UPPER REPUBLICAN BASIN TOTAL MAXIMUM DAILY LOAD

Waterbody/Assessment Unit: Beaver Creek
Water Quality Impairment: Dissolved Oxygen

1. INTRODUCTION AND PROBLEM IDENTIFICATION

Subbasin: Beaver, Little Beaver, & South Fork Beaver

Counties: Decatur, Rawlins, Cheyenne & Sherman

HUC 8: 10250014, 10250013, & 10250012

HUC 11 : 10250014 (010, 031); 10250013 (010, 020); 10250012 (015, 020)

Drainage Area: 1,618 square miles above stateline gage and sampling station; 1,411 square miles above Ludell

Main Stem Segment: WQLS: 2 (Beaver Creek) starting at the Kansas-Nebraska state line and traveling upstream southwesterly through Decatur and Rawlins counties with North Fork Beaver Creek (Segment 2) and Little Beaver Creek (Segments 1,3 & 4) branching off above Atwood and with headwaters extending into Cheyenne and Sherman counties and Colorado (**Figure 1**).

Tributaries: Most tributaries are located near the Colorado border and are not likely to contribute flow except in the most extreme conditions.

Designated Uses: Expected Aquatic Life Support, Secondary Contact Recreation (b), Domestic Water Supply; Food Procurement; Ground Water Recharge; Industrial Water Supply Use; Irrigation Use; Livestock Watering Use for Beaver Creek in Rawlins and Decatur counties.

Impaired Use: Aquatic Life Support

Water Quality Standard: 5 mg/liter for Aquatic Life (KAR 28-16-28e(d) and table 1g)

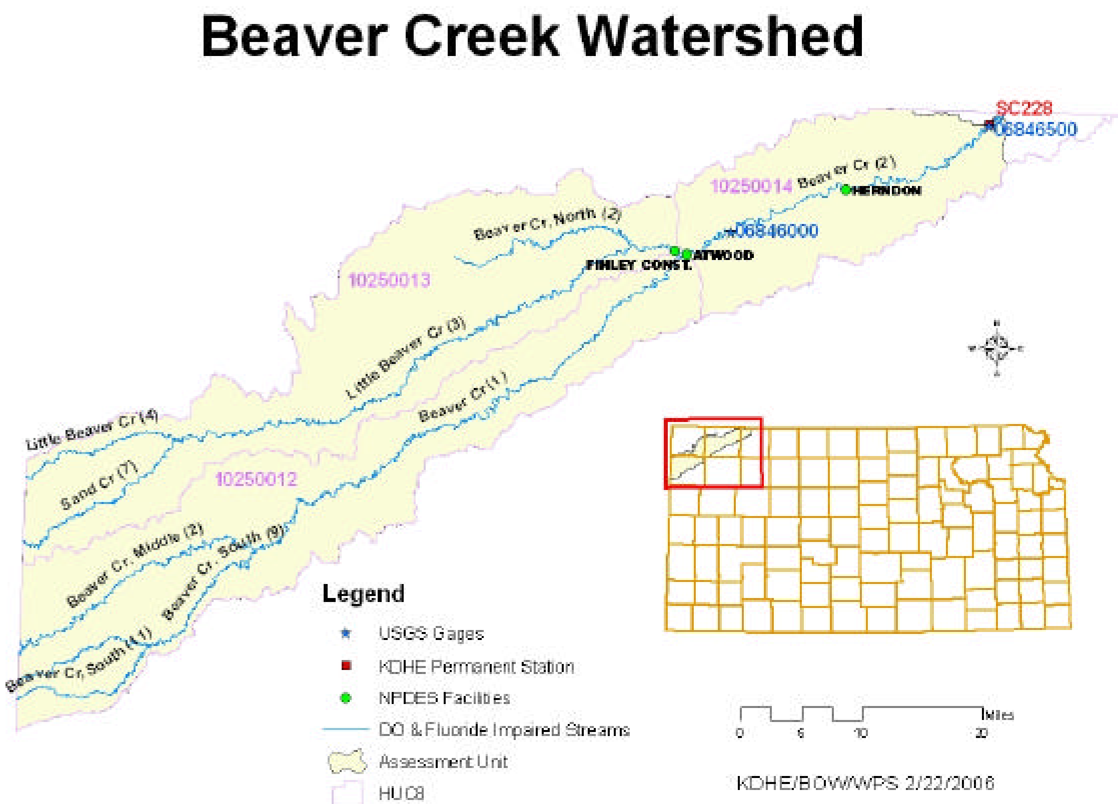


Figure 1- Base Map of Beaver Creek Watershed, along with monitoring sites and NPDES facilities.

2. CURRENT WATER QUALITY CONDITION AND DESIRED ENDPOINT

Level of Support for Designated Use under 2004 303(d): Not Supporting Aquatic Life

Monitoring Sites: Station 228 at Cedar Bluffs.

Period of Record Used: 1993-2005 for Station 228 (**Figure 2**)

Flow Record: Beaver Creek at Ludell (USGS Station 06846000); 1995-2005 & at Cedar Bluffs (USGS Station 06846500); 1970-2005 (**Figure 3**).

Long Term Flow Conditions: 90% Exceedance = 0 cfs, 75% Exceedance = 0 cfs, 50% Exceedance = 0 cfs, 25% Exceedance = 0.01 at Ludell, 1.8 cfs at Cedar Bluffs, 10% Exceedance Flows = 5.7 cfs at Ludell, 7.1 cfs at Cedar Bluffs. Mean Flow at Cedar Bluffs = 3.4 cfs.

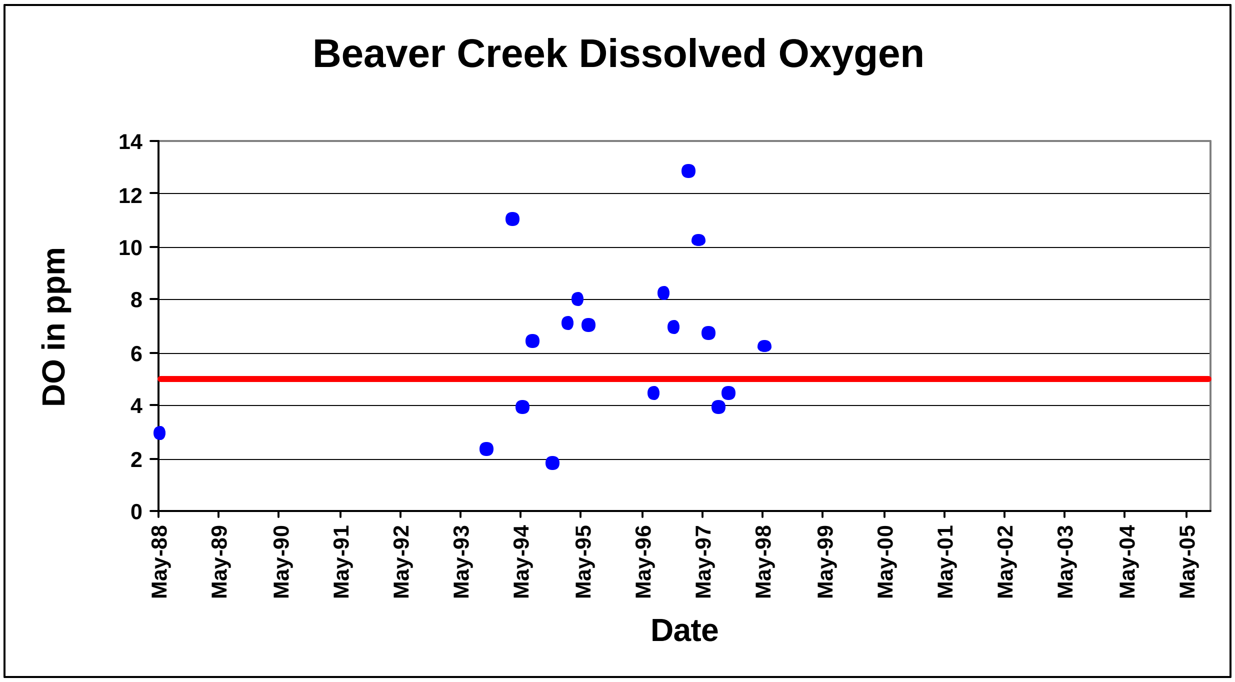


Figure 2. Dissolved oxygen concentrations seen on Beaver Creek. Red line indicates water quality criterion for Kansas waters. Dates without data correspond to no-flow events when KDHE personnel visited the site or dates with dubious data.

