LOWER ARKANSAS BASIN TOTAL MAXIMUM DAILY LOAD

Waterbody: Quivira Little Salt Marsh and Quivira Big Salt Marsh
Water Quality Impairment: Siltation bundled with Eutrophication
Revision to Eutrophication TMDLs originally approved September 11, 2000

1. INTRODUCTION AND PROBLEM IDENTIFICATION

Subbasin: Rattlesnake

Counties: Clark, Ford, Kiowa, Edwards, Pratt, Stafford, Pawnee, Reno and Rice

HUC 8: 11030009
HUC 10 (12): 01 (01, 02, 03, 04, 05, 06, 07)
02 (01, 02, 03, 04, 05, 06, 07)
03 (01, 02, 03, 04, 05, 06, 07, 08)
04 (01, 02, 03, 04, 05)

Ecoregion: Central Great Plains, Great Bend Sand Prairie (27c)
Central Great Plains, Rolling Plains and Breaks (27b)

Drainage Area: Quivira Little: 1,084 square miles
Quivira Big: 103 square miles

Conservation Pool: **Quivira Little:**
Surface Area = 704 acres
Watershed/Lake Ratio: 985:1
Maximum Depth = 1.0 meters
Mean Depth = 0.1 meters
Annual Mean Precipitation = 24.1 inches
Annual Mean Evaporation = 62.4 inches
Storage Volume = 231 acre-feet
Estimated Retention Time = 0.02 years
Mean Annual Discharge = 42,076 acre-feet/year
Quivira Big:
Surface Area = 388 acres
Watershed/Lake Ratio: 170:1
Maximum Depth = 1.0 meters
Mean Depth = 0.1 meters
Annual Mean Precipitation = 24.1 inches
Annual Mean Evaporation = 62.4 inches
Storage Volume = 127 acre-feet
Estimated Retention Time = N/A
Mean Annual Discharge = N/A

Designated Uses: Primary Contact Recreation Class B; Special Aquatic Life Support;

Food Procurement; Ground Water Recharge; Industrial Water Supply; Irrigation Use; Livestock Watering Use.

303(d) Listngs: Quivira Little Salt Marsh, Lower Arkansas River Basin Lakes:
Siltation & Eutrophication: 2004, 2008, 2010, 2012
Quivira Big Salt Marsh, Lower Arkansas River Basin Lakes:
Siltation & Eutrophication: 2002, 2004, 2008, 2010, 2012

Impaired Use: All uses are impaired to a degree by eutrophication and siltation

Water Quality Criteria: Suspended Solids – Narrative: Suspended solids added to surface waters by artificial sources shall not interfere with the behavior, reproduction, physical habitat or other factors related to the survival and propagation of aquatic or semi-aquatic or terrestrial wildlife (K.A.R. 28-16-28e(d)(2)(B)).

Nutrients – Narrative: The introduction of plant nutrients into streams, lakes, or wetlands from artificial sources shall be controlled to prevent the accelerated succession or replacement of aquatic biota or the production of undesirable quantities or kinds of aquatic life (KAR 28-16-28e(c)(2)(A)).
The introduction of plant nutrients into surface waters designated for primary or secondary contact recreational use shall be controlled to prevent the development of objectionable concentrations of algae or algal by-products or nuisance growths of submersed, floating, or emergent aquatic vegetation (KAR 28-16-28e(c)(7)(A)).

2. CURRENT WATER QUALITY CONDITION AND DESIRED ENDPOINT

Level of Eutrophication: Quivira Little: Hypereutrophic, Trophic State Index = 75.1
Quivira Big: Hypereutrophic, Trophic State Index = 75.3

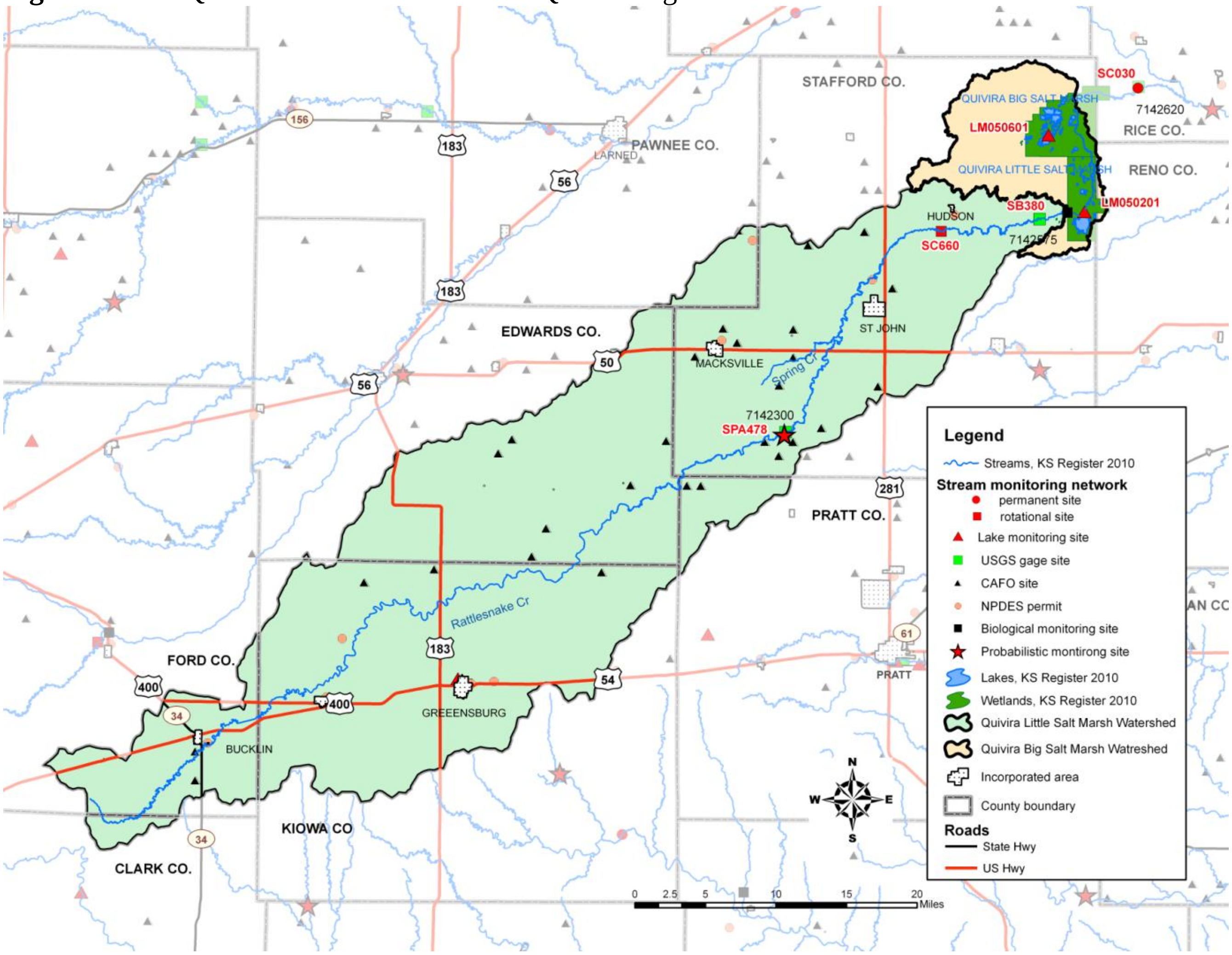
The Trophic State Index (TSI) is derived from the chlorophyll *a* concentration. Trophic state assessments of potential algal productivity were made based on chlorophyll *a*, nutrient levels, and values of the Carlson Trophic State Index (TSI). Generally, some degree of eutrophic conditions is seen with chlorophyll *a* over 12 µg/L and hypereutrophy occurs at levels over 30 µg/L. The Carlson TSI derives from the chlorophyll *a* concentrations and scales the trophic state as follows:

1. Oligotrophic TSI < 40
2. Mesotrophic TSI: 40 - 49.99
3. Slightly Eutrophic TSI: 50 - 54.99
4. Fully Eutrophic TSI: 55 - 59.99
5. Very Eutrophic TSI: 60 - 63.99
6. Hypereutrophic TSI: $\geq$ 64

Level of Siltation Impairment: Quivira Little Salt Marsh and Quivira Big Salt Marsh have high turbidity and high levels of siltation. During moderate to high inflow events siltation is aggravated when sediment is transported into the marsh by Rattlesnake Creek. In addition, there is a significant contribution to the siltation impairment from the degradation of the abundant macrophyte population and algal communities in the marshes.

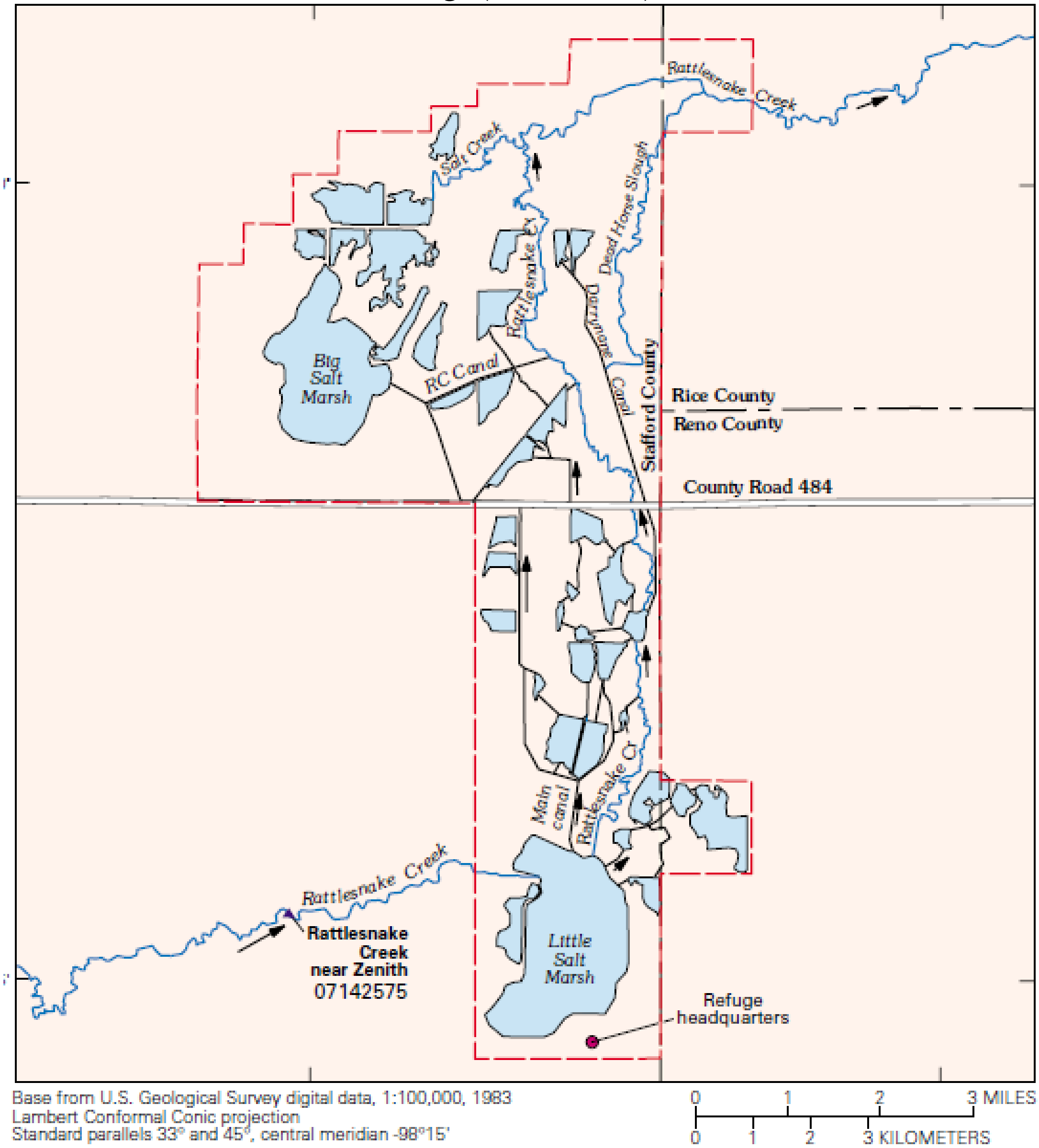
Lake Monitoring Sites:	KDHE Station LM050201 at Quivira Little Salt Marsh (Figure 1). KDHE Station LM050601 at Quivira Big Salt Marsh (Figure 1). Periods of Record: Ten surveys conducted by KDHE in the summers of calendar years 1988, 1991, 1994, 1997, 1998, 1999, 2000, 2003, 2006 and 2009.
Stream Chemistry Sites:	KDHE Rotational Station SC660 on Rattlesnake Creek above Quivira Little Salt Marsh. Period of Record: Bi-monthly sampling during calendar years 1992, 1996, 2000, 2004 and 2008. KDHE Permanent Station SC030 on Rattlesnake Creek below Quivira Big Salt Marsh. Period of Record: Bi-monthly sampling during calendar years 1975 through 2010.
Flow Record:	USGS Gage 07142575: Rattlesnake Creek near Zenith, KS, above Quivira Little Salt Marsh. Period of Record: January 1, 1975 through December 31, 2010. USGS Gage 07142620: Rattlesnake Creek near Raymond, KS, below Quivira Big Salt Marsh. Period of Record: January 1, 1975 through September 30, 1998.

Figure 1. The Quivira Little Salt Marsh and Quivira Big Salt Marsh watershed.



Hydrologic Conditions: The Quivira National Wildlife Refuge (QNWR) lies near the downstream end of Rattlesnake Creek which drains about 709 mi^2 before it enters the refuge and flows directly into the Quivira Little Salt Marsh located in the southern part of QNWR. Rattlesnake Creek continues to flow through the marsh where canals and ponds have been constructed to provide the entire marsh with dependable surface-water supply (Figure 2). North of Quivira Big Salt Marsh, Rattlesnake Creek joins with Salt Creek before flowing out of the northeastern corner of QWNR and on to its confluence with the Arkansas River about 10 miles downstream in Rice County. Additionally, substantial quantities of water are supplied by natural ground-water seepage in the northern part of the refuge near Quivira Big Salt marsh (USGS, 2001). In 1996 the U.S. Geological Survey developed a computer-based water-budget and flow-routing model to assist the U.S. Fish and Wildlife Service in managing flow conditions in QNWR. Using the model to simulate the 1996 operating conditions in QNWR results in an average estimated inflow of 7.25 cfs to Quivira Big Salt Marsh with approximately 45% of the inflow arriving via the canal system and 55% of the inflow arriving from the Quivira Big watershed (USGS, 1998).

Figure 2. Quivira National Wildlife Refuge (USGS, 2001).



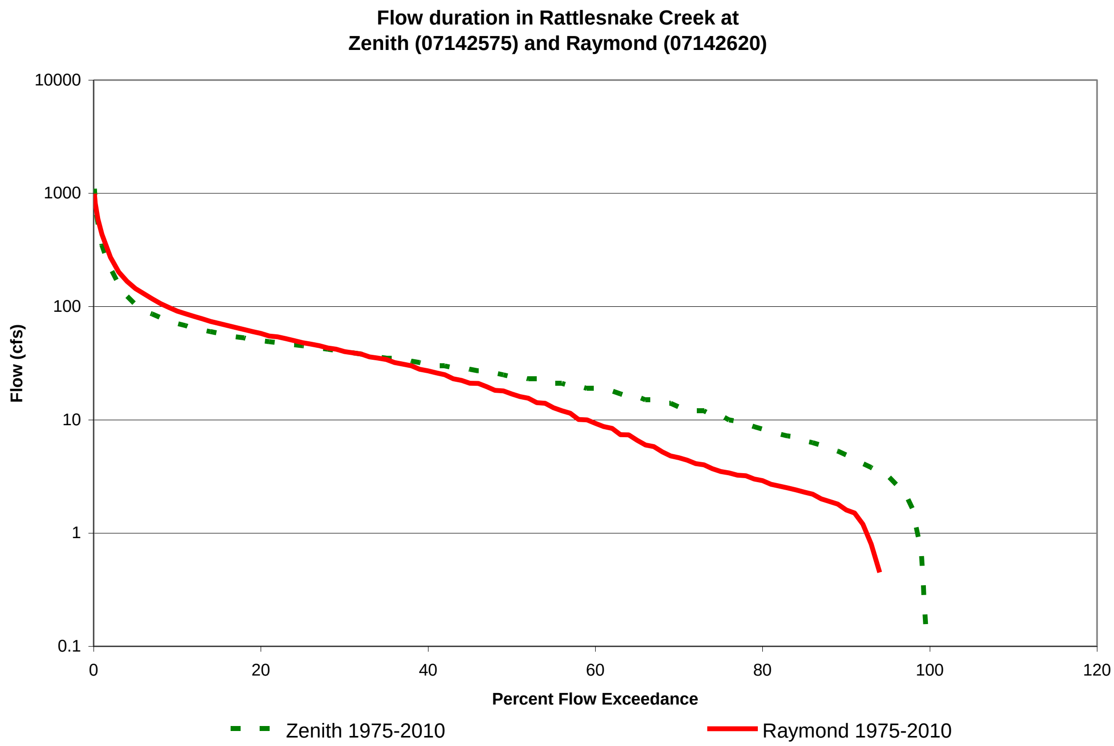
Rattlesnake Creek is a gaining stream and just prior to entering QNWR it has an average flow of 42.9 cfs. Due to its altered course, evapotranspiration and ground water infiltration, flow is dampened as the creek travels through the marsh resulting in an average flow of 41.8 cfs on Rattlesnake Creek below QNWR (Table 1).

Table 1. Flow conditions (cfs) for Rattlesnake Creek above Quivira Little Salt Marsh and below Quivira Big Salt Marsh for the period of record.

Location	Mean Flow	90%	75%	50%	25%	10%
Rattlesnake Creek near Zenith USGS 07142575 (Above Quivira Little Salt Marsh)	42.9	4.9	11.0	24.0	45.0	71.0
Rattlesnake Creek near Raymond USGS 07142620 (Below Quivira Big Salt Marsh)	41.8	1.6	3.5	16.9	48.0	91.0

Figure 3 displays the decline in the flow of Rattlesnake Creek below QNWR when the creek is at base and low flow and the marsh is functioning effectively. Under high flow conditions, however, flow out of QNWR outpaces that of flow into the marsh indicating the marsh may undergo flushing during high flow events.

Figure 3. Flow Duration curves for Rattlesnake Creek at USGS 07142575 and USGS 07142620 for the period of record.



Annual average inflow for QNWR is variable and is reflective of rainfall totals in the respective years (Table 2). Annual average discharge is generally lower than the average inflow and is characteristic of the level of evapotranspiration and ground water infiltration occurring in the marsh. Years where the average discharge is higher than average inflow possibly reflects periods where seepage into the marsh increased due to higher than normal ground water levels or where the water level in the marsh was manually lowered by pumping.

Table 2. Average annual inflow and discharge to QNWR based on streamflow measurements at USGS gage 07142575, Rattlesnake Creek near Zenith above QNWR and USGS gage 0714620, Rattlesnake Creek near Raymond below QNWR. Flow measurements at USGS gage 0714620 ceased in October, 1998 thus average discharge for 1998-2009 were estimated by regression analysis with USGS gage 07142575 flow.

Year	Average Annual Inflow Acre-Feet	Average Annual Discharge Acre-Feet	Annual Precipitation Total at Hudson, KS Inches
1988	16,796	13,031	15.0
1989	13,325	9,670	22.5
1990	13,853	17,045	31.1
1991	4,220	1,798	15.2
1992	9,177	6,729	31.5
1993	138,984	91,339	38.7
1994	14,749	17,660	17.0
1995	42,098	51,802	32.0
1996	31,929	27,261	26.5
1997	36,444	37,013	32.6
1998	41,878	55,186	28.0
1999	36,589	40,885	29.8
2000	34,989	38,947	29.9
2001	28,423	30,364	25.4
2002	10,953	8,043	30.1
2003	11,359	9,101	24.3
2004	10,566	7,095	33.4
2005	13,117	10,657	28.8
2006	7,073	3,526	27.1
2007	66,937	72,811	42.4
2008	36,130	40,363	33.8
2009	50,895	57,628	25.9
Average	**30,477**	**29,452**	**28.2**

Current Conditions: Designated as an Outstanding National Resource Water, Quivira National Wildlife Refuge (QNWR) is managed by the U.S. Fish and Wildlife Service and in 2002 was designated as a wetland of international importance with its listing as a Ramsar Site. The Quivira Little Salt Marsh and Quivira Big Salt Marsh were sampled once during the summers of 1988, 1991, 1994, 1997, 1998, 1999, 2000, 2003, 2006 and 2009 resulting in an average total suspended solids (TSS) concentration of 92.6 mg/L in the Quivira Little Salt Marsh and an average TSS concentration of 136 mg/L in the Quivira Big Salt Marsh. TSS concentrations in Quivira Little ranged from 57.5 mg/L in 2003 to 167 mg/L in 2000 while TSS concentrations in Quivira Big ranged from 15.5 mg/L in 1991 to 238 mg/L in 2000 (Figure 4). Chlorophyll *a* concentrations in Quivira Little and Quivira Big average 110 µg/L and 158 µg/L, respectively (Figure 5). Total phosphorus in Quivira Little ranged from 320 µg/L in 1991 to 155 µg/L in 1994 and 2003 resulting in average concentration of 232 µg/L for the period of record (Table 3). Total phosphorus concentrations in Quivira Big average 310 µg/L for the period of record with a high value of 560 µg/L occurring in 2006 and the low concentration of 90 µg/L recorded in 2003 (Figure 6). Figure 7 shows total nitrogen concentrations average 3.91 mg/L and 3.98 mg/L in Quivira Little and Quivira Big, respectively, with a high concentration of 7.14 mg/L occurring in 1999 in Little Quivira and a high concentration of 9.38 mg/L occurring n 2006 in Quivira Big (Table 4). Turbidity values in Quivira Little averaged 44.1 NTU while Quivira Big averaged 69.2 NTU for the period of record (Figure 8). According to the USGS Lake Hydro data, both the Quivira Little and Quivira Big Salt Marsh have a maximum depth of 1.0 meter and a mean depth of 0.1 meter with KDHE sampling resulting in an average secchi depth of 0.2 meters, in both marshes, for the period of record. While the Quivira Big Salt Marsh does receive some inflow from Rattlesnake Creek via canals in QNWR, the average TSS, turbidity and Chlorophyll *a* concentrations are likely lower in the Quivira Little Salt Marsh due to the direct inflow from Rattlesnake Creek.

Figure 4. TSS concentrations in Quivira Little (LM050201) and Quivira Big (LM050601) Salt Marsh by sampling date.

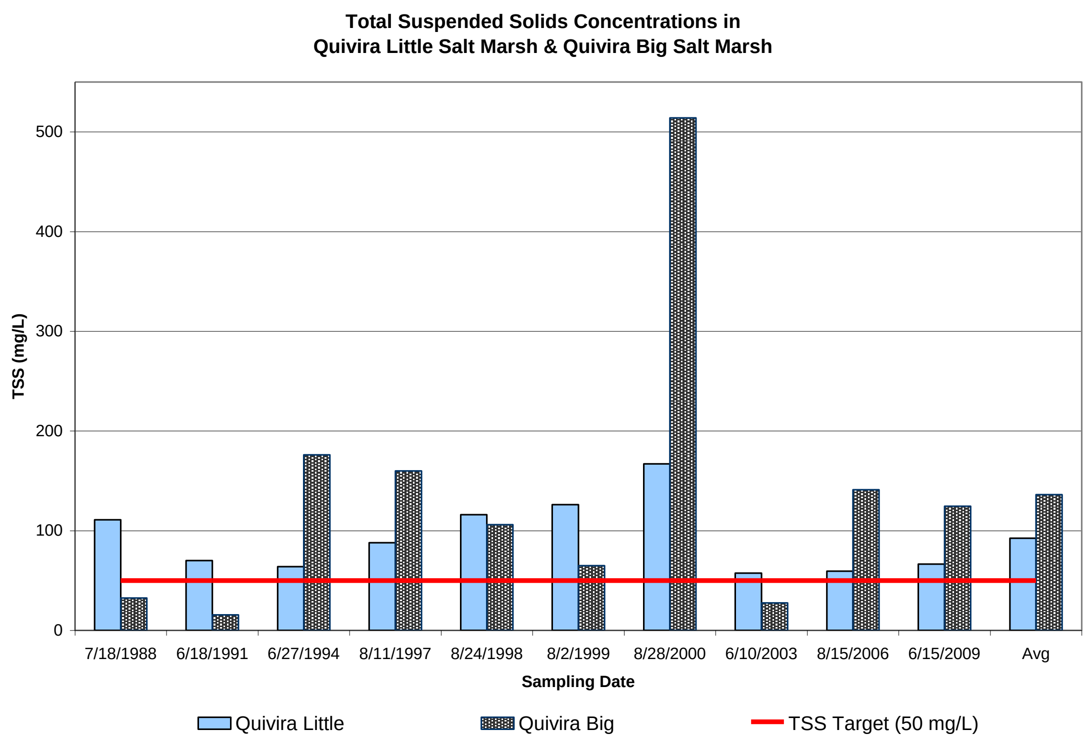


Figure 5. Chlorophyll *a* concentrations in Quivira Little (LM050201) and Quivira Big (LM050601) Salt Marsh by sampling date.

