PANOCHE DRAINAGE DISTRICT
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May 20, 2005

Michael Delamore
US Bureau of Reclamation
1243 N Street
Fresno CA 93721-1813

Subject: San Joaquin River Water Quality Improvement Project, 2004 Wildlife Monitoring Report

Dear Mike:

Enclosed is the 2004 Monitoring Report for the San Joaquin River Water Quality Improvement Project (SJRIP) prepared by H.T. Harvey & Assoc. This is the fourth year of bird egg monitoring at the project site. The number of egg samples has been significantly increased since the monitoring started in 2001 to better characterize the conditions with a larger sample size. Eggs were collected from black-necked stilt, American avocet, killdeer and red-winged blackbird. Except for an anomaly that occurred in 2003, data since monitoring began shows a relative leveling off of selenium levels, as shown in the attached figure. The monitoring is continuing in 2005 for the project.

In 2003, a pasture at the SJRIP was inadvertently flooded from late April through mid-May 2003. This flooding attracted recurvirostrids and caused an increase in the overall geometric mean selenium egg concentrations in the project area for stilts and avocets. Equipment and procedures were put in place to prevent a recurrence of this flooding event, and the 2004 monitoring results indicate that the measures were effective.

As you will note, reference levels for egg selenium concentrations are relatively high in this area and are comparable to the results from the SJRIP Project. Although pre-project background levels are not available, it is likely that such background levels were at or above the current SJRIP levels. This is because prior to the project, the land was not managed to prevent ponding. In addition all of the open drains within the area existed and collected subsurface drainage water, so birds utilizing the area for nesting probably experienced even higher exposure to selenium than under present conditions.

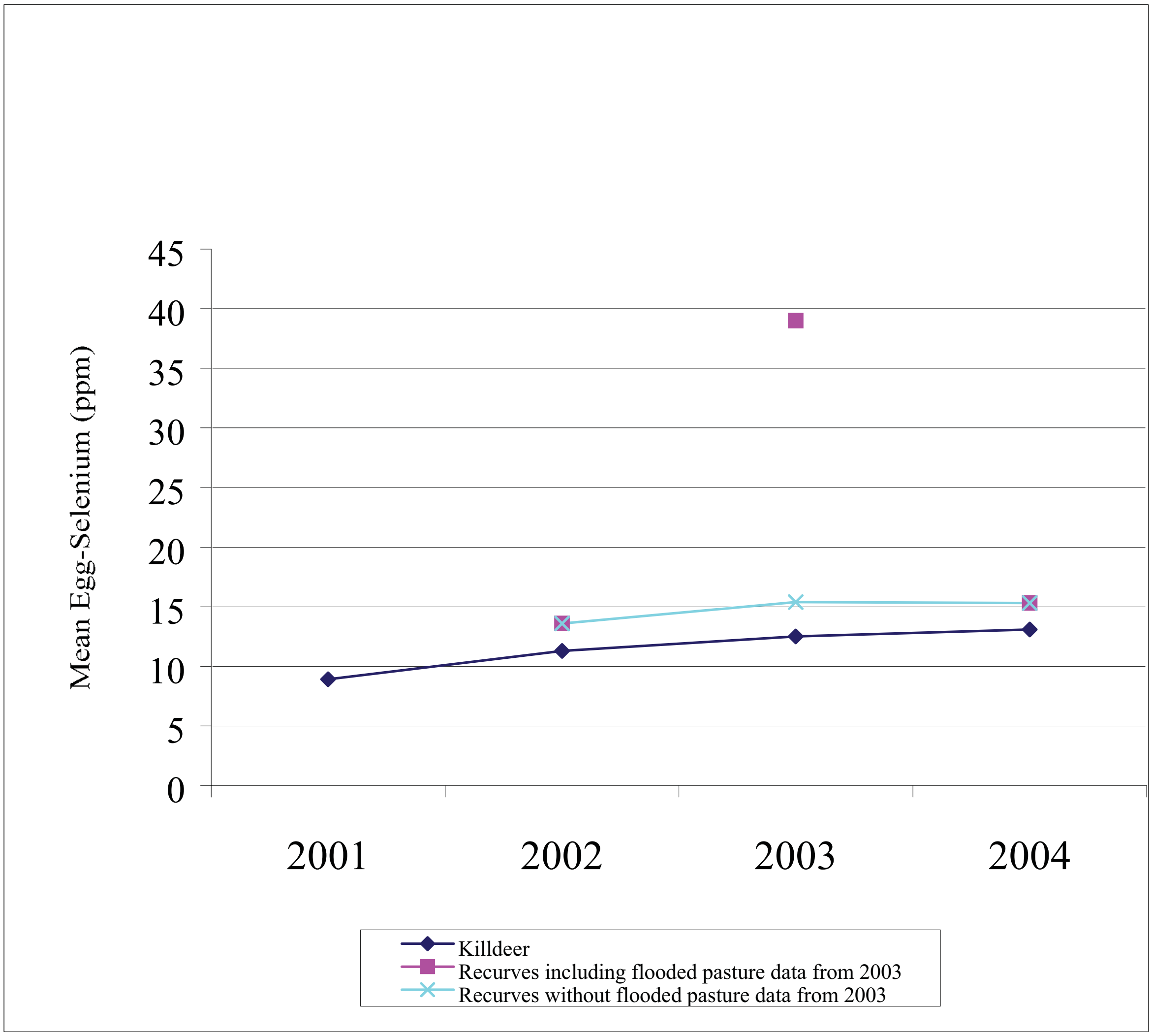
Questions regarding this data should be directed toward Joe McGahan, Drainage Coordinator for the Grassland Bypass Project. He can be reached at 559-582-9237.

Very truly yours,

Dennis Falaschi
General Manager

Cc: Kathy Wood
US Bureau of Reclamation
1243 N Street
Fresno CA 93721-1813

Project Site Mean Egg-Selenium Results at Panoche Drainage District's San Joaquin River Water Quality Improvement Project 2001 to 2004.



SAN JOAQUIN RIVER WATER QUALITY IMPROVEMENT PROJECT, PHASE I WILDLIFE MONITORING REPORT 2004

Prepared by:

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TABLE OF CONTENTS

TABLES:

FIGURES:

EXECUTIVE SUMMARY

The fourth-year biological monitoring results for Phase I of the San Joaquin River Water Quality Improvement Project are presented in this report. The San Joaquin River Water Quality Improvement Project is designed to reduce the amount of salt and selenium delivered to the San Luis Drain and Mud Slough through the Grassland Bypass. At this point in the project, approximately 2,700 acres, of the 4,000-acre project site, have been planted with salt-tolerant crops and irrigated with agricultural drainwater.

An ornithologist from H. T. Harvey & Associates monitored bird use on 2,500 acres of the project site on six occasions from April 23 to June 7, 2004. The diversity of avian species found, and the number of individuals observed, were relatively low for a 2,500-acre site. In addition, the site supported primarily species common in disturbed and ruderal habitats.

H. T. Harvey & Associates' ornithologists collected eggs from the project site for each of three avian species groups including: 15 Killdeer eggs, 17 American Avocet and Black-necked Stilt eggs, and 11 Red-winged Blackbird eggs. The collected eggs were analyzed for selenium and boron concentrations. In addition, 15 Killdeer eggs, 17 eggs from the American Avocet and Black-necked Stilt group, and 11 Red-winged Blackbird eggs were collected from the project vicinity, hereafter referred to as the reference area, to provide data on the local "background" concentrations of selenium and boron.

Nearly all analyzed eggs contained partially-elevated selenium concentrations. The geometric mean egg-selenium concentrations from the project site were: 13.1 ppm for Killdeer, 15.3 ppm for recurvirostrids (Black-necked Stilt and American Avocet combined) and 6.0 ppm for Red-winged Blackbirds. For the reference area, the geometric mean egg-selenium concentrations were 3.5 ppm, 10.8 ppm and 4.2 ppm, respectively. The mean selenium levels in eggs collected from the project site were significantly higher than those from the reference area (t-tests, all $P < 0.001$) for both Killdeer and Red-winged Blackbirds. The mean selenium levels in recurvirostrid eggs collected from the project site were also higher than those from the reference area, but the difference was not statistically significant ($P = 0.2$).

Five of the Killdeer eggs and seven of the recurvirostrid eggs collected at the project site contained egg-selenium concentrations greater than 18 ppm, values associated with a high probability of reproductive effects, including reduced hatchability and increased occurrence of embryo deformities (teratogenesis). Six Killdeer eggs and seven recurvirostrid eggs contained selenium concentrations within the range (8-18 ppm dry wt) associated with increased probability of reduced hatchability.

The boron analysis of eggs collected from the project site revealed that the three avian species groups all had egg boron concentrations at or above the 3 ppm dry weight considered background: Killdeer mean = 3.3 ppm, range = 1.6-5.6 ppm; recurvirostrids mean = 2.8 ppm, range = 1.0-11.3 ppm; and Red-winged Blackbirds mean = 4.3 ppm, range = 2.4-11.7 ppm. The elevated boron content in eggs collected from the project site indicates that boron levels should continue to be monitored.

INTRODUCTION

To reduce the amount of salt and selenium delivered to the San Luis Drain and Mud Slough through the Grassland Bypass Project, the Panoche Drainage District implemented Phase I of the San Joaquin River Water Quality Improvement Project (SJRIP). The Panoche Drainage District, acting as the lead agency under the California Environmental Quality Act (CEQA), prepared a Negative Declaration for SJRIP in September 2000. The Negative Declaration included the provision of a biological monitoring program, to be developed in collaboration with the U. S. Fish and Wildlife Service (the Service), which would detect migratory bird impacts resulting from the project. This report represents the biological monitoring results for the fourth year (2004) of Phase I of the SJRIP.

