EVALUATION OF WATER QUALITY FOR WILDLIFE HABITAT AND AGRICULTURE: MERCED NATIONAL WILDLIFE REFUGE

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October 1988

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
CENTRAL VALLEY REGION

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Summary

The Agricultural Unit of the Regional Water Quality Control Board sampled and evaluated the water quality of the Merced National Wildlife Refuge (Merced NWR) water supply to establish background water quality data for this wildlife area, and to determine if current water quality is within the recommended guidelines for beneficial use. Ground water is the primary water supply at the Merced refuge, but future water supply plans include the importation of surface water which may be comingled with agricultural return flows and subsurface drainage water. Background water quality data may be used to determine if irrigated agriculture has affected the refuge water supply. Large subsurface drainage projects are planned for agricultural land upslope of this refuge which may affect future Eastside Bypass water quality, and thus refuge water supply. Merced Irrigation District (MID) may also provide a future water supply to the refuge. MID operates several hundred drainage wells which discharge to their supply canals, and would therefore deliver a blended water into the refuge. The presence of a large pumping depression in the unconfined aquifer produces a southeast direction of flow which could at some time pull poorer quality ground water from lands to the west where subsurface agricultural drainage water is presently a disposal problem.

The beneficial uses of water at Merced NWR are wildlife habitat and irrigation supply. The current ground water supply is of acceptable water quality for these beneficial uses. Selenium and trace elements were measured at low levels below the current established guidelines and criteria for the protection of freshwater aquatic life. The only immediate impact on beneficial use is the possible affect of salinity on agricultural crop production, but potential problems can be overcome by sound irrigation management. The implementation of a scientific irrigation scheduling program may improve the management of the agricultural water supply, and minimize pumping costs.

Merced National Wildlife Refuge

Merced National Wildlife Refuge is approximately nine miles southwest of the city of Merced, Merced County, in the San Joaquin River Basin (Fig. 1). The 2561 acre refuge was established in 1951 by authority of the Lea Act. The legal mandate of the refuge is to provide wildlife habitat to help reduce waterfowl depredation on adjacent croplands.

Wildlife

The refuge is one of the most important wintering areas in California and the Pacific Flyway for the Lesser Sandhill Crane. Waterfowl, shore and wading birds, raptorial birds, upland game, and furbearers all utilize the refuge. Appendix A lists the key animal species which have been observed at Merced NWR.

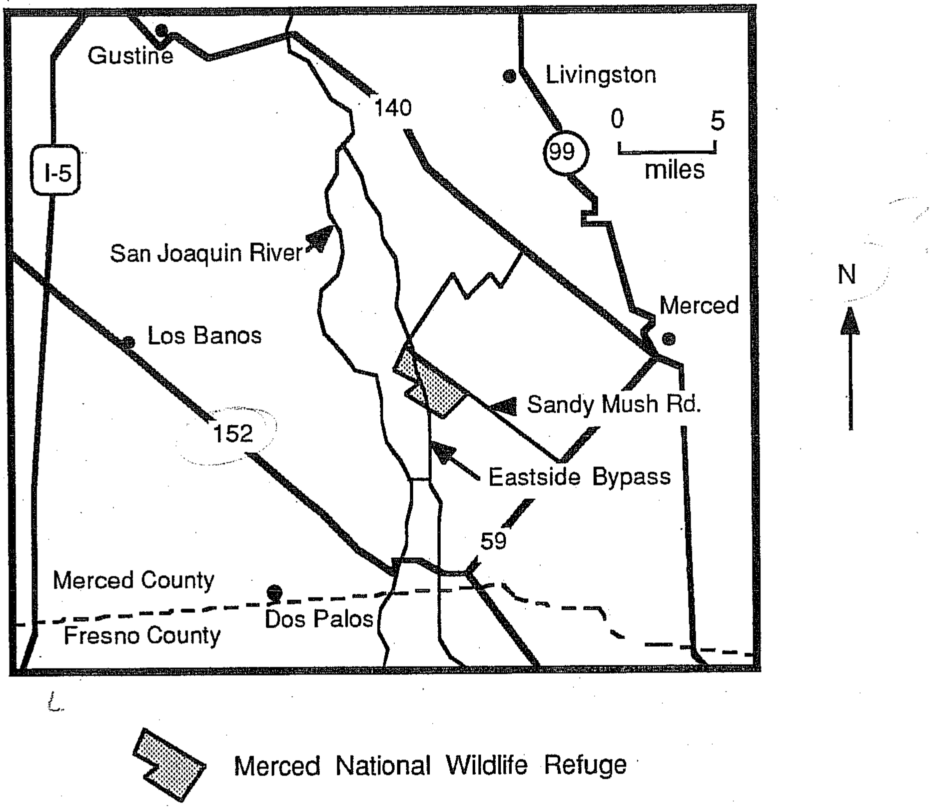

Figure 1. Location Map - Merced National Wildlife Refuge

Land Use

The Merced refuge is in a poorly drained saline - alkali basin known as the "sandy mush country". Cattle ranching is the predominant form of agriculture on surrounding land with similar saline-alkali soils, and rice has been planted in small areas of fine-textured saline-alkali soils as part of a soil reclamation project.

