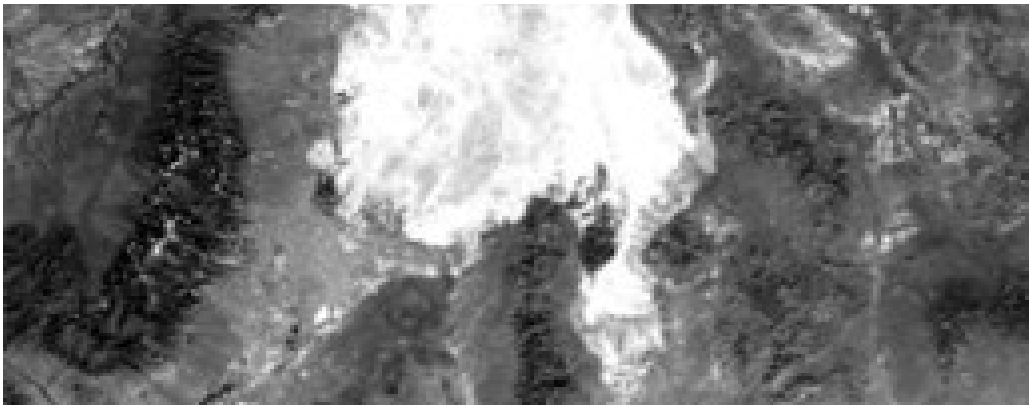
ATTACHMENT 10

Large Attachments to Salton Sea Authority Comment Letter

Image extracted from: W.W. White, III. 2002. Salt Laydown Project - Replenishment of Salt to the Bonneville Salt Flats. Pages 433 - 486 in J. Wallace Gwynn, ed., Great Salt Lake: An Overview of Change. Special Publication of the Utah Department of Natural Resources.
Document downloaded November 14, 2006 from BLM website (www.ut.blm.gc

<---------- approximately 45 miles ----------> (Wendover to bend in I-80)

^
approximately 116 miles



<---------- approximately 45 miles ---------->
(Wendover to bend in I-80)

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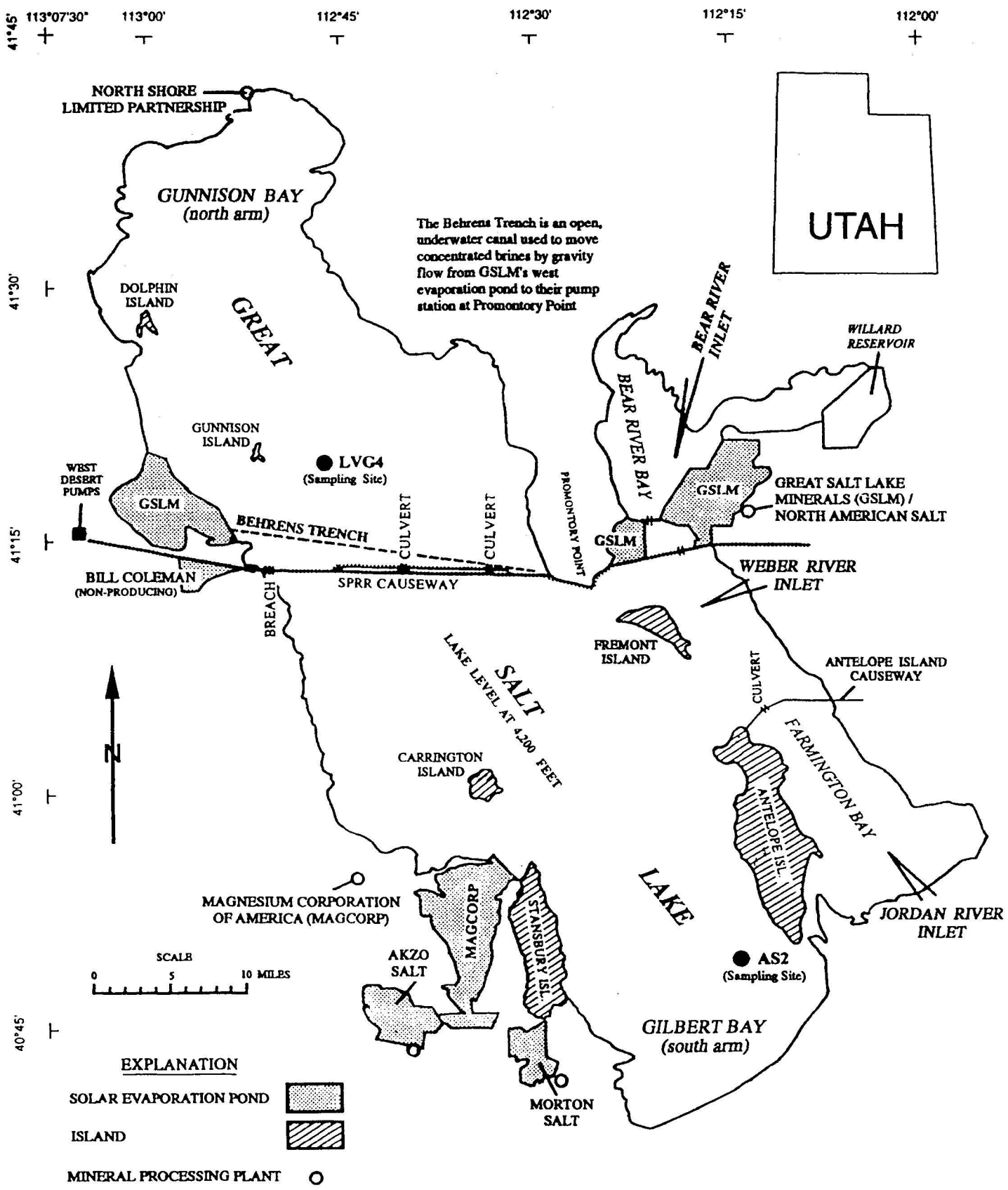


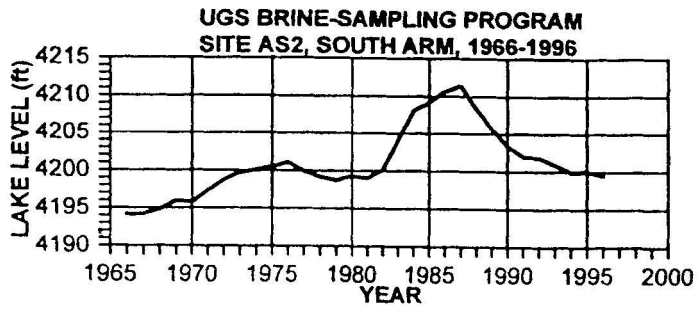
Public Information Series 51
Utah Geological Survey
a division of
Utah Department of Natural Resources

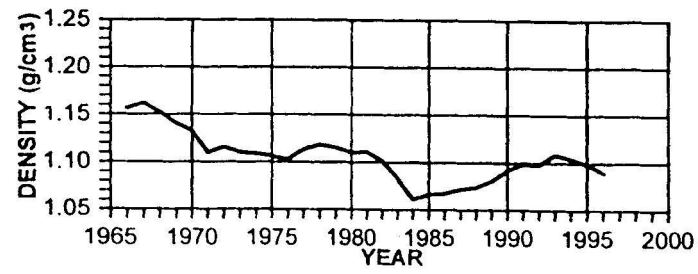
BRINE PROPERTIES, MINERAL EXTRACTION INDUSTRIES, AND SALT LOAD OF GREAT SALT LAKE, UTAH

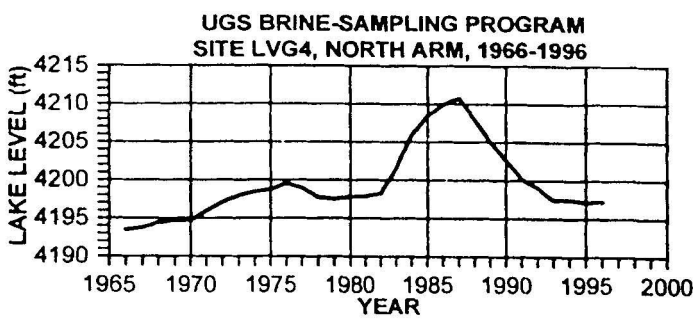
J. Wallace Gwynn - 1997

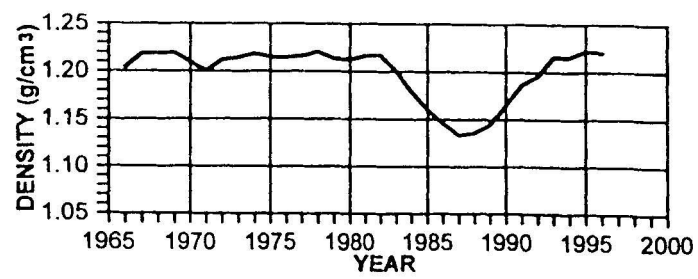
WATER DENSITY VERSUS LAKE ELEVATION

The graphs show average yearly lake elevation (feet above mean sea level) and water density (g/cm^3), a measure of salinity or salt content, for the south (site AS2) and north (site LVG4) arms of the lake from 1984 through 1996 (see map). The density of the south arm, which is fed by fresh-water tributaries, varies inversely with lake elevation. The north arm, which is fed by salty south-arm water, is more saline and less influenced by lake level. Farmington and Bear River Bays are much less saline than either the north or south arms of the lake.









WATER CHEMISTRY

Water chemistry, or the relative abundance of dissolved ions (dry-weight basis), remains relatively constant throughout both arms of the lake.

Table 1 shows the composition of dissolved salts in Great Salt Lake compared with the ocean (average composition), the Dead Sea, and Sevier Lake (Millard County, Utah).

Table 1. Comparison of different water chemistries

ION	GREAT SALT LAKE	OCEAN	DEAD SEA	SEVIER LAKE UTAH
Sodium	32.1	30.8	12.3	35.5
Potassium	2.3	1.1	2.3	1.4
Magnesium	3.7	3.7	12.8	1.6
Calcium	0.3	1.2	5.2	0.2
Chloride	54.0	55.5	67.1	49.1
Sulfate	7.6	7.7	0.1	12.1

MINERAL-EXTRACTION INDUSTRIES

Six mineral-extraction industries currently operate on Great Salt Lake (table 2). Cumulatively, these industries produced nearly 2.8 million tons of products during 1995, valued at about $300 million.

Table 2. Active mineral extraction industries

INDUSTRY	PRODUCT(S)
Magnesium Corporation of America (MAGCORP)	Primary magnesium metal, alloys, and chlorine gas
AKZO Salt Company	Sodium chloride products
Morton Salt Company	Sodium chloride products
Great Salt Lake Minerals Corporation (GSLM)	Potassium sulfate (fertilizer), magnesium chloride products
North American Salt Company	Sodium chloride products
North Shore Ltd. Partnership/ Mineral Resources International	Concentrated brines/ processed into dietary supplements

SALT LOAD AND POTENTIAL RESOURCES

Great Salt Lake contains about 4.5 billion tons of salt. Major changes in lake conditions, such as the 1980s flooding, breaching the Southern Pacific Railroad (SPRR) causeway in 1984, and West Desert pumping in 1987, have altered the balance of salt between the two arms. Raising the SPRR causeway during the 1980s reduced the permeability of the causeway and the bi-directional transfer of brines between the southern and northern arms. Because of this, there has been a constant loss of salt from the south arm of the lake to the north arm since 1994. The reduction in salinity is of great concern to the south-arm mineral-extraction industries and to the lake's multi-million dollar brine shrimp industry.

A buried, wedge-shaped body of natural sodium sulfate (mirabilite) extends westward from Promontory Point, beneath the SPRR causeway. Sodium sulfate is found cementing the near-shore sediments at shallow depths at numerous locations around the perimeter of the lake.

Information Sheet 51 downloaded November 18, 2006 from: http://geology.utah.gov/utahgeo/gsl/index.htm

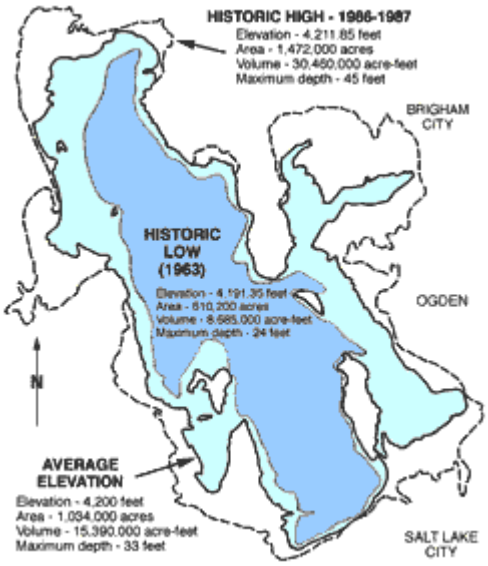
Great Salt Lake

PI-39 Commonly Asked Questions About Utah's Great Salt Lake and Ancient Lake Bonneville

How big and how deep is the lake, and why does it change in size?

Great Salt Lake averages approximately 75 miles long by 35 miles wide at a surface elevation of about 4,200 feet. At this elevation, the lake covers an area of 1,034,000 acres, and has a maximum depth of about 33 feet.

It is reported to be the 33rd largest lake in the world, and the largest fresh or saltwater lake in the United States after the Great Lakes. Its size and depth, however, vary both seasonally and over the long term. The magnitude of these changes depends on the balance between the total amount of water that enters the lake and that which leaves.

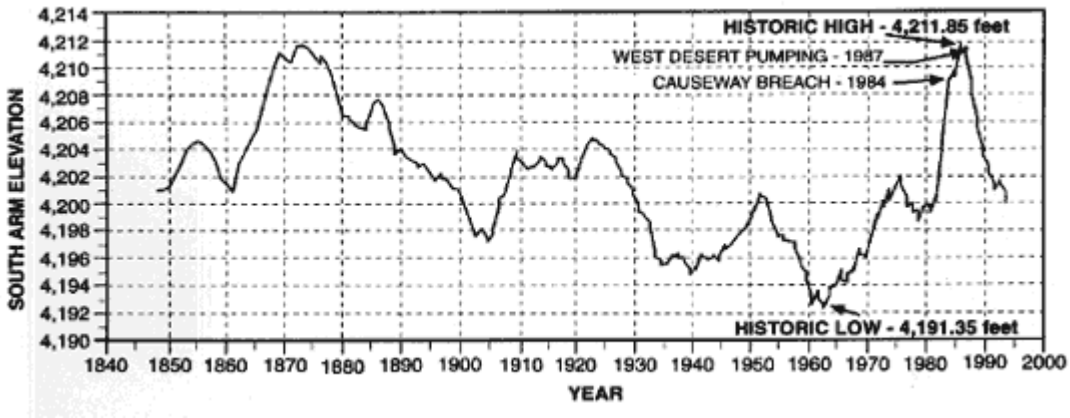


Areal extent, elevation, volume, and maximum depth of Great Salt Lake at historic high, average, and historic low-water levels.

On average, the lake level fluctuates one to two feet annually, rising to its highest level during May through July (following the melting of the mountain snowpack) and dropping to its lowest point during October through November (after the hot summer months).

In historical time (1847 to present), fluctuations of the lake level have varied over a range of 20 feet from a low of 4,191.35 feet in 1963 to a high of 4,211.85 feet in 1986-1987. The historical average elevation of the lake is about 4,200 feet.

Because of the very shallow nature of the lake, even modest changes in its elevation result in relatively large changes in the lake's area and volume. The accompanying map shows the high, average, and low elevations of the lake and pertinent information for each of these elevations.



Historical elevations (in feet above mean sea level) of the southern arm of the Great Salt Lake (at its highest point for the year), 1847-1994 (USGS provisional lake records).

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Great Salt Lake

PI-39 Commonly Asked Questions About Utah's Great Salt Lake and Ancient Lake Bonneville

How much salt is in Great Salt Lake, and why does the salinity vary?

The total amount of salt dissolved in Great Salt Lake is about 4.5 to 4.9 billion tons. As the lake rises, its salinity drops because the same amount of salt is dissolved in more water. The lower the lake level, the saltier the lake becomes. In historical time, the lake's salinity has ranged from a little less than 5 percent, (just above that of sea water), to nearly 27 percent (beyond which water cannot hold more salt).

Can I float in Great Salt Lake?

You can easily float in Great Salt Lake if the water is salty enough. At the lake's average elevation of 4,200 feet, the south arm of the lake contains about 13 percent salt, which makes it salty enough for most people to float with little effort. When the lake is higher than 4,200 feet, it is less salty and therefore less buoyant. Swimmers float easily in the north arm because it is twice as salty as the south arm.

What is the chemical composition of Great Salt Lake?

The chemical composition of Great Salt Lake is similar to that of typical ocean water. Sodium and chloride are the major ions in the water, followed by sulfate, magnesium, calcium, and potassium. For comparison, the table below shows the concentration of the six major ions in water of Great Salt Lake, a typical ocean, and the Dead Sea.

Chemical compositions (dry weight percents) of Great Salt Lake, typical ocean, and the Dead Sea waters.

Source	Sodium	Potassium	Magnesium	Calcium	Chloride	Sulfate
Great Salt Lake	32.8	2.0	3.3	0.2	54.5	7.2
Ocean (typical)	30.8	1.1	3.7	1.2	55.5	7.7
Dead Sea	12.3	2.3	12.8	5.3	67.2	0.1

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Great Salt Lake

PI-39 Commonly Asked Questions About Utah's Great Salt Lake and Ancient Lake Bonneville

What minerals are produced from Great Salt Lake? How and by whom are they recovered?

In 1995, five mineral-extraction companies operated near the lake. These companies used solar evaporation to concentrate the lake waters to produce either salts or highly concentrated brine (water with high salt content) products. These companies paid a royalty to the State of Utah (owner of the lake), on the salts and other materials produced and sold.

Sodium chloride (common salt) is produced by: (1) evaporating the water in shallow ponds that cover many thousands of acres, (2) precipitating the salt, and (3) harvesting it from the bottom of the ponds.The collected salt is rinsed, washed, dried, and screened to produce different product sizes and grades.

Common salt is also pressed into pellets for use in water softeners, and formed into salt-lick blocks (some with added minerals) for livestock consumption. Large quantities of bulk salt are shipped out-of-state for use in industry. Much of the salt is used locally for melting ice on roadways.

Harvesting potassium-bearing salts from large solar-evaporation pond. Salts will by processed into potassium sulfate, a mineral fertilizer.

Food-grade, or table salt is not produced from the lake, because its purity cannot be guaranteed without additional, costly processing. The table salt used in Utah comes from salt-processing facilities in New York, Ohio, Kansas, Louisiana, Texas, or California.

Great Salt Lake also yields salt products other than common salt. The salt industry produces potassium sulfate, a commercial fertilizer derived from potassium and magnesium salts.

Magnesium-chloride brine is used in the production of magnesium metal and chlorine gas and as a dust suppressant. The production of these salts and highly concentrated brines requires additional evaporation beyond that needed to precipitate common salt. These products also require complex chemical processing.

Mirabilite, a hydrated sodium-sulfate salt, commonly used in the production of sodium sulfate or salt cake, precipitates from concentrated lake water only during the cold winter months.

The table below lists the names of the five salt companies that operated on the Great Salt Lake and the products they produced.

Companies extracting mineral products from the Great Salt Lake, and their products (1995).

COMPANY	PRODUCTS
AKZO Salt of Utah	Sodium chloride
Great Salt Lake Minerals Corp.	Potassium sulfate and magnesium chloride products
Magnesium Corporation of America	Magnesium metal, chlorine gas
Morton Salt Company	Sodium chloride
North American Salt Company	Sodium chloride

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Excerpt from: Whelan, J. A. and Carol A. Petersen. 1975. Great Salt Lake, Utah: Chemical and Physical Variations of the Brine, Water Year 1973. Utah Geological and Mineral Survey. Water-Resource Bulletin 20.
Document downloaded December 7, 2006 from Utah Department of Natural Resources Library website (www.dnrlibrary.utah.gov).

Table 2. Composition of dissolved solids in the three brine types of Great Salt Lake for various years.
[computed in weight-percent]

	South arm shallow brines					South arm deep brines			North arm brines			
	March 1930[1] d<20 ft.	April 1960[2] d<20 ft.	1966[3] d<20 ft.	1972[3] d<20 ft.	WY 1973 d<20 ft.	1966[3] d>20 ft.	1972[3] d>20 ft.	WY 1973 d>20 ft.	December 1963[4]	1966	1972	WY 1973
Cl^-	57.05	55.88	55.02	55.56	55.26	55.51	55.20	55.05	56.04	52.98	56.17	55.97
Mg^{++}	2.75	2.91	3.53	3.54	3.81	3.57	3.71	4.03	4.66	4.10	3.72	3.95
Ca^{++}	0.17	0.12	0.15	0.12	0.22	0.12	0.08	0.04	0.09	0.11	0.05	0.08
Na^+	32.90	32.71	31.54	30.36	30.61	30.95	30.27	31.35	29.08	31.59	29.20	30.41
K^+	1.61	1.71	2.35	2.64	2.47	2.26	2.69	2.51	2.75	2.79	2.95	2.65
$SO_4^=$	5.47	6.60	7.35	7.69	7.54	7.53	7.99	6.84	7.28	8.36	7.83	6.85
Br^-	–	–	0.04	0.05	0.06	0.04	0.03	0.04	–	0.05	0.05	0.05
Li^+	–	–	0.02	0.01	0.01	0.02	0.02	0.02	–	0.02	0.02	0.02
B	–	0.01	–	0.03	0.02	–	0.02	0.02	0.01	–	0.01	0.02
SiO_2	–	0.002	–	–	–	–	–	–	0.001	–	–	–
Bicarbonate as carbonate, $CO_3^=$	0.05	0.06	–	–	–	–	–	–	0.09	–	–	–

[1] Most recent published pre-fill analysis (Hahl and Handy, 1969, p. 14).
[2] First published analysis of shallow (d<20 feet) south arm brines after completion of railroad fill (Hahl and Handy, 1969, p. 14).
[3] Median values of average analysis for each sampling date; sum recomputed to 100 percent.
[4] First published analysis of north arm brines after completion of railroad fill (Hahl and Handy, 1969, p. 14).

Table 3. Estimated composition and concentration of total dissolved load of Great Salt Lake, Utah, if fill had been opened: for selected years 1930, 1969, 1972, and water-year 1973.
[compositions in weight-percent; concentrations in grams per liter]

	1930[1]	1966[2]	1972[2]	Water-year 1973[2]
Cl^-	57.05	54.20	55.82	55.50
Mg^{++}	2.75	3.77	3.65	3.88
Ca^{++}	0.17	0.13	0.08	0.15
Na^+	32.90	31.53	29.77	30.62
K^+	1.61	2.53	2.80	2.54
$SO_4^=$	5.47	7.78	7.79	7.23
Br^-	–	0.05	0.05	0.05
Li^+	–	0.02	0.02	0.01
B	–	–	0.02	0.02
Bicarbonate as carbonate, $CO_3^=$	0.05	–	–	–
Estimated median concentration		265	216	189

[1] Included for comparison (Hahl and Handy, 1969, p. 14).
[2] Post-fill data calculated as if fill had been removed.

Table 4. Total concentrations of dissolved solids of Great Salt Lake brines, water-year 1973.
[concentrations reported in grams per liter]

Date	Shallow south arm d<20 ft.	Deep south arm d>20 ft.	North arm
10-25-72			334.90
10-27-72	151.10	250.91	
1-22-73	141.84	255.96	
2-16-73			313.71
6-19-73	125.99	218.44	
6-20-73			331.75
8-13-73	136.72	274.96	
8-15-73	136.28	260.82	
10- 5-73	138.78	251.88	
10-10-73			340.25
10-11-73			339.60
Mean	138.45	252.16	331.87
Median	137.75	253.92	334.90
Standard deviation	8.18	18.70	10.68
Range	25.11	56.52	26.54

Cadmium

Cadmium in Great Salt Lake north arm brines is present in amounts of less than 0.0001 ppm. Cadmium probably occurs as Cd^{++} and $CdSO_4$.

Mercury

Mercury occurs in Great Salt Lake north arm brines in amounts of less than 0.01 ppm. What mercury is present is probably present as $HgCl_3^-$ or $HgCl_4^=$.

PHYSICAL PROPERTIES

Color

Even the casual observer notes the difference between the blue-green color of the south arm and the pink color of the north arm. According to Quinn (1966, p. 30-31), the red color of the north arm is caused by the algae *Coccochloris elabans*.

Transparency/Turbidity

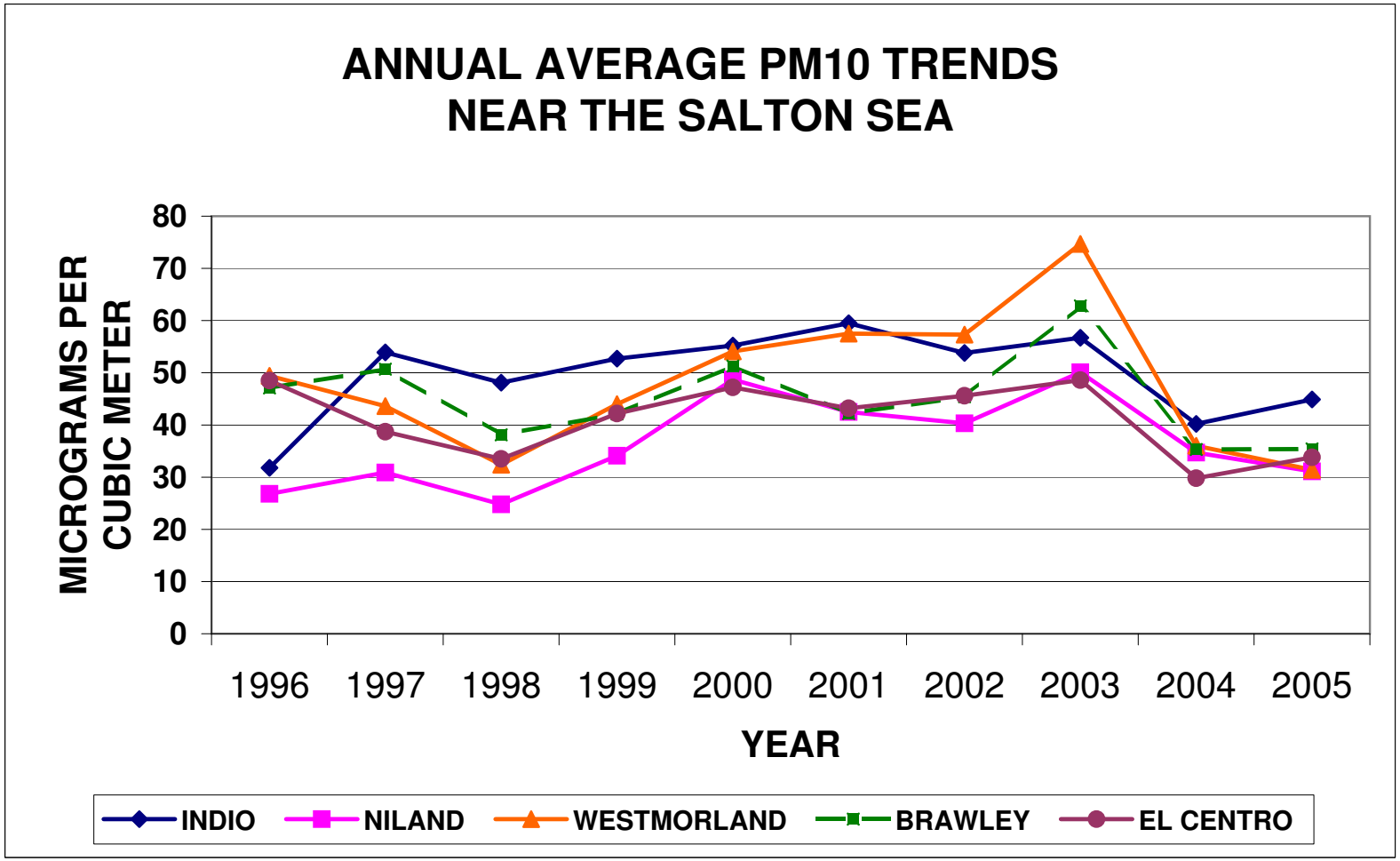
The transparency of the south arm of Great Salt Lake varies widely. During the summer, one may see to depths of 20 feet; but during the winter objects only a few feet deep are invisible. Walter M. Katzenberger has observed that the transition between high transparency and low transparency occurs in May, within a period of one day. The water temperature during this period of transition is about 55° F. The brines of the north arm have low transparency throughout the year.

PM10 AIR QUALITY DATA FOR MONITORING STATIONS NEAR THE SALTON SEA

Year	Estimated Days Above 24-Hour Standards		Annual Average PM10 Concentration (ug/m^3)		3-Year Mean Concentration (ug/m^3)		Highest 24-Hour Average Concentration (ug/m^3)		Expected Peak Day Concentration (ug/m^3)
	Federal (150 ug/m^3)	State (50 ug/m^3)	Federal Procedures	State Procedures	Federal Procedures	State Procedures	Federal Procedures	State Procedures	
PALM SPRINGS STATION, RIVERSIDE COUNTY									
1996	0.0	11.8	29.1	29.1	28	29	130	130	83.6
1997	0.0	insuff. data	27.1	insuff. data	28	29	63	63	87.3
1998	0.0	18.5	26.4	26.3	28	29	72	72	91.9
1999	0.0	19.3	28.9	28.9	27	29	104	104	82.6
2000	0.0	insuff. data	24.2	insuff. data	27	29	44	44	79.1
2001	insuff. data	insuff. data	31.1	insuff. data	28	29	432	432	158.5
2002	0.0	insuff. data	27.2	insuff. data	28	insuff. data	75	73	insuff. data
2003	0.0	23.0	27.1	26.5	28	26	108	106	insuff. data
2004	0.0	insuff. data	26.4	insuff. data	27	26	79	78	90.2
2005	0.0	13.1	25.9	25.4	26	26	66	64	89.4
AVERAGE			**27.3**						
INDIO STATION, RIVERSIDE COUNTY									
1996	13.1	189.2	31.8	55.2	27	55	215	215	180.2
1997	13.0	insuff. data	53.9	insuff. data	37	55	182	182	232.4
1998	3.3	146.2	48.1	48.4	45	55	158	158	205.9
1999	0.0	insuff. data	52.7	insuff. data	52	48	119	119	174.3
2000	8.6	183.2	55.2	55.4	52	55	201	201	171.8
2001	17.6	170.6	59.5	59.0	56	59	604	604	308.4
2002	9.0	174.1	53.8	53.9	56	54	276	276	insuff. data
2003	9.1	158.2	56.7	56.1	57	56	309	302	insuff. data
2004	2.9	74.1	40.2	40.6	50	56	161	161	238.8
2005	0.0	121.7	44.9	45.4	47	56	106	106	197.6
AVERAGE			**49.7**						
NILAND STATION, IMPERIAL COUNTY									
1996	insuff. data	insuff. data	26.8	insuff. data	insuff. data	insuff. data	71	71.0	insuff. data
1997	insuff. data	insuff. data	30.9	insuff. data	insuff. data	insuff. data	191	191	insuff. data
1998	insuff. data	insuff. data	24.8	insuff. data	28	insuff. data	75	72	insuff. data
1999	0.0	37.4	34.1	34.2	30	34	58	58	insuff. data
2000	13.2	122.5	48.7	48.0	36	48	214	214	169.2
2001	6.6	insuff. data	42.5	insuff. data	42	48	377	370	226.4
2002	0.0	83.5	40.3	40.4	44	48	127	128	245.7
2003	19.1	insuff. data	50.1	insuff. data	44	40	402	406	292.8
2004	insuff. data	insuff. data	34.7	insuff. data	42	40	141	138	254.7
2005	0.0	32.0	31.1	31.1	39	31	77	75	248.6
AVERAGE			**36.4**						
WESTMORLAND STATION, IMPERIAL COUNTY									
1996	11.9	119.0	49.4	49.3	38	49	229	229	insuff. data
1997	7.1	insuff. data	43.6	insuff. data	44	49	213	213	192.9
1998	0.0	52.2	32.4	32.1	42	32	81	81	insuff. data
1999	0.0	114.4	44.0	44.3	40	44	130	126	insuff. data
2000	12.6	128.5	54.1	53.6	44	54	250	249	174.1
2001	6.1	insuff. data	57.5	insuff. data	52	54	647	634	291.2
2002	18.3	124.8	57.3	57.5	56	57	297	301	393.3
2003	12.3	188.4	74.7	73.8	63	74	840	848	524.5
2004	insuff. data	insuff. data	36.0	insuff. data	56	74	201	195	453.5
2005	0.0	11.5	31.4	31.4	47	74	54	57	354.2
AVERAGE			**48.0**						
BRAWLEY STATIONS, IMPERIAL COUNTY (station was moved to a new location on same street in 2004)									
1996	6.1	131.0	47.1	46.8	47	47	257	257	182.0
1997	5.8	insuff. data	50.7	insuff. data	48	47	532	532	236.2
1998	0.0	56.2	38.1	38.7	45	39	81	84	insuff. data
1999	0.0	97.3	42.1	42.8	44	43	89	88	insuff. data
2000	7.1	129.8	51.3	51.6	44	52	204	204	140.4
2001	0.0	81.3	42.2	42.7	45	52	120	122	147.1
2002	12.1	70.2	45.4	45.8	46	52	220	222	194.5
2003	insuff. data	insuff. data	62.8	insuff. data	50	46	509	511	309.7
2004	insuff. data	insuff. data	35.3	insuff. data	insuff. data	insuff. data	163	160	insuff. data
2005	0.0	29.4	35.4	35.2	26	35	71	71	insuff. data
AVERAGE			**45.0**						
EL CENTRO STATION, IMPERIAL COUNTY									
1996	6.1	91.7	48.5	48.6	45	49	359	359	185.0
1997	0.0	110.2	38.7	38.5	43	49	120	120	191.4
1998	0.0	56.9	33.5	33.6	40	34	90	87	insuff. data
1999	0.0	60.3	42.2	42.2	38	42	92	95	insuff. data
2000	6.1	118.7	47.2	insuff. data	41	42	180	176	144.9
2001	insuff. data	insuff. data	43.2	insuff. data	44	42	383	375	204.0
2002	5.8	110.7	45.6	45.6	45	46	263	254	247.6
2003	6.1	159.4	48.6	48.6	46	49	180	181	243.7
2004	insuff. data	insuff. data	29.8	insuff. data	41	49	135	132	195.1
2005	0.0	35.6	33.8	33.9	37	49	81	85	152.1
AVERAGE			**41.1**						

Data downloaded from CARB website (www.arb.ca.gov/adam/welcome.html) on December 9, 2006.

ANNUAL AVERAGE PM10 TRENDS:



OZONE AIR QUALITY DATA FOR MONITORING STATIONS NEAR THE SALTON SEA

Year	Days Over Standards: 1-Hour Standards, Federal	Days Over Standards: 1-Hour Standards, State	Days Over Standards: 8-Hour Standards, Federal	1-Hour Data, Parts Per Million (ppm): Maximum	1-Hour Data, Parts Per Million (ppm): 3-Year 4th High	8-Hour Data, Parts Per Million (ppm): Maximum	8-Hour Data, Parts Per Million (ppm): 3-Year 4th High	Expected Peak Day Concentration (ppm)
PALM SPRINGS STATION, RIVERSIDE COUNTY								
1996	12	60	52	0.160	0.158	0.125	0.111	0.154
1997	4	45	26	0.155	0.152	0.117	0.107	0.152
1998	8	40	30	0.173	0.155	0.136	0.107	0.153
1999	1	27	20	0.126	0.143	0.104	0.100	0.143
2000	0	40	28	0.124	0.133	0.104	0.099	0.138
2001	6	53	39	0.137	0.128	0.113	0.100	0.130
2002	2	49	46	0.136	0.132	0.124	0.105	0.134
2003	4	54	43	0.141	0.133	0.110	0.108	0.135
2004	1	36	32	0.125	0.131	0.106	0.104	0.131
2005	4	41	35	0.139	0.130	0.116	0.104	0.130
INDIO STATION, RIVERSIDE COUNTY								
1996	0	27	23	0.118	0.124	0.100	0.094	0.125
1997	0	1	1	0.102	0.124	0.094	0.089	0.129
1998	2	16	12	0.134	0.118	0.115	0.088	0.128
1999	1	13	7	0.126	0.121	0.107	0.086	0.118
2000	0	7	7	0.112	0.121	0.096	0.090	0.116
2001	0	21	15	0.114	0.112	0.098	0.089	0.111
2002	0	24	15	0.114	0.112	0.110	0.092	0.112
2003	0	24	19	0.123	0.114	0.105	0.096	0.116
2004	0	23	18	0.111	0.113	0.099	0.097	0.114
2005	0	18	18	0.114	0.113	0.095	0.095	0.114
NILAND STATION, IMPERIAL COUNTY								
1996	no data	no data	no data	no data	no data	no data	no data	no data
1997	0	1	0	0.100	0.080	insuff. data	insuff. data	insuff. data
1998	0	5	4	0.110	0.100	0.100	insuff. data	0.106
1999	0	0	0	0.090	0.100	insuff. data	insuff. data	0.103
2000	no data	no data	no data	no data	no data	no data	no data	no data
2001	0	2	1	0.105	0.090	0.086	insuff. data	0.100
2002	0	5	5	0.102	0.100	0.092	insuff. data	0.100
2003	0	0	0	0.090	0.100	0.075	0.079	0.099
2004	0	0	0	0.092	0.098	0.081	0.078	0.095
2005	0	0	0	0.091	0.090	0.078	0.072	0.089
WESTMORLAND STATION, IMPERIAL COUNTY								
1996	no data	no data	no data	no data	no data	no data	no data	no data
1997	no data	no data	no data	no data	no data	no data	no data	no data
1998	0	10	8	0.120	0.100	0.096	0.091	0.113
1999	10	24	7	0.145	0.142	0.107	0.092	0.113
2000	no data	no data	no data	no data	no data	no data	no data	no data
2001	0	1	1	0.105	0.142	insuff. data	insuff. data	insuff. data
2002	0	0	0	0.092	0.091	0.080	insuff. data	0.091
2003	1	5	0	0.144	0.097	0.077	insuff. data	0.099
2004	0	6	0	0.109	0.106	0.083	0.073	0.102
2005	0	11	10	0.112	0.110	0.100	0.079	0.111
EL CENTRO STATION, IMPERIAL COUNTY								
1996	6	41	28	0.140	0.140	0.113	0.099	0.145
1997	2	29	11	0.130	0.140	0.111	0.099	0.148
1998	1	12	1	0.130	0.130	0.087	0.092	0.135
1999	2	9	0	0.140	0.130	insuff. data	0.085	0.129
2000	no data	no data	no data	no data	no data	no data	no data	no data
2001	2	13	2	0.135	0.127	insuff. data	insuff. data	0.123
2002	0	19	9	0.122	0.116	0.098	0.086	0.121
2003	2	19	8	0.130	0.127	0.092	0.087	0.125
2004	0	1	0	0.096	0.118	0.080	0.085	0.119
2005	0	8	5	0.122	0.121	0.097	0.084	0.115

Data downloaded from CARB website (www.arb.ca.gov/adam/welcome.html) on December 9, 2006.

Reference: Ross, W. H. 1915. The Chemical Composition of the Water of Salton Sea and its Annual Variation in Concentration. Pages 37 - 41 in H. T. Cory, The Imperial Valley and the Salton Sink. John J. Newbegin. San Francisco, CA. Document downloaded from the Redlands Institute Salton Sea Database website (www.institute.redlands.edu/salton/library.html).

Element or Compound	Weight Percents of Dissolved Minerals					
	Lake Forming Salton Sink Salt Beds	Salton Sea, 1907	Salton Sea, 1913	Colorado River	Great Salt Lake	Ocean
Na	33.14%	31.29%	32.30%	19.75%	33.39%	30.59%
K	0.30%	0.65%	0.34%	2.17%	1.08%	1.11%
Ca	1.37%	2.80%	1.97%	10.35%	0.42%	1.20%
Mg	1.55%	1.81%	1.62%	3.14%	2.60%	3.72%
AlO_2, FeO_2		0.02%	0.01%			
SiO_2		0.26%	0.16%	3.04%		
Cl	52.62%	47.83%	47.38%	19.92%	56.54%	55.29%
Br	trace	trace				0.19%
SO_4	11.00%	13.41%	12.46%	28.61%	5.97%	7.69%
CO_2			1.13%			
CO_3		1.85%		13.02%		0.21%
HCO_3			1.57%			
Other		0.08%	1.06%			
Salinity, ppm		3,553.9	9,699.6	695.9	195,580.0	35,190.0

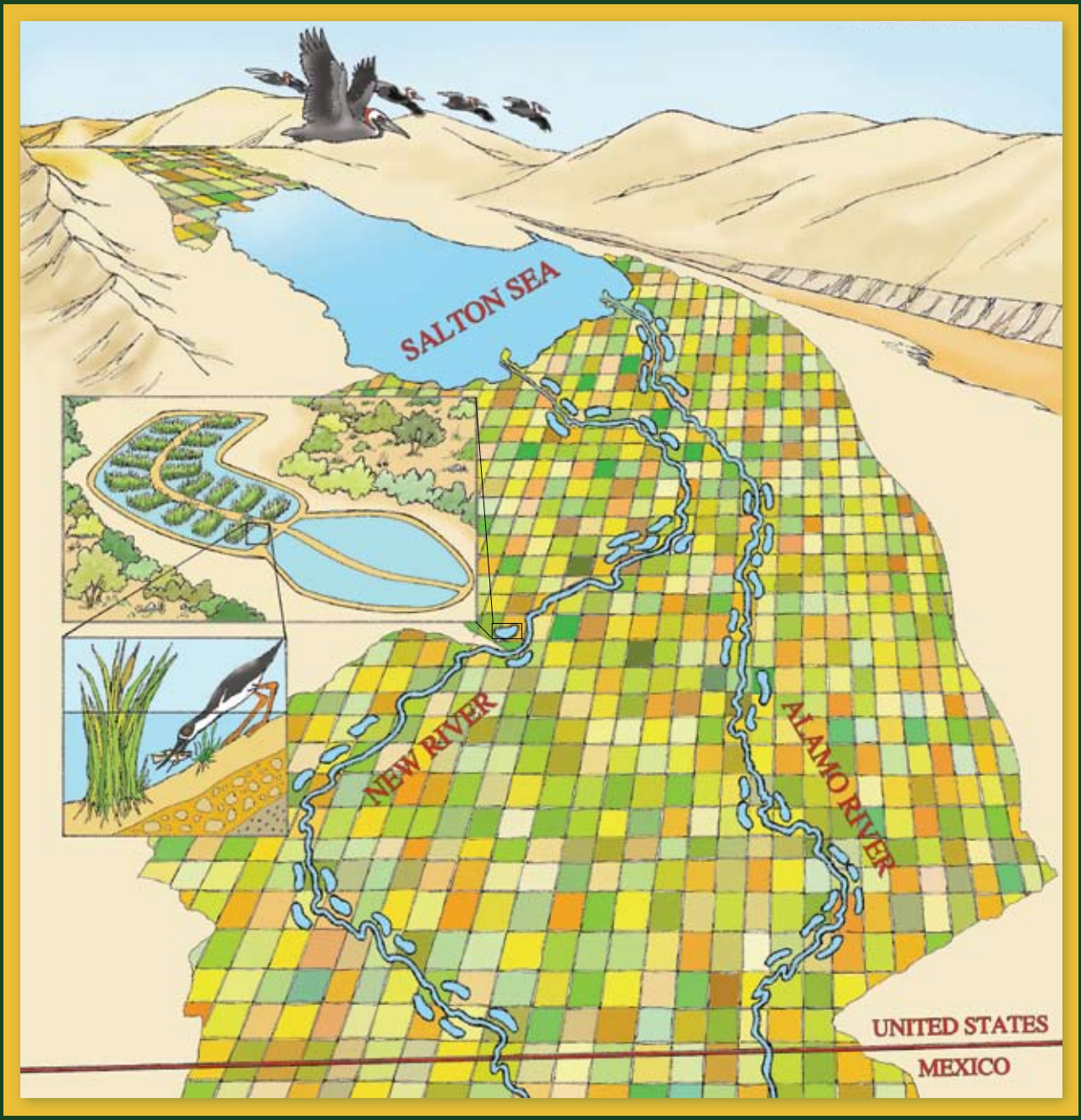
Composition of lake forming Salton Sink residual salt beds extrapolated by salt balance difference between Salton Sea in 1907 and Coloroado River water.

ATTACHMENT 11

Large Attachments to Salton Sea Authority Comment Letter

New and Alamo River Wetlands Master Plan

Final Report
November 30, 2006



Prepared for: **Wildlife Conservation Board** Sacramento, CA — **Salton Sea Authority** La Quinta, CA

Prepared by: **Tetra Tech, Inc.** Lafayette, CA — **Wetlands Management Services** Chelsea, MI

New and Alamo River Wetlands Master Plan

Final Report
November 30, 2006

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Table of Contents

Executive Summary ES-1

Chapter 1 Introduction 1-1

1.1 Summary of Prior Work 1-1
1.2 Organization of Master Plan Report 1-6

Chapter 2 Historical Water Quality Data in the Alamo and New River Basins 2-1

2.1 New and Alamo River Flow and Water Quality Data 2-1
2.2 Box Plot Summaries of Data 2-6
2.3 Water Quality – Alamo River 2-13
2.4 Agricultural Drain Flow and Water Quality Data 2-21
2.5 New River – Agricultural Drain Water Quality 2-23
2.6 Alamo River – Agricultural Drain Water Quality 2-27
2.7 NPDES Flow and Water Quality Data 2-29
2.8 NPDES Flow – Alamo River 2-31
2.9 New River – NPDES Facility Water Quality 2-32
2.10 Alamo River – NPDES Facility Water Quality 2-33
2.11 Other Flow and Water Quality Data 2-34
2.12 Summary 2-35

Chapter 3 Synoptic Survey Data for 2005 3-1

3.1 Water Quality 3-1
3.2 Results Summary 3-4
3.3 Overall Surface Water Quality 3-20
3.4 Data Quality Assessment 3-32

Chapter 4 Biological Sampling 4-1

4.1 Introduction 4-1
4.2 2005 Field Collections 4-1
4.3 2006 Field Collections 4-11

Chapter 5 Biological Inventory of Potential Wetland Sites 5-1

5.1 Results 5-3
5.2 Discussion 5-9

Chapter 6 Overview of Composite Watershed/Wetland Model 6-1

6.1 Objectives 6-1
6.2 Conceptual Model 6-2
6.3 Watershed Flow Model 6-2
6.4 Watershed Quality Model 6-3
6.5 Wetland Flow Model 6-4
6.6 Wetland Quality Model 6-4
6.7 Model Mathematical Formulation 6-5

6.8 Model Implementation for the New and Alamo River Watersheds 6-12
6.9 Model Calibration 6-19
6.10 Sensitivity to Wetland Pollutant Removal Rate and Hydrologic Parameters 6-36
6.11 Model Development: Summary 6-39

Chapter 7 Base Case Distribution of Flows and Loads 7-1

7.1 Overview of the Alamo and New River Watersheds 7-1
7.2 New River Watershed 7-1
7.3 Alamo River Watershed 7-2
7.4 Characterization of Primary Sources 7-2
7.5 Identification of Primary Drain Sources 7-13
7.6 Magnitude and Location of Drain Sources 7-31
7.7 Distribution of Flows and Loads: Conclusions 7-37

Chapter 8 Scenarios with Wetlands 8-1

8.1 Introduction 8-1
8.2 Scenario 1: Thirty-Five (35) Top-Ranked Wetland Sites 8-2
8.3 Scenario 2: Thirty-Five (35) Top-Ranked Wetland Sites with Reduced Wetland Areas 8-8
8.4 Scenario 3: Thirty-Five (35) Top-Ranked Wetland Sites with Reduced Wetland Areas and Mixed Reactor Flow Wetlands 8-10
8.5 Summary 8-12

Chapter 9 Wetland Network Design: Optimal Site Selection 9-1

9.1 Introduction 9-1
9.2 Optimization Analyses of Number and Locations of Wetlands 9-1
9.3 Scenario 4: Top Five (5) Wetlands 9-3
9.4 Scenario 5: Top Ten (10) Wetlands 9-7
9.5 Scenario 6: Top Performance Wetlands 9-8
9.6 Scenario 7: Maximum Load Reduction 9-9
9.7 Scenario 8: Additional Wetlands in Northern Reaches of New and Alamo Rivers ... 9-14
9.8 Scenario 9: Impact of Cross-Border Flows in the New River 9-16
9.9 Scenario 10: Impact of IID Conservation 9-17
9.10 Scenario 11: IID Surveyed Sites 9-18

Chapter 10 Ecological Risk Assessment 10-1

10.1 Introduction 10-1
10.2 Guidance 10-3
10.3 Problem Formation 10-3
10.4 Ecological Characterization 10-5
10.5 Chemicals of Potential Ecological Concern 10-7
10.6 Assessment Endpoints and Measures 10-8
10.7 Ecological Conceptual Site Model 10-10
10.8 Analysis 10-15
10.9 Exposure Characterization 10-15
10.10 Exposure Analysis 10-19
10.11 Ecological Effects Characterization 10-28

10.12 Risk Characterization 10-40
10.13 Risk Estimation 10-40
10.14 Potential Ecological Risks 10-61
10.15 Uncertainty Analysis 10-74
10.16 Conclusions 10-78

Chapter 11 Cost Effectiveness of Treatment Options 11-1

11.1 Constructed Wetland Costs 11-1
11.2 Wastewater Treatment Plant Costs 11-4
11.3 Summary of Cost Effectiveness Evaluation 11-7

Chapter 12 Operation and Maintenance Plan 12-1

12.1 General Operation and Maintenance Activities 12-1
12.2 Routine Operation and Maintenance Activities 12-2
12.3 Major Operation and Maintenance Activities 12-5
12.4 Emergency Operation and Maintenance Activities 12-9
12.5 Wildlife Monitoring and Identification of Sensitive Habitats 12-9
12.6 Operation and Maintenance Checklist 12-9

Chapter 13 Summary and Conclusions 13-1

References R-1

Appendices

Appendix A Historical water quality data for the New River
Appendix B Historical water quality data for the Alamo River
Appendix C Historical water quality data for agricultural drains flowing into the New River
Appendix D Historical water quality data for agricultural drains flowing into the New River
Appendix E Historical water quality data for NPDES facilities flowing into New River
Appendix F Historical water quality data for NPDES facilities flowing into Alamo River
Appendix G Laboratory data reports for 2005 sampling
Appendix H Laboratory data reports for 2006 sampling
Appendix I Biological Inventory Supporting Information
Appendix J Flows for individual drain reaches
Appendix K Composite Watershed/Wetland Model for the New and Alamo River Basins.
Appendix L Estimates of exposure to chemicals of potential ecological concern for each receptor considered
Appendix M Detailed cost analysis for chemical treatment facility

EXECUTIVE SUMMARY

The New and Alamo River Wetlands Master Plan provides scientific analysis to evaluate the overall effectiveness of a network of water quality treatment wetlands being considered for construction along these rivers. The proposed wetlands are all to be constructed near the New and Alamo Rivers, using either river water or agricultural drain water for treatment. An example of these wetlands that has already been constructed for demonstration purposes (on the New River at Imperial), is shown in Figure ES-1. An initial determination of the placement of 35 proposed wetlands is shown in Figure ES-2. This Master Plan builds on a considerable amount of prior work, including the construction and intensive monitoring at two pilot wetlands along the New River, and routine and special monitoring in the rivers and drains in the Imperial Valley over the last decade. The work described here consisted of the development of a computer model to estimate the pollutant loading benefits of various configurations of wetland networks and a detailed ecological risk assessment to estimate the likelihood of risks to biota in the wetlands. In support of these two major tasks, an exhaustive data gathering effort was performed to catalog all relevant data previously collected. Following this, a focused field sampling program was conducted to obtain data specifically required for the modeling and risk analysis. Finally, supporting analyses were performed to estimate costs of wetlands as compared to traditional chemical treatment systems, and an operation and maintenance plan was developed. The results of these tasks are summarized below.

Historical water quality and flow data in the New and Alamo Rivers and in the drains were collected from a variety of sources including state and federal government agencies, international agencies, and universities. Data were available from more than 30 river locations and from 45 drain locations on parameters such as nutrients, coliforms, suspended sediments, and selenium. The data gathering effort also obtained information from point sources (NPDES permitted discharges). There were seven such dischargers in the Imperial Valley. A repository for all of the data collected was developed and is included as electronic appendices to this report. In addition to supporting the Master Plan work, this repository should help to simplify future endeavors focusing on the water quality characteristics of the New and Alamo Rivers.

Following the historical data compilation, a synoptic survey of water quality throughout the Imperial Valley was performed, with data being collected on all parameters of interest in the Master Plan: nitrogen and phosphorus species, selenium species, coliforms, and suspended sediments. Data were collected from 47 river, drain, and sump locations, and from 15 locations within the pilot wetlands. These data, in conjunction with the historical data, were

used to define current water quality conditions that may be improved by the addition of wetlands. An example of the trends in total phosphorus concentrations along the length of the New and Alamo Rivers, from the U.S.-Mexico international boundary to the Salton Sea, is shown in Figure ES-3. This figure shows the continuous addition of phosphorus from agricultural sources in the Alamo River, in contrast with the very high concentrations from trans-border sources in the New River.

Figure ES-1. Imperial pilot wetland on the New River.

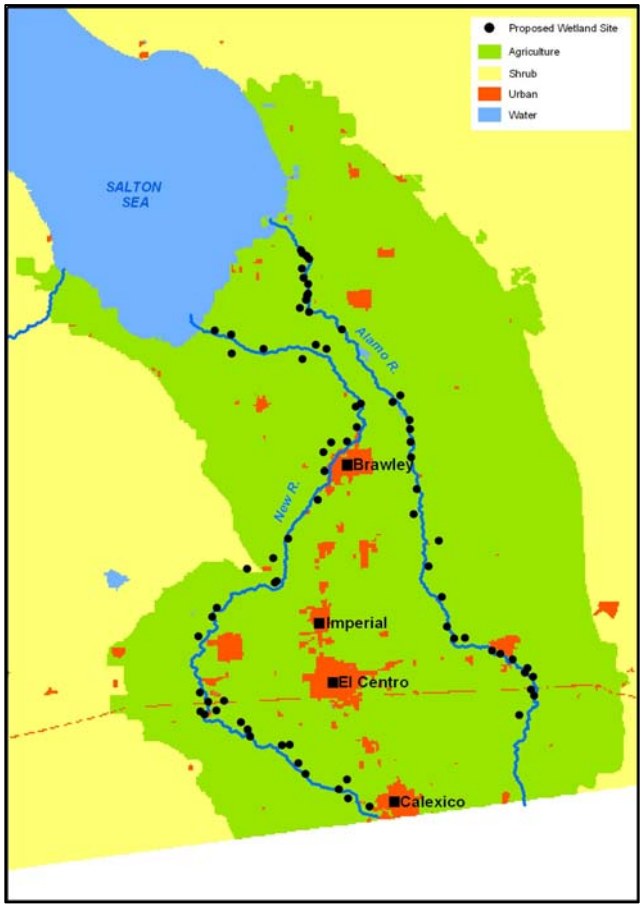


Figure ES-2. Potential network of wetlands identified in prior work.

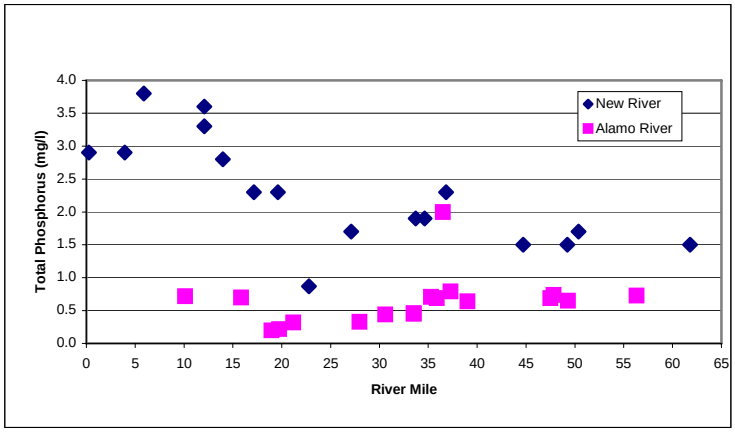


Figure ES-3. Total phosphorus concentrations in the New and Alamo Rivers during November 2005 synoptic survey.

To support the ecological risk assessment of the treatment wetlands, sampling to measure concentrations of selenium and pesticides in biological tissues was performed in 2005 and 2006. Sampling in 2005 was limited in nature, due to the low abundance of the target biota. In 2006, a larger and more comprehensive field sampling campaign was conducted. Concentration data were collected for a variety of environmental media, including fish, invertebrates, plants, algae, sediments, and water. The data collected from 2006 was used in a predictive ecological risk assessment as discussed below.

A reconnaissance level survey of habitat and biota was conducted at ten proposed wetland sites along the New and Alamo Rivers. Data collected at each site to estimate mean use included prominent plant species and their percent cover, animal species present, and avian point-count surveys. The invasive weed *Tamarix sp.* has overrun and out-competed the native species at all of the proposed wetland sites, as shown in Figure ES-4. Although *Tamarix sp.* provides suitable habitat for certain species (i.e., doves, white-faced ibis, pocket mice), it has displaced numerous plant and animal species (i.e. *Salicornia virginica*, *Atriplex sp.*, *Salix sp.*, *Pluchea sericea*, Gila woodpecker, Crissal thrasher). The restoration of these proposed wetland sites, which could include the removal of invasive species such as *Tamarix sp.* and *Arundo donax*, would significantly increase the diversity and abundance of native plant and animal species. Many avian species were observed flying over the proposed wetland sites, such as the American white pelican and California brown pelican (*Pelecanus occidentalis californicus*), barn swallow (*Hirundo rustica*), belted kingfisher (*Ceryle alcyon*), egret and heron, common moorhen (*Gallinula chloropus*), cormorant, killdeer (C*haradrius vociferus*), osprey, grebe, red-winged blackbird (*Agelaius phoeniceus*), ruddy duck (*Oxyura jamaicensis*), spotted sandpiper (*Actitis macularius*). Some are typical of natural wetland habitats, although many of these species are only wintering or passing through the area instead of breeding. Creation of wetlands at these sites is expected to provide suitable nesting habitat for the reestablishment of the historical breeders such as the American white pelican, egret, and heron..

Figure ES-4. Proposed wetland site on New River (NR 26 looking north). The site consists primarily of Tamarix sp.

Published data water and mass balance modeling approaches were used to develop a model of flows and chemical concentrations with and without individual wetlands in the Alamo and New River systems. The model is shown conceptually in Figure ES-5. The level of detail used in the watershed/wetland model is similar to that used recently by the Colorado River Basin Regional Water Quality Control Board for TMDL analyses of the New and Alamo Rivers. This resolution was chosen to be consistent with the available data and hydrologic complexity of these river systems. The model includes all major and minor agricultural flows, which are the principal additions to river flows, as well as contributions from groundwater accretion, overland flow, and NPDES discharges. The watersheds associated with individual reaches are shown in Figure ES-6. These reaches correspond to the initially conceived wetland locations from Figure ES-1 and can be modified if wetlands are considered for addition at new locations. The watershed model also incorporated proposed wetlands to simulate removal of a portion of the river or drain flow for treatment before returning the treated flow to the river. The impacts of future constructed wetlands on New and Alamo River water quality were simulated using wetland sub-models. The wetland models have been calibrated to data from the Imperial and Brawley pilot wetlands.

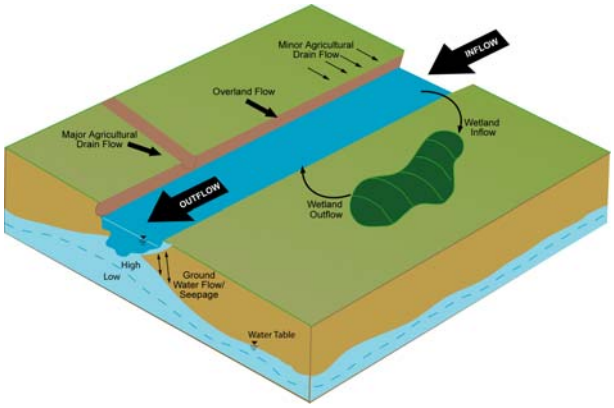


Figure ES-5. Schematic representation of flows in individual river reaches for the watershed/wetland flow and water quality model.

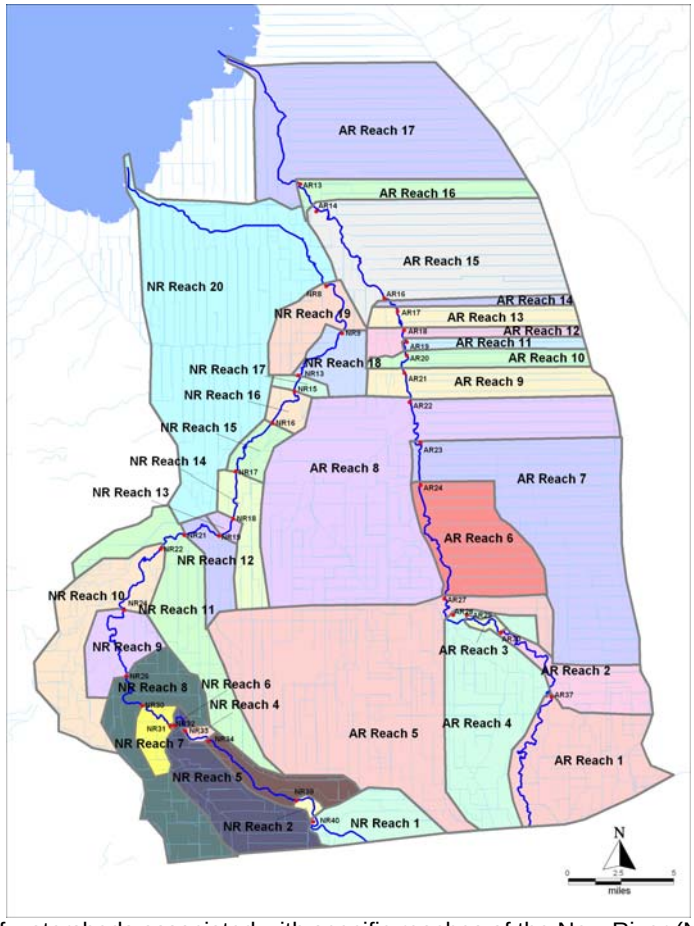


Figure ES-6 Delineation of watersheds associated with specific reaches of the New River (NR) and Alamo River (AR) in the watershed/wetland model.

Following the calibration of the watershed model to data, base case conditions for flows and loads were developed. These numbers provide the baseline against which the performance of the wetland treatment system can be evaluated. Total flows in the New River and Alamo River to the Salton Sea are about 1.2 million AF/yr, which discharges total phosphorus loads of about 1.4 million kg/yr, total nitrogen loads of about 14 million kg/yr, TSS loads of about 425 million kg/yr; selenium loads of about 7,700 kg/yr; and total coliform loads of about 1.8 x 10^{18} MPN/yr.

The load distribution for phosphorus by source in the two rivers is shown in Figure ES-7. Similar calculations have been prepared for other constituents of interest. For the New River, almost 55 percent of the total phosphorus load consists of cross-border inflows from Mexico, while the remaining 45 percent of the total phosphorus load originates in the U.S. Agricultural return flows in Imperial Valley account for almost 47 percent of the New River total phosphorus load, while NPDES discharges in Imperial Valley contribute about 1.8 percent of the New River total phosphorus load. For the Alamo River, only 0.1 percent of the total phosphorus load consists of cross-border inflows from Mexico and 99.9 percent of the total phosphorus load originates in the U.S. Agricultural return flows in Imperial Valley account for almost 99 percent of the Alamo River total phosphorus load, while NPDES discharges in Imperial Valley contributes 0.2 percent of the Alamo River total phosphorus load. For both the New River and Alamo River, approximately 6 to 8 drains in each river provide 50 percent of total drain flow and load. The Alamo River has especially high loads in two very small areas: 20 miles north of the border at the Central and South Central Mains and

30 miles north of the border at the Rose and Holtville Mains. Both rivers have high flows and loads from many minor drains located in the far north of their watersheds, and these drains are beyond the area where wetlands have been proposed.

As an example of the loading estimates prepared in this work, drain contributions of selenium to the New and Alamo Rivers are shown in Figure ES-8. For both rivers, there are limited data available for drain selenium concentrations, and thus the current estimated selenium distribution is not well defined. The current patterns of selenium distribution basically mirror the flow distribution, as the available data show that selenium concentrations do not vary significantly among the drains. With the collection of future drain selenium data, it is thought that this will likely change, as other factors such as the selenium concentrations reported in agricultural field sumps show much more spatial variability than depicted in the current drain selenium database.

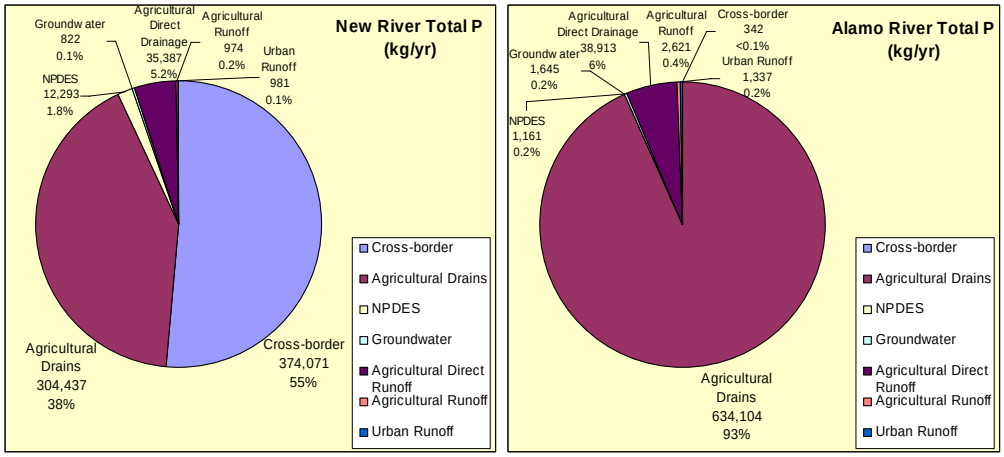


Figure ES-7 Sources associated with total loads of phosphorus delivered by the New and Alamo Rivers to the Salton Sea.

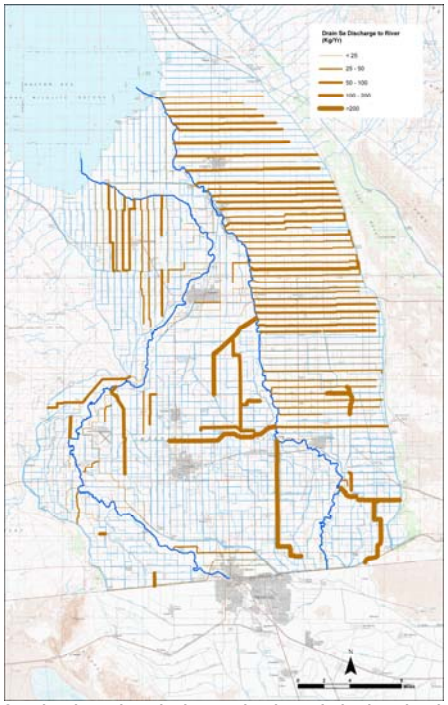


Figure ES-8 Magnitude and location of selenium loads in agricultural drains in the New River and Alamo River watersheds.

Total phosphorus transported along the rivers at current levels and with the full construction of a network of 35 wetlands are shown in Figure ES-9. Phosphorus loads delivered to the Salton Sea on the New River and Alamo River are about 729,000 and 685,000 kg/yr without wetlands. With the addition of 2,775 acres of wetlands along the New River treating 48,660 acre-feet per month (AF/mo) of river and drain flows, the total phosphorus load in the New River at the Salton Sea is reduced to a range of 310,000 to 370,000 kg/yr (depending on the assumed wetland loss rate). Total phosphorus loss in the New River wetlands account for a reduction between 155,000 and 280,000 kg/yr. Total phosphorus retention in New River wetlands' seepage losses accounts for a reduction between 138,000 and 204,000 kg/yr. Thus, there is a 21 to 38 percent reduction in the total phosphorus load due to wetland removal processes and a 19 to 28 percent reduction in the total phosphorus load due to retention in wetland seepage in the New River. With the addition of 1,501 acres of wetlands along the Alamo River treating 24,932 AF/mo of river and drain flows, the total phosphorus load in the Alamo River at the Salton Sea is reduced to a range of 520,000 to 557,000 kg/yr. Total phosphorus loss in the Alamo River wetlands accounts for a reduction between 58,000 and 114,000 kg/yr. Total phosphorus retention in Alamo River wetland seepage losses accounts for a reduction of 51,000 to 70,000 kg/yr. Thus, there is a 8 to 17 percent reduction in the total phosphorus load due to wetland removal processes and a 7 to 10 percent reduction due to retention in wetland seepage in the Alamo River.

There are much higher removal rates in the New River wetlands than the Alamo River wetlands. This is primarily due to the higher wetland treatment area and flow in the New River than the Alamo River. The chemical concentrations in the rivers and drains in each watershed also influence removal rates. For example, the higher total phosphorus removal rate for the New River wetlands is attributed to the higher total phosphorus concentrations in the New River, especially in the more southerly reaches of the New River near the U.S.-Mexico border. The New River wetlands have higher area-specific removal rates for total phosphorus, while the Alamo River wetlands have higher area-specific removal rates for total nitrogen, selenium, and TSS.

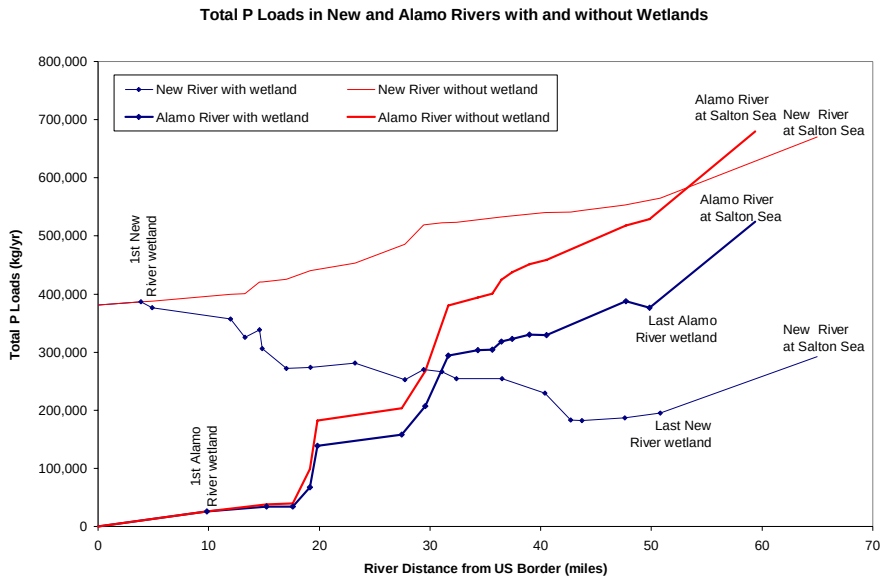


Figure ES-9. New and Alamo River transects showing total phosphorus loads along the river courses from the U.S. border to the Salton Sea for all 35 proposed wetlands being constructed.

The composite watershed/wetland model evaluated the performance of the 35 top-ranked wetland sites identified in the reconnaissance inventory (Nolte, 2002) proposed for the New and Alamo Rivers under a variety of different water flow, chemical load, and wetland design conditions. The model results show the potential for significant reductions in loadings with the construction of the 35 wetlands covering 4,276 acres (see Figure ES-10). The total phosphorus load reduction to the Salton Sea is in the range of 31 to 37 percent from base case conditions. The total nitrogen, TSS, and total coliform load reductions are estimated at 22, 37, and 71 percent from base case conditions. Total selenium load reductions range between 2 and 11 percent.

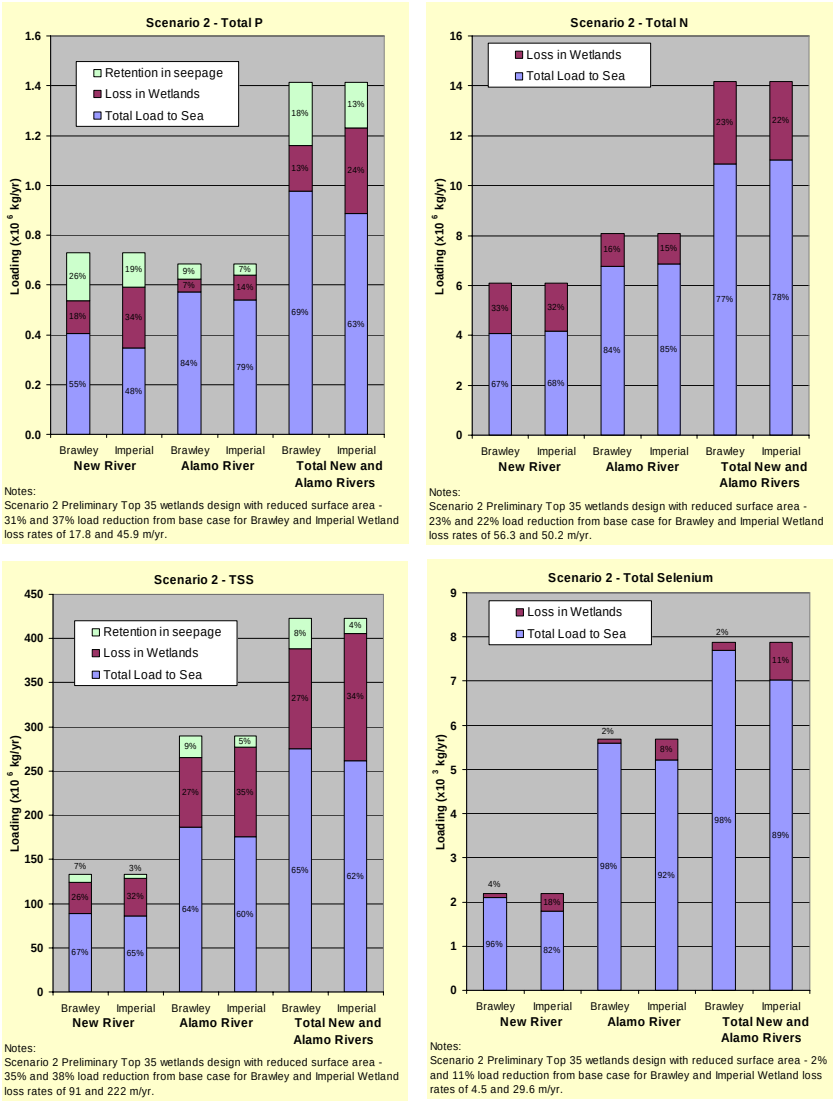


Figure ES-10. Total phosphorus, total nitrogen, total suspended solids (TSS), and total selenium loadings in the New and Alamo River watersheds with the top ranked wetland sites all being constructed.

The model was used to evaluate optimal wetland system design by determining which wetlands of the top 35 ranked wetland sites provided the most total phosphorus removals (see Table ES-1). This evaluation may be used to identify which wetlands should be constructed first, or to screen out wetland sites that do not provide significant nutrient reductions to the overall New and Alamo River system. Two methods were used, one based on optimizing the

maximum total phosphorus removal and one based on optimizing the maximum area-specific removal rates.

Based on the evaluation, several conclusions can be made. Design of a wetland system that prioritizes wetland selection based on an area-specific removal rate will achieve a higher loading reduction for the same total wetland acreage (and thus cost). For instance, a 10-wetland scenario based on maximizing area-specific removal rates achieves the same total phosphorus loading reduction of 17 percent as the top 5 wetland scenario based on maximizing the area-specific removal rates, with 32 percent less total wetland acreage. The maximum removal rates are generally correlated to the larger design inflows (which are correlated to wetland area). The top performing wetlands for the maximum area-specific removal rates are correlated to the maximum inflow concentrations. The New River wetlands can achieve much greater reductions in the total phosphorus load than the Alamo River wetlands for the same wetland area size. This is attributed to the higher overall total phosphorus concentrations in the New River and its' drains. Thus, an optimum wetland system for both rivers would place more wetlands along the New River to take advantage of the higher removal efficiencies for the New River.

The total phosphorus load reduction becomes less efficient with the addition of more wetlands. The lesser performing wetlands contribute only a small incremental benefit to the overall system performance. Almost half of the 35 wetlands have an incremental benefit that is equal to or less than one percent of the overall system total phosphorus removals. Increasing the size of the Top 35 wetlands increases the load reduction, but at the cost of significantly larger wetland areas. This is due to several factors. First, approximately 20 percent of the total phosphorous load enters the New and Alamo Rivers downstream of the proposed wetland sites. Second, as more wetlands are added, the lower the influent concentrations to downstream wetlands and thus lower removal efficiencies are achieved.

The model evaluated the addition of a wetland in the northern reaches of each of the New and Alamo Rivers, where no treatment wetlands are currently proposed. The modeling for the combined river system demonstrated that by increasing the wetland acreage by only 7 percent, the total phosphorus removals can be increased by up to 10 percent. For instance, the addition of a 143 acre wetland in each northern reach can increase total phosphorus removals from 35 percent with 35 wetlands to 38 percent with 37 wetlands. If wetland sites can be identified, there is significant benefit to adding wetlands in the northern reaches.

Several potential future changes in the Imperial Valley watershed were evaluated with the composite watershed/ wetland model. If the cross-border flows to the New River are eliminated due to treatment and reuse of water sources in Mexico, the total phosphorus loads would be reduced by 26 percent to 1 million kg/yr. If the flows are eliminated and the Top 35 wetlands constructed, the total phosphorus loads would be reduced by 46 percent to 0.76 million kg/yr (Figure ES-11). As part of the Quantification Settlement Agreement (QSA), the IID must conserve roughly 200,000 AF/yr, or 20 percent of the flow to the Salton Sea. If flows to agricultural drains are reduced by 20 percent, total phosphorus loads remain constant, and the wetlands are constructed, the model predicts that the total phosphorus load into the Salton Sea will decrease to 846,000 kg/yr, which is a 40 percent load reduction. The most recent IID study identified 25 potential wetland sites with a total wetland area of 2,493 acres by feasibility studies and topographic surveys (Davey-Cairo Engineers, 2005a,b, 2006a,b). These are a subset of IID's Top 35 ranked wetland sites from the reconnaissance survey (Nolte, 2002). With the 25 wetland sites, the combined rivers' total phosphorus load to the Salton Sea would be 1.1 million kg/yr, which is a 25 percent load reduction(Figure ES-12). In comparison, the initial Top 35 wetland scenario would lead to a 35 percent load reduction.

Table ES-1
Comparison of Total Phosphorus Load Reductions for Different Wetland Scenarios

Scenario	Details	Total Phosphorus Load Reduction[1] (%)
Preliminary 35 Top-Ranked Wetland Sites	Top 35 wetlands identified in reconnaissance survey (Nolte, 2002). This scenario assumes all wetlands designed for plug flow. Includes revised wetland surface areas and design inflows reduced for non-wetted areas.	35
Optimization Scenario: Top 5 wetlands based on maximum removal rates	Top 5 wetlands selected based on ranking of preliminary 35 top-ranked wetlands by maximum removal rates.	17
Optimization Scenario: 10 wetlands based on maximum area-specific removal rates	These wetlands selected based on ranking of the area-specific removal rates.	17
Additional wetland in northern reaches	Two wetlands added to Top 35 wetland scenario. These wetlands added to northern reaches of New and Alamo Rivers where large load are entering the rivers and no proposed wetlands exist.	38
No Mexico Flows	Elimination of cross-border flows for New River due to WWTP upgrades and water reuse. Includes Top 35 wetlands.	46
IID Conservation	IID conservation efforts ongoing to meet GSA requirements. Scenario assumes 20 percent reduction in flow but not reduction in load. Includes Top 35 wetlands.	40
IID 25 wetland sites based on topographic survey	Surveyed wetlands considered feasible and with revised wetland areas based on topographic survey (Davey-Cairo, 2006a,b).	25

Notes:
1. Base case load of 1.4 million kg/yr. Base case does not include treatment wetlands.

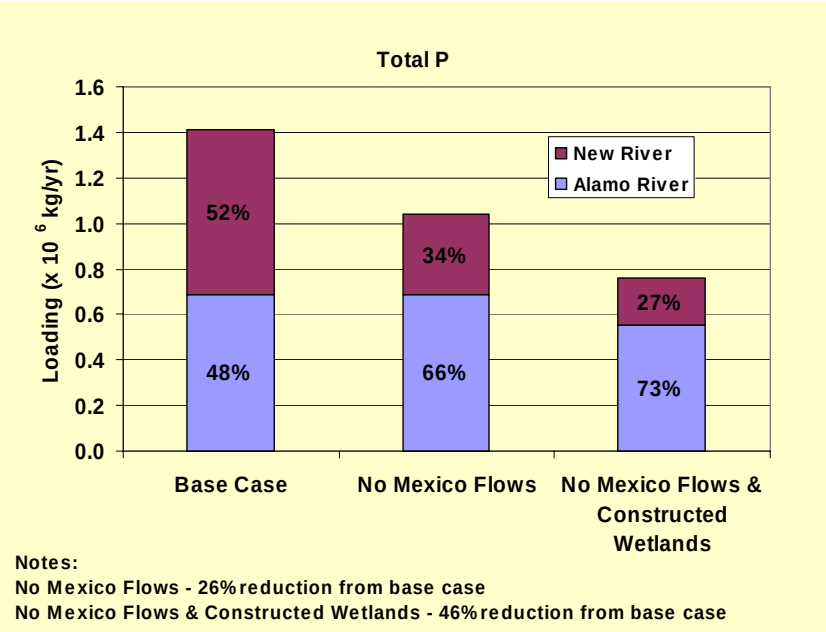


Figure ES-11 Impact of cross-border flows from Mexico on total phosphorus loading to Salton Sea.

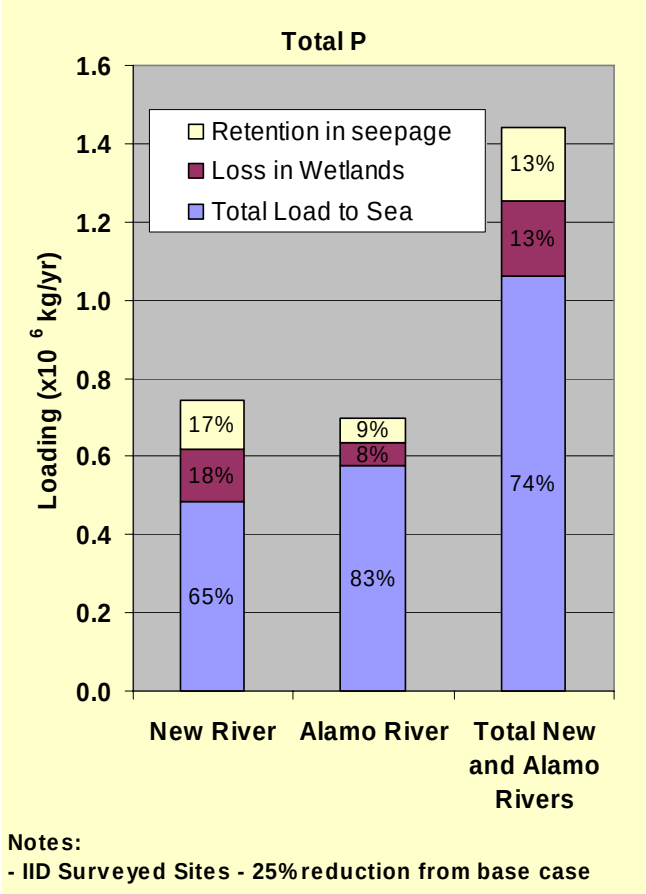


Figure ES-12 Total phosphorus loading to Salton Sea based on IID surveyed wetland sites (Davey-Cairo Engineers, 2006a,b).

One of the concerns regarding the use of wetlands to enhance water quality in the region is that they may result in the bioaccumulation of toxic constituents in biota. An initial comparison of data collected from the Brawley and Imperial Pilot Wetlands in 2005 indicated that there was the potential for risks to ecological receptors at these locations. Follow-up studies were conducted in 2006 to evaluate that potential and the data collected in 2006 was used in a baseline ecological risk assessment.

This baseline ecological risk assessment evaluated the potential for adverse ecological effects to ecological receptors that may be exposed to selenium and organochlorine pesticides in the Brawley and Imperial Pilot Wetlands. The receptors evaluated included in this assessment included: emergent plants, benthic invertebrates, aquatic biota (i.e., algae and aquatic plants, aquatic invertebrates, fish, and amphibians), aquatic and terrestrial birds (i.e., least sandpiper, black-necked stilt, pied-billed grebe, American coot, double-breasted cormorant, and red-winged blackbird) and piscivorous mammals (i.e., raccoon). A representation of the food web and the risk pathways for the receptors of interest is shown in Figure ES-13.

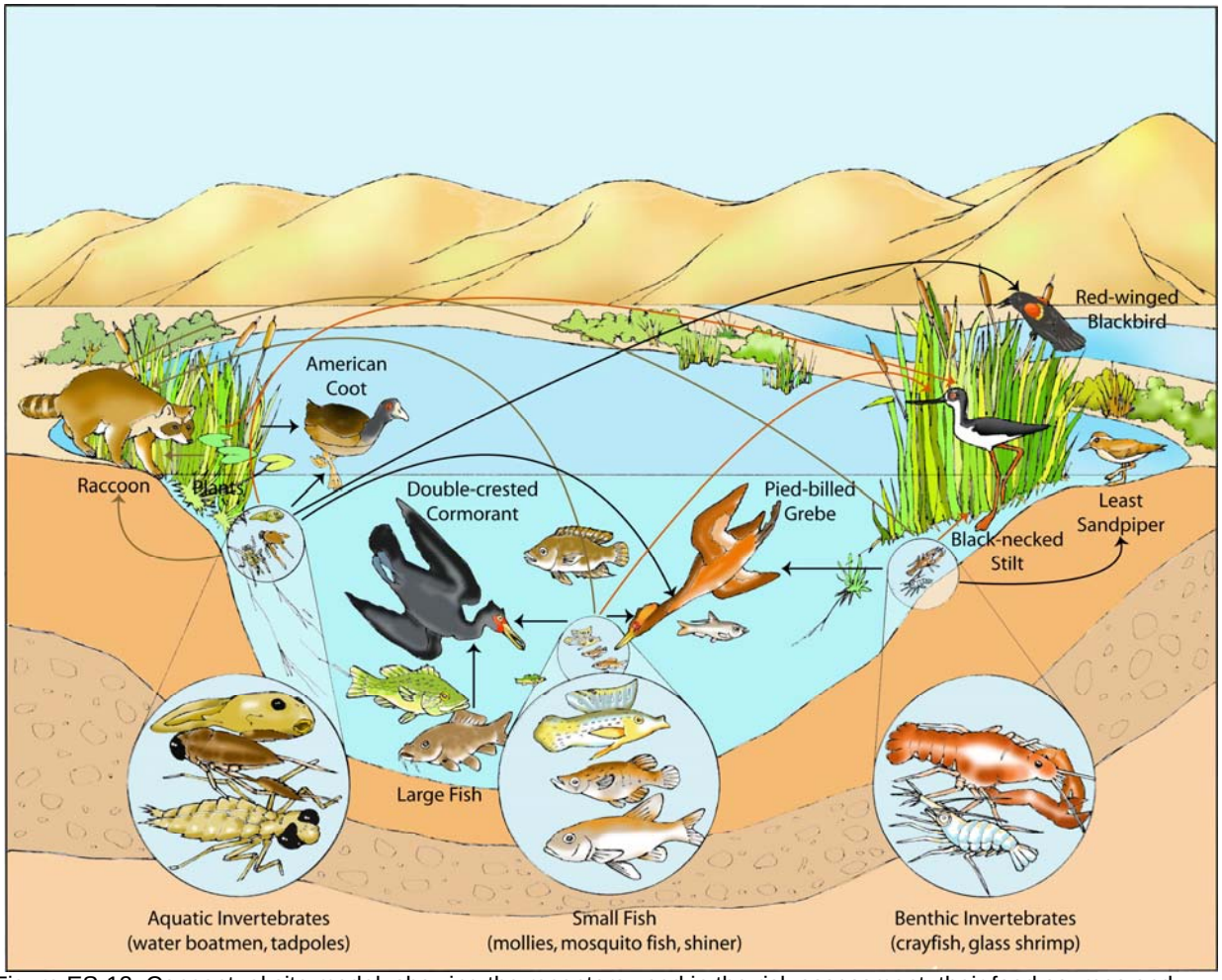


Figure ES-13. Conceptual site model, showing the receptors used in the risk assessment, their food sources and pathways of risk.

In addition to estimating risks for ecological receptors at the pilot wetlands, risks were estimated for the same receptors for three different types of local background conditions; i.e., agricultural drains in the Imperial Valley, in the New and Alamo Rivers, and at the Salton Sea.

Hazard indices, which aggregate the risks of multiple contaminants, were computed for each of the receptors. An example of the hazard index calculation for the least sandpiper is shown in Figure ES-14. For the wetlands, potential exposures to selenium and 4,4'-DDE may result in low levels of risk to benthic invertebrates, birds, and raccoons. However, the risk estimates are based on highly conservative assumptions regarding calculated exposures and regarding the level of a chemical that would be likely to cause adverse effects. Most importantly, the estimated risks from potential exposures to selenium and organochlorine pesticides by ecological receptors in the agricultural drains, New and Alamo Rivers, and Salton Sea were all much higher than at the treatment wetlands.

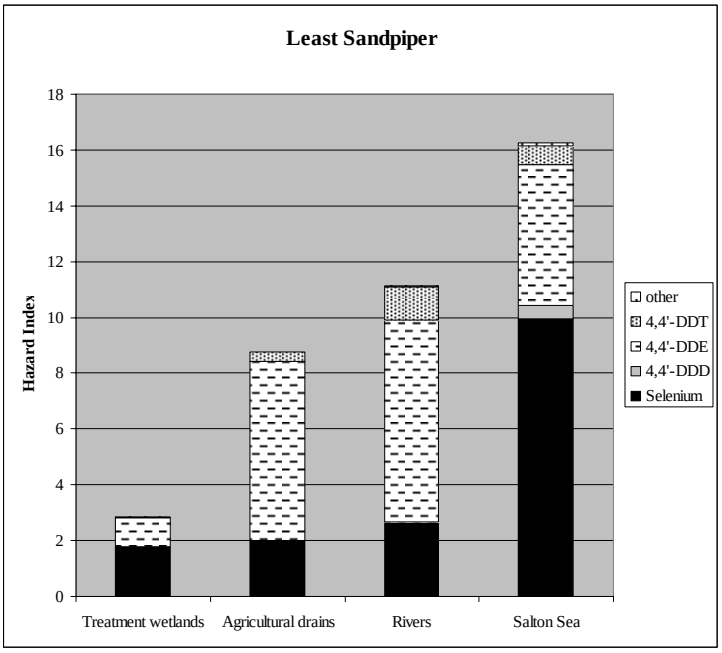


Figure ES-14 Hazard Indices for the Least Sandpiper.

This report shows that treatment wetlands, while they do pose some minimal level of risk to ecological receptors, represent better habitat than the agricultural drains, New and Alamo Rivers, and the Salton Sea. Elevated levels of suspended sediments make the rivers generally poor habitat. For instance during the field studies, no crayfish were found in the rivers and fish of all kinds were much less abundant in the rivers than in the treatment wetlands or agricultural drains. This is especially true in the southern stretches of the New River, where the dissolved oxygen was extremely low and no aquatic biota were observed during sampling. Therefore, the construction of treatment wetlands can be regarded as improving the habitat for wildlife in this area. Habitat improvements like this should be regarded as vital, since the Salton Sea is on the Pacific Flyway and the available resting locations for migratory birds on the Pacific Flyway has dwindled to the point that the Salton Sea is one of the last remaining stop-overs in the southern United States.

The Master Plan includes an estimate of the costs of wetlands compared to a chemical treatment plant. Because of the site specific data on the construction of the pilot wetlands on the New River, there are fairly good estimates of the cost of construction of treatment wetlands, which are estimated to cost approximately $183 million for the construction of the 35 proposed wetlands, achieving about 35% phosphorous reduction. In the absence of pilot study data, there are considerable uncertainties regarding the design and cost of a chemical treatment plant. Using various assumptions regarding the design, preliminary calculations show that a complete system, with coagulation and filtration, can cost upwards of $350 million for a 49% phosphorous reduction. The costs are substantially lower (about $200 million) for a chemical treatment plant without filtration. These costs are based on greater treatment levels than is achievable with wetlands, and the chemical treatment plant option may be considered for exploration only if wetlands cannot be constructed or if the greater water quality improvement is desired. The most significant difference is the substantially lower operation and maintenance costs of the wetlands, because of which, the 50-year capitalized present worth of the wetland network is approximately $250 million, which is about a quarter to a third of the chemical treatment plant with or without filtration ($990 or $710 million). Besides the differences in overall costs, wetlands also have the significant

advantage that they can constructed gradually over an extended period of time, with partial benefits being derived.

Given the objective of water quality improvement in the New and Alamo Rivers and the need for reducing nutrient loads to the Salton Sea, the technical analyses prepared in this Master Plan are supportive of the construction of wetlands. As summarized above and discussed in detail in this report, the reasons for this finding include the estimation of substantial pollutant load removal, ease of maintenance and construction, relatively lower capital and O&M costs, and the ability to spread this cost over an extended period of time, and generally lower risks to wildlife than other habitats in the Imperial Valley, including the drains, rivers, and the Salton Sea.

CHAPTER 1 INTRODUCTION

The New and Alamo Rivers, which together provide about 80% of the flow into the Salton Sea, are polluted by nutrients, pesticides, naturally occurring elements, such as arsenic and selenium, pathogens, and high suspended sediments. Treatment wetlands have been under consideration for several years to reduce pollutant concentrations in the flows of the New and Alamo Rivers by treating the agricultural inflows as well as a portion of the river flows. To develop an understanding of the effectiveness of wetlands at reducing pollutant loads in this regional and climatic setting, two pilot wetlands were constructed and monitored since 2001. The project was funded by the US Environmental Protection Agency and Bureau of Reclamation, and was built under the direction of the Citizens Congressional Task Force on the New River. Characteristics of wetland performance have been reported in Tetra Tech (2006). In addition, an evaluation of potential wetland sites along the two rivers has also been conducted (Nolte, 2002). This report (termed the Wetlands Master Plan) presents the results of a data compilation, field monitoring, and modeling study to evaluate the benefits of treatment wetlands to improve the quality of water in the Alamo and New Rivers as they flow into the Salton Sea.

1.1 Summary of Prior Work

The locations of the two pilot wetlands in the Salton Sea basin, at Brawley and Imperial, are shown in Figure 1-1. The Imperial Wetland has a total a total area of 43 acres, of which 22 acres are wetted, and the Brawley wetland has a total area of 9 acres of which 6 are wetted. Figure 1-2 shows the design drawings of the Imperial and Brawley wetlands, and Figures 1-3 and 1-4 show aerial views of the wetlands in 2002.

An analysis of the inflows, outflows, and potential evapotranspiration indicated that in both wetlands there was substantial infiltration of water (i.e., movement of wetland surface water and its accompanying solutes into the soils underlying the wetland). Brawley showed greater infiltration that Imperial, likely due to its history of agricultural use and the presence of a subsurface tile drain system that was not completely removed during wetland construction. Infiltration rates were often greater than 50% of influent volume in the Brawley wetland. The performance of the wetlands for major constituents is summarized in Table 1-1.

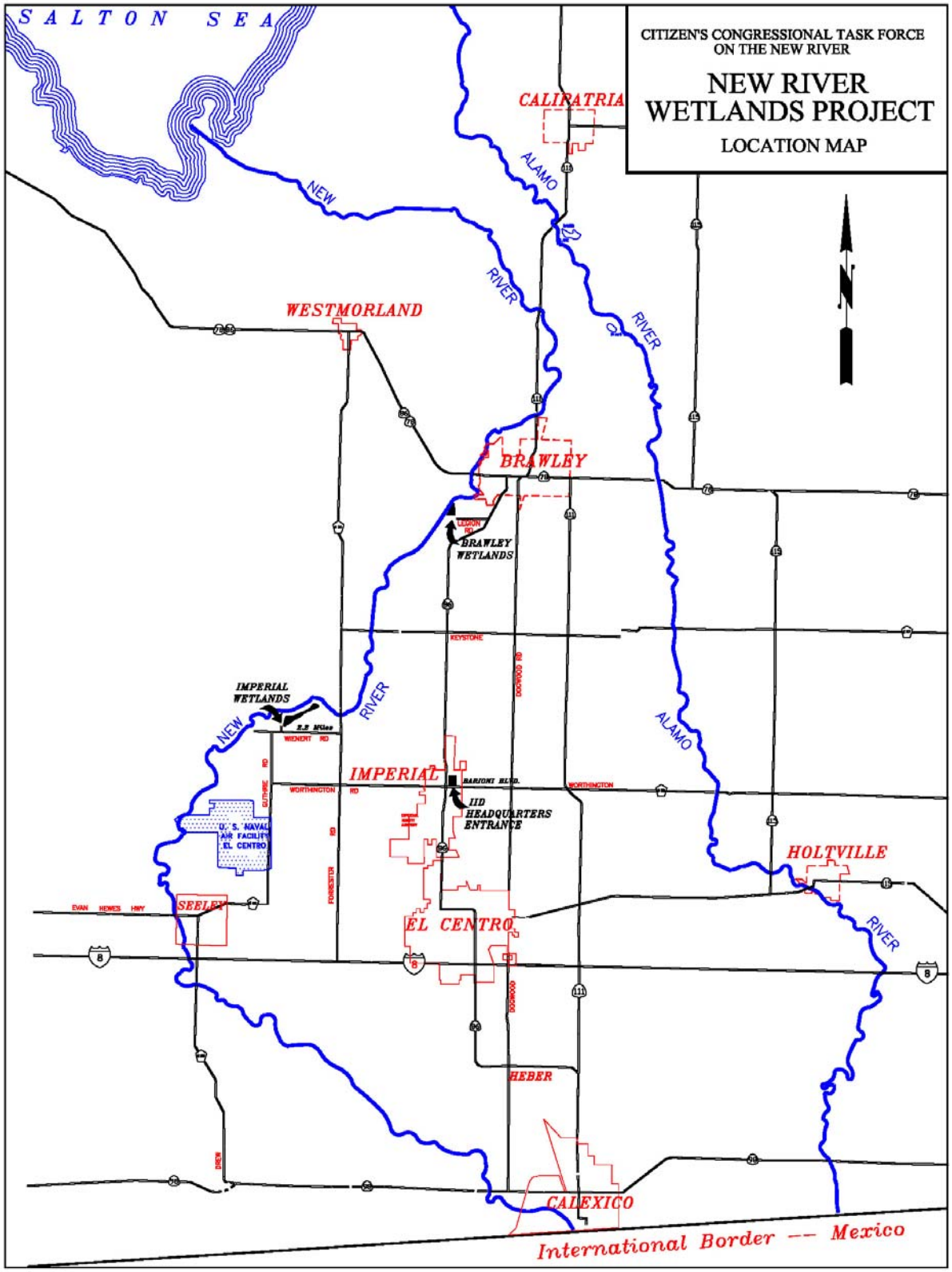


Figure 1-1 Location of two pilot wetlands near Brawley and Imperial in the Salton Sea basin. (Source: Imperial Irrigation District).

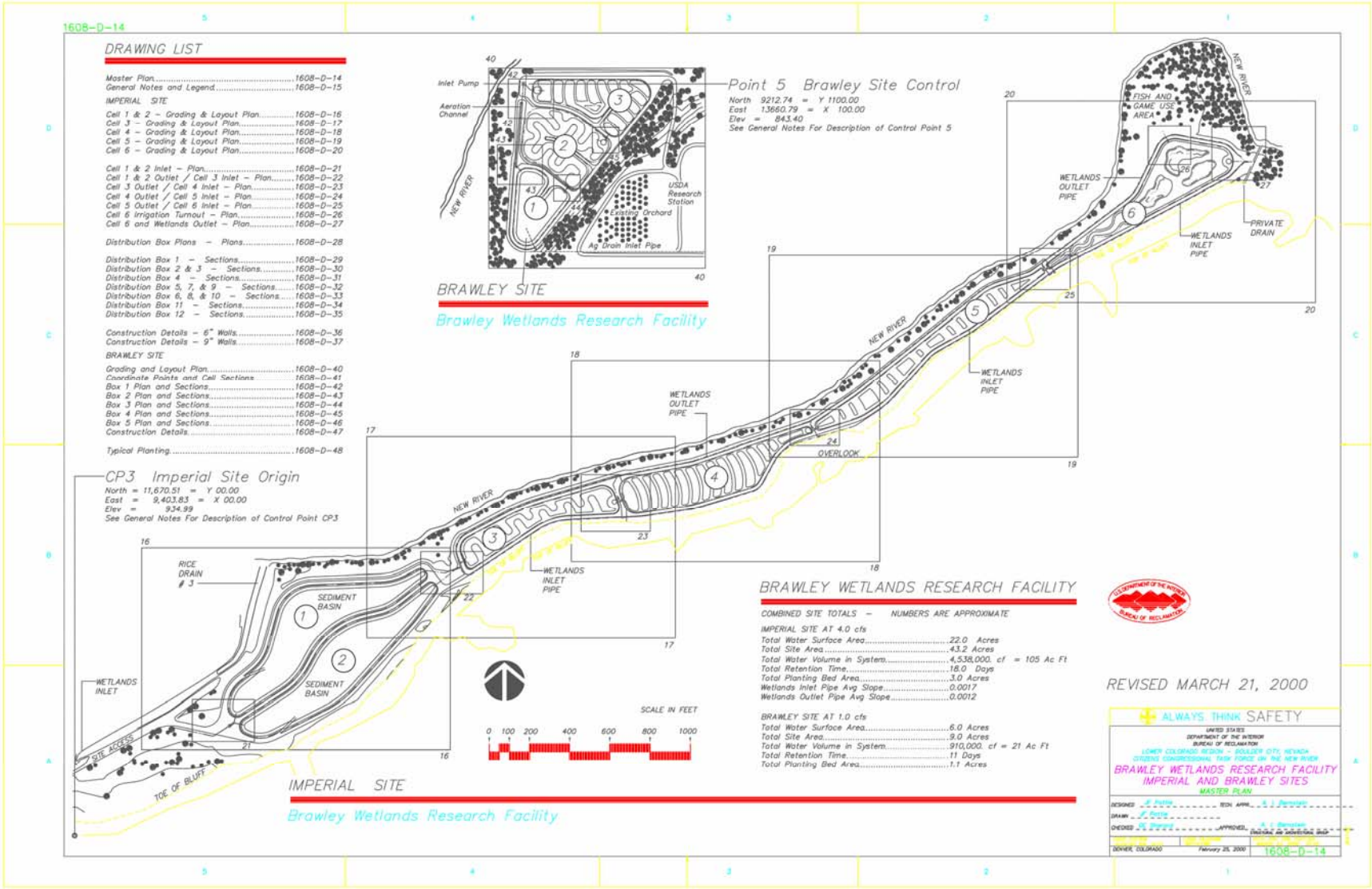


Figure 1-2 Design drawings for the Imperial and Brawley wetlands (Source: Imperial Irrigation District).

Figure 1-3 Aerial view of the Imperial wetland in April 2002 (Source: Imperial Irrigation District).

Figure 1-4 Aerial view of the Brawley wetland in December 2001 (Source: Imperial Irrigation District).

Table 1-1
Fate of major constituents in different compartments (Inflow = 100)

Wetland and Constituent	Outflow	Infiltration	Retention
Brawley Total Nitrogen	17	24	13
Imperial Total Nitrogen	37	24	7
Brawley Total Phosphorus	30	23	48
Imperial Total Phosphorus	43	22	35
Brawley Selenium	50	45	5
Imperial Selenium	46	30	24
Brawley Total Suspended Sediments	6		94
Imperial Total Suspended Sediments	4		96

In addition to the construction of the pilot wetlands, a reconnaissance of potential wetland sites, and ranking for suitability of wetland construction, has been performed by Nolte Engineers in 2002 (Nolte, 2002). This study considered more than 80 potential sites and found 35 of them to be suitable for treatment wetland construction (Figure 1-5). The sites were ranked in three general areas: constructability, social factors, and maintenance. Ten criteria within these general areas were defined and quantified for each site. For constructability the factors include topography such that pumping needs are minimized, ease of access, and existing infrastructure. For social factors, these include location near population centers, public support for the project, and potential for multiple uses. For maintenance the criteria considered are location, such that multiple sites can be accessed from a single geographic location, access to maintenance vehicles, and site size, with larger sites being favored over smaller sites. The 35 top ranked sites comprise a total area of nearly 4,300 acres, and range in size from 585 to 23 acres.

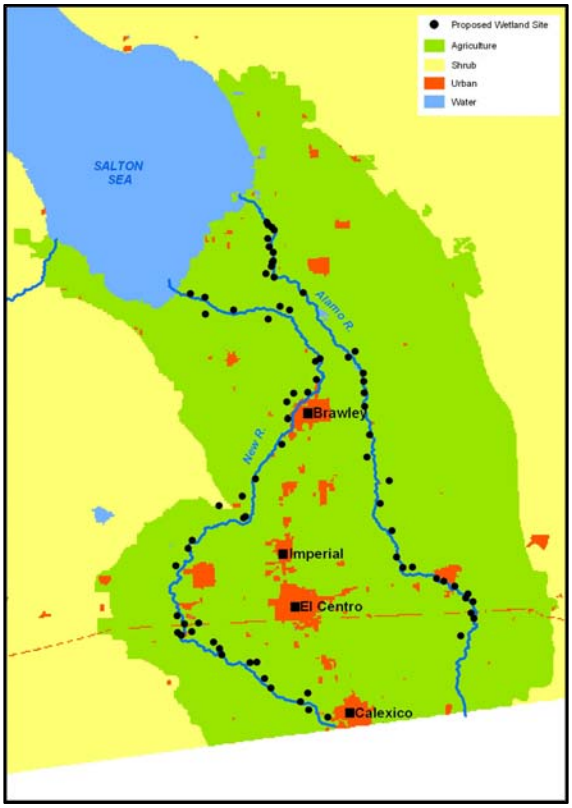


Figure 1-5 The location of 35 sites with high potential for construction of wetlands (site location from Nolte, 2002).

1.2 Organization of Master Plan Report

This report presents a set of scientific and technical evaluations to determine the benefits and adverse impacts of a network of wetlands along the New and Alamo Rivers. The benefits are quantified in terms of pollutant loads removed, and the adverse impacts are quantified in terms of risks to wildlife that may happen to use the wetland. Wildlife risks are a potential concern because these wetlands, like other constructed wetlands, tend to bioaccumulate certain substances, such as selenium and pesticides, in their sediments and food web to levels possibly higher than would naturally be present in the surrounding region. The suitability of wetlands for water quality improvement in this region will depend both on the levels of pollutant loads removed and on the management of potential wildlife risk.

This report is divided into twelve additional chapters.

- Chapter 2 presents a summary of previously collected flow and water quality data in the New and Alamo Rivers and the drains that flow into them. These data, supplemented with additional synoptic survey data, summarized below, were used to characterize loads of key pollutants at different locations in the watershed. This distribution of loads was used to evaluate the removal that could be accomplished through a network of wetlands.
- Chapter 3 presents a summary of water quality data specifically collected as part of this Master Plan. Additional data collection was considered important to fill gaps in existing data, and also to create a data set of current conditions using a consistent set of analytical methods. These data, in conjunction with historical data presented in Chapter 2, were used in the wetland load evaluation.
- Chapter 4 contains details on the biological data collected in support of the ecological risk assessment. Data were collected on tissue concentrations of selenium and key pesticides from the pilot wetlands, agricultural drains, and the two rivers.
- Chapter 5 presents the results of a biological inventory conducted at a subset of the proposed wetland sites. The inventory identified the presence of various plant, avian, and amphibian and mammalian species, including threatened and endangered species that might be affected by wetland construction and/or benefit from the wetland habitat that might be created.
- Chapter 6 describes the mathematical model developed for the Master Plan. The model combines three key elements, the rivers, the drains, and wetlands. The model can be configured to estimate loads of various pollutants of interest for the current conditions and for different scenarios of wetland construction.
- Chapter 7 presents a detailed distribution of flows and of nitrogen, phosphorus, selenium, coliforms, and suspended sediment loads throughout the Alamo and New River basins. The most significant sources of each pollutant are quantified.
- Chapter 8 described the application of the model to scenarios where the entire network of wetlands proposed in the Nolte (2002) report is constructed. Although the full network is not expected to be constructed for many years, these calculations provide an estimate of the overall benefit of wetlands in the general restoration of the Salton Sea.
- Chapter 9 presents alternative wetland network designs evaluation, in particular, the benefits of having a limited number of wetlands, or at the other extreme, increasing the wetland area by a large amount.
- Chapter 10 is a detailed predictive ecological risk assessment of wetlands including a comparison to conditions in the drains, the rivers, and the Salton Sea. Because of the known presence of selenium and pesticides in the Imperial Valley, and the potential of

wetlands to biomagnify the background concentrations, the risk assessment is a vital component of the analyses that will determine whether the wetland construction will go forward or not.

- Chapter 11 presents a comparison of the cost effectiveness of the treatment wetland network with the construction and operation of a chemical treatment plant to reduce contaminant loads in the New and Alamo Rivers before they flow into the Salton Sea.
- Chapter 12 is an operation and maintenance plan for the treatment wetlands highlighting activities that need to be undertaken to ensure effective performance of the wetlands and is based on direct field experience in the New River pilot wetlands as well as other literature reports.
- Chapter 13 summarizes the results of the various technical analyses in preceding chapters and provides the overall conclusions with respect to the future construction of treatment wetlands.

CHAPTER 2
HISTORICAL WATER QUALITY DATA IN THE ALAMO AND NEW RIVER BASINS

Historical water quality and flow data from the Alamo and New River Basins were collected and summarized for this study, prior to the collection of new data discussed in the following chapter. Sources of data included State and Federal government agencies, international agencies, and universities. Data were compiled for several key locations in each river basin. These locations included multiple sites on each of the rivers, major and minor agricultural drains, and NPDES facilities discharging into a waterbody of interest. For each of these sites, flow and any available data for nutrients, suspended solids, or key parameters of concern (e.g., total coliforms and selenium) were compiled. Historical data collected from January 1995 to December 1999 were used as the baseline for modeling simulations conducted as part of this project and presented in Chapters 6-9. A detailed discussion of the historical data collected from the rivers, agricultural drains, and NPDES facilities is provided in the following sections. Figure 2-1 provides a map of the rivers and shows the various sampling locations along the river and in the Imperial Valley where the historical water quality data discussed in this chapter were collected.

2.1 New and Alamo River Flow and Water Quality Data

2.1.1 Flow – New River

There were two stations on the New River with available flow data: the international boundary and Westmorland. These are both United States Geological Survey (USGS) gauging stations, and data were obtained from the USGS's National Water Information System (NWIS) website (http://waterdata.usgs.gov/nwis). Daily flow data for the New River at the international boundary were available from 1979 to 2004; the average flow over that time period was 237.7 cfs. During the modeling period for this study - 1995 through 1999 - the average daily flow was 215.9 cfs. Daily flow data for the New River at Westmorland were available from 1943 to 2004; the average flow was 616.4 cfs.

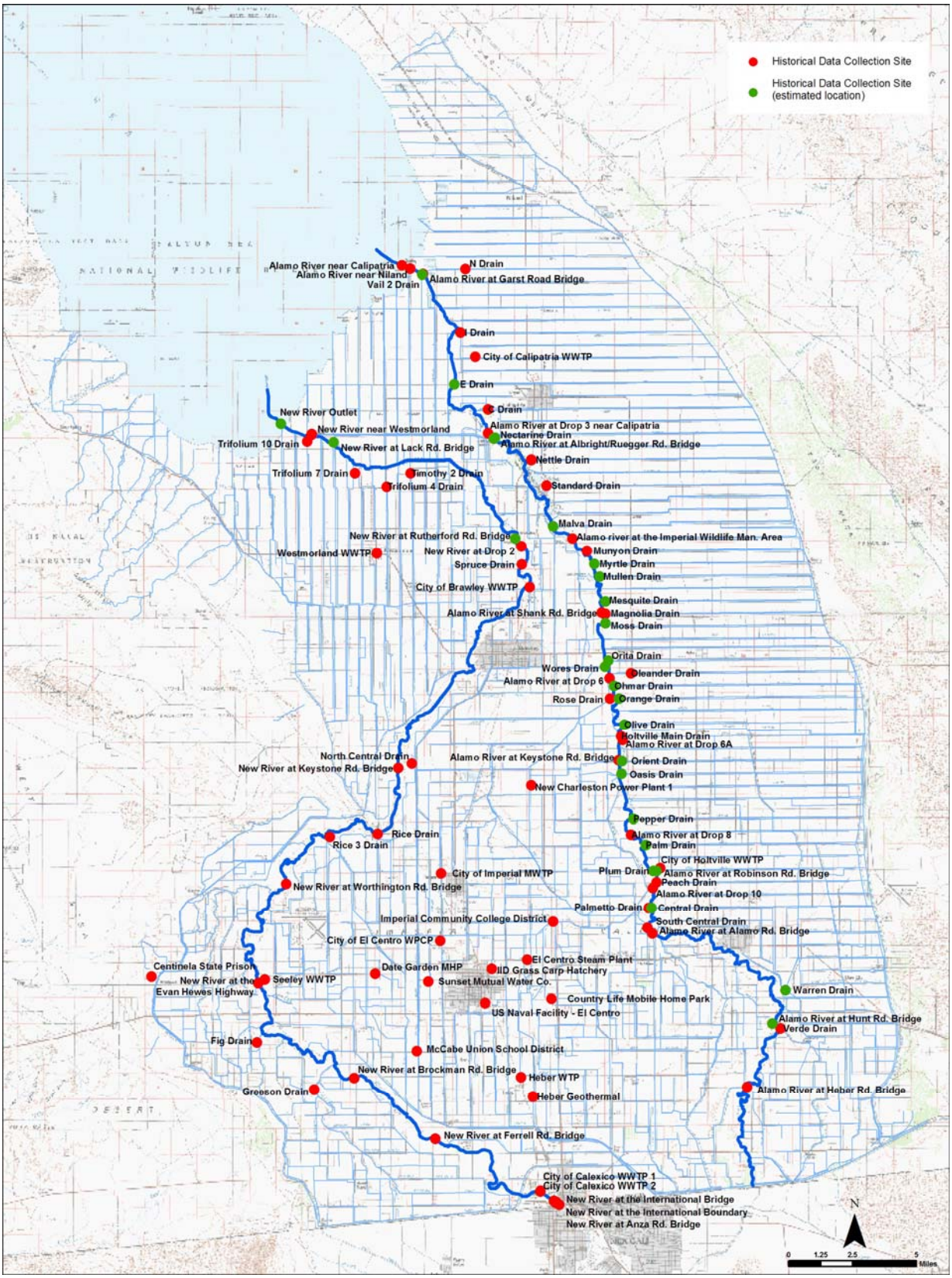


Figure 2-1 Map of the historical water quality data sampling locations for the New and Alamo Rivers. Coordinates of some locations were available from the original data sources used. Other coordinate locations were estimated based on station descriptions. The two types of stations are shown in the map legend.

Figures 2-2a and b show the flow data for the two sites from 1980 to 2004. At the international boundary site, the maximum daily flow value observed during this time period was 735 cfs on December 9, 1982 and again on February 5, 1983. For the Westmorland site, the maximum daily flow value observed during this same period was 2000 cfs on December 10, 1982. Higher flows are typically observed in the river from August to March, and can likely be attributed to the fact that the agricultural drains feeding into the river also have higher flows during this same period.

2.1.2 Flow – Alamo River

The Alamo River had three stations with available flow data: the international boundary, near Niland, and Drop 3 near Calipatria. The Niland and Calipatria stations were USGS gauging stations, so the data were obtained electronically from the NWIS website. The data for the Alamo River at the international boundary were obtained from the International Boundary and Water Commission's (IBWC) website (http://www.ibwc.state.gov/wad/histflo3.htm). Daily flow data for the Niland station were available from 1960 to 2004. The average daily flow was 850.1 cfs, compared to 862.5 cfs for the modeling period (1995 through 1999). For the Calipatria site, daily flow data were available from 1979 to 2003, averaging 718.5 cfs, compared to 728.6 cfs over the modeling period. For the international boundary site, daily flow data were available from 1947 to 2002, averaging 2.7 cfs.

Figures 2-3a, b, and c show the flow data for these three sites from January 1, 1980 to the last available data record. At the international boundary site, the maximum daily flow value during this time period was 11.3 cfs on July 1, 1996. For the Niland site, the maximum daily flow value was 4000 cfs on March 3, 1983. The Calipatria site had a maximum daily flow value of 4670 cfs on March 27, 1992. As was the case with the New River, higher flows are typically observed in the Alamo River from August to March. The Alamo River flow plots show that there is a large increase in flow between the border and the outlet at Niland. Agricultural drainage flows entering the river are the primary reason for the higher flows at the outlet.

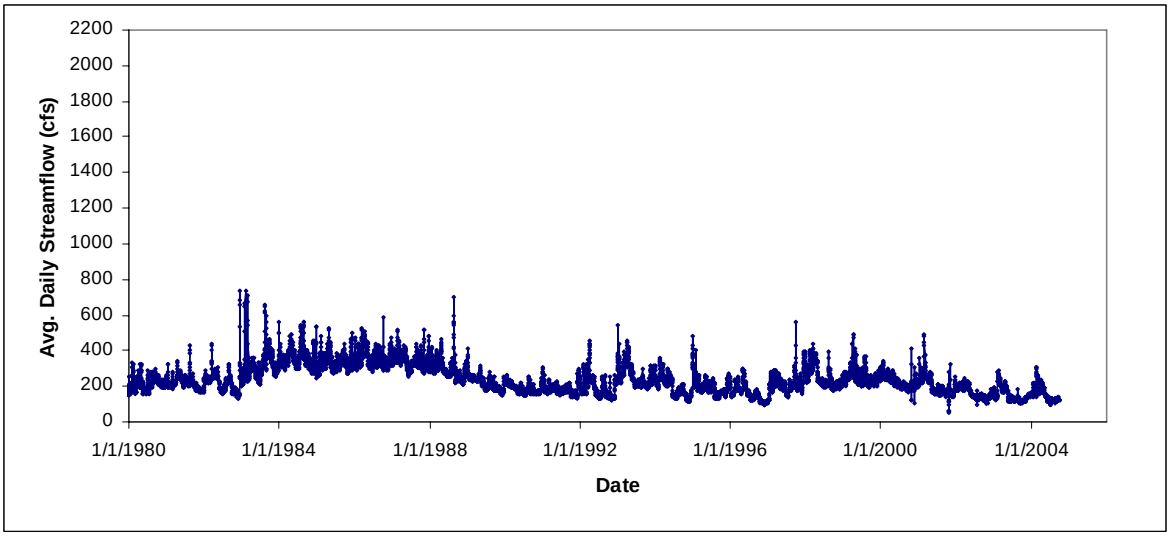


Figure 2-2a Average daily flow from the New River at the international boundary.

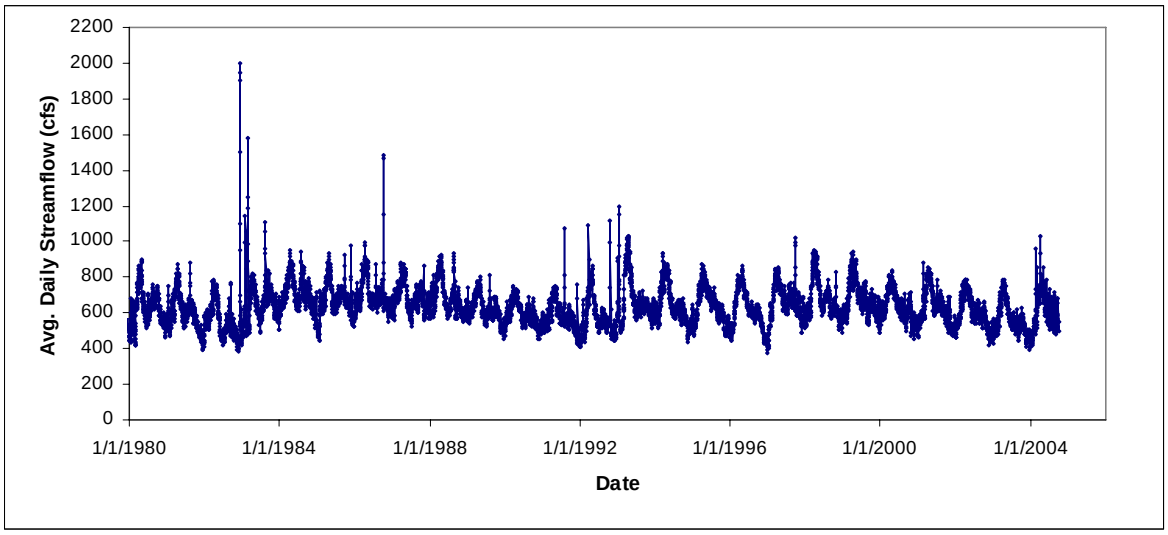


Figure 2-2b Average daily flow from the New River at Westmorland.

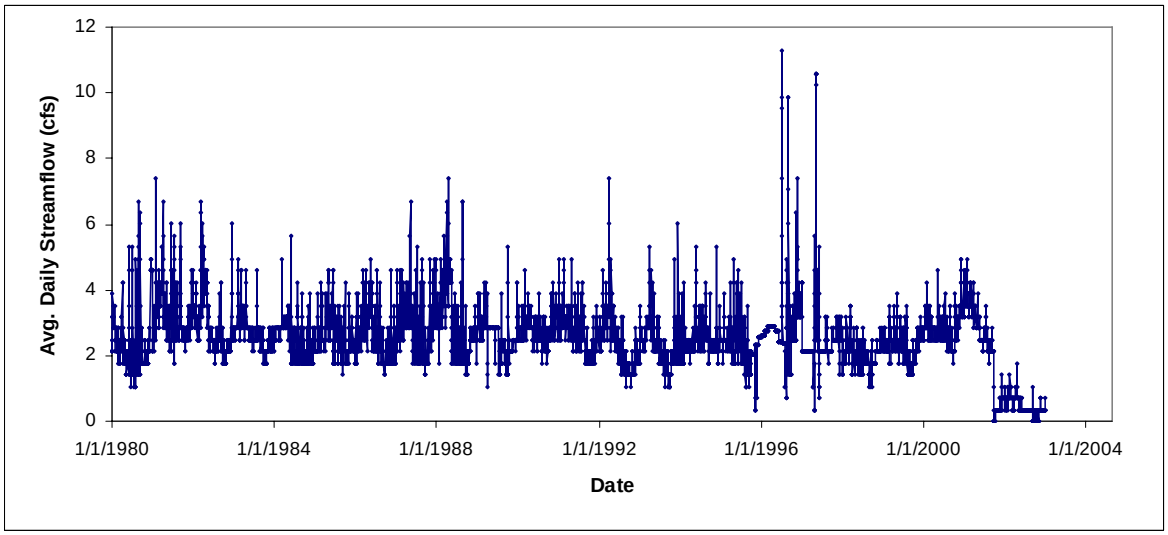


Figure 2-3a Average daily flow from the Alamo River at the international boundary.

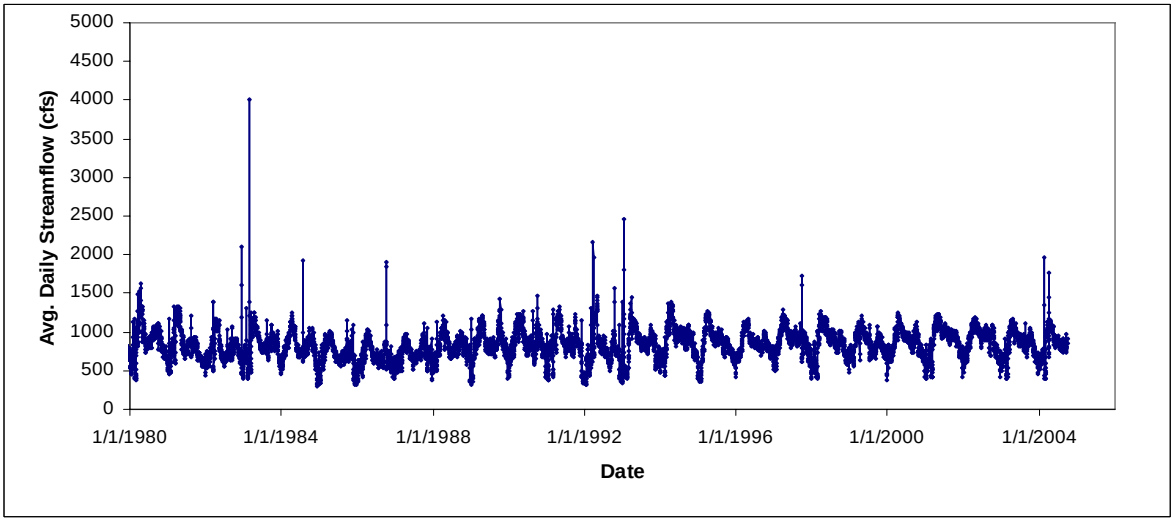


Figure 2-3b Average daily flow from the Alamo River near Niland.

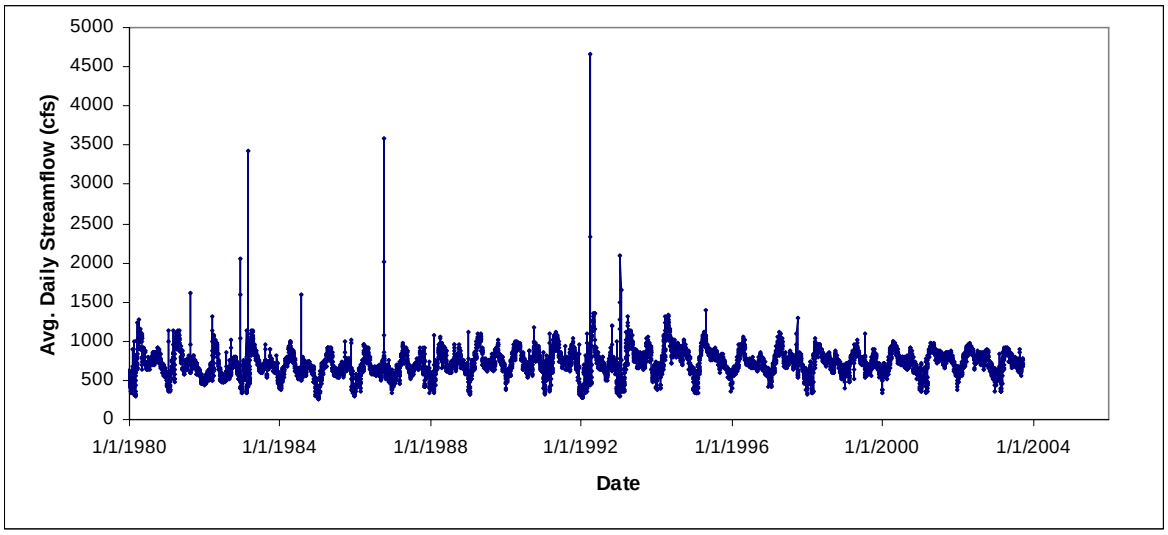


Figure 2-3c Average daily flow from the Alamo River at Drop 3 near Calipatria.

2.1.3 Water Quality – New River

Historical water quality data for the New River were compiled from numerous sources: USGS's NWIS database, EPA's STORET database, the Regional Water Quality Control Board (RWQCB) – Region 7 website, the Imperial Irrigation District (IID), the New River Silt/Sedimentation TMDL, and a University of California at Davis study. The majority of the historical water quality data for the New River came from the USGS's NWIS database and the RWQCB - Region 7 website. Appendix A provides a summary of all of the historical data compiled by Tetra Tech for the New River.

The USGS's NWIS database provides data in an electronic spreadsheet format for requested locations (http://waterdata.usgs.gov/nwis). The database included two sites on the New River: the international boundary and near Westmorland. The parameters for these two sites included total N, ammonia-N, nitrate-N, nitrite-N, TKN, organic N, total P, ortho-P, total phosphate, total selenium, TSS, fecal coliforms, and total coliforms. The data compiled from the NWIS database were collected at irregular intervals varying by parameter between November 15, 1966 and April 4, 1992. The bulk of the data were collected from the mid-70s to the mid-80s.

The EPA's STORET database also provides data in an electronic spreadsheet format for requested locations (http://www.epa.gov/storet/dbtop.html). The STORET database included the same two New River sites as the NWIS database and the following parameters of interest over the period from August 14, 1975 to June 5, 1984: ammonia-N, nitrate, TKN, total P, ortho-P, fecal coliforms, and total coliforms. As for the NWIS database, the period of record and number of analyses varied by parameter. In cases of duplicated samples, the NWIS data were used to avoid the same samples appearing twice in Tetra Tech's historical water quality database.

Data were obtained from the RWQCB Region 7 website for the New River at the international boundary (http://www.waterboards.ca.gov/coloradoriver/newriver/dataindex.html). The parameters of interest at this site included: ammonia-N, nitrate-N, nitrite-N, total P, ortho-P, total selenium, TSS, and fecal coliforms over the period from January 1997 to June 2005. Region 7 personnel provided additional monthly data from 1995 and 1996 for the international boundary site. A second electronic database provided by Region 7 included data collected

over the period March 2003 to June 2005 from four sites on the New River: the international boundary, the Evan Hewes Highway, Drop 2, and the Outlet. The parameters of interest included in this database were ammonia-N, nitrate-N, nitrite-N, total P, ortho-P, total N, total selenium, TSS, total coliforms, and fecal coliforms.

Data were obtained from the Imperial Irrigation District (IID) in several electronic databases (Excel spreadsheets). The IID data were collected from a site on the New River near the outlet on a monthly basis from January 1996 to December 1997. The parameters of interest included in this data set were ammonia-N, nitrate-N, total P, total selenium, and TSS. Additional data were provided from the inlet to the Brawley Pilot Wetland for the period from January 2001 to July 2005.

The New River Silt/Sedimentation TMDL included TSS data for one site on the New River at the international boundary from January 1995 to February 2000. The data were obtained from Region 7's website (http://www.waterboards.ca.gov/coloradoriver/tmdl/TMDL_Status.htm).

A UC Davis study (Houston et al., 2000) included data from a one time sampling conducted on March 31, 1999. Seven sites on the New River were sampled: Anza Rd. Bridge, Brockman Rd. Bridge, Ferrell Rd. Bridge, Keystone Rd. Bridge, Lack Rd. Bridge, Rutherford Rd. Bridge, and Worthington Rd. Bridge. The parameters of interest analyzed as part of this study included nitrate-N, ortho-P, total selenium, and TSS.

The primary water quality constituents of interest for the modeling portion of the current study were total P, total N, total selenium, TSS, and total coliforms. The concentrations of each of these parameters in the New River will be discussed in detail in the following sections. This discussion provides summary statistics for each constituent and plots showing any changes in the concentrations over time. Separate plots were prepared to conduct seasonal trend analyses for the chemical data from the New River. Figure 2-4 shows an example of one of the plots used to conduct the seasonal trend analyses.

Summary statistics were provided for two sites on the New River: at the international boundary and at the outlet. Table 2-1 summarizes data for the primary parameters of interest along with other nutrients with available data. The table is divided into two time periods for comparison purposes: one period combining all the available data and a second time period showing the data that were measured during the modeling period from January 1995 through December 1999.

2.2 Box Plot Summaries of Data

A box plot shows the distribution of a set of data by using the median, quartiles, and the extremes of the data set. The box plots in the following sections were generated for the primary chemicals of interest for several locations on each river and for the major and minor drains flowing into the rivers. The number of sites/locations on each plot may vary due to the availability of chemical data for each location. Data from the entire historical data collection period was used to generate the box plots. For each parameter, data collected on different dates from a site were combined to create the boxes on each plot. The boxes for the major and minor drains were created by combining the data collected, for a given parameter, from all the major or all of the minor drains on each of the rivers. The data used to create these plots can be found in the historical data set included in the Appendices.

2.2.1 Total Phosphorus

The average total P concentrations calculated using all the data were 1.5 mg/L at the international boundary and 0.8 mg/L at the outlet. The higher concentrations at the border

may be due to effluent water that is discharged into the New River from a wastewater treatment plant in Mexico located near the border. For both the border and the outlet, the average total P concentration was higher for the modeling period than over the entire period of record (Table 2-1a and b). The maximum concentration of total P measured in the river was 11.5 mg/L at the international boundary on December 7, 1976. The highest average total P concentration occurred at the international boundary, followed by the IID data collected near the outlet (Figure 2-5). The total P concentrations in the inlet to the Brawley Pilot Wetland ranged from 0.76 to 2 mg/L, and averaged 1.4 mg/L.

The total P data for the New River was assessed for changes over time. Figure 2-6 shows a plot of all of the historical total P data collected near the outlet versus time. This plot suggests a slight increase in the total P concentrations at the outlet over the last 25 to 30 years. The seasonal trend analysis conducted on the sites on the New River showed that total P concentrations are typically lower during the low flow/low rainfall months of April to July.

2.2.2 *Total Nitrogen*

The average total N concentrations calculated using all the data were similar between the international boundary and the outlet locations. The average total N concentrations from these sites were 6.9 mg/L and 6.8 mg/L, respectively. There were no total N data collected during the modeling period, so a comparison between the time periods could not be made. The maximum total N concentration was 21 mg/L at the international boundary on November 18, 1975. The highest average concentration of total N was at the outlet site (Figure 2-7). However, there were only two data points from this site. When this data set is combined with the data from the site near Westmorland, which is also near the outlet, the average total N data were similar for both the international boundary and the outlet locations. The total N in the inlet to the Brawley Pilot Wetland ranged from 5.9 to 9.1 mg/L, and averaged 7.6 mg/L. The average total N at this location was higher than at the border, although the maximum concentration was much lower.

For total N, there was a limited amount of data from the outlet, so a concentration versus time plot was done for nitrate alone since it constituted over 50% of the total N. As shown on Figure 2-8, minimal data were available from the earlier time periods, so it was not possible to detect any changes in the concentration over time.

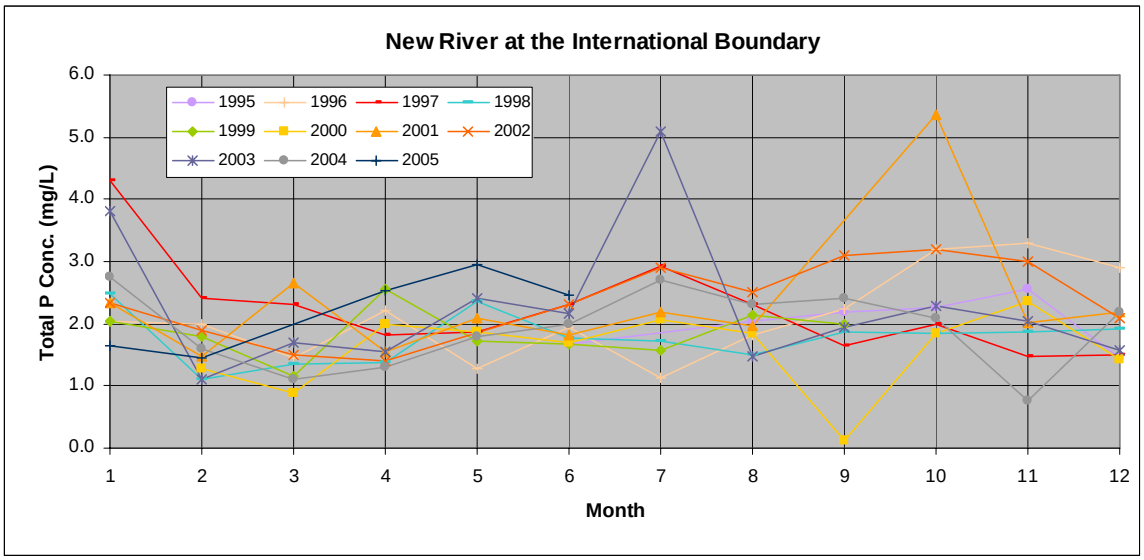


Figure 2-4 Example of the type of plot used to conduct seasonal trend analyses.

Table 2-1a
Summary statistics for the New River at the international boundary

New River at the international boundary							
Parameter	**Units**	**All Data Count**	**All Data Range**	**All Data Mean**	**Modeling Period* Count**	**Modeling Period* Range**	**Modeling Period* Mean**
Ammonia-N	mg/L	793	0.33 - 19.5	4.31	51	2.9 - 11.2	5.8
Nitrate-N	mg/L	215	ND (0.01) - 21.14	3.41	42	ND (0.2) - 1.5	0.33
Nitrite-N	mg/L	112	ND (0.01) - 0.65	0.09	35	All ND	0.04
Organic N	mg/L	91	ND (0.2) - 11	3.2	-	-	-
TKN	mg/L	174	0.04 - 15	5.3	-	-	-
Total N	mg/L	107	0.17 - 21	7.0	-	-	-
Total P	mg/L	419	ND (0.01) - 11.5	1.54	51	1.1 - 4.3	2.0
Ortho-P	mg/L	90	ND (0.033) - 2.2	0.8	-	-	-
Selenium, total	ug/L	70	ND (1) - 72	4.5	-	-	-
Fecal Coliforms	MPN/100 mL	1128	$1.1x10^3$ – $2.4x10^8$	$2.7x10^6$	243	$2.0x10^4$ – $1.6x10^7$	$7.2x10^5$
Total Coliforms	mg/L	240	$1.2x10^4$ - $2.4x10^8$	$1.7x10^7$	-	-	-
TSS	mg/L	255	ND (10) - 3130	98.3	58	10 - 233	49.6

*The modeling period was from 1/1/95 to 12/31/99.
The value in parentheses is the lowest detected value

Table 2-1b
Summary statistics for the New River at the outlet for the parameters of interest.

New River at the outlet**							
Parameter	**Units**	**All Data Count**	**All Data Range**	**All Data Mean**	**Modeling Period* Count**	**Modeling Period* Range**	**Modeling Period* Mean**
Ammonia-N	mg/L	133	ND (0.08) - 9.6	1.6	24	2.1 - 9.6	3.8
Nitrate-N	mg/L	70	1.1 - 16	5.5	24	2.7 - 16	4.3
Nitrite-N	mg/L	15	0.006 - 7	1.2	-	-	-
Organic N	mg/L	69	0.09 - 3.9	1.5	-	-	-
TKN	mg/L	140	0.24 - 46.7	2.0	-	-	-
Total N	mg/L	42	3.4 - 9.6	6.8	-	-	-
Total P	mg/L	135	0.24 - 6.2	0.83	24	0.82 - 1.9	1.3
Ortho-P	mg/L	89	0.02 - 1.3	0.36	-	-	-
Selenium, total	ug/L	24	ND (2.9) - 11	3.9	28	ND (2.9) - 11	3.7
Fecal Coliforms	MPN/100 mL	57	40 – $1.6x10^6$	$4.5x10^4$	-	-	-
Total Coliforms	mg/L	39	$1.7x10^3$ – $4.0x10^5$	$1.0x10^5$	-	-	-

*The modeling period was from 1/1/95 to 12/31/99
**New River at the outlet includes New River IID data and New River near Westmorland data
The value in parentheses is the lowest detected value

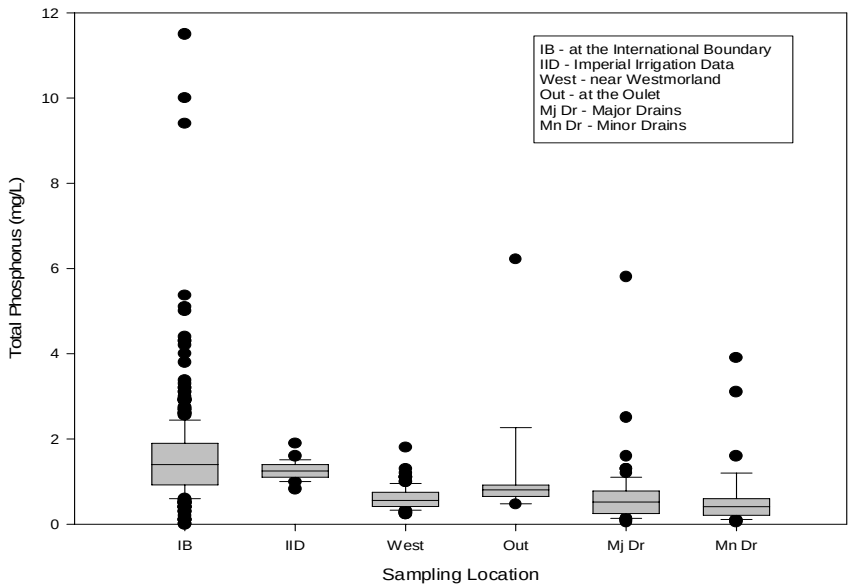


Figure 2-5 Box Plot of total P for various locations in the New River and for the agricultural drains flowing into the river.