PROJECT DESCRIPTION AND SETTING

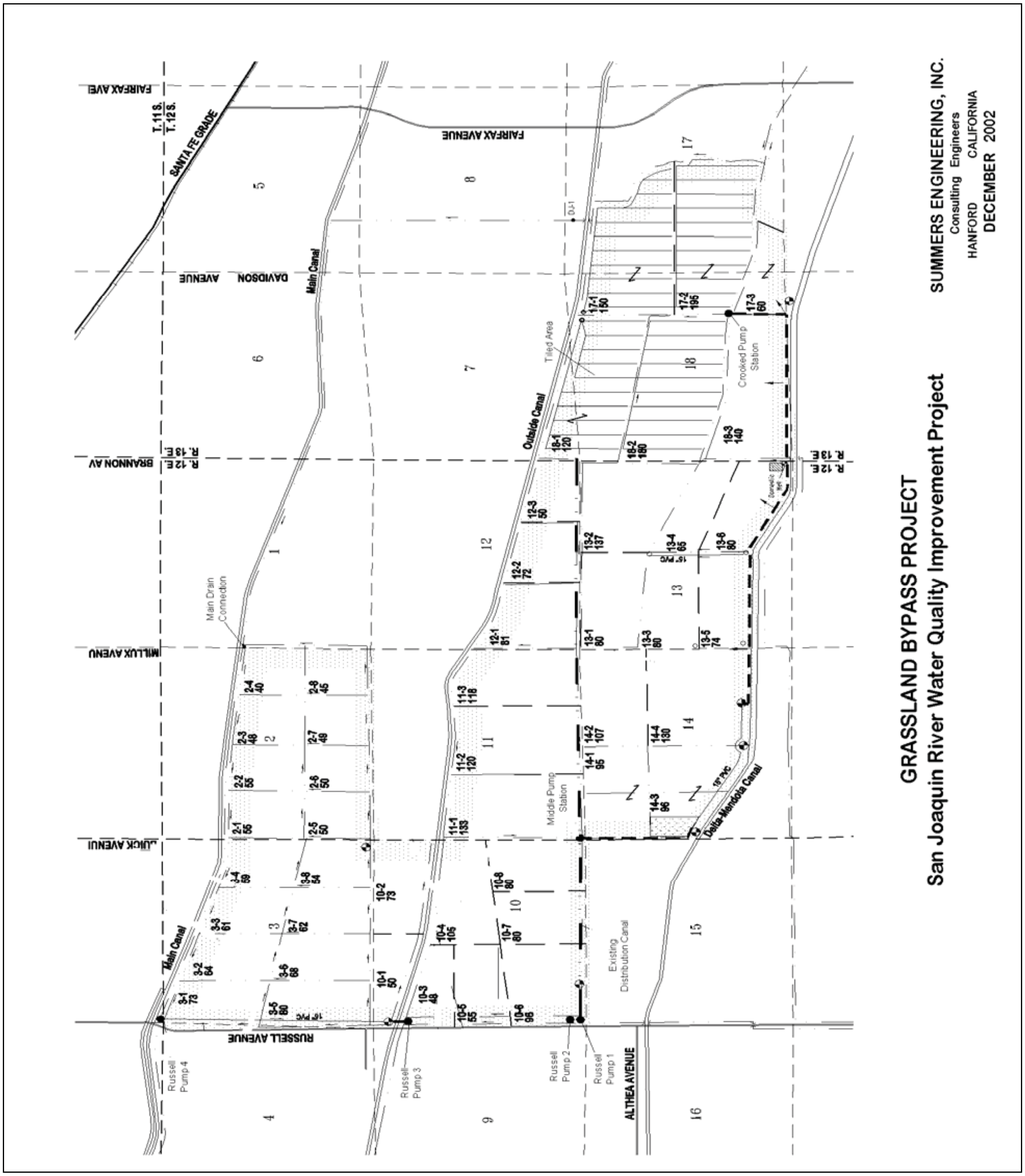
Only a portion of Phase I was put into effect in 2004. Crops were planted on approximately 2,700 of the 4,000 acres obtained by the Panoche Drainage District. The project site is located west of the city of Firebaugh in Fresno County, California. The irregularly shaped project site is bordered on the north by the Main Canal and on the south by the Delta-Mendota Canal. Russell Avenue borders the eastern edge of the project site and the western edge extends nearly to Fairfax Avenue (Figure 1).

The project is the initial development of an In-Valley Treatment/Drainage Reuse Facility on up to 6,200 acres of land within the Grassland Drainage Area (GDA) (Figure 1). The 6,200 acres of GDA land designated for purchase is made up of irrigated field crops and related irrigation ditches, drain ditches, conveyance canals and farm structures. The topography is nearly level to grade and flood/furrow irrigated. The highest elevation is found near the southeast corner at 164 feet above mean sea level, while the lowest point is found near a north-central point at 136 feet above mean sea level. Thus, the elevation change within the 6,200-acre property is approximately 28 feet. The shape of the property is irregular, conforming to the area's adjacent canals. Russell Avenue provides access to the property via a paved county road. Typical, improved farm roads provide access to the interior of the site.

The reuse facility will dedicate specific lands for the irrigation of salt-tolerant crops with subsurface drainwater to reduce drainwater volume; treat the concentrated drainwater to remove salt, selenium and boron; and eventually dispose of the removed elements to prevent discharge into the San Joaquin River. The reuse facility will process up to one-quarter of the total drainwater produced in the GDA (25 percent of 52,000 acre-feet or approximately 15,000 acre-feet) and will be implemented in three phases, described below:

- Phase I: Purchase of land and planting of salt-tolerant crops
- Phase II: Installation of subsurface drainage and collection systems, initial treatment system
- Phase III: Complete construction of treatment removal and salt disposal systems

Figure 1. Location of the Panoche Drainage District's San Joaquin River Water Quality Improvement Project.



In Phase I, subsurface drainwater from the GDA is used to irrigate salt-tolerant crops on ideally situated land. Channels containing collected drainwater flow adjacent to this location, so water can easily be captured and placed on the land. Also, because this land is at the lowest elevation within the drainage area, collected water can be applied without excessive pumping costs.

Approximately four thousand acres have been purchased by the Panoche Drainage District to date. Approximately 2,700 acres of crops have been planted since 2001 and irrigated with water that otherwise would have been discharged into the San Joaquin River. Soil and water constituents at this project site will continue to be monitored to prevent irreversible soil changes and to protect groundwater from contamination.

In Phase II of the SJRIP, the application of saline water to lands developed in Phase I will continue. Subsurface drainage systems will be installed to leach the land and maintain a favorable salt balance. The water percolating below the root zone will be captured in the drainage system and passed on to more salt-tolerant crops. In Phase II, the system will sequentially reuse drainwater on increasingly salt-tolerant crops to concentrate, and decrease, the volume of drainwater produced. Salt, selenium and other constituents will be conveyed by water exiting the subsurface drainage systems. An initial treatment phase will remove the salt, the selenium and much of the other constituents, leaving water for beneficial uses such as agriculture. The treatment system will be designed to incorporate into the reuse system at any point. The remaining salt will be deposited into approved waste units that will result in additional reductions in salt and selenium discharges into the San Joaquin River.

The third and final phase of the SJRIP will maximize improvement in water-quality and meet reductions needed for future water-quality objectives. This phase will expand the initial treatment (under Phase II) to include additional treatment facilities and waste-disposal units.

Each phase of the facility will significantly reduce the amount of drainwater discharged to the San Joaquin River. Water sufficient for reuse on GDA agricultural lands could also be produced by the treatment systems. The project will be designed to assist Grasslands Area Farmers in meeting applicable water-quality objectives for the 2006 water year (October 1, 2005). The 2006 annual, selenium-load limit, based on the current applicable total maximum monthly load, is 3,087 pounds. In comparison, the load value for the 2001 water year was 5,661 lbs. This reduction in load size requires implementation of additional drainage management methods.

An Initial Study and Negative Declaration adopted September 9, 2000 by Panoche Drainage District, evaluated Phase I of the facility. The second and third phases of the facility were evaluated in the Grassland Bypass Project EIS/EIR, finalized May 25, 2001. Phase I is independent and does not exclude the consideration of alternatives to the larger project or project site. Even if the In-Valley Treatment/Drainage Reuse Project progress was to halt at Phase I, the drainage management alone would be valuable. In addition, the proposed cropping patterns are reversible should later phases of the project not be implemented.

In 1997, a portion of the project site was evaluated for conversion to salt-tolerant crops and drainage reuse by Mercy Springs Water District, which encompasses 3,392 acres (55 percent) of the site. The Mercy Springs Water District prepared an Environmental Assessment for the transfer of its Central Valley Project Class I water supply to the Pajaro Valley Water Management Agency (ESA 1997). A Finding of No Significant Impact approved the transfer of 13,300 acre-feet of annual water supply to the Pajaro Valley Water Management Agency on November 6, 1998. In 1999, a Final Environmental Assessment and Finding of No Significant Impact were issued for the transfer of 6,260 acre-feet per year of annual Central Valley Project contract water to the Pajaro Valley Water Management Agency, Santa Clara Valley Water District and Westlands Water District (Provost & Pritchard 1999). These documents covered the impact of water transfers, including drainwater reuse, groundwater pumping and cumulative effects. The current phase of the proposed In-Valley Project does not include water transfers or additional groundwater pumping over existing conditions.

MATERIALS AND METHODS

BIRD CENSUSES

An ornithologist from H. T. Harvey & Associates monitored bird use at the project site on six occasions from April 23 to June 7, 2004. Censuses were completed by driving the perimeter roads of each field. Birds were identified and counted using 10X binoculars and a 20-60X spotting scope mounted on a tripod. Censuses were conducted to determine species composition and relative abundance of bird species on the project site during the breeding season.