Wetlands, croplands, and uplands are the three classifications of land use at the Merced refuge (Fig. 2). Approximately 38% of the acreage (1000 acres) is devoted to seasonal wetlands. The wetlands are diked shallow marshy ponds which are seeded with aquatic waterfowl food plants every two to three years. These marshes are flooded in the fall and are attractive to migrating waterfowl from mid-September to April. An additional 38% of the refuge remains in unirrigated grassy uplands. The upland areas are designated as potential habitat for the endangered San Joaquin Kit Fox and Blunt-nosed Leopard Lizard. Raptorial birds and upland game frequent these areas. The remaining 23% of the refuge lands (approximately 600 acres) are devoted to the production of crops for waterfowl food. Irrigated crops grown on the refuge are corn and alfalfa, and dryland cereal crops grown for waterfowl food are winter wheat and barley. Irrigated pasture is also maintained for critical sandhill crane habitat. In recent years, small grain cropland has been converted to pasture for this purpose.

Water Supply

A dependable water supply is needed at Merced NWR for wildlife habitat and crop irrigation (U.S. Bureau of Reclamation, 1986). The water for wildlife habitat is needed June through February each year, with the majority of the supply needed mid-September through February. Water for crop irrigation is needed from February through August, with the heaviest demands April through August.

The existing water supply facilities at Merced NWR are shown in Figure 3. Mariposa Slough (Eastside Bypass) and Deadman Slough bisect the refuge, but provide only minimal amounts of water on an irregular basis. These sloughs are both tributary to the San Joaquin River, and support very low flows which are predominantly agricultural return flows. The refuge has rights to 3000 acre feet per year from Deadman Slough. During the peak runoff period, a 10 horsepower lift pump is used to flood 160 acres of shallow marsh from this source. The refuge has the capacity to pump 1500 acre feet of water from Mariposa Slough, but this has also been an insignificant water source.

Ground water is currently the major water source at Merced NWR. A well field of 23 water wells with pump capacities ranging from 20 to 60 horsepower can supply an average of 13,500 acre-feet of ground water to the refuge each year.