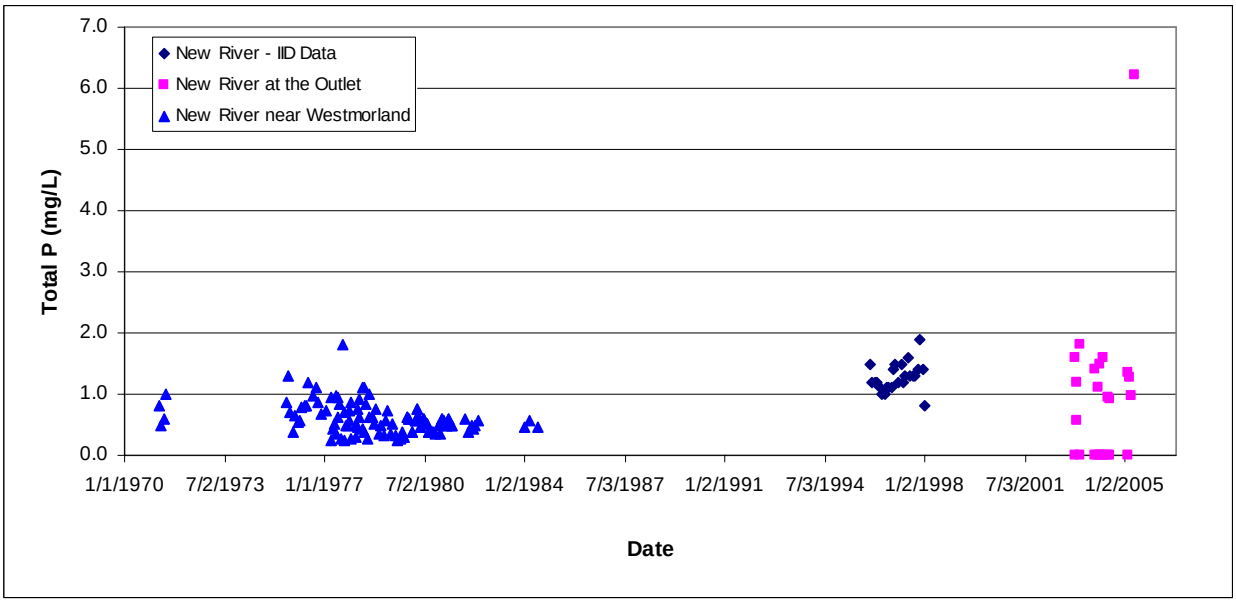


Figure 2-6 Total P concentration vs. time from New River outlet samples.

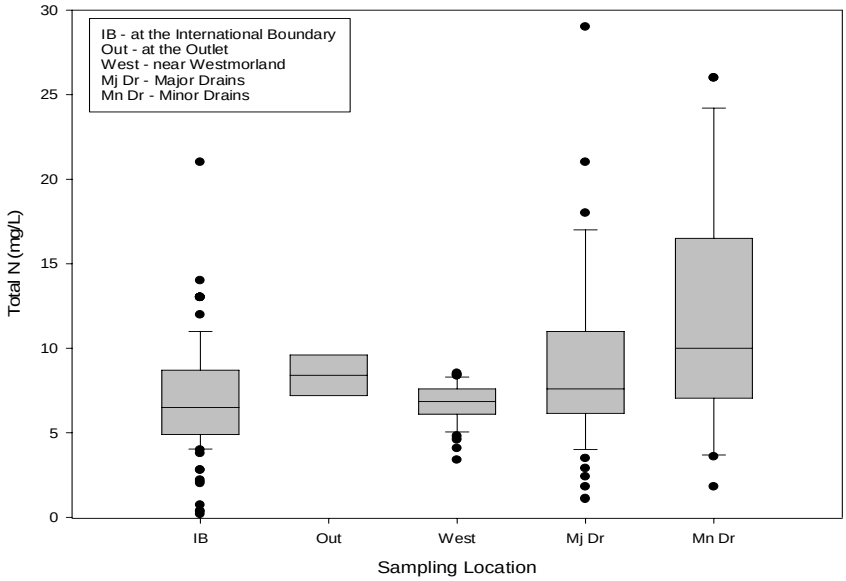


Figure 2-7 Box plot of total N data for various locations in the New River and for the agricultural drains flowing into the river.

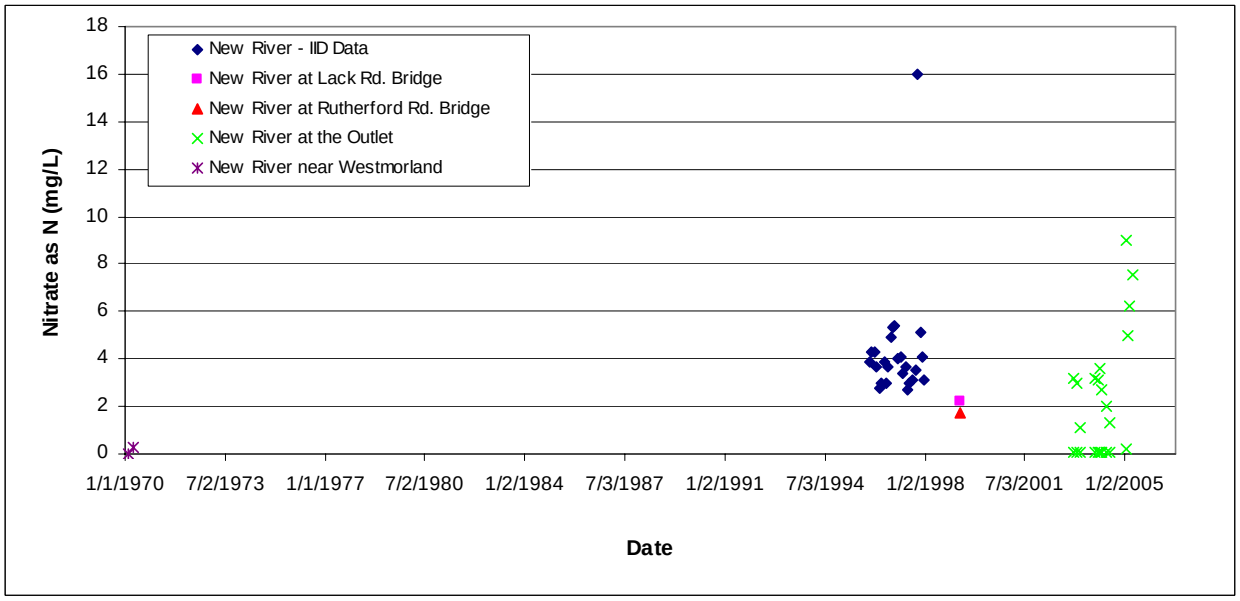


Figure 2-8 Nitrate as N concentration vs. time from New River outlet samples.

2.2.3 Selenium

The average total selenium concentrations calculated using all the data were similar for the international boundary and outlet sampling locations. The average total selenium concentrations from these sites were 3.5 µg/L and 3.9 µg/L, respectively. For both sites, the average total selenium concentration was higher for the data from the modeling period than over the entire time period (Table 2-1a and b). At the international boundary, all 35 of the samples collected during the modeling period were below detection (<5 µg/L). The maximum concentration of total selenium measured in the river was 72 µg/L at the international

boundary on September 24, 2002. Dissolved selenium was measured at the inlet to the Brawley pilot wetland from the New River, ranging from 6.2 to 29.4 µg/L and averaging 10.7 µg/L. Figure 2-9 shows that the average selenium concentrations from the different river sites and from the agricultural drains were similar, although maximum concentrations differed. There was not enough total selenium data to assess the changes in the concentration over time at the outlet or determine seasonal trends.

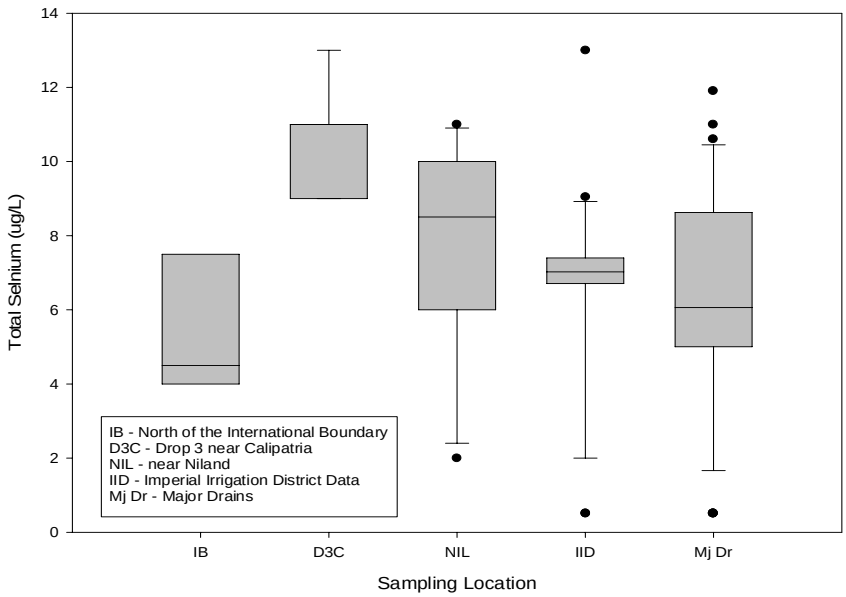


Figure 2-9 Box plot of total selenium data for various locations in the New River and for the agricultural drains flowing into the river.

2.2.4 Total Suspended Solids

The average TSS concentrations calculated using all the data were much lower at the international boundary compared to the outlet. The average TSS concentrations from these sites were 98.3 mg/L and 239.9 mg/L, respectively. This difference can likely be attributed to the fact that the agricultural return flows entering the river have high concentrations of suspended solids which would lead to an increase in suspended solids as you move closer to the Salton Sea. Figure 2-10 shows an increase in the TSS concentration as you move closer to the Salton Sea. For the international boundary site, the average TSS concentration is higher over the entire time period, while for the outlet site, the modeling period is higher (Table 2-1a and b). The maximum concentration of TSS measured in the river was 3,130 mg/L at the international boundary on March 22, 2000. This is considerably higher than the TSS measured at the New River site at the inlet to the Brawley pilot wetland, which ranged from 50.5 to 253.1 mg/L and averaged 144.2 mg/L.

There was ample TSS data to assess changes over time and trends in seasonality. Figure 2-11 shows a plot of all of the TSS data collected near the outlet versus time. There is a slight decline in the TSS concentration over time. This is especially true between the samples collected in 1988-89 and those collected in the mid to late 1990s. A seasonal trend analysis conducted on various sites in the New River showed that higher concentrations of TSS generally occur during late spring and throughout the summer months.

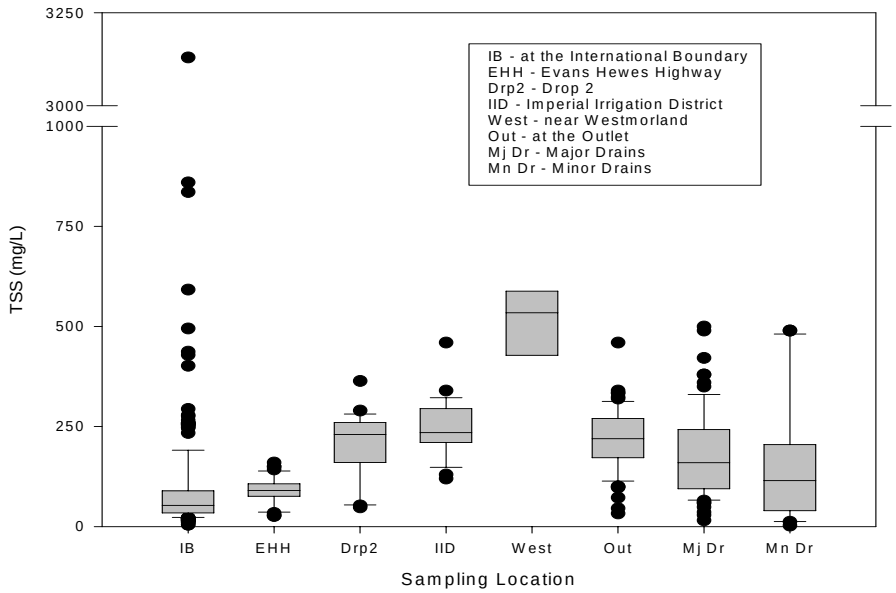


Figure 2-10 Box plot of TSS data for various locations in the New River and for the agricultural drains flowing into the river.

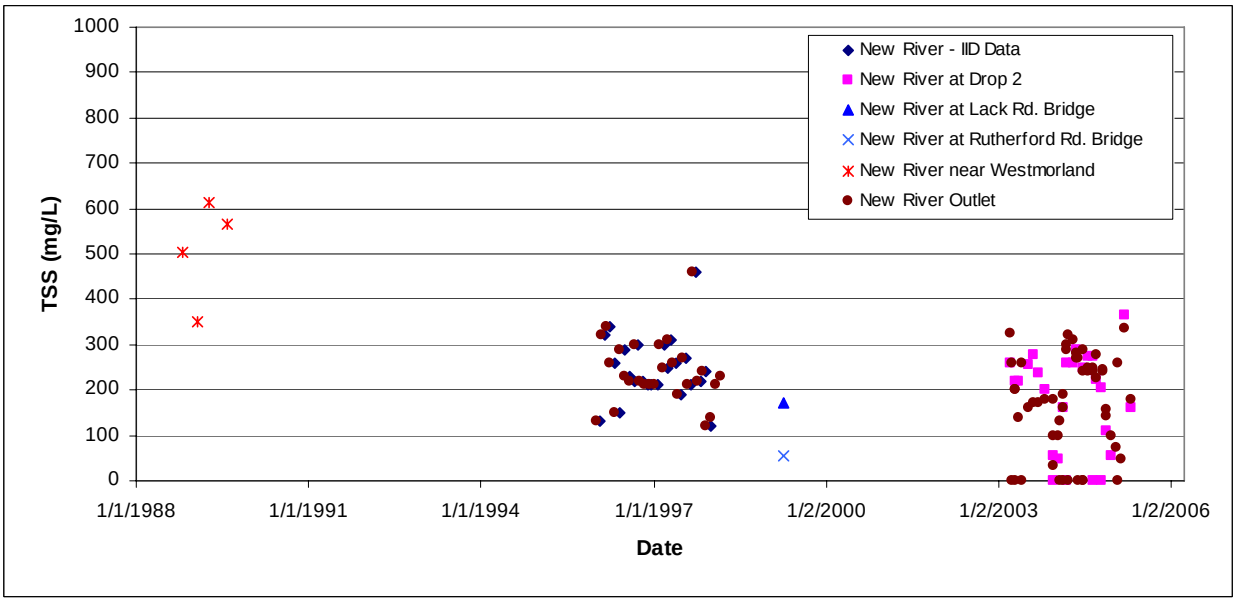


Figure 2-11 TSS concentration vs. time from New River outlet samples.

2.2.5 *Total Coliforms*

The average total coliform concentrations calculated using all the data were much higher at the international boundary compared to the outlet. The average total coliform concentrations from these sites were 1.7×10^7 MPN/100 mL and 1.0×10^5 MPN/100 mL, respectively. The higher concentrations occurring at the international boundary may be the result of sewage effluent water discharged into the New River from a treatment plant in Mexico located near the border. There were no total coliform data collected during the modeling period, so a comparison between the time periods could not be made. The maximum concentration of

total coliforms measured in the river was 2.4×10^8 MPN/100 mL at the international boundary on three dates in late 1977. Figure 2-12 shows the total coliform data distribution from the river sites where it was measured. The agricultural drains are not included on this plot, because total coliform data were not available. The plot clearly shows that the concentration of total coliforms is much higher at the international boundary compared to the other river sites. The New River site at the Brawley pilot wetland also had lower concentrations than at the border (average 1.6×10^6 MPN/100 mL). There were not enough available data to evaluate changes over time or seasonal trends.

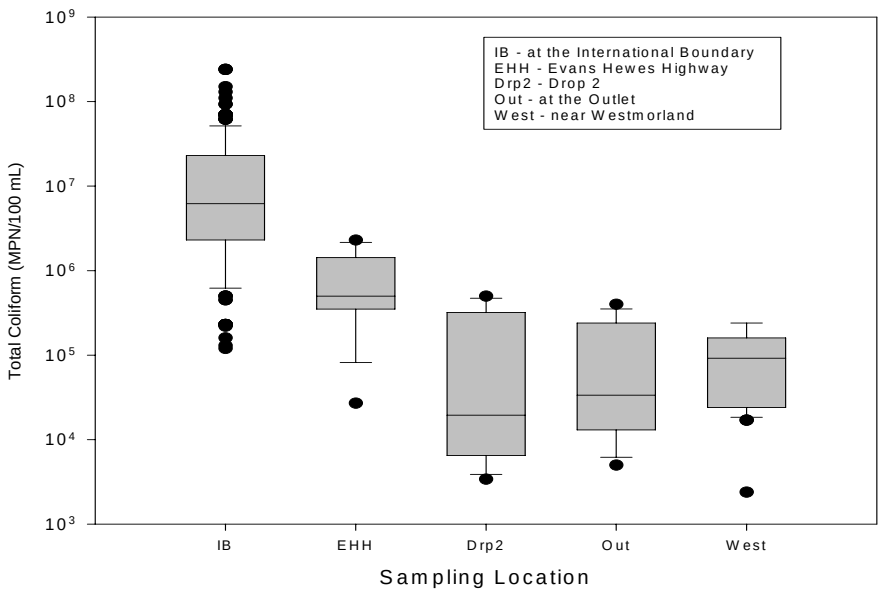


Figure 2-12 Box plot of total coliforms data for various locations in the New River.

2.3 Water Quality – Alamo River

Historical water quality data for the Alamo River were compiled from numerous sources for various locations in the river. Sources of data included: USGS's NWIS database, EPA's STORET database, the RWQCB 7 website, Imperial Irrigation District (IID), an International Boundary and Water Commission (IBWC) website, a U.S. Bureau of Reclamation website, the Alamo River Silt/Sedimentation TMDL, and a University of California at Davis study. The majority of the historical water quality data for the Alamo River came from the USGS's NWIS database. Appendix B provides a summary of all of the historical data compiled by Tetra Tech for the Alamo River.

The USGS's NWIS database included data for two sites on the Alamo River: Drop 3 near Calipatria and near Niland (http://waterdata.usgs.gov/nwis). The parameters of interest in the database for these two sites included: total N, ammonia-N, nitrate-N, nitrite-N, TKN, organic N, total P, ortho-P, total phosphate, total selenium, TSS, and fecal coliforms. The period of record and number of analyses varied for each of the chemicals of interest. The historical data collected from the NWIS database spanned the period from 1963 to 2002, however, most of the NWIS data used for this study were collected from the mid-70s to the mid-80s.

The STORET database included data collected from 1951 to 1982 for three sites on the Alamo River: the international boundary, north of the international boundary, and near

Calipatria. (http://www.epa.gov/storet/dbtop.html). The parameters of interest included: ammonia-N, TKN, total P, fecal coliforms, and total coliforms.

Data were obtained from the RWQCB Region 7 in an electronic database for seven sites on the Alamo River including: the international boundary, Drop 3, Drop 6, Drop 6A, Drop 8, Drop 10, and the Garst Rd. Bridge. The data included in this database were collected from 2003 to 2005. The parameters of interest were ammonia-N, nitrate-N, nitrite-N, total P, ortho-P, total N, TKN, and TSS.

Data were obtained from the Imperial Irrigation District (IID) in several electronic databases (Excel spreadsheets). The IID data were collected from a site on the Alamo River near the outlet on a monthly basis from 1996 through 1997. The parameters of interest included in this data set were ammonia-N, nitrate-N, total P, total selenium, and TSS.

The IBWC Alamo River website contained a small amount of data for one site - Alamo River north of the international boundary - collected between 1992 and 2000. (http://www.ibwc.state.gov/EMD/Water_Bulletins/pages/colorado_stations/Alamo_River.htm). The only parameters of interest included in this data set were fecal coliforms and TSS, but TSS was only analyzed on one date.

A small amount of data were also obtained from a U.S. Bureau of Reclamation website (http://www.usbr.gov/niwqp/data/study_areas/ssea.htm). This website contained data for three sites on the Alamo River: the international boundary, near Niland, and the Imperial Wildlife Management Area. However, only the Alamo River at the international boundary site had parameters relevant to this study; total selenium was measured on four dates from October 1988 to August 1989.

The Alamo River Silt/Sedimentation TMDL provided TSS data for two sites on the Alamo River: the international boundary and the outlet. The data included in the TMDL were collected from 1980 to 2000 (http://www.waterboards.ca.gov/coloradoriver/tmdl/TMDL_Status.htm).

A UC Davis study (Houston et al., 2000) provided data from a one time sampling conducted on March 2, 1999. Eight sites on the Alamo River were sampled as part of the study: Alamo Rd. Bridge, Albright/Ruegger Rd. Bridge, Garst Rd. Bridge, Heber Rd. Bridge, Hunt Rd. Bridge, Keystone Rd. Bridge, Robinson Rd. Bridge, and Shank Rd. Bridge. The parameters of interest analyzed as part of this study included nitrate-N, ortho-P, total selenium, and TSS.

As indicated above, the primary water quality constituents of interest for the modeling portion of this study were total P, total N, total selenium, TSS, and total coliforms. However, there were minimal data collected for total coliforms in the Alamo River, so the fecal coliform data for the river are discussed instead. The concentrations of each of these constituents in the Alamo River will be discussed in detail in the following sections. This discussion presents summary statistics for each constituent, changes in concentrations over time, and any seasonal trends. Concentration versus time plots are provided for each of the constituents for all the available data. Separate plots were prepared to conduct a seasonal trend analysis where possible.

Summary statistics were provided for two sites on the Alamo River: the international boundary and the outlet. Table 2-2a and b provides data for the primary water quality constituents along with other nutrients with available data. The table is divided into two time periods for comparison purposes: one period combining all the available data and a second time period showing the data that were measured during the modeling period (1995 through 1999).

2.3.1 Total Phosphorus

The average total P concentrations calculated using all the data were 0.17 mg/L at the international boundary, compared to 0.66 mg/L at the outlet. The international boundary site did not have data for the modeling period, but the outlet site did. At the outlet, the average concentration of total P data from the modeling period was slightly higher than from the entire time period (Table 2-2a and b). The maximum concentration of total P in the river was 2.6 mg/L for the Niland site on August 23, 1977. The highest average concentration of total P from all the river sites sampled was from the IID data sampled near the outlet (Figure 2-13).

Figure 2-14 shows a plot of all of the total P data collected near the outlet versus time, showing that the concentrations have remained fairly stable over time. A seasonal trend analysis conducted on various sites in the Alamo River showed that total P concentrations are typically lower during the low flow/low rainfall months of April to July.

Table 2-2a
Summary statistics for the Alamo River at the international boundary.

Alamo River at the international boundary**							
Parameter	**Units**	**All Data Count**	**All Data Range**	**All Data Mean**	**Modeling Period* Count**	**Modeling Period* Range**	**Modeling Period* Mean**
Ammonia-N	mg/L	11	ND (0.44) - 5.4	0.68	-	-	-
Nitrate-N	mg/L	-	-	-	-	-	-
Nitrite-N	mg/L	-	-	-	-	-	-
Organic N	mg/L	-	-	-	-	-	-
TKN	mg/L	14	0.34 - 1.2	0.74	-	-	-
Total N	mg/L	-	-	-	-	-	-
Total P	mg/L	11	0.05 - 0.3	0.17	-	-	-
Ortho-P as P	mg/L	-	-	-	-	-	-
Selenium, total	ug/L	4	4 - 10	5.8	-	-	-
Fecal Coliforms	MPN/100 mL	68	ND (30) – $3.5x10^4$	$2.6x10^3$	45	30 – $1.1x10^4$	$1.8x10^3$
Total Coliforms	mg/L	-	-	-	-	-	-
TSS	mg/L	37	6 - 196	59.4	1	16.3	16.3

*The modeling period was from 1/1/95 to 12/31/99.
**Alamo River at the international boundary also includes the site just north of the international boundary.
The value in parentheses is the lowest detected value.

Table 2-2a
Summary statistics for the Alamo River at the outlet for the chemical parameters of interest.

Alamo River at the outlet**							
Parameter	**Units**	**All Data Count**	**All Data Range**	**All Data Mean**	**Modeling Period* Count**	**Modeling Period* Range**	**Modeling Period* Mean**
Ammonia-N	mg/L	78	ND (0.01) - 4	0.94	24	0.3 - 2.5	1.4
Nitrate-N	mg/L	57	3.2 - 25	9.0	24	4.6 - 8.2	6.3
Nitrite-N	mg/L	2	0.6 - 1.1	0.86	-	-	-
Organic N	mg/L	68	ND (0.3) - 8	1.5	-	-	-
TKN	mg/L	45	1.1 - 12	3	-	-	-
Total N	mg/L	40	3.1 - 25	10.9	-	-	-
Total P	mg/L	78	0.14 - 2.6	0.66	24	0.25 - 1.4	0.74
Ortho-P as P	mg/L	76	0.016 - 1.0	0.24	-	-	-
Selenium, total	ug/L	24	ND (2) - 13	7.0	18	ND (5.5) - 13	6.8
Fecal Coliforms	MPN/100 mL	-	-	-	-	-	-
Total Coliforms	mg/L	-	-	-	-	-	-
TSS	mg/L	73	76 - 3040	381.2	28	230 - 399	303.9

*The modeling period was from 1/1/95 to 12/31/99.
**Alamo River at the outlet includes the Alamo River IID data and the Alamo River near Niland data.
The value in parentheses is the lowest detected value.

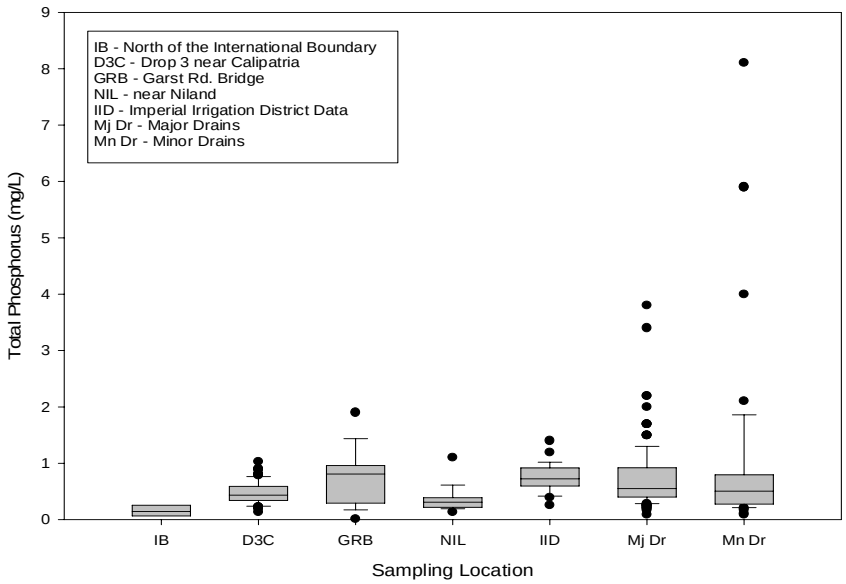


Figure 2-13 Box plot of total phosphorus data for various locations in the Alamo River and for the agricultural drains flowing into the river.

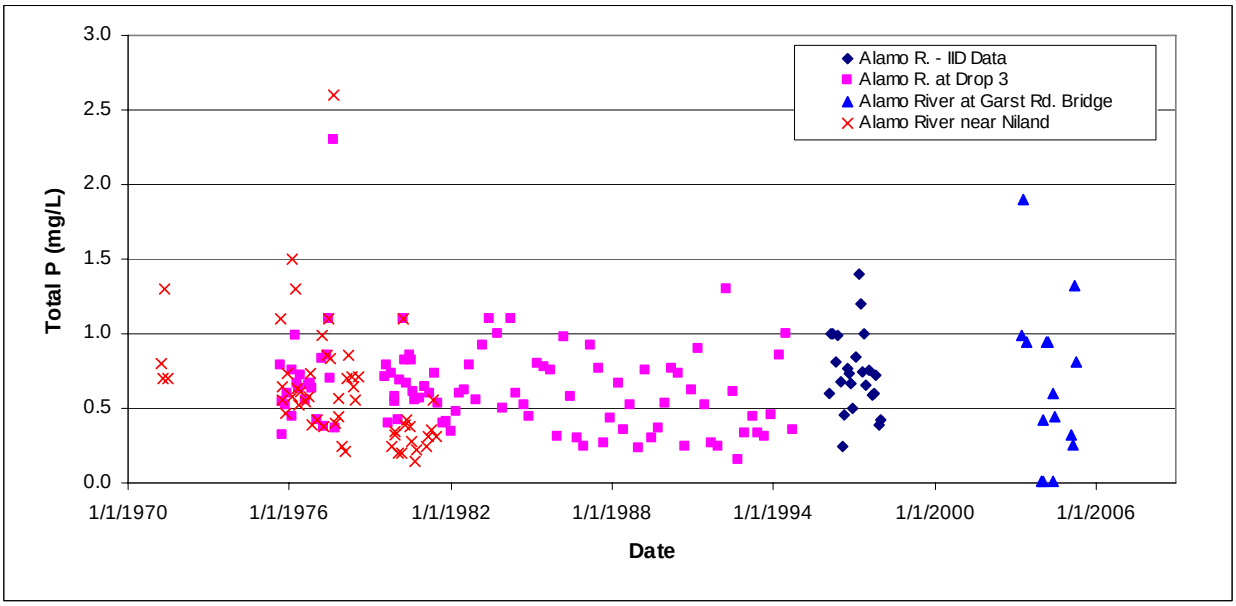


Figure 2-14 Total P concentration vs. time from Alamo River outlet samples.

2.3.2 *Total Nitrogen*

The average concentration of total N from the outlet samples for all the data was 10.9 mg/L; no data were available for the modeling period. No total N data were available at the international boundary, so a comparison between the two sites could not be made. The maximum concentration of total N in the river samples was 25 mg/L at the Niland site on May 23, 1978. Figure 2-15 shows that the total N concentrations near the river outlet do not show much variation between the different sites.

For total N, there was a limited amount of data from the outlet, so a concentration versus time plot was prepared for nitrate since it accounts for over 75% of the total N in samples where both values are reported. Figure 2-16 shows a decline in the concentration of nitrate at the outlet over the last 25 to 30 years. A seasonal trend analysis conducted on various sites showed that the concentrations of total N are typically lower during the low flow/low rainfall months of April to July. However, this trend was not as strong as the one observed for total P.

2.3.3 Selenium

The average total selenium concentrations calculated using all the data were similar for the international boundary (5.8 µg/L) and the outlet (7.0 µg/L). There were no selenium data collected during the modeling period at the international boundary, so a comparison between the two time periods at this site could not be made. At the outlet, the concentrations for the two time periods were similar (Table 2-2b). The maximum concentration of total selenium measured in the river was 13 µg/L at the IID site near the outlet on September 24, 1997 and at Drop 3 on January 16, 1980 and January 14, 1981. Figure 2-17 shows that highest average selenium concentration was measured at Drop3, and the lowest average concentrations are found at the international border site. There were not enough available total selenium data to evaluate changes over time or seasonal trends.

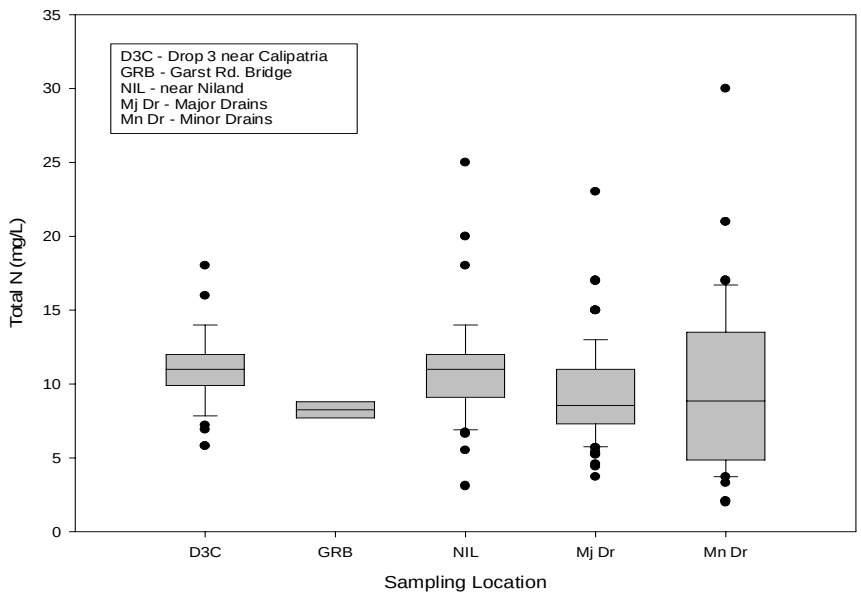


Figure 2-15 Box plot of total N data for various locations in the Alamo River and for the agricultural drains flowing into the river.

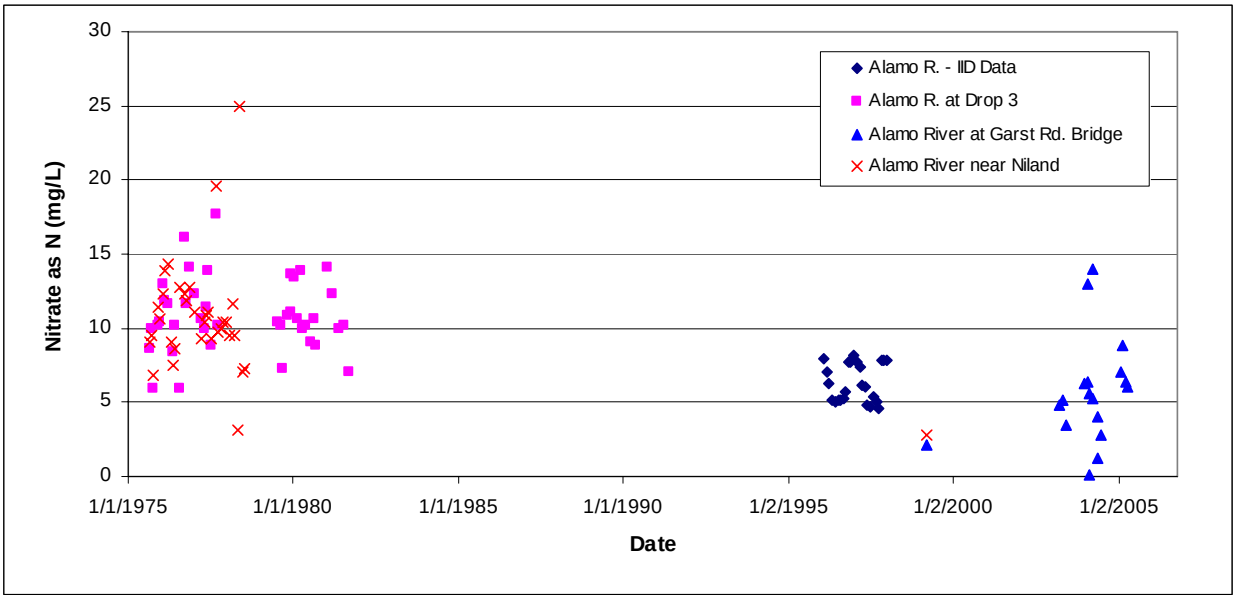


Figure 2-16 Nitrate as N concentration vs. time from Alamo River outlet samples.

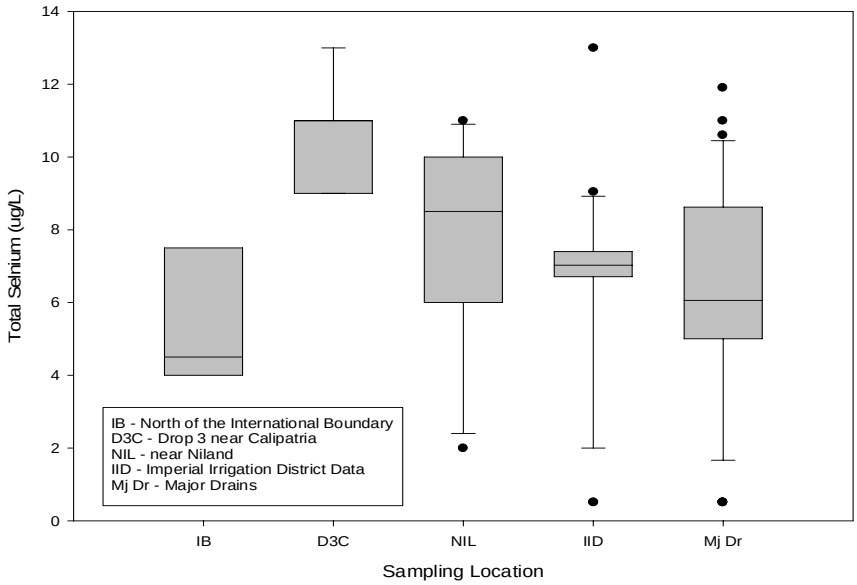


Figure 2-17 Box plot of total selenium data for various locations in the Alamo River and for the agricultural drains flowing into the river.

2.3.4 Total Suspended Solids

As was seen in the New River, the average TSS concentrations in the Alamo River calculated using all the data were much lower at the international boundary (59.4 mg/L) than at the outlet (381.2 mg/L). For both the international boundary and the outlet, the average TSS concentration was lower for the data from the modeling period than for the data over the entire time period (Table 2-2a and b). Figure 2-18 shows that there is a significant increase in the TSS concentration between the international boundary and the Salton Sea, and that there is typically an increase in suspended sediments as you move downstream. It also shows that

the agricultural drains contain significant amounts of suspended sediments. The maximum concentration of TSS measured in the river was 3040 mg/L at the Outlet site on March 1, 1983.

The TSS data showed both changes in the concentration over time and a seasonal trend. Figure 2-19 shows a plot of all of the TSS data collected near the outlet versus time. The plot shows a decline in the TSS concentration over the last 25 to 30 years. A seasonal trend analysis conducted on various sites showed that higher concentrations of TSS generally occur during late spring and throughout the summer months.

2.3.5 Fecal Coliforms

Fecal coliform data were collected at the international boundary and at Drop 3. The average fecal coliform concentrations calculated using all the data from these two sites were 2.6×10^3 MPN/100 mL and 1.9×10^4 MPN/100 mL, respectively. The international border site was the only location with samples collected during the modeling period. Fecal coliform concentrations were lower during the modeling period than over the entire data collection period (Table 2-2a). The maximum concentration of fecal coliforms measured in the river was 3.0×10^5 MPN/100 mL at Drop 3 on October 23, 1979. A box plot was not constructed for fecal coliforms, because data were available for only two river sites and no agricultural drains.

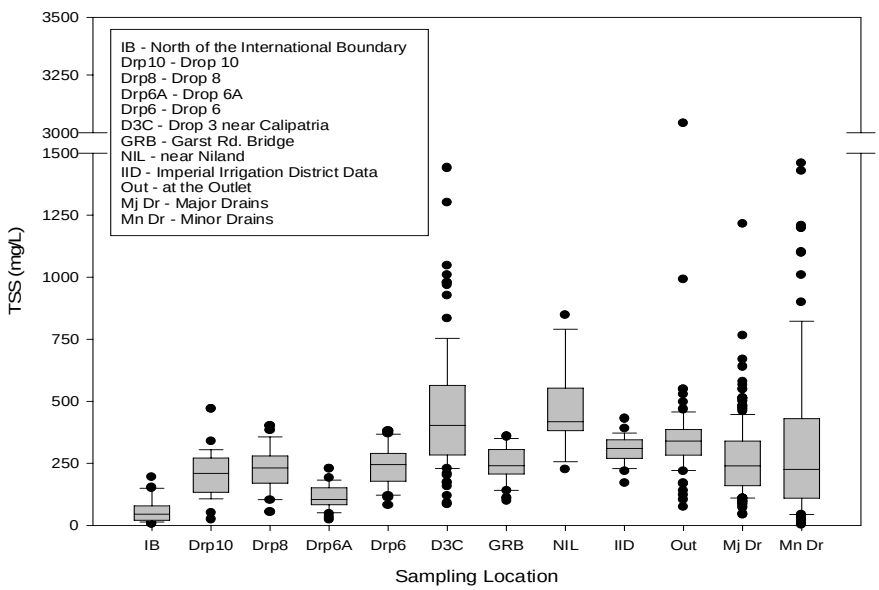


Figure 2-18 Box plot of TSS data for various locations in the Alamo River and for the agricultural drains flowing into the river.

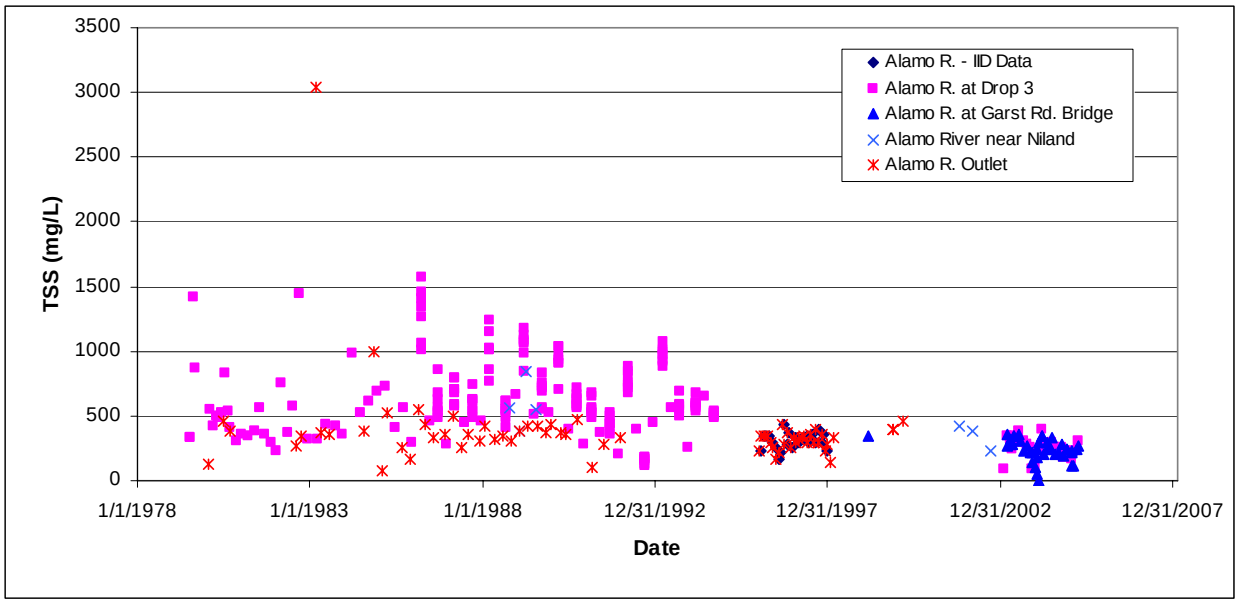


Figure 2-19 TSS concentration vs. time from Alamo River outlet samples.

The fecal coliform data from Drop 3 were used to evaluate changes in concentration over time. Figure 2-20 shows a sharp decline in the fecal coliform concentrations in the late 70s and early 80s. A seasonal trend analysis showed that lower concentrations of fecal coliforms generally occur during low flow/low rainfall months of April to July.

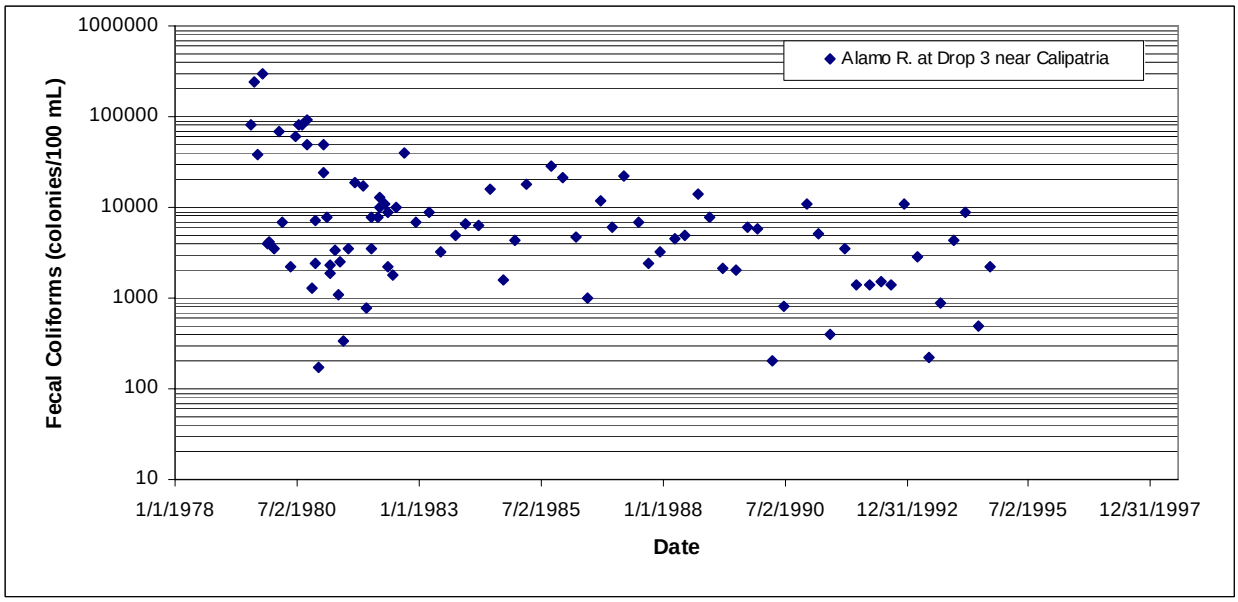


Figure 2-20 Fecal coliforms vs. time from Alamo River outlet samples.

2.4 Agricultural Drain Flow and Water Quality Data

2.4.1 Agricultural Drain Flow – New River

Flow data for the years 1995 to 2000 were compiled from the New River Silt/Sedimentation TMDL (http://www.waterboards.ca.gov/coloradoriver/tmdl/TMDL_Status.htm) for sixty agricultural drains with discharges to the New River. Four of these drains were categorized as major drains, and fifty-six were categorized as minor drains.

The four major drains discharging to the New River are the Greeson, Fig, Rice 3 and Rice drains. The flows reported for the major drains were primarily based upon gauged data with a few estimated values as described in the TMDL report. The average monthly flows ranged from 386.4 to 2011.4 AF. The Greeson Drain had the highest average monthly flow, followed by the Rice 3 Drain (Table 2-3). The highest monthly flow value recorded was 3036.5 AF from the Greeson Drain during May of 1999. The seasonal patterns in the flows show that lower flows typically occur from November to March; higher flows occur from April to October with peak flows in mid-summer.

The flow data for the minor drains from the TMDL were all estimated values, using a proportional relationship between drain return flows and irrigation water deliveries to the particular area served by the drain. The average monthly flows ranged from 3.4 to 3230.7 AF in the minor drains. The Salt Creek Drain had the highest average monthly flow followed by the Trifolium 7 Drain (Table 2-3). The highest monthly flow value recorded for the minor drains was 3097 AF from the Salt Creek Drain during April of 1996.

2.4.2 Agricultural Drain Flow – Alamo River

Flow data for the years 1994 to 1999 were compiled from the Alamo River Silt/Sedimentation TMDL (http://www.waterboards.ca.gov/coloradoriver/tmdl/TMDL_Status.htm) for seventy-three agricultural drains with discharges to the Alamo River. Five of these drains were categorized as major drains, and sixty-eight were categorized as minor drains.

Table 2-3
Average monthly agricultural drain flows for New River drains.

Drain	Average Monthly Flow (acre-feet)
Major Drains	
Fig	878.3
Greeson	2011.4
Rice 3 Main	1589.5
Rice Main	386.4
Minor Drains	
All American 10	299.7
All American 14	3.4
All American 9	152.8
Baughman	120.0
Beech	471.8
Best	142.0
Birch 3	40.0
Blue Lake	252.3
Bullhead Slough	266.8
Cole	181.5
Cook	97.1
Elder	32.9
Elder 1	90.7
Elder 14	352.1
Elder 3	38.7
Fern	297.5
Fillaree	1007.8
Flax Drain	122.7
Flax Waste	5.9
Gardner Drain	184.9
Livesley	272.8
Malan	29.0
Malan No 1	148.8
Meserve	59.4
North Central	721.0
O'Brien	56.8
Pinner	311.3
Raymond	287.9
Reed 13	61.1
Reed 15	47.4
Riley 1	56.5
Salt Creek	2221.2
Seeley	491.0
Similax	13.2
Spruce	449.6
Spruce 1	181.2
Spruce 3	105.3
Spruce 4	47.5
Sumac	289.8
Sumac Lateral 1 Spill	5.9
Sumac No 2	148.8
Sunbeam	5.9
Tamarack	241.3
Timothy 1	833.1
Timothy2	162.7
Trifolium 10	766.5
Trifolium 11	372.2
Trifolium 3	611.3
Trifolium 4	588.5
Trifolium 6	937.3
Trifolium 7	1358.1
Trifolium 8	650.9
Trifolium 9	1120.5
Vail	189.3
Wixom	163.8
Wormwood	300.2

The five major drains discharging to the Alamo River are the Central, Holtville, Rose, South Central, and Verde drains. As for the New River drains, the flows reported for the major drains were primarily based upon gauged data with a few estimated values as described in the TMDL report. The average monthly flows ranged from 2192.1 to 6816.3 AF in the major drains. The Holtville Drain had the highest average monthly flow followed by the Central Drain (Table 2-4). The highest monthly flow value recorded was 8446 AF from the Holtville Drain during April of 1994. The seasonal patterns in the flows from the major drains on the Alamo River are similar to those observed on the New River with lower flows typically from November to March and higher flows from April to October and peak flows in mid-summer.

The flow data for the minor drains were all estimated values using a proportional relationship between drain return flows and irrigation water deliveries to the particular area served by the drain. The average monthly flows ranged from 5.9 to 2629.8 AF in the minor drains. The Barbara Worth Drain had the highest average monthly flow followed by the Mesquite Drain (Table 2-4). The highest monthly flow value recorded for the minor drains was 3746.8 AF from the Barbara Worth Drain during April of 1998.

2.5 New River – Agricultural Drain Water Quality

Historical water quality data for the New River agricultural drains were obtained from three sources: Imperial Irrigation District (IID), U.S. EPA's STORET database, and a University of California at Davis study. The majority of the historical water quality data were provided by the Imperial Irrigation District in an electronic database (Excel spreadsheets). Appendix C provides a summary of all of the historical data compiled by Tetra Tech for the New River agricultural drains.

The IID data included chemical data for eight agricultural drains that discharge into the New River (Fig, Greeson, North Central, Rice 3 Main, Rice Main, Spruce, Timothy 2, and Trifolium 10). The data were collected from 1996 to 2005, and the chemical parameters included ammonia-N, nitrate-N, nitrite-N, total P, ortho-P, total N, TKN, total selenium, and TSS. The IID data set included samples from the Rice 3 drain on a monthly basis for the period from January 2001 to July 2005, which was used as the source water for the Imperial Pilot Wetland.

The EPA's STORET database provides data in an electronic spreadsheet format for requested locations (http://www.epa.gov/storet/dbtop.html). This database included data for three agricultural drains that discharge into the New River (Greeson, Rice 3 Main, and Trifolium 7). The parameters of interest included ammonia-N, TKN, total P, and fecal coliforms. However, the historical data included in the STORET was old with sampling dates ranging from 1976 to 1978.

The UC Davis study (Houston et al., 2000) provided data for four major drains from a one time sampling event conducted on March 3, 1999. The parameters of interest included ammonia-N, nitrate-N, ortho-P, TKN, total N, total P, total selenium, and TSS.

Table 2-5 provides summary statistics for the combined major drain and combined minor drain samples for the primary water quality constituents of interest and for other nutrient parameters. The distribution of the combined data for the New River major and minor agricultural drains is shown on the box plots in the previous section of the report. There were not enough available data from the New River agricultural drains to assess changes over time or seasonal trends.

Table 2-4
Average monthly agricultural drain flows for Alamo River drains.

Drain	Average Monthly Flow (acre-feet)
Major Drains	
Central Main	6009.7
Holtville Main	6816.3
Rose main	5702.7
South Central Main	2253.3
Verde Main	21+2.1
Minor Drains	
All-American 6 &6A	93.3
Bailey	65.9
Barbara Worth	2629.8
Bryant	376.3
C	975.7
D	131.5
Darling	421.7
E	773.9
G	1223.1
Graeser	104.5
I	986.0
J	605.3
Jones	35.4
K	605.6
L	513.8
Lewis	171.9
M	400.2
Magnolia	294.2
Malva	372.1
Maple	542.3
Marigold	532.6
Mayflower	623.5
Mesquite	1813.5
Moorehead Drain	72.8
Moorehead Spill	5.9
Moss	402.9
Mulberry	677.7
Mullen	553.7
Munyon	435.7
Myrtle	404.5
N	395.0
Narcissus	564.2
Nectarine	578.1
Nettle	586.5
Ninth St.	77.5
Nutmeg	584.9
Oak	434.4
Oasis	200.4
Oat	207.8
Occident	235.9
Ohmar	600.3
Oleander	567.8
Olive	677.1
Orange	487.6
Orient	231.6
Orita	491.7
Osage	484.1
Oxalis	599.0
Palm	540.6
Palmetto	860.5
Peach	270.9
Pepper	309.2
Pine	420.4
Plum	314.9
Pomelo	302.5
Redwood 4	5.9
Redwood9	5.9
Rockwood	181.8
Schali	256.1
South Alamo	86.9
Standard	665.5
Toland	16.3
Township	314.1
Vail 1	63.9
Vail 2	33.9
Warren	869.7
Wills	207.0
Wores	136.9

2.5.1 Total Phosphorus

Total P was measured in all four of the major agricultural drains. The Rice 3 Drain had the highest average total P concentration (1.1 mg/L) followed by the Greeson Drain (0.54 mg/L) (Table 2-6). The maximum detected concentration of total P from the major drains was 7.5 mg/L for the Rice 3 Drain on March 1, 2001.

For the minor drains, total P was analyzed in only five out of fifty-six minor agricultural drains. The Timothy 2 Drain had the highest average total P concentration (1.4 mg/L) followed by the Trifolium 10 Drain (0.61 mg/L) (Table 2-6). The maximum detected concentration of total P from the minor drains was 3.9 mg/L from the Timothy 2 Drain on February 9, 2005. The major drains had a higher average concentration of total P compared to the minor drains (Table 2-5).

Table 2-5
Summary statistics for chemical parameters of interest from major and minor drains discharging into the New River.

Major Drains				
Parameter	**Units**	**All Data Count**	**All Data Range**	**All Data Mean**
Ammonia-N	mg/L	89	ND (0.1) - 22	2.9
Nitrate-N	mg/L	75	0.25 - 7.5	3.8
Nitrite-N	mg/L	48	ND (0.12) - 0.9	0.36
TKN	mg/L	52	0.22 - 21	4.8
Total N	mg/L	99	1.1 - 29	7.8
Total P	mg/L	144	0.04 - 7.5	0.86
Ortho-P	mg/L	52	ND (0.03) - 2	0.403
Selenium, total	ug/L	21	ND (3.1) - 33	6.1
Selenium, dissolved*	ug/L	51	3.1 - 38.1	8.3
Fecal Coliforms	MPN/100 mL	58	$70 – 6.1x10^5$	$4 – 4x10^4$
Total Coliforms	MPN/100 mL	49	$70 – 6.1x10^5$	$1.4x10^5$
TSS	mg/L	126	6.2 - 653	181
Minor Drains				
Parameter	**Units**	**All Data Count**	**All Data Range**	**All Data Mean**
Ammonia-N	mg/L	32	ND (0.1) - 11	1.6
Nitrate-N	mg/L	24	ND (0.45) - 25	8.3
Nitrite-N	mg/L	24	ND (0.1) - 0.94	0.24
TKN	mg/L	27	ND (0.8) - 12	3.5
Total N	mg/L	24	1.8 - 26	12.2
Total P	mg/L	35	0.05 - 3.9	0.61
Ortho-P	mg/L	24	ND (0.06) - 5	0.43
Selenium, total	ug/L	-	-	-
Fecal Coliforms	MPN/100 mL	6	$6.2x10^2 – 2.4x10^4$	$6.7x10^3$
Total Coliforms	MPN/100 mL	-	-	-
TSS	mg/L	24	ND (12) - 490	157

The value in parentheses is the lowest detected value.
*Imperial Wetland samples collected monthly from 1/01 to 3/05.

Table 2-6
Average concentrations of the primary water quality constituents of interest from individual agricultural drains discharging into the New River.

Drain Name	Total N (mg/L)	Total P (mg/L)	TSS (mg/L)	Total Selenium (ug/L)	Total Coliforms (MPN/100 mL)	Fecal Coliforms (MPN/100 mL)
Major Drains						
Greeson	9.8 (18)	0.54 (53)	175.1 (42)	4.8 (18)	NA	3375 (4)
Fig	7.9 (6)	0.38 (6)	141.3 (7)	3.1 (1)	NA	NA
Rice 3 Main	7.1 (69)	1.1 (79)	197 (70)	7.1 (1); 8.3 (51)*	$1.4x10^5$ (49)	$4.3x10^4$ (54)
Rice Main	9.3 (6)	0.42 (6)	110.6 (7)	33 (1)	NA	NA
Combined Major Drains	7.8 (99)	0.86 (144)	181 (126)	6.1 (21)	$1.4x10^5$ (49)	$4.1x10^4$ (58)
Minor Drains						
North Central	6.1 (6)	0.35 (6)	81.8 (6)	NA	NA	NA
Spruce	14.4 (6)	0.34 (6)	150.5 (6)	NA	NA	NA
Timothy 2	10.7 (6)	1.4 (6)	163.3 (6)	NA	NA	NA
Trifolium 7	NA	0.48 (11)	NA	NA	NA	$6.7x10^3$ (6)
Trifolium 10	17.6 (6)	0.61 (6)	227 (6)	NA	NA	NA
Combined Minor Drains	12.2 (24)	0.61 (35)	157 (24)	NA	NA	6720 (6)

The value in parentheses is the number of samples.
*Average of fifty-one dissolved selenium samples collected from the Imperial Wetland

2.5.2 Total Nitrogen

Total N data were available for all four of the major agricultural drains. The Greeson Drain had the highest average total N concentration (9.8 mg/L) followed by the Rice Drain (9.3 mg/L) (Table 2-6). The maximum detected concentration of total N from the major drains was 29 mg/L from the Rice 3 Drain on February 9, 2005.

Four out of fifty-six minor agricultural drains had total N data. The Trifolium 10 Drain had the highest average total N concentration (17.6 mg/L) followed by the Spruce Drain (14.4 mg/L) (Table 2-6). The maximum detected concentration of total N from the minor drains was 26 mg/L from the Spruce Drain on February 24, 2004 and the Trifolium 10 Drain on November 17, 2004. The minor drains had a higher average concentration of total N than the major drains.

2.5.3 Total Suspended Solids

TSS data was measured in all four of the major agricultural. The Rice 3 Drain had the highest average TSS concentration (197 mg/L) followed by the Greeson Drain (175.1 mg/L) (Table 2-6). The maximum detected concentration of TSS from the major drains was 653 mg/L from the Rice 3 Drain on March 1, 2003.

For the minor drains, TSS was measured in only four out of fifty-six minor agricultural drains. The Trifolium 10 Drain had the highest average TSS concentration (227 mg/L) followed by the Timothy 2 Drain (163.3 mg/L) (Table 2-6). The maximum detected concentration of TSS from the minor drains was 490 mg/L from the Timothy 2 Drain and Trifolium 10 Drain on February 9, 2005. The major drains had a slightly higher average concentration of TSS compared to the minor drains.

2.5.4 Total Selenium

Total selenium data were measured in all of the major drains. However, in three of the major drains only one sample was collected. The Greeson Drain had 18 samples analyzed for total selenium, averaging 4.8 μg/L (Table 2-6). The maximum detected concentration of total selenium from the major drains was 33 μg/L for the Rice Drain on March 31, 1999. The average total selenium concentration from all the combined major drain samples was 6.1

μg/L (Table 2-5). Dissolved selenium was measured in the wetland inlet samples from the Rice 3 drain, ranging from 3.1 to 38.1 μg/L; the average of 52 samples was 8.3 μg/L.

2.5.5 Total Coliforms

Total coliforms were analyzed from only one major drain - the Rice 3 Drain - where forty-nine samples were analyzed. The average total coliform concentration from this site was $1.4x10^5$ MPN/100 mL (Table 2-6). The maximum detected concentration was $6.1x10^5$ on July 1, 2003.

2.5.6 Fecal Coliforms

Fecal coliforms were analyzed from two major drains - the Rice 3 and Greeson - and only one minor drain, Trifolium 7. The average fecal coliform concentrations from these drains were $4.4x10^5$ MPN/100 mL and $3.4x10^3$ MPN/100 mL, respectively (Table 2-6). The Rice 3 Drain receives two NPDES stormwater discharges, so the Rice 3 Drain may not be representative of other drains that do not receive NPDES discharges. The maximum detected concentration of fecal coliforms from the major drains was $6.1x10^5$ MPN/100 mL from the Rice 3 Drain on July 1, 2003. The average fecal coliform concentration from the Trifolium 7 Drain was $6.7x10^3$ MPN/100 mL (Table 2-6).

2.6 Alamo River – Agricultural Drain Water Quality

Historical water quality data for the Alamo River agricultural drains were obtained from three sources: Imperial Irrigation District (IID), the Alamo River Silt/Sedimentation TMDL, and a University of California at Davis study. The majority of the historical water quality data for the Alamo River agricultural drains were provided by the Imperial Irrigation District in an electronic database (Excel spreadsheets). Appendix D provides a summary of all of the historical data compiled by Tetra Tech for the Alamo River agricultural drains.

The IID data included chemical data for fourteen agricultural drains that discharge into the Alamo River. The IID data set included samples collected from 1996 to 2005. The parameters of interest included in the IID data were ammonia-N, nitrate-N, nitrite-N, total P, ortho-P, total N, TKN, total selenium, and TSS.

The Alamo River Silt/Sedimentation TMDL provided TSS data for thirty-two agricultural drains (http://www.waterboards.ca.gov/coloradoriver/tmdl/TMDL_Status.htm). The data included in the TMDL were collected from 1980 to 2000.

The UC Davis study (Houston et al., 2000) provided data for five major drains from a one time sampling event conducted on March 3, 1999. The parameters of interest analyzed as part of this study included nitrate-N, ortho-P, total selenium, and TSS.

Table 2-7 provides summary statistics for the combined major drain and combined minor drain samples for the primary water quality constituents of interest and for other nutrient parameters. The distribution of the combined data for the Alamo River major and minor agricultural drains were shown on the box plots in a previous section of the report. There were not enough available data to assess changes over time or seasonal trends.

2.6.1 Total Phosphorus

Total P was measured in all five of the major agricultural drains. The Rose Drain had the highest average total P concentration (1.1 mg/L) followed by the Central Drain (0.87 mg/L) (Table 2-8). The maximum detected total P concentration from the major drains was 3.8 mg/L for the Rose Drain on March 21, 2005.

For the minor drains, total P was analyzed in only nine out of sixty-eight minor drains. The N Drain had the highest average total P concentration (2.3 mg/L) followed by the I Drain (1.7 mg/L) (Table 2-8). The maximum detected total P concentration from the minor drains was 8.1 mg/L for the N Drain on March 21, 2005. The minor drains had a higher average concentration of total P compared to the major drains (Table 2-7).

2.6.2 Total Nitrogen

Total N data were available for all five of the major agricultural drains. The South Central Drain had the highest average total N concentration (11.8 mg/L) followed by the Holtville Drain (9.9 mg/L) (Table 2-8). The maximum total N concentration from the major drains was 23 mg/L for the South Central Drain on January 12, 2005.

Nitrogen compounds were measured in nine out of sixty-eight minor agricultural drains discharging into the Alamo River. The N Drain had the highest average total N concentration (12.5 mg/L) followed by the C Drain (11.7 mg/L) (Table 2-8). The maximum total N concentration from the minor drains was 30 mg/L for the N Drain on December 15, 2004. The minor drains had a slightly higher average concentration of total N compared to the major drains (Table 2-7).

Table 2-7
Summary statistics for chemical parameters of interest from major and minor drains discharging into the Alamo River.

Major Drains Parameter	Units	All Data Count	All Data Range	All Data Mean
Ammonia-N	mg/L	138	ND (0.11) - 14	1.6
Nitrate-N	mg/L	143	1.7 - 16	7.0
Nitrite-N	mg/L	90	ND (0.1) - 1.8	0.38
TKN	mg/L	90	0.18 - 8.3	2.9
Total N	mg/L	90	3.7 - 23	9.4
Total P	mg/L	138	0.09 - 3.8	0.73
Ortho-P	mg/L	95	0.046 - 2.9	0.402
Selenium, total	ug/L	41	ND (2.4) - 11.9	6.4
TSS	mg/L	208	44 - 1216	264
Minor Drains				
Parameter	**Units**	**All Data Count**	**All Data Range**	**All Data Mean**
Ammonia-N	mg/L	48	ND (0.1) - 12	2.2
Nitrate-N	mg/L	48	0.56 - 29	5
Nitrite-N	mg/L	48	ND (0.13) - 1.1	0.27
TKN	mg/L	48	0.43 - 16	4.3
Total N	mg/L	48	2 - 30	9.6
Total P	mg/L	48	0.09 - 8.1	0.93
Ortho-P	mg/L	48	ND (0.053) - 4.8	0.45
Selenium, total	ug/L	-	-	-
TSS	mg/L	86	ND (7) - 1460	341

The value in parentheses is the lowest detected value.

2.6.3 Total Suspended Solids

TSS data was measured in all five of the major agricultural drains. The Central Drain had the highest average TSS concentration (315 mg/L) followed by the South Central Drain (305 mg/L) (Table 2-8). The maximum detected concentration of TSS from the major drains was 1,216 mg/L from the Central Drain on March 1, 1987.

For the minor drains, TSS was measured in thirty out of sixty-eight minor agricultural drains. The Mullen Drain had the highest average TSS concentration (1,460 mg/L) followed by the Mesquite Drain (1,207 mg/L) (Table 2-8). However, the Mullen Drain and the Mesquite Drain only had one sample each. This was also the case for fifteen of the thirty minor drains with measured TSS data. The maximum detected concentration of TSS from the minor drains

was 1,460 mg/L from the Mullen Drain on March 3, 2000. The minor drains had a higher average concentration of TSS compared to the major drains (Table 2-7).

2.6.4 Total Selenium

Total selenium data were measured in all five of the major drains. However, in three of the major drains only one sample was collected. The South Central Drain and the Holtville Drain had 19 samples analyzed for total selenium. The average total selenium concentrations from these two drains were 7.7 µg/L and 5.0 µg/L, respectively (Table 2-8). The maximum detected concentration of total selenium from the major drains was 11.9 µg/L for the South Central Drain on December 29, 1997. The average total selenium concentration from all the combined major drain samples was 6.4 µg/L (Table 2-7).

2.7 NPDES Flow and Water Quality Data

2.7.1 NPDES Flow – New River

Flow data were compiled for eight facilities with NPDES discharges that reach the New River. Flow data were unavailable for the Second Imperial Geothermal Company. The New River TMDL counted the Calexico WWTP plants as one facility, because they are under the same permit. However, the data for each of the Calexico WWTP plants will be presented separately in this section. Of these nine facilities, five discharge directly to the New River, and four of them discharge to agricultural drains that flow into the New River (Table 2-9).

The flow data presented were obtained from the New River Silt/Sedimentation TMDL (http://www.waterboards.ca.gov/coloradoriver/tmdl/TMDL_Status.htm). The TMDL contained flow data from 1995 through 2000 for the various NPDES facilities. Additional flow data were also obtained for some facilities for the last eighteen months from the U.S. EPA's Envirofacts database (http://www.epa.gov/enviro/html/ef_overview.html). The Envirofacts database contained limited flow data that were only measured once per month for each facility. Based on the limited nature of this data, it was not included in the summary statistics. However, it was stored in the historical database compiled by Tetra Tech.

Gauged flows for the NPDES facilities were obtained from the Regional Water Quality Control Board permit files for the TMDL. The average monthly flows ranged from 0.14 to 328.1 AF. The City of Brawley WWTP had the highest average monthly flow followed by the City of Calexico WWTP 1 (Table 2-9). The highest monthly flow value recorded for the NPDES facilities was 372 AF from the City of Brawley during October of 1998.

Table 2-8
Average concentrations of the primary chemicals of interest from individual agricultural drains discharging into the Alamo River.

Drain Name	Average Concentration			
	Total N* (mg/L)	Total P* (mg/L)	TSS* (mg/L)	Total Selenium* (ug/L)
Major Drains				
Central Main	9.6 (18)	0.87 (18)	315 (59)	6.6 (1)
Holtville Main	9.9 (18)	0.57 (42)	212 (59)	5.0 (19)
Rose Main	7.0 (18)	1.1 (18)	297 (21)	6 (1)
South Central Main	11.8 (18)	0.78 (42)	305 (48)	7.7 (19)
Verde Main	9.0 (18)	0.49 (18)	137 (21)	10.4 (1)
Combined Major Drains	9.4 (90)	0.73 (138)	264 (208)	6.4 (41)
Minor Drains				
C	11.7 (6)	0.67 (6)	275 (7)	NA
E	NA	NA	505 (1)	NA
I	8.2 (6)	1.7 (6)	186 (7)	NA
Jones	NA	NA	9 (1)	NA
Magnolia	7.2 (6)	0.52 (6)	436 (7)	NA
Malva	NA	NA	279 (2)	NA
Mesquite	NA	NA	1207 (1)	NA
Moss	NA	NA	135 (1)	NA
Mullen	NA	NA	1460 (1)	NA
Munyon	8.0 (6)	0.86 (6)	336 (7)	NA
Myrtle	NA	NA	692 (1)	NA
N	12.5 (6)	2.3 (6)	285 (7)	NA
Nectarine	NA	NA	125 (3)	NA
Nettle	11 (1)	0.72 (1)	390 (1)	NA
Oasis	NA	NA	823 (1)	NA
Ohmar	NA	NA	114 (1)	NA
Oleander	9.9 (6)	0.46 (6)	328 (6)	NA
Olive	NA	NA	547 (2)	NA
Orange	NA	NA	204 (1)	NA
Orient	NA	NA	416 (1)	NA
Orita	NA	NA	558 (3)	NA
Palm	NA	NA	138 (1)	NA
Palmetto	NA	NA	222 (1)	NA
Peach	8.0 (6)	0.35 (6)	181 (6)	NA
Pepper	NA	NA	163 (2)	NA
Plum	NA	NA	1062 (2)	NA
Standard	11.1 (5)	0.57 (5)	398 (8)	NA
Vail 2	NA	NA	169 (1)	NA
Warren	NA	NA	57 (2)	NA
Wores	NA	NA	128 (1)	NA
Combined Minor Drains	9.6 (48)	0.93 (48)	341 (86)	-

*The value in parenthese is the number of samples.

Table 2-9
Average monthly flows for NPDES facilities with discharges reaching the New River.

Facility	Count	Average Monthly Flow (acre-feet)*
Facilities Discharging to the New River		
City of Brawley WWTP	72	328.1
City of Calexico WWTP 1	61	166.3
City of Calexico WWTP 2	44	81.2
Second Imperial Geothermal Company	NA	NA
Seeley WWTP	70	9.1
U.S. Naval Facility - El Centro	66	10.9
Facilities Discharging to Agricultural Drains		
Centinela State Prison	71	47.0
Date Garden MHP	70	0.89
McCabe Union School District	57	0.14
Westmorland WWTP	70	19.4

*Flow data were available from the New River Silt/Sedimentation TMDL from 1/95 to 12/00.

2.8 NPDES Flow – Alamo River

Flow data were compiled for thirteen facilities with NPDES discharges that reach the Alamo River. Flow data were unavailable for the Gateways of the Americas WWTP. Of these fourteen facilities, only one discharges directly to the Alamo River; the other facilities discharge to agricultural drains that flow into the Alamo River (Table 2-10).

The flow data for the period from 1994 through 1999 were obtained from the Alamo River Silt/Sedimentation TMDL (http://www.waterboards.ca.gov/coloradoriver/tmdl/TMDL_Status.htm). Additional flow data were also obtained for some facilities from the U.S. EPA's Envirofacts database for the last eighteen months (http://www.epa.gov/enviro/html/ef_overview.html). The Envirofacts database contained limited flow data that were only measured once per month for each facility. Based on the limited nature of this data, it was not included in the summary statistics. However, it was stored in the historical database compiled by Tetra Tech.

Gauged flows for the NPDES facilities were obtained from the Regional Water Quality Control Board permit files for the TMDL. The average monthly flows ranged from 3.0 to 417.9 AF. The City of El Centro WPCP had the highest average monthly flow followed by the City of Calipatria WWTP (Table 2-10). The highest monthly flow value recorded for the NPDES facilities was 613.2 AF from the City of El Centro WPCP during August of 1995.

Table 2-10
Average monthly flows for NPDES facilities with discharges reaching the Alamo River.

Facility	Count	Average Monthly Flow (acre-feet)*
Facilities Discharging to the Alamo River		
Gateways of the Americas WWTP	NA	NA
Facilities Discharging to Agricultural Drains		
City of Calipatria WWTP	64	84.5
City of El Centro WPCP	55	417.9
City of Holtville WWTP	66	50.7
City of Imperial MWTP	46	55.7
Country Life Mobile Home Park	25	4.0
El Centro Steam Plant	68	19.8
Heber Geothermal	66	4.4
Heber WTP	43	36.5
IID Grass Carp Hatchery	55	9.6
Imperial Community College District	63	3.0
New Charleston Power Plant 1	12	7.7
Star Group 1A	53	45.2
Sunset Mutual Water Co.	63	3.4

*Flow data were available from the Alamo River Silt/Sedimentation TMDL from 1/94 to 12/99.

2.9 New River – NPDES Facility Water Quality

Historical water quality data for the New River NPDES facilities were obtained from two sources: the New River Silt/Sedimentation TMDL and the U.S. EPA's Envirofacts database. The majority of the data were obtained by the New River TMDL. Appendix E provides a summary of all of the historical data compiled by Tetra Tech for the New River NPDES facilities.

The New River Silt/Sedimentation TMDL provided primarily TSS data for eight NPDES facilities (http://www.waterboards.ca.gov/coloradoriver/tmdl/TMDL_Status.htm). The data included in the TMDL were collected from 1995 to 2000.

The U.S. EPA's Envirofacts database provides chemical data for NPDES facilities for the last eighteen months (http://www.epa.gov/enviro/html/ef_overview.html). The Envirofacts database included data for two NPDES facilities that have discharges reaching the New River. The parameters of interest included for these NPDES facilities were ammonia-N, total N, nitrate-N, nitrite-N, organic phosphorus, ortho-P, TSS, and fecal coliforms.

The primary water quality constituents of interest with data from the New River NPDES facilities were total N, TSS, and fecal coliforms. However, most of the available data for these facilities were for TSS. The concentrations of each of these constituents will be discussed in detail below.

2.9.1 Total Nitrogen

Total N data were only available for one of the - the City of Calexico WWTP. The average concentration of total N in six samples was 23.0 mg/L (Table 2-11), and the maximum was 26.9 mg/L on March 31, 2005.

2.9.2 Total Suspended Solids

TSS data were measured in nine out of the ten facilities. The City of Calexico WWTP 2 had the highest average TSS concentration (63 mg/L) followed by the Seeley WWTP (47.9 mg/L) (Table 2-11). The maximum detected TSS from the NPDES facilities was 93.5 mg/L from the Centinela State Prison in June of 2000.

2.9.3 Fecal Coliforms

Fecal coliform data were only available for one of the facilities - the City of Brawley. The average concentration of fecal coliforms in these samples was 29 MPN/100 mL (Table 2-11). The maximum detected concentration of fecal coliforms from this facility was 102 MPN/100 mL on January 31, 2004.

Table 2-11
Average concentrations of the primary chemicals of interest from individual NPDES facilities with discharges that reach the New River.

Facility	Average Total N (mg/L)	Average TSS (mg/L)	Average Fecal Coliforms (mg/L)
Facilities Discharging to the New River			
City of Brawley WWTP	NA	32.8 (89)	29.2 (17)
City of Calexico WWTP 1	23.0 (6)	23.2 (62)	NA
City of Calexico WWTP 2	NA	63 (46)	NA
Second Imperial Geothermal Company	NA	NA	NA
Seeley WWTP	NA	47.9 (71)	NA
U.S. Naval Facility - El Centro	NA	19.2 (59)	NA
Facilities Discharging to Agricultural Drains			
Centinela State Prison	NA	45.9 (71)	NA
Date Garden MHP	NA	8.3 (70)	NA
McCabe Union School District	NA	9.3 (50)	NA
Westmorland WWTP	NA	32.3 (70)	NA

The value in parentheses is the number of samples.

2.10 Alamo River – NPDES Facility Water Quality

Historical water quality data for the Alamo River NPDES facilities were obtained from two sources: the Alamo River Silt/Sedimentation TMDL and the U.S. EPA's Envirofacts database. The majority of the historical water quality data were from the Alamo River TMDL. The information provided was primarily TSS data. Appendix F provides a summary of all the historical data compiled by Tetra Tech for the Alamo River NPDES facilities.

The Alamo River Silt/Sedimentation TMDL provided TSS data for thirteen NPDES facilities (http://www.waterboards.ca.gov/coloradoriver/tmdl/TMDL_Status.htm). The data included in the TMDL were collected from 1994 through 1999.

The U.S. EPA's Envirofacts database (http://www.epa.gov/enviro/html/ef_overview.html) included data for four facilities that have NPDES discharges reaching the Alamo River. The parameters of interest included in the Envirofacts database for these facilities were ammonia-N, total N, nitrate-N, nitrite-N, total P, ortho-P, total phosphate, total selenium, and TSS. The Envirofacts database contains data collected during the last eighteen months from the various facilities.

The primary water quality constituents of interest with data from the Alamo River NPDES facilities were total N, total P, total selenium, and TSS. However, most of the available data for these facilities was TSS data. The concentrations of each of these primary chemical parameters in the Alamo River NPDES facilities will be discussed in detail below.

2.10.1 Total Phosphorus

Total P data were only available for two facilities. The City of El Centro WPCP had ten samples, and the Country Life Mobile Home Park had seven samples. The average concentrations of total P from these facilities were 1.6 mg/L and 1.3 mg/L, respectively (Table 2-12). The maximum detected concentration of total P was 4.5 mg/L from the El Centro Steam Plant on October 31, 2004.

2.10.2 Total Nitrogen

Total N data were available for only two facilities. The City of El Centro WPCP had ten samples, and the Country Life Mobile Home Park had seven samples. The average concentrations of total N from these facilities were 22.2 mg/L and 3.6 mg/L, respectively (Table 2-12). The maximum detected concentration of total N was 32 mg/L from the City of El Centro WPCP on February 28, 2005.

2.10.3 Total Suspended Solids

TSS data were measured in thirteen out of fourteen. The Heber Geothermal Plant had the highest average TSS concentration (224.2 mg/L) followed by the IID Grass Carp Hatchery (80.8 mg/L) (Table 2-12). The maximum detected concentration of TSS was 923 mg/L from the IID Grass Carp Hatchery in September of 1999.

2.10.4 Selenium

Total selenium data were only available for two facilities. The City of El Centro WPCP had ten samples, and the El Centro Steam Plant had seven samples, but these were below detection limits. The average concentration of total selenium from the City of El Centro WPCP was 5.6 µg/L (Table 2-12), and the maximum detected concentration was 9.8 µg/L on July 31, 2005.

2.11 Other Flow and Water Quality Data

For the watershed modeling presented in Chapters 6-9, additional flow and water quality data were obtained from the following sources:

- Volume of urban and agricultural runoff from precipitation – Values are given for the entire New River and Alamo River watersheds in the New River and Alamo River TMDL Reports (CRB RWQCB 2002a and 2002b);
- Volume of groundwater discharge into the New and Alamo Rivers – Values are given for the entire New River and Alamo River watersheds in the IID Water Conservation and Transfer Project EIS/EIR (IID, 2002);
- Water Quality of urban runoff from Precipitation – Values are given for typical urban watersheds in terms of a range of common in EPAs' TMDL Protocol Documents, (USEPA, 1999);
- Water Quality of agricultural runoff from precipitation – Values are given for typical agricultural watersheds in terms of a range of common in EPAs' TMDL Protocol Documents, (USEPA, 1999);
- Water quality of groundwater discharge into the New and Alamo Rivers – Values are taken from the USGS Imperial Valley database of groundwater well concentrations, available on at http://nwis.waterdata.usgs.gov/ca/nwis/qwdata

Details regarding the numerical ranges and use of these data are given in Chapters 6-9 of this report.

Table 2-12
Average concentrations of the primary chemicals of interest from individual NPDES facilities with discharges that reach the Alamo River.

Facility	Average Total N (mg/L)	Average Total P (mg/L)	Average TSS (mg/L)	Average Total Selenium (ug/L)
Facilities Discharging to the Alamo River				
Gateways of the Americas WWTP	NA	NA	NA	NA
Facilities Discharging to Agricultural Drains				
City of Calipatria WWTP	NA	NA	29.9 (70)	NA
City of El Centro WPCP	22.2 (10)	1.6 (10)	12.7 (65)	5.6 (10)
City of Holtville WWTP	NA	NA	17.8 (65)	NA
City of Imperial MWTP	NA	NA	4.7 (46)	NA
Country Life Mobile Home Park	3.6 (7)	1.27 (7)	5.3 (25)	NA
El Centro Steam Plant	NA	NA	9.2 (75)	ND (7)*
Heber Geothermal	NA	NA	224.2 (79)	NA
Heber WTP	NA	NA	8.9 (61)	NA
IID Grass Carp Hatchery	NA	NA	80.8 (55)	NA
Imperial Community College District	NA	NA	6 (63)	NA
New Charleston Power Plant 1	NA	NA	28.7 (10)	NA
Star Group 1A	NA	NA	27.3 (52)	NA
Sunset Mutual Water Co.	NA	NA	7.4 (64)	NA

The value in parentheses is the number of samples.
*ND - Not Detected (method detection limit not provided for these samples).

2.12 Summary

Historical water quality data were collected from a variety of sources for this report including from State and Federal government agencies, international agencies, and universities. One of the major benefits from collecting and organizing the available historical water quality data from these various sources was the generation of an electronic repository for all of the water quality data collected (all data gathered as part of this effort are provided electronically in Appendices A through F). This repository should help to simplify future endeavors focusing on the water quality characteristics of the New and Alamo Rivers.

For the New River, there were fourteen river sampling locations with historical water quality data. However, the majority of the historical water quality data were collected at the international boundary and near the outlet to the Salton Sea. The dates of the historical data collected ranged from October 1949 to June 2005. The chemicals that were measured the most from these river sites were fecal coliforms followed by ammonia as N and then total P. There were four major agricultural drains and six minor agricultural drains with discharges reaching the New River with available historical water quality data. There were six NPDES facilities with direct discharges to the New River and four with discharges into agricultural drains that reach the New River with available historical water quality data.

For the Alamo River, there were nineteen river sampling locations with historical water quality data. However, the majority of the historical water quality data were collected near the international boundary and at Drop 3 near Calipatria. The dates of the historical data collected ranged from February 1951 to July 2005. The chemicals that were measured the most from these river sites were TSS followed by sulfate and then ammonia as N. There were five major agricultural drains and thirty minor agricultural drains with discharges reaching the Alamo River with available historical water quality data. There was one NPDES facility with direct discharges to the Alamo River, but no water quality data were available for it. Thirteen NPDES facilities with discharges into agricultural drains that reach the Alamo River had available historical water quality data.

CHAPTER 3
SYNOPTIC SURVEY DATA FOR 2005

The objective of the synoptic survey described here was to obtain a snapshot of water quality in the New and Alamo River watersheds using a consistent set of sampling and analytical techniques. The data thus collected is designed to supplement the historical dataset summarized in the previous chapter, and to form the basis for water quality modeling presented in Chapters 6 through 9. Water quality data on suspended solids, nutrients, coliforms, and selenium, were analyzed at river, drain, and pilot wetland stations in the Imperial Valley. In addition, field data were obtained on pH, dissolved oxygen, electrical conductivity, and oxidation-reduction potential. The details of the specific sampling and analytical methods can be located in the QAPP for this project entitled, *Quality Assurance Project Plan for New and Alamo River Wetland Master Plan: Phase I Studies* (Tetra Tech, October 27, 2005, provided electronically on the attached CD-ROM). A brief discussion of the samples collected, analysis parameters, methods used, and a summary of the results for each of the sample matrices is presented in the following sections.

3.1 Water Quality

Twenty-three water quality parameters were measured from samples collected at 47 river gauging stations, sump stations, agricultural drains, and riverbank stations along the New and Alamo Rivers (Figure 3-1), and from 15 stations within the Brawley and Imperial pilot wetlands (Figure 3-2). The water quality parameters measured, the analytical methods used, number of stations sampled and the total number of grab samples collected are presented in Table 3-1. Field parameters were measured using a YSI Multiparameter Probe (model 6920). A field GPS unit was used to record elevation and barometric pressure, as well as location. The date and time that sampling started was also recorded for each location.

Grab samples were collected by Tetra Tech staff by filling pre-cleaned and labeled sample bottles that were then stored in the dark in coolers containing a combination of wet ice and Blue-Ice. Selenium samples were transported under Chain-of-Custody via overnight courier to Brooks-Rand (Seattle, WA). All other samples were stored in sample coolers containing wet ice and maintained under Chain-of-Custody by Tetra Tech staff until the following morning when a courier from E.S. Babcock & Sons (Riverside, CA) picked them up. Once at their respective labs, the samples were logged in and processed for analysis. More detailed descriptions of the sampling and sample handling procedures can be found in the Field Sampling Plan for this project entitled, *Field Sampling Plan for New and Alamo River Wetland Master Plan: Phase I Studies* (Tetra Tech, October 27, 2005). Field replicates were collected at two river sites and one drain site.

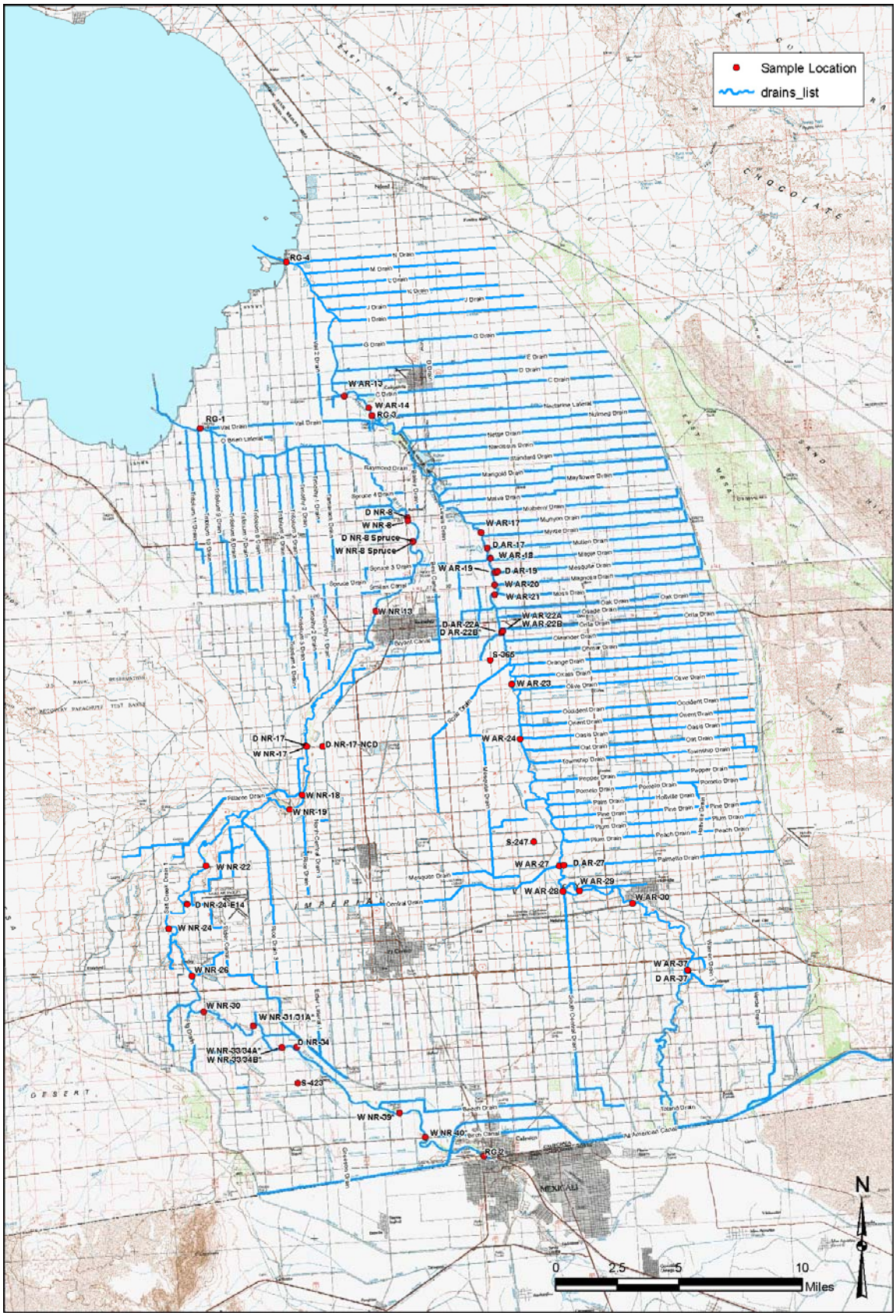


Figure 3-1 Field sampling locations

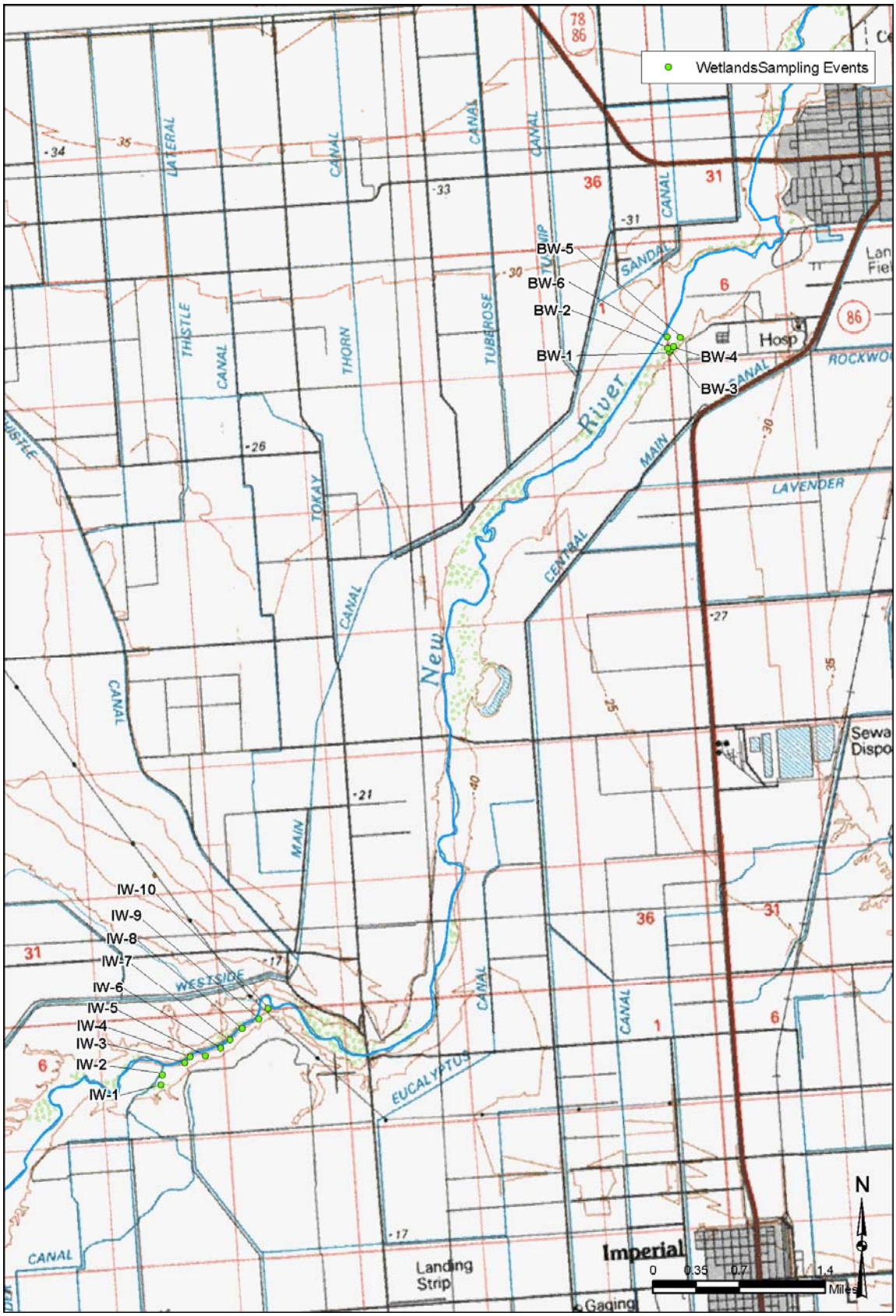


Figure 3-2 Brawley and Imperial Pilot Wetland Stations

Not all parameters were measured at every station. Samples to be analyzed for total coliform concentrations were collected from only those stations sampled after 10:00 AM because of hold-time constraints, thus reducing the number of stations sampled for total coliform to 40. Samples to be analyzed for inorganic selenium and selenite (Se(IV)) were collected from four stations (one riverbank and one drain from each river), with the organic selenium and selenate (Se(VI)) values being calculated using equations 1 and 2:

Equation 1: Organic selenium = Total Se – inorganic Se

Equation 2: Selenate (Se(VI)) = Inorganic Se – Se(IV).

The organic selenium and Se(VI) concentrations associated with samples from the New River riverbank site were not calculated because laboratory quality control percent recoveries for inorganic selenium and Se(IV) were outside of acceptable criteria (see Data Quality Assessment at end of Section 2.4.1). Dissolved selenium was analyzed in samples collected from the 15 Brawley and Imperial pilot wetland stations.

Table 3-1
Summary of Water Quality Parameters Measured

Parameter	Method	Number of Stations	Total # Samples
Laboratory:			
Total Coliform	EPA 1604	40	43
Sulfate	EPA 300	47	50
Nitrate-N	EPA 300	47	50
Nitrite-N	SM4500NO2 B	47	50
Ammonia-N	SM4500NH3 H	47	50
Total Kjeldahl Nitrogen	EPA 351.2	47	50
Ortho-Phosphate	SM4500P E	47	50
Total Phosphorus	SM4500B E	47	50
Total Suspended Solids	SM2540D	47	50
Total Selenium	EPA 1638 (modified)	62	65
Dissolved Selenium	EPA 1638 (modified)	15	15
Inorganic Selenium	BR-0023	4	8
Selenite (Se(IV))	BR-0023	4	8
Organic Selenium	BR-0023	4	8
Selenate (Se(VI))	BR-0023	4	8
Field:			
Temperature	Meter	62	62
Specific Conductivity	Meter	62	62
Electrical Conductivity	Meter	62	62
Dissolved Oxygen	Meter	62	62
Dissolved Oxygen (saturation)	Meter	62	62
pH	Meter	62	62
Oxidation Reduction Potential	Meter	62	62
Turbidity	Meter	62	62

3.2 Results Summary

Four river gauging stations, two along the New River (RG-1 and RG-2) and two along the Alamo River (RG-3 and RG-4); three Sump stations, one near the New River (S-423) and two near the Alamo River (S-247 and S-365); six agricultural drain stations along the New River, 14 wetland stations on the New River; five agricultural drain stations along the Alamo River; and 14 wetland stations on the Alamo River were sampled between November 8 and 10, 2005 for the following surface water parameters: total coliform, sulfate, nitrate, nitrite, ammonia, total Kjeldahl nitrogen, ortho-phosphate, total phosphorus, total suspended solids, total selenium, and field parameters. The wetland stations were located on the river at potential locations where new treatment wetlands may be constructed, as described in the

Nolte 2002 report. Figures 3-3 through 3-7 provide the relative magnitudes of total coliform, total nitrogen, total phosphorus, total suspended solids, and total selenium at each of the monitoring locations. Additionally, inorganic selenium, selenate, selenite, and organic selenium were quantified at one agricultural drain and wetland site for each river (Tables 3-2 through 3-7). Total and dissolved selenium were quantified in samples collected from the Brawley and Imperial Pilot Wetlands (Tables 3-8 and 3-9). These results are discussed in greater detail in the following sections. Laboratory data reports from this sampling effort are included electronically in the CD-ROM as Appendix G.

The average flow of the New River ranged from 132 to 136 cfs at the international border (RG-2) over the 3-day sampling period and increased to 509 to 538 cfs near the outlet (RG-1). The average flow of the New River during sampling was less than the average flow for the modeling period (654.3 cfs from 1994-1999). The average flow of the Alamo River near the outlet (RG-4) varied from 845 to 873 cfs over the same period. The average flow of the Alamo River was similar to that of the modeling period (862.5 cfs from 1994-1999).

Table 3-2
Summary of River Gauging Station Data

	Station ID			
Parameter	**RG-1 New River at Westmorland**	**RG-2 New River at International Boundary**	**RG-3 Alamo River at Drop 3 near Calipatria**	**RG-4 Alamo River near Niland**
Total Coliform (MPN/100 ml)	$3.9x10^5$	$>2.4x10^5$	$2.0x10^5$	$1.2x10^5$
Sulfate (mg/l)	800	670	1,200	840
Nitrate-N (mg/l)	3.9	<0.20	7.9	7.4
Nitrite-N (mg/l)	0.47	<0.10	0.34	0.34
Ammonia-N (mg/l)	3.5	9.3	0.24	0.45
Total Kjeldahl Nitrogen (mg/l)	5.6	13	1.4	1.4
Ortho-Phosphate (mg/l)	0.98	1.8	0.35	034
Total Phosphorus (mg/l)	1.5	2.9	0.70	0.72
Total Suspended Solids	160	34	220	240
Total Selenium (ug/l)	2.46	0.99	5.65	5.66
Temperature (ºC)	20.40	23.05	20.82	20.22
Dissolved Oxygen (mg/l)	5.94	2.78	8.93	8.02
Dissolved Oxygen (% saturation)	66.8	33.0	102.8	89.6
pH	7.61	7.73	7.85	7.93
Electrical Conductivity (uS/cm)	3951	4293	2981	2872
Specific Conductivity (uS/cm^2)	4328	4458	3236	3160
Turbidity (NTU)	87.1	106.4	74.5	154.7
Oxidation Reduction Potential (mV)	71.4	37.1	64.9	71.0

Figure 3-3 Field Sample Locations and Coliform Results (MPN/100 ml)
*Value may be greater

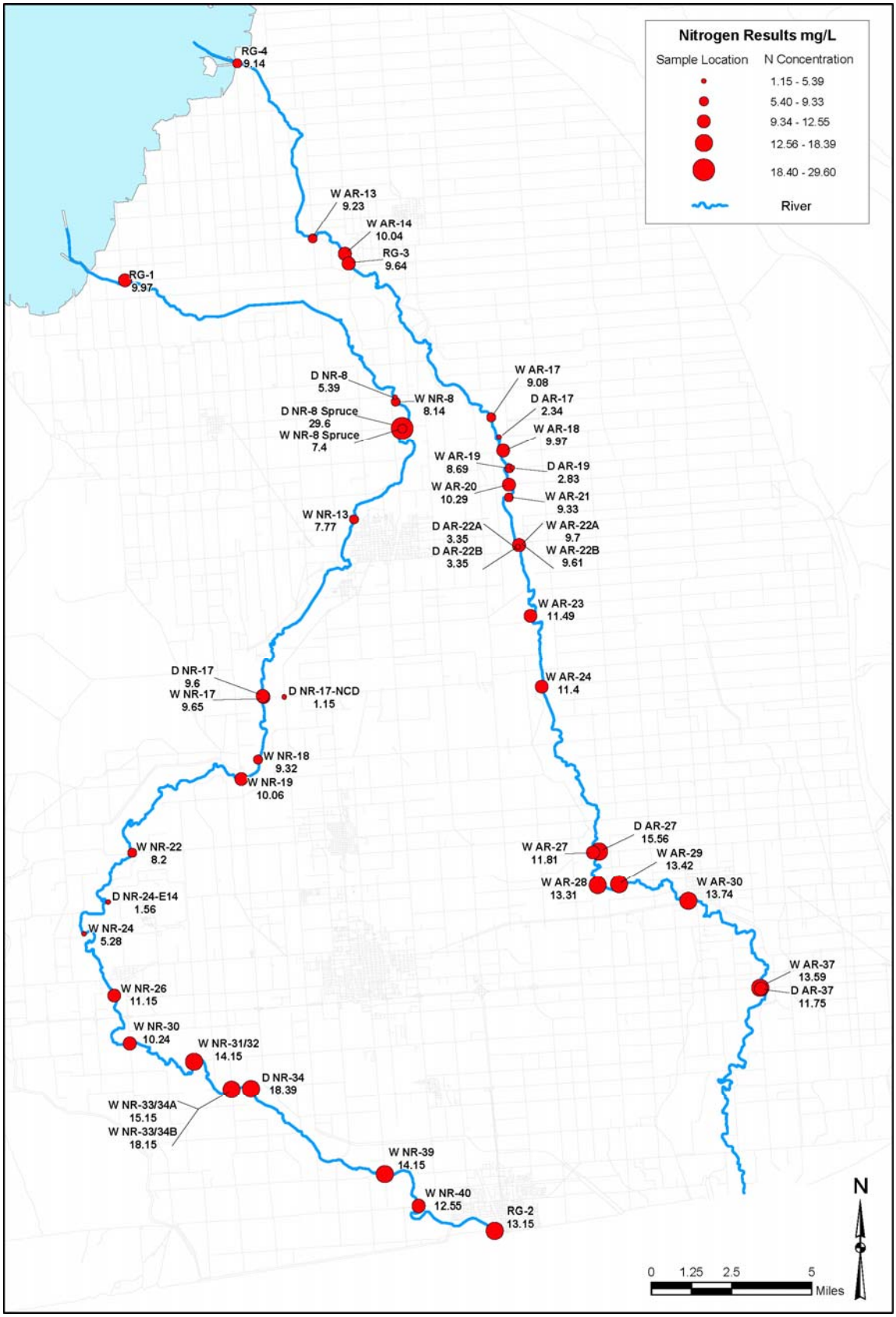


Figure 3-4 Field Sample Locations and Nitrogen Results (mg/L)

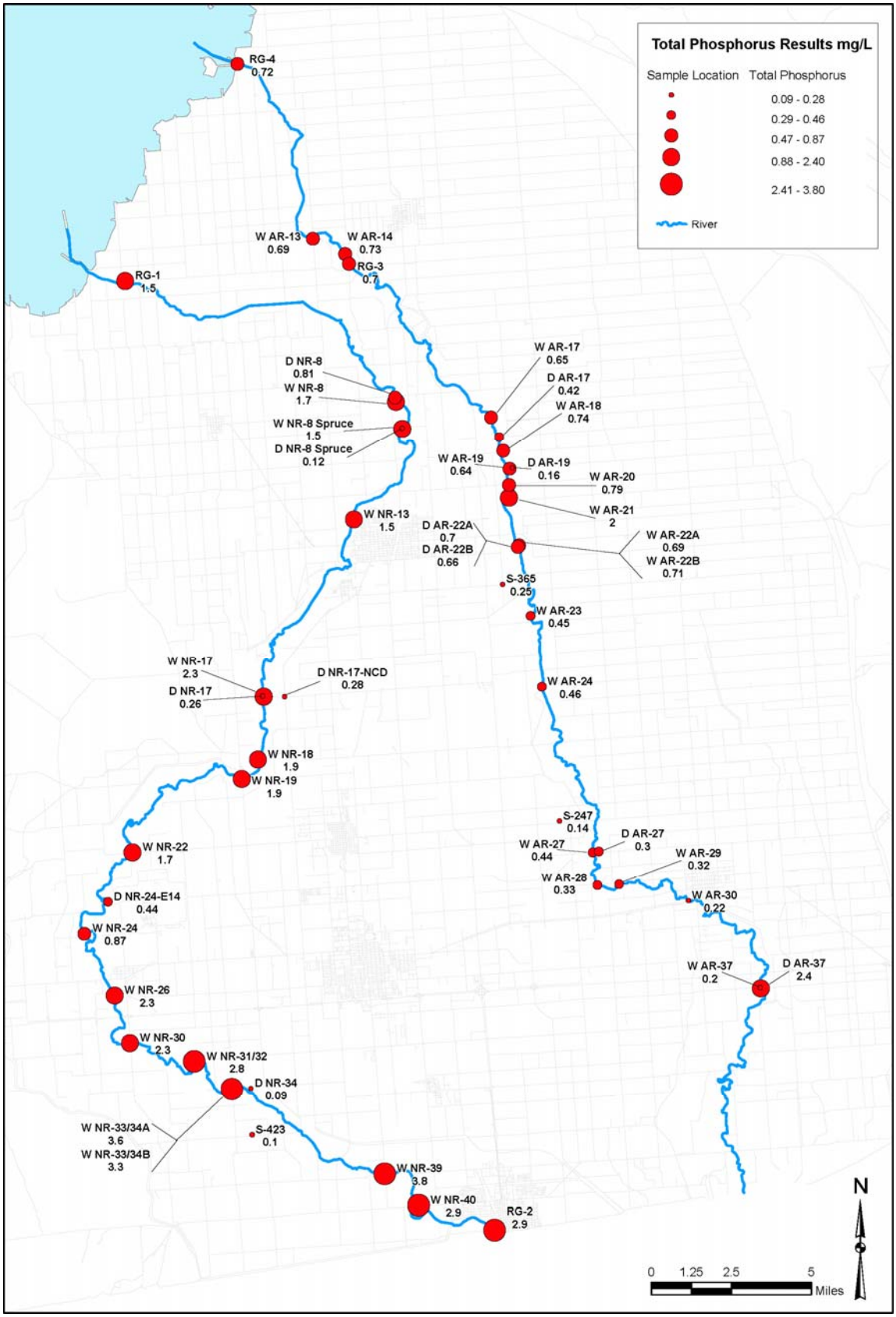


Figure 3-5 Field Sample Locations and Total Phosphorus Results (mg/L)

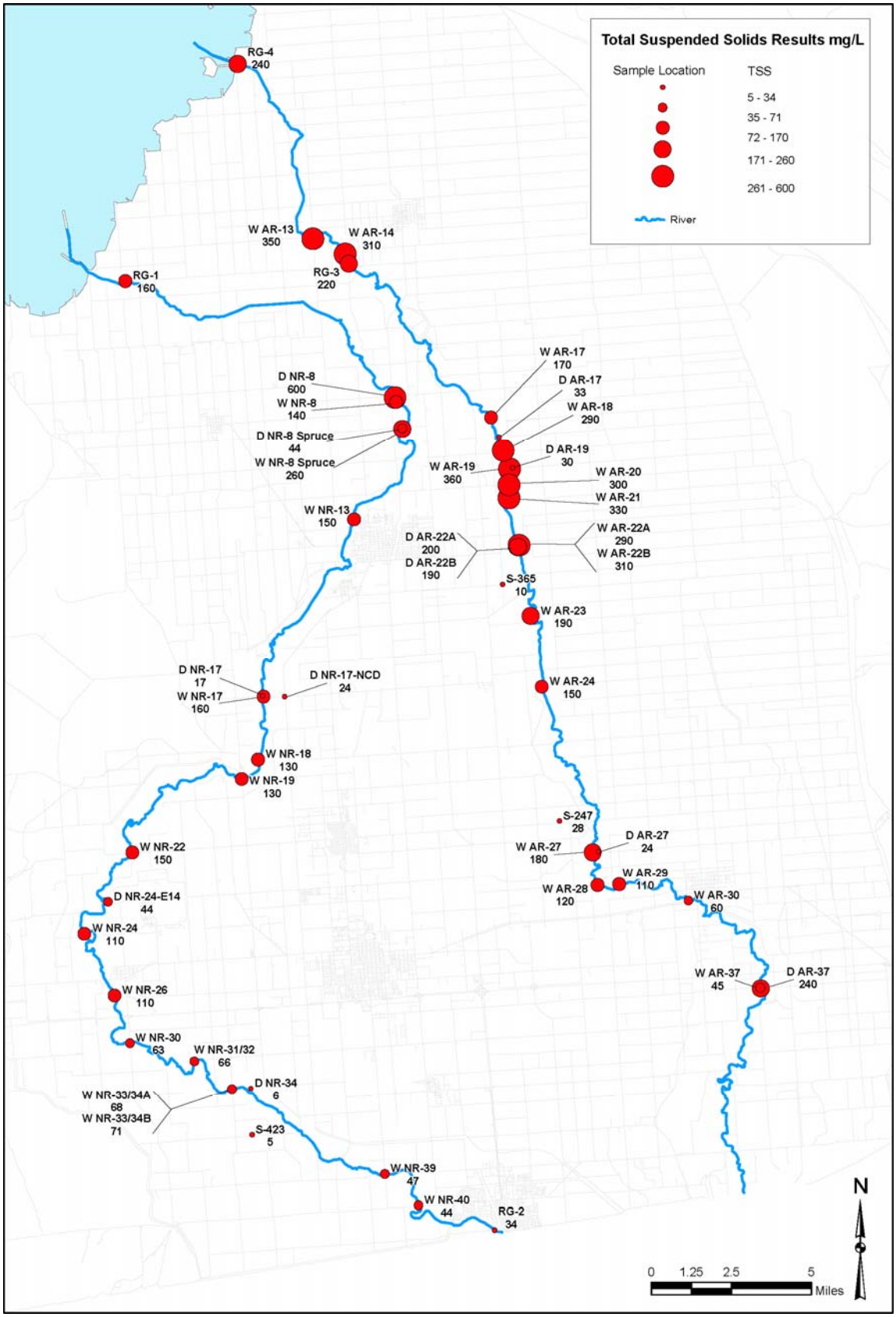


Figure 3-6 Field Sample Locations and Total Suspended Solids Results (mg/L)

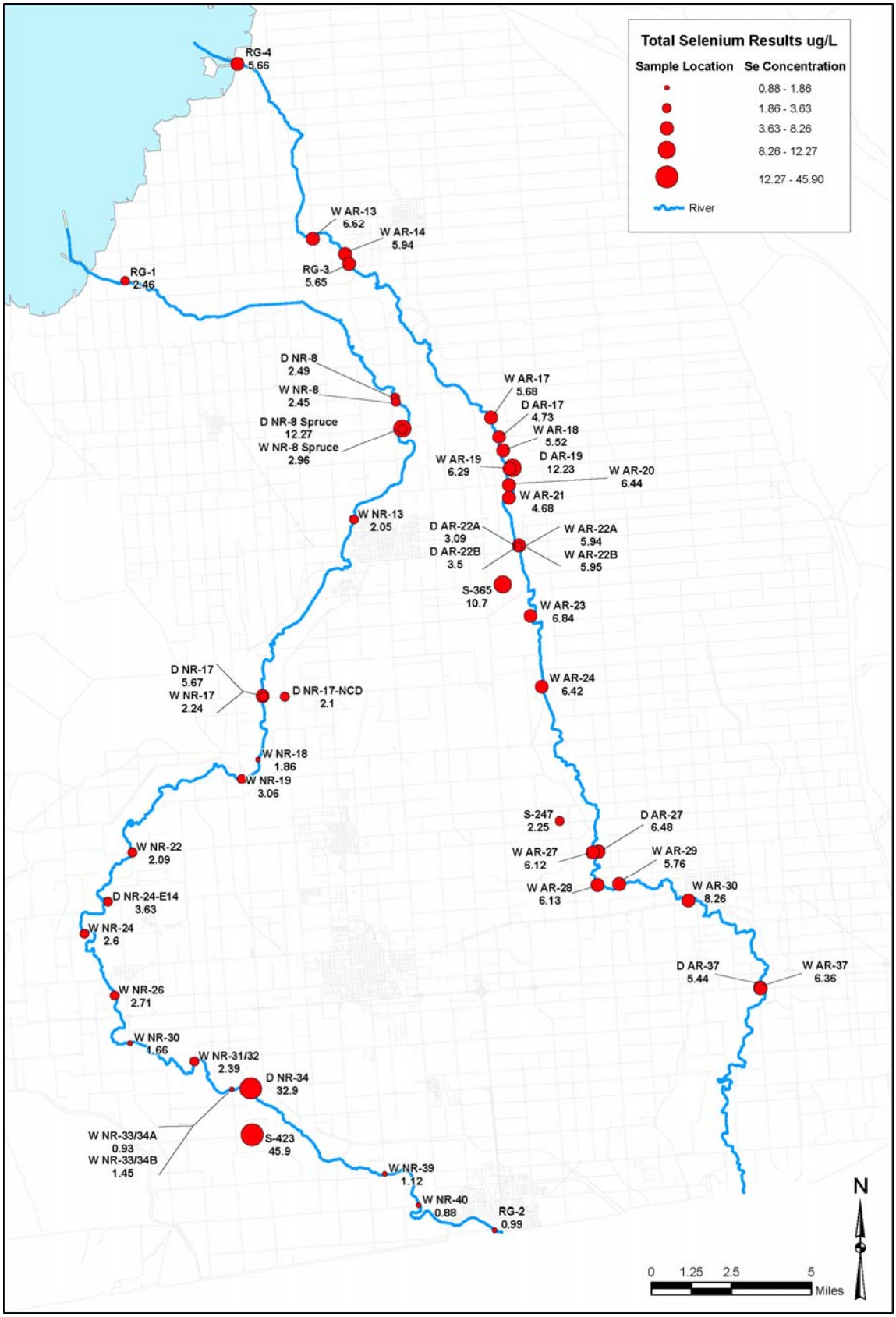


Figure 3-7 Field Sample Locations and Total Selenium Results (ug/L)

Table 3-3
Summary of Sump Station Data

Parameter	Station ID S-423	S-247	S-365
Total Coliform (mpn/100 ml)	$9.0x10^2$	---	$1.0x10^3$
Sulfate (mg/l)	2,900	200	2,000
Nitrate-N (mg/l)	23	5.8	3.3
Nitrite-N (mg/l)	<0.10	<0.10	<0.10
Ammonia-N (mg/l)	<0.10	<0.10	<0.10
Total Kjeldahl Nitrogen (mg/l)	<0.10	0.77	0.35
Ortho-Phosphate (mg/l)	<0.050	<0.050	0.081
Total Phosphorus (mg/l)	<0.10	0.14	<0.25
Total Suspended Solids	5	28	10
Total Selenium (ug/l)	45.9	2.25	10.7
Temperature (ºC)	23.91	18.72	23.42
Dissolved Oxygen (mg/l)	3.52	9.00	4.65
Dissolved Oxygen (% saturation)	43.0	97.0	57.9
pH	6.78	7.98	6.65
Electrical Conductivity (uS/cm)	11,739	1,205	16,463
Specific Conductivity (uS/cm^2)	12,013	1,369	16,973
Turbidity (NTU)	<0.1	12.1	<0.1
Oxidation Reduction Potential (mV)	88.5	53.2	112.7

S-423 (77) is west of the New River, south of NR-34.
S-247 (93) is west of the Alamo River, north of AR-27.
S-365 (54) is west of the Alamo River, opposite AR-22.
These locations were sampled by the USGS (Setmire et al, 1993). The designations used in the USGS report are listed in parentheses.

Table 3-4
Summary of New River Agricultural Drain Station Data

Parameter	Station ID						
	DNR-8 (Spruce)	DNR-8 (Best)	DNR-17 (Sumac)	DNR-17-NCD	DNR-24-E14	DNR-34a (Elder No. 1)	DNR-34b (Elder No. 1)
Total Coliform (mpn/100 ml)	$4.3x10^4$	$8.3x10^4$	$1.9x10^4$	$1.2x10^4$	$1.2x10^5$	---	---
Sulfate (mg/l)	1,200	380	2,200	560	690	3,100	---
Nitrate-N (mg/l)	24	3.7	9.0	<0.20	0.59	18	---
Nitrite-N (mg/l)	1.4	0.19	<0.10	<0.10	<0.10	<0.10	---
Ammonia-N (mg/l)	1.9	0.40	0.26	0.47	<0.10	<0.10	---
Total Kjeldahl Nitrogen (mg/l)	3.20	1.5	0.55	1.0	0.92	0.34	---
Ortho-Phosphate (mg/l)	<0.050	<0.050	0.15	0.19	0.35	<0.050	---
Total Phosphorus (mg/l)	0.12	0.81	0.26	0.28	0.44	0.09	---
Total Suspended Solids	44	600	17	24	44	6	---
Total Selenium (ug/l)	12.27	2.49	5.67	2.1	3.63	32.9	
Inorganic Selenium (ug/l)	---	---	---	---	---	20.9	31
Selenite (SeIV) (ug/l)	---	---	---	---	---	0.163	0.132
Selenate (SeVI) (ug/l)	---	---	---	---	---	12	2
Organic Selenium (ug/l)	---	---	---	---	---	20.7	31
Temperature (ºC)	22.67	17.40	22.84	19.94	20.90	23.34	---
Dissolved Oxygen (mg/l)	8.80	9.75	8.32	6.96	10.34	7.44	---
Dissolved Oxygen (% saturation)	103.4	102.3	98.6	77.1	115.7	88.6	---
pH	7.94	8.04	8.08	7.67	8.09	7.45	---
Electrical Conductivity (uS/cm)	3,353	1,179	5,136	2,211	2,133	3,995	---
Specific Conductivity (uS/cm^2)	3,509	1,379	5,354	2,446	2,314	4,129	---
Turbidity (NTU)	14.9	296	3.6	17.2	25.8	1.0	---
Oxidation Reduction Potential (mV)	51.7	42.1	52.2	62.3	34.2	26.4	---

Table 3-5
Summary of New River Wetland Station Data

	Station ID						
Parameter	**WNR-8 (Spruce)**	**WNR-8**	**NR-13**	**WNR-17**	**NR-18**	**NR-19**	**NR-22**
Total Coliform (mpn/100 ml)	$1.3x10^5$	$3.1x10^5$	---	$1.3x10^6$	---	---	$5.2x10^5$
Sulfate (mg/l)	780	840	120	910	820	810	800
Nitrate-N (mg/l)	0.59	0.88	0.77	<0.20	0.27	0.41	0.45
Nitrite-N (mg/l)	0.21	0.26	0.10	<0.10	<0.10	<0.10	<0.10
Ammonia-N (mg/l)	3.3	3.9	4.3	4.8	6.2	6.3	4.3
Total Kjeldahl Nitrogen (mg/l)	6.6	7.0	6.9	9.5	9.0	9.6	7.7
Ortho-Phosphate (mg/l)	1.0	1.0	0.96	1.3	1.1	1.2	0.92
Total Phosphorus (mg/l)	1.5	1.7	1.5	2.3	1.9	1.9	1.70
Total Suspended Solids	260	140	150	160	130	130	150
Total Selenium (ug/l)	2.96	2.45	2.05	2.24	1.86	3.06	2.09
Inorganic Selenium (ug/l)	---	---	---	---	---	---	---
Selenite (SeIV) (ug/l)	---	---	---	---	---	---	---
Selenate (SeVI) (ug/l)	---	---	---	---	---	---	---
Organic Selenium (ug/l)	---	---	---	---	---	---	---
Temperature (ºC)	23.13	20.09	19.96	20.41	20.16	20.15	20.92
Dissolved Oxygen (mg/l)	11.14	8.23	7.04	2.06	5.68	5.60	6.77
Dissolved Oxygen (% saturation)	132	92.2	78.7	23.6	62.8	62.5	77.0
pH	7.59	7.61	7.49	7.55	7.55	7.57	7.51
Electrical Conductivity (uS/cm)	4,833	4,428	4,367	4,353	4,592	4,470	4,474
Specific Conductivity (uS/cm^2)	5,010	4,886	4,827	4,770	5,060	4,925	4,851
Turbidity (NTU)	74.1	72.0	88.2	71.9	82.5	95.0	97.5
Oxidation Reduction Potential (mV)	169.2	60.4	153.8	52.2	112.7	126.0	124.8

Table 3-5
Summary of New River Wetland Station Data, Continued

	Station ID						
Parameter	**WNR-24**	**NR-26**	**NR-30**	**NR-31/32**	**NR-33/34a**	**NR-33/34b**	**NR-39**
Total Coliform (mpn/100 ml)	$9.2x10^5$	---	---	$>2.4x10^5$	$>2.4x10^5$	$>2.4x10^5$	$>2.4x10^5$
Sulfate (mg/l)	570	730	1,600	1,500	1,400	1,500	1,400
Nitrate-N (mg/l)	0.65	<0.20	0.59	<0.20	<0.20	<0.20	<0.20
Nitrite-N (mg/l)	0.13	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Ammonia-N (mg/l)	2.0	7.8	7.3	9.6	11.0	11.0	9.5
Total Kjeldahl Nitrogen (mg/l)	4.5	11	9.6	14	15	18	14
Ortho-Phosphate (mg/l)	0.29	0.97	1.3	2.00	2.4	2.2	2.9
Total Phosphorus (mg/l)	0.87	2.3	2.3	2.8	3.6	3.3	3.8
Total Suspended Solids	110	110	63	66	68	71	47
Total Selenium (ug/l)	2.6	2.71	1.66	2.39	0.93	1.45	1.12
Inorganic Selenium (ug/l)	---	---	---	---	Q	Q	---
Selenite (SeIV) (ug/l)	---	---	---	---	Q	Q	---
Selenate (SeVI) (ug/l)	---	---	---	---	Q	Q	---
Organic Selenium (ug/l)	---	---	---	---	Q	Q	---
Temperature (ºC)	20.38	19.89	19.90	22.50	21.3	---	24.02
Dissolved Oxygen (mg/l)	4.93	<0.1	1.42	2.34	1.34	---	0.64
Dissolved Oxygen (% saturation)	55.2	---	16.4	27.5	16.1	---	7.9
pH	7.71	6.50	7.38	7.71	7.58	---	7.65
Electrical Conductivity (uS/cm)	2,394	4,422	4,631	4,806	4,793	---	4,669
Specific Conductivity (uS/cm2)	2,626	4,896	5,130	5,033	5,156	---	4,749
Turbidity (NTU)	50.1	5.20	35.5	100	50	---	68.1
Oxidation Reduction Potential (mV)	49.4	-350.5	41.0	4.5	-178.5	---	-174.0

Table 3-5
Summary of New River Wetland Station Data, Continued

Parameter	Station ID NR-40
Total Coliform (mpn/100 ml)	$>2.4x10^5$
Sulfate (mg/l)	690
Nitrate-N (mg/l)	<1.0
Nitrite-N (mg/l)	<0.10
Ammonia-N (mg/l)	8.3
Total Kjeldahl Nitrogen (mg/l)	12
Ortho-Phosphate (mg/l)	2.0
Total Phosphorus (mg/l)	2.9
Total Suspended Solids	44
Total Selenium (ug/l)	0.88
Inorganic Selenium (ug/l)	---
Selenite (SeIV) (ug/l)	---
Selenate (SeVI) (ug/l)	---
Organic Selenium (ug/l)	---
Temperature (ºC)	21.56
Dissolved Oxygen (mg/l)	1.67
Dissolved Oxygen (% saturation)	20.20
pH	7.70
Electrical Conductivity (uS/cm)	3,640
Specific Conductivity (uS/cm^2)	3,903
Turbidity (NTU)	86.7
Oxidation Reduction Potential (mV)	-65.4

Table 3-6
Summary of Alamo River Wetland Station Data

Parameter	Station ID					
	DAR-17 (Mullen)	DAR-19 (Mesquite)	DAR-22a (Bryant)	DAR-22b (Bryant)	DAR-27 (Palmetto)	DAR-37 (Verde)
Total Coliform (mpn/100 ml)	$1.3x10^5$	$2.2x10^5$	$7.3x10^5$	$>2.4x10^6$	$4.9x10^5$	$1.5x10^4$
Sulfate (mg/l)	840	1,700	550	500	1,400	800
Nitrate-N (mg/l)	1.5	2.1	1.6	1.6	5.6	10
Nitrite-N (mg/l)	<0.10	<0.10	<0.10	<0.10	0.56	<0.10
Ammonia-N (mg/l)	<0.10	<0.10	<0.10	0.10	6.7	<0.10
Total Kjeldahl Nitrogen (mg/l)	0.79	0.68	1.7	1.7	9.4	1.7
Ortho-Phosphate (mg/l)	0.33	0.093	0.34	0.34	0.22	1.6
Total Phosphorus (mg/l)	0.42	0.16	0.70	0.66	0.30	2.4
Total Suspended Solids	33	30	200	190	24	240
Total Selenium (ug/l)	4.73	12.23	3.09	3.50	6.48	5.44
Inorganic Selenium (ug/l)	---	---	1.72	0.96	---	---
Selenite (SeIV) (ug/l)	---	---	0.536	0.386	---	---
Selenate (SeVI) (ug/l)	---	---	1.37	2.54	---	---
Organic Selenium (ug/l)	---	---	1.18	0.57	---	---
Temperature (ºC)	21.39	20.98	17.29	---	18.87	22.28
Dissolved Oxygen (mg/l)	10.58	11.08	9.84	---	11.55	7.38
Dissolved Oxygen (% saturation)	121.2	126.4	104.4	---	126.3	86.1
pH	8.12	7.91	7.74	---	8.08	7.90
Electrical Conductivity (uS/cm)	2,364	5,143	1,929	---	2,985	4,340
Specific Conductivity (uS/cm^2)	2,539	5,569	2,262	---	3,380	4,574
Turbidity (NTU)	27.4	128.3	120.7	---	19.0	158.9
Oxidation Reduction Potential (mV)	200.5	208.7	175.8	---	213.1	122.6

Table 3-7
Summary of Alamo River Wetland Station Data

	Station ID							
Parameter	**WAR-13**	**AR-14**	**WAR-17**	**AR-18**	**WAR-19**	**AR-20**	**AR-21**	**WAR-22a**
Total Coliform (mpn/100 ml)	$2.0x10^6$	$1.8x10^4$	$6.1x10^5$	$4.4x10^5$	$6.1x10^5$	$5.8x10^5$	$1.3x10^6$	$4.6x10^5$
Sulfate (mg/l)	870	900	960	920	1,100	910	800	880
Nitrate-N (mg/l)	7.6	8.3	7.6	8.2	7.1	8.4	6.2	8.1
Nitrite-N (mg/l)	0.33	0.34	0.28	0.27	0.29	0.29	0.23	0.30
Ammonia-N (mg/l)	0.20	0.19	0.14	0.24	0.20	0.28	0.70	0.20
Total Kjeldahl Nitrogen (mg/l)	1.3	1.4	1.2	1.5	1.3	1.6	2.9	1.3
Ortho-Phosphate (mg/l)	0.33	0.30	0.30	0.34	0.32	036	0.70	0.31
Total Phosphorus (mg/l)	0.69	0.73	0.65	0.74	0.64	0.79	2.0	0.69
Total Suspended Solids	350	310	170	290	360	300	330	290
Total Selenium (ug/l)	6.62	5.94	5.68	5.52	6.29	6.44	4.68	5.94
Inorganic Selenium (ug/l)	---	---	---	---	---	---	---	5.21
Selenite (SeIV) (ug/l)	---	---	---	---	---	---	---	0.111
Selenate (SeVI) (ug/l)	---	---	---	---	---	---	---	0.73
Organic Selenium (ug/l)	---	---	---	---	---	---	---	0.51
Temperature (ºC)	21.02	20.40	23.61	20.33	20.39	20.24	19.29	19.79
Dissolved Oxygen (mg/l)	8.72	9.08	12.29	10.42	10.56	11.03	11.06	11.60
Dissolved Oxygen (% saturation)	99.0	101.75	146.8	114.9	120.2	124.0	121.1	128.2
pH	7.87	7.96	7.26	7.91	7.84	7.91	7.91	7.65
Electrical Conductivity (uS/cm)	2,919	3,055	1,696	3,173	3,042	3,127	2,634	2,975
Specific Conductivity (uS/cm^2)	3,156	3,349	1,737	3,483	3,275	3,438	2,949	3,303
Turbidity (NTU)	102.5	143.5	116.3	165.2	140.7	175.0	196.0	188.2
Oxidation Reduction Potential (mV)	79.5	84.1	176.6	128.1	213.5	113.3	115.0	190.4

Table 3-7
Summary of Alamo River Wetland Station Data, Continued

Parameter	Station ID							
	WAR-22b	AR-23	AR-24	WAR-27	AR-28	AR-29	AR-30	WAR-37
Total Coliform (mpn/100 ml)	$4.9x10^5$	$1.9x10^5$	$2.5x10^5$	$2.9x10^5$	$4.0x10^4$	$3.6x10^4$	$6.9x10^4$	$4.1x10^4$
Sulfate (mg/l)	980	1,200	970	1,000	880	810	940	1,000
Nitrate-N (mg/l)	7.9	10	9.7	10	12	12	13	13
Nitrite-N (mg/l)	0.31	0.29	0.40	0.31	0.21	0.22	0.14	<0.10
Ammonia-N (mg/l)	0.20	0.17	0.23	0.50	0.14	0.56	0.39	0.21
Total Kjeldahl Nitrogen (mg/l)	1.4	1.2	1.3	1.5	1.1	1.2	0.60	0.54
Ortho-Phosphate (mg/l)	0.30	0.18	0.22	0.19	0.13	0.12	0.11	0.099
Total Phosphorus (mg/l)	0.71	0.45	0.46	0.44	0.33	0.32	0.22	0.20
Total Suspended Solids	310	190	150	180	120	110	60	45
Total Selenium (ug/l)	5.95	6.84	6.42	6.12	6.13	5.76	8.26	6.36
Inorganic Selenium (ug/l)	5.68	---	---	---	---	---	---	---
Selenite (SeIV) (ug/l)	0.324	---	---	---	---	---	---	---
Selenate (SeVI) (ug/l)	0.27	---	---	---	---	---	---	---
Organic Selenium (ug/l)	5.36	---	---	---	---	---	---	---
Temperature (ºC)	---	20.56	20.40	20.51	20.65	20.62	20.17	22.54
Dissolved Oxygen (mg/l)	---	12.05	11.56	11.06	9.61	9.82	8.17	8.78
Dissolved Oxygen (% saturation)	---	135.2	126.6	124.2	111.1	111.0	91.7	102.4
pH	---	7.93	7.90	7.92	7.88	7.88	7.85	8.08
Electrical Conductivity (uS/cm)	---	3,271	3,328	2,906	2,960	2,962	3,210	3,170
Specific Conductivity (uS/cm^2)	---	3,574	3,644	3,178	3,228	3,233	3,536	3,330
Turbidity (NTU)	---	111.0	88.9	62.7	73.3	76.3	27.5	20.2
Oxidation Reduction Potential (mV)	---	105.8	135.4	201.3	134.5	120.8	51.5	114.1

Table 3-8
Summary of Brawley Pilot Wetland Surface Water Data

Parameter	Station ID					
	BW-1	BW-2	BW-3	BW-4	BW-6	BWD
Total Selenium (ug/l)	1.610	1.610	1.700	1.360	1.200	0.396*
Dissolved Selenium (ug/l)	1.690	1.420	1.460	1.230	1.070	2.800*
Temperature (ºC)	18.53	18.79	17.16	16.96	17.17	13.56
Dissolved Oxygen (mg/l)	7.24	7.68	3.65	4.74	8.76	5.17
Dissolved Oxygen (% saturation)	78.3	83.6	38.3	49.8	92.4	50.6
pH	7.64	7.63	7.57	7.57	7.70	7.75
Electrical Conductivity (uS/cm)	3,714	3,794	3,663	3,961	4,272	3,985
Specific Conductivity (uS/cm^2)	4,237	4,295	4,307	4,680	5,022	5,098
Turbidity (NTU)	30.8	86.2	16.4	21.7	9.1	28.6
Oxidation Reduction Potential (mV)	215.1	203.1	64.5	75.8	201	24.2

* **Anomalously large data inversion – data are not useable**

Table 3-9
Summary of Imperial Pilot Wetland Surface Water Data

	Station ID								
Parameter	**IW-1**	**IW-2**	**IW-3**	**IW-4**	**IW-5**	**IW-6**	**IW-7**	**IW-8**	**IW-10**
Total Selenium (ug/l)	3.310	2.520	2.920*	3.600	3.040	3.110	3.440	3.000	3.080
Dissolved Selenium (ug/l)	3.640	3.010	4.320*	3.390	3.130	3.150	2.380	2.800	0.295**
Temperature (ºC)	18.92	17.69	19.09	19.03	18.56	15.71	16.04	16.39	16.9
Dissolved Oxygen (mg/l)	15.46	12.25	16.3	18.54	10.86	4.12	3.66	2.38	7.21
Dissolved Oxygen (% saturation)	167.9	129.8	177.7	201.5	117.1	41.8	37.4	24.5	75
pH	8.76	8.51	8.81	8.88	8.50	8.04	7.84	7.71	8.00
Electrical Conductivity (uS/cm)	2,581	2,450	2,535	2,516	2,496	2,342	2,385	2,380	2,476
Specific Conductivity (uS/cm^2)	2,920	2,847	2,860	2,839	2,846	2,847	2,876	2,848	2,929
Turbidity (NTU)	24.8	12.5	17	19.3	32.4	28	25.4	16	12.3
Oxidation Reduction Potential (mV)	234.7	50.8	52.7	59.4	46.1	12.8	35.9	46.4	78.2

***** **Anomalously large data inversion – data are not useable**

3.3 Overall Surface Water Quality

Surface water quality at the 47 monitoring stations can be characterized as being warm, eutrophic, turbid, and having significantly elevated total coliform levels (Tables 2-2 through 2-7). Comparison of these data to applicable regional and state water quality standards indicates the following potential concerns:

3.3.1 Biostimulatory Substances

The Regional Water Quality Board, Region 7 (RWQCB-7) Basin Plan provides the following narrative water quality objective for surface waters within the Imperial Valley:

Waters shall not contain biostimulatory substances in concentrations that promote aquatic growths to the extent that such growths cause nuisance or adversely affect beneficial uses. Nitrate and phosphate limitations will be placed on industrial discharges to New and Alamo Rivers and irrigation basins on a case-by-case basis, taking into consideration the beneficial uses of these streams.

Samples collected from every monitoring station contained quantifiable concentrations of nitrogen, sulfate, and phosphorus. Concentrations of nitrate and nitrite were generally greater in the samples collected from the Alamo River wetland sites than in the New River, but the reverse was true for ammonia, total Kjeldahl nitrogen, ortho-phosphate, and total phosphorus. Concentrations of sulfate were similar between the two rivers, with the New River containing both the lowest and highest sulfate values (Figures 3-8 through 3-14). There was no clear delineation between New and Alamo River agricultural drainages or sumps because of the minimal data set.

