Acronyms and Abbreviations

ac	Acres
AIWD	Atwell Island Water District
ANOVA	Analysis of variance
BLM	Bureau of Land Management
BO	Biological Opinion
CDFG	California Department of Fish and Game
CDWR	California Department of Water Resources
CIMIS	California Irrigation Management Information System
cm	Centimeters
CNDDB	California Natural Diversity Database
COC	Constituents of concern
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
DOI	Department of the Interior
dS/m	DeciSiemens per meter
EA	Environmental Assessment
EC	Electrical conductivity
EPA	Environmental Protection Agency
ER	Ecological Reserve
ESRI	Environmental Systems Research Institute
ESRP	Endangered Species Recovery Program
EUP	Experimental Use Permit
ft	Foot or feet
FWS	U.S. Fish and Wildlife Service
GIS	Geographic Information System
GPS	Global Positioning System
ha	Hectares
HRS	Habitat Restoration Study
IPM	Integrated pest management
km	Kilometer
LRDP	Land Retirement Demonstration Project
LRP	Land Retirement Program
LRT	Land Retirement Team
m	Meter
mg/kg	Milligrams per kilogram
mi	Miles
µg/L	Micrograms per liter
µS/cm	MicroSiemens/centimeter
mg/L	Milligrams per liter
mm	Millimeter
MOU	Memorandum of Understanding
msl	Mean sea level
NRCS	Natural Resources Conservation Service

NWR	National Wildlife Refuge
PEMA	Deer mouse
pH	Symbol for logarithm of the reciprocal of hydrogen ion concentration in gram atoms per liter
ppb	Parts per billion
ppm	Parts per million
PVC	Polyvinyl Choride
QAPP	Quality Assurance Project Plan
REC	Recognized environmental condition
Reclamation	Bureau of Reclamation
SJVDP	San Joaquin Valley Drainage Program
TU	Tritium units
USDA	U.S. Department of Agriculture
USDI	U.S. Department of the Interior
USGS	U.S. Geological Survey
WWD	Westlands Water District

Executive Summary

Irrigated agriculture in areas with shallow groundwater tables and little or no drainage outlet, as practiced in the center and western side of the San Joaquin Valley, has resulted in high salt concentrations that inhibit plant growth. More than 708,200 hectares (ha) (1,750,000 acres) of agricultural land in the San Joaquin Valley are considered drainage-impaired. Adverse effects to plants, fish, and wildlife can occur from this saline drain water, especially with its high concentrations of the trace elements, selenium, and boron. Selenium is of a primary concern because it is widely distributed throughout the valley and has proven to be toxic to certain vertebrate species, especially in aquatic habitats. Decades of irrigation have transferred soluble selenium from the upper soils to the shallow groundwater.

The Central Valley Project (CVP) provides water deliveries to San Joaquin Valley farms on more than 404,700 ha (1,000,000 acres). As the majority of the watershed was urbanized or converted to agricultural production, less than 5 percent of the lands remained uncultivated. This change in land use resulted in the loss of native wetland, saltbush scrub, alkali sink, and California prairie habitats, which contributed to the listing of numerous endemic species of plants and wildlife (FWS 1998).

The selective retirement of irrigated lands characterized by low productivity, poor drainage and high selenium concentrations in the shallow groundwater was recommended. The Central Valley Project Improvement Act (CVPIA), enacted in 1992 as Public Law 102-575 Title 34, Section 3408(h), authorized the purchase of land, water and other property interests from willing sellers who received CVP water. The program goals were to reduce drainage, enhance fish and wildlife resources, and make water available for other CVPIA purposes. The Land Retirement Program (LRP) was developed cooperatively by an interagency Department of the Interior team with representatives from the Bureau of Reclamation (Reclamation), the U.S. Fish and Wildlife Service (FWS), and the Bureau of Land Management (BLM).

Because concerns were raised about the magnitude of the project and the lack of knowledge about its effects on listed species, the Land Retirement Demonstration Project (LRDP) was implemented to provide site-specific scientific data. The FWS Biological Opinion (BO) for the LRDP in 1999 raised specific concerns about the scope and degree of land retirement impacts on groundwater levels, groundwater and surface water quality, soil chemistry, and biota. There was a need to monitor selenium loads at different trophic levels for corresponding groundwater levels and quality.