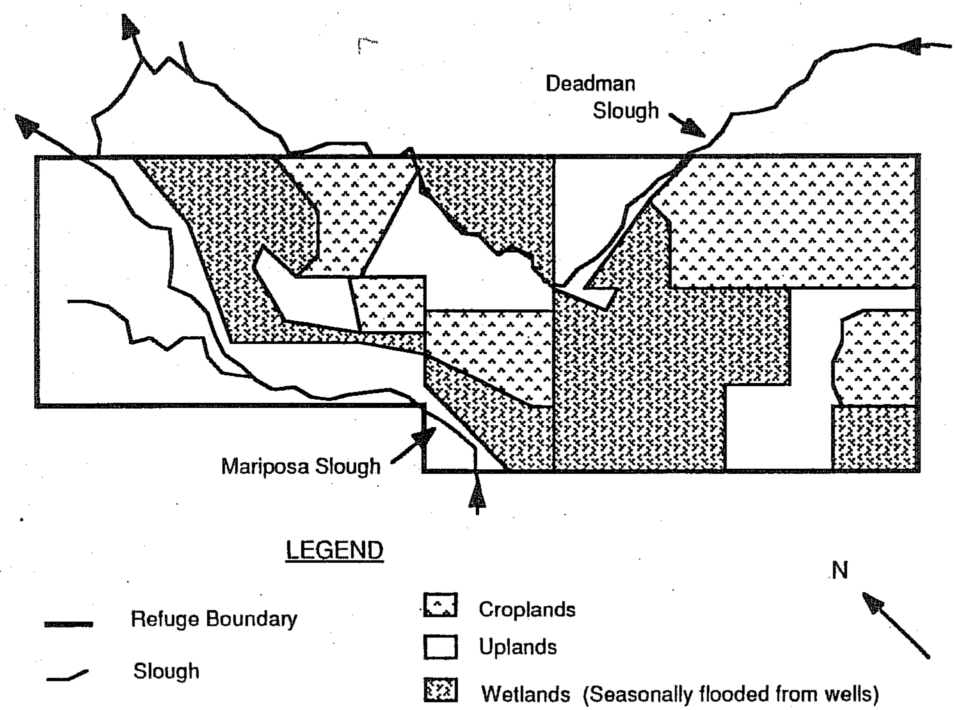

Figure 2. Land Use at Merced National Wildlife Refuge

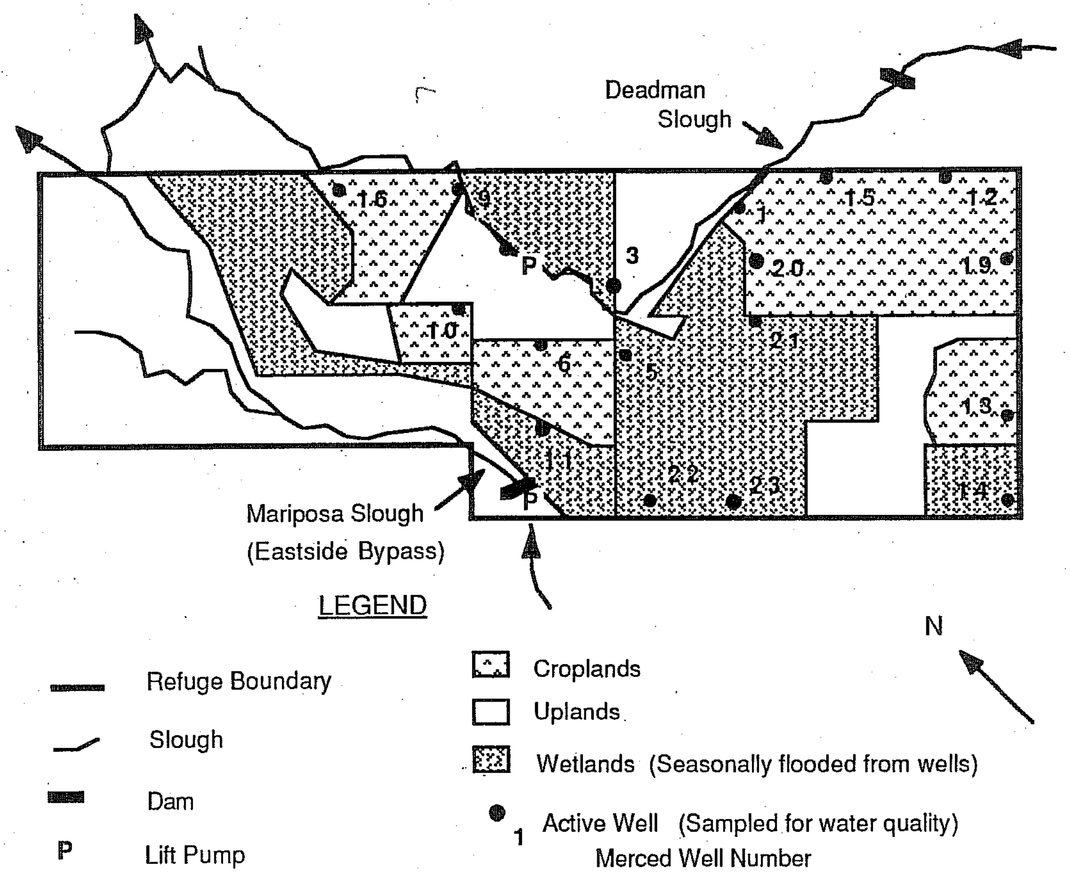

Figure 3. Existing Water Supplies - Merced National Wildlife Refuge

The safe annual yield of the aquifer is estimated to be 16,000 acre feet per year (U.S. Bureau of Reclamation, 1981). The average water application rate for wildlife habitat at Merced is 12.2 acre-feet per acre, and 3.0 acre-feet per acre is applied to cropland (U.S. Bureau of Reclamation, 1986). The refuge is expensive to operate due to high energy costs associated with the reliance on ground water to support critical habitat. Alternatives for future refuge water supply include surface water diversions from the Merced Irrigation District Casebeer Lateral, or surface water diversions from the El Nido Irrigation District via the Chowchilla River to the Mariposa Slough.

Hydrogeologic Setting

Both an unconfined and a confined water bearing zone occur under the Merced refuge (Hotchkiss, 1972). The unconfined water bearing zone occurs in unconsolidated deposits above the E-clay (blue clay) confining bed which restricts the vertical movement of water. This clay stratum is probably equivalent to the Pleistocene age Corcoran Clay member of the Tulare Formation. The E-clay is approximately 60 feet thick and extends from 190 to 260 feet below the ground surface in the vicinity of the refuge. The confined water body lies below the E-clay and extends to the base of fresh water.

