UPPER REPUBLICAN BASIN TOTAL MAXIMUM DAILY LOAD

Waterbody/Assessment Unit: Lower South Fork Republican River
Water Quality Impairment: pH

1. INTRODUCTION AND PROBLEM IDENTIFICATION

Subbasin: S. Fk. Republican River **County:** Cheyenne

HUC 8: 10250003

HUC 11 (HUC 14s)**:** **150** (010, 020, 030, 040, 070, 080 and 090)
160 (010, 020, 030, 040, 050 and 060)

Drainage Area: 550.6 square miles

Main Stem Segment: WQLS: 2, 4, 6 and 7 (S. Fk. Republican River) starting at the Kansas-Nebraska state line and traveling upstream to confluence of Battle Creek in southwest Cheyenne County (**Figure 1**).

Tributaries:
Big Timber Cr (61)
Delay Cr (66)
Hackberry Cr (3)
Bluff Cr (70)
Valley Cr (69)
Spring Cr (67)
Sand Cr (68)
Drury Cr (60)
Crosby Cr (72)
Battle Cr (71)

Designated Uses: Special Aquatic Life Support, Primary Contact Recreation, Domestic Water Supply; Food Procurement; Ground Water Recharge; Industrial Water Supply Use; Irrigation Use; Livestock Watering Use for Main Stem Segments.

Impaired Use: Aquatic Life Support Use

Water Quality Standard: Artificial sources of pollution shall not cause the pH of any surface water outside a zone of initial dilution to be below 6.5 and above 8.5 (KAR 28-16-28e(c)(2)(C)

Lower S. Fk. Republican River Watershed
pH TMDL - HUC and Stream Segment Map

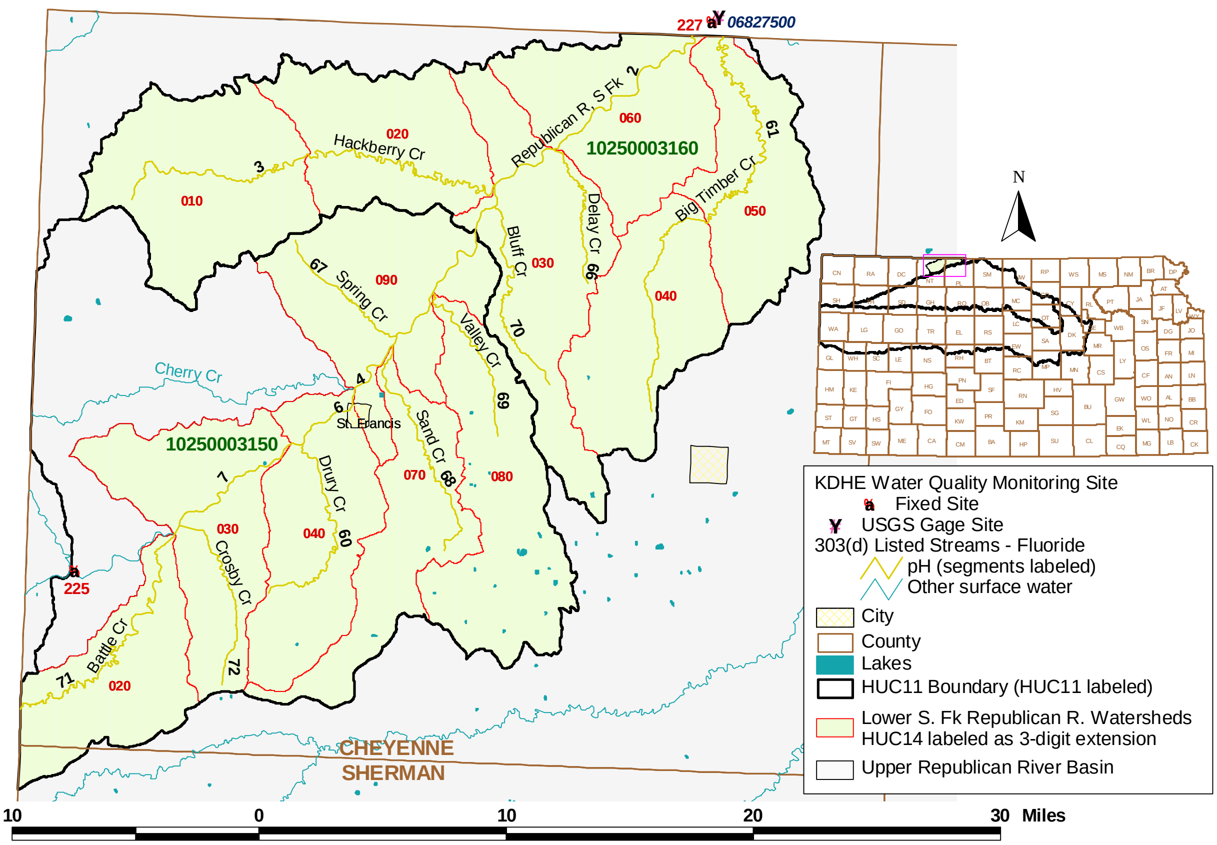


Figure 1

2. CURRENT WATER QUALITY CONDITION AND DESIRED ENDPOINT

Level of Support for Designated Use under 2002 303(d): Not Supporting Aquatic Life

Monitoring Sites: Stations 227 near Benkelman, NE.

Period of Record Used: 1990 –2001 for Stations 227 (**Figure 2**)

Flow Record: S. Fk. Republican R. near Benkelman, NE (USGS Station 06827500); 1970-2002.