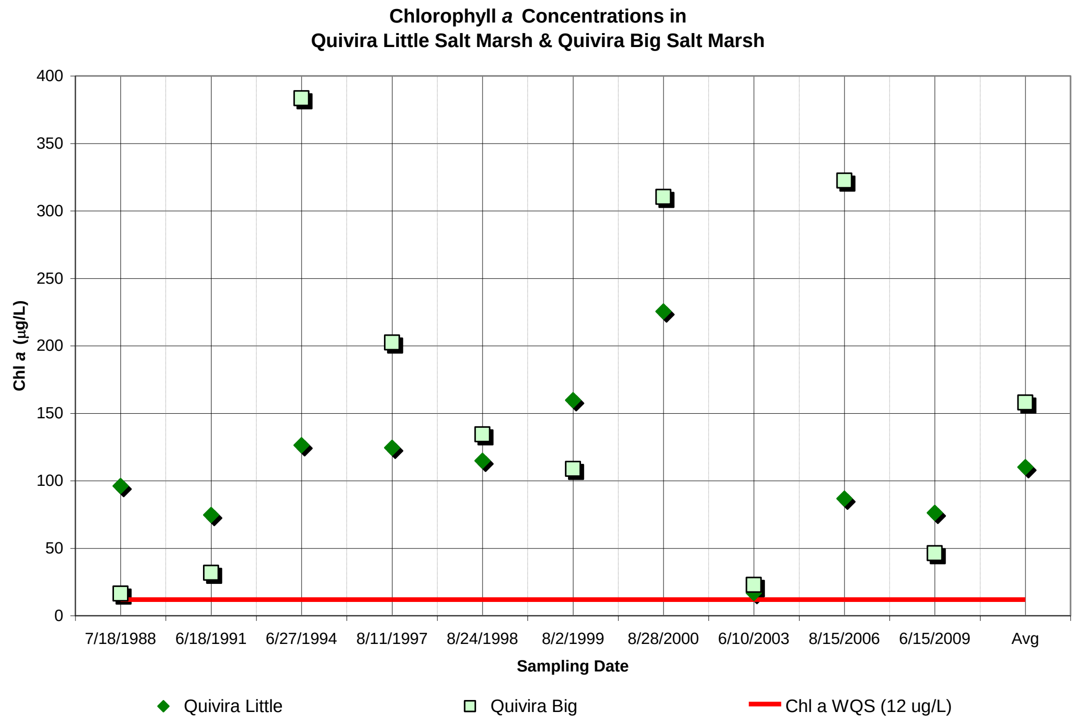


Figure 6. Total Phosphorus (TP) concentrations in Quivira Little (LM050201) and Quivira Big (LM050601) Salt Marsh by sampling date.

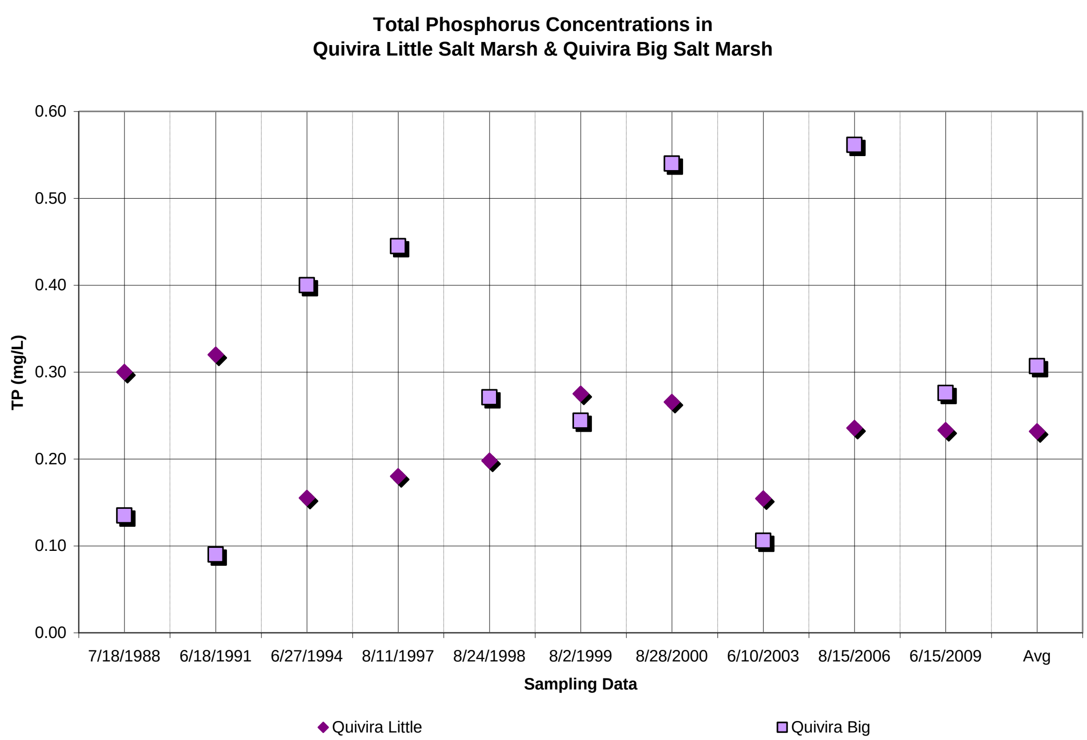


Figure 7. Total Nitrogen (TN) concentrations in Quivira Little (LM050201) and Quivira Big (LM050601) Salt Marsh by sampling date. Sample data was not available for the 7/18/88 & 6/24/94 sampling dates.

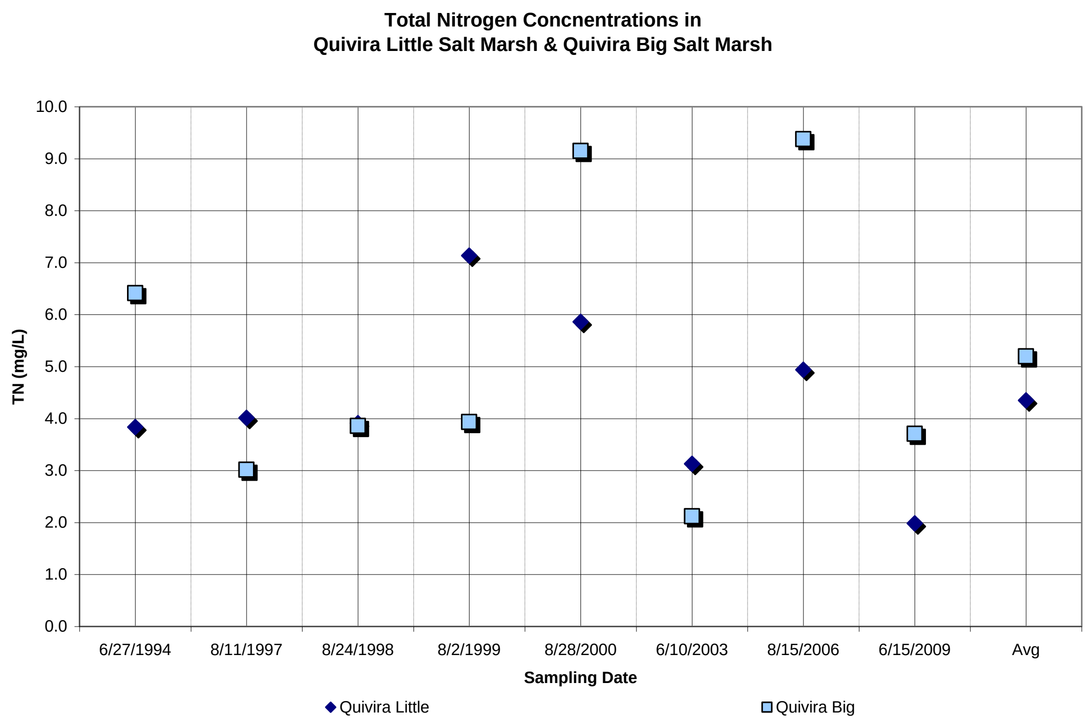


Figure 8. Turbidity values in Quivira Little (LM050201) and Quivira Big (LM050601) Salt Marsh by sampling date.

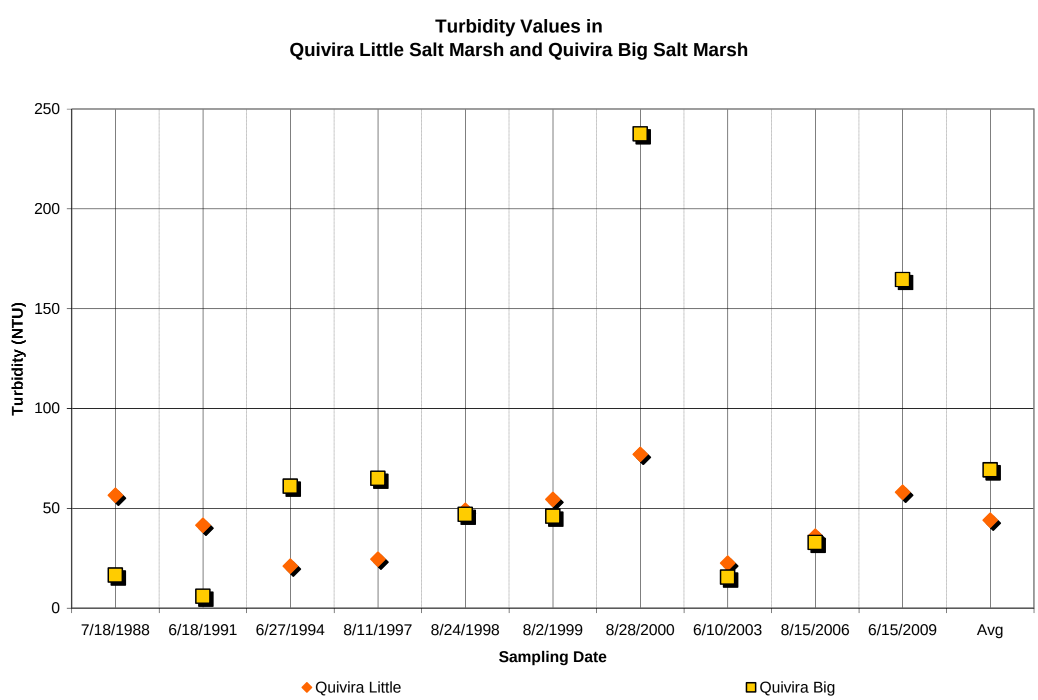


Table 3. Water quality data for Quivira Little Salt Marsh at LM050201. Flow values are sampling date daily averages at USGS gage 07142575, Rattlesnake Creek near Zenith, above QNWR.

Quivira Little Salt Marsh Water Quality							
Sampling Date	**TSS (mg/L)**	**Chl *a* (mg/L)**	**Total Nitrogen (mg/L)**	**Total Phosphorus (mg/L)**	**Turbidity (NTU)**	**Secchi Depth (m)**	**Flow (cfs)**
7/18/1988	111	96.2	No Data	0.30	56.5	No Data	7.8
6/18/1991	70.0	74.7	No Data	0.32	41.5	0.20	5.8
6/27/1994	64.0	126	3.84	0.16	21.0	No Data	6.2
8/11/1997	88.0	124	4.01	0.18	24.5	0.25	38
8/24/1998	116	115	3.91	0.20	49.0	0.19	7.1
8/02/1999	126	160	7.14	0.28	54.5	0.15	22
8/28/2000	167	225	5.86	0.27	77.0	0.10	8.5
6/10/2003	57.5	16.8	3.13	0.15	22.5	0.34	15
8/15/2006	59.5	86.8	4.94	0.24	36.1	0.33	6.1
6/15/2009	66.5	76.3	1.98	0.23	58.0	0.34	135
Median	*79.0*	*100*	*3.91*	*0.236*	*49.0*	*0.20*	*N/A*
Average	*92.6*	*110*	*4.35*	*0.230*	*44.1*	*0.20*	*N/A*

Table 4. Water quality data for Quivira Big Salt Marsh at LM050601. Flow values are sampling date daily averages at USGS gage 07142575, Rattlesnake Creek near Zenith, above QNWR.

Quivira Big Salt Marsh Water Quality							
Sampling Date	**TSS (mg/L)**	**Chl *a* (mg/L)**	**Total Nitrogen (mg/L)**	**Total Phosphorus (mg/L)**	**Turbidity (NTU)**	**Secchi Depth (m)**	**Flow (cfs)**
7/18/1988	32.5	16.4	No Data	0.14	56.5	No Data	7.8
6/18/1991	15.5	31.8	No Data	0.09	41.5	0.20	5.8
6/27/1994	176	383	6.42	0.40	21.0	No Data	6.2
8/11/1997	160	203	3.02	0.45	24.5	0.25	38
8/24/1998	106	134	3.86	0.27	49.0	0.19	7.1
8/02/1999	65.0	109	3.94	0.24	54.5	0.15	22
8/28/2000	514	310	9.15	0.54	77.0	0.10	8.5
6/10/2003	27.5	22.9	2.12	0.11	22.5	0.34	15
8/15/2006	141	322	9.38	0.56	36.1	0.33	6.1
6/15/2009	125	46.3	3.71	0.28	58.0	0.34	135
Median	*125*	*123*	*3.98*	*0.280*	*46.5*	*0.19*	*N/A*
Average	*136*	*158*	*5.20*	*0.310*	*69.2*	*0.21*	*N/A*

The ratio of total nitrogen and total phosphorus has been used to determine which of these nutrients is most likely limiting plant growth in Kansas aquatic ecosystems. Generally, lakes that are nitrogen limited have water column TN:TP ratios < 8 (mass); lakes that are co-limited by nitrogen and phosphorus have water column TN:TP ratios between 9 and 21; and lakes that are phosphorus limited have water column TN:TP ratios > 29 (Dzialowski et al., 2005). The TN:TP ratios in Quivira Little and Quivira Big indicate the marshes are primarily nitrogen/phosphorus co-limited. The higher ratio evident in Quivira Little indicates the marsh may be moving toward phosphorus limitation (Figure 9).

Figure 9. TN:TP Ratio in Quivira Little (LM050201) and Quivira Big (LM050601) Salt Marsh by sampling date. Sample data was not available for the 7/18/88 & 6/24/94 sampling dates.

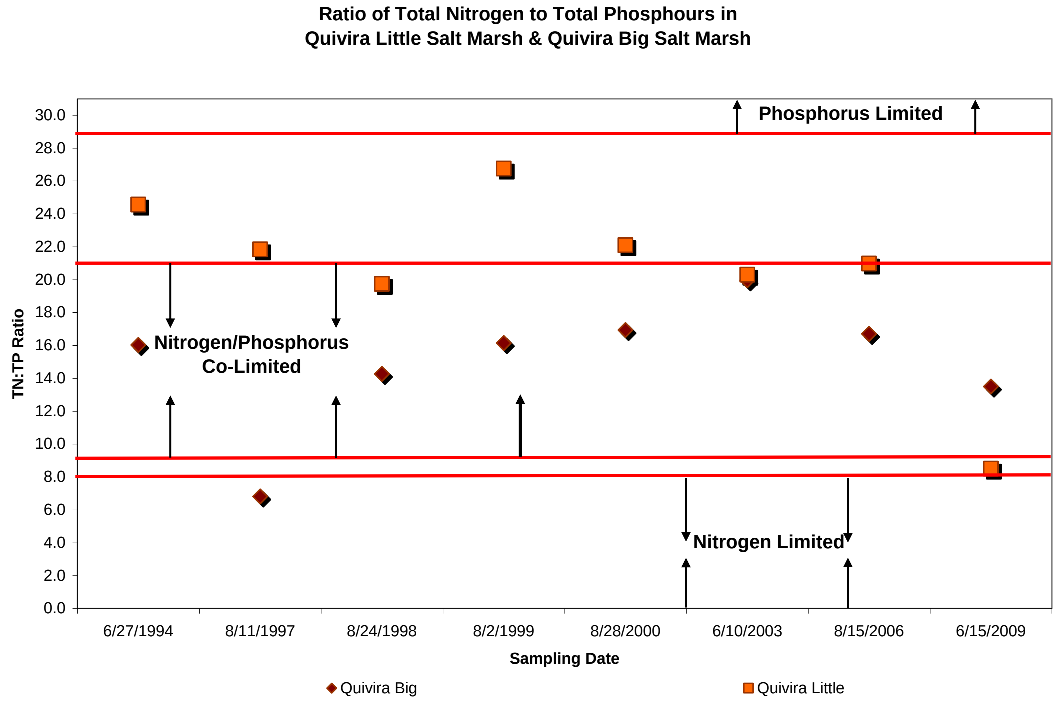


Table 5 and 6 list the six metrics measuring the roles of light and nutrients in Quivira Little and Quivira Big Salt Marsh. Non-algal turbidity (NAT) uses chlorophyll *a* and Secchi depth values to estimate the degree of non-chlorophyll light attenuation and was calculated using the formula developed by Jones and Hubbart (Jones and Hubbart, 2011). NAT values $<0.4 m^{-1}$ indicates there are very low levels of suspended silt and/or clay. The values between 0.4 and $1.0 m^{-1}$ indicate inorganic turbidity assumes greater influence on water clarity but would not assume a significant limiting role until values exceed $1.0 m^{-1}$.

Table 5. Limiting factor metrics for Quivira Little Salt Marsh (LM050201)

Sampling Year	Non-algal Turbidity **NAT**	Light Availability in the Mixed Layer **Zmix*NAT**	Partitioning of Light Extinction between Algae & Non-algal Turbidity **Chl-a*SD**	Algal use of Phosphorus Supply **Chl-a/TP**	Light Availability in the Mixed Layer for a Given Surface Light **Zmix/SD**	Shading in Water Column due to Algae and Inorganic Turbidity **Shading**	Chl-*a* (µg/L)
1988	No Data	No Data	No Data	0.321	No Data	No Data	96.2
1991	3.66	0.0732	14.9	0.232	0.100	0.560	74.7
1994	No Data	No Data	No Data	0.816	No Data	No Data	126
1997	1.94	0.0389	31.1	0.694	0.080	0.603	124
1998	3.34	0.0669	21.8	0.581	0.105	0.659	115
1999	4.10	0.0820	23.9	0.590	0.133	0.836	160
2000	6.48	0.1296	22.5	0.849	0.200	1.172	225
2003	2.48	0.0496	5.71	0.109	0.059	0.316	16.8
2006	1.51	0.0303	28.6	0.369	0.061	0.467	86.8
2009	1.58	0.0315	25.9	0.328	0.059	0.440	76.3

Table 6. Limiting factor metrics for Quivira Big Salt Marsh (LM050601).

Sampling Year	Non-algal Turbidity **NAT**	Light Availability in the Mixed Layer **Zmix*NAT**	Partitioning of Light Extinction between Algae & Non-algal Turbidity **Chl-a*SD**	Algal use of Phosphorus Supply **Chl-a/TP**	Light Availability in the Mixed Layer for a Given Surface Light **Zmix/SD**	Shading in Water Column due to Algae and Inorganic Turbidity **Shading**	Chl-*a* (µg/L)
1988	No Data	No Data	No Data	0.121	No Data	No Data	16.4
1991	4.30	0.086	6.35	0.353	0.100	0.470	31.8
1994	No Data	No Data	No Data	0.957	No Data	No Data	383
1997	3.48	0.070	30.4	0.457	0.133	0.925	203
1998	2.80	0.056	26.9	0.497	0.100	0.684	134
1999	3.72	0.074	19.6	0.448	0.111	0.664	109
2000	7.72	0.154	24.8	0.577	0.250	1.50	310
2003	1.82	0.036	9.62	0.217	0.048	0.295	22.9
2006	0.92	0.018	54.8	0.574	0.118	1.13	322
2009	3.24	0.065	11.1	0.168	0.083	0.451	46.3

The depth of the mixed layer in meters (Z) multiplied by the NAT value assesses light availability in the mixed layer. There is abundant light within the mixed layer of the lake and potentially a high response by algae to nutrient inputs when this value is less than 3. Values greater than 6 would indicate the opposite.

The partitioning of light extinction between algae and non-algal turbidity is expressed as Chl-a*SD (Chlorophyll *a* * Secchi Depth). Inorganic turbidity is not responsible for light extinction in the water column and there is a strong algal response to changes in nutrient levels when this value is greater than 16. Values less than 6 indicate that inorganic turbidity is primarily responsible for light extinction in the water column and there is a weak algal response to changes in nutrient levels.

Values of algal use of phosphorus supply (Chl-a/TP) that are greater than 0.4 indicate a strong algal response to changes in phosphorus levels, where values less than 0.13 indicate a limited response by algae to phosphorus.

The light availability in the mixed layer for a given surface light is represented as Zmix/SD. Values less than 3 indicate that light availability is high in the mixed zone and there is a high probability of strong algal responses to changes in nutrient levels.

Shading values less than 16 indicate that self-shading of algae does not significantly impede productivity. This metric is most applicable to lakes with maximum depths of less than 5 meters (Carney, 2004).

Although the above metrics indicate that both Quivira Little and Quivira Big have sufficient light to allow for a strong algal response to nutrient levels, the low Secchi depths combined with high total suspended concentrations in the marshes make abundant light availability unlikely as indicated by the non-algal turbidity values. Self shading does not appear to be impeding algal productivity in the marshes.

Another method for evaluating limiting factors is the TSI deviation metrics. Figures 10 and 11 (Multivariate Deviation Graphs) summarize the current trophic conditions in Quivira Little and Quivira Big using a multivariate TSI comparison chart for the period of record. Where TSI(Chl-a) is greater than TSI(TP), the situation indicates phosphorus is limiting chlorophyll *a,* whereas negative values indicate turbidity limits chlorophyll *a.* Where TSI(Chl-a)-TSI(SD) is plotted on the horizontal axis, if the Secchi depth (SD) trophic index is less than the chlorophyll *a* trophic index, then there is dominant zooplankton grazing. Transparency would be dominated by non-algal factors such as color or inorganic turbidity if the Secchi depth index were more than the chlorophyll *a* index. Points near the diagonal line occur in turbid situations where phosphorus is bound to clay particles and therefore turbidity values are closely associated with phosphorus concentrations.

The multivariate TSI comparison charts in Figure 10 and 11 show that non-algal turbidity is a dominating factor in the marshes likely due to their shallow depths. Non-algal turbidity in Quivira Little and Quivira Big may be limiting chlorophyll *a* production in the marshes.

Figure 10. Multivariate TSI comparison chart for Quivira Little Salt Marsh (LM050201).