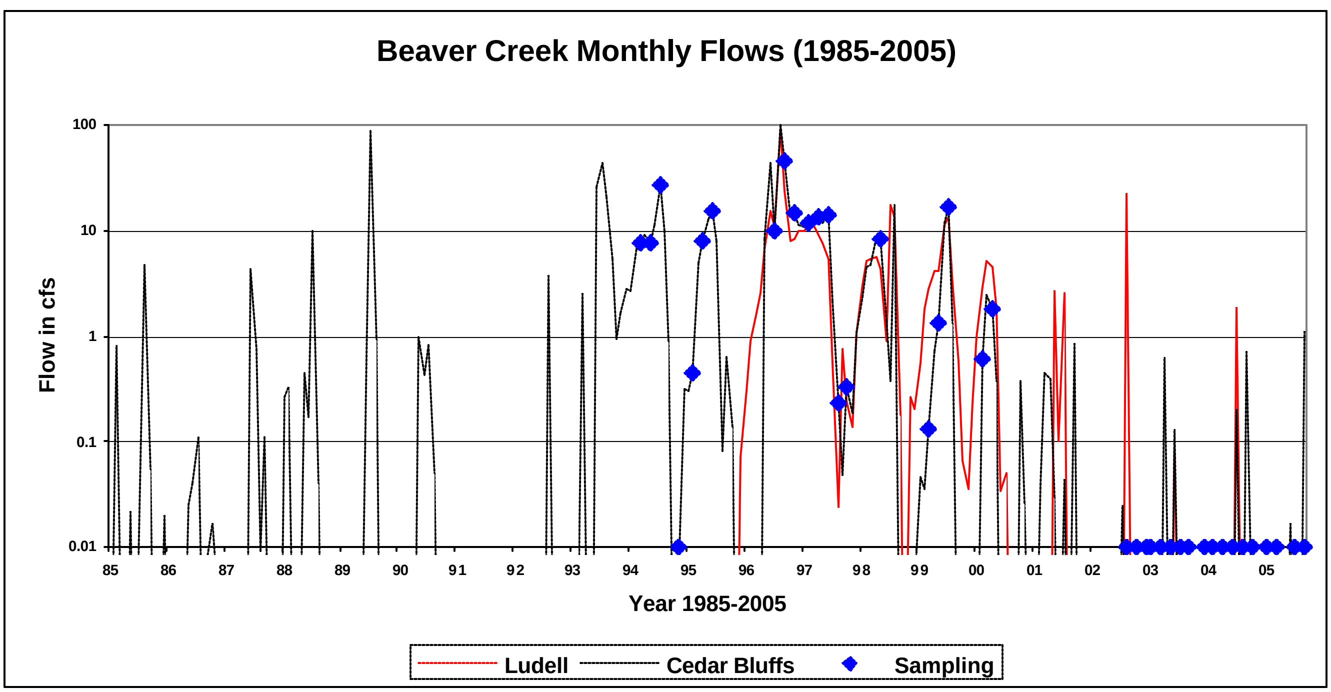


Figure 3. 20-year flow record on Beaver Creek. Blue diamonds indicate sampling dates. Dates with 0.01 cfs were no flow events, and samplings during no flow events indicate that KDHE personnel visited the site and found insufficient water to conduct routine sampling. Since 2000, all 18 site visits corresponded to no-flow events.

Current Conditions: Since loading capacity varies as a function of the flow present in the stream, this TMDL may be represented as a continuum of desired conditions over the entire flow spectrum rather than fixed at a single value. High flows and runoff equate to lower flow durations; baseflow and point source influences generally occur in the 75-99% range. However, Beaver Creek baseflow is depleted to the degree that flow is seen less than 25% of the time. Point source effluent likely infiltrates through the stream channel rather than flow downstream to the monitoring station. Since the percent exceedance does not have much meaning for displaying the context of the dissolved oxygen levels seen on Beaver Creek, an alternative expression for flow condition was derived. Flows on the date of sampling were divided by the mean daily flow for Beaver Creek (3.4 cfs). This percent of mean flow gives a more accurate perspective of flow distribution on a depleted system **(Figure 4).** Five of the deficit oxygen situations were well below mean flow, including an extremely low flow in winter. Two springtime deficits occurred with runoff, indicated by large percentages of mean flow. Most good quality situations, indicated by dissolved oxygen levels of 6 mg/l or more occurred with higher flows.

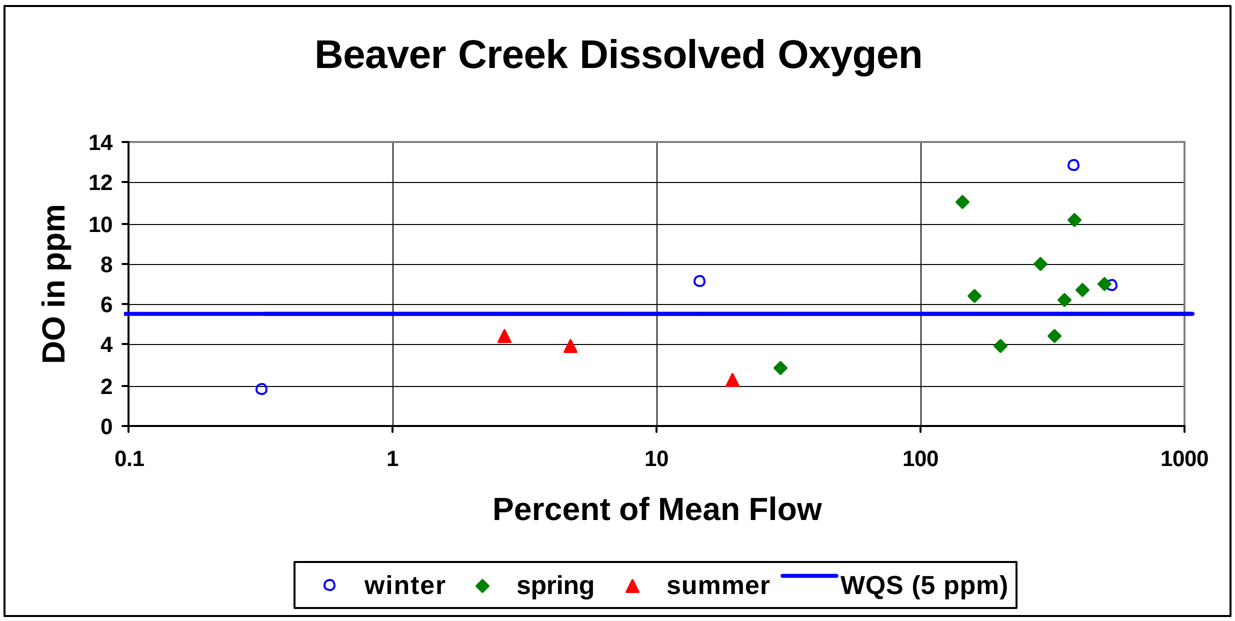


Figure 4. Distribution of dissolved oxygen over flow conditions expressed as percentage of mean daily flow on Beaver Creek (3.4 cfs).

