Investigation of the Changes in Water Quality in the Little Bear River Watershed in Response to the Implementation of Best Management Practices

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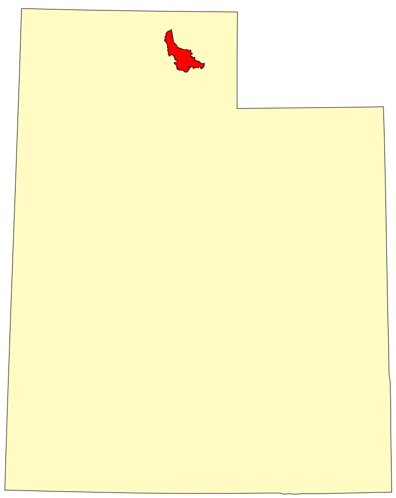


UtahState UNIVERSITY

Introduction and Objectives

This CSREES Conservation Effectiveness Assessment Project is evaluating whether adoption of several agricultural best management practices in a Northern Utah watershed have had a measurable impact on phosphorus loadings into the Little Bear River. Historical ambient water quality data suggest an aggregate decline in phosphorus loadings in the Little Bear River watershed. We are analyzing fine-grained data from throughout this watershed to determine whether these changes are related to the implementation of management practices or to other factors such as changes in land use or long term drought conditions during the years since the completion of most of the BMPs. This poster presents preliminary findings after one year of our three year project.

The core research objectives that are being addressed by this project include:

- **To determine whether publicly-funded programs to promote the adoption of agricultural conservation best management practices were able to reduce phosphorus loadings into surface waters in the Little Bear River watershed.**
- **To critically examine the strengths and weaknesses of different water quality monitoring techniques, and**
- **To make recommendations to policymakers, agricultural conservation field staff, and other interested parties to ensure that future agricultural management efforts are targeted towards the most effective and socioeconomically viable best management practices.**

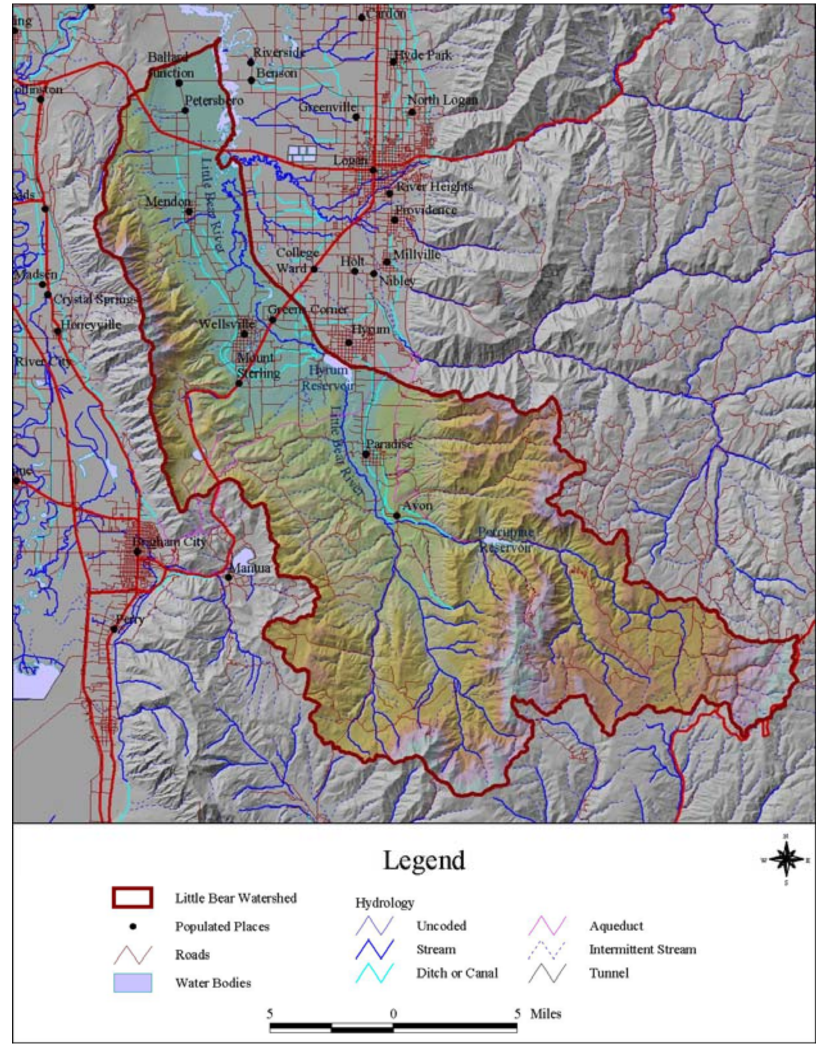
Project Area Description and History

The Little Bear River watershed, located in northern Utah, encompasses approximately 74,000 ha of primarily agricultural lands. Approximately 70 % is grazing land and forest, 19 % is irrigated cropland, and 7 % is dry cropland. The area is home to over 50 dairies, with an average size of 120 milk cows. The area is also experiencing rapid population growth, with a 32 % increase in population between 1990 and 2000.