The LRDP was designed as a 5-year project to provide site-specific scientific data to determine the effects of land retirement on drain water volume, groundwater depth and quality, soils, and biota. Contaminants analysis was regularly performed on surface and groundwater, soils, vegetation, invertebrates, and vertebrates. Techniques were tested to determine effective, safe, and economical upland habitat restoration. Various efforts were taken to educate stakeholders about the effects of land retirement and habitat restoration techniques. The need for continued use of acquired water on LRDP lands was evaluated.

A resource monitoring plan (Selmon et al. 1999) that outlined the focus of habitat restoration research and established wildlife monitoring protocols was prepared and implemented by the California State University, Stanislaus, Endangered Species Recovery Program (ESRP). The plan included a Habitat Restoration Study (HRS) to monitor four restoration treatments and the vegetative and wildlife response to those treatments. Twenty study plots were established and a wide-range of data were collected over the 5 years. Selenium levels in a variety of trophic levels were monitored. Results of the LRDP are reported in this document and represent the culmination of the 5-year research and monitoring efforts implemented in 1999 and concluded in 2004. Although habitat restoration research and active site restoration efforts were included in the plan, results of those tasks will be given in a later report.

The Land Retirement Demonstration Project has two study sites located in two drainage-impaired basins. The Tranquillity site is located in western Fresno County and the Atwell Island site is located in Kings and Tulare Counties. The lands purchased were previously in agricultural production—primarily cotton, tomatoes, grain, and sugar beets.

The full 5-year study was completed at the Tranquillity site. Accordingly, this report primarily focuses on data from that site, but does include information from Atwell Island on the physical impacts and on selenium. Only at the Tranquillity site were 5 years of data collected for the Habitat Restoration Study. Activities at Atwell Island included baseline sampling prior to installation of treatments in 2001 and 1 year of post-treatment sampling conducted in early 2002. Physical impacts monitoring is discussed for the Atwell Island site. Due to reductions in CVPIA funding, all responsibilities for restoration research, site management, and monitoring of biota and selenium levels were reassigned from ESRP to BLM in 2002. BLM reports accomplishments and survey results for Atwell Island annually. The 5 year report for the site activities and research will be produced in 2007.

Appropriate habitat restoration must accompany land retirement to maximize benefits for wildlife and endangered species. Land retirement without habitat restoration often leads to large fields infested with weeds and pests that impact neighboring agriculture and require extensive and continuous management. Although land retirement has the potential to enhance wildlife values and improve ecological systems in the San Joaquin Valley, it is recognized that land uses other than wildlife habitat may take precedence on some lands. Some land uses, particularly grazing and dryland farming can be compatible with and may even contribute to habitat values for wildlife.

Restoration activities were expanded to include the collection of more than 100 native upland plant species from Ecological Reserves and isolated, small remnants of native habitat within an 80 kilometer (km) or (50 mile [mi]) radius of the Tranquillity site. Native plant research continues at an on-site nursery and is yielding large quantities of seed for use in replicated restoration trials and other restoration efforts. The results of these efforts will be reported at a later date.

Tranquillity Site Physical Impacts Monitoring Results

Five years of groundwater monitoring at the Tranquillity site supports conceptual and numerical models that predicted a declining shallow water table in response to land retirement. The performance objective established by FWS regarding water table response to land retirement stated that the depth to groundwater shall not show a net increasing trend (i.e. not rise to the land surface) over the life of the project. The FWS performance objective at the Tranquillity site was clearly met. Groundwater levels in all the wells monitoring the shallow water table at the site showed a declining trend (increasing depth to groundwater from land surface) during the study. Percolation of applied irrigation water prior to land retirement was the primary source of groundwater recharge that sustained the high water table. In the absence of irrigation recharge, the shallow water table has steadily receded from the land surface over the 5-year study. Large downward hydraulic gradients measured at the site confirm the presence of perched water table conditions in the fine-grained Coast Range deposits at the site. Discharge of the shallow groundwater occurs primarily through slow downward percolation through the thick, low-permeability, surficial clay deposits at the site. Some shallow groundwater was also undoubtedly discharged by evaporation from the water table when it was in proximity to the land surface at the beginning of the study. The water table response observed at the Tranquillity site is representative of conditions that would be present at a high percentage of lands that are targeted for retirement on the lower alluvial fan and basin rim settings in the western San Joaquin Valley.