Long Term Flow Conditions: 10% Exceedance Flows = 48 cfs**,** 95% = 0.0 cfs

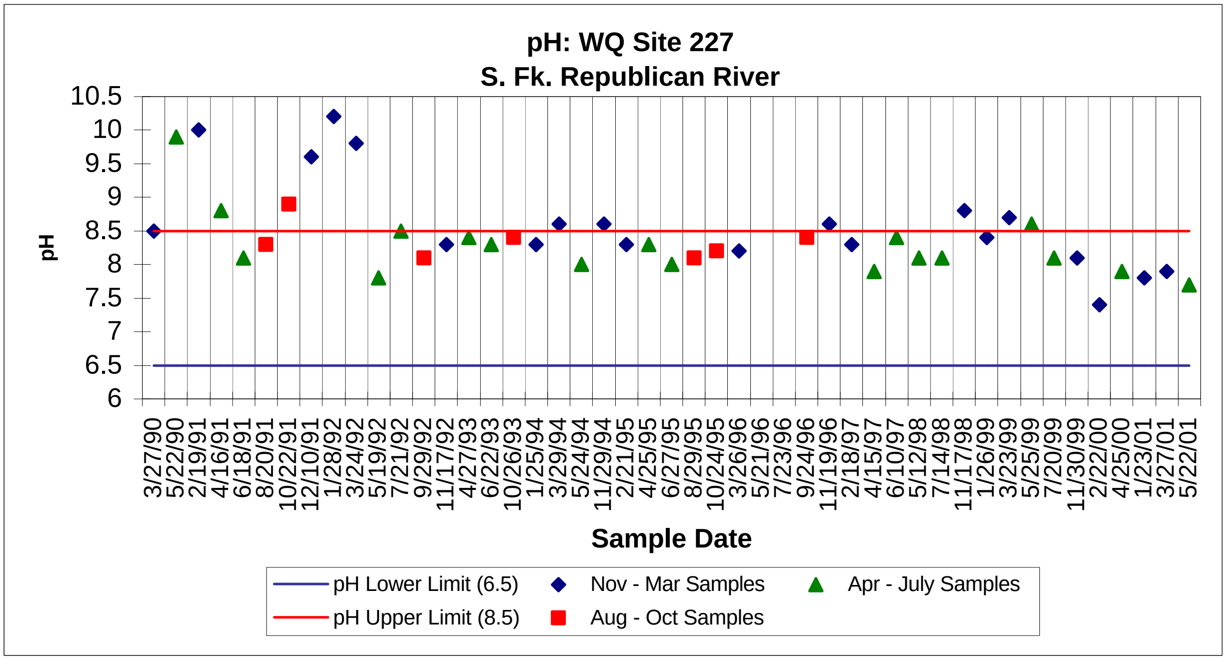


Figure 2

Current Conditions: Sample data for the sampling site were categorized for three defined seasons: Spring (Apr-Jul), Summer-Fall (Aug-Oct) and Winter (Nov-Mar). These data are plotted in **Figure 2** for site 227. Excursions from pH criteria were noted in each of the three defined season. The magnitude of excursions is smaller toward the end of the sample record than those excursions seen at the beginning of the record.

Seventeen percent of the Spring samples and 14% of the Summer-Fall samples were over the pH upper limit criterion. Forty-five percent of the Winter samples were over the pH upper limit criterion. Overall, 29% of the samples from station 227 were over the pH limit representing a condition of non-support of the impaired designated use (**Table 1**).

Excursions were noted across all flow conditions in the S. Fork Republican River (**Table 1**). The 25 – 75% flow exceedance range appears to contain the greatest number of those exceedances.

Table 1

NUMBER OF SAMPLES OUTSIDE pH STANDARD (6.5 – 8.5) BY FLOW AND SEASON								
Station	**Season**	**0 to 10%**	**10 to 25%**	**25 to 50%**	**50 to 75%**	**75 to 90%**	**90 to 100%**	**Cum. Freq.**
S. Fk. Republican R. near Benkelman, NE (227)	Spring	0	0	3	0	No Flow	No Flow	3/18 = 17%
	Summer/Fall	0	0	1	0	No Flow	No Flow	1/7 = 14%
	Winter	1	2	4	2	No Flow	No Flow	9/20 = 45%

Comparison tables were created (**see Tables 3 and 4 Appendix**) for samples collected at Site 227 and samples collected on the same date approximately 43 river miles upstream of Site 227 at Site 225 on the S. Fk. Republican River. Table 2 in the Appendix contains selected comparison parameters for concurrent sampling dates at Sites 227 and 225. Table 3 is a subset of Table 2 that contains those data for concurrent sampling dates when a pH violation occurred at Site 227.

Five of the seven pH exceedances (noted as red values in Table 3) that occurred from 1990-1992 were extremely high (>9.0) relative to the exceedances that occurred since 1994. The concentrations of the major cations and anions and the field parameters other than pH were not significantly different during times pH exceeded 8.5 during 1990-1992 and those times pH exceeded 8.5 during 1994-1999. One would expect the calcium and alkalinity in the stream to buffer the pH in a much narrower range than observed prior to 1992. One sample pH field value on February 19, 1991 was 10.0, but its corresponding lab pH measurement was 8.4, suggesting that errors in field measurement may have occurred in the record of 1990-1992 for Site 227.

Inspection of Table 3 in the Appendix indicates that median concentrations at Site 227 for calcium, alkalinity and sulfate appear higher that those concentrations at upstream site 225 (likely due to evapotranspiration concentration of the dissolved solids) while nitrate appears lower than median concentrations at the upstream site 225. The median concentrations of all other parameters appear much the same. These observations were supported by Mann-Whitney tests comparing the each sampling station for each parameter.

Analysis of variance was performed on nutrient data for periods of high pH and those of pH below 8.5 at Sites 225 and 227. These data included the period of 1990-1992, on the assumption that field pH was above 8.5 on those dates, although not as high as recorded. For ammonia, nitrate and total phosphorus, there were no significant differences in mean values taken from the two pH conditions. Ammonia was slightly less under high pH conditions at both stations as was phosphorus. Nitrate was slightly greater under high pH conditions at both stations.

Comparing ammonia, nitrate and phosphorus levels between the two stations indicates there were significant decreases in nitrate at the downstream station and significant increases in phosphorus at Site 227. The decrease in nitrate in the downstream direction might be due to biological assimilation along the stream path. The increase in phosphorus is likely due to extended interaction with the drainage area between the two stations, but again the levels are higher when there are no pH problems.

Dissolved oxygen at Site 227 (Table 3) is often slightly higher than concurrent samples taken at Site 225 (not statistically significant) and also appears higher than the median for the entire sampling record when comparing Table 3 to Table 2.

Generally, there is a seasonal recession to no flow at Site 227 once irrigation begins, followed by a gradual return of base flow in the Fall after the irrigation season ends. The off-season flow is dominated by a fairly constant base flow (very few large runoff events) and it is during these extended periods of stable flow that most of the pH exceedances have occurred.

Thirty day antecedent flow conditions to each pH exceedance at Site 227 are graphed in **Figure 6 of the Appendix**. In practically each case, relatively stable, baseflow dominated or flow recession conditions typified the period prior to pH exceedances at station 227. Most of the excursion from the water quality standard occurred at flow between 10 and 40 cfs, therefore a critical flow range can be identified for this TMDL and is demonstrated in **Figure 3**.

The above information indicates that the probable cause of the modest pH rises at Site 227 is growth of periphyton. The South Fork Republican River is a clear stream with a sandy substrate subject to seasonal, yet stable, flow. Although the data suggest the growing conditions for algae occur during the colder months of the year, the morphology is still conducive to its growth. The river is clear allowing light to fully penetrate its water column for optimal periphyton growth. Because of the long periods of relatively constant baseflow, the periphyton have a stable environment in which to grow

During photosynthesis, periphyton take up carbon dioxide and give off oxygen. In this reaction, water molecules are cleaved. The organism takes up the hydrogen cation and the remaining hydroxyl anion remains in solution. The pH value increases with the decrease in available hydrogen cations. Peaks in pH occur in the afternoon, when the greatest amount of radiant energy reaches the river.

