation and associated soil salinization. The conceptual model for land retirement assumes that the high water table conditions exist due to percolation of irrigation water applied on site. When the land is retired irrigation is greatly reduced, and therefore the source of recharge to the high water table is cut off; resulting in a declining water table. This conceptual model assumes that lateral inflow from “up slope” lands that continue to be irrigated is small, and that the predominant direction of groundwater flow in the upper aquifer system is downward. Groundwater monitoring data obtained at the demonstration site to date support this conceptual model.

1. Perched Water Table

The demonstration site is located in the Valley trough and is underlain by a flood basin clay deposit with a thickness of about 30 feet that rests directly upon coarser Sierran Sand deposits. Groundwater monitoring data indicate that perched water table conditions exist at the site. Belitz and Heimes (1990) noted perched conditions in the study area. According to the authors, “Pumping from the Sierran deposits has lowered groundwater levels in the Sierran sand below the interface between the overlying flood basin deposits and the Sierran sands, producing an unsaturated zone “ (between the two units). “The low diffusivity of the clays in the flood basin deposits has allowed these deposits to remain saturated as the water table in the semi-confined zone declined below the interface”. Groundwater level measurements at well clusters at the site indicate perched conditions. Downward groundwater flow gradients measured at well clusters at the site exceeding one are common, and provide evidence that perched water table conditions exist in the shallow groundwater system. The hydrographs for wells 15A1 and 15A2 shown in Figure 17 illustrate typical downward gradients observed at the site. Wells 15A1 and 15 A2 constitute a well cluster, that is the two wells are located side by side but monitor different depths. Well 15A1 is completed at a depth of 26 feet and monitors the shallow groundwater system, while well 15 A2 is completed at a depth of 60 feet, and monitors the underlying semi-confined groundwater system. Water levels observed in well 15A1 are typically 30 feet higher than those in the adjacent well 15 A2. Vertical hydraulic gradients of this magnitude indicate that the upper, perched system is not in direct hydraulic connection with the underlying semi -confined system, and that unsaturated conditions exist between the two units. Pre-project water levels measured in monitor wells and sumps completed in the flood basin deposits (shallow, perched groundwater system) range from less than 5 to greater than 10 feet below land surface, while water levels measured in wells completed in the underlying Sierran sands range from about 40 to 50 feet below land surface.

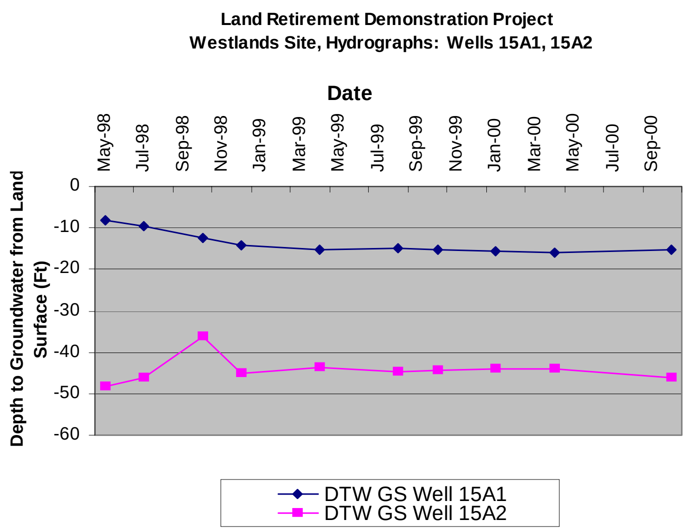

Figure 17. Hydrographs for monitor wells 15A1 and 15A2 showing typical vertical hydraulic gradients measured at the site. DTW GS = Depth to Water from Ground Surface.

2. Groundwater Recharge

Water levels in the shallow, perched groundwater system at the site vary in response to the amount of water added to the system (recharge) and the water removed from the system (discharge). If the recharge to the system exceeds the discharge from the system, additional water is stored in the system, resulting in a rising water table. The drainage problem in the western San Joaquin Valley results from the fact that the water is added to the system (recharge) at a rate that greatly exceeds the discharge capacity of the system. A quantitative water budget for the shallow groundwater system at the demonstration site has not been computed as part of this study, however, it is useful to qualitatively examine the different components of the system in order to better understand the response of the shallow perched water table to land retirement. Recharge to the shallow "perched" groundwater system at the site occurs as a result of deep percolation of irrigation water applied onsite, seepage losses from irrigation tailwater ditches that traverse the site, infiltration of ponded stormwater runoff, and lateral inflow from upgradient irrigated lands. As previously discussed in this report, deep percolation of applied irrigation water past crop roots did not contribute significantly toward recharging the perched groundwater system at the site during 2000.

Seepage of surface water from tailwater ditches that cross the site probably provided the most significant component of recharge to the perched groundwater during 2000. Leakage from the Westlands Water District's distribution system also was detected during the summer of 2000. The District was notified and the leak was repaired. The WWD lateral seven water supply canal that bisects the site was not used during 2000, and therefore did not contribute seepage losses toward recharge of the shallow groundwater system. The site received very little stormwater runoff or direct rainfall. Precipitation data from the CIMIS station indicate that the site received 5.1 inches of precipitation during 2000 (DWR 2000). Due to dry soil conditions, and the timing of rainfall events, infiltration of ponded storm water did not provide a significant amount of recharge to the shallow groundwater system. No ponded surface water was observed on the site. Lateral inflow of shallow groundwater from adjacent irrigated lands undoubtedly provided some recharge to the shallow groundwater system at the site, however due to the extremely low horizontal gradients in the perched groundwater system and low hydraulic conductivities of the clay soils, lateral subsurface flow onto the site is estimated to be minimal.

3. Groundwater Discharge

Discharge from the shallow "perched" groundwater system at the site occurs as a result of direct evaporation from the shallow water table, transpiration of groundwater by vegetation, downward seepage losses of water to the underlying regional groundwater table, and lateral flow to adjacent down gradient properties. The most significant components of discharge from the shallow groundwater system at the site are direct evaporative losses from the shallow water table and seepage losses to the underlying semi-confined aquifer. Lateral outflow of shallow groundwater to adjacent lands is expected to be minimal due to the extremely low horizontal gradients in the perched groundwater system and low horizontal hydraulic conductivities of the clay soils. Transpiration of perched groundwater by vegetation was also minimal. The barley cover crop was the predominant vegetation present at the site, and the high salinity of the shallow groundwater and the shallow rooting depth of the cover crop preclude a significant amount of transpiration of the shallow groundwater by the barley.

H. Groundwater Level Monitoring

One of the objectives of the Demonstration Project is to measure the response of the shallow water table to land retirement. There are 50 monitor wells and three drain sumps in the project vicinity that are used to measure groundwater levels beneath the site on a quarterly basis. The well and sump locations and summary statistics are shown on Figure 18. Existing wells constructed prior to the 1998 purchase of the demonstration project lands were installed by WWD and the USBR for the primary purpose of measuring depths to groundwater beneath drainage impacted lands in WWD. These existing wells are constructed of PVC casing ranging in diameter from 0.75 to 4 inches and vary in depth from 3 to 86 feet below the ground surface. These wells were installed using various construction techniques that range from jetting a short length of pipe into the ground to standard rotary drilling with hydraulic drill rigs. During the summer of 1999, the USBR installed 15 additional wells for the purpose of measuring groundwater levels and obtaining representative groundwater samples for water quality analyses for the Land Retirement Demonstration. The new wells were installed using a hollow stem auger drill rig and are constructed of 2 -inch PVC casing. Well construction diagrams for the new wells are included in the 1999 Anuual Monitoring Report (Selmon, et al 2000). Well construction diagrams for the previously existing wells are unavailable. There are also 18 subsurface drain water collection sumps located in a north to south alignment bisecting the northern half of Section 15 at the site. The sumps are part of an experimental drainage system that was installed at the site during the 1960's. Subsurface tile drains lines were installed beneath the northwest quarter of Section 15 at a depth of approximately 8 feet, with a drain spacing of approximately 150 feet. The drain lines are approximately 6 inches in diameter and discharge to 3 foot diameter concrete sumps that are open to the atmosphere. Water levels have been measured quarterly in three of the drain sumps at the site (Figure 18).