In the late 1980's, the Little Bear River was identified as having significant water quality impairment. During the 1990s, state and federal cost share programs were used to help landowners adopt a number of recommended conservation practices.

During the course of the project, more than 100 framers voluntarily implemented conservation practices that were designed to reduce nutrient and sediment runoff to the river from dairies, rangeland, and pastures. These practices have included:

- Installation of animal waste management systems on at least 45 farms within the watershed
- Stream bank vegetation that reduced erosion on more than 5 miles of the river and tributaries
- A major dumpsite on McMurdie Hollow was cleaned up
- Improved vegetation and grazing management reduced erosion from 7500 acres of rangeland.



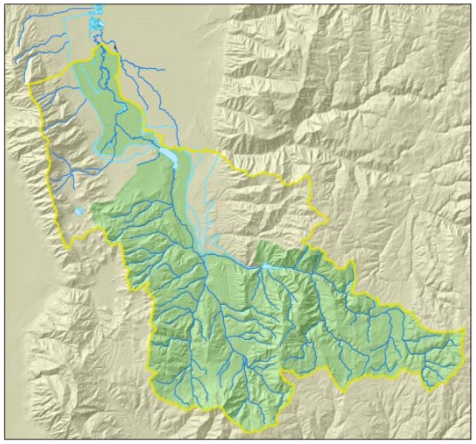
Introduction and Objectives

Best Management Practices that were implemented within areas of the watershed critical to the generation of pollutant loads (i.e., areas near the river with high runoff and erodable soils) have the greatest likelihood of impacting downstream water quality. We are in the process of examining the Little Bear River watershed to identify critical areas that may be important in contributing pollutant loads to the river. A variety of methods are being used, including:

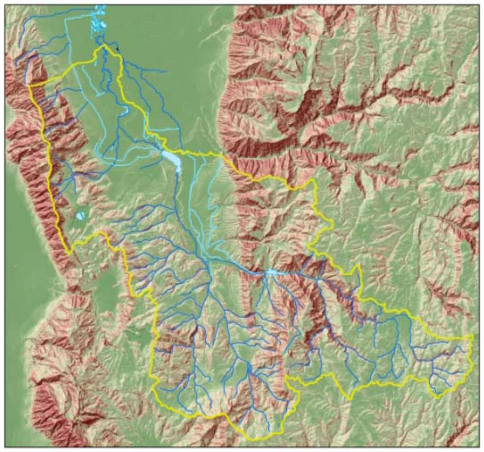
- Terrain analysis using a digital elevation model (DEM) to identify flow paths, contributing areas, and distances to active water courses
- Evaluation of the USLE and other methods for determining the potential for sediment generation and runoff
- Risk based analysis that combines several variables into a composite index indicating the potential for pollutant load generation

The results of these analyses are being used to narrow data collection efforts and participant surveys within the watershed. The following are examples of considerations in critical area analysis:

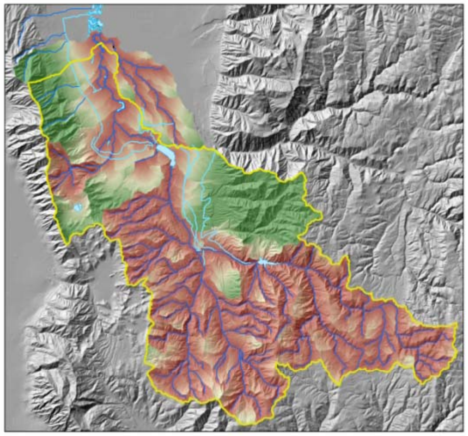
- Interception of runoff by canals is an important consideration in critical area analysis. The figure below shows that the true contributing area of the watershed may be much smaller because of interception of runofff by irrigation canals.
- In the figure below, areas of high slope are shown in red. These areas my have a higher potential for contributing runoff and pollutant loads, especially when combined with erodable soils.
- The distance from a BMP to an existing stream is another factor that controls its effectiveness in reducing phosphorus loading to the Little Bear river.