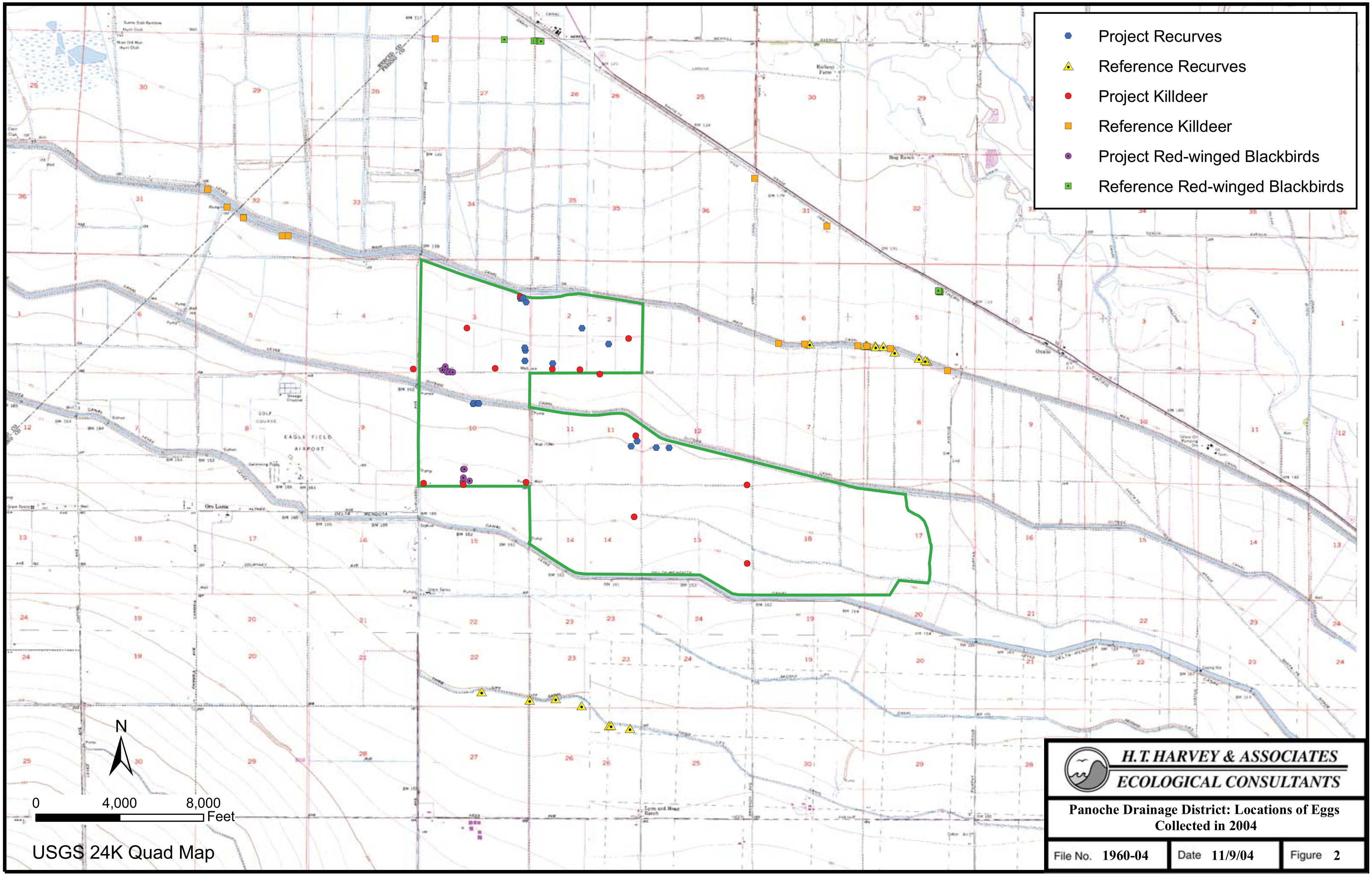
EGG COLLECTION AND PROCESSING

Fifteen Killdeer (*Charadrius vociferus*) eggs, 17 eggs from American Avocets (*Recurvirostra americana*) or Black-necked Stilts (*Himantopus mexicanus*) (recurvirostrids) and 11 Red-winged Blackbird (*Agelaius phoeniceus*) eggs were collected from the project site for selenium and boron analysis. The locations from which eggs were collected are illustrated in Figure 2. A scientific collecting permit was obtained from the California Department of Fish and Game (CDFG) for the collection of bird eggs on the site. One egg was randomly collected from separate, full-clutch (four eggs) nests. Three additional sets of 15 reference Killdeer, 17 recurvirostrid and 11 Red-winged Blackbird eggs were collected (Figure 2) from the project vicinity to provide reference data on regional selenium and boron concentrations outside the project area.

All eggs were labeled with a permanent marker, placed in an egg carton and transported from the field. Upon returning to the lab, all of the egg contents (including membranes) were removed from the shell and transferred to one ounce Dynalon jars. The embryos were photographed and examined for abnormalities and to determine the stage of incubation (age). Eggs were also examined to determine whether embryos were alive or dead. Egg contents were stored by freezing (0^{o} C).

EGG CHEMISTRY ANALYSIS

All egg contents collected by H. T. Harvey & Associates were shipped overnight, on dry ice, to the Oscar E. Olson Biochemical Laboratory at South Dakota State University. Selenium concentrations were determined using the Association of Official Analytical Chemists (AOAC) method 996.16. The boron was done on a nitric acid/peroxide digest in a microwave oven and quantitation by an inductively coupled plasma optical emission spectrometer (ICPOES). All egg-selenium and egg-boron concentrations were presented as parts per million (ppm) based on dry tissue weight (dry weight). For quality control, selected sub-samples were divided into two aliquots. The duplicate was spiked with known amounts of selenium or boron, and the samples were tested to determine the accuracy of analysis.



Panoche Drainage District: Locations of Eggs Collected in 2004

File No. 1960-04 | Date 11/9/04 | Figure 2

Within species groups, a standard t-test was used to examine differences between project site and reference area egg-selenium and egg-boron concentration means. Selenium and boron concentration values were log-transformed (log base 10) to satisfy assumptions of normality. For Killdeer and recurvirostrids, multiple regression analyses were used to statistically examine relationships between egg-selenium levels, sites (project versus reference), and years (2002 to 2004 for Killdeer and 2003 to 2004 for recurvirostrids) using STATA (Stata Corp 1995). Recurvirostrids were analyzed two separate ways. The first used recurvirostrid eggs from 2003 and 2004 excluding eggs collected from a pasture that was accidentally flooded in 2003. Recurvirostrid eggs collected from this site in 2003 contained significantly higher egg selenium concentrations than recurvirostrid eggs collected from the remainder of the project site (H. T. Harvey & Associates 2004). The second used all recurvirostrid eggs collected from 2003 and 2004. Egg-selenium concentration was the dependent variable in these analyses. The selenium concentration values were log-transformed (log base 10) to satisfy assumptions of normality in the regression model (Skewness/Kurtosis Test for Normality of Residuals, $P > 0.05$). In each regression analysis, site and year were analyzed as continuous terms.

RESULTS

BIRD CENSUSES

In the Phase I area, 44 avian species were observed between April 23 and June 7, 2004 (Table 1). Avian numbers were highest in April and early May, when Cattle Egrets (*Bublucus ibis*) and migrating shorebirds such as, Whimbrels (*Numenius phaeopus*) were present (Table 1). Red-winged Blackbird was the most numerous avian species observed on the project site. Twenty species were either observed nesting, or were suspected of nesting on the site, based on observations of courtship behavior or young. Total bird numbers declined in late May and June as fewer migrants were detected.

EGG COLLECTION AND PROCESSING

Forty-three eggs, comprising 15 Killdeer, 17 recurvirostrid (ten Black-necked Stilt and seven American Avocet) and 11 Red-winged Blackbird eggs were collected from the project site. Three of the Killdeer embryos were nine or more days old and were alive and in normal condition. Another eight Killdeer embryos were alive, but too young (three to nine days old) to determine their condition. The remaining four Killdeer embryos were less than three days old (Table 2). Three of the recurvirostrid eggs contained a live, normal, greater than nine-day-old embryo. The remaining stilt and avocet embryos were too young (less than nine days old) to determine the embryo condition, though three were old enough (more than three days old) to determine that they were alive (Table 3). All 11 of the Red-winged Blackbirds were too undeveloped for their condition to be assessed, though four were developed enough to determine that they were alive (Table 4).

Forty-three eggs, 15 Killdeer, 17 recurvirostrid (13 Black-necked Stilts and four American Avocets) and 11 Red-winged Blackbird were collected from the vicinity of the project site. Four of the Killdeer embryos from the reference area were more than nine days old, were alive and in normal condition. Another six Killdeer embryos were alive, but too young (three to nine days old) to determine their condition. The remaining five Killdeer embryos were less than three days old (Table 5). Three of the recurvirostrid eggs contained a live, more than nine-day-old embryo. The remaining stilt and avocet embryos were too young (fewer than nine days old) to determine the embryo condition, though three were old enough (greater than three days old) to determine that they were alive (Table 6). All 11 of the Red-winged Blackbirds were too undeveloped for their condition to be assessed, though four were developed enough (they contained feathered embryos), to determine that they were alive (Table 7).

Table 1. Avian census results at Panoche Drainage District's San Joaquin River Water Quality Improvement Project.

		2004					
	Species	April 23	May 07	May 14	May 24	June 01	June 07
	American Bittern		1				
	Great Blue Heron	2	2	3	3	3	1
	Great Egret	6	8	18	1	1	1
	Snowy Egret	9	16	23	6	4	1
	Cattle Egret	34	117	49	8		
	Black-crowned Night Heron	4	6	6	1	1	2
	White-faced Ibis	73	127	14	69		
*	Mallard	7	6	8	10	11	14
*	Cinnamon Teal	4	2		2		
*	Gadwall		2				
	Northern Harrier	1	3	4	3	4	3
	Swainson's Hawk	2	42	3	2	2	2
*	Red-tailed Hawk	4	5	4	6	6	4
	American Kestrel	1	2	2	2	1	2
*	Ring-necked Pheasant	2		1			
	Common Moorhen	2	2	2	2	1	1
*	Killdeer	24	26	36	42	39	43
*	Black-necked Stilt	34	38	36	37	38	44
*	American Avocet	27	28	27	29	32	33
	Greater Yellowlegs	11	1				
	Whimbrel	159	211	71			
	Long-billed Curlew	5	46	4			
	Black Tern			1	6	4	4
	Mourning Dove						
*	Great Horned Owl		1	1	1	1	1
*	Burrowing Owl	7	8	8	21	20	16
*	Western Kingbird	24	26	22	28	29	24
*	Loggerhead Shrike	5	4	6	5	5	4
	Common Raven	5	10	111	14	5	3
*	Horned Lark	34	42	17	5	6	4
	Tree Swallow	2	4				
	Barn Swallow	5	6	12	5	4	3
	Cliff Swallow	10					
	American Pipit	74	10				
	Savannah Sparrow	21	7	2			
*	Song Sparrow	16	14	16	18	18	18
	Blue Grosbeak		2	2	1	1	1
*	Red-winged Blackbird	245	355	406	416	425	310
	Tricolored Blackbird	16	22				
*	Western Meadowlark	25	26	24	26	21	20
*	Brewer's Blackbird	36	31	33	28	25	24
*	Brown-headed Cowbird	22	38	45	44	22	20
*	House Finch	18	19	18	21	23	16
*	House Sparrow	14	15	16	13	9	7
	Total	**990**	**1330**	**1051**	**875**	**761**	**626**
	* = Species for which evidence of nesting was observed this year.						

Table 2. Project site Killdeer concentrations at Panoche Drainage Districts San Joaquin River Water Quality Improvement Project.

ID Number	Species	Date 2004	Embryo Condition [a]	Embryo Status [b]	Embryo Age (days)	Selenium (ppm dry wt)	Log base 10	Anti-log
01	Killdeer	April 30	U	U	<3	7.98	0.9020	
02	Killdeer	April 30	L	U	3	18.2	1.2601	
03	Killdeer	April 30	L	U	3	31.3	1.4955	
04	Killdeer	May 06	U	U	<3	7.54	0.8774	
05	Killdeer	May 21	L	U	3	30.6	1.4857	
06	Killdeer	May 24	L	U	3	9.98	0.9991	
07	Killdeer	May 26	U	U	<3	4.29	0.6325	
08	Killdeer	May 26	L	N	12-15	39.2	1.5933	
09	Killdeer	June 01	U	U	<3	17.1	1.2330	
10	Killdeer	June 01	L	N	9	2.79	0.4456	
11	Killdeer	June 11	L	U	3-6	14.3	1.1553	
12	Killdeer	June 11	L	N	17-19	17.6	1.2455	
13	Killdeer	June 11	L	U	6-9	18.7	1.2718	
14	Killdeer	June 22	L	U	6-9	11.0	1.0414	
15	Killdeer	June 22	L	U	3	13.9	1.1430	
Arith/**Geo Mean**						6.1	1.1188	***13.1***
SD						1.7	0.3153	***2.1***
SE							0.1410	***1.4***
95% CI							0.8424	***7.0***
							1.3951	***24.8***

[a]) L= Live, D= Dead, U= Unknown, [b]) N= Normal, A= Abnormal, U= Unknown.