Desired Endpoints of Water Quality (Implied Load Capacity) at Site 228 over 2008 – 2012

The ultimate endpoint for this TMDL will be to achieve the Kansas Water Quality Standards fully supporting Aquatic Life, indicated by dissolved oxygen concentrations of 5 mg/l or more. The lack of consistent flow will aggravate situations of deficient dissolved oxygen, particularly at flows below mean flow.

Seasonal variation has been incorporated in this TMDL through the documentation of high dissolved oxygen levels during spring when flows are typically the highest. Achievement of the endpoint indicates any loads of oxygen-demanding substances are within the loading capacity of the stream, water quality standards are attained and full support of the designated uses of the stream has been restored.

3. SOURCE INVENTORY AND ASSESSMENT

Correlation of DO with other Parameters

Dissolved oxygen is significantly correlated with streamflow, fluoride and selenium and inversely correlated with ammonia and total phosphorus. Though not significant, dissolved oxygen was also negatively correlated with parameters typically associated with runoff (BOD, fecal coliform, fecal strep and total suspended solids) as well as water temperature. **Table 1** and **Figures 5-9** display possible cause and effect relationships with low dissolved oxygen.

Table 1. Seasonal Cause and Effect Evaluation of Low Dissolved Oxygen

Factor	Season	Spring	Summer	Winter
Number of Samples < 5 mg/l DO	Delineator	3	3	1
Low Flow	Mean Flow	1/3	3/3	1/1
High Temperature	15 deg C	3/3	1/3	0
High Biochemical Oxygen Demand	3 mg/l	1/3	3/3	NA
High Fecal Coliform	100 counts	2/3	3/3	0
High Fecal Strep	100 counts	3/3	2/3	0
High Total Suspended Solids	100 mg/l	2/3	1/3	0

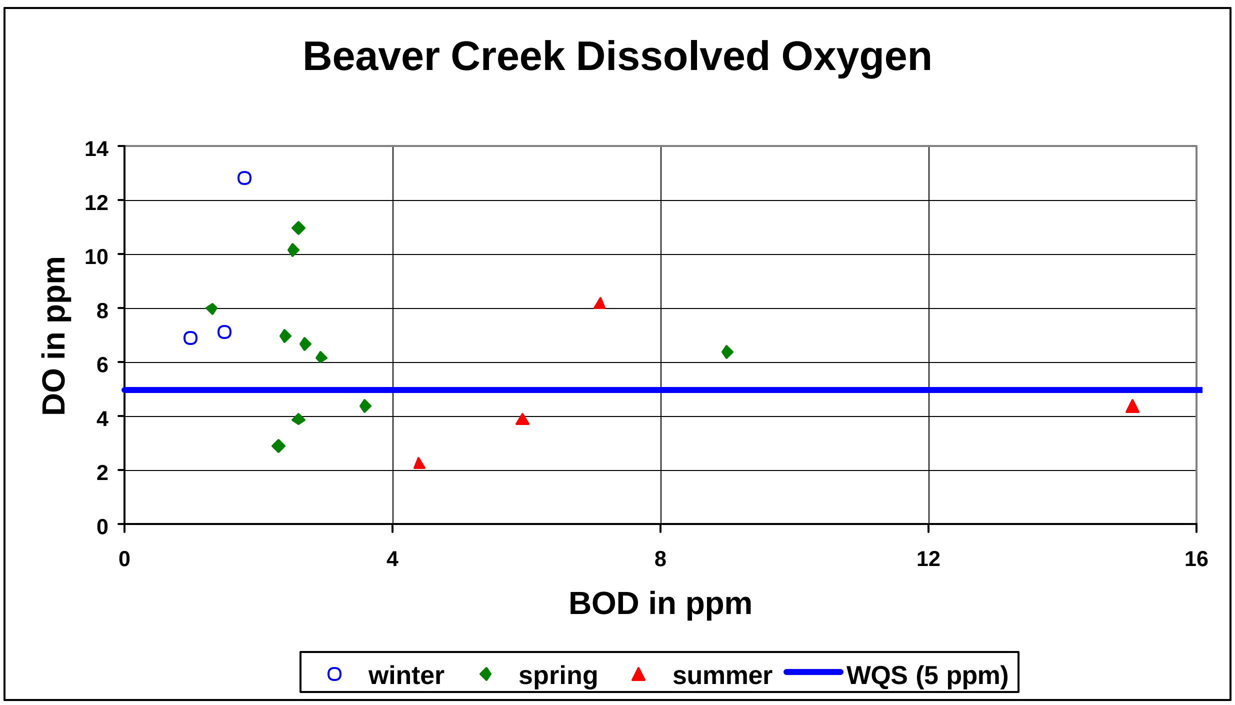


Figure 5. Relationship of Dissolved Oxygen and Biochemical Oxygen Demand in Beaver Creek

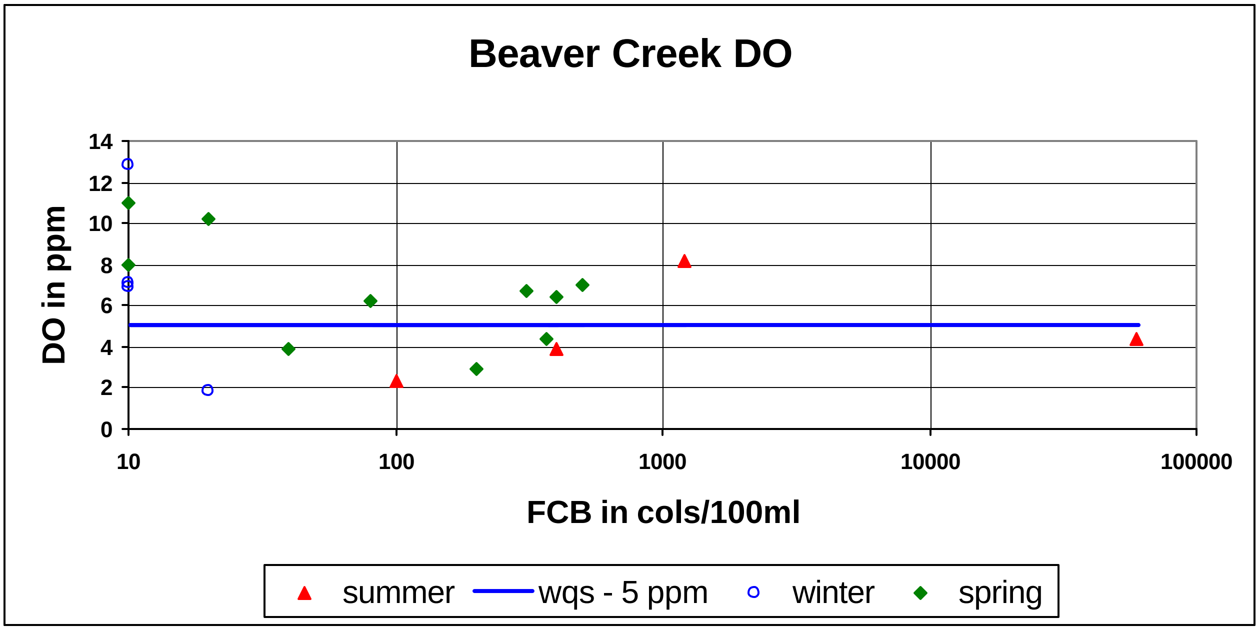


Figure 6. Relationship between Dissolved Oxygen and Fecal Coliform Bacteria on Beaver Creek