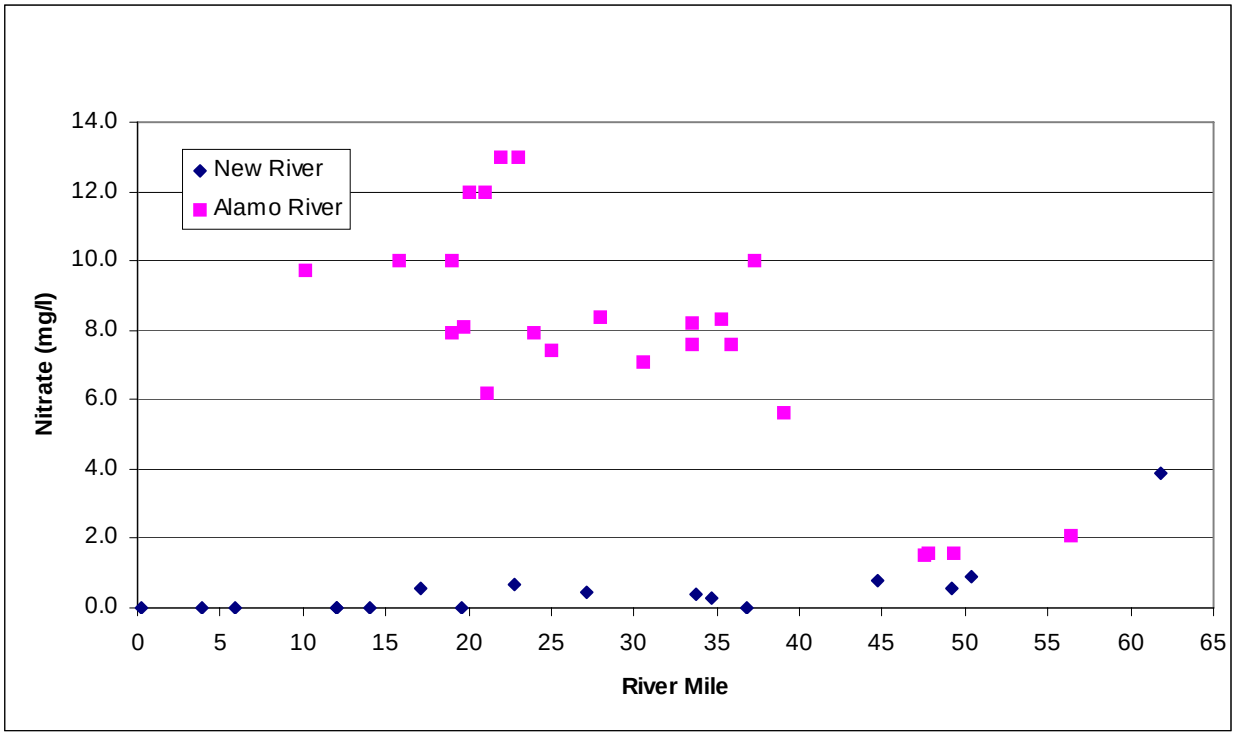


Figure 3-8. Nitrate concentration comparison between the New and Alamo River Wetland Stations

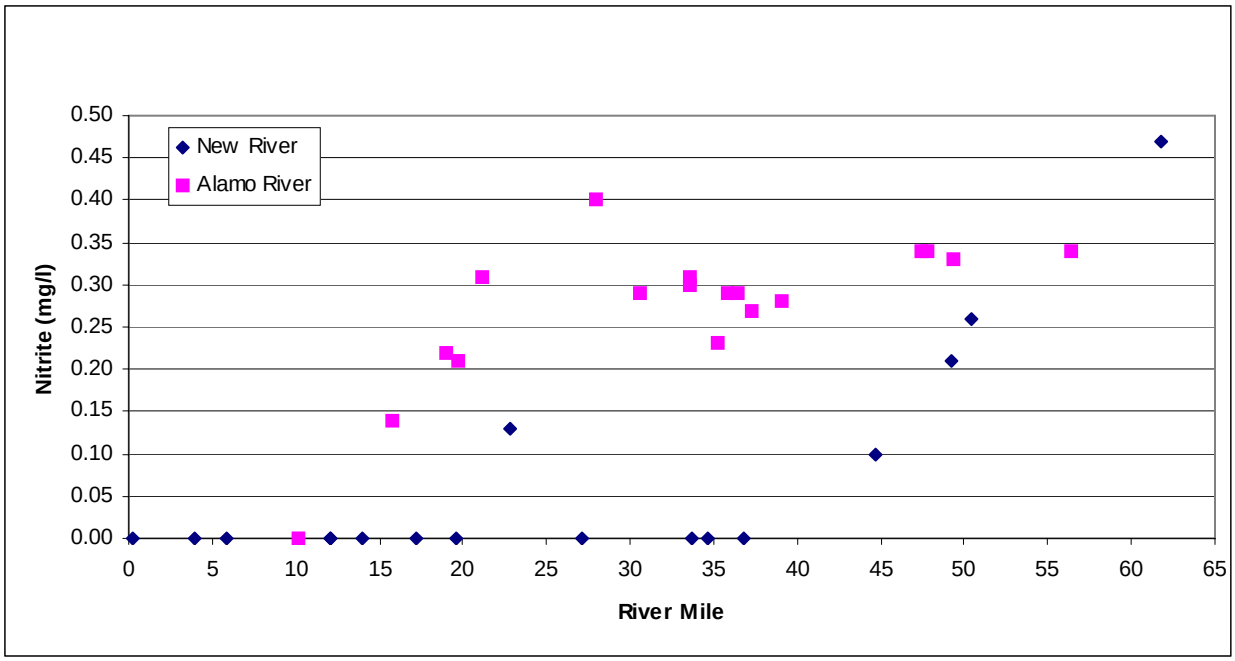


Figure 3-9. Nitrite concentration comparison between the New and Alamo River Wetland Stations

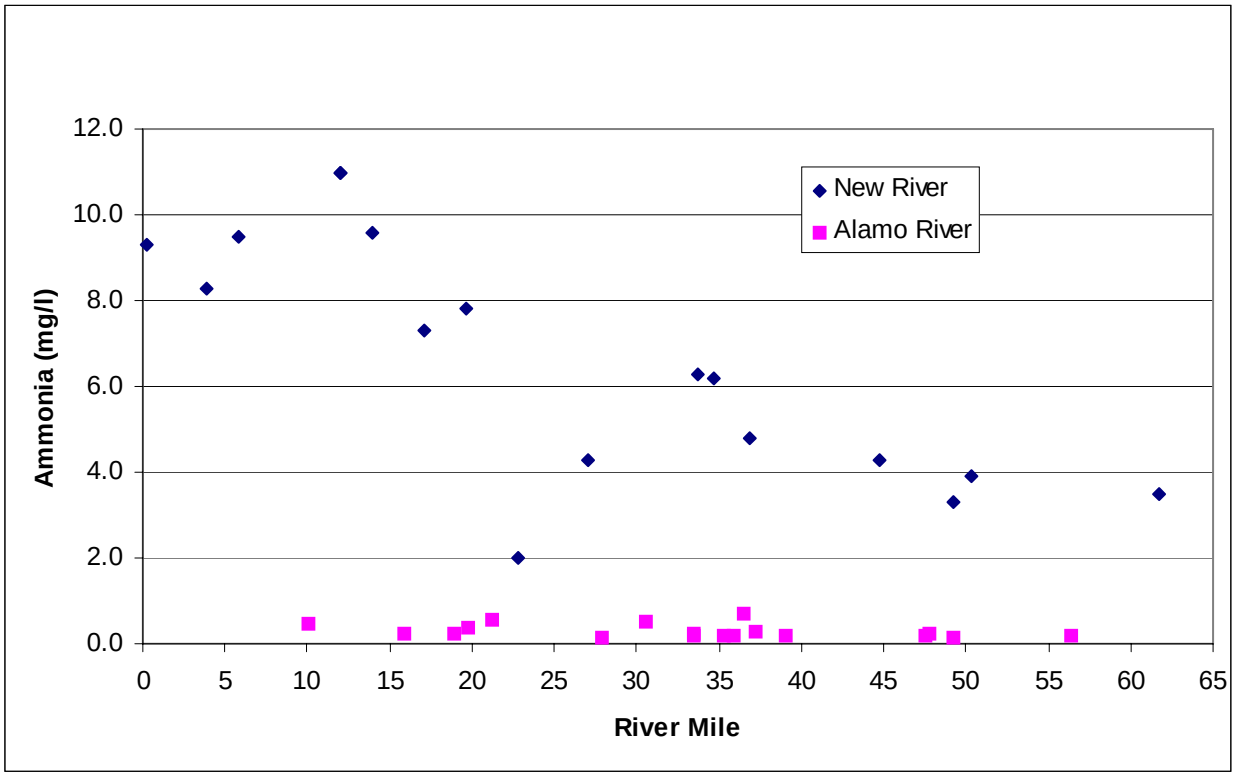


Figure 3-10. Ammonia concentration comparison between the New and Alamo River Wetland Stations

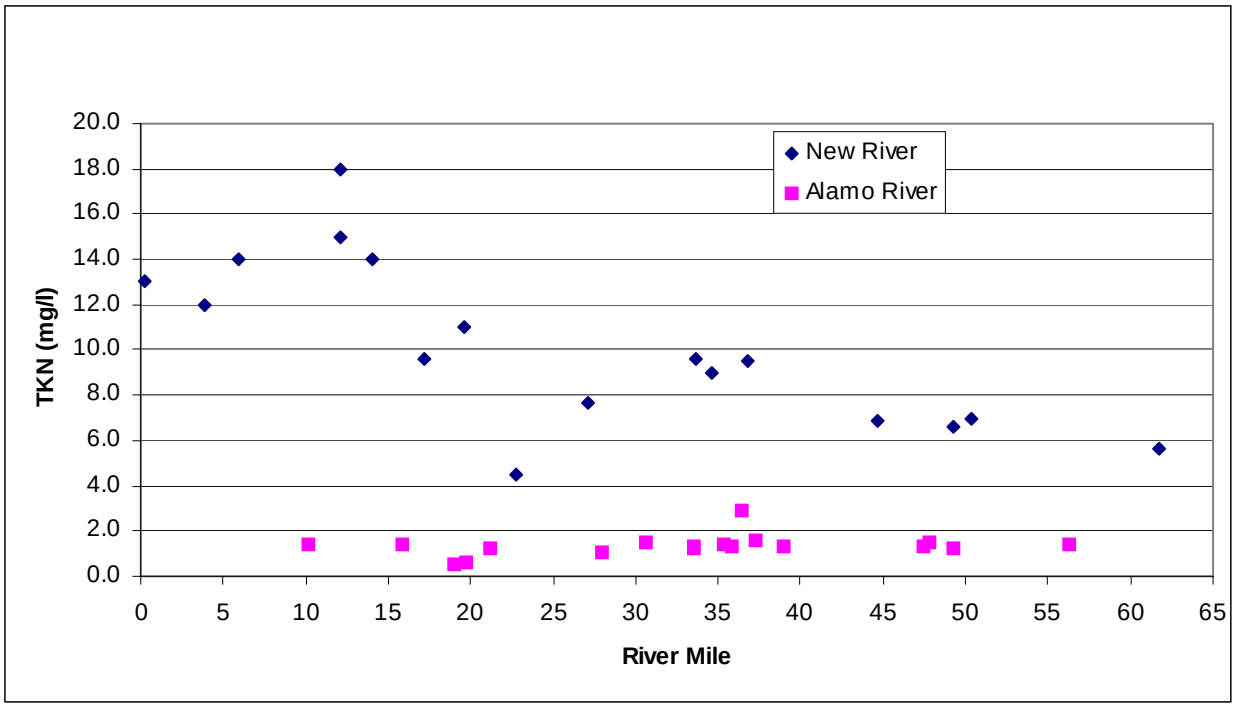


Figure 3-11. Total Kjeldahl Nitrogen concentration comparison between the New and Alamo River Wetland Stations

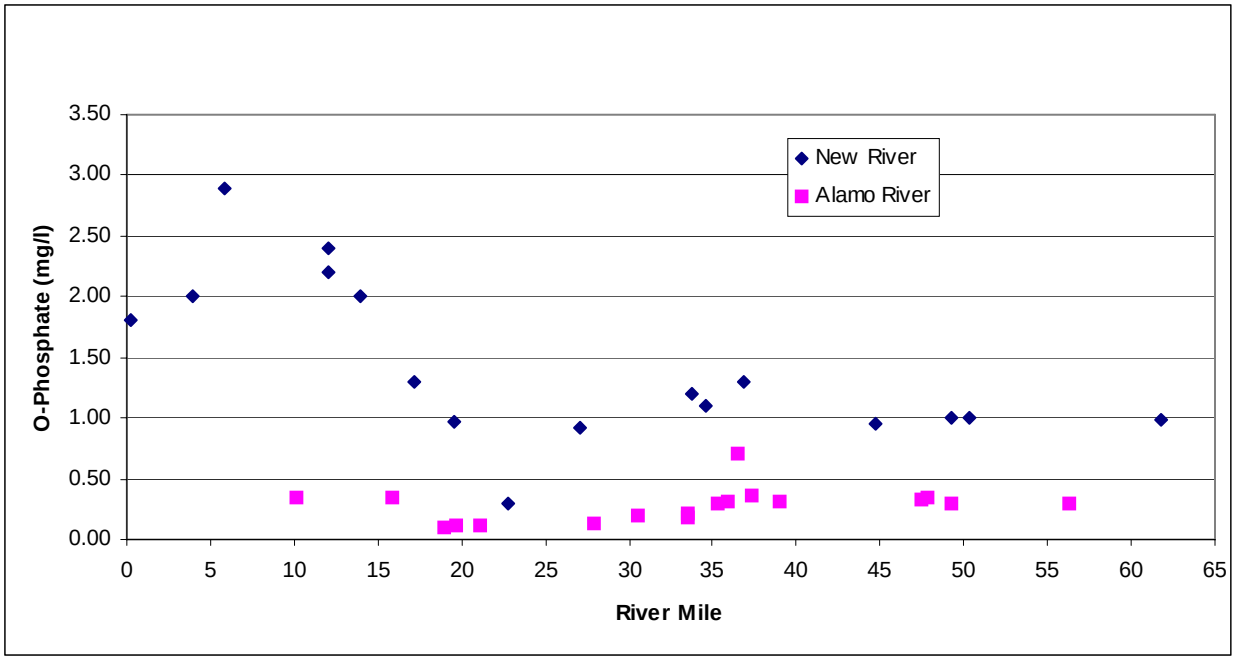


Figure 3-12. Ortho-Phosphate concentration comparison between the New and Alamo River Wetland Stations

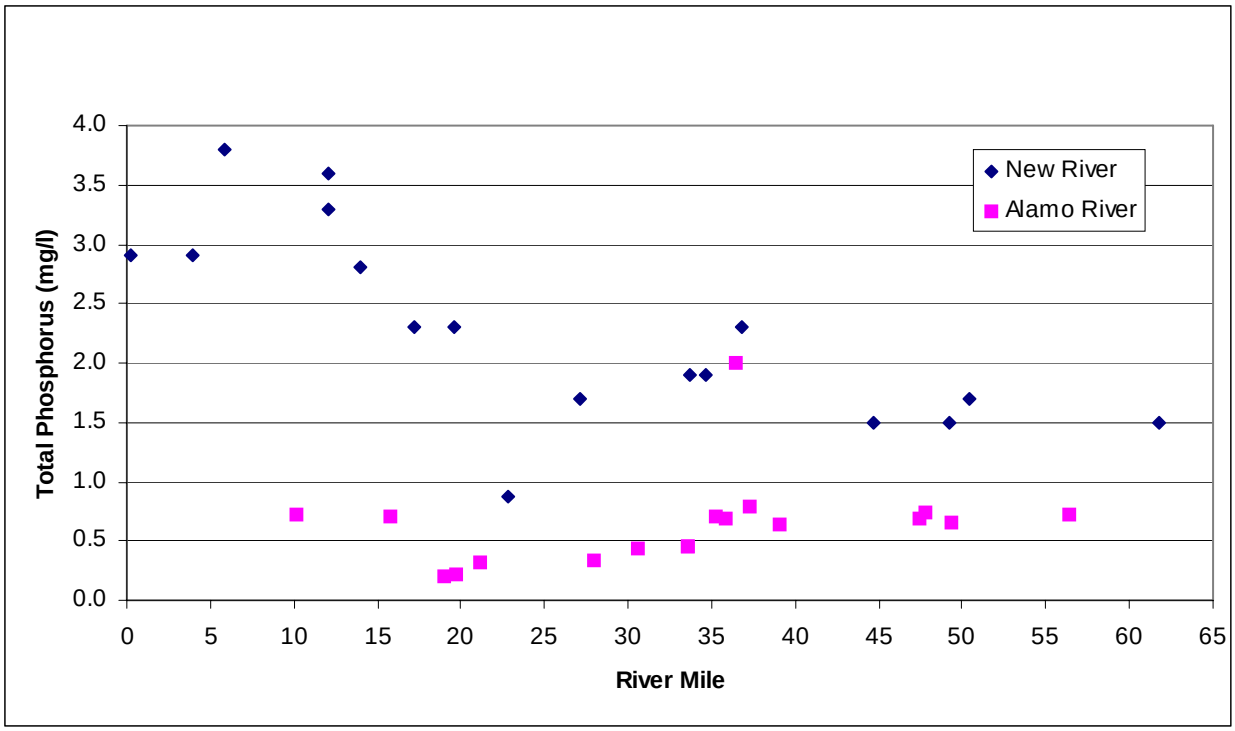


Figure 3-13. Total Phosphorus concentration comparison between the New and Alamo River Wetland Stations

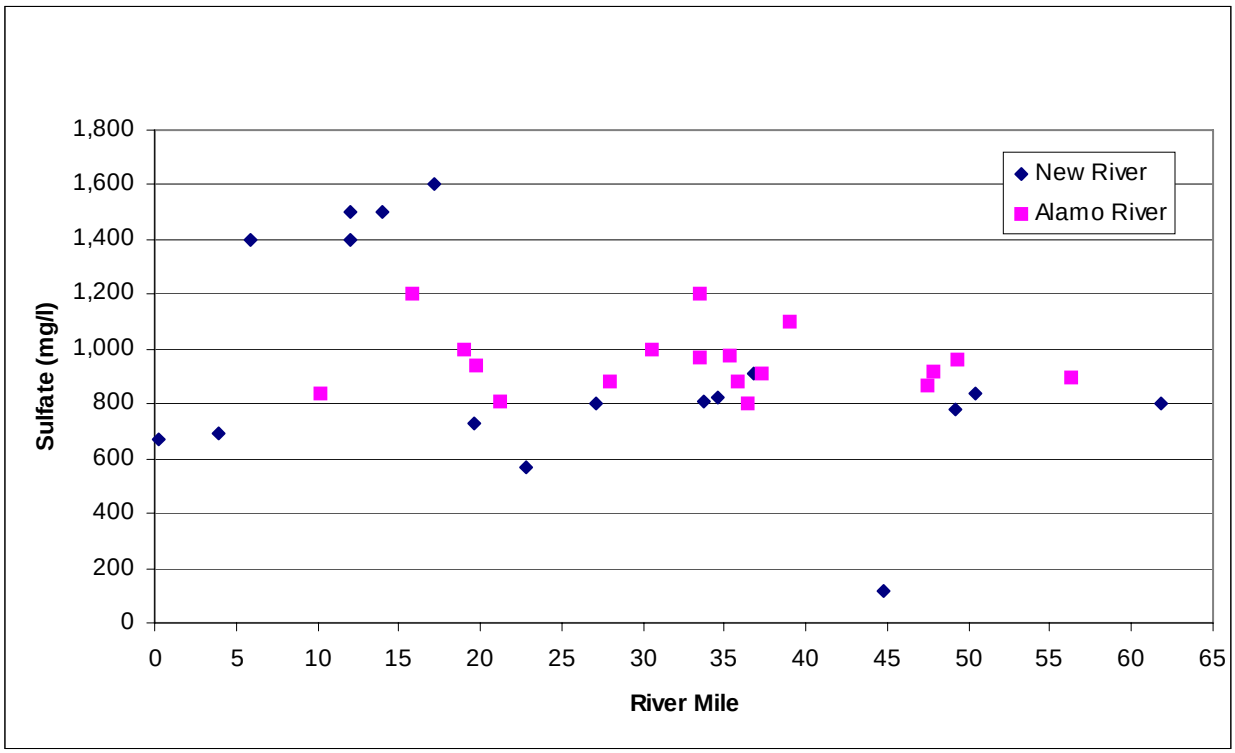


Figure 3-14. Sulfate concentration comparison between the New and Alamo River Wetland Stations

3.3.2 Dissolved Oxygen

The RWQCB-7 has classified the New and Alamo Rivers as having warm water habitat beneficial uses. A warm water habitat beneficial use classification is designed to protect warm water ecosystems "including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates."

The RWQCB-7 Basin Plan states that the dissolved oxygen concentration shall not be reduced below 5.0 mg/l at any time for waterbodies that have been assigned the WARM beneficial use.

Twenty-two percent of the sample stations (all located in the New River wetland and sump stations) had dissolved oxygen concentrations that were less than 5.0 mg/l. These sample stations were located in the New River and sump stations (Tables 3-2, 3-3, and 3-5). Similarly, 27 percent of the samples collected from the Brawley and Imperial Pilot Wetland sites had dissolved oxygen levels that were less than 5.0 mg/l (Tables 3-8 and 3-9).

The concentration of dissolved oxygen follows a diel pattern, where concentrations are lowest overnight and early morning and highest in the afternoon and early evening. Point measurements of the type used during this study capture only the dissolved oxygen concentration at that particular point in time, thus without having measurements that span the entire 24-hour light:dark cycle, it is difficult to quantify the actual minima with any certainty. These data do, however, indicate that the potential for significantly low dissolved oxygen concentrations exists.

3.3.3 Bacteria

The Mexican-American Water Treaty, Minute No. 264, "Recommendation for Solution of the New River Border Sanitation Problem at Calexico, California – Mexicali, Baja California Norte" (RWQCB-7 Basin Plan) provides the following quantitative standards for coliforms:

New River Upstream of Discharge Canal: 30,000 Colonies per 100 ml, with no single sample to exceed 60,000 colonies per 100 ml.

Additionally, the Basin Plan provides the following "not to exceed" coliform objectives:

Rec 1 = 400 colonies/100 ml

Rec II = 2,000 colonies/100 ml

Seventy-nine percent of the samples collected from the New and Alamo Rivers contained total coliform levels that exceeded the 60,000 colonies/100 ml limit set by the Mexican-American Water Treaty, with concentrations that reached >2.4 million colonies/100 ml (Tables 3-2 through 3-7). The sumps contained the lowest total coliform levels, with the concentration at S-365 being 1000-colonies/100 ml and at S-423 being 900-colonies/100 ml. These concentrations exceed the Basin Plan's not-to-exceed objectives for Rec-1.

Current beneficial uses for the New and Alamo Rivers include both contact and non-contact recreation, albeit illicit.

3.3.4 Total Selenium

The Alamo River wetland site samples contained higher levels of total selenium than were found in the New River wetland sites (Figure 3-15). There was no such pattern for the Alamo and New River Agricultural Drainage samples (Figure 3-16).

The California Toxics Rule (CTR) (May 2000) provides the appropriate standards for total selenium when the Basin Plan does not provide one. The CTR provides a long-term, or

chronic, exposure standard of 5.0 μg/l for the protection of aquatic life. Comparisons of the New and Alamo River wetland site and agricultural drainage data to the CTR criterion indicate that total selenium concentrations in the Alamo River wetland sites consistently exceed the 5 μg/l criterion, while all samples collected from the New River wetland sites had total selenium concentrations that were lower than the criterion (Figure 3-15). Total selenium exceedances were mixed for the agricultural drain sites, with an equal number of samples from each river being greater than and less than the CTR criterion (Figure 3-16).

Total selenium concentrations in the gauging stations along the Alamo and New Rivers exhibited a pattern that was identical to that found for the wetland site samples, with total selenium concentrations at RG-3 and RG-4 along the Alamo River being 5.65 and 5.66 μg/l, respectively. Total selenium concentrations at RG-1 and RG-2 along the New River were 2.46 and 0.99 μg/l, respectively (Table 3-2). Total selenium concentrations in the sump samples were also elevated but did not follow the pattern observed with the wetland or gauging station samples, with the S-423 (near the New River) containing 45.9 μg/l total selenium and the sumps near the Alamo River (S-247 and S-365) containing 2.25 and 10.7 μg/l total selenium, respectively (Table 3-3).

Inorganic selenium, selenite, selenate, and organic selenium were quantified in samples collected from one New River wetland and one New River agricultural drain station (Table 3-4). Similar samples were collected from an Alamo River wetland and agricultural drainage station, but could not be quantified because of laboratory quality control issues (see following section). There are no existing water quality objectives for these species of selenium.

Total and dissolved selenium was quantified in nine samples collected from the Brawley and Imperial Pilot Wetlands (Tables 3-8 and 3-9; Figures 3-17 and 3-18), respectively. All concentrations were lower than the relevant CTR criterion for selenium. The close correlation between the total and dissolved selenium concentrations indicates that much of the selenium in the Pilot Wetland samples was either dissolved or not sorbed to particulates greater than 0.45 um, which is the pore-size of the filter used to isolate the dissolved phase. This is also evidenced by the presence of data inversions (i.e., total Se < dissolved Se). Data inversions occurred in samples collected from six of the nine samples (Tables 3-8 and 3-9). The largest inversions were observed in samples collected from IW-3 and BWD. The impact of these large inversions is discussed in the Data Quality Assessment located below.

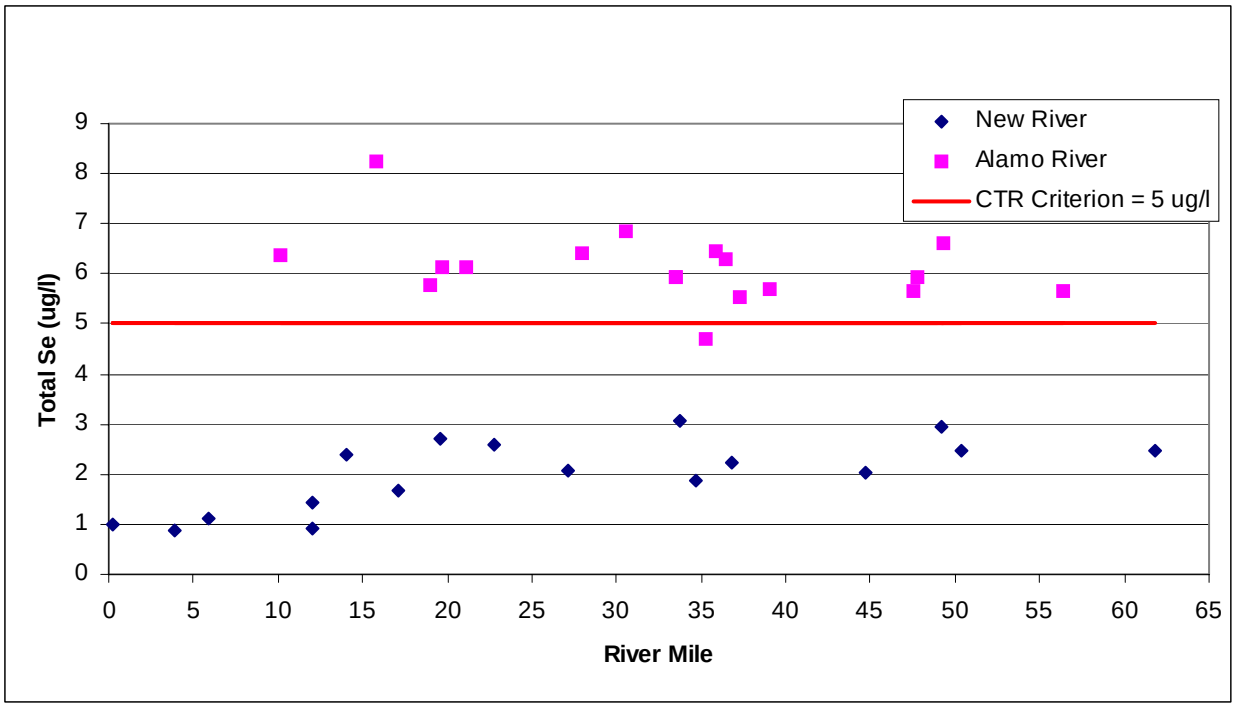


Figure 3-15. Total Selenium concentration comparison between the New and Alamo River Wetland Stations

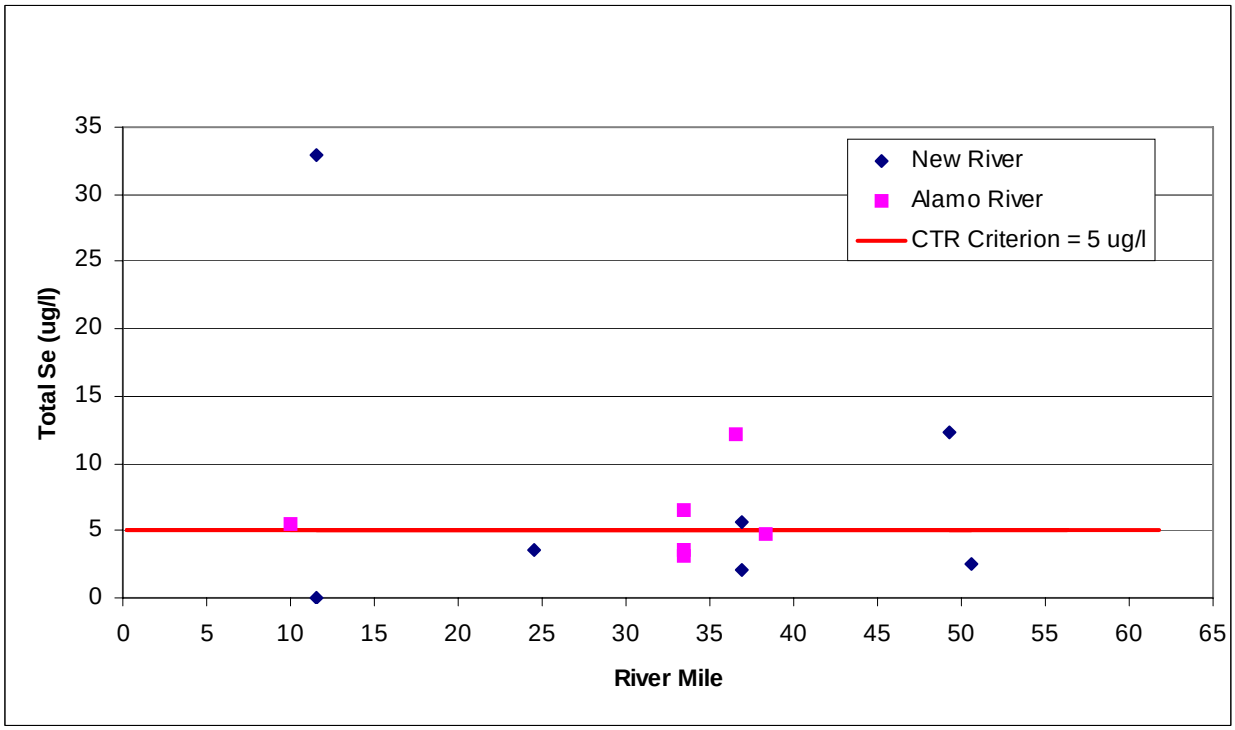


Figure 3-16. Total Selenium Concentration comparison between the New and Alamo River Agricultural Drain Stations

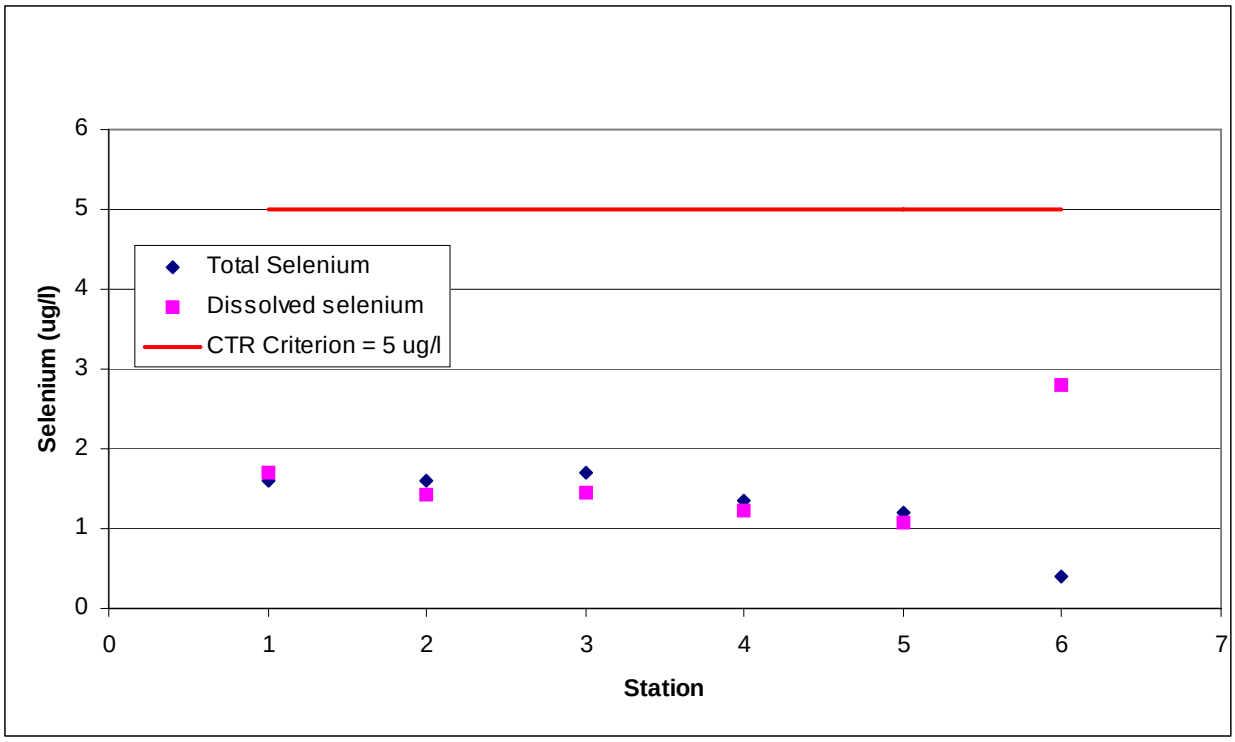


Figure 3-17. Selenium concentrations in the Brawley Pilot Wetland Stations

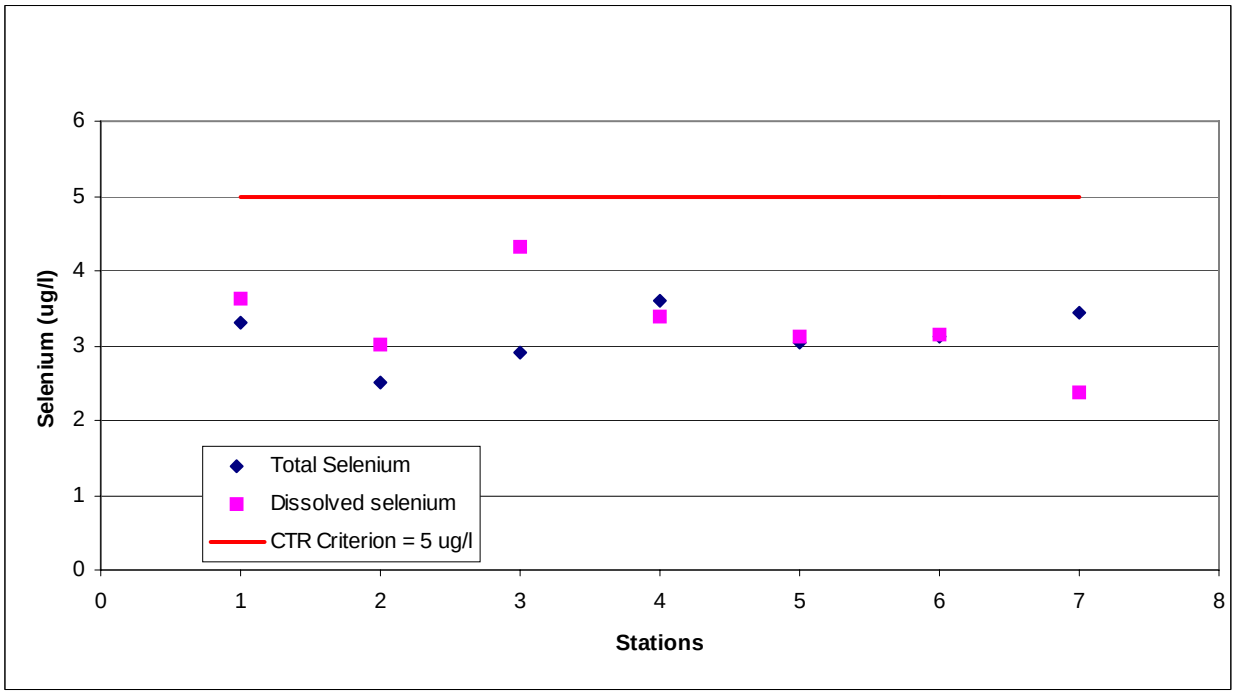
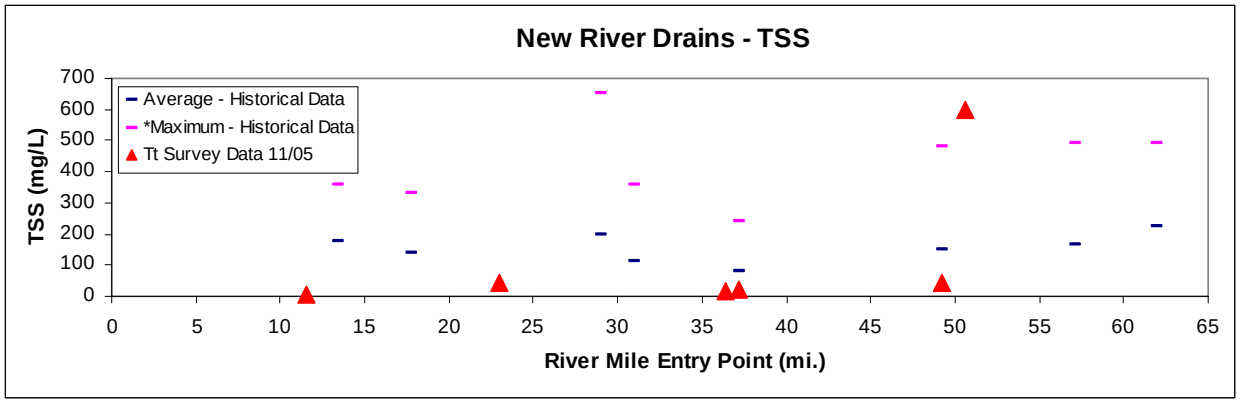
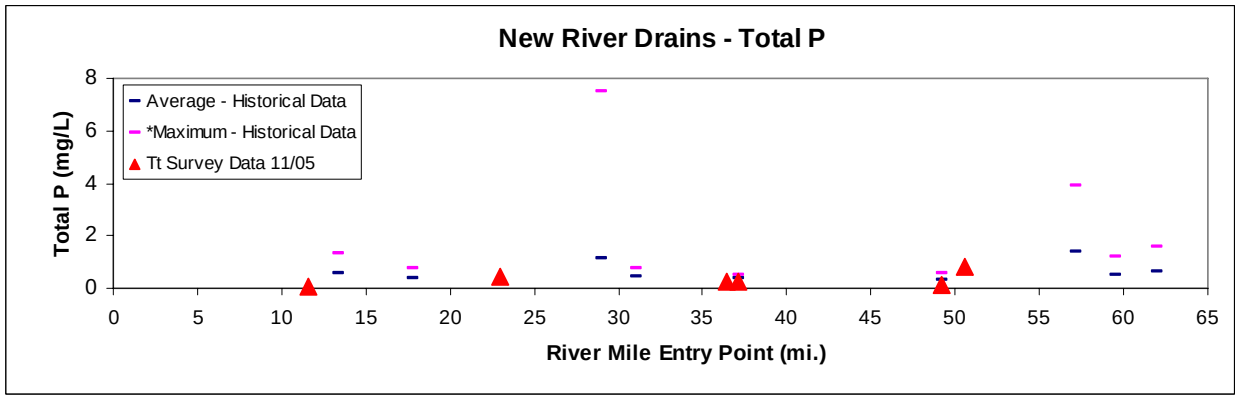


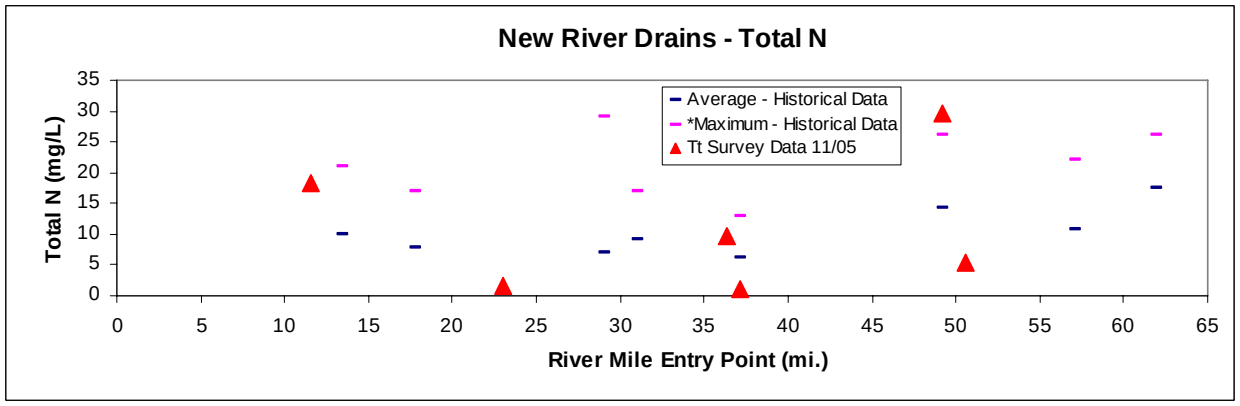
Figure 3-18. Selenium concentrations in the Imperial Pilot Wetland Stations

Two New River drains that have historical data, the North Central and Spruce, were also sampled in 2005. As seen in Figure 3-19, the concentrations of TSS, total P, and total N were within the range of previous data, although less than the average. TSS and total P in the Spruce drain were slightly less than the previous range of concentrations, while total N was slightly higher. Selenium has not been measured previously in either the North Central or Spruce drains. Total and fecal coliform concentrations have been measured previously only in the Rice 3 drain, as shown in Figure 3-20. The total and fecal coliform concentrations measured in the drains in 2005 were similar to the average in the Rice 3 drain.

Three drains to the Alamo River had been sampled previously for TSS: Mesquite, Mullen, and Verde. The Mullen and Mesquite drains had been sampled only once before, and the TSS was higher, perhaps due to the higher flows in March 2000 than in November 2005 when the new data were collected (See Figure 3-20). The Verde drain had slightly higher TSS concentrations (240 mg/L) than the previous measurements (44 to 220 mg/L). The new data for total N for the Verde drain (11.75 mg/L) were within the range of previous data (4.6 to 17 mg/L), while the new total P concentration (2.4 mg/L) was higher than previously measured (0.19 to 1.5 mg/L). Total selenium had been measured in March 1999 at the Verde drain. In both, the 2005 concentrations were less than in 1999. Total or fecal coliform concentrations have not been measured in any of the Alamo River drains previously.







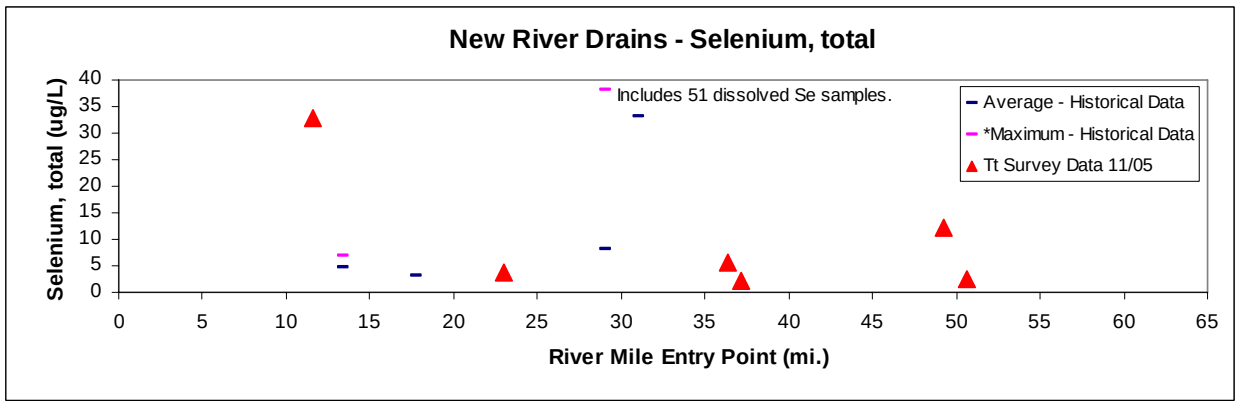
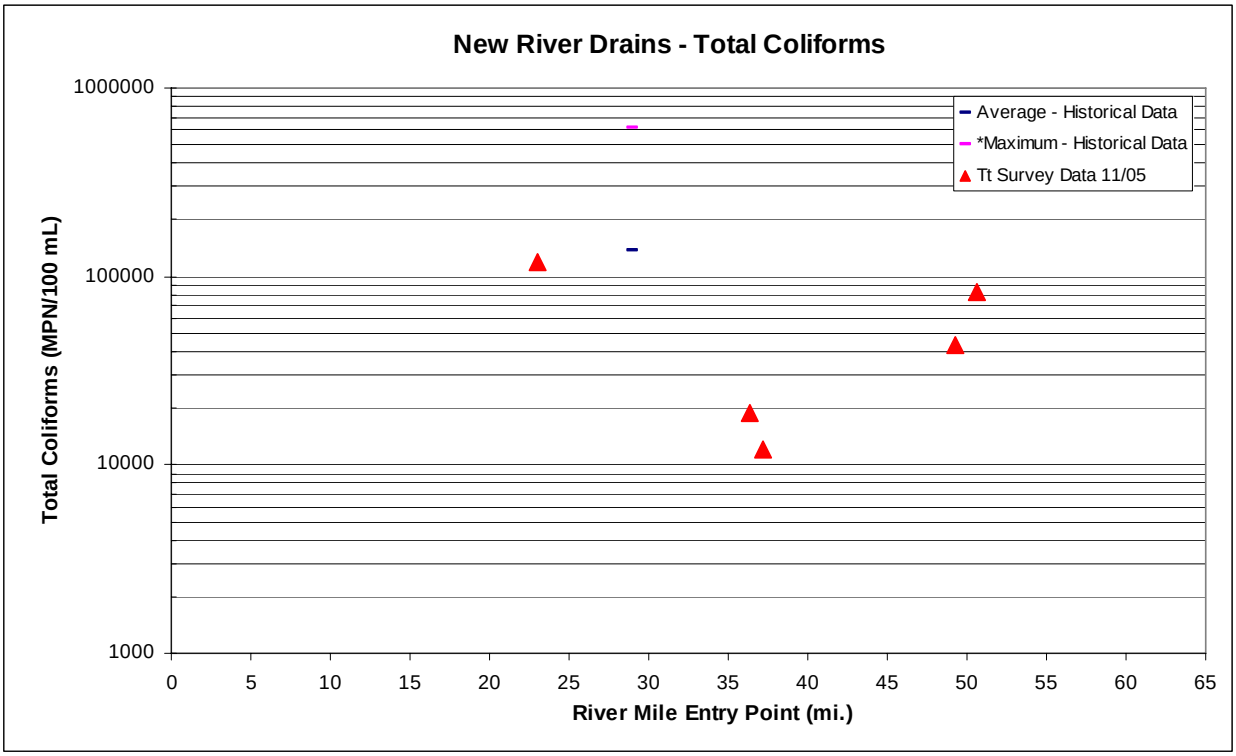


Figure 3-19. Comparison of drain water quality data for New River

*The maximum value was only shown when multiple data points were available.



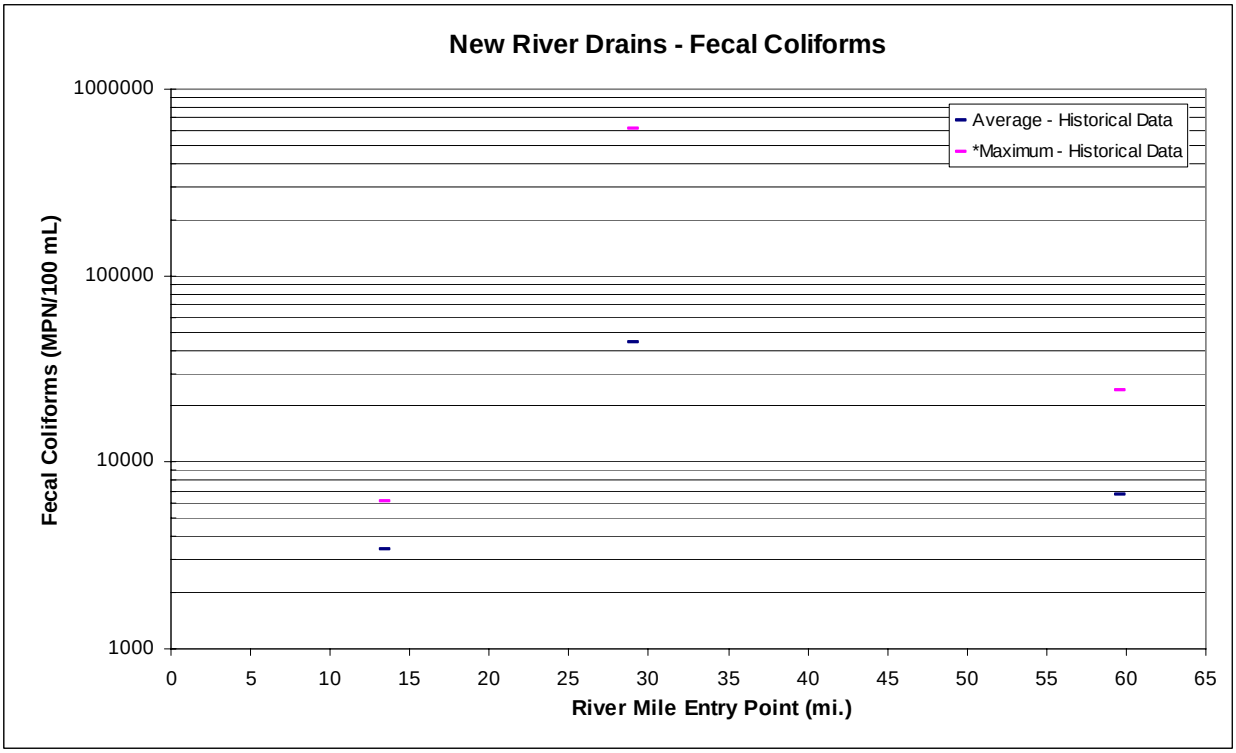


Figure 3-20. Comparison of drain coliform data for New River

*The maximum value was only shown when multiple data points were available.

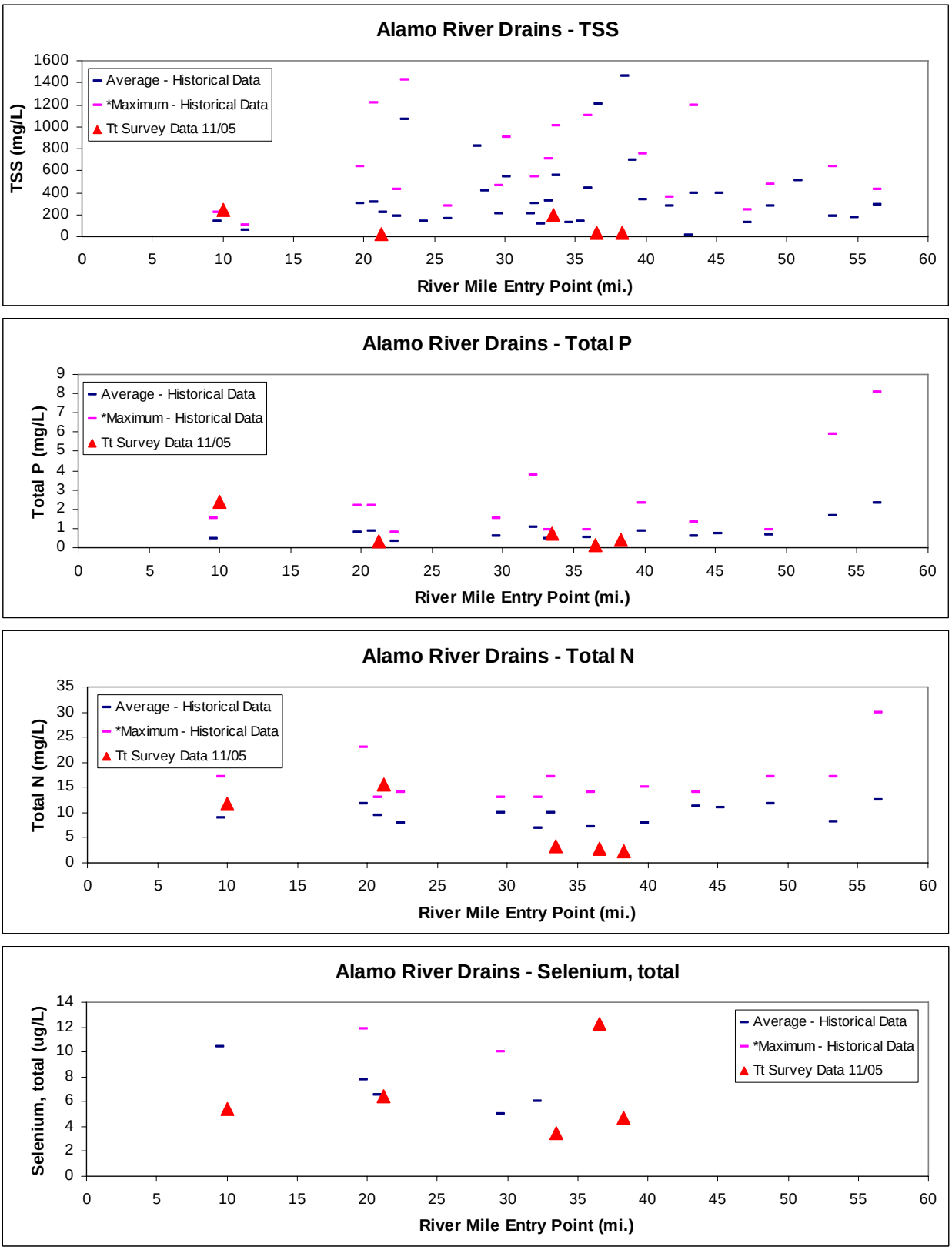


Figure 3-21. Comparison of drain water quality data for Alamo River

*The maximum value was only shown when multiple data points were available.

3.4 Data Quality Assessment

The surface water quality data generated during this study were assessed for analytical precision, accuracy, representativeness, and completeness. All samples collected met the data quality objectives described in the QAPP for this project (Tetra Tech, October 27, 2005a), with the following exceptions for inorganic Se, Se(IV), organic selenium, and Se(VI):

- NR-33/34A and its replicate,
- NR-33/34B
- IW3, IW10, and BWD

3.4.1 Inorganic Selenium

The matrix spike analysis of sample "NR-33/34A" yielded a recovery of 2.4%, failing to meet the recovery criterion (Recovery = 65 – 135%). The laboratory analyzed this sample at two different dilutions in an effort to overcome the apparent matrix interference. Based on the native sample analyses, as well as the matrix spike recovery, the laboratory provided an "N" qualifier for this sample for failing to meet the spike recovery criterion and an "E" qualifier for matrix interference. The laboratory also identified sample "NR-33/34B" as being of similar matrix and qualified it with "E" for potential matrix interference. As such, both sample results should be considered estimates.

3.4.2 Selenite, Se(IV)

The matrix spike and matrix spike duplicate analyses of samples "NR-33/34A" and "NR-33/34B" yielded matrix spike recoveries of 2.1 and 36.5%, respectively and a matrix spike duplicate for sample "NR-33/34A" yielded a recovery of 0.3%. These reported recoveries failed to meet the recovery criterion (Recovery = 65 – 135%). The laboratory reports that the "matrix suppression was not to be overcome by dilution." Both of these samples have been given qualifiers of "N" for failing to meet the spike recovery criterion and "E" for the presence of matrix interference. As such, both sample results should be considered estimates.

3.4.3 Selenate, Se(VI) and Organic Selenium

Based on the presence of matrix interference and the qualifiers identified above, SeVI and organic selenium concentrations were not calculated for these samples.

3.4.4 Completeness

These samples were the only samples scheduled to be collected from one New River wetland site (33/34). Since the concentrations of inorganic Se, selenite, organic Se, and selenate could not be quantified, and the level of uncertainty in the reported values is significantly large, the dataset for one New River wetland site (33/34) must be deemed incomplete.

3.4.5 Data Inversions and Inconsistencies

Large inversions between the total and dissolved concentrations of Se were observed in samples collected from sites IW-3 and BWD. The magnitude of these inversions indicates that they were caused by something other than the small inversions that are typical of samples where the dissolved phase dominates. The most probable cause of large inversions is sample contamination, the source of which is unknown. The level of uncertainty in the validity of the total and dissolved selenium values is large enough to justify excluding them from the dataset.

The dissolved selenium concentration reported for station IW-10 is inconsistent with other dissolved selenium values that were observed at the wetland. It is, however similar to the total selenium value reported for station BWD. This could indicate that bottles and/or labels became mixed-up, either in the field or in the laboratory but there is no way to confirm which. Thus, these data should be excluded from the dataset.

CHAPTER 4
BIOLOGICAL SAMPLING

4.1 Introduction

To support the ecological risk assessment of the treatment wetlands, sampling was conducted separately in 2005 and 2006. Sampling in 2005 was limited in nature, due to the low abundance of the target biota. Therefore, the data collected in 2005 was used to plan the next round of sample collection and to provide a preliminary indication of the risks to ecological receptors at the collection sites, by comparison to screening concentrations. In 2006, a larger and more comprehensive field sampling campaign was conducted. Concentration data were collected for a variety of environmental compartments, including fish, invertebrates, plants, algae, and supporting data on sediments and water. The data collected from 2006 was, therefore, used in a predictive ecological risk assessment that is presented in Chapter 10. This chapter provides a summary of the sampling methods and the results from the 2005 and 2006 sampling campaigns.

4.2 2005 Field Collections

In 2005, field sampling was performed in November-December. Surface water, sediments, and biota (i.e., plants, crayfish, shrimp, and fish) were collected from the Brawley and Imperial wetlands. The sampling methods used are described briefly below and in more detail in the Field Sampling Plan (Tetra Tech 2005). The sampling locations are shown in Figure 4-1. Laboratory data reports from the 2005 sampling effort are included electronically in the CD-ROM as Appendix G.

4.2.1 Biota sampling

Baited minnow traps were placed at each sampling location over night. Traps were baited with canned cat food. A small buoy was attached to each trap with a nylon rope. Traps were put in place using a grappling hook. Biota caught in the traps were immediately placed in the appropriate sample containers and the sample containers were placed on ice. To supplement what was caught in the traps, long handled (i.e., 12 to 18 ft) swimming pool cleaning nets were used to catch small fish (*i.e.*, mosquitofish) and glass shrimp. All specimens were immediately placed in the appropriate sample containers and the sample containers were placed on ice. Crayfish samples were collected from two locations and analyzed for total selenium and organochlorine pesticides. Glass shrimp samples were collected from six locations and analyzed for total selenium. Small fish (including mosquitofish, bluegill fry, and sailfin mollies) samples were collected from 15 locations. Three samples were analyzed

for both organochlorine pesticides (OCP) and total selenium. The remaining twelve samples were only analyzed for total selenium.

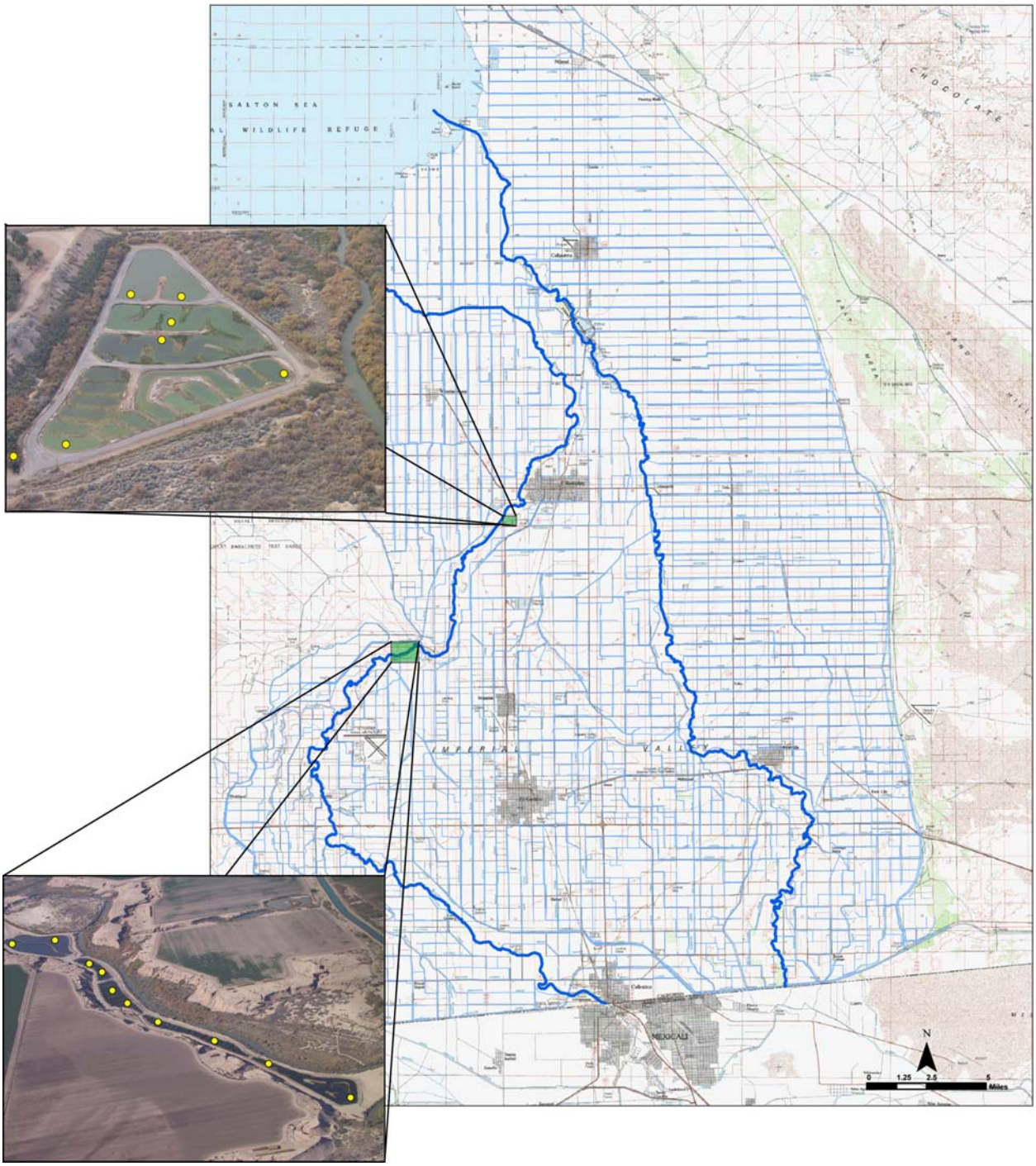


Figure 4-1 Biota sampling in the treatment wetlands during 2005 sampling

At each location where small fish were collected, cattails were also collected. Living cattails were pulled out from the banks and both the above ground green portions and below ground white portions were used to make up the sample. Roots were also collected, where possible. All specimens were immediately placed in the appropriate sample containers and the sample

containers were placed on ice. Fourteen plant samples were collected. Two samples were analyzed for organochlorine pesticides (OCP) and total selenium. The remaining twelve samples were only analyzed for total selenium.

The biota samples collected from each sampling location were homogenized by category (*i.e.*, small fish, crayfish, glass shrimp, and plants) prior to analysis.

4.2.2 Water/sediment sampling

At each location where small fish were collected, surface water and sediment samples were also collected. Surface water and sediment samples were collected as near to the center of the area in which biota samples were collected as possible. Surface water was collected using a 500 ml HDPE container on a pole-mounted grab sampler (i.e., a NASCO Swing Sampler). Before each surface water sample was collected, the container on the end of the grab sampler was rinsed three times with the target water. Sediment samples were collected using disposable plastic spoons. All samples were immediately placed in the appropriate sample containers and the sample containers were placed on ice.

Surface water samples were analyzed for total selenium and dissolved selenium. Fifteen sediment samples were collected. Three samples were analyzed for both organochlorine pesticides and selenium, while the remaining twelve samples were only analyzed for selenium.

4.2.3 Field measurements

A YSI multiprobe (model 6920) was used to record water temperature, conductivity, dissolved oxygen, pH, ORP, and turbidity. A field GPS unit was used to record elevation and barometric pressure, as well as X and Y coordinates. The date and time that sampling started was also recorded for each location.

The sampling locations are shown in Figure 4-1.

4.2.4 Surface water

Surface water samples were collected at each sampling location. The results were presented previously in Chapter 3.

4.2.5 Sediments

The parameters measured, analytical method used, number of stations sampled, and the total number of samples collected are presented in Table 4-1.

Sediment samples were collected from six stations in the Brawley Pilot Wetland and from 9 stations in the Imperial Pilot Wetland and analyzed for total selenium and organochlorine pesticides (Tables 4-2 and 4-3). Only sediments collected from sites having sufficient biological tissue volumes (Section 3.3) were analyzed for organochlorine pesticides.

Table 4-1
Summary of Sediment Parameters Measured

Parameter	Method	Number of Stations	Total # Samples
Total Selenium	EPA 1638 (modified)	15	15
Organochlorine Pesticides	EPA 8081A	3	3

Table 4-2
Summary of Brawley Pilot Wetland Sediment Data

Parameter	Station ID					
	BW-1	BW-2	BW-3	BW-4	BW-6	BWD
Total Se (ug/g – dry wt)	3.309	0.421	1.151	<0.287	0.432	1.075
Total Solids (%)	64.04	76.02	69.88	69.61	50.96	37.22
Organochlorine Pesticides (ug/kg-dry wt.)	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed	
alpha-BHC						<1.8
beta-BHC						<7.5
gamma-BHC (Lindane)						<2.7
delta-BHC						<2.0
Heptachlor						<2.1
Aldrin						<1.2
Heptachlor Epoxide						<3.4
gamma-Chlordane						<0.72
Endosulfan						<1.0
alpha-Chlordane						<1.4
Dieldrin						<0.56
4,4'-DDE						**2.9**
Endrin						<0.69
Endosulfan II						<1.1
4,4'-DDD						<0.65
Endrin Aldehyde						<0.99
Endosulfan Sulfate						<0.74
4,4'-DDT						<1.1
Endrin Ketone						<0.75
Methoxychlor						<2.4
Toxaphene						<59

Table 4-3
Summary of Imperial Pilot Wetland Sediment Data

Parameter	Station ID					
	IW-1	IW-2	IW-3	IW-4	IW-5	IW-6
Total Se (ug/g – dry wt)	<0.294	0.33	0.955	<0.251	<0.277	1.055
Total Solids (%)	67.96	69.6	56.56	79.76	72.2	60.12
Organochlorine Pesticides (ug/kg-dry wt.)	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed

Table 4-3
Summary of Imperial Pilot Wetland Sediment Data, Continued

Parameter	Station ID		
	IW-7	IW-8	IW-10
Total Se (ug/g – dry wt)	4.055	0.828	0.275
Total Solids (%)	57.95	70.08	72.82
Organochlorine Pesticides (ug/kg-dry wt.)			Not analyzed
alpha-BHC	<1.5	<1.1	
beta-BHC	<5.7	<3.4	
gamma-BHC (Lindane)	<2.1	<1.6	
delta-BHC	<1.5	<1.2	
Heptachlor	<1.6	<1.2	
Aldrin	<1.2	<0.67	
Heptachlor Epoxide	<2.7	<2.0	
gamma-Chlordane	<0.57	<0.42	
Endosulfan	<0.65	<0.48	
alpha-Chlordane	<1.1	<0.76	
Dieldrin	<4.8	<0.42	
4,4'-DDE	**4.0**	**2.4**	
Endrin	<0.54	<0.40	
Endosulfan II	<0.85	<0.62	
4,4'-DDD	<0.51	<0.38	
Endrin Aldehyde	<0.77	<0.57	
Endosulfan Sulfate	<0.67	<0.43	
4,4'-DDT	<0.84	<0.62	
Endrin Ketone	<5.0	<0.43	
Methoxychlor	<1.9	<1.4	
Toxaphene	<46	<34	

Total Selenium – Selenium concentrations in the Brawley Pilot Wetlands ranged from non-detectable (<0.29 µg/g-dry wt. at BW-4) to 3.3 µg/g-dry wt. at BW-1. Concentrations in the Imperial Pilot Wetlands ranged from non-detectable (<0.251 µg/g-dry wt at IW-4) to 4.06 µg/g-dry wt. at IW-7 (Tables 4-2 and 4-3). Total selenium was also below detection in IW-1 and IW-5.

There are currently no applicable sediment quality criteria for selenium.

Organochlorine Pesticides – Although there are no existing sediment quality criteria for organochlorine pesticides, NOAA (1999) provides screening-level guidelines (SQuiRT) that are useful in determining the potential affect that a limited number of pollutants might pose to aquatic life.

The appropriate endpoint to assess the potential for impairment of infaunal aquatic life is the Threshold Effects Level (TEL). The TEL is the concentration below which adverse effects are expected to occur only rarely (NOAA 1999).

The only organochlorine pesticide that was present in quantifiable concentrations was 4,4'-DDE, which was found in the Brawley Pilot Wetland's station BWD (2.9 µg/kg-dry wt.) and at the Imperial Pilot Wetland's station IW-7 (4.0 µg/kg-dry wt.) and IW-8 (2.4µg/kg-dry wt.) (Tables 4-2 and 4-3). All values exceed the TEL for 4,4'-DDE of 1.42 µg/kg-dry wt.

Data Quality Assessment – The sediment quality data generated during this study were assessed for analytical precision, accuracy, representativeness, and completeness. All samples collected and analyzed for total selenium and organochlorine pesticides met the data quality objectives for precision and accuracy as described in the QAPP for this project (Tetra Tech, October 27, 2005a). However, a preliminary assessment has indicated that representativeness and completeness were affected for the organochlorine pesticide (OCP) analyses because only those sediments that were collected from sample stations having a sufficient quantity of tissue were analyzed for OCPs. Thus, the dataset must be deemed incomplete since only three samples were analyzed for OCPs (i.e., one from the Brawley pilot wetlands and two from the Imperial pilot wetlands).

4.2.6 Biota Collected

Tissue samples from fish, aquatic invertebrates, and aquatic plants were collected from six stations in the Brawley pilot wetland and from 9 stations in the Imperial pilot wetland and analyzed for total selenium and organochlorine pesticides. The limited availability and low quantities of some types of tissue resulted in a reduction of the number of analytes measured at each site. The parameters measured, analytical method used, number of stations sampled, and the total number of samples collected are presented in Table 4-4.

Table 4-4
Summary of Tissue Parameters Measured

Species	Parameter	Method	Number of Stations	Total # Samples
Cattails				
	Total Selenium	EPA 1638 (modified)	14	14
	OCPs	EPA 8081A	2	2
Crayfish				
	Total Selenium	EPA 1638 (modified)	2	2
	OCPs	EPA 8081A	2	2
Shrimp				
	Total Selenium	EPA 1638 (modified)	5	5
	OCPs	EPA 8081A	-	-
Fish				
	Total Selenium	EPA 1638 (modified)	15	15
	OCPs	EPA 8081A	3	3

The minnow traps that were used in an attempt to catch crayfish and mosquitofish proved to be ineffective, with biota only being caught in two of the traps (i.e., BW-D [crayfish and fish] and IW-8 [crayfish]). To supplement what was caught in the minnow traps, long handled (i.e., 12 to 18 ft long) swimming pool cleaning nets were used. With these nets, mosquitofish (*Gambusia* spp.), glass shrimp (*Palaemonetes* spp.), and bluegill fry (*Lepomis* sp.) were collected.

Cattails (*Typha* sp) were collected from each location where mosquitofish were captured. Living cattails were pulled out from the banks and both the above ground green portions and below ground white portions were used to make up the sample. Roots were also collected, where possible.

All tissue samples were collected by Tetra Tech staff and placed into pre-cleaned and labeled sample jars and stored in sample coolers containing wet-ice and maintained under Chain-of-Custody. At the end of each sampling day, the tissue samples were transferred into a secure freezer where they remained until they were re-packed into sample coolers containing dry-ice and frozen Blue-ice. The sample coolers were shipped, under Chain-of-Custody, via overnight courier to Brooks-Rand (Seattle, WA) and Columbia Analytical Services (Kelso, WA) where they were analyzed for total selenium and organochlorine pesticides, respectively. More detailed descriptions of the sampling, and sample handling, procedures can be found in the Field Sampling Plan for this project entitled, *Field Sampling Plan for New and Alamo River Wetland Master Plan: Phase I Studies* (Tetra Tech, October 27, 2005).

The analytical results will be discussed below separately by tissue type.

4.2.7 Cattails (*Typha* sp)

The analytical results for the Cattail (*Typha* sp) tissue samples are summarized below in Tables 4-5 and 4-6 for the Brawley and Imperial Pilot Wetlands, respectively.

Table 4-5.
Summary of Brawley Pilot Wetland Cattails (*Typha* sp) Data (dry wt)

	Station ID				
Parameter	**BW-1**	**BW-2**	**BW-3**	**BW-4**	**BW-6**
Total Se (ug/g – dry wt)	<1.13	<0.78	<0.90	<0.78	<0.93
Total Solids (%)	9.7	14.1	12.3	14.0	11.5
OCPs (ug/kg-dry wt.)	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed

Table 4-6.
Summary of Imperial Pilot Wetland Cattails (Typha sp) Data (dry wt)

	Station ID					
Parameter	**IW-1**	**IW-2**	**IW-3**	**IW-4**	**IW-5**	**IW-6**
Total Se (ug/g – dry wt)	<0.62	1.19J	1.79	<0.68	<1.07	<0.73
Total Solids (%)	17.71	11.73	26.27	16.25	10.28	15.01
OCPs (ug/kg-dry wt.)	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed

Table 4-6
Summary of Imperial Pilot Wetland Cattails
(*Typha* sp) Data (dry wt), Continued

Parameter	Station ID IW-7	IW-8
Total Se (ug/g – dry wt)	1.06J	<1.44
Total Solids (%)	22.68	7.66
OCPs (ug/kg-dry wt)		
Aldrin	<1.2	<19
alpha-BHC	<2	<17
beta-BHC	<3.1	<38
gamma-BHC (Lindane)	<9.5	**5.4J**
delta-BHC	**4.0J**	<4.6
gamma-Chlordane	<2.4	<19
alpha-Chlordane	<1.8	<19
Dieldrin	<0.77	<5.8
4,4'-DDE	<9.5	<2.3
4,4'-DDD	<17	<37
4,4'-DDT	<1.7	<3.2
Endrin	<0.84	<9
Endosulfan	<1.6	<4.5
Endosulfan II	<2.2	<21
Endrin Aldehyde	<2.4	<18
Endosulfan Sulfate	<1.6	<5.1
Endrin Ketone	<2.3	<4.6
Heptachlor	<3.7	<3.6
Heptachlor Epoxide	<2.4	<20
Methoxychlor	<2.0	<4.0
Toxaphene	<180	<520

Total Selenium – Selenium was not detected in cattail samples from the Brawley Pilot Wetlands. Concentrations in cattail samples from the Imperial Pilot Wetlands ranged from non-detectable to 1.79 µg/g-dry wt at IW-3 (Tables 4-5 and 4-6).

Organochlorine Pesticides – The only organochlorine pesticides that were present in quantifiable concentrations were gamma-BHC (Lindane) and delta-BHC. BHC was detected only in cattail samples from the Imperial Wetland, with gamma-BHC detected only in the sample from IW-7 (4.0 µg/kg-dry wt) and delta-BHC detected only in the sample from IW-8 (5.4 µg/kg-dry wt) (Tables 4-5 and 4-6).

There are currently no applicable aquatic plant criteria for either selenium or organochlorine pesticides.

4.2.8 Glass shrimp (Palaemonetes spp.)

The results of the glass shrimp (*Palaemonetes* spp.) analyses are summarized in Tables 4-7 and 4-8 for the Brawley and Imperial Pilot Wetlands.

Table 4-7
Summary of Glass Shrimp (*Palaemonetes* spp.) Samples (dry wt)

Parameter	Brawley Wetlands BW-1	BW-2	BW-3	BW-4	BW-6	Imperial Wetlands IW-1
Total Se (ug/g – dry wt)	3.31	3.52	3.09	1.04	0.79	0.71
Total Solids (%)	24.48	24.17	26.22	---	---	---
OCPs (ug/kg-dry wt)	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed

Total Selenium – Total selenium concentrations in glass shrimp samples from the Brawley Pilot Wetlands ranged from 0.79 µg/g-dry wt to 3.52 µg/g-dry wt. Only one glass shrimp sample was collected from the Imperial Pilot Wetlands. The sample collected at IW-1 had a selenium concentration of 0.71 µg/g-dry wt (Table 4-7).

Screening criteria for selenium protective of freshwater invertebrates are available from only one source; i.e., the National Irrigation Water Quality Program (NIWQP). These screening criteria are summarized in Table 4-8 below:

Table 4-8
NIWQP Screening criteria for selenium in aquatic invertebrates

Receptor	Effect	Concentration (mg/kg dw)
Amphipods, midge larvae	Growth	2.5-15
Amphipods, midge larvae	Reproduction	30
Crayfish	Respiration	30
Diet - fish (bluegill)	Reproduction (IC_{10})	10
Diet - fish (bluegill)	Reproduction (IC_{100})	30-35
Diet - birds	Reproduction	3-8

Measured selenium concentrations in glass shrimp exceeded the NIWQP criteria protective of 1) growth in amphipods and midge larvae and 2) reproduction effects in birds from the consumption of aquatic biota. It should be noted that the screening criterion for selenium effects on amphipods and midge larvae may not be entirely applicable to glass shrimp.

Organochlorine Pesticides – Organochlorine pesticides were not analyzed in glass shrimp (*Palaemonetes* spp.) at the Brawley or Imperial Pilot Wetlands as insufficient sample mass was collected for analysis.

4.2.9 Crayfish

The results of the crayfish analyses are summarized in Table 4-9, below.

Table 4-9
Summary of Brawley Pilot Wetland Crayfish Data (dry wt)

	Station ID	
Parameter	**BW-D**	**IW-8**
Total Se (ug/g – dry wt)	1.8	3.36
Total Solids (%)	33.83	23.82
OCPs (ug/kg-dry wt.)		
Aldrin	<12	<9.1
alpha-BHC	<5.7	<11
beta-BHC	<2.5	<3
gamma-BHC (Lindane)	<7.6	<12
delta-BHC	<1.9	<2.2
gamma-Chlordane	<1.9	<2.3
alpha-Chlordane	<4.9	<9.1
Dieldrin	<4.8	<9.1
4,4'-DDD	<26	<26
4,4'-DDE	**15**	**47**
4,4'-DDT	<1.3	<1.9
Endosulfan	<5.3	<3.5
Endosulfan II	<2.3	**3.8J**
Endosulfan sulfate	<1.3	<1.7
Endrin	**3.7J**	<0.8
Endrin aldehyde	<1.6	<7.9
Endrin ketone	<1.9	<2.2
Heptachlor	<1.5	<1.3
Heptachlor epoxide	<1.9	<9.1
Methoxychlor	<1.6	<2
Toxaphene	<290	<280

Total Selenium – The selenium concentration in crayfish collected from the Brawley Pilot Wetlands at BW-D in was 1.80 µg/g-dry wt and the concentration of selenium from the crayfish collected at IW-8 from the Imperial Pilot Wetlands was 3.36 µg/g-dry wt. (Table 4-9).

The concentration of selenium in crayfish at BW-D did not exceed any of the screening criteria for aquatic invertebrates (Table 4-8). However, the concentration of selenium in

crayfish from IW-8 exceeded the screening criteria protective of 1) growth in amphipods and midge larvae and 2) reproduction effects in birds from the consumption of aquatic biota. It should be noted that the screening criterion for selenium effects on amphipods and midge larvae may not be entirely applicable to crayfish.

Organochlorine Pesticides – Screening values appropriate for crayfish are available from Jarvinen and Ankley (1999) and the NIWQP (1989). The screening values from these two sources are shown in Table 4-10 below.

Table 4-10
Screening criteria for OCPs in aquatic invertebrates

Chemical	Source	Receptor	Effect	Concentration (ug/kg dw)
DDE	1	Diet - waterfowl	eggshell thinning	10,000-30,000
Endosulfan (technical)	2	Crayfish	mortality (LC_{50})	700
Endrin	2	Saltwater shrimp	reduced reproduction	50

Sources: 1-NIWQP (1998) 2-Jarvinen and Ankley (1999)

The only organochlorine pesticides that were detected in crayfish were 4,4'-DDE, endrin, and endosulfan II. 4,4'-DDE was detected in crayfish collected from BW-D in the Brawley Pilot Wetland and IW-8 from the Imperial Wetland. Endrin was detected only in crayfish from BW-D in the Brawley Wetland. Endosulfan II was detected only in crayfish from IW-8 in the Imperial Wetland station (Table 4-9). None of the detected concentrations of these pesticides exceeded the available screening criteria. However, there are relatively few screening criteria available.

4.2.10 Fish

The results of the fish analyses are summarized in Tables 4-11 and 4-12 for the Brawley and the Imperial Pilot Wetlands, respectively.

Table 4-11
Summary of Brawley Pilot Wetland Fish Data (dry wt)

	Station ID					
Parameter	**BW-1**	**BW-2**	**BW-3**	**BW-4**	**BW-6**	**BW-D**
Fish composited	A	A	A	A	A	A, B, C
Total Se (ug/g – dry wt)	2.75	3.57	2.74	3.41	6.46	2.87
Total Solids (%)	24.71	24.35	22.3	22.85	23.98	23
OCPs (ug/kg-dry wt.)	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed	
Aldrin						<9
alpha-BHC						<1.9
beta-BHC						**31**
gamma-BHC (Lindane)						<13
delta-BHC						<2.2
gamma-Chlordane						<9
alpha-Chlordane						**7.7J**
Dieldrin						<9
4,4'-DDD						<16
4,4'-DDE						**700**
4,4'-DDT						**4.2J**
Endrin						**12**
Endrin aldehyde						<1.8
Endrin ketone						<2.2
Endosulfan						**10**
Endosulfan II						<1.7
Endosulfan sulfate						<6.8
Heptachlor						<1.2
Heptachlor epoxide						<2.3
Methoxychlor						<1.9
Toxaphene						<650

Note: A = mosquitofish, B = bluegill (fry), C = sailfin molly

Table 4-12
Summary of Imperial Pilot Wetland Fish Data (dry wt)

Parameter	Station ID IW-1	IW-2	IW-3	IW-4	IW-5	IW-6	IW-10
Fish composited	A	A	A	A	A	A, B	A
Total Se (ug/g – dry wt)	4.01	2.77	3.93	3.87	4.24	6.03	4.71
Total Solids (%)	32.2	26.36	25.68	26.9	27.6	24.86	27.41
OCPs (ug/kg-dry wt.)	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed

Note: A = mosquitofish, B = bluegill (fry)

Table 4-12
Summary of Imperial Pilot Wetland Fish Data (dry wt), Continued

Parameter	Station ID IW-7	IW-8
Fish composited	A	A
Total Se (ug/g – dry wt)	4.96	5.39
Total Solids (%)	26.19	23.38
OCPs (ug/kg-dry wt)		
Aldrin	**6.5J**	<5
alpha-BHC	<1.8	<2
beta-BHC	**47**	**57**
gamma-BHC (Lindane)	<7.4	<30
delta-BHC	<3.6	<8.7
gamma-Chlordane	<5.4	<4.6
alpha-Chlordane	<1.6	**2J**
Dieldrin	**24**	<9.5
4,4'-DDD	**31**	**28**
4,4'-DDE	**260**	**160**
4,4'-DDT	<2.6	<4.5
Endrin	<5	**4J**
Endrin aldehyde	<8.1	<17
Endrin ketone	<3.8	<2.3
Endosulfan	<3.5	<9.5
Endosulfan II	<0.74	**1.7J**
Endosulfan sulfate	**12**	**13**
Heptachlor	<1.1	<62
Heptachlor epoxide	<8.5	**7.6J**
Methoxychlor	<1.8	<2
Toxaphene	<380	<270

Note: A = mosquitofish

Total Selenium **–** Selenium concentrations fish samples collected from the Brawley Pilot Wetlands ranged from 2.74 µg/g-dry wt at BW-3 to 6.46 µg/g-dry wt at BW-6. Concentrations in fish samples collected from the Imperial Pilot Wetlands ranged from 2.77 µg/g-dry wt at IW-2 to 6.03 µg/g-dry wt at IW-6 (Tables 4-11 and 4-12).

Concentrations of selenium in fish tissues collected from both the Brawley and Imperial Wetlands exceeded the lower bound of the NIWQP criterion of 4-6 mg/g-dry wt. This criterion is the estimated threshold range (LC_{10}) for reproductive impairment in sensitive species (perch, bluegill, salmon) (Table 4-13). In addition, concentrations of selenium in fish tissues collected from both the Brawley and Imperial Wetlands exceeded the lower bound of the NIWQP criterion of 3-8 mg/g-dry wt for reproductive effects in bids. However, none of the measured concentrations exceeded 8 mg/kg, the upper bound of this criterion.

Table 4-13
Screening Criteria for Chemicals in Fish tissues

Chemical	Source	Receptor	Effect	Concentration
				(mg/kg dry wt)
Selenium	2	perch, bluegill	reproduction (IC_{10})	4-6
	2	bluegill	reproduction (IC_{100})	15-20
	2	Diet - birds	reproductive impairment	3-8
	2	Diet - birds	toxicity in non-breeding birds	10-15
	3	fish	survival	7.91
				(ug/kg dry wt)
Aldrin				
beta-BHC	1	Guppy	Reduced juvenile survival (alpha-BHC)	170,000
	1	Fathead minnow	Reduced juvenile survival (gamma-BHC)	9,530
alpha-Chlordane				
Dieldrin	1	Rainbow trout	Reduced juvenile survival (LC_{50})	5,650
DDD/DDE/DDT	1	Fathead minnow	Mortality (LC_{25})	57,000
	1	Sailfin molly	Reduced survival, growth	77,300
	1	Green sunfish	Reduced juvenile survival	24,000
Endosulfan (II and sulfate)	1	Tilapia	Reduced juvenile survival (LC_{40})	360
	1	Tilapia	Reduced sub-adult survival	115
Endrin	1	Bluegill	Reduced survival	300
Heptachlor epoxide	1	Fathead minnow	No effect	17,730

Sources: 1 Jarvinen and Ankley (1999), 2 NIWQP (1998), 3 USEPA (2004)

Organochlorine Pesticides **–** Eight organochlorine pesticides were detected in fish samples collected from the Brawley and Imperial Pilot Wetlands (Tables 4-11 and 4-12). None of the OCPs were detected at concentrations exceeding screening criteria protective of fish. However, no screening criteria were available for aldrin and alpha-chlordane. Screening criteria were also not available for the protection of piscivorous birds, which may be lower than screening criteria protective only of the fish themselves.

4.2.11 Data Quality Assessment

The tissue quality data generated during this study were assessed for analytical precision, accuracy, representativeness, and completeness. All samples collected and analyzed for total selenium met the data quality objectives for precision and accuracy as described in the QAPP for this project (Tetra Tech, October 27, 2005a).

A preliminary assessment of the OCP data has indicated that representativeness and completeness were affected for the organochlorine pesticide (OCP) analyses. This is because sufficient fish and/or aquatic invertebrate tissue sample mass was not available at most sites for OCP analysis. At most sampling locations, it was barely feasible to obtain the 2 g of fish and/or aquatic invertebrate tissue necessary for selenium analysis was, making the 20 g of tissues required for OCP analysis impossible to obtain at most locations. Thus, only three samples were analyzed for OCPs (one from the Brawley pilot wetlands and two from the Imperial pilot wetlands). This data set will be supplemented with additional field sampling in the pilot wetlands, rivers, and drains in May 2006.

4.3 2006 Field Collections

In 2006, field sampling was performed in May-June. Surface water, sediments, and biota (i.e., algae, aquatic macrophytes, tadpoles, crayfish, shrimp, and juvenile and adult fish) were collected from the Brawley and Imperial wetlands as well as several drains and at the New and Alamo Rivers. The sampling methods used are described briefly below and in more detail in the Field Sampling Plan (Tetra Tech 2006). The sampling locations are shown in Figure 4-2.

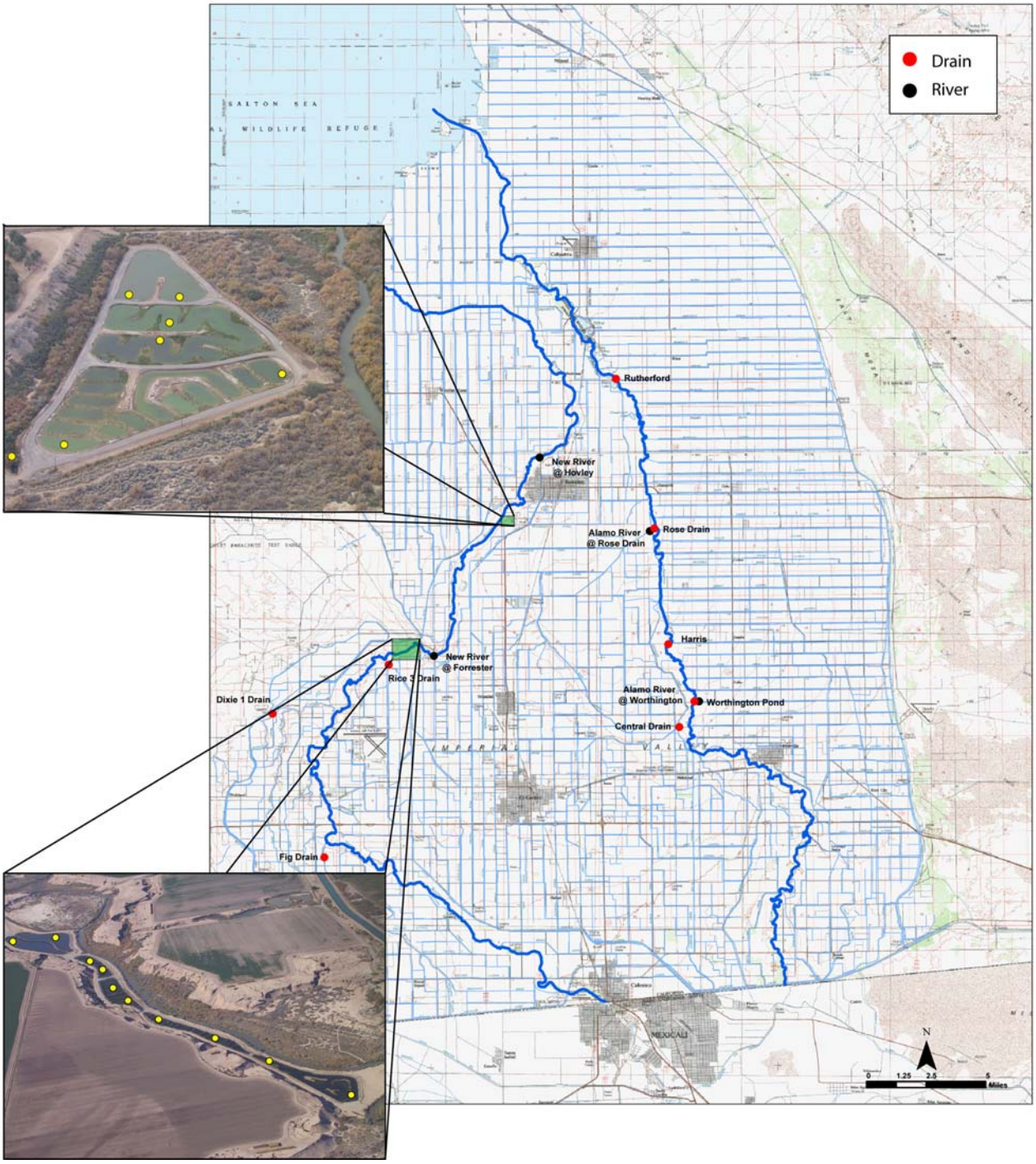


Figure 4-2 Biota sampling in the treatment wetlands during 2006 sampling

4.3.1 Biota sampling

Baited minnow traps were placed at each sampling location over night. A small buoy was attached to each trap with a nylon rope. Biota caught in the traps were immediately placed in the appropriate sample containers and the sample containers were placed on ice. Traps were put in place using a grappling hook. Traps were first baited with chicken liver placed in perforated plastic jars. The perforations allowed aquatic biota to smell the chicken liver but

not to eat it; thus, eliminating the need to depurate any biota captured in the traps. Results were similar to the previous year's sampling efforts, with only a few specimens being captured. Whole chicken legs were then tried in order to catch crayfish without success. To supplement what was caught in the traps, long handled (i.e., 12 to 18 ft) swimming pool cleaning nets and hand-held cast nets were used to catch small fish (i.e., mosquitofish), crayfish, and glass shrimp. Additionally, the Department of Fish and Game used gill nets to catch larger fishes.

All specimens were immediately placed in the appropriate sample containers and the sample containers were placed on dry ice. Samples ready for shipment were shipped overnight to the appropriate analytical laboratories with dry ice the day of collection. Some samples (i.e., a few biota samples and all larger fishes (see below)) were temporarily (maximum of two and a half weeks) stored frozen until shipment.

Smaller biota (e.g., mosquitofish, crayfish, glass shrimp, etc) were submitted in single jars with all specimens in a jar to be homogenized. Larger fish (i.e., bass, bluegill carp, shad, tilapia) were stored frozen until the sampling effort was complete. The, larger fish were partially thawed, their total lengths were measured, and the fish were divided up into specimens for discrete analysis and composite analysis. The specimens to be composited were chosen according to the following criteria: 1) from the same species, 2) from the same sampling location; and 3) within 25% of the length of the largest individual composited. Larger fishes that were not composited were analyzed only for selenium, whereas those that were composited were analyzed for both selenium and OCPs. All larger fish were shipped in plastic bags to Applied Speciation. At Applied Speciation, the fish were homogenized and sub-samples of the homogenates from the composite samples were sent onwards to Columbia Analytical in the appropriate sample containers for OCP analysis.

USFWS staff visited the treatment wetlands and agricultural drains to collect bird eggs as part of this study. Despite extensive searches of nesting sites conducted over a period od three days, no viable bird eggs were found. A limited amount of bird egg data exists from a prior study conducted in 2003 by USFWS and was used for the ecological risk assessment in Chapter 10.

The analyses performed are summarized in Table 4-14 and the samples that were collected are summarized in Table 4-15. Laboratory data reports from the 2006 sampling effort are included electronically in the CD-ROM as Appendix H.

Table 4-14
2006 Biological Data Analyses

Medium	Analyses			
	Total Se[a]	Dissolved Se[a]	Se species[b]	OCPs[c]
Surface water	28	28	28	-
Sediment	28	-	28	28
Aquatic plants				
algae[d]	17	-	-	13
aquatic macrophytes	2	-	-	2
Aquatic Invertebrates				
corixids	5	-	-	-
crayfish	6	-	-	3
dragonfly nymphs	2	-	-	-
glass shrimp	6	-	-	-
tadpoles	3	-	-	3
Small fishes				
carp (juveniles)[e]	2	-	-	-
mosquitofish	28	-	-	-
red shiner	5	-	-	-
sailfin molly	2	-	-	1
shortfin molly	4	-	-	-
Large fishes				
bass	1	-	-	1
carp	15	-	-	9
threadfin shad	11	-	-	11
tilapia	29	-	-	5

Notes:
a - Analyzed using ICP-DRC-MS; EPA 200.8 for water and tissue; EPA 6020 for sediments
b - Analyzed using IC-ICP-DRC-MS; ASC-084.1 for water; ASC-067.1 for sediments
c - Analyzed using EPA Method 8081A.
d - Includes *Cladophora* spp., algae mixed with detritus, and *Enteromorpha* spp.
e - Juvenile carp were up to 4 cm in length. 2 g of material were composited for analysis.

Table 4-15
2006 Biological Data Collected at Each Sampling Location

	Treatment Wetlands									
Location	**IW-1**	**IW-2**	**IW-3**	**IW-4**	**IW-5**	**IW-6**	**IW-7**	**IW-8**	**IW-9**	**IW-10**
date	24-May	24-May	24-May	24-May	23-May	23-May	23-May	23-May	24-May	24-May
pH	8.14	8.36	8.06	8.13	7.88	7.6	7.54	8.56	7.59	8.04
DO (mg/L)	10.63	12.9	8.62	7.26	5.55	2.65	1.4	9.42	2.95	8.55
Turbidity (NTU)	32.8	22.8	43.5	63.5	59.2	8	7	13.4	9.3	20.3
Temp (°C)	24.66	24.66	24.8	25.12	29.94	25.23	25.1	26.1	24.82	26.21
Water (Se only)	X	X	X	X	X	X	X	X	X	X
Sediments (Se and OCPs)	X	X	X	X	X	X	X	X	X	X
Se in biota										
algae[b]	X	X	X	X		X	X	X		X
aquatic macrophytes										
corixids				X	X	X	X			
crayfish										
dragonfly nymphs								X		
glass shrimp							X			
tadpoles										
carp (juveniles)[c]							X			
mosquitofish	X	X	X	X	X	X	X	X		X
red shiner										
sailfin molly										
shortfin molly										
OCPs in various media										
algae[b]	X	X	X	X			X	X		X
aquatic macrophytes										
crayfish										
tadpoles										
sailfin mollies										
Large fish										
bass									X	
carp	X	X	X	X	X	X	X			X
threadfin shad	X	X	X	X	X			X	X	X
tilapia										

Definitions:
X - Sample collected.
NS - Not sampled.
Notes:
a - BW-1 and BW-2 were treated as a single sampling location for large fishes.
b - Includes *Cladophora* spp., algae mixed with detritus, and *Enteromorpha* spp.
c - Juvenile carp were up to 4 cm in length. 2 g of material were composited for analysis.

Table 4-15 (continued)
2006 Biological Data Collected at Each Sampling Location

		Treatment Wetlands						
Location		**BW-1[a]**	**BW-2[a]**	**BW-3**	**BW-4**	**BW-5**	**BW-6**	**BW-D**
	date	25-May	25-May	25-May	25-May	25-May	25-May	25-May
	pH	7.96	7.64	8.24	8.43	7.75	8.03	8.05
DO	**(mg/L)**	10.96	5.37	14.42	15.9	4.98	7.95	8.14
Turbidity	**(NTU)**	18.6	46.5	31.9	19.7	12	7	37
Temp	**(°C)**	26.45	25.11	27.35	27.48	28.87	29.2	28.33
Water (Se only)		X	X	X	X	X	X	X
Sediments (Se and OCPs)		X	X	X	X	X	X	X
Se in biota								
	algae[b]			X	X	X	X	
	aquatic macrophytes							
	corixids							
	crayfish		X					X
	dragonfly nymphs					X		
	glass shrimp	X	X	X	X	X		
	tadpoles			X				
	carp (juveniles)[c]							
	mosquitofish	X	X	X	X	X	X	X
	red shiner							
	sailfin molly							X
	shortfin molly							
OCPs in various media								
	algae[b]				X		X	
	aquatic macrophytes							
	crayfish							X
	tadpoles			X				
	sailfin mollies							X
Large fish								
	bass							
	carp		X		X			
	threadfin shad		X	X	X			
	tilapia		X		X			X

Definitions:
X - Sample collected.
NS - Not sampled.
Notes:
a - BW-1 and BW-2 were treated as a single sampling location for large fishes.
b - Includes *Cladophora* spp., algae mixed with detritus, and *Enteromorpha* spp.
c - Juvenile carp were up to 4 cm in length. 2 g of material were composited for analysis.

Table 4-15 (continued)
2006 Biological Data Collected at Each Sampling Location

		Ag Drains					
Location		**Dixie 1 Drain**	**Rice 3 Drain**	**Rose Drain**	**Central Drain**	**Fig Drain**	**Worthington Pond**
	date	30-May	30-May	31-May	31-May	1-Jun	2-Jun
	pH	7.84	7.7	7.27	7.62	8.06	7.85
DO	**(mg/L)**	7.36	5.56	4.7	6.94	10.81	2.92
Turbidity	**(NTU)**	100.1	179.9	154.2	168.7	44.2	19.5
Temp	**(°C)**	28.08	28.12	23.05	26.49	23.47	25.49
Water (Se only)		X	X	X	X	X	X
Sediments (Se and OCPs)		X	X	X	X	X	X
Se in biota							
	algae[b]	X					X
	aquatic macrophytes					X	X
	corixids						X
	crayfish	X	X	X		X	
	dragonfly nymphs						
	glass shrimp						
	tadpoles	X					X
	carp (juveniles)[c]						
	mosquitofish	X	X	X	X	X	X
	red shiner	X		X	X		
	sailfin molly				X		
	shortfin molly	X		X		X	
OCPs in various media							
	algae[b]	X					X
	aquatic macrophytes					X	X
	crayfish	X				X	
	tadpoles	X					X
	sailfin mollies						
Large fish							
	bass						NS
	carp		X				NS
	threadfin shad						NS
	tilapia	X			X	X	NS

Definitions:
X - Sample collected.
NS - Not sampled.
Notes:
a - BW-1 and BW-2 were treated as a single sampling location for large fishes.
b - Includes *Cladophora* spp., algae mixed with detritus, and *Enteromorpha* spp.
c - Juvenile carp were up to 4 cm in length. 2 g of material were composited for analysis.

Table 4-15 (continued)
2006 Biological Data Collected at Each Sampling Location

Location	New River at Forrester	New River at Hovley	Rose Drain	Alamo River at Worthington	Alamo River at Harris	Alamo River at Rutherford
date	1-Jun	1-Jun	31-May	2-Jun	2-Jun	2-Jun
pH	7.6	7.56	7.78	7.77	7.74	7.74
DO (mg/L)	0.28	4.01	7.7	7.58	7.34	7.61
Turbidity (NTU)	128.3	110.4	228.3	137.2	141	165.2
Temp (°C)	27.38	27.19	24.62	24.65	25.55	27.05
Water (Se only)		X	X	X	X	X
Sediments (Se and OCPs)	X	X		X	X	X
Se in biota						
algae[b]	X		X		X	
aquatic macrophytes						
corixids						
crayfish						
dragonfly nymphs						
glass shrimp						
tadpoles						
carp (juveniles)[c]						
mosquitofish	X	X	X	X	X	X
red shiner			X			X
sailfin molly						
shortfin molly		X				
OCPs in various media						
algae[b]			X		X	
aquatic macrophytes						
crayfish						
tadpoles						
sailfin mollies						
Large fish						
bass			NS			
carp			NS			X
threadfin shad			NS			
tilapia			NS			

Definitions:
X - Sample collected.
NS - Not sampled.
Notes:
a - BW-1 and BW-2 were treated as a single sampling location for large fishes.
b - Includes *Cladophora* spp., algae mixed with detritus, and *Enteromorpha* spp.
c - Juvenile carp were up to 4 cm in length. 2 g of material were composited for analysis.

4.3.2 Water/sediment sampling

Surface water and sediment samples were collected as near to the center of the area in which biota samples were collected as possible. Surface water was collected using a 500 ml HDPE container mounted on a pole-mounted grab sampler (i.e., a NASCO Swing Sampler). Before each surface water sample was collected, the container on the end of the grab sampler was rinsed three times with the target water. Sediment samples for total selenium and OCP analysis were collected using a Wildco stainless steel hand corer. The corer was washed with distilled water between sampling locations. For selenium speciation, cellulose acetate liners were used with the hand corer. Following initial collection, the liner was removed from the corer and the bottom cap was placed on the liner. Then, the liner was allowed to stand so that any sediments in the water left within the liner could settle out. Following that, the remaining water was poured off, the extra liner was cut off, and the top was capped. Lastly, the sediment cores were secured with tape and the top and bottom of each core was labeled. All samples were immediately placed in the appropriate sample containers, the sample containers were placed on dry ice until shipment, and were shipped with dry ice to the appropriate analytical laboratory. All sediment cores and water samples were shipped via overnight express the day of collection. Most sediment samples were also shipped the day of collection, although a few

were kept frozen for up to four days prior to shipment. Sediment samples were analyzed for total selenium, selenium species, and OCPs. Water samples were analyzed for total selenium, dissolved total selenium, and selenium species.

The analyses performed are summarized in Table 4-14 and the samples that were collected are summarized in Table 4-15.

4.3.3 Field measurements

A YSI 6920 Multiparameter Probe and Flow Cell was used to record water temperature, dissolved oxygen, pH, and turbidity. A field GPS unit was used to record elevation, as well as X and Y coordinates. The date and time that sampling started was also recorded for each location.

4.3.4 Surface water

Surface water samples were collected from 7 stations in the Brawley Pilot Wetland, 10 stations in the Imperial Pilot Wetland, four locations on the Alamo River, two locations in the New River, and 6 agricultural drains. All surface water samples were analyzed for total selenium, dissolved selenium, and selenium species (Table 4-14).

No surface water sample was collected on the New River at Forrester Road as the dissolved oxygen was exceedingly low (i.e., 0.28 mg/l). This low level of dissolved oxygen meant that very little biota was present at this sampling location (e.g., after extensive effort, only one mosquitofish was caught and the “algae” that was sampled was more detritus than algae). Thus, the decision was made that a water sample at this location would not provide much meaningful data. Upriver from this location, the river was even more odorous and darker in color, leading to the assumption that the biota present upriver from Forrester Road would be even more difficult to locate and sample.

The analytical results for the sediment samples collected are presented in Table 4-16.

Table 4-16
2006 Surface Water Concentrations

			Unfiltered		Dissolved		
Location	**Date**	**Units**	**Total Selenium**	**Total Selenium**	**Selenate**	**Selenite**	**Organic Selenium[1]**
Alamo R. @ Harris	6/2/2006	ug/L	5.27	4.72	<0.0147	<0.0163	4.72
Alamo R. @ Rose Drain	5/31/2006	ug/L	5.24	4.94	3.87	0.73	0.33
Alamo R. @ Rutherford	6/2/2006	ug/L	5.12	4.39	<0.0147	<0.0163	4.39
Alamo R. @ Worthington	6/2/2006	ug/L	4.91	4.74	2.35	0.54	1.84
New R. @ Hovley	6/1/2006	ug/L	2.74	2.25	1.05	0.84	0.35
BW-1	5/25/2006	ug/L	2.61	2.47	1.01	0.87	0.59
BW-2	5/25/2006	ug/L	2.91	2.62	1.25	0.90	0.48
BW-3	5/25/2006	ug/L	2.23	2.09	0.81	0.78	0.51
BW-4	5/25/2006	ug/L	2.10	2.11	2.19	2.44	0
BW-5	5/25/2006	ug/L	1.01	0.91	0.81	1.51	0
BW-6	5/25/2006	ug/L	1.46	1.49	0.19	0.80	0.50
BW-D	5/25/2006	ug/L	0.88	0.73	0.11	0.14	0.49
IW-1	5/24/2006	ug/L	4.28	4.12	2.36	0.73	1.03
IW-2	5/24/2006	ug/L	4.14	4.09	1.93	0.61	1.56
IW-3	5/24/2006	ug/L	4.37	4.03	2.21	0.79	1.03
IW-4	5/24/2006	ug/L	4.07	4.09	2.25	0.93	0.90
IW-5	5/23/2006	ug/L	4.30	3.27	1.85	0.80	0.62
IW-6	5/23/2006	ug/L	3.61	3.15	1.44	0.87	0.84
IW-7	5/23/2006	ug/L	3.34	3.03	1.41	1.11	0.51
IW-8	5/23/2006	ug/L	2.43	2.45	0.21	1.13	1.12
IW-9	5/24/2006	ug/L	3.39	2.40	1.44	0.86	0.10
IW-10	5/24/2006	ug/L	3.14	2.30	1.13	0.98	0.19
Central Drain	5/31/2006	ug/L	6.40	5.68	4.24	0.72	0.72
Dixie Drain	5/30/2006	ug/L	3.41	3.16	0.98	0.41	1.77
Fig Drain	6/1/2006	ug/L	3.12	2.92	2.23	0.36	0.33
Rice Drain	5/30/2006	ug/L	5.32	4.70	4.08	0.77	0
Rose Drain	5/31/2006	ug/L	4.09	3.52	2.44	0.62	0.46
Worthington Pond	6/2/2006	ug/L	2.78	2.73	<0.0147	<0.0163	2.73

Definitions:
<-Not detected with method detection limit to the right of the less than symbol.
Notes:
1-Calculated by difference; i.e., organic selenium = total selenium - (selenite + selenate)

4.3.5 Sediments

Sediment samples were collected from 7 stations in the Brawley Pilot Wetland, 10 stations in the Imperial Pilot Wetland, three locations on the Alamo River, two locations on the New River, and 6 agricultural drains. All sediment samples were analyzed for total selenium, selenium species, and OCPs (Table 4-14).

No sediment samples were collected on the Alamo River at the Rose drain as the walls of the river were vertical, preventing access to the bottom material.

The analytical results for the sediment samples collected are presented in Table 4-17.

Table 4-17
2006 Sediment Analytical Results

Location	Date	Solids, Total	Total Selenium	Selenate[1]	Selenite[1]	4,4'-DDD	4,4'-DDE	4,4'-DDT	Aldrin	beta-BHC	delta-BHC	gamma-Chlordane	Dieldrin	Endosulfan I	Endrin aldehyde
		(%)	(mg/kg)	(mg/kg)	(mg/kg)	(ug/kg)	(ug/kg)	(ug/kg)	(ug/kg)	(ug/kg)	(ug/kg)	(ug/kg)	(ug/kg)	(ug/kg)	(ug/kg)
Alamo R. @ Harris	6/2/2006	72.3	0.55	<0.015	0.0591	<0.17	38	8.2	<0.21	<0.42	<0.077	4.2P	<0.41	<0.24	<0.074
Alamo R. @ Rutherford	6/2/2006	69.8	0.64	<0.015	0.1068	1.3P	52	2.7	<0.22	<0.43	<0.079	<0.092	1.6	<0.25	1.2
Alamo R. @ Worthington	6/2/2006	71	0.76	<0.015	0.0938	<0.17	20	<0.091	<0.22	<0.43	<0.078	<0.091	<0.41	<0.24	<0.075
New R. @ Forrester	6/1/2006	73.4	0.48	<0.015	0.1063	<0.17	4.4	1.1P	<0.21	<0.41	<0.075	<0.088	<0.40	<0.24	<0.073
New R. @ Hovley	6/1/2006	69.3	0.83	<0.015	0.0591	<1.1	9.5	<0.093	<0.22	<0.44	<0.080	1.4P	2.3	1.4P	<0.077
BW-1	5/26/2006	72.2	0.57	<0.019	0.1485	<0.17	2.9	<0.089	<0.21	<0.42	<0.077	<0.089	<0.41	<0.24	<0.074
BW-2	5/26/2006	74.2	0.42	<0.019	0.0735	<0.17	5	<0.087	2.3P	<1.2	<0.075	1.8P	2.4	1.2P	<0.072
BW-3	5/26/2006	72.2	0.49	<0.019	0.0953	<0.17	2.8	<0.089	<0.21	<0.42	<0.077	<0.089	<0.41	<0.24	<0.074
BW-4	5/26/2006	67.3	0.65	<0.019	0.0887	<0.18	6.2	<0.096	<0.23	<0.45	<0.082	<0.096	<0.44	<0.26	<0.079
BW-5	5/26/2006	72.7	0.65	<0.019	0.1171	<0.17	6.4	<0.089	<0.21	<0.42	<0.076	<0.089	<0.40	<0.24	<0.073
BW-6	5/26/2006	77.5	0.93	0.0552	0.2273	<0.16	2.7	<0.083	<0.20	<1.5	<0.071	<0.083	<0.38	<0.22	<0.069
BW-D	5/26/2006	64.6	0.31	<0.019	0.2619	<0.93	16	<0.5	<1.2	<2.4	<0.43	<0.5	<2.3	<1.4	<0.42
IW-1	5/26/2006	80.5	0.27	<0.019	0.0798	<0.15	3.4	<0.080	<0.19	<0.38	<0.069	<0.080	<0.37	<0.22	<0.066
IW-1 (dupe)	5/26/2006	80.4	-	-	-	-	-	-	-	-	-	-	-	-	-
IW-2	5/26/2006	81.2	0.38	<0.019	0.0904	<0.15	3.1	<0.079	<0.19	<0.37	<0.068	<0.079	<0.36	<0.21	<0.066
IW-3	5/26/2006	80.7	0.27	<0.019	0.0851	<0.15	7.4	<0.080	<0.19	<0.38	<0.069	<0.080	<0.36	<0.22	<0.066
IW-4	5/26/2006	77.2	0.32	<0.019	0.0589	<0.16	4.4	<0.083	<0.20	<0.39	<0.072	<0.083	<0.38	<0.23	<0.069
IW-5	5/26/2006	81.4	0.17	<0.019	0.0991	<0.15	2.2	<0.079	<0.19	<0.37	<0.068	<0.079	<0.36	<0.21	<0.066
IW-6	5/26/2006	75.6	0.25	<0.019	0.1395	<0.16	1.1	<0.085	<0.20	<0.40	<0.073	<0.085	<0.39	<0.23	<0.071
IW-7	5/26/2006	73.8	0.50	<0.019	0.0408	<0.17	3.2P	<0.087	<0.21	<1.4	<0.075	<0.087	<0.40	1.4P	<0.072
IW-8	5/26/2006	73.1	0.56	<0.019	0.1215	<0.17	6.4	<0.088	<1.5	<0.42	<0.076	<0.088	<0.40	<0.24	<0.073
IW-9	5/26/2006	79.9	0.39	<0.019	0.0987	<0.16	2.4	<0.081	<0.19	<0.38	<0.069	<0.081	<0.37	<0.22	<0.067
IW-10	5/26/2006	67.8	0.52	<0.019	0.1945	<0.18	2	<0.095	<0.23	2.4P	<0.082	<0.095	<0.43	<0.26	<0.079
IW-10 (dupe)	5/26/2006	67.6	-	-	-	-	-	-	-	-	-	-	-	-	-
Central Drain	5/31/2006	77	0.35	<0.015	0.0561	<0.16	12	<0.084	<0.20	<0.39	<0.072	<0.084	<0.38	<0.23	<0.069
Dixie Drain	5/26/2006	66.1	0.44	<0.015	0.0217	<0.19	1.6	<0.097	<0.23	<0.46	<0.084	<0.097	<0.44	<0.26	<0.081
Fig Drain	6/1/2006	63.8	0.46	<0.015	0.1671	<0.19	6.1	<0.11	<1.1	<0.48	1.7P	<0.11	<0.46	<1.8	<0.084
Rice Drain	5/26/2006	63.4	0.72	<0.015	0.0943	<0.19	31	1.4P	<0.24	<0.48	<0.087	<0.11	<0.46	<0.27	<0.084
Rose Drain	5/31/2006	67.9	0.50	<0.015	0.1133	1.6P	33	1.9	<0.23	<2.3	<0.082	<1.1	1.2	<1.5	<0.079
Rose Drain (dupe)	5/31/2006	67.9		-	-	-	-	-	-	-	-	-	-	-	-
Worthington Pond	6/2/2006	76.7	0.49	<0.015	0.0793	1.2P	53	1.5P	<0.20	1.6	<0.072	<0.084	<0.38	<0.23	<0.070

All weights are presented on a dry weight basis.

Notes:

1-Collected via sediment core. All others are sediment grab samples.

Definitions:

<-Not detected with method detection limit to the right of the less than symbol.

P-Data is P qualified. Indicates an unknown interference and should be treated as unusable data.

--Not analyzed

4.3.6 Plants/algae

Algae (including filamentous algae like *Cladophora* spp., algae mixed with detritus, and *Enteromorpha* spp.) samples were collected from four stations in the Brawley Pilot Wetland, 8 stations in the Imperial Pilot Wetland, two locations in the Alamo River, one locations in the New River, and two agricultural drains. Aquatic macrophytes were only collected from two agricultural drains (Table 4-15). All algae and aquatic macrophyte samples were analyzed for total selenium (Table 4-14) and where sufficient sample mass was collected, samples were also analyzed for OCPs (Tables 4-14 and 4-15).

The analytical results for the algae and aquatic macrophytes samples collected are presented in Table 4-18.

4.3.7 Aquatic invertebrates

The aquatic invertebrates that were collected include corixids (i.e., water boatmen), crayfish, dragonfly nymphs, and glass shrimp. All samples were analyzed for total selenium, but only crayfish were collected in enough mass for OCP analysis (i.e., a minimum of 20 g of material is required for OCP analysis). No other aquatic invertebrates were found at the sampling locations in quantities that could be used for chemical analysis (i.e., a minimum of 2 g for Se analysis and 20 g for OCP analysis).

Corixids were collected from four locations at the Imperial Pilot Wetland and one agricultural drain. Crayfish were collected from two locations at the Brawley Pilot Wetland and in four agricultural drains. However, sufficient crayfish sample mass for OCP analysis was only collected at three locations (i.e., one from the Brawley Pilot Wetland and two agricultural drains). Dragonfly nymphs were collected from one location in each pilot wetland. Glass shrimp were collected from 6 locations at the Brawley Pilot Wetland and one location at the Imperial Wetland (Table 4-15).

The analytical results for the aquatic invertebrate samples collected are presented in Table 4-19.

Table 4-18
2006 Plant Tissue Analytical Results

Location	Date	Sample Type	Moisture, Total	Total Selenium	4,4'-DDD	4,4'-DDE	Aldrin	Dieldrin	Endosulfan I	Endosulfan II	Endosulfan sulfate	gamma-Chlordane
			(%)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
Alamo R. @ Harris	6/2/2006	Algae/detritus	0.58	2.1	<3.6	94	4.6P	3.6P	<0.38	<0.21	3.4	<0.60
Alamo R. @ Rose Drain	5/31/2006	Algae/detritus	0.78	2.4	<6.8	131	<0.50	6.3	10	12	13	<1.1
New R. @ Forrester	6/1/2006	Algae/detritus	0.71	3.9	-	-	-	-	-	-	-	-
BW-3	5/25/2006	Algae/detritus	0.83	2.3	-	-	-	-	-	-	-	-
BW-4	5/25/2006	Algae/detritus	0.88	0.47	<0.81	9.1	<0.91	11P	<1.3	<0.72	<1.3	12P
BW-5	5/25/2006	Algae	0.89	1.3	-	-	-	-	-	-	-	-
BW-6	5/25/2006	Algae	0.92	<0.62	<1.3	<1.5	<1.4	<1.0	<2.1	<1.1	<2.1	<3.2
IW-1	5/24/2006	Algae	0.69	1.3	<0.32	13	<4.8	<0.26	<0.52	<0.28	<4.2	<3.5
IW-2	5/24/2006	Algae/detritus	0.85	2.3	<0.63	78	<0.71	7.8P	<1.0	<0.56	15P	24P
IW-3	5/24/2006	Algae/detritus	0.87	2.4	<0.74	18P	<0.83	<0.61	<1.2	<0.65	<1.2	<1.9
IW-4	5/24/2006	Algae/detritus	0.89	3.3	<0.93	19	<1.0	<0.76	<1.5	<0.82	<11	<2.4
IW-6	5/23/2006	Algae	0.78	2.7	-	-	-	-	-	-	-	-
IW-7	5/23/2006	Algae (Enteromorpha)	0.89	<0.43	<0.87	<1.1	<0.98	<0.72	<1.4	<0.77	<1.4	<2.2
IW-8	5/23/2006	Algae	0.80	0.96	<0.49	<0.60	<0.55	<0.40	<0.80	<0.43	<0.80	<1.2
IW-10	5/24/2006	Algae	0.93	1.3	<1.3	<1.7	<1.5	<1.1	<2.2	<1.2	<2.2	<3.4
Dixie Drain	5/26/2006	Algae (Enteromorpha)	0.91	<0.53	<1.1	<1.3	<1.2	<0.89	<1.8	<0.96	<1.8	<2.8
Fig Drain	6/1/2006	Aquatic macrophyte	0.90	1.6	<1.1	13P	<1.2	<0.82	<1.6	<0.89	<1.8	<2.7
Worthington Pond	6/1/2006	Aquatic macrophyte	0.92	1.1	<1.2	<55	<1.4	<1.0	31	<1.1	<2.0	<3.1
Worthington Pond	6/2/2006	Algae (Enteromorpha)	0.90	<0.51	<1.0	14	<1.2	<0.85	<1.7	<0.91	<1.7	<2.6

All weights reported on a dry weight basis
Definitions:
<-Not detected with method detection limit to the right of the less than symbol.
P-Data is P qualified. Indicates an unknown interference and should be treated as unusable data.
--Not analyzed

Table 4-19
2006 Invertebrate Tissue Analytical Results

Location	Date	Sample Type	Lipids, Total (%)	Moisture (%)	Total Selenium (mg/kg)	4,4'-DDE (ug/kg)	alpha-BHC (ug/kg)	gamma-BHC (ug/kg)	alpha-Chlordane (ug/kg)	gamma-Chlordane (ug/kg)	Dieldrin (ug/kg)	Endosulfan I (ug/kg)
BW-1	5/25/2006	Glass shrimp	-	0.78	3.9	-	-	-	-	-	-	-
BW-2	5/25/2006	Crayfish	-	0.79	3.7	-	-	-	-	-	-	-
BW-2	5/25/2006	Glass shrimp	-	0.77	3.8	-	-	-	-	-	-	-
BW-3	5/25/2006	Glass shrimp	-	0.77	2.9	-	-	-	-	-	-	-
BW-3	5/25/2006	Tadpoles	0.57	0.84	8.2	19	8.8	<0.94	<1.1	<1.6	<0.51	<1.0
BW-4	5/25/2006	Glass shrimp	-	0.76	2.3	-	-	-	-	-	-	-
BW-5	5/25/2006	Dragonfly larvae	-	0.84	2.5	-	-	-	-	-	-	-
BW-5	5/25/2006	Glass shrimp	-	0.77	4.4	-	-	-	-	-	-	-
BW-D	5/25/2006	Crayfish	1	0.73	1.5	21	3.8	<0.56	<0.68	3.8P	<0.30	<0.60
IW-4	5/24/2006	Corixids	-	0.71	2.8	-	-	-	-	-	-	-
IW-5	5/23/2006	Corixids	-	0.70	3.0	-	-	-	-	-	-	-
IW-6	5/23/2006	Corixids	-	0.70	5.0	-	-	-	-	-	-	-
IW-7	5/23/2006	Corixids	-	0.69	4.1	-	-	-	-	-	-	-
IW-7	5/23/2006	Glass shrimp	-	0.77	5.2	-	-	-	-	-	-	-
IW-8	6/5/2006	Dragonfly larvae	-	0.84	4.1	-	-	-	-	-	-	-
Dixie Drain	6/5/2006	Crayfish	1.9	0.81	2.8	22	<1.1	<0.78	<0.94	<1.3	<0.42	<0.83
Dixie Drain	6/5/2006	Tadpoles	0.84	0.79	7.4	17	<1.0	<0.73	<0.87	<1.2	<0.39	<0.78
Fig Drain	6/1/2006	Crayfish	1.8	0.77	1.8	60	<0.90	4.7P	<0.77	5.1	<0.35	<0.68
Rice Drain	5/30/2006	Crayfish	-	0.76	2.9	-	-	-	-	-	-	-
Rose Drain	6/5/2006	Crayfish	-	0.84	3.6	-	-	-	-	-	-	-
Worthington Pond	6/2/2006	Corixids	-	0.77	4.2	-	-	-	-	-	-	-
Worthington Pond	6/2/2006	Tadpoles	0.99	0.82	3.8	276	<1.2	<0.83	6.1P	<1.4	6.1	5.5

All weights reported on a dry weight basis

Definitions:

<-Not detected with method detection limit to the right of the less than symbol.

P-Data is P qualified. Indicates an unknown interference and should be treated as unusable data.

--Not analyzed

4.3.8 Amphibians

Unidentified tadpoles were collected from three locations; i.e., one in the Brawley Pilot Wetland and at two agricultural drains. The tadpoles that were collected were very large, being almost as long as the width of an adult male hand. All tadpole samples were analyzed for total selenium and OCPs (Tables 4-14 and 4-15).

4.3.9 Small fishes

The small fishes that were collected include mosquitofish (*Gambusia affinis*), red shiners (*Cyprinella lutrensis*), sailfin mollies (*Poecilia latipinna*), and shortfin mollies (*Poecilia mexicana*). For the shortfin mollies, it is possible that these may also be sailfin mollies, as identifications were made in the field and only females were collected from some locations. No other small fishes were collected or observed. All samples were analyzed for total selenium, but only sailfin mollies were collected in enough mass for OCP analysis (i.e., a minimum of 20 g of material is required for OCP analysis).

Mosquitofish were collected from 7 stations in the Brawley Pilot Wetland, 9 stations in the Imperial Pilot Wetland, four locations on the Alamo River, two locations in the New River, and 6 agricultural drains. Red shiners were collected from two locations on the Alamo River and in three agricultural drains. Sailfin mollies were collected from one location at the Brawley Pilot Wetland and one agricultural drain; however, sufficient sample mass for OCP analysis was only collected from the Brawley Pilot Wetland. Shortfin mollies were collected from one location on the New River and from three agricultural drains (Table 4-15).

The analytical results for the fish samples collected are presented in Table 4-20.

4.3.10 Large fishes

The large fishes that were collected include bass (*Micropterus salmoides*), common carp (*Cyprinus carpio*), threadfin shad (*Dorosoma petenense*), and tilapia (*Tilapia spp.*). The only other large fish that was collected was the bluegill (*Lepomis macrochirus*). However, only two individuals were collected at the Imperial Wetlands and, therefore, it was decided that this species was not widespread enough for the analytical results to be meaningful in the ecological risk assessment. Therefore, the bluegill collected were returned to the waters where collected and not analyzed. No other large fishes were collected or observed. Two different types of large fish samples were analyzed: 1) individual fish were analyzed for total selenium and 2) composites of up to 5 fishes were analyzed for total selenium and OCPs. The fishes that were composited were all within 25% of the length of the largest individual. The lengths of the fishes that were composited are shown in Table 4-21.

Table 4-20
2006 Fish Tissue Analytical Results

Location	Date	Sample Type	Composite?[1]	Lipids, Total (%)	Moisture (%)	Total Selenium (mg/kg)	4,4'-DDD (ug/kg)	4,4'-DDE (ug/kg)	4,4'-DDT (ug/kg)	Aldrin (ug/kg)	alpha-BHC (ug/kg)	beta-BHC (ug/kg)	gamma-BHC (ug/kg)	delta-BHC (ug/kg)	alpha-Chlordane (ug/kg)	gamma-Chlordane (ug/kg)	Dieldrin (ug/kg)	Endosulfan I (ug/kg)	Endosulfan II (ug/kg)	Endosulfan sulfate (ug/kg)	Endrin (ug/kg)	Endrin aldehyde (ug/kg)	Heptachlor (ug/kg)	Heptachlor epoxide (ug/kg)	Methoxychlor (ug/kg)
Alamo R. @ Harris	6/2/2006	Mosquitofish	Y	-	0.77	7.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Alamo R. @ Rose Drain	5/31/2006	Mosquitofish	Y	-	0.77	4.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Alamo R. @ Rose Drain	5/31/2006	Red Shiner	Y	-	0.71	6.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Alamo R. @ Rutherford	6/2/2006	Mosquitofish	Y	-	0.77	5.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Alamo R. @ Rutherford	6/2/2006	Red Shiner	Y	-	0.73	6.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Alamo R. @ Rutherford	6/6/2006	Carp	1	3.5	0.75	7.0	<20	7,186	80	<0.44	<0.84	5.6	<0.60	<0.96	18	44P	<16	40	<28	<15	<0.35	<25	<0.52	16	<76
Alamo R. @ Worthington	6/2/2006	Mosquitofish	Y	-	0.77	6.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
New R. @ Forrester	6/1/2006	Mosquitofish	Y	-	0.75	9.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
New R. @ Hovley	6/1/2006	Shortfin molly	Y	-	0.69	3.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
New R. @ Hovley	6/1/2006	Mosquitofish	Y	-	0.77	3.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BW-1	5/25/2006	Mosquitofish	Y	-	0.73	3.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BW-1	5/30/2006	Carp - 26 cm	N	-	0.76	5.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BW-1	5/30/2006	Carp	5	3.5	0.75	4.0	17.5P	447	<0.69	8.9P	<17.5	<12.2	<0.61	<0.97	13P	4.9P	8.9	11P	<0.35	<0.65	5.7	<0.81	<11	<5.3	<29
BW-1	5/30/2006	Shad	5	8.3	0.7	1.9	<3.3	501	<5.7	<3.7	<7.0	<40.1	<5.0	<8.0	<6.0	<8.3	53	<5.3	<2.9	<5.3	<2.9	<6.7	<4.3	<8.3	<7.0
BW-1 (dupe)	5/30/2006	Shad	5	8.5	0.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BW-1	5/30/2006	Tilapia - 29 cm	N	-	0.68	4.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BW-1	5/30/2006	Tilapia	4	4	0.68	4.5	10	215	5.0	<6.9	<9.0	<5.6	<7.2	<0.75	<4.4	<0.78	13	<0.50	<0.27	<0.50	<0.27	8.1P	<0.40	<5.3	<0.65
BW-2	5/25/2006	Mosquitofish	Y	-	0.77	3.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BW-3	5/20/2006	Shad	5	3.6	0.75	3.3	9.2P	296	<0.68	<0.44	<0.84	<4.8	<8.0	<0.96	4.8	<6.4	19	10	<0.35	<0.64	<10	<0.80	6.0P	<1.0	<34
BW-3	5/25/2006	Mosquitofish	Y	-	0.75	3.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BW-4	5/25/2006	Mosquitofish	Y	-	0.74	3.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BW-4	5/30/2006	Carp - 55 cm	N	-	0.64	4.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BW-4	5/30/2006	Shad	5	7	0.71	2.8	13.6P	409	5.1	<0.38	<8.2	<4.4	<6.8	<0.82	13	<0.85	38	15	<0.30	5.8P	<0.30	<0.68	<0.44	<0.85	<0.72
BW-4	5/30/2006	Tilapia - 19.2 cm	N	-	0.74	7.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BW-5	5/25/2006	Mosquitofish	Y	-	0.79	6.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BW-6	5/25/2006	Mosquitofish	Y	-	0.74	5.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BW-D	5/23/2006	Sailfin molly	Y	4.2	0.75	2.7	7.9	147	<0.67	<0.44	<0.83	<1.3	<0.59	<0.95	<0.71	<0.99	4.4	6.3	<0.34	4.4	<0.35	<0.79	<0.51	<0.99	<0.83
BW-D	5/25/2006	Mosquitofish	Y	-	0.76	4.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BW-D	5/30/2006	Tilapia	5	3.6	0.72	4.1	<0.35	87	<0.61	<4.3	<0.76	<13.7	<8.3	<0.87	<0.65	<0.90	13P	<7.6	<0.31	<0.58	<0.32	<0.72	5.4	<0.90	<0.76
BW-D	5/30/2006	Tilapia - 13.1 cm	N	-	0.72	4.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BW-D	5/30/2006	Tilapia - 8.3 cm	N	-	0.72	5.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BW-D	5/30/2006	Tilapia - 6.6 cm	N	-	0.73	5.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BW-D	5/30/2006	Tilapia - 9.1 cm	N	-	0.71	4.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BW-D	5/30/2006	Tilapia - 7.6 cm	N	-	0.68	4.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BW-D	5/30/2006	Tilapia - 11.5 cm	N	-	0.71	4.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BW-D	5/30/2006	Tilapia - 7.7 cm	N	-	0.75	5.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IW-1	5/24/2006	Mosquitofish	Y	-	0.73	3.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IW-1	5/30/2006	Carp	4	4.7	0.71	3.3	35	1,697	<0.59	<0.38	<9.3	<5.5	<0.52	<0.83	14P	8.7P	48	16P	<6.2	<5.5	<0.30	<3.8	3.8P	<5.5	4.8P
IW-1	5/30/2006	Carp - 29cm	N	-	0.75	4.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IW-1	5/30/2006	Shad	5	5.9	0.75	5.8	44	###	14	<0.44	<9.1	<6.8	<0.60	<0.95	23	<5.6	87	<8.7	11	64P	<0.35	<0.79	<7.9	<6.0	<0.83
IW-2	5/24/2006	Mosquitofish	Y	-	0.72	4.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IW-2	5/30/2006	Carp	5	4.6	0.75	4.4	40.7P	2,119	<0.69	24.9P	<7.7	<6.1	<24	<0.98	<11	<7.3	41	<8.6	<0.35	16P	<15	28P	<0.53	<19	<15
IW-2	5/30/2006	Carp - 28.5 cm	N	3.7	0.74	4.4	31	1,632	<0.66	13	<4.3	<7.0	<0.58	<35	<7.0	<4.7	33	30P	<0.34	15P	<0.34	<0.78	<16	7.0P	<7.4
IW-2	5/30/2006	Shad	5	7.2	0.72	3.4	44	1,525	9.1	<7.3	<4.4	10.2P	<0.54	<0.87	16	<0.91	105	24P	36P	30P	<5.1	47P	36P	<4.4	<0.76
IW-3	5/24/2006	Mosquitofish	Y	-	0.74	3.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IW-3	5/31/2006	Carp	4	4.4	0.73	3.8	28	1,124	<0.64	<0.41	<0.79	<28.1	<7.5	<0.90	4.9P	5.2P	36	11	<0.33	7.9P	<0.33	<0.75	<5.2	<17	<0.79
IW-3	5/31/2006	Shad	5	5.2	0.69	3.5	30	1,045	5.9	<0.36	<0.69	<4.6	<0.49	<0.78	13	<0.82	69	13P	<6.5	22P	<0.29	<0.65	10P	<0.82	<22
IW-4	5/24/2006	Mosquitofish	Y	-	0.74	3.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IW-4	5/31/2006	Shad	5	7.7	0.71	3.6	31	1,010	<0.59	<0.38	<0.73	<8.0	<3.8	<0.84	11	<0.87	73	15	<10	29	<0.31	<6.3	9.1	<0.87	<0.73
IW-4	6/1/2006	Carp	3	5.3	0.73	4.6	28	937	<0.64	9.4	<0.79	<41.2	<9.4	<0.90	7.5P	<5.2	45	12	<0.33	15P	<0.33	9.7P	7.9	<0.94	<0.79
IW-5	5/23/2006	Mosquitofish	Y	-	0.76	4.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IW-5	5/31/2006	Carp	3	7.2	0.65	3.8	23.4P	762	<3.9	<0.31	<0.59	5.9P	<3.4	<3.9	<5.4	<4.8	34	7.1	<3.1	16P	<7.1	11P	<16	<0.71	<0.59
IW-5	5/31/2006	Shad	4	3.2	0.75	4.7	25	847	<0.69	8.9	<0.85	<20.6	<0.60	<0.97	14P	<1.0	38	7.7	<0.35	22P	<0.35	<0.81	8.1	<8.9	<0.85
IW-6	5/23/2006	Mosquitofish	Y	-	0.67	7.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IW-6	5/31/2006	Carp - 47.5 cm	N	-	0.72	7.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IW-7	5/23/2006	Carp - juvenile		-	0.79	7.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IW-7	6/7/2006	Carp - juvenile		-	0.79	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IW-7	5/23/2006	Mosquitofish	Y	-	0.75	7.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IW-7A	6/1/2006	Carp - 41 cm	N	-	0.69	4.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 4-20 (continued)
2006 Fish Tissue Analytical Results

Location	Date	Sample Type	Composite?1	Lipids, Total (%)	Moisture (%)	Total Selenium (mg/kg)	4,4'-DDD (ug/kg)	4,4'-DDE (ug/kg)	4,4'-DDT (ug/kg)	Aldrin (ug/kg)	alpha-BHC (ug/kg)	beta-BHC (ug/kg)	gamma-BHC (ug/kg)	delta-BHC (ug/kg)	alpha-Chlordane (ug/kg)	gamma-Chlordane (ug/kg)	Dieldrin (ug/kg)	Endosulfan I (ug/kg)	Endosulfan II (ug/kg)	Endosulfan sulfate (ug/kg)	Endrin (ug/kg)	Endrin aldehyde (ug/kg)	Heptachlor (ug/kg)	Heptachlor epoxide (ug/kg)	Methoxychlor (ug/kg)
IW-8	5/23/2006	Mosquitofish	Y	-	0.76	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IW-8	6/1/2006	Shad	2	13.1	0.66	5.5	17	535	<4.5	<6.8	<3.9	<9.2	<0.45	3.6P	12P	<8.3	33	5.6P	<0.26	12P	<19	4.5P	<4.2	<4.8	<0.62
IW-9	6/1/2006	Shad	5	11.7	0.69	5.3	19	583	<0.55	<0.36	<14.4	<14.6	<0.49	<3.9	8.8	<5.2	78	5.2	<6.8	39	<0.29	14	26	<0.81	<0.68
IW-9	6/5/2006	Bass	2	6.7	0.75	7.5	35	920	5.6P	39.6P	<0.84	<18	<25	<0.96	8.0P	4.8P	96	12	<0.35	<0.64	5.2P	11P	<4.8	<6.4	<5.2
IW-9 (dupe)	6/5/2006	Bass	2	6.8	0.75	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IW-10	5/24/2006	Mosquitofish	Y	-	0.75	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IW-10	6/1/2006	Shad	5	6.1	0.71	5.6	21	577	<0.58	<6.5	<0.71	<9.2	7.8P	<0.82	10P	<0.85	51	9.2P	<4.1	25	<0.30	<0.68	<6.1	<11	4.4
IW-10	6/2/2006	Carp - 34 cm	N	-	0.73	6.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Central Drain	5/31/2006	Sailfin molly	Y	-	0.72	5.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Central Drain	5/31/2006	Mosquitofish	Y	-	0.77	7.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Central Drain	5/31/2006	Red Shiner	Y	-	0.71	8.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Central Drain	6/5/2006	Tilapia	5	2.6	0.73	10	124	4,117	28	<0.41	<0.79	<1.2	<7.1	<0.90	5.2P	12	90	29P	9.73	22P	<7.9	<0.75	<0.49	<0.94	<4.1
Central Drain	6/3/2006	Tilapia - 21.6 cm	N	-	0.74	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Central Drain	6/3/2006	Tilapia - 12.2 cm	N	-	0.75	8.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Central Drain	6/3/2006	Tilapia - 18.8 cm	N	-	0.72	8.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dixie Drain	5/30/2006	Mosquitofish	Y	-	0.77	7.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dixie Drain	5/30/2006	Red Shiner	Y	-	0.74	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dixie Drain	6/5/2006	Shortfin molly	Y	-	0.75	5.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dixie Drain	6/5/2006	Tilapia	3	2.5	0.74	6.0	<0.37	83	<0.64	<0.42	<0.80	<1.2	<0.57	<0.91	<0.68	4.5P	4.5	<0.61	<0.33	<0.61	<0.33	<0.76	3.8	<0.95	<5.3
Dixie Drain	6/5/2006	Tilapia - 10.6 cm	N	-	0.74	7.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dixie Drain	6/5/2006	Tilapia - 9.7 cm	N	-	0.75	6.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dixie Drain	6/5/2006	Tilapia - 27.4 cm	N	-	0.78	6.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fig Drain	6/1/2006	Shortfin molly	Y	-	0.73	2.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fig Drain	6/1/2006	Mosquitofish	Y	-	0.77	3.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fig Drain	6/5/2006	Tilapia	5	2.5	0.73	3.1	<0.36	130	<0.63	<0.41	<0.78	<13.8	<8.2	<0.89	<0.67	<0.93	4.5	<0.60	<0.32	<0.60	<0.33	4.8P	5.6	<7.8	<0.78
Fig Drain	6/5/2006	Tilapia - 10.9 cm	N	-	0.76	6.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fig Drain	6/5/2006	Tilapia - 13.9 cm	N	-	0.69	2.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fig Drain	6/5/2006	Tilapia - 8.8 cm	N	-	0.74	5.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fig Drain	6/5/2006	Tilapia - 11.3 cm	N	-	0.75	5.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fig Drain	6/5/2006	Tilapia - 8.2 cm	N	-	0.75	5.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fig Drain	6/5/2006	Tilapia - 9.4 cm	N	-	0.76	3.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fig Drain	6/5/2006	Tilapia - 8.8 cm	N	-	0.76	5.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fig Drain	6/5/2006	Tilapia - 11.0 cm	N	-	0.74	3.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fig Drain	6/5/2006	Tilapia - 16.1 cm	N	-	0.75	2.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rice Drain	5/30/2006	Mosquitofish	Y	-	0.75	6.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rice Drain	6/2/2006	Carp	3	11	0.69	6.2	87	4,487	19	3.5P	5.4P	<1.0	<0.48	<0.77	18	30	215	42P	32P	<20	4.2P	<28	<0.42	3.8P	<96
Rose Drain	5/31/2006	Mosquitofish	Y	-	0.78	6.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rose Drain	6/5/2006	Shortfin molly	Y	-	0.76	4.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rose Drain	6/5/2006	Red Shiner	Y	-	0.71	4.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Worthington Pond	6/2/2006	Mosquitofish	Y	-	0.75	6.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

All weights reported on a dry weight basis

Notes:

1-Y = numerous small individuals were composited to make up 2 g for Se analysis and 20 g for OCP analysis

N = single specimen examined

= number of larger fish composited

Defintions:

<-Not detected with method detection limit to the right of the less than symbol.

P-Data is P qualified. Indicates an unknown interference and should be treated as unusable data.

--Not analyzed

Table 4-21
Lengths of Fish (in centimeters) in Composite Samples by Location

Location	Carp	Threadfin shad	Tilapia
BW-1	24	13.2	16.6
BW-1	22	12.6	16.8
BW-1	23	12.6	17.3
BW-1	22	13.4	20.4
BW-1	25	13.9	
BW-3	-	12.9	-
BW-3	-	13.9	-
BW-3	-	13.2	-
BW-3	-	13.1	-
BW-3	-	13.2	-
BW-4	-	14	-
BW-4	-	14.9	-
BW-4	-	14.1	-
BW-4	-	13.9	-
BW-4	-	14	-
BW-D	-	-	8.8
BW-D	-	-	7.2
BW-D	-	-	8.6
BW-D	-	-	7.2
BW-D	-	-	8.9
Central drain	-	-	15.5
Central drain	-	-	17
Central drain	-	-	14.1
Central drain	-	-	15.1
Central drain	-	-	13.3
Dixie drain	-	-	22.2
Dixie drain	-	-	16.6
Dixie drain	-	-	19.4
Fig Drain	-	-	11.1
Fig drain	-	-	11.1
Fig drain	-	-	13.5
Fig drain	-	-	14.6
Fig drain	-	-	14.6
IW-1	37	13.4	-
IW-1	33	14	-
IW-1	39	12.8	-
IW-1	30	13.3	-
IW-1		13.7	-
IW-10	-	9.6	-
IW-10	-	10.5	-
IW-10	-	9.8	-
IW-10	-	10.4	-
IW-10	-	9.1	-
IW-2	29	9.9	-
IW-2	29.5	9.2	-
IW-2	28	10.3	-
IW-2	28	10	-
IW-2	27	9.2	-
IW-3	37	12.2	-
IW-3	38	10.6	-
IW-3	37	14	-
IW-3	39	14.1	-
IW-3		13.2	-
IW-4	35	12.1	-
IW-4	36	12.8	-
IW-4	31	13.7	-
IW-4		13.5	-
IW-4		10.9	-
IW-5	48	12.6	-
IW-5	49	13.1	-
IW-5	42	13.1	-
IW-5		12.8	-
IW-8	-	12.4	-
IW-8	-	13.2	-
IW-9	-	10.9	-
IW-9	-	13.2	-
IW-9	-	12.3	-
IW-9	-	13.3	-
IW-9	-	13.4	-
Rice drain	43.5	-	-
Rice drain	40.5	-	-
Rice drain	32.5	-	-
Alamo River at Rutherford	41.5	-	-

Notes:
A "-" indicates that a composite sample was not available for the indicated species at a particular location.

Bass were collected from 1 stations in the Imperial Pilot Wetland. Carp were collected from 8 stations in the Imperial Pilot Wetland, two locations in the Brawley wetland, one location on the Alamo River, and one agricultural drain. Threadfin shad were collected from 8 stations in the Imperial Pilot Wetland and three locations in the Brawley wetland. Tilapia were collected from three locations at the Brawley Pilot Wetland and three agricultural drains (Table 4-15).

The analytical results for the fish samples collected are presented in Table 4-20.

4.3.11 Bird Eggs

A comprehensive effort was made to obtain bird eggs from the pilot wetlands, drains, and rivers, in coordination with the other biological sampling discussed above. This included the participation of several US Fish and Wildlife Service scientists (Carol Roberts, Katie Zeeman, and Scott Sobiech) and included exhaustive searches of nests with viable eggs at different target locations. However, over the time period of the sampling (last week of May, 2006 and the first week of June, 2006), all nests found had been subject to predation or other damage, and no usable eggs were found. Bird eggs data from the pilot wetlands, albeit limited, were obtained in previous work by the USFWS in 2003. It is conceivable that egg data may be obtained in future assessments in the wetlands.

4.3.12 Data Quality Assessment

The validation review of the environmental data showed quantitative levels of total selenium, filtered total selenium, selenite, selenate, selenocyanate, and organochlorine pesticides in the sediment, tissue, and water samples that were collected from the New and Alamo Rivers during May and June 2006. Most QC criteria were within control limits, and the laboratory generated data results were used as stated and did not require any qualification, with the following exception:

Columbia Analytical Services Organochlorine Pesticide (EPA 8081A) Analyses - The confirmation comparison criteria of 40% difference for a few analytes were exceeded in a few of the samples. The higher of the two values was reported when no evidence of a peak anomaly was observed. The lower of the two values was reported when there was an apparent interference on the alternate column produced the higher value.

These data were flagged by the laboratory with a “P” qualifier. In general, “P” qualifiers can result when the following conditions occur:

- There is interference caused by PCB’s
- Column co-elution issues.