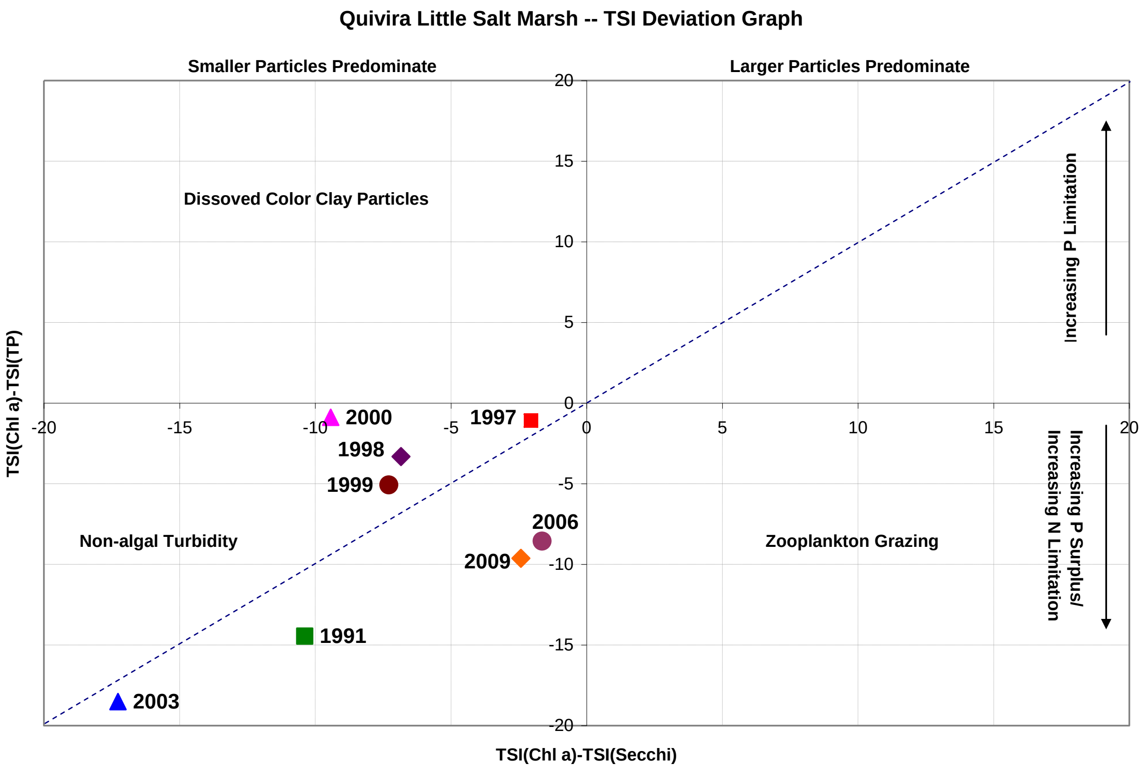
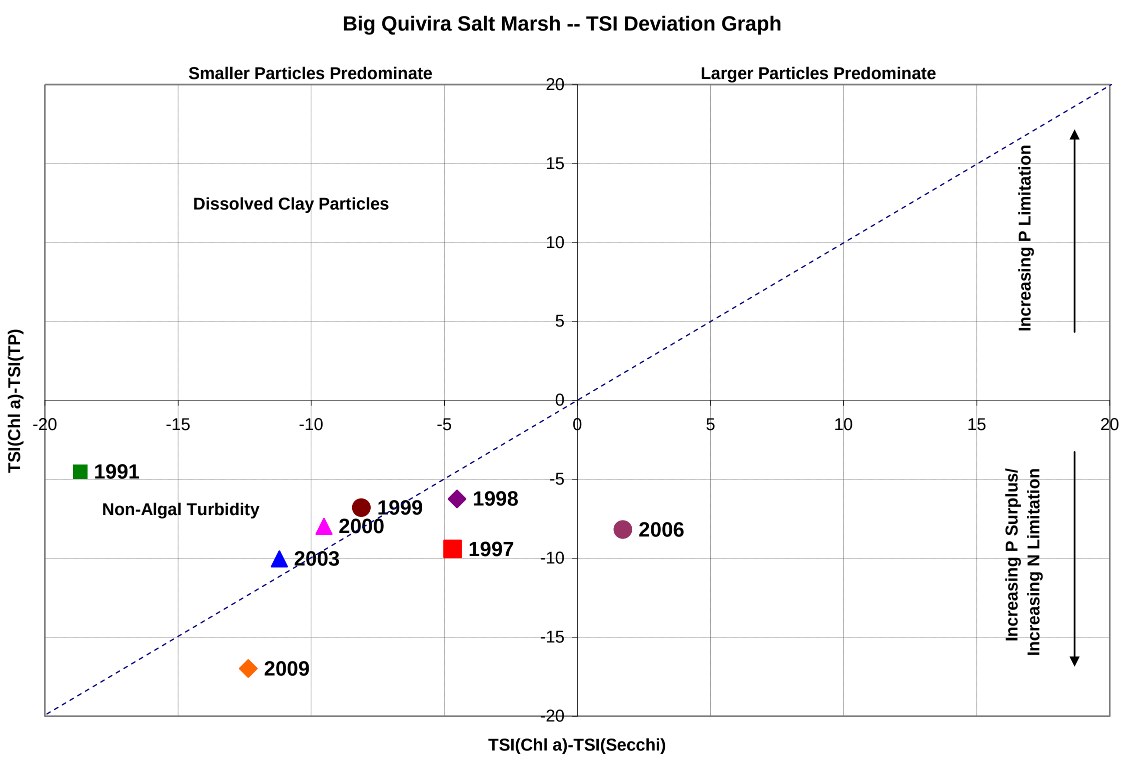


Figure 11. Multivariate TSI comparison chart for Quivira Big Salt Marsh (LM050601).



The Carlson Trophic State Indices for chlorophyll *a*, Secchi depth and total phosphorus in the Quivira Little and Quivira Big Salt Marsh show the marshes' trophic condition has been in a hypereutrophic state for each of the indicators for the period of record (Figures 12 &13).

Figure 12. Quivira Little Salt Marsh Trophic State Indices. No Secchi depths were available for 1988 & 1994.

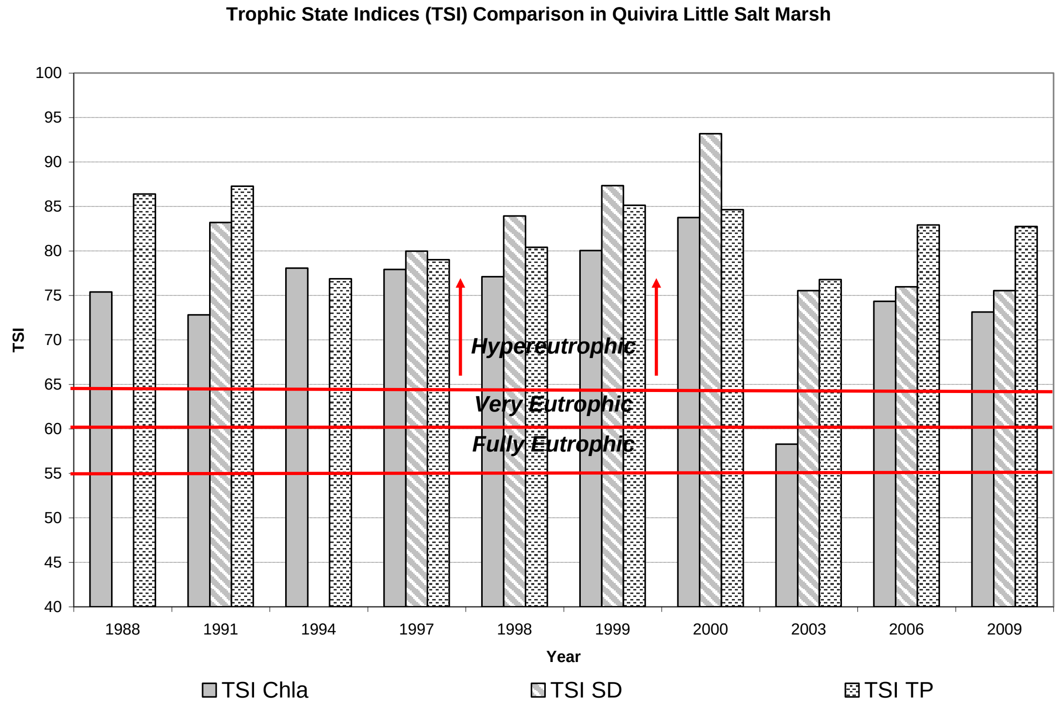
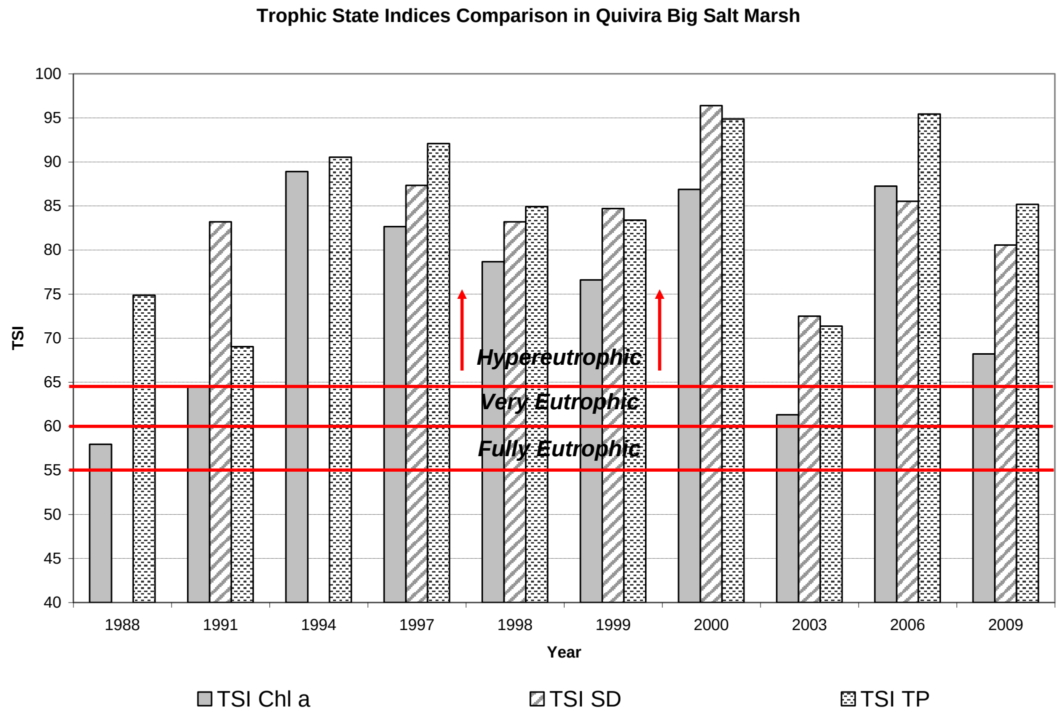


Figure 13. Quivira Big Salt Marsh Trophic State Indices. No Secchi depths were available for 1988 & 1994.



Algal Communities: Total algal cell counts in the marshes are reflected in the chlorophyll *a* concentrations for the years algae data was available for Quivira Little and Quivira Big Salt Marshes (Tables 7 & 8). Blue Green algae dominated the algal communities in Quivira Little four of five years and it was dominant in Quivira Big three of the five years the marshes were surveyed for algal constituents.

Table 7. Algal communities observed in Quivira Little Salt Marsh.

Sampling Date	Total Cell Count cells/mL	Percent Composition				Chl-*a* µg/L
		Green	Blue Green	Diatom	Other	
1991	73,800	17	78	4	<1	74.7
1994	354,060	9	91	0	<1	126
2003	9,702	77	0	16	7	16.8
2006	343,980	11	87	1	<1	86.8
2009	183,267	18	78	3	1	76.3

Table 8. Algal communities observed in Quivira Big Salt Marsh.

Sampling Date	Total Cell Count cells/mL	Percent Composition				Chl-*a* µg/L
		Green	Blue Green	Diatom	Other	
1991	63,900	38	59	1	2	31.8
1994	81,270	71	0	28	1	383
2003	70,812	18	78	3	1	22.9
2006	852,012	11	87	1	<1	322
2009	49,802	93	0	7	<1	46.3

Relationships: In the Quivira Little Salt Marsh there are strong relationships between TSS and chlorophyll *a*; TSS and turbidity; TSS and Secchi depth; and between chlorophyll *a* and Secchi depth (Figure 14). Moderate relationships exist in Quivira Little between total nitrogen and total phosphorus; total nitrogen and chlorophyll *a*; total nitrogen and TSS; total phosphorus and turbidity; and between total phosphorus and Secchi depth. In the Quivira Big Salt Marsh there are strong relationships between chlorophyll *a* and total phosphorus; chlorophyll *a* and total nitrogen and total phosphorus and total nitrogen (Figure 15). Moderate relationships exist between TSS and chlorophyll *a;* TSS and Secchi depth; TSS and total phosphorus; TSS and total nitrogen; chlorophyll *a* and Secchi depth; and Secchi depth and total phosphorus.

Figure 14. Relationship between total suspended solids (TSS), chlorophyll *a*, turbidity, Secchi depth total phosphorus (TP) and total nitrogen (TN) with coefficient of determination (R^2 value) displayed as a percentage in Quivira Little Salt Marsh.

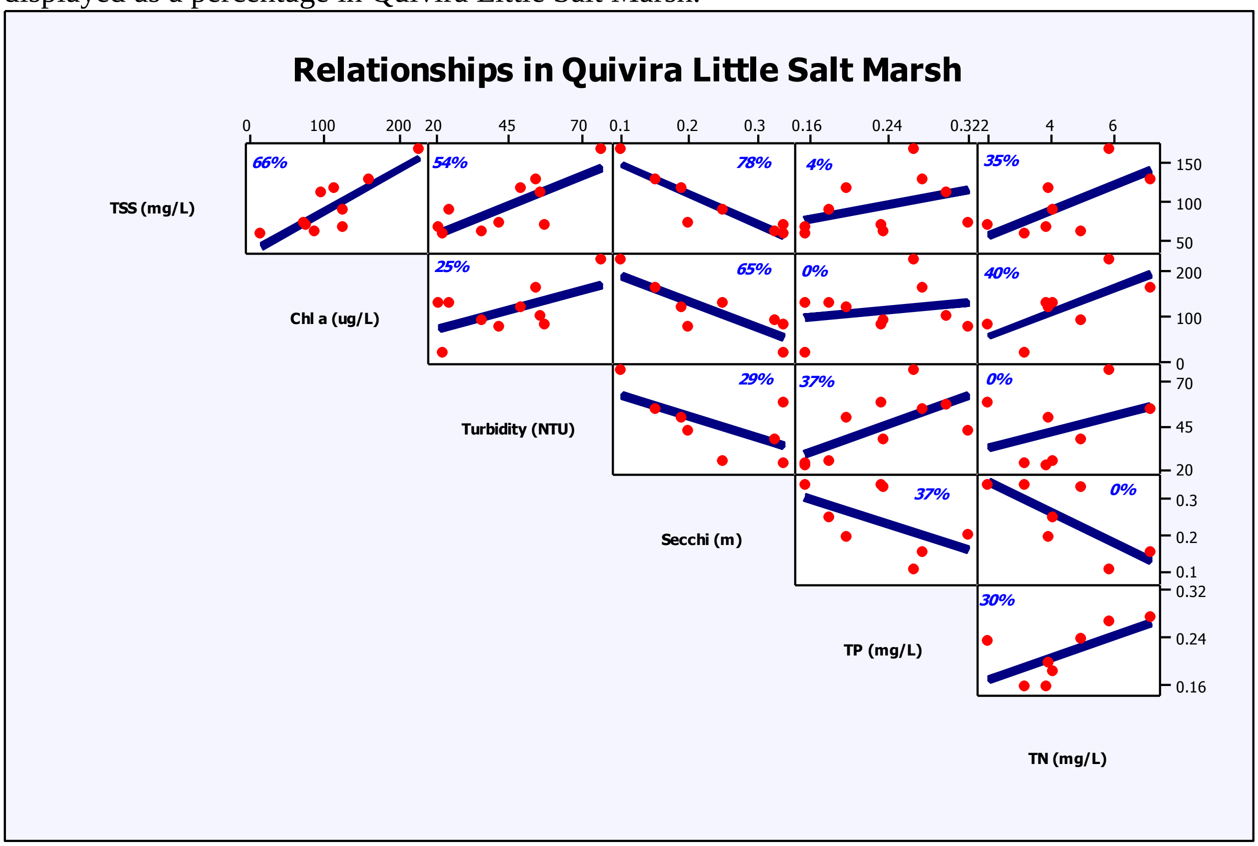
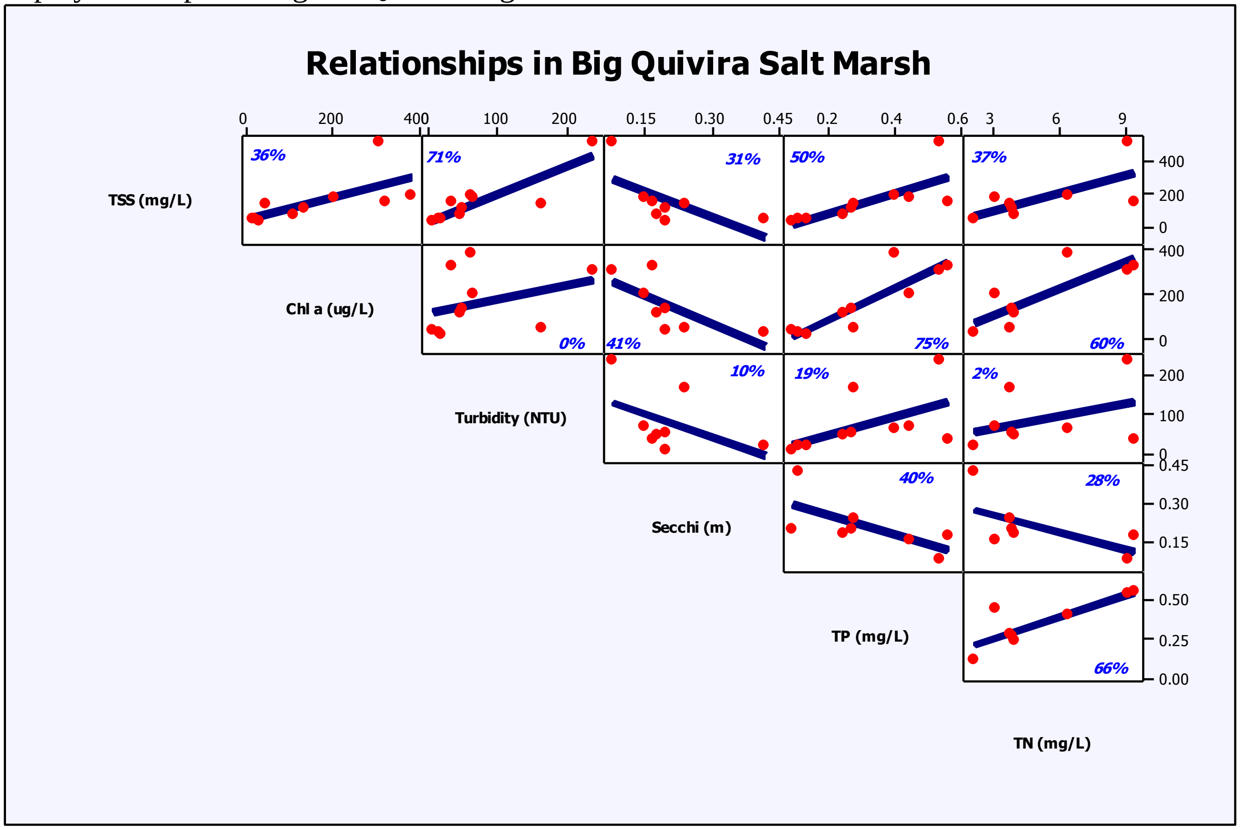
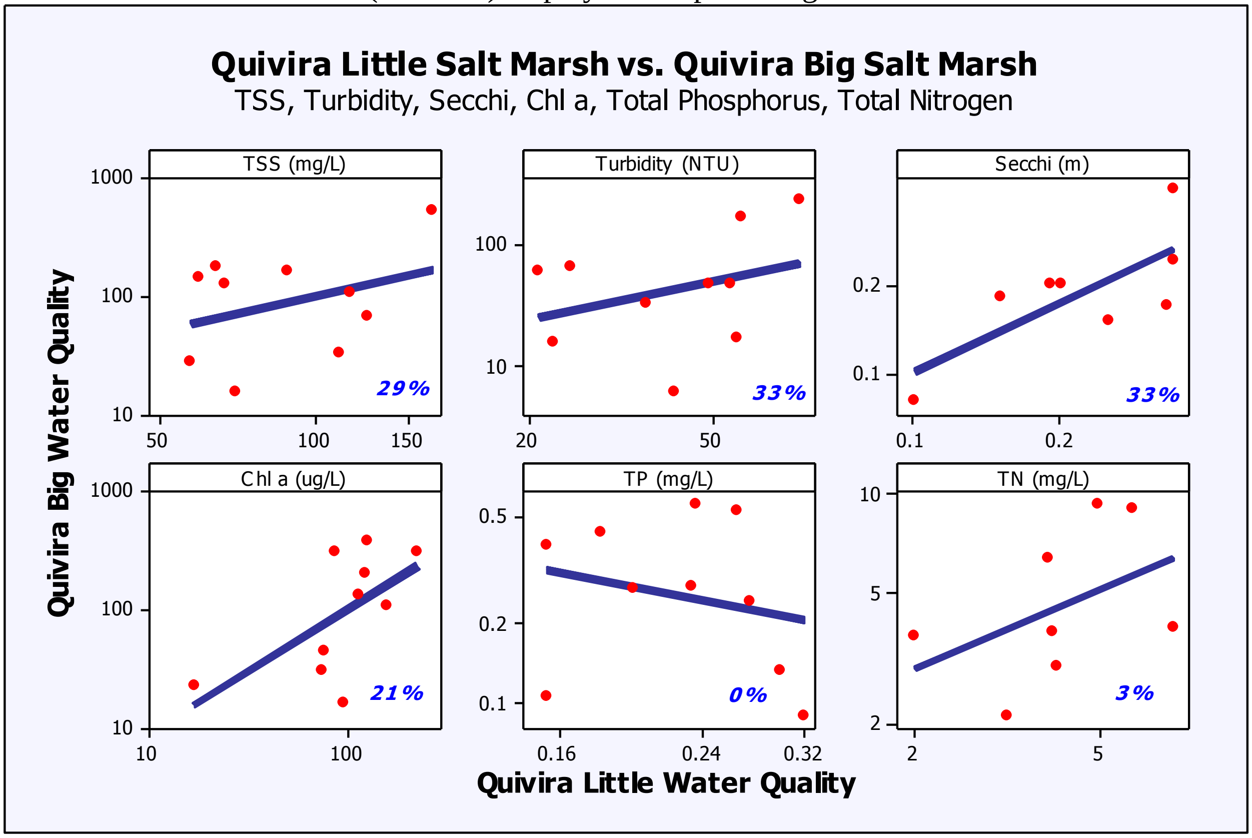


Figure 15. Relationship between total suspended solids (TSS), chlorophyll *a*, turbidity, Secchi depth, total phosphorus (TP) and total nitrogen (TN) with coefficient of determination (R^2 value) displayed as a percentage in Quivira Big Salt Marsh.



The relationship of water quality between the marshes is moderate for the linked water quality parameters of TSS, turbidity and Secchi depth (Figure 16). There is a minor relationship between the chlorophyll *a* values, however; there is no correlation between total phosphorus and total nitrogen. The lack of strong relationships between the marshes for these parameters illustrates how these marshes, although both located in QNWR, function independently of one another.

Figure 16. Relationships between Quivira Little Salt Marsh and Quivira Big Salt Marsh with coefficient of determination (R^2 value) displayed as a percentage.



Comparing TSS, chlorophyll a, total phosphorus and total nitrogen to the average inflow to the marsh during the 3 days and 30 days prior to sampling shows very little correlation between flow to the marsh via Rattlesnake Creek and those water quality parameters. Interestingly, only total nitrogen shows any correlation with flow with an R^2 value of 0.21 when total nitrogen in Quivira Little and the 3 day average flow are compared (Figure 17). When total nitrogen in Quivira Big is compared to the 30 day inflow a correlation with an R^2 value of 0.12 is generated (Figure 18).

Figure 17. TSS, chlorophyll a, total phosphorus (TP) and total nitrogen (TN) concentrations in Quivira Little Salt Marsh vs. the average flow in Rattlesnake Creek above QNWR (USGS 07142575) during the 3 days and 30 days preceding the sampling date. Coefficient of determination values (R^2) are displayed as a percentage.