Regional ground water movement in the unconfined water bearing zone is westward and southwestward toward the valley trough. However, unconfined ground water in the vicinity of the Merced refuge moves southeast in response to a pumping depression in the El Nido Irrigation District (Page and Balding, 1973). The hydraulic head in the confined water bearing zone is less than that in the upper water bearing zone because of heavy deep well pumping to the west of the refuge. For example, the water levels in wells 22 and 23 completed below the E-clay were measured at 67 and 58 feet below the ground surface which are lower than the 30 and 41 foot water levels measured in unconfined wells 12 and 20 (Pacific Gas & Electric Company, 1985). Unconfined ground water may move slowly through the E-clay to the lower confined water bearing zone as a result of this head differential. Lateral ground water movement in the confined water bearing zone is generally westward toward the valley trough.

Depth to water was measured in seven wells during pump tests by PG&E in March 1985. The water levels below the ground surface ranged from 30 to 41 feet below the ground surface in known unconfined wells, and from 62 to 67 feet in deeper confined wells. The seasonality of the ground water table elevation has not been measured, but it is likely highest during the winter and spring.

elevation

Water Quality Sampling

Ground water wells at Merced NWR were sampled for general minerals and total recoverable trace element concentrations in November 1986 and August

1987 to assess the quality of the water supply for the current beneficial uses, and to establish a background ground water quality database for this area. There are a total of 23 wells at the Merced refuge. The 17 wells sampled in this survey are the wells which currently supply water for wildlife habitat and/or irrigation. Table 1 provides information about these wells and their beneficial uses.

Well logs are identifiable for eleven of the seventeen refuge wells. The depths of these eleven wells range from 141 to 660 feet. Wells 1,6,12,13,14, 15, 16, and 20 are completed above the E-Clay in the upper water bearing zone. The depths of these wells range from 141 - 300 feet. Wells 3, 22, and 23 are completed and perforated below the blue clay. These confined wells are 580,640, and 660 feet deep, respectively.

A minimum of three casing volumes were pumped from each well before sampling. Ten percent duplicate samples were obtained and 50 percent of the duplicates were spiked for laboratory quality assurance. Analytical results fell within acceptable water quality assurance tolerances. Electrical conductivity, pH, and water temperature were recorded in the field. Standard procedures for the preservation of trace element samples were followed.

Water Quality for Wildlife Habitat

Water quality guidelines and criteria for the protection of freshwater aquatic life and irrigation supply are shown in Table 2.

It should be recognized that the EPA criteria for the protection of aquatic life are specifically developed for the protection of fish, shellfish, and other invertebrates. These criteria may not be directly applicable to the protection of wildlife and refuge habitat because of the many differences between the species, and the biomagnification of trace elements in the food chain (U.S. General Accounting Office, 1987). EPA, U.S. Fish and Wildlife Service, and the State of California have not established guidelines or criteria for the protection of wildlife habitat, and therefore criteria for the protection of aquatic life are often used as a guideline for the prevention of potential problems higher in the food chain.

Water quality samples were obtained 20 November 1986 from twelve wells which were used to flood seasonal wetlands. The water samples were analyzed for a complete general mineral series and total recoverable trace elements. Results of the mineral analysis are reported in Table 3. Salinity measured as electrical conductivity ranged from 450 µmhos/cm to 2200 µmhos/cm with a median salinity of 845 µmhos/cm. A Piper trilinear diagram was evaluated to illustrate differences in composition of water being extracted

TABLE 1. WELL AND WATER USE INFORMATION

MERCED WELL NO.	STATE WELL NO.	WELL DEPTH	WATER USE*	SOIL TYPE/ WATER APPLICATION AREA
1	9S/12E-2A	215	I	Fresno Loam, strongly saline-alkali
3	9S/12E-2G	640	W	Landlow Clay, slightly saline-alkali
5	9S/12E-2K		I,W	Pachappa Fine Sandy Loam, slightly saline-alkali
6	9S/12E-2M	300	I,W	Pachappa Fine Sandy Loam, slightly saline-alkali
9	9S/12E-3A		I,W	Rossi Clay, mderately saline - alkali
10	9S/12E-3J		I,W	Rossi Clay Loam, moderately saline-alkali
11	9S/12E-2P		W	Fresno Loam, strongly saline-alkali
12	9S/12E-1A	200	I,W	Fresno Loam, strongly saline-alkali
13	9S/12E-1J	168	I	Traver Fine Sandy Loam, moderately saline-alkali
14	9S/12E-12A	141	W	Rossi Clay, strongly saline - alkali
15	9S/12E-1B	197	I	Fresno Loam, strongly saline - alkali
16	9S/12E-3C	188	W	Traver Fine Sandy Loam, strongly saline alkali
19	9S/12E-1H		I,W	Fresno Loam, strongly saline - alkali
20	9S/12E-1E	195	I,W	Fresno Loam, strongly saline - alkali
21	9S/12E-1M		W	Fresno Loam, strongly saline - alkali
22	9S/12E-11B	580	W	Fresno Loam, strongly saline - alkali
23	9S/12E-12D	660	W	Fresno Loam, strongly saline - alkali