The area of the watershed not intercepted by canals is shown in green.



Areas of higher slope are shown in red.



Areas near an existing waterway are shown in red.

Documenting Conservation Behavior

An important element of our project is to document actual changes in agricultural land management as a result of the Little Bear Watershed Project. We have begun collection of detailed information about two kinds of behavior:

- **Behaviors that were directly related to the project**. This includes information about the type, location, and timing for all Best Management Practices (BMPs) that were part of producer contracts in the watershed,
- **Behaviors that were indirectly related to the project**. These include changes in associated behaviors that maximize the benefits of contracted practices (such as change in manure management that a manure storage structure can facilitate), as well as information about whether producers were able to continue using recommended practices after the expiration of their original contracts.

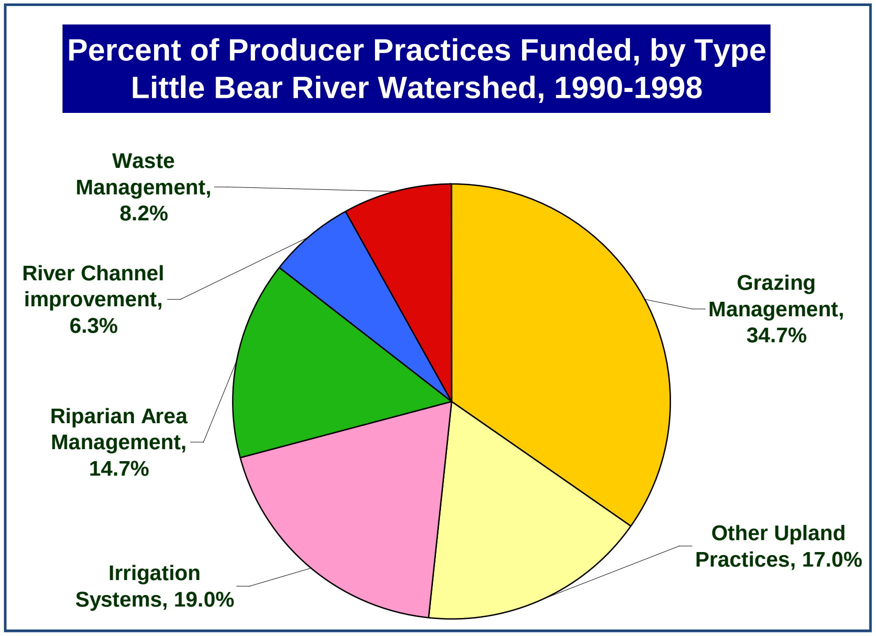
Although this information is available in USDA/NRCS files, it has taken significant time to access and record the essential data. Concerns about protecting the confidentiality of program participants led to development of a rigorous protocol that governs how information from NRCS files can be handled and analyzed. In addition, changes in record-keeping programs and standards over time have made collection of consistent program participation information challenging.

Important Conservation BMPs in the Watershed

Project files indicate that the most important categories of conservation practices funded under this project are grazing and other upland management practices, irrigation system improvements, streambank and stream-channel restoration, and livestock waste management (see the figure at right).

Interviewing Project Participants

Although a significant amount of information can be gleaned from NRCS files, we plan to conduct field interviews with most of the project participants. These interviews will help us understand how implementation of BMPs was experienced by producers and whether or not they were able to maintain these practices beyond the life of their original NRCS contract.



Analysis of Historical Monitoring Data

Are there statistically significant trends in phosphorus loading in the Little Bear River Watershed?

Cluster/Discriminant Analysis

Six clusters of water quality data at an upstream (Avon) and a downstream (Mendon Road) monitoring station supported the following description of major time-period related water quality conditions:

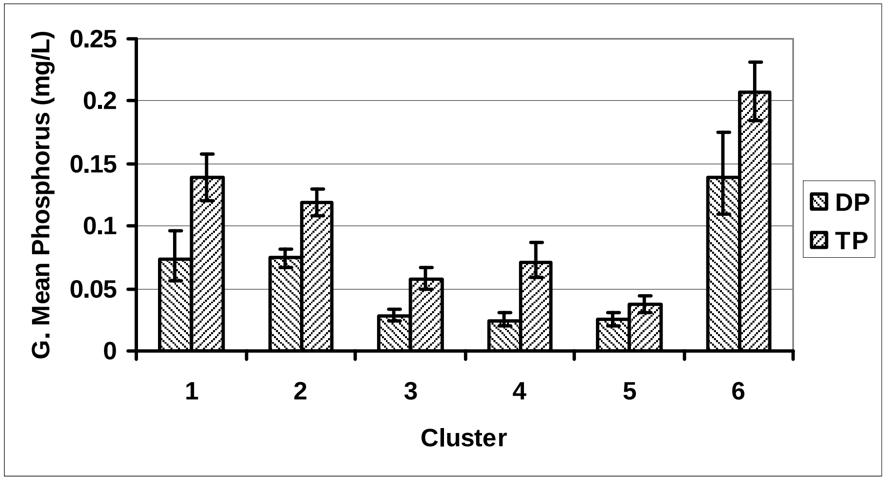
Ground water with relatively low phosphorus concentrations dominates stream flow except during spring snow-melt periods