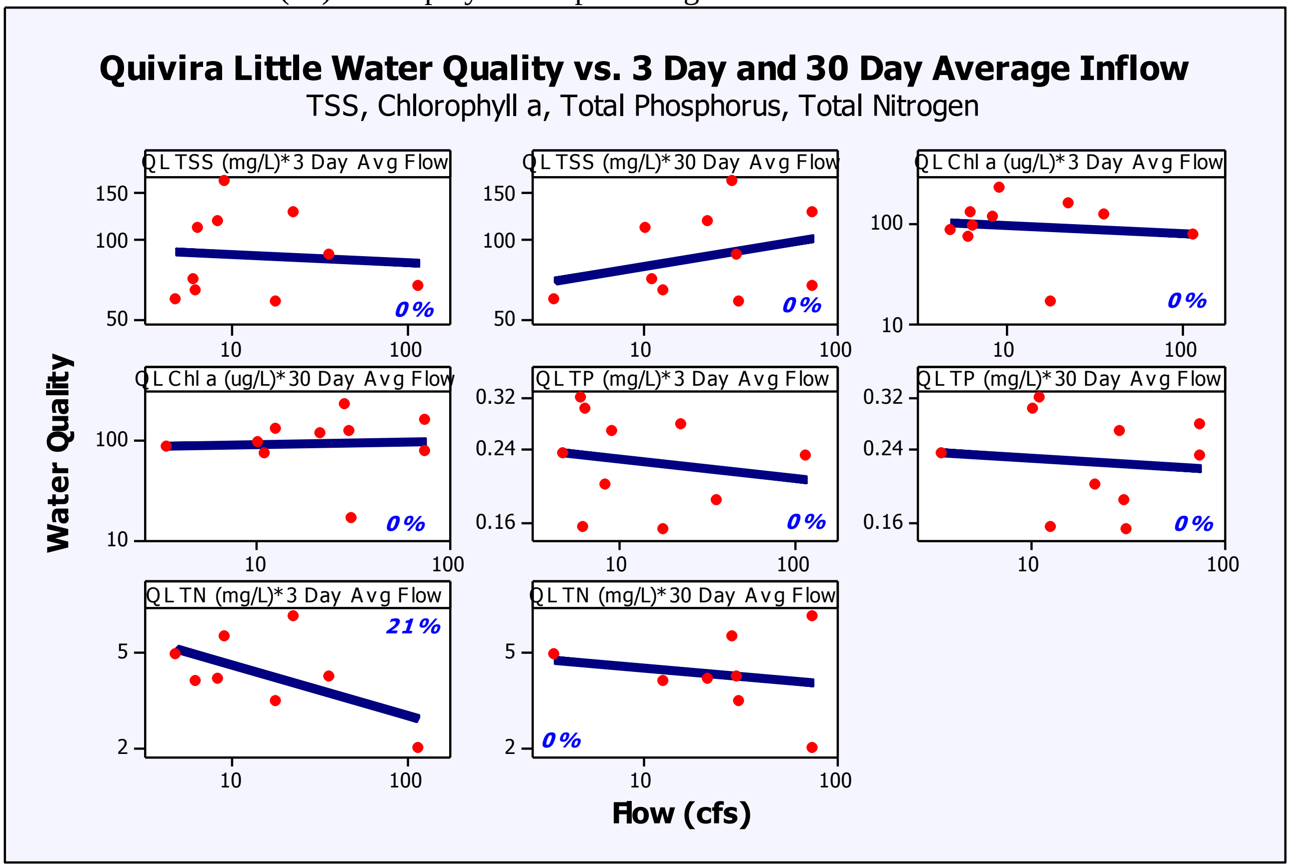
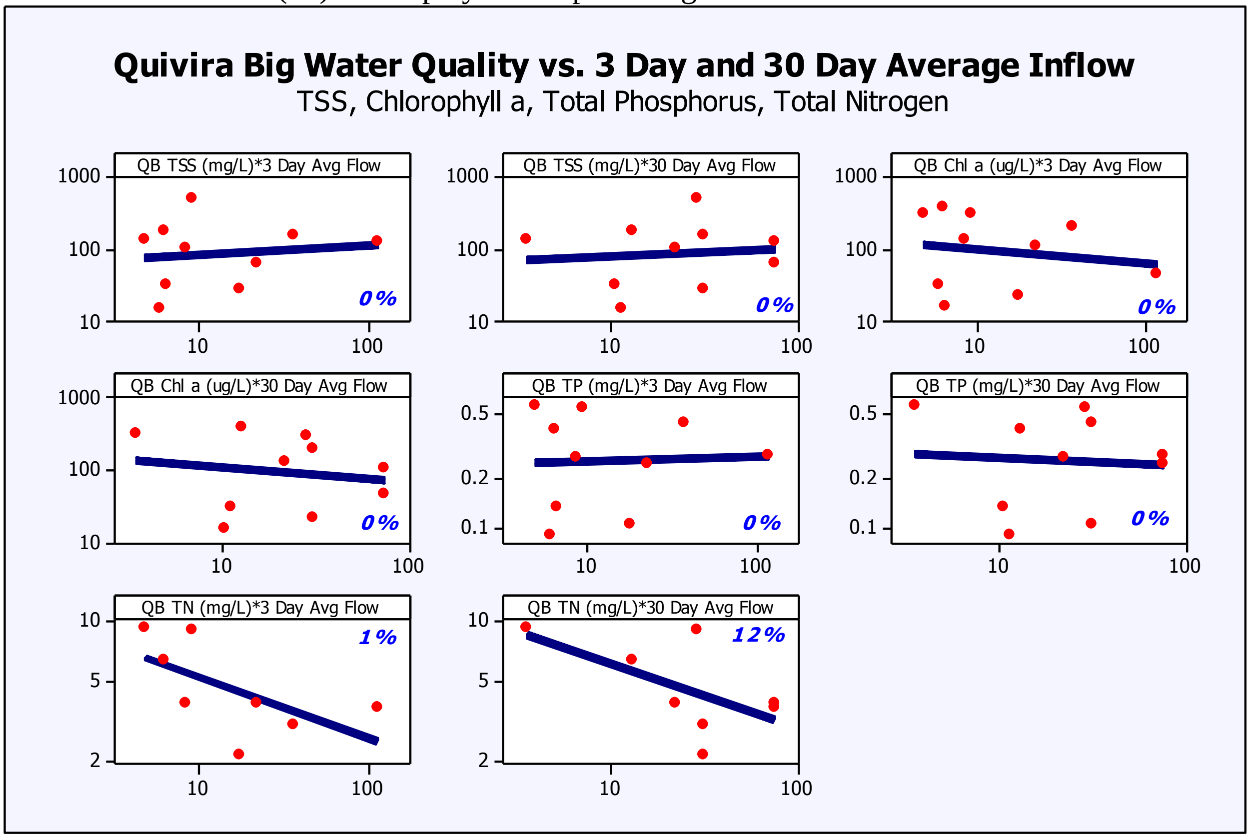


Figure 18. TSS, chlorophyll a, total phosphorus (TP) and total nitrogen (TN) concentrations in Quivira Big Salt Marsh vs. the average flow in Rattlesnake Creek above QNWR (USGS 07142575) during the 3 days and 30 days preceding the sampling date. Coefficient of determination values (R^2) are displayed as a percentage.



Stream Data: The average TSS concentration in Rattlesnake Creek, for the period of record, is higher above QNWR (SC660) than below the refuge (SC030) demonstrating the sediment trapping function of the marsh (Figure 19). Seasonally, the highest averages occur during the Spring season (April-June) which coincides with the seasonal high intensity precipitation events that generate runoff conditions (Figure 20). Averages drop considerably during the Summer-Fall season (July-October) with Winter season (November-March) averages dropping to 29 mg/L and 28 mg/L above and below QNWR, respectively, (Table 9).

Analysis of samples taken in Rattlesnake Creek above and below QNWR on the same day reveals that prior to the December 2004 samplings there were two instances, in January 1992 and November 1996, where higher TSS concentrations were leaving the marsh at SC030 than those entering the marsh at SC660 (Figure 21). Beginning in December 2004, TSS concentrations in the creek below QNWR at SC030 have been consistently higher than those in the creek above QNWR at SC660 possibly due to lost trapping efficiency resulting from the accumulation of sediment and decayed organic material in the marsh (Table 10).

Figure 19. Total suspended solids concentrations for KDHE sampling sites on Rattlesnake Creek above and below QNWR for years sampled.

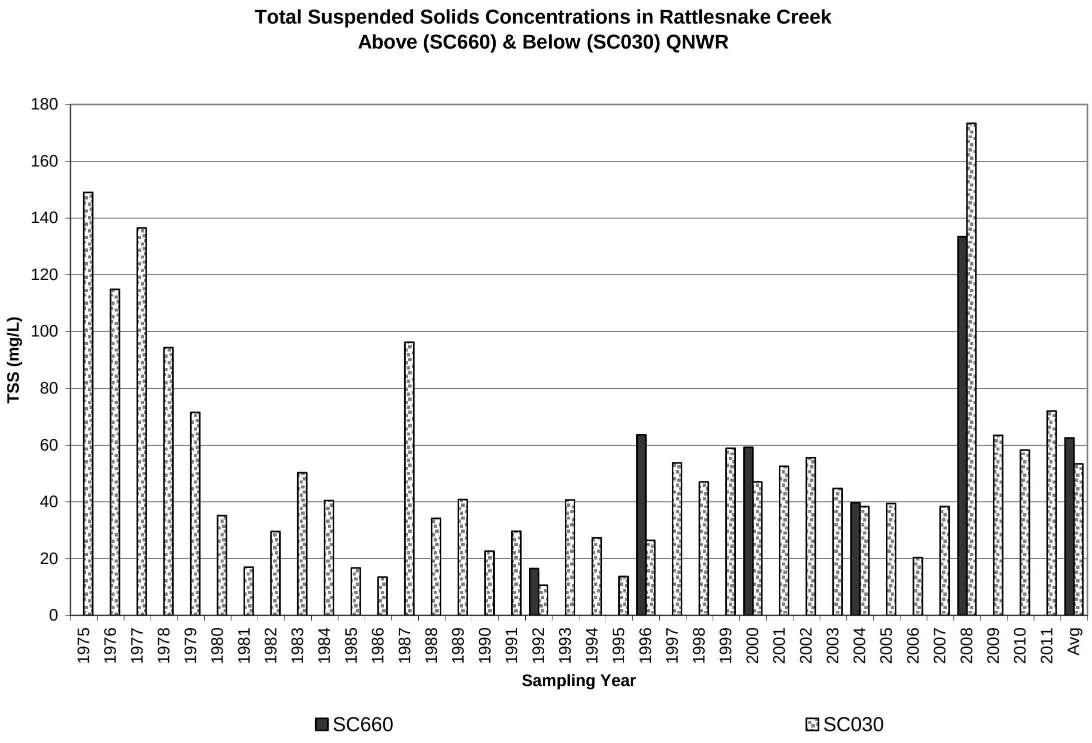


Figure 20. Average and median TSS concentration by season for Rattlesnake Creek at SC660 (1992-2008) & SC030 (1975-2011).

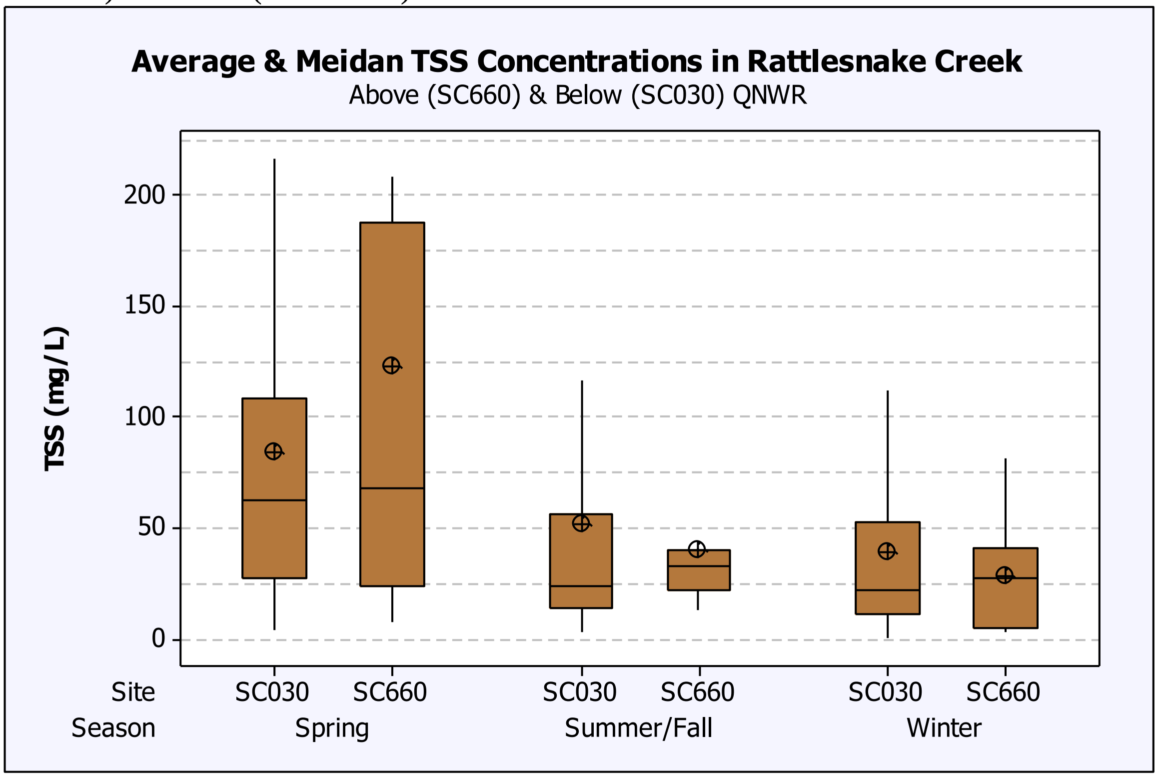


Table 9. TSS concentrations in Rattlesnake Creek at SC660 (1992-2008) & SC030 (1975-2011).

TSS Concentration by Season in Rattlesnake Creek (mg/L)										
Stream Flow (% Exceedance)	**Spring Averages**		**Summer-Fall Averages**		**Winter Averages**		**All Season Median**		**All Season Average**	
	SC660	SC030	SC660	SC030	SC660	SC030	SC660	SC030	SC660	SC030
High (0-10%)	No Data	83	118	128	No Data	78	118	65	118	91
Base (11-50%)	211	109	33	152	31	52	70	56	111	76
Low (51-100%)	41	34	29	30	26	19	32	19	30	27
All Flow Median	68	62	33	24	28	22	34	29	N/A	N/A
All Flow Avg.	123	84	39	51	28	39	N/A	N/A	60	54

Figure 21. TSS concentration in samples taken on the same day at SC660 and SC030 (1992-2008).

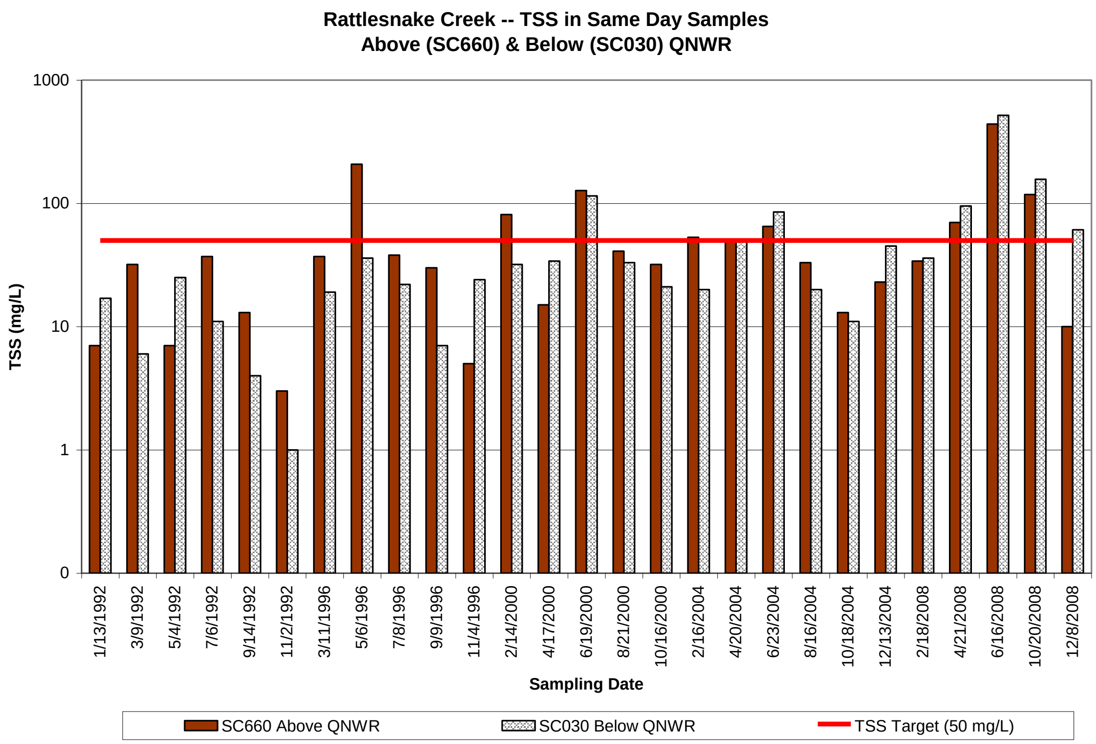
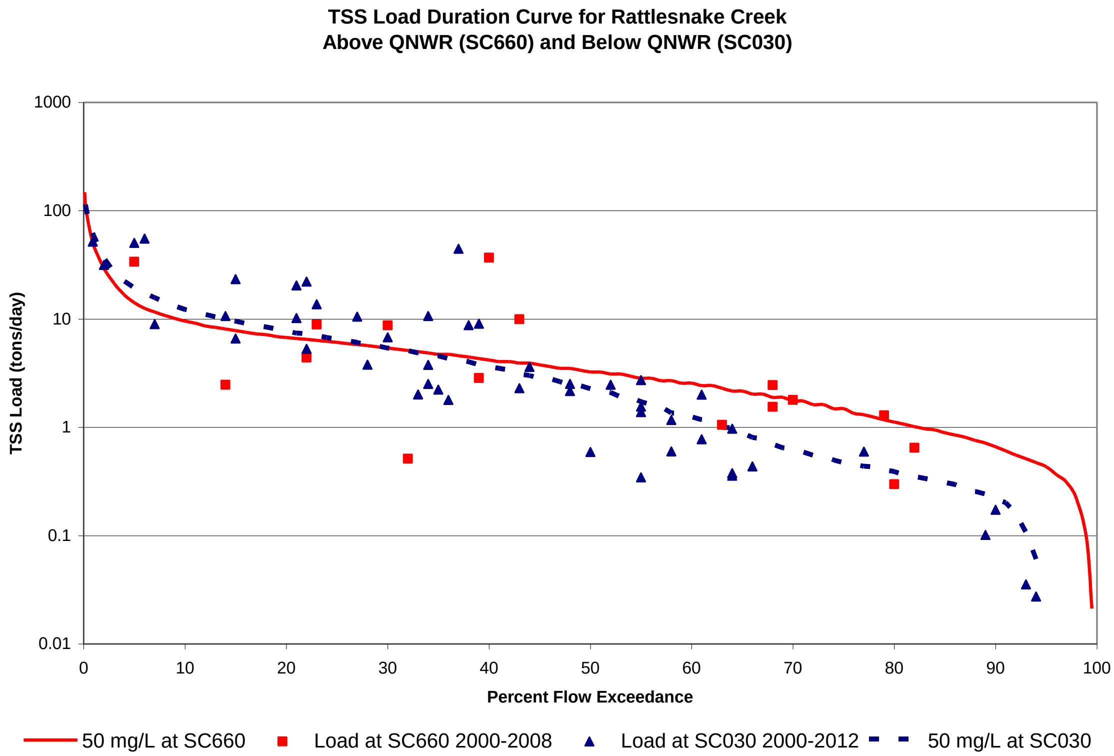


Table 10. Median May through August TSS concentrations for common sampling years at SC660 and SC030.

Sampling Period	Median TSS (mg/L)	
	SC660	SC030
May-August 1992	22	18
May-August 1996	123	47
May-August 2000	84	74
May-August 2004	49	53
May-August 2008	440	518

Listing methodology for TSS in the 2008, 2010 and 2012 303(d) lists detail the breakpoint between good biotic quality and indications of impairment in Kansas streams is in the vicinity of 50 mg/L TSS. Load duration curves for Rattlesnake Creek above and below QNWR were developed using a TSS value of 50 mg/L and reveal loads in the creek have routinely been above loading capacity when flows are greater than median (Figure 22).

Figure 22. Load Duration Curves for KDHE sampling sites SC660 & SC030 on Rattlesnake Creek above and below QNWR, respectively. Flow data from USGS gages 07142575 (above QWNR) and 0714620 (below QNWR) was used to establish curves.



Total phosphorus concentrations in Rattlesnake Creek average 151 µg/L at SC660 and 122 µg/L at SC030, above and below QNWR, respectively (Figure 23). Although the Summer-Fall season average total phosphorus at SC660 is slightly higher (0.208 mg/L) than the total phosphorus values for the Spring season (0.200), concentrations generally follow the seasonal pattern of higher values in the Spring season coinciding with seasonal high intensity precipitation events that generate runoff conditions (Figure 24). Averages drop considerably during the Summer-Fall season at SC030 with Winter season averages falling to 0.059 mg/L and 0.084 mg/L at SC660 and SC030, respectively (Table 11).

Analysis of same day samples in Figure 25 reveals that total phosphorus concentrations in the QNWR outflow in Rattlesnake Creek were higher than inflow concentrations twelve of sixteen times since the beginning of 2000 indicating the marsh may be losing nutrient trapping efficiency. However, analysis of samples taken May through August for the years both sites were sampled reveal average concentrations are lower at SC030 than at SC660 in all years sampled except 2000 when averages were only slightly different (Table 12).

Figure 23. Total phosphorus concentrations for KDHE sampling sites on Rattlesnake Creek above and below QNWR.

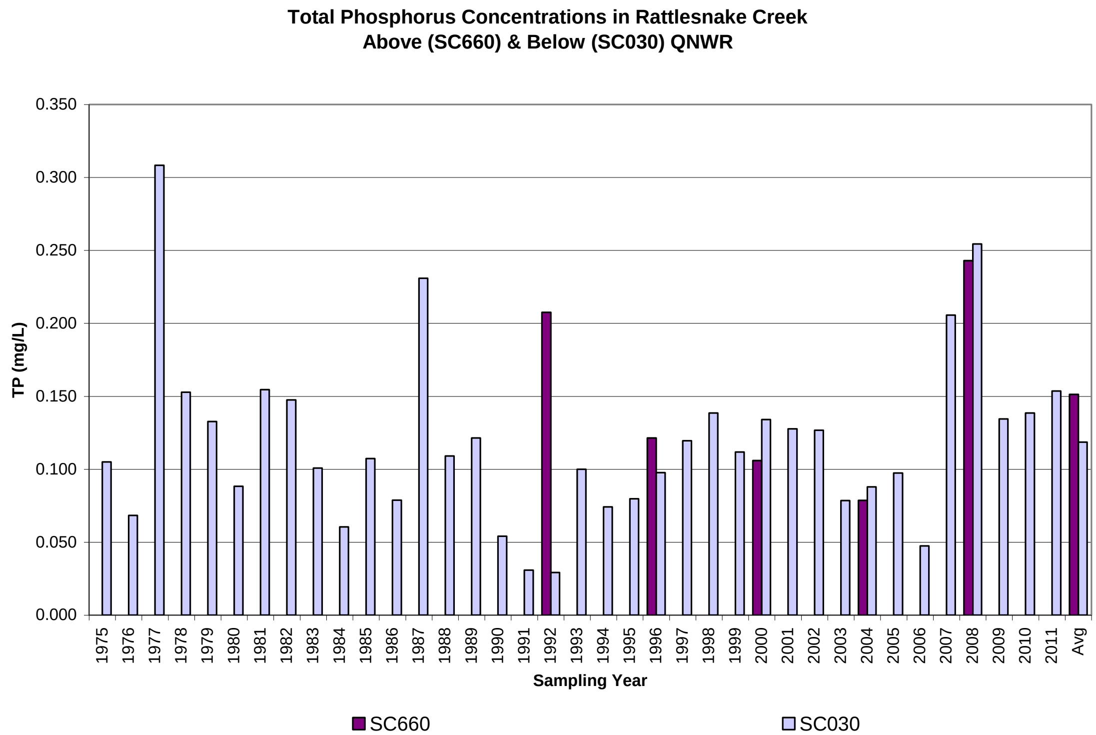


Figure 24. Average and median TSS concentration by season for Rattlesnake Creek at SC660 (1992-2008) & SC030 (1975-2011).

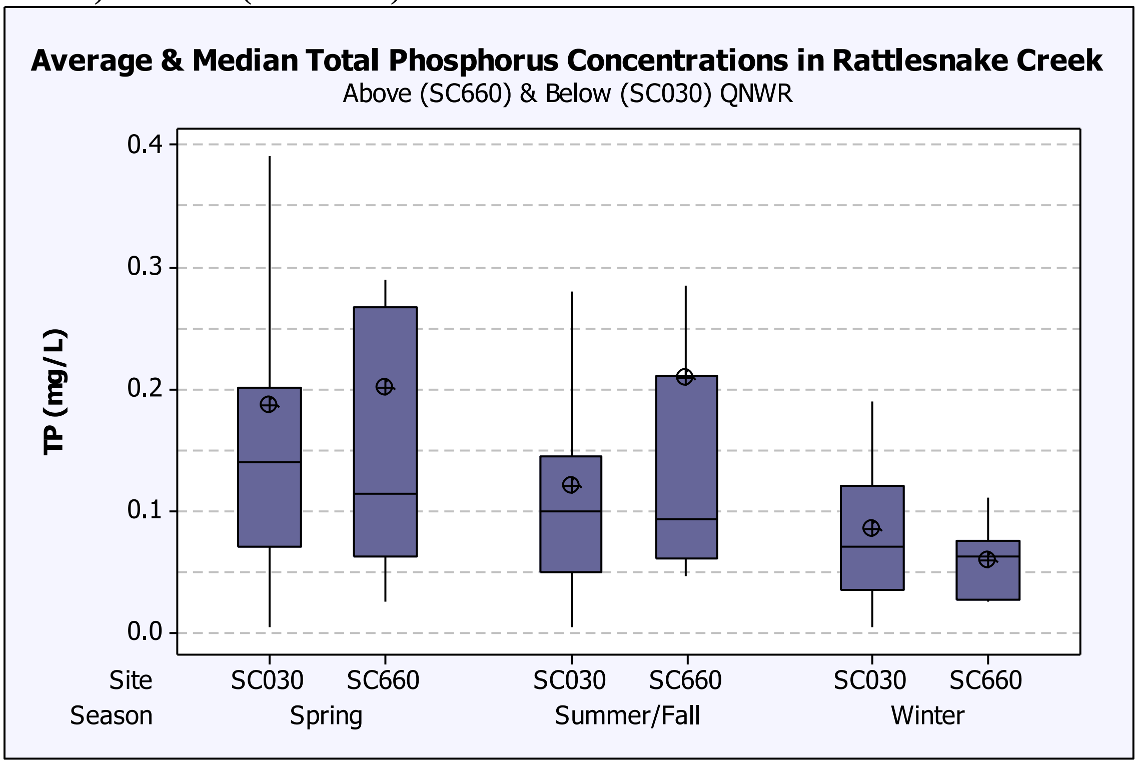


Table 11. Total phosphorus concentrations in Rattlesnake Creek at SC660 (1992-2008) & SC030 (1975-2011).