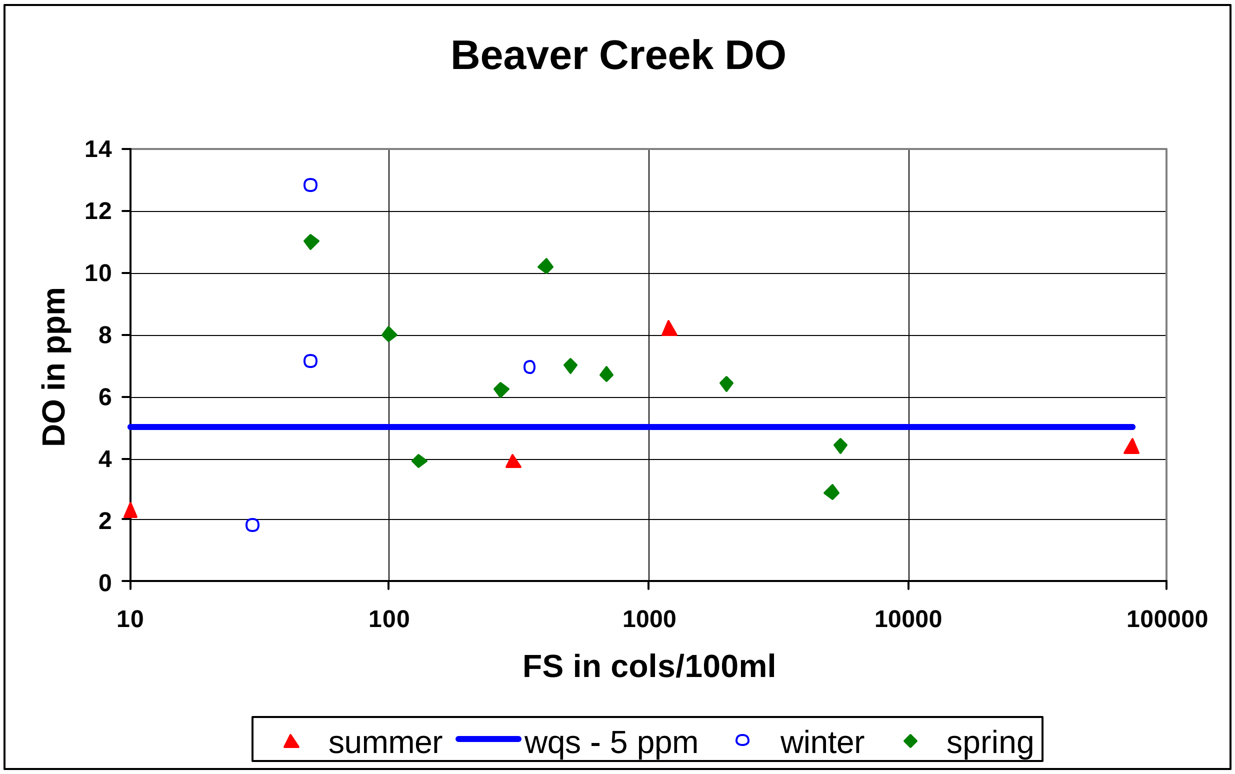


Figure 7. Relationship between Dissolved Oxygen and Fecal Strep on Beaver Creek

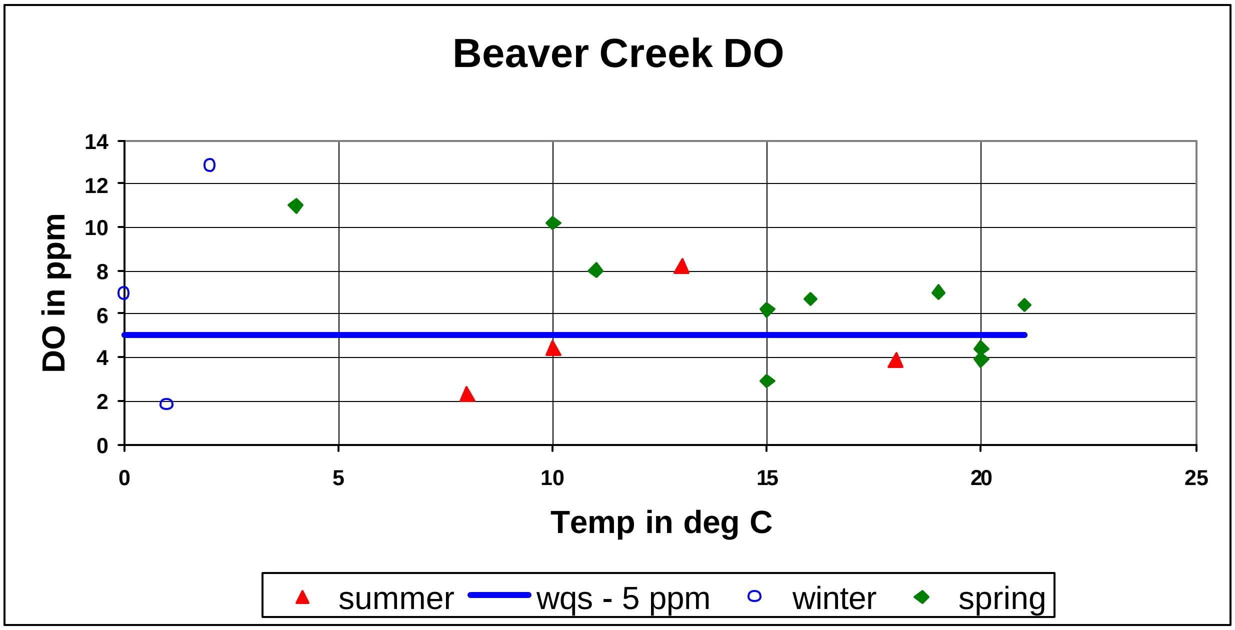


Figure 8. Relationship between Dissolved Oxygen and Water Temperature on Beaver Creek