Spring runoff may contain both phosphorus laden and relatively low phosphorus water quality depending on the elevation and rate of snow melt events

Higher sediment associated phosphorus concentrations occur during later summer/early fall at the Mendon Road station

The results of these analyses will be used to help design the water quality model for the Little Bear River basin.

This analysis suggests that monitoring programs should be designed or modified based on the temporal patterns of nutrient transport to improve sensitivity to water quality changes in response to management



Cluster geometric mean dissolved (DP) and total (TP) phosphorus at the "downstream" Mendon Road site. Cluster median dates: 1-Aug. 21, 2-Jun. 6, 3-May 11, 4-Jul. 15, 5-Apr. 20, 6-Jul.16.

Analysis of Historical Monitoring Data

Are the changes in phosphorus loading due to implementation of BMPs or a result of other factors such as land use changes, climatic conditions, or other exogenous factors?

A series of ANCOVA tests were conducted for total phosphorus (TP) and dissolved total phosphorus (DTP) samples from the upper (LITTLE BEAR R W OF AVON AT CR XING) and lower (LITTLE BEAR R @ CR376 XING--MENDON RD) Little Bear River monitoring sites with the largest datasets. Important results from these analyses were as follows:

For ANCOVA blocking over months with year as a covariate: TP loading (1977-2004) declined significantly over time for the period of record for both sites; however, TP loading did not decline significantly over the period 1990-2004 at either site. DTP loading (1990-2004) declined significantly over time for the lower site only.

For ANCOVA blocking over periods 1977-1989, 1990-1994, 1995-2004 with flow as a covariate: TP concentration was significantly higher in 1977-1989 than in the later time periods for both sites. TP concentration was lower (but not significantly) in 1995-2004 than in 1990-1994 for the lower site, but the reverse was true for the upper site. For DTP concentration, samples were only collected after 1989. DTP concentration was significantly lower during 1995-2004 than for 1990-1994 for both sites. TP and DTP concentrations increased significantly as a function of flow.

These analyses suggest a period of high loading prior to 1990 with a subsequent decline after 1990. DTP declined in the lower site between 1990-1994 and 1995-2004, while TP was not observed to decline after 1990 at either site. Significant declines in DTP concentration with the effect of flow removed suggests potentially less loading of DTP post 1995.

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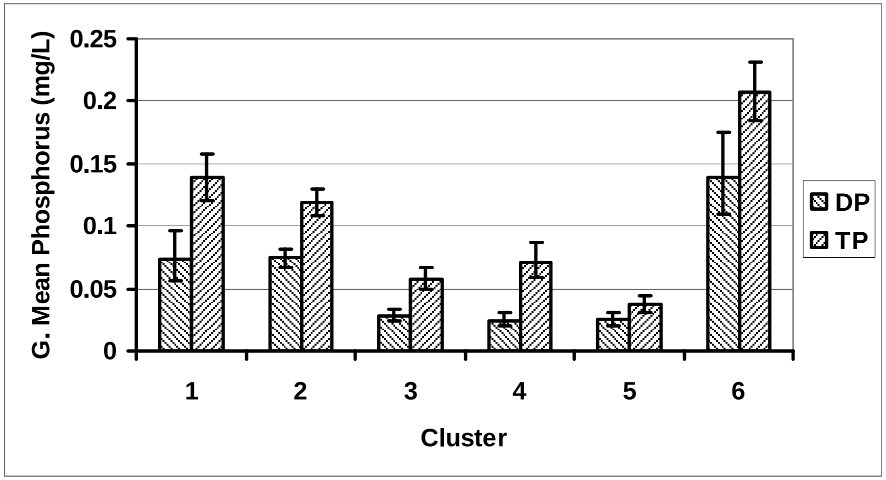