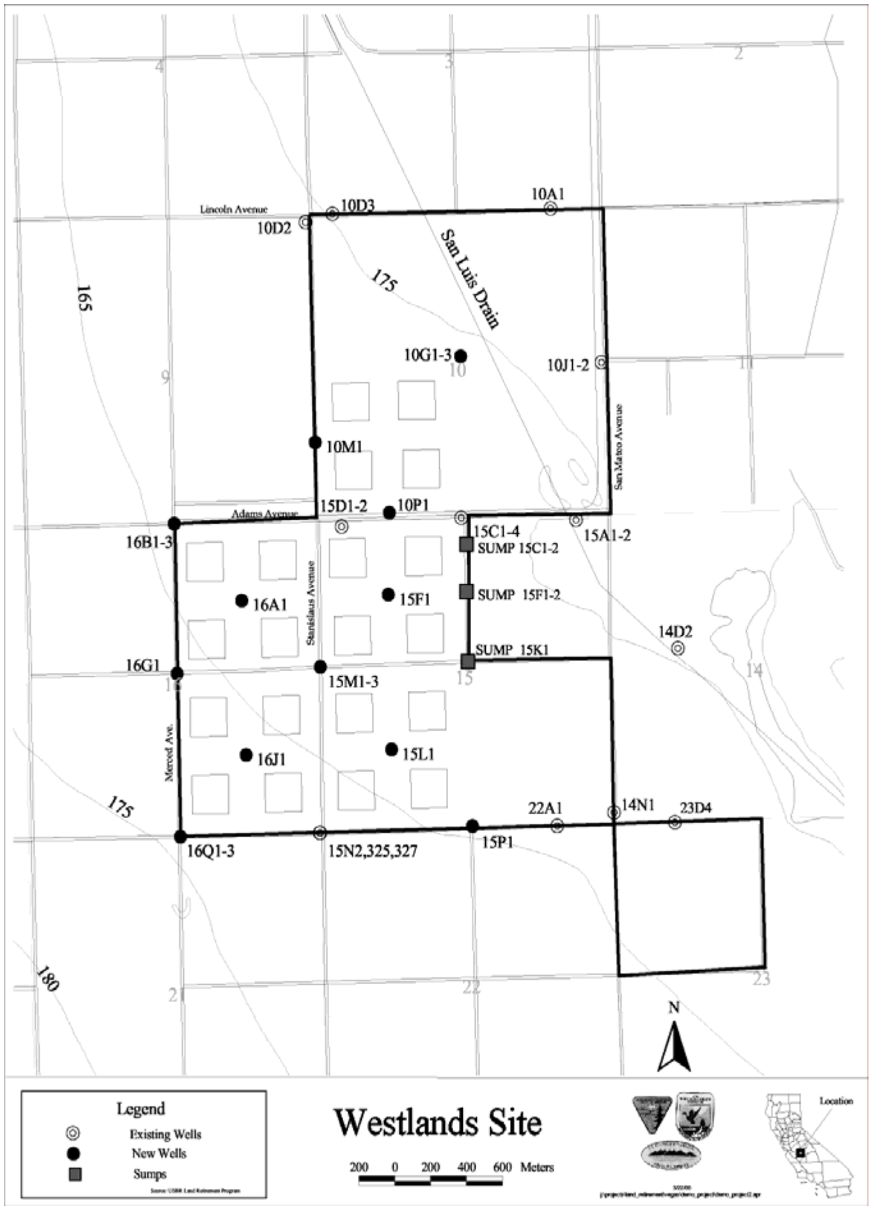

Figure 18. Monitor well and sump location map, Westlands Site.

1. Groundwater Levels

Groundwater monitoring at the demonstration site to date supports the conceptual model of a declining shallow groundwater table in response to land retirement. Dry climatic conditions observed during the first two years of monitoring undoubtedly also contributed toward a declining shallow water table. A hydrograph is a commonly used method to graphically display groundwater level trends. Hydrographs are plots of water levels measured in monitor wells over time. A declining trend in groundwater levels for the shallow perched groundwater system at the site is illustrated by the hydrographs shown in Figure 19. The hydrographs represent water levels measured in three drain sumps (15C1, 15F2, 15K1) during the time period from July 1998 to July 2000. The drain sumps are connected to tile drain lines that underlie the northwest quarter of Section 15, and are useful for measuring shallow groundwater trends in that portion of the site. The drain sump locations are shown on Figure 18. All three of these sumps show an overall declining trend in groundwater levels for the period of record. Total water level declines observed in sumps 15C1, 15F2 and 15K1 are 4.5, 3.0, and 2.4 feet, respectively. Sumps 15C1 and 15 F2 were observed to be completely dry starting in January 2000, while sump 15C1 was observed to be completely dry starting in October 2000. A declining water level trend was observed at the southwest corner of Section 15 in monitor wells 325 and 326. The hydrographs and locations for these wells are shown in Figure 18 and 20. The total water level declines observed in wells 325 and 326 for the period of record are 5.2 and 5.6 feet, respectively. A similar declining trend was observed in wells 15M1 and 16B1 (Figure 21). The total water level declines observed in wells 15M1 and 16B1 were 3.5 and 3.9 feet, respectively.

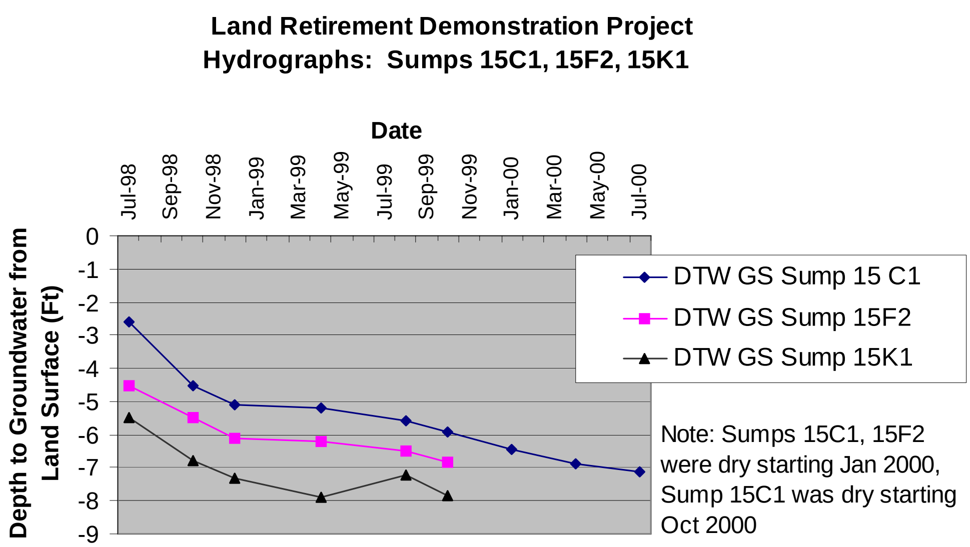

Figure 19. Hydrographs for three agricultural drain sumps at the Westlands Site showing a decliining shallow groundwater trend. DTWGS = depth to water from ground surface.

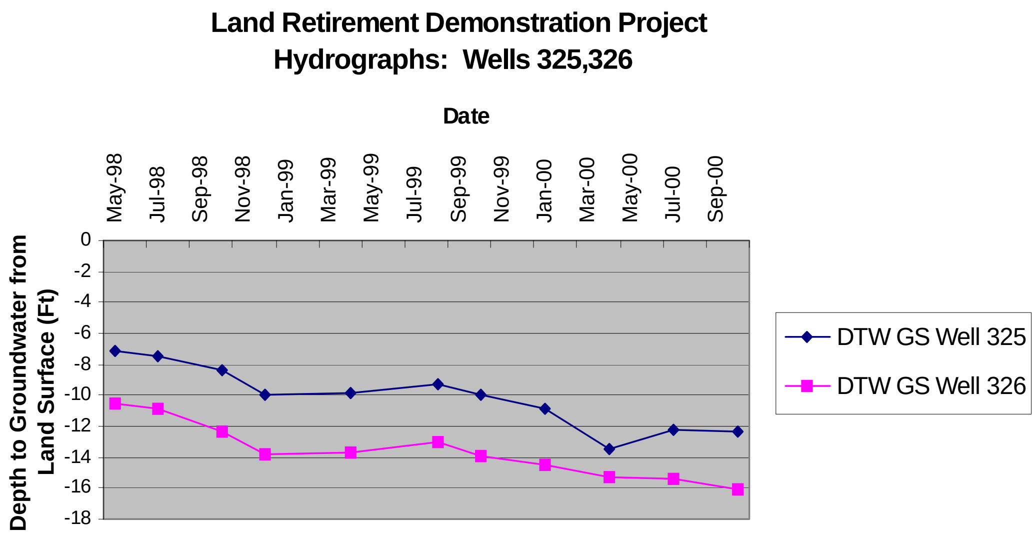

Figure 20. Hydrograph for monitor wells 325 and 326 at the Westlands Site showing typical vertical hydraulic gradient and the declining shallow groundwater trend observed.

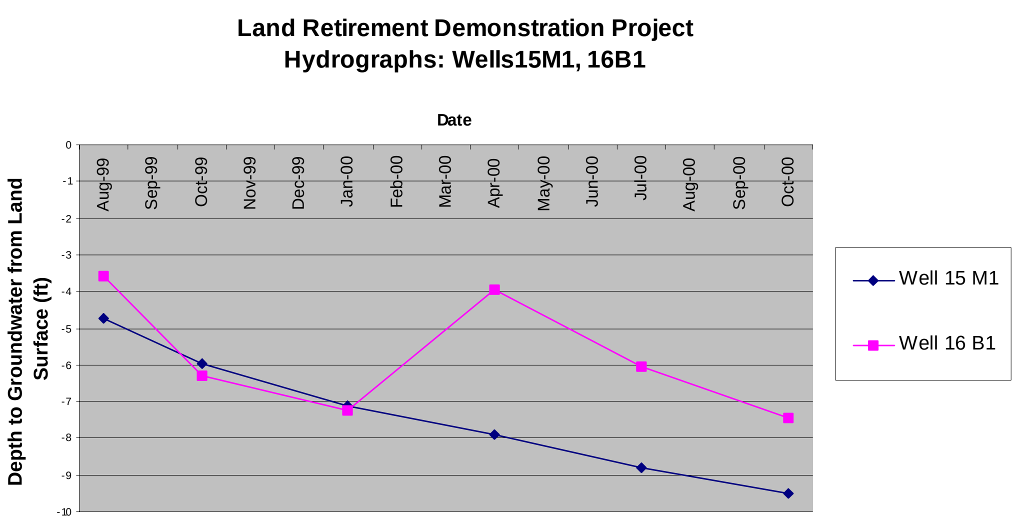

Figure 21. Hydrograph for monitor wells 15M1 and 16B1 at the Westlands Site showing and overall declining shallow groundwater trend.

