APPENDIX G

ECOLOGICAL RISK ASSESSMENT IN-VALLEY DISPOSAL ALTERNATIVE

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Acronyms

BCF	bioconcentration factor
CDFG	California Department of Fish and Game
EC	electrical conductivity
EC_{10}	effects concentration to 10 percent of the population
EIS	Environmental Impact Statement

LOAEL	lowest-observable-adverse-effect level
µg/L	microgram(s) per liter
mg/kg	milligram(s) per kilogram
mg/L	milligram(s) per liter
NOAEL	no-observable-adverse-effect level
ppb	part(s) per billion
ppm	part(s) per million
ppt	part(s) per thousand
Se	selenium
Service	U.S. Fish and Wildlife Service
TDS	total dissolved solids
USEPA	U.S. Environmental Protection Agency

G1 INTRODUCTION

This report evaluates the potential for adverse ecological effects to avian receptors due to increased selenium (Se) exposure that may result from creation of the evaporation basins proposed with the In-Valley Disposal Alternative. Once Se enters the aquatic environment, it has the potential to bioaccumulate in primary and secondary consumers (e.g., zooplankton and benthic invertebrates), and biomagnify as it reaches top-level predators (e.g., predatory fish, birds, and mammals). Biomagnification is a form of bioaccumulation in which the concentration of a chemical in a higher-trophic-level organism is greater than the concentration in the food that this organism consumes. This phenomenon has been observed to result in a two- to sixfold increase in Se concentrations between primary producers and forage fish (Lemly 1999).

Se is an essential element necessary for proper enzyme formation and function (Eisler 1985). However, chronic exposure to significantly elevated Se levels in the diet or water can also cause severe toxicological effects, including death. The concentration range separating effects of Se deficiency from those of toxicity (i.e., selenosis) is very narrow (Luoma and Presser 2000). With the exception of mortality, the two major toxicological effects to aquatic organisms from chronic exposure are reproductive effects and teratogenesis (i.e., malformations in developing fetus). Excessive Se contamination is often associated with localized extinction of certain species and reduction in biodiversity. Based on field and laboratory studies with fish and wildlife, it is apparent that elevated Se concentrations in environmental media, including dietary components, can cause reproductive abnormalities. These abnormalities include congenital malformations, selective bioaccumulation by the organism, and growth retardation (Eisler 1985).

The primary guidance documents used to develop the approach for this evaluation were the *Guidelines for Ecological Risk Assessment* (U.S. Environmental Protection Agency [USEPA] 1998), *Ecological Risk Assessment Guidance for Superfund* (USEPA 1997), and *Guidance for Ecological Risk Assessment at Hazardous Waste Sites and Permitted Facilities* (Cal-EPA 1996).

G1.1 Objectives of Evaluation

The primary objectives of this evaluation were to:

- Identify groups of ecological receptors most likely to be exposed to Se in the evaporation basins.
- Identify potential toxicological effects of Se.
- Provide estimates of probable adverse effects due to Se exposure via the food chain.
- Identify other water quality constituents that have potential to cause adverse effects to ecological receptors using evaporation basins.

G1.2 General Approach

Water quality modeling results were reviewed and the ecological setting was evaluated to develop a conceptual site model and identify potentially complete exposure pathways for the chemicals present. Assessment and measurement endpoints were identified for each ecological group likely to be exposed. To evaluate toxicity to receptors exposed to the Se via bioaccumulation, plant and invertebrate tissue concentrations were estimated using available data on Se bioaccumulation in existing Central Valley evaporation basins. A literature search on Se toxicity was conducted to determine probable effects of predicted plant and invertebrate tissue concentrations on upper trophic level receptors.

It should be noted that this assessment was conducted under the assumption that no mitigation habitat is provided. Although the evaporation basins would be designed to minimize bird use, it is assumed that all birds using the evaporation basins would be obtaining 100 percent of their food from the evaporation basins. Therefore, no dietary dilution of Se concentrations would occur, and the risk assessment results would represent the worst-case scenario. The results of this risk assessment will be used as a tool to help determine mitigation requirements to reduce the risk of Se toxicity to populations of birds utilizing the evaporation basins.

G1.3 Terminology

Several terms used throughout this section are defined below:

Direct toxicity refers to adverse effects to an organism caused by contact between the organism and contaminated environmental media, i.e., water or sediment.

Acute toxicity refers to adverse effects, often lethality, that occur from short-term exposure to a chemical (usually less than 96 hours).

Chronic toxicity refers to sublethal adverse effects (such as reduced growth or reproduction) during long-term exposure.

Bioconcentration is the process by which living organisms can retain and concentrate chemicals present in their surrounding medium (usually water).

Bioaccumulation is the process by which living organisms can retain and concentrate chemicals both directly from their surrounding environment (i.e., from water, bioconcentration) and indirectly from sediments, soil, and their food.

Biomagnification is a form of bioaccumulation in which the concentration of a chemical in a higher-trophic-level organism (predatory fish, bird, or mammal) is greater than the concentration in the lower trophic level food items that this organism consumes.

A *food-web receptor* is an ecological receptor whose primary exposure to chemicals occurs by way of diet, i.e., bioaccumulation. Most food-web receptors evaluated in ecological risk assessment are birds and mammals.

Ecological risk assessment is a process that evaluates the likelihood that adverse ecological effects may occur as a result of exposure to one or more stressors (USEPA 1997).

The *exposure,* or dose, represents the average amount of a chemical that an individual member of a population ingests. The exposure is a function of a receptor's foraging behavior and depends on life-history strategies such as dietary preferences, food ingestion rates, and seasonal behavior.

G2 SITE CHARACTERIZATION AND ENVIRONMENTAL SETTING

Data have been collected on existing sediment and water quality as well as on the ecology and biology of the areas that would be affected by construction of the evaporation basins.

Evaporation basins have been used in the San Joaquin Valley for about two decades as a means of disposal of irrigation drainwater. About 4,000 acres of evaporation basins are currently in operation within the valley.

G2.1 Site Characterization for Proposed Evaporation Basins

It is estimated that a total of approximately 2,870 acres (average wetted area under typical conditions) to 3,290 acres (maximum wetted area under wet conditions) of evaporation basin will be needed for the four basin sites. This acreage is a gross estimate and is based on the flow of water being provided by the reuse areas. The final areas will be fine-tuned based upon the flow from the reuse areas and the amount of water treatment provided to the influent. Four areas are under investigation for three evaporation basins that would be located adjacent to the reuse facilities:

- Northerly Reuse Area (Evaporation Basin A)
- Westlands North Reuse Area (Evaporation Basin B)
- Westlands Central Reuse Area (Evaporation Basin C)
- Westlands South Reuse Area (Evaporation Basin D)

Section 2.4.1.3 provides a summary description of the evaporation basins. Figure 2.4-1 shows the generalized areas under consideration for selection of specific sites for the evaporation basins. The figure also shows the proximity of the evaporation basins to the reuse areas.

G2.2 Water Quality

Typical ranges for water quality parameters expected to occur in the water flowing into the proposed evaporation basins are presented in Section 5.2.4 and Appendix C of the Environmental Impact Statement (EIS). Constituents present at high concentrations include Se, boron, molybdenum, and salinity. Mean Se concentrations in influent water are predicted to be approximately 10 micrograms per liter (µg/L). Molybdenum concentrations are expected to range from approximately 170 to 690 µg/L, and boron concentrations from 31,000 to 52,000 µg/L. Total dissolved solids (TDS) in influent water is predicted to range from approximately 24,000 to 32,000 milligrams per liter (mg/L). As water evaporates from the basins, concentrations of these constituents are expected to become more concentrated.

G2.3 Ecological Setting

G2.3.1 General Habitat

Evaporation basins are used for disposal of agricultural drainwater, and the areas adjacent to the evaporation basins are typically utilized for irrigated agriculture. In general, they are comprised of evaporation basins hydrologically interconnected by the main drainage conveyance facilities. The basins are generally sited and constructed above the 100-year flood level, and a network of levees and the topographic characteristics of the area would protect the evaporation basins from being inundated with floodwater. Each individual evaporation basin is made up of a series of levees constructed of consolidated soil. Interior levee slopes are typically 3:1 or less. Drainwater flowing into the evaporation basin and between basin cells is regulated by a series of valves and control weirs.

The evaporation basins collect and store subsurface agricultural drainwater, which evaporates, concentrating salts and other constituents such as Se. They are operated as a closed hydrologic unit, have no surface water discharge, and typically have extremely high concentrations of salts and other constituents. For example, in the Tulare Lake Drainage Basin, salinity ranged from 20 percent of seawater (10 microSiemens per centimeter electrical conductivity [EC], or approximately 7 parts per thousand [ppt]) to 6 times seawater (300 microSiemens per centimeter EC, or approximately 210 ppt) (Euliss, Jarvis, and Gilmer 1991). Since salts tend to concentrate in evaporation basins over time, the biota will show a change to more hypersaline adapted organisms as the salt concentration increases.

The high salinity in evaporation basins creates harsh aquatic environments. Most of the aquatic organisms present have limited osmoregulatory abilities and the high concentration of dissolved minerals is likely the most important factor determining biological characteristics of these systems (Parker and Knight 1992). Due to this situation, species diversity within evaporation basins is very low. However, since evaporation basins have extensive surface areas relative to storage volumes, receive direct sunlight throughout the day, and receive irrigation drainage rich in nutrients, the basins exhibit very high primary productivity (Parker and Knight 1992), which is typical of shallow, saline aquatic systems in general.

G2.3.2 Plant Communities

Widgeongrass (*Ruppia maritima*), a submergent macrophyte, is frequently the dominant macrophyte present in the basins, covering up to 80 percent of the surface of the basins in some cases (Parker and Knight 1992). Algae are very common in evaporation basins and typical species include *Dunaliella*, *Chaetoceros* sp., *Nitzchia* sp., *cyanobacteria*, and *Synechoccus* Nageli (Tanner, Glenn, and Moore 1999).

G2.3.3 Invertebrate Communities

Waterboatmen (*Trichorixa reticulata*), midges (*Tanypus* sp., *Tanypus grodhausi* Sublette), damselflies (*Enallagma iile*), brine flies (*Ephydra* sp.), and brine shrimp (*Artemia franciscana franciscana*) are the dominant macroinvertebrates present in evaporation basins. At lower salinity levels, waterboatmen are the most dominant species. In some basins, waterboatmen made up 70 to 90 percent of total macroinvertebrate density (Parker and Knight 1992). In another study, waterboatmen and *T. grodhausi* made up 96.3 percent of total dry mass (Euliss, Jarvis, and Gilmer 1991). At higher salinities (greater than 50 ppt), brine flies and brine shrimp were co-dominant, although waterboatmen were also present (Fan et al. 2002).

G2.3.4 Bird Communities

Evaporation basins support a relatively diverse group of birds, including grebes, gulls, waterfowl, terns, shorebirds, and passerines. Raptors such as owls, kestrels, and hawks may feed on birds that forage in evaporation basins. Black-necked stilts (*Himantopus mexicanus*), American avocets (*Recurvirostra americana*), eared grebes (*Podiceps nigricollis*), ruddy ducks (*Oxyura jamaicensis*), and Wilson's phalaropes (*Phalaropus tricolor*) tolerate hypersaline environments, forage on brine shrimp, and are common in evaporation basins in the Central Valley (Hanson Environmental 2003).

Historical survey data for birds from various sites in the Central Valley were collected by H.T. Harvey & Associates, Fresno, CA, and Hanson Environmental, Inc, Walnut Creek, CA, between 1993 and 2003 (Hanson Environmental 2003; H.T. Harvey & Associates, 1996a, 1996b, 1998, 2000, 2001a, 2001b, 2001c, 2001d, 2001e, 2002a, 2002b, 2002c, 2002d, 2002e). These records include ten evaporation basins and eight associated mitigation sites, and each site was surveyed for 2 to 11 years in an approximate interval of every 2 weeks, though most mitigation sites were not surveyed during the winter months (Nov-Jan).

The size of basins varied significantly. For evaporation basins, the size ranged from 20 acres (Westlake Farms, Experimental Evaporation Pond) to 1,793 acres (Tulare Lake Drainage District, South Basin Evaporation Pond). For mitigation sites, the size ranged from 8 acres (Britz, Alternative Wetland) to 740 acres (Westlake Farms, Section 23). For this analysis, the general size of the site was considered, rather than the flooded acreage (which varies by season), in the calculation of bird density. Hence, the basin size was assumed to be fixed in all historical surveys for each site.

The data analysis was discretized into four seasons: spring migration (Feb-Apr), breeding (May-Jul), fall migration (Aug-Oct), and winter (Nov-Jan); and six bird categories as described in Table G-1: dabblers, divers, breeding shorebirds, nonbreeding shorebirds, other upland birds, and other waterbirds. These categories are broken down based on distinct types of foraging behavior, dietary composition, and seasonal use patterns and, therefore, address different potentials for Se exposure. Species assigned to each of the bird categories are listed in Table G-2.

For each individual survey, the number of birds from a given bird category (all species within that category) were summed up and then divided by the corresponding site acreage. Hence, the unit of analysis was birds per acre (or more precisely, birds per acre per survey). The results are summarized in Table G-3.

It should be noted that each survey was considered as an equal-weighted data point, given that the number of surveys was fairly similar across all sites. However, the result is that sites that were surveyed more frequently are more heavily weighted in the analysis. It was also assumed that the duration of time spent observing birds during each survey was similar, and that the times of day surveys occurred was similar, although little information on survey methods or duration was available in the monitoring reports.

The histograms of bird density (in birds/acre) indicate that the data distribution is highly skewed (see histograms in Attachment G1). Therefore, an appropriate measure of central tendency is the sample median, rather than the sample mean (which may be affected by extremely high measurements). The median is defined as the middle measurement in an ordered set of data, that is, just as many observations are larger than the median as smaller. The median of a highly skewed distribution is generally smaller than the arithmetic mean. The median and mean bird densities presented in Table G-3 represent the bird densities (of all bird species within the relevant bird category) at a given time.

Table G-1
Bird Categories

Guild	Description
Dabblers (surface-feeding waterfowl)	Dabblers generally occur in shallower water than divers. They feed mostly on vegetation or very small invertebrates.
Divers	Divers generally occur in open water and forage beneath the surface, most often on benthic invertebrates. Divers tend to occur most frequently in evaporation basins during the nonbreeding season.
Breeding shorebirds (likely to breed at evaporation basins)	Breeding shorebirds include those that are known to breed on the edges of evaporation basin sites that have been monitored in the Central Valley. Black-necked stilts and American avocets are long-legged waders. Killdeer and snowy plover exhibit foraging patterns similar to short-legged waders.
Nonbreeding shorebirds (not likely to breed at evaporation basins)	Long-legged waders are those species with a mean tarsal length greater than 2 inches (5 centimeters). Long-legged waders, in general, share feeding habitats and display similar foraging methods. These species tend to concentrate at the water's edge or in shallow waters where they probe in the substrate for invertebrate prey. Long-legged waders include whimbrels, greater yellowlegs, dowitchers, plovers, long-billed curlew, egrets, herons, and godwits. Short-legged waders are those species with a mean tarsal length less than 2 inches (5 centimeters). These species tend to forage on exposed tidal flats at slightly higher intertidal elevations than long-legged waders, where they also feed on invertebrate prey. Short-legged waders include sandpipers and sanderlings.
Other water birds	These species include all other water bird species that were observed in the evaporation basins, including gulls, terns, and phalaropes. Gulls and terns are ecologically and taxonomically related, and tend to congregate in flocks on tidal flats, open water, pilings, or seawalls. However, gulls feed from the surface of the water and terns dive from the air to capture their prey. Both feed on a variety of fish that occupy the upper water column. In addition, gulls forage on a wide variety of food sources. Phalaropes have a foraging style that is distinct from other shorebirds. They typically forage by paddling in a circle in shallow open water for aquatic invertebrates.
Other upland birds	These species include all upland bird species that were observed around evaporation basins, including gulls, terns, and phalaropes. These species are not expect to obtain a significant amount of their diet within the evaporation basins. However, some raptor species may feed on water birds and shorebirds.

Table G-2
Total Number of Bird Observations by Species

Bird Category	Bird Species Abbreviation	Bird Species	Evaporation Basin–All Sites	Mitigation Habitat–All Sites	Total
Dabbler	AMCO	American Coot	131,932	28,419	160,351
Dabbler	AMWI	American Wigeon	5,546	599	6,145
Dabbler	BWTE	Blue-Winged Teal	71	192	263
Dabbler	CITE	Cinnamon Teal	19,120	15,378	34,498
Dabbler	COMO	Common Moorhen	2	107	109
Dabbler	DABB	Dabbling Duck Sp.	24,723	123	24,846
Dabbler	EUWI	Eurasian Wigeon	6	1	7
Dabbler	GADW	Gadwall	35,127	5,639	40,766
Dabbler	GWTE	Green-Winged Teal	7,297	5,214	12,511
Dabbler	MALL	Mallard	22,226	26,156	48,382
Dabbler	NOPI	Northern Pintail	16,383	9,874	26,257
Dabbler	NOSH	Northern Shoveler	462,878	10,832	473,710
Dabbler	TEAL	Teal Species	537	6	543
Diver	AECH	Aechmophorus Sp.	12	0	12
Diver	AYTH	Aythya Sp.	1	0	1
Diver	BUFF	Bufflehead	5,118	4	5,122
Diver	CANV	Canvasback	1,295	0	1,295
Diver	CLGR	Clark's Grebe	487	2	489
Diver	COGO	Common Goldeneye	333	0	333
Diver	COLO	Common Loon	4	0	4
Diver	COME	Common Merganser	1,906	11	1,917
Diver	DCCO	Double-Crested Cormorant	9,647	56	9,703
Diver	EAGR	Eared Grebe	284,703	57	284,760
Diver	GRSC	Greater Scaup	11	0	11
Diver	GRSP	Grebe Species	400	0	400
Diver	HOGR	Horned Grebe	10	0	10
Diver	HOME	Hooded Merganser	6	0	6
Diver	LESC	Lesser Scaup	9,337	9	9,346
Diver	OLDS	Long-Tailed Duck	14	0	14
Diver	PBGR	Pied-Billed Grebe	1,716	164	1,880
Diver	RBME	Red-Breasted Merganser	2	0	2
Diver	REDH	Redhead	21,361	483	21,844
Diver	RNDU	Ring-Necked Duck	474	4	478
Diver	RUDU	Ruddy Duck	444,487	333	444,820
Diver	SUSC	Surf Scoter	38	0	38
Diver	WEGR	Western Grebe	517	0	517
Breeding Shorebird	AMAV	American Avocet	329,523	79,610	409,133
Breeding Shorebird	BNST	Black-Necked Stilt	203,587	35,382	238,969
Breeding Shorebird	KILL	Killdeer	5,638	3,399	9,037
Breeding Shorebird	SNPL	Snowy Plover	19,231	1,228	20,459

Table G-2
Total Number of Bird Observations by Species

Bird Category	Bird Species Abbreviation	Bird Species	Evaporation Basin–All Sites	Mitigation Habitat–All Sites	Total
Nonbreeding Shorebird	AMGP	American Golden Plover	1	1	2
Nonbreeding Shorebird	BASA	Baird's Sandpiper	282	9	291
Nonbreeding Shorebird	BBPL	Black-Bellied Plover	66,941	6,300	73,241
Nonbreeding Shorebird	BLTU	Black Turnstone	3	0	3
Nonbreeding Shorebird	COSN	Common Snipe	16	7	23
Nonbreeding Shorebird	CUSA	Curlew Sandpiper	1	0	1
Nonbreeding Shorebird	DOWI	Dowitcher Sp.	33,763	72,670	106,433
Nonbreeding Shorebird	DUNL	Dunlin	177,623	17,451	195,074
Nonbreeding Shorebird	GPSP	Golden-Plover Species	7	0	7
Nonbreeding Shorebird	GRYE	Greater Yellowlegs	23,861	7,561	31,422
Nonbreeding Shorebird	JURE	Juv. Recurvirostridae	96	1,346	1,442
Nonbreeding Shorebird	LBDO	Long-Billed Dowitcher	73,627	1,019	74,646
Nonbreeding Shorebird	LEGP	Lesser Golden-Plover	5	0	5
Nonbreeding Shorebird	LESA	Least Sandpiper	178,686	14,324	193,010
Nonbreeding Shorebird	LEYE	Lesser Yellowlegs	539	127	666
Nonbreeding Shorebird	LOCU	Long-Billed Curlew	13,690	6,833	20,523
Nonbreeding Shorebird	MAGO	Marbled Godwit	2,160	66	2,226
Nonbreeding Shorebird	PESA	Pectoral Sandpiper	14	2	16
Nonbreeding Shorebird	PGPL	Pacific Golden-Plover	5	2	7
Nonbreeding Shorebird	PHAL	Phalarope Sp.	10,608	0	10,608
Nonbreeding Shorebird	REKN	Red Knot	135	20	155
Nonbreeding Shorebird	REPH	Red Phalarope	3	1	4
Nonbreeding Shorebird	RUFF	Ruff	41	5	46
Nonbreeding Shorebird	RUTU	Ruddy Turnstone	31	7	38
Nonbreeding Shorebird	SAND	Sanderling	1,027	15	1,042
Nonbreeding Shorebird	SAPI	Sandpiper Sp.	493	0	493
Nonbreeding Shorebird	SBDO	Short-Billed Dowitcher	26	1	27
Nonbreeding Shorebird	SEPL	Semipalmated Plover	1,134	346	1,480
Nonbreeding Shorebird	SESA	Semipalmated Sandpiper	35	6	41
Nonbreeding Shorebird	SORA	Sora	0	47	47
Nonbreeding Shorebird	SOSA	Solitary Sandpiper	1	0	1
Nonbreeding Shorebird	SPSA	Spotted Sandpiper	80	13	93
Nonbreeding Shorebird	STSA	Stilt Sandpiper	45	4	49
Nonbreeding Shorebird	TURN	Turnstone Species	1	0	1
Nonbreeding Shorebird	WELE	Western/Least Sandpiper	45,701	2,009	47,710
Nonbreeding Shorebird	WESA	Western Sandpiper	357,272	83,506	440,778
Nonbreeding Shorebird	WHIM	Whimbrel	6,607	15,597	22,204
Nonbreeding Shorebird	WILL	Willet	10,320	504	10,824
Nonbreeding Shorebird	WIPH	Wilson's Phalarope	165,186	552	165,738
Nonbreeding Shorebird	WRSA	White-Rumped Sandpiper	1	0	1

Table G-2
Total Number of Bird Observations by Species

Bird Category	Bird Species Abbreviation	Bird Species	Evaporation Basin–All Sites	Mitigation Habitat–All Sites	Total
Nonbreeding Shorebird	YELL	Yellowlegs Sp.	390	0	390
Other Upland	AMCR	American Crow	5	0	5
Other Upland	AMKE	American Kestrel	5	0	5
Other Upland	AMPI	American Pipit	3,609	107	3,716
Other Upland	BASW	Bank Swallow	1,064	57	1,121
Other Upland	BBSP	Blackbird Sp.	1,382	5	1,387
Other Upland	BHCO	Brown-Headed Cowbird	35	0	35
Other Upland	BLPH	Black Phoebe	46	0	46
Other Upland	BRBL	Brewer's Blackbird	2,614	3	2,617
Other Upland	BUOR	Bullock's Oriole	1	0	1
Other Upland	BUOW	Burrowing Owl	30	0	30
Other Upland	CLSW	Cliff Swallow	16,770	1,748	18,518
Other Upland	CORO	Common Raven	247	0	247
Other Upland	EUST	European Starling	2	0	2
Other Upland	FALC	Large Falco Sp.	1	0	1
Other Upland	FEHA	Ferruginous Hawk	4	0	4
Other Upland	FOSP	Fox Sparrow	1	0	1
Other Upland	GCSP	Golden-Crowned Sparrow	3	0	3
Other Upland	HOFI	House Finch	265	0	265
Other Upland	HOLA	Horned Lark	2,713	31	2,744
Other Upland	HOSP	House Sparrow	30	1	31
Other Upland	HUMM	Hummingbird Sp.	2	0	2
Other Upland	LISP	Lincoln's Sparrow	2	0	2
Other Upland	LOSH	Loggerhead Shrike	99	0	99
Other Upland	MAWR	Marsh Wren	136	0	136
Other Upland	MERL	Merlin	8	0	8
Other Upland	MODO	Mourning Dove	4	0	4
Other Upland	MOPL	Mountain Plover	22	0	22
Other Upland	NOHA	Northern Harrier	368	1	369
Other Upland	NOMO	Northern Mockingbird	1	0	1
Other Upland	NRWS	N. Rough-Winged Swallow	124	16	140
Other Upland	PEFA	Peregrine Falcon	68	1	69
Other Upland	PRFA	Prairie Falcon	11	1	12
Other Upland	RCKI	Ruby-Crowned Kinglet	1	0	1
Other Upland	RLHA	Rough-Legged Hawk	1	0	1
Other Upland	RNPH	Ring-Necked Pheasant	1	0	1
Other Upland	ROWR	Rock Wren	6	0	6
Other Upland	RTHA	Red-Tailed Hawk	96	0	96
Other Upland	RUHU	Rufous Hummingbird	0	1	1
Other Upland	RWBL	Red-Winged Blackbird	1,594	17	1,611

Table G-2
Total Number of Bird Observations by Species

Bird Category	Bird Species Abbreviation	Bird Species	Evaporation Basin–All Sites	Mitigation Habitat–All Sites	Total
Other Upland	SACR	Sandhill Crane	42	0	42
Other Upland	SAPH	Say's Phoebe	40	0	40
Other Upland	SATH	Sage Thrasher	5	0	5
Other Upland	SAVS	Savannah Sparrow	1,109	6	1,115
Other Upland	SEOW	Short-Eared Owl	1	0	1
Other Upland	SOSP	Song Sparrow	156	0	156
Other Upland	SPAR	Sparrow Sp.	11	0	11
Other Upland	SWAL	Swallow Sp.	3,333	1	3,334
Other Upland	SWHA	Swainson's Hawk	0	1	1
Other Upland	TRBL	Tricolored Blackbird	408	0	408
Other Upland	TRSW	Tree Swallow	31,319	378	31,697
Other Upland	TUVU	Turkey Vulture	16	2	18
Other Upland	VASW	Vaux's Swift	19	0	19
Other Upland	VESP	Vesper Sparrow	1	0	1
Other Upland	VGSW	Violet-Green Swallow	3	1	4
Other Upland	WCSP	White-Crowned Sparrow	555	0	555
Other Upland	WEKI	Western Kingbird	86	3	89
Other Upland	WEME	Western Meadowlark	211	1	212
Other Upland	WIWA	Wilson's Warbler	1	0	1
Other Upland	WTKI	White-Tailed Kite	8	0	8
Other Upland	YHBL	Yellow-Headed Blackbird	961	7	968
Other Upland	YRWA	Yellow-Rumped Warbler	67	0	67
Other Waterbird	AMBI	American Bittern	0	25	25
Other Waterbird	AMPE	American White Pelican	12,745	1,859	14,604
Other Waterbird	ARTE	Arctic Tern	2	0	2
Other Waterbird	BCNH	Black-Crowned Night Heron	223	2,283	2,506
Other Waterbird	BLSW	Black Swan	1	0	1
Other Waterbird	BLTE	Black Tern	2,551	68	2,619
Other Waterbird	BOGU	Bonaparte's Gull	3,792	74	3,866
Other Waterbird	BRAN	Black Brant	14	8	22
Other Waterbird	CAEG	Cattle Egret	69	258	327
Other Waterbird	CAGO	Canada Goose	935	27	962
Other Waterbird	CAGU	California Gull	8,572	700	9,272
Other Waterbird	CATE	Caspian Tern	3,403	767	4,170
Other Waterbird	COTE	Common Tern	3	0	3
Other Waterbird	EGRE	Egret Sp.	1	0	1
Other Waterbird	FOTE	Forster's Tern	1,568	1,100	2,668
Other Waterbird	FRGU	Franklin's Gull	30	3	33
Other Waterbird	GBHE	Great Blue Heron	938	340	1,278
Other Waterbird	GLGU	Glaucous Gull	1	1	2

Table G-2
Total Number of Bird Observations by Species

Bird Category	Bird Species Abbreviation	Bird Species	Evaporation Basin–All Sites	Mitigation Habitat–All Sites	Total
Other Waterbird	GREG	Great Egret	1,060	1,128	2,188
Other Waterbird	GRHE	Green Heron	1	12	13
Other Waterbird	GULL	Gull Sp.	1,417	130	1,547
Other Waterbird	GWFG	Greater White-Fronted Goose	623	163	786
Other Waterbird	HEGU	Herring Gull	835	128	963
Other Waterbird	LEBI	Least Bittern	0	2	2
Other Waterbird	LETE	Least Tern	142	7	149
Other Waterbird	LTJA	Long-Tailed Jaeger	2	0	2
Other Waterbird	OSPR	Osprey	3	0	3
Other Waterbird	RBGU	Ring-Billed Gull	10,359	6,570	16,929
Other Waterbird	RNPA	Red-Necked Phalarope	42,923	292	43,215
Other Waterbird	ROGO	Ross's Goose	59	0	59
Other Waterbird	SAGU	Sabine's Gull	8	0	8
Other Waterbird	SNEG	Snowy Egret	6,199	5,199	11,398
Other Waterbird	SNGO	Snow Goose	41	5	46
Other Waterbird	TUSW	Tundra Swan	10	0	10
Other Waterbird	VIRA	Virginia Rail	0	31	31
Other Waterbird	WFIS	White-Faced Ibis	834	5,773	6,607

Evaporation basins in California receive use by much higher numbers of nonbreeding birds than breeding birds. An estimated 10 to 12 million waterfowl winter or pass through the Central Valley of California each year (Heinz and Fitzgerald 1993a). Ruddy ducks, eared grebes, and American coots (*Fulica americana*) are the most abundant species that winter on large, open, and deep agricultural evaporation basins in the San Joaquin Valley (Gordus, Shivaprasad, and Swift 2002). Generally, overwintering birds arrive in the Central Valley in the fall and migrate north in early spring. The degree of site fidelity exhibited by overwintering waterfowl in the Central Valley is not well documented. Understanding the movement of individuals on a daily basis is dependent on radio telemetry studies. Previous studies have shown strong site fidelity by female northern pintails on a regional basis, but on a smaller scale, movements can be highly flexible depending on prey abundance and other factors (Cox and Afton 2000). Pintails studied on National Wildlife Refuges during the winter tend to make extensive daily flights between feeding sites, but choose the same sites consistently among years (Cox and Afton 2000).

Nonbreeding shorebirds, on the other hand, are more abundant within the Pacific Flyway during short, intense migratory periods during the fall and spring. Some species are known to overwinter in the Central Valley.

In general, the degree of site fidelity in birds is thought to be linked most closely to the predictability or physical stability of a site or food source (Ehrlich, Dobkin, and Wheye 1988). Birds tend to have higher levels of fidelity to foraging grounds during the breeding season when they have an established nesting site. Individuals may range farther in search of food during the winter period when a mate or nestlings are not dependent.

G2.3.5 Special-Status Species

Two Federally and State-listed species are known to occur in or around existing Central Valley evaporation basins (Hanson Environmental 2003):

- American peregrine falcon (*Falco peregrinus anatum*)
- Swainson's hawk (*Buteo swainsoni*).

Twelve Federal and State species of special concern are known to occur or have potential to occur in or around existing Central Valley evaporation basins:

Species with Both Federal and State Species of Concern Status

- Tricolored blackbird (*Agelaius tricolor*) (nesting sites only)
- Western burrowing owl (*Athene cunicularia hypugea*) (nesting sites only)
- Ferruginous hawk (*Buteo regalis*) (wintering only)
- Black tern (*Chlidonias niger*) (nesting sites only)
- Long-billed curlew (*Numenius americanus*) (nesting sites only)
- White-faced ibis (*Plegadis chihi*) (nesting sites only)

Table G-3
Bird Density in Central Valley Evaporation Basins

		Evaporation Basin															Mitigation Habitat												
		All Sites					Britz, Evaporation Pond	Lost Hills, Evaporation Basin	Rainbow Ranch Evaporation Basin, Evaporation Pond	Tulare Drainage District, Hacienda	Tulare Drainage District, North Basin Evaporation Pond	Tulare Drainage District, South Basin Evaporation Pond	Westlake Farms, Experimental Evaporation Pond	Westlake Farms, North Evaporation Basin	Westlake Farms, South Evaporation Basin	Westlake Farms, South Evaporation Basin, Cell A1A	All Sites					Britz, Alternative Wetland	Britz, Compensation Site	Lost Hills, Alternative Wetland	Lost Hills, Experimental Alternative Habitat	Tulare Drainage District, Compensation Habitat	Westlake Farms, Section 16	Westlake Farms, Section 23	Westlake Farms, Section 3
	Size (Acres)	4,707					25	345	100	1,108	264	1,793	20	260	740	52	1,518					8	10	130	120	307	135	740	68
	Year	1993 - 2003					1994 - 2003	1996 - 2003	1994 - 1997	1998 - 2002	1998 - 2002	1998 - 2002	1993 - 2001	1993 - 2003	1993 - 2003	1995 - 2003	1993 - 2003					1996 - 2002	1995 - 2002	1999 - 2003	1997 - 1998	1998 - 2002	1993 - 2001	1995 - 2001	1993 - 2002
Season	Bird Category	Mean - 2 Std Dev	Mean - 1 Std Dev	Mean	Mean + 1 Std Dev	Mean + 2 Std Dev											Mean - 2 Std Dev	Mean - 1 Std Dev	Mean	Mean + 1 Std Dev	Mean + 2 Std Dev								
Spring Migration (Feb-Apr)	Dabblers	0.000	0.000	**1.474**	3.941	6.408	0.115	0.003	0.083	1.236	5.375	0.923	3.136	1.023	0.574	3.008	0.000	0.000	**3.021**	7.078	11.136	3.350	5.500	1.057	1.350	0.315	2.778	0.877	5.629
	Divers	0.000	0.000	**1.748**	3.987	6.226	0.042	1.655	2.412	2.218	3.541	3.224	1.972	0.420	1.023	3.204	0.000	0.000	**0.016**	0.070	0.124	0.000	0.000	0.021	0.000	0.000	0.012	0.002	0.039
	Breeding Shorebirds	0.000	0.000	**0.493**	1.653	2.812	0.261	0.249	0.851	0.520	1.454	0.116	0.391	0.611	0.464	0.347	0.000	0.000	**2.360**	6.140	9.920	1.563	5.225	0.560	1.800	0.653	0.949	0.149	5.472
	Nonbreeding Shorebirds	0.000	0.000	**1.244**	3.451	5.659	0.097	0.183	1.368	1.924	2.630	0.427	0.305	2.493	2.082	0.679	0.000	0.000	**7.601**	22.574	37.548	0.600	29.738	2.443	0.667	0.828	7.181	0.892	11.312
	Other Uplands	0.000	0.000	**0.082**	0.529	0.975	0.000	0.000	0.000	0.213	0.930	0.088	0.000	0.000	0.000	0.000	0.000	0.000	**0.020**	0.104	0.188	0.000	0.000	0.000	0.000	0.191	0.000	0.000	0.000
	Other Waterbirds	0.000	0.000	**0.035**	0.165	0.294	0.009	0.001	0.081	0.062	0.015	0.030	0.060	0.049	0.016	0.046	0.000	0.000	**0.259**	0.881	1.503	0.025	0.769	0.051	0.033	0.001	0.318	0.027	0.441
Breeding (May-Jul)	Dabblers	0.000	0.000	**0.458**	1.513	2.567	0.033	0.002	0.016	0.446	2.949	0.145	0.436	0.474	0.102	0.879	0.000	0.000	**1.234**	2.831	4.428	2.035	2.300	0.741	1.817	0.134	0.896	0.199	1.722
	Divers	0.000	0.000	**0.187**	0.692	1.197	0.006	0.019	0.026	0.409	0.412	0.642	0.115	0.058	0.056	0.544	0.000	0.000	**0.019**	0.074	0.129	0.008	0.002	0.036	0.019	0.000	0.012	0.002	0.052
	Breeding Shorebirds	0.000	0.000	**0.702**	1.794	2.887	0.418	0.094	0.963	1.401	2.359	1.248	0.493	0.793	0.355	0.294	0.000	0.000	**2.404**	5.643	8.881	2.168	3.136	1.323	2.079	1.745	1.458	0.189	5.177
	Nonbreeding Shorebirds	0.000	0.000	**0.894**	3.063	5.231	0.067	0.042	1.937	1.729	2.107	1.978	0.435	1.610	0.598	0.146	0.000	0.000	**2.068**	7.965	13.863	0.152	4.378	1.186	1.873	0.839	1.276	0.132	4.398
	Other Uplands	0.000	0.000	**0.075**	0.349	0.622	0.000	0.000	0.000	0.343	0.582	0.220	0.000	0.000	0.000	0.000	0.000	0.000	**0.012**	0.073	0.134	0.000	0.000	0.000	0.000	0.121	0.000	0.000	0.000
	Other Waterbirds	0.000	0.000	**0.110**	0.464	0.818	0.024	0.002	0.037	0.114	0.070	0.127	0.164	0.083	0.064	0.430	0.000	0.000	**0.456**	1.402	2.347	0.055	0.769	0.114	0.377	0.007	0.503	0.058	1.103
Fall Migration (Aug-Oct)	Dabblers	0.000	0.000	**0.954**	2.582	4.211	0.091	0.008	0.196	2.732	2.538	2.753	1.045	0.655	0.172	0.617	0.000	0.000	**1.450**	4.352	7.254	1.133	1.600	0.228	0.028	0.000	0.957	0.194	2.830
	Divers	0.000	0.000	**0.697**	2.424	4.151	0.026	0.545	0.854	1.147	0.947	1.484	0.745	0.156	0.251	1.483	0.000	0.000	**0.012**	0.044	0.076	0.000	0.017	0.003	0.042	0.000	0.003	0.003	0.026
	Breeding Shorebirds	0.000	0.000	**1.218**	3.546	5.874	0.170	0.083	1.934	2.587	3.644	1.426	1.305	0.984	0.828	0.807	0.000	0.000	**1.961**	6.581	11.200	0.675	1.250	0.580	0.067	0.176	0.639	0.332	4.590
	Nonbreeding Shorebirds	0.000	0.000	**2.295**	5.646	8.997	2.193	0.049	3.819	3.887	6.266	2.381	0.828	3.942	1.190	0.980	0.000	0.000	**4.930**	14.996	25.062	0.692	4.508	3.699	0.106	0.484	2.124	1.576	10.340
	Other Uplands	0.000	0.000	**0.080**	0.479	0.877	0.000	0.000	0.000	0.067	0.855	0.134	0.000	0.000	0.000	0.000	0.000	0.000	**0.004**	0.033	0.062	0.000	0.000	0.000	0.000	0.130	0.000	0.000	0.000
	Other Waterbirds	0.000	0.000	**0.462**	1.802	3.141	0.076	0.002	0.628	0.547	0.434	0.397	1.230	0.500	0.226	0.519	0.000	0.000	**0.865**	2.781	4.698	0.025	0.458	0.390	0.306	0.000	0.624	0.189	1.892
Winter (Nov-Jan)	Dabblers	0.000	0.000	**1.355**	4.948	8.541	0.110	0.034	0.200	2.418	1.876	1.977	4.057	0.199	0.471	1.806	0.000	0.000	**2.396**	4.794	7.191	-	-	1.019	0.475	-	-	-	2.584
	Divers	0.000	0.000	**1.972**	5.306	8.639	0.078	1.330	3.789	1.637	2.089	1.808	2.404	0.786	1.040	5.379	0.000	0.000	**0.069**	0.215	0.361	-	-	0.000	0.017	-	-	-	0.077
	Breeding Shorebirds	0.000	0.000	**0.625**	2.370	4.115	0.062	0.125	0.781	0.729	0.857	0.098	1.375	0.792	0.587	0.485	0.000	0.000	**1.569**	4.097	6.625	-	-	0.000	0.317	-	-	-	1.744
	Nonbreeding Shorebirds	0.000	0.000	**2.957**	19.246	35.535	0.220	0.057	2.150	1.968	3.654	0.550	10.663	3.683	2.213	1.056	0.000	0.000	**4.421**	9.711	15.000	-	-	0.100	1.692	-	-	-	4.876
	Other Uplands	0.000	0.000	**0.053**	0.238	0.423	0.000	0.000	0.000	0.072	0.533	0.055	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**	0.000	0.000	-	-	0.000	0.000	-	-	-	0.000
	Other Waterbirds	0.000	0.000	**0.159**	0.945	1.730	0.000	0.004	0.045	0.178	0.056	0.041	0.690	0.132	0.062	0.158	0.000	0.000	**0.714**	1.535	2.356	-	-	0.000	0.000	-	-	-	0.799

Bird Density (Median Number of Birds per Acre per Survey)

		Evaporation Pond															Mitigation Habitat												
		All Sites					Britz, Evaporation Pond	Lost Hills, Evaporation Basin	Rainbow Ranch Evaporation Basin, Evaporation Pond	Tulare Drainage District, Hacienda	Tulare Drainage District, North Basin Evaporation Pond	Tulare Drainage District, South Basin Evaporation Pond	Westlake Farms, Experimental Evaporation Pond	Westlake Farms, North Evaporation Basin	Westlake Farms, South Evaporation Basin	Westlake Farms, South Evaporation Basin, Cell A1A	All Sites					Britz, Alternative Wetland	Britz, Compensation Site	Lost Hills, Alternative Wetland	Lost Hills, Experimental Alternative Habitat	Tulare Drainage District, Compensation Habitat	Westlake Farms, Section 16	Westlake Farms, Section 23	Westlake Farms, Section 3
	Size (Acres)	4,707					25	345	100	1,108	264	1,793	20	260	740	52	1,518					8	10	130	120	307	135	740	68
	Year	1993 - 2003					1994 - 2003	1996 - 2003	1994 - 1997	1998 - 2002	1998 - 2002	1998 - 2002	1993 - 2001	1993 - 2003	1993 - 2003	1995 - 2003	1993 - 2003					1996 - 2002	1995 - 2002	1999 - 2003	1997 - 1998	1998 - 2002	1993 - 2001	1995 - 2001	1993 - 2002
Season	Bird Category	10%	25%	Median (50%)	75%	90%											10%	25%	Median (50%)	75%	90%								
Spring Migration (Feb-Apr)	Dabblers	0.000	0.039	**0.412**	1.556	4.607	0.080	0.000	0.020	1.005	4.091	0.248	1.975	0.504	0.502	1.327	0.108	0.410	**1.535**	4.070	7.485	2.188	2.150	1.073	1.350	0.235	1.963	0.419	4.691
	Divers	0.000	0.163	**1.012**	2.536	4.482	0.000	1.339	1.915	2.395	3.201	3.068	0.925	0.252	0.853	2.462	0.000	0.000	**0.000**	0.000	0.049	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Breeding Shorebirds	0.000	0.002	**0.121**	0.534	1.323	0.080	0.180	0.635	0.482	1.189	0.076	0.000	0.058	0.319	0.000	0.030	0.179	**0.951**	2.322	7.860	1.375	4.550	0.335	1.800	0.557	0.700	0.089	3.485
	Nonbreeding Shorebirds	0.000	0.000	**0.262**	1.419	4.034	0.000	0.054	0.975	1.286	2.045	0.235	0.000	0.508	1.466	0.000	0.009	0.216	**1.566**	6.747	24.860	0.250	25.950	1.296	0.667	0.469	1.237	0.203	6.588
	Other Upland Birds	0.000	0.000	**0.000**	0.000	0.099	0.000	0.000	0.000	0.116	0.466	0.036	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**	0.000	0.007	0.000	0.000	0.000	0.000	0.150	0.000	0.000	0.000
	Other Waterbirds	0.000	0.000	**0.000**	0.018	0.067	0.000	0.000	0.000	0.031	0.011	0.015	0.000	0.004	0.005	0.000	0.000	0.000	**0.045**	0.250	0.728	0.000	0.200	0.019	0.033	0.000	0.093	0.007	0.294
Breeding (May-Jul)	Dabblers	0.000	0.000	**0.070**	0.350	1.301	0.000	0.000	0.000	0.330	2.343	0.076	0.100	0.288	0.051	0.337	0.010	0.132	**0.608**	1.657	3.500	1.625	1.600	0.642	0.967	0.073	0.726	0.116	1.213
	Divers	0.000	0.000	**0.016**	0.156	0.469	0.000	0.001	0.010	0.284	0.239	0.451	0.000	0.013	0.013	0.077	0.000	0.000	**0.000**	0.008	0.059	0.000	0.000	0.015	0.000	0.000	0.000	0.000	0.007
	Breeding Shorebirds	0.014	0.104	**0.308**	0.753	1.831	0.320	0.072	0.620	0.704	1.864	0.739	0.150	0.331	0.283	0.125	0.055	0.506	**1.431**	2.900	5.760	1.750	2.900	1.231	2.308	1.775	1.267	0.097	4.206
	Nonbreeding Shorebirds	0.000	0.000	**0.032**	0.451	3.332	0.000	0.003	0.130	1.182	0.621	0.581	0.000	0.094	0.057	0.000	0.000	0.000	**0.176**	1.279	4.695	0.000	0.300	0.719	0.200	0.256	0.052	0.002	0.529
	Other Upland Birds	0.000	0.000	**0.000**	0.000	0.207	0.000	0.000	0.000	0.203	0.369	0.019	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**	0.000	0.000	0.000	0.000	0.000	0.000	0.050	0.000	0.000	0.000
	Other Waterbirds	0.000	0.000	**0.019**	0.096	0.248	0.000	0.000	0.010	0.065	0.025	0.069	0.050	0.019	0.035	0.125	0.000	0.005	**0.111**	0.450	1.271	0.000	0.200	0.092	0.117	0.000	0.244	0.043	0.728
Fall Migration (Aug-Oct)	Dabblers	0.000	0.000	**0.201**	1.231	3.286	0.000	0.000	0.170	2.610	2.167	2.936	0.250	0.327	0.085	0.019	0.000	0.013	**0.500**	1.890	3.544	0.500	1.300	0.081	0.025	0.000	0.170	0.062	1.706
	Divers	0.000	0.000	**0.091**	0.657	2.086	0.000	0.009	0.180	0.777	0.479	1.076	0.000	0.033	0.034	0.019	0.000	0.000	**0.000**	0.006	0.044	0.000	0.000	0.000	0.017	0.000	0.000	0.000	0.000
	Breeding Shorebirds	0.000	0.041	**0.417**	1.534	3.414	0.120	0.041	1.610	2.440	2.390	0.880	0.000	0.429	0.519	0.096	0.000	0.000	**0.254**	1.958	5.404	0.000	0.200	0.200	0.058	0.112	0.033	0.039	1.162
	Nonbreeding Shorebirds	0.000	0.029	**0.741**	3.496	6.910	0.080	0.009	3.280	3.212	4.612	1.713	0.000	2.863	0.704	0.038	0.000	0.000	**0.815**	5.353	16.885	0.000	0.000	0.600	0.000	0.015	0.478	0.172	5.426
	Other Upland Birds	0.000	0.000	**0.000**	0.000	0.087	0.000	0.000	0.000	0.007	0.477	0.006	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**	0.000	0.000	0.000	0.000	0.000	0.000	0.111	0.000	0.000	0.000
	Other Waterbirds	0.000	0.000	**0.088**	0.435	1.180	0.000	0.000	0.290	0.310	0.246	0.136	0.100	0.106	0.097	0.154	0.000	0.028	**0.289**	0.834	2.150	0.000	0.350	0.369	0.250	0.000	0.259	0.112	1.015
Winter (Nov-Jan)	Dabblers	0.000	0.034	**0.231**	1.288	3.196	0.040	0.003	0.100	1.890	1.867	1.707	0.550	0.092	0.241	0.346	0.082	0.592	**1.853**	3.143	7.407	-	-	1.019	0.475	-	-	-	1.956
	Divers	0.000	0.160	**0.991**	2.460	3.558	0.000	0.826	3.320	1.651	2.133	1.802	0.275	0.546	0.843	2.346	0.000	0.000	**0.015**	0.029	0.329	-	-	0.000	0.017	-	-	-	0.015
	Breeding Shorebirds	0.000	0.000	**0.166**	0.570	1.269	0.000	0.119	0.560	0.577	0.576	0.091	0.000	0.215	0.507	0.000	0.000	0.007	**0.199**	2.636	5.485	-	-	0.000	0.317	-	-	-	0.279
	Nonbreeding Shorebirds	0.000	0.012	**0.577**	2.588	5.150	0.000	0.023	1.300	1.887	3.068	0.445	0.000	2.000	1.385	0.000	0.116	0.636	**2.375**	7.121	13.349	-	-	0.100	1.692	-	-	-	2.603
	Other Upland Birds	0.000	0.000	**0.000**	0.000	0.129	0.000	0.000	0.000	0.031	0.443	0.022	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**	0.000	0.000	-	-	0.000	0.000	-	-	-	0.000
	Other Waterbirds	0.000	0.000	**0.010**	0.069	0.259	0.000	0.000	0.000	0.071	0.023	0.025	0.000	0.046	0.021	0.000	0.000	0.066	**0.493**	1.029	2.065	-	-	0.000	0.000	-	-	-	0.588

Number of Surveys

		Evaporation Pond															Mitigation Habitat												
Season		All Sites					Britz, Evaporation Pond	Lost Hills, Evaporation Basin	Rainbow Ranch Evaporation Basin, Evaporation Pond	Tulare Drainage District, Hacienda	Tulare Drainage District, North Basin Evaporation Pond	Tulare Drainage District, South Basin Evaporation Pond	Westlake Farms, Experimental Evaporation Pond	Westlake Farms, North Evaporation Basin	Westlake Farms, South Evaporation Basin	Westlake Farms, South Evaporation Basin, Cell A1A	All Sites					Britz, Alternative Wetland	Britz, Compensation Site	Lost Hills, Alternative Wetland	Lost Hills, Experimental Alternative Habitat	Tulare Drainage District, Compensation Habitat	Westlake Farms, Section 16	Westlake Farms, Section 23	Westlake Farms, Section 3
Spring Migration (Feb-Apr)		**402**					39	44	26	26	27	26	48	60	60	46	**184**					10	16	26	1	19	36	27	49
Breeding (May-Jul)		**455**					55	56	33	30	30	30	53	60	60	48	**297**					32	45	38	7	30	47	38	60
Fall Migration (Aug-Oct)		**395**					32	41	17	30	30	30	49	60	59	47	**133**					15	12	12	3	4	24	18	45
Winter (Nov-Jan)		**339**					24	31	15	28	27	28	42	51	52	41	**28**					0	0	2	1	0	0	0	25

Species with State Species of Special Concern Status Only

- Sharp-shinned hawk (*Accipiter striatus*) (nesting only)
- Golden eagle (*Aquila chrysaetos*) (nesting and wintering sites)
- Short-eared owl (*Asio flammeus*) (nesting sites only)
- Northern harrier (*Circus cyaneus*) (nesting sites only)
- Loggerhead shrike (*Lanius ludovicianus*) (nesting sites only)
- California gull (*Larus californicus*) (nesting sites only)

All of these listed species and species of special concern have the potential to forage and/or overwinter in or near evaporation basins. The breeding distribution of the following species of special concern is also known to encompass the Central Valley: tricolored blackbird, western burrowing owl, black tern, white-faced ibis, northern harrier, and loggerhead shrike. Tricolored blackbirds, black tern, white-faced ibis, and northern harrier prefer freshwater marshes as nesting habitat. Loggerhead shrikes nest in shrubs or trees. Both of these habitat types are typically absent from the vicinity of evaporation basins. Therefore, of the abovementioned species of special concern, only the western burrowing owl has the potential to nest in the vicinity of evaporation basins. Federally and State-listed species are discussed individually below, as well as the western burrowing owl, which has the potential to nest in the area.

G2.3.5.1 American Peregrine Falcon

This raptor has been recently delisted from the federal Endangered Species Act, but is still listed as a State endangered species. Peregrines generally nest on protected ledges of high cliffs in woodland, forest, and coastal habitats. However, pairs are also known to nest on human-made structures such as bridges and buildings (CDFG 2003). Peregrine falcons are known to exhibit high nest site fidelity. Peregrine falcons forage over most wetland habitats, including salt ponds, that harbor many bird species it uses as prey. Peregrines prey on bird species such as ducks, shorebirds, and doves (Goals Project 2000). However, this species does not nest in the Central Valley.

G2.3.5.2 Swainson's Hawk

The Swainson's hawk is listed as threatened under the California Endangered Species Act. They eat mice, gophers, ground squirrels, rabbits, large arthropods, amphibians, reptiles, birds, and, rarely fish. They may also walk on ground to catch invertebrates and other prey. Their typical habitat is open desert, grassland, or cropland containing scattered, large trees or small groves, but they are usually found near water in the Central Valley (CDFG 2003). Swainson's hawks nest in open riparian habitat, in scattered trees or small groves in sparsely vegetated flatlands. This species is an uncommon breeding resident and migrant in the Central Valley (CDFG 2003).

G2.3.5.3 Burrowing Owl

The western burrowing owl (*Athene cunicularia hypurgea*) is designated as a California Department of Fish and Game (CDFG) and U.S. Fish and Wildlife Service (Service) species of concern. Burrowing owls prefer annual and perennial grasslands, typically with sparse or nonexistent tree or shrub canopies. In California, they are found in close association with California ground squirrel burrows (*Spermophilus beecheyi*), which provide them with year-round shelter and seasonal nesting habitat. Burrowing owls also use human-made structures such as culverts, debris piles, or openings beneath pavement as shelter and nesting habitat (CDFG 1995). Burrowing owl populations have been on the decline due to diminishing habitat (CDFG 1995) and burrowing mammal control (Zarn 1974). Burrowing owls exhibit a high degree of nest site fidelity and as habitat becomes increasingly fragmented and isolated by development, these sites become increasingly inhospitable for breeding burrowing owls.

G3 CHEMICALS OF POTENTIAL ECOLOGICAL CONCERN

This section summarizes the potential effects that may occur as a result of exposure to Se and other water constituents. Occurrence of effects depends on the level and duration of exposure and the sensitivity of the species.

Although arsenic, boron, mercury, and other elements found in agricultural drainwater are known to adversely affect fish and wildlife species, Se is generally considered the most harmful drainwater contaminant in the San Joaquin Valley. While other trace elements such as arsenic, boron, and molybdenum may also occur at elevated concentrations in drainwater, they generally do not occur at concentrations associated with adverse effects (Ohlendorf and Hothem 1995; Hothem and Welsh 1994; Skorupa and Ohlendorf 1991). No significant risk of adverse effects to wildlife as a result of exposure to these other constituents within evaporation basin water has been documented (Hanson Environmental 2003).

Toxic chemicals have a variety of different modes of action. Combinations may work additively, synergistically, or antagonistically to cause toxic effects. Some chemicals are more likely to cause acute effects, while others are more likely to cause chronic problems through bioaccumulation and food-chain transfer. Examples of chronic effects include mutagenic, carcinogenic, or teratogenic effects, as well as changes in behavior and decreased reproduction.

G3.1 Selenium

Once Se enters the aquatic environment, it has the potential to bioaccumulate in primary and secondary consumers (e.g., zooplankton, benthic invertebrates), and biomagnify as it reaches top-level predators (e.g., predatory fish, birds and mammals). This phenomenon has been observed to result in a two- to six-fold increase in Se concentrations between primary producers and forage fish (Lemly 1999).

G3.1.1 Environmental Chemistry

Se can exist in several oxidation states (IV, VI, 0, -II) as well as in organic and inorganic forms, and can exist as a dissolved species, or can be attached to suspended particulate matter in the water column, or to bedded sediment and detritus. The following oxidation states can occur in the dissolved phase:

- Selenide or organo-selenium (-II), substituting for S (-II) in proteins seleno-methionine, or seleno-cysteine
- Selenite, SeO_3^{-2} (IV), an analog to sulfite
- Selenate (VI), an analog to sulfate
- Elemental Se, which has low solubility although it may exist as a suspended colloidal species

The reduced organic, elemental, or selenite forms of inorganic Se are converted to the selenite or selenate forms through the oxidation process. Methylation is the process by which inorganic or organic Se is converted to an organic form that contains one or more methyl groups (usually resulting in a volatile form). Assimilative reduction is the process in which oxidized forms are taken into cells and reduced to organic species such as seleno-methionine and seleno-cysteine. These organo-Se forms can then be released to the water column following death or depuration. These processes are responsible for converting relatively less bioavailable inorganic forms of Se to highly bioavailable organic forms.

Four oxidation and methylation processes also contribute to the bioavailability of Se in aquatic systems:

- Oxidation and methylation of inorganic and organic Se by plant roots and microorganisms
- Biological mixing and associated oxidation of sediments that results from burrowing of benthic invertebrates and foraging activities of wildlife
- Physical agitation and chemical oxidation associated with water circulation and mixing (e.g., wind, current, stratification)
- Oxidation of sediments through plant photosynthesis (Lemly 1999)

G3.1.2 Toxicity

Se is an essential element necessary for proper enzyme formation and function. Insufficient Se in the diet may have harmful and sometimes fatal consequences on terrestrial and aquatic organisms. Se is an essential nutrient with dietary concentrations ranging from 0.05 to 0.3 milligram per kilogram (mg/kg). The amount of Se required in the diet of a particular species is dependent on the amount of Vitamin E in the diet (Ohlendorf 1989). Studies on animals, including humans, indicate that Se deficiency can cause susceptibility to cancer, arthritis, hypertension, heart disease, and possibly periodontal disease and cataracts (Eisler 1985).

However, chronic exposure to significantly elevated Se levels in the diet or water can also cause severe toxicological effects, including death. The concentration range separating effects of Se deficiency from those of toxicity (i.e., selenosis) is very narrow (Luoma and Presser 2000). With the exception of mortality, the two major toxicological effects to aquatic organisms from chronic exposure are reproductive effects and teratogenesis (i.e., malformations in developing fetus). Excessive Se contamination is often associated with localized extinction of certain species and reduction in biodiversity. Based on field and laboratory studies with fish and wildlife, it is apparent that elevated Se concentrations in environmental media, including dietary components, can cause reproductive abnormalities. These abnormalities include congenital malformations, selective bioaccumulation by the organism, and growth retardation (Eisler 1985).

Many studies have been conducted on the adverse effects of elevated Se concentrations to wildlife. Some of these studies were performed in the field, in habitats similar to that which is proposed for the evaporation basins, and others were performed in a laboratory environment. Under both In-Valley Disposal Alternative conditions, the organic form of Se, i.e., selenomethionine (the most bioavailable form), has proven to be more toxic than inorganic Se (e.g., sodium selenate and sodium selenite). Selenates are relatively soluble compounds, while elemental Se and selenites are virtually insoluble (Goyer 1986). However, adverse reproductive effects have been produced with both inorganic and organic forms in the laboratory.

G3.1.2.1 Mechanism of Action

The major organs affected by subchronic and chronic exposure to Se appear to be the liver, skin, blood, central nervous system, and endocrine system (ATSDR 2001). Chronic selenosis can result in teratogenic and mutagenic effects in wildlife, including aquatic-dependant birds. The exact mechanism of action of Se is not completely understood, and information specific to birds is scarce. At high exposure levels, Se can replace sulfur in biomolecules (i.e., amino acids and proteins), and this substitution is believed to be a mechanism of toxicity (ATSDR 2001). Once absorbed into the blood, Se rapidly becomes protein-bound. Because it is an essential nutrient, Se is incorporated into selenoproteins through a specific selenocysteine tRNA. It is found as selenocysteine in glutathione peroxidase and is incorporated into other proteins, such as tetraiodothyronine deiodinase and selenoprotein (WHO 1996). Glutathione peroxidase (the Se-containing enzyme) destroys hydrogen peroxide in cells, causing tissue peroxide levels in the body to decrease. Animal studies suggest that the cytotoxicity of Se results from the pro-oxidant catalytic activity of the selenide anions, which produce reactive metabolites such as super oxide anions and hydrogen peroxide. In addition, selenomethionine has been shown to randomly substitute for methionine in protein synthesis, which is another mechanism for subchronic or chronic toxicity (ATSDR 2001).