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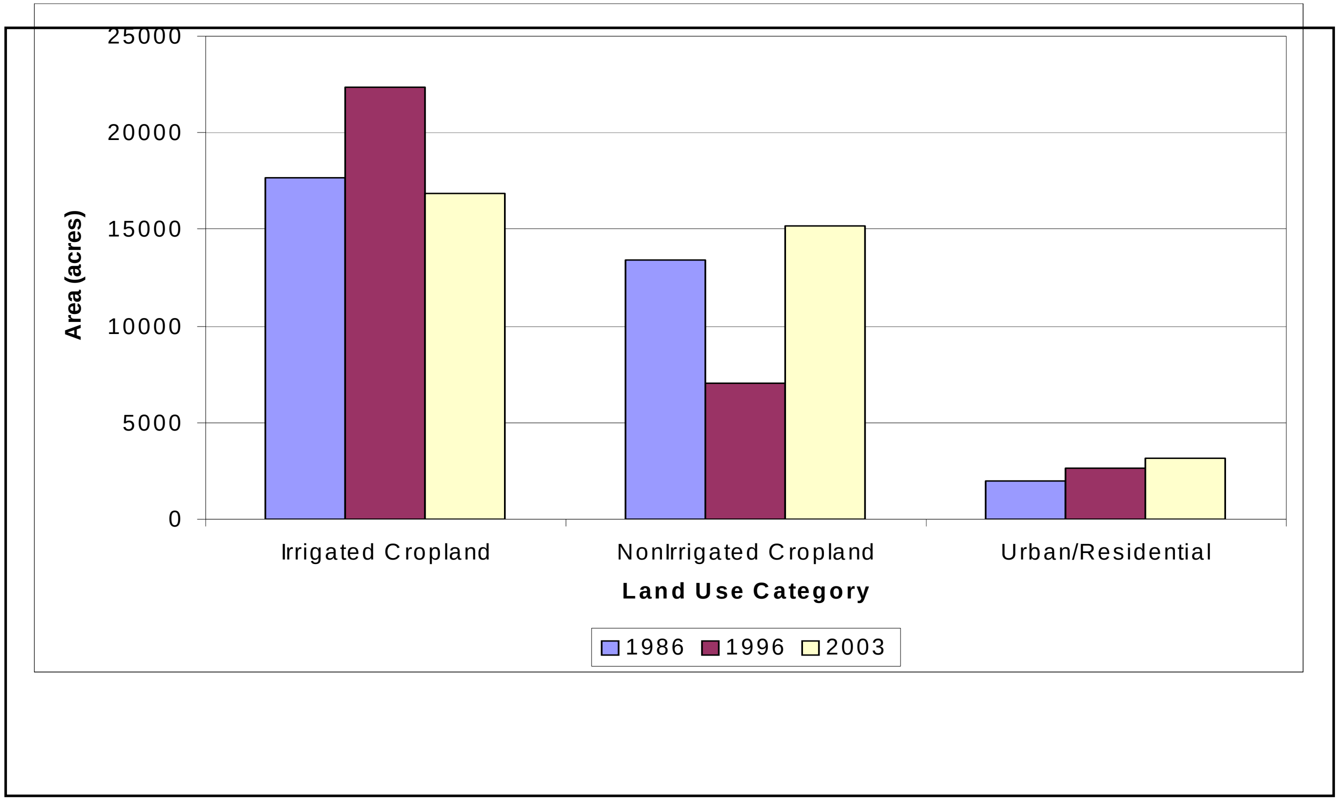
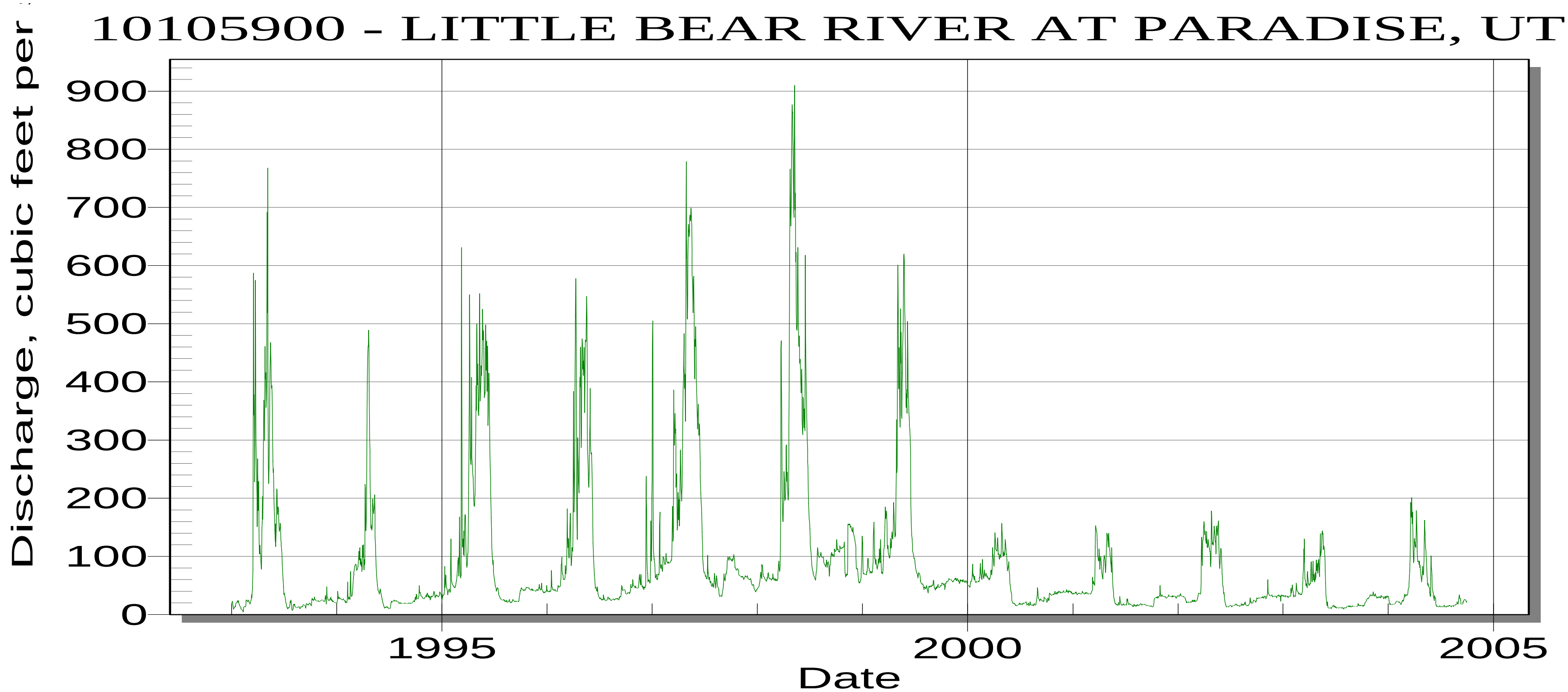