Synoptic depth to groundwater maps are another useful way to portray the decline of the shallow water table beneath the demonstration project lands. Figure 22 and 23 show the depth to groundwater from the land surface as measured in monitor wells at the site in October 1999 and October 2000, respectively. The depth to groundwater data was contoured using Environmental Systems Research Institute (ESRI) Arcview Spatial Analyst software to produce the maps. The time of year shown on the maps generally corresponds to seasonal low groundwater levels in the area. During October,1999 approximately 30 % (600 acres) of the site was underlain by a water table within 7 feet of the land surface. During October 2000 approximately 3 % of the site (55 acres) was underlain by a water table within 7 feet of the land surface. Another aspect of the site hydrogeology shown by the synoptic maps is the fact that the site can be divided into two distinct areas based on the depth to groundwater observations. The depth to the water table north of Adams Avenue (Section 10) is significantly greater than that observed south of Adams Avenue. The differences can be attributed to two factors. This area of the site (Section 10) has been retired from irrigated agriculture since 1994, and has not received significant application of irrigation water (groundwater recharge) since that time. Section 10 is also underlain by more permeable Sierran sand deposits, which transmit groundwater more rapidly than the area south of Adams Avenue, which is underlain by less permeable deposits derived from the coastal ranges.

The extent to which the declining shallow water table trend is attributable to land retirement alone is uncertain. The combination of dry climatic conditions and greatly reduced irrigation applications associated with land retirement have resulted in measurable shallow water table declines at the demonstration site during the first 2 years of monitoring. It is useful to examine water levels from a well located offsite to gain insight into “background” water level trends in the vicinity of the project. Table 41 shows the measured water level declines for ten shallow wells within the demonstration project in comparison to an offsite well (Well 15A1) for two different periods of record. Well 15 A1 is located in the northeast corner of Section 15 along the San Luis Drain right-of -way (Figure 18). Water levels in Well 15A1 are presumably unaffected by land retirement and serve as an indicator of “background” conditions. The average water level decline in the ten onsite wells exceeds the water level declines in well 15A1 by 2.5 and 1.2 feet, for the two periods of record shown in Table 42. The fact that water level declines observed onsite exceed those observed offsite indicates that land retirement has contributed to the declining water table beneath the demonstration project. Continued groundwater level monitoring over the 5 year demonstration project under a variety of climatic conditions will provide further insight into the effects that land retirement has on shallow water table conditions in the project area.

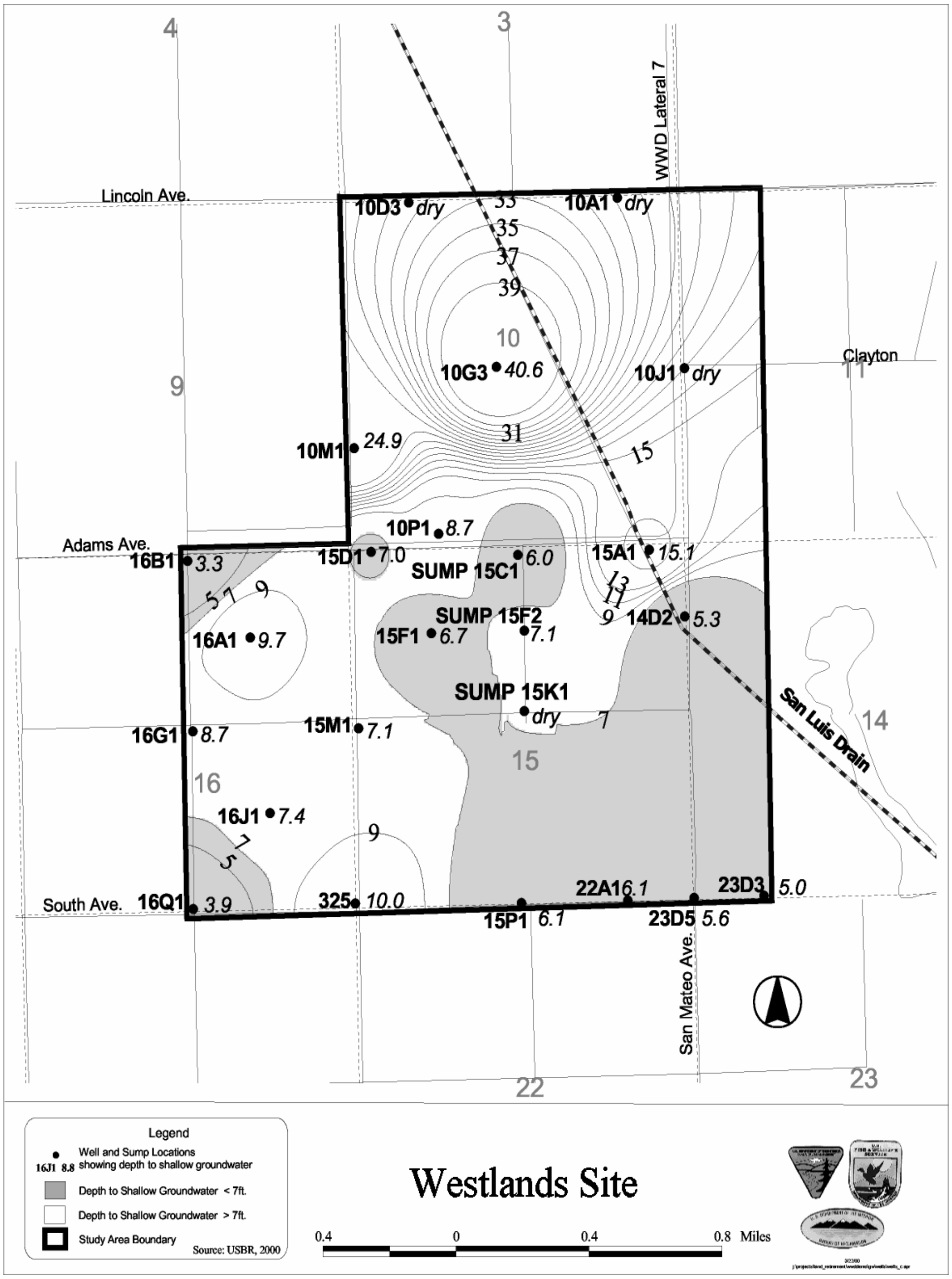

Figure 22. Depth to shallow groundwater, October, 1999. The project area underlain by shallow groundwater within 7 feet of the land surface is approximately 600 acres.

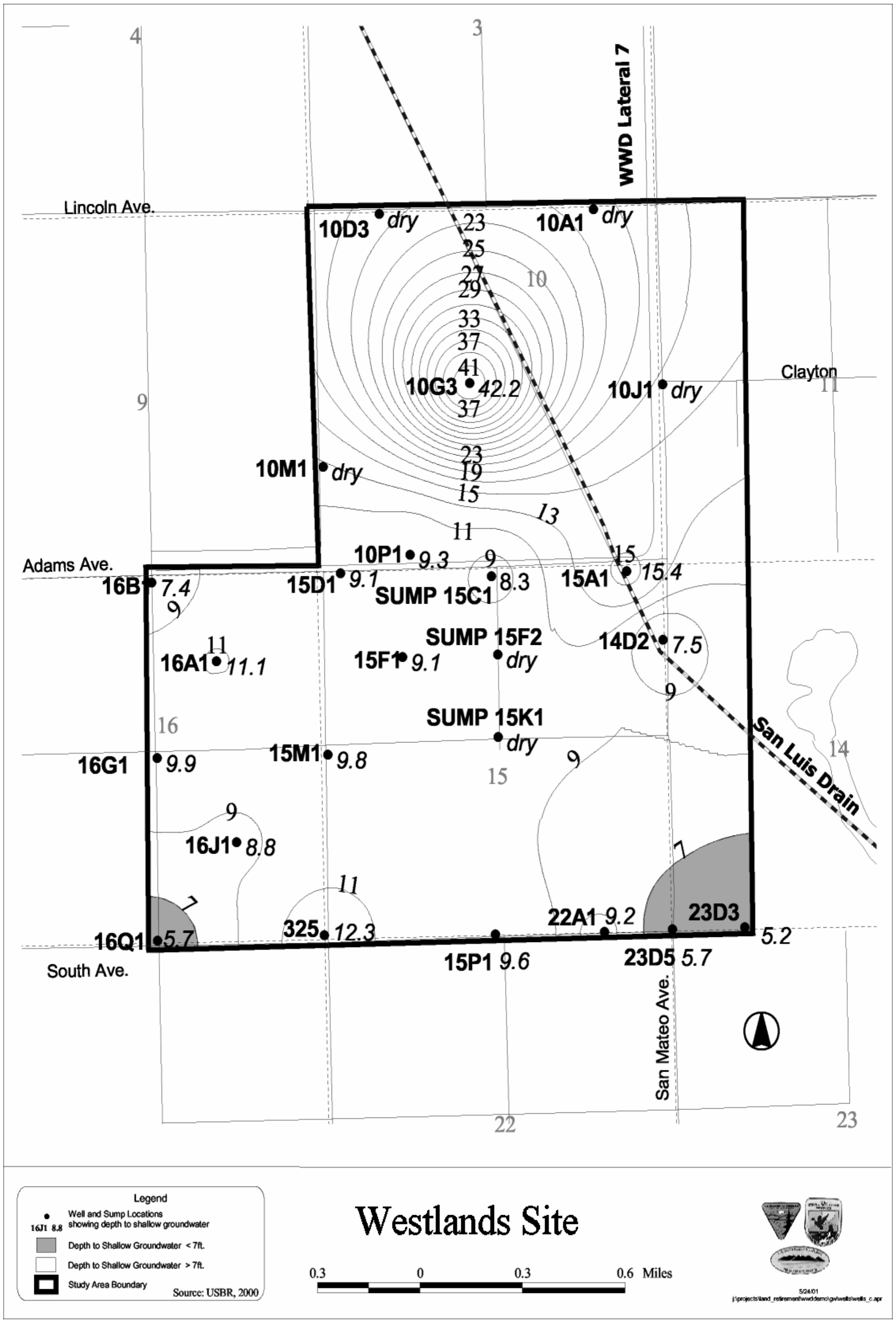

Figure 23. Depth to shallow groundwater, October, 2000. The project area underlain by shallow groundwater within 7 feet of the land surface has been reduced to approximately 55 acres.