G3.1.2.2 Potential Adverse Effects

Aquatic invertebrates and aquatic-dependent birds that forage on invertebrates in evaporation basins, such as black-necked stilts and American avocets (members of the Recurvirostridae family, or recurvirostrids), comprise the focus of this toxicological evaluation, as well as waterfowl (e.g., mallards). Additionally, dose-response information pertaining to chickens, quails, and other birds was reviewed due to the paucity of dietary studies conducted on wild birds in the field.

Aquatic Invertebrates

Limited data exist on the adverse effects of Se to invertebrates in the field, but these organisms appear to be rather insensitive to Se exposure. Aquatic invertebrates, such as daphnids (*Daphnia magna*) and midges (*Chironomus riparius*), can tolerate exposure to waterborne Se concentrations that have been shown to cause adverse effects in fish and bioaccumulate through the food chain. Because these aquatic invertebrates generally are not sensitive to the toxic effects of Se, they have the capacity to accumulate this chemical to high levels in their tissues. However, tissue concentrations of 14.7 and 31.7 mg/kg in daphnids have been correlated with reduced grown and reproduction, respectively (Ohlendorf 2003). In addition, significant reductions in growth were observed in midges exposed to about 10 mg/kg in plant substrate.

Under laboratory conditions, selenite proved to be more toxic than selenate to aquatic invertebrates, causing lethal and sublethal (e.g., reproductive impairment) effects (Ohlendorf 2003). Toxicity was found to increase with increasing exposure durations up until roughly 2 weeks. Some examples of toxicity test results are presented below to provide a range of the levels of Se associated with mortality in aquatic invertebrates.

Invertebrate Species	Exposure Duration	Endpoint	Concentrations (µg/L)
Hyalella azteca	96 hours	Lethality – LC50	340–760
Hyalella azteca	14 days	Lethality – LC50	70
Daphnia magna	96 hours	Lethality – LC50	710
Daphnia magna	14 days	Lethality – LC50	430

As presented in Ohlendorf (2003).

Aquatic Birds

Chronic effects of Se exposure in birds include decreased egg weight, reduced hatching success, embryo deformities, and offspring mortality. A significant portion of the Se consumed by birds is transferred to their offspring and can kill developing embryos in the egg or induce lethal or sublethal teratogenic deformities. Adults that experience dietary exposure may suffer complete reproductive failure without exhibiting clinical symptoms themselves (Lemly 1999).

In addition to lethality, Se exposure can induce sublethal changes in birds, including emaciation, liver lesions, and atrophy of feather follicles and lymphoid tissues. Studies have shown that excess Se in the diet actually alters feather structure on a microscopic level, decreasing the capacity for water repellence (O'Toole and Raisbeck 1997).

Reproductive and developmental changes that can affect a species at the population level occur from chronic exposure to Se. Female birds with excess Se in their diet just prior to egg-laying have been shown to transfer Se to the eggs at harmful levels (Ohlendorf 2003). Examples of effects on growth and reproduction include reduced egg hatchability (embryo mortality), egg infertility, teratogenesis, and increased juvenile mortality. Egg fertility and egg hatchability are distinct endpoints because the former implies an effects mechanism acting on an adult, and the latter on embryonic physiology (Ohlendorf 2003). Furthermore, egg fertility does not appear to be as sensitive an endpoint as egg hatchability (Heinz et al. 1987; Smith et al. 1988; Heinz and Hoffman 1996, 1998).

Chronic selenosis usually results in multiple congenital malformations; some examples of gross abnormalities associated with embryo development are anophthalmia (absence of the globe and ocular tissue from the orbit), incomplete beak development, and brain and foot defects. Examples of teratogenic effects that are less apparent include an enlarged heart, edema, gastroschisis (open fissure of the abdomen), and liver disorders (Hanson Environmental 2003).

The available literature indicates that avian embryos are very sensitive to Se exposure. Sensitivity to Se exposure can vary substantially even in closely related species, like stilts and avocets. Existing toxicity data indicate that mallards are more sensitive to Se than avocets and stilts (Ohlendorf 2003). Unpublished data collected by Skorupa et al. indicate that the reproductive toxicity EC50 for stilts would be overly protective of avocets, but may not be adequately protective of other aquatic-dependant species. The unpublished data that support this idea were collected from several species of waterfowl, as well as stilts and avocets. The EC50 for overt teratogenesis was estimated to be 31 mg Se/kg egg tissue of dabbling ducks, whereas, the respective EC50s for stilts and avocets are 58 and 105 mg Se/kg egg tissue. These results indicate that ducks may be twice as sensitive to Se exposure as recurvirostrids, and avocets are relatively insensitive to selenosis (Skorupa 1998). The species examined in this study can be summarized as “sensitive” (duck), “average” (stilt), and “tolerant” (avocet) (Ohlendorf 2003).

Other studies have shown that growth of mallard ducklings is less sensitive to dietary Se exposure than growth of chickens and Japanese quails (Heinz, Hoffman, and Gold 1988). Mallards were found to be less sensitive to sodium selenite than chickens or quails in a study conducted by Heinz et al. (1987). O’Toole and Raisbeck (1997) conducted a literature review on the various sensitivities of bird species to embryonic effects related to Se and ranked the following birds in order of most sensitive to least sensitive: chicken > quail > mallard > black-crowned night heron = screech owl. A recent publication by Byron et al. (2003) confirmed this hierarchy of avian sensitivity levels and concluded that mallards are the most sensitive wild species, while stilts and killdeer are moderately sensitive and avocets are the least sensitive. Based on the sensitivity information discussed above pertaining to stilts and avocets, embryo toxicity in recurvirostrids would likely be less sensitive than for mallards, chickens, and quails, but similar to night herons, screech owls, and killdeer.

As previously stated, organic forms of Se generally have a greater capacity for toxicity than inorganic forms. However, the level of dietary exposure may influence the toxicity potential for inorganic forms of Se. Selenomethionine appears to be more toxic to mallard ducklings than sodium selenite at lower concentrations (i.e., 10 mg/kg dry weight in diet; Heinz et al. 1987). However, other studies indicate that sodium selenite is as toxic, or even slightly more toxic, than selenomethionine to mallard ducklings at highly elevated concentrations (i.e., 40 mg/kg dry weight in diet; Heinz et al. 1988). In addition, selenomethionine has been reported to be more toxic than selenocysteine (Heinz, Hoffman, and Gold 1989).

Mammals

Ingestion of Se in dietary items has been shown to cause congenital malformations in rodents and livestock. Generally, offspring of females chronically exposed to Se in their diet were emaciated and unable to nurse. In another study, mice given Se in drinking water reproduced normally for three generations, but had fewer and smaller litters. Pups were runts with high mortality before weaning, and most survivors were infertile (Eisler 1985).

G3.1.3 Accumulation and Elimination

This section describes the processes of uptake, accumulation, and elimination of Se by organisms. These processes are important in determining the exposure and effects of Se on various ecological receptor groups. Accumulation refers to the amount of Se that is retained in tissues after ingestion, absorption, metabolism, and excretion. The rate of accumulation is influenced by factors such as foraging strategy, dietary composition, the form of Se the organism ingests, and the ability of the organism to absorb, metabolize, and excrete Se. The predominant form of Se in oxidized surface water is predicted to be selenate. Selenate can be converted to less soluble forms such as selenite and elemental Se in reducing conditions. Although elemental Se may be immobilized in sediments and assimilated by some bivalves, assimilation of Se in this form is less efficient than organic Se (Luoma et al. 1992).

G3.1.3.1 Foraging Strategy

A study conducted on bivalves in Grizzly Bay reported the highest accumulation of Se in the Asian clam (*Potamocorbula amurensis*), a suspension feeder found in high abundance in the Bay (Schlekat et al. 2000). Lower Se concentrations were detected in crustaceans (Baines, Fisher, and Stewart 2002). These data correspond to Se concentrations measured in fish species that consume these organisms. For example, tissue residues in sturgeon (which mainly consume clams) were much higher than in striped bass (which mainly consume crustaceans).

Luoma et al. (1992) studied the effects of Se exposure on another common bivalve in the Bay, the balthic clam (*Macoma balthica*). The balthic clam is a deposit feeder with suspension feeding capabilities. Like the Asian clam, the balthic clam primarily consumes benthic and suspended microorganisms (diatoms) and detritus. The results of this study showed that organic Se present in diatoms was retained much more efficiently than elemental Se. Additionally, the average absorption efficiency of organic Se was 86 percent, which indicates that Se is persistent in the digestive tract of bivalves following consumption of microorganisms. Little information is available on the detrital pathway, although Se uptake via this pathway is expected to be less efficient than uptake from living plant material (Luoma and Presser 2000).

G3.1.3.2 Ingestion, Absorption, and Metabolism

Se compounds are biotransformed through incorporation into amino acids or proteins (as discussed above under Section G3.1.2.1, Mechanism of Action) or through methylation. Plants and animals can produce methylated forms of Se, such as dimethyl selenide, from inorganic Se, as well as some organic forms. The formation of methylated Se compounds by animals is believed to be one mechanism of detoxification, as the toxicity of dimethyl selenide is 500 to 1,000 times lower than the toxicity of selenide (Se2-) (Nagpal and Howell 2001; ATSDR 2001).

Selenate and selenomethionine are believed to be absorbed by the intestine without changes to their original chemical forms, while selenite and selenocysteine are metabolized during absorption (ATSDR 2001). After absorption, these compounds are biotransformed into excretable metabolites, such as methylated selenides (WHO 1996).

G3.1.3.3 Detoxification and Elimination

In the body, Se (as selenides) can react with heavy metals (arsenic, cadmium, copper, mercury, and zinc) to form metal selenides, which have low solubility and affect absorption and distribution processes within the body (Goyer 1986). The formation of metallic selenides can aid in detoxification, reducing the magnitude of adverse effects. For example, Stanley et al. (1994) demonstrated that dietary exposure of mallards to arsenic can alleviate the toxic effects of selenomethionine, such as impaired reproduction and reduced duckling growth and survival. The results of a study conducted by Heinz and Hoffman (1998) indicate that methylmercury chloride and selenomethionine may have antagonistic effects on adult mallards and syngergistic effects on ducklings.

Most (49-70 percent) Se is excreted in urine (WHO 1996). Although waterbirds rapidly accumulate Se, rapid depuration also occurs with low dietary Se concentrations. This process would reduce the potential for adverse effects in transient and migratory species (Hanson Environmental 2003).

Elimination rates for Se also vary among aquatic organisms and are another major determinant of the time required for and the magnitude of bioaccumulation. The time for 50 percent excretion of accumulated Se has ranged from 13 to 181 days in various species of marine and freshwater fauna. Time for 50 percent excretion in 30-day elimination trials was approximately 15 days from the gills and erythrocytes (i.e., red blood cells); however, essentially no elimination occurred from the spleen, liver, kidney, or muscle. Studies on crustaceans have revealed higher Se concentrations in fecal pellets than in the actual diet. Therefore, fecal pellets may represent a possible biological mechanism for downward vertical transport of Se in marine and freshwater environments (Eisler 1985).

Experiments suggest that Se concentrations in fish tissue resulting from dietary uptake do not reach equilibrium until at least 90 days of constant exposure (Reclamation 2001). Evaluation of water and tissue data collected in the Central Valley indicate that Se concentrations in fish tissue were best predicted using the average water concentration 1 to 7 months prior to collection of the fish sample. Se concentrations in aquatic invertebrate tissue were best predicted using the average water concentration 30 to 60 days prior to collection of the fish sample (Reclamation 2001).

G3.2 Other Constituents of Potential Ecological Concern

Trace elements such as arsenic, boron, and molybdenum have been documented to occur at elevated concentrations in drainwater. However, they generally do not occur in evaporation basins at concentrations associated with adverse effects (Ohlendorf and Hothem 1995; Hothem and Welsh 1994; Skorupa and Ohlendorf 1991), and no significant risk of adverse effect to wildlife as a result of exposure to these constituents within evaporation basin water has been documented (Hanson Environmental 2003). However, the potential for these elements to cause adverse ecological effect to wildlife utilizing evaporation basins has not been ruled out. In addition, the high levels of salinity that generally occur in evaporation basins may result in adverse effects to wildlife. Potential effects of these constituents on birds are discussed briefly in the following sections, but a quantitative assessment was not conducted as part of this evaluation.

G3.2.1 Arsenic

Signs of inorganic trivalent arsenite poisoning in birds include muscular incoordination, debility, slowness, jerkiness, falling hyperactivity, fluffed feathers, drooped eyelid, huddled position, unkempt appearance, loss of righting reflex, immobility, and seizures. Arsenic typically acts by destroying the blood vessels that line the gut, resulting in decreased blood pressure and shock. Arsenic is a teratogen (a substance that causes developmental malformations) and carcinogen, and malformations through placental barrier transfer and fetal death has been noted. Arsenic has the potential to bioaccumulate, but is not known to biomagnify (Eisler 1988).

In the Grasslands Wildlife Management Area in the San Joaquin Valley only 2 of 64 eggs analyzed for arsenic in 1986 contained detectable levels of arsenic. Results of laboratory studies indicate that the embrotoxicity threshold for dietary exposure to arsenic is greater than 1.3 mg/kg (Ohlendorf and Hothem 1995).

G3.2.2 Boron

Boric acid accumulates in the brain, liver, kidney, and white muscle. Forty-eight-hour symptoms of boron toxicosis include diarrhea, ataxia, incoordination, hypertonia, and sometimes death. Consumption causes decrease in growth, decreased hematocrit and hemoglobin, decreased liver and spleen weights, reduced egg fertility, and increased embryo mortality (Sample et al. 1997). Boron is a potent teratogen to domestic chicken embryos when injected into eggs. Injection of boron into the yolk sac of chicken embryos during the first 96 hours produced a wide range of developmental abnormalities, including rumplessness, facial defects, and melanin formations. Consumption of boron by mallards adversely affected mallard growth, behavior, and brain biochemistry (Eisler 1990).

Boron concentrations predicted in the influent water to the evaporation basins range from 30,000 to 52,000 µg/L. Boron concentrations measured in the eggs of aquatic birds in the Tulare Basin have been substantially lower than the adverse-effect thresholds determined in laboratory studies (CH2M Hill et al. 1993). Boron concentrations in water were significantly higher at Kesterson Reservoir than at reference sites, and at one basin the mean concentration in widgeongrass was high enough to potentially impair avian reproduction (Ohlendorf and Hothem 1995). Boron concentrations in eggs of shorebirds and ducks collected at the Grasslands area were below levels associated with reduced hatchability in laboratory mallards (Ohlendorf and Hothem 1995).

G3.2.3 Molybdenum

Molybdenum is found in all living organisms and is considered to be an essential or beneficial micronutrient. However, molybdenum poisoning has been reported in several areas of the world. Molybdenum poisoning in chickens results in reduced egg production, severe growth depression, weight loss, and mortality (Eisler 1989). Molybdenum concentrations predicted in the influent water to the evaporation basins range from 170 to 690 µg/L. Elevated levels of molybdenum in bird eggs collected from evaporation basins are usually well below thresholds for avian embryotoxicity (Skorupa and Ohlendorf 1991).

G3.2.4 Salinity

Sodium concentrations in influent water to the proposed evaporation basins are expected to range from approximately 4,000 to 9,500 mg/L. TDS concentrations are predicted to range from approximately 24,000 to 52,000 mg/L. As water evaporates, salinity concentrations within the basins are likely to increase over time. Elevated levels of salinity have the potential to cause salt toxicosis and feather encrustation in aquatic birds (Gordus et al. 2002; CH2M Hill et al. 1993; Hanson Environmental 2003). The risk of salt encrustation is more likely to occur during very cold weather, and impacts of salt encrustation appear to pose greater risk for less mobile, relatively sedentary species such as ruddy ducks (Gordus et al. 2002; Hanson Environmental 2003). Ingestion of highly saline water may cause elevated reduced growth rates and increased mortality in ducklings (Hanson Environmental 2003; Gordus et al. 2002). An EC of 70,000 micromhos per centimeter (approximately 50,000 mg/L TDS) has been identified as the threshold for high risk of salt encrustation during winter months when temperatures are at or below 32°F (Hanson Environmental 2003; Gordus et al. 2002).

Salt toxicosis has been documented in ruddy ducks using an agricultural evaporation basin near Lost Hills in the San Joaquin Valley (Gordus et al. 2002). Dead birds collected in December 1998 and January 1999 were found to contain sodium concentrations in the brain ranging from 1,890 to 3,670 parts per million (ppm) wet weight. Sodium concentration thresholds considered diagnostic of salt toxicosis range from 1,900 to 2,000 ppm wet weight (Gordus et al. 2002). Although concentrations of other elements such as Se, cadmium, iron, and zinc were also elevated in bird tissue, concentrations of these elements did not exceed levels associated with adverse effects (Gordus et al. 2002). Therefore, salinity was determined to be the cause of mortality. The TDS concentration measured in basin water in October 1998 was 120,000 mg/L, and the EC was 100,000 micromhos per centimeter.

G4 PRIMARY EXPOSURE PATHWAYS

Since many environmental factors can have a significant effect on the mechanism by which waterborne Se is transferred to wildlife, concentrations of dissolved Se measured in surface water are often not useful for predicting exposure to upper trophic levels. For example, uptake of selenite from solution was too slow to account for the high tissue residues measured in clams (*Macoma balthica*) and Mediterranean mussels (*Mytilus galloprovincialis*) (Luoma et al. 1992). In fact, the uptake rate of dissolved selenite was responsible for less than 5 percent of the tissue residues of Se measured in clams. When Se is absent in surface water but present in sediment, it can still be transferred through the food chain. Se uptake by rooted plants and benthic invertebrates are two primary pathways that facilitate Se movement through the food chain. Long-term cycling of potentially toxic Se concentrations is highly dependent upon these pathways. Ingestion of rooted plants and benthic invertebrates often represents a source of continuous exposure to fish and wildlife, even when surface water is characterized by very low Se concentrations (Lemly 1999).

Some studies have generated data that show a statistical correlation between Se concentrations in surface water and biota. For example, a study on evaporation basins in the Tulare Lake basin provided evidence to suggest that Se in water was a better indicator of Se in eggs of black-necked stilt than was Se in sediment (Hamilton and Lemly 1999). Based on the available literature, however, estimation of Se uptake through measured concentrations in sediment or surface water alone are not good predictors of bioaccumulation, as dietary exposure is usually responsible for the largest proportion of Se accumulation (Luoma and Presser 2000).

G4.1 Conceptual Site Model

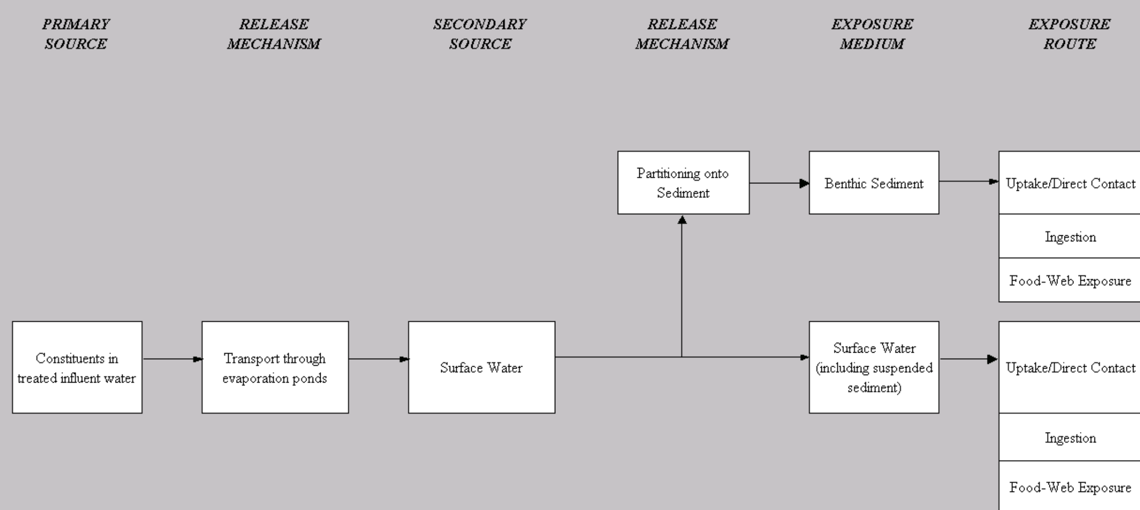
For effects to occur, a receptor and a complete exposure pathway must be present. An exposure pathway is only considered complete when all four of the following elements are present: site-related source of a chemical, a mechanism of release of the chemical from the source to the environment, a mechanism of transport of the chemical to the ecological receptor, and a route by which the receptor is exposed to the chemical.

The exposure routes associated with the complete pathways include sediment ingestion, water ingestion, direct contact, and food-web exposure. The conceptual site model (Figure G-1) was developed to provide a schematic representation of the links between sources, release and transport mechanisms, affected media, exposure routes, and potentially exposed ecological receptors. Although several complete exposure pathways may exist, not all pathways are comparable in magnitude or significance. The significance of a pathway as a mode of exposure depends on the identity and nature of the chemicals involved, the magnitude of the likely exposure dose, and the specific characteristics of the biological receptors. For birds and mammals, ingestion is generally the most significant exposure pathway. Dermal contact is expected to be insignificant relative to ingestion, and unquantifiable due to the frequent movement, ranging habits, and furry or feathery outer skin of most wildlife species.

G4.2 Bioaccumulation in the Aquatic Food Web

The adverse effects associated with bioaccumulative chemicals relate to their propensity to transfer through the food web and accumulate preferentially in tissue. Basic routes of exposure to bioaccumulative compounds by organisms are the transport of dissolved contaminants in water across biological membranes and ingestion of contaminated food or sediment particles, with subsequent transport across the gut. For upper-trophic-level species, ingestion of contaminated food is the predominant route of exposure. Uptake through ingestion of or direct exposure to water or sediment can also be important (USEPA 2000). Se bioavailability in sediment is affected by factors such as diagenesis (physical and chemical changes during deposition and consolidation); sorption/desorption interactions with organic matter, sulfides, and carbonates; and physical attributes of the particle (Burton 2001).

Se accumulates in the organs of biological systems to differing degrees. Crustaceans usually accumulate the highest Se levels in their exoskeletons, while the visceral mass and gills of mollusks usually contain the highest levels. In marine shrimps that were exposed to Se through their diet, highest concentrations were observed in the viscera and exoskeleton, suggesting that ingested Se is readily transferred from internal to external tissues. Highest Se concentrations in fish were found in the liver, kidney, and gills. Similarly, the highest concentrations in birds and mammals are often found in the liver and kidneys. However, Se concentrations in the muscle tissue of Hawaiian coots (*Fulica americana alai*) have been detected at sufficiently elevated levels to warrant the posting of consumption advisories (Eisler 1985).



Exposure Medium	Exposure Route	POTENTIAL ECOLOGICAL RECEPTORS: *Phytoplankton*	*Benthic Invertebrates*	*Aquatic Invertebrates*	*Birds Breeding on Site*	*Birds Foraging on Site*	*Birds - Raptors*
Benthic Sediment	Uptake/Direct Contact	N	N	N	M	M	M
	Ingestion	IC	N	N	D	D	D
	Food-Web Exposure	IC	N	N	D	D	D
Surface Water (including suspended sediment)	Uptake/Direct Contact	N	N	N	M	M	M
	Ingestion	IC	N	N	M	M	M
	Food-Web Exposure	IC	N	N	C	C	C

Legend:
C Potentially complete pathway (evaluated in a quantitative way)
D Not quantified because insufficient data available
N Not quantified because receptor not considered an assessment endpoint
M Minor or insignificant pathway
IC Incomplete pathway

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CONCEPTUAL SITE EXPOSURE MODEL
In-Valley Disposal Alternative

Figure G-1

G4.3 Assessment and Measurement Endpoints

Ecological risk assessment involves multiple species that are likely to be exposed to differing degrees and respond differently to the same contaminant. It is not practical or possible to directly evaluate risks to all of the individual components of the ecosystem that could be adversely affected by contaminants from the site. Instead, assessment endpoints focus the risk assessment on components of the ecosystem that are judged to have high potential for adverse effects. USEPA defines an assessment endpoint as an “explicit expression of an environmental value to be protected” (USEPA 1997). Assessment endpoints define both the valued ecological entity at the site and a characteristic of the entity to protect, such as individual survival, population success, production per unit area, or changes in species distribution in an ecosystem community. Generally, each assessment endpoint includes a guild or a functional group within an ecosystem, rather than one particular species. However, for purposes of evaluation, a representative or surrogate species is selected. When threatened or endangered species are present, it is often appropriate to define assessment endpoints based on protection of an individual. Other assessment endpoints are typically defined on the basis of protection of a population or a community.

The selection of assessment endpoints depends on the following:

- The contaminants present and their concentrations
- Mechanisms of toxicity of the contaminants to different groups of organisms
- Potentially complete and significant exposure pathways
- Ecologically relevant receptor groups that are potentially sensitive if highly exposed to the contaminant
- Societally significant valued resources (such as protected species)

USEPA defines measurement endpoints as “a measurable ecological characteristic that is related to the valued characteristic chosen as the assessment endpoint and is a measure of biological effects (e.g., mortality, reproduction, growth)” (USEPA 1997). Measurement endpoints can include measures of exposure or effect and are frequently numerical expressions of observations that can be compared statistically to a control or reference site or scientific study to predict adverse responses to a site-specific chemical.

In this evaluation, effects to populations of avian receptors are the primary concern. Although benthic and aquatic invertebrates may experience toxic effects due to concentrations of Se and other constituents, these organisms are not considered appropriate assessment endpoints. Rather, the evaporation basins will be designed and managed to minimize populations of invertebrates to decrease the food supply and discourage the utilization of the basins by birds. Fish are not expected to occur in evaporation basins due to high salinities and lack of hydrologic connection with natural water bodies. Few occurrences of mammals have been documented at other existing evaporation basins; therefore, mammals are not considered an appropriate assessment endpoint in this evaluation.

The assessment endpoints defined in this evaluation include the following:

- Protection of populations of migratory ducks, waterfowl, and other birds likely to overwinter or forage but not breed at the proposed evaporation basins
- Protection of populations of shorebirds such as stilts and avocets, and other birds likely to nest, breed, and forage at the proposed evaporation basins
- Protection of individuals of threatened or endangered raptor species such as the American peregrine falcon that are likely to prey on aquatic birds that forage at evaporation basins

The measurement endpoint used in this evaluation consisted of predicting Se concentrations in the tissue of dietary items (plants and invertebrates), and comparing these predicted tissue concentrations to dietary thresholds associated with adverse effects in avian receptors. A literature search was conducted to identify Se dietary thresholds associated with adverse effects, including acute effects such as adult and chick mortality, as well as chronic sublethal effects such as reduced reproduction and embryo deformities.

G5 EXPOSURE ASSESSMENT

Only potentially complete exposure pathways are considered relevant in an ecological risk assessment, as effects cannot occur without exposure. The exposure routes associated with the complete pathways include sediment and water ingestion, direct contact (dermal exposure), and food-web exposure (bioaccumulation) for wildlife. For higher-trophic-level receptors, the exposure dose is estimated as a function of the chemical concentrations in the water, several other parameters related to biotransfer through the food web, and the manner in which receptors use the habitat (e.g., behavior, dietary composition, food ingestion rates, etc).

In this evaluation, only food-web exposure to avian receptors is evaluated quantitatively. A substantial amount of data are available that link dietary tissue concentrations to effects in birds. Therefore, the exposure assessment for this evaluation consists of predicting average Se concentrations in plant and invertebrate tissue. In the effects assessments, predicted plant and invertebrate tissue concentrations are used to determine whether adverse effects are likely in birds feeding at the evaporation basins.

G5.1 Concentrations in Water

Invertebrates are assumed to be exposed to the Se concentrations in influent water (C_{WATER}). It is assumed that Se concentrations in influent water will be representative of typical Se concentrations throughout the evaporation basins. The methods used to predict Se concentrations in influent water to the four proposed evaporation basins are described in Section 5.0 of the EIS. The Se concentration of 10 µg/L used in this evaluation is representative of the final effluent conditions predicted.

G5.2 Concentrations in Plant and Invertebrate Tissue

It is possible to predict concentrations in invertebrate prey in the evaporation basins based on concentrations of Se predicted in the water and sediments of the evaporation basins. However, a large amount of uncertainty may be related to these predictions, due to various factors including:

- Limited information on the speciation of Se expected to be present in influent water

- Limited information on the speciation of Se expected to be present in water and sediments throughout the evaporation basin
- Spatial and temporal variation in factors that affect bioavailability, such as salinity, dissolved oxygen, sulfides, etc.
- Fluctuations in Se concentrations and bioavailability over time;
- Chemical interactions with other constituents
- Highly variable Se bioaccumulation in different plant and invertebrate species
- Differences in primary production and algal biomass in various systems
- Length of exposure duration for prey species

Monitoring reports available for existing evaporation basins are based on untreated effluent, which may have very different speciation compositions than the treated influent to the proposed evaporation basins. Even if the speciation of Se in the treated influent to the basins could be predicted with a reasonable amount of certainty, it is difficult to predict what will happen to the Se speciation when the water flows through the basin. Because speciation is dependent on various chemical and physical parameters that are characteristic of conditions in the evaporation basins, the speciation will eventually change if the residence time is long enough. Alaimo et al. (1994) measured Se speciation in four evaporation basins, and found that speciation varied considerably. In the Westlake Farms basins (where the total Se concentration in water was 4.3 μg/L), the Se was measured as 100 percent selenate (the least bioavailable form). In contrast, the Se in the Bowman Farms evaporation basins was found to be 78 percent organic selenide (the most bioavailable form), even though the total Se concentration (10.8 μg/L) was in the same range of that in the Westlake Farms basin. Total Se concentrations in the Lost Hills Water District and Sumner Peck Ranch basins were substantially higher (320 and 679 μg/L, respectively). The Lost Hills basin contained all three forms of Se (selenate, selenite, and organic selenide), while only selenate and selenite were measured in the Sumner Peck Ranch basin water. These data demonstrate that no typical Se speciation distribution can be assumed for conditions in evaporation basins.

Amweg et al. (2003) investigated Se bioavailability and bioaccumulation in the effluent of a pilot-scale algal-bacterial Se reduction system similar to the treatment system proposed for the In-Valley Disposal Alternative. This study measured concentrations of organo-Se and selenate (combined analysis) and selenite in treatment effluent, as well as tissue concentrations in two species of invertebrates (*Lumbriculus variegatus* and *Helisoma* sp.). It should be noted that these species are standard toxicity test organisms and are not representative of invertebrate species typically found in large numbers in evaporation basins. Using these data, bioconcentration factors (BCFs) were calculated. The BCF is defined as the ratio of the average Se concentration in bivalve tissue (dry weight) to the average dissolved Se concentration in water. Concentrations in aquatic invertebrates are estimated by multiplying the water concentration by the BCF:

$$C_{inv} \text{ (mg Se/kg tissue (dw))} = C_w \text{ (mg/L)} \times \text{BCF (L/kg)}$$

BCFs based on the Amweg et al. (2003) study results were calculated to be 603 for *Lumbriculus variegatus* and 618 for *Helisoma* sp. The Amweg study measured only total Se concentrations in water, not dissolved concentrations. However, because the treated effluent includes a filtration step, it is assumed that most of the total Se is present in the dissolved form.

Subsequent to completion of this study, the design of the treatment system has been modified, and due to these modifications it is expected that bioavailability of Se in the final effluent will be lower than that measured by Amweg et al. In addition, Se bioaccumulation varies considerably among different invertebrate species, and BCFs calculated for *Lumbriculus variegatus* and *Helisoma* sp. may not be representative of BCFs for species more typically found in evaporation basins.

Fan et al. (2002) investigated Se bioavailability and bioaccumulation in agricultural drainwater and evaporation basins in the San Joaquin Valley. This study analyzed total Se concentrations in surface water, microphytes, macroinvertebrates, and fish. Water column macroinvertebrates primarily included brine shrimp (*Artemia franciscana franciscana*) and water boatmen (*Corixidae*). Benthic macroinvertebrates primarily included midge larvae (*Chironomidae*), and brine fly larvae (*Edaphae*). Using these data, the average water-to-invertebrate BCF calculated for all samples in both evaporation basins was 1,565.

However, the authors noted that Se concentrations in tissue did not correlate well with waterborne Se concentrations. (Use of BCFs to predict tissue concentrations assumes a linear relationship between Se concentrations in water and tissue.)

Ohlendorf (2003) reported that among the invertebrates samples at Kesterson Reservoir, Se concentrations were highest in benthic species such as midge larvae (*Chironomidae*), and lowest in aquatic species such as waterboatmen (*Coroxidae*). Se bioaccumulation factors for invertebrates samples at Kesterson ranged from 168 to 3,700, with a mean of 1,090 (Ohlendorf 2003). Most aquatic insects collected at Kesterson Reservoir in 1983, including damselfly nymphs (*Zygoptera*), dragonfly nymphs (*Anisoptera*), and midge larvae (*Chirononmidae*), averaged more than 100 mg/kg Se. Water boatmen contained lower concentrations (geometric mean of about 20 mg/kg). Se concentrations in water entering Kesterson Reservoir during 1983 to 1985 averaged about 300 µg/L Se. Waterborne Se concentrations generally decreased as water moved through a series of basins, but water in the downstream basins still contained 50 to 200 µg/L Se. BCFs were calculated by dividing the Se concentrations in biota by those in water samples collected at the same sites and times in 1983 (Ohlendorf 1989). Most biota at Kesterson Reservoir accumulated Se concentrations to levels more than 1,000 times the concentration in water and some more than 5,000 times (Ohlendorf and Hothem 1995).

The use of BCFs assumes a linear relationship between Se concentration in water and Se concentration in tissue. However, the true relationship is expected to be logarithmic, with the ratio of Se concentration in tissue to the Se concentration in water decreasing at higher concentrations. Therefore, a regression equation based on data collected at varying Se concentrations is expected to more accurately predict bioaccumulation. Also, because birds within the various bird categories described in Table G-1 differ considerably with regard to foraging habitats and dietary composition, the Se bioaccumulation prediction for this evaluation has been broken down by different types of dietary components – plant matter, nektonic invertebrates, and benthic invertebrates.

Moore et al. (1990) compiled historical data on Se concentrations in water, plants, and invertebrates of evaporation basins in the San Joaquin Valley. These data were extracted from a wide variety of sources including scientific journals, technical reports, and lay publications published by public agencies, universities, private organizations, and individuals. These data, as well as the more recent data collected by Fan et al. (2002) (described above), were used in this evaluation to develop regression equations to predict bioaccumulation for each of the dietary components (plant matter, nektonic invertebrates, and benthic invertebrates). Data for widgeongrass were used to represent Se uptake in plants, data for waterboatmen were used to represent Se uptake in nektonic invertebrates, and data for fly larvae (all available species) were used to represent Se uptake in benthic invertebrates. For nektonic and benthic invertebrates, the data set used to develop the regression equations was limited to Se concentrations in water that were no greater than 20 parts per billion (ppb). Because the Se concentrations of water entering the evaporation basins are expected to be approximately 10 ppb, data that were representative of these conditions were used for the regression equation. However, for vegetation not enough data were available within this range to develop a regression equation with high confidence (the r^2 value was less than 0.25).

It should be noted that for this analysis, the raw data sets were not readily available and the mean Se concentrations for each study site were used. The regression was weighted by the sample sizes for the tissue samples from each site. As a result, it is likely that the r^2 values obtained are higher than would have been the case if the raw data had been used (variability would have been greater).

G5.2.1 Vegetation

Historical data for widgeongrass from Moore et al. (1990) were used to represent Se uptake in plants. Initially, the data set was limited to Se concentrations in water that were no greater than 20 ppb. However, not enough data were available within this range to develop a regression equation with high confidence (the r^2 value was less than 0.25). Therefore, a regession equation with the entire data set (all available concentrations) was developed. Results are shown on Figure G-2, and the following predictive equation was calculated:

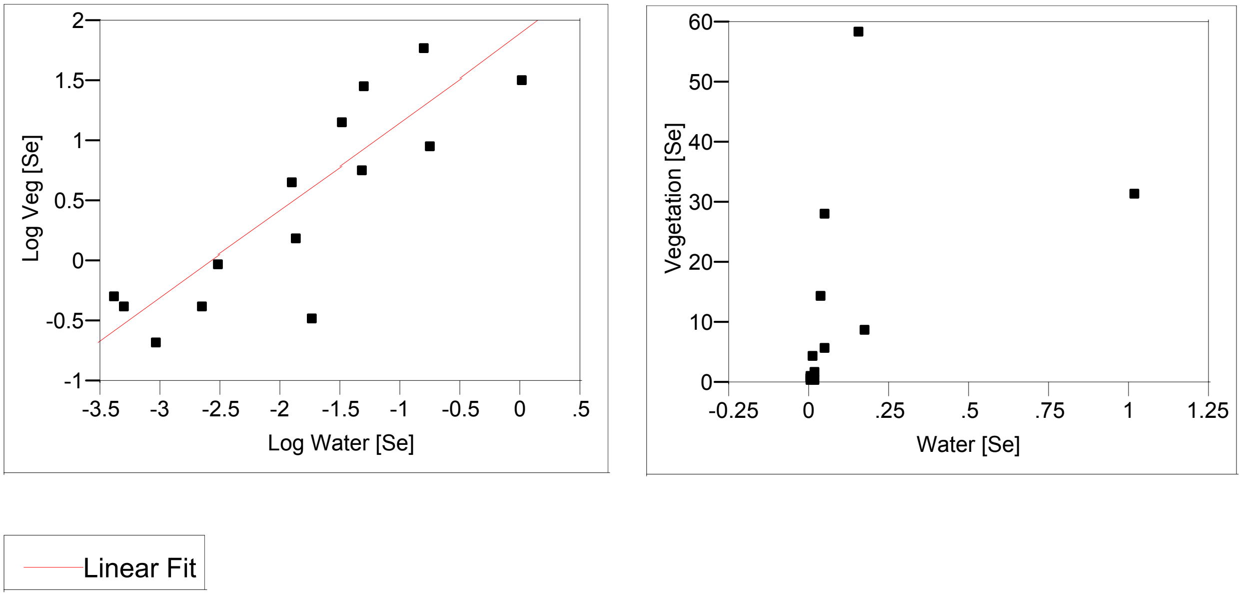
$$\text{Veg [Se]} = 10^{\,1.8985 + 0.7350 \,\text{Log}_{10}\, \text{Water [Se]}}$$

Where:

Veg [Se]	=	Vegetation tissue Se concentration in mg/kg dry weight
Water [Se]	=	Total recoverable waterborne Se concentration in mg/L

At a water concentration of 10 µg/L total Se, the predicted Se concentration in plant tissue would be 2.7 mg/kg.

Figure G-2 Bivariate Fit of Log Vegetation [Se] By Log Water [Se]



Linear Fit

Log Veg [Se] = 1.8984682 + 0.7350269 Log Water [Se]

Summary of Fit

Rsquare	0.72979
RSquare Adj	0.707273
Root Mean Square Error	2.082061
Mean of Response	0.721051
Observations (or Sum Wgts)	238.5

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	140.49644	140.496	32.4100
Error	12	52.01971	4.335	Prob > F
C. Total	13	192.51615		0.0001

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	1.8984682	0.246881	7.69	<.0001
Log Water [Se]	0.7350269	0.129111	5.69	0.0001

G5.2.2 Nektonic Invertebrates

Historical data for waterboatmen (*Chorixids*) from Moore et al. (1990), as well as the more recent data collected by Fan et al. (2002) were used to represent Se uptake in nektonic invertebrates. Because the Se concentrations of water entering the evaporation basins are expected to be approximately 10 ppb, data that were representative of these conditions (Se concentrations no greater than 20 µg/L in water) were used for the regression equation. Results are shown on Figure G-3, and the following predictive equation was calculated:

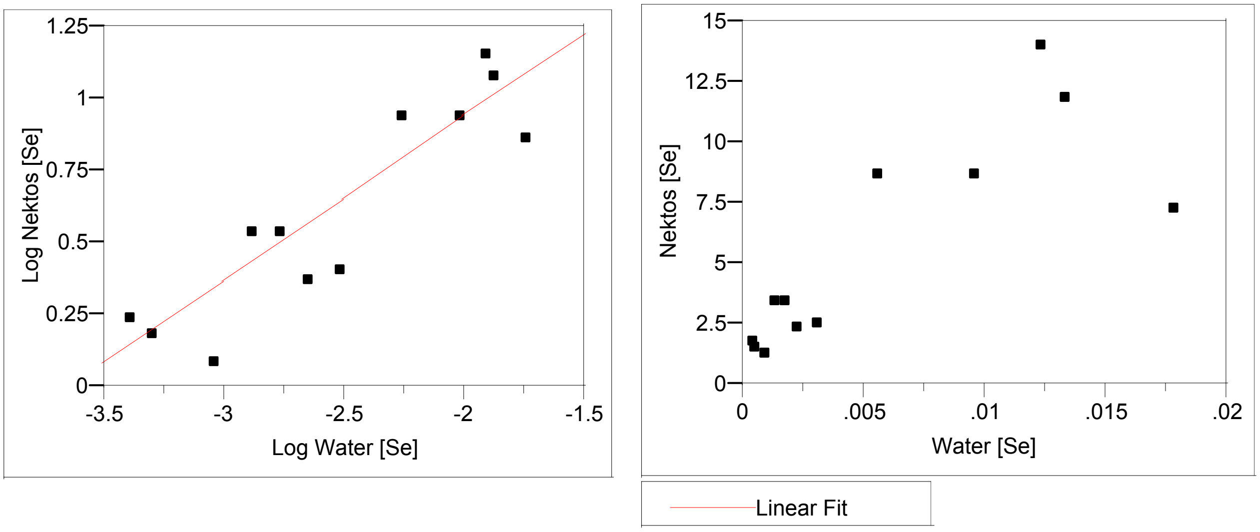
$$\text{Nektos [Se]} = 10^{2.0804 + 0.5711\ \text{Log}_{10}\ \text{Water [Se]}}$$

Where:

Nektos [Se]	=	Nektos tissue Se concentration in mg/kg dry weight
Water [Se]	=	Total recoverable waterborne Se concentration in mg/L

At a water concentration of 10 µg/L total Se, the predicted Se concentration in nektonic invertebrate tissue would be 8.7 mg/kg.

Figure G-3 Bivariate Fit of Log Nektos [Se] By Log Water [Se]



Linear Fit

Log Nektos [Se] = 2.0803684 + 0.5711376 Log Water [Se]

Summary of Fit

Rsquare	0.816157
RSquare Adj	0.797772
Root Mean Square Error	0.659202
Mean of Response	0.678347
Observations (or Sum Wgts)	180.5

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	19.291334	19.2913	44.3942
Error	10	4.345466	0.4345	Prob > F
C. Total	11	23.636800		<.0001

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	2.0803684	0.216067	9.63	<.0001
Log Water [Se]	0.5711376	0.085719	6.66	<.0001

G5.2.3 Benthic Invertebrates

Historical data for fly larvae (all available species) from Moore et al.(1990), as well as the more recent data collected by Fan et al. (2002) were used to represent Se uptake in benthic invertebrates. Because the Se concentrations of water entering the evaporation basins are expected to be approximately 10 ppb, data that were representative of these conditions (Se concentrations no greater than 20 µg/L in water) were used for the regression equation. Results are shown on Figure G-4, and the following predictive equation was calculated:

$$\text{Benthos [Se]} = 10^{2.8625 + 0.8345 \text{ Log}_{10} \text{ Water [Se]}}$$

Where:

Benthos [Se]	=	Benthos tissue Se concentration in mg/kg dry weight
Water [Se]	=	Total recoverable waterborne Se concentration in mg/L

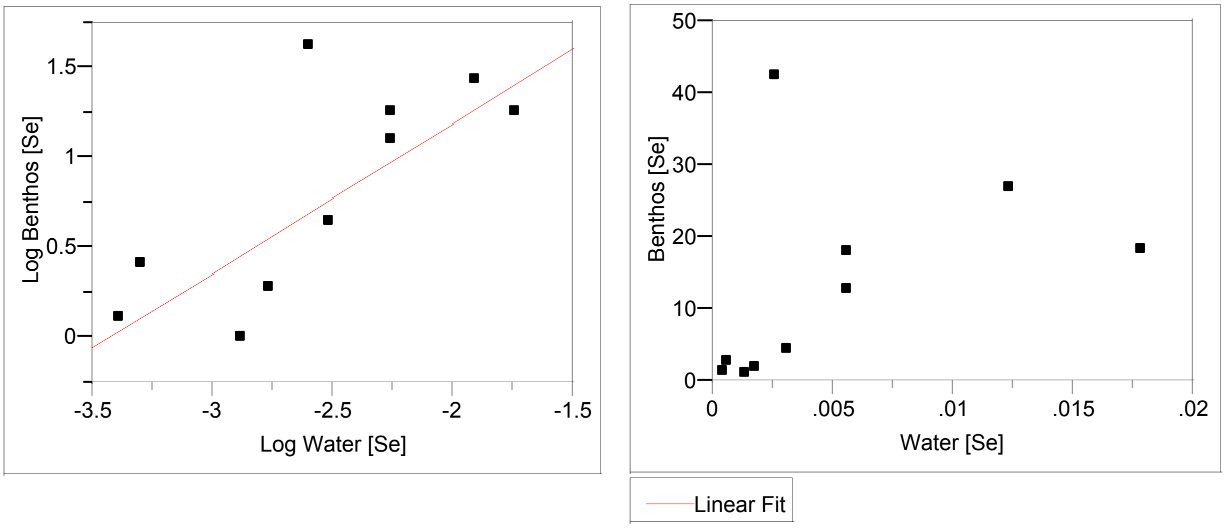
At a water concentration of 10 µg/L total Se, the predicted Se concentration in nektonic invertebrate tissue would be 15.6 mg/kg.

G5.3 Bird Exposure

For this evaluation it is assumed that the avian receptors obtain 100 percent of their food from the evaporation basins, and that they feed primarily on plants, nektonic invertebrates, and benthic invertebrates. Exposure to Se via incidental ingestion of water and sediment is assumed to be negligible compared to the dose received via food consumption.

To identify representative dietary compositions for each of the bird categories described in Table G-1, it was necessary to conduct a literature review of data on dietary composition for bird species in each of the categories considered for this analysis. The results of this review are presented in Table G-4. For each bird category, all species with at least 10 observances at all existing evaporation basins for all surveys (see Table G-2) were considered for dietary composition and included in Table G-4. Species with less than 10 observances were considered infrequent users of evaporation basins. For each bird species within each category, dietary data specific to Central Valley evaporation basins were considered primarily, when available, and data collected from other locations were considered secondarily. Because dietary composition for some species is known to change considerably during the breeding season, the data were separated into breeding season and nonbreeding season data.

Figure G-4 Bivariate Fit of Log Benthos [Se] By Log Water [Se]



Linear Fit

Log Benthos [Se] = 2.8625227 + 0.8345153 Log Water [Se]

Summary of Fit

Rsquare	0.810551
RSquare Adj	0.78687
Root Mean Square Error	0.922559
Mean of Response	0.758121
Observations (or Sum Wgts)	117.5

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	29.131702	29.1317	34.2277
Error	8	6.808924	0.8511	Prob > F
C. Total	9	35.940626		0.0004

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	2.8625227	0.369631	7.74	<.0001
Log Water [Se]	0.8345153	0.142641	5.85	0.0004

Table G-4
Bird Dietary Composition Data

Bird			Reference Number*	Central Valley Data - Breeding Season Dietary Composition (percent)						Central Valley Data - Nonbreeding Season Dietary Composition (percent)						Other Data - Breeding Season Dietary Composition (percent)						Other Data - Nonbreeding Season Dietary Composition (percent)					
Guild	Species	Common Name		Benthic Invertebrates	Nektonic Invertebrates	Terrestrial Invertebrates	Plants	Fish	Unspecified Animal Material	Benthic Invertebrates	Nektonic Invertebrates	Terrestrial Invertebrates	Plants	Fish	Unspecified Animal Material	Benthic Invertebrates	Nektonic Invertebrates	Terrestrial Invertebrates	Plants	Fish	Unspecified Animal Material	Benthic Invertebrates	Nektonic Invertebrates	Terrestrial Invertebrates	Plants	Fish	Unspecified Animal Material
Dabblers	*Anas acuta*	Northern pintail	1, 98							41.7 -g	8.6 -g		61 -b, 49.5 -g		29 -b, 0.2 -g												77 -b
	Anas americana	American wigeon	60										97 -b		3 -b				62 to 81 -b		18 to 41 -b						
	Anas clypeata	Northern shoveler	20, 98							4.5 -g	87.7 -g		7.5 -g		0.3 -g	94 -g					5 -g	55 -g	7 -g		10 -g	7 -g	
	Anas crecca	Green-winged teal	45										62.3 -a		37.6 -a										90.7 -c		9.3 -c
	Anas cyanoptera	Cinnamon teal	29										11 -d		89 -d								33 -d		67 -d		
	Anas discolor	Blue-winged teal	78																9 to 15 -b		85 to 91 -b				46 to 99 -b		1 to 54 -b
	Anas platyrhynchus	Mallard	19																30 -c		70 -c				74 -c		26 -c
	Anas strepera	Gadwall	49																42 to 54 -a		23 to 46 -a				95 to 97 -a		3 to 5 -a
	Fulica americana	American coot	6																				11 -a		89 -a		
Divers	*Melanitta perspicillata*	Surf scoter	83													100 -h						90 -h			7 -h		
	Mergus merganser	Common merganser	54																			5.9 -e				82.5 -e	11.6 -e
	Phalacrocorax auritus	Double-crested cormorant	38																							99 -a	1 -a
	Aechmorphorus clarkii	Clark's grebe	86																							81 to 100 -a	
	Aechmorphorus occidentalis	Western grebe	86																							81 to 100 -a	
	Aythya affinis	Lesser Scaup	2														90 -d		10 - d				75 -a		25 -a		
	Aythya americana	Redhead	95														77 -g		23 -g						70		
	Aythya collaris	Ring-necked Duck	40													25 -a	65 -a		10 -a				38		62		
	Aythya marila	Greater Scaup	46																			25 -b			70 -b		
	Aythya valisineria	Canvasback	61																90 -a		10 -a				90		10
	Bucephala albeola	Bufflehead	30																			66.8 --a	3.6 -a		9.5 -a	16.6 -a	3.3 -a
	Bucephala clangula	Common Goldeneye	24																			8.1 -a	31.4 -a		7.7 -a	46 -a	6.1 -a
	Clangula hyemalis	Long-tailed duck (Oldsquaw)	74														100 -a						99 -a		1 -a		
	Oxyura jamaicensis	Ruddy duck	4, 96, 97, 98	85 -a			15 -a			53.4-g, 89.3-g	36.7 -g, 1.4 -g, 92 -a		9.8 -g, 8.5 -g, 8 -a				95 -k		5 -k				57 -k		43 -k		
	Podiceps auritus	Horned grebe	85																			35 -c	35 -c			28 to 34.6 -c	
	Podiceps nigricollis	Eared grebe	14																				100 -a				
	Podilymbus podiceps	Pied-billed grebe	65																			74.8 -f				20.2 -f	
Nonbreeding Shorebirds	*Actitis macularia*	Spotted sandpiper	68																								
	Arenaria interpres	Ruddy turnstone	66														97.3 -a		2.7 -a				70		30		
	Tringa flavipes	Lesser yellowlegs	91																			75 to 80 -c		20 - 25 -c			
	Tringa melanoleuca	Greater yellowlegs	26																			60 to 65 -a	23 to 30 -a			6 to 10 -a	
	Caladris alba	Sanderling	53																			>95					
	Calidris alpina	Dunlin	92													73 to 75 -f		19 to 50 -f				70 -f	60 -f, 42 -f				
	Calidris bairdii	Baird's sandpiper	59																			100 -a					
	Calidris canutus	Red Knot	37																			100 -a					
	Calidris himantopus	Stilt sandpiper	47																90 -a		10 -a				29.9 -a		70.1 -a
	Calidris mauri	Western sandpiper	93																			100 -a					
	Calidris melanotos	Pectoral sandpiper	42													50 to 78	22 to 50					76.8 -a12.7 -a			10.5 -a		
	Calidris minutilla	Least Sandpiper	13																			54 -f		24 -f	19 -f		
	Calidris pusilla	Semipalmated sandpiper	34													60 to 85 -a		15 to 20 -a	0 to 10 -a			60 to 85 -a		15 to 20 -a	0 to 10 -a		
	Catoptrophorus semipalmatus	Willet	51																								
	Charadrius semipalmatus	Semipalmated plover	67																			78 to 100 -a		0 to 15 -a	0 to 8 -a		
	Gallinago gallinago	Common snipe	63																				6 to 8 -d	25 to 56 -d	46 to 66 -d		
	Limnodromus griseus	Short-billed dowitcher	44																			54 - a	3 -a	29 -a	12 -a		
	Limnodromus scolopaceus	Long-billed dowitcher	88																5 -h			15 -a	71 -a		12 -h		
	Limosa fedoa	Marbled godwit	35																			14 to 97 -c			33 to 86 -c		
	Numenius americanus	Long-billed curlew	21																			94 -a					7 -a
	Numenius phaeopus	Whimbrel	84															64 -a	11 -a		25 -a	37 -a				1 -a	62 -a
	Phalaropus lobatus	Red-necked phalarope	79																				100 -f				
	Phalaropus tricolor	Wilson's phalrope	11																				34 to 66 -f		11 -f		
	Philomachus pugnax	Ruff	96																					100			
	Pluvialis squatarola	Black-bellied plover	71																			100 -c					
Breeding Shorebirds	*Charadrius alexandrinus*	Snowy plover	69																								
	Charadrius vociferus	Killdeer	43																						0 to 2 -f		98 to 100 -f
	Himantopus mexicanus	Black-necked stilt	75, 97	~63 to 79 -j	~21 to 35 -j				~ 0 to 2 -j													7.9 -a	85.1 -a		1.1 -a	3.2 -a	2.7 -a
	Recurvirostra americana	American avocet	76, 97	~84 to 96 -j	~3 to 13 -j				~1 to 3 -j													8.6 - j	41.2 - j		34.9 - j		14.5 - j

Table G-4
Bird Dietary Composition Data

Bird			Reference Number*	Central Valley Data - Breeding Season Dietary Composition (percent)						Central Valley Data - Nonbreeding Season Dietary Composition (percent)						Other Data - Breeding Season Dietary Composition (percent)						Other Data - Nonbreeding Season Dietary Composition (percent)					
Guild	Species	Common Name		Benthic Invertebrates	Nektonic Invertebrates	Terrestrial Invertebrates	Plants	Fish	Unspecified Animal Material	Benthic Invertebrates	Nektonic Invertebrates	Terrestrial Invertebrates	Plants	Fish	Unspecified Animal Material	Benthic Invertebrates	Nektonic Invertebrates	Terrestrial Invertebrates	Plants	Fish	Unspecified Animal Material	Benthic Invertebrates	Nektonic Invertebrates	Terrestrial Invertebrates	Plants	Fish	Unspecified Animal Material
Other Waterbirds	*Anser albifrons*	Greater white-fronted goose	27										100 - a						100 -a								
	Ardea alba	Great egret	55																							90 -b	10 -b
	Ardea herodias	Great blue heron	10																	mostly							
	Branta bernicla	Brant	73																100 -a						100 -a		
	Branta canadensis	Canada goose	62																100						100		
	Bubulcus ibis	Cattle egret	89																					100			
	Chen caerulescens	Snow goose	63																						100		
	Chen rossii	Ross' goose	81																						100		
	Chlidonias niger	Black tern	23																					30 -e		93 -e	
	Cygnus columbianus	Tundra swan	50																					1.3 -a	98.7 -a		
	Larus argentatus	Herring gull	72																			86 to 100 -a				0 to 14 -a	
	Larus californicus	California gull	94																					77 -c	5 -c		5 -c
	Larus delawarensis	Ring-billed gull	80																			5 to 42 -f		0 to 8 -f	5 to 31 -f	0 to 61 -f	2 to 97 -f
	Larus philadelphia	Bonaparte's gull	9																			17 to 93 -f		0 to 33 -f		7 to 50	
	Larus pipixcan	Franklin's gull	8																						61 -f		
	Laterallus jamaicensis	Black rail	25																				14 to 73 -c	14 to 95 -c	16 to 51 -c		
	Nycticorax nycticorax	Black-crowned night-heron	16																			21 -f	5 -f	16 -f		29 to 59 -f	30 -f
	Pelecanus erythrorhyncos	American white pelican	28																							100 -a	
	Plegadis chihi	White-faced ibis	82																								
	Sterna antillarum	Least tern	90																			5 -a				57 -a	38 -a
	Sterna caspia	Caspian tern	15																			0 to 2 -a				98 to 100 -a	
	Sterna elegans	Elegant tern	7																			0 to 1 -a				99 to 100 -a	
	Sterna forsteri	Forster's tern	57																			0 to 1 -a				99 to 100 -a	

* - See end of reference list for numbered references cited in Table G-
a - unspecified units
b - aggregate percentages
c - percent by volume (esophageal of stomach contents
d - percent total dry weigh
e - percent by frequency of prey choic
f - percent stomach containing item
g - percent aggregate dry weigh
h - percent wet weigh
j - percent weight not specified dry or we
k - percent aggregate wet weigh

Dietary composition percentages used for this evaluation are presented in Table G-5, and discussed in the following sections. The following equation is used to calculate the average dietary Se concentration for each bird category:

$$BX_{group} = (P_v * Veg\ [Se]) + (P_n * Nektos\ [Se]) + (P_b * Benthos\ [Se])$$

Where:

BX_{group} = Average dietary concentration for birds within the category being considered (mg Se/kg tissue (dry weight))

P_v = Proportion of diet from vegetation

P_n = Proportion of diet from nektonic inverts

P_b = Proportion of diet from benthic invertebrates

Table G-5
Estimated Dietary Composition for Bird Categories

Bird Category	Dietary Composition (Percent)							
	Breeding Season				Nonbreeding Seasons			
	Benthic Invertebrates	Nektonic Invertebrates	Plants	Source	Benthic Invertebrates	Nektonic Invertebrates	Plants	Source
Dabblers (except for Northern Shoveler)	77	8	15	Estimated from data presented in Table G-4 (no Central Valley data)	42	9	49	Euliss et al. (1991) (Central Valley data on northern pintail)
Northern Shoveler	0	100	0	Estimated from data presented in Table G-4 and Euliss et al. (1991)	5	88	7	Euliss et al. (1991) (Central Valley data)
Divers	85	0	15	Brua (2002) (Ruddy duck at Tulare Basin)	53	37	10	Euliss et al. (1991) (Central Valley data on ruddy duck)
Shorebirds ("Breeding" and "Nonbreeding)	96	4	0	Cooper et al. (unpublished) (Central Valley stilts and avocets)	96	4	0	Cooper et al. (unpublished) (Central Valley stilts and avocets)

G5.3.1 Dabblers

For dabblers, no studies were found on dietary composition conducted in the Central Valley during the breeding season. Central Valley data collected during other seasons indicate that plants make up approximately 61 to 97 percent of the diet of the dabbler species investigated, but little information is available on nektonic or benthic invertebrates in the diet. A review of dietary data collected from other areas indicates that, in general, dabblers forage primarily on plant material during most seasons. However, during the breeding season, benthic and/or nektonic invertebrates can compose up to 100 percent of the diet. Northern shovelers tend to feed primarily on invertebrates throughout the year, and are not typical of other dabblers in this respect. Therefore, for the purposes of the exposure and risk analysis, the northern shoveler will be evaluated separately from other birds in the "dabbler" category.