Land use change in the watershed has been significant. Current areas of irrigated and non-irrigated agriculture in the watershed are similar to those of the mid 1980s, but the 1990s show a significantly different distribution. Urban and residential land within the watershed continues to grow steadily.

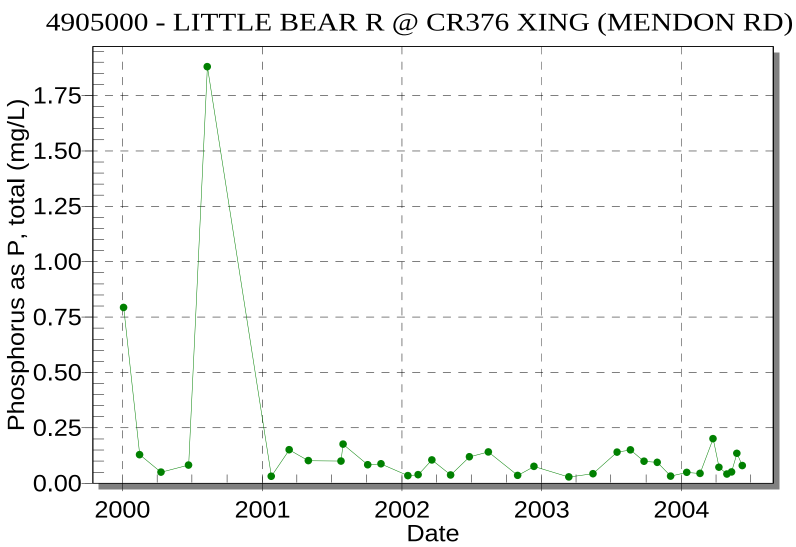
Analysis of Historical Monitoring Data



This plot of streamflow from the Little Bear River near Paradise, UT illustrates the variability in flows that are a result of climate conditions in this watershed. The period over which many of the management practices were implemented in the watershed (1990 -2000) experienced much higher flows than have been measured in the last several years.