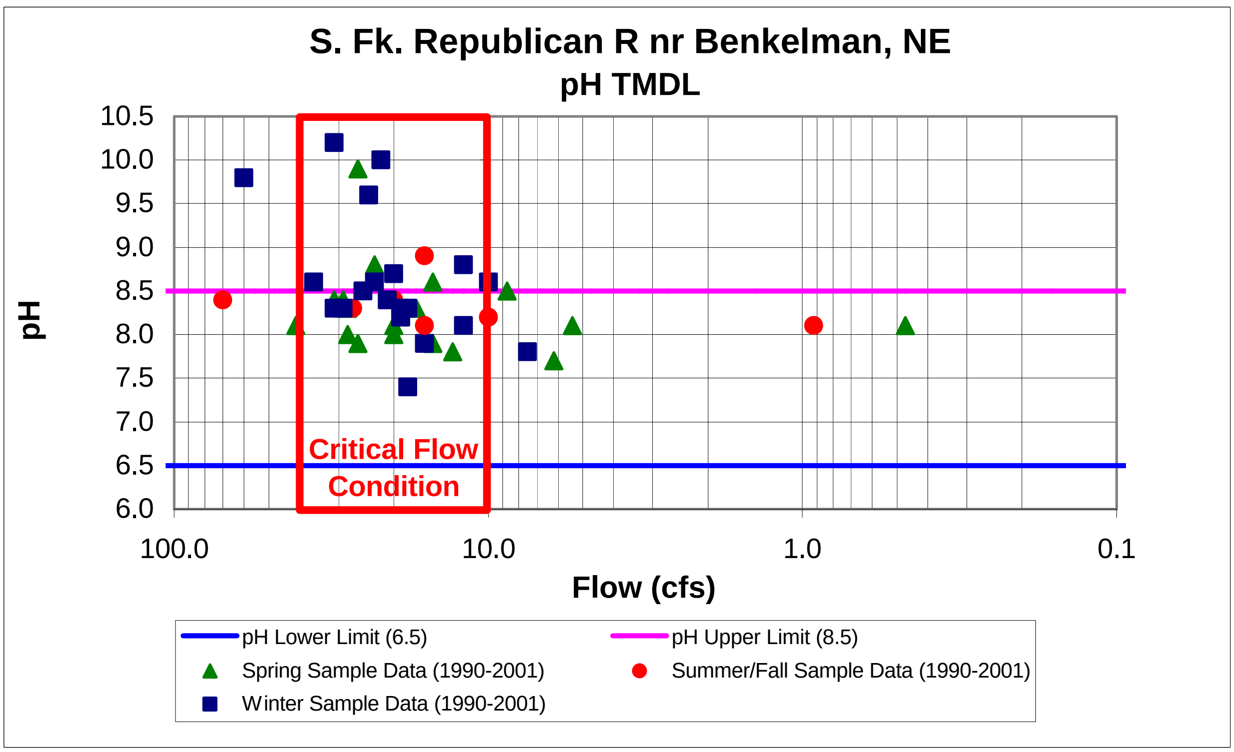


Figure 3

Desired Endpoints of Water Quality (Implied Load Capacity) at Site 227 over 2008 – 2012

The ultimate endpoint for this TMDL will be to achieve the Kansas Water Quality Standards fully supporting aquatic life. The current standard of pH between 6.5 and 8.5 was used to establish the pH/flow duration TMDL curve. The morphology of the South Fork Republican River may foster periphyton growth, even during the colder seasons. This periphyton activity can cause the modest rises in pH over 8.5 seen occasionally from 1994 to 1999. While phytoplankton growth may be triggered by excessive nutrients, the current database of nutrient levels does not indicate any significant relationships. In fact, for two nutrients, ammonia and phosphorus, the data contra-indicate the typical relationship, with greater concentrations seen during periods of compliance. Therefore, this TMDL will be phased with an interim endpoint to maintain average nitrate levels at or below 1.12 mg/l, the average level seen in the upstream reaches during compliant conditions. Subsequent revisions of this TMDL and its endpoints will be forthcoming when Kansas adopts numeric nutrient criteria into its Water Quality Standards.

Achievement of the endpoints indicate loads are within the loading capacity of the stream, water quality standards are achieved and full support of the impaired designated use of the stream has been restored.

3. SOURCE INVENTORY AND ASSESSMENT

NPDES: There is one NPDES municipal permitted wastewater discharger within the watershed (**Figure 4**). This system is outlined below in **Table 2**. St. Francis Sand and Ready Mix has a non-discharging industrial pond that may discharge to Segment 6 of the South Fork Republican River under extreme precipitation events (stream flows associated with such events are typically exceeded only 1-5 % of the time). Such events would not occur at a frequency or of a duration that they would constitute a chronic impairment to the designated uses of the river. All non-discharging lagoon systems are prohibited from discharging to the surface waters of the state. Under standard conditions of these non-discharging facility permits, when the water level of the lagoon rises to within two feet of the top of the lagoon dikes, the permit holder must notify KDHE. Steps may be taken to lower the water level of the lagoon and diminish the probability of a bypass of industrial waste during inclement weather. Bypasses may be allowed if there are no other alternatives and 1) it would be necessary to prevent loss of life, personal injury or severe property damage; 2) excessive stormwater inflow or infiltration would damage the facility; or 3) the permittee has notified KDHE at least seven days before the anticipated bypass. Any bypass is immediately reported to KDHE.

Table 2

Facility	NPDES Permit	Stream Reach	Segment	Design Flow	Type
St. Francis WTF	M-UR18-OO01	Sand Cr	68	0.212 mgd	Lagoon
Cheyenne Co Feedyard	A-URCN-C001			Non-Disch.	Lagoon
Callicrate Cattle Co.	A-URCN-C002			Non-Disch	Lagoon
St. Francis Feedyard	A-URCN-C002			Non-Disch	Lagoon

The population projection for St. Francis to the year 2020 indicates a nominal increase (< 1% growth). Projections of future water use and resulting wastewater for the city appear to be within the design flows of the current system's treatment capacity. Effluent monitoring records for the city were reviewed for the 1999-2002 period. The pH values reported were generally within permit limits for the city. Permit pH exceedances did occur about 15% of the time, however, the rate of effluent discharge (0.327 cfs), even at design flow for the lowest flow (10 cfs) that a pH excursion was seen at Site 227, is only about 3% of the flow present in the stream. At site 227, most excursions from the water quality standard occurred in the 10-40 cfs flow range, therefore the effluent portion of stream flow was usually much less than this already negligible amount during the other pH exceedances noted in the watershed. Given the magnitude of other sources in the watershed and the chemistry of the water entering the watershed at Site 225, point sources are not considered a significant source contributing to the pH problem.