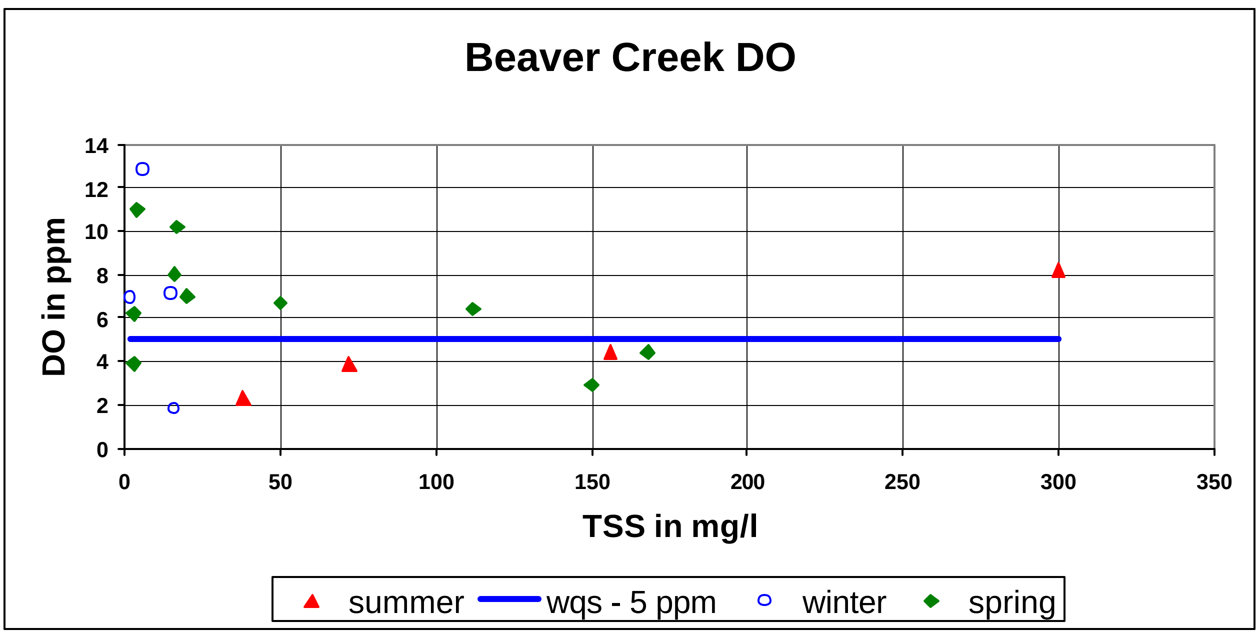


Figure 9. Relationship between Dissolved Oxygen and Total Suspended Solids on Beaver Creek

These limited data indicate that low dissolved oxygen levels on Beaver Creek are typically caused by a combination of low flows, warm water temperatures and some organic material loading into the stream. The exception is the winter deficit which defies ready explanation except the extremely low flow occurring during that sample.

NPDES: There are three NPDES permitted dischargers within the Beaver Creek watershed (**Figure 1**), all of them located in the lower portion of the stream system. None of the facilities contribute enough flow to deliver loads down to the Cedar Bluffs monitoring site (**Table 2**). The cities have permit limits for BOD in their effluent, (weekly averages of 45 mg/l; monthly averages of 30 mg/l). Atwood averaged 19 mg/l BOD in samples of effluent over 2004-2005. Herndon has not discharged since 2002. Finley Construction does not discharge BOD. Streeter-Phelps modeling indicate the two municipal dischargers do not cause any significant DO sag below 5 mg/l (**Appendix A**). Regardless, any discharges from the lagoon systems infiltrate through the stream channel a short distance below their outfall and it is unlikely the wastewater reaches Monitoring Station 228.

There are also a number of non-discharging systems located in the watershed in Cheyenne and Sherman counties. None of these are expected to contribute any loadings monitored at station SC228.

Table 2. Discharging Wastewater Systems in the Beaver Creek Watershed

Facility	NPDES#	KS Permit #	Type	Receiving Stream	Design Q	Permit Expires	BOD Limits
Atwood	**KS0095265**	**M-UR02-OO01**	**3-Cell Lagoon**	**Beaver Creek**	**0.20 MGD**	**06/30/2007**	**30 mg/l monthly; 45 mg/l weekly**
Herndon	**KS0025551**	**M-UR10-OO01**	**3-Cell Lagoon**	**Beaver Creek**	**0.035 MGD**	**09/30/2007**	**30 mg/l monthly; 45 mg/l weekly**
Finley Construction	**KSG110122**	**I-UR02-PR01**	**Concrete Plant**	**Little Beaver Creek**	**None from Settling Basin**	**09/30/2007**	**None**

Livestock Waste Management Systems: There are a number of confined animal feeding operations within the watershed, but only four between Atwood and monitoring station SC228 (**Figure 10**). The other facilities located in the upper portions of the watershed are not likely contributors of any pollutant causing the impairment because they are designed not to discharge and the stream system is depleted sufficiently that any spill would likely infiltrate into the immediate stream channel and not flow down into the lower reaches of Beaver Creek. The four facilities along the lower river are summarized in **Table 3**. Despite their proximity to the creek, they are certified not to cause significant pollution to the stream except in situations of extreme precipitation events (stream flows associated with such events are typically exceeded only 1% of the time). Such events would not occur at a frequency or of a duration that they would constitute a long-term impairment to the designated uses of the river. All four operations maintain relatively small numbers of animals within open lots ranging in area from about 3-10 acres. Any runoff from the open lots goes over cropland or grassy buffer strips before reaching small tributaries of Beaver Creek. Because these operations tend to be used for over-wintering and any herds are dispersed over the summer period, it seems unlikely these facilities are the active source of organic matter reaching the stream in the past. However, manure disposal techniques should be evaluated, particularly for the older operations near the bottom of the watershed.

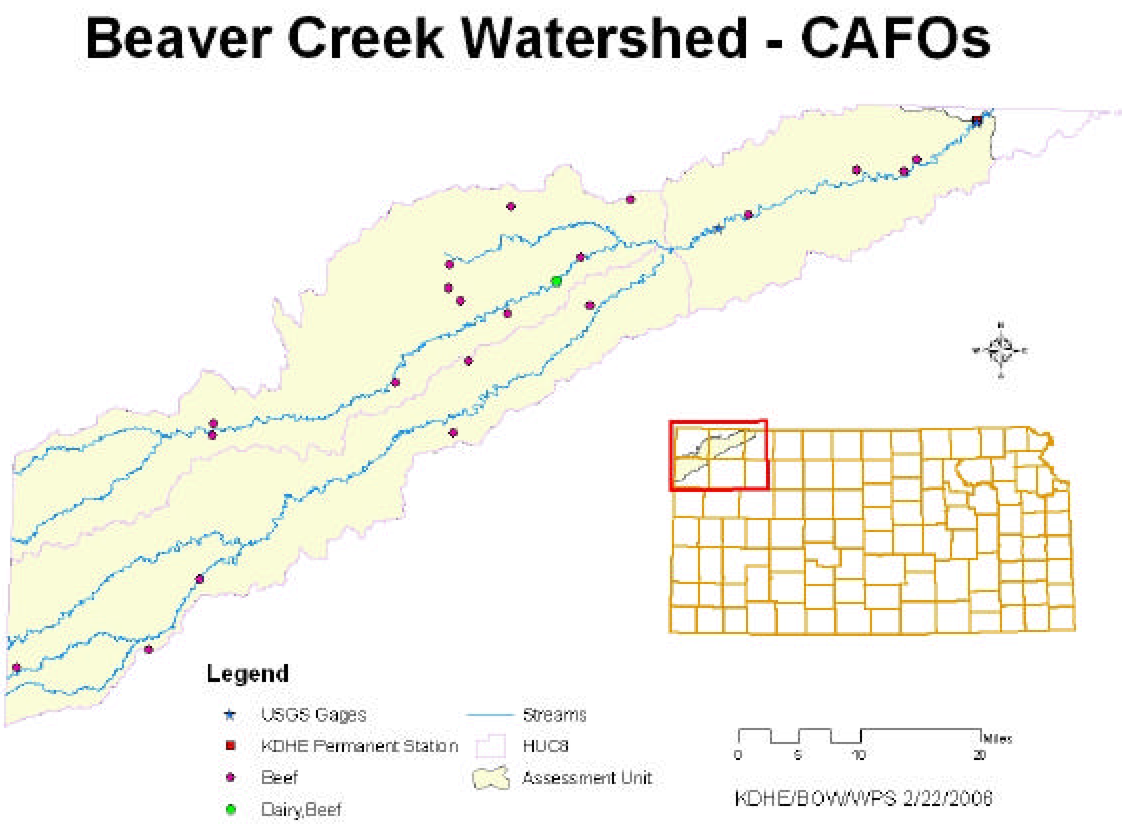


Figure 10. Animal Feeding Operations in the Beaver Creek Watershed.