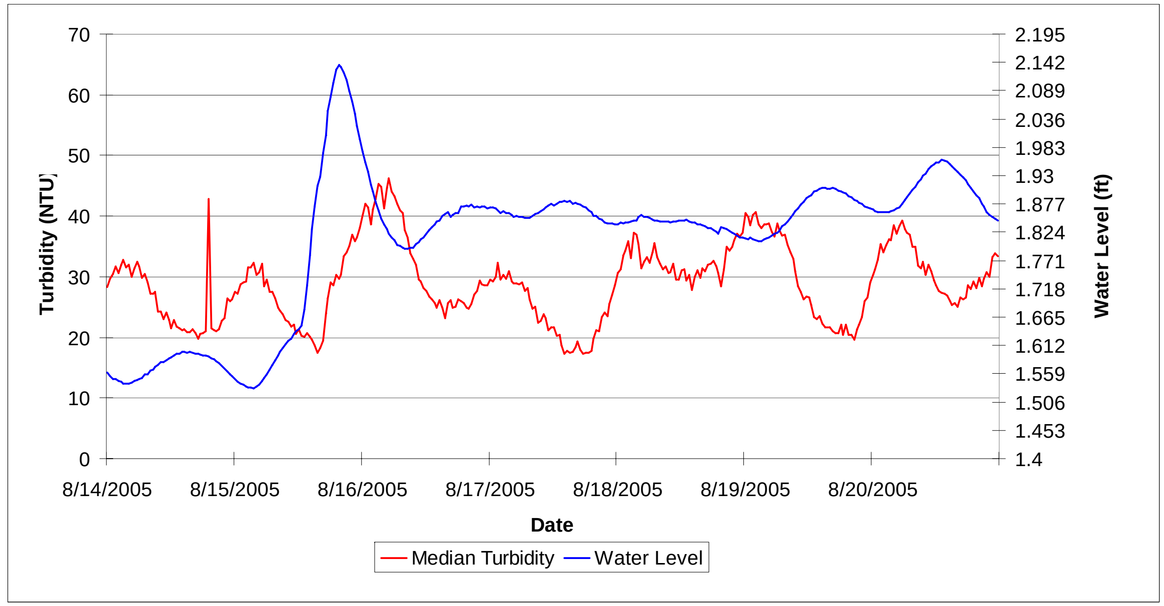
Critical Analysis of Monitoring Techniques

We are examining the effectiveness of different monitoring techniques in characterizing pollutant loads



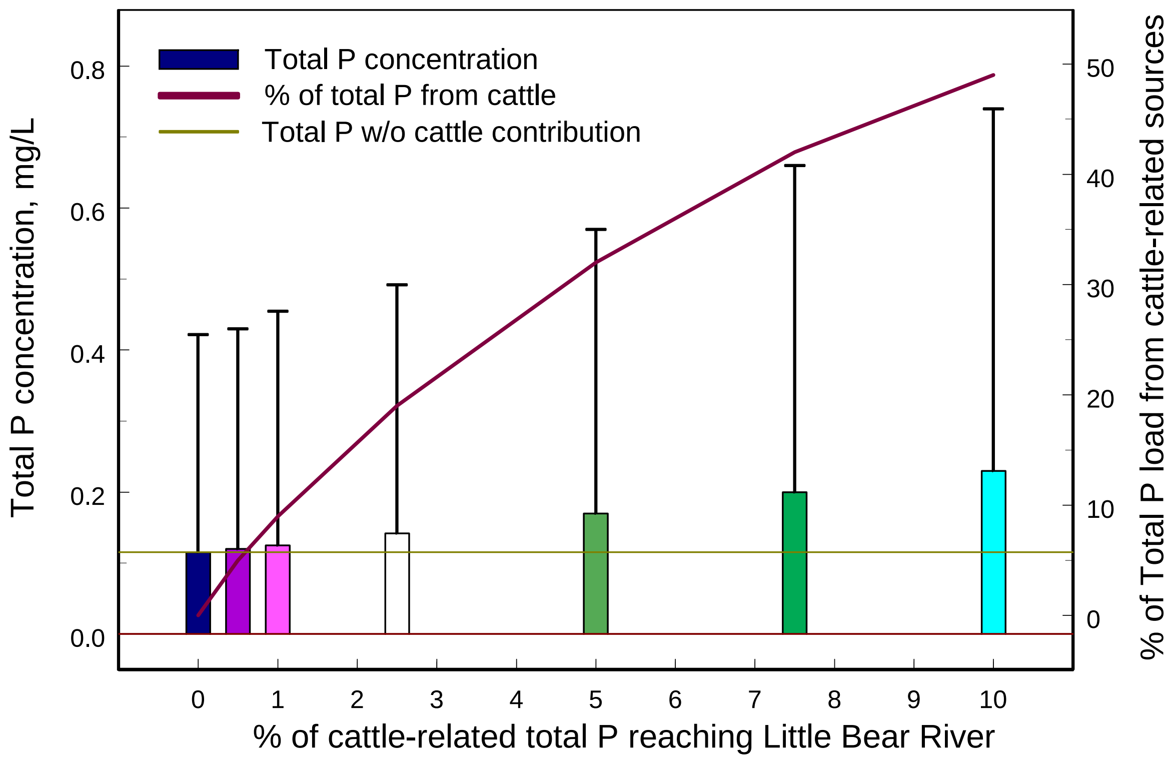
The figure above shows the available observations of total phosphorus collected by the State of Utah Division of Water Quality at the Mendon road sampling site from 2000 through 2004. Samples are collected infrequently and are likely not characteristic of the dynamic nature of water quality conditions in this watershed. However, these are the only available data to characterize nutrient concentrations and loads!