The declining shallow water table is a very important aspect of land retirement due to the poor quality of the shallow groundwater observed beneath the Tranquillity site. The high salinity and selenium concentrations in the shallow groundwater found in the Coast Range deposits at the site are a result of leaching from soils under irrigated conditions and evaporation from the shallow water table. Evaporation from the shallow water table has concentrated salts and trace elements in the shallow groundwater. The performance objective for selenium in groundwater at the Tranquillity site established by FWS stated that the selenium concentration in groundwater shall not show a net increasing trend over the life of the project. The FWS performance objective was clearly not met. Rising levels of selenium observed in the shallow groundwater in the Coast Range deposits are likely a result of oxidation and advective transport of mobile selenium species in the alkaline conditions near the falling shallow water table. As long as the water table continues to decline, as expected in response to land retirement, the high concentrations of selenium in the groundwater should have no consequences to biota at the site. In contrast, selenium is present at very low concentrations in the groundwater found in the coarse-textured Sierran deposits at the Tranquillity site. In the reducing geochemical environment observed in the Sierran groundwater, selenium is relatively insoluble and immobile.

The Tranquillity site is underlain by flood basin and basin rim deposits that consist primarily of moderately to densely compacted clays that range in thickness from 1.5 to 10.7 meters (m) (5 to 35 feet) thick. The clay soils have low-permeability and provide poor drainage conditions for irrigated agricultural production. The predominant soil type at the Tranquillity site is Tranquillity clay. This is the most extensive soil type mapped by the U.S. Department of Agriculture on the lower alluvial fans and basin rim landforms in the areas targeted for land retirement. Soils at the Tranquillity site contain moderately elevated concentrations of selenium (average 1.0 milligrams per kilogram [mg/kg]) when compared to the common range (0.1-1.4 mg/kg) for western U.S. and San Joaquin Valley soils; however, they are still well within the range commonly found in western soils.

Total selenium concentrations, soluble selenium concentrations, and salinity (EC_e) in the surface soil (depth 0- 30 cm—centimeters [1 foot]) showed a decreasing trend over the 5 years of monitoring at the Tranquillity site. The decreasing selenium and salinity trends in the surface soil indicate that upward flux of salt and selenium from capillary rise and evaporation of shallow groundwater at the soil surface is minimal, and that some leaching of soluble selenium and salt from surface soils occurred during the 5-year study despite dryer than average climatic conditions.

About 10-20 percent of the selenium present in the subsoils (depth 0.6 to 0.9 m and 1.2 to 1.5 m [2-3 and 4-5 feet]) is soluble and mobile in the alkaline, oxidizing chemical conditions found in the soil. Soluble selenium concentrations (average 4.6 parts per billion [ppb] in saturation extracts) and percentages are much lower in the surface soils (depth 0-1 foot). Even if surface water ponding should occur during very wet periods, it is probable that selenium concentrations in the ponded water would be below the aquatic life criteria of 5 ppb based on the soil selenium saturation extract data. No performance objectives were established for soil selenium levels for the demonstration project; however, the maximum surface soil concentration (1.7 mg/kg) observed during the 5 years of monitoring at the Tranquillity site was well below typical soil toxicity thresholds for selenium in sediment (4 mg/kg).

FWS established performance standards for selenium and mercury in ponded surface water that lasts for more than 30 days. Due to dry climatic and soil conditions during the study, no surface water ponding was observed at the site that lasted for more than 30 days. Monitoring of precipitation during the course of the study suggests that the precipitation threshold to cause ponding of surface water at the site is well in excess of 5 centimeters (cm) (2 inches) of rainfall per month. The extensive network of dessication cracks in the clay soils at the Tranquillity site greatly inhibits the formation of surface water ponds.

Atwell Island Site Physical Impacts Monitoring Results

The Atwell Island site lies on the southwestern margin of the Tulare Lake bed. The site is underlain by lakebed and marsh deposits consisting primarily of clay and silt with some sand. Soils in the Atwell Island study area consist of silt and sand loams that are formed from alluvium derived from igneous and sedimentary rocks. The U.S. Department of Agriculture soil mapping units found at the site in order of abundance include the Posochanet silt loam, Nahrumb silt loam, Westcamp silt loam, Excelsior fine sandy loam, and Lethent fine sandy loam. Baseline soil chemistry data from three research areas at the site were collected during 2002. The surface soils (0 to 30 cm [0-12 inch] depth) at the research sites are moderately to highly saline (mean EC_e 3.85-9.25 deciSiemens/meter [dS/m]) and contain low selenium concentrations (mean total selenium 0.097-0.114 milligrams per kilogram [mg/kg]). By comparison, the mean selenium concentration in western U.S. soil is about 0.34 mg/kg.