Total Phosphorus Concentration by Season & Flow in Rattlesnake Creek (mg/L)										
Stream Flow (% Exceedance)	**Spring Averages**		**Summer-Fall Averages**		**Winter Averages**		**All Season Median**		**All Season Average**	
	SC660	SC030	SC660	SC030	SC660	SC030	SC660	SC030	SC660	SC030
High (0-10%)	No Data	0.179	0.284	0.231	No Data	0.139	0.284	0.141	0.284	0.178
Normal (11-50%)	0.330	0.227	0.093	0.270	0.066	0.092	0.101	0.120	0.186	0.151
Low (51-100%)	0.074	0.114	0.214	0.090	0.055	0.069	0.064	0.060	0.068	0.086
All Flow Median	0.114	0.140	0.093	0.100	0.063	0.070	0.072	0.090	N/A	N/A
All Flow Avg.	0.200	0.185	0.208	0.120	0.059	0.084	N/A	N/A	0.151	0.122

Figure 25. Total phosphorus concentration in samples taken on the same day at SC660, Rattlesnake Creek above QNWR and at SC030, Rattlesnake Creek below QNWR.

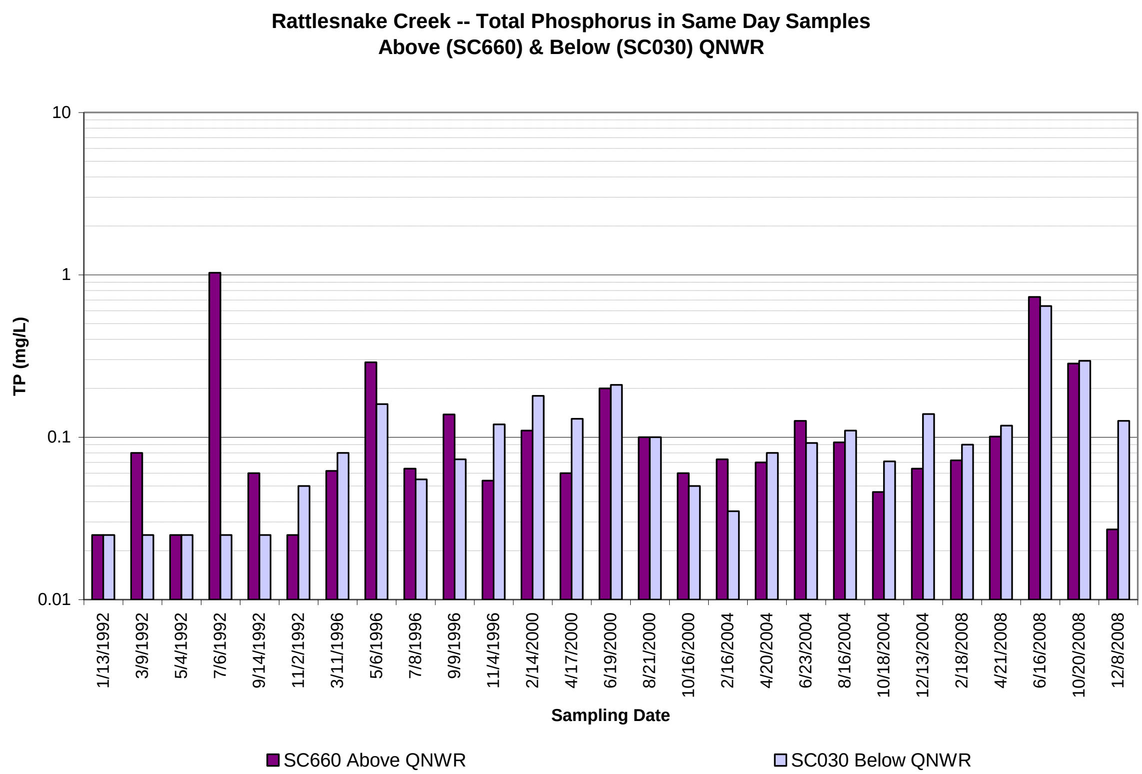


Table 12. Median May through August total phosphorus concentrations for common sampling years at SC660 and SC030.

Sampling Period	**Median TP (mg/L)**	
	SC660	**SC030**
May-August 1992	0.528	0.025
May-August 1996	0.177	0.108
May-August 2000	0.150	0.155
May-August 2004	0.110	0.101
May-August 2008	0.731	0.643

As with TSS and total phosphorus, average total nitrogen concentrations in Rattlesnake Creek, for the period of record, is higher above QNWR (SC660) than below the refuge (SC030) at 2.12 mg/L and 1.63 mg/L, respectively (Figure 26). Seasonally, the highest averages occur during the Spring season which coincides with the seasonal high intensity precipitation events that generate runoff conditions (Figure 27). Averages drop during the Summer-Fall season with Winter season averages rising to 2.14 mg/L and 1.47 mg/L at SC660 and SC030, respectively (Table 13).

Analysis of samples taken in Rattlesnake Creek above and below QNWR on the same day reveals total nitrogen concentrations have been higher leaving the marsh at SC030 than those coming into the marsh at SC660 38% (6 of 16) of the time (Figure 28). However, analysis of samples taken May through August for the years both sites were sampled reveal average concentrations are higher at SC030 than at SC660 in 2004 and 2008, the most recent years the creek was sampled at both sites, once again indicating the marsh may be losing its trapping efficiency due to the accumulation of sediment and decayed organic material (Table 14).

Figure 26. Total nitrogen concentrations for KDHE sampling sites on Rattlesnake Creek above and below QNWR.

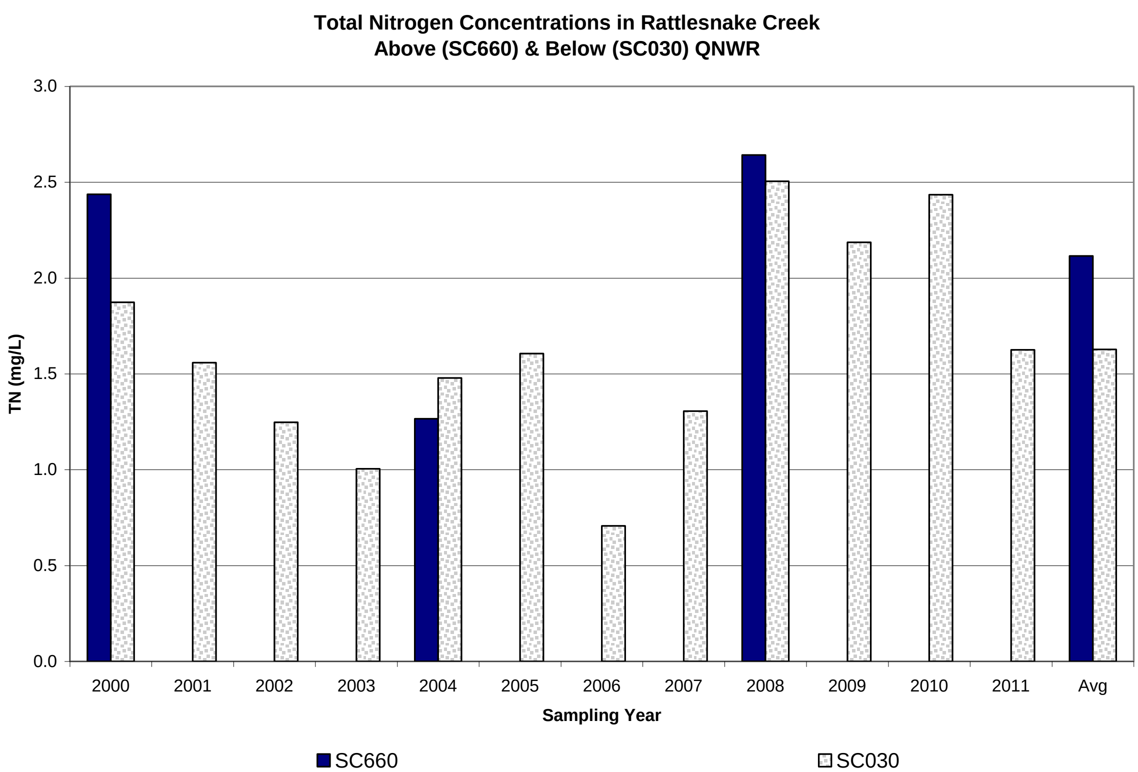


Figure 27. Average and median total nitrogen concentration by season for Rattlesnake Creek above Quivira NWR (SC660) and below Quivira NWR (SC030).

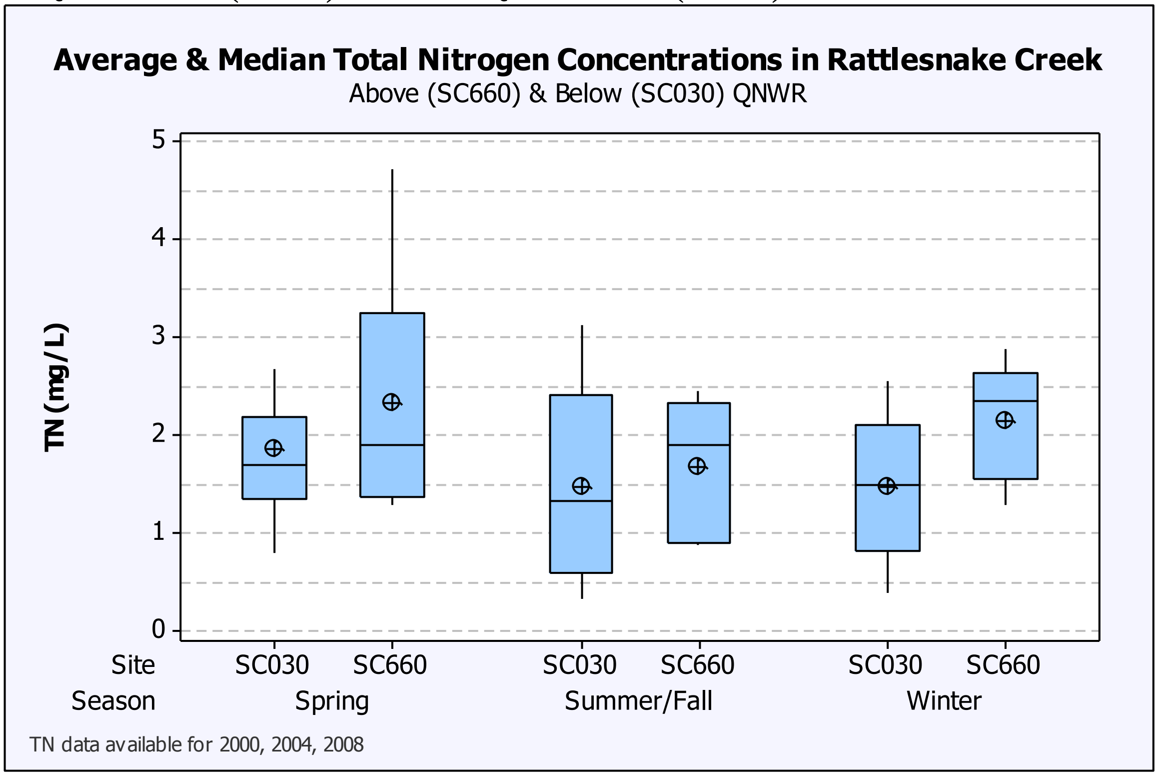


Table 13. Total nitrogen concentrations in Rattlesnake Creek at SC660 (1992-2008) & SC030 (1975-2011).

Total Phosphorus Concentration by Season & Flow in Rattlesnake Creek (mg/L)										
Stream Flow (% Exceedance)	**Spring Averages**		**Summer-Fall Averages**		**Winter Averages**		**All Season Median**		**All Season Average**	
	SC660	SC030	SC660	SC030	SC660	SC030	SC660	SC030	SC660	SC030
High (0-10%)	No Data	1.55	1.90	1.92	No Data	No Data	1.90	1.76	1.90	1.77
Normal (11-50%)	3.11	2.06	0.880	2.43	2.53	1.86	2.39	2.04	2.54	1.94
Low (51-100%)	1.35	1.58	1.85	1.26	1.56	1.06	1.40	1.02	1.62	1.24
All Flow Median	1.89	1.70	1.90	1.32	2.34	1.48	1.91	1.61	N/A	N/A
All Flow Avg.	2.32	1.86	1.67	1.47	2.14	1.47	N/A	N/A	2.06	1.58

Figure 28. Total nitrogen concentration in samples taken on the same day at SC660, Rattlesnake Creek above QNWR and at SC030, Rattlesnake Creek below QNWR.

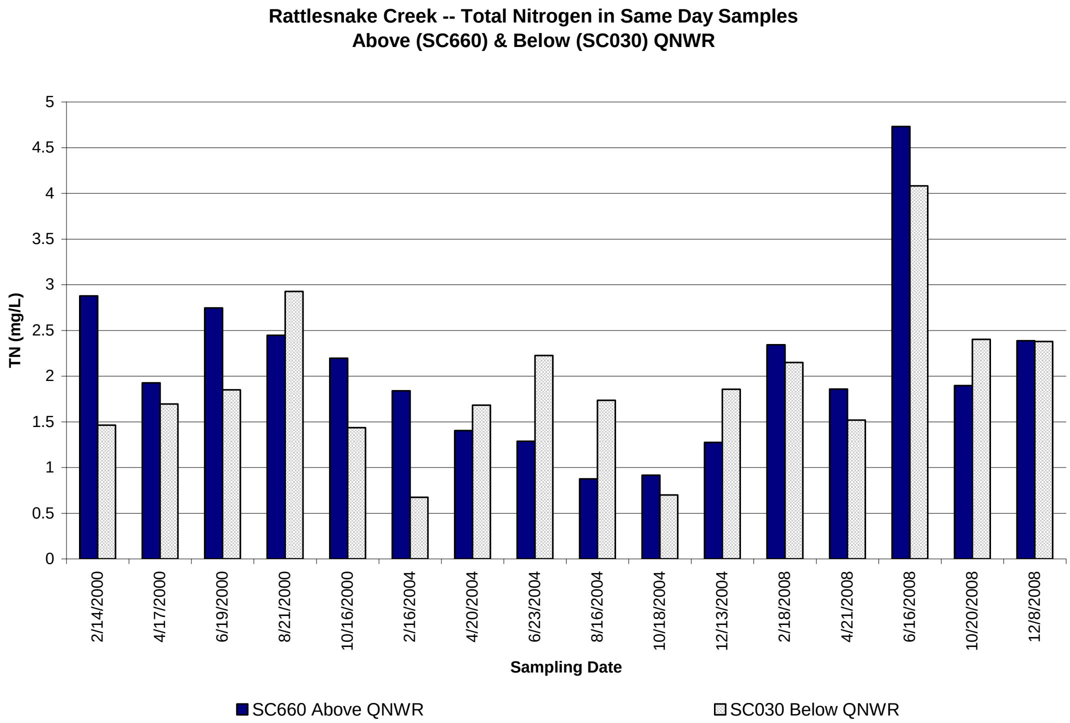


Table 14. Median May through August total nitrogen concentrations for common sampling years (2000, 2004, 2008) at SC660 and SC030.

Sampling Period	Median TN (mg/L)	
	SC660	SC030
May-August 2000	2.60	2.39
May-August 2004	1.08	1.98
May-August 2008	3.29	4.08

Total phosphorus and total suspended solids loads were calculated for same day samples in Rattlesnake Creek at SC660 and SC030 with the difference between the load entering QNWR at SC660 and exiting QNWR at SC030 compared to the change in flow (seven day average) at those stations (Figures 28 & 29). For the most part, the marsh maintains its total phosphorus trapping efficiency when flow into QNWR during the seven days prior to sampling is greater than the flow leaving as displayed in the lower left quadrant of Figure 28. However, when the seven day average flow is higher below the marsh than above it, nutrient flushing may be occurring as displayed by the 2000 and 2008 data points in Figure 28. TSS loads follow a similar pattern although there is more deviation with sediment trapping continuing to occur when the seven day average flow is greater out of the marsh than in. The 1996 TSS loads in the upper left quadrant of Figure 29 were greater leaving than entering the marsh despite the favorable flow condition indicating the marshes may have undergone mixing, possibly by the wind or wildlife, prior to sampling. The 1996 load in the lower left quadrant of both Figure 28 and Figure 29 indicate a runoff event in Rattlesnake Creek watershed above QNWR.

Figure 28. Comparison of the change in the total phosphorus load coming into QNWR at SC660 to total phosphorus load exiting QNWR at SC030 versus the change in the 7 day average flow prior to sampling at those stations.

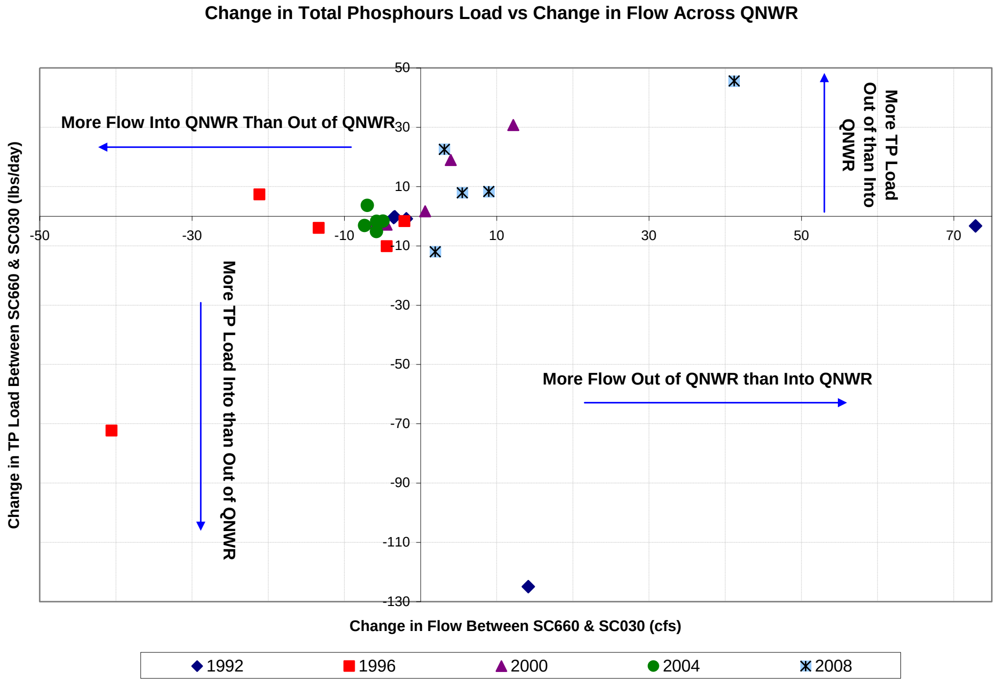
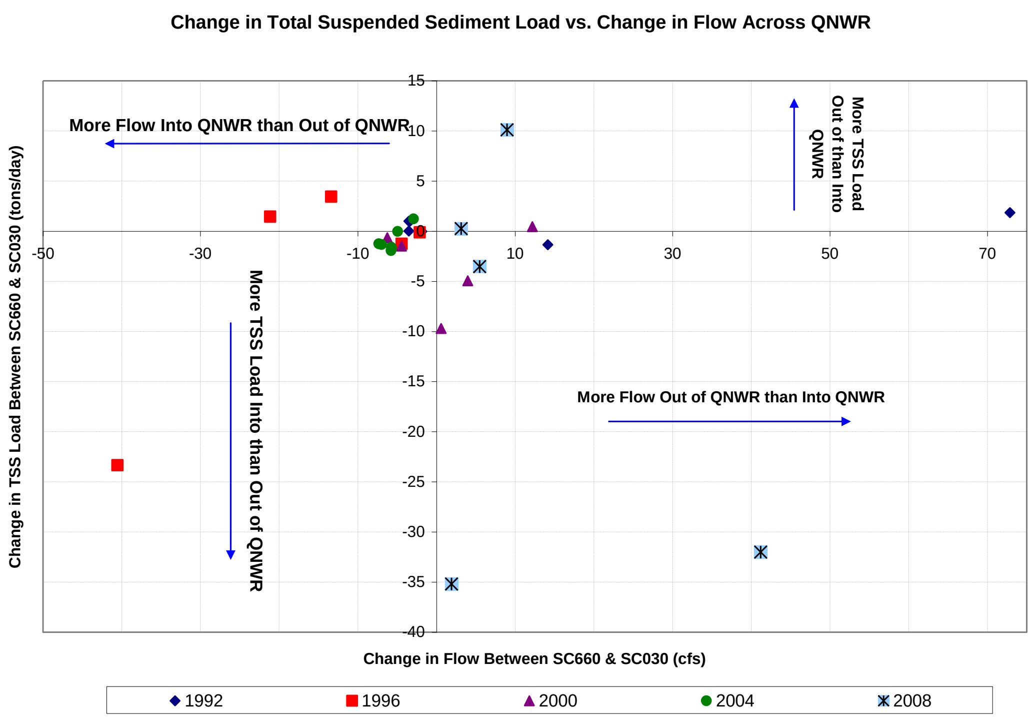


Figure 29. Comparison of the change in the total suspended solids load coming into QNWR at SC660 to the total suspended solids load exiting QNWR at SC030 versus the change in the 7 day average flow prior to sampling at those stations.



Desired Endpoints of Water Quality (Implied Load Capacity) in the Quivira Little Salt Marsh (LM050201) and the Quivira Big Salt Marsh (LM05061):

The ultimate endpoint for this TMDL will be to achieve the Kansas Water Quality Standards fully supporting Special Aquatic Life Use and Primary Contact Recreation Class B by eliminating impacts associated with excessive suspended solids and excessive eutrophication. This TMDL applies across flow conditions effectively addressing the critical condition brought about by high flow events when nutrient and sediment loading in the marshes occurs at exaggerated rates. Seasonal variation has been incorporated in this TMDL since peaks of algal growth occur in the summer months.

Sediment loading in the marshes was calculated using the estimated volume, retention time, trapping efficiency and the current average TSS concentration:

Quivira Little Salt Marsh:
Tons of Sediment/Year Exiting the Marsh = [Marsh Volume (231 ac-ft)]*[TSS (92.6 mg/L)]*[Marsh Retention Time (365 days/retention time (2.92 days))]*[Unit Conversion Factors (1,233,482 L/ac-ft)*(2.204 lbs/1,000,000 mg)*(1 ton/2000 lbs)]

= 3,635 tons of sediment exiting Quivira Little annually

Assuming a 95% trapping efficiency of the marsh, the annual amount of sediment accumulated in Quivira Little Salt Marsh is calculated as:

3,635 tons/year exiting / 0.05 (assumes a 95% trapping efficiency)
= 72,690 tons of sediment exported from the watershed annually

Subtracting the sediment exiting the marsh from the total tons of sediment exported from the watershed results in tons of sediment deposited in the marsh annually:

72,690 tons (exported annually from watershed) –
3,635 tons (exiting the marsh annually)
= 69,056 tons of sediment deposited annually in Quivira Little Salt Marsh

Quivira Big Salt Marsh:
Tons of Sediment/Year Exiting the Marsh = [Marsh Volume (127 ac-ft)]*[TSS (136 mg/L)]*[Marsh Retention Time (365 days/retention time (21.7 days))]*[Unit Conversion Factors (1,233,482 L/ac-ft)*(2.204 lbs/1,000,000 mg)*(1 ton/2000 lbs)]

= 395 tons of sediment exiting Quivira Big annually

Assuming a 95% trapping efficiency of the marsh, the annual amount of sediment accumulated in Quivira Big Salt Marsh is calculated as:

395 tons/year exiting / 0.05 (assumes a 95% trapping efficiency)
= 7,898 tons total sediment exported from the watershed annually

Subtracting the sediment exiting the marsh from the total tons of sediment exported from the watershed results in tons of sediment deposited in the marsh annually:

7,898 tons (exported annually from watershed) –
385 tons (exiting the marsh annually)
= 7,503 tons of sediment deposited annually in Quivira Big Salt Marsh

Under current TSS conditions and assuming a 95% trapping efficiency, Quivira Little Salt Marsh retains 69,056 tons of sediment per year and Quivira Big Salt Marsh retains 7,503 tons of sediment per year (Table 15).