Table 42. Water level declines observed for ten onsite project wells compared to an offsite well (Well 15A1) for two overlapping periods of record.

Well	Water Level Decline (Ft) Aug. 1999 - Jan. 2001	Water Level Decline (Ft) Jan. 2000 - Jan. 2001
15P1	5.18	2.78
15L1	0.77	0.57
15M1	4.42	2.79
15F1	3.03	2.49
16G1	4.28	1.55
16Q1	3.86	1.17
16A1	5.01	1.82
16B1	4.49	0.81
15N1(325)	3.82	2.22
15C1	2.60	1.37
MINIMUM	0.77	0.57
MAXIMUM	5.18	2.79
AVERAGE	3.75	1.76
Well 15A1 (Offsite)	1.26	0.54

I. Groundwater Quality Monitoring

The purposes of groundwater quality monitoring at the site are to establish baseline conditions that can be used as a basis for comparison for change detection analyses, and to collect data that can be used to evaluate exposure risk to wildlife via the groundwater pathway. Baseline groundwater samples were taken on a quarterly basis during the first year of monitoring. Groundwater sampling was conducted in October 1999 and February, May and July 2000. Groundwater samples will be collected on an annual basis during the spring of the subsequent monitoring years over the 5 year project lifetime. The springtime sampling was chosen to coincide with the seasonal high water table in the region. The annual groundwater quality monitoring data will be compared to the baseline data set to evaluate changes in groundwater quality. Unfiltered groundwater samples were taken from 12 wells and two drain sumps to assess baseline groundwater quality at the site. Standard operating procedures for groundwater sampling used by the Mid-Pacific Region of the USBR and those outlined in the Quality Assurance Project Plan (CH2MHill 1999) were employed to obtain groundwater samples.

1. Groundwater Chemical Analysis

Unfiltered groundwater samples were analyzed for major ions (calcium, magnesium, potassium, sodium, chloride, sulfate, total alkalinity), trace elements (selenium, boron, iron, manganese) and isotopes (H-2, O-18 and H-3). Specific conductance (electrical conductivity), pH, temperature and turbidity of groundwater samples were measured in the field at the time of sampling. Flourometric analyses of groundwater samples for selenium were performed by Olsen Biochemistry Laboratories, South Dakota State University. Analyses for isotopes (H-2, O-18) were performed by the USGS Water Resources Division laboratory in Reston, Virginia. Analyses for tritium (H-3) were performed by the USGS Water Resources Division laboratory in Menlo Park, California. All other analyses were performed by Caltest Analytical Laboratory in Napa, California. The Quality Assurance Project Plan (QAPP) for the Land Retirement Demonstration Project describes in detail the analytical procedures and quality assurance measures taken to ensure groundwater data quality (CH2MHill 1999).

2. Groundwater Salinity

A general indication of the total dissolved ionic constituents in the groundwater can be obtained by determining the capability of a groundwater sample to conduct an applied electrical current. This property is reported as specific conductance (also electrical conductivity or EC), and is expressed in terms of the condutivity of a cube of water 1 square centimeter on a side. EC is expressed in units of microSiemens/cm (uS/cm).

Baseline EC data for the groundwater samples collected during the first year of monitoring are presented in Tables 43 and 44. The data show that the shallow, perched groundwater is extremely saline in nature. Salinity in the shallow groundwater and drain sump samples, expressed as specific conductance ranged from 11,500 to 76,980 uS/cm, with a median value of 43,925 uS/cm. By comparison, drinking water typically is less than 750 uS/cm, irrigation water is less than 1,250 uS/cm, and seawater is about 50,000 uS/cm. The groundwater samples obtained from the underlying semi-confined aquifer is much less saline. Salinity in the groundwater samples obtained from the deep wells (greater than 50 feet deep), expressed as specific conductance ranged from 5,630 to 18,580 uS/cm, with a median value of 7,675 uS/cm.

The extreme salinity of the shallow groundwater at the site is a result of the irrigation of saline soils. Naturally occurring salts have been leached from the soil profile under irrigated conditions. Salts have also been transported to the site in the applied irrigation water. Direct evaporation from the shallow water table and transpiration of applied water by crops has concentrated salts in the shallow groundwater, resulting in high concentrations of dissolved solids.

Table 43. Summary of baseline groundwater chemistry data for the shallow wells: field parameters and major ions.

Statistic	Number of Samples	EC(field) (uS/cm)	pH (field)	Calcium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)
Minimum	44	11,500	6.74	250	42	2,300
25th percentile	44	32,620	7.54	400	250	8,725
Median	44	43,260	7.78	420	525	13,000
75th percentile	44	52,350	7.90	450	663	16,500
Maximum	44	76,980	8.37	500	1,300	25,000
Mean	44	41,987	7.73	417	515	13,00

Statistic	Number of Samples	Potassium (mg/l)	Total Alkalinity (mg/l)	Chloride (mg/l)	Sulfate (mg/l)
Minimum	44	7	150	380	4,300
25th percentile	44	20	260	1,150	18,750
Median	44	30	330	2,700	24,500
75th percentile	44	42	423	3,200	31,000
Maximum	44	94	610	4,100	62,000
Mean	44	32	351	2,332	26,330

Table 44. Summary of baseline groundwater chemistry data for the deep wells: field parameters and major ions.

Statistic	Number of Samples	EC(field) (uS/cm)	pH (field)	Calcium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)
Minimum	12	5,630	6.82	280	280	760
25th percentile	12	6,763	7.13	300	300	823
Median	12	7,675	7.21	320	310	1,100
75th percentile	12	17,315	7.28	360	328	2,425
Maximum	12	18,580	7.46	390	350	3,800
Mean	12	10,633	7.21	327	315	1,714

Table 44 (continued). Summary of baseline groundwater chemistry data for the deep wells: field parameters and major ions.

Statistic	Number of Samples	Potassium (mg/l)	Total Alkalinity (mg/l)	Chloride (mg/l)	Sulfate (mg/l)
Minimum	12	6	200	300	2,100
25th percentile	12	9	250	410	2,750
Median	12	13	270	540	3,100
75th percentile	12	14	329	1,700	5,525
Maximum	12	20	340	1,900	7,300
Mean	12	12	277	924	4,067

3. Groundwater - Major Ion Chemistry

Baseline major ion chemistry for the groundwater samples collected during the first year of monitoring are presented in Tables 43 and 44. The groundwater comprising the shallow, perched water, and in the underlying semi-confined aquifer is best described as a sodium sulfate type of water. Sodium is the dominant major cation found in the shallow groundwater samples, with sodium concentrations ranging from 2,300 to 25,000 milligrams/litre (mg/l), and a median concentration of 13,000 mg/l. Sodium is also the dominant major cation found in groundwater samples taken from the deep wells, with concentrations ranging from 760 to 3,800 mg/l, and a median concentration of 1,100 mg/l. Sulfate is the dominant major anion found in both the shallow, perched groundwater and in the underlying semi-confined groundwater at the site.

Sulfate concentrations found in groundwater samples from the shallow wells (less than 50 feet deep) ranged from 4,300 to 62,000 mg/l, with a median concentration of 24,500 mg/l. Sulfate concentrations in groundwater samples from the deep wells (greater than 50 feet deep) completed in the semi-confined aquifer ranged from 2,100 to 7,300 mg/l, with a median concentration of 3,100 mg/l (Figure 24).

High sodium and sulfate concentrations in the groundwater on the west side of the San Joaquin Valley result from weathering of sulfate rich rocks in the adjacent Coast Ranges. Davis (1961) hypothesized that the sulfate in groundwater in the study region originates from the oxidation of organic marine shales containing reduced iron sulfide minerals. Presser and others (1990) have reported oxidation of iron sulfide minerals for west-side streams in the study vicinity. Another significant source of sulfate in the shallow groundwater is gypsum (calcium sulfate) that has historically been applied to soils by farmers in the region as a method of salinity control in the crop root zone.