Soils at the Atwell Island site are relatively low in both soluble and total selenium. Boron concentrations were moderate in surface soils and are elevated in subsoils. Both boron and soil salinity are plant growth limiting factors at the Atwell Island sites. Study Area 1 appeared to be using moisture from the water table. While this has benefitted plant growth in the short term, it may indicate soil salinity problems in the future. The medium textured soils at the Study Area 1 site exhibited capillary fringe zones approaching 1.5 m (5 feet) thick. A declining shallow water table in response to land retirement will lessen the likelihood of salinization of surface soils.

Monitoring wells were installed at the site in the fall of 2001 to establish baseline groundwater conditions. Initial groundwater level measurements indicate the presence of a perched water table beneath much of the site. Groundwater levels observed to date in the shallow groundwater system range from approximately 1.2 to 4.6 m (4 – 15 feet) below land surface. The water table is generally shallowest (nearest to the land surface) in the northwest portion of the site and becomes deeper to the southeast. A declining shallow water table in response to land retirement has been observed on portions of the site where irrigation has ceased or been greatly reduced.

The shallow groundwater underlying the Atwell Island site is moderately saline in nature. Salinity in the shallow groundwater samples, expressed as electrical conductivity (EC), ranged from 575 to 52,925 microSiemens/centimeter (µS/cm), with a median value of 13,740 µS/cm. By comparison, drinking water typically is less than 750 µS/cm, irrigation water is less than 1,250 µS/cm, and seawater is about 50,000 µS/cm. The shallow groundwater at the site 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 469 to 15,100 milligrams/liter (mg/L), and a median concentration of 4,500 mg/L. Sulfate is the dominant major anion found in the shallow groundwater, with sulfate concentrations ranging from 261 to 22,200 mg/L, and a median concentration of 5,700 mg/L. Selenium concentrations measured in the shallow groundwater wells at the site during the baseline year of monitoring range from less than the detection limit of 0.4 to 208 micrograms per liter (µg/L), with a median concentration of 8.56 µg/L. The Environmental Protection Agency (EPA) water-quality criterion for long-term exposure to selenium in aquatic environments is 5 µg/L (EPA 1988). Approximately 50 percent of the groundwater samples (35 of 72 samples) collected during the baseline year of sampling had selenium concentrations that were less than the EPA aquatic life criteria.

No ephemeral surface water pools resulting from rainfall were observed at the site to date. Selenium concentrations in three surface water samples taken from the artificial wetland at the site are below the EPA aquatic life criteria, and ranged from below the detection limit (less than 0.4 µg/L) to 0.6 µg/L.

Selenium Monitoring in Biota

As required by the LRDP Biological Opinion (FWS 1999), we monitored selenium levels in plants, invertebrates, and small mammals on retired agricultural lands over a 5-year period at the Tranquillity site and over a 3-year period at the Atwell Island site. Results are compared to performance standards established by FWS for the project (FWS 1999) and to selenium levels in biota from selenium-normal situations in the western United States (USDI 1998). We compare the concentrations of selenium in biota from our study sites to concentrations of selenium in biota found at Kesterson National Wildlife Refuge (NWR).

The mean concentration of selenium in plants, invertebrates, and small mammals at both the Atwell Island and Tranquillity sites was below the established performance standards, within the range for biota typically found in selenium-normal situations in the western United States, and usually about an order of magnitude less than selenium levels found at Kesterson NWR. Selenium levels in biota from Atwell Island tended to be lower than at Tranquillity. Generally, no clear differences in selenium levels were found between years. At the Tranquillity site, selenium levels in plants and small mammals tended to be greater on cultivated (irrigated) lands than on uncultivated (non-irrigated lands). Approximately 6 percent of all samples were considered unusually high in selenium (exceeding one standard deviation of the data set). The outliers suggest the need for selenium monitoring on newly acquired lands and continued monitoring on existing retired lands.

Results of the Habitat Restoration Study

The Biological Opinion for the Land Retirement Demonstration Project required that a 5-year Habitat Restoration Study be conducted to determine the responses of wildlife to land retirement and restoration efforts. We designed a study with four levels of restoration treatments (seeding with native plants, installing topographic contours, a combination of seeding and contouring, and control) and applied these treatments to twenty 4 ha (10-acre [ac]) study plots in a randomized block design. On the plots, we monitored vegetation, invertebrates, and amphibians and reptiles once each year, and we monitored birds and small mammals four times each year. Other monitoring at the site included track station surveys, spotlighting, winter raptor surveys, and monitoring of bird nesting success.