* I = IRRIGATION, W = WILDLIFE HABITAT (seasonal marsh) (Reference: U.S.D.A., 1962)

Table 2. Water Quality Guidelines and Criteria for the Protection of Beneficial Uses

	Ambient criteria to protect freshwater aquatic life		Irrigation Degree of Restriction on Use		
Constituent	4 day average -µg/l-*	1 hour average	None	Slight to Moderate -mg/l-	Severe
Arsenic	190	360	0.1		
Boron			< 0.7	0.7-3.0	> 3
Cadmium	0.55	1.4	0.01		
Chromium (VI)	11	16	0.1		
Copper	5.4	7.5	0.2		
Iron			5		
Lead (inorganic)	0.99	25	5		
Mercury	0.012	2.4			
Molybdenum			0.01		
Nickel	73	653	0.02		
Selenium	5	20	0.02		
Zinc	49	54	2		
TDS (mg/l)			< 450	450 - 2000	>2000
EC			< 700	700 - 3000	>3000

* Acid soluble metals

(References: Ayers and Westcot, 1985; EPA, 1985; EPA, 1987; Marshack, 1987; and SWRCB, 1987.)

TABLE 3. MERCED NATIONAL WILDLIFE REFUGE
GROUND WATER QUALITY: MINERAL ANALYSIS

MERCED WELL NO.	STATE WELL NO.	WELL DEPTH-ft	DATE	Ca	Mg	Na	K	Cl	SO4	Total Alk	Hard	SS	EC	pH	B	adjRNa
							-----	mg/L	-----				µmhos/cm		mg/L	
1	9S/12E-2A	215	8/4/87					22	48	310			740	7.2	0.01	
3	9S/12E-2G	640	8/4/87					40	60	310			830	7.3	0.05	
5	9S/12E-2K		11/20/86	22	4.7	74	1.4	31	16	160	63	<4	450	7.9	0.04	
			8/4/87					29	16	160			450	7.9	0.02	3.78
6	9S/12E-2M	300	11/20/86	86	88	140	2.4	310	240	280	520	<4	1900	7.5	0.01	
			8/4/87					280	240	240			1900	7.2	<0.01	2.8
9	9S/12E-3A		11/20/86	51	50	41	1.3	120	93	210	380	<4	940	7.4	0.01	
			8/4/87					120	83	200			920	7.4	<0.01	1.04
10	9S/12E-3J		11/20/86	110	110	160	24	380	270	280	800	<4	2200	7.4	0.02	
			8/4/87					400	320	260			2500	7.2	0.01	2.87
11	9S/12E-2P		11/20/86	76	81	230	2.2	360	210	360	570	<4	2200	7.4	0.04	
			8/4/87					340	190	360			2300	7.2	0.02	4.89
12	9S/12E-1A	200	11/20/86	36	26	31	0.8	19	28	210	210	<4	520	7.6	<0.01	
			8/4/87					10	28	250			610	7.4	0.06	1.04
13	9S/12E-1J	168	8/25/87					180	72	130			994	7.3	0.03	
14	9S/12E-12A	141	8/4/87					560	160	220			3100	7.2	<0.01	
15	9S/12E-1B	197	8/4/87					8	36	340			740	7.4	<0.01	
16	9S/12E-3C	188	11/20/86	63	69	89	1.9	235	120	265	490	<4	1400	7.5	0.04	
			8/4/87					190	120	260			1400	7.3	<0.01	1.99
19	9S/12E-1H		11/20/86	31	32	33	0.9	21	39	250	240	<4	610	7.6	0.01	
			8/25/87					18	25	172			446	7.5	0.02	1.05
20	9S/12E-1E	195	11/20/86	60	52	61	1.4	86	82	310	400	<4	1000	7.6	0.01	
			8/4/87					95	77	230			950	6.9	0.06	1.57
21	9S/12E-1M		11/20/86	25	10	77	1.6	35	28	180	99	<4	520	8.0	0.04	
			8/25/87					160	125	155			1035	7.2	0.04	1.98
22	9S/12E-11B	580	11/20/86	40	20	99	1.9	90	43	200	160	<4	750	7.6	0.03	
			8/4/87					280	140	360			1900	7.4	0.02	3.5
23	9S/12E-12D	660	11/20/86	22	9.6	81	2.1	44	22	170	80	<4	530	7.9	0.04	
			8/4/87					320	160	270			2000	7.5	0.02	3.66