Table 15. Current condition sediment retention in Quivira Little and Quivira Big Salt Marsh.

Parameter	Quivira Little LM050201	Quivira Big LM050601
Volume (acre-feet)	231	127
Retention Time (days)	2.92	21.7
Average TSS Concentration (mg/L)	92.6	136
Trapping Efficiency	95%	95%
Total Sediment Exported from Watershed (tons/year)	***72,690***	***7,898***
Current Sediment Exiting QNWR (tons/year)	***3,635***	***395***
Current Annual Sediment Retention (tons/year)	***69,056***	***7,503***
Current Daily Sediment Load (tons/day)*	***534***	***58***

*See Appendix B for Daily Load Calculation

TSS endpoints of 45.4 mg/L for Quivira Little Salt Marsh and 45.2 mg/L for Quivira Big Salt Marsh were developed using turbidity and Secchi depth data collected from 19 small lakes, as described in Kansas Biological Survey Report 120 (Wang et al., 2003), and a Secchi depth value of 70 cm which is detailed in the 2002 KDHE Lake and Wetland report as a “reasonably good threshold criteria for water clarity and turbidity versus recreational and aesthetic use support” (Appendix D). A 51% reduction in the sediment load going to Quivira Little Salt Marsh and a 67% reduction in the sediment load going to Quivira Big Salt Marsh is required in order for the marshes to fully support the Special Aquatic Life Use and to meet sediment portion of this TMDL (Table 16).

Table 16. Current Condition and TMDL for Quivira Little and Quivira Big Salt Marsh.

Parameter	Current Average Condition	TMDL	Percent Reduction
LM050201 Quivira Little Salt Marsh			
TSS (mg/L)	92.6	45.4	51%
Sediment Annual Load (tons/year)	72,690	35,639	51%
LM050601 Quivira Big Salt Marsh			
TSS (mg/L)	136	45.2	67%
Sediment Annual Load (tons/year)	7,898	2,625	67%

In order to improve the trophic condition of the Quivira Little Salt Marsh and the Quivira Big Salt Marsh from their hypereutrophic status, the desired endpoint will be to maintain summer chlorophyll *a* concentrations at or below 12 μg/L. Although the data suggests the marshes are nitrogen/phosphorus co-limited, reductions will be focused on total phosphorus as it is expected that practices implemented to reduce total phosphorus loading will also achieve reductions in total nitrogen loading to the watershed. A chlorophyll *a* endpoint of 12 μg/L will also ensure long-term protection to fully support Special Aquatic Life and Primary Contact Recreation class B uses within the marshes. Based on CNET reservoir eutrophication model (Appendix A), the total phosphorus entering Quivira Little Salt Marsh and Quivira Big Salt Marsh must be reduced by 85% and 93%, respectively, to meet the chlorophyll *a* endpoint of 12 μg/L (Tables 17 & 18). This phosphorus reduction at the inflow to Quivira Little and Quivira Big will reduce the total phosphorus concentrations to 42 μg/L and 44 μg/L in the marshes, respectively. These reductions in total phosphorus concentrations are expected to reduce the chlorophyll *a* concentrations by 89% in the Quivira Little Salt Marsh and 92% in Quivira Big Salt Marsh to 12 μg/L. Achievement of the endpoint indicates loads are within the loading capacity of the lake, the water quality standards are attained, and full support of the designated uses of the marshes has been achieved.

Table 17. Quivira Little Salt Marsh current average condition and TMDL based on CNET.

Quivira Little Salt Marsh	Current Avg. Condition	TMDL	Reduction
Total Phosphorus – Annual Load (lbs/year)	22,788	3,323	85%
Total Phosphorus – Daily Load* (lbs/day)	168	24.4	85%
Total Phosphorus – Lake Concentration (μg/L)	230	42	82%
Chlorophyll *a* Concentration (μg/L)	110	12	89%

*****See Appendix B for Daily Load Calculations

Table 18. Quivira Big Salt Marsh current average condition and TMDL based on CNET.

Quivira Big Salt Marsh	Current Avg. Condition	TMDL	Reduction
Total Phosphorus – Annual Load (lbs/year)	3,606	205	93%
Total Phosphorus – Daily Load* (lbs/day)	26.5	1.97	93%
Total Phosphorus – Lake Concentration (μg/L)	310	44	86%
Chlorophyll *a* Concentration (μg/L)	158	12	92%

*****See Appendix B for Daily Load Calculations

3. SOURCE INVENTORY AND ASSESSMENT

Point Sources: There are eight NPDES permitted facilities in the Quivira Little Salt Marsh watershed and one NPDES permitted facility in the Quivira Big Salt Marsh watershed (Table 19). Heft & Sons, LLC is a ready-mix concrete plant utilizing an earthen pit for wastewater control and would only contribute a nutrient or sediment load under extreme precipitation or flooding events. The Cheyenne Plains Gas Pipeline uses an amine/water solution to strip natural gas of carbon dioxide and hydrogen disulfide; however, pipeline liquids generated in the process are treated in scrubbers and then collected in a double synthetic lined storage tank before they are shipped offsite for proper disposal, hence, there is no contribution to the nutrient or sediment load from this facility. The Northern Natural Gas Company operates a natural gas compressor station that discharges wastewater to a one-cell double lined lagoon that is prohibited from discharging and would only contribute a nutrient or sediment load under extreme precipitation or flooding events. Four facilities, including the City of Hudson, the lone permittee in the Quivira Big watershed, are municipal non-overflowing lagoon systems that are prohibited from discharging and would only contribute a nutrient or sediment load under extreme precipitation or flooding events. The City of Bucklin and the City of St. John, located in the Quivira Little watershed, are permitted to discharge to the Rattlesnake Creek watershed and a wasteload allocation for total phosphorus and total suspended solids have been calculated that will apply at KDHE sampling station LM050201. Total phosphorus limits are not established in either of the discharge permits for the City of St. John and the City of Bucklin, consequently, wasteloads were calculated using the design/permitted flow established in the discharge permits and a total phosphorus concentration of 2 mg/L which is the typical phosphorus concentration observed in the effluent of lagoon systems in Kansas. The resulting total phosphorus wasteload allocations are 1.9 lbs/day for the City of Bucklin and 3.4 lbs/day for the City of St. John.

The NPDES permits for both the City of St. John and the City of Bucklin include a requirement for monitoring total suspended solids when discharging with a monthly average limit of 80 mg/L. Between January 1, 2008 and January 28, 2013 the City of Bucklin reported discharging thirty-five days with an average TSS concentration of 166 mg/L while the City of St. John reported discharging sixteen days with an average TSS concentration of 151 mg/L for the same time period. Total suspended solids wasteload allocations for both the City of Bucklin and the City of St. John were calculated based on a TSS concentration of 80 mg/L and the design/permitted flow established in the discharge permits resulting in a total suspended solids wasteload allocation at LM050201 of 76.9 lbs/day and 137 lbs/day for the cities of Bucklin and St. John, respectively (Table 19).

Table 19. NPDES permitted facilities in the Quivira Little Salt Marsh watershed.

Name	NPDES Permit #	State Permit #	Type	Receiving Stream	Expiration Date	Design Capacity (MGD)	Avg TSS (mg/L)	Avg TP (mg/L)	TP WLA (lbs/day)	Sediment WLA (lbs/day)
Quivira Little NPDES Permitted Facilities										
City of Bucklin	KS0026166	M-AR13-OO01	3 Cell Lagoon	Rattlesnake Cr via W Fork Rattlesnake Cr	6/30/17	0.115	166	No Data	1.9	76.9
City of Mullinville	KSJ000446	M-AR63-NO01	Non-Overflowing	N/A	1/31/13	N/A	N/A	N/A	N/A	0
Heft & Sons, LLC	KSG110115	I-AR38-PR01	Earthen Settling Basin	N/A	9/30/17	N/A	N/A	N/A	N/A	0
City of Greensburg	KSJ000460	M-AR38-NO01	Non-Overflowing	N/A	12/31/13	N/A	N/A	N/A	N/A	0
Cheyenne Plains	KSJ000625	I-AR63-NP01	Non-Overflowing Lined Pond	N/A	12/31/13	N/A	N/A	N/A	N/A	0
City of Macksville	KSJ000443	M-AR57-NO01	Non-Overflowing	N/A	7/31/13	N/A	N/A	N/A	N/A	0
Northern Natural Gas Co.	KSJ000518	I-AR57-NO01	Non-Overflowing	N/A	1/31/13	N/A	N/A	N/A	N/A	0
City of St. John	KS0027791	M-AR77-OO01	3 Cell Lagoon	Rattlesnake Cr	6/30/17	0.204	151	No Data	3.4	137
Quivira Big NPDES Permitted Facilities										
City of Hudson	KSJ000451	M-AR47-NO01	Non-Overflowing	N/A	10/31/13	N/A	N/A	N/A	N/A	0

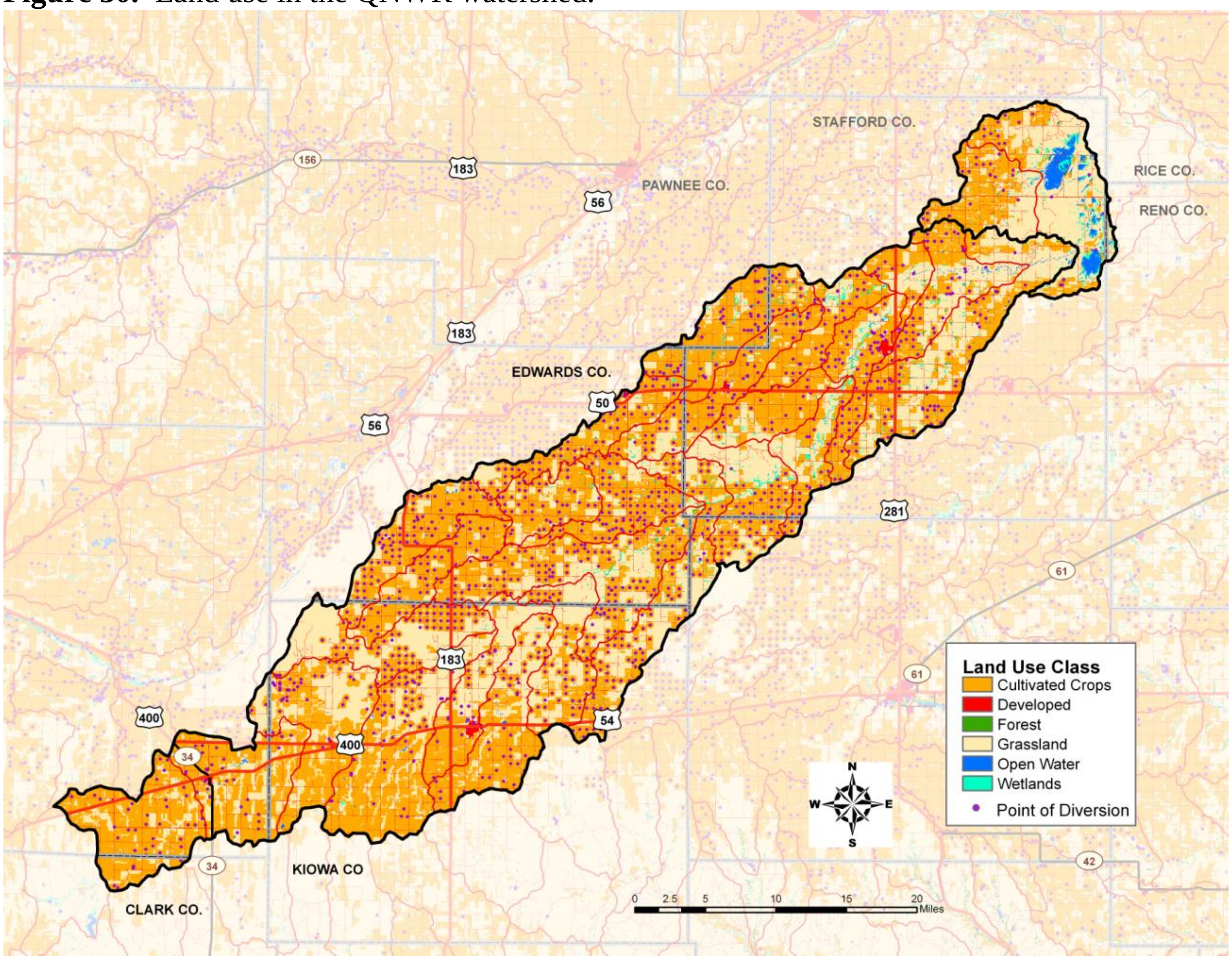
Nonpoint Sources and Background: Siltation and eutrophication in the marshes is due to nonpoint loading of nutrient laden sediment from the Rattlesnake Creek corridor and from the decomposition of the abundant macrophyte and algal communities in the marsh lands themselves. This recycling of nutrients combined with the incoming nutrient load from the creek allows for excessive growth of plant and algae communities. The eventual decomposition of these communities release nutrients back into the system and leave the decayed organic matter behind as silt which contributes to the sedimentation of the marshes. Although there are many factors that affect the vertical accretions rates in marshes, freshwater, created marshes have been reported to have sediment accumulation rates ranging from 12.4 to 69.7 kg/m^2-yr (Harter, Mitsch 2003).

Waterfowl, shorebirds, sandhill cranes, bald eagles, whooping cranes, and Mississippi kites travel through the Quivira National Wildlife Refuge during their migration. Their waste, as well as waste from numerous other types of wildlife, increases the levels of phosphorus in the marsh (KDHE, 2000). The migratory wildlife also resuspend the phosphorus containing sediment while they are feeding in the marshes. Leaf litter from the forested riparian areas in the watershed and from the tree life within QNWR may also be contributing to the nutrient load. Geological formations contain small amounts of phosphorus (up to 0.5% of total weight) and may contribute to phosphorus loads (KDHE, 2000).

Land Use: The predominant land uses in the Quivira Little Salt Marsh watershed are cultivated cropland (60%) and grassland (34%), according to the 2001 National Land Cover Data. Together they account for 94% of the total land area in the watershed with the remaining land area composed of developed land (4.2%), wetlands (0.92%), open water (0.24%), and forest (0.16%) (Figure 30). Grassland and cultivated cropland are also the primary land uses in the Quivira Big Salt Marsh watershed at 54% and 31%, respectively, accounting for 85% of the total land area in the watershed. The remaining land use in the Quivira Big watershed are made up of open water (6.8%), developed (3.9%), wetlands (3.7%) and forest (0.6%).

During precipitation runoff events, the cultivated cropland in the watershed may contribute to the siltation and nutrient loads in the marshes. Grasslands could also contribute to the siltation and nutrient load during high flow events, particularly on livestock grazing lands located in the riparian areas of the watershed.

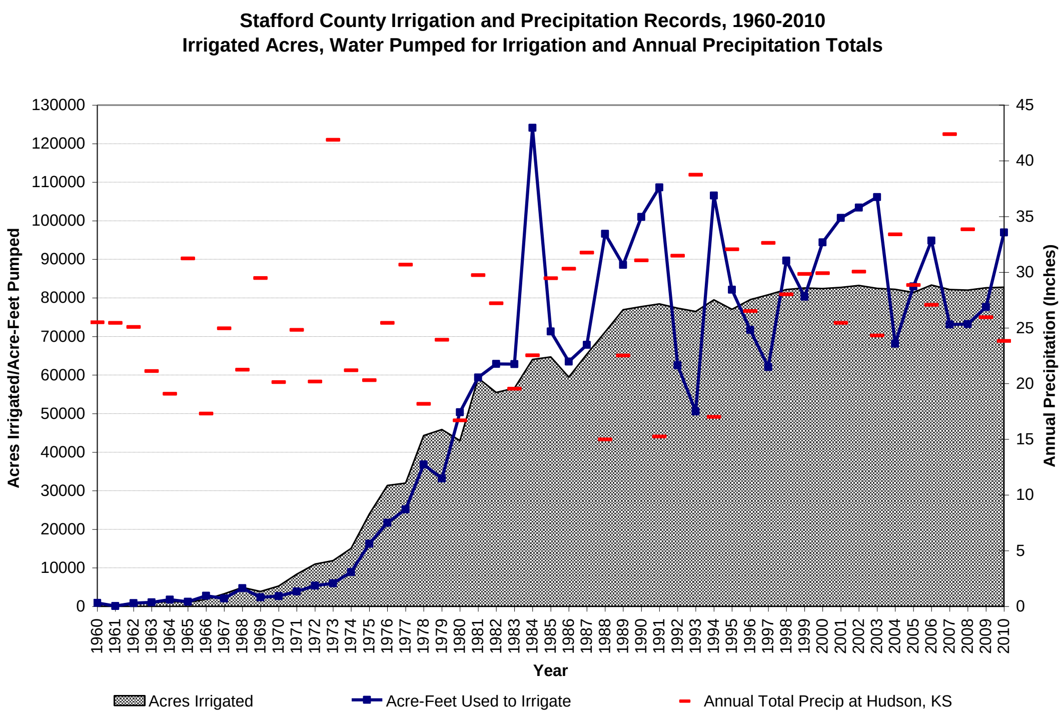
Figure 30. Land use in the QNWR watershed.



Points of Diversion and Irrigation: The Quivira Little Salt Marsh watershed has 1,160 active points of diversion with over 90% of the points identified as for use in irrigation. Moving northeastward through the watershed there is a decline in the number of points of diversion largely due to the increase in salinity resulting in water that is unsuitable for most uses. The Quivira Big Salt Marsh watershed however does have 37 active points of diversion, including three surface water rights to the flow in Rattlesnake Creek owned by the U.S. Department of Interior and managed by the U.S. Fish & Wildlife Service. These rights are used to maintain water levels in Quivira National Wildlife Refuge and, although they authorize nearly 44,000 acre-feet per year for diversion, the average diversion for years in which KDHE sampled QWNR was about 4,070 acre-feet per year.

The Stafford County irrigation record in Figure 31 displays the number of acres irrigated and the acre-feet reported as groundwater pumped for the purpose of irrigation from 1960-2010. The number of acres irrigated in the county began to stabilize at about 82,000 in 1998 while the acre-feet pumped is reflective of annual rainfall totals in the area.

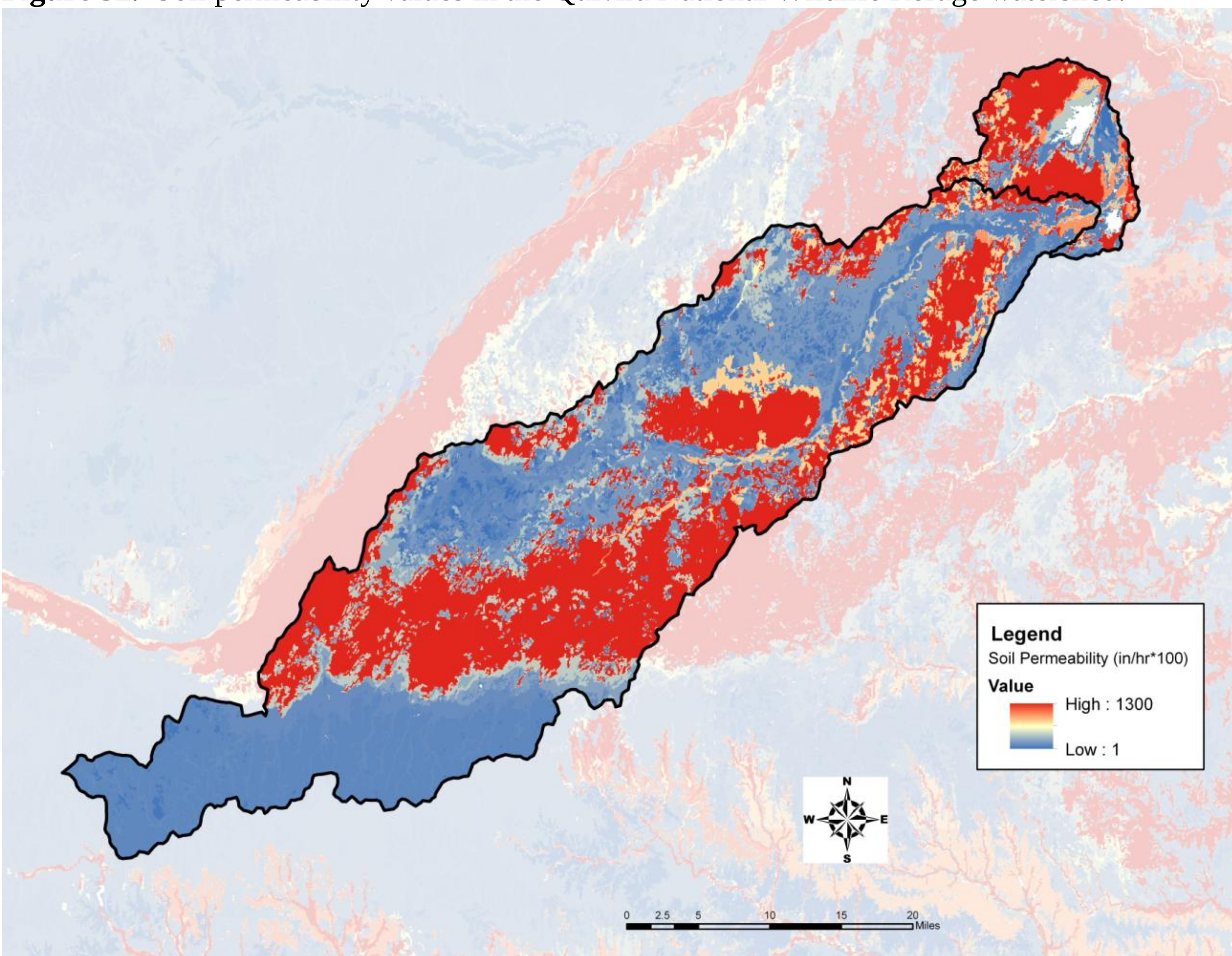
Figure 31. Irrigation and precipitation in Stafford County, Kansas, 1960-2010.



Excessive irrigation in the watershed may decrease the base flow in Rattlesnake Creek thereby diminishing the stream's ability to naturally dilute the nutrient and sediment loading in QNWR.

Contributing Runoff: The Quivira Little Salt Marsh and Quivira Big Salt Marsh watersheds have mean soil permeability values of 6.22 and 8.84 inches/hour, respectively (Figure 32). The permeability values range from 0.01 to 13.00 inches/hour according to NRCS STATSGO database, however, about 10% of the Quivira Little Salt Marsh watershed has a permeability value less than 2.29 inches/hour while nearly 70% of the watershed has a very high permeability value of 13.0 inches/hour or greater. Almost 74% of the Quivira Big Salt Marsh watershed has a permeability value of 13.0 inches/ hour and 8% of the watershed has a permeability value of 8.10 inches/hour or less. According to a USGS open-file report (Juracek, 2000), the threshold soil-permeability values are set at 3.43 inches/hour for very high, 2.86 inches/hour for high, 2.29 inches/hour for moderate, 1.71 inches/hour for low, 1.14 inches/hour for very low, and 0.57 inches/hour for extremely low soil-permeability. Runoff is primarily generated as infiltration excess when soil profiles become saturated and produce excess overland flow due to rainfall intensities that are greater than soil permeability.

Figure 32. Soil permeability values in the Quivira National Wildlife Refuge watershed.



Livestock Waste Management Systems: There are twenty-eight certified or permitted confined animal feeding operations (CAFOs) within the Quivira Little Salt Marsh watershed. Ten of the twenty-eight are large enough to require an NPDES permit and animals in the watershed total 49,377 (Appendix C). These permitted or certified livestock facilities have waste management systems designed to minimize runoff entering their operation or detaining runoff emanating from their facilities. In addition, they are designed to retain a 25-year, 24-hr rainfall/runoff event as well as an anticipated two weeks of normal wastewater from their operations. Typically, this rainfall event coincides with stream flow occurring less than 1-5% of the time. There are no certified or permitted CAFOs located in the Quivira Big watershed. It is likely that there are some smaller, unregistered livestock operations in the area and, depending on their proximity to Rattlesnake Creek, runoff from feedlots and grazing lands may be contributing to the nutrient impairment in the marshes.

On-Site Waste Systems: The Quivira National Wildlife Refuge watershed is a rural agricultural area that lies across Ford, Kiowa, Edwards and Stafford Counties. It can be assumed that all of the rural residences in the watershed are not connected to public sewer systems and, according to the 1990 U.S. Census, there are 1,722, 344, 603 and 848 septic systems in Ford, Kiowa, Edwards and Stafford Counties, respectively. Failing on-site septic may contribute to the nutrient load in the watershed.