Table 3. Project site recurvirostrid egg-selenium concentrations at Panoche Drainage District's San Joaquin River Water Quality Improvement Project.

ID Number	Species	Date 2004	Embryo Condition [a]	Embryo Status [b]	Embryo Age (days)	Selenium (ppm dry wt)	Log base 10	Anti-log
01	Black-necked Stilt	May 14	L	N	12	9.36	0.9713	
02	American Avocet	May 14	U	U	3	15.2	1.1818	
03	American Avocet	May 14	U	U	3	14.1	1.1492	
04	American Avocet	May 19	U	U	<3	39.5	1.5966	
05	Black-necked Stilt	May 24	U	U	<3	8.59	0.9340	
06	American Avocet	May 26	U	U	<3	27.5	1.4393	
07	American Avocet	May 26	U	U	3	21.9	1.3404	
08	Black-necked Stilt	May 26	U	U	3	23.4	1.3692	
09	Black-necked Stilt	June 01	U	U	<3	11.2	1.0492	
10	Black-necked Stilt	June 01	U	U	<3	7.75	0.8893	
11	Black-necked Stilt	June 01	U	U	<3	5.65	0.7520	
12	Black-necked Stilt	June 01	L	U	3	11.3	1.0531	
13	American Avocet	June 01	L	N	9-12	7.53	0.8768	
14	American Avocet	June 01	U	U	<3	10.1	1.0043	
15	Black-necked Stilt	June 07	L	U	3-6	26.9	1.4298	
16	Black-necked Stilt	June 07	L	N	9	48.7	1.6875	
17	Black-necked Stilt	June 07	L	U	6-9	25.8	1.4116	
Arith/**Geo Mean**						18.5	1.1844	***15.3***
SD						12.2	0.2744	***1.9***
SE							0.1227	***1.3***
95% CI							0.9440	***8.8***
							1.4249	***26.6***

[a]) L= Live, D= Dead, U= Unknown, [b]) N= Normal, A= Abnormal, U= Unknown.

Table 4. Project site Red-winged Blackbird egg-selenium concentrations at Panoche Drainage District's San Joaquin River Water Quality Improvement Project.

ID Number	Species	Date 2004	Embryo Condition [a]	Embryo Status [b]	Embryo Age (days)	Selenium (ppm dry wt)	Log base 10	Anti-log
01	R.W. Blackbird	April 30	U	U	yolk	7.26	0.8609	
02	R.W. Blackbird	April 30	U	U	yolk	6.09	0.7846	
03	R.W. Blackbird	April 30	U	U	yolk	5.94	0.7738	
04	R.W. Blackbird	May 07	L	U	<6	5.76	0.7604	
05	R.W. Blackbird	May 07	L	U	<6	5.66	0.7528	
06	R.W. Blackbird	May 07	L	U	9	5.28	0.7226	
07	R.W. Blackbird	May 07	L	U	<6	4.79	0.6803	
08	R.W. Blackbird	May 07	U	U	<3	5.67	0.7536	
09	R.W. Blackbird	May 07	U	U	<3	6.13	0.7875	
10	R.W. Blackbird	May 07	U	U	yolk	7.11	0.8519	
11	R.W. Blackbird	May 07	U	U	yolk	7.17	0.8555	
Arith/**Geo Mean**						6.1	0.7804	***6.0***
SD						0.8	0.0571	***1.1***
SE							0.0255	***1.1***
95% CI							0.7303	***5.4***
							0.8304	***6.8***

[a]) L= Live, D= Dead, U= Unknown, [b]) N= Normal, A= Abnormal, U= Unknown.

Table 5. Reference area Killdeer egg-selenium concentrations at Panoche Drainage District's San Joaquin River Water Quality Improvement Project.

ID Number	Species	Date 2004	Embryo Condition [a]	Embryo Status [b]	Embryo Age (days)	Selenium (ppm dry wt)	Log base 10	Anti-log
01	Killdeer	April 23	L	U	<6	4.47	0.6503	
02	Killdeer	April 23	L	N	20	3.18	0.5024	
03	Killdeer	April 28	L	N	20	3.74	0.5729	
04	Killdeer	April 28	U	U	<3	3.40	0.5315	
05	Killdeer	June 01	L	N	15	2.76	0.4409	
06	Killdeer	June 01	L	N	20	3.25	0.5119	
07	Killdeer	June 07	L	U	3-6	2.73	0.4362	
08	Killdeer	June 07	U	U	<3	4.65	0.6675	
09	Killdeer	June 07	U	U	<3	3.58	0.5539	
10	Killdeer	June 11	L	U	6	3.56	0.5514	
11	Killdeer	June 22	L	U	3-6	3.76	0.5752	
12	Killdeer	June 22	U	U	<3	2.77	0.4425	
13	Killdeer	June 22	U	U	<3	2.94	0.4683	
14	Killdeer	June 22	L	U	3-6	4.24	0.6274	
15	Killdeer	June 22	L	U	3-6	3.44	0.5366	
Arith/**Geo Mean**						3.5	0.5379	***3.5***
SD						0.6	0.0738	***1.2***
SE							0.0330	***1.1***
95% CI							0.4733	***3.0***
							0.6026	***4.0***

[a]) L= Live, D= Dead, U= Unknown, [b]) N= Normal, A= Abnormal, U= Unknown.

Table 6. Reference area Recurvirostrid egg-selenium concentrations at Panoche Drainage District's San Joaquin River Water Quality Improvement Project.

ID Number	Species	Date 2004	Embryo Condition [a]	Embryo Status [b]	Embryo Age (days)	Selenium (ppm dry wt)	Log base 10	Anti-log
01	Black-necked Stilt	May 06	L	N	12	33.9	1.5302	
02	Black-necked Stilt	May 12	U	U	3	24.6	1.3909	
03	Black-necked Stilt	May 12	U	U	3	5.35	0.7284	
04	Black-necked Stilt	May 12	U	U	<3	3.65	0.5623	
05	Black-necked Stilt	May 14	U	U	<3	23.2	1.3655	
06	American Avocet	May 14	U	U	<3	6.70	0.8261	
07	Black-necked Stilt	May 14	U	U	3	7.84	0.8943	
08	Black-necked Stilt	May 14	U	U	3	21.3	1.3284	
09	Black-necked Stilt	May 19	U	U	<3	6.38	0.8048	
10	American Avocet	May 19	U	U	<3	13.1	1.1173	
11	Black-necked Stilt	May 24	U	U	<3	28.0	1.4472	
12	Black-necked Stilt	May 24	L	U	3	20.7	1.3160	
13	Black-necked Stilt	May 24	L	N	9-12	7.20	0.8573	
14	American Avocet	June 02	U	U	<3	3.75	0.5740	
15	Black-necked Stilt	June 02	L	U	3-6	3.14	0.4969	
16	Black-necked Stilt	June 07	L	N	9	27.4	1.4378	
17	American Avocet	June 07	L	U	6-9	7.71	0.8871	
Arith/**Geo Mean**						14.3	1.0332	***10.8***
SD						10.3	0.3513	***2.2***
SE							0.1571	***1.4***
95% CI							0.7253	***5.3***
							1.3411	***21.9***

[a]) L= Live, D= Dead, U= Unknown, [b]) N= Normal, A= Abnormal, U= Unknown.

Table 7. Reference area Red-winged Blackbird egg-selenium concentrations at Panoche Drainage District's San Joaquin River Water Quality Improvement Project.

ID Number	Species	Date 2004	Embryo Condition [a]	Embryo Status [b]	Embryo Age (days)	Selenium (ppm dry wt)	Log base 10	Anti-log
01	R.W. Blackbird	May 19	U	U	yolk	3.87	0.5877	
02	R.W. Blackbird	May 19	U	U	yolk	5.21	0.7168	
03	R.W. Blackbird	May 19	U	U	yolk	6.06	0.7825	
04	R.W. Blackbird	May 19	L	U	<6	3.90	0.5911	
05	R.W. Blackbird	May 19	L	U	<6	3.55	0.5502	
06	R.W. Blackbird	June 11	L	U	9	4.06	0.6085	
07	R.W. Blackbird	June 11	L	U	<6	7.99	0.9025	
08	R.W. Blackbird	June 11	U	U	<3	3.96	0.5977	
09	R.W. Blackbird	June 11	U	U	<3	3.58	0.5539	
10	R.W. Blackbird	June 11	U	U	yolk	2.80	0.4472	
11	R.W. Blackbird	June 11	U	U	yolk	3.50	0.5441	
Arith/**Geo Mean**						4.4	0.6257	***4.2***
SD						1.5	0.1275	***1.3***
SE							0.0570	***1.1***
95% CI							0.5139	***3.3***
							0.7374	***5.5***

[a]) L= Live, D= Dead, U= Unknown, [b]) N= Normal, A= Abnormal, U= Unknown.

EGG CHEMISTRY ANALYSIS

Egg-Selenium Data Analysis Between Sites

Egg-selenium concentrations were significantly higher in eggs collected from the project site relative to eggs collected from the reference area in 2004 for both Killdeer (t-test, $t = 6.95$, $df = 28$, $P < 0.001$, Table 8) and Red-winged Blackbirds (t-test, $t = 3.67$, $df = 20$, $P < 0.001$, Table 8). For recurvirostrids, however, there was no significant difference in eggs collected at the two sites (t-test, $t = 1.40$, $df = 32$, $P = 0.2$, Table 8).

Table 8. Geometric mean egg-selenium concentrations from Panoche Drainage District's San Joaquin River Water Quality Improvement Project.

Selenium			
Species **Location**	**n**	**Geo. Mean** **ppm se (dry wt)**	**Range**
Killdeer			
Project Site	15	13.1	2.79-31.3
Off-site Reference Samples	15	3.5	2.73-4.65
Significance difference ($t = 6.95$, $df = 28$, $P < 0.001$) between sites.			
Recurvirostrids			
Project Site	17	15.3	7.53-48.7
Off-site Reference Samples	17	10.8	3.14-33.9
No significant difference ($t = 1.40$, $df = 32$, $P = 0.2$) between sites.			
Red-winged Blackbirds			
Project Site	11	6.0	4.79-7.26
Off-site Reference Samples	11	4.2	2.80-7.99
Significance difference ($t = 3.67$, $df = 20$, $P < 0.001$) between sites.			