Euliss et al. 1991 collected dietary composition data on northern pintails during September through March (fall and winter seasons), but no data for spring or summer (breeding season). A review of the data presented by Euliss et al. (1991) indicates that during October 100 percent of the diet was plant material. September was the only other fall month for which data were collected, and these data indicate that approximately 43 percent of the diet was plant material, 43 percent was benthic invertebrates, and 14 percent was nektonic invertebrates. During winter, Euliss et al. (1991) presented data for the three months of January, February, and March. During January, 100 percent of the diet was composed of vegetation. However, during February, approximately 11 percent of the diet was benthic invertebrates, and 18 percent was nektonic invertebrates. During March, approximately 75 percent of the diet was benthic invertebrates and 8 percent was unspecified animal material. No data were collected during November or December by Euliss et al., but it is assumed that the diet during this time would be close to 100 percent plant material.

Based on the data presented by Euliss et al. (1991), the aggregated percent dry weight dietary data for northern pintails collected over the entire study period (September–March) are used to represent dietary composition for dabblers during the nonbreeding seasons (August–April): 42 percent benthic invertebrates, 9 percent nektonic invertebrates, and 49 percent plant material (see Table G-5).

The data presented in Table G-4 indicate that at least some dabbler species (blue-winged teal, mallard, and gadwall) tend to eat higher quantities of invertebrates during the breeding season than during other periods of the year. In most cases, the types of invertebrates or animal material were not specified. Therefore, the following dietary composition for dabblers are used during the breeding season (May–July): 77 percent benthic invertebrates, 8 percent nektonic invertebrates, and 15 percent plant material (see Table G-5). While data presented in Table G-4 indicate that the blue-winged teal may consume a higher percentage of invertebrates (85 to 91 percent) during the breeding season, this species is infrequently observed at evaporation basins compared to other dabbler species (see Table G-2).

The Euliss et al. (1991) study also included data on the dietary composition of northern shovelers foraging at evaporation basins. Again, no data for spring or summer were presented. However, data from other areas indicate that during the breeding season, this species consumed 94 percent benthic invertebrates and 5 percent unspecified animal material. Because this species has been observed to forage primarily on nektonic species in Central Valley evaporation basins, it is reasonable to assume that during the breeding season, northern shovelers foraging at evaporation basins in the Central Valley may consume up to 100 percent nektonic invertebrates.

Based on the data presented by Euliss et al. (1991), aggregated percent dry weight dietary data for northern shovelers collected over the entire study period (September–March) are used to represent dietary composition for this species during the nonbreeding seasons (August–April): 5 percent benthic invertebrates, 88 percent nektonic invertebrates, and 7 percent plant material (see Table G-5).

G5.3.2 Divers

The Euliss et al. (1991) study included data on the dietary composition of ruddy ducks foraging at evaporation basins. Again, no data for spring or summer were presented in this study. However, data collected at evaporation basins in Tulare Basin indicate that this species consumed 85 percent benthic invertebrates and 15 percent plant matter during March and April, right before the breeding season (Brua 2002). Data collected from other areas indicate that other species of divers consume 65 to 100 percent nektonic invertebrates during the breeding season (see Table G-4). The long-tailed duck was reported to consume 100 percent nektonic invertebrates; however, this species was infrequently observed at evaporation basins compared to other species of divers (see Table G-2). Therefore, the data collected for the ruddy duck at Tulare Basin are used to represent the dietary composition of divers at evaporation basins during the breeding season (see Table G-5).

Based on the data presented by Euliss et al. (1991), aggregated percent dry weight dietary data for ruddy ducks collected over the entire study period (September–March) are used to represent dietary composition for divers during the nonbreeding seasons (August–April): 53 percent benthic invertebrates, 37 percent nektonic invertebrates, and 10 percent plant material (see Table G-5).

G5.3.3 Shorebirds (“Breeding” and “Nonbreeding”)

Cooper et al. (unpublished) collected data on the dietary composition of the American avocet and black-necked stilt foraging at San Joaquin Valley evaporation basins. The report does not present numbers for dietary percentages; data are presented in charts and graphs from which the reader must estimate numerical percentages. 1992 data for the American avocet indicated that benthic invertebrates composed approximately 96 percent of the diet. For the black-necked stilt, benthic invertebrates composed approximately 63 and 79 percent of the diet in 1991 and 1992, respectively. Although data from other locations (see Table G-4) indicate that the diet of these two species may be composed of a larger percentage of nektonic invertebrates in some cases, site-specific data were preferred for this evaluation. To be adequately protective of all shorebird species, the assumed dietary composition is 96 percent benthic invertebrates, 4 percent nektonic invertebrates throughout the year (both breeding and nonbreeding seasons) (see Table G-5). These values apply to both “breeding shorebirds” (those species that are expected to breed at evaporation basins) and to “nonbreeding shorebirds” (those species that are expected to forage but are not likely to breed at evaporation basins).

G5.3.4 Other Waterbirds and Upland Birds

Dietary composition data for birds in the “other waterbirds” category are presented in Table G-4. A review of these data indicates that many of these species feed primarily on fish or terrestrial plants and invertebrates, and it is unlikely that aquatic invertebrates and plants from the evaporation basins would compose a high percentage of their diets. Similarly, it is expected that birds categorized as “upland birds” in Table G-2 obtain most of their food from terrestrial sources. Therefore, no quantitative evaluation of risks was conducted for the species categorized as “other waterbirds” or “upland birds” as these species are unlikely to experience significant exposure to Se via feeding on plants or invertebrates at evaporation basins. An exception is for raptors that may potentially be affected by feeding on water birds contaminated with Se from evaporation basins. Potential effects to raptors are addressed in Section G7.2.3.

G6 EFFECTS ASSESSMENT

The effects assessment is a qualitative and quantitative description of the relationship between the predicted chemical concentration or dose and the nature of possible effects elicited in exposed receptors, populations, or ecological communities. In this evaluation, predicted plant and invertebrate tissue concentrations are used to determine whether adverse effects are likely in birds feeding at the evaporation basins.

As described in Section G4.3, the assessment endpoints defined in this evaluation include the following:

- Protection of populations of migratory ducks, waterfowl, and other birds likely to overwinter or forage but not breed at the proposed evaporation basins
- Protection of populations of shorebirds such as stilts and avocets, and other birds likely to nest, breed, and forage at the proposed evaporation basins
- Protection of individuals of threatened or endangered raptor species such as the American peregrine falcon that are likely to prey on aquatic birds that forage at evaporation basins

The measurement endpoint used in this evaluation consisted of predicting Se concentrations in the plant and invertebrate tissue, and comparing these predicted tissue concentrations to dietary thresholds associated with adverse effects in avian receptors. A literature search was conducted to identify Se dietary thresholds associated with adverse effects, including acute effects such as adult and chick mortality, as well as chronic sublethal effects such as reduced reproduction and embryo deformities. Duration of exposure was also considered, as birds that are nesting and breeding at the site are likely to receive longer-term, continuous exposure than birds that are overwintering or resting at the evaporation basins.

G7 RESULTS AND DISCUSSION

G7.1 Selenium Concentrations in Water, Plant, and Invertebrate Tissue

Table G-6 presents the predicted Se concentrations in influent water and plant, nektonic invertebrate, and benthic invertebrate tissue for the proposed evaporation basins.

Table G-6
Predicted Selenium Concentrations in Influent Water and Dietary Tissue

[Se] in Influent Water (µg/L)	[Se] in Plant Tissue (mg/kg dry weight)	[Se] in Nektonic Invertebrate Tissue (mg/kg dry weight)	[Se] in Benthic Invertebrate Tissue (mg/kg dry weight)
10	2.7	8.7	15.6

Table G-7 presents the average predicted Se concentrations in the dietary items of each bird category. These estimates were calculated based on the estimated dietary composition of each bird category, as described in Section G5.3.

Table G-7
Predicted Average Selenium Concentration in Diet of each Bird Category

Bird Category	Average Dietary [Se] (mg/kg dry weight)	
	Breeding Season	Nonbreeding Seasons
Dabblers (except for Northern Shoveler)	13.1	8.7
Northern Shoveler	8.7	8.6
Divers	13.7	11.8
Shorebirds (“Breeding” and “Nonbreeding”)	15.3	15.3

The following sections describe the Se levels associated with acute and chronic toxicity in birds, and characterize the potential effects likely to occur in the proposed evaporation basins.

G7.2 Avian Toxicity Thresholds for Selenium

A literature search was conducted to identify Se dietary thresholds associated with adverse effects, including acute effects such as adult and chick mortality, as well as chronic sublethal effects such as reduced reproduction and embryo deformities. Avian feeding studies indicate that dietary Se concentrations that cause avian mortality are much higher than concentrations causing reproductive impairment (Peterson and Nebeker 1992). Of the reproductive effects studied, reduced egg hatchability is believed to be a more sensitive endpoint than teratogenesis.

Duration of exposure was also considered, as birds that are nesting and breeding at the site are likely to receive longer term, continuous exposure than birds that are overwintering or resting at the evaporation basins.

Little quantitative information is available on potential Se-related effects to birds that utilize evaporation basins outside the breeding season, as migratory resting habitat or for overwintering (Hanson Environmental 2003; CH2M HILL 1993). Potential nonlethal effects may include weight loss, atrophy of feather follicles, and atrophy of lymphoid tissue (Hanson Environmental 2003). It is unknown whether these effects are likely to contribute to lower reproductive success. However, at high Se concentrations in dietary items, lethal effects are also possible.

The following sections describe the results of the literature search on Se toxicity. First, data on reproductive effects are described. These are the types of effects most often documented for Se, and are most relevant to birds that are likely to breed at the proposed evaporation basins. In the next section, data on mortality associated with Se exposure are summarized. In areas with high Se concentrations, lethal effects may be relevant both for migratory birds that receive relatively short term exposure, as well as for nesting birds that receive longer term exposure.

G7.2.1 Reproductive Effect Thresholds

Threshold effect levels for Se exposure have been estimated for breeding birds in the San Joaquin Valley (Hanson Environmental 2003). Thresholds have been developed for waterborne Se, dietary items (aquatic plants and invertebrates), and avian egg tissues. The incidence of adverse effects is likely to increase at concentrations in exceedance of these threshold levels. The majority of these thresholds correspond to bird tissue concentrations, primarily in eggs. Although many of these data were reviewed and are presented below, the objective of the current evaluation is to identify dietary Se concentrations that correspond to adverse effects in waterbirds.

G7.2.1.1 Concentrations in Dietary Components

Se concentrations in dietary components of aquatic birds at Kesterson Reservoir and the San Luis Drain were highly elevated in the 1980s. Se concentrations measured in algae, rooted plants, net plankton, and various aquatic insects ranged from 20 to 332 mg/kg dry weight (Ohlendorf 2002). Total Se concentrations measured in aquatic invertebrates from 1983 through 1985 ranged from 45 to 215 mg/kg at Kesterson (Williams, Hothem, and Ohlendorf 1989). These concentrations are well above dietary levels estimated in the laboratory. Current Service guidelines indicate that the background concentration of Se in dietary components is <3 mg/kg dry weight, while concentrations between 3 to 7 mg/kg dry weight have the potential to cause adverse effects. Lemly (1996) reviewed data on Se toxicity and assigned a hazard ranking for dietary toxicity and reproductive failure in fish and aquatic birds from ingestion of Se-contaminated macroinvertebrates. A Se concentration of 2 to 3 mg/kg (dry weight) was assigned a hazard ranking of minimal toxicity, 3 to 4 mg/kg was assigned a hazard ranking of low toxicity, 4 to 5 mg/kg was assigned a hazard ranking of moderate toxicity, and greater than 5 mg/kg was assigned a hazard ranking of high toxicity. Peterson and Nebeker (1992) described the results of several comprehensive reviews on the effects of Se on animals. They concluded that it is widely agreed that chronic exposure to Se dietary concentrations greater than 5 mg/kg can result in adverse effects to birds and mammals. Dietary concentrations in exceedance of 7 mg/kg (i.e., the toxicity threshold) are associated with a high probability of adverse reproductive effects in birds (Byron et al. 2003).

Based on the studies discussed above, the significance threshold used to determine potential for adverse reproductive effects in this evaluation is a predicted average invertebrate tissue concentration exceeding 4 mg/kg Se (dry weight). The results of several dietary studies are provided in Table G-8.

It should be noted that no data exist that relate dietary Se concentrations to birds most likely to nest and breed at the site (recurvorostrids such as stilts and avocets). However, the egg tissue data presented below do include results of studies conducted on recurvorostrids, which indicates that birds in this family may be less sensitive to Se than some of the species included in the studies list in Table G-8.

Table G-8
Dietary Selenium Concentrations Associated with Adverse Reproductive Effects in Birds

Bird Species	Life Stage	Endpoint	Duration	Threshold Concentrations (dry weight)	Reference
Mallard	embryo	hatching success	chronic	NOAEL = 3.5 mg selenomethionine/kg feed LOAEL = 7 mg selenomethionine/kg feed	Stanley et al. 1996
Mallard	embryo	hatching success	chronic	EC_{10} = 4.87 mg Se/kg feed (form of Se not specified)	Ohlendorf 2003
Mallard	embryo	hatching success	chronic	EL = 3 to 5 mg selenomethionine/kg feed	Heinz and Fitzgerald 1993a,b
Mallard	embryo/ duckling	hatching success/ survival	chronic - 0 to 6 days old	EL = 10 mg selenomethionine/kg feed	Heinz and Hoffman 1996
Mallard	duckling	survival/ number produced per hen	chronic – 0 to 21 days	EL = 10 mg selenomethionine/kg feed NOAEL = 10 mg sodium selenite/kg feed LOAEL = 25 mg sodium selenite/kg feed	Heinz et al. 1987
Mallard	duckling	survival	chronic - 0 to 6 weeks old	NOAEL = 20 mg selenomethionine/kg feed LOAEL = 40 mg selenomethionine/kg feed	Heinz, Hoffman, and Gold 1988
Mallard	duckling	survival	Chronic 0 to 6 days old	NOAEL = 4 mg selenomethionine/kg feed LOAEL = 8 mg selenomethionine/kg feed	Heinz, Hoffman, and Gold 1989
Chicken	embryo	hatching success	chronic	LOAEL = 5 mg sodium selenite/kg feed	Ort and Latshaw 1978
Black-Crowned Night Heron	embryo	hatching success	chronic	NOAEL = 3.3 mg selenomethionine/kg feed	Smith et al. 1988
Japanese Quail	embryo	hatching success	chronic	EL = 6 mg sodium selenite/kg feed	El-Begearmi, Sunde, and Ganther 1977
Japanese Quail	embryo	hatching success	chronic	EL = 5 mg selenomethionine/kg feed	Martin 1988, as cited in Heinz 1996

EL = effect level
LOAEL = lowest-observable-adverse-effect level
NOAEL = no-observable-adverse-effect level

Data from several studies were used to develop dose-response relationships for reproductive effects based on dietary Se concentrations. Because a substantial number of studies were conducted on mallards, only data on this species were used in the data set. Three endpoints were evaluated: percentage of fertile eggs hatched, percentage survival of ducklings to 6 days of age, and number of 6-day old ducklings produced per hen. Measured values for each of these endpoints were plotted against dietary Se concentrations on Figures G-5, G-6, and G-7.

For the endpoint of percentage eggs hatched, data were sufficient to evaluate two forms of Se: selenomethionine and sodium selenite. Figure G-5 shows that the percentage of fertile eggs hatched begins to decrease when the dietary concentration of selenomethionine exceeds approximately 4 mg/kg, and when the dietary concentration of sodium selenite exceeds approximately 8 mg/kg. Hatching success decreases by approximately 50 percent when the dietary concentration of selenomethionine reaches about 8 mg/kg, and hatching success is close to zero at a dietary selenomethionine concentration of 16 mg/kg. This endpoint is less sensitive to sodium selenate in the diet; at 25 mg/kg a decrease in hatching success of approximately 10 percent was exhibited. However, selenomethionine is the form of Se that occurs predominantly in invertebrate tissue. The fitted regression equations calculated based on the data are:

- Selenomethionine: Percent Eggs Hatched = 150.2 - 84.06 * exp(0.03547*[Se])
- Sodium selenite: Percent Eggs Hatched = 123.6 - 53.67 * exp(0.01087*[Se])

For the other two endpoints (percentage survival of ducklings to 6 days of age, and number of 6-day-old ducklings produced per hen), data were sufficient to evaluate only one form of Se: selenomethionine. Figure G-6 shows that the percentage survival begins to decrease when the dietary concentration of selenomethionine exceeds approximately 8 mg/kg, and survival is close to zero at a dietary selenomethionine concentration of 16 mg/kg. Figure G-7 shows that the number of surviving ducklings per hen begins to decrease when the dietary concentration of selenomethionine exceeds approximately 4 mg/kg, and survival is close to zero at a dietary selenomethionine concentration of 16 mg/kg. The fitted regression equations calculated based on the data are:

- Percent Survival = 105.8 - 5.058 * exp(0.1901*[Se])
- Number of Ducklings = 17.32 - 8.634 * exp(0.04374*[Se])

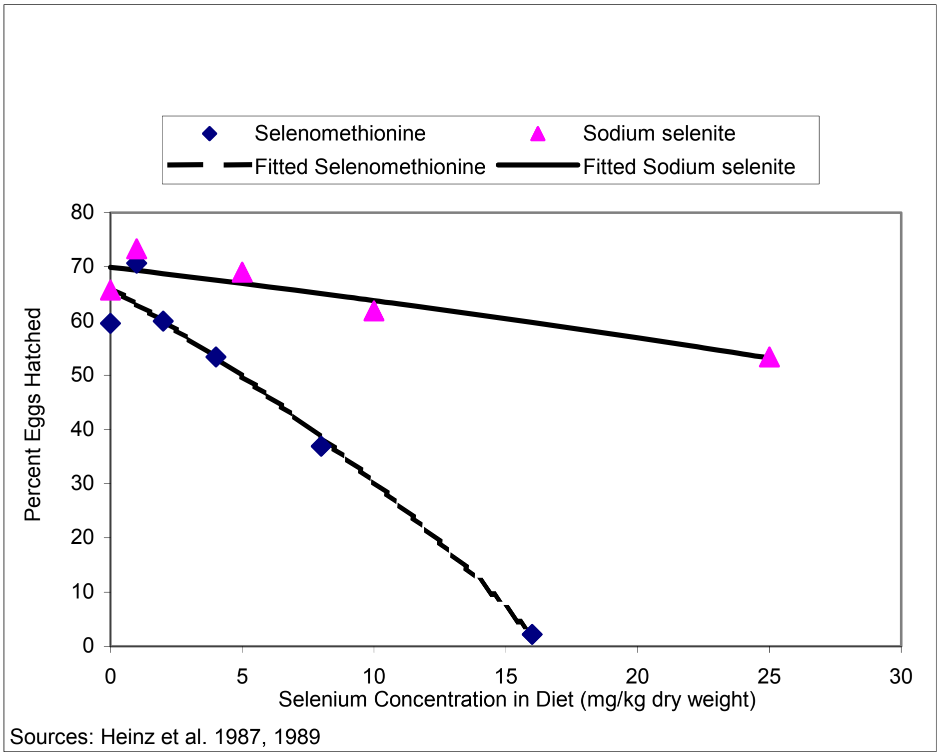


Figure G-5 Percentage of Fertile Eggs Hatched vs. Selenium Concentration in Diet of Mallard Ducks

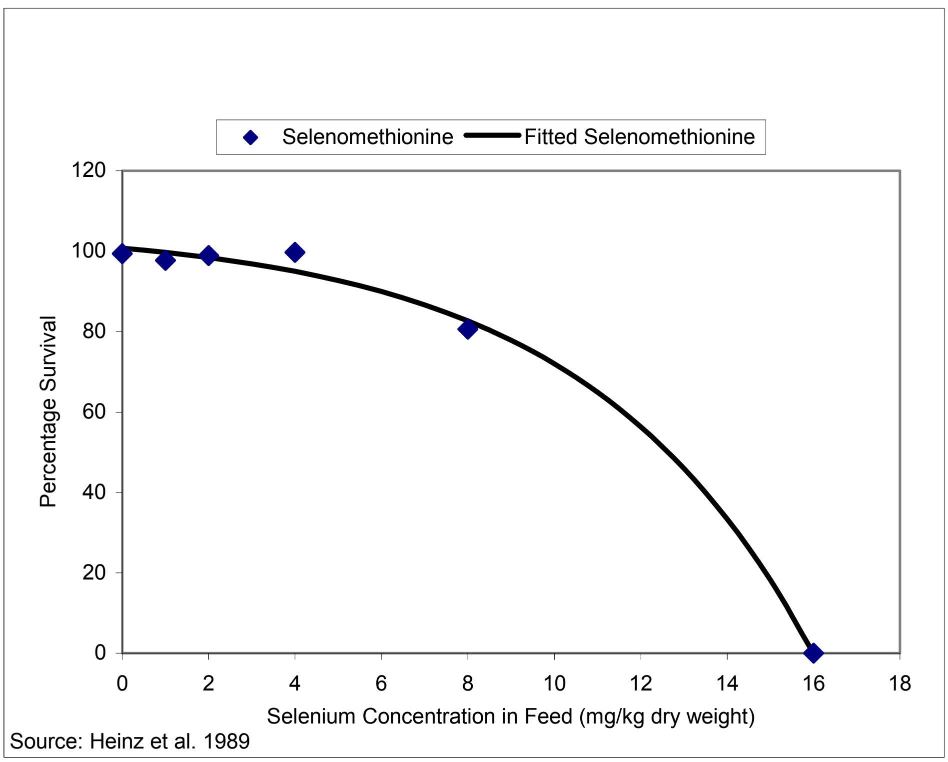


Figure G-6 Percentage Survival of Mallard Ducklings to 6 Days of Age vs. Selenium Concentration in Diet of Parents

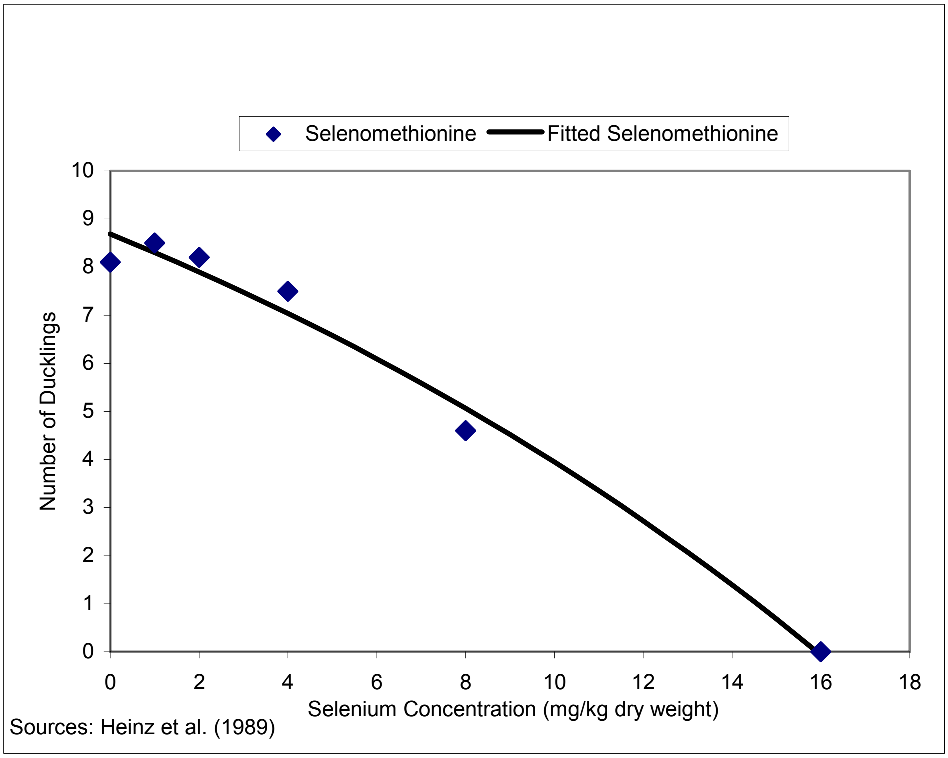


Figure G-7 Number of 6-Day-Old Mallard Ducklings Produced per Hen vs. Selenium (as Selenomethionine) Concentration in Diet

G7.2.1.2 Concentrations in Egg Tissue

Eggs of various bird species were collected from Kesterson Reservoir from 1983 through 1985 (Ohlendorf and Hothem 1995). Mean Se concentrations in these eggs ranged from 3.2 to 180 mg/kg dry weight. Table G-9 provides the ranges of Se concentrations in eggs of waterbirds collected from Kesterson during this 3-year time period. Embryo deformities and malformations were observed at Kesterson during this time period. In fact, of the 578 nests monitored at Kesterson, including nests of waterbirds and some terrestrial species, at least 39 percent contained at least one dead or deformed embryo or chick. A direct correlation was found between Se concentrations in eggs and these adverse effects, such that embryo death or deformity increased and hatching success decreased as Se concentrations increased (Ohlendforf and Hothem 1995).

The effects concentration to 10 percent of the population (EC_{10}) in egg tissue corresponding to teratogenesis in mallards, stilts, and avocets vary substantially, with EC_{10}s of 23 mg/kg, 37 mg/kg, and 74 mg/kg, respectively (Ohlendorf, in press, as cited in Hanson Environmental 2003). Teratogenesis is a severe response and, therefore, it is a relatively insensitive endpoint. More subtle developmental effects, such as reduced hatchability, are expected to provide better estimates of chronic exposure levels (Heinz 1996; Skorupa 1998; Ohlendorf 2003). Some recent studies provide data to support the idea that reduced egg hatchability is a more sensitive endpoint than teratogenesis. For example, an EC_{10} of 16 mg/kg based on reduced hatchability was reported for mallards (Fairbrother et al. 1996, as cited in Hanson Environmental 2003). In addition, Ohlendorf (2003) calculated a geometric mean egg Se threshold level (EC_{10}) of 12.5 mg/kg from the available data on mallards.

Table G-9
Selenium Concentrations in Bird Eggs Collected from Kesterson Reservoir, 1983–1985

Species	Egg Concentrations (mg/kg dry weight)
Eared grebe (*Podilymbus nigricollis*)	44–130
Mallard (*Anas platyrhynchos*)	3.6–31
Cinnamon teal (*Anas cyanoptera*)	3.9–37
Gadwall (*Anas strepera*)	7.3–33
American coot (*Fulica americana*)	17–74
Killdeer (*Charadrius vociferus*)	14–180
Black-necked stilt (*Himantopus mexicanus*)	4.3–100
American avocet (*Recurvirostra americana*)	3.2–88
Forster's tern (*Sterna forster*)	6.7–18

Skorupa and Ohlendorf (1991) established two linear regression models to evaluate the relationships between (1) waterborne Se and concentrations in the food chain and (2) dietary Se and mean egg Se residues. The first model incorporated field data from evaporation basins within the San Joaquin Valley, and the second model was based on laboratory studies with farm-raised mallards exposed to selenomethionine in their diet. The results of the regression analysis indicated that water-borne Se concentrations of 0.5–2.3 µg/L represent the range not exceeding the egg tissue threshold level of 3 mg/kg dry weight (0.9 mg/kg wet weight). At the time the models were established, this level was assumed to equal the natural background concentration because embryo deformities were seen in only 3 of 55 populations of birds at this concentration (Hanson Environmental. 2003). However, the egg tissue threshold level of 3 mg/kg dry weight was later re-evaluated (as discussed below) based on a more robust and current data set.

Subsequent to the analysis of additional egg tissue data for stilts and avocets in relation to the incidence of reproductive effects, Skorupa (1998) calculated a threshold level of 6 mg Se/kg egg tissue dry weight. This threshold level represents an upper bound estimate of safe exposure levels for stilt embryos and is currently proposed by the Service as the threshold level for Se in avian egg tissue. This value was applied to the regression model to generate the Service recommended chronic water quality criterion of 2 µg/L for the protection of waterbirds. Current guidelines (Service) indicate that the respective background concentrations of Se in water (as total recoverable Se) and waterbird eggs are <2 µg/L and <6 mg/kg dry weight. Concentrations in water between 2 to 5 µg/L and in eggs between 6 to 10 mg/kg dry weight have the potential to cause effects. Finally, Se concentrations in exceedance of 5 µg/L in water and 10 mg/kg dry weight in egg tissue are associated with a high probability of adverse effects in birds (Byron et al. 2003). The current USEPA ambient water quality criterion for chronic Se exposure of 5 µg/L is above the recommended Service criterion (i.e., "no effects" threshold level) of 2 µg/L.

Brix (2000) evaluated the scientific justification used to establish the egg Se threshold level of 6 mg/kg dry weight proposed by the Service in an effort to develop an alternative threshold level.

Brix (2000) derived dose-response relationships for the laboratory data available for mallards and dose-response relationships for existing field data for mallards and recurvirostrids, and then compared the results. By pooling the laboratory data for mallards, Brix (2000) established a dose-response relationship for duckling mortality and teratogenicity. The findings of this study indicate that conservative threshold levels (EC_{10}s) are 16 mg/kg dry weight for chick mortality (i.e., reduced hatchability) and 26 mg/kg dry weight for teratogenic effects. The threshold level for chick mortality is more than two times greater than the level developed by Skorupa (1998) of 6 mg/kg dry weight, but the levels for teratogenesis are fairly similar (i.e., 26 mg/kg versus 23 mg/kg in the Skorupa [1998] study). Brix (2000) cites the main reason for the discrepancy between the two chick mortality threshold levels as the use of field data (in the Skorupa [1998] study), which is not a Se-specific endpoint due to the numerous other factors that could contribute to chick mortality. These confounding factors inherent in the field data are attributed to the much lower threshold level. Some of the confounding factors cited in the study include the presence of other contaminants, predators, weather, and starvation.

G7.2.2 Mortality Thresholds

Heinz and Fitzgerald (1993b) evaluated the effects of overwinter exposure to Se on reproduction of mallards. Forty pairs of mallards were fed a dietary concentration of 15 mg/kg Se as selenomethionine for about 21 weeks during winter. The dietary concentration of 15 mg/kg Se was selected to represent a severe, prolonged exposure that would be likely to result in sublethal reproductive effects, without causing significant mortality in adults. However, four adults died during the 21 weeks of treatment. The Se treatment was discontinued at the start of the breeding season. Treated females lost weight, and their egg laying was delayed. During the first 2 weeks of egg laying, the hatching success in the treated group was lower than that in the control group, and a few of the early eggs contained deformed embryos. However, Se was quickly depurated from tissues, and after a period of about 2 weeks off the Se-treated diet, reproductive success returned to a level comparable to that of the control group (Heinz and Fitzgerald 1993b).

A concentration of 80 ppm sodium selenite in the diet of 6-week-old mallard ducklings resulted in 97.5 percent mortality by 6 weeks. A concentration of 80 ppm selenomethionine in the diet of 6-week-old mallard ducklings resulted in 100 percent mortality by 6 weeks. At 40 ppm, these two forms of Se resulted in 25 percent and 12.5 percent mortality, respectively. No mortality occurred at 20 ppm (Heinz, Hoffmann, and Gold 1988).

Eleven out of 12 adult mallards fed a diet containing 100 ppm Se as sodium selenate died within 16 to 39 days. One of 20 adult mallards fed a diet containing 25 ppm Se died at 57 days (Heinz 1987).

Adult male mallards were fed diets containing 0, 10, 20, 40, and 80 mg/kg Se as selenomethionine, with 20 birds in each treatment group. After 1 week of treatment, body weights were significantly lower in the 20, 40, and 80 mg/kg treatment groups, but not in the 10 mg/kg group. Mortality began in the 40 and 80 mg/kg treatment groups during the third week of treatment. By the fourth week, mortality in birds fed 80 mg/kg Se was significantly greater than at 10 or 20 mg/kg Se. By the eighth week, all birds in the 80 mg/kg treatment group had died. Mortality occurred by the 16th week in 19 out of 20 birds in the 40 mg/kg treatment group, but the one survivor died 5 days after treatment ended. Mortality among mallards fed 20 mg/kg Se was significantly greater than the control group by the 13th week, and 25 percent died by the

16th week. No mortality occurred among birds fed 10 mg/kg Se during the 16-week treatment period. Mallards that died from Se treatments were severely emaciated. The lowest dietary concentration of Se associated with significant weight loss or mortality was 20 mg/kg (Heinz and Fitzgerald 1993a).

Based on results in this study and previous studies conducted, Heinz and Fitzgerald (1993a) concluded that the dietary threshold of Se causing weight loss and mortality in adult mallards is likely to be between 10 and 15 mg/kg dry weight. The threshold may be higher during warm weather. Diseases and other natural stressors, such as migration, breeding, and food shortages, may also affect the threshold. In addition, differences are likely to occur in the toxicity of different forms of Se, as well as differences in the sensitivity of various bird species (Heinz and Fitzgerald 1993a).

In another study conducted on adult male mallards over a 21-week warm weather period (March to July), groups of 21 birds each were fed diets containing 0, 10, 20, 40, and 80 mg/kg Se as selenomethionine. All ducks receiving 80 mg/kg Se died, and 15 percent of ducks receiving 40 mg/kg Se died during the treatment period. The authors hypothesized that the lower threshold for mortality observed in the Heinz and Fitzgerald (1993a) study may have been due to increased stress of cold temperatures (Albers et al. 1996).

In 16- and 20-week studies, no adverse effects on mortality rates, body weight, or food consumption were observed among Japanese quail administered a concentration of 6 ppm Se as sodium selenite in their diet. Increased mortality at 12 weeks, reduced egg production and hatchability, and increased deformities were observed among Japanese quail administered a concentration of 12 ppm Se as sodium selenite in their diet (El-Begearmi et al. 1977).

G7.2.3 Potential Effects to Raptors

Predatory birds may feed on aquatic birds that forage on invertebrates in the evaporation basins. Aquatic birds that obtain a large amount of their diet from evaporation basins are likely to contain elevated Se levels in their tissue. Therefore, predatory birds are likely to receive Se exposure by feeding on these birds. American peregrine falcons (*Falco peragrinus*) have been observed feeding on shorebirds at the Tulare Lake Drainage District evaporation basins (Hanson Environmental 2003). Two sick American peregrine falcons were recovered during mid-summer 1992, and blood and feather samples collected from these birds contained elevated Se levels. One birds was too weak to fly. Both birds experienced full recovery after being fed a diet containing a normal Se concentration (Hanson Environmental 2003).

Santolo et al. (1999) investigated effects on reproduction in captive American kestrels (*Falco sparverius*) fed 6 and 12 mg/kg selenomethionine for 11 weeks. No statistically significant difference was observed between these groups and the control group in terms of percentage of pairs that laid eggs, numbers of pairs that were fertile, or hatchability of fertile eggs. The percentage of the total number of fertile eggs produced was lower in the group fed the 12 mg/kg Se diet than in the other two groups, but the difference was not statistically significant. The authors indicated that results were not conclusive regarding Se embryotoxicity, but suggested that kestrels may be less sensitive to Se than are aquatic species such as mallards (Santolo et al. 1999).

Peregrine falcons are in the same family as kestrels (*Falconidae*), but feed primarily on birds, while the kestrels also feed on worms, insects, amphibians, reptiles, and small mammals (USEPA 1993). The size of the kestrel's territory in winter has been estimated to range from approximately 10 to 452 hectares, and the territory size in summer has been estimated to range from approximately 21 to 500 hectares (USEPA 1993).

G7.3 Effects Characterization

This section describes probable ecological effects predicted to occur in each bird category as a result of Se exposure at the proposed evaporation basins. Probable effects are determined by comparing the predictive average dietary concentrations with toxicity threshold data.

To estimate the number of birds in each category that would be exposed to Se at the proposed evaporation basins, the total size of the evaporation basins was multiplied by the bird density calculated using historical data (see Table G-3). Estimates were made for average conditions, when the total evaporation basin area would be approximately 2,870 acres, and for wet conditions, when the maximum total evaporation basin area would be approximately 3,290 acres. As discussed in Section G2.3.4, the median bird density is expected to best represent the central tendency. However, the mean would better account for pulses in densities, such as those that would occur during migrations. As there is uncertainty about how long individual birds would be likely to stay at the evaporation basins during the migration seasons (several days or several weeks), it may be useful to take into account temporary increases in densities. Therefore, the total number of birds in each category that would be expected to utilize the evaporation basins during each season were calculated using both the mean and the median bird densities, and results are presented in Tables G-10 and G-11, respectively.

Table G-10
Estimated Total Number of Birds Assuming Mean Density

Season	Bird Category	Estimated Total Number of Birds (assuming mean density)	
		2,870 Acres Total Evaporation Basins (average wetted area)	3,290 Acres Total Evaporation Basins (maximum wetted area)
Spring Migration (Feb-Apr)	Dabblers	4,232	4,851
	Divers	5,018	5,752
	Breeding Shorebirds	1,415	1,622
	Nonbreeding Shorebirds	3,570	4,092
	Other Upland Birds	235	270
	Other Waterbirds	101	116
Breeding (May-Jul)	Dabblers	1,315	1,508
	Divers	537	616
	Breeding Shorebirds	2,015	2,310
	Nonbreeding Shorebirds	2,567	2,942
	Other Upland Birds	217	248
	Other Waterbirds	316	362
Fall Migration (Aug-Oct)	Dabblers	2,739	3,140
	Divers	2,001	2,294
	Breeding Shorebirds	3,496	4,008
	Nonbreeding Shorebirds	6,586	7,550
	Other Upland Birds	230	264
	Other Waterbirds	1,326	1,520
Winter (Nov-Jan)	Dabblers	3,890	4,459
	Divers	5,660	6,488
	Breeding Shorebirds	1,794	2,057
	Nonbreeding Shorebirds	8,487	9,729
	Other Upland Birds	152	174
	Other Waterbirds	456	523

Table G-11
Estimated Total Number of Birds Assuming Median Density

Season	Bird Category	Estimated Total Number of Birds (assuming median density)	
		2,870 Acres Total Evaporation Basins (average wetted area)	3,290 Acres Total Evaporation Basins (maximum wetted area)
Spring Migration (Feb-Apr)	Dabblers	1,181	1,354
	Divers	2,904	3,329
	Breeding Shorebirds	347	398
	Nonbreeding Shorebirds	751	860
	Other Upland Birds	0	0
	Other Waterbirds	0	0
Breeding (May-Jul)	Dabblers	201	230
	Divers	47	53
	Breeding Shorebirds	883	1,012
	Nonbreeding Shorebirds	92	105
	Other Upland Birds	0	0
	Other Waterbirds	55	63
Fall Migration (Aug-Oct)	Dabblers	578	662
	Divers	261	299
	Breeding Shorebirds	1,198	1,373
	Nonbreeding Shorebirds	2,127	2,438
	Other Upland Birds	0	0
	Other Waterbirds	254	291
Winter (Nov-Jan)	Dabblers	662	759
	Divers	2,843	3,259
	Breeding Shorebirds	477	547
	Nonbreeding Shorebirds	1,656	1,898
	Other Upland Birds	0	0
	Other Waterbirds	29	33

G7.3.1 Dabblers

As presented in Table G-7, mean dietary Se concentrations for dabblers foraging solely at the proposed evaporation basins are estimated to be 8.7 mg/kg dry weight during the nonbreeding seasons and 13.1 mg/kg dry weight during the breeding season. Because most dabblers are expected to forage at the evaporation basins primarily during the nonbreeding season, the effects assessment focuses on this period.

The data summarized in Section G7.2.2 indicate that the threshold for significant increases in adult mortality during winter is likely to be between 10 and 15 mg/kg, and probably varies depending on factors such as bird species and physical stresses such as weather. The average dietary Se concentrations predicted for dabblers during the nonbreeding seasons are below this range. Data indicate that during late spring as the breeding season approaches, dabblers tend to eat more invertebrates rather than plants. Assuming that during this period the average dietary Se concentrations approaches 13.1 mg/kg dry weight, some potential for effects to adult dabblers may occur. However, Heinz and Fitzgerald (1999b) found that a dietary concentration of 15 mg/kg Se was associated with the death of 10 percent of adult mallards over a 21-week period, longer than most dabblers would typically be expected to forage at evaporation basins during late spring as the breeding season approaches.

Although the proposed evaporation basins are not expected to provide appropriate breeding habitat for dabblers because vegetation is controlled to minimize nesting habitat, it is possible that some individuals will nest close by and may forage primarily at the evaporation basins during the breeding season. Individual dabblers foraging primarily on invertebrates at evaporation basins during the breeding season are expected to have an average dietary Se concentration of approximately 13.1 mg/kg dry weight, which exceeds the threshold for reproductive effects (approximately 4 mg/kg) and may also cause loss of body weight and possibly mortality in adults over an extended period (several months).

As described in Section G7.2.1.1, Figure G-5 shows that the percentage of fertile eggs hatched begins to decrease when the dietary concentration of selenomethionine exceeds approximately 4 mg/kg. Hatching success decreases by approximately 50 percent when the dietary concentration of selenomethionine reaches about 10 mg/kg, and hatching success is close to zero at a dietary selenomethionine concentration of 16 mg/kg. Figure G-6 shows that the percentage of survival of ducklings begins to decrease when the dietary concentration of selenomethionine exceeds approximately 8 mg/kg, and survival is close to zero at a dietary selenomethionine concentration of 16 mg/kg. Figure G-7 shows that the number of surviving ducklings per hen begins to decrease when the dietary concentration of selenomethionine exceeds approximately 4 mg/kg, and survival is close to zero at a dietary selenomethionine concentration of 16 mg/kg. Based on these findings, significant decreases in reproduction (at least 50 percent reduction), and possibly elimination of successful reproduction, would be expected in birds that obtain 100 percent of their food from the evaporation basins for a period of at least several weeks during the breeding season.

As described in Section 5.3.1, the diet of the northern shoveler is atypical of other dabblers, as it tends to forage primarily on nektonic invertebrates year-round. Mean dietary Se concentrations for northern shovelers foraging solely at the proposed evaporation basins are estimated to be 8.6 mg/kg dry weight during the nonbreeding seasons and 8.7 mg/kg dry weight during the breeding season. Therefore, the northern shoveler population would be unlikely to experience lethal effects due to Se concentrations in diet, but northern shoveler individuals nesting close by and foraging primarily at evaporation basins during the breeding season may experience some decrease in reproductive success.

As shown in Table G-10, the number of dabblers estimated to be present at the proposed evaporation basins (assuming mean densities) ranges from 1,315 during the breeding season under average conditions to 4,851 during spring migration under wet conditions (maximum wetted area). As shown in Table G-11, the number of dabblers estimated to be present at the proposed evaporation basins (assuming median densities) ranges from 201 during the breeding season under average conditions to 1,354 during spring migration under wet conditions (maximum wetted area). As can be seen from Table G-2, approximately 64% of the dabblers observed at evaporation basins are northern shovelers (the total count of northern shovelers over the monitoring period was 462,878, while the total count for all dabblers was 725,848.

If it is assumed that the dabblers present during breeding season obtain all of their food from the evaporation basins with an average concentration of 13.1 mg/kg Se for dabblers other than the northern shoveler, and 8.7 mg/kg for the northern shoveler, it would be expected that approximately 60 (assuming median densities under average conditions) to 473 (assuming mean densities and maximum wetted area) individuals would experience a significant decrease in reproductive success, and some may also experience loss of body weight and possibly death. Dabblers present during other times of the year would not be expected to experience significant effects.

G7.3.2 Divers

As presented in Table G-7, mean dietary Se concentrations for divers foraging solely at the proposed evaporation basins are estimated to be 11.8 mg/kg dry weight during the nonbreeding seasons and 13.7 mg/kg dry weight during the breeding season. Similarly to dabblers, most divers are expected to forage at the evaporation basins primarily during the nonbreeding season.

The average dietary Se concentrations predicted for divers during both the nonbreeding and breeding seasons are within the range likely to cause a low level of adult mortality (10 to 15 mg/kg). Based on data collected by Heinz and Fitzgerald (1993b), a concentration of approximately 15 mg/kg Se would be expected to result in the death of approximately 10 percent of adults over a period of several months.

Although the proposed evaporation basins are not expected to provide appropriate breeding habitat for divers because vegetation is controlled to minimize nesting habitat, it is possible that some individuals will nest close by and may forage primarily at the evaporation basins during the breeding season. Individual divers foraging primarily on invertebrates at evaporation basins during the breeding season are expected to have an average dietary Se concentration of approximately 13.7 mg/kg dry weight, which would be expected to decrease reproductive success by close to 100 percent.

As shown in Table G-10, the number of divers estimated to be present at the proposed evaporation basins (assuming mean densities) ranges from 537 during the breeding season under average conditions to 6,488 during winter under wet conditions (maximum wetted area). As shown in Table G-11, the number of divers estimated to be present at the proposed evaporation basins (assuming median densities) ranges from 47 during the breeding season under average conditions to 3,329 during spring migration under wet conditions (maximum wetted area).

If it is assumed that the divers present during breeding season obtain all of their food from the evaporation basins with an average concentration of 13.7 mg/kg Se, it would be expected that approximately 47 (assuming median densities under average conditions) to 537 (assuming mean densities and maximum wetted area) individuals would experience a significant decrease in reproductive success, and some may also experience loss of body weight and possibly death. If it is assumed that the divers present during winter or spring migration season (up to 6,488 during winter under wet conditions) are obtaining all of their food from the evaporation basins with an average concentration of 11.8 mg/kg Se over a period of at least several months, it is possible that a small proportion of these individuals (less than 10 percent of the total number of individuals present, or up to 649) may experience loss of body weight and possibly death.

G7.3.3 Shorebirds ("Breeding" and "Nonbreeding")

As presented in Table G-7, mean dietary Se concentrations for shorebirds foraging solely at the proposed evaporation basins are estimated to be 15.3 mg/kg dry weight during both the breeding and the nonbreeding seasons. This means that all types of shorebirds (both "breeding" and "nonbreeding") feeding primarily at the proposed evaporation basins for at least several months at a time may experience an increase in mortality due to elevated Se concentrations in their diets. Based on data collected by Heinz and Fitzgerald (1993b), a concentration of approximately 15 mg/kg Se would be expected to result in the death of approximately 10 percent of adults.

Because those shorebirds likely to breed at the evaporation basins (avocets, black-necked stilts, killdeer, and snowy plovers) are more likely to forage there than "nonbreeding" shorebirds, these species are more likely to experience increased mortality. In addition, the average predicted dietary concentration of 15.3 mg/kg Se is high enough to decrease reproductive success by close to 100 percent.

As shown in Table G-10, the number of breeding shorebirds estimated to be present at the proposed evaporation basins (assuming mean densities) ranges from 1,415 during the spring migration season under average conditions to 4,008 during fall migration under wet conditions (maximum wetted area). As shown in Table G-11, the number of breeding shorebirds estimated to be present at the proposed evaporation basins (assuming median densities) ranges from 347 during the spring migration season under average conditions to 1,373 during spring migration under wet conditions (maximum wetted area).

If it is assumed that the breeding shorebirds present during breeding season are obtaining all of their food from the evaporation basins with an average concentration of 15.3 mg/kg Se, it would be expected that approximately 883 to 2,310 individuals would experience a significant decrease in reproductive success, and some (about 10 percent or less) may also experience loss of body weight and possibly death. If it is assumed that the breeding shorebirds present during winter or spring and fall migration seasons are obtaining all of their food from the evaporation basins with an average concentration of 15.3 mg/kg Se over a period of at least several months, it is possible that small proportion (about 10 percent or less) of these individuals may experience loss of body weight and possibly death.

As shown in Table G-10, the number of nonbreeding shorebirds estimated to be present at the proposed evaporation basins (assuming mean densities) ranges from 2,567 during the breeding season under average conditions to 9,729 during winter under wet conditions (maximum wetted area). As shown in Table G-11, the number of breeding shorebirds estimated to be present at the proposed evaporation basins (assuming median densities) ranges from 92 during the breeding season under average conditions to 2,438 during fall migration under wet conditions (maximum wetted area).

If it is assumed that the nonbreeding shorebirds present during breeding season are obtaining all of their food from the evaporation basins with an average concentration of 15.3 mg/kg Se for a period of at least several months, it would be expected that approximately 883 (assuming median densities under average conditions) to 2,310 (assuming mean densities and maximum wetted area) individuals would experience a significant decrease in reproductive success, and some (about 10 percent or less of the total number of individuals present) may also experience loss of body weight and possibly death. If it is assumed that the nonbreeding shorebirds present during winter or spring and fall migration seasons (up to 9,729 during winter assuming maximum wetted area) are obtaining all of their food from the evaporation basins with an average concentration of 15.3 mg/kg Se over a period of at least several months, it is possible that small proportion (about 10 percent or less of the total number of individuals present, or up to 973) of these individuals may experience loss of body weight and possibly death.

G7.3.4 Other Waterbirds and Upland Birds

As discussed in Section G5.3.4, dietary composition data for birds in the “other waterbirds” category are presented in Table G-4. A review of these data indicates that many of these species feed primarily on fish or terrestrial plants and invertebrates, and it is unlikely that aquatic invertebrates and plants from the evaporation basins would compose a high percentage of their diets over an extended period of time. Similarly, it is expected that birds categorized as “upland birds” in Table G-2 obtain most of their food from terrestrial sources. In addition, the numbers of “upland birds” and “other waterbirds” observed are relatively low compared to the number of birds in other categories (see Tables G-10 and G-11). Therefore, no quantitative evaluation of risks was conducted for the species categorized as “other waterbirds” or “upland birds” as these species are unlikely to experience significant exposure to Se via feeding on plants or invertebrates at evaporation basins, in comparison to the other bird categories.

An exception is raptors that may potentially be affected by feeding on water birds contaminated with Se from evaporation basins. Raptors that obtain a significant portion of their prey in the form of birds that forage on evaporation basins may also experience toxicosis and/or mortality. However, due to their large foraging ranges, it is unlikely that raptors would obtain 100 percent of their prey from the evaporation basins.

G7.4 Uncertainty

Any evaluation of ecological effects has a number of limitations, including the degree of success in meeting objectives, range of conditions over which conclusions can be applied, and certainty with which conclusions can be drawn (USEPA 1989). The conclusions of an effects assessment are useful once they have been placed into perspective relative to the uncertainties associated with the evaluation. The major sources of uncertainty pertinent to this evaluation are discussed below.

G7.4.1 General Sources of Uncertainty

Due to the multiplicity of potential receptor species and general lack of knowledge regarding their life cycles, feeding habits, and relative toxicological sensitivity, the uncertainty surrounding estimates of ecological effects may be substantial. Most of the criteria and parameters used in this assessment are intended to provide a conservative (high end) evaluation of potential effects. The measurement endpoints utilized are chemical-specific and, as such, cannot address the additive, antagonistic, or synergistic effects of the mixtures of chemicals typically found in the environment. Furthermore, they do not account for many site-specific conditions regulating chemical contact and bioavailability, the potential toxicity of other constituents that were not quantified, or the pervasive influence of physical stressors associated with short-term and long-term disruption by human activities.

G7.4.2 Specific Sources of Uncertainty

In addition to the broadly influential general sources discussed above, several discrete sources of uncertainty are described below.

G7.4.2.1 Temporal and Spatial Distribution of Selenium Concentrations in Water

Because this ecological evaluation is based on predicted concentrations of Se in water, all results are based on the accuracy of the water quality modeling results. Assumptions and uncertainties in the water quality modeling of influent Se concentrations are described in detail in Appendix C. In addition, it was assumed that the influent Se concentrations would be representative of Se concentrations in water throughout the evaporation basins. Se concentrations in water are likely to change as the water flows through the system, due to factors such as partitioning and bioaccumulation. However, it is difficult to quantitatively predict changes in concentrations.

G7.4.2.2 Selenium Speciation and Bioavailability

Limited information is available to predict what forms of Se will exist in the proposed evaporation basins. Even if the speciation of Se in the treated influent to the basins could be predicted with a reasonable amount of certainty, it is difficult to predict what will happen to the Se speciation when the water flows through the basin. Because speciation is dependent on various chemical and physical parameters that are characteristic of conditions in the evaporation basins, the speciation is likely to eventually change if the residence time is long enough.

G7.4.2.3 Species Sensitivity

No data could be found that relate dietary Se concentrations to effects to the birds species most likely to nest and breed at the site (recurvorostrids such as stilts and avocets). However, available egg tissue effects data do include results of studies conducted on recurvorostrids, which indicates that birds in this family may be less sensitive to Se than some other species such as mallards (Ohlendorf 2003). Sensitivity to Se exposure can vary substantially even in closely related species, like stilts and avocets. The EC50 for overt teratogenesis was estimated to be 31 mg Se/kg egg tissue of dabbling ducks, whereas, the respective EC50s for stilts and avocets are 58 and 105 mg Se/kg egg tissue. These results indicate that ducks may be twice as sensitive to Se exposure as recurvirostrids, and avocets are relatively insensitive to selenosis (Skorupa 1998). The species examined in this study can be summarized as “sensitive” (duck), “average” (stilt), and “tolerant” (avocet) (Ohlendorf 2003).

The toxicity data used in this assessment were based mainly on studies conducted on mallards; therefore, potential effects to recurvorostrids such as stilts and avocets may be overpredicted.

G7.4.2.4 Exposure Assessment

This evaluation assumed that birds nesting at the evaporation basins would be ingesting food obtained from the evaporation basins only. If adjacent foraging habitat is available, it is likely that birds would obtain a portion of their food from areas with lower Se concentration, and exposure would be lower than predicted in this assessment.

In addition, a significant amount of uncertainty exists regarding the duration of time that migrating and wintering birds would spend at one location. At the range of Se concentrations predicted to occur in the proposed evaporation basins, it is expected that several weeks to several months of continuous exposure would be required for individual birds to experience adverse effects. It was assumed (as a worst-case scenario) that most birds at the site would spend a sufficient amount of time at the site to allow for Se concentrations to accumulate in their tissues.

Although predictions of bird density are based on a substantial amount of historical monitoring data at existing evaporation basins, uncertainty exists in these predictions. Bird densities varied considerably at different evaporation basins, as shown in Table G-3. Densities may also vary from year to year and depending on factors such as nearby habitats and food availability.

This evaluation also assumed that the dietary compositions of all bird species and all individuals within each bird category would be identical. However, dietary composition is likely to vary considerably, depending on numerous factors such as species, food availability, and time of year. In general, this evaluation assumed dietary composition that would predict Se exposure at the high end of the range (i.e., more consumption of benthic invertebrates, which accumulate higher Se levels).

Se exposure in birds is a function of two main factors: Se concentration in dietary items and food ingestion rates. Ingestion rates may vary substantially among species and at different times of the year. However, ingestion rates were not considered in this evaluation.