Table 3. Animal Feeding Operations Along Lower Beaver Creek

Permit #	Type	Number of Animal Units	Remarks	Certificate Date
URRA-BA06	**Beef**	**600 Head**	**2.75 acre open lot; runoff flows over 700 feet of cropland and 300 feet of grass strips before Beaver Creek**	**July 1, 2002**
URRA-BA05	**Beef**	**150 Head**	**10 acre open lot; runoff flows over 900 feet of grass areas before small trib of Beaver Creek**	**March 13, 2001**
URDC-BA04	**Beef**	**150 Head**	**3 acre open lots**	**July 19, 1977**
URDC-BA02	**Beef**	**600 Head**	**5 acre open lots; runoff flows over 0.5 mile of cropland and 1 mile of grassy draw before Beaver Creek**	**January 20, 1975**

Land Use: National Land Cover Database GIS layers were used to assess land use in the basin. Most of the watershed is grassland (48% of the area) or cropland (47%) (**Figure 11**). Major crops were estimated by county level National Agricultural Statistics records. The majority of crop production is dryland wheat and irrigated corn and sorghum. Irrigation water likely draws on deepwater wells drawing from the High Plains Aquifer, although irrigation along the lower reaches of Beaver Creek probably uses alluvial water as its water supply.

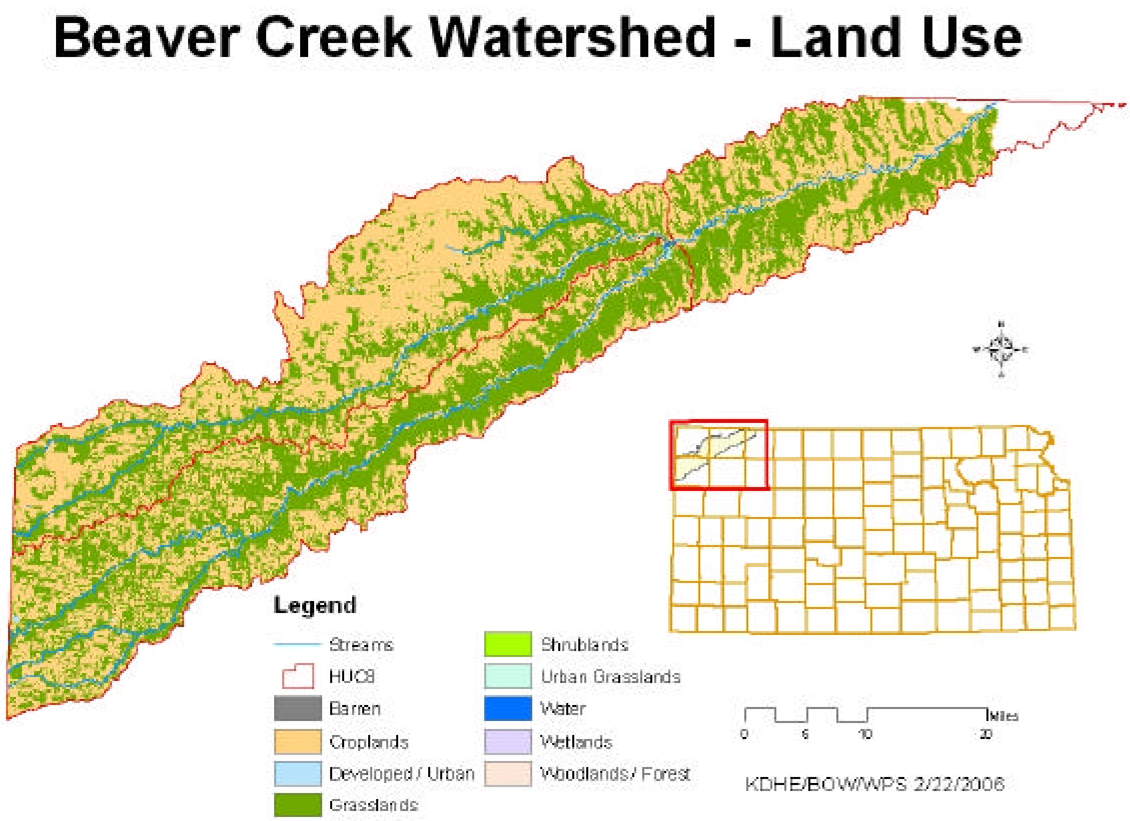


Figure 11. Land Use in the Beaver Creek Watershed

Irrigation: In 2003, over 111,300 acre-feet of water were used for irrigation in the Beaver Creek Watershed. Between 2000-2004, an average of 5075 acre-feet were used in the lower watershed below Atwood. Irrigation between Atwood and Herndon used 2000 acre-feet, and the balance was used between Herndon and the stateline. Much of the irrigation occurs in the western portion of the watershed supported by the High Plains Aquifer (**Figure 12**). This irrigation may not directly divert from Beaver Creek and its alluvium, but the accumulated withdrawal of water from the Ogallala formation and concurrent lowering of ground water levels have rendered

Beaver Creek as a perpetual losing stream. There are pockets of perched ground water that intersect the stream channel along portions of the southern branch of Beaver Creek. A surface water diversion for irrigation has consistently been used (approximately 26 acre-feet annually). Field observations made in March 2006 found some flow in Beaver Creek in southwest Rawlins County above Atwood. This flow disappeared within a mile above Atwood. Lake Atwood within the city has been all but dry for two decades. Six year average monthly flows have shown decline since 1980 (**Figure 13**); some of this depletion is loss of baseflow because of pervasive lowering of regional ground water tables; some of the loss of flow is reduction in runoff because of improvements in land treatment holding precipitation in place; and some of the loss may be attributed directly to lack of consistent precipitation since 2000.

Beaver Creek water use is governed by the Republican River Compact between Kansas, Nebraska and Colorado. Kansas has an allocation of 6400 acre-feet of consumptive use under the Compact. Ground water modeling done under the administration of a Special Master assigned by the Supreme Court to establish impacts of the three states to the Republican River and its tributaries indicates the average impact to Beaver Creek by Kansas pumping is 5150 acre-feet per year. Most of the recharge to the aquifers in the watershed is from precipitation, followed by return flow from ground water irrigation, but there is no surface water recharge. Hence, the stream suffers depletion of flow since there is generally no baseflow available to discharge from the aquifers to the creek and any precipitation and runoff generally is directed to recharge of the soil profiles and aquifers, rather than discharge to the streams. Lack of flow is certainly a principal cause of deficient dissolved oxygen seen on lower Beaver Creek.