from wells in the refuge (Fig. 4). The Piper diagram shows relative contributions of major cations and anions to the total ion content of the water. Wells which tap the upper water bearing zone show a predominant bicarbonate anion, but these wells have a mixed cation character which reflects recent recharge and evapoconcentration processes in the near surface zone. Wells 22 and 23 are confined to drawing water from below the E Clay. These deep wells pump a sodium bicarbonate type water. Wells 5 and 21 show a similar mineral content which suggests that these wells also draw water from the deeper water bearing zone.

Results of the total recoverable trace element analysis are reported in Table 4. Molybdenum, copper, chromium, lead, nickel, and zinc levels were all well below the recommended criteria for the protection of freshwater aquatic life. The selenium criteria has recently been lowered to 5 µg/L (EPA, 1987). This revised criteria considers potential effects on waterfowl, and is not limited to effects on invertebrates. The range of selenium in the wells used for fall marsh floodup was 0.1 - 2.5 µg/L with a median of 1.4 µg/L. The data show that trace elements are not likely to pose a limitation to the beneficial use of ground water for wildlife habitat.

Water Quality for Agriculture

A second well sampling survey was conducted in August 1987 to confirm earlier results, and to characterize the water quality of wells which are utilized for agricultural crop production. Seven of the seventeen wells sampled in August serve a dual purpose and provide water for both seasonal marsh and irrigation. The water quality samples obtained in August were analyzed for a partial mineral series (Cl, SO_4, total alkalinity, EC, pH, and boron). The August samples were also analyzed for selenium and molybdenum, but a full trace element scan was not performed as trace element analysis results from the November sampling were extremely low. Molybdenum levels in all samples were well below the 0.01 mg/L guideline for irrigation water. Selenium levels in the summer samples ranged from 0.2 - 2.5 µg/L with a median of 1.3 µg/L. The selenium levels in the ground water quality samples extracted at Merced do not show a significant seasonal difference. The trace element levels are well below the guidelines for irrigation water, and should not pose a problem to wildlife which come in contact with the irrigation water.

The range of salinity for all irrigation well samples was 446 - 2,500 µmhos/cm with a median salinity of 920 µmhos/cm. Refuge personnel expressed concern with the salinity of some of the wells, and questioned the need for irrigation management to prevent further salt buildup in the soil root zone. Electrical conductivities of up to 3,000 µmhos/cm should only pose slight to moderate restrictions on irrigation water use (Table 2).