Upper and Lower S. Fk. Republican R. Watershed
NPDES and Livestock Waste Management Facilities

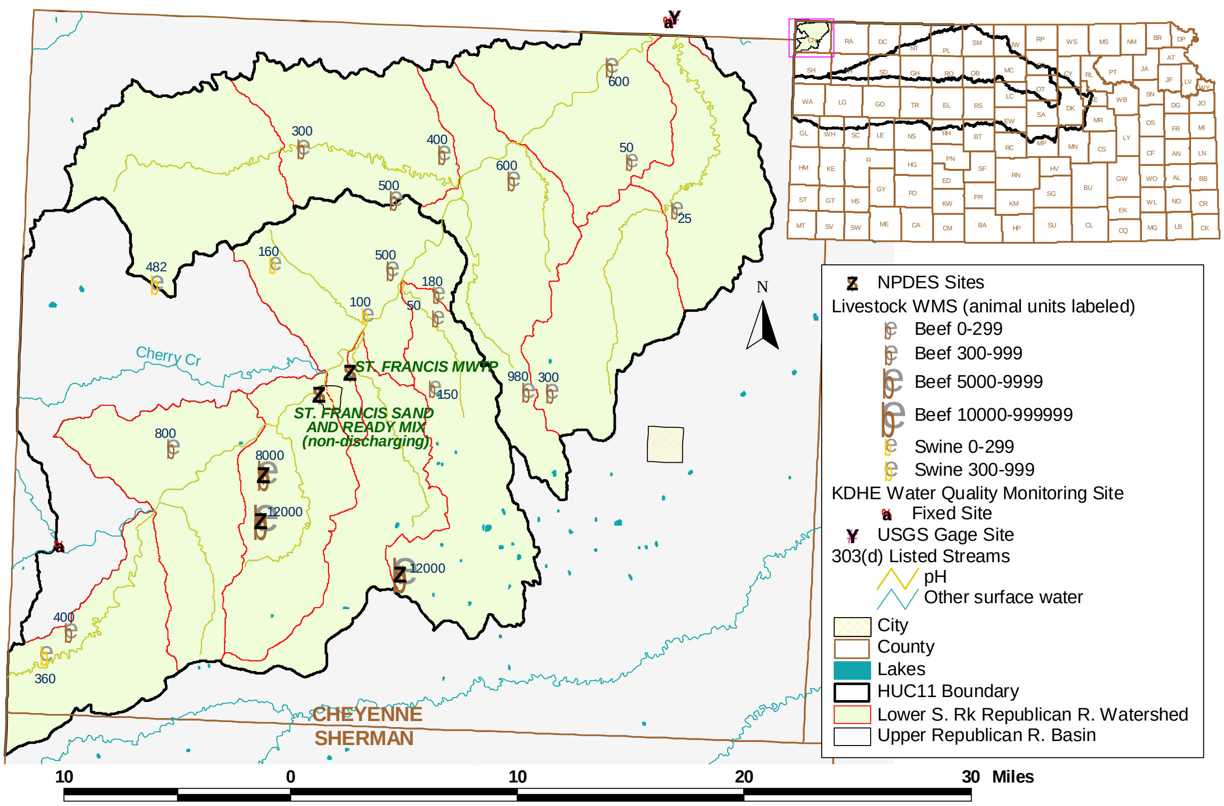


Figure 4

Livestock Waste Management Systems: Twenty-two operations are registered, certified or permitted within the watershed. These facilities, either beef or swine, are evenly distributed across the watershed (**Figure 4**). Three beef facilities are NPDES permitted, non-discharging facilities (**Figure 4 and Table 2**) located toward the upper end of the watershed south of the main stem in the drainage of Segment 6 or 4 of South Fork Republican River. Permitted livestock facilities have waste management systems designed to minimize runoff entering their operations or detaining runoff emanating from their areas. Such systems are designed to retain the 25 year, 24 hour rainfall/runoff event, as well as an anticipated two weeks of normal wastewater from their operations. Such rainfall events typically coincide with stream flows which are exceeded less than 1 - 5 percent of the time. Therefore, events of this type, infrequent and of short duration, are not likely to cause chronic impairment of the designated uses of the waters in this watershed. Requirements for maintaining the water level of the waste lagoons a certain distance below the lagoon berms ensures retention of the runoff from these intense, local storm events. In Cheyenne County, such an event would generate 4.1 inches of rain, yielding 3.0 to 3.8 inches of runoff in a day. The watershed's total potential animal units, for all facilities combined, is 41,221. The actual number of animal units on site is variable, but typically less than potential numbers.

Land Use: Most of the watershed is grassland (52% of the area) or cropland (47%). Most of the cropland is located at higher elevations in the watershed (lesser slope) and to a smaller extent in the watershed's alluvial valley (**Figure 5**). Based on 1998 water use reports, about 34% of the cropland in the watershed is irrigated.