4. ALLOCATION OF POLLUTANT REDUCTION RESPONSIBILITY

Point Sources: There are two discharging point sources in the Quivira Little Salt Marsh watershed. A total suspended solids wasteload allocation and total phosphorus wasteload allocation will be established in this TMDL for the City of Bucklin and the City of St. John. Wasteload allocations for total suspended solids were developed based on the design/permitted flow and a TSS concentration of 80 mg/L, both of which are established in the respective discharge permits resulting in a TSS wasteload allocation of 14.0 tons/year for the City of Bucklin and 24.9 tons/year for the City of St. John for a total TSS wasteload allocation of 38.9 tons/year at LM050201 (Table 20). As both the City of Bucklin and City of St. John are lagoon systems that intermittently discharge, a total phosphorus concentration of 2 mg/L and the design/permitted flow detailed in the discharge permits was used to develop a total phosphorus wasteload allocation of 1,246 lb/year for the City of St. John and 702 lb/year for the City of Bucklin totaling 1,948 lbs/year at LM050201. There are no discharging point sources in the Quivira Big Salt Marsh watershed, hence, the wasteload allocation for total suspended solids and total phosphorus is zero at LM050601.

Table 20. Wasteload allocations for Quivira Little Salt Marsh (LM050201)

Facility	NPDES Permit Number	Total Phosphorus		Sediment	
		lbs/day	lbs/year	lbs/day	tons/year
City of Bucklin	KS0026166	1.9	702	76.9	14.0
City of St. John	KS0027791	3.4	1,246	137	24.9

Nonpoint Sources: Sediment and nutrient loading comes predominantly from nonpoint source pollution and, based on the soil characteristics of the watershed, overland runoff can easily carry sediment and nutrient loads to Rattlesnake Creek and into the marsh itself. Fertilized cropland and pasture used for livestock grazing may exacerbate the loading especially under runoff conditions. The abundant macrophyte and algal communities in the marsh also contribute to the siltation and nutrient loads as they undergo decomposition.

Sediment TMDLs were calculated using target TSS concentrations of 45.4 mg/L and 45.2 mg/L in Quivira Little and Quivira Big Salt Marshes, respectively (Appendix D). This reduction in TSS concentration results in a 51% reduction in sediment load for a TMDL of 35,639 tons/year in Quivira Little Salt Marsh and a 67% reduction in sediment load for a TMDL of 2,625 tons/year in Quivira Big Salt Marsh (Tables 21 & 22).

Sediment loads were calculated on an annual basis with the translating daily load calculation displayed in Appendix B. The wasteload allocation was calculated on a daily basis and converted to an annual basis by multiplying by 365. Because sediment wasteloads generated by the two lagoon facilities in the Quivira Little watershed are seen at LM050201 and in order to align daily load calculations, the wasteload allocation of 0.107 tons/day of sediment has been included as part of the sediment nonpoint source load as an assimilated wasteload allocation in Table 21.

Table 21. Sediment TMDL in Quivira Little Salt Marsh.

Quivira Little Salt Marsh (LM050201) Sediment TMDL		
Description	**Allocations (tons/year)**	**Allocations (tons/day)***
Sediment Nonpoint Source Load & Assimilated Wasteload Allocation	32,075	235.8
Sediment Margin of Safety	3,564	26.2
Sediment TMDL	35,639	262

*See Appendix B for Daily Load Calculations

Table 22. Sediment TMDL in Quivira Big Salt Marsh.

Quivira Big Salt Marsh (LM050601) Sediment TMDL		
Description	**Allocations (tons/year)**	**Allocations (tons/day)***
Sediment Nonpoint Source Load	2,362	17.37
Sediment Margin of Safety	263	1.93
Sediment TMDL	2,625	19.3

*See Appendix B for Daily Load Calculations

The total phosphorus allocations for Quivira Little (Table 23) and Quivira Big (Table 24) were generated with the CNET lake eutrophication model using the current conditions in the marshes. The Quivira Big Salt Marsh CNET model includes an assignment for the inflow from Quivira Little via the canal system at 3.25 cfs and a concentration of 230 mg/L TP and inflow of 4.00 cfs from the watershed was entered to reflect the Quivira Big inflow of 7.25 detailed in the 2001 USGS report on the water balance in the marshes. Based on the models (Appendix A), an 85% reduction in the total phosphorus entering Quivira Little Salt Marsh and a 93% reduction in the total phosphorus entering Quivira Big Salt Marsh is necessary to achieve the TMDL endpoint of an in marsh chlorophyll *a* concentration of 12 μg/L. This reduction in total phosphorus in the inflow to the marshes should result in the reduction of total phosphorus concentrations in Quivira Little and Quivira Big to 42 μg/L and 44 μg/L, respectively.

The CNET models present loads on an annual basis with the translating daily load calculation displayed in Appendix B. The wasteload allocation was calculated on a daily basis and converted to an annual basis by multiplying by 365. Because total phosphorus wasteloads generated by the two lagoon facilities in the Quivira Little watershed are seen at LM050201 and in order to align daily load calculations, the wasteload allocation of 5.3 lbs/day of total phosphorus has been included as part of the phosphorus nonpoint source load as an assimilated wasteload allocation in Table 23.

Table 23. Total Phosphorus TMDL for Quivira Little Salt Marsh.

Quivira Little Salt Marsh (LM050201) Total Phosphorus TMDL		
Description	**Allocations (lbs/year)**	**Allocations (lbs/day)***
Total Phosphorus Atmospheric Load	63	0.46
Total Phosphorus Nonpoint Source Load and Assimilated Wasteload Allocation	2,928	21.5
Total Phosphorus Margin of Safety	332	2.44
Total Phosphorus TMDL	3,323	24.4

*See Appendix B for Daily Load Calculations

Table 24. Total Phosphorus TMDL for Quivira Big Salt Marsh.

Quivira Big Salt Marsh (LM050601) Total Phosphorus TMDL		
Description	**Allocations (lbs/year)**	**Allocations (lbs/day)***
Total Phosphorus Atmospheric Load	35	0.25
Total Phosphorus Nonpoint Source Load Allocation	205	1.52
Total Phosphorus Margin of Safety	27	0.197
Total Phosphorus TMDL	267	1.97

*See Appendix B for Daily Load Calculations

Defined Margin of Safety: The margin of safety provides some hedge against the uncertainty of variable annual total suspended solids loads and total phosphorus loads. Therefore, the margin of safety is explicitly set at 10% of the loading capacity of total suspended solids and total phosphorus which compensates for the lack of knowledge about the relationship between the allocated loadings and the resulting water quality. The margin of safety is expressed in Tables 21, 22, 23, & 24.

State Water Plan Implementation Priority: Because both the Quivira Little Salt Marsh and the Quivira Big Salt Marsh are considered outstanding natural resource waters, this TMDL will be a High Priority for implementation.

Unified Watershed Assessment Priority Ranking: This watershed lies within the Rattlesnake Creek Basin (HUC 8: 11030009) with a priority ranking of 15 (High Priority for restoration work).

Priority HUC 12: The Spreadsheet Tool for Estimating Pollutant Load (STEPL) was utilized to identify priority HUC 12s within the watershed. STEPL is a simple watershed model that provides both agricultural and urban annual average sediment and nutrient simulations as well as implementation evaluation of best management practices. Preliminary STEPL results for sediment are illustrated in Figure 33. Based on these results initial priorities should focus on the top three HUC 12 subwatersheds in Table 25 for the reduction of sediment. The total phosphorus load will also be reduced as the sediment load diminishes due total phosphorus' proclivity for adsorbing to sediment particles.

Figure 33. STEPL results for sediment loading the QNWR watershed.

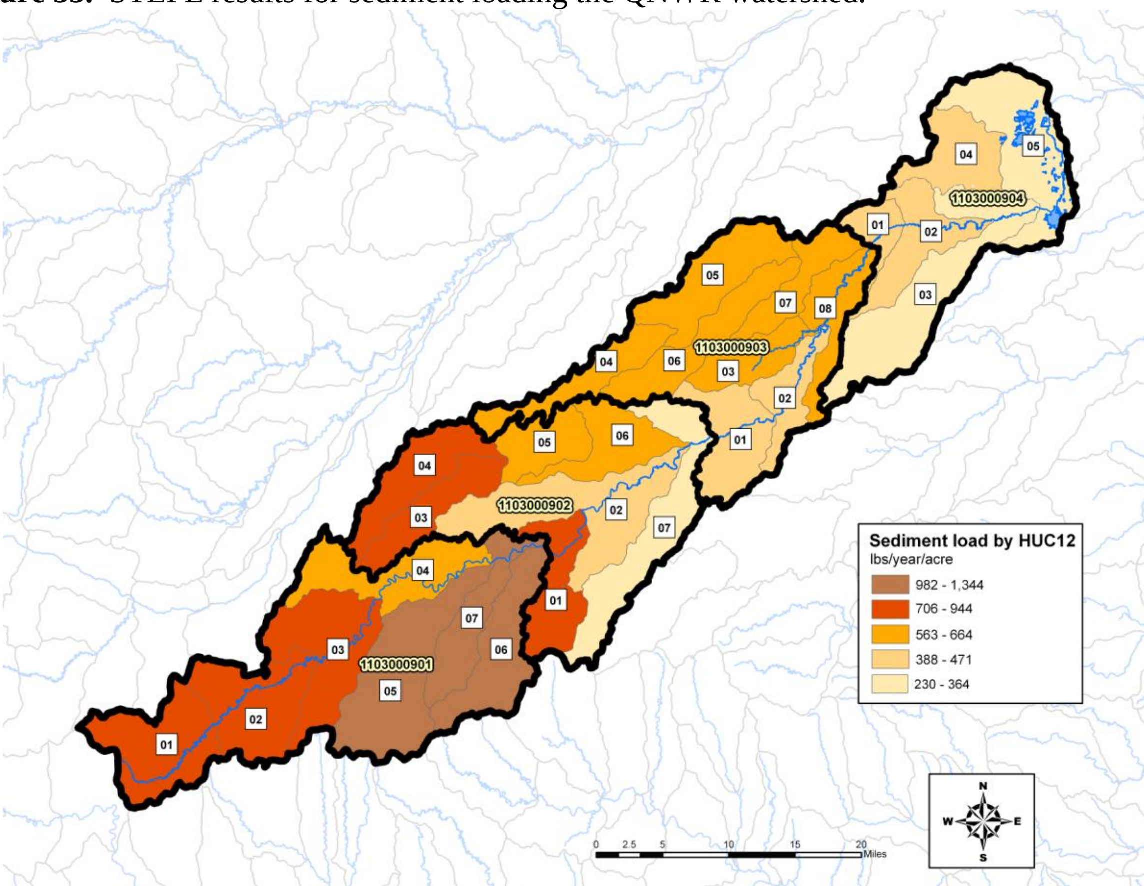


Table 25. Priority HUC 12 subwatersheds as identified through STEPL.

HUC 12	Acres	Sediment Load (tons/year)	Sediment Acre lbs/acre/year	Preliminary Implementation Priority Ranking
110300090106	30,926	20,785	1344	1
110300090105	47,609	29,535	1241	2
110300090107	22,137	10,865	982	3
110300090103	37,453	17,674	944	4
110300090101	35,926	16,124	898	5
110300090102	34,650	13,628	787	6
110300090203	20,915	7,517	719	7
110300090201	23,225	8,198	706	8
110300090206	21,562	7,162	664	9
110300090205	17,559	5,649	643	10
110300090204	25,733	8,175	635	11
110300090303	17,138	5,337	623	12
110300090305	30,571	9,411	616	13
110300090307	16,909	5,121	606	14
110300090104	30,767	8,981	584	15
110300090304	21,655	6,136	567	16
110300090306	25,873	7,320	566	17
110300090308	20,111	5,660	563	18
110300090202	47,617	11,208	471	19
110300090401	9,742	2,285	469	20
110300090302	15,971	3,510	440	21
110300090404	22,744	4,455	392	22
110300090402	22,404	4,388	392	23
110300090301	26,307	5,104	388	24
110300090207	39,925	7,260	364	25
110300090403	49,075	8,827	360	26
110300090405	37,354	4,296	230	27

5. IMPLEMENTATION

Desired Implementation Activities: There is good potential that agricultural best management practices will improve the condition of Quivira Little Salt Marsh and Quivira Big Salt Marsh. Some of the recommended agricultural practices are as follows:

1. Maintain conservation tillage and contour farming to minimize cropland erosion.
2. Promote and adopt continuous no-till cultivation to increase the amount of water infiltration and minimize cropland soil erosion.
3. Install grass buffer strips along streams and drainage channels in the watershed.
4. Reduce activities within riparian areas.
5. Implement nutrient management plans to manage manure land applications and runoff potential.
6. Adequately manage fertilizer utilization in the watershed and implement runoff control measures.

Implementation Programs Guidance:

NPDES and State Permits – KDHE

a. NPDES and state permits for facilities in the watershed will be renewed in 2012 and 2013 with continued TSS monitoring and any appropriate permit conditions that work to reduce TSS loading to Quivira Little & Quivira Big Salt Marsh.

Watershed Management Program – KDHE

a. Support selected Section 319 project activities including demonstration projects and outreach efforts dealing with erosion and sediment control.

Water Resource Cost Share and Nonpoint Source Pollution Control Programs – KDA, Division of Conservation

a. Apply conservation farming practices and/or erosion control structures, including no-till, terraces and contours, sediment control basins and constructed wetlands.
b. Provide sediment control practices to minimize erosion and sediment.
c. Re-evaluate nonpoint source pollution control methods.

Riparian Protection Program – KDA, Division of Conservation

a. Establish, protect or re-establish natural riparian systems, including vegetative filter strips and streambank vegetation.
b. Develop riparian restoration projects.

Buffer Initiative Program – KDA, Division of Conservation

a. Install grass buffer strips near streams.
b. Leverage Conservation Reserve Enhancement Program to hold riparian land out of production.

Time Frame for Implementation: Implementation of abatement practices and rural runoff management should commence in 2013 and should continue through 2016. Additional implementation may be required over 2017 to 2021 to achieve the endpoints of this TMDL.

Targeted Participants: Primary participant for implementation will be agricultural producers and stakeholders within the Quivira National Wildlife Refuge watershed.

Milestones for 2016: In accordance with the TMDL development schedule for the State of Kansas, the year 2016 marks the next cycle of 303(d) activities in the Lower Arkansas Basin. At that point in time, monitoring data from Quivira Little Salt Marsh and Quivira Big Salt Marsh will be reexamined to confirm the impaired status of the lake and the suggested background concentration. Should the cause of impairment remain, source assessment, allocation and implementation activities may begin.

Delivery Agents: The primary delivery agents for program participation will be the Kansas Department of Health and Environment, the Kansas Department of Wildlife, Parks and Tourism, the U.S. Fish and Wildlife Service, and the Kansas Department of Agriculture, Division of Conservation.

Reasonable Assurances:
Authorities: The following authorities may be used to direct activities in the watershed to reduce pollutants and to assure allocations of pollutant to point and nonpoint sources can be attained.

1. K.S.A. 65-171d empowers the Secretary of KDHE to prevent water pollution and to protect the beneficial uses of the waters of the state through required treatment of sewage and established water quality standards and to require permits by persons having a potential to discharge pollutants into the waters of the state.

2. K.S.A. 2-1915 empowers the State Conservation Commission to develop programs to assist the protection, conservation and management of soil and water resources in the state, including riparian areas.

3. K.A.R. 28-16-69 to 71 implements water quality protection by KDHE through the establishment and administration of critical water quality management areas on a watershed basis.

4. K.S.A 75-5657 empowers the State Conservation Commission to provide financial assistance for local project work plans developed to control nonpoint source pollution.

5. K.S.A. 82a-901, et. seq. empowers the Kansas Water Office to develop a state water plan directing the protection and maintenance of surface water quality for the waters of the state.

6. K.S.A. 82a-951 creates the State Water Plan Fund to finance the implementation of the Kansas Water Plan, including selected Watershed Restoration and Protection Strategies.

7. The Kansas Water Plan and the Lower Arkansas Basin Plan provide the guidance to state agencies to coordinate programs intent on protecting water quality and to target those programs to geographic areas of the state for high priority in implementation.

8. K.S.A. 32-807 authorizes the Kansas Department of Wildlife and Parks to manage lake resources.

Funding: The State Water Plan Fund annually generates $16-18 million and is the primary funding mechanism for implementing water quality protection and pollutant reduction activities in the state through the *Kansas Water Plan*. The state water planning process, overseen by the Kansas Water Office, coordinates and directs programs and funding toward watersheds and water resources of highest priority. Typically, the state allocates at least 50% of the fund to programs supporting water quality protection. Additionally, $2 million has been allocated between the State Water Plan Fund and EPA 319 funds to support implementation of Watershed Restoration and Protection Strategies. This watershed and its TMDL are a **High** priority consideration and should receive funding.

Effectiveness: Nutrient and sediment control has been proven effective through conservation tillage, contour farming and the use of grass waterways and buffer strips. In addition, the proper implantation of comprehensive livestock waste management plans has proven effective at reducing nutrient runoff associated with livestock facilities. The key to success will be widespread utilization of conservation farming and proper livestock waste management within the watershed cited in this TMDL.

6. MONITORING

KDHE will continue its 3-year sampling schedule in order to assess the TSS impairment in Quivira Little Salt Marsh and Quivira Big Salt Marsh. Based on these sampling results, the status of the 303(d) listing will be evaluated in 2022.

7. FEEDBACK

Public Notice: An active Internet Web site was established at www.kdheks.gov/tmdl/ to convey information to the public on the general establishment of TMDLs and specific TMDLs for the Lower Arkansas Basin.

Public Hearing: A Public Hearing was held on September 21, 2012 in Wellington to receive comments on this TMDL.

Basin Advisory Committee: The Lower Arkansas River Basin Advisory Committee met to discuss these TMDLs on May 31, 2012 in Hutchinson and September 12, 2012 in Halsted.

Milestones Evaluation: In accordance with the TMDL development schedule for the State of Kansas, the year 2016 marks a future cycle of 303(d) activities in the Lower Arkansas Basin. At that point in time, sample data from Quivira Little Salt Marsh and Quivira Big Salt Marsh will be reexamined to assess improved conditions in the marshes. Should the impairment remain adjustments to source assessment, allocation, and implementation activities may occur.

Consideration for 303d Delisting: Quivira Little Salt Marsh and Quivira Big Salt Marsh will be evaluated for delisting under Section 303d, based on the monitoring data over 2012-2021. Therefore, the decision for delisting will come about in the preparation of the 2022-303d list. Should modifications be made to the applicable water quality criteria during the implementation period, consideration for delisting, desired endpoints of this TMDL and implementation activities may be adjusted accordingly.

Incorporation into Continuing Planning Process, Water Quality, Management Plan and the Kansas Water Planning Process: Under the current version of the Continuing Planning Process, the next anticipated revision would come in 2012. Recommendations of this TMDL will be considered in the Kansas Water Plan implementation decisions under the State Water Planning Process for Fiscal Years 2012-2021.

Developed 7/16/13

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Appendix A. CNET Eutrophication Model for Quivira Little Salt Marsh and Quivira Big Salt Marsh.

Inputs – Quivira Little

Parameter	Input Value (Current)
Drainage Area (km^2)	2807
Precipitation (m/yr)	0.612
Evaporation (m/yr)	1.58
Unit Runoff (m/yr)	0.016
Stream Total P (ppb)	230
Surface Area (km^2)	2.85
Max Depth (m)	1.0
Mean Depth (m)	0.1
Observed Phosphorus (ppb)	230
Observed Chlorophyll *a* (ppb)	110
Observed Secchi Depth (m)	0.20
Total P Model Number	8
Chl *a* Model Number	4

Outputs – Quivira Little

Parameter	Calculated Values
Stream Total P (ppb)	33
Total Inflow (hm^3/yr)	39
Total Outflow (hm^3/yr)	35
Predicted Marsh Phosphorus (ppb)	42
Predicted Marsh Chlorophyll *a* (ppb)	12
Predicted Marsh Secchi Depth (m)	0.41

Inputs – Quivira Big

Parameter	Input Value (Current)
Drainage Area (km^2)	267
Precipitation (m/yr)	0.612
Evaporation (m/yr)	1.58
Unit Runoff (m/yr)	0.016
Stream Total P (ppb)	230
Canal Flow (hm^3/yr)	2.79
Canal Total P Conc (ppb)	230
Surface Area (km^2)	1.57
Max Depth (m)	1.0
Mean Depth (m)	0.1
Observed Phosphorus (ppb)	310
Observed Chlorophyll *a* (ppb)	158
Observed Secchi Depth (m)	0.20
Total P Model Number	8
Chl *a* Model Number	4

Outputs – Quivira Big

Parameter	Calculated Values
Stream Total P (ppb)	15
Total Inflow (hm^3/yr)	5.1
Total Outflow (hm^3/yr)	2.6
Predicted Marsh Phosphorus (ppb)	44
Predicted Marsh Chlorophyll *a* (ppb)	12
Predicted Marsh Secchi Depth (m)	0.42

Quivira Little CNET

RESERVOIR EUTROPHICATION MODELING WORKSHEET — TITLE -> Quivira Little — Based on CNET.WK1 VERSION 1.0

VARIABLE	UNITS	Current	LC
WATERSHED CHARACTERISTICS...	drop down select unit - conversion is automatic	Latitude	38
Drainage Area	km2	2807	2807
Precipitation	m/yr	0.612	0.612
Evaporation	m/yr	1.58	1.58
Unit Runoff	m/yr	0.016	0.016
Stream Total P Conc.	ppb	230	33
Stream Ortho P Conc.	ppb	46	11
Atmospheric Total P Load	kg/km2-yr	10	10
Atmospheric Ortho P Load	kg/km2-yr	0	0
POINT SOURCE CHARACTERISTICS...			
Flow	hm3/yr	0.000	0.000
Total P Conc	ppb	0	0
Ortho P Conc	ppb	0	0
RESERVOIR CHARACTERISTICS...			
Surface Area	km2	2.85	2.85
Max Depth	m	1.0	1.0
Mean Depth	m	0.1	0.1
Non-Algal Turbidity (1/m)	Dzialowski	3.20	0.91
Mean Depth of Mixed Layer	m	0.01	0.01
Mean Depth of Hypolimnion	m	0.10	0.10
Observed Phosphorus	ppb	230	42
Observed Chl-a	ppb	110	12
Observed Secchi	m	0.20	0.7
MODEL PARAMETERS...			
BATHTUB Total P Model Number	(1-8)	8	8
BATHTUB Total P Model Name		TP ONLY	
BATHTUB Chl-a Model Number	(2,4,5)	4	4
BATHTUB Chl-a Model Name		P-LIN	
Beta = 1/S vs. C Slope (m2/mg)	Default	0.0455	0.1190
P Decay Calibration (normally =1)		1	1
Chlorophyll-a Calib (normally = 1)		1	1
Chla Temporal Coef. of Var.		0.35	0.35
Chla Nuisance Criterion	ppb	12	12
WATER BALANCE...			
Precipitation Flow	hm3/yr	1.74	1.74
NonPoint Flow	hm3/yr	37.69	37.69
Point Flow	hm3/yr	0.00	0.00
Total Inflow	hm3/yr	39	39
Evaporation	hm3/yr	4.5	4.5
Outflow	hm3/yr	35	35

VARIABLE	UNITS	Current	LC
AVAILABLE P BALANCE...			
Precipitation Load	kg/yr	29	29
NonPoint Load	kg/yr	10330	1482
Point Load	kg/yr	0	0
Total Load	b	10358	1511
Sedimentation	kg/yr	1496	41
Outflow	kg/yr	8863	1469
PREDICTION SUMMARY...			
P Retention Coefficient	-	0.144	0.027
Mean Phosphorus	ppb	254	42
Mean Chlorophyll-a	ppb	71	12
Algal Nuisance Frequency	%	100	41
Mean Secchi Depth	meters	0.16	0.43
Hypol. Oxygen Depletion A	mg/m2-d	2023	824
Hypol. Oxygen Depletion V	mg/m3-d	20228	8237
Organic Nitrogen	ppb	2018	494
Non Ortho Phosphorus	ppb	198	38
Chl-a x Secchi	mg/m2	11.0	5.1
Principal Component 1	-	4.05	2.75
Principal Component 2	-	0.75	0.57
	Observed	Pred	Target
Carlson TSI P	82.6	84.0	58.1
Carlson TSI Chl-a	76.7	72.4	54.8
Carlson TSI Secchi	83.2	86.8	72.1
OBSERVED / PREDICTED RATIOS...			
Phosphorus		0.91	1.00
Chlorophyll-a		1.55	1.02
Secchi		1.29	1.62
OBSERVED / PREDICTED T-STATISTICS...			
Phosphorus		-0.36	-0.01
Chlorophyll-a		1.61	0.07
Secchi		0.93	1.77