Fig. 4. Chemical Composition of Water from Refuge Suppy Wells

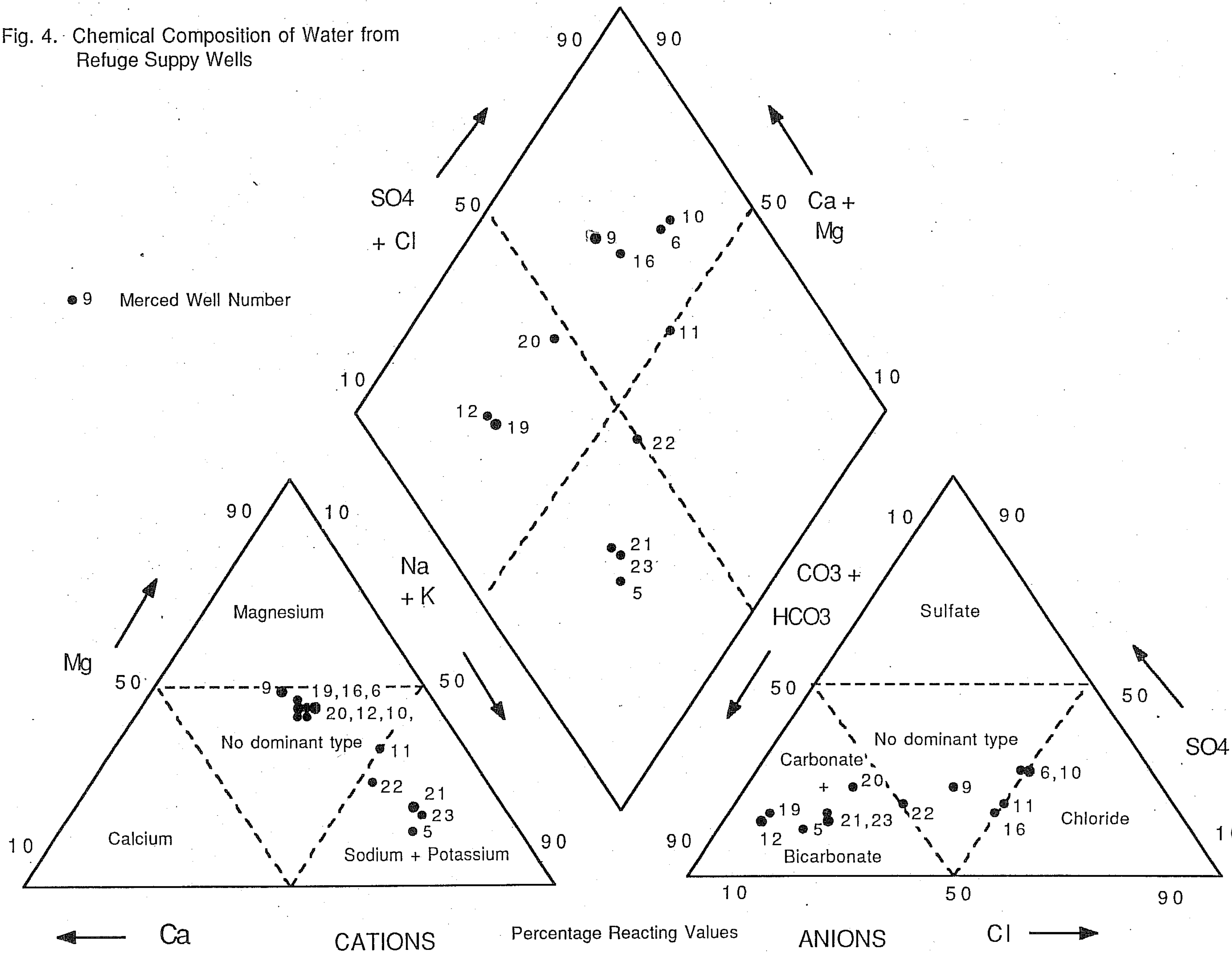

TABLE 4. MERCED NATIONAL WILDLIFE REFUGE
GROUND WATER QUALITY: TOTAL RECOVERABLE TRACE ELEMENT ANALYSIS

MERCED WELL NO.	STATE WELL NO.	WELL DEPTH-ft	SAMPLE DATE	Se	Mo	Cu	Cr	Pb	Ni	Zn
				----	----	----	µg/L	----	----	----
1	9S/12E-2A	215	8/4/87	1.6	2					
3	9S/12E-2G	640	8/4/87	1.1	1					
5	9S/12E-2K		11/20/86	< 0.2	<5	<1	<1	<5	<5	<1
			8/4/87	0.3	5					
6	9S/12E-2M	300	11/20/86	2.3	2	1	1	<5	<5	<1
			8/4/87	2.2	2					
9	9S/12E-3A		11/20/86	2.3	2	<1	<1	<5	<5	<1
			8/4/87	2.2	1					
10	9S/12E-3J		11/20/86	2.1	2	1	2	<5	<5	<1
			8/4/87	2.5	1					
11	9S/12E-2P		11/20/86	1.1	5	<1	<1	<5	<5	<1
			8/4/87	0.7	5					
12	9S/12E-1A	200	11/20/86	1.6	<5	<1	12	<5	<5	<1
			8/4/87	1.6	2					
13	9S/12E-1J	168	8/25/87	1.4						
14	9S/12E-12A	141	8/4/87	0.7	2					
15	9S/12E-1B	197	8/4/87	2.0	3					
16	9S/12E-3C	188	11/20/86	0.9	<5	<1	<1	<5	<5	<1
			8/4/87	0.7	1					
19	9S/12E-1H		11/20/86	1.7	4	<1	11	<5	<5	<1
			8/25/87	1.3						
20	9S/12E-1E	195	11/20/86	2.5	3	<1	<1	<5	<5	<1
			8/4/87	1.8	2					
21	9S/12E-1M		11/20/86	0.2	<5	<1	<1	<5	<5	<1
			8/25/87	0.2						
22	9S/12E-11B	580	11/20/86	< 0.2	<5	<1	<1	<5	<5	<1
			8/4/87	0.4	6					
23	9S/12E-12D	660	11/20/86	< 0.2	<5	<1	<1	<5	<5	<1
			8/4/87	0.4	7					

It is important to emphasize that the water quality management guidelines are only useful if scientific irrigation scheduling is in place. Sound irrigation management is essential to limit water applications to the crop water needs and leaching requirement. Over irrigation will raise pumping costs, the ground water table, and saline drainage to the water-bearing zone.