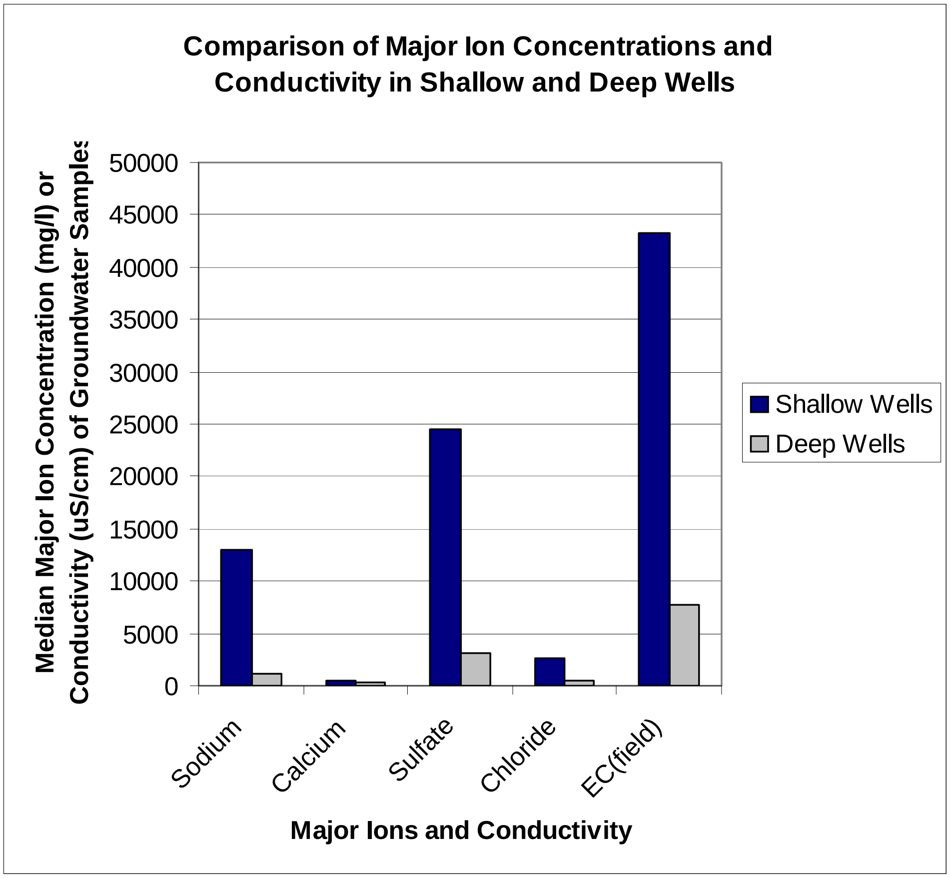

Figure 24. Comparison of dominant major ion concentrations and electrical conductivity for groundwater samples from shallow and deep wells.

4. Groundwater - Trace Elements

The trace elements of concern monitored for this study include selenium and boron. High concentrations of selenium and boron in the shallow groundwater are of concern due to potential toxicity to wildlife and plants. Iron and manganese concentrations were also monitored because they provide insight into geochemical conditions in the groundwater system. A summary of baseline trace element data for the first year of groundwater monitoring is presented in Tables 45 and 46.

Table 45. Summary of baseline groundwater chemistry data for shallow wells: trace elements and tritium.

Statistic	Number of Samples	Boron (mg/l)	Iron (mg/l)	Manganese (mg/l)	Selenium (mg/l)	Tritium (TU)
Minimum	44	10	0.1	0.008	0.005	0.0
25th percentile	44	26	0.8	0.110	0.195	0.9
Median	44	46	2.1	0.230	1.280	2.4
75th percentile	44	55	15.0	1.100	3.812	3.7
Maximum	44	81	160.0	3.900	5.390	6.0
Mean	44	42	19.4	0.757	2.095	2.3

Table 46. Summary of baseline groundwater chemistry data for deep wells: trace elements and tritium.

Statistic	Number of Samples	Boron (mg/l)	Iron (mg/l)	Manganese (mg/l)	Selenium (mg/l)	Tritium (TU)
Minimum	12	10	0.1	0.008	0.005	0.0
25th percentile	12	30	1.1	0.140	0.466	1.2
Median	12	44	8.6	0.494	1.688	2.4
75th percentile	12	53	18.3	1.014	3.383	3.3
Maximum	12	81	160.0	3.900	5.390	6.0
Mean	12	43	32.9	1.018	2.130	2.5

5. Groundwater - Selenium

Selenium concentrations measured in the shallow groundwater wells and sumps (less than 50 feet deep) at the site during the first year of monitoring show considerable spatial variation. In general, selenium concentrations in the shallow groundwater system are extremely high, ranging from 5 to 5,390 micrograms/litre (g/l), with a median concentration of 1,280 g/l. By comparison, the United States Environmental Protection Agency (EPA) water quality criteria for long-term exposure in aquatic environments is 5 g/l (EPA 1988). It becomes clear why the conceptual model of a declining shallow water table is an essential element of land retirement in light of the extremely high concentrations of selenium observed in the shallow groundwater. If these waters were exposed at the land surface, wildlife could be exposed to potentially toxic conditions. Deverel and Millard (1988) concluded that the main factors affecting selenium concentrations in the shallow groundwater of the western San Joaquin Valley are the degree of groundwater salinity and the geologic source of the alluvial soils.

Selenium concentrations measured in the deep wells (greater than 50 feet deep) at the site also show considerable spatial variation. Selenium concentrations found in well 15M3 (69 feet deep), ranged from 1,840 to 1,950 g/l during the first year of monitoring, while selenium concentrations found in Wells 15C3 and 10G3 (83 and 75 feet deep, respectively) range from the analytical limit of detection (< 0.0004) to 0.0005 g/l. The extreme variation in selenium concentration seen in the deep wells may be explained due to differing geochemical conditions found in Coast Range deposits and the Sierran sands underlying the site. Well 15M3 is constructed in Coast Range sediments, while wells 15C3 and 10G3 are constructed in sediments derived from the Sierra Nevada Range. Dubrovsky and others (1993) noted high concentrations of selenium in shallow groundwater in Coast Ranges sediments, and low concentrations in underlying Sierra Nevada sediments in previous groundwater quality investigations in the western San Joaquin Valley. The authors hypothesized that the absence of selenium in groundwater from wells screened in the Sierra Nevada deposits may be due to a redox (chemical reduction or oxidation) process.

Selenium can exist in four valence states; -2,0,+4, and +6. The +6 and +4 valences occur as the oxyanions selenate (Se O_4^{2-}) and selenite (Se O_3^{2-}) under alkaline, oxidizing conditions. Selenate is the most oxidized form of selenium, is relatively mobile in aqueous environments and does not associate with solid phase materials (Hingston et al.1974 ; Frost and Griffin 1977 and Leckie et al., 1980). Fujii and Deverel (1988) reported that the selenium in soil solutions and shallow groundwater in the western San Joaquin Valley is in the selenate form, and a very small percentage of soil selenium is in the absorbed phase. Although no attempt has been made to speciate selenium in groundwater samples from the Land Retirement Demonstration Project, the selenium found in the shallow groundwater at the site probably occurs predominantly as selenate. Under more reduced conditions, such as those found in the underlying Sierra Nevada deposits in the northern part of the site, selenium can exist as elemental selenium (zero valence) and selenide (Se^{2-}).

The solubility of selenate minerals generally is high (Elrashadi et al. 1987), and there are no apparent solubility constraints on selenate in shallow groundwater in the western San Joaquin Valley, even in groundwater saturated with respect to sulfate minerals (Deverel and Gallanthine 1989). Consequently, selenate tends to behave conservatively in oxidizing groundwater. The mobility of selenite in groundwater is severely constrained by adsorption onto a variety of mineral surfaces (Balistrieri and Chao 1987; Neal et al. 1987; Goldberg and Glanbig 1988). The solubilities of the reduced forms of selenium (elemental selenium and selenide) are extremely low (Elrashadi et al. 1987). Field and laboratory studies of selenium contamination at Kesterson Reservoir demonstrated selenium removal by reduction of selenate to less mobile forms (Lawrence Berkely Laboratory 1987; White et al. 1988; Weres, Jaouni, and Tsao 1989). Similar geochemical processes may be responsible for the extremely low selenium concentrations observed in Wells 15C3 and 10G3 at the Westlands Site.

Dubrovsky and others (1993) noted that selenium concentrations in groundwater decreased rapidly at the same depth at which manganese concentrations increase at a research site in the western San Joaquin Valley. The authors concluded that the decrease in selenium is due to a process that occurs under reducing conditions. High concentrations of dissolved iron and manganese in groundwater can indicate geochemically reducing conditions. A similar trend is observed at the land retirement study site when ratios of selenium to manganese concentrations are plotted verses well depth. As shown in Figure 25, the selenium/manganese ratios are generally high in the shallow wells and extremely low in the deep wells, especially those monitoring the Sierran deposits. This supports the conceptual model that oxidizing conditions are prevalent in the shallow groundwater, and that reducing conditions are prevalent in the deep groundwater found in the Sierran deposits. Reducing geochemical conditions in the Sierran deposits probably play a significant role in the extremely low selenium concentrations observed in wells 15C3 and 10G3.