Further investigation by Tetra Tech indicated that The "P" qualifiers were most likely not caused by PCB interference, which suggests that there may be an unknown compound that elutes at one RT (retention time) on one column and co-elutes with the target compound on the other column, thus providing values that differed enough to fail the %D criteria. This results in an unacceptable level of uncertainty and those results having the “P” qualifier were considered suspect and not used.

Based on the results of the Level III Data Validation effort, it was concluded that the data were usable as reported and that the target analyte identifications are considered correct and reliable, with the noted “P” qualifier exceptions. The DQOs were satisfied as per the QAPP for this project and the data are usable for their intended purpose.

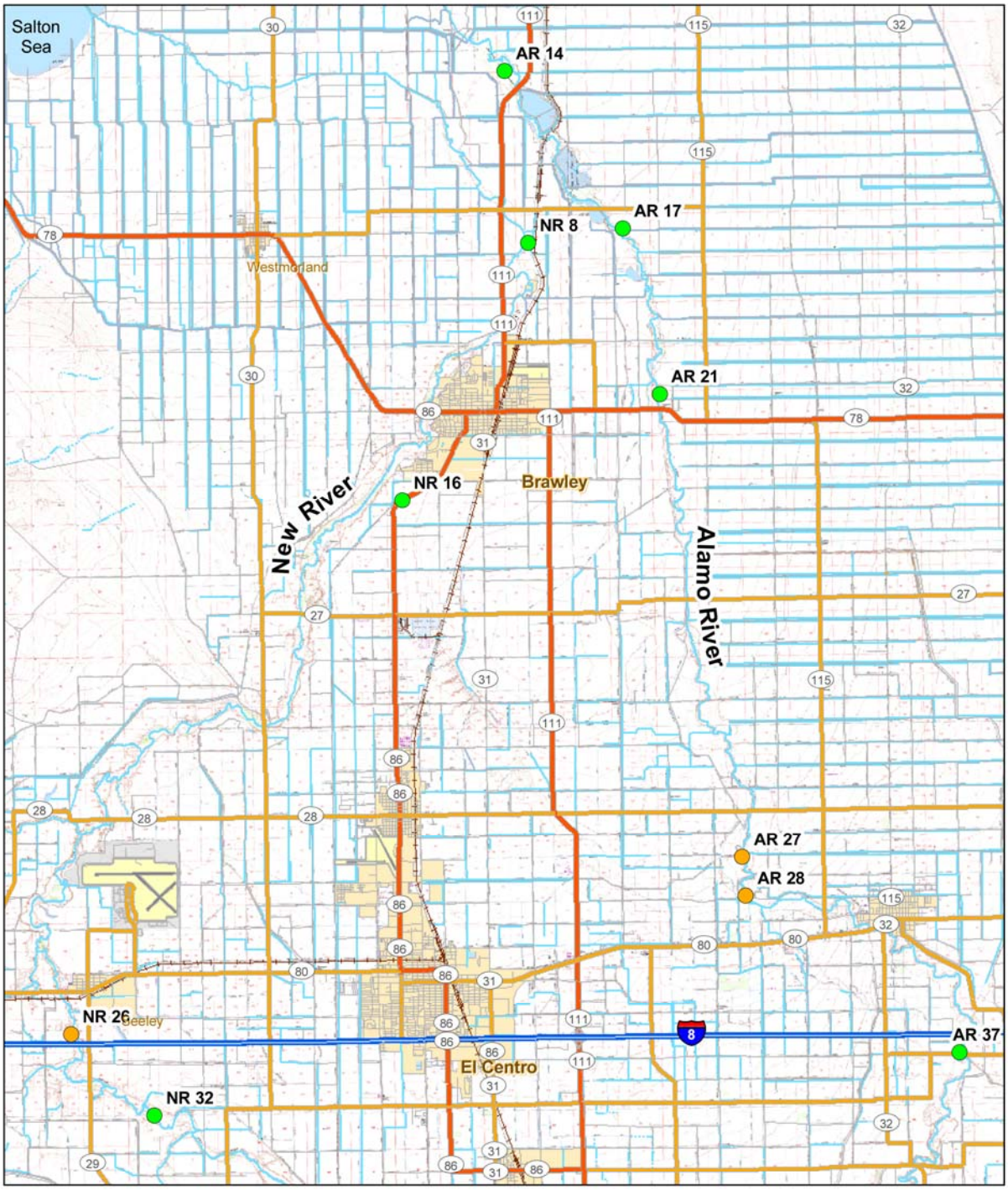
CHAPTER 5
BIOLOGICAL INVENTORY OF POTENTIAL WETLAND SITES

A reconnaissance level survey of habitat and biota at ten proposed wetland sites along the New and Alamo Rivers (see Figure 5-1) was conducted in September, 2006. Seven of the eight preferred sites (NR 22 was inaccessible) and three alternative sites were surveyed. Data collected at each site included:

- GPS coordinates of survey locations (Table 5-1)
- Site photographs
- Prominent plant species and their percent cover
- Animal species present
- Avian point-count surveys to estimate mean use

The prominent terrestrial and aquatic plant species were identified and their respective percent ground cover estimated for the areas proposed for wetland restoration. Aquatic plants that were located in the river water were not included in the calculations. The occurrence of invasive and sensitive species was noted. Tetra Tech identified animal species by direct observation and the presence of sign (e.g., this includes scat, fur, etc.).

One variable circular-plot avian point-count survey was conducted at each of the ten proposed wetland sites. The number of birds observed at each site may have been influenced by the time of day, so the individual sites are not directly comparable to each other. Avian use was derived by calculating the average number of birds observed per plot per 30-minute survey period. The number of birds seen during each point count survey was standardized to a unit area and a unit time surveyed. The standardized unit of time was 30 minutes, and the standardized unit area was 2.01 km^2 (800 m radius viewshed for each station). For the standardized avian use estimate, only observations of birds detected within 800 m of the observer were used.



Legend

Proposed Restortation Site

- Prefered Site for Biological Inventory
- Alternative Site for Biolooical Inventory

N 0 1.5 3 Miles

Figure 5-1 Proposed Restoration Sties Surveyed Along the New and Alamo Rivers

Table 5-1
GPS coordinates of the survey locations

Site	GPS Coordinates (NAD 83)	
	Easting	Northing
NR 8	638521	3655960
NR 16	633977	3646656
NR 26	622013	3627288
NR 32	625025	3624369
AR 14	637660	3662210
AR 17	641929	3656496
AR 21	643272	3650483
AR 27	646246	3633738
AR 28	646371	3632331
AR 37	654101	3626636

5.1 Results

5.1.1 Plants

The ten proposed wetland sites that were surveyed are all dominated by the invasive weed Salt Cedar (*Tamarix sp.*) (trees and shrubs). *Tamarix sp.* ground cover ranges from 50 to 90 percent at the ten proposed sites. Other non-native species occurring at the proposed sites include giant reed (*Arundo donax)* and Washington fan palm (*Washingtonia robusta*). Arrow weed (*Pluchea sericea*) is the most abundant native species present; however, it does not account for more than 10 percent of the total ground cover at any of the nine sites observed. No special-status plant species were observed. Many of the proposed sites contained domestic debris trash dumps.

See Table 5-2 for all prominent plant species and their respective percent cover.

5.1.2 Animals

Tetra Tech identified 46 avian species, one amphibian species, three reptilian species, two mammalian species, and one invertebrate species during the reconnaissance surveys (see Table 5-3). Of the 53 species encountered, eight avian species are special-status species (see Appendix I): American white pelican (*Pelecanus erythrorhynchos*), burrowing owl (*Athene cunicularia*), California brown pelican (*Pelecanus occidentalis californicus*), Cooper's hawk (*Accipiter cooperii*), double-crested cormorant (*Phalacrocorax auritus*), osprey (*Pandion haliaetus*), white-faced ibis (*Plegadis chihi*), and yellow warbler (*Dendroica petechia brewsteri*). No special-status amphibian, reptilian, mammalian, or invertebrate species were observed.

During the avian point-count surveys, a total of 421 birds were observed during the ten surveys. A total of 37 identifiable species were observed, with an average of 9.2 species detected per 30-minute survey. Since individual birds were not marked, these counts do not distinguish individual birds and are therefore meant to provide an estimate of use only. Use of the terms 'abundant' or 'abundance' represent relative use estimates and do not indicate absolute density or number of individuals.

Table 5-4 summarizes the total number of birds observed, mean use, and the frequency of occurrence. The most abundant birds were white-faced ibis (31.8 percent of observations), red-winged blackbirds (15.0 percent of observations), and mourning doves (13.3 percent of observations). All other species each comprised less than six percent of the total number of birds observed.

Table 5-2
Percent cover of prominent plant species at the proposed restoration sites

Species		Plant Type	Native?	Percent Cover by Site									
Scientific Name	Common Name			NR 8	NR 16	NR 26	NR 32	AR 14	AR 17	AR 21	AR 27	AR 28	AR 37
Salicornia virginica	Pickleweed	Annual	Yes			2.0%			5.0%	2.5%			2.0%
Arundo donax	Giant reed	Perennial	No	5.0%	2.0%		3.0%				10.0%		3.0%
Distichlis spicata	Saltgrass	Perennial	Yes		2.0%							3.0%	
Atriplex lentiformis	Big saltbush	Shrub	Yes			2.0%				2.5%			
Atriplex sp.	Saltbush	Shrub	Yes			2.0%							
Encelia farinosa	Brittlebrush	Shrub	Yes					2.0%			2.0%		
Larrea tridentata	Creosote bush	Shrub	Yes										1.0%
Pluchea sericea	Arrow weed	Shrub	Yes	10.0%	6.0%		8.0%	8.0%	5.0%	5.0%	2.0%	5.0%	5.0%
Acacia sp.	Acacia	Tree	Yes	1.0%									
Cercidium floridum	Palo verde	Tree	Yes									3.0%	
Salix exigua	Narrow-leaved willow	Tree	Yes	1.0%									
Washintonia robusta	Washington fan palm	Tree	No				2.0%						
Prosopis pubescens	Screwbean mesquite	Tree/Shrub	Yes				1.0%				1.0%		4.0%
Tamarix sp.	Saltcedar	Tree/Shrub	No	68.0%	90.0%	85.0%	50.0%	80.0%	90.0%	80.0%	85.0%	82.0%	75.0%
	Bare ground/grasses			15.0%		9.0%	36.0%	10.0%		10.0%		7.0%	10.0%

Table 5-3
Animal species identified at the proposed restoration sites (alphabetical by common name)

Species		Site									
Common Name	Scientific Name	NR 8	NR 16	NR 26	NR 32	AR 14	AR 17	AR 21	AR 27	AR 28	AR 37
BIRDS											
Abert's towhee	*Pipilo aberti*		X		X				X		
American kestrel	*Falco sparverius*	X	X	X	X		X				X
American white pelican[1]	*Pelecanus erythrorhynchos*			X							
Barn owl	*Tyto alba*		X								
Barn swallow	*Hirundo rustica*	X							X		
Belted kingfisher	*Ceryle alcyon*								X	X	X
Black phoebe	*Sayornis nigricans*	X	X		X	X			X	X	X
Black-crowned night-heron	*Nycticorax nycticorax*			X							
Brown-headed cowbird	*Molothrus ater*	X									
Burrowing owl[1]	*Athene cunicularia*										X
Cactus wren	*Campylorhynchus brunneicapillus*	X									
California brown pelican[1]	*Pelecanus occidentalis californicus*			X							
Caspian tern	*Sterna caspia*	X	X								
Cattle egret	*Bubulcus ibis*									X	
Common ground-dove	*Columbina passerina*	X				X				X	X
Common moorhen	*Gallinula chloropus*				X						
Cooper's hawk[1]	*Accipiter cooperii*		X								
Double-crested cormorant[1]	*Phalacrocorax auritus*			X							
Eurasian collared-dove	*Streptopelia decaocto*		X							X	
European starling	*Sturnus vulgaris*	X									
Gambel's quail	*Callipepla gambelii*		X						X		
Great blue heron	*Ardea herodias*			X							X
Great egret	*Ardea alba*			X					X		
Greater roadrunner	*Geococcyx californianus*	X			X				X		X
Green heron	*Butorides virescens*					X		X	X		X
House finch	*Carpodacus mexicanus*		X								
Inca dove	*Columbina inca*			X							
Killdeer	*Charadrius vociferus*	X							X		X
Loggerhead shrike	*Lanius ludovicianus*	X	X		X					X	
Mourning dove	*Zenaida macroura*	X	X	X	X		X	X	X	X	X
Northern mockingbird	*Mimus polyglottos*		X							X	
Osprey[1]	*Pandion haliaetus*			X							
Pied-billed grebe	*Podilymbus podiceps*	X									
Red-tailed hawk	*Buteo jamaicensis*				X					X	X
Red-winged blackbird	*Agelaius phoeniceus*	X	X			X	X		X	X	X
Ring-necked pheasant	*Phasianus colchicus*										X
Ruddy duck	*Oxyura jamaicensis*			X							
Say's phoebe	*Sayornis saya*	X			X				X		X
Snowy egret	*Egretta thula*			X			X				
Song sparrow	*Melospiza melodia*					X					
Spotted sandpiper	*Actitis macularius*					X					
Turkey vulture	*Cathartes aura*					X	X		X		X
Unidentified gnatcatcher	*Polioptila* sp.		X								
Unidentified passerine			X						X	X	X
Unidentified raptor			X								
Unidentified wren			X								
Verdin	*Auriparus flaviceps*						X		X	X	
White-crowned sparrow	*Zonotrichia leucophrys*				X					X	
White-faced ibis[1]	*Plegadis chihi*		X	X	X						
Yellow warbler[1]	*Dendroica petechia*	X								X	
AMPHIBIANS & REPTILES											
Common side-blotched lizard	*Uta stansburiana*							X			
Desert iguana	*Dipsosaurus dorsalis*										X
Spiny softshell turtle	*Trionyx spiniferus*			X							
Western whiptail	*Cnemidophorus tigris*					X		X		X	X
MAMMALS											
Desert cottontail	*Sylvilagus audubonii*	X				X					
White-tailed antelope squirrel	*Ammospermophilus leucura*								X		
INVERTEBRATES											
Desert hairy scorpion	*Hadrurus arizonensis*							X			

[1]Sensitive species - see Appendix I

Table 5-4
Results of the avian point-count surveys

Species	Total # of Birds Observed	Mean Use (# of Birds/Plot/30 min)	Frequency of Occurrence (% of Surveys where Detected)
White-faced ibis[1]	134	13.40	30
Red-winged blackbird	63	6.30	60
Mourning dove	56	5.60	80
Caspian tern	22	2.20	20
Black phoebe	16	1.60	50
Gambel's quail	16	1.60	10
Common ground-dove	11	1.10	40
White-crowned sparrow	9	0.90	20
Eurasian collared-dove	8	0.80	20
Turkey vulture	8	0.80	40
Verdin	8	0.80	30
Unidentified passerine	6	0.60	40
American kestrel	5	0.50	30
Green heron	5	0.50	40
House finch	5	0.50	10
Yellow warbler[1]	5	0.50	20
Abert's towhee	4	0.40	30
Killdeer	4	0.40	30
Belted kingfisher	3	0.30	30
Great egret	3	0.30	20
Loggerhead shrike	3	0.30	30
Barn swallow	2	0.20	20
Cattle egret	2	0.20	10
Greater roadrunner	2	0.20	20
Inca dove	2	0.20	10
Northern mockingbird	2	0.20	20
Red-tailed hawk	2	0.20	20
Say's phoebe	2	0.20	20
Unidentified raptor	2	0.20	10
Black-crowned night-heron	1	0.10	10
Brown-headed cowbird	1	0.10	10
Cactus wren	1	0.10	10
Common moorhen	1	0.10	10
European starling	1	0.10	10
Great blue heron	1	0.10	10
Pied-billed grebe	1	0.10	10
Snowy egret	1	0.10	10
Song sparrow	1	0.10	10
Spotted sandpiper	1	0.10	10
Unidentified gnatcatcher	1	0.10	10
Total	**421**	**42.10**	

[1]Sensitive species - see Appendix I

Mean use was highest for white-faced ibis (13.4 birds per survey), red-winged blackbirds (6.3 birds per survey), and mourning doves (5.6 birds per survey). All other birds had mean use of less than 2.2 birds per survey. The species that occurred most frequently (i.e., based on the percent of surveys during which they were detected) were mourning doves (observed in 80 percent of all point-count surveys), red-winged blackbirds (60 percent), and black phoebes (50 percent).

5.1.3 New River Sites

Site photographs can be found in Appendix I.

5.1.3.1 NR 8

Photographs 1, 2, & 3

This proposed restoration site is overgrown with *Tamarix sp. Tamarix sp.* represents 68 percent of the ground cover, bare ground/grasses 15 percent, *Pluchea sericea* ten percent,

Arundo donax five percent, and acacia (*Acacia sp.*) and narrow-leaved willow (*Salix exigua*) one percent each (Table 5-3). This site contained a trash dump area on the west side of the river. Access to the proposed wetlands was limited because of impenetrable *Tamarix sp.* stands.

Seventeen animal species were observed (16 avian, one mammalian) (Table 5-3). Special-status species observed included 20 Caspian terns and one yellow warbler. Caspian terns headed north were observed flying over the site, and the yellow warbler was observed in the *Tamarix sp.*

5.1.3.2 NR 16

Photographs 4 & 5

This proposed restoration site is overgrown with *Tamarix sp. Tamarix sp.* represents 90 percent of the ground cover, *Pluchea sericea* six percent, and saltgrass (*Distichlis spicata*) and *Arundo donax* two percent each (Table 5-2). This site contained a trash dump area on the west side of the river. Access to the river bank was limited because of the impenetrable *Tamarix sp.* stands.

Eighteen animal species were observed (all avian) (Table 5-3). Special-status species observed included approximately 50 white-faced ibis, two Caspian terns, and a Cooper's hawk. The white-faced ibis and Caspian terns were observed flying north over the site. A Cooper's hawk was perched in a *Tamarix sp.* tree with a pair of barn owls.

5.1.3.3 NR 22

No access was available to this site because of the lack of roads, private property surrounding the proposed site, and impenetrable tamarisk.

5.1.3.4 NR 26

Photographs 6, 7, 8, & 9

This alternative proposed restoration site, just north of Interstate 8, is overgrown with *Tamarix sp. Tamarix sp.* represents 85 percent of the ground cover, bare ground/grasses nine percent, and big saltbush (*Atriplex lentiformis*), saltbush (*Atriplex sp.*), and pickleweed (*Salicornia virginica*) two percent each (Table 5-2).

Fourteen animal species were observed (13 avian, one turtle) (Table 5-3). Special-status species observed included 28 white-faced ibis, 15 brown pelicans, one American white pelican, one osprey, and a small group of double-crested cormorants. The white-faced ibis were observed flying south over the site. The brown pelicans, American white pelican, osprey, and double-crested cormorants were all observed in the nearby Fig Lagoon, which is just south of Interstate 8.

5.1.3.5 NR 32

Photographs 10, 11, & 12

This proposed restoration site is overgrown with *Tamarix sp. Tamarix sp.* represents 50 percent of the ground cover, bare ground/grasses 36 percent, *Pluchea sericea* eight percent, *Arundo donax* three percent, *Washingtonia robusta* two percent, and *Prosopis pubescens* one percent (Table 5-2). This site contained trash dump areas at the northern edges of the proposed wetlands. Access to the proposed wetlands and river banks was limited because of the impenetrable *Tamarix sp.* stands.

Eleven animal species were observed (all avian) (Table 5-3). Special-status species observed included 56 white-faced ibis flying southwest over the site.

5.1.4 Alamo River Sites

Site photographs can be found in Appendix I.

5.1.4.1 AR 14

Photographs 13, 14, & 15

This proposed restoration site, located next to the University of California at Santa Barbara wildlife array station, is overgrown with *Tamarix sp. Tamarix sp.* represents 80 percent of the ground cover, bare ground/grasses ten percent, *Pluchea sericea* eight percent, and Encelia farinosa two percent (Table 5-2). This site contained a trash dump area near the wildlife array station. This site was easily accessible because of the maintained access road to the wildlife array station.

Nine animal species were observed (seven avian, one reptile, one mammal) (Table 5-3). No special-status species were observed.

5.1.4.2 AR 17

Photographs 16, 17, & 18

This proposed restoration site, which runs parallel to a power line array, is overgrown with Tamarisk sp. *Tamarix sp.* represents 90 percent of the ground cover, and *Pluchea sericea* and *Salicornia virginica* five percent each (Table 5-2). This site contained trash dump areas on the east side of the Alamo River. Access to the proposed wetland site was limited because of impenetrable *Tamarix sp.*

Six animal species were observed (all avian) (Table 5-3). No special-status species were observed.

5.1.4.3 AR 21

Photographs 19 & 20

This proposed restoration site, which was crossed by a diversion structure, is overgrown with *Tamarix sp. Tamarix sp.* represents 80 percent of the ground cover, bare ground/grasses ten percent, *Pluchea sericea* five percent, and *Salicornia virginica* and *Atriplex lentiformis* 2.5 percent each (Table 5-2). This site contained a trash dump area on the east side of the Alamo River. Access to the proposed wetland was limited because of impenetrable *Tamarix sp.*

Five animal species were observed (two avian, two reptilian, one invertebrate) (Table 5-3). No special-status species were observed.

5.1.4.4 AR 27

Photographs 21, 22, 23, & 24

This alternative proposed restoration site is overgrown with *Tamarix sp. Tamarix sp.* represents 85 percent of the ground cover, *Arundo donax* ten percent, *Pluchea sericea*) and brittlebrush (*Encelia farinose*) two percent each, and screwbean mesquite (*Prosopis pubescens*) one percent (Table 5-2). This site contained a trash dump area between the two proposed wetland sites. Access to parts of the sites was limited because of impenetrable *Tamarix sp.*

Sixteen animal species were observed (15 avian, one mammalian) (Table 5-3). No special-status species were observed.

5.1.4.5 AR 28

Photographs 25, 26, & 27

This alternative proposed restoration site is overgrown with *Tamarix sp.* Tamarisk represents 82 percent of the ground cover, bare ground/grasses seven percent, arrow weed (*Pluchen sericea*) five percent, and palo verde (*Cercidium floridum*) and *Distichlis spicata* three percent each (Table 5-2). This site contained a trash dump area between the Alamo River and the southern portion of the proposed wetland site. Access to the proposed wetland sites was limited because of impenetrable *Tamarix sp.*

Fifteen animal species were observed (14 avian, one reptilian) (Table 5-3). Special-status species observed included four yellow warblers in the *Tamarix sp.*

5.1.4.6 AR 37

Photographs 28, 29, 30, 31, & 32

This proposed restoration site, bisected by Hunt Road, is overgrown with *Tamarix sp.* *Tamarix sp.* represents 75 percent of the ground cover, bare ground/grasses ten percent, *Pluchea sericea* five percent, *Prosopis pubescens* four percent, *Arundo donax* three percent, *Salicornia virginica* two percent, and creosote bush (*Larrea tridentate*) one percent (Table 5-2). This site contained a trash dump area on the western boundary of the proposed wetland. The site was easily accessible.

Eighteen animal species were observed (16 avian, two reptilian) (Table 5-3). Special-status species observed included a burrowing owl perched on a bank of an adjacent agricultural field.

5.2 Discussion

The invasive weed *Tamarix sp.* has overrun and out-competed the native wetland species at all of the proposed restoration sites. Although *Tamarix sp.* provides suitable habitat for certain species (i.e. doves, white-faced ibis, pocket mice), it has displaced numerous plant and animal species (i.e. *Salicornia virginica*, *Atriplex sp.*, Salix sp., *Pluchea sericea*, Gila woodpecker, Crissal thrasher). The restoration of these proposed wetland sites, which could include the removal of invasive species such as *Tamarix sp.* and *Arundo donax*, would significantly increase the diversity and abundance of native plant and animal species.

Many of the avian species were observed flying over the proposed wetland sites. These individuals were included in the mean use analysis because birds utilize habitats in three dimensions, so not only are they using the habitat at ground level (i.e. nesting, ground foraging, resting/roosting), but also the open space above the habitat (i.e. movement corridors, aerial foraging). Many of the birds, such as American white pelican and California brown pelican (*Pelecanus occidentalis californicus*), barn swallow (*Hirundo rustica*), belted kingfisher (*Ceryle alcyon*), egret and heron, common moorhen (*Gallinula chloropus*), cormorant, killdeer (C*haradrius vociferus*), osprey, grebe, red-winged blackbird (*Agelaius phoeniceus*), ruddy duck (*Oxyura jamaicensis*), spotted sandpiper (*Actitis macularius*), and ibis, observed at and around the proposed restoration sites are typical of natural wetland habitats. However, many of these species are only wintering or passing through the area instead of breeding. Restoration of these sites is expected to provide suitable nesting habitat for the reestablishment of these historical breeders.

Trash dump areas consisting of domestic debris are quite common along the New and Alamo Rivers. Restoration of the wetland sites would include the clean-up and removal of these areas, consequently greatly improving the quality of wetland habitat and water quality.

CHAPTER 6
OVERVIEW OF COMPOSITE WATERSHED/WETLAND MODEL

6.1 Objectives

The objectives of the composite watershed/wetland model constructed for this study are the following:

- To build a screening level predictive tool (a computer model) that assesses the water quality impacts of constructing one or more wetlands at key locations along the New and Alamo Rivers; and
- To use this computer model to make a priori judgments of the benefits of the wetland master plan and to prioritize potential sites for wetland construction.

A screening level computer model of the Alamo and New Rivers has been developed that is based on a representation of water flows and chemical concentrations from different sources in the watersheds. Flows in river reaches are shown schematically in Figure 6-1. The modeling approach uses simplified forms of watershed and water quality models similar to models used in EPA's TMDL applications and watershed protection plans.

Published data and modeling approaches were used to independently develop a model of flows and chemical concentrations with and without individual wetlands in the Alamo and New River systems. The level of detail used in the watershed/wetland model is similar to that used recently by the Colorado River Basin Regional Water Quality Control Board (CRBRWQCB) for TMDL analyses of the New and Alamo Rivers (CRBRWQCB, 2002a and 2002b), and was chosen specifically to be consistent with the available data and hydrologic complexity of these river systems given the objectives of this study. The model includes all major and minor agricultural flows, which are the principal additions to river flows, as well as contributions from groundwater accretion, overland flow, and NPDES discharges. The watershed model also incorporated proposed wetlands to simulate removal of a portion of the river or drain flow for treatment before returning the treated flow to the river. The impacts of future constructed wetlands on New and Alamo River water quality were simulated using wetland sub-models. The wetland models have been calibrated to the Imperial and Brawley pilot wetlands, as documented in a separate report (*Performance Evaluation of the New River Demonstration Wetlands*, Tetra Tech, 2006).

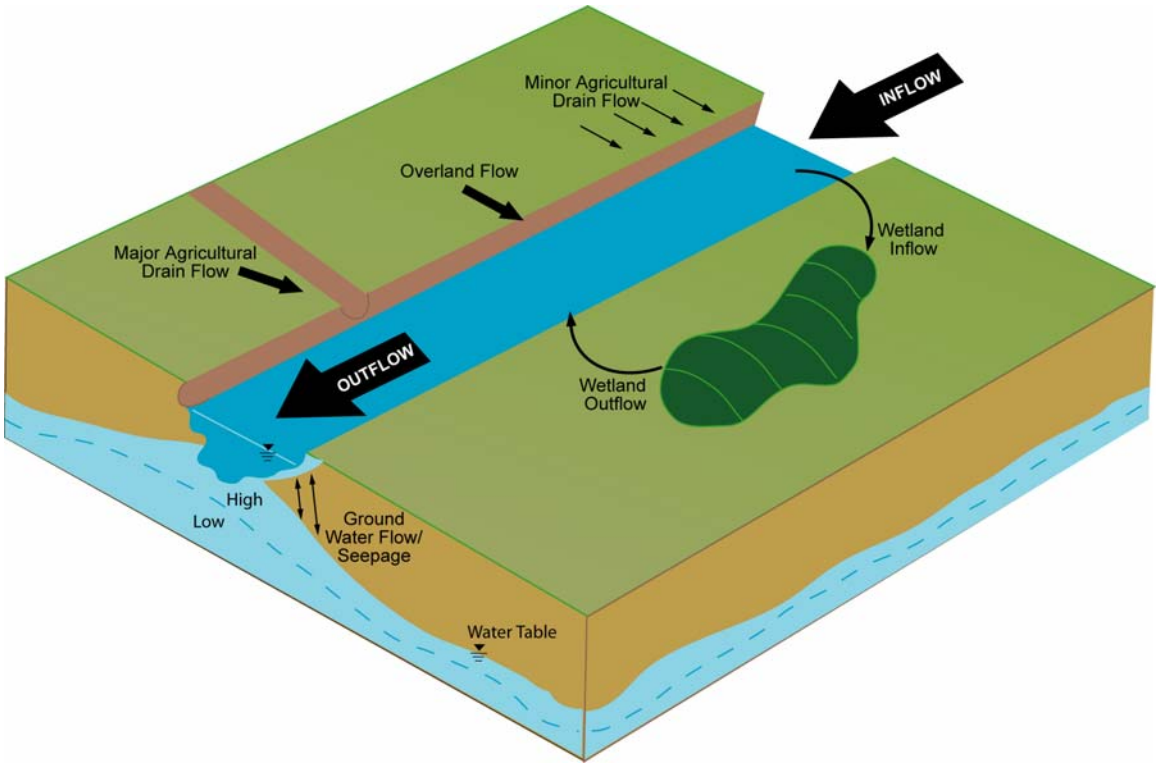


Figure 6-1 Schematic representation of flows in individual river reaches for the watershed/wetland flow and water quality model.

6.2 Conceptual Model

A conceptual model of flows and chemical loads in the New and Alamo River Basin was developed considering river inflows from agricultural drains, groundwater accretion, irrigation return flow, precipitation runoff, and NPDES discharges. The model was also constructed considering drain and river withdrawals for wetlands and subsequent wetland return flows. The wetland model considers internal wetland processes such as wetland chemical transformations, seepage to groundwater, and evapotranspiration. The conceptual model succinctly represents the current understanding of issues pertaining to water flow and chemical transport in this system, and identifies key fate and transport processes and sources of water and chemicals in the New and Alamo River Watersheds.

6.3 Watershed Flow Model

The water flow model of the New and Alamo River watersheds follows the water balance approach adopted by the CRBRWQCB in the Sediment/Siltation TMDLs for the Alamo River (CRBRWQCB, 2002a) and the New River (CRBRWQCB, 2002b) for a five-year period in the late 1990s. This approach allocates watershed flows on a monthly basis as follows:

- *Major Drain Return Flows*: Irrigation return flow to rivers from major agricultural drains is estimated based upon major agricultural drain flow measurements from IID. This flow includes all tilewater, tailwater, seepage water, and canal spill water conveyed in the drains;
- *Minor Drain Return Flows*: Irrigation return flow to rivers from minor agricultural drains is estimated based upon a return fraction of the irrigation water applied in the drainage

areas of the minor agricultural drains. The return fraction is estimated using statistical correlations between measured return flow and applied water in the major drains, and extrapolating that relationship to the minor drains. This flow includes all tilewater, tailwater, seepage water, and canal spill water conveyed in the drains;

- *Direct to River Irrigation Return Flow:* Irrigation return flow to rivers from agricultural fields directly bordering the rivers is estimated based upon a return fraction of irrigation water that is applied in the drainage areas of these fields. This is estimated in the same manner used for the Minor Drains, except that these fields discharge directly to the river, not to a minor drain. This flow includes all tilewater, tailwater, seepage water, and canal spill water conveyed directly to the river.
- *NPDES Flows:* NPDES discharges in the watershed are estimated using the reports filed by dischargers. NPDES flows directly discharged to the river are included explicitly in the conceptual model, while NPDES flows to major and minor drains are implicitly included with the major and minor drain flow estimates;
- *US-Mexico Border Flows:* US-Mexico Border Flows into the watershed are estimated using gauging and water quality data collected at the border on the New River and Alamo River;
- *Agricultural Runoff from Precipitation:* Overland flow of precipitation draining from agricultural land use areas is estimated using the agricultural area acreage and a runoff fraction of precipitation.
- *Urban Runoff from Precipitation:* Overland flow of precipitation draining from urban land use areas is estimated using the urban area acreage and a runoff fraction of precipitation.
- *Groundwater Discharge directly to the River:* Groundwater that discharges directly to the rivers is estimated using groundwater accretion rates, which are estimated from the volume of groundwater that discharges directly to rivers and the river length. Note this regional groundwater discharge includes only the portion of regional groundwater discharging directly to the river, as regional groundwater discharging directly to drains in already included in the major and minor drain flows.

6.4 Watershed Quality Model

A water quality model has been developed for nutrients (total phosphorus and total nitrogen), total suspended solids (TSS), total coliforms, and total selenium. The water quality model of the New and Alamo River watersheds follows a mass balance approach, whereby chemical loading for the watershed sources are estimated by multiplying the water fluxes by the measured or estimated concentration data available for each of the specified sources. The water fluxes for the watershed sources are discussed above. Measured chemical concentrations are generally available at the international border, for most major drains, for some minor drains, and for some NPDES facilities. These data are discussed in Section 2; data from 1987 to 2005 are used in the modeling. Concentrations for drains without measured data are estimated from measured concentrations from nearby drains, or those of similar flows. Estimated urban runoff concentrations are taken from the literature (www.stormwater.net). Estimated NPDES concentrations are based on measured concentrations from other NPDES facilities.

For the Alamo River, drain flows represent almost all the inflow to the river. Measured concentration data are available for 14 drains. Holtville Main and South Central drains are the

only drains with measured concentration data in the entire 5-year calibration period (in 1996-1997); they represent 16 percent of the total flow to the river. However, 9 other drains (e.g., C, I, N, Munyon, Magnolia, Oleander, Standard, Nettle, Peach) had quarterly data in 2004 and 2005 and 4 other drains (e.g., Verde Main, Central Main, Rose Main, All American Canal) had monthly data in parts of 2004 and 2005. These data were used to construct monthly variable data for those drains for the 5-year calibration period.

For the New River, measured concentration data from cross-border flows were generally available for the entire 5-year calibration period. A few assumptions were made. For instance, fecal coliform data were assumed for total coliform at the international border; this appears to be a good assumption based on a few data comparisons. Cross-border flow comprises 32 percent of flows in the New River. Total nitrogen is primarily ammonia and organic N at the international border (see notes on Figure 6-10). Greeson drain was the only drain with measured data in the entire 5-year calibration period (in 1996-1997). However several drains (e.g., Fig, North Central, Rice, Spruce, Timothy 2, Trifolium 10) had quarterly data in 2004 and 2005 and the Rice 3 drain (measured at the inlet to the Imperial pilot wetland) had monthly values from 2001 to 2005. These data were used to construct monthly variable data for those drains for the 5-year calibration period. Drain flow comprises 56 percent of flows in the New River.

6.5 Wetland Flow Model

The water flow model of the New and Alamo River watersheds also follows a water balance approach. Flows associated with future proposed wetlands are estimated as follows.

Inflows to wetlands can come from diversions from nearby drains and/or the rivers. The current model configuration is for flow to first come from nearby drains. If the wetland flow demand is not met by available drain flow, then the remaining water is routed from the river. The hydraulic loading rate for each proposed wetland is pre-determined by the wetland design and wetland objectives. Low hydraulic loading rates result in longer residence times that can allow for larger reductions in constituent concentrations. However, higher hydraulic loading rates allow for the treatment of greater volumes of water and can produce larger reductions in the chemical loads. Physical characteristics of the wetland may constrain the hydraulic loading rate as well.

Wetland outflows were estimated as the difference between wetland inflows and wetland water losses due to evapotranspiration and seepage. Wetland evapotranspiration is estimated based upon wetland area and a monthly evapotranspiration rate. Seepage losses from the wetlands are estimated as a fraction of total inflow based upon the data collected from the Brawley and Imperial pilot wetlands. Seepage from the wetland is assumed to return to the rivers based upon the regional hydrogeologic conditions, since the New and Alamo Rivers are strong groundwater discharge areas (Loeltz et al., 1975).

6.6 Wetland Quality Model

Two types of models, plug-flow and completely stirred tank reactor (CSTR), are included in the wetland model. The plug-flow model was derived by Kadlec and Knight (1996). The CSTR model assumes three reactors in series to represent a hypothetical CSTR wetland design. The two models are mathematically presented in Section 6.3. The models consider inflow, outflow, seepage, and removal with a first order rate constant in units of length over time (such as m/yr), where the rate constant lumps the effects of numerous transformations in wetlands. The rate constants for the five modeled constituents and the two model types were fitted to the Brawley and Imperial pilot wetlands.

The inflow concentration is calculated based on a mass balance between the possible influxes to the wetland. Drain fluxes estimated as the wetland inflow rates times the drain chemical concentrations (measured or estimated); river fluxes are predicted for the river by the watershed quality model.

Chemical water quality in the wetland seepage returning to the river is chemical-specific and based upon the adsorption characteristics of each chemical. Strongly-sorbing species (i.e., total phosphorus, suspended solids, total coliforms) are assumed to have complete removal in the regional groundwater and discharge to the river is at concentrations equal to those of the regional groundwater. Non-sorbing, conservative species (i.e., total nitrogen, selenium) are assumed to have no removal in regional groundwater and discharges to the river at wetland seepage concentrations.

6.7 Model Mathematical Formulation

The mathematical formulations of the flow and transport models described in the conceptual model are provided herein. The formulations of the flow and transport models are based upon water and chemical mass balances for each river reach and wetland.

6.7.1 Watershed Flow Model Equations

For steady-state flow conditions, the net water flowing out of the river segment (${}^{s}Q_{out}$) is equal to the sum of all sources of water flowing into the river segment. Mathematically, water flow in each river reach is described as follows assuming steady-state conditions:

$$Q^{s}_{out} = Q^{s}_{in} + \sum_{k} Q^{s}_{D_k} \cdot \left(1 - f^{w}_{D_k}\right) + Q^{s}_{gw} + \sum_{l} Q^{s}_{NPDES_l} + Q^{S}_{\substack{urban\\runoff}} + Q^{S}_{\substack{ag.\\runoff}} + Q^{s}_{DD}$$

$$+ Q^{w-1}_{seepage} + Q^{w-1}_{out} - Q^{w}_{in}$$

Where:

$$Q^{s}_{in} = Q^{s-1}_{out}$$

$$Q^{s}_{gw} = Q^{River}_{gw} \cdot \frac{L^{s}}{L^{River}} \cdot \frac{1}{12}$$

$$Q^{S}_{\substack{urban\\runoff}} = Q^{River}_{\substack{urban\\runoff}} \cdot f^{s}_{urban}$$

$$Q^{S}_{\substack{ag.\\runoff}} = Q^{River}_{\substack{ag.\\runoff}} \cdot f^{s}_{ag}$$

$$Q^{s}_{DD} = Q^{River}_{DD} \cdot \frac{L^{s}}{L^{River}}$$

Q_{out}^{s} = Outflow concentration from reach s, AF/mo

Q_{in}^{s} = Flow entering reach s from reach s - 1, $= Q_{out}^{s-1}$, AF/mo

$Q_{D_k}^{s}$ = Flow from drain k into reach s, AF/mo

$f_{D_k}^{w}$ = Fraction of drain k flow to wetland w, -

Q_{gw}^{s} = Groundwater flow into reach s, AF/mo

Q_{gw}^{River} = Total groundwater flow into river, AF/yr

$Q_{NPDES_l}^{s}$ = Flow from NPDES discharger l (direct river discharges only), AF/mo

$Q_{urbam\ runoff}^{s}$ = Urban land runoff into reach s, AF/mo

$Q_{urbam\ runoff}^{River}$ = Urban land runoff into river, AF/mo

$Q_{ag\ runoff}^{s}$ = Agricultural runoff into reach s, AF/mo

$Q_{ag\ runoff}^{River}$ = Agricultural runoff into river, AF/mo

Q_{DD}^{s} = Agricultural direct discharge flow into reach s, AF/mo

Q_{DD}^{River} = Agricultural direct discharge flow into river, AF/mo

$Q_{seepage}^{w-1}$ = Wetland seepage from wetland w - 1 that returns to reach s, AF/mo

Q_{out}^{w-1} = Wetland outflow from wetland w - 1 associated with reach s - 1, AF/mo

Q_{in}^{w} = River flow to wetland w from reach s, AF/mo

L^{s} = reach length for reach s, mile

$\mathrm{L}^{\mathrm{River}}$ = Cumulative river length, mile

f_{urban}^{s} = fraction of urban land in reach s, -

f_{ag}^{s} = fraction of agricultural land in reach s, -

The terms related to flow to the wetland, f_{D}^{w} and Q_{in}^{w}, are described in the wetlands flow model.

These water flow equations are applied to each river reach to calculate the total flow exiting the rivers to the Salton Sea, and also used to calculate the chemical loads in the chemical transport equations.

6.7.2 Watershed Quality Model Equations

For steady-state chemical transport conditions, the net chemical mass flowing out of the river reach (M_{out}) is equal to the sum of all sources of mass flowing into the river reach minus the amount of mass lost in the river reach due to transformations. A well-mixed assumption is used for each river reach and a first-order aggregate chemical mass loss is assumed. Mathematically, chemical transport in each river reach is described as follows assuming steady-state conditions:

$$\dot{M}_{in} - \dot{M}_{out} - \dot{M}_{loss} = \frac{dM}{dt} = 0$$

Where

$$\begin{aligned}\dot{M}_{in} = {}^{s}Q_{in}^{Total}\,{}^{s}C_{in}^{Total} &= Q_{in}^{s} \cdot C_{in}^{s} + \sum_{k} Q_{D_k}^{s} \cdot \left(1 - f_{D_k}^{w}\right) C_{D_k}^{s} + Q_{gw}^{s} C_{gw}^{s} \\ &+ \sum_{l} Q_{NPDES_l}^{s} C_{NPDES_l}^{s} + Q_{\substack{urban\\runoff}}^{s} C_{\substack{urban\\runoff}}^{s} + Q_{\substack{ag\\runoff}}^{s} C_{\substack{ag\\runoff}}^{s} + Q_{DD}^{s} C_{DD}^{s} \\ &+ Q_{seepage}^{w-1} \cdot C_{seepage}^{w-1} + Q_{out}^{w-1} \cdot C_{out}^{w-1}\end{aligned}$$

$$\dot{M}_{out} = Q_{in}^{w} \cdot C_{out}^{s} + Q_{out}^{s} C_{out}^{s}$$

$$\dot{M}_{loss} = k_R \cdot C_{out}^{s} \cdot V^{s}$$

The concentration of the chemical in the reach is calculated using the following relation for a steady-state well-mixed system (Tchobanoglous and Schroeder, 1985):

$$C_{out}^{s} = \frac{{}^{s}Q_{in}^{Total}\,{}^{s}C_{in}^{Total}}{Q_{in}^{w} + Q_{out}^{s} + k_R V^{s}}$$

$$V^{s} = L^{s} \cdot \left(\frac{A_{up}^{s} + A_{down}^{s}}{2}\right) \cdot \frac{5280\,ft}{mi} \cdot \frac{acre}{43560.17\,ft^{2}}$$

Where

${}^{s}Q_{in}^{Total}\,{}^{s}C_{in}^{Total}$ = Total mass loading entering reach s, mg/L · AF/mo or MPN/100 mL · AF/mo

C_{in}^{s} = Inflow river concentration to reach s from reach s - 1 $= C_{out}^{s-1}$, mg/L or MPN/100 mL

C_{out}^{s} = Outflow river concentration from reach s, mg/L or MPN/100 mL

$C_{D_k}^{s}$ = Concentration from drain k in reach s, mg/L or MPN/100 mL

C_{gw}^{s} = Groundwater concentration entering reach s, mg/L or MPN/100 mL

$C_{NPDES_l}^{s}$ = Concentration of NPDES discharger l, mg/L or MPN/100 mL

$C_{\substack{urbam\\runoff}}^{s}$ = Urban land concentration entering reach s, mg/L or MPN/100 mL

$C_{\substack{ag\\runoff}}^{s}$ = Agricultural runoff concentration entering reach s, mg/L or MPN/100 mL

C_{DD}^{s} = Agricultural direct discharge concentration, mg/L or MPN/100 mL

C_{out}^{w-1} = Wetland outflow from previous wetland, w - 1, mg/L or MPN/100 mL

$C_{seepage}^{w-1}$ = Wetland seepage from previous wetland, w - 1, mg/L or MPN/100 mL

k_R = Loss rate constant in river, 1/mo

V^s = Volume in reach s, AF

A_{up}^{s} = Cross - sectional area on upstream edge of reach s, ft^2

A_{down}^{s} = Cross - sectional area on downstream edge of reach s, ft^2

River cross-sectional areas are calculated using cross-section data reported in a UC Davis study of the New and Alamo Rivers (Huston et al., 2000). Cross-sectional areas reported by Huston et al. (2000) were measured at flow conditions of 510 cubic feet per second in the New River and 810 cubic feet per second in the New River. Cross-sectional areas for different river flow conditions were adjusted upwards or downwards in proportion to the river flow conditions. These river cross-sectional areas result in typical river flow velocity values of between 1 and 3 feet per second, and typical river flow times between the US-Mexico border and the Salton Sea of 2 days.

The chemical transport equations are applied to each river reach to calculate the total chemical load exiting the rivers to the Salton Sea, and also used to calculate chemical loads in the diversions to wetlands for the wetland equations below.

6.7.3 Wetland Flow Model Equations

For steady-state flow conditions, the net water flowing out of each wetland (${}^{w}Q_{out}$) is equal to the sum of all sources of water flowing into each wetland minus any losses due to evapotranspiration or seepage. Mathematically, water flow in each wetland is described as follows assuming steady-state conditions:

$$Q_{out}^{w} = Q_{in-total}^{w} + P^{w} - E^{w} - Q_{seepage}^{w}$$

Where

$$Q_{in-total}^{w} = \cdot \min(Q_{design}^{w}, Q_{in}^{w} + \sum Q_{D_k}^{s} f_{D_k}^{w})$$

$$P^{w} = P \cdot A^{w}$$

$$E^{w} = E \cdot A^{w}$$

$$Q_{seepage}^{w} = Q_{in-total}^{w} \cdot f_{seepage}$$

$Q_{in-total}^{w}$ = Total inflow from drains and river to meet wetland design flow, AF/mo

Q_{design}^{w} = Maximum possible inflow based on wetland design and size, AF/mo

P^{w} = Precipitation to wetland w, AF/mo

P = Monthly historical precipitation in Imperial Valley, ft/mo

A^{w} = Wetland area, acres

E^{w} = Evapotranspiration from wetland w, AF/mo

E = Monthly historical precipitation in Imperial Valley, ft/mo

$Q_{seepage}^{w}$ = Groundwater seepage from wetland w, AF/mo

$f_{seepage}$ = fraction of total inflow to seepage, -

These water flow equations are applied to each wetland to calculate the flow exiting the wetlands and returning to the rivers, and also used to calculate chemical loads in the chemical transport equations below.

6.7.4 Wetland Quality Model Equations

For steady-state chemical transport conditions, the net chemical mass flowing out of the wetland is equal to the sum of all sources of mass flowing into the wetland minus any losses in the wetland due to transformations or seepage. Two models are considered. The first model is based on a plug flow reactor as outlined by Kadlec and Knight (1996). The second model is based on the completely stirred tank reactor (CSTR) model.

For the plug flow reactor model, the inlet, outlet, and seepage concentrations are written as:

$$C_{in-total}^{w} = \frac{Q_{in}^{w} C_{in}^{w} + \sum_{k} Q_{D_k} f_{D_k}^{w} C_{D_k}}{Q_{in-total}^{w}}$$

$$C_{out}^{w} = (C_{in-total}^{w} - \mathrm{C_a})(\frac{q_o}{q_i})^{-(1+\frac{k+I}{q_o - q_i})} + \mathrm{C_a}$$

$$C_{gw}^{w} = \frac{C_{in-total}^{w} - \mathrm{C_a}}{\alpha - \alpha\beta}[(1+\alpha)^{(1-\beta)} - 1] + \mathrm{C_a}$$

$$\alpha = \frac{q_o - q_i}{q_i}$$

$$\beta = 1 + \frac{k + I}{q_o - q_i}$$

$$q_o = \frac{Q_{out}^w}{A^w} \cdot *.3048 m / ft$$

$$q_i = \frac{Q_{in-total}^w}{A^w} \cdot *.3048 m / ft$$

$$I = \frac{Q_{seepage}^w}{A^w} \cdot 12 mo / yr * .3048 m / ft$$

Where

$C_{in-total}^w$ = Total inflow concentration, mg/L

Q_{in}^w = Reach flow to wetland, mg/L

C_{in}^w = Reach concentration for reach s that enters wetland w, mg/L or MPN/100mL

C_D = Drain concentration, mg/L or MPN/100mL

$Q_{in-total}^w$ = Total inflow to wetland w, AF/mo

C_{out}^w = Outflow from wetland w, mg/L or MPN/100mL

C_a = Plateau concentration, mg/L or MPN/100mL

C^* = Background concentration, = C_a, mg/L or MPN/100mL

k = Loss rate constant for all wetlands, m/yr

I = Seepage rate, m/yr

q_o = outlet hydraulic loading rate, m/yr

q_i = inlet hydraulic loading rate, m/yr

A^w = Wetland area, acres

$Q_{seepage}^w$ = Wetland seepage flow, AF/mo

The mass fluxes for the inlet, outlet, seepage, and wetland mass loss are calculated as:

$$M_{in-total}^w = C_{in-total}^w \cdot Q_{in-total}^w$$

$$M_{out}^w = C_{out}^w \cdot Q_{out}^w$$

$$M_{gw}^w = C_{gw}^w \cdot Q_{gw}^w$$

$$M_{loss}^w = k \cdot A^w \left[\frac{C_{in-total}^w - C_a}{\alpha - \alpha\beta}[(1+\alpha)^{(1-\beta)} - 1] + C_a - C^*\right]$$

For the CSTR model, the wetland model is implemented as three CSTRs in series. The wetland is divided into three equal area wetland cells. The outlet concentration for each cell *i* is written as:

$$C_{out_i}^{w} = \frac{C_{in}^{w} \cdot Q_{in_i}^{w} + kA_i C^*}{Q_{out_i}^{w} + Q_{gw_i}^{w} + kA_i^{w}}$$

$$C_{gw_i}^{w} = C_{out_i}^{w}$$

The mass fluxes for the inlet and outlet are calculated the same as for the plug flow model. The mass fluxes for the seepage and wetland mass loss are calculated as:

$$M_{gw}^{w} = (C_{gw_{i=1}}^{w} + C_{gw_{i=2}}^{w} + C_{gw_{i=3}}^{w}) \cdot Q_{gw}^{w}$$

$$M_{loss}^{w} = (C_{out_{i=1}}^{w} + C_{out_{i=2}}^{w} + C_{out_{i=3}}^{w}) \cdot k \cdot A^{w}$$

As noted in Section 6.2.4, water quality in the wetland seepage returning to the river is chemical-specific. Total phosphorus, total suspended solids, and total coliforms are assumed to have complete removal in the regional groundwater and discharge to the river is at concentrations equal to those of the regional groundwater. The non-sorbing species (i.e., total nitrogen, selenium) are assumed to have no removal in regional groundwater and discharges to the river at wetland seepage concentrations.

6.7.5 Composite Watershed/Wetland Model Solution

The water flow and chemical transport equations for the river segments and wetlands are solved sequentially for each time period from the upstream river reaches to the downstream river reaches. This is done because the equations at the lower reaches are dependent on the results from the upper reaches, while the equations for the upper reaches are independent of the reaches below it. The model equations for various time periods are assumed to independent of the previous time by assuming steady-state flow and transport conditions. The equations are implemented for monthly variations in flow and water quality. This assumption was made because:

- Changes over time in the system water volume and chemical mass are small relative to the total system volume, mass, flows, and loads; and
- Changes in the system flows and loads that do occur happen relatively quickly since river residence time of two days is quite small compared to the model monthly time increments.

The composite watershed/wetlands model is developed as a Microsoft Excel spreadsheet program. Therefore, all model data can be easily entered, modified, and viewed, and model calculations are transparent to all reviewers. The model is designed to allow for quick evaluation of different wetland designs so wetland characteristics (such as the number, locations, and properties of the constructed wetlands) can be easily reconfigured.

The model includes an annual water and mass balance summary. The summary provides water flow and chemical load data from all the major sources that generate inflows to the rivers, and a summary of the water flows and chemical loads that flow out of the New and Alamo Rivers to the Salton Sea. There is nearly perfect agreement between the water and chemical mass inflows from the sources to the rivers and water and chemical mass outflows from the rivers to the Salton Sea. This results in very small mass balance errors in both magnitude and as a percent of total flows. From a water and chemical accounting perspective, this indicates that the model appears to be from any major coding or conceptual errors that typically would be manifested as mass balance errors between the model inflows and outflows. The model was executed for a variety of conditions with and without wetlands, and

model inflows, outflows, and losses always were found to result in very small mass balance errors.

6.8 Model Implementation for the New and Alamo River Watersheds

One possible design for treatment wetlands on the New and Alamo Rivers is provided by a reconnaissance and ranking of potential wetland and sedimentation basin sites by Nolte Engineers (2002). The report recommends 35 wetland sites as suitable for treatment wetland construction. These recommended 35 wetlands are included in the initial model implementation presented in this report. This included 19 wetlands on the New River and 16 wetlands on the Alamo River.

The New and Alamo River watersheds were sub-divided into a series of river reaches and subwatersheds that were defined by the locations of these proposed wetlands. The upstream limit of each reach is the location of the closest upstream wetland located at the end of the previous reach, while the downstream limit of each reach is the location of the next downstream wetland that is located within that reach. The exceptions are the first river reach, where the upstream limit of the reach is the US-Mexico Border, and the last river reach, where the downstream limit of the reach is the river discharge to the Salton Sea. Thus, 37 river reaches were included in the model setup, with one reach defined per wetland and the last reach defined for the outlet to the Salton Sea.

Figure 6-2 depicts the New and Alamo Rivers as initially simulated in the composite watershed/wetland model. The agricultural drains in the Imperial Valley are depicted as light blue lines, the New and Alamo Rivers are depicted as dark blue lines, the drainage areas for each river reach are depicted by the colored areas, and the locations of the proposed wetlands are depicted as red dots. Drains that flow directly to the Salton Sea (i.e., not to one of the rivers) are excluded from the model.

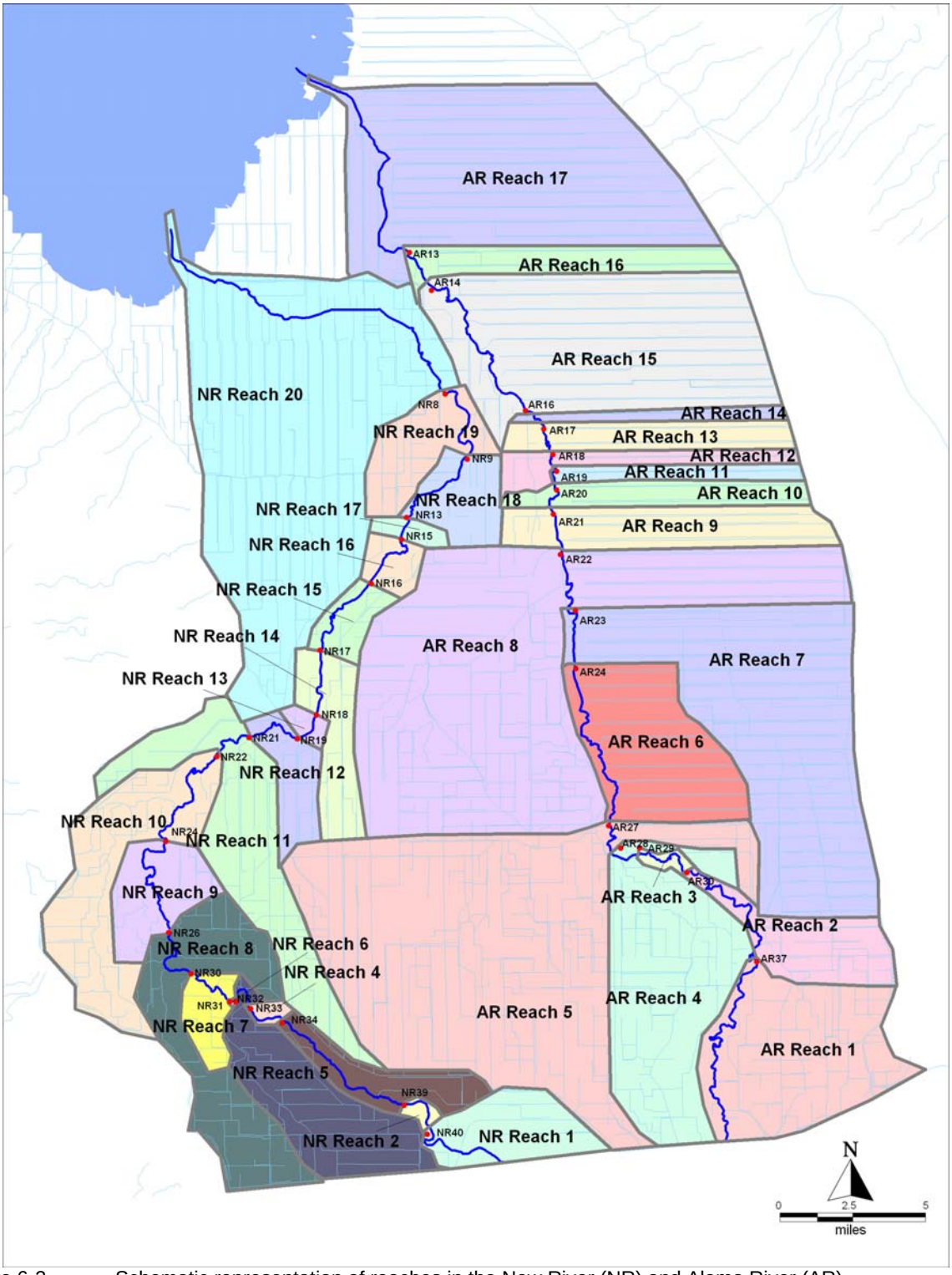


Figure 6-2 Schematic representation of reaches in the New River (NR) and Alamo River (AR) watershed/wetland model.

The two main rivers in the watershed are broken into discrete reaches with upstream inflows, downstream outflows, accretions, and diversions over the reach as discussed in Section 6.2. Figures 6-3 and 6-4 present example river reaches in the Alamo River (Reach 1) and the New River (Reach 20) with their associated watershed sources. In Figures 6-3 and 6-4, the white rectangle represents the river, the green square represents the proposed wetland, the solid line arrows represent drain, border, and NPDES flows, and the dashed lines represent non-point sources such as overland flows and groundwater discharge. The upstream limit of each reach is the location of the closest upstream wetland located at the end of the previous reach, while the downstream limit of each reach is the location of the next downstream wetland that is located within that reach. The exceptions are the first river reach, where the upstream limit of the reach is the US-Mexico Border (e.g., Figure 6-3), and the last river reach, where the downstream limit of the reach is the river discharge to the Salton Sea (e.g., Figure 6-4). The conceptual figures for all reaches are in Appendix J.

The model data for the agricultural return flows, point sources, stormwater runoff, urban runoff, and groundwater seepage are the historical water quality and flow data from the Alamo and New River Basins that were collected and summarized for this study. The data are discussed in detail in Section 2 and model use summarized in Section 6.2. The flow data are directly taken from flow data and analyses presented in the Silt/Sedimentation TMDLs for the New and Alamo Rivers.

Drain and NPDES flows are allocated to each reach based upon their location relative to the reach drainage area depicted in Figure 6-2, resulting in a series of linked reaches similar to the example schematics given in Figures 6-3 and 6-4. Other flows are allocated based upon reach properties as follows:

- Groundwater flow: estimated based upon reach length in miles and the river groundwater accretion rate in acre-feet per year per mile;
- Urban Runoff from precipitation: estimated based upon the reach urban land use area (in acres) and a runoff coefficient in feet per year;
- Agricultural Runoff from Precipitation: estimated based upon the reach agricultural land use area (in acres) and a runoff coefficient in feet per year; and
- Direct to River Irrigation Return Flow: estimated based upon reach length in miles and the river direct irrigation accretion rate in acre-feet per year per mile (this excludes all irrigation flows conveyed by manor and minor drains, which are given explicitly for each reach);

Water quality data for phosphorus, nitrogen, total suspended solids, selenium, and coliforms are presented in Section 2 and briefly summarized in Section 6.2.2 . Based upon the available information, these loadings vary from reach to reach.

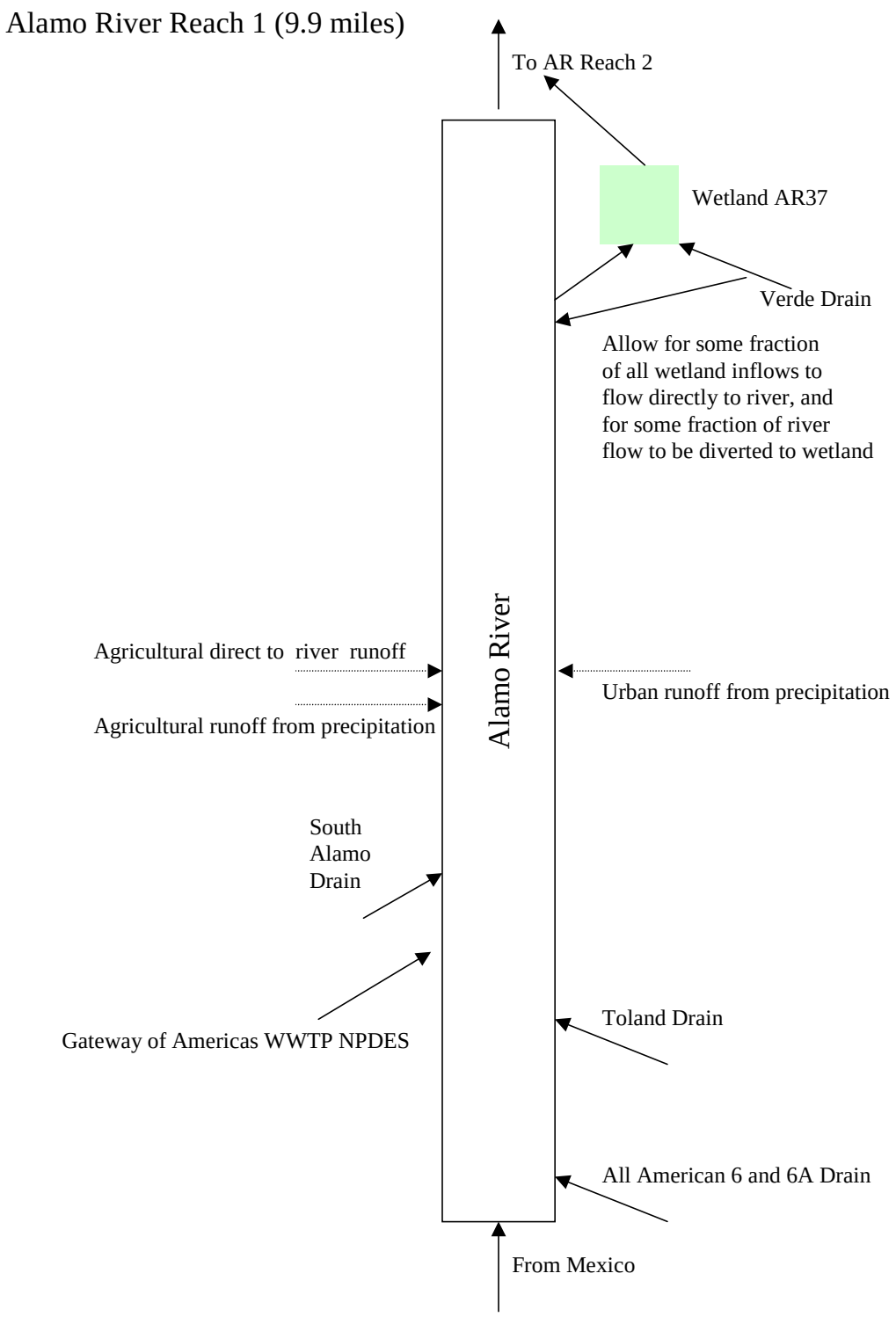


Figure 6-3 Conceptual representation of flows in the watershed/wetland model: Alamo River Reach 1 and Wetland AR37.

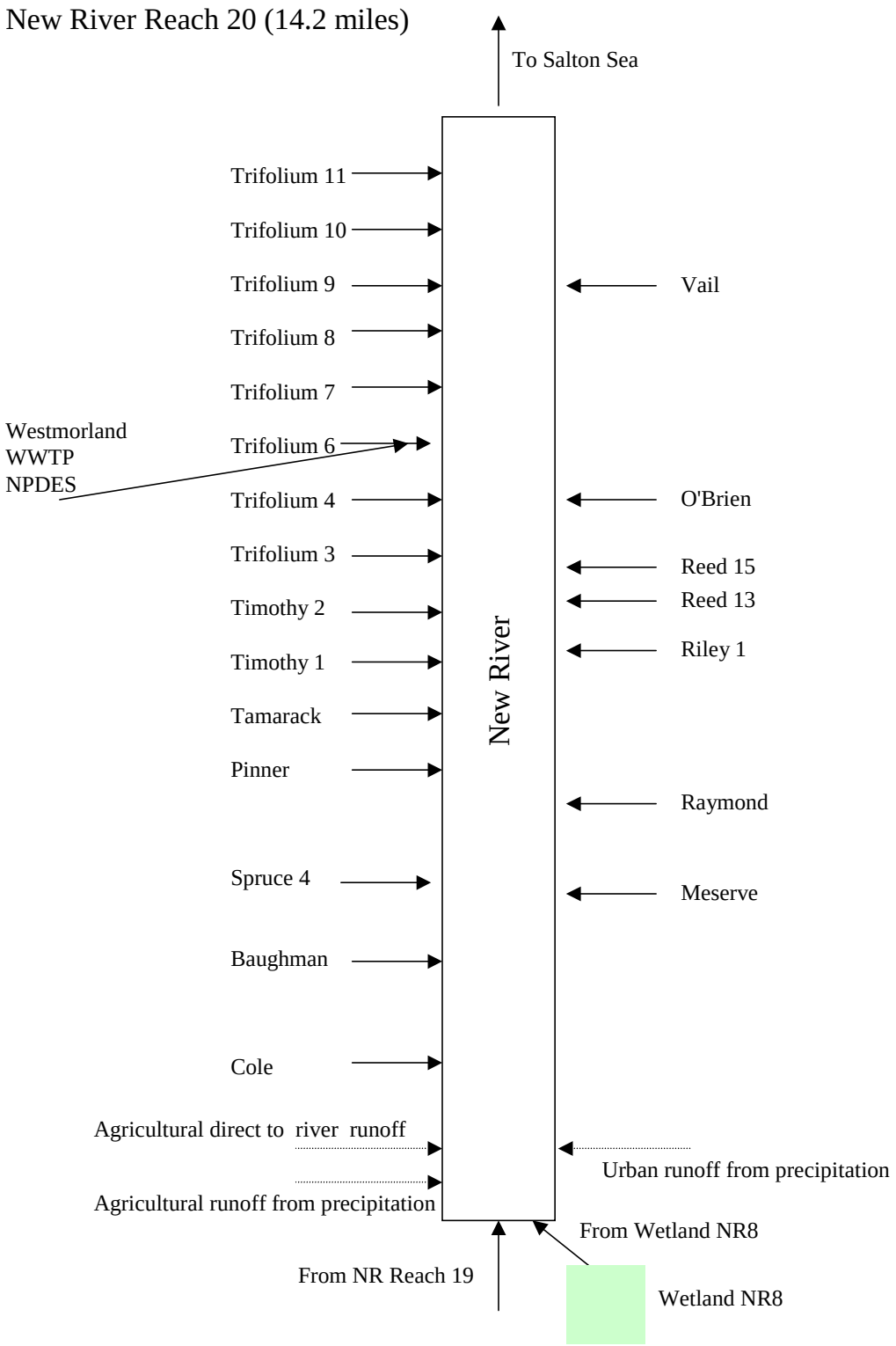


Figure 6-4 Conceptual representation of flows in the watershed/wetland model: New River Reach 20 and Wetland NR8.

Preliminary wetland designs for the top thirty-five (35) wetlands along the New and Alamo Rivers were provided in Nolte (2002) and the conceptual design parameters required for the wetland model are listed in Table 6-1. The preliminary wetland inflows draw primarily from the rivers, but include interception of adjacent agricultural drains. For the 35 proposed wetland sites, there were 19 wetland sites along the New River covering 2,775 acres and diverting up to 583,918 AF/yr of water from the river and drains, and there were 16 wetland sites along the Alamo River covering 1,501 acres and potentially diverting up to 299,187 AF/yr of water from the river and drains. These flows resulted from wetland loading rates that ranged from 11 to 25 cm/day depending on each wetland's design conditions; the overall average wetland loading rates was 18 cm/day.

The model, as described above, including the watershed and drain details was coded in Microsoft Excel, and a fully functional copy of it is included electronically as Appendix K.

Wetland evapotranspiration was estimated based upon wetland area and an annual average wetland evapotranspiration rate of 5.77 feet per year, based on data from 2001 to 2004 in Imperial Valley. Wetland evapotranspiration rates were applied seasonally with the highest values in the summer months (e.g., 0.763 ft/mo for June) and the lowest values in the winter months (e.g., 0.184 ft/mo for December). The net wetland water loss due to evapotranspiration was 16,127 AF/yr from the New River and 8,723 AF/yr from the Alamo River. Seepage losses from the wetlands was estimated as a fraction of total inflow (40 percent) based upon the data collected from the two pilot wetlands. These seepage losses equate to infiltration rates of 4.4 to 10 cm/day within the wetlands.

The two wetland water quality models were applied to the two pilot wetlands and the model parameters such as removal rates and plateau concentrations were fit to the pilot wetland data. The fitted model parameters are listed in Table 6-2. These rates assumed to apply to the proposed wetlands in the composite watershed/wetland modeling analyses. One exception was for wetland modeling of selenium in the New River. The levels of selenium in the New River are substantially lower than those entering the pilot wetlands. Therefore, a lower plateau concentration of 1 ug/L was used in the New River watershed only.

Two alternative wetland designs are presented in Table 6-3. The first alternative wetland design assumes reduced wetland surface areas and is based on the preliminary *wetted* areas estimated in Nolte (2002), rather than the entire wetland site area. For some wetlands, this change included a reduced design inflow estimate as well. Both the original Nolte (2002) and reduced wetland area designs are based on a plug flow design. A second alternative examined the design of mixed reactor flow wetlands, if the physical site characteristics allowed such a configuration. The mixed reactor flow model allows for a higher volume flow through the wetland, and thus higher load reduction.

Table 6-1
35 Top-Ranked Wetland Sites (Nolte, 2002)

River	Wetland Site	Located in Reach	Area (acres)	Design Inflow (AF/mo)
Alamo River				
	AR37	1	42	833
	AR30	2	29	417
	AR29	3	187	2,916
	AR28	4	149	2,856
	AR27	5	68	952
	AR24	6	160	2,916
	AR23	7	82	1,131
	AR22	8	109	2,380
	AR21	9	53	1,190
	AR20	10	32	774
	AR19	11	77	1,309
	AR18	12	31	714
	AR17	13	79	1,428
	AR16	14	26	417
	AR14	15	313	3,868
	AR13	16	64	833
	Total			**24,932**
New River				
	NR40	1	23	540
	NR39	2	75	1,620
	NR34	3	94	1,860
	NR33	4	74	1,800
	NR32	5	93	2,100
	NR31	6	190	3,060
	NR30	7	59	1,320
	NR26	8	65	720
	NR24	9	391	6,300
	NR22	10	124	1,860
	NR21	11	85	1,320
	NR19	12	104	2,040
	NR18	13	122	1,860
	NR17	14	320	5,280
	NR16	15	585	9,900
	NR15	16	54	840
	NR13	17	76	1,440
	NR9	18	80	1,260
	NR8	19	161	3,540
	Total			**48,660**

Notes:
1. Wetland surface areas based on preliminary reconnaissance survey (Nolte, 2002).
2. Design flow defined as sum of available drain and river treatment rates from Table ES-2 (Nolte, 2002). This scenario assumes all wetlands designed for plug flow.

Table 6-2
Wetland Model Paramters

Chemical	Wetland Loss Rate (m/yr)			Plateau Concentration	
	Brawley	**Imperial**	**Average**		
Total Phosphorus	18	46	32	0.02	mg/L
Total Nitrogen	56	50	53	1.5	mg/L
TSS	91	222	157	5	mg/L
Selenium	4.5	30	17	3	ug/L
Total Coliforms	134	263	199	500	MPN/100 ml

Source: Tetra Tech, 2006

6.9 Model Calibration

Since drain flows are by far the dominant source of water and chemicals in both the New and Alamo River watersheds, accurate data for drain flow and concentrations are key criteria for choosing an appropriate calibration time period. A good choice for a calibration event would be a time period with both good data available for drain flows and concentrations (the main watershed source and model input data), and good data available for the river flows and concentrations (the main watershed outlet and the model output data). The most comprehensive data set available for calibrating the model was a five-year period in the late 1990s when there are detailed drain flow data as described in the New River and Alamo River TMDL studies (CRBRWQCB, 2002a and 2002b).

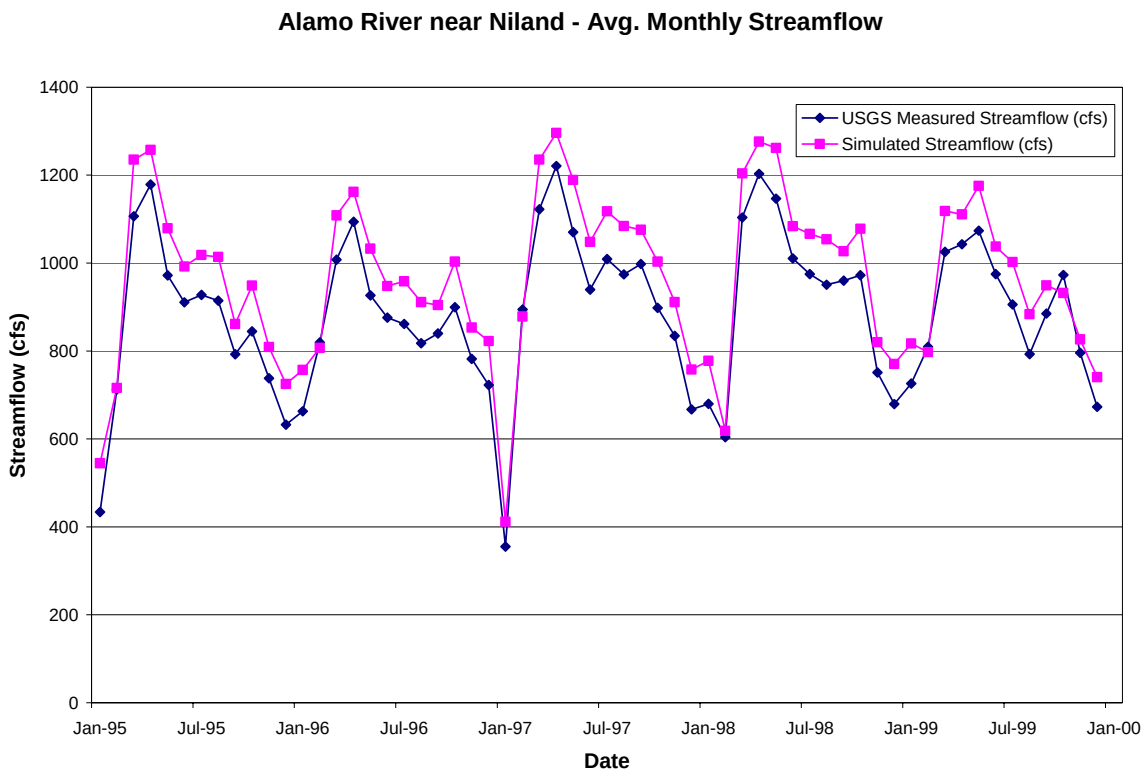
The composite watershed/wetland model was configured with drain, NPDES, and cross-border data for a five-year period in the late 1990s, and then compared with USGS monitoring data for the Alamo River near Niland, California (Figure 6-5) and for the New River near Westmorland, California (Figure 6-6). There is very good comparison between the model simulated values and the measured streamflow data as depicted in both time-series plots and statistical cross-plots. For example, for the Alamo River (Figure 6-5), the mean error is only 56 cfs, the standard deviation of the error is only 35 cfs, and the relative model error (defined as the standard deviation divided by the range of the observed data) is only 4 percent. For the New River (Figure 6-7), the mean error is only 14 cfs, the standard deviation of the error is only 10 cfs, and the relative model error is only 2 percent. The net conclusion is that the model simulations of New River and Alamo River flows result in a good quantitative prediction of average flow conditions, seasonal flow variations, and inter-annual flow variations as depicted in Figures 6-5 and 6-6.

The model flow data as described above were then used with model parameters for chemical concentrations in the drains, NPDES discharges, and cross-border locations to compare with chemical concentration data at the outlets of the Alamo River and New River. Although there are five years of flow data for calibration in the late 1990s, there are only two years of chemical data with sufficient monitoring data in the rivers and the watershed sources for calibration.

Table 6-3
Alternative Configurations for 35 Top-Ranked Wetland Sites

			Reduced Wetland Area Scenario[1]		Reduced Wetland Area Scenario & Inclusion of CSTR-type Wetlands[2]		
River	Wetland Site	Located in Reach	Area (acres)	Design Inflow (AF/mo)	Area (acres)	Design Inflow (AF/mo)	Wetland Type
Alamo River							
	AR37	1	36	833	36	1,666	CSTR
	AR30	2	25	417	25	833	CSTR
	AR29	3	159	2,916	159	5,831	CSTR
	AR28	4	127	2,856	127	5,712	CSTR
	AR27	5	58	952	58	1,904	CSTR
	AR24	6	136	2,916	136	2,916	plug
	AR23	7	70	1,131	70	2,261	CSTR
	AR22	8	93	751	93	751	plug
	AR21	9	45	1,190	45	2,380	CSTR
	AR20	10	27	774	27	1,547	CSTR
	AR19	11	65	1,309	65	2,618	CSTR
	AR18	12	26	714	26	714	plug
	AR17	13	67	1,428	67	2,856	CSTR
	AR16	14	22	417	22	833	CSTR
	AR14	15	266	3,868	266	7,736	CSTR
	AR13	16	54	833	54	1,666	CSTR
	Total			**23,303**		**42,225**	
New River							
	NR40	1	20	540	20	1,080	CSTR
	NR39	2	64	1,620	64	3,240	CSTR
	NR34	3	80	1,860	80	3,720	CSTR
	NR33	4	63	1,800	63	3,600	CSTR
	NR32	5	79	2,100	79	4,200	CSTR
	NR31	6	162	3,060	162	6,120	CSTR
	NR30	7	50	1,320	50	2,640	CSTR
	NR26	8	55	720	55	1,440	CSTR
	NR24	9	332	6,300	332	6,300	plug
	NR22	10	105	1,860	105	1,860	plug
	NR21	11	72	1,320	72	1,320	plug
	NR19	12	88	1,638	88	1,638	plug
	NR18	13	104	1,860	104	3,720	CSTR
	NR17	14	272	5,280	272	10,560	CSTR
	NR16	15	497	4,031	497	4,031	plug
	NR15	16	46	840	46	840	plug
	NR13	17	65	1,440	65	2,880	CSTR
	NR9	18	68	1,260	68	2,520	CSTR
	NR8	19	137	3,540	137	7,080	CSTR
	Total			**42,388**		**68,788**	

Notes:
1. Revised wetland surface areas and design inflows reduced for non-wetted areas shown in Nolte (2002). This scenario assumes all wetlands designed for plug flow.
2. This scenario suggests an alternative wetland design for many wetland sites, based on a mixed reactor flow model (CSTR = complete stirred tank reactor).



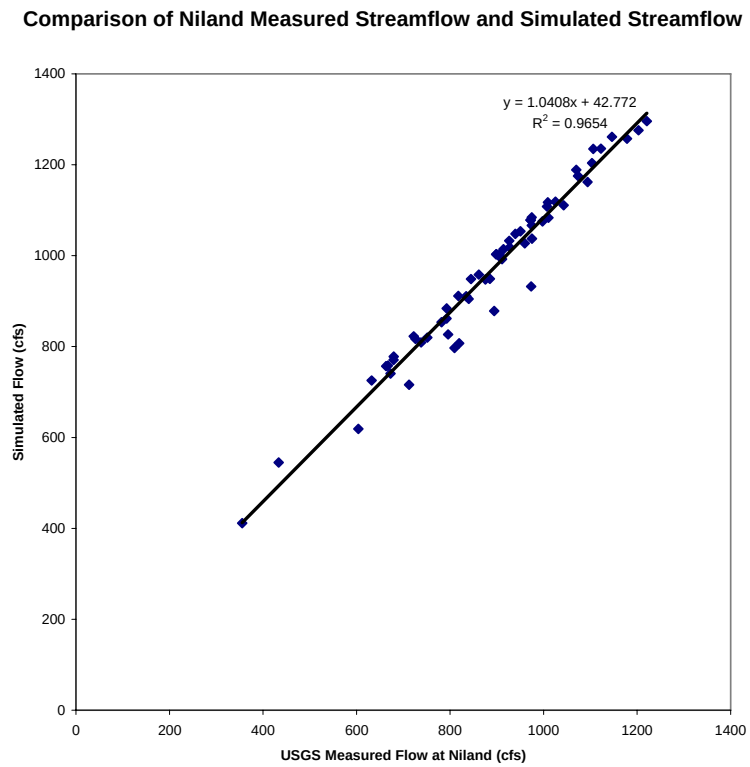
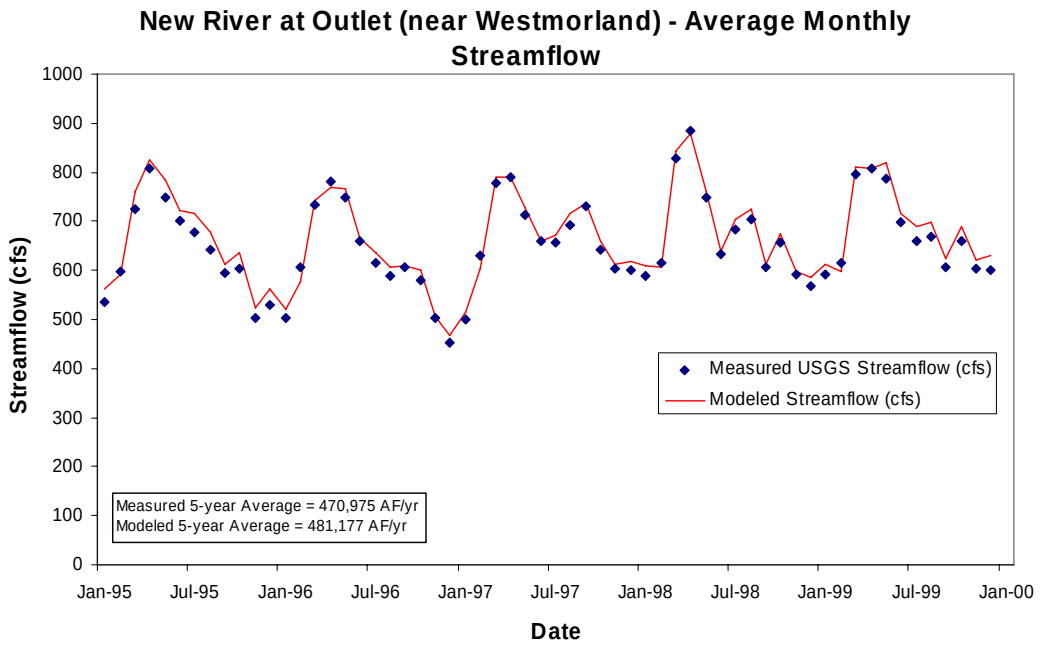


Figure 6-5. Comparison of modeled and measured streamflows in the Alamo River near Niland: Time trends from 1995 through 1999 (top) and statistical cross-plot (bottom).



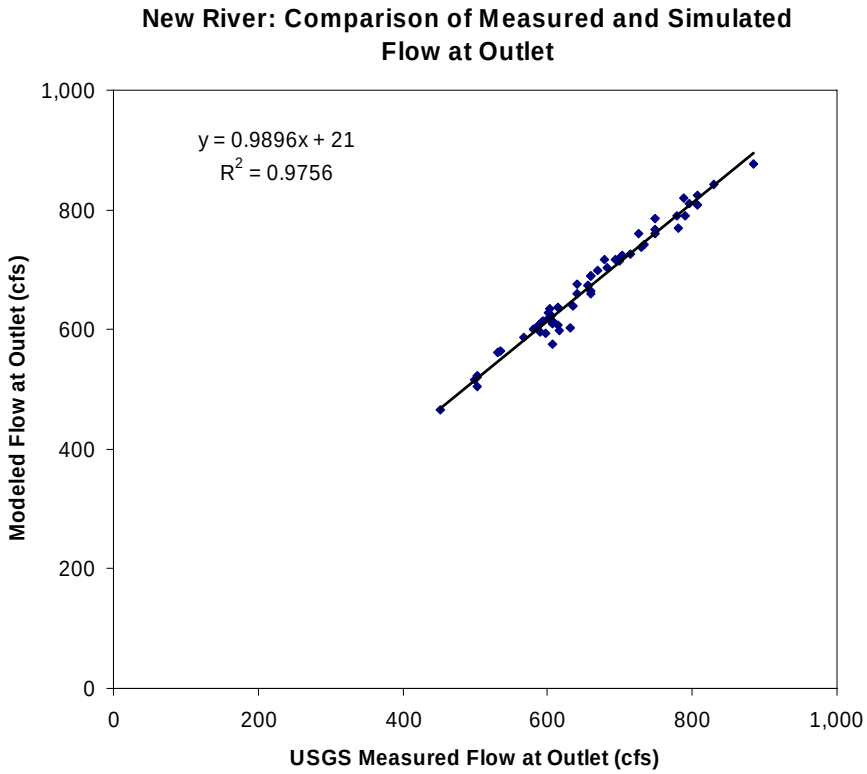
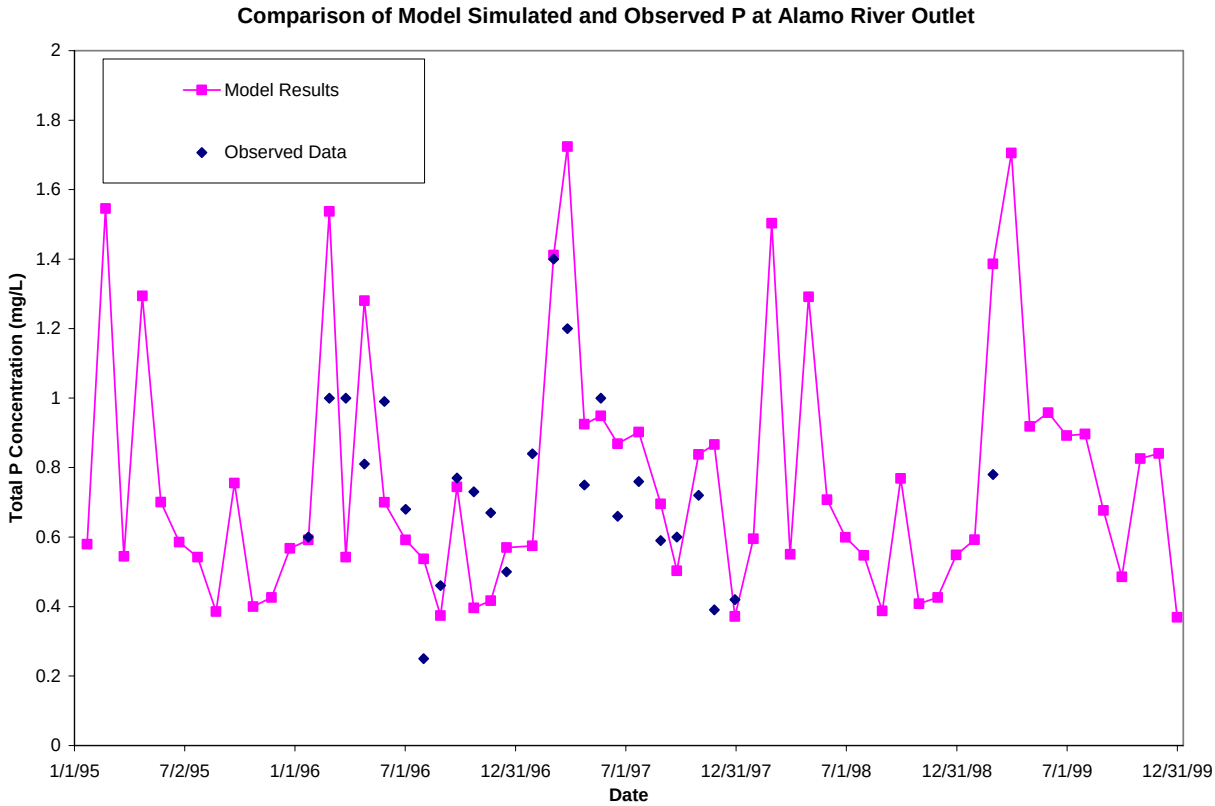


Figure 6-6. Comparison of modeled and measured streamflow at the New River outlet near Westmorland: Time trends from 1995 through 1999 (top) and statistical cross-plot (bottom).

The model results for total phosphorus concentrations in the Alamo River and New River are given along with river monitoring data in Figures 6-7 and 4-8, respectively. During the two-year calibration period of 1996 and 1997, the average measured total phosphorus concentration at the Alamo River outlet is 0.74 mg/L in comparison to the average model simulated value of 0.8 mg/L (an average error of +0.06 mg/L). At the New River outlet, the average measured total phosphorus concentration is 1.28 mg/L in comparison to the average model simulated value of 1.29 mg/L (an average error of 0.00 mg/L). However, the standard deviation of the error is 0.28 mg/L for the Alamo River outlet and 0.23 mg/L for the New River outlet, resulting in a relative model error of 24 percent for the Alamo River and 21 percent for the New River. Note that the New River outlet concentrations are significantly higher than the Alamo River concentrations because of the cross-border flows from Mexico start with an average concentration of 2 mg/L. Thus, the simulated and measured total phosphorus concentrations in both the Alamo River and New River outlets show a good comparison of the average total phosphorus concentrations. The model can only mimic the seasonality and inter-annual variations depicted in the data in Figures 6-7 and 6-8 because the actual monthly source concentrations are largely unknown for the majority of sources over the 5-year period (see Section 6.2.2). For instance, for the New River, only the total phosphorus data for the cross-border flow, which represents 32 percent of the total flow, and the Greeson Drain, which represents 5 percent of the total flow, are known measured inputs. Comparisons were made of the model predicted concentrations to the measured data as a function of distance along the two rivers (see lower plots in Figures 6-7 and 6-8). The maximum and minimum predictions generally span the range of the measurements and the average predictions generally match the average measured concentrations as the rivers reach the outlet.

The comparisons of the model results and river monitoring data for the other constituents are similar to that observed for total phosphorus. That is, there is a good comparison of the average outlet concentrations, a general mimicking of the seasonal and inter-annual variations, and a good overall comparison as a function of distance along the two rivers. The details of the comparisons for total nitrogen, TSS, selenium, and total coliforms are presented below.

The model-predicted total nitrogen concentrations in the Alamo River and New River are given along with river monitoring data in Figures 6-9 and 6-10, respectively. During the two-year calibration period of 1996 and 1997, the average measured total nitrogen concentration in the Alamo River is 8.90 mg/L in comparison to the average model simulated value of 8.95 mg/L (an average error of +0.05 mg/L). In the New River, the average total nitrogen concentration is 10.2 mg/L, based on measured ammonia and nitrate data and a regression equation for TKN based on ammonia and TKN data from 2003 to 2005 data. Note the average total nitrogen concentration from 2003 to 2005 is 10.8 mg/L. The average model simulated value of 10.1 mg/L (an average error of 0.09 mg/L). The standard deviation of the error is 1.58 mg/L for the Alamo River and 3.0 mg/L for the New River, resulting in a relative model error of 34 percent for the Alamo River and 22 percent for the New River. Like the phosphorus comparison, there is good general agreement between the simulated and measured results for both rivers. One exception was in the upper half of the Alamo River, where the Tetra Tech survey data were higher than the model upper bound.



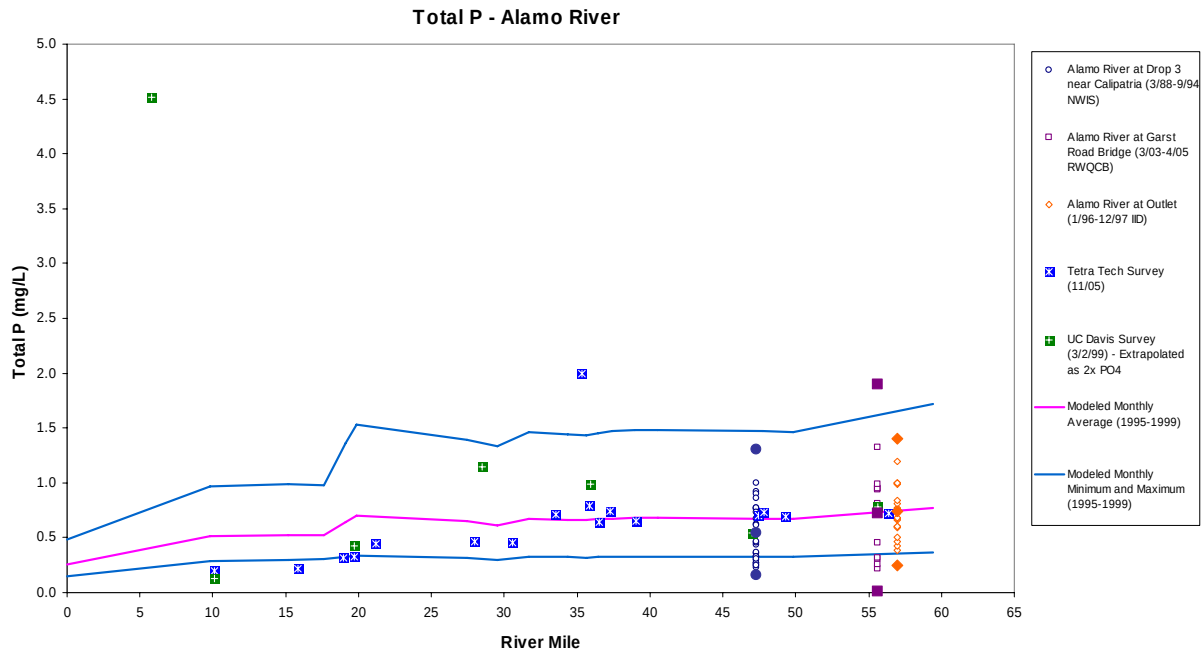
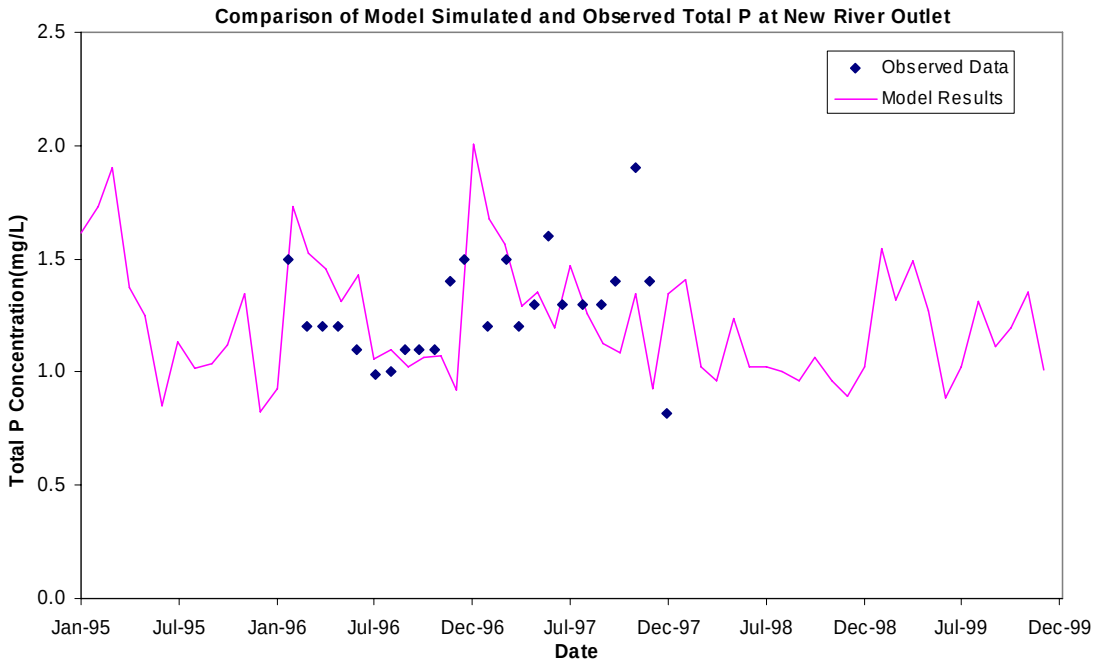
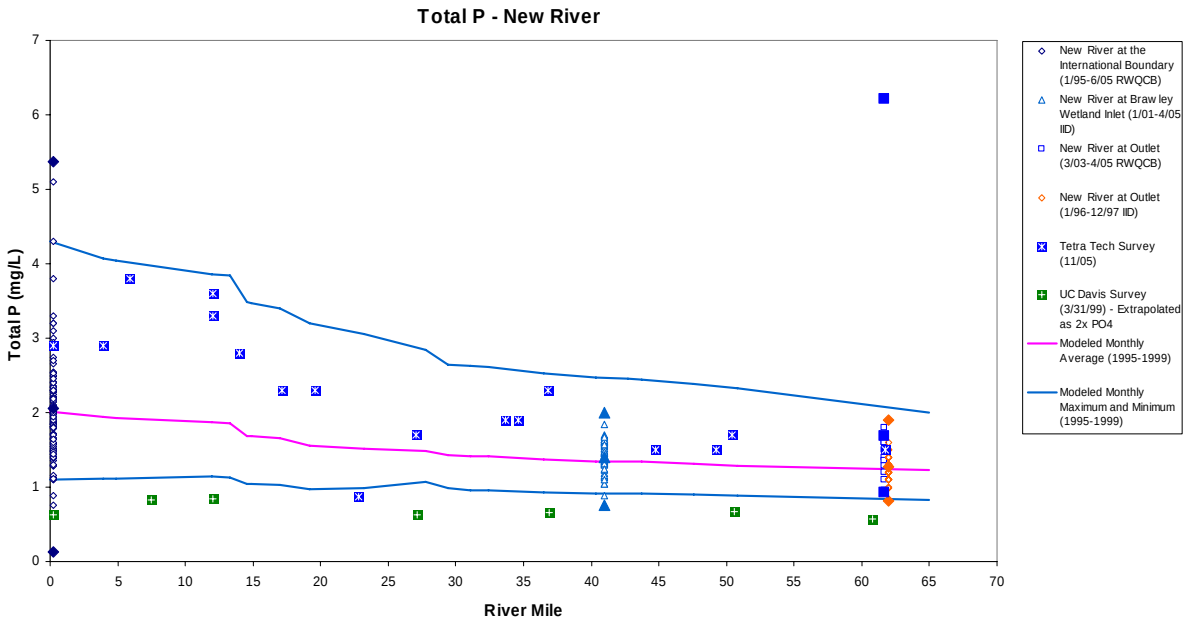


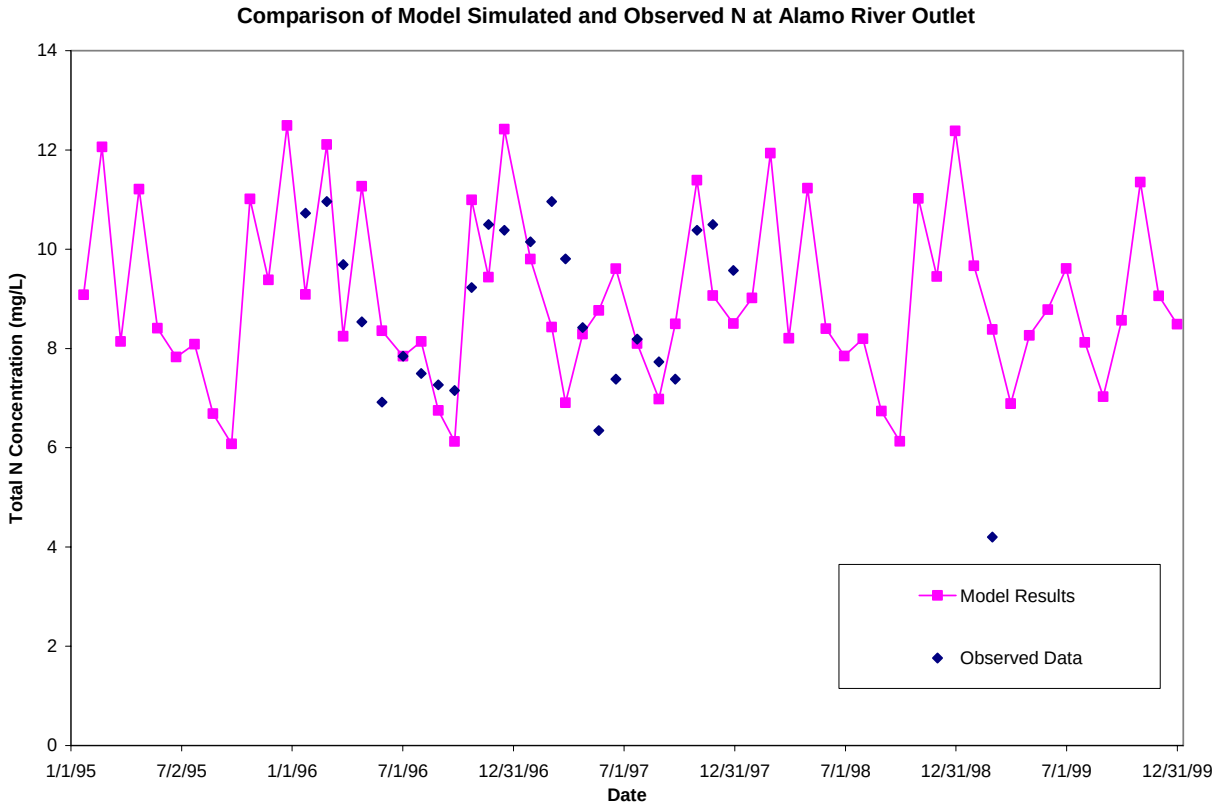
Figure 6-7. Comparison of modeled and measured total phosphorus concentrations in the Alamo River near Niland: Time trends from 1995 through 1999 (top) and as a function of distance along the Alamo River (bottom).





Note: Larger symbols indicate average, maximum and minimum of multiple sampling events at single location.

Figure 6-8. Comparison of model simulated and measured total phosphorus concentrations in the New River: Time trends from 1995 through 1999 at the New River outlet (top) and as a function of distance along the New River (bottom).



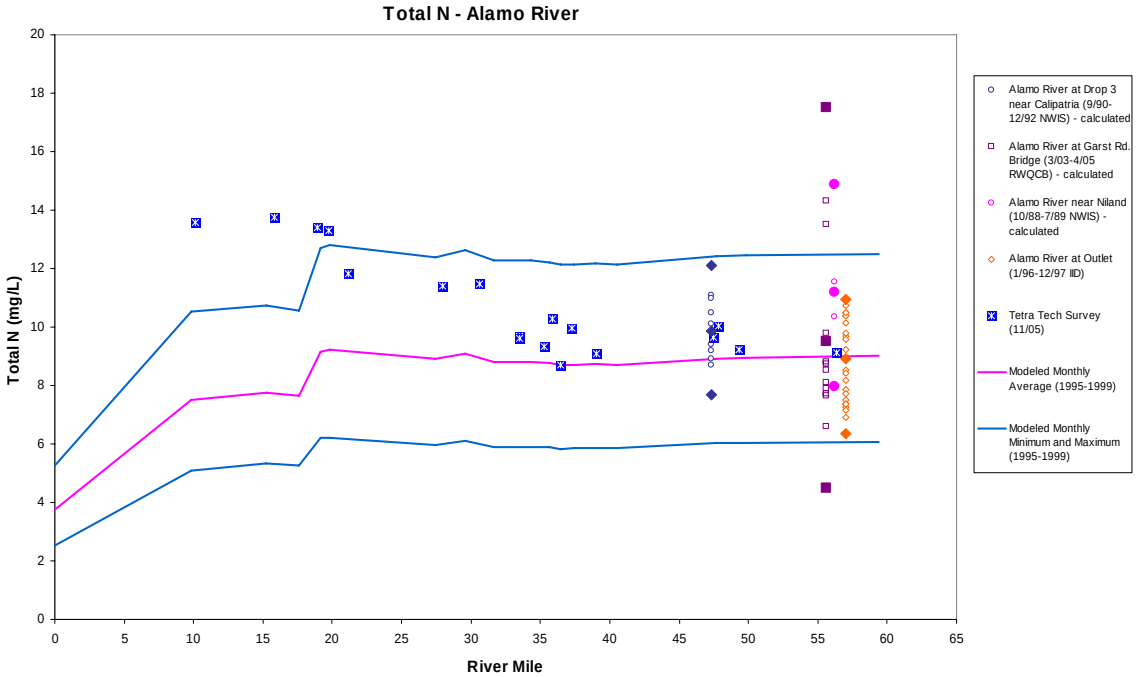
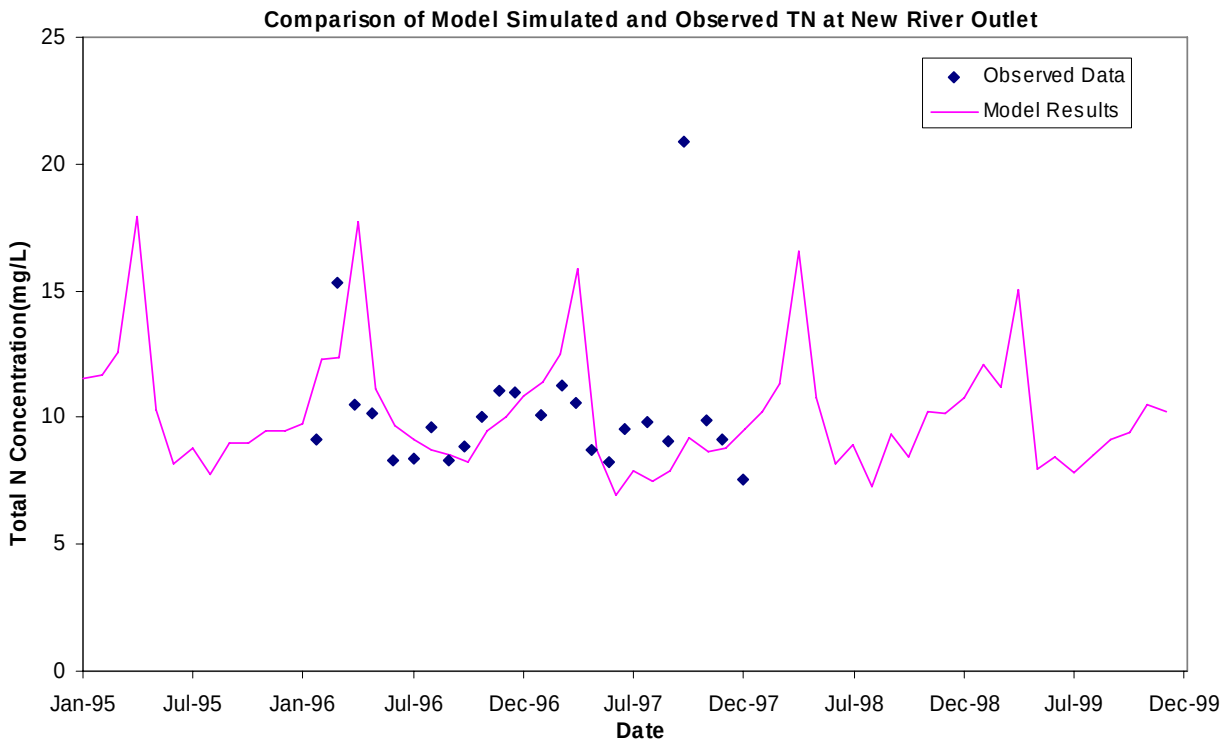
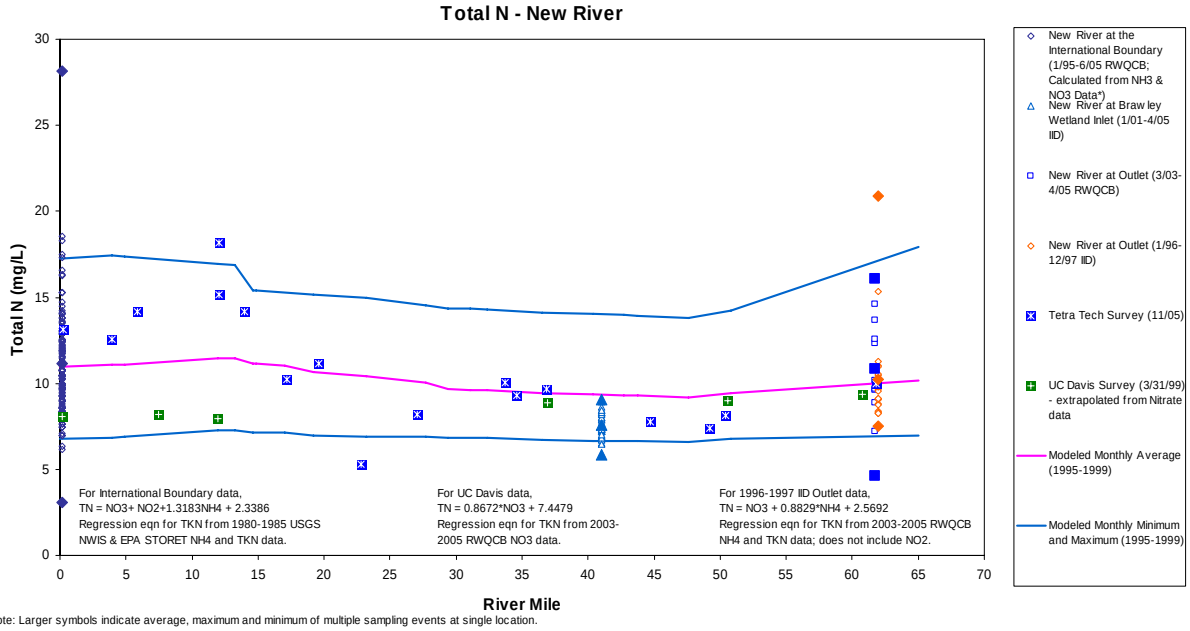


Figure 6-9. Comparison of modeled and measured total nitrogen concentrations at the Alamo River near Niland: Time trends from 1995 through 1999 (top) and as a function of distance along the Alamo River (bottom).



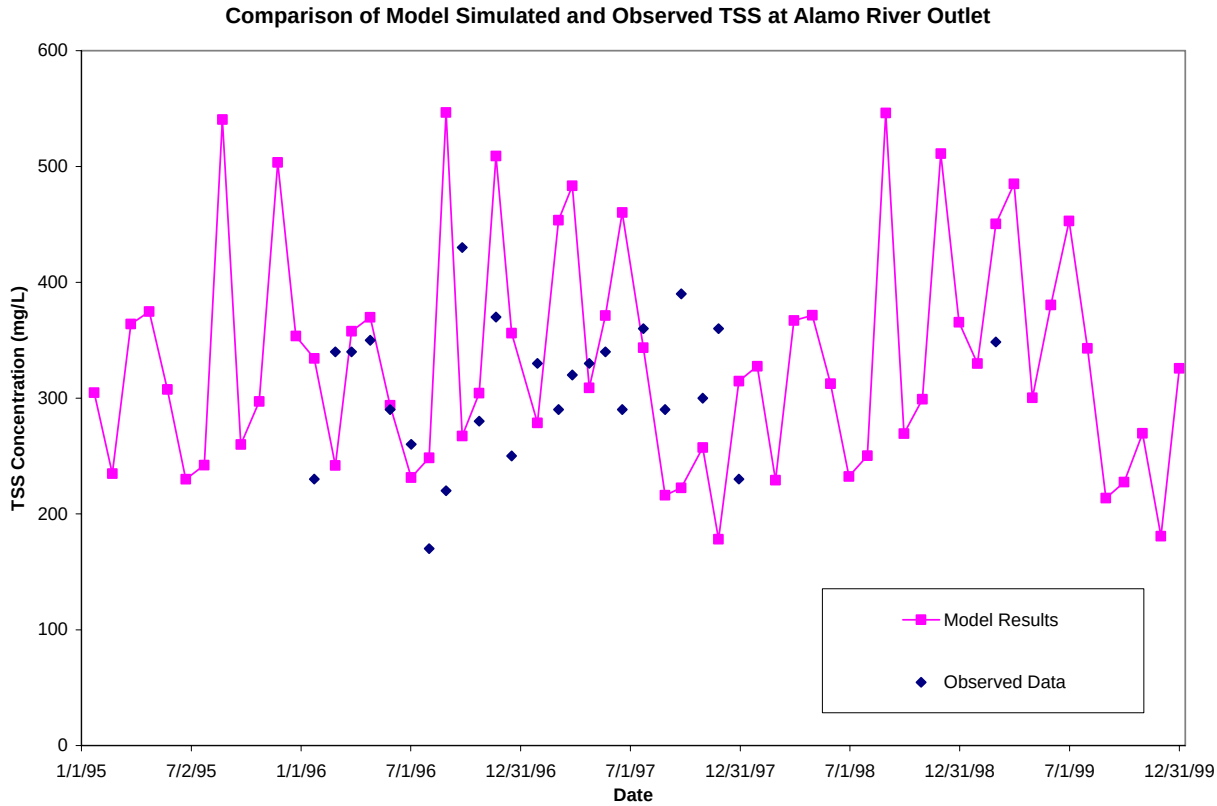


Note: Larger symbols indicate average, maximum and minimum of multiple sampling events at single location.

Figure 6-10. Comparison of model simulated and measured total nitrogen concentrations in the New River: Time trends from 1995 through 1999 at the New River outlet (top) and as a function of distance along the New River (bottom).

The model-predicted TSS concentrations in the Alamo River and New River are given along with river monitoring data in Figures 6-11 and 6-12, respectively. During the two-year calibration period, the average measured TSS concentration in the Alamo River is 307 mg/L in comparison to the average model simulated value of 329 mg/L (an average error of +22 mg/L). In the New River, the average measured TSS concentration is 247 mg/L in comparison to the average model simulated value of 226 mg/L (an average error of 20 mg/L). The standard deviation of the error is 118 mg/L for the Alamo River and 34 mg/L for the New River, resulting in a relative model error of 45 percent for the Alamo River and 10 percent for the New River. The simulated and measured TSS concentrations in both the Alamo River and New River show a good comparison of the average TSS concentrations, mimics the seasonality and inter-annual variations, and the model generally bounds the measured data, with a few exceptions.

The model-predicted total selenium concentrations in the Alamo River and New River are given along with river monitoring data in Figures 6-13 and 4-14, respectively. During the two-year calibration period, the average measured selenium concentration in the Alamo River is 6.81 mg/L in comparison to the average model simulated value of 6.12 mg/L (an average error of -0.69 mg/L). In the New River, the average measured Selenium concentration is 4.1 mg/L in comparison to the average model simulated value of 4.0 mg/L (an average error of 0.6 mg/L). The standard deviation of the error is 1.07 mg/L for the Alamo River and 1.5 mg/L for the New River, resulting in a relative model error of 9 percent for the Alamo River and 19 percent for the New River. For the Alamo River, the statistical model error for selenium differs from other chemicals (total phosphorus, total nitrogen, and TSS) because of the very large deviation from the mean values in the first two months of sampling (January and February 1996). The simulated and measured selenium concentrations in both the Alamo River and New River show a good comparison of the average selenium concentrations, mimics the seasonality and inter-annual variations, and the model generally follows the pattern of the Tetra Tech and UC Davis survey data, with a few exceptions. For the New River, the measurements at Brawley Wetland Inlet, which takes New River water, seem biased toward the high end of likely values, given measurements of other selenium historical surveys. It appears that data are not representative of not fully mixed New River water but are disproportionately influenced by adjacent drain discharges to the New River.



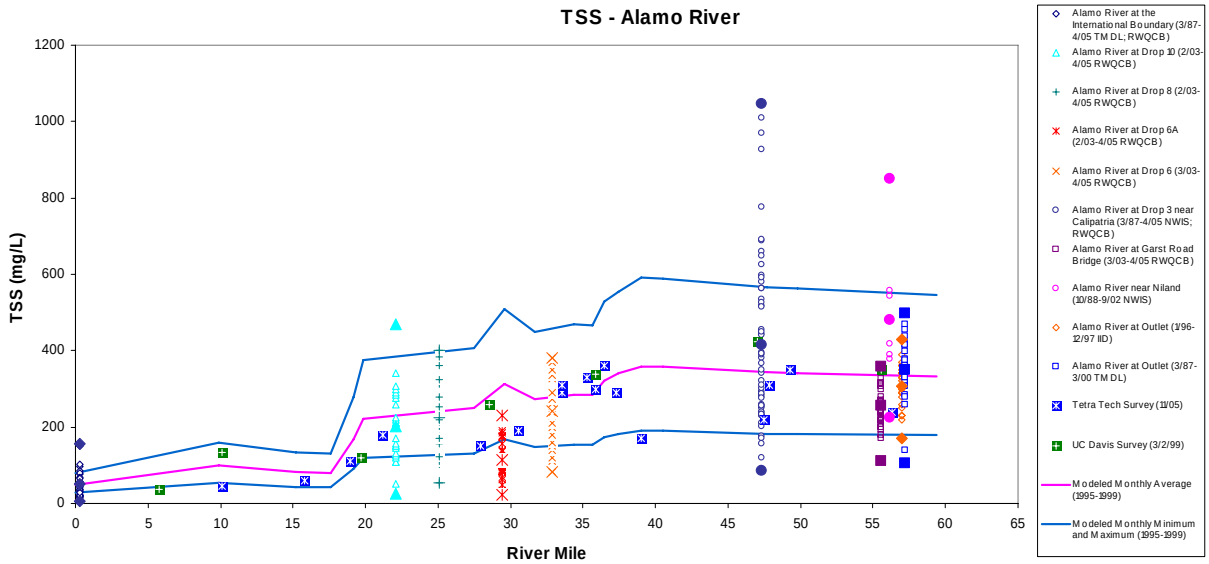


Figure 6-11. Comparison of model simulated and measured TSS concentrations: Time trends from 1995 through 1999 in the Alamo River near Niland (top) and i and as a function of distance along the Alamo River (bottom).

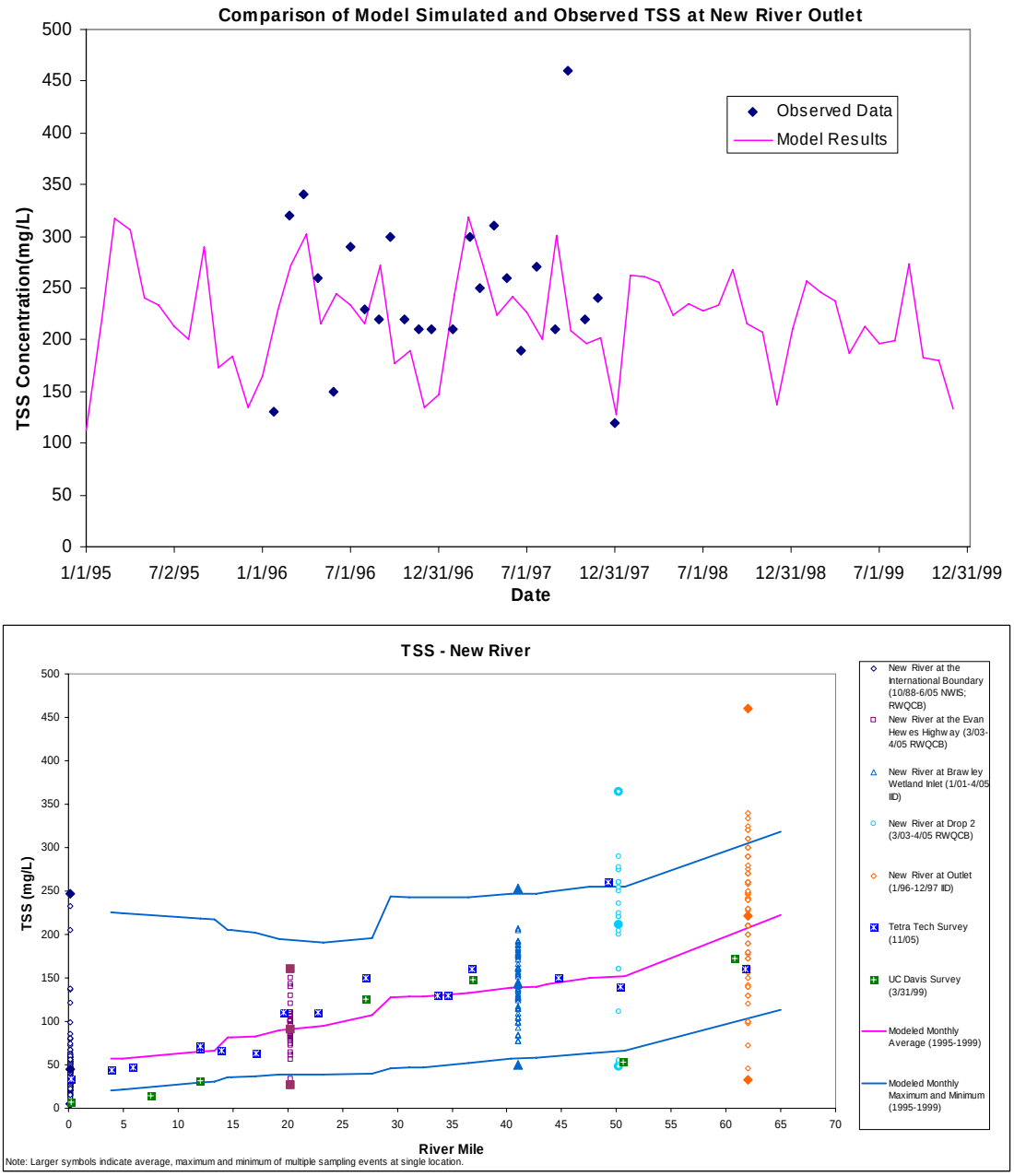
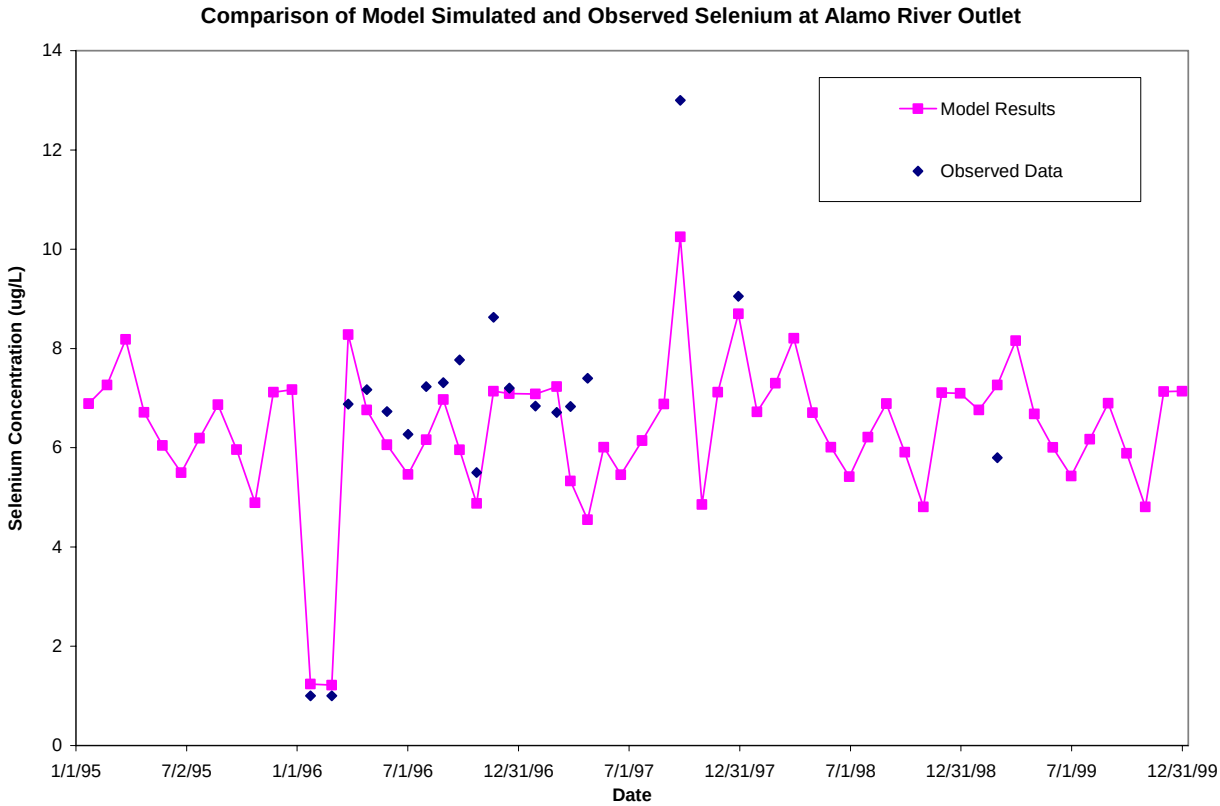


Figure 6-12. Comparison of model simulated and measured TSS concentrations in the New River: Time trends from 1995 through 1999 at the New River outlet (top) and as a function of distance along the New River (bottom).



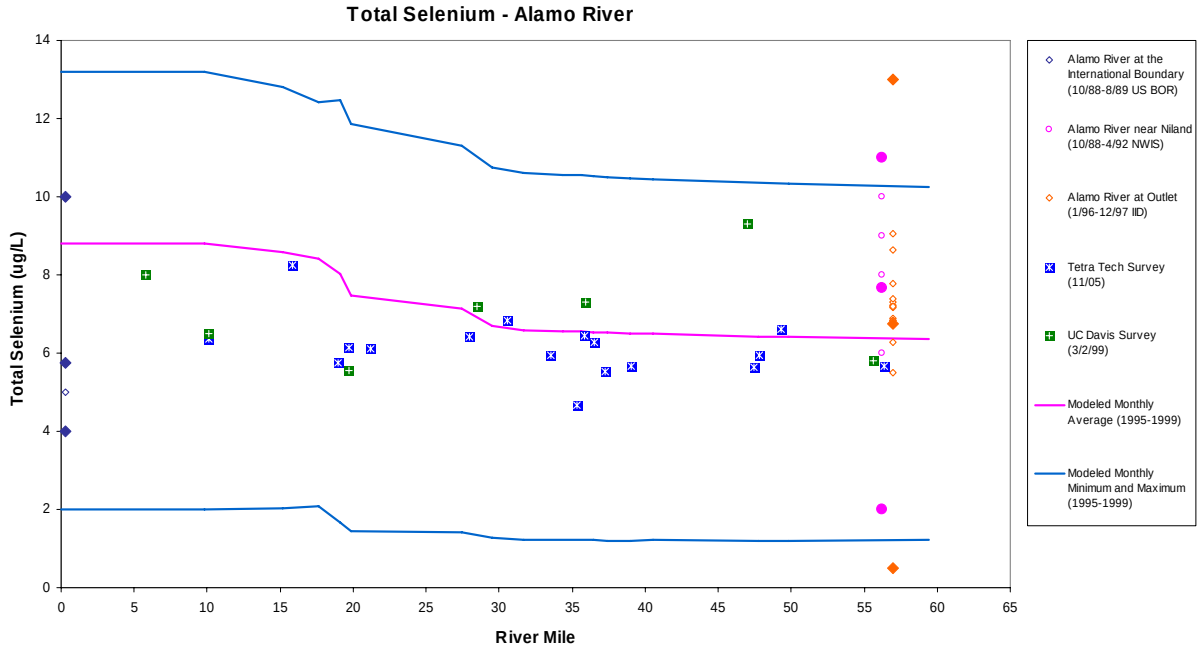
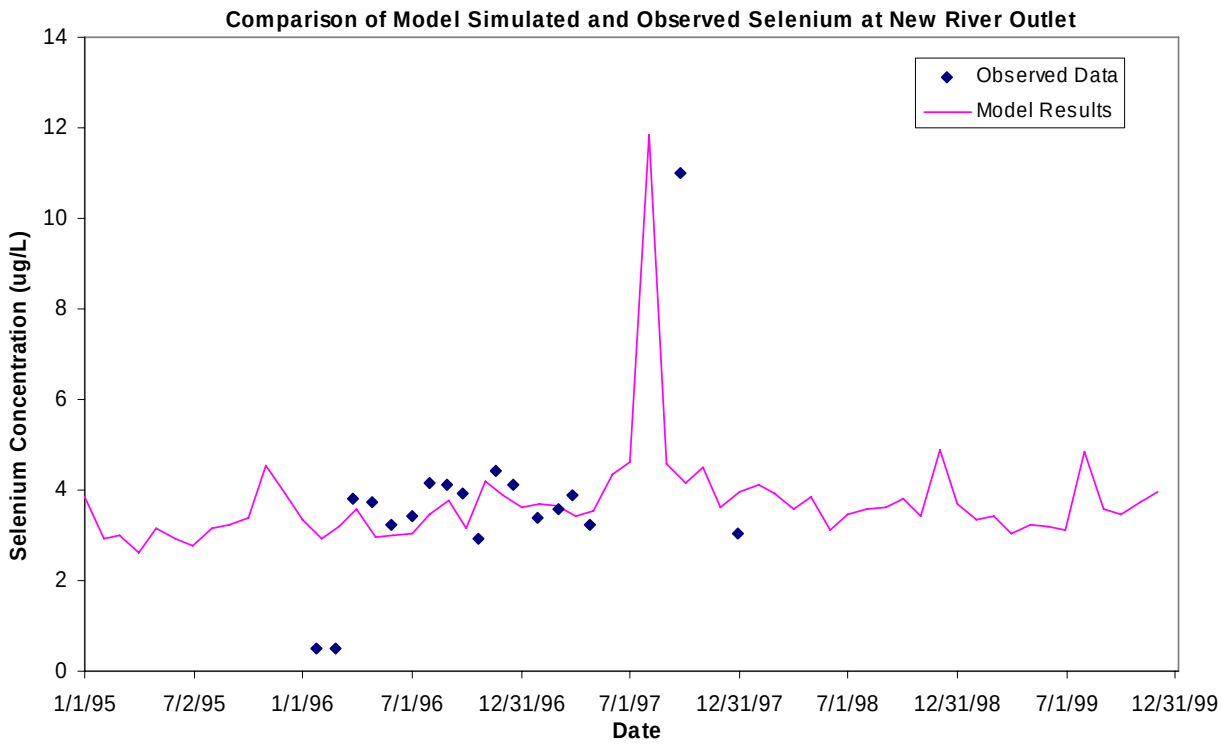
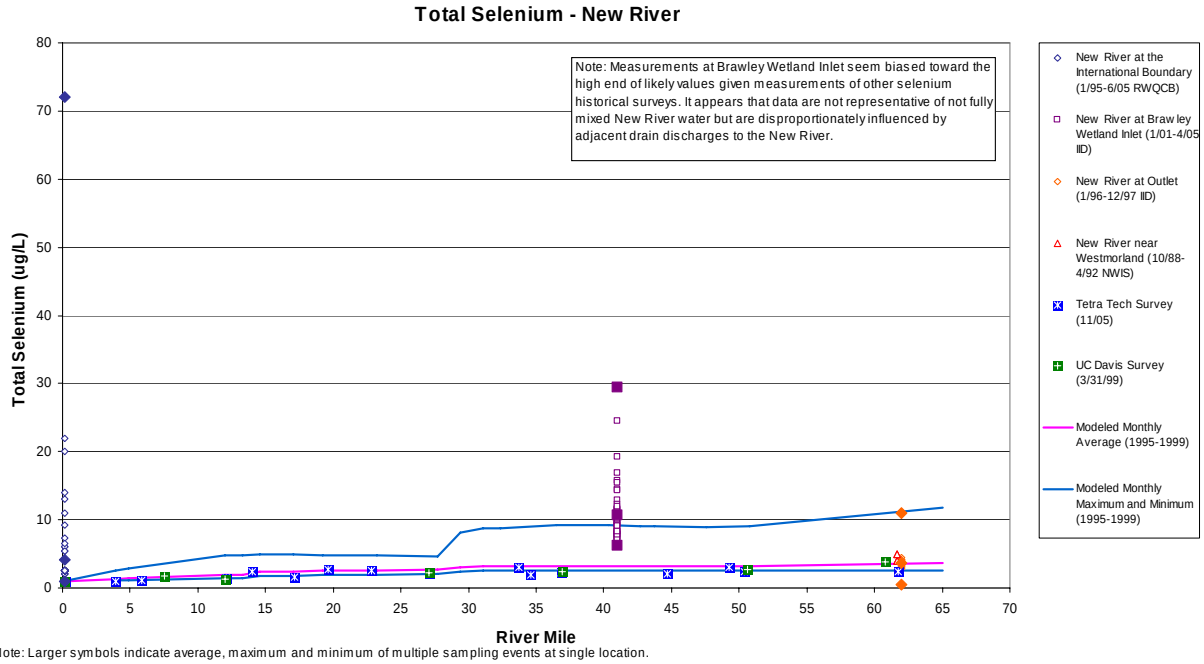


Figure 6-13. Comparison of model simulated and measured total selenium concentrations: Time trends from 1995 through 1999 in the Alamo River near Niland (top) and as a function of distance along the Alamo River (bottom).

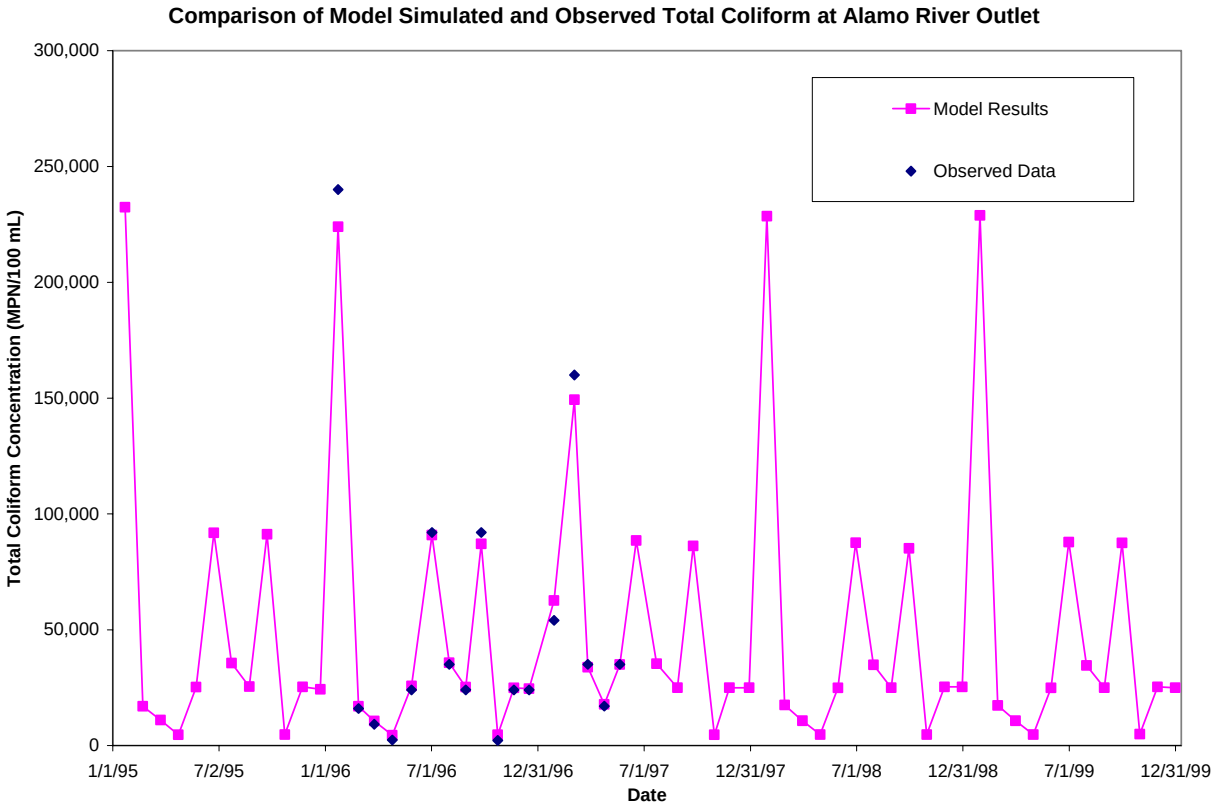




Note: Larger symbols indicate average, maximum and minimum of multiple sampling events at single location.

Figure 6-14. Comparison of model simulated and measured total selenium concentrations in the New River: Time trends from 1995 through 1999 at the New River outlet (top) and as a function of distance along the New River (bottom).

The model-predicted total coliforms concentrations in the Alamo River and New River are given along with river monitoring data in Figures 6-15 and 4-16, respectively. In the Alamo River, no total coliform measurements were made in the 5-year period, and most recent total coliform measurements were made in 1980 to 1982. The average measured total coliforms concentration in the Alamo River is 52,106 MPN/100mL in comparison to the average model simulated value of 47,475 MPN per 100 milliliter for the entire 5-year period. The total coliforms prediction in the Alamo River was calibrated to the outlet data from the 1980s (see Figure 6-15). The river loss rate constant for total coliforms was calibrated to 9.15 mo^{-1}. The total coliforms concentrations in the Alamo River show a good comparison of the average, seasonality and inter-annual variations in total coliforms concentrations. This is due to very limited amount of drain total coliforms data, such that the only practical way to calibrate the model was to back allocate the seasonality in drain concentrations to match the seasonality observed in the river. The comparison to the 2005 Tetra Tech synoptic survey appears biased to the high end of likely values given measurements of other coliform indicators in prior historical surveys. In the New River, no total coliform measurements were made in the 5-year period, and a few (8) total coliform measurements were made in 2003, 2004 and 2005. The average measured total coliforms concentration is 122,250 MPN per 100 milliliter in comparison to the average model simulated value of 130,942 MPN per 100 milliliter. The predicted total coliforms concentrations in the New River captures the general trend of the measured total coliforms concentrations as a function of distance along the New River (see Figure 6-16).