Critical Analysis of Monitoring Techniques



The figure above shows continuous monitoring data with a frequency of 30 minutes collected at the Mendon Road site near the mouth of the watershed. These data, collected over a period of seven days using in-situ monitoring equipment shown at left, show daily fluctuations in flow (as evidenced by changes in water level) and water quality that are likely important to characterizing pollutant loading but that are not captured in the traditional monitoring data shown above.

Pollutant Loading Sensitivity Analysis



Potential Load Contribution from Agriculture

Although these results are preliminary, several observations are of interest.

- Even if all phosphorus generated by cattle in the lower watershed was retained on the soil, the downstream total phosphorus concentration would exceed the State of Utah guideline of 0.05 mg/L.
- A reasonable upper bound of 10% of cattle-derived phosphorus entering the stream provides 50% of the total P load in the Littler Bear River.
- The uncertainty in the downstream concentration is large – future, more detailed, analysis will approach the mass balance with more analytical rigor.

Ultimately, predictions will be made using the watershed water quality model currently under development.

Pollutant Loading Sensitivity Analysis

Potential Load Contribution from Other Sources

Parameter		Period of record Value	Period of record Standard deviation	Period of record n	1990 - 1996 Value	1990 - 1996 Standard deviation	1990 - 1996 n	1997 - 2004 Value	1997 - 2004 Standard deviation	1997 - 2004 n
Upstream (490565)										
Flow	**m^3/d**	84896	201600	54	98916	225576	44	30966	34587	10
TP	**mg/L**	0.066	0.116	61	0.076	0.129	48	0.026	0.012	13
Load *	**kg/d**	5.57			7.56			0.794		
Load **	**kg/d**	11.3	45.2	45	11.8	46.2	43	0.22	0.07	2
Point sources										
Flow	**m^3/d**	1529	1529	86	1716	1615	66	851	968	20
TP	**mg/L**	2.13	1.87	64	2.85	1.91	42	0.750	0.5199	22
load*	**kg/d**	3.26			4.89			0.638		
Load**	**kg/d**	6.32	7.06	39	10.01	6.71	24	0.42	0.83	15
Cows										
# cows		2000			2000			2000		
TP/cow/day		0.048			0.048			0.048		
Load to landscape		96			96			96		
Load to stream		4.8			4.8			4.8		
% cow contribution		54.35% 21.45%	5% to stream		38.52% 18.06%	5% to stream		334% 88.2%	5% to stream	
Calc. Downstream										
Flow	**m^3/d**	86425	201606		100631	225582		31817	34600	
TP	**mg/L**	0.102	0.803		0.124	0.752		0.045	0.188	
load*	**kg/d**	8.83			12.46			1.44		
Load**	**kg/d**	22.4	45.7		26.6	46.7		5.4	0.8	
Data Downstream										
Flow	**m^3/d**	195730	186978	112	177049	172282	71	225811	215665	38
TP	**mg/L**	0.119	0.168	145	0.120	0.058	85	0.119	0.252	60
load*	**kg/d**	23.3			21.2			26.8		
Load**	**kg/d**	20.9	24.1	145	19.9	17.9	70	23.1	34.9	30

Load * = load calculated from average flow and average tp
load** = load calculated from average of individual loads

Total phosphorus loads in the lower Little Bear River due to reservoir release, point loads, and cattle-related activities.

Each set of results refers to either the entire Period of Record, 1990 - 1996 and 1997-2004.

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