6. Groundwater - Boron

The presence of high concentrations of boron in the shallow groundwater are of concern due to potential toxicity to plants and wildlife. Boron concentrations in the shallow groundwater at the site are extremely high. The boron concentrations measured in the shallow wells range from 10 to 81 mg/l, with a median value of 45.5 mg/l (Table 45). No water quality criteria for boron exist for aquatic life or human health. There is an irrigation water criterion of 750 g/l of boron sensitive crops (EPA 1986). Perry and others (1994) have proposed a toxicity threshold in water for crops and aquatic plants of 10 mg/l. Deverel and Millard (1988) noted that boron is geochemically mobile and present as oxyanions in oxidized, alkaline environments such as the western San Joaquin Valley shallow groundwater. The authors also reported high correlation between log transformed boron and specific conductance data for shallow groundwater in the western San Joaquin Valley. Boron concentrations observed in the deep wells at the site are an order of magnitude lower than those in the shallow wells (Table 46). Boron concentrations measured in the deep wells during the first year of monitoring range from 2.5 to 8.3 mg/l, with a median concentration of 3.2 mg/l. The large difference in boron concentration between the shallow and deep groundwater at the site may be due to adsorption onto soil surfaces or differing geochemical conditions between the shallow and deep groundwater systems. Adsorption of boron on soil particles can affect and limit its solubility (Keren and Bingham 1985). Fujii and Swain (1995) concluded that that the relatively conservative behavior of boron observed in shallow groundwater in the San Joaquin Valley probably reflects the presence of high concentrations of competing constituents for adsorption sites.

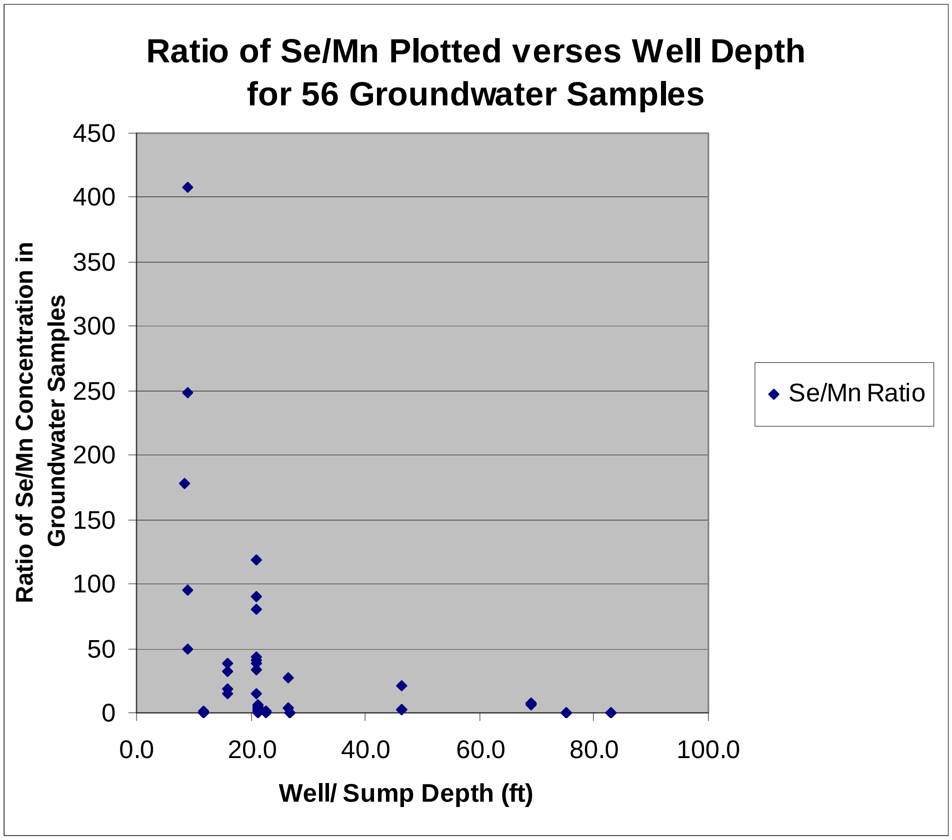

Figure 25. Ratio of Selenium to Manganese (Se/Mn) concentration in groundwater samples plotted verses well depth. The Se/Mn ratio shows a decreasing trend with depth indicating oxidizing geochemical conditions in the shallow wells and reducing conditions in the deep wells.

7. Groundwater - Origin and Isotopic Composition

Groundwater samples were analyzed for tritium and stable isotope ratios of oxygen and hydrogen during the first year of monitoring. A summary of the tritium data is presented in Tables 45 and 46. The oxygen and hydrogen isotope data was not available at the time of publication for this report. The oxygen and hydrogen isotope data can provide insight into the evaporation history of the water, and will be analyzed and presented in the year 2001 annual monitoring report.

8. Groundwater Age

The levels of tritium, a radioactive isotope of hydrogen with a half-life of 12.43 years, rose in the environment during the 1950's and 1960's because of atmospheric detonation of nuclear weapons. Tritium concentrations can be used to develop an understanding of the origin and history of water samples. Tritium concentrations in water samples are reported in tritium units (TU). Prior to 1952, precipitation contained less than 5 TU. Due to radioactive decay, groundwater derived from precipitation before 1952 now has less than 0.5 TU. Groundwater derived from precipitation recharged since 1952, including canal water used as irrigation since 1968, commonly has a tritium concentration exceeding 10 TU. Groundwater with a tritium concentration of less than 1.6 TU either has recharged prior to 1952 or may have originated as post-1952 irrigation water from deep wells. This large contrast in tritium concentration allows comparison of older groundwater, much of which was recharged prior to agricultural development, to young water recharged since 1952 and derived from irrigation (Dubrovsky et al. 1993).

The tritium data from the shallow wells indicate that the shallow, perched groundwater consist of a mixture of water recharged before and after 1952. Tritium concentrations of the shallow groundwater samples range from 0 to 6 Tritium Units (TU), with a median concentration of 2.4 TU. Low tritium concentrations (<1 TU) observed in wells 16Q1 and 16F1 may indicate recharge from irrigation water that was pumped from deep production wells completed in the sub-Corcoran aquifer. The tritium data from the deep wells (Well 15M3 and 16B3) completed in coastal range deposits indicate that the groundwater was recharged before 1952. Tritium concentrations observed in these two wells ranged from 0 to 0.5 TU, with a median concentration of 0.1 TU. The tritium data from the deep wells completed in Sierra Nevada sediments indicate that the groundwater has been recharged since 1952. Tritium concentrations found in wells 15C3 and 10G3 range from 9.6 to 14.0 TU, with a median concentration of 10.5 TU.

VI. CONCLUSIONS

This second annual report covers baseline conditions and the first year of data collection after applying treatments to the Westlands Site. Various descriptions of ancillary trials and methods of restoration applied to LRDP lands have been discussed but monitoring of the trials and restoration has not yet occurred. Accordingly, the following conclusions reflect preliminary trends observed from the Habitat Restoration Study only.

On the Westlands HRS plots imprinting appears to be a successful method of seeding both native annuals and perennials, whereas the planting of seedlings was largely unsuccessful. Seedling failure can be attributed to a lack of water once planted, small size of seedlings, a diversity of seedling quality and hardiness, and other factors. Many of the seeded annuals and perennials survived and produced seed. We expect successful germination in spring 2001.

There was an increase in native plant cover and richness on seeded plots. There also appears to be a trend of increasing abundance and species diversity among invertebrates, birds, and small mammals on the seeded plots. These measures are indicative of successful restoration. The trend of increasing structural heterogeneity on the restored plots is especially noticeable among plants and small mammals on those plots that were both seeded and where microtopographic contours were installed.

The examination of the relationships between habitat components is necessary to determine the success of ecosystem restoration. For example, an increase in vegetation richness and invertebrate abundance should lead to an increase in granivorous and insectivorous birds. Such analyses are not possible at this time because the collection of 1 year of pretreatment data and 1 year of post treatment data is insufficient.

There appears to be a trend of lower concentrations of selenium in biological samples taken from non-irrigated lands indicting that land retirement and habitat restoration may lead to a reduction in the bioaccumulation of selenium. As restored lands mature and gain biological complexity, ongoing monitoring efforts should provide more definitive conclusions on the biotic effects of land retirement.

The Westlands Site is underlain by flood basin deposits consisting of moderately to densely compacted clays that range in thickness from 5 to 35 feet. The flood basin clays have low permeability and greatly impede the downward movement of applied irrigation water. Baseline soil chemistry data collected during 1999 indicate that the site soils are moderately to highly saline and contain elevated concentrations of Se and boron when compared to other soils in the San Joaquin Valley. Soil chemistry data collected during the first year of monitoring are adequate for establishing project baseline soil conditions.

Groundwater monitoring data collected to date support the conceptual model of a declining shallow water table in response to land retirement. The average water level decline observed in 10 project wells for the period between August 1999 and January 2001 is 3.75 feet. By comparison the water level in a nearby offsite well monitoring the shallow groundwater system declined 1.26 feet during the same time period. The area of the site underlain by a shallow groundwater table within 7 feet of the land surface decreased from 600 acres (30% of the site) to 55 acres (3% of the site) during the time period from October 1999 to October 2000. Extreme vertical groundwater gradients measured at the site indicate perched water table conditions in the shallow groundwater system.

Baseline groundwater quality data taken during 1999 indicate that the shallow groundwater is of extremely poor quality. The shallow groundwater underlying the site is a sodium sulfate type of water, is highly saline, and contains high concentrations of selenium and boron. Selenium concentrations observed in deep wells completed in the underlying Sierra Nevada deposits at the site are below the analytical detection limit for this study. Reducing geochemical conditions in the Sierran deposits may account for this observation. Isotopic (tritium) data from the shallow monitor wells indicate that the shallow, perched groundwater consists of a mixture of water recharged before and after 1952. Tritium data from the deep wells completed in the Coast Range deposits at the site indicate the groundwater was recharged before 1952. Groundwater quality data collected during 1999 are adequate for establishing baseline project conditions.