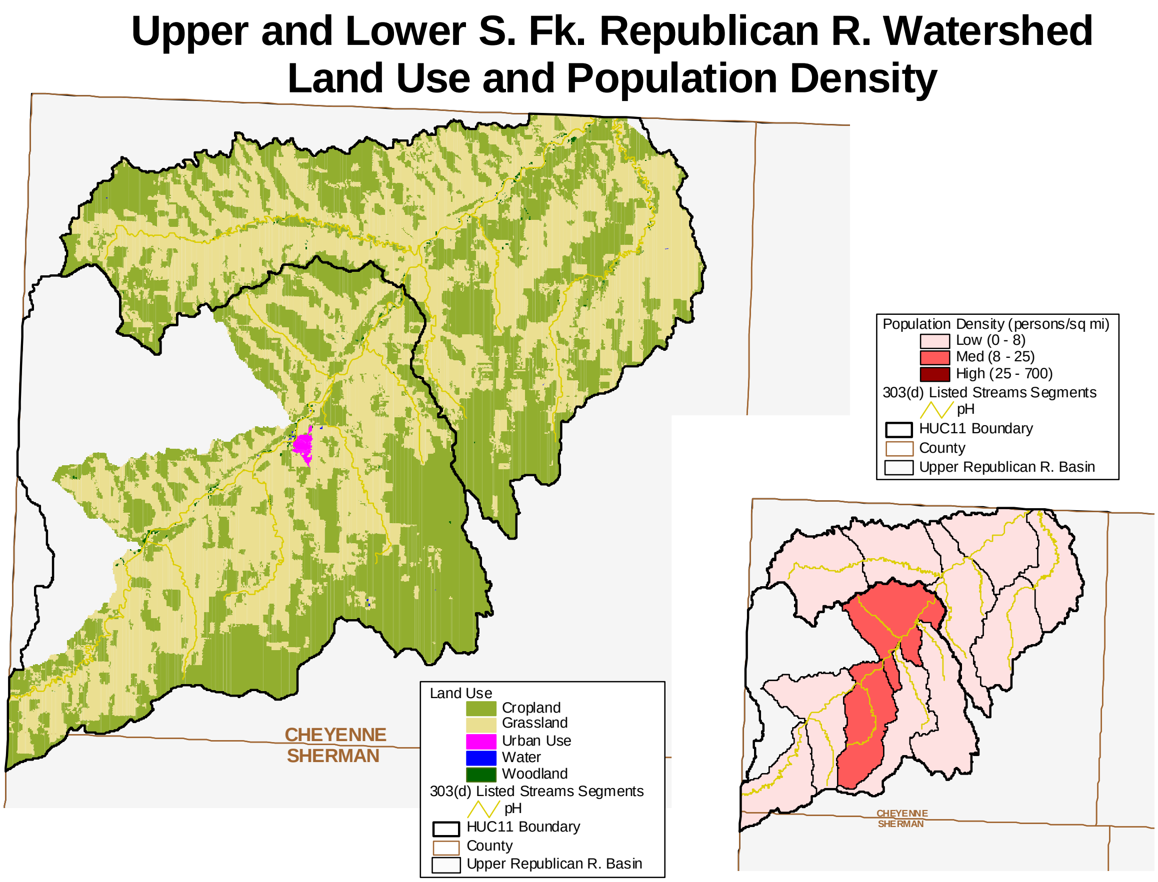


Figure 5

Background: It is most probable that the primary cause of the pH impairment of the Lower South Fork Republican River watershed is based on the relatively unique morphology of the main stem. The South Fork Republican River, much like a few of the streams in south central Kansas such as the North and South Fork Ninnescah River and the Arkansas River between Great Bend and Hutchinson where pH is also an issue, is a relatively clear, shallow stream with a sandy substrate. As a result, sunlight easily penetrates the river's entire water column. The flow duration curve for the South Fork Republican River is comparatively flat across 75 – 20% exceedances, allowing consistently stable flows and water levels; ideal for algae growth even during the colder months when most pH exceedances were observed. As previously noted, during photosynthesis, periphyton take up carbon dioxide and give off oxygen, a reaction that cleaves water molecules. The organism takes up the hydrogen cation and the remaining hydroxyl anion remains in solution, raising the pH of the stream.

On-Site Waste Systems: Most of the watershed's population density is low when compared to densities elsewhere in the Upper Republican Basin (<2 person/mi^2) except for those areas associated with the city of St. Francis where the density is average for the Upper Republican Basin (12-24 persons/mi^2) (**Figure 5**). The rural population projection for Cheyenne County through 2020 shows slight declines (7% decrease). Based on 1990 census data, about 34% of households in Cheyenne County are on septic systems

4. ALLOCATION OF POLLUTION REDUCTION RESPONSIBILITY

It is believed that adequate nutrient availability, coupled with the geographically unique morphology of the South Fork Republican River (consistent base flow conditions, low turbidity and sandy substrate) are conducive to growth in the stream's algal community. The resultant photosynthetic activity, despite the colder water temperatures during the period of pH excursions, causes pH to rise above the water quality standard of 8.5. Thus, these pH excursions for the water quality standard at monitoring site 227 are seen as a natural consequence of the availability of current nutrient levels in the lower S. Fk. Republican River system. Since baseflow dominates the flow condition during which pH excursions were observed (**Figure 6, Appendix**) the nutrient loading that appears to drive the pH excursions is most likely the result of transmission of nutrients already in the stream at Site 225 rather than a runoff type load from within the watershed. Median phosphorus concentrations were usually near the detection limit for Sites 225 and 227 (Tables 3 and 4, Appendix) therefore a load reduction to phosphorus would be trivial in affecting improvements to pH levels in the watershed. However, for those dates when pH exceedances were noted at Site 227, nitrate was significantly higher at Site 225 as compared to the median nitrate concentrations at Site 227 (**Table 4, Appendix**: 1.3 and 0.5, from upstream to downstream). A reduction in the nitrate load should improve pH conditions in the stream at Site 227. This TMDL represents the "Best Professional Judgment" regarding the indeterminate relationship between physical/biological factors, stream morphololgy and pH.

As an interim management goal in this phase of the TMDL, median nitrate should be reduced from 1.3 mg/L to 1.12 mg/L; a 14% reduction from the median nitrate concentration in **Table 4 of the Appendix** at Site 225. This target is established by the median nitrate concentration at Site 225 when the pH standard was attained at Site 227.

Point Sources: As previous noted in the source assessment section, the loading from the currently existing facility discharging to the stream is extremely small in relation to the existing instream load during the flow conditions that pH exceedances were observed. Presuming an interim management goal of reducing instream nitrate to 1.12 mg/L, the Wasteload Allocation would average 7.1 lbs/day based upon the point source's design flow, as shown in **Table 5, Appendix**. The non-discharging St. Francis Sand and Ready Mix facility will have a wasteload allocation of zero.

There will be a wasteload allocation of zero for state and NPDES permitted CAFO's within the drainage because of requirements for no discharge of livestock waste except at 25 year, 24 hour storm events. Management of available freeboard and required holding capacities in these livestock waste management systems should ensure rare contributions of nutrients to the S. Fk. Republican River.

Non-Point Sources: In order to maintain a reduced concentration of nitrate (1.12 mg/L) at flows ranging from 10 – 40 cfs, the resulting nitrate concentration would range from 1.02 mg/L at 10 cfs to 1.1 mg/L at 40 cfs. The Load Allocation associated with these targets would be 55.1 – 237.6 pounds per day for nitrate for that critical 10 – 40 cfs flow range (see **Table 5 in Appendix**).

Defined Margin of Safety: The Margin of Safety provides some hedge against the uncertainty of loading and the nitrate endpoints for the S. Fk. Republican River system and is considered implicit in this TMDL. This is based on a conservative assumption that critical flow median nitrate concentrations are expected to be reduced below current medians, despite the fact that the majority of the samples collected in this flow range which were greater than the established target exhibited no pH excursions.

State Water Plan Implementation Priority: Because it appears this watersheds' pH condition is predominately a natural response to the physical and chemical environment fostering photosynthesis, this TMDL will be a low Priority for implementation.

Unified Watershed Assessment Priority Ranking: This watershed lies within the South Fork Republican Basin (HUC 8: 10250003) and is classified as a Category II watershed under the unified assessment.

Priority HUC 11s and Stream Segments: 10250003150 and 10250003160 within the defined watershed.

5. IMPLEMENTATION

Desired Implementation Activities

1. Evaluate and minimize artificial influents on stream pH.
2. Evaluate future trends in stream pH and nutrient levels.

Implementation Programs Guidance

NPDES - KDHE

a. Condition future permits of new facilities to maintain pH below 8.5 for the watershed.
b. Incorporate nutrient limits on permitted facilities in future after development of nutrient criteria.
c. Monitor nutrient content of wastewater effluent from permitted facilities

Non-Point Source Pollution – KDHE

a. Evaluate any potential anthropogenic activities which might contribute nutrients to the river as part of an overall Watershed Restoration and Protection Strategy
b.

Water Quality Monitoring – KDHE

a. Monitor future levels of pH and in-stream nutrients and evaluate trends.

Timeframe for Implementation: Evaluation of trends and activities should be accomplished over 2004-2008.

Targeted Participants: Primary participants for implementation will be KDHE.

Milestone for 2007: The year 2008 marks the mid-point of the ten-year implementation window for the watershed. At that point in time, additional monitoring data from S. Fk Republican River will be reexamined to confirm the impaired status of the river relative to the current condition documented by this TMDL. Should the case of impairment remain, source assessment, allocation and implementation activities will ensue.

Delivery Agents: The primary delivery agents for program participation will be the Kansas Department of Health and Environment.

Reasonable Assurances:

Authorities: The following authorities may be used to direct activities in the watershed to reduce pollution.

1. K.S.A. 65-164 and 165 empowers the Secretary of KDHE to regulate the discharge of sewage into the waters of the state.

2. 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.

3. 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.