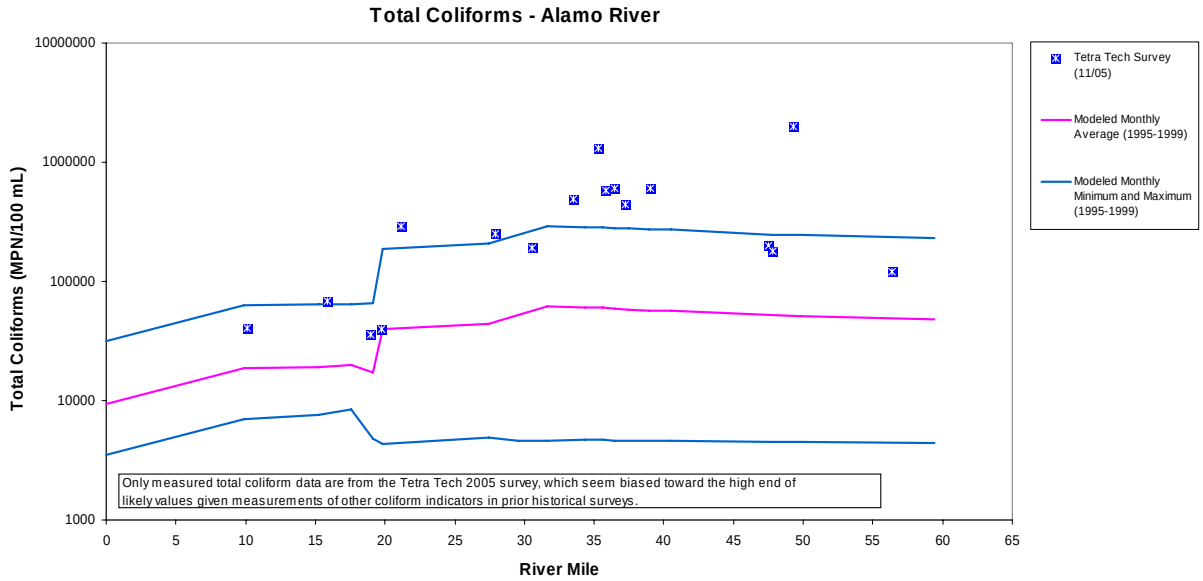
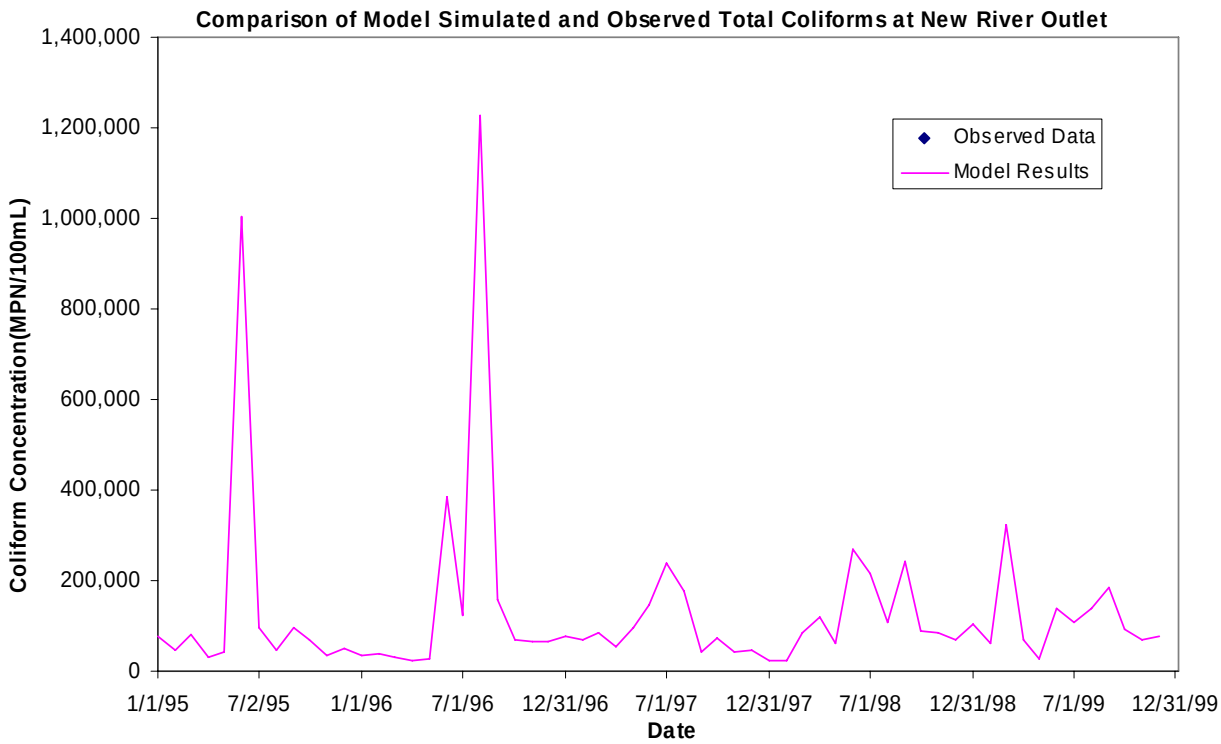
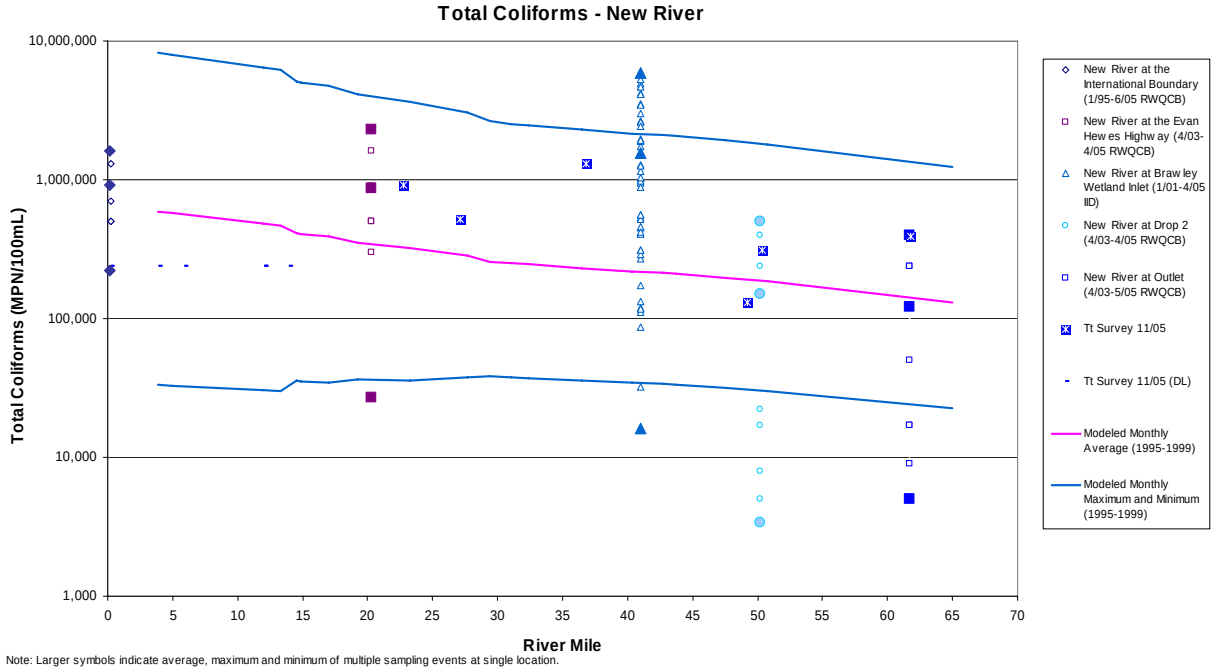


Figure 6-15. Comparison of model simulated and measured total coliform concentrations: Time trends from 1995 through 1999 in the Alamo River near Niland (top) and as a function of distance along the Alamo River (bottom).





Note: Larger symbols indicate average, maximum and minimum of multiple sampling events at single location.

Figure 6-16. Comparison of model simulated and measured total coliform concentrations in the New River: Time trends from 1995 through 1999 at the New River outlet (top) and as a function of distance along the New River (bottom).

6.10 Sensitivity to Wetland Pollutant Removal Rate and Hydrologic Parameters

To evaluate the sensitivity of the wetland-watershed model, sensitivity analyses of pollutant removal were performed on the two key model parameters:

- The wetland chemical loss rate. For example, for total phosphorus an average value of 32 m/yr was used in the model base case predictions, but wetland total phosphorus loss rates may range from 5 to 70 m/yr depending on conditions.
- Groundwater retention of chemical loads in wetland seepage losses. For example, depending on the chemical properties, groundwater retention of chemical loads can vary from nearly complete retention to almost none. For the model base case predictions, nearly complete retention was assumed for total phosphorus; complete retention was assumed for TSS and total coliforms; and no retention was assumed for total nitrogen and selenium. However, groundwater retention of loads may vary depending on conditions. For example, total phosphorus adsorption could eventually saturate the aquifer, resulting in greater total phosphorus return flows into the rivers from wetland seepage losses than currently predicted. Conversely, there may bio-geochemical mechanisms that attenuate total nitrogen to some degree, resulting in less total nitrogen return flows into the rivers from wetland seepage losses than currently predicted.

The results are given for total phosphorus loads in the Alamo River in Figure 6-17, Figure 6-18, and Table 6-4. The total phosphorus wetland chemical loss rate constant was varied from 20 m/yr to 60 m/yr relative to the base case value of 40 m/yr. The Alamo River total phosphorus load for the no wetlands scenario is 680,000 kg/yr, which is reduced 22 percent to 530,000 kg/yr for the wetlands base case scenario where the wetland chemical loss rate is 40 m/yr and wetland seepage is returned to the river are at a concentration equal to the regional groundwater total phosphorus concentration of 0.1 mg/L. For this Alamo River wetlands base case scenario, wetland seepage return flows to the river at the regional groundwater total phosphorus concentration results in an 84 percent retention of the total phosphorus load in the wetland seepage losses.

For the scenario where the wetland chemical loss rate is increased to 60 m/yr, the Alamo River total phosphorus load is 516,750 kg/yr, a total phosphorus load reduction of 24 percent relative to the no wetlands scenario and an increase of 8.8 percent (13,250 kg/yr) relative to the wetlands base case scenario. This increase in total phosphorus removal occurs because the wetland chemical loss increases from 80,000 kg/yr in the wetlands base case scenario to 93,250 kg/yr in the high chemical loss rate scenario. Thus, wetland chemical losses increase by 17 percent relative to the wetland base case scenario if the chemical loss rate is increased from 40 m/yr to 60 m/yr.

For the scenario where the wetland chemical loss rate is decreased to 20 m/yr, the Alamo River total phosphorus load is 554,200 kg/yr, a total phosphorus load reduction of 19 percent relative to the no wetlands scenario and a decrease 14.1 percent (21,200 kg/yr) relative to the wetlands base case scenario. This increase in total phosphorus removal occurs because the wetland chemical loss decreases from 80,000 kg/yr in the wetlands base case scenario to 58,800 kg/yr in the low chemical loss rate scenario. Thus, wetland chemical losses decrease by 27 percent relative to the wetland base case scenario if the chemical loss rate is decreased from 40 m/yr to 20 m/yr.

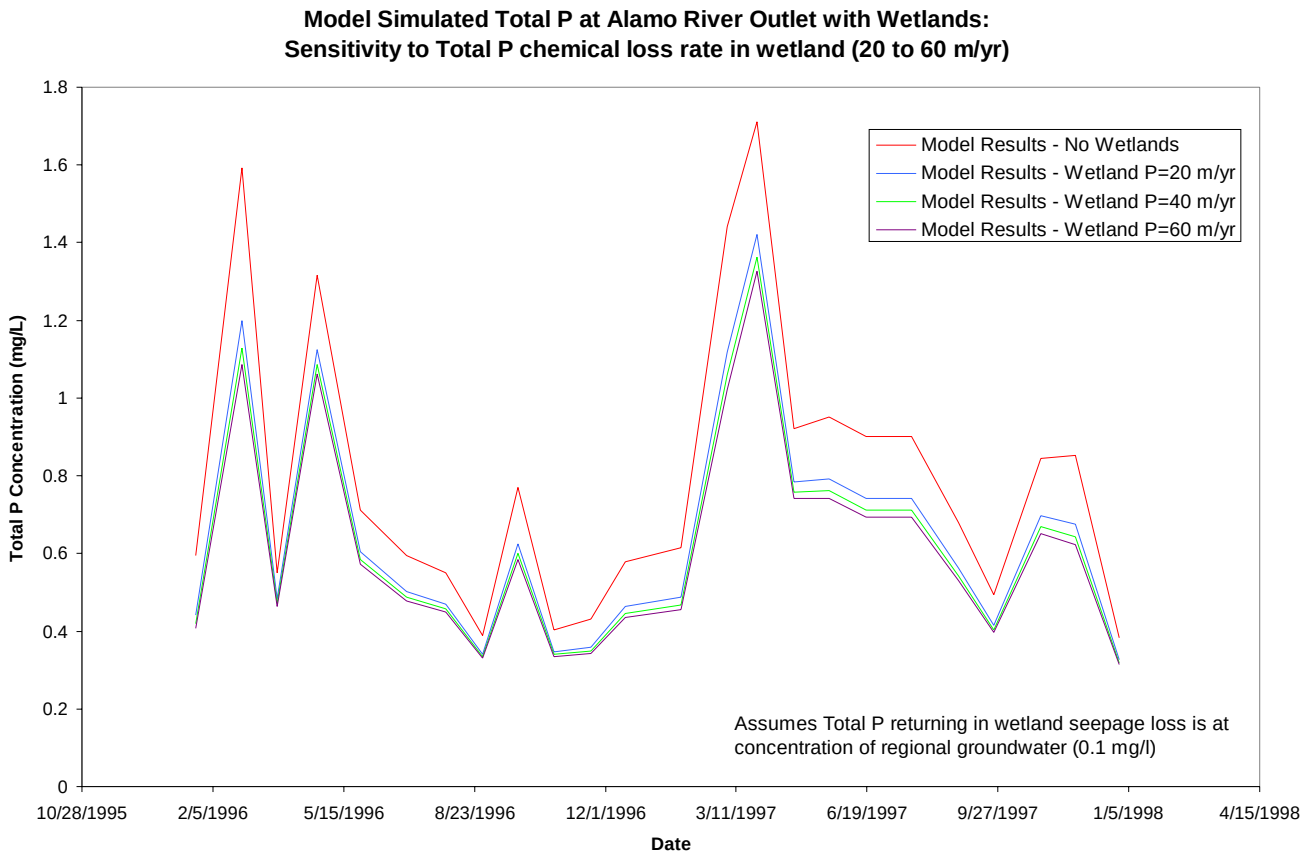


Figure 6-17. Example Model Sensitivity: Impact of wetland chemical loss rate on total phosphorus removals.

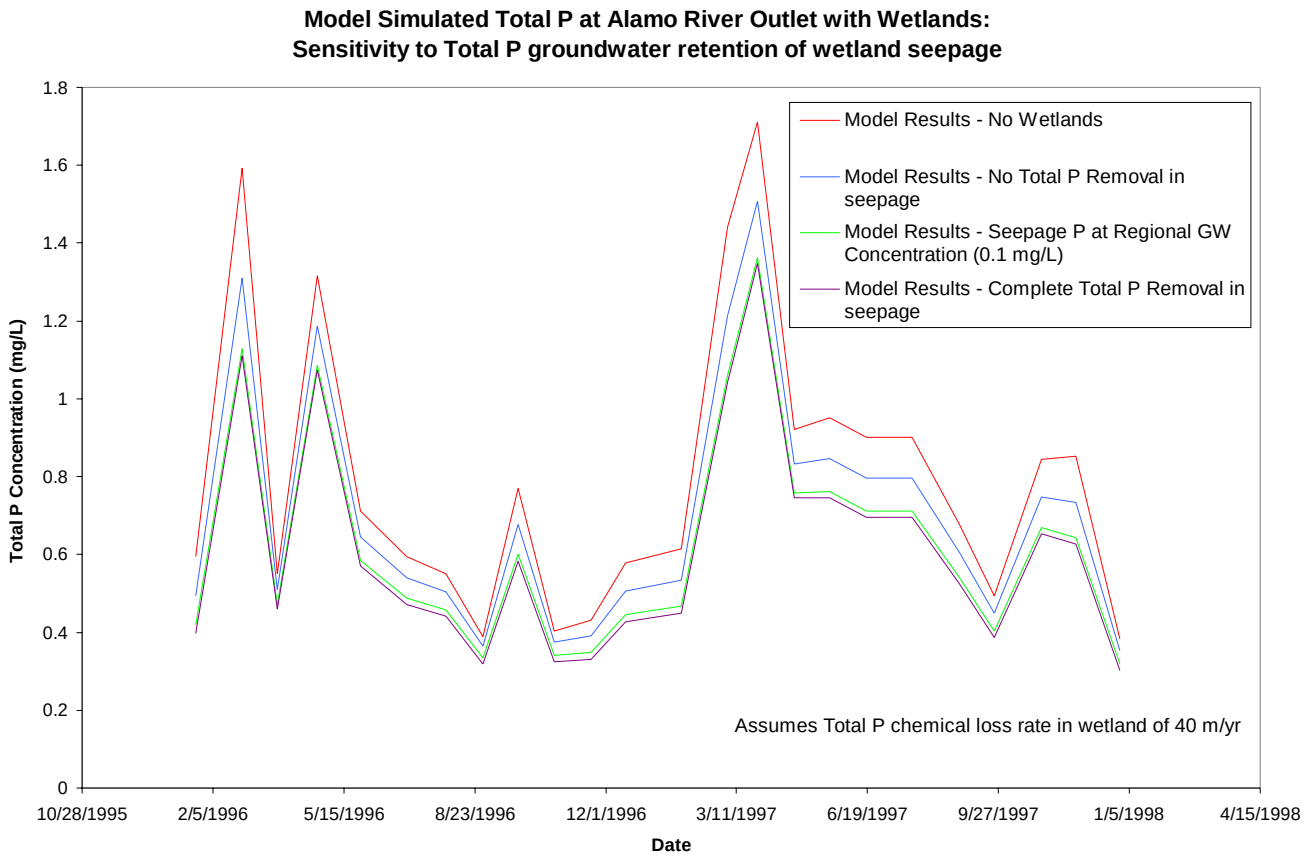


Figure 6-18. Example Model Sensitivity: Impact of wetland chemical retention in groundwater seepage on total phosphorus removals.

For the scenario where the wetland seepage retention is increased to 100 percent of the seepage loss load, the Alamo River total phosphorus load is 517,220 kg/yr, a total phosphorus load reduction of 24 percent relative to the no wetlands scenario and an increase of 9.2 percent (13,780 kg/yr) relative to the wetlands base case scenario. This increase in total phosphorus removal occurs because the wetland seepage retention increases from 70,000 kg/yr in the wetlands base case scenario to 83,780 kg/yr in the high wetland seepage retention scenario. Thus, wetland seepage retention losses increase by 20 percent relative to the wetland base case scenario if wetland seepage retention is increased from the base case retention (83 percent) to 100 percent retention.

For the scenario where the wetland seepage retention is decreased to 0 percent of the seepage loss load, the Alamo River total phosphorus load is 600,000 kg/yr, a total phosphorus load reduction of 12 percent relative to the no wetlands scenario and an increase of 47 percent (70,000 kg/yr) relative to the wetlands base case scenario. This decrease in total phosphorus removal occurs because the wetland seepage retention decreases from 70,000 kg/yr in the wetlands base case scenario to 0 kg/yr in the low wetland seepage retention scenario. Thus, wetland seepage retention losses decrease by 100 percent relative to the wetland base case scenario if wetland seepage retention is decreased from the base case retention (83 percent) to 0 percent retention.

Table 6-4
Alamo River total phosphorus loads: Sensitivity to wetland chemical loss rate and groundwater retention in wetland seepage

	Total P Load	Total P Wetland Loss	Total P Seepage Retention	Total P Wetland Load Reduction		Change in Total P Load Reduction relative to Wetland Base Case	
Scenario	kg/yr	kg/yr	kg/yr	kg/yr	Percent	kg/yr	Percent
No wetlands	680,000	NA	NA	NA	NA	NA	NA
Wetlands Base Case	530,000	80,000	70,000	150,000	22.1%	NA	NA
Wetlands, chemical loss rate 60 m/yr	516,750	93,250	70,000	163,250	24.0%	13,250	8.8%
Wetlands chemical loss rate 20 m/yr	551,200	58,800	70,000	128,800	18.9%	-21,200	-14.1%
Wetlands, 100% seepage retention	516,220	80,000	83,780	163,780	24.1%	13,780	9.2%
Wetlands, no seepage retention	600,000	80,000	0	80,000	11.8%	-70,000	-46.7%

Based upon the model sensitivity results presented above, the model predictions are most sensitive to an increase in the amount of total phosphorus that returns to the river from the wetland seepage losses due to decreased aquifer retention, and least sensitive to an increase in the wetland chemical loss rate to 60 m/yr. Total phosphorus loads from the Alamo River ranged from 516,750 to 600,000 kg/yr depending on the model wetland chemical loss rate and seepage retention parameters. These loads represent decreases in the Alamo River total phosphorus load of 163,250 kg/yr (24 percent) to 80,000 kg/yr (12 percent) relative to the scenario without wetlands.

There is currently very little data on groundwater retention of phosphorus (or the other constituents of concern) in the Imperial Valley. However, the sensitivity analysis above shows that this process can be an important determinant in the overall performance of the wetlands. The sensitivity analyses presented for total phosphorus loads in the Alamo River are also directly applicable to the other constituent loads addressed in this study; to the New River loads; and to the Salton Sea loads from both the New and Alamo Rivers.

6.11 Model Development: Summary

A model integrating the New and Alamo Rivers with a potential network of wetlands was developed to explore the role of adding wetlands on improvement of water quality in the rivers. The spatial and temporal resolution of the model were specifically tailored to meet the requirements of this study and also to be consistent with available flow and water quality data. However, the model retains the flexibility for a user to modify the network of wetlands, including adding and deleting wetlands at specific locations, and also changing the properties of existing wetlands. The model, as described here, including the watershed and drain details was coded in Microsoft Excel, and a fully functional copy of it is included electronically as Appendix K. In the following chapters this model is applied to document base case loads of selected constituents at the drain level throughout the New and Alamo River basins, and then to estimate the changes in calculated loads for different designs of the wetland network.

CHAPTER 7
BASE CASE DISTRIBUTION OF FLOWS AND LOADS

The composite watershed/wetland model described in the previous chapter simulates water flow and chemical loads from point and non-point sources to the New River, Alamo River, and Salton Sea. The two main rivers in the watershed are broken into discrete reaches with upstream inflows, downstream outflows, accretions, and diversions over the reach. The model is primarily driven by upstream inflows, irrigation return flow, groundwater accretion, precipitation runoff, NPDES discharges, and wetland diversion/return flows. Using the data summarized in Chapter 2, key model input parameters are reviewed in this section to determine the relative contribution of various sources to overall loads in the watersheds. These calculations provide the base case concentrations of flows, water quality constituent concentrations, and loads at the level of individual drains, and along the rivers, and serve as the basis against which the performance of potential treatment wetlands can be evaluated.

7.1 Overview of the Alamo and New River Watersheds

The New River and Alamo River watersheds are sub-watersheds of the Salton Sea Transboundary Watershed. The Salton Sea Transboundary Watershed encompasses about 8,360 square miles, and major waterbodies include the Salton Sea, the Alamo River, the New River, the Imperial Valley Agricultural Drains, the Coachella Valley Stormwater Channel, San Felipe Creek, and Salt Creek. Most of the Salton Sea watershed is in Imperial County, but it also receives drainage from Coachella Valley in Riverside County and the Mexicali Valley in Mexico via the New River. Nutrients, pesticides, heavy metals, pathogens, and high suspended sediments pollute the New and Alamo Rivers, which together provide about 80% of the flow into the Salton Sea.

7.2 New River Watershed

The New River originates in Mexico about twenty miles south of the International Boundary, and flows northward into the United States about 60 miles to its terminus at the Salton Sea in Imperial County, California. The New River is dominated by wastewater discharges from Imperial Valley agriculture and Mexico's agriculture and industry.

The New River watershed is located in southeastern California and northern Baja California, Mexico, in the Colorado Desert region of the Sonoran Desert. The New River watershed has

an extremely arid climate and drains approximately 175,000 acres from Imperial Valley, and 300,000 acres from the Mexicali metropolitan area and Mexicali Valley. Its flow at the International Boundary is about 150 to 200 cfs, and its flow at the Salton Sea is about 600 cfs. The river flows into the US from Mexico carry agricultural runoff; partially treated and untreated municipal and industrial wastewater; stormwater; and urban runoff. As the river travels through Imperial Valley, it carries urban runoff; agricultural runoff; treated industrial wastes; and treated, disinfected and non-disinfected domestic wastes from the Imperial Valley. Within the US, the New River is sustained and dominated by agricultural return flows discharged from Imperial Valley farmland primarily through Imperial Valley Agricultural Drains.

7.3 Alamo River Watershed

The Alamo River originates approximately 2 miles south of the International Boundary with Mexico, and flows northward across the border for about 60 miles until it empties into the Salton Sea. The Alamo River is the main tributary to the Salton Sea. The Alamo River's watershed has an extremely arid climate and consists almost entirely of highly productive agricultural lands irrigated with water imported from the Colorado River. The water in the Alamo River consists almost entirely of discharges from agricultural operations from the Imperial Valley, although it carries approximately 15 to 27 cfs of treated wastewater from point sources in Imperial Valley.

The Alamo River watershed encompasses approximately 340,000 acres within the Imperial Valley. Its flow at the international boundary is 3 to 5 cfs, and its flow at the Salton Sea is about 800 to 1000 cfs. Land uses within the watershed consist chiefly of irrigated farmland, with minor amounts of urban and industrial land uses, and confined animal feeding operations. The river flow rapidly increases as it travels through the Imperial Valley where it is fed by over 900 miles of agricultural drains. The Alamo River is the Salton Sea's largest tributary, contributing about 50% of the Sea's annual inflows, and therefore has a major influence on the water quality of the Sea.

7.4 Characterization of Primary Sources

7.4.1 Flow

The magnitudes of various flow sources in the New River and Alamo River Watersheds are given in Figure 7-1. For the New River, almost one-third of the total flow consists of cross-border inflows from Mexico, while the remaining two-thirds of the total flow originates in the US. New River flows at the US-Mexico border are 70 percent derived from irrigation return flows from Mexicali Valley, 23 percent derived from partially treated and untreated municipal and industrial wastewater from Mexicali, and 7 percent derived from stormwater runoff from Mexicali Valley. Agricultural return flows in Imperial Valley account for almost two-thirds (64 percent) of the total New River flow, while groundwater accretion and NPDES discharges in Imperial Valley each contribute about 1 percent of the total New River flow, and urban and agricultural runoff from precipitation each contribute less than 0.4 percent of the total New River flow.

For the Alamo River, only 0.2 percent of the total flow consists of cross-border inflows from Mexico and 99.8 percent of the total flow originates in the US. Agricultural return flows in Imperial Valley account for almost 97 percent of the total Alamo River flow, while groundwater accretion in Imperial Valley contributes about 2 percent of the total Alamo

River flow. NPDES discharges, urban runoff from precipitation, and agricultural runoff from precipitation each contribute less than 0.4 percent of the total Alamo River flow.

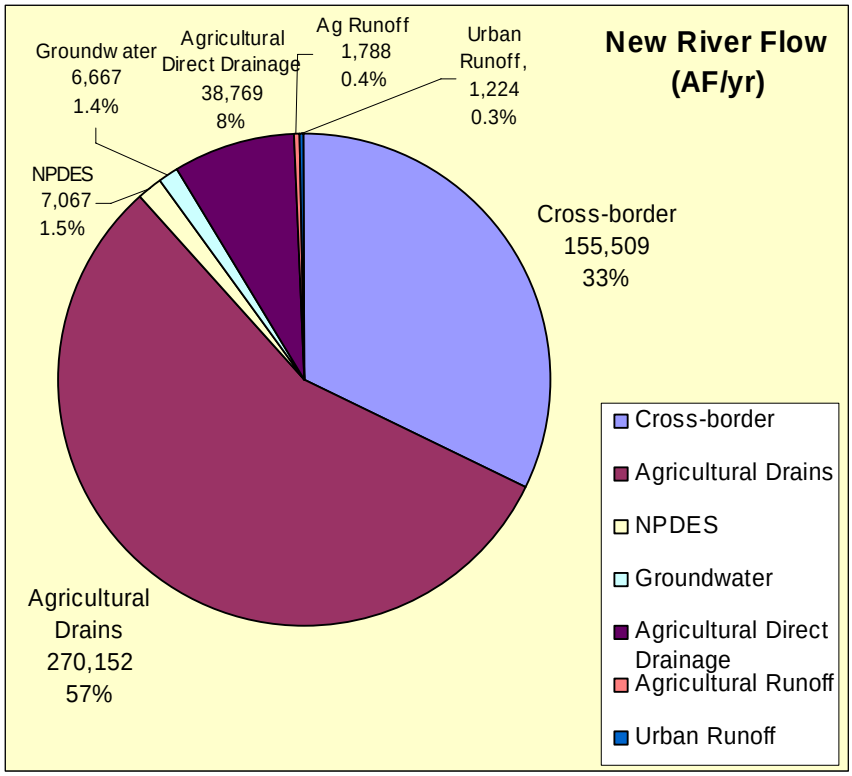
Total flows from both the New River and Alamo River are about 1.2 million AF/yr, which is 59 percent from the Alamo River and 41 percent from the New River. Flow from Mexico accounts for 13.3 percent of the total New River and Alamo River flows, and 99 percent of the flow from Mexico enters the watersheds via the New River.

7.4.2 Phosphorus

The magnitudes of various total phosphorus sources in the New River and Alamo River Watersheds are illustrated in Figure 7-2. For the New River, almost 55 percent of the total phosphorus load consists of cross-border inflows from Mexico, while the remaining 45 percent of the total phosphorus load originates in the US. Agricultural return flows in Imperial Valley account for almost 43 percent of the New River total phosphorus load, while NPDES discharges in Imperial Valley contribute about 1.8 percent of the New River total phosphorus load. Groundwater accretion, urban runoff from precipitation, and agricultural runoff from precipitation each contribute less than 0.1 percent of the New River total phosphorus load.

For the Alamo River, only 0.1 percent of the total phosphorus load consists of cross-border inflows from Mexico and 99.9 percent of the total phosphorus load originates in the US. Agricultural return flows in Imperial Valley account for almost 99 percent of the Alamo River total phosphorus load, while NPDES discharges in Imperial Valley contributes 0.2 percent of the Alamo River total phosphorus load. Groundwater accretion, urban runoff from precipitation, and agricultural runoff from precipitation each contribute about 0.2 to 0.4 percent of the Alamo River total phosphorus load.

Total phosphorus loads from both the New River and Alamo River are about 1.4 million kg/yr, which is 50 percent from the New River and 50 percent from the Alamo River. Total phosphorus loads from Mexico accounts for 27 percent of the New River and Alamo River total phosphorus loads, and over 99 percent of the total phosphorus from Mexico enters the watersheds via the New River.



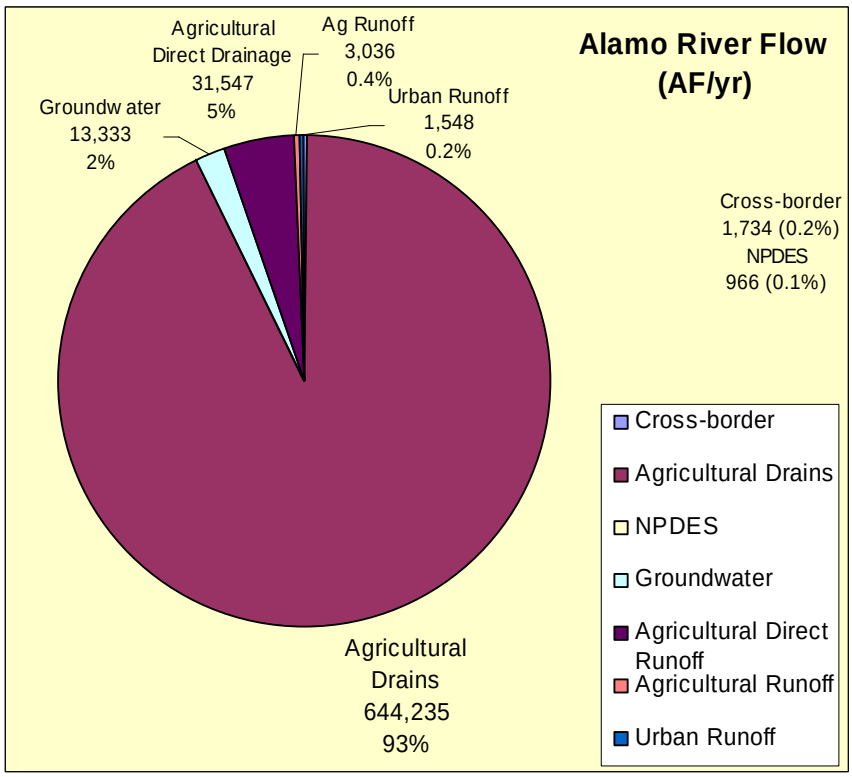
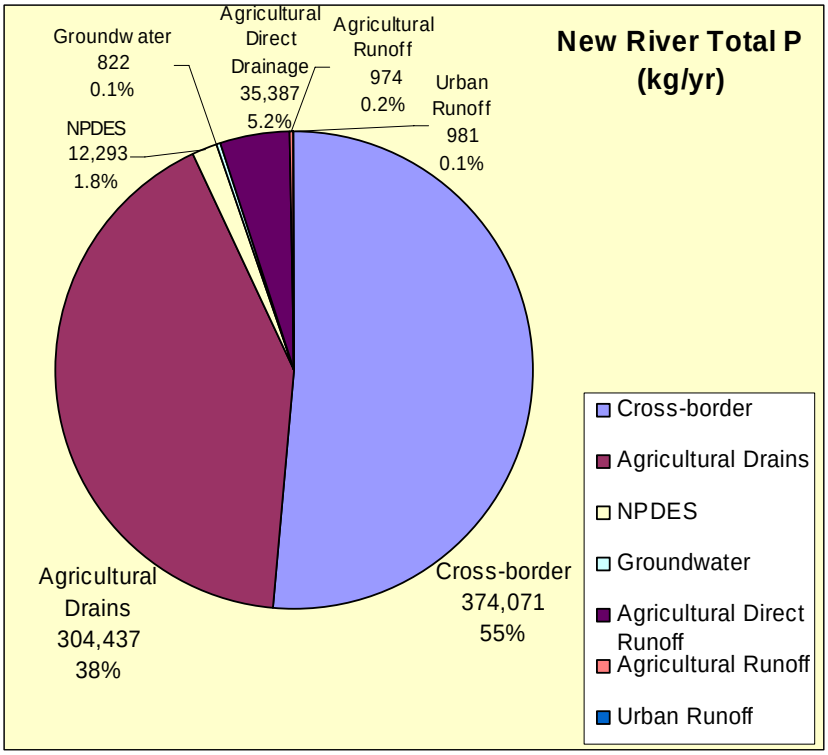


Figure 7-1 Magnitude and distribution of flow sources in the New River and Alamo River watersheds.



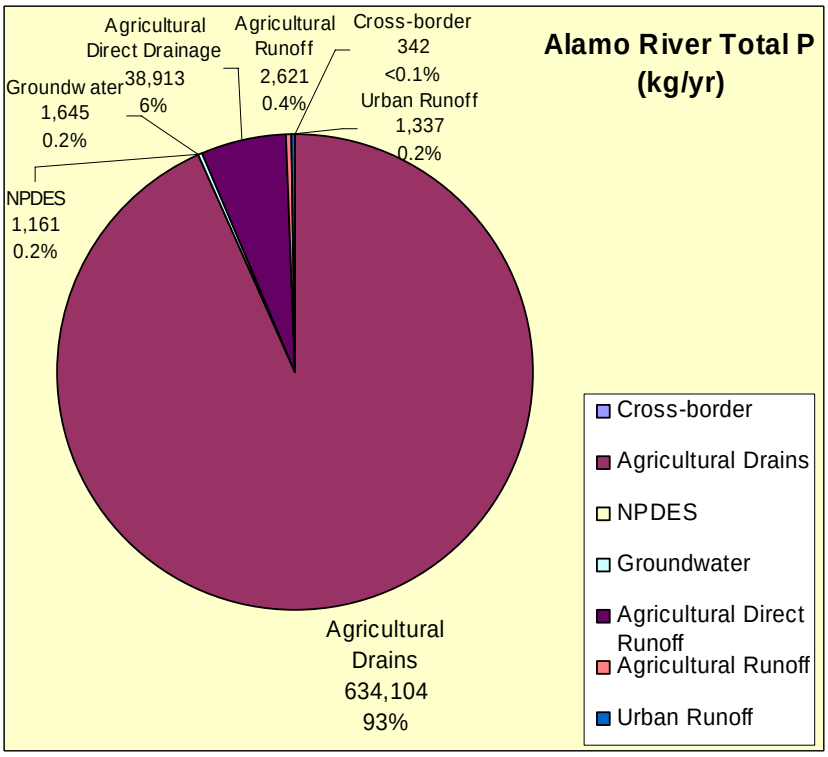


Figure 7-2 Magnitude and distribution of total phosphorus sources in the New River and Alamo River watersheds.

7.4.3 Nitrogen

The magnitudes of various total nitrogen sources in the New River and Alamo River Watersheds are illustrated in Figure 7-3. For the New River, almost 31 percent of the total nitrogen load consists of cross-border inflows from Mexico, while the remaining 69 percent of the total nitrogen load originates in the US. Agricultural return flows in Imperial Valley account for almost 63 percent of the New River total nitrogen load, while NPDES discharges in Imperial Valley contribute about 3 percent of the New River total nitrogen load. Groundwater accretion, urban runoff from precipitation, and agricultural runoff from precipitation each contribute 1 percent or less of the New River total nitrogen load.

For the Alamo River, less than 0.01 percent of the total nitrogen load consists of cross-border inflows from Mexico and 99.99 percent of the total nitrogen load originates in the US. Agricultural return flows in Imperial Valley account for 97.4 percent of the Alamo River total nitrogen load, while groundwater accretion in Imperial Valley contributes about 2 percent of the Alamo River total nitrogen load. NPDES discharges, urban runoff from precipitation, and agricultural runoff from precipitation each contribute less than 0.3 percent of the Alamo River total nitrogen load.

Total nitrogen loads from both the New River and Alamo River are about 14.3 million kg/yr, which is 43 percent from the New River and 57 percent from the Alamo River. Total nitrogen loads from Mexico accounts for 14 percent of the New River and Alamo River total nitrogen loads, and over 99 percent of the total nitrogen from Mexico enters the watersheds via the New River.

7.4.4 Total Suspended Solids

The magnitudes of various TSS sources in the New River and Alamo River Watersheds are illustrated in Figure 7-4. For the New River, 7 percent of the TSS load consists of cross-border inflows from Mexico, while the remaining 93 percent of the TSS load originates in the US. Agricultural return flows in Imperial Valley account for about 91 percent of the New River TSS load, while NPDES discharges in Imperial Valley contribute about 0.2 percent of the New River TSS load. Groundwater accretion contributes about 0.1 percent to the New River TSS load. Urban runoff from precipitation and agricultural runoff from precipitation each contribute about 0.2 percent of the New River TSS load.

For the Alamo River, less than 0.01 percent of the TSS load consists of cross-border inflows from Mexico and 99.99 percent of the TSS load originates in the US. Agricultural return flows in Imperial Valley account for 99.5 percent of the Alamo River TSS load, while groundwater accretion in Imperial Valley does not contribute to the Alamo River TSS load. NPDES discharges and urban runoff from precipitation.

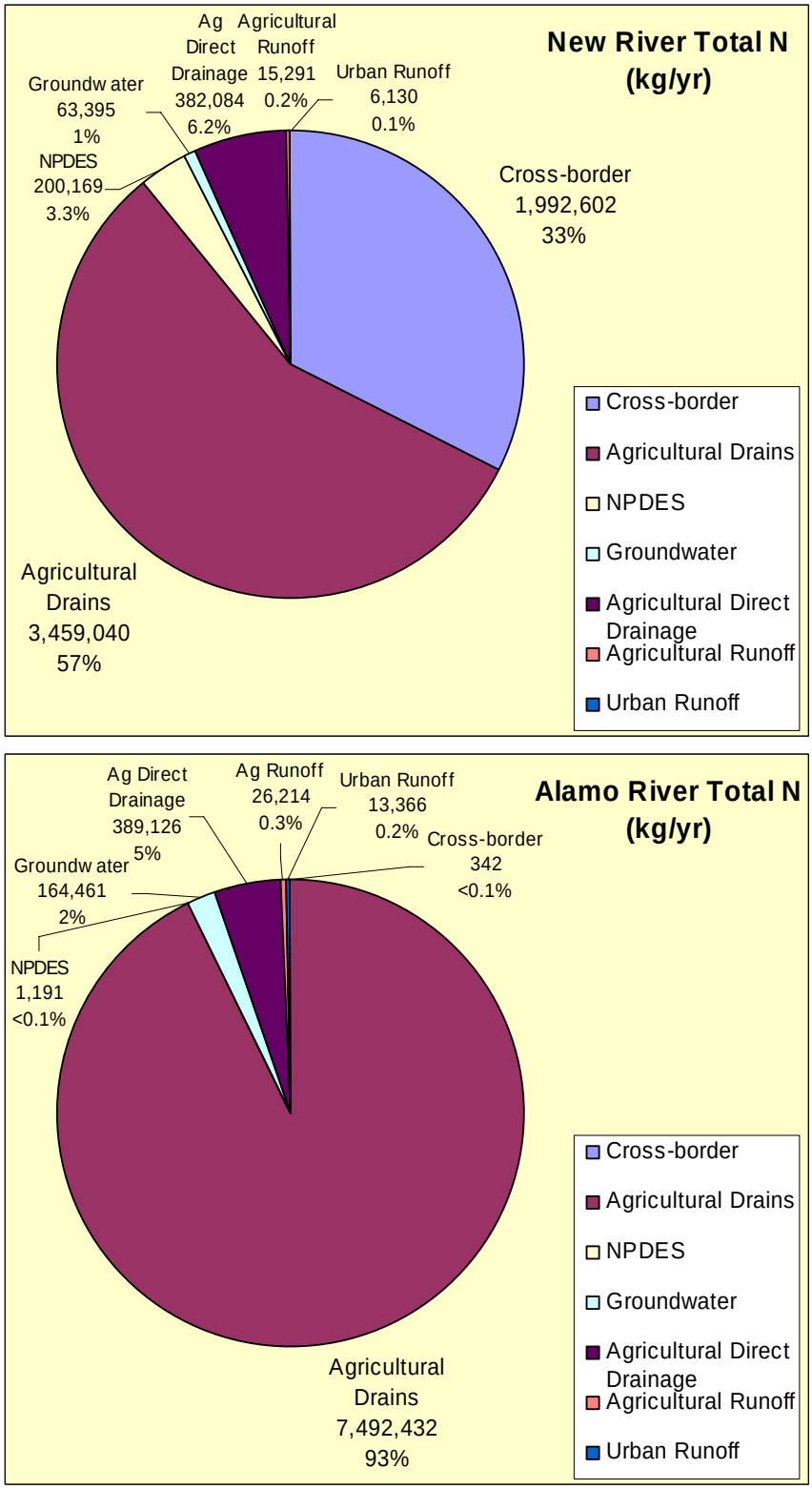


Figure 7-3 Magnitude and distribution of total nitrogen sources in the New River and Alamo River watersheds.

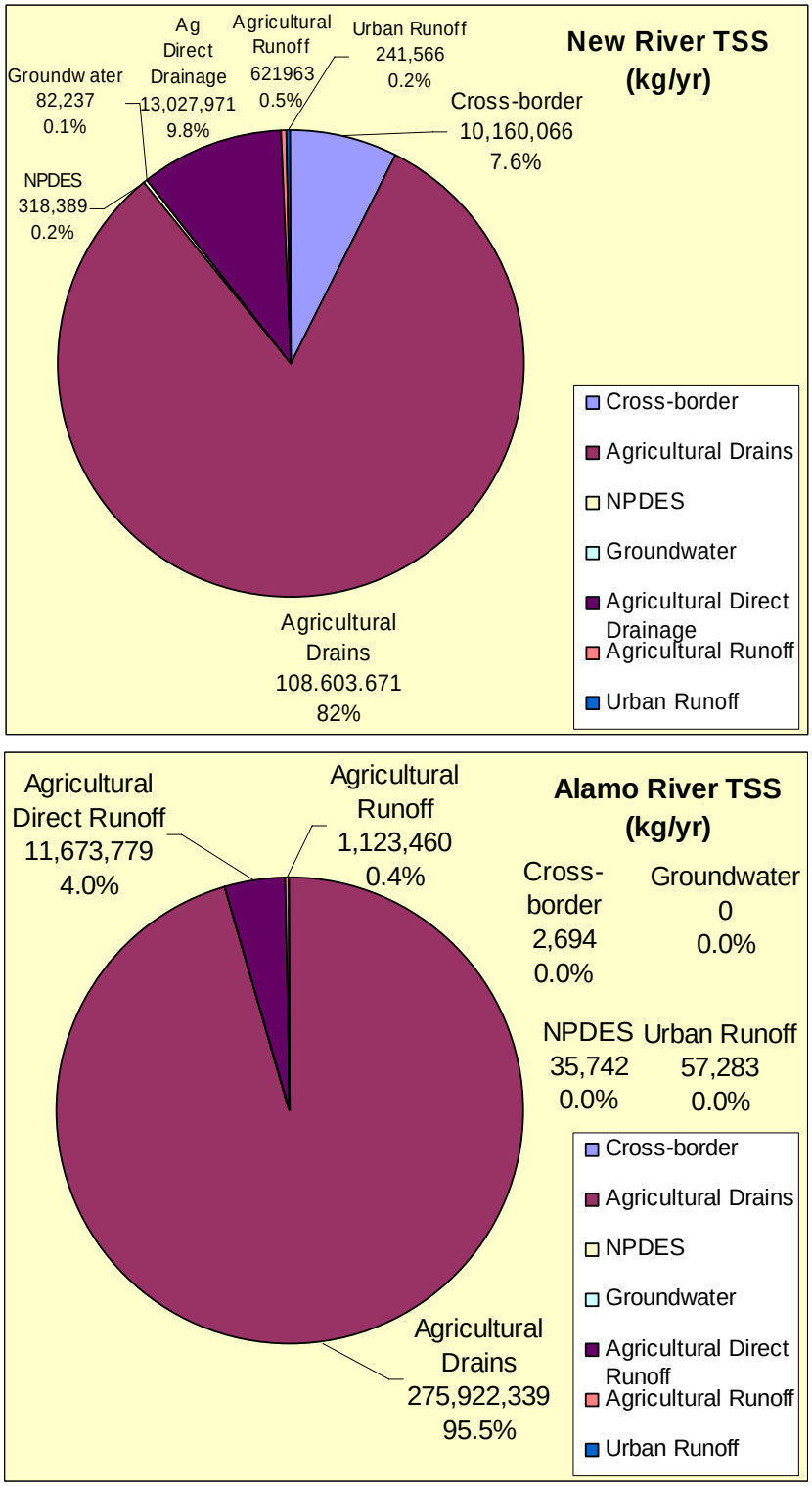


Figure 7-4 Magnitude and distribution of TSS in the New River and Alamo River watersheds. Each contribute less than 0.1 percent of the Alamo River TSS load, and agricultural runoff from precipitation contributes about 0.4 percent of the Alamo River TSS load.

TSS loads from both the New River and Alamo River are about 425 million kg/yr, which are about 32 percent from the New River and 68 percent from the Alamo River. TSS loads from Mexico accounts for 2 percent of the New River and Alamo River TSS loads, and over 99 percent of the TSS load from Mexico enters the watersheds via the New River.

7.4.5 Selenium

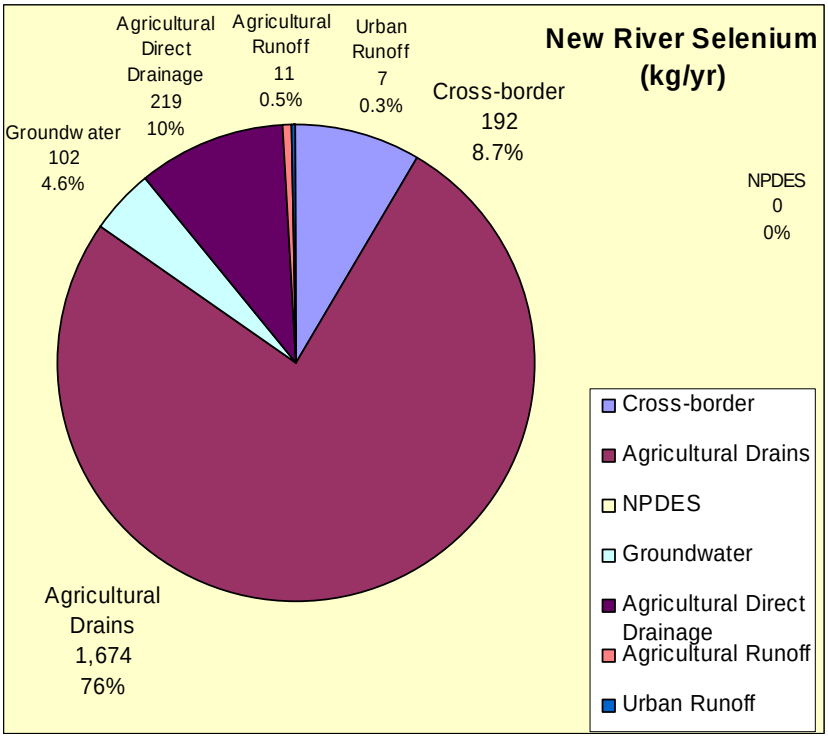
The magnitudes of various selenium sources in the New River and Alamo River Watersheds are illustrated in Figure 7-5. For the New River, almost 9 percent of the selenium load consists of cross-border inflows from Mexico, while the remaining 81 percent of the selenium load originates in the US. Agricultural return flows in Imperial Valley account for about 86 percent of the New River selenium load. Groundwater accretion contributes 4.6 percent of the New River selenium load, while urban runoff from precipitation and agricultural runoff from precipitation each contribute less than 0.5 percent of the New River selenium load.

For the Alamo River, about 0.01 percent of the selenium load consists of cross-border inflows from Mexico and 99.99 percent of the selenium load originates in the US. Agricultural return flows in Imperial Valley account for 96.4 percent of the Alamo River selenium load, while groundwater accretion in Imperial Valley contributes about 3 percent of the Alamo River selenium load. NPDES discharges contribute less than 0.01 percent of the Alamo River selenium load. Urban runoff from precipitation and agricultural runoff from precipitation each contribute 0.2 and 0.5 percent, respectively, of the Alamo River selenium load.

Selenium loads from both the New River and Alamo River are about 7,660 kg/yr, which 33 percent from the New River and 67 percent from the Alamo River. Selenium loads from Mexico accounts for 6 percent of the New River and Alamo River selenium loads, and over 99 percent of the selenium from Mexico enters the watersheds via the New River.

7.4.6 Total Coliforms

The magnitudes of various total coliform sources in the New River and Alamo River Watersheds are illustrated in Figure 7-5. For the New River, almost 82 percent of the total coliform load consists of cross-border inflows from Mexico, while the remaining 18 percent of the total coliform load originates in the US. Agricultural return flows in Imperial Valley account for approximately 18 percent of the New River total coliform load. Groundwater accretion, urban runoff from precipitation, and agricultural runoff from precipitation each contribute less than 0.1 percent of the New River total coliform load.



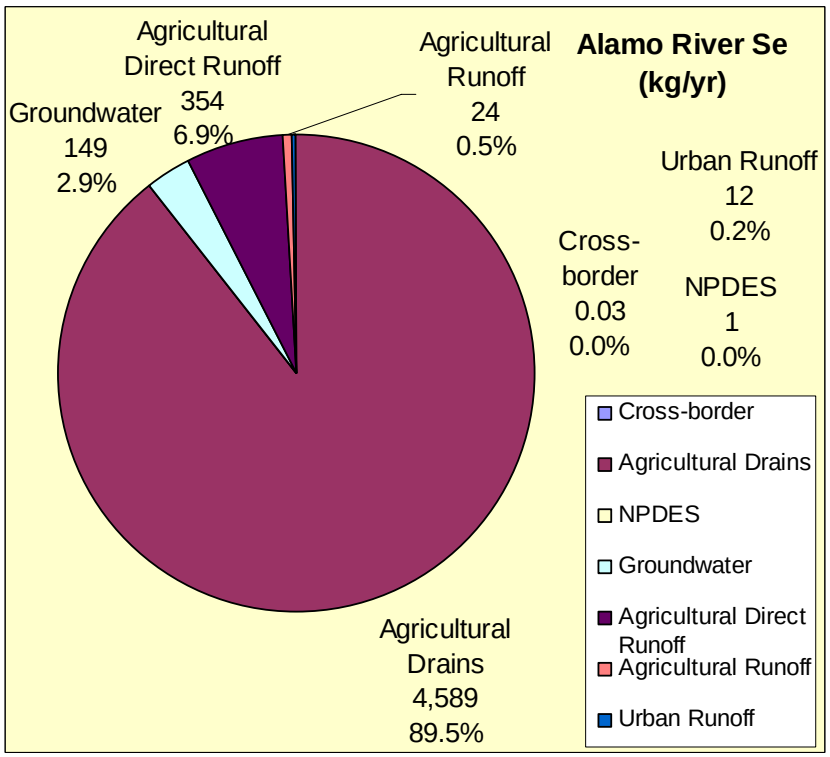
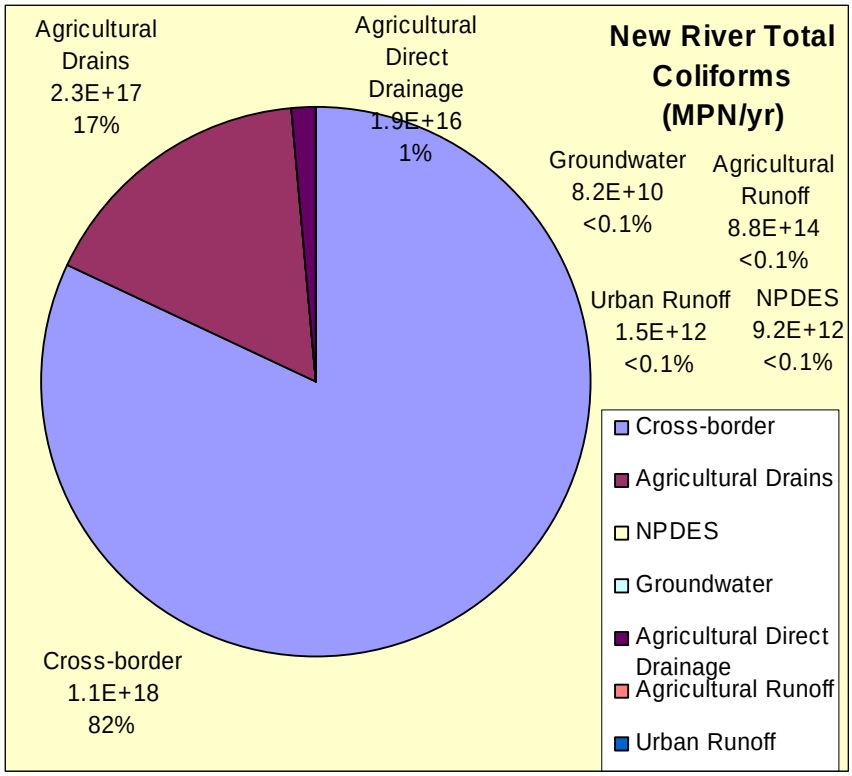


Figure 7-5 Magnitude and distribution of selenium in the New River and Alamo River watersheds.

For the Alamo River, less than 0.01 percent of the total coliform load consists of cross-border inflows from Mexico and 99.99 percent of the total coliform load originates in the US. Agricultural return flows in Imperial Valley account for almost 100 percent of the Alamo River total coliform load, while groundwater accretion in Imperial Valley does not contribute to the Alamo River total coliform load. NPDES discharges, urban runoff from precipitation, and agricultural runoff from precipitation each contribute less than 0.01 percent of the Alamo River total coliform load.

Total coliform loads from both the New River and Alamo River are about 1.8×10^{18} MPN/yr, which is 77 percent from the New River and 23 percent from the Alamo River. Total coliform loads from Mexico accounts for 35 percent of the New River and Alamo River total coliform loads, with essentially all of the total coliforms from Mexico entering via the New River.



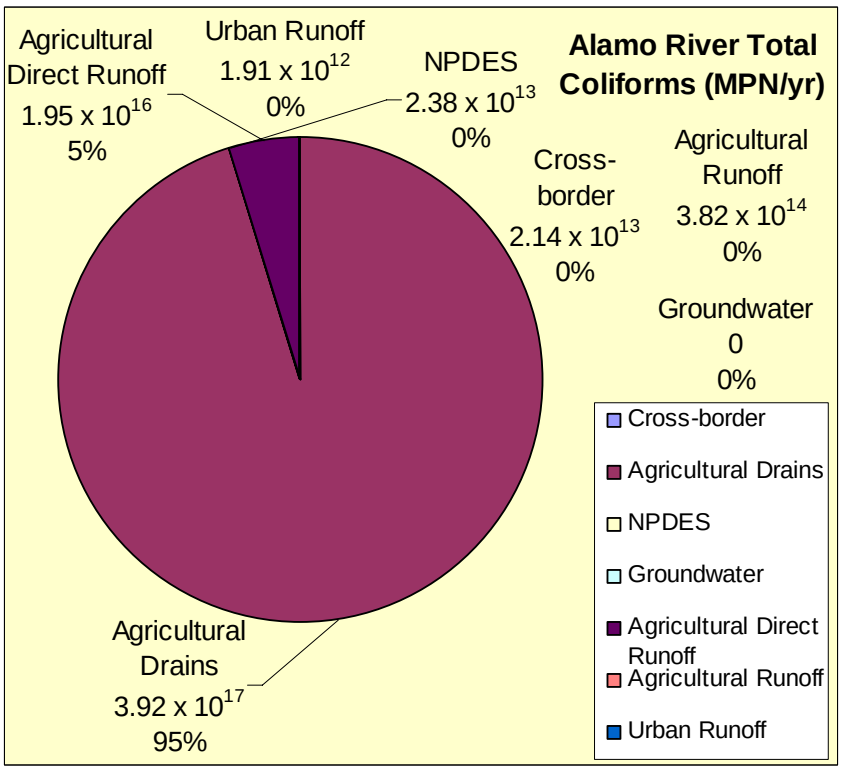


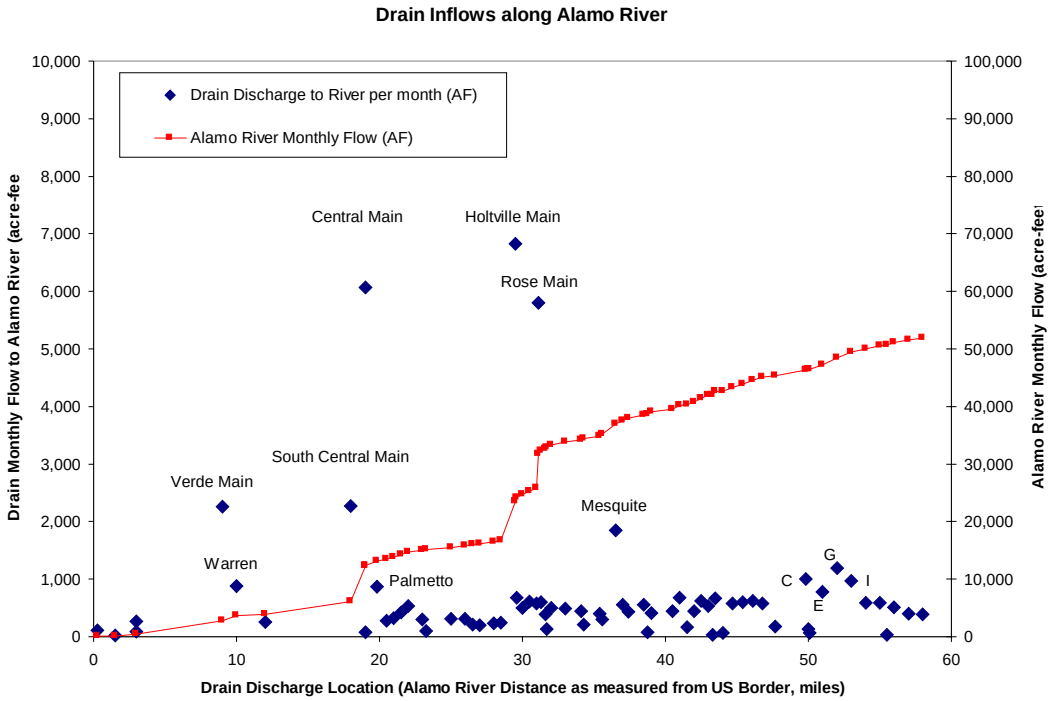
Figure 7-6 Magnitude and distribution of total coliforms in the New River and Alamo River watersheds.

7.5 Identification of Primary Drain Sources

7.5.1 Flow

Irrigation return drains are the dominant sources of flows and chemical loadings in the Alamo River and New River Watersheds. The locations and names of the most important irrigation return drains in the Alamo River and New River Watersheds -ranked based upon flow- are identified in Figures 7-7 and 7-8, respectively. Each figure shows two plots. The upper plots in Figures 7-7 and 7-8 show the individual discharge rate for each drain as it flows into the river, and the total flow in the river, plotted as a function of distance from the US-Mexico Border. These upper plots can be used to define sections of the rivers where large drain inflows occur over small distances. For example, the upper plot in Figure 7-7 shows that there are large drain inflows into the Alamo River at about 10 river miles (the Verde Main and Warren Drains); 20 river miles (the Central Main, South Central Main, and Palmetto Drains); 30 river miles (the Holtville Main and Rose Main Drains); 38 river miles (the Mesquite Drain); and 50 river miles (the C, E, G, and I Drains). The upper plot in Figure 7-8 shows that there are large drain inflows into the New River at about 15 river miles (the Greeson Main and Fig Main Drains); 30 river miles (Salt Creek, Rice 3 Main, Fillaree, Rice Main, and North Central Drains); and 60 river miles (the Timothy 1, Trifolium 6, Trifolium 7, and Trifolium 9 Drains).

The lower plots in Figures 7-7 and 7-8 show the fraction of each individual drain discharge rate relative to the total drain flows in the river, sorted and plotted from the highest to lowest drain flows. The cumulative fraction of the sorted drain discharge rates relative to the total drain flow in the river is also shown in the lower plots in Figures 7-7 and 7-8. These lower plots can be used to define which are the largest individual drains and groups of drains, and what fraction of the total drain flow a certain group contributes. For example, the lower plot in Figure 7-7 shows that only three large drain inflows into the Alamo River (the Holtville Main, Central Main, and Rose Main Drains) account for 36 percent of the total Alamo River drain flow to the Salton Sea, and thirteen large drain inflows into the Alamo River (the Holtville Main, Central Main, Rose Main, South Central Main, Verde Main, Mesquite, G, C, I, Warren, Palmetto, E, and Olive Drains) account for 61 percent of the total Alamo River drain flow to the Salton Sea. The lower plot in Figure 7-8 shows that only five large drain inflows into the New River (Salt Creek, Greeson, Rice 3, Trifolium 7, and Trifolium 9 Drains) account for 37 percent of the total New River drain flow to the Salton Sea, and eleven large drain inflows into the New River (Salt Creek, Greeson, Rice 3, Trifolium 7, Trifolium 9, Fillaree, Trifolium 6, Fig, Timothy 1, North Central, and Trifolium 10 Drains) account for 59 percent of the total New River drain flow to the Salton Sea.



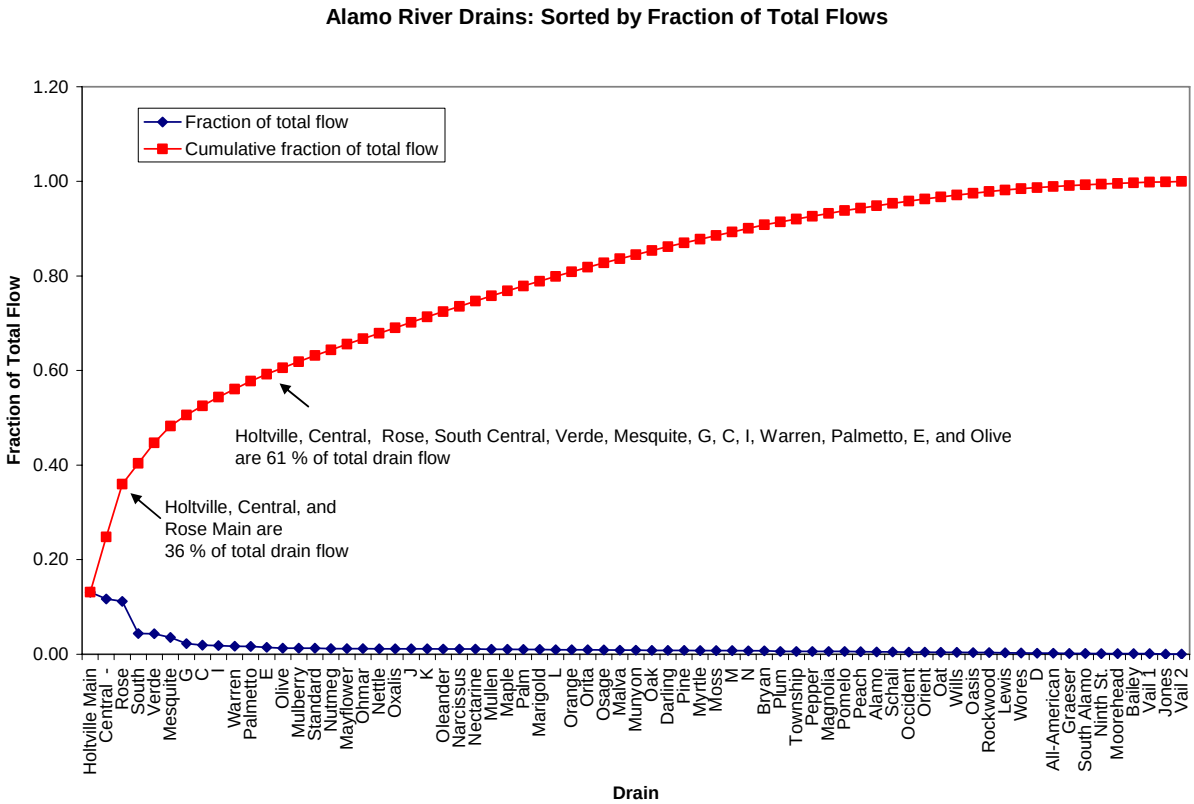
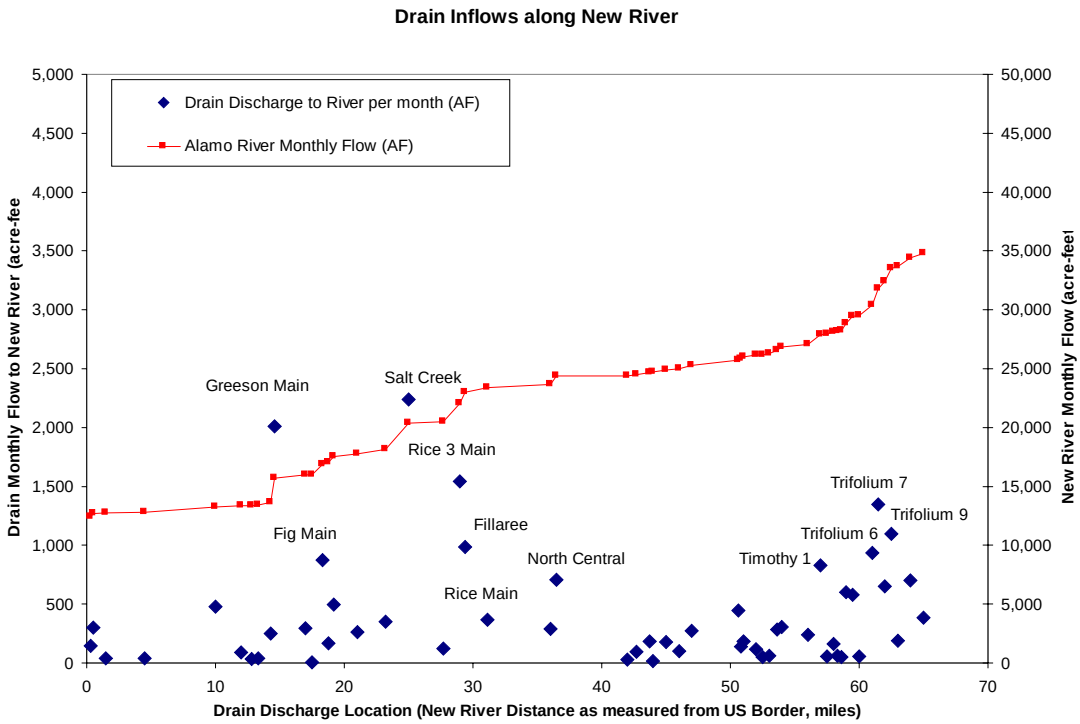


Figure 7-7 Drain flow rates into the Alamo River: Individual and cumulative drain flows along the river length (top), and individual and cumulative fraction of total drain flows sorted from highest to lowest (bottom).



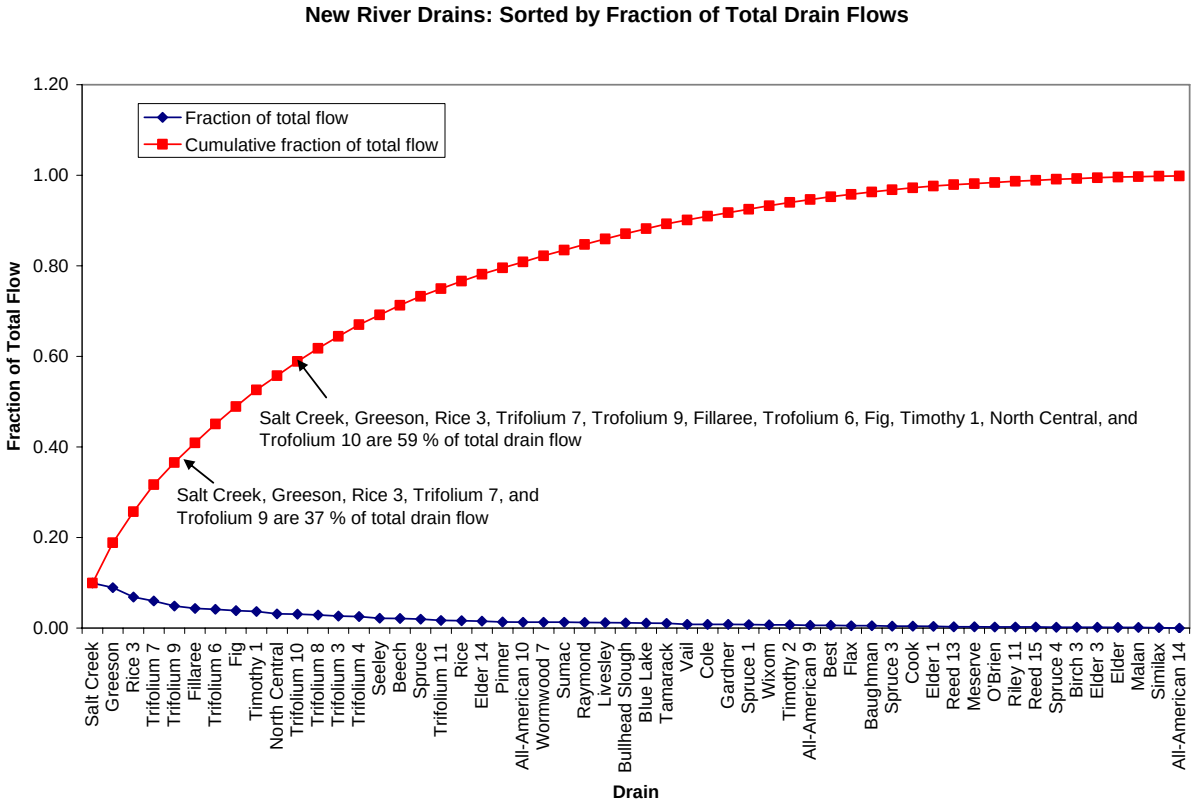


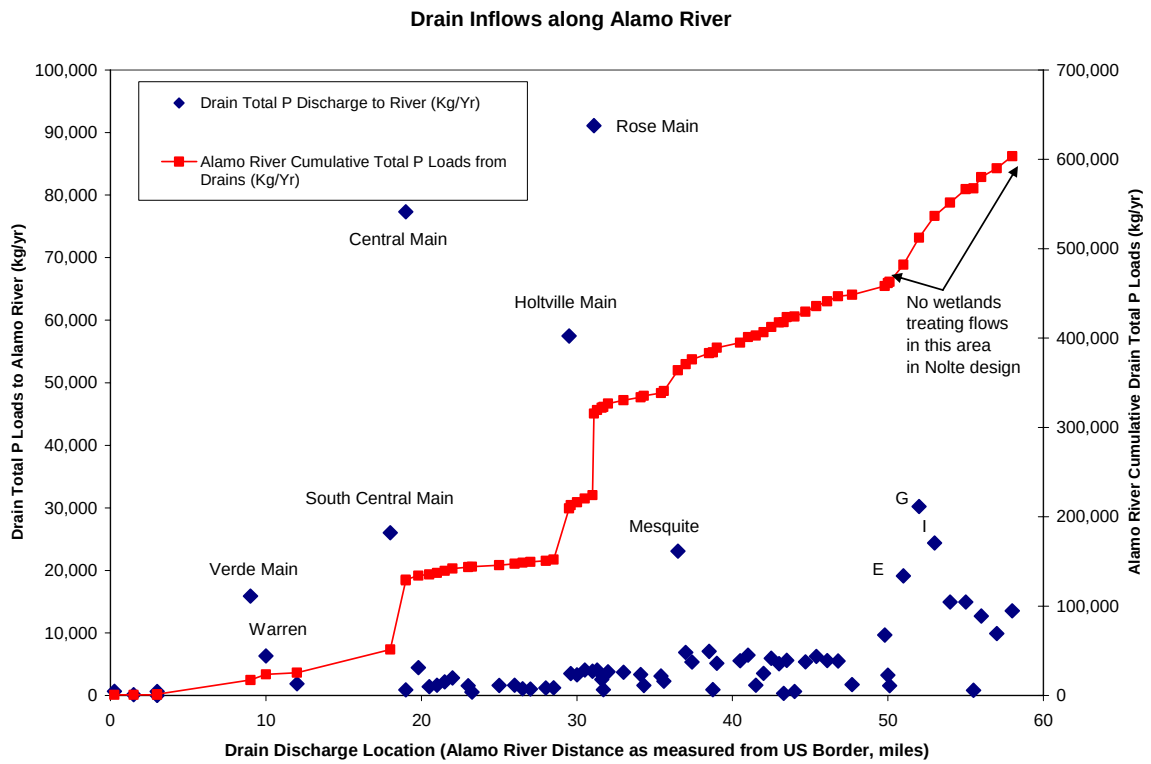
Figure 7-8 Drain flow rates into the New River: Individual and cumulative drain flows along the river length (top), and individual and cumulative fraction of total drain flows sorted from highest to lowest (bottom).

7.5.2 Total Phosphorus

The locations and names of the most important irrigation return drains in the Alamo River and New River Watersheds -ranked based upon total phosphorus loads- are identified in Figures 7-9 and 7-10, respectively. These figures show two plots for total phosphorus using the same format discussed in Section 7.3.1 for Figures 7-7 and 7-8, which are based upon flow. The upper plot in Figure 7-9 shows that there are large drain total phosphorus loads into the Alamo River at about 10 river miles (the Verde Main and Warren Drains); 20 river miles (the Central Main and South Central Main Drains); 30 river miles (the Holtville Main and Rose Main Drains); 38 river miles (the Mesquite Drain); and 50 river miles (the E, G, and I Drains). The upper plot in Figure 7-10 shows that there are large drain total phosphorus loads into the New River at about 15 river miles (the Greeson Main Drain); 30 river miles (Salt Creek and, Rice 3 Main Drains); and 60 river miles (the Trifolium 3, Trifolium 6, Trifolium 7, Trifolium 8, and Trifolium 9 Drains).

The lower plot in Figure 7-9 shows that only three large drain inflows into the Alamo River (the Rose Main, Central Main, and Holtville Main Drains) account for 38 percent of the total Alamo River drain total phosphorus loads to the Salton Sea, and nine large drain inflows into the Alamo River (the Rose Main, Central Main, Holtville Main, G, South Central Main, I, Mesquite, E, and Verde Main Drains) account for 61 percent of the total Alamo River drain total phosphorus loads to the Salton Sea. The lower plot in Figure 7-10 shows that only four large drain inflows into the New River (Salt Creek, Rice 3, Trifolium 7, and Trifolium 9 Drains) account for 42 percent of the total New River drain total phosphorus loads to the Salton Sea, and seven large drain inflows into the New River (Salt Creek, Rice 3, Trifolium 7, Trifolium 9, Trifolium 6, Greeson, Trifolium 8, and Trifolium 3 Drains) account for 61 percent of the total New River drain total phosphorus loads to the Salton Sea.

The total phosphorus load plots in Figures 7-9 and 7-10 are similar to the flow plots in Figures 7-7 and 7-8, but there are some differences that are due to differences in the total phosphorus concentrations of the drains. In general, though, there is a lot of similarity between the chemical load plots and the flow plots, indicating that flows are one of the most important factors in estimating loads.



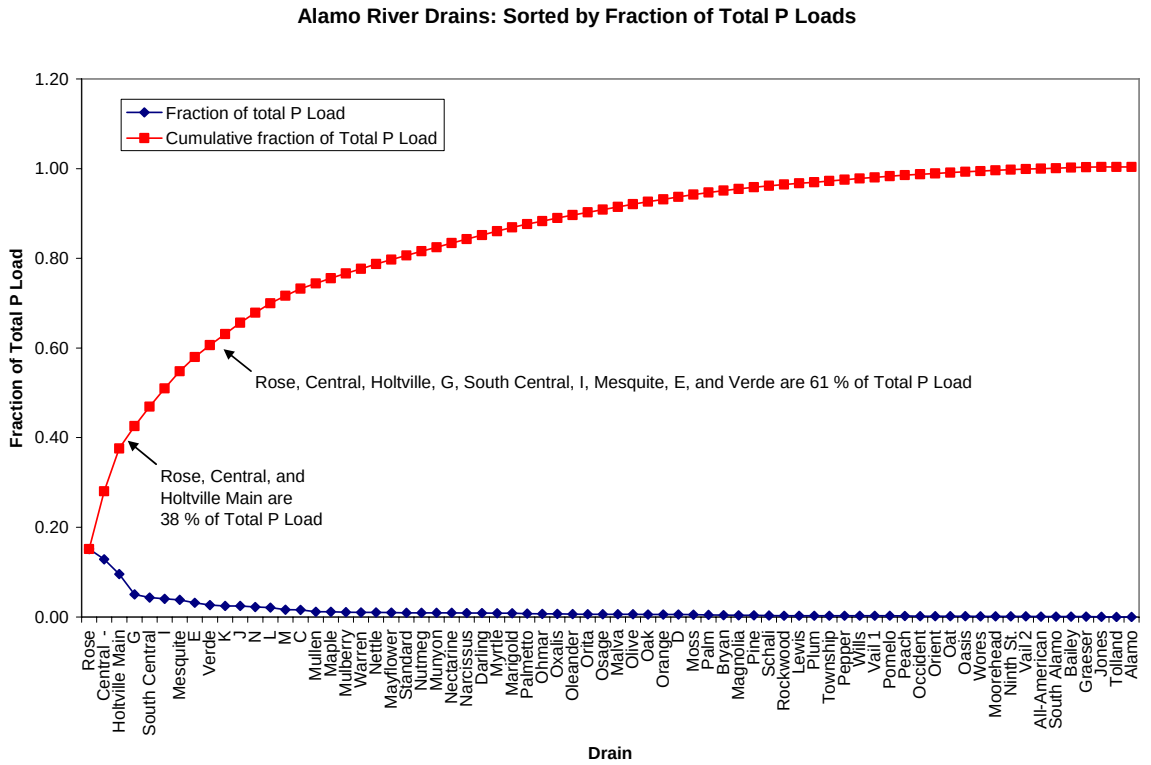
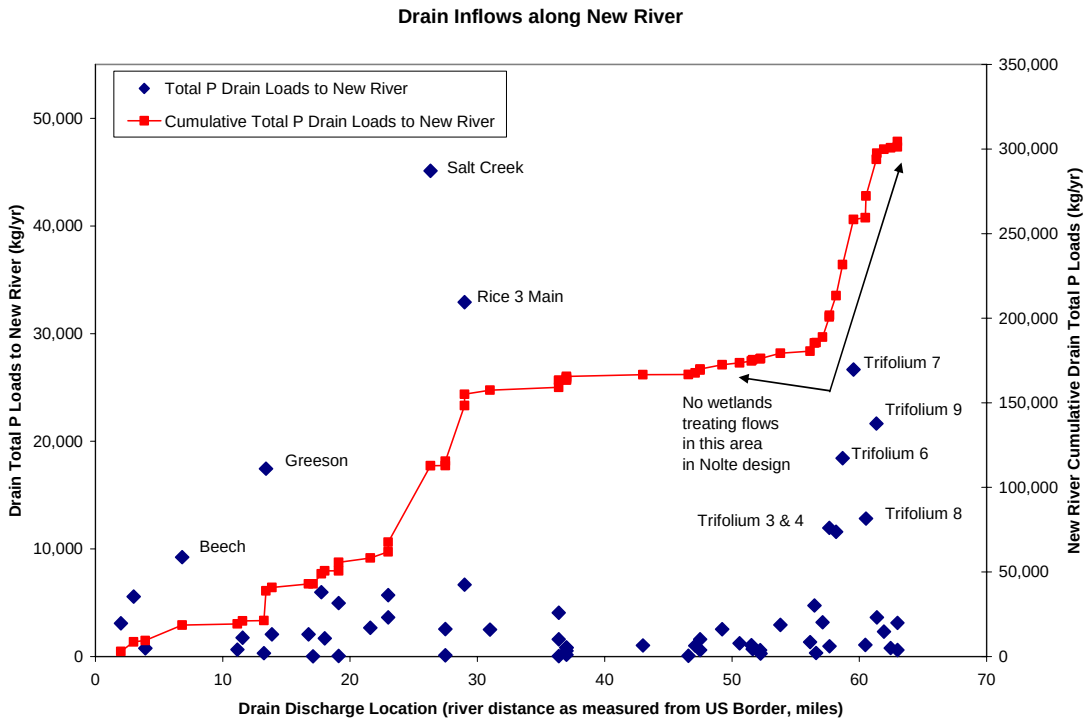


Figure 7-9 Drain Total P loads into the Alamo River: Individual and cumulative drain total loads along the river length (top), and individual and cumulative fraction of total drain total P loads sorted from highest to lowest (bottom).



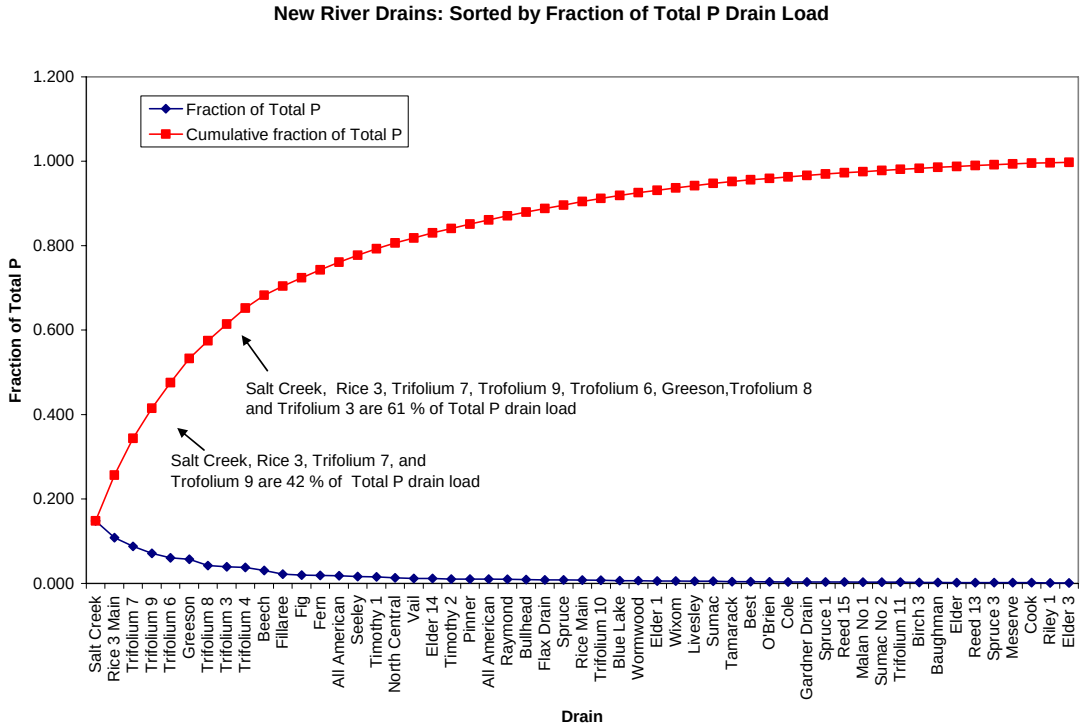


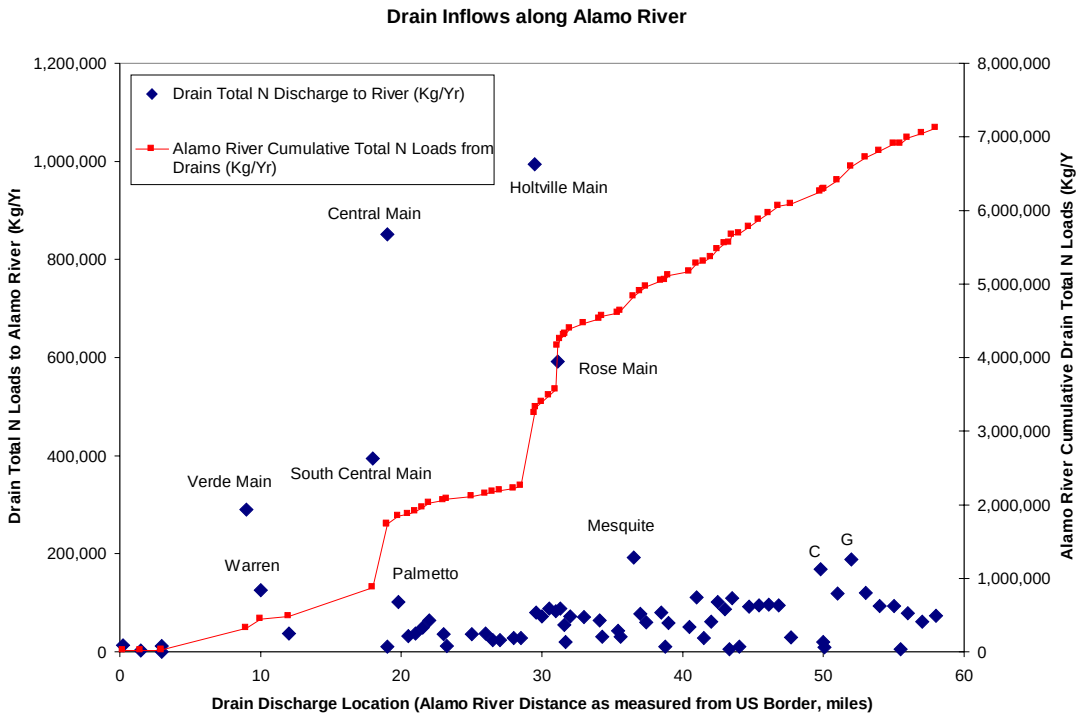
Figure 7-10 Drain Total P loads into New River: Individual and cumulative drain total P loads along the river length (top), and individual and cumulative fraction of total drain total P loads sorted from highest to lowest (bottom).

7.5.3 Total Nitrogen

The locations and names of the most important irrigation return drains in the Alamo River and New River Watersheds -ranked based upon total nitrogen loads- are identified in Figures 7-11 and 7-12, respectively. These figures show two plots for total nitrogen using the same format discussed in Section 7.3.1 for Figures 7-7 and 7-8, which are based upon flow. The upper plot in Figure 7-11 shows that there are large drain total nitrogen loads into the Alamo River at about 10 river miles (the Verde Main and Warren Drains); 20 river miles (the Central Main, South Central Main, and Palmetto Drains); 30 river miles (the Holtville Main and Rose Main Drains); 38 river miles (the Mesquite Drain); and 50 river miles (the C and G Drains). The upper plot in Figure 7-12 shows that there are large drain total nitrogen loads into the New River at about 15 river miles (the Greeson, Beech, and Fig Main Drains); 30 river miles (Salt Creek, Rice 3 Main, and Fillaree); and 60 river miles (the Timothy 1, Trifolium 6, Trifolium 7, and Trifolium 9 Drains).

The lower plot in Figure 7-11 shows that only three large drain inflows into the Alamo River (the Holtville Main, Central Main, and Rose Main Drains) account for 34 percent of the total Alamo River drain total nitrogen loads to the Salton Sea, and thirteen large drain inflows into the Alamo River (the Holtville Main, Central Main, Rose Main, South Central Main, Verde, Mesquite, G, C, Warren, I, E, Mulberry and Standard Drains) account for 60 percent of the total Alamo River drain total nitrogen loads to the Salton Sea. The lower plot in Figure 7-12 shows that only six large drain inflows into the New River (Greeson, Trifolium 7, Salt Creek, Trifolium 9, Trifolium 6 and Timothy 1 Drains) account for 39 percent of the total New River drain total nitrogen loads to the Salton Sea, and 12 large drain inflows into the New River (Greeson, Trifolium 7, Salt Creek, Trifolium 9, Trifolium 6, Timothy 1, Rice 3, Trifolium 8, Beech, Trifolium 3, Trifolium 4, and Spruce Drains) account for 61 percent of the total New River drain total nitrogen loads to the Salton Sea.

The total nitrogen load plots in Figures 7-11 and 7-12 are similar to the flow plots in Figures 7-7 and 7-8, but there are some differences that are due to differences in the total nitrogen concentrations of the drains. In general, though, there is a lot of similarity between the chemical load plots and the flow plots, indicating that flows are one of the most important factors in estimating loads.



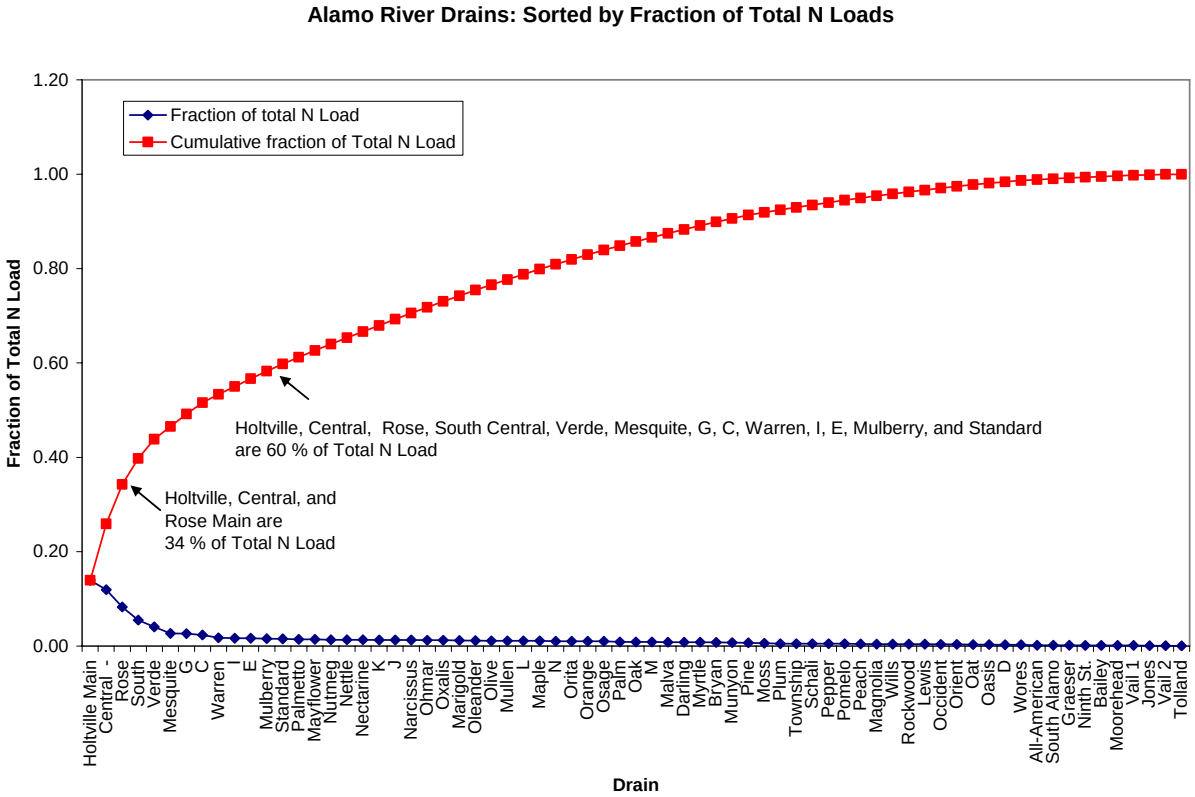
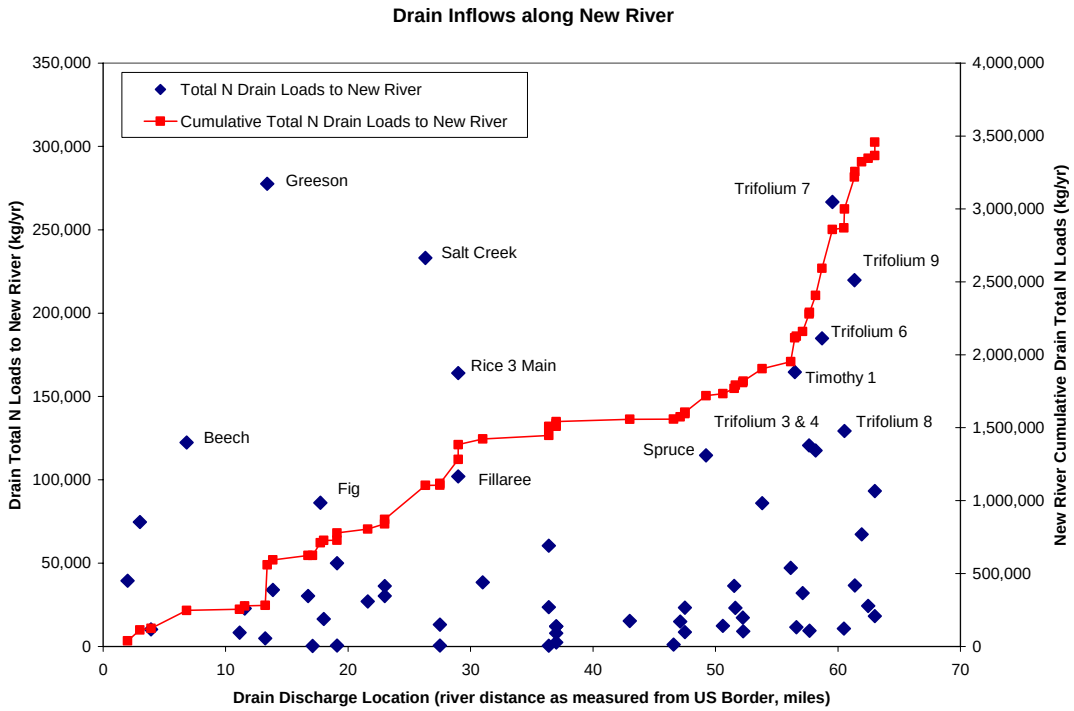


Figure 7-11 Drain Total N flow rates into Alamo River: Individual and cumulative drain total N load along the river length (top), and individual and cumulative fraction of total drain total N load sorted from highest to lowest (bottom).



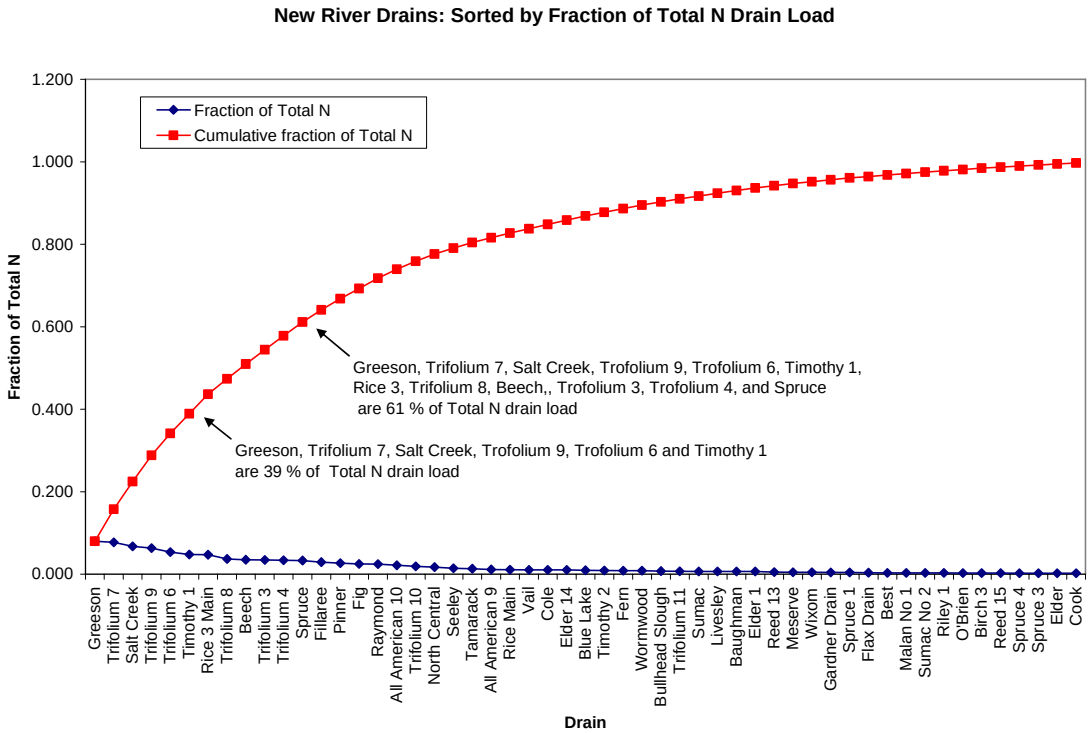


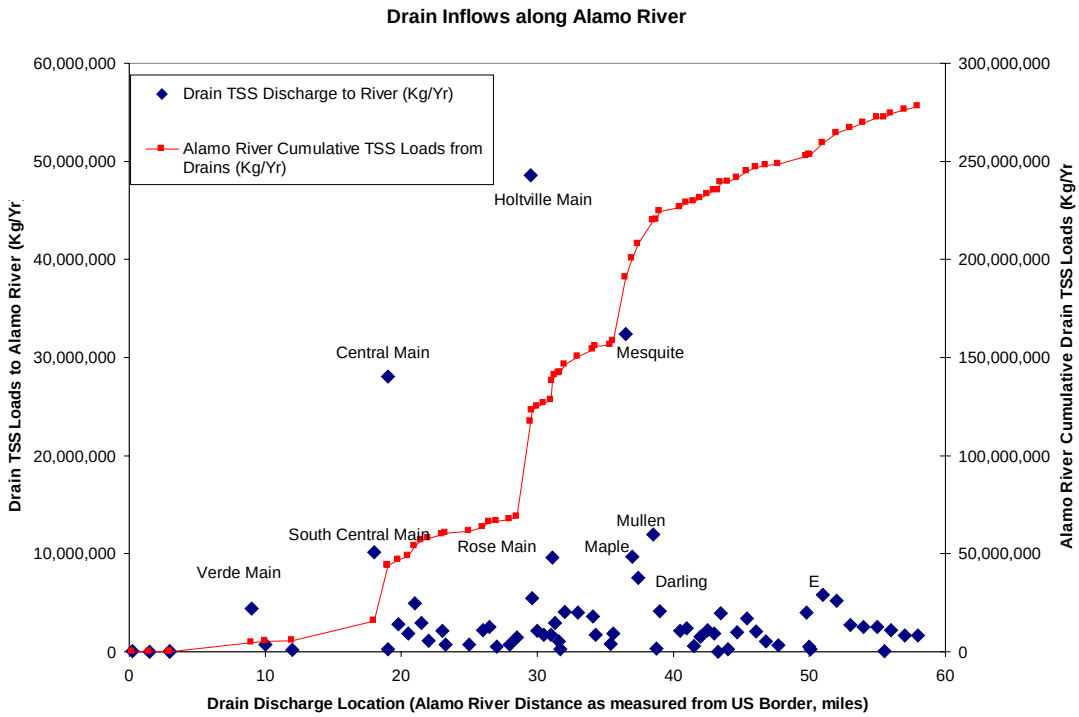
Figure 7-12 Drain total N loads into New River: Individual and cumulative drain total n loads along the river length (top), and individual and cumulative fraction of total drain total N loads sorted from highest to lowest (bottom).

7.5.4 Total Suspended Solids

The locations and names of the most important irrigation return drains in the Alamo River and New River Watersheds -ranked based upon Total Suspended Solids loads- are identified in Figures 7-13 and 7-14, respectively. These figures show two plots for Total Suspended Solids using the same format discussed in Section 7.3.1 for Figures 7-7 and 7-8, which are based upon flow. The upper plot in Figure 7-13 shows that there are large drain TSS loads into the Alamo River at about 10 river miles (the Verde Main Drain); 20 river miles (the Central Main and South Central Main Drains); 30 river miles (the Holtville Main and Rose Main Drains); 38 river miles (the Mesquite, Maple, Mullen, and Darling Drains); and 50 river miles (the E Drain). The upper plot in Figure 7-14 shows that there are large drain TSS loads into the New River at about 15 river miles (the Greeson Main and Fig Main Drains); 30 river miles (Salt Creek, Rice 3 Main, Fillaree, and North Central Drains); and 60 river miles (the Timothy 1, Trifolium 6, Trifolium 7, and Trifolium 9 Drains).

The lower plot in Figure 7-13 shows that only three large drain inflows into the Alamo River (the Holtville Main, Mesquite, and Central Main Drains) account for 39 percent of the total Alamo River drain Total Suspended Solids loads to the Salton Sea, and ten large drain inflows into the Alamo River (Holtville Main, Mesquite, Central Main, Mullen, South Central Main, Maple, Rose Main, Darling, E, and Olive Drains) account for 61 percent of the total Alamo River drain Total Suspended Solids loads to the Salton Sea. The lower plot in Figure 7-14 shows that only five large drain inflows into the New River (Salt Creek, Greeson, Rice 3, Trifolium 7, and Trifolium 9 Drains) account for 37 percent of the New River drain Total Suspended Solids loads to the Salton Sea, and ten large drain inflows into the New River (Salt Creek, Greeson, Rice 3, Trifolium 7, Trifolium 9, Fillaree, Trifolium 6, Fig, Timothy 1, North Central, and Trifolium 10 Drains) account for 59 percent of the total New River drain Total Suspended Solids loads to the Salton Sea.

The Total Suspended Solids load plots in Figures 7-13 and 7-14 are similar to the flow plots in Figures 7-7 and 7-8, but there are some differences that are due to differences in the Total Suspended Solids concentrations of the drains. In general, though, there is a lot of similarity between the chemical load plots and the flow plots, indicating that flows are one of the most important factors in estimating loads.



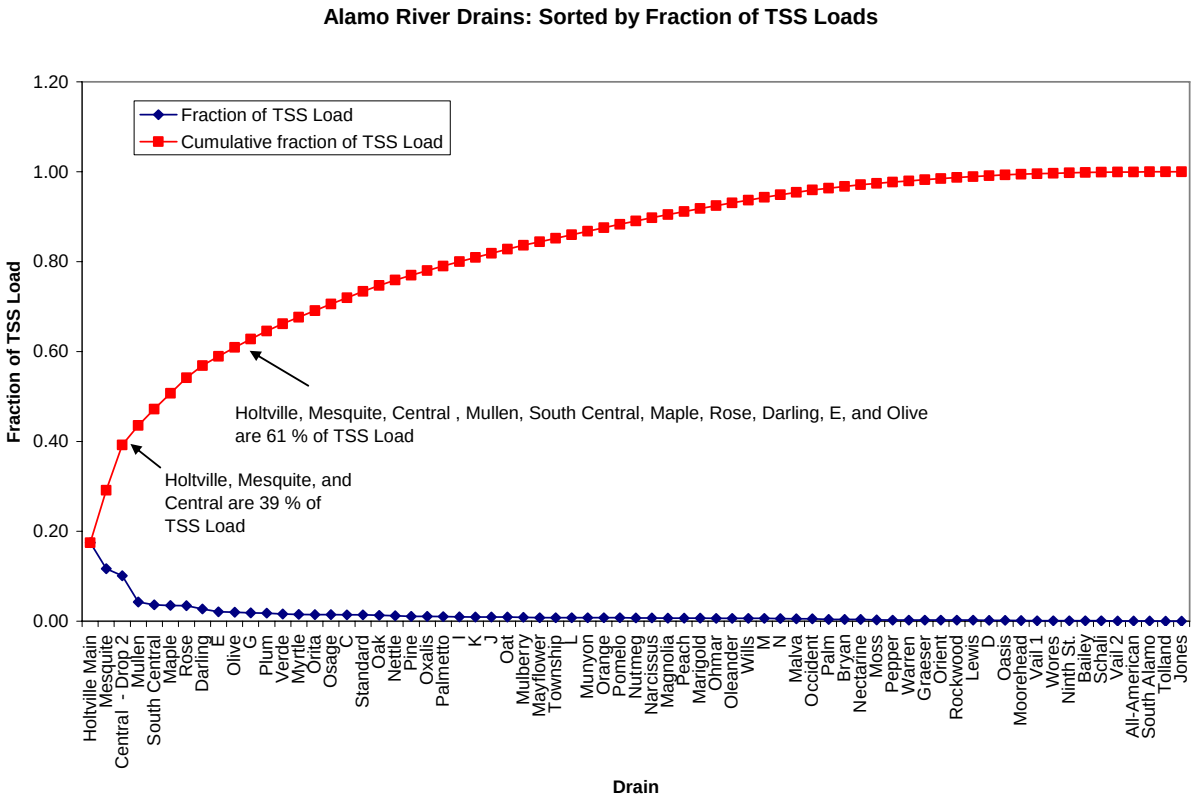
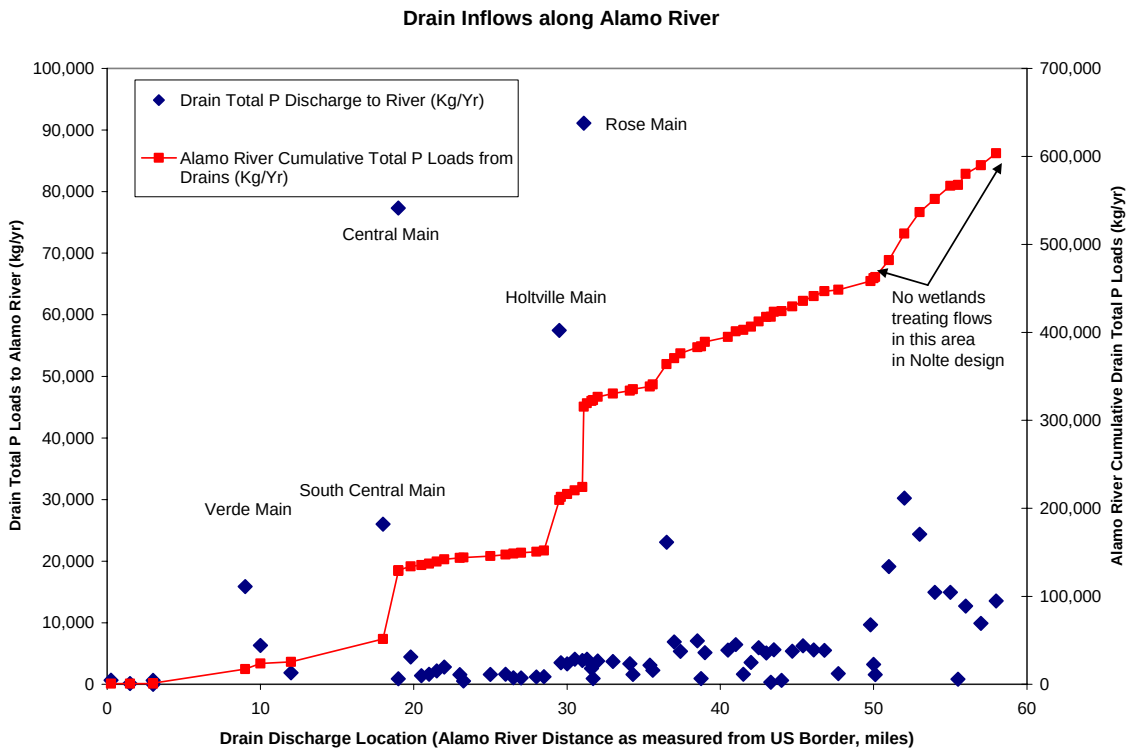


Figure 7-13 Drain TSS loads into Alamo River: Individual and cumulative drain TSS loads along the river length (top), and individual and cumulative fraction of total drain TSS loads sorted from highest to lowest (bottom).



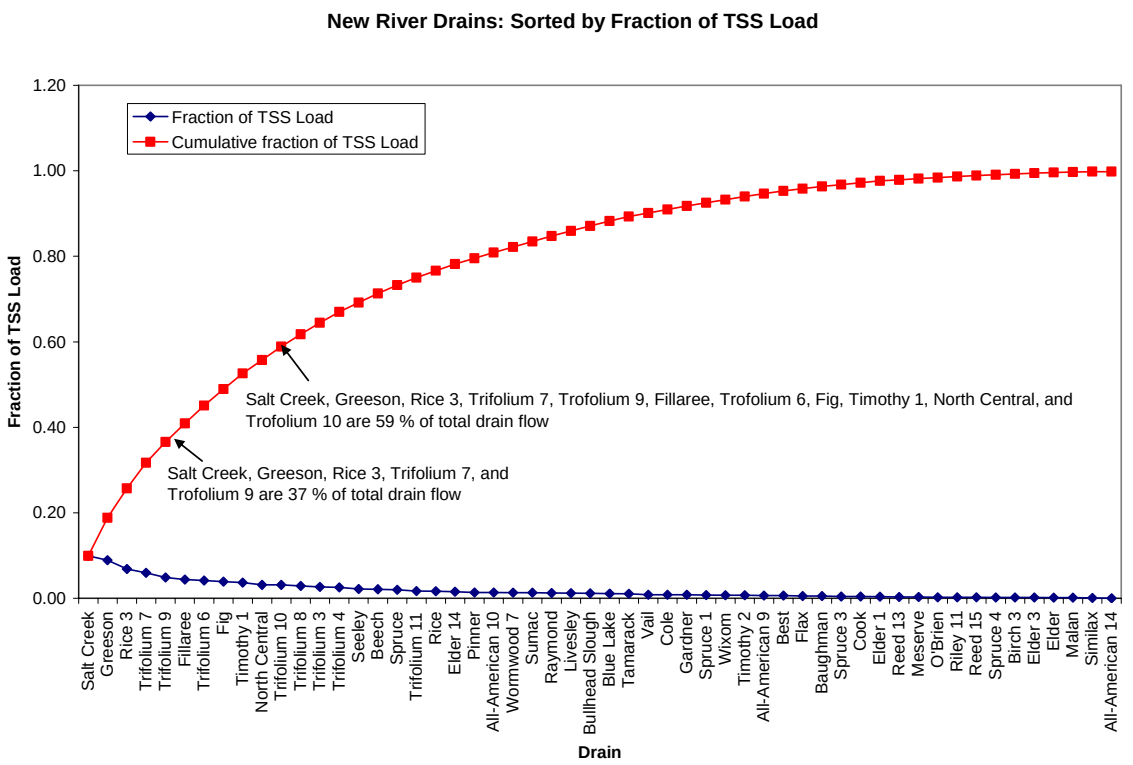


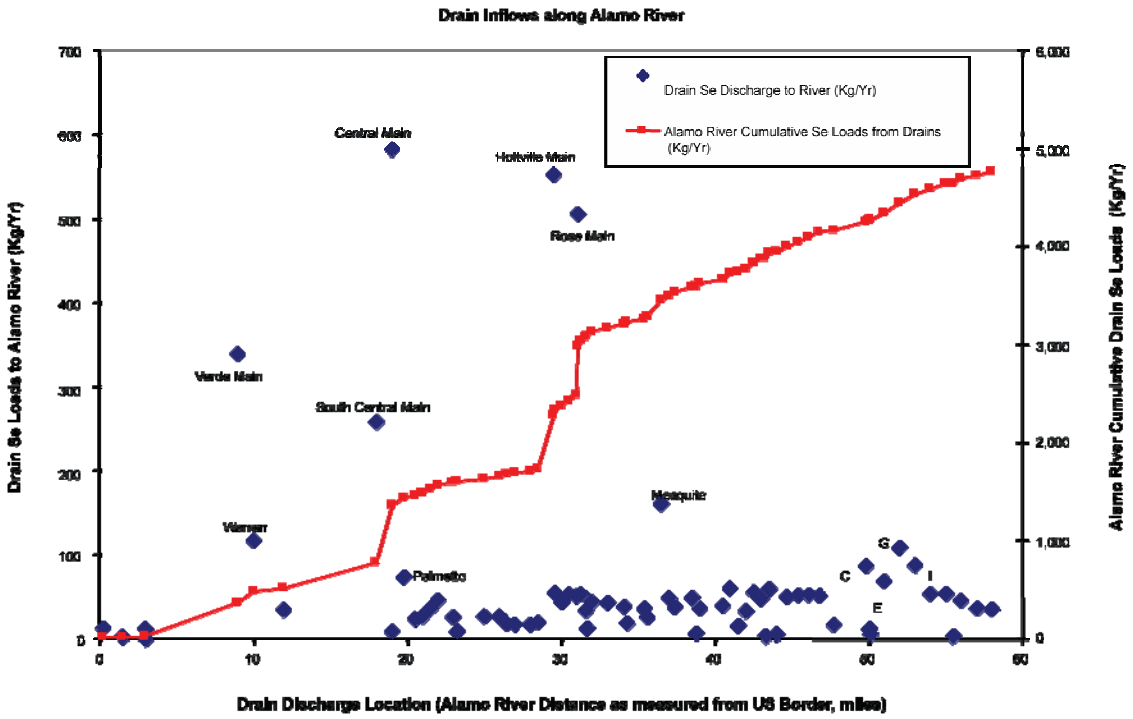
Figure 7-14 Drain loads into New River: Individual and cumulative drain TSS loads along the river length (top), and individual and cumulative fraction of total drain TSS loads sorted from highest to lowest (bottom).

7.5.5 Selenium

The locations and names of the most important irrigation return drains in the Alamo River and New River watersheds -ranked based upon selenium loads- are identified in Figures 7-15 and 7-16, respectively. These figures show two plots for selenium using the same format discussed in Section 7.3.1 for Figures 7-7 and 7-8, which are based upon flow. There is limited data available for drain selenium concentrations, and the current data shows that selenium concentrations do not vary much among the drains. Thus, the selenium plots should look very much like the flow plots in Figure 7-7 and 7-8. The upper plot in Figure 7-15 shows that there are large drain selenium loads into the Alamo River at about 10 river miles (the Verde Main and Warren Drains); 20 river miles (the Central Main, South Central Main, and Palmetto Drains); 30 river miles (the Holtville Main and Rose Main Drains); 38 river miles (the Mesquite Drain); and 50 river miles (the C, E, G, and I Drains). The upper plot in Figure 7-16 shows that there are large drain selenium loads into the New River at about 15 river miles (the Beech, Greeson Main, Seeley, and Fig Main Drains); 30 river miles (Salt Creek, Rice 3 Main, Fillaree, Rice Main, and North Central Drains); and 60 river miles (the Timothy 1, Trifolium 6, Trifolium 7, and Trifolium 9 Drains).

The lower plot in Figure 7-15 shows that only three large drain inflows into the Alamo River (the Central Main, Holtville Main, and Rose Main Drains) account for 34 percent of the total Alamo River drain selenium loads to the Salton Sea, and eleven large drain inflows into the Alamo River (Central Main, Holtville Main, Rose Main, Verde, South Central Main, Mesquite, Warren, G, I, C, and Palmetto Drains) account for 60 percent of the total Alamo River drain selenium loads to the Salton Sea. The lower plot in Figure 7-16 shows that only five large drain inflows into the New River (Rice 3, Salt Creek, Greeson, Trifolium 7, and Trifolium 9 Drains) account for 40 percent of the New River drain selenium loads to the Salton Sea, and ten large drain inflows into the New River (Rice 3, Salt Creek, Greeson, Trifolium 7, Trifolium 9, Fillaree, Trifolium 6, Timothy 1, North Central, and Trifolium 8 Drains) account for 59 percent of the total New River drain selenium loads to the Salton Sea.

The selenium load plots in Figures 7-15 and 7-16 are very similar to the flow plots in Figures 7-7 and 7-8, but there are some very minor differences that are due to differences in the selenium concentrations of the drains. In general, though, there is a great deal of similarity between the selenium load plots and the flow plots, indicating that flows are one of the most important factors in estimating loads.



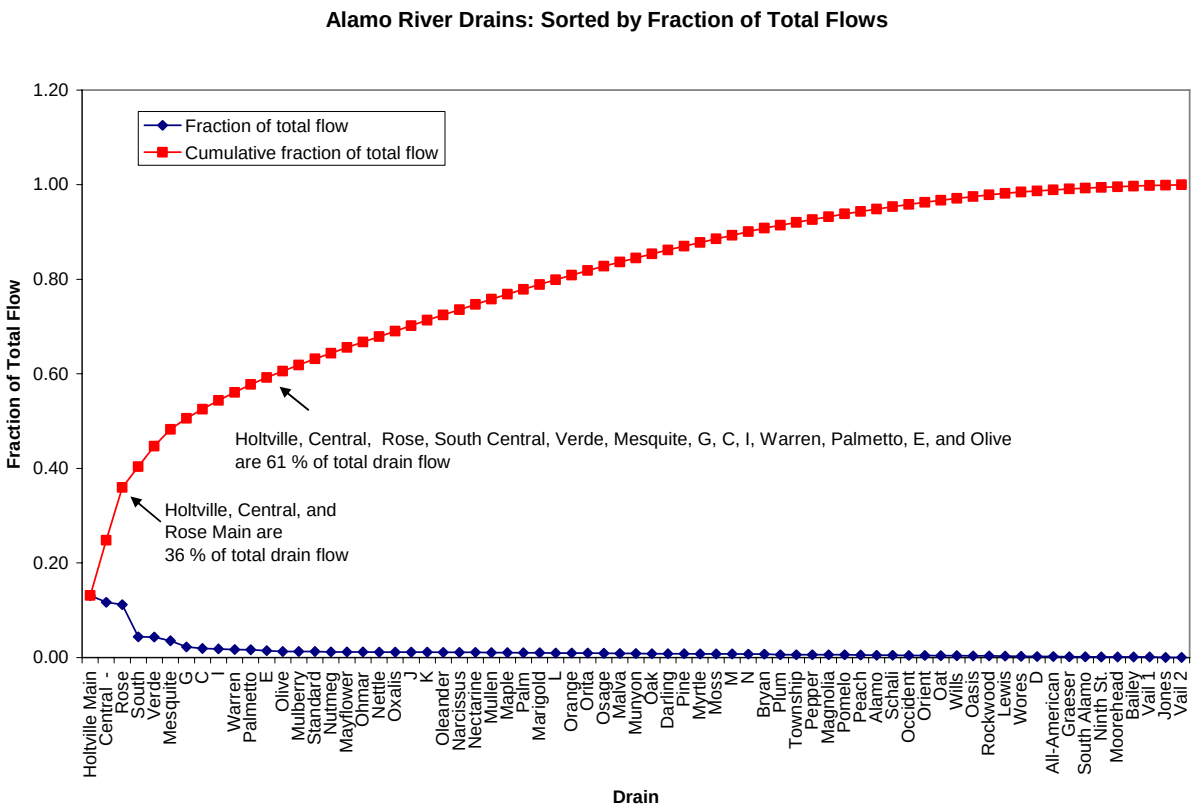
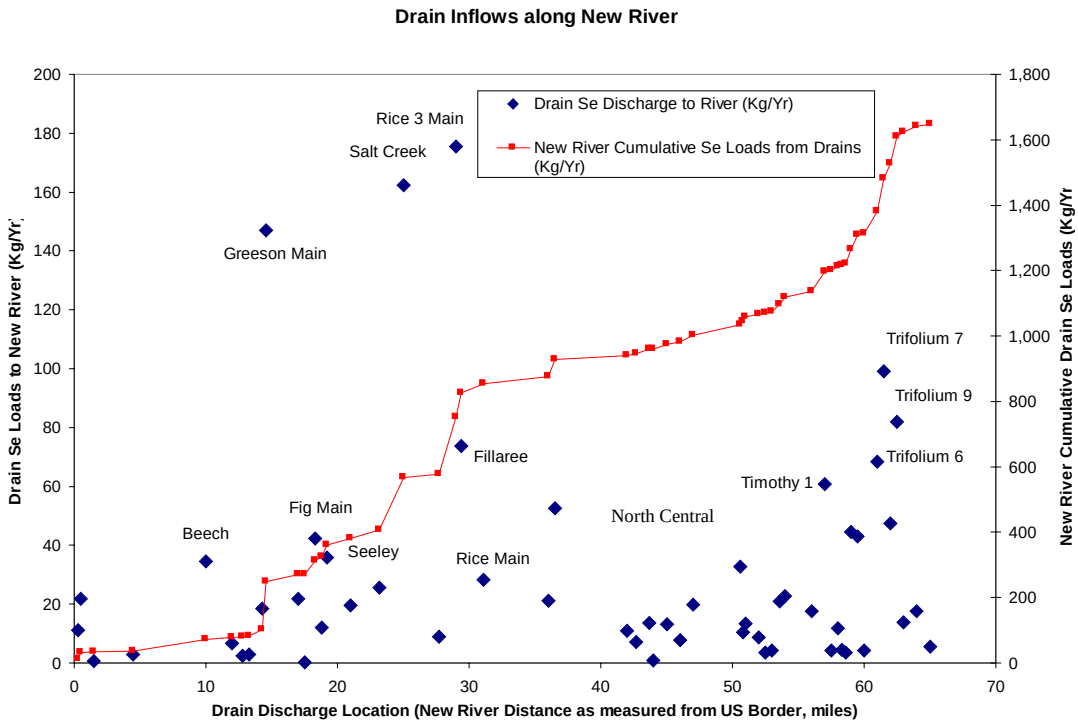


Figure 7-15 Drain selenium loads into Alamo River: Individual and cumulative drain selenium loads along the river length (top), and individual and cumulative fraction of total drain selenium loads sorted from highest to lowest (bottom).



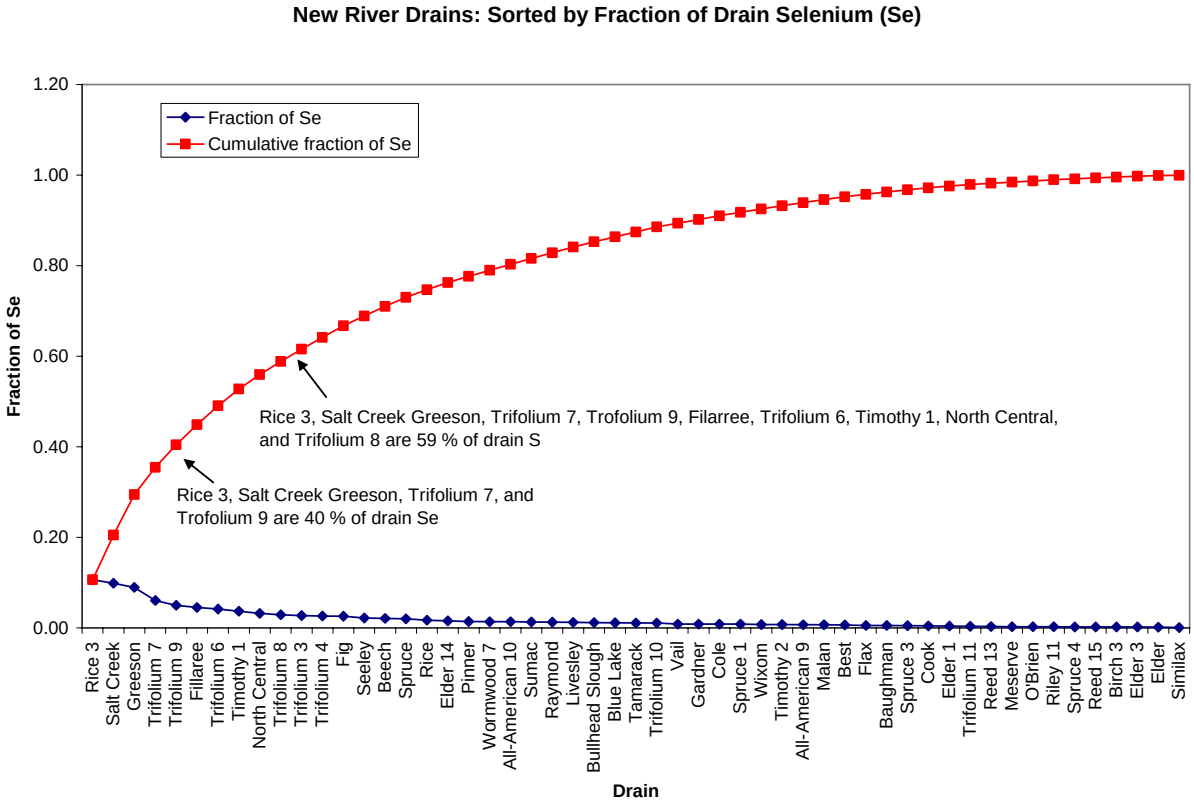


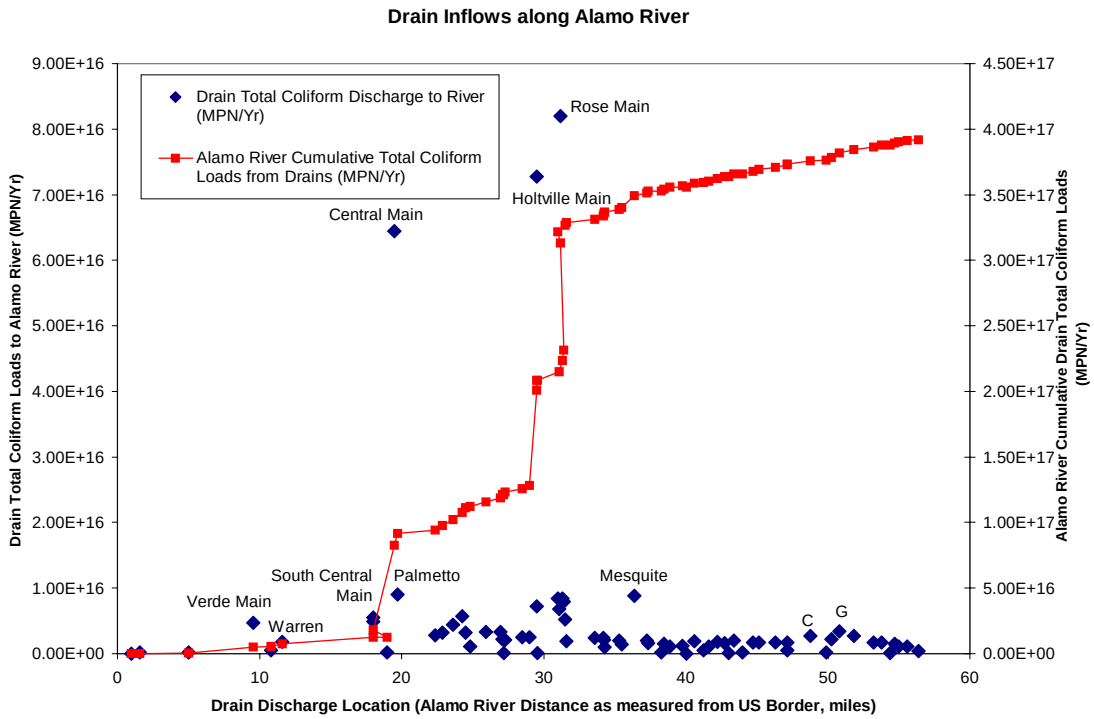
Figure 7-16 Drain selenium loads into New River: Individual and cumulative drain selenium loads along the river length (top), and individual and cumulative fraction of total drain selenium loads sorted from highest to lowest (bottom).

7.5.6 Total Coliforms

The locations and names of the most important irrigation return drains in the Alamo River and New River Watersheds -ranked based upon total coliforms loads- are identified in Figures 7-17 and 7-18, respectively. These figures show two plots for total coliforms loads using the same format discussed in Section 7.3.1 for Figures 7-7 and 7-8, which are based upon flow. The upper plot in Figure 7-17 shows that there are large drain total coliforms loads into the Alamo River at about 20 river miles (the Central Main and Palmetto Drains); 30 river miles (the Holtville Main and Rose Main Drains); and 38 river miles (the Mesquite Drain). The upper plot in Figure 7-18 shows that there are large total coliform drain loads into the New River at about 15 river miles (the Greeson Main and Fig Main Drains) and 30 river miles (Salt Creek and Rice 3 Main Drains).

The lower plot in Figure 7-17 shows that only two large drain inflows into the Alamo River (the Rose Main and the Holtville Main Drains) account for 39 percent of the total Alamo River drain total coliforms loads to the Salton Sea, and ten large drain inflows into the Alamo River (Rose Main, Holtville Main, Central Main, Palmetto, and Mesquite Drains) account for 60 percent of the total Alamo River drain total coliforms loads to the Salton Sea. The lower plot in Figure 7-18 shows that only two large drain inflows into the New River (Salt Creek and Greeson Drains) account for 43 percent of the New River total coliform drain loads to the Salton Sea, and three large drain inflows into the New River (Salt Creek, Greeson, and Rice 3 Drains) account for 58 percent of the total New River total coliform drain loads to the Salton Sea.

The total coliform load plots in Figures 7-17 and 7-18 are similar to the flow plots in Figures 7-7 and 7-8, but there are some differences that are due to differences in the total coliform concentrations of the drains. A very small number of drains in the middle of the Alamo River watershed (between 20 and 30 river miles) carry most of the total coliform load, due to data that indicates much higher drain total coliform concentrations in this area than in the drains in the north or south of the watershed. In general, though, there is a lot of similarity between the chemical load plots and the flow plots, indicating that flows are one of the most important factors in estimating loads.



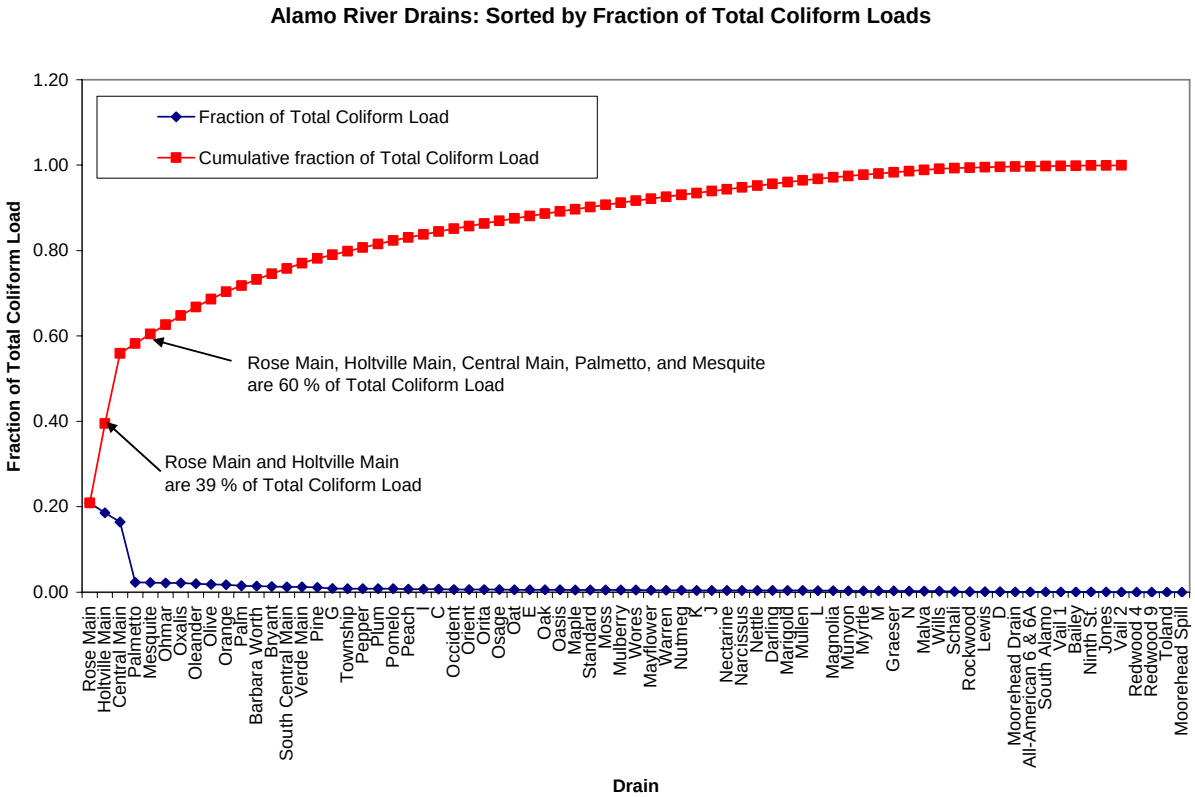
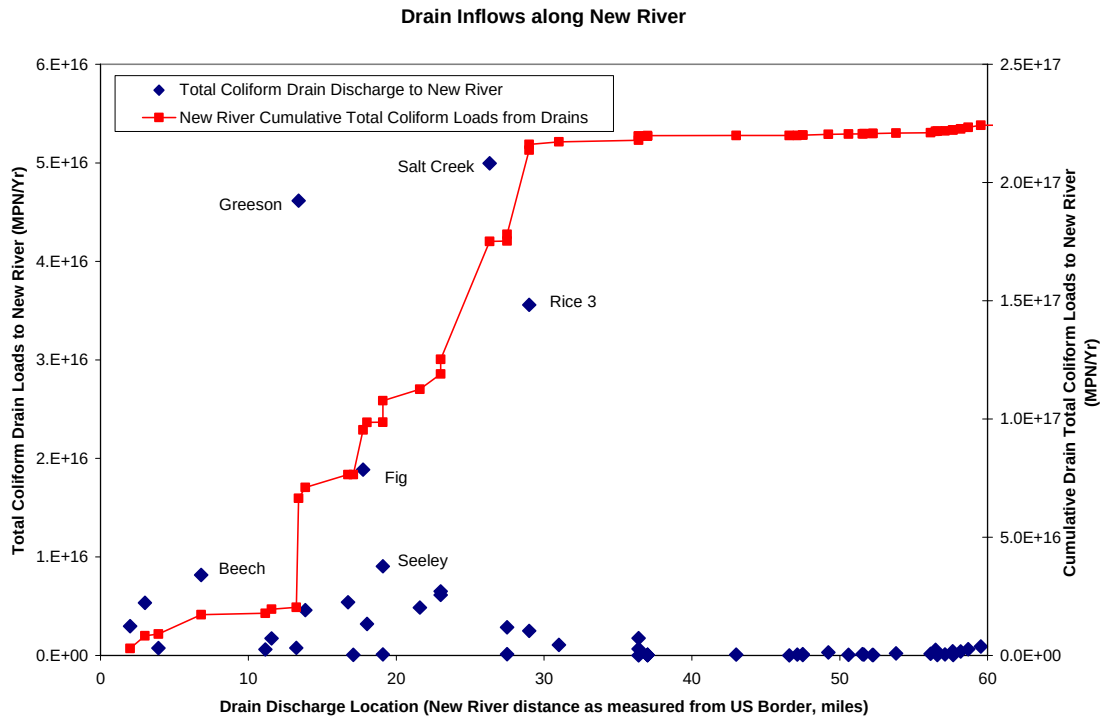


Figure 7-17 Total Coliform Drain Load to the Alamo River: Individual and cumulative drain coliform loads along the river length (top), and individual and cumulative fraction of total coliform drain loads sorted from highest to lowest (bottom).



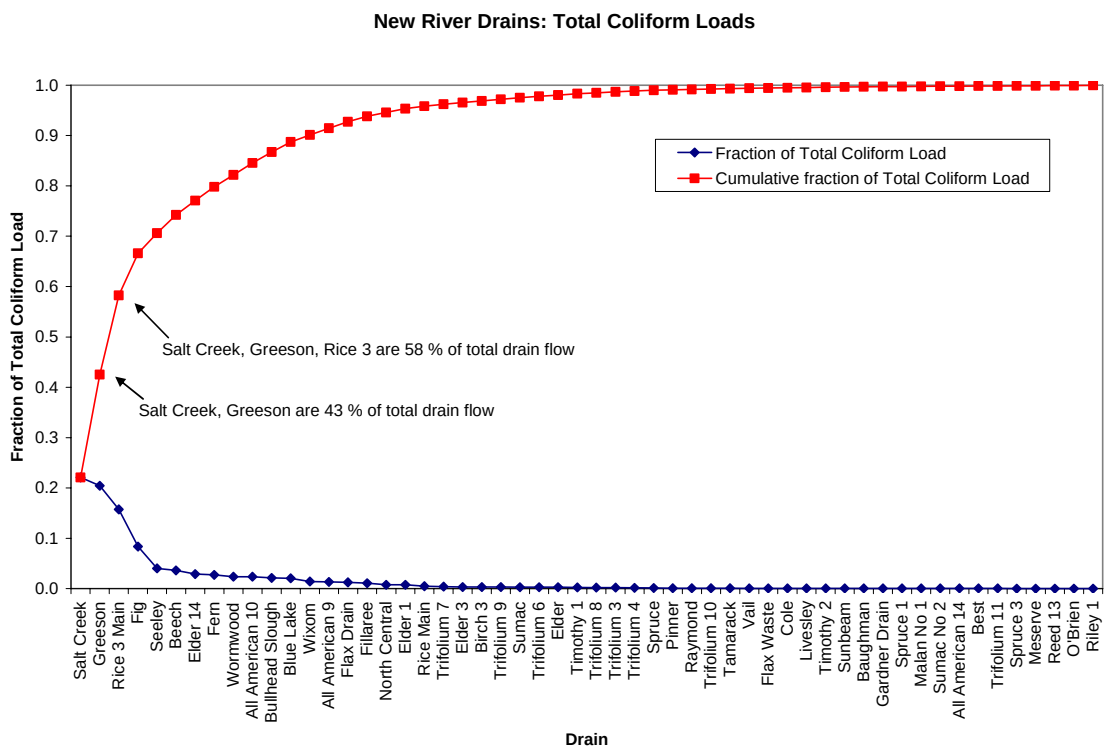


Figure 7-18 Total Coliform Drain Load to the New River: Individual and cumulative drain coliform loads along the river length (top), and individual and cumulative fraction of total drain loads sorted from highest to lowest (bottom).

7.6 Magnitude and Location of Drain Sources

7.6.1 Total Phosphorus

The dominant source of flows and chemical loadings in the Alamo River and New River Watersheds are agricultural drains. The magnitude and location of total phosphorus loads in individual irrigation return drain flows are identified for the Alamo River and New River Watersheds in Figure 7-19. Figure 7-19 shows a thematic map where the individual agricultural drains are plotted with line thickness values that are defined by the amount of total phosphorus load from each drain into the rivers. As shown in the map legend, there are five classes of drain total phosphorus loads depicted in Figure 7-19: drains with total phosphorus loads less than 3,000 kg/yr; drains with total phosphorus loads between 3,000 and 6,000 kg/yr; drains with total phosphorus loads between 6,000 and 15,000 kg/yr; drains with total phosphorus loads between 15,000 and 30,000 kg/yr; and drains with total phosphorus loads greater than 30,000 kg/yr. Figure 7-19 shows in a map format the same features identified in Figures 7-9 and 7-10, such as the following:

- Very large drain total phosphorus loads of over 30,000 kg/yr occurs in main drains in the south and center of the Alamo River watershed, where the Verde Main, South Central Main, Central Main, and Rose Main discharge large loads at discrete intervals along the Alamo River;
- Large drain total phosphorus loads between 6,000 and 15,000 kg/yr occurs in main drains in the center of the New River watershed, where the Rice 3 Main and Rice Main discharge large loads at discrete intervals along the New River; and
- Large drain total phosphorus loads that are typically over 15,000 kg/yr occurs in many minor drains in the far north the Alamo River watershed, and loads that are typically between 6,000 and 15,000 kg/yr occurs in many minor drains in the far north the New River watershed. Here, minor drains such as the G, E, and I drains discharge large loads in a fairly continuous interval along the Alamo River, and minor drains such as the Timothy 1, Trifolium 6, Trifolium 7, and Trifolium 9 drains discharge large loads in a fairly continuous interval along the New River.

The Alamo River also shows a fairly continuous interval in the east-central portion of the watershed with very many smaller drains that each have total phosphorus loads in the 3,000 to 6,000 kg/yr category.