VARIABLE	UNITS	Current	LC
RESPONSE CALCULATIONS...			
Reservoir Volume	hm3	0.285	0.285
Residence Time	yrs	0.0082	0.0082
Overflow Rate	m/yr	12.3	12.3
Total P Availability Factor		1.00	1
Ortho P Availability Factor		0	0
Inflow Ortho P/Total P		0.199	0.196
Inflow P Conc	ppb	296.5	43.2
P Reaction Rate - Mods 1 & 8		0.2	0.0
P Reaction Rate - Model 2		0.3	0.0
P Reaction Rate - Model 3		0.2	0.0
1-Rp Model 1 - Avail P		0.856	0.973
1-Rp Model 2 - Decay Rate		0.794	0.956
1-Rp Model 3 - 2nd Order Fixed		0.832	0.967
1-Rp Model 4 - Canfield & Bach		0.694	0.876
1-Rp Model 5 - Vollenweider 19		0.917	0.917
1-Rp Model 6 - First Order Dec		0.992	0.992
1-Rp Model 7 - First Order Set		0.925	0.925
1-Rp Model 8 - 2nd Order Tp Or		0.856	0.973
1-Rp - Used		0.856	0.973
Reservoir P Conc	ppb	253.7	42.1
Gp		0.007	0.007
Bp	ppb	403.2	34.4
Chla vs. P, Turb, Flush	2	349.2	33.2
Chla vs. P Linear	4	71.0	11.8
Chla vs. P 1.46	5	262.3	19.0
Chla Used	ppb	71.0	11.8
m1 - Nuisance Freq Calc.		4.2	2.4
z		-4.906	0.228
r		0.000	0.389
w		0.380	0.929
x		0.000	0.410

ORTHO P LOADS...	UNITS	Current	LC	TOTAL P LOADS... BAF Override (KS) (see below)	OrP %	Current	LC
Precipitation	kg/yr	0.00	0	0	0%	29	29
NonPoint	kg/yr	2065.95	296	0	20%	10330	1482
Point	kg/yr	0.00	0	0	0%	0	0
Total	kg/yr	2065.95	296			10358	1511
Total	lbs/yr	4545.09	652			22788	3323

Quivira Big CNET

RESERVOIR EUTROPHICATION MODELING WORKSHEET TITLE -> Quivira Big

Based on CNET.WK1 VERSION 1.0

VARIABLE	UNITS	Current	LC
WATERSHED CHARACTERISTICS...	drop down select unit - conversion is automatic	Latitude	37
Drainage Area	km2	267	267
Precipitation	m/yr	0.612	0.612
Evaporation	m/yr	1.58	1.58
Unit Runoff	m/yr	0.016	0.016
Stream Total P Conc.	ppb	230	15
Stream Ortho P Conc.	ppb	46	3
Atmospheric Total P Load	kg/km2-yr	10	10
Atmospheric Ortho P Load	kg/km2-yr	0	0
POINT SOURCE CHARACTERISTICS...			
Flow from Canal	hm3/yr	2.790	2.790
Total P Conc	ppb	230.000	15.000
Ortho P Conc	ppb	0	0
RESERVOIR CHARACTERISTICS...			
Surface Area	km2	1.57	1.57
Max Depth	m	1.0	1.0
Mean Depth	m	0.1	0.1
Non-Algal Turbidity (1/m)	Dzialowski	2.79	0.91
Mean Depth of Mixed Layer	m	0.01	0.01
Mean Depth of Hypolimnion	m	0.10	0.10
Observed Phosphorus	ppb	310	47.0
Observed Chl-a	ppb	158	12.0
Observed Secchi	m	0.20	0.70
MODEL PARAMETERS...			
BATHTUB Total P Model Number	(1-8)	8	8
BATHTUB Total P Model Name		TP ONLY	
BATHTUB Chl-a Model Number	(2,4,5)	4	4
BATHTUB Chl-a Model Name		P-LIN	
Beta = 1/S vs. C Slope (m2/mg)	Default	0.0316	0.1190
P Decay Calibration (normally =1)		1	1
Chlorophyll-a Calib (normally = 1)		1	1
Chla Temporal Coef. of Var.		0.35	0.35
Chla Nuisance Criterion	ppb	12	12
WATER BALANCE...			
Precipitation Flow	hm3/yr	0.96	0.96
Watershed Flow	hm3/yr	1.37	1.37
Canal Flow	hm3/yr	2.79	2.79
Total Inflow	hm3/yr	5.1	5.1
Evaporation	hm3/yr	2.5	2.5
Outflow	hm3/yr	2.6	2.6

VARIABLE	UNITS	Current	LC
AVAILABLE P BALANCE...			
Precipitation Load	kg/yr	15.70	15.70
NonPoint Load	kg/yr	981.71	64.02
Point Load	kg/yr	641.70	41.85
Total Load	b	1639.11	121.57
Sedimentation	kg/yr	529.33	5.76
Outflow	kg/yr	1109.79	115.81
PREDICTION SUMMARY...			
P Retention Coefficient	-	0.323	0.047
Mean Phosphorus	ppb	420	44
Mean Chlorophyll-a	ppb	118	12
Algal Nuisance Frequency	%	100.0	45.7
Mean Secchi Depth	meters	0.15	0.42
Hypol. Oxygen Depletion A	mg/m2-d	2604	841
Hypol. Oxygen Depletion V	mg/m3-d	26037	8411
Organic Nitrogen	ppb	3051	506
Non Ortho Phosphorus	ppb	271.5	39.3
Chl-a x Secchi	mg/m2	18.1	5.2
Principal Component 1	-	4.33	2.78
Principal Component 2	-	0.90	0.57

	Observed	Pred	Target
Carlson TSI P	86.9	91.3	58.7
Carlson TSI Chl-a	80.3	77.4	55.2
Carlson TSI Secchi	83.2	87.0	72.5

	Current	LC
OBSERVED / PREDICTED RATIOS...		
Phosphorus	0.74	1.07
Chlorophyll-a	1.34	0.98
Secchi	1.30	1.66
OBSERVED / PREDICTED T-STATISTICS...		
Phosphorus	-1.12	0.25
Chlorophyll-a	1.08	-0.09
Secchi	0.97	1.87

VARIABLE	UNITS	Current	LC
RESPONSE CALCULATIONS...			
Reservoir Volume	hm3	0.157	0.157
Residence Time	yrs	0.0595	0.0595
Overflow Rate	m/yr	1.7	1.7
Total P Availability Factor		1.00	1
Ortho P Availability Factor		0	0
Inflow Ortho P/Total P		0.120	0.105
Inflow P Conc	ppb	620.8	46.0
P Reaction Rate - Mods 1 & 8		0.7	0.1
P Reaction Rate - Model 2		1.9	0.2
P Reaction Rate - Model 3		3.7	0.3
1-Rp Model 1 - Avail P		0.677	0.953
1-Rp Model 2 - Decay Rate		0.505	0.875
1-Rp Model 3 - 2nd Order Fixed		0.402	0.817
1-Rp Model 4 - Canfield & Bach		0.394	0.751
1-Rp Model 5 - Vollenweider 19		0.804	0.804
1-Rp Model 6 - First Order Dec		0.944	0.944
1-Rp Model 7 - First Order Set		0.627	0.627
1-Rp Model 8 - 2nd Order Tp Or		0.677	0.953
1-Rp - Used		0.677	0.953
Reservoir P Conc	ppb	420.3	43.9
Gp		0.003	0.003
Bp	ppb	805.2	36.4
Chla vs. P, Turb, Flush	2	749.6	35.9
Chla vs. P Linear	4	117.7	12.3
Chla vs. P 1.46	5	548.2	20.2
Chla Used	ppb	117.7	12.3
m1 - Nuisance Freq Calc.		4.7	2.4
z		-6.348	0.109
v		0.000	0.397
w		0.321	0.965
x		0.000	0.457

ORTHO P LOADS...	UNITS	Current	LC	TOTAL P LOADS... BAF Override (KS) (see below)	OrP %	Current	LC
Precipitation	kg/yr	0	0	0	0%	16	16
Watershed	kg/yr	196	13	0	20%	982	64
Canal	kg/yr	0	0	0	0%	642	42
Total	kg/yr	196	13			1639	122
Total	lbs/yr	432	28			3606	267

Appendix B. Conversion to Daily Loads as Regulated by EPA Region VII

The TMDL has estimated annual average loads for Total Suspended Solids (TSS) and Total Phosphorus (TP) that if achieved should meet the water quality targets. A recent court decision often referred to as the "Anacostia decision" has dictated that TMDLs include a "daily" load (Friend of the Earth, Inc v. EPA, et al.).

Expressing this TMDL in daily time steps could be misleading to imply a daily response to a daily load. To translate long-term averages to maximum daily load values, EPA Region 7 has suggested the approach described in the Technical Support Document for Water Quality Based Toxics Control (EPA/505/2-90-001)(TSD).

Maximum Daily Load (MDL) = (Long-Term Average Load) * $e^{[Z\sigma - 0.5\sigma^2]}$

where $\sigma^2 = \ln(CV^2 + 1)$

CV = Coefficient of variation = Standard Deviation / Mean

Z = 2.326 for 99th percentile probability basis

LTA= Long Term Average
ATM = Atmospheric Load
LA= Load Allocation
WLA = Wasteload Allocation
MOS= Margin of Safety

Parameter	LTA	CV	$e^{[Z\sigma - 0.5\sigma^2]}$	TMDL	ATM lbs/year	NonPoint LA + Assimilated WLA	MOS (10%)
Quivira Little TSS	35,639 tons/year	0.5	2.68	262 tons/day	N/A	235.8 tons/day	26.2 tons/day
Quivira Big TSS	2,625 tons/year	0.5	2.68	19.3 tons/day	N/A	17.37 tons/day	1.93 tons/day
Quivira Little TP	3,323 lbs/year	0.5	2.68	24.4 lbs/day	0.46 lbs/day	21.5 lbs/day	2.44 lbs/day
Quivira Big TP	267 lbs/year	0.5	2.68	1.97 lbs/day	0.25 lbs/day	1.52 lbs/day	0.197 lbs/day

Maximum Daily Load Calculation

Annual TSS Load = 35,639 tons/year (Quivira Little) and 2,625 tons/year (Quivira Big)

Maximum Daily TSS Load = [(35,639 tons/yr)/(365 days/yr)]*$e^{[2.326*(0.472)-0.5*(0.472)^2]}$
= 262 tons/day in Quivira Little
= [(2,625 tons/yr)/(365 days/yr)]*$e^{[2.326*(0.472)-0.5*(0.472)^2]}$
= 19.3 tons/day in Quivira Big

Annual TP Load = 3,323 lbs/year (Quivira Little) and 267 lbs/year (Quivira Big)

Maximum Daily TP Load = [(3,323 lbs/yr)/(365 days/yr)]*$e^{[2.326*(0.472)-0.5*(0.472)^2]}$
= 24.4 lbs/day in Quivira Little
= [(267 lbs/yr)/(365 days/yr)]*$e^{[2.326*(0.472)-0.5*(0.472)^2]}$
= 1.97 lbs/day in Quivira Big

Margin of Safety (MOS) for Daily Load

Annual TSS MOS = 3,564 tons/year (Quivira Little) and 262 tons/year (Quivira Big)

Daily TSS MOS = [(3,564 tons/yr)/(365 days/yr)]*$e^{[2.326*(0.472)-0.5*(0.472)^2]}$
= 26.2 tons/day in Quivira Little
= [(263 tons/yr)/(365 days/yr)]*$e^{[2.326*(0.472)-0.5*(0.472)^2]}$
= 1.93 tons/day in Quivira Big

Annual TP MOS = 332 lbs/yr (Quivira Little) and 27 lbs/year (Quivira Big)

Daily TP MOS = [(332 lbs/yr)/(365 days/yr)]*$e^{[2.326*(0.472)-0.5*(0.472)^2]}$
= 2.44 lbs/day in Quivira Little
= [(27 lbs/yr)/(365 days/yr)]*$e^{[2.326*(0.472)-0.5*(0.472)^2]}$
= 0.197 lbs/day in Quivira Big

Source- *Technical Support Document for Water Quality-based Toxics Control (EPA/505/2-90-001)*

Appendix C. Registered, certified or permitted confined animal feeding operations (CAFOs) in the Quivira Little and Quivira Big Salt Marsh watersheds. Facilities with animal totals $\geq$ 1,000 are assigned a federal NPDES Permit. Facilities with animal totals < 1,000 are either registered or certified with KDHE. Three digit Kansas permit numbers are place holders and indicate an application in process.

Kansas Permit Number	Federal NPDES Permit Number	Animal Type	County	Animal Total
A-ARED-B001	N/A	Beef	Edwards	700
A-ARED-C003	KS0094919	Beef	Edwards	2000
A-ARED-C004	KS0097403	Beef	Edwards	3000
A-ARED-C006	KS0097543	Beef	Edwards	1500
A-ARED-C002	KS0088251	Beef	Edwards	2500
A-ARED-C005	KS0098868	Beef	Edwards	3500
A-ARFO-B002	N/A	Beef	Ford	540
A-ARFO-BA01	N/A	Beef	Ford	570
A-ARKW-BA01	N/A	Beef	Kiowa	996
A-ARKW-BA03	N/A	Beef	Kiowa	450
A-ARKW-C002	KS0098876	Beef	Kiowa	9500
A-ARPR-BA01	N/A	Beef	Pratt	600
A-ARPR-B005	N/A	Beef	Pratt	999
874	N/A	Beef	Pratt	900
A-ARSF-BA05	N/A	Beef	Stafford	450
A-ARSF-BA03	N/A	Beef	Stafford	600
A-ARSF-BA02	N/A	Beef	Stafford	750
A-ARSF-BA09	N/A	Beef	Stafford	500
A-ARSF-BA06	N/A	Beef	Stafford	500
A-ARSF-C003	KS0115681	Beef	Stafford	4000
A-ARSF-B004	N/A	Beef	Stafford	999
A-ARSF-B007	N/A	Beef	Stafford	999
A-ARSF-B003	N/A	Beef	Stafford	800
A-ARSF-B002	N/A	Beef	Stafford	994
A-ARSF-H001	KS0089958	Swine	Stafford	4530
A-ARSF-T001	N/A	Truck Wash	Stafford	0
A-ARSF-C002	KS0085839	Beef	Stafford	5000
A-ARSF-C004	KS00089117	Beef	Stafford	1500

Appendix D. Development of TSS targets.

Appendix A of the KDHE's 2002 Lake and Wetland Report presents analysis of lake water clarity and trophic state data in lakes sampled in Kansas from 1998 through 2002. The special report establishes a Secchi Depth target of >70 cm in lakes for full support of Primary Contact Recreation in lakes where clarity is influenced more by soil derived inorganic turbidity than by algae. The relationship between the turbidity and Secchi depths for lakes included in the small lake study (Wang, 2003) plus period of record averages for the respective marshes was used to generate turbidity targets using the Secchi depth target of 70 cm resulting in NTU values of 21.1 and 21.5 for Quivira Little and Quivira Big, respectively (Table D1, Figures D1 & D2).

Table D1. Small lake and marsh values used to develop turbidity/Secchi depth relationships.

Lake	**Turbidity (NTU)**	**Secchi (cm)**
Afton	33	65.0
Browson	11	177.0
Central Park	44.5	52.0
Centralia	42.5	44.0
Crystal	20.5	66.5
Dillon Park	44	42.0
Edgerton	55	26.5
Gage Park	52	46.0
Gardner City	7	124.5
Hiawatha	48	51.5
Kingman	47.5	40.0
Mary's	23	51.5
Mingenback	398	7.0
Mission	88.5	24.5
Mound City	29.5	53.0
Newton City Park	104	24.0
Pony Creek	16.5	75.0
Pratt County (Main)	37	39.0
Sunflower	130.5	13.0
Quivira Little	44.06	23.8
Quivira Big	69.2	20.5

Figure D1. Secchi depth vs. Turbidity relationship used to generate turbidity target for Quivira Little.

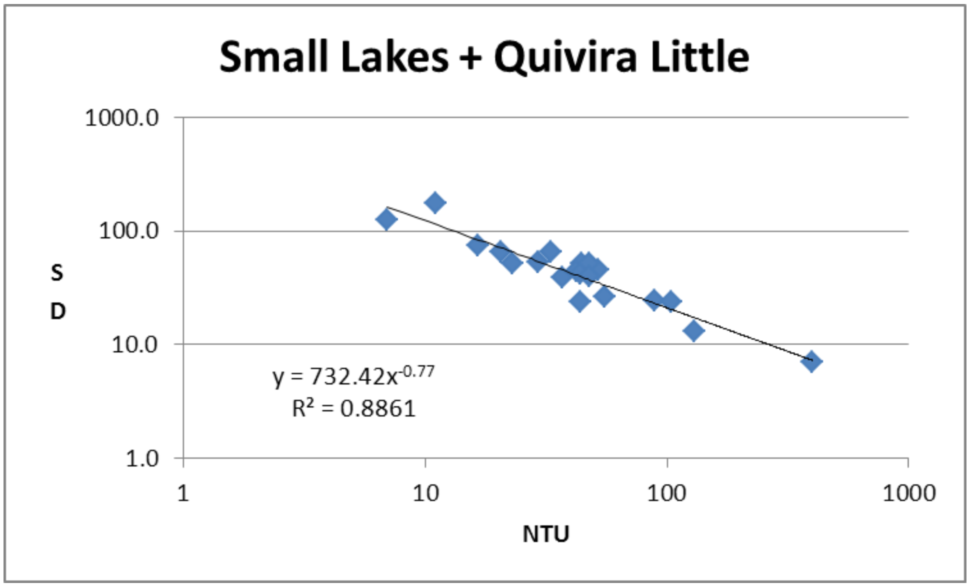
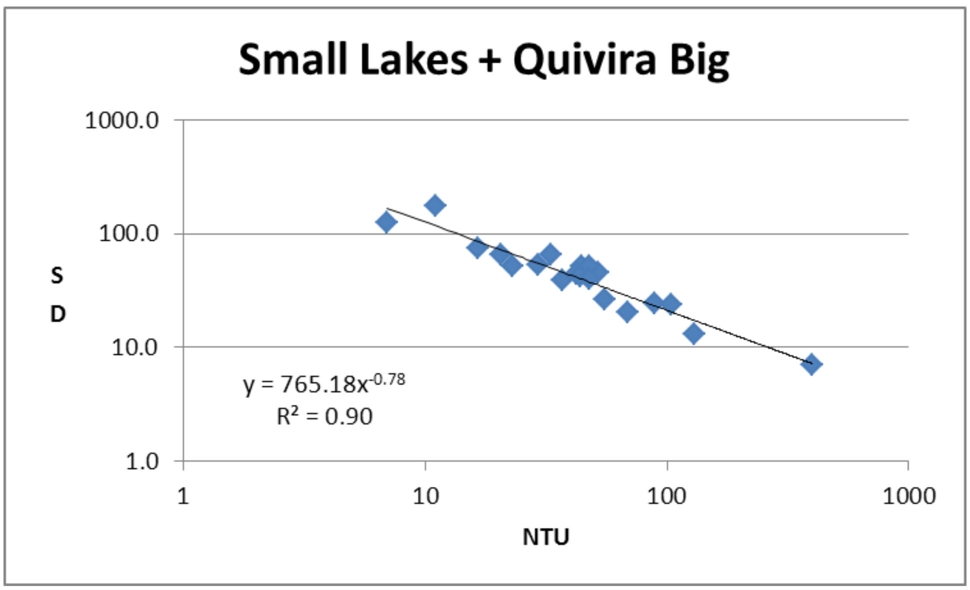


Figure D2. Secchi depth vs. Turbidity relationship used to generate turbidity target for Quivira Big.



Using annual averages, the relationship between turbidity and total suspended solids was developed for each marsh and, by using the NTU values developed above, TSS targets of 45.4 mg/L and 45.2 mg/L were generated for Quivira Little and Quivira Big, respectively (Tables D2 & D3, Figures D3 & D4).

Table D2. Marsh data used to develop turbidity/TSS relationships in the marshes.

Date	NTU -- BQ	TSS -- BQ	NTU -- LQ	TSS -- LQ
7/18/1988	16.50	32.5	56.50	111.00
6/18/1991	5.95	15.5	41.50	70.0
6/27/1994	61.00	176	21.00	64.00
8/11/1997	65.00	160	24.50	88.00
8/24/1998	47.00	106	49.00	116.00
8/2/1999	46.00	65.0	54.50	126.00
8/28/2000	237.50	514	77.00	167.00
6/10/2003	15.50	27.5	22.50	57.50
8/15/2006	32.90	141	36.10	59.50
6/15/2009	164.50	125	58.00	66.50

Figure D3. Turbidity vs. TSS relationship used to generate TSS target for Quivira Little.

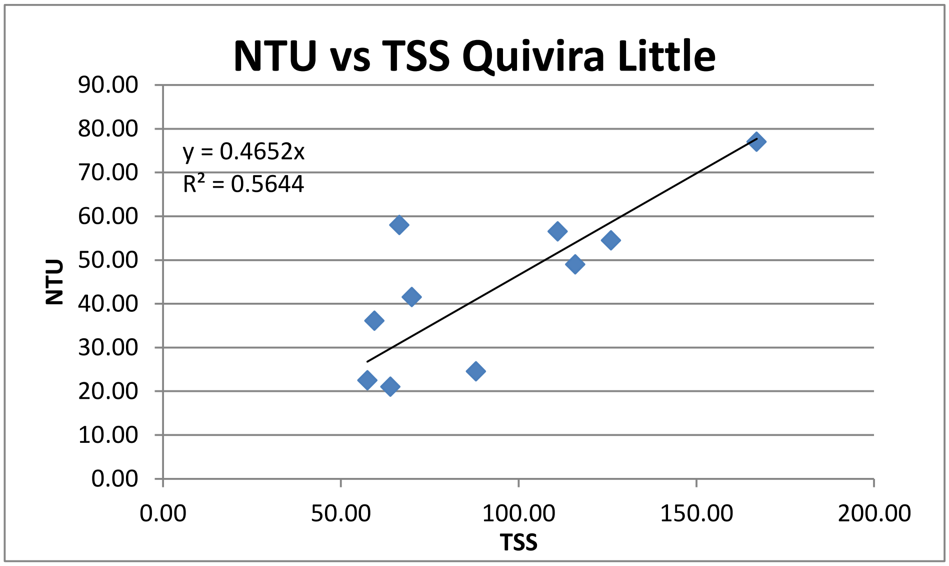


Figure D4. Turbidity vs. TSS relationship used to generate TSS target for Quivira Big.

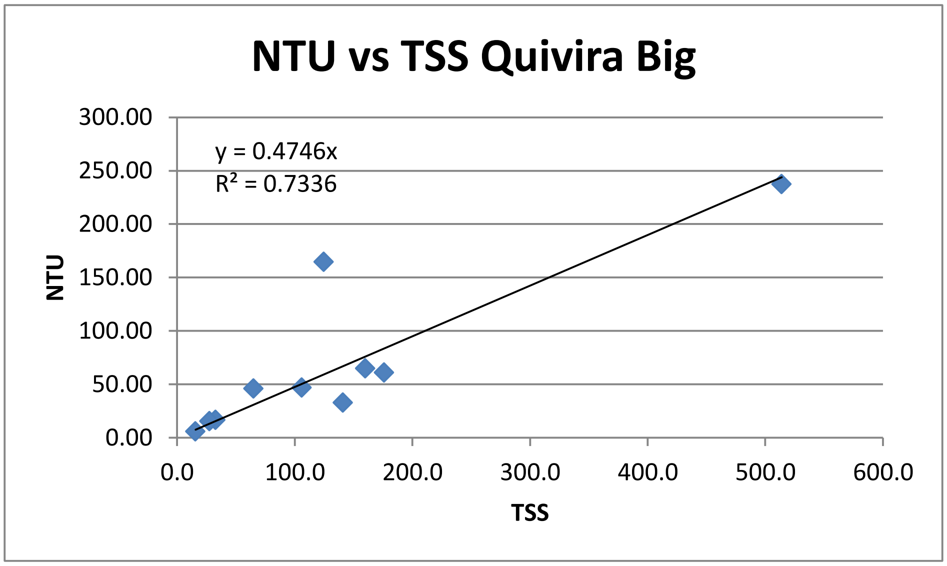


Table D3. TSS target development in Quivira Little and Quivira Big Salt Marshes.

Quivira Little		
Secchi/NTU relationship	Secchi Depth Target (cm)	NTU
$y=732.42x^{-.77}$	70	21.1
NTU/TSS relationship	NTU	TSS
y=.4652x	21.1	45.4
Quivira Big		
Secchi/NTU relationship	Secchi Depth Target (cm)	NTU
$y=765.18x^{-.78}$	70	21.5
NTU/TSS relationship	NTU	TSS
y=.4746x	21.5	45.2