4. K.S.A. 82a-951 creates the State Water Plan Fund to finance the implementation of the *Kansas Water Plan*.

5. The *Kansas Water Plan* and the Upper Republican 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.

Funding: The State Water Plan Fund, annually generates $16-18 million and is the primary funding mechanism for implementing water quality protection and pollution 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. This watershed and its TMDL are a Low Priority consideration and should not receive funding.

Effectiveness: Minimal control can be exerted on natural contributions to loading. Best Management Practices are effective in reducing nutrient loadings to stream if installed at a sufficiently high density and in proximity to streams.

6. MONITORING

As the opportunity and funding present themselves, KDHE will sample the phytoplankton content of the South Fork Republican River during periods of stable baseflow. In addition, KDHE will continue to collect bimonthly samples at Stations 225 and 227, including pH and nutrient samples, in each of the three defined seasons. Based on that sampling, trends will be evaluated in 2008 and the 303(d) listing status will be evaluated in 2012.

7. FEEDBACK

Public Meetings: Public meetings to discuss TMDLs in the Upper Republican Basin were held October 2, 2002 in Oberlin, January 6, 2003 in Norton and March 4, 2003 in Colby. An active Internet Web site was established at http://www.kdhe.state.ks.us/tmdl/ to convey information to the public on the general establishment of TMDLs and specific TMDLs for the Upper Republican Basin.

Public Hearing: Public Hearings on the TMDLs of the Upper Republican Basin were held in Atwood on June 3, 2003.

Basin Advisory Committee: The Upper Republican Basin Advisory Committee met to discuss the TMDLs in the basin on October 2, 2002, January 6, March 4, and June 3, 2003.

Milestone Evaluation: In 2008, evaluation will be made to confirm the degree of impairment that has occurred within the watershed of the South Fork Republican River. Subsequent decisions will be made regarding the need for an implementation approach.

Consideration for 303(d) Delisting: The stream will be evaluated for delisting under Section 303(d), based on the monitoring data over the period 2004-2008. Therefore, the decision for delisting will come about in the preparation of the 2008 303(d) list. Should modifications be made to the applicable water quality criteria during the intervening 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 (CPP), the next anticipated revision will come with the adoption of the new EPA Watershed Rule which will emphasize implementation of TMDLs. At that time, incorporation of this TMDL will be made into the CPP. Recommendations of this TMDL will be considered in *Kansas Water Plan* implementation decisions under the State Water Planning Process after Fiscal Year 2008.