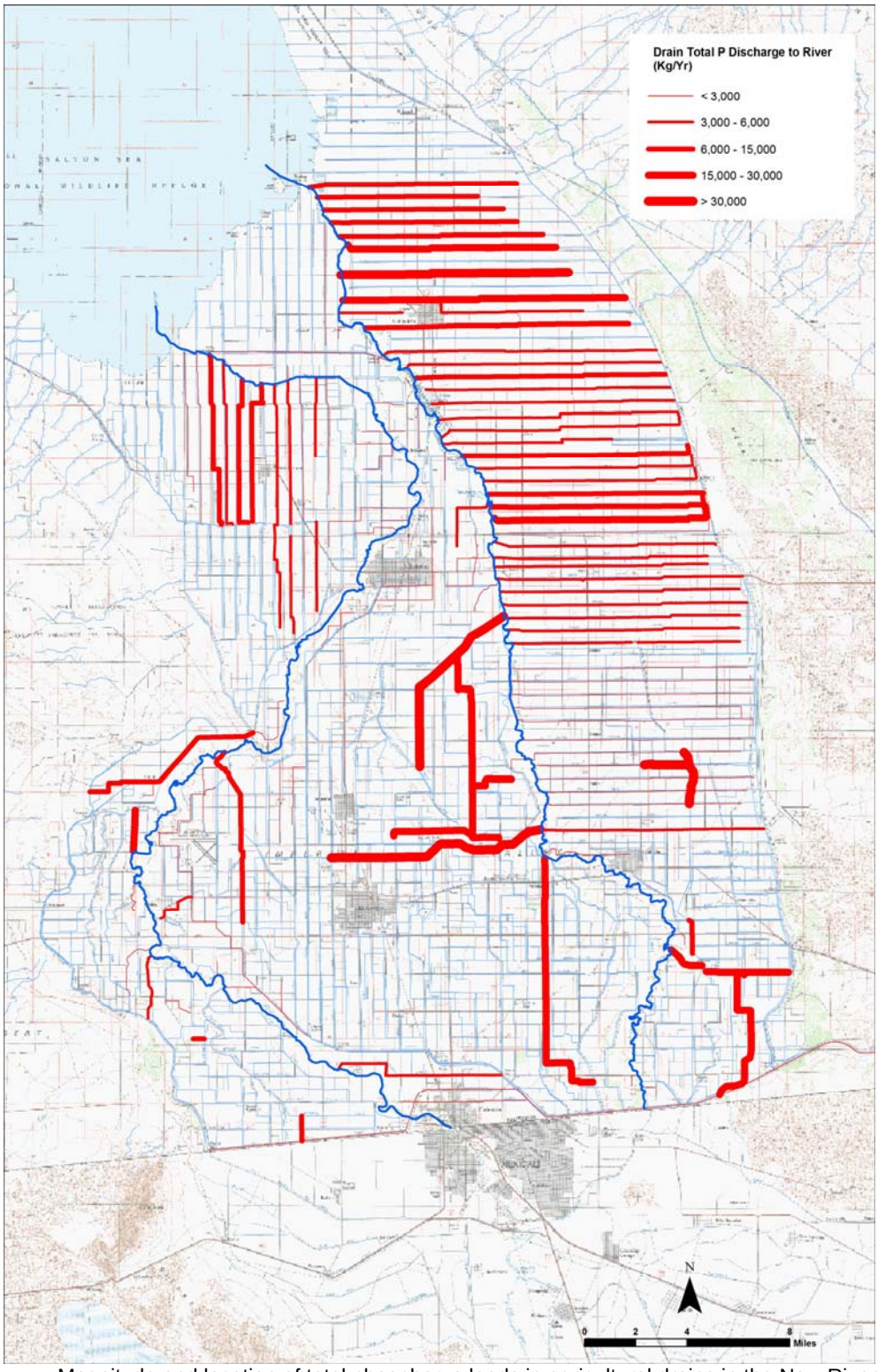


Figure 7-19 Magnitude and location of total phosphorus loads in agricultural drains in the New River and Alamo River watersheds.

7.6.2 Total Nitrogen

The dominant source of flows and chemical loadings in the Alamo River and New River Watersheds are agricultural drains. The magnitude and location of total nitrogen loads in individual irrigation return drain flows are identified for the Alamo River and New River Watersheds in Figure 7-20. Figure 7-20 shows a thematic map where the individual agricultural drains are plotted with line thickness values that are defined by the amount of total nitrogen load from each drain into the rivers. As shown in the map legend, there are five classes of drain total nitrogen loads depicted in Figure 7-20: drains with total nitrogen loads less than 30,000 kg/yr; drains with total nitrogen loads between 30,000 and 70,000 kg/yr; drains with total nitrogen loads between 70,000 and 140,000 kg/yr; drains with total nitrogen loads between 140,000 and 400,000 kg/yr; and drains with total nitrogen loads greater than 400,000 kg/yr. Figure 7-20 shows the same features identified in Figures 7-11 and 7-12, such as the following:

- Very large drain total nitrogen loads of over 140,000 kg/yr occurs in main drains in the south and center of the Alamo River watershed, where the Verde Main, South Central Main, Central Main, and Rose Main discharge large loads at discrete intervals along the Alamo River;
- Very large drain total nitrogen loads of over 140,000 kg/yr in main drains occurs in the center of the New River watershed, where the Rice 3 Main and Rice Main discharge large loads at discrete intervals along the New River; and
- Large drain total nitrogen loads typically between 70,000 and 100,000 kg/yr occurs in many minor drains in the far north of both the Alamo River and New River watersheds. Here, minor drains such as the C, G, E, and I drains discharge large loads in a fairly continuous interval along the Alamo River, and minor drains such as the Timothy 1, Trifolium 6, Trifolium 7, and Trifolium 9 drains discharge large loads in a fairly continuous interval along the New River.

The Alamo River also shows a fairly continuous interval in the east-central portion of the watershed with very many smaller drains that each have total nitrogen loads in the 30,000 to 70,000 kg/yr category.

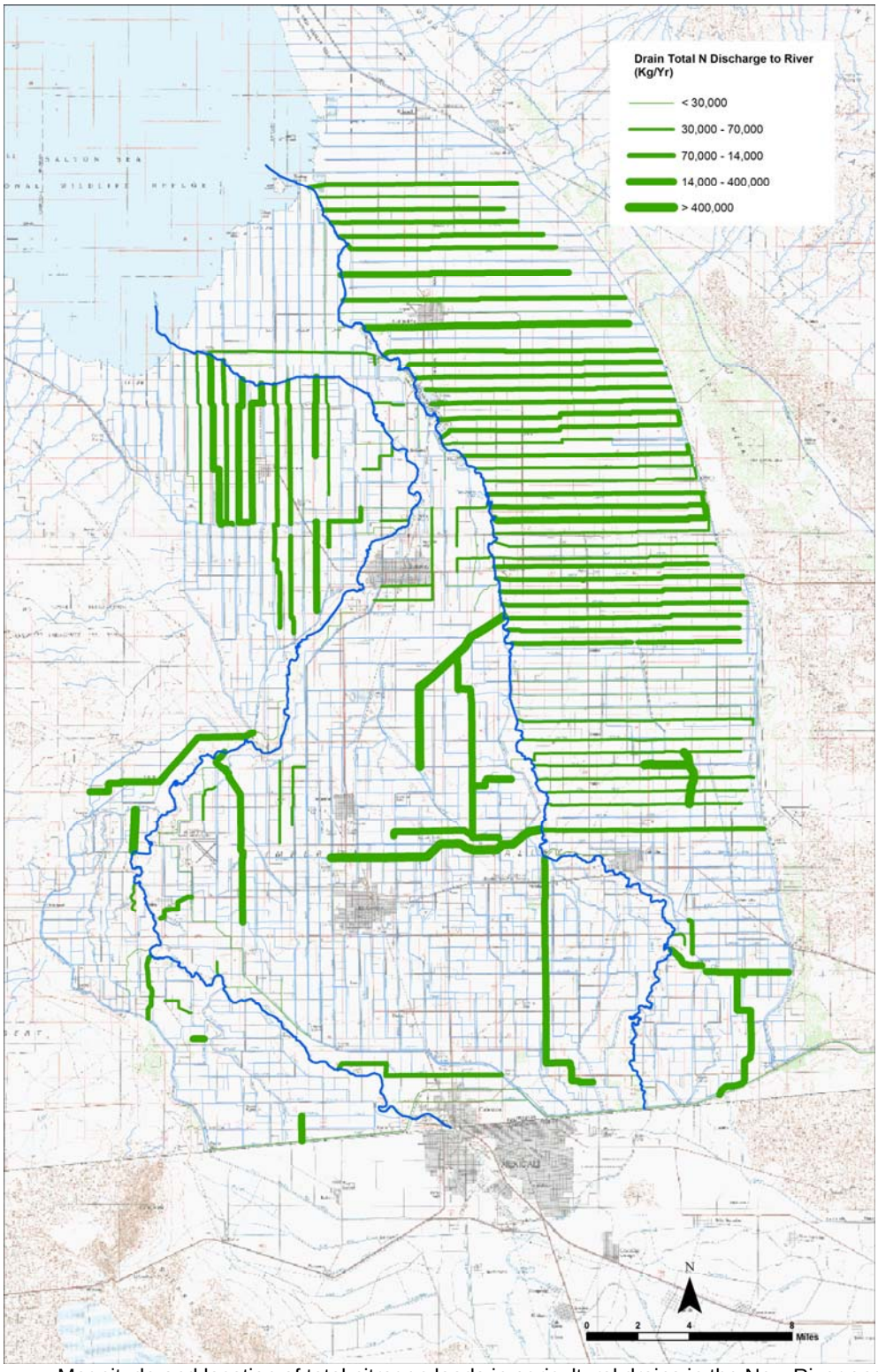


Figure 7-20 Magnitude and location of total nitrogen loads in agricultural drains in the New River and Alamo River watersheds.

7.6.3 Selenium

The magnitude and location of selenium loads in individual irrigation return drain flows, the dominant source of flows and chemical loadings in the Alamo River and New River Watersheds, are identified in Figure 7-21. There is limited data available for drain selenium concentrations, and the current data shows that selenium concentrations do not vary much among the drains. Figure 7-21 shows a thematic map where the individual agricultural drains are plotted with line thickness values that are defined by the amount of selenium load from each drain into the rivers. As shown in the map legend, there are five classes of drain selenium loads depicted in Figure 7-21: drains with selenium loads less than 25 kg/yr; drains with selenium loads between 25 and 50 kg/yr; drains with selenium loads between 50 and 100 kg/yr; drains with selenium loads between 100 and 200 kg/yr; and drains with selenium loads greater than 200 kg/yr. Figure 7-21 shows the same features identified in Figures 7-15 and 7-16, such as the following:

- Very large drain selenium loads of over 200 kg/yr occurs in main drains in the south and center of the Alamo River watershed, where the Verde Main, South Central Main, Central Main, and Rose Main discharge large loads at discrete intervals along the Alamo River;
- Large drain selenium loads of over 100 kg/yr occurs in main drains in the center of the New River watershed, where the Rice 3 Main and Rice Main discharge large loads at discrete intervals along the New River; and
- Large drain selenium loads typically between 50 and 100 kg/yr occurs in many minor drains in the far north of both the Alamo River and New River watersheds. Here, minor drains such as the C, G, E, and I drains discharge large loads in a fairly continuous interval along the Alamo River, and minor drains such as the Timothy 1, Trifolium 6, Trifolium 7, and Trifolium 9 drains discharge large loads in a fairly continuous interval along the New River.

The Alamo River also shows a fairly continuous interval in the east-central portion of the watershed with very many smaller drains that each have selenium loads in the 25 to 50 kg/yr category.

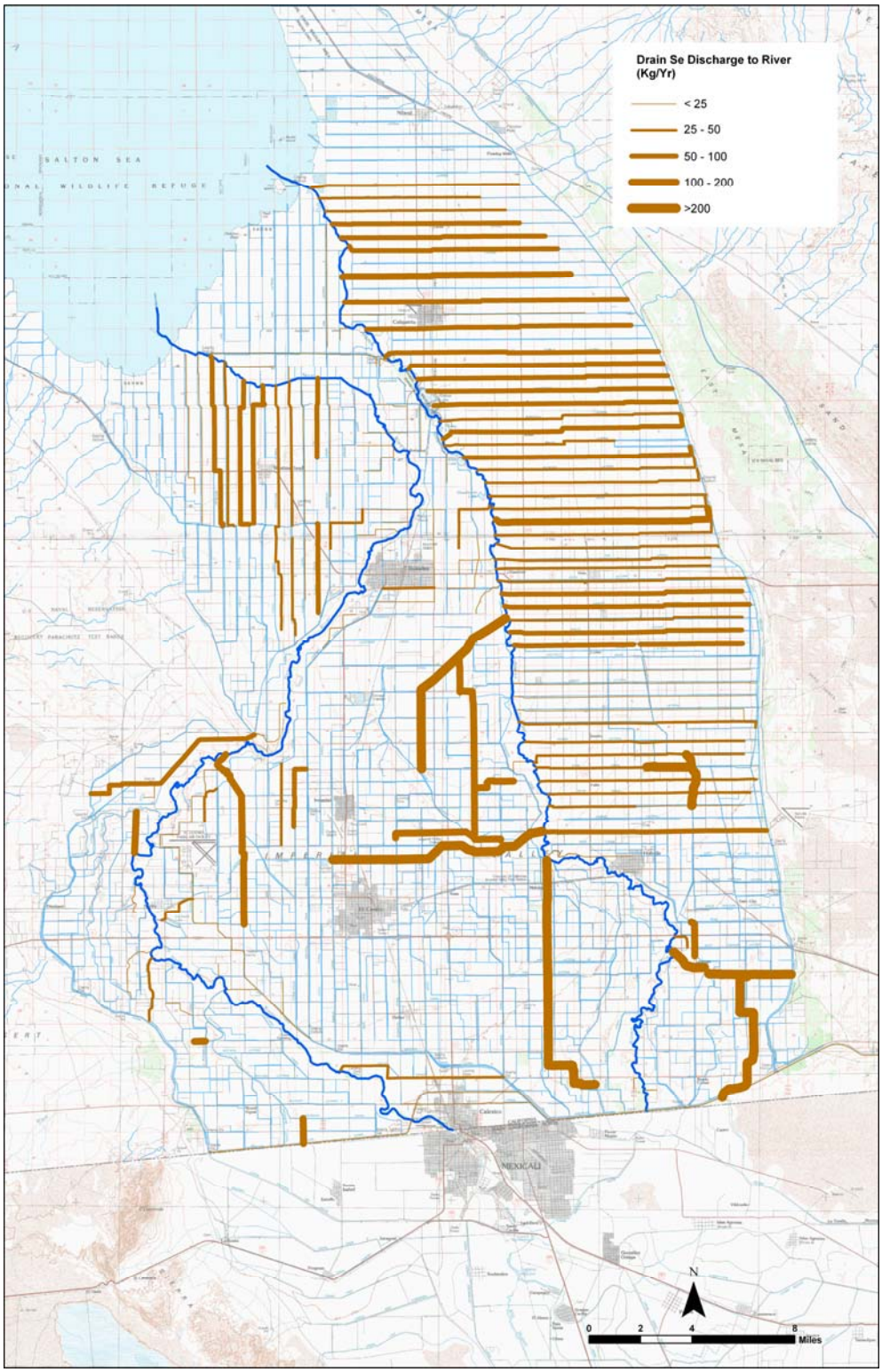


Figure 7-21 Magnitude and location of selenium loads in agricultural drains in the New River and Alamo River watersheds.

7.7 Distribution of Flows and Loads: Conclusions

Total flows the New River and Alamo River to the Salton Sea are about 1.2 million AF/yr, which discharges total phosphorus loads of about 1.4 million kg/yr, total nitrogen loads of about 14 million kg/yr, TSS loads of about 425 million kg/yr; selenium loads of about 7,700 kg/yr; and total coliforms loads of about 1.8 x 10^{18} MPN/yr. Agricultural drains provide 83 percent of the flow, 70 percent of the total phosphorus load, 78 percent of the total nitrogen load, 97 percent of the TSS load, 90 percent of the selenium load, and 35 percent of the total coliforms load. Cross-border discharges provide 13 percent of the flow, 28 percent of the total phosphorus load, 15 percent of the total nitrogen load, 2 percent of the TSS load, 6 percent of the selenium load, and 63 percent of the total coliform load. NPDES discharges provide less than 1 percent of the flow, 1 percent of the total phosphorus load, 3 percent of the total nitrogen load, 0.1 percent of the TSS load, 0.01 percent of the selenium load, and 0.002 percent of the total coliform load.

For both the New River and Alamo River, approximately 6 to 8 drains per river provide 50 percent of total drain flow and load. Approximately 8 drains in total (the Holtville Main, Rose Main, Central Main, Salt Creek, Greeson, Rice 3, Trifolium 7, and Trifolium 9) provide about 40 percent of the total drain flow and load. The Alamo River has especially high loads in 2 very small areas: 20 miles north of the border at the Central and South Central Mains and 30 miles north of the border at the Rose and Holtville Mains. Both rivers have high flows and loads from many minor drains located in the far north of their watersheds, and these drains are beyond the area where the Top 35 wetlands (Nolte, 2002) would provide treatment. For the New River, almost 50% of drain loads are in these last 10-15 miles before the Salton Sea, an area not treated by the 35 Top Wetlands recommended in Nolte (2002).

For both rivers, there are limited data available for drain selenium concentrations, and thus the current estimated selenium distribution is not well defined. The current patterns of selenium distribution now basically mirror the flow distribution, as the current data shows that selenium concentrations do not vary significantly among the drains. With the collection of future drain selenium data, it is thought that this will likely change, as other factors such as the selenium concentrations reported in agricultural field sumps, show much more spatial variability than depicted in the current drain selenium database.

CHAPTER 8
SCENARIOS WITH WETLANDS

8.1 Introduction

A key use of the composite watershed/wetland model presented in Sections 4 and 5 is to evaluate the performance of the wetland system proposed for the New and Alamo Rivers under a variety of different water flow, chemical load, and wetland design conditions. The key variables that are evaluated include:

- The numbers and locations of treatment wetlands;
- The conceptual design of individual wetlands (e.g., size, inflow rate, plug flow versus mixed reactor);
- The sensitivity of wetland chemical removals in wetland performance; and
- The impact of varying river and drain chemical concentrations due to seasonal, climatic, and regional water resource management factors.

Consideration of costs using information developed in Section 11 will also be used to assist in the selection of the number and timing of the construction of individual treatment wetlands.

The list of scenarios that were investigated is presented in Table 8-1. Development of the first three scenarios and an examination of their modeling results are presented in the subsections below. The impacts of uncertainty in wetland chemical removals rates are evaluated by varying wetland pollutant removal rate coefficients and hydrologic parameters across the range of values observed in the IID demonstration wetlands. This is the main focus of the first three scenarios and are discussed in this section. Scenarios 4 through 11 are discussed in Section 7. These scenarios examine the impact of alternative wetland systems from the Top 35 wetland sites recommended in Nolte (2002) and also evaluate the impact of known future changes to the water management of the New and Alamo Rivers watershed sources. Evaluation of alternative numbers and locations of treatment wetlands is a focus of Scenarios 4 through 8. Scenarios 9 and 10 evaluate the impact of planned IID water conservation efforts and planned reductions in cross-border flows from Mexico due to wastewater treatment plant upgrades and water reuse. Scenario 11 evaluates IID's more recent list of 25 potential wetland sites identified by feasibility studies and topographic surveys of wetland sites (Davey-Cairo Engineers, 2005a,b; 2006a,b).

Table 8-1
List of Wetland Scenarios

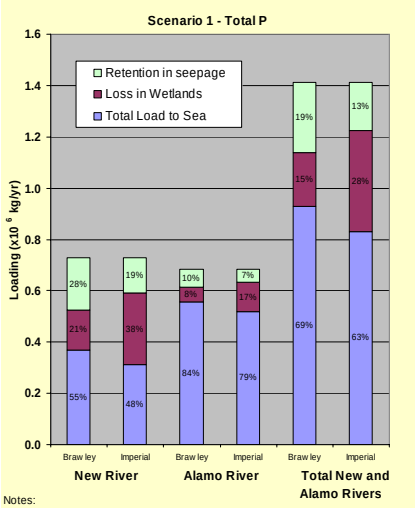
Scenario	Description	Details
1	Preliminary 35 Top-Ranked Wetland Sites (Nolte, 2002)	Entire wetland areas and design inflows presented in Table ES-1 in Nolte (2002). This scenario assumes all wetlands designed for plug flow. See Table 6-1 for areas and design inflows.
2	Preliminary 35 Top-Ranked Wetland Sites with Reduced Wetland Areas	Revised wetland surface areas and design inflows reduced for non-wetted areas shown in Nolte (2002). This scenario assumes all wetlands designed for plug flow. See Table 6-3 for areas and design inflows.
3	Reduced Wetland Area Scenario & Inclusion of CSTR-type Wetlands	Revised wetland surface areas and design inflows reduced for non-wetted areas shown in Nolte (2002). Alternative wetland design for many wetland sites, based on a mixed reactor flow model. See Table 6-3 for areas and design inflows.
4	Top 5 Wetlands	Top 5 wetlands selected based on ranking of preliminary 35 top-ranked wetlands. See Table 8-9 for list of wetlands.
5	Top 10 Wetlands	Top 10 wetlands selected based on ranking of preliminary 35 top-ranked wetlands. See Table 8-9 for list of wetlands.
6	Top Performance Wetlands	These wetlands selected based on ranking of the area-specific removal rates. See Table 8-11 for list of wetlands.
7	Maximum Total Phosphorus Load Reduction	Optimized wetland systems based in increasing wetland size (and flow) were analyzed to achieve the maximum possible load reduction.
8	Additional Wetlands in Northern Reaches	Two wetlands added to 35 top-ranked wetland scenario. These wetlands added to northern reaches of New and Alamo Rivers where large load are entering the rivers and no proposed wetlands exist.
9	No Mexico Flows	Elimination of cross-border flows for New River due to WWTP upgrades and water reuse
10	IID Conservation	IID conservation efforts ongoing to meet GSA requirements. Scenario assumes 20 percent reduction in flow but not reduction in load.
11	IID 25 Surveyed Wetland Sites	Surveyed wetlands considered feasible and with revised wetland areas based on topographic survey (Davey-Cairo, 2006a,b).

The five-year model calibration time period from 1995 to 1999 (Section 4.5) was used as a base case for evaluating the performance of constructed wetlands. This assumes all elements of the conceptual model and model parameters from the 1995 to 1999 time period are applicable for predicting the seasonal, inter-annual, and long-term performance of the wetlands. Thus, the watershed parameters for the wetland performance predictions are exactly as reported in Sections 4 and 5 for the model calibration.

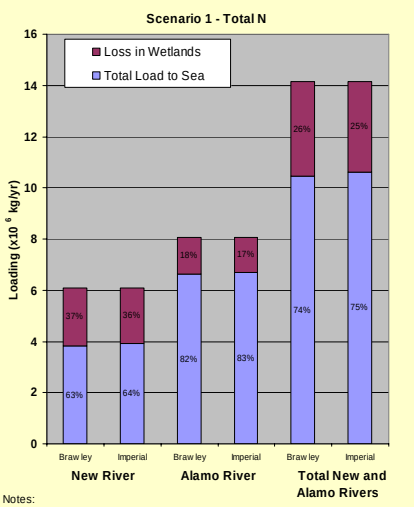
8.2 Scenario 1: Thirty-Five (35) Top-Ranked Wetland Sites

The model was configured for the potential construction of the thirty-five (35) top-ranked wetland sites as described in Section 4.4 and Table 4-1. The resulting model predictions of total phosphorus, total nitrogen, TSS, total selenium, and total coliform loads to the Salton Sea from the New River, Alamo River, and combined rivers are summarized in Figure 8-1. For model scenarios with and without wetlands, Figure 8-2 also contains transect plots along the New and Alamo Rivers of total phosphorus and total nitrogen loads along the river course from the US Border to the Salton Sea. Each constituent is discussed in Figure 8-1.

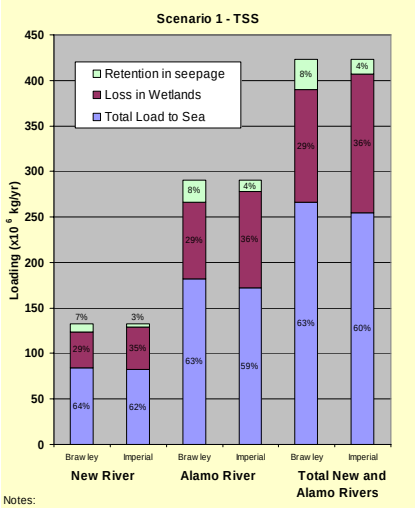
The wetland scenarios were simulated using both the chemical removal rates reported for the pilot Brawley and Imperial wetlands (see Table 4-2). There is a good comparison between the model estimated water losses and chemical removal rates per acre of wetland treatment area and those reported in the pilot wetlands.



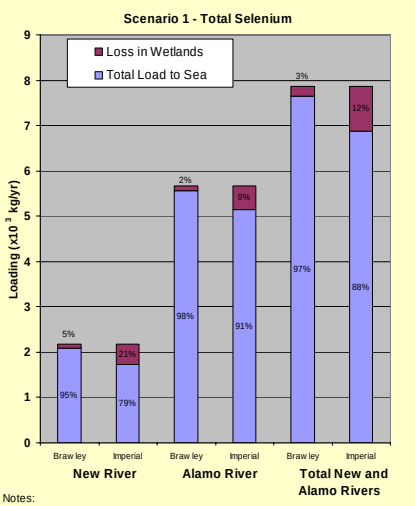
Notes:
Scenario 1 Preliminary Top 35 wetlands design (Nolte, 2002) - 34% and 41% load reduction from base case for Brawley and Imperial Wetland loss rates of 17.8 and 45.9 m/yr.



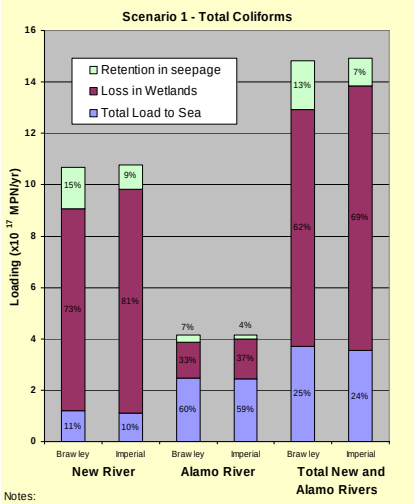
Notes:
Scenario 1 Preliminary Top 35 wetlands design (Nolte, 2002) - 26% and 25% load reduction from base case for Brawley and Imperial Wetland loss rates of 56.3 and 50.2 m/yr.



Notes:
Scenario 1 Preliminary Top 35 wetlands design (Nolte, 2002) - 37% and 40% load reduction from base case for Brawley and Imperial Wetland loss rates of 91 and 222 m/yr.



Notes:
Scenario 1 Preliminary Top 35 wetlands design (Nolte, 2002) - 3% and 11% load reduction from base case for Brawley and Imperial Wetland loss rates of 4.5 and 29.6 m/yr.



Notes:
Scenario 1 Preliminary Top 35 wetlands design (Nolte, 2002) - 75% and 76% load reduction from base case for Brawley and Imperial Wetland loss rates of 134 and 263 m/yr.

Figure 6-1 Total phosphorus, total nitrogen, TSS, total selenium, and total coliform loadings in the New and Alamo River watersheds with preliminary Top 35 wetlands design described in Nolte (2002)

8.2.1 Total Phosphorus

Total phosphorus loads from the New River and Alamo River are about 729,000 and 685,000 kg/yr without wetlands (Figure 8-2). With the addition of 2,775 acres of wetlands along the New River treating 48,660 acre-feet per month (AF/mo) of river and drain flows, the total phosphorus load in the New River at the Salton Sea is reduced to 370,000 kg/yr (Brawley wetland loss rate) and 310,000 kg/yr (Imperial wetland loss rate). Total phosphorus loss in the New River wetlands account for a reduction of 155,000 kg/yr (Brawley wetland loss rate) and 280,000 kg/yr (Imperial wetland loss rate). Total phosphorus retention in New River wetlands' seepage losses accounts for a reduction of 204,000 kg/yr (Brawley wetland loss rate) and 138,000 kg/yr (Imperial wetland loss rate). Thus, there is a 21 to 38 percent reduction in the total phosphorus load due to wetland removal processes and a 28 to 19 percent reduction in the total phosphorus load due to retention in wetland seepage in the New River.

With the addition of 1,501 acres of wetlands along the Alamo River treating 24,932 AF/mo of river and drain flows, the total phosphorus load in the Alamo River at the Salton Sea is reduced to 557,000 kg/yr (Brawley wetland loss rate) and 520,000 kg/yr (Imperial wetland loss rate). Total phosphorus loss in the Alamo River wetlands accounts for a reduction of 58,000 kg/yr (Brawley wetland loss rate) and 114,000 kg/yr (Imperial wetland loss rate). Total phosphorus retention in Alamo River wetland seepage losses accounts for a reduction of 70,000 kg/yr (Brawley wetland loss rate) and 51,000 kg/yr (Imperial wetland loss rate). Thus, there is a 8 to 17 percent reduction in the total phosphorus load due to wetland removal processes and a 10 to 7 percent reduction in the total phosphorus load due to retention in wetland seepage in the Alamo River.

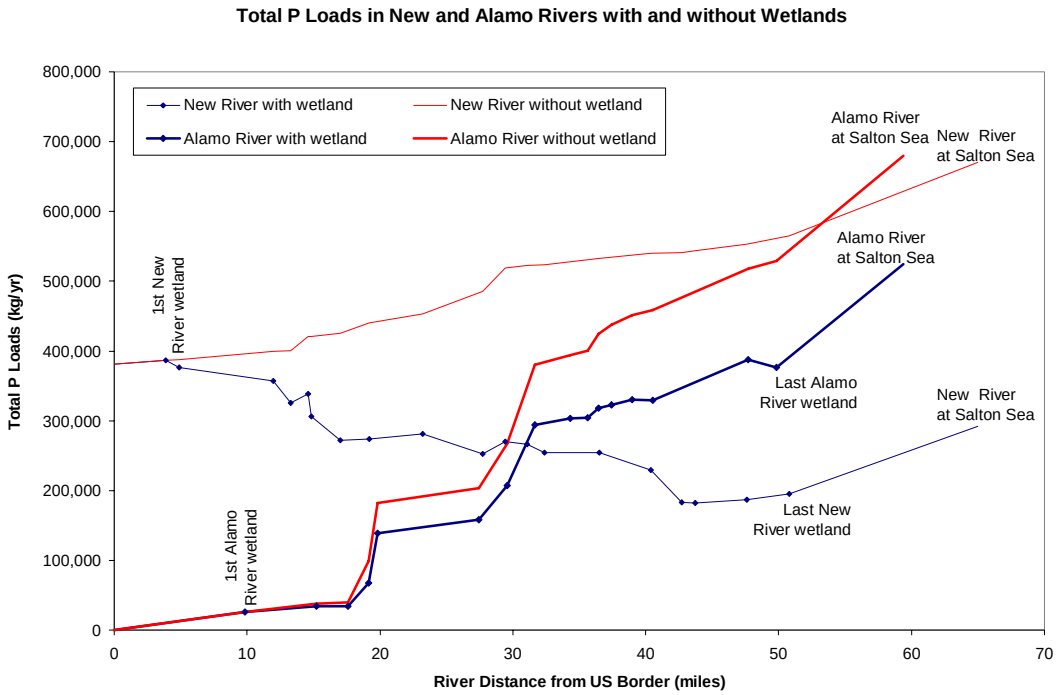
Comparing the total phosphorus results for the New and Alamo Rivers, the removal rates in the New River (360,000 - 420,000 kg/yr) are 2.5 to 3 times higher than the Alamo River (130,000 – 170,000 kg/yr) given the Top 35 Wetlands design conditions. This is due to the combined effects of the following two factors:

- The New River has a much greater wetland acreage and wetland treatment volume than the Alamo River. The wetland acreage is 1.8 times larger and the treatment volume is 2 times larger.
- The New River wetlands are more efficient in total phosphorus removals per square meter of wetland treatment area than the Alamo River wetlands. For example, the area-specific total phosphorus removal rate for the New River wetlands is 32 to 37 g/m^2-yr of wetland area, while the area-specific total phosphorus removal rate for the Alamo River wetlands is 23 g/m^2-yr of wetland area.

Since the average hydraulic loading rates for the New River wetlands (17.5 cm/day) and the Alamo River wetlands (16.6 cm/day) are nearly the same, the higher total phosphorus removal rate for the New River wetlands is attributed to the higher total phosphorus concentrations in the New River, especially in the more southerly reaches of the New River near the U.S.-Mexico border (Figure 8-2). The higher total phosphorus concentrations in the New River result in greater removal efficiencies since the wetland influent total phosphorus concentration is higher relative to the wetland total phosphorus plateau concentration of 0.02 mg/L.

For this wetland scenario, the total phosphorus load to the Salton Sea ranges from 0.93 to 0.83 x 10^6 kg/yr, given the Brawley and Imperial wetland loss rates. This is a load reduction of 34 to 41 percent, compared to the base case load of 1.4 x 10^6 kg/yr. Thus, there is a 15 to 28 percent reduction (0.21 to 0.39 x 10^6 kg/yr) in the total phosphorus load due to wetland

removal processes and a corresponding 19 to 13 percent reduction (0.27 to 0.19 x 10^6 kg/yr) in the total phosphorus load due to retention in wetland seepage.



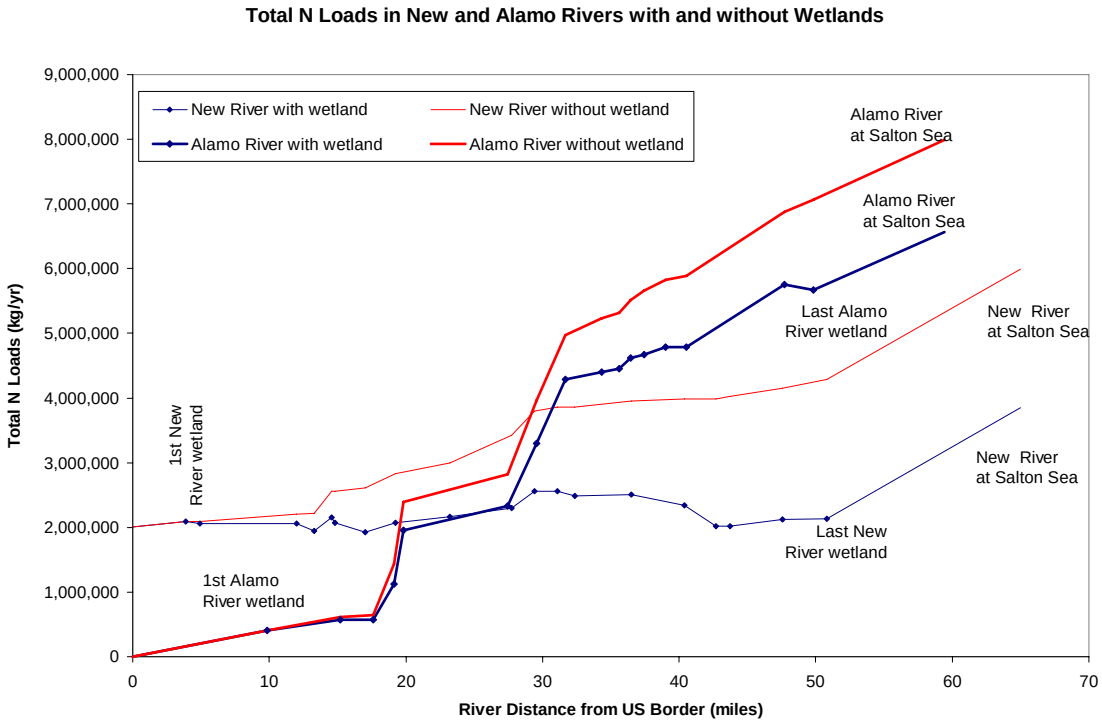


Figure 8-2 New and Alamo River transects showing total phosphorus loads (top) and total nitrogen loads (bottom) along river course from the U.S. border to the Salton Sea for Wetland Scenario 1.

8.2.2 Total Nitrogen

The resulting model predictions of total nitrogen loads in the New River, Alamo River, and from these rivers to the Salton Sea are summarized in Figure 8-1. Figure 8-2 also contains transect plots along the New and Alamo Rivers that shows total nitrogen loads along the river course from the U.S.-Mexico border to the Salton Sea for model cases with and without wetlands.

Total nitrogen loads to the Salton Sea from the New River and Alamo River are about 3.8 x 10^6 kg/yr and 6.6 x 10^6 kg/yr, respectively, and 10.5 x 10^6 kg/yr from both rivers. The total nitrogen loads to the Salton Sea are reduced by 26 percent for the combined rivers compared to the base case load of 14 x 10^6 kg/yr, with reductions of 37 and 18 percent in the New River and Alamo River, respectively. There was little difference between the two pilot wetland loss rates. The reduction is due to total nitrogen loss in the wetlands, since total nitrogen in wetland seepage losses is not expected to be significantly attenuated and seepage losses are assumed to return to the rivers.

Comparing the total nitrogen results for the New and Alamo Rivers, the removal rates in the New River (2.3 x 10^6 kg/yr) are 1.5 times higher than the Alamo River (1.5 x 10^6 kg/yr) given the Nolte Top 35 Wetlands design conditions. The New River load reduction is higher due to the larger wetland acreage. However, the removal rate is not as high as the total phosphorus reduction because the New River wetlands are less efficient in total nitrogen removal per square meter of wetland treatment area than the Alamo River wetlands. The area-specific total nitrogen removal rate for the New River wetlands is about 200 g/m^2-yr of wetland area, versus about 250 g/m^2-yr for the Alamo River wetlands. The lower total nitrogen concentrations in the New River result in lower removal efficiencies since the wetland influent total nitrogen concentration is lower relative to the wetland total nitrogen plateau concentration of 1.5 mg/L.

8.2.3 Total Suspended Solids

TSS loads to the Salton Sea from the New River and Alamo River are about 82 to 85 x 10^6 kg/yr and 172 to 182 x 10^6 kg/yr, respectively, and 255 to 266 x 10^6 kg/yr from both rivers. The range in loads is based on the two pilot wetland loss rates; there was little difference in loads between the two pilot wetland loss rates. The TSS loads to the Salton Sea are reduced by roughly 37 and 39 percent in the New River and Alamo River, with a total reduction of roughly 39 percent for the combined rivers compared to the base case load of 423 x 10^6 kg/yr. The reduction is due primarily to TSS loss in the wetlands (between 29 to 36 percent), compared to TSS wetland seepage losses of 4 to 8 percent.

Comparing the TSS results for the New and Alamo Rivers, the removal rates in the Alamo River are roughly 2.2 times higher than the New River. The New River load reduction is higher due to the larger wetland acreage. Similar to total nitrogen, the New River wetlands are less efficient in TSS removal per square meter of wetland treatment area than the Alamo River wetlands. The area-specific TSS removal rate for the New River wetlands is about 4,400 g/m^2-yr of wetland area, versus about 18,500 g/m^2-yr for the Alamo River wetlands. The much higher TSS removal rate for the Alamo River wetlands is attributed to the much higher TSS concentrations in the Alamo River and drains. For example, the Alamo River has drains treated in the wetlands with TSS concentrations as high as 1,460 mg/L, while the highest New River wetland influent TSS concentrations are only 560 mg/L. The higher TSS concentrations in the Alamo Rivers and drains result in higher removal efficiencies since the wetland influent TSS concentration is higher relative to the wetland TSS plateau concentration of 5 mg/L.

8.2.4 Selenium

Total selenium loads to the Salton Sea from the New River and Alamo River are about 1,700 to 2,100 kg/yr and 5,200 to 5,600 kg/yr, respectively, and 6,900 to 7,700 kg/yr from both rivers. The range in loads is based on the two pilot wetland loss rates. The total selenium loads to the Salton Sea are reduced by 5 to 21 percent and 2 to 9 percent in the New River and Alamo River, with a total reduction of 3 to 12 percent for the combined rivers compared to the base case load of 8,000 kg/yr. The reduction is due to total selenium loss in the wetlands, since total selenium in wetland seepage losses is not expected to be significantly attenuated and seepage losses are assumed to return to the rivers.

8.2.5 Total Coliforms

Total coliform loads to the Salton Sea from the New River and Alamo River are about 1.2 x 10^{17} MPN/yr and 2.5 x 10^{17} MPN/yr, respectively, and 3.7 x 10^{17} MPN/yr from both rivers. The total coliform loads to the Salton Sea are reduced by 89 percent and 40 percent in the New River and Alamo River, with a total reduction of 75 percent for the combined rivers compared to the base case load of 12 x 10^{17} MPN/yr. There was little difference in the Salton Sea loads due to the two pilot wetland loss rates.

The wetland removal rates were significantly different between the two rivers. The total coliform load reduction in the New River is due to the large total selenium loss in the wetlands (7.9 to 8.7 x 10^{17} MPN/yr; 73 to 83 percent loss). There was a 0.9 to 1.6 x 10^{17} MPN/yr (9 to 15 percent) loss due to wetland seepage losses in the New River wetlands. For the Alamo River, the wetland losses ranged between 1.4 to 1.6 x 10^{17} MPN/yr (33 and 37 percent), with 0.2 to 0.3 x 10^{17} MPN/yr (4 to 7 percent) loss due to wetland seepage losses. There was a larger difference in the wetland loss rate and retention in seepage terms between the two rivers due to the two pilot wetland loss rates.

Comparing the total coliforms results for the New and Alamo Rivers, the removal rates in the New River are roughly 5.7 times higher than the Alamo River. The New River wetlands are more efficient in total coliforms removal per acre of wetland treatment area than the Alamo River wetlands. For example, the total coliforms removal rate for the New River wetlands is 8.4 x 10^{10} MPN /m^2-yr of wetland area, while the total coliforms removal rate for the Alamo River wetlands is 2.7 x 10^{10} MPN/m^2-yr of wetland area. This difference is largely due to the high total coliform concentrations at the U.S.-Mexico border in the New River. For example, the Alamo River has wetland influent total coliforms concentrations as high as 631,000 MPN per 100 mL, while the highest New River wetland influent TSS concentrations are 8,231,000 MPN per 100 mL. The higher total coliforms concentrations in the New River result in higher removal efficiencies since the wetland influent concentration is higher relative to the wetland plateau concentration of 500 MPN per 100 mL.

8.2.6 Loading Summary

The model results show the potential for significant reductions in loadings with the construction of the 35 top-ranked wetland sites as described in Nolte (2002) covering 4,276 acres. The total phosphorus load reduction is in the range of 34 to 41 percent from base case conditions. The total nitrogen, TSS, and total coliform load reductions are estimated at 26, 38, and 75 percent from base case conditions. Total selenium load reductions range between 3 and 12 percent.

Given the Top 35 wetland design recommended in Nolte (2002), there are much higher removal rates in the New River than the Alamo River. This is primarily due to the higher wetland treatment area and flow in the New River than the Alamo River. However, the chemical concentrations in the rivers and drains in each watershed also influences removals.

The New River wetlands has higher area-specific removal rates for total phosphorus, while the Alamo River wetlands have higher area specific removal rates for total nitrogen, selenium, and especially TSS.

8.2.7 Flow Impacts

The model results also predict the impact on the quantity of water reaching the Salton Sea from constructing the Top 35 wetlands along these two rivers. The wetlands are estimated to lose about 2 percent of their total inflow, or 24,000 AF/yr, to evapotranspiration from 4,300 acres of wetlands. The wetlands also will lose about 353,000 acre-feet per year or 40 percent of their inflow to seepage losses, but the seepage loss is very likely to discharge directly back into the rivers. Thus, the seepage losses will return to the river and ultimately the Salton Sea.

These reductions in flow are not thought to significantly impact the salinity in the Salton Sea for the following reasons:

- The reduction in flow due to wetlands is much smaller than due to other factors, such as the reduction of flow from Mexico to the New River, and due to water transfers; and
- Plans to address the reduced inflows and the potential impacts to salinity in the Salton Sea are being made by the Salton Sea Authority and other entities.

Thus, the nutrient removal impacts on the Salton Sea associated with wetland development are likely to significantly outweigh any water loss impacts on the Salton Sea that may be due to the wetlands.

8.3 Scenario 2: Thirty-Five (35) Top-Ranked Wetland Sites with Reduced Wetland Areas

The model was configured for the future construction of the thirty-five (35) top-ranked wetland sites as described in Section 4.4 and Table 4-3. The Scenario 2 wetland design assumes reduced wetland surface areas from Scenario 1 and is based on the preliminary *wetted* areas estimated in Nolte (2002), rather than the entire wetland site area. There is a total of 3,635 acres of wetlands in this scenario, compared to 4,276 acres in Scenario 1. This is a reduction of 641 acres (15 percent) with a reduction of 225 and 416 acres from the Alamo River and New River wetlands, respectively. Compared to Scenario 1, there is a reduction of treated inflow by 7,901 AF/mo (11 percent) with 1,629 and 6,272 AF/mo from the Alamo River and New River wetlands, respectively. This reduced wetland area design scenario is based on a plug flow design like Scenario 1. The resulting model predictions of total phosphorus, total nitrogen, TSS, total selenium, and total coliform loads to the Salton Sea from the New River, Alamo River, and combined rivers are summarized in Figure 8-3.

There was a surprisingly small change to the Scenario 2 loadings to the Salton Sea as a result of the reduced wetland areas and inflows. The loadings decreased by only a few percentages (up to 4 percent). The total phosphorus loads decreased from the base case (i.e., no wetlands case) by 31 to 37 percent, based on the Brawley and Imperial Wetland loss rate, respectively. This is a decrease of 3.5 to 3.9 percent from Scenario 1. The total nitrogen loads decreased from the base case by 23 to 22 percent, based on the Brawley and Imperial Wetland loss rate, respectively. This is a decrease of 2.8 percent from Scenario 1. The TSS loads decreased from the base case by 35 to 38 percent, based on the Brawley and Imperial Wetland loss rate, respectively. This is a decrease of 2.1 to 1.6 percent from Scenario 1. The total selenium loads decreased from the base case by 2 to 11 percent, based on the Brawley and Imperial wetland loss rate, respectively. This is a decrease of 0.4 to 1.6 percent from Scenario 1. The total coliform loads decreased from the base case by 71 to 72 percent, based on the Brawley and Imperial Wetland loss rate, respectively. This is a decrease of 4 percent from Scenario 1.

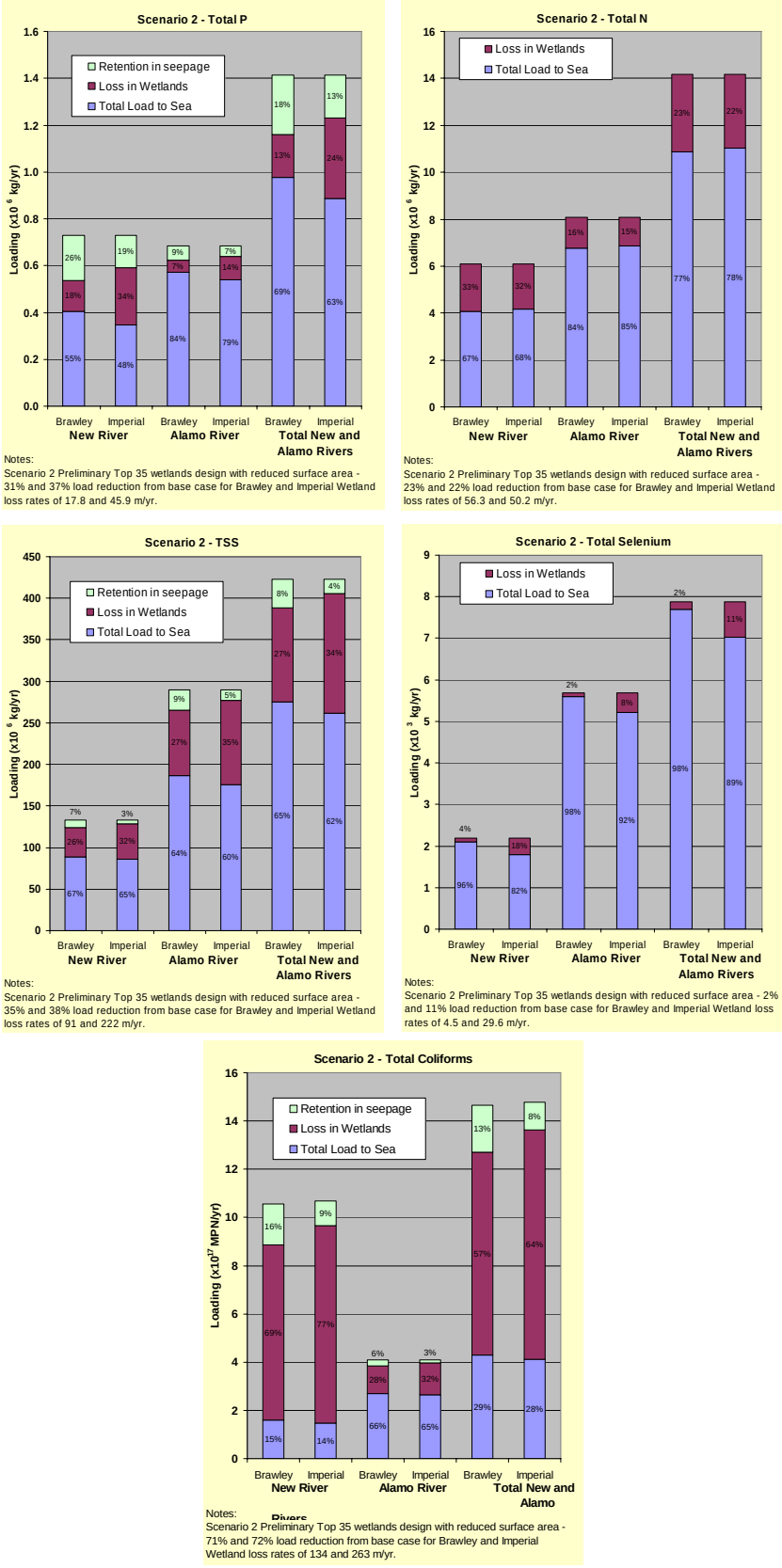


Figure 6-3. Total phosphorus, total nitrogen, TSS, total selenium, and total coliform loadings in the New and Alamo River watersheds with preliminary Top 35 wetlands but reduced wetland surface area and associated inflows.

8.4 Scenario 3: Thirty-Five (35) Top-Ranked Wetland Sites with Reduced Wetland Areas and Mixed Reactor Flow Wetlands

The model was configured for the future construction of the thirty-five (35) top-ranked wetland sites as described in Section 4.4 and Table 4-3. This scenario is based on the reduced wetland areas and inflows defined in Scenario 2. In addition, this scenario also examined the design of mixed reactor flow wetlands, if the physical site characteristics allowed such a configuration. The mixed reactor flow model allows for a higher volume flow through the wetland, and thus higher load reduction. For the Alamo River, 13 of the 16 wetland sites were reconfigured in the modeling analysis as mixed reactor flow wetlands. For the New River, 13 of the 19 wetland sites were reconfigured as mixed reactor flow wetlands. Compared to Scenario 1, this leads to a significant increase of treated inflow by 37,421 AF/mo (51 percent) with 17,293 and 20,128 AF/mo from the Alamo River and New River wetlands, respectively. The resulting model predictions of total phosphorus, total nitrogen, TSS, total selenium, and total coliform loads to the Salton Sea from the New River, Alamo River, and combined rivers are summarized in Figure 8-4.

There was a relatively small change to the Scenario 3 loadings to the Salton Sea as a result of the significantly increased inflows. The total phosphorus loads decreased from the base case (i.e., no wetlands case) by 39 to 44 percent, based on the Brawley and Imperial Wetland loss rate, respectively. This is an increase in wetland performance of 6.6 to 7.8 percent from Scenario 2, which is based solely on plug flow design of the wetlands. The total nitrogen loads decreased from the base case by 24 to 25 percent, based on the Brawley and Imperial Wetland loss rate, respectively. This is an increase in wetland performance of only 1.4 to 1.6 percent from Scenario 2. The TSS loads decreased from the base case by 41 to 47 percent, based on the Brawley and Imperial Wetland loss rate, respectively. This is an increase of 5.8 to 8.4 percent from Scenario 2. The total selenium loads decreased from the base case by 2 to 11 percent, based on the Brawley and Imperial Wetland loss rate, respectively. Basically there was no change from Scenario 2. The total coliform loads decreased from the base case by 80 to 82 percent, based on the Brawley and Imperial wetland loss rate, respectively. This is an increase of 9.2 to 10.2 percent from Scenario 2.

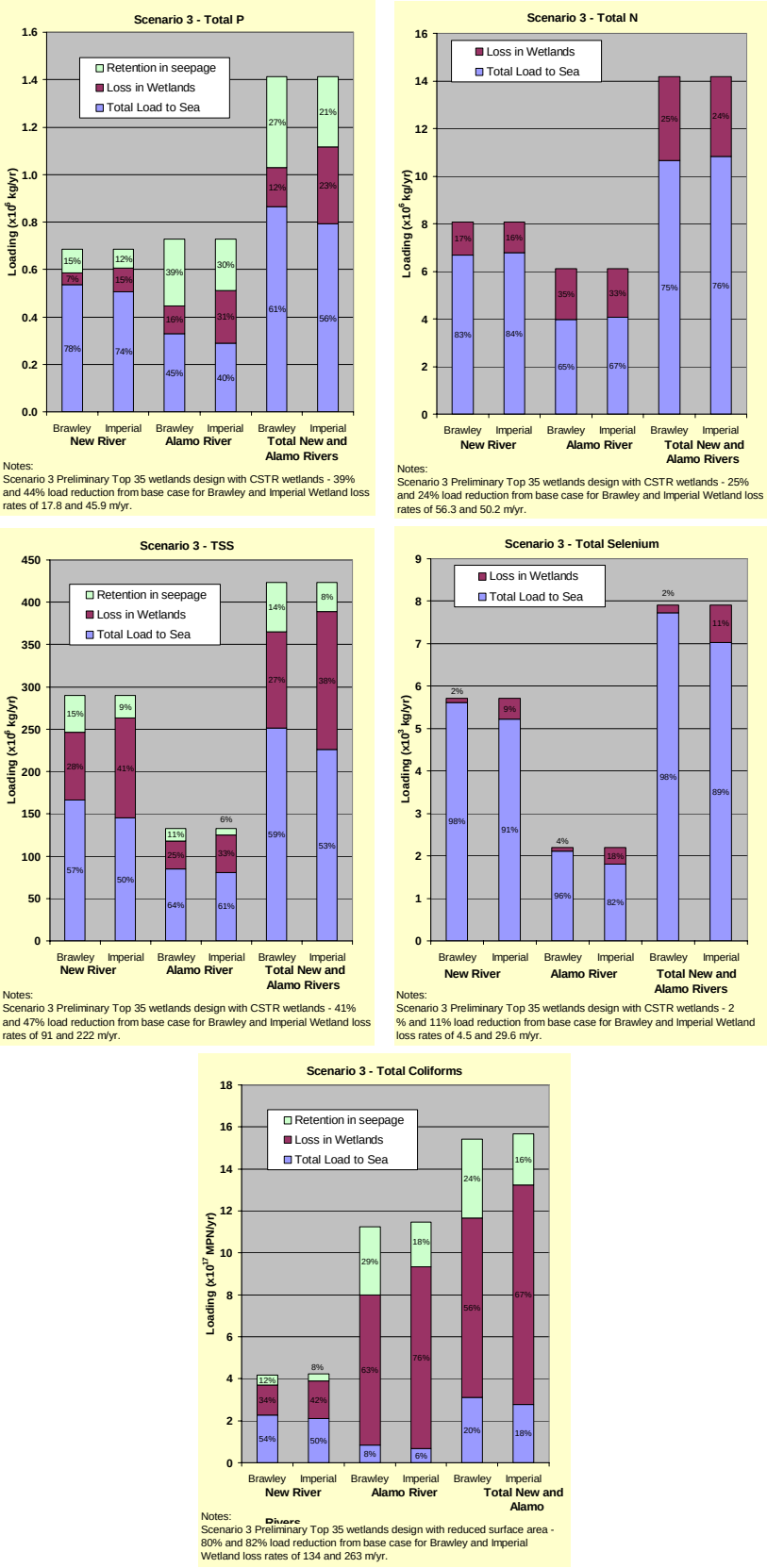


Figure 6-4 Total phosphorus, total nitrogen, TSS, total selenium, and total coliform loadings in the New and Alamo River watersheds with preliminary Top 35 wetlands but reduced wetland areas and inclusion of CSTR-type wetlands.

8.5 Summary

Given the preliminary selection and design for the Top 35 wetlands presented in Nolte (2002), the composite watershed/wetland model was used to predict nutrient, TSS, selenium, and total coliform removals for wetland design parameters that were typical of the pilot wetland performance (see Table 4-2). The model results indicated that significant differences exist between the removal rates for wetlands in the New River and Alamo River. The loadings to the Salton Sea, along with the wetland loss and seepage rates, are summarized in Tables 8-2 to 8-6 for the total phosphorus, total nitrogen, TSS, total selenium, and total coliforms.

Additional model analyses, to be discussed in Section 7, reveal that these differences are due not only to the different numbers and sizes of wetlands in the two watersheds, but also due to differences in the area-specific removal rates of each wetland. Differences in the area-specific removal rates of each wetland are primarily attributed to different wetland influent concentrations, because the individual wetlands are each assigned similar wetland chemical removal rate constants, wetland seepage retention parameters, wetland plateau concentrations, and wetland hydraulic loading rates.

Table 8-2
Total Phosphorus Loads for Scenarios 1, 2, and 3

		Brawley Pilot Wetland Rates Total Phosphorus Fluxes (x 10^6 kg/yr)				Imperial Pilot Wetland Rates Total Phosphorus Fluxes (x 10^6 kg/yr)			
Watershed	**Scenario**	**To Salton Sea**	**Wetland Loss**	**Seepage Loss**	**Total Loss**	**To Salton Sea**	**Wetland Loss**	**Seepage Loss**	**Total Loss**
New River									
	Base Case (No Wetlands)	0.73	-	-	-	0.73	-	-	-
	Wetlands Scenario 1	0.37	0.15	0.20	0.36	0.31	0.28	0.14	0.42
	Wetlands Scenario 2	0.40	0.13	0.19	0.33	0.35	0.25	0.14	0.38
	Wetlands Scenario 3	0.33	0.12	0.28	0.40	0.29	0.22	0.22	0.44
Alamo River									
	Base Case (No Wetlands)	0.69	-	-	-	0.69	-	-	-
	Wetlands Scenario 1	0.56	0.06	0.07	0.13	0.52	0.11	0.05	0.17
	Wetlands Scenario 2	0.57	0.05	0.06	0.11	0.54	0.10	0.05	0.15
	Wetlands Scenario 3	0.54	0.05	0.10	0.15	0.51	0.10	0.08	0.18
Combined New and Alamo Rivers									
	Base Case (No Wetlands)	1.41	-	-	-	1.41	-	-	-
	Wetlands Scenario 1	0.93	0.21	0.27	0.49	0.83	0.39	0.19	0.58
	Wetlands Scenario 2	0.98	0.18	0.25	0.44	0.89	0.34	0.18	0.53
	Wetlands Scenario 3	0.87	0.16	0.38	0.55	0.79	0.32	0.30	0.62

Table 8-3
Total Nitrogen Loads for Scenarios 1, 2, and 3

		Brawley Pilot Wetland Rates Total Nitrogen Fluxes (x 10^6 kg/yr)				Imperial Pilot Wetland Rates Total Nitrogen Fluxes (x 10^6 kg/yr)			
Watershed	**Scenario**	**To Salton Sea**	**Wetland Loss**	**Seepage Loss**	**Total Loss**	**To Salton Sea**	**Wetland Loss**	**Seepage Loss**	**Total Loss**
New River									
	Base Case (No Wetlands)	6.1	-	-	-	6.1	-	-	-
	Wetlands Scenario 1	3.8	2.3	-	2.3	3.9	2.2	-	2.2
	Wetlands Scenario 2	4.1	2.0	-	2.0	4.2	1.9	-	1.9
	Wetlands Scenario 3	4.0	2.1	-	2.1	4.1	2.0	-	2.0
Alamo River									
	Base Case (No Wetlands)	8.1	-	-	-	8.1	-	-	-
	Wetlands Scenario 1	6.6	1.5	-	1.5	6.7	1.4		1.4
	Wetlands Scenario 2	6.8	1.3	-	1.3	6.9	1.2		1.2
	Wetlands Scenario 3	6.7	1.4	-	1.4	6.8	1.3		1.3
Combined New and Alamo Rivers									
	Base Case (No Wetlands)	14.2	-	-	-	14.2	-	-	-
	Wetlands Scenario 1	10.4	3.7	-	3.7	10.6	3.5	-	3.5
	Wetlands Scenario 2	10.9	3.3	-	3.3	11.0	3.1	-	3.1
	Wetlands Scenario 3	10.6	3.5	-	3.5	10.8	3.4	-	3.4

Table 8-4
Total Suspended Solids Loads for Scenarios 1, 2, and 3

		Brawley Pilot Wetland Rates TSS Fluxes (x 10^6 kg/yr)				Imperial Pilot Wetland Rates TSS Fluxes (x 10^6 kg/yr)			
Watershed	**Scenario**	**To Salton Sea**	**Wetland Loss**	**Seepage Loss**	**Total Loss**	**To Salton Sea**	**Wetland Loss**	**Seepage Loss**	**Total Loss**
New River									
	Base Case (No Wetlands)	133	-	-	-	133	-	-	-
	Wetlands Scenario 1	85	39	10	48	82	47	4	51
	Wetlands Scenario 2	89	35	9	44	86	43	4	47
	Wetlands Scenario 3	85	33	15	48	81	44	8	52
Alamo River									
	Base Case (No Wetlands)	290	-	-	-	290	-	-	-
	Wetlands Scenario 1	182	85	23	108	172	106	12	118
	Wetlands Scenario 2	187	78	25	103	175	101	13	115
	Wetlands Scenario 3	166	80	43	124	145	118	26	145
Combined New and Alamo Rivers									
	Base Case (No Wetlands)	423	-	-	-	423	-	-	-
	Wetlands Scenario 1	266	124	33	157	255	152	16	168
	Wetlands Scenario 2	275	113	34	148	261	144	18	162
	Wetlands Scenario 3	251	114	58	172	226	163	34	197

Table 8-5
Total Selenium Loads for Scenarios 1, 2, and 3

		Brawley Pilot Wetland Rates TSS Fluxes (x 10^3 kg/yr)				Imperial Pilot Wetland Rates TSS Fluxes (x 10^3 kg/yr)			
Watershed	**Scenario**	**To Salton Sea**	**Wetland Loss**	**Seepage Loss**	**Total Loss**	**To Salton Sea**	**Wetland Loss**	**Seepage Loss**	**Total Loss**
New River									
	Base Case (No Wetlands)	2.21	-	-	-	2.21	-	-	-
	Wetlands Scenario 1	2.08	0.10	-	0.10	1.73	0.45	-	0.45
	Wetlands Scenario 2	2.10	0.09	-	0.09	1.80	0.39	-	0.39
	Wetlands Scenario 3	2.11	0.09	-	0.09	1.81	0.39	-	0.39
Alamo River									
	Base Case (No Wetlands)	5.71	-	-	-	5.71	-	-	-
	Wetlands Scenario 1	5.57	0.11	-	0.11	5.15	0.53	-	0.53
	Wetlands Scenario 2	5.59	0.09	-	0.09	5.22	0.46	-	0.46
	Wetlands Scenario 3	5.61	0.09	-	0.09	5.22	0.49	-	0.49
Combined New and Alamo Rivers									
	Base Case (No Wetlands)	7.91	-	-	-	7.91	-	-	-
	Wetlands Scenario 1	7.65	0.21	-	0.21	6.88	0.98	-	0.98
	Wetlands Scenario 2	7.69	0.18	-	0.18	7.02	0.85	-	0.85
	Wetlands Scenario 3	7.72	0.18	-	0.18	7.03	0.87	-	0.87

Table 8-6
Total Coliform Loads for Scenarios 1, 2, and 3

		Brawley Pilot Wetland Rates Total Coliform Fluxes (x 10^{17} MPN/yr)					Imperial Pilot Wetland Rates Total Coliform Fluxes (x 10^{17} MPN/yr)				
Watershed	**Scenario**	**To Salton Sea**	**River Loss**	**Wetland Loss**	**Seepage Loss**	**Total Loss**	**To Salton Sea**	**River Loss**	**Wetland Loss**	**Seepage Loss**	**Total Loss**
New River											
	Base Case (No Wetlands)	7.8	5.8	-	-	5.8	7.8	5.8	-	-	5.8
	Wetlands Scenario 1	1.2	2.9	7.9	1.6	12.3	1.1	2.8	8.7	0.9	12.4
	Wetlands Scenario 2	1.6	3.0	7.2	1.7	11.9	1.5	2.9	8.2	1.0	12.1
	Wetlands Scenario 3	0.8	2.3	7.1	3.3	12.7	0.7	2.1	8.7	2.1	12.9
Alamo River											
	Base Case (No Wetlands)	3.8	1.2	-	-	1.2	3.8	1.2	-	-	1.2
	Wetlands Scenario 1	2.5	0.9	1.4	0.3	2.5	2.4	0.8	1.6	0.2	2.6
	Wetlands Scenario 2	2.7	0.9	1.2	0.2	2.3	2.6	0.9	1.3	0.1	2.4
	Wetlands Scenario 3	2.3	0.8	1.4	0.5	2.7	2.1	0.8	1.8	0.3	2.9
Combined New and Alamo Rivers											
	Base Case (No Wetlands)	11.6	7.0	-	-	7.0	11.6	7.0	-	-	7.0
	Wetlands Scenario 1	3.7	3.7	9.2	1.9	14.9	3.6	3.6	10.3	1.1	15.0
	Wetlands Scenario 2	4.3	3.9	8.4	2.0	14.3	4.1	3.8	9.5	1.1	14.4
	Wetlands Scenario 3	3.1	3.1	8.6	3.8	15.4	2.8	2.9	10.5	2.4	15.8

CHAPTER 9
WETLAND NETWORK DESIGN: OPTIMAL SITE SELECTION

9.1 Introduction

Seven additional scenarios were also evaluated using the composite watershed/wetland model (see Table 6-1 for complete list of scenarios). Evaluation of alternative numbers and locations of treatment wetlands is the focus of Scenarios 4 through 8, based on optimization analyses to define the wetlands that provide the highest nutrient removals. Two scenarios evaluate the impact of known future changes to the water management of the New and Alamo Rivers watershed sources. Scenario 9 evaluates the impact of planned IID water conservation efforts. Scenario 10 evaluates planned reductions in cross-border flows from Mexico due to wastewater treatment plant upgrades and water reuse. Scenario 11 evaluates IID's more recent list of 25 potential wetland sites identified by feasibility studies and topographic surveys of wetland sites (Davey-Cairo Engineers, 2005a,b; 2006a,b).

This effort focused on total phosphorus removals because phosphorus is likely the key limiting nutrient in the Salton Sea, and total phosphorus removals has been the focus of other study designs to improve water quality within the Salton Sea. These scenarios are based on the Top 35 wetland design based on the reduced wetted surface areas (see Table 6-3). Also, given the small response range of load removals to the pilot wetland model loss rates, the average of the Brawley and Imperial wetland rates was used for these scenarios (see Table 6-2).

The optimization analyses are described in Section 9.2. Scenarios 4 to 11 are described in Sections 9.3 to 9.10.

9.2 Optimization Analyses of Number and Locations of Wetlands

Given the preliminary selection and design for the Top 35 wetlands presented in Nolte (2002), the composite watershed/wetland model was used to predict nutrient, TSS, selenium, and total coliforms removals for wetland design parameters that were typical of the pilot wetland performance (see Table 6-2). The model results indicated that significant differences exist between the removal rates for wetlands in the New River and Alamo River. Additional model analyses revealed that these differences are due not only to the different numbers and

sizes of wetlands in the two watersheds, but also due to differences in the area-specific removal rates of each wetland. Differences in the area-specific removal rates of each wetland are primarily attributed to different wetland influent concentrations, because the individual wetlands are each assigned similar wetland chemical removal rate constants, wetland seepage retention parameters, wetland plateau concentrations, and wetland hydraulic loading rates.

In order to aid in optimizing the wetland system design, the model was executed for many different scenarios in order to define the wetlands that provide the most nutrient removals. Since wetland total phosphorus removal rates are dependent on the wetland influent water quality, the total phosphorus removal rates for each individual wetland will vary depending on whether there are other wetlands present upstream that may impact the water quality in the wetland influent.

To illustrate this point, Tables 9-1 and 9-2 present the total phosphorus removal rates of each of the Top 35 wetlands for different extreme wetland design scenarios. The total phosphorus removal rates in Table 9-1 are for 35 different scenarios where only one wetland is present in the watersheds. Thus, the wetland total phosphorus removal rates given in Table 9-2 represent the highest possible total phosphorus removal rates for each individual wetland since all other wetlands are not treating water and the wetland influent concentration is the highest possible. The total phosphorus removal rates in Table 9-2 are derived from the difference between the wetland scenario with all 35 wetlands present and from 35 different scenarios where only 34 wetlands are present in the watersheds. The total phosphorus removal rates in Table 9-2 are estimated as the difference between the 35 wetland scenario and the 34 wetland scenario where that particular wetland in not active. Thus, the values in Table 9-2 represent the incremental benefit for each wetland when the entire 35 wetland system is constructed. Therefore, the wetland total phosphorus removal rates given in Table 9-2 represent the lowest possible total phosphorus removal rates for each individual wetland since all other wetlands are treating water and the wetland influent concentration is as low as possible. These analyses are simulated using the system loads and flows from the 5-year model calibration period and the design conditions for the Top 35 Wetlands Scenario 2 with the midpoint of the Brawley and Imperial wetland loss rates. Tables 9-1 and 9-2 also show the area-specific removal rate in g/m^2-yr of wetland area.

The wetlands are listed in Tables 9-1 and 9-2 from the highest load removal to the lowest. For the single wetland scenarios in Table 9-1, the highest individual wetland total phosphorus removal rate of about 89,000 kg/yr occurs in wetland NR24, and the total phosphorus removal rate of all 35 single wetland scenarios is roughly 701,000 kg/yr. By comparison, the total phosphorus removals for the 35-wetland scenario are only 492,000 kg/yr. Thus, the addition of wetlands upstream can reduce the performance of a downstream wetland significantly, as highlighted by lower area-specific removal rates in the 35-wetland scenario (36 g/m^2-yr) than in the single wetland case (average of 43 g/m^2-yr). There is much more of an impact for the New River wetlands, where the individual wetland performance is almost double the 35-wetland scenario, than for the Alamo River wetlands, where the individual wetland performance is only about 10 percent higher than the 35-wetland scenario. This is because roughly 90 percent of the New River wetland water is pulled from the river and 10 percent from the drains, while roughly 40 percent of the Alamo River wetland water is pulled from the river and 60 percent from the drains. The New River water concentrations are significantly higher due to the cross-border flow from Mexico. The net result is that one wetland – NR24 – can achieve 13 percent (89,000 kg/yr) of the total phosphorus removals of the system of 35 wetlands because wetland NR24 is both large (it has 9 percent of the 35 wetland system area) and almost twice as efficient on an area specific basis as the average wetland in the 35-wetland system (56 versus 36 g/m^2-yr).

For the wetland system scenarios in Table 9-2, the highest individual wetland total phosphorus removal rate of roughly 36,000 kg/yr also occurs in wetland NR24. The combined total phosphorus removal rate of all individual wetland scenarios is roughly 333,000 kg/yr, versus 492,000 kg/yr for the 35-wetland scenario. Thus, the addition of wetlands upstream reduces the performance and incremental benefit of a downstream wetland significantly, as highlighted by higher average area-specific removal rates in the 35-wetland scenario (36 g/m^2-yr) than for the average incremental wetland case (21 g/m^2-yr). There is much more of an impact for the New River wetland system, where the incremental wetland performance is about 50 percent lower than the 35-wetland scenario, than for the Alamo River wetland system, where the incremental wetland performance is only about 13 percent lower than the 35-wetland scenario. Again, this is because the New River wetland water is pulled mainly from the river where the concentrations are much higher, while Alamo River wetland water is pulled mainly from the drains. The net result is that the lesser performing wetlands contribute only a small incremental benefit to the overall system performance; for example, almost half of the 35 wetlands have an incremental benefit that is equal to or less than one percent of the overall system total phosphorus removals.

In order to choose an optimum system of wetlands that may achieve performance close to the system of 35 wetlands, but with a much smaller number of wetlands, the wetland performances in the extreme wetland scenarios given in Tables 9-1 and 9-2 are summarized and compared in Table 9-3. For each wetland, Table 9-3 shows the total phosphorus removals, the wetland rank in the two-river system, and the wetland rank in each river. There was not a significant difference between the two ranking approaches both for the overall ranking and for the individual river ranking. The top performing nine out of ten wetlands are on the New River while the worst performing nine out of ten wetlands are on the Alamo River. As discussed above, the primary difference is the significantly higher concentrations in the New River due to the cross-border flows from Mexico. Thus, these rankings were used to systematically evaluate a subset of wetlands that would yield the highest possible performance for the number of wetlands considered.

9.3 Scenario 4: Top Five (5) Wetlands

A Top 5 Wetland scenario was developed using the ranking developed above in Tables 9-1 to 9-3. Eight scenarios on the New River and five scenarios on the Alamo River were simulated, where each scenario adds one more wetland to the system. Table 9-4 also gives the incremental benefit in terms of total phosphorus load reduction for the addition of each new wetland to the system. The eight New River scenarios show the results for one to eight wetlands on the New River, where the wetlands are added into the system in the order of their wetland removals. Total phosphorus losses vary from roughly 89,000 kg/yr with one wetland to roughly 281,000 kg/yr with eight wetlands. For comparison, with all 19 wetlands on the New River the total phosphorus loss is 360,000 kg/yr. This is because there are diminishing returns with each additional wetland, from an incremental increase of 52,000 kg/yr for two wetlands, but only an incremental increase of 12,000 kg/yr for the eighth wetlands. The five Alamo River scenarios show the results for one to five wetlands on the Alamo River, where the wetlands are added into the system in the order of their wetland removals. Total phosphorus losses vary from roughly 26,000 kg/yr with one wetland to roughly 78,000 kg/yr with five wetlands. For comparison, with all 16 wetlands on the Alamo River the total phosphorus loss is 132,000 kg/yr. This is because there are diminishing returns with each additional wetland, from an incremental increase of 18,000 kg/yr for two wetlands, but only an incremental increase of 9,000 kg/yr for five wetlands.

Using the total phosphorus loss results and total phosphorus loss differences given in Table 9-4, it is straightforward to identify the Top 5 wetlands that would maximize total phosphorus removal. For example, the rankings for the Top Five are: NR24, NR16, NR17, AR14, and NR31. AR14 ranks above NR31 since it adds about 26,000 kg/yr versus 22,000 kg/yr.

Thus, the model predicts that constructing only the Top 5 Wetlands would result in a decrease in total phosphorus loads to the Salton Sea of roughly 243,000 kg/yr. This is 17 percent of the load reduction from the base case (i.e., no wetlands case), and 49 percent of the Top 35 Wetland scenario. These 5 wetlands (NR24, NR16, NR17, AR14, and NR31) have a total combined area of 1,799 acres, or about 42 percent of the total acreage for all 35 wetlands (4,276 acres). Figure 9-1 presents the total phosphorus loadings for each river and combined.

Table 9-1
Maximum Total Phosphorus Removal Per Wetland

Wetland Site	Area (acres)	Design Inflow (AF/mo)	Total Wetland Loss[1] (kg/yr)	Removal Rate (gm/m^2-yr)	Rank
NR24	391	6,300	88,551	56	1
NR16	585	9,900	61,816	26	2
NR17	320	5,280	59,801	46	3
NR31	190	3,060	49,255	64	4
NR8	161	3,540	35,151	54	5
NR34	94	1,860	30,968	81	6
NR33	74	1,800	28,043	94	7
NR39	75	1,620	27,632	91	8
NR22	124	1,860	26,871	54	9
AR14	313	3,868	26,198	21	10
NR18	122	1,860	25,455	52	11
NR19	104	2,040	18,737	45	12
AR28	149	2,856	18,679	31	13
NR21	85	1,320	16,003	47	14
NR30	59	1,320	15,905	67	15
NR9	80	1,260	15,774	49	16
NR13	76	1,440	15,753	51	17
AR24	160	2,916	14,822	23	18
AR29	187	2,916	13,805	18	19
NR32	93	2,100	13,444	36	20
NR15	54	840	10,830	50	21
AR17	79	1,428	10,147	32	22
AR19	77	1,309	10,087	32	23
AR22	109	2,380	9,797	22	24
NR40	23	540	9,031	97	25
AR27	68	952	7,977	29	26
NR26	65	720	7,379	28	27
AR23	82	1,131	5,970	18	28
AR21	53	1,190	5,684	27	29
AR13	64	833	5,187	20	30
AR18	31	714	5,004	40	31
AR37	42	833	3,280	19	32
AR20	32	774	3,238	25	33
AR16	26	417	3,235	31	34
AR30	29	417	2,002	17	35

Notes:
1. Includes wetland transformation loss and seepage loss.

Table 9-2
Minimum Total Phosphorus Removal Per Wetland

Wetland Site	Area (acres)	Design Inflow (AF/mo)	Total Wetland Loss[1] (kg/yr)	Removal Rate (gm/m^2-yr)	Rank
NR24	391	6,300	35,531	22	1
NR16	585	9,900	25,159	11	2
NR17	320	5,280	24,165	19	3
AR14	313	3,868	20,530	16	4
NR31	190	3,060	17,277	22	5
AR28	149	2,856	15,519	26	6
NR8	161	3,540	14,580	22	7
AR24	160	2,916	10,860	17	8
NR34	94	1,860	10,481	28	9
NR21	85	1,320	10,312	30	10
NR22	124	1,860	10,134	20	11
AR29	187	2,916	9,735	13	12
NR33	74	1,800	9,353	31	13
AR19	77	1,309	9,347	30	14
NR39	75	1,620	9,184	30	15
NR18	122	1,860	9,179	19	16
AR22	109	2,380	9,050	21	17
AR17	79	1,428	8,906	28	18
NR19	104	2,040	7,032	17	19
AR27	68	952	6,823	25	20
NR13	76	1,440	5,902	19	21
NR9	80	1,260	5,721	18	22
AR23	82	1,131	5,518	17	23
NR30	59	1,320	5,261	22	24
NR32	93	2,100	5,073	13	25
AR13	64	833	5,047	19	26
AR21	53	1,190	4,690	22	27
AR18	31	714	4,625	37	28
NR15	54	840	3,833	18	29
AR16	26	417	2,982	28	30
NR26	65	720	2,981	11	31
AR20	32	774	2,886	22	32
NR40	23	540	2,848	31	33
AR37	42	833	1,542	9	34
AR30	29	417	922	8	35

Notes:
1. Includes wetland transformation loss and seepage loss.

Table 9-3
Comparison of Ranking of Maximum and Minimum Total Phosphorus Removals Per Wetland

	Maximum Removal Per Wetland				Minimum Removal Per Wetland			
Wetland Site	Total Wetland Loss[1] (kg/yr)	Overall Rank	Rank for New River Only	Rank for Alamo River Only	Total Wetland Loss[1] (kg/yr)	Overall Rank	Rank for New River Only	Rank for Alamo River Only
NR24	88,551	1	1		35,531	1	1	
NR16	61,816	2	2		25,159	2	2	
NR17	59,801	3	3		24,165	3	3	
NR31	49,255	4	4		17,277	5	4	
NR8	35,151	5	5		14,580	7	5	
NR34	30,968	6	6		10,481	9	6	
NR33	28,043	7	7		9,353	13	9	
NR39	27,632	8	8		9,184	15	10	
NR22	26,871	9	9		10,134	11	8	
AR14	26,198	10		1	20,530	4		1
NR18	25,455	11	10		9,179	16	11	
NR19	18,737	12	11		7,032	19	12	
AR28	18,679	13		2	15,519	6		2
NR21	16,003	14	12		10,312	10	7	
NR30	15,905	15	13		5,261	24	15	
NR9	15,774	16	14		5,721	22	14	
NR13	15,753	17	15		5,902	21	13	
AR24	14,822	18		3	10,860	8		3
AR29	13,805	19		4	9,735	12		4
NR32	13,444	20	16		5,073	25	16	
NR15	10,830	21	17		3,833	29	17	
AR17	10,147	22		5	8,906	18		7
AR19	10,087	23		6	9,347	14		5
AR22	9,797	24		7	9,050	17		6
NR40	9,031	25	18		2,848	33	19	
AR27	7,977	26		8	6,823	20		8
NR26	7,379	27	19		2,981	31	18	
AR23	5,970	28		9	5,518	23		9
AR21	5,684	29		10	4,690	27		11
AR13	5,187	30		11	5,047	26		10
AR18	5,004	31		12	4,625	28		12
AR37	3,280	32		13	1,542	34		15
AR20	3,238	33		14	2,886	32		14
AR16	3,235	34		15	2,982	30		13
AR30	2,002	35		16	922	35		16

Notes:
1. Includes wetland transformation loss and seepage loss.

Table 9-4
Top 5 and Top 10 Wetlands for Maximum Total Phosphorus Removal

Wetland Scenario	Cumulative Wetland Area (acres)	Cumulative Wetland Inflow (AF/mo)	Salton Sea Loading (kg/yr)	Total Wetland Loss (kg/yr)	Differential Loss from Previous Scenario (kg/yr)	Top 5 Rank	Top 10 Rank
New River							
NR24	391	6,300	640,368	88,551	88,551	1	1
NR24, NR16	976	16,200	588,333	140,519	51,968	2	2
NR24, NR16, NR17	1,296	21,480	543,523	185,292	44,773	3	3
NR24, NR 16, NR17, NR31	1,486	24,540	511,995	216,798	31,505	4	4
NR24, NR 16, NR17, NR31, NR8	1,647	28,080	489,746	239,028	22,231		6
NR24, NR 16, NR17, NR31, NR8, NR34	1,741	29,940	473,419	255,344	16,316		8
NR24, NR 16, NR17, NR31, NR8, NR34, NR33	1,815	31,740	459,832	268,922	13,579		9
NR24, NR 16, NR17, NR31, NR8, NR34, NR33, NR 39	1,890	33,360	447,405	281,341	12,419		
Alamo River							
AR14	313	3,868	659,058	26,198	26,198	5	5
AR14, AR28	462	6,724	641,361	43,878	17,680		7
AR14, AR28, AR24	622	9,640	628,603	56,617	12,739		10
AR14, AR28, AR24, AR29	809	12,555	616,945	68,253	11,636		
AR14, AR28, AR24, AR29, AR17	888	13,983	607,652	77,537	9,284		
Top 5 Wetland Scenario	1,799	28,408	1,171,053	242,995			
Top 10 Wetland Scenario	2,437	41,380	1,088,435	325,540			

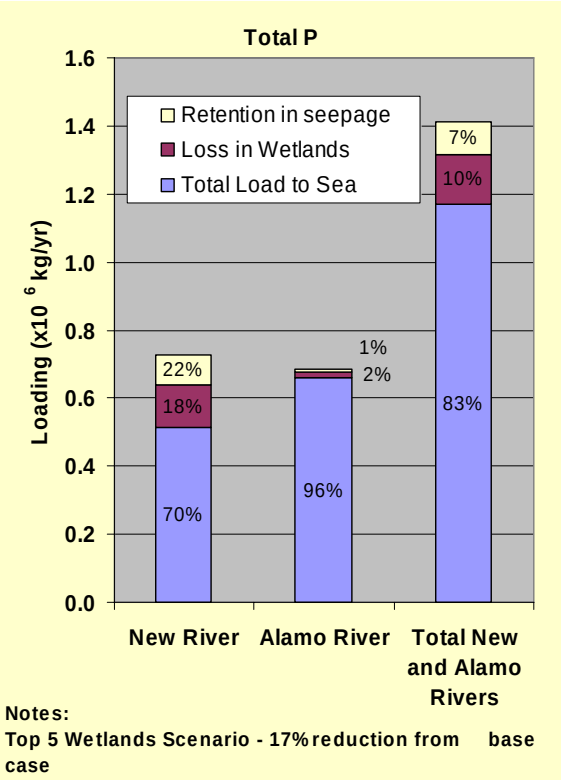


Figure 9-1 Total phosphorus loadings in the New and Alamo River watersheds with Top 5 wetlands.

Thus, constructing these 5 wetlands will require only 42 percent of the Top 35 wetlands in terms of area, and the model predicts these 5 wetlands can achieve 49 percent of the benefit of the 35 Wetlands in terms of reductions in total phosphorus loads to the Salton Sea. Overall, this is 17 percent of the load reduction from the base case (i.e., no wetlands case).

9.4 Scenario 5: Top Ten (10) Wetlands

A Top 10 Wetland scenario was developed using the ranking developed above in Tables 9-1 to 9-3 and as described above for the Top 5 Wetland scenario. The rankings for the Top 10 Wetlands are: NR24, NR16, NR17, AR14, NR31, NR8, AR28, NR34, NR33, and AR24. Thus, the model predicts that constructing only the Top 10 Wetlands would result in a decrease in total phosphorus loads to the Salton Sea of roughly 326,000 kg/yr. This is 23 percent of the load reduction from the base case (i.e., no wetlands case), and 66 percent of the Top 35 Wetland scenario. These 10 wetlands have a total combined area of 2,437 acres, or about 57 percent of the total acreage for all 35 wetlands (4,276 acres). Figure 9-2 presents the total phosphorus loadings for each river and combined.

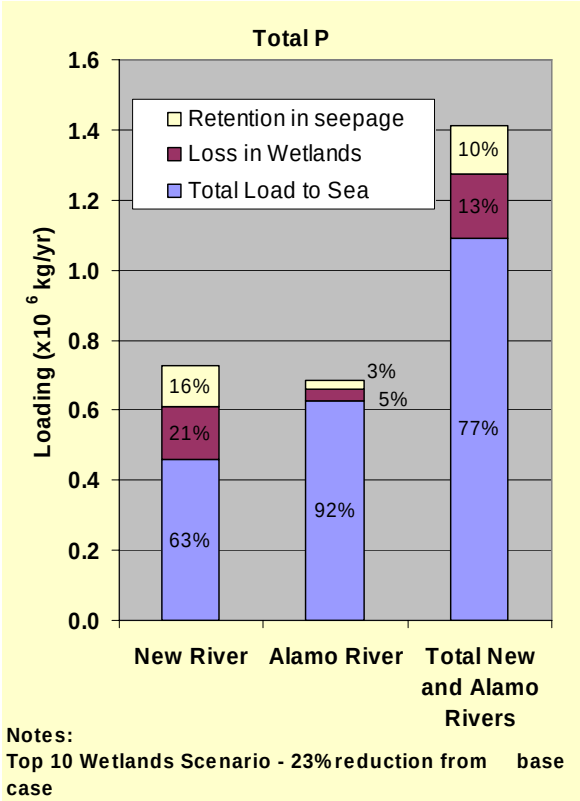


Figure 9-2 Total phosphorus loadings in the New and Alamo River watersheds with Top 10 wetlands.

Thus, constructing these 10 wetlands will require only 57 percent of the Top 35 wetlands in terms of area, and the model predicts these 10 wetlands can achieve 66 percent of the benefit of the 35 Wetlands in terms of reductions in total phosphorus loads to the Salton Sea. Overall, this is 23 percent of the load reduction from the base case (i.e., no wetlands case).

9.5 Scenario 6: Top Performance Wetlands

Sections 9.3 and 9.4 present the Top 5 and Top 10 Wetlands in terms of total phosphorus load reductions to the Salton Sea. These Top 5 and 10 Wetlands are locations that are generally large in terms of area and flows, and they also have fairly good total phosphorus removal rates on an area-specific basis. However, as shown in Tables 9-1 and 9-2, the Top 10 Wetlands do not always have the highest total phosphorus removal rates on an area-specific basis. Therefore, they do not necessarily represent the maximum possible total phosphorus removal rates for a given wetland area. In order to define the maximum possible total phosphorus removal rates for a given wetland area, the wetlands were ranked according to the area-specific total phosphorus removal rates in Table 9-5.

For each wetland, Table 9-5 shows the total phosphorus removals, the wetland rank in the two-river system, and the wetland rank in each river. There was not a significant difference between the two ranking approaches both for the overall ranking and for the individual river ranking. The top performing wetlands are on the New River while the worst performing wetlands are on the Alamo River. As discussed above, the primary difference is the significantly higher concentrations in the New River due to the cross-border flows from Mexico.

However, the top performing wetlands are different than those identified in Table 9-3. The underlying difference is the top performers based on the maximum removal rates are generally correlated to the larger design inflows. The top performers identified in Table 9-5, for the area-specific top removal rates, are correlated to the maximum inflow concentrations. These are generally the wetlands on the upper reaches of the New River, where the highest phosphorus concentrations are coming in across the U.S.-Mexico border.

To compare the difference in approaches, the rankings in Table 9-5 were used to define wetlands that achieve the same total phosphorus removal as the Top 5 Wetlands Scenario (i.e., 243,000 kg/yr). The same procedure for incrementally adding wetlands according to their rank is shown in Table 9-6. In this scenario, the optimum wetland system that achieves the same total phosphorus removal consists of 10 wetlands, with a total acreage of 1,222 acres with flows of 22,614 AF/mo. This is a 32 percent smaller total wetland acreage.

Therefore, it appears that design of a wetland system that prioritizes wetland selection based on an area-specific removal rate will achieve a higher loading reduction for the same total wetland acreage (and thus cost).

9.6 Scenario 7: Maximum Load Reduction

Sections 7.3 to 7.5 define the top performance wetlands and the possible total phosphorus removals for these various wetland scenarios with a limited number of wetlands. This allows an estimate of wetland total phosphorus removals as a function of the total wetland acreage in both the New and Alamo Rivers. This concept is extrapolated from a limited number of the Top 5 and 10 wetlands to a system of wetlands comprising all of the Top 35 wetlands, where the wetland area at each potential wetland location may be increased beyond that given in Table 6-3. The objective is to develop an estimate of the total phosphorus removals versus wetland area that spans a wider range of possible conditions than given in the prior scenarios in Sections 7.3 through 7.5. For example, the recommended Top 35 wetland design achieves total phosphorus removals of approximately 490,000 kg/yr or 35 percent of the current load with 3,637 acres of wetlands, but it may be desirable to have a wetland system that achieves higher total phosphorus removals. This section seeks to define what load reductions may be possible with both larger and smaller wetland systems using the results of the Top 5 and Top 10 wetlands as a guide in choosing the optimum wetland locations and sizes. The premise of this choice is that the wetlands would be chosen based upon those which would provide the highest removal rate for a given overall system wetland area.

Table 9-5
Ranking of Maximum and Minimum Area-Specific Total Phosphorus Removals per Wetland

	Maximum Removal Per Wetland				Minimum Removal Per Wetland			
Wetland Site	Removal Rate (gm/m2-yr)	Overall Rank	Rank for New River Only	Rank for Alamo River Only	Removal Rate (gm/m2-yr)	Overall Rank	Rank for New River Only	Rank for Alamo River Only
NR40	97	1	1		31	3	2	
NR33	94	2	2		31	2	1	
NR39	91	3	3		30	4	3	
NR34	81	4	4		28	9	5	
NR30	67	5	5		22	16	9	
NR31	64	6	6		22	12	6	
NR24	56	7	7		22	13	7	
NR8	54	8	8		22	14	8	
NR22	54	9	9		20	19	10	
NR18	52	10	10		19	23	13	
NR13	51	11	11		19	21	11	
NR15	50	12	12		18	25	15	
NR9	49	13	13		18	24	14	
NR21	47	14	14		30	6	4	
NR17	46	15	15		19	22	12	
NR19	45	16	16		17	27	16	
AR18	40	17		1	37	1		1
NR32	36	18	17		13	30	17	
AR19	32	19		2	30	5		2
AR17	32	20		3	28	8		4
AR28	31	21		4	26	10		5
AR16	31	22		5	28	7		3
AR27	29	23		6	25	11		6
NR26	28	24	18		11	32	18	
AR21	27	25		7	22	17		8
NR16	26	26	19		11	33	19	
AR20	25	27		8	22	15		7
AR24	23	28		9	17	26		11
AR22	22	29		10	21	18		9
AR14	21	30		11	16	29		13
AR13	20	31		12	19	20		10
AR37	19	32		13	9	34		15
AR29	18	33		14	13	31		14
AR23	18	34		15	17	28		12
AR30	17	35		16	8	35		16

Table 9-6
Optimum Wetland Design to Match Top 5 Wetlands for Maximum Total Phosphorus Removal

Wetland Scenario	Cumulative Wetland Area (acres)	Cumulative Wetland Inflow (AF/mo)	Salton Sea Loading (kg/yr)	Total Wetland Loss (kg/yr)	Differential Loss from Previous Scenario (kg/yr)
New River					
NR40	23	540	719,931	9,031	9,031
NR40, NR33	97	2,340	692,538	36,416	27,384
NR40, NR33, NR39	172	3,960	667,540	61,405	24,989
NR40, NR33, NR39, NR 34	266	5,820	641,411	87,524	26,118
NR40, NR33, NR39, NR 34, NR30	325	7,140	628,720	100,208	12,684
NR40, NR33, NR39, NR 34, NR30, NR31	515	10,200	591,496	137,409	37,201
NR40, NR33, NR39, NR 34, NR30, NR31, NR24	906	16,500	529,530	199,330	61,921
NR40, NR33, NR39, NR 34, NR30, NR31, NR24, NR8	1,067	20,040	506,421	222,420	23,090
NR40, NR33, NR39, NR 34, NR30, NR31, NR24, NR8, NR22[1]	1,191	21,900	490,875	237,952	15,531
NR40, NR33, NR39, NR 34, NR30, NR31, NR24, NR8, NR22, NR18	1,313	23,760	476,696	252,117	14,165
Alamo River					
AR18[1]	31	714	680,285	5,004	5,004
AR18, AR19	108	2,023	670,198	15,082	10,078
AR18, AR19, AR17	187	3,451	660,161	25,110	10,028
AR18, AR19, AR17, AR28	336	6,307	641,647	43,607	18,497
Optimum Design Scenario based on Area-Specific Removal Rates to match Top 5 Wetlands reduction	1,222	22,614	1,171,160	242,956	
Top 5 Wetland Scenario[2]	1,799	28,408	1,171,053	242,995	

Notes:
1. These 10 wetlands achieve same load reduction for 30% less constructed wetland area.
2. This scenario is based on maximum loss rates defined in Table 7-5.

Figure 9-3 shows a plot of total phosphorus loads from the New River to the Salton Sea as a function of wetland system size in acres. The New River wetland system for various wetland area sizes was determined as follows:

- For sizes from 391 to 1,890 acres, the total phosphorus removals are as given for the Top 8 New River wetlands in Table 9-4;
- For a size of 2,359 acres, the total phosphorus removals are as given for the 19 wetland reduced wetland area design given in Scenario 2 (Section 6.3);
- For sizes from 2,750 to 4,249 acres, the total phosphorus removals are defined for 19 wetlands, where the size of the New River Top 8 wetlands is doubled from that given in Table 9-4 and the size for the remaining 11 wetlands is as given in Table 6-3; and
- For sizes from 4,718 to 37,744 acres, the total phosphorus removals are defined for 19 wetlands where the size of each wetland is increased from the reduced wetland area design given in Scenario 2 in proportion to the overall system size (i.e., by factors of 2 for 4,718 acres and by factors of 16 for 37,744 acres).

As shown in Figure 9-3, the slope of the line continually decreases from about 227 kg/acre-yr (56 g/m^2-yr) to 13 kg/acre-yr (3 g/m^2-yr) reflecting the general trend towards decreasing treatment efficiency with increasing wetland system size. This is in agreement with the prior results for the Top 5 and Top 10 wetlands. Figure 9-3 shows that a 60 percent load reduction can be obtained for the New River with about 3,800 acres of wetlands; a 70 percent load reduction can be obtained for the New River with about 7,000 acres of wetlands; and an 80 percent load reduction cannot practically be obtained for the New River.

Figure 9-4 shows a plot of total phosphorus loads from the Alamo River to the Salton Sea as a function of wetland system size in acres. The Alamo River wetland system for various wetland area sizes was determined as follows:

- For sizes from 313 to 888 acres, the total phosphorus removals are as given for the Top 5 Alamo River wetlands in Table 9-4;
- For a size of 1,276 acres, the total phosphorus removals are as given for the 16 wetland reduced wetland area design given in Scenario 2 (Section 6.3);
- For sizes from 1,589 to 2,164 acres, the total phosphorus removals are defined for 16 wetlands, where the size of the Alamo River Top 5 wetlands is doubled from that given in Table 9-4 and the size for the remaining 11 wetlands is as given in as given in Table 6-3; and
- For sizes from 2,552 to 40,832 acres, the total phosphorus removals are defined for 16 wetlands where the size of each wetland is increased from the reduced wetland area design given in Scenario 2 in proportion to the overall system size (i.e., by factors of 2 for 2,552 acres and by factors of 32 for 40,832 acres).

As shown in Figure 9-4, the slope of the line continually decreases from about 95 kg/acre-yr (23 g/m^2-yr) to 10 kg/acre-yr (2 g/m^2-yr) reflecting the general trend towards decreasing treatment efficiency with increasing wetland system size. Figure 9-4 shows that a 60 percent load reduction can be obtained for the Alamo River with about 10,000 acres of wetlands; a 70 percent load reduction can be obtained for the New River with about 40,000 acres of wetlands; and an 80 percent load reduction cannot be obtained for the Alamo River. Even a 70 percent load reduction for the Alamo River cannot be practically obtained since the acreage requirement is so high.

Comparing the results for the New and Alamo Rivers in Figures 9-3 and 9-4, it is apparent that the New River wetlands can achieve much greater reductions in the total phosphorus load than the Alamo River wetlands for the same wetland area size. This is in agreement with the higher removal efficiencies for the New River, which are attributed to the higher overall total phosphorus concentrations in the New River and its' drains. Thus, an optimum wetland system for both rivers would place more wetlands along the New River to take advantage of the higher removal efficiencies for the New River. Figure 9-5 shows a plot of total phosphorus load reduction for both rivers, where the size and locations of wetlands are defined using the data for each river from Figures 9-3 and 9-4, but sorted based upon a preference for higher wetland efficiency. As shown in Figure 9-5:

- A system of 7,200 acres of wetlands (4,700 acres on the New River and 2,500 acres on the Alamo River) can achieve an overall total phosphorus load reduction of 50 percent;
- A system of 12,000 acres of wetlands (7,000 acres on the New River and 5,000 acres on the Alamo River) can achieve an overall total phosphorus load reduction of 60 percent; and
- A 70 percent load reduction cannot be practically obtained since the acreage requirement is so high (about 30,000 acres).

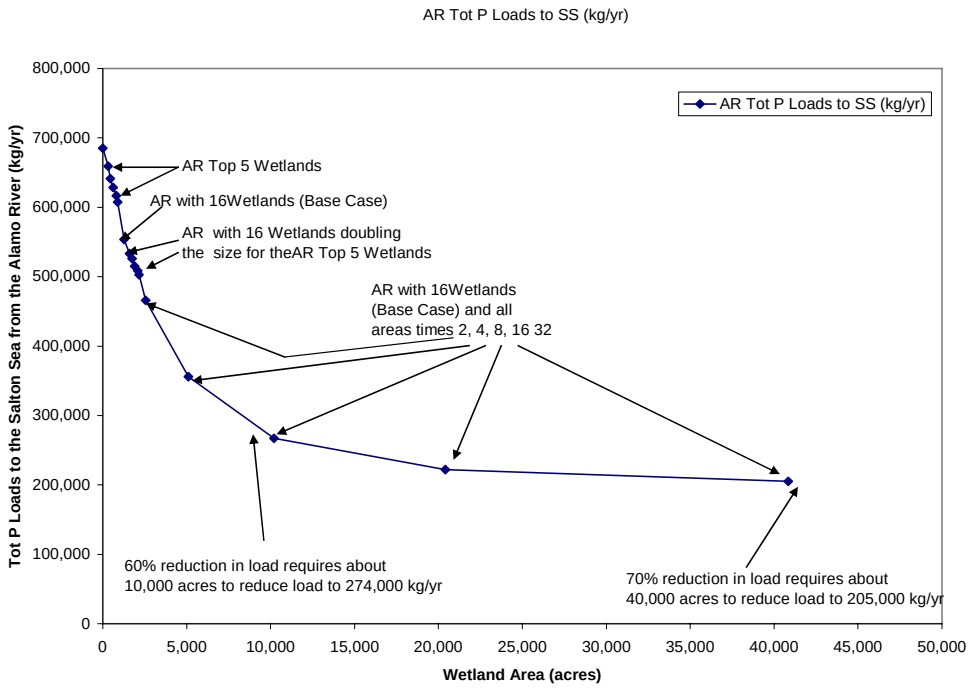


Figure 9-3 Total phosphorus loads from the New River to the Salton Sea as a function of wetland system size.

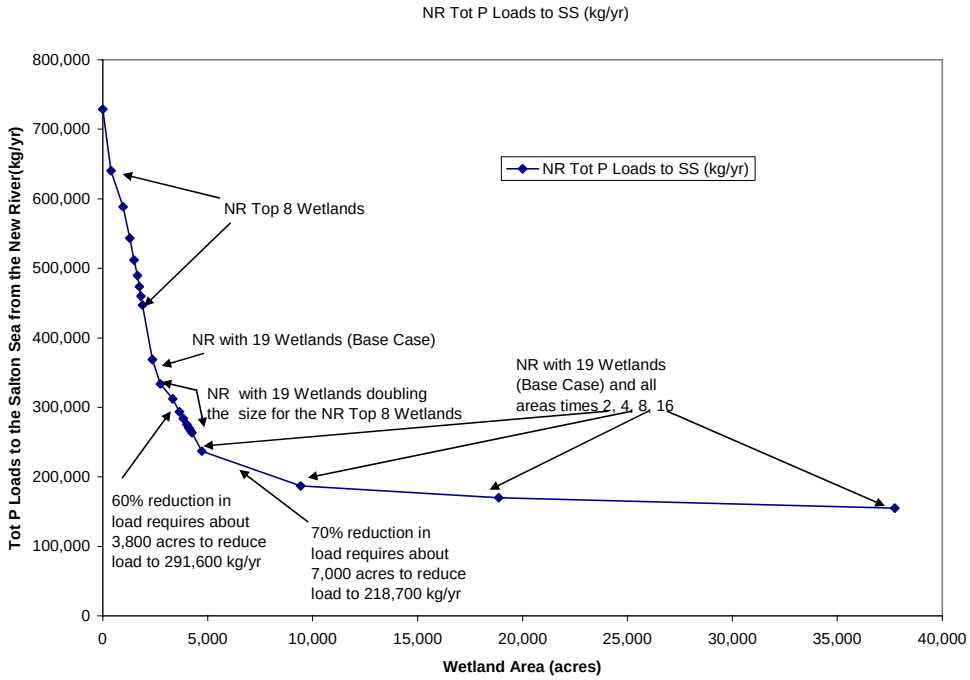


Figure 9-4 Total phosphorus loads from the Alamo River to the Salton Sea as a function of wetland system size.

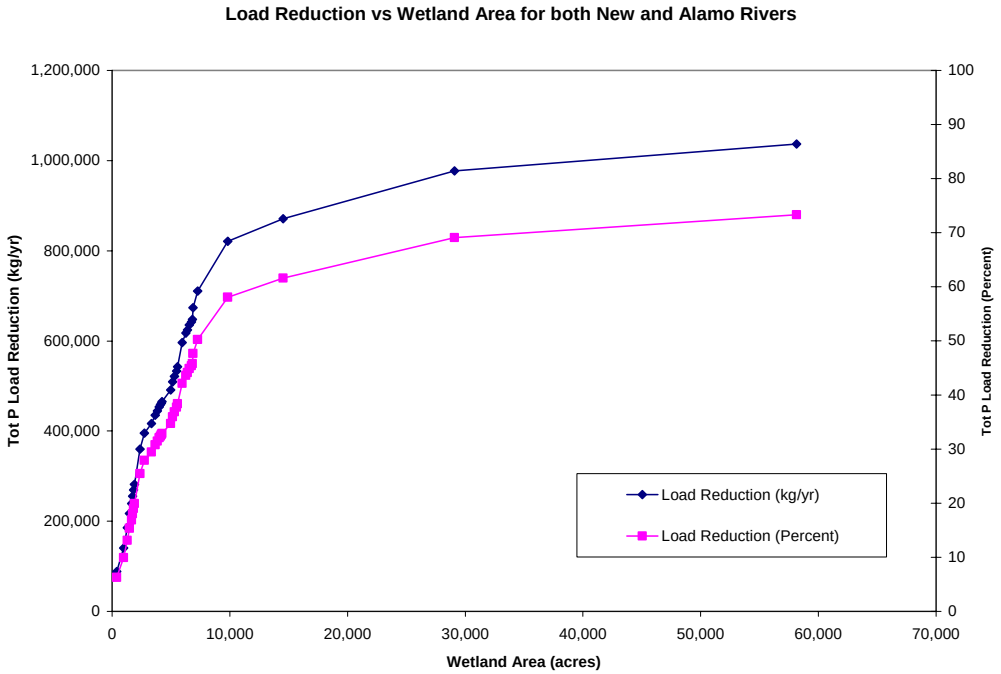


Figure 9-5 Reduction in total phosphorus loads from both the New and Alamo Rivers to the Salton Sea as a function of wetland system size.

9.7 Scenario 8: Additional Wetlands in Northern Reaches of New and Alamo Rivers

The Top 35 wetland design includes 16 wetlands along the Alamo River, with the last wetland (AR13) located 9.6 river miles south of the Salton Sea. As discussed in Section 5, some 25 percent of the total phosphorus load enters the Alamo River north of wetland AR13 in this 9.6 mile reach of the river, including inflows from large minor drains such as the E, G, and I drains. Thus, a large portion of the river total phosphorus load in this far north portion of the Alamo River watershed is untreated by the Top 35 wetland design. Likewise, the Top 35 wetland design includes 19 wetlands along the New River, with the last wetland (NR8) 14.2 river miles south of the Salton Sea. As discussed in Section 5, some 25 percent of the total phosphorus load enters the New River north of wetland NR8 in this 14.2 mile reach of the river, including inflows from large minor drains such as the Timothy 1, Trifolium 6, Trifolium 7, and Trifolium 9 drains. Thus, a large portion of the river total phosphorus load in this far north portion of the New River watershed is untreated by the Top 35 wetland design.

In this section, a 37 wetland design is considered where two new wetlands are added in this area, one in the 9.6 mile long reach in the far north of the Alamo River and one in the 14.2 mile long reach in the far north of the New River. Tables 9-7 and 9-8 give the model predicted total phosphorus removals for one new 143 acre wetland treating 2,561 AF/yr located at various positions along these two reaches of the rivers. The wetland size and hydraulic loading used were chosen to reflect the approximate average of the values for all wetlands. Locations considered for the wetlands in Tables 9-7 and 9-8 were chosen based upon proximity to drains with large total phosphorus loads discharging into the river. Scenarios considered both the treatment of only river water, and the treatment of both drain and river water.

For the scenario with a new wetland along the Alamo River, total phosphorus loads varied from approximately 527,000 to 542,000 kg/yr, in comparison to total phosphorus loads of 554,000 kg/yr in the Top 35 reduced area wetland scenario and 685,000 kg/yr in the base case (i.e., no wetland) scenario. Thus, the addition of one wetland can increase total phosphorus removals in the Alamo River from 19 percent of the total phosphorus load with 16 wetlands to as much as 23 percent of the total phosphorus load with 17 wetlands. Thus, by increasing the wetland acreage by only 10 percent, the total phosphorus removals can be increased by up to 20 percent. This is because the incremental total phosphorus removal efficiency for the new wetland - as high as 45 g/m^2-yr (Table 9-8) - exceeds the average total phosphorus removal efficiency of 26 g/m^2-yr and the typical incremental total phosphorus removal efficiency of 23 g/m^2-yr (Table 9-6). Optimum removal occurred with the wetland located near G Drain treating both river water and G drain water.

Table 9-7
Phosphorus Removals for New Wetland in North Alamo River Watershed
(North of Wetland AR13)

Wetland Location[1] (River mile)	Total Phosphorus Load (kg/yr)	Drains Treated	Incremental Total Phosphorus Load Reduction (kg/yr)	Incremental Total P Removal Efficiency (g/m^2-yr)
50.9	541,537	river water only	12,059	20
50.9	532,524	river water and E Drain	21,072	36
51.9	541,028	river water only	12,568	21
51.9	527,016	river water and G Drain	26,580	45
53.3	540,793	river water only	12,803	22
53.3	529,622	river water and I Drain	23,974	41
55.1	540,003	river water only	13,593	23
55.1	539,634	river water and Vail 2 Drain	13,962	24
55.1	534,284	river water and L Drain	19,312	33
55.1	533,908	river water and Vail 2 and L Drains	19,688	33
Results for 1,276 acres	553,596		131,696	26

Notes:
[1]New wetland size is 146 acres, treating 2561 acre-ft/month of water.

Table 9-8
"Phosphorus Removals for New Wetland in North New River Watershed (North of Wetland NR8)"

Wetland Location[1] (River mile)	Total Phosphorus Load (kg/yr)	Drains Treated	Incremental Total Phosphorus Load Reduction (kg/yr)	Incremental Total P Removal Efficiency (g/m^2-yr)
53.8	354,994	river water only	14,050	24
53.8	354,666	river water and Raymond Drain	14,378	24
56.5	354,629	river water only	14,415	24
56.5	354,416	river water and Timothy 1 Drain	14,628	25
59.6	351,260	river water only	17,784	30
59.6	349,140	river water and Trifolium 6 Drain	19,904	34
59.6	349,204	river water and Trifolium 7 Drain	19,840	34
59.6	347,010	river water and Trifolium 6 and Trofolium 7 Drains	22,034	37
61.4	351,071	river water only	17,973	30
61.4	351,123	river water and Trifolium 9 Drain	17,921	30
61.4	348,814	river water and Vail Drain	20,230	34
61.4	348,863	river water and Vail and Trifolium 9 Drains	20,181	34
64.6	350,865	river water only	18,179	31
Results for 2,359 acres	369,044		359,921	33

Notes:
[1]New wetland size is 146 acres, treating 2561 acre-ft/month of water.

For the scenario with a new wetland along the New River, total phosphorus loads varied from approximately 347,000 to 355,000 kg/yr, in comparison to total phosphorus loads of 369,000 kg/yr in the Top 35 reduced area wetland scenario and 729,000 kg/yr in the base case no wetland scenario. Thus, the addition of one wetland can increase total phosphorus removals in the New River from 49 percent of the total phosphorus load with 19 wetlands to as much as 53 percent of the total phosphorus load with 20 wetlands. Thus, by increasing the wetland acreage by only 5 percent, the total phosphorus removals can be increased by up to 10 percent. This is because the incremental total phosphorus removal efficiency for the new wetland - as high as 37 g/m^2-yr (Table 9-8)- exceeds the average total phosphorus removal efficiency of 33 g/m^2-yr and the typical incremental total phosphorus removal efficiency of 17 g/m^2-yr (Table 9-6). Optimum removal occurred with the wetland located near Trifolium 6 and Trifolium 7 Drains treating both river water, and Trifolium 6 and Trifolium 7 drain water.

Thus, for the scenario with one new wetland each along the Alamo River and the New River, total phosphorus loads varied from approximately 874,000 to 897,000 kg/yr, in comparison to total phosphorus loads of 923,000 kg/yr in the Top 35 reduced area wetland scenario and 1,414,000 kg/yr in the base case no wetland scenario. Thus, the addition of one wetland can increase total phosphorus removals from 35 percent with 35 wetlands to as much as 38 percent with 37 wetlands. Thus, for the combined river system, by increasing the wetland acreage by only 7 percent, the total phosphorus removals can be increased by up to 10 percent.

9.8 Scenario 9: Impact of Cross-Border Flows in the New River

The 1995-1999 estimated total phosphorus load in the New River is 729,000 kg/yr, and 374,000 kg/yr of this load is estimated to come from flows that cross the US-Mexico border in the New River. Thus, the cross-border loads of total phosphorus in the New River are significant, comprising 51 percent of the total phosphorus load from the New River to the Salton Sea. Currently, there are plans to treat the sources of the total phosphorus loads in

Mexico –agricultural return flows, industrial wastewater discharges, and municipal wastewater discharges – and reuse this treated water in Mexico. This could result in a dramatic reduction in both the water flow and total phosphorus load crossing the US-Mexico border in the New River. The water quality model was used to evaluate the impact of this possible future condition, by eliminating the water flow and total phosphorus load in the New River at the US-Mexico border crossing.

For this condition, the model predicts the New River total phosphorus load into the Salton Sea will decline from about 729,000 kg/yr to about 355,000 kg/yr and the combined rivers load will decline from 1,414,000 to 1,040,000 kg/yr (Figure 9-6). With the construction of the 19 proposed wetlands along the New River, the total phosphorus load with no cross-border flows in the New River would reduce further to 208,000 kg/yr. For the wetlands scenario, the total phosphorus load reduction comes from loss in the wetlands of 92,000 kg/yr and loss in wetland seepage of 55,000 kg/yr. The combined rivers total load to the Salton Sea would then be 762,000 kg/yr, which is a 46 percent reduction from base case conditions.

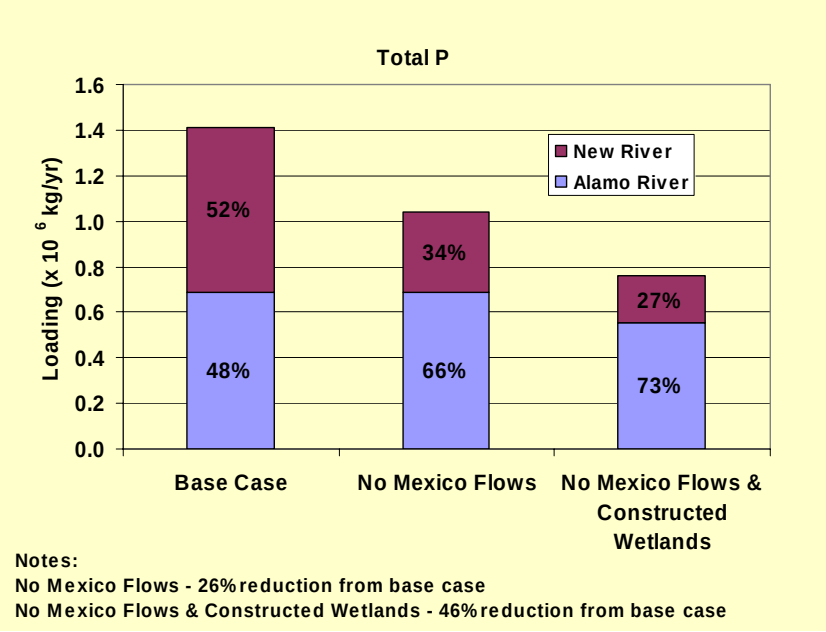


Figure 9-6 Impact of cross-border flows from Mexico on total phosphorus loading to Salton Sea.

9.9 Scenario 10: Impact of IID Conservation

As part of the Quantification Settlement Agreement (QSA), the Imperial Irrigation District (IID) agreed to a transfer of water to the San Diego County Water Authority and the Coachella Valley Water District. By 2028, the IID must be conserving and transferring nearly 303,000 acre-feet annually. At least two-thirds of that total will need to come from on-farm savings, with the first on-farm savings required no later than 2013 (IID Definite Plan website http://www.definiteplan.com/intro-to-definite-plan.html, 2006). The 1995-1999 estimated flow from agricultural drains is about 914,000 AF/yr and comprise 78 percent of the total flow to the Salton Sea. Thus, the QSA could result in a reduction in the water flow around 20 percent.

The water quality model was used to evaluate the impact of IID conservation efforts. Flows to agricultural drains were assumed to be reduced by 20 percent; however, total phosphorus loads were assumed to remain constant. The wetlands are assumed to be constructed. For this scenario, the model predicts the total phosphorus load into the Salton Sea will decline from

1,414,000 to 846,000 kg/yr, which is a 40 percent reduction from base case conditions (Figure 9-7). For the wetlands modeling, the total phosphorus load reduction comes from loss in the wetlands of 299,000 kg/yr and loss in wetland seepage of 231,000 kg/yr.

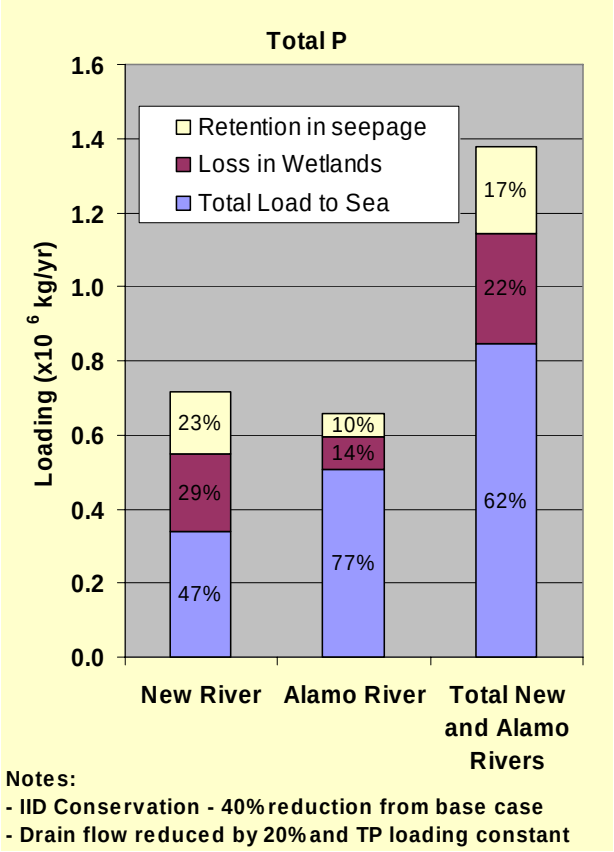


Figure 9-7 Impact of IID conservation efforts on total phosphorus loading to Salton Sea.

9.10 Scenario 11: IID Surveyed Sites

The Imperial Irrigation District (IID) and the Citizens Congressional Task Force on the New River (Task Force) conducted analytical transect surveys and topographic surveys for assessing the overall feasibility of the 42 potential wetland and sedimentation basin sites identified by Nolte Engineering (2002). Profiles of the potential wetland sites were created from field surveyed transects to determine hydraulic feasibility for gravity flow. Each site was evaluated based on the feasibility of gravity flow and potential site constraints. If the site was determined to be not feasible for gravity flow, the site as a whole was characterized as infeasible. A full topographic survey was performed for sites that were determined to be hydraulically feasible for gravity flow (Davey-Cairo Engineers, 2005a, 2005b, 2006a, 2006b).

The recent survey identifies 25 surveyed sites. Fourteen sites are located on the Alamo River, of which 2 are sedimentation basins only, for a total of 970 acres. Eleven wetland sites are located on the New River for a total of 1,523 acres. The total wetland area of 2,493 acres represents a reduction of 42 percent of the Top 35 Wetland Scenario presented in Section 8, which totaled 4,276 acres.

Table 9-9 presents the surveyed wetlands, wetted areas, and design flow. Wetted areas are defined as 85 percent of the total surveyed areas. The design inflows are calculated from a

regression equation (r^2=0.96) based on the Top 35 wetland areas and design inflows (see Table 6-1).

Table 9-7
IID 2006 Surveyed Wetland Sites

River	Site	Area[1] (acres)	Design Inflow[2] (AF/mo)
Alamo River			
	Calipatria	44	873
	AR30	43	858
	AR28	25	572
	AR23	45	889
	AR22	100	1,761
	AR21	53	1,016
	AR19	60	1,127
	AR18	9	318
	AR17	19	477
	AR16	25	572
	AR15	500	8,104
	AR14	22	525
	AR7[3]	20	493
	AR3[3]	5	255
	Total	**970**	**17,841**
New River			
	NR32	75	1,365
	NR30	59	1,111
	NR28	12	366
	NR26	25	572
	NR24	250	4,140
	NR21	37	762
	NR19	104	1,825
	NR18	80	1,444
	NR17	280	4,615
	NR16	525	8,500
	NR13	76	1,381
	Total	**1,523**	**26,082**
Combined Rivers		**2,493**	**43,922**

Notes:
1. Wetland surface areas based on topographic surveys (Davey-Cairo Engineers, 2006a,b). Wetted areas defined as 85% of total surveyed areas.
2. Design flow defined by regression equation (r^2=0.96), based on design flow as a function of area (see Table 6-1 for data used to develop regression equation). This scenario assumes all wetlands designed for plug flow.
3. Sedimentation basins only.

For this scenario, the model predicts the New River total phosphorus load into the Salton Sea will decline from about 729,000 kg/yr to about 486,000 kg/yr and the Alamo River total phosphorus load into the Salton Sea will decline from about 685,000 kg/yr to about 575,000 kg/yr (Figure 9-8). The total phosphorus load reduction comes from loss in the wetlands of 192,000 kg/yr and loss in wetland seepage of 188,000 kg/yr. The combined rivers total load to the Salton Sea would then be 1,060,000 kg/yr, which is a 25 percent reduction from base case conditions.

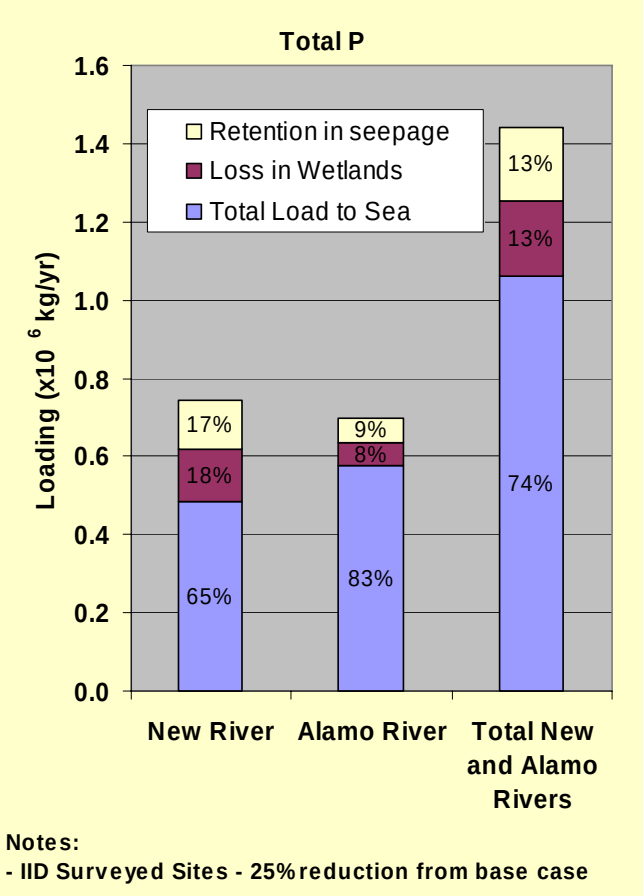


Figure 9-9 Total phosphorus loading to Salton Sea based on IID surveyed wetland sites (Davey-Cairo Engineers, 2006a,b).

CHAPTER 10
ECOLOGICAL RISK ASSESSMENT

10.1 Introduction

The New and Alamo Rivers are polluted by nutrients, pesticides, heavy metals, pathogens, and suspended sediments. The New and Alamo Rivers are listed by California State Water Resources Control Board Region 7 on the 303(d) List of Water Quality Limited Segments because they both have constituents that exceed water quality objectives. Total maximum daily loads (TMDLs) for the New and Alamo Rivers have been completed by the Regional Board (California Regional Water Quality Control Board 2002a, 2002b, 2002c, 2002d, 2006). These documents have mandated the reduction of pathogenic bacteria, pesticides (especially, DDD, DDE, DDT, and toxaphene), selenium, 1,2,4-trimethylbenzene, chloroform, m,p-xylenes, nutrients, dissolved organic matter, dissolved oxygen, o-xylene, p-cymene, p-dichlorobenzene (DCB), sediment/silt, trash, and toluene concentrations in the New and Alamo Rivers. Similarly, agricultural drains in the Imperial Valley, which feed into the New and Alamo Rivers, were also listed on the 303(d) list for silt, pesticides, and selenium (California Regional Water Quality Control Board 2002a, 2005).

Although constructed wetlands may remove nitrogen, phosphorus, fecal coliforms, and total suspended solids as discussed in preceding chapters, they may also serve to concentrate the selenium and organochlorine pesticides that are already in the agricultural drainage water and New and Alamo Rivers. This may lead to elevated risks to wildlife that may use the treatment wetlands. To determine whether selenium and organochlorine pesticides present in the treatment wetlands represent a risk to wildlife, Tetra Tech collected water, sediment, aquatic plant/algae, aquatic invertebrate, and fish samples from the treatment wetlands and sites representative of background conditions. The analytical results from these samples were used to evaluate the potential ecological risks to aquatic invertebrates, mosquitofish, larger fish (*e.g.,* bluegill), representative resident and migratory birds, and resident piscivorous mammals.

The main objectives of this assessment were the following:

1) characterize the wildlife potentially present at treatment wetlands on the New and Alamo Rivers;

2) characterize selenium and organochlorine pesticides in water, sediment, aquatic invertebrates, and fishes at

a) the Brawley and Imperial Pilot Wetlands and

b) locations representative of ambient conditions in the New and Alamo Rivers as well as agricultural drains in the area

3) conduct an ecological risk assessment for receptors at the Brawley and Imperial Pilot Wetlands.

The methods used to accomplish each of these objectives are explained below.

10.1.1 Ecological Risk Assessment

An ecological risk assessment (ERA) evaluates the potential for adverse ecological effects that might occur as a result of assumed exposures to selenium and organochlorine pesticides at the treatment wetlands. The ERA process systematically evaluates and organizes data, assumptions, and uncertainties to help understand and predict the relationships between chemical stressors and ecological effects in a way that is useful for decision-making. The predictive ERA for the treatment wetlands was conducted in accordance with State and federal guidance (DTSC 1996a,b; U.S. EPA 1992a, 1997, 1998, 2006a) and consists of the following elements:

- Problem Formulation;
- Analysis; and
- Risk Characterization.

Each of these elements of the ERA is explained below.

10.1.1.1 Problem Formulation

The problem formulation establishes the scope of the ecological risk assessment, identifies the major factors to be considered, and ensures that both the ecological receptors most likely to be exposed and the exposure scenarios most likely to contribute to ecological risks are evaluated. The problem formulation consists of the following tasks, each of which will be discussed in further detail in Section 3:

- Identify potentially affected aquatic plants, invertebrates, amphibians, birds, piscivorous mammals, and fish;
- Identify chemicals of potential ecological concern (COPECs);
- Identify potentially complete exposure pathways; and
- Establish assessment endpoints.

10.1.1.2 Analysis

The analysis phase consists of an evaluation of the data required to estimate exposures and to characterize effects (U.S. EPA 1992a, 1998). The analysis phase consists of the following tasks, each of which will be discussed in further detail in Section 4:

- Select indicator species and wildlife exposure factors;
- Characterize bioaccumulation of chemicals through the food chain; and
- Establish toxicity reference values (TRVs).

10.1.1.3 Risk Characterization

The risk characterization integrates the results of the analysis phase (*i.e.*, exposure and effects) to evaluate the likelihood of adverse ecological impacts associated with exposure to COPECs (U.S. EPA 1992a). The risk characterization consists of the following subtasks:

- Calculate risk estimates (*i.e.*, hazard quotients);
- Identify and characterize sources of uncertainty; and
- Conduct risk interpretation.

10.2 Guidance

This ERA was performed according to the following guidance documents and work plans:

- Guidance for Ecological Risk Assessment at Hazardous Waste Sites and Permitted Facilities (DTSC 1996a, 1996b)
- HERD Ecological Risk Assessment Notes 2 and 4 (DTSC Human and Ecological Risk Division (HERD), 1999, 2000)
- Guidelines for Ecological Risk Assessment (U.S. EPA 1998)
- Ecological Risk Assessment Guidance for Superfund Sites: Process for Designing and Conducting Ecological Risk Assessments – Interim Final (U.S. EPA 1997)
- Framework for Ecological Risk Assessment (U.S. EPA 1992a)
- Assessing Risks to Populations at Superfund and RCRA Sites Characterizing Effects on Populations (U.S. EPA 2006a)
- Work Plan for New and Alamo River Wetland Master Plan: Phase I Studies (Tetra Tech 2006a)

10.3 Problem Formation

The problem formulation presents and evaluates information that is used to develop and focus the analysis component of the ERA. The problem formulation phase is a process for generating and evaluating preliminary hypotheses about why ecological effects have occurred, or may occur, from environmental conditions at the site in question. As such, the problem formulation lays the foundation for the risk assessment and, therefore, requires the careful integration of many pieces of information. The information evaluated includes:

- Site Background: provides a description of the physical setting, climate, historical activity at the site, and previous site investigations that have been conducted.
- Ecological Characterization: provides a description of the ecological setting, including identification of habitats and potential ecological receptors.
- Chemicals of Potential Ecological Concern (COPECs): provides a description of the preliminary identification of COPECs based on the sampling efforts, including preliminary evaluations of data usability, and comparisons of preliminary data to screening effect levels to identify COPECs.
- Assessment Endpoints and Measures: provides a description of the development of assessment endpoints (*i.e.*, important aspects of the site to be protected), risk hypotheses (*i.e.*, statements of how potential exposure to stressors could occur at the site and

potential adverse effects), and measures (of exposure, effect, and of ecosystem and receptor characteristics).

A principal result of the problem formulation phase is an ecological conceptual site model (CSM) that describes potential ecological receptors that may be affected at the site. This conceptual site model is also used to guide the development of the analysis plan which delineates the assessment design, data needs, measures, and methods for conducting the analysis phase of the risk assessment. Upon completion of the problem formulation, the next step in the ERA process is the analysis.

10.3.1 Site Background

10.3.1.1 Location and Setting

The location and setting of the Brawley and Imperial Pilot Wetlands are discussed thoroughly in Chapter 1. Both wetlands contain baffles and benches with vegetation to retain the water for a longer period of time by creating a meandering pathway for the water to flow through. However, both wetlands still contain significant areas of open water, as shown in aerial photographs (see Chapter 1).

10.3.1.2 Climate

The Brawley and Imperial wetlands are located in the Salton Sea Basin, which is located in the Lower Colorado River Valley of the Sonoran desert (Phillips and Comus 2000). In the Sonoran desert, there are two rainy seasons; one is from December to March and the other is from July to mid-September. Winters in the area are mild, with frosts rarely occurring (Phillips and Comus 2000). Meteorological data from 1927 to 2005 indicate that this area is very arid, with an average annual rainfall of just 2.66 inches. The lowest temperatures occur in December and January, when the average temperature is 39° F. The highest temperatures occur in July, when the average temperature is 107° F; however, the average temperature is above 100° F from June through September (Western Regional Climate Center 2006).

10.3.1.3 Site History

Prior to the construction of the Brawley and Imperial wetlands, the area was sparsely vegetated with desert scrub brush. No buildings were located on the Site prior to the construction of the Wetlands.

10.3.1.4 Previous Investigations

10.3.2 Imperial Irrigation District Surface Water, Sediment, and Biota Monitoring

The Imperial Irrigation District (IID) collected data from January 2001 through May 2005 to assess the effectiveness of Brawley and Imperial Pilot Wetlands. Data collected from the pilot wetlands included flows, aqueous constituent concentrations, sediment constituent concentrations, and concentrations of various constituents in biota, including fish, plant tissues, bird eggs, and sediments (Tetra Tech 2006b).

A screening ecological risk assessment was conducted by comparing measured concentrations of selenium and pesticides to published criteria protective of sensitive ecological receptors. Surface water concentrations of selenium exceeded the screening criteria, although the concentrations of selenium in the wetlands are the same as in the source waters. For sediments, DDE, DDT, and selenium exceeded screening criteria. For aquatic

plant tissues, the maximum concentration of selenium was greater than the screening levels. For fish, the maximum concentrations of selenium in several fish species exceeded screening criteria. For aquatic invertebrates, none of the measured tissue concentrations exceeded the screening criteria. A limited number of eggs of wetland-dwelling birds were also collected and analyzed. Selenium concentrations observed in the bird eggs were at the upper end of background concentrations observed in the environment.

10.3.3 Imperial Irrigation District Bird Surveys

More than 400 species of birds use the Salton Sea region for permanent habitat, nesting grounds, or migratory uses (University of Redlands 2002). The relatively open waters of wetlands provide excellent foraging opportunities, where birds are likely to forage for aquatic invertebrates and small fish. Birds likely to inhabit wetlands in this area include the American coot, snowy egret, and the common moorhen.

Bird surveys were performed by the IID at the Brawley and Imperial wetlands between March 2001 and December 2003 to determine the bird species present. Detailed data from these surveys are presented in *Performance Evaluation of the New River Demonstration Wetlands* (Tetra Tech 2006b, see Appendix B). The most commonly observed species are summarized here. At the Brawley wetlands, the most commonly observed birds were the red-winged blackbird (*Agelaius phoeniceus*), the yellow-rumped warbler (*Dendroica coronata*), American coot (*Fulica americana*), yellow-headed blackbird (*Xanthocephalus xanthocephalus*), cliff swallow (*Petrochelidon pyrrhonota*), and common moorhen (*Gallinula chloropus*). At the Imperial wetlands, the most commonly observed birds were the yellow-rumped warbler (*Dendroica coronata*), red-winged blackbird (*Agelaius phoeniceus*), American coot (*Fulica americana*), yellow-headed blackbird (*Xanthocephalus xanthocephalus*), cattle egret (*Bubulcus ibis*), and pied-billed grebe (*Podilumbus podiceps*). A higher total number of birds were sighted at the Imperial wetland, probably due to its larger size.

10.3.4 Solar Evaporation Ponds Ecological Risk Assessment

One option for managing salinity in the Salton Sea is the use of evaporation ponds to remove salts from water withdrawn from the Sea. However, in addition to concentrating salts, evaporation ponds may concentrate contaminants present in these waters. Contaminants known to occur at the Salton Sea include PCBs, organochlorine pesticides, and heavy metals, especially selenium. A demonstration project was implemented to test the effectiveness of one type of evaporation ponds; *i.e.*, solar evaporation ponds. To determine if contaminants potentially present in the Solar Evaporation Ponds (SEP) represent a risk to birds that might use them as habitat, water and invertebrate tissue samples from the Salton Sea and SEP test facility were analyzed for PCBs, organochlorine pesticides, and heavy metals (Tetra Tech 2004). The analytical results from the samples collected at the Salton Sea and SEP test facility were used to evaluate the potential ecological risks to four indicator bird species; *i.e.*, snowy plovers, black-necked stilts, American avocets, and eared grebes. Potential ecological risks were also evaluated for the aquatic invertebrates that occur at the SEP. The risks for birds at the SEP were generally higher than for birds at the Salton Sea.

10.4 Ecological Characterization

Both the Brawley and Imperial wetlands are freshwater treatment wetlands located southwest of the Salton Sea (Figure 4-1). The wetlands appear to be highly productive as the edges are covered with dense reeds and infrequent large shrubs. The wetlands also serve as habitat for a large number of birds.

10.4.1 Identification of Habitats

The habitats at the Brawley and Imperial wetlands are very similar and are described together below. The New and Alamo Rivers are also described, along with the agricultural drains in the Imperial Valley and the Salton Sea.

10.4.1.1 Pilot Wetlands

In both wetlands, baffles and benches with vegetation create a meandering pathway for water to flow through. The edges of the wetlands are lined with dense reeds with a buildup of dead matter. In some area of each wetlands, there are large shrubs lining the wetland shoreline. The shorelines are generally steep, with the depth reaching several feet rapidly. No submerged aquatic plants are visible in either wetland, although floating algae (e.g., *Cladophora* sp., *Entereomorpha* sp., etc) is present at some times of the year. Mallards, coots, cormorants, cattle egrets, and American avocets were observed during sampling in November 2005 and May 2006. According to the IID bird survey, the most abundant species at the wetlands are: 1) red-winged blackbirds, 2) yellow-rumped warblers, 3) American coots, and 4) yellow-headed blackbirds (Tetra Tech 2006b). The California Department of Fish and Game (DFG) used a gill net to collect fish from these wetlands in 2004 and 2006. Fish caught by the DFG included bluegill, common carp, sailfin mollies, threadfin shad, and tilapia. Bass occur in the Imperial wetland, but at a very low density. Tetra Tech also collected mosquitofish, corixids, and glass shrimp from the treatment wetlands. Crayfish were found to occur in the wetlands, but very infrequently. Muskrats were observed swimming in the wetlands and raccoon footprints were observed around the edges.

10.4.1.2 Drains

Agricultural drains in the Imperial Valley are typically unlined channels with an average depth of 8 to 11 feet and width of 7 feet (CH2M Hill 2002). The banks are usually soft with a ratio of 1:1. The drains carry agricultural runoff (*i.e.*, freshwater) to the rivers and, as such, have variable flows and may have high levels of sediments at times. The biota found in the drains varies widely by location and condition. The following is a brief overview of the biota known from the drains (CH2M Hill 2002). Vegetation is usually limited to the banks of the drains, as the drains are dredged to maintain flow rates. Vegetation on the banks includes shrubs, salt cedar, tamarisk, reeds, and grasses. Aquatic macrophytes are also present in some locations. The drains are used as habitat by a number of birds, including herons, egrets, American avocets, red-winged blackbirds, burrowing owls, yellow-headed blackbirds, coots, and mallards. Muskrats, raccoons, and turtles also use the drains. The fish found in the drains include carp, shortfin mollies, sailfin mollies, catfish, threadfin shad, bass, bluegill, tilapia, mosquitofish, red shiner, and desert pupfish. Crayfish, amphibians, and corixids may also be locally abundant. Clams and snails are commonly observed in the dredge spoils of some drains.

10.4.1.3 New and Alamo Rivers

Aquatic habitat in the New and Alamo Rivers should be regarded as poor due to high turbidity, unstable substrates (CH2MHill 2002), low dissolved oxygen, and high bacterial counts (see Chapter 3). The rivers are lined with dense vegetation, including tamarisk and salt cedar. Fish populations in the rivers are probably limited by food availability and water quality, not by the water flow rates (CH2MHill 2002). Fish known to occur in the rivers include carp, sailfin mollies, catfish, cichlids, bass, tilapia, mosquitofish, and red shiner (CH2MHill 2002). Desert pupfish are not known from the rivers (CH2MHill 2002). Muskrats

have been observed in the rivers. The same birds that visit the agricultural drains and pilot wetlands are likely to visit the rivers. Crayfish, clams, and snails may occur in some areas.

10.4.1.4 Salton Sea

The Salton Sea is a eutrophic hypersaline (*i.e.*, salinity is 46 g/L) body of water. Because it is eutrophic, there are occasional algal blooms that lead to episodes of anoxia and fish die-offs. However, the eutrophic conditions support a relatively high productivity (Tetra Tech 2000). Phytoplankton are the dominant primary producers in the Sea, with larger plants in the Sea being largely restricted to areas near freshwater inflows. Invertebrates are abundant in the Sea and include copepods, barnacles, amphipods, corixids, and pileworms (*Neanthes* sp). Crayfish and clams are largely restricted to areas near freshwater inflows. Presently, the Salton Sea supports several species of fish, including porthole livebearer (*Poeciliopsis gracilis)*, longjaw mudsucker (*Gillichthys mirabilis)*, mosquitofish (*Gambusia affinis*), tilapia (*Oreochromis mossambicus* and *Tilapia zillii*), bairdiella (*Bairdiella icistia)*, sargo (*Anisotremus davidsoni)*, orange-mouth corvina (*Cynoscion xanthulus), and* desert pupfish (*Cyprinodon macularius*). However, as the salinity in the Sea continues to increase, the number of fish species present will decrease. The Salton Sea has become the center of avian biodiversity in the American Southwest, supporting over 400 species and averaging over 1.5 million birds annually. The Sea is an integral part of the Pacific Flyway, providing essential habitat for both resident and migrant species. The breeding bird communities on the Salton Sea represent a significant proportion of the breeding populations of many of these species. In addition, numerous species of migratory waterfowl depend on Salton Sea habitats.

10.4.2 Special-Status Species

Receptors of regulatory concern include federally and California state-listed threatened or endangered species, candidate species, or California Species of Special Concern. To identify receptors of regulatory concern that may occur along the New and Alamo Rivers, the California Natural Diversity Database (CNDDB; CDFG 2005) was queried for the following USGS quadrants: Brawley, Brawley NW, Calexico, Heber, Mount Signal, Obsidian Butte, Seeley Westmorland, Alamorio, Bond's Corner, Calexico, Holtville East, Holtville West, and Niland. The CNDDB lists 28 plant and animal species that are either state or federally listed and occur within the Salton Sea area. Of these 28 species, five are plants (*i.e.*, the Abram's spurge, chaparral sand-verbena, the hairy stickleaf, rock nettle, and sand food), two are invertebrates (*i.e.*, *Melitta californica* [an insect] and brown turban snail [intertidal snails]), one is an amphibian (*i.e.*, the California river toad), one is a reptile (*i.e.*, the flat-tailed horned lizard), 14 are birds (*i.e.*, the black skimmer, black-tailed gnatcatcher, burrowing owl, Caspian tern, the Crissal thrasher, the ferruginous hawk, gray-headed junco, gull-billed tern, Le Conte's thrasher, mountain plover, short-eared owl, white-faced ibis, yellow warbler, and the Yuma clapper rail), two are fish (*i.e.*, the desert pupfish and the razorback sucker), and three are mammals (*i.e.*, the Western yellow bat, American badger, and the Colorado Valley woodrat). In addition, the wildlife surveys conducted in the pilot treatment wetlands were used to identify receptors of regulatory concern that may occur there.

The areas surrounding and within the wetlands may also provide suitable habitat, nesting grounds, or stopover grounds for numerous migratory bird species.

10.5 Chemicals of Potential Ecological Concern

Chemicals of potential ecological concern (COPECs) are chemicals detected in potentially affected areas that may adversely impact the identified receptors of concern. Surface water, aquatic plants, sediment, aquatic invertebrates, fish, and tadpoles were sampled analyzed for

organochlorine pesticides and selenium. Only the data from the 2006 sampling event are used in selection of COPECs and the estimation of exposures.