Egg-Selenium Data Analysis Across Years

Killdeer: selenium levels. Egg-selenium levels were significantly higher at the Project site compared to the Reference site (Table 9, Appendix A). Egg-selenium levels differed insignificantly among years, but there was a significant interaction between the effects of study site and year on egg selenium. Although selenium levels were higher at the Project site than the Reference site in all three years, the interaction reflected a difference of lesser magnitude in 2002 than in either 2003 or 2004 (Appendix A).

Recurvirostrids: selenium levels excluding the accidentally flooded pasture in 2003. Excluding eggs from the accidentally flooded pasture in 2003, there was no significant difference (Table 10, Appendix A) in egg-selenium levels with year or between the project and reference sites.

Recurvirostrids: selenium levels including the accidentally flooded pasture in 2003. When eggs from the pasture accidentally flooded in 2003 are included in the analysis, egg-selenium levels are significantly higher in eggs collected at the project site compared to the reference site (Table 11; Appendix A), and were higher during 2003 compared to 2004. The interaction between the effects of project versus reference site and that of year on egg selenium was insignificant, indicating that the relationship between egg selenium and study site varied little among years at the flooded fields.

Table 9. Multiple regression analysis to examine selenium levels (log-base 10) among all Killdeer eggs collected from 2002 to 2004.

Term	Coefficient	*F*-value	*P*-value	df
Model: $F_{[5,65]}$ = 23.83, 64.7% of variance explained.				
Main effects:				
Site	(-)	101.82	<0.0001	1
Year	ns*	1.02	0.4	2
Interaction:				
Site and Year	----	3.19	<0.05	2
* ns = not significant				
The interaction between "year" and "site" was tested after the main effects for the two respective variables had been tested.				

Table 10. Multiple regression analysis to examine selenium levels (log-base 10) among recurvirostrid eggs (excluding eggs collected at the accidentally flooded pasture in 2003) collected in 2003 and 2004.

Term	Coefficient	*F*-value	*P*-value	df
Model: $F_{[3,46]} = 1.32$, model not significant.				
Main effects:				
Site	ns*	1.17	0.3	1
Year	ns	1.83	0.2	1
Interaction:				
Site and Year	ns	1.23	0.3	1
* ns = not significant				
The interaction between "year" and "site" was tested after the main effects for the two respective variables had been tested.				

Table 11. Multiple regression analysis to examine selenium levels (log-base 10) among recurvirostrid eggs (including eggs collected at the accidentally flooded pasture in 2003) collected in 2003 and 2004.

Term	Coefficient	*F*-value	*P*-value	df
Model: $F_{[2,61]} = 16.13$, 34.6% of variance explained.				
Main effects:				
Site	(-)	9.49	<0.01	1
Year	(-)	17.51	<0.0001	1
Interaction:				
Site and Year	ns*	1.70	0.2	1
* ns = not significant				
The interaction between "year" and "site" was tested after the main effects for the two respective variables had been tested.				

Egg-Boron Analysis

The difference in egg-boron concentrations between the project site and reference area was different for each species group. Boron concentrations were significantly higher in Killdeer eggs collected from the project site than Killdeer eggs collected from the reference area (t-test, t = 6.51, df = 28, P < 0.0001, Table 12). There was no significant difference in recurvirostrid eggs collected from the two sites (t-test, t = 1.08, df = 32, P = 0.3, Table 12). Red-winged Blackbird eggs collected from the reference area were significantly higher than Red-winged Blackbird eggs collected from the project site (t-test, t = 3.49, df = 20, P < 0.01, Table 12). The raw boron data are presented in Appendices B, C and D.

Table 12. Geometric mean egg-boron concentrations from Panoche Drainage District's San Joaquin River Water Quality Improvement Project.

Boron			
Species **Location**	**n**	**Geo. Mean** **ppm B (dry wt)**	**Range**
Killdeer			
Project Site	15	3.3	1.6-5.6
Off-site Reference Samples	15	1.5	1.0-2.4
Significance difference (t =6.51, df = 28, P <0.0001) between sites.			
Recurvirostrids			
Project Site	17	2.8	1.0-11.3
Off-site Reference Samples	17	2.1	0.6-8.2
No significant difference (t =1.08, df = 32, P = 0.3) between sites.			
Red-winged Blackbirds			
Project Site	11	4.3	2.4-11.7
Off-site Reference Samples	11	8.1	5.1-15.5
Significance difference (t =3.49, df = 20, P <0.01) between sites.			

QUALITY ASSURANCE/QUALITY CONTROL ANALYSIS

The selenium-recovery rate for four egg samples spiked with 0.08 ug of selenium and two eggs spiked with 0.16 ug of selenium ranged between 77 percent and 113 percent with a mean selenium recovery rate of 98 percent (Appendix E). Additionally, an average value of 0.760 ug/g Se was obtained on NIST Standard Reference Material 1577b (certified value = 0.73 $\pm$ 0.06 ug/g). An Average value of 400 ug/g Se (n=20) was obtained on an in-house selenate standard (value = 400 ug/g Se). The standard deviation of duplicate egg samples ranged between 0.0000 and 0.7778 with a mean standard deviation of 0.1042 (Appendix E).

The standard deviation of boron results from 12 duplicate egg samples ranged between 0.0000 and 0.0599, and the mean standard deviation was 0.0235 (Appendix F).

DISCUSSION

The census data indicate that the project site is utilized by bird species common in San Joaquin Valley agricultural habitats. Both species diversity and relative abundance are lower than expected in native, undisturbed habitats. The tall vegetation within several pastures provided nesting habitat for Red-winged Blackbirds. Irrigation of pastures and alfalfa provide temporary foraging opportunities for birds such as White-faced Ibis (*Plegadis chihi*), Whimbrels and blackbirds.

Swainson's Hawks (*Buteo swainsoni*), which are listed as threatened by the state of California, were observed foraging on the project site. In 2004, as in 2002 and 2003, one pair of Swainson's Hawks successfully nested just north of the project site. Three species listed as "species of concern" by the state of California, the Burrowing Owl (*Athene cunicularia*), the Loggerhead Shrike (*Lanius ludovicianus*) and the California Horned Lark (*Eremophila alpestris actia*) were observed nesting on the project site. The White-faced Ibis, another "species of concern" was observed foraging, but not nesting, on the project site.

Eggs are the best biotic indicator for selenium transfer and toxic biological effects to avian species (Skorupa and Ohlendorf 1991, Ohlendorf *et al.* 1993). Less than 3-ppm (dry wt) egg-selenium is the accepted population (or *geometric mean*) background level for birds (Skorupa and Ohlendorf 1991, CH2M-Hill *et al.* 1993, Maier and Knight 1994). Eight ppm (dry wt) egg-selenium is considered the threshold level at which the probability of impaired hatchability increases in a population (Skorupa and Ohlendorf 1991, CH2M-Hill *et al.* 1993, Maier and Knight 1994). Eight-ppm selenium is the approximate lower boundary for mean egg-selenium levels associated with population-level impaired hatchability for stilts and avocets in the Tulare Lake Basin (Skorupa and Ohlendorf 1991). Ten ppm (dry wt) selenium is the lower boundary for impaired embryo viability associated with an individual egg (Skorupa and Ohlendorf 1991). The threshold for mean egg-selenium associated with increased teratogenic effects in bird populations ranges from 13 to 24 ppm (Skorupa and Ohlendorf 1991, CH2M-Hill *et al.* 1993). The Cumulative Impact Report on impacts of agricultural evaporation basins in the southern San Joaquin Valley (CH2M-Hill *et al.* 1993) used the midpoint of 18-ppm selenium as the teratogenic threshold. Ohlendorf *et al.* (1993) reported that mean egg-selenium concentrations greater than 20 ppm were associated with increased reproductive impairment within a given population.

Based on additional data collected in 1993, the embryo-toxicity threshold for Black-necked Stilts is between 6 and 7-ppm selenium (Skorupa 1998). Because stilt embryos have been shown to be more sensitive than avocets to *in ovo* selenium exposure (Skorupa 1998), it is assumed safe to apply this threshold to recurvirostrids as a whole. In addition, based on updated recurvirostrid egg-selenium data, the Service has proposed increasing the performance standard for mitigation sites to a maximum geometric mean of 4.0-ppm selenium (J. Skorupa, pers. comm.).

More recently, additional papers on selenium toxicity thresholds have been published. A recent analysis of laboratory data for Mallards (CH2M-Hill 2000) suggests that there is a 10 percent depression in egg hatchability at 8.4-ppm egg-selenium concentration. Fairbrother *et al.* (1999) and Adams *et al.* (2004) have proposed alternative selenium toxicity thresholds for birds. Adams *et al.* (2004) argue that about 12 to 15 ppm selenium in Mallard eggs is required to create a 10 percent depression in egg hatchability, based on a review of lab studies. The authors also argue that, based on their analysis of Service field data on stilts, a 10 percent depression in egg hatchability does not occur until a 21 to 31 ppm selenium threshold is reached. The above authors calculated threshold findings based on locating the EC 10 (*i.e.*, the concentration level at which 10 percent of the population is effected) level, whereas, Skorupa (1998) calculated the 6 to 7 ppm threshold by locating the EC 3 level.