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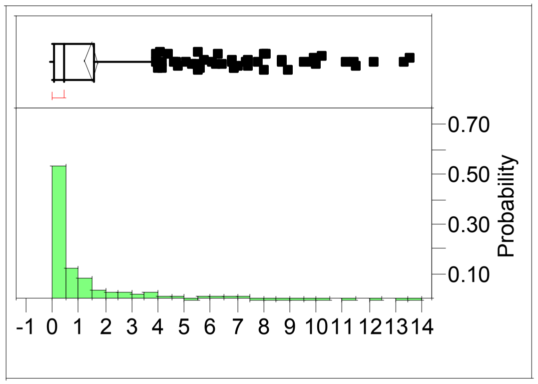
AttachmentG1

Bird Density Histograms

Pond Type=Evaporation Pond, Season=(1) Spring Migration, Bird Category=(1) Dabbler

Distributions

Birds/Acre



Quantiles

100.0%	maximum	13.500
99.5%		13.289
97.5%		9.766
90.0%		4.607
75.0%	quartile	1.556
50.0%	median	0.412
25.0%	quartile	0.039
10.0%		0.000
2.5%		0.000
0.5%		0.000
0.0%	minimum	0.000

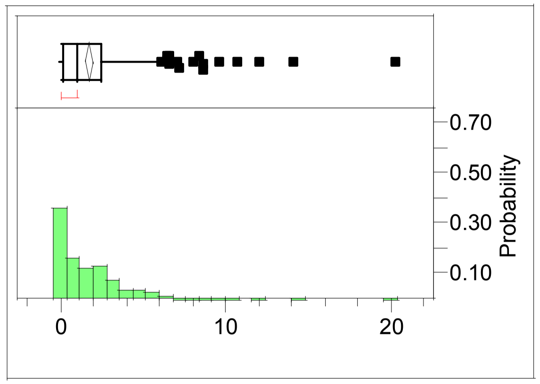
Moments

Mean	1.4744398
Std Dev	2.4668189
Std Err Mean	0.1230337
upper 95% Mean	1.7163115
lower 95% Mean	1.232568
N	402

Pond Type=Evaporation Pond, Season=(1) Spring Migration, Bird Category=(2) Diver

Distributions

Birds/Acre



Quantiles

100.0%	maximum	20.300
99.5%		14.007
97.5%		7.094
90.0%		4.482
75.0%	quartile	2.536
50.0%	median	1.012
25.0%	quartile	0.163
10.0%		0.000
2.5%		0.000
0.5%		0.000
0.0%	minimum	0.000

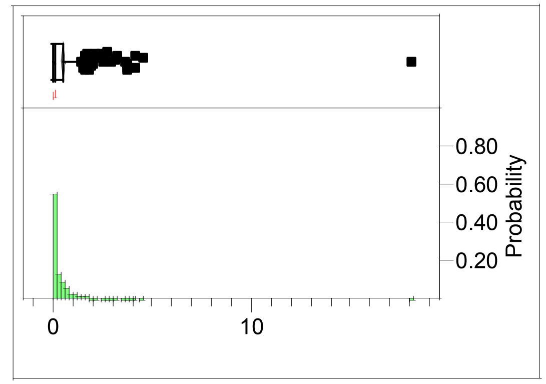
Moments

Mean	1.7484753
Std Dev	2.238743
Std Err Mean	0.1116584
upper 95% Mean	1.9679842
lower 95% Mean	1.5289664
N	402

Pond Type=Evaporation Pond, Season=(1) Spring Migration, Bird Category=(3) Breeding Shorebird

Distributions

Birds/Acre



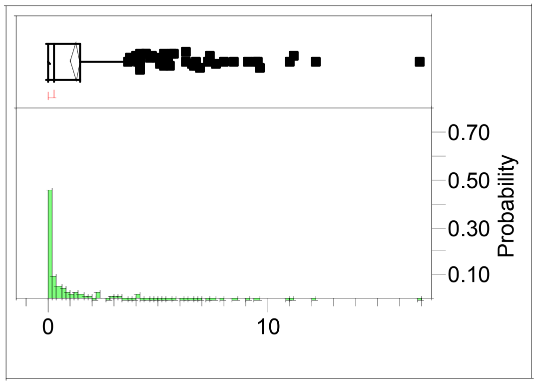
Quantiles

100.0%	maximum	18.050
99.5%		4.479
97.5%		3.153
90.0%		1.323
75.0%	quartile	0.534
50.0%	median	0.121
25.0%	quartile	0.002
10.0%		0.000
2.5%		0.000
0.5%		0.000
0.0%	minimum	0.000

Moments

Mean	0.4930844
Std Dev	1.1594457
Std Err Mean	0.0578279
upper 95% Mean	0.6067681
lower 95% Mean	0.3794007
N	402

Pond Type=Evaporation Pond, Season=(1) Spring Migration, Bird Category=(4) Nonbreeding Shorebird
Distributions
Birds/Acre



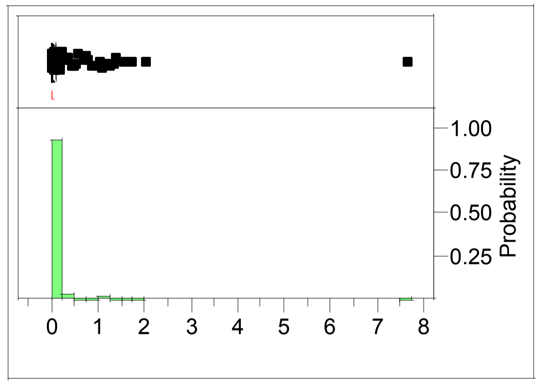
Quantiles

100.0%	maximum	16.896
99.5%		12.165
97.5%		7.925
90.0%		4.037
75.0%	quartile	1.419
50.0%	median	0.272
25.0%	quartile	0.000
10.0%		0.000
2.5%		0.000
0.5%		0.000
0.0%	minimum	0.000

Moments

Mean	1.251029
Std Dev	2.2058674
Std Err Mean	0.1100187
upper 95% Mean	1.4673144
lower 95% Mean	1.0347436
N	402

Pond Type=Evaporation Pond, Season=(1) Spring Migration, Bird Category=(5) Other Upland
Distributions
Birds/Acre



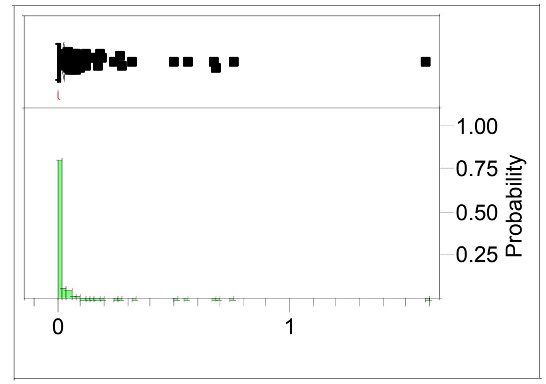
Quantiles

100.0%	maximum	7.6439
99.5%		1.9922
97.5%		1.0731
90.0%		0.1027
75.0%	quartile	0.0000
50.0%	median	0.0000
25.0%	quartile	0.0000
10.0%		0.0000
2.5%		0.0000
0.5%		0.0000
0.0%	minimum	0.0000

Moments

Mean	0.0834219
Std Dev	0.4479047
Std Err Mean	0.0223395
upper 95% Mean	0.127339
lower 95% Mean	0.0395048
N	402

Pond Type=Evaporation Pond, Season=(1) Spring Migration, Bird Category=(6) Other Waterbird
Distributions
Birds/Acre



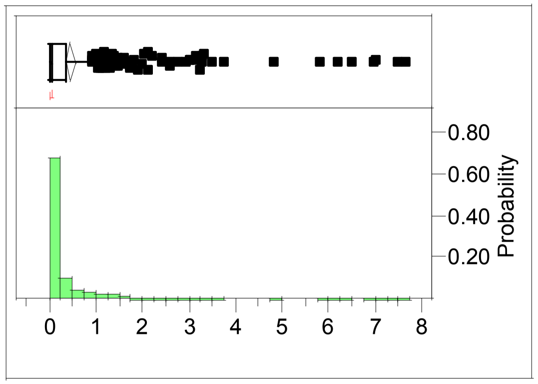
Quantiles

100.0%	maximum	1.5800
99.5%		0.7490
97.5%		0.2361
90.0%		0.0523
75.0%	quartile	0.0114
50.0%	median	0.0000
25.0%	quartile	0.0000
10.0%		0.0000
2.5%		0.0000
0.5%		0.0000
0.0%	minimum	0.0000

Moments

Mean	0.0266974
Std Dev	0.1107138
Std Err Mean	0.0055219
upper 95% Mean	0.0375529
lower 95% Mean	0.0158419
N	402

**Pond Type=Evaporation Pond,
Season=(2) Breeding,
Bird Category=(1) Dabbler
Distributions
Birds/Acre**



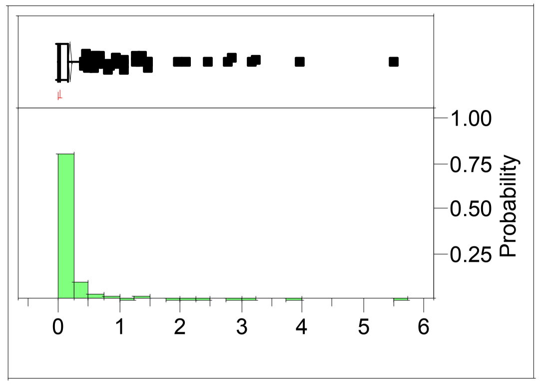
Quantiles

100.0%	maximum	7.6477
99.5%		7.3420
97.5%		3.2923
90.0%		1.3010
75.0%	quartile	0.3500
50.0%	median	0.0700
25.0%	quartile	0.0000
10.0%		0.0000
2.5%		0.0000
0.5%		0.0000
0.0%	minimum	0.0000

Moments

Mean	0.4582912
Std Dev	1.0544652
Std Err Mean	0.0494341
upper 95% Mean	0.5554392
lower 95% Mean	0.3611432
N	455

**Pond Type=Evaporation Pond,
Season=(2) Breeding,
Bird Category=(2) Diver
Distributions
Birds/Acre**



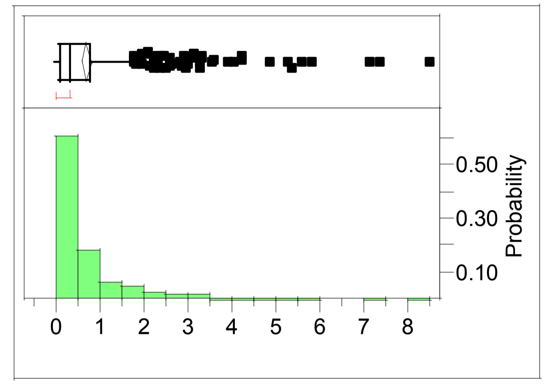
Quantiles

100.0%	maximum	5.5000
99.5%		3.7377
97.5%		1.4491
90.0%		0.4688
75.0%	quartile	0.1562
50.0%	median	0.0162
25.0%	quartile	0.0000
10.0%		0.0000
2.5%		0.0000
0.5%		0.0000
0.0%	minimum	0.0000

Moments

Mean	0.1872679
Std Dev	0.5046821
Std Err Mean	0.0236599
upper 95% Mean	0.2337643
lower 95% Mean	0.1407714
N	455

**Pond Type=Evaporation Pond,
Season=(2) Breeding,
Bird Category=(3) Breeding Shorebird
Distributions
Birds/Acre**



Quantiles

100.0%	maximum	8.4774
99.5%		7.2759
97.5%		3.9666
90.0%		1.8311
75.0%	quartile	0.7527
50.0%	median	0.3077
25.0%	quartile	0.1043
10.0%		0.0145
2.5%		0.0000
0.5%		0.0000
0.0%	minimum	0.0000

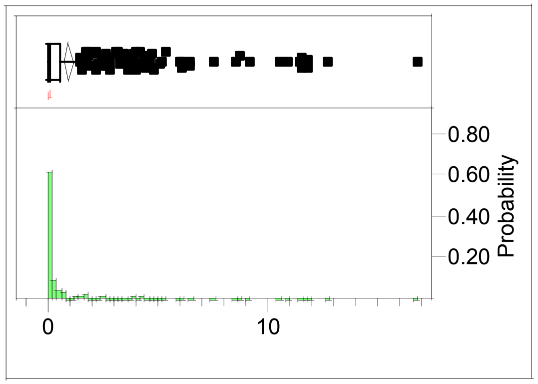
Moments

Mean	0.7019918
Std Dev	1.092294
Std Err Mean	0.0512075
upper 95% Mean	0.8026249
lower 95% Mean	0.6013586
N	455

Pond Type=Evaporation Pond, Season=(2) Breeding, Bird Category=(4) Nonbreeding Shorebird

Distributions

Birds/Acre



Quantiles

100.0%	maximum	16.758
99.5%		12.463
97.5%		8.582
90.0%		3.332
75.0%	quartile	0.577
50.0%	median	0.070
25.0%	quartile	0.003
10.0%		0.000
2.5%		0.000
0.5%		0.000
0.0%	minimum	0.000

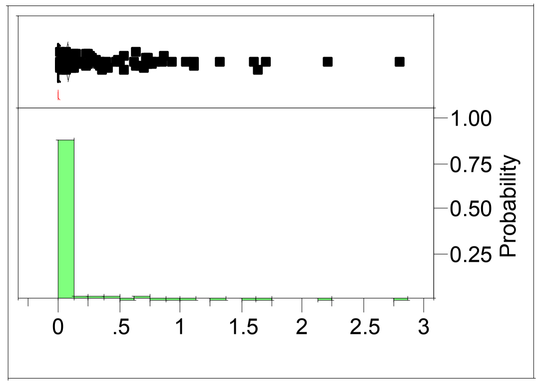
Moments

Mean	0.9380664
Std Dev	2.1668951
Std Err Mean	0.1015856
upper 95% Mean	1.1377027
lower 95% Mean	0.73843
N	455

Pond Type=Evaporation Pond, Season=(2) Breeding, Bird Category=(5) Other Upland

Distributions

Birds/Acre



Quantiles

100.0%	maximum	2.7879
99.5%		2.0612
97.5%		0.8530
90.0%		0.2176
75.0%	quartile	0.0041
50.0%	median	0.0000
25.0%	quartile	0.0000
10.0%		0.0000
2.5%		0.0000
0.5%		0.0000
0.0%	minimum	0.0000

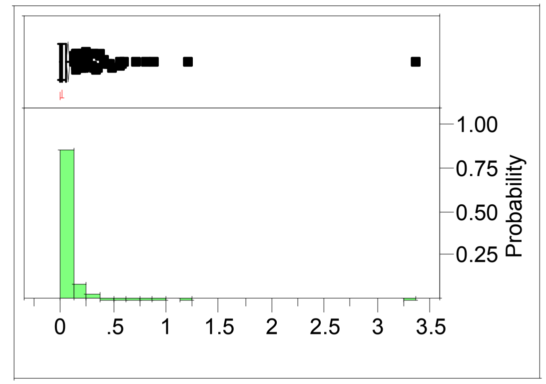
Moments

Mean	0.0784756
Std Dev	0.2740236
Std Err Mean	0.0128464
upper 95% Mean	0.1037214
lower 95% Mean	0.0532298
N	455

Pond Type=Evaporation Pond, Season=(2) Breeding, Bird Category=(6) Other Waterbird

Distributions

Birds/Acre



Quantiles

100.0%	maximum	3.3654
99.5%		1.1127
97.5%		0.4537
90.0%		0.1899
75.0%	quartile	0.0500
50.0%	median	0.0078
25.0%	quartile	0.0000
10.0%		0.0000
2.5%		0.0000
0.5%		0.0000
0.0%	minimum	0.0000

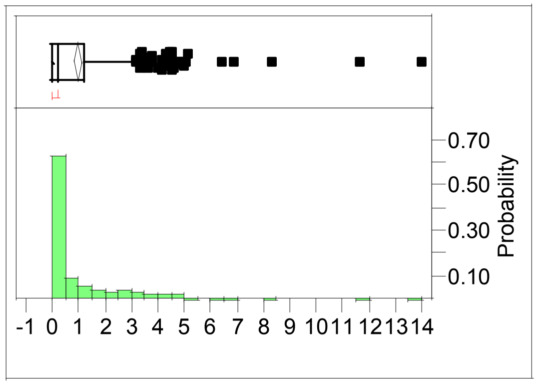
Moments

Mean	0.0633509
Std Dev	0.1988419
Std Err Mean	0.0093219
upper 95% Mean	0.0816703
lower 95% Mean	0.0450316
N	455

Pond Type=Evaporation Pond, Season=(3) Fall Migration, Bird Category=(1) Dabbler

Distributions

Birds/Acre



Quantiles

100.0%	maximum	13.950
99.5%		11.645
97.5%		4.722
90.0%		3.286
75.0%	quartile	1.231
50.0%	median	0.201
25.0%	quartile	0.000
10.0%		0.000
2.5%		0.000
0.5%		0.000
0.0%	minimum	0.000

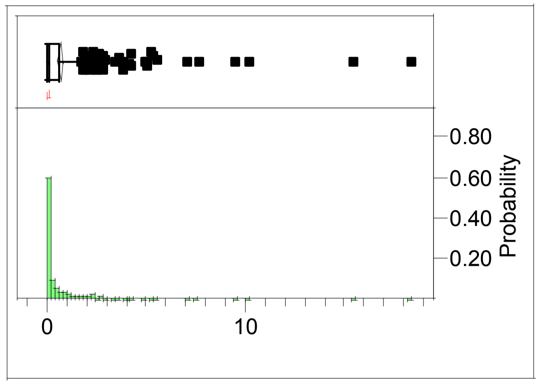
Moments

Mean	0.9542645
Std Dev	1.6282335
Std Err Mean	0.0819253
upper 95% Mean	1.11533
lower 95% Mean	0.7931991
N	395

Pond Type=Evaporation Pond, Season=(3) Fall Migration, Bird Category=(2) Diver

Distributions

Birds/Acre



Quantiles

100.0%	maximum	18.346
99.5%		15.508
97.5%		5.019
90.0%		2.086
75.0%	quartile	0.657
50.0%	median	0.091
25.0%	quartile	0.000
10.0%		0.000
2.5%		0.000
0.5%		0.000
0.0%	minimum	0.000

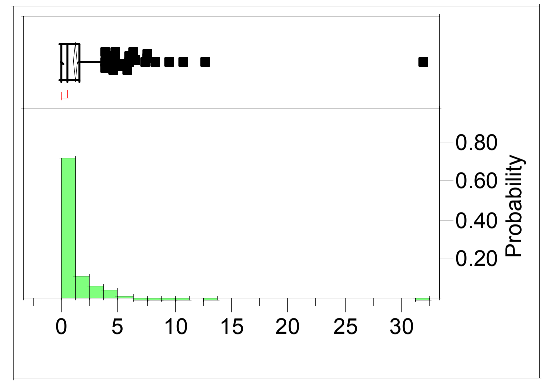
Moments

Mean	0.6973686
Std Dev	1.7267979
Std Err Mean	0.0868846
upper 95% Mean	0.8681841
lower 95% Mean	0.5265532
N	395

Pond Type=Evaporation Pond, Season=(3) Fall Migration, Bird Category=(3) Breeding Shorebird

Distributions

Birds/Acre



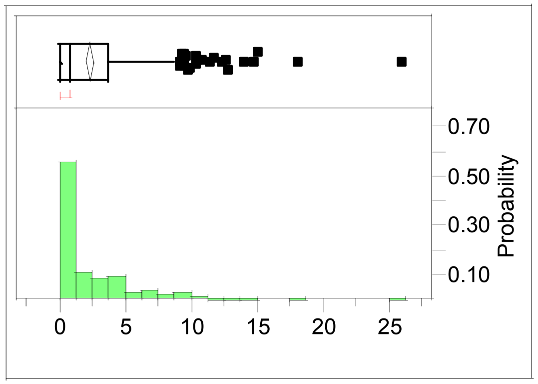
Quantiles

100.0%	maximum	31.900
99.5%		13.074
97.5%		6.294
90.0%		3.414
75.0%	quartile	1.534
50.0%	median	0.417
25.0%	quartile	0.041
10.0%		0.000
2.5%		0.000
0.5%		0.000
0.0%	minimum	0.000

Moments

Mean	1.2182151
Std Dev	2.3276693
Std Err Mean	0.1171178
upper 95% Mean	1.448469
lower 95% Mean	0.9879612
N	395

Pond Type=Evaporation Pond,
Season=(3) Fall Migration,
Bird Category=(4) Nonbreeding Shorebird
Distributions
Birds/Acre



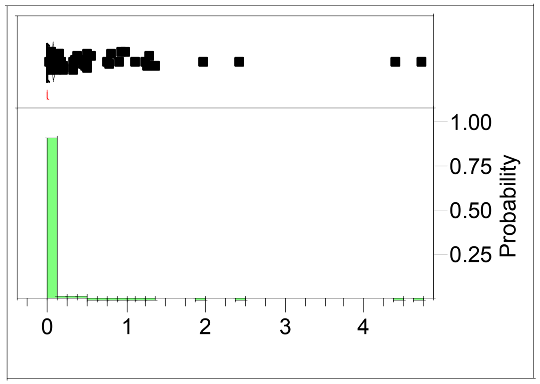
Quantiles

100.0%	maximum	25.883
99.5%		18.197
97.5%		11.430
90.0%		6.942
75.0%	quartile	3.655
50.0%	median	0.846
25.0%	quartile	0.080
10.0%		0.000
2.5%		0.000
0.5%		0.000
0.0%	minimum	0.000

Moments

Mean	2.36909
Std Dev	3.338068
Std Err Mean	0.1679564
upper 95% Mean	2.6992929
lower 95% Mean	2.0388871
N	395

Pond Type=Evaporation Pond,
Season=(3) Fall Migration,
Bird Category=(5) Other Upland
Distributions
Birds/Acre



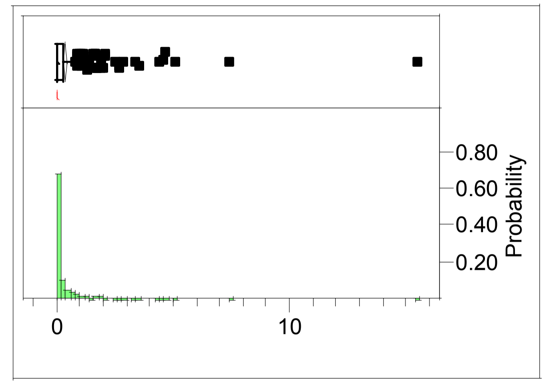
Quantiles

100.0%	maximum	4.7008
99.5%		4.4001
97.5%		0.9856
90.0%		0.1038
75.0%	quartile	0.0100
50.0%	median	0.0000
25.0%	quartile	0.0000
10.0%		0.0000
2.5%		0.0000
0.5%		0.0000
0.0%	minimum	0.0000

Moments

Mean	0.0863742
Std Dev	0.400007
Std Err Mean	0.0201265
upper 95% Mean	0.125943
lower 95% Mean	0.0468054
N	395

Pond Type=Evaporation Pond,
Season=(3) Fall Migration,
Bird Category=(6) Other Waterbird
Distributions
Birds/Acre



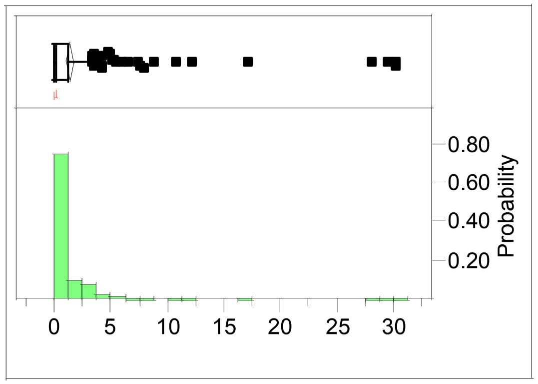
Quantiles

100.0%	maximum	15.450
99.5%		7.561
97.5%		2.704
90.0%		1.034
75.0%	quartile	0.319
50.0%	median	0.036
25.0%	quartile	0.000
10.0%		0.000
2.5%		0.000
0.5%		0.000
0.0%	minimum	0.000

Moments

Mean	0.3814525
Std Dev	1.0902423
Std Err Mean	0.054856
upper 95% Mean	0.4892997
lower 95% Mean	0.2736054
N	395

Pond Type=Evaporation Pond,
Season=(4) Winter,
Bird Category=(1) Dabbler
Distributions
Birds/Acre



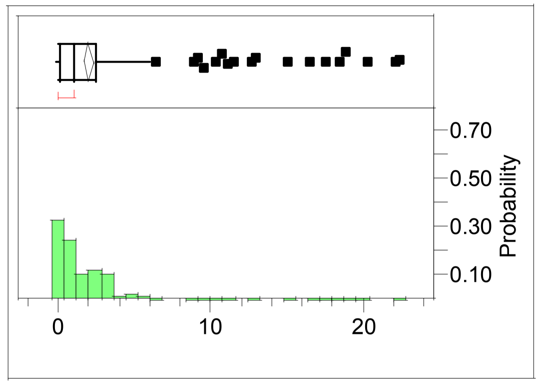
Quantiles

100.0%	maximum	30.150
99.5%		30.115
97.5%		8.243
90.0%		3.196
75.0%	quartile	1.288
50.0%	median	0.231
25.0%	quartile	0.034
10.0%		0.000
2.5%		0.000
0.5%		0.000
0.0%	minimum	0.000

Moments

Mean	1.3554905
Std Dev	3.5925974
Std Err Mean	0.1951231
upper 95% Mean	1.739299
lower 95% Mean	0.9716819
N	339

Pond Type=Evaporation Pond,
Season=(4) Winter,
Bird Category=(2) Diver
Distributions
Birds/Acre



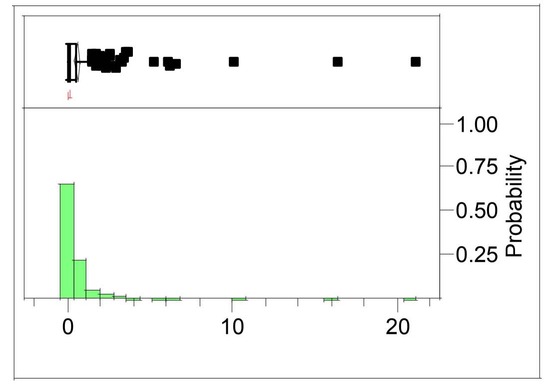
Quantiles

100.0%	maximum	22.327
99.5%		22.179
97.5%		13.990
90.0%		3.558
75.0%	quartile	2.460
50.0%	median	0.991
25.0%	quartile	0.160
10.0%		0.000
2.5%		0.000
0.5%		0.000
0.0%	minimum	0.000

Moments

Mean	1.971963
Std Dev	3.3337385
Std Err Mean	0.1810638
upper 95% Mean	2.3281168
lower 95% Mean	1.6158091
N	339

Pond Type=Evaporation Pond,
Season=(4) Winter,
Bird Category=(3) Breeding Shorebird
Distributions
Birds/Acre



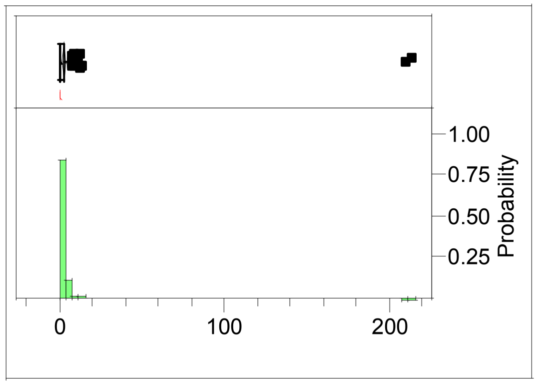
Quantiles

100.0%	maximum	21.100
99.5%		17.775
97.5%		3.548
90.0%		1.269
75.0%	quartile	0.570
50.0%	median	0.166
25.0%	quartile	0.000
10.0%		0.000
2.5%		0.000
0.5%		0.000
0.0%	minimum	0.000

Moments

Mean	0.6251144
Std Dev	1.7449691
Std Err Mean	0.0947737
upper 95% Mean	0.811535
lower 95% Mean	0.4386938
N	339

Pond Type=Evaporation Pond,
Season=(4) Winter,
Bird Category=(4) Nonbreeding Shorebird
Distributions
Birds/Acre



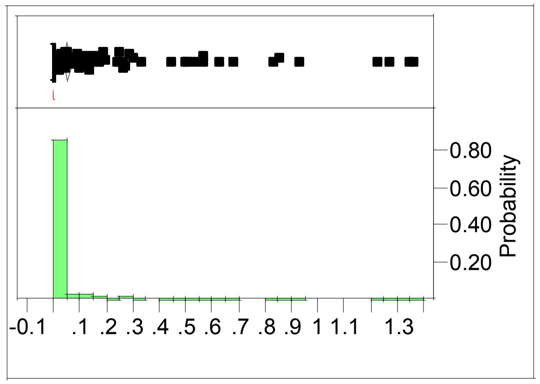
Quantiles

100.0%	maximum	213.55
99.5%		210.89
97.5%		11.08
90.0%		5.16
75.0%	quartile	2.60
50.0%	median	0.67
25.0%	quartile	0.02
10.0%		0.00
2.5%		0.00
0.5%		0.00
0.0%	minimum	0.00

Moments

Mean	2.9800317
Std Dev	16.29622
Std Err Mean	0.8850892
upper 95% Mean	4.7210086
lower 95% Mean	1.2390548
N	339

Pond Type=Evaporation Pond,
Season=(4) Winter,
Bird Category=(5) Other Upland
Distributions
Birds/Acre



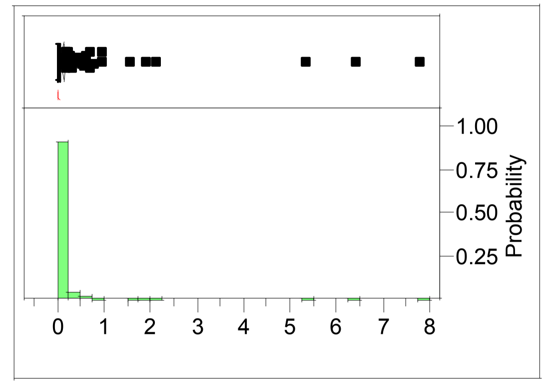
Quantiles

100.0%	maximum	1.3598
99.5%		1.3466
97.5%		0.6496
90.0%		0.1288
75.0%	quartile	0.0056
50.0%	median	0.0000
25.0%	quartile	0.0000
10.0%		0.0000
2.5%		0.0000
0.5%		0.0000
0.0%	minimum	0.0000

Moments

Mean	0.0540708
Std Dev	0.1848054
Std Err Mean	0.0100373
upper 95% Mean	0.0738141
lower 95% Mean	0.0343274
N	339

Pond Type=Evaporation Pond,
Season=(4) Winter,
Bird Category=(6) Other Waterbird
Distributions
Birds/Acre



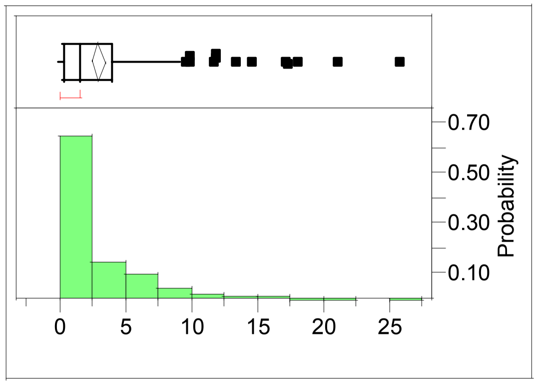
Quantiles

100.0%	maximum	7.7500
99.5%		6.8050
97.5%		0.8500
90.0%		0.2041
75.0%	quartile	0.0577
50.0%	median	0.0076
25.0%	quartile	0.0000
10.0%		0.0000
2.5%		0.0000
0.5%		0.0000
0.0%	minimum	0.0000

Moments

Mean	0.1349893
Std Dev	0.6460991
Std Err Mean	0.0350913
upper 95% Mean	0.2040141
lower 95% Mean	0.0659645
N	339

**Pond Type=Mitigation Habitat,
Season=(1) Spring Migration,
Bird Category=(1) Dabbler
Distributions
Birds/Acre**



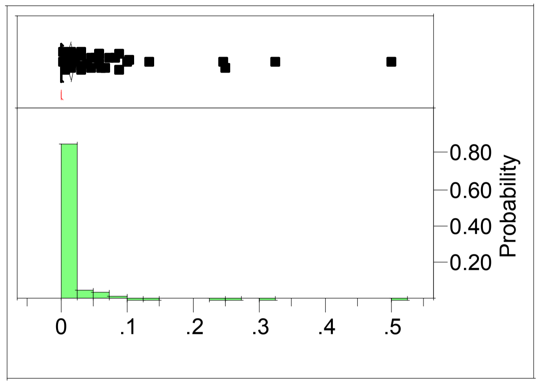
Quantiles

100.0%	maximum	25.700
99.5%		25.700
97.5%		17.162
90.0%		7.485
75.0%	quartile	4.070
50.0%	median	1.535
25.0%	quartile	0.410
10.0%		0.108
2.5%		0.000
0.5%		0.000
0.0%	minimum	0.000

Moments

Mean	3.020666
Std Dev	4.0576141
Std Err Mean	0.2991313
upper 95% Mean	3.6108556
lower 95% Mean	2.4304764
N	184

**Pond Type=Mitigation Habitat,
Season=(1) Spring Migration,
Bird Category=(2) Diver
Distributions
Birds/Acre**



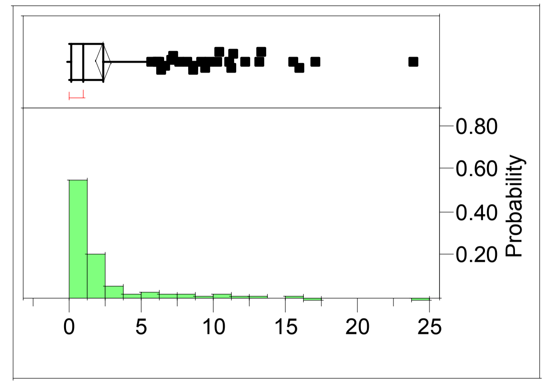
Quantiles

100.0%	maximum	0.50000
99.5%		0.50000
97.5%		0.17503
90.0%		0.04900
75.0%	quartile	0.00000
50.0%	median	0.00000
25.0%	quartile	0.00000
10.0%		0.00000
2.5%		0.00000
0.5%		0.00000
0.0%	minimum	0.00000

Moments

Mean	0.0158541
Std Dev	0.0541178
Std Err Mean	0.0039896
upper 95% Mean	0.0237257
lower 95% Mean	0.0079825
N	184

**Pond Type=Mitigation Habitat,
Season=(1) Spring Migration,
Bird Category=(3) Breeding Shorebird
Distributions
Birds/Acre**



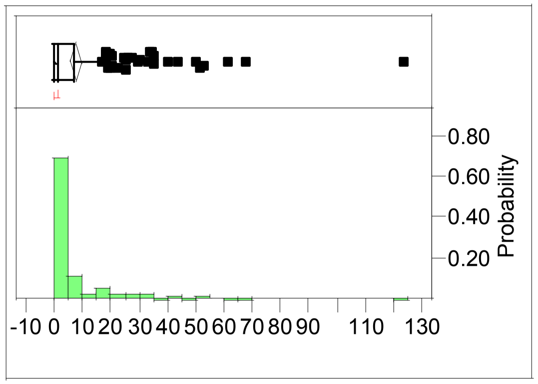
Quantiles

100.0%	maximum	23.809
99.5%		23.809
97.5%		14.074
90.0%		7.860
75.0%	quartile	2.322
50.0%	median	0.951
25.0%	quartile	0.179
10.0%		0.030
2.5%		0.000
0.5%		0.000
0.0%	minimum	0.000

Moments

Mean	2.3604088
Std Dev	3.7797156
Std Err Mean	0.2786443
upper 95% Mean	2.9101774
lower 95% Mean	1.8106402
N	184

Pond Type=Mitigation Habitat,
Season=(1) Spring Migration,
Bird Category=(4) Nonbreeding Shorebird
Distributions
Birds/Acre



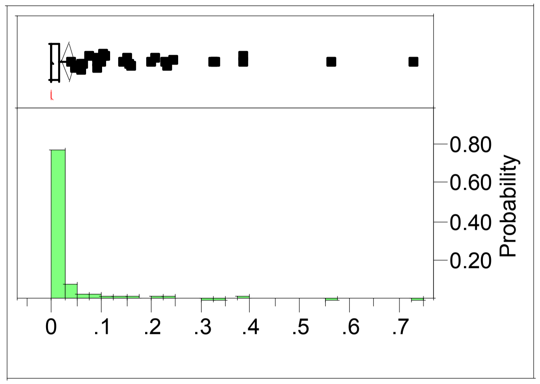
Quantiles

100.0%	maximum	123.13
99.5%		123.13
97.5%		51.79
90.0%		24.94
75.0%	quartile	6.77
50.0%	median	1.59
25.0%	quartile	0.25
10.0%		0.03
2.5%		0.00
0.5%		0.00
0.0%	minimum	0.00

Moments

Mean	7.6370776
Std Dev	15.005055
Std Err Mean	1.1061873
upper 95% Mean	9.8195984
lower 95% Mean	5.4545568
N	184

Pond Type=Mitigation Habitat,
Season=(1) Spring Migration,
Bird Category=(5) Other Upland
Distributions
Birds/Acre



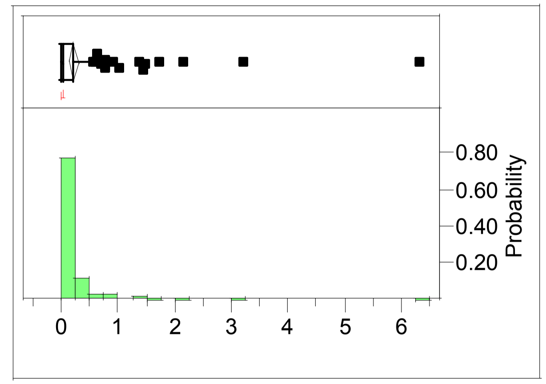
Quantiles

100.0%	maximum	0.72638
99.5%		0.72638
97.5%		0.34900
90.0%		0.09886
75.0%	quartile	0.01485
50.0%	median	0.00000
25.0%	quartile	0.00000
10.0%		0.00000
2.5%		0.00000
0.5%		0.00000
0.0%	minimum	0.00000

Moments

Mean	0.0334171
Std Dev	0.0930638
Std Err Mean	0.0068608
upper 95% Mean	0.0469535
lower 95% Mean	0.0198808
N	184

Pond Type=Mitigation Habitat,
Season=(1) Spring Migration,
Bird Category=(6) Other Waterbird
Distributions
Birds/Acre



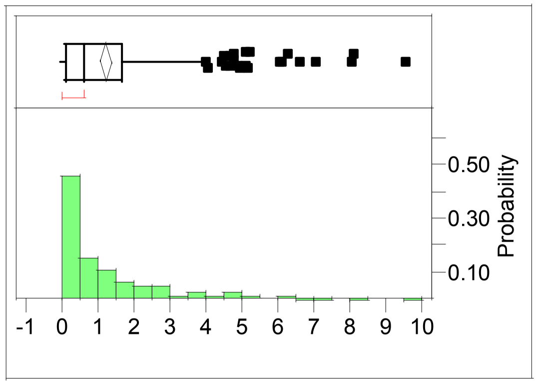
Quantiles

100.0%	maximum	6.3000
99.5%		6.3000
97.5%		1.5449
90.0%		0.4870
75.0%	quartile	0.2000
50.0%	median	0.0226
25.0%	quartile	0.0000
10.0%		0.0000
2.5%		0.0000
0.5%		0.0000
0.0%	minimum	0.0000

Moments

Mean	0.2096202
Std Dev	0.5940506
Std Err Mean	0.043794
upper 95% Mean	0.2960263
lower 95% Mean	0.1232142
N	184

Pond Type=Mitigation Habitat,
Season=(2) Breeding,
Bird Category=(1) Dabbler
Distributions
Birds/Acre



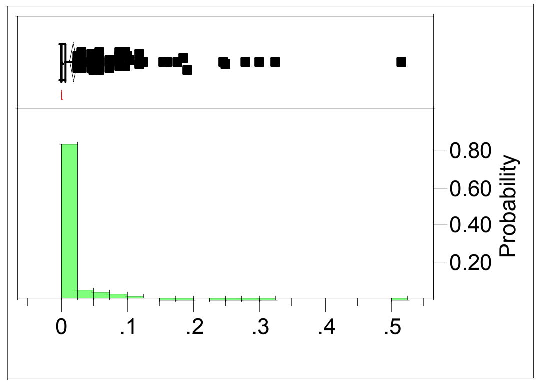
Quantiles

100.0%	maximum	9.5000
99.5%		8.8140
97.5%		6.0550
90.0%		3.5000
75.0%	quartile	1.6568
50.0%	median	0.6081
25.0%	quartile	0.1317
10.0%		0.0098
2.5%		0.0000
0.5%		0.0000
0.0%	minimum	0.0000

Moments

Mean	1.2340286
Std Dev	1.5970284
Std Err Mean	0.092669
upper 95% Mean	1.4164022
lower 95% Mean	1.0516551
N	297

Pond Type=Mitigation Habitat,
Season=(2) Breeding,
Bird Category=(2) Diver
Distributions
Birds/Acre



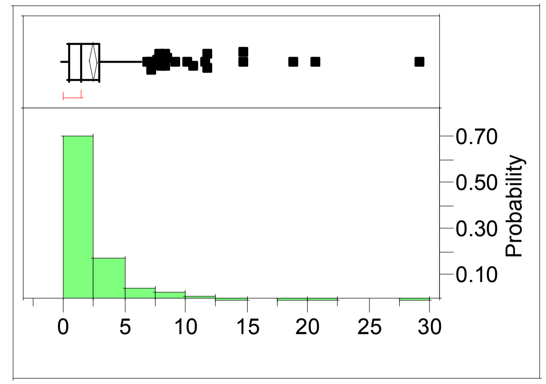
Quantiles

100.0%	maximum	0.51471
99.5%		0.42103
97.5%		0.18822
90.0%		0.05882
75.0%	quartile	0.00755
50.0%	median	0.00000
25.0%	quartile	0.00000
10.0%		0.00000
2.5%		0.00000
0.5%		0.00000
0.0%	minimum	0.00000

Moments

Mean	0.0189218
Std Dev	0.0552085
Std Err Mean	0.0032035
upper 95% Mean	0.0252263
lower 95% Mean	0.0126172
N	297

Pond Type=Mitigation Habitat,
Season=(2) Breeding,
Bird Category=(3) Breeding Shorebird
Distributions
Birds/Acre



Quantiles

100.0%	maximum	29.103
99.5%		24.895
97.5%		11.582
90.0%		5.760
75.0%	quartile	2.900
50.0%	median	1.431
25.0%	quartile	0.506
10.0%		0.055
2.5%		0.000
0.5%		0.000
0.0%	minimum	0.000

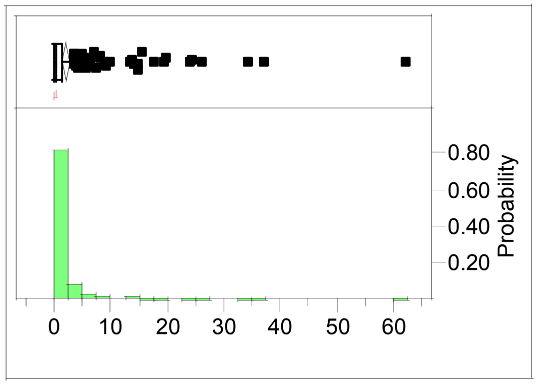
Moments

Mean	2.4039595
Std Dev	3.2387086
Std Err Mean	0.1879289
upper 95% Mean	2.7738057
lower 95% Mean	2.0341134
N	297

Pond Type=Mitigation Habitat, Season=(2) Breeding, Bird Category=(4) Nonbreeding Shorebird

Distributions

Birds/Acre



Quantiles

100.0%	maximum	61.900
99.5%		49.569
97.5%		19.511
90.0%		4.840
75.0%	quartile	1.326
50.0%	median	0.235
25.0%	quartile	0.015
10.0%		0.000
2.5%		0.000
0.5%		0.000
0.0%	minimum	0.000

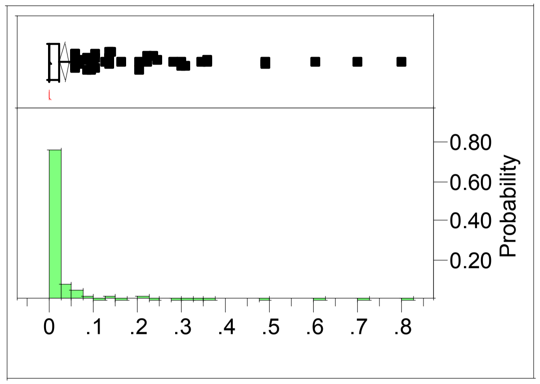
Moments

Mean	2.1334192
Std Dev	5.9197928
Std Err Mean	0.3435012
upper 95% Mean	2.8094332
lower 95% Mean	1.4574051
N	297

Pond Type=Mitigation Habitat, Season=(2) Breeding, Bird Category=(5) Other Upland

Distributions

Birds/Acre



Quantiles

100.0%	maximum	0.80000
99.5%		0.75100
97.5%		0.34919
90.0%		0.09311
75.0%	quartile	0.02222
50.0%	median	0.00000
25.0%	quartile	0.00000
10.0%		0.00000
2.5%		0.00000
0.5%		0.00000
0.0%	minimum	0.00000

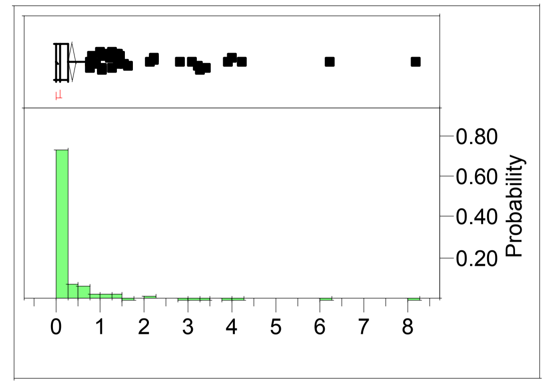
Moments

Mean	0.0352318
Std Dev	0.0990397
Std Err Mean	0.0057469
upper 95% Mean	0.0465417
lower 95% Mean	0.0239219
N	297

Pond Type=Mitigation Habitat, Season=(2) Breeding, Bird Category=(6) Other Waterbird

Distributions

Birds/Acre



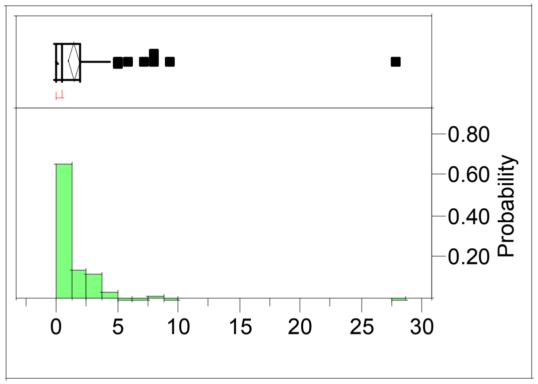
Quantiles

100.0%	maximum	8.1618
99.5%		7.2005
97.5%		3.2356
90.0%		1.0029
75.0%	quartile	0.2952
50.0%	median	0.0735
25.0%	quartile	0.0000
10.0%		0.0000
2.5%		0.0000
0.5%		0.0000
0.0%	minimum	0.0000

Moments

Mean	0.3675578
Std Dev	0.8692883
Std Err Mean	0.0504412
upper 95% Mean	0.4668267
lower 95% Mean	0.2682889
N	297

**Pond Type=Mitigation Habitat,
Season=(3) Fall Migration,
Bird Category=(1) Dabbler
Distributions
Birds/Acre**



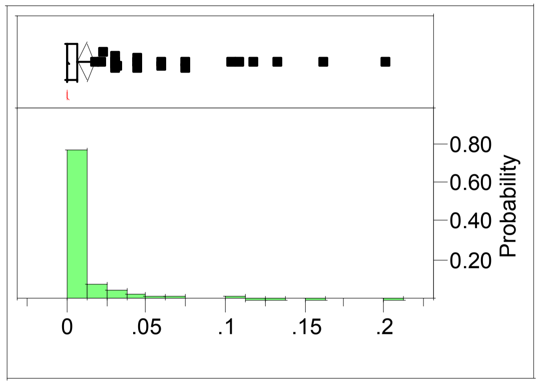
Quantiles

100.0%	maximum	27.779
99.5%		27.779
97.5%		7.906
90.0%		3.544
75.0%	quartile	1.890
50.0%	median	0.500
25.0%	quartile	0.013
10.0%		0.000
2.5%		0.000
0.5%		0.000
0.0%	minimum	0.000

Moments

Mean	1.4499124
Std Dev	2.9022326
Std Err Mean	0.2516555
upper 95% Mean	1.9477118
lower 95% Mean	0.952113
N	133

**Pond Type=Mitigation Habitat,
Season=(3) Fall Migration,
Bird Category=(2) Diver
Distributions
Birds/Acre**



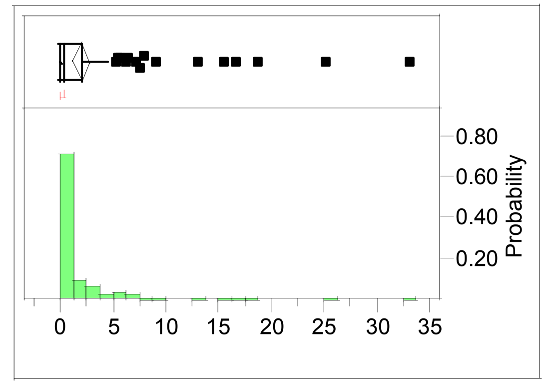
Quantiles

100.0%	maximum	0.20000
99.5%		0.20000
97.5%		0.12721
90.0%		0.04412
75.0%	quartile	0.00641
50.0%	median	0.00000
25.0%	quartile	0.00000
10.0%		0.00000
2.5%		0.00000
0.5%		0.00000
0.0%	minimum	0.00000

Moments

Mean	0.0123177
Std Dev	0.0318045
Std Err Mean	0.0027578
upper 95% Mean	0.0177729
lower 95% Mean	0.0068625
N	133

**Pond Type=Mitigation Habitat,
Season=(3) Fall Migration,
Bird Category=(3) Breeding Shorebird
Distributions
Birds/Acre**



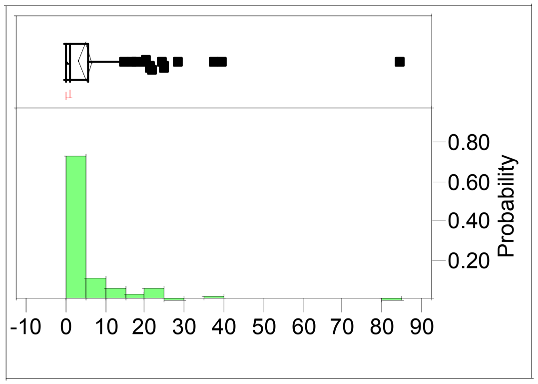
Quantiles

100.0%	maximum	33.000
99.5%		33.000
97.5%		17.937
90.0%		5.404
75.0%	quartile	1.958
50.0%	median	0.254
25.0%	quartile	0.000
10.0%		0.000
2.5%		0.000
0.5%		0.000
0.0%	minimum	0.000

Moments

Mean	1.9611108
Std Dev	4.6195792
Std Err Mean	0.4005683
upper 95% Mean	2.7534745
lower 95% Mean	1.168747
N	133

Pond Type=Mitigation Habitat,
Season=(3) Fall Migration,
Bird Category=(4) Nonbreeding Shorebird
Distributions
Birds/Acre



Quantiles

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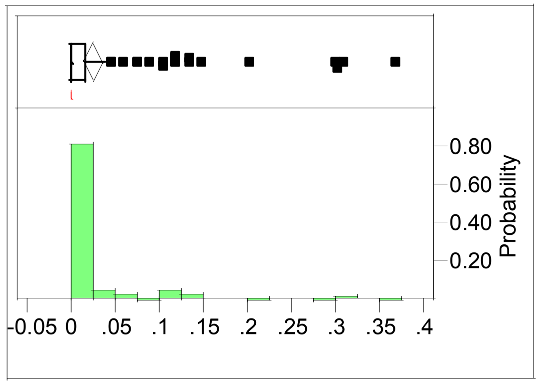
99.5%		84.074
97.5%		34.007
90.0%		16.979
75.0%	quartile	5.654
50.0%	median	0.882
25.0%	quartile	0.041
10.0%		0.000
2.5%		0.000
0.5%		0.000
0.0%	minimum	0.000

Moments

Mean	5.1246229
Std Dev	10.294896
Std Err Mean	0.8926807
upper 95% Mean	6.8904336
lower 95% Mean	3.3588123
N	133

Pond Type=Mitigation Habitat,
Season=(3) Fall Migration,
Bird Category=(5) Other Upland
Distributions
Birds/Acre



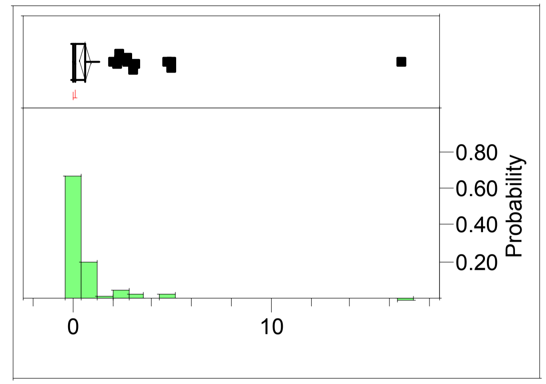
Quantiles

100.0%	maximum	0.36765
99.5%		0.36765
97.5%		0.29989
90.0%		0.10402
75.0%	quartile	0.01481
50.0%	median	0.00000
25.0%	quartile	0.00000
10.0%		0.00000
2.5%		0.00000
0.5%		0.00000
0.0%	minimum	0.00000

Moments

Mean	0.0247104
Std Dev	0.0637395
Std Err Mean	0.0055269
upper 95% Mean	0.0356431
lower 95% Mean	0.0137776
N	133

Pond Type=Mitigation Habitat,
Season=(3) Fall Migration,
Bird Category=(6) Other Waterbird
Distributions
Birds/Acre



Quantiles

100.0%	maximum	16.529
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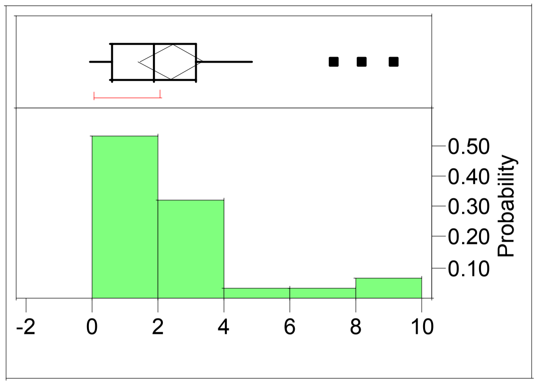
97.5%		4.826
90.0%		2.115
75.0%	quartile	0.600
50.0%	median	0.142
25.0%	quartile	0.003
10.0%		0.000
2.5%		0.000
0.5%		0.000
0.0%	minimum	0.000

Moments

Mean	0.6497741
Std Dev	1.6849457
Std Err Mean	0.1461033
upper 95% Mean	0.9387809
lower 95% Mean	0.3607673
N	133

Pond Type=Mitigation Habitat,
Season=(4) Winter,
Bird Category=(1) Dabbler
Distributions
Birds/Acre



Quantiles

100.0%	maximum	9.1029
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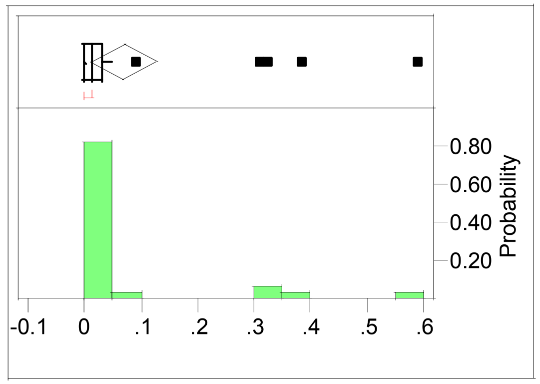
97.5%		9.1029
90.0%		7.4074
75.0%	quartile	3.1434
50.0%	median	1.8529
25.0%	quartile	0.5919
10.0%		0.0824
2.5%		0.0000
0.5%		0.0000
0.0%	minimum	0.0000

Moments

Mean	2.3964892
Std Dev	2.3972794
Std Err Mean	0.4530432
upper 95% Mean	3.3260571
lower 95% Mean	1.4669212
N	28

Pond Type=Mitigation Habitat,
Season=(4) Winter,
Bird Category=(2) Diver
Distributions
Birds/Acre



Quantiles

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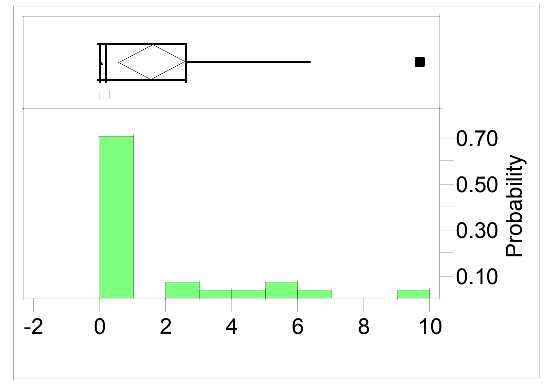
97.5%		0.58824
90.0%		0.32941
75.0%	quartile	0.02941
50.0%	median	0.01471
25.0%	quartile	0.00000
10.0%		0.00000
2.5%		0.00000
0.5%		0.00000
0.0%	minimum	0.00000

Moments

Mean	0.0693978
Std Dev	0.1456012
Std Err Mean	0.027516
upper 95% Mean	0.125856
lower 95% Mean	0.0129395
N	28

Pond Type=Mitigation Habitat,
Season=(4) Winter,
Bird Category=(3) Breeding Shorebird
Distributions
Birds/Acre



Quantiles

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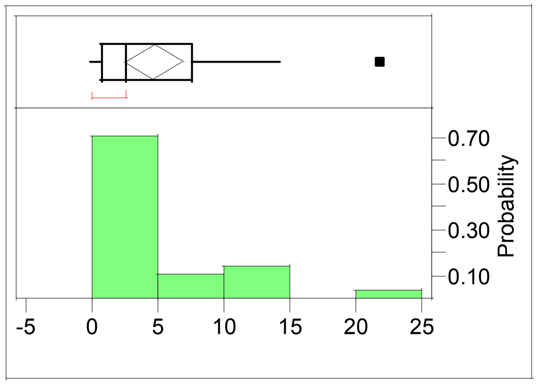
97.5%		9.6471
90.0%		5.4853
75.0%	quartile	2.6360
50.0%	median	0.1985
25.0%	quartile	0.0074
10.0%		0.0000
2.5%		0.0000
0.5%		0.0000
0.0%	minimum	0.0000

Moments

Mean	1.5685574
Std Dev	2.5283117
Std Err Mean	0.477806
upper 95% Mean	2.5489343
lower 95% Mean	0.5881805
N	28

Pond Type=Mitigation Habitat,
Season=(4) Winter,
Bird Category=(4) Nonbreeding Shorebird
Distributions
Birds/Acre



Quantiles

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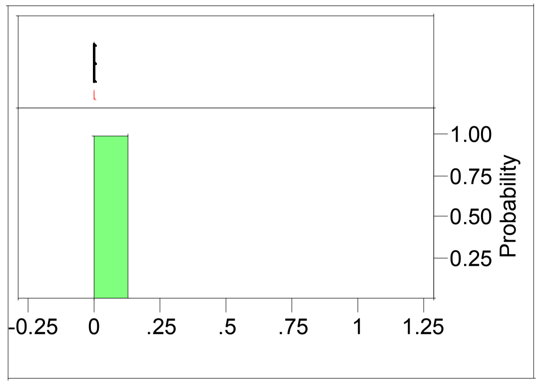
99.5%		21.721
97.5%		21.721
90.0%		13.484
75.0%	quartile	7.533
50.0%	median	2.544
25.0%	quartile	0.721
10.0%		0.324
2.5%		0.000
0.5%		0.000
0.0%	minimum	0.000

Moments

Mean	4.7167192
Std Dev	5.4814583
Std Err Mean	1.0358982
upper 95% Mean	6.8422068
lower 95% Mean	2.5912315
N	28

Pond Type=Mitigation Habitat,
Season=(4) Winter,
Bird Category=(5) Other Upland
Distributions
Birds/Acre



Quantiles

100.0%	maximum	0
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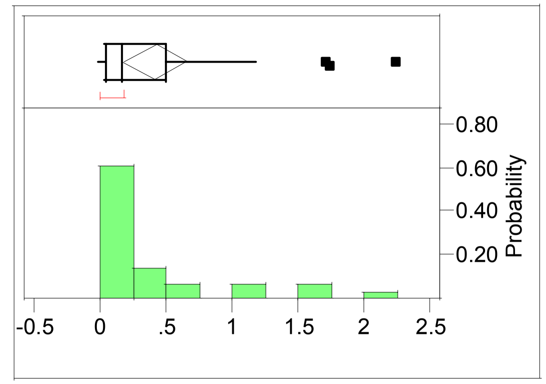
97.5%		0
90.0%		0
75.0%	quartile	0
50.0%	median	0
25.0%	quartile	0
10.0%		0
2.5%		0
0.5%		0
0.0%	minimum	0

Moments

Mean	0
Std Dev	0
Std Err Mean	0
upper 95% Mean	0
lower 95% Mean	0
N	28

Pond Type=Mitigation Habitat,
Season=(4) Winter,
Bird Category=(6) Other Waterbird
Distributions
Birds/Acre



Quantiles

100.0%	maximum	2.2353
99.5%		2.2353
97.5%		2.2353
90.0%		1.7088
75.0%	quartile	0.5074
50.0%	median	0.1691
25.0%	quartile	0.0441
10.0%		0.0000
2.5%		0.0000
0.5%		0.0000
0.0%	minimum	0.0000

Moments

Mean	0.4180672
Std Dev	0.6001307
Std Err Mean	0.113414
upper 95% Mean	0.6507736
lower 95% Mean	0.1853609
N	28

APPENDIX H

GEOLOGY AND SEISMICITY

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Acronyms

Delta	Sacramento-San Joaquin River Delta
Ma	million years old
M_L	Richter local magnitude
MM	Modified Mercalli Intensity
MCE	maximum credible earthquake
CRSB	Coast-Range Sierran Block Boundary
PKHF	Pittsburg-Kirby Hills fault

H1 AFFECTED ENVIRONMENT

The following paragraphs discuss the geologic conditions and hazards that may be encountered during the construction and implementation of the alternatives for the San Luis Drainage Feature Re-evaluation. The focus of this appendix is the geologic and seismic characteristics of the Great Valley and the Coast Ranges geomorphic provinces, which may influence the selection of a preferred alternative due to the geologic conditions and potential geologic hazards associated with these regions.

H1.1 Great Valley Geomorphic Province

The existing San Luis Drain is situated near the western margin of San Joaquin Valley (Figure 9-1), which comprises the southern region of the Great Valley geomorphic province (Harden 1998). The Great Valley Province is one of the largest agricultural basins in the world and comprises the Sacramento Valley in the north and San Joaquin Valley in the south, separated by the San Joaquin-Sacramento River Delta (the Delta).