All detected chemicals were selected as COPECs:

- Selenium; and
- Organochlorine pesticides.

COPECs specific to each medium in the Brawley and Imperial Wetlands, agricultural drains, and New and Alamo Rivers are identified in Table 10-1. All chemicals identified as COPECs were quantitatively evaluated in the risk assessment.

10.6 Assessment Endpoints and Measures

A key goal of an ERA is to identify and characterize the potential for significant adverse impacts resulting from exposures at a site, so that methods to reduce, avoid, or eliminate these impacts may be considered. Assessment endpoints link the risk assessment to management concerns to ensure that the ERA provides information to assist in risk management decision-making. To support the risk evaluation, assessment endpoints for this ERA help define significant adverse impacts and focus ERA analyses.

Measures of exposure are contaminant concentrations in environmental media to which ecological receptors may be exposed (U.S. EPA 1998), including contaminant concentrations in surface water and sediment at the site. Receptor exposures were estimated from contaminant concentrations measured in environmental media using a variety of regulatory-based exposure models and methods, such as those found in the U.S. EPA's Wildlife Exposure Factors Handbook (1993).

Measures of effect are measurable responses by ecological receptors to contaminants (U.S. EPA 1998). The primary measures of effect used in this ERA were chronic reproductive or developmental impairment toxicity data.

10.6.1 Assessment Endpoints

A key task of problem formulation is the establishment of assessment endpoints. Assessment endpoints are "explicit expressions of the actual environmental value that is to be protected" (U.S. EPA 1992a, 1998) and provide the basis for all subsequent ERA efforts. Assessment endpoints have been established to protect potentially affected emergent plants, benthic invertebrates, aquatic invertebrates, fish, amphibian, bird, and piscivorous mammal populations at the Brawley and Imperial Wetlands. Assessment endpoints are comprised of two elements: (1) the receptor of concern and (2) a characteristic of that receptor that is important to protect and is potentially at risk (U.S. EPA 1992a).

Table 10-1
Chemicals of Potential Ecological Concern
New and Alamo Rivers, California

	Brawley and Imperial Wetlands							Agricultural Drains							New and Alamo Rivers			
Chemical	**Sediment**	**SW**	**Plant Tissue**	**Aquatic Insects**	**Tadpole Tissue**	**Crayfish and Glass Shrimp Tissue**	**Fish Tissue**	**Sediment**	**SW**	**Plant Tissue**	**Aquatic Insects**	**Tadpole Tissue**	**Crayfish and Glass Shrimp Tissue**	**Fish Tissue**	**Sediment**	**SW**	**Plant Tissue**	**Fish Tissue**
Inorganics																		
Selenium	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Pesticides																		
4,4'-DDD							•							•				
4,4'-DDE	•		•		•	•	•	•		•		•	•	•	•		•	•
4,4'-DDT							•	•						•	•			•
Aldrin							•											•
alpha-BHC					•	•												
alpha-Chlordane							•							•				•
beta-BHC								•										•
delta-BHC																		
Dieldrin	•						•	•				•		•	•		•	
Endosulfan I							•			•		•					•	•
Endosulfan II							•							•			•	
Endosulfan Sulfate							•										•	
Endrin							•											
Endrin aldehyde							•											
gamma-BHC (Lindane)															•			
gamma-Chlordane													•	•				•
Heptachlor	•						•							•				
Methoxychlor							•											

Definitions:
COPEC-Chemical of potential ecological concern.
SW-Surface water.
Notes:
• -COPEC in soil, surface water, or tissues
All detected organic compounds were selected as COPECs.

Assessment endpoints at the Brawley and Imperial Pilot Wetlands are:

- Survival and persistence of plants, benthic invertebrates, and aquatic invertebrates chronically exposed to COPECs;
- Survival and reproduction of fish and amphibians chronically exposed to COPECs;
- Survival and reproduction of birds chronically exposed to COPECs; and
- Survival and reproduction of piscivorous mammals chronically exposed to COPECs.

10.6.2 Measures

Three categories of measures are predictive of the assessment endpoints: (1) measures of exposure; (2) measures of effect; and (3) measures of ecosystem and receptor characteristics (U.S. EPA 1998). In this ERA, the following measures are used to determine the assessment endpoints.

- **Measures of Exposure:** The concentration of COPECs in surface waters, sediments, emergent plants, sediment invertebrates, aquatic invertebrates, and fishes.
- **Measures of Effects:** The adverse effects in plants, benthic invertebrates, aquatic invertebrates, fish, amphibians, and birds in response to exposure to a COPEC. Different adverse effects may have been selected in the development of the NOAEL TRV (based on the No-Observable Adverse Effects Level [NOAEL]) and the LOAEL TRV (based on the Lowest-Observable Adverse Effects Level [LOAEL]).
- **Measures of Ecosystem and Receptor Characteristics:** Abundance and distribution of plants and invertebrates occurring at the Brawley and Imperial Wetlands. The natural reproduction, growth, and mortality of bird populations visiting and foraging at the Brawley and Imperial Wetlands.

10.7 Ecological Conceptual Site Model

The ecological conceptual site model (CSM) combines information about the COPECs, potential ecological receptors, and potential exposure pathways to provide an overall picture of site-related exposures that is used to refine and focus the ERA evaluation. An ecological CSM for the Brawley and Imperial Wetlands is presented in Figure 10-1.

10.7.1 Identification of Representative Species

As it is impractical to evaluate all receptors at a site, this baseline ERA evaluates risks for a set of representative species. Risks estimated for representative species are subsequently used to infer the potential for adverse impacts to taxonomically and functionally related receptors of concern.

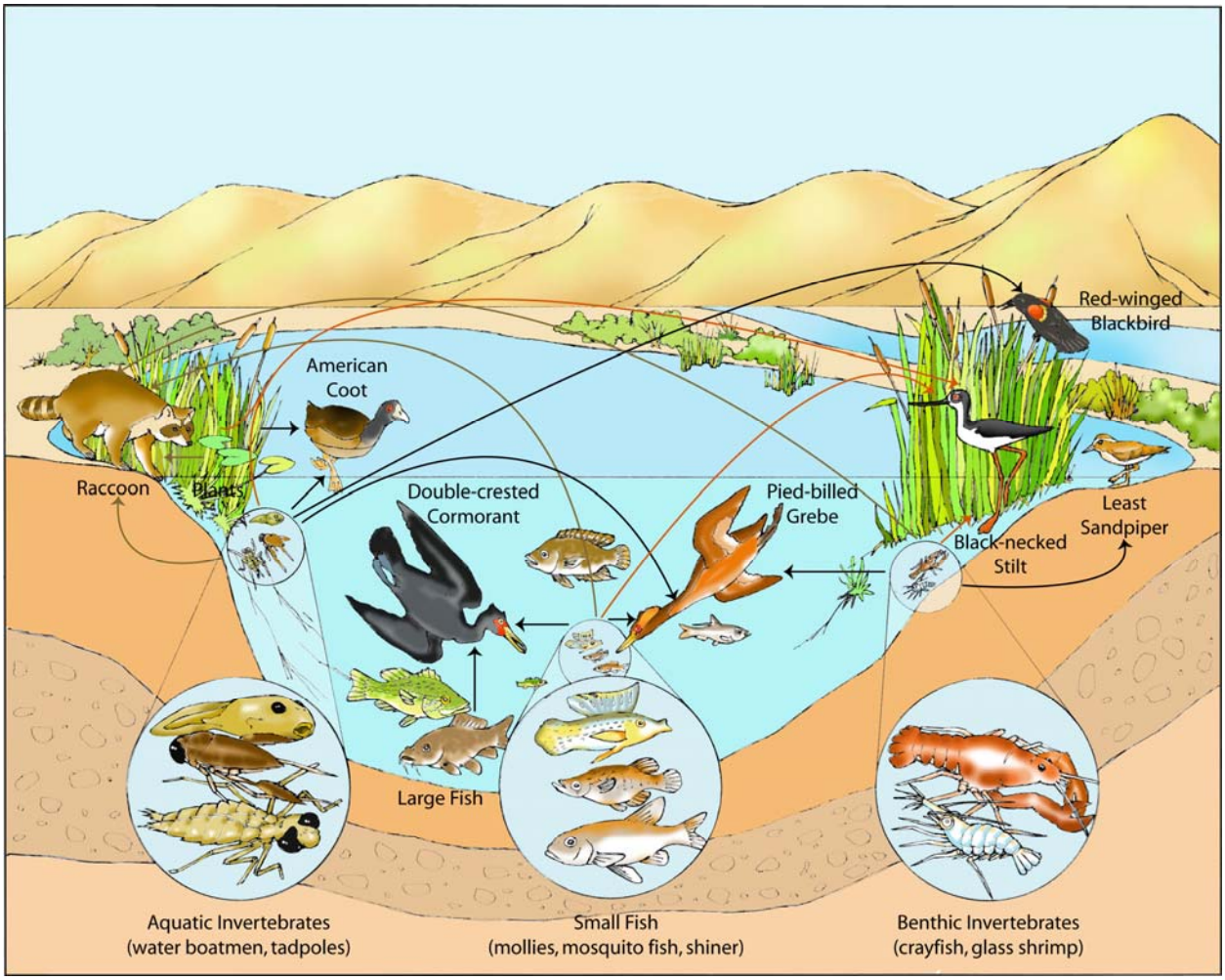


Figure 10-1 Conceptual site model, showing the receptors used in the risk assessment, their food sources and pathways of risk.

Representative ecological receptors were identified as the biological organisms most likely to be exposed to the COPECs at the New and Alamo River sites and were determined through direct observations of wildlife at the Brawley and Imperial Wetlands in conjunction with listings of special-status species that may be found in the area. Representative ecological receptors were selected to fulfill as many of the following criteria as possible:

- Species that have been observed, or are likely to occur, at the Brawley and Imperial Wetlands;
- Species that are likely to be maximally exposed to the COPECs;
- Species that are known to play an integral role in the ecological community structure at the site; and
- Species that are representative of specific foraging guilds or serve as food items for higher trophic levels.

The representative ecological receptors selected for the Brawley and Imperial Wetlands ERA are:

- Emergent plants;

- Benthic invertebrates;
- Aquatic biota (*i.e.*, algae and aquatic plants, aquatic invertebrates, fish, and amphibians);
- Aquatic and terrestrial birds (*i.e.*, least sandpiper, black-necked stilt, pied-billed grebe, American coot, double-breasted cormorant, and red-winged blackbird); and
- Piscivorous mammals (*i.e.*, raccoon).

Each of the selected representative species is described below.

Emergent plants: Emergent plants (*i.e.*, cattails, grasses, and sedges) are found at the wetlands and provide food, nesting sites, and cover for a variety of bird, insect, amphibian, and mammal species. Emergent plants were assumed to be exposed to COPECs in sediment at the wetlands.

Aquatic biota:

Aquatic plants (*i.e.*, macrophytes and filamentous algae) are found at the wetlands and provide food, nesting sites, and cover for a variety of bird, insect, and amphibian species. Aquatic plants were assumed to be exposed to COPECs in water at the wetlands.

Several types of aquatic invertebrates are likely to occur at the wetlands, including crayfish, glass shrimp, and water boatmen. All aquatic invertebrate species are prey items for birds as well as raccoons. Aquatic invertebrates were assumed to be exposed to COPECs in water and sediment at the wetlands.

Both small fish species (*i.e.*, mosquitofish and sailfin molly) and larger fish species (*i.e.,* bluegill, common carp, tilapia, and threadfin shad) are found throughout the Brawley and Imperial wetlands. Fish are exposed to COPECs through water, sediment, and food items, which may include plants, algae, and aquatic invertebrates. Fish are an essential part of the diet for a variety of bird species found at the wetlands. Raccoons may also prey upon fish at the wetlands.

Amphibians such as salamanders, newts, frogs, and toads may breed in or inhabit the wetlands. Amphibians are exposed to COPECs through water, sediment, and food items including aquatic invertebrates. Amphibians may be preyed upon by birds and raccoons in the wetlands.

Birds: Six bird species were selected as representative receptors. These bird species are representative of six feeding guilds and represent both resident and migratory species. The species selected as representative receptors are described below.

Least sandpiper: This bird species has been observed at both the Brawley and Imperial wetlands. It is a summer and winter visitor at the nearby Salton Sea, and may be a resident along the New and Alamo Rivers. The least sandpiper is a likely breeder at the Brawley and Imperial wetlands. It is considered representative of a small probing shore bird (mean body weight = 21 g (Dunning 1984, Cooper 1994)), and forages on small benthic invertebrates in marshes, mudflats, ditches, and fields. Since the least sandpiper is assumed to breed at the wetlands, the site presence index (SPI) was set equal to 1.0. The site presence index (SPI) is the proportion of the time a species is expected to spend at the site. The rate of incidental ingestion of sediment was assumed to be 7.3% (Beyer *et al.* 1994).

Black-necked stilt: This bird species has been observed at both the Brawley and Imperial wetlands, where it was seen probing/picking the water for invertebrates. It is considered representative of the “probing shore bird” foraging guild, and is larger than the least sandpiper, with a mean body weight of 170 g (Robinson *et al.* 1999). It is a year-round

resident and breeder at the Salton Sea and surrounding areas, including the New and Alamo Rivers. The rate of incidental ingestion of sediment was assumed to be 20%, calculated as the average for 5 species of probing shorebirds (Beyer *et al.* 1994, Hui and Beyer 1998). Since the black-necked stilt was assumed to breed at the wetlands, the SPI was assumed to be 1.0.

Pied-billed grebe: This bird is a frequently observed resident at the Brawley and Imperial wetlands, and is assumed to breed at the wetlands. This bird feeds opportunistically on crustaceans (especially crayfish), aquatic insects, and fish by diving and picking. Pied-billed grebes are moderately sized birds, with a mean body weight of 358 g (Muller *et al.* 1999). The incidental sediment ingestion rate of 3.0% used in this risk assessment was calculated from the average for eight species of ducks (Beyer *et al.* 1994, Beyer *et al.* 1999). The foraging area for the pied-billed grebe is 1.2 ha (Zeiner *et al.* 1990, Muller *et al.* 1999), which, as compared with the site area of 17.4 ha for the Brawley Wetland and 3.6 ha for the Imperial Wetland, results in SPIs of 1.0 for the wetlands.

American coot: This bird is a frequently observed breeding resident at the Brawley and Imperial wetlands. This bird forages on aquatic plants, primarily pondweeds, sedges, algae, and grasses, and will occasionally eat insects. The mean body weight for the American coot is 560 g (Brisbin *et al.* 2002). The incidental sediment ingestion rate was assumed to be similar to the wood duck, which had the highest sediment ingestion rate among the eight species of ducks for which sediment ingestion rates are known (Beyer *et al.* 1994, Beyer *et al.* 1999). The sediment ingestion rate of 11.0%, was considered appropriate, as the actual measured proportion of sediment in American coot stomach contents ranges up to 44% (Beyer *et al.* 1994, Beyer *et al.* 1999, Brisbin *et al.* 2002). The foraging area for the American coot is 0.15 ha (Brisbin *et al.* 2002), which, as compared with the site area of 17.4 ha for the Brawley Wetland and 3.6 ha for the Imperial Wetland, results in SPIs of 1.0 for the wetlands.

Double-crested cormorant: Double-crested cormorants occur at the Brawley and Imperial wetlands as both breeding and non-breeding, residents and visitors. This bird forages exclusively on fish, which it captures by diving through the water. The mean body weight for the double-crested cormorant is 2,056 g (Hatch *et al.* 1999). As these birds feed only in the water column, their contact with sediment is expected to be minimal. Therefore, their incidental sediment ingestion rate was assumed to be 1.0%, taken from the minimum sediment ingestion rate among the eight species of ducks for which sediment ingestion rates are known (see Beyer *et al.* 1994, Beyer *et al.* 1999). The foraging area for the double-crested cormorant is 2,830 ha, based on an average foraging distance of 3 km from their nesting site (Hatch *et al.* 1999). Although this area is larger than the combined site areas of the wetlands (21 ha), the SPI was conservatively assumed to be 1.0 to be protective of cormorants that may be chronically exposed to COPECs in the wetlands while breeding.

Red-winged blackbird: The red-winged blackbird is considered to be representative of terrestrial birds found throughout the Brawley and Imperial wetlands. As the most abundant species sighted during the bird survey at the pilot treatment wetlands, red-winged blackbirds are common residents that breed at the sites. This bird forages on both terrestrial invertebrates and emergent vegetation, but may exclusively consume invertebrates during the breeding season. The mean body weight for red-winged blackbirds is 41.5 g (Yasukawa *et al.* 1995). The incidental sediment ingestion rate was assumed to be similar to that of the American woodcock, or 10.4% (Beyer *et al.* 1994). Although red-winged blackbirds may forage up to 80 km outside of their territories, an SPI of 1.0 was assumed to account for breeding females that forage within the territories. Defended territories are approximately 0.03 to 0.1 ha.

Piscivorous mammals: The raccoon was selected as representative of piscivorous mammals at the site. This mammalian species is expected to occur at both the Brawley and Imperial

wetlands. It is expected to be a year-round resident along the New and Alamo Rivers. The raccoon is an omnivorous, opportunistic mammal that is expected to forage on plant materials including fruits, insects, aquatic invertebrates (*i.e.*, crayfish), amphibians, snails, and fish when found in aquatic environments. Since the raccoon is assumed to breed at the wetlands, the site presence index (SPI) was set equal to 1.0.

10.7.2 Exposure Pathway Inclusion/Exclusion

The exposure pathway inclusion/exclusion evaluation is based on information gathered from the problem formulation (Section 10.4), ecological characterization (Section 10.5), COPEC selection (Section 10.6), representative species selection (Section 10.8.1), the probable completeness of each exposure pathway, and the potential for that pathway to be a major or minor route of exposure and risk.

An exposure pathway describes the course that a chemical takes from a source to an exposed individual. A complete exposure pathway consists of the following four factors:

- A source of potentially toxic chemicals;
- A contaminated medium (e.g., surface water);
- An exposure or contact point with the contaminated medium (e.g., ingestion); and
- An exposure route for chemical intake by a receptor (e.g., uptake through the gastrointestinal tract).

Designation of an exposure pathway as complete indicates that ecological exposure is possible, but does not necessarily mean that exposure will occur, or that exposure will occur at the levels estimated in this report. When any one of the factors is missing in a pathway, it is considered to be incomplete. Incomplete exposure pathways do not pose hazards and were not evaluated in this risk assessment.

The CSM provides the basis for identifying and evaluating the potentially complete exposure pathways at the Brawley and Imperial Wetlands. As shown in the CSM (Figure 10-1), the main potential source of COPECs at the Brawley and Imperial Wetlands is agricultural runoff (at Imperial Wetland) and the New River (at the Brawley Wetland). An exposure pathway is complete when there is a point at which chemical uptake or ingestion by an ecological receptor may occur. Exposure routes considered in this ecological risk assessment include:

- Uptake or ingestion of COPECs in surface water by aquatic biota (*i.e.*, aquatic plants, aquatic invertebrates, fish, and amphibians);
- Ingestion of surface water by birds and mammals;
- Uptake of COPECs in sediments by emergent plants and benthic invertebrates;
- Incidental ingestion of COPECs in sediments by fish, amphibians, birds, and mammals;
- Ingestion of COPECs in food items (*i.e.*, plant, invertebrate, or fish tissues).

For aquatic invertebrates, fish, and amphibians, uptake is the absorption of chemicals through their outer layers from the surrounding surface water. For birds and mammals, surface water can be ingested as a drinking water source or incidentally during the ingestion of aquatic prey items. Drinking rates for representative bird species are calculated using equations provided in the Wildlife Exposure Factors Handbook (U.S. EPA 1993).

Dermal absorption of COPECs was considered to be an insignificant exposure pathway for the avian and mammalian receptors at the Brawley and Imperial wetlands and was not

evaluated. No volatile COPECs were identified at the Brawley and Imperial wetlands. Thus, volatiles are not expected to be emitted to the air at the Brawley and Imperial wetlands and the inhalation of COPECs in air was considered to be an incomplete pathway.

Sediment exposures were considered to be a complete pathway for emergent plants, benthic invertebrates, fish, amphibians, aquatic birds, and mammals. For birds and mammals, sediment can be directly ingested incidentally while foraging (*i.e.,* probing) for prey through the sediment, as well as of incidental sediment particles on the food items, and by preening.

10.8 Analysis

The analysis phase provides the information necessary to determine or predict ecological responses to COPECs under exposure conditions of interest. This phase consists of two assessments: (1) exposure assessment and (2) effects assessment (U.S. EPA 1992a). Potential risks to aquatic invertebrates in the Brawley and Imperial wetlands and exposures to representative birds at the Brawley and Imperial wetlands were estimated using wildlife exposure factors, bioaccumulation models, and exposure point concentrations. To evaluate the effects of the COPECs on the representative birds and mammals at the Brawley and Imperial wetlands, chronic NOAEL-equivalent and chronic LOAEL-equivalent TRVs were established.

10.9 Exposure Characterization

The exposure characterization includes consideration of near-site background conditions, an exposure analysis for the selected representative species, and an exposure profile.

10.9.1 Background Evaluation

Selenium and each organochlorine pesticide detected were identified as COPECs in the Brawley and Imperial Wetlands. Three sets of background data were also evaluated: 1) the Salton Sea, 2) New and Alamo Rivers, and 3) agricultural drains in the Imperial Valley.

The Salton Sea was identified as a suitable background location for comparison with the Brawley and Imperial Wetlands due to the extensive wetland habitats fringing the Sea, which are likely used for breeding and residence by many of the same bird and mammals species occurring at the wetlands. Three sources of data on selenium and organochlorine pesticides from the Salton Sea were reviewed (Schroeder *et al.* 2002; Sapozhnikova *et al.* 2004; CH2M Hill 2005). Since the data were not available for statistical comparisons, maximum detected concentrations in sediments, surface water, plant, invertebrate, and fish tissues from the Salton Sea were compiled (Table 10-2[b]). These data were used to calculate risk estimates for regional background conditions represented by the Salton Sea. Risk calculations for the Salton Sea were performed using the same approach as for the Brawley and Imperial Wetlands, agricultural drains, and New and Alamo Rivers. Interpretation of the HQs and comparison to HQs for the wetlands is presented in Section 10.15.6.

Table 10-2a
Sediment, Water, and Tissue RMEs for ERA Calculations
New and Alamo Rivers, California

	Brawley and Imperial Wetlands									
Chemical	**Sediment (mg/kg)**	**Water (µg/L)**	**Aquatic Plant (mg/kg)**	**Aquatic Insects (Corixids & Dragonfly Larvae) (mg/kg)**	**Crayfish and Glass Shrimp (mg/kg)**	**Tadpole (mg/kg)**	**Macro Invertebrate (Crayfish) (mg/kg)**	**Small Fish (Mosquitofish, Shiner, Molly) (mg/kg)**	**Medium Fish (Mosquitofish, Shiner, Molly, Carp, Shad, Tilapia) (mg/kg)**	**Large Fish (Bass, Carp, Shad, Tilapia) (mg/kg)**
Metals:										
Selenium	0.53	3.4	2.1	4.4	4.3	8.2	3.7	11	6.1	4.7
Pesticides:										
4,4'-DDD	-	-	-	-	-	-	-	0.008	0.03	0.03
4,4'-DDE	0.006	-	0.08	-	0.02	0.02	0.02	0.15	1.2	1.1
4,4'-DDT	-	-	-	-	-	-	-	-	0.01	0.01
Aldrin	-	-	-	-	-	-	-	-	0.009	0.009
alpha BHC	-	-	-	-	0.004	0.009	0.004	-	-	-
alpha-Chlordane	-	-	-	-	-	-	-	-	0.01	0.01
beta BHC	-	-	-	-	-	-	-	-	-	-
Dieldrin	0.001	-	-	-	-	-	-	0.004	0.06	0.06
Endosulfan I	-	-	-	-	-	-	-	0.006	0.01	0.01
Endosulfan II	-	-	-	-	-	-	-	-	0.008	0.008
Endosulfan Sulfate	-	-	-	-	-	-	-	0.004	0.04	0.04
Endrin	-	-	-	-	-	-	-	-	0.006	0.006
Endrin Aldehyde	-	-	-	-	-	-	-	-	0.01	0.012
gamma BHC	-	-	-	-	-	-	-	-	-	-
gamma-Chlordane	-	-	-	-	-	-	-	-	-	-
Heptachlor	0.0004	-	-	-	-	-	-	-	0.01	0.009
Methoxychlor	-	-	-	-	-	-	-	-	0.004	0.004

Definitions:
- - indicates that a COPEC was not detected in that media.
RME-Reasonable Maximum Exposure (*i.e.*, the lesser of the maximum detected concentration and the UCL_{95}).
italics-indicates a predicted RME. All other numbers are measured.
Notes:
All tissue concentrations shown here were detected in samples.

Table 10-2a (continued)
Sediment, Water, and Tissue RMEs for ERA Calculations
New and Alamo Rivers, California

	Agricultural Drains									
Chemical	**Sediment (mg/kg)**	**Water (µg/L)**	**Aquatic Plant (mg/kg)**	**Aquatic Insects (Corixids & Dragonfly Larvae) (mg/kg)**	**Crayfish and Glass Shrimp (mg/kg)**	**Tadpole (mg/kg)**	**Macro Invertebrate (Crayfish) (mg/kg)**	**Small Fish (Mosquitofish, Shiner, Molly) (mg/kg)**	**Medium Fish (Mosquitofish, Shiner, Molly, Carp, Shad, Tilapia) (mg/kg)**	**Large Fish (Bass, Carp, Shad, Tilapia) (mg/kg)**
Metals:										
Selenium	0.60	5.3	1.5	4.2	3.9	7.4	3.6	7.2	7.2	9.8
Pesticides:										
4,4'-DDD	-	-	-	-	-	-	-	0.12	0.12	0.12
4,4'-DDE	0.04	-	0.04	-	-	0.28	0.06	4.5	4.5	4.5
4,4'-DDT	0.002	-	-	-	-	-	-	0.03	0.03	0.03
Aldrin	-	-	-	-	-	-	-	-	-	-
alpha BHC	-	-	-	-	-	-	-	-	-	-
alpha-Chlordane	-	-	-	-	-	-	-	0.02	0.02	0.02
beta BHC	0.002	-	-	-	-	-	-	-	-	-
Dieldrin	0.001	-	-	-	-	0.01	-	0.20	0.20	0.20
Endosulfan I	-	-	0.03	-	-	0.01	-	-	-	-
Endosulfan II	-	-	-	-	-	-	-	0.01	0.01	0.01
Endosulfan Sulfate	-	-	-	-	-	-	-	-	-	-
Endrin	-	-	-	-	-	-	-	-	-	-
Endrin Aldehyde	-	-	-	-	-	-	-	-	-	-
gamma BHC	-	-	-	-	-	-	-	-	-	-
gamma-Chlordane	-	-	-	-	-	-	0.01	0.03	0.03	0.03
Heptachlor	-	-	-	-	-	-	-	-	-	0.01
Methoxychlor	-	-	-	-	-	-	-	-	-	-

Definitions:
- - indicates that a COPEC was not detected in that media.
RME-Reasonable Maximum Exposure (*i.e.*, the lesser of the maximum detected concentration and the UCL95).
italics-indicates a predicted RME. All other numbers are measured.
Notes:
All tissue concentrations shown here were detected in samples.

Table 10-2a (continued)
Sediment, Water, and Tissue RMEs for ERA Calculations
New and Alamo Rivers, California

			New and Alamo Rivers			
Chemical	**Sediment (mg/kg)**	**Water (µg/L)**	**Aquatic Plant (mg/kg)**	**Small Fish (Mosquitofish, Shiner, Molly) (mg/kg)**	**Medium Fish (Mosquitofish, Shiner, Molly, Carp, Shad, Tilapia) (mg/kg)**	**Large Fish (Bass, Carp, Shad, Tilapia) (mg/kg)**
Metals:						
Selenium	0.79	5.3	3.9	7.3	7.0	7.0
Pesticides:						
4,4'-DDD	-	-	-	-	-	-
4,4'-DDE	0.04	-	0.09	7.2	7.2	7.2
4,4'-DDT	0.007	-	-	0.08	0.08	0.08
Aldrin	-	-	-	0.02	0.02	0.02
alpha BHC	-	-	-	-	-	-
alpha-Chlordane	-	-	-	0.02	0.02	0.02
beta BHC	-	-	-	0.01	0.01	0.01
Dieldrin	0.002	-	0.01	-	-	-
Endosulfan I	-	-	0.01	0.04	0.04	0.04
Endosulfan II	-	-	0.01	-	-	-
Endosulfan Sulfate	-	-	0.003	-	-	-
Endrin	-	-	-	-	-	-
Endrin Aldehyde	-	-	-	-	-	-
gamma BHC	0.001	-	-	-	-	-
gamma-Chlordane	-	-	-	0.03	0.03	0.03
Heptachlor	-	-	-	-	-	-
Methoxychlor	-	-	-	-	-	-

Definitions:
- - indicates that a COPEC was not detected in that media.
RME-Reasonable Maximum Exposure (*i.e.*, the lesser of the maximum detected concentration and the UCL_{95}).
italics-indicates a predicted RME. All other numbers are measured.
Notes:
All tissue concentrations shown here were detected in samples.

Table 10-2b
Sediment, Water, and Tissue Concentrations from the Salton Sea Used for Comparative Risk Calculations
New and Alamo Rivers, California

			Salton Sea				
Chemical	**Water (µg/L)**	**Sediment (mg/kg)**	**Aquatic Plants and Algae (mg/kg)**	**Benthic Invertebrate Tissue (mg/kg)**	**Aquatic Invertebrate Tissue (mg/kg)**	**Large Fish Tissue (mg/kg)**	**Small Fish Tissue (mg/kg)**
Metals:							
Selenium[1]	2.1[a]	8.5[b]	1.7[c]	12.1[d]	11[e]	26.6[f]	13.4[g]
Pesticides:							
Aldrin	-	-	-	-	-	-	-
alpha BHC	-	-	-	-	-	-	-
alpha-Chlordane	-	-	-	-	-	-	-
4,4'-DDD	-	0.0028[h]	-	-	-	0.0056[i]	0.0056[j]
4,4'-DDE	-	0.0306[h]	-	-	-	0.0436[i]	0.0436[j]
4,4'-DDT	-	0.004[h]	-	-	-	0.03[i]	0.03[j]
Dieldrin	-	0.0123[h]	-	-	-	0.0124[i]	0.0124[j]
Endosulfan I	-	-	-	-	-	-	-
Endosulfan II	-	-	-	-	-	-	-
Endosulfan sulfate	-	-	-	-	-	-	-
Endrin	-	-	-	-	-	0.016[i]	0.016[j]
Endrin aldehyde	-	-	-	-	-	-	-
Heptachlor	-	0.0045[h]	-	-	-	0.0332[i]	0.0332[j]
Methoxychlor	-	-	-	-	-	-	-

Notes:
All sediment and tissue concentrations are in dry weight.
a - Maximum concentration reported in Holdren and Montano (2002), as cited in CH2MHill (2005).
b - Maximum concentration reported from 75 locations in Levine Fricke (1999), as cited in CH2MHill (2005).
c - Maximum concentration reported in filamentous green algae in Setmire *et al.* (1993), as cited in CH2MHill (2005).
d - Maximum concentration reported in pileworms in Setmire *et al.* (1993), as cited in CH2MHill (2005).
e - Maximum concentration reported in waterboatmen in Audet *et al.* (undated), as cited in CH2MHill (2005).
f - Maximum concentration reported in tilapia in the south Salton Sea (TSMP [1978-2000], as cited in CH2MHill [2005]). Converted from wet weight to dry weight assuming a 75 percent moisture content in fish (U.S. EPA 1993).
g - Maximum geometric mean reported in bairdiella (croakers) in the Salton Sea National Refuge (Moreau [2004], as cited in CH2MHill [2005]). Converted from wet weight to dry weight assuming a 75 percent moisture content in fish (U.S. EPA 1993).
h - Maximum concentration in sediments in Sapozhnikova *et al.* (2004).
i - Maximum concentration in corvina and tilapia muscle tissues in Sapozhnikova *et al.* (2004). Converted to dry weight from wet weight assuming a 75% moisture content in fish tissues (U.S. EPA 1993).
j - No data for small fish available; based on data from large fish tissues.

Background data from the agricultural drains and New and Alamo Rivers was collected in this study and were evaluated along with the wetlands data to generate risk estimates. As with the Salton Sea, risk estimates for these background areas were intended to place for the HQs calculated for receptors at the Brawley and Imperial Wetlands in perspective.

10.10 Exposure Analysis

The exposure analysis describes the relationships between the concentrations of COPECs at the site and the ecological receptors. Information used to establish this link includes the pathway by which the receptors are exposed to the COPECs in each medium, estimates of exposure point concentrations (EPCs), and calculations of reasonable maximum daily dosages from chemical accumulation in the food chain for aquatic birds and mammals.

To estimate exposures of COPECs to ecological receptors, six essential inputs were needed:

- Representative species;
- Exposure profile;
- EPCs for each COPEC;
- Bioaccumulation models;

- Exposure equations; and
- Wildlife exposure factors.

The selection of representative species was previously discussed in Section 10.8.1. The following sections describe the technical approach for quantifying the uptake and ingestion of COPECs for each of the receptors.

10.10.1 Exposure Profile

The exposure profile describes the complete exposure pathways between COPECs and receptors based on the potential for exposure under current conditions at the sites. Complete exposure pathways were established through identification of ecological receptors and identification of COPECs in the media at the site. The pathways are evaluated by calculating EPCs for each COPEC in each environmental medium and calculating reasonable maximum daily dosages for each receptor. Daily doses were based on the most likely exposure scenario for each receptor, from both abiotic and biotic sources.

The potential exposure pathways for various receptors in the Brawley and Imperial Wetlands were evaluated in the CSM presented in Section 10.8. The identified receptors and the pathways by which they are assumed to be exposed to the COPECs at the Brawley and Imperial Wetlands, drains, and rivers are listed below:

- **Emergent plants** – Contact with and uptake of COPECs in sediment;
- **Benthic invertebrates** – Contact with and uptake of COPECs in sediment;
- **Aquatic biota** (*i.e.*, plants, aquatic invertebrates, fish, and amphibians) – Contact with and uptake of COPECs in surface water;
- **Birds** – Ingestion of COPECs in plants, invertebrates, and fish tissues, incidental ingestion of COPECs in sediments, and ingestion of surface water; and
- **Piscivorous Mammals** – Ingestion of COPECs in plants, invertebrates, and fish tissues, incidental ingestion of COPECs in sediments, and ingestion of surface water.

For emergent plants and benthic invertebrates, exposures to COPECs were estimated as the measured concentrations of the COPECs in sediment ($mg_{COPEC}/kg_{sediment}$). For aquatic biota, exposures to COPECs were estimated as the measured concentrations of the COPECs in water ($\mu g_{COPEC}/L_{water}$). Exposures of fish were also assessed on the basis of tissue concentrations (mg_{COPEC}/kg_{tissue}). For birds and mammals, exposures to COPECs are expressed as doses in milligrams per kilogram of body weight-day ($mg_{COPEC}/ kg_{body\ wt}$-day). Estimates of exposure to the COPEC for each receptor are provided in Appendix L. Additionally, from the selenium dose calculated for the four bird receptors, the amount of selenium potentially transferred to the birds' eggs was also estimated.

This exposure information was used, along with the ecological effects information described in Section 10.12, to estimate the potential risks to receptors at the Brawley and Imperial Wetlands presented in the risk characterization (Section 10.13).

10.10.2 Exposure Point Concentrations

Exposure point concentrations (EPCs) were estimated using the reasonable maximum exposure (RME) concentration. This method ensures that the potential risks calculated from these concentrations are conservative and will not underestimate the possible risks. The RME concentration is defined as the 95th percentile upper confidence limit (UCL_{95}) of the mean concentration or the maximum observed concentration, whichever is less (U.S. EPA 1989a,

1992b, 2002). The UCL_{95} was calculated following current USEPA (2002) guidance using the latest version of ProUCL (USEPA 2004a).

The EPCs are provided in Table 10-2. The distributions for each chemical detected in surface water, sediment, and tissues are provided in Appendix L-1. Also provided in Appendix L-1 are tabulations of each COPEC's detection frequency, concentration range, mean, minimum, maximum, and UCL_{95} concentration, when available. The summary statistics are provided separately for each COPEC detected in each of the areas evaluated. The UCL_{95} or maximum detected concentration, whichever is lower, was used as a protective estimate of the RME concentration in determining potential ecological risks.

10.10.3 Exposure Equations

Exposures to COPEC for birds at the Brawley and Imperial Pilot Wetlands were calculated using pathway-specific exposure equations of the general form:

$$\text{Exposure} = \frac{\text{EPC} \times \text{CR} \times \text{FC} \times \text{AF}}{\text{BW}}$$

where:

EPC = exposure point concentration; the concentration of a COPEC in media that is likely to be contacted by receptors of concern.

CR = contact rates or intake rates; including ingestion and drinking rates.

FC = fraction of media contacted; including site presence index and diet portions.

AF = assimilation fraction; the amount of the COPEC absorbed through the gastrointestinal tract, lungs or skin (100 percent assimilation is assumed in the baseline ERA).

BW = body weight of the receptor.

Exposure equations used in this baseline ERA are consistent with federal and state guidance (DTSC 1996a,b; U.S. EPA 1989b, 1993). The total exposure to each COPEC for birds and mammals at the Brawley and Imperial Wetlands was calculated as the sum of exposure via water ingestion, sediment ingestion, and the ingestion of food items. This can also be written as follows:

Exposure Dose = Exposure from water ingestion + Exposure from sediment ingestion + Exposure from food ingestion

Putting this equation in the form of the general equation given above for calculating exposure, the following equation is produced:

$$\text{Exposure dose} = \left[\frac{\text{EPC}_{\text{water}} \times \text{DR} \times \text{FC} \times \text{AF}}{\text{BW}}\right] + \left[\frac{\text{EPC}_{\text{sediment}} \times \text{IR} \times \text{FC} \times \text{SPI} \times AF}{\text{BW}}\right] + \left[\frac{\text{EPC}_{\text{tissue}} \times \text{IR} \times \text{FC} \times \text{SPI} \times \text{AF}}{\text{BW}}\right]$$

where:

EPC_{water} = EPC for a COPEC in water (in µg/L);

$EPC_{sediment}$ = EPC for a COPEC in sediment (in mg/kg);

EPC_{tissue} = EPC for a COPEC in plant, invertebrate, or fish tissues (mg/kg dry weight);

DR = Drinking Rate (ml/day);

IR	=	Ingestion rate of sediment or food (mg/day dry weight);
FC	=	Fraction contacted (unitless; assumed to be 1);
AF	=	Assimilation fraction (unitless; assumed to be 1);
SPI	=	Site presence index (unitless; assumed to be 1); and
BW	=	Body weight (kg).

The derivation of the EPCs was previously explained in Section 10.11.2. Each of the remaining variables is explained in the section below.

10.10.4 Wildlife Exposure Factors

Wildlife exposure factors that were used to estimate exposures for the selected ecological receptors are listed in Table 10-3. Body weights for each bird species were estimated from the average male and female body weights published in the literature for locations in the western United States. Body weights were used to estimate food ingestion and drinking rates using allometric equations and to metabolically adjust toxicity benchmarks (Nagy 2001, U.S. EPA 1993). Food and sediment ingestion rates and drinking rates were then used to estimate the exposure dose (see equation above).

Diet proportions (*i.e.*, relative proportions of food in the total diet) were used to partition or allocate the various doses of ingested items. Dietary compositions assumed for this risk assessment are shown in Table 10-3. For invertivorous birds (*i.e.*, the least sandpiper and red-winged blackbird) in this risk assessment, the proportion of invertebrates in the diet was assumed to be 1. For the exclusively piscivorous double-breasted cormorant, the proportion of fish in the diet was assumed to be 1. Fish sampled in this investigation were grouped into three categories: small fish (*i.e.*, mosquitofish, red shiner, shortfin and sailfin mollies), all fish excluding bass (*i.e.*, mosquitofish, red shiner, shortfin and sailfin mollies, carp, shad, and tilapia), and large fish (*i.e.*, bass, carp, shad, and tilapia). Small fish were assumed to be eaten by the black-necked stilt and raccoon, all fish excluding bass were assumed to be eaten by the pied-billed grebe, and large fish were assumed to be eaten by the double-crested cormorant. Note that the incidental ingestion of sediment was considered to be in addition to the dietary requirements for each animal. Therefore, the total ingestion of food items for each receptor adds up to 100% and sediment ingestion is considered in addition to the ingestion of food items.

Drinking water rates for each species were derived using the Wildlife Exposure Factors Handbook (U.S. EPA 1993). The incidental ingestion of sediment for each representative bird species was estimated as a fraction of the total ingestion rate and is dependent on the feeding behavior of each representative bird species.

To provide a protective ERA, the assimilation fraction was assumed to be 1. That is, all of the COPEC ingested was assumed to actually be taken up across the gastro-intestinal tract.

The site presence index (SPI) is an estimate of the fraction of time a receptor spends within a given area. The SPIs for all six bird species and the raccoon were protectively assumed to be 1, though this is expected to be less for all birds, and substantially less for migratory birds (e.g., double-crested cormorant). Further, raccoons are unlikely to obtain all of their food from aquatic habitats, as assumed here.

Table 10-3
Wildlife Exposure Parameters for ERA Calculations
New and Alamo Rivers, California

Exposure Parameters	Units	Value	Reference	Notes
Least Sandpiper (*Calidris minutilla*)				
Body Weight	kg (FW)	0.021	1, 5	Range for birds in CA: 18-24 g
Foraging Area	ha	-	-	
Ingestion Rate	g/day (DW)	5.41	2	Calculated using the Charadriiformes food requirement equation
Drinking Rate	mL/day	4.42	3	Calculated using the all birds water intake equation
Soil/Sediment Diet Fraction	% IR(DW)	7.3%	4	
Food Diet Fraction	% IR(DW)	100%	-	
Species Status	-	-	9, 11	
Diet Composition	%	100% Benthic invertebrates	5	Based on reported diet of small amphipods, chironomids, dipterans, and isopods
Feeding depth	cm	4	5	Depth of water in which will feed
Biological Information	-	Returns to previous nesting sites for breeding. Prefers marsh habitats, mud flats, ponds, ditches, flooded fields. Feeds on small amphipods, chironomids, dipterans, and isopods, up to 4-5 mm (5). Summer and winter visitor to Salton Sea, possible resident and breeder at wetlands (10).		
Black-necked Stilt (*Himantopis mexicanus*)				
Body Weight	kg (FW)	0.16955	7	n = 76 males and 69 females from Lassen Co. (CA) and Churchill Co. (NV)
Foraging Area	ha	2-42 m	6	
Ingestion Rate	g/day (DW)	27.04	2	Calculated using the Charadriiformes food requirement equation
Drinking Rate	mL/day	17.97	3	Calculated using the all birds water intake equation
Soil/Sediment Diet Fraction	% IR(DW)	20%	4, 8	Average of 5 probing and pecking shorebirds.
Food Diet Fraction	% IR(DW)	100%	-	
Status	-	-	9, 11	
Diet Composition	%	92.1% Aquatic invertebrates (represented by corixids and dragonfly larvae) 3.2% Small fish (mosquitofish, shiner, molly) 1% Crayfish 1% Plants (macrophytes, algae) 2.7% Tadpoles	7	Based on stomach contents from California, Utah, Florida, and Puerto Rico: 35% true bugs (Hemiptera) 32.4% beetles 9.7% flies 7.9% snails 3.3% caddisflies (Trichoptera) 3.2% fish 2.9% dragonfly nymphs (Odonata) 2.9% mayflies, plants, crayfish 2.7% misc. (grasshoppers, frog)
Feeding depth	cm	To 13 cm for males, 11 cm for females	7	Depth of water in which will feed
Biological Notes	-	In freshwater wetlands: water boatmen, crayfish, beetles, fly larvae, snails, small fish (7). Year round resident and breeder at Salton Sea, likely at wetlands also (10).		
Pied-Billed Grebe (*Podilymbus podiceps podiceps*)				
Body Weight	kg (FW)	0.358	13	Male 474.0 ± 60.6, (321-568, 36); Female 358.0 ± 51.0, (253-479, 40)
Foraging Area	ha	1.2	13, 6	
Ingestion Rate	g/day (DW)	75	13	Based on low range of captive bird (75-150 g/day). Using Charadriiformes eq, 48.04 g/day.
Drinking Rate	mL/day	29.65	3	
Soil/Sediment Diet Fraction	% IR(DW)	3.0%	4, 12	Average for eight duck species, assume some incidental ingestion from ingesting macroinvertebrates.
Food Diet Fraction	% IR(DW)	100%	-	
Status	-	-	9, 11	
Diet Composition	%	60.8% Aquatic invertebrates (represented by corixids and dragonfly larvae) 21.6% Fish (mosquitofish, shiner, molly, carp, shad, tilapia) 17.6% Crayfish and glass shrimp	13	Decapod crustaceans, aquatic insects, fishes. Opportunistic. (Based on stomach contents from United States:) 33% beetles 20.5% bugs 20.2% fishes 16.5% decapods (crayfish, crab, shrimp, etc.) 3.5% dragonfly nymphs (Anisoptera) 6.3% snails, mussels, other
Feeding depth	cm	Dives	13	
Biological Notes	-	Breeds on seasonal or permanent ponds ≥0.2 ha, wetlands, agricultural fields, or channels, ranging from fresh water to moderately brackish. Associated with dense emergent/aquatic vegetation (13). Breeding resident (10).		

Table 10-3 (continued)
Wildlife Exposure Parameters for ERA Calculations
New and Alamo Rivers, California

Exposure Parameters	Units	Value	Reference	Notes
American Coot (*Fulica americana americana*)				
Body Weight	kg (FW)	0.56	14	Mean for females (range 427-628 g, n=20); males: 724 g (576–848 g, n=27).
Foraging Area	ha	0.15	14	
Ingestion Rate	g/day (DW)	67.77	2	Calculated using the Charadriiformes food requirement equation
Drinking Rate	mL/day	40.01	3	Calculated using the all birds water intake equation
Soil/Sediment Diet Fraction	% IR(DW)	11.0%	4, 14	Based on Wood duck. Actual findings for stomach contents range from 44.4%-12.3% gravel.
Food Diet Fraction	% IR(DW)	100%	-	
Status	-	-	9, 11	
Diet Composition	%	89.4% Plants (macrophytes, algae) 10.6% Aquatic invertebrates (represented by corixids and dragonfly larvae)	14	Based on stomach contents from North America: 89.4% plants (pondweeds, sedges, algae, grasses) 10.6% animals (incl. insects, mollusks)
Feeding depth	cm	< 6 m	14	
Biological Notes	-	Pondweeds, sedges, algae, grasses, occasionally insects (14). Breeding resident (10)		
Double-Crested Cormorant (*Phalacrocorax auritus albociliatus*)				
Body Weight	kg (FW)	2.056	15	Mean for female in New Mexico (range 1,750-2,400, n=17); mean for male 2,453 g (range 2,200–2,750, n = 15).
Foraging Area	ha	2,830	15	Accounts of birds flying average of <3 km to forage, range 1-40 km (15); also 8-16 km (6).
Ingestion Rate	g/day (DW)	175.84	2	Calculated using the Pelecaniformes food requirement equation
Drinking Rate	mL/day	95.63	3	
Soil/Sediment Diet Fraction	% IR(DW)	1.0%	4	Minimum of bird species; presume absolute minimum ingestion of sediment because feeds in water column only.
Food Diet Fraction	% IR(DW)	100%	-	
Status	-	-	9, 11	
Diet Composition	%	100% Shad, bass, tilapia, carp	15	Winter diet composition in Texas: Shad, sunfish, catfish, bass, crappies, blue tilapia, and carp.
Feeding depth	cm	4,700	15	
Biological Notes	-	Breeding and non-breeding resident and visitor (10).		
Red-winged Blackbird (*Agelaius phoeniceus*)				
Body Weight	kg (FW)	0.0415	16	Mean for female (range 29-55, n=249); male average is 63.6 (52.9-81.1, n=290).
Foraging Area	ha	-	16	Forage up to 80 km from roost; territories at wetlands range from 0.03-0.1 ha. Will assume SPI of 1.0.
Ingestion Rate	g/day (DW)	8.03	2	
Drinking Rate	mL/day	7.00	3	
Soil/Sediment Diet Fraction	% IR(DW)	10.4%	4	
Food Diet Fraction	% IR(DW)	100%	-	
Status	-	-	9, 11	
Diet Composition	%	100% Invertebrates (represented by corixids and dragonfly larvae)	16	Based on stomach contents from marshes in Manitoba during breeding season.
Feeding depth	cm	5	Assumed	
Biological Notes	-	Common resident and breeder (10).		

Table 10-3 (continued)
Wildlife Exposure Parameters for ERA Calculations
New and Alamo Rivers, California

Exposure Parameters	Units	Value	Reference	Notes
Raccoon (*Procyon lotor*)				
Body Weight	kg (FW)	5		Body weight from USEPA 1993 (mean adult male and female body weight)
Foraging Area	ha	39		Foraging area from USEPA 1993 (year round adult female home range)
Ingestion Rate	g/day (DW)	147		Ingestion rate from Nagy 2001 (calculated using omnivore allometric equation [IR(g/day)=0.432(bw in grams)^0.678])
Drinking Rate	mL/day	455.4		
Soil/Sediment Diet Fraction	% IR(DW)	9.4%		Soil diet fraction from Beyer *et al.* 1994
Food Diet Fraction	% IR(DW)	100%	-	
Diet Composition	%	16.5% Crayfish 31.4% Insects 6% Tadpoles 2% Fish (mosquitofish, shiner, molly) 44.1% Plants (represented by macrophytes and algae)		Diet proportions from U.S. EPA 1993 (sum of % seasonal dietary fractions from forested bottomlands in Maryland): 57% Crayfish 19% Snails 109% Insects 21% Reptiles/amphibians 7% Fish 17% Rodents 153% Plants and fruit
Status	-	-		
Feeding depth	cm	-		
Biological Notes	-	Omnivorous and opportunistic; will forage upon any vegetable matter, animal matter, or insect, including crayfish, shrimp, and frogs.		

Definitions:
FW- Fresh weight
ha- Hectares
DW- Dry weight
% IR(DW)- Percent of the dry-weight-based ingestion rate from each food source.

References:
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10.10.5 Bioaccumulation Models

The preferred COPEC concentrations in food items were measured concentrations in the plant, invertebrate, and fish tissue samples collected at the Brawley and Imperial Wetlands, agricultural drains, and New and Alamo Rivers. Bioconcentration or bioaccumulation models were used to estimate COPEC concentrations in tissues from COPEC concentrations in water or sediment for chemicals and areas where site-specific data were not available. Due to insufficient tissue sample sizes, this was necessary for selenium and pesticides in small

benthic invertebrates (*i.e.*, consumed by the least sandpiper); pesticides in aquatic insects; selenium and pesticides in crayfish, glass shrimp, and tadpoles in the rivers; selenium in crayfish, glass shrimp and tadpoles in the Salton Sea; and pesticides in plants, crayfish, and glass shrimp in the Salton Sea. Pesticide data for the all fish excluding bass category were applied as surrogates for pesticides in small fish in the drains and rivers, since small fish provided insufficient sample size for pesticide analysis. Likewise, small fish data for selenium and pesticides in the Salton Sea were based on available data for the larger tilapia, croaker, and corvina.

Several methods are available to estimate the bioaccumulation of inorganic and organic chemicals in plants and invertebrates. The specific models used in this ERA are shown in Table 10-4. The order of preference of these models is summarized below:

1. Bioaccumulation regression models derived from tissue burdens measured during site-specific sampling;
2. Literature-based bioaccumulation factors (U.S. EPA 1999a); and
3. Bioconcentration factors (BCFs) for organics in plants calculated from chemical-specific log K_{ow} values.

Table 10-4
Bioaccumulation Models Used for ERA Calculations
New and Alamo Rivers, California

Chemical	Bioaccumulation Model	Source
Selenium	**Aquatic insects:**	
	ln(Se in corixids and dragonfly tissues [mg/kg dry wt.]) = -0.889 + 0.7057 * *ln*(Se in surface water [µg/L])	Site-specific data[a]
	$N = 7$, $p = 0.03$, $r^2 = 0.6$	
	Benthic Invertebrates:	
Selenium	Sediment-to-benthic invertebrate BCF = 0.9 (mg Se / kg wet tissue[b]) / (mg Se / kg dry sediment)	U.S. EPA (1999a)
4,4'-DDE	Sediment-to-benthic invertebrate BCF = 0.95 (mg 4,4'-DDE / kg wet tissue[b]) / (mg 4,4'-DDE / kg dry sediment)	U.S. EPA (1999a)
Heptachlor	Sediment-to-benthic invertebrate BCF = 1.67 (mg heptachlor / kg wet tissue[b]) / (mg heptachlor / kg dry sediment)	U.S. EPA (1999a)[c]
	Emergent Plants:	
4,4'-DDD	Soil-to-plant BCF = 0.0128	Travis and Arms (1988)[d]
4,4'-DDE	Soil-to-plant BCF = 0.0067	Travis and Arms (1988)[d]
4,4'-DDT	Soil-to-plant BCF = 0.0039	Travis and Arms (1988)[d]
Dieldrin	Soil-to-plant BCF = 0.0382	Travis and Arms (1988)[d]
Heptachlor	Soil-to-plant BCF = 0.0115	Travis and Arms (1988)[d]

Notes:
a - Based on selenium data from the Brawley and Imperial Wetlands and agricultural drains
b - Wet weight concentrations were converted to dry weight using the following tissue moisture contents: fish (75%), benthic/aquatic invertebrates (78.7%), and tadpoles (85%) (U.S. EPA 1993).
c - Based on heptachlor epoxide.
d - log(plant BCF) = 1.588 - 0.578 log K_{ow}

Site-specific bioaccumulation regressions were calculated for measured concentrations of selenium in aquatic insects, crayfish, glass shrimp, and tadpoles, using concentrations in surface water or sediments as the independent variable. Only one regression produced a significant relationship, that for selenium in aquatic insects and surface water (Table 10-4). This regression was used to estimate selenium concentrations in aquatic insects in the rivers and Salton Sea. It was also used to predict selenium concentrations in crayfish, glass shrimp, and tadpoles where these site-specific measurements were not available. This bioaccumulation extrapolation was considered potentially more reliable than the water-to-aquatic invertebrate BCF for selenium of 1,262 ($mg_{selenium}/kg_{wet\ tissue}$) / ($mg_{dissolved\ selenium}/L_{water}$) (U.S. EPA [1999a]), since the latter was based on limited, non-site-specific data.

Sediment-to-benthic invertebrate BCFs for selenium, 4,4'-DDE, and heptachlor reported in U.S. EPA (1999a) were used to fill data gaps (Table 10-4). The BCFs for 4,4'-DDE and heptachlor were applied as surrogates for other organochlorine pesticides, depending on the similarity of their respective log K_{ow}s. These benthic invertebrate BCFs were also extrapolated directly to estimate concentrations of pesticides in other invertebrates (aquatic insects, crayfish, and glass shrimp) and tadpoles.

Pesticide concentrations in plant tissues in the Salton Sea were estimated using log K_{ow}-estimated soil-to-plant BCFs (Travis and Arms 1988) (Table 10-4).

Uncertainties in bioaccumulation models used in the risk assessment are discussed in Section 10.16.1.3.

10.10.6 Teratogenesis and Egg-Inviability Assessment

Seiler *et al.* (2003) provide equations to calculate the probability of selenium-induced teratogenesis (*i.e.*, developmental deformation) in the eggs of mallard ducks, black-necked stilts, and American avocets. Additionally, equations are provided to calculate the percentage of black-necked stilt clutches with at least one inviable egg. These equations are based on the selenium concentration within the bird's eggs. Although egg concentrations of selenium were not measured for this ERA, they can be estimated from the concentration in the parent's food source. The food sources for each bird species are shown in Table 10-3. Biotransfer of selenium from the parent's food to their eggs was estimated using the following equation (Skorupa and Ohlendorf 1991):

$$\text{Log}_{10}(\text{Se in eggs}) = \text{Log}_{10}(\text{Se in food}) \times 1.17 - 0.142$$

where:

Se in eggs = Concentration of selenium in egg tissues (µg/kg dry weight); and

Se in food = Concentration of selenium in food source (µg/kg dry weight). For birds with multiple food types, a weighted EPC was calculated by weighing the selenium EPC concentration in each food source by that source's proportion in the diet..

The equation above resolves to:

$$\text{Se in eggs} = 10^{(\log_{10}(\text{Se in food}) \times 1.17 - 0.142)}$$

Given the concentration of selenium in the parent's food source calculated above, the following model is used to calculate the probability of teratogenesis for each egg (Seiler *et al.* 2003):

$$p = \frac{e^{(\beta_0 + \beta_1 \times \text{Se in eggs})}}{1 + e^{(\beta_0 + \beta_1 \times \text{Se in eggs})}}$$

where:

p = Probability of teratogenicity;

β_0 = Model coefficient (ducks: -8.973; stilts: -6.136; and avocets: -7.479);

β_1 = Model coefficient (ducks: 0.2978; stilts: 0.1067; and avocets: 0.0710); and

Se in eggs is in units of ug/g dw.

In addition to the probability of teratogenesis, Seiler *et al.* (2003) provide an equation to calculate the percentage of black-necked stilt clutches with at least one inviable egg. This equation was calculated from 409 data points compiled from studies at Kesterson National

Wildlife Refuge and at the Salton Sea (Seiler *et al.* 2003). The percentage of stilt clutches with at least one inviable egg is calculated as follows:

$$p = \frac{e^{(-2.327+0.0503\times \text{Se in eggs})}}{1+e^{(-2.327+0.0503\times \text{Se in eggs})}}$$

where:

p = Raw percentage of clutches with at least one inviable egg.

For this risk assessment, the regression for stilts was applied to both black-neck stilts and least sandpipers; whereas the regression for ducks was applied to American coots.

The natural background rate of egg failures is not taken into account in the above equation. To calculate the percentage of hens with inviable eggs above the background rate, the following equation (Seiler *et al.* 2003) is used for stilts:

$$\text{Actual percentage} = \frac{(1-8.9\%)-(1-p)}{1-8.9\%}$$

Background rates of egg failures were not available for other species and were not evaluated.

10.11 Ecological Effects Characterization

10.11.1 Effects Assessment

The effects assessment identifies and quantifies potential adverse effects caused by exposures to the COPECs at the site and, where possible, evaluates cause-and-effect relationships (U.S. EPA 1992a). This baseline ERA used toxicity data obtained from the primary literature, review documents, and available toxicity databases. Potential adverse effects are quantitatively calculated as Hazard Quotients (HQs). Hazard Quotients are calculated by dividing a receptor's exposure to a COPEC by the COPEC's TRV; *i.e.*,

$$HQ = \frac{Exposure}{TRV}$$

10.11.2 Toxicity Benchmarks and TRVs

For emergent plans and benthic invertebrates, the measures of exposure used to calculate risks is the EPC in sediment for each COPEC, and the TRV is a concentration in sediment. Both are in units of mg/kg. Likewise, for aquatic biota the measure of exposure is the EPC in water, and the TRV is a concentration in water. Both are in units of µg/L. For birds and mammals, the measure of exposure used to calculate risks is the ingested dose (see Section 10.11.3) and the TRV is an experimentally derived ingestion dose. Both are in units of mg/kg-day.

TRVs for ecological receptors were calculated for selenium and 16 organic compounds identified as COPECs at the Brawley and Imperial Pilot Wetlands. TRVs were derived for each receptor as follows:

1) Toxicity benchmark selected from relevant toxicity studies;
2) Uncertainty factors are applied; and
3) Allometric scaling factors are applied.

Both NOAEL as well as LOAEL equivalent TRVs were selected for the evaluation of risks at the Brawley and Imperial Wetlands. A NOAEL is the highest level known to be without

adverse effects whereas a LOAEL is the level associated with the onset of adverse effects (*i.e.*, the lowest observed adverse effects).

10.11.2.1 Selection of Studies

The TRVs used in this ERA were derived from studies which were reviewed and summarized in various documents. These documents were selected because they are generally accepted as sources for toxicity benchmarks and include: Sample *et al.* (1996), EFA West (1998) (Navy BTAG), Vandenberg AFB Toxicity Profiles (U.S. Air Force 2003a), Handbook of Chemical Risk Assessment (Eisler 2000), National Recommended Water Quality Criteria (U.S. EPA 1999b), Cal Toxics Rule (U.S. EPA 2000), Buchman (1999), MacDonald *et al.* (2000), Suter and Tsao (1996), Efroymson *et al.* (1997), National Irrigation Water Quality Program (NIWQP 1998a, b), Water Quality Objectives (California Ocean Plan 2001), and the Edwards AFB TRV list (U.S. Air Force 2003b). All of the toxicity benchmarks were derived from studies that have been published in peer reviewed journals or documents. Once review of the toxicity studies was complete, the most appropriate studies for the chemicals and receptors of concern were identified. These studies were then used to derive appropriate TRVs.

In order for a study to be considered, it had to contain the following information:

- Chemical administered;
- Dose administered;
- Duration of exposure;
- Route of exposure; and
- Effect or response that was induced.

The criteria used to select the study for use as the toxicity benchmark upon which the TRV would be based included the following:

- Chronic exposure;
- Multiple doses, with a dose-response relationship identified (both a NOAEL and a LOAEL);
- Endpoints that measured reproductive effects;
- Wildlife species similar to the receptor species;
- Exposure routes and media similar to those in the field.

Whenever possible, studies that identified mortality as the endpoint were not selected because detrimental effects on ecosystems may occur at doses much lower than those that cause death of individual organisms. In cases where both (1) a study met few of the above criteria but measured reproductive effects and (2) a study that met more of the above criteria but measured non-reproductive effects available, the study that met more of the criteria (*i.e.*, study 1) was chosen. The study that met more of the criteria may have used a more relevant species or exposure route in testing, or it could have identified a chronic outcome instead of an acute outcome.

10.11.2.2 Uncertainty Factors

Where limited toxicity data was available, the use of uncertainty factors (UFs) was employed. This standard practice was used in order to calculate a conservative TRV, which, in turn, assured that HQs were calculated that are protective of adverse effects. The UFs employed in

this ERA were (1) factors that adjusted from a lethal dose in 50 percent of the animals in an experiment (LC_{50}) to a chronic dose, (2) from an acute or subchronic dose to a chronic dose, or (3) from a LOAEL to a NOAEL or NOAEL to LOAEL. These UFs are given in Table 10-5.

Table 10-5
Uncertainty Factors for Toxicity Reference Values
New and Alamo Rivers, California

Extrapolation	Uncertainty Factor (UF)
Acute LC_{50} to $NOAEL_{chronic}$	100
Acute LC_{50} to $LOAEL_{chronic}$	10
Subchronic to Chronic	10
LOAEL to NOAEL	10
NOAEL to LOAEL	10

Notes:
LC_{50} - A lethal concentration/dose in 50 percent of the animals in an experiment
NOAEL - No Observable Adverse Effect Level
LOAEL - Lowest Observable Adverse Effect Level

All reproductive studies were considered chronic studies regardless of the duration of the dosing. Reproduction and early development are sensitive life stages, during which critical effects can occur. Certain chemicals may induce serious adverse effects during embryonic and fetal stages of development. If adverse effects are induced at this stage, the likelihood of adverse effects to wildlife populations may be quite high. Therefore, due to the high sensitivity of adverse exposures during this life stage, all studies evaluating reproductive effects were considered chronic.

In instances where an LC_{50}, acute, or subchronic study evaluated an outcome other than reproduction, an uncertainty factor was applied. This allowed for adjustment to a longer duration of exposure, and also helps to ensure that a health-protective TRV was used. Table 10-5 provides the UF used for these adjustments.

Ideally, NOAELs and LOAELs are experimentally derived values. However, in some cases, a study may have identified a LOAEL, but the dosing regime did not include a level low enough to determine a NOAEL. In other cases, the highest dose administered might have been identified as a NOAEL; therefore, a LOAEL was not determined. In these cases, an uncertainty factor was used to adjust to the dose level needed (see Table 10-5); *i.e.*, to estimate a LOAEL from a NOAEL and *vice versa*.

In all cases, except with the NOAEL to LOAEL adjustment, the selected dose is divided by the uncertainty factor to arrive at the adjusted TRV. When adjusting a NOAEL dose to a LOAEL, the dose was multiplied by the UF. Multiple UFs may be applied to a selected dose. For example, a study that identified a LOAEL over a subchronic period of time would require two UFs; *i.e.*, (1) a subchronic-to-chronic UF and (2) a LOAEL-to-NOAEL UF.

The TRVs derived for each of the COPECs are presented in Tables 10-6 to 10-13. No uncertainty factors or allometric scaling were applied to the TRVs for emergent plants, benthic invertebrates, or aquatic biota.

Table 10-6
Aquatic Toxicity Reference Values (TRVs) for ERA Calculations
New and Alamo Rivers, California

Chemical	Freshwater TRV (µg/L)	Source of TRV
	Aquatic Invertebrates	
Metals		
Selenium	5.0	California Toxics Rule[a]

Notes:
µg/L - micrograms (chemical) per liter (surface water) per day
a - U.S. EPA (2000)

Table 10-7
Sediment Toxicity Reference Values (TRVs) for ERA Calculations
New and Alamo Rivers, California

Chemical	TRV ($mg/kg_{sediment}$-day)	Source of TRV
	Emergent Plants	
Metals		
Selenium	1.0	Efroymson *et al.* 1997
	Sediment-Associated Invertebrates	
Metals		
Selenium	1.0[a]	NOAA SQUIRTS[b]
Organics		
4,4'-DDD	0.005	MacDonald *et al.* 2000
4,4'-DDE	0.003	MacDonald *et al.* 2000
4,4'-DDT	0.004	MacDonald *et al.* 2000
Aldrin	0.002	MacDonald *et al.* 2000
Dieldrin	0.002	MacDonald *et al.* 2000
Heptachlor	0.003	MacDonald *et al.* 2000

Notes:
$mg/kg_{sediment}$-day - milligrams (chemical) per killograms (sediment) per day
a - This TRV was derived for exposure to saltwater.
b - Buchman (1999).

Table 10-8
Reported Ranges of Reproductive and Developmental Toxicity Data for Amphibians[a]
New and Alamo Rivers, California

Chemical	No. of Relevant Studies	Effect Level	Endpoint	Species	Exposure Duration	Age of Test Animals	Reference	Reported Concentration	Converted Concentration (mg/L)	UF	Chronic NOAEL - Equiv. Concentration (mg/L)
Selenium	2	LC50 Low	Mortality	Eastern Narrowmouth Toad	7 Days	Embryo - 4 days	Birge *et al.*, 1979	0.09 ppm	90	100	0.9
		LC50 High	Mortality	African Clawed Frog	72 Hours	Larvae	Browne and Dumont, 1979	8.04 ppm	8,040	100	80

Definitions:
UF – Uncertainty factor.
Notes:
a – Compiled from the Canadian Wildlife Service's Reptile and Amphibian Toxicology Literature (RATL) Database, 2002

Table 10-9
Fish Toxicity Reference Values (TRVs) for ERA Calculations
New and Alamo Rivers, California

Chemical	NOAEL TRV (mg/kg)	LOAEL TRV (mg/kg)	Source of TRV
Metals			
Selenium	0.8	7.9	USEPA 2004b
Pesticides			
4,4'-DDD	2.7	27	Jarvinen and Ankley 1999
4,4'-DDE	2.7	27	Jarvinen and Ankley 1999
4,4'-DDT	2.7	27	Jarvinen and Ankley 1999

Notes:
mg/kg - milligrams (chemical) per kilogram (dry fish tissue) per day

Table 10-10
Avian No Observed Adverse Effect Level (NOAEL) Toxicity Reference Values (TRVs) for ERA Calculations
New and Alamo Rivers, California

	Primary Study Information						Uncertainty Factors				
Chemical	Test Species	Observed Effect	Chronic/ Subchronic	Effect level	Body Weight (kg)	Unadjusted TRV[a] (mg/kg-day)	Subchronic to Chronic UF	LOAEL to NOAEL UF	Adjusted NOAEL-Equivalent TRV[b] (mg/kg-day)	Source of TRV	Source/TRV Provided by
Metals											
Selenium	Mallard Ducks	Growth, adult survival, duckling survival, deformed embryos	Chronic	NOAEL	1.1	0.36	-	-	0.36	Heinz *et al.* 1989	U.S. Air Force 2003a
Organics											
Aldrin	Mallard	Some mortality	Subchronic	LOAEL	1	5	10	10	0.05	Hudson *et al.* 1984	U.S. Air Force 2003a
alpha-Chlordane	Red-winged black birds	Mortality	Subchronic	NOAEL	0.064	2.2	10	-	0.22	Stickel et al 1983	U.S. Air Force 2003b
gamma-Chlordane	Red-winged black birds	Mortality	Subchronic	NOAEL	0.064	2.2	10	-	0.22	Stickel et al 1983	U.S. Air Force 2003b
alpha BHC	Japanese quail	Reproduction (egg hatchability)	Chronic	NOAEL	0.15	0.563	-	-	0.563	Vos *et al.* 1971 (Mixed isomers)	Sample *et al.* 1996
beta BHC	Japanese quail	Reproduction (egg hatchability)	Chronic	NOAEL	0.15	0.563	-	-	0.563	Vos *et al.* 1971 (Mixed isomers)	Sample *et al.* 1996
delta BHC	Japanese quail	Reproduction (egg hatchability)	Chronic	NOAEL	0.15	0.563	-	-	0.563	Vos *et al.* 1971 (Mixed isomers)	Sample *et al.* 1996
gamma BHC (Lindane)	Mallard	No adverse effects on food intake, water consumption, body weight, egg laying frequency, egg size and weight, eggshell thinning, and eggshell porosity	Chronic	LOAEL	1.0	20.0	-	10	2	Chakravarty & Lahiri 1986	Sample *et al.* 1996
4,4'-DDD	Brown Pelican	Reproduction	Chronic	NOAEL	3.5	0.009	-	-	0.009	Anderson *et al.* 1975 (DDT as surrogate)	U.S. Air Force 2003a
4,4'-DDE	Brown Pelican	Reproduction	Chronic	NOAEL	3.5	0.009	-	-	0.009	Anderson *et al.* 1975 (DDT as surrogate)	U.S. Air Force 2003a
4,4'-DDT	Brown Pelican	Reproduction	Chronic	NOAEL	3.5	0.009	-	-	0.009	Anderson *et al.* 1975	U.S. Air Force 2003a
Dieldrin	Barn Owl	Reproduction (egg shell thickness, eggs hatched, eggs laid, % eggs broken, embryo or nestling mortality)	Chronic	NOAEL	0.466	0.077	-	-	0.077	Mendenhall *et al.* 1983	Sample *et al.* 1996
alpha Endosulfan (I)	Gray Partridge	Reproduction	Chronic	NOAEL	0.4	10	-	-	10	Abiola 1992 (Endosulfan sulfate as surrogate)	U.S. Air Force 2003a
beta Endosulfan (II)	Gray Partridge	Reproduction	Chronic	NOAEL	0.4	10	-	-	10	Abiola 1992 (Endosulfan sulfate as surrogate)	U.S. Air Force 2003a
Endosulfan sulfate	Gray Partridge	Reproduction	Chronic	NOAEL	0.4	10	-	-	10	Abiola 1992	U.S. Air Force 2003a
Endrin	Screech Owl	Reproduction	Chronic	LOAEL	0.181	0.1	-	10	0.01	Fleming *et al.* 1982	Sample *et al.* 1996
Heptachlor epoxide	Japanese quail	Mortality	Acute	LC50	0.043	20.4	*100 (LC50 to NOAEL)*		0.2	Hill *et al.* 1975	U.S. Air Force 2003a

a - Unadjusted TRV is the value derived from the primary literature, with no uncertainty factors applied.
b - Adjusted NOAEL-equivalent TRV is the value after uncertainty factors have been applied.

Notes:
LC_{50} - A lethal concentration/dose in 50 percent of the animals in an experiment
NOAEL - No Observable Adverse Effect Level
LOAEL - Lowest Observable Adverse Effect Level
mg/kg-day - milligrams (chemical) per killograms (bird body weight) per day

Table 10-10 (continued)
Avian No Observed Adverse Effect Level (NOAEL) Toxicity Reference Values (TRVs) for ERA Calculations
New and Alamo Rivers, California

Chemical	Test Species	Test Species Body Weight (kg)	Source of TRV	NOAEL-Equivalent TRV (mg/kg-day)	Avian Allometric Scaling Factor[a]	Allometrically Adjusted TRVs					
						Least Sandpiper	Black-Necked Stilt	Pied-Billed Grebe	American Coot	Double-Crested Cormorant	Red-Winged Blackbird
Metals											
Selenium	Mallard Ducks	1.1	Heinz *et al.* 1989	0.36	1.2	0.163	0.248	0.288	0.315	0.408	0.187
Organics											
Aldrin	Mallard Ducks	1	Hudson *et al.* 1984	0.05	1.338	0.014	0.027	0.035	0.041	0.064	0.017
alpha-Chlordane	Red-winged black birds	0.064	Stickel et al 1983	0.22	2.492	0.041	0.941	2.871	5.596	38.961	0.115
alpha-Chlordane	Red-winged black birds	0.064	Stickel et al 1983	0.22	2.492	0.041	0.941	2.871	5.596	38.961	0.115
alpha BHC	Japanese quail	0.15	Vos *et al.* 1983	0.563	1.2	0.380	0.577	0.670	0.733	0.950	0.435
beta BHC	Japanese quail	0.15	Vos *et al.* 1983	0.563	1.2	0.380	0.577	0.670	0.733	0.950	0.435
delta BHC	Japanese quail	0.15	Vos *et al.* 1983	0.563	1.2	0.380	0.577	0.670	0.733	0.950	0.435
gamma BHC (lindane)	Mallard	1	Chakravarty & Lahiri 1986	2	1.813	0.086	0.473	0.868	1.248	3.594	0.150
DDD	Brown Pelican	3.5	See DDT	0.009	1.268	0.002	0.004	0.005	0.006	0.008	0.003
DDE	Brown Pelican	3.5	See DDT	0.009	1.268	0.002	0.004	0.005	0.006	0.008	0.003
DDT	Brown Pelican	3.5	Anderson *et al.* 1975	0.009	1.268	0.002	0.004	0.005	0.006	0.008	0.003
Dieldrin	Barn Owl	0.466	Mendenhall *et al.* 1983	0.077	1.201	0.041	0.063	0.073	0.080	0.104	0.047
alpha Endosulfan	Gray Partridge	0.4	See Endosulfan sulfate	10	0.563	36.324	14.551	10.497	8.633	4.890	26.916
beta Endosulfan	Gray Partridge	0.4	See Endosulfan sulfate	10	0.563	36.324	14.551	10.497	8.633	4.890	26.916
Endosulfan sulfate	Gray Partridge	0.4	Abiola 1992	10	0.563	36.324	14.551	10.497	8.633	4.890	26.916
Endrin	Screech Owl	0.181	Fleming *et al.* 1982	0.01	1.25	0.006	0.010	0.012	0.013	0.018	0.007
Heptachlor epoxide	Japanese quail	0.043	See Heptachlor	0.2	1.086	0.188	0.225	0.240	0.249	0.279	0.199

a - From Sample and Arenal, 1999. Scaling factor applied as follows: $TRV_{receptor\ species} = TRV_{test\ species} * (BW_{test\ species}/BW_{receptor\ species})$^(1-Scaling Factor)

Notes:
NOAEL - No Observable Adverse Effect Level
BW - Body Weight
mg/kg-day - milligrams (chemical) per killograms (bird body weight) per day

Table 10-11
Avian Lowest Observed Adverse Effect Level (LOAEL) Toxicity Reference Values (TRVs) for ERA Calculations
New and Alamo Rivers, California

	Primary Study Information						Uncertainty Factors				
Chemical	Test Species	Observed Effect	Chronic/ Subchronic	Effect level	Body Weight (kg)	Unadjusted TRV[a] (mg/kg-day)	Subchronic to Chronic UF	NOAEL to LOAEL UF	Adjusted LOAEL Equivalent TRV[b] (mg/kg-day)	Original Source of TRV	Source/TRV Provided by
Metals											
Selenium	Mallard Ducks	Growth, adult survival, duckling survival, deformed embryos.	Chronic	LOAEL	1.1	0.73	-	-	0.73	Heinz *et al.* 1989	U.S. Air Force 2003[a]
Organics											
Aldrin	Mallard Ducks	Mortality	Subchronic	LOAEL	1	5	10	-	0.5	Hudson *et al.* 1984	U.S. Air Force 2003[a]
alpha-Chlordane	Red-winged black birds	Mortality	Subchronic	LOAEL	0.064	1.1	10	-	1.1	Stickel et al 1983	U.S. Air Force 2003[b]
gamma-Chlordane	Red-winged black birds	Mortality	Subchronic	LOAEL	0.064	1.1	10	-	1.1	Stickel et al 1983	U.S. Air Force 2003[b]
alpha BHC	Japanese quail	Reproduction (egg hatchability)	Chronic	LOAEL	0.15	2.25	-	-	2.25	Vos *et al.* 1971 (Mixed isomers)	Sample *et al.* 1996
beta BHC	Japanese quail	Reproduction (egg hatchability)	Chronic	LOAEL	0.15	2.25	-	-	2.25	Vos *et al.* 1971 (Mixed isomers)	Sample *et al.* 1996
delta BHC	Japanese quail	Reproduction (egg hatchability)	Chronic	LOAEL	0.15	2.25	-	-	2.25	Vos *et al.* 1971 (Mixed isomers)	Sample *et al.* 1996
gamma BHC (Lindane)	Mallard	No adverse effects on food intake, water consumption, body weight, egg laying frequency, egg size and weight, eggshell thinning, and eggshell porosity	Chronic	LOAEL	1.0	20.0	-	-	20	Chakravarty & Lahiri 1986	Sample *et al.* 1996
4,4'-DDD	Brown Pelican	Reproduction	Chronic	LOAEL	3.5	0.028	-	-	0.028	Anderson *et al.* 1975 (DDT as surrogate)	U.S. Air Force 2003[a]
4,4'-DDE	Brown Pelican	Reproduction	Chronic	LOAEL	3.5	0.028	-	-	0.028	Anderson *et al.* 1975 (DDT as surrogate)	U.S. Air Force 2003[a]
4,4'-DDT	Brown Pelican	Reproduction	Chronic	LOAEL	3.5	0.028	-	-	0.028	Anderson *et al.* 1975	U.S. Air Force 2003[a]
Dieldrin	Mallard Ducks	Mortality	Subchronic	LOAEL	1	5	10	-	0.5	Hudson *et al.* 1984 (Aldrin as surrogate)	U.S. Air Force 2003[a]
alpha Endosulfan (I)	Gray Partridge	Reproduction	Chronic	NOAEL	0.4	0.4	-	10	4	Abiola 1992 (Endosulfan sulfate as surrogate)	U.S. Air Force 2003[a]
beta Endosulfan (II)	Gray Partridge	Reproduction	Chronic	NOAEL	0.4	0.4	-	10	4	Abiola 1992 (Endosulfan sulfate as surrogate)	U.S. Air Force 2003[a]
Endosulphan sulfphate	Gray Partridge	Reproduction	Chronic	NOAEL	0.4	0.4	-	10	4	Abiola 1992	U.S. Air Force 2003[a]
Endrin	Screech owl	Reproduction	Chronic	LOAEL	0.181	0.1	-	-	0.1	Fleming *et al.* 1982	Sample *et al.* 1996
Heptachlor epoxide	Japanese quail	Mortality	Acute	LC50	0.043	20.4	*10 (LC50 to LOAEL)*		2.04	Hill *et al.* 1975	U.S. Air Force 2003[a]

a - Unadjusted TRV is the value derived from the primary literature, with no uncertainty factors applied.
b - Adjusted LOAEL-equivalent TRV is the value after uncertainty factors have been applied.

Notes:
LC_{50} - A lethal concentration/dose in 50 percent of the animals in an experiment
NOAEL - No Observable Adverse Effect Level
LOAEL - Lowest Observable Adverse Effect Level
mg/kg-day - milligrams (chemical) per killograms (bird body weight) per day

Table 10-11 (continued)
Avian Lowest Observed Adverse Effect Level (LOAEL) Toxicity Reference Values (TRVs) for ERA Calculations
New and Alamo Rivers, California

Chemical	Test Species	Test Species Body Weight (kg)	Source of TRV	LOAEL-Equivalent TRV (mg/kg-day)	Avian Allometric Scaling Factor[a]	Allometrically Adjusted TRVs					
						Least Sandpiper	Black-Necked Stilt	Pied-Billed Grebe	American Coot	Double-Crested Cormorant	Red-Winged Blackbird
Selenium	Mallard Ducks	1.1	Heinz *et al.* 1989	0.73	1.2	0.330	0.502	0.583	0.638	0.827	0.379
Aldrin	Mallard Ducks	1	Hudson *et al.* 1984	0.5	1.338	0.135	0.274	0.353	0.411	0.638	0.171
alpha-Chlordane	Red-winged black birds	0.064	Stickel et al 1983	1.1	2.492	0.207	4.706	14.354	27.981	194.806	0.576
alpha-Chlordane	Red-winged black birds	0.064	Stickel et al 1983	1.1	2.492	0.207	4.706	14.354	27.981	194.806	0.576
alpha BHC	Japanese quail	0.15	Vos *et al.* 1971 (Mixed isomers)	2.25	1.2	1.517	2.306	2.678	2.928	3.798	1.740
beta BHC	Japanese quail	0.15	Vos *et al.* 1971 (Mixed isomers)	2.25	1.2	1.517	2.306	2.678	2.928	3.798	1.740
delta BHC	Japanese quail	0.15	Vos *et al.* 1971 (Mixed isomers)	2.25	1.2	1.517	2.306	2.678	2.928	3.798	1.740
gamma BHC (Lindane)	Mallard	1.0	Chakravarty & Lahiri 1986	20	1.813	0.862	4.726	8.676	12.483	35.935	1.505
4,4'-DDD	Brown Pelican	3.5	Anderson *et al.* 1975 (DDT as surrogate)	0.028	1.268	0.007	0.012	0.015	0.017	0.024	0.009
4,4'-DDE	Brown Pelican	3.5	Anderson *et al.* 1975 (DDT as surrogate)	0.028	1.268	0.007	0.012	0.015	0.017	0.024	0.009
4,4'-DDT	Brown Pelican	3.5	Anderson *et al.* 1975	0.028	1.268	0.007	0.012	0.015	0.017	0.024	0.009
Dieldrin	Mallard Ducks	1	Hudson *et al.* 1984 (Aldrin as surrogate)	0.5	1.201	0.230	0.350	0.407	0.445	0.578	0.264
alpha Endosulfan (I)	Gray Partridge	0.4	Abiola 1992 (Endosulfan sulfate as surrogate)	4	0.563	14.530	5.820	4.199	3.453	1.956	10.766
beta Endosulfan (II)	Gray Partridge	0.4	Abiola 1992 (Endosulfan sulfate as surrogate)	4	0.563	14.530	5.820	4.199	3.453	1.956	10.766
Endosulphan sulfphate	Gray Partridge	0.4	Abiola 1992	4	0.563	14.530	5.820	4.199	3.453	1.956	10.766
Endrin	Screech owl	0.181	Fleming *et al.* 1982	0.1	1.25	0.058	0.098	0.119	0.133	0.184	0.069
Heptachlor epoxide	Japanese quail	0.043	Hill *et al.* 1975	2.04	1.086	1.917	2.295	2.448	2.544	2.845	2.034

a - Unadjusted TRV is the value derived from the primary literature, with no uncertainty factors applied.
b - Adjusted LOAEL-equivalent TRV is the value after uncertainty factors have been applied.

Notes:
LC_{50} - A lethal concentration/dose in 50 percent of the animals in an experiment
NOAEL - No Observable Adverse Effect Level
LOAEL - Lowest Observable Adverse Effect Level
mg/kg-day - milligrams (chemical) per killograms (bird body weight) per day

Table 10-12
Mammalian No Observed Adverse Effect Level (NOAEL) Toxicity Reference Values (TRVs) for ERA Calculations
New and Alamo Rivers, California

	Primary Study Information							Uncertainty Factors				Allometrically Adjusted TRVs		
Chemical	Test Species	Observed Effect	Chronic/ Subchronic	Effect level	Body Weight (kg)	Unadjusted TRV[a] (mg/kg-day)	Non-sensitive to sensitive	Subchronic to Chronic UF	LOAEL to NOAEL UF	Adjusted NOAEL-Equivalent TRV[b] (mg/kg-day)	Sample & Arenal 1999 Mammalian Allometric Scaling Factor	Raccoon	Source of TRV	Source/TRV Provided by
Metals														
Selenium	Mouse	Hepatic lesions	Chronic	NOAEL	0.0246	0.05	-	-	-	0.05	0.94	0.036	EFA West, 1998	EFA West, 1998
Organics														
Aldrin	Rat	Neurobehavioral	Chronic	LOAEL	0.065	1	-	-	10	0.1	0.858	0.10	EFA West, 1998	EFA West, 1998
alpha-Chlordane	Mouse	Liver toxicity	Chronic	NOAEL	0.03	0.12	-	-	-	0.12	0.829	0.049	Khasawinah and Grutsch 1989 (Chlordane)	Rocketdyne, 2003
gamma-Chlordane	Mouse	Liver toxicity	Chronic	NOAEL	0.03	0.12	-	-	-	0.12	0.829	0.049	Khasawinah and Grutsch 1989 (Chlordane)	Rocketdyne, 2003
alpha BHC	Mink	Kit mortality and body weight	Chronic	LOAEL	1	0.137	-	-	10	0.0137	0.855	0.014	Bleavins *et al.* 1984 (mixed isomers)	Sample *et al.* 1996
beta BHC	Rat	Reproduction - gonadal atrophy	Subchronic	NOAEL	0.35	4	-	10	-	0.4	0.855	0.40	Van Velsen *et al.* 1986	Sample *et al.* 1996
delta BHC	Mink	Kit mortality and body weight	Chronic	LOAEL	1	0.137	-	-	10	0.0137	0.855	0.014	Bleavins *et al.* 1984 (mixed isomers)	Sample *et al.* 1996
gamma BHC (Lindane)	Rat	Liver and kidney toxicity	Subchronic	NOAEL	0.35	0.33	-	10	-	0.033	0.855	0.033	Zoecon Corp. 1983	USEPA 2006b
4,4'-DDD	Rat	Reproduction	Chronic	NOAEL	0.32	0.8	-	-	-	0.8	1.268	0.80	EFA West, 1998	EFA West, 1998
4,4'-DDE	Rat	Reproduction	Chronic	NOAEL	0.32	0.8	-	-	-	0.8	1.268	0.80	EFA West, 1998	EFA West, 1998
4,4'-DDT	Rat	Reproduction	Chronic	NOAEL	0.32	0.8	-	-	-	0.8	1.268	0.80	EFA West, 1998	EFA West, 1998
Dieldrin	Rat	Reproduction	Chronic	LOAEL	0.35	0.2	-	-	5	0.04	0.94	0.040	Treon and Cleveland 1955	Rocketdyne, 2003
alpha Endosulfan (I)	Beagle dog	Behavior, weight gain	Chronic	NOAEL	12.7	0.57	-	-	-	0.57	0.563	0.57	Hoechst Celanese Corp. 1989a	USEPA 2006b
beta Endosulfan (II)	Beagle dog	Behavior, weight gain	Chronic	NOAEL	12.7	0.57	-	-	-	0.57	0.563	0.57	Hoechst Celanese Corp. 1989a	USEPA 2006b
Endosulfan sulfate	Beagle dog	Behavior, weight gain	Chronic	NOAEL	12.7	0.57	-	-	-	0.57	0.563	0.57	Hoechst Celanese Corp. 1989a	USEPA 2006b
Endrin	Dog (Beagle)	Convulsions, liver weight, liver histolopathological effects	Chronic	NOAEL	12.7	0.025	-	-	-	0.025	0.967	0.025	Velsicol Chemical Corporation. 1969	USEPA 2006b
Heptachlor epoxide	Rat	Reproduction	Chronic	LOAEL	0.1	1.29	-	-	10	0.129	1.086	0.129	EFA West, 1998	EFA West, 1998
Methyxychlor	Rat	Reproduction	Chronic	NOAEL	0.35	4	-	-	-	4	1.224	4.0	Gray *et al.* 1988	Sample *et al.* 1996

Notes:
LC_{50} - A lethal concentration/dose in 50 percent of the animals in an experiment
NOAEL - No Observable Adverse Effect Level
LOAEL - Lowest Observable Adverse Effect Level
mg/kg-day - milligrams (chemical) per killograms (bird body weight) per day

Table 10-13
Mammalian Lowest Observed Adverse Effect Level (LOAEL) Toxicity Reference Values (TRVs) for ERA Calculations
New and Alamo Rivers, California

	Primary Study Information							Uncertainty Factors				Allometrically Adjusted TRVs		
Chemical	Test Species	Observed Effect	Chronic/ Subchronic	Effect level	Body Weight (kg)	Unadjusted TRV[a] (mg/kg-day)	Non-sensitive to sensitive	Subchronic to Chronic UF	NOAEL to LOAEL UF	Adjusted NOAEL-Equivalent TRV[b] (mg/kg-day)	Sample & Arenal 1999 Mammalian Allometric Scaling Factor	Raccoon	Source of TRV	Source/TRV Provided by
Metals														
Selenium	Mouse	Reproduction	Chronic	EL	0.0246	1.21	-	-	-	1.21	0.94	0.876	EFA West, 1998	EFA West, 1998
Organics														
Aldrin	Rat	Neurobehavioral	Chronic	LOAEL	0.065	1	-	-	-	1	0.858	1	EFA West, 1998	EFA West, 1998
alpha-Chlordane	Mouse	Liver toxicity	Chronic	LOAEL	0.03	0.6	-	-	-	0.6	0.829	0.247	Khasawinah and Grutsch 1989 (Chlordane)	Rocketdyne, 2003
gamma-Chlordane	Mouse	Liver toxicity	Chronic	LOAEL	0.03	0.6	-	-	-	0.6	0.829	0.247	Khasawinah and Grutsch 1989 (Chlordane)	Rocketdyne, 2003
alpha BHC	Mink	Kit mortality and body weight	Chronic	LOAEL	1	0.137	-	-	-	0.137	0.855	0.137	Bleavins *et al.* 1984 (mixed isomers)	Sample *et al.* 1996
beta BHC	Rat	Reproduction - gonadal atrophy	Subchronic	LOAEL	0.35	20	-	10	-	2	0.855	2	Van Velsen *et al.* 1986	Sample *et al.* 1996
delta BHC	Mink	Kit mortality and body weight	Chronic	LOAEL	1	0.137	-	-	-	0.137	0.855	0.137	Bleavins *et al.* 1984 (mixed isomers)	Sample *et al.* 1996
gamma BHC (Lindane)	Rat	Liver and kidney toxicity	Subchronic	LOAEL	0.35	1.55	-	10	-	0.155	0.855	0.155	Zoecon Corp. 1983	USEPA 2006b
4,4'-DDD	Rat	Reproduction	Chronic	EL	0.32	16	-	-	-	16	1.268	16	EFA West, 1998	EFA West, 1998
4,4'-DDE	Rat	Reproduction	Chronic	EL	0.32	16	-	-	-	16	1.268	16	EFA West, 1998	EFA West, 1998
4,4'-DDT	Rat	Reproduction	Chronic	EL	0.32	16	-	-	-	16	1.268	16	EFA West, 1998	EFA West, 1998
Dieldrin	Rat	Reproduction	Chronic	LOAEL	0.35	0.2	-	-	-	0.2	0.94	0.2	Treon and Cleveland 1955	Rocketdyne, 2003
alpha Endosulfan (I)	Beagle dog	Behavior, weight gain	Chronic	LOAEL	12.7	1.9	-	-	-	1.9	0.563	1.9	Hoechst Celanese Corp. 1989a	USEPA 2006b
beta Endosulfan (II)	Beagle dog	Behavior, weight gain	Chronic	LOAEL	12.7	1.9	-	-	-	1.9	0.563	1.9	Hoechst Celanese Corp. 1989a	USEPA 2006b
Endosulfan sulfate	Beagle dog	Behavior, weight gain	Chronic	LOAEL	12.7	1.9	-	-	-	1.9	0.563	1.9	Hoechst Celanese Corp. 1989a	USEPA 2006b
Endrin	Dog (Beagle)	Convulsions, liver weight, liver histolopathological effects	Chronic	LOAEL	12.7	0.05	-	-	-	0.05	0.967	0.05	Velsicol Chemical Corporation. 1969	USEPA 2006b
Heptachlor epoxide	Rat	Development - pup weight gain	Chronic	EL	0.204	6.8	-	-	-	6.8	1.086	6.8	EFA West, 1998	EFA West, 1998
Methyxychlor	Rat	Reproduction	Chronic	LOAEL	0.35	8	-	-	-	8	1.224	8	Gray *et al.* 1988	Sample *et al.* 1996

a - Unadjusted TRV is the value derived from the primary literature, with no uncertainty factors applied.
b - Adjusted NOAEL-equivalent TRV is the value after uncertainty factors have been applied.

Notes:
LC_{50} - A lethal concentration/dose in 50 percent of the animals in an experiment
NOAEL - No Observable Adverse Effect Level
LOAEL - Lowest Observable Adverse Effect Level
mg/kg-day - milligrams (chemical) per killograms (bird body weight) per day

10.11.2.3 Allometric Scaling Factors

Allometric scaling factors were also used to adjust doses when the test species differed from the receptor species (Sample and Arenal 1999). These factors adjust for differences in body weight, metabolism, pharmacokinetics and tissue sensitivity to provide the best available estimates of species-specific toxicity.

The equation used for adjusting doses with allometric scaling factors is (Sample and Arenal 1999):

$$A_w = A_t \times \left(\frac{BW_t}{BW_w}\right)^{(1-b)}$$

Where:

A_w = Toxicity value for a particular wildlife species;

A_t = Toxicity value for a test species;

BW_t = Body weight of test species;

BW_w = Body weight of wildlife species; and

b = Allometric scaling factor provided by Sample and Arenal (1999).

The allometrically adjusted TRVs are presented in Tables 10-10 to 10-13.

10.12 Risk Characterization

Risk characterization integrates available exposure and effects information to evaluate the likelihood of adverse ecological impacts associated with exposure to COPECs (U.S. EPA 1992a, 1998). This risk characterization describes the risk estimates for receptors in the two treatment wetlands and background areas (drains and rivers) and the uncertainty associated with the risk estimates. As identified in current ERA guidance (U.S. EPA 1998), professional judgment plays a significant role when characterizing potential risks.

10.13 Risk Estimation

10.13.1 Hazard Quotient and Other Lines of Evidence

As stated in Section 10.12.1, HQs were used to estimate the potential for adverse ecological impacts when sufficient exposure and toxicity data existed. An HQ is the ratio of the exposure to the TRV:

$$HQ = \frac{Exposure}{TRV}$$

An HQ less than 1 indicates that there is a negligible potential for adverse ecological impacts due to exposure to a particular COPEC, whereas an HQ greater than 1 indicates that there is a potential for adverse ecological impacts due to exposure to that COPEC. However, there are a large number of conservative assumptions that are incorporated in the estimated HQs. Therefore, HQs that are in the single digits (*i.e.*, <10) are often not considered to represent significant risks.

For birds and mammals, both NOAEL TRVs and LOAEL TRVs were derived, and were used to calculate corresponding NOAEL HQs and LOAEL HQs. A NOAEL HQ gives a

conservative estimate of the comparison between exposure at site conditions and maximum safe exposure levels. A NOAEL HQ less than 1 would indicate that no risks are likely to occur from that particular exposure. The LOAEL HQ represents a comparison of exposure at site conditions with doses known to result in effects. A LOAEL HQ greater than or equal to 1 would indicate that a potential for risks exists. If the NOAEL HQ is greater than or equal to 1, and the LOAEL HQ is less than 1, a conclusion must be drawn by close evaluation of several factors (including, but not limited to, exposure parameters, magnitude of the HQ, source of the TRV, probability of site use by the receptor, and special-status of the receptor).

10.13.2 Ecological Significance of Potential Risks

Several lines of evidence were examined in order to evaluate the ecological significance of risks. Risks are generally not considered to warrant remedial action if exposures are comparable to or less than background conditions. HQs calculated for the agricultural drains, New and Alamo Rivers, and Salton Sea are representative of background risks and are discussed to place potential risks at the Brawley and Imperial Wetlands in perspective. Information on the size and nature of potentially affected habitats can support interpretations of the ecological significance of predicted effects. Conditions that may affect small areas may pose less of an ecological risk compared to conditions that may affect large areas.

10.13.3 Risk Estimates

Risk tables are provided for each representative species evaluated in the wetlands, drains, and rivers (Appendix L). These risk tables present the input variables, estimated exposures, TRVs, and HQs for all COPECs and representative species considered in each area. Tables showing a summary of the total exposures, TRVs, and calculated HQs were prepared to support discussions of the risks to biota in each area (Tables 10-14 through 10-45). Finally, summaries of the calculated HQs for all receptors in a given area are provided in Tables 10-47 to 10-50.

Table 10-14
Exposures and HQs for Emergent Plants Due to Contact with COPECs in Sediments
Brawley and Imperial Wetlands, California

Chemical	Sediment EPC (mg/kg)	TRV (mg/kg)	HQ
Metals			
Selenium	0.53	1.0	0.53
Pesticides			
4,4'-DDE	0.006	-	-
Dieldrin	0.001	-	-
Heptachlor	0.0004	-	-

Definitions:
EPC-Exposure point concentration.
HQ-Hazard quotient.
mg/kg-Milligrams per kilogram (dry weight)
TRV-Toxicity reference value
COPEC-Chemical of potential ecological concern.
Notes:
A dash indicates the absence of an applicable TRV and corresponding calculated HQ.

Table 10-15
Exposures and HQs for Benthic Invertebrates Due to Contact with COPECs in Sediment
Brawley and Imperial Wetlands, California

Chemical	Sediment EPC (mg/kg)	TRV (mg/kg)	HQ
Metals			
Selenium	0.53	1.0	0.53
Pesticides			
4,4'-DDE	0.006	0.003	2.0
Dieldrin	0.001	0.002	0.52
Heptachlor	0.0004	0.003	0.15

Definitions:
EPC-Exposure point concentration.
HQ-Hazard quotient.
mg/kg-Milligrams per kilogram (dry weight)
TRV-Toxicity reference value
COPEC-Chemical of potential ecological concern.
Notes:
Shaded cells indicate HQs greater than 1

Table 10-16
Exposures and HQs for Aquatic Invertebrates Due to Contact with COPECs in Surface Water
Brawley and Imperial Wetlands, California

Chemical	Surface Water EPC (µg/L)	TRV (µg/L)	HQ
Metals			
Selenium	3.1	5.0	0.62

Definitions:
EPC-Exposure point concentration.
HQ-Hazard quotient.
µg/L-Micrograms per Liter
TRV-Toxicity reference value
COPEC-Chemical of potential ecological concern.

Table 10-17
Exposures and HQs for Least Sandpiper Due to Ingestion of Invertebrates and Surface Water
Brawley and Imperial Wetlands, California

Chemical	Sediment Invertebrate Ingestion Dose (mg/kg-day)	Incidental Sediment Ingestion Dose (mg/kg-day)	Drinking Dose (mg/kg-day)	Total Ingestion Dose (mg/kg-day)	NOAEL TRV (mg/kg-day)	NOAEL HQ	LOAEL TRV (mg/kg-day)	LOAEL HQ
Metals								
Selenium	0.58	0.01	0.001	0.59	0.16	3.6	0.33	1.8
Pesticides								
4,4'-DDE	0.01	0.0001	-	0.01	0.002	3.2	0.01	1.0
Dieldrin	0.002	0.00002	-	0.002	0.04	0.05	0.23	0.01
Heptachlor	0.001	0.00001	-	0.001	0.19	0.004	1.9	0.0004

Definitions:
µg/L-Micrograms per liter.
mg/kg-day-Milligrams per kilogram fresh body weight per day
BCF-Bioconcentration factor.
EPC-Exposure point concentration.
HQ-Hazard quotient.
LOAEL-Lowest observable adverse effect level.
NOAEL-No observable adverse effect level.
RME-Reasonable maximum exposure
TRV-Toxicity reference value.
Notes:
A dash indicates the absence of a COPEC in a medium of relevance to the representative species
Refer to reference section for full citations.
Sediment EPCs and tissue concentrations are in dry weight basis.
Ingestion doses and TRVs are in fresh weight basis.
Shaded cells indicate HQs greater than 1.

Table 10-18
Exposures and HQs for Black-Necked Stilt Due to Ingestion of Invertebrates and Surface Water
Brawley and Imperial Wetlands, California

Chemical	Food Ingestion Dose (mg/kg-day)	Incidental Sediment Ingestion Dose (mg/kg-day)	Drinking Dose (mg/kg-day)	Total Ingestion Dose (mg/kg-day)	NOAEL TRV (mg/kg-day)	NOAEL HQ	LOAEL TRV (mg/kg-day)	LOAEL HQ
Metals								
Selenium	0.74	0.02	0.0004	0.76	0.25	3.1	0.50	1.5
Pesticides								
4,4'-DDD	4.0E-5	-	-	4.0E-5	0.004	0.01	0.01	0.003
4,4'-DDE	0.005	2.0E-4	-	0.005	0.004	1.3	0.01	0.43
alpha BHC	4.4E-5	-	-	4.4E-5	0.58	7.6E-5	2.3	1.9E-5
Dieldrin	0.001	3.1E-5	-	0.001	0.06	0.02	0.35	0.003
Endosulfan Sulfate	2.2E-5	-	-	2.2E-5	15	1.5E-6	5.8	3.8E-6
Heptachlor	4.6E-4	1.2E-5	-	4.7E-4	0.23	0.002	2.3	2.1E-4

Definitions:
µg/L-Micrograms per liter.
mg/kg-day-Milligrams per kilogram fresh body weight per day
BCF-Bioconcentration factor.
EPC-Exposure point concentration.
HQ-Hazard quotient.
LOAEL-Lowest observable adverse effect level.
NOAEL-No observable adverse effect level.
RME-Reasonable maximum exposure
TRV-Toxicity reference value.
Notes:
A dash indicates the absence of a COPEC in a medium of relevance to the representative species
Shaded cells indicate HQs greater than 1.

Table 10-19
Exposures and HQs for Double-Crested Cormorant Due to Ingestion of Invertebrates and Surface Water
Brawley and Imperial Wetlands, California

Chemical	Fish Ingestion Dose (mg/kg-day)	Incidental Sediment Ingestion Dose (mg/kg-day)	Drinking Dose (mg/kg-day)	Total Ingestion Dose (mg/kg-day)	NOAEL TRV (mg/kg-day)	NOAEL HQ	LOAEL TRV (mg/kg-day)	LOAEL HQ
Metals								
Selenium	0.41	0.0005	0.0002	0.41	0.41	1.0	0.83	0.49
Pesticides								
4,4'-DDD	0.003	-	-	0.003	0.01	0.34	0.02	0.11
4,4'-DDE	0.10	0.00001	-	0.10	0.01	12	0.02	4.0
4,4'-DDT	0.001	-	-	0.001	0.01	0.12	0.02	0.04
Aldrin	0.001	-	-	0.001	0.06	0.01	0.64	0.001
alpha-Chlordane	0.001	-	-	0.001	39	0.00003	195	0.00001
Dieldrin	0.01	0.000001	-	0.01	0.10	0.05	0.58	0.01
Endosulfan I	0.001	-	-	0.001	4.9	0.0002	2.0	0.0004
Endosulfan II	0.001	-	-	0.001	4.9	0.0001	2.0	0.0003
Endosulfan Sulfate	0.003	-	-	0.003	4.9	0.001	2.0	0.002
Endrin	0.0005	-	-	0.0005	0.02	0.03	0.18	0.003
Endrin Aldehyde	0.001	-	-	0.001	0.02	0.06	0.18	0.01
Heptachlor	0.001	0.0000003	-	0.001	0.28	0.003	2.8	0.0003

Definitions:
µg/L-Micrograms per liter.
mg/kg-day-Milligrams per kilogram fresh body weight per day
BCF-Bioconcentration factor.
EPC-Exposure point concentration.
HQ-Hazard quotient.
LOAEL-Lowest observable adverse effect level.
NOAEL-No observable adverse effect level.
RME-Reasonable maximum exposure
TRV-Toxicity reference value.
Notes:
A dash indicates the absence of a COPEC in a medium of relevance to the representative species
Shaded cells indicate HQs greater than 1.

Table 10-20
Exposures and HQs for Pied-Billed Grebe Due to Ingestion of Invertebrates and Surface Water
Brawley and Imperial Wetlands, California

Chemical	Food Ingestion Dose (mg/kg-day)	Incidental Sediment Ingestion Dose (mg/kg-day)	Drinking Dose (mg/kg-day)	Total Ingestion Dose (mg/kg-day)	NOAEL TRV (mg/kg-day)	NOAEL HQ	LOAEL TRV (mg/kg-day)	LOAEL HQ
Metals								
Selenium	0.99	0.003	0.0003	0.99	0.29	3.5	0.58	1.7
Pesticides								
4,4'-DDD	0.001	-	-	0.001	0.005	0.27	0.02	0.09
4,4'-DDE	0.06	0.00004	-	0.06	0.005	12	0.02	3.8
4,4'-DDT	0.0005	-	-	0.0005	0.005	0.10	0.02	0.03
Aldrin	0.0004	-	-	0.0004	0.04	0.01	0.35	0.001
alpha BHC	0.0001	-	-	0.0001	0.67	0.0002	2.7	0.0001
alpha-Chlordane	0.001	-	-	0.001	2.9	0.0002	14	0.00004
Dieldrin	0.004	0.00001	-	0.004	0.07	0.05	0.41	0.01
Endosulfan I	0.0004	-	-	0.0004	10	0.00004	4.2	0.0001
Endosulfan II	0.0004	-	-	0.0004	10	0.00003	4.2	0.0001
Endosulfan Sulfate	0.002	-	-	0.002	10	0.0002	4.2	0.0004
Endrin	0.0003	-	-	0.0003	0.01	0.02	0.12	0.002
Endrin Aldehyde	0.001	-	-	0.001	0.01	0.04	0.12	0.004
Heptachlor	0.001	0.000002	-	0.001	0.24	0.003	2.4	0.0003
Methoxychlor	0.0002	-	-	0.0002	-	-	-	-

Definitions:
µg/L-Micrograms per liter.
mg/kg-day-Milligrams per kilogram fresh body weight per day
BCF-Bioconcentration factor.
EPC-Exposure point concentration.
HQ-Hazard quotient.
LOAEL-Lowest observable adverse effect level.
NOAEL-No observable adverse effect level.
RME-Reasonable maximum exposure
TRV-Toxicity reference value.
Notes:
A dash indicates the absence of one of the following:
• A COPEC in a medium of relevance to the representative species
• An applicable TRV and corresponding calculated HQ
Shaded cells indicate HQs greater than 1.

Table 10-21
Exposures and HQs for American Coot Due to Ingestion of Invertebrates and Surface Water
Brawley and Imperial Wetlands, California

Chemical	Food Ingestion Dose (mg/kg-day)	Incidental Sediment Ingestion Dose (mg/kg-day)	Drinking Dose (mg/kg-day)	Total Ingestion Dose (mg/kg-day)	NOAEL TRV (mg/kg-day)	NOAEL HQ	LOAEL TRV (mg/kg-day)	LOAEL HQ
Metals								
Selenium	0.28	0.01	0.0002	0.29	0.31	0.92	0.64	0.46
Pesticides								
4,4'-DDE	0.01	0.0001	-	0.01	0.01	1.6	0.02	0.52
Dieldrin	0.0001	0.00001	-	0.0001	0.08	0.001	0.0003	0.002
Heptachlor	0.00004	0.000005	-	0.00004	0.25	0.0002	2.5	0.00002

Definitions:
µg/L-Micrograms per liter.
mg/kg-day-Milligrams per kilogram fresh body weight per day
BCF-Bioconcentration factor.
EPC-Exposure point concentration.
HQ-Hazard quotient.
LOAEL-Lowest observable adverse effect level.
NOAEL-No observable adverse effect level.
RME-Reasonable maximum exposure
TRV-Toxicity reference value.
Notes:
Shaded cells indicate HQs greater than 1.

Table 10-22
Exposures and HQs for Red-Winged Blackbird Due to Ingestion of Invertebrates and Surface Water
Brawley and Imperial Wetlands, California

Chemical	Food Ingestion Dose (mg/kg-day)	Incidental Sediment Ingestion Dose (mg/kg-day)	Drinking Dose (mg/kg-day)	Total Ingestion Dose (mg/kg-day)	NOAEL TRV (mg/kg-day)	NOAEL HQ	LOAEL TRV (mg/kg-day)	LOAEL HQ
Metals								
Selenium	0.85	0.01	0.001	0.86	0.19	4.6	0.38	2.3
Pesticides								
4,4'-DDE	0.01	0.0001	-	0.01	0.003	2.0	0.01	0.65
Dieldrin	0.001	0.00002	-	0.002	0.05	0.03	0.26	0.01
Heptachlor	0.001	0.00001	-	0.001	0.20	0.003	2.0	0.0003

Definitions:
µg/L-Micrograms per liter.
mg/kg-day-Milligrams per kilogram fresh body weight per day
BCF-Bioconcentration factor.
EPC-Exposure point concentration.
HQ-Hazard quotient.
LOAEL-Lowest observable adverse effect level.
NOAEL-No observable adverse effect level.
RME-Reasonable maximum exposure
TRV-Toxicity reference value.
Notes:
A dash indicates the absence of a COPEC in a medium of relevance to the representative species
Shaded cells indicate HQs greater than 1.

Table 10-23
Exposures and HQs for Raccoon Due to Ingestion of Invertebrates and Surface Water
Brawley and Imperial Wetlands, California

Chemical	Food Ingestion Dose (mg/kg-day)	Incidental Sediment Ingestion Dose (mg/kg-day)	Drinking Dose (mg/kg-day)	Total Ingestion Dose (mg/kg-day)	NOAEL TRV (mg/kg-day)	NOAEL HQ	LOAEL TRV (mg/kg-day)	LOAEL HQ
Metals								
Selenium	0.10	0.14	0.0003	0.23	0.01	28	0.20	1.2
Pesticides								
4,4'-DDD	0.000004	-	-	0.000004	0.80	0.00001	16	0.0000003
4,4'-DDE	0.001	0.002	-	0.003	0.80	0.004	16	0.0002
alpha BHC	0.00003	-	-	0.00003	0.01	0.002	0.14	0.0002
Dieldrin	0.0001	0.0003	-	0.0003	0.04	0.01	0.20	0.002
Endosulfan Sulfate	0.000002	-	-	0.000002	0.57	0.000004	1.9	0.000001
Heptachlor	0.00002	0.0001	-	0.0001	0.13	0.001	6.8	0.00002
Endosulfan I	0.000003	-	-	0.000003	0.57	0.00001	1.9	0.000002

Definitions:
µg/L-Micrograms per liter.
mg/kg-day-Milligrams per kilogram fresh body weight per day
BCF-Bioconcentration factor.
EPC-Exposure point concentration.
HQ-Hazard quotient.
LOAEL-Lowest observable adverse effect level.
NOAEL-No observable adverse effect level.
RME-Reasonable maximum exposure
TRV-Toxicity reference value.
Notes:
A dash indicates the absence of a COPEC in a medium of relevance to the representative species
Shaded cells indicate HQs greater than 1.

Table 10-24
Exposures and HQs for Emergent Plants Due to Contact with COPECs in Sediments
Agricultural Drains at the Brawley and Imperial Wetlands, California

Chemical	Sediment EPC (mg/kg)	TRV (mg/kg)	HQ
Metals			
Selenium	0.60	1.0	0.60
Pesticides			
4,4'-DDE	0.04	-	-
4,4'-DDT	0.002	-	-
beta BHC	0.002	-	-
Dieldrin	0.001	-	-

Definitions:
EPC-Exposure point concentration.
HQ-Hazard quotient.
mg/kg-Milligrams per kilogram (dry weight)
TRV-Toxicity reference value
COPEC-Chemical of potential ecological concern.
Notes:
A dash indicates the absence of an applicable
TRV and corresponding calculated HQ.

Table 10-25
Exposures and HQs for Benthic Invertebrates Due to Contact with COPECs in Sediment
Agricultural Drains at the Brawley and Imperial Wetlands, California

Chemical	Sediment EPC (mg/kg)	TRV (mg/kg)	HQ
Metals			
Selenium	0.60	1.0	0.60
Pesticides			
4,4'-DDE	0.04	0.003	12
4,4'-DDT	0.002	0.004	0.45
beta BHC	0.002	0.002	0.68
Dieldrin	0.001	0.002	0.58

Definitions:
EPC-Exposure point concentration.
HQ-Hazard quotient.
mg/kg-Milligrams per kilogram (dry weight)
TRV-Toxicity reference value
COPEC-Chemical of potential ecological concern.
Notes:
Shaded cells indicate HQs greater than 1

Table 10-26
Exposures and HQs for Aquatic Invertebrates Due to Contact with COPECs in Surface Water
Agricultural Drains at the Brawley and Imperial Wetlands, California

Chemical	Surface Water EPC (µg/L)	TRV (µg/L)	HQ
Metals			
Selenium	4.7	5.0	0.95

Definitions:
EPC-Exposure point concentration.
HQ-Hazard quotient.
µg/L-Micrograms per Litre
TRV-Toxicity reference value
COPEC-Chemical of potential ecological concern.

Table 10-27
Exposures and HQs for Least Sandpiper Due to Ingestion of Invertebrates and Surface Water
Agricultural Drains at the Brawley and Imperial Wetlands, California

Chemical	Sediment Invertebrate Ingestion Dose (mg/kg-day)	Incidental Sediment Ingestion Dose (mg/kg-day)	Drinking Dose (mg/kg-day)	Total Ingestion Dose (mg/kg-day)	NOAEL TRV (mg/kg-day)	NOAEL HQ	LOAEL TRV (mg/kg-day)	LOAEL HQ
Metals								
Selenium	0.65	0.01	0.001	0.66	0.16	4.1	0.33	2.0
Pesticides								
4,4'-DDE	0.04	0.001	-	0.05	0.002	20	0.01	6.4
4,4'-DDT	0.002	0.00004	-	0.002	0.002	0.98	0.01	0.31
beta BHC	0.003	0.00003	-	0.003	0.38	0.01	1.5	0.002
Dieldrin	0.002	0.00002	-	0.002	0.04	0.05	0.23	0.01

Definitions:
µg/L-Micrograms per liter.
mg/kg-day-Milligrams per kilogram fresh body weight per day
BCF-Bioconcentration factor.
EPC-Exposure point concentration.
HQ-Hazard quotient.
LOAEL-Lowest observable adverse effect level.
NOAEL-No observable adverse effect level.
RME-Reasonable maximum exposure
TRV-Toxicity reference value.
Notes:
A dash indicates the absence of a COPEC in a medium of relevance to the representative species
Shaded cells indicate HQs greater than 1.

Table 10-28
Exposures and HQs for Black-Necked Stilt Due to Ingestion of Invertebrates and Surface Water Agricultural Drains at the Brawley and Imperial Wetlands, California

Chemical	Food Ingestion Dose (mg/kg-day)	Incidental Sediment Ingestion Dose (mg/kg-day)	Drinking Dose (mg/kg-day)	Total Ingestion Dose (mg/kg-day)	NOAEL TRV (mg/kg-day)	NOAEL HQ	LOAEL TRV (mg/kg-day)	LOAEL HQ
Metals								
Selenium	0.69	0.02	0.001	0.71	0.25	2.9	0.50	1.4
Pesticides								
4,4'-DDD	0.001	-	-	0.001	0.004	0.16	0.01	0.05
4,4'-DDE	0.05	0.001	-	0.05	0.004	13	0.01	4.1
4,4'-DDT	0.001	0.0001	-	0.001	0.004	0.36	0.01	0.12
alpha-Chlordane	0.0001	-	-	0.0001	0.94	0.0001	4.7	0.00002
beta BHC	0.002	0.0001	-	0.002	0.58	0.003	2.3	0.001
Dieldrin	0.002	0.00003	-	0.002	0.06	0.04	0.35	0.01
Endosulfan I	0.0001	-	-	0.0001	15	0.00001	5.8	0.00001
Endosulfan II	0.00005	-	-	0.00005	15	0.000003	5.8	0.00001
gamma-Chlordane	0.0002	-	-	0.0002	0.94	0.0002	4.7	0.00003

Definitions:
µg/L-Micrograms per liter.
mg/kg-day-Milligrams per kilogram fresh body weight per day
BCF-Bioconcentration factor.
EPC-Exposure point concentration.
HQ-Hazard quotient.
LOAEL-Lowest observable adverse effect level.
NOAEL-No observable adverse effect level.
RME-Reasonable maximum exposure
TRV-Toxicity reference value.
Notes:
A dash indicates the absence of a COPEC in a medium of relevance to the representative species
Shaded cells indicate HQs greater than 1.

Table 10-29
Exposures and HQs for Double-Crested Cormorant Due to Ingestion of Invertebrates and Surface Water Agricultural Drains at the Brawley and Imperial Wetlands, California

Chemical	Fish Ingestion Dose (mg/kg-day)	Incidental Sediment Ingestion Dose (mg/kg-day)	Drinking Dose (mg/kg-day)	Total Ingestion Dose (mg/kg-day)	NOAEL TRV (mg/kg-day)	NOAEL HQ	LOAEL TRV (mg/kg-day)	LOAEL HQ
Metals								
Selenium	0.84	0.001	0.0002	0.84	0.41	2.1	0.83	1.0
Pesticides								
4,4'-DDD	0.01	-	-	0.01	0.01	1.4	0.02	0.44
4,4'-DDE	0.38	0.00003	-	0.38	0.01	49	0.02	16
4,4'-DDT	0.002	0.000002	-	0.002	0.01	0.31	0.02	0.10
alpha-Chlordane	0.002	-	-	0.002	39	0.00004	195	0.00001
beta BHC	-	0.000001	-	0.000001	0.95	0.000001	3.8	0.0000004
Dieldrin	0.02	0.000001	-	0.02	0.10	0.16	0.58	0.03
Heptachlor	0.0005	-	-	0.0005	0.28	0.002	2.8	0.0002
Endosulfan II	0.001	-	-	0.001	4.9	0.0002	2.0	0.0004
gamma-Chlordane	0.003	-	-	0.003	39	0.0001	195	0.00001

Definitions:
µg/L-Micrograms per liter.
mg/kg-day-Milligrams per kilogram fresh body weight per day
BCF-Bioconcentration factor.
EPC-Exposure point concentration.
HQ-Hazard quotient.
LOAEL-Lowest observable adverse effect level.
NOAEL-No observable adverse effect level.
RME-Reasonable maximum exposure
TRV-Toxicity reference value.
Notes:
A dash indicates the absence of a COPEC in a medium of relevance to the representative species
Shaded cells indicate HQs greater than 1.

Table 10-30
Exposures and HQs for Pied-Billed Grebe Due to Ingestion of Invertebrates and Surface Water Agricultural Drains at the Brawley and Imperial Wetlands, California

Chemical	Food Ingestion Dose (mg/kg-day)	Incidental Sediment Ingestion Dose (mg/kg-day)	Drinking Dose (mg/kg-day)	Total Ingestion Dose (mg/kg-day)	NOAEL TRV (mg/kg-day)	NOAEL HQ	LOAEL TRV (mg/kg-day)	LOAEL HQ
Metals								
Selenium	1.00	0.004	0.0004	1.0	0.29	3.5	0.58	1.7
Pesticides								
4,4'-DDD	0.01	-	-	0.01	0.005	1.1	0.02	0.37
4,4'-DDE	0.23	0.0002	-	0.23	0.005	47	0.02	15
4,4'-DDT	0.003	0.00001	-	0.003	0.005	0.55	0.02	0.18
alpha-Chlordane	0.001	-	-	0.001	2.9	0.0003	14	0.0001
beta BHC	0.002	0.00001	-	0.002	0.67	0.003	2.7	0.001
Dieldrin	0.01	0.00001	-	0.01	0.07	0.14	0.41	0.03
Endosulfan II	0.0004	-	-	0.0004	10	0.00004	4.2	0.0001
gamma-Chlordane	0.001	-	-	0.001	2.9	0.0005	14	0.0001

Definitions:
µg/L-Micrograms per liter.
mg/kg-day-Milligrams per kilogram fresh body weight per day
BCF-Bioconcentration factor.
EPC-Exposure point concentration.
HQ-Hazard quotient.
LOAEL-Lowest observable adverse effect level.
NOAEL-No observable adverse effect level.
RME-Reasonable maximum exposure
TRV-Toxicity reference value.
Notes:
A dash indicates the absence of a COPEC in a medium of relevance to the representative species
Shaded cells indicate HQs greater than 1.

Table 10-31
Exposures and HQs for American Coot Due to Ingestion of Invertebrates and Surface Water Agricultural Drains at the Brawley and Imperial Wetlands, California

Chemical	Food Ingestion Dose (mg/kg-day)	Incidental Sediment Ingestion Dose (mg/kg-day)	Drinking Dose (mg/kg-day)	Total Ingestion Dose (mg/kg-day)	NOAEL TRV (mg/kg-day)	NOAEL HQ	LOAEL TRV (mg/kg-day)	LOAEL HQ
Metals								
Selenium	0.22	0.01	0.0004	0.23	0.31	0.72	0.64	0.35
Pesticides								
4,4'-DDE	0.01	0.001	-	0.01	0.01	1.3	0.02	0.41
4,4'-DDT	0.0001	0.00003	-	0.0001	0.01	0.02	0.02	0.01
beta BHC	0.0002	0.00002	-	0.0002	0.73	0.0002	2.9	0.0001
Dieldrin	0.0001	0.00001	-	0.0001	0.08	0.002	0.44	0.0003
Endosulfan I	0.003	-	-	0.003	8.6	0.0004	3.5	0.001

Definitions:
µg/L-Micrograms per liter.
mg/kg-day-Milligrams per kilogram fresh body weight per day
BCF-Bioconcentration factor.
EPC-Exposure point concentration.
HQ-Hazard quotient.
LOAEL-Lowest observable adverse effect level.
NOAEL-No observable adverse effect level.
RME-Reasonable maximum exposure
TRV-Toxicity reference value.
Notes:
A dash indicates the absence of a COPEC in a medium of relevance to the representative species
Shaded cells indicate HQs greater than 1.

Table 10-32
Exposures and HQs for Red-Winged Blackbird Due to Ingestion of Invertebrates and Surface Water Agricultural Drains at the Brawley and Imperial Wetlands, California

Chemical	Food Ingestion Dose (mg/kg-day)	Incidental Sediment Ingestion Dose (mg/kg-day)	Drinking Dose (mg/kg-day)	Total Ingestion Dose (mg/kg-day)	NOAEL TRV (mg/kg-day)	NOAEL HQ	LOAEL TRV (mg/kg-day)	LOAEL HQ
Metals								
Selenium	0.81	0.01	0.001	0.82	0.19	4.4	0.38	2.2
Pesticides								
4,4'-DDE	0.03	0.001	-	0.03	0.003	13	0.01	4.0
4,4'-DDT	0.002	0.00004	-	0.002	0.003	0.61	0.01	0.20
beta BHC	0.002	0.00003	-	0.002	0.44	0.01	1.7	0.001
Dieldrin	0.002	0.00002	-	0.002	0.05	0.04	0.26	0.01

Definitions:
µg/L-Micrograms per liter.
mg/kg-day-Milligrams per kilogram fresh body weight per day
BCF-Bioconcentration factor.
EPC-Exposure point concentration.
HQ-Hazard quotient.
LOAEL-Lowest observable adverse effect level.
NOAEL-No observable adverse effect level.
RME-Reasonable maximum exposure
TRV-Toxicity reference value.
Notes:
A dash indicates the absence of a COPEC in a medium of relevance to the representative species
Shaded cells indicate HQs greater than 1.

Table 10-33
Exposures and HQs for Raccoon Due to Ingestion of Invertebrates and Surface Water Agricultural Drains at the Brawley and Imperial Wetlands, California

Chemical	Food Ingestion Dose (mg/kg-day)	Incidental Sediment Ingestion Dose (mg/kg-day)	Drinking Dose (mg/kg-day)	Total Ingestion Dose (mg/kg-day)	NOAEL TRV (mg/kg-day)	NOAEL HQ	LOAEL TRV (mg/kg-day)	LOAEL HQ
Metals								
Selenium	0.09	0.15	0.0004	0.24	0.01	29	0.20	1.2
Pesticides								
4,4'-DDD	0.0001	-	-	0.0001	0.80	0.0001	16	0.000004
4,4'-DDE	0.01	0.01	-	0.01	0.80	0.02	16	0.001
4,4'-DDT	0.0001	0.0005	-	0.001	0.80	0.001	16	0.00004
alpha-Chlordane	0.00001	-	-	0.00001	0.05	0.0002	0.25	0.00004
beta BHC	0.0001	0.0004	-	0.001	0.40	0.001	2.0	0.0003
Dieldrin	0.0002	0.0003	-	0.0005	0.04	0.01	0.20	0.002
Endosulfan I	0.0004	-	-	0.0004	0.57	0.001	1.9	0.0002
Endosulfan II	0.00001	-	-	0.00001	0.57	0.00001	1.9	0.000003
gamma-Chlordane	0.00004	-	-	0.00004	0.05	0.001	0.25	0.0002

Definitions:
µg/L-Micrograms per liter.
mg/kg-day-Milligrams per kilogram fresh body weight per day
BCF-Bioconcentration factor.
EPC-Exposure point concentration.
HQ-Hazard quotient.
LOAEL-Lowest observable adverse effect level.
NOAEL-No observable adverse effect level.
RME-Reasonable maximum exposure
TRV-Toxicity reference value.
Notes:
A dash indicates the absence of a COPEC in a medium of relevance to the representative species
Shaded cells indicate HQs greater than 1.

Table 10-34
Exposures and HQs for Emergent Plants Due to Contact with COPECs in Sediments
New and Alamo Rivers, California

Chemical	Sediment EPC (mg/kg)	TRV (mg/kg)	HQ
Metals			
Selenium	0.79	1.0	0.79
Pesticides			
4,4'-DDE	0.04	-	-
4,4'-DDT	0.01	-	-
Dieldrin	0.002	-	-
Endrin aldehyde	0.001	-	-

Definitions:
EPC-Exposure point concentration.
HQ-Milligrams per kilogram (dry weight)
mg/kg-Milligrams per kilogram.
TRV-Toxicity reference value
COPEC-Chemical of potential ecological concern.
Notes:
A dash indicates the absence of an applicable TRV and corresponding calculated HQ.

Table 10-35
Exposures and HQs for Benthic Invertebrates Due to Contact with COPECs in Sediment
New and Alamo Rivers, California

Chemical	Sediment EPC (mg/kg)	TRV (mg/kg)	HQ
Metals			
Selenium	0.79	1.0	0.79
Pesticides			
4,4'-DDE	0.04	0.003	14
4,4'-DDT	0.01	0.004	1.7
Dieldrin	0.002	0.002	0.97
Endrin aldehyde	0.001	0.002	0.54

Definitions:
EPC-Exposure point concentration.
HQ-Milligrams per kilogram (dry weight)
mg/kg-Milligrams per kilogram.
TRV-Toxicity reference value
COPEC-Chemical of potential ecological concern.
Notes:
Shaded cells indicate HQs greater than 1

Table 10-36
Exposures and HQs for Aquatic Invertebrates Due to Contact with COPECs in Surface Water
New and Alamo Rivers, California

Chemical	Surface Water EPC (µg/L)	TRV (µg/L)	HQ
Metals			
Selenium	4.9	5.0	0.99

Definitions:
EPC-Exposure point concentration.
HQ-Hazard quotient.
µg/L-Micrograms per Litre
TRV-Toxicity reference value
COPEC-Chemical of potential ecological concern.

Table 10-37
Exposures and HQs for Least Sandpiper Due to Ingestion of Invertebrates and Surface Water
New and Alamo Rivers, California

Chemical	Sediment Invertebrate Ingestion Dose (mg/kg-day)	Incidental Sediment Ingestion Dose (mg/kg-day)	Drinking Dose (mg/kg-day)	Total Ingestion Dose (mg/kg-day)	NOAEL TRV (mg/kg-day)	NOAEL HQ	LOAEL TRV (mg/kg-day)	LOAEL HQ
Metals								
Selenium	0.86	0.01	0.001	0.88	0.16	5.4	0.33	2.7
Pesticides								
4,4'-DDE	0.05	0.001	-	0.05	0.002	22	0.01	7.2
4,4'-DDT	0.01	0.0001	-	0.01	0.002	3.7	0.01	1.2
Dieldrin	0.004	0.00003	-	0.004	0.04	0.09	0.23	0.02
Endrin aldehyde	0.002	0.00002	-	0.002	0.01	0.42	0.06	0.04

Definitions:
µg/L-Micrograms per liter.
mg/kg-day-Milligrams per kilogram fresh body weight per day
BCF-Bioconcentration factor.
EPC-Exposure point concentration.
HQ-Hazard quotient.
LOAEL-Lowest observable adverse effect level.
NOAEL-No observable adverse effect level.
RME-Reasonable maximum exposure
TRV-Toxicity reference value.
Notes:
A dash indicates the absence of a COPEC in a medium of relevance to the representative species
Shaded cells indicate HQs greater than 1.

Table 10-38
Exposures and HQs for Black-Necked Stilt Due to Ingestion of Invertebrates and Surface Water
New and Alamo Rivers, California

Chemical	Food Ingestion Dose (mg/kg-day)	Incidental Sediment Ingestion Dose (mg/kg-day)	Drinking Dose (mg/kg-day)	Total Ingestion Dose (mg/kg-day)	NOAEL TRV (mg/kg-day)	NOAEL HQ	LOAEL TRV (mg/kg-day)	LOAEL HQ
Metals								
Selenium	0.25	0.03	0.001	0.27	0.25	1.1	0.50	0.54
Pesticides								
4,4'-DDE	0.07	0.001	-	0.07	0.004	17	0.01	5.5
4,4'-DDT	0.01	0.0002	-	0.01	0.004	1.4	0.01	0.45
alpha-Chlordane	0.0001	-	-	0.0001	0.94	0.0001	4.7	0.00002
beta BHC	0.00003	-	-	0.00003	0.58	0.00005	2.3	0.00001
Dieldrin	0.002	0.0001	-	0.002	0.06	0.04	0.35	0.01
Endosulfan I	0.0002	-	-	0.0002	15	0.00001	5.8	0.00004
Endosulfan II	0.00002	-	-	0.00002	15	0.000001	5.8	0.000003
Endosulfan Sulfate	0.00001	-	-	0.00001	15	0.0000004	5.8	0.000001
Endrin aldehyde	0.001	0.00004	-	0.001	0.01	0.15	0.10	0.02
Heptachlor epoxide	0.0001	-	-	0.0001	0.23	0.0004	2.3	0.00004

Definitions:
µg/L-Micrograms per liter.
mg/kg-day-Milligrams per kilogram fresh body weight per day
BCF-Bioconcentration factor.
EPC-Exposure point concentration.
HQ-Hazard quotient.
LOAEL-Lowest observable adverse effect level.
NOAEL-No observable adverse effect level.
RME-Reasonable maximum exposure
TRV-Toxicity reference value.
Notes:
A dash indicates the absence of a COPEC in a medium of relevance to the representative species
Shaded cells indicate HQs greater than 1.

Table 10-39
Exposures and HQs for Double-Crested Cormorant Due to Ingestion of Invertebrates and Surface Water
New and Alamo Rivers, California

Chemical	Fish Ingestion Dose (mg/kg-day)	Incidental Sediment Ingestion Dose (mg/kg-day)	Drinking Dose (mg/kg-day)	Total Ingestion Dose (mg/kg-day)	NOAEL TRV (mg/kg-day)	NOAEL HQ	LOAEL TRV (mg/kg-day)	LOAEL HQ
Metals								
Selenium	0.60	0.001	0.0002	0.60	0.41	1.5	0.83	0.73
Pesticides								
4,4'-DDE	0.61	0.00004	-	0.61	0.01	79	0.02	25
4,4'-DDT	0.01	0.00001	-	0.01	0.01	0.88	0.02	0.28
alpha-Chlordane	0.002	-	-	0.002	39	0.00004	195	0.00001
beta BHC	0.0005	-	-	0.0005	0.95	0.001	3.8	0.0001
Dieldrin	-	0.000002	-	0.000002	0.10	0.00002	0.58	0.000003
Endosulfan I	0.003	-	-	0.003	4.9	0.001	2.0	0.002
Endrin aldehyde	-	0.000001	-	0.000001	0.02	0.0001	0.18	0.00001
Heptachlor epoxide	0.001	-	-	0.001	0.28	0.005	2.8	0.0005

Definitions:
µg/L-Micrograms per liter.
mg/kg-day-Milligrams per kilogram fresh body weight per day
BCF-Bioconcentration factor.
EPC-Exposure point concentration.
HQ-Hazard quotient.
LOAEL-Lowest observable adverse effect level.
NOAEL-No observable adverse effect level.
RME-Reasonable maximum exposure
TRV-Toxicity reference value.
Notes:
A dash indicates the absence of a COPEC in a medium of relevance to the representative species
Shaded cells indicate HQs greater than 1.

Table 10-40
Exposures and HQs for Pied-Billed Grebe Due to Ingestion of Invertebrates and Surface Water
New and Alamo Rivers, California

Chemical	Food Ingestion Dose (mg/kg-day)	Incidental Sediment Ingestion Dose (mg/kg-day)	Drinking Dose (mg/kg-day)	Total Ingestion Dose (mg/kg-day)	NOAEL TRV (mg/kg-day)	NOAEL HQ	LOAEL TRV (mg/kg-day)	LOAEL HQ
Metals								
Selenium	0.54	0.005	0.0004	0.54	0.29	1.9	0.58	0.93
Pesticides								
4,4'-DDE	0.36	0.0003	-	0.36	0.005	73	0.02	24
4,4'-DDT	0.01	0.00005	-	0.01	0.005	1.8	0.02	0.59
alpha-Chlordane	0.001	-	-	0.001	2.9	0.0003	14	0.0001
beta BHC	0.0003	-	-	0.0003	0.67	0.0004	2.7	0.0001
Dieldrin	0.002	0.00001	-	0.002	0.07	0.03	0.41	0.01
Endosulfan I	0.002	-	-	0.002	10	0.0002	4.2	0.0004
Endrin aldehyde	0.002	0.00001	-	0.002	0.01	0.13	0.12	0.01
Heptachlor epoxide	0.001	-	-	0.001	0.24	0.003	2.4	0.0003

Definitions:
µg/L-Micrograms per liter.
mg/kg-day-Milligrams per kilogram fresh body weight per day
BCF-Bioconcentration factor.
EPC-Exposure point concentration.
HQ-Hazard quotient.
LOAEL-Lowest observable adverse effect level.
NOAEL-No observable adverse effect level.
RME-Reasonable maximum exposure
TRV-Toxicity reference value.
Notes:
A dash indicates the absence of a COPEC in a medium of relevance to the representative species
Shaded cells indicate HQs greater than 1.

Table 10-41
Exposures and HQs for American Coot Due to Ingestion of Invertebrates and Surface Water
New and Alamo Rivers, California

Chemical	Food Ingestion Dose (mg/kg-day)	Incidental Sediment Ingestion Dose (mg/kg-day)	Drinking Dose (mg/kg-day)	Total Ingestion Dose (mg/kg-day)	NOAEL TRV (mg/kg-day)	NOAEL HQ	LOAEL TRV (mg/kg-day)	LOAEL HQ
Metals								
Selenium	0.44	0.01	0.0004	0.45	0.31	1.4	0.64	0.71
Pesticides								
4,4'-DDE	0.01	0.001	-	0.01	0.01	2.4	0.02	0.77
4,4'-DDT	0.0004	0.0001	-	0.001	0.01	0.09	0.02	0.03
Dieldrin	0.001	0.00002	-	0.001	0.08	0.01	0.44	0.002
Endosulfan I	0.001	-	-	0.001	8.6	0.0001	3.5	0.0003
Endosulfan II	0.001	-	-	0.001	8.6	0.0002	3.5	0.0004
Endosulfan Sulfate	0.0004	-	-	0.0004	8.6	0.00004	3.5	0.0001
Endrin aldehyde	0.0001	0.00002	-	0.0001	0.01	0.01	0.13	0.001

Definitions:
µg/L-Micrograms per liter.
mg/kg-day-Milligrams per kilogram fresh body weight per day
BCF-Bioconcentration factor.
EPC-Exposure point concentration.
HQ-Hazard quotient.
LOAEL-Lowest observable adverse effect level.
NOAEL-No observable adverse effect level.
RME-Reasonable maximum exposure
TRV-Toxicity reference value.
Notes:
A dash indicates the absence of a COPEC in a medium of relevance to the representative species
Shaded cells indicate HQs greater than 1.

Table 10-42
Exposures and HQs for Red-Winged Blackbird Due to Ingestion of Invertebrates and Surface Water
New and Alamo Rivers, California

Chemical	Food Ingestion Dose (mg/kg-day)	Incidental Sediment Ingestion Dose (mg/kg-day)	Drinking Dose (mg/kg-day)	Total Ingestion Dose (mg/kg-day)	NOAEL TRV (mg/kg-day)	NOAEL HQ	LOAEL TRV (mg/kg-day)	LOAEL HQ
Metals								
Selenium	0.26	0.02	0.001	0.27	0.19	1.5	0.38	0.72
Pesticides								
4,4'-DDE	0.04	0.001	-	0.04	0.003	14	0.01	4.5
4,4'-DDT	0.01	0.0001	-	0.01	0.003	2.3	0.01	0.75
Dieldrin	0.003	0.00004	-	0.003	0.05	0.06	0.26	0.01
Endrin aldehyde	0.002	0.00002	-	0.002	0.01	0.27	0.07	0.03

Definitions:
µg/L-Micrograms per liter.
mg/kg-day-Milligrams per kilogram fresh body weight per day
BCF-Bioconcentration factor.
EPC-Exposure point concentration.
HQ-Hazard quotient.
LOAEL-Lowest observable adverse effect level.
NOAEL-No observable adverse effect level.
RME-Reasonable maximum exposure
TRV-Toxicity reference value.
Notes:
A dash indicates the absence of a COPEC in a medium of relevance to the representative species
Shaded cells indicate HQs greater than 1.

Table 10-43
Exposures and HQs for Raccoon Due to Ingestion of Invertebrates and Surface Water
New and Alamo Rivers, California

Chemical	Food Ingestion Dose (mg/kg-day)	Incidental Sediment Ingestion Dose (mg/kg-day)	Drinking Dose (mg/kg-day)	Total Ingestion Dose (mg/kg-day)	NOAEL TRV (mg/kg-day)	NOAEL HQ	LOAEL TRV (mg/kg-day)	LOAEL HQ
Metals								
Selenium	0.07	0.20	0.0004	0.27	0.01	33	0.20	1.4
Pesticides								
4,4'-DDE	0.01	0.01	-	0.02	0.80	0.02	16	0.001
4,4'-DDT	0.001	0.002	-	0.002	0.80	0.003	16	0.0001
alpha-Chlordane	0.00001	-	-	0.00001	0.05	0.0002	0.25	0.00004
beta BHC	0.000003	-	-	0.000003	0.40	0.00001	2.0	0.000002
Dieldrin	0.0003	0.0005	-	0.001	0.04	0.02	0.20	0.004
Endosulfan I	0.0001	-	-	0.0001	0.57	0.0003	1.9	0.0001
Endosulfan II	0.0001	-	-	0.0001	0.57	0.0003	1.9	0.0001
Endosulfan Sulfate	0.00004	-	-	0.00004	0.57	0.0001	1.9	0.00002
Endrin aldehyde	0.0001	0.0003	-	0.0004	0.03	0.01	0.07	0.01
Heptachlor epoxide	0.00001	-	-	0.00001	0.13	0.0001	6.8	0.000001

Definitions:
µg/L-Micrograms per liter.
mg/kg-day-Milligrams per kilogram fresh body weight per day
BCF-Bioconcentration factor.
EPC-Exposure point concentration.
HQ-Hazard quotient.
LOAEL-Lowest observable adverse effect level.
NOAEL-No observable adverse effect level.
RME-Reasonable maximum exposure
TRV-Toxicity reference value.
Notes:
A dash indicates the absence of a COPEC in a medium of relevance to the representative species
Shaded cells indicate HQs greater than 1.