The presence of the sodium ion in irrigation water represents a potential water quality problem to soils and crops with respect to the water infiltration rate and potential plant toxicity. Excessive sodium weakens the soil structure and inhibits the infiltration rate of water into the root zone. Irrigation water salinity and its sodium to calcium and magnesium ratio are the water quality factors which influence the infiltration rate. This potential infiltration problem can be evaluated by the calculation of the adjusted sodium adsorption ratio (adjRNa, Ayers and Westcot, 1985).

The adjusted sodium adsorption ratio for all Merced wells with full mineral analysis data is also presented in Table 3. This data is evaluated with respect to the degree of restriction on use (Table 5). The water quality of 50% of the twelve wells posed no restrictions on infiltration. The water quality of the remaining 50% of the wells may result in only slight to moderate infiltration problems, but these can likely be overcome with good management practices and it is not expected that these levels will limit crop production. The quality of this water should not limit agricultural use due to plant toxicity.

TABLE 5. EVALUATION OF WATER QUALITY WITH RESPECT TO POTENTIAL INFILTRATION PROBLEMS (Ayers and Westcot, 1985)

POTENTIAL INFILTRATION PROBLEM				Degree of Restriction on Use	
			None	Slight/Moderate	Severe
				- µmhos/cm -	
	adj RNa = 0 - 3	and ECw =	> 700	700 - 200	< 200
	adj RNa = 3 - 6	and ECw =	> 1200	1200 - 300	< 300
	adj RNa = 6 - 12	and ECw =	> 1900	1900 - 500	< 500
	adj RNa = 12 - 20	and ECw =	> 2900	2900 - 1300	< 1300
	adj RNa = 20 - 40	and ECw =	> 5000	5000 - 2900	< 2900
EVALUATION: WELL NO.	adj RNa	ECw			
5	3.78	450		X	
6	2.80	1900	X		
9	1.04	940	X		
10	2.87	2200	X		
11	4.89	2200	X		
12	1.04	520		X	
16	1.99	1400	X		
19	1.05	610		X	
20	1.57	1000	X		
21	1.98	520		X	
22	3.50	750		X	
23	3.66	530		X	

L ECw = salinity of the irrigation water

$$\text{adj RNa} = \frac{Na}{\sqrt{\dfrac{Cax + Mg}{2}}}$$

where Na = sodium in the irrigation water (me/L)
Cax = calcium in applied irrigation water modified due to applied water salinity, HCO3/Ca ratio, and the estimated partial pressure of CO2 in the surface soil.
Mg = magnesium in the irrigation water (me/L)

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APPENDIX A

Wildlife Resources at Merced National Wildlife Refuge

Ducks, Geese, Swans, and Coots

Mallard
Green-winged Teal
Pintail
Ruddy Duck
Redhead
Cinnamon Teal
Gadwall
Blue-winged Teal
Bufflehead
Wood Duck
Lesser Scaup

American Widgeon
Northern Shoveler
Canvasback
Ring-necked Duck
Snow Goose
Ross Goose
White-fronted Goose
Canada Goose
Cackling Canada Goose
Tundra Swan
American Coot

Shore and Wading Birds

American Avocet
Black-necked Stilt
Common Snipe
Long-billed Dowitcher
Least Sandpiper
Dunlin
Western Sandpiper
Greater Yellowlegs
Long-billed Curlew
Killdeer
Pied-billed Grebe
California Gull

White Pelican
American Bittern
Great Blue Heron
Great Egret
White-faced Ibis
Snowy Egret
Black-crowned Night Heron
Lesser Sandhill Crane
Greater Sandhill Crane
Virginia Rail
Sora
Common Moorhen

Raptorial Birds

Turkey Vulture
Sharp-shinned Hawk
Swainson's Hawk
Short-eared Owl
Black-shouldered Kite
Cooper's Hawk
American Kestrel
Great Horned Owl
Northern Harrier
Red-tailed Hawk
Barn Owl
Burrowing Owl
Golden Eagle

Upland Game

Mourning Dove
Cottontail Rabbit
Ring-necked Pheasant
Black-tailed Rabbit

Furbearers

Coyote
Skunk
Raccoon
Muskrat
Long-tailed Weasel

Source: USBR, 1986 and USFWS refuge records.