Several problems arose on the Westlands Site that potentially affected some data collection and data interpretation. Poor weather conditions affected the timing of imprinting and planting and also prohibited the completion of some of our monitoring surveys. Imprinting and planting occurred later than planned. This may have affected the germination rates of some of the seed of native species and likely affected the survivorship of the seedlings that were planted. Also, heavy rain resulted in cancellation of the February 2000 small mammal census.

Because of the late imprinting the volunteer barley on the treatment plots began to interfere with the growth of the native plants. To alleviate this competition, the plots that were seeded were mowed. Accordingly, the seeded plots and the plots that were not seeded were treated differently making some comparisons difficult.

Volunteer sugar beets grew aggressively on block 2 during 1999 and 2000. The presence of sugar beets on the plots is a violation of County Agricultural Department regulations. Sugar beets are a reservoir for the curly leaf top virus. The beets were removed by hand and disposed of offsite.

False chinch bugs invaded all plots in early summer 2000. The heaviest infestation occurred on block 5; most vegetation was destroyed. Other blocks were infested to varying degrees resulting in unequal impacts to the vegetation. Fortunately, plant cover and productivity data was collected prior to the infestation. The decimation of native annuals and perennials occurred prior to those plants setting seed. Accordingly, native plant sustainability will likely be lower than on the unaffected blocks. The long term affects of this infestation may make some comparisons between blocks difficult and is likely to add to the variability observed among treatments.

VII. References

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APPENDIX A.

Land Retirement Demonstration Project Pre-Project Biological Inventory for Tulare and Kings County Lands

Prepared by: Michelle Selmon and Karen Dulik
California State University, Stanislaus
Endangered Species Recovery Program
1900 N. Gateway Blvd. #101
Fresno, CA 93727

INTRODUCTION

The federal Land Retirement Program, recommended in the San Joaquin Valley Drainage Program Final Report (SJVDP 1990) and funded with the passage of the Central Valley Project Improvement Act (CVPIA) in 1992, has allowed for purchase of lands in drainage impacted lands in Western Fresno, Tulare and Kings counties for retirement from irrigated cultivation.

A demonstration project has been initiated to study the physical and biotic effects of land retirement. Approximately 8,000 acres in the Tulare Basin region near Alpaugh (Alpaugh) will be retired from irrigated cultivation and monitored for a minimum of 5 years.

This report contains results of the pre-project biological inventory for 2,643 acres of land acquired for the Alpaugh Site. This acreage represents lands acquired as of summer 2000. This inventory is performed prior to any manipulation, including planting of cover crops or other disturbance, to document initial conditions on the site.

As more lands are acquired for the Westlands and Alpaugh project sites, additional biological inventories will be conducted to document initial conditions.

METHODS

The Alpaugh Site was divided into three distinct areas, based on recent land-use patterns (Figure 1). Location A refers to the westernmost portion of the project site, which has been retired from agricultural production for over 10 years. It contains approximately 1000 acres and was previously assessed by ESRP for its biological values (Uptain 1998). Location B refers to a portion of the project site that has been in recent cultivation, mostly oats. This area contains 600 acres of land. Location C contains 960 acres of land that has been grazed for at least 3 years.

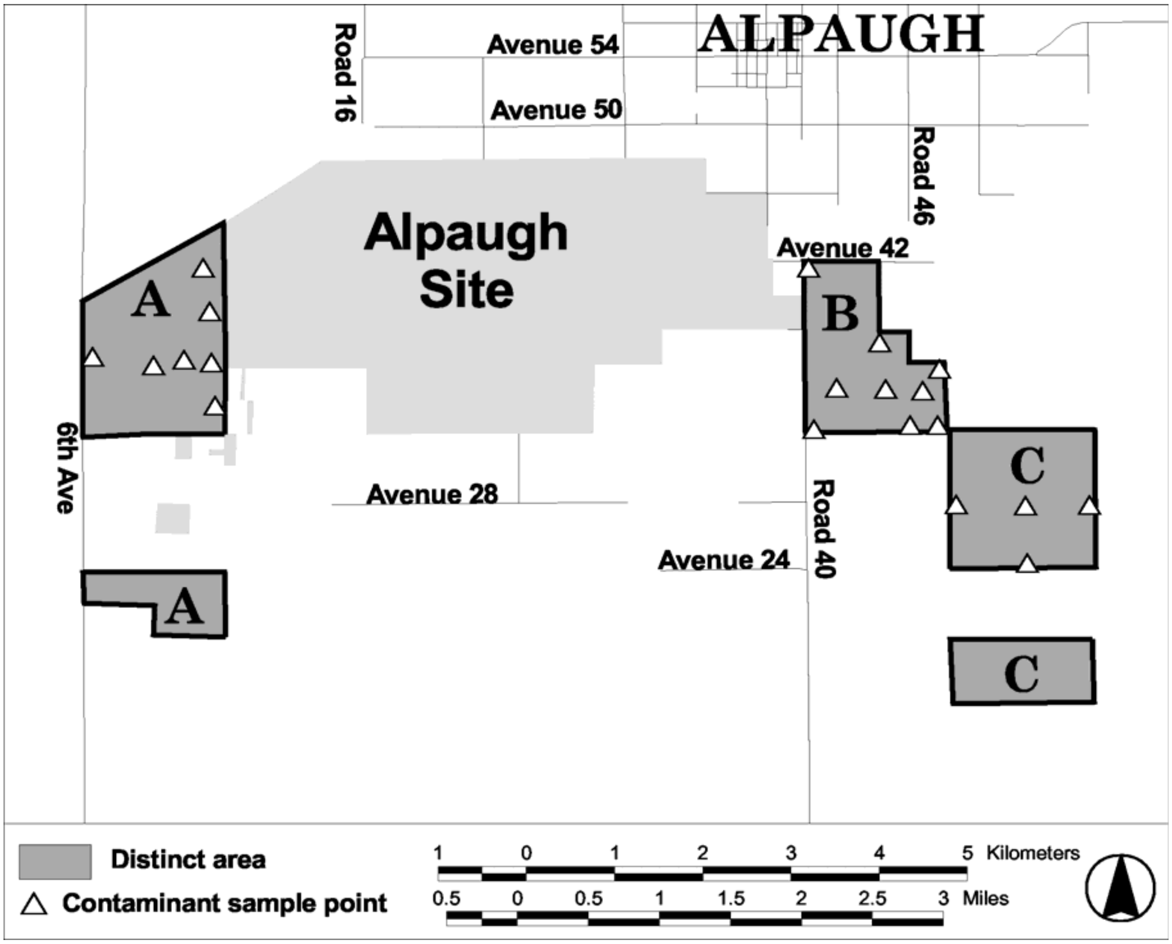

Figure 1. Alpaugh site sampling locations

Vegetative composition was assessed in May 2000 by the project coordinator and the project botanist. All species observed on the project site were recorded. Species not identified in the field were returned to the lab for identification.

Recently cultivated fields were examined primarily at the edges for vegetation, where plant species other than the target crop tend to germinate. Idled fields were walked over in a meandering fashion in order to observe as many species as possible.

Visual encounter surveys were conducted from 18 April to 19 April 2000 beginning within an hour of sunrise. Researchers walked transects across all fields at a slow pace recording birds heard or observed, in addition to any mammal or reptile species observed.

Spotlighting surveys were conducted on 18 April and 19 April 2000 within an hour of sunset to observe nocturnal species that were using the project site. Researchers drove roads at 5-10 mph using a 1,000,000 candlepower spotlight and recorded all animal species observed.

Previous surveys on parts of the Alpaugh Demonstration Project Site (Uptain, et al. 1998) indicated that a variety of small mammals persist on those lands. To determine the extent of small mammal use of the site, trapping was conducted on 18 April and 19 April 2000. Traps were baited just prior to sunset with white proso millet and a paper towel was added for shredding material. Traps were checked approximately 2-3 hours after sunset and closed.

Many plant species were sampled at the Alpaugh Site to determine which species were potentially accumulating selenium. All plant species sampled would be suitable for use in future monitoring since they are almost all important forage plants for wildlife. Vegetation contaminants samples were collected in the same manner at the Alpaugh Site as the Westlands Site. Samples were collected from both recently fallowed and long-term idled lands. Some of the recently fallowed lands supported many non-native plant species. At each collection location, composite samples consisting of at least 2 grams of vegetative (and reproductive, if available) parts from a minimum of three individuals were collected and placed in a Whirl-pak bag, which was then labeled with the appropriate field ID codes (Figure 1). Samples were kept cold in an ice-chest while in the field and were frozen immediately upon return to the laboratory.

The Alpaugh site contaminant samples were processed and sent to the same lab as the Westlands site samples. A brief description of quality control and extraction procedures can be found in the corresponding section of this report for the Westlands Site.

Invertebrate samples were collected from the Alpaugh Site using pitfall traps. Three traps were set in each area for 3 nights. Invertebrates were collected with forceps, sorted in the field by group into labeled Whirl-pak bags and kept cold until they could be frozen in the field laboratory.

Small mammals were captured using Sherman traps baited with white proso millet seed at X locations in three areas of the Alpaugh Site. All species captured were noted on a datasheet, although only deer mice and house mice were collected for contaminants analysis. Mammals were euthanized in the field and immediately frozen. Livers were removed at a later date just prior to lab preparation, at which time measurements were taken and the animals were examined for abnormalities of any kind.