We successfully established plant cover to stabilize soils, established plant cover to provide wildlife habitat, and established native wildlife. Some of the restoration approaches used on the HRS plots showed promise. Microtopographic contouring appeared to have both positive effects in promoting establishment of native vegetation, and providing habitat heterogeneity for small mammals and other biota. Shrub establishment—particularly of *Atriplex polycarpa*—was very successful and approached densities that would be considered appropriate habitat for some species of concern. Nevertheless, restoration response was generally less than optimal. Factors contributing to the limited success of native plant restoration are thought to include inadequate seed delivery methods (imprinting may not be appropriate for use on the HRS soil types and for many of the species), competition from invasive species (primarily black mustard, London rocket, and tumbling saltweed), inappropriate seed source (most of the seed was purchased commercially and was not obtained from the proximity of the project site), and drought conditions experienced throughout the term of the project.

Because there were few notable differences among the restoration treatments, there were also few observable trends in wildlife diversity and abundance associated with the treatments. However, the information on wildlife diversity and abundance that was obtained shows that retired agricultural lands are valuable to wildlife. Over a 5-year period, we identified 101 families within 21 orders of invertebrates, 1 species of amphibian, 4 species of reptiles, 48 species of birds, and 8 species of small mammals, 1 species of canid (coyote), 2 species of mustelids (skunk and long-tailed weasel), and 2 domesticated species (cat and dog) that utilize the Tranquillity site. Nine species of birds utilized the study area as breeding habitat and 12 species of sensitive birds were using the study area. One factor that may have limited the abundance and diversity of native wildlife on the study plots is the lack of nearby lands that support wildlife which could disperse onto the study plots. Only small, remnant parcels of native habitat exist in the vicinity.

There were no indications the HRS lands supported greater agricultural pest densities than did surrounding retired and fallowed lands. Rather, agriculturally beneficial species were common and widespread on the site, especially in restored areas.

Although this pilot project did not necessarily emphasize the establishment of threatened and endangered wildlife on the study plots, we were successful in providing suitable habitat for a number of rare species of birds. With the incorporation of appropriate management actions, the habitat that has been established should be suitable for various other rare species.

The wildlife information generated by this project is immensely valuable as a description of baseline conditions that, if compared to data collected from retired lands that are restored to prime native habitats, would provide insight into the value of restoration to wildlife. There have been no other wildlife studies or monitoring efforts in the central San Joaquin Valley of this duration or scope, making this a unique data set that describes the wildlife community existing on lands dominated by non-native plant species. Within the San Joaquin Valley, similar conditions are common and widespread among scattered, remnant patches of land that are not intensively farmed.

Recommendations

A number of tasks remain to be accomplished to fulfill the intent of this pilot project and to ensure that land retirement and the restoration of retired lands can proceed. Some of these include:

- Publish findings of completed and ongoing research in open scientific literature.
- Develop a long-term management and monitoring plan for the Tranquillity site.
- Continue maintenance and expansion of the native plant nursery and seed collecting activities.
- Continue research on development of restoration technologies, including seed delivery techniques, weed control methods, harvesting techniques, and seed cleaning techniques, which are promising and have begun to bear fruit.

- Document and protect localities of known populations of native plants and animals in the project vicinity to ensure the survival and persistence of existing populations.

- Develop criteria and methods for the propagation and translocation of threatened and endangered species to restored lands.

- Provide public awareness of the positive effects and benefits of land retirement, such as increased depth to groundwater and establishment of native shrub species using various habitat restoration techniques.

Based upon the findings presented in this report and experiences gained during this 5-year project, the Land Retirement Team and the Endangered Species Recovery Program fully support land retirement. We believe that land retirement has the potential to solve a variety of drainage issues while concurrently providing habitat for wildlife. Restoration can improve the overall ecosystem function by improving air quality, reducing weed loads, creating wildlife habitat, and assisting with recovery of sensitive species. Land retirement is expected to be beneficial to adjacent farming operations by improving water quality, improving air quality through dust abatement, and increasing abundance and diversity of invertebrate pollinators and predators. These benefits are justification for continuation and expansion of retiring drainage impacted lands, continued research of restoration techniques, and restoration of selected parcels of retired lands in the San Joaquin Valley.