APPENDIX: Lower South Fork Republican River - pH TMDL

Table 3

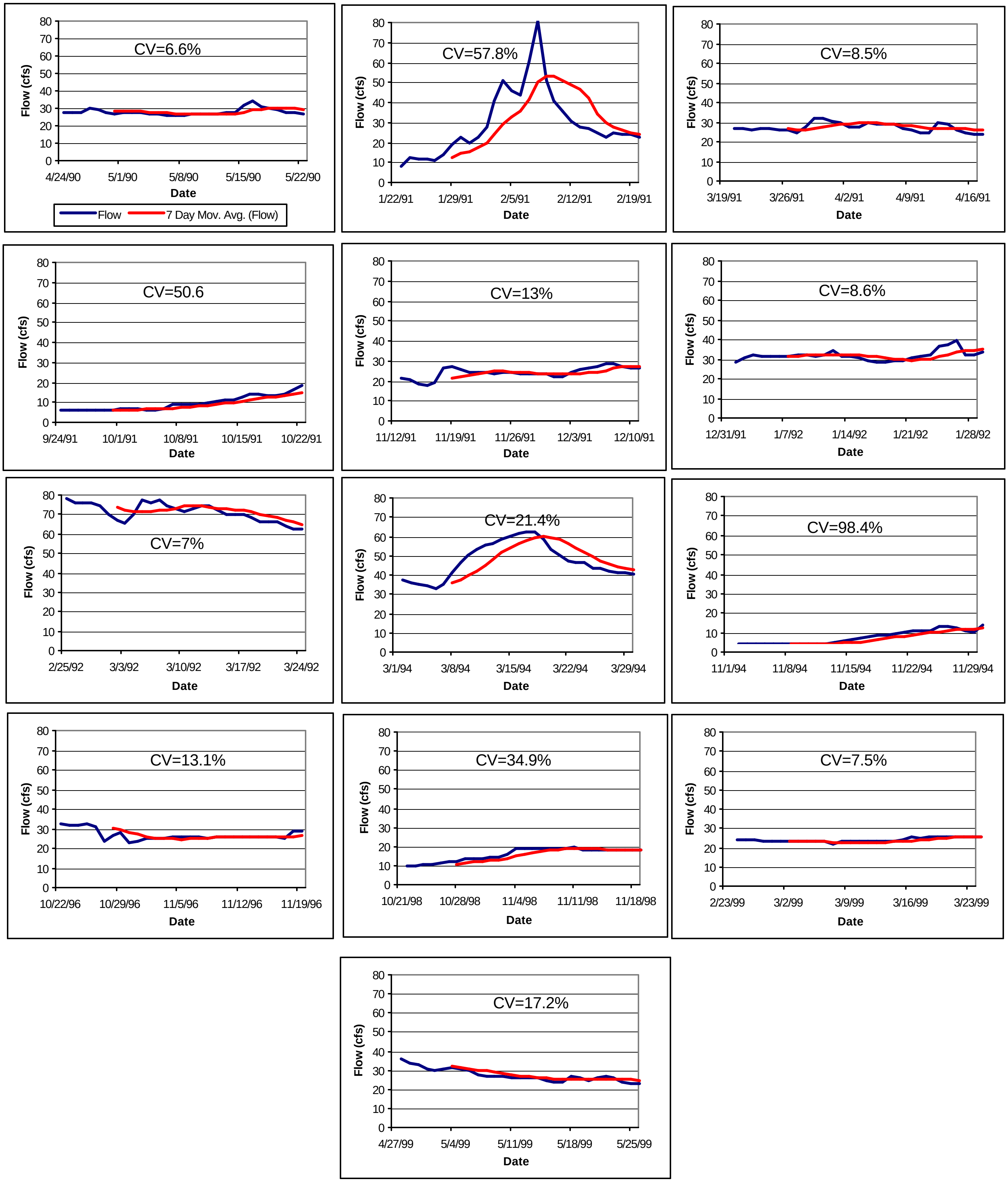
COL_DATE	COL_TIME		PHFIELD		AMMONIA		BOD		DISOXY		FECCOLI		NITRATE		TEMP		PHOSPHU		TSS		TURBIDITY		SULFATE		ALKALINTY		CALCIUM		FLOW
	225	227	225	227	225	227	225	227	225	227	225	227	225	227	225	227	225	227	225	227	225	227	225	227	225	227	225	227	6827500
3/27/90	1028	1207	8.3	8.5	0.2	0.02	-----	-----	10	11.9	100	100	1.47	0.71	6	8	0.03	0.02	8	7	3.4	2.6	27	87	221	230	56	58	25
5/22/90	1032	1212	**9.2**	**9.9**	0.04	0.1	1.1	1.7	8.8	9.9	100	100	1.27	0.16	19	23	0.02	0.04	5	12	3	5.6	27	88	234	253	58	62	26
2/19/91	1040	1215	**9.6**	**10**	0	0	-----	-----	12.7	12.6	10	10	1.61	0.94	3	5	0.02	0.02	25	3	5.6	8	26	76	232	260	56	59	22
4/16/91	1045	1230	**9.2**	**8.8**	0	0	1.4	2	9.6	9.7	130	50	1.32	0.56	8	10	0.02	0.1	11	43	4.5	24	26	86	219	266	54	66	23
6/18/91	1054	1303	7.8	8.1	0	0	1.2	1.2	8.7	5	200	30	1.25	0.33	21	27	0.07	0.11	16	9	4.5	4.2	27	93	236	275	53	64	20
8/20/91	1145	1358	7.9	8.3	0.1	0.1	7.7	6.5	7.8	7.3	500	100	1.13	0.83	20	24	0.13	0.17	48	53	19.2	29.2	26	68	234	265	56	64	27
10/22/91	1045	1305	**8.6**	**8.9**	0	0	6.7	5.6	9.8	10.1	400	100	1.17	0.38	11	14	0.05	0.05	10	18	9	7.1	541	198	246	294	53	62	16
12/10/91	1105	1244	**9.4**	**9.6**	0	0	2	2.1	11.6	13.9	100	100	1.43	0.22	4	2	0.05	0.05	5	3	3.5	4.3	28	73	231	258	53	60	24
1/28/92	1116	1319	**9.4**	**10.2**	0.05	0	1.6	1.4	11.9	13.1	100	100	1.35	1	5	5	0.05	0.05	8	15	5.5	7	24	80	236	269	51	59	31
3/24/92	1135	1430	**9.5**	**9.8**	0.05	0.05	1	1.7	10.9	11.5	10	10	0.61	0.43	11	15	0.05	0.07	10	35	5	19.5	32	62	199	236	44	55	58
5/19/92	1110	1354	**10**	7.8	0.05	0.05	1.6	1.7	10.1	8.7	100	100	1.49	0.69	19	25	0.05	0.06	10	16	48	9.7	31	109	209	238	55	59	13
7/21/92	1050	1230	8.2	8.5	0.05	0.05	1	1.2	3.8	4.8	190	400	1.39	0.45	18	23	0.06	0.16	23	72	11.1	35.2	28	141	218	194	53	70	8.5
9/29/92	1145	1328	8	8.1	0.05	0.05	1.3	2.2	9.8	8.2	300	50	1.62	0.95	13	17	0.05	0.05	7	19	5.8	13	31	107	249	251	54	70	16
11/17/92	1113	1247	8	8.3	0.05	0.05	1.3	1	10.4	11.7	20	10	1.48	1.14	6	6	0.07	0.05	7	14	2.7	7.5	29	88	239	275	55	66	19
4/27/93	1055	1230	8.4	8.4	0.05	0.05	1.8	2.1	7	7.6	74	118	1.29	0.7	12	15	0.05	0.09	16	48	8	25	28	93	220	197	-----	-----	31
6/22/93	1115	1248	8.3	8.3	0.05	0.05	1.2	1.9	8.3	7.9	400	200	1.12	0.86	20	26	0.05	0.18	20	86	6	34	27	95	225	280	55	75	17
10/26/93	1035	1215	8.3	8.4	0.05	0.05	1	1.1	7.3	7.6	30	50	1.22	0.71	7	8	0.05	0.07	5	48	5	23	31	81	219	188	54	61	20
1/25/94	1035	1150	8.3	8.3	0.05	0.05	2.4	2.8	6.4	10	10	10	1.32	1.33	3	0	0.05	0.16	2	114	3.3	1	33	69	239	195	47	61	29
3/29/94	1020	1152	8.4	**8.6**	0.05	0.05	2.3	2.3	10.5	11.5	10	20	1.32	0.62	5	7	0.05	0.05	12	15	5.4	10.6	29	63	231	251	57	55	36
5/24/94	1034	1200	8.1	8	0.05	0.05	1.6	2	8.5	8.2	400	100	1.06	0.64	18	22	0.05	0.12	32	58	9	21	28	82	236	273	50	62	20
11/29/94	1026	1214	**8.8**	**8.6**	0.05	0.06	2	1.8	10	7.5	10	10	1.47	1.6	1	1	0.01	0.16	29	3	11	2	32	133	228	278	51	70	10
2/21/95	1034	1200	8.4	8.3	0.02	0.09	1	1.4	7.3	7.5	10	200	1.09	0.55	-----	-----	0.02	0.02	15	10	0.7	0.6	23	76	237	262	48	53	18
4/25/95	1025	1155	8.4	8.32	0.04	0.04	1	1	6.1	10.8	-----	30	1.01	0.3	10	13	0.01	0.03	14	16	2	2	24	78	243	275	51	57	28
6/27/95	0945	1102	8.2	8	0.03	0.01	1	1	7.9	9.5	100	50	0.3	0.09	20	22	0.02	0.03	27	13	3	2	27	66	229	277	44	58	28
8/29/95	0922	1042	8.3	8.1	0.372	0.106	4.2	5.9	7.6	7.1	200	300	0.88	0.1	19	23	0.04	0.02	47	20	5	4	38	246	243	298	49	78	1.1
10/24/95	0915	1115	**8.7**	8.2	0.079	0.198	2.8	4.7	8.4	8.5	10	10	0.77	0.32	3	2	0.01	0.046	12	17	2	7	31	112	235	264	55	68	9.8
3/26/96	1029	1145	8.1	8.2	0.079	0.205	3.5	3.2	12.3	11.7	13	2	1.15	0.9	0	1	0.1	0.108	66	27	11.9	4.4	26	105	241	297	63	76	19
9/24/96	1010	1130	8.2	8.4	0.01	0.01	4.5	2.9	7.9	8.2	180	390	1.39	0.44	12	14	0.059	0.119	14	17	6	10	31	68	249	278	65	74	72
11/19/96	1030	1155	8.5	**8.6**	0.02	0.02	1	1	8.3	5.7	50	10	1.07	0.79	5	4	0.027	0.05	5	3	1	2	30	90	249	288	57	68	23
2/18/97	0905	1040	8.1	8.3	0.02	0.02	1	1.8	10.1	10.9	10	30	1.08	0.79	4	4	0.011	0.026	6	8	2	2	29	83	248	277	58	66	31
4/15/97	0910	1027	7.6	7.9	0.033	0.029	4.83	1.98	9.5	10.7	230	10	1.11	0.56	8	8	0.024	0.066	9	20	2.6	8.5	37	87	244	286	62	75	26
6/10/97	1000	1142	8.2	8.4	0.02	0.02	1	1	9.3	8.9	400	300	0.85	0.4	15	19	0.05	0.14	30	51	7	16	31	72	244	280	62	71	29
5/12/98	0820	0942	7.7	8.1	0.063	0.037	4.38	2.88	7.7	7.1	3000	380	2.1	0.08	12	14	0.032	0.038	11	17	4.6	3.8	30	67	234	276	59	61	42
7/14/98	0915	1058	7.9	8.1	0.02	0.02	1	1	8.5	7.6	710	550	0.7	0.1	20	24	0.07	0.2	37	17	15	6.2	24	49	235	243	56	62	5.2
11/17/98	0908	1055	**8.6**	**8.8**	0.02	0.02	1	1.59	10.2	11	90	500	1.13	0.51	6	6	0.03	0.04	19	10	6	4	31	69	244	276	59	70	12
1/26/99	0900	1021	8.2	8.4	0.02	0.02	2.265	3.93	10.75	11.9	35	10	1.225	0.87	1	1	0.05	0.05	19.5	12	4	3.3	24	68	240	273	56	64	21
3/23/99	1057	1249	**8.9**	**8.7**	0.02	0.02	1	1	21.5	19.5	20	10	1.12	0.31	8	11	0.03	0.03	14	10	3.5	2.6	24	72	244	264	57	60	20
5/25/99	1050	1250	8.3	**8.6**	0.04	0.08	3.15	3.6	13.7	9.4	380	130	0.84	0.01	16	21	0.06	0.105	21	25	8.7	8.6	24	71	238	271	56	64	15
7/20/99	1102	1310	7.9	8.1	0.04	0.02	1	1	7.4	8.5	430	250	0.52	0.01	24	29	0.064	0.1	32	15	11	4.6	24	186	242	299	54	98	0.47
11/30/99	1040	1228	8	8.1	0.06	0.02	2.52	2.04	14.4	13.9	30	30	0.8	0.36	6	5	0.05	0.07	6	7	2.5	2.9	24	84	244	273	58	69	12
2/22/00	0936	1143	7.1	7.4	0.04	0.02	1.23	1.38	20.1	17.1	50	10	1.07	0.71	5	5	0.02	0.05	12	9	4	2.6	24	69	241	268	54	62	18
4/25/00	1000	1200	7.4	7.9	0.02	0.04	1	1.83	16.1	12.3	110	400	0.84	0.17	10	15	0.04	0.1	17	45	2.4	20	23	68	241	265	54	57	15
1/23/01	0900	1045	7.5	7.8	0.02	0.02	1	1	11.2	12.2	10	10	1.03	0.65	2	5	0.04	0.06	11	1	3.2	3.6	23	80	242	260	60	69	7.4
3/27/01	0850	1100	8	7.9	0.02	0.02	1.62	1.41	10.7	12.5	80	10	1.63	0.98	4	4	0.04	0.01	15	4	3.6	8.6	26	78	241	281	52	58	16
5/22/01	0845	1050	7.1	7.7	0.025	0.02	2.46	1	9.5	9.6	480	50	0.64	0.01	11	11	0.051	0.055	38	2	14	1.3	20	81	240	282	55	65	6.1
		Median	8.3	8.3	0.04	0.029	1.4	1.8	9.6	9.7	100	50	1.1	0.6	9	11	0.05	0.055	14	16	5	6.2	27	81	237.6	271.1	54.7	63.6	20