Table 10-44
Exposures and HQs for Amphibians Due to Contact with Surface Water
New and Alamo Rivers, California

Chemical	Range of Toxicity Values (µg/L)[a] No. Studies	Low	High	Surface Water Concentration[b] (µg/L)
Brawley and Imperial Wetlands				
Selenium	2	0.9	80	**3.12**
Agricultural Drains				
Selenium	2	0.9	80	**4.74**
New and Alamo Rivers				
Selenium	2	0.9	80	**4.94**

Definitions:
NOAEL-No observed adverse effect level.
µg/L-Micrograms per liter.
SW-Surface water.
BOLD-The value exceeds the low toxicity value for amphibians.
Notes:
a-Range of toxicity values from dissolved data for embryo-larval stages of amphibians from the Canadian Wildlife Service's Reptile and Amphibian Toxicology Literature (RATL) Database (Pauli *et al.* 2000). Toxicity values were converted to NOAEL-equivalent concentrations.
b -Dissolved metal.

Table 10-45
Exposures and HQs for Fish Due to Contact with Surface Water
New and Alamo Rivers, California

	All Fish		TRVs		HQ	
Location	Chemical	EPC (mg/kg)	NOAEL (mg/kg)	LOAEL (mg/kg)	NOAEL (mg/kg)	LOAEL (mg/kg)
Treatment wetlands	4,4'-DDD	2.95E-02	2.65	26.5	0.01	0.001
Treatment wetlands	4,4'-DDE	1.17E+00	2.65	26.5	0.44	0.04
Treatment wetlands	4,4'-DDT	1.06E-02	2.65	26.5	0.004	0.0004
Treatment wetlands	Aldrin	8.89E-03	-	-	-	-
Treatment wetlands	alpha-Chlordane	1.14E-02	-	-	-	-
Treatment wetlands	Dieldrin	5.96E-02	-	-	-	-
Treatment wetlands	Endosulfan I	9.93E-03	-	-	-	-
Treatment wetlands	Endosulfan II	7.60E-03	-	-	-	-
Treatment wetlands	Endosulfan Sulfate	3.32E-02	-	-	-	-
Treatment wetlands	Endrin	5.68E-03	-	-	-	-
Treatment wetlands	Endrin Aldehyde	1.15E-02	-	-	-	-
Treatment wetlands	Heptachlor	8.91E-03	-	-	-	-
Treatment wetlands	Methoxychlor	4.42E-03	-	-	-	-
Treatment wetlands	Total Selenium	6.10E+00	0.79	7.9	7.7	0.77
Agricultural drains	4,4'-DDD	1.24E-01	2.65	26.5	0.05	0.005
Agricultural drains	4,4'-DDE	4.49E+00	2.65	26.5	1.7	0.17
Agricultural drains	4,4'-DDT	2.84E-02	2.65	26.5	0.01	0.001
Agricultural drains	alpha-Chlordane	1.76E-02	-	-	-	-
Agricultural drains	Dieldrin	1.95E-01	-	-	-	-
Agricultural drains	EndosulfanII	9.73E-03	-	-	-	-
Agricultural drains	gamma-Chlordane	2.98E-02	-	-	-	-
Agricultural drains	TotalSelenium	7.16E+00	0.79	7.9	9.1	0.91
Rivers	4,4'-DDE	7.19E+00	2.65	26.5	2.7	0.27
Rivers	4,4'-DDT	7.98E-02	2.65	26.5	0.03	0.003
Rivers	alpha-Chlordane	1.80E-02	-	-	-	-
Rivers	beta-BHC	5.59E-03	-	-	-	-
Rivers	EndosulfanI	3.95E-02	-	-	-	-
Rivers	HeptachlorEpoxide	1.60E-02	-	-	-	-
Rivers	TotalSelenium	7.25E+00	0.79	7.9	9.2	0.92
Salton Sea	4,4'-DDD	5.60E-03	2.65	26.5	0.002	0.0002
Salton Sea	4,4'-DDE	4.36E-02	2.65	26.5	0.02	0.002
Salton Sea	4,4'-DDT	3.00E-02	2.65	26.5	0.01	0.001
Salton Sea	Dieldrin	1.24E-02	-	-	-	-
Salton Sea	Endrin	1.60E-02	-	-	-	-
Salton Sea	Heptachlor	3.32E-02	-	-	-	-
Salton Sea	Total Selenium	1.34E+01	0.79	7.9	17	1.7

Definitions:
mg/kg-Milligrams per kilogram.
EPC-Exposure point concentration.
HQ-Hazard quotient.
LOAEL-Lowest observable adverse effect level.
NOAEL-No observable adverse effect level.
TRV-Toxicity reference value.
Notes:
Shaded cells indicate HQs greater than 1
A dash indicates the absence of a TRV and HQ

Table 10-46
Summary of Hazard Quotients for the Brawley and Imperial Wetlands

					Least Sandpiper		Black-Necked Stilt		Pied-Billed Grebe	
Chemical	Type	Emergent Plants	Benthic Invertebrates	Aquatic Biota[a]	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ
Selenium	Metal	0.53	0.53	0.62	3.6	1.8	3.1	1.5	3.5	1.7
4,4'-DDD	Pesticide	N/A	N/A	N/A	N/A	N/A	0.01	0.003	0.27	0.09
4,4'-DDE	Pesticide	-	2.0	N/A	3.2	1.0	1.3	0.43	12	3.8
4,4'-DDT	Pesticide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.10	0.03
Aldrin	Pesticide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.01	0.001
alpha BHC	Pesticide	N/A	N/A	N/A	N/A	N/A	0.0001	0.00002	0.0002	0.0001
alpha-Chlordane	Pesticide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.0002	0.00004
Dieldrin	Pesticide	-	0.52	N/A	0.05	0.01	0.02	0.003	0.05	0.01
Endosulfan I	Pesticide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.00004	0.0001
Endosulfan II	Pesticide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.00003	0.0001
Endosulfan Sulfate	Pesticide	N/A	N/A	N/A	N/A	N/A	0.000002	0.000004	0.0002	0.0004
Endrin	Pesticide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.02	0.002
Endrin aldehyde	Pesticide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.04	0.004
Heptachlor	Pesticide	-	0.15	N/A	0.004	0.0004	0.002	0.0002	0.003	0.0003

Definitions:
COPEC-Chemical of potential ecological concern.
HQ-Hazard quotient
LOAEL-Lowest observable adverse effect level.
NOAEL-No observable adverse effect level.
N/A-Not applicable (not a COPEC for the specified receptor).
TRV-Toxicity reference value
Notes:
A dash indicates the absence of an applicable TRV.
Shaded values indicate HQs greater than 1.
a - Aquatic biota include plants, aquatic invertebrates, and fish in the water column.

Table 10-46 (continued)
Summary of Hazard Quotients for the Brawley and Imperial Wetlands

	American Coot		Double-Crested Cormorant		Red-Winged Blackbird		Raccoon	
Chemical	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ
Selenium	0.92	0.46	1.0	0.49	4.6	2.3	28	1.2
4,4'-DDD	N/A	N/A	0.34	0.11	N/A	N/A	0.00001	0.0000003
4,4'-DDE	1.6	0.52	12	4.0	2.0	0.65	0.004	0.0002
4,4'-DDT	N/A	N/A	0.12	0.04	N/A	N/A	N/A	N/A
Aldrin	N/A	N/A	0.01	0.001	N/A	N/A	N/A	N/A
alpha BHC	N/A	N/A	N/A	N/A	N/A	N/A	0.002	0.0002
alpha-Chlordane	N/A	N/A	0.00	0.00	N/A	N/A	N/A	N/A
Dieldrin	0.001	0.0003	0.05	0.01	0.03	0.01	0.01	0.002
Endosulfan I	N/A	N/A	0.0002	0.0004	N/A	N/A	0.00001	0.000002
Endosulfan II	N/A	N/A	0.0001	0.0003	N/A	N/A	N/A	N/A
Endosulfan Sulfate	N/A	N/A	0.001	0.002	N/A	N/A	0.000004	0.000001
Endrin	N/A	N/A	0.03	0.003	N/A	N/A	N/A	N/A
Endrin aldehyde	N/A	N/A	0.06	0.01	N/A	N/A	N/A	N/A
Heptachlor	0.0002	0.00002	0.003	0.0003	0.003	0.0003	0.001	0.00002

Definitions:
COPEC-Chemical of potential ecological concern.
HQ-Hazard quotient
LOAEL-Lowest observable adverse effect level.
NOAEL-No observable adverse effect level.
N/A-Not applicable (not a COPEC for the specified receptor).
TRV-Toxicity reference value
Notes:
A dash indicates the absence of an applicable TRV.
Shaded values indicate HQs greater than 1.
a - Aquatic biota include plants, aquatic invertebrates, and fish in the water column.

Table 10-47
Summary of Hazard Quotients for the Agricultural Drains

					Least Sandpiper		Black-Necked Stilt		Pied-Billed Grebe	
Chemical	Type	Emergent Plants	Benthic Invertebrates	Aquatic Biota[a]	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ
Selenium	Metal	0.60	0.60	0.95	4.1	2.0	2.9	1.4	3.5	1.7
4,4'-DDD	Pesticide	N/A	N/A	N/A	N/A	N/A	0.16	0.05	1.1	0.37
4,4'-DDE	Pesticide	-	12	N/A	20	6.4	13	4.1	47	15
4,4'-DDT	Pesticide	-	0.45	N/A	0.98	0.31	0.36	0.12	0.55	0.18
alpha-Chlordane	Pesticide	N/A	N/A	N/A	N/A	N/A	0.0001	0.00002	0.0003	0.0001
beta BHC	Pesticide	-	0.68	N/A	0.01	0.002	0.003	0.001	0.003	0.001
Dieldrin	Pesticide	-	0.58	N/A	0.05	0.01	0.04	0.01	0.14	0.03
Endosulfan I	Pesticide	N/A	N/A	N/A	N/A	N/A	0.00001	0.00001	N/A	N/A
Endosulfan II	Pesticide	N/A	N/A	N/A	N/A	N/A	0.000003	0.00001	0.00004	0.0001
gamma-Chlordane	Pesticide	N/A	N/A	N/A	N/A	N/A	0.0002	0.00003	0.0005	0.0001
Heptachlor	Pesticide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Definitions:
COPEC-Chemical of potential ecological concern.
HQ-Hazard quotient
LOAEL-Lowest observable adverse effect level.
NOAEL-No observable adverse effect level.
N/A-Not applicable (not a COPEC for the specified receptor).
TRV-Toxicity reference value
Notes:
A dash indicates the absence of an applicable TRV.
Shaded values indicate HQs greater than 1.
a - Aquatic biota include plants, aquatic invertebrates, amphibians, and fish.

Table 10-47 (continued)
Summary of Hazard Quotients for the Agricultural Drains

	American Coot		Double-Crested Cormorant		Red-Winged Blackbird		Raccoon	
Chemical	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ
Selenium	0.72	0.35	2.1	1.0	4.4	2.2	29	1.2
4,4'-DDD	N/A	N/A	1.4	0.44	N/A	N/A	0.0001	0.000004
4,4'-DDE	1.3	0.41	49	16	13	4.0	0.02	0.001
4,4'-DDT	0.02	0.01	0.31	0.10	0.61	0.20	0.001	0.00004
alpha-Chlordane	N/A	N/A	0.00004	0.00001	N/A	N/A	0.0002	0.00004
beta BHC	0.0002	0.0001	0.000001	0.0000004	0.01	0.001	0.001	0.0003
Dieldrin	0.002	0.0003	0.16	0.03	0.04	0.01	0.01	0.002
Endosulfan I	0.0004	0.001	0.0002	0.0004	N/A	N/A	0.001	0.0002
Endosulfan II	N/A	N/A	N/A	N/A	N/A	N/A	0.00001	0.000003
gamma-Chlordane	N/A	N/A	0.0001	0.00001	N/A	N/A	0.001	0.0002
Heptachlor	N/A	N/A	0.002	0.0002	N/A	N/A	N/A	N/A

Definitions:
COPEC-Chemical of potential ecological concern.
HQ-Hazard quotient
LOAEL-Lowest observable adverse effect level.
NOAEL-No observable adverse effect level.
N/A-Not applicable (not a COPEC for the specified receptor).
TRV-Toxicity reference value
Notes:
A dash indicates the absence of an applicable TRV.
Shaded values indicate HQs greater than 1.
a - Aquatic biota include plants, aquatic invertebrates, amphibians, and fish.

Table 10-48
Summary of Hazard Quotients for the New and Alamo Rivers

					Least Sandpiper		Black-Necked Stilt		Pied-Billed Grebe	
Chemical	Type	Emergent Plants	Benthic Invertebrates	Aquatic Biota[a]	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ
Selenium	Metal	0.79	0.79	0.99	5.4	2.7	1.1	0.54	1.9	0.93
4,4'-DDE	Pesticide	-	14	N/A	22	7.2	17	5.5	73	24
4,4'-DDT	Pesticide	-	1.7	N/A	3.7	1.2	1.4	0.45	1.8	0.59
alpha-Chlordane	Pesticide	N/A	N/A	N/A	N/A	N/A	0.0001	0.00002	0.0003	0.0001
beta BHC	Pesticide	N/A	N/A	N/A	N/A	N/A	0.00005	0.00001	0.0004	0.0001
Dieldrin	Pesticide	-	0.97	N/A	0.09	0.02	0.04	0.01	0.03	0.01
Endosulfan I	Pesticide	N/A	N/A	N/A	N/A	N/A	0.00001	0.00004	0.0002	0.0004
Endosulfan II	Pesticide	N/A	N/A	N/A	N/A	N/A	0.000001	0.000003	N/A	N/A
Endosulfan Sulfate	Pesticide	N/A	N/A	N/A	N/A	N/A	0.0000004	0.000001	N/A	N/A
Endrin aldehyde	Pesticide	-	0.54	N/A	0.42	0.04	0.15	0.02	0.13	0.01
Heptachlor epoxide	Pesticide	N/A	N/A	N/A	N/A	N/A	0.0004	0.00004	0.003	0.0003

Definitions:
COPEC-Chemical of potential ecological concern.
HQ-Hazard quotient
LOAEL-Lowest observable adverse effect level.
NOAEL-No observable adverse effect level.
N/A-Not applicable (not a COPEC for the specified receptor).
TRV-Toxicity reference value
Notes:
A dash indicates the absence of an applicable TRV.
Shaded values indicate HQs greater than 1.
a - Aquatic biota include plants, aquatic invertebrates, amphibians, and fish.

Table 10-48 (continued)
Summary of Hazard Quotients for the New and Alamo Rivers

	American Coot		Double-Crested Cormorant		Red-Winged Blackbird		Raccoon	
Chemical	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ
Selenium	1.4	0.71	1.5	0.73	1.5	0.72	33	1.4
4,4'-DDE	2.4	0.77	79	25	14	4.5	0.02	0.001
4,4'-DDT	0.09	0.03	0.88	0.28	2.3	0.75	0.003	0.0001
alpha-Chlordane	N/A	N/A	0.00004	0.00001	N/A	N/A	0.0002	0.00004
beta BHC	N/A	N/A	0.001	0.0001	N/A	N/A	0.00001	0.000002
Dieldrin	0.01	0.002	0.00002	0.000003	0.06	0.01	0.02	0.004
Endosulfan I	0.0001	0.0003	0.001	0.002	N/A	N/A	0.0003	0.0001
Endosulfan II	0.0002	0.0004	N/A	N/A	N/A	N/A	0.0003	0.0001
Endosulfan Sulfate	0.00004	0.0001	N/A	N/A	N/A	N/A	0.0001	0.00002
Endrin aldehyde	0.01	0.001	0.0001	0.00001	0.27	0.03	N/A	N/A
Heptachlor epoxide	N/A	N/A	0.005	0.0005	N/A	N/A	0.0001	0.000001

Definitions:
COPEC-Chemical of potential ecological concern.
HQ-Hazard quotient
LOAEL-Lowest observable adverse effect level.
NOAEL-No observable adverse effect level.
N/A-Not applicable (not a COPEC for the specified receptor).
TRV-Toxicity reference value
Notes:
A dash indicates the absence of an applicable TRV.
Shaded values indicate HQs greater than 1.
a - Aquatic biota include plants, aquatic invertebrates, amphibians, and fish.

Table 10-49
Summary of Hazard Quotients for the Salton Sea

Chemical	Type	Emergent Plants	Benthic Invertebrates	Aquatic Biota[a]	Least Sandpiper NOAEL HQ	Least Sandpiper LOAEL HQ	Black-Necked Stilt NOAEL HQ	Black-Necked Stilt LOAEL HQ	Pied-Billed Grebe NOAEL HQ	Pied-Billed Grebe LOAEL HQ
Metals										
Selenium	Metal	8.5	8.5	0.03	20	10	8.2	4.0	11	5.3
Pesticides										
4,4'-DDD	Pesticide	-	2.3	N/A	1.4	0.46	0.51	0.16	0.48	0.15
4,4'-DDE	Pesticide	-	15	N/A	16	5.1	5.5	1.8	5.0	1.6
4,4'-DDT	Pesticide	-	3.4	N/A	2.1	0.7	0.8	0.2	0.9	0.3
Dieldrin	Pesticide	-	17	N/A	0.6	0.1	0.2	0.043	0.2	0.041
Endrin	Pesticide	N/A	N/A	N/A	N/A	N/A	0.008	0.001	0.06	0.006
Heptachlor	Pesticide	-	15	N/A	0.049	0.005	0.025	0.002	0.012	0.001

Definitions:
COPEC-Chemical of potential ecological concern.
HQ-Hazard quotient
LOAEL-Lowest observable adverse effect level.
NOAEL-No observable adverse effect level.
N/A-Not applicable (not a COPEC for the specified receptor).
TRV-Toxicity reference value
Notes:
A dash indicates the absence of an applicable TRV.
Shaded values indicate HQs greater than 1.
a - Aquatic biota include plants, aquatic invertebrates, amphibians, and fish.

Table 10-49 (continued)
Summary of Hazard Quotients for the Salton Sea

Chemical	American Coot NOAEL HQ	American Coot LOAEL HQ	Double-Crested Cormorant NOAEL HQ	Double-Crested Cormorant LOAEL HQ	Red-Winged Blackbird NOAEL HQ	Red-Winged Blackbird LOAEL HQ	Raccoon NOAEL HQ	Raccoon LOAEL HQ
Metals								
Selenium	1.4	0.7	5.6	2.8	12	6.1	284	12
Pesticides								
4,4'-DDD	0.037	0.012	0.06	0.020	0.9	0.3	0.001	0.0001
4,4'-DDE	0.40	0.13	0.48	0.15	9.8	3.2	0.012	0.001
4,4'-DDT	0.05	0.017	0.33	0.11	1.3	0.4	0.002	0.0001
Dieldrin	0.018	0.003	0.010	0.002	0.40	0.07	0.11	0.023
Endrin	N/A	N/A	0.07	0.007	N/A	N/A	0.0003	0.0002
Heptachlor	0.002	0.0002	0.010	0.001	0.035	0.003	0.011	0.000

Definitions:
COPEC-Chemical of potential ecological concern.
HQ-Hazard quotient
LOAEL-Lowest observable adverse effect level.
NOAEL-No observable adverse effect level.
N/A-Not applicable (not a COPEC for the specified receptor).
TRV-Toxicity reference value
Notes:
A dash indicates the absence of an applicable TRV.
Shaded values indicate HQs greater than 1.
a - Aquatic biota include plants, aquatic invertebrates, amphibians, and fish.

Table 10-50
Summary of Hazard Indices for the
New and Alamo Rivers ERA

	Brawley and Imperial Wetlands		Agricultural Drains		New and Alamo Rivers		Salton Sea	
Receptor	NOAEL HI	LOAEL HI	NOAEL HI	LOAEL HI	NOAEL HI	LOAEL HI	NOAEL HI	LOAEL HI
Emergent Plants	0.53	-	0.60	-	0.79	-	8.5	-
Benthic Invertebrates	3.2	-	14	-	18	-	61	-
Aquatic Biota[a]	0.62	-	0.95	-	0.99	-	0.03	-
Least Sandpiper	6.9	2.8	25	8.8	32	11	40	16
Black-Necked Stilt	4.4	1.9	16	5.7	20	6.5	15	6.3
Pied-Billed Grebe	16	5.7	53	18	77	25	17	7.4
American Coot	2.5	0.97	2.0	0.77	3.9	1.5	1.9	0.85
Double-Crested Cormorant	14	4.7	53	17	81	26	6.6	3.0
Red-Winged Blackbird	6.7	2.9	18	6.4	18	6.0	25	10
Raccoon	28	1.2	29	1.2	33	1.4	285	12

Definitions:
HI-Hazard Index
LOAEL-Lowest observable adverse effect level.
NOAEL-No observable adverse effect level.
Notes:
A dash indicates the absence of a hazard index.
Shaded values indicate HIs greater than 1.
a - Aquatic biota include plants, aquatic invertebrates, amphibians, and fish.

10.14 Potential Ecological Risks

The risks from potential exposures to each of the COPECs in each of the areas identified in Section 10.5.1 are discussed here. The receptor groups evaluated in each area are as follows:

- Emergent (*i.e.*, sediment-rooted) plants;
- Benthic invertebrates;
- Aquatic biota (including aquatic plants, aquatic invertebrates, amphibians, and fish);
- Amphibians;
- Birds (six receptors); and
- Raccoons.

The emergent plants, benthic invertebrates, aquatic invertebrates, and amphibians evaluated here are general categories and are not species-specific. All six of the representative bird species (*i.e.*, least sandpiper, black-necked stilt, pied-billed grebe, American coot, double-breasted cormorant, and red-winged blackbird) and the raccoon were evaluated for potential exposures in each area. Risks to each receptor were evaluated primarily on the basis of HQs, with the exception of amphibians. Amphibian risks were assessed semi-quantitatively due to the limited toxicity data available. For amphibians, selenium exposure point concentrations were compared to the range of available NOAEL-based toxicity values to provide an indication of risks.

10.14.1 Potential Risks in the Agricultural Drains

Risk estimates for the agricultural drains were calculated for the same receptors and exposure pathways as for the wetlands. Exposures and risks for the drains are indicative of local background conditions near the treatment wetlands.

10.14.1.1 Potential Risks to Sediment-Associated Receptors

- HQs for receptors in the agricultural drains that are primarily exposed to sediments are shown in Tables 10-24 and 10-25. The selenium HQ for emergent plants was less than 1, but HQs for 4,4'-DDE, 4,4'-DDT, beta-BHC, and dieldrin could not be calculated due to the lack of plant toxicity data (Table 10-24). The benthic invertebrate HQ for 4,4'-DDE was 12 (Table 10-25). Benthic invertebrate HQs for selenium, 4,4'-DDE, 4,4'-DDT, beta-BHC, and dieldrin were less than 1.

10.14.1.2 Potential Risks to Surface Water-Associated Receptors

- HQs for receptors in the agricultural drains that are primarily exposed to surface water are shown in Tables 10-26, 10-44, and 10-45. The selenium HQ for aquatic biota was less than 1 (Table 10-26). For amphibians, the surface water concentration of selenium exceeded the low NOAEL-based toxicity value but was substantially lower than the high NOAEL-based toxicity value (Table 10-43). Due to the generally high variability in species-specific toxicity data for amphibians and the limited availability of data for selenium (see Section 10.16.1.3), the exceedance of the low toxicity value is uncertain and does not necessarily indicate a hazard.
- Selenium and 4,4'-DDE concentrations in fish tissues from the drains exceeded the tissue-based NOAEL TRVs, resulting in NOAEL HQs of 9.1 and 1.7, respectively (Table 10-45). However, the LOAEL HQs were less than 1, indicating that the potential for adverse effects from these chemicals may be low.

10.14.1.3 Potential Risks to Birds and Mammals

HQs for birds and the raccoon in the agricultural drains are presented in Tables 10-27 to 10-33 and in more detail in Appendix L. The HQs are summarized in Table 10-48. Of the 11 COPECs evaluated in the drains, alpha-chlordane, beta-BHC, dieldrin, Endosulfan I, Endosulfan II, endosulfan sulfate, endrin aldehyde, and heptachlor epoxide had HQs less than 1. The HQs for selenium, 4,4'-DDD, and 4,4'-DDE exceeded 1 as described below.

- Selenium: Both the NOAEL and LOAEL HQs exceeded the threshold HQ of 1 for the least sandpiper, black-necked stilt, pied-billed grebe, double-crested cormorant, red-winged blackbird, and raccoon.
- 4,4'-DDD: The NOAEL HQ slightly exceeded the threshold HQ of 1 for the pied-billed grebe and double-crested cormorant.
- 4,4'-DDE: Both the NOAEL and LOAEL HQs exceeded the threshold HQ of 1 for the least sandpiper, black-necked stilt, pied-billed grebe, double-crested cormorant, and red-winged blackbird. The NOAEL HQ for the American coot slightly exceeded 1, but the LOAEL HQ was less than 1.

At least some of the potential risks from COPECs in the drains may represent limited hazards to birds and mammals due to the following:

- All NOAEL and LOAEL HQs for selenium were less than 5, with the exception of the NOAEL HQ for the raccoon, which was 29. Risks to the raccoon were likely overestimated because this largely terrestrial mammal was assumed to forage and ingest sediments exclusively from the wetlands. In addition, the selenium HQs for the raccoon were based on sensitive mammalian TRVs (a NOAEL and LOAEL for hepatic lesions [EFA West 1998]), which may not relate directly to impacts on reproduction or survival (see Section 10.16.1.3).

- The NOAEL HQs for 4,4'-DDD only slightly exceeded 1 for the pied-billed grebe and double-crested cormorant. No LOAEL HQs were greater than 1.
- The NOAEL HQ for 4,4'-DDE only slightly exceeded 1 for the American coot, and the LOAEL HQ was less than 1.
- The LOAEL HQs for 4,4'-DDE were less than 10 for the least sandpiper, black-necked stilt, and red-winged blackbird.
- No other COPECs in the drains had HQs greater than 1.

This evaluation suggests that selenium and 4,4'-DDD are unlikely to represent imminent risks to birds or the raccoon in the drains. 4,4'-DDE may pose a potential for adverse effects to the piscivorous pied-billed grebe and double-crested cormorant.

10.14.1.4 Hazard Indices

HIs calculated for receptors in the drains are presented in Table 10-51, and bar graphs of HIs (LOAEL-based for birds and the raccoon) are provided in Figures 10-2 to 10-7. Based on calculated HIs above 1 in the drains (ranging from 2.0 to 53 for NOAEL HIs and 1.2 to 18 for LOAEL HIs) (Table 10-51), there are potential cumulative impacts to receptors from selenium and pesticides. Cumulative effects are most likely for the piscivorous pied-billed grebe and double-crested cormorant, whose LOAEL HIs exceeded 10. The relatively low magnitudes of other LOAEL HIs (*i.e.*, less than 10) for the sandpiper, stilt, blackbird, and raccoon suggest that these receptors may not be subject to cumulative impacts.

10.14.2 Potential Risks in the New and Alamo Rivers

Risk estimates for the New and Alamo Rivers were calculated for the same receptors and exposure pathways as for the wetlands and drains. Exposures and risks for the rivers are indicative of local background conditions near the treatment wetlands.

10.14.2.1 Potential Risks to Sediment-Associated Receptors

HQs for receptors in the rivers that are primarily exposed to sediments are shown in Tables 10-34 and 10-35. The selenium HQ for emergent plants was less than 1, but HQs for 4,4'-DDE, 4,4'-DDT, dieldrin, and endrin aldehyde could not be calculated due to the lack of plant toxicity data (Table 10-34). The benthic invertebrate HQs for 4,4'-DDE and 4,4'-DDT were 14 and 1.7, respectively (Table 10-35). Benthic invertebrate HQs for selenium, 4,4'-DDE, 4,4'-DDT, dieldrin, and endrin aldehyde were less than 1.

10.14.2.2 Potential Risks to Surface Water-Associated Receptors

HQs for receptors in the rivers that are primarily exposed to surface water are shown in Tables 10-36, 10-44, and 10-45. The selenium HQ for aquatic biota was less than 1 (Table 10-36). For amphibians, the surface water concentration of selenium exceeded the low NOAEL-based toxicity value but was substantially lower than the high NOAEL-based toxicity value (Table 10-44). Due to the generally high variability in species-specific toxicity data for amphibians and the limited availability of data for selenium (see Section 10.16.1.3), the exceedance of the low toxicity value is uncertain and does not necessarily indicate a hazard.

Selenium and 4,4'-DDE concentrations in fish tissues from the rivers exceeded the tissue-based NOAEL TRVs, resulting in HQs of 9.2 and 2.7, respectively (Table 10-45). However,

the LOAEL HQs were less than 1, indicating that the potential for adverse effects from these chemicals may be low.

10.14.2.3 Potential Risks to Birds and Mammals

HQs for birds and the raccoon in the rivers are presented in Tables 10-37 to 10-43 and in more detail in Appendix L. The HQs are summarized in Table 10-49. Of the 11 COPECs evaluated in the rivers, 4,4'-DDD, dieldrin, endrin, and heptachlor had HQs less than 1. The HQs for selenium, 4,4'-DDE, and 4,4'-DDT exceeded 1 as described below.

- Selenium: Both the NOAEL and LOAEL HQs exceeded the threshold HQ of 1 for the least sandpiper and raccoon. Only the NOAEL HQs exceeded 1 for the black-necked stilt, pied-billed grebe, American coot, double-crested cormorant, and red-winged blackbird.
- 4,4'-DDE: Both the NOAEL and LOAEL HQs exceeded 1 for the least sandpiper, black-necked stilt, pied-billed grebe, double-crested cormorant, and red-winged blackbird. Only the NOAEL HQ for the American coot exceeded 1.
- 4,4'-DDT: Both the NOAEL and LOAEL HQs exceeded 1 for the least sandpiper. Only the NOAEL HQs exceeded 1 for the black-necked stilt, pied-billed grebe, and red-winged blackbird.

At least some of the potential risks from COPECs in the rivers may represent limited hazards to birds and mammals due to the following:

- All NOAEL HQs for selenium were less than 10, with the exception of the NOAEL HQ for the raccoon, which was 33. Risks to the raccoon were likely overestimated because this largely terrestrial mammal was assumed to forage and ingest sediments exclusively from the wetlands. In addition, the selenium HQs for the raccoon were based on a TRV protective of hepatic lesions [EFA West 1998), which may not relate directly to impacts on reproduction or survival (see Section 10.16.1.3). All LOAEL HQs for selenium were less than 5.
- The LOAEL HQs for 4,4'-DDE were less than 10 for the least sandpiper, black-necked stilt, and red-winged blackbird, and less than 1 for the American coot and raccoon.
- The LOAEL HQs for 4,4'-DDT were less than 5 for the least sandpiper, and less than 1 for black-necked stilt, pied-billed grebe, American coot, double-crested cormorant, red-winged blackbird, and raccoon.
- No other COPECs in the rivers exhibited HQs greater than 1.

This evaluation suggests that selenium and 4,4'-DDT likely do not represent imminent risks to birds or the raccoon in the New and Alamo Rivers. 4,4'-DDE may pose a potential for adverse effects to the piscivorous pied-billed grebe and double-crested cormorant.

10.14.2.4 Hazard Indices

HIs calculated for receptors in the rivers are presented in Table 10-51, and bar graphs of HIs (LOAEL-based for birds and the raccoon) are provided in Figures 10-2 to 10-7. Based on calculated HIs above 1 in the rivers (ranging from 3.9 to 81 for NOAEL HIs and 1.4 to 26 for LOAEL HIs) (Table 10-51), there are potential cumulative impacts to receptors from selenium and pesticides. Cumulative effects are most likely for the least sandpiper, pied-billed grebe, and double-crested cormorant, whose LOAEL HIs exceeded 10. The relatively low magnitudes of other LOAEL HIs (*i.e.*, less than 10) for the stilt, coot, blackbird, and raccoon suggest that these receptors may not be subject to cumulative impacts.

10.14.3 Potential Risks in the Salton Sea

Risk estimates for the Salton Sea were calculated for the same receptors and exposure pathways as for the wetlands, drains, and rivers. Exposures and risks for the Salton Sea are indicative of regional background conditions for the treatment wetlands. Risk tables for the Salton Sea are provided in Appendix L, and HQs are summarized in Table 10-50.

10.14.3.1 Potential Risks to Sediment-Associated Receptors

The selenium HQ for emergent plants in the Salton Sea exceeded 1, but HQs for 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, dieldrin, and heptachlor could not be calculated due to the lack of plant toxicity data (Table 10-49). The benthic invertebrate HQs for selenium, 4,4'-DDE, 4,4'-DDD, 4,4'-DDT, dieldrin, and heptachlor exceeded 1.

10.14.3.2 Potential Risks to Surface Water-Associated Receptors

The selenium HQ for aquatic biota in the Salton Sea was less than 1 (Table 10-50). Risks were not calculated for amphibians because amphibians do not occur in the highly saline conditions of the Sea.

Selenium concentrations in fish tissues from the rivers exceeded the tissue-based NOAEL and LOAEL TRVs, resulting in HQs of 17 and 1.7, respectively (Table 10-45).

10.14.3.3 Potential Risks to Birds and Mammals

HQs for birds and the raccoon in the Salton Sea are presented in Appendix L and are summarized in Table 10-49. Of the seven COPECs evaluated in the Sea (corresponding to those evaluated in the other habitats assessed), dieldrin, endrin, and heptachlor had HQs less than 1. The HQs for selenium, 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT exceeded 1 as described below.

- Selenium: Both the NOAEL and LOAEL HQs exceeded the threshold HQ of 1 for the least sandpiper, black-necked stilt, pied-billed grebe, double-crested cormorant, red-winged blackbird, and raccoon. Only the NOAEL HQs exceeded 1 for the American coot.
- 4,4'-DDD: The NOAEL HQ for the least sandpiper slightly exceeded 1.
- 4,4'-DDE: Both the NOAEL and LOAEL HQs exceeded 1 for the least sandpiper, black-necked stilt, pied-billed grebe, and red-winged blackbird.
- 4,4'-DDT: NOAEL HQs for the least sandpiper and red-winged blackbird slightly exceeded 1.

At least some of the potential risks from COPECs in the Sea may represent limited hazards to birds and mammals due to the following:

- All LOAEL HQs for selenium were less than 10, with the exception of the least sandpiper and raccoon. Although the NOAEL HQ for the raccoon was 284, risks to the raccoon were likely overestimated because this largely terrestrial mammal was assumed to forage and ingest sediments exclusively from the wetlands. In addition, the selenium HQs for the raccoon were based on a TRV protective of hepatic lesions [EFA West 1998], which may not relate directly to impacts on reproduction or survival (see Section 10.16.1.3).
- The LOAEL HQs for 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT were all less than 10.
- No other COPECs in the Sea exhibited HQs greater than 1.

This evaluation suggests that selenium in the Salton Sea poses a potential for adverse effects to the least sandpiper. Although risks to birds from organochlorine pesticides are not pronounced, there is uncertainty in this evaluation due to the limited data available for pesticide concentrations in fish and invertebrate prey.

10.14.4 Potential Risks at the Brawley and Imperial Pilot Wetlands

Potential ecological risks were estimated from assumed exposures to the COPECs in (1) sediments to emergent plants and benthic invertebrates, from (2) surface water to aquatic biota and amphibians, from (2) surface water, sediments, plants, aquatic invertebrates, tadpoles, and/or fish to birds and the raccoon.

10.14.4.1 Potential Risks to Sediment-Associated Receptors

HQs for receptors at the Brawley and Imperial Wetlands that are primarily exposed to sediments are presented in Tables 10-14 and 10-15. The selenium HQ for emergent plants was less than 1, but HQs for 4,4'-DDE, dieldrin, and heptachlor could not be calculated due to the lack of plant toxicity data (Table 10-14). The benthic invertebrate HQ for 4,4'-DDE was 2 (Table 10-15). HQs for selenium and other pesticides were less than 1. These results suggest that potential risks due to chemical exposures in sediments at the Brawley and Imperial Wetlands do not represent imminent hazards to emergent plants and benthic invertebrates, given:

- 4,4'-DDE was the only pesticide with an HQ greater than 1 for benthic invertebrates.
- The HQ for 4,4'-DDE (2.0), which was based on the threshold effect concentration (TEC; MacDonald *et al.* 2000), does not significantly exceed 1. However, the sediment EPC for 4,4'-DDE (0.00631 mg/kg) was less than the probable effects level (PEL) of 0.00675 mg/kg (MacDonald *et al.* 2000). The TEC indicates concentrations below which harmful effects are not expected, while the PEL represents the concentration above which adverse effects are expected to occur frequently. This indicates that harmful effects may occur, but are not expected to occur frequently.
- The HQ for 4,4'-DDE was significantly lower than the corresponding HQs for benthic invertebrates in the agricultural drains (Table 10-48) and in the New and Alamo Rivers (Table 10-49), which are representative of background conditions.
- No other COPECs had HQs greater than 1.

10.14.4.2 Potential Risks to Surface Water-Associated Receptors

HQs for receptors at the Brawley and Imperial Wetlands that are primarily exposed to surface water are presented in Tables 10-16, 10-44, and 10-45. The selenium HQ for aquatic biota was less than 1 (Table 10-16). For amphibians, the surface water concentration of selenium exceeded the low NOAEL-based toxicity value but was substantially lower than the high NOAEL-based toxicity value (Table 10-44). Due to the generally high variability in species-specific toxicity data for amphibians and the limited availability of data for selenium (see Section 10.16.2.1), the exceedance of the low toxicity value is uncertain and does not necessarily indicate a hazard. Moreover, the low magnitude of the aquatic biota HQ (Table 10-16) and the lower risks from selenium in the wetlands than in the background areas (Table 10-44) suggest that potential hazards (above background) in the wetlands are unlikely.

Selenium concentrations in fish tissues from the wetlands exceeded the tissue-based NOAEL TRV, resulting in a NOAEL HQ of 7.7 (Table 10-45). However, the LOAEL HQ was less

than 1, and potential hazards to fish from selenium in the agricultural drains, New and Alamo Rivers, and particularly the Salton Sea were greater than those identified in the wetlands.

10.14.4.3 Potential Risks to Birds and Mammals

HQs for birds and the raccoon at the Brawley and Imperial Wetlands are presented in Tables 10-17 to 10-23 and in more detail in Appendix L. The HQs are summarized in Table 10-47. Of the 14 COPECs evaluated in the wetlands for which TRVs were available, all but two had HQs less than 1. The HQs for selenium and 4,4'-DDE exceeded 1 as described below.

Selenium:

- NOAEL HQ: The NOAEL HQ exceeded the threshold HQ of 1 for the least sandpiper, black-necked stilt, pied-billed grebe, red-winged blackbird, and raccoon.
- LOAEL HQ: The LOAEL HQ exceeded 1 for the least sandpiper, black-necked stilt, pied-billed grebe, red-winged blackbird, and raccoon.

4,4'-DDE:

- NOAEL HQ: The NOAEL HQ exceeded the threshold HQ of 1 for the least sandpiper, black-necked stilt, pied-billed grebe, American coot, double-crested cormorant, and red-winged blackbird.
- LOAEL HQ: The LOAEL HQ equaled 1 for the least sandpiper, and exceeded 1 for the pied-billed grebe and double-crested cormorant.

Bird HQs were not calculated for methoxychlor due to the absence of applicable avian toxicity data. Since methoxychlor was only detected in one shad sample from the Imperial Wetland and was not detected in sediments or other tissues in either wetland, the absence of a bird TRV is not considered a significant data gap.

The potential risks due to assumed exposures to the COPECs at the wetlands may represent limited hazards to birds and mammals due to the following:

- All NOAEL and LOAEL HQs for selenium were less than 5, with the exception of the NOAEL HQ for the raccoon, which was 28. Risks to the raccoon were likely overestimated because this largely terrestrial mammal was assumed to forage and ingest sediments exclusively from the wetlands. In addition, the selenium HQs for the raccoon were based on for a TRV for hepatic lesions [EFA West 1998], which may not relate directly to impacts on reproduction or survival (see Section 10.16.2.1).
- The LOAEL HQs for 4,4'-DDE were less than 1 for the black-necked stilt, American coot, and red-winged blackbird, despite the corresponding exceedances of 1 by the NOAEL HQs. In addition, LOAEL HQs for the least sandpiper, pied-billed grebe, and double-crested cormorant were less than 5.
- The selenium HQs for the least sandpiper and raccoon in the wetlands and the 4,4'-DDE HQs for all birds were lower than the corresponding HQs in the New and Alamo Rivers, agricultural drains, and the Salton Sea (Tables 10-46 through 10-49, respectively). In addition, the selenium HQs for the pied-billed grebe in the wetlands were equal to those in the drains and less than the HQ for the Salton Sea. Potential risks to these receptors in the wetlands are thus comparable to risks in nearby habitats representative of background.
- Selenium HQs for the black-necked stilt and red-winged blackbird were higher in the wetlands than in the rivers (Tables 10-46 and 10-48). However, there is uncertainty in

these comparisons because selenium exposures in the rivers were driven by estimated concentrations in aquatic insects, while concentrations in aquatic insects in the wetlands were directly measured (see Section 10.16.1.3). Selenium concentrations in sediments and surface water were higher in the rivers than in the wetlands (Table 10-2[a]), suggesting that the selenium concentrations in aquatic invertebrates could actually be higher in the rivers than the wetlands, in contrast to what was assumed in the ERA.

- No other COPECs in the wetlands had HQs greater than 1.

In summary, selenium and 4,4'-DDE do not appear to represent imminent risks to birds or the raccoon in the Brawley and Imperial Wetlands. Estimated risks in the wetlands are generally lower than those associated with background conditions.

10.14.4.4 Hazard Indices

Hazard indices (HIs) were calculated by summing the HQs for selenium and organochlorine pesticides to identify if multiple chemical exposures could have a cumulative impact on receptors (Table 10-50). Bar graphs of HIs (sums of HQs) for the different areas are provided in Figures 10-2 to 10-7. For birds and the raccoon, the HIs are LOAEL-based (*i.e.*, sums of LOAEL HQs). Based on calculated HIs above 1 in the wetlands (ranging from 2.5 to 28 for NOAEL HIs and 1.2 to 5.7 for LOAEL HIs) (Table 10-50), there are potential cumulative impacts to receptors from selenium and pesticides. However, the relatively low magnitudes of all LOAEL HIs (*i.e.*, less than 10) suggest that there are likely to be no imminent cumulative impacts. Moreover, HIs for receptors in the wetlands did not exceed background for all receptors except for aquatic biota, the American coot, and the double-crested cormorant in the Salton Sea. Cumulative ecological risks are thus generally higher in habitats representative of background conditions than in the Brawley and Imperial Wetlands.

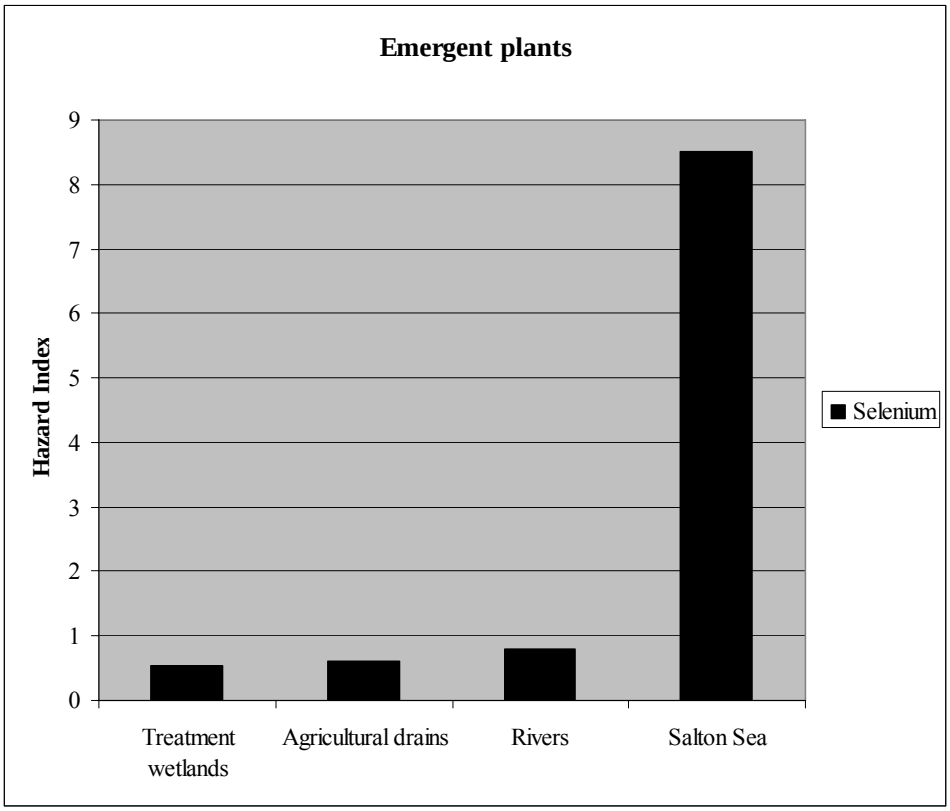

Figure 10-2a Hazard Indices for Emergent Plants.

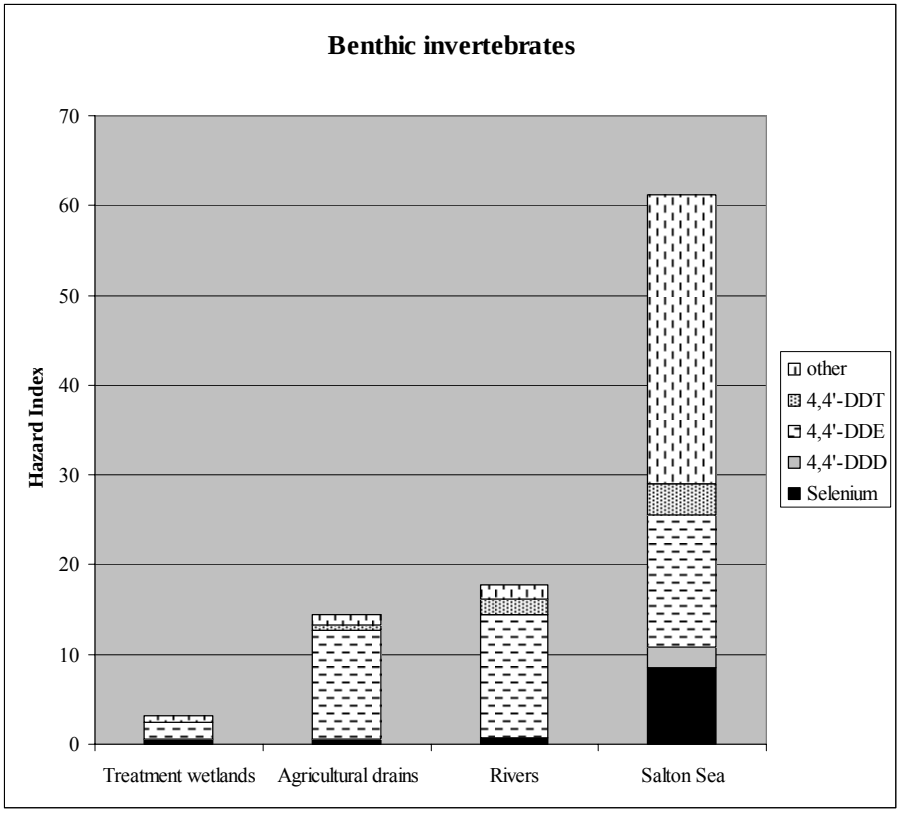

Figure 10-2b Hazard Indices for Benthic Invertebrates.

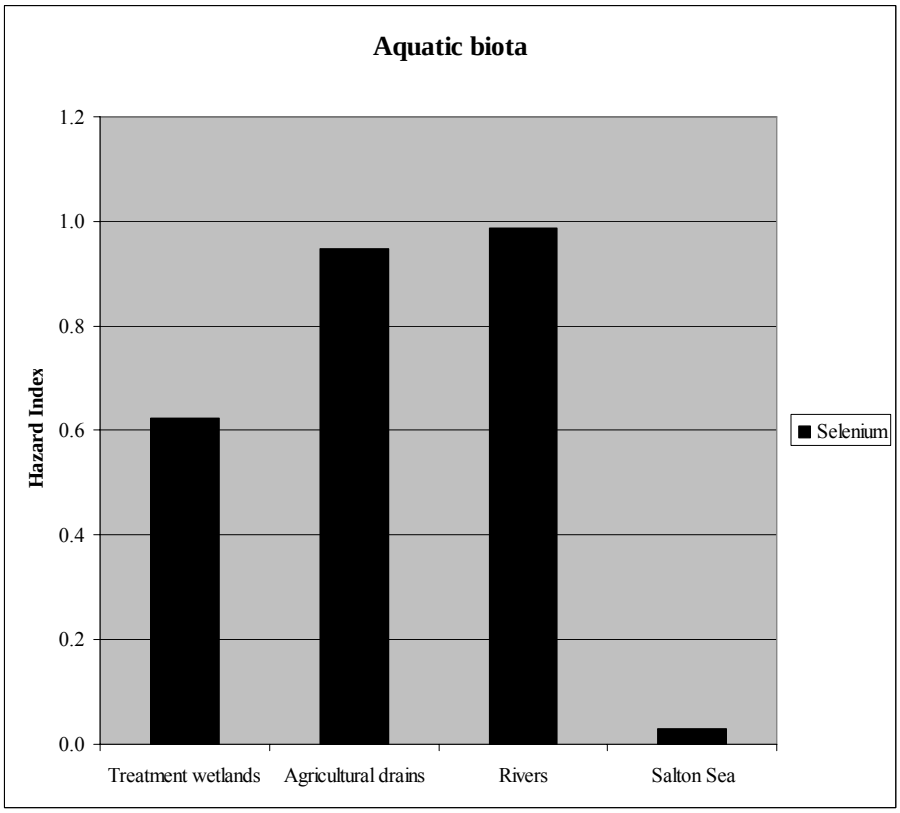

Figure 10-3a Hazard Indices for Aquatic Biota (Plants, Aquatic Invertebrates, Fish, and Amphibians).

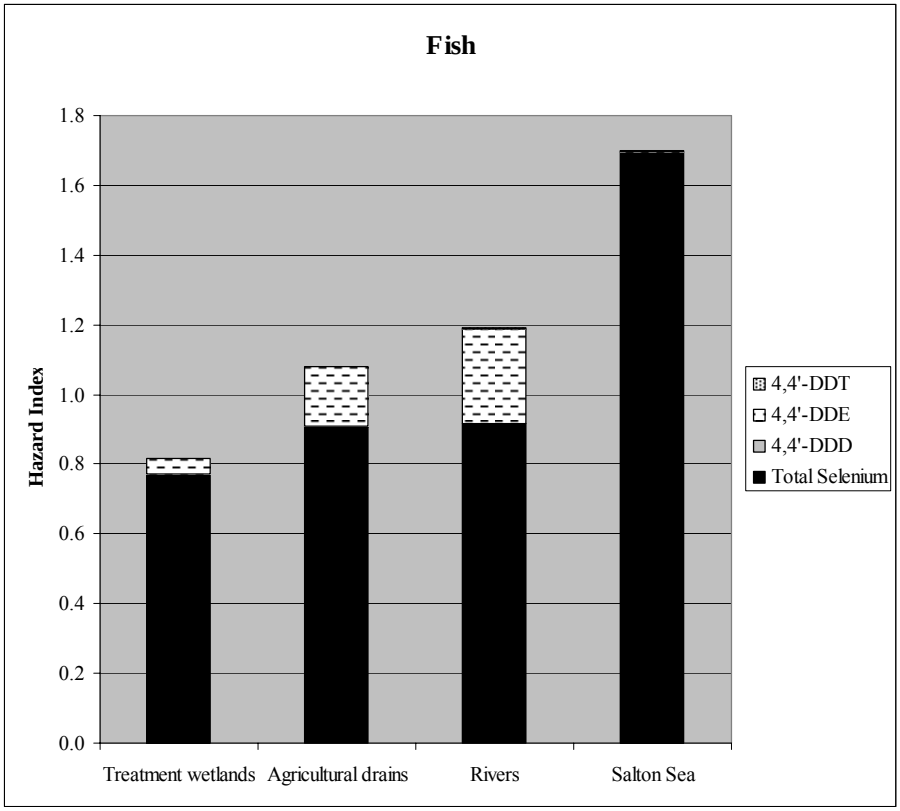

Figure 10-3b Hazard Indices for Fish Based on Tissue-Based LOAEL Hazard Quotients.

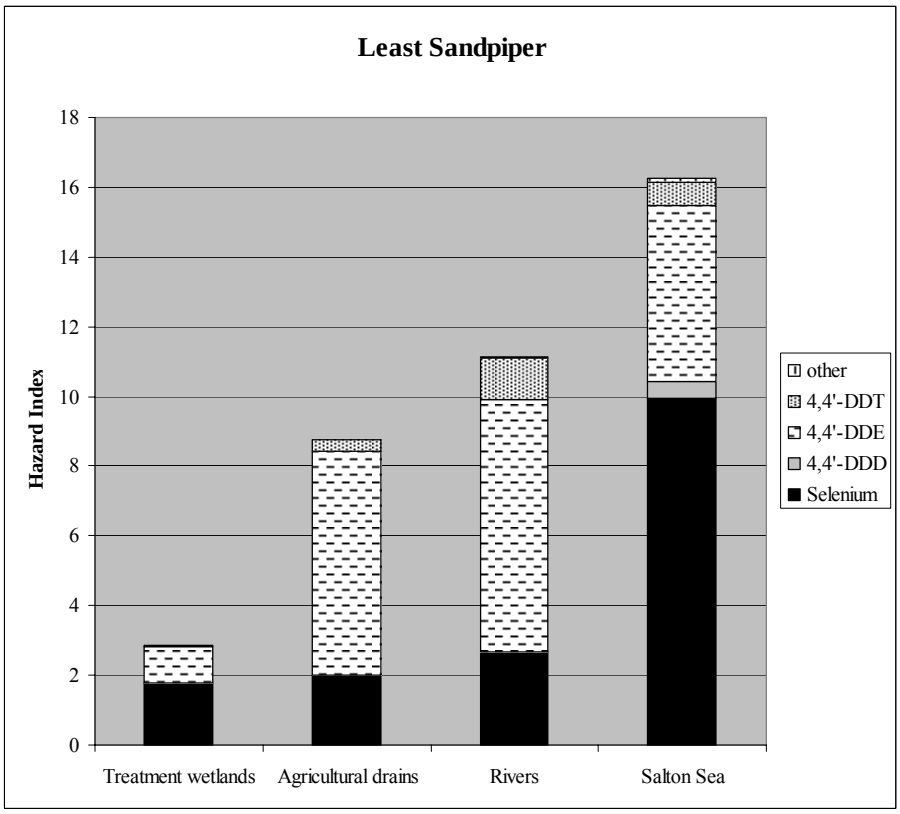

Figure 10-4a Hazard Indices for the Least Sandpiper Based on LOAEL Hazard Quotients.

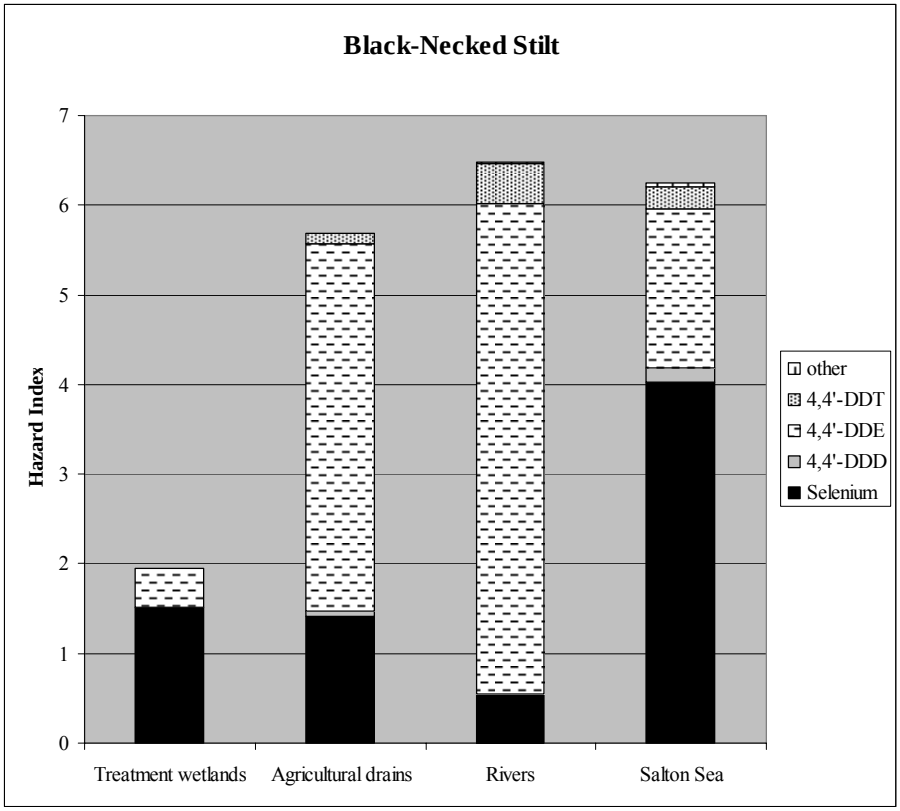

Figure 10-4b Hazard Indices for the Black-Necked Stilt Based on LOAEL Hazard Quotients.

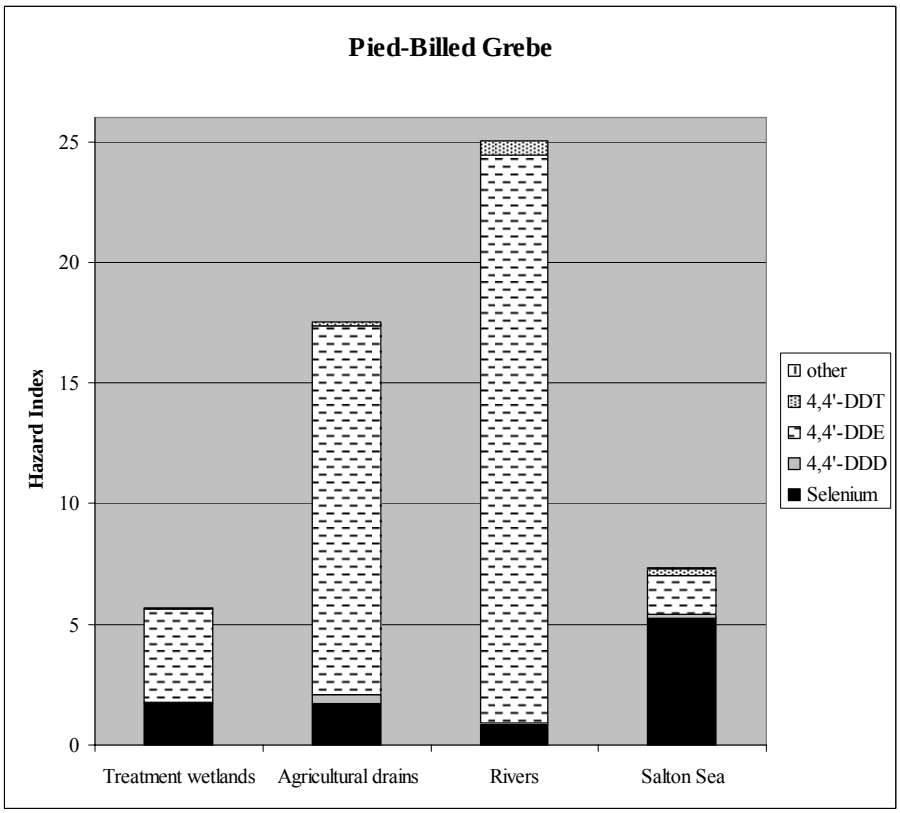

Figure 10-5a Hazard Indices for the Pied-billed Grebe Based on LOAEL Hazard Quotients.

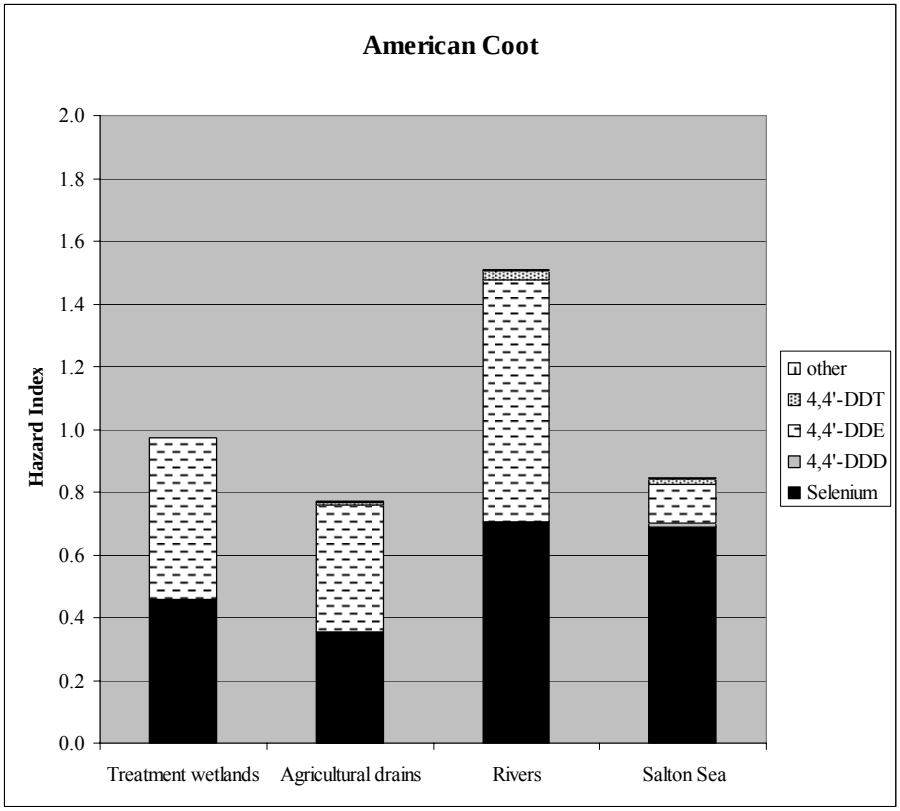

Figure 10-5b Hazard Indices for the American Coot Based on LOAEL Hazard Quotients.

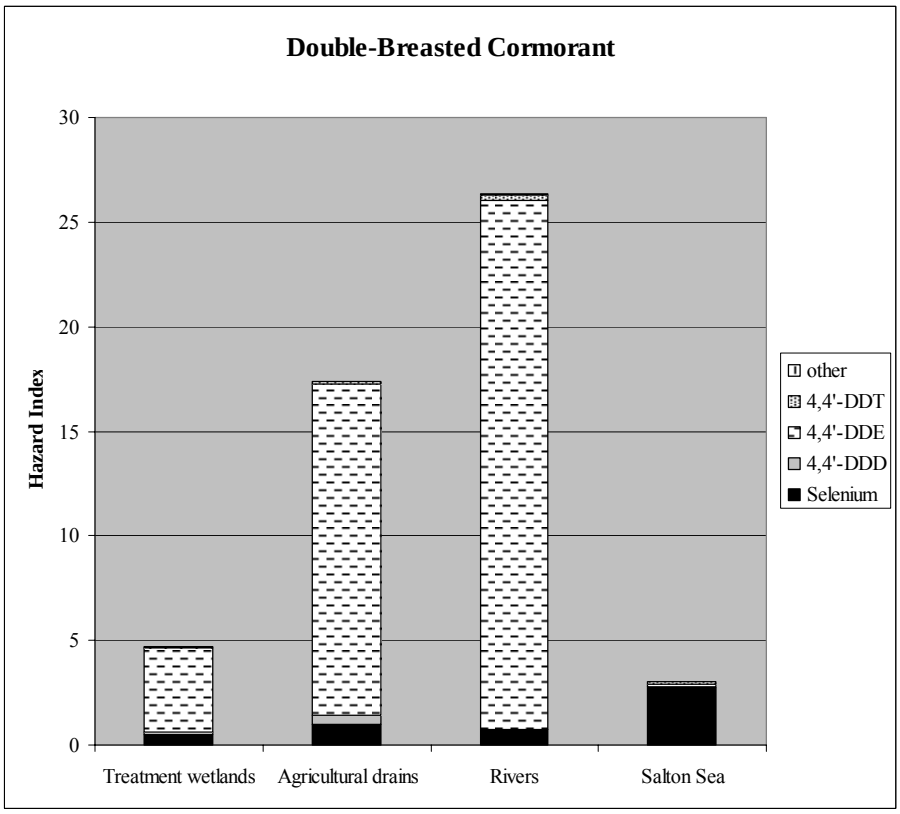

Figure 10-6a Hazard Indices for the Double-crested Cormorant Based on LOAEL Hazard Quotients.

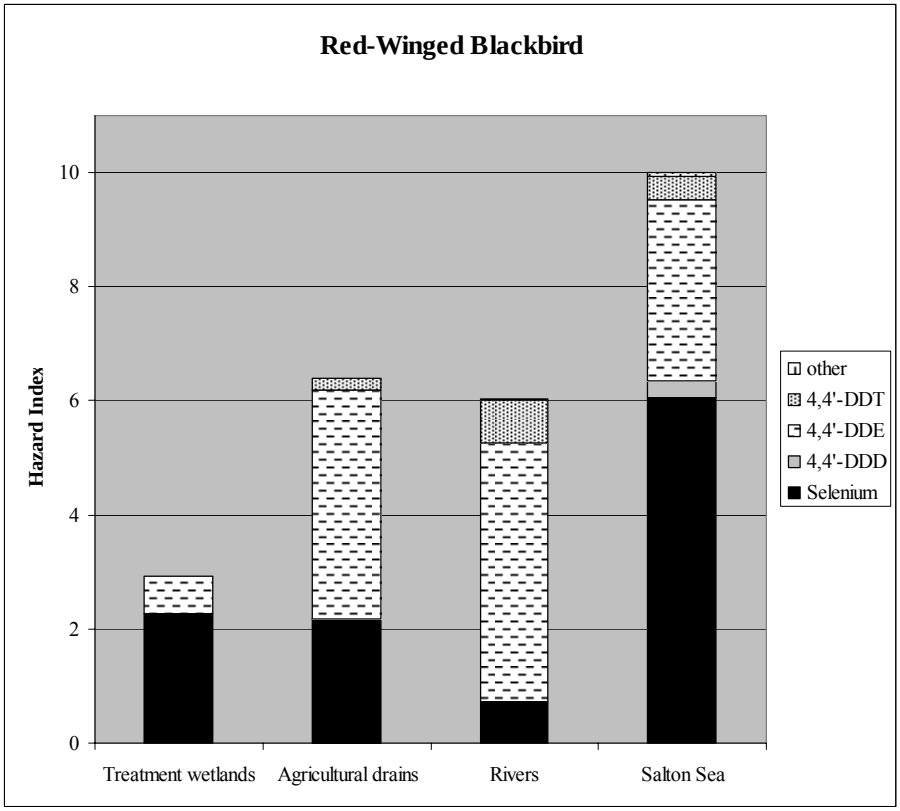

Figure 10-6b Hazard Indices for the Red-winged Blackbird Based on LOAEL Hazard Quotients.

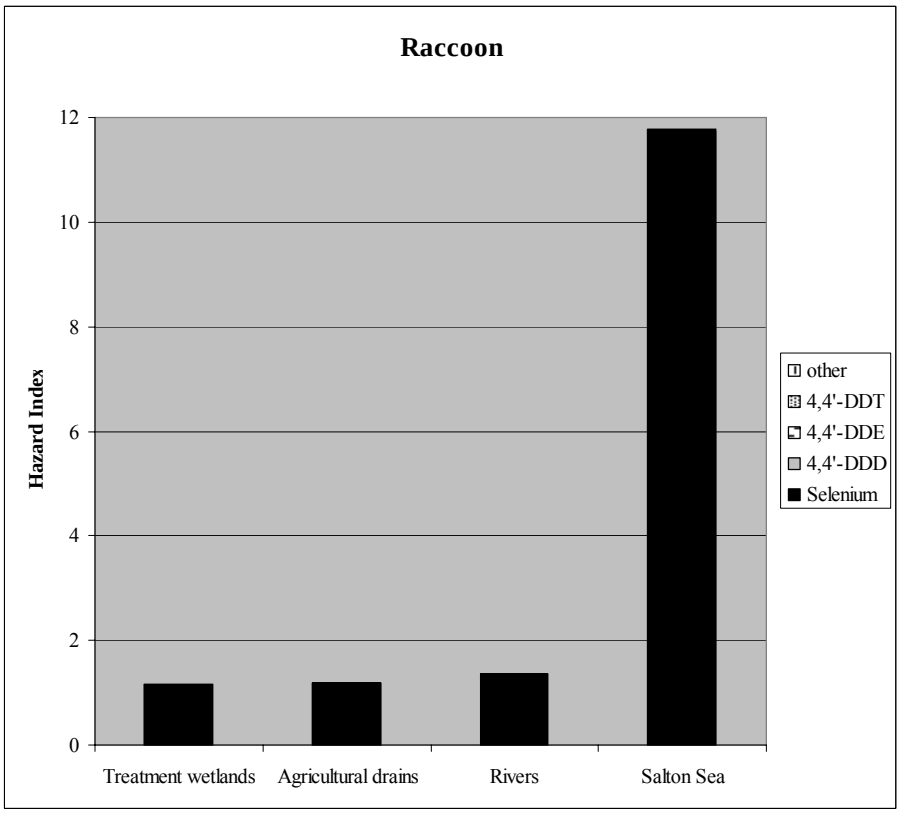

Figure 10-7 Hazard Indices for the Raccoon Based on LOAEL Hazard Quotients.

10.14.5 Avian Egg Inviability Assessment for the Salton Sea and SEP

The concentration of selenium in eggs was estimated from the weighted dietary selenium EPC concentration using an equation from Skorupa and Ohlendof (1991). The EPCs used are from Table 10-2 and were weighted according to the proportion in the diet (Table 10-3). Predicted concentrations of selenium in eggs were then used in the equations developed by Seiler *et al.* (2003) to predict the percentage of teratogenesis in the eggs of black-necked stilts, least sandpipers, and American coots. Although Seiler *et al.* (2003) did not develop equations to predict teratogenesis in the eggs of least sandpipers and American coots, the regressions for black-necked stilts and mallards were used for these bird species, respectively. Additionally, the percentage of black-necked stilt clutches with at least one inviable egg were also predicted using the equations developed by Seiler *et al.* (2003). The results of these evaluations are presented in Table 10-46.

From results presented in Table 10-46, it can be seen that the percentage of teratogenesis does not exceed 1% for any of the three bird species evaluated in the treatment wetlands. Further, the predicted levels of teratogenesis are functionally equivalent in the treatment wetlands and agricultural drains, although both are slightly higher than was predicted for eggs at the New and Alamo Rivers. All of these predictions, however, were much lower than predicted for eggs of birds feeding at the Salton Sea. The percentage of black-necked stilt clutches with at least one inviable egg was also estimated, this shows the same relative pattern as for the percentage of teratogenesis.

10.14.5.1 Hazard Indices

HIs calculated for receptors in the Salton Sea are presented in Table 10-51, and bar graphs of HIs (LOAEL-based for birds and the raccoon) are provided in Figures 10-2 to 10-7. Based on calculated HIs above 1 in the Sea (ranging from 1.9 to 285 for NOAEL HIs and 3.0 to 16 for LOAEL HIs) (Table 10-51), there are potential cumulative impacts to receptors from selenium and pesticides. Cumulative effects are most likely for the least sandpiper, red-winged blackbird, and raccoon, whose LOAEL HIs exceeded 10. The relatively low magnitudes of other LOAEL HIs (*i.e.*, less than 10) for the stilt, grebe, and cormorant suggest that these receptors may not be subject to cumulative impacts.

10.15 Uncertainty Analysis

The uncertainty analysis identifies the key assumptions and data gaps associated with the analyses performed. There are three major types of uncertainties in all risk assessments: (1) variability, (2) uncertainty of the true value (*i.e.*, measurement error), and (3) data gaps (U.S. EPA 1998). Topics included in this uncertainty analysis address all three types of uncertainties.

The approach used in this risk assessment was designed to mitigate the effects of uncertainties that may result in the underestimation of risks. Conservative assumptions were used throughout the exposure and effects analyses to minimize the probability of underestimating ecological risks.

10.15.1 Uncertainties in the Exposure Assessment

Sources of uncertainty in the exposure assessment include the areas of COPEC concentrations, exposure routes and parameters, and bioaccumulation models. These are discussed here in detail, along with whether they are likely to under or over-estimate exposures to COPECs.

10.15.1.1 Uncertainty in the COPECs at Each Area

COPEC concentrations in media were based on samples collected in one sampling event, and the results were used to assess the risks under those conditions at the time of sampling. Exposure estimates are based on these results and do not take into account possible fluctuations in COPEC concentration that may occur over time or vary with other environmental factors.

Chemical analyses of tissues (e.g., plants, fish, aquatic insects, crayfish, and tadpoles) were subject to limitations in availability during field sampling. Characterization of COPEC concentrations in biota may be biased in favor of organisms that were more abundantly collected in each habitat. The assumption that concentrations measured in these tissues are representative of those to which herbivores and predators may be exposed during feeding is uncertain.

Chemicals for which analyses were not conducted and chemicals that were not detected above laboratory detection limits were not included in the analysis. This may result in an underestimation of the risks to receptors.

10.15.1.2 Uncertainty in the Exposures

One of the primary assumptions made for this ERA is that each invertebrate, bird, and mammal receptor would spend all of its time in only one area; *i.e.*, there would be no migration between the Brawley and Imperial Wetlands and the New and Alamo Rivers or agricultural drains, or movement to and from the Salton Sea. For birds, this assumption is unlikely and it may also be unlikely for water boatmen, which can fly. However, this assumption was made to provide the maximum information for site managers on the relative risks at each site. The effect of this assumption is unclear, as it depends on the abundance of foods and the birds and raccoons tracking those foods among habitats. Some species (e.g., the red-winged blackbird and raccoon) can forage in adjacent terrestrial habitats, and may receive a significant portion of their exposures outside of the aquatic habitats assessed in this ERA. Although somewhat unrealistic, the assumption that these species spend all of their time in the aquatic habitats examined here provides useful information for comparing relative risks among the aquatic sites.

An EPC was computed for each chemical in a specific exposure medium to represent the reasonable maximum exposure for each receptor. This value was used in risk calculations to estimate potential risks to a specific receptor through comparison to TRVs. The EPCs used in the comparison were the 95 percent upper confidence limit (or UCL_{95}) of the mean, unless the UCL_{95} exceeded the maximum detected concentration, in which case the maximum detected concentration was used as the EPC. As the sample sizes for each area were small, the EPCs in each area were more likely to be based on maximum detected values than the UCL_{95} concentrations. Using the maximum detected value as the EPC may result in an overestimation of the risks.

All COPECs were assumed to be 100 percent bioavailable to receptors, which would likely overestimate exposure.

Birds and the raccoon were assumed to be exposed by ingestion of contaminated sediments, water, and prey. These receptors may also be exposed to the COPECs via dermal contact with the surface water. Dermal absorption of COPECs was considered to be an insignificant exposure pathway for the identified wildlife receptors of concern because results of exposure studies indicate that exposures due to dermal absorption are insignificant compared to ingestion for terrestrial receptors (Peterle 1991).

A variety of exposure parameters are used in the exposure calculations (see Section 10.11.4). Values for these parameters were obtained from various literature sources (*i.e.*, body weights and diet fractions) and care was taken to select the most appropriate values. However, body weights and diet fractions were not site-specific. Quantitative diet compositions were based on available data from the literature. Chemical concentrations in some dietary components (e.g., fruits, snails, adult amphibians, reptiles, crabs, and mollusks) were not sampled from the sites and could not be predicted with bioaccumulation models. Diets of receptors were, therefore, adjusted on the basis of which food items were likely available for consumption or were sampled at the sites (see Table 10-3). Other parameter values, such as ingestion rates, have been calculated using regulatory-approved formulas and are subject to additional uncertainty (Nagy 2001; U.S. EPA 1993). It is unknown whether these assumptions would result in an underestimate or overestimate of risks.

Risks from selenium and organochlorine pesticides in the Salton Sea were calculated to provide comparative background risks. Only pesticides that were detected in the Brawley and Imperial Wetlands, agricultural drains, or New and Alamo Rivers in this study were included in the Salton Sea evaluation. It should be noted that a larger set of pesticides were detected in sediments and fish of the Salton Sea (Sapozhnikova *et al.* 2004), not all of which were incorporated in the HIs for the Sea that were compared to the wetlands. Data for pesticide concentrations in fish tissues from the Salton Sea were limited, and thus the estimated dietary concentrations for fish-eating birds and the raccoon were uncertain.

10.15.1.3 Uncertainty in the Bioaccumulation Estimates

In assessing exposures to avian and mammalian receptors, it was necessary to estimate exposure to COPECs that may accumulate in their plant, invertebrate, fish, or amphibian prey. Where possible, it is always preferable to use site-specific data. Tissue concentrations were measured in the wetlands, agricultural drains, and New and Alamo Rivers. The tissue results were used directly in the ingestion calculations for the birds and raccoons. One limitation of the available field data was that smaller fish (*i.e.*, mosquitofish, shiner, molly) in the drains and rivers provided insufficient sample sizes for pesticide analysis. The pesticide EPCs for larger fish (all fish excluding bass) were used as surrogates for the smaller fish in evaluating dietary exposures of the black-necked stilt and raccoon. Similarly, selenium and pesticide data for small fish were unavailable for the Salton Sea, and were based on surrogate data for large fish (*i.e.*, tilapia and croaker).

Due to the absence of invertebrates and tadpoles sampled from the rivers, concentrations of both selenium and organochlorine pesticides in these tissues had to be predicted from available sediment or surface water data using bioaccumulation models. Selenium concentrations in aquatic insects were estimated from a site-specific regression incorporating selenium concentrations in surface water and corixids and dragonfly larvae (Table 10-4). However, the regression was applied to a selenium surface water concentration in the rivers outside of its range and the assumption was made that the shape of the relationship between water and tissue concentrations would not change outside of the measured range. Another source of uncertainty was the use of the site-specific water-to-aquatic insect regression to predict concentrations of selenium in crayfish, glass shrimp, and tadpoles in the rivers and Salton Sea. Literature-based models for selenium in these organisms were not available.

Various literature sources were consulted to identify applicable models for the remaining pesticide COPECs. A bioaccumulation factor (BAF; the ratio, at steady state, of the concentration in a food item to its concentration in a medium, assuming uptake or ingestion of food, water , and/or sediment) is acceptable for modeling COPEC concentrations in invertebrate tissues. Linear sediment-to-benthic invertebrate BAFs for 4,4’-DDE and

heptachlor were obtained from a U.S. EPA ERA protocol document (U.S. EPA 1999a). Both of these BAFs were also applied to other pesticides, dependent on the closeness of their log octanol-water partition coefficients (log K_{ow}) to those of 4,4'-DDE and heptachlor. Concentrations of pesticides in aquatic plants in the Salton Sea were estimated from sediment concentrations using a log K_{ow}-based soil-to-plant bioconcentration factor (Travis and Arms 1988). There is much uncertainty associated with estimating tissue burdens from generalized models. Models incorporate only one site parameter (*i.e.*, water concentration) and do not take into account the various factors and environmental conditions that may affect uptake. Uptake of a COPEC from water into tissues frequently varies with properties of the surface water body and the organisms present. Water characteristics that may affect bioaccumulation include pH, salinity, hardness, temperature, dissolved oxygen content, and the presence and concentration of other chemicals (especially metals) in the water (Barron 2003, Xu *et al.* 2000). The invertebrates themselves will take up COPECs at different levels depending on species, feeding strategies, position in the water column or sediment, duration of exposure, acclimation to the water chemistry, and lipid partitioning of organics within the organism. Additionally, more bioavailable forms of chemicals are more likely to be accumulated; however, this was not taken into account in the BAFs used in this ERA. The large number of uncertainties associated with BAFs makes it impossible to predict whether this has resulted in the under- or over estimation of risks. Another source of uncertainty was the use of the sediment-to-benthic invertebrate BAFs to predict concentrations of pesticides in crayfish, glass shrimp, and tadpoles in the drains, rivers, and the Sea. Literature-based models for organochlorine pesticides in these organisms were not available.

The concentrations of selenium in bird eggs were estimated using non-site-specific regressions. This alone adds quite a bit of uncertainty to the estimated selenium concentrations in bird eggs. Additionally, the relationships used to predict the concentrations of selenium in eggs do not account for selenium ingested in drinking water and may, therefore, under-estimate the concentration of selenium in eggs. The concentrations of selenium measured in coot eggs by the USGS in 2003 (see Tetra Tech 2006) ranged from 2.7 to 5.0 mg/kg dw in the pilot wetlands (N = 8), while one pied-billed grebe egg was collected with a concentration of 5.2 mg/kg dw. In comparison, the predictions presented in Table 10-46 were 5.75 mg/kg for coots and 13.9 mg/kg for grebes. This indicates that the predictions for selenium in coot eggs appears to be accurate, although the prediction for selenium in grebe eggs appears to be high. However, as stated above, these predictions are based on a number of non-site-specific assumptions.

10.15.2 Uncertainties in the Effects Assessment

When it was necessary to fill a data gap, conservative assumptions were used to minimize the probability of underestimating ecological risks. Assumptions used to characterize estimates of COPEC effects include:

- Use of chronic NOAEL-equivalent TRVs to calculate HQs;
- Use of species-to-species toxicity extrapolations;
- Use of laboratory-to-field toxicity extrapolations;
- Use of individual-to-population level effect extrapolations;
- Use of chemical-to-chemical extrapolations; and
- Lack of relevant toxicity data.

These sources of uncertainty should be taken into account when making decisions based upon the risk estimates presented here.

10.15.2.1 Uncertainty Associated with Toxicity Reference Values

Some of the inherent uncertainties have been addressed in the assessment by using uncertainty or extrapolation factors to adjust the TRVs (Table 10-5) (DTSC 1996a,b). Doses used to derive the TRVs were primarily obtained from studies using sensitive measures including physiological and reproductive endpoints. As concurrent organ function tests were not conducted in these studies, the relevance of the observed effects on the health of the individual is not known. In addition, how much the observed physiological changes affect individual growth, survival, or reproductive function are generally not known. However, as avian and mammalian species exhibit unique physiological adaptations, it is unknown whether these TRVs may over- or under-estimate effects on individuals in the field. One TRV that may exhibit notable uncertainty was the selenium NOAEL TRV for mammals (EFA West 1998) (Table 10-12). This TRV was based on hepatic lesions, a sensitive endpoint that may be difficult to relate directly to observable health, survival, or reproductive effects.

It should be noted that benchmark doses derived from multiple-dose toxicity tests show a high positive correlation with observed impacts in the environment (U.S. EPA 1991). NOAELs and LOAELs for sublethal effects (*e.g.*, reproduction) have been selected in order to provide a protective risk assessment.

Potential risks to amphibians were not assessed with formal TRVs due to the sparse availability of relevant toxicity data for amphibian exposures to selenium. To assess potential risks to amphibians, selenium concentrations in surface water were compared to ranges of toxicity values summarized in the Canadian Wildlife Service's Reptile and Amphibian Toxicology Literature (RATL) database (Pauli *et al.*, 2000) (Tables 10-8 and 10-44). These toxicity values are based on lethal effects to sensitive embryo-larval life stages of amphibian species. These screening results should be viewed in the context of limited and uncertain toxicity values. In particular, any exceedance of the low toxicity value may not represent adverse effects, as there is considerable variability in the toxicity of chemicals in the RATL database for amphibian test species. Most chemicals with more than one data value exhibited between two to four orders of magnitude difference between the lowest and highest toxicity value. The low toxicity value for selenium was based on a study performed on the eastern narrowmouth toad (*Gastrophryne carolinensis*), which is typically the most sensitive of all amphibian test species with respect to metal toxicity (Sparling *et al.*, 2000). These toxicity values represent highly protective benchmarks. Some of the variability between the low and high toxicity values could be a product of differing water conditions among toxicity studies; pH, alkalinity, hardness, and organic carbon will modify the bioavailability of inorganic and organic chemicals. In view of the wide range of species-specific toxicity of these chemicals, these thresholds for effects are uncertain.

10.16 Conclusions

The initial comparison of data collected from the Brawley and Imperial Pilot Wetlands in 2005 indicated that there was the potential for risks to ecological receptors at these locations. Follow-up studies were conducted in 2006 to evaluate that potential and the data collected in 2006 was used in a baseline ecological risk assessment.

This baseline ecological risk assessment evaluated the potential for adverse ecological effects to ecological receptors that may be exposed to selenium and organochlorine pesticides in the Brawley and Imperial Pilot Wetlands. In addition to estimating risks for ecological receptors

at the pilot wetlands, risks were estimated for the same receptors for three different types of local background conditions; *i.e.*, 1) agricultural drains in the Imperial Valley, 2) at the New and Alamo Rivers, and 3) the Salton Sea.

The most important finding of the risk assessment is that although exposures to selenium and organochlorine pesticides may result in low levels of risks to ecological receptors, the risks from potential exposures by the same receptors in the agricultural drains, New and Alamo Rivers, and Salton Sea were all much higher. However, in evaluating the risk estimates for the wetlands, the following should be remembered:

- The only NOAEL HQs that were significantly greater than 1 (*i.e.*, greater than 5) were the HQs for selenium exposure by raccoons and 4,4'-DDE exposure by cormorants. As the NOAEL HQs are very protective, this indicates that few ecological receptors are likely to experience adverse effects at the wetlands.
- All LOAEL HQs for birds and raccoons potentially exposed to selenium and 4,4'-DDE were not significantly greater than 1 (*i.e.*, all were less than 5). As LOAEL HQs significantly greater than 1 indicate that adverse effects are likely, this result indicates that ecological receptors are unlikely to experience adverse effects at the wetlands.
- Since 4,4'-DDE in sediments was present at concentrations greater than the TEC, but less than the PEL, 4,4'-DDE in sediments may not pose a risk to benthic invertebrates.
- The risks to raccoons are likely to have been over estimated as it was assumed that their diet was made up of entirely aquatic organisms, which is a very conservative assumption. Further, the TRV used to evaluate the impact of selenium on raccoons was based on a histopathological endpoint with no known ecological consequences.

Further, the elevated levels of suspended sediments in the rivers makes them generally poor habitat, such that we were unable to catch crayfish in the rivers and fish of all kinds were much less abundant in the rivers than in the treatment wetlands or agricultural drains. This is especially applicable in the southern portion of the New River, where the dissolved oxygen was extremely low and no aquatic biota was observed during sampling.

This risk assessment has shown that treatment wetlands, while they do pose some low level of risk to ecological receptors, represent better habitat than the agricultural drains, New and Alamo Rivers, and the Salton Sea. Therefore, the construction of treatment wetlands can be regarded as improving the habitat for wildlife in this area. Habitat improvements like this should be regarded as vital, since the Salton Sea is on the Pacific Flyway and the available resting locations for migratory birds on the Pacific Flyway has dwindled to the point that the Salton Sea is one of the last remaining stop-overs in the southern United States.

CHAPTER 11
COST EFFECTIVENESS OF TREATMENT OPTIONS

Using construction, operation, and maintenance data on the pilot wetlands from IID and other sources, an estimate of constructed wetland treatment costs are provided. The wetland costs are also compared to the costs of the installation and operation of a traditional chemical treatment plant.

11.1 Constructed Wetland Costs

The constructed wetland costs are defined with respect to capital costs and operations and maintenance (O&M) costs. The costs are based on the two pilot wetlands, Imperial and Brawley Wetlands, which were constructed in 2000, from data from other wetland sites, and generic cost data available in the literature.

11.1.1 Capital Costs

Cost data from IID for the pilot wetland program are provided in Table 11-1. The capital costs for construction of the 9-acre Brawley Wetland and the 43-acre Imperial Wetland are approximately $2.04 million. The design and construction costs are approximately $39,000 per total acre. The Imperial Wetland consists of two sedimentation basins which operate in parallel followed by four wetland cells in series. The Brawley Wetland consists of a single sedimentation basin and two wetland cells in series.

Table 11-1
Capital Cost Data for the Pilot Wetland Program

Capital Cost	Cost
Labor	$658,386
Materials	$1,035,312
Equipment	$320,012
Transportation	$22,322
TOTAL CAPITAL COSTS	$2,036,031
Capital Cost Per Acre	$39,154

Source: (IID, 2006)

The preliminary cost estimate for the Top 35 Wetland Scenario was also analyzed by Nolte Engineers (2002). Costs were broken out by the categories: land acquisition, surveying, construction, biological survey, cultural survey, permitting, environmental compliance, and

engineering design. The total cost per acre is $42,900. The breakdown of the total cost per acre is shown in Table 11-2, with a majority of the cost coming from actual construction.

Table 11-2
Estimated Capital Cost Data Per Acre for the Top 35 Wetland Scenario

Capital Cost	Cost Per Acre
Land Acquisition	$840
Surveying	$70
Construction	$37,600
Biological Survey	$70
Cultural Resources	$400
Permitting	$10
Environmental Compliance	$90
Engineering Design	$3,800
TOTAL CAPITAL COSTS	$42,900
TOTAL FOR TOP 35 WETLANDS (4,262 ACRES)	$182,850,000

The preliminary total capital cost estimate by Nolte Engineers (2002) is in general agreement with the known costs for the pilot wetlands. To be conservative, the total capital cost for the Top 35 Wetland Scenario is estimated at $182.85 million based on the higher Nolte Engineers estimate (2002). These costs are considered to be a good preliminary estimate, although Nolte Engineers (2002) warns the actual costs could vary as much as 30%. The costs for the two pilot wetlands were 7% lower.

11.1.2 Operations and Maintenance Costs

The reported O&M costs for the two pilot wetlands over five years (2001 through 11/2005) are about $700,000, as presented in Table 11-3. The overall monitoring costs are not considered representative since intensive monitoring for the demonstration project would not be expected for the full wetland system. Pump maintenance costs only incur for the Brawley Wetland. About 7 AF/yr is pumped from the New River into the Brawley Wetland, whereas the Imperial Wetland is gravity fed.

Table 11-3
O&M Cost Data for the Pilot Wetland Program

Operating and Maintenance[1]		Brawley Wetland (9-acre)	Imperial Wetland (43-acre)
System Operations		$6,968	$6,612
Pump Maintenance		$27,163	N/A
Misc. Maintenance		$6,273	$13,926
Road Maintenance		$1,488	$28,798
Pond Maintenance		$6,824	$10,259
Monitoring[2]		$345,827	$354,824
Total O&M Costs		$394,543	$414,419
Excluding Pump Maintenance & Monitoring			
Annual O&M Costs		$4,311	$11,919
Annual O&M Costs Per Acre		$479	$277
Pump Maintenance Costs			
Annual Pump Maintenance Costs		$5,433	NA
Annual Pump Maintenance Costs Per Acre		$604	NA
Source: (IID, 2006) Notes: 1. O&M cost data from 2001 to 11/2005. 2. Annual monitoring per year as follows:			
Constituent Monitoring Frequency	**Year**	**Brawley Wetland**	**Imperial Wetland**
Unknown	2000	$5,891	$10,176
Twice monthly	2001	$60,122	$64,513
Weekly	2002	$100,137	$108,206
Weekly	2003	$88,810	$103,373
Monthly	2004	$73,331	$95,393
Quarterly	2005	$14,537	$15,779

The annualized O&M costs are $4,300 and $11,900 for the two wetlands, excluding pump maintenance and monitoring costs. The pump maintenance costs for the Brawley Wetland were excluded because the chosen Top 35 wetlands are expected to be gravity-driven. Monitoring data from the pilot wetlands included continuous flows, aqueous constituent concentrations, soil constituent concentrations, and concentrations of various constituents in biota. The concentrations of aqueous constituents were measured twice monthly in 2001, weekly in 2002 and 2003, monthly in 2004, and quarterly thereafter at the wetland inlets and outlets.

The annualized O&M costs for the Top 35 Wetlands scenario range between $2.4 and $3.3 million based on the Brawley and Imperial Wetland O&M costs, respectively (see Table 11-4). The pump maintenance costs were included because the 14 of the 35 wetlands may require pumping, based on preliminary survey information by Davey-Cairo Engineering (2006a,b). Pumping costs are $604 per acre based on the Brawley Wetland. Annual O&M costs (excluding pump maintenance costs and monitoring) were $479 and $277 per acre per year for the Brawley and Imperial Wetlands, respectively. The annual monitoring costs are estimated on a per wetland basis, based on the 2005 monitoring costs, which average $15,000 per wetland site. Annual costs for 2005, which are based on quarterly monitoring, were considered a fair representation of typical annual costs.

Table 11-4
Estimated Cost Data for the Top 35 Wetland Scenario

Cost Element	Lower Bound	Upper Bound
Capital Cost[1]	$182	$182
Annual O&M Cost[2]	$2.4	$3.3
Event-Based O&M Cost		
Dredging[3]	$14	$14
Plant Harvesting[4]	$0.5	$0.5
Total O&M Cost 50-Year Present Worth	$58	$79
Total Capitalized 50-Year Present Worth[5]	$241	$262
Total Annual Cost[5]	$10.3	$11.2

Notes:
1. Based on $42,000/acre (Nolte, 2002) and 4,262 acres for the Top 35 Wetland Scenario (see Table 2).
2. Based on IID pilot wetland O&M costs (see Table 3). Assumes quarterly monitoring costs of $15,000 per wetland. Assume 14 of 35 wetlands requires pumps based on preliminary survey information (Davey-Cairo, 2006).
3. Dredging of sedimentation basins only (estimated wetted area of 909 acres and 2.5 feet sediment thickness). Cost based on 2004 U.S. Army Corps of Engineers cost of $2.73/cubic yard. Dredging required every 9 years, based on sedimentation rate of 8.5 cm/yr (Tetra Tech 2006).
4. Costs for plant harvesting of wetland cells (estimated wetted area of 3,635 acres and 50% plant coverage) are $400/acre, based on 2006 Washington Department of Ecology data on costs. Assume harvesting occurs every 6 years.
5. Assumes 3.5% interest and no inflation.

Plant harvesting and dredging are additional, potential O&M requirements for constructed wetlands that do not occur on an annual basis. Dredging and harvesting have not yet been performed at the pilot wetlands so no costs are available. Plant harvesting is planned for October 2006 in the Imperial wetland treatment cell 3. The preliminary costs are estimated as follows.

Dredging requirements are based on the sedimentation rate. Sediment accumulation rates of 7 - 10 cm/yr can be expected in the sedimentation basins, and 0.4 – 0.5 cm/yr in the wetlands (Tetra Tech, 2006). The sedimentation basins will be up to 10 feet deep (Nolte, 2002). The depth of the open water will be 4 to 6 feet in the wetland. It is assumed that the sedimentation basins would require dredging approximately every 9 years, when 2.5 feet of sediment has accumulated. The sediment accumulation rates in the wetland cells are significantly lower and are estimated to take 100 years to accumulate 1.5 feet of sediment. Thus, dredging costs for the wetland cells are not included.

Dredging costs from U.S. Army Corps of Engineers (USACE) from the most recently available year, 2005, are $3.75/cubic yard, based on all dredging work (USACE, 2006). USACE cost breakdowns range from $3.51/cubic yard for federal dredging projects to $8.97/cubic yard for non-federal dredging. Sedimentation basins are assumed to comprise 25% of the wetland sites and for the entire wetted acreage of 3,635 acres, 910 acres would be sedimentation wetted acres. Therefore, preliminary costs would be $13.7 million per each dredging event based on the rate for all dredging work of $3.75/cubic yard (US ACE, 2006). However, the estimate could be a factor of 2 higher depending on whether the work is federally or non-federally supported.

The Brawley and Imperial pilot wetlands have been designed to minimize vegetative coverage. Plant coverage is designed for approximately 50% of wetland cells wetted areas (1,270 acres) (Nolte, 2002). Costs per acre vary with numbers of acres harvested, accessibility of disposal sites to the harvested areas, density and species of the harvested plants, and whether a private contractor or public entity does the work. Costs as low as $250 per acre have been reported; private contractors generally charge $500 to $800 per acre (Washington Department of Ecology, 2006). If a public entity is assumed to perform the work at a cost of $400 per acre, the harvesting cost is estimated at $0.5 million per plant harvesting event. Plant harvesting is planned for October 2006 in the Imperial wetland treatment cell 3. For costing purposes, it is assumed that plant harvesting will occur every 6 years.

11.1.3 Total Costs

For a 50-year lifespan, the total present worth capitalized costs, including O&M costs, is estimated to be between $241 and $262 million, based on an interest rate of 3.5% (see Table 11-4). The estimated annual costs to construct and operate the facilities for 50 years are also presented in Table 11-4. All assumptions are listed above.

11.2 Wastewater Treatment Plant Costs

One alternative that has been proposed by the Salton Sea Authority is use of a chemical treatment plant sited on the Alamo River that would remove sediments, salts, and nutrients from the New and Alamo Rivers. The primary basis for the planning, design and construction of a conventional physical-chemical water treatment plant is to significantly reduce the phosphorus concentrations in the New and Alamo Rivers immediately before the waters flow into the Salton Sea. The principal objective is to reduce the loading of total phosphorus in the combined flow of the New and Alamo Rivers.

The physical-chemical treatment technology conventionally used for phosphorus removal involves precipitation of the phosphorus using metal ions of aluminum, calcium, or iron as collectors. In general, alum, a hydrated aluminum sulfate, has proven to be the most cost-effective and efficient chemical for precipitation of orthophosphates and collection of organic and inorganic phosphorus. The practical lower limit for total phosphorus removal using only gravity sedimentation has been reported to be approximately 0.5 mg/L. If conventional rapid filtration or membrane filtration is employed subsequent to gravity sedimentation, then the total phosphorus concentration can be consistently reduced so that the residual total phosphorus concentration is in the range of 0.020 to 0.040 mg/L. For the purposes of the analysis presented herein, it is assumed that the total phosphorus concentration can be reduced to achieve treated water with total phosphorus concentration of approximately 0.025 mg/L. An alum dose equal to a mole ratio of 2 moles of aluminum per mole of phosphorus was assumed based on experience and data reported in the literature for other water similar in nature that required treatment to achieve this low residual phosphorus concentration.

The treatment facility would start with a fine screen headworks to remove all debris greater than 0.125 inches. The resulting debris from the screening system would be washed, compacted, and then disposed of as green waste. After screening, liquid alum would be blended into the water to precipitate the dissolved phosphorus and to stimulate the coagulation of the suspended and colloidal solids in the water. The resulting coagulated water would be conveyed to flocculating type circular clarifiers outfitted with a sludge thickening and collection mechanism. Sludge would be pumped from each of the clarifiers at a solids concentration of approximately 1% solids and conveyed to solar sludge drying beds or lagoons. Based on the climatic conditions in the area, non-mechanical sludge dewatering of the sludge might be the most cost-effective means for dewatering the solids. The amount of land required for sludge drying beds or lagoons would range between 350 to 700 acres.

11.2.1 Capital Costs

Three scenarios were developed to evaluate costs for a range of treatment levels. Scenario A is the most aggressive approach. It is designed to reduce the phosphorus loading to the Salton Sea from 1.23 million kg/yr to approximately 0.1 million kg/yr, which is a reduction of 92 percent. This corresponds to an average concentration of approximately 0.08 mg/L total phosphorus for the combined average flow for both rivers. To accomplish this level of phosphorus reduction, approximately 84 percent of the flow of the New River and 100 percent of the flow of the Alamo River would be intercepted and pumped to the physical-chemical treatment facility. It is assumed that the water from each of the respective rivers would be intercepted and pumped to a common treatment facility. Scenario 2 is designed for a 79 percent reduction, or loading of 0.26 million kg/yr. Approximately 48 percent of the New River flow and 100 percent of the Alamo River flow would be intercepted and pumped to the physical-chemical treatment facility. Scenario 3 is designed for a 49 percent reduction, or loading of 0.63 million kg/yr. Approximately 50 percent of the New River flow and 50 percent of the Alamo River flow would be intercepted. Table 11-5 presents a generalized basis for design for the three scenarios.

Construction costs were principally estimated using the cost models generated by the United States Environmental Protection Agency (EPA, 2001) and then adjusted to current costs using the Engineering News Record Construction Cost Indexes for the years that the cost models were generated. The respective cost indices are shown on the cost estimate data sheets for each respective treatment scenario. Costs for engineering design, construction management, permitting and project contingency were developed using percentages of the estimated construction costs that are characteristically applied to project of this magnitude and complexity. Table 11-5 presents the cost results for total capital investment.

Table 11-5 also presents the costs for treatment for the same scenarios, except the cost for filtration has been excluded. Although in most studies report that filtration is required after sedimentation to reliably reduce total phosphorus below 0.050 mg/L, pilot testing accomplished for the South Florida Water Management District (2000) indicated that total phosphorus concentrations of 0.010 mg/L could be achieved through coagulation/precipitation with alum followed by flocculation and sedimentation alone without the need for filtration. As shown in the cost tables herein, the project costs for both capital facility investment and operation and maintenance requirements would be significantly lower if filtration was not required. Site pilot testing would be recommended to determine if the low levels of total phosphorus can be achieved in treating the New and Alamo River water without the need to include filtration as part of the treatment process.

Table 11-5
Estimated Cost Data for Chemical Treatment Plant[1]

	Scenario A	Scenario B	Scenario C	Scenario A - Without Filtration[2]	Scenario B - Without Filtration[2]	Scenario C - Without Filtration[2]
Design Criteria						
Average Operating Rate (mgd)	883	739	473	883	739	473
Annual Treatment Volume (AF/yr)	989,000	828,000	530,000	989,000	828,000	530,000
Percentage of Alamo River to be Treated (%)	100	100	50	100	100	50
Percentage of New River to be Treated (%)	84	48	50	84	48	50
Total Phosphorus Reduction (%)	92	79	49	92	79	49
Total Phosphorus Load to Salton Sea After Treatment (kg/yr)	1,129,343	969,739	599,927	1,129,343	969,739	599,927
Phosphorus Concentration to Salton Sea After Treatment (mg/L)	0.08	0.20	0.48	0.08	0.20	0.48
Capital Cost (in millions)	$M	$M	$M	$M	$M	$M
Treatment Plant[3]	$329	$275	$198	$141	$122	$94
Pump Station and Intake/Diversion Structure	$52	$44	$34	$52	$44	$34
Engineering Design (15%)	$57	$48	$35	$29	$25	$19
Construction Management (15%)	$57	$48	$35	$29	$25	$19
Permitting (3%)	$11	$10	$7	$6	$5	$4
Contingencies (30%)	$114	$96	$70	$58	$50	$38
TOTAL CAPITAL COSTS	**$620**	**$520**	**$378**	**$314**	**$270**	**$208**
Operating & Maintenance (O&M) Cost (in millions)	$M/year	$M/year	$M/year	$M/year	$M/year	$M/year
Labor & Supervision	$1	$1	$1	$1	$1	$1
Maintenance & Materials	$16	$13	$12	$12	$10	$10
Residuals Management	$5	$5	$5	$5	$5	$5
Utilities	$1	$1	$1	$1	$1	$1
TOTAL ANNUAL O&M COSTS	**$24**	**$21**	**$19**	**$20**	**$18**	**$17**
Total Capitalized Present Worth (3.5% interest, 50 years)	**$1,175**	**$1,154**	**$990**	**$781**	**$763**	**$713**
Total Annual Cost	**$50**	**$49**	**$38**	**$32**	**$33**	**$28**
Cost per Kilogram of Phosphorus Removed	**$9**	**$10**	**$13**	**$6**	**$7**	**$10**

Notes:
1. See Appendix M for detailed breakdown of costs, including all design criteria.
2. Most studies report that filtration is required after sedimentation to reliably reduce total phosphorus below 0.050 mg/L. Pilot testing performed for the South Florida Water Management District (2000) indicated that total phosphorus concentrations of 0.010 mg/L could be achieved through coagulation/precipitation with alum followed by flocculation and sedimentation alone, without the need for filtration. Site pilot testing would be needed to determine if the low levels of total phosphorus can be achieved without filtration.
3. Treatment plant includes headworks and fine screen, flocculation and clarification, filters, chemical storage tanks, chemical feed system, sludge handling, admistration building and laboratory, emergency power, and supervisory control and data acquisition system.

Appendix M presents the detailed analysis of the chemical treatment facility. Detailed cost breakdowns for the major process facilities are also provided for each scenario. The basic design criteria for the diversion structures and pumping facilities required to convey the water from the respective rivers to new treatment plant are also provided. The concept is to pump up to the treatment facility so that the water all flows through the treatment plant and into the downstream channel of the respective rivers after treatment. The piping conveyance systems are assumed to be incidental to the design of the pump station since the treatment plant is envisioned to be located in near proximity to both diversion pump stations. The design criteria and basis for estimating costs for the chemical treatment is also presented in detail, including estimated land requirements for the each of the diversion pump stations and the treatment. Land requirements for the non-mechanical sludge dewatering process are included for reference. Additional land will be required for the ultimate disposal of the sludge solids.

11.2.2 Operations and Maintenance Costs

The analysis also addresses long-term costs associated with operation and maintenance of the treatment plant. Operations and maintenance labor costs were generated based on best professional judgment. Annual maintenance of mechanical equipment and facilities was estimated at 2 percent of the estimated construction cost. Alum, polymer, electrical power,

and sludge haul costs based on the estimated usage rates shown and best professional judgment.

Table 11-5 presents the cost results for total capital investment, and annual operation and maintenance costs. Present worth of the pumping and treatment systems for each scenario are also presented based on a 50 year facility life cycle including both capital costs and operation and maintenance costs. The estimate annual cost to construct and operate the facilities for 50 years is presented as well as a cost for treatment with respect to the mass of phosphorus removed.

11.3 Summary of Cost Effectiveness Evaluation

In the absence of pilot data, there are considerable uncertainties regarding the design and cost of a chemical treatment plant to treat the New and Alamo River waters. Using various assumptions regarding the design, preliminary calculations show that a complete system, with coagulation and filtration, can cost several hundred million dollars. The costs are substantially lower (about half) for a chemical treatment plant without filtration, as was proposed in similar cost estimation in the Florida Everglades. These costs are based on greater treatment levels than is achievable with wetlands, and the chemical treatment plant option must be considered for exploration only if wetlands cannot be constructed or if the greater water quality improvement is desired.

Because of the site specific data on the construction of the pilot wetlands on the New River, there are fairly good estimates of the cost of construction of treatment wetlands, which are estimated to cost approximately $183 million for the construction all 35 proposed wetlands. However, the most significant differences are in substantially lower operation and maintenance costs of the wetlands, because of which, the 50-year capitalized present worth of the wetland network is a third of the least expensive treatment option. Besides the differences in overall costs, wetlands also have the significant advantage that they can constructed gradually over an extended period of time, with partial benefits being derived.

CHAPTER 12
OPERATION AND MAINTENANCE PLAN

As part of the Master Plan development for wetlands in the New and Alamo Rivers, an operation and maintenance plan has been prepared to identify the activities needed to be undertaken to keep the system functioning in a healthy condition for multi-decade time frames. The specific objectives of this operation and maintenance (O&M) plan are:

1) To optimize the water quality treatment efficiency of the New and Alamo River wetlands

2) To minimize any negative environmental impacts within or downstream of the wetlands

3) To enhance the aesthetic and environmental quality of the wetlands

The operation and maintenance plan will specify the various management techniques required to optimize the performance of the wetlands and maintain the overall health of the wetland systems. The O&M plan also provides a schedule for routine and major maintenance activities. The maintenance plan may need to be modified over time based on operational experience, monitoring results, and program evaluations.

12.1 General Operation and Maintenance Activities

An O&M plan is described in the subsequent sections for the New and Alamo River wetlands. The plan identifies the types of activities that need to be performed within each wetland to ensure their optimal performance. Operation and maintenance activities will take into account sensitive habitats and species of special concern. This may include avoiding certain maintenance activities in sensitive areas or during specific times of the year. The breeding and nesting period for birds may be a time when special precautions need to be taken. A biologist or wildlife specialist should be consulted to help identify species of concern or sensitive habitats.

The operation and maintenance plan is divided into three categories: routine, major, and emergency activities. A maintenance log should be kept to note all maintenance activities conducted in the wetlands.

12.2 Routine Operation and Maintenance Activities

12.2.1 Site Inspection

The New and Alamo River wetlands should be inspected on a routine basis to ensure that the wetlands are operating properly and to help identify any special needs or areas of concern. These inspections should include visually inspecting the physical appearance of the wetlands such as the condition of the berms and embankments, condition of diversion structures, health of the vegetation, and other related parameters. They should also include checking the operational aspects of the wetlands including the water levels, water quality, pumps and valves, and the flow control structures (weirs, inlet, and outlet structures).

During these routine inspections, the need for trash or debris for removal should be identified. Small trash that does not require the use of machinery for removal should be removed during the routine inspections. The inspector should also note any signs of vandalism so repairs can be ordered in a timely manner when necessary. At the beginning of the O&M activities, these inspections should be conducted on a weekly basis. The frequency of site inspections may vary depending on the site, monitoring requirements, and the season of the year. Once it is established that wetlands are functioning properly, the frequency of these visits can be scaled down.

12.2.2 Inlet, Outlet, and Weir Inspection

The proper maintenance of the inlet, outlet, and weir structures is necessary to ensure that water can freely flow through the wetland systems. During the site inspections, these structures should be visually inspected to identify any type of damage or impediment of flow through these structures. Equipment being used in the wetlands or vandals may cause damage to these structures. Trash, floating vegetation, or woody debris can also build up in these structures and impede the flow of water. Floating vegetation may be a major problem in the fall after the end of the growing season. However, these structures may become clogged with debris at other times of the year as well, so it is important to routinely check them. It may be necessary to remove debris and trash from the flow structures 3 to 4 times per year depending upon how much litter/debris is being produced by the wetland system. The debris removed from the system should be hauled away and not left on the access roads.

12.2.3 Water Level Management

Water level management is a critical factor in determining the health of a wetland vegetation community and the successful operation of a constructed wetland treatment system. Maintaining water levels within the tolerance limits of the desired wetland plant species will help to establish and maintain the desired plant community (Davis, 1994). Certain species of emergent wetland plants may require periodic drawdown of the water levels to encourage the growth of new shoots. Water levels can also be manipulated to control prolific growth and the spread of undesirable weedy plants (Hammer, 1989). During the routine inspections, the water levels should be checked and adjusted accordingly. Any major drop in the water level should be reported immediately, so that the cause can be identified and the necessary repairs or corrections can be made as soon as possible. A wetland specialist may need to be consulted to determine the optimal water levels or drawdown periods to maintain a healthy plant community within the wetlands.

12.2.4 Water Quality Sampling

Water quality sampling needs to be conducted to evaluate the treatment effectiveness of individual wetlands. Data from the pilot wetlands has shown that inflow and outflow

concentrations of most parameters of interest are variable over time, and multiple measurements need to be taken over the course of a year to obtain a reasonable representation of wetland functioning. Although intensive laboratory analysis of water quality parameters, as performed during the pilot wetland testing, may be too expensive for routine operation and maintenance and evaluation, it is proposed that a combination of regular field testing combined with less frequent laboratory testing be conducted to characterize the performance of individual wetlands. Field measurements or tests may be taken during routine site inspections to help identify any potential problems. A simple water quality meter or field test kit that measures standard field water quality parameters is a quick and easy way to check the general water quality conditions in the wetland. A water quality measurement can be taken at the inlet, a point in the middle, and at the outlet of the wetland to get a quick feel for the overall water quality in the wetland. A more detailed water quality analysis, with the collection of additional chemical parameters, will be conducted based on the requirements of the monitoring plan. A more detailed evaluation of the water quality is typically conducted on a quarterly basis. Table 12-1 shows a list of water quality parameters that should be collected in the field and the additional chemical parameters that will be analyzed in a laboratory during quarterly monitoring efforts.

Table 12-1
List of water quality parameters for field and laboratory analyses.

Parameter
Field measurements:
Temperature
Specific Conductivity
Electrical Conductivity
Dissolved Oxygen
Dissolved Oxygen (saturation)
pH
Oxidation Reduction Potential
Turbidity
Laboratory measurements:
Total Coliforms
Sulfate
Nitrate-N
Nitrite-N
Ammonia-N
Total Kjeldahl Nitrogen
Ortho-Phosphate
Total Phosphorus
Total Suspended Solids
Total Selenium
Dissolved Selenium
Inorganic Selenium
Selenite (Se(IV))
Organic Selenium
Selenate (Se(VI))

12.2.5 Trash and Debris Removal

Trash and debris within and near the wetlands should be removed on an as needed basis. It is necessary to remove this waste, because it can get into the wetland itself and impede the flow of water through flow structures. It can also lead to access problems within the wetland by blocking or piling up on the access roads. During the site inspections, small trash and debris can be removed at any time. However, larger debris and trash may need to be removed through the use of large machinery.

12.2.6 Minor Vegetation Maintenance

The removal of excess vegetation growing along the berms and embankments in constructed wetlands is important for maintaining good access to different parts of the wetlands. Having easy access to weirs and drains along the access roads simplifies the routine maintenance activities to be conducted in the wetlands (water level and flow control). Due to the steep nature of the berms and embankments surrounding the New and Alamo River wetlands, traditional rotary mowers and riding mowers can not be used for the removal of vegetation from the berms and embankments. A tractor with a boom flail attachment or using a hand-held gas-powered trimmer may be the best methods for removing brush and vegetation along the berms and embankments. A tractor with a boom flail attachment is specially designed for removing vegetation in hard to reach places like pond embankments or ditches. Berms and embankments should be mowed 3 to 4 times a year to help maintain easy access to the wetlands.

12.2.7 Minor Sediment Removal

Sediment deposits are likely to build up around the inlet structures or in the deep pools in front of these structures. These deposits can obstruct water flow, reduce sedimentation performance, and may contain elevated levels of contaminants (IRWD, 2005). It is necessary to remove these sediment deposits to maintain the overall performance of the constructed wetland systems. These sediment prone areas should be checked 3 to 4 times per year and the sediment deposits should be removed when excess accumulation is noted. The sediment that is removed should be tested for contaminants to determine if special handling of the material is required.

12.2.8 Nuisance Wildlife

Muskrats and beavers can be especially destructive in constructed wetlands. Numerous muskrats have been observed in the pilot wetland systems. Muskrats can cause major damage to berms, embankments, and access roads by burrowing or digging into them and leading to increased bank erosion or leakage from certain areas within the wetlands. It may be necessary to trap and remove muskrats or beavers from the wetlands to prevent further damage. Muskrats and beavers can be trapped using both leg-hold and conibear traps. According to the California Department of Fish and Game, a special plan would need to be developed and a federally licensed trapper would need to be used for any trapping activities conducted in the wetlands. For further information on the trapping of nuisance wildlife, contact the local game warden at the California Department Fish and Game office at 909-484-0167. Inspection for damage created by muskrats and beavers should be conducted at least 4 times per year.

12.2.9 Insect Control

One of the major human health concerns from constructed wetlands is the excessive production of mosquitoes or other nuisance insects from the wetlands. Mosquitoes can transmit pathogens such as West Nile virus, encephalitis, and malaria (Russell, 1999). The best approach to avoiding mosquito problems in constructed wetlands is to create conditions that are not suitable to larval development. These conditions include eliminating stagnant backwaters, shading the water surface, creating a good balance between open water areas and vegetation, and dispersing floating mats of duckweed or other floating plants (Davis, 1994).

The production of mosquitoes can also be controlled through the use or introduction of mosquitofish, with biological sprays, or with chemical sprays. A healthy population of mosquitofish was observed in the New and Alamo River wetlands, so it may be important to maintain conditions in the wetlands that are suitable for mosquitofish to help control the

mosquito population. As a last resort, it may be required to use an insecticide to control the mosquito population. If the use of an insecticide is required, then one that is suited for use in environmentally sensitive areas should be selected (temephos is an example of a suitable pesticide). Any application of chemical or biological agents should be performed by a certified professional in accordance with manufacturer guidelines and following applicable California laws and regulations. During the site inspection, the abundance of mosquitoes or other biting insects should be noted. A simple hand net can be used to help determine the abundance of mosquitoes in the wetland. One larva per 2 or 3 scoops may be an indication that additional management activities may be necessary to control the mosquito population (IRWD, 2005).

As was noted above, a healthy population of mosquitofish was observed in the new and Alamo River constructed wetlands. However, it may be necessary to stock additional mosquitofish in the future if populations decline. A fisheries biologist should be contacted prior to mosquitofish stocking to help determine the optimal conditions, location, and time of the year to stock mosquitofish. According to the California Department of Fish and Game, there are no special requirements or restrictions for stocking moquitofish into these wetlands.

12.2.10 Pump/Valve Inspection and Cleaning

The pumps, valves, and other mechanical equipment used in the constructed wetlands should be routinely inspected. These types of equipment require regular maintenance to ensure that they are functioning properly and to help optimize the overall performance of the wetland systems. Pumps and valves can be adjusted during the routine site inspections to help optimize their performance. Any major malfunctions should be noted during site inspections and repairs to the equipment should be made as quickly as possible.

The pump and electrical dosing unit should be inspected and cleaned annually. The cleaning should include removing any debris caught in the pump and making sure that the various parts are wiped down and oiled where necessary. The impeller, shaft sleeve, and shaft seal should be inspected for any damage. The impeller may need to be periodically changed depending upon the operating conditions. It may be a good practice to have a back-up pump in case one breaks down. This will help to reduce the downtime of the wetland systems.

12.3 Major Operation and Maintenance Activities

Major operation and maintenance activities are described in the following sections. A checklist of these activities including a maintenance schedule is included at the end of the O&M Chapter (Table 12-2).

12.3.1 Major Vegetation Removal and Replanting

Maintenance of the wetland plant community is a critical component to assure that the wetland system continues to function properly. Emergent wetland plants provide for microbial growth and pollutant assimilation (Kadlec and Knight, 1996). Vegetation management will help to enhance nutrient removal capabilities of the wetland system, especially for nitrogen (Thullen et al., 2002). To maintain a healthy emergent plant community, it is necessary to control optimal water levels for plant growth, remove undesirable weed species from the wetland, harvest or thin vegetation community, and remove dead or floating debris from the wetland system.

The removal of undesirable weed or wetland plant species should be conducted on an annual basis (CASQA, 2003). The removal of undesirable species may require hand picking or the use of herbicides to remove them. Herbicides should be used as a last resort for the removal

of undesirable species due to the negative impacts that they may have on the ecological functioning of the wetland system. Any application of herbicides should be performed in accordance with manufacturer guidelines and following applicable California laws and regulations.

Saltcedar or tamarisk is an undesirable plant species that was observed in both of the pilot wetlands. Tamarisk provides few benefits to native wildlife and crowds out desirable wetland plant species (Nature Conservancy, 2001). It is recommended that tamarisk and other undesirable plant species be removed from both wetlands as soon as possible to prevent further spreading. This should be done in a manner to cause the least amount of disturbance to native wildlife and beneficial plants. A wildlife biologist may need to be consulted to determine the most appropriate methods for removal and the optimal time of the year to conduct this type of maintenance.

Harvesting or thinning of emergent wetland vegetation is necessary to maintain the capability of the wetland system to remove soluble nutrients and pollutants (Schueler, 1992). It also helps to promote new plant growth and improves the overall health of the vegetation community. By harvesting some of the emergent wetland vegetation, larger areas of open water are created in the wetland. A study conducted by Thullen et al. in 2002, found that interspersion of emergent wetland vegetation with open water areas enhanced the treatment of ammonia-dominated, secondary-treated effluent in wetland research cells in Southern California. Creating more open water areas can also help to reduce the number of mosquitoes being produced in the wetland. Deeper habitats with cleaner steeper margins, and more open water, produce fewer mosquitoes (Russell, 1999).

Recommended techniques for harvesting emergent wetland vegetation include the use of floating mowers, hand-held devices with the aid of a boat or by wading, tractor mounted mowers (flail, rotary, etc.), or dredging the wetland. Hand-held devices that could be used include scythes or gas-powered trimmers. Using large tractor-type mowers requires parts of the wetland to be drained and damages the bottom substrate of the system. Dredging typically leads to the complete removal of the plant root system and causes major disturbances to the bottom substrate of the wetland system. As was the case with removing undesirable weed species, it is important to try and minimize disturbances to native wildlife. The removal of vegetation should not be conducted during the bird nesting season. Once again, a wildlife biologist may need to be consulted to help determine the optimal method and time of year to remove emergent vegetation.

It is highly recommended that cut vegetation be removed to prevent the release of nutrients back into the system and to decrease the chances of the cut vegetation clogging weirs or drainage structures. Burning to remove vegetation or burning of the cut vegetation is not recommended, because fire mobilizes the stored nutrients and pollutants into water-soluble forms and permits the release of the materials that the wetland was designed to store (Kadlec and Knight, 1996). At a minimum, harvesting or thinning of the wetland vegetation should be conducted on an annual basis. In productive systems, it may be necessary to remove some of the vegetation on a semi-annual basis (CASQA, 1997). The chemical content of vegetation removed from the wetland should be tested to determine if any special disposal methods are required.

The removal of floating or woody debris from a constructed wetland system helps to control odor problems from decaying plants, prevent the release of pollutants or nutrients, improve the overall ecological health of the system, and minimize the clogging of weirs or drainage structures. Eliminating excess litter is often necessary to restore the treatment capabilities of

the constructed wetland (Thullen et al., 2005). Any debris removed from the wetland should be hauled away and not piled on or along access roads.

If there is a large die-off of emergent vegetation or voids are created by dead vegetation, it may be necessary to replant or reseed certain areas of the wetland system. At least 50% of the constructed wetland area should have an established plant community on it (CASQA, 1997). For best survival and growth during the first growing season, the substrate for small stalks (2-5 cm) should only be saturated, not flooded, and as the plants grow the water level can be raised proportionally (Hammer, 1989). Excessive flooding kills most wetland plant seedlings (NRCS, 2002). Water level control is the most critical aspect of plant survival during the first year of growth. Plants can be replaced on an as needed basis, but an annual inventory of the plant community system should be conducted by a qualified wetland scientist to determine the overall health of the system and to identify potential areas of concern.

12.3.2 Major Sediment/Bottom Substrate Maintenance

Due to the high concentrations of TSS in the inflow waters, it is necessary to periodically remove the solids that settle out in the wetlands. The sediment forebays of these constructed wetlands are specifically designed to reduce the amount of TSS in the inflow water prior to it entering the treatment cells of the wetlands. Therefore, the sediment forebays require more frequent removal or dredging of sediment from them. Given estimated sediment accumulation rates of 7 - 10 cm/yr (Tetra Tech, 2006) and a forebay depth of 10 feet, an estimated 25% of the forebay volume would be filled in 8-11 years at the New and Alamo River wetlands. For the treatment cells, the estimated sediment accumulation rates are 0.4 – 0.5 cm/yr in the treatment cells (Tetra Tech, 2006). The amount of time it takes to fill the treatment cells will likely increase if the sediment forebays are properly maintained. An annual estimate of sediment accumulation in the wetland should be conducted to help determine appropriate maintenance needs.

Pollutant levels in the sediment should be monitored to help determine risks to wildlife. Although this has not occurred anywhere in the pilot wetlands over five years of operation, sediment may need to be removed from the wetland if it becomes too toxic to fish and other wildlife. At present it is proposed that wetland sediment sampling be conducted every two to three years to evaluate the buildup of potentially bioaccumulative and toxic substances. The results from these monitoring activities should be compared to established toxicity levels, discussed as part of the ecological risk assessment, to determine if unacceptable concentrations of pollutants exist in the sediment.

Dredging will be required to remove large amounts of sediment from the pilot wetlands. Due to the size of the sediment forebays in the wetlands, a different style or size of dredge may need to be used to remove sediment from them compared to the treatment cells. Mechanical dredging from shore or the use of a cable driven horizontal auger hydraulic dredge are examples of methods that may be used for removing sediment from the forebays. The cable driven horizontal auger dredge has been widely used for dredging industrial ponds and waste water treatment ponds. A smaller hydraulic dredge (6 to 10 in. diameter) capable of dredging in tight areas (surgical dredging) and causing less disturbances to the surrounding environment than larger dredges may be the best option for dredging the treatment cells in the wetlands. These small hydraulic dredges float on the water surface and do not require the wetland to be drained. Sediment being removed from the wetland should be sampled and tested for contaminants to determine if any special handling or disposal is required. All sediment removed should be disposed of in accordance with applicable laws and regulations.

Best Management Practices (BMPs) should be used to control water flow and sediment losses during sediment removal operations. These BMPs may include bypassing flows around the

removal zone, damming/detaining flows to isolate sediment within the sediment removal zone, filtering water leaving the zone, or other standard management practices (IRWD, 2005).

12.3.3 Berms and Embankments (Erosion Control)

During site visits in 2005 and 2006, it was observed that there were several areas in both wetlands where severe bank erosion is occurring. The main causes of erosion appear to be from muskrats or from wave action. The sediment forebays seem to be particularly susceptible to erosion from wave action. This is most apparent along the stretches of shore that are devoid of emergent vegetation. The emergent vegetation growing along the shoreline appears to protect it from being eroded by wave action. To prevent further erosion from occurring in certain areas, it may be necessary to replant the shoreline areas that are devoid of vegetation with bulrushes or other types of emergent vegetation found in the wetlands. It will also be necessary to repair or stabilize the areas in the wetlands where the most severe erosion has occurred. Some of these areas with severe erosion are along the access roads in the wetlands, and if preventative measures are not taken, then the roads may be washed out and access to certain parts of the wetlands would be limited.

Preventative measures to control bank erosion include planting vegetation in erosion prone areas, building erosion control structures, using fiber rolls for bank stabilization, and grading areas where erosion is occurring. Encouraging the growth of small shrubs, grass, and other herbaceous plants in erosion prone areas can help to reduce erosion through the soil binding properties of these plants root systems. Emergent aquatic plants can be used to stabilize bottom sediments and dampen wave action in certain areas (WDNR, 2004a). Fiber rolls are cylindrical tubes made of coconut fibers or excelsior fibers. These rolls are bound together with twine or plastic netting and placed along erosion prone areas. The fiber roll protects the bank by stabilizing the toe of the slope and trapping sediment from the sloughing bank (WDNR, 2004b).

Erosion control structures that can be put in place to control severe erosion include rip-rap (rocks of various sizes over erosion prone areas), bulkheads, gabions (rock-filled baskets), and railroad ties. It is important to note that the construction of some of these erosion control structures involve the use of heavy equipment and require some technical expertise and planning prior to implementation. Erosion control activities should be conducted in the wetlands as soon as possible to prevent further damage or sediment loading to the wetland from eroding banks.

12.3.4 Pump/Valve Replacement

Maintaining proper flow through a constructed wetland is an important factor for the overall performance of the wetland. Ensuring that the water pumps supplying inflow water to the wetland are functioning properly is a critical component to maintaining proper flows. The mechanical equipment used in constructed wetlands has expected useful lives of 1 to 50 years or more (IRWD, 2005). Based on this fact, at some point all of the equipment being used will need to be removed and replaced. This type of work usually involves the use of heavy equipment and a crew of 1 to 5 people (IRWD, 2005). This type of maintenance can be conducted on as needed basis. However, it is important to note that there may be times when such failures create an emergency situation, and it requires immediate attention to keep the wetlands functioning properly.

12.4 Emergency Operation and Maintenance Activities

In rare instances, there may be the need to perform operation and maintenance activities in order to protect people, property, or wildlife. Accidental spills of hazardous materials such as fuels or other hazard substances into the wetlands or floods from a catastrophic rupture are examples of occurrences that may create the need for an emergency response. If such events do occur, the appropriate regulatory agencies should be contacted immediately. The County or cities are typically responsible for hazardous waste clean up, but additional personnel may need to be there to assist or assess the extent of damage. In these emergency situations, all available man power and the necessary equipment to adequately respond to the situation should be made available.

12.5 Wildlife Monitoring and Identification of Sensitive Habitats

A qualified wildlife biologist should be utilized to identify any sensitive areas or species of special concern within the wetlands. Any Federally or State listed endangered or threatened species should be identified and special precautions should be taken during O&M activities to minimize any intrusions on their habitat. A log should be kept during O&M activities to note any sighting or signs of species of special concern in the wetlands. The wildlife biologist should also identify certain areas or times of the year when particular maintenance activities should be avoided to limit disturbances to native wildlife (i.e. during the waterfowl or shorebird nesting season). The wildlife biologist can also be used to assist with the identification of nuisance plant species within the wetlands and recommend the appropriate removal methods for these nuisance or invasive plant species.

12.6 Operation and Maintenance Checklist

Table 12-2 provides a summary checklist and recommended schedule for the routine and major maintenance activities to be conducted in the New and Alamo River wetlands. Details on each of these maintenance activities have been provided in the previous sections of this chapter.

Table 12-2
Checklist for operation and maintenance activities in the pilot wetlands.

Routine O&M Activities	Suggested Frequency
Site inspection	Weekly (once it has been established that wetlands are functioning properly the timeframe can be scaled down)
Inlet, outlet, and weir inspection	Check during site inspection (report malfunctions or damage immediately); remove debris and trash from flow structures at least 3 to 4 times per year
Water level control	Check during site inspection (make adjustments as necessary)
Water quality sampling	Test the field parameters during site inspections; collect additional samples based on monitoring plan on a quarterly basis
Trash and debris removal	Remove small debris during site inspection; larger debris removed on an as needed basis
Mow/trim vegetation on berms, embankments, and along access roads	4 times per year
Minor sediment removal	Check sediment prone areas 3 to 4 times per year and remove when necessary
Nuisance wildlife	Inspect 3 to 4 times a year for wildlife related damage; remove nuisance wildlife when necessary
Insect control	Check with dip net for presence of larvae during site inspection (initiate management activities when necessary)
Restock wetlands with mosquitofish to control mosquito production	As needed maintenance
Pump/Valve inspection and cleaning	Check during site inspection (note any malfunctions); full inspection and cleaning on an annual basis
Major O&M Activities	
Remove undesirable weed or wetland plant species	Annual maintenance
Harvest or thin wetland plant species if they become too thick or are eliminating the desired amount of open-water areas	Annual maintenance (may not be required every year)
Removal of floating or woody debris from wetland system and inlet/outlet structures	3 to 4 times per year
Replace wetland vegetation to maintain healthy cover	As needed maintenance (infrequent)
Dredge sediment from forebay to avoid excess sediment from entering the treatment basin	Every 8-11 years or when 25% of forebay volume is filled with sediment
Dredge sediment from treatment basin in wetland	When accumulated sediment volume exceeds 10-20% of the volume in the treatment basin
Check for erosion along banks and access roads	Annual inspection (repair as needed)
Pump/valve replacement	As needed basis

CHAPTER 13
SUMMARY AND CONCLUSIONS

The New and Alamo River Wetlands Master Plan provides a variety of analyses to support decision-making on the construction and overall effectiveness of a network of water quality treatment wetlands. The work involved review of existing data on contaminant concentrations and flow, field collection of new data, development of a model to represent the functioning of an integrated river-wetland system in the Imperial Valley, the evaluation of potential risks due to accumulating toxins, and cost estimation for comparison with other treatment approaches, specifically, the construction of a chemical treatment plant to improve water quality. Key findings of each of these aspects of the Master Plan are summarized below.

Historical water quality and flow data in the New and Alamo Rivers and in the drains were collected from a variety of sources including state and federal government agencies, international agencies, and universities. Data were available from more than 30 river locations and from 45 drain locations on parameters such as nutrients, coliforms, suspended sediments, and selenium. A repository for all of the data collected was developed and is included as electronic appendices to this report. In addition to supporting the Master Plan, this repository should help to simplify future endeavors focusing on the water quality characteristics of the New and Alamo Rivers.

Following the historical data compilation, a synoptic survey of water quality throughout the Imperial Valley was performed. Data were collected for all parameters of interest in the master plan: nitrogen and phosphorus species, selenium species, coliforms, and suspended sediments. Data were collected from 47 river, drain, and sump locations, and from 15 locations within the pilot wetlands. These data, in conjunction with the historical data, defined current water quality conditions against which the performance of wetlands may be assessed. In addition to the water quality data collection, tissue concentrations of selected toxins (selenium and organochlorine pesticides) were collected in the wetlands, the drains, and rivers. These data formed the basis of the modeling and the ecological risk assessment.

A model of flows and chemical concentrations was developed for the Alamo and New River systems. Following calibration of the watershed model to data, base case conditions for flows and loads were developed. These numbers provided the baseline against which the performance of the wetland treatment system was evaluated.

The composite watershed/wetland model evaluated the performance of the 35 top-ranked wetland sites identified in the reconnaissance inventory (Nolte, 2002) proposed for the New and Alamo Rivers under a variety of different water flow, chemical load, and wetland design conditions. The model results show the potential for significant reductions in loadings with the construction of the 35 wetlands covering 4,276 acres. The total phosphorus load reduction to the Salton Sea is in the range of 31 to 37 percent from base case conditions. The total nitrogen, TSS, and total coliform load reductions are estimated at 22, 37, and 71 percent from base case conditions. Total selenium load reductions range between 2 and 11 percent.

There are much higher removal rates in the New River than the Alamo River. This is primarily due to the higher wetland treatment area and flow in the New River than the Alamo River. The chemical concentrations in the rivers and drains in each watershed also influence removal rates. For example, the higher total phosphorus removal rate for the New River wetlands is attributed to the higher total phosphorus concentrations in the New River, especially in the more southerly reaches of the New River near the U.S.-Mexico border. The New River wetlands have higher area-specific removal rates for total phosphorus, while the Alamo River wetlands have higher area specific removal rates for total nitrogen, selenium, and TSS.

The model evaluated optimal wetland system design by determining which wetlands of the Top 35 ranked wetland sites provided the most total phosphorus removals. This may be used to identify which wetlands should be constructed first, or to screen out wetland sites that do not provide significant nutrient reductions to the overall New and Alamo River system. Two methods were used, one based on optimizing the maximum total phosphorus removal and one based on optimizing the maximum area-specific removal rates.

Based on the evaluation, several conclusions can be made. Design of a wetland system that prioritizes wetland selection based on an area-specific removal rate will achieve a higher loading reduction for the same total wetland acreage (and thus cost). For instance, a 10 wetland scenario based on maximizing area-specific removal rates (see Table 9-6) achieves the same total phosphorus loading reduction of 17 percent as the Top 5 wetland scenario based on maximizing the area-specific removal rates, with 32 percent less total wetland acreage. The maximum removal rates are generally correlated to the larger design inflows (which are correlated to wetland area). The top performing wetlands for the maximum area-specific removal rates are correlated to the maximum inflow concentrations. The New River wetlands can achieve much greater reductions in the total phosphorus load than the Alamo River wetlands for the same wetland area size. This is attributed to the higher overall total phosphorus concentrations in the New River and its' drains. Thus, an optimum wetland system for both rivers would place more wetlands along the New River to take advantage of the higher removal efficiencies for the New River.

The total phosphorus load reduction becomes more inefficient with the addition of more wetlands. The lesser performing wetlands contribute only a small incremental benefit to the overall system performance. Almost half of the 35 wetlands have an incremental benefit that is equal to or less than one percent of the overall system total phosphorus removals. Increasing the size of the Top 35 wetlands increases the load reduction, but at the cost of significantly larger wetland areas. This is due to several factors. First, approximately 20 percent of the total phosphorous load enters the New and Alamo Rivers downstream of the proposed wetland sites. Second, as more wetlands are added, the lower the influent concentrations to downstream wetlands and thus lower removal efficiencies are achieved.

The model evaluated the addition of a wetland in the northern reaches of each of the New and Alamo Rivers, where no treatment wetlands are currently proposed. The modeling for the

combined river system demonstrated that by increasing the wetland acreage by only 7 percent, the total phosphorus removals can be increased by up to 10 percent. For instance, the addition of a 143 acre wetland in each northern reach can increase total phosphorus removals from 35 percent with 35 wetlands to 38 percent with 37 wetlands. If wetland sites can be identified, there is significant benefit to adding wetlands in the northern reaches.

Several potential future changes were evaluated with the composite watershed/wetland model. If the cross-border flows to the New River are eliminated due to treatment and reuse of water sources in Mexico, the total phosphorus loads would be reduced by 26 percent to 1 million kg/yr. If the flows are eliminated and the Top 35 wetlands constructed, the total phosphorus loads would be reduced by 46 percent to 0.76 million kg/yr. As part of the Quantification Settlement Agreement (QSA), the IID must conserve roughly 200,000 AF/yr, or 20 percent of the flow to the Salton Sea. If flows to agricultural drains are reduced by 20 percent, total phosphorus loads remain constant, and the wetlands are constructed, the model predicts that the total phosphorus load into the Salton Sea will decrease to 846,000 kg/yr, which is a 40 percent load reduction. The most recent IID study identified 25 potential wetland sites with a total wetland area of 2,493 acres by feasibility studies and topographic surveys (Davey-Cairo Engineers, 2005a,b, 2006a,b). These are a subset of IID's Top 35 ranked wetland sites from the reconnaissance survey (Nolte, 2002). With the 25 wetland sites, the combined rivers total phosphorus load to the Salton Sea would be 1.1 million kg/yr, which is a 25 percent load reduction. In comparison, the initial Top 35 wetland scenario would lead to a 35 percent load reduction.

An ongoing concern regarding the use of wetlands to enhance water quality in the region is that they may result in the bioaccumulation of toxic constituents in biota. An ecological risk assessment was performed as part of the Master Plan to evaluate the potential for adverse ecological effects to receptors that may be exposed to selenium and organochlorine pesticides in the Brawley and Imperial Pilot Wetlands. The receptors evaluated included in this assessment included: emergent plants, benthic invertebrates, aquatic biota (i.e., algae and aquatic plants, aquatic invertebrates, fish, and amphibians), aquatic and terrestrial birds (i.e., least sandpiper, black-necked stilt, pied-billed grebe, American coot, double-breasted cormorant, and red-winged blackbird); piscivorous mammals (i.e., raccoon). In addition to estimating risks for ecological receptors at the pilot wetlands, risks were also estimated for the same receptors for three different types of local background conditions; i.e., agricultural drains in the Imperial Valley, in the New and Alamo Rivers, and at the Salton Sea.

The risk assessment approach computes the dietary intake of a contaminant and compares this against safe or toxic levels of intake. This information is normally presented as a ratio of the estimated intake and the safe or toxic level, and is called the hazard quotient. By summing hazard quotients over multiple contaminants, a hazard index is computed. Hazard indices for different species were used to compare the relative risks to different background sites. For the wetlands, potential exposures to selenium and 4,4'-DDE may result in low levels of risk to benthic invertebrates, birds, and raccoons. However, the risk estimates are based on highly conservative assumptions regarding calculated exposures and regarding the level of a chemical that would be likely to cause adverse effects. Most importantly, the estimated risks from potential exposures to selenium and organochlorine pesticides by ecological receptors in the agricultural drains, New and Alamo Rivers, and Salton Sea were all much higher than at the treatment wetlands.

This report has shown that treatment wetlands, while they may pose some minimal level of risk to ecological receptors, represent better habitat than the agricultural drains, New and Alamo Rivers, and the Salton Sea. Elevated levels of suspended sediments makes the rivers generally poor habitat. For instance, during the field studies crayfish were not found in the

rivers and fish of all kinds were much less abundant in the rivers than in the treatment wetlands or agricultural drains. This is especially true in the southern stretches of the New River, where the dissolved oxygen was extremely low and no aquatic biota were observed during sampling. Therefore, the construction of treatment wetlands can be regarded as improving the habitat for wildlife in this area. Habitat improvements like this should be regarded as vital, since the Salton Sea is on the Pacific Flyway and the available resting locations for migratory birds on the Pacific Flyway has dwindled to the point that the Salton Sea is one of the last remaining stop-overs in the southern United States.

The Master Plan includes an estimate of the costs of wetlands compared to a chemical treatment plant. Because of the site specific data on the construction of the pilot wetlands on the New River, there are fairly good estimates of the cost of construction of treatment wetlands, which are estimated to cost approximately $183 million for the construction of the 35 proposed wetlands, achieving about 35% phosphorous reduction. In the absence of pilot study data, there are considerable uncertainties regarding the design and cost of a chemical treatment plant. Using various assumptions regarding the design, preliminary calculations show that a complete system, with coagulation and filtration, can cost upwards of $350 million for a 49% phosphorous reduction. The costs are substantially lower (about $200 million) for a chemical treatment plant without filtration, as was proposed in similar cost estimation in the Florida Everglades. These costs are based on greater treatment levels than is achievable with wetlands, and the chemical treatment plant option must be considered for exploration only if wetlands cannot be constructed or if the greater water quality improvement is desired. The most significant difference is the substantially lower operation and maintenance costs of the wetlands, because of which, the 50-year capitalized present worth of the wetland network is approximately $250 million, which is about a quarter to a third of the chemical treatment plant with or without filtration ($990 or 710 million). Besides the differences in overall costs, wetlands also have the significant advantage that they can constructed gradually over an extended period of time, with partial benefits being derived.

Given the objective of water quality improvement in the New and Alamo Rivers and the need for reducing nutrient loads to the Salton Sea, the technical analyses prepared in this Master Plan are supportive of the construction of wetlands. As summarized above and discussed in details in the preceding chapters, the reasons for this finding include the estimation of substantial pollutant load removal, ease of maintenance and construction, relatively lower cost, and the ability to spread this cost over an extended period of time, and generally lower risks to wildlife than other habitats in the Imperial Valley, including the drains, rivers, and the Salton Sea.

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