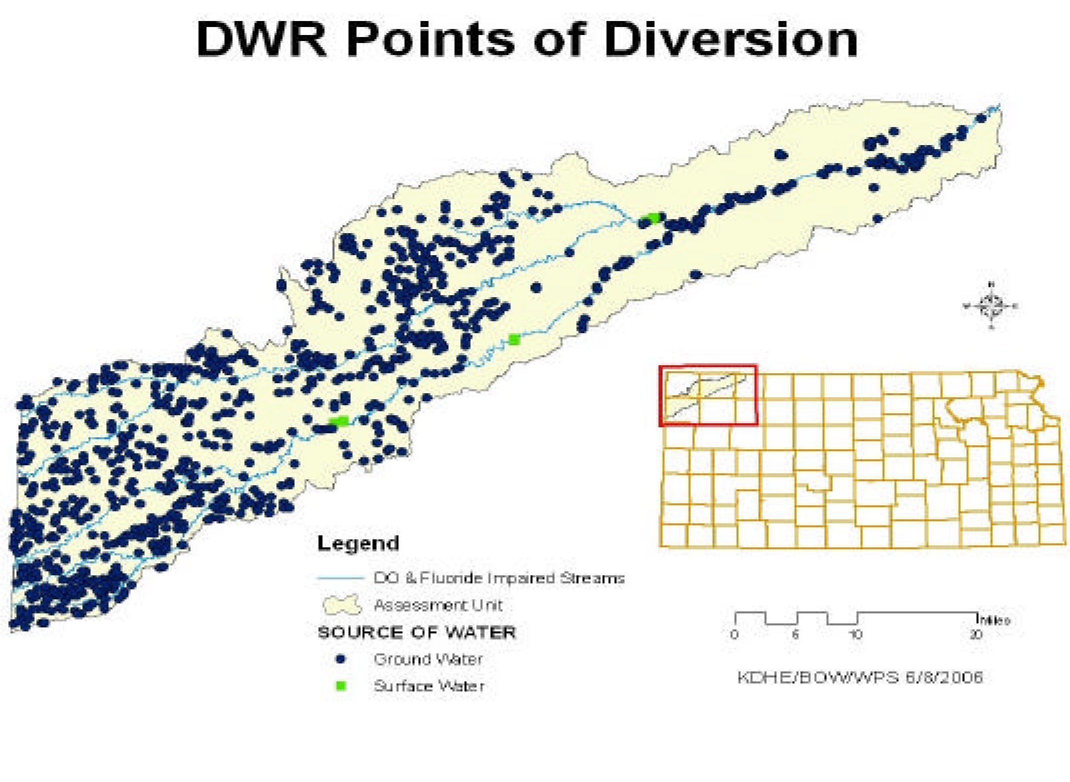


Figure 12. Water Right Points of Diversion (Mostly Irrigation) in the Beaver Creek Watershed

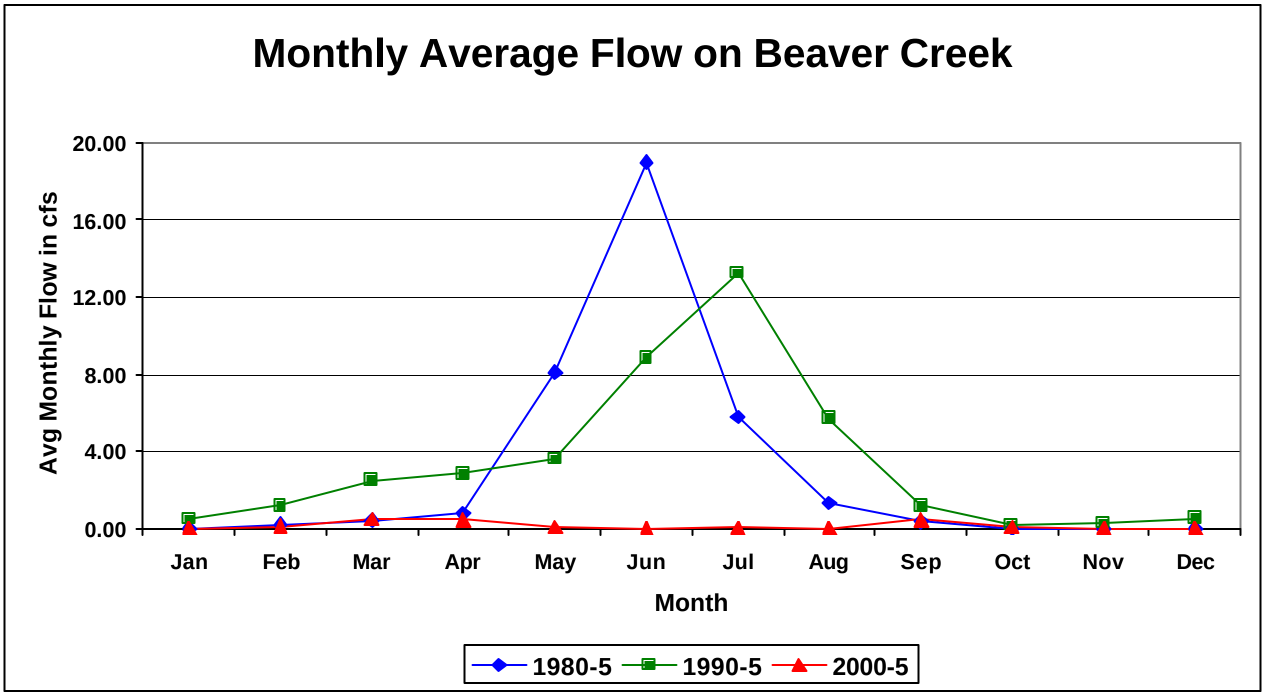


Figure 13. Six Year Monthly Average Flows on Beaver Creek by Decade

Population Density: Population density is low throughout most of the watershed. Estimates of 2004 population in Cheyenne, Rawlins and Decatur counties show declines over time and a low density of about 3 people per square mile. Estimates by the Kansas Water Office indicate declining population through 2020, although current Census estimates for 2004 already approach KWO estimates of lower population for 2010-2020.

4. ALLOCATION OF POLLUTION REDUCTION RESPONSIBILITY

Lack of sufficient dissolved oxygen is caused by a combination of introduction of organic material into Beaver Creek, mostly under warm water temperatures and with insufficient flow to either dilute the organic material or to provide re-aeration to the stream.

Point Sources:
Above Station 228, current Wasteload Allocations will be set for Herndon and Atwood, based on their current permit limits for BOD (30 mg/l) and the design flows of their wastewater treatment facilities. Therefore, Herndon will receive a Wasteload Allocation of 8.8 pounds per day of BOD, while Atwood will receive an allocation of 50 pounds per day. Neither point source with active discharge is seen as a main contributor to the depressed dissolved oxygen seen along Beaver Creek because of the lack of transmission of their effluent through the course of the stream channel to Station 228 and analysis through Streeter-Phelps modeling (**Appendix A**).

There will be a Wasteload Allocation of zero for Finley Construction and any state or NPDES permitted CAFO's within the drainage because such facilities should not discharge to Beaver Creek, except under extreme conditions and such conditions are not conducive to incidents of low dissolved oxygen in the Beaver Creek.

Non-Point Sources: Introduction of organic matter into Beaver Creek from runoff events might be the principal source causing the incidents of low dissolved oxygen. Based on observation of dissolved oxygen problems, a threshold of 3 mg/l for BOD seems an appropriate target since 4 of 6 dissolved oxygen deficits occurred when BOD was above 3 mg/l, while nine of the 11 samples with adequate dissolved oxygen had BOD below 3 mg/l. Using 3 mg/l as the threshold for organic matter loading into the stream, the associated BOD loading will be estimated as 55 pounds per day at mean flow (3.4 cfs). Over time, additional indicators of excessive organic matter in the stream, such as E coli bacteria or fecal strep levels or Total Organic Carbon (TOC), will be used to further assess the causal factors in low dissolved oxygen beyond the chronic low flow conditions typical of a depleted stream system such as Beaver Creek.