RESULTS

Location A of the Alpaugh Site has been in the Conservation Reserve Program since 1988 and has some native plant habitat already established. Many native plant species were found at this location as compared to the other two locations (Table 1). Location B supports many non-native plant species (weeds), having just come out of crop production, while location C has been grazed for several years and is fairly stable. Native plants from location A will be used as local genotyoes to seed the other areas. This location can also be used as a model for the other sites. The proximity of the sites to the canals increases the diversity of plants, birds and other wildlife.

The visual encounter, spotlighting and the small mammal surveys allowed us to develop a list of species seen on the sites (Table 2, 3 and 4). From this list we get a better idea of the stability of the land and learn what species are known to use the surrounding areas. This will allow for better comparison after restoration is complete.

Selenium levels in vegetation samples from the Alpaugh site were very low in the three areas sampled (Table 5). The highest selenium level (1.4 ppm) was found in a *Distichlis spicata* (saltgrass, a selenium accumulator) sample from location A. Other plant samples ranged from below the detection limit (0.2 ppm) to 0.5 ppm.

As expected, selenium levels in the Alpaugh site invertebrate samples (Table 6) were higher than those found in the vegetation. The geometric mean of all samples collected from each of the three sampling areas do not exceed the maximum recommended concentrations established by the USFWS (USFWS 1998). However, invertebrate samples from location A had higher selenium levels than at the other two Alpaugh sites and at the Westlands sampling sites. In fact, the highest levels recorded for isopods (3 ppm) and spiders (5 ppm) did exceed the minimums for selenium concentrations (2 ppm) in invertebrates established by the USFWS. The high Se concentrations in invertebrates from this area may be caused by the presence of a tailwater pond located in the northeast corner of that area, but a positive determination of this cannot be made from the samples that were collected. Future samples will be collected near the tailwater pond and in areas isolated from the pond in an attempt to determine if high levels of Se in invertebrates are confined to areas near the pond or if high concentrations of Se are more widespread on the site.

Only deer mice were captured and analyzed for selenium content. Selenium levels in deer mice tissues were very similar across all three sampling areas (Table 7). As expected, the selenium levels in liver tissue (GM: 2.29, 2.65, 2.20) were greater than those in the body tissue (GM: 0.68, 0.72, 0.60). Neither the geometric mean of the samples nor individual samples exceeded the maximum recommended concentrations of selenium (Ohlendorf and Santolo 1994). Furthermore, the range and the geometric mean of selenium levels in both body and liver samples of the deer mice captured at the Alpaugh site were lower than the range and the geometric mean of selenium levels in samples from deer mice at Westlands.

Table 1. Plant species observed on the Alpaugh Site - Spring 2000. Plant species in boldface are natives.

Plant Species	Locations		
	A	B	C
Acroptilon repens		X	
Allenrolfea occidentalis	X		
Amsinckia menziesii	X	X	X
Atriplex argentea	X	X	X
Avena fatua		X	X
Bassia hyssopifolia	X	X	X
Brassica nigra		X	
Bromus madritensis rubens	X	X	X
Bromus diandrus		X	X
Cressa truxillensis	X	X	X
Distichlis spicata	X	X	X
Erodium cicutarium	X	X	X
Helianthus annuus	X	X	
Heliotropium curassavicum	X	X	
Hemizonia pungens	X	X	X
Hordeum murinum	X	X	X
Isocoma acradenia	X	X	
Lactuca serriola	X	X	
Malva parviflora		X	X
Malvella leprosa		X	
Medicago sativa		X	
Melilotus indica	X	X	X
Monolepis nuttalliana		X	
Phalaris minor		X	X
Polypogon monspeliensis		X	
Rumex crispus		X	X
Salsola tragus	X	X	
Scirpus acutus			X
Sesuvium verrucosum	X	X	X
Sisymbrium irio	X	X	X
Sonchus oleraceus		X	
Tamarix parviflora	X		

Table 2. Visual encounter survey results for the Alpaugh Site – April 2000.

Species Observed	Status	Locations		
Common Name		A	B	C
Mallard		x	X	X
Red-winged blackbird		X	X	X
Cliff swallow		X	X	X
Whimbrel			X	X
Western meadowlark		X	X	X
Brewer's blackbird		X	X	X
Northern harrier		X	X	X
Mourning dove			X	X
Grest blue heron		X		X
Snowy egret		X	X	
Great egret		X		X
Black-crowned night heron		X	X	X
Western kingbird		X	X	X
Gull spp.		X		
Tern spp.		X		X
Northern rough-winged swallow		X		
Barn swallow				X
Tree swallow			X	
Savanna sparrow		X	X	
Double-crested cormorant		X	X	X
Long-billed curlew	?	X	X	X
Loggerhead shrike	SSC	X	X	X
Burrowing owl	SSC	X	X	
Cottontail		X		
Northern pintail			X	
American crow		X	X	X
Horned lark	SSC	X		X
Common raven		X		
Turkey (escaped from turkey ranch)		X		
White-tailed kite	SSC	X	X	
Side-blotched lizard		X		
Lark sparrow		X	X	
Plover spp.				X
American coot			X	
California ground squirrel		X		Xa
Ring-necked pheasant		X	X	
American avocet		X		X
White-crowned sparrow		X		X
Brown-headed cowbird			X	
Black-necked stilt		X		
Killdeer		X	X	X
Dunlin		X	X	
Red-tailed hawk			X	X
Nutria				X
Pocket gopher (dead)				X
Coyote		X		
Song sparrow		X		
Gopher snake		X		
Black-tailed hare		X		

Table 3. Spotlighting survey results for the Alpaugh Site – April 2000.

Species Observed	**Status**	**Locations**		
		A	**B**	**C**
Tree frog			x	X
Western toad		X		X
Barn owl			x	X
Black-tailed hare		X		X
Black-crowned night heron		X		X
Desert cottontail		X		
Duck spp.				X
Bat			x	X
Burrowing owl	SSC			X
Kangaroo rat		X	x	
Dunlin			x	

Table 4. Small mammal species captured on the Alpaugh Site – April 2000.

Species Observed	**Locations**		
	A	**B**	**C**
Dipodomys heermani	**7**	**1**	**0**
Peromyscus maniculatus	**4**	**0**	**0**

Table 5. Vegetation contaminants monitoring results at the Alpaugh Site.

Location	N	Range Se (ppm)
Location A		
Atriplex argentea	5	<0.2-0.4
Cressa truxillensis	5	<0.2-0.3
Distichlis spicata	5	<0.2-1.4
Hordeum murinum	5	<0.1-<0.2
Hemizonia pungens	5	<0.1-<0.2
Melilotus indica	5	<0.1-<0.3
Sysimbrium irio	4	<0.1-<0.2
Location B		
Atriplex argentea	5	all <0.2
Brassica nigra	5	<0.2-0.5
Brassica nigra (seeds)	5	all <0.2
Cressa truxillensis	4	<0.2-0.3
Hordeum murinum	2	<0.2
Hemizonia pungens	2	<0.2-0.2
Melilotus indica	2	<0.1-<0.2
Location C		
Hordeum murinum	3	all <0.2
Melilotus indica	2	all <0.2
Bromus madritensis	1	<0.2
Hemizonia pungens	1	<0.2

Table 6. Invertebrate contaminants monitoring results at the Alpaugh.Site.

	N	GM Se	Range Se (ppm)
Location A			
Beetles	4		<0.9-<2.0
Isopods	2		<0.1-<3.0
Spiders	3		<1.0-<5.0
Location B			
Isopods	5	0.33	0.1-0.6
Spiders	4		<0.7-<2.0
Location C			
Beetles	3		<0.2-<0.7
Isopods	4		<0.3-<0.6
Spiders	4	0.56	0.4-0.6

Table 7. Vertebrate Contaminants Results at Alpaugh.

	N	GM Se	Range Se (ppm)
Location A			
PEMA body	5	0.68	0.5-0.82
PEMA liver	5	2.29	1.9-3.4
Location B			
PEMA body	3	0.72	0.67-0.76
PEMA liver	3	2.65	2.3-2.8
Location C			
PEMA body	2	0.6	0.59-0.61
PEMA liver	2	2.2	2-2.4

DISCUSSION

Many species were observed during the 3-day survey period on the Alpaugh Site. Portions of the site that have been idled show a high diversity of plant and animal life. However, the areas that have been actively grazed or cultivated within the past few years also supported many species, particularly birds.

The Alpaugh Site has a high potential for restoration due to the fairly high species diversity on parts of the site, and the proximity to native lands such as the Kern and Pixley Wildlife Refuges and Allensworth Ecological Reserve. Seed sources are much more readily available near the Alpaugh Site compared to the Westlands Site. Initial conditions are favorable for a recovery of many native plants and animals. Restoration and monitoring activities over the life of the Demonstration Project and beyond will provide data that will be critical for successful restoration of retired agricultural lands in this region of California.

These preliminary samples give an indication of background Se levels on recently and long-term idled lands at the Alpaugh Site. It was unexpected that we found Se levels on the lands that had been idled the longest (Location A). Location A has been in a CRP program (a different type of land retirement program) for the past 10 years and supports a greater abundance and diversity of wildlife (Uptain 1998).

Recently fallowed lands on the Alpaugh Site with non-native monocultures were found to be relatively lacking invertebrates, hindering collection of desired sample size. Such low numbers provide a striking picture of the paucity of biological resources that exist on recently fallowed lands.

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