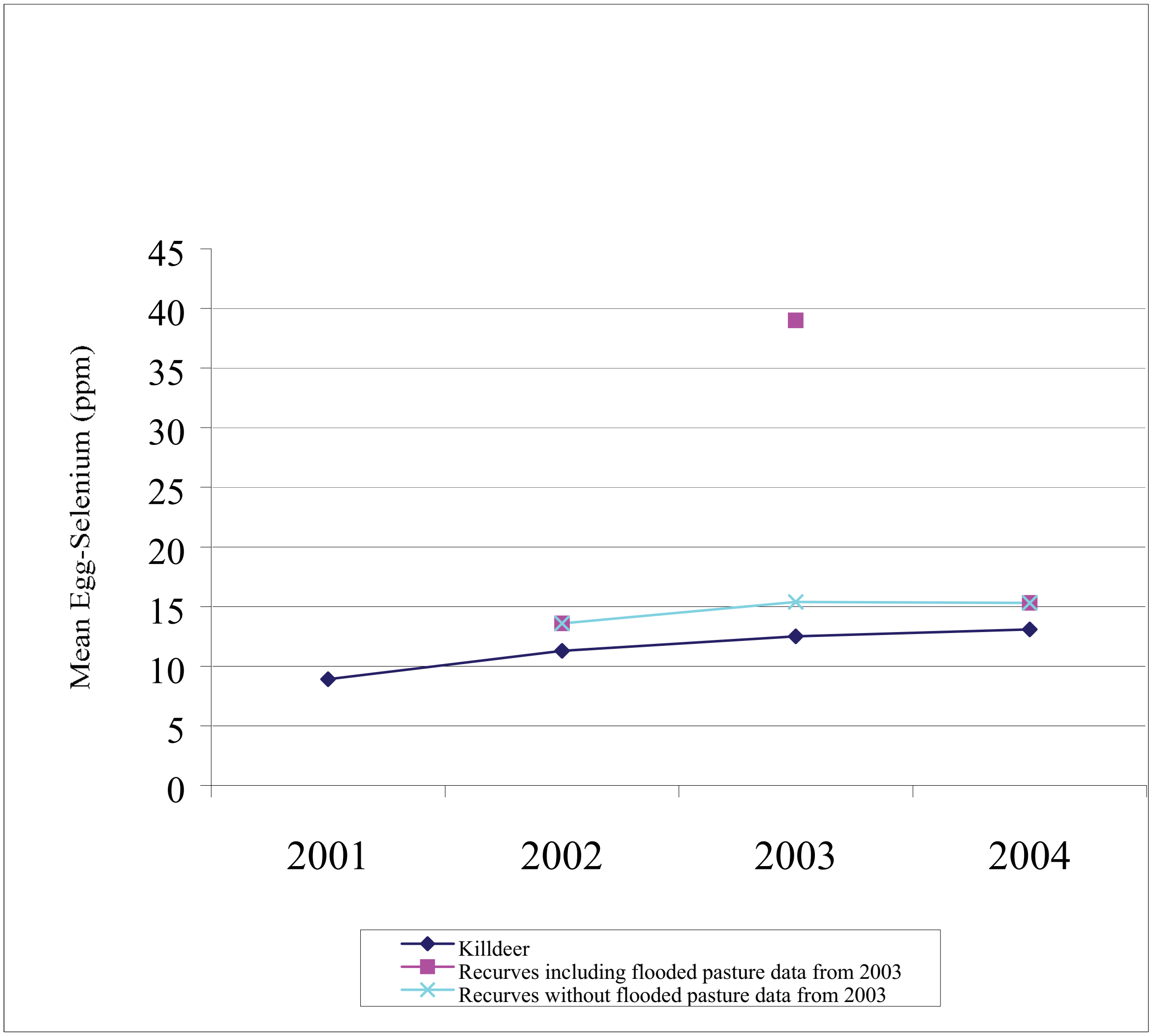
Nine reference and three project-site recurvirostrid eggs contained selenium concentrations within the range (3 to 7.9 ppm) associated with an increased probability of effects on avian reproduction. Seven of the recurvirostrid eggs from the project site and one of the recurvirostrid eggs from the reference area contained eggs with selenium concentrations within the range (8-18 ppm dry wt) associated with an increased probability of reduced hatchability within a population (CH2M-Hill *et al.* 1993). The remaining seven project site and seven reference area recurvirostrid eggs were in the range (>18 ppm) associated with a high probability of population-level reproductive effects, including reduced hatchability and increased occurrence of embryo deformities (teratogenesis) (CH2M-Hill *et al.* 1993).

There were four Killdeer eggs from the reference area and one egg from the project site that were below the background standard of 3 ppm (CH2M-Hill *et al.* 1993). Eleven reference and three project site Killdeer eggs contained selenium concentrations within the range (3 to 7.9 ppm) associated with an increased probability of effects on avian reproduction. Six Killdeer eggs from the project site contained selenium concentrations within the range (8-18 ppm dry wt) associated with an increased probability of reduced hatchability. The remaining five Killdeer eggs from the project site were in the range (>18 ppm) associated with a high probability of reproductive effects, including reduced hatchability and increased occurrence of embryo deformities (teratogenesis) in a population.

Killdeer eggs have not differed significantly in selenium concentration between years from 2002 to 2004 for eggs collected from both the project site and the reference area. Project site Killdeer eggs have had significantly higher egg-selenium concentrations than reference area Killdeer eggs in each of those years and when the years are considered together.

Recurvirostrid eggs did not differ significantly in selenium concentration between 2003 and 2004 for eggs collected from either the project site and reference area when the eggs collected from the accidentally flooded pasture in 2003 are not included. In this case, there is no significant difference in egg-selenium concentration between recurvirostrid eggs collected from the project site of the reference area. However, when the eggs collected from the accidentally flooded pasture in 2003 are included, there is a significant difference in egg selenium between eggs collected in 2003 and 2004 and between the project site and the reference area. These results underscore the importance of preventing accidental flooding events as occurred in 2003 and indicate that it is possible to minimize project impacts to nesting recurvirostrids by doing so. The difference in mean egg-selenium concentrations when data from the accidentally flooded pasture in 2003 are included and excluded is illustrated in Figure 3.

Figure 3. Project Site Mean Egg-Selenium Results at Panoche Drainage District's San Joaquin River Water Quality Improvement Project 2001 to 2004.



Previously collected data, from various freshwater sites in the San Joaquin Valley, detected low levels of egg-selenium content within Killdeer eggs (Table 13). Fifteen of the 18 Killdeer eggs (83 percent) contained less than 2-ppm selenium. Seventeen of the 18 eggs (94 percent) contained less than 2.3 ppm selenium. The median geometric mean egg-selenium content for the 11 freshwater sites is 1.7 ppm. The elevated selenium levels found in the reference eggs for Killdeer, collected off of the project site (mean = 6.7 ppm, range 5.2 - 8.6 ppm), indicates that this set of eggs does not represent true background, but is rather an indicator of the ambient selenium exposure from the project area. All of the Killdeer nests, from which eggs were collected both on and off the project site, were adjacent to, or in close proximity of, open drainwater ditches. It is likely that these drainwater ditches were the source of elevated selenium levels found in the sampled eggs.

Table 13. Killdeer egg-selenium content from San Joaquin Valley freshwater sites.

Reference Site	Sample Size	Geometric Mean Egg Selenium (ppm)
1988 Semitropic Storage Basin	2	1.9
1989 Corcoran Sewage Ponds	3	1.8
1991 Corcoran Sewage Ponds	1	1.7
1991 Kern NWR	1	0.6
1993 Kern NWR	2	1.2
1993 Pixley NWR	1	1.0
1994 Westlake Demo Wetland	1	2.2
1994 Buena Vista Canal	2	1.1
1995 Hacienda East Flood Basin	1	1.7
1996 Westlake Demo Wetland	3	2.1
1997 Los Banos WMA	1	2.2

Source: J. P. Skorupa, USFWS, unpublished data.

A sampling of previously collected data from several freshwater sites throughout the western states indicates that normal background egg-selenium concentration for Red-winged Blackbird eggs is approximately 1 to 3 ppm. For example, in 1995 Butler *et al*. found and an average of 1.6-ppm egg-selenium in six Red-winged Blackbird eggs collected in Dawson Draw, Colorado. Samples of water (< 1ppb Se), algae (< 1 ppm Se) and a Sora (*Porzana carolina*) egg (1. 7 ppm Se) taken from the same site indicate a selenium normal environment. Thirty-one Red-winged Blackbird eggs collected at a gravel pit along the Los Pinos River in Colorado averaged 2.7 ppm (Butler *et al*. 1993). Again, algae samples (0.2 ppm Se) indicate a selenium normal environment.

In contrast, five eggs randomly sampled in 2000 from Red Rock Ranch, a highly selenium contaminated site, showed egg selenium concentrations of 5.3, 6.2, 7.8, 8.2 and 8.8 ppm (geometric mean = 7.1 ppm) (J. Skorupa, unpublished data.). Though not conclusive, these data indicate that Red-winged Blackbird eggs containing selenium concentrations as low as 5 ppm could be considered elevated. Selenium embryo toxicity thresholds for Red-winged Blackbirds are less well known than the shorebird thresholds described above.

It has been suggested that boron impacts wildlife at the evaporation basins in the San Joaquin Valley (Ohlendorf *et al.* 1993). Boron has only one oxidation state (+3), with boric acid being the primary form in evaporation basins, but may convert to borax as evaporation concentrates the salts (Tanji and Grismer 1989). Boron bioconcentrates in aquatic organisms (plants and invertebrates), but evidence is lacking that biomagnification occurs in aquatic ecosystems (Maier and Knight 1991). Most sets of avian eggs from evaporation basins average less than 5-ppm boron (Ohlendorf *et al.* 1993). Current information indicates that slightly elevated boron in eggs does not cause embryo toxicity (Ohlendorf *et al.* 1993).

Egg-boron concentrations at the project site were higher in Red-winged Blackbirds than in both Killdeer and recurvirostrids, while the opposite was true of selenium. A possible explanation is that boron is more readily absorbed by plants than selenium (Maier and Knight 1991). Although Red-winged Blackbirds forage on invertebrates, especially during the reproductive period, Red-winged Blackbirds consume a higher percentage of plant material as diet, relative to the shorebirds in this study, thus, both increasing dietary exposure to boron and decreasing dietary exposure to selenium. The boron analysis of the Red-winged Blackbird eggs collected from the project site (mean = 4.3 ppm, range = 2.4-11.7 ppm), the reference Red-winged Blackbird eggs (mean = 8.1 ppm, range = 5.1-15.5 ppm) and the project site Killdeer eggs (mean = 3.3 ppm, range = 1.6-5.6 ppm) indicated that the egg-boron concentrations in the species groups were slightly above the 3-ppm dry weight background level. The presence of elevated boron-egg content indicates that eggs collected from the project site should continue to be monitored for boron.

The elevated selenium levels in reference recurvirostrid and Killdeer eggs, collected in the vicinity of the project site, indicate that pathways to selenium exposure may exist outside of the immediate project site. Especially when considering the background levels in true control Killdeer eggs, which were collected elsewhere in the San Joaquin Valley, are considered. Thus, selenium contamination at this site may be complex in relation to the agricultural drainwater basin systems.

LITERATURE CITED

Adams, W. J., K. V. Brix, M. Edwards, L. M. Tear, D. K. DeForest, and A. Fairbrother. 2004. Analysis of field and laboratory data to derive selenium toxicity thresholds for birds. Parametrix, Inc. Kirkland, Washington. 32 pp.

Butler, D.L., R.P. Kreuger, B.C. Osmundson, A.L. Thompson, J.J. Formea, and D.W. Wickman. 1993. Reconnaissance investigation of water quality, bottom sediment, and biota associated with irrigation drainage in the Pine River Project area, southern Ute Indian Reservation, southwestern Colorado and northwestern New Mexico, 1988-89. Water-Resources Investigations Report United States Geological Survey. 105 pp.