Defined Margin of Safety: The Margin of Safety provides some hedge against the uncertainty of loading and the dissolved oxygen endpoint for the Beaver Creek system and is considered implicit in this TMDL. Relative to point source loading, conservative assumptions are made regarding discharging at design flows in the face of declining service population and discharging at current BOD limits, whereas actual BOD concentrations of effluent are typically less than permitted. The most conservative assumption is the wastewater from either of the two municipalities actually transits a significant distance downstream to the monitoring station, when the true situation is the flow moves vertically more readily than laterally. Relative to non-point sources, the load allocation is made at mean flow, representing a more sustained flow condition on Beaver Creek than what actually occurs with episodic runoff events. Certified animal feeding operations below permitting thresholds will be the focus of implementation for this TMDL with inspection of seasonal use by livestock and manure disposal practices typically large distances away from Beaver Creek. The conservative assumption is that non-point BOD loads actually enter the stream and transit down to the monitoring station.

State Water Plan Implementation Priority: Because the streamflow of Beaver Creek is severely depleted and any loading of organic material is episodic with runoff events, this TMDL will be a Medium Priority for implementation. Low dissolved oxygen levels seen in Beaver Creek may be a consequence of pervasive lack of flow and warm temperatures.

Unified Watershed Assessment Priority Ranking: The lower Beaver Creek watershed (HUC 8: 10250014) is classified as a Category I, priority 54 watershed under the Unified Watershed Assessment, a low priority for restoration.

Priority HUC 11s and Stream Segments: Because of the lack of hydrologic connectivity among the stream segments above Monitoring Station 228, the priority segment for any implementation will be the lower segment below Atwood to the Nebraska stateline.

5. IMPLEMENTATION

Desired Implementation Activities

1. Conduct inspections of currently certified animal feeding operations in lower reach
2. Monitor NPDES performance of BOD treatment and downstream transit of wastewater
3. Restore some level of perennial flow to Beaver Creek

Implementation Programs Guidance

Municipal Programs - KDHE

a. Continue permit limits for Atwood and Herndon and monitoring requirements, including visual inspection of extent wastewater moves downstream on Beaver Creek

Livestock Waste Management – KDHE

a. Conduct inspection of certified animal feeding operations to ensure they have not become significant potential to pollute Beaver Creek
b. Evaluate disposal of manure from operations and potential to move into Beaver Creek during runoff events.

Republican River Compact Administration – KDA – DWR

a. Work to restore supply and demand balance to the water resources of Beaver Creek, consistent with the provisions of the Republican River Compact between Kansas, Nebraska and Colorado.

Timeframe for Implementation: Assessment of flow conditions and associated dissolved oxygen levels will be done with the 2009 review of Upper Republican Basin TMDLs, and again in 2014.

Targeted Participants: Primary participants for implementation will be the Livestock Waste Management section of KDHE and the Northwest District Office

Milestone for 2011: The year 2011 marks the mid-point of the ten-year implementation window for the watershed. At that point in time, additional monitoring data from Beaver Creek will be reexamined to confirm the impaired status of the river. Additionally, the Division of Water Resources should report on the level of compact compliance in the Beaver Creek watershed since 2005.

Delivery Agents: The primary delivery agents for program participation will be the Kansas Division of Water Resources and KDHE – Northwest District Office

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 Medium Priority consideration and should not receive funding at this time.

Effectiveness: Effective controls can be placed on municipal and livestock waste to minimize wastewater and oxygen demanding substances entering Beaver Creek.

6. MONITORING

KDHE will continue to collect bimonthly samples at Station 228, including DO measurements, in each of the three defined seasons over 2006-2010, provided streamflow is present at the station. Based on that sampling, the stream will be evaluated in 2011 for possible delisting in 2012 and in 2014 if more stringent controls might be necessary.

7. FEEDBACK

Public Meetings: Public meetings to discuss TMDLs in the Upper Republican Basin were held March 2, 2006 in Atwood. An active Internet Web site was established at http://www.kdheks.gov/tmdl/index.htm 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 March 2, 2006.

Basin Advisory Committee: The Upper Republican Basin Advisory Committee met to discuss the TMDLs in the basin on March 2, 2006.

Milestone Evaluation: In 2011, evaluation will be made to confirm the degree of impairment that has occurred within the watershed of Beaver Creek. Subsequent decisions will be made regarding the need for an implementation approach if dissolved oxygen levels show deficits when flows improve on Beaver Creek.

Consideration for 303(d) Delisting: The stream will be evaluated for delisting under Section 303(d), based on the monitoring data over the period 2006-2011. Therefore, the decision for delisting will come about in the preparation of the 2012 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.

Revised June 26, 2006

Appendix A-1

Streeter-Phelps DO Sag Model - Atwood - Beaver Creek Model

Single Reach - Single Load

1 cfs = .0283 m^3/s

0.25 mph =0 .11176 m/s

		Elev (ft)	Dist (km) to Herndon	Min DO	Crit Dist DO
0.0087560	Design Flow (Atwood)	2850	24.46	5.00	0.01
	Downstream Elev	2666			

Elevation Correction (DO)

Elevation	**2850**	ft
Correctn Factor (DO_{sat})	0.9088	mg/L

Unless modified by upstream pt. source, upstream BOD set as target for basin

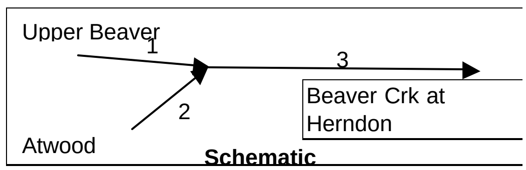
Upstream DO (where appropriate) elevation corrected and set at 90% sat.

Velocity	0.1		
BOD coef	0.23	Theta	1.056
O2 coef	(see Calc K_r)	Theta	1.024

Distance (km)
Flow (m^3/s)
Concentration (mg/L)
Temp (C)
Vel (m/s)

		Flow	BOD	DO	T	Dist (km)	Slope (ft.mi)	Calc K_r
2	**Atwood**	0.0087560	30	5	25	24.46	12.11	3.22
1	Upstream	0	0	0	0	-----		
3	Downstream to Station 228	0.00875602	12.7	6.35	25			
	Conditions at end of mixing zone		29.7	5				
							Adjusted Kr=	3.2

Kr Values (Foree 1977) using	0.42 (0.63 + 0.4S^1.15)
for q < 0.05 where q = cfs/mi^2 and	S (ft/mile)



Schematic

Appendix A-2

Streeter-Phelps DO Sag Model - Herndon - Beaver Creek Model
Single Reach - Single Load

1 cfs = .0283 m^3/s
0.25 mph =0 .11176 m/s

		Elev (ft)	Dist (km) to Stat 228	Min DO	Crit Dist DO
0.0015323	Design Flow (Atwood)	2666	19.31	5.80	0.01
	Downstream Elev	2549			

Elevation Correction (DO)

Elevation	**2666**	ft
Correctn Factor (DO_{sat})	0.914688	mg/L

Distance (km)
Flow (m^3/s)
Concentration (mg/L)
Temp (C)
Vel (m/s)

Unless modified by upstream pt. source, upstream BOD set as target for basin
Upstream DO (where appropriate) elevation corrected and set at 90% sat.

Velocity	0.1		
BOD coef	0.23	Theta	1.056
O2 coef	(see Calc K_r)	Theta	1.024

		Flow	BOD	DO	T	Dist (km)	Slope (ft.mi)	Calc K_r
2	**Herndon**	0.0015323	30	5.8	25	19.31	9.75	2.57
1	Upstream	0	0	0	0	-----		
3	Downstream to Station 228	0.001532304	12.8	6.02	25			
	Conditions at end of mixing zone		29.61	5.63				
							Adjusted Kr=	2.57

Kr Values (Foree 1977) using	0.42 (0.63 + 0.4S^1.15)
for q < 0.05 where q = cfs/mi^2 and	S (ft/mile)