The San Joaquin Valley is an asymmetrical topographic and structural basin with the axis offset to the west (Figure 9-2), and a gentle topographic downward slope to the north. The valley encompasses approximately 10,000 square miles and is bounded to the east by the Sierra Nevada Range, to the west by the Central Coast Ranges, to the south by the Tehacapi Mountains of the Transverse Ranges geomorphic province, and to the north by the Delta. The Sierra Nevada is composed of igneous and metamorphic rocks of pre-Tertiary age. The granitic rocks of the Sierra Nevada comprise the basement complex beneath the Great Valley. Overlying the basement complex is approximately 9,200 meters (30,000 feet) of Late Cenozoic sedimentary deposits in central and northern San Joaquin Valley. The present-day basin evolved from a late Jurassic to middle Tertiary (40-150 million years old [Ma]) marine fore-arc basin (Castillo and Zoback 1994). In the late Tertiary (25-30 Ma), a change in the relative motion between the Pacific and North American plates resulted in the gradual uplift of the Coast Ranges and the eventual isolation of the basin from the ocean. More recent Miocene and lower Pliocene sediments were derived from the neighboring Coast Ranges and the Sierra Nevada (Perkins 1987). By the late Pliocene (2-3 Ma), subaerial depositional conditions prevailed and Sierra Nevada-derived sediments were deposited in the basins (Bartow 1987).

A veneer of Quaternary alluvial and lacustrine sediments cover the Cenozoic rocks of the Great Valley (Figure 9-3). Along the western margin of the valley, these deposits were deposited primarily in alluvial fan settings. At the distal edges of these fans the deposits are commonly alluvial flood plain, lacustrine, and alluvial channel in origin (Lettis 1982). In central San Joaquin Valley these deposits tend to consist mostly of unconsolidated silty sands, poorly graded sands, clayey sands, silts, and sandy clays at shallow depths. The silty sands, clayey sands, and poorly graded sands tend to be the major water-bearing units beneath the valley (Ferriz 2001). To a lesser extent, groundwater has been encountered in sandy silt and sandy clay layers, but these tend to be poor groundwater-producing zones. Organic soils make up the upper 3 meters (10 feet) of the valley in some areas; however, through the intensive farming conducted in the region, the organic soils are missing or vacant in areas south of the Delta. Along the western and southern boundaries of the valley, farming in areas has been limited due to the buildup of salts and drainwater containing selenium (Se) in the soil (see Section 6.1). Concentrations of salts and Se and drainage problems within the western and southern areas of the valley would likely increase over time should the treatment and drainage of irrigation water within these areas not be implemented.

Coarser sediments from fluvial processes are mostly located on the eastern part of the valley and are associated with large alluvial fans that extend from the Sierra Nevada to the trough (topographic low point) of the valley (Poland and Lofgren 1984). The west side of San Joaquin Valley receives less rainfall due to the rain shadow effect from the Coast Ranges and, therefore, the soils are generally more fine-grained.

The Delta region consists of a low triangular area between Sacramento to the north, Stockton to the south, and Suisun Bay to the west. The Delta is located approximately 80 km (50 miles) from the Pacific Ocean and is currently growing inland as sediments are being deposited around its margins. Recent studies indicate that the Delta grows and recedes during periods of high and low sea level resulting from glacial and interglacial periods (Knowles and Cayan 2002). The sediments deposited in the Delta are a mix of glacially-derived fluvial deposits and marine-estuarine-deltaic deposits (Norris and Webb 1990).

The central and northern San Joaquin Valley groundwater-bearing units are comprised of several interbedded and unconsolidated layers of coarse- and fine-grained sediments. The groundwater-bearing sedimentary deposits beneath the valley can be subdivided into two principal hydrologic units: an upper unit and a lower unit (Ferriz 2001). The upper unit consists of a semiconfined aquifer system, which extends from the ground surface to the top of the Corcoran Clay Unit, at depths ranging from the ground surface to approximately 275 meters (900 feet) below the ground surface. The lower unit is considered to be a confined aquifer, which extends from below the Corcoran Clay Unit to the deep saline groundwater-bearing units and ranges in thickness between 61 to 610 meters (200 and 2,000 feet). The Corcoran Clay Unit has an average thickness of (20 meters) 65 feet and is the principal confining layer beneath nearly half of San Joaquin Valley (Ferriz 2001; Poland and Lofgren 1984).

The San Joaquin Valley drains by way of the San Joaquin, Merced, Tuolomne, Stanislaus, and Calaveras rivers through the Delta. In central San Joaquin Valley, the Kings, Kaweah, and Tule rivers naturally drain toward a large basin located between the towns of Kettleman City and Stratford, which until recently contained Tulare Lake. Within the southern end of San Joaquin Valley, the Kern River until recently drained into Lake Buena Vista. Tulare Lake and Lake Buena Vista were both seasonal lakes. Water from the rivers that formed both of the lakes has been diverted for agricultural use, through flood control measures (i.e., dam and canal construction). The former Tulare Lake and Lake Buena Vista lake beds are now used for agriculture.

Overdraft of shallow groundwater resources within San Joaquin Valley began in the middle 1920s when an estimated 2,025,000 acre-feet was pumped from the shallow subsurface strata for irrigation purposes. The amount of overdraft continued to increase and by the 1940s an estimated 3,000,000 acre-feet was removed from the shallow aquifers on a yearly basis. By 1966 the amount of groundwater overdraft exceeded 9,720,000 acre-feet/year (Poland and Lofgren 1984). Removal of such large volumes of groundwater resulted in dramatic subsidence within several areas of the Southern San Joaquin Valley (Holzer 1984). Through the importation of large amounts of surface water beginning in 1968 from the California Aqueduct, and other irrigation projects, overdraft of the groundwater supplies decreased sharply.

H1.2 Coast Ranges Geomorphic Province

The Ocean, Delta-Chipps Island, and Delta-Carquinez Disposal options all traverse the Coast Ranges geomorphic province (Figure 9-1). Physiographically, the Coast Ranges can be divided into two subprovinces, the northern and southern subprovinces separated by San Francisco Bay and the Delta. The latter represents the only major breach in the Coast Ranges and allows drainage of the Sierra Nevada and the Sacramento-San Joaquin Valley. The division of the Coast Ranges into two subprovinces is more for convenience rather than driven by geologic or physiographic differences. The only major geologic difference between the two subprovinces is that south of San Francisco Bay, the Coast Ranges are predominantly located to the west of the San Andreas fault, while the entire northern subprovince is located to the east of the main San Andreas fault. Several secondary faults of the San Andreas fault system do however traverse the Coast Ranges between San Francisco Bay and Cape Mendocino.

Four main orogenic (mountain-building) episodes have been proposed for evolution of the Coast Ranges (Norris and Webb 1990):

1. Early (?) Cretaceous mountain-building accompanied by granitic intrusion in the Salinian block (located to the west of the San Andreas), and by metamorphism of older rocks

2. Early Tertiary thrusting of rocks of the Great Valley Group over Franciscan basement

3. Followed by strike-slip faulting along the San Andreas fault system

4. The Late Pliocene and Pleistocene formation of the present-day Coast Ranges

The Coast Range orogeny is responsible for the topography that is seen today in the Coast Ranges. Earlier deformation involved compression across the Coast Ranges, resulting in uplift of the ranges and corresponding depression of intervening basins (Norris and Webb 1990). Erosion from the ranges quickly filled the basins with terrestrial clastic sediments such as the Livermore Gravels that outcrop on the southern side of Mount Diablo. Deformation during this orogenic episode, however, was dominated by the right-lateral strike-slip movement on faults of the San Andreas system. The total amount of movement on these faults is considerable; however, estimates of the absolute amount of movement on individual faults, in particular the San Andreas, are contentious.

The Coast Ranges are underlain by uplifted and intensely deformed Upper Jurassic (150 Ma) and younger rocks of the Franciscan Formation and the Salinian metamorphic and granitic complex, which are in fault contact with the less deformed Great Valley sediments (Figure 9-3). The Coast Ranges are characterized by elongate topographic and lithologic strips underlain by discrete basement blocks separated by major structural discontinuities. To the east is the Coast Ranges-Sierran block boundary zone (buried beneath the sediments of the Great Valley province). The major boundary to the west is the San Andreas fault zone separating Franciscan Formation rocks from the Salinian assemblage. The pervasive late Cenozoic deformation observed within the

Coast Ranges is due to compression orthogonal to the Pacific-North American plate contact, i.e., perpendicular to the strike of the San Andreas fault system. Ophiolites of the Coast Ranges are deformed by a series of thrust faults. The majority of these faults, although exhibiting extensive evidence for late Tertiary and early Quaternary movement, now appear to be inactive, or at least significantly less active than the strike-slip faults of the San Andreas system.

The Diablo Range, at the northern end of which the Delta-Carquinez and Delta-Chipps Island Disposal Alternatives cross, extends from the Delta, south for 210 km (130 miles) along the western side of the San Joaquin Valley to just north of Coalinga (Figure 9-4). The range is up to 48 km (30 miles) wide and reaches a maximum elevation of 1,598 meters (5,243 feet) at San Benito Mountain. Rocks of the Mesozoic Great Valley rest upon Franciscan basement along the San Joaquin Valley margin throughout the Diablo Range. This contact is often a thrust fault (Irwin 1990). Younger Paleocene to Pleistocene sedimentary units from are widely distributed along the margins of the range and also in some intermontane areas, like the Livermore basin. Despite the Diablo Range containing rocks of every Tertiary epoch, nowhere in the range is a complete Tertiary sequence located.

The Diablo Range is separated from the remainder of the Coast Ranges by faults of the San Andreas system. The Calaveras fault separates the Mount Diablo massif from the remainder of the East Bay Hills. Mount Diablo is separated from the southern extension of the Diablo Range by the Livermore Valley, an east-west-trending thrust-bounded Cenozoic basin. To the east, the Diablo Range is bounded by the Coast Range-Sierran block boundary zone (CRSB) that is, in general, created by a series of blind and partially concealed thrust faults (Wong et al. 1988; Unruh and Moores 1992). In the area of Mount Diablo, the main east bounding structure is the San Joaquin fault (Sowers, Noller, and Unruh 1992).

The general structural pattern of the Diablo Range is a series of large anticlinal folds, cored by Franciscan rocks, aligned in an *en echelon* manner and separated by synclines containing younger rocks. This sequence of folds is cored by, and often dissected by, a series of thrust faults that verge both to the east and the west. These thrust faults are, in turn, truncated by or offset by contemporary strike-slip movement on the northwest-striking, right-lateral faults of the San Andreas fault system. Along-strike complexities along these strike-slip faults give rise to areas of compression (restraining left-steps) or extension (releasing right-steps). An example of the former is the Mount Diablo uplift (Unruh and Sawyer 1997; Unruh and Lettis 1998).

The Ocean Disposal Alternative crosses the southern Coast Ranges. West of the San Andreas fault, this part of the Coast Ranges is underlain by the Salinian block (Figure 9-3) consisting of granitic and crystalline metamorphic basement rocks with a thin cover of Mesozoic and Cenozoic sediments bounded by the Rinconada fault to the west (Clark et al. 1994). Unlike the remainder of the Coast Ranges, there is little internal deformation and low rates of contemporary seismicity within the Salinian block (Clark et al. 1994; Page, Thompson, and Coleman 1998). Historical seismicity is concentrated along the bounding faults. To the west, the Salinian block is bordered by the Rinconada fault with the Coastal Franciscan domain. This tectonic block consists of predominantly Franciscan Complex basement, bounded to the west by the San Gregorio-San Simeon-Hosgri fault system. Many faults and folds that exhibit late Cenozoic movement traverse this domain. Contemporary seismicity rates are considerably higher than for the Salinian block and, although predominantly diffuse in nature, epicenters can, in some cases, be shown to be aligned along specific faults.

H1.3 Seismotectonic Setting

The California Coast Ranges are a domain of right-lateral strike-slip faulting (Figure 9-4), dominated by the San Andreas fault system, that accommodates about 75 percent of the motion between the Pacific and North American plates (Wallace 1990). In addition to the right-lateral strike-slip deformation, compression oriented normal to the plate boundary is transferred east of the main strike-slip faults by means of east-west to east-northeast-directed crustal shortening. Locally, within the Coast Ranges, this shortening is oriented more northeast-southwest and is accommodated as a series of folds and thrusts along the CRSB zone along the western margin of the Great Valley (Wakabayashi and Smith 1994). These thrusts and folds trend subparallel to the faults of the San Andreas system. In contrast, regional shortening within the Coast Ranges themselves, for example in the Mount Diablo and Mount Oso regions, has a more northerly orientation, resulting in folds and thrust that are oriented at an oblique angle to the main strike-slip faults. These tectonic features are discussed in more detail in the following sections.

H1.4 Seismicity

The historical earthquake record for the San Joaquin Valley and much of California only extends to the mid-1800s, coinciding with the influx of miners and settlers during the Gold Rush (Wong and Ely 1983). Until adequate seismographic coverage came into existence in southern California in the 1930s, earthquake detection was generally limited to those events that produced felt or physical effects. Earthquakes as small as Richter local magnitude (M_L) 3 were probably not completely observed throughout the San Joaquin Valley until about 1960. Thereafter, seismographic coverage in southern California improved significantly, and currently earthquakes as small as M_L 1.5 can be detected for most portions of the San Joaquin Valley.

The San Luis Drain Feature Re-evaluation is located in an area that historically has not been seismically active (Figure 9-5). In general, the largest historical earthquakes have generally occurred along the valley margins. A historical catalog was compiled for the study region and the epicentral locations are shown on Figure 9-5.

The catalog was compiled from the following data sources: the National Earthquake Information Center's Preliminary Determination of Epicenters; Stover, Reagor, and Algermission's U.S. historical catalog; the catalog of the California Division of Mines and Geology, 1735–1974; the catalog of the Decade of North American Geology; and the Northern California Seismic Network and the Southern California Earthquake Center catalogs. The resulting catalog (1864–2001) of approximate M_L 3 and greater is shown on Figure 9-5. The most significant of these events are annotated and discussed in more detail below.

H1.4.1 1857 Fort Tejon Earthquake

At about 8:00 am (PST) on 9 January 1857, the largest earthquake within the study region ruptured the San Bernardino, Mohave, Carrizo, and Cholame segments of the San Andreas fault. A moment magnitude (M) 8 has been estimated for the event based on the rupture length, average slip, and based on comparison to the 1906 earthquake in northern California (Sieh 1978). The earthquake epicenter was located near Fort Tejon (Real et al. 1978), approximately 72 km west-southwest of the site. Fort Tejon was destroyed (maximum Modified Mercalli Intensity [MMI] IX) and the effects were felt over an area of at least 350,000 km2 (Townley and Allen

1939). The site likely experienced a maximum intensity of MM VII-IX (Stover and Coffman 1993). Instances of fissuring, sand blows, and hydrologic changes were reported from Sacramento to the Colorado River delta. One report describes liquefaction in the region between Stockton and Sacramento (Stover and Coffman 1993). Surface rupture extended over a distance of 230 km, possibly as great as 360 km, from San Bernardino to San Benito County. Offset channels and alluvial deposits are evidence for at least 7 meters of right-lateral slip during the 1857 event (Grant and Sieh 1993).

H1.4.2 1868 Hayward Earthquake

This M_L 6.8 earthquake probably occurred on the southern Hayward fault. It was one of the most destructive in California history, because it occurred in a populated area. Significant damage was sustained in towns along the fault in the eastern San Francisco Bay area, as well as in San Francisco and San Jose.

H1.4.3 1889 Collinsville Earthquake

Of all known earthquakes of M 6.0 or greater in the San Francisco Bay region, this earthquake occurred closest to the project alignment (Figure 9-5). It may have been associated with the Pittsburg-Kirby Hills fault (PKHF). In Collinsville, a house was toppled over from ground shaking. In Antioch, many chimneys toppled and two small fissures were reported on Main Street. Toppozada et al. (1981) estimated the magnitude of the earthquake to be M_L 6 while Ellsworth (1990) estimated the event to be M 6 ¼.

H1.4.4 1906 San Francisco Earthquake

The **M** 7.9 Great San Francisco earthquake of 1906, centered near Olema, was arguably the most destructive historical earthquake to have occurred in northern California. It was felt from southern Oregon to south of Los Angeles, and as far east as central Nevada. It ruptured the northernmost 430 km of the San Andreas fault, from San Juan Bautista to the Mendocino Triple Junction. Damage was widespread in northern California and injury and loss of life was particularly severe. Ground shaking and fire caused the deaths of more than 3,000 people and injured approximately 225,000. Damage from shaking was most severe in areas of saturated or loose, young soils.

H1.4.5 1857, 1881, 1901, 1922, 1934, 1966, and 2004 Parkfield Earthquakes

Seven earthquakes of approximately **M** 6.0 occurred along the Parkfield segment of the San Andreas fault since 1857. The January 1857 earthquake has been considered a foreshock to the 1857 Fort Tejon **M** 8 earthquake. The 2 February 1881 event knocked down a few chimneys in Imusdale, which would later become Parkfield. The 3 March 1901 earthquake was accompanied by some ground cracking and landsliding. The 10 March 1922 earthquake caused only minor damage because of the sparse population in the area at the time. The 8 June 1934 earthquake caused toppling of chimneys in the town of Parkfield and minor damage to nearby bridges. The 27 June 1966 earthquake caused minor damage to roads and bridges in the area around the town of Parkfield. The 29 September 2004 earthquake caused little damage but was well-monitored because it was an event that was long anticipated by scientists. Because of the similarities in magnitude, location, and rupture propagation, Bakun and McEvilly (1984) suggested that these events are characteristic of earthquake activity along the Parkfield segment of the San Andreas fault.

H1.4.6 1983 Coalinga Earthquake

The **M** 6.4 mainshock of a sequence of earthquakes occurred on 2 May, 1983 near the town of Coalinga beneath the Coalinga anticline (Figure 9-5). More than 6,000 aftershocks were recorded over a 4-month period, with seven greater than **M** 5. The town of Coalinga was heavily damaged; a four-block industrial area downtown was destroyed. Numerous houses and public buildings suffered significant damage (Stover and Coffman 1993). Although no surface faulting was associated with the mainshock, Anticline Ridge, northeast of Coalinga, was uplifted by 0.5 meter (Stein and Ekström 1992). Surface rupture occurred along about 3 km of the Nunez fault, northwest of Coalinga, associated with an aftershock of **M** 5.2 in June 1983 (Rymer, Harms, and Clark 1984).

H1.4.7 1985 North Kettleman Hills Earthquake

A **M** 6.2 earthquake occurred beneath the Kettleman Hills North Dome anticline on 4 August, 1985. Over 400 aftershocks were recorded in a 4-week period following the mainshock (Ekström et al. 1992). Buildings and water lines in the town of Avenal suffered significant damage. Minor damage was more widespread throughout the region and the earthquake was felt over much of central and southern California (Stover and Coffman 1993).

H1.4.8 1989 Loma Prieta Earthquake

The 17 October 1989 M 6.9 Loma Prieta earthquake occurred on or adjacent to the southern Santa Cruz segment of the San Andreas fault. The cities of Los Gatos, Watsonville, and Santa Cruz were hard hit with damage, as was San Francisco and Oakland. Shaking was felt throughout the San Francisco Bay area and as far away as San Diego and Nevada. While the Loma Prieta earthquake was one of the most expensive natural disasters in U.S. history, causing in excess of $6 billion damage, the loss of life was significantly less than in 1906. Sixty-two people died and about 3,500 were injured. About 12,000 people were displaced from their homes. As in the 1906 earthquake, the worst damage from shaking occurred to buildings on unconsolidated or saturated soils, with unreinforced masonry walls or improperly designed structures.

H1.4.9 Contemporary Seismicity

The contemporary seismicity along the margins of the Central Valley and within the Coast Ranges provinces is characterized by linear alignments of epicenters along the main faults of the San Andreas fault system, most prominently the San Andreas, Calaveras, Hayward, Nacimiento, and Hosgri faults (Hill et al. 1991)(Figure 9-5). Seismicity along the western margin of the Central Valley (the CRSB) is more diffuse and clustered as aftershock sequences around the epicenters of the 1983 Coalinga and 1985 Kettleman Hills mainshocks. Earthquake focal mechanisms in the Coast Ranges exhibit predominantly right-lateral strike-slip faulting along the faults of the San Andreas system and reverse/thrust faulting in the intervening areas consistent with observed folds that are underlain by reverse/thrust faults (Hill et al. 1991). Focal mechanisms also exhibit reverse/thrust faulting along the CRSB boundary zone indicative of the fold and thrust deformation occurring along the west side of the Central Valley (Wong et al. 1988). Maximum focal depths, which indicate the thickness of the seismogenic brittle crust, are typically in the 12 to 15 km range beneath the Coast Ranges and gradually deepen eastward to the Sierra Nevada to as much as 40 km (Hill et al. 1991)

H1.5 Significant Faults

The southern San Joaquin Valley is surrounded by a number of active and potentially active faults, some of which have generated large, damaging earthquakes during historic time. The most significant of these are shown on Figure 9-4 for each fault. Maximum earthquake magnitude estimates for each fault are based on the Working Group for Northern California Earthquake Potential (WGNCEP 1996), Working Group for California Earthquake Probabilities (WGCEP 1999), and empirical relationships amongst fault rupture length, fault rupture area, and maximum magnitude (Wells and Coppersmith 1994) (Table 9-1). The most significant Quaternary faults within 100 km of the project are discussed in brief detail below.

H1.5.1 San Andreas Fault Zone

The dominant active fault structure in this region is the San Andreas fault (Figure 9-4). It extends from the Gulf of California, Mexico, to Point Delgada on the Mendocino Coast in northern California, a total distance of 1,200 km (745 miles). The San Andreas fault accommodates the majority of the motion between the Pacific and North American plates. This fault is the largest active fault in California and is responsible for the largest known earthquake in Northern California, the 1906 **M** 7.9 San Francisco earthquake (Wallace 1990). Movement on the San Andreas fault is right-lateral strike-slip, with a total offset of some 560 km (348 miles) (Irwin 1990). In northern California, the San Andreas fault is clearly delineated, striking northwest, approximately parallel to the vector of plate motion between the Pacific and North American plates. Over most of its length, the San Andreas fault has a relatively simple, linear fault trace. Immediately south of the Bay, however, the fault splits into a number of branch faults or splays, including the Calaveras and Hayward faults (each is discussed below). In the Bay Area, the main trace of the San Andreas fault forms a linear depression along the Peninsula, occupied by the Crystal Springs and San Andreas Lake reservoirs. Geomorphic evidence for multiple episodes of Holocene faulting includes fault scarps in Holocene deposits, right-laterally offset streams, shutter ridges, and closed linear depressions (Wallace 1990). The 1906 earthquake resulted from rupture of the fault from San Juan Bautista north to Point Delgada, a distance of approximately 475 km (295 miles). The average amount of slip on the fault during this earthquake was 5.1 meters (17 feet) in the area to the north of the Golden Gate and 2.5 meters (8 feet) in the Santa Cruz Mountains (WGNCEP 1996).

Based on differences in geomorphic expression, fault geometry, paleoseismic chronology, slip rate, seismicity, and historic fault ruptures, the San Andreas fault is divided into a number of fault segments. Each of these segments is capable of rupturing either independently or in conjunction with adjacent segments. In the Bay Area, these segments include the Santa Cruz Mountains, the Peninsula, and the North Coast segments. These segments have estimated maximum earthquakes of **M** 7.2, 7.3, and 7.7, respectively. The North Coast segment may also be subdivided into two shorter segments with a boundary at Point Arena. These northern and southern North Coast segments are capable of generating earthquakes of **M** 7.5 and 7.7, respectively. The North Coast segment, or an adjacent fault branch, was the source of the August 18, 1999 **M** 5.0 earthquake located near Bolinas.

South of the Golden Gate, the fault slip rate is 17 - 3/+ 7 mm/yr (Hall, Wright, and Clahan 1999). North of the Golden Gate, the slip rate increases to 24 ± 5 mm/yr (Niemi and Hall 1992). WGCEP (1999) assigns a recurrence interval of 361 years to a **M** 7.9 1906-type event on the San Andreas fault, with a 21 percent probability of a **M** 6.7 or larger earthquake on the San Andreas in northern California in the time period 2000 to 2030. Recent investigations by Niemi (2002) indicate that the repeat time for large earthquakes on the North Coast segment may be less than 250 years.

The fault segments nearest to the San Luis Drainage Feature Re-Evaluation are the Carrizo, Cholame, Parkfield, and Creeping segments. The 1857 **M** 8 Fort Tejon earthquake ruptured these fault segments and parts of neighboring segments between the Coachella Valley and San Benito. From empirical relations between fault length and earthquake magnitude (Wells and Coppersmith 1994), the Carrizo, Cholame, and Parkfield fault segments have calculated maximum earthquakes of **M** 7.6, 7.2, and 6.5 respectively. The 1857 **M** 8 rupture is considered the maximum credible earthquake (MCE) for this reach of the San Andreas fault. The creeping segment of the fault is not considered to be an independent seismic source; it is undergoing aseismic creep, *i.e.*, slow steady movement without generating earthquakes. The rate of creep is equivalent to the long-term geologic slip rate; therefore, no buildup of strain occurs along this section of the fault.

The Ocean Disposal Alternative crosses the San Andreas fault at the boundary between the Parkfield and Cholame segments. This part of the fault ruptured during the 1857 Fort Tejon earthquake. Estimates of lateral displacement during this earthquake are at least 7 meters (Grant and Sieh 1993)

H1.5.2 Hayward Fault

The Hayward fault extends for about 100 km from the area of Mount Misery, east of San Jose, to Point Pinole on San Pablo Bay (Figure 9-4). At Point Pinole, the Hayward fault extends northward into San Pablo Bay. The northern continuation of this fault system is the Rodgers Creek fault(Figure 9-4). The two faults are separated by a 5-km-wide (3-mile-wide) right step beneath San Pablo Bay (the Rodgers Creek fault is discussed below). Systematic right-lateral geomorphic offsets and creep offset of cultural features have been well documented along the entire length of the fault (Lienkaemper 1992). The last major earthquake on the Hayward fault, in October 1868, occurred along the southern segment of the fault. This **M** 6.8 event caused toppling of buildings in Hayward and other localities within about 5 km (3 miles) of the fault. The surface rupture associated with this earthquake is thought to have extended for approximately 30 km (19 miles), from Warm Springs to San Leandro, with a maximum reported displacement of 1 meter. The Hayward fault is considered the most likely source of the next major earthquake in the Bay Area (WGCEP 1999). As well as undergoing coseismic ruptures, the Hayward fault also moves by aseismic creep. Measurements along the fault over the last two decades show that the creep rate is 5 to 9 mm/yr (Lienkaemper and Galehouse 1997).

Recent research of historical documents has led to the conclusion that an earthquake in 1836, previously thought to have occurred on the northern Hayward fault, probably occurred elsewhere and not on the Hayward fault (Toppozada and Borchardt 1998). This observation increases the time since the last earthquake on this segment of the fault. Recent paleoseismic trenching along the northern Hayward fault indicates that the last surface rupturing earthquake along this part of the fault was sometime between 1626 and 1724 (Lienkaemper et al. 1997). This study also indicated at least four surface-rupture earthquakes occurred in the last 2,250 years. The WGCEP (1999) assigns maximum earthquakes of **M** 6.6 and 6.9, and recurrence intervals of 387 and 371 years, for the northern and southern segments of the Hayward fault, respectively. Rupture of the entire fault zone would generate an earthquake of **M** 7.1. Using more recent rupture area – magnitude relationships, **M** 6.9, 7.1, and 7.3 were assigned to rupture of the northern and southern segments, and entire Hayward fault, respectively. A third Hayward fault segment – the southeast extension – was also incorporated that has an estimated maximum earthquake of **M** 6.5. This part of the fault has a slip rate of 3 ± 2 mm/yr. The WGCEP (1999) considers the Hayward-Rodgers Creek fault system the most likely source of the next **M** 6.7 or larger earthquake in the Bay Area, with a 32 percent probability of occurring in the time period 2000 to 2030. Our model also incorporates a scenario where the Hayward fault ruptures along with the Rodgers Creek fault. Rupture of the entire length of both faults would generate a maximum earthquake of **M** 7.6. Rupture of the Rodgers Creek fault and the northern segment of the Hayward fault would generate a maximum event of **M** 7.4.

H1.5.3 Concord-Green Valley Fault

The Concord fault, and its continuation on the northern side of Suisun Bay, the Green Valley fault, is a northwest-striking right-lateral strike-slip fault of the San Andreas system (Figure 9-4). The Concord fault extends for 18 km (11 miles) along the eastern margin of Ygnacio Valley, from the northern slopes of Mount Diablo to Suisun Bay. North of the Bay, the Green Valley fault extends northward for a distance of approximately 43 km (27 miles). The northern end of the Green Valley fault is defined by a change in fault strike and a gap in microseismicity (WGCEP 1999). The WGCEP (1999) also included the Cordelia fault within the Concord-Green Valley fault system.

Both the Concord and Green Valley faults exhibit aseismic creep at the rate of 3 to 6 mm/yr (Galehouse 1992). Relatively few paleoseismic data exist for either fault. Wills, Snyder, and Borchardt (1994) showed 30 to 60 meters (98 to 196 feet) of right-lateral offset has occurred across the Concord fault during the Holocene (the last 10,000 years). Snyder, Borchardt, and Wills (1994) estimate a slip rate range of 2.6 to 10.8 mm/yr. The WGCEP (1999) has assigned a slip rate of 4 ± 2 mm/yr for the Concord and 5 ± 2 mm/yr for the Green Valley fault. Baldwin, Koehler, and Barron (2001) calculate a slip rate of 3.8 to 4.8 mm/yr for both the Concord and southern Green Valley faults. Based on differences in geomorphic expression, fault geometry, paleoseismic chronology, slip rate, and seismicity, the Concord-Green Valley fault is divided into three fault segments: the Concord fault, the southern Green Valley fault, and northern Green Valley fault. The segment boundary between the Concord and Green Valley faults is taken to be the middle of Suisun Bay. The boundary between the southern and northern Green Valley segments is located at the northern end of Green Valley, north of Cordelia. Independent rupture of the Concord and Green Valley faults would generate maximum earthquakes of **M** 6.5 and 7.0, respectively. The Green Valley fault may also rupture as independent north and south segments, generating maximum earthquakes of **M** 6.7each. A rupture along the entire length of both faults would generate a maximum earthquake of **M** 7.1. The Delta-Carquinez Strait Disposal Alternative crosses the Concord fault.

H1.5.4 Coast Range-Sierran Block Boundary

The CRSB is a complex zone of thrust faulting that forms the boundary between the Coast Range block and Sierran basement rocks that are concealed beneath the Great Valley sedimentary rocks of the Sacramento and San Joaquin valleys (Figure 9-4). The basal detachment within the CRSB is a low-angle, west-dipping thrust accommodating eastward thrusting of the Coast Range block over the Sierran block. Above this detachment is a complex array of west-dipping thrusts and east-dipping back-thrusts. The CRSB extends for over 500 km (311 miles), from near Red Bluff in the northern Sacramento Valley to Wheeler Ridge in the southern San Joaquin Valley (Wakabayashi and Smith 1994; Wong, Ely, and Kollman 1988).

The CRSB was the probable source of the two **M** 6¼ to 6½ 1892 Vacaville-Winters earthquakes and the 1983 **M** 6.5 Coalinga earthquake (Wong, Ely, and Kollman 1988; Unruh and Moores 1992 O'Connell, Unruh, and Block 2001). Although the faults themselves do not rupture to the surface, the CRSB is marked along much of its length by an alignment of fault-propagation folds that form a series of low hills along the western side of the Sacramento and San Joaquin valleys (*e.g.*, the Kettleman Hills). This relatively simple geomorphic expression is interrupted by the Delta where the CRSB takes a right-step between the Montezuma Hills to the north and the Los Medanos Hills to the south (Wakabayashi and Smith 1994). This complexity is most likely due to left-stepping restraining bends along right-lateral strike-slip faults that belong to the San Andreas fault system (Unruh et al. 1997; Wakabayashi and Smith 1994).

Based on differences in geomorphic expression and fault geometry, Wakabayashi and Smith (1994) divided the CRSB into a number of segments. WGNCEP (1996) has since modified this segmentation model, using the rupture geometry of the 1983 Coalinga earthquake as a "characteristic" event. Recent investigations by Unruh and Hector (1999) and O'Connell, Unruh, and Block (2001) have further refined the segmentation of the CRSB in the region surrounding the Delta. These faults are discussed in the following sections. The CRSB faults are considered independent seismogenic sources, capable of generating maximum earthquake in the range **M** 6.5 to 7.0. Where no further information is available, fault activity is expressed in terms of slip rate as determined by Wakabayashi and Smith (1994) and refined by WGNCEP (1996). The preferred geologic slip rate is 1.5 ±0.5 mm/yr.

The Ocean Disposal Alternative crosses the Kettleman Hills segments of the CRSB. This segment is capable of generating a MCE of **M** 6.8. The Delta-Carquinez and Delta-Chipps Island Disposal Alternatives cross the Delta fault segments of the CRSB.

H1.5.5 Sacramento-San Joaquin River Delta Faults

Recent investigations in the Delta region have revealed a number of Quaternary active thrust faults beneath a series of right-stepping *en echelon* anticlines to the north of Mount Diablo (Unruh and Hector 1999; Weber-Band 1998) (Figure 9-4). These faults include the Roe Island thrust, Potrero Hills thrust fault, PKHF, and the Midland fault.

Previous seismic source models for the Delta region have assumed a through-going buried or blind thrust fault representing the local continuation of the CRSB through the central part of the Delta (Wakabayashi and Smith 1994). The lack of Coalinga-type anticlines through the Delta region suggests that blind thrusts of the CRSB, if present, must have lower slip rates than the “type” structures of the CRSB to the south. Unruh and Lettis (1998) proposed an alternative kinematic model for the deformation in this region that does not involve a through-going CRSB thrust structure; instead, they have a series of smaller, less active thrust faults.

The Roe Island thrust underlies the asymmetric Roe Island anticline in Suisun Bay (Figure 9-4). This fold and underlying thrust fault are well documented from gas exploration wells and seismic reflection data (Unruh and Hector 1999). The northeast-dipping thrust fault is considered capable of generating a maximum earthquake of **M** 5.5 to **M** 6.0 (Unruh and Hector 1999). Slip-rate estimates range from 0.3 to 0.7 mm/yr, with a preferred value of 0.5 mm/yr.

Unruh and Hector (1999) interpret the Los Medanos thrust to underlie the asymmetric, southwest-tilted Los Medanos and Concord anticlines (Figure 9-4). Based on an estimate of potential fault rupture area from the length of the overlying folds and the down-dip width from structural cross sections, Unruh et al. (1997) estimate a maximum earthquake magnitude of **M** 6 for the Los Medanos thrust fault. However, due to uncertainties of fault geometry and the interaction of the fault with neighboring faults, namely the Roe Island thrust to the northwest and the PKHF to the east, the maximum event for the Los Medanos thrust ranges from **M** 5¾ to **M** 6¼. Estimates for the slip rate on the Los Medanos thrust range from 0.3 to 0.7 mm/yr. Although they have slightly different geometries, the Los Medanos and Rose Island thrusts may merge at a common decollement horizon; thus, a possibility exists that they may rupture simultaneously, generating a maximum earthquake of **M** 6.6.

The Potrero Hills thrust fault underlies the north-tilted Potrero Hills anticline, located just south of Fairfield (Figure 9-4). Unruh and Hector (1999) consider this fault capable of generating a maximum earthquake of **M** 6. Estimates of fault slip-rate range from 0.1 to 0.6 mm/yr, with 0.3 mm/yr representing the best estimate for the long-term slip rate.

The PKHF is a right-lateral tear fault that bounds the eastern margin of a series of folds and thrusts in the Grizzly Bay-Van Sickle Island area (Unruh et al. 1997) (Figure 9-4). The PKHF is highlighted by a linear alignment of microseismicity, which is unusual in that it occurs to depths of 20 to 25 km (12 to 16 miles) rather than the typical 15 km (9 miles) observed throughout most of coastal California (Wong et al.1988). Weber-Band (1998) argued that the PKHF is an east-dipping reverse fault, however, focal mechanisms indicate that the movement on the fault is almost pure right-lateral strike-slip. The 1889 **M** 6 Antioch earthquake may possibly have occurred on the PKHF (Unruh and Lettis 1998). Empirical relations among fault length, fault rupture area, and earthquake magnitude indicate that the maximum earthquake for the PKHF is **M** 6.7. Estimates for the slip rate of the PKHF range from 0.3 to 0.7 mm/yr. (Clark Fenton, URS, pers. comm., 2002)

The Midland fault is a west-dipping fault located along the eastern margin of the Montezuma Hills (Figure 9-4). This fault accommodated subsidence of the Sacramento basin during early Tertiary time. Based on detailed analysis of seismic reflection data, late Cenozoic reactivation of the Midland fault to accommodate reverse slip and horizontal crustal shortening has occurred (Weber-Band 1998). This reverse reactivation of the Midland fault has resulted in uplift of the eastern Montezuma Hills. From the offset of known Cenozoic reflectors, the Midland fault is estimated to have a slip rate of 0.1 to 0.6 mm/yr with a preferred estimate of 0.15 mm/yr (Jeff Unruh, William Lettis and Associates, Inc., pers. comm., 1999). The maximum earthquake for the Midland fault is **M** 6.3 ± 0.3.

H1.5.6 Coast Range-Sierran Block Boundary South of the Delta

Previous models for segmentation of the CRSB south of the Sacramento River inferred a continuous zone of faulting along the eastern side of the Diablo Range (Wakabayashi and Smith 1994; WGNCEP 1996). More recent studies have shown that the regional fault geometry is more complex. Instead of one, continuous through-going fault zone, there is in fact a broad zone of *en echelon* folds and thrusts, including the Mount Diablo blind thrust, between the Delta and the Livermore Valley (Figure 9-4). The CRSB *sensu stricto* begins again along the eastern range front of the Altamont Hills. Two segments of this southern part of the CRSB are of importance to ground shaking hazard to the In-Delta storage project. These are the range front faults west of Tracy (herein called the 'Tracy segment') and the range front faults west of Vernalis (the 'Vernalis' segment). The geometry of these structures is not known, but from analogy with other sections of the CRSB, it is assumed that these are west-dipping blind thrusts located beneath east-facing monoclinal warps (a fault-propagation fold geometry). Assuming a 15° dip and a 'Coalinga-type' geometry (fault extending from a 4- to 10-km [2.5- to 6-mile] depth), the Tracy and Vernalis blind thrusts are considered capable of generating maximum earthquakes of **M** 6.8 and 6.6, respectively. Rupture of both segments would generate a maximum earthquake of **M** 7.0. The slip rate for these faults is between 0.29 and 2.3 mm/yr, with a preferred estimate of 0.42 mm/yr based on vertical separation rates calculated by Sowers and Ludwig (2000).

H1.5.7 Mount Diablo 'Blind' Thrust

The Mount Diablo thrust fault is a northeast-dipping, southwest propagating thrust fault beneath the Mount Diablo anticline (Figure 9-4). Unruh and Sawyer (1995) proposed that slip on the northern Greenville fault appears to die out northward because the fault steps left to the northwest across Mount Diablo to join with the right-lateral Concord fault. This model argues that the Mount Diablo anticline is a contractional left-stepover between the Greenville and Concord faults. Unruh and Sawyer (1995) specifically proposed that Mount Diablo is an asymmetric, southwest-vergent fault-propagation fold underlain by a northeast-dipping blind thrust fault that links the northern Greenville fault to the Concord fault.

Long-term average Quaternary shortening rates across the Mount Diablo region, estimated from construction of balanced cross sections, are 3.4 ± 0.9 mm/yr (Unruh and Sawyer 1997). Considering the likely fault geometry, an average slip rate for the Mount Diablo thrust would be approximately 4.1 ± 1.4 mm/yr. This blind thrust fault is capable of generating a maximum earthquake of **M** 6.9. Along-strike complexities indicate that the Mount Diablo thrust may be segmented, with the segments separated by northeast-striking tear faults. If this is the case, then the maximum earthquake for each segment would be **M** 6.2 to 6.6. Based on an average coseismic slip during the maximum event and the calculated slip rate, Unruh and Sawyer (1997) proposed an average recurrence of approximately 230 to 740 years for the Mount Diablo thrust.

H1.5.8 Greenville Fault

The north-northwest- to northwest-striking Greenville fault is a strike-slip fault of the San Andreas system in the northern Diablo Range (Figure 9-4). The fault extends from Bear Valley to just north of Livermore Valley. Evidence for right-lateral displacement on the Greenville fault includes right-laterally offset drainages and sidehill benches, and right-lateral surface offsets observed along traces of the fault following the January 1980 Livermore earthquake sequence (Hart 1981). Seismicity associated with the fault is characterized by a subvertical alignment of hypocenters extending to depths of approximately 17 km (11 miles) at the latitude of Livermore Valley (Hill, Eaton, and Jones 1990). Focal mechanisms indicate primarily right-lateral strike-slip motion on northwest-striking nodal planes (Oppenheimer and Macgregor-Scott 1992). The Greenville fault generally is assumed to continue north of Livermore Valley as the Marsh Creek-Clayton system; however, the well-defined surface trace of the fault dies out or diminishes markedly several km north of Livermore Valley. The Marsh Creek-Clayton fault system is considerably less active than the northern Greenville fault east of Livermore. The restraining step-over model of Unruh and Sawyer (1997) indicates that slip from the Greenville fault is transferred to the Concord fault, and therefore the Clayton-Marsh Creek fault is either inactive or not part of the Greenville fault system.

Available data on the late Quaternary slip rate of the Greenville fault are sparse and have significant uncertainties. Based on correlation of terraces south of Livermore Valley offset by the Greenville fault, Wright et al. (1982) documents approximately 90 meters (295 feet) of Pleistocene displacement. The deformed terraces were estimated by Wright et al. (1982) to be 125,000 to 180,000 years old, based on soil profile development, thus implying a slip rate of 0.5 to 0.7 mm/yr. Paleoseismic trench investigations across one strand of the northern Greenville fault document evidence for Holocene surface-rupturing events. Wright et al. (1982) estimated a horizontal slip rate of approximately 0.1 to 0.3 mm/yr using an assumed 1:3 ratio of vertical to horizontal separation.. The WGNCEP (1996) assigned a maximum earthquake of **M** 6.9 and a minimum slip rate of 2 mm/yr to the Greenville fault. The recurrence interval is estimated to be on the order of 550 years. Recent investigations indicate a 70 km (43-mile) length for the active Greenville fault (Unruh and Sawyer 1998; Sawyer and Unruh 2002). Preliminary Holocene slip rate estimates from a site at the northern end of the Livermore Valley are 4.1 ± 1.8 mm/yr (Sawyer and Unruh 2002).

H1.5.9 Ortigalita Fault

The Ortigalita fault is a 66-km-long (41-mile-long), north-northwest-striking, right-lateral strike-slip fault located in the southern Diablo Range. The fault extends from Panoche to southeast of Mount Stakes. It consists of two distinct geometric sections, separated by a 5-km-wide (3-mile-wide) right-step across San Luis Reservoir. Much of the fault is delineated by persistent microseismicity and is marked by geomorphic evidence for recent strike-slip faulting, including deflected drainages, shutter ridges, sidehill benches, and vegetation lineaments (Anderson, LaForge, and Anders 1982; Anderson and Piety 2001). Paleoseismic trenching investigations have estimated a slip rate of 0.5 to 2.5 mm/yr for the fault north of San Luis Reservoir. South of the reservoir, the slip rate is considerably less, approximately 0.2 to 1.0 mm/yr (Anderson and Piety 2001). The maximum earthquake for rupture of the entire Ortigalita fault is **M** 7.4. Independent rupture of the northern segment would generate a maximum earthquake **M** 7.0

while the southern segment would generate a maximum earthquake of **M** 7.2. The geometric complexity of the southern part of the Ortigalita fault, generally forming 17- to 27-km-long fault strands, would more likely rupture as smaller earthquakes, of **M** 6.5 to 6.7.

H1.5.10 Mount Oso Anticline

The Mount Oso anticline is located in the left-step between the Ortigalita and Greenville faults (Figure 9-4). The location of this fold, in what is considered a restraining step between two active right-lateral strike-slip faults, indicates that it may be undergoing active contractional deformation. In addition, the southwest-vergent geometry of this fold suggests that it may be underlain by a northwest-dipping blind thrust, similar to that beneath Mount Diablo (Jeff Unruh, Willam Lettis & Associates, Inc., pers. comm., 2002). The geometry and activity of this structure is the subject of speculation. Without further information, this zone was assigned a probability of activity of 0.5. Conservatively, the entire zone beneath Mount Oso between the Greenville and Ortigalita faults was assumed to be underlain by a blind thrust dipping at 20°. The fault was also assumed capable of generating a similar size MCE to the Mount Diablo blind thrust (**M** 6.9).

H1.5.11 San Juan Fault

The San Juan fault splays from the San Andreas just to the north of Cholame (Figure 9-4). This right-lateral strike-slip fault is approximately 86-km-long (53-mile-long), running along the western side of the Carrizo plain, at the foot of the La Panza range. The fault is a broad, complex zone, of *en echelon* fault strands. The northern extent of this fault, namely the Red Hills and Gillis Canyon faults, have ruptured during Holocene time (Jennings 1994). Although only the northern part of this fault zone displays evidence for recent activity, in the absence of detailed geologic or paleoseismic data, the entire fault zone was conservatively assumed to be active and capable of generating a MCE of **M** 7¼.

H1.5.12 La Panza Thrust

The La Panza thrust is a northwest-striking, northeast-dipping reverse fault along the southwestern margin of the La Panza Range (Figure 9-4). Jennings (1994) depicts the La Panza thrust as being Quaternary in age, i.e., it cuts Pleistocene deposits. The fault is approximately 71 km long (44 miles) and consists of two sections, a 38-km-long (24-mile-long) southeast and 33-km-long (21-mile-long) northwest section, separated by a prominent right bend. No paleoseismic data indicate timing of recent movement on the La Panza thrust; therefore, it is assumed that the entire fault ruptures at once, generating a MCE of **M** 7¼.

H1.5.13 Rinconada Fault

The Rinconada fault extends from near King City, along the western side of the Salinas Valley to the Rinconada Mine at the southern end of the Santa Margarita Valley (Figure 9-4). Jennings (1994) shows the Rinconada fault as a right-lateral strike-slip fault of late Quaternary age (i.e., cuts Pleistocene deposits). Based on fault geometry and geomorphic expression, the Rinconada fault can be divided into three segments. Hart (1985) defined them as the Espinosa segment between King City and Lake San Antonio, the San Marcos segment between Lake San Antonio and Paso Robles, and the Rinconada segment between Paso Robles and Rinconada Mine. Hart

(1985) also includes the southern Nacimiento fault between Rinconada Mine and Big Pine as the southernmost segment of the Rinconada fault. The southern Nacimiento fault is in fact a southwest-dipping thrust fault with no geomorphic evidence of recent movement. Unlike the rest of the Rinconada fault, which forms a basin-bounding range front, the southern Nacimiento fault traverses the uplands of the Sierra Madre Mountains. Therefore, the southern Nacimiento fault is concluded to not be part of the Rinconada fault zone and to be inactive. Thus, the southern end of the Rinconada fault coincides with the southern end of the Santa Margarita Valley, where it apparently truncates against a southwest-dipping thrust fault.

Analysis of aerial photographs and a field reconnaissance along the Rinconada segment reveal plentiful geomorphic evidence for latest Pleistocene and possibly even Holocene movement. The fault is marked by prominent southwest-facing fault scarps, right-laterally deflected drainages, scarps on alluvium, spring lines, and vegetation/tonal lineaments.

Geometric complexities and changing geomorphic character of the Rinconada fault suggests that it ruptures as discrete segments. The youthful geomorphology along the Rinconada segment indicates that it apparently either more active (has a higher slip rate), or has ruptured more recently, than the San Marcos segment immediately to the north. The increase in range front height from the San Marcos to the Espinoza segment indicates a greater amount of displacement on the Espinoza segment. However, without site-specific paleoseismic data the Rinconada fault has to be considered capable of experiencing a multisegment rupture. Rupture of the Rinconada segment alone would generate an earthquake of **M** 7. Rupture of both the Rinconada and the San Marcos segments would generate an earthquake of **M** 7¼. Rupture of all three segments would generate an earthquake of **M** 7½. In accordance with WGCEP (1995), rupture of the entire Rinconada fault generating a **M** 7½ is considered as the MCE.

H1.5.14 Nacimiento Fault

The Nacimiento fault extends from near Point Lopez, south of Big Sur, southeast to near San Luis Obispo, where it merges with the Oceanic/Huasna fault systems (Figure 9-4). The Nacimiento fault comprises a complex zone of anastamosing fault strands that mark the boundary between the coastal Franciscan block and the interior Salinian granitic terrane. This zone consists of numerous, predominantly northwest-striking faults with long complex histories of strike-slip. normal, and reverse movement. Although no evidence for Quaternary movement exists along any of these faults (Clark et al. 1994), low to moderate seismicity along this fault trend suggests that it is a potentially active structure that is releasing at least some of the strain accumulation across the central Coast Ranges. The southern continuation of the Nacimiento fault depicted by Jennings (1994) is actually a southwest-dipping thrust fault that shows no evidence of Quaternary movement. No contemporary seismicity occurs along this southern continuation of the Nacimiento fault (Jennings 1994). The structural complexity of the Nacimiento fault zone and the lack of geologic or geomorphic evidence for Quaternary movement along the southern portion of the fault indicates that it is unlikely the Nacimiento fault would rupture in a single, through-going event. Contemporary seismicity along the fault between Point Lopez and San Luis Obispo, however, indicates that the Nacimiento fault is likely active. Rupture of the entire fault would generate an earthquake of **M** 7¼. However, based on the lack of evidence for activity of the southern part of the fault it is more likely that the fault breaks as shorter segments with little of no surface expression. A conservative estimate for such an event would be a MCE of **M** 6½ to 7.

H1.5.15 Oceanic/West Huasna Fault

The Oceanic fault is a long, complex series of fault strands that bounds the eastern side of the Los Osos Valley and separates the San Luis and Santa Lucia Ranges. Jennings (1994) shows the Oceanic fault as a 28-km-long (17-mile-long), Pleistocene active fault. The West Huasna may be southern continuation of the Oceanic fault. Anderson and LaForge (1985) indicate that the West Huasna fault may offset Pleistocene sands and gravels. The Oceanic fault's position at the base of the prominent Santa Lucia Range front, the offset of late Pleistocene deposits, and contemporary seismicity along the Oceanic/West Huasna trend indicate that the faults are active (Clark et al., 1994). Rupture of the Oceanic fault would generate a MCE of **M** 6¾ at a distance of 11 km from the dam site.

H1.5.16 Cambria Fault

The Cambria fault is a small west-dipping thrust or reverse fault that splays from the Oceanic/West Huasna fault to the south of the Ocean Disposal Corridor alignment (Figure 9-4). The fault extends from Pismo Creek in the south to Cambria. The San Luis Drainage Feature Re-evaluation Ocean Disposal Corridor crosses the Cambria fault about 3 km (2 miles) east of Point Estero. Clark et al. (1994) suggest that the association with contemporary seismicity and reported offset of late Pleistocene deposits indicate that the Cambria fault is a potentially active structure. Based on a mapped fault length of 63 km (39 miles), the MCE for the Cambria fault is estimated as **M** 7.1.

H1.5.17 Hosgri Fault

The Hosgri fault is part of a large right-lateral strike-slip fault system, including the San Simeon, Sur/Palo Colorado, and San Gregorio faults (Figure 9-4). The majority of this fault system lies offshore and, therefore, has had relatively little study. The Hosgri fault lies entirely offshore, and has recently been mapped using seismic reflection data (Steritz and Luyendyk 1994). It extends from near Point Conception in the south, to near Point Estero, north of Estero Bay. Jennings (1994) only shows a 32-km-long (20-mile-long) section of the fault as having Holocene displacement. Although the fault is predominantly right-lateral strike-slip, portions of it exhibit high-angle reverse displacements on seismic reflection profiles (Steritz and Luyendyk 1994). The entire Hosgri fault zone is approximately 120 km long (74 miles), however, the complex geometry and discontinuous nature of the fault zone suggests that it does not rupture in a single through-going event. Assuming that the 32-km-long (20-mile-long) Holocene active section depicted by Jennings (1994) is a typical rupture segment, this would indicate that the Hosgri fault is capable of generating an earthquake of **M** 6¾. Rupture of the entire 120-km (74-mile) fault length would generate an earthquake of **M** 7½. The structural complexity of the fault zone indicates that this is not a likely event. WGCEP (1995) models the Hosgri as a two 60-km-long (37-mile-long) segments, each capable of generating an earthquake of **M** 7¼, which is adopted here as the MCE for the Hosgri fault.

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APPENDIX I

LAND AND SOIL RESOURCES OF THE SAN LUIS UNIT

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Acronyms

AF	acre-foot or acre-feet
APE	area of potential effect
CPT	cone penetrometer testing
CV%	coefficient of variation expressed as a percentage
dS/m	deciSiemen(s) per meter
EC	electrical conductivity
ECe	electrical conductivity of the soil saturation extract
ECsw	electrical conductivity of soilwater
EM38	electromagnetic instrument used to measure soil salinity
Emh	EM38 meter reading in the horizontal, effective depth 0 to 3 feet
Emv	EM38 meter reading in the vertical, effective depth 0 to 5 feet
EIS	Environmental Impact Statement
ET	evapotranspiration by plants

FSI	Farmland of Statewide Importance
GPDR	groundwater pumping drainage relief
mS/m	milliSiemen(s) per meter
NRCS	Natural Resources Conservation Service
pHp	pH paste
Reclamation	Bureau of Reclamation
Unit	San Luis Unit
vadose zone	The substrata layers between the saturated zone (water table) and the bottom of the root zone
Westlands	Westlands Water District

The lands and soils of the San Luis Unit (the Unit) are a valuable natural resource. Nearly all the lands in the survey area are considered either Prime Farmland or Farmland of Statewide Importance (FSI). Due to increasing drainage problems and associated deteriorating soil salinity conditions, the Natural Resources Conservation Service (NRCS) has removed about 120,000 acres from the Prime Farmland category since 1985. Although these lands are no longer considered to be Prime Farmland, they are still considered to be FSI by the State of California. Attachment I1 lists all the Prime Farmlands and Attachment I2 lists the FSI by county. Current maps of the Unit (Attachment I3) indicate about 55 percent of the lands are Prime Farmland, about 40 percent are FSI, and less than 5 percent are uncategorized lands. Uncategorized lands consist of stream channels, sediment basins, feedlots, steep areas, very heavy fine textured soils of the valley basin, and highly saline lands (electrical conductivity of the soil saturation extract [Ece] over 16 decimeters per meter [dS/m]). Since nearly all the lands of the Unit are either Prime Farmland or FSI, this effect analysis for lands and soil resources covers the entire Unit. While some of the area is well suited for irrigation, the lower portions of the Unit are affected by shallow groundwater and would require artificial drainage to maintain high potential productivity and Prime Farmland status.

The areas affected by shallow groundwater are termed the area of potential effect (APE). Although the APE would be farmed less intensively during the 50-year life of this analysis, it is important that land productivity and soil quality be maintained at a level that would permit production of food on these lands in the future when the value of food products increases due to increasing world population pressures. Nearly all effects to groundwater, water quality, and water supplies would eventually and primarily affect the productivity of valuable land and soil resources. Remedial measures, including land retirement, on-farm drainwater source control, drainwater reuse, and construction-related effects have the potential to adversely affect land productivity if not done in a technically sound manner.

Environmental effects to land and soil resulting from various action alternative features are discussed below.

I1 EVAPORATION BASINS

Site selection criteria for evaporation basins or "ponds" indicate that these ponds would be sited on lands that are some of the least productive for irrigated farming in the area. These lands would be further degraded to the point that future irrigation would be precluded. In the event the evaporation basins are no longer needed, they could be either capped with 2 to 3 feet of cover and used for dryland activities, or the salts could be scraped off the surface of the ponds and landfilled at another site. Salt harvesting and sale is another possibility. In either scenario a very large quantity of soluble salt would remain in the soils. Although leaching of these salts is possible, it would be very expensive and would contribute a tremendous, salt, selenium, and boron load to discharge facilities.

Current plans call for salts collected in evaporation basins to be scraped off, isolated, consolidated, and buried in one end of the basin. Eventually, it is hoped salts could be harvested and sold.

Evaporative concentration of salts could also result in concentration of toxic elements. Water treatment plants are planned to reduce selenium and nitrate levels; however, high levels of elements such as such molybdenum, mercury, nickel, and boron could complicate salt disposal and management of evaporation basin salts. The chemical reduction and lowering of pH associated with selenium removal could also affect the toxicity of other elements in the evaporation basin waters, which in turn could complicate management procedures and increase costs.

I2 SALT SINK AREAS

Salt sinks are usually barren or nearly barren areas with little or no vegetation. Surface soil salts are very high. Since no plants are usually present to use the soil water, the subsoil is often moist below a depth of 3 inches or so. Soil salinity often decreases with depth. Shallow groundwater is often present at depths shallower than 6 feet. The high soil salinity tends to impart a soft or very friable flocculated condition to the surface soil. The salty surface soil of this type is subject to wind erosion. Surrounding lands may be damaged by windborne salts from the salt sink area. The salt sink will continue to expand until surface evaporation comes into balance with recharge, or the source of recharge is controlled by artificial drainage, canal lining, or shallow groundwater pumping to reduce or eliminate the source of recharge. In some cases land retirement or a reduction of deep percolation in the source area would be needed to arrest salt sink development. Salt sink areas would greatly exceed salinity levels considered for Prime Farmland or FSI.

Currently, Westland's Water District (Westlands) has about 700 acres of salt sinks. These areas have been caused by deep cuts for land leveling of fields, canal seepage, and salt concentration in reuse areas, or in some cases are remnants of natural subsurface discharges and associated salinity in basin rim locations. One salt sink is the result of an abandoned evaporation basin.

I2.1 Evidence for Further Salt Sink Development

In his March 26, 1991, Travel Report (Busch 1991) Bureau of Reclamation (Reclamation) Drainage Engineer Leo Busch indicated he believed that potential existed for development of 10,000 to 20,000 acres of salt sinks in the San Luis Unit. The trip report further stated: "*These areas are normally associated with lateral groundwater movement that is decreased or stopped by downslope impedance.*" Following field inspection of potential salt sink areas Mr. Busch had the following conclusions: "*Definite evidence of salt sink potential was observed in the field. The degree of this problem will be determined by the source control measures practiced upslope. These measures are especially important in the areas above potential areas of salt sinks due primarily to increased hydraulic gradient due to excessive deep percolation water, combined with the funneling effect of the sand stringers. These stringers tend to concentrate subsurface flows and hydraulic energy which magnify the potential for the creation of salt sinks.*"

In recent years incipient salt sink areas are beginning to develop in interfan and mid-fan topographic positions. Growers in some of these areas (e.g., Red Rock Ranch) have installed drains and salt harvesting facilities to restore the lands to a more productive state. Other growers have installed drains and reuse areas but currently have no salt disposal or harvesting facilities. In these situations salt sinks tend to form near the tail of reuse fields or on the lower fields in the reuse field sequence. Attachment I4 indicates the location of some existing salt sinks (E), existing reuse areas (R), and some potential salt sink areas (P). This drawing is intended to show examples of some affected areas and is not intended to be a comprehensive inventory of all potential areas in the Unit.

I2.2 Recent Studies of Salt Sink Potential

Multiple water pressure readings at 23 cone penetrometer testing (CPT) sites indicated upward gradients at 15 sites, downward gradients at 2 sites, and nearly no gradient at 6 sites. The CPT pressure measurements were done in successive sandy layers to a depth of 50 feet. Some of the CPT logs also indicated groundwater salinity discontinuities in coarse textured layers, which suggest low salinity recharge from upslope areas moving in preferential flow paths. Virtually all CPT and drill logs indicated multiple fine-textured barriers and/or confining layers, and a few sites indicated nearly all fine-textured material to a depth of 50 feet. The shallow aquifer is often described as semiconfined. This term implies that upward gradients exist in at least part of the APE. In areas where a barrier to downward flow exists and a discontinuous shallow confining layer is above the barrier, salt sinks could form in areas where the discontinuous confining later is absent. Data from Appendix E Groundwater Resources seem to indicate that some subsurface drainwater samples had rather low chloride concentrations especially in central and southern areas of Westlands, suggesting that the primary source of these waters is not deep percolation from irrigation but is canal seepage, floodwater recharge, or recharge from other water sources that have somehow bypassed root zone evapotranspiration processes and moved directly into shallow aquifers. In some cases these waters appear to have moved laterally several miles from the potential recharge sources.

Generally, salt sink areas tend to form where subsurface drainwaters from upslope carried in coarse-textured preferential flow paths encounter a lateral barrier of fine-textured soils or other flow restriction. In the absence of artificial drains, or in some areas, increased shallow groundwater pumping the drainwaters tend to rise to near the ground surface and greatly increase bare soil evaporation potential.

A description of one salt sink area (about 40 acres in size) and the remedial measures taken to improve the situation (Red Rock Ranch) is given in the California Vegetable Grower (Thompson 1998) In this case eucalyptus (red gum) trees were used to intercept a portion of the upslope lateral flows. The variety of red gum used was specifically developed to withstand western San Joaquin valley soil salinity and climatic factors. Extensive drainage systems were also installed. Several other cases of the use of trees to intercept upslope flows were also noted in the San Luis Unit. These treelines should work as biological interceptors until soil salinity becomes limiting for tree growth. Based on EM38 surveys of existing treelines at Red Rock Ranch and the Panoche reuse area, it appears this variety of red gum trees can tolerate a soil salinity of about ECe 10 dS/m before growth is restricted. Estimated tree diameter at breast height was reduced about 6.6 percent per ECe unit until with an ECe of about 25 dS/m all the red gum trees were dead. Athel trees appear much more salt tolerant. Red gum trees at the Panoche reuse area also showed classic boron toxicity symptoms on the leaves. Soil boron content appears to be the more limiting than soil salinity for red gum growth in northerly areas.

Some of the land retirement alternatives would tend to deliver additional water supplies to upslope lands that were formerly in Priority 2 water supply areas, which will increase deep percolation on these lands and may also reduce the historically high groundwater pumping demands in these areas. Since large acreages of lands will be retired in the APE, groundwater pumping will sharply decrease in the APE. A reduction in groundwater pumping will reduce the vertical drainage relief in these areas. Increased subsurface flows moving downslope from well-drained lands could encounter lateral barriers and increase the size, severity, and number of salt sinks relative to existing conditions.

Salt sink areas are also expected to increase under the No Action Alternative relative to the existing situation, since the effects of recent water transfers to upslope lands have not yet fully affected downslope areas. However, groundwater pumping to irrigate a portion of the 65,000 acres of acquired lands that are not eligible for Central Valley Project water would limit the potential for salt sink development on many lands.

I2.3 Identification of Potential Salt Sink Areas

Attachment I4 (intended to show examples of some affected areas and not to be a comprehensive inventory of all potential areas in the San Luis Unit) indicates the location of some existing salt sinks (E) and some potential salt sinks (P). Current reuse areas are designated with an (R) on the map. The (N) designations indicate that salt sink potential only exists with the No Action Alternative at the site. Circled designations indicate higher potential for salt sink development due to increased recharge anticipated from upslope irrigation and reduced groundwater pumping in retired areas. More than 100 potential and existing salt sink areas were identified. The reuse areas are located in areas with current drainage problems and could also be potential salt sink areas if the drains were plugged and/or the reuse area abandoned. Ground-truthing activities removed some of the potential sites initially designated on the map. The most common reason for removal was an observation well was sited in a location that would tend to give false positive (too shallow) results for shallow groundwater levels. In some cases current crop condition or EM survey indicated nonsaline conditions in area originally designated as highly saline. The following criteria were used to identify existing salt sink areas:

- Salts visible on the soil surface
- Little or no vegetation or severely stressed vegetation
- Temperature adjusted (25°C) EM38 horizontal readings over 500 milliSiemens per meter (mS/m)
- Surface soil ECe over 30 dS/m
- Recent aerial photography indicating high salts on soil surface

Potential salt sink areas were identified using the following indicators:

- Relatively steep groundwater gradients that suddenly flatten.
- Relatively steep topographic gradients that suddenly flatten.
- Aerial photo or drill log indicates some soil surface salt accumulation, but soil salinity information is not available or measured soil salinity values do not meet the criteria for salt sinks.
- Recent April observation well groundwater readings shallower than 4 feet and do not subside below 6 feet in October.

- Recent October groundwater levels shallower than 5 feet.
- Hydrologic model indicates bare soil evaporation potential in general area.
- Hydrologic model indicates water table 7 feet or shallower in the general area on nonirrigated land or indicates groundwater levels of 2 to 3 feet on irrigated lands.
- Grower reports of equipment bog down in springtime unless cultural operations are delayed.
- Existing drainage system sumps handle unusually large volumes of drainwater for the area drained, and tend to keep running even when the drained field is fallowed.
- CPT logs from June 2003 indicate groundwater readings shallower than 5 feet and/or artesian pressure potentials at shallow depth.
- Reclamation drill logs indicate groundwater levels shallower than 4 feet in June 2004 and/or upward groundwater gradients.
- Existing drainwater reuse area.
- NRCS soil survey data indicate soils with ECe levels over 16 ds/m in the top meter of soil.
- Field inspection indicated visual evidence of surface salt accumulation or poor crop conditions.

I2.3.1.1 Quantification of Adverse Effects Associated with Salt Sinks

Strictly speaking, evaporation basins and salt-harvesting facilities are salt sinks; however, the salts are under control in these areas and selenium hazards are reduced and/or mitigated for. In uncontrolled salt sinks, the salts may accumulate in irregular polygons where an 80-acre salt sink may render a much larger area unproductive due to isolation of better lands and field size issues. Prevailing winds can blow the salts to other nearby lands and cause severe damage. Bare soil evaporation and associated soil surface salt deposition processes can also lead to accumulation of harmful trace elements on the soil surface. Soil samples collected in salt sink areas had high soluble selenium concentrations. Based on the information presented above, salt sink areas are rated two times more adverse than evaporation basins and salt harvesting facilities for the land and soil resources effects analysis.

The size of the existing 18 salt sink areas range from about 10 to 80 acres with an average size of roughly 40 acres. The average size of the salt sinks is expected to expand under some alternatives.

Since the acreage of salt sinks is difficult to predict, often no remediation or mitigation measures are undertaken. The grower has probably retired the land and would have no income from farming to finance remediation or mitigation measures. The grower or land owner is generally not responsible for the increase in upslope flows causing the problem on his lands; therefore, the salt sink problem should be addressed as a regional problem. One way to handle the problem would be to assess a fee to all growers in contributing drainage areas to create a fund that could be used to remediate or mitigate salt sink conditions that may develop over time.

I2.4 Land Retirement Effects on Vast Majority of the Area of Potential Effect

Reclamation's land retirement demonstration area research indicates that shallow groundwaters have receded about 14 inches per year since the lands were retired from irrigation. Surface soil salinity has also decreased indicating the absence of bare soil evaporation from the water table. The demonstration area is located on basin and basin rim lands and is isolated from recharge from actively irrigated areas by many miles of retired lands. Field estimates of specific yield and pumping-induced drainage indicate that in the absence of recharge from lateral flows the water table depths on most retired lands should subside between 2 and 3 feet per year following cessation of irrigation. Based on this rate of groundwater subsidence, nearly all lands on lower-alluvial fans and basin rims should not be subject to any bare soil evaporation potential 2 years following land retirement. Extensive drill and CPT logs from 2003–2004 drainage and land investigations generally indicate shallow groundwater levels somewhat deeper than expected in areas in the vicinity of retired lands.

The HydroFocus groundwater model predicts that groundwater levels would subside following land retirement on the vast majority of APE lands as long as groundwater pumping at the safe yield rate is continued.

Reclamation's land retirement research on Basin rim lands seems to indicate that groundwater levels would recede following land retirement and that bare soil evaporation would not occur. Based on Reclamation's land retirement research, HydroFocus groundwater modeling results, and the implementation of source control measures on upland areas under some of the action alternatives, it is believed the potential for salt sink development in the 50-year effects analysis period is more on the order of 6,000 acres rather than the 10,000–20,000 acres predicted by Reclamation Drainage Engineer Leo Busch in 1991. Salt sink analysis based entirely on HydroFocus modeling groundwater levels in the northern areas would indicate about 5,000 acres of retired lands would develop salt sinks by the year 2050 (all retired lands with shallow groundwater levels of 7 feet or less). Scaling of this acreage outside of the model area to the entire district would indicate about 12,000 acres of potential salt sinks. This approach was not used since conditions on the Arroyo Pasajero fan, Cantua Creek fan, and the interfan area may not have the same salt sink potential as the modeled area. (Panoche and Little Panoche Creek fans). The model also predicted shallow groundwater levels on the eastern boundary of the modeled area. These areas may not represent retired lands since they tend to overly basin alluvium of mixed sources and border on irrigated areas.

I2.5 Summary

The salt sink analysis has found some widely scattered areas that appear to have the potential for salt sink development after land retirement. These areas are mostly in interfan areas and relatively high on the alluvial fans. About 1.5 percent (6,000 acres) of the APE is predicted to have good potential for salt sink development. The current area of salt sinks consists of 18 widely scattered areas, comprising a total of about 700 acres of land. Salt sink areas will not qualify for FSI due to very high soil salinity levels.

I3 REUSE AREAS

These areas would be sited on FSI. Although these lands would increase in soil salinity due to irrigation with water high in total dissolved solids, salinity would not increase to the point that the lands would be too saline to be classified as FSI. Reclamation design criteria provide for an excellent deep artificial drainage system complete with water-level control capability. Short irrigation runs, large heads of water, and basins leveled to uniform grades would facilitate relatively high application efficiencies. Drainwater bypass criteria and operational flexibility would also permit these lands to be managed for soil salinity control. In the event these lands are converted back to commercial farmland, the versatile deep drainage system would permit a relatively rapid leaching of active root zone salts down to levels associated with Prime Farmlands.

Several existing reuse areas are located in the APE. The location of these areas is designated with an (R) on the salt sink evaluation drawing (Attachment I4). Some of these facilities have sequential reuse systems, salt disposal and harvesting facilities, as well as selenium treatment facilities; however, most of the areas are one stage reuse with salt-tolerant crops and grasses. Salt tends to accumulate in these reuse areas. Currently, growers have the option of expanding the reuse areas; however, at some point the salt disposal question will have to be addressed. Salt levels on most reuse area lands would still qualify these lands for the FSI category. Concentrating/harvesting/selling salts has some potential; however, this solution has not been fully explored. These reuse systems could also be incorporated into San Luis Drainage Feature Re-evaluation reuse areas for Out-of-Valley and In-Valley-Disposal Alternatives. Most of these areas are located in shallow groundwater problem areas and would be likely locations for salt sink development if drainage facilities were plugged and/or the reuse areas abandoned.

I4 SALT BALANCE AND STORAGE OF SALTS

Although regional salt balance is not a stated goal of the drainage program, it does have an important influence on future land productivity. Most of the salts imported in San Luis Canal water supplies are currently being stored in drainage-study-area soils, vadose zones, and aquifers. Eventually, the aquifers will become too saline for irrigation use and pumping for irrigation will cease. Following cessation of irrigation pumping, water levels will rise and drainage problems could be much worse. A cursory salt balance is presented in Table I-1.

Table I-1
Westlands Salt Balance
(Salt imports 800 pounds/AF [0.4 tons/AF] or 320,000 tons/year [800,000 AF/year])

Alternative	Salts Removed	Disposal Method
No Action	5,000	Salt harvesting
Delta Disposal	354,000 tons	Discharge in Delta
Ocean Disposal	354,000 tons	Discharge in ocean
In-Valley Disposal	354,000 tons	Salt burial, isolation
In-Valley/Water Quality Land Retirement	282,000 tons	Salt burial, isolation
In-Valley/Water Needs Land Retirement	153,000 tons	Salt burial, isolation
In-Valley/Drainage Area Land Retirement	0	None, all salts stored in aquifers or salt sinks

The data presented above are based on a post reuse area drainwater salt concentration of 20,000 parts per million or 27.2 tons/acre-feet (AF). All the Out-of-Valley Alternatives would provide a positive salt balance for the San Joaquin Valley. The In-Valley Disposal Alternative could also provide a positive salt balance if salts were marketed, sold, and transported out of the valley.

I5 USE OF RETIRED DRAINAGE-IMPAIRED LANDS

Several options for uses of retired lands have been discussed. Effects associated with different post-retirement land uses are presented below.

I5.1 Dryland Farming, Grazing, and Wildlife Habitat Lands

Retired lands could be used for habitat mitigation for effects on wildlife from evaporation basins. Reclamation is currently evaluating a 2,000-acre demonstration area in Westlands. Soil data from the baseline, 3-year, and 5-year soil sampling events indicate that soil salinity is decreasing at the site, especially in surface soil layers. The depth to shallow groundwater has receded by approximately 14 inches per year to well below the 7-foot target groundwater level (Lee 2003) to prevent bare ground evaporation from the water table, and upflux and deposition of salts on the soil surface. Electromagnetic salinity surveys indicate that areas of wildlife habitat are slightly lower in salinity than buffer zone lands that have received a small amount of supplemental irrigation water and are used for barley production.

Based on the data to date, it appears that the vast majority of retired lands that are used for grazing or wildlife habitat would not be physically damaged. To date, no occurrence of harmful levels of salinity, boron, or selenium have been observed or measured on surface soils at the land retirement demonstration area. Although these lands would not be damaged, they would not qualify as FSI since they would no longer be irrigated. Saturation extract data from the 3 and 5 year soil-sampling events are presented below:

Parameter	Average of all sites (0-1 foot)
ECe	4.2 dS/m
Boron	3.7 mg/L
Selenium	4.6 µg/L

I5.2 Dry Farmed Grain Land

Preliminary data from dry land barley fields grown in buffer strips at the land retirement demonstration site indicate that the shallow groundwater level has receded and soil salinity has decreased. Lands used for dryland grain would probably be summer-fallowed to accumulate enough moisture for a viable crop. Dryland grain fields (no summer fallow) planted in January 2004 (dry year) produced very little grain. Most fields did not appear to be worth harvesting. Strip-cropping may be desirable to reduce wind erosion potential and blowing dust. Summer fallowing would store moisture for the crop from the previous year, facilitate weed control, and discourage buildup of plant diseases and harmful insect infestations.

I5.3 Supplemental Irrigation for Limited Crop Production

Grainlands on Reclamation's Westlands land retirement demonstration site have occasionally received small amounts of irrigation water to supplement rainfall for barley production. Despite the water applications (which average about 4 inches per year), the water table has receded about 14 inches per year at the site. Soil salinity has also decreased on these lands; however, EM38 ground surveys indicate they are slightly more saline than lands used for nonirrigated wildlife habitat. Limited irrigation would permit growing a viable small grain crop on an annual basis. If grain were grown on an annual basis, occasional summer fallowing or rotation with other low water use winter crops would be desirable. Water applications should not exceed 6 inches per year. Possible rotation crops for small grains would be oat/vetch hay or possibly dry peas or lentils. The recent increased development of dairies near the APE may increase the demand for winter forage mixes and grains that are chopped for silage. For most years, 6 inches of well-timed irrigation would permit a marketable crop of winter forage on retired lands.

Under the No Action Alternative it is assumed that 10 percent of lands acquired by Westlands (65,000 acres) on average could be irrigated with groundwater or other non-Central Valley Project sources. Salt-tolerant, relatively low-water-use crops (such as cotton, sugar beets, and small grains) could be grown with groundwater. Use of groundwater for irrigation would also help relieve drainage problems in the APE.

I6 SALT AND DRAINWATER MANAGEMENT SCENARIOS

Some of the alternatives contain on-farm salt and groundwater management scenarios designed to reduce the volume of drainwater needing expensive treatment. Possible effects of these scenarios are presented below.

I6.1 Recycling of Drainwater Over Large Areas

Blending of drainwater with good quality surface water supplies is generally not recommended by salinity experts. The utility of the surface water for irrigation is greatly affected. Although annual leaching fractions should be adequate to ensure no permanent soil damage, the use of blended water for salt-sensitive vegetable crops and early crop irrigation of many sensitive and moderately sensitive crops could reduce yields.

I6.2 Shallow Groundwater Management

This option would permit growers to use water table control structures to raise the water table during periods when crops can safely use higher salinity water. Some crops such as cotton, sugar beets, small grains, and alfalfa seed can use large quantities of shallow groundwater with little effect on yield. The grower would then lower the water table and leach any accumulated salts prior to planting other most salt-sensitive crops.

I7 UPLAND SOIL SALT BALANCE

These areas are not affected by shallow groundwater, and no upflux of salts is anticipated. The net downward flow would provide a favorable regular soil salinity profile. The cropwater use distribution pattern is assumed to be 40, 30, 20, and 10 from the first 4 feet of soil depth. (The first foot of soil supplies 40 percent of the crop's water use and the second foot 30 percent, etc.) Natural drainage rates are estimated at about 0.3 foot per year. Growers have an incentive to maintain high irrigation efficiencies on these lands, since water supplies are often limited and costs to pump groundwater are high. A gypsum baseload is not assumed in the top 3 feet of soil (active root zone); however, residual gypsum is present in some soils near the foothills and in substrata materials below the active root zone. In any case, any gypsum present would be discounted when crop salt tolerance tables are used. Therefore, the most common condition (no residual gypsum in the active root zone) is assumed for well-drained middle and upper alluvial fans. Based on an average irrigation application of about 30 inches per year and a 3.6-inch-deep percolation below the root zone, a 12 percent leaching fraction is assumed. The irrigation water is comprised of 88 percent surface water from the San Luis Canal and 12 percent groundwater. A weighted average electrical conductivity (EC) is estimated at 0.9 dS/m for the water. Salt balance calculations assume the soil water salinity is 200 percent of the saturation extract value. Every effort should be made to irrigate these lands as efficiently as possible since a portion of the deep percolation from upslope lands would move laterally downslope and contribute to salt sink formation on lower lands. The soil salinity profile for the upland areas is shown in Table I-2.

Table I-2
Soil Salinity Profile for Upland Areas

Depth (inches)	Leaching Fraction (%)	Ecsw* (dS/m)	ECe (dS/m)	Depth Average (inches)	ECe
1	100	0.90	0.45	0-12	0.54
12	72	1.25	0.63	12-24	0.85
24	42	2.14	1.07	24-36	1.56
36	22	4.09	2.05	36-48	2.78
48	12	7.50	3.50	48-60	3.50
60	12	7.5	3.50	0-36	0.98

*Ecsw = electrical conductivity of soil water

Although the mass balance equations show the ECe values of less than 1.0 for the top 24 inches of soil, actual soil salinity measurements would probably be slightly higher due to annual fertilizer applications and the tendency for saturation extracts to dissolve a small amount of residual salts not present in the soil water. Based on the factors discussed, the average ECe of the active root zone at upland sites is estimated at about 1.2 dS/m in the 0- to 36-inch active root zone. This level of salinity is suitable for the growth of all climatically adapted crops including all salt-sensitive vegetables and orchard crops.

The average ECe associated with fan terrace lands is assumed to be about 3.2 dS/m due to the presence of residual gypsum at many of these sites. For crop salt-tolerance estimation purposes, the gypsum component of the soil ECe was subtracted from the actual EC present at field soil-water moisture levels.

The agricultural research service program *Watsuit* was also used to evaluate soil salinity on the well-drained upland areas. Even with leaching fractions as low as 5 percent, active root zone salinity values remained below an ECe value of 1.0 dS/m when 100 percent San Luis Canal water was assumed for irrigation supply. Examples of *Watsuit* output are found in Attachment I5.

I8 SOIL SALT BALANCE IN THE AREA OF POTENTIAL EFFECT

Current soil salinity was measured at many sites in the APE. Although these sites tend to be clustered in certain areas on and near the proposed reuse areas and land retirement areas, they do give an indication of the current soil salinity and salt distribution of lands in the APE. Soil salinity measurements were made with an EM38 ground conductivity meter. The meter readings were adjusted based on soil texture, temperature, and moisture content, and calibrated to laboratory-determined ECe values obtained at a limited number of sites. An ECe/Emh correlation graph is presented in Attachment I6. A graph comparing ECe values predicted by *Emetrsp* with laboratory-determined saturation extract ECe values at calibration sites is also presented. The Reclamation EM38 calibration program *Emetrsp* was used for ECe estimations presented later on in Table I-3 since insufficient calibration site data were available at low salinity ranges to make a San Luis Drainage Feature Re-evaluation-specific correlation. Over 10,000 individual EM38 measurements were made in the APE during the Reconnaissance and Feasibility land investigations. A summary of the APE soil salinity measurements collected in Reconnaissance surveys are listed below in Table I-3.

Table I-3
Area of Potential Effect Soil Salinity Summary

Site Location/Number	Number of Observations	Emh avg (ms/m)	Emv avg (ms/m)	Emh CV (%)	Est. ECe 0-36" (dS/m)	Field Use
Red Rock Reuse slu1	18	364.9	411.8	6.8	16.5	RU
Slu2	23	367.6	386.4	27.5	17.9	RU
Slu3	41	111.4	148.1	11.3	6.61	CA
Slu5	19	276.7	280.7	19.0	14.7	RU
Slu6	16	259.5	279	10.0	12.9	RU
Slu7	16	376.9	386.3	9.0	18.8	RU
Slu8	15	334.2	373.1	17.2	16.7	RU
Slu9	5	120	170	Nr	5.2	CA
Panoche Reuse T1	50	163.1	206.9	18.6	7.9	RU
T2	16	197.6	236.4	9.3	9.7	RU
T3	28	327.6	352.3	15.5	21.9	RU
T3a	8	216	211	9.1	11.5	RU
T4	43	205.7	234.4	22.7	11.0	RU
T5	31	166.4	222.6	13.2	6.3	RU
T6	26	182.5	238.9	15.6	7.9	RU
T7	30	235.6	276.6	15.4	12.3	RU
T8	23	276.1	306.0	12.6	17.4	RU
T9	44	190.7	226.6	24.5	10.5	RU
T10	29	227.9	263.6	13.3	9.6	RU
Rs-03-12	10	77.1	96.7	11.5	3.8	CA
Rs-03-11	9	113.9	140.2	5.1	7.6	CA
Rs-03-12a	15	84.9	117.6	7.6	4.6	CA
Rs-03-13	9	53.7	92.1	20.4	1.2	CA
Rs-03-17	12	110.8	139.8	13.1	4.5	CA
Rs-03-09	8	91.3	117.1	6.6	5.1	CA
Rs-03-15	10	112	168.2	9.7	4.2	CA
Rum1	10	92.4	126.2	19.9	4.1	CA
Rum2	8	102.3	155.4	5.2	9.1	CA
RT1	9	77.8	130.4	26.8	2.8	CA
Rt15	7	54.6	101.3	15.3	1.5	CA
Rt15b	8	67.4	119.9	12.1	2.8	CA
Ren1	8	86.3	117.9	29.0	7.1	CA
Ren2	5	78	83.8	4.4	5.0	CA
Ren5	8	150.4	209.4	7.6	8.4	CA
Ren6	8	115.5	138.3	5.3	6.0	CA
Ren7	10	55.2	77.7	6.4	2.0	CA
Ren8	8	142.4	204.1	10.1	6.3	CA
Ren9	8	97.4	106.4	11.7	6.4	CA
Pru1	60	266.6	348	14.7	14.4	RU
Pru2	36	506.3	565.3	20.2	26.1	RU

Table I-3
Area of Potential Effect Soil Salinity Summary

Site Location/Number	Number of Observations	Emh avg (ms/m)	Emv avg (ms/m)	Emh CV (%)	Est. ECe 0-36” (dS/m)	Field Use
Pru3	8	101.5	139	7.9	2.4	CA
Pru4	30	454.3	550.1	15.2	20.2	RU
Pru5	15	162.2	278.2	5.3	5.8	RU
Pru6	42	225.8	319.7	14.6	8.6	RU
Pru7	9	421.9	506	12.4	21.8	RU
Pru8	8	100.1	109.5	7.9	3.6	CA
Rs-03-01	8	107.6	173.6	6.2	3.8	CA
Rs-03-02	8	157.1	201.4	87.6	8.3	CA

CA = commercial agricultural use
RU = reuse facility

Soil Sampling Summary: Although the soil sampling sites were not selected in a strictly random manner, they do represent over 1,700 individual soil salinity measurements. Most of the data from reconnaissance studies were collected in a stratified random manner from a 100-foot-diameter area surrounding a central calibration site. A statistical summary of the data collected in Reconnaissance level investigations is presented below:

- Commercial cropland: CA
- Number of sites: 25
- Average ECe 0 to 3 feet: 4.90 dS/m
- 95 percent confidence interval: 4.03–5.75 dS/m

Existing reuse areas only (RU):

- Number of sites: 23
- Average ECe 0 to3 feet: 13.9 dS/m
- 95 percent confidence interval: 11.7–16.2 dS/m

Feasibility Study Salinity Data: The following statistical summary is for all soil salinity transect data collected for reuse area feasibility level studies. Transects were typically conducted from the head of the field to the tail of the field to get a complete picture of soil salinity conditions in the field. Data from current reuse areas are not included. The mean values are affected by some highly saline areas of retired land that are included. The median or geometric mean values are probably the best representations of current soil salinity conditions on APE lands. Each transect represents an average salinity of from 12 to 40 EM38 measurements.

- All lands including retired lands: ECe summary
- Number of transects: 172
- Average: 7.46 dS/m

- 95 percent confidence interval: 6.76–8.16 dS/m
- Median: 6.9 dS/m
- Geomean: 5.9 dS/m

A portable EC meter was used to measure shallow groundwater salinity at many substrata permeability testing sites. A summary of data collected to date (representing more northerly areas) is presented below:

- Number of observations: 85
- Average specific conductance: 13,050
- 95 percent confidence interval: 10,330–15,770
- Median: 8,300
- Geomean: 7,920

I9 ESTIMATES OF GROUNDWATER PUMPING DRAINAGE RELIEF (GPDR)

Many Environmental Impact Statement (EIS) narratives including this document describe the GPDR as natural drainage; however, it is important to understand that only a very small component of this drainage is truly natural drainage. Most of the drainage is induced by groundwater pumping.

Based on the groundwater resources analysis, feasibility study drainage investigations to date, and data from an intensively monitored land retirement site located on lower alluvial fans and basin rim landform areas, it appears that GPDR drainage rates range from less than 0.1 to about 0.3 foot per year in the San Luis Unit. Many relative barriers in the upper semiconfined aquifer affect natural drainage rates. Reclamation soil scientists noted only slightly moist to moist conditions below wet zones on well over 50 percent of the drill logs on recent drilling investigations on or near potential reuse areas. NRCS soil scientists and State of California drillers report similar findings, indicating that these zones were either not saturated or were possibly previously saturated, but the specific yield was so low that the soil seemed near or below field capacity. In either case a relative barrier to downward deep percolation is indicated. The first barrier to vertical flow and the head on the barrier would control the natural drainage rates in the Unit as long as sufficient pumping below the Corcoran clay continues to facilitate some natural drainage below the semiconfined aquifer. Attachment I7 contains NRCS maps of soil salinity, landform type, and drainage conditions in the Unit.

The depth to water table was measured at nearly all drill sites. A summary of data collected to date (mostly in the northern APE) is presented below:

- Number of observations: 44
- Average depth to groundwater: 8.57 feet
- 95 percent confidence interval: 7.05–10.09 feet

The depth to shallow groundwater was measured in the spring in April and May 2003 before the summer irrigation season. The drill holes commonly remained open during the 1- to 2-hour hydraulic conductivity testing period; however, some of the water table levels were measured after a 12-hour period (overnight). In some cases the water level in the drill holes rose following the overnight period. All borings were located at the edge of the fields just outside of the farmed area.

The average GPDR value for Westlands lands is estimated by HydroFocus at 0.25 foot per year, while the average value for the Northerly Area is estimated at 0.23 foot per year. One factor in this analysis is the flux across the Corcoran clay layer. This flux is partially dependent on the number of wells and associated gravel packs penetrating the Corcoran clay as well as the hydraulic head on the Corcoran layer. Many of the upslope lands without a drainage problem were traditionally in a Priority 2 or Priority 3 water availability status, which encourages the installation and pumping of wells and the use of groundwater for irrigation. The heavy demand for groundwater and the presence of many wells below the Corcoran clay in this area and the potential for lateral downslope relief would tend to permit natural drainage rates in the range of 0.3 to 0.4 foot per year, while lands such as the retired lands near the lower alluvial fans and basin rims would have a rate more in the range of 0.1 AF/year. Lands in the interfan areas and lower alluvial fans most likely to be artificially drained would probably have intermediate natural drainage rates in the 0.2 foot per year range. It should be noted, however, that some of these areas are most vulnerable to canal seepage and recharge from upslope lateral flow. Based on this analysis, GRDR is estimated to average about 0.2 foot per year on lands that would be drained, about 0.2 foot per year on lands that would be irrigated and not drained, and about 0.15 foot per year on reuse areas. All well-drained lands above the San Luis Canal should have a GRDR of about 0.3 foot per year or greater. HydroFocus provided vertical drainage rates for the northern APE. It should be noted that these estimates are for natural drainage below a depth of 50 feet. Many APE areas contain restrictive clay barriers that restrict natural drainage at depths shallower than 50 feet. A copy of the HydroFocus natural drainage rate map is provided as Attachment I8.

I10 SOIL SALINITY IN DRAINAGE-IMPAIRED AREAS

Soil salinity and crop adaptability modeling data developed by Steve Hatchett of Western Resource Economics for Section 12, Agricultural Production and Economics of this EIS were used to predict qualitative soil salinity and cropping pattern changes for the areas affected by shallow groundwater (APE). This model is referred to as the APSIDE model in this EIS. The APSIDE model uses inputs from the HydroFocus regional groundwater model as well as soil and economics relationships developed for the San Luis Unit.

Although this model was not comprehensively reviewed, inputs to the model, and the general assumptions and soil relationships used, were evaluated. It was determined that the model output could be reliably used to estimate soil salinity trends, however, the following changes to APSIDE model inputs were recommended:

- The average growing season depth to groundwater for the drained condition should be 5 feet below grade, while the average growing season depth for the irrigated undrained condition should be about 4 feet below grade. Source control from irrigated lands tends to favor shallow drainage systems or force growers to regulate deeper drainage systems. Crops would consume some of the shallow groundwater as evapotranspiration (ET). The original calculations assumed a shallow groundwater depth of 6 feet below grade during the growing season. Based on a clay to clay loam substrata texture, upflux for the drained condition would be about 20 percent of ET, while upflux from the irrigated undrained condition would be about 25 percent of ET (ASCE 1990, Figure 12-8, page 251).

- The natural drainage value for lower alluvial fans should be about 0.15 to 0.2 foot per year rather than the 0.25 foot originally assumed.
- The model uses a gypsum baseload concept, which is considered valid in the saline soils. The ECe data presented as model output are based on the relationship of ECsw = 2ECe. Since the model works from a soil-water basis, no gypsum adjustment is needed for crop salt-tolerance estimates. It should be noted that measured ECe values from soil samples collected in irrigated fields may be 1 to 3 dS/m higher than values predicted by the model due to increased gypsum dissolution in the saturation extract, which is considerably more dilute than soil-water concentrations.
- A uniform salinity profile is assumed for drainage-impaired lands. This assumption is judged valid for drained lands due to the continuous upflux of water and salt from the water table balanced by downward flow following irrigation events. Some of the undrained irrigated lands may even exhibit inverted soil salinity profiles where the surface salts are higher than subsoil salts. When this condition occurs, then the grower could elect to either install drains or temporarily idle the lands until the water table subsides and rainfall can leach the seedbed, or grow only very salt-tolerant, low-water-use crops such as barley that would tolerate saline conditions at equilibrium with the very low natural drainage rates (0.1 to 0.20 foot per year). Very careful irrigation management, scheduling, and water application efficiencies will be needed on undrained, irrigated lands in the APE.

Soil Scientist Dr. David Miller of Grant Davids Engineering reviewed the model in more detail. His recommendations are as follows:

- Specific yield values for the model input should be reduced from 13 to 10 percent, and more documentation on specific yield estimation procedures and assumptions should be available for review.

This recommendation was followed, and Reclamation technical staff have prepared further documentation of specific yield findings to date. Specific yield data are from four drill logs and extensive hydraulic conductivity testing. Generally, bulk densities of the active root zone are in the 1.2 to 1.4 specific gravity range. Below this depth the density increases to a specific gravity of about 1.5 to 1.8. Total porosities in the substrata are in the 30 to 40 percent range. Estimated specific yields on soil samples from 4 drill cores are based on the difference of drained-out field moisture levels and total porosity indicate a range of specific yields from 6 to 17 percent, with an average value of 56 samples of 11.1 percent. U.S. Geological Survey data on deeper borings indicates total porosity values averaging about 40 percent at depths from 50 to 500 feet. Specific yield data (mostly from the 4- to 12-foot-deep zone) based on correlations with extensive hydraulic conductivity testing are presented below:

U.S. Department of Agriculture Texture	Average Hydraulic Conductivity (inches/hour)	Specific Yield (percent)
Clay	0.58	8
Silty clay	1.2	11
Silty clay loam	1.6	13
Loam, silt loam, fsl, scl	4.0	17
Loamy sands	5.0	18

The average specific yields in the 4- to 12-foot-deep zones are about 14 percent. The average specific yield in the 0- to 5-foot-deep zone is estimated at about 10.7 percent, although it is noted that ET processes typically deplete soil moisture and greatly increase the effective soil storage.

The HydroFocus groundwater model inputs into the APSIDE model assume an upflux of 1 AF/year to bare soil evaporation processes when the depth to shallow groundwater is 4 feet or less. The salt sink analysis in the land and soil resources analysis assumes higher upflux quantities and, therefore, increased bare soil evaporation potential when predicted water tables are shallower than 4 feet.

I11 RECLAMATION STANDARDS AND CRITERIA FOR LAND EVALUATION

Reclamation classified the San Luis Unit prior to delivery of Central Valley Project water supplies. The specifications presented below in Table I-4 were used to classify the lands. Only the standards most applicable to this EIS are presented. Salinity standards have been converted from "percent salt" to ECe to be consistent with other soil salinity data presented in this report. The Irrigation Suitability land classification acreages presented in this EIS are based on these standards. Other factors, such as soil texture and slope, are also considered in Reclamation's land classification system.

Table I-4
Reclamation Irrigation Suitability Standards, San Luis Unit 1978

Land Characteristic	Class 1	Class 2	Class 3	Class 4
Irrigation Suitability Rating	Excellent	Good	Fair	Marginal
Soil Salinity (ECe)				
Surface	Less than 4	Less than 8	Less than 12	Less than 15
Subsoil	Less than 4	Less than 8	Less than 12	Less than 25
Alkalinity, Soil Reaction pHp				
Surface	Less than 8.3	Less than 8.7	Less than 9.0	Less than 9.0
Subsoil	Less than 8.5	Less than 9.0	Less than 9.4	Less than 9.4
Slope	> 4 percent	> 8 percent	< 12 percent	Up to 25 percent
Drainage Requirements	None	Slight	Moderate	High

PHp = pH paste

I12 LAND USE

The survey area has been intensively irrigated for many years and agriculture has been the dominant land use. Two aspects of land use are evaluated in this section. The first analysis addresses land use in the general sense. Broad categories of general land use include Irrigated cropland; Dryland cropland; Urban lands, such as commercial, residential, and industrial; Developed lands of Lemoore Naval Air Station including the operational area were placed in this category; Wildlife habitat, including long-term fallow, recreational, and endangered species habitat management areas; and Municipal uses such as highways, transportation corridors, detention basins, and evaporation basins. Water conveyance, storage, treatment, reuse, and disposal facilities were also broadly categorized as municipal use. The irrigated area includes many small right-of-way ditches and drains; therefore, the actual irrigated acreage is somewhat smaller than the amounts presented in Table I-5.

County maps, recent aerial photos, and Westlands maps were used for this analysis. Several pending actions that could affect land use, such as the sale of the Broadview Water District lands and various land retirement scenarios, were also considered in this analysis. The level of land retirement was assumed to be about 109,000 acres for the No Action Alternative and about 2,100 acres for existing conditions (2001). Some land uses could fall into two categories: for example, the current Arroyo Pasajero sediment basins could be used for wildlife habitat, while its primary use would be considered as a flood control and sediment detention facility (municipal use).

Features such as proposed reuse sites were only considered for the action alternatives. Table I-5 presents a summary of the broad land use categories by alternative.

Table I-5
Land Use Summary

Alternative	Retired Land (K ac.)	Irrigated Cropland (K ac.)	Dryland Cropland (K ac.)	Dryland Pasture (K. ac.)	Wildlife Habitat (K ac.)	Municipal (K ac.)	Urban (K ac.)
Existing	3	710	1	1	1	0	0
No Action	109	625	25	25	25	18	12
Out-of-Valley	44	672	7	7	7	25	12
In-Valley	44	667	7	7	7	30	12
Groundwater Quality Land Retirement	94	619	18	18	18	45	12
Water Needs Land Retirement	194	518	46	55	46	53	12
Drainage-Impaired Area Land Retirement	308	406	86	97	86	45	12

K ac. = 1,000 acres

The second category of land use includes review of qualitative trends in cropping patterns. Much of this analysis is based on output from the agricultural production model (APSIDE), land suitability factors, and anticipated future water supplies. Existing cropping pattern trends were modified based on the above factors. Although economic factors were not directly input into the analysis, it is assumed that they are reflected in Westlands cropping pattern trends. Table I-6 presents current cropping patterns and trends for the San Luis Unit (Westlands 2001). Changes in cropping patterns by alternative are presented in the agricultural production and economics analysis in Section 12 of the EIS.

Table I-6
Crop Summary Data, Westlands Water District

Crop	1978 acres	1990 acres	2001 acres	General Trend
Alfalfa hay	13,771	10,716	9,701	Decrease
Cotton	272,061	235,290	188,569	Decrease
Orchards, vineyards	13,012	25,139	59,495	Increase
Small grain	129,130	34,994	50,631	Decrease-stable
Tomatoes	30,224	95,159	85,122	Increase- stable
Other vegetables	37,839	73,706	88,088	Increase
Sugar beets	6,746	7,393	5,007	Variable-stable
Other Field crops	16,584	14,206	7,484	Decrease
Alfalfa seed	17,337	10,716	2,214	Decrease
Fallow, idle	36,335	52,544	73,802	increase
Double crop	9,021	7,069	12,873	Variable

Several local zoning ordinances, laws, Westlands policies, and restrictions imposed by the authorizing legislation for the Unit also affect the land use analysis, some of which are briefly described below:

- **Williamson Act.** This California tax law gave agricultural producers a tax break if they agree to keep their lands in agriculture for a specified period of time. This law can affect landowner's land use decisions, since a penalty for conversion of agricultural lands to other uses may apply.
- **County Zoning Ordinances.** These ordinances can restrict the types of land use and development in unincorporated portions of the survey area. The vast majority of the survey area is currently zoned for agriculture. Land retirement as well as other proposed land uses for retired lands are inconsistent with current zoning.
- **County General Plans.** County land use plans designate broad uses that are subsequently implemented through zoning. County plans for Fresno, Merced, and Kings counties call for the San Luis Unit lands to be used for agriculture. Provisions for limited expansion of urban areas in and around small farming communities, limited farm labor housing on farms, and light industrial uses supporting agriculture (e.g., cotton gins, food sorting, and packing) are included in the plans. The Natural Vegetation/Wildlife Element in county general plans encourages preservation of existing wildlife areas in their natural state and calls for the management of vegetation and wildlife resources in a responsible and productive manner.
- **Authorizing Legislation for the San Luis Unit.** This legislation contained land ownership restrictions such as acreage limitation provisions and restrictions on crop types grown on newly irrigated lands. An understanding of these provisions is needed to evaluate land use trends in the Unit. Repayment specialists (Phillips 2003) from Reclamation's Fresno office

were consulted to determine the affect the action alternatives may have on contract or authorizing legislation factors related to land use.

- **Westlands Water Priority System.** This system generally resulted in more water being applied to downslope drainage-impaired lands (Priority 1). The more productive lands on the upper fans were mostly in Priority 2 areas that had limited surface-water supplies, especially in dry years. Landowners could not purchase Priority 1 downslope lands to move water to their more productive upslope lands. Portions of this policy have been repealed by Westlands, with the net result of water moving upslope into the well-drained Priority 2 areas. This move has reduced water supply uncertainty in the upslope areas, which in turn has encouraged more long-term land use decisions such as planting orchards and vineyards on land that was formerly used intermittently for field crops.
- **Farmland Protection Policy Act.** This act requires that all National Environmental Policy Act evaluations consider and document the effect of action alternatives on prime and unique farmlands. Much of the land and soil analyses presented in this EIS are in response to this requirement. Local NRCS personnel (Arroues, pers comm., 2003) were consulted on several occasions to assist with the scope and effect analysis presented in this EIS. A listing of important farmlands in western Fresno, Kings, and western Merced counties is presented in Attachment I2. A soil map showing the location and extent of these lands is also provided in Attachment I6. Estimates of acres were based on a visual estimation from this map.
- **Wildlife Habitat Conservation Plans or Natural Community Conservation Plans.** These plans are prepared to offset or mitigate for certain types of development or continuing effects on wildlife habitat. For example, Reclamation set aside several small wildlife conservation areas bordering the San Luis Canal. These areas were planted with quailbush or other plants that are considered beneficial to wildlife. It is possible that some action alternatives could preclude the use of some of these sites for wildlife habitat.

  The U.S. Fish and Wildlife Service and private parties agree to wildlife habitat conservation plans as a way to offset and mitigate the effects of certain ongoing actions on endangered species. A number of these plans cover areas in the Unit. Each plan was evaluated individually to determine if any significant effects would occur from any of the action alternatives.

  The California Department of Fish and Game and landowners enter into natural community conservation plans to preserve unique natural vegetative communities. None of these plans are currently in effect for the Unit.

I13 CONSTRUCTION-RELATED LAND AND SOIL EFFECTS

The various action alternatives include many features such as open canals, buried pipelines, evaporation basins, reuse areas, treatment plants, pumping stations, tunnels, and outfall facilities. Types of environmental effects on land resources associated with reuse areas and evaporation basins have already been discussed. Conveyance facilities and associated features also affect land and soil resources. Where possible, existing facilities would be rehabilitated and used for the action alternatives; however, some new conveyance facilities would be required for all of the action alternatives.

All conveyance routes were compared to NRCS (1986, 1990, 2003) soil survey maps to determine what types of soils were affected. Land uses were also estimated from these surveys, although in some cases the aerial photography was over 10 years old. To supplement the office evaluation, the main out-of-valley conveyance routes were spot-checked in the field to determine potential land and soil effects. Environmentally sensitive areas such as wetlands and coastal areas were given a priority for on-site inspection. Some of the findings of the spot checks are presented below:

- Many new permanent crops such as vineyards and orchards have been developed in areas that appear to be on the Ocean Disposal Alternative conveyance route. Pipelines installed in these areas would probably destroy a sizeable acreage of orchards and vineyards. These vineyards could be replanted or the landowners would need to be compensated for their loss. Pipeline construction could also destroy some native oak trees in range and forest areas.
- The Ocean Disposal Alternative pipeline skirts a few miles of habitat for the endangered snowy plover. The pipeline may have to be located in upslope areas away from the coastline.
- The Delta-Chipps Island and Delta-Carquinez Strait Disposal Alternatives outfall routes are located on railroad right-of-ways in some sensitive areas, but in other areas they appear to be on tidal wetlands. Some of these wetlands already support large active and inactive military and industrial complexes. Therefore, the pipeline route appears to be somewhat consistent with current and past activities in the area. The pipeline trench in some areas may have to be drained due to shallow groundwater at excavation depth. A small portion of adjacent wetland area may also be drained temporarily during construction activities.

At this stage of the study, conveyance effects were handled somewhat generically, since the construction-related effects listed in Table I-7 are common to most conveyance features and are typically mitigatable.

Table I-7
Construction Effects and Mitigation Methods

Effects	Mitigation Methods
Canals	
Severance of land uses or ownerships	Provide bridges and crossings.
Canal seepage	Provide toe drains if needed. Use membrane linings under concrete.
Canal is source of noxious weeds	Control weeds on canal banks.
Canal is attractive nuisance for children	Fence and post canal. Control access.
Canal bank erosion	Plant grasses on canal bank. Use erosion control methods before grass is established.
Pipelines	
Destruction of current permanent crops	Replant orchards, compensate landowner.
Backfill less productive than original soil	Stockpile topsoil and replace in proper position.
Grassland or crop destroyed	Reseed range land. Compensate landowner for destroyed crops.
Temporary exclusion of grazing animals	Compensate landowner.
Construction activities create excessive dust	Uses water trucks to wet down areas for dust abatement.
Temporary drainage of wetlands during construction	Rewet area as soon as possible following construction.

I14 REFERENCES

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Attachment I1

Prime Farmland Listing by County

Table I1-I
Prime Farmland Soils
Fresno County, California

Map Unit	Map Unit Name
115	Bolfar Loam, Drained, 0 to 1 Percent Slopes
311	Bisgani Sandy Loam, Drained, 0 to 1 Percent Slopes
320	Elnido Sandy Loam, Drained, 0 to 1 Percent Slopes
325	Palazzo Sandy Loam, Drained, 0 to 1 Percent Slopes
406	Guijarral Sandy Loam, Drained, 2 to 5 Percent Slopes
412	Yribarren Clay Loam, 0 to 2 Percent Slopes
414	Dospalos Clay Loam, Drained, 0 to 1 Percent Slopes
415	Dospalos Clay, Drained, 0 to 1 Percent Slopes
425	Kimberlina Sandy Loam, 0 to 2 Percent Slopes
426	Kimberlina Sandy Loam, 2 to 5 Percent Slopes
436	Panoche Loam, 0 to 2 Percent Slopes
437	Panoche Sandy Loam, 0 to 2 Percent Slopes
438	Panoche Loam, 2 to 5 Percent Slopes
442	Panoche Clay Loam, 0 to 2 Percent Slopes
445	Excelsior Sandy Loam, 0 to 2 Percent Slopes
447	Excelsior Sandy Loam, Sandy Substratum, 0 to 2 Percent Slopes
448	Excelsior Sandy Loam, Sandy Substratum, 0 to 1 Percent Slopes, Eroded
451	Milham Sandy Loam, 0 to 2 Percent Slopes
452	Milham Sandy Loam, 2 to 5 Percent Slopes
454	Polvadero Sandy Loam, 0 to 2 Percent Slopes
455	Polvadero Sandy Loam, 2 to 5 Percent Slopes
459	Ciervo Clay, 0 to 2 Percent Slopes
466	Paver Clay Loam, 0 to 2 Percent Slopes
468	Deldota Clay, Partially Drained, 0 to 1 Percent Slopes
474	Westhaven Loam, 0 to 2 Percent Slopes
477	Westhaven Clay Loam, 0 to 2 Percent Slopes
479	Cerini Sandy Loam, 0 to 2 Percent Slopes
479	Cerini Clay Loam, 0 to 2 Percent Slopes
481	Cerini Caly Loam, 2 to 5 Percent Slopes
488	Wasco Sandy Loam, 0 to 2 Percent Slopes
469	Wasco Sandy Loam, 2 to 5 Percent Slopes
490	Cerini Sandy Loam, Subsided, 0 to 5 Percent Slopes
491	Cerini Clay Loam, Subsided, 0 to 5 Percent Slopes
492	Panoche Loam, Subsided, 0 to 5 Percent Slopes
493	Panoche Clay Loam, Subsided, 0 to 5 Percent Slopes
823	Ayar Clay, 5 to 6 Percent Slopes
849	Chaqua Loam, 2 to 8 Percent Slopes
851	Los Banos Clay Loam, 0 to 2 Percent Slopes
852	Los Banos Clay Loam, 2 to 8 Percent Slopes
853	Los Banos-Plieto Complex, 2 to 8 Percent Slopes
863	Vernalis Loam, 0 to 2 Percent Slopes
872	Vernalis Loam, 2 to 5 Percent Slopes

Table I1-2
Prime Farmland Soils
Kings County, California

Map Unit	Map Unit Name
102	Avenal Loam, 0 to 5 Percent Slopes
108	Corona Silt Loam
120	Grangeville Fine Sandy Loam, Partially Drained
131	Kimberlina Fine Sandy Loam, Sandy Substratum
144	Milham Sandy Loam, Silty Substratum
147	Nord Fine Sandy Loam
149	Nord Complex
150	Panoche Loam
165	Twisselman Silty Clay
174	Wasco Sandy Loam, 0 to 5 Percent Slopes
176	Westhaven Loam, 0 to 2 Percent Slopes
177	Westhaven Loam, 2 to 5 Percent Slopes

Table I1-3
Prime Farmland Soils
Merced County, California

Map Unit	Map Unit Name
106	Anela Gravelly Loam, 0 to 2 Percent Slopes
109	Apollo Clay Loam, 2 to 8 Percent Slopes (where slope is 4.6 % or less)
116	Arbuckle Variant Sandy Loam
123	Ayar Clay, 5 to 8 Percent Slopes (where slope is 6 % or less)
131	Ballvar Loam, 2 to 8 Percent Slopes (where slope is 6 % or less)
132	Ballvar-Pedcat, Eroded Association, 0 to 5 Percent Slopes (Ballvar Soil only)
137	Bisgani Loamy Sand, Partially Drained
139	Bolfar Clay Loam, Partially Drained
144	Capay Clay Loam
145	Capay Clay
149	Chaqual Loam, 2 to 8 Percent Slopes (where slope is 6 % or less)
154	Cole Variant Clay Loam, 2 to 5 Percent Slopes
161	Damluis Clay Loam, 0 to 2 Percent Slopes
163	Damluis Gravelly Clay Loam, 0 to 2 Percent Slopes
164	Damluis Gravelly Clay Loam, 2 to 8 Percent Slopes (where slope is 6 % or less)
167	Deldota Clay, Partially Drained
170	Dospalos Clay Loam, Partially Drained
171	Dospalos Clay, Partially Drained
174	Dospalos-Urban Land Complex, Partially Drained (Dospalos Soil only)
178	Elnido Sandy Loam, Partially Drained
180	Elnido Clay Loam, Partially Drained
181	Escano Clay Loam, Partially Drained
192	Henmel Clay Loam, Partially Drained
193	Herito Loam
206	Los Banos Clay Loam, 0 to 2 Percent Slopes
207	Los Banos Clay Loam, 2 to 8 Percent Slopes (where slope is 6 % or less)
209	Los Banos-Plieto Clay Loam, 2 to 8 Percent Slopes (where slope is 6 % or less)
210	Los Banos Variant Gravelly Sandy Clay Loam
228	Palazzo Sandy Loam, Partially Drained
229	Paver Clay Loam, 0 to 2 Percent Slopes
230	Paver Clay Loam, 2 to 5 Percent Slopes
246	San Emigdio Fine Sandy Loam
247	San Emigdio Loam
253	Stanislaus Clay Loam
254	Stanislaus Clay Loam, Wet
255	Stanislaus-Dosamigos-Urban Land Complex (Stanislaus and Dosamigos Soils only)
263	Vernalis Loam, 2 to 5 Percent Slopes
274	Woo Loam, 0 to 2 Percent Slopes
275	Woo Loam, Gravelly Substratum, 0 to 2 Percent Slopes
278	Woo Sandy Clay Loam, 0 to 2 Percent Slopes
277	Woo Clay Loam, 0 to 2 Percent Slopes
278	Woo Clay Loam, 2 to 5 Percent Slopes
279	Woo Clay Loam, Wet, 0 to 2 Percent Slopes
280	Woo Clay, 0 to 2 Percent Slopes
281	Woo-Anela-Urban Land Complex, 0 to 2 Percent Slopes (Woo and Anela Soils only)
282	Woo-Urban Land Complex, 0 to 2 Percent Slopes (Woo Soil only)

Attachment I2

Farmland Soils of Statewide Importance by County

Table I2-1
Farmland Soils of Statewide Importance
Fresno County, California; Western Part

Map Unit	Map Unit Name
101	Armona Loam, Partially Drained, 0 to 1 Percent Slopes
120	Altaslough Clay Loam, 0 to 1 Percent Slopes
130	Gepford Clay, 0 to 1 Percent Slopes
282	Tachi Clay, 0 to 1 Percent Slopes
285	Tranquillity-Tranquillity Wet Complex, Saline-Sodic, 0 to 1 Percent Slopes
286	Tranquillity Clay, Saline-Sodic, Wet, 0 to 1 Percent Slopes
404	Milham-Guijarral Association, 5 to 15 Percent Slopes
405	Polvadero-Guijarral Complex, 5 to 15 Percent Slopes
434	Lethent Clay Loam, Wet, 0 to 1 Percent Slopes
435	Lethent Clay Loam, 0 to 1 Percent Slopes
453	Milham Sandy Loam, 5 to 9 Percent Slopes
461	Ciervo Clay, Saline-Sodic, Wet, 0 to 1 Percent Slopes
462	Ciervo, Wet-Ciervo Complex, Saline-Sodic, 0 to 1 Percent Slopes
470	Chateau Clay, Partially Drained, 0 to 1 Percent Slopes
472	Wekoda Clay, Partially Drained, 0 to 1 Percent Slopes
475	Posochanet Clay Loam, Saline-Sodic, Wet, 0 to 1 Percent Slopes
476	Posochanet Clay Loam, Saline-Sodic, 0 to 2 Percent Slopes
480	Calflax Clay Loam, Saline-Sodic, 0 to 2 Percent Slopes
482	Calflax Clay Loam, Saline-Sodic, Wet, 0 to 2 Percent Slopes

Table I2-2
Farmland Soils of Statewide Importance
Kings County, California

Map Unit	Map Unit Name
101	Armona Loam, Partially Drained
103*	Boggs Sandy Loam, Partially Drained
104	Cajon Sandy Loam
112	Excelsior Sandy Loam
113*	Garces Loam
115*	Gepford Clay, Partially Drained
116*	Gepford Clay, Sandy Substratum, Partially Drained
117*	Goldberg Loam, Drained
118	Goldberg Loam, Partially Drained
119	Grangeville Sandy Loam, Saline-Alkali
121	Grangeville Fine Sandy Loam, Saline-Alkali, Partially Drained
125	Houser Fine Sandy Loam, Drained
126	Houser Clay, Partially Drained
130	Kimberlina Fine Sandy Loam, Saline-Alkali
134	Lakeside Loam, Partially Drained
135	Lakeside Clay Loam, Drained
136	Lakeside Clay, Partially Drained
137	Lemoore Sandy Loam, Partially Drained
138	Lethent Fine Sandy Loam
139	Lethent Clay Loam
140	Melga Silt Loam
148	Nord Fine Sandy Loam, Saline-Alkali
151	Panoche Clay Loam, Saline-Alkali
153	Pitco Clay, Partially Drained
155	Rambla Loamy Sand, Drained
158	Remnoy Very Fine Sandy Loam (if ripped)
162	Sandridge Loamy Fine Sand
136	Tulare Clay, Partially Drained
164*	Tulare Variant Clay, Partially Drained
166*	Twisselman Silty Clay, Saline-Alkalli
168	Vanguard Sandy Loam, Partially Drained
175	estcamp Loam, Partially Drained
178	Westhaven Clay Loam, Saline-Alkali, 0 to 2 Percent Slopes
180	Yout Fine Sandy Loam (if ripped)

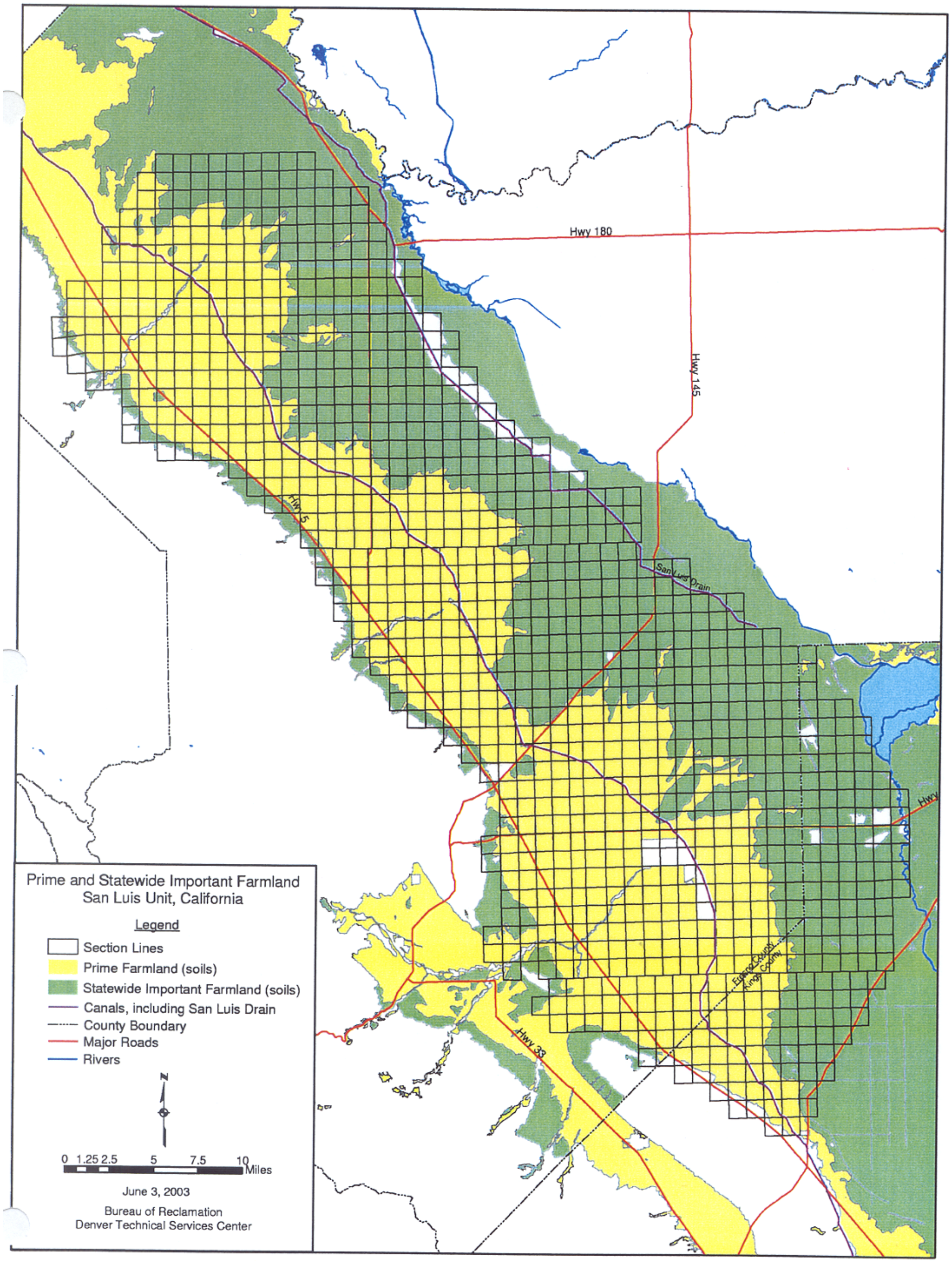
* This unit is of statewide importance if the saturation extrace is less than 16 mmhos/cm, the pH is less than 9.0, and the ESP is less than 25.

Table I2-3
Farmland Soils of Statewide Importance
Merced County, California

Map Unit	Map Unit Name
113	Alros Clay Loam, Partially Drained
117	Arburua Loam, 2 to 8 Percent Slopes
140	Bolfar Clay Loam, Hummocky
146	Carranza Gravelly Loam, 0 to 2 Percent Slopes
147	Carranza Gravelly Clay Loam, 2 to 8 Percent Slopes
150	Chateau Clay, Partially Drained
153	Chinvar Loam
162	Damluis Clay Loam, 2 to 8 Percent Slopes
166	Damluis Variant Clay Loam
168	Dosamigos Clay Loam, Partially Drained
169	Dosamigos Clay, Partially Drained
172	Dospalos Clay, Hummocky
173	Dospalos-Bolfar Complex, Occasionally Flooded
175	Edminster Loam
176	Edminster-Kesterson Complex
177	Edminster Variant Sand
198	Kesterson Sandy Loam
200	Kesterson Loam, Ponded
201	Kesterson-Edminster Complex
212	Marcuse Clay, Leveled
239	Plieto Gravelly Clay Loam, 8 to 15 Percent Slopes
258	Trulae Silty Clay, Partially Drained
266	Volta Clay Loam, Partially Drained
267	Wekoda Clay Loam, Partially Drained
285	Yokut Sandy Loam
286	Yokut Loam

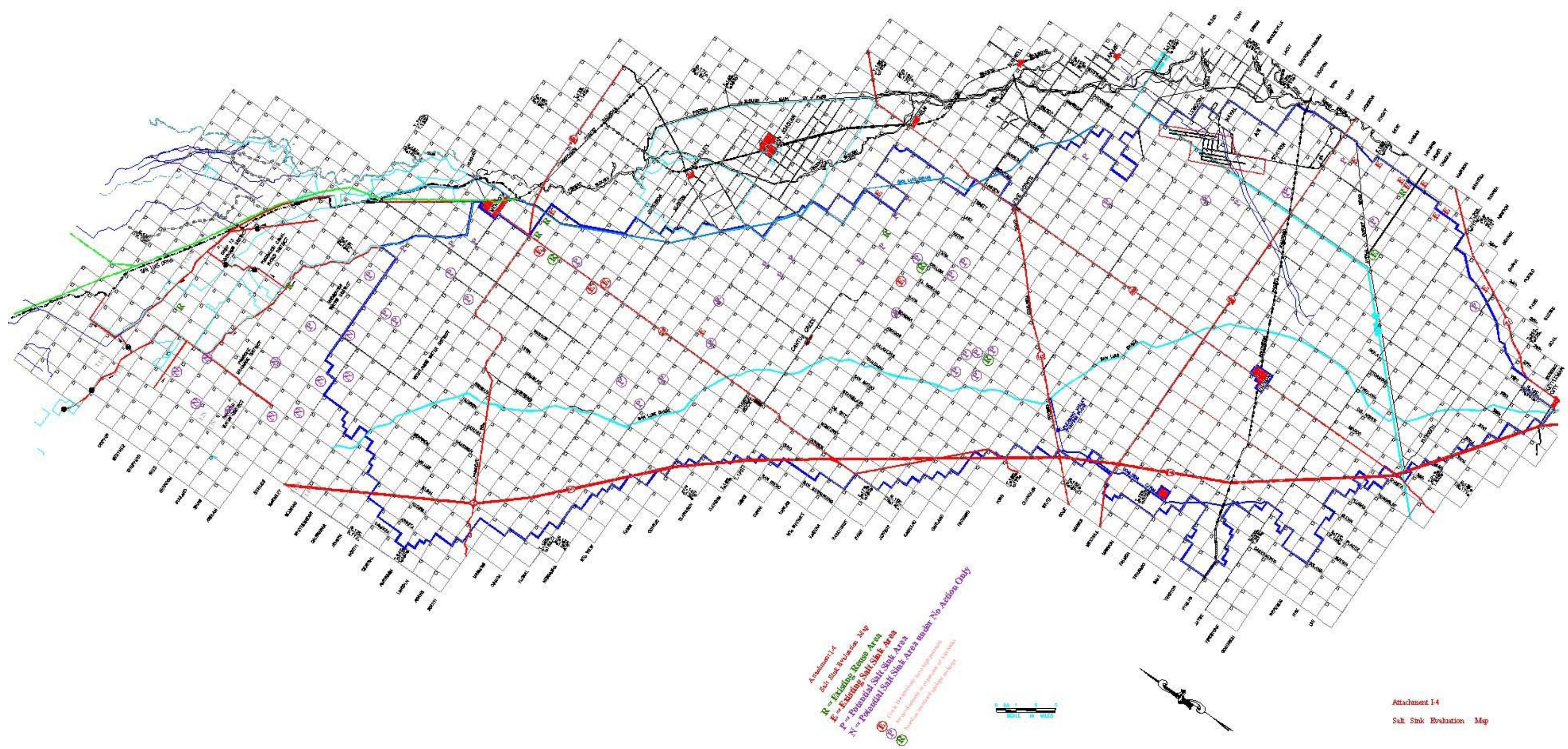
Attachment I3

Map of Prime and Statewide Important Farmland in the San Luis Unit


Prime and Statewide Important Farmland
San Luis Unit, California
Legend
Section Lines
Prime Farmland (soils)
Statewide Important Farmland (soils)
Canals, including San Luis Drain
County Boundary
Major Roads
Rivers
0 1.25 2.5 5 7.5 10 Miles
June 3, 2003
Bureau of Reclamation
Denver Technical Services Center
Hwy 180
Hwy 145
Hwy 5
San Luis Drain
Hwy 33
Hwy

Attachment I4

Salt Sink Evaluation Map



Attachment I4

Attachment I5

Watsuit Model Output

The EC and ion concentrations given on these tables are on a soil-water basis. To estimate equivalent saturation extract levels, divide the tabular concentration values by two.

Note: All concentrations are in meq/L

Case ID: Westlands Alluvial Upland areas
Amendments: None
Leaching fraction treatment: 0.05

Depth	LF	"1/LF"	Ca	Mg	Na+K	Cl	CO_3	HCO_3	SO_4
0	1.00	1.00	1.86	1.25	3.04	2.84	0.45	1.92	0.94
1	0.62	1.61	3.49	2.02	4.90	4.58	0.43	3.88	1.52
2	0.33	3.03	5.04	3.79	9.21	8.61	0.44	6.15	2.85
3	0.14	7.14	5.45	8.93	21.71	20.29	0.47	8.62	6.71
4	0.05	20.00	4.60	25.00	60.80	56.80	0.64	14.16	18.80

Depth	pH	Ca/Mg	Sum Cat.	EC	SAR	Lime	Gypsum
0	8.22	1.490	6.15	0.64	2.37	-0.76	0.00
1	7.65	1.732	10.41	1.02	2.88	-1.72	0.00
2	7.36	1.331	18.04	1.71	4.27	-1.71	0.00
3	7.29	0.610	36.09	3.43	7.89	2.41	0.00
4	7.34	0.184	90.40	8.47	15.39	17.40	0.00

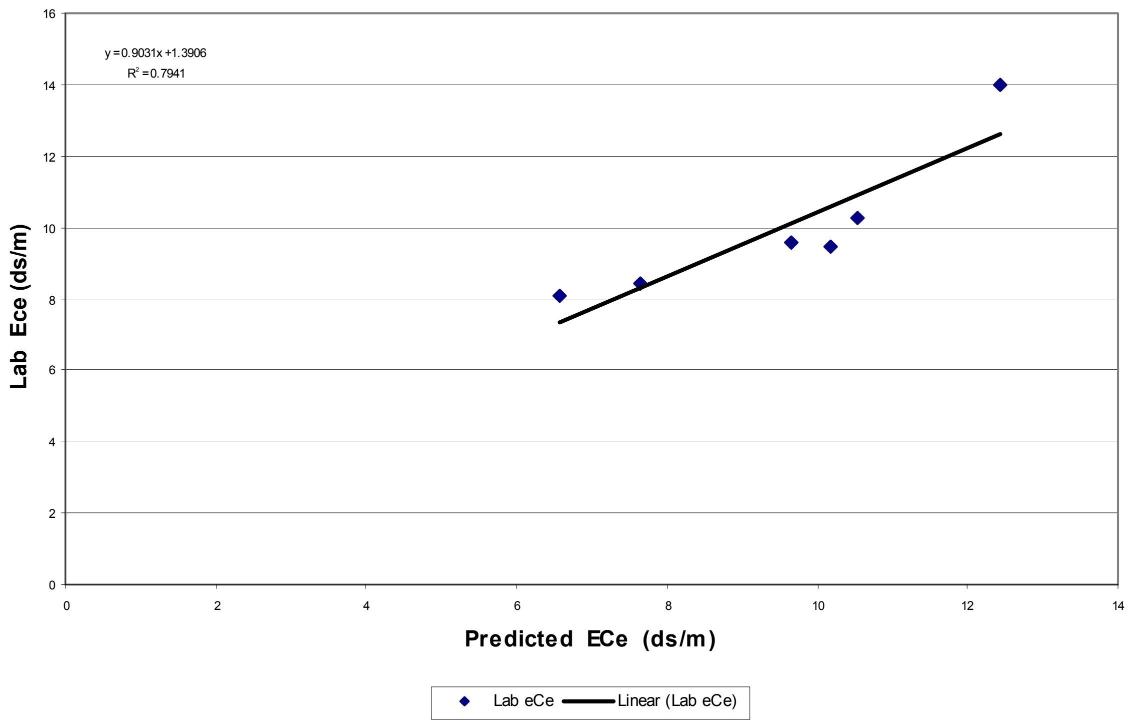
Case ID: Westlands Alluvial Upland areas
Amendments: None
Leaching fraction treatment: 0.10

Depth	LF	"1/LF"	Ca	Mg	Na+K	Cl	CO_3	HCO_3	SO_4
0	1.00	1.00	1.86	1.25	3.04	2.84	0.45	1.92	0.94
1	0.64	1.56	3.50	1.95	4.75	4.44	0.43	3.86	1.47
2	0.37	2.70	5.08	3.38	8.22	7.68	0.43	6.03	2.54
3	0.19	5.26	5.69	6.58	16.00	14.95	0.45	7.92	4.95
4	0.10	10.00	5.76	12.50	30.40	28.40	0.49	10.37	9.40

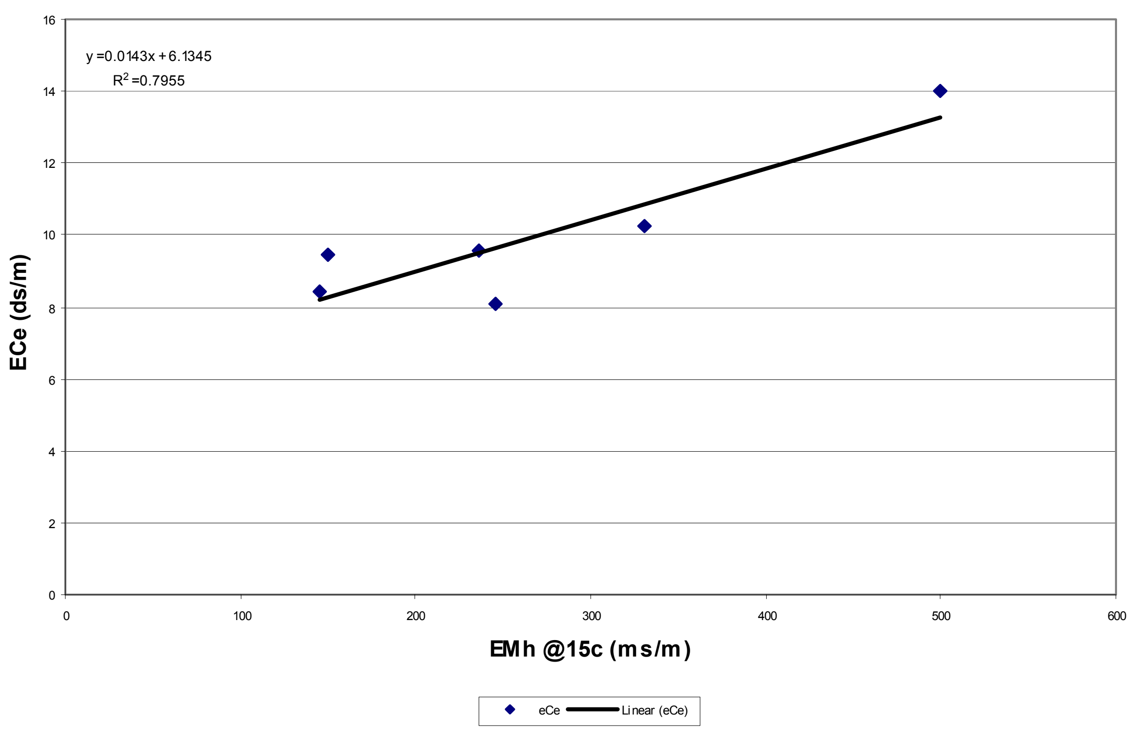
Depth	pH	Ca/Mg	Sum Cat.	EC	SAR	Lime	Gypsum
0	8.22	1.490	6.15	0.64	2.37	-0.76	0.00
1	7.65	1.791	10.20	1.00	2.80	-1.78	0.00
2	7.35	1.504	16.67	1.58	3.89	-2.11	0.00
3	7.26	0.865	28.27	2.68	6.29	0.10	0.00
4	7.24	0.461	48.66	4.64	9.80	5.24	0.00

Attachment I6
EM38 Meter Calibration Graphs

Soil salinity calibration curve, San Luis Reuse sites, EMTERSP program

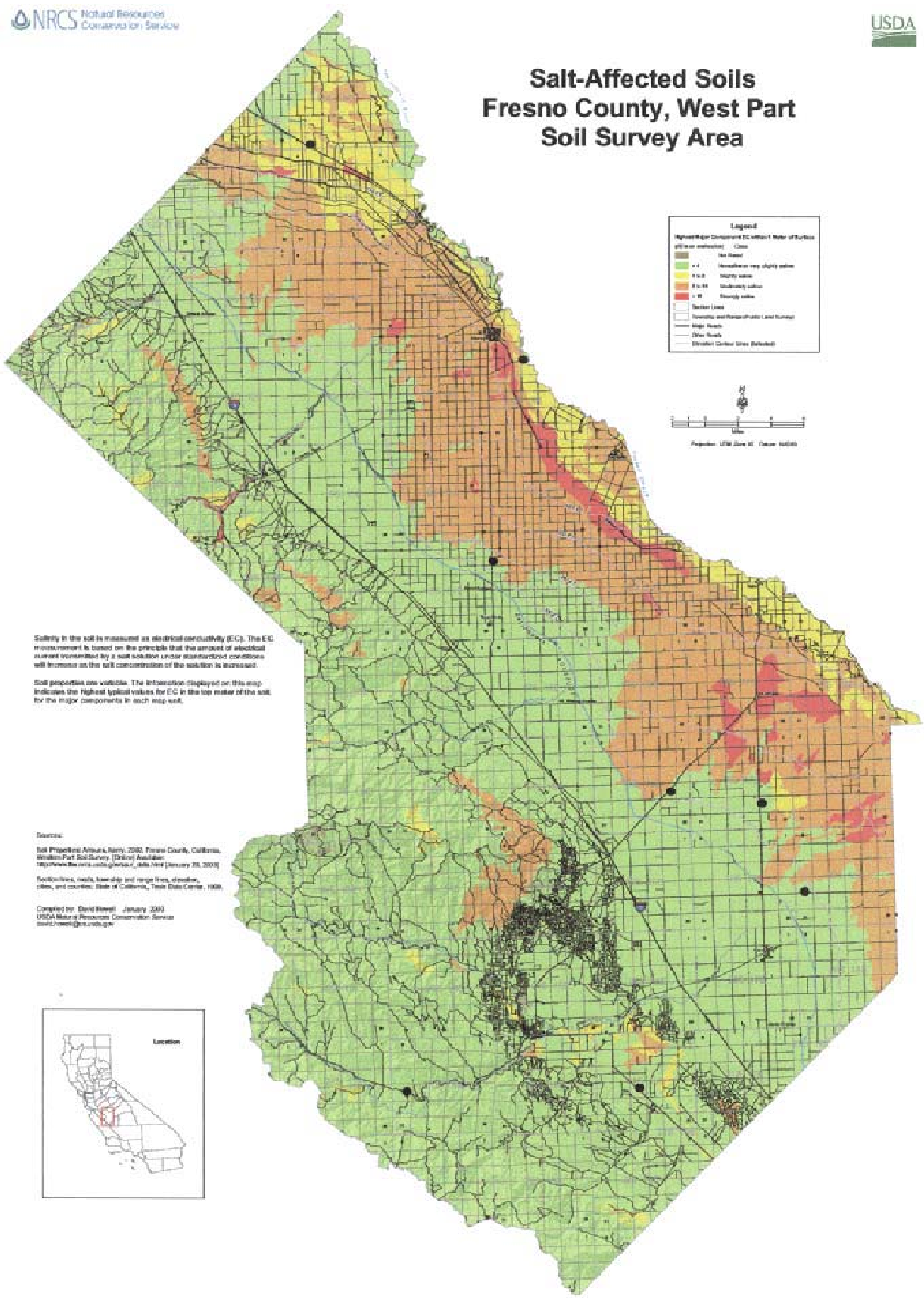


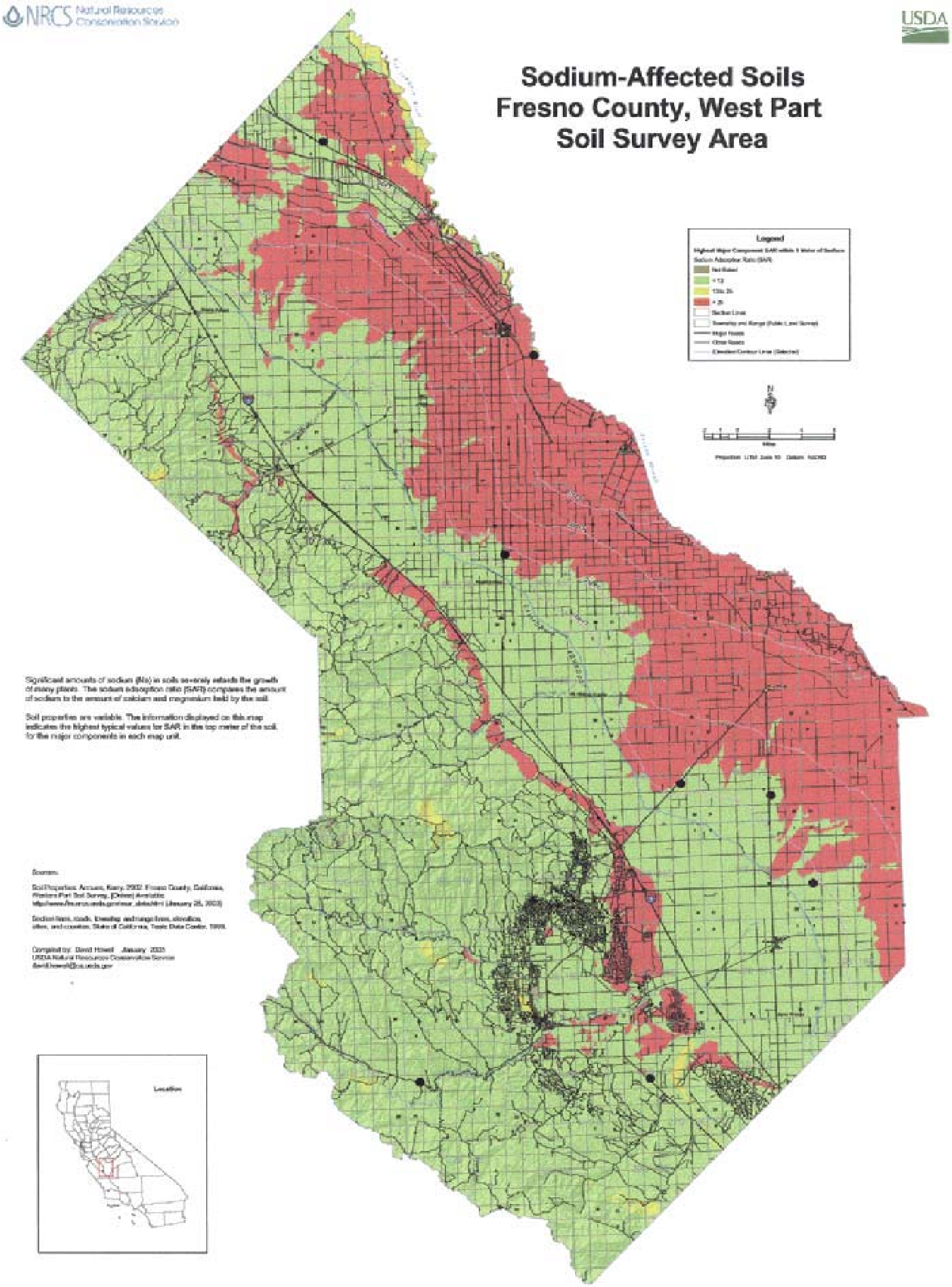
Soil Salinity Relationships, San Luis Reuse Areas

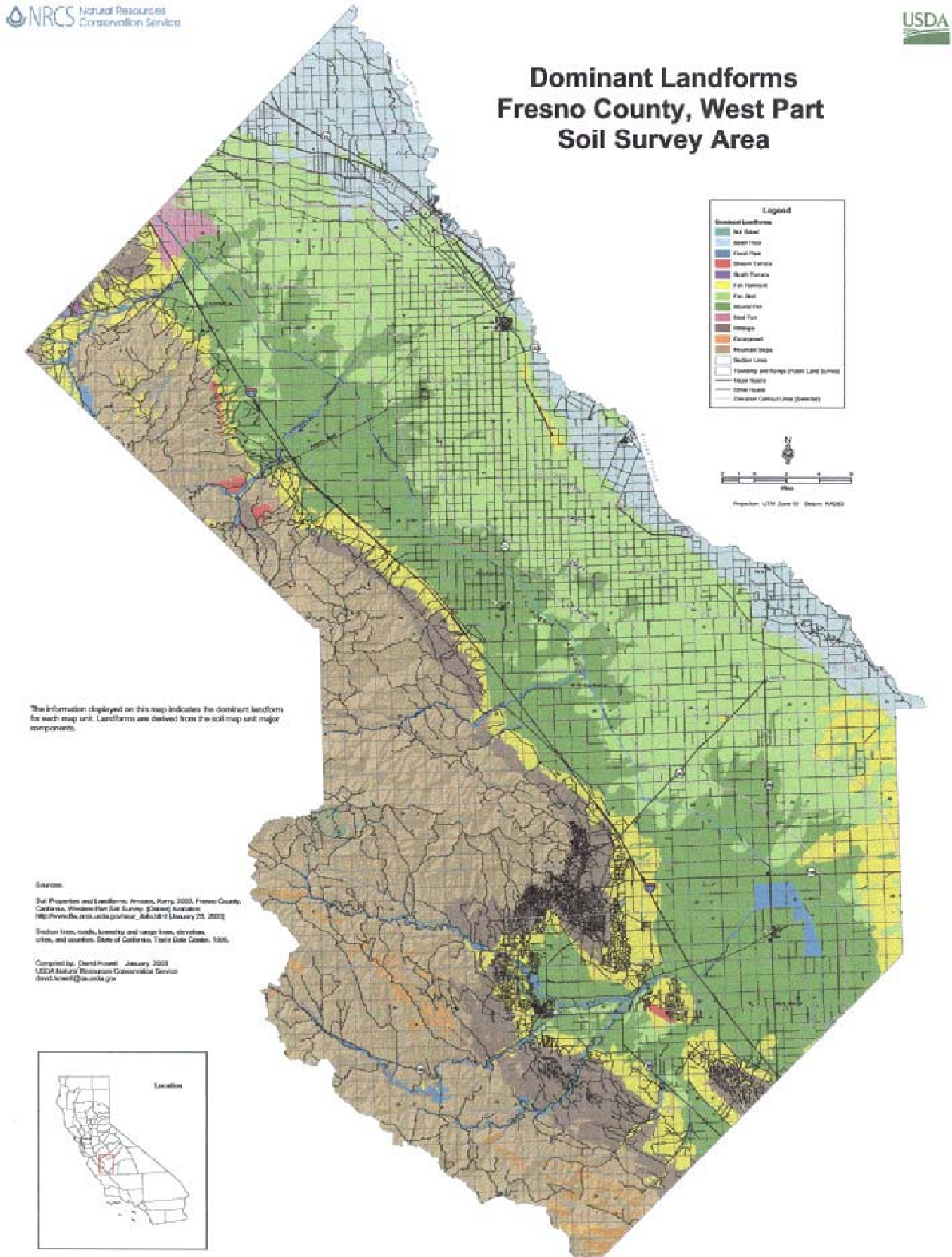


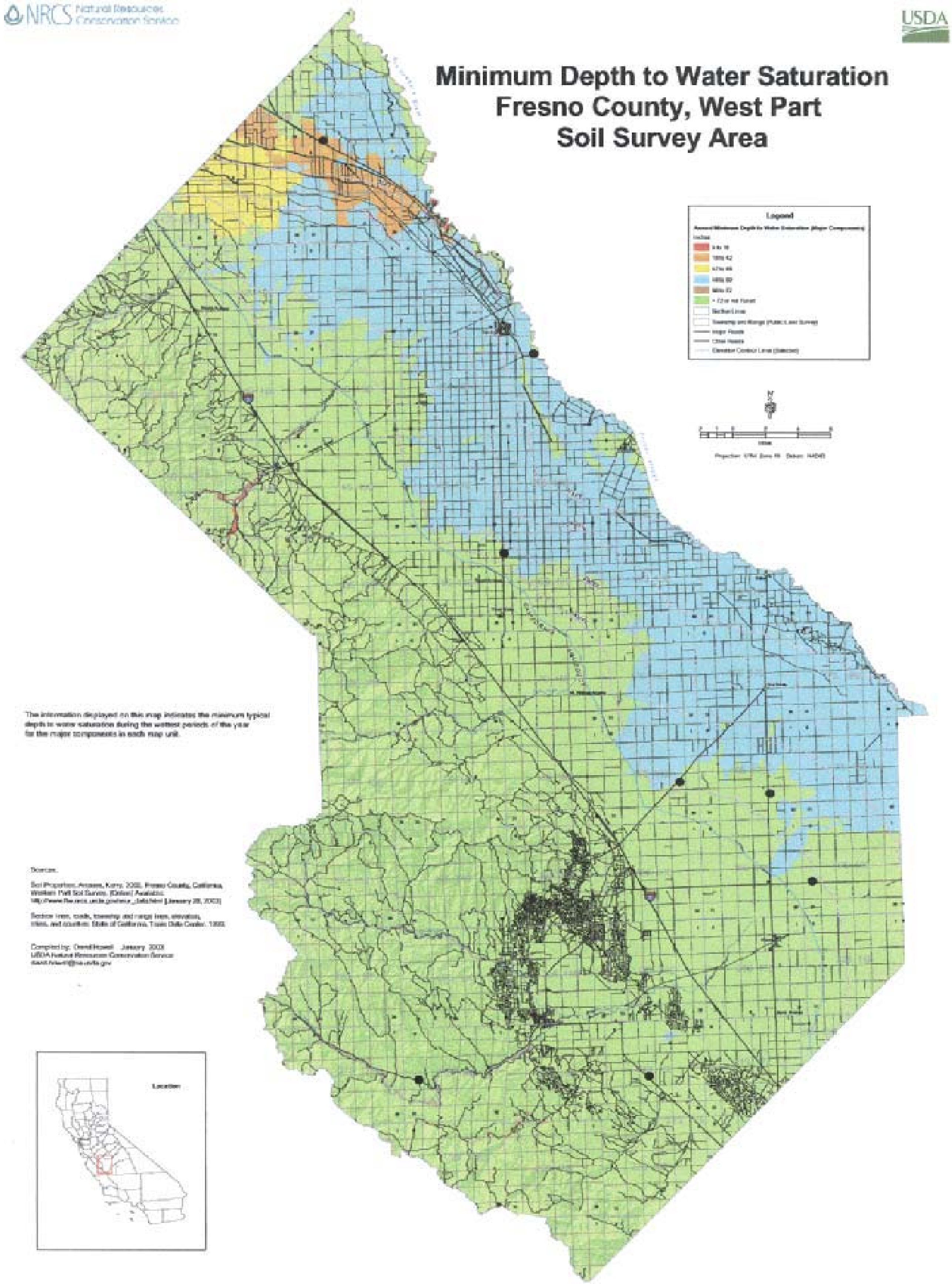
Attachment I7

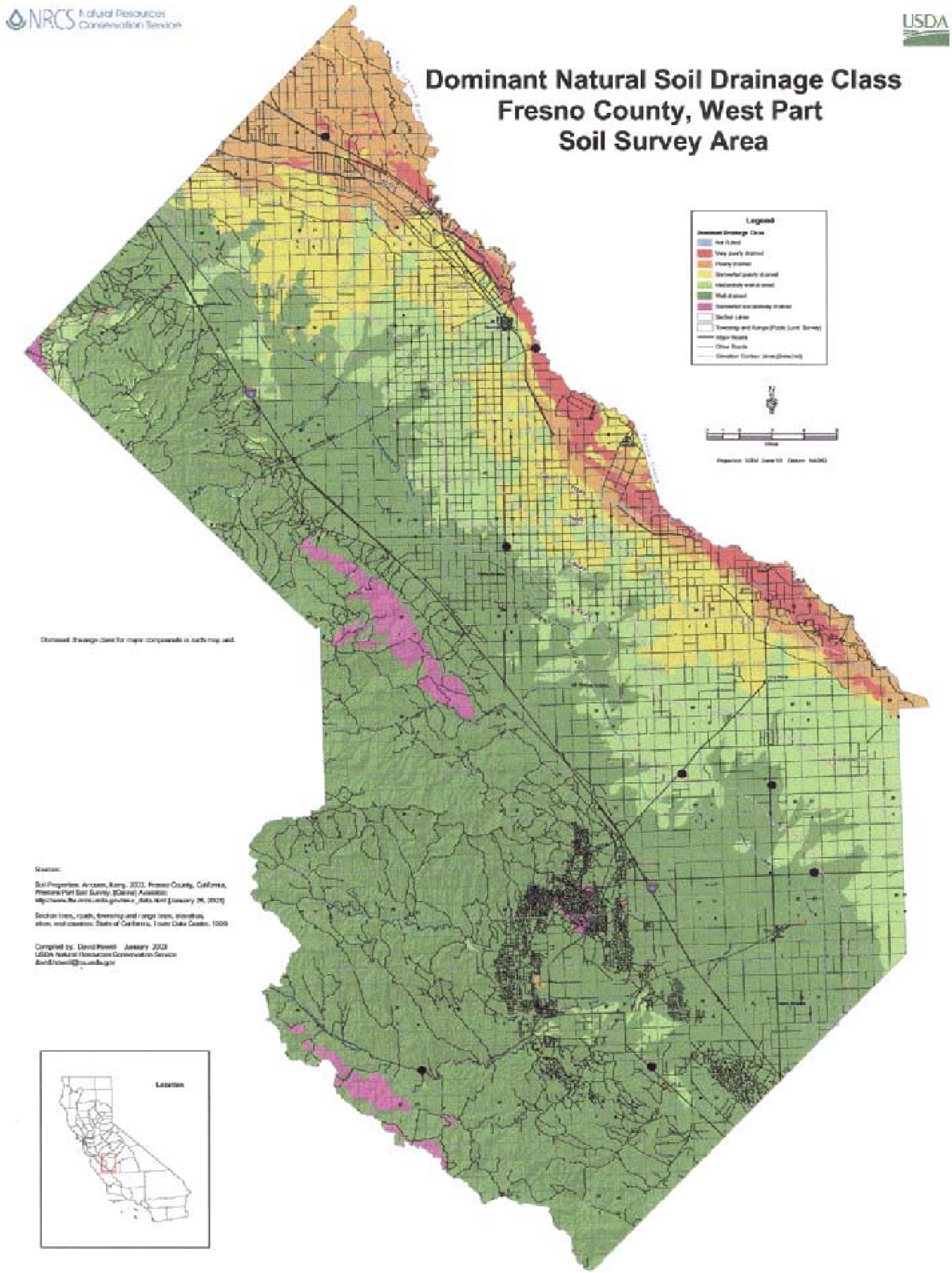
NRCS Soil Salinity, Landform, and Drainage Maps of the San Luis Unit


Salt-Affected Soils
Fresno County, West Part
Soil Survey Area
Legend
Location


NRCS Natural Resources Conservation Service
USDA
Sodium-Affected Soils
Fresno County, West Part
Soil Survey Area
Legend
Significant amounts of sodium (Na) in soils severely effects the growth of many plants. The sodium adsorption ratio (SAR) compares the amount of sodium to the amount of calcium and magnesium held by the soil.
Soil properties are variable. The information displayed on this map indicates the highest typical values for SAR in the top meter of the soil for the major components in each map unit.
Location


NRCS Natural Resources Conservation Service
USDA
Dominant Landforms
Fresno County, West Part
Soil Survey Area
Legend
The information displayed on this map indicates the dominant landform for each map unit. Landforms are derived from the soil map unit major components.
Sources:
Location


NRCS Natural Resources Conservation Service
USDA
Minimum Depth to Water Saturation
Fresno County, West Part
Soil Survey Area


NRCS Natural Resources Conservation Service
USDA
Dominant Natural Soil Drainage Class
Fresno County, West Part
Soil Survey Area
Legend

Attachment I8

Natural Drainage Map
for Northern Drainage-Impaired Areas

Simulated 2050 natural drainage below 50-foot depth, in feet/yr.

APPENDIX J

Implementation of In-Valley Alternatives

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J1 Feasibility Designs and Cost Estimates J-1

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J6 Environmental Mitigation J-3

J7 Evaluation of Innovative Technologies J-4

Acronyms

Reclamation	Bureau of Reclamation
RO	reverse osmosis
Se	selenium
Unit	San Luis Unit
Westlands	Westlands Water District

Preliminary implementation schedules for the In-Valley Alternatives are shown in bar charts in Section 2 of the main report. These alternatives are comprised of the following common drainage service components:

- Collection System: Closed pipelines that collect drainwater from farm lands.
- Reuse Facilities: Farm lands that reuse the collected drainwater to irrigate salt-tolerant crops. Drainwater from these facilities is collected by tile drains for treatment and disposal.
- Conveyance System: Closed pipelines that convey drainwater from the reuse facilities to the treatment and disposal areas.
- Reverse Osmosis (RO) Treatment: Desalination of drainwater to recover high-quality product water, which can be reused for irrigation or other beneficial use.
- Selenium (Se) Biotreatment: Saline concentrate waste stream from RO is treated to remove Se.
- Evaporation Basins: Treated effluent from biotreatment is discharged to evaporation basins to precipitate salts for in-place disposal.
- Evaporation Basin Mitigation: Constructed or enhanced wetland habitats sited and managed to reduce or compensate for adverse effects to waterbirds from operation of the evaporation basins.

The differences among the In-Valley Alternatives are simply the number, size, and locations of these components, which are determined by the amount and location of future retired lands. Consequently, most aspects of drainage service construction and operation will be the same among these alternatives.

Implementation activities include feasibility designs and cost estimates, permitting, final design, land acquisition, phased construction, environmental mitigation, and evaluation of innovative technologies.

J1 FEASIBILITY DESIGNS AND COST ESTIMATES

This activity evaluates technical feasibility of the alternatives and generates cost estimates for construction and operation. Feasibility evaluation includes field investigations, data analysis, engineering designs, quantity estimates, and cost estimates. The cost estimates are used to obtain authorization and funding from Congress to construct the project. The feasibility design will also include a more detailed plan and schedule than is presented herein for all of the subsequent implementation activities. This activity is currently underway for the In-Valley Alternatives and is scheduled for completion in 2006.

J2 PERMITTING

One or more of the components of drainage service will require permits to construct and/or operate. Notable among these, evaporation systems require permits from the Regional Walter Quality Control Board, which also identify initial mitigation measures. The Bureau of Reclamation (Reclamation) will apply for the necessary permits upon selection of the final drainage service alternative. The length of time to complete the permitting process is uncertain but may take about 2 years. The regulatory environment and compliance requirements described in Section 4 of the main report are addressed through the permitting process.

J3 FINAL DESIGN

A final design of the drainage service project will commence when the final alternative is selected. The final design builds upon the feasibility design but is more detailed and comprehensive. The product of final design consists of several packages of written engineering specifications and drawings that are used for contracting and construction of the project. Some components or packages of the final design will be completed before others, which will enable the contracting and construction process to begin before final design of the entire project is completed in 2008.

J4 LAND ACQUISITION

Implementation of drainage service will require the acquisition of easements and real estate property to construct and operate the various components of drainage service. Construction of collection and conveyance systems can likely be accomplished by granting easements. Land area needed for reuse, treatment, disposal, and mitigation components will require the purchase of land to construct and operate these facilities. Leasing of lands or other contractual arrangements with local districts and farmers may also be considered. If the selected drainage service alternative includes land retirement, land acquisition steps can be undertaken immediately for the purpose of retiring these lands from irrigated agricultural production. Where technically feasible, retired lands will be used for project facilities, reducing overall land acquisition requirements. Land acquisition will occur concurrently with permitting and final design activities for drainage service facilities.

J5 PHASED CONSTRUCTION

Specifications and drawings produced in final design are used to prepare bid and contract documents for the various components and phases of drainage service to be constructed. The implementation schedules shown in Section 2 of the main report assume that construction activities gradually ramp up after the Record of Decision in 2006, and level out at a spending rate of approximately $100 million per year until completion. For all In-Valley Alternatives, it is anticipated that initial construction efforts will begin in the Northerly Area to meet discharge requirements, and proceed southward through the San Luis Unit (Unit).

- Northerly Area Construction: A large portion of the Northerly Area is currently drained. Local farming districts have constructed and are operating collection and reuse components of drainage service. Implementation of Federal drainage service will expand the existing collection and reuse infrastructure, and add the treatment, disposal, and mitigation components. Construction of treatment, disposal, and initial mitigation components would receive highest priority to accommodate existing drainage flows and are expected to be completed in 2009.
- Westlands Water District (Westlands) Construction: Initial construction efforts will focus on construction of collection and reuse components. Completion of these components will

permit partial implementation of drainage service because it is anticipated that collection and reuse facilities may operate at least 2 years while conveyance, treatment, disposal, and mitigation systems are being constructed.

Construction of drainage service components in Westlands will likely proceed simultaneously with the Northerly Area, but will take several years longer to complete because it covers a much larger area and does not have significant existing drainage infrastructure. Among the drainage service alternatives for Westlands, The In-Valley Disposal Alternative provides drainage service to the largest geographic area, requires the largest constructed facilities, and will require more years to construct than the other land retirement alternatives.

Although the Government will construct various components of drainage service, it is up to the individual farmer or Westlands to install on-farm, subsurface tile drains to collect the drainwater and pump it into the federal collection system for further reuse, treatment, and disposal. It is anticipated that not all eligible farmers in Westlands will utilize the drainage service. It is also assumed that those farmers who choose to install tile drains will do so gradually over the 50-year planning period. Therefore, drainage service components will be constructed in two or more phases to meet the projected capacity requirements over the 50-year planning period. For example, the initial construction phase may only install about 50 percent of the total projected capacity needed over 50 years. After about 20 years, a second construction phase will install the additional capacity needed for full build-out. Only the initial construction phase for Westlands is shown in the implementation schedule bar charts in Section 2 of the main report.

The phased construction of drainage service in Westlands reduces the overall cost of construction and provides greater flexibility in responding to changes in drainage quality and quantity over time. Phased implementation also permits monitoring of environmental impacts of evaporation basins and refinement of mitigation measures to reduce and compensate for these impacts, and continuing evaluation and incorporation of technical innovations to improve or optimize the treatment and disposal systems.

J6 ENVIRONMENTAL MITIGATION

Reclamation anticipates adverse effects to waterbirds during operation of the evaporation basins. Evaluation and quantification of potential environmental impacts is subjective and uncertain. Likewise, the effectiveness of potential mitigation measures to reduce and compensate for these impacts is uncertain. Initial estimates of potential impacts and corresponding mitigation measures will be developed during design and permitting activities. Initial mitigation and monitoring measures will be implemented during the first phase of construction of drainage service components.

Operation of the evaporation basins and mitigation facilities will be closely monitored and modified as needed to reduce and compensate for the environmental effects. Changes to the construction and operation of these facilities will be implemented as part of the phased construction process. It is anticipated that monitoring impacts and modification of operations and facilities will be repeated during the life of the project. This iterative continual process of implementing environmental mitigation is referred to as adaptive management and consists of the following steps:

1. Develop initial estimates of environmental impacts caused by the evaporation basins. Estimates of impacts will be based upon a variety of factors: impacts observed and data collected at other similar evaporation facilities, Se bioaccumulation data collected at a test pond in the Northerly Area, existing or modified risk assessment models, and consultation with Federal and State regulating agencies. The uncertainty of these estimates will result in a range of potential impacts.
2. Develop an initial plan for mitigation of environmental impacts. The estimates of environmental impacts will be used to evaluate various mitigation measures. The range of potential impacts will also result in a range of mitigation requirements. In collaboration with Federal and State agencies, Reclamation will develop an initial mitigation plan that falls within this range. This plan will also contain contingency provisions to modify or increase the mitigation up to the estimated maximum in case the initial measures prove to be inadequate.
3. Implementation of initial mitigation measures. The mitigation facilities described in the initial plan will be constructed during the first phase of drainage service.
4. Monitoring of environmental impacts and effectiveness of mitigation measures for the constructed facilities. Monitoring activities will include tracking the concentrations and fate of drainwater contaminants in the evaporation basins (including groundwater monitoring wells), field observations of waterbird use and data collection of Se bioaccumulation at the evaporation basins and mitigation facilities, and measurements of the effectiveness of the mitigation measures to reduce and compensate for impacts.
5. Analysis and modification of mitigation measures. Data collected from monitoring activities will be evaluated to determine actual environmental impacts and mitigation requirements. The effectiveness of existing mitigation measures will be analyzed. Modifications will be implemented to address and conform to actual field conditions. Modifications may include changes to the design and operation of the evaporation basins as well as the mitigation facilities. Individual mitigation measures may be increased, decreased, or modified depending on their effectiveness and need.
6. Repeat Steps 4 and 5 throughout the life of the project.

J7 EVALUATION OF INNOVATIVE TECHNOLOGIES

The primary barrier to achieving in-valley drainage service during the past 30 years has been the lack of affordable technologies to reduce or eliminate the associated environmental impacts. Recent advances in technologies for desalination and Se removal have significantly reduced the treatment costs and potential impacts of releasing irrigation drainwater into the environment. These treatment technologies have been implemented and proven at other locations, field-tested at the San Luis Unit, and are now integral components of all In-Valley Alternatives.

As part of the overall implementation strategy, Reclamation continues to monitor and investigate enhancements to these technologies as well as other innovative technologies that can potentially lower the costs and environmental risks of drainage service. Evaluation and implementation of innovative technologies occur through a process of technology review, laboratory and field studies, and demonstration:

- Technology Review: Reclamation staff monitors technological developments and consults with outside researchers; they review ongoing research and determine potential applicability to drainwater treatment and disposal.
- Laboratory and Field Studies: Bench- and pilot-scale studies are conducted to gather performance and operation data to assist in the designs for full-scale implementation of reuse, RO treatment, Se biotreatment, and evaporation disposal of drainwater. Reclamation is currently performing laboratory and field investigations for all of these components and will continue to evaluate these and other innovative technologies during implementation of drainage service as funding permits.
- Demonstration: Reclamation is also developing plans for a larger demonstration facility in the Northerly Area as an intermediate step towards implementation of drainage service. The demonstration facility would receive drainwater from existing reuse sites and provide RO treatment, Se biotreatment, and evaporation disposal. This facility would be used to optimize the existing systems to site specific conditions and evaluate technology enhancements to be used in the full-scale design.

The current status and potential implementation of innovative technologies for each of the treatment and disposal components is described below:

- RO Treatment: Conventional RO treatment has been pilot-tested in the San Luis Unit and found to be effective in desalinating the drainwater. Product water recovery, however, is limited to about 50 percent of the influent feedwater due to high calcium concentrations. Reclamation is collaborating with PCI Membranes and WaterTech Partners to evaluate the patented DP3RO process, which removes calcium from the RO feedwater to increase product water recovery up to about 90 percent. A laboratory bench-scale study was completed and a pilot study is scheduled to begin in March 2005. Based on the results of this pilot study, a technical and economic analysis will determine whether this innovative technology should be added as a pretreatment step to RO. This determination will likely be made by August 2005.

  Reclamation is also evaluating recent technological advancements related to boron removal. Membrane manufacturers have announced a new generation of membranes that are effective in separating boron during RO treatment. Also, a new ion exchange resin was recently field-tested for boron removal from RO product water in the Unit. This information will be reviewed and perhaps more field studies will be performed to determine whether either of these options should be incorporated into the RO treatment process by August 2005.

- Se Treatment: Reclamation has conducted bench- and pilot-scale studies of the patented ABMet® biotreatment process to remove Se from the RO concentrate and found this technology to be superior in performance to all other available technologies. An additional pilot study of this technology will be conducted in 2005 to incorporate recent design improvements in an effort to optimize the treatment process and maximize Se removal.

  Se speciation studies are currently underway to quantify and characterize the residual Se in the treated effluent and the Se that is removed from the drainwater and stored within the bioreactor tanks of the treatment system. This information will be used to assess potential post-treatment operations to render the residual Se less bioavailable, and to assess potential beneficial uses or disposal methods of the Se that is removed from the drainwater.

Bench- and pilot-scale studies will be performed in 2005 to evaluate biological oxidation as a method of converting organic residual Se into less bioavailable inorganic forms. The results of all of the above studies will provide information by August 2005, which will be used to perform full-scale designs, determine Se disposal requirements, and reduce uncertainty of environmental impacts of the treated effluent.

- Evaporation Technologies: The In-Valley Alternatives incorporate evaporation basins as the final step in the treatment and disposal process of drainwater. This method has proven effective at existing basins in the Unit for concentrating drainwater and precipitating salts for final disposal. A variety of innovative technologies to increase the evaporation rate have been or are currently being tested at locations within and outside of the Unit. These technologies include dewvaporation, Solar Bee mixers, salt-gradient solar ponds, wind turbines, and different configurations of sprinkler systems. Reclamation is monitoring, reviewing, and in some cases funding research on these evaporation technologies for applicability to the Unit.

  By August 2005, recommendations will be made as to whether any of these options should be incorporated into the full-scale design of evaporation basins or if on-site field investigations should be pursued. Reclamation constructed small evaporation basins in the Northerly Area for the purpose of monitoring Se bioaccumulation, but enhanced evaporation is not being studied at this site.

  Manipulation and recovery of precipitated salts for beneficial reuse is another area of interest that is being evaluated in conjunction with evaporation technologies. Field studies are needed to determine whether salt recovery is technically and economically feasible in the Unit. Reclamation is consulting with technology vendors and seeking funding for field studies in 2005 and 2006. If successful, a salt recovery process will be incorporated into the full-scale design and implementation of evaporation technologies.

APPENDIX K

Land Retirement Analysis

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K-2	San Luis Drainage Alternative cost Comparison Annual Equivalent Costs

Acronyms

EIS	Environmental Impact Statement
PFR	Plan Formulation Report
ppb	parts per billion
Reclamation	Bureau of Reclamation
Se	selenium
Unit	San Luis Unit
Westlands	Westlands Water District

K1 LAND RETIREMENT ALTERNATIVES

Westlands Water District (Westlands) and several environmental and other interests in the San Luis Unit (the Unit) requested that the Bureau of Reclamation (Reclamation) include a land retirement alternative in the Environmental Impact Statement (EIS). Specifically, these interests suggested that Reclamation consider the Westlands proposed land retirement plan or an alternative that retires sufficient lands to eliminate the drainage problem in the Unit. The land retirement analysis in the 2002 Plan Formulation Report (PFR) was broadened to respond to requests from stakeholders and interested agencies. Preliminary alternatives were developed, refined, and optimized based on specific criteria. The optimization process led to the selection of three additional alternatives that incorporated land retirement. The rationale for eliminating other land retirement alternatives is provided in this section as well.

On February 5, 2004, Reclamation submitted to the Court an *Amended Plan of Action for Drainage to the San Luis Unit*. The Amended Plan of Action states that Reclamation will continue to refine and evaluate all five alternatives (including No Action) described in the PFR for inclusion in the EIS. Additionally, Reclamation will formulate alternative(s) that use land retirement as a method to control drainage need, by comparing costs, benefits, and effects for alternatives with different amounts of land retirement.

In October 2003, Reclamation began land retirement alternatives development by meeting with project stakeholders to define the parameters that would constitute a complete land retirement program and the range of sizes (acreage) for alternatives. Stakeholders included representatives from San Luis Unit districts (San Luis Water District, Broadview Water District, Westlands Water District, and Panoche Water and Drainage District), San Joaquin River Exchange Contractors Water Authority, and environmental and Delta interests (Environmental Defense, Contra Costa County, Contra Costa Water District). The initial range of alternatives included alternatives based on the following reports and comments provided by the stakeholders:

- Westside Regional Drainage Plan (San Joaquin River Exchange Contractors Water Authority et al. 2003) including lands within Westlands and the Northerly Area.
- U.S. Fish and Wildlife Service comments on the PFR, including an alternative that would retire all drainage-impaired lands in the San Luis Unit
- "Drainage Without a Drain" concept proposed by a coalition of environmental groups and local agencies downstream of the San Joaquin Valley[1]

The Project Team refined the initial alternatives developed from the public outreach process to arrive at complete alternatives that include the disposal of any residual drainwater. Factors considered included:

- Amount of land retirement
- Land retirement implementation method
- Future retired land use and ownership

[1] The Bay Institute, Contra Costa County, Contra Costa County Water Agency, Contra Costa Water District, and Environmental Defense.

- Future use of water currently used to irrigate land that would be retired
- Extent of drainage reduction measures including irrigation efficiencies and groundwater pumping
- Inclusion of drainage service components necessary to provide a complete disposal alternative

By December 2003, the following five concepts were identified for further refinement and optimization:

- Locally Preferred 1: Westside Regional Drainage Plan
- Locally Preferred 2: Optimized Retirement
- Reclamation 1: Federal Management
- Reclamation 2: Maximum Retirement
- Environmental: Drainage Without a Drain

K1.1 Refinement and Optimization Process

Beginning in December 2003, Reclamation refined the alternatives by determining how the cost, benefit, and potential environmental effects of the resulting drainage service plan compared to previous alternatives using a variety of modeling and analysis tools. Using an iterative evaluation process, Reclamation considered the following factors for varied levels of land retirement:

- **Improved irrigation efficiency** balanced with deep percolation rates to maintain salt balance in the root zone.
- The **amount of drainage** to be expected under the different land retirement scenarios using the regional groundwater model.
- Estimated **costs of drainage service** for the land retirement scenarios using engineering cost curves, which calculated the cost for each component of drainage service (e.g., collector system, treatment system, and disposal) for a corresponding drainage rate.
- The **economic benefits** of each scenario to provide another measure to select a final set of alternatives for analysis.
- **Indicators of environmental effect** (such as acres of reuse and evaporation basins needed, or amount of drainwater reclaimed for irrigation) for each scenario.

Reclamation developed and analyzed potential alternatives that include combinations of land retirement, source reduction (including reduced percolation losses from irrigation, and drainwater recycling and reuse), and treatment and disposal. These potential alternatives, called land retirement scenarios, were compared primarily using costs. Scenarios mix different levels of land retirement, source reduction, and treatment/disposal. Alternatives that provided for partial retirement of drainage-impaired lands were further evaluated to balance the amount of land retired with the implementation of drainage-reduction measures to improve farm profits. The primary drainage-reduction measure evaluated was increases in irrigation efficiencies.

Because the cost of selenium (Se) removal from drainwater is high, Reclamation developed a land retirement alternative that was based on retiring lands with high Se concentrations in the shallow groundwater and that used groundwater well monitoring data to estimate the Se concentration in shallow groundwater. Several different groundwater concentrations were used as criteria for selecting land retirement areas. The alternatives were assessed based on the amount of land that would be retired and the potential decrease in Se concentration in drainwater. In addition, the effect of retiring lands already acquired by Westlands because of drainwater quality was also evaluated.

Another two-step process was used to evaluate, compare, and screen land retirement scenarios. The first step covered a fairly wide range of retirement and source control combinations and was used to:

- Screen out scenarios that were clearly inferior (e.g., more costly for the same or less benefit).
- Screen out scenarios that were technically impractical or questionable.
- Identify potential scenarios that might be more effective and/or less costly.

The second step evaluated four scenarios in comparison to the In-Valley Disposal Alternative, including the change in applied water.

K1.1.1 First Screening Step

Three land retirement levels and three levels of increased irrigation efficiencies were evaluated. The three retirement levels were:

- Lands retired as in the In-Valley Disposal Alternative (approximately 44,100 acres within Westlands drainage-impaired area)
- 200,000 acres retired within the Westlands drainage-impaired area
- All drainage-impaired lands in the San Luis Unit retired (298,000 acres in Westlands and 45,000 acres in the Northerly Area)

Three increased irrigation efficiency rates were evaluated for the first two retirement levels (because with all drainage-impaired lands retired, reducing drainage with source controls is not needed).

The following conclusions were drawn from this screening:

- Comparison of the cost for land retirement (land acquisition and land management costs) versus the cost for collection, treatment, and disposal indicated that land retirement was more costly. In other words, it cost more to avoid the drainage through land retirement than to collect, treat, and dispose of the drainwater.
- Further analysis is needed to estimate the value of water that land retirement makes available for other uses, which should be factored into a comparison of final alternatives.
- Root zone salinity analysis indicated that Level 2 deep percolation reduction (i.e., increased irrigation efficiency) probably does not allow for salinity balance in the root zone for the drainage-impaired area. Level 2 deep percolation reduction was eliminated from further consideration.

- Level 1 deep percolation reduction did appear to be technically feasible and cost-effective, but root zone salinity balance in the Westlands drainage-impaired area could be achieved only with extremely careful management. It was agreed to include Level 1 reduction in further screening of scenarios, although questions were raised about the practicality of growers being able to achieve deep percolation rates of 0.27 foot/year.
- Full retirement of drainage-impaired lands eliminated the need for drainage service, but the 200,000-acre retirement level did not. Analysis of additional intermediate levels of retirement was suggested to see if some acreage less than full retirement could eliminate the need for drainage in Westlands.
- Other implications besides cost and drainage volume were requested for consideration in the land retirement scenario screening. Specifically, a scenario could target retirement of lands based on Se concentrations in shallow groundwater. Two target levels were suggested: greater than 20 parts per billion (ppb) and greater than 50 ppb Se in shallow groundwater.

Retirement of the remaining 35,000 acres of lands in the northerly San Luis Unit (lands other than the 10,000 acres in Broadview Water District) was not included in scenarios for further analysis. This Project Team decision was supported by a variety of factors, including the following:

- Initial screening showed land retirement to be more costly than drainage service. Consequently, land retirement combined with the Out-of-Valley Alternatives was also not cost-effective.
- Northerly Unit lands already have a substantial investment in installed drainage system components (drains, collector system, recirculation systems, reuse areas, etc.). These systems have been funded using a variety of local funding and State and Federal grants, loans, and bond funds. Repayment of the remaining obligation from the 12 million dollars funded from the State Revolving Loan funds would add to the cost of land retirement.
- Other non-Unit lands in the Northerly Area could not be retired under the current San Luis Unit authorization. Retirement of the remaining northerly Unit lands would result in approximately 36,000 acres of lands outside the Unit needing drainage service. Drainage flows would continue to occur on these lands including seepage into deep open drains, drainwater and tailwater (from continued non-Unit farms) that is not able to be recycled, and runoff from storm events. In the absence of drainage service, these uncontrolled flows would continue downstream and could reach the adjacent wildlife refuges or the San Joaquin River, resulting in adverse effects to water quality and wildlife.

K1.1.2 Second Screening Results

Four scenarios were evaluated and compared to the In-Valley Disposal Alternative in this screening:

- Revision of the In-Valley Disposal Alternative to include Level 1 deep percolation reduction and 55,311 total acres retired in Westlands (including lands for project facilities).

- Retirement of all lands in Westlands with Se concentration greater than 50 ppb and implementing Level 1 deep percolation reduction. Total land retired would be 88,576 acres in Westlands and the 10,000 acres of Broadview Water District in the Northerly Area.
- Retirement of all lands in Westlands with Se concentration greater than 20 ppb and implementing Level 1 deep percolation reduction. Total land retired would be 129,051 acres in Westlands and the 10,000 acres of Broadview Water District in the Northerly Area.
- Retirement of 198,000 acres within the drainage-impaired area of Westlands plus 10,000 acres in the Northerly Area. Implementation of Level 1 deep percolation reduction.

Some additional groundwater modeling analysis was performed to see if the need for drainage could be eliminated by combinations of deep percolation reduction and land retirement (less than complete retirement of all lands in the drainage-impaired area). Only a few combinations were tested, but it appeared that eliminating all need for current or future drainage service in the Unit could only be assured by retiring all drainage-impaired lands.

K1.2 Selected Land Retirement Scenarios

Based on the screening of the many combinations of land retirement and other drainwater reduction measures, three land retirement scenarios were selected (as variations on the In-Valley Disposal Alternative) as reasonable alternatives for analysis in the EIS. All three assume 10,000 acres would be retired in Broadview Water District in the Northerly Area. The first of the three scenarios would retire land with Se concentration greater than 50 ppb in shallow groundwater (approximately 83,100 acres in Westlands). The second would retire land in Westlands up to the level at which the water made available could be used to fulfill other irrigation demands in the San Luis Unit (195,000 acres). The third would retire the entire drainage-impaired area in Westlands (298,000 acres). All three are assumed to be variations of the original In-Valley Disposal Alternative and, therefore, the methods of collection, treatment, and disposal of drainwater for the three In-Valley Land Retirement Alternatives are essentially the same as the In-Valley Disposal Alternative.

K1.2.1 In-Valley/Groundwater Quality Land Retirement Alternative

This alternative consists of retiring all the lands in Westlands with Se concentration greater than 50 ppb in the shallow groundwater and lands acquired by Westlands (83,100 acres). It would also retire 10,000 acres in Broadview Water District in the Northerly Area for a total of 93,100 acres of land retirement. This alternative would also include irrigation system improvements to reduce deep percolation to shallow groundwater. Lands remaining in production within the drainage-impaired area would be eligible for drainage service.

K1.2.2 In-Valley/Water Needs Land Retirement Alternative

This alternative would retire enough lands to meet the internal water use needs of the San Luis Unit (195,000 acres). This value would include lands with Se concentrations greater than 20 ppb in Westlands, lands acquired by Westlands, and 10,000 acres in Broadview Water District. The alternative would include irrigation system improvements to reduce deep percolation to shallow groundwater. Lands remaining in production within the drainage-impaired area would be eligible for drainage service.

K1.2.3 In-Valley/Drainage-Impaired Area Land Retirement Alternative

This alternative consists of retiring 308,000 acres, including all the drainage-impaired lands in Westlands – approximately 298,000 acres. The Northerly Area (non-Westlands) is excluded from land retirement except for 10,000 acres in Broadview Water District, and drainage collection, treatment, and disposal facilities would be avoided in the Westlands drainage-impaired areas. Water made available from this alternative would exceed the agricultural water required by the remaining lands within the Unit, and would be available for reallocation to other purposes.

K2 OUT-OF-VALLEY DISPOSAL ALTERNATIVES WITH LAND RETIREMENT

Based on the screening of the many combinations of land retirement and other drainwater reduction measures, three land retirement scenarios were selected as partial alternatives for analysis in the EIS. As indicated above, these alternatives are all variations of the original In-Valley Disposal Alternative. The collection, treatment, and disposal of drainwater collected from drained lands are essentially the same as the In-Valley Disposal Alternative, except that the amount of drainage would vary depending on the amount of drainage-impaired land that would be retired. All three land retirement alternatives assume that 10,000 acres of the Broadview Water District, located in the Northerly Area would be retired.

Preliminary analyses of various land retirement scenarios were conducted during the plan formulation process to compare the costs of retiring varying amounts of drainage-impaired lands versus the cost of providing drainage service to those same lands. These initial analyses were based on comparing the In-Valley Disposal Alternative with land retirement to the least expensive Out-of-Valley Disposal Alternative (Chipps Island) with the same level of land retirement. The analyses indicated that the In-Valley Disposal Alternative was consistently less expensive than the least expensive Out-of-Valley Disposal Alternative, regardless of the amount of land retirement. Consequently, it was assumed that since land retirement costs were greater than the corresponding savings of reduced treatment and disposal costs for the In-Valley Disposal Alternative, land retirement would be even less cost-effective for any Out-of-Valley Disposal Alternative.

However, as the cost estimates of various project features were refined for the Feasibility Study, the cost differences between the alternatives changed. The most notable changes that occurred as feature costs changed were (1) the costs of the In-Valley Disposal Alternative increased, (2) the cost of the conveyance systems for all of the Out-of-Valley Disposal Alternatives decreased, and (3) the Ocean Disposal Alternative became the least expensive Out-of-Valley Disposal Alternative. As a result of these changes, it was decided to conduct another brief analysis of land retirement with the Ocean Disposal Alternative to determine if a more thorough analysis would be required.

Two land retirement scenarios were analyzed for comparison with the In-Valley/Land Retirement Alternatives. The first scenario analyzed assumed essentially the same amount of land retirement as the In-Valley/Water Supply Land Retirement Alternative (195,000 acres retired in Westlands and 10,000 acres in the Broadview Water District). The second scenario assumed retirement of all drainage-impaired lands in Westlands, or 298,000 acres plus 10,000 in Broadview. These analyses indicated that, even though the cost differences between the various alternatives were much closer than they had been previously, the In-Valley Disposal Alternative was still consistently less expensive than the least costly Out-of-Valley Disposal Alternative, regardless of the amount of land retirement. Consequently, the Out-of-Valley Disposal Alternatives with additional land retirement were not carried forward into this EIS for full analysis. The results of this analysis are summarized in Tables K-1 and K-2.

Table K-1
San Luis Drainage Alternative Cost Comparison
Annual Equivalent Costs
($1,000)

	In-Valley Disposal Alternatives			
		Land Retirement Alternatives		
Project Features	In Valley Disposal	Groundwater Quality (93,090 ac)	Water Supply (205,000 ac)	Retire All WWD DIA Land (308,000 ac)
FEDERAL PROJECT COSTS				
Federal Costs - Alternative Specific				
Conveyance System	1,597	1,501	1,302	130
Evaporation Ponds	6,898	6,149	4,850	2,387
Wetland Mitigation Facilities	na	na	na	na
Reverse Osmosis Facilities	5,138	4,684	3,688	1,822
Biological Selenium Treatment	3,591	3,189	2,458	1,281
Land Retirement	645	8,443	25,061	43,635
Subtotal - Specific Alt Federal Funding Rqmts	**17,869**	**23,966**	**37,360**	**49,256**
Subtotal - NED Adjusted Federal Project Costs	**17,224**	**15,523**	**12,298**	**5,620**
Common Federal Costs				
Drainage Collection System	11,194	9,530	5,351	167
Regional Reuse Facilities	4,621	4,038	3,685	2,047
DMC Drainage Collection/Reuse	104	105	106	106
Subtotal - Common Federal Costs	**15,919**	**13,673**	**9,142**	**2,320**
SUBTOTAL - FEDERAL PROJECT FUNDING RQMTS	**33,789**	**37,640**	**46,501**	**51,576**
SUBTOTAL - NED Adjusted Federal Project Costs	**33,144**	**29,197**	**21,440**	**7,940**
NON-FEDERAL PROJECT COSTS				
Drainage Reduction Measures				
Drain Water Recycling	3,229	2,799	1,920	832
Seepage Reduction	519	518	517	517
Shallow Groundwater Mgt	662	558	311	9
On-Farm Irrigation Improvements	768	768	768	768
Subtotal - Drainage Reduction	**5,178**	**4,642**	**3,516**	**2,126**
On-Farm Tile Drainage System	3,279	3,004	2,442	498
SUBTOTAL - NON-FEDERAL PROJECT COSTS	**8,457**	**7,647**	**5,958**	**2,625**
TOTAL PROJECT FUNDING REQUIREMENTS	**42,246**	**45,286**	**52,460**	**54,200**
TOTAL NED ADJUSTED PROJECT COSTS	**41,601**	**36,843**	**27,398**	**10,565**

Table K-2
San Luis Drainage Alternative Cost Comparison
Annual Equivalent Costs
($1,000)

	Ocean Disposal		
		Land Retirement	
Project Features	Point Estero	Water Supply (205,000 ac)	Retire All WWD DIA Land (308,000 ac)
FEDERAL PROJECT COSTS			
Federal Costs - Alternative Specific			
Conveyance System	17,430	13,087	9,157
Evaporation Ponds	0	0	0
Wetland Mitigation Facilities	na	na	na
Reverse Osmosis Facilities	0	0	0
Biological Selenium Treatment	0	0	0
Land Retirement	645	18,921	36,628
Subtotal - Specific Alt Federal Funding Rqmts	**18,075**	**32,008**	**45,785**
Subtotal - NED Adjusted Federal Project Costs	**17,430**	**13,087**	**9,157**
Common Federal Costs			
Drainage Collection System	11,072	5,149	158
Regional Reuse Facilities	4,633	4,086	2,431
DMC Drainage Collection/Reuse	103	103	104
Subtotal - Common Federal Costs	**15,807**	**9,337**	**2,694**
SUBTOTAL - FEDERAL PROJECT FUNDING RQMTS	**33,883**	**41,346**	**48,479**
SUBTOTAL - NED Adjusted Federal Project Costs	**33,238**	**22,424**	**11,851**
NON-FEDERAL PROJECT COSTS			
Drainage Reduction Measures			
Drain Water Recycling	3,192	1,926	879
Seepage Reduction	520	520	519
Shallow Groundwater Mgt	666	311	9
On-Farm Irrigation Improvements	768	768	768
Subtotal - Drainage Reduction	**5,147**	**3,524**	**2,175**
On-Farm Tile Drainage System	3,291	2,478	543
SUBTOTAL - NON-FEDERAL PROJECT COSTS	**8,437**	**6,002**	**2,718**
TOTAL PROJECT FUNDING REQUIREMENTS	**42,320**	**47,348**	**51,197**
TOTAL NED ADJUSTED PROJECT COSTS	**41,675**	**28,427**	**14,569**

APPENDIX L

REGULATORY ENVIRONMENT AND COMPLIANCE REQUIREMENTS

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Acronyms

Basin Plan	Water Quality Control Plan for the Sacramento River and San Joaquin River Basins
BMPs	best management practices
CBC	California Building Code
CDFG	California Department of Fish and Game
CEQA	California Environmental Quality Act
CWA	Clean Water Act
DHS	California Department of Health and Safety
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
FEMA	Federal Emergency Management Agency
NEHRP	National Earthquake Hazards Reduction Program
NEP	National Earthquake Loss Reduction Program
NEPA	National Environmental Policy Act
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollution Discharge Elimination System
RCRA	Resource Conservation and Recovery Act
Regional Board	San Francisco Bay Regional Water Quality Control Board
State Board	California State Water Resources Control Board
SWPPP	Storm Water Pollution Prevention Plan
UIC	Underground Inspection Control (Program)
USACE	U.S. Army Corps of Engineers

Construction and operation of any of the action alternatives under consideration would be subject to numerous regulatory compliance actions that are in place to safeguard the human and biological environment. This appendix explains the legislation and regulatory requirements, and several require Reclamation to obtain, or ensure that, the applicable approvals are obtained.

L1 Environmental Compliance Regulations

The National Environmental Policy Act (NEPA) and the California Environmental Quality Act (CEQA) apply to actions that a Federal or State agency may undertake directly, approve by issuing a permit or other authorization, or fund wholly or in part. NEPA provides a commitment that Federal agencies will consider the environmental effects of their actions. It requires that an Environmental Impact Statement (EIS) be prepared for all major Federal actions with significant environmental effects. The CEQA requirements are similar to the NEPA requirements and require the preparation on an Environmental Impact Report for major State actions significantly affecting the quality of the physical and social environment. The President's Council on Environmental Quality regulations encourages the preparation of joint environmental documents to reduce duplication of analysis and paperwork. Both NEPA and CEQA require that an agency consider the environmental effects of its actions at the earliest point in time in which the analysis is meaningful. NEPA and CEQA are intended to inform decision makers and the public of the environmental consequences of the proposed action, provide an analysis of alternatives, and ensure consideration of mitigation options. Under both statutes, the environmental documentation and analysis are circulated for public review and comment before a final document is completed and before a decision is made to approve the proposed action or other alternative.

- CEQA Compliance: This document has been written to facilitate State and local agencies using the document to meet their CEQA obligations.
- NEPA Compliance: The Draft EIS is being circulated for public review. Following the Final EIS and signature of the Record of Decision, Reclamation will have fully complied with NEPA.

L2 Biological Resource Legislation and Requirements

Both the Federal and State governments have enacted biological resource legislation and requirements to ensure that projects do not needlessly harm these resources. The major biological resource legislative requirements applicable to the alternatives under consideration are discussed below.

L2.1 Fish and Wildlife Coordination Act

The Fish and Wildlife Coordination Act (Public Law 85-624) mandates that conservation, rehabilitation, and enhancement of fish and wildlife resources receive equal consideration and be coordinated with other features of water resource development programs and provide an opportunity for the "appropriate wildlife agencies" (U.S. Fish and Wildlife Service [Service] and the National Oceanic and Atmospheric Administration [NOAA] Fisheries) to consult on Federal water development projects or on non-Federal projects that require a Federal permit or license. The agencies are provided the opportunity to conduct surveys and investigations to determine the potential damage to fish and wildlife resources with project implementation and to identify the mitigation measures that should be undertaken. The findings are incorporated into an official Section 2(b) report. The Coordination Act Report is provided as Appendix M.

Compliance: Specific activities, including the draft Coordination Act Report, are described in Section 21.2.4.

Similarly, Sections 13450 et seq. of the California Fish and Game Code provide opportunities for the California Department of Fish and Game (CDFG) to report its recommendations for wildlife conservation and development, and the expected results, and, describe the damage to wildlife attributable to the project and the measures proposed for mitigating or compensating for these damages. These provisions, however, do not apply to fish in irrigation canals or works, or to mammals destroyed or birds killed while damaging crops.

Compliance: CDFG will have an opportunity to provide input through their review of the Coordination Act Report.

L2.2 Migratory Bird Treaty Act

The Migratory Bird Treaty Act prohibits the intentional or unintentional taking of migratory birds except under specific authorized and permitted activities. The Service has indicated that operation of the evaporation basins to dispose of subsurface agricultural drainage could result in the incidental take of migratory birds (including the American avocet, black-necked stilt, gadwall, mallard, northern pintail, and snowy plover), in violation of this act. The Service has recommended that lands producing drainwater exceeding threshold levels for agricultural toxicants should either be retired from irrigated agriculture or the drainwater be disposed of in a manner that avoids wildlife contact, such as deep-well injection or treatment to render the drainage harmless to the environment. The Service has developed protocols that provide guidance criteria for agricultural drainage basin operations. These criteria include design criteria to prevent waterfowl attraction and to require substitute wetlands for mitigation.

Compliance: Reclamation is designing the In-Valley Disposal Alternatives to minimize waterfowl attraction and to provide alternative and compensation wetlands to reduce the incidental take of protected migratory waterbirds.

L2.3 Endangered Species Act

The Federal Endangered Species Act (ESA), as amended (16 *United States Code* 1536), establishes a national program for the conservation of threatened and endangered species of fish, wildlife, and plants and the preservation of the ecosystems upon which they depend. Section 7(a)(2) of the ESA requires Federal agencies to consult with the Service and/or NOAA Fisheries on any activities that may affect any species listed as threatened or endangered or designated critical habitat. These potential effects require initiation of the Section 7 consultation process.

Compliance: A list of Federal and State threatened, endangered, proposed, candidate, rare, species of concern, and/or species of special concern that may occur in the project area was obtained from the Service and NOAA Fisheries and is included as Appendix F. Pursuant to Section 7 of the ESA, information addressing potential adverse effects on listed and proposed species will be incorporated into the NEPA document. Based on Reclamation's effects determination, formal consultation with the Service and NOAA Fisheries may be requested in compliance with Section 7.

L2.4 California Endangered Species Act

The California ESA is similar to the Federal ESA.

Compliance: A list of State threatened, endangered, proposed, candidate, rare, species of concern, and/or species of special concern that may occur in the project area were requested from the CDFG. Information addressing potential effects on listed and proposed species will be incorporated into the NEPA document, as appropriate, and provided to the CDFG for their analysis and comment.

L2.5 Magnuson-Stevens Fishery Conservation and Management Act

The Magnuson-Stevens Fishery Conservation and Management Act requires all Federal agencies to consult with NOAA Fisheries on all actions or proposed actions, permitted, funded, or undertaken by an agency, that may adversely affect Essential Fish Habitat (EFH). EFH is defined as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." Only species managed under a Federal fishery management plan are covered. Species for which this act applies for this project are Sacramento River winter-run salmon, Central Valley spring-run salmon, Central Valley fall/late fall-run salmon, and Central Valley steelhead. Consultation generally requires that an EFH Assessment be prepared and submitted to NOAA Fisheries. Information that is normally included in an EFH Assessment will be incorporated into the NEPA document.

Compliance: None of the alternatives would affect the species subject to this act.

L2.6 California Fish and Game Code (Section 1601) Streambed Alteration Agreement

Pursuant to Section 1601 of the California Fish and Game Code, before any State or local governmental agency or public utility begins a construction project that will (1) divert, obstruct, or change the natural flow or the bed, channel, or bank of any river, stream, or lake; (2) use materials from a streambed; or (3) result in the disposal or deposition of debris, waste, or other material containing crumbled, flaked, or ground pavement where it can pass into any river, stream, or lake, it must first notify the CDFG of the proposed project. Based on the notification materials submitted to the CDFG, the CDFG will determine if the proposed project may affect fish or wildlife resources. If the CDFG determines that the proposed project may substantially adversely affect existing fish or wildlife resources, a Lake or Streambed Alteration Agreement will be required, unless the proposed project is otherwise exempt.

Compliance: Not applicable to Reclamation; however, comments from CDFG will be considered in the Final EIS.

L2.7 Executive Order 11990 (Protection of Wetlands)

Executive Order 11990 (Protection of Wetlands) requires Federal agencies to take actions to minimize the destruction, loss, or degradation of wetlands, and to preserve and enhance the natural and beneficial values of wetlands when undertaking Federal activities and programs. Any agency considering a proposal that might affect wetlands must evaluate factors affecting wetland quality and survival. These factors should include the proposal's effects on the public health, safety, and welfare due to modifications in water supply and water quality; maintenance of natural ecosystems and conservation of flora and fauna; and other recreational, scientific, and cultural uses.

Compliance: Action alternative facilities could be sited so as to avoid and minimize impacts to wetland resources.

L2.8 Executive Order 13186 (Responsibilities of Federal Agencies to Protect Migratory Birds)

Executive Order 13186 requires all Federal agencies taking actions that have, or are likely to have, a measurable negative effect on migratory bird populations to develop and implement a Memorandum of Understanding with the Service to promote the conservation of migratory bird populations. The order requires departments and agencies of the Federal government, to the extent practicable and permitted by budgetary limits and in harmony with their agency's missions, to (1) avoid or minimize the negative effect of their actions on migratory birds, (2) restore and enhance the habitat of migratory birds, (3) prevent or abate the pollution or detrimental alteration of the environment for the benefit of migratory birds, (4) incorporate migratory bird habitat and population conservation measures, principles, and practices into their agency activities and planning efforts, and (5) minimize the intentional and unintentional take of species of concern during the conduct of agency actions. A number of other measures to promote the protection and conservation of migratory bird resources are also directed under the order.

Compliance: If actions implemented under the selected alternative are determined to have measurable negative effects on migratory birds, Reclamation will develop and implement an appropriate Memorandum of Understanding with the Service as prescribed in the order.

L2.9 Marine Mammal Protection Act (16 United States Code 1361-1407)

In 1972, the Marine Mammal Protection Act was passed by the U.S. Congress to protect the many mammals that live in the world's oceans. This legislation is the basis for policies preventing the harassment, capture, injury, or killing of all species of whales, dolphins, seals, and sea lions, as well as walruses, manatees, dugongs, sea otters, and polar bears.

The law sets up a management regime to reduce marine mammal mortalities and injuries in their interactions with fisheries (gear entanglement, etc.); regulates scientific research in the wild; establishes basic requirements for public display of captive marine mammals; addresses issues specific to the tuna fishery in the eastern tropical Pacific Ocean where dolphins associate with tuna and are harassed, injured, and sometimes killed by fishing practices there; creates a management regime for native subsistence hunting of marine mammals in Alaska; and regulates the import and export of marine mammals and their products.

The primary government agency responsible for enforcing this act is NOAA Fisheries. Under this act, NOAA Fisheries is responsible for the management and conservation of whales and dolphins (cetaceans) and pinnipeds other than the walrus. Walruses, manatees and dugongs (sirenians), sea otters, and polar bears are under the jurisdiction of the Service.

This act underwent some significant changes in its 1994 amendments, especially with respect to switching the emphasis on pinnipeds from protection to management.

Compliance: No marine mammals would be affected by the Ocean Disposal Alternative or other action alternatives.

L3 Disposal/Discharge-Related Requirements, Permits, and/or Approvals

Both the Federal and State governments have enacted disposal/discharge-related legislation and requirements to ensure that projects do not needlessly harm the environment. The major legislative requirements applicable to the alternatives under consideration are discussed below. Reclamation will commit to compliance with applicable Federal, State, and local legislation, requirements, permits, and approvals.

L3.1 Clean Water Act

The Clean Water Act (CWA) gave the U.S. Environmental Protection Agency (EPA) the authority to develop a program to make all waters of the United States “fishable and swimmable.” The CWA has an antidegradation policy imposed by the EPA. Except under certain specified conditions, States must maintain levels of water quality established in 1977. This program has included identifying existing and proposed beneficial uses and methods to protect and/or restore those beneficial uses. In California, the EPA has designated planning and permitting authority to the California Environmental Protection Agency, which is comprised of the State Water Resources Control Board (State Board) and nine Regional Water Quality Control Boards (Regional Boards).

The CWA contains many provisions, including provisions that regulate the discharge of pollutants into waterbodies. The discharges may be direct flows from point sources, such as an effluent from a wastewater treatment plant, or a nonpoint source, such as eroded soil particles from a construction site. Numerous provisions could affect implementation of the proposed project. The following focuses on the main provisions that require compliance.

Every 2 years, the State Board submits a report on the State’s water quality to the EPA pursuant to CWA Section 305(b). The report provides water quality information to the general public and serves as the basis for the EPA’s National Water quality Inventory Report to Congress. Section 303(d) requires States to develop a list of waterbodies that, after application of technology-based effluent controls, will not achieve water quality objectives and to develop a prioritization schedule for conducting total maximum daily load studies to allocate pollutant discharges from each source such that water quality objectives will be achieved. This list is included in the Section 305(b) report. The Section 303(d) list identifies impaired waterbodies and sources of contamination, such as mine drainage, agricultural drainage, urban and industrial runoff, and municipal and industrial wastewater discharges for each contaminant. In California, the EPA has designated planning and permitting authority to the California Environmental Protection Agency, which is comprised of the State Board and nine Regional Boards. The State Board is responsible for the triennial review process and for developing the Section 303(d) list. In May 2003, the EPA approved a new Section 303(d) list submitted by the State Board that includes 685 surface waters that are currently listed as not meeting water quality standards.

The EPA also has developed the National Guidance on Water Quality Criteria under Section 304 (a) for pollutants to protect human health and aquatic life. Relevant pollutants are identified under Section 307 of the CWA.

Under Section 401, the State Board, acting for the EPA, certifies that Federally licensed or funded projects are consistent with maintenance or attainment of water quality standards. The need for Section 401 certification is required for Section 404 permits (as well as Rivers and Harbors Act Section 10 permits) and will need to be determined on a site-specific basis. Section 404 identifies conditions under which a regulatory permit is required for activities that result in the placement of dredged or fill materials into waters of the United States (which includes wetlands). The U.S. Army Corps of Engineers (USACE) administers the regulatory program. Section 401 water quality certification will be requested from the applicable Regional Board for Section 404/Section 10 activities, and other regulated activities (unless water quality certification has been waived, i.e., applicable primarily to Section 404/Section 10 general or nationwide permits, or otherwise determined not to be required). If certification is issued or waived, the State would certify that the proposed work would not violate State water quality standards.

Section 402 regulates discharges of any pollutant, or combination of pollutants, notwithstanding Section 301 (a), upon condition that such discharge will meet all applicable requirements under Sections 301, 302, 307, 308, and 403. Stormwater discharges from construction activities and discharges of wastewaters are regulated by this section of the CWA. The applicable Regional Board regulates this section of the CWA. Section 402 (l)(1) excludes permit requirements under Section 402 for discharges composed entirely of return flows from irrigated agriculture except as provided in Section 307 for a toxic pollutant injurious to human health. The Delta and Ocean Disposal Alternatives will need to apply for and obtain a National Pollution Discharge Elimination System (NPDES) permit in compliance with CWA Section 402. The State Board has been designated in the Basin Plan for the Central Valley Regional Board as the appropriate permitting agency for Delta discharge alternatives. Discharges to the ocean would be regulated either by the State Board or by the Central Coast Regional Board. In either case, the discharge permits will be in compliance with the requirements of Section 402.

Stormwater discharges from construction activities involving a total of 1 acre of disturbed land must be authorized by a Section 402 NPDES general permit. Reclamation will require that a Stormwater Pollution Prevention Plan (SWPPP) be developed, and implemented that specifies best management practices (BMPs) that will prevent all construction pollutants from contacting stormwater and address measures that will control erosion and keep sediment from moving off site into receiving waters. A Notice of Intent to utilize the NPDES General Permit for Stormwater Discharges Associated with Construction Activity (Water Quality Order 99-08-DWQ) and a site map showing the proposed activities and control measures will be submitted to the State Board to comply with the filing requirements for the General Permit. In addition, a SWPPP will be developed and maintained on site prior to construction. The SWPPP will be available at all construction sites during construction and available to contractors and representatives of the State Board or local agencies.

The SWPPP will include (1) the identification of pollutant sources that may affect the quality of stormwater associated with construction activity, (2) the identification of stormwater pollution prevention measures and BMPs that would be utilized to reduce pollutants in stormwater discharges during and after construction, and (3) a list of responsible parties. Therefore, the SWPPP will include a description of potential pollutants to stormwater from erosion, management of any dredged sediments, and any hazardous materials that may be on site during construction (including vehicle and equipment fuels). The SWPPP will also include details of how sediment and erosion control practices outlined above would be implemented.

Regulation of wastewaters would require either a separate Federal or State permit (called Waste Discharge Requirements). The applicable Regional Board could, however, waive regulation for those activities where no effect on water quality is expected. A Waste Discharge Requirements permit/waiver will be requested from the applicable Regional Board for dewatering and depressurization activities. If issued or waived, the State will certify that the proposed work will not violate State water quality standards.

Section 403 addresses ocean discharge criteria. No permit under Section 402 for a discharge into the territorial sea, the waters of the contiguous zone, or the oceans will be issued, after promulgation of guidelines established under Subsection (c) of this section, except in compliance with such guidelines.

Reclamation will make application to the USACE for CWA Section 404 authorization for activities that are regulated by the USACE and will result in the deposition of dredged or fill materials into waters of the United States. Either an individual, general, or nationwide permit may apply, depending on the ultimate parameters of the proposed project. If the proposed work can be accomplished under a general or nationwide permit, it will be prosecuted pursuant to the general or nationwide permit conditions and BMPs applicable at the time of authorization. If an individual permit is required, a public notice is generally issued by the USACE requesting public comment on the proposed action (but this requirement may be foregone due to the extensive public involvement effort that has been conducted for this project). After the close of the public notice comment period, all comments received would be forwarded to Reclamation for response. The USACE would ultimately prepare a “finding of fact” and make a determination whether to issue a permit, with or without special conditions, for the proposed work.

L3.2 Rivers and Harbors Act of 1899

Section 10 of the Rivers and Harbors Act of 1899, as amended, prohibits the unauthorized obstruction or alteration of any navigable water of the United States without authorization by the USACE. Such activity requires a permit from the USACE.

L3.3 Safe Drinking Water Act

The Safe Drinking Water Act (Public Law 99-339) became law in 1974 and was reauthorized in 1986 and again in August 1996. Through this act, the United States Congress gave the EPA the authority to set standards for contaminants in drinking water supplies. Amendments to this act provide more flexibility, more State responsibility, and more problem prevention approaches. The law changes the standard-setting procedure for drinking water and establishes a State Revolving Loan Fund to help public water systems improve their facilities and to ensure compliance with drinking water regulations and to support State drinking water program activities.

Under the provisions of this act, the California Department of Health Services (DHS) has the primary enforcement responsibility. The California Health and Safety Code establishes this authority and stipulates drinking water quality and monitoring standards. To maintain primacy, a State's drinking water regulations cannot be less stringent than the Federal standards.

L3.4 Underground Injection Control Program

The Underground Injection Control (UIC) Program, part of the Safe Drinking Water Act, provides the Federal authority for regulating deep-well injection. This program establishes a scheme for the regulation of public drinking water systems and sets minimum standards for drinking water supplies. The UIC Program utilizes the very complex operating, tracking, and monitoring requirements set up under the Federal hazardous waste statutes. Disposal of hazardous waste into an injection well generally requires compliance with both the Federal and State regulatory schemes: compliance with the UIC Program, including Federal operating permit, a hazardous waste facilities permit from the DHS, and submission of a hydrological assessment report to the DHS and the Regional Board.

L3.5 Resource Conservation and Recovery Act

The Resource Conservation and Recovery Act (RCRA) applies to agricultural operations, and, in general, comprehensively regulates the design and operation of surface impoundments. It regulates hazardous waste and the generation, transportation, treatment, storage, and disposal of that waste. It excludes from its hazardous waste regulations "irrigation return flows." To the extent that the RCRA does apply to subsurface drainwater, the concentrations of toxins found in the Central Valley's drainwater already exceed or are approaching the threshold levels that would subject evaporation basins to the highly complex standards for design and operation, and that may subject the growers to the rather onerous controls that apply to "generators" or "transporters" of hazardous waste. These controls include, primarily, requirements to test and monitor the waste stream.

L3.6 California Porter-Cologne Water Quality Act

The Porter-Cologne Water Quality Act provides a comprehensive water quality control scheme that is administered by the State Board and the Regional Board. The jurisdiction of this act extends to all "waters of the State," including surface and subsurface waters, and saline waters. Unlike the CWA, the Porter-Cologne Act does not exclude irrigation return flows from its purview. The State Board establishes policy guidelines while the Regional Boards adopt Water Quality Control Plans (Basin Plans) and develop waste discharge limitations as necessary to protect beneficial uses.

This act requires anyone discharging or proposing to discharge waste within any region of the State to file a report with the Regional Board describing the action taken and to comply with such other requirements as established by the regional Basin Plans. The Regional Boards have promulgated requirements for discharges to their respective waterways for the major aggravating constituents in agricultural drainwater to comply with the provisions of the CWA. The criteria can be numerical or based upon biological assessment methods, for all priority pollutants for which the EPA has published criteria under Section 304(a) of the CWA. The Regional Boards must also comply with the CWA antidegradation policy, which requires the Regional Boards to, at a minimum, (1) maintain whatever water quality is necessary to protect existing instream uses and (2) preserve the quality of waters that exceed levels necessary to support the propagation of fish, wildlife, and recreation.

The serious problem associated with ponding drainwater laden with high concentrations of selenium and arsenic is, if that if they are high enough to meet the hazardous waste threshold, then they are subject not only to the Regional Board requirements but also to the more stringent requirements established under the Hazardous Waste Management Act administered by the DHS.

The real regulatory problem with the disposal of hazardous drainage centers around the Federal policy of treating surface impoundments as the “least favored method” of disposal and the State statutory policy of generally prohibiting the development of new hazardous waste impoundments. The State Hazardous Waste Management Act prohibits the disposal of hazardous agricultural drainwater in evaporation basins beyond 1990 unless it is treated. Drainwater is not deemed to be treated if it contains any persistent or biocumulative toxic substances in excess of the DHS soluble threshold limit concentrations.

L3.7 California Toxic Pits Control Act

The Toxic Pits Control Act was enacted to prevent environmental contamination from leaking waste impoundments. It prohibits the discharge of liquid hazardous wastes into an evaporation basin if the basin or the land beneath it already contains hazardous wastes <u>and</u> the basin is within ½ mile upgradient from a <u>potential</u> source of drinking water. The discharge of hazardous drainwater to evaporation basins located in other areas may be permitted after submission of a hydrogeologic assessment report to the DHS and the Regional Board, and compliance with this act’s many design, operation, and maintenance regulations, including the use of double liners and leachate collection systems and the monitoring of groundwater. The drainwater ponded may not contain selenium, arsenic, or other bioaccumulative constituents in excess of the DHS soluble threshold limit concentrations.

L3.8 California Hazardous Waste Control Act

The Hazardous Waste Control Act is the State’s counterpart to the Federal RCRA statute. It comprehensively regulates “hazardous” waste.

L3.9 California Hazardous Waste Management Act

The Hazardous Waste Management Act of 1986, an amendment to the Hazardous Waste Control Act, is significant in that it generally prohibits land disposal of liquid wastes and hazardous wastes after 1990, except for “treated” hazardous waste or solid waste generated in the cleanup of a contaminated site. This act prohibits the land disposal of hazardous waste beyond May 8, 1990, unless it is treated. Thus, unless “treated” or excepted by another provision, an agricultural waste discharge will have to comply with the exemption criteria of this act.

L3.10 California Toxic Injection Well Control Act

The State has authority to regulate the deep-well injection of hazardous waste under the Toxic Injection Well Control Act and the Hazardous Waste Management Act. The Toxic Pits Control Act is inapplicable here as it only attempts to regulate surface impoundments. Both this act and the Hazardous Waste Management Act recognize the increased occasion of contaminant migration from land treatment facilities, such as injection wells, and, therefore, provide authority for State regulation.

L3.11 Federal and State Deep-Well Injection Regulations

Injection wells are regulated by the EPA, DHS, and Regional Board. The Federal regulatory authority is extensive and very complex. Certain wells are subject to EPA's UIC Program, while others are subject to the State's regulatory scheme. Some wells are subject to both the Federal and State requirements. Both regulatory schemes require permits for construction of a well and include a complex set of criteria and rules for operation. The Federal UIC Program utilizes the very complex operating, tracking, and monitoring requirements set up under the Federal hazardous waste statutes.

Disposal of hazardous waste into an injection well generally requires compliance with both the Federal and State regulatory schemes: compliance with the Federal UIC Program, including Federal operating permit, a hazardous waste facilities permit from the DHS, and submission of a hydrological assessment report to the DHS and the Regional Board.

L3.12 California Water Conservation and Water Bond Laws

The Water Conservation and Water Quality Bond Law of 1986 was passed to provide funds for the construction of "cost effective containment structures and treatment facilities for the treatment, storage and disposal of agricultural drainage water". The fund was established to provide monies to assist local agencies in their water conservation programs and "to aid in the construction of drainage water management units for the treatment, storage, or disposal of agricultural drainage water …." The term "drainage water management units" includes treatment facilities to remove or substantially reduce the level of constituents that pollute or threaten to pollute State waters, evaporation basins, and injection wells.

Other State bond laws working on similar principles are the Clean Water Bond Laws of 1970, 1974, 1984, and the State Water Pollution Control Revolving Fund; Clean Water and Conservation Bond Law of 1978; and Department of Water Resources and State Board Loans for Recharge and Irrigation Drainage.

L3.13 Surface Water Rights and Compliance

Applies to all projects that involve any change to surface water rights and/or existing diversions.

L3.14 Groundwater Rights and Management and Compliance

Actions may be subject to a county ordinance, approval by a local agency or district, or the terms of judicial adjudication, if they involve: (1) the use, replenishment, transfer, or sale of groundwater; (2) the use of a groundwater basin for storage; or, (3) the construction, abandonment, or destruction of a well.

L4 Bay/Delta/Coastal Requirements, Permits, and/or Approvals

Both the Federal and State governments have enacted legislation and requirements to ensure that projects do not needlessly harm Bay/Delta/coastal resources. Major legislative requirements applicable to the alternatives under consideration in this EIS are discussed below.

L4.1 Coastal Zone Management Act and Coastal Zone Act Reauthorization Amendments of 1990

The Coastal Zone Management Act and the Coastal Zone Reauthorization Act Amendments of 1990 make Federal funds available to encourage States to develop comprehensive management programs in an effort to increase the effective management, beneficial use, protection, and development of the coastal zone. These acts apply to all actions that are located within a designated coastal zone. Sections 307(c)(1) and (2) state that any Federal agency whose activities directly affect the coastal zone will, to the maximum extent practicable, be consistent with approved State management programs. In other words, Federal actions must conform to the requirements of State-approved programs.

Thus, any applicant seeking a permit or license to conduct an activity affecting land and water uses in a State's coastal zone must certify to the Federal permit or licensing agency that the activity will be conducted in a manner consistent with the State-approved program.

L4.2 California Coastal Commission

The California Coastal Commission was established by voter initiative in 1972 (Proposition 20) and made permanent by the Legislature in 1976 (the Coastal Act). The primary mission of the Commission, as the lead agency responsible for carrying out California's Federally approved coastal management program, is to plan for and regulate land and water uses in the coastal zone consistent with the policies of the Coastal Act.

The Commission is one of California's two designated coastal management agencies for the purpose of administering the Federal Coastal Zone Management Act in California. The most significant provisions of this Federal act give State coastal management agencies regulatory control (Federal consistency review authority) over all Federal activities and Federally licensed, permitted or assisted activities, wherever they may occur (i.e., landward or seaward of the respective coastal zone boundaries fixed under State law) if the activity affects coastal resources. Examples of such Federal activities include outer continental shelf oil and gas leasing, exploration, and development; designation of dredge material disposal sites in the ocean; military projects at coastal locations; CWA Section 404 permits; certain Service permits; National Park projects; highway improvement projects assisted with Federal funds; and commercial space launch projects on Federal lands. Federal consistency is an extremely important coastal management tool because it is often the only review authority over Federal activities affecting coastal resources given to any State agency. The San Francisco Bay Conservation and Development Commission has this authority within San Francisco Bay, while the Coastal Commission exercises this authority relative to the rest of California's coastal zone.

Either commission's jurisdiction in the coastal zone (which is specifically mapped) is broad and applies to all private and public entities and covers virtually all manner of development activities, including any division of land, a change in the intensity of use of State waters and of public access to them. The Coastal Act includes specific policies (see Division 20 of the Public Resources Code) relating to public access and recreation, lower cost visitor accommodations, terrestrial and marine habitat protection, visual resources, landform alteration, agricultural lands, commercial fisheries, industrial uses, water quality, offshore oil and gas development, transportation, development design, power plants, ports, universities, and public works. These policies constitute the statutory standards applied to planning and regulatory decisions pursuant to the Coastal Act.

L4.3 San Francisco Bay Conservation and Development Commission

The San Francisco Bay Conservation and Development Commission regulates all filling and dredging in San Francisco Bay (which includes San Pablo and Suisun bays, sloughs, and certain creeks and tributaries that are part of the Bay system, salt ponds and certain other areas that have been diked off from the Bay). It provides protection to Suisun Marsh, the largest remaining wetland in California, by administering the Suisun Marsh Preservation Act in cooperation with local governments. It regulates new development within the first 100 feet inland from the Bay to ensure that maximum feasible public access to the Bay is provided. It minimizes pressures to fill the Bay by ensuring that the limited amount of shoreline area suitable for high priority water-oriented uses is reserved for ports, water-related industries, water-oriented recreation, airports, and wildlife areas. The Commission pursues an active planning program to study Bay issues so that Commission plans and policies are based upon the best available current information. It administers the Federal Coastal Zone Management Act within the San Francisco Bay segment of the California coastal zone to ensure that Federal activities reflect Commission policies. It participates in the regionwide State and Federal program to prepare a Long Term Management Strategy for dredging and dredge material disposal in San Francisco Bay. It participates in California's oil spill prevention and response planning program.

L5 Land Use and Regional, County, and Local Requirements, Permits, and/or Approvals

Both the Federal and State governments have enacted land use and regional, county, and local legislation and requirements to ensure that projects do not needlessly harm the environment. These major requirements are discussed below.

L5.1 California State Lands Commission Lease and Permit

A real estate lease or permit may be required from the California State Lands Commission for placement of project facilities on State lands.

L5.2 California Department of Transportation Encroachment Permit

A California Department of Transportation encroachment permit would be required for any project that would include an area within, under, or over a State highway right-of-way, including opening or excavating a State roadway for any purpose; placing, changing, or renewing an encroachment; planting or tampering with vegetation growing along any State roadway; constructing and maintaining road approaches or connections to the right-of-way on any State roadway; and conducting any activity that affects the use of the roadway.

L5.3 California County Permits

Conceptual plans will be submitted to appropriate California county Building and Planning Departments, who will, in turn, determine if planning, building, or electrical permits for the project are required. In addition, Land Division approval may be required by the counties.

Local regulatory compliance would include actions that involve earthmoving activities including those that involve changes to gravel mining practices, activities within local road right-of-ways, building of a structure or significant modification or renovation of an existing structure, and construction inconsistent with local land use designations. These actions include the following:

- Grading Permits
- Encroachment Permits
- Building Permits
- Special Use or Conditional Use Permits
- Subdivision Map Approval
- Specific Plan Approval
- Zoning Ordinance Approval
- Surface Mining and Reclamation Act Compliance
- Williamson Act Compliance

L5.4 Levee District Permits

Levee district permits may be required for project work.

L5.5 Reclamation Board Encroachment Permit

Applies to actions that would include (1) the placement, construction, reconstruction, removal, or abandonment of any landscaping, culvert, bridge, conduit, fence, projection, fill, embankment, building, structure, obstruction, or encroachment within an area under the jurisdiction of the Reclamation Board, including designated floodways, project levees and areas between levees, and streams within the Central Valley; or (2) work of any kind within an area with an adopted flood control plan.

L5.6 State, Areawide, and Local Plan and Program Consistency

Agencies must consider the consistency of a proposed action with approved State and local plans and laws. Given the extremely large number of State and local jurisdictions within the project area, not all of the individual plans and laws were reviewed. In accordance with Executive Order 12372, the environmental documents are being prepared with input from the Cooperating

Agencies and Consulting Agencies. During the NEPA and CEQA review periods, the environmental documents will be circulated to the appropriate State agencies and to the State Clearinghouse to satisfy review and consultation requirements.

L5.7 Coordination with Related Federal, State, and Local Programs

Reclamation will conduct a formal coordination process to identify other programs that could significantly affect the assumptions, implementation, or effectiveness of the proposed project. In addition, Reclamation will actively include interested or affected parties or programs as part of its Public Involvement Program for the proposed project. Programs will include the following:

- The Westside Integrated Resources Plan
- Various Central Valley Project Yield Improvement studies
- Land retirement studies and implementation
- San Joaquin Valley Drainage Implementation Program
- Grassland Bypass Project and related studies

L5.8 San Joaquin Valley Air Pollution Control District Conservation Management Plans

Current rulemaking in the San Joaquin Valley Air Pollution Control District requires owners and operators of agricultural operations in the San Joaquin Valley to develop and implement Conservation Management Practice plans to reduce particulate matter less than 10 microns in diameter fugitive dust from on-farm sources such as unpaved roads and equipment yards, land preparation, harvest activities, and other cultural practices. Examples of the practices required under this program include activities that reduce or eliminate the need to move or disturb the soil, protect the soil from wind erosion, equipment modifications, application of dust suppressants, speed reductions and unpaved roads, alternatives to burning brush/prunings, and activities that reduce chemical applications.

Compliance: Implementation of San Joaquin Valley Air Pollution Control District Rule 4550 Conservation Management Practices by agricultural operations, as discussed in Section 11.2.11, reduces the potential for cumulative effects to air quality.

L6 Additional Environmental Legislation and Requirements

During the NEPA and CEQA environmental documentation process, the following additional environmental legislation and/or requirements will also be addressed.

L6.1 Central Valley Project Improvement Act

This act amends the previous authorizations of the California Central Valley Project to include fish and wildlife protection, restoration, and mitigation as project purposes having equal priority with irrigation and domestic uses and fish and wildlife enhancement as a project purpose equal to power generation. Section 3406(b) directs the Secretary to develop and implement a program to ensure that natural production of anadromous fish in Central Valley rivers and streams will be sustainable, and authorizes acquisition of a water supply to supplement the quantity of water dedicated to fish and wildlife purposes utilizing the following options:

- Improvements in or modifications of the operations of the project
- Water banking
- Conservation
- Transfers
- Conjunctive use
- Temporary and permanent land fallowing

Section 3408 (j) directs the Secretary to submit a plan to increase the yield of the Central Valley Project by the amount dedicated to fish and wildlife purposes, using the following options:

- Improvements in, modification of, or additions to the facilities and operations of the project
- Conservation
- Transfers
- Conjunctive use
- Purchase of water
- Purchase and idling of agricultural land
- Direct purchase of water rights

Compliance: Each of the action alternatives includes some amount of drainwater recycling (conservation) and permanent agricultural land retirement.

L6.2 Clean Air Act

The Clean Air Act, as amended, requires that any Federal entity engaged in an activity that may result in the discharge of air pollutants must comply with all applicable air pollution control laws and regulations (Federal, State, or local).

Compliance: Construction-related effects on air quality would be mitigated (see Section 11.2.11), and the design and operation of the treatment facilities evaporation basins for the In-Valley Disposal Alternatives would avoid emissions.

L6.3 National Historic Preservation Act of 1966

Section 106 of the National Historic Preservation Act requires that Federal agencies evaluate the effects of Federal undertakings on historical, archeological, and cultural resources and afford the Advisory Council on Historic Preservation and State Historic Preservation Officer opportunities to comment on the proposed undertaking. The first step in the process is to identify cultural resources included on (or eligible for inclusion on) the National Register of Historic Places that are located in or near the project area. The second step is to identify the possible effects of proposed actions.

Compliance: Reclamation will examine whether feasible alternatives exist that would avoid such effects. If an effect cannot reasonably be avoided, measures could be taken to minimize or mitigate potential adverse effects.

L6.4 Wild and Scenic Rivers Act of 1968

The Wild and Scenic Rivers Act designates qualifying free-flowing river segments as wild, scenic, or recreational. This act establishes requirements applicable to water resource projects affecting wild, scenic, or recreational rivers within the National Wild and Scenic Rivers System, as well as rivers designated on the National Rivers Inventory. Under this act, a Federal agency may not assist the construction of a water resources project that would have a direct and adverse effect on the free-flowing, scenic, and natural values of a wild or scenic river. If the project would affect the free-flowing characteristics of a designated river or unreasonably diminish the scenic, recreational, and fish and wildlife values present in the area, such activities should be undertaken in a manner that would minimize adverse effects and should be developed in consultation with the appropriate Federal agency having administrative responsibility (e.g., National Park Service).

Compliance: None of the alternative features would affect any rivers that are designated as wild, scenic, or recreational.

L6.5 California Wild and Scenic Rivers Act

The California Wild and Scenic Rivers Act is similar to the Federal Wild and Scenic Rivers Act and it applies to projects that are located on a California-designated wild and scenic river.

Compliance: None of the alternative features would affect any rivers that are California-designated as wild, scenic, or recreational.

L6.6 Wilderness Act of 1964, as Amended

The Wilderness Act establishes requirements applicable to water resource projects affecting designated wilderness. Under this act, a Federal agency may not assist the construction of a water resources project that would have a direct and adverse effect on designated wilderness. If the project would affect a designated wilderness or unreasonably diminish the scenic, recreational, and fish and wildlife values present in the area, such activities should be undertaken in a manner that would minimize adverse effects and should be developed in consultation with the appropriate Federal agency having administrative responsibility (e.g., National Park Service, U.S. Forest Service, U.S. Fish and Wildlife Service, etc.).

Compliance: None of the alternative features would affect any designated wilderness areas or unreasonably diminish the scenic recreational, and fish and wildlife values present in the area.

L6.7 Federal Water Project Recreation Act

Section 4(f) of the Federal Water Project Recreation Act establishes requirements applicable to water resource projects affecting Section 4(f) lands. Under this act, a Federal agency may not assist the construction of a water resources project that would have a direct and adverse effect on

Section 4(f) lands. If the project would affect these lands or unreasonably diminish the scenic, recreational, and fish and wildlife values present in the area, such activities should be undertaken in a manner that would minimize adverse effects and should be developed in consultation with the appropriate Federal agency having administrative responsibility (e.g., National Park Service).

Compliance: The evaporation basins for the In-Valley Disposal Alternatives would be located and designed to discourage wildlife use. Potential mitigation areas would encourage wildlife use and could provide recreational value.

L6.8 Executive Order 11988, Floodplain Management

If a Federal agency program will affect a floodplain, the agency must consider alternatives to avoid adverse effects in the floodplain or to minimize potential harm. Executive Order 11988 requires Federal agencies to evaluate the potential effects of any actions they might take in a floodplain and to ensure that planning, programs, and budget requests reflect consideration of flood hazards and floodplain management.

Compliance: The design and location of the alternatives would take into consideration flood hazards and floodplain management.

L6.9 Executive Order 12898, Environmental Justice

Executive Order 12898 requires each Federal agency to achieve environmental justice as part of its mission, by identifying and addressing disproportionately high and adverse human health or environmental effects, including social and economic effects, of its programs, policies, and activities on minority populations and low-income populations of the United States.

There are no significant adverse effects to environmental justice from the action alternatives.

L6.10 Indian Trust Assets

The United States Government's trust responsibility for Indian resources requires Reclamation and other agencies to take measures to protect and maintain trust resources. These responsibilities include taking reasonable actions to preserve and restore tribal resources. Indian Trust Assets are legal interests in property and rights held in trust by the United States for Indian tribes or individuals. Indian reservations, rancherias, and allotments are common Indian Trust Assets.

Compliance: The alternative alignments would be further than 8 miles from the nearest Indian rancheria. Reclamation will continue to review any changes in the alternative alignments throughout the planning process to determine whether consultation would be necessary in the future.

L6.11 Executive Order 13007 (Indian Sacred Sites on Federal Land)

Executive Order 13007 provides that in managing Federal lands, each Federal agency with statutory or administrative responsibility for management of Federal lands will, to the extent practicable and as permitted by law, accommodate access to and ceremonial use of Indian sacred sites by Indian religious practitioners, and avoid adversely affecting the physical integrity of such sacred sites.

Compliance: Reclamation would, to the extent practicable and as permitted by law, allow access to and ceremonial use of Indian sacred sites.

L6.12 American Indian Religious Freedom Act

The American Indian Religious Freedom Act applies to all actions that are located on Federal land, sponsored by a Federal agency, or funded with Federal monies; and that could involve adverse effects on the observance of traditional Native American Religions.

Compliance: The alternatives would not involve adverse effects on the observance of traditional Native American religions.

L6.13 Farmland Protection Policy Act and Farmland Preservation

Two policies require Federal agencies to include assessments of the potential effects of a project on prime and unique farmland. These policies are the Farmland Protection Policy Act of 1981, and the Memoranda on Farmland Preservation, dated August 30, 1976, and August 11, 1980, respectively, from the President's Council on Environmental Quality. Under requirements set forth in these policies, Federal agencies must determine these effects before taking any action that could result in converting designated prime or unique farmland for nonagricultural purposes. If implementing a project would adversely affect farmland preservation, the agencies must consider alternatives to lessen those effects. Federal agencies also must ensure that their programs, to the extent practicable, are compatible with State, local, and private programs to protect farmland. The Natural Resources Conservation Service is the Federal agency responsible for ensuring that these laws and polices are followed.

Compliance: Two of the In-Valley Disposal Alternatives (the In-Valley Disposal and In-Valley/Groundwater Quality Land Retirement Alternatives) would increase the productivity of project land meeting the criteria for Prime Farmland. However, the In-Valley/Water Needs Land Retirement and In-Valley/Drainage-Impaired Area Land Retirement Alternatives would remove large acreages from irrigated production and would not be in compliance with the Farmland Protection Policy Act and Farmland Preservation. The Out-of-Valley Disposal Alternatives would not remove lands from irrigated production because they would not include evaporation basins and not incorporate additional land retirement.

L6.14 Earthquake Hazards Reduction Act of 1977 (Public Law 95-124)

In October 1977, Congress passed the Earthquake Hazards Reduction Act (Public Law 95-124) to "reduce the risks to life and property from future earthquakes in the United States through the establishment and maintenance of an effective earthquake hazards reduction program." To accomplish this, this act established the National Earthquake Hazards Reduction Program (NEHRP). This program was significantly amended in November 1990 by the National Earthquake Hazards Reduction Program Act (Public Law 101-614) by refining the description of the agency responsibilities, program goals and objectives.

The four NEHRP agencies are the Federal Emergency Management Agency (FEMA), National Institute of Standards and Technology, National Science Foundation, and United States Geological Survey.

To meet the above goal, NEHRP's mission includes improved understanding, characterization and prediction of hazards and vulnerabilities; improved model building codes and land use practices; risk reduction through post-earthquake investigations and education; development and improvement of design and construction techniques; improved mitigation capacity; and accelerated application of research results. This act designates FEMA as the lead agency of the program, and assigns several planning, coordinating and reporting responsibilities.

Compliance: Facilities would be designed to current building and seismic design codes and should reduce the risk to life and property from future earthquakes.

L6.15 National Earthquake Loss Reduction Program

The National Earthquake Loss Reduction Program (NEP) was formed as a result of the report "Strategy for National Earthquake Loss Reduction" prepared by the Office of Science and Technology Policy in April 1996. The NEP "aims to focus scarce research and development dollars on the most effective means for saving lives and property and limiting the social disruptions from earthquakes, coordinate Federal earthquake mitigation research and development and emergency planning in a number of agencies beyond those in NEHRP to avoid duplication and ensure focus on priority goals, and cooperate with the private sector and with State and local jurisdictions to apply effective mitigation strategies and measures." The NEP does not replace NEHRP, but encompasses a wider range of earthquake hazard reduction activities than those supported by the NEHRP agencies, and provides a framework within which these activities can be more effectively coordinated.

FEMA's earthquake program was established in 1977, under the authority of the Earthquake Hazards Reduction Act of 1977, enacted as Public Law 101-614. FEMA serves as lead agency among the four primary NEHRP Federal partners, responsible for planning and coordinating the Program.

Mitigation involves developing and implementing strategies for reducing losses from earthquakes by incorporating principles of seismic safety into public and private decisions regarding the siting, design, and construction of structures (i.e., updating building and zoning codes and ordinances to enhance seismic safety), and regarding buildings' nonstructural elements, contents and furnishings.

In addition to the above actions, a number of FEMA guidelines cover seismic hazards and design strategies for various types of buildings, including the seismic rehabilitation of existing buildings (FEMA-273 and FEMA-274) and seismic design for both new and existing steel moment buildings (FEMA-350 through FEMA-354).

Compliance: Alternative features would be designed to incorporate the principles of seismic safety into the siting, design, and construction of structures.

L6.16 Executive Order 12699 Seismic Safety of Federal and Federally Assisted or Regulated New Building Construction

The purposes of these requirements are to reduce risks to the lives of occupants of buildings owned by the Federal Government, leased for Federal uses or purchased or constructed with Federal assistance and to persons who would be affected by the failures of Federal buildings in earthquakes, to improve the capability of essential Federal buildings to function during or after an earthquake, and to reduce earthquake losses of public buildings, all in a cost-effective manner. A building means any structure, fully or partially enclosed, used or intended for sheltering persons or property.

Each Federal agency responsible for the design and construction of each new Federal building has to ensure that the building is designed and constructed in accord with appropriate seismic design and construction standards. This requirement pertains to all building projects for which detailed plans and specifications were initiated subsequent to the issuance of the order.

Additionally, each Federal agency responsible for the construction and lease of a new building has to also ensure that the building is designed and constructed in accord with appropriate seismic design and construction standards. Local building codes are used in design and construction and augmented when necessary to achieve appropriate seismic design and construction standards.

According to Office of Management and Budget Circular A-119 of January 17, 1980, entitled “Federal Participation in the Development and Use of Voluntary Standards,” nationally recognized private sector standards and practices will be used unless the responsible agency finds that none is available that meets its requirements. This circular states that design criteria should consider the seismic hazards in various areas of the country, as shown in the most recent edition of the American National Standards Institute Standards A58, Minimum Design Loans for Buildings and Other Structures, or subsequent maps adopted for Federal use. Local building codes determined by the responsible agency or by the Interagency Committee for Seismic Safety in Construction to provide adequately for seismic safety, or special seismic standards and practices required by unique agency mission needs, may be used.

Compliance: Reclamation would ensure that the design and construction of new facilities are in accordance with appropriate seismic design and construction standards.

L6.17 1998 California Building Code

The California Building Code (CBC) contains the minimum standards for design and construction in California. Local standards other than the CBC may be adopted if those standards are stricter. Some design considerations associated with seismic hazards will have to address the appropriate building codes for each location. The CBC involves the standards associated with seismic engineering detailed in the Uniform Building Code of 1997. California has not adopted the Uniform Building Code of 2000.

Compliance: Facilities would be designed to current building and seismic design codes.

L6.18 California Public Resources Code § 25523(a); 20 California Code of Regulations § 1752(b) and (c). 1972 Alquist-Priolo Earthquake Fault Zoning Act (amended 1994)

The Alquist-Priolo Earthquake Fault Zoning Act was passed in 1972 to mitigate the hazard of surface faulting to structures for human occupancy. This State law was a direct result of the 1971 San Fernando Earthquake, which was associated with extensive surface fault ruptures that damaged numerous homes, commercial buildings, and other structures. Surface rupture is the most easily avoided seismic hazard.

This act's main purpose is to prevent the construction of buildings used for human occupancy on the surface trace of active faults. The Act only addresses the hazard of surface fault rupture and is not directed toward other earthquake hazards. The Seismic Hazards Mapping Act, passed in 1990, addresses nonsurface fault rupture earthquake hazards, including liquefaction and seismically induced landslides.

The law requires the State Geologist to establish regulatory zones (known as Earthquake Fault Zones) around the surface traces of active faults and to issue appropriate maps. ("Earthquake Fault Zones" were called "Special Studies Zones" prior to January 1, 1994.) The maps are distributed to all affected cities, counties, and State agencies for their use in planning and controlling new or renewed construction. Local agencies must regulate most development projects within the zones. Projects include all land divisions and most structures for human occupancy. Single family wood-frame and steel-frame dwellings up to two stories not part of a development of four units or more are exempt. However, local agencies can be more restrictive than State law requires.

Before a project can be permitted, cities and counties must require a geologic investigation to demonstrate that proposed buildings will not be constructed across active faults. An evaluation and written report of a specific site must be prepared by a licensed geologist. If an active fault is found, a structure for human occupancy cannot be placed over the trace of the fault and must be set back from the fault (generally 50 feet).

Earthquake Fault Zones are regulatory zones around active faults. The zones are defined by turning points connected by straight lines. Most of the turning points are identified by roads, drainages, and other features on the ground. Earthquake Fault Zones are plotted on topographic maps at a scale of 1 inch equals 2,000 feet. The zones vary in width, but average about one-quarter mile wide.

A fault is a fracture in the crust of the earth along which rocks on one side have moved relative to those on the other side. Most faults are the result of repeated displacements over a long period of time. A fault trace is the line on the earth's surface defining the fault. For the purposes of the Act, an active fault is one that has ruptured in the last 11,000 years.

Effective June 1, 1998, the Natural Hazards Disclosure Act requires that sellers of real property and their agents provide prospective buyers with a "Natural Hazard Disclosure Statement" when the property is being sold lies within one or more state-mapped hazard areas, including Earthquake Fault Zones.

Compliance: A geologic investigation would be conducted prior to construction to ensure that facilities would not be constructed across active faults. If an active fault is to be crossed, facilities could be designed to ensure that they could withstand the seismic hazard.

L6.19 California Public Resources Code Chapter 7.8, 1990 Seismic Hazards Mapping Act

This law addresses shaking, landsliding, and liquefaction hazards. It expands from the surface fault-rupture hazard addressed in the Alquist-Priolo Act to other seismic hazards including shaking, landsliding, and liquefaction. This act requires the State Geologist to prepare seismic hazard maps that cities and counties must then use in preparing their general plan safety elements, and in regulating new development to avoid or mitigate these seismic hazards. The California Geological Survey (formerly the California Division of Mines and Geology) has adopted regulations for the mapping process under 14 California Code of Regulations.

The Seismic Hazards Mapping Act of 1990 allows the lead agency to withhold permits until geologic investigations are conducted and mitigation measures are incorporated into plans. The Seismic Hazards Mapping Act not only addresses seismically induced hazards, but also includes such things as expansive soils, settlement, and slope stability. If required, cities and counties can adopt more stringent criteria and policies as they see fit.

Compliance: Site-specific geotechnical investigations would be required to identify and subsequently mitigate for areas of potential seismic hazards.

L6.20 Historic Structures – California Public Resources Code Section 5028

Enacted following the 1989 Loma Prieta Earthquake, Historic Structures provides that structures listed on the National Register, the California Register, or a local historic register, damaged by an earthquake or other natural disaster, may not be demolished, destroyed, or significantly altered unless the structure presents an imminent threat to public safety or its demolition or alteration has been approved by the State Historic Preservation Officer.

It is important to note that for any Federally assisted project, Section 106 of the National Historic Preservation Act requires Federal review of the project's effects on historic resources and requires that demolitions proposed for reimbursement by FEMA be reviewed for their effect on properties either listed in the National Register or eligible for listing.

Compliance: In the event that an earthquake or other natural disaster damages a structure listed on the National Register, Reclamation would coordinate with appropriate State and Federal agencies prior to demolition.