Butler, D.L., R.P. Kreuger, B.C. Osmundson, and E.G. Jenson. 1995. Reconnaissance investigation of water quality, bottom sediment, and biota associated with irrigation drainage in the Dolores Project area, southwestern Colorado and southeastern Utah, 1990-91. Water-Resources Investigations Report 94-4041. United States Geological Survey. 126 pp.

CH2M-Hill. 2000. Relative Sensitivity of Avian Species to Selenium-related Reproductive Effects. Prepared for Chevron Richmond Refinery. 2485 Natomas Park Drive, Suite 600. Sacramento, CA 95833-2937.

CH2M-Hill, H. T. Harvey & Associates, and Gerald L. Horner. 1993. Cumulative impacts of agriculture evaporation basins on wildlife. Prepared for Department of Water Resources.

Environmental Science Associates (ESA). 1997. CVP Water Assignment from Mercy Springs District (Contract No. 14-06-200-3365A) to Pajaro Valley Water Management Agency, Preliminary Environmental Assessment. Prepared for Pajaro Valley Water Management Agency and Mercy Springs Water District. March 13, 1997.

Fairbrother, A., K. V. Brix, J. E. Toll, S. McKay, and W. J. Adams. 1999. Egg Selenium concentrations as predictors of avian toxicity. *Human and Ecological Risk Assessment*. 5:1229-1253.

H. T. Harvey & Associates. 2004. San Joaquin River Water Quality Improvement Project, Phase I Wildlife Monitoring Report 2003. Prepared for Panoche Drainage District. 42 pp.

Maier, K. J., and A. W. Knight. 1991. The toxicity of waterborne boron to *Daphnia magna* and *Chironomus decorus* and the effects of water hardness and sulfate on boron toxicity. Archives of Environmental Contamination and Toxicology 20:282-287.

Maier, K. J., and A. W. Knight. 1994. Ecotoxicology of selenium in freshwater systems. Reviews of Environmental Toxicology 134:31-48.

Ohlendorf, H., J. Skorupa, M. K. Saiki, and D. A. Barnum. 1993. Food-chain transfer to trace elements to wildlife. pp. 596-603 *In* (R.G. Allen and C.M.U. Neals, eds.). Management of Irrigation and Drainage Systems: Integrated Perspectives, Proceedings of the 1993 National Conference on Irrigation and Drainage Engineering, American Society of Civil Engineers, New York, N.Y.

Provost and Pritchard, Inc. 1999. CVP Water Supply Partial Contract from Mercy Springs Water District (Contract No. 14-06-200-3365A) to Pajaro Valley Water Management Agency, Santa Clara Valley Water District, and Westland Water District, Final Environmental Assessment and Finding of No Significant Impact. U. S. Bureau of Reclamation. April 12, 1999.

SAS Institute Inc. 1985. SAS User's Guide: Statistics. 5th Edition. SAS Institute Inc., Cary, NC.

Skorupa, J. 1998. Selenium poisoning of fish and wildlife in nature: twelve real-world examples. pp. 315-354 *In* (W. T. Frankenberger, Jr., and R. A. Engberg, eds.). Environmental Chemistry of Selenium. Marcel Dekker, New York, N.Y.

Skorupa, J., and H. Ohlendorf. 1991. Contaminants in drainage water and avian risk thresholds. pp. 345-368 *In* (A. Dinar and D. Zilberman, eds.). The Economics and Management of Water and Drainage in Agriculture. Kluwer Academic Publishers.

STATA Corp, 1995. STATA Reference Manual: release 5.1, 6th ed. Stata Corporation, College Station, TX.

Tanji, K., and M. Grismer. 1989. Physiochemical efficacy of agricultural evaporation ponds: an interim literature review and synthesis. Prepared for Department of Water Resources, Agreement No. B-56769.

APPENDIX A. DATA FOR EGG-SELENIUM ANALYSIS ACROSS YEARS AND SITES.

Species Location	n	Geo Mean	Mean Se (log transformed)	Standard Deviation
Killdeer				
2002	10	8.4	0.9229	± 0.2518
2003	31	8.4	0.9228	+ 0.2994
2004	30	6.7	0.8283	± 0.3713
Project Site	40	12.6	1.0988	± 0.2288
Reference Site	31	11.7	1.0677	± 0.1590
Recurvirostrids (excluding flooded pasture in 2003)				
2003	16	16.5	1.2179	± 0.2170
2004	34	12.8	1.1088	± 0.3197
Project Site	23	15.3	1.1852	± 0.2574
Reference Site	27	12.8	1.1084	± 0.3209
Recurvirostrids (including flooded pasture in 2003)				
2003	30	29.7	1.4732	± 0.3310
2004	34	12.8	1.1088	± 0.3197
Project Site	37	25.4	1.4056	± 0.3638
Reference Site	27	12.8	1.1084	± 0.3209

APPENDIX B. KILLDEER EGG-BORON CONCENTRATIONS AT PANOCHE DRAINAGE DISTRICT'S SAN JOAQUIN RIVER WATER QUALITY IMPROVEMENT PROJECT.

Project Site				Reference Area			
ID Number	**Boron (ppm dry wt)**	**Log Base 10**	**Anti-log**	**ID Number**	**Boron (ppm dry wt)**	**Log Base 10**	**Anti-log**
01	2.82	0.4502		01	1.55	0.1903	
02	5.63	0.7505		02	2.44	0.3874	
03	4.64	0.6665		03	1.54	0.1875	
04	5.77	0.7612		04	1.23	0.0899	
05	4.61	0.6637		05	1.01	0.0043	
06	3.71	0.5694		06	1.65	0.2175	
07	2.62	0.4183		07	1.06	0.0253	
08	4.23	0.6263		08	1.24	0.0934	
09	2.80	0.4472		09	2.14	0.3304	
10	1.61	0.2068		10	1.77	0.2480	
11	3.67	0.5647		11	1.60	0.2041	
12	2.59	0.4133		12	1.43	0.1553	
13	3.87	0.5877		13	2.28	0.3579	
14	3.07	0.4871		14	0.99	-0.0044	
15	1.78	0.2504		15	1.63	0.2122	
Arith/**Geo Mean**	3.56	0.5242	***3.3***	Arith/**Geo Mean**	1.57	0.1800	***1.5***
SD	1.3	0.1641	***1.5***	SD	0.4	0.1225	***1.3***
SE		0.0734	***1.2***	SE		0.0548	***1.1***
95% CI		0.3803	***2.4***	95% CI		0.0726	***1.2***
		0.6681	***4.7***			0.2873	***1.9***

APPENDIX C. RECURVIROSTRID EGG-BORON CONCENTRATIONS AT PANOCHE DRAINAGE DISTRICT'S SAN JOAQUIN RIVER WATER QUALITY IMPROVEMENT PROJECT.

Project Site				Reference Area			
ID Number	**Boron (ppm dry wt)**	**Log Base 10**	**Anti-log**	**ID Number**	**Boron (ppm dry wt)**	**Log Base 10**	**Anti-log**
01	1.01	0.0043		01	2.58	0.4116	
02	1.53	0.1847		02	2.51	0.3997	
03	1.38	0.1399		03	2.49	0.3962	
04	11.3	1.0531		04	1.94	0.2878	
05	2.01	0.3032		05	2.29	0.3598	
06	3.42	0.5340		06	1.03	0.0128	
07	9.21	0.9643		07	8.19	0.9133	
08	2.44	0.3874		08	2.29	0.3598	
09	1.27	0.1038		09	2.38	0.3766	
10	2.19	0.3404		10	1.31	0.1173	
11	3.62	0.5587		11	2.55	0.4065	
12	6.30	0.7993		12	3.50	0.5441	
13	1.06	0.0253		13	4.65	0.6675	
14	2.78	0.4440		14	0.59	-0.2291	
15	1.19	0.0755		15	1.59	0.2014	
16	6.32	0.8007		16	2.14	0.3304	
17	6.75	0.8293		17	1.21	0.0828	
Arith/**Geo Mean**	3.75	0.4440	***2.8***	Arith/**Geo Mean**	2.54	0.3317	***2.1***
SD	3.11	0.3426	***2.2***	SD	1.74	0.2578	***1.8***
SE		0.1532	***1.4***	SE		0.1153	***1.3***
95% CI		0.1437	***1.4***	95% CI		0.1057	***1.3***
		0.7443	***5.6***			0.5577	***3.6***

APPENDIX D. RED-WINGED BLACKBIRD EGG-BORON CONCENTRATIONS AT PANOCHE DRAINAGE DISTRICT'S SAN JOAQUIN RIVER WATER QUALITY IMPROVEMENT PROJECT.

Project Site				**Reference Area**			
ID Number	**Boron (ppm dry wt)**	**Log Base 10**	**Anti-log**	**ID Number**	**Boron (ppm dry wt)**	**Log Base 10**	**Anti-log**
01	5.09	0.7067		01	5.08	0.7059	
02	3.81	0.5809		02	5.77	0.7612	
03	11.7	1.0682		03	5.56	0.7451	
04	5.97	0.7760		04	6.07	0.7832	
05	6.55	0.8162		05	7.35	0.8663	
06	4.46	0.6493		06	14.6	1.1644	
07	2.52	0.4014		07	11.6	1.0645	
08	3.28	0.5159		08	10.1	1.0043	
09	3.07	0.4871		09	8.09	0.9079	
10	3.51	0.5453		10	15.5	1.1903	
11	2.37	0.3747		11	6.51	0.8136	
Arith/**Geo Mean**	4.76	0.6293	***4.3***	Arith/**Geo Mean**	8.75	0.9097	***8.1***
SD	2.67	0.2036	***1.6***	SD	3.70	0.1716	***1.5***
SE		0.0911	***1.2***	SE		0.0767	***1.2***
95% CI		0.4508	***2.8***	95% CI		0.7593	***5.7***
		0.8078	***6.4***			1.0601	***11.5***

APPENDIX E: SELENIUM ANALYSIS QUALITY ASSURANCE/QUALITY CONTROL RESULTS

Selenium Control Spikes.

ID Number	Tissue	Spiked Selenium (ug)	% Recovery
TH-01	egg	80	77
TH-01	egg	80	83
PDP-R-K-01	egg	80	113
PDR-Rc-17	egg	80	108
PDP-B-11	egg	160	106
PDR-B-11	egg	160	104
		Mean	98
		Standard deviation	14.8

Additionally, an average value of .760 ug/g Se was obtained on NIST Standard Reference Material 1577b (certified value = .73 $\pm$ 0.06 ug/g).
An average value of .400 ug/g Se (n = 20)was obtained on an in-house selenate

Standard (value + .400 ug/g Se)

Appendix E. Selenium QA/QC Summary, 2004.