Table 4

COL_DATE	COL_TIME		PHFIELD		AMMONIA		BOD		DISOXY		FECCOLI		NITRATE		TEMP		PHOSPHU		TSS		TURBIDITY		SULFATE		ALKALINTY		CALCIUM		FLOW
	225	227	225	227	225	227	225	227	225	227	225	227	225	227	225	227	225	227	225	227	225	227	225	227	225	227	225	227	6827500
5/22/90	1032	1212	**9.2**	**9.9**	0.04	0.1	1.1	1.7	8.8	9.9	100	100	1.27	0.16	19	23	0.02	0.04	5	12	3	5.6	27	88	234	253	58	62	26
2/19/91	1040	1215	**9.6**	**10**	0	0	-----	-----	12.7	12.6	10	10	1.61	0.94	3	5	0.02	0.02	25	3	5.6	8	26	76	232	260	56	59	22
4/16/91	1045	1230	**9.2**	**8.8**	0	0	1.4	2	9.6	9.7	130	50	1.32	0.56	8	10	0.02	0.1	11	43	4.5	24	26	86	219	266	54	66	23
10/22/91	1045	1305	**8.6**	**8.9**	0	0	6.7	5.6	9.8	10.1	400	100	1.17	0.38	11	14	0.05	0.05	10	18	9	7.1	541	198	246	294	53	62	16
12/10/91	1105	1244	**9.4**	**9.6**	0	0	2	2.1	11.6	13.9	100	100	1.43	0.22	4	2	0.05	0.05	5	3	3.5	4.3	28	73	231	258	53	60	24
1/28/92	1116	1319	**9.4**	**10.2**	0.05	0	1.6	1.4	11.9	13.1	100	100	1.35	1	5	5	0.05	0.05	8	15	5.5	7	24	80	236	269	51	59	31
3/24/92	1135	1430	**9.5**	**9.8**	0.05	0.05	1	1.7	10.9	11.5	10	10	0.61	0.43	11	15	0.05	0.07	10	35	5	19.5	32	62	199	236	44	55	58
3/29/94	1020	1152	8.4	**8.6**	0.05	0.05	2.3	2.3	10.5	11.5	10	20	1.32	0.62	5	7	0.05	0.05	12	15	5.4	10.6	29	63	231	251	57	55	36
11/29/94	1026	1214	**8.8**	**8.6**	0.05	0.06	2	1.8	10	7.5	10	10	1.47	1.6	1	1	0.01	0.16	29	3	11	2	32	133	228	278	51	70	10
11/19/96	1030	1155	8.5	**8.6**	0.02	0.02	1	1	8.3	5.7	50	10	1.07	0.79	5	4	0.027	0.05	5	3	1	2	30	90	249	288	57	68	23
11/17/98	0908	1055	**8.6**	**8.8**	0.02	0.02	1	1.59	10.2	11	90	500	1.13	0.51	6	6	0.03	0.04	19	10	6	4	31	69	244	276	59	70	12
3/23/99	1057	1249	**8.9**	**8.7**	0.02	0.02	1	1	21.5	19.5	20	10	1.12	0.31	8	11	0.03	0.03	14	10	3.5	2.6	24	72	244	264	57	60	20
5/25/99	1050	1250	8.3	**8.6**	0.04	0.08	3.15	3.6	13.7	9.4	380	130	0.84	0.01	16	21	0.06	0.105	21	25	8.7	8.6	24	71	238	271	56	64	15
		Median	8.9	8.8	0.02	0.02	1.5	1.75	10.5	11	90	50	1.3	0.5	6	7	0.03	0.05	11	12	5.4	7	28	76	234	266	55.5	62.4	23

Table 5

S. Fk Republican R. Dilution Calculations					
Flow (cfs)		Nitrate Level (mg/L)		Mix	Instream
St Francis	Site 225	St Francis	Site 225	Result	Nitrate Target
0.329	10	4	1.02	1.115	1.12
0.329	40	4	1.10	1.124	1.12



Appendix: Figure 6