Duplicates. (SD = Standard Deviation)

ID Number	Replication	Result Selenium	ID Number	Replication	Result Selenium
PDP-K-01	1	2.07	PDR-Rc-01	1	8.33
	2	2.17		2	8.47
SD*		***0.0707***	***SD***		***0.0990***
PDP-K-02	1	4.85	PDR-Rc-02	1	6.45
	2	4.84		2	6.48
SD		***0.0071***	***SD***		***0.0212***
PDP-K-03	1	7.77	PDR-Rc-03	1	1.190
	2	7.76		2	1.300
SD		***0.0071***	***SD***		***0.0778***
PDP-K-04	1	1.92	PDR-Rc-04	1	1.000
	2	1.87		2	0.991
SD		***0.0354***	***SD***		***0.0064***
PDP-K-05	1	8.32	PDR-Rc-05	1	6.41
	2	8.15		2	6.55
SD		***0.1202***		3	6.52
PDP-K-06	1	2.67		4	6.37
	2	2.50	***SD***		***0.0862***
SD		***0.1202***	PDR-Rc-06	1	1.64
PDP-K-07	1	1.16		2	1.60
	2	1.17	***SD***		***0.0283***
SD		***0.0071***	PDR-Rc-07	1	2.100
PDP-K-08	1	10.60		2	2.120
	2	10.20	***SD***		***0.0141***
SD		***0.2828***	PDR-Rc-08	1	5.25
PDP-K-09	1	4.44		2	5.22
	2	4.41	***SD***		***0.0212***
SD		***0.0212***	PDR-Rc-09	1	1.560
PDP-K-10	1	0.79		2	1.340
	2	0.768	***SD***		***0.1556***
SD		***0.0156***	PDR-Rc-10	1	3.64
PDP-K-11	1	3.81		2	2.97
	2	3.80	***SD***		***0.4738***
SD		***0.0071***	PDR-Rc-11	1	7.59
				2	6.94
			SD		***0.4596***

Appendix E. Selenium QA/QC Summary, 2004. Duplicates (continued)

PDP-K-12	1	4.57	PDR-Rc-12	1	5.53
	2	4.80		2	5.32
SD		***0.1626***	***SD***		***0.1485***
PDP-K-13	1	5.00	PDR-Rc-13	1	1.850
	2	5.53		2	1.680
SD*		***0.3748***	***SD***		***0.1202***
PDP-K-14	1	2.83	PDR-Rc-14	1	0.996
	2	2.76		2	0.919
SD		***0.0495***	***SD***		***0.0544***
PDP-K-15	1	3.57	PDR-Rc-15	1	0.657
	2	3.46		2	0.919
SD		***0.0778***		3	0.76
PDP-R-01	1	2.58	***SD***		***0.1320***
	2	2.63	PDR-Rc-16	1	7.27
SD		***0.0354***		2	6.83
PDP-R-02	1	4.13	***SD***		***0.3111***
	2	4.42	PDR-Rc-17	1	1.79
SD		***0.2051***		2	1.66
PDP-R-03	1	3.61	***SD***		***0.0919***
	2	4.11	PDR-B-01	1	0.607
SD		***0.3536***		2	0.624
PDP-R-04	1	9.79	***SD***		***0.0120***
	2	9.80	PDR-B-02	1	0.774
SD		***0.0071***		2	0.757
PDP-R-05	1	2.27	***SD***		***0.0120***
	2	2.23	PDR-B-03	1	0.937
SD		***0.0283***		2	0.882
PDP-R-06	1	6.39	***SD***		***0.0389***
	2	6.33	PDR-B-04	1	0.568
SD		***0.0424***		2	0.617
PDP-R-07	1	6.42	***SD***		***0.0346***
	2	6.14	PDR-B-05	1	0.548
	3	5.87		2	0.547
SD		***0.2750***	***SD***		***0.0007***
PDP-R-08	1	5.42	PDR-B-06	1	0.675
	2	5.53		2	0.673
SD		***0.0778***	***SD***		***0.0014***

Appendix E. Selenium QA/QC Summary, 2004. Duplicates (continued)

PDP-R-09	1	2.87	PDR-B-07	1	1.24
	2	2.78		2	1.23
SD		***0.0636***	***SD***		***0.0071***
PDP-R-10	1	2.12	PDR-B-08	1	0.573
	2	2.06		2	0.558
SD		***0.0424***	***SD***		***0.0106***
PDP-R-11	1	1.41	PDR-B-09	1	0.521
	2	1.40		2	0.503
SD		***0.0071***	***SD***		***0.0127***
PDP-R-12	1	3.080	PDR-B-10	1	0.598
	2	3.030		2	0.597
SD		***0.0354***	***SD***		***0.0007***
PDP-R-13	1	1.920	PDR-B-11	1	0.587
	2	1.910		2	0.566
SD		***0.0071***	***SD***		***0.0148***
PDP-R-14	1	2.100	BZE-01	1	11.50
	2	2.180		2	11.00
	3	2.440	***SD***		***0.3536***
	4	2.150	BZE-02	1	11.30
SD		***0.1520***		2	10.80
PDP-R-15	1	8.3	***SD***		***0.3536***
	2	8.2	BZE-03	1	21.0
SD		***0.0990***		2	19.9
PDP-R-16	1	11.7	***SD***		***0.7778***
	2	12.1	BZE-04	1	21.4
SD		***0.2828***		2	20.2
PDP-R-17	1	6.5	***SD***		***0.8485***
	2	6.4	BZE-05	1	11.60
SD		***0.0636***		2	11.10
PDP-B-01	1	1.33	***SD***		***0.3536***
	2	1.27	BZG-01	1	0.342
SD		***0.0424***		2	0.333
PDP-B-02	1	1.02	***SD***		***0.0064***
	2	0.987	BZG-02	1	11.70
SD		***0.0233***		2	10.70
PDP-B-03	1	0.938	***SD***		***0.7071***
	2	0.921	BZG-03	1	0.491
SD		***0.0120***		2	0.522
			SD		***0.0219***

Appendix E. Selenium QA/QC Summary, 2004. Duplicates (continued)

PDP-B-04	1	0.863	BZG-04	1	0.339
	2	0.809		2	0.316
SD		***0.0382***	***SD***		***0.0163***
PDP-B-05	1	0.856	BZG-05	1	0.482
	2	0.809		2	0.448
SD		***0.0332***	***SD***		***0.0240***
PDP-B-06	1	0.895	LHM-01	1	0.909
	2	0.848		2	0.850
SD		***0.0332***	***SD***		***0.0417***
PDP-B-07	1	0.727	LHM-02	1	1.00
	2	0.691		2	0.966
SD		***0.0255***	***SD***		***0.0240***
PDP-B-08	1	0.869	LHM-03	1	0.775
	2	0.820		2	0.767
SD		***0.0346***	***SD***		***0.0057***
PDP-B-09	1	1.07	LHM-04	1	23.10
	2	1.05		2	22.90
SD		***0.0141***	***SD***		***0.1414***
PDP-B-10	1	1.10	LHM-05	1	8.98
	2	1.09		2	9.13
SD		***0.0071***	***SD***		***0.1061***
PDP-B-11	1	1.2	TH-01	1	4.57
	2	1.2		2	4.34
SD*		***0.0141***	***SD***		***0.1626***
PDR-K-01	1	1.24	TH-02	1	3.78
	2	1.18		2	3.28
SD		***0.0424***	***SD***		***0.3536***
PDR-K-02	1	0.892	TH-03	1	3.13
	2	0.982		2	2.84
SD		***0.0636***	***SD***		***0.2051***
PDR-K-03	1	0.89	TH-04	1	2.61
	2	0.996		2	2.37
SD		***0.0750***	***SD***		***0.1697***
PDR-K-04	1	0.876	TL-C-01	1	0.602
	2	0.891		2	0.552
SD		***0.0106***	***SD***		***0.0354***
PDR-K-05	1	0.764	TL-C-02	1	0.769
	2	0.762		2	0.814
SD		***0.0014***	***SD***		***0.0318***

Appendix E. Selenium QA/QC Summary, 2004. Duplicates (continued)

PDR-K-06	1	0.776	TL-C-03	1	0.632
	2	0.861		2	0.62
SD		***0.0601***	***SD***		***0.0085***
PDR-K-07	1	0.639	TL-C-04	1	0.745
	2	0.748		2	0.727
SD		***0.0771***	***SD***		***0.0127***
PDR-K-08	1	1.03	TL-C-05	1	0.634
	2	1.14		2	0.634
SD		***0.0778***	***SD***		***0.0000***
PDR-K-09	1	0.911	WLS-01	1	1.66
	2	1.03		2	1.59
SD		***0.0841***	***SD***		***0.0495***
PDR-K-10	1	0.87	WLS-02	1	1.08
	2	1.02		2	1.02
SD		***0.1061***	***SD***		***0.0424***
PDR-K-11	1	0.857	WLS-03	1	1.91
	2	1.12		2	1.750
SD		***0.1860***	***SD***		***0.1131***
PDR-K-12	1	0.643	WLS-04	1	1.98
	2	0.756		2	1.86
SD		***0.0799***	***SD***		***0.0849***
PDR-K-13	1	0.739	WLS-05	1	1.93
	2	0.834		2	1.91
SD		***0.0672***	***SD***		***0.0141***
PDR-K-14	1	0.968			
	2	1.17			
SD		***0.1428***			
PDR-K-15	1	0.898			
	2	0.898			
SD		***0.0000***			
PDR-B6	1	1.04			
	2	0.983			
SD*		***0.0403***			

Mean SD: 0.1042
Low SD: 0.0000
High SD: 0.7778

APPENDIX F: BORON ANALYSIS QUALITY ASSURANCE/QUALITY CONTROL RESULTS

Boron QA/QC Summary, 2004.
Duplicates. (SD = Standard Deviation)

ID Number	Replication	Result Selenium	ID Number	Replication	Result Selenium
PDP-K-11	1	1.00	PDR-K-15	1	0.440
	2	0.951		2	0.410
SD*		***0.0346***	***SD***		***0.0212***
PDP-R-05	1	0.530	PDR-Rc-05	1	0.679
	2	0.520		2	0.599
SD		***0.0071***	***SD***		***0.0566***
PDP-R-06	1	0.791	PDR-Rc-07	1	2.190
	2	0.791		2	2.220
SD		***0.0000***	***SD***		***0.0212***
PDP-R-15	1	0.370	PDR-Rc-08	1	0.58
	2	0.360		2	0.55
SD		***0.0071***	***SD***		***0.0212***
PDP-R-16	1	1.55	PDR-Rc-13	1	1.12
	2	1.54		2	1.16
SD		***0.0071***	***SD***		***0.0283***
PDR-K-06	1	0.240	PDR-Rc-15	1	0.380
	2	0.32		2	0.410
SD		***0.0559***	***SD***		***0.0212***

Mean SD: 0.0235
Low SD: 0.000